Chapter 4
Environmental Baseline

Section 4.1
General Baseline Perspective
4 ENVIRONMENTAL BASELINE

**SUMMARY OF ENVIRONMENTAL BASELINE**

- Over the last century and a half, habitat degradation, hatchery influences, harvest rates and dams have adversely affected spring Chinook and winter Steelhead populations and their designated critical habitat.

- The quantity and quality of remaining spawning and rearing habitat has been significantly degraded by multiple factors. The dams have major impacts on both species in terms of flow, water temperature regime, downstream sediment and large wood transport, and channel complexity.

- The construction of the Willamette Project dams has blocked access to a substantial proportion of the historical habitat and has adversely affected habitats downstream. The best quality habitat is located in the headwater areas, with many of these areas not accessible to fish due to the impassable dams. The dams also have major impacts on both species in terms of flow, water temperature regime, downstream sediment and large wood transport, and channel complexity.

- Hatchery Chinook have significantly affected the genetic integrity of all Chinook populations. Hatchery fish spawning in the wild with natural-origin fish has been extensive.

- Fishery harvest levels were high in the past, but have now been reduced significantly. Harvest is no longer a limiting factor for Willamette Chinook and steelhead.

The “environmental baseline” for Biological Opinions is defined in the ESA section 7 implementing regulations as:

“the past and present impacts of all Federal, state, or private actions and other human activities in an action area, the anticipated impacts of all proposed Federal projects in an action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions that are contemporaneous with the consultation in process” (50 CFR §402.2)

The ESA Section 7 Consultation Handbook (USFWS and NMFS 1998) further states that the environmental baseline is:

“an analysis of the effects of past and ongoing human and natural factors leading to the current status of the species, its habitat (including designated critical habitat), and ecosystem within the action area. The environmental baseline is a “snapshot” of a species’ health at a specified point in time.”
NMFS’ analysis of conditions in the environmental baseline begins with a brief discussion of factors that affect multiple populations followed by discussions of conditions in each tributary basin, starting with the Middle Fork Willamette basin and progressing northward culminating with a discussion of conditions in and around the mainstem Willamette River, in the lower Columbia River, Estuary and plume.

### 4.1 General Basinwide Perspective

The Willamette River Basin (Figure 4.1-1) historically supported large numbers of spring Chinook and winter steelhead. The diversity of habitats, ranging from the cold, snow-melt headwater streams in the Cascade Mountains downstream to the meandering and highly complex Willamette River, produced diverse and productive populations of salmon and steelhead. Historical populations had multiple juvenile life history types and adults returned at higher ages than is currently the case (Willis et al. 1995). Juvenile salmon and steelhead reared in the headwater streams and the mainstem Willamette River. Juveniles emigrated to the ocean over a number of months, with spring and fall migrations predominating.

Over the last 150 years UWR Chinook salmon and UWR steelhead have been adversely affected by dams, habitat degradation, fishing, and interactions with hatchery-origin fish. In the late 1800s, fish harvest in the Lower Columbia River had the most profound effect on Willamette runs, already causing noticeable declines in run sizes by 1878 (Stone 1878). In the early 1900s, European colonization of the Willamette Basin increased rapidly, with associated development and natural resource extraction greatly affecting the quality of salmonid habitat. Discharge of pollution by timber and paper mills into the mainstem Willamette River was so severe that massive die-offs of aquatic species including salmon and steelhead were prevalent. The problem was severe and public outcry to clean up the mainstem Willamette began as early as the late 1930s.
Figure 4.1-1  Principal Corps of Engineers facilities in the Willamette Basin

The Draft Willamette Salmon and Steelhead Recovery Plan (ODFW 2007b) identifies the most important key and secondary limiting factors and threats impacting spring Chinook and winter steelhead in the Willamette Basin. Limiting factors are the physical, biological, or chemical conditions experienced by the fish that limit their natural production or VSP attributes (McElhany et al. 2000). Threats are activities that have an effect on the fish and/or the
environmental conditions they need to survive and reproduce. The limiting factors and threats are discussed in more detail for each of the populations, below. However, the following is a general summary of the key and secondary limiting factors and threats that have been identified in the Draft Recovery Plan (ODFW 2007b):

**Spring Chinook Salmon**
- Impaired access to habitat above hydropower/flood-control dams throughout the Willamette Basin.
- Direct mortality of juvenile fish associated with downstream passage through the hydropower/flood-control dams and reservoirs.
- Prespawning mortality of adult Chinook over-summering below the hydropower/flood-control dams.
- Hatchery Chinook interbreeding with natural-origin fish resulting in a risk of genetic introgression.
- Predation and competition with hatchery fish of all species.
- Altered water temperature regimes downstream of the hydropower/flood-control dams.
- Altered habitat conditions downstream of the hydropower/flood-control dams caused by reduced peak flows, reduced large woody debris, and reduced substrate recruitment.
- Altered habitat conditions in the tributaries caused by land management activities.
- Toxicity due to agricultural, urban, and industrial practices.
- Degraded estuarine habitat.

**Winter Steelhead**
- Altered habitat conditions caused by land management activities (timber, agricultural, urban).
- Toxicity due to agricultural, urban, and industrial practices in tributaries and mainstem Willamette.
- Impaired access to habitat above hydropower/flood-control dams throughout the Willamette Basin.
- Direct mortality of juvenile fish associated with downstream passage through the hydropower/flood-control dams and reservoirs.
- Hatchery fish interbreeding with natural-origin fish resulting in a risk of genetic introgression from use of an out-of-DPS stock (summer steelhead).
- Predation and competition with hatchery fish of all species.
- Altered water temperature regimes downstream of the hydropower/flood-control dams.
- Unscreened diversions create impediments and barriers to juvenile steelhead.
- Altered habitat conditions downstream of the hydropower/flood-control dams caused by reduced peak flows, reduced large woody debris, and reduced substrate recruitment.
4.1.1 Project Effects in the Environmental Baseline

4.1.1.1 Blockage of Upstream Habitats

From the late 1940s through the 1960s, construction of 13 dams by the USACE blocked access to the majority of historical habitat for spring Chinook and, to a lesser extent, winter steelhead (Figure 4.1-2). Because these dams were high-head storage dams greater than 200 feet in height, volitional upstream fish passage (e.g. fish ladders) was considered to be infeasible and no fish passage facilities were built at most of the dams (USACE 2000). At some Project dams, traps were built to lift or transport adults upstream and simple collection devices for downstream juvenile migrants were used. Injury and mortality associated with these early systems greatly reduced the productivity of salmon and steelhead populations despite access to historical habitat above these dams. Fisheries managers tried to compensate for lost production with hatchery supplementation until improved passage facilities became feasible. From the 1960s to the present, as wild Chinook runs have precipitously declined, hatchery fish have made up a greater proportion of the returns. Human population growth and land development on the floodplain continued to increase, with the Willamette Basin now supporting approximately 75% of the human population of the state of Oregon. Habitat quantity and quality in the low elevation reaches below the dams has declined in response.
4.1.1.2  Flow Alteration

By seasonally putting water into storage and releasing it later in the year, the large water storage facilities of the Willamette Project have affected the streamflow characteristics of each affected tributary and the mainstem Willamette River. The Willamette Project’s large storage facilities are drafted each fall for flood control and refilled each spring for other uses. The Project can also cause unusually large discharge changes over very short periods. These hydrologic effects seasonally modify fish habitat characteristics in the stream reaches downstream from these facilities.

These effects are discussed in detail in the stream-segment specific discussions below (Sections 4.2 through 4.11).

4.1.1.3  Water Quality

*Water Temperature Effects*

Water development influences water temperatures through storage, diversion, and irrigation return flows. These changes in water temperatures have significant implications for anadromous fish survival.

Among the primary water temperature effects of recent Willamette Project operations is a phenomena termed: thermal inertia. Thermal inertia refers to the tendency for the temperature of water released from a reservoir to temporally lag the temperature of incoming water (Figure 4.1-3). For example, in Figure 4.1-3, water coming into the reservoir (labeled “- above”) warms by mid-summer and then begins to cool, while that flowing out of the reservoir (labeled “+ - below”) lags behind by nearly 100 days, not reaching highest temperatures until fall.
Biological Effects
Thermal inertia changes the seasonal water temperature regime. Cooler water temperatures than normal in late-spring and early summer can delay upstream migration of UWR Chinook. For fall spawning species like UWR Chinook, warmer fall temperatures can delay spawning and accelerate incubation. Warmer fall temperatures can also exceed the thermal tolerance for incubating eggs, reducing viability. Eggs from spring spawning UWR steelhead develop more slowly at reduced temperatures. For both species, thermal inertia modifies emergence timing. Assuming that these fish are well adapted to the environment in which they evolved, such changes in emergence timing places the fish at a disadvantage. Ecological issues such as the abundance of predator and prey species changes through time. For example, an early-emerging Chinook alevin may have little to eat. Such thermal inertia effects may reduce the potential utility of habitat downstream from the dams and reduce the viability of the affected populations.

In 2003, EPA collaborated with NMFS and other regional resource managers to establish guidance for developing water quality standards. With regard to water temperature, the EPA reviewed the scientific literature and established recommended thresholds for a variety of salmonid life stage reactions (Table 4.1.-1).
Table 4.1-1  Summary of the EPA Water Temperature Guidelines and Potential Effects to Salmon. (Source: EPA 2003a).

<table>
<thead>
<tr>
<th>LIFE STAGE</th>
<th>LIFE STAGE REACTION</th>
<th>THRESHOLD (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>Lethal (1 week exposure)</td>
<td>21-22</td>
</tr>
<tr>
<td></td>
<td>Migration Blockage</td>
<td>21-22</td>
</tr>
<tr>
<td>Disease Risk</td>
<td>High</td>
<td>18-20</td>
</tr>
<tr>
<td></td>
<td>Elevated</td>
<td>14-17</td>
</tr>
<tr>
<td></td>
<td>Minimized</td>
<td>12-13</td>
</tr>
<tr>
<td>Swim Performance</td>
<td>Reduced</td>
<td>&gt;20</td>
</tr>
<tr>
<td></td>
<td>Optimal</td>
<td>15-19</td>
</tr>
<tr>
<td>Overall Reduction in Migration Fitness</td>
<td></td>
<td>&gt;17-18</td>
</tr>
<tr>
<td>Spawning</td>
<td>Spawning Behavior Observed in the Field</td>
<td>4-14</td>
</tr>
<tr>
<td>Eggs &amp; Incubation</td>
<td>Good Survival</td>
<td>4-12</td>
</tr>
<tr>
<td></td>
<td>Optimal Incubation</td>
<td>6-10</td>
</tr>
<tr>
<td></td>
<td>Reduced Viability of Gametes</td>
<td>&gt;13</td>
</tr>
<tr>
<td>Emergence &amp; Juvenile Rearing</td>
<td>Lethal (1 week exposure)</td>
<td>23-26</td>
</tr>
<tr>
<td></td>
<td>Optimal Growth</td>
<td>13-20</td>
</tr>
<tr>
<td></td>
<td>Unlimited Food</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limited Food</td>
<td>10-16</td>
</tr>
<tr>
<td></td>
<td>Rearing Preference Temperature</td>
<td>10-17</td>
</tr>
<tr>
<td></td>
<td>Impaired Smoltification</td>
<td>12-15</td>
</tr>
<tr>
<td>Disease Risk</td>
<td>High</td>
<td>&gt;18-20</td>
</tr>
<tr>
<td></td>
<td>Elevated</td>
<td>14-17</td>
</tr>
<tr>
<td></td>
<td>Minimized</td>
<td>12-13</td>
</tr>
</tbody>
</table>

Of particular concern in the mainstem Willamette River is water temperatures during the spring emigration of steelhead smolts (April – June). At water temperatures above 15 °C a parasitic myxosporean, *Ceratomyxa shasta*, becomes highly virulent, and recent research has shown that
the probability of an outmigrating smolt returning as an adult is reduced when water temperatures exceed 15 °C during outmigration (ODFW 2007b). Chinook salmon are somewhat more resistant to this disease but are also affected.

Global warming has increased average annual Columbia basin air temperatures by about 1 degree C over the past century, and water temperatures have been similarly affected (ISAB 2007). The influence of this and other large-scale environmental variations are discussed in Section 4.1.2 below.

**Total Dissolved Gas**
Spill at Project dams can cause downstream waters to become supersaturated with dissolved atmospheric gasses. Supersaturated total dissolved gas (TDG) conditions can cause gas bubble trauma (GBT) in adult and juvenile salmonids resulting in injury or death. Biological monitoring at nearby dams on the Columbia River shows that the incidence of GBT in both migrating smolts and adults remains between 1-2% when TDG concentrations in the upper water column do not exceed 120% of saturation. When those levels are exceeded, there is a corresponding increase in the incidence of signs of GBT symptoms. At times, TDG in Project dam discharges has exceeded 120% of saturation concentration.

### 4.1.2 Large-scale Environmental Variation

This section discusses inter-annual climatic variations (e.g. El Niño and La Niña), longer term cycles in ocean conditions pertinent to salmon survival (e.g., Pacific Decadal Oscillation), and ongoing global climate change and its implications for both oceanic and inland habitats and fish survivals. Because these phenomena have the potential to affect salmonid’s survival over their entire range and multiple life stages, they are an area of substantial scientific investigation.

Salmonid population abundance is substantially affected by inter-annual changes in the freshwater and marine environments, particularly by conditions early in their life histories. Generally, the inland environment (including rivers, tributaries, and the associated uplands) is most favorable to salmon when there is a cold, wet winter, leading to substantial snowpack. This normally results in higher levels of runoff during spring and early summer, when many of the juvenile salmon are migrating to the ocean. The higher levels of runoff are associated with lower water temperatures, greater turbidity, and higher velocity in the river, all of which are beneficial to juvenile salmon. However, in years with exceptionally high snow pack and rain-on-snow events, severe flooding may constrain populations. The low return of Lewis River bright fall Chinook salmon in 1999, for example, has been attributed to flood events during 1995 and 1996.

Within the ocean environment, near-shore upwelling, which brings nutrients up from depth into the photic zone, is a key determinant of ocean productivity because it affects the availability of food for juvenile salmon at the critical time when they first enter the ocean. The upwelling results from ocean currents driven by spring and early summer winds which, in turn, result from oscillations in the jet stream that follow certain cycles. Within a year there are cycles of 20-40 days that affect upwelling and among years there are longer-lasting conditions, such as El Niño/La Niña, cycles of 2-3 years, and the Pacific Decadal Oscillation (PDO). The latter may have cycles of 30-40 years or more that influence upwelling.
Scheurell and Williams (2005) showed that the coastal upwelling index is a strong determinant of year-class strength and subsequent smolt-to-adult return ratios. The Northwest Fisheries Science Center currently monitors a number of ocean conditions and provides a forecast on their website for salmon returns to the Columbia River based on these and other observations.

In some instances, the inland conditions and ocean conditions appear to be correlated; that is, the same weather patterns producing a cold, wet winter with good snowpack and high spring runoff are also likely to bring the later winds that yield good upwelling and favorable feeding conditions in the ocean. However, it is also possible for inland and ocean conditions to diverge, and years have been observed where there have been favorable river conditions but poor ocean conditions, and vice versa.

While strong salmon runs are a product of both good in-river conditions and good ocean conditions, favorable ocean conditions appear to be especially important. For example, 2001 was the second-lowest flow year recorded on the Columbia River, but the near-shore temperatures were generally cool, observed ocean productivity was good, and resulting adult returns from the 2001 juvenile outmigration class were in the average or better range for most of the runs.

### 4.1.2.1 The Southern Oscillation Index, El Niño & La Niña

In an effort to predict the likely strength of the annual monsoons over India, which greatly affected human life through floods and famines, in the 1920s, Sir Gilbert Walker conducted extensive statistical analyses of long-term weather observations for many locations around the globe. Among his many findings was that deviations from long-term average seasonal differences in atmospheric pressure between the western Pacific and the eastern Pacific (typically Darwin, Australia, to Tahiti), were strongly correlated with subsequent climatic conditions in other parts of the globe. Walker termed these deviations, the “Southern Oscillation Index” (SOI). In general, substantial negative SOIs tend to correlate well with above average tropical sea-surface temperatures and positive SOIs tend to correlate with below average sea-surface temperatures, particularly in the eastern Pacific. Both have been found to have “teleconnections” to climatic and oceanic conditions in regions far distant from the south Pacific, including the Pacific Northwest. Although in modern usage a broader array of oceanic and atmospheric characteristics have been found to provide greater predictive power, these teleconnections between conditions in the south Pacific and subsequent climatic conditions elsewhere have come into routine use, including pre-season predictions of runoff in some portions of the Columbia basin.

Atmospheric conditions correlated with unseasonably warm south Pacific sea-surface temperatures are termed El Niños. El Niños typically last 6 to 18 months. Among the consequences are warmer near-surface ocean water temperatures along the U.S. west coast and generally warmer, drier weather in the inland Pacific Northwest, particularly during the winter. When winds do not blow south, the forces that create upwelling off the U.S. coast are reduced, as are nutrient inputs to the euphotic (well lit, near surface) zone, reducing near-shore ocean productivity. This reduction in ocean productivity has been shown to reduce juvenile salmon
growth and survival (Scheurell and Williams 2005). Warmer surface waters can also change the spatial distribution of marine fishes, including potential predators and prey of salmon.

The warmer, drier weather in the Pacific Northwest often associated with El Niño can also cause or increase the severity of regional droughts. Droughts reduce streamflows through the Columbia and Snake River migratory corridor, increase water temperatures, and reduce the extent of suitable habitat in some drainages. Each of these physical effects has been shown to reduce salmon survival. Thus, El Niño events are associated with poor returns of salmon and steelhead.

Unseasonably cool south Pacific sea surface temperatures, typically associated with a positive SOI, tend to have quite different effects in the north Pacific and the Columbia basin. Termed La Niña, positive SOIs tend to be associated with cooler north Pacific surface water temperatures, and cooler, wetter fall and winter conditions inland. Conditions associated with La Niña tend to increase snowpack and runoff in the Interior Columbia basin, improving outmigration conditions through the lower Columbia River, and ocean conditions tend to be more conducive for coastal upwelling early in the spring, providing better feeding conditions for young salmon.

Currently, NOAA Physical Sciences Division calculates a “Multivariate El Niño Southern Oscillation Index” or MEI, which effectively inverts the SOI relationships: a positive MEI indicates El Niño conditions and a negative MEI a La Niña. Once established, El Niño and La Niña conditions tend to persist for a few months to two years although El Niño conditions have dominated the Pacific since 1977 and persisted from 1990 through 1995 (Figure 4.1-4 below). It is likely that the dominance of El Niño conditions since the late 1970s has contributed to the depressed status of many stocks of anadromous fish in the PNW.

![Multivariate ENSO Index](image)

**Figure 4.1-4 Time-series of MEI conditions from 1950 through November 2007. Source: NOAA 2008**

### 4.1.2.2 Pacific Decadal Oscillation

First defined by Steven Hare in 1996, the Pacific Decadal Oscillation (PDO) index is the leading principal component (a statistical term) of variability in North Pacific sea surface temperatures (poleward of 20° N for the 1900-1993 period; JISAO 2008).
Major changes in northeast Pacific marine ecosystems have been correlated with phase changes in the PDO; warm eras have seen enhanced coastal ocean biological productivity in Alaska and inhibited productivity off the west coast of the contiguous United States, while cool PDO eras have seen the opposite north-south pattern of marine ecosystem productivity (e.g., Hare et al. 1999). Thus, smolt-to-adult return ratios for Columbia basin salmon tend to be high when the PDO is in a cool phase and low when the PDO is in a warm phase.

Two main characteristics distinguish the PDO from El Niño: first, 20th century PDO "events" persisted for 20-to-30 years, while typical El Niño events persisted for 6 to 18 months; second, the climatic fingerprints of the PDO are most visible in the North Pacific/North American sector, while secondary signatures exist in the tropics – the opposite is true for El Niño. Several independent studies find evidence for just two full PDO cycles in the past century: "cool" PDO regimes prevailed from 1890-1924 and again from 1947-1976, while "warm" PDO regimes dominated from 1925-1946 and from 1977 through (at least) the mid-1990s (Figure 4.1-5). Minobe (1997) has shown that 20th century PDO fluctuations were most energetic in two general periods, one from 15 to 25 years, and the other from 50 to 70 years.

Figure 4.1-5 Monthly Values for the PDO Index: 1900-January 2008

Mantua and Hare (2002) state, “The physical mechanisms behind the PDO are not currently known.” Likewise, the potential for predicting this climate oscillation is not known. Some climate simulation models produce PDO-like oscillations, although often for different reasons. Discovery of mechanisms giving rise to the PDO will determine whether skillful decades-long PDO climate predictions are possible. For example, if a PDO arises from air-sea interactions that require 10 year ocean adjustment times, then aspects of the phenomenon could, theoretically, be predictable at lead times of up to 10 years. Even in the absence of a theoretical understanding, PDO climate information improves season-to-season and year-to-year climate forecasts for North America because of its strong tendency for multi-season and multi-year persistence. From the perspective of societal impact, recognition of PDO is important because it shows that "normal" climate conditions can vary over time scales (decades) used to describe the length of a human's lifetime.
Recent evidence suggests that marine survival of salmonids fluctuates in response to the PDO’s 20 to 30 year cycles of climatic conditions and ocean productivity (Cramer et al. 1999). Ocean conditions that affect the productivity of Northwest salmonid populations appear to have been in a low phase of the cycle for some time and to have been an important contributor to the decline of many stocks. The survival and recovery of these species will depend on their ability to persist through periods of unfavorable hydrologic and oceanographic conditions.

4.1.2.3 Global Climate Change

Ongoing global climate change has implications for the current and likely future status of anadromous fish in the Pacific Northwest. Recent studies, particularly by the Independent Scientific Advisory Board (ISAB 2007), describe the potential impacts of climate change in the Columbia River Basin. These effects, according to the ISAB, may alter precipitation and temperature levels in the basin and, in particular, impact the operation of the Willamette Project and the Federal Columbia River Power System and habitat used by rearing and migrating life-stages of salmon and steelhead. In the Columbia Basin, which relies on cooler winter temperatures to store a spring/summer water supply in the snowpack, alterations to precipitation and temperature levels may have the following physical impacts:

- Warmer air temperatures will result in a shift to more winter/spring rain and runoff, rather than snow that is stored until the spring/summer melt season.
- With a shift to more rain and less snow, the snowpacks will diminish in those areas that typically accumulate and store water until the spring freshet.
- With a smaller snowpack, these watersheds will see their runoff diminished and exhausted earlier in the season, resulting in lower streamflows in the June through September period.
- River flows in general and peak river flows are likely to increase during the winter due to more precipitation falling as rain rather than snow.
- Water temperatures will continue to rise, especially during the summer months when lower streamflow and warmer air temperatures will contribute to the warming regional waters.

Such responses to warming air temperatures and changing precipitation will not be spatially homogeneous across the entire Columbia River Basin. Following anticipated air temperature increases, the distribution and duration of snowpack in those portions of the basin at elevations high enough to maintain temperatures well below freezing for most of the winter and early spring would be less affected. Low-lying areas in the Interior, which historically have received scant precipitation, have contributed little to total streamflow. This condition would also be relatively unaffected. The most noticeable changes will occur in the “transient snow” watersheds such as the Willamette Basin where the threshold between freezing and non-freezing temperatures is much more sensitive to warming. Not only would changes in the distribution of precipitation between rain and snow affect the shape of the annual hydrograph and water temperature regimes, but more frequent and more severe rain-on-snow events could affect flood frequency with implications for scouring out incubating and young-of-the-year-fish (ISAB 2007).

The ISAB report also anticipates that large-scale ecological changes will occur over a 35-year time period. For example, the frequency and magnitude of insect infestations of forested lands
and the frequency and intensity of forest fires are likely to become larger during this time period as well. As reported by the ISAB (2007), “fire frequency and intensity have already increased in the past 50 years, and especially the past 15 years, in the shrub steppe and forested regions of the West. Drought and hot, dry weather already have led to an increase in outbreaks of insects in the Columbia Basin, especially mountain pine beetle, and insect outbreaks are likely to become more common and widespread.”1 Such landscape changes have implications for salmon habitat and survival.

The ISAB (2007) identified the following list of likely effects of projected climate changes on Columbia basin salmon:

- Anticipated water temperature increases, and the subsequent depletion of cold water habitat, could reduce the areal extent of suitable inland salmon habitats. ISAB (2007) assessed the potential impacts of climate warming on Pacific Northwest salmon habitat. Locations that were likely to experience an average weekly maximum temperature that exceeded the upper thermal tolerance limit for a species were considered to be lost habitat. Projected salmon habitat loss would be most severe in Oregon and Idaho with potential losses exceeding 40% of current by 2090. Loss of salmon habitat in Washington would be a less severe case of about 22% loss by 2090. O’Neal’s approach assumed a high rate of greenhouse gas emissions and used a climate model that projected a 5 degree C in global temperatures by 2090, a value that is higher than the scenarios considered most likely (ISAB 2007). This conservative estimate of potential habitat loss does not consider the associated impact of changing hydrology.

- Variations in intensity of precipitation may alter the seasonal hydrograph. With reduced snowpack and greater rainfall, the timing of stream flow will likely shift, depreciable reducing spring and summer stream flow, and increasing peak river flows (ISAB 2007). This reduction in stream flow may impact the quality and quantity of tributary rearing habitat, greatly affecting spring and summer salmon and steelhead runs. In addition, the Pacific Northwest’s low late-summer and early-fall stream flows are likely to be further reduced. Reduced late-summer and early-fall flows, in conjunction with rising water temperatures, are likely to adversely impact juvenile fall Chinook and chum salmon by depleting essential summer shallow mainstem rearing habitat.

- Considering both the water temperature and hydrologic effects of climate change, Crozier et al. (2008) showed that the abundance of four studied Snake River spring/summer Chinook populations would be substantially decreased (20-50% decline from simulated average abundance based on historical 1915-2002 climate) and extinction risks substantially increased by long-term exposure to climate conditions likely to exist in 2040. Hydrologic and physical changes in the Pacific Northwest environment have implications for the habitat, populations, and spatial distributions of Pacific salmonids (Zabel et al. 2006).

- Eggs of fall and winter spawning fish, including Chinook, coho, chum, and sockeye salmon, may suffer higher levels of mortality when exposed to increased flood flows. Higher winter water temperatures also could accelerate embryo development and cause premature emergence of fry.

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1 Removal of trees from riparian areas by fire or insects will lead, at least temporarily, to an increase in solar radiation reaching the water and exacerbate the water temperature. The potential for climate-induced fire and insect outbreaks has the potential to disproportionately impact habitats of key importance to native fish and wildlife populations (ISAB 2007).
Increases in seasonal mainstem Snake and Columbia River water temperature would accelerate the rate of egg development of fall Chinook that spawn in the mainstem of the Snake and Columbia rivers, and lead to earlier emergence at a smaller average size than historically. Also, dam and reservoir passage survival is affected by water temperatures with the lowest rates of survival typically occurring when water temperatures are warmest. Potential impacts of increased water temperatures on adult salmon include delay in dam passage, failure to enter fish ladders, increased fallback, and loss of energy reserves due to increased metabolic demand. Increases in mortality also may be caused by fish pathogens and parasites as these organisms often do not become injurious until their host becomes thermally stressed.

Earlier snowmelt and earlier, higher spring flows, warmer temperatures, and a greater proportion of precipitation falling as rain rather than snow, may cause spring Chinook and steelhead yearlings to smolt and emigrate to the estuary and ocean earlier in the spring. The early emigration coupled with a projected delay in the onset of coastal upwelling could cause these fish to enter the ocean before foraging conditions are optimal. The first few weeks in the ocean are thought to be critical to the survival of salmon off Oregon and Washington, so a growing mismatch between smolt migrations and coastal upwelling would likely have significant negative impacts on early ocean survival rates.

Within the Columbia estuary, increased sea levels in conjunction with higher winter river flows could cause the degradation of estuary habitats created by increasing wave damage during storms. Numerous warm-adapted fish species, including several non-indigenous species, normally found in freshwater have been reported from the estuary and might expand their populations with the warmer water and seasonal expansion of freshwater habitats. Climate change also may affect the trophic dynamics of the estuary due to upstream extension of the salt wedge in spring-early summer caused by reduced river flows. The landward head of the salt wedge is characterized by a turbulent region known as the estuary turbidity maximum, an area with high concentrations of fish food organisms such as harpacticoid copepods. Changes in the upstream extension of the salt wedge will influence the location of this zone, but it is difficult to forecast the effect this change will have on juvenile salmon.

Scientific evidence strongly suggests that global climate change is already altering marine ecosystems from the tropics to polar seas. Physical changes associated with warming include increases in ocean temperature, increased stratification of the water column, and changes in the intensity and timing of coastal upwelling. These changes will alter primary and secondary productivity, the structure of marine communities, and, in turn, the growth, productivity, survival, and migrations of salmonids.

Changing ocean temperatures may alter salmon behavior, distribution, and migrations, increasing the distance to migrations from their home streams to ocean feeding areas. Energetic demands are increased at warmer temperatures, requiring increased consumption of prey to maintain a given growth rate. This could lead to intensified competition among species, as well as an increased reduction in growth rates, further exacerbating the prey/predator relationship. In addition, food availability in the ocean may be altered by climate change. Increasing concentration of CO₂ in the oceans lowers pH, which reduces the availability of carbonate for shell-forming marine animals. Pteropods are expected to be negatively affected, and they can comprise up to 40% or more of the diet of some salmon species, although another suitable prey item might replace them in the ecosystem. If salmon migrate farther to the north and/or food is less available, longer times may
be required to reach maturity, delaying the usual times of adult migrations into coastal water and rivers.

- Global climate change in the Pacific Northwest may be similar to those experienced during past periods of strong El Niños and warm phases of the PDO.

EPA (2008) presents a series of environmental indicators to measure current status and trends of the U.S. environment. Among the indicators presented is a nationwide evaluation of streamflow changes through time. This indicator shows that while both high flows and low flows have varied over the past 50 years, no long-term trend in either parameter was established. However, the national trend is toward a reduced annual variability in streamflow, likely a result of increased streamflow regulation (i.e. dams), not climate change.

An extensive hydrologic trend analysis was conducted for the Willamette River (Gregory et al. 2007). While substantial alteration of the natural hydrologic regime was identified by the analysis, the identified effects are attributable to the operation of Willamette Project dams, particularly operations designed to prevent flooding.

Given the broad natural variability in streamflow, the strength of short-term climate fluctuations and their effects on streamflow (e.g. El Nino), and the highly developed nature of the Willamette watershed, it will likely be difficult to identify climate-driven trends in Willamette basin streamflows from analysis of measured flow time-series until such effects are quite strong.

The effects of climate change are considered qualitatively in this Opinion. In addition, NMFS explicitly considers actions which are consistent with the ISAB’s mitigation recommendations (see ISAB recommendations in Chapter 5.1 for further detail). However, the time frame, and the scope of climate change is not clear. Many climate change predictions describe changes up to 100 years. For the 15-year term of this Opinion, NMFS uses conservative assumptions and sets the stage for mitigation actions should they become necessary.

### 4.1.3 Water Diversions

Surface water is removed from the rivers and streams of the Willamette Basin for a multitude of municipal, industrial, and agricultural purposes. Most water diversions are relatively small, but cumulatively they have an impact, especially in localized situations, such as in tributaries with lower flows, or in water-deficit years. Water diversions present hazards for fish. Fish can be inadvertently intercepted and entrained into water flowing to municipal, industrial and agricultural uses, leading to their death. Some diversions are associated with small dams that can pose barriers to migration. The water removed from the stream reduces flow and water depth, reducing its quality as fish habitat. Most of the water diversions are small pumps, but some are gravity diversions.

Some surface water diversions in the Willamette Basin have had adequate fish protective measures installed, such as appropriate screens, but many have not and there is no current or pending requirement mandating fish protective measures to be installed at existing diversions. Most older diversions are not required under current State and Federal law to install and operate fish protective
measures such as screens and thus are likely to continue to operate indefinitely without adequate fish protective measures.

Reclamation contracts to sell stored water impounded by the Willamette Project’s USACE dams, thus providing a regulatory nexus to require fish protective measures for those diversions associated with these federal water contracts. However, these represent a small subset of all the diversions in the basin, and of the overall hazards presented by diversions within the Willamette Basin.
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Section 4.2
Middle Fork Willamette Baseline
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4.2 THE MIDDLE FORK WILLAMETTE

The Middle Fork Willamette River watershed is the largest tributary watershed in the Willamette River basin (Figure 4.2-1). The watershed is approximately 3,500 km² (865,000 acres) and is predominately forest land cover type (Figures 4.2-2). Eighty-two percent of the watershed is under public ownership (Figures 4.2-2, NRCS 2006a). The private land is predominately located at the lower end of the watershed below Dexter Dam near the city of Eugene.

Once a major producer of natural-origin UWR Chinook, the Middle Fork system now has salmon runs that are composed almost entirely of hatchery origin fish. Extensive salmon production areas in the system have been blocked by USACE dams, and conditions found in those areas still accessible to UWR Chinook below the dams appear insufficient to sustain a natural population. Habitat that remains available below the dams has been hydrologically, thermally, and structurally altered by land use practices and urbanization. Any naturally produced salmon returning to this habitat as adults must then share spawning areas with hatchery-origin spawners that stray from programs intended to offset the salmon production lost above the dams.
Figure 4.2-1  Map of the Middle Fork Willamette watershed. The uppermost extent of natural passage is near the town of Lowell, where Dexter and Fall Creek dams block upstream migration.
4.2.1 Historical Populations of Anadromous Salmonids in the Middle Fork Subbasin

The Middle Fork subbasin is home to a native run of UWR Chinook salmon but is not thought to be within the natural distribution of UWR steelhead. Historically, the run of UWR Chinook in the Middle Fork Willamette may have been the largest population of these fish above Willamette Falls (Hutchison 1966a; Thompson et al. 1966). McElhany et al. (2007) have suggested that the Middle Fork subbasin once likely produced tens of thousands of adult spring Chinook. Based on egg collections at the Willamette River Hatchery (Dexter Ponds; 1909 to the present), the largest egg collection, 11.3 million in 1918 (Wallis 1962), would correspond to 3,559 females (at 3,200 eggs/female) that escaped intense fisheries downstream in the lower Willamette and Columbia Rivers. This leads to an estimated minimum adult return to the subbasin of about 7,100 adult spring Chinook for the area that is now above Lookout Point Dam (assuming a 1:1 sex ratio). This estimate does not include fish that spawned downstream of the hatchery rack (such as in the lower mainstem Middle Fork Willamette and in the Fall Creek watershed). Mattson (1948) estimated adult returns of 2,550 naturally-produced spring Chinook to the Middle Fork subbasin in 1947. In the years immediately prior to Fall Creek Dam construction in 1966, there were about 450 spring Chinook salmon spawning in Fall Creek above the dam site USFWS (1962).

Mattson (1948) and Parkhurst et al. (1950) reported spawning aggregations of Chinook salmon in Fall Creek, Salmon Creek, the North Fork of the Middle Willamette River, the mainstem Middle Fork Willamette River, and Salt Creek. Mattson (1948) estimated that 98% of the 1947 run in the Middle Fork Willamette system spawned upstream of the Lookout Point dam site and the remaining 2% spawned upstream of the Fall Creek dam site.

From 1953 through 1966 (after construction of Dexter and Lookout Point Dams blocked access to most of the Middle Fork population’s historical spawning grounds), an average of 3,502 Chinook salmon were caught in the trap at the base of Dexter Dam (Wallis 1962; Hutchison et al. 1966b). These total counts probably included some hatchery-origin fish. Thompson et al. (1966) estimated a total population of 6,100 naturally- and artificially-produced adults in the Middle Fork Willamette subbasin below the dams in the mid-1960s.
Figures 4.2-2 Maps of the Middle Fork Willamette subbasin (ODEQ 2006a; top) and of land use patterns within the subbasin (NRCS 2006a, bottom).
4.2.2  Current Status of Anadromous Salmonids within the Middle Fork Willamette Subbasin

4.2.2.1  UWR Chinook Salmon

Population Viability
The Middle Fork population of UWR Chinook salmon is considered to be at very high risk of extinction, based on an analysis of its recent abundance, productivity, spatial structure, and diversity (McElhany et al. 2007). Chronically unfavorable conditions for the population within a dramatically reduced geographic range create most of this risk, but the potential for catastrophic events such as landslides and disease epidemics, is also a contributor (WLCTRT 2003).

Abundance & Productivity
The Middle Fork Willamette Chinook population’s limited natural abundance and productivity pose a very high extinction risk (McElhany et al. 2007), an issue of particular concern given that it is a core population identified as critical to the long-term persistence of the ESU (see section 3.2.1.3 in Chapter 3, Rangewide Status). Abundances of wild spawners are low, pre-spawn mortality rates for these fish are high, and recent use of natural spawning areas has been dominated by fish of hatchery origin (Schroeder et al. 2006).

Adult UWR Chinook returning to the Middle Fork subbasin are counted at Dexter Dam, the upper limit of habitat that is now naturally accessible in the mainstem Middle Fork Willamette River, and at Fall Creek Dam as the USACE passes them into the watershed upstream. Counts of redds and spawned-out fish are conducted along the lower mainstem and on Fall Creek above the dam. Natural spawning apparently did not occur in the mainstem below Dexter before the dam was built (Lindsay et al. 1999). This indicates that the habitat below Dexter is not as high quality as that above the dams.

Numbers of adult UWR Chinook that have been counted at Dexter and Fall Creek dams during the years following dam completion are given in Figure 4.2-3. Annual counts at Dexter have varied from a low of 802 in 1960 to a high of nearly 18,000 in 1990, and have exceeded 5,500 adults since 2000. Wild fish are thought to have comprised a very small fraction of the Dexter counts except for the single generation of salmon whose adults were actually blocked from returning to their natal habitats. Annual returns to Fall Creek Dam averaged approximately 300 fish in the 1980s and about 150 fish during the 1990s, before exhibiting a recent upswing that apparently reflects improved ocean conditions and an expanded hatchery supplementation effort. The adult counts at Fall Creek Dam have for decades have been a mixture of naturally produced fish whose parents spawned above the dam combined with fish that were out-planted as juveniles into or below Fall Creek Reservoir in an effort to maintain natural production despite poor passage conditions at the dam.
Improvements to fish marking and monitoring efforts within the Willamette Basin now allow a high level of confidence in distinguishing hatchery-origin from wild (natural-origin) UWR Chinook. Under contract to the USACE, ODFW has since 2002 conducted intensive monitoring of hatchery and wild Chinook returning to Dexter Dam and to spawning areas in the lower Middle Fork, and in Fall Creek above Fall Creek Dam (Schroeder et al. 2006; McLaughlin et al. 2008). Monitoring results from 2002 through 2005 showed that returns of wild adults to the lower Middle Fork were very low, with an annual average of fewer than 50 captured at Dexter, and what appear to have been even lower numbers of wild spawners present in mainstem spawning areas between the town of Jasper\(^1\) and Dexter Dam (Schroeder et al. 2006; McLaughlin et al. 2008). Hatchery fish accounted for 82-95% of the spawners in the lower river during the 2002-2005 period, and annual pre-spawn mortality rates averaged 92% (Schroeder et al. 2006; McLaughlin et al. 2008). This situation makes it unlikely that the lower river has sustained a “wild” population.

Recent monitoring by ODFW on upper Fall Creek indicates that it is more successfully used as a Chinook spawning area than is the mainstem Middle Fork, but the potential for the run of UWR Chinook in this stream to become self-sustaining without major passage improvements appears low. Although densities of Chinook redds (nests) have been substantially higher in Fall Creek above the reservoir than in the Middle Fork (Figure 4.2-4), the proportions of hatchery-origin spawners in the stream have been quite high (74-100%) (McLaughlin et al. 2008). Rates of pre-spawn mortality for adult UWR Chinook above Fall Creek Reservoir averaged 44-58% during the 2002-2005 period (Schroeder et al. 2006).

---

\(^1\) 7 miles below Dexter Dam, RM 195.
Spatial Structure
The majority of the historical spawning areas of Middle Fork Willamette Spring Chinook have been blocked by dams, and the remaining naturally accessible habitats do not appear to provide the full suite of conditions needed to sustain a natural salmon population. This situation poses a high to very high risk of extinction to the persistence of what little remains of the subbasin’s natural population of UWR Chinook (McElhany et al. 2007).

Diversity
The lack of diversity of the Middle Fork Willamette population of spring Chinook reflects a high risk of extinction, based on an examination of life history traits, effective population size, hatchery impacts, anthropogenic mortality, and habitat diversity. Their greatest concern was the large proportion of hatchery-origin fish in natural spawning areas (McElhany et al. 2007).

4.2.2.1 Limiting Factors & Threats to Recovery for UWR Chinook salmon
The limiting factors and threats currently inhibiting the survival and recovery of UWR Chinook salmon in the Middle Fork Willamette watershed, as identified in the Draft Willamette Salmon and Steelhead Recovery Plan (ODFW 2007b), are shown in Table 4.2-1. Primary causes for the severely limited natural production of this species in the Middle Fork subbasin include blockage from critical habitat by Willamette Project dams, high pre-spawning mortality of adults, and altered water temperatures during egg incubation in the remaining habitat below the dams. Even though the limiting factors and threats are broken into two groups, key and secondary, the secondary factors are important to address as well as the key factors.
### Table 4.2-1  Summary of key and secondary limiting factors and threats for Chinook in the Middle Fork Willamette watershed (ODFW 2007b). The entire life cycle limiting factors and threats assessment is found in section 4.1.

<table>
<thead>
<tr>
<th>Threats</th>
<th>Species</th>
<th>Tributaries (Streams and Rivers within Population Area)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Egg</td>
</tr>
<tr>
<td>Harvest</td>
<td>Chinook</td>
<td></td>
</tr>
<tr>
<td>Hatchery</td>
<td>Chinook</td>
<td></td>
</tr>
<tr>
<td>Hydropower/Flood Control</td>
<td>Chinook</td>
<td>9f</td>
</tr>
<tr>
<td>Landuse</td>
<td>Chinook</td>
<td>8a</td>
</tr>
<tr>
<td>Introduced Species</td>
<td>Chinook</td>
<td></td>
</tr>
</tbody>
</table>

Black cells indicated key concerns; Gray cells indicated secondary concerns.

### Key threats and limiting factors

1f  Mortality at Middle Fork Willamette hydropower/flood control dams. This mortality is due to direct mortality in the turbines and/or smolts being trapped in the reservoirs.

2e  Impaired access to habitat above Middle Fork Willamette hydropower/flood control dams.

2m  Pre-spawning mortality due to crowding and high water temperatures below Middle Fork Willamette hydropower/flood control dams.

3   Hatchery fish interbreeding with wild fish resulting in a risk of genetic introgression.

7f  Lack of gravel recruitment below Middle Fork Willamette hydropower/flood control dams due to gravel capture in upstream reservoirs.

8a  Impaired physical habitat from past and/or present land use practices (tributaries).

9f  Elevated water temperatures below Middle Fork Willamette hydropower/flood control dams resulting in premature hatching and emergence.

10d Reduced peak flows leading to decreased channel complexity and diversity of fish habitat by reducing channel movement that is important for recruitment of gravel and large wood, and maintaining varying seral stages of riparian vegetation. Lower peak flows also reduces scour and formation of pools.

### Secondary threats and limiting factors

7g  Streambed coarsening below Middle Fork Willamette hydropower/flood control dams due to reduced peak flows.

8a  Impaired physical habitat from past and/or present land use practices (presmolts, Westside tributaries).

9a  Elevated water temperatures from past and/or present land use practices resulting in decreased survival and/or growth.
4.2.2.2 UWR Steelhead

Although native winter steelhead may have occasionally been present in the Middle Fork Willamette subbasin, the W/LC TRT concluded that this subbasin did not support an independent population, and the UWR steelhead DPS does not include steelhead in this subbasin (Myers et al. 2006). However, some winter steelhead are observed each year at Fall Creek, below Fall Creek Dam (ODFW 2002).

4.2.3 Environmental Conditions

Within the Middle Fork Willamette watershed, the USACE built four flood control and re-regulating dams since the late 1940’s (see Figure 4.2-1). Dexter Dam (on the lower Middle Fork Willamette) and Fall Creek Dam (on lower Fall Creek) are the lowermost dams that block all volitional upstream migration of fish. Lookout Point Dam is located upstream from Dexter Dam. Hills Creek Dam is located upstream of Lookout Point Dam.

Below is a summary of past and ongoing effects of these dams and reservoirs on UWR Chinook salmon and their habitat in the Middle Fork Willamette. The effects are described in four broad categories: Habitat Access, Water Quantity/Hydrograph, Water Quality, and Physical Habitat.

4.2.3.1 Habitat Access

USACE’s construction of impassable Willamette Project dams in the Middle Fork Willamette watershed adversely impacted this UWR Chinook population. These dams were built at low elevation in the watershed, eliminating access to nearly all significant habitat upstream (Figure 4.2-1) that UWR Chinook used for spawning and rearing, with the remaining accessible downstream habitat of marginal value. Egg to fry survival is very low in this remaining downstream habitat below Dexter Dam. This once large population now produces few natural-origin adult fish downstream from Dexter, the lowermost dam, and most spring Chinook that do spawn below the dam are of hatchery origin (Table 4.2-2).

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of naturally produced origin</th>
<th>Number of local hatchery origin</th>
<th>Number of stray hatchery origin</th>
<th>Total</th>
<th>% wild</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>15</td>
<td>318</td>
<td>0</td>
<td>333</td>
<td>5</td>
</tr>
<tr>
<td>2003</td>
<td>4</td>
<td>110</td>
<td>0</td>
<td>114</td>
<td>4</td>
</tr>
<tr>
<td>2004</td>
<td>22</td>
<td>152</td>
<td>0</td>
<td>174</td>
<td>13</td>
</tr>
<tr>
<td>2005</td>
<td>3</td>
<td>41</td>
<td>0</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>4 year Average</td>
<td>11</td>
<td>155</td>
<td></td>
<td>166</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 4.2-2 Estimated number of adult spring Chinook salmon carcasses in spawning areas that were of naturally produced (“wild”), local hatchery, and stray hatchery origin for the Middle Fork Willamette River (Dexter to Jasper), and including Fall Creek, 2002-2005 (Schroeder et al. 2006).
4.2.3.1.1 Fish Passage at Dexter & Lookout Point Dams

Dexter and Lookout Point dams were built without fish passage facilities, but since construction of Dexter Dam in 1954, upstream migrating fish have been collected in a trap below Dexter dam (see Figure 4.2-1). For many years these fish were primarily taken to the Willamette Hatchery for spawning, but in 1993, ODFW began releasing some adult spring Chinook into areas above Dexter-Lookout Point and Hills Creek Dam. This outplanting effort originally was intended as a benefit to bull trout by providing nutrients to the stream environment from Chinook carcasses and a food source (juvenile Chinook). However, many of the outplanted Chinook reproduced naturally in their historical habitat, and juvenile Chinook were observed in the reservoirs and emigrating through the dams. Ziller (2002) estimated 162 redds in over 35 miles of habitat in the North Fork of Middle Fork Willamette River. Based on these results (and other encouraging observations elsewhere in the Willamette Basin), the outplanting program has transitioned into an effort to encourage natural production of spring Chinook salmon in recent years. Chinook are now released above the impassable dams to determine the feasibility of restoring natural production in the areas above the dams and reservoirs (Beidler and Knapp 2005, Table 4.2-3). Success of the outplanting program to date has been limited, though, partly due to high prespawning mortality of outplanted fish that has greatly reduced the number of spawning fish. The reasons for this high pre-spawning mortality are not well understood at this time, but it is speculated that trapping and handling effects, temperature effects, downstream habitat conditions, and timing effects are likely contributing to the poor survival rates observed. Additionally, because the outplanted fish in the Middle Fork Willamette River above Dexter Dam have all been hatchery-origin adults, NMFS would expect high pre-spawning mortality because these adults may be looking for a hatchery entrance rather than native spawning grounds. Upstream survival could be improved by upgrading fish collection facilities and transport and release operations consistent with NMFS criteria.

Limited data are available regarding downstream passage and survival of juvenile Chinook through Lookout Point and Dexter reservoirs and dams. In a 2001 and 2002 study, survival through the turbines at Lookout Point Dam was estimated at approximately 88% (Ziller 2002). Survival through the Kaplan turbines at Dexter is unknown but may be similar to the 92% measured at Foster dam (USACE 2007a). There are no downstream passage facilities for juvenile Chinook salmon at either Lookout Point or Dexter dams.
Table 4.2-3 Numbers of adult spring Chinook salmon in the Middle Fork Willamette subbasin released above USACE dams, including Fall Creek Dam, 1993-2006. Asterisk (*) indicated that some fish were also placed in Hills Creek. Source: (Mamoyac and Ziller 2001; Ziller 2002; McLaughlin et al. 2008; Beidler and Knapp 2005)

<table>
<thead>
<tr>
<th>Year</th>
<th>Middle Fork, above Hills Creek Dam</th>
<th>Middle Fork above Lookout Point Reservoir</th>
<th>Fall Creek, above Fall Creek Dam</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>North Fork Middle Fork</td>
<td>Middle Fork</td>
</tr>
<tr>
<td>1991</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1992</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1993</td>
<td>796</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1994</td>
<td>177</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1995</td>
<td>522</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1996</td>
<td>341</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1997</td>
<td>956</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1998</td>
<td>572</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1999</td>
<td>1,073</td>
<td>578</td>
<td>0</td>
</tr>
<tr>
<td>2000</td>
<td>2,006</td>
<td>798</td>
<td>0</td>
</tr>
<tr>
<td>2001</td>
<td>2,261</td>
<td>1,650</td>
<td>0</td>
</tr>
<tr>
<td>2002</td>
<td>2,793</td>
<td>3,765</td>
<td>535</td>
</tr>
<tr>
<td>2003</td>
<td>1,500</td>
<td>1,695</td>
<td>0</td>
</tr>
<tr>
<td>2004</td>
<td>2,416*</td>
<td>2,703</td>
<td>0</td>
</tr>
<tr>
<td>2005</td>
<td>1,052</td>
<td>298</td>
<td>0</td>
</tr>
<tr>
<td>2006</td>
<td>769*</td>
<td>827</td>
<td>0</td>
</tr>
</tbody>
</table>

4.2.3.1.2 Fish Passage at Fall Creek Dam

Fall Creek Dam was constructed in 1966 with fish passage facilities, namely a trap at the base of the dam for upstream migrating adults and a downstream migrant collector systems consisting of “fish horns” on the upstream face of the dam. However, as described in this section, the downstream passage system was not effective at safely collecting and passing fish, and the regulating outlets are now considered the primary downstream fish passage route.

The fish horn apertures were installed at the 800-, 765-, and 720-foot elevations on the upstream face of the dam to collect downstream migrants, but these proved to be ineffective. Smith and Korn (1970) assessed the passage of downstream migrants by releasing marked yearling Chinook salmon and 2-year-old winter steelhead at the head of the reservoir during 1966 through 1969 and collecting the smolts in the evaluator. Chinook smolt recoveries never exceeded 15.6%, and winter steelhead emigrated at even lower rates (Table 6 in Smith and Korn 1970). Smith and Korn attributed the poor collection efficiency to improper placement of the fish horns compared to the vertical distribution of emigrants in the reservoir, and to low attraction flow into the horns.
during much of the emigration period. Earlier studies had shown that smolted Chinook and steelhead inhabited the upper 15 feet of water, near the shoreline, during the spring months. In a year of average inflow at Fall Creek, the entrances to the transport system attracted fish from 30 feet below the surface of the reservoir and about 150 feet offshore from the face of the dam (Smith and Korn 1970). Smith and Korn recommended that the USACE continue to completely evacuate the reservoir in the late fall or early winter of each year as a means of passing emigrants through the outlets.

The USACE passed smolts by draining the reservoir in the fall, per Smith and Korn’s advice, through 1977. After 1977, the reservoir was kept up through Labor Day (for recreation) and smolts were forced to exit through the two gates on the regulating outlet under high head and high flow. Downey and Smith (1992) estimated 19% to 29% survival under these conditions; injury and mortality generally increased with head and flow and the greatest injury and mortality rates were thought to occur as the fish passed under the gates. Downey and Smith (1992) estimated approximately 32% survival through the fish horn system, with most of the survivors receiving severe head and eye abrasions. Because lowering the reservoir during September and October would decrease the head and flow through the outlets, Downey and Smith (1992) recommended that reservoir operations be returned to a modified version of the pre-1977 operation. The recommended drawdown procedure was implemented from 1992 through 1998, but was halted when ODFW stopped rearing hatchery fingerlings in the reservoir in favor of releasing marked smolts below the dam. The horn system is now used to supplement the water supply to the adult collection facility during summer and early fall, and juveniles exiting the reservoir during that period also use that route. After the middle of October, when the fish ladder is shut down, outmigrants exit through the regulating outlet.

The existing adult fish trap at the base of Fall Creek Dam does not meet NMFS’ current design criteria, although some improvements made in recent years have likely reduced fish handling stress and injury. USACE (2000) states that upstream migrants could experience abrasion, mechanical injury, and stress in the trapping facility and may experience delay in migration and disease when water temperatures are above maximum. Trucking and release upstream could lead to mechanical injury and could expose adults to low dissolved oxygen concentrations. Originally most adult spring Chinook salmon and some winter steelhead trapped at Fall Creek Dam were trucked to the McKenzie and other hatcheries, but some were released at a site about two miles above the edge of the reservoir. Beginning in 1998, all of the spring Chinook returning to the collection facility were released above the dam (USACE 2007a).

4.2.3.1.3 Fish Passage at Hills Creek Dam
Hills Creek Dam (RM 230) was built in 1961 on the Middle Fork of the Willamette River without upstream or downstream fish passage facilities. ODFW began releasing adult spring Chinook salmon above Hills Creek Reservoir in 1993 to increase nutrient inputs and to provide a prey base for bull trout. As at Lookout Point, occasional releases of hatchery-reared Chinook fingerlings were intended to augment the recreational trout fishery in Hills Creek Reservoir. In a 1999 and 2000 study, ODFW estimated survival of outmigrant Chinook through the turbines and regulating outlets at about 41% and 68%, respectively (Ziller 2002).
4.2.3.2 Water Quantity/Hydrograph

Flows have been controlled by the Lookout Point-Dexter project and Hills Creek and Fall Creek dams since 1954, 1961, and 1965, respectively. Operating the projects for flood control and other purposes has substantially altered the natural hydrologic regime (Figures 4.2-5 A, B & C).

Middle Fork Willamette River natural streamflow displays the same general seasonal distribution as other Willamette basin tributaries, with the majority of runoff occurring during the winter rainy season and low flows during July and August. Headwater elevations are high enough to develop a seasonal snowpack so the hydrograph exhibits a bimodal distribution, with a secondary peak due to snowmelt in May and June. Flows in the Middle Fork Willamette River are naturally highest in winter and spring and lowest in early fall (Figures 4.2-5 A, B & C). Operations of the Hills Creek, Lookout Point/Dexter, and Fall Creek projects have reduced the median daily April flow downstream from Dexter by 44% compared to the pre-dam condition. Median daily August flows have been increased by 185%.

Flows in Fall Creek are naturally highest in the winter and early spring and lowest in late summer/early fall (Figures 4.2-6 A, B & C). Operation of the Fall Creek project has reduced the median daily April flow by 23% and has increased the median daily August flow by 418%.

Before dam construction, the lowest average daily flow observed at the Jasper gage in the lower Middle Fork, below the mouth of Fall Creek (USGS Station No. 14152000), was the 530 cfs observed on several occasions from September through November 1907. The lowest average daily flow observed at Jasper since all four Middle Fork projects were completed was 536 cfs in April 1977. An instantaneous minimum flow of 366 cfs was observed in December 1954, shortly after Lookout Point Dam was built. The minimum instantaneous discharge observed at the Fall Creek gage, downstream from Fall Creek Dam and the mouth of Winberry Creek (USGS Station No. 14151000), was 1.5 cfs, in October 1965.

The Middle Fork Willamette River is lightly used to supply water for domestic, industrial, and agricultural uses. The OWRD has issued permits for surface water withdrawals totaling 196 cfs from the Middle Fork Willamette River (OWRD 2003). This is a maximum diversion right and a smaller amount is actually diverted. Due to high level of development, the OWRD water availability process (OAR 690-400-001) has determined that natural flow water is not available for out-of-stream use from the Middle Fork Willamette River from February through November. Further, the Willamette Basin Program Classifications (OAR 690-502-0110) require that new surface water users in the subbasin obtain water service contracts from USBR (i.e., for the use of water stored in Willamette Project reservoirs during the summer months, including irrigation). The USBR has issued contracts for the delivery of 241 acre-feet of water annually (equivalent to about 1.2 cfs) from the Middle Fork reservoirs to users diverting from the Middle Fork Willamette River and Fall Creek (USACE 2007a).

This modification of the Middle Fork’s hydrologic regime has several implications for salmon and steelhead.
Figures 4.2-5 A, B & C. Simulated discharge (cfs) of Middle Fork Willamette River below Dexter Dam under unregulated conditions (Unreg), with project operating criteria prior to 2000 (Pre-2000), and with project operating criteria after 2000 (Post-2000), depicting the 80th, 50th (median), and 20th percentile (respectively) for each scenario.

Figure 4.2-5 A

Figure 4.2-5 B
Figures 4.2-6 A, B & C. Simulated discharge (cfs) of Fall Creek below Fall Creek Dam under unregulated conditions (Unreg), with project operating criteria prior to 2000 (Pre-2000), and with project operating criteria after 2000 (Post-2000), depicting the 80th, 50th (median), and 20th percentile for each scenario.
4.2.3.2.1 Peak Flow Reduction

Flood control operations at the USACE dams have substantially decreased the magnitude and frequency of instantaneous peak flow events in the Middle Fork Willamette River. Flows greater than 20,000 cfs were common above Salt Creek (which enters the Middle Fork just above the town of Oakridge) before construction of Hills Creek Dam. Since construction of Hills Creek, no flows greater than about 10,000 cfs have occurred in this reach, and the magnitude of the 2-year recurrence interval event has decreased from 11,800 to 5,200 cfs (USACE 2000, Figure F-2). A similar peak flow reduction has been observed in Fall Creek, where the magnitude of the two-year recurrence interval event has decreased from about 10,000 to 3,800 cfs (USACE 2000, Figure F-6).
Reductions in peak flows caused by flood control operations at USACE projects within the Middle Fork Willamette River and its Coast Fork Willamette River tributary have contributed to the loss of habitat complexity in the Middle Fork Willamette River by substantially reducing the magnitude of the channel-forming dominant discharge (i.e., the 1.5- to 2-year flood) and greatly extending the return intervals of larger floods. Over time, flood control tends to reduce channel complexity (e.g., reduces the frequency of side channels, and woody debris recruitment) and reduces the movement and recruitment of channel substrates. Side channels, backwaters, and instream woody debris accumulations have been shown to be important habitat features for rearing juvenile salmonids. Operation of USACE’s dams is only partly responsible for the reduction in channel complexity noted in the Middle Fork Willamette River. Bank stabilization measures and land leveling and development in the basin have directly reduced channel complexity and associated juvenile salmon rearing habitat (see Section 4.2.3.4.1). Because of its unconfined nature, the river reach downstream from Dexter Dam has the greatest potential for alteration of its channel due to flow. As a result, however, reductions in peak flows affect it more strongly than other portions of the river, making it more susceptible to reductions in channel complexity.

Controlling peak flows prevents the flushing of fine sediments that accumulate on the river bed. Interstitial sediments finer than 1 mm can decrease the hydraulic conductivity of spawning gravels, reducing intragravel flow and the supply of oxygenated water to incubating eggs (Kondolf and Wilcock 1996). Somewhat coarser sediments (1 to 9 mm diameter) can fill interstices and physically block emergence of fry from the bed. Aquatic invertebrates also use open interstices in cobbles and gravel, and fine sediment can eliminate this habitat. The potential reduction in interstitial spaces may also affect juvenile salmonids, which are known to use interstitial spaces for cover during winter periods (Bjornn and Reiser 1991).

Controlling peak flows may beneficially affect incubating Chinook eggs and alevins by reducing the potential for redd scouring.

**4.2.3.2.2 Altered Flow Effects on Spawning Success**

Under the current project operations, when adults select spawning sites in late summer and early fall, the USACE releases higher flows than natural flows to draft the reservoirs for flood control. These higher flows allow the fish to select higher elevation spawning sites than would otherwise be available. Then, following spawning, lower minimum flows during active flood control operations during the winter can dewater these high-elevation redds, prior to emergence (USACE 2000, §6.1.1.6.; USACE 2007a, p 5-29). Depending on the duration and rate of desiccation, dewatering salmon redds can kill incubating eggs and alevins (Reiser and White 1983). The potential for these project-caused effects is greatest in the river reaches immediately below the dams (USACE 2000, §6.1.1.6.)

Taylor observed this effect below Dexter Dam when Chinook salmon spawned at higher elevation sites during high discharges, and then these redds were exposed when flows dropped during the incubation period (Taylor 2008a). This adverse effect is of particular concern below Dexter, where the last remaining naturally-accessible spawning area exists for fish that historically spawned above this site. There is less spawning habitat available below Fall Creek dam, and as noted above, ODFW transports all collected fish to release locations above the dam rather than leave them to spawn in this more unsuitable habitat. However, the USACE notes that adults have been stranded during some historical abrupt flow variations from 150 cfs to 50 cfs,
and bank stability and invertebrate production might have also been adversely affected during ramping (USACE 2000, §6.1.1.10.)

4.2.3.2.3 Flow Fluctuations, Entrapment, and Stranding

The Middle Fork Willamette River is subject to rapid water level fluctuations, particularly when flows are reduced abruptly to prevent downstream flooding. Discharges can also fluctuate over the course of the day to meet peak demand for power generation. At the Hills Creek project, discharge can vary between 300 and 1,500 cfs daily depending on seasonal conditions, although the facility is operated primarily as a base load project with relatively steady flows. Historically, the USACE limited ascending ramp rates at Hills Creek to protect the public from dangerous surges in river elevation downstream, but the downramping rate was allowed to reach 4,000 cfs per half-hour. Discharge due to load-following operations at Lookout Point Dam varies between zero and 8,100 cfs over a 24-hour period, but these fluctuations are re-regulated at Dexter Dam downstream. Historically, the maximum permissible downramping rate at Dexter Dam ranged between 700 and 5,000 cfs per hour during high flow periods, and between 300 and 700 cfs per hour during low flow periods. During low flows, ramping rates at Lookout Point Dam were designed to limit the rate of fall in tailwater surface elevations to 0.3 feet per hour and 0.5 feet per day (USACE 1989a).

Ramping operations at Lookout Point and Hills Creek dams were modified in 2006 to reduce fishery impacts. Currently, USACE attempts to maintain ramping rates of 0.1 ft. per hour at night and 0.2 ft. per hour during daylight hours except during active flood damage reduction operations. However, the USACE noted (USACE 2007a Table 3-5 footnote for nighttime ramping rates) that at lower flows several of their dams are unable to conform to recommended ramping rates. For example, at Hills Creek Dam on the Middle Fork, where flows sometimes can be down to 400 cfs, the USACE is unable to provide the recommended 0.1 ft/hr ramping rate when flows are lower than 1700 cfs, due to equipment limitations (USACE 2000, p. 6-26).

There are no hydropower facilities at Fall Creek Dam and discharge fluctuates primarily during flood control operations. However, in recent years USACE has occasionally sent pulsed discharges (i.e., a maximum of 150 cfs and minimum of 50 cfs within a 24-hour period) downstream to conserve water while trying to provide flows identified by ODFW as beneficial to juvenile salmon rearing (150 cfs). It is not known whether pulsing operations at Fall Creek have stranded and entrapped juvenile salmon or resulted in higher survival as intended.

Juvenile salmonids may become stranded and entrapped when discharge is reduced precipitously during power peaking and winter flood events. Additionally, as noted in this section, the USACE has limited ability to meet ramping rate restrictions at low flows, yet it is at these low flows when juvenile stranding is more likely to be a problem. This issue is of greatest concern downstream from Dexter Dam, the current upstream limit of the UWR Chinook salmon ESU, but may also be a concern in reaches above Dexter and Lookout Point dams for offspring of adult fish outplanted above Dexter Dam. As noted above in Section 4.2.3.1.1, outplanting of adults above Dexter Dam has resulted in natural production in areas upstream from Dexter Dam (Beidler and Knapp 2005). Power peaking operations and rapid discharge reductions at the Hills Creek Project have the potential to strand or entrap offspring of outplanted Chinook salmon in the Middle Fork Willamette from Hills Creek dam to Dexter Dam, including rearing fish in Dexter and Lookout Point reservoirs.
4.2.3.3 Water Quality

4.2.3.3.1 Water Temperature
Changes in seasonal temperature patterns in the lower Middle Fork Willamette River and in lower Fall Creek caused by the artificial reservoirs behind USACE dams have left much of the remaining habitat still accessible to UWR Chinook in the Middle Fork subbasin poorly suited to natural production.

The only remaining spawning habitat naturally accessible to spring Chinook are the areas below Dexter Dam and Fall Creek Dam (the extreme downstream area of the watershed as shown in Figure 4.2-1). Historically, spawning of spring Chinook was very unlikely in these lower reaches (Mattson 1948). The temperature regime of water released from the dams is significantly different than natural stream temperatures that the fish are naturally adapted to, as represented by water temperature of flow coming into the reservoir from upstream. Water released from the dams is colder mid-summer and warmer in the fall than streamflow entering the reservoir (Figure 4.2-7). Consequently, eggs incubating in the gravel below the dams are exposed to unnaturally high temperatures and the result has been a very low survival rate. Taylor and Garletts (2007) reported a 100% mortality rate of eggs incubating below Dexter Dam, compared to a 20% mortality rate of eggs incubating above the dam at the hatchery (Figure 4.2-8).

![Figure 4.2-7](typical_stream_temperature_effect_downstream_from_willamette_dams.png)

**Typical stream temperature effect downstream from Willamette dams**
(data from C. Willis, USACE 2007)

- **N Fk Santiam above**
- **N Fk Santiam below**

**Legend:**
- Warmer than normal
- Colder than normal

**Biological Result:** significant egg/alevin mortality from warm water. Fish that do survive emerge earlier during harsh winter conditions.

*Figure 4.2-7 Typical example of altered stream temperature regime below Willamette flood control dams. Even though this data is specifically from the North Santiam subbasin, it is representative of the pattern observed in all Willamette subbasins.*
Impacts of warm water temperatures on spring Chinook egg survival
(data from Taylor and Garletts, USACE 2007)

<table>
<thead>
<tr>
<th>Location</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willamette Hatchery</td>
<td>81%</td>
</tr>
<tr>
<td>(upstream, natural temperature)</td>
<td></td>
</tr>
<tr>
<td>Below Dexter Dam</td>
<td>0%</td>
</tr>
<tr>
<td>(downstream; altered temperatures)</td>
<td></td>
</tr>
</tbody>
</table>

- 3,200 eggs from the same 32 pairs
- incubated in different locations
- monitored survival, incidence of fungus

Figure 4.2-8 Comparison of spring Chinook egg survival above and below Dexter Dam. Data from Taylor and Garletts 2007, USACE 2007a.

Water Temperature affected by Dexter & Lookout Point Dams
Operations of the Dexter/Lookout Point dam complex have altered the temperature regime below Dexter Dam. The temperature of water flowing into Lookout Point Reservoir peaks at 62°F (16.7°C) in July, while outflow temperatures peak at 59°F (15°C) two months later (USACE 2000, p. 6-55). The ODEQ’s 2004/2006 Integrated Report database indicates there are insufficient data to determine if summer maximum temperatures for core rearing (summer rearing that occurs in the most important juvenile production areas, 61°F or 16°C) and non-core rearing and adult and juvenile migration (64°F or 18°C) are exceeded in the mainstem Middle Fork Willamette River below Dexter Dam. However, the altered temperatures have led to warmer water releases during fall, which leads to poor egg survival. In November, 1971, observers counted 219 spring Chinook redds in the first mile below Dexter, but many of the eggs were coated with fungus (ODFW 1990a).

Both average daily inflow and outflow temperatures reach the 52°F (11°C) threshold for upstream salmon migration in mid-May. A TMDL for the Willamette Basin was approved for temperature in 2006 (ODEQ 2006a). In this TMDL, ODEQ identified target temperatures for releases below Dexter/Lookout Point Dams, based on stream temperature inputs to the reservoirs and representing natural temperature regimes prior to dam construction (Table 4.2-4).
As illustrated in Table 4.2-4 (above), the Dexter/Lookout Point dam complex modifies natural temperature patterns in downstream reaches. These modifications include colder summer water temperatures (June- July) and warmer fall water temperatures (September- October).

**Water Temperature affected by Fall Creek Dam**

Similar water temperature patterns have been observed below Fall Creek Dam as below Dexter Dam: water is cool in the spring and warm in the fall (USACE 2000). The ODEQ 2004/2006 Integrated Report database indicates exceedences of summer maximum temperatures for core cold-water habitat (rearing) (61°F; 16°C) above and below Fall Creek Dam. The USACE (2000) does not indicate when the crucial temperature of 52°F (11°C) for upstream migration is reached below Fall Creek Dam, and it is unclear from the information available in the ODEQ 2004/2006 database. Although there are no pre-project temperature data for Fall Creek Dam, it is still possible to consider temperature effects of the dams by using known temperature requirements for spring Chinook salmon. In the TMDL, ODEQ identified target temperatures for releases below Fall Creek Dam, based on stream temperatures inputs to the reservoirs and representing natural temperature regimes prior to dam construction (ODEQ 2006a, Table 4.2-5).

**Table 4.2-4 Monthly Median seven-day rolling average temperatures downstream of Dexter/Lookout Point dams, and established ODEQ monthly target temperatures for salmon (ODEQ 2006a). No data presented for December through March; allocations/targets were not determined necessary for November through March.**

<table>
<thead>
<tr>
<th>Month</th>
<th>Dexter/Lookout Point Release Temperatures</th>
<th>ODEQ Target for Dexter/Lookout Point Releases</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>8.7</td>
<td>6.5</td>
</tr>
<tr>
<td>May</td>
<td>9.5</td>
<td>8.6</td>
</tr>
<tr>
<td>June</td>
<td>11.7</td>
<td>13.2</td>
</tr>
<tr>
<td>July</td>
<td>14.0</td>
<td>17.4</td>
</tr>
<tr>
<td>August</td>
<td>16.9</td>
<td>16.5</td>
</tr>
<tr>
<td>September</td>
<td>18.3</td>
<td>13.9</td>
</tr>
<tr>
<td>October</td>
<td>15.9</td>
<td>10.2</td>
</tr>
<tr>
<td>November</td>
<td>12.3</td>
<td>10.2</td>
</tr>
</tbody>
</table>

**Table 4.2-5 Monthly Median seven-day rolling average temperatures downstream of Fall Creek Dam, and established ODEQ monthly target temperatures for salmon (ODEQ 2006a, Chapter 4). No data presented for December through March; allocations/targets were not determined necessary for these months.**

<table>
<thead>
<tr>
<th>Month</th>
<th>Fall Creek Dam Release Temperatures</th>
<th>ODEQ Target for Fall Creek Dam Releases</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>7.5</td>
<td>6.5</td>
</tr>
<tr>
<td>May</td>
<td>11.3</td>
<td>8.6</td>
</tr>
<tr>
<td>June</td>
<td>14.0</td>
<td>12.2</td>
</tr>
<tr>
<td>July</td>
<td>17.2</td>
<td>15.9</td>
</tr>
<tr>
<td>August</td>
<td>16.6</td>
<td>15.8</td>
</tr>
<tr>
<td>September</td>
<td>9.8</td>
<td>13.5</td>
</tr>
<tr>
<td>October</td>
<td>12.9</td>
<td>10.6</td>
</tr>
<tr>
<td>November</td>
<td>10.8</td>
<td>10.6</td>
</tr>
</tbody>
</table>
Water Temperature affected by Hills Creek Dam

Hills Creek Dam, located upstream of the Lookout Point/Dexter complex, influences water temperature in the mainstem Middle Fork Willamette between the dam and the head of Lookout Point Reservoir. Although effects decrease substantially downstream of Hills Creek Dam with the moderating effect of tributary inflow (USACE 2000), in general spring and summer (mid-April through mid-September) releases are cooler than inflow and fall and winter releases are warmer than inflow (USACE 2000, Figure 6-11). Data collected 13 miles below Hills Creek Dam, below the mouth of the North Fork Middle Fork Willamette, show that average water temperatures have been as much as 6°F (3.4°C) cooler than historically during the summer and as much as 4°F (2.2°C) warmer in the fall (USACE 2000, Figure 6-12). The ODEQ’s 2004-2006 Integrated Report database\(^2\) indicates exceedences of maximum temperature criteria for both cold water habitats (61°F; 16°C) and salmonid spawning (55°F; 13°C) in reaches above Hills Creek Reservoir. These temperature changes can delay upstream migration rates of the Chinook outplanted above Dexter/Lookout Point Dams and result in high egg mortality during incubation (similar to the results found below Dexter Dam mentioned above).

The target water temperatures below Hills Creek Dam identified in ODEQ’s TMDL are compared to existing monthly temperatures in 4.2-6.

<table>
<thead>
<tr>
<th>Month</th>
<th>Hills Creek Release Temperatures</th>
<th>ODEQ Target for Hills Creek Releases</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>7.8</td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>7.9</td>
<td>11.0</td>
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<tr>
<td>July</td>
<td>8.6</td>
<td>14.2</td>
</tr>
<tr>
<td>August</td>
<td>11.0</td>
<td>13.6</td>
</tr>
<tr>
<td>September</td>
<td>16.0</td>
<td>12.5</td>
</tr>
<tr>
<td>October</td>
<td>9.6</td>
<td></td>
</tr>
<tr>
<td>November</td>
<td>9.6</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.2-6 Monthly Median seven-day rolling average temperatures downstream of Hills Creek Dam, and established ODEQ monthly target temperatures for salmon (ODEQ 2006a, Chapter 4). No data presented for December through March; allocations/targets were not determined necessary for November through March.

Water Temperature Control & Site-Specific TMDL Requirements

Operating projects to optimize temperature conditions downstream for fish is often inconsistent with TMDL temperature targets, even with a temperature control tower such as the one constructed at Cougar Dam. Experience in implementing water temperature control operations in the Sound Fork McKenzie River downstream of Cougar Dam to achieve more normative water temperatures suggest that special site-specific considerations may be required for such actions with respect to achieving ODEQ TMDLs. An operational requirement for successfully avoiding high temperature discharges in the fall (i.e., during spring Chinook salmon incubation) is to evacuate as much warm surface water as possible from the reservoir throughout the summer months while operating within the range of appropriate downstream temperature criteria for each month identified by ODFW. That is, it is necessary to balance the effect of warm water temperatures downstream of the dam across the spring, summer and fall periods to achieve the

\(^2\) [http://www.deq.state.or.us/wq/assessment/rpt0406/search.asp](http://www.deq.state.or.us/wq/assessment/rpt0406/search.asp)
most appropriate overall biological effect. In the South Fork McKenzie River, the requirement resulted in summer water temperatures below Cougar Dam that were will above the draft TMDLs identified by ODEQ during April through September (Figure 4.3-6) in order to provide more favorable temperatures during the critical incubation period in the fall. A focus on achieving the cooler TMDL temperature targets during summer would have adversely affected the temperature conditions achievable during the fall spawning and incubation period for spring Chinook because more warm surface water would have been retained in the reservoir over summer.

**Water Temperature in Reaches above Project Dams and Reservoirs**

The ODEQ 2004/2006 Integrated Report database indicates exceedences of maximum temperature criteria for both cold water habitats (61°F; 16°C) and salmon and steelhead spawning (55°F; 13°C) in reaches above the Willamette Project, including the upper Middle Fork Willamette above Hills Creek Reservoir; Salt Creek; the North Fork of the Middle Fork Willamette; Lost Creek; and Fall Creek above Fall Creek Reservoir. A TMDL for the Willamette Basin was approved for temperature in 2006 (ODEQ 2006a).

4.2.3.3.2 Total Dissolved Gas

Another important water quality parameter affected by the USACE dams is total dissolved gas (TDG). Releasing water from the dam spillways and regulating outlets can entrain atmospheric gasses, which can enter into solution at concentrations above the natural saturation level – termed total dissolved gas supersaturation. High TDG (above 120% saturation) can cause gas bubble trauma disease in fish and can cause mortality of eggs and juvenile fish if exposure is prolonged or acute. Monk et al. (1975) measured total dissolved gas levels of 104.9% (March 1972) to 125.5% of saturation (June 1970) within 0.3 miles below Dexter Dam and levels between 109.2% and 112.5% at sites 2.3 and 4.6 miles downstream (March 1972). USACE (1998) determined that dissolved gas levels were minimized when spilled water (1,200 to 8,000 cfs) was distributed across all of the spill gates. Total dissolved gas levels measured 2 miles downstream were generally less than 110% of saturation. Levels within the tailrace were 108.6% to 121.5% downstream of the turbine outlet works, and 107.3% to 119.0% downstream of spill gate number 7. Fish caught along the left bank (next to spill gate 7) and in the Dexter holding ponds during the study did not show signs of gas bubble disease (USACE 1998). Spring Chinook salmon yolk sac fry could be present below Dexter during March, but the USACE has not assessed the risk of gas bubble trauma at this location. Chinook spawning also occurs in the areas below Dexter Dam. It is unknown how the incubating eggs are affected by total dissolved gas, but since supersaturation has been reported downstream, it is likely eggs are affected.

4.2.3.4 Physical Habitat Characteristics

Generally, rearing UWR Chinook salmon use stream areas with large woody debris, gravel, and complex channel habitat. Spawning fish select redd sites with large gravel to cobble substrates and also benefit from channel complexity as complexity improves intragravel flows and the retention of suitable substrates. The general relationships between large wood, sediment transport, and channel complexity and the habitat requirements of UWR Chinook salmon are described in detail in Appendix A. Construction and operation of the USACE dams in the Middle Fork Willamette River subbasin has significantly impacted the quantity and quality of UWR Chinook habitat downstream from the dams; and, except for a small outplanting program, the dams have blocked access to more suitable upstream habitats. The large reservoirs behind
the dams have inundated many miles of spring Chinook salmon spawning and rearing habitat in the watershed.

4.2.3.4.1 Habitat Conditions Downstream from Dexter, Lookout Point, & Hills Creek Dams
Following completion of the four Willamette Project dams in the Middle Fork Willamette basin, the amount of large wood in the stream channel has decreased, composition size of the substrate has increased on average, and stream beds have become channelized and less complex.

Substrate
Prior to the construction of Dexter, Lookout Point, and Hills Creek Dams, the lower Middle Fork Willamette River was described as having large areas of gravel bars and riffles with gravel and cobble substrates (USACE 2000). Parkhurst et al. (1950) noted that the lower river had an extensive floodplain with up to five different channels. The construction of the four USACE dams in the subbasin deprives lower Fall Creek and most of the mainstem Middle Fork Willamette River of sediment and large wood. Dexter-Lookout Point Dams and Hills Creek Dam, completed in 1954 and 1961, respectively, trap sediment and large wood from approximately 1,000 square miles. Fall Creek Dam, completed in 1966, traps sediment and large wood from nearly another 200 square miles. Together, these projects have reduced the area contributing sediment and large wood to the lower Middle Fork Willamette River by approximately 90%. The only remaining tributaries that contribute sediment and large wood are Little Fall Creek, a tributary to Fall Creek below the dam, and several small streams including Lost Creek. In the Middle Fork Willamette River below Hills Creek Dam and below Dexter Dam, the reduction in sediment supply has most likely resulted in substrate coarsening and channel downcutting. For example, ODFW has recently observed that the mouths of tributaries below the dams are perched above the Middle Fork Willamette channel, an indication of channel downcutting (USACE 2000).

Large Wood
Along the lower mainstem Middle Fork Willamette River, about 24% of the total length of the riparian corridor along the mainstem has high large wood recruitment potential, about 50% has moderate recruitment potential, and the remaining 26% has low recruitment potential (MFWWC 2002). Additionally, nearly half of the tributaries along the lower Middle Fork have low large wood recruitment potential, and only 25% are rated as having high large wood recruitment potential. Many riparian areas in the lower reaches of these drainages include non-native blackberry and other invasive weeds that prevent proper development of riparian forests, and many of the areas dominated by these species lack adequate stream shading.

Dykaar (2005) reviewed survey data from 1938 through 2004 in the lower mainstem Willamette River, and concluded that large woody debris jams have been nearly eliminated since the Project dams were constructed (Figure 4.2-9).
Channel Complexity, Off-Channel Habitat, Floodplain Connectivity
Andrus and Walsh (2002) described changes in channel conditions in the lower Middle Fork Willamette River below Dexter Dam in the Eugene/Springfield area by air photo analysis. Overall, most of the reaches showed loss of sinuosity, side channel length, alcoves, and gravel bars, which indicates an overall loss of channel complexity in the lower river (Dykaar 2005, Figure 4.2-10). Gravel bar surface area decreased by 65%, and alcove length decreased by 35% (Table 4.2-7). Reduced gravel bar area reflects the dramatic reduction in channel-forming hydrologic events as a result of flood control in the Middle Fork Willamette. These gravel bars are colonized by riparian vegetation, which stabilizes the features and further inhibits movement and creation of new bars. Additionally, 50% of the lower 8 miles of the Middle Fork are protected by levees or revetments, which has likely increased the transport capacity of the river and facilitated further downcutting and floodplain isolation (USACE 2000).
Alcoves, side channels, and overall channel complexity have decreased significantly in the mainstem Middle Fork Willamette downstream of Dexter Dam, such that gravel bar area is only 35% of its extent in 1944. Due to peak flow reduction and sediment deprivation, it is likely that the bed material has coarsened downstream of Dexter Dam. The loss of complexity and coarsening of bed material could limit available spawning area downstream of Dexter, which could limit production in the Middle Fork, even if the temperature-related problems downstream of Dexter are resolved. Some spawning habitat is available in Fall Creek, but some areas have been scoured down to bedrock and while containing adequate resting pools, do not have a good supply of gravel and cobble, which could limit both spawning and rearing in the drainage. Half of the drainages within the upper Middle Fork drainage have embeddedness ratings that exceed the viable standards for salmonid spawning and incubation, which is 20% (WNF BRBD 1996), which could hinder spawning success if this habitat is made available to anadromous salmonids.
Willamette National Forest Lowell Ranger District (WNF LRD 1997) studied changes in the Middle Fork Willamette River channel in the five mile reach above Lookout Point Reservoir from 1944 to 1996. This reach is approximately 15 miles below Hills Creek Dam, which began operation in 1961. Aerial photos from 1944 indicate a sinuous, braided channel meandering across the valley bottom throughout most of this reach. Before the dam was built, the main channel and side channels shifted in response to floods that inundated the wide floodplain. After the dam was built, peak flows and bedload sediment delivery were reduced, grossly affecting the rate and nature of channel dynamics. This has resulted in the development of a single, simplified channel as old side channels have been abandoned and the river has lost its ability to create new side channels and other floodplain features (WNF LRD 1997).

### 4.2.3.5 Habitat Conditions in Reaches above Dexter, Lookout Point, and Hills Creek Dams

Land management and other activities over the last century in the Middle Fork Willamette watershed has reduced watershed function and degraded stream habitat. Above Dexter/Lookout dams (the lowermost dams), the watershed is predominately forested, federal land under the jurisdiction of the U.S. Forest Service-Willamette National Forest (WNF). Road building and timber harvest has been extensive in this area with associated adverse effects on stream habitat (Meehan and Bjornn 1991).

**Substrate**

Above the Project dams, sediment delivery and transport through streams is reflective of natural processes. These processes have been modified within some areas by wood removal or other activities, but a strong emphasis on aquatic conservation in the federally managed areas that predominate above the dams is anticipated to lead to more desirable conditions through time.

**Large Wood**

In many of the Middle Fork Willamette tributaries above Dexter and Lookout Point dams as well as the mainstem Fall Creek above Fall Creek Dam, large wood and pool levels are below Willamette National Forest (WNF) objectives, indicating that holding and rearing habitat quality is not ideal (WNF ORD 1995). The WNF initiated restoration efforts (in the form of large wood placement) in many tributaries which should facilitate habitat formation and maintenance.

**Channel Complexity, Off-Channel Habitat, Floodplain Connectivity**

In combination with watershed disturbance, flooding has also strongly affected channel characteristics in the Middle Fork watershed. For example, during the 1964 flood, landslides in tributaries of the Middle Fork, primarily associated with timber harvests and roads, contributed large quantities of sediment to the Middle Fork. As a result, the channel widened between 25% and 250%, with most channel widening and creation of side channels occurring near tributary junctions (Lyons and Beschta 1983). Large wood decreased following the 1964 flood, which Lyons and Beschta (1983) attribute to a combination of downstream transport, burial in sediment as the channel aggraded, and intentional salvage log removal. Since the 1970's, the channel has gradually narrowed as the aggraded alluvium was colonized by vegetation.
Riparian vegetation in the Middle Fork Willamette subbasin varies by drainage due to natural differences in geology, precipitation, elevation, and fire regimes, and by man-caused factors including: timber harvesting, road building, and land use.

Over 35% of riparian reserves in the upper Middle Fork drainage have been harvested, but over 41% remain in mature or old growth. The Swift Creek drainage has the least amount of mature riparian vegetation, but its headwaters contain some mature riparian vegetation located in the Diamond Peak Wilderness (WNF RRD 1996). Historically, nearly all riparian areas in the upper Middle Fork consisted of mature coniferous vegetation, but much has been replaced with either smaller-diameter or deciduous trees that do not perform the ecosystem functions described in Appendix A.

Although physical habitat characteristics in much of the Middle Fork’s headwater streams is currently suboptimum, these streams are still functional and productive for salmon spawning and rearing and represent the best remaining habitat in the basin. The cooler, forested headwater habitat above Dexter/Lookout Dams is highly suitable for adult spring Chinook holding throughout the summer and spawning in the fall. Because these areas are predominately U.S. Forest Service land managed under the Aquatic Conservation Strategy of the Northwest Forest Plan, watershed processes are improving and these streams will continue to provide the best potential for providing quality habitat into the future.

**Conclusion:** Middle Fork Willamette habitat conditions in the baseline, especially in the reaches below Dexter and Fall Creek dams, are severely degraded. Large wood is depleted, decreasing the number of pools used for adult holding and juvenile rearing habitat. Channels have lost much of their complexity, decreasing the number of side channels normally used for juvenile rearing and refugia. Riparian vegetation has been modified, decreasing its value to salmon because the vegetation helps shade the streams and hold back sediment.

### 4.2.4 Hatchery Programs

Hatchery Chinook salmon were first released in the Middle Fork Willamette subbasin in 1919 (ODFW 1990a). Before 1950, two temporary collecting racks were set up in the Middle Fork each year, one about 2 miles above the town of Oakridge and the other 1 mile above the mouth of Salmon Creek (Mattson 1948; ODFW 1990a). Little is known about the contribution of hatchery releases to natural production during this period, but few adults are thought to have returned from releases made before the 1960s due to poor hatchery practices (Howell et al. 1985; ODFW 1990a).

The Willamette Hatchery was built to mitigate lost natural production of spring Chinook in the Middle Fork Willamette due to the construction and operation of Fall Creek, Dexter, Lookout Point, and Hills Creek dams and reservoirs. Since Fall Creek and Dexter Dams were completed and blocked upstream passage, hatchery broodstock has been collected at the base of the dams. It is likely the returns of wild Chinook declined precipitously shortly after the dams were built because more than 90% of their historic habitat was lost. Hatchery fish returns comprised a greater and greater proportion of the return to the Middle Fork Willamette. Presently nearly all of the Chinook are of hatchery-origin; although some natural-origin fish are still collected and passed upstream of Fall Creek Dam. Due to the significant temperature problems described above in section 4.2.3.3.1, successful natural reproduction below Dexter and Fall Creek dams is
minimal by Chinook of either hatchery- or natural-origin. Hatchery fish represent nearly all of the spawners observed below Dexter and Fall Creek Dams.

The original hatchery program was initiated to support harvest in freshwater and ocean fisheries. However, following the listing of the species as threatened under the ESA, efforts began to transform the program into a conservation/supplementation role, due to the poor status of this population. The current hatchery program is being used to evaluate the potential for the reintroduction of Chinook to their historic habitat above the dams (USACE 2007a). Due to extremely poor natural reproduction and the dominance of hatchery-produced fish in the run, hatchery fish likely contain the only genetic remnants of the historic run available. These fish are the only remaining source of fish for outplanting efforts. The results of the outplanting program have been mixed (Beidler and Knapp 2005). Natural reproduction by hatchery fish has been observed in historic habitat upstream of the dams. However, prespawning mortality of the adults trapped at the base of the dams, trucked upstream, and released has been very high (see 4.2.3.1.1 for expanded explanation). This results in fewer successful redds in habitat above the dams, and is currently limiting the productivity of this outplanting program.

The hatchery program is also being reformed into an integrated broodstock, where the broodstock incorporates natural-origin fish on a regular basis so that the hatchery broodstock is as similar as possible to the natural-origin population. However, due to the extremely low numbers of natural-origin fish observed recently in this population, significant improvements are needed in the key and secondary limiting factors before this broodstock can be fully integrated. Recently, less than 1% of the broodstock has been natural-origin fish (Schroeder et al. 2006).

Hatchery programs in the Middle Fork Willamette continue to pose risks and some potential benefits to natural-origin Chinook salmon. Having all hatchery fish marked since 2001 has facilitated determining the status of natural-origin fish in this population. Hatchery fish will continue to represent the majority of natural spawners in this population until other limiting factors are addressed that allow natural production to increase.

### 4.2.5 Fisheries

UWR Chinook salmon returning to the Willamette River have supported many commercial and recreational fisheries, which contributed to their decline. In the past, harvest of natural-origin spring Chinook was permitted. However, recently fisheries management has focused on protecting natural-origin stocks, and more conservative fishing regimes have been implemented. In the past, cumulative harvest rates of spring Chinook salmon in ocean and freshwater fisheries have been high. Until recently spring Chinook salmon were subjected to relatively intense commercial and recreation fisheries in the lower Columbia and Willamette rivers that were directed primarily at the abundant hatchery-origin fish. Terminal area exploitation rates (the fishery impact to natural-origin fish) have been on the order of 40-50% in past years (Figure 4.2-11). Fishery objectives in the Willamette River have also changed to emphasize the protection of natural-origin fish. The State of Oregon developed a Fisheries Management and Evaluation Plan under NMFS’ 4(d) Rule for the management of spring Chinook salmon fisheries in the Willamette River. This management plan specifies the harvest regime for spring Chinook salmon and has been approved by NMFS under the ESA. Total exploitation rates in commercial and sport fisheries occurring in freshwater are capped at 15%. However, fishery impacts since implementation of catch-and-release fisheries for wild spring Chinook have been in the range of
8-12% (Kern 2006). Impacts on natural-origin spring Chinook have been significantly reduced, yet the overall harvest of hatchery-origin fish has remained relatively high; emphasizing the benefits of selective fisheries to wild fish conservation and fishery harvest (Figure 4.2-12).

**Figure 4.2-11** Exploitation rates of Willamette spring Chinook in freshwater commercial and sport fisheries. Data from Kern (2006).

![Graph showing exploitation rates of Willamette spring Chinook in freshwater commercial and sport fisheries](image)

**Figure 4.2-12** Freshwater fishery impacts and harvest of Willamette spring Chinook salmon before and after implementation of selective fisheries (where only adipose finclipped, hatchery Chinook can be retained). Data from Kern (2006).

![Graph showing freshwater fishery impacts and harvest of Willamette spring Chinook salmon](image)

Willamette spring Chinook salmon have a unique ocean distribution for a Columbia Basin spring Chinook stock. Willamette Chinook are a far north migrating stock and so are caught primarily in Southeast Alaska (SEAK) and North Coast British Columbia (NCBC) fisheries (Figure 4.2-
13). They return back to freshwater earlier than most other stocks and thus they tend to be missed by more southerly ocean fisheries off West Coast Vancouver Island, Washington and Oregon Coasts. The average exploitation rates of Willamette Chinook in ocean fisheries during the 1990’s was 17%. The exploitation rates agreed to in the Pacific Salmon Treaty (PST) between the U.S. and Canada is 10-20%. However, the PST is being renegotiated and a new agreement expected in 2008.

**Figure 4.2-13**
Distribution of Willamette spring Chinook salmon coded wire tag recoveries in ocean fisheries. Data from Myers et al. (2006).

### Conclusion
Impacts of fisheries on natural-origin UWR Chinook salmon have been significantly reduced, yet the overall harvest of hatchery-origin fish has remained relatively high; emphasizing the benefits of selective fisheries to wild fish conservation and fishery harvest.
4.2.6 Status of PCEs of Designated Critical Habitat and Factors Affecting those PCEs in the Middle Fork Willamette Subbasin

NMFS has determined that the following occupied or potentially occupied areas of the Middle Fork Willamette subbasin either contain or do not contain Critical Habitat for UWR Chinook, as indicated (NMFS 2005d; maps are included in section 3.3 of this Opinion):

- Habitat of high or medium conservation value for these fish, and deemed important to their recovery, is present in 9 of the 10 watersheds within the Middle Fork subbasin (NMFS 2005g). In aggregate, these nine watersheds contain 166.1 miles of PCEs for spawning rearing, 98.8 miles of PCEs for rearing/migration, and 5.4 miles for migration/presence (NMFS 2005g). All nine of the watersheds containing these PCEs were designated as Critical Habitat (NMFS 2005d), as described below:
  - Seven watersheds (including Fall Creek) that are partly or entirely above USACE dams provide 138.1 miles of spawning/rearing habitat, 83.4 miles of rearing/migration habitat, and 5.4 miles of migration habitat (NMFS 2005g). This includes 188 miles of Critical Habitat above USACE dams that is accessible to UWR Chinook only through experimental trap-and-haul programs. The blocked habitat (70% of that designated) historically produced over 90% of the Chinook salmon from this subbasin.
  - The Fall Creek watershed, which includes Fall Creek Dam on Fall Creek at Mile 7.0, contains 24.2 miles of spawning/rearing habitat, 14.1 miles of rearing/migration habitat, and 5.1 miles of migration/presence critical habitat (NMFS 2005g). Approximately 36.5 miles (84%) of this habitat is above Fall Creek Dam.
  - Two watersheds that are as accessible to UWR Chinook today as they were historically, Lower Middle Fork Willamette and Little Fall Creek, contain 28.0 miles of spawning/rearing habitat and 15.4 miles of rearing/migration habitat (NMFS 2005g).

- The Salmon Creek watershed, which NMFS (2005g) identified as containing 2.8 miles of PCEs for spawning/rearing, was excluded from the critical habitat designation (NMFS 2005d), as described in section 3.3.

Bank protection measures associated with USACE activities total 30,742 linear feet (5.82 miles) of riverbank within the lower 8.5 miles of the Middle Fork Willamette River (USACE 2000). These measures all affect spawning/rearing habitats designated as Critical Habitat.

NMFS (2005g) identified the key management activities that affect these PCEs. Key management activities include forestry, dams, road building and maintenance, channel modifications/diking, dams, agriculture.

Four large-scale dams have been constructed in the Middle Fork subbasin: Dexter/Lookout Point, Hills Creek, and Fall Creek dams. Dexter/Lookout Point and Fall Creek dams blocked access to upstream spawning and rearing habitats representing over 90% of the historical production areas, reduced downstream migrant survival, altered flows downstream, reduced or eliminated marine-derived nutrients from these upper watersheds, and limited the downstream transport of habitat building blocks. These dams have negatively altered downstream water temperatures and habitat through the mainstem Middle Fork and Fall Creek below each dam since the 1960s. These dams have also adversely affected upstream habitats by inundation of over 30 miles of riverine habitats for the four reservoirs.
Table 4.2-8 summarizes the condition of PCEs within the Middle Fork Willamette River. Many of the habitat indicators are not in a condition suitable for salmon conservation. In most cases, this is primarily the result of the past operation and the continuing effects of the existence of the Project dams as well as the effects of other human activities (e.g., development, agriculture, and logging).
Table 4.2-8  Critical habitat primary constituent elements (PCEs) and associated pathways, indicators, current conditions, and limiting factors for the Middle Fork Willamette River Watershed under the environmental baseline.

<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Causative Factors</th>
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</thead>
<tbody>
<tr>
<td>Freshwater migration</td>
<td>Habitat</td>
<td>Physical</td>
<td><em>Barriers Below Dexter and Fall Creek Dams</em></td>
<td>Privately owned dams</td>
</tr>
<tr>
<td>corridors</td>
<td>Access</td>
<td>Barriers</td>
<td>Canal to Springfield mill pond (N44.0263/W 122 9760), located 2.5 miles above confluence with Coast Fork. This dam no longer exists, but its canal still diverts water through an industrial area in Springfield with a mill pond, near South A street in Springfield.</td>
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<tr>
<td>Freshwater migration</td>
<td>Habitat</td>
<td>Physical</td>
<td><em>Fall Creek Dam as a Barrier to Upstream Migration</em></td>
<td>USACE project (Fall Creek)</td>
</tr>
<tr>
<td>corridors</td>
<td>Access</td>
<td>Barriers</td>
<td>Most adult spring Chinook salmon and some winter steelhead trapped at Fall Creek Dam were trucked to McKenzie and other hatcheries; some released at a site two miles above head of reservoir Since 1998, all spring Chinook salmon returning to the collection facility have been released above the dam Upstream migrants could experience abrasion, mechanical injury, stress, migration delay, disease, and low dissolved oxygen concentrations in the trapping and transport facilities 77 (incl. 27 unmarked) spring Chinook were found dead at release site in August 2002 when large run overwhelmed the collection facility, leading to a clogged pipe in the fish transfer truck that resulted in dewatering the fish; USACE has since taken corrective action</td>
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<td>PCE</td>
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</tbody>
</table>
| Freshwater migration corridors | Habitat Access | Physical Barriers | *Fall Creek Dam as a Barrier to Downstream Migration*  
Fish horn apertures on the upstream face of the dam were ineffective  
Chinook smolt recoveries never exceeded 15.6% and winter steelhead emigrated at even lower rates  
USACE passed smolts by draining the reservoir in the fall; 19 to 29% juvenile Chinook survival under this condition compared with 32% through the (mothballed) fish horn system (where most of the survivors had severe head and eye abrasions) | USACE project (Fall Creek)           |
| Dexter/Lookout Point dams as barriers to migration | Habitat Access | Physical Barriers | *Dexter and Lookout Point dams as barriers to migration*  
Neither project built with fish passage facilities  
Upstream migrants trapped at Dexter are trucked to the Willamette Hatchery near Oakridge for spawning  
ODFW began releasing adult spring Chinook into the North Fork of the Middle Fork Willamette in 1999 and 2002, and into Salt Creek in 2001  
The ODFW released Chinook fingerlings into the reservoir to augment the recreational trout fishery; 88% survival through turbines at Lookout Point Survival through the Kaplan turbines at Dexter unknown (may be similar to Foster Dam, 92%) | USACE project (Dexter/Lookout Point) |
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<th>PCE</th>
<th>Pathway</th>
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<tr>
<td>Freshwater migration corridors</td>
<td>Habitat Access</td>
<td>Physical Barriers</td>
<td><em>Hills Creek Dam as a Barrier to Migration</em></td>
<td>USACE project (Hills Creek)</td>
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<td>Hills Creek built without fish passage facilities</td>
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<td>ODFW began releasing adult spring Chinook salmon above Hills Creek Reservoir in 1993 and has</td>
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<td>occasionally released hatchery-reared Chinook fingerlings into the reservoir</td>
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<td>41% survival of juvenile Chinook through the turbines;</td>
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<td>68% through the regulating outlet</td>
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<td>Freshwater spawning sites</td>
<td>Water Quantity (Flow/Hydrology)</td>
<td>Change in Peak/Base flow</td>
<td>Frequency of channel-forming flows not of sufficient magnitude to create and maintain channel complexity and provide nutrients, organic matter, and sediment inputs from floodplain areas</td>
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<tr>
<td>Freshwater rearing</td>
<td></td>
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<td>Increased fall flows may allow spring Chinook to spawn in areas that will be dewatered during active flood control operations</td>
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<tr>
<td>Freshwater migration corridors</td>
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<td>Winter and spring flow reductions may have reduce rearing area and the survival of steelhead fry</td>
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<td>Increased summer flows may increase rearing area and moderate naturally warmer water temperatures</td>
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<td>Low summer flows in specific reaches (due to diversions) may reduce the juvenile rearing habitat area, block adult passage to upstream spawning areas, and decrease the heat capacity of the stream</td>
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<td>Flow fluctuations now occur at rates rapid enough to entrap and strand juvenile anadromous fish.</td>
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<td>Flood control operations at USACE’s Fall Creek, Dexter/ Lookout Point, and Hills Creek reservoirs</td>
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<td>Winter flood control and late winter and spring refill operations at USACE reservoirs</td>
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<td>Flow augmentation operations at USACE dams to meet mainstem flow targets</td>
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<td>Summer diversions for out-of-stream uses</td>
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<td>Power peaking at Hills Creek Dam</td>
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<td></td>
<td>Flood control operations at USACE’s Fall Creek, Dexter/ Lookout Point, and Hills Creek dams cause rapid flow reductions</td>
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<tr>
<td></td>
<td>Freshwater spawning sites</td>
<td></td>
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<td>Spring and summer releases from Hills Creek Dam are cooler than inflow; winter releases are warmer than inflow. This cool water delays UWR Chinook migration to spawning areas, and then warm water after spawning accelerates egg development, increasing egg mortality rates.</td>
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<tr>
<td></td>
<td>Freshwater rearing</td>
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<td>USACE operations (Hills Creek)</td>
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<td></td>
<td>Freshwater migration corridors</td>
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<td></td>
<td>USACE operations (Lookout Point/Dexter, and Fall Creek)</td>
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<td></td>
<td>Water Quality</td>
<td>Temperature</td>
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<td>Timber harvest</td>
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<td>Clearing for floodplain development</td>
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<td>USACE operations (Hills Creek)</td>
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</table>

Spring and summer releases from Fall Creek and Lookout Point/Dexter dams are cooler than inflow; fall/winter releases are warmer than inflow. The temperature of water flowing into Lookout Point Reservoir peaks at 62°F (16.7°C) in July, while outflow temperatures peak at 59°F (15°C) in September.

The ODEQ 2004/2006 Integrated Report database indicates exceedences of summer maximum temperatures for core cold-water habitat (rearing) (61°F; 16°C) in Fall Creek.

The ODEQ 2004/2006 Integrated Report database indicates exceedences of maximum temperature criteria for both cold water habitats (61°F; 16°C) and salmon and steelhead spawning (55°F; 13°C) in reaches that are not affected by Willamette Project flow management, including the upper Middle Fork Willamette above Hills Creek Reservoir; Salt Creek; the North Fork of the Middle Fork Willamette; Lost Creek; and Fall Creek above Fall Creek Reservoir.
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<th>PCE</th>
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<th>Condition</th>
<th>Causative Factors</th>
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<tbody>
<tr>
<td></td>
<td>Freshwater spawning sites</td>
<td>Water Quality</td>
<td>The ODEQ 2004/2006 Integrated Report database does not report any streams as water quality limited due to turbidity</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Freshwater rearing</td>
<td>Total Suspended Solids/ Turbidity</td>
<td>The ODEQ 2004/2006 Integrated Report database does not indicate that any streams were water quality limited due to excess nutrients or toxics</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Freshwater migration corridors</td>
<td>Water Quality</td>
<td>The ODEQ 2004/2006 Integrated Report database indicates that Anthony and Lost creeks were water quality limited for dissolved oxygen year round for fish passage, spawning and rearing (ODEQ 2006b).</td>
<td>May be related to causes of elevated temperatures</td>
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<td>PCE</td>
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<td>------------------</td>
</tr>
<tr>
<td>Freshwater spawning sites Freshwater rearing Freshwater migration corridors</td>
<td>Water Quality</td>
<td>Total Dissolved Gas (TDG)</td>
<td>TDG measurements up to 125.5% of saturation within 0.3 miles below Dexter Dam and up to 112.5% at sites 2.3 and 4.6 miles downstream. Spill over approximately 1,000 cfs through 1 spillway bay (there are 7 bays) at Dexter Dam generates more than 115% TDG below Dexter Dam.</td>
<td>USACE operations (Dexter Dam)</td>
</tr>
<tr>
<td>Freshwater rearing sites Freshwater migration corridors</td>
<td>Habitat elements</td>
<td>Pool Frequency and Quality</td>
<td>Pool frequency and quality in the Middle Fork below Dexter Dam and Fall Creek below Fall Creek dam is low due to absence of pool forming elements such as LWD and sediment.</td>
<td>Downstream LWD and sediment transport blocked by project dams, roads, channel scour, land uses such as timber harvest, and diking in the lower river.</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Habitat Elements</td>
<td>Substrate</td>
<td>Substrate has coarsened in the Middle Fork downstream of Dexter Dam Channel downstream of USACE dams could lack spawning gravel USACE reservoirs block sediment into the lower Middle Fork from 90% of the Middle Fork subbasin Current sediment budget not creating and maintaining habitat needed by anadromous salmonids downstream of Dexter Dam</td>
<td>USACE reservoirs trap sediment and large wood from headwaters USACE operates Fall Creek, Hills Creek, Lookout Point, and Dexter Dams to reduce the magnitude and frequency of peak flows USACE and private revetments Gravel mining</td>
</tr>
</tbody>
</table>
## Freshwater rearing sites

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Causative Factors</th>
</tr>
</thead>
</table>
| Habitat elements                             | Large Woody Debris | *In the mainstem Middle Fork*  
Large wood into the lower Middle Fork Willamette River is blocked from 90% of the subbasin  
The lower Middle Fork lacks large wood downstream of Dexter Dam                     | USACE remove large wood from reservoirs  
USACE removed snags in lower river for navigation  
Inadequate recruitment from riparian forests  
Removal of large wood by landowners and boaters for navigation and/or firewood       |
| Habitat elements                             | Large Woody Debris | *In Tributaries and Upper Middle Fork Mainstem*  
Large wood does not meet USFS targets in most low-gradient upper Middle Fork tributaries, most of the North Fork Middle Fork drainage, Salmon Creek, Hills Creek, and the mainstem Fall Creek (WNF ORD 1995)  
Some large wood restoration efforts are underway in the upper subbasin (Salt Creek, Fall Creek) (WNF ORD 1995) | Timber harvesting  
Stream clean-out  
Fire suppression  
Constraint by roads  
Downstream LWD transport blocked by Project dams; historic removal of LWD and logjams |
<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Causative Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Channel conditions and dynamics</td>
<td>Streambanks do not support natural floodplain function in the lower river.</td>
<td>Diking; residential and agricultural land uses; development; timber harvest; reservoir operations.</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Streambank condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater migration corridors</td>
<td>Habitat elements</td>
<td>Middle Fork Willamette River between Lookout Point and Hills Creek Dam is confined primarily to a single channel</td>
<td>USACE operates Fall Creek, Hills Creek, Lookout Point, and Dexter Dams to reduce the magnitude and frequency of peak flows</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater migration corridors</td>
<td>Off-channel habitat</td>
<td>Gravel bar surface area has decreased by 65% below Lookout Point Dam</td>
<td>USACE and private revetments</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater migration corridors</td>
<td>Off-channel habitat</td>
<td>50% of lower 8 miles of the Middle Fork are protected by revetments</td>
<td>USACE and EWEB remove large wood from reservoirs</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater migration corridors</td>
<td>Off-channel habitat</td>
<td>Poor connectivity (generally absent or extremely limited) to off-channel habitat in lower river.</td>
<td>Gravel mining in lower river</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater migration corridors</td>
<td>Off-channel habitat</td>
<td></td>
<td>Diking, dredging, and human development.</td>
</tr>
<tr>
<td>Freshwater rearing</td>
<td>Channel conditions and dynamics</td>
<td>Floodplain connectivity</td>
<td>Floodplain is not frequently inundated, with less over-bank flow and side channel connectivity</td>
<td>USACE operates Fall Creek, Hills Creek, Lookout Point, and Dexter Dams to reduce the magnitude and frequency of peak flows</td>
</tr>
<tr>
<td>Freshwater rearing</td>
<td>Channel conditions and dynamics</td>
<td>Floodplain connectivity</td>
<td>Reduced nutrient exchange, reduced sediment exchange, reduced flood refugia for fish, and reduced establishment of new riparian forests</td>
<td>USACE and private revetments</td>
</tr>
<tr>
<td>Freshwater rearing</td>
<td>Channel conditions and dynamics</td>
<td>Floodplain connectivity</td>
<td>The Middle Fork Willamette is disconnected from its historical floodplain by dikes and flood control operations that have reduced peak flows.</td>
<td>Residential development</td>
</tr>
<tr>
<td>PCE</td>
<td>Pathway</td>
<td>Indicator</td>
<td>Condition</td>
<td>Causative Factors</td>
</tr>
<tr>
<td>-------------------------</td>
<td>------------------</td>
<td>-----------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| Freshwater spawning sites | Freshwater rearing | Watershed Conditions | Disturbance regime is dominated by timber harvesting  
Forests are dominated by early- to mid-successional stages, with few late-successional forests  
Timber harvesting has increased sediment delivery to streams, but decreased large wood input, resulting in degraded aquatic habitat  
Upper watershed is forested, but some is managed for timber production rather than ecosystem health  
Lower watershed is predominantly privately-owned, and while 65% of the lower watershed is managed for timber production, the remainder consists of agricultural, urban, and residential development | Fire suppression  
Timber harvesting  
Conversion to agricultural, urban, and rural uses                                                                                                           |
<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Causative Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pathway</td>
<td>Indicator</td>
<td>Freshwater spawning sites</td>
<td><strong>Headwater forests riparian conditions</strong></td>
<td>Timber harvesting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Freshwater rearing</td>
<td>Riparian areas in some tributaries contain mature riparian vegetation (e.g., small tributaries of Lookout Point Reservoir, Fall Creek) but others (e.g., the North Fork Middle Fork Willamette, Salt Creek, Little Fall Creek, and small tributaries of the lower Middle Fork) are dominated by deciduous trees or conifers</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Freshwater migration corridors</td>
<td>Many tributaries do not provide adequate shading or large wood recruitment</td>
<td>Stream clean-out practices</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Watershed conditions</td>
<td>Decreased extent of streamside riparian vegetation</td>
<td>Extensive inundation of streamside riparian vegetation by USACE reservoir construction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Riparian reserves</td>
<td><strong>Floodplain forest riparian conditions</strong></td>
<td>Clearing for agriculture or development</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Many remaining patches of floodplain forest are interspersed with pastureland, highways, and residential development</td>
<td>USACE and private revetments</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Floodplain forests along lower river invaded by non-native species that hinder development of natural community</td>
<td>USACE’s operation of Fall Creek, Hills Creek, Lookout Point, and Dexter Dams alters the hydrologic regime</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>74% of riparian forests along lower Middle Fork have low or medium large wood recruitment potential.</td>
<td>Timber harvest</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Decreased surface area of gravel bars for potential young riparian stand recruitment</td>
<td></td>
</tr>
</tbody>
</table>
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McKenzie Baseline
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4.3 THE MCKENZIE SUBBASIN

The McKenzie River is approximately 90 miles long and drains an area of about 1,340 square miles (Figure 4.3-1). Moving downstream from groundwater-fed headwaters associated with porous volcanic landforms high in the Cascades, the river’s major tributaries include Horse Creek at about RM 67, the South Fork McKenzie (RM 59), Blue River (RM 57), and Mohawk River (RM 14). Much of the subbasin is mountainous, though there are flat bottomlands along the lower McKenzie and the Mohawk River. About 70% of the subbasin is federal forestland, with the Willamette National Forest accounting for nearly the entire area above the Blue River confluence except for private in-holdings near the main McKenzie. Forested tributaries to the McKenzie below Blue River, and particularly below Vida (at RM 41), have mixed to strongly private ownership as the river flows to and through Willamette Valley bottom-lands that begin near Deerhorn Bridge at RM 32. Much of the valley floor below this bridge has been converted to agriculture or put to residential use (MWC 1996).

The McKenzie River channel decreases in slope from about 1.2% above Belknap Springs (near RM 75) to less than 0.4% through a glacial valley above Blue River, to less than 0.2% when the river enters the Willamette Valley (USACE 2000). High dams affecting the river include those in the Carmen-Smith Hydroelectric Project (above and including Trail Bridge Dam near RM 82), and two USACE structures: Cougar Dam at Mile 4.2 on the South Fork McKenzie and Blue River Dam at RM 1.3 on Blue River. A small, ladder-equipped dam on the McKenzie at approximately RM 29 (Leaburg Dam) diverts water into a power canal as part of the Leaburg-Walterville Hydroelectric Project.
Figure 4.3-1  Map of the McKenzie subbasin
Figures 4.3-1 Maps of the McKenzie subbasin (ODEQ 2006a, top) and of land use patterns within the subbasin (NRCS 2006b, bottom).
4.3.1 Historical Populations of Anadromous Salmonids in the McKenzie Subbasin

4.3.1.1 UWR Chinook Salmon

Historical spawning areas for UWR Chinook within the McKenzie subbasin included the mainstem McKenzie River, Smith River, Lost Creek, Horse Creek, the South Fork, Blue River, Gate Creek, and Mohawk River (Mattson 1948, Parkhurst et al. 1950). Habitat that remained suitable for, and available to, these fish in the 1940s was estimated to have the capacity to support about 80,000 spawners (Parkhurst et al. 1950). However, adult runs this large were never documented. The Oregon Fish Commission estimated that the largest run of UWR Chinook salmon into the McKenzie River subbasin for which it had data was one of about 46,000 adults in 1941. This estimate was based on an assumption that 39 percent of the UWR Chinook salmon adults counted passing over Willamette Falls were bound for the McKenzie subbasin (Mattson 1948, USACE 1995). Estimated run sizes of UWR Chinook returning to the McKenzie subbasin from 1945-1960 averaged 18,000 adults (USACE 1995). A run of 4,300 adult Chinook escaped to spawn in the South Fork alone in 1958 (USFWS 1959).

4.3.1.2 UWR Steelhead

UWR steelhead are sometimes found within lower elevation areas of the McKenzie subbasin, but these areas are not thought to have supported a historical population of the species.

4.3.2 Current Status of ESA-Listed Anadromous Salmonids within the Subbasin

4.3.2.1 UWR Chinook Salmon

Population Viability
The latest status assessment of UWR Chinook salmon, by McElhany et al. (2007), rated the McKenzie population as being at moderate risk of extinction based on an evaluation of its abundance, productivity, spatial structure, and diversity. Within-subbasin contributors to this risk include habitat degradation associated with USACE dams, land use, and the ecological and genetic effects of a very large fish hatchery program within the subbasin. Potentially catastrophic events that could unfavorably affect the population include landslides, hatchery-related disease epidemics, and pollution discharges from roadway/transportation spills (WLCTRT 2003).

Abundance & Productivity (A&P)
McElhany et al. (2007) classified the UWR Chinook population in the McKenzie subbasin as facing a moderate extinction risk based on its abundance and productivity, with a modest level of uncertainty. The population was once one of, if not the largest within the Willamette Basin, but now has greatly reduced numbers of spawning adults. McElhany et al. (2007) estimated the spawning population’s long-term (1970-2005) geometric mean abundance as 1,655 natural-origin spawners, its short-term (1990-2005) geometric mean abundance as 2,104.
Adult UWR Chinook returning to the McKenzie River are counted as they pass over Leaburg Dam and surveys are conducted in the natural spawning areas of these fish both above and below this dam. Figure 4.3-2 gives the numbers of wild (natural-origin) and all (wild plus hatchery-origin) adult Chinook estimated to have passed Leaburg Dam each year from 1970 through 2006. Estimates of the wild component of the run were relatively uncertain until 2001, when expanded hatchery fish marking and monitoring programs enabled accurate discrimination of wild fish. Annual numbers of wild adult Chinook passing Leaburg Dam during the most recent 5-year period for which data are available (2002-2006) ranged from a high of 4,899 fish in 2003 to a low of 2,189 fish in 2006, and averaged 3,509 fish (McLaughlin et al. 2008). The number of wild adults passing the dam in 2003 was similar in magnitude to the largest estimates of wild fish escapement over the dam since 1970.

![Figure 4.3-2](image_url)

Figure 4.3-2  Estimated annual number of wild and all (wild and hatchery-origin) adult spring Chinook salmon passing above Leaburg Dam on the McKenzie River, Oregon, 1970-2006. Data sources: Chilcote (2007) and McLaughlin et al. (2008).

Hatchery-origin fish continue to pass Leaburg Dam and enter the natural spawning areas of McKenzie spring Chinook above the dam, posing a potential risk to the productivity of the naturally spawning population (Table 4.3-1). McLaughlin et al. (2008) have, for Chinook runs since 2001, developed two sets of estimates of the annual percentage of adults passing above the dam that were of hatchery-origin. One set is based on straight dam counts and the other has an adjustment for what is thought to be fall-back (false passage) of hatchery-origin fish. Dam counts unadjusted for fall-back suggest that the annual percentages of hatchery-origin adults upstream of Leaburg Dam have ranged from 21% to 51%, and averaged 38% during the last 5 years (McLaughlin et al. 2008). The adjusted counts suggest lower percentages of hatchery fish above the dam, ranging from 17% to 39%, and averaging 30% during the last 5 years, and are
thought to provide a better indication of the proportion of hatchery fish in the naturally spawning population (McLaughlin et al. 2008).

Table 4.3-1  Estimated number of adult spring Chinook salmon of natural (wild) and hatchery origin passing upstream of Leaburg Dam, 2001-2005, as determined by analyses of otoliths in non-fin-clipped fish and coded wire tags in fin-clipped fish (McLaughlin et al. 2008).

<table>
<thead>
<tr>
<th>Year</th>
<th>Wild adults (natural-origin)</th>
<th>Adults of hatchery origin</th>
<th>Total</th>
<th>Percent hatchery-origin adults*</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>2,880</td>
<td>1,422</td>
<td>4,302</td>
<td>33 (32)</td>
</tr>
<tr>
<td>2002</td>
<td>3,602</td>
<td>2,485</td>
<td>6,087</td>
<td>41 (35)</td>
</tr>
<tr>
<td>2003</td>
<td>4,899</td>
<td>4,428</td>
<td>9,327</td>
<td>47 (39)</td>
</tr>
<tr>
<td>2004</td>
<td>4,419</td>
<td>4,615</td>
<td>9,034</td>
<td>51 (39)</td>
</tr>
<tr>
<td>2005</td>
<td>2,435</td>
<td>659</td>
<td>3,094</td>
<td>21 (18)</td>
</tr>
<tr>
<td>2006</td>
<td>2,189</td>
<td>981</td>
<td>3,170</td>
<td>31 (17)</td>
</tr>
<tr>
<td>5-year average (2002-2006)</td>
<td>3,509</td>
<td>2,634</td>
<td>6,143</td>
<td>38 (30)</td>
</tr>
</tbody>
</table>

* Percent hatchery values given in parentheses are intended to provide an adjustment for what appears to be dam fall-back of non-clipped fish.

The distribution of hatchery-origin Chinook spawners among natural spawning areas within the McKenzie subbasin is far from uniform and suggests that certain components of the population may be somewhat less affected by whatever influence stray hatchery spawners have on the productivity of wild fish. During 2001-2004, Schroeder et al. (2005) found lower proportions of hatchery-origin spawners in carcasses recovered in the mainstem upstream of a point near the South Fork confluence (Forest Glen) and in Lost and Horse creeks than were found in the South Fork or areas downstream. Hatchery spawners constituted a particularly high fraction of spawners in the lower McKenzie below Leaburg Dam (Schroeder et al. 2005).

Carcass recoveries from Chinook spawning areas suggest that rates of pre-spawn mortality above Leaburg Dam are relatively low compared to those seen for UWR Chinook in other spawning areas within the Willamette Basin. From 2001 through 2006, carcass recoveries above the dam suggest annual pre-spawn mortality rates ranging from 1% to 16%, and averaging 9%.

**Spatial Structure**

McElhany et al. (2007) rate the spatial structure of McKenzie spring Chinook salmon as characteristic of a population having a low to moderate risk of extinction. ODFW (2005b) estimates that 16% of the population’s historical habitat has been blocked by dams. Cougar Dam now blocks access to most of the productive South Fork watershed, and Blue River Dam and the Carmen-Smith hydroelectric project block smaller amounts of habitat. High quality habitats remain accessible in significant portions of the subbasin not blocked by dams, but habitat degradation apparently extirpated a spawning aggregate in the Mohawk watershed a century ago (Parkhurst et al. 1950) and historically-significant rearing habitat in the upper Willamette River mainstem has been lost or damaged.
Diversity
McElhany et al. (2007) rated the diversity of the McKenzie population of UWR Chinook as reflecting a moderately high risk of extinction, based on an examination of available information on life history traits, effective population size, hatchery impacts, anthropogenic mortality, and habitat diversity. Key concerns in this regard were the genetic influences of the large hatchery program in the basin and the effects of altered thermal regimes below the USACE dams on fish life-histories.

4.3.2.2 UWR Steelhead

UWR Steelhead are sometimes found within lower elevation areas of the McKenzie subbasin, but these areas are not thought to have supported a historical population of the species.

4.3.2.3 Limiting Factors & Threats to Recovery

Factors within the McKenzie subbasin that are unfavorably affecting the status of its population of UWR Chinook have been summarized by ODFW (2007b) and are given in Table 4.3-2. Key limiting factors and threats to the species within the subbasin include a variety of dam effects, a large hatchery program developed partly to help offset dam effects, and the cumulative effects of multiple land and water use practices on aquatic habitat. Dams that lack effective passage facilities prevent wild fish from using historically important habitats on Federal lands in upper portions of the McKenzie subbasin, particularly above Cougar Dam on the South Fork McKenzie River. Habitat changes along the mainstem Willamette River and in the Columbia River estuary some related to the Willamette Project dams or to other USACE programs, also limit the populations.

In all, 2 of 4 primary limitations and 2 of 6 secondary limitations on the recovery of the McKenzie’s ESA-listed population of UWR Chinook are related to USACE dams or programs (ODFW 2007b, Table 4.3-2). Even though the limiting factors and threats are broken into two groups, the secondary factors are important to address as well as the key factors.
Table 4.3-2 Key and secondary within-subbasin limiting factors and threats to recovery of McKenzie Spring Chinook (source: ODFW 2007b).

<table>
<thead>
<tr>
<th>Threats</th>
<th>Species</th>
<th>McKenzie Subbasin (Streams and Rivers within Population Area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvest</td>
<td>Chinook</td>
<td></td>
</tr>
<tr>
<td>Hatchery</td>
<td>Chinook</td>
<td>Egg 4b, Alevin, Fry 6c, Parr 6d</td>
</tr>
<tr>
<td>Hydropower/Flood Control</td>
<td>Chinook</td>
<td>Egg 9g, Parr 10d, Smolt 2d, Adult 7e</td>
</tr>
<tr>
<td>Landuse</td>
<td>Chinook</td>
<td>Parr 8a, 8a, 9a</td>
</tr>
<tr>
<td>Introduced Species</td>
<td>Chinook</td>
<td></td>
</tr>
</tbody>
</table>

Black cells indicate key concerns; Gray cells indicate secondary concerns.

Key threats and limiting factors

2d Impaired access to habitat above McKenzie hydropower/flood control dams.
3 Hatchery fish interbreeding with wild fish resulting in a risk of genetic introgression.
8a Impaired physical habitat from past and/or present land use practices.
10d Reduced peak flows leading to decreased channel complexity and diversity of fish habitat by reducing channel movement that is important for recruitment of gravel and large wood, and maintaining varying seral stages of riparian vegetation. Lower peak flows also reduces scour and formation of pools.

Secondary threats and limiting factors

4b Competition with naturally produced progeny of hatchery spring Chinook.
6c Predation by hatchery summer steelhead smolts.
6d Predation by hatchery rainbow.
7e Lack of gravel recruitment below McKenzie hydropower/flood control dams due to gravel capture in upstream reservoirs.
8a Impaired physical habitat from past and/or present land use practices.
9a Elevated water temperatures from past and/or present land use practices resulting in decreased survival and/or growth.
9g Elevated water temperatures below McKenzie hydropower/flood control dams resulting in premature hatching and emergence.

---

1 Cougar water temperature control tower addressed temperature in South Fork McKenzie and most of the mainstem McKenzie River.
4.3.3 Environmental Conditions

4.3.3.1 Habitat Access

General relationships between safe passage and access to historical habitat and the habitat requirements of UWR Chinook salmon are described in Appendix E. Table 4.3-4 summarizes the status of safe passage and access to historical habitat in the McKenzie subbasin under the environmental baseline, which is described in more detail below.

There are currently five dams in the McKenzie River Subbasin that affect anadromous fish. The USACE owns two of these dams: Cougar Dam on the South Fork McKenzie River, and Blue River Dam on the Blue River. The three other dams are owned and operated by Eugene Water and Electric Board (EWEB): Leaburg Dam on the mainstem McKenzie River, Trail Bridge Dam on the mainstem McKenzie near the headwaters, and Smith Dam at Mile 2.1 on Smith River, above Trail Bridge Dam. EWEB also operates the Walterville Canal (at RM 28.5) and Powerhouse (RM 20.9), and the Leaburg Canal (RM 38.8) and Powerhouse (RM 33.3), all located adjacent to the mainstem McKenzie River on the right bank.

Up- and downstream fish passage conditions at the facilities just identified vary from meeting modern standards of effectiveness to being inadequate to sustain migratory fish populations that would otherwise depend on such passage. Passage conditions at Cougar and Blue River dams are of the latter type, with those at Cougar severely affecting natural salmon production in what was once the McKenzie river tributary most heavily used by UWR Chinook.

4.3.3.1.1 Fish Passage at Leaburg & Walterville Hydroelectric Projects

For many years, adult Chinook salmon were delayed in the tailraces of EWEB’s Leaburg and Walterville powerhouses. Under the terms of EWEB’s renewed FERC license (NMFS and USFWS 2001), the construction of tailrace barriers during 2003 has reduced the likelihood of attraction and delay. Delay was further reduced at Leaburg Dam in 2004 by modifying the left-bank fish ladder and redesigning and reconstructing the right-bank fish ladder to meet current design criteria. The terms of EWEB’s new FERC license also included improvements for downstream fish passage. Construction of a new screen at the entrance to the Walterville Canal and reconstruction of the existing screens at the Leaburg canal, and associated bypass systems, have reduced passage mortality of downstream migrating Chinook salmon to less than 0.5%. The Walterville screens were completed in 2002, and the Leaburg screens were completed in 2004.

Similarly, recent changes in instream flow requirements for the mainstem McKenzie River at these projects have benefited migrating fish. Prior to 1991, EWEB’s diversions into the power canals left as little as 465 cfs in the bypassed mainstem reach at Leaburg and as little as 350 cfs at Walterville, affecting migration conditions (habitat availability and instream temperatures) for migrating juvenile and adult Chinook salmon. As a requirement of its new FERC license, EWEB now maintains instantaneous minimum flows immediately downstream of Leaburg Dam and at the Walterville intake at 1,000 cfs.
4.3.3.1.2 Fish Passage at Trail Bridge & Smith Dams

At the upper end of the mainstem McKenzie River, EWEB’s Trail Bridge and Smith dams exclude spring Chinook salmon from a portion of their historical range (about 8 miles) because neither dam was built with fish passage facilities. As mitigation for the lost habitats, EWEB constructed a spawning channel below Trail Bridge Dam when the dam was constructed. The spawning channel was originally designed to accommodate a minimum of 200 spawning Chinook (100 pairs), which is the estimated number of fish that historically spawned in the areas above Trail Bridge Dam. Chinook spawn in the channel annually, but numbers of returning Chinook have generally been below 200 fish until recent years. It is unclear if the increases were due to increased ocean survival, returns of progeny from ODFW outplants of adult hatchery Chinook above Trail Bridge, or a combination of both factors.

In 2006, EWEB filed a license application with FERC to relicense the Carmen Smith Hydroelectric Project, which includes Trail Bridge and Smith Dams. EWEB’s proposed action included providing both up- and downstream passage facilities at Trail Bridge Dam. Once these facilities are constructed, UWR Chinook salmon would be able to access about 8 miles of historic spawning and rearing habitat.

4.3.3.1.3 Fish Passage at Cougar Dam

Cougar Dam was built in 1963 with adult and juvenile fish passage facilities that ultimately proved incapable of maintaining what was once a very large run of spring Chinook salmon into the 56 km of spawning and rearing habitat found in the South Fork McKenzie watershed above the dam. The dam will prevent recovery of the salmon production potential of this watershed unless or until effective fish passage is provided.

**Upstream Passage**

Adult salmon were initially trapped at a collection facility in the tailrace and trucked upstream to a release point near the head of the reservoir. The system was evaluated in a 4-year study, beginning in 1964, by the Oregon Fish Commission. After the first 2 years, serious problems were evident. Adult spring Chinook salmon entered the permanent trap in the tailrace channel in August and September rather than as expected in June and July (Ingram and Korn 1969). Ingram and Korn observed that many fish were attracted to the surface water discharged through the regulating outlet, and, in an attempt to collect those fish, ODFW built a temporary trap into the weir at the downstream end of the regulating outlet channel. When both traps were operating, the trap in the RO channel collected virtually all of the fish. Ingram and Korn concluded that the poor return of adults to Cougar Dam was related to the temperature of water in the tailrace, which was 10°F (5.6°C) cooler than in the RO channel. The original fish trap was judged a failure and last used to collect adult spring Chinook salmon for transfer to areas above Cougar Dam in 1966.

In 2009, USACE will construct a new fish trapping facility for collecting adult Chinook salmon and other species at the base of Cougar Dam and hauling them to upstream release sites. Although NMFS completed consultation on trap construction (NMFS 2007a), the Action Agencies included the continued operation of the facility as part of the larger Proposed Action that is the subject of this consultation. Hence, only the construction of the new trap, not its operation is part of the baseline for this consultation.
**Downstream Passage**

The original downstream passage system for juvenile fish at Cougar was intended to collect fish through one of five horns\(^2\) incorporated into the dam’s water intake tower. Like the upstream passage system, it did not work as well as envisioned. Ingram and Korn (1969) found that the fish horns collected only a low percentage of the juvenile Chinook available in the reservoir and many of those collected were injured or killed. An estimated 28.2% of the test fish (marked hatchery yearling Chinook) that Ingram and Korn released into the South Fork above the reservoir during the spring of 1965 emigrated downstream and 21.1% in 1966. Two test groups released into the forebay in 1966 emigrated at rates of 22.5% and 21.0%, respectively. One of the reasons for poor emigration may have been that the operating collection horn was under a considerable depth of water (10 to 45 feet) during much of the test period; whereas gill net catches showed that Chinook were distributed mainly in the upper 15 feet of the forebay at that time (Ingram and Korn 1969). Of the total numbers of wild fish collected at the downstream evaluator, dead fish constituted 40% in 1965, 30% in 1966, and 28% in 1967. Many of the live fish in the evaluator were seriously injured, and Ingram and Korn (1969) suggested that extensive delayed mortality may have occurred. Based on their data, Ingram and Korn judged that the juvenile passage facilities at Cougar Dam, like those for adult passage, were inadequate.

ODFW began releasing hatchery-reared fingerling Chinook into Cougar Reservoir in 1963, to augment the recreational trout fishery (Mamoyac and Ziller 2001), and then started releasing hatchery-origin adult Chinook above Cougar Dam in 1993 to restore inputs of marine-derived nutrients and a prey base for bull trout in the upper South Fork watershed. ODFW originally assumed that most of the juvenile salmon produced by these adults would be killed during passage through the turbines or regulating outlet if they tried to leave the reservoir. However, between 1994 and 1997, field observations provided circumstantial evidence that some juveniles were surviving passage (Taylor 2000). During the first year of a 2-year passage survival study (November 1998 through March 1999), approximately 14,000 juvenile Chinook migrated through the regulating outlet (67.4% survival) and about 1,500 to 3,900 through the turbines (92.9% survival; Taylor 2000). Turbine survival was 81.9% during the second year of study (1999 through 2000), which may have been due to a 2-cm increase in smolt size compared to the previous year (survival appeared to decrease with increasing fish size and may have been as low as 50% for fish >20 cm in length). Taylor (2000) could not determine why survival was lower through the regulating outlet than through the turbines.

**Outplant Program above Cougar Dam**

ODFW’s hatchery adult outplanting program in the upper South Fork watershed has expanded in the last several years to include consideration of re-establishing natural use of habitat above Cougar Dam to aid recovery of UWR Chinook salmon. Releases of adult Chinook above Cougar Dam that have been made as part of this program are included in Table 4.3-3. Limited evaluations of the program suggest that adult Chinook are spawning successfully and producing juvenile fish above the dam (Beidler and Knapp 2005). Pre-spawn mortality of released adults

\(^2\) A “fish horn” (or “reduced velocity fish entrance port”) is a loudspeaker-shaped aperture on the upstream face of a dam. At Cougar, five fish horns are spaced 39.5 feet apart down the upstream face (Ingram and Korn 1969). Each horn is 20 feet high and 9 feet wide at the opening. With a maximum allowable head of 50 feet over a horn, flow into the horn is 350 cfs. Reservoir level determines head and therefore which horn is operated at any one time.
appears low compared to that seen in other hatchery outplanting programs in the Willamette Basin (Beidler and Knapp 2005).

<table>
<thead>
<tr>
<th>Year</th>
<th>Above Cougar Dam</th>
<th>Above Trail Bridge Dam</th>
</tr>
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<tbody>
<tr>
<td>1993</td>
<td>55</td>
<td>0</td>
</tr>
<tr>
<td>1994</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1995</td>
<td>0</td>
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<td>3,409</td>
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</tr>
<tr>
<td>2005</td>
<td>868</td>
<td>111</td>
</tr>
<tr>
<td>2006</td>
<td>1,018</td>
<td>116</td>
</tr>
</tbody>
</table>

Table 4.3-3 Numbers of adult hatchery spring Chinook salmon in the McKenzie River subbasin released above Cougar Dam (USACE dam), and Trail Bridge Dam (EWEB-owned), 1993-2006. Data sources: Mamoyac and Ziller (2001), McLaughlin et al. 2008), and (Beidler and Knapp 2005)

4.3.3.1.4 Fish Passage at Blue River Dam
Blue River Dam was built without fish passage facilities and was never designed to sustain the small run of salmon that once returned to upstream areas. Before the dam was completed, 4.5 miles of Blue River were accessible to adult spring Chinook salmon, up to a 6- to 10-foot falls that was passable only under high spring flows (Willis et al. 1960). The watershed probably once supported a population of about 200 adult Chinook salmon (WNF BRRD 1996).

4.3.3.2 Water Quantity/Hydrograph

The McKenzie River drains a large subbasin along the west flank of the Cascade mountain range. The majority of runoff occurs during the winter, and flows are lowest during July, August and September. Gages in the upper basin exhibit a pronounced bimodal peak resulting from winter runoff and spring snowmelt.

In general, seasonal flow variations in the McKenzie River are less than in other Willamette River basin tributaries because of the abundance of springs and lakes in the upper basin which tend to attenuate flow fluctuations. As noted above, flows are naturally lowest in the late summer and early fall. The average daily flow in September prior to construction of the Cougar and Blue River dams was 2,030 cfs. Since construction of the projects, the average daily flow in September has increased to 2,956 cfs (Moffatt et al. 1990). Post-project summer flows are greater than occurred historically, because storage is available at USACE facilities to redistribute
flood volumes and release water later in the year for flow augmentation purposes. There are no consumptive water diversions upstream of Vida (Hubbard et al. 1996).

Water development in the McKenzie basin dates back to the beginning of the 20th Century and grew with the local demand for electrical energy. The Eugene Water Board (currently Eugene Water & Electric Board – EWEB) began developing the river’s hydroelectric potential in 1910 with construction of Matlock Station (currently termed the Walterville development). With expanding electrical demand came the Leaburg development, which began to produce electricity in 1930. Neither of these facilities provides substantial storage and both are currently operated as run-of-river facilities. Both diversion dams were fitted with fish passage systems.

Leaburg dam and powerhouse are at RM 28 and 23, respectively with a short tailrace. Waterville dam and powerhouse are at RM 17 and 13 respectively with a 2-mile-long tailrace and terminating in a fish barrier. The Leaburg and Walterville projects directly affect 5.8 miles and 7.3 miles, respectively, with an approximately 5 mile long undeveloped reach in between. Both facilities have been recently improved to screen juvenile fish, to minimize tailrace attraction, and to maintain suitable instream flows in the diverted reaches.

EWEB also operates two dams on the upper McKenzie River (Trail Bridge and Carmen Dams), and one dam (Smith River Dam) near the headwaters. The Trail Bridge-Carmen complex was completed in 1963, the same year as Cougar Dam.

### 4.3.3.2.1 Seasonal Flows
McKenzie River hydrology is strongly driven by groundwater inputs and prior to dam construction tended to display relatively constant flows (Figures 4.3-3 A, B & C). Vast areas of porous lava in the upper watershed retard surface runoff and act as a natural reservoir for large, relatively constant-flowing springs. Winter (December through February) monthly median flows were only about 2½ times as high as late summer (August and September) monthly median flows and the minimum flows recorded at Vida, Oregon. The majority of runoff occurs during winter, and flows are lowest during July, August, and September. Operation of Blue River Dam has reduced median daily April flows in the lower 1.8 miles of Blue River by 46% and has increased median daily August flows by 353% (Figures 4.3-4 A, B & C). Operation of Cougar Dam has reduced median daily April flows in the South Fork McKenzie River by 44% and has increased median daily August flows by 121% (Figures 4.3-5 A, B & C). The combined operation of Blue River and Cougar dams has reduced median daily April flows in the mainstem McKenzie River at Vida by 14% and has increased median daily August flows by 27% (Figures 4.3-3 A, B & C).
Figures 4.3-3 A, B & C  Simulated discharge (cfs) of McKenzie River at Vida, Oregon under unregulated conditions (Unreg), with project operating criteria prior to 2000 (Pre-2000), and with project operating criteria after 2000 (Post-2000), depicting the 80th, 50th (median), and 20th percentile for each scenario.

**Figure 4.3-3 A**

<table>
<thead>
<tr>
<th></th>
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<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
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**Figure 4.3-3 B**

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<thead>
<tr>
<th></th>
<th>Oct</th>
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<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
</tr>
</thead>
</table>
Figures 4.3-4 A, B & C  Simulated discharge (cfs) of the Blue River below Blue River Dam under unregulated conditions (Unreg), with project operating criteria prior to 2000 (Pre-2000), and with project operating criteria after 2000 (Post-2000), depicting the 80th, 50th (median), and 20th percentile for each scenario.

Figure 4.3-4 A
Figure 4.3-4 B

Figure 4.3-4 C
Figures 4.3-5 A, B & C  Simulated discharge (cfs) of South Fork McKenzie below Cougar Dam under unregulated conditions (Unreg), with project operating criteria prior to 2000 (Pre-2000), and with project operating criteria after 2000 (Post-2000), depicting the 80th, 50th (median), and 20th percentile for each scenario.

Figure 4.3-5 A

Figure 4.3-5 B
Prior to dam construction, low flows typically occurred during August and September in the Blue and South Fork McKenzie rivers. Since dam construction, low flows typically occur during April (when the USACE refills the reservoirs before the summer recreation season), or July (before large withdrawals are need to protect water quality downstream in the mainstem Willamette), or September (due to natural precipitation and runoff conditions). Before dam construction, the lowest average daily flow observed in Blue River was 14 cfs in October 1939. After construction, the lowest flow has been 3.7 cfs, observed in October 1969. In recent years, flows in Blue River have seldom fallen below 30 cfs. In the South Fork McKenzie River, the lowest pre-dam average daily flow was 200 cfs, in October 1960. Since dam construction, the lowest average daily flow has been 85 cfs, observed during April 1977, presumably to maximize refill, probably during that year’s severe drought. During winter high flow events, Cougar Dam discharge rates may decrease to about 100 cfs to reduce flooding in the McKenzie and Willamette rivers. In recent years, flows lower than 200 cfs downstream from Cougar Dam have been rare.

In recent years, USACE has attempted to meet flow targets established in cooperation with ODFW for downstream fish protection. At Cougar Dam these flows are 400 cfs year-round. At Blue River Dam these flows are 50 cfs year-round. However, the USACE has reduced flows below these target minima when necessary to reduce downstream flood risks and during other emergencies.

The McKenzie River has been extensively developed to supply water for agricultural, municipal, and industrial land uses. The OWRD has issued permits for surface water withdrawals totaling 11,994 cfs from the McKenzie River. This is a maximum allowable diversion right, and actual diversions are much lower at any particular time. Almost all of the water diverted for hydropower use and roughly half the water diverted for other uses returns to the river downstream from the point of diversion. Flows in the river reaches between the point of discharge.
diversion (e.g., the Leaburg and Walterville canals) and the point of return (e.g., Leaburg and Walterville powerhouse tailraces) are at times substantially reduced.

The OWRD water availability process (OAR 690-400-011) has determined that natural flow is available for out-of-stream use in all months from the McKenzie River at the confluence with the Willamette River (OWRD 2008). However, the Willamette Basin Program Classifications (OAR 690-502-0110) require that new surface water users in the sub-basin obtain water service contracts from USBR (i.e., for use of water stored in Willamette Project reservoirs) for uses that would include the summer months (e.g., irrigation). The USBR has issued contracts for 2,373 acre-feet of water from Cougar and Blue River reservoirs (Eggers 2002).

The largest diversions from the McKenzie River are associated with hydropower developments. At River Mile (RM) 35 Leaburg Dam diverts up to 2,500 cfs into the Leaburg canal, which reduces flows in about 5.8 miles of the McKenzie River. Flows in the reach between the diversion and the powerhouse tailrace may be reduced to 1,000 cfs in accordance with the project’s hydropower license (FERC 1996). At about RM 25, up to 2,577 cfs is diverted into the Walterville canal, which reduces flows in about 7.3 miles of the McKenzie River. Flows in the intervening river reach may also be reduced to 1,000 cfs. Flows approaching these minima are most likely to occur during July, August, September, and October. The river also provides domestic water supplies to the city of Eugene, Oregon, through a diversion located at Hayden Bridge (maximum withdrawal rate of 300 cfs).

To prevent substantial adverse effects on migrating adult or rearing juvenile UWR spring Chinook, the FERC license issued for the Leaburg-Walterville Project requires that EWEB maintain flows of 1,000 cfs in the 5.8-mile river reach bypassed by the Leaburg project and the 7.3-mile river reach bypassed by the Walterville project. Reducing flows to 1,000 cfs increases the river’s response to summer heat. EWEB estimated that by reducing flows to 1,000 cfs in the McKenzie River’s bypassed reaches, the Leaburg-Walterville project typically increased August water temperatures by about 0.7 °C during normal years (EA Engineering 1994). Water temperature effects, including “worst-case” temperature impacts for the Leaburg-Walterville project, are discussed in Section 4.3.3.3.

Cougar and Blue River Dams’ effects of reducing late winter and spring flows on UWR spring Chinook are unknown. Of concern is the difference between flows in late summer and early fall, when spring Chinook select spawning sites and the reservoirs are being drafted for flow augmentation and flood control, and the minimum flows discharged during active flood control operations in the winter. This difference can result in redds established in the late summer and fall being dewatered during the winter, prior to emergence. Depending on the duration and rate of desiccation, dewatering salmon redds can kill incubating eggs and alevins (Reiser and White 1983). It can also cause entrapment and stranding of juvenile salmonids. The potential for these project-caused effects is greatest in the South Fork McKenzie downstream from Cougar Dam, which is an important spawning and rearing area for spring Chinook.

The increase in late summer and fall flows provided by flow augmentation operations at Cougar and Blue River dams probably benefits juvenile salmonids by increasing habitat area and reducing the rate that water temperature responds to thermal loads (increased heat capacity).
Increased fall flows associated with reservoir drafting to provide flood storage may affect spawning spring Chinook that spawn downstream from Cougar Dam. Increasing flows increases the habitat area available to spawning fish. However, this increase in areal dispersion of spawning opportunity increases the risk that subsequent sudden discharge reductions would harm incubating eggs by dewatering them (see Flow fluctuations, above).

4.3.3.2 Peak Flow Reduction

Peak flows on the McKenzie River have been controlled by Cougar and Blue River dams since 1963. EWEB’s Carmen-Trail Bridge complex also attenuates peak flows. The combined operations of these projects has substantially decreased the magnitude and frequency of extreme high flow events in the lower river, although the influence of the Carmen-Trail Bridge complex is small relative to the USACE projects because they are small and operated essentially as run-of-the-river projects. Prior to dam construction, the highest flow recorded on the McKenzie River at Vida was 64,400 cfs in December 1945 with flows greater than 40,000 cfs were not uncommon (Hubbard et al. 1996). Since construction of the projects, the two-year recurrence interval event at Vida has decreased from about 29,200 cfs to about 17,500 cfs; no flows greater than about 35,000 cfs have occurred.

Prior to 1963, when work on the Cougar and Blue River projects began, the highest flow at Vida, Oregon was 64,400 cfs, recorded in December 1945, and annual peak flows greater than 40,000 cfs were common (Hubbard et al. 1997). Since construction (1970), the magnitude of the two-year recurrence interval event has decreased from about 29,200 cfs to 17,500 cfs and no events have exceeded 35,000 cfs.

Reductions in peak flows caused by flood control operations at Blue River and Cougar dams have contributed to the loss of habitat complexity in the McKenzie River by substantially reducing the magnitude of the channel-forming dominant discharge (i.e., the 1.5- to 2-year flood) and greatly extending the return intervals of larger floods. Over time, flood control tends to reduce channel complexity (e.g., reduces the frequency of side channels, and woody debris recruitment) and reduce the movement and recruitment of channel substrates. Side channels, backwaters, and instream woody debris accumulations have been shown to be important habitat features for rearing juvenile salmonids.

The operation of USACE’s Blue River and Cougar dams is only partly responsible for the reduction in channel complexity noted in the McKenzie River. Bank stabilization measures and land leveling and development in the basin have directly reduced channel complexity and associated juvenile salmon rearing habitat (Section 5.2.3). Changes in channel form in response to reductions in peak flows are probably highest in the unconfined portions of the channel, which extend from near Vida to the river’s confluence with the Willamette River in Springfield, Oregon.

Armoring, the process of increasing the dominant substrate particle sizes, also reduces the availability of suitable spawning substrates. EA Engineering (1991) and Minear (1994) have documented channel armoring in the lower McKenzie River.

These effects in the McKenzie River downstream from Blue River and Cougar dams persist unabated through most of the river downstream from Blue River, Oregon because of the lack of
any sizable downstream tributaries that could replenish flows or sediment and woody debris loads. These effects are exacerbated by storage of sediment and woody debris in the Leaburg Dam pool.

Controlling peak flows beneficially reduces the potential for scouring UWR Chinook redds during extreme flow events.

### 4.3.3.2.3 Flow Fluctuations, Entrapment and Stranding

Juvenile salmonids may become entrapped and stranded in the South Fork McKenzie River when discharge is reduced precipitously at Cougar Dam during winter flood events. The South Fork McKenzie River downstream from Cougar Dam is an important spawning and rearing area for UWR Chinook salmon. Salmon fry currently emerge from January through March, the flood control/refill season, and juveniles reside in the river year-round. This potential effect is somewhat reduced by channel morphometry. The South Fork McKenzie River channel is relatively well confined downstream from Cougar Dam (i.e., the valley is narrow and the total wetted area changes relatively slowly, with discharge over a wide range of flows). However, at some low flow conditions, the stream’s wetted area would begin to rapidly decrease with decreases in flow, increasing the potential for entrapment and stranding. The flow at which this break-point in the wetted area v. flow relationship occurs is presently unknown.

Rapid discharge reductions at Blue River Dam may also affect juvenile salmonids, but this potential is reduced by the very low numbers of juvenile salmonids known to rear in the Blue River. The potential for rapid flow reductions during flood control operations to cause entrapment and stranding in the mainstem McKenzie River is small, as these projects control only about 36 % of the river’s runoff upstream of Blue River, Oregon (Minear 1994). When flows high enough to warrant flood control operations at Cougar and Blue River dams are occurring, flows in the mainstem McKenzie River would likely be high enough to mask the diminishment caused by dam operations.

Historically, ramping rates at Cougar Dam were limited to 500 cfs per hour during high flow and 200 cfs per hour during low flow (USACE 2000). Changes in river stage corresponding to these discharge ramping rates have not been defined. Upramping limits at Blue River range from 50 cfs per hour at total project flows of 50 to 100 cfs to 600 cfs per hour at flows greater than 2000 cfs (USACE 2000). The maximum downramping rate was 30% of total project discharge per hour.

Ramping operations at Cougar and Blue River dams were modified in 2006 to reduce fishery impacts. Currently, USACE attempts to maintain ramping rates of 0.1 ft. per hour at night and 0.2 ft. per hour during daylight hours except during active flood damage reduction operations.

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3 Recent emergence timing was earlier than would have occurred prior to project development, due to the thermal effects of Cougar reservoir. This problem has been addressed by completion and operation of the Cougar Water Temperature Control Project. The project is operated to mimic pre-dam water temperatures. Overwintering juveniles would continue to be susceptible to entrapment and stranding, but juveniles tend to hold in somewhat deeper water than emerged fry and are thus less likely to be entrapped and stranded.
4.3.3.2.4 Summary

Human-caused alterations of the hydrologic regimes of the lower McKenzie River and its principal tributaries have generally diminished flow-related habitat quantity and quality and have probably reduced the abundance, productivity, and life history diversity of UWR Chinook salmon and limited the production potential of accessible habitat in much of the basin. Recent agreements to meet minimum streamflows at the Leaburg-Walterville Project, Blue River Dam, and Cougar Dam have likely provided sufficient flow for upstream migration and juvenile rearing habitat requirements, but these flow increases do not address water temperature conditions in the South Fork McKenzie, described in section 4.3.3.3 below. Large storage dams in the subbasin have reduced the magnitude and frequency of large flow events in the mainstem McKenzie, preventing channel forming processes that maintain complex habitat for rearing Chinook salmon.

4.3.3.3 Water Quality

Owing to the dominance of spring discharges in the river’s headwaters with groundwater residence times of 5 to 10 years (Grant et al. 2004), the McKenzie has excellent natural water quality with low concentrations of nutrients (nitrogen and phosphorus), very low sediment loads and turbidity, high concentrations to dissolved oxygen, and a neutral pH. Human activity has added small amounts of waste contaminants (e.g., fecal coliforms) to the river, and dam operations have altered the river’s thermal regime and to a modest extent, total dissolved gas concentrations.

4.3.3.3.1 Water Temperatures

Until 2006, both the USACE’s Cougar and Blue River projects substantially altered downstream water temperatures in the lower South Fork McKenzie and Blue River, respectively, and, to a lesser extent, in the mainstem McKenzie downstream to below Leaburg Dam (RM 38). Outflow temperatures were cooler than inflow in the late spring and summer and warmer than inflow in fall and early winter (USACE 2000). By the time water reached the mainstem McKenzie River, the effect of temperature shifts due to USACE operations was moderated by flows originating above the mouth of Blue River as well as equilibration between stream and ambient air temperatures over 8 miles between the mouth of Blue River and Leaburg Dam (USACE 2000). This tendency for large reservoirs to offset natural water temperature regimes by a month or more is often termed “thermal inertia” and is more severe downstream from reservoirs that thermally stratify and have fixed hypolimnetic discharge intakes. Thermal inertia has an array of implications for anadromous fish survival, particularly by disrupting natural reproduction schedules (e.g., delayed spawning, accelerated incubation).

According to ODEQ’s 2002 CWA section 303(d) database, water temperatures in the South Fork McKenzie below Cougar Dam exceeded the maximum for salmonid spawning, incubation, and emergence (55°F; 12.8°C) during summer and fall 1991 through 1994. Temperatures in the lower 1.8 miles of Blue River (below the USACE dam) have exceeded the maximum for salmonid spawning, incubation, and emergence, and the maxima for core migration (61°F; 16°C) and non-core rearing and adult and juvenile migration (64°F; 17.8°C). The 2002 database also indicates that the maximum temperature for spawning, incubation, and emergence has been exceeded in the mainstem McKenzie from RM 0 to RM 54.5 (Finn Rock). Temperature maxima for core rearing and non-core rearing and adult and juvenile migration have been recorded in
several streams that are not affected by Willamette Project flow management: Deer Creek, the Mohawk River, and tributaries to the Mohawk River.

 Cooler water temperatures in the late spring and summer probably impeded the upstream migration of UWR Chinook salmon compared to predevelopment conditions. Warmer fall/winter temperatures accelerate egg incubation and the timing of fry emergence. These factors likely subjected Chinook fry to unfavorable conditions such as high flows and scarce food, leading to poor survival. The apparent shift to later spawn timing could be a result of environmental conditions favoring late-emerging fry (Homolka and Downey 1995).

 Completed in December 2004 and fully operational in 2005, the water temperature control (WTC) structure at Cougar Dam has the ability to discharge water mimicking the water temperatures that would occur without the dam (Figure 4.3-6). Operation for temperature control requires selectively withdrawing water from different elevations in the pool to meet target outflow temperatures. Decisions on the flow distribution are based on outflow and data from temperature instrumentation on the face of the structure. This instrumentation allows for effective remote operation of the selective WTC tower. In addition to controlling the volume of flows, temperature data is required to determine thermal stratification in the reservoir and finally outflow temperatures. The capability to mix water from different levels to achieve a target temperature and volume is required. Gates can be “throttled” at different levels to control the proportion of flow from different levels. In addition, the electrical generation system was upgraded to include replacement of turbine runners with minimum gap technology intended to improve fish passage survival.

 Since its initial operation in January 2005, the newly constructed WTC structure has substantially shifted Cougar Dam’s discharge thermal regime toward natural conditions for the South Fork of the McKenzie River downstream from the dam. Cougar Dam is the only federal project in the Willamette Basin with temperature control capability. At the present time, biological responses to these physical changes have not been fully evaluated.

 **Water Temperature Control & Site-Specific TMDL Requirements**

 Operating projects to optimize temperature conditions downstream for fish is often inconsistent with TMDL temperature targets, even with a temperature control tower such as the one constructed at Cougar Dam. Experience in implementing water temperature control operations in the South Fork McKenzie River downstream of Cougar Dam to achieve more normative water temperatures suggest that special site-specific considerations may be required for such actions with respect to achieving ODEQ TMDLs. An operational requirement for successfully avoiding high temperature discharges in the fall (i.e., during spring Chinook salmon incubation) is to evacuate as much warm surface water as possible from the reservoir throughout the summer months while operating within the range of appropriate downstream temperature criteria for each month identified by ODFW. That is, it is necessary to balance the effect of warm water temperatures downstream of the dam across the spring, summer and fall periods to achieve the most appropriate overall biological effect. In the South Fork McKenzie River, the requirement resulted in summer water temperatures below Cougar Dam that were will above the draft TMDLs identified by ODEQ during April through September (Figure 4.3-6) in order to provide more favorable temperatures during the critical incubation period in the fall. A focus on achieving the cooler TMDL temperature targets during summer would have adversely affected
the temperature conditions achievable during the fall spawning and incubation period for spring Chinook because more warm surface water would have been retained in the reservoir over summer.

By diverting water EWEB’s Leaburg Dam and Walterville diversion affect mainstem McKenzie River water temperatures. These two projects affect flows and water temperatures in a 5.8-mile stretch between Leaburg Dam and the confluence with the tailrace of the Leaburg powerhouse (called the “Leaburg bypass reach”) and a 7.3-mile section between the intake for the Walterville powerhouse and the point of confluence with the Walterville tailrace (the “Walterville bypass reach”). The water temperature model developed during the FERC relicensing process predicted that, under a worst-case (hot and dry) climatological scenario, water temperatures could become elevated by 2.7 and 3.6°F (1.5 and 2.0°C), respectively, at the lower end of each mainstem bypass reach (EA Engineering 1994) and may occasionally cause the water temperatures to exceed Oregon state standards.

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**Figure 4.3-6** Cougar Dam daily discharge water temperatures for 2006, regulatory targets and pre-water temperature control discharge water temperatures in the South Fork McKenzie River downstream from Cougar Dam (USACE 2007a, Figure 3-12.)

Notes:
1 Downstream temperatures measured at USGS gage 14159500 located 0.6 miles downstream of dam.
2 Resource Agencies Target Temperatures from letter dated September 14, 1984, signed by representatives from NOAA, FWS, and ODFW.
3 Willamette TMDL as approved by EPA on September 29, 2006.
4 Daily average historical temperatures below Cougar Dam from 01OCT1963 to 30SEP2003 measured at USGS gage 14159500 located 0.6 miles downstream of dam.
5 Biological criteria developed by DEQ as outlined in Oregon Administrative Rules (OAR), Chapter 340, Division 041, Water Quality Standards: Beneficial Uses, Policies, and Criteria for Oregon.
6 Life history of Spring Chinook above Willamette Falls, below Willamette Reservoir taken from Willamette Project Biological Assessment, April 2000. Dark Color represents normal peak period.
4.3.3.2 Dissolved Oxygen

In a USGS study (Pogue and Anderson 1995), dissolved oxygen concentrations in the lower mainstem McKenzie River (between RM 7.1 and 19.3) attained levels required for salmonid spawning and rearing during both the July and August 1994 sampling periods. The 2002 CWA 303(d) database shows that dissolved oxygen concentrations below ODEQ’s numerical criterion for salmonid spawning (i.e., <11.0 mg/L or 95% saturation) were recorded at RM 1.5 in the Mohawk River, an unregulated tributary to the mainstem McKenzie, during October 1 through May 31.

4.3.3.3 Total Dissolved Gas

Monk et al. (1975) measured TDG levels of 97.8% to 124.1% saturation near the base of Cougar Dam; 99.5% to 115.7% at a site 3,000 feet downstream; and 103.4% to 108.6% at a site 2.7 miles downstream, during November (1970), when yolk sac fry may have been present. In April 2006, USACE tested TDG under increasing spill from the Cougar Dam regulating outlet and turbine discharge ranging from 0 to 530 cfs (Britton 2006). When regulating outlet discharge reached 2000 cfs, TDG exceeded 120% in the South Fork McKenzie just below the confluence of the regulating outlet channel and the tailrace. Because TDG is compensated at greater depths, TDG was estimated at 100% at depths ranging from 0.8 to 2.2 meters. The risk of gas bubble trauma during spills at the dam would thus tend to be at the depth of redds constructed under the low flow conditions typical of the spring Chinook spawning season, but juvenile Chinook nearer the water surface might be at risk. Levels of dissolved gases measured below Blue River Dam in March (1971 and 1972) ranged from 107.9% to 120.4% saturation. Symptoms of gas bubble trauma have not been reported in juvenile or adult anadromous salmonids in the McKenzie subbasin.

4.3.3.4 Turbidity

Turbidity is generally very low in the South Fork and mainstem McKenzie rivers; background levels are less than 5 NTU.

2002 Turbidity event

During the spring of 2002, as the USACE drew down Cougar Reservoir to prepare for construction of the water temperature control tower, the South Fork McKenzie River incised a channel through the sediment delta at the head of the reservoir that had formed due to impoundment. Some of the sediments remobilized by this process were released in a turbid plume, detectable from April through July, 2002. The median turbidity recorded from April 1 to June 16 at USGS Station No. 14159500 (approximately ½ mile below the dam) was 98 NTU. The measurements included a maximum of 379 NTU on April 28 (USACE 2007a). Further, sampling revealed DDT and its byproducts in the reservoir sediments. DDT is highly toxic to aquatic life and the potential for mobilization caused concern. The extended period of elevated turbidity raised questions about potential effects on spawning gravels, juvenile and adult spring Chinook salmon, and macroinvertebrate communities that are integral to the Chinook salmon food web (NMFS 2002).

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In response to NMFS’ request to examine the effects of the sustained turbidity event, the USACE contracted with researchers from Oregon State University’s Department of Geosciences and the USFS’ Pacific Research Station to determine (1) to what extent and depth fine sediments associated with the reservoir drawdown intruded into gravels in the South Fork McKenzie below the dam, and (2) how much of the sediment released from the reservoir traveled in suspension through the McKenzie system and how much had settled out of suspension and was still stored in the subbasin. The first objective was addressed by Stewart et al. (2002), who concluded that there were higher proportions of fine sediments (especially clays) in the gravel bars below Cougar Dam compared to reaches above the reservoir. Clay enrichment was highest immediately below the dam and decreased rapidly downstream; there was no discernable effect of fines (silt and clay) from Cougar Reservoir below the confluence of the South Fork and the mainstem McKenzie River. Stewart et al. could not prove that the clay enrichment below the dam occurred during the 2002 reservoir release because there were no pre-drawdown samples for comparison. However, Grant et al. (2002) observed that, after the spring 2002 turbidity events, clouds of sediment were stirred up in the South Fork below Cougar Dam, and to some extent in the mainstem McKenzie, and there did not seem to be a layer of fine sediment on the gravels above the dam. The Grant et al. (2002) observation that the turbidity event was probably the source of the fine sediment on the gravels below Cougar Dam was supported by D. Cushman, a USGS technician who has operated stream gages and monitors in the area (Anderson 2003).

Following thorough investigation by the Anderson (2007), very little long-term adverse effect of this visually spectacular event was identified. The researchers concluded that sediment concentrations entering Cougar reservoir during April 2002 were unusually high but that erosion of reservoir sediments was a substantial net contributor to downstream sediment loads. Downstream movement of DDT and byproducts of DDT, a concern due to past forest practices, was low immediately following the April 2002 event and nonexistent during later storm events. Although fine sediments were found among stream substrates downstream from Cougar Dam, all other stream reaches affected by flow regulation showed similar fine sediment accumulations leading the study team to suspect that the cause was primarily peak flow reduction associated with flood control operations, not the 2002 sediment-plume episode. These investigators suggest that prior to engaging in future projects requiring reservoir drawdown, a network of turbidity monitoring monitors should be installed, coupled with collection of suspended-sediment data prior to the drawdown to facilitate post-construction evaluation of the role of the construction on sediment transport and areas of likely deposition.

The USACE also collected samples of benthic invertebrates above and below Cougar Reservoir in August 2002 following the high turbidity events of spring 2002. The sampling design was intended to determine whether there had been immediate and catastrophic effects to benthic macroinvertebrate communities as a result of the recent drawdown and release of suspended materials. The analysis indicated that the “biotic integrity”5 of the benthic macroinvertebrate community below Cougar Dam was degraded in comparison to the community located above the reservoir (USACE 2003). However, the same trend was observed in samples collected in 2000

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5 Communities that score high have very high habitat complexity, are minimally impacted by human activities, and have a strong, perennial flow of cool/cold water (Aquatic Biology Associates 2000).
and 2001, before the drawdown. The USACE stated that this effect is not unusual for areas located below dams, citing studies in the Clackamas River system as an example.

4.3.3.3.5 Nutrients
The ODEQ’s 2002 CWA section 303(d) database does not indicate that any streams in the McKenzie subbasin are water quality limited due to excess nutrients.

4.3.3.6 Toxics
The ODEQ’s 2002 CWA section 303(d) database does not indicate that any streams in the McKenzie subbasin are water quality limited due to toxics.

4.3.3.4 Physical Habitat Characteristics

The McKenzie subbasin contains some of the better freshwater habitat still available to UWR Chinook, both within the Willamette Valley lowlands and in its forested uplands. This does not, however, mean that salmon habitat within the subbasin is of consistently good quality. Collectively, physical habitat in the mainstem McKenzie River and its tributaries has been affected to varying degrees by multiple unfavorable human influences. These include timber harvest activities, failures of forest roads, wood removal, rural and residential development near streams, conversions of lowland areas to agriculture, bank protection efforts, and altered patterns of water, sediment, and wood movement in riverine channels below dams. Unfavorable influences on salmon habitat within the subbasin have tended to be more pronounced in the valley lowlands or Cascade foothills than in higher elevation watersheds above Vida, where federal lands predominate. Streams on the federal lands in upper portions of the subbasin are being managed with a stronger focus on aquatic conservation than is generally seen in the private and mixed-ownership watersheds lower in the subbasin.

Substrate
Varied combinations of the influences noted above affect substrate conditions in salmon streams within the McKenzie subbasin. Above USACE dams on the South Fork McKenzie (Cougar Dam) and Blue River (Blue River Dam), and to perhaps a lesser degree above EWEB’s Trail Bridge Dam on the upper McKenzie, timber harvest and roads have increased rates of sediment input to stream channels (WNF MRD 1995; WNF BRRD 1996; Stillwater Sciences 2006). These inputs have likely affected substrate composition in channels above the dams, but have not affected riverine habitats below the dams because the reservoirs created by the dams function as sediment traps.

All coarse sediment transported from the watersheds above Trail Bridge, Cougar, and Blue River dams is now captured by reservoirs and lost to the river system. This sediment contributed historically to the maintenance of high-quality riverine habitats downstream, including spawning sites for UWR Chinook, and its loss has not been without consequence. The losses of sediment, in combination with losses of large woody debris and diminished flooding, have led to a coarsening of riverbed substrates and reductions in fresh gravel bar surfaces in the mainstem McKenzie (Minear 1994), the lower South Fork (WNF BRRD 1994), and probably lower Blue River.

Substrate coarsening in riverine channels downstream of USACE and EWEB dams likely reduces the availability of spawning gravel for UWR Chinook, though the degree to which
gravel availability limits the subbasin’s population of these fish is unclear. Ligon et al. (1995) suggested that spawning gravel limitations may already be causing redd superimposition in the mainstem McKenzie above Leaburg Dam. However, the USACE (2000) reported that only 1% of the available gravel is used by Chinook salmon in the mainstem McKenzie River. More recently, results from habitat surveys conducted on the South Fork McKenzie below Cougar Dam point to the distribution of spawning gravels as being perhaps a bigger issue than the aggregate quantity of them in the system as a whole. The quantity (730m$^2$) of good spawning habitat that R2 Resource Consultants (2007) suggest is now available to UWR Chinook in the South Fork, once the McKenzie tributary most heavily used by spawning salmon, may barely be adequate to accommodate the diminished numbers of redds (up to 142) that Schroeder et al. (2005) have counted there in the last several years.

Streambed substrates in undammed salmon streams tributary to the McKenzie vary naturally and in response to differing patterns of human disturbance. Two of these streams that head in the Three Sisters Wilderness, Lost and Horse creeks, have watersheds almost entirely within the Willamette National Forest, remain well used as UWR Chinook spawning areas (Schroeder et al. 2005), and are presumed to provide desirable substrate conditions for the fish. Horse Creek, substantially the larger of these two tributaries, plays a vital role in recruiting sediment into the upper McKenzie River. Gate Creek near Vida, downstream of the South Fork and Blue River, drains a mixed-ownership watershed managed largely for timber production but is in good enough condition to remain a lightly used spawning area for UWR Chinook. Channels within the Mohawk River system that Parkhurst et al. (1950) indicate were once used by UWR Chinook have never recovered from historic logging practices, including log drives and splash damming$^6$, that scoured channels to bedrock in some areas and left bed instability problems in others (Huntington 2000).

**Large Woody Debris**

Large woody debris is an important component of high-quality salmonid habitat because it adds structural complexity, influences sediment storage and channel form, and provides hiding cover (see Appendix E). Under natural conditions it is frequently abundant in streams, and this remains the case in those forested watersheds within the McKenzie subbasin that have been least affected by old timber harvest practices and (misguided) stream cleaning operations. Such watersheds frequently have older-aged forests within many streamside areas and thus also have significant potential for the natural recruitment of additional wood to streams.

Within the portions of the McKenzie subbasin above Cougar, Blue River, and Trail Bridge dams, woody debris abundance in streams is variable. For example, many streams within the South Fork watershed above Cougar Dam fall below Forest Service targets for in-channel wood, but others, including streams in the Three Sisters Wilderness Area, often have abundant wood (WNF BRRD 1994). Many of the wilderness streams, including a significant section of the upper South Fork itself, have streamside conifers that provide high wood recruitment potential. Wood-deficient streams are common within the roaded drainage above Blue River Dam, but sections of

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$^6$Timber harvesters created small “splash” dams to form temporary ponds for log storage. They would explode the dam, sending the mass of water and logs downstream, which often removed all existing large wood in a stream and frequently scoured streams down to bedrock.
Quentin, Quartz, North Fork Quartz, and Lookout creeks have reasonably high abundances of in-channel wood (WNF BRRD1996). The last two of these streams have high wood recruitment potential (WNF BRRD1996).

All woody debris that streams transport from the watersheds above Cougar, Blue River, and Trail Bridge dams (about half of the McKenzie’s historic contributing area above Vida) is now trapped in reservoirs and fails to reach lower portions of the river system. Such wood is thought to have once contributed to the maintenance of high-quality salmonid habitats downstream by influencing how river channels interacted with their banks and floodplains and by providing hydraulic diversity and hiding cover. The wood could have created logjams, secondary channels, pools and stable gravel deposits, all habitats utilized by salmonids and the invertebrates upon which they feed.

Without large wood recruited from above-dam watersheds, the lower-most segments of the South Fork and Blue River, as well as the mainstem McKenzie below Trail Bridge Dam, are entirely dependent on wood recruited from their banks, floodplains, or below-dam tributaries. The lower South Fork below Cougar Dam exhibits a general lack of large woody debris and has low wood recruitment potential (WNF BRRD 1994). The same appears to be true for Blue River below its dam. Wood loading and recruitment potential are more variable along the mainstem McKenzie.

Dam-affected reaches of the mainstem McKenzie contain limited quantities of large wood due to the combined effects of reduced input and active wood removals for flood control, navigation, or commercial purposes (Minear 1994). However, the river corridor from Trail Bridge Dam down to Hendricks Bridge remains primarily conifer-dominated and capable in places of recruiting large wood to the river (Minear 1994). Opportunities for riparian wood recruitment along the river are relatively high near Trail Bridge and tend to decline in the downstream direction due to past timber harvest, increased residential or commercial development, roadway encroachment, and reduced flooding (Minear 1994). Reductions in recruitment potential become more pronounced along the river below the South Fork, where Minear (1994) indicates much of the riparian timber was harvested during the late-1950s. Within bottomlands that extend from Hendricks Bridge to the mouth, the McKenzie corridor is naturally hardwood dominated but now consists of a much-narrowed strip of vegetation with few old trees (Alsea Geospatial et al. 2000) and a low potential for recruiting large wood to the river.

The potential for the mainstem McKenzie to receive large wood from its un-dammed tributaries varies considerably among these streams. Those un-dammed tributaries that enter the river above the South Fork confluence (e.g., Deer, Lost, and Horse Creeks) are primarily in public ownership, typically have modest abundances of instream wood, and have frequent riparian patches of old-growth conifers that offer good recruitment potential (WNF BRRD 1994; WNF MRD 1997). Past wood removal from some of these streams had unfavorable effects upon the fish habitat within them, but the Forest Service has since begun placing wood back into stream channels (WNF MRD 1995). Un-dammed tributaries lower in the drainage network (e.g., Quartz Creek and Mohawk River) have watersheds with mixed or private ownership, low levels of large instream wood, and riparian corridors that often have relatively low wood recruitment potential (Weyerhaeuser 1994; BLME 1995I; Alsea Geospatial et al. 2000).
Channel Complexity, Off-channel Habitat & Floodplain Connectivity

Reductions in channel-forming flows, decreased inputs of sediment and large wood, alteration or removal of riparian vegetation, and bank armoring can all impair the formation and maintenance of complex riverine and floodplain habitats important to salmonids (Appendix E). Each of these disturbances has influenced channel conditions downstream of the dams in the McKenzie subbasin. Along the mainstem McKenzie River from EWEB’s Trail Bridge Dam down to the South Fork confluence, pool habitat has declined (Sedell et al. 1991; Minear 1994) and multiple river segments have lost sinuosity and abandoned side channels (Minear 1994). The lower South Fork has down-cut, become less dynamic, experienced vegetative encroachment, and lost active alluvial features and secondary channels since the completion of Cougar Dam (WNF BRRD 1994). Losses of channel complexity have also been documented along the mainstem McKenzie between the South Fork confluence and the mouth.

Multiple researchers have documented losses of channel complexity and habitats important to salmonids within different and often over-lapping segments of the lower McKenzie River following USACE completion of flood-control dams on the South Fork and Blue River. EA Engineering (1991) interpreted historic air photos and concluded that the channel of the lower McKenzie was very active prior to dam construction, but that it became less dynamic and lost large proportions of its islands and associated habitats during a 40-year period (1950-1990) that bracketed construction. More than half of the islands (53%), island area (51%), and island edges (58%) from Deerhorn Park to the mouth were lost during this period (EA Engineering 1991). Sedell et al. (1991) reported that the number of large pools in the McKenzie below Leaburg Dam decreased by 67% during a similar period (1938-1991). Alsea Geospatial et al. (2000) found that side channels are much less abundant than they once were along the river between Hendricks and Hayden bridges, but that alcoves have increased there, possibly because dampened peak flows have allowed vegetative encroachment and sediment to fill the upper ends of side channels.

Effects of Cougar and Blue River dams are only partially responsible for the channel simplification that has occurred along the lower McKenzie. Within the lower Cascade foothills and Willamette Valley lowlands, activities that have altered or removed streamside forests have also contributed (Minear 1994; Alsea Geospatial et al. 2000), as have bank stabilization measures. As of 1989 the USACE had constructed more than 10.7 miles of revetments along the river (USACE 2000), and additional riverbanks have been armored with rock rip-rap to protect private residences built after floods were controlled (Alsea Geospatial et al. 2000). The combination of artificially erosion-resistant banks and flood-control now limit channel migration and impair the ability of many sections of the lower river to create or maintain complex habitats by interacting with its floodplain. For example, side channels and alcoves have become scarce along the river downstream of the I-5 Bridge, due to extensive bank armoring installed to aid gravel extraction activities and to protect property within the City of Springfield (Alsea Geospatial et al. 2000).

Project operations that have reduced flooding of the mainstem McKenzie decrease floodplain inundation, reduce inputs of sediment, nutrients, and organic material to the river, and prevent juvenile salmon access to potential floodplain refugia during high-water events.
Riparian Reserves & Disturbance History

Riparian vegetation along streams in the McKenzie subbasin varies in response to natural differences in geology, precipitation, elevation, and disturbance regimes, and to man-caused factors including: timber harvest, road building, and other land uses. At present, near-stream vegetation is generally least disturbed in federally managed portions of the subbasin, particularly on the Willamette National Forest, and most disturbed along lowland channels passing through areas affected by agricultural or rural-residential development.

Patches of mature or old-growth forest remain within the Three Sisters Wilderness Area and along segments of multiple streams in significant federally-managed portions of the subbasin, including parts of the South Fork, Blue River, Horse Creek, and Upper McKenzie watersheds (WNF BRRD 1994, 1996; WNF MRD 1997). However, timber harvest and road networks elsewhere within the identified watersheds and on other federal forestlands in the subbasin have left many riparian areas dominated by early- to mid-successional vegetation. Streams within the private forestlands that predominate in tributary watersheds downriver from Vida, including the Mohawk River watershed, generally have recently disturbed riparian areas that are dominated by alder and young conifers and that provide reduced wood recruitment potential and potentially less shade than is found within mature riparian forests (Huntington 2000; BLME 1995a).

Riparian vegetation along the upper McKenzie River has been influenced by a variety of disturbances including timber harvest, road construction, and rural-residential development. Mature conifers now account for 17 to 39% of the riparian corridor between Trail Bridge Dam and the South Fork confluence, with the highest percentages found at the upper end of this section of river (Minear 1994). Mature conifers become sparse within the river corridor downstream of the South Fork (Minear 1994), where first younger conifers and then hardwoods are dominant.

Within its lowlands, which were once covered with a broad hardwood forest, the mainstem McKenzie is bordered by a narrow band of hardwoods and shrubs, with few trees greater than 40 years old and frequent intrusions from riverfront homes (Alsea Geospatial et al. 2000). Peak flows and woody debris necessary to maintain a dynamic channel with fresh alluvial surfaces and diverse riparian vegetation have been diminished. Riparian intrusions by agriculture, residential development, roads, USACE revetments, and private bank armoring are prevalent (Alsea Geospatial et al. 2000) and inhibit riparian recovery.

4.3.4 Hatchery Programs

McKenzie River Hatchery Chinook salmon are now listed under the ESA as a component of the UWR Chinook salmon ESU. These fish are produced at McKenzie Hatchery, released into the lower McKenzie River as smolts, harvested in fisheries, and return to the hatchery to complete the cycle. Some hatchery returns in excess of broodstock needs are typically out-planted into the South Fork McKenzie above Cougar Reservoir, the mainstem McKenzie River above Trail Bridge Dam, and the Mohawk River, all areas where they are not expected to interact with wild adult Chinook. However, many adult hatchery-origin Chinook fail to return to the hatchery and stray into the natural spawning areas of wild Chinook along the McKenzie River above and below Leaburg Dam (see Section 4.3.2.1), the South Fork McKenzie, Horse Creek, and Lost Creek.
Hatchery programs for McKenzie spring Chinook salmon, as well as other hatchery programs in the McKenzie subbasin, pose risks that ODFW, the USACE, and others are working to better define and resolve. These include:

- Adult hatchery fish interbreeding with wild fish resulting in a risk of genetic introgression.
- Competition with naturally produced progeny of hatchery spring Chinook.
- Predation upon wild juvenile Chinook salmon by hatchery summer steelhead smolts released into waters occupied by these fish.
- Predation upon wild juvenile Chinook salmon by hatchery rainbow trout released into waters occupied by these fish.

4.3.5 Fisheries

Until recently, wild spring Chinook salmon were subjected to relatively intense commercial and recreation fisheries in the lower Columbia and Willamette rivers that were directed primarily at the abundant hatchery-origin fish. Freshwater harvest rates for McKenzie River fish were on the order of 35-40% prior to ESA listing of UWR Chinook, but have since been reduced (Figure 4.3-7). Fishery objectives in the Willamette River have been changed to emphasize the protection of natural-origin fish.

The State of Oregon developed a Fisheries Management and Evaluation Plan under NMFS’ 4(d) Rule for the management of spring Chinook salmon fisheries in the Willamette River. This management plan specifies the harvest regime for spring Chinook salmon and has been approved by NMFS under the ESA. Total mortality in commercial and sport fisheries occurring in freshwater are capped at 15%. However, annual mortality rates since implementation of selective, catch-and-release fisheries for wild spring Chinook have more typically been in the range of 8-12% (ODFW 2008c). Impacts on natural-origin spring Chinook have been significantly reduced while maintaining a relatively high harvest of hatchery-origin adults.
4.3.6 Status of PCEs of Designated Critical Habitat in the McKenzie Subbasin

NMFS has determined that the following occupied or potentially occupied areas of the McKenzie subbasin either contain or do not contain Critical Habitat for UWR Chinook, as indicated (NMFS 2005d; maps are included in section 3.3 of this Opinion):

- Habitat of high conservation value for these fish, and thus important to their recovery, is present in five of the seven watersheds within the McKenzie subbasin (NMFS 2005g). The five watersheds include Upper McKenzie River, Horse Creek, South Fork McKenzie River, McKenzie River/Quartz Creek, and Lower McKenzie River. These watersheds were designated as Critical Habitat by NMFS (2005d) and contain 138.9 miles of PCEs for spawning rearing, 68.3 miles of PCEs for rearing/migration, and 1.8 miles of migration/presence habitat (NMFS 2005g).

- The South Fork McKenzie River watershed, where the Corps owns and operates Cougar Dam, contains 22.5 miles of spawning/rearing habitat, 18.8 miles of rearing/migration habitat, and 0.8 miles of migration/presence habitat, most of it above Cougar Dam (NMFS 2005g).

- The Lower McKenzie River watershed, which has been significantly affected by the operation of the Blue River and Cougar dams, includes 58.9 miles of spawning/rearing habitat.
habitat, 33.5 miles of rearing/migration habitat, and 2 miles of migration/presence habitat (NMFS 2005g).

- The Blue River and Mohawk River watersheds were rated by NMFS (2005g) as having lower conservation value for UWR Chinook, and were excluded from the final designation of critical habitat as described in section 3.3. Combined, these areas contain 8.5 miles of PCEs for spawning/rearing, 45.4 miles for rearing/migration, and 4.4 miles for migration/presence (NMFS 2005g). The Blue River watershed, where the Corps owns and operates Blue River Dam, provides 1.4 miles of spawning/rearing habitat, 0.1 miles of rearing/migration habitat, and 0 miles of migration/presence habitat below the dam (NMFS 2005g).

Bank protection measures, such as revetments, associated with USACE activities total 56,324 linear feet (10.7 miles) between RM 0.8 and Leaburg Dam (RM 38.8), with 18,103 feet (3.4 miles) on the right bank, and 38,221 (7.3 miles) on the left bank (USACE 2000). These measures affect spawning/rearing habitat that NMFS (2005d), designated as critical habitat, in lower McKenzie River. (NMFS 2005g).

NMFS (2005g) identified the key management activities that affect these PCEs. Key activities affecting the upper watersheds include dams, forestry, and agriculture. Key activities affecting the mid and lower watershed include road building and maintenance, channel modifications and urbanization, in addition to dams, forestry, and agriculture.

As discussed in Section 4.3.3.1, Cougar and Blue River Dams block access to upstream spawning and rearing habitats, reduce downstream migrant survival, alter flows downstream, reduce or eliminate marine-derived nutrients from these upper watersheds, and limit the downstream transport of habitat building blocks. Cougar Dam also alters the habitat above the dam by creating a 6.5 mile-long reservoir from about RM 4 to RM 10, which inundates historical spawning habitats (Myers et al. 2006). Until the WTC was completed in 2002, Cougar Dam also negatively altered downstream water temperatures. Blue River Dam also alters the habitat above the dam, with the reservoir inundating 2.7 miles of historical anadromous habitat. Blue River continues to negatively alter downstream water temperatures in Blue River and the mainstem McKenzie River below the Blue River confluence.

Table 4.3-4 summarizes the condition of PCEs within the McKenzie River subbasin. Many of the habitat indicators are not in a condition suitable for salmon and steelhead conservation. In most cases, this is the result of the past operation and the continuing effects of the existence of the Projects or the effects of other human activities (e.g., development, agriculture, and logging). However, to the extent these conditions would be perpetuated by future operations or existence of the project, only the past impacts and project existence are included in the baseline.
### Table 4.3-4 Matrix of Pathways and Indicators for the condition of primary constituent elements of critical habitat in the McKenzie River Subbasin under the environmental baseline.

<table>
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<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Limiting Factors</th>
</tr>
</thead>
</table>
| Freshwater migration corridors| Habitat Access| Physical Barriers | Adult passage and delay, up to 14.5% mortality of outmigrating smolts, and low flows in the Leaburg and Walterville bypass reaches of the lower mainstem; corrected during 2002-2004 under terms of the new FERC license  
Trail Bridge and Smith dams exclude spring Chinook salmon (~8 miles) from a portion of their historical range | EWEB’s Leaburg and Walterville hydro projects  
EWEB’s and Carmen-Smith-Trail Bridge hydro projects |
| Freshwater migration corridors| Habitat Access| Physical Barriers | *Cougar Dam as a barrier to upstream migrants*—currently there is no upstream passage at Cougar Dam, which blocks over 37 miles of upstream historical habitat. The USACE has proposed to construct a permanent trap and haul facility to provide upstream passage.  
*Cougar Dam and Reservoir as a barrier to downstream migrants*—Cougar Dam was built with juvenile fish passage facilities; juveniles entered through one of five fish horns on the upstream face of the intake tower. Fish horns collected only a low percent of the juvenile Chinook in the reservoir; many of those were injured or killed. For hatchery-reared fingerling Chinook released into Cougar Reservoir in 1963-2002, survival was 67.4% through the regulating outlet and 93% through the turbines; survival decreased with increasing fish size. | Cougar Dam is currently an upstream migration barrier, but USACE intends to construct upstream fish passage facilities by April 2009.  
Cougar Dam is a downstream migration barrier and currently does not provide safe downstream fish passage conditions. |
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<th>PCE Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Limiting Factors</th>
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</thead>
<tbody>
<tr>
<td>Freshwater migration corridors</td>
<td>Habitat Access</td>
<td><em>Blue River Dam as a barrier to migration</em> --Blue River Dam blocks access to 2.7 miles of historical habitat below a falls that was probably a natural historical barrier at low flows.</td>
<td>Blue River Dam is a migration barrier, and does not have up or downstream fish passage facilities.</td>
</tr>
<tr>
<td></td>
<td>Physical Barriers</td>
<td>Frequency of flows in the South Fork McKenzie, Blue River, and lower McKenzie River not of sufficient magnitude to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas</td>
<td>Flood control operations at USACE’s Cougar and Blue River dams reduce the magnitude and frequency of peak flows</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flow fluctuations now occur at rates rapid enough to entrap and strand juvenile anadromous fish</td>
<td>Flood control operations at USACE’s Cougar Dam cause rapid flow reductions</td>
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<td></td>
<td></td>
<td>Increased fall flows may allow spring Chinook to spawn in areas that will be dewatered during active flood control operations</td>
<td>Fall releases from Cougar and Blue River reservoirs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Winter and spring flow reductions may reduce rearing area and the survival of steelhead fry</td>
<td>Winter flood control and late winter and spring refill operations at Cougar and Blue River dams</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increased summer flows may increase rearing area and the heat capacity of the stream</td>
<td>Flow augmentation from Cougar and Blue River dams to meet mainstem flow targets</td>
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<td></td>
<td>Low summer flows in specific reaches (due to diversions) may reduce the juvenile rearing habitat area, block adult passage to upstream spawning areas, and decrease the heat capacity of the stream.</td>
<td>Summer diversions at EWEB’s Leaburg and Walterville Project</td>
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</table>
### Table: Condition and Limiting Factors

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<th>PCE</th>
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<th>Limiting Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Water Quality</td>
<td>Temperature: Cooler water temperatures in the late spring and summer have impeded upstream migration of spring Chinook salmon; warmer fall/winter temperatures accelerated egg incubation and fry emergence.</td>
<td>USACE operations (Cougar Dam until 2005; Blue River Dam)</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater migration corridors</td>
<td>Water Quality</td>
<td>Temperature: EWEB’s Leaburg-Walterville project diverts flow into two power canals downstream of RM 38; water at lower ends of the two mainstem bypass reaches could increase by 2.7 and 3.6°F, respectively, due to diversions.</td>
<td>EWEB’s Leaburg and Waterville Projects</td>
</tr>
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<td></td>
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<td>The ODEQ 2004/2006 Integrated Report database indicates that temperatures in the South Fork McKenzie below Cougar Dam have exceeded the maximum for salmonid spawning and rearing (55°F; 12.8°C) during summer and fall.</td>
<td>USACE operations (Cougar)</td>
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<tr>
<td></td>
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<td></td>
<td>The ODEQ 2004/2006 Integrated Report database indicates that temperatures in the lower 1.8 miles of Blue River have exceeded the maximum for core cold-water habitat (61°F; 16°C).</td>
<td>USACE operations (Blue River)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The ODEQ 2004/2006 Integrated Report database also indicates that the maximum for salmon and steelhead spawning has been exceeded in the mainstem McKenzie from RM 0 to RM 54.5 (Finn Rock).</td>
<td>USACE operations (Cougar and Blue River), EWEB’s Leaburg and Walterville diversions</td>
</tr>
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<td></td>
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<td></td>
<td>The ODEQ 2004/2006 Integrated Report database indicates that temperature maxima for core rearing and non-core rearing and adult and juvenile migration have been recorded in several streams that are not affected by Willamette Project flow management: Deer Creek, Horse Creek, the Mohawk River, and tributaries to the Mohawk River.</td>
<td>Degraded riparian areas due to clearing for floodplain development, and timber harvest.</td>
</tr>
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<td>Limiting Factors</td>
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<tr>
<td></td>
<td>Freshwater spawning sites</td>
<td>Water Quality</td>
<td>Generally, turbidity levels in the McKenzie subbasin are low (&lt;5 NTUs). Release of turbid water during the spring 2002 drawdown of Cougar Reservoir for construction of the water temperature control tower resulted in elevated turbidity levels, including a maximum of 379 NTU (compared to background of 5 NTU) After the turbidity event, higher proportions of fine sediments in gravel bars below Cougar Dam compared to reaches above the reservoir; clay enrichment decreased rapidly downstream; clouds of sediment stirred up while wading in the South Fork below Cougar Dam, and to some extent in the mainstem McKenzie.</td>
<td>N/A USACE construction of the Cougar WTC tower</td>
</tr>
<tr>
<td></td>
<td>Freshwater rearing</td>
<td>Total Suspended Solids/ Turbidity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Freshwater migration corridors</td>
<td>Chemical Contamination/Nutrients</td>
<td>The ODEQ 2004/2006 Integrated Report database indicates that elevated concentrations of iron and manganese are present in some river reaches of the McKenzie subbasin. The ODEQ 2004/2006 Integrated Report database does not indicate that any streams in the McKenzie subbasin are water quality limited due to excess nutrients</td>
<td>Unknown</td>
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N/A
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<thead>
<tr>
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<th>Limiting Factors</th>
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<tr>
<td></td>
<td>Freshwater spawning sites</td>
<td></td>
<td>The ODEQ 2004/2006 Integrated Report database indicated a low percentage of samples (6%) taken in the McKenzie River (RM 0 to 34.1) did not meet the criterion for dissolved oxygen (&gt;11 mg/l and applicable % saturation). Insufficient data exists to determine whether ODEQ standards are met.</td>
<td>Unknown</td>
</tr>
<tr>
<td></td>
<td>Freshwater rearing</td>
<td>Water Quality</td>
<td>TDG levels of 97.8 to 124.1% saturation near the base of Cougar Dam; 99.5 to 115.7% approximately 3,000 feet downstream; and 103.4 to 108.6% at a site 2.7 miles downstream during November (1970). 2006 monitoring below Cougar dam indicated that TDG levels in the RO channel ranged from about 107 percent to 118 percent for flows. Corresponding depth-compensated TDG levels ranged from below 100 percent to about 106 percent, respectively. TDG levels of 107.9 to 120.4% saturation in March (1971 and 1972) below Blue River Dam</td>
<td>USACE operations (Cougar Dam) USACE operations (Cougar Dam) USACE operations (Blue River Dam)</td>
</tr>
</tbody>
</table>
### Freshwater spawning sites

<table>
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<tr>
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<th>Indicator</th>
<th>Condition</th>
<th>Limiting Factors</th>
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<tbody>
<tr>
<td>Habitat Elements</td>
<td>Substrate</td>
<td>Substrate has coarsened in the mainstem McKenzie downstream of Cougar and Blue River Dams.</td>
<td>USACE and EWEB reservoirs trap sediment and large wood from headwaters</td>
</tr>
<tr>
<td></td>
<td></td>
<td>South Fork McKenzie River downstream of Cougar reservoir has stabilized</td>
<td>USACE operates Cougar and Blue River Dams to reduce the magnitude and frequency of peak flows</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Channel downstream of USACE dams lack spawning gravel</td>
<td>USACE and private revetments</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Current sediment budget not creating and maintaining habitat needed by anadromous salmonid</td>
<td>Gravel mining</td>
</tr>
</tbody>
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### Freshwater rearing sites

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<th>Condition</th>
<th>Limiting Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat elements</td>
<td>Large Woody Debris</td>
<td>In Headwater Tributaries Large wood does not meet USFS targets in some tributaries (Lower Deer Creek, Quartz Creek, Mohawk River, the South Fork and some of its tributaries)</td>
<td>Timber harvesting Stream clean-out Fire suppression</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Large wood meets USFS targets in some tributaries (North Fork Quartz Creek, Lookout Creek, some South Fork tributaries)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Some tributaries, such as Horse Creek, have high recruitment potential</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Some restoration efforts are underway in the McKenzie subbasin</td>
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</table>
### Habitat Elements

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<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Freshwater rearing sites</td>
<td>Habitat Elements</td>
<td>Large Woody Debris</td>
<td><em>In the mainstem McKenzie River</em>—The upper McKenzie River below EWEB’s Trail Bridge Dam is deprived of large wood, although some restoration efforts have begun. The South Fork McKenzie below Cougar Dam, and Blue River below Blue River Dam are deprived of large wood from the headwaters. The McKenzie River below Cougar and Blue River dams is deprived of large wood from the South Fork and Blue River. Inadequate recruitment of large wood from riparian areas along mainstem McKenzie and tributaries downstream from Cougar and Blue River dams. Lack of large wood-associated habitat for anadromous salmonids and invertebrates upon which they feed.</td>
<td>USACE and EWEB remove large wood from reservoirs. USACE removed snags in lower river for navigation. Inadequate recruitment from riparian forests. Removal of large wood by landowners and boaters for navigation and/or firewood.</td>
</tr>
<tr>
<td>Freshwater migration corridors</td>
<td>Habitat Elements</td>
<td>Pool Frequency and Quality</td>
<td>Pool frequency and quality in the lower mainstem McKenzie has been reduced due to absence of pool forming elements such as LWD, reduction of channel forming flows, and bank protection measures have reduced channel migration and resulted in simplification of habitats.</td>
<td>Downstream LWD transport blocked by project dams; land uses such as timber harvest. Urbanization, development, and diking in the lower river.</td>
</tr>
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<tr>
<td></td>
<td>Freshwater spawning sites</td>
<td>Habitat Elements</td>
<td>Off-Channel Habitat</td>
<td>The South Fork McKenzie below Cougar Dam has stabilized and lost side channels. The mainstem McKenzie below the Deerhorn Park lost 53% of its islands, and many side channels have filled in and become alcoves. The McKenzie prior to dam construction migrated frequently, and has since stabilized. The lower McKenzie is simplified and channelized, resulting in poor connectivity to off-channel habitat in lower river.</td>
</tr>
<tr>
<td></td>
<td>Freshwater rearing</td>
<td>Channel Conditions and Dynamics</td>
<td>Streambank Condition</td>
<td>Streambanks do not support natural floodplain function in the lower mainstem river, or in the South Fork reach below Cougar Dam.</td>
</tr>
<tr>
<td>PCE</td>
<td>Pathway</td>
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<td>Condition</td>
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<tr>
<td>Freshwater</td>
<td>Freshwater rearing</td>
<td></td>
<td>Floodplain is not frequently inundated, with less over-bank flow and side channel connectivity</td>
<td>USACE operates Cougar and Blue River Dams to reduce the magnitude and frequency of peak flows</td>
</tr>
<tr>
<td>migration</td>
<td>Freshwater migration corridors</td>
<td></td>
<td>Reduced nutrient exchange, reduced sediment exchange, reduced flood refugia for fish, and reduced establishment of new riparian forests</td>
<td>USACE and private revetments</td>
</tr>
<tr>
<td>corridor</td>
<td>Channel Conditions and Dynamics</td>
<td></td>
<td>The lower river is disconnected from its historical floodplain by dikes and flood control operations that have reduced peak flows.</td>
<td>Residential development</td>
</tr>
<tr>
<td></td>
<td>Floodplain connectivity</td>
<td></td>
<td></td>
<td>Dikes; Project operations.</td>
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<tr>
<td>Freshwater</td>
<td>Freshwater spawning sites</td>
<td></td>
<td>High road densities exist in the lower McKenzie River Basin, including Highway 126 which runs adjacent to the McKenzie River for many miles. Road networks, including those for timber harvest, exist in the upper watershed. USACE (2007a) characterized the South Fork and Blue River watersheds as having moderate to low road densities.</td>
<td>Urban, agricultural, and industrial development. Timber harvest.</td>
</tr>
<tr>
<td>migration</td>
<td>Freshwater rearing</td>
<td>Watershed conditions</td>
<td></td>
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<tr>
<td>corridor</td>
<td></td>
<td>Road density and location</td>
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McKenzie Baseline

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July 11, 2008
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<tr>
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<td>Freshwater spawning sites</td>
<td>Freshwater migration corridors</td>
<td>Watershed Conditions</td>
<td>Riparian Reserves</td>
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<td></td>
<td></td>
<td></td>
<td>Headwater forests riparian conditions</td>
<td>Riparian areas in some tributaries contain mature riparian vegetation (e.g., Horse Creek and the South Fork McKenzie) but others (e.g., Quartz Creek, Mohawk River) are dominated by young alder or conifers</td>
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<td>Many tributaries do not provide adequate shading or large wood recruitment</td>
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<td>Riparian vegetation along confined reaches of the upper McKenzie River contains only 39% mature conifers</td>
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<td>Floodplain forest riparian conditions</td>
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<td></td>
<td>Many remaining patches of floodplain forest are interspersed with pastureland, highways, and residential development</td>
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<td>Extent of floodplain vegetation restricted to a narrow band along river</td>
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<td></td>
<td>Low large wood recruitment potential</td>
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<td></td>
<td>Timber harvesting</td>
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<td>Stream clean-out practices</td>
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<td></td>
<td>Clearing for agriculture or development</td>
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<td>USACE and private revetments</td>
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<td></td>
<td>USACE operation of Cougar and Blue River Dams alters the hydrologic regime</td>
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<td>Timber harvest</td>
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<td>Fire suppression</td>
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<td></td>
<td></td>
<td>Timber harvesting</td>
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<tr>
<td></td>
<td></td>
<td>Conversion to agricultural, urban, residential, and rural uses</td>
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Calapooia Baseline
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4.4 CALAPOOIA SUB-BASIN

The Calapooia River subbasin is the smallest of the six east-side and upper Willamette River subbasins (Molalla, North Santiam, South Santiam, Calapooia, McKenzie, and Middle Fork Willamette) located above Willamette Falls in the Willamette River basin. These six are the primary salmon and steelhead-bearing subbasins.

The Calapooia River flows out of the western Cascade Mountains to join the Willamette River at the City of Albany. The subbasin encompasses about 970 km² (240,000 acres) of land and supports a variety of land uses and fish and wildlife habitats. The subbasin’s headwaters drain the south side of the Green Mountain Ridge.

Elevations within the subbasin range from 5,185 feet at the summit of Tidbits Mountain to less than 200 feet where the Calapooia River joins the Willamette River in Albany, OR. Cool rainy winters, and hot, dry summers characterize the climate of the subbasin. Only 5% of the annual precipitation falls from July through September (Hulse et al. 2002). Winter precipitation usually falls as rain in the lower elevations of the subbasin and snow in the mountainous areas above 3,500 feet.

The subbasin is fairly evenly divided between agricultural use (approximately 483 km² or 50% of the land use area) in the lower subbasin and forest or shrub area (approximately 429 km² or 44% of the land use area) in the upper subbasin, as depicted in Figures 4.4-1. Four percent (approximately 38 km²) of the land use is in grasslands, and only about one percent (approximately 13 km²) is currently developed.

While only a small portion of the land has been developed, the human population density in the Calapooia subbasin is second only to the Molalla subbasin among the Willamette’s east-side tributaries. Major population centers within the subbasin include the southern portions of the cities of Albany, Lebanon, and Sweet Home. Ninety-four percent of the subbasin is in private ownership (Figures 4.4-1).
Figure 4.4 Calapooia Sub Basin
Figures 4.4-1  Location, land cover (top) and ownership patterns (bottom) of the Calapooia subbasin (source: WLCTRT 2004).
4.4.1 Historical Populations of Anadromous Salmonids in the Calapooia Subbasin Context

Both UWR Chinook salmon and UWR steelhead occur in the Calapooia River subbasin. Historically, the spring Chinook salmon run in the Calapooia River may have been in the hundreds and the winter steelhead run size may have been in excess of 1,000 adults. Mattson (1948) estimated the adult run of spring Chinook to the Calapooia River in 1947 was about 30 fish.

Most of the spring Chinook salmon and winter steelhead in the Willamette Basin spawn above Willamette Falls at Oregon City. Upper Willamette River spring Chinook are one of the most genetically distinct groups of Chinook salmon in the Columbia River Basin. Before the construction of fish ladders at Willamette Falls, passage by returning adults was only possible during the winter and spring high flow periods. The early run timing of the Willamette River spring Chinook relative to other lower Columbia spring-run populations is an adaptation to flow conditions at the Willamette Falls. High river flows in the late winter and early spring provide the best conditions for passage over the falls. Spring Chinook enter the Willamette as 3, 4, or 5-year old fish with the presence of some jacks (young 2-year-old male fish). The run begins to enter the Willamette River in February, with the majority of the run ascending Willamette Falls in April and May.

Once above Willamette Falls, adult spring Chinook migrate upstream at an average rate of 10 to 20 miles per day (Snelling et al. 1993). Chinook enter the Calapooia River beginning in late April to May with the migration continuing into July. In observations of adult spring Chinook at Sodom Dam over several seasons, peak counts occurred in early June and fish continued to be observed at the dam until early July (ODFW 2004b). (See section 4.4.3 for a detailed discussion of passage issues on the Calapooia)

Historically, spring Chinook salmon used the Calapooia mainstem between Holley (RM 45) and just upstream from the confluence with United States Creek (RM 80) for spawning and rearing. Spawning activity began in August and could extend into November (Wevers et al. 1992).

Adult winter steelhead are present in the Calapooia River during February through May, with peak spawning in April and May (Wevers et al. 1992). Most of the winter steelhead spawning takes place in the river channel and tributary streams above Holley. Winter steelhead cannot access the upper 2 miles of the Calapooia River due to a natural waterfall on Forest Service Land above United States Creek. The North Fork Calapooia River, and Biggs, McKinley, Potts, and King creeks are important tributary streams for spawning.

The subbasin can be subdivided into three parts based upon stream gradient and other key habitat characteristics (CWC 2004). The lower subbasin extends from the confluence of the Calapooia River with the Willamette River in Albany to the upstream end of the Sodom Ditch diversion, about three miles downstream of Brownsville (RM 1 to RM 28.5). Major tributary streams joining the Calapooia River along this section include Oak, Lake, Butte, and Courtney Creeks. The valley in this portion of the subbasin is broad and relatively flat. The highest proportion of low gradient stream and river channels in the Calapooia River subbasin are within this area. The
Calapooia River through this section has less than 0.1% gradient, and most of the tributary streams are very flat, with a few steep streams confined to the upper portions of Butte, Cochran, and Courtney Creeks. The lower subbasin is characterized by wide flood plain forests with numerous side channels and ponds along the river.

The middle subbasin includes the Calapooia River from the upper end of Sodom Ditch diversion, through Brownsville, and continuing to the beginning of forest land, approximately 4 miles above Holley (RM 28.5 to RM 48). Major tributary streams in this section include Warren, Brush, Johnson, and Pugh Creeks. Within this portion of the subbasin, the Calapooia River transitions from a broad valley floor into a narrower valley surrounded by forested hillsides. The Calapooia River through this section ranges from 0.15 % to 0.44 % gradient. The tributary streams begin as steep headwater channels that transition into lower gradients as they flow out of the forested hills. In this middle portion of the Calapooia River subbasin, the river meanders across the flood plain cutting new channels and depositing gravels and wood in the channel.

The upper subbasin includes the Calapooia River from the beginning of forest land above Holley to the mountainous upper subbasin on U.S. Forest Service land (RM 48 to RM 75). Major tributary streams include Biggs, McKinley, and Potts Creeks, and the North Fork of the Calapooia River. The Calapooia River flows through a narrow valley surrounded by the steep slopes of the western Cascade Mountains. The gradient of the Calapooia River through this section increases from 0.44% at the beginning of forest land to 1.94% where the North Fork Calapooia joins the river. This portion of the subbasin has the highest proportion of steep headwater tributary streams. Many of these high gradient stream channels transport debris torrents during flood events, depositing logs and gravels in the river (Weyerhaeuser 1998).

The greatest diversity of fish species is found in the lower Calapooia River subbasin. The most abundant fish species are non-salmonids, both native and non-native. Fish such as three-spine stickleback, redside shiner, and various suckers are more numerous than trout or salmon. In the upper subbasin, salmonids are the most abundant species and non-salmonids are less common.

While the lower river has relatively fewer salmonids throughout the year, it is an essential area for salmon, trout, and other species during part of their life cycle. The lower river is important as a migration corridor for anadromous winter steelhead, spring Chinook salmon, and Pacific lamprey. Winter steelhead and spring Chinook salmon must pass through the river in the lower and middle portions of the subbasin to reach spawning grounds in the upper subbasin. In addition, the tributary streams provide important rearing and high-flow sanctuary habitat during the winter and spring for juvenile salmonid species, including spring Chinook salmon and winter steelhead.

The City of Albany funded a study in which ODFW surveyed streams within, and adjacent to, the city to document fish presence. In addition to native fish species, fish populations in the lower Calapooia River include nonnative fish in the river up to the City of Brownsville (RM 30), in the lower portions of tributary streams such as Lake Creek, Butte Creek, and Cochran Creek, and in Shedd, Walton and Wright sloughs. Non-native fish species were found in most streams, including Oak Creek. Largemouth bass, smallmouth bass, bluegill, western mosquito fish, yellow bullhead, and brown bullhead were all found in Oak Creek and elsewhere.
4.4.2 Current Status of Anadromous Salmonids within the Calapooia Subbasin

4.4.2.1 UWR Chinook Salmon

Spawning surveys in the 1960s and 1970s indicated that very few spring Chinook were returning to the Calapooia River. The 1969 to 1974 average run size was estimated to be 18 fish, and in 1975 and 1976 no redds were found (Wevers et al. 1992). By the 1970s the Calapooia River population of spring Chinook probably was no longer viable (CWC 2004). Blocked fish passage, timber harvest, and urban and rural development within the subbasin have all contributed to the degradation of habitat and of local population viability. Adult fish passage problems at small dams on the Calapooia River has been a major contributing factor to the likely extirpation (and lack of success in restoration) of spring Chinook salmon (Wevers et al. 1992). Since the 1970s, hatchery spring Chinook (from the South Santiam River) have been released to reestablish naturally reproducing populations. In addition, fish straying from other Willamette tributary populations are probably entering the Calapooia River at some unknown rate.

Presently, most of the naturally producing spring Chinook spawn in the upper river above the Weyerhaeuser property boundary (RM 50). Adults must hold over the summer in pools. Spawning can begin in late August and peaks in September extending into October.

Since 1996, ODFW has been conducting annual counts of spring Chinook adults, redds, and juveniles in the upper Calapooia River. Adult and juvenile counts are done in August and redd counts are completed in September. In August 2002, 19.8 miles were surveyed and 35 adults were observed (Figure 4.4-2). Adult counts range from a maximum of 66 fish in 2001 to a minimum of 10 fish in 1997. In a survey conducted in 1971, 13 adult fish were counted.

Counts of spring Chinook redds have varied widely, ranging from a maximum of over 5 redds per mile in 1998 to a minimum of nearly 1 redd per mile in 2001 (Figure 4.4-3). There is also considerable variation in the number of rearing juveniles observed during snorkeling surveys (Figure 4.4-4). Juvenile counts are usually very low, with one to seven fish observed in most years and no fish observed in 1996. In 2001, however, an estimated 1,765 juvenile spring Chinook were observed. These high numbers may be from successful natural spawning of the 371 adults stocked in the Calapooia River during the prior year.
Figure 4.4-2 Annual snorkel counts of adult UWR Chinook in the upper Calapooia River, 1996-2002 (source: CWC 2004).

Figure 4.4-3 Annual densities (number/mile) for UWR Chinook redds counted in the upper Calapooia River, 1996-2002 (source: CWC 2004).

Figure 4.4-4 Annual snorkel counts of juvenile UWR Chinook in the upper Calapooia River, 1996-2002 (source: CWC 2004).
Variation in the observed numbers of juveniles in the Calapooia River may be due to young spring Chinook leaving the system to rear further downstream. ODFW has observed a range of ages for juvenile spring Chinook migration in the Willamette Basin (Schroeder et al. 2002). Fry (age 0) migrate in the late winter through early spring; fingerlings (age 0+) migrate in the fall; and yearling smolts (age 1+) migrate in early spring.

Because adult spring Chinook hold in the upper Calapooia River over the summer months, they have specific habitat needs and they are vulnerable to poaching and harassment. Spring Chinook prefer cool, deep pool habitat with abundant large wood and undercut banks for cover. Juvenile spring Chinook may spend considerable time rearing in the Calapooia River. Juvenile spring Chinook require cold water, and deep pools for feeding and cover from predators. Access to side channels, backwater areas, and tributary streams for refuge during high flows in the winter and spring is also important.

ODFW has developed objectives for recovering the Calapooia River spring Chinook population. The long-term objective (2020) is 650 adults returning to the subbasin; the interim objective (2006) is for 100 returning adults. In 2002, 35 returning adults were counted (CWC 2004).

4.4.2.2 UWR Steelhead

ODFW has been conducting annual winter steelhead spawning surveys in the upper Calapooia River subbasin since 1985. Most of the spawning surveys take place in May. While the spawning surveys do not look at the entire length of suitable spawning habitat, they do cover most of the high quality spawning areas. Since 2000, the spawning surveys have covered 7.5 miles of habitat in the Calapooia River channel and the lower portions of key tributary streams including the following.

- Calapooia River: River miles 65 to 72.5
- North Fork Calapooia River: The lower 1 mile
- Potts Creek: The lower 1 mile

Counts of winter steelhead redds have varied widely, ranging from a high of over 16 redds per mile in 1985 to a low of 1 redd per mile in 1996 (Figure 4.4-5). The variation in redd counts in the upper Calapooia River subbasin generally follow the trends for adult winter steelhead fish counted at Willamette Falls (Figure 4.4-6).
Juvenile winter steelhead typically spend two or more years rearing in the Calapooia River and its tributary streams before moving downstream to the ocean (Wevers et al. 1992). They require cold water, and deep pools for feeding and for shelter from predators. These habitat features are present in the upper subbasin. Access to tributary streams is also important to escape high water temperatures in the summer and to find refuge from high flows during the winter. Spring Chinook salmon require larger river habitat which is more degraded than habitat used by winter steelhead in the Calapooia subbasin.

The Oregon Department of Fish and Wildlife has developed objectives for recovering the Calapooia River winter steelhead population (Wevers et al. 1992). The long-term objective by year 2020 is 1,170 adults returning to the subbasin (25 redds per mile); the interim objective by year 2006 is for 15 redds per mile (Wevers et al. 1992). Since 1997 the redd counts have averaged about 7 redds per mile.
ODFW’s Fish Management Plan covering the Calapooia River Subbasin (Wevers et al. 1992) identified protection, restoration, and enhancement of habitat and improved adult fish passage at Thompson’s Mill and Brownsville dams as key components in their recovery strategy for spring Chinook salmon. Brownsville Dam (RM 36) was recently removed and is, therefore, no longer a concern. Habitat located in the area between the towns of Holley and Dollar (RM 46-56) was identified as an area of emphasis. Screening of the Brownsville irrigation diversion was also identified as an important action. The outplanting of hatchery fish will be necessary to reestablish a naturally reproducing local population, which should become a naturally self-sustaining population upon the completion of necessary fish passage and habitat improvements.

### 4.4.2.3 Factors Limiting Productivity

The limiting factors and threats currently inhibiting the survival and recovery of spring Chinook salmon and winter steelhead in the Calapooia River subbasin, as identified in the Draft Willamette Chinook and Steelhead Recovery Plan (ODFW 2007b), are shown in Table 4.4-1. Even though the limiting factors and threats are broken into two groups (i.e., key and secondary), the secondary factors are important to address as well as the primary key factors.

#### Table 4.4-1 Key and Secondary Limiting Factors and Threats to Recovery of Calapooia Spring Chinook and Winter Steelhead.

<table>
<thead>
<tr>
<th>Threats</th>
<th>Species</th>
<th>Tributaries (Streams and Rivers within Population Area)</th>
<th>West Side Tributaries</th>
<th>Mainstem Willamette (above falls)</th>
<th>Estuary (below Bonneville and Willamette Falls)</th>
<th>Ocean</th>
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<tbody>
<tr>
<td>Harvest</td>
<td>Chinook</td>
<td>Egg Alevin Fry Summer Parr Winter Parr Smolt Adult Spawner Kelt Presmolt Parr Smolt Fingering/ Sub-yearling Yearling Adult</td>
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<td></td>
<td></td>
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<td>Steelhead</td>
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<tr>
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<td>Steelhead</td>
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<tr>
<td>Hydropower/ Flood Control</td>
<td>Chinook</td>
<td></td>
<td>10d</td>
<td>5a,5b,7h,10f</td>
<td>4a</td>
<td></td>
</tr>
<tr>
<td>Hydropower/ Flood Control</td>
<td>Steelhead</td>
<td></td>
<td>10c</td>
<td>5a,5b,7h,10f</td>
<td></td>
<td>9j</td>
</tr>
<tr>
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<td>Steelhead</td>
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</tbody>
</table>

Black cells indicated key concerns; Gray cells indicated secondary concerns.

**Key threats and limiting factors**

2h Impaired access to habitat above Calapooia dams.

3 Hatchery fish interbreeding with wild fish resulting in a risk of genetic introgression.

5a Reduced macrodetrital inputs from near elimination of overbank events and the separation of the river from its floodplain.

5b Increased microdetrital inputs due to reservoirs.

7h Impaired fine sediment recruitment due to dam blockage.

8a Impaired physical habitat from past and/or present land use practices.

8b Loss of holding pools from past and/or present land use practices resulting in increased prespawning mortality.

9a Elevated water temperatures from past and/or present land use practices resulting in decreased survival and/or growth.

9c Elevated water temperatures from past and/or present land use practices leading to prespawning mortality.

10c Reduced flows during spring reservoir filling result in increased water temperatures that lead to increased disease.

Calapooia Baseline 4.4 - 12 July 11, 2008
Altered flows due to hydropower system that result in changes to estuarine habitat and plume conditions, impaired access to off-channel habitat, and impaired sediment transport.

Secondary threats and limiting factors

2a Impaired access to habitat due to road crossings and other land use related passage impediments on wadeable sized streams.
2h Impaired access to habitat above Calapooia dams.
4a Competition with hatchery fish of all species.
6e Predation by birds as a result of favorable habitat conditions for birds created by past and/or present land use activities.
7a Fine sediment in spawning gravel from past and/or present land use practices.
8a Impaired physical habitat from past and/or present land use practices.
9a Elevated water temperatures from past and/or present land use practices resulting in decreased survival and/or growth.
9h Toxicity due to agricultural practices.
9i Toxicity due to urban and industrial practices.
9j Elevated water temperatures due to reservoir heating.
10b Insufficient streamflows due to land use related water withdrawals resulting in impaired water quality and reduced habitat availability.
10d Reduced peak flows leading to decreased channel complexity and diversity of fish habitat by reducing channel movement that is important for recruitment of gravel and large wood, and maintaining varying seral stages of riparian vegetation. Lower peak flows also reduces scour and formation of pools.

4.4.3 Structures Impeding Fish Passage

Impediments to fish passage can limit access to important areas for spawning or to cool tributary streams when the mainstem Calapooia River or its tributaries warm during the summer months. Fish passage impediments on the mainstem Calapooia River and its tributary streams are an issue affecting fish production throughout the subbasin. There are several dams and diversions that limit upstream migration. The dams and diversions within the Thompson’s Mill complex (RM 19.5 to 28.5) cause delay and blockage of upstream migration and injury and mortality to downstream migrants, as described in detail in section 4.4.3.1 below. (CWC 2004). Brownsville Dam (RM 36) was recently removed, substantially improving fish passage from the lower to the middle part of the Calapooia River subbasin. There are numerous unscreened small diversions within the subbasin (WRI 2004).

The mainstem Calapooia River, in comparison to tributary streams, provides most of the important fish habitat, particularly for spring Chinook salmon and winter steelhead. The mainstem of the river is the primary corridor for migrating fish and it provides most of the important spawning and rearing habitat. The river’s dams – within the Thompson’s Mill complex – delay fish moving upstream to spawning areas in the upper subbasin and may prevent the movement of adult and juvenile fish during parts of the year. Delaying the migration of spring Chinook and winter steelhead stresses the fish, leading to reduced spawning success, and provides opportunities for poaching and harassment.

Road crossings and culverts also present a problem for salmon and steelhead in the Calapooia subbasin. Fish passage at road crossings is important for providing access for adult salmon, trout and steelhead to spawning areas and for providing access for juvenile fish to escape unfavorable conditions such as warm water temperatures in the summer and high flows in the winter. Juvenile winter steelhead and spring Chinook salmon use the lower portions of seasonally intermittent and perennial tributary streams.
4.4.3.1 Lower Calapooia Subbasin

Fish passage has been assessed for dams along the lower Calapooia River corridor, but there are no comprehensive inventories of fish passage barriers for tributary streams. Some road crossings have been assessed through an inventory conducted in upper Courtney Creek and the middle portions of the subbasin (Brush, Pugh, and other tributaries).

Migrating fish encounter significant passage impediments between river mile 19.5 and 28.5 of the Calapooia River. At this location, there is a complex of dams and diversion ditches associated with Thompson’s Mills (Figure 4.4-7). Historically, water was diverted through the Mill for producing flour and for generating electricity. In the late 1990s after UWR Chinook salmon and UWR steelhead were listed under the ESA, the Mill owner began working with Federal and State agencies to find a solution to fish passage problems without shutting down this historically valuable mill. The Thompson’s Mills Working Group was formed to identify options for addressing fish passage problems and to explore ways of preserving the historical site. Part of the solution was for Oregon Parks and Recreation Department (OPRD) to purchase the property, including rights to water use and hydropower generation. The sale of Thompson’s Mills project took place on March 18, 2004 (OPRD filed the License Assignment with the Federal Energy Regulatory Commission on August 2, 2006). Subsequently, on February 27, 2008, OPRD filed an application with FERC to surrender the FERC license to generate commercial hydropower and that application stated that OPRD ceased power production in 2005. The OPRD is interested in preserving the mill in its historic condition as an operating grain mill, so they retain an interest in diverting smaller and less frequent amounts of flow for this purpose. The working group continues to work with OPRD to develop permanent solutions for the relic diversion structures, which are not needed for the demonstration of the grain mill.
Currently, water is diverted for purposes of demonstration of milling techniques. A series of dams (Sodom and Shear Dams) and ditches (Sodom and Thompson Diversion ditches), divert the Calapooia River’s flow, creating problems for migrating fish. These diversions allow OPRD to operate Thompson’s Mills with water diverted by Sodom Dam and Shear Dam (labeled Thompson Dam on the Halsey USGS Quadrangle map). Sodom Diversion ditch was built as a high water diversion for the purposes of diverting high stream flows away from the mill and a ten-mile stretch of river downstream. Unfortunately, it was too effective and in 1890, Sodom Dam was built to help divert river water out of the ditch and back into the Calapooia River. Shear Dam diverts water from the Calapooia River into the mill race.

The primary difficulties that the aforementioned fish passage obstacles pose for UWR Chinook salmon and UWR Steelhead, as well as other fish species, are described below:
**Fish Passage at the Dams**

Fish encounter problems moving over Sodom (about 11 feet high) and Shear dams (about 5 feet high). During late winter and early spring high flows, more water passes through Sodom Ditch and is diverted away from the Mill, reducing flow through the mainstem Calapooia River channel. Migrating winter steelhead move through Sodom Ditch and pass over the fish ladder at Sodom Dam. In addition to delaying upstream migration of winter steelhead, the dam presents significant obstacles to UWR Chinook salmon as they must pass over in the late spring when river flows have dropped. Water flowing over the dam creates velocities that attract adult UWR Chinook salmon to the base of the dam and outcompete the fishway flows, which attracts fish away from the fish ladder and inhibits efficient passage. As a result, UWR Chinook salmon will hold for a period of time in the pool at the base of the dam, delaying their migration to spawning locations in the upper subbasin, making the delayed fish vulnerable to harassment and poaching. In addition, the fishway does not meet current requirements for passage and provides inadequate passage conditions. In addition to all of these concerns, Sodom Dam fishway is likely to fail at some point as the fishway is in poor structural condition. The concrete is no longer watertight and deterioration is occurring rapidly. If this occurs, then a complete passage barrier will occur. The Shear Dam fishway does not meet current requirements for fish passage and provides inadequate fish passage conditions.

**Steelhead Spawning in Sodom Ditch**

Winter steelhead, as well as Pacific lamprey, have been observed spawning in Sodom Ditch. Suitable spawning gravels are also present in the river reaches immediately upstream. The diversions of significant river flows into Sodom Ditch have led to a situation where the habitat and flows may attract winter steelhead. However, spawning in Sodom ditch may be attributed to delay of fish passage at Sodom Dam. Spawning in the ditch is a concern because the juvenile winter steelhead probably do not survive the high summer water temperatures in this reach of the river (ODFW 2004a).

**Calapooia River Channel**

During the winter and spring high flow periods, most of the Calapooia River’s discharge flows through Sodom Ditch. This dramatic reduction in high flows moving through the Calapooia River has changed the river channel and associated floodplain within this reach of the river. The river channel has narrowed and, because there is reduced flooding, homes have been built in the historic floodplain. With these changes, there are limited alternatives for increasing high flows through the Calapooia River channel. Sodom Dam is identified as major factor for interruption of Calapooia river gravel transport. The Thompson’s Mill Working Group is examining alternative water allocation through the river channel and Sodom Ditch and the implications for fish migration, aquatic habitat, geomorphology, and future operation of the Mill.

To help understand and identify fish passage solutions and options for future operation of the Mill, the Working Group has collected information on fish habitat within the river and on diversion ditches; tracked fish holding patterns and movement through the complex and over the dams; monitored water temperatures; and measured water flow rates in the river and ditches. In addition, the Working Group has developed a water distribution model that will identify options for allocation of water through the river channel and diversion ditches. The Working Group will be completing a plan for water management and fish passage improvements to OPRD by 2009, but there is no certainty that OPRD will have funds to carry out the Group’s recommendations.
4.4.3.2 Middle Calapooia Subbasin

Fish passage issues have been examined at the Brownsville Dam and on selected tributary streams in the middle Calapooia River subbasin. Brownsville Dam was removed in 2007 eliminating fish passage problems on the mainstem Calapooia River associated with that structure.

**Fish Passage Barriers on Tributary Streams**

Potential fish passage barriers were assessed for most of the tributary streams in the middle Calapooia River subbasin and middle and upper reaches of Courtney Creek in the spring of 2003. Over 80 road crossings were inventoried on county, federal, and private lands (CWC 2004). The culverts were evaluated for their ability to provide fish passage based on criteria developed by ODFW. A majority of the evaluated crossings in the subbasin do not meet these fish passage criteria.

In addition to culverts at road crossings on tributaries in the middle Calapooia River subbasin and Courtney Creek, there is a private water diversion dam on the West Fork of Brush Creek. Although this dam has not been inventoried for fish passage, it is probably a barrier to fish movement.

4.4.3.3 Upper Calapooia Subbasin

In comparison to the lower and middle subbasin areas, fish passage is not a significant issue in the upper Calapooia River subbasin. There are no dams in the mainstem river channel. Weyerhaeuser and the Forest Service have inventoried culverts in the upper subbasin for fish passage at road crossings. Many culverts were replaced after the 1996 flood, and Weyerhaeuser has corrected most of the identified fish passage problems in the streams identified to have the highest quality habitat (CWC 2004).

4.4.4 Hatchery Program

In the past, South Santiam stock spring Chinook salmon from South Santiam hatchery were sporadically outplanted in the Calapooia River to bolster natural production in the population because of the extremely low number of adults returning. However, ODFW last released hatchery fish into the Calapooia River in 2003, and the fish that are naturally reproducing in this subbasin are largely offspring of hatchery releases from previous generations (although some native Calapooia genetic material may still be present if native fish spawned with hatchery-origin fish). The Willamette Hatchery Mitigation Program for spring Chinook salmon may result in continuing threats and exert key adverse effects on attempts to re-establish a locally adapted, naturally reproducing, and self-sustaining population of spring Chinook salmon in the Calapooia River (ODFW 2007b). However, the potential risk of genetic introgression resulting from interbreeding is diminished now that outplanting has been discontinued.

4.4.5 Fisheries

In their draft Upper Willamette Chinook and Steelhead Recovery Plan, ODFW concluded that harvest was not a key threat at any life stage for Calapooia River steelhead or spring Chinook.
salmon populations (ODFW 2007b). Currently, there are no hatchery programs in the subbasin, relatively small numbers of naturally produced fish migrate from the basin each year, river harvest for spring Chinook salmon (both outside of, and within, the Willamette River Basin) has been curtailed to identifiable marked hatchery fish, and there are no directed harvest seasons for either spring Chinook salmon or winter steelhead within the Calapooya River subbasin.

4.4.5.1 Spring Chinook

In the past, there was little documented sport catch of adult spring Chinook in the Calapooya River. The average annual catch during 1963 to 1974 was 13 fish with a range of 0 to 34 fish (Wevers et al. 1992). The subbasin has been closed to spring Chinook salmon angling since 1988, although there is some evidence of continued illegal harvest (CWC 2004).

4.4.5.2 Steelhead

To protect young winter steelhead (which often cannot be distinguished from cutthroat trout), ODFW has restricted trout fishing to catch-and-release with barbless hooks. There is currently no directed harvest season for adult winter steelhead. There are winter steelhead harvest records in the Calapooya River from 1977 through 1988. During this period, the maximum catch was 122 adult fish in 1979 (Wevers et al. 1992).

4.4.6 Status of PCEs of Designated Critical Habitat and Factors Affecting those PCEs in the Calapooya River Subbasin

Natural vegetation comprises from about 25% to 70% (with a median of about 45%) of the stream corridor within 500 feet of the mainstem Calapooya River in the middle and lower parts of the subbasin (i.e., downstream of Holley). Hardwoods are the primary natural vegetation growing within 200 feet of the Calapooya River main channel. Relatively old stands consist of Oregon ash, black cottonwood, bigleaf maple, and red alder occurring in combination. Younger hardwood stands are relatively scarce.

An evaluation by Weyerhaeuser (1998) of riparian conditions on forest land in the upper subbasin along the main channel of the Calapooya River and other fish-bearing tributaries (55 miles total) indicates that a majority of riparian zones (64%) are bordered by vegetation that has low near-term potential for providing large wood to the river channel. Only 14% of areas surveyed were bordered by stands that had a high potential for providing large wood in the near term.

Because the main channel of the Calapooya River is so wide (75 to 100 feet in most reaches) even the tallest trees along the river provide little shade during the summer. On forest land in the upper subbasin, low amounts of shading (less than 40%) on the main channel persist up to the North Fork Calapooya River confluence (Weyerhaeuser 1998). Upstream of this confluence the river is narrow, and shading levels alternate between moderate (40-70%) and high (>70%).

There are no comprehensive assessments of aquatic habitat for all of the river channel and tributary streams in the lower Calapooya River subbasin. ODFW has assessed aquatic habitat for
the portion of the river channel within the Thompson’s Mill complex and the diversion ditches (ODFW 2004a).

The lower Calapooia River subbasin is used by anadromous fish for migration and rearing. Aerial photo interpretation of the lower river channel and riparian areas provides some insights into fish habitat features (CWC 2004). Based on this analysis, the Calapooia River channel has the highest sinuosity downstream of Sodom Ditch. Channels with high sinuosity contain habitat features that are favorable for fish, including ponds, islands, alcoves, side channels, and gravel bars. Natural ponds, side channels and tributary streams in the lower Calapooia River subbasin provide important habitat for a number of fish. Salmon and steelhead juveniles use these areas as a “refuge” from high water flow velocities in the main river channel during reoccurring flooding periods during the winter and early spring. Although there is very little information documenting the loss of off-channel habitats in the lower Calapooia River subbasin, these habitats have probably been lost through various activities, including rip-rap armoring of stream banks, filling wetlands, and construction of fish passage barriers that disconnect tributary streams and sloughs from the river.

ODFW has inventoried stream habitat for the river above Holley. In addition, ODFW has examined fish habitat for the river between Holley and the Sodom Dam. An aerial photo interpretation of the river channel and riparian areas provides some information on fish habitat features in the middle portion of the subbasin (CWC 2004). Based on this analysis, the Calapooia River channel in the middle portion of its subbasin still has considerable sinuosity. In the upper part of this area, the channel is less sinuous and is constrained by areas of bedrock. The river channel from Sodom Ditch diversion to Brownsville Dam has the greatest amounts of gravel deposition. Since this is a depositional area, large trees and logs in the channel would help to create pools and diverse fish habitats.

There are no comprehensive assessments of stream habitat for tributary streams in the middle portion of the Calapooia River subbasin. The lower reaches of the tributary streams provide important high-flow sanctuary and winter rearing areas for spring Chinook salmon and for winter steelhead.

The upper Calapooia River subbasin includes the river channel and tributary streams in the forest lands above Holley. The river in this section flows through the Western Cascade Mountains with a narrow valley often paralleled by a road. There are numerous tributary streams, many with high gradient channels. Salmonid species are the most common fish found in this part of the subbasin. The upper subbasin is the key area for spring Chinook salmon and winter steelhead spawning and juvenile rearing because of the relatively high quality of available habitat in this area. As a result, it is important to improve access to this area to achieve protection and recovery of these ESA listed species. Cutthroat trout and mountain whitefish are also common in this area.

In 1991, ODFW completed aquatic habitat inventories for the river and important tributaries in the upper Calapooia River subbasin. The inventories covered the upper Calapooia River (three reaches), the North Fork (one reach), and Potts Creek (three reaches). The inventories used
ODFW’s standard methods, which focus on collecting data on key fish habitat features, including active channel width, number of pools, pool depth, gravels, and pieces of large wood.

With the exception of Reach 3 in the Calapooia River, all of the river reaches have very few pieces of large wood (greater than 30 feet long and 24-inches in diameter). There was no large wood found in Potts Creek and the North Fork Calapooia. Significantly, all of the inventoried reaches had low to moderate pool numbers and percentages of area in pools. Pool areas of more than 25% are an indication of high quality habitat. Potts Creek was the only inventoried stream with pool areas exceeding 25%.

The ODFW inventory was completed before the 1996 flood. The 1996 flood event created a number of landslides and debris torrent in the upper Calapooia River subbasin. Many of these torrents delivered wood to the lower portions of tributary streams and the river channel (Weyerhaeuser 1998). As a result, there is probably more wood in the river and stream channels than is reflected in the 1991 surveys. A separate aquatic habitat inventory was completed for the Calapooia River on Forest Service Land in 1998. The lower portions of the Forest Service inventory overlapped Reach 3 of the ODFW inventory. The 1998 inventory found large numbers of wood pieces in the river, much of it in large log jams that were delivered in the 1996 flood (CWC 2004). Significantly, many of these large log jams created side channels. Side channels create high quality fish habitat by providing backwater areas for fish feeding and refuge from high flows.

Suitably sized gravel in riffle areas is an indication of potential spawning habitat for winter steelhead, spring Chinook, and cutthroat trout. Riffle gravels ranged from 13% to 45% of habitat area in reaches surveyed in the upper Calapooia River subbasin, with 30% or more indication relatively high quality spawning habitat according to ODFW criteria. About half (50.33%) of the 33.2 miles surveyed contained areas of high quality for spawning. To improve habitat, Weyerhaeuser has added large wood to the channel in the North Fork to increase wood volumes, create pools, and capture spawning gravels (CWC 2004).

Historically, there were frequent and large log drives down the lower Calapooia River. These log drives and the associated removal of wood and log jams, probably continue to affect the river channel by limiting the current quantity of wood in the channel. The reduced number of logs and other wood in the river’s channel limit the creation of pools and rearing or holding habitat for fish. Large sediment loads resulting from bank failures associated with timber harvest have resulted in siltation and compaction of spawning gravels in some areas.

The loss of wood from the river channel is further exacerbated by current wood removal. Logs continue to be removed from the Calapooia River and tributary streams. Logs are removed to prevent bank erosion, reduce damage to property and bridges, and, in some cases, to allow recreational boaters to pass down the channel (CWC 2004). In addition, the lack of large trees growing along some sections of the river and streams contributes to the long-term shortage of wood in channels. The status of streamside forests and the wood removal actions have cumulatively impacted the river channel and fish habitat quality, reducing the formation of pools, limiting hiding cover, and slowing the trapping of spawning gravels.
Conclusions
In summary, present or historical land use practices exert key adverse effects on juvenile life history stages of the Calapooia winter steelhead and spring Chinook populations in the Calapooia subbasin (ODFW 2007b). Land use impacts also exert key adverse effects on the adult life stage of Chinook in the Calapooia basin. Limiting factors in the Calapooia basin include:

Water Quality
Naturally low flows in the basin are aggravated by water withdrawals, which increase water temperatures. Water temperatures exceed criteria in the Calapooia River and some tributaries, particularly in the lower subbasin. In general, water temperatures are lower in the forested upper subbasin than in the lower subbasin (CWC 2004). Elevated water temperatures decrease survival and/or growth of juvenile Chinook, as well as increase prespawning mortality of adult Chinook.

Long-term monitoring of bacteria in the Calapooia River at the Queen Avenue Bridge (in Albany downstream of Oak Creek) by the Oregon Department of Environmental Quality has indicated chronic high levels of E. coli (CWC 2004).

Physical Habitat Quality
Modifications to key habitats and the natural processes that form and maintain them have affected all life stages of fish. Impaired physical habitat particularly reduces rearing potential for Chinook and steelhead winter parr. Loss of holding pools causes increased prespawning mortality of adult Chinook. Habitat quality has declined through changes in interactions between stream systems and their floodplain that have reduced the delivery and transport of large wood, modified gravel deposition, reduced the frequency and depth of pools, minimized hiding cover for adult and juvenile fish, and reduced available spawning areas. Flow modifications and channel confinement and in-stream barriers have reduced access to off-channel habitats essential for juvenile rearing and winter refuge and decreased connectivity between habitats throughout the subbasin and the dynamic processes needed to form and maintain habitat diversity (WRI 2004).

NMFS determined that the following occupied areas of the Calapooia subbasin contain Critical Habitat for UWR Chinook salmon or UWR steelhead (NMFS 2005IV; maps are included in Section 3.3 of this opinion):

UWR Chinook (spring-run)
- Two watersheds contain UWR Chinook habitat in the Calapooia subbasin. This habitat, all found in the mainstem Calapooia River (and Sodom Ditch) provides 36.4 miles of PCEs for spawning/rearing, 42.3 miles for rearing/migration, and 0 miles for migration/presence (NMFS 2005VII).
- The Calapooia River watershed (HUC 1709000303) was rated as being of moderate importance to the conservation of the ESU and provides 36.4 miles of PCEs for spawning/rearing and 24.9 miles of PCEs for rearing/migration (NMFS 2005VII).
- The Oak Creek watershed (HUC 1709000304) contains the lower 17.4 miles of the Calapooia River, which are rearing/migration habitat for UWR Chinook (NMFS 2005VII).
UWR Steelhead

- Two watersheds contain UWR steelhead habitat in the Calapooia subbasin. This habitat, found in the mainstem Calapooia River, Sodom Ditch, and multiple tributaries, provides 56.3 miles of PCEs for spawning/rearing, 33.8 miles for rearing/migration (NMFS 2005VII). 

- The Calapooia River watershed (HUC 1709000303) was rated as being of high importance to the conservation of the ESU and contains 56.3 miles of PCEs for spawning/rearing and 16.4 miles of PCEs for rearing/migration (NMFS 2005VII).

- The Oak Creek watershed (HUC 1709000304) provides 17.4 miles of rearing/migration habitat for UWR steelhead (NMFS 2005VIII).

NMFS (2005g) identified the key management activities that affect these PCEs. Key management activities include forestry, dams, road building and maintenance, channel modifications/diking, and agriculture.

Table 4.4-2 summarizes the condition of PCEs within the Calapooia River. Many of the habitat indicators are not in a condition suitable for salmon and steelhead conservation. In most cases, this is primarily the result of human activities (e.g., development, agriculture, and logging).
Table 4.4-2 Critical habitat primary constituent elements (PCEs) and associated pathways, indicators, current conditions, and limiting factors for the Calapooia River subbasin under the environmental baseline.

<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Causative Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater migration corridors</td>
<td>Habitat</td>
<td>Physical</td>
<td><em>Lower Calapooia subbasin</em></td>
<td>Non-federally owned dams</td>
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<td></td>
<td>Access</td>
<td>Barriers</td>
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The Thompson’s Mill complex of dams and diversion ditches (RM 19.5 to 28.5) delays and partially blocks UWR Chinook salmon and UWR steelhead upstream migration, leaving fish vulnerable to harassment and poaching. Sodom Dam fishway is rapidly deteriorating, and if it fails, will cause a complete passage barrier.
<table>
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<tr>
<th>PCE</th>
<th>Pathway</th>
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<th>Condition</th>
<th>Causative Factors</th>
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</thead>
<tbody>
<tr>
<td>Freshwater migration corridors</td>
<td>Habitat Access</td>
<td>Physical Barriers</td>
<td><em>Middle Calapooia subbasin</em>&lt;br&gt;The Calapooia subbasin Council identified high priority opportunities to correct fish passage problems associated with road crossings and culverts at about 80 locations. Most culverts in small streams with high gradients were on forest lands. Many of the forest landowners in the subbasin have replaced culverts with installations that provide for fish passage.&lt;br&gt;Highest priority culverts for improvement of fish passage were identified. These culverts are on county, BLM and private lands. Most of the identified culverts are in streams that are in the lower portions of the subbasin and have significant fish habitat above the culvert. Because the culverts have excessive jump heights, many of these culverts are barriers to adult fish movement and prevent use of these areas as high-flow sanctuary and overwinter rearing habitat by juvenile UWR Chinook salmon and steelhead.&lt;br&gt;Numerous unscreened small diversions within the subbasin affect juvenile UWR Chinook salmon and steelhead. A private water diversion dam on the West Fork of Brush Creek is probably a barrier to upstream fish movement.</td>
<td>Private land management and lumber operations&lt;br&gt;Private, local government, and federal land management&lt;br&gt;Agriculture on private lands</td>
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<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Water Quantity (Flow/Hydrology)</td>
<td>Mainstem Calapooia River flows have been altered as a result of dams constructed primarily in the lower part of the subbasin. Brownsville Dam was removed in 2007, restoring more normative hydrologic function to the mainstem channel in the upper part of the lower subbasin area. The Thompson’s Mill complex of dams and diversions still impacts hydrology in the lower subbasin area, resulting in reduced floodplain connectivity, reduced sediment and gravel transport, and in channel and habitat simplification. Naturally low flows in the basin are aggravated by water withdrawals.</td>
<td>Privately owned dams</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Water Quality</td>
<td>Decreased flow in Sodom Ditch in the summer when Thompson’s Mills takes water down the Calapooia results in increased water temperatures in the Ditch when UWR steelhead fry would be rearing. The ODEQ 2004/2006 Integrated Report database indicates that the Calapooia River and at least three associated water bodies, Brush Creek, Sodom Ditch, and the North Fork Calapooia River, exceed state water quality criteria for temperature. Removal of riparian forest and other effects of development contributing to elevated summer water temperature, particularly in the lower part of the Calapooia subbasin, decrease survival and/or growth of juvenile UWR Chinook salmon and increase prespawning mortality of adult Chinook.</td>
<td>Private hydropower production</td>
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<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Water Quantity</td>
<td>Change in Peak/Base Flow</td>
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<td>Freshwater migration corridors</td>
<td>Water Quality</td>
<td>Temperature</td>
<td>Agricultural, urban, and rural development</td>
<td>Agricultural and private development</td>
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<td>PCE</td>
<td>Pathway</td>
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<tr>
<td>Freshwater spawning sites</td>
<td>Water Quality</td>
<td>Total Suspended Solids/Turbidity</td>
<td>The ODEQ 2004/2006 Integrated Report database does not report any streams as water quality limited due to turbidity in the Calapooia subbasin.</td>
<td>N/A</td>
</tr>
<tr>
<td>Freshwater rearing</td>
<td>Water Quality</td>
<td>Chemical Contamination/Nutrients</td>
<td>Monitoring of bacteria in the Calapooia River at the Queen Avenue Bridge in Albany (downstream of Oak Creek and near the mouth) by ODEQ has indicated chronic high levels of E. coli. However, the ODEQ 2004/2006 Integrated Report database suggests that high bacteria levels are not common above Oak Creek.</td>
<td>Urban and rural development</td>
</tr>
<tr>
<td>Freshwater migration corridors</td>
<td>Water Quality</td>
<td>Dissolved Oxygen (DO)</td>
<td>The ODEQ 2004/2006 Integrated Report database indicates that the lower 31.2 miles of the Calapooia River are water quality limited for dissolved oxygen during the late winter and spring spawning period (ODEQ 2006b).</td>
<td>May be related to causes of nitrification and elevated temperatures</td>
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<td>PCE</td>
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<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Water Quality</td>
<td>The ODEQ 2004/2006 Integrated Report database does not indicate that any streams in the Calapooia subbasin were water quality limited due to excess TDG measurements</td>
<td>N/A</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater migration corridors</td>
<td>Total Dissolved Gas (TDG)</td>
<td></td>
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<tr>
<td>Freshwater spawning sites</td>
<td>Habitat Elements</td>
<td>Substrate</td>
<td>The channel downstream of the Thompson’s Mill complex dams may have coarsened and could lack spawning gravel.</td>
<td>Privately owned dams</td>
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<td>About half (50.33%) of 33.2 miles surveyed in the upper subbasin contained gravel bars providing relatively high quality spawning habitat.</td>
<td>Timber harvest</td>
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<td>Large sediment loads resulting from bank failures associated with timber harvest have resulted in siltation and compaction of spawning gravels in some areas.</td>
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<td>Freshwater rearing sites</td>
<td>Freshwater migration corridors</td>
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<td>Habitat Elements</td>
<td>Large Woody Debris</td>
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<td>Large wood is blocked from access into the lower Calapooia River from about 65% of the subbasin by the Thompson’s Mill complex. The Calapooia subbasin lacks large wood in most stream channel areas of the basin except for parts of the upper mainstem. Logs continue to be removed from the Calapooia River and tributary streams to prevent bank erosion, reduce damage to property and bridges, and to allow recreational boaters to pass down the channel. The lack of large trees growing along some sections of the river and streams contributes to the long-term shortage of wood in channels. The status of streamside forests and wood removal from streams have cumulatively impacted the river channel and fish habitat quality, reducing the formation of pools, limiting hiding cover, and slowing the trapping of spawning gravels.</td>
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<td>Privately owned dams</td>
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<td>Historic splash dams and log drives, snag and removal of logs and log jams.</td>
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<td>Removal of large wood by landowners and boaters for navigation and/or firewood</td>
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<td>Local development and agricultural development in the lower subbasin resulting in riparian area depletion.</td>
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<td>Potts Creek was the only inventoried stream with high quality pool habitat (i.e., with pools exceeding 25% of total habitat area). Pool habitat is of moderate quality (ranging 21% to 24% of total habitat area) in the upper mainstem Calapooia River. Pool frequency and quality in most of the Calapooia subbasin is low due to absence of pool forming elements such as LWD and/or sediment.</td>
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<td>Removal of LWD, downstream LWD and sediment transport blocked by private dams, roads, channel scour, land uses such as timber harvest, and diking in the middle and lower river.</td>
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<td>PCE</td>
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</table>
| Freshwater   | Freshwater spawning sites              | Habitat Elements           | Loss of off-channel habitats in the middle and lower Calapooia River subbasin have occurred as a result of rip-rap armoring of stream banks (5,605 linear feet in the middle Calapooia subbasin area), filling of wetlands, and construction of fish passage barriers that disconnect small tributary streams, side channels, and sloughs from the river channel. There is poor connectivity to off-channel habitat in lower river. | USACE and private revetments  
Reduction in the magnitude and frequency of peak flows as a result of private dam and diversion operations  
Diking, dredging, and human development |
| Freshwater   | Freshwater rearing                     | Off-channel Habitat        |                                                                             |                                                                                  |
| Freshwater   | Freshwater migration corridors          | Channel Conditions and Dynamics | Streambanks do not support natural floodplain function in the lower half of the subbasin. | USACE and private revetments  
Diking, dredging, agricultural and other human development |
<table>
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<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Causative Factors</th>
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</thead>
<tbody>
<tr>
<td>Freshwater rearing</td>
<td>Freshwater migration corridors</td>
<td>Channel Conditions and Dynamics</td>
<td>Floodplain Connectivity</td>
<td>The floodplain is not frequently inundated, with reduced over-bank flow and side channel connectivity. Reduced nutrient exchange, reduced sediment exchange, reduced flood refugia for fish, and reduced establishment of new riparian forests. The lower Calapooia subbasin is disconnected from its historical floodplain by dams and diversions that have reduced peak mainstem flows and by streamside revetments.</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Watershed Conditions</td>
<td>Disturbance History</td>
<td>The disturbance regime is dominated by timber harvesting. Forests are dominated by early- to mid-successional stages, with few late-successional forests. Timber harvesting has increased sediment delivery to streams, but decreased large wood input, resulting in degraded aquatic habitat. Upper subbasin is forested, but some is managed for timber production rather than ecosystem health. Most of the subbasin (94%) is in private ownership. Lower subbasin is predominantly agricultural, urban, and residential development.</td>
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<td>PCE</td>
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<td>Causative Factors</td>
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<tr>
<td></td>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Riparian Reserves</td>
<td>There has been decreased quality and extent of streamside riparian vegetation, especially in the middle and lower parts of the subbasin.</td>
</tr>
<tr>
<td></td>
<td>Freshwater migration corridors</td>
<td>Watershed Conditions</td>
<td>There has been decreased quality and extent of streamside riparian vegetation, especially in the middle and lower parts of the subbasin.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Watershed Conditions</td>
<td>Riparian Reserves</td>
<td>Natural vegetation comprises about 45% of the stream corridor within 500 feet of the mainstem in the middle and lower parts of the subbasin. Relatively old stands of mixed hardwoods are the primary natural vegetation growing within 200 feet of the channel.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Riparian Reserves</td>
<td>Watershed Conditions</td>
<td>The upper subbasin is more heavily forested with stands of conifers. Only 14% of areas surveyed in the upper subbasin were bordered by stands that had a high potential for providing large wood in the near term.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Watershed Conditions</td>
<td>Riparian Reserves</td>
<td>Low amounts of shading (less than 40%) occur on the main channel of the lower and middle subbasin. In the upper subbasin, shading levels range from moderate (40-70%) to high (&gt;70%).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Riparian Reserves</td>
<td>Watershed Conditions</td>
<td>In the lower basin, remaining patches of floodplain forest are interspersed with agricultural and residential development. Floodplain forests along the lower river have been invaded by non-native species that hinder natural vegetative development.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Watershed Conditions</td>
<td>Riparian Reserves</td>
<td>There has been a decrease in surface area of gravel bars for potential young riparian stand recruitment, especially in the middle and lower parts of the subbasin.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Riparian Reserves</td>
<td>Watershed Conditions</td>
<td>Clearing for agriculture, urban, and rural development</td>
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<td></td>
<td>Watershed Conditions</td>
<td>Riparian Reserves</td>
<td>Timber harvest</td>
<td></td>
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<td>Riparian Reserves</td>
<td>Watershed Conditions</td>
<td>Stream clean-out practices</td>
<td></td>
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<td></td>
<td>Watershed Conditions</td>
<td>Riparian Reserves</td>
<td>USACE and private revetments</td>
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<tr>
<td></td>
<td>Riparian Reserves</td>
<td>Watershed Conditions</td>
<td>Private dams and diversions alter the hydrologic regime</td>
<td></td>
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South Santiam Baseline
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4.5 SOUTH SANTIAM SUBBASIN

The South Santiam River is about 63 miles long and drains an area of about 1,000 square miles with the headwaters dominated by forestlands (Figures 4.5-1). Approximately 32% of this subbasin is in public ownership, including headwaters in the Willamette National Forest (ODFW 1990b). Some land in the lower portion of the subbasin is managed by the BLM (Salem District), but most of the area that contributes flow to the river is downstream of the lower-most USACE dam (Foster) is private.

The South Santiam’s headwaters are characterized by steep, forested drainages that originate on basalts and andesites (materials of volcanic origin), and then flow through narrow valleys toward the broader alluvial valley in the lower subbasin. Larger drainages above Foster Dam include the South Santiam mainstem, the Middle Fork, and Quartzville Creek. Channel slopes along the mainstem decline in the downstream direction, to approximately 0.4% between Foster Dam and Lebanon, and to less than 0.1% in the alluvial valley below. Wiley Creek joins the South Santiam immediately downstream of Foster Dam, while Crabtree and Thomas creeks enter the South Santiam near the river’s confluence with the North Santiam River.
Figure 4.5-1 South Santiam Subbasin
4.5.1 Historical Populations of Anadromous Fish in the South Santiam Subbasin

UWR Chinook salmon
UWR Chinook salmon are native to the South Santiam River and once spawned in the mainstem South Santiam, the Middle Santiam, and in all major tributaries including Wiley, Thomas, Crabtree, Quartzville, and Canyon creeks (Willis et al. 1960; Thompson et. al 1966; Fulton 1968; WNF SHRD 1995, 1996). Returns to the river had declined substantially by the mid-1900s but was still estimated to include about 1,300 spawners in 1947, with the most heavily used spawning areas located above the town of Foster (Mattson 1948). The species’ access to much of the area where Mattson (1948) observed spawning during 1947 has been either blocked or impaired since completion of Foster and Green Peter dams by the USACE in 1968.

USFWS (1963) reported an annual spawning run of about 1,400 above the current site of Foster Dam. About 70% of these adult fish originated in the Middle Santiam River (above the current site of Green Peter Dam), 7% in the reach that is now under Foster Reservoir, and 23% in the South Santiam River above Foster. Thompson et al. (1966) estimated a total annual run size (natural- and hatchery-origin) of 3,700 adults during the 1960s. Estimates based on the sport catch and returns to Foster Dam indicate that the minimum total (natural plus hatchery-origin fish) run size to the subbasin during the 1970s and 1980s varied from less than 500 to nearly 10,000 per year (Chilcote 2007).

Hatchery broodstock collection efforts within the subbasin began in 1923, at a weir placed across the river near the town of Foster (Wallis 1961). The South Santiam Hatchery began operations in 1966 to mitigate for loss of Chinook salmon production in areas above Foster Dam (passage was ineffective at Foster).
Figures 4.5-1 Maps of the South Santiam subbasin (ODEQ 2006a, top) and of land use patterns within the subbasin (NRCS 2005a, bottom).
UWR Steelhead
UWR steelhead are also native to the South Santiam subbasin. These fish spawned historically in upper portions of the subbasin, above the sites of Foster and Green Peter dams, as well as in downstream tributaries (Olsen et al. 1992). No estimates of pre-1960s abundance are available for the subbasin’s native winter steelhead. However, ineffective downstream passage at Foster and Green Peter Dams, and inadequate upstream passage at the latter facility are believed to have caused up to a 75% reduction in the native steelhead population in the upper subbasin over time (USACE 2000). After the dams were constructed, Buchanan et al. (1993) estimated that 2,600 winter steelhead spawned in the entire South Santiam River basin, including the upper mainstem above the dams and in Thomas, Crabtree, McDowell, Wiley, Canyon, Moose, and Soda Fork creeks.

4.5.2 Current Status of ESA-Listed Salmon and Steelhead within the Subbasin

4.5.2.1 UWR Chinook salmon

Population Viability
The South Santiam population of UWR Chinook is considered to be at very high risk of extinction, based on an analysis of its abundance, productivity, spatial structure, and diversity (McElhany et al. 2007). Chronically unfavorable conditions have influenced this risk, as does the potential for catastrophic events. WLCTRT (2003) rated the risks of catastrophic loss as high from landslides (based on geology and precipitation patterns), epidemics (due to hatchery releases), and pollution (related to roadway transportation spills).

Abundance & Productivity
In the draft viability assessment for South Santiam spring Chinook, McElhany et al. (2007) rated the population’s limited abundance and productivity as posing a very high extinction risk. As described in this section, abundances of wild spawners are generally low, pre-spawn mortality rates for these fish are high, and recent use of natural spawning areas has been dominated by fish of hatchery origin (Schroeder et al. 2006).

Adult UWR Chinook returning to the South Santiam River are counted at a fish trap near the base of Foster Dam, and their redds are counted in spawning areas downriver as well as in a few tributaries. Figure 4.5-2 gives the numbers of adult fish counted in the Foster Trap each year from 1984 to 2005. During this period the returns have been strongly dominated by hatchery fish, peaked in 1990 at more than 7,000 fish, and peaked again in 2004 at more than 10,000. Returns were below average from 1992 to 1997, increased through 2004, and then decreased during 2005.
Improvements to fish marking and monitoring efforts within the Willamette Basin now allow a high level of confidence in distinguishing hatchery-origin from wild (natural-origin) UWR Chinook. Under contract to the USACE, ODFW has since 2002 conducted intensive monitoring of hatchery and wild spring Chinook returning to Foster Dam and to mainstem spawning areas downstream in the lower South Santiam (Schroeder et al. 2006; McLaughlin et al. 2008). Monitoring results from 2002 through 2005 showed that returns of natural origin adults to the South Santiam River were much lower than those of hatchery fish, that hatchery fish dominated the trap catch at Foster Dam and in the spawning areas downstream, and that fewer wild Chinook were spawning successfully in the lower river (<300 fish per year) than returned to the Foster Trap (234-1457 fish per year). Hatchery fish accounted for 79-91% of the spawners in the river from Foster Dam down to Waterloo during this period, and annual pre-spawning mortality rates ranged from 26-72% (McLaughlin et al. 2008). This situation, extended over the long term, would make it improbable that the run of fish could include many natural origin individuals more than a few generations removed from the hatchery. Both natural and hatchery-origin Chinook that enter the Foster Trap are used as hatchery broodstock or are released to spawn in streams above and below Foster Dam, in the Molalla River system, or in the Calapooia River (Beidler and Knapp 2005).

Recent UWR Chinook use of spawning areas within the lower South Santiam subbasin has been intense in the river immediately below Foster Dam and considerably more sparse elsewhere (Figure 4.5-3). Use of all spawning areas that have been monitored within the subbasin has been dominated by the presence of hatchery-origin spawners to the detriment of wild fish (Schroeder et al. 2006).

Figure 4.5-2 Annual returns of spring Chinook salmon to Foster Dam from 1984-2005 (Streamnet trend 58668), including 2002-2005 estimates of the wild component that were developed by McLaughlin et al. (2008).
Spatial Structure
Reduced spatial structure caused by a lack of effective fish passage at USACE dams and by diminished habitat quality in areas not blocked by dams leads to a high risk of extinction for the South Santiam population of spring Chinook (McElhany et al. 2007). ODFW (2005b) estimates that 40% of the habitat historically suitable for spring Chinook in the South Santiam subbasin is now inaccessible, and McElhany et al. (2007) note that the inaccessible areas held some of the best habitat for the species. ODFW (2005b) estimates that 70% of the subbasin’s spring Chinook population once spawned in areas that are inaccessible now.

Diversity
McElhany et al. (2007) rated the current diversity of the South Santiam population of spring Chinook as contributing to a high risk of extinction, based on evidence of life history traits, small effective population size, hatchery impacts, anthropogenic mortality, and reduced habitat diversity. Their greatest concern was the large proportion of hatchery-origin fish in natural spawning areas.

4.5.2.2 Winter Steelhead

Population Viability
The South Santiam population of UWR Steelhead is at low to moderate risk of extinction with considerable uncertainty, based on an analysis of its abundance, productivity, spatial distribution, and diversity (McElhany et al. 2007). The potential for catastrophic events contributes to this risk. WLCTRT 2003 reported the risk of catastrophic losses was high from landslides (based on
Abundance & Productivity

In the draft viability assessment for UWR Steelhead (McElhany et al. 2007), South Santiam winter steelhead were rated as most likely in the low extinction risk category for abundance and productivity, with a high degree of uncertainty. The population is relatively large, with McElhany et al. (2007) estimating a long-term geometric mean of 2,727 wild spawners and a recent geometric mean of 2,302.

Abundance of winter steelhead in the South Santiam subbasin is monitored by counting adult fish at Foster Dam and during annual counts of redds within a sub-sample of the available spawning areas. Figure 4.5-4 gives annual counts of the native late-winter run of these fish returning to upper portions of the subbasin, above Foster Dam, from 1967 to 2007. Numbers have declined considerably from those seen in the earliest years following completion of Foster and Green Peter dams. Annual counts of natural origin late-run fish rose above 1,000 for the first time in more than 25 years in 2002 and 2004, but declined to fewer than 500 fish in more recent years.

Available information suggests that greater numbers of natural origin winter steelhead return to spawn in the lower South Santiam subbasin each year than return to the Foster trap and are released to spawn above Foster Dam. Annual estimates of numbers spawning in the subbasin as a whole averaged 1,953 fish from 2000 to 2006, with an average of 1,236 (63%) of these fish spawning downstream of Foster (Table 4.5-1).
Table 4.5-1 Abundance estimates for native wild South Santiam winter steelhead spawning above and below Foster Dam, 2000-2006. Sources: ODFW (2005b)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>SPAWNER ABUNDANCE BY RETURN YEAR</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Above Foster Dam (from dam count)</td>
<td>Below Foster Dam (from ODFW redd counts)</td>
<td>Total</td>
</tr>
<tr>
<td>2000</td>
<td>326</td>
<td>687</td>
<td>1,013</td>
</tr>
<tr>
<td>2001</td>
<td>783</td>
<td>2,751</td>
<td>3,534</td>
</tr>
<tr>
<td>2002</td>
<td>1,002</td>
<td>1,663</td>
<td>2,665</td>
</tr>
<tr>
<td>2003</td>
<td>850</td>
<td>873</td>
<td>1,723</td>
</tr>
<tr>
<td>2004</td>
<td>1,015</td>
<td>1,531</td>
<td>2,546</td>
</tr>
<tr>
<td>2005</td>
<td>626</td>
<td>681</td>
<td>1,307</td>
</tr>
<tr>
<td>2006</td>
<td>419</td>
<td>466</td>
<td>885</td>
</tr>
<tr>
<td>Average</td>
<td>718</td>
<td>1,236</td>
<td>1,953</td>
</tr>
</tbody>
</table>

**Spatial Structure**
Winter steelhead spawned historically throughout much of the upper South Santiam subbasin, above the sites of Foster and Green Peter dams, and in Thomas, Crabtree, McDowell, and Wiley creeks, and many smaller streams in the lower subbasin (Willis et al. 1960). However, as described in section 4.5.3.1, ineffective upstream and downstream passage facilities at Foster and Green Peter dams are believed to have caused a drastic reduction in the status of native winter steelhead in the upper subbasin. Early counts of winter steelhead at Green Peter Dam (StreamNet trend 50300), above which they are no longer passed, accounted for as much as 30% of the run above Foster Dam during the first few years after dam completion.

Risks posed to the South Santiam winter steelhead population by reductions in spatial structure appear moderate (McElhany et al. 2007). Fish access to historical habitats above Foster has been impaired by USACE dams, but access to habitat in lower portions of the South Santiam subbasin remains unaffected by these dams (McElhany et al. 2007). ODFW (2005b) estimates that 17% of the habitat historically available to winter steelhead is now blocked at Green Peter Dam. Within lower portions of the subbasin, the distribution of winter steelhead has been affected by low-head passage impediments at non-federal dams, culverts, and diversions in the upper reaches of many low-elevation tributaries and by habitat degradation caused by land and water use practices (McElhany et al. 2007).

**Diversity**
McElhany et al. (2007) considered available information on the life history traits, small effective population size, hatchery impacts, anthropogenic mortality, and habitat diversity of South Santiam winter steelhead and suggested that the population’s current diversity reflects a moderate extinction risk. Primary risk factors include the legacy of hatchery operations, continued releases of summer steelhead, and reduced habitat diversity.
4.5.2.3 Limiting Factors and Threats to Recovery

Factors adversely affecting the status of the South Santiam populations of UWR Chinook and UWR Steelhead have been summarized by ODFW (2007b). Key limiting factors and threats to both species include a variety of dam effects, large hatchery programs developed partly to help offset dam effects, and the cumulative effects of multiple land and water use practices on aquatic habitat. For the spring Chinook in particular, USACE dams lack effective passage facilities preventing natural origin fish from using historically important habitats in upper portions of the South Santiam subbasin and instead, must rely upon habitats below Foster Dam that have been structurally, hydrologically, and thermally altered. These altered habitats often contain hatchery produced salmonids, or their direct offspring, that compete or interbreed with the wild fish. Habitat changes along the mainstem Willamette River and in the Columbia River estuary, some related to the Willamette Project dams or to other USACE programs, also limit the population.

In all, 14 of 17 primary limitations and 14 of 25 secondary limitations on the recovery of these two ESA-listed populations are related to USACE dams or programs (ODFW 2007b, Table 4.5-2).

Table 4.5-2 Key and secondary limiting factors and threats to recovery of South Santiam Spring Chinook and Winter Steelhead (ODFW 2007b).

<table>
<thead>
<tr>
<th>Threats</th>
<th>Species</th>
<th>Tributaries (Streams and Rivers within Population Area)</th>
<th>West Side Tributaries</th>
<th>Mainstem Willamette (above falls)</th>
<th>Estuary (below Bonneville and Willamette Falls)</th>
<th>Ocean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvest</td>
<td>Chinook</td>
<td>Egg: 4b, Fry: 6c, Parr: 10d, Winter: 1e, Adult: 3</td>
<td></td>
<td></td>
<td></td>
<td>4a</td>
</tr>
<tr>
<td></td>
<td>Steelhead</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hatchery</td>
<td>Chinook</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Steelhead</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydropower/Flood Control</td>
<td>Chinook</td>
<td>Egg: 9e, Parr: 10d, Winter: 1e, Adult: 2c</td>
<td>2c</td>
<td>21</td>
<td></td>
<td>5a,5b,7h,10f</td>
</tr>
<tr>
<td></td>
<td>Steelhead</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5a</td>
</tr>
<tr>
<td>Landuse</td>
<td>Chinook</td>
<td>Egg: 8a, Parr: 8a, Winter: 2g</td>
<td>8a</td>
<td>8a</td>
<td></td>
<td>5a,6a,8a,9a,9h,9i</td>
</tr>
<tr>
<td></td>
<td>Steelhead</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Introduced Species</td>
<td>Chinook</td>
<td>Egg: 7a, Parr: 10b, Winter: 8a</td>
<td>8a</td>
<td>8a</td>
<td></td>
<td>5a,6a,8a,9a,9h,9i</td>
</tr>
<tr>
<td></td>
<td>Steelhead</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Black cells indicated key concerns; Gray cells indicated secondary concerns.

Key threats and limiting factors

1e Mortality at South Santiam hydropower/flood control dams due to direct mortality in the turbines and/or smolts being trapped in the reservoirs.
2c Impaired access to habitat above South Santiam hydropower/flood control dams.
2g Impaired access to habitat above Lebanon dam1.
3 Hatchery fish interbreeding with wild fish resulting in a risk of genetic introgression.
4c Competition with naturally produced progeny of hatchery summer steelhead.

1 This was addressed through FERC-licensed fish passage in 2006
4d Competition with residualized hatchery summer steelhead smolts.
5a Reduced macrondetrital inputs from near elimination of overbank events and the separation of the river from its floodplain.
5b Increased microdetrital inputs due to reservoirs.
6b Predation by non-native largemouth bass in Green Peter reservoir.
7h Impaired fine sediment recruitment due to dam blockage.
8a Impaired physical habitat from past and/or present land use practices.
9a Elevated water temperatures from past and/or present land use practices resulting in decreased survival and/or growth.
9e Altered water temperatures below the South Santiam hydropower/flood control dams resulting in premature hatching and emergence of Chinook and delayed hatching and emergence of winter steelhead.
10c Reduced flows during spring reservoir filling result in increased water temperatures that lead to increased disease.
10d Reduced peak flows leading to decreased channel complexity and diversity of fish habitat by reducing channel movement that is important for recruitment of gravel and large wood, and maintaining varying seral stages of riparian vegetation. Lower peak flows also reduces scour and formation of pools.
10e Elevated flows during spawning and dewatering of redds below the South Santiam hydropower/flood control dams.
10f Altered flows due to hydropower system that result in changes to estuarine habitat and plume conditions, impaired access to off-channel habitat, and impaired sediment transport.

Secondary threats and limiting factors

2a Impaired access to habitat due to road crossings and other land use related passage impediments on wadeable sized streams.
2j Impaired downstream passage at South Santiam hydropower/flood control dams.
2l Prespawning mortality due to crowding below South Santiam hydropower/flood control dams.
4a Competition with hatchery fish of all species.
4b Competition with naturally produced progeny of hatchery spring Chinook.
6c Predation by hatchery summer steelhead smolts.
6e Predation by birds as a result of favorable habitat conditions for birds created by past and/or present land use activities.
7a Fine sediment in spawning gravel from past and/or present land use practices.
7d Streambed coarsening below South Santiam hydropower/flood control dams due to reduced peak flows.
8a Impaired physical habitat from past and/or present land use practices.
9a Elevated water temperatures from past and/or present land use practices resulting in decreased survival and/or growth.
9e Elevated water temperatures below the South Santiam hydropower/flood control dams resulting in premature hatching and emergence.
9h Toxicity due to agricultural practices.
9i Toxicity due to urban and industrial practices.
9j Elevated water temperatures due to reservoir heating.
10b Insufficient streamflows due to land use related water withdrawals resulting in impaired water quality and reduced habitat availability.

10d Reduced peak flows leading to decreased channel complexity and diversity of fish habitat by reducing channel movement that is important for recruitment of gravel and large wood, and maintaining varying seral stages of riparian vegetation. Lower peak flows also reduces scour and formation of pools.

4.5.3 Environmental Conditions

4.5.3.1 Habitat Access

UWR Chinook salmon and UWR steelhead migrations to and from areas above Foster are currently limited by passage conditions at Foster and Green Peter dams and in the reservoirs created by these dams. Prior to construction of the two USACE dams, migrations to and from habitats within the upper South Santiam subbasin had already been influenced by inadequate fish passage on the lower Santiam River at Lebanon Dam (at Mile 21) and in some years by fish weirs constructed at locations on the South and Middle Santiams to collect adult Chinook salmon for hatchery operations. Fish passage measures at Lebanon Dam, a FERC-licensed project that was recently relicensed, were upgraded in 2005 and 2006, with new screens to prevent fish entrainment into the water diversion and fish ladders to minimize delay and injury during upstream fish migration. The temporary hatchery collection weirs had been abandoned by the time the USACE dams were constructed.

**Foster & Green Peter Dams as Migration Barriers**

Green Peter and Foster dams were both built with fish traps and elevators designed to capture adult salmonids for hatchery broodstock collection and for passage above the dams. Upstream passage for UWR steelhead, but not for UWR Chinook, has been maintained at Foster since dam construction. Passage of anadromous fish was abandoned in the 1980s at Green Peter, when it became clear that wild runs into the Middle Santiam system could not be sustained with existing passage facilities for reasons described below.

**Upstream Passage of Adults at Foster**

The existing fish trap at the base of Foster Dam is outdated and does not provide adequate upstream fish passage. Fish passing upstream at Foster Dam enter either the tailrace or spillway ladder and then pass up a short section to a trapping area. At the top of the ladder, fish enter a holding pool, where they may be delayed until the next trapping cycle. The holding pool incorporates a combination fish crowder/lifting device to transfer fish to an anesthetic tank. After lifting fish into the tank of water which is infused with dissolved carbon dioxide, and waiting a few minutes for the fish to become hypoxic and easy to handle, hatchery personnel physically climb into the tank and manually remove each incapacitated fish. There are several potential dispositions for fish at this point:

- **Lift bucket:** Natural-origin steelhead can be placed into the lift bucket, lifted to the top of the dam, and then either 1) lowered and released into the forebay; or 2) placed into trucks waiting at the top of the dam, and transported to release points upstream of Foster Reservoir

- **Fish transport tubes:** Natural-origin winter steelhead and Chinook salmon and hatchery Chinook salmon and summer steelhead can be placed into one of two fish transport tubes for delivery into
trucks waiting about 200 feet below the dam. One truck takes hatchery fish and some natural-origin fish to the hatchery for broodstock, while the other truck transports fish to upstream release sites. and then

- Holding area: Fish can also be returned to the small holding area at the top of the ladder for deferred disposition

Wagner and Ingram (1973) observed numerous sources of injury and mortality of adult salmonids at Foster Dam, primarily associated with fish crowding in the anesthetic tank, handling in the holding pool, and operation of the hopper. It is unclear how many of these problems have been corrected, but concerns include the following:

- The dated design does not include facilities for safe holding, handling, examining, and sorting hatchery-from natural-origin fish (for flexibility in disposition)
- The operator cannot see how many fish are in the trap, creating the potential for crowding and injury during handling
- Inexperienced personnel could injure fish by operating the device improperly
- Use of carbon dioxide as an anesthetic
- Potential injury in the transport tubes (pipe bells are installed downstream, which increase the likelihood of abrasion)

**Adult Fallback at Foster**

UWR steelhead that are passed above Foster Dam are usually released in the forebay of the reservoir and an estimated 2.5 to 4% of these adults fall back over the dam after release. Studies with marked (floy-tagged) wild adult winter steelhead in 1983 through 1987 indicated a fallback rate (i.e., the proportion released in the forebay and recaptured at the Foster trap) of less than 4%, with little effect of release site in Foster Reservoir (Buchanan et al. 1993). Wagner and Ingram (1973) estimated a fallback rate for wild winter steelhead of 2.5%. They listed the following possible causes for adult fish returning downstream after release into the forebay: injury due to handling, only partial recovery from the anesthetic, rejection of the forebay water, high flow through the adjacent tainter gates attracting fish downstream before they became oriented to the Foster forebay environment, and putting fish into the forebay that were not destined for areas above that dam. The authors thought that some regulation of the spillway tainter gates could reduce the number of fish returning to the tailrace and, in 1971, requested that the USACE avoid spilling from gate 4 (located adjacent to the hopper release site) during periods of upstream migration. On May 5, 1971, Wagner and Ingram (1973) released 100 tagged steelhead into Foster forebay (spill greater than 2,500 cfs until May 15). One tagged adult (1% of the release) was recaptured in the Foster ladder, indicating that this could be a valid operational method of reducing the fallback rate. Buchanan et al. (1993) showed that, for returning hatchery-origin adults, fallback rate was affected by smolt release site. None of the 101 adult hatchery steelhead that were released as smolts high in the watershed, in Moose Creek or Green Peter Reservoir, in 1984 recycled after their release above Foster Dam.

**Recent Efforts to Reestablish Adult Chinook Passage at Foster**

Since 1996, ODFW has transported and released some of the adult spring Chinook captured in the Foster trap each year into the South Santiam River above Foster Reservoir, in an effort to reestablish a natural run of these fish above the dam. The number released increased from 120
fish in 1996 to 1,850 in 2004. Although juvenile production has been documented from this effort, adult pre-spawning mortality has been high in most years (Beidler and Knapp 2005).

**Downstream Passage of Juvenile Fish at Foster**
At the time of construction, the Kaplan turbines and subsurface spill gates at Foster Dam were expected to function as downstream fish passage routes; however, studies and observations indicate that downstream fish passage at Foster is less efficient and safe than originally anticipated. Wagner and Ingram (1973) estimated 89.9% survival for juvenile Chinook through the Kaplan turbines during fall, winter, and spring, with slightly higher survival at full pool (91.7% to 92.6%) than at minimum conservation pool (86.6% to 88.9%). Survival rates for juvenile steelhead were similar. Kelts recovered in the downstream nets frequently carried injuries indicating that they had likely been cut by the turbine blades (41% mortality in 1970 tests). The ODFW reported that kelt mortality at Foster Dam was ongoing problem (Krasnow 2001).

Although the turbine intakes were intended to pass juvenile fish, the fish hesitated to sound or dive to the depth of the intakes. Depending on reservoir level, migrating fish must dive about 23 to 49 feet (7 to 15 m) to reach the penstock entrance and 16 to 43 feet (5 to 13 m) to reach the spill gate (USACE 1995). In 1983, ODFW and USACE began a surface spill program to flush juvenile steelhead from the reservoir during the peak migration period. From April 15 until at least mid-May, the reservoir is brought down to elevation 614 feet NGVD (National Geodetic Vertical Datum) and a surface spill of about 300 cfs is provided (USACE 2000). Buchanan et al (1993) reported that smolts passing over the spillway did not appear to suffer injuries and that gas supersaturation was not considered a problem with this operation. This program provides a route for juvenile steelhead that does not require them to dive deep enough to find the penstock entrances or even the depth of the spill gate outlets. Nonetheless, anglers continue to report observations of steelhead “chopped in half” during late winter and early spring (Krasnow 2001). Mortality may be exacerbated if spill is limited in low flow years.

Downstream migrants could also enter the hatchery’s unscreened water supply inlet or the unscreened water supply line for the trap. The mortality associated with each of these routes has not been assessed.

**Upstream Passage of Adults at Green Peter**
The fish trap at the base of Green Peter Dam is similar to that at Foster but was mothballed in 1988 because the water in the ladder was too cold to attract adults. The ODFW has not released adult Chinook salmon or steelhead above Green Peter in recent years.

**Adult Fallback at Green Peter Dam**
Adult spring Chinook and winter steelhead released in the forebay of Green Peter Dam sometimes fell back down to the tailrace via the turbines and possibly through the spillway.

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2 Several radio-tagged adults reached the Green Peter tailrace without delay and then remained near the outlet of the smolt bypass and only occasionally approached the entrance to the adult fishway (Buchanan et al. 1993). Relatively warm surface water emerged from the smolt bypass outlet while water in the adult fishway, drawn from the bottom of Green Peter Reservoir, is colder.
(Buchanan et al. 1993). Adult salmon and steelhead were probably killed when they fell back through the penstock entrance and passed through the turbines; those that survived had to move upstream through the fish passage facility a second time, increasing the likelihood of injury.

**Downstream Passage of Juvenile Fish at Green Peter**

Green Peter Dam was designed with downstream juvenile collection facilities. Downstream migrating juvenile fish were collected at the dam with a juvenile surface collector (this device could move up and down according to varying pool elevations) located well above the turbine intakes, then passed down the face of dam in a pipe (open-channel, shallow flow conditions, initially) then through an evaluator, and then finally released into the tailrace. However, ODFW discontinued releasing both Chinook salmon and steelhead above Green Peter Dam in the late 1980s because survival rates through the reservoir was low (Buchanan 1993) hypothesized to be due to predation.

Tests conducted during the 1980s indicated that the proportion of marked steelhead smolts released above Green Peter Dam and recaptured at the evaluator declined with distance from the forebay and over time (Buchanan et al. 1993). Only a small number of juvenile outmigrants appeared to reach the dam. USACE (1995) hypothesized that the observed decline in collection efficiency from approximately 35% for smolts released into the forebay to 1 or 2% for smolts released into the Middle Santiam River above the head of the reservoir, was related to the slow water velocity and long, convoluted shoreline of the reservoir. USACE (1995) also suggested that the decline in collection efficiency for winter steelhead that Buchanan et al. (1993) observed over time (from less than 90% in the early 1980s to less than 50% by 1988) may have been related to predation by populations of native northern pikeminnow and introduced large-mouth bass. Neither of these hypotheses was evaluated, however. Spring Chinook experienced a similar drop in the percentage of fish collected, from 22% in 1966 to less than 1% in 1985 (USACE 1995). Finally, experiments by Buchanan et al. (1993) showed high rates of injury and mortality for steelhead captured in the evaluator (cloudy eyes, bruises, split tails, and descaling), at least some of which was probably due to the experience in the bypass.

**Downstream Passage through the Reservoirs**

Predation of juvenile salmon and steelhead by warmwater fish species as well as hatchery rainbow trout has not been directly studied at Foster and Green Peter reservoirs, although, as described above, USACE (1995) hypothesized that it might be a factor in low juvenile fish collection efficiencies at Green Peter. Both reservoirs support a variety of non-native warmwater fish species in addition to native nongame fish including northern pikeminnow (USACE 1982). Green Peter Reservoir supports an introduced population of large mouth bass.

Juvenile fish may be delayed or fail to migrate (termed, “residualize”) from the reservoirs as a result of slow water velocities. As noted above, because of its length, Green Peter reservoir’s low currents could be partly responsible for low collection efficiencies at the juvenile bypass (USACE 1995).

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3 112 feet above the turbine inlet when the pool was at 922 MSL.
Passage in the Lower South Santiam River and Tributaries
A number of irrigation diversions create migration impediments or barriers along some of the tributaries to the lower South Santiam, including on Crabtree, and Thomas creeks. Some of these diversions have long affected fish passage conditions in these tributaries, particularly for spring Chinook salmon which pass upstream during periods of relatively lower flows (Willis et al. 1960), and add to the constraints that Foster and Green Peter dams place on the distributions of anadromous fish within the South Santiam subbasin.

Summary: Safe Passage & Access to Historical Habitat in the South Santiam Subbasin
Foster and Green Peter dams have delayed adult migrants and have killed and injured juvenile and adult UWR Chinook salmon and UWR steelhead, reducing the abundance and productivity of their populations in the South Santiam subbasin due to ineffective passage. The effect of inadequate passage facilities at Foster Dam continues to limit spatial distribution into much of the historical habitat above this dam. Lack of upstream and downstream passage at Green Peter Dam prevents access to much of the historical Chinook salmon spawning habitat and about 17% of historical steelhead habitat.

4.5.3.2 Water Quantity/Hydrograph

Human-caused alterations of the hydrologic regimes of the South Santiam River and its principal tributaries have generally diminished flow-related habitat quantity and quality and have probably reduced the numbers, productivity, and life history diversity (adult run timing and juvenile outmigrant strategies) of UWR Chinook salmon and UWR steelhead, limiting the production potential of accessible habitat in much of the subbasin. Many of these alterations are attributable to the presence and operation of Green Peter and Foster dams.

4.5.3.2.1 Seasonal discharge pattern
USACE operations intended to control floods and improve water quality have reduced spring flows and increased summer and early fall flows in the lower South Santiam River, below Foster Dam. The increases during summer and early fall offset flow reductions caused by water diversion from the lower mainstem and its tributaries for irrigation, hydropower, and other purposes.

Low flows occur naturally in the South Santiam River and its tributaries but their severity, timing, and frequency have been affected by Green Peter and Foster project operations and an array of downstream and tributary water developments. Green Peter and Foster refill operations have reduced flows in the lower South Santiam River during late winter and spring months (Figures 4.5-5 A, B & C). Operation of Green Peter and Foster dams has reduced median daily April flows below Foster by 17%. In some systems, recruitment of age-0 rainbow trout (O. mykiss) has been found to be correlated with late winter flows (Mitro et al. 2003). Thus, spring flow reduction may also reduce the survival of steelhead juveniles. The USACE releases higher than natural flows in September and October to provide space for flood control and to meet mainstem Willamette flow targets, and then drops flow releases in November and December to lower minimums. This release pattern allows UWR Chinook salmon to spawn in elevated areas below Foster Dam during high flows, and these redds may be dewatered prior to emergence, during lower winter flows. Depending on the duration and rate of desiccation, these operations
can kill incubating eggs and alevins (Reiser and White 1983). This effect is most severe near Foster Dam and diminishes downstream as unregulated tributaries enter the river.

**Figures 4.5-5 A, B & C.** Simulated discharge (cfs) of South Santiam River below Foster Dam under unregulated conditions (Unreg), with project operating criteria prior to 2000 (Pre-2000), and with project operating criteria after 2000 (Post-2000), depicting the 80th, 50th (median), and 20th percentile for each scenario.
Flow reductions associated with diversions for irrigation, domestic, and industrial water uses contribute to low flow conditions in the mainstem South Santiam River below Foster Dam and its tributaries, particularly in late summer and early fall (E&S 2000). The South Santiam River supplies water for agricultural, municipal, and industrial water uses. The largest diversion on the mainstem South Santiam is the Lebanon-Albany Canal, located downstream of the Waterloo gage (USGS no. 14187500). The canal can continuously divert between 25 and 200 cfs from the South Santiam River at Lebanon, although diversions never exceeded 156 cfs between 1991 and 1998 (E&S 2000). Most of the diverted water is used by the City of Albany for hydroelectric power, and return flows are released into the Calapooia River, just above its confluence with the mainstem Willamette River. The canal entrance was screened in 2006 as part of the city's FERC license for the project.

The OWRD water availability process (OAR 690-400-011) has determined that natural flow is not available for out-of-stream use from the South Santiam River during the months of August and September. Further, the Willamette Basin Program Classifications (OAR 690-502-0110) require that new surface water users in the subbasin obtain water service contracts from Reclamation (i.e., for the use of water stored in Willamette Project reservoirs during the summer months, including irrigation). In the South Santiam subbasin, those water service contracts are served primarily by water stored in Green Peter Reservoir. Reclamation has contracted a total of 1,096 acre-feet of water from the USACE reservoirs for irrigation within the South Santiam subbasin. Green Peter and Foster reservoirs, as well as Big Cliff and Detroit reservoirs, can also be used to serve contracts for points of diversion of 1,485 acre-feet on the mainstem Santiam River (USACE 2007a).

Water development has also depleted flows in several tributaries to the South Santiam downstream of Foster. E&S (2000) rated the potential for channel dewatering along portions of Neal, Thomas, Ames, and Crabtree creeks as high, and that along Hamilton and McDowell...
creeks as moderate. These flow reductions generally result from water diversions for irrigation, domestic, and industrial water uses, (E&S 2000), and reduce the habitat available to rearing juvenile spring Chinook salmon and winter steelhead, and in some cases, reduce the available Chinook spawning habitat. In the lower mainstem South Santiam, the effects of water withdrawals are partially offset during July and August when water is released from Green Peter and Foster reservoirs to help meet minimum flow targets at Albany and Salem (see Table 2-10 in Section 2, Proposed Action). The effects of September water withdrawals from the lower South Santiam are reduced by USACE flow releases during the annual fall reservoir draw-down. When the western Oregon rainy season begins in October, natural flows rise and water withdrawals for irrigation are substantially reduced.

4.5.3.2.2 Peak flow reduction
The magnitude and frequency of peak flows in the South Santiam River downstream from Foster Dam have been reduced by flood control operations at Green Peter and Foster dams. Over time, such flood control reduces recruitment and movement of channel substrates and large woody debris, diminishing channel complexity. Side channels, backwaters, and instream woody debris accumulations that would otherwise be created or maintained by floods have been shown to be important habitat features of rearing habitat for juvenile salmonids.

Flows in the lower South Santiam River have been controlled by Green Peter and Foster dams since 1966. Prior to dam construction, the highest instantaneous flow recorded at the Waterloo gage, 14 miles downstream from Foster Dam, was 95,200 cfs and flows greater than 50,000 cfs were common (Hubbard et al. 1997). The maximum flow observed at this site since completion of the projects has been 29,300 cfs. The magnitude of the two-year recurrence flood has decreased in volume from 37,900 to 15,800 cfs. Two major unregulated tributaries, Crabtree and Thomas creeks, enter the South Santiam downstream of Foster Dam and the Waterloo gage, and contribute some flood flows (though to a much less extent than occurred prior to Project dam construction) to the mainstem just upstream of its confluence with the North Santiam River.

Controlling peak flows prevents the flushing of fine sediments that accumulate on the river bed. Interstitial sediments finer than 1 mm can decrease the flow through spawning gravels, reducing the supply of oxygenated water to incubating eggs (Kondolf and Wilcock 1996). Somewhat coarser sediments (1 to 9 mm diameter) can fill interstices and physically block emergence of fry from the bed. Aquatic invertebrates also use open interstices in cobbles and gravel, and fine sediment can eliminate this habitat. The potential reduction in interstitial spaces may also affect juvenile salmonids which are known to use these niches for cover during winter periods (Bjornn and Reiser 1991). These effects are likely to be strongest below Foster Dam and to diminish in a downstream direction as flows and sediments enter the river from unregulated tributaries.

One possible benefit of reduced peak flows is that redds are less likely to be damaged by scouring. Spring Chinook are more likely to benefit from this effect than steelhead because their eggs are incubating through the winter months when floods are most likely to occur.

4.5.3.2.3 Effects of seasonal flow patterns on spawning success
Enhanced flows in the lower South Santiam River during late summer and early fall allow UWR Chinook to spawn close to the edge of the active channel. These are at risk of de-watering and desiccation when flows are reduced during winter flood control operations (ODFW 2007b).
4.5.3.2.4 Flow fluctuations, entrapment & stranding
The South Santiam River downstream from Foster Dam is subject to rapid water level fluctuations, particularly during active flood control operations when discharge may decrease sharply to prevent downstream flooding. Some juvenile salmonids become entrapped and stranded downstream from Foster Dam when discharge is reduced precipitously during winter flood events. This is most pronounced immediately downstream of Foster Dam and diminishes in a downstream direction as flow fluctuations attenuate and unregulated tributaries enter the river. In the South Santiam River, the reach of stream where severe flow reductions are unmitigated by tributary flows is about ½ mile long. At that point, Wiley Creek, a major tributary, enters along the river’s left bank.

Ramping rates below Green Peter Dam are unrestricted and highly variable, causing water levels in Foster Reservoir to change by 5 to 15 feet per day (USFWS 1961; USACE 1989a). The magnitude and frequency of flow fluctuations may have rendered the length of the Middle Santiam River between Green Peter Dam and Foster Reservoir unsuitable for fish habitation (USACE 2000).

Prior to 2006, the maximum allowable downramping rate at Foster Dam was 30% of discharge per half-hour. Upramping rates varied from 500 cfs per hour at initial flows between 500 and 1,000 cfs, to 2,500 cfs per hour when initial flows are higher than 18,000 cfs. Ramping operations at Foster Dam were modified in 2006 to reduce fishery impacts. Currently, USACE attempts to maintain ramping rates of 0.1 ft. per hour at night and 0.2 ft. per hour during daylight hours except during active flood damage reduction operations.

4.5.3.3 Water Quality
The ODEQ has rated water quality in the South Santiam basin as excellent (ODEQ WQISR 1996-2005).

4.5.3.3.1 Water temperature
Green Peter and Foster dams affect seasonal water temperature patterns in the lower South Santiam River and to a lesser extent, temperatures in the mainstem Willamette River (see Section 4.10.3.3.1). Within the South Santiam subbasin, their primary influence has been to lower summer temperatures below Foster as a consequence of discharging colder and greater quantities of water into the lower river.

The USACE operates Green Peter Reservoir for meeting mainstem Willamette minimum flows and to attempt to keep it full for summer recreation and drawn down in the fall to create storage space for fall and winter storms. Water is withdrawn from near the bottom and there is a direct relationship between project operations and thermal effects on downstream waters. Although pre- versus post-construction comparisons are difficult (due to differences in the time series available for the USGS gauging stations), operation of Foster and Green Peter reservoirs appears to have reduced average water temperatures in the South Santiam River by up to as much as 5.4°F (3°C) during late spring and as much as 12.6°F (7°C) during summer (May through July),
then to increase temperatures by 1.8 to 5.4°F (1 to 3°C) during most of the rest of the year. Most of the effect is due to Green Peter, the larger of the two reservoirs.\(^4\)

Differences between pre- and post-project water temperatures decrease in magnitude with distance downstream. At the Waterloo gage (South Santiam RM 23), average summer water temperatures are about 9.0 to 10.8°F (5 to 6°C) cooler than pre-dam levels (Figure 6-6 in USACE 2000). Hansen and Crumrine’s (1991) simulation indicated that, near the mouth of the South Santiam, pre- versus post-construction temperatures differed by less than 1.8°F (1°C). The ODEQ 2004/2006 Integrated Report database indicates that temperatures in the mainstem South Santiam River have exceeded the maximum temperature for salmon and steelhead spawning (55°F; 13°C) in several reaches between RM 0 and RM 60.4. Exceedances have also occurred for core cold water habitat and (61°F; 16°C), and rearing migration (64°F; 18°C) in the South Santiam up through RM 63.4. The USACE (1988) states that average summer water temperatures in the South Santiam River were high before Green Peter was built, often nearing or exceeding 68°F (20°C) (Figures 6-5 and 6-6 in USACE 2000).\(^5\) The USACE (1995) speculated that cooler discharges from Green Peter during early spring and summer may prevent the South Santiam from reaching even warmer, more detrimental temperatures in the fall.

A TMDL for the Willamette Basin was approved for temperature in 2006 (ODEQ 2006a). In this TMDL, ODEQ identified target temperatures for releases below Foster/Green Peter dams, based on stream temperatures inputs to the reservoirs and representing natural temperature regimes prior to dam construction (Table 4.5-3).

<table>
<thead>
<tr>
<th>Month</th>
<th>Foster/Green Peter Release Temperatures</th>
<th>ODEQ Target for Foster/ Green Peter Dam Releases</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>7.7</td>
<td>6.1</td>
</tr>
<tr>
<td>May</td>
<td>8.9</td>
<td>8.2</td>
</tr>
<tr>
<td>June</td>
<td>10.1</td>
<td>12.4</td>
</tr>
<tr>
<td>July</td>
<td>11.7</td>
<td>18.4</td>
</tr>
<tr>
<td>August</td>
<td>11.9</td>
<td>18.0</td>
</tr>
<tr>
<td>September</td>
<td>12.2</td>
<td>15.5</td>
</tr>
<tr>
<td>October</td>
<td>12.2</td>
<td>12.6</td>
</tr>
<tr>
<td>November</td>
<td>10.4</td>
<td>12.6</td>
</tr>
</tbody>
</table>

\(^4\) Green Peter Reservoir is 10 miles (16.1 km) long with a useable storage volume of 312 kaf. Foster Reservoir is 3.5 miles (5.6 km) long with useable volume of only 28 kaf. (Sources: USACE 2006; USACE 1989a)

\(^5\) Compared to the North Santiam, the headwaters of the South Santiam are lower in elevation and the snowpack is usually smaller.
As illustrated in Table 4.5-3, the Foster/Green Peter dam complex modified natural temperature patterns in downstream reaches. These modifications include colder summer (June-September) water temperatures.

**Water Temperature Control and Site-Specific TMDL Requirements**

Operating projects to optimize temperature conditions downstream for fish is often inconsistent with TMDL temperature targets, even with a temperature control tower such as the one constructed at Cougar Dam. Experience in implementing water temperature control operations in the Sound Fork McKenzie River downstream of Cougar Dam to achieve more normative water temperatures suggest that special site-specific considerations may be required for such actions with respect to achieving ODEQ TMDLs. An operational requirement for successfully avoiding high temperature discharges in the fall (i.e., during spring Chinook salmon incubation) is to evacuate as much warm surface water as possible from the reservoir throughout the summer months while operating within the range of appropriate downstream temperature criteria for each month identified by ODFW. That is, it is necessary to balance the effect of warm water temperatures downstream of the dam across the spring, summer and fall periods to achieve the most appropriate overall biological effect. In the South Fork McKenzie River, the requirement resulted in summer water temperatures below Cougar Dam that were will above the draft TMDLs identified by ODEQ during April through September (Figure 4.3-6) in order to provide more favorable temperatures during the critical incubation period in the fall. A focus on achieving the cooler TMDL temperature targets during summer would have adversely affected the temperature conditions achievable during the fall spawning and incubation period for spring Chinook because more warm surface water would have been retained in the reservoir over summer.

Summer and fall exceedances of temperature criteria for salmonid uses are not limited to reaches affected by Willamette Project operations. The ODEQ 2004/2006 Integrated Report database indicates exceedances of the maximum temperature for spawning (55°F; 13°C) and for both core cold water habitat (61°F; 16°C) and rearing and migration (64°F; 18°C) in the South Santiam above Foster Reservoir (up to RM 63.4, near the mouth of Elk Creek). Exceedances of the non-core rearing and migration maximum have also been recorded in the Middle Santiam River above Green Peter Reservoir (up to RM 37.1, near the mouth of Ethyl Creek); Quartzville Creek (up to RM 26.8); and in Beaver, Crabtree, Neal, Hamilton, McDowell, Thomas, and Wiley creeks, which are tributaries to the South Santiam River below Foster Dam. The South Santiam Watershed Assessment (E&S 2000) stated that temperature exceedance was a widespread problem through the lower drainages of the South Santiam subbasin, and that there was some evidence that stream temperatures may already exceed standards before flowing through the poorly shaded portions of the watershed. For example, Wiley Creek exceeded standards in its headwaters, where stream shading was assumed to be high.

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6 Temperatures that exceed the maximum for non-core rearing and adult and juvenile migration also exceed the maximum for core rearing areas (61°F; 16°C).
4.5.3.3.2 Other Water Quality Constituents

Dissolved Oxygen
The ODEQ 2004/2006 Integrated Report database does not indicate that any streams in the South Santiam subbasin are water quality limited due to low levels of dissolved oxygen, but acknowledges there is insufficient data in many reaches in the basin to determine if the ODEQ standard is met. Historically, the lower reach of the South Santiam River, from the mouth of the river to approximately RM 19, was highly polluted with chemical waste from a paper mill and sewage from the city of Lebanon (McIntosh et al. 1995). The USACE noted that this reach experienced an oxygen block during summer months (USACE 1982). Improved paper pulping processes, secondary wastewater treatment, and summer flow augmentation operations at Foster and Green Peter dams (Section 4.5.2.3) have helped correct these water quality problems.

Total Dissolved Gas
Spill from Foster Dam causes exceedances of TDG in the South Santiam below Foster Dam. On January 25, 1971, Monk et al. (1975) measured a TDG level of 129.2% saturation in the tailrace area (0.4 miles below Foster Dam) during a period when spill was approximately 50% of total flow. A year later (March 3, 1972), TDG was 115.8% at a gage 1.2 miles below the dam (81% spill), and 113.3% another 3.5 miles downstream (78% spill). A background level of 102.9% was measured in the South Santiam River above Foster Reservoir (1.2 miles upstream of Cascadia) on March 7, 1972. Buchanan et al. (1993) reported TDG levels less than or equal to 110.6% of saturation below spillway number 4 during 1979 tests. The 129.2% saturation measured in the tailrace could have caused gas bubble trauma in juvenile salmonids rearing in this area (Appendix E in NMFS 2000b); levels above 105% saturation could adversely affect Chinook yolk sac larvae incubating in this reach. The USACE has not assessed the risk at this location, which would depend on hydrostatic pressure at the depth of the redd and the presence of yolk sac fry during supersaturated conditions. Symptoms of gas bubble trauma have not been reported in juvenile or adult anadromous salmonids in the South Santiam subbasin.

Turbidity
Although landslides may occur in the upper reaches of the South Santiam subbasin, there are no reports of turbidity levels adversely affecting the habitat requirements of spring Chinook salmon or winter steelhead. The ODEQ 2004/2006 Integrated Report database does not list any streams in this subbasin as water quality limited for turbidity.

Nutrients
The ODEQ 2004/2006 Integrated Report database does not indicate that any streams in the South Santiam subbasin are impaired due to excessive nutrient loadings. Operations at Green Peter and Foster dams that increased summer flows may have reduced nutrient loads in the mainstem South Santiam River.

Toxics
The ODEQ 2004/2006 Integrated Report database does not indicate that any streams in the South Santiam subbasin are water quality limited due to toxics.
4.5.3.4 Physical Habitat Characteristics

Unfavorable human influences on the physical characteristics of habitat for UWR Chinook and of UWR Steelhead tend to be more pronounced in lower portions of the South Santiam subbasin, below Foster, than they are above Foster. A key reason for this is the pattern of ownership and a strong focus on aquatic conservation by public land managers on the Willamette National Forest, within upper portions of the subbasin.

Substrate

Substrates within many streams that are, or have been, used by the South Santiam’s Chinook salmon and steelhead populations are influenced by the cumulative effects of various land-use activities and, within the lower South Santiam River, by the effects of Foster and Green Peter dams. As noted, unfavorable influences on habitat tend to be more pronounced in lower portions of the subbasin.

All coarse sediment transported from watersheds above Foster Dam (50% of the South Santiam subbasin) is now trapped by Foster and Green Peter reservoirs. This sediment was historically important to the maintenance of a complex channel network of high-quality salmonid habitats in the lower South Santiam River, including good spawning habitat. One consequence of the reduced quantity of coarse sediment delivered to the lower river has apparently been a coarsening of channel substrates downstream of Foster Dam, potentially reducing the availability of spawning habitat for anadromous salmonids and particularly UWR Chinook salmon. Reduced peak flows, also associated with the USACE dams, have increased the potential for fine sediments to intrude and accumulate in the channel bed and reduce the quality of salmonid spawning habitat in the lower river.

Recent surveys by R2 Resource Consultants (2007) documented the amount of spawning habitat available to UWR Chinook in the mainstem South Santiam between Waterloo and Foster as well as that available to these fish in the mainstems of the upper South Santiam River, the Middle Fork of the Santiam River, and Quartzville Creek, if adult passage is provided at the USACE dams. The surveys did not include several once-used streams above Foster and Green Peter, and therefore provide minimum estimates of what is available above the dams, but found that 21,150 m² (66%) of 32,190 m² of spawning habitat within the areas surveyed was upstream of Foster.

Large Woody Debris

Streams within the old-growth forests that remain in parts of the upper South Santiam subbasin retain large quantities of in-channel wood. However, a combination of natural disturbances, historical splash-damming, timber harvest, road construction, and other activities have diminished the abundance of large wood in a substantial portion of the drainage network above Foster (WNF SHRD 1995; E&S 2000; BLMS and WNF SHRD 2002). The near-term potential for natural recruitment of large woody debris to many wood-deficient reaches on public lands in the upper subbasin is low enough in some areas that active placement is considered an important option (WNF SHRD 1995). Prospects for significant, widespread large wood recruitment into streams on private lands upstream of Foster is relatively limited (E&S 2000).

All large woody debris that is transported from watersheds above Foster Dam now becomes trapped within Foster and Green Peter reservoirs, and is subsequently removed by the USACE.
Such wood is thought to have contributed historically to the maintenance of a complex channel network of high-quality salmonid habitats in the lower South Santiam River by influencing how the river interacted with its banks and floodplain and by providing hydraulic diversity and hiding cover. Large wood also creates pools and stable gravel deposits in streams (Abbe and Montgomery 1996), habitats utilized by holding or rearing salmonids and the invertebrates upon which they feed.

Without wood from the upper subbasin, the lower South Santiam is dependent on wood recruited from its banks, floodplain, or tributary watersheds. Sources along the banks and floodplain have been diminished by land use and are captured less frequently by the river due to flood control. The three largest tributaries to the lower mainstem, Wiley, Thomas, and Crabtree creeks, drain watersheds whose streams themselves have relatively low wood loading (E&S and 2000). Although intensive timber management and agricultural clearing have reduced wood recruitment potential within these three watersheds, interpretations of air photos suggest that they still have moderate to high recruitment potential in many areas (E&S 2000).

**Channel Complexity, Off-channel Habitat & Floodplain Connectivity**

Reductions in channel-forming flows, decreased inputs of sediment and large wood, revetments, and bank armoring, can impair the formation and maintenance of complex riverine habitats preferred by salmonids (Appendix E, section E.5). Each of these disturbances has influenced channel conditions along the lower South Santiam River but the effects have not been quantified. However, it is apparent that habitat simplification such as has been documented on the Middle Fork Willamette and lower McKenzie rivers has occurred. The South Santiam below Foster Dam was described in 1947, prior to construction of Foster and Green Peter dams, as being very sinuous, divided by large islands in many places, and actively eroding (USACE 2000). Today, the lower South Santiam River is confined primarily to a single main channel, with few active gravel bars. It also has few perennial secondary channels, and many abandoned alcoves, meander bends, and side-channels that are visible on aerial photographs.

The effects of Green Peter and Foster dams on channel processes downstream in the lower South Santiam River are only partly responsible for the channel simplification that has occurred in the lower South Santiam subbasin. Bank stabilization measures and land leveling for development have also reduced channel complexity and associated juvenile salmon rearing habitat. As of 1989, more than 15 miles of channel bank along the lower South Santiam was protected by rip-rap or revetments, so that 35 percent of the channel downstream of Mile 19 has artificial banks (USACE 1989). USACE projects account for a total of 7.6 miles of this bank armoring, all below Mile 8.3 (USACE 2000). Additional bank stabilization projects completed along the river downstream of Foster have been documented by E&S (2000).

**Riparian reserves & disturbance history**

Riparian vegetation along streams in the South Santiam subbasin varies in response to natural differences in geology, precipitation, elevation, and fire regimes, and to man-caused factors.

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7 E&S (2000) define large wood recruitment potential in the following manner: “High” potential areas have sparse or dense mature forest, while “moderate” potential include sparse or dense young forests and riparian wetland vegetation, and “low” recruitment areas consist of urban areas or where grass and shrubs dominate the riparian area.
including: timber harvesting, road building, and land use. It is typically least disturbed in upper portions of the subbasin within the Willamette National Forest and most disturbed along lowland channels passing through areas affected by agricultural, rural residential, or municipal development.

Old-growth forests remain along streams in significant federally-managed portions of the upper South Santiam subbasin, particularly within the Middle Santiam and Quartzville Creek drainages. However, timber harvest, near-stream road construction, and fires have removed these forests from much of the public land and from essentially all private forestlands upstream of Foster (WNF SHRD 1996; E&S 2000; BLMS and WNF SHRD 2002). Recently disturbed riparian forests on federal lands within the upper South Santiam subbasin are now being managed to recover high levels of natural function under the President’s Forest Plan. Lower levels of riparian recovery are to be expected along streams on private lands.

The lower South Santiam River, below Foster, has a riparian corridor that includes some significant patches of wide and continuous woody vegetation. However, less than 30% of the lower mainstem is bordered by riparian forest more than 30 m wide, and discontinuous vegetation is common along the channel (E&S 2000). Vegetation has been cleared from much of the lower river’s historical floodplain for agricultural or other purposes. Revetments constructed by the USACE, other bank protections, and diminished flooding, inhibit the formation of new riparian forest. Three non-native species have invaded riparian areas along the lower river as well as many of its tributaries: scotch broom, Himalayan blackberry, and reed canary grass.

Tributaries to the lower South Santiam have riparian corridors that have typically been disturbed by land use (E&S 2000). For example, Wiley Creek and its tributaries drain predominantly private timberlands managed under short harvest rotations and with the riparian protections required by the Oregon FPA. The Thomas and Crabtree drainages are also dominated by private lands, but have a mix of federal (BLM), state, and predominantly private forestlands along their middle and upper reaches combined with significant lowland reaches strongly affected by agricultural development. E&S (2000) rated the majority of streamside areas within forested areas of the Crabtree and Thomas creek watersheds as having good or fair riparian continuity but the potential for recruiting large wood to these streams is low because nearly all riparian vegetation in these drainages is less than 80 years old, and most is less than 40 years old. Riparian conditions were generally poorer where the lower mainstems of these streams passed through agricultural lowlands.

4.5.4 Hatchery Programs

UWR Chinook Salmon
Hatchery produced spring Chinook have been present in the South Santiam River since egg collection activities began in 1923 near the town of Foster (Mattson 1948, Wallis 1961). In many early years, sporadic and inefficient operation of a fish collection weir probably allowed a large fraction of the salmon run to escape fish culturists and spawn upstream (Wallis 1961), but in others the hatchery may have collected much of the wild run for broodstock. The South Santiam Hatchery began operations in 1966 to mitigate for Foster Dam, which blocked spring Chinook from most of their historical spawning areas.
The current management strategy for the hatchery Chinook program, as described in section 2.10, is to incorporate some wild fish into the broodstock (so that the hatchery broodstock reflects local adaptation) and to control the percentage of hatchery fish spawning in the wild. The current smolt production goal in the South Santiam is 1.02 million juvenile spring Chinook. NMFS’ biological opinion on the USACE hatchery program for UWR Chinook salmon expired in September 2003.

Available information suggests that hatchery-origin spring Chinook are numerically dominant in natural spawning areas within the lower South Santiam subbasin, particularly in the mainstem river immediately below Foster Dam (see section 4.5.2.1). This would appear to pose a threat to the productivity of the natural population (ODFW 2007b). Most freshwater coded-wire tag recoveries from South Santiam hatchery spring Chinook salmon have been made within six miles of the hatchery (Myers et al. 2002).

During the past decade, some of the hatchery-origin spring Chinook returning to Foster Trap have been outplanted in an effort to test the ability to reinitiate or rebuild runs of UWR Chinook in historically occupied areas. Some of these adult fish have been released above Foster Reservoir, often accompanied by natural-origin fish that were also collected at the trap (see section 4.5.3.1). Others have been released, also sometimes accompanied by natural-origin adults from the trap, into tributaries to the lower South Santiam River (Table 4.5-4) or outside the subbasin. Pre-spawn mortality of the adults released has generally been high (Beidler and Knapp 2005). Those fish that have spawned appear to have been able to produce juvenile Chinook in the receiving streams, though survival rates from egg deposition to juvenile lifestages is unknown (Beidler and Knapp 2005).

<table>
<thead>
<tr>
<th>Table 4.5-4 Numbers of adult spring Chinook salmon outplanted in the South Santiam subbasin 1998-2006 (Beidler and Knapp 2005) and (McLaughlin et al. 2008).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>YEAR</strong></td>
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<td>1998</td>
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<td>2004</td>
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<td>2005</td>
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<tr>
<td>2006</td>
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</tbody>
</table>
Summer Steelhead & UWR Steelhead (winter)
Hatchery-origin winter steelhead returning to the South Santiam River were reared at the former South Santiam Hatchery on Coal Creek from 1926 through 1944. After 1944, the South Santiam stock was infrequently reared in a hatchery (ODFW 1986) and was often supplemented with fish from the Marion Forks Hatchery in the North Santiam subbasin (ODFW 1990a). Hatchery releases of winter steelhead have not occurred in this basin since 1989 (Chilcote 1997).

4.5.5 Fisheries
Until recently, wild spring Chinook salmon were subjected to relatively intense commercial and recreation fisheries in the lower Columbia and Willamette rivers that were directed primarily at the abundant hatchery-origin fish. Freshwater harvest rates for Willamette spring Chinook were on the order of 35-40% prior to ESA listing of UWR Chinook, but have since been reduced to approximately 8-12% since 2001. Fishery objectives in the Willamette River have been changed to emphasize the protection of natural-origin fish.

The State of Oregon developed a Fisheries Management and Evaluation Plan under NMFS’ 4(d) Rule for the management of spring Chinook salmon fisheries in the Willamette River. This management plan specifies the harvest regime for spring Chinook salmon and has been approved by NMFS under the ESA. Total mortality in commercial and sport fisheries occurring in freshwater are capped at 15%. However, annual mortality rates since implementation of selective, catch-and-release fisheries for wild spring Chinook have more typically been in the range of 8-12% (ODFW 2008c). Impacts on natural-origin spring Chinook have been significantly reduced while maintaining a relatively high harvest of hatchery-origin adults.

4.5.6 Status of PCEs of Designated Critical Habitat in the South Santiam Subbasin
NMFS determined that the following occupied or unoccupied areas of the South Santiam subbasin contain Critical Habitat for UWR Chinook salmon or UWR steelhead (NMFS 2005d; maps are included in section 303 of this Opinion):

UWR Chinook (spring-run)

- Habitat of high or medium conservation value for these fish, and deemed important to their recovery, is present in all six occupied watersheds within the South Santiam subbasin (NMFS 2005g). In aggregate, these six watersheds contain 79.3 miles of PCEs for spawning/rearing and 89.4 miles of PCEs for rearing/migration (NMFS 2005g). All of the evaluated watersheds have been designated as Critical Habitat (NMFS 2005d), as described below:
  - The South Santiam River and South Santiam River/Foster Reservoir watersheds, both above Foster Dam, have high conservation value and combine to provide 25.4 miles of spawning/rearing habitat and 4.7 miles of rearing/migration habitat (NMFS 2005g).
  - The Hamilton Creek/South Santiam River watershed, below Foster Dam, has high conservation value and provides 16.5 miles of spawning/rearing habitat and 40.7 miles of rearing/migration habitat (NMFS 2005g).
• The Wiley Creek, Thomas Creek, and Crabtree Creek watersheds, all below Foster Dam, have moderate conservation value and contain a total of 37.4 miles of spawning/rearing habitat and 44.0 miles of rearing/migration habitat (NMFS 2005g).

Two watersheds that account for all South Santiam tributaries above Green Peter Dam, Middle Santiam River and Quartzville Creek, are unoccupied at present but did support the species prior to dam construction. They have not been fully evaluated as potential critical habitat, but contain as much as 38.3 miles of habitat once used by UWR Chinook and may be important to species conservation (NMFS 2005g).

UWR steelhead

Habitat of high conservation value, and important to the recovery of these fish, is present in all six occupied watersheds within the South Santiam subbasin (NMFS 2005g). In aggregate, these six watersheds contain 152.1 miles of PCEs for spawning/rearing, 72.2 miles of PCEs for rearing/migration, and 5.4 miles of migration/presence habitat (NMFS 2005g). All of the occupied watersheds have been designated as Critical Habitat (NMFS 2005d), as described below:

• The South Santiam River and South Santiam River/Foster Reservoir watersheds are above Foster Dam and combine to provide 44.6 miles of spawning/rearing habitat and 8.3 miles of rearing/migration habitat (NMFS 2005g).

• The Hamilton Creek/South Santiam River, Wiley Creek, Thomas Creek, and Crabtree Creek watersheds are all below Foster Dam and contain a total of 107.5 miles of spawning/rearing habitat, 63.9 miles of rearing/migration habitat, and 5.4 miles of migration/presence habitat (NMFS 2005g).

Two watersheds that account for all South Santiam tributaries above Green Peter Dam, Middle Santiam River and Quartzville Creek, are unoccupied at present but did support UWR steelhead prior to dam construction. The watersheds have not been fully evaluated as potential critical habitat, but contain as much as 48.4 miles of habitat once used by UWR steelhead and may be important to species conservation (NMFS 2005g).

Bank protection measures associated with USACE activities total 95,164 linear feet (18.02 miles) between RM 0.9 and RM 29.1 in the South Santiam, with 40,620 feet (7.69 miles) on the right bank, and 54,544 feet (10.33 miles) on the left bank, In the Santiam River below the confluence of the South Fork between RM 0.8 and RM 8.3, there are an additional 40,258 linear feet (7.62 miles) of bank protection measures, with 24,599 feet (4.66 miles) on the right bank and 15,659 (2.97 miles) on the left bank (USACE 2000). These measures affect spawning/rearing and rearing/migration habitats, designated as critical habitat, in the South Santiam and lower Santiam rivers (NMFS 2005d).

NMFS (2005g) identified the key management activities that affect these PCEs. Key management activities affecting the upper watersheds include dams and forestry management. Key activities affecting the mid and lower watershed include agriculture, channel modifications/diking, irrigation impoundments and water withdrawals, road building and maintenance, and urbanization, in addition to dam and forestry activities.

As discussed in previous sections, Foster and Green Peter dams blocked or reduced access to upstream spawning and rearing habitats, reduced downstream migrant survival, altered flows
downstream, reduced or eliminated marine-derived nutrients from upper watersheds, and limited the downstream transport of habitat building blocks. Green Peter Dam altered the habitat above the dam by creating a 10 mile-long reservoir from about RM 5.7 to RM 15.7 inundating 10 miles of riverine habitat. Foster Dam also inundates riverine habitats within critical habitat above the dam by creating a 3.5 mile-long reservoir. Foster and Green Peter dam operations also negatively altered downstream water temperatures.

Table 4.5-5 summarizes the condition of PCEs within the South Santiam River. Many of the habitat indicators are not in a condition suitable for salmon and steelhead conservation. In most cases, this is the result of the past operation and the continuing effects of the existence of the Projects or the effects of other human activities (e.g., development, agriculture, and logging). However, to the extent these conditions would be perpetuated by future operations or existence of the project, only the past impacts and project existence are included in the baseline.
Table 4.5-5 Critical habitat primary constituent elements (PCEs) and associated pathways, indicators, current conditions, and limiting factors for ESA-listed anadromous salmonids in the South Santiam subbasin under the environmental baseline.

<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Limiting Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater spawning sites</td>
<td>Water Quality</td>
<td>Temperature</td>
<td>Operation of USACE reservoirs reduced spring/summer temperatures in the South Santiam River and increased temperatures during most of the rest of the year</td>
<td>USACE operations (Green Peter)</td>
</tr>
</tbody>
</table>
| Freshwater rearing sites    |                                |           | The ODEQ 2004/2006 Integrated Report database indicates that temperatures in the mainstem South Santiam River have exceeded the maximum temperature for salmon and steelhead spawning (55°F; 13°C) in several reaches between RM 0 and RM 60.4. Exceedences have also occurred for core cold water habitat and (61°F; 16°C), and rearing migration (64°F; 18°C) in the South Santiam up through RM 63.4. Summer water temperatures in the South Santiam River often neared or exceeded 68°F before Green Peter; cooler spring/summer discharges from Green Peter may prevent the lower South Santiam from reaching warmer temperatures in the fall. ODEQ 2002 CWA 303(d) database indicates exceedences of the maximum for spawning (13°C), core cold water habitats (16°C), and rearing and migration (18°C) in the South Santiam above Foster Reservoir; exceedences of the maximum for rearing and migration maximum have also been recorded in the Middle Santiam River above Green Peter Reservoir; and for core coldwater habitat, and rearing and migration in Quartzville Creek. Temperatures below Foster Dam (1968-1972) were less than 52°F during May through early July – cold enough to delay upstream migration of spring Chinook.                                                                                                                                 | Agriculture  
Revetments  
Natural conditions  
Benefit of USACE operations  
Timber harvest  
USACE operations (especially Green Peter)                                                                 |
### PCE Pathway | Indicator | Condition | Limiting Factors
---|---|---|---
Freshwater spawning sites | Water Quality | Total Suspended Solids/Turbidity | No reports of turbidity levels adversely affecting the habitat requirements of spring Chinook salmon or winter steelhead. The ODEQ 2004/2006 Integrated Report database does not list any streams in this subbasin as water quality limited for turbidity. | N/A |
Freshwater rearing | Water Quality | Chemical Contamination/Nutrients | The ODEQ 2004/2006 Integrated Report database does not indicate that any streams are water quality limited due to the presence of toxics. The ODEQ 2004/2006 Integrated Report database does not indicate that streams in the South Santiam subbasin are impaired due to excessive nutrient loadings. Operations at Green Peter and Foster dams that increased summer flows may have reduced nutrient loads in the mainstem South Santiam River. | N/A |
Freshwater migration corridors | Water Quality | Chemical Contamination/Nutrients | Benefit of USACE operations | N/A |
### Freshwater spawning sites

#### Indicator
- Water quality

#### Condition
**Historical pollution due to pulp mill effluent and sewage in the lower 19 miles; oxygen block during summer months**

#### Limiting Factors
- Pulp mill
- Municipal sewage

#### Improved paper pulping processes, secondary wastewater treatment, and summer flow augmentation from Foster and Green Peter dams helped correct the problem

#### The ODEQ 2004/2006 Integrated Report database does not indicate that any streams in the South Santiam subbasin are water quality limited due to low levels of dissolved oxygen

### Freshwater rearing

#### Indicator
- Dissolved Oxygen (DO)

#### Condition
**A TDG level of 129.2\% saturation, measured in the tailrace in January 1971, was high enough to cause gas bubble trauma in juvenile salmonids rearing in the area and could kill Chinook yolk sac larvae incubating in this reach**

#### Limiting Factors
- Regulating outlet spill – USACE operations at Foster Dam

#### TDG levels of 115.8\% at 1.2 miles below Foster Dam and 113.3\% another 2.3 miles downstream (March 1972) could also have killed yolk sac larvae

#### Symptoms of gas bubble trauma have not been reported in juvenile or adult anadromous salmonids in the South Santiam subbasin
<table>
<thead>
<tr>
<th>PCE Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Limiting Factors</th>
</tr>
</thead>
</table>
| Freshwater migration corridors | Habitat access | Physical barriers | Barriers below Foster Dam  
Rebuilt ladders and new screen at Lebanon Dam (RM 21), which diverts water into the Lebanon-Albany power canal for irrigation, hydropower, and municipal use, allows safe passage of juvenile fish downstream and adult fish in both directions past this small dam on the lower S. Santiam River  
Several older fish ladders in tributaries allow passage of adult spring Chinook salmon but probably cause some migration delay  
Irrigation diversions on the lower tributaries of Crabtree and Thomas creeks pose migration barriers to adult spring Chinook  
Barriers above Foster and Green Peter reservoirs  
Hatchery broodstock collection began near the site of Foster Dam in 1923 and was discontinued in the 1930s  
A weir was on the Middle Santiam River, a few miles upstream from the confluence with the South Santiam River; fell into disuse in the 1930s | Privately-owned diversions, dams, and hydroelectric facilities  
State hatchery operations |
<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Limiting Factors</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Freshwater migration</td>
<td>Habitat</td>
<td>Foster Dam as a barrier to upstream migrants</td>
<td>USACE operations (Foster)</td>
</tr>
<tr>
<td></td>
<td>corridors</td>
<td>access</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Physical</td>
<td>No estimates of upstream passage mortality at Foster Dam</td>
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<tr>
<td></td>
<td></td>
<td>barriers</td>
<td>Dated design does not allow facilities for holding, handling, examining,</td>
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<td></td>
<td></td>
<td></td>
<td>and sorting hatchery- from natural-origin fish (flexibility in disposition)</td>
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<td>The operator is unable to see how many fish have accumulated in the trap,</td>
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<td>leading to potential crowding and injury during handling</td>
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<td>The device can be operated improperly by inexperienced personnel, leading</td>
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<td>to fish injury</td>
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<tr>
<td></td>
<td>Freshwater migration</td>
<td>Habitat</td>
<td>Foster Dam and Reservoir as a barrier to downstream migrants</td>
<td>USACE operations (Foster)</td>
</tr>
<tr>
<td></td>
<td>corridors</td>
<td>access</td>
<td>Kaplan turbines expected to safely pass juveniles but fish hesitate to</td>
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<td></td>
<td></td>
<td>Physical</td>
<td>dive to intakes</td>
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<td></td>
<td></td>
<td>barriers</td>
<td>Surface spill used to flush juvenile steelhead from the reservoir since</td>
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<td></td>
<td></td>
<td>1983</td>
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<td></td>
<td>89.9% survival for juvenile Chinook through Kaplan turbines (similar rates</td>
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<td></td>
<td></td>
<td></td>
<td>for juvenile steelhead)</td>
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<td>41% mortality of steelhead kelts recovered in the downstream nets</td>
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<td></td>
<td>Fallback at Foster Dam</td>
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<td></td>
<td>Estimated fallback rates for wild winter steelhead of 2.5 to 4%</td>
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<td>PCE</td>
<td>Pathway</td>
<td>Indicator</td>
<td>Condition</td>
<td>Limiting Factors</td>
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<tr>
<td></td>
<td>Freshwater migration corridors</td>
<td>Habitat access</td>
<td>Green Peter Dam as a barrier to upstream migrants</td>
<td>USACE operations (Foster)</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Adult passage facility at Green Peter mothballed in 1988; water in the ladder was too cold to attract adults</td>
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<td>Green Peter Dam and Reservoir as a barrier to downstream migrants</td>
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<td>Slow water velocity and long, convoluted reservoir shoreline</td>
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<td></td>
<td>Populations of native northern pikeminnow and introduced large-mouth bass</td>
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<td></td>
<td>High rates of injury and mortality for steelhead captured in bypass evaluator</td>
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<td></td>
<td></td>
<td>Physical barriers</td>
<td>Fallback at Green Peter Dam</td>
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<td></td>
<td>Adult spring Chinook and winter steelhead released in the forebay of Green Peter Dam sometimes fall back down to the tailrace via turbines (and possibly through the spillway)</td>
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<td>Surviving fallback had to move upstream through the fish passage facility a second time, increasing the likelihood of injury</td>
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<td>USACE operations (Green Peter)</td>
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<td></td>
<td>USACE operations (Green Peter)</td>
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</tbody>
</table>
### Freshwater migration corridors

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Limiting Factors</th>
</tr>
</thead>
</table>
| Habitat access| Physical barriers | Predation as a barrier to reservoir migration  
Foster and Green Peter reservoirs support native northern pikeminnow  
Green Peter supports a population of nonnative large mouth bass | USACE operations (Foster and Green Peter)                                           |

### Freshwater spawning sites

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Limiting Factors</th>
</tr>
</thead>
</table>
| Habitat elements | Substrate | Substrate has coarsened downstream of Foster Dam.  
River channel downstream of Foster Dam may be downcutting.  
Channel downstream of Foster Dam could lack spawning gravel  
Many areas scoured to bedrock  
Current sediment budget not creating and maintaining side channel and gravel bar habitat needed by anadromous salmonids | USACE reservoirs trap sediment from headwaters  
USACE operates Foster/Green Peter Dams to reduce the magnitude and frequency of peak flows  
USACE and private revetments  
Gravel mining  
Historical log drives |
<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Limiting Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater rearing sites</td>
<td>Freshwater migration corridors</td>
<td>Habitat elements</td>
<td>Large Woody Debris</td>
<td>In Tributaries and upper South Santiam mainstem</td>
</tr>
<tr>
<td></td>
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<td>Large wood is lacking in most small tributaries and the upper South Santiam; very few reaches meet the ODFW benchmarks</td>
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<tr>
<td></td>
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<td>Future recruitment potential for large wood is low along the lower portions of surveyed streams, but relatively high in upper reaches</td>
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<td>In the mainstem South Santiam River--</td>
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<td>Reaches of the South Santiam River below Green Peter and Foster dams are deprived of large wood</td>
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<td></td>
<td>Inadequate recruitment of large wood from riparian areas along mainstem South Santiam and tributaries downstream from Foster Dam</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>Lack of large wood-associated habitat for anadromous salmonids and invertebrates upon which they feed</td>
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<td>USACE and private revetments prevent recruitment from banks.</td>
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<td></td>
<td>USACE operation of Green Peter and Foster dams reduces frequency of channel-forming flows needed to recruit large wood from banks.</td>
</tr>
<tr>
<td>PCE</td>
<td>Pathway</td>
<td>Indicator</td>
<td>Condition</td>
<td>Limiting Factors</td>
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</tr>
<tr>
<td></td>
<td>Freshwater rearing sites</td>
<td>Habitat elements</td>
<td>Pool Frequency and Quality</td>
<td>N/A</td>
</tr>
<tr>
<td>Freshwater rearing sites</td>
<td>Habitat elements</td>
<td>Off-channel habitat</td>
<td>Floodplain is not frequently inundated, with less over-bank flow and side channel connectivity</td>
<td>USACE operates Foster/Green Peter Dams to reduce the magnitude and frequency of peak flows. USACE and private revetments.</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing sites</td>
<td>Habitat elements</td>
<td>Channel forming processes in the South Santiam River downstream of the Green Peter/Foster dam complex have been restricted by changes to the natural hydrograph and by reductions in sediment load and LWD derived from areas located above the dams. Flow regulation, fractionation of the sediment load passed to below the dams, and accumulation of fine sediment fractions below Foster Dam have resulted in bank and substrate armoring (i.e., compaction and stabilization) and in habitat simplification.</td>
<td>USACE reservoirs trap sediment from headwaters. USACE operates Foster/Green Peter Dams to reduce magnitude/frequency of peak flows. USACE and private revetments.</td>
</tr>
<tr>
<td>PCE</td>
<td>Pathway</td>
<td>Indicator</td>
<td>Condition</td>
<td>Limiting Factors</td>
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</tr>
<tr>
<td></td>
<td>Freshwater spawning sites</td>
<td>Channel conditions and dynamics</td>
<td>Streambanks do not support natural floodplain function in the lower South Santiam River downstream of the Green Peter/Foster dam complex.</td>
<td>USACE operates Foster/Green Peter dams to reduce the magnitude/frequency of peak flows</td>
</tr>
<tr>
<td></td>
<td>Freshwater rearing</td>
<td>Channel conditions and dynamics</td>
<td>Streambank condition</td>
<td>USACE and private revetments</td>
</tr>
<tr>
<td></td>
<td>Freshwater migration corridors</td>
<td>Channel conditions and dynamics</td>
<td>Floodplain connectivity</td>
<td>USACE operates Foster/Green Peter Dams to reduce the magnitude and frequency of peak flows</td>
</tr>
<tr>
<td></td>
<td>Freshwater rearing</td>
<td>Channel conditions and dynamics</td>
<td>Floodplain connectivity</td>
<td>USACE and private revetments</td>
</tr>
<tr>
<td></td>
<td>Freshwater migration corridors</td>
<td>Channel conditions and dynamics</td>
<td>Floodplain connectivity</td>
<td>USACE removes large wood from reservoirs</td>
</tr>
<tr>
<td></td>
<td>Freshwater rearing</td>
<td>Floodplain connectivity</td>
<td>Reduced nutrient exchange, reduced sediment exchange, reduced flood refugia for fish, and reduced establishment of new riparian forests</td>
<td>Gravel mining in lower river</td>
</tr>
<tr>
<td></td>
<td>Freshwater migration corridors</td>
<td>Floodplain connectivity</td>
<td>Floodplain is not frequently inundated, with less over-bank flow and side channel connectivity</td>
<td>USACE traps sediment in Green Peter and Foster reservoirs.</td>
</tr>
<tr>
<td></td>
<td>Freshwater rearing</td>
<td>Floodplain connectivity</td>
<td>Lower South Santiam is confined primarily to a single main channel.</td>
<td></td>
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<tr>
<td></td>
<td>Freshwater migration corridors</td>
<td>Floodplain connectivity</td>
<td>While no quantitative data are available, the South Santiam likely contains fewer off-channel habitats, simplified mainstem habitat, and few new gravel bars or side channels.</td>
<td></td>
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<tr>
<td>PCE</td>
<td>Pathway</td>
<td>Indicator</td>
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<td>Limiting Factors</td>
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<tr>
<td></td>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Freshwater migration corridors</td>
<td>Water Quantity (Flow/Hydrology)</td>
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</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Watershed conditions</td>
<td>Road density and location</td>
<td>Moderate to high road densities exist in South Santiam watershed above and below the Green Peter/Foster dam complex. These roads are managed by Oregon Dept. Transportation and by USFS; corrective measures are not included as a part of the revised proposed action.</td>
</tr>
<tr>
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<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Watershed conditions</td>
<td>Disturbance history</td>
<td>Some forests in the upper watershed are dominated by early- to mid-successional stages, but up to 39% of the Middle Santiam and 43% of the Quartzville drainages contain late-successional forests. Disturbance regime is dominated by timber harvesting, which can increase sediment delivery to streams, while decreasing large wood input. Upper watershed is predominantly forested. Lower watershed contains extensive agricultural, urban, rural, and residential development.</td>
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<td></td>
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<td></td>
<td></td>
<td>Fire suppression</td>
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<td>Timber harvesting</td>
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<td>Conversion to agricultural, urban, residential, and rural uses</td>
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<td></td>
<td>Flood control provided by USACE operations at Green Peter and Foster dams has probably increased agricultural, urban, rural, and residential development within the South Santiam floodplain.</td>
</tr>
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<td>PCE</td>
<td>Pathway</td>
<td>Indicator</td>
<td>Condition</td>
<td>Limiting Factors</td>
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<td></td>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Freshwater migration corridors</td>
<td>Watershed conditions</td>
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<td>Width and continuity of riparian areas are good along Thomas and Crabtree Creeks in the lower South Santiam subbasin, but almost all vegetation is less than 80 years old</td>
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<td>Riparian areas in many tributaries do not provide adequate shading or large wood recruitment</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>Floodplain forest riparian conditions</td>
<td>Low large wood recruitment potential because:</td>
</tr>
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<td></td>
<td>Less than 30% of the riparian forest along the mainstem South Santiam river is greater than 30 m wide</td>
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<td>Many remaining patches of floodplain forest are interspersed with pastureland</td>
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North Santiam Baseline
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4.6 North Santiam Subbasin

The North Santiam River is about 92 miles long and drains an area of approximately 763 square miles as it flows from headwaters in the Mount Jefferson Wilderness Area of the Willamette National Forest to its confluence with the South Santiam River near Jefferson, Oregon (Figures 4.6-1 and 4.6-2). Eighty-two percent of the contributing area is forested and 65% is in public ownership (NRCS 2006c). Major tributaries to the North Santiam include Marion Creek (RM 85.3), the Breitenbush River (RM 65.9), Blowout Creek (RM 64.0), and the Little North Santiam River (RM 39.1). The Little North Santiam is the only major tributary that enters the North Santiam between the USACE’s Big Cliff and Detroit Dams (located at RM 58.1 and 60.9, respectively) and the South Santiam River. Below the South Santiam confluence a river segment 11.6 miles long and known as the mainstem Santiam flows to the mainstem Willamette River. The main Santiam is frequently included in discussions of the North Santiam and in measuring river distances (RM) from the mainstem Willamette, and is here.

Above the reservoirs associated with Detroit and Big Cliff dams, the North Santiam drainage is characterized by steep, forested terrain that lies almost entirely within the Willamette National Forest, although there are some private in-holdings. Below the dams, the North Santiam River passes through a steep forested canyon to approximately RM 50, near the town of Gates, where the canyon widens, the channel gradient decreases, and the river begins to meander (USACE 2000). The river valley widens and the channel gradient decreases further (to <0.3%) near Mehama (at RM 37, just downstream of the Little North Fork confluence). The North Santiam channel becomes more sinuous below this point and was once described by the USACE (1947) as “crooked and frequently divided by large islands.”

Most of the land along the reach of the North Santiam from Mehama to its confluence with the South Santiam River, as well as the 12-mile mainstem Santiam River, is used to grow agricultural crops or graze livestock. The remainder consists of urban areas, coniferous forests, mixed deciduous forests, and riparian forests that now comprise less than 7% of the vegetation (E&S 2002). Most of the subbasin’s residential and rural-residential development is downstream of the USACE dams, on the valley floor and in the foothills.
Figure 4.6-1 North Santiam Subbasin
Figures 4.6-2 Maps of the North Santiam subbasin (ODEQ 2003; top) and of land use patterns within the subbasin (NRCS 2006c, bottom).
4.6.1 Historical Populations of Anadromous Salmonids in the Subbasin

The North Santiam subbasin is the natural home of an independent population of UWR Chinook and independent population of UWR steelhead. Historical information on these populations is given below.

UWR Chinook
The mainstem North Santiam River is free of natural barriers up to its headwaters, approximately 35 mainstem miles above Detroit Dam (WNF DRD 1995). Before the USACE dams were constructed, adult Chinook salmon spawned in the upper reaches of the North Santiam River and in headwater tributaries such as the Marion Creek, the Breitenbush River, and Blowout Creek (WNF DRD 1994, 1996, 1997), as well as in the mainstem below the dam sites and in Little North Santiam River (Parkhurst et al. 1950). Historical estimates of the abundance of these fish in the North Santiam subbasin range from 8,250 adults escaping to spawn upstream of Detroit Dam in 1934 (Wallis 1963) despite intense downstream fisheries, to 2,830 spawners throughout the entire subbasin in 1947 (Mattson 1948). Parkhurst et al. (1950) estimated that there was sufficient habitat in the North Santiam to accommodate at least 30,000 adults. Mattson (1948) estimated that 71% of the spring Chinook production in the North Santiam subbasin occurred in areas that have since been blocked by Detroit and Big Cliff Dams.

UWR Steelhead
Surveys conducted in 1940, before the dams were constructed, led to estimates of at least 2,000 steelhead spawning in the mainstem North Santiam, with additional runs to the Breitenbush River, Marion Fork, Pamela and Blowout creeks, and the Little North Santiam (Parkhurst et al. 1950). The species also used many smaller streams in these and other tributary drainages (BLMS 1998; Olsen et al. 1992; WNF DRD 1994, 1995, 1996, 1997). After construction of the dams, Thompson et al. (1966) estimated that the entire North Santiam subbasin supported a population of 3,500 winter steelhead, including an unknown proportion of hatchery fish, in the 1950s and early 1960s, including adults trapped at Minto.

4.6.2 Current Status of Native Anadromous Salmonids within the Subbasin

4.6.2.1 UWR Chinook Salmon

Population Viability
The North Santiam population of UWR Chinook is considered to be at a high risk of extinction (with considerable certainty) based on an assessment of its abundance, productivity, spatial structure, and diversity (McElhany et al. 2000). Chronically unfavorable conditions within a reduced geographic distribution create much of this risk, but the potential for catastrophic events such as landslides, hatchery-related disease outbreaks, or volcanic events, is also a contributor.

Abundance & Productivity
The North Santiam Chinook population’s limited abundance and productivity pose a very high risk of extinction (McElhany et al. 2007). Pre-spawn mortality rates are high, abundances of successful natural-origin (wild) spawners are low, and recent use of natural spawning areas has been dominated by fish of hatchery origin (Schroeder et al. 2006). The wild component of the spawning population is not thought to be self-sustaining (Good et al. 2005).
Adult UWR Chinook returning to the North Santiam River are counted as they pass over Bennett Dam (at RM 31.5) and later if they are captured in a fish trap (Minto Trap) at a hatchery barrier dam about 3 miles below Big Cliff. Figure 4.6-3 gives the numbers of adult Chinook salmon counted at Minto Trap (above all natural spawning areas accessible to the North Santiam population) each year from 1981-2006. Fish arriving at the trap are predominantly hatchery fish, but the extent to which hatchery fish outnumber natural-origin (wild) ones at the trap has only become certain within the last decade as improvements have been made to fish marking and monitoring efforts in the Willamette Basin. Annual counts of adult UWR Chinook at Minto Trap have risen erratically since the early 1980s, perhaps in part due to more effective collections of the fish that accumulate at the barrier dam, and averaged 3,887 fish during the most recent 5-year period. An average of 239 (6%) of the fish counted at the trap during this recent period were classified as wild (McLaughlin et al. 2008). These wild fish were either incorporated into the local hatchery broodstock or released into spawning areas on the Little North Santiam River (McLaughlin et al. 2008).

![Figure 4.6-3 Annual returns of spring Chinook salmon to Minto Trap on the North Santiam River at RM 31.5 from 1984-2006 (StreamNet trend no. 50969), including 2002-2006 estimates of the wild component that were developed by McLaughlin et al. (2008).](image)

During 2001-2005, the most recent 5-year period for which annual counts of UWR Chinook passing over Bennett Dam are available, numbers of wild adults ranged from 220 to 667 and averaged 450 fish (McLaughlin et al. 2008, Table 4.6-1). These wild fish accounted for an average of 6% of all adults passing the dam during this period, the same fraction seen recently in the catch at Minto Trap (see above). Wild fish passing Bennett Dam but not later counted at Minto Trap either spawn successfully in the North or Little North Santiam Rivers or die prior to doing so.
Table 4.6-1  Estimated numbers of wild and hatchery-origin adult UWR Chinook passing upstream at Bennett Dam, North Santiam River, 2001-2005, as determined by analyses of otoliths in non fin-clipped fish and coded wire tags in fin-clipped fish (McLaughlin et al. 2008).

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of wild adults</th>
<th>Number of hatchery-origin adults</th>
<th>Total adults passing upstream at Bennett Dam</th>
<th>Percent wild</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>220</td>
<td>6,566</td>
<td>6,786</td>
<td>3</td>
</tr>
<tr>
<td>2002</td>
<td>604</td>
<td>7,036</td>
<td>7,640</td>
<td>8</td>
</tr>
<tr>
<td>2003</td>
<td>271</td>
<td>12,561</td>
<td>12,832</td>
<td>2</td>
</tr>
<tr>
<td>2004</td>
<td>489</td>
<td>13,042</td>
<td>13,531</td>
<td>4</td>
</tr>
<tr>
<td>2005</td>
<td>667</td>
<td>4,216</td>
<td>4,883</td>
<td>14</td>
</tr>
<tr>
<td>5- year average</td>
<td>450</td>
<td>8,684</td>
<td>9,134</td>
<td>6</td>
</tr>
</tbody>
</table>

Under contract to the USACE, ODFW has since 2001 conducted intensive monitoring of the spawning grounds of UWR Chinook in the North Santiam and Little North Santiam rivers. Monitoring results from 2001 through 2006 showed that annual pre-spawn mortality rates of these fish were high in both the North Santiam (mean = 59%) and Little North Santiam (mean = 51%), and that an average of 90% of the spawners along the mainstem and 49% of those in the Little North Santiam were of hatchery origin (McLaughlin et al. 2008). Further, the numbers of successful spawners appear likely to have included an average of fewer than 100 wild adults in each river. Extended over the long term, the combination of low abundance of wild adults, high pre-spawn mortality, and high percentages of hatchery fish in spawning areas, would make it improbable that the river’s “wild” run could include many individuals more than a few generations removed from the hatchery.

Recent counts of UWR Chinook redds (nests) in known spawning areas on the North Santiam and Little North Santiam rivers are given in Table 4.6-2. An average of 302 redds (range: 144-661) has been counted annually in the two rivers from 1997 through 2006, with nearly 90% of these redds seen in the North Santiam (ODFW 2007a).

The intensity of UWR Chinook use of spawning areas within the North Santiam itself is strongly skewed toward the reach of river immediately below the barrier dam at Minto (Schroeder et al. 2006). The concentration of spawners in areas relatively closer to Big Cliff would seem to increase the potential for the USACE dams and their reservoirs to affect fish survival (hence productivity) by influencing water quality, flow, or physical habitat conditions.
Spatial Structure
The reduced access of spring Chinook in the North Santiam subbasin to high-quality habitats reflects a high or very high extinction risk. Mattson (1948) estimated that 71% of the spring Chinook production in the North Santiam subbasin occurred above the current sites of USACE dams. More recently, ODFW (2005b) estimated that 42% of the historically suitable habitat for spring Chinook is now inaccessible. However, the now inaccessible areas were high quality habitats, and the primary spawning areas in the North Santiam (McElhany et al. 2007). Much of the remaining habitat is not well-suited for spring Chinook, although some favorable reaches may still be found in the Little North Santiam.

Diversity
Diversity-related risks posed by losses of life history traits, low effective population size, hatchery impacts, anthropogenic mortality, and habitat diversity, can affect the viability of salmonid populations. McElhany et al. (2007) considered such risks to pose a high risk of extinction for the North Santiam population of UWR Chinook. Their primary concerns in this regard included known changes in spawn, emergence, and juvenile migration timing (Myers et al. 2002), the small size of the naturally-produced spawning component, and the potential for hatchery domestication.

4.6.2.2 UWR Steelhead

Population Viability
McElhany et al. (2007) have rated the North Santiam population of UWR steelhead as being at low to moderate risk of extinction with considerable uncertainty, based on an assessment of its abundance, productivity, spatial structure, and diversity. Key chronic risk factors include reductions in spatial structure caused by USACE dams, reduced habitat diversity, genetic
legacies of past hatchery programs, and potential competition from the juvenile offspring of hatchery-produced summer-run steelhead of non-native stock. Catastrophic risks, including landslides, disease epidemics from hatchery releases into the system, and volcanic activity (from Mt. Jefferson), also contribute (WLCTRT 2003).

**Abundance & Productivity**

McElhany et al. (2007) classified the winter-run steelhead population in the North Santiam subbasin as facing a low extinction risk based on its abundance and productivity, though they expressed a high degree of uncertainty. The population is relatively large, with a long-term (1980-2005) geometric mean abundance of 2,722 natural-origin spawners and a short-term (1990-2005) geometric mean abundance of 2,109 (McElhany et al. 2007).

The abundance of late-run winter steelhead in the North Santiam subbasin has been monitored most effectively by counting redds within a sub-sample of available spawning areas. Figure 4.6-4 gives estimates that Chilcote (2007) developed of the annual abundance of spawners from 1980 through 2005 that are somewhat uncertain but form the basis of viability analyses by McElhany et al. (2007). The estimates suggest a mean annual abundance of 4,499 spawners during the most recent five years in the time series after a period of relatively lower abundance during the 1990s.

![Figure 4.6-4 Estimates of the annual numbers of adult native late-winter steelhead of all (wild plus hatchery) and wild origin that spawned in streams within the North Santiam subbasin, 1980-2005 (data source: Chilcote 2007).](image)

An additional index of the annual abundance of late-winter steelhead adults in the North Santiam subbasin is available from counts made at Bennett Dam on the lower North Santiam River, downstream of most natural spawning areas (Table 4.6-3). The Bennett Dam counts may exhibit
negative bias related to how passage estimates are expanded to account for days when fish movements through the fish ladder are not monitored (Firman et al. 2005. The Bennett counts suggest an average of 2,396 adults passing the dam during the same 2000-2004 period for which the Chilcote (2007) time series suggests an average of 4,367 wild adults in the subbasin as a whole.

<table>
<thead>
<tr>
<th>Year</th>
<th>Winter steelhead passage estimate for Bennett Dam</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>1,409*</td>
</tr>
<tr>
<td>1999</td>
<td>1,111*</td>
</tr>
<tr>
<td>2000</td>
<td>1,448*</td>
</tr>
<tr>
<td>2001</td>
<td>3,639</td>
</tr>
<tr>
<td>2002</td>
<td>2,694</td>
</tr>
<tr>
<td>2003</td>
<td>1,261</td>
</tr>
<tr>
<td>2004</td>
<td>2,939</td>
</tr>
<tr>
<td>5 year average (2000-2004)</td>
<td>2,396</td>
</tr>
</tbody>
</table>

* Counts affected by hatchery-origin returns to the North Santiam subbasin.

### Spatial Structure

McElhany et al. (2007) have classified the current spatial structure of the North Santiam steelhead population as most likely reflective of a population with a moderate to high risk of extinction, due substantially to blocked access to historically important habitats above USACE dams. Since 1953, winter steelhead have been restricted to that portion of the North Santiam subbasin below Big Cliff Dam. The fish now spawn in the mainstem above the Minto weir (to Big Cliff Dam) and downstream of the weir, as well as in tributaries that include the Little North Santiam River, Mad Creek, and Rock Creek.

Tributaries to the upper Little North Santiam River, such as Elkhorn Creek and Sinker Creek, are also used extensively. ODFW (2005b) estimates that 46% of the historically suitable habitat is now inaccessible. The blocked areas include some of the subbasin’s most productive habitats for this species (McElhany et al. 2007).

### Diversity

McElhany et al. (2007) considered available information on the life history traits, effective population size, hatchery impacts, anthropogenic mortality, and habitat diversity of North Santiam winter steelhead and suggested the population’s diversity reflects a moderate risk of extinction. The authors’ primary concern was the potential effect on life history diversity of the loss of higher elevation spawning areas above the USACE dams.

#### 4.6.2.3 Limiting Factors & Threats to Recovery

Factors unfavorably affecting the status of the North Santiam populations of UWR Chinook and UWR Steelhead have been summarized by ODFW (2007b) and are given in Table 4.6-4. Key
limiting factors and threats to both species include a variety of dam effects, large hatchery programs developed partly to help offset dam effects, and the cumulative effects of multiple land and water use practices on aquatic habitat. For the spring Chinook in particular, USACE dams that lack effective passage facilities prevent wild fish from using historically important habitats on Federal lands in upper portions of the subbasin and force a severely diminished population to rely upon habitats below Big Cliff Dam that have been structurally, hydrologically, and thermally altered. These altered habitats often contain hatchery produced salmonids, or their direct offspring, that may compete or interbreed with the wild fish.

In all, 6 of 11 primary and 6 of 12 secondary within-subbasin limitations on the recovery of these two ESA-listed populations are related to USACE dams or programs (ODFW 2007b, Table 4.6-4).

Table 4.6-4  Key and secondary limiting factors and threats to recovery of North Santiam Spring Chinook and Winter Steelhead (ODFW 2007b).

<table>
<thead>
<tr>
<th>Threats</th>
<th>Species</th>
<th>North Santiam Subbasin (Streams and Rivers within Population Area)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Egg</td>
</tr>
<tr>
<td>Harvest</td>
<td>Chinook</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Steelhead</td>
<td></td>
</tr>
<tr>
<td>Hatchery</td>
<td>Chinook</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Steelhead</td>
<td></td>
</tr>
<tr>
<td>Hydropower/Flood Control</td>
<td>Chinook</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Steelhead</td>
<td></td>
</tr>
<tr>
<td>Landuse</td>
<td>Chinook</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Steelhead</td>
<td></td>
</tr>
<tr>
<td>Introduced Species</td>
<td>Chinook</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Steelhead</td>
<td></td>
</tr>
</tbody>
</table>

Black cells indicated key concerns; Gray cells indicated secondary concerns.

**Key threats and limiting factors**

1d  Mortality at North Santiam hydropower/flood control dams due to direct mortality in the turbines and/or smolts being trapped in the reservoirs.
2b  Impaired access to habitat above North Santiam hydropower/flood control dams.
2f  Impaired access to habitat above Upper and Lower Bennett dams.
3   Hatchery fish interbreeding with wild fish resulting in a risk of genetic introgression.
4c  Competition with naturally produced progeny of hatchery summer steelhead.
4d  Competition with residualized hatchery summer steelhead smolts.
8a  Impaired physical habitat from past and/or present land use practices.
NMFS
Willamette Project Biological Opinion

9a Elevated water temperatures from past and/or present land use practices resulting in decreased survival and/or growth.
9b Elevated water temperatures below the North Santiam hydropower/flood control dams resulting in premature hatching and emergence.
10a Elevated flows during spawning and dewatering of redds below North Santiam hydropower/flood control dams.
10d Reduced peak flows leading to decreased channel complexity and diversity of fish habitat by reducing channel movement that is important for recruitment of gravel and large wood, and maintaining varying seral stages of riparian vegetation. Lower peak flows also reduces scour and formation of pools.

Secondary threats and limiting factors
2a Impaired access to habitat due to road crossings and other land use related passage impediments on wadeable sized streams.
2i Impaired downstream passage at North Santiam hydropower/flood control dams.
2k Prespawning mortality due to crowding below North Santiam hydropower/flood control dams.
4b Competition with naturally produced progeny of hatchery spring Chinook.
6c Predation by hatchery summer steelhead smolts.
7a Fine sediment in spawning gravel from past and/or present land use practices.
7b Streambed coarsening below North Santiam hydropower/flood control dams due to reduced peak flows.
7c Lack of gravel recruitment below North Santiam hydropower/flood control dams due to gravel capture in upstream reservoirs.
8a Impaired physical habitat from past and/or present land use practices.
9a Elevated water temperatures from past and/or present land use practices resulting in decreased survival and/or growth.
9d Cool water temperatures below North Santiam hydropower/flood control dams impede development or growth.
10b Insufficient streamflows due to land use related water withdrawals resulting in impaired water quality and reduced habitat availability.

4.6.3 Environmental Conditions

4.6.3.1 Habitat Access

Access to large portions of once-productive habitat for spring Chinook and winter steelhead is blocked by the USACE’s Detroit and Big Cliff dams (McElhany et al. 2007). The importance of safe access to historical habitats and the relationship of such access to the requirements of UWR Chinook salmon and steelhead are described in detail in Appendix E. Basically, the subbasin’s naturally produced UWR Chinook and steelhead need access to historical habitat because what is left to them downstream of the dams is of lesser quality, appears insufficient by itself to support strongly viable populations, and must often be shared with fish from massive hatchery-based mitigation programs that may reduce natural productivity through competition, disease transmission, or (in the case of spring Chinook) unfavorably high levels of interbreeding.

4.6.3.1.1 Migratory Obstacles below Big Cliff Dam

McIntosh et al. (1995) described several artificial obstructions in the North Santiam River below the current site of Big Cliff Dam, based on an August 1940 survey by Parkhurst and Bryant. These included early configurations of the diversions and canals near Stayton, owned by the Santiam Water Control District (SWCD) and City of Salem, which are used for irrigation and hydroelectric production. Upper Bennett Dam, located at RM 31.5, splits the river into North
and South channels and diverts water into the North Channel. Lower Bennett Dam is located on the North Channel (about RM 29 of the North Santiam) and directs water towards the SWCD Power Canal, located downstream. Water that does not enter the Power Canal headgate flows over a third dam, the Spillway Dam, and is returned to the North Santiam River via the North Channel. The Spillway Dam contains a fish ladder, and the headgate also contains a fish ladder to return adults migrating up the SWCD Power Canal before returning to the North Santiam River.

Some of the passage impacts, unrelated to flow, have been addressed. The City of Salem installed a new fish ladder at Upper Bennett Dam in 2006 to improve upstream migration and reduce delay. The City may be replacing the existing fish ladder at Lower Bennett Dam in the future, but has no specific plan or dates for construction. The SWCD completed installation of a fish screen and tailrace barrier in the SWCD Power Canal in 2004. Thus, anadromous fish can no longer enter the SWCD Power Canal from either direction. NMFS determined that this proposal would not jeopardize listed Chinook salmon and steelhead in its March, 2003, biological opinion (NMFS 2003b). However, the flow related impacts associated with this project continue:

- In 20% of the 50 years for which there are relevant flow data, diversions into the North Channel left less than 25% of the width of the South Channel available for upstream passage by adult Chinook salmon during July and August. (NMFS 2003b)

- When the Rousch and Water Street hydroelectric facilities are operating and flow is diverted for irrigation purposes, the majority of river flow from the North Santiam is diverted into the North Channel and then into the Power Canal, leaving as little as 50 cfs in the North Channel.

In addition to these ongoing impacts, in 2007 the SWCD applied for an exemption to operate the Stayton Hydroelectric Project again, which would increase diversions into the SWCD Power Canal by as much as 760 cfs (up to 1,100 cfs total diversion). This additional diversion would further decrease available flows in this section of the North Santiam River.

Several other diversions within the same reach present hazards for downstream migrating Chinook salmon and steelhead. Just upstream from Lower Bennett Dam and the SWCD Power Canal, the unscreened Salem Ditch diverts up to 100 cfs from the North Channel of the North Santiam River to Mill and Pringle creeks, which flow through the City of Salem prior to joining the mainstem Willamette River. The City of Salem also withdraws up to 116 cfs (with a water right for 227 cfs) from an intake on the North Channel of the North Santiam River for its municipal water supply. The City of Salem installed screens on its municipal intake in 1998 that were designed to meet NMFS’ criteria.

The Salem Ditch, the City of Salem municipal intake, and the other irrigation withdrawals can limit the abundance, productivity, and behavior of listed Chinook and steelhead in many ways:
Juveniles and downstream-migrating smolts and kelts can be entrained into the unscreened Salem Ditch and then into Mill or Pringle Creeks. Thirty to 50 cfs of water from the Salem Ditch and Mill Creek is diverted into the unscreened Salem Mill Race, which supplies a historic hydroelectric plant, Mission Mill, in the City of Salem. The City of Salem completed ESA consultation with NMFS in 2003 regarding its proposal to install a fish exclusion screen at the Mill Race (NMFS 2003b).

Water diverted from the North Santiam River via the Salem Ditch enters the Willamette River via Mill Creek and Pringle Creek. Adult fish migrating upstream in the mainstem Willamette could delay at the mouths of (or attempt passage up) these two creeks, where they detect the scent of the North Santiam River. The City of Salem is currently in consultation with NMFS to address further increased municipal withdrawals.

The numerous withdrawals from the North Santiam River in the vicinity of Geren Island dramatically decrease flow in the North Santiam River during summer, particularly in the South Channel below Upper Bennett Dam. Low water levels could delay migrating adult Chinook and limit spawning and rearing in this reach.

There are numerous smaller diversions in the 15 miles of the North Santiam River downstream of the SWCD project and in the main Santiam River below the confluence with the South Santiam. Information is not available on juvenile fish screening at these diversions (USACE 2000).

On the Little North Santiam River, Salmon Falls (also sometimes referred to as Elkhorn Falls) blocks adult fish passage at RM 16. A fish ladder installed in 1958 has allowed passage of adult UWR Chinook salmon and steelhead up to the next impassable falls (at RM 24). The ladder has been used more frequently by steelhead than Chinook (BLMS 1998). A total of 514 adult UWR steelhead were counted at this ladder in 1963 (Thompson et al. 1966).

During construction of Detroit and Big Cliff dams in the early 1950s, a concrete weir (Minto Dam) was built about three miles downstream of the dams to replace the old hatchery rack. Minto Dam has blocked volitional passage of all adult spring Chinook salmon and most winter steelhead to the three mile section of river immediately downstream of the site of Big Cliff Dam since 1952.

4.6.3.1.2 Fish Passage at the Detroit/Big Cliff Project
The USACE’s Big Cliff Dam (RM 58.1) and Detroit Dam (RM 60.9), both completed in 1953, form a complete barrier to upstream fish passage. The ODFW has, on occasion, released hatchery-reared fingerling Chinook into Detroit Reservoir (i.e., to augment the recreational trout fishery) (Mamoyac and Ziller 2001). Preliminary screw trap studies indicate a survival rate for these juveniles past the concrete at Detroit Dam of approximately 51% to 60.5%. The survival rate at Big Cliff Dam was approximately 69%, indicating a combined survival rate for fish that pass both dams of approximately 35% to 42% (Ziller et al. 2002). There are no estimates of reservoir survival for juvenile salmonids at the Detroit/Big Cliff Project, but concerns about predation by northern pikeminnow are low due to cold water temperatures above Detroit Dam. Combined with early hatchery operations, the dams have reduced the geographic distribution of spring Chinook salmon and winter steelhead and thus limited the abundance and productivity of the naturally-spawning populations. They have also increased the risk of losing these
populations to natural or man-made catastrophes that may affect the mainstem downstream of the USACE dams.

Since 1998, many adult spring Chinook of hatchery origin have been collected at the Minto Trap and out-planted into the North Santiam River between the trap and Big Cliff Dam, and into areas above Detroit Dam, to begin re-establishing fish access to blocked natural spawning areas (Table 4.6-5). During the most recent five-year period for which data are available (2002-2006), annual releases have averaged 250 hatchery-origin adults into the North Santiam between Minto and Big Cliff Dam, 1,948 into the North Santiam River above Detroit Reservoir, and 144 into the Breitenbush River (Beidler and Knapp 2005; McLaughlin et al. 2008). Releases into the Breitenbush have been inconsistent.

<table>
<thead>
<tr>
<th>Year</th>
<th>N. Santiam R. above Minto Trap</th>
<th>N. Santiam R. above Detroit Reservoir</th>
<th>Breitenbush River</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>1,155</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1999</td>
<td>1,098</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2000</td>
<td>967</td>
<td>707</td>
<td>226</td>
</tr>
<tr>
<td>2001</td>
<td>292</td>
<td>540</td>
<td>528</td>
</tr>
<tr>
<td>2002</td>
<td>729</td>
<td>1,680</td>
<td>893</td>
</tr>
<tr>
<td>2003</td>
<td>203</td>
<td>1,869</td>
<td>1,017</td>
</tr>
<tr>
<td>2004</td>
<td>144</td>
<td>1,689</td>
<td>822</td>
</tr>
<tr>
<td>2005</td>
<td>30</td>
<td>614</td>
<td>0</td>
</tr>
<tr>
<td>2006</td>
<td>143</td>
<td>1,123</td>
<td>720</td>
</tr>
<tr>
<td>5-year avg. (2002-2006)</td>
<td>250</td>
<td>1,948</td>
<td>144</td>
</tr>
</tbody>
</table>

ODFW conducted limited snorkel surveys in the late 1990s and early 2000s during summer months in the North Santiam above Detroit reservoir, in the Breitenbush River above Detroit, below Big Cliff Dam, and in the Little North Santiam River below Big Cliff Dam (Beidler and Knapp 2005). ODFW documented significant juvenile production in the Breitenbush River and the North Santiam above Detroit, with much less production evident in the North Santiam below Big Cliff Dam. Extremely few juveniles were observed in the Little North Santiam, but this could be a result of high pre-spawning mortality. Firman et al (2004) estimated 93% of the outplanted females died prior to spawning in 2003, and similar results have been documented in other years. Additionally, it is possible that the Little North Santiam is suited to produce ocean-type fish, meaning that most juveniles would emigrate downstream as fry, leaving few to be observed during summer snorkel surveys.
4.6.3.2 Water Quantity/Hydrograph

The general relationships between flow, hydrology and the habitat requirements of UWR Chinook salmon and steelhead are described in Appendix E. Table 4.6-8 summarizes habitat characteristics of flow and hydrology in the North Santiam subbasin under the environmental baseline, which is also described in more detail below.

Human-caused alterations of the hydrologic regimes of the lower North Santiam River and its principal tributaries have generally diminished flow-related habitat quantity and quality and have probably reduced the numbers, productivity, and life history diversity (adult run timing and juvenile outmigrant strategies) of spring Chinook salmon and winter steelhead, and limited the production potential of accessible habitat in much of the subbasin. Within the lower North Santiam itself, the effect of Project operations has been to control flood peaks, reduce spring and early summer flows, and increase late summer and fall flows (Figures 4.6-5 A, B & C).

Figures 4.6-5 A, B & C Simulated discharge (cfs) of North Santiam River at Niagara, Oregon under unregulated conditions (Unreg), with project operating criteria prior to 2000 (Pre-2000), and with project operating criteria after 2000 (Post-2000), depicting the 80th, 50th (median), and 20th percentile for each scenario.
Low flows are a natural occurrence in the North Santiam River and its tributaries but the degree, timing, and frequency of low flows have been affected by Detroit and Big Cliff project operations and an array of downstream mainstem and tributary water developments. Detroit and Big Cliff operations have reduced the minima seen in the lower North Santiam River during late winter and spring months. As a result, it is likely that the available habitat for juvenile Chinook and steelhead rearing is also reduced. In some systems, recruitment of age 0 rainbow trout (*O. mykiss*) has been found to be directly correlated with late winter flows (Mitro et al. 2003).
The increase in late summer and fall flows provided by flow augmentation operations at Detroit and Big Cliff dams probably benefits juvenile salmonids by increasing habitat area and reducing the rate at which water temperature responds to thermal loads. Water released at Big Cliff Dam tends to be cooler than inflows during midsummer, further cooling the river during that period (Figure 4.1-3). Increased fall flows associated with reservoir drafting (to create flood storage space) may affect spring Chinook spawning downstream from Big Cliff Dam by increasing the available habitat area. However, nests created at higher elevations would be vulnerable to dewatering during sudden reductions in discharge.

The OWRD has established instream flow water rights in five watersheds within the North Santiam subbasin (North Santiam River at its mouth, Stout Creek at its mouth, North Santiam River upstream of Little North Santiam River, Rock Creek at its mouth, and Mad Creek at its mouth) to support aquatic life (E&S 2002). However, because these instream flow water rights are junior to nearly all water uses in the basin they primarily protect aquatic life from further degradation. Diversions for irrigation, power generation and domestic and industrial water uses from the mainstem near Stayton, well downstream of Big Cliff Dam, and in some of the lower river’s tributaries, exacerbate low flow conditions in late summer and early fall. Low summer flows limit juvenile rearing habitat and sudden increases in diversion rates can entrap and strand juveniles rearing in the vicinity. High rates of water consumption in the lowermost North Santiam River and Stout Creek indicate the potential for substantial reductions in habitat area and production potential for anadromous fish. The effects of diversion-caused flow reductions in the mainstem North Santiam are somewhat offset during July, August, and September by releases of stored water at Detroit and Big Cliff reservoirs to meet tributary and mainstem Willamette minimum flow objectives (section 2.8, Table 2-8 and 2-10) as well as to ensure reservoir drawdown in the fall for flood control.

Water in the North Santiam River is used extensively by agriculture, municipalities, power generators, and industries. The OWRD has issued permits for surface water withdrawals for 2,730 cfs from the North Santiam River (OWRD 2003). This is a maximum allowable diversion right, and actual diversions have been lower, by perhaps half, at any particular time. Much of the diverted water is used for hydroelectric power purposes and is returned to the river downstream from the point of diversion.

The OWRD water availability process (OAR 690-400-011) has determined that natural flow is not available for out-of-stream use from the North Santiam River during the months of August and September. Further, the Willamette Basin Program Classifications regulation (OAR 690-502-0110) requires that new summer surface water users in the sub-basin (e.g., irrigators) obtain water service contracts from Reclamation for use of water stored in Willamette Project reservoirs. As of March 2007, Reclamation had contracted a total of 9,474 acre-feet of water stored in Detroit and Big Cliff reservoirs to irrigators along the North Santiam River (USACE 2007a), which constitutes a small fraction of the surface water withdrawals issued by OWRD. Another 1,485 acre-feet are contracted from storage in Detroit and Big Cliff reservoirs (as well as some storage from Green Peter and Foster reservoirs in the South Santiam River) to users diverting from the mainstem Santiam River downstream from the confluence of the North and South Santiam Rivers.
The Santiam Water Control District, the primary water provider in the basin, and the City of Salem, own a series of structures (including Upper and Lower Bennett dams) near Stayton, Oregon, that divert water for irrigation, hydroelectric power production, and municipal water supplies. The City of Salem currently diverts up to 102 cfs (with a water right for up to 227 cfs) from the North Santiam River just upstream of the SWCD project area for its municipal water supply. There are numerous smaller diversions in the 15 miles of the North Santiam River downstream from the SWCD project and in the 11 miles of the mainstem Santiam River downstream from the confluence with the South Santiam.

The Stayton complex of dams and diversions has been shown to delay adult salmon passage when total river flows are less than about 555 cfs downstream from Bennett Dam (ODFW 1994; Schreck et al. 1994). Passage problems at the complex are most common in May. With the maximum allowable diversion rate of about 900 cfs at the Stayton complex, total river inflows of 1,455 cfs at the upstream end of the complex would be needed to minimize passage delays at the maximum allowable diversion rate. By storing water during the spring, Detroit and Big Cliff reservoirs therefore increase the potential for adult migration delay at the Stayton complex. The (screened) large-scale diversions in the Stayton area where low flow conditions have been common are of particular concern.

There has been very little water development in the basin upstream of Detroit Dam (upper North Santiam basin), but water development has severely depleted flows in the North Santiam River downstream from Stayton, Oregon, and in Stout Creek. E&S (2002) rated the dewatering potential at the mouth of the North Santiam River as “moderate” (26.6% of flow consumed) and at the mouth of Stout Creek (a tributary to the lower river) as “high” (38.8% of flow consumed).1

4.6.3.2.1 Peak Flow Reduction

Reductions in peak flows caused by flood control operations at Detroit and Big Cliff dams have contributed to the loss of habitat complexity in the North Santiam River by substantially reducing the magnitude of the channel-forming dominant discharge (i.e., the 1.5- to 2-year flood) and greatly extending the return intervals of larger floods.2 Over time, flood control reduces channel complexity (e.g., reduces the number of side channels, and diminishes woody debris recruitment) and reduces the movement and recruitment of channel substrates (Appendix E). Side channels, backwaters, and instream woody debris accumulations have been shown to be important habitat features for rearing juvenile salmonids.

Prior to dam construction, the highest instantaneous peak flow recorded at Niagara, 0.8 miles below Big Cliff Dam, was 63,200 cfs (Hubbard et al. 1997) and flows greater than 40,000 cfs were common (USACE 2000). Since project completion, the maximum instantaneous flow in this reach has been 18,700 cfs. Unregulated inflows from tributaries such as the Little North Santiam River continue to produce flood events in the lower mainstem North Santiam (BLMS 1998). For example, flows as high as 67,200 cfs have been recorded at the USGS’ Mehama gage, 0.5 miles below the mouth of the Little North Santiam. However, even with this influence

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1 These assessments are based on the fraction of each stream’s 80% exceedence discharge (the rate of flow that is exceeded 80% of the time during the summer months) that is consumed by various uses.

2 Bank stabilization measures and land leveling and development are also responsible for reducing channel complexity and associated juvenile salmon rearing habitat (Appendix E).
and at a distance 20 miles below Big Cliff Dam, the magnitude of the two-year recurrence interval event has decreased from 34,200 to 19,700 cfs.

Controlling peak flows inhibits the flushing of fine sediments that accumulate on the river bed. Interstitial sediments finer than 1 mm can reduce intragravel flow and the supply of oxygenated water to incubating eggs (Kondolf and Wilcock 1996). Somewhat coarser sediments (1 to 9 mm diameter) can fill interstices and physically block emergence of fry from the bed. Aquatic invertebrates occupy open spaces in cobbles and gravel, and fine sediment can eliminate this habitat. The potential reduction in interstitial spaces may also affect juvenile salmonids which are known to use interstitial spaces for cover during winter periods (Bjornn and Reiser 1991). The significance of these effects in the North Santiam River downstream from Big Cliff Dam is unknown but probably diminishes in a downstream direction as flows and sediments enter the river from unregulated tributaries.

Controlling peak flows also reduces the potential for redd scouring. Spring Chinook would be more likely to benefit from this effect than steelhead because their eggs are incubating through the winter months when floods are most likely and the reservoir space necessary for flood attenuation most available. However, the rate at which flows would be reduced during flood control operations is also a factor (see below).

4.6.3.2.2 Altered Flow Effects on Spawning Success
There is concern that the difference between Project-elevated flows in the lower North Santiam River during late summer and early fall when spring Chinook select spawning sites, and the minimum flows discharged during active flood control operations during winter may dewater salmon redds prior to fry emergence (Ross 2008). Depending on the duration and rate of desiccation, dewatering salmon redds can kill incubating eggs and alevins (Reiser and White 1983). It can also cause entrapment and stranding of newly emerged salmonids. The potential for these Project-related effects is probably greatest near Big Cliff Dam and diminishes downstream as water from unregulated tributaries enters the river.

4.6.3.2.3 Flow Fluctuations, Entrapment & Stranding
The North Santiam River downstream from Big Cliff Dam was historically subject to rapid water level fluctuations, particularly during active flood control operations when discharge dropped sharply to prevent downstream flooding. Discharge levels in the lower river have also fluctuated as a consequence of power generation, though Big Cliff Dam is operated to limit such occurrences. Load-following or ‘peaking’ operations (i.e., timing discharge through the turbines to coincide with the demand for energy generation) result in rapid changes in discharge rates from the turbines at Detroit Dam ranging between 0 and 5,340 cfs. Such changes in discharge occur routinely into the approximately one-mile reach of the North Santiam River above Big Cliff Reservoir, with no restrictions on ramping rates because this area is generally inaccessible to migratory fish. Operations at Big Cliff re-regulate discharge fluctuations from load-following operations at Detroit. This re-regulating operation causes the elevation of Big Cliff Reservoir to fluctuate as much as 24 feet daily while keeping discharge rates to the North Santiam River fairly constant.
The USACE has since 2006 limited maximum down-ramping rates below Big Cliff Dam to 0.1 ft/hour during nighttime and to 0.2 ft/hour during daytime unless such restriction has been infeasible with existing equipment at the dam (USACE 2007a). The result has been adherence to these downramp rates at moderate to moderately low river flows, but not at high or prescribed minimum flows. Maximum up-ramping rates vary from 500 cfs per hour at initial flows between 100 and 1,000 cfs to 2,000 cfs per hour at initial flows above 17,000 cfs.

During winter flood events, as well as during emergency events that may occur at any time of the year, juvenile Chinook salmon and steelhead could be stranded and entrapped below Big Cliff Dam, particularly as flows approach the prescribed minimums. The physical effect of downramping is most pronounced immediately below Big Cliff Dam and decreases in a downstream direction as pulses in flow attenuate and water from unregulated tributaries enters the river.

### 4.6.3.3 Water Quality

The general relationships between water quality and the habitat requirements of UWR Chinook salmon and steelhead are described in Appendix E. Generally, ODEQ monitoring indicates that water quality in the North Santiam River is excellent (Mrazik 2006). The characteristics of water quality and its status in the North Santiam subbasin under the environmental baseline are summarized in Table 4.6-8 and described in more detail below.

#### 4.6.3.3.1 Water Temperature

Water temperatures in streams used, or once used, by UWR Chinook or UWR steelhead within the North Santiam subbasin are subject to a variety of human-caused influences, including the USACE dams on the mainstem North Santiam River.

**Water Temperatures Unaffected or Relatively Unaffected by USACE Dams**

Human activities have affected maximum summer water temperatures in areas of the subbasin not affected by Willamette Project operations. The maximum temperatures for rearing, and adult and juvenile migration have been exceeded in streams above Detroit Reservoir (Marion Creek), and in tributaries to the lower reaches of the North Santiam (Chehulpum Creek, Bear Branch, and the Little North Santiam River, including Stout and Elkhorn creeks) (ODEQ 2006a). A week-long exposure to the high temperatures recorded in the Little North Santiam River, and in the mainstem Santiam River below the confluence of the North and South Santiam rivers (i.e., >73.4°F [>23°C]), could subject juvenile Chinook salmon and steelhead to lethal conditions (Appendix E, Table E-2), directly reducing juvenile outmigrant production and indirectly limiting population abundance and productivity.

**Water Temperature Effects of the USACE Dams**

Operations at Detroit and Big Cliff dams have altered seasonal thermal regimes in the North Santiam River (Figure 4.6-6). Because the water released at Detroit Dam is drawn from near the bottom of the reservoir, discharge temperatures are up to 5.4 to 9°F (3 to 5°C) cooler than inflow temperatures from spring through late-summer (USACE 1988) and warmer than natural during fall. Hansen and Crumrine’s (1991) simulation of pre- versus post-project temperatures along the lower North Santiam River indicated that summer conditions were 6.8 to 16.9°F (3.8 to 9.7°C) cooler under post-project conditions, with the magnitude of effect varying among sites.
along the river and the years studied. Fall water temperatures were 6.1 to 12.8°F (3.4 to 7.1°C) warmer than pre-project conditions (Table 4 in Hansen and Crumrine 1991), also depending upon the study site and year. At the lower-most study site on the river, near Jefferson, daily temperatures appeared to be cooler than pre-project conditions for an average of 134 days per year and warmer for an average of 71 days per year (Table 5 in Hansen and Crumrine 1991). These effects of the USACE projects on the seasonal thermal regime could persist as far downstream as Jefferson.

Water temperatures at the USGS gage below Big Cliff Dam have been cooler than pre-project temperatures during May through mid-September. Average daily water temperatures have often been below 52°F (11°C) during May through late-June since the Project was completed, cooler than natural conditions and cool enough to have delayed the upstream migration of adult Chinook salmon. The cooler temperatures during spring and early summer may also have delayed the emergence of steelhead fry, although neither of these effects has actually been reported in the North Santiam subbasin.

There is indirect evidence that warmer fall water temperatures have shortened the incubation time of Chinook salmon eggs below the USACE projects on the North Santiam, leading to early fry emergence. Within the Willamette Basin many young, naturally produced Chinook emigrate to downstream rearing areas soon after emergence in late winter and spring (ODFW 1990c). However, in 1989, well after completion of Detroit and Big Cliff dams, salmon fry were found to begin migrating past Stayton earlier than would otherwise be expected, as early as Thanksgiving and with an apparent peak in January (Cramer et al. 1996). Average daily water temperatures in

Figure 4.6-6  Water temperature changes caused in the North Santiam River by Detroit and Big Cliff reservoirs, 1968-1985. Julian Day 300 is October 28.
the river below Big Cliff Dam can now exceed 43 to 55°F (6 to 13°C), the optimal range for egg incubation, from September through mid-November (see Figure 4.6-5), and thus may affect egg survival as well as the timing of fry emergence.

According to the ODEQ 2004/2006 Integrated Report (ODEQ 2006b), the maximum temperatures considered desirable for salmon and steelhead spawning (13°C) and core cold-water habitats (16°C) have been exceeded in the North Santiam River (at RM 0-38.8 and RM 0-45.3, respectively). Criteria for salmonid spawning, rearing and migration have been exceeded in the lower Santiam River (RM 0-12) due to loss of vegetation and shading as riparian woodlands were converted to agriculture (see Appendix E). High temperatures during Chinook spawning (September and October), can reduce the viability of gametes in holding adults. Temperatures in the mainstem Santiam River have also exceeded the 64°F (17.8°C) maximum temperature for summer uses, which include non-core rearing and adult and juvenile migration. As shown in Appendix E, Table E-2, exposure to temperatures above 64°F can reduce the growth of juvenile Chinook salmon and steelhead, impair smoltification, and increase the risk of disease. The maximum also has been exceeded in the lower 10 miles of the North Santiam River. All of these factors directly reduce juvenile outmigrant production and indirectly limit population abundance and productivity.

A TMDL for the Willamette Basin, approved for temperature in 2006 (ODEQ 2006a), identified target temperatures for releases below Big Cliff/Detroit Dam based on stream temperatures entering the reservoirs and representing temperature regimes under existing baseline conditions but as if the dams were not in place (Table 4.6-6).

<table>
<thead>
<tr>
<th>Month</th>
<th>Big Cliff/ Detroit Release Temperatures</th>
<th>ODEQ Target for Big Cliff/ Detroit Dam Releases</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>5.8</td>
<td>5.4</td>
</tr>
<tr>
<td>May</td>
<td>6.7</td>
<td>7.3</td>
</tr>
<tr>
<td>June</td>
<td>8.8</td>
<td>9.7</td>
</tr>
<tr>
<td>July</td>
<td>10.0</td>
<td>12.8</td>
</tr>
<tr>
<td>August</td>
<td>11.2</td>
<td>12.8</td>
</tr>
<tr>
<td>September</td>
<td>12.6</td>
<td>10.9</td>
</tr>
<tr>
<td>October</td>
<td>13.6</td>
<td>7.7</td>
</tr>
<tr>
<td>November</td>
<td>10.5</td>
<td>7.7</td>
</tr>
</tbody>
</table>

Table 4.6-6 monthly rolling average of the median of 7-day temperatures downstream of Big Cliff and Detroit dams and established ODEQ monthly target temperatures (ODEQ 2006a, Chapter 4). No data presented for December through March; allocations/targets were not determined necessary for November through March.
Water Temperature Control and Site-Specific TMDL Requirements

Operating projects to optimize temperature conditions downstream for fish is often inconsistent with TMDL temperature targets, even with a temperature control tower such as the one constructed at Cougar Dam. Experience in implementing water temperature control operations in the Sound Fork McKenzie River downstream of Cougar Dam to achieve more normative water temperatures suggest that special site-specific considerations may be required for such actions with respect to achieving ODEQ TMDLs. An operational requirement for successfully avoiding high temperature discharges in the fall (i.e., during spring Chinook salmon incubation) is to evacuate as much warm surface water as possible from the reservoir throughout the summer months while operating within the range of appropriate downstream temperature criteria for each month identified by ODFW. That is, it is necessary to balance the effect of warm water temperatures downstream of the dam across the spring, summer and fall periods to achieve the most appropriate overall biological effect. In the South Fork McKenzie River, the requirement resulted in summer water temperatures below Cougar Dam that were above the draft TMDLs identified by ODEQ during April through September (Figure 4.3-6) in order to provide more favorable temperatures during the critical incubation period in the fall. A focus on achieving the cooler TMDL temperature targets during summer would have adversely affected the temperature conditions achievable during the fall spawning and incubation period for spring Chinook because more warm surface water would have been retained in the reservoir over summer.

Emergency Shutdown & Experimental Temperature Control in 2007

Following a fire at the Detroit Dam powerhouse on June 19, 2007, the powerhouses of both the Detroit and Big Cliff projects were taken out of service, forcing water to be released through the projects’ regulating outlets and spillways. Ad hoc efforts were made to manage these releases in a manner that provided beneficial downstream water temperatures. Immediately following the accident, all discharge at Detroit Dam occurred through the spillway which draws water from near the surface of the reservoir. In early July, Detroit Dam’s regulating outlet, located deeper in the reservoir was opened to cool outflows to better protect incubating UWR steelhead downstream from Big Cliff Dam. In August, the USACE increased spillway flows, releasing warmer surface water (about 15 ºC) in an effort to reduce the volume of warm water in Detroit Lake in order to have cooler water in September for spawning UWR Chinook. To protect pre-emergent UWR steelhead fry, this operation took place after the emergence. When UWR Chinook spawning began in September, releases were managed toward cooler temperatures to more closely replicate natural fall temperatures that would allow for longer incubation period, thereby improving egg and fry survival. Shortly thereafter it was no longer possible to discharge water through the Detroit Dam spillway because the reservoir water surface elevation had fallen below the spillway crest. All discharge occurred through the project’s regulating outlet located deep in the reservoir, resulting in colder water releases, until the autumnal turnover brought warmer water to the regulating outlet.

Throughout this period, plunging discharges from Detroit Dam into Big Cliff reservoir created elevated TDG conditions in the river. Efforts were made to determine if this TDG event adversely affected fish, particularly pre-emergent UWR steelhead fry. No adverse effects (i.e. dead fish) were detected and TDG conditions approached the regulatory standard (110 percent of saturation concentration) within several miles of the Big Cliff tailrace.
This ad hoc experiment demonstrated that managed operation of existing facilities at the Detroit and Big Cliff dams could reduce the thermal effects of the dams in the North Santiam River (Figure 4.6-6), although the balance obtained was inconsistent.

4.6.3.3.2 Total Dissolved Gas
On March 8, 1972, Monk et al. (1975) measured total dissolved gas (TDG) levels of 117.9 and 129% of saturation at stations 211 and 950 feet downstream from Big Cliff Dam, respectively, and 120.2% at a site 2 miles downstream. Spill was 50% and 74% of total river flow at the first two stations (respectively) at the time of these measurements, which were taken at a depth of 1 meter. Some yolk sac fry may be exposed to TDG levels greater than 120% because ODFW releases unmarked spring Chinook salmon to spawn in the 3-mile reach between the Minto weir and Big Cliff Dam. The USACE has not assessed the risk of gas bubble trauma in this location, which depends on hydrostatic pressure at the depth of the redd and the presence of yolk sac fry during supersaturated conditions. Symptoms of gas bubble trauma have not been reported in juvenile nor adult anadromous salmonids in the North Santiam subbasin.

4.6.3.3.3 Nutrients
The ODEQ 2004/2006 Integrated Report database does not indicate that any streams below Big Cliff Dam are impaired due to excess nutrients. Operations at Detroit and Big Cliff dams
that increase summer flows may have reduced nutrient loads in the mainstem North Santiam and Santiam Rivers.

4.6.3.3.4 Turbidity
Although high turbidity events have been reported in the North Santiam subbasin in recent years, there is no indication that turbidity has adversely affected the habitat requirements of anadromous salmonids. A February 1996 flood event in the North Santiam River\(^3\) caused high turbidity that persisted for several months, with levels peaking near 140 Nephelometric Turbidity Units (NTU) (USGS 2002). This event halted operations for two weeks at the City of Salem’s water treatment plant.\(^4\) Subsequent high-flow events have caused persistent high turbidity, but effects of turbidity on local ecosystem function have not been assessed.

4.6.3.3.5 Toxics

4.6.3.4 Physical Habitat Characteristics

The general relationships between riparian conditions, large wood, sediment transport, channel complexity, and the habitat requirements of UWR Chinook salmon and steelhead are described in Appendix E. Habitat characteristics of large wood, sediment transport, and channel complexity, and their status in the North Santiam subbasin under the environmental baseline are summarized in Table 4.6-8 and described in greater detail below.

Unfavorable human influences on the physical characteristics of habitat used now or historically by UWR Chinook and UWR steelhead tend to be least pronounced in those areas within the North Santiam subbasin that are dominated by federal lands. Consequently, much of the better habitat for these species now lies within currently inaccessible areas above Detroit Reservoir and in portions of the Little North Santiam watershed. This pattern reflects a stronger focus on aquatic conservation by federal land managers and a more diverse set of management objectives for the private lands found in lower portions of the subbasin.

**Substrate**
Substrates within many streams that are, or have been, used by the North Santiam’s Chinook salmon and steelhead populations are influenced by the cumulative effects of various land-use activities and, within the lower North Santiam River, by the effects of Detroit and Big Cliff dams. Streambed substrates suitable for use by spawning Chinook salmon appear to be more abundant above than below these two dams (R2 Resource Consultants 2007). As suggested earlier, unfavorable influences on this habitat are thought be more pronounced in lower portions of the subbasin, below the dams.

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\(^3\) During the February 1996 flood, 8 to 15 inches of precipitation fell in a 4-day period.

\(^4\) The Salem water treatment plant uses a slow-sand filtration process that is unable to treat water with turbidity levels greater than 10 NTU. A pretreatment facility was built in 1997 to handle high turbidity conditions.
All coarse sediments transported from watersheds above Big Cliff Dam (60% of the North Santiam subbasin) are now trapped by Detroit or Big Cliff reservoirs and can no longer contribute to the creation or maintenance of high-quality habitats downstream in the lower North Santiam River. Assessments of these upper watersheds by the Forest Service (WNF DRD 1994, 1995, 1996, 1997) suggest that some of them, and particularly that of the Breitenbush River, may have once contributed disproportionately large quantities of coarse sediment to the river system. For example, approximately 2 million cubic yards of sediment had been trapped in Detroit Reservoir from the Breitenbush River alone within the first 40 years after dam construction (WNF DRD 1995).

Eliminating natural sediment delivery from areas above Detroit has made the lower river entirely reliant on its banks or floodplain, unstable areas along a narrow alluvial canyon immediately below Big Cliff Dam, the Little North Santiam River, and multiple small tributaries as sources of coarse sediment. The consequences, despite flow-related reductions in the lower river’s transport capacity, have been a loss of finer textured gravel bars below Big Cliff Dam and a scouring of some areas near this dam down to bedrock with scattered boulders (WNF BRRD1994). This type of channel coarsening reduces the diversity of riverbed substrates and the availability of spawning habitat for anadromous salmonids.

Riverbed coarsening below dams in the Willamette system progresses at rates that vary locally (based in part on stream size, gradient, and alternate sources of sediment), but was assumed to travel downstream at 2,000 feet per year USACE (2000). If the coarsening of the lower North Santiam’s riverbed has extended downstream at something close to this rate, its effect below Big Cliff may have extended downstream well into the alluvial canyon reach above Mehama that is heavily used by spawning salmon, and may be approaching the river’s confluence with the Little North Santiam River. The degree to which the substrate coarsening process will be offset by sediment contributions from the Little North Santiam, or from multiple small foothill tributaries within the lower subbasin that have variable but often limited potential for sediment production (E&S 2002), is unclear.

The BLMS (1997) describes substrate conditions in streams within the Little North Santiam River watershed. Most surveyed reaches of streams in this watershed were rated fair to good for gravel quantity, and gravel quality was rated excellent in the mainstem of the Little North Santiam but variable in surveyed tributaries. Data from surveys conducted by ODFW on a limited number of the small streams flowing into the lower North Santiam River from private and state lands (http://oregonstate.edu/dept/ODFW/freshwater/inventory/nworgis.html) indicate variable substrate conditions, with segments of some streams exhibiting high levels of fine sediment in their beds.

**Large Woody Debris**

Large woody debris is frequently abundant within streams flowing through mature or old-growth forests on the Willamette National Forest, but timber harvest, road construction, and past stream clean-out operations have reduced the amount of wood found in streams draining some of the more intensively managed public watersheds above Detroit Reservoir (WNF DRD 1994, 1995, 1996, 1997). Reduced large wood levels can dramatically accelerate the transport of fine bed material and sediment out of small streams (Keller and MacDonald 1983; Beschta 1979) and degrade salmonid habitat. The Forest Service (WNF DRD 1994, 1995, 1996, and
NFMS
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1997) describes evidence that this has happened to streams above Detroit Reservoir that now have long, continuous riffles and little pool habitat or that have segments scoured to bedrock. Riparian areas along these altered streams are often in early- to mid-seral stages (WNF DRD 1995), and thus have limited near-term potential for contributing the large wood needed to restore damaged habitat. The Forest Service recognizes that this is an undesirable situation, and has begun restoration efforts that involve placing large woody debris back into wood-deficient stream segments above Detroit Reservoir.

All large wood that is transported from watersheds above Big Cliff Dam (60% of the North Santiam subbasin) now becomes trapped within Detroit and Big Cliff reservoirs, and is subsequently removed by the USACE. Such wood is thought to have historically exerted an important influence on habitat conditions within the lower river, particularly by contributing to channel complexity and the formation of pools, side channels, woody debris accumulations, and spawning habitats in unconfined, low gradient reaches (Abbe and Montgomery 1996). While there is little quantitative information on the magnitude of the effect this reduction in wood delivery had on aquatic habitat in the lower river, the volume of wood blocked by the dams suggests that the effect has likely been substantial. For example, an accumulation of large wood covering approximately 230 acres was removed from Detroit Reservoir following the 1964 flood (WNF DRD 1995).

Without wood from the upper subbasin, the lower North Santiam is now dependent on wood recruited from its banks, floodplain, or tributary watersheds. However, sources along the river’s banks and floodplain have been diminished by land use (E&S 2002) and wood is captured less frequently from these areas due to flood control and bank stabilization projects. Prospects for wood recruitment from the lower river’s tributaries have also been diminished. Surveyed streams within the Little North Santiam watershed typically contain less than desired levels of woody debris, and approximately half of the riparian areas evaluated within that watershed have low near-term potential for recruiting large wood to the stream network (BLMS 1998). Streams that have been evaluated within smaller watersheds tributary to the lower mainstem generally contain less than desirable levels of woody debris and have riparian areas with poor near-term wood recruitment potential (E&S 2002).

**Channel Complexity, Off-Channel Habitat & Floodplain Connectivity**

Reductions in channel-forming flows, decreased inputs of sediment and large wood, alteration or removal of riparian vegetation, revetments, and bank armoring, can impair the formation and maintenance of complex riverine and floodplain habitats important to salmonids (Appendix E, section E.5). Each of these disturbances has influenced channel conditions along the lower North Santiam River (E&S 2002) but the effects on salmonid habitats have not been quantified. Regardless, it is likely that the kinds of habitat simplification that have been documented elsewhere in the Willamette system (EA Engineering 1991; Minear 1994; Benner and Sedell 1997) have occurred along the lower North Santiam.

The effects of Detroit and Big Cliff dams on channel processes downstream in the lower river are only partly responsible for channel simplification that has occurred in the lower North Santiam subbasin. Bank stabilization measures and agricultural development have also affected channel complexity and associated salmonid habitat. For example, as of 1989 the
USACE had installed revetments along 3.2 miles (5.1 km) of bank within the lower 20 miles of the North Santiam River an additional 7.6 miles (12.3 km) of revetments downstream of the South Santiam confluence (USACE 1989b). These types of structures constrain the river and its access to floodplain areas, limiting channel migration, the river’s ability to capture woody debris from floodplain areas, and the formation of new side channels, pools, and other desirable salmonid habitats.

Analyses by Klingeman (1973) suggest that channel bed elevations in the lower-most reaches of the Santiam system may have lowered as a consequence of bank protection works, sand and gravel mining, or channel degradation extending upstream from the main Willamette. Such lowering would tend to diminish channel complexity and connections between river and floodplain. Log drives and removal of wood for navigation and flood control purposes, once common practices in Oregon (Sedell and Froggat 1984), may have contributed to this channel degradation by reducing the potential for sediment storage.

**Riparian Reserves & Disturbance History**

Riparian vegetation along streams in the North Santiam subbasin varies in response to natural differences in geology, precipitation, elevation, and disturbance regimes, and to man-caused factors including: timber harvesting, road building, and other land uses. At present, it is typically least disturbed in federally managed portions of the subbasin above the USACE dams or in the upper reaches of the Little North Santiam system, and most disturbed along lowland channels passing through areas affected by agricultural or rural-residential development.

Mature or old-growth forests remain along streams within significant portions of the extensive federal lands above the USACE dams and in the headwaters of the Little North Santiam River. However, timber harvest and near-stream road construction have removed or altered these forests along streams on other federal lands, both above the dams and in some areas (including portions of the Little North Santiam watershed) below the dams (WNF DRD 1994, 1995, 1996, 1997; BLMS 1997). All riparian areas on federal lands within the North Santiam subbasin are now being managed to maintain or recover high levels of natural function. Many of the riparian areas disturbed by timber harvest on these lands are already providing good stream shading (e.g., see BLMS 1997), but recovery of their natural potential to recruit large wood to stream channels and restructure salmonid habitats will require an extended period of recovery.

Riparian vegetation along the lower North Santiam River differs above and below Mehama, near the Little North Santiam confluence. Streamside forests along the reach of river from the site of Big Cliff Dam down to Mehama were once dominated by large conifers, but now include relatively few large conifers and consist of primarily small to moderate-sized trees (E&S 2002). Bottomland forests of black cottonwood, Oregon ash, and other native species that once dominated streamside and floodplain areas along the North Santiam River from Mehama to the mouth have been removed, altered, and fragmented by agricultural development, the construction of revetments, or other activities (E&S 2002). Riparian areas downriver from Mehama have now lost about 75% of their forest, and often include pastureland or other agriculturally-influenced vegetation like hedgerows or black hawthorn (E&S 2002). All of these changes in vegetation along the lower river have unfavorably affected natural processes that create and maintain high-quality salmonid habitats.
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Many sections of riverbank downstream of Mehama have been diked or otherwise hardened by private landowners to limit flooding or bank erosion, but the exact locations and extent of these changes have not been quantified (E&S 2002). As noted earlier, the USACE has installed revetments above and below the South Santiam confluence. These dikes and revetments have displaced riparian vegetation, hinder vegetative re-growth, and inhibit interactions between the river and its floodplain.

Air photo interpretations suggest that riparian conditions on private lands bordering many of the small tributaries to the lower North Santiam are less than needed to maintain good salmonid habitat. Stream shade is low along significant segments of many of these streams, particularly within lowland areas, and the potential for wood recruitment from their riparian areas is poor (E&S 2002). Riparian vegetation along some lowland streams is likely insufficient to filter agricultural chemicals from surrounding farmland.

4.6.4 Hatchery Programs

Chinook
The native population of spring Chinook in the North Santiam has been affected by hatchery production since the first egg-take by the Oregon Fish Commission (OFC) in 1906 (Wallis 1963). Although over the past century most of the fish released into the North Santiam have come from locally-collected broodstock, stocks from outside the ESU have also been released. The existing program at Marion Forks Hatchery began in 1951 as mitigation for the loss of production upstream of Detroit and Big Cliff dams (construction completed in 1953). Hatchery fish have probably spawned in the wild every year since this hatchery program began. Genetic analyses of naturally-produced juveniles from the North Santiam River indicated that these fish were most closely related to other naturally- and hatchery-produced spring Chinook from the Upper Willamette River ESU (though they were still significantly different, P>0.05, Myers et al. 1998). Wild fish have probably been incorporated into the hatchery broodstock since the collections began at the Minto weir. However, until the 2001 return year, when hatchery fish could be distinguished from wild fish, the numbers of hatchery fish that spawned in the wild and of wild fish incorporated into the hatchery program were unknown. Now that all hatchery fish are externally marked, the current management strategy (NMFS 2000a) is to incorporate local adaptation into the broodstock by using some wild fish and to limit the percentage of hatchery fish spawning in the wild. NMFS’ last biological opinion on the USACE hatchery program for UWR Chinook salmon expired in September 2003.

Steelhead
Native winter steelhead first were artificially propagated at the North Santiam Hatchery in 1930, when a record 2.8 million eggs (686 females at 4,170 eggs/female) were taken (Wallis 1963). Beginning in 1952, ODFW tried to compensate for the loss of wild production areas above Detroit and Big Cliff dams by releases of hatchery winter steelhead, but these attempts were generally unsuccessful (ODFW 1990a). The ODFW ended the winter steelhead hatchery
program in the Santiam in 1998 due to concerns that residualized hatchery-origin steelhead\(^5\) could interbreed and affect the genetic diversity of the native population, and the cost effectiveness of the program\(^6\) (ODFW 2004a).

Although artificially propagated winter steelhead are no longer released into the North Santiam subbasin, annual releases of 161,000 hatchery-produced Skamania stock summer-run steelhead smolts continue to be made into the North Santiam system (ODFW 2004b). The purpose of this hatchery program is to augment the sport fishery while minimizing natural production (i.e., straying) by summer steelhead (NMFS 2000a).

Recent studies on the Clackamas River have shown that adult summer steelhead from hatchery programs can stray into and spawn in the natural spawning areas of wild winter steelhead, producing offspring that may be good competitors with juvenile winter steelhead even though such offspring may not themselves return as adult fish (Kostow et al. 2003). The consequence for a wild winter steelhead population of this type of juvenile competition with non-native summer steelhead can be reduced abundance and productivity (Kostow et al. 2003). Recent USACE-funded monitoring by ODFW has shown that adult summer steelhead returning from the releases of hatchery smolts into the North Santiam do in fact appear to be spawning in streams used by the North Santiam’s winter steelhead (Table 4.6-7). Risks posed by the hatchery summer steelhead program are being further evaluated.

<table>
<thead>
<tr>
<th>Stream</th>
<th>Winter steelhead reds</th>
<th>Summer steelhead* reds</th>
<th>Percent summer steelhead reds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock Cr.</td>
<td>49</td>
<td>19</td>
<td>28%</td>
</tr>
<tr>
<td>Mad Cr.</td>
<td>27</td>
<td>26</td>
<td>49%</td>
</tr>
<tr>
<td>Elkhorn Cr.</td>
<td>18</td>
<td>6</td>
<td>25%</td>
</tr>
<tr>
<td>Sinker Cr.</td>
<td>13</td>
<td>14</td>
<td>52%</td>
</tr>
<tr>
<td>All</td>
<td>107</td>
<td>65</td>
<td>38%</td>
</tr>
</tbody>
</table>

*Redds counted prior to March 10 were identified as summer steelhead reds, though it was acknowledged, that pre-March 10 counts may have included redds from early spawning winter steelhead. Future genetic analyses of spawning adults and/or naturally produced juveniles from the subject streams will determine or confirm stock origin.

\(^5\) Cold water at the Marion Forks Hatchery precluded the accelerated growth typical of most hatchery programs and all smolts were released at age 2 instead of age 1. The protracted development period resulted in a high percentage of precocial males (up to 25%) which residualized in the system.\(^6\)

\(^6\) Cost effectiveness was low, in part, because of the residualism mentioned above.
4.6.5 Fisheries

Chinook

UWR spring Chinook are primarily intercepted in the southeast Alaskan and north-central British Columbia ocean fisheries. They have been subject to high cumulative harvest rates in the past, but these have declined since 1975. Under the Pacific Salmon Treaty, ocean harvest rates on UWR Chinook have been in the range of 10 to 15% or less for more than a decade (PSC 2008), and given increasing emphasis on stock conservation it seems reasonable to assume that rates of less than 20% will continue into the future.

The average harvest rate on the North Santiam stock in the freshwater fishery (i.e., the mainstem Columbia, Willamette, and North Santiam rivers) was approximately 36% during 1970 through 2001, ranging as high as 52%. Under ODFW’s Fisheries Management and Evaluation Plan (FMEP), freshwater anglers can retain only fin-clipped fish and the fishery is managed so as not to exceed a handling mortality rate of 15% and an average fishery rate of 10 to 11% (ODFW 2001a).

NMFS expects the targeted freshwater fishery on fin-clipped fish to improve the population growth rate for the North Santiam subbasin population. The average annual harvest rate on wild fish ranged from 27.3 to 41.1% (overall average = 32.8%) during 1980 through 1995 (total harvest minus the Clackamas River sport fishery, from Table A-2 in ODFW 2001a). ODFW (2001a) estimates that the expanded marking program and targeted fishery will reduce the average annual harvest rate on naturally-spawned fish from 32.8% to less than 8%, resulting in an incremental increase in survival of 37%.

ODFW’s FMEP for Upper Willamette spring Chinook requires freshwater fishery impacts to wild spring Chinook to be less than 15%. ODFW estimates that the impact to wild Upper Willamette spring Chinook was 12.4% for the North Santiam River population (ODFW 2007a).

Steelhead

A popular sport fishery targets the adult summer steelhead of hatchery origin that return to the North Santiam each year. These fish are marked with adipose fin-clips prior to release from the hatchery as smolts, and only those steelhead captured in the fishery that are missing this fin may be kept. All unmarked (assumed wild) steelhead captured by sport fisherman must be released unharmed. Incidental mortality of wild winter steelhead associated with this fishery is very low.

7 ODFW now externally marks all hatchery-reared fish with an adipose fin clip, which distinguishes them from wild fish. Marking will allow fisheries to take hatchery fish while releasing wild fish and will allow removal of hatchery fish straying into wild production areas (ODFW 2001 = FMEP). The expanded hatchery fish-marking program was phased in beginning with the 1996 broods in the North Santiam and McKenzie subbasins (1997 broods in the South Santiam and Middle Fork subbasins) (ODFW 2001a).
4.6.6 Status of PCEs of Designated Critical Habitat and Factors Affecting those PCEs in the North Santiam Subbasin

NMFS determined that the following areas of the North Santiam subbasin contain or may contain Critical Habitat for UWR Chinook salmon or UWR steelhead (NMFS 2005d; maps are included in section 303 of this Opinion):

**UWR Chinook (spring-run)**

- Habitat that is of high or medium conservation value for these fish, and deemed important to their recovery, is present in all three watersheds occupied by UWR Chinook within the North Santiam subbasin (NMFS 2005g). These watersheds are all below Big Cliff Dam and contain 80.1 miles of PCEs for spawning/rearing and 45.3 miles of PCEs for rearing/migration of the species (NMFS 2005g). All three watersheds have been designated as Critical Habitat (NMFS 2005d), as described below:
  - The Middle North Santiam River and Little North Santiam River watersheds, both below Big Cliff Dam, have high conservation value and combine to provide 43.0 miles of spawning/rearing habitat and 1.8 miles of rearing/migration habitat (NMFS 2005g).
  - The Lower North Santiam River watershed has moderate conservation value and provides 37.15 miles of spawning/rearing habitat and 43.5 miles of rearing/migration habitat (NMFS 2005g).

- The three additional watersheds account for the unoccupied portion of the subbasin, above Big Cliff Dam. These include the Upper North Santiam, North Fork Breitenbush River, and Detroit Reservoir/Blowout Divide Creek watersheds. They have not been fully evaluated as potential critical habitat, but contain as much as 45.3 miles of habitat that was once used by UWR Chinook (NMFS 2005g). NMFS did not have enough information to warrant designation of these watersheds as Critical Habitat for UWR Chinook at the time the final rule was published, but they may be important to species recovery (NMFS 2005g).

**UWR steelhead**

- Habitat that is of high conservation value for UWR steelhead, and thus important to their recovery, is present in all three occupied watersheds within the North Santiam subbasin (NMFS 2005g). These watersheds contain 99.4 miles of PCEs for spawning/rearing, 37.3 miles of PCEs for rearing/migration, and 0.0 miles of migration/presence habitat (NMFS 2005g). All three watersheds have been designated as Critical Habitat (NMFS 2005d), as described below:
  - The Middle North Santiam watershed has high conservation value and 27.9 miles of spawning/rearing habitat for UWR steelhead (NMFS 2005g).
  - The Little North Santiam River watershed has high conservation value for UWR steelhead and provides 27.9 miles of spawning/rearing habitat (NMFS 2005g).
  - The Lower North Santiam River watershed contains 43.6 miles of spawning/rearing habitat and 37.3 miles of rearing/migration habitat (NMFS 2005g).

- The three watersheds that account for all of the North Santiam system above Big Cliff Dam are unoccupied at present but did support UWR steelhead prior to dam construction. These
watersheds have not been fully evaluated as potential critical habitat for this species (NMFS 2005g). NMFS did not have enough information to warrant designation of these watersheds as Critical Habitat for UWR steelhead at the time the final rule was published, but they may be important to species conservation (NMFS 2005g).

Bank hardening measures associated with USACE flood control activities total 17,070 linear feet (3.23 miles) between Mile 12.5 and Mile 30 of the North Santiam River, with 10,309 feet (1.95 miles) on the right bank, and 6,761 (1.28 miles) on the left bank (USACE 2000). These measures adversely affect spawning/rearing areas designated as critical habitat.

NMFS (2005g) identified the key management activities that affect these PCEs. Key activities affecting the unoccupied, upper watersheds were not evaluated. Key activities affecting the Middle and Little North Santiam River watersheds below Big Cliff and Detroit dams include non-federal dams, agriculture, forestry, road building and maintenance, and mineral mining. In addition to the above factors, irrigation impoundment and withdrawals, sand and gravel mining, and urbanization are key factors affecting the Lower North Santiam watershed.

As described in previous sections, Big Cliff and Detroit dams block access to upstream spawning and rearing habitats, reduce downstream migrant survival, alter flows downstream, reduce or eliminate marine-derived nutrients from these upper watersheds, and limits the downstream transport of habitat building blocks. Detroit Dam also alters the formerly productive habitat above the dam by creating a 9.0 mile-long reservoir from about RM 61 to RM 70 (Mattson 1948). Big Cliff acts as a re-regulating dam for flows below Detroit Dam, and the Big Cliff Reservoir inundated an additional 2.8 miles of riverine habitat (RM 58.1-61). The Big Cliff/Detroit dam complex also negatively altered downstream water temperatures in North Santiam River. While the habitats upstream of these dams, unoccupied at the time the final rule was published, have not been designated as critical habitat, this habitat may be essential for conservation of UWR spring Chinook and UWR steelhead (NMFS 2005g).

Table 4.6-8 summarizes the condition of PCEs within the North Santiam River. Many of the habitat indicators are not in a condition suitable for salmon and steelhead conservation. In most cases, this is the result of the past operation and the continuing effects of the existence of the Projects or the effects of other human activities (e.g., development, agriculture, and logging). However, to the extent these conditions would be perpetuated by future operations or existence of the project, only the past impacts and project existence are included in the baseline.
<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Causative Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater spawning sites</td>
<td>Water Quality</td>
<td>Temperature</td>
<td>Indirect evidence that warmer fall temperatures have shortened the incubation and emergence timing of Chinook salmon fry</td>
<td>USACE operations (Detroit)</td>
</tr>
<tr>
<td>Freshwater rearing</td>
<td></td>
<td></td>
<td>The ODEQ 2004/2006 Integrated Report database indicates that maximum temperatures for spawning, incubation, and fry emergence have been exceeded in the lower North Santiam River (up to RM 26.5), and in the Santiam River below the mouth of the South Santiam</td>
<td>USACE operations (Detroit)</td>
</tr>
<tr>
<td>Freshwater migration corridors</td>
<td></td>
<td></td>
<td>Maxima for core and non-core rearing and adult and juvenile migration have been exceeded in the mainstem Santiam River and in the North Santiam River up to RM 10</td>
<td>Agriculture</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>USACE operations</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Agriculture</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maxima for core cold water habitat, spawning, rearing and migration also have been exceeded in streams above Detroit Reservoir (Marion Creek), and in tributaries to the lower reaches of the North Santiam (Chehulpum Creek, Bear Branch, and the Little North Santiam River, including Stout and Elkhorn creeks).</td>
<td>Timber harvest</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Average daily temperatures less than 52°F during May through late June, cool enough to have delayed the upstream migration of adult spring Chinook salmon</td>
<td>USACE operations (Detroit)</td>
</tr>
</tbody>
</table>
### PCE Pathway Indicator Condition Causative Factors

<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Causative Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing, Freshwater migration corridors</td>
<td>Water Quality</td>
<td>Total Suspended Solids/Turbidity</td>
<td>Although high turbidity events have been reported in the North Santiam subbasin in recent years, there is no indication that turbidity has adversely affected the habitat requirements of anadromous salmonids. The ODEQ 2004/2006 Integrated Report database does not include any exceedances of water quality criteria for excess turbidity.</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing, Freshwater migration corridors</td>
<td>Water Quality</td>
<td>Chemical Contamination/Nutrients</td>
<td>The ODEQ 2004/2006 Integrated Report database does not indicate that any streams are impaired due to excess nutrients. Summer operations, which discharge flows higher than those flowing into the reservoir, may have improved water quality by diluting nutrient loads in the mainstem North Santiam and Santiam rivers.</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing, Freshwater migration corridors</td>
<td>Water Quality</td>
<td>Dissolved Oxygen (DO)</td>
<td>The ODEQ 2004/2006 Integrated Report database indicates dissolved oxygen concentrations lower than the criterion for salmonid spawning and rearing (11 mg/L or 95% saturation) at RM 9.3 and RM 11.2 in the mainstem Santiam River (below the mouth of the South Santiam). May be caused by same factors that cause high temperatures in this reach.</td>
</tr>
</tbody>
</table>

*Note: USACE operations (Detroit and Big Cliff)*
<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Causative Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Freshwater migration corridors</td>
<td>Water quality</td>
<td>Total Dissolved Gas (TDG) level of 129% saturation measured 950 feet below Big Cliff Dam; 120.2% measured 2 miles downstream</td>
</tr>
<tr>
<td>Freshwater migration corridors</td>
<td>Habitat access</td>
<td>Physical barriers</td>
<td>Barriers below Big Cliff Dam</td>
<td>Reduced flows for upstream passage and juvenile entrainment into power and water supply canals in the lower subbasin</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>During construction of Detroit and Big Cliff dams (early 1950s), a concrete weir (Minto Dam) was built about three miles downstream of the dams to replace the old hatchery rack. Minto Dam has blocked passage of all adult spring Chinook salmon and most winter steelhead since 1952</td>
<td>State hatchery operations</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Barriers above Detroit Reservoir</td>
<td>A hatchery rack near the mouth of the Breitenbush River (now under Detroit Reservoir) intercepted a large proportion of the adult spring Chinook salmon and winter steelhead runs from 1911 through 1941</td>
</tr>
<tr>
<td>PCE Pathway</td>
<td>Pathway</td>
<td>Indicator</td>
<td>Condition</td>
<td>Causative Factors</td>
</tr>
<tr>
<td>-------------</td>
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<td>-----------</td>
<td>-----------</td>
<td>------------------</td>
</tr>
</tbody>
</table>
| Freshwater migration corridors | Habitat access | Physical barriers | *Big Cliff and Detroit projects as barriers*  
Both projects were built without fish passage facilities; populations are restricted to below Big Cliff Dam  
Preliminary screw trap studies indicate survival rates for juvenile spring Chinook of 51-60.5% at Detroit Dam and 69% at Big Cliff Dam; the combined survival rate for fish that pass both dams was 35-42%  
No estimate of reservoir survival available | USACE projects (Big Cliff/Detroit) |
| Freshwater migration corridors | Habitat access | Physical barriers | *Predation as a Barrier to Reservoir Migration*  
Cool water temperatures above Detroit Dam limit production of northern pikeminnows | USACE projects (Big Cliff/Detroit) – cold water in reservoir and dams as barrier to passage |
| Freshwater spawning sites | Habitat elements | Substrate | Substrate has coarsened downstream of Big Cliff Dam.  
River channel downstream of Big Cliff reservoir may be downcutting  
Channel downstream of Big Cliff Dam could lack spawning gravel  
Many areas scoured to bedrock  
Current sediment budget not creating and maintaining side channel and gravel bar habitat needed by anadromous salmonids | USACE reservoirs trap sediment from headwaters  
USACE operation of Detroit/Big Cliff reduces the magnitude and frequency of peak flows  
USACE and private revetments  
Gravel mining  
Historical log drives |
<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Causative Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>FW</td>
<td>Habitat elements</td>
<td>Pool Frequency and Quality</td>
<td>Reduced wood supply (USACE 2007a) has likely affected the frequency and quality of pools in the lower Santiam River below Detroit/Big Cliff.</td>
<td>Downstream LWD transport blocked by project dams; wood inputs from the lower subbasin are affected by riparian alterations, diking in the lower river, and flood control.</td>
</tr>
<tr>
<td>FW</td>
<td>Habitat elements</td>
<td>Large Woody Debris</td>
<td>In the tributaries and upper mainstem North Santiam rivers</td>
<td>Timber harvesting Stream clean-out Fire suppression</td>
</tr>
<tr>
<td>FW</td>
<td>Habitat elements</td>
<td>Large Woody Debris</td>
<td>In the mainstem North Santiam and Santiam rivers</td>
<td>USACE removes large wood from reservoirs</td>
</tr>
<tr>
<td>FW</td>
<td>Habitat elements</td>
<td>Large Woody Debris</td>
<td>Reaches of the North Santiam River below Detroit and Big Cliff dams are deprived of large wood</td>
<td>USACE removed snags in lower river for navigation</td>
</tr>
<tr>
<td>FW</td>
<td>Habitat elements</td>
<td>Large Woody Debris</td>
<td>Inadequate recruitment of large wood from riparian areas along mainstem North Santiam and tributaries downstream from Big Cliff Dam.</td>
<td>Inadequate recruitment from riparian forests</td>
</tr>
<tr>
<td>FW</td>
<td>Habitat elements</td>
<td>Large Woody Debris</td>
<td>Lack of large wood-associated habitat for anadromous salmonids and invertebrates upon which they feed.</td>
<td>USACE and private revetments prevent recruitment of large wood from banks</td>
</tr>
<tr>
<td>FW</td>
<td>Habitat elements</td>
<td>Large Woody Debris</td>
<td>USACE operation of Detroit and Big Cliff dams reduces frequency of channel-forming flows needed to recruit large wood from banks</td>
<td></td>
</tr>
</tbody>
</table>
## Freshwater spawning sites

**Pathway:** Freshwater rearing

**Indicator:** Habitat elements

**Condition:** Off-channel habitat

> While no quantitative data are available, the North Santiam likely contains fewer off-channel habitats, simplified mainstem habitat, and few new gravel bars or channel surfaces

**Causative Factors:**
- USACE operation of Detroit/Big Cliff reduces the magnitude and frequency of peak flows
- USACE and private revetments
- USACE removes large wood from reservoirs
- Gravel mining in lower river
- USACE traps sediment from 60% of upper subbasin in Detroit and Big Cliff reservoirs

## Freshwater rearing

**Pathway:** Freshwater migration corridors

**Indicator:** Channel conditions and dynamics

**Width/depth ratio**

> Channel form in the lower watershed has been restricted by dikes and by loss of LWD; reservoir operations have restricted some channel forming processes (USACE 2000; E&S 2002).

**Causative Factors:**
- Dikes; reduced LWD; Project reservoirs and reservoir operations.

## Freshwater migration corridors

**Pathway:** Channel conditions and dynamics

**Streambank condition**

> Streambanks do not support natural floodplain function in the lower river (USACE 2000; E&S 2002)

**Causative Factors:**
- Diking; residential and agricultural land uses; timber harvest; roads; reservoir operations.
<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Causative Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freshwater rearing</td>
<td>Freshwater migration corridors</td>
<td>Channel conditions and dynamics</td>
<td>Floodplain is not frequently inundated, with less over-bank flow and side channel connectivity</td>
</tr>
<tr>
<td></td>
<td>Freshwater rearing</td>
<td>Freshwater migration corridors</td>
<td>Floodplain connectivity</td>
<td>Reduced nutrient exchange, reduced sediment exchange, reduced flood refugia for fish, and reduced establishment of new riparian forests</td>
</tr>
<tr>
<td></td>
<td>Freshwater spawning sites</td>
<td>Freshwater migration corridors</td>
<td>Watershed conditions</td>
<td>Roads enter streamside areas (E&amp;S 2002)</td>
</tr>
<tr>
<td></td>
<td>Road density and location</td>
<td>Road density and location</td>
<td></td>
<td></td>
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<tr>
<td>PCE</td>
<td>Pathway</td>
<td>Indicator</td>
<td>Condition</td>
<td>Causative Factors</td>
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</tr>
<tr>
<td></td>
<td>Freshwater spawning sites</td>
<td>Water Quantity (Flow/Hydrology)</td>
<td>Change in peak/base flow</td>
<td>Frequency of channel-forming flows not of sufficient magnitude to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas</td>
</tr>
<tr>
<td></td>
<td>Freshwater rearing</td>
<td></td>
<td></td>
<td>Increased fall flows may allow spring Chinook to spawn in areas that will be dewatered during active flood control operations</td>
</tr>
<tr>
<td></td>
<td>Freshwater migration corridors</td>
<td></td>
<td></td>
<td>Winter and spring flow reductions may reduce rearing area and the survival of steelhead fry</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Increased summer flows may increase rearing area and the heat capacity of the stream</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low summer flows in specific reaches (due to diversions) may reduce the juvenile rearing habitat area, block adult passage to upstream spawning areas, and decrease the heat capacity of the stream</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Flow fluctuations now occur at rates rapid enough to entrap and strand juvenile anadromous fish</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Flood control operations at USACE’s Detroit and Big Cliff dams reduce the magnitude and frequency of peak flows</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fall releases from Detroit and Big Cliff dams to create storage space</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Winter flood control and late winter and spring refill operations at Detroit and Big Cliff reservoirs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Flow augmentation from Detroit and Big Cliff dams to meet mainstem targets</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Summer diversions at SWCD’s Stayton Complex and other diversions, including those served by USBR contracts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Active flood control operations at USACE’s Detroit and Big Cliff dams cause rapid flow reductions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rapid changes in diversion rates at the SWCD’s Stayton Complex</td>
</tr>
</tbody>
</table>
### PCE Pathway Indicator Condition Causative Factors

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Causative Factors</th>
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</thead>
<tbody>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Freshwater migration corridors</td>
<td>Watershed conditions</td>
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<td></td>
<td></td>
<td></td>
<td>Disturbance regime is dominated by timber harvesting, which has increased sediment delivery to streams while decreasing large wood input</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Upper watershed is forested, but some is managed for timber production rather than ecosystem health</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lower watershed contains extensive agricultural, urban, rural, and residential development</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Only 8% of lower watershed contains native Willamette Valley vegetation</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Freshwater migration corridors</td>
<td>Watershed conditions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Most riparian areas in small tributaries are vegetated, but consist of alder or young coniferous riparian areas.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Some drainages contain up to 33% mature riparian vegetation (e.g. Little North Fork), but others have less (e.g. Breitenbush).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Many tributaries do not provide adequate shading or large wood recruitment.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Floodplain forest riparian conditions</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The lower watershed contains only 25% of original extent of floodplain forest</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Many remaining patches of floodplain forest are interspersed with pastureland</td>
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</tbody>
</table>
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Molalla Baseline
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4.7 MOLALLA BASELINE

The Molalla River subbasin (Figure 4.7-1) is the third largest of the six east-side and upper Willamette River subbasins (Molalla, North Santiam, South Santiam, Calapooia, McKenzie, and Middle Fork Willamette) located above Willamette Falls in the Willamette River basin. These are the primary salmon and steelhead bearing subbasins.

The Molalla River flows out of the western Cascade Mountains to join the Willamette River north of the City of Canby. The Molalla watershed (including its largest tributary, the Pudding River) encompasses about 2,206 km² (852 miles²; 545,114 acres) of land and supports a variety of land uses and fish and wildlife habitats. The Molalla River’s headwaters drain the north, south, and western sides of the Table Rock Wilderness area managed by the Salem District of the U.S. Bureau of Land Management. The Pudding River’s headwaters begin in the low elevation Waldo Hills east of Salem.

The Molalla River is approximately 49 miles long and enters the Willamette River at RM 36; the Pudding River is 62 miles long and enters the Molalla River at RM 0.75. The watershed has a maximum elevation of 2,600 feet and the hydrology is dominated by winter rainfall. The mainstem Pudding River has lower flows and higher water temperatures than the Molalla River drainage. The lower 20 miles of the Molalla River has a gradient of 0.2%. Almost the entire Pudding River channel is within the flat Willamette Valley floor, with a gradient of 0.04% for the first 50 miles.
Figure 4.7-1  Map of the Molalla subbasin
The land cover or use is forest and shrubs (52%), agricultural (42%), and residential (Figure 4.7-2). Agriculture and rural residential development are the dominant land uses in the lower subbasin, with most of the development concentrated in the Pudding drainage.

**Figure 4.7.2 Land cover and use of the Molalla Subbasin (source: NRCS 2005b).**

Most of the western half of the watershed is developed or in agricultural use, while the eastern half is primarily forested. Ninety percent of the watershed is in private ownership (Figure 4.7-3), with the balance in federal (9%) or state (1%) forestry management (WLCTRT 2004). There are numerous small communities and growing urban areas within the lower subbasin, including the cities of Canby, Silverton, and Molalla. The two largest population centers are the City of Canby at 12,000 people and the City of Molalla at 6,000 people. In addition, portions of the cities of Salem and Woodburn are within the lower subbasin. Forestland uses predominate in the upper Molalla River drainage and on tributaries to the Pudding River that drain the Cascade Range (e.g., Butte, Silver, and Abiqua creeks).
4.7.1 Historical Populations of Anadromous Salmonids

Both UWR Chinook salmon and UWR steelhead occur in the Molalla River subbasin.

There is very little information on the historical run size or distribution of the Molalla spring Chinook population, but it was estimated in the 1950s that there was sufficient habitat in the Molalla River Subbasin to accommodate at least 5,000 fish (Parkhurst et al. 1950). By 1903, the abundance of spring Chinook salmon in the subbasin had already decreased dramatically (Myers et al. 2002). Surveys in 1940 and 1941 recorded 882 and 993 spawning spring Chinook salmon, respectively (Parkhurst et al. 1950). Surveys in the 1940s observed 250 spring Chinook salmon in Abiqua Creek, a tributary to the Pudding River (Parkhurst et al. 1950). In 1947, Mattson (1948) estimated the run size to be 550.

There are no estimates of the historical winter steelhead production in the Molalla/Pudding Subbasin, although spawning areas are dispersed over approximately 110 miles of mainstem and tributary streams in the Molalla River watershed and 57 miles in the Pudding River watershed (WRI 2004). The historical population likely numbered in the thousands based on the quantity of available habitat.

4.7.2 Current Status

4.7.2.1 UWR Chinook Salmon

The UWR Chinook salmon population in the Molalla subbasin remains low in numbers compared to historical conditions. The current run of Chinook is almost entirely of hatchery origin, and consists of adult returns from hatchery outplants into the subbasin, adult strays from hatchery releases of juvenile fish into other tributaries of the Willamette River, and a few naturally produced offspring of hatchery-origin parents.
The historical population of spring Chinook in the Molalla and Pudding watersheds likely declined to the point where it was no longer viable during, or prior to, the 1960s (Cramer et al. 1996). Hatchery releases of spring Chinook have been made in the Molalla watershed since 1964 in an attempt to restore the population, although there is no evidence that this population has become self-sustaining (USACE 2000). There have been no recent observations of adult spring Chinook in the Pudding River watershed (WRI 2004).

A 2002 survey of 16.3 miles of stream in the Molalla found 52 redds. However, 93% of the carcasses recovered in the Molalla in 2002 were fin-clipped, indicating that they were of hatchery origin (Schroeder et al. 2002). Fin-clip recovery fractions for spring Chinook in the Willamette tend to underestimate the proportion of hatchery-origin spawners, so the true fraction is in excess of 93% and is likely to be near 100%. The natural population of Molalla spring Chinook is thought to be extirpated, or nearly so (USACE 2000). Hatchery releases to the Molalla River from 1964 to 1997 are shown in Table 4.7-1.

Table 4.7-1  Documented releases of hatchery-origin UWR Chinook into the Molalla subbasin (source: WRI 2004). [Note: data obtained from ODFW and included with submission of this draft could be used to update hatchery releases through 2007]

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Lifestage</th>
<th>Duration</th>
<th>Years</th>
<th>Source</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molalla</td>
<td>Juveniles</td>
<td>1991</td>
<td>1</td>
<td>Clackamas FH</td>
<td>469,890</td>
</tr>
<tr>
<td></td>
<td>Juveniles</td>
<td>1964-1997</td>
<td>8</td>
<td>McKenzie FH</td>
<td>2,892,050</td>
</tr>
<tr>
<td></td>
<td>Juveniles</td>
<td>1981-1992</td>
<td>3</td>
<td>N Santiam FH</td>
<td>2,032,335</td>
</tr>
<tr>
<td></td>
<td>Juveniles</td>
<td>1964-1965</td>
<td>2</td>
<td>Unknown</td>
<td>375,209</td>
</tr>
<tr>
<td></td>
<td>Juveniles</td>
<td>1982-1999</td>
<td>12</td>
<td>Willamette FH</td>
<td>10,717,425</td>
</tr>
<tr>
<td></td>
<td>Juveniles</td>
<td>1991</td>
<td>1</td>
<td>Oxbow FH</td>
<td>71,380</td>
</tr>
<tr>
<td>Pudding</td>
<td>Juveniles</td>
<td>1964</td>
<td>1</td>
<td>McKenzie FH</td>
<td>82,550</td>
</tr>
<tr>
<td></td>
<td>Juveniles</td>
<td>1983-1985</td>
<td>3</td>
<td>Willamette FH</td>
<td>453,479</td>
</tr>
<tr>
<td>Total</td>
<td>Juveniles</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>17,074,318</td>
</tr>
</tbody>
</table>

4.7.2.2 UWR Steelhead

The UWR steelhead population in the Molalla River remains low in numbers compared to historical conditions. This run is of natural origin. There is currently no hatchery program for winter steelhead anywhere in the Willamette Basin, although there is a hatchery mitigation program for introduced (Skamania stock) summer steelhead. These hatchery fish have not been released directly into the Molalla River watershed since 1997, but adults originating from releases into other tributaries and returning to the Willamette River may stray into the Molalla River and spawn.

Current key spawning areas in the Molalla/Pudding Subbasin include the North Fork, Table Rock Fork, Milk Creek, and Copper Creek in the Molalla River watershed and Butte and Abiqua creeks in the Pudding River watershed. Chilcote (2007) estimated the number of winter steelhead spawners returning to the Molalla River from 1980 through 2005 based upon spawning redd counts and other related data (Figure 4.7-4).
Native (i.e., late-run) hatchery winter steelhead were released annually in the Molalla River for 21 years from 1957 through 1977, and in 1982 (Table 4.7-2). In more recent years (1970-1997), hatchery fish releases into the Molalla River were of non-native steelhead stocks and included many early-run winter steelhead from the lower Columbia River and summer steelhead from the Columbia River’s Skamania stock.

### Table 4.7-2  Winter and summer-run hatchery steelhead releases into the Molalla River, 1957-1997.

**Sources of summer-run fish are identified by an asterisk (*)**.

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Duration</th>
<th>Years</th>
<th>Source</th>
<th>From within ESU</th>
<th>From outside ESU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molalla</td>
<td>1970-1996</td>
<td>10</td>
<td>Gnat Creek</td>
<td>497,922</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1984-1997</td>
<td>7</td>
<td>Skamania*</td>
<td>909,134</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1976-1993</td>
<td>17</td>
<td>Big Creek</td>
<td>908,516</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1970-1974</td>
<td>4</td>
<td>Alsea River</td>
<td>156,683</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1957-1977</td>
<td>6</td>
<td>Marion Forks/S. Santiam</td>
<td>270,912</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1982</td>
<td>1</td>
<td>Marion Forks</td>
<td>23,492</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>294,404</td>
<td>2,472,255</td>
</tr>
</tbody>
</table>

**Figure 4.7-4** Estimated returns of native UWR Steelhead to the Molalla subbasin, 1980-2005 (source: Chilcote 2007).
4.7.2.3 Factors Limiting Productivity

The limiting factors and threats currently inhibiting the survival and recovery of UWR Chinook salmon and UWR steelhead in the Molalla River Subbasin, as identified in the Draft Willamette Chinook and Steelhead Recovery Plan (ODFW 2007b), are shown in Table 4.7-3. Even though the limiting factors and threats are broken into two groups (i.e., key and secondary), the secondary factors are important to address as well as the primary key factors.

Table 4.7-3 Key and Secondary Limiting Factors and Threats to Recovery of Molalla Spring Chinook and Winter Steelhead.

<table>
<thead>
<tr>
<th>Threats</th>
<th>Species</th>
<th>Tributaries (Streams and Rivers within Population Area)</th>
<th>West Side Tributaries</th>
<th>Mainstem Willamette (above falls)</th>
<th>Estuary (below Bonneville and Willamette Falls)</th>
<th>Ocean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvest</td>
<td>Chinook</td>
<td>Egg Alevin Fry Parr Parr Smolt Adult Spawner Kelt Presmolt Parr Smolt Sub-yearling Yearling Adult Adult</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hatchery</td>
<td>Steelhead</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydropower/ Flood Control</td>
<td>Chinook</td>
<td>4a</td>
<td>5a,5b,7h,10f</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Steelhead</td>
<td>9</td>
<td>5a,5b,7h,10f</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landuse</td>
<td>Chinook</td>
<td>7a 8a 9a</td>
<td>8a 9a 8b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Steelhead</td>
<td>7a 10b</td>
<td>2a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Introduced Species</td>
<td>Chinook</td>
<td>9a</td>
<td>6,8a,9a,9h,9i</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Steelhead</td>
<td>5a</td>
<td>6,8a,9a,9h,9i</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Black cells indicated key concerns; Gray cells indicated secondary concerns.

Key and threats and limiting factors

3 Hatchery fish interbreeding with wild fish resulting in a risk of genetic introgression.
5a Reduced macrodetrital inputs from near elimination of overbank events and the separation of the river from its floodplain.
5b Increased microdetrital inputs due to reservoirs.
7h Impaired fine sediment recruitment due to dam blockage.
8a Impaired physical habitat from past and/or present land use practices.
8b Loss of holding pools from past and/or present land use practices resulting in increased prespawning mortality.
9a Elevated water temperatures from past and/or present land use practices resulting in decreased survival and/or growth.
9c Elevated water temperatures from past and/or present land use practices leading to prespawning mortality.
10f Altered flows due to hydropower system that result in changes to estuarine habitat and plume conditions, impaired access to off-channel habitat, and impaired sediment transport.

Secondary and threats and limiting factors

2a Impaired access to habitat due to road crossings and other land use related passage impediments on wadeable sized streams.
4a Competition with hatchery fish of all species.
6e Predation by birds as a result of favorable habitat conditions for birds created by past and/or present land use activities.
7a Fine sediment in spawning gravel from past and/or present land use practices.
8a Impaired physical habitat from past and/or present land use practices.
4.7.3 Environmental Conditions

4.7.3.1 Habitat Access

Impediments to fish passage can limit access to important areas for pre-spawner holding, for spawning, for refuge from high flow velocities, or for access to cool tributary streams when the mainstem Molalla and Pudding rivers or their tributaries warm during the summer months. Fish passage is restricted throughout the subbasin, in part by a number of small dams on Butte, Abiqua, and Silver creeks. Many of these dams are laddered for fish passage, but the effectiveness of the fish ladders is unknown (WRI 2004). Culverts on numerous small streams within the subbasin impede or block fish access to historical habitats, although the degree to which this limits population abundance has not been evaluated.

The fish ladder at Silverton’s water diversion on Abiqua Creek has an inadequate entrance and is a partial fish passage barrier. There are unscreened diversions on the mainstem Molalla River near Shady Cove. Labish Ditch is an unscreened diversion that provides an inter-basin connection between Claggett Creek and the Little Pudding River.

The only active FERC hydroelectric power project in the Molalla Subbasin is a relatively small project on Woodcock Creek, a tributary to the Molalla River.

4.7.3.2 Water Quantity and Quality

Naturally low flows in the lower Pudding drainage are aggravated by water withdrawals, which contribute to increased summer water temperatures. High water temperatures are also aggravated by loss of riparian cover, reduced wetland areas, channel simplification, and increased impervious surfaces, particularly in the Pudding drainage. In general, summer water temperatures are lower in the forested portions of the upper subbasin tributaries of the Pudding River (i.e., Butte, Silver, and Abiqua creeks) and of the Molalla River.

Channelization of tributaries, modification of runoff patterns as a result of agriculture, impervious surfaces, and urban/residential development; and loss of storage capacity in floodplains and wetlands (particularly in the Pudding drainage) have accelerated runoff and increased peak flows. Nutrient and toxic runoff from agricultural and urban areas is an issue in the Pudding drainage. There has been extensive loss of wetlands throughout the subbasin. Loss of wetlands and floodplain habitats has affected water quality and quantity (i.e., storage and timing of peak and low flows).
The Molalla and Pudding rivers are listed by ODEQ as water quality impaired for temperature (11 segments), dissolved oxygen (2 segment), and bacteria (2 segments). In addition, one segment is listed for flow modification, and one segment each is listed for arsenic, iron, manganese, and DDT.

4.7.3.3 Physical Habitat Characteristics

The Molalla River is a gravel bed river characterized by multiple channels formed through active lateral stream migration and periodic avulsions. The stream has been substantially altered resulting from channelization, from placement of streambank revetments, and from loss of riparian habitat, including both forested and wetland areas (WRI 2004). Agriculture, urban, and rural development have encroached on local ecosystem function, separating the channel from its floodplain and limiting natural stream processes such as stream migration and formation of secondary and high water channels.

The USACE placed 5.07 miles of revetments along streambanks in the Molalla subbasin between 1938 and 1982, 2.49 miles of which are still maintained by the agency. Channels in the lower portions of the Molalla River, particularly near the city of Molalla (RM 20), and some tributaries have been simplified through placement of revetment and other actions. Revetments, roads, and other structures constrain sections of the lower Molalla River. Large portions of the lower Pudding River and sections of tributary streams have confined channels as a result of the placement of riprap and actions that restrict channel movement (WRI 2004). Revetments have simplified channels throughout the lower Pudding River and tributaries as a result of rural residential development and small community development near the stream channels.

Large wood is notably absent from large portions of the stream system, some of which was simplified by historical splash damming operations that sent artificial floods down channels to transport logs downstream toward mills. Historical removal of large wood from the rivers and their tributary streams, reduced transport and delivery of wood through channels, and changes in riparian vegetation have all interacted to reduce the quantity and distribution of large wood in the Molalla River Subbasin. Mature riparian forests make up a small proportion of the riparian areas in the lower subbasin (Hulse et al. 2002). Over time, a number of practices (such as splash dams and stream cleaning) removed large wood from the Molalla and Pudding rivers and tributary channels. While riparian areas in the forested upper subbasin have greater numbers of conifer trees than the lower subbasin does, historical wood removal from streams and riparian harvest has reduced large wood in the channels. Limited large wood in channels is particularly pronounced in the lower subbasin.

Reduced wood in the river and tributary channels has reduced the frequency and depth of pools, thus reducing habitat complexity important for adult fish (i.e., pre-spawner) holding and for juvenile rearing. Limited wood in tributary streams has reduced retention of spawning gravels.

Riparian areas along the river and tributaries, especially in the lower subbasin, are reduced in width, connectivity, and quality. There is some high-quality floodplain forest remaining along the lower Pudding River. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of native vegetation needed for natural habitat and channel
formation processes. The loss of wetland, floodplain and off-channel habitats has affected the quantity and quality of adult holding areas and of juvenile rearing and high-flow refuge areas.

4.7.4 Hatchery Programs

ODFW has been releasing hatchery spring Chinook salmon in the Molalla River since 1964 (see Current Status, section 4.7.2). The current run of Chinook salmon is primarily of hatchery origin, comprised of hatchery outplants in the Molalla subbasin or strays originating from other Willamette Basin tributaries. Hatchery releases in the Molalla subbasin have been made in an attempt to restore a naturally self-sustaining population, although there is no evidence that this has been successful. Is it at all effective even if not successful or do all the fish die?

A 2002 survey of 16.3 miles of stream in the Molalla found 52 redds. 93% of the carcasses recovered were fin-clipped, indicating that they were of hatchery origin (Schroeder et al. 2002). Fin-clip recovery fractions for spring Chinook in the Willamette tend to underestimate the proportion of hatchery-origin spawners actually present, so the true fraction is in excess of 93% and is likely near 100%.

Hatchery threats exert key adverse effects on Molalla Chinook at the adult spawning life stage. Hatchery Chinook interbreeding with naturally produced Molalla Chinook presents a risk of continuing genetic introgression, preventing the development of a self-sustaining, naturally adapted, local population. Currently, about 100,000 Chinook smolts from South Santiam hatchery are released annually into the Molalla. These fish comprise most of the hatchery fish on the spawning grounds. Few redds have been observed from either naturally produced or hatchery spawners.

Native (i.e., late-run) hatchery winter steelhead were released annually in the Molalla subbasin for 21 years from 1957 through 1977, and finally in 1982, after which time the hatchery was closed. In more recent years (1970-1997), hatchery steelhead releases into the subbasin were of non-native stocks and included many early-run winter steelhead from the lower Columbia River and summer steelhead from the Columbia River’s Skamania stock. Currently, no hatchery steelhead are released into the Molalla subbasin.

Summer steelhead present a risk to the abundance, productivity, spatial structure, and diversity of the local Molalla population of winter steelhead. While hatchery fish have not been released directly into the Molalla River subbasin since 1997, low densities of summer steelhead spawning have been observed in the mainstem Molalla River, in the North Fork Molalla River, and in Abiqua, Cougar and Lost creeks. Studies show adverse effects from non-native summer run steelhead on native winter run steelhead, especially when summer run fish spawn in the same areas as winter run fish (Kostow et al. 2003).
4.7.5 Fisheries

4.7.5.1 Spring Chinook

Harvest is a key threat at the adult life stage of the local Molalla River population of spring Chinook salmon, but only within the Molalla subbasin. Impacts to the Molalla spring Chinook population involve mortality caused by a catch and release fishery.

Relatively small numbers of naturally produced fish migrate from the Molalla subbasin each year. Most are progeny of naturally spawning hatchery fish released in the subbasin as juveniles. Sport fishing harvest within the Molalla River subbasin is restricted to possession of marked hatchery-origin fish. This is also true regarding harvest of spring Chinook salmon both outside of, and within, the Willamette River Basin. Harvest of naturally produced fish has, therefore, been curtailed to incidental catch beyond the identifiably marked hatchery fish. Given the small numbers of spring Chinook salmon naturally produced in the Molalla subbasin, even the otherwise incidental mortality associated with their capture and release may be a significant factor curtailing re-establishment of a naturally self-sustaining population and achievement of local population recovery.

4.7.5.2 Steelhead

To protect young winter steelhead (which often cannot be distinguished from cutthroat trout), ODFW has restricted trout fishing to catch-and-release. There is currently no direct harvest of naturally produced steelhead in the Molalla subbasin, although fin-marked (hatchery-origin) fish that stray into the subbasin may be kept.

4.7.6 Habitat Alteration (Status of PCEs of Designated Critical Habitat and Factors Affecting those PCEs in the Molalla River Subbasin)

NMFS determined that the following occupied areas of the Molalla River subbasin contain Critical Habitat for the UWR Chinook salmon and the UWR steelhead ESUs (NMFS 2005d; maps are included in section 3.3 of this Opinion):

- Mainstem Molalla River (for Chinook and steelhead)
- Gribble Creek (for Chinook and steelhead)
- Buckner Creek (for steelhead)
- Cedar Creek (for steelhead)
- Milk Creek (for Chinook and steelhead) and tributaries (for steelhead)
- Woodcock Creek (for steelhead)
- North Fork Molalla River (for Chinook and steelhead) and tributaries (for steelhead)
- Trout Creek (for steelhead)
- Pine Creek (for steelhead)
- Table Rock Fork Molalla River (for Chinook and steelhead) and tributaries (for steelhead)
Copper Creek (for steelhead)
- Mainstem Pudding River (for Chinook and steelhead)
- Little Pudding River (for steelhead)
- Abiqua Creek and tributaries (for steelhead)
- Silver Creek (for steelhead)

NMFS (2005g) identified the key management activities that affect these streams and their
PCEs: forestry, road building and maintenance, channel modifications, streambank armoring,
agriculture, and urban/rural development. Indicators for temperature, bacteria, chemical
contamination, streambank condition, stream channel condition, and riparian habitat condition
are the basis for considering that these critical habitat features are currently at risk or not
properly functioning (NMFS 2005h).

NMFS (2005d) identified the key management activities that affect these PCEs that include
forestry, road building and maintenance, channel modifications, streambank armoring,
agriculture, and urban/rural development. Indicators for temperature, bacteria, chemical
contamination, streambank condition, stream channel condition, and riparian habitat condition
are the basis for considering that these critical habitat features are currently at risk or not
properly functioning (NMFS 2005h).

Table 4.7-4 summarizes the condition of PCEs within the Molalla and Pudding rivers. Many of
the habitat indicators are not in a condition suitable for salmon and steelhead conservation. In
most cases, this is primarily the result of human activities (e.g., development, agriculture, and
logging).
Table 4.7-4 Critical habitat primary constituent elements (PCEs) and associated pathways, indicators, current conditions, and limiting factors for the Molalla River Watershed under the environmental baseline.

<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Causative Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater migration corridors</td>
<td>Habitat</td>
<td>Access</td>
<td>Molalla River and Tributaries (except the Pudding River)</td>
<td>Road crossings and rural development</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Physical Barriers</td>
<td>Fish passage is restricted throughout the subbasin. Numerous culverts throughout the subbasin present barriers to adult and juvenile refuge habitat, and to juvenile rearing habitat.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>There are unscreened diversions on the mainstem Molalla River near Shady Cove.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The only active FERC hydroelectric power project in the Molalla Subbasin is a relatively small project on Woodcock Creek, a tributary to the Molalla River.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pudding River and Tributaries</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fish passage is restricted throughout the subbasin, in part by a number of small dams on Butte, Abiqua, and Silver creeks. Many of these dams are ladders for fish passage, but the effectiveness of the fish ladders is unknown.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Numerous culverts throughout the subbasin present barriers to adult and juvenile refuge habitat, and to juvenile rearing habitat.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The fish ladder at Silverton’s water diversion on Abiqua Creek has an inadequate entrance and is a partial fish passage barrier.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Labish Ditch is an unscreened diversion that provides an inter-basin connection between Claggett Creek and the Little Pudding River.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Agricultural and rural development
Privately owned dams

Private dams
Road crossings and rural development
Private dams
Agriculture and rural development
<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Causative Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater spawning</td>
<td>Freshwater spawning sites</td>
<td>Freshwater spawning sites</td>
<td>Naturally low flows in the lower Pudding drainage are aggravated by water withdrawals</td>
<td>Agricultural, urban, and rural development</td>
</tr>
<tr>
<td></td>
<td>rearing</td>
<td>rearing</td>
<td>Channelization of tributaries; modification of runoff patterns as a result of agriculture, impervious surfaces, and urban/residential development; and loss of storage capacity in floodplains and wetlands (particularly in the Pudding drainage) have accelerated runoff and increased peak flows.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>migration corridors</td>
<td>migration corridors</td>
<td>There has been extensive loss of wetlands throughout the subbasin. Loss of wetlands and floodplain habitats has affected water quality and quantity (i.e., storage and timing of peak and low flows).</td>
<td></td>
</tr>
</tbody>
</table>
### Molalla Baseline

<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Causative Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater spawning sites</td>
<td>Water Quality</td>
<td>Temperature</td>
<td>Naturally low flows in the lower Pudding drainage are aggravated by water withdrawals, which contribute to increased summer water temperatures. High water temperatures are also aggravated by loss of riparian cover, reduced wetland areas, channel simplification, and increased impervious surfaces, particularly in the Pudding drainage.</td>
<td>Agricultural, urban, and rural development</td>
</tr>
<tr>
<td>Freshwater rearing</td>
<td></td>
<td></td>
<td>Summer water temperatures are lower in the forested portions of the upper subbasin tributaries of the Pudding River (i.e., Butte, Silver, and Abiqua creeks) and of the Molalla River.</td>
<td></td>
</tr>
<tr>
<td>Freshwater migration corridors</td>
<td></td>
<td></td>
<td>The ODEQ 2004/2006 Integrated Report database lists 11 stream segments as water quality limited due to high summer temperatures.</td>
<td></td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Water Quality</td>
<td>Total Suspended Solids/Turbidity</td>
<td>The ODEQ 2004/2006 Integrated Report database does not report any streams as water quality limited due to turbidity.</td>
<td>N/A</td>
</tr>
<tr>
<td>PCE</td>
<td>Pathway</td>
<td>Indicator</td>
<td>Condition</td>
<td>Causative Factors</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>--------------------------------------</td>
<td>----------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Water Quality</td>
<td>The ODEQ 2004/2006 Integrated Report database indicates that 2 stream segments were water quality limited for occurrence of E. coli bacteria during summer low flow periods. One stream segment each was indicated as water quality limited for arsenic, iron, manganese, and DDT.</td>
<td>Agriculture, urban, and rural development</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Water Quality</td>
<td>The ODEQ 2004/2006 Integrated Report database indicates that 2 stream segments were water quality limited for dissolved oxygen (ODEQ 2006b).</td>
<td>Agriculture, urban, and rural development</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater migration corridors</td>
<td>Dissolved Oxygen (DO)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCE</td>
<td>Pathway</td>
<td>Indicator</td>
<td>Condition</td>
<td>Causative Factors</td>
</tr>
<tr>
<td>-----</td>
<td>---------</td>
<td>----------</td>
<td>-----------</td>
<td>------------------</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Habitat Elements</td>
<td>Substrate</td>
<td>The Molalla River is a gravel bed river characterized by multiple channels formed through active lateral stream migration and periodic avulsions. The stream has been substantially altered resulting from channelization, from placement of streambank revetments, and from loss of riparian habitat, including both forested and wetland areas. Limited wood in tributary streams has reduced retention of spawning gravels.</td>
<td>Agriculture, urban, and rural development</td>
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<tr>
<td>Freshwater rearing sites</td>
<td>Habitat Elements</td>
<td>Large Woody Debris</td>
<td>Large wood is notably absent from the system which has been subject to historical splash damming. Historical removal of large wood from the rivers and their tributary streams, reduced transport of wood through channels, and changes in riparian vegetation have all interacted to reduce the quantity and distribution of large wood throughout the Molalla subbasin. Mature riparian forests make up a small proportion of the riparian areas in the lower subbasin. Splash dams and stream cleaning removed large wood from the Molalla and Pudding rivers and tributary channels. Riparian areas in the forested upper subbasin have greater numbers of conifer trees than the lower subbasin, but historical wood removal from these streams and riparian area has also reduced large wood in their channels. Limited large wood in channels is particularly pronounced in the lower subbasin.</td>
<td>Privately forest practices Historical splash dams and log drives Snag and removal of logs and log jams Removal of large wood by landowners and boaters for navigation and/or firewood Local development and agricultural development in the lower watershed resulting in riparian area depletion</td>
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<td>PCE</td>
<td>Pathway</td>
<td>Indicator</td>
<td>Condition</td>
<td>Causative Factors</td>
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<td>Freshwater rearing sites</td>
<td>Freshwater migration corridors</td>
<td>Habitat elements</td>
<td>Development has encroached on local ecosystem function, separating the stream channel from its floodplain and limiting natural stream processes such as stream migration and formation of pools, secondary and high water channels. Reduced wood in the river and tributary channels has reduced the frequency and depth of pools, thus reducing habitat complexity.</td>
<td>Agriculture, urban, and rural development Removal of LWD, roads, channel scour, land uses such as timber harvest, and bank armoring in the lower river</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater migration corridors</td>
<td>Habitat elements</td>
<td>USACE placed 26,759 feet of revetment along streambanks in the Molalla River drainage between 1938 and 1982. Channels in the lower portions of the Molalla River, particularly near the city of Molalla (RM 20), and some tributaries have been simplified through placement of revetment and other actions. Revetments, roads, and other structures constrain sections of the lower Molalla River, portions of the lower Pudding River, and sections of tributary streams. Revetments have simplified channels throughout the lower Pudding River and its tributaries.</td>
<td>USACE and private revetments Reduction in the magnitude and frequency of peak flows as a result of agricultural, urban, and rural development</td>
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<td>PCE</td>
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<td>Freshwater migration corridors</td>
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| | Channel conditions and dynamics | Streambank condition | Streambanks do not support natural floodplain function in the lower watershed. | USACE and private revetments  
Agricultural, urban, and rural development |
| Freshwater rearing | | |  |  |
| | Freshwater migration corridors | | |  |
| | Channel conditions and dynamics | Floodplain connectivity | The Molalla has been substantially altered, including both forested and wetland areas. There has been extensive loss of wetlands throughout the subbasin. Loss of wetlands and floodplain habitats has affected water quality and quantity (i.e., storage and timing of peak and low flows). | Channelization, placement of streambank revetments, and loss of riparian habitat  
Private forest practices  
USACE and private revetments  
Agricultural, urban, and rural development |
### Condition

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<tr>
<td>Freshwater spawning sites</td>
<td>Watershed conditions</td>
<td>The disturbance regime is dominated by timber harvesting in the upper watershed.</td>
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<td>Disturbance history</td>
<td>Timber harvesting has increased sediment delivery to streams, but decreased large wood input, resulting in degraded aquatic habitat.</td>
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<td>Upper watershed is forested, but some is managed for timber production rather than ecosystem health. Most of the watershed (90%) is in private ownership.</td>
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<td>Lower watershed is predominantly agricultural, urban, and residential development.</td>
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<td>Freshwater spawning sites</td>
<td>Watershed conditions</td>
<td>Fire suppression</td>
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<td>Timber harvesting</td>
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<td>Conversion to agricultural, urban, and rural uses</td>
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<td>USACE and private revetments</td>
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<td>Agricultural, urban, and rural development has altered the hydrologic regime</td>
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4.8 CLACKAMAS SUBBASIN

The Clackamas River enters the mainstem Willamette River at RM 25.1 (1.7 miles below Willamette Falls) after draining an area of 941 square miles, and is the fourth largest of the Willamette’s tributaries. The Clackamas arises from the southern flank of Mt. Hood in the Cascade Mountains and has several major tributaries, including the Collawash River, Oak Grove Fork, and Fish Creek in the upper portion of its drainage network, and Eagle, Deep, and Clear creeks along the lower river (Figure 4.8-1). In all, 87% of the Clackamas subbasin is forestland and 69% of the subbasin is in public ownership (Figures 4.8-2).

The upper portion of the Clackamas system, above River Mill Dam and Estacada, is characterized by moderate to high-gradient stream reaches within mountainous terrain, while more gently sloped stream channels and topography dominate in the lower portion. The upper portion of the subbasin is heavily forested and primarily within the Mt. Hood National Forest. The lower portion, below Estacada, is more highly developed, and includes a variety of forest, agricultural, rural-residential, urban, and industrial land uses. The degree of landscape alteration within the subbasin increases with proximity to urban areas near the Willamette River. Industrial uses of the river’s lowlands, particularly near the Willamette, include food processing, recycling of volatile organic compounds, feedlot and dairy farm operations, and rock and aggregate mining. Estacada is the largest city entirely within the subbasin, although the Portland suburbs of Gladstone, Johnson City, and Oregon City are located near the mouth.

The Portland General Electric Company (PGE) operates a multi-dam hydroelectric complex within the Clackamas subbasin, with the lower-most dam (River Mill) at RM 23.3 of the mainstem Clackamas not far below the city of Estacada. PGE’s Clackamas River Hydroelectric Project also includes Faraday Diversion and North Fork dams on the mainstem Clackamas (at RM 28.4 and 30, respectively), and two additional dams on the Oak Grove Fork above areas naturally accessible to anadromous fish. Fish passage facilities that PGE has constructed and maintained at their dams on the mainstem Clackamas River provide anadromous fish access to all historically occupied streams above River Mill Dam.

4.8.1 Historical Populations of Anadromous Salmonids in the Clackamas Subbasin

The Clackamas subbasin once supported independent populations of wild anadromous salmonids from four ESA-listed evolutionary groups: LCR Chinook salmon, LCR coho salmon, LCR chum salmon, and LCR steelhead (Meyers et al. 2006). Historical information on each population is incomplete, but all of them were once substantially more abundant than at present. LCR Chinook native to the subbasin included a spring-run population and a fall-run, both of which were severely depleted by the early to mid-1900s. The distribution and abundance of the historical chum salmon population were never documented.
Figure 4.8-1 Map of the Clackamas subbasin
Figures 4.8-2 Patterns of land ownership (top) and land use/land cover (bottom) in the Clackamas subbasin (source: NRCS 2005b).
Spring-run Chinook Salmon
Approximately 8,000 adult spring Chinook were harvested from the lower Clackamas River in 1893 and about 12,000 were taken in 1894 for hatchery broodstock (Murtaugh et al. 1992). These numbers only partly reflect the historical productive capacity of the system, because many of the river’s spring Chinook were also being harvested in fisheries on the lower Columbia River and portions of the annual runs were avoiding fisheries and hatchery operations to spawn naturally in the Clackamas subbasin. Most of the historical run is believed to have spawned in the Clackamas and its larger tributaries upstream of the current site of River Mill Dam, though Eagle Creek was also an important spawning stream (McIntosh et al. 1995). The majority of historical spring Chinook salmon production probably came from the mainstem Clackamas and Collawash rivers (Willis et al. 1960).

By the time early hydroelectric dams were constructed on the Clackamas, first Faraday Dam in 1904, then River Mill Dam in 1911, fishermen had already noticed severe declines in the subbasin’s run of spring Chinook (SPC&A 2001). These declines had likely been caused by over-fishing, early habitat damage in the lower Clackamas subbasin, and broodstock collections at temporary weirs that were operated by ineffective hatchery programs. The dams worsened the situation for the run by further impeding fish migrations to spawning areas in the upper subbasin and providing fish culturists an opportunity to use fish ladders to collect much of what remained of the natural salmon population for hatchery broodstock. For several years beginning in 1911, all spring Chinook salmon that reached River Mill Dam and entered its ladder were used as hatchery broodstock (Taylor 1999). From 1917-1939, fish access to areas above Faraday was blocked after that dam’s ladder was destroyed by floodwaters (Taylor 1999).

Upstream passage was restored at the dams on the mainstem Clackamas in 1939, allowing anadromous salmonids to recolonize the upper subbasin (SPC&A 2001). However, the spring Chinook run that became established above the dams after passage was improved was derived from a population in the lower subbasin strongly influenced by hatchery programs that frequently used broodstock from the UWR Chinook populations found above Willamette Falls. The spring Chinook population now found throughout the Clackamas subbasin is more closely related genetically to UWR Chinook than to the LCR Chinook presumed to have once been present (Meyers et al. 2006).

Fall-run Chinook Salmon
A fall-run of LCR Chinook salmon was abundant historically in the Clackamas subbasin and apparently spawned in the mainstem river up to a point above the current site of North Fork Dam (Fulton 1968). However, this native population was extirpated during the 1930s as a consequence of severe water pollution problems in the mainstem Willamette River below Willamette Falls (Parkhurst et al. 1950). Dimick and Merryfield (1945) reported that the native run had entered the Willamette in September and October and spawned soon after entering the Clackamas River. In 1902, for example, approximately 10 million fall Chinook salmon eggs were collected between 22 September and 08 November at a hatchery weir constructed on the lower Clackamas, with peak collections on 15 October (Titcomb 1904). Assuming fecundities reported by Titcomb (~4,380 eggs/female) and that about half the 1902 run was female, returns of fall Chinook to the lower Clackamas River weir site exceeded 4,500 fish in that year.
Fall Chinook were actively reintroduced into the Clackamas subbasin after the severe water pollution problems in the lower Willamette were addressed by wastewater treatment and baseflow augmentation from the USACE’s Willamette Project. Hatchery stocks derived from fall-run populations in other tributaries to the lower Columbia River were released into the subbasin from 1952 to 1981 in an effort to reestablish a natural run (Meyers et al. 2006). Returns of fall Chinook to the Clackamas declined to low levels after the hatchery releases were terminated (McElhany et al. 2007).

**LCR Coho Salmon**
Abernethy (1886) reported that the coho salmon run in the Clackamas River lasted from mid-September to mid-December, and that it was about equal to the Chinook salmon run. Barin (1886) observed that coho in the system began spawning in about mid-January. Coho salmon passage at North Fork Dam historically was unimodal with a peak in mid-November, but run timing at the dam is now bimodal with peaks in September and January (Cramer and Cramer 1994). Of the two runs, the late run is thought to be native, while the early run is considered to be the result of hatchery introductions (Olsen et al.1992).

Recent EDT-based analyses of the Clackamas subbasin suggest a historic capacity to produce a run of about 15,000 adult coho under average ocean survival conditions (WRI 2004). A compilation of data on the subbasin’s coho from the late 1950s forward (Chilcote 2007) suggests that the subbasin produced many more wild coho than this during multiple years when ocean survival conditions were high.

**CR Chum Salmon**
Barin (1886) reported that a native run of dog (chum) salmon appeared in the Clackamas River by November and spawned soon afterward. However, by 1944 these fish were not found during biological surveys (Dimick and Merryfield 1945) and had probably been extirpated by the same water-quality problems in the lower Willamette that had eliminated the Clackamas’s native run of fall Chinook. No data are available on the historical spawning distribution or abundance of these chum salmon.

**LCR Steelhead**
The Clackamas subbasin’s native run of winter steelhead represents one of 23 historical, demographically independent populations of LCR Steelhead (Myers et al. 2006). Although information on the historical abundance of the Clackamas population are incomplete, they indicate that steelhead runs in the subbasin were once much larger than under current conditions. Recent EDT-based analyses of the Clackamas subbasin suggest a historic capacity to produce a run of about 10,000 adult steelhead under average ocean survival conditions (WRI 2004). Because of their association with swifter flowing habitats, steelhead would have been distributed throughout much of the subbasin, and present even in areas that were not used by Chinook or coho salmon (SPC&A 2001).
4.8.2 Current status of ESA-Listed Salmon and Steelhead in the Subbasin

4.8.2.1 UWR (spring-run) Chinook Salmon

Population Viability
The Clackamas population of UWR Chinook is considered to be at a relatively low risk of extinction based on an assessment of its abundance, productivity, spatial structure, and diversity (McElhany et al. 2007). Contributors to extinction risks that the Clackamas population faces within the subbasin include:

- reductions in diversity and productivity caused by a combination of genetic introgression from non-local hatchery stocks and a 22+ year period when the natural population was excluded from its natural habitats in the upper Clackamas subbasin (ODFW 2007b);
- fish passage injury, mortality, and delay at the Clackamas River Hydroelectric Project;
- diminished habitat quality in the lower Clackamas subbasin; and
- potentially catastrophic events such as landslides or disease outbreaks caused by hatchery operations (WLCTRT 2003).

Abundance & Productivity
The natural-origin UWR Chinook in the Clackamas subbasin constitute one of only two populations out of seven (the McKenzie is the other) that appear abundant and productive enough not to be at high near-term risk of extinction (McElhany et al. 2007). Estimates of the annual abundance of wild Clackamas spring Chinook since 1958 (Chilcote 2007, Figure 4.8-3) suggest a long-term (1958-2005) geometric mean of 902 spawners and a recent (1990-2005) geometric mean of 1,656 spawners (McElhany et al. 2007). These fish appear to experience lower rates of pre-spawn mortality than do the populations of UWR Chinook that lack access to habitats above the dams on other Willamette River tributaries, with annual rates of loss above North Fork Dam estimated at 9-26% (mean = 19%) from 2003-2005 (Schroeder et al. 2005).

Although stray hatchery-origin fish with fin clips are sorted at a fish trap below Faraday Dam to prevent their entry into the upper Clackamas subbasin, ineffective marking (regenerated adipose fins that were originally clipped) by the large hatchery program in the lower subbasin allows sizeable numbers of hatchery-origin spawners to be passed upstream. Schroeder et al. (2005) found an average of 26% hatchery-origin fish among spring Chinook carcasses recovered from upper basin spawning grounds during 2003 and 2004. The proportion of hatchery-origin fish found decreased with increasing distance upstream from North Fork Dam (Schroeder et al. 2005).
Figure 4.8-3  Estimated annual abundance of natural-origin (“wild”) Clackamas spring Chinook, 1958-2007 (data source: Chilcote 2007).

Spatial Structure
The spatial structure of the Clackamas’ spring Chinook population poses a low risk of extinction. Spring Chinook in the subbasin have access to nearly all of the areas that were available to the historical population (ODFW 2007b). A portion of the historical rearing habitat for these fish has been inundated by the construction of PGE’s three dams on the mainstem Clackamas, but rearing conditions within the reservoirs behind these dams is known to be well used by juvenile Chinook (SPC&A 2001). Mainstem habitats in the lower subbasin have been degraded, but are believed to have been secondary to upper basin habitats in importance to the historical population (ODFW 2007b).

Diversity
Clackamas spring Chinook have likely experienced losses of diversity characteristic of a population at moderate risk of extinction (McElhany et al. 2007). As noted earlier, access to the productive spring Chinook habitat in the upper subbasin was eliminated for an extended period of time and the population has been genetically influenced by hatchery programs based on out-of-subbasin broodstocks. Life history traits of the current population, particularly the time of spawning, differ from those described for the historical population (ODFW 2007b) and may be a poorer match to the habitat conditions found in the subbasin (SPC&A 2001).
4.8.2.2  LCR (fall-run) Chinook Salmon

The fall run of Chinook salmon in the Clackamas subbasin has declined in the decades since hatchery supplementation ended, is quite small, and is not a primary focus of monitoring efforts.

Within the Clackamas subbasin, these fish are largely confined to the mainstem below River Mill Dam and the lower reaches of the major tributaries (Deep, Clear and Eagle creeks) to the lower river (personal communication, Doug Cramer, PGE). Available data on the population’s abundance are of uncertain reliability, and the population should be considered “extirpated or nearly so” (McElhany et al. 2007). The HSRG (2008) has estimated that average annual returns of natural-origin LCR (fall) Chinook to the Clackamas subbasin (~50 adults) are exceeded by the average number of stray hatchery-origin fish entering the subbasin from programs elsewhere in the Lower Columbia region (~70 adults).

4.8.2.3  LCR Coho Salmon

Population Viability
Natural-origin coho in the Clackamas subbasin appear to constitute one of only two LCR coho salmon populations in Oregon that have maintained significant natural production and genetic continuity with their historical predecessors. Based on an assessment of the Clackamas population’s abundance, productivity, spatial structure, and diversity, McElhany et al. (2007) classified it as having a low to moderate risk of extinction. This makes the Clackamas population the only one that might be considered viable within the entire LCR Coho ESU (McElhany et al. 2007). Contributors to extinction risks the population faces within the Clackamas subbasin include:

- habitat degradation in the lower subbasin (WRI 2004);
- reductions in diversity and productivity that may remain as legacies of intense commercial fisheries that have only recently become managed with a strong emphasis on conserving natural coho populations (Cramer and Cramer 1994; McElhany et al. 2007);
- imperfect fish passage at the Clackamas River Hydroelectric Project that is in the process of being improved; and
- high proportions of stray hatchery-origin coho in natural spawning areas within the lower subbasin (WLCTRT 2003).

Abundance & Productivity
In their viability assessment of Clackamas coho, McElhany et al. (2007) rated the natural-origin population’s abundance and productivity as reflecting a low extinction risk. Data compiled by Chilcote (2007) show that adult abundance dropped to very low levels during multiple years in the 1990s but has since rebounded to somewhat higher levels (Figure 4.8-4).
Spatial Structure
The spatial structure of the Clackamas coho population, which expanded after fish passage to the upper subbasin was restored in 1939, was rated by McElhany et al. (2007) as posing a low risk of extinction. The historical Clackamas coho population had access to an estimated 385 km of habitat (ODFW 2005b). Virtually all (97%) of this habitat is now accessible to these fish (ODFW 2005b), with limited losses of accessibility in higher order tributary streams, primarily due to watershed development in the lower subbasin (McElhany et al. 2007).

Diversity
McElhany et al. (2007) rated the diversity of the LCR Coho in the Clackamas subbasin as that of a salmonid population facing low to moderate risk of extinction, with concerns including changes in life history, recent abundance bottlenecks (see Figure 4.8-4), and high proportions of hatchery-origin fish using spawning areas in the lower subbasin. Cramer and Cramer (1994) observed that the wild population had experienced a shift to later adult return and spawn timing, hypothesizing that this caused a reduction in spawning distribution, later fry emergence, a shortened growing season, and changes in juvenile migration. They attributed the shift to severely high adult harvest rates. McElhany et al. (2007) suggest that these changes may reverse themselves in response to recent reductions in harvest rates. Stray early-run coho from Eagle Creek Hatchery account for half or more of the fish surveyed in spawning areas within the portion of the subbasin below the sorting facility at Faraday (McElhany et al. 2007), although in Clear Creek, a major tributary that enters the Clackamas below the sorting facility, no hatchery-origin spawners have been found with natural-origin fish (Suring et al. 2006).
4.8.2.4 LCR Chum Salmon

McElhany et al. (2007) noted that chum salmon are now rarely observed in any of the Oregon tributaries to the lower Columbia River but that it is likely some low level of spawning has gone undetected in some areas. Recent genetic analysis of Washington chum suggests that very small remnant populations may have persisted even when there have been no consistent observations of fish (Small et al. 2006). Regardless, a lack of recent sightings of chum in the Clackamas subbasin suggests that the species is either absent or very nearly so. USFWS (2007) indicates that the species is “functionally extinct” in the subbasin.

4.8.2.5 LCR Steelhead

Population Viability
The population of LCR steelhead native to the Clackamas subbasin is in better condition than other Oregon populations within this evolutionary group. An assessment of the Clackamas population’s abundance, productivity, spatial structure, and diversity suggests a low to moderate risk of extinction (McElhany et al. 2007). Contributors to risks the population faces include:

- habitat degradation in the lower Clackamas subbasin and passage conditions [which are being improved] at PGE’s hydroelectric dams on the mainstem Clackamas (WRI 2004)
- potential genetic introgression from a non-local hatchery stock of winter steelhead that is now excluded from the upper subbasin but may still stray into natural spawning areas in the lower subbasin (McElhany et al. 2007);
- competitive displacement of native winter steelhead by introduced hatchery-origin summer steelhead that are now excluded from the upper subbasin but still present in the lower subbasin (Kostow et al. 2003)
- potential legacy effects on population productivity and diversity of a 22+ year period when the native run was excluded from habitats in the upper Clackamas subbasin (SPC&A 2001); and
- potentially catastrophic events with a moderate probability of occurrence, such as landslides, disease outbreaks from hatchery operations, and pollutant spills (WLCTRT 2003).

Abundance & Productivity
The Clackamas’ native winter steelhead population has a long-term geometric mean abundance of about 1,800 natural origin spawners (McElhany et al. 2007), and has recently rebounded from low abundances recorded during the 1990s (Chilcote 2007; Figure 4.8-5). The population’s abundance is high enough to suggest a low extinction risk, but there is moderate uncertainty in this assessment because of difficulties in evaluating the effects of stray hatchery fish and other factors on population productivity (McElhany et al. 2007).
Figure 4.8-5  Estimated abundance of natural-origin (“wild”) Clackamas late-run winter steelhead, 1958-2005 (data source: Chilcote 2007).

Spatial Structure
The spatial structure of Clackamas winter steelhead suggests a low risk of extinction, with moderate uncertainty (McElhany et al. 2007). Virtually all of the habitat historically accessible to winter steelhead in the Clackamas subbasin remains accessible to them (ODFW 2005b), but the population’s spatial structure has been affected by substantial habitat degradation in lower portions of the subbasin.

Diversity
McElhany et al. (2007) rated the diversity of the Clackamas’ native population of winter steelhead as reflecting a low to moderate risk of extinction, based on an examination of life history traits, effective population size, hatchery impacts, anthropogenic mortality, and habitat diversity. Their key concerns included the presence of non-native hatchery stocks of winter and summer-run steelhead in the lower subbasin, potential lingering effects of the 20+ year period of exclusion from the upper subbasin during the early 1900s, and diminished habitat quality in the lower subbasin.

4.8.2.6 Limiting Factors and Threats to Recovery
Factors unfavorably affecting the status of the Clackamas population of UWR Chinook and the Clackamas subbasin’s other ESA-listed populations of anadromous salmonids include a variety of within-basin dam effects, including imperfect fish passage, large hatchery programs, and the cumulative effects of multiple land and water use practices on aquatic habitat. Habitat degradation is a particular concern in the lower Clackamas subbasin, below the dams, where the
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historic capacity to produce anadromous salmonids has been substantially diminished (WRI 2004). Conditions affecting fish from these populations when in the lower mainstem Willamette and Columbia Rivers, some of them related to USACE Project dams and operations, are discussed in sections 4.10 and 4.11.

4.8.3 Environmental Conditions

4.8.3.1 Habitat Access

Anadromous salmonid passage to and from their habitats within the Clackamas subbasin is affected by PGE’s Clackamas River Hydroelectric Project and by migration impediments at road crossings of small streams (WRI 2004). Fish passage conditions at the hydroelectric project have been an important factor limiting anadromous fish production in the upper portion of the Clackamas subbasin (WRI 2004). Deficient conditions at road crossings are remedied as opportunities are identified.

Upstream Passage of Anadromous Fish at the Clackamas River Hydroelectric Project
Facilities for the passage of upstream migrating salmonids are currently provided at all three of PGE’s hydroelectric dams on the mainstem Clackamas River (Figure 4.8-6). Upstream passage is provided by two fish ladders: (1) the River Mill fish ladder, which provides passage over River Mill Dam into Estacada Lake; and (2) the Faraday-North Fork fish ladder, which spans 1.7 mi (2.7 km), allows sorting of fish at a trap near its entrance, and provides passage over both Faraday Diversion Dam and North Fork Dam. At the sorting trap, natural origin fish are returned to the ladder to resume their upstream migration, and hatchery fish are removed so they do not continue up the ladder. As part of the Biological Opinion on the Interim Operation of PGE Projects (NMFS 2003c) associated with relicensing the hydroelectric project, the River Mill ladder has just been rebuilt by PGE to bring its design and performance up to modern standards. Operational measures, such as a pulsed-flow regime down the Faraday Bypass reach, are being evaluated for their effectiveness at encouraging adult spring Chinook salmon to avoid potential migration delays at the Faraday Powerhouse and below the entrance to the Faraday-North Fork fish ladder.
Downstream Passage of Anadromous Fish at the Hydroelectric Project

PGE operates downstream fish passage facilities at the North Fork and River Mill dams, but not at Faraday Dam or the Faraday Powerhouse. The juvenile bypass facility at North Fork Dam, considered only partly effective (FERC 2006), consists of a surface collection system, the Faraday-North Fork fish ladder, a separator, an evaluation station, and a bypass pipeline. A portion of the juvenile salmonids migrating downstream from the upper Clackamas subbasin are attracted to a surface collection facility in North Fork Reservoir and are passed into the Faraday-North Fork fish ladder. Near the lower end of the 1.7-mi (2.7 km) long fish ladder, the downstream migrants pass through a “separator,” where they are screened out, passed through a passive integrated transponder (PIT)-tag detector, and then diverted into a pipeline that conveys them 5 mi (8 km) to the tailrace of River Mill Dam. The separator also collects a sample of fish into a holding box where they are counted, passed through a PIT-tag detector, and measured before being released into the downstream migrant pipeline. The outlet of the pipeline was just renovated to provide added protection of juvenile downstream migrants. Spilled flows up to 500 cfs pass through a screen that diverts juveniles to the juvenile bypass facility. Spilled flows exceeding 500 cfs are not screened and attract fish to a spillway shown to cause high levels of injury and mortality.

PGE follows spill management protocols at Faraday Dam that encourage fish to pass into the Faraday Bypass reach, rather than toward the Faraday Powerhouse via its diversion canal, whenever spills over North Fork Dam pass juveniles downriver. These protocols compensate for

Figure 4.8-6  PGE hydroelectric dams on the mainstem Clackamas River (source: Shibahara et al. 2001).
the lack of fish passage structures at Faraday and will remain in effect until the partial forebay net to be constructed at North Fork is proven effective.

River Mill Dam, originally constructed in 1910–1911, is an 85 ft high spillway dam and powerhouse between rock abutments. Since its initial construction there have been multiple modifications to address safety concerns and to improve fish passage, but recent evaluations identified additional passage improvements that would be helpful. As part of the Biological Opinion on the Interim Operation of PGE Projects (NMFS 2003c) associated with relicensing the hydroelectric project, PGE has modified the dam’s spillway to limit injury and mortality of juvenile salmonids passing downstream via that route.

**Other Passage Impediments**

Fish passage is impeded or blocked at multiple road crossings of small tributary streams in both the upper and lower portions of the Clackamas subbasin, and affects fish access to historical coho and steelhead habitat within both areas (WRI 2004). Such barriers are likely more frequent along tributary streams in the lower subbasin due to higher road density than in the upper subbasin. Within the Deep and Goose Creek watersheds, for example, WPN (2005) identified 39 partial or total migration barriers on fish-bearing streams. Artificial structures such as the dams that create farm ponds, common in the lower subbasin (WPN 2002, 2005), may also affect fish access to some areas.

### 4.8.3.2 Water Quantity/Hydrograph

Natural streamflows in the Clackamas subbasin, those to which the native salmonids are adapted, are similar to those described for other eastside tributaries to the Willamette River elsewhere in this document. Flows from the upper subbasin are greatest during major winter storms, remain relatively high during spring snowmelt, and decline during the summer dry season. Streams lower in the subbasin drain watersheds that receive little snowfall, are dominated by rainfall runoff, and experience earlier declines in flow than are seen at higher elevations in the upper subbasin. Natural streamflows in tributaries to the lower Clackamas tend to be very low during summer and early fall.

Flows within many of the subbasin’s streams have been influenced by landuse, but such changes are generally subtle in comparison to the effects of direct diversions of water for hydroelectric power generation, irrigation, residential use, or municipal and industrial use. PGE’s hydroelectric project has substantial local effects on flows in sections of the lower Oak Grove Fork and the mainstem Clackamas River that are important to anadromous salmonids. Other consumptive uses of water have altered seasonal flow patterns within lower portions of the subbasin, exacerbating low flow conditions and contributing to elevated water temperatures in many stream channels used by these fish.

#### 4.8.3.2.1 Flow Reductions

**Reductions for Hydropower Production**

Flow patterns in the 4.4 mile section of the Oak Grove Fork naturally accessible to anadromous fish, and in the 4.9 miles of the Clackamas River from the mouth of this tributary to PGE’s Oak Grove Powerhouse, are affected by large diversions of water (up to 585 cfs) from the tributary...
and to the powerhouse at RM 48 on the mainstem Clackamas. Flows in the Oak Grove Fork below the diversion point were historically quite stable due to strong groundwater influences within its watershed, but have for decades been severely diminished by hydropower operations that greatly reduce flows year-round and cut summer-fall minimums within the reach from perhaps 250-300 cfs to 0-10 cfs (McBain and Trush 2004).

Flows in the mainstem Clackamas between the Oak Grove Fork and Oak Grove Powerhouse are most altered by hydropower operations during periods of low flow, when the tributary would naturally contribute about 40-50% of the flow found below its mouth (McBain and Trush 2004).

Between the Oak Grove Powerhouse and North Fork Reservoir, daily average flows in the Clackamas River are relatively unaffected by PGE’s hydroelectric operations, but daily and weekly fluctuations downstream of the powerhouse are modified by power peaking (Gomez and Sullivan 2001). The peaking generally occurs on weekdays, in the morning and evening, and is discussed in section 4.8.3.2.2.

PGE also reduces flow substantially in the mainstem Clackamas River below Faraday Dam. Unless river flows exceed a diversion capacity of more than 5,000 cfs, a minimum flow of approximately 120 cfs has been maintained in the Faraday Bypass reach to provide upstream passage and rearing habitat for anadromous salmonids. This minimum constituted less than a quarter of the lowest flows reaching the dam each year. The sufficiency of the 120 cfs minimum flow, particularly for effective fish passage, has long been debated.

Below River Mill Dam, flows in the Clackamas River follow a natural seasonal pattern and cause localized flooding during many winters.

**Consumptive Uses of Water**

Valid rights for consumptive diversions of water from streams in the lower elevation watersheds tributary to Clackamas River below River Mill can approach or exceed natural summer low flows in some of these streams. Such situations have been documented in assessments of the Clear, Foster, Deep, and Goose Creek watersheds (WPN 2002, 2005). Although not all water rights are exercised concurrently when flows are at their lowest, water diversions within the lower subbasin do tend to reduce streamflows, diminish rearing space, and increase water temperatures in many of the smaller streams used by ESA-listed anadromous salmonid. For example, low summer flow conditions that appear barely adequate to unsuitable for salmonids have been reported in both the Rock and Richardson Creek watersheds (Ecotrust 2000).

Streamflow conditions within the lower Clackamas River’s tributary watersheds differ from those in the mainstem, because flows in the lower mainstem benefit from sustained late-season water yields from the upper subbasin. However, what appears to be relatively abundant high-quality water has made the lower Clackamas a key source area for long-range plans to continue expanding the region’s municipal/industrial water supply. The river now provides municipal water to over 200,000 residents in the Portland metropolitan region, and an increased demand for water is anticipated (EES 2004). At present, water providers, including the City of Lake Oswego, Clackamas River Water, the South Fork Water Board, and the North Clackamas County Commission, have Clackamas River water rights totaling nearly 300 cfs, about half of which are being exercised using existing diversion facilities. Expansions of diversion and treatment
facilities by the water providers are anticipated (EES 2004), and may at some point conflict with salmon conservation objectives. Consultants to the providers (Annear and Wells 2006) have developed a model to address mainstem water availability questions and examined the potential for supplementing lower Clackamas River flows with water stored in the upper subbasin.

4.8.3.2.2 Flow Fluctuations, Entrapment & Stranding
Unnaturally rapid declines in flow can cause losses of small juvenile salmonids, as noted on multiple occasions earlier in this document. Such changes in flow and river stage have occurred in the past along the mainstem Clackamas as a result of PGE’s operation of the Clackamas River Hydroelectric Project.

Potential losses of juvenile salmonids caused by rapid water-level fluctuations in the mainstem Clackamas downstream from power peaking operations at Oak Grove Powerhouse (RM 48) have been considered during field reconnaissance and hydraulic simulations of channel cross-sections measured at sensitive locations. Daily maximum down-ramp rates during summer and early fall (a period when salmonid fry are present and ramp rates are relatively high) were estimated to have averaged 0.17 ft/hr at the sensitive locations in 1998 and 0.16 ft/hr in 1999, and exhibited absolute peaks at 0.66 ft/hr each year (Doughty 2004). Studies summarized by Hunter (1992) suggest that the average rates estimated by Doughty should have been reasonably safe for small salmonids but not the annual peak rates.

Peaking operations at the Faraday Powerhouse are anticipated to pose lesser risks, because the powerhouse discharges almost directly into the upper end of the reservoir created by River Mill Dam (Estacada Lake).

4.8.3.3 Water Quality

4.8.3.3.1 Water Temperature
Salmonids are sensitive to changes in water temperature and can be unfavorably affected by shifts in thermal regimes during the summer rearing or spawning/incubation period. Unfavorable shifts in temperature have occurred in some streams used by anadromous salmonids in the upper Clackamas subbasin and a greater number of streams in the lower subbasin. For example, the ODEQ 2004/2006 Integrated Report database identifies 68.7 stream miles as exceeding temperature criteria for core salmonid rearing habitat (16°C), including segments of Collawash R. and Fish Cr. in the upper subbasin, plus Eagle Cr., N. Fk. Eagle Cr., and Bear Cr. in the lower subbasin. A combined 25.5 miles of the lower Clackamas R. and Cow Cr. have been identified as exceeding temperature criteria for general salmonid rearing (18°C), and an additional 25.1 miles of Eagle Cr., Nohorn Cr., and Collawash R. exceed temperature criteria for salmon and steelhead spawning habitat (13°C).

Elevated temperatures in Clackamas River tributaries are attributable to altered riparian vegetation and, in the lower subbasin, diminished streamflows. However, water quality modeling identifies PGE’s mainstem reservoirs as a significant source of heating and thermal alteration of the lower mainstem Clackamas (ODEQ 2006a, Figure 4.8-7). Heating that occurs in the reservoirs warms stored water and has caused a shift in temperature patterns downstream of River Mill Dam.
4.8.3.3.2 Other Water Quality Constituents

**Dissolved Oxygen**
Although Ecotrust (2000) suggests that low concentrations of dissolved oxygen occur in some small streams within the lower Clackamas subbasin, there is little data because monitoring of this water quality constituent in most of these streams has generally been limited. However, the ODEQ 2004/2006 Integrated Report database does not identify any streams within the Clackamas subbasin as being water quality impaired due to low concentrations of dissolved oxygen.

**Total Dissolved Gas**
The ODEQ 2004/2006 Integrated Report database does not identify any streams within the Clackamas subbasin that are known to have water quality impairment due to excessive TDG levels.

**Turbidity**
Suspended sediment and turbidity levels have been elevated in some streams within the lower Clackamas subbasin (WPN 2002). However, the ODEQ 2004/2006 Integrated Report database does not identify any streams within the Clackamas subbasin as being water quality impaired due to turbidity.
Nutrient levels are elevated in some streams within the lower subbasin but none of these streams are identified by the ODEQ 2004/2006 Integrated Report database as being water quality impaired for this reason. The database does, however, identify a combined 52.0 miles of 8 streams in the lower subbasin as water quality impaired by intermittently high concentrations of *E. coli* bacteria. These include the lower 15 miles of the mainstem Clackamas, as well as Deep Cr., N. Fk. Deep Cr., Tickle Cr., Cow Cr., Barfield Cr., Rock Cr., and Sieben Cr. There are a number of potential sources of the bacterial contamination, including livestock and poorly functioning septic systems in rural-residential areas. The Clackamas River itself receives effluent from Estacada and Clackamas waste treatment plants, and probably picks up contaminants from tributaries and non-point sources along its route.

Toxics

ODEQ has identified a risk of bio-accumulation of mercury in North Fork Reservoir.

**4.8.3.4 Physical Habitat Characteristics**

Unfavorable human influences on the physical characteristics of habitat for ESA-listed anadromous salmonids are greater in lower portions of the Clackamas subbasin, below River Mill, than they are above that dam. A key reason for this is the pattern of land ownership with most of the lower subbasin in private ownership and the upper subbasin publicly owned. Most of the upper subbasin is managed by the Mt. Hood National Forest which emphasizes aquatic conservation in its habitat management policies (USDA&USDI 1994).

Physical habitat quality is generally poorer in the lower subbasin due to reduced habitat diversity and increased levels of fine sediment (WRI 2004). The reductions in habitat diversity in the lower subbasin have been a function of a decline in large woody debris (LWD) and channel simplifications that have resulted from active manipulation and changes in riparian conditions. In many cases changes in stream conditions within the lower subbasin have been dramatic (SPC&A 2001). Habitat in the upper basin is in considerably better shape than that in the lower subbasin, but has also lost diversity in many areas due to reductions in LWD. These reductions have been due to changes in riparian forests and stream-cleaning efforts that occurred before the importance of wood in the creation and maintenance of high-quality salmonid habitats was fully understood.

**Substrate**

Substrate conditions within streams used by the Clackamas subbasin’s ESA-listed salmonid populations have been influenced by the effects of varied land-use activities. These effects tend to be more pronounced in the lower subbasin, where WRI (2004) has identified elevated levels of fine sediments as a frequent limiting factor. Along the mainstem Clackamas, trapping of coarse sediments in PGE reservoirs prevents delivery of an average of more than 66,000 yd³/yr of this material to the river channel below River Mill Dam (Wampler and Grant 2003). Over time this has caused dramatic riverbed coarsening, down-cutting, and channel simplification for 2 miles below the dam and contributed to changes in channel processes and features for as much as 9 miles below the dam (Wampler and Grant 2003). In combination with aggregate mining and isolation of the floodplain by bank protection structures, elimination of sediment delivery from
the upper subbasin has helped create a less dynamic lower river with fewer active sidechannels and less salmon spawning habitat.

**Large Woody Debris**

Streams within portions of the upper Clackamas subbasin retain substantial quantities of in-channel wood, but a combination of natural disturbances, timber harvest, road construction, and stream-cleaning have diminished the abundance of LWD and the condition of fish habitat in other parts of the drainage network above River Mill Dam (Everest et al. 1987; USFS 1988, 1995; Cramer et al. 1997). Past losses of LWD have been offset in some streams on the Mt. Hood National Forest by direct placements into channels where its abundance was low.

All LWD transported from watersheds above River Mill Dam is trapped within PGE reservoirs and cannot influence channel processes and habitat quality in the lower Clackamas River without active intervention. This lost LWD delivery has likely contributed to reductions in the complexity and quality of anadromous salmonid habitat in the river.

Similar losses of habitat function and quality due to reduced quantities of LWD have been common elsewhere in the lower subbasin. Past uses of channels and riparian vegetation have left instream abundances of LWD as well as wood recruitment potential low across much of the drainage network (SPC&A 2001; WPN 2002, 2005).

**Channel complexity, Off-channel Habitat & Floodplain Connectivity**

Stream channel complexity, off-channel habitats, and floodplain connectivity are important elements of high-quality salmonid habitat that have been reduced in the Clackamas subbasin, frequently as a result of low LWD abundance or direct channel manipulations. The reductions appear to have been acute in areas of relatively gentle topography within watersheds below River Mill, where agricultural development and urbanization often influence stream conditions. For example, WPN (2005) identified 21.5 miles of ditched channels in these types of areas within the Deep and Goose Creek watersheds. Off-channel habitat and floodplain connectivity along the lower Clackamas River have been affected by bank stabilization and diking (WRI 2004). The USACE maintains 1.6 miles of revetments it has constructed along the lower river between RM 1.5 and RM 20.1.

**Riparian Reserves & Disturbance History**

Riparian vegetation along streams within lower portions of the Clackamas subbasin is often recently disturbed or in early- to mid-successional stages as a consequence of man-caused disturbances, while that along streams within the upper subbasin more frequently includes older aged conifers (ODEQ 2006a). Conditions in the upper subbasin are improving, due to an increased focus on aquatic conservation by the U.S. Forest Service. However, the lower subbasin has predominantly private forestlands managed with less emphasis on aquatic conservation and is dominated by more intrusive agricultural, rural-residential, municipal, or industrial landuses in lowland areas or where the topography is gentle. Riparian vegetation provides variable but frequently good shading along streams in the lower subbasin, though along these streams it often consists of narrow bands of trees or shrubs and includes invasive species when bordered by non-forest landuses (Ecotrust 2000; WPN 2002, 2005). Along the lower Clackamas, bank protection structures such as the USACE revetments described in the last paragraph have removed riparian vegetation and contribute to deficiencies in LWD recruitment.
potential and shade. As indicated earlier, the near-term potential for riparian recruitment of LWD to streams is low across most of the lower subbasin.

### 4.8.4 Hatchery Programs

Hatchery programs for anadromous salmonids began operating in the Clackamas subbasin more than 100 years ago and have had a substantial influence on the subbasin’s wild runs of fish. Descriptions of the earliest programs, which focused on spring and then fall Chinook salmon (SPC&A 2001), raise substantial questions about the harm done to these runs. More recent programs within the subbasin are believed to be far more effective at returning adult fish, because of improvements in hatchery practices that began in the 1950s and 1960s. Hatchery programs within the subbasin have expanded to propagate Chinook salmon, coho salmon, and steelhead.

Hatchery produced spring Chinook and early-run coho smolts are released into the lower Clackamas subbasin each year. These programs have in the past focused almost exclusively on fishery augmentation, but are being modified so as to improve their consistency with ESA mandates for the conservation of natural-origin fish runs. All hatchery-origin salmon released into the subbasin are fin-clipped, allowing managers to screen any strays, other than a fraction with imperfect or regenerated fin clips, out of the upper basin run at Faraday. This fraction has been as high as 26% at times as described above in 4.8.2.1.

There are also three hatchery stocks of steelhead that are currently released into the Clackamas River, early-winter (introduced), late-winter (native), and summer run (introduced). Since 1999, only unmarked steelhead (those presumed to be natural-origin) have been allowed to pass above North Fork Dam. The ODFW Clackamas Hatchery currently rears a winter run broodstock (122W) developed from unmarked fish at North Fork Dam. The Big Creek Hatchery stock of winter steelhead returns to the Clackamas River from October to early March, earlier than the February to June run timing of the native winter steelhead (Murtagh et al. 1992). Furthermore, the peak spawning period for Big Creek derived fish is January to early March compared with May and June for native Clackamas River winter steelhead.

Hatchery summer steelhead that are released into the Clackamas River basin are fin-clipped and have been excluded from passage at North Fork since 1999. Prior to that time, these fish strayed to and spawned in streams within the upper subbasin that were used by wild winter steelhead (McElhany et al. 2007). The consequence for the wild late-winter fish was a reduction in productivity attributed to competition with the juvenile offspring of the summer steelhead (Kostow et al. 2003). The potential for stray hatchery summer steelhead to spawn and compete in streams with wild late-winter steelhead still present in the lower subbasin has not been studied.

### 4.8.5 Harvest

Recent harvest rates on the wild runs of ESA-listed anadromous salmonids in the Clackamas subbasin vary by species. Recently instituted marks-only regulations for the sport fishery and precautionary management of Columbia River commercial fisheries have lowered harvest mortality rates on the Clackamas subbasin’s wild population of UWR (spring) Chinook from an
average of about 55% prior to its listing under the ESA to approximately 20% today (Chilcote 2007). The freshwater sport and commercial fisheries are causing about half of this mortality, with the remainder reflecting an assumption of loss rates in ocean fisheries. Harvest rates on wild fall-run LCR Chinook such as are found at very low abundance in the lower Clackamas at present are managed to stay below a maximum combined Rebuilding Exploitation Rate (RER) of 49% in all ocean and freshwater fisheries. Freshwater harvest of wild LCR chum salmon is not allowed in Oregon and incidental handling in fisheries for other species is managed to keep maximum take below 2%. Harvest-related mortality rates for the Clackamas’ wild, late-run populations of coho salmon and winter steelhead are now about 30% and 5%, respectively (Chilcote 2007).

There is a very popular steelhead sport fishery on the Clackamas River. However, all hatchery steelhead are now fin-clipped and it is illegal to retain wild steelhead. Other than hooking mortality during catch-and-release, there appears to be little negative effect from harvest on wild LCR steelhead populations in the Clackamas.

4.8.6 Status of PCEs of Designated Critical Habitat in the Clackamas Subbasin

NMFS has determined that the following occupied areas of the Clackamas subbasin contain Critical Habitat for UWR Chinook, LCR Chinook, LCR Coho, LCR Chum, and LCR Steelhead (NMFS 2005g; NMFS 2005d – Maps are included in Section 3.3 of this Opinion):

**UWR Chinook (spring-run)**

- Habitat of high conservation value for these fish, and thus important to their recovery, is present within five of the six watersheds within the Clackamas subbasin. This habitat includes 110.4 miles of PCEs for spawning/rearing, 18.7 miles of PCEs for rearing/migration, and 0.0 miles for migration/presence (NMFS 2005g). All five of the watersheds containing habitat of high conservation value were designated as Critical Habitat (NMFS 2005d), as listed below:
  - The Collawash River watershed contains 16.9 miles of spawning/rearing habitat and 0.2 miles of rearing/migration habitat (NMFS 2005g).
  - The Upper Clackamas watershed contains 23.7 miles of spawning/rearing habitat and 1.8 miles of rearing/migration habitat (NMFS 2005g).
  - The Oak Grove Fork watershed contains 4.0 miles of spawning/rearing habitat (NMFS 2005g).
  - The Middle Clackamas watershed contains 33.9 miles of spawning/rearing habitat and 3.3 miles of rearing/migration habitat (NMFS 2005g).
  - The Lower Clackamas watershed contains 22.9 miles of spawning/rearing habitat and 13.4 miles of rearing/migration habitat (NMFS 2005g).

- Habitat of low conservation value to UWR Chinook was not designated as Critical Habitat (NMFS 2005d). The Eagle Creek watershed was given a low conservation value to UWR Chinook and contains 13.8 miles of spawning/rearing habitat and 3.2 miles of rearing/migration habitat (NMFS 2005g).
LCR Chinook (fall-run)

- These fish are found in two watersheds within the Clackamas subbasin, Lower Clackamas River and Eagle Creek (NMFS 2005g).
- The Lower Clackamas River watershed contains habitat of high conservation value for LCR Chinook that was designated as Critical Habitat (NMFS 2005d). This watershed segment contains 34.8 miles of spawning/rearing habitat and 2.7 miles of rearing/migration habitat (NMFS 2005g).
- Habitat of low conservation value to LCR Chinook was not designated as Critical Habitat (NMFS 2005d). The Eagle Creek watershed was given a low conservation value to LCR Chinook and contains 13.8 miles of spawning/rearing and 3.2 miles of rearing/migration habitat (NMFS 2005g)

LCR Coho Salmon

- NMFS has not yet designated Critical Habitat for this evolutionary group of anadromous salmonids, although these fish are found throughout much of the lower Clackamas subbasin and in portions of the upper subbasin.

LCR Chum Salmon

- NMFS did not designate Critical Habitat for LCR Chum Salmon within the Clackamas Subbasin (NMFS 2005d).

LCR Steelhead

- Habitat of high conservation value for these fish, and thus important to their recovery, is present within all six watersheds within the Clackamas subbasin. This habitat includes 263.3 miles of PCEs for spawning/rearing, 12.4 miles of PCEs for rearing/migration, and 2.8 miles for migration/presence (NMFS 2005g). The habitat in all of these watersheds, listed below, was designated as Critical Habitat for LCR Steelhead (NMFS 2005d).
  - The Collawash River watershed contains 34.0 miles of spawning/rearing habitat (NMFS 2005g).
  - The Upper Clackamas watershed contains 53.0 miles of spawning/rearing habitat (NMFS 2005g).
  - The Oak Grove Fork watershed contains 4.2 miles of spawning/rearing habitat (NMFS 2005g).
  - The Middle Clackamas watershed contains 45.6 miles of spawning/rearing habitat, 2.5 miles of rearing/migration habitat, and 0.4 miles of migration/presence habitat (NMFS 2005g).
  - The Lower Clackamas watershed contains 89.8 miles of spawning/rearing habitat and 9.9 miles of rearing/migration habitat, and 2.4 miles of migration/presence habitat (NMFS 2005g).
  - The Eagle Creek watershed contains 36.7 miles of spawning/rearing habitat (NMFS 2005g).

Table 4.8-1 summarizes the condition of PCEs within the Clackamas subbasin. All of the habitat indicators reflect sub-optimal conditions for salmon and steelhead.
Table 4.8-1 Critical habitat primary constituent elements (PCEs) and associated pathways, indicators, current conditions, and limiting factors for ESA-listed anadromous salmonids in the Clackamas subbasin under the environmental baseline.

<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Limiting Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater migration corridors</td>
<td>Habitat Access</td>
<td>Physical Barriers</td>
<td>Up- and downstream fish passage conditions at the Clackamas River Hydroelectric Project are a key limiting factor for upper basin fish runs.</td>
<td>Hydroelectric dams and reservoirs</td>
</tr>
<tr>
<td>Freshwater migration corridors</td>
<td>Habitat Access</td>
<td>Physical Barriers</td>
<td>Culverts beneath road crossings of streams impair anadromous fish access to some historical habitats within the upper subbasin.</td>
<td>Forest roads</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Culverts beneath road crossings and other physical structures on streams in the lower subbasin impede or block anadromous fish movements into some historical habitats within the lower subbasin.</td>
<td>Roads or other structures associated with forestry, agriculture, rural-residential land use, and urbanization</td>
</tr>
</tbody>
</table>
### Pathway & Indicator Table

<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Limiting Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater spawning sites</td>
<td>Water Quality</td>
<td>Temperature</td>
<td>The ODEQ 2004/2006 Integrated Report database identifies 68.7 stream miles as exceeding temperature criteria for core salmonid rearing (16°C), including segments of Bear Cr., Eagle Cr., and N.Fk. Eagle Cr. in the lower subbasin, and Collawash R. and Fish Cr. in the upper subbasin. The database also identifies a combined 25.5 miles of the lower Clackamas R. and Cow Cr. as exceeding criteria for general salmonids rearing (18°C).</td>
<td>Forest practices, agriculture, rural-residential development</td>
</tr>
<tr>
<td>Freshwater rearing</td>
<td>Water Quantity</td>
<td>Change in Peak/Base Flow</td>
<td>Naturally low summer flows are exacerbated in the lower subbasin by water withdrawals</td>
<td>Agricultural, rural-residential, municipal, and industrial development.</td>
</tr>
<tr>
<td>Freshwater migration corridors</td>
<td>Water Quantity</td>
<td>Change in Peak/Base Flow</td>
<td>The ODEQ 2004/2006 Integrated Report database identifies 25.1 miles of Eagle Cr., Nohorn Cr., and Collawash R. as exceeding criteria for salmon and steelhead spawning (13°C)</td>
<td>PGE hydroelectric reservoirs, land use practices</td>
</tr>
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<td>Freshwater rearing</td>
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</tr>
</tbody>
</table>
The ODEQ 2004/2006 Integrated Report database does not identify any streams within the Clackamas subbasin as water quality impaired due to turbidity.

Livestock, rural-residential, and municipal development.

Nutrient levels are elevated in some streams within the lower subbasin but none are identified by the ODEQ database as being water quality impaired for this reason.

Agricultural and rural-residential development
<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Limiting Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Water Quality</td>
<td>The ODEQ 2004/2006 Integrated Report database does not identify any streams within the Clackamas subbasin that are known to have water quality impairment due to low dissolved oxygen.</td>
<td>NA</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Water Quality</td>
<td>The ODEQ 2004/2006 Integrated Report database does not identify any streams within the Clackamas subbasin that are known to have water quality impairment due to excessive TDG levels.</td>
<td>NA</td>
</tr>
</tbody>
</table>
### PCE Pathway Indicator Condition Limiting Factor

<p>| Freshwater spawning sites | Habitat Elements | Substrate Channel substrate conditions within the Clackamas subbasin reflect the cumulative effects of past watershed development and current landuse. Elevated levels of fine sediments have the potential to limit salmonid production in the lower subbasin. Reservoirs above dams on the mainstem Clackamas River trap coarse sediment and block its delivery from the upper subbasin to the lower river. This has affected channel complexity and the availability of spawning gravels below River Mill Dam | Forest practices, road construction, and riparian alteration due to near-stream agricultural, rural-residential, and municipal development | PGE hydroelectric dams and reservoirs |
| Freshwater rearing sites Freshwater migration corridors | Habitat Elements Large Woody Debris Large woody debris (LWD) abundance and recruitment potential have been reduced along many streams, particularly in the lower subbasin where private lands predominate. Reservoirs above dams on the mainstem Clackamas River trap LWD and block its delivery from the upper subbasin to lower river. This has affected the complexity and quality of salmonid habitat in the lower Clackamas. | Forest practices, riparian alteration due to near-stream development, active wood removal | PGE hydroelectric dams and reservoirs |</p>
<table>
<thead>
<tr>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Limiting Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Habitat Elements</td>
<td>Channel complexity and the availability of off-channel habitats important to juvenile salmonids has been reduced by reductions in LWD, direct channel alterations that have included USACE construction of revetments along the lower Clackamas River, reduced coarse sediment supply in the Clackamas River below River Mille Dam, and floodplain development.</td>
</tr>
<tr>
<td>Watershed Conditions</td>
<td>Road density and location</td>
<td>Road densities are moderate to high across large portions of the Clackamas subbasin, and are generally highest in the lower subbasin.</td>
<td>Forestry, agriculture, rural-residential and other development.</td>
</tr>
<tr>
<td>PCE</td>
<td>Pathway</td>
<td>Indicator</td>
<td>Condition</td>
</tr>
<tr>
<td>-----</td>
<td>---------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Freshwater migration corridors</td>
<td>Watershed Conditions</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Freshwater migration corridors</td>
<td>Watershed Conditions</td>
</tr>
</tbody>
</table>

Forests in both the upper and lower portions of the subbasin have an abundance of early- to mid-successional stages, with many forestlands in the lower subbasin having been harvested at least two or three times.

The lower subbasin is partially forested but is generally dominated by agricultural, rural-residential, municipal, or industrial landuses in lowland areas or where the topography is gentle.

Riparian vegetation in both the upper and lower portions of the Clackamas subbasin is frequently in early- to mid-successional stages as a consequence of past human-caused disturbances. Conditions in the upper subbasin are improving, due to an increased focus on aquatic conservation by the U.S. Forest Service. Riparian conditions in the lower subbasin, particularly in areas of low topographic relief where agricultural, rural-residential, or municipal landuses predominate near streams are often poor. Opportunities for improvement may be limited in urbanizing areas.

Timber harvest

Other land uses

Forest practices, agricultural practices, rural-residential development, and urbanization.
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Section 4.9
Coast Fork & Long Tom Baseline
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4.9 COAST FORK & LONG TOM SUBBASINS

Seven subbasins drain all but a very small fraction of the west side of the Willamette Basin, between the mainstem Willamette River and the Coast Range (Figure 4.9-1). These westside subbasins include the Coast Fork Willamette, Long Tom, Marys, Luckiamute, Rickreal, Yamhill, and Tualatin. The Coast Fork (draining 665 mi^2) and Long Tom (410 mi^2) are both currently occupied by UWR Chinook (rearing juveniles) and are affected by USACE flood control operations. In addition, the USACE is consulting on the maintenance of revetments in the Row River (Coast Fork subbasin). Therefore, the Coast Fork and Long Tom subbasins below the Corps dams are within the action area for this consultation. Westside subbasins differ in several respects from those found in the eastern portion of the basin and discussed earlier in this document. Westside subbasins tend to have gentler topography, lower elevation headwaters, no spring snowpack, and summer baseflows that are naturally quite low. The majority of forestland within each subbasin is privately owned, and about half or more of that in the Long Tom lies within lowland areas converted to agricultural, rural-residential, or other ecologically disruptive land uses. Efforts to restore anadromous salmonid habitat within these subbasins will generally depend more strongly upon changes in private land management than will be the case in most of the Willamette’s eastside subbasins. Due to relatively limited historical use by anadromous salmonids and uncertainty that they ever supported persistent, self-sustaining runs of UWR Chinook or UWR steelhead (Meyers et al. 2003), the westside subbasins are not anticipated to be a major focus of efforts to recover these fish (e.g., see ODFW 2007b).

In the Coast Fork subbasin, Cottage Grove Dam on the Coast Fork Willamette River (RM 29) and Dorena Dam on the Row River (RM 7.5) lack passage facilities. Above these two dams, the Umpqua National Forest and the Bureau of Land Management’s Eugene District manage federally-owned public lands for multiple uses, and privately-owned lands are generally used for timber production and some agriculture. Mercury mined or leached from rich deposits above both dams creates health risks in waterbodies downstream (ODEQ 2006a). In addition, sand and gravel are mined from the channels in the lower Coast Fork Willamette and Row rivers, and adjacent bottomlands have been developed for agriculture.

Fern Ridge Dam on the Long Tom (RM 15) has regulated flow since 1941. The lower reaches have been extensively modified (channels straightened and diked for flood control). The river was severely degraded prior to dam construction, and Parkhurst et al. (1950) stated that its value to anadromous salmonids was doubted in 1938. Lowland portions of the subbasin are dominated by agriculture but include the urban landscape found in and around the city of Eugene (Thieman 2000).
Figure 4.9-1  Map of the Willamette Basin with an emphasis on the Coast Fork Willamette and Long Tom
4.9.1 Historical Status of Anadromous Salmonids in the Coast Fork Willamette and Long Tom Subbasins

4.9.1.1 UWR Chinook Salmon

The Myers et al. (2002) did not identify either the Coast Fork or Long Tom subbasin as having supported a historical, demographically independent population of UWR Chinook salmon. However, the lower (valley floor) reaches of these streams were likely important as seasonal rearing areas for juvenile Chinook from populations that spawned in the Willamette’s eastside tributaries. Historical accounts do indicate that small numbers of spawning UWR Chinook were once present in the Coast Fork (Dimick and Merryfield 1945), but these stocks had become depleted by the time their presence was documented by biologists.

The historical distribution and abundance of UWR Chinook within the Coast Fork subbasin are uncertain. Native spring-run Chinook were reported to have once spawned in the Row River drainage above the site of Dorena Dam (Dimick and Merryfield 1945), but any native run was probably extirpated by splash dams used in early logging operations (USFWS 1948). Even less is known about the historical use (or lack of use) of other parts of the subbasin. A 1938 survey by the Bureau of Commercial Fisheries attributed a lack of anadromous salmonids in the mainstem Coast Fork at that time to artificial passage obstructions and water pollution (McIntosh et al. 1995).

4.9.1.2 UWR Steelhead

Information on the historical distribution of UWR steelhead above Willamette Falls is incomplete, but it is generally thought that significant populations of these fish were restricted to the Willamette’s largest eastside tributary systems from the Calapooia downriver to the Molalla. WLCTRT (2003) identified four historically independent populations above the Falls, each within a subbasin draining the Cascade Range, but none native to the Willamette’s westside subbasins.

4.9.2 Current Status of Anadromous Salmonids in the Coast Fork Willamette and Long Tom Subbasins

4.9.2.1 UWR Chinook Salmon

Little information exists regarding the current abundance of naturally produced UWR Chinook salmon in the Coast Fork Willamette and Row rivers. Myers et al. (2003) did not consider UWR Chinook that spawn and rear in the Coast Fork subbasin likely to constitute an independent population. Symbiotics (2005) found no adult or juvenile Chinook salmon during surveys in the lower Row River below Dorena Dam in 2003 through 2005.

In multiple years since 1998, ODFW released adult hatchery-origin spring Chinook into Mosby Creek, the largest below-dam tributary to Row River, to see whether these fish would spawn successfully and produce viable offspring in that stream (Table 4.9-1). This effort became more formal in 2006, when ODFW began to record water quality in the area, survey spawning areas,
estimate the habitat capacity of Mosby Creek, and trap juvenile Chinook produced by the outplanting effort (Moberly 2008). Results of this monitoring have shown that pre-spawn mortality is relatively high (59% of 73 carcasses recovered during 2006 and 2007 failed to spawn); however, some of the adult fish released into Mosby Creek are spawning successfully in the stream and some of its tributaries and are producing juvenile spring Chinook (Moberly 2008).

**Table 4.9-1  Annual numbers of adult, hatchery-origin spring Chinook salmon released (outplanted) into Mosby Creek in the Coast Fork Subbasin, 1998-2007**

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of adult spring Chinook released into Mosby Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>221</td>
</tr>
<tr>
<td>1999</td>
<td>0</td>
</tr>
<tr>
<td>2000</td>
<td>212</td>
</tr>
<tr>
<td>2001-05</td>
<td>0</td>
</tr>
<tr>
<td>2006</td>
<td>119</td>
</tr>
<tr>
<td>2007</td>
<td>43</td>
</tr>
</tbody>
</table>

The Long Tom subbasin is not thought to have supported a spawning population of anadromous salmonids. Recent sampling by ODFW indicates that yearling Chinook may over-winter in the lower Long Tom, when temperatures are within criteria for salmonid rearing (Kenaston 2003). Schroeder et al (2005) found juvenile Chinook during winter in non-natal tributaries to the Willamette as far as 23.3 miles from the mainstem; however he did not report finding them this high in the Long Tom River. Small dams in the river’s lower 12 miles (as described in section 4.9.3.1) likely block juvenile and adult fish from accessing much of the Long Tom. Additionally, fish habitat from Fern Ridge Dam downstream to the mouth has been lost as a result of flow management from Fern Ridge Dam, land use changes, and bank protection projects. These past and ongoing actions have degraded riparian vegetation, floodplain function, large wood and sediment transport functions, and channel complexity.

### 4.9.2.2 UWR Steelhead

Modest numbers of naturally spawning steelhead are present now in some of the Willamette’s westside tributaries, but there is considerable debate as to whether the existing fish are native or derived from introduced stocks (Myers et al. 2003). Hatchery summer steelhead have been observed spawning in the Coast Fork subbasin, but Parkhurst et al. (1950) did not report the presence of winter steelhead in westside streams.

### 4.9.2.3 Limiting Factors and Threats to Recovery

UWR Chinook and UWR steelhead, particularly those populations that are key to the long term viability of their respective species, make limited use of aquatic habitats in the westside subbasins. Habitats within these subbasins that are most frequently used by the eastside populations are seasonally suitable (i.e., fall-winter) lowland channels or associated backwater areas near the mainstem Willamette River. These habitats have been substantially degraded by...
direct alterations of stream channels and floodplains as well as by more than a century of cumulative watershed effects (USACE 2000, WRI 2004, and others). The degraded condition of these habitats likely has small, negative effects on the abundance and productivity of the ESA-listed populations that use them.

4.9.3 Environmental Conditions

Environmental conditions within the westside subbasins that affect UWR Chinook or UWR steelhead are described below. These habitat elements and their existing baseline condition are summarized in Table 4.9-3 at the end of this section.

4.9.3.1 Habitat Access

A number of migratory obstacles and barriers affect the ability of salmonids to migrate freely within the westside subbasins (WRI 2004). These include a variety of low and high dams plus large numbers of road culverts that are partial or complete fish barriers. The general relationship between such migratory impediments and the habitat requirements of UWR Chinook salmon and steelhead are described in Appendix E.

Six dams constructed by the USACE have the potential to impede anadromous salmonid access to habitats in the Coast Fork and Long Tom subbasins: Dorena and Cottage Grove in the Coast Fork subbasin, and Fern Ridge plus three smaller dams (Monroe, Stroda, and Ferguson) on the mainstem Long Tom River.

Dorena & Cottage Grove Dams in the Coast Fork Subbasin

There are no up- or down-stream passage facilities at either of these dams. However, as described in section 4.9.1.1, UWR Chinook may once have used areas above these dams for spawning and rearing, but few native anadromous salmonids now stray into the Coast Fork or Row River.

Barriers below Fern Ridge Dam on the Long Tom River

A 10-foot high concrete grade-control dam spans the Long Tom River at the town of Monroe (RM 6.7) and two more grade-control dams (Stroda at RM 10.2 and Ferguson at RM 12.7). These small dams were constructed by the USACE to address channel erosion associated with the Project and only one (Monroe) has a fish ladder. Schroeder and Kenaston (2004) noted that juvenile Chinook were captured near the lower dam at Monroe. The ladder at the Monroe Dam is in disrepair and probably does not effectively pass juvenile fish into upstream rearing habitat in the Long Tom River. Neither of the other two grade-control dams is equipped with passage structures.

Fern Ridge Dam on the Long Tom River

The USACE owns and operates Fern Ridge Dam on the Long Tom River (RM 25.7). The dam lacks fish passage facilities. However, there is no evidence that juvenile Chinook or steelhead use habitat that far upstream, and the lack of passage facilities at two of the grade-control dams downstream likely precludes them from reaching Fern Ridge Dam.
4.9.3.2 Water Quantity/Hydrograph

Westside subbasins experience high streamflows during late fall through winter followed by declining or low flows until fall. Natural low summer and early fall flows in these subbasins limit habitat availability for salmonids and the situation is exacerbated by diversions from streams for agricultural, domestic, and industrial uses. Permits that have been issued for such diversions often have aggregate flow volumes that exceed the amount of water naturally available during low flow periods. Although actual water withdrawals are typically lower than allowed by permit, volumes of water that are withdrawn stress these aquatic systems.

The OWRD water availability process (OAR 690-400-011) has determined that no additional natural flow is available for out-of-stream use from the westside subbasins for periods ranging from 1 to 10 months, depending on the existing level of water development in each subbasin.

USACE dams have diminished flooding and augmented late-season flows in the lower Coast Fork Willamette and Long Tom rivers. These hydrologic effects, and their implications for native anadromous salmonids, are discussed below.

**Coast Fork Subbasin**

Operation of Dorena and Cottage Grove dams has affected seasonal flow patterns in the lower Coast Fork Willamette River and lower Row River (Figures 4.9-2 and 4.9-3). The greatest project-induced reduction in flow below these dams has been during February; the project lowers median daily flows during that month by about 48% in the lower Coast Fork and by about 41% in the lower Row River. The project has reduced median daily April flows by 38% and increased median daily August flows by 92% in the Coast Fork below Cottage Grove Dam. The project has reduced median daily April flows by 20% and increased median daily August flows by 156% in Row River below Dorena Dam. In both rivers, natural flows are lowest in the summer and early fall, but the USACE stores winter floods, redistributing and releasing water later in the year for the purpose of augmenting flows in the mainstem Willamette River.
Figures 4.9-2 A, B & C  Simulated discharge (cfs) of the Coast Fork below Cottage Grove Dam under unregulated conditions (Unreg), with project operating criteria prior to 2000 (Pre-2000), and with project operating criteria after 2000 (Post-2000), depicting the 80th, 50th (median), and 20th percentile for each scenario.

Figure 4.9-2 A

Figure 4.9-2 B
Figures 4.9-3 A, B & C. Simulated discharge (cfs) of Row River below Dorena Dam under unregulated conditions (Unreg), with project operating criteria prior to 2000 (Pre-2000), and with project operating criteria after 2000 (Post-2000), depicting the 80th, 50th (median), and 20th percentile for each scenario.

Figure 4.9-3 A
Figure 4.9-3 B

Figure 4.9-3 C
The USACE attempts to release authorized minimum flows at Dorena and Cottage Grove dams. At Dorena Dam these flows are 190 cfs from December through June and 100 cfs from July through November. At Cottage Grove Dam these flows are 75 cfs from December through June and 50 cfs from July through November. Actual flows are below these targets when necessary to reduce downstream flood risk and during other project-related emergencies. The lowest natural daily mean flow recorded at the Goshen gage was 36 cfs in September 1909. Following dam construction, the lowest daily mean flow has been 86 cfs, observed in November 1953.

The Coast Fork supplies water for domestic, industrial, and agricultural uses. The OWRD has issued permits for surface water withdrawals of up to 177 cfs from the Coast Fork Willamette River (OWRD 2003). This is a maximum allowable diversion and actual withdrawals are typically lower than allowed by permit. Due to high water demands downstream, the OWRD water availability process (OAR 690-400-001) has determined that natural flow is not available for out-of-stream use from the Coast Fork Willamette River during February through November. Further, the Willamette Basin Program Classifications (OAR 690-502-0110) require that new surface water users in the subbasin obtain water service contracts from USBR (i.e., for irrigation use of water stored in Willamette Project reservoirs during the summer months). The USBR has issued contracts for a total of 1,272 acre-feet of water stored in Cottage Grove and Dorena reservoirs to be diverted from the Row and Coast Fork Willamette Rivers (USACE 2007a).

Summer streamflows below the USACE dams in the Coast Fork subbasin are higher now than they were before dam construction. Summer is a period of rapid growth for juvenile Chinook salmon, and this increase in flows likely offsets other water diversions and provides some benefit for juvenile Chinook salmon growth and survival. However, with very low use of the Coast Fork watershed by anadromous fish, this benefit would only be realized for fish holding and rearing near the mouth of the Coast Fork Willamette, and possibly in the mainstem Willamette River.

**Long Tom Subbasin**

Operation of the Fern Ridge project has altered seasonal flow patterns downstream in the Long Tom River (see Figure 4.9-4). The project has reduced average daily April flows by 39% and has increased average daily August flows by 238% at the Monroe gage. Post-project summer flows are generally greater than they were historically because the USACE releases water as required to serve irrigation demand while meeting minimum flow targets in the summer months at Monroe on the Long Tom River. Fern Ridge Reservoir is not drafted to meet instream flow requirements on the mainstem Willamette River during the summer because of its high priority for reservoir recreation.

The USACE attempts to release its authorized minimum flows of 50 cfs from December through June and 30 cfs from July through November. However, the USACE releases flows below these targets when necessary to reduce downstream flood risks and during other emergencies. Prior to dam construction, the lowest flow recorded at Alvadore, Oregon (USGS Station No. 14169000), immediately downstream from Fern Ridge Dam, was 7 cfs during October 1939. The lowest flow recorded since the project was completed was 2 cfs, observed during October 1945. In recent years, discharges have rarely been less than 20 cfs.

The Long Tom River is used extensively to supply water for domestic, industrial, and agricultural activities. The OWRD has issued permits for surface water withdrawals for 331 cfs
from the Long Tom River. This is a maximum allowable diversion right and actual diversions are lower at any particular time. The OWRD water availability process (OAR 690-400-011) has determined that natural flow is not available for out-of-stream use from the Long Tom River during August. Further, the Willamette Basin Program Classifications (OAR 690-502-0110) require that new surface water users in the subbasin obtain water service contracts from USBR for irrigation uses of water during summer months. The USBR has issued contracts totaling 24,053 acre-feet of water from Fern Ridge Reservoir to be diverted from the Long Tom River (USACE 2007a).

There is no known anadromous fish reproduction in the Long Tom subbasin. The only known use of the Long Tom River by anadromous fish is occasional use by rearing juveniles when conditions are favorable (fall through spring). By reducing spring flows, the operation of the Fern Ridge project reduces available juvenile rearing habitat during the spring in the Long Tom River. Because such use is small, this adverse effect is estimated to have only a slight effect on UWR Chinook or steelhead.

![Graph showing average daily streamflow in the Long Tom River](image_url)

*Figure 4.9-4. Mean monthly discharge in the Long Tom River at Monroe (USGS gauge no. 1417000), before (1922-1940) and after (1942-1987) construction of Fern Ridge Dam.*
4.9.3.2.1 Peak Flow Reduction

Reductions of natural peak flows can diminish dynamic channel forming processes that are important to creating and maintaining high-quality salmonid habitats in rivers. Project operations have caused such reductions to occur along large river channels in both the Coast Fork and Long Tom subbasins.

Coast Fork Subbasin

Flows in the Coast Fork and Row rivers have been controlled by Dorena and Cottage Grove dams since the 1940s. Flood control operations at the two dams have substantially decreased the magnitude and frequency of extreme high flow events in the lower reaches of the rivers. Flows greater than 15,000 cfs were common in the Row River near Cottage Grove, Oregon before the construction of Dorena Dam (USACE 2000). Since construction, the two-year recurrence interval event has decreased from about 11,100 cfs to about 4,900 cfs, but flows up to 15,000 cfs have occurred on rare occasions. Although the pre-dam flow record below Cottage Grove Dam is not long enough to conduct a similar comparison, the degree of flood flow reduction in that location is probably similar to that observed on the Row River downstream from Dorena Dam.

Reductions in peak flows caused by flood control operations at Cottage Grove and Dorena dams have contributed to a loss of habitat complexity in the lower Coast Fork Willamette River by substantially reducing the magnitude of the channel-forming dominant discharge (i.e., the 1.5- to 2-year flood) and greatly extending the return intervals of larger floods. Over time, flood control tends to reduce channel complexity (e.g., reduces the frequency of side channels, and large wood recruitment) and reduces the movement and recruitment of channel substrates. Side channels, backwaters, and instream large wood accumulations have been shown to be important habitat features for rearing juvenile salmonids.

Operation of USACE’s Cottage Grove and Dorena dams is only partly responsible for the reduction in channel complexity noted in the lower Coast Fork. Bank stabilization measures and land leveling and development in the basin have directly reduced channel complexity and associated juvenile salmon rearing habitat (see section 4.9.3.4).

Long Tom Subbasin

Fern Ridge Reservoir has regulated flow in the Long Tom River since 1941. Flood control operations at Fern Ridge Dam have decreased the magnitude and frequency of extreme flow events, although the overall reduction has been relatively small compared to that caused by other Willamette Basin projects. The highest flow on record at Monroe, Oregon (USGS Station No.14170000), 19,300 cfs, occurred in 1943, 2 years after Fern Ridge was completed (USACE 2000). Operation of Fern Ridge Dam has reduced magnitude of the 2-year recurrence interval flood event from greater than 8,000 to less than 5,000 cfs (see Figure F-27 in USACE 2000).

Reductions in peak flows have contributed to a loss of habitat complexity in the lower Long Tom River by reducing the magnitude of the channel-forming dominant discharge (i.e., the 1.5- to 2-year flood) and greatly extending the return intervals of larger floods. However, virtually the entire reach of the Long Tom River has been channelized, straightened, leveed, or otherwise modified by projects related to drainage and irrigation (Thieman 2000).
At the time of construction, maintaining channel complexity for anadromous fish was considered a minor concern along the lower Long Tom River because the system did not appear to support either migratory or resident salmonids (U.S. Engineer Office 1939; Craig and Townsend 1946). However, ODFW caught yearling Chinook in a screw trap in the lower Long Tom River (about 7 miles from the Willamette) in recent years, indicating that this area may be used as winter rearing habitat (Schroeder and Kenaston 2004).

4.9.3.2.3 Effects of Seasonal Flow Patterns on Spawning Success
Native anadromous salmonids are not known to spawn at present in the Coast Fork below Cottage Grove Dam nor in Row River below Dorena dams, and it seems unlikely that they have ever spawned in the Long Tom River above or below Fern Ridge Dam. If the offspring of adult UWR Chinook outplanted into Mosby Creek were to return as adults and spawn below Dorena Dam on the Row River, flows that are greatly elevated by reservoir drafting operations during the September-October spawning period may encourage fish to use areas near the channel margins that could become dewatered during periodic flood-control operations during late fall and winter. Chinook embryos incubating in redds constructed along the channel margins would thus be at risk of mortality due to dewatering. However, although there are no data available regarding adult returns from the Mosby Creek outplanting effort, it is likely that most returns would spawn in Mosby Creek rather than in the mainstem Row River below Dorena Dam.

4.9.3.2.4 Flow Fluctuations, Entrapment, and Stranding
Rapid fluctuations in flow levels below hydropower or flood control dams have the potential to kill young salmonids by trapping and stranding them on exposed riverbed surfaces. Such risks are present below USACE dams in the Coast Fork and Long Tom subbasins during major storm events in late fall through winter, when flows below the dams can drop quickly in order to reduce the potential for flooding downstream along the mainstem Willamette River.

Coast Fork Subbasin
There are currently no powerhouses at the Dorena or Cottage Grove projects. Symbiotics LLC has proposed to install turbines and a powerhouse at Dorena Dam, but this proposal would not alter operations (Symbiotics 2004). Rapid fluctuations in discharge would occur only during flood control or other emergency operations. The USACE currently operates both the Dorena and Cottage Grove projects with no limit on the rate of discharge reduction during high flow conditions. Under low flows the downramping rate is 200 cfs per hour and 500 cfs per day at Dorena Dam and 100 cfs per hour at Cottage Grove. No specific studies have been conducted documenting the effects of downramping at Dorena or Cottage Grove dams. With little current or future expected use of the Coast Fork Willamette River by spring Chinook, these issues may be of limited consequence for the recovery of ESA-listed anadromous salmonids in the Willamette Basin.

Long Tom Subbasin
There is no powerhouse at the Fern Ridge project. Rapid fluctuations in discharge would occur only during flood control or some other emergency operation. The USACE currently operates the Fern Ridge project to limit the rate of change in discharge (increasing and decreasing) to 200 cfs per hour during low flows, and during high flows, tries to limit upramping to 750 cfs per hour with a maximum rate of 1,000 cfs per hour. There is no limit on downramping rates during high flows.
The principal risk that flow fluctuations pose for anadromous salmonids is the potential for entrapment and stranding of rearing juveniles during rapid winter down-ramping operations. UWR Chinook salmon are known to rear in the lower 7.6 miles of the Long Tom River and may be affected by ramping at Fern Ridge, though no data are available to document the frequency or severity of this potential effect.

4.9.3.3 Water Quality

Water quality is impaired in many streams within the Willamette’s westside subbasins, particularly in lowland areas affected by agricultural, rural-residential, and urban development. Much of the Willamette River’s non-point source pollution originates within these subbasins. Common water quality problems found within them include elevated temperatures, increased nutrient concentrations (particularly phosphorous), bacterial contamination, and lowered levels of dissolved oxygen. In the Coast Fork subbasin, mercury is also a problem. TMDLs and associated Water Quality Management Plans have been developed to address these problems.

The following sections discuss water quality conditions specific to the Coast Fork and Long Tom subbasins, in areas where Willamette Project dams may affect ESA-listed salmonids. Mercury contamination in the Coast Fork and Row River below USACE dams has the potential to affect the health of fish residing in those waterways and make re-establishing self-sustaining anadromous salmonid populations in those rivers difficult.

4.9.3.3.1 Water Temperature

Warm summer temperatures are a chronic problem in many streams within the westside subbasins. This problem appears reduced in the lower Coast Fork and Row rivers by Project dams that then elevate river temperatures during fall in ways that would be unfavorable for naturally spawning UWR Chinook if present. Warming that occurs in Fern Ridge Reservoir may warm summer temperatures in the lower Long Tom River.

Coast Fork Subbasin

The ODEQ 2004/2006 Integrated Report Database indicates that summer water temperatures are warmer than criteria for salmonid rearing and migration in the Coast Fork Willamette and Row rivers below Cottage Grove and Dorena dams. Exceedences have also been reported in some unregulated reaches within the subbasin (i.e., not affected by Willamette Project flow management). A TMDL for the Willamette Basin was approved for temperature in 2006 (ODEQ 2006a). In that TMDL, ODEQ identified target temperatures for releases below Cottage Grove and Dorena dams, based on the seasonal temperature patterns of water entering the reservoirs immediately upstream (Table 4.9-2).
Table 4.9-2  Monthly rolling average of 7-day median temperatures downstream of Cottage Grove and Dorena dams, and established ODEQ monthly target temperatures (ODEQ 2006a, Chapter 4). No data presented for December through March; allocations/targets were not determined necessary for November through March.

<table>
<thead>
<tr>
<th>Month</th>
<th>Cottage Grove Release Temperatures</th>
<th>ODEQ Target for Cottage Grove Releases</th>
<th>Dorena Release Temperature</th>
<th>ODEQ Target for Dorena Releases</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>9.5</td>
<td>9.4</td>
<td>8.8</td>
<td>8.8</td>
</tr>
<tr>
<td>May</td>
<td>10.4</td>
<td>11.4</td>
<td>10.2</td>
<td>10.8</td>
</tr>
<tr>
<td>June</td>
<td>11.9</td>
<td>15.5</td>
<td>11.1</td>
<td>16.5</td>
</tr>
<tr>
<td>July</td>
<td>13.7</td>
<td>19.9</td>
<td>13.3</td>
<td>22.3</td>
</tr>
<tr>
<td>August</td>
<td>17.1</td>
<td>18.3</td>
<td>13.2</td>
<td>20.4</td>
</tr>
<tr>
<td>September</td>
<td>19.5</td>
<td>16.4</td>
<td>14.1</td>
<td>18.2</td>
</tr>
<tr>
<td>October</td>
<td>15.5</td>
<td>13.5</td>
<td>16.2</td>
<td>15.3</td>
</tr>
<tr>
<td>November</td>
<td>10.6</td>
<td>--</td>
<td>10.3</td>
<td>--</td>
</tr>
</tbody>
</table>

As illustrated in Table 4.9-2 (above), both Cottage Grove and Dorena dams modify natural temperature patterns in downstream reaches. These modifications include cooler summer water temperatures (Jun-Aug) and warmer fall water temperatures (September-October). Cooler summer temperatures make the rivers below the dams more hospitable for juvenile salmonid rearing at that time of year. Elevated temperatures during September and October make the rivers less suitable for use by spring Chinook by lowering egg survival rates, accelerating the development of any embryos incubating in riverbed gravels, and causing fry to emerge earlier than is optimal for survival and growth.

Long Tom Subbasin
According to the ODEQ’s 2002 CWA section 303(d) database, 98% (41/42) of the summer temperature measurements taken at RM 4.7 in the Long Tom River exceeded maxima for salmonid rearing and migration (17.7°C; 64°F) during the period 1986 through 1995 (ODEQ 2002). The maximum measured value was 29°C (84.2°F), which can be lethal to juvenile salmonids (Appendix A, Table A-2). The ODEQ listed the entire mainstem Long Tom below Fern Ridge Dam as water quality-limited for temperature. The Long Tom Watershed Council (Thieman 2000) reported that 36% of 45 temperature measurements collected in the reach below Fern Ridge Dam during the 1990s exceeded summer maxima for non-core rearing and juvenile and adult migration (64°F), a status the LTWC considered “moderately impaired.” During winter, when temperatures are below the maximum for rearing, the ODFW has captured juvenile spring Chinook in a screw trap in the lower Long Tom near Monroe (Kenaston 2003). These fish probably rear in the lower Long Tom before emigrating from the system the following spring.

High water temperatures are likely to preclude juvenile Chinook from rearing in the lower Long Tom River during summer. The Thieman (2000) reported that water temperature conditions in tributaries to Fern Ridge Reservoir were “moderately impaired” and that Fern Ridge Reservoir itself was “impaired.” Given the reservoir’s shallow depth, and the residence time of water
within the reservoir, it is possible that USACE operations at Fern Ridge are responsible for elevated temperatures in the lower Long Tom River.

4.9.3.3.2 Dissolved Oxygen
Dissolved oxygen levels were once an issue in the lower reaches of many lowland streams in the westside subbasins, and remain so in some of them today. Within the Coast Fork and Long Tom subbasins, flows augmented by Project reservoirs have helped reduce such problems in the lower Coast Fork and Long Tom rivers.

Coast Fork Subbasin
In July and August 1994, the USGS documented the spatial extent and daily variability of dissolved oxygen concentrations in selected reaches of the upper Willamette River basin (Pogue and Anderson 1995). Results of the study indicated that the Coast Fork Willamette River from RMs 21.7 to 12.5 had dissolved oxygen concentrations that fluctuated below ODEQ’s numerical criteria, presumably due to the breakdown of treated sewage effluent. The ODEQ 2004/2006 Integrated Report database confirms that the Coast Fork below Cottage Grove Dam continues to experience dissolved oxygen conditions that do not fully support salmon and steelhead spawning but that will support other river uses by cold-water aquatic life (ODEQ 2006b). A TMDL was approved in 1996 for this reach.

Dissolved oxygen is known to fall below desirable concentrations in the lower levels of Dorena Reservoir, but there are few records of low dissolved oxygen occurring in Row River below Dorena Dam. When monitored during 2003 and 2004, dissolved oxygen concentrations dropped below ODEQ’s absolute minimum of 6.5 mg/L for cold water habitat in the bottom waters of the reservoir in July or August, but not in the river downstream (Symbiotics 2006). Water is aerated as it is released from the dam through the existing outlet gates, resulting in DO levels ranging from just below 10 to over 12 mg/L below the dam.

ODEQ maintains a Row River monitoring site 5 miles downstream of Dorena Dam. The ODEQ 2004/2006 Integrated Report database indicates that at this site, 1 out of 16 samples did not meet DO criteria for cold-water aquatic life (i.e., too DO low); and 0 out of 3 samples did not meet the criteria for spawning anadromous and resident fish (ODEQ 2006b). Insufficient data is currently available to develop a TMDL for this reach.

Long Tom Subbasin
High summer water temperatures documented in the lower Long Tom River reflect watershed conditions that might be expected to contribute periodically to low dissolved oxygen concentrations in this subbasin’s streams. The Long Tom Watershed Council (Thieman 2000) reports that dissolved oxygen concentrations ranged from 7 to 13 mg/L in 45 water samples collected from the river below Fern Ridge Dam during the 1990s, suggesting that conditions in the lower river do occasionally fall below levels desirable for cold-water organisms. However, ODEQ’s 2002 CWA section 303(d) list of impaired waterbodies does not identify any streams in the Long Tom watershed that are water quality limited due to low dissolved oxygen concentrations (ODEQ 2002).
4.9.3.3 Total Dissolved Gas
High total concentrations of dissolved gases (TDG) are generally not a water quality problem found in most of the westside tributaries, but they have been found below some Project dams in the Willamette Basin. Available information on occurrences of high TDG levels associated with USACE dams in the Coast Fork and Long Tom subbasins is given below.

Coast Fork Subbasin
The ODEQ 2004/2006 Integrated Report database does not identify any streams in the Coast Fork Willamette subbasin that are water quality limited due to high TDG concentrations (ODEQ 2006b). However, Symbiotics (2005) measured TDG in the deep bottom waters of Dorena Reservoir as well as in the Row River just below the existing outlet gates at Dorena Dam. TDG levels deep in the reservoir exceeded ODEQ’s 110% maximum saturation standard during February and March. Symbiotics also concluded that aeration through the dam’s outlet gates causes TDG below the dam to exceed DEQ’s standard in July and August. There are no other data on TDG concentrations in areas of the Coast Fork Willamette subbasin used by listed anadromous salmonids.

Long Tom Subbasin
The ODEQ’s 2002 CWA section 303(d) list does not identify any streams in the Long Tom watershed are water quality limited due to excessive amounts of total dissolved gas (ODEQ 2002).

4.9.3.3.4 Nutrients
Elevated nutrient levels are a common problem in lowland streams within westside subbasins, though less so in the Coast Fork subbasin due to relatively higher proportions of forestlands and public ownership in that area. Project dams may have reduced (but not eliminated) the potential for lowland development to cause such problems along the lower mainstem reaches of the Coast Fork and Long Tom subbasins by augmenting summer flows.

Coast Fork Subbasin
The lower Coast Fork of the Willamette River, from Cottage Grove Dam to the mouth, had a TMDL for phosphorous approved in March 1995.

Long Tom Subbasin
The Thieman (2000) reported that nearly all (98%) of 43 water samples ODEQ collected from the Long Tom River below Fern Ridge Dam during the 1990s had total phosphorus concentrations that exceeded 0.05 mg/L, a condition described as “impaired.” The ODEQ has not set a numerical criterion for total phosphorus in the Long Tom subbasin.

4.9.3.3.5 Turbidity
Coast Fork Subbasin
The ODEQ 2004/2006 Integrated Report database does not indicate that any streams in the Coast Fork Willamette subbasin are water quality limited due to excess turbidity.
**Long Tom Subbasin**
The Long Tom River downstream of Fern Ridge Dam is generally described as turbid (Ely 1981; McIntosh et al. 1995). Thieman (2000) reported that only 5% of 41 turbidity measurements in the reach below Fern Ridge Dam during the 1990s had turbidity levels that exceeded 50 NTU. However, 16% of the total dissolved solids measurements exceeded 100 mg/L, a condition which was described in the watershed assessment as “moderately impaired.”

### 4.9.3.3.6 Toxics

Toxic substances are a concern in both the Coast Fork and Long Tom subbasins. Mercury contamination is of particular concern in the Coast Fork subbasin and pesticides are a concern in the Long Tom subbasin.

**Coast Fork Subbasin**

Mineral-bearing intrusive dikes are common in the headwaters of the Row River, an area that continues to be mined both commercially and recreationally. Mercury has been mined intensively in the Black Butte area, located in the upper Coast Fork drainage, which has been the most productive mining district in the Oregon Cascades for gold, silver, copper, lead, zinc, and antimony (USACE 2000). Mercury has been found in fish from Cottage Grove and Dorena reservoirs at levels potentially hazardous to humans. The highest mercury loadings are typically seen in large resident fish that prey on other fish, including bass, northern pikeminnow, and large trout. Both lakes have fishing regulations that are aimed at limiting the consumption of these fish. Mercury probably enters Dorena and Cottage Grove reservoirs as a result of mining and natural sources higher up in the watershed, but the relative contribution of mining compared to natural inputs from soils, volcanic rocks, and geothermal water sources is unknown. Park and Curtis (1997) indicated that a point source, Black Butte Mine, resulted in mercury concentrations in Cottage Grove Reservoir that are higher than would be expected from natural (background) sources, atmospheric deposition, and use of the metal during processing of gold.

The ODFW reared juvenile spring Chinook salmon in Cottage Grove Reservoir during 1969 through 1976, but the resulting smolts were believed to have low survival upon entering salt water as a result of accumulated mercury (ODFW 1990c). High mercury levels have also been found in several fish species collected throughout the length of the mainstem Coast Fork Willamette River. The ODEQ 2004/2006 Integrated Report database listed the mainstem Coast Fork reach from the mouth to RM 38.8 (including Cottage Grove Reservoir) and the Row River from its mouth to RM 20.8 (including Dorena Reservoir) as impaired for anadromous fish passage, resident fish, aquatic life, and human health due to mercury contamination (ODEQ 2006a). A TMDL for mercury was approved in 2006.

**Long Tom Subbasin**

Fourteen pesticides were detected at a site on the Long Tom River near Bundy Bridge, at RM 1, during four sampling periods in 1994 (Rinella and Janet 1998). Compared to the streams that USGS sampled, this site had the highest number and concentrations of pesticides (Thieman 2000). The EPA has recommended a numerical criterion for the protection of aquatic life for one of the 14 compounds, chlorpyrifos (0.04 μg/L), and the highest concentration detected in the Long Tom samples was much lower (0.009 μg/L). The fact that the pesticide data are based on only four sampling periods makes it difficult to draw any conclusions about the overall impact of pesticides on water quality in this subbasin (Thieman 2000).
4.9.3.4 Physical Habitat Characteristics

Changes to aquatic habitats within the westside subbasins have affected the productivity, capacity, and diversity of their salmonid populations, including Chinook salmon, steelhead, and resident salmonids (WRI 2004), and the magnitude of these changes has been considerable in many areas. However, many of the changes that have occurred in these subbasins are peripheral to an assessment of the influence of the Willamette Project and its various programs on the future viability of UWR Chinook and UWR Steelhead. The following discussion of baseline habitat conditions within these subbasins will therefore be somewhat less detailed than have earlier discussions of habitat in eastside subbasins, and will focus primarily on those subbasins in which the USACE operates dams: the Coast Fork and Long Tom.

As elsewhere in the Willamette Basin, adverse human effects on the physical characteristics of salmonid habitat tend to be more pronounced in lowland portions of the westside subbasins than they are in the forested uplands. This pattern is attributable to differing land-use histories, uneven levels of land-use regulation, and cumulative effects that tend to increase in the downstream direction.

4.9.3.4.1 Substrate
Historical splash-damming, active removals of large wood, intentional channel alterations, and increased rates of fine sediment delivery to streams caused by chronic land disturbances, have affected the stability and composition of streambed sediments in westside subbasins. These changes have likely diminished aquatic productivity and the quantity and quality of spawning gravels available to salmonids in the areas affected. Within the Coast Fork and Long Tom subbasins, USACE dams are also playing a role in the movement of sediment to and through streams. Coarse sediments once transported from the upper to lower portions of the drainage networks in these two subbasins are now trapped in reservoirs above USACE dams.

**Coast Fork Subbasin**
All coarse sediment from approximately 54% of the 680 square mile Coast Fork subbasin is trapped behind Cottage Grove Dam and Dorena Dams (USACE 2000), creating a sediment starved system in the Row and Coast Fork Willamette rivers downstream of the dams. This problem has been exacerbated by gravel mining in these reaches, further reducing sediment supply (BLME 1995b). The result has likely been a coarsening of the riverbeds downstream of the dams (USACE 2000) and a reduction in substrate diversity and spawning areas for salmonids.

**Long Tom Subbasin**
Construction of Fern Ridge Dam blocked the downstream transport of sediment from over 60% of the Long Tom subbasin and left the lower Long Tom River dependent on tributaries or the erosion of its channel as sources of sediment. The river’s tributaries appear to be less than prolific sources of coarse sediment, leaving channel erosion as a likely response to the reduction in sediment supply (USACE 2000). Three small concrete dams have been constructed in the lower Long Tom River to control degradation of the riverbed.
Only two small tributaries within the Long Tom watershed (Ferguson and Bear Creeks) have been extensively surveyed, but surveys of these streams revealed elevated sand and silt content in each reach surveyed.

### 4.9.3.4.2 Large Woody Debris

Stream cleaning practices and past management of riparian areas have substantially reduced in-channel wood and the potential for natural recruitment of large wood to streams within the westside subbasins. The loss of in-channel wood has reduced the quality of salmonid habitat present by modifying gravel deposition patterns, reducing the frequency and depth of pools, and limiting the availability of hiding cover for adult and juvenile fish (WRI 2004). Such habitat deficiencies tend to be most pervasive and severe in valley floor settings where extensive agricultural, rural-residential, and urban development have removed or altered much of the vegetation once found on streambanks or floodplains. Given low potentials for natural wood recruitment, the prognosis for substantial near-term improvements in this situation without active intervention is poor.

Levels of large wood in streams and riparian corridors within the Coast Fork and Long Tom subbasins are as just described for westside subbasins as a group, with the exception that (federal) land in the upper Coast Fork subbasin is managed with a stronger conservation emphasis than is found across most of the Willamette Basin’s westside. Additionally, reservoirs behind the USACE dams in these two subbasins function as woody debris traps, eliminating the transport of large wood from upper to lower portions of the watersheds within which they have been constructed. This has left the lower Coast Fork, Row, and Long Tom rivers entirely dependent on the diminished wood resources available along their banks, floodplains, and tributaries to help create or maintain the pools, side channels, debris jams, and near-bank cover that are important features of good salmonid habitat.

#### Coast Fork Subbasin

Abundances of large wood in streams channels within the Coast Fork subbasin above Dorena and Cottage Grove Dams, and prospects for natural recruitment of additional wood to those channels, have been characterized by BLME (1995b, 1997, and 1999) and WRI (2004). Many streams in the upper Coast Fork and Row River drainages lack large wood, large pools, and the high-quality rearing areas generally associated with high wood abundance (BLME 1995b, 1997).

Most large wood that enters Dorena and Cottage Grove Dams is removed from the river system. This leaves the lower Coast Fork and Row rivers dependent on wood that might be recruited naturally from areas where most potential riparian or floodplain sources of such wood have been depleted by a variety of human activities such as clearing for agriculture and urban development, road construction, and timber harvest.

#### Long Tom Subbasin

Historical accounts of the Long Tom River describe large quantities of in-channel wood that made navigation difficult and that persisted for a period of time despite USACE efforts to remove obstructions from the river (Thieman 2000). This is no longer the case. Splash damming, stream cleaning, removal of riparian forests, and channelization of the lower river by the USACE have diminished both in-channel wood and the potential for recruitment of new large wood to the system. Today, many miles of streams within the subbasin have lost the structural complexity
associated with abundant in-channel wood (WRI 2004) and riparian forests in both the upper and lower portions of the system are not capable of producing large wood at levels comparable to their historical capacity (Thieman 2000). The result along the lower Long Tom River, below Fern Ridge Dam, has been a wood-depleted reach with salmonid habitat of substantially lower than historical quality.

4.9.3.4.3 Channel Complexity, Off-channel Habitat & Floodplain Connectivity
Throughout the westside subbasins, the consequence of more than a century of watershed development has been a notable reduction in stream channel complexity, off-channel habitats, and the degree of interaction between streams and their floodplains (WRI 2004). These changes have tended to be of greater magnitude in lowland than in upland channels, and have diminished the abundance, productivity, and diversity of salmonid populations (WRI 2004).

Losses of stream complexity within the Coast Fork and Long Tom subbasins have followed the pattern seen in the Willamette’s other westside tributary systems, though conservation-focused management on federal forests in upper portions of the Coast Fork subbasin increases prospects for habitat recovery in that area. In both of these subbasins, USACE dams and revetments have been central to losses of habitat complexity along lowland river channels.

**Coast Fork Subbasin**
Active wood removals, alterations of bottomland forests, dam-caused reductions in wood and sediment delivery, and constraints that revetments and flood control have imposed on river-floodplain interactions, have impaired natural processes that create and maintain complex, high-quality salmonid habitats in the lower Coast Fork and Row rivers. As a result, channel complexity has been reduced and salmonid habitat diminished. USACE revetments that have contributed to this loss include five miles of structures built along the banks of the lower Coast Fork to protect agricultural development from flood damage, and another mile of revetments along the lower Row River (USACE 2000).

As noted above in section 4.9.2.1, Middle Fork Willamette Chinook salmon may use lower reaches of the Coast Fork for juvenile overwintering rearing. Thus, reduced habitat complexity and diminished availability of backwaters or floodplain refugia along lowland channels in the Coast Fork subbasin have the potential to reduce habitat availability for a small number of individual fish each year. This loss is likely to result in a small incremental decrease in abundance and productivity of Middle Fork Willamette Chinook salmon.

**Long Tom Subbasin**
Flooding remained a problem for Long Tom residents even after construction of Fern Ridge Dam, so the USACE constructed a levee on both sides of the Long Tom River from Fern Ridge Dam to the mouth, installed rip-rap revetments to minimize bank erosion, and added culverts to drain adjacent farmland. Later, the USACE constructed check dams to prevent down-cutting associated with the increased transport capacity of the straightened channel, and re-positioned the confluence of the Long Tom and Willamette rivers. The lower Long Tom River now has a highly simplified channel network and is cut off from side channels and floodplain areas that once provided quality rearing habitat and off-channel flood refugia for rearing juvenile Chinook and steelhead in winter months. Prospects for habitat improvement along the lower Long Tom without active intervention are low given the severity of channel alteration, reduced sediment
supply, and limited inputs of large wood. Severe habitat simplification has also occurred along multiple stream channels in the Amazon Creek watershed, tributary to the lower Long Tom River, as a consequence of flood protection efforts in and around the City of Eugene (Thieman 2000).

Simplification of lowland channels in the Long Tom subbasin has reduced their value as seasonal (fall-winter) rearing areas for UWR Chinook and UWR steelhead juveniles. This has the potential to reduce habitat availability for a small number of individual fish each year. This loss is likely to result in a small decrease in abundance and productivity of Middle Fork Willamette, McKenzie, and Calapooia populations of these fish.

4.9.3.4.4 Riparian Reserves & Disturbance History
Riparian vegetation has been altered along most streams within the westside subbasins (WRI 2004). The severity of these alterations has generally been greater along lowland than upland stream channels, a pattern that is evident in both the Coast Fork and Long Tom subbasins.

Coast Fork Subbasin
In upper portions of the Coast Fork subbasin, timber harvest and road construction have reduced riparian vegetation. Recent channel surveys indicate that riparian vegetation in most of these forestlands is less than 60 years old, and that one third of the riparian areas are dominated by alder or other hardwoods rather than conifers. The majority of streams in the upper subbasin do not have riparian trees capable of recruiting adequate large wood to the stream.

In lower portions of this subbasin, losses of riparian vegetation and function have been substantial. For example, recent analyses by ODEQ (2006a) suggest that streamside trees along the lower Coast Fork are currently providing only 64% of site potential shade, and those along the lower Row Rivers are providing only 44%. USACE’s construction of five miles of revetments along the banks of the lower Coast Fork to protect agricultural development from flood damage, and another mile of revetments along the lower Row River (USACE 2000), have contributed to such losses of function.

Long Tom Subbasin
Thieman (2000) has quantified extensive changes that have occurred in riparian communities within the Long Tom subbasin since settlement by examining the losses of ecological function associated with altered spatial distributions and extents of each vegetation type. In many upland areas, deciduous trees now dominate riparian stands that historically contained conifers, primarily due to timber harvesting. In the subbasin’s lowlands, nearly 50% of the original bottomland forests along streams are gone and about 20% have experienced a moderate loss of function associated with shifts to young trees and a very narrow width of riparian forest. Additionally, about 200 miles of the subbasin’s riparian areas are now dominated by shrubland although this vegetation type occupied only 12 miles of riparian area prior to settlement.

A high proportion of the riparian forests within the Long Tom subbasin are not currently capable of producing large wood at levels comparable to their historical capacity, and many do not provide desirable levels of stream shade. Substantial losses of ecological function along approximately 70% of the lowland channels once bordered by bottomland forest reflect a situation in which channels like that of the lower Long Tom River have limited near-term
prospects for large wood recruitment. Analyses by ODEQ (2006a) suggest that vegetation along the lower Long Tom River now provides only 44% of site potential shade.

4.9.4 Hatchery Programs

There are no salmon or steelhead hatcheries operating within the westside subbasins, though salmon and steelhead of hatchery origin have been released into these subbasins at various times and locations in the past. Adult UWR Chinook of hatchery origin are currently being released into Mosby Creek in the Coast Fork subbasin in an effort to restart natural production in that area (Moberly 2008). Adult hatchery-origin summer steelhead stray from hatchery programs in eastside subbasins and spawn in streams within the Coast Fork subbasin (Schroeder et al. 2006) and perhaps others.

4.9.5 Fisheries

Naturally produced adult UWR Chinook are not generally found in westside subbasins, but adult UWR steelhead are apparently present in the Tualatin and Yamhill subbasins. Harvest of non-adipose fin-clipped Chinook salmon or steelhead is prohibited in the Willamette Basin (ODFW 2008c); unmarked fish incidentally caught must be released unharmed.

4.9.6 Status of Critical Habitat in Coast Fork Willamette & Long Tom Subbasins

NMFS did not designate critical habitat in the Coast Fork Willamette or Long Tom subbasins because of its relatively low importance to recovery for either UWR Chinook or UWR steelhead.
Table 4.9-3  Habitat elements and associated pathways, indicators, current conditions, and limiting factors for ESA-listed anadromous salmonids in the Coast Fork Willamette and Long Tom subbasins under the environmental baseline.

<table>
<thead>
<tr>
<th>Habitat Element</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Limiting Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater migration corridors</td>
<td>Habitat access</td>
<td>Physical barriers</td>
<td>Coast Fork subbasin: Dorena Dam blocks Chinook salmon access to historical habitat, however, the W/LC TRT does not believe this habitat supported a demographically independent population. No human-made barriers limit the viability of a demographically independent population.</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Long Tom subbasin: Three small USACE check-dams on the Long Tom below Fern Ridge Dam that may limit juvenile fish access to historical rearing areas.</td>
<td>USACE</td>
</tr>
<tr>
<td>Water Quantity (Flow/Hydrology)</td>
<td>Change in peak/base flow</td>
<td></td>
<td>Coast Fork and Long Tom subbasins: Frequency of channel-forming flows not of sufficient magnitude to create and maintain channel complexity and provide nutrients, organic matter, and sediment inputs from floodplain areas. Increased summer flows may increase rearing area and the heat capacity of the stream. Low streamflow conditions are affected by water development and reservoir operations. Flow fluctuations now occur at rates rapid enough to entrap and strand juvenile anadromous fish.</td>
<td>Flood control operations at USACE’s dams reduce the magnitude and frequency of peak flows. Flow augmentation from USACE reservoirs to meet mainstem flow targets. Summer diversions for out-of-stream use. Flood control operations at USACE dams cause rapid flow reductions.</td>
</tr>
<tr>
<td>Habitat Element</td>
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<tr>
<td></td>
<td>Water Quality</td>
<td>Temperature</td>
<td></td>
<td>USACE operations (Cottage Grove and Dorena dams)</td>
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<td></td>
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<td>Water diversions and return flows</td>
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<td>Loss of riparian vegetation for shading</td>
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<td>Clearing for floodplain development</td>
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</tbody>
</table>

**Coast Fork subbasin:**

The ODEQ 2004/2006 Integrated Report database indicates exceedances of temperature criteria (18°C) for rearing and migration of salmon and trout for reaches below Cottage Grove and Dorena dams during summer and early fall. A temperature TMDL was approved for these and other areas of the Willamette Basin in 2006.

Exceedances have also been reported in some unregulated reaches for both spawning and non-spawning periods (i.e., not affected by Willamette Project flow management).

**Long Tom subbasin:**

ODEQ 2002 CWA 303(d) database indicates that 98% of summer temperature measurements at RM 4.7 exceeded maxima for core rearing (16°C) and non-core rearing and adult and juvenile migration (18°C) during the period 1986 through 1995. Temperatures high enough to be lethal or nearly so to juvenile salmonids have been measured during summer.

Juvenile Chinook occupy the lower Long Tom during winter, when temperatures are below maxima.

USACE operations (Fern Ridge Dam)
Timber harvest (upper subbasin)
Livestock operations
## Habitat Element
- Freshwater spawning sites
- Freshwater rearing
- Freshwater migration corridors

<table>
<thead>
<tr>
<th>Habitat Element</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Limiting Factors</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Water Quality</td>
<td>Total Suspended Solids/Turbidity</td>
<td><strong>Coast Fork subbasin:</strong> The ODEQ 2004/2006 Integrated Report database does not report any streams as water quality limited due to excess turbidity</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
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<td></td>
<td><strong>Long Tom subbasin:</strong> 5% of 41 turbidity measurements below Fern Ridge Dam during the 1990s had levels that exceeded 50 NTU, described as “impaired” 16% of total dissolved solids measurements exceeded 100 mg/L, described as “moderately impaired”</td>
<td>Streambank erosion due to grazing Agriculture Timber harvest (upper watershed) Road construction and maintenance</td>
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<td>Habitat Element</td>
<td>Pathway</td>
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<td>------------------</td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Water Quality</td>
<td>Chemical Contamination/Nutrients</td>
<td>Coast Fork subbasin: The ODEQ 2004/2006 Integrated Report database lists the mainstem Coast Fork Willamette River from the mouth to RM 31.3, Cottage Grove Reservoir, the Row River from RM 0 to 20.8, and Dorena Reservoir, as impaired for aquatic life, due to mercury contamination from mining activities in the upper drainage. The ODEQ 2004/2006 Integrated Report database listed the mainstem Coast Fork below and including Cottage Grove Reservoir) as impaired for aquatic life due to increased iron concentrations (ODEQ 2006a). The ODEQ 2004/2006 Integrated Report does not identify any streams are water quality limited due to excess nutrients. However, occurred during low-flow periods on the Row River below Dorena Dam (the ODEQ OWQIR (1986-1995)) (Cude 1996a).</td>
<td>Mining City of Creswell’s sewage treatment plant, agriculture, nursery operations, logging operations (ODEQ WQ Index Report (1986-1995) (Cude 1996a).</td>
</tr>
<tr>
<td>Freshwater rearing</td>
<td></td>
<td></td>
<td>Long Tom subbasin: 98% of 43 water samples collected below Fern Ridge Dam during the 1990s had total phosphorus concentrations that exceeded 0.05 mg/L, a condition described as “impaired” per GWEB recommendations. Fourteen pesticides were detected at a site near Bundy Bridge (Long Tom RM 1) during four sampling periods in 1994</td>
<td>Agriculture Rural development (fertilizers) Agriculture Transportation Rural development</td>
</tr>
<tr>
<td>Habitat Element</td>
<td>Pathway</td>
<td>Indicator</td>
<td>Condition</td>
<td>Limiting Factors</td>
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</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Water Quality</td>
<td>Dissolved Oxygen (DO)</td>
<td><strong>Coast Fork subbasin:</strong> The ODEQ 2004/2006 Integrated Report database indicates that areas below Cottage Grove Dam is limited for salmon and steelhead spawning; but attaining some criteria for cold-water aquatic life. The ODEQ 2004/2006 Integrated Report database indicates that on the Row River 1 out of 16 samples exceeded criteria for cold-water aquatic life; and 0 out of 3 sample exceeded criteria for spawning anadromous and resident fish. In August 2003 and July 2004, DO measured in Dorena Reservoir bottom waters dropped below 6.5 mg/L. Water is aerated as it is released through the existing outlet gates, resulting in higher DO levels below the dam (Symbiotics 2005)</td>
<td></td>
</tr>
<tr>
<td>Freshwater rearing sites</td>
<td>Water Quality</td>
<td>Dissolved Oxygen (DO)</td>
<td><strong>Long Tom subbasin:</strong> ODEQ 2002 CWA 303(d) list does not indicate that any streams in the Long Tom watershed are water quality limited due to low dissolved oxygen concentrations</td>
<td></td>
</tr>
<tr>
<td>Freshwater migration corridors</td>
<td>Water Quality</td>
<td>Total Dissolved Gas (TDG)</td>
<td><strong>Coast Fork subbasin:</strong> Total dissolved gas may exceed DEQ’s 110% saturation standard in the reservoir during February and March, and as water passes through the outlet gates total dissolved gas increases to exceed DEQ’s standard during July and August (Symbiotics 2005)</td>
<td></td>
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<tr>
<td>Freshwater migration corridors</td>
<td>Water Quality</td>
<td>Total Dissolved Gas (TDG)</td>
<td><strong>Long Tom subbasin:</strong> Total Dissolved Gas (TDG) ODEQ 2002 CWA 303(d) list does not indicate that any streams in the Long Tom watershed are water quality limited due to total dissolved gas</td>
<td></td>
</tr>
</tbody>
</table>

City of Creswell's sewage treatment plant
Other local sources, agriculture return flows, logging operations
N/A
Corps’ reservoir and operations
N/A
### Habitat Element:
- **Freshwater spawning sites**
- **Freshwater rearing sites**

<table>
<thead>
<tr>
<th>Habitat Element</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Limiting Factors</th>
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<tbody>
<tr>
<td><strong>Freshwater spawning sites</strong></td>
<td>Habitat Elements</td>
<td>Substrate</td>
<td><em>Coast Fork and Long Tom subbasins:</em> Substrate has probably coarsened downstream of Cottage Grove and Dorena Dams, and the river channels in those areas have likely down-cut. Current sediment budget not creating and maintaining habitat needed by anadromous salmonids In the Long Tom subbasin, Amazon Creek and the lower Long Tom have been channelized, so sediment transport capacity increased and the channels have incised</td>
<td>USACE reservoirs trap sediment from headwaters USACE and private channel modifications Cumulative effects of varied land use Gravel mining Log drives</td>
</tr>
<tr>
<td><strong>Freshwater rearing sites</strong></td>
<td>Habitat Elements</td>
<td>Large Woody Debris</td>
<td><em>Coast Fork and Long Tom subbasins:</em> Large wood abundance has been diminished in most small tributaries and throughout most of the lower portions of these subbasins. Recruitment potential for large wood is low along most surveyed streams</td>
<td>Timber harvesting Stream clean-out Fire suppression Splash-damming of some tributary streams</td>
</tr>
<tr>
<td>Habitat Element</td>
<td>Pathway</td>
<td>Indicator</td>
<td>Condition</td>
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<tr>
<td>Freshwater rearing sites</td>
<td>Habitat Elements</td>
<td>Pool Frequency</td>
<td>Coast Fork and Long Tom subbasins: Pool frequency and quality in the Coast Fork and the Long Tom subbasins have been reduced due to reductions in LWD</td>
<td>Downstream LWD transport blocked by project dams; land uses such as timber harvest, stream clean out, and fire suppression reduce LWD recruitment to stream channels.</td>
</tr>
<tr>
<td>Freshwater migration corridors</td>
<td>Habitat Elements</td>
<td>Off-channel Habitat</td>
<td>Coast Fork and Long Tom subbasins: While no quantitative data are available, the Coast Fork, Row River, and Long Tom River, probably contain fewer off-channel habitats, simplified mainstem habitat, and few new gravel bars or channel surfaces</td>
<td>USACE dam operations reduce the magnitude and frequency of peak flows</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Extensive sections of the mainstem Long Tom River and of its tributary Amazon Creek have been channelized</td>
<td>USACE and private revetments</td>
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<td></td>
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<td></td>
<td></td>
<td>USACE removes large wood from reservoirs</td>
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<td></td>
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<td>Gravel mining in the lower Coast Fork</td>
</tr>
<tr>
<td>Freshwater rearing</td>
<td>Channel Conditions and Dynamics</td>
<td>Width/depth ratio</td>
<td>Coast Fork and Long Tom subbasins: While no quantitative data are available, channel form in the lower mainstem rivers has been restricted by revetments, roads and by loss of LWD; reservoir operations have restricted some channel forming processes (USACE 2007a).</td>
<td>Revetments, urbanization, road construction, timber harvest, and agricultural development</td>
</tr>
<tr>
<td>Freshwater migration corridors</td>
<td></td>
<td></td>
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<td>Corps Project reservoirs and reservoir operations</td>
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<tr>
<td>Habitat Element</td>
<td>Pathway</td>
<td>Indicator</td>
<td>Condition</td>
<td>Limiting Factors</td>
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<tr>
<td>Freshwater spawning sites</td>
<td>Channel Conditions and Dynamics</td>
<td>Streambank Condition</td>
<td><em>Coast Fork and Long Tom subbasins:</em> Streambanks do not support natural floodplain function along the lower mainstem rivers (USACE 2007a).</td>
<td>Revetments, urbanization, agricultural development, road construction, timber harvest</td>
</tr>
<tr>
<td>Freshwater rearing</td>
<td>Channel Conditions and Dynamics</td>
<td>Floodplain Connectivity</td>
<td><em>Coast Fork and Long Tom subbasins:</em> Floodplain is not frequently inundated, with less over-bank flow and side channel connectivity Reduced nutrient exchange, reduced sediment exchange, reduced flood refugia for fish, and reduced establishment of new riparian forests</td>
<td>USACE operation of dams reduces the magnitude and frequency of peak flows USACE and private revetments USACE channel straightening on the mainstem Long Tom</td>
</tr>
<tr>
<td>Habitat Element</td>
<td>Pathway</td>
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<td>Condition</td>
<td>Limiting Factors</td>
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<tr>
<td>Freshwater spawning sites</td>
<td>Watershed conditions</td>
<td>Riparian reserves</td>
<td><strong>Coast Fork subbasin:</strong>&lt;br&gt;Most riparian vegetation within forested watersheds is less than 60 years old&lt;br&gt;Many tributaries do not provide adequate shading or large wood recruitment&lt;br&gt;Floodplain riparian forests have been diminished&lt;br&gt;Riparian area in lower watershed constrained by I-5</td>
<td>Timber harvesting&lt;br&gt;Stream clean-out practices&lt;br&gt;Clearing for agriculture or development&lt;br&gt;USACE and private revetments&lt;br&gt;USACE operation of dams alters hydrologic regime</td>
</tr>
<tr>
<td>Freshwater rearing</td>
<td></td>
<td></td>
<td><strong>Long Tom subbasin:</strong>&lt;br&gt;Portions of the upper watershed are forested, but most of it is managed for timber production rather than ecosystem health. More than half (55%) of the riparian corridors in the uplands have had a moderate to high loss of ecological function.&lt;br&gt;Portions of the upper watershed are heavily urbanized&lt;br&gt;Lower portions of the watershed have experienced extensive agricultural, urban, and residential development, causing a high loss of ecological function in 46% of the historical closed bottomland forest.</td>
<td>Timber harvesting&lt;br&gt;Lowland conversions to agriculture, rural-residential, or urban development&lt;br&gt;USACE and private revetments and levees&lt;br&gt;USACE channel straightening&lt;br&gt;USACE operation of Fern Ridge Dam alters the hydrologic regime</td>
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Mainstem Willamette Baseline
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4.10 MAINSTEM WILLAMETTE

The following information addresses both the entire Willamette River basin, and also specifics related only to the mainstem.

The mainstem Willamette River flows northward from the confluence of the Coast Fork and Middle Fork Willamette rivers for 187 miles before joining with the Columbia River at Portland, Oregon (Figure 4.10-1). At its mouth, the Willamette drains an area of 11,478 square miles and has an annual average runoff of 24 million acre-feet. Upstream of the Santiam confluence (RM 108), the mainstem channel is extensively braided, with many side channels and islands. Downstream of the Santiam confluence, the gradient is lower, complex braided channels are more localized, and lateral changes in the river channel are limited (Hulse 1998). Between the Santiam confluence and Willamette Falls (RM 26), the Salem hills, which cross the Willamette Valley from east to west, and other geologic features constrain the mainstem Willamette so that the channel is much simpler than in the upper subbasin.

The subbasins that drain the east slope of the Coast Range are quite different from those that drain the west slope of the Cascade Range (west slope drainages) (Rosenfeld 1985). The westslope drainages are underlain by older geological formations of a sedimentary origin than are the eastslope watersheds and subbasins, which are of volcanic origin. Accordingly, westslope stream channels tend to be mature, with more downcutting and larger amounts of fine sediment. Westslope streams drain much smaller areas than eastslope streams, and a higher proportion of each westslope stream is on the floor of the Willamette Valley. No westslope streams have headwaters with the snowpack or water-rich volcanic formations associated with large eastslope streams, so their high winter flows decline quickly in spring to very low levels during summer.

Approximately 64% of the land in the Willamette Basin (including all of the subbasins discussed in preceding sections), is privately-owned. The BLM manages 5%, primarily in the Cascade and Coast Range foothills. Within the Willamette valley ecoregion (which extends up to the Coast and Cascade foothills), the vast majority of land is privately-owned with 42% in agriculture, 31% forested, and 11% covered by built features, including urban, rural, and transportation structures (Hulse et al. 2002).

Approximately 1.4 million acres of the Willamette River basin are used for crop production and about 25% of this acreage is irrigated. Rangeland accounts for only a small portion of the lands adjacent to the mainstem, with most located along the mainstem tributaries. Effects of water withdrawals for irrigation are aggravated by agricultural practices that influence erosion, sedimentation and water quality. Extensive sand and gravel mining has occurred in and adjacent to the Willamette mainstem. Aggregate mining within the bed and banks of the river is restricted to bar scalping, except for dredging that is permitted at the Newberg Pool area (USACE 2000).

The largest cities in the upper Willamette Valley include Eugene (population 137,893 in 2000) and Springfield (52,864). Corvallis (population 49,322), Albany (40,852), and Salem (136,924) are the largest mid-valley cities (USCB 2004). Portland (population 529,121 in 2000) is the largest city in the lower Willamette Valley.
Figure 4.10-1  Map of the mainstem Willamette River, its major tributaries, and drainage basin (source: Rounds 2007).
4.10.1 Historical Populations of Anadromous Salmonids in the Mainstem

Multiple populations and ESUs of anadromous salmonids use the mainstem Willamette as a migratory corridor and seasonal rearing area, though the mainstem itself is not known to have ever supported an independent spawning population of these fish. Use of the mainstem above Willamette Falls (Mile 26.6) was restricted historically to the populations of UWR Chinook and UWR Steelhead identified earlier in this document. Below the Falls, these populations shared the mainstem with fish from one or more demographically independent populations of Lower Columbia River (LCR) Chinook, LCR Coho salmon, LCR Chum salmon, and LCR Steelhead. The Clackamas subbasin supported below-Falls populations of fish from each of these lower river ESUs, and smaller spawning aggregates of fish from these ESUs were present in other below-Falls tributaries.

4.10.2 Current Status of Native Anadromous Salmonids in the Mainstem

4.10.2.1 UWR Chinook Salmon

UWR Chinook migrate as adults up the mainstem Willamette during spring, to hold and spawn in eastside tributaries identified in earlier sections of this document, and to rear in and migrate down the mainstem as juveniles after leaving the tributaries. Some juvenile UWR Chinook over-winter at low densities in accessible habitats on the river’s floodplain, in intermittent tributaries, and along the lower-most reaches of some larger tributaries in which adults do not spawn (Bayley and Baker 2000; Bayley et al. 2001; Kenaston 2003).

Adult spring Chinook salmon begin appearing in the lower Willamette River in February. The majority of the run ascends Willamette Falls in April and May, with a peak in mid-May (Myers et al. 2002). The early-spring run timing of UWR Chinook salmon relative to other populations in the lower Columbia River is probably an adaptation to low flow conditions at Willamette Falls during summer and fall. Mattson (1963) discussed the existence of a late spring-run Chinook salmon that once ascended the falls in June. These fish were apparently much larger (25 to 30 pounds) and older (presumably 6-year olds) than the earlier part of the run. He speculated that this part of the run intermingled with the earlier-run fish on the spawning grounds and therefore was not distinct. The June run disappeared in the 1920s and 1930s as water quality declined in the lower Willamette River (Myers et al. 2002).

Based on a June 1938 survey described in McIntosh et al. (1995), the upper reaches of the mainstem Willamette, from a point seven miles below the mouth of the McKenzie River upstream to the confluence of the Middle and Coast Forks, contained the best Chinook salmon spawning areas. A short distance below, the river became very sluggish, with mud and silt covering the available spawning rubble. This condition, together with increasing amounts of pollution, lack of good riffle areas, and the high temperatures prevailing in the entire lower section of the Willamette, was reported to render most of the mainstem unsuitable for salmon spawning (McIntosh et al. 1995). More recently (1998), ODFW surveyed the mainstem Willamette River from Island Park (RM 185), near the confluence of the Coast Fork Willamette and Middle Fork Willamette (RM 187) down to Harrisburg (RM 161) on October 1 and October
8, 1998 and found only two redds (Lindsay et al. 1999). These were located approximately four miles below the mouth of the McKenzie River.

Mattson (1962) reported three distinct downstream migrations of juvenile spring Chinook in the Willamette River (Lake Oswego area): a late winter-spring movement of zero-aged fish, a late fall-early winter movement of age-1 fish, and a second spring movement by age-1 fish. More recent work by Schroeder et al. (2005) suggests that these migrations still occur, but at reduced abundance and with temporal shifts in the earliest migrations from Willamette River tributaries that are related to altered thermal regimes below USACE dams. Schroeder et al. (2005) also report that juvenile Chinook exhibit low-density winter use of habitats that are available on the Willamette’s floodplain, in intermittent tributaries, and some larger tributaries in which the species does not spawn.

Mattson (1962) found that less than half of each year’s brood emigrated in the late winter and early spring as zero-age fish (length 40-90 mm); less than half in the fall as age-1 fish (length 100-130 mm), and less than a third during spring as age-2 smolts (length 100-140 mm). The largest smolts that Mattson (1962) observed in the lower river were 140 mm fork length, a size that by current hatchery standards is small even for juveniles released as 1-year old fish.

Portland General Electric (PGE) monitors juvenile salmonid passage at their T.W. Sullivan hydropower plant at Willamette Falls. During 1992 through 1994, the passage of both hatchery- and naturally-produced fish at the Falls peaked in March, with a subsequent and much smaller peak in late November (hatchery fish) and early December (natural fish), similar to the historical timing described by Mattson (1962).

The ODFW conducted beach seines for juvenile Chinook in the upper Willamette River (RM 142 to 177) during summer 2000, 2001, and 2002 (Lindsay et al. 2000; Schroeder et al. 2001, 2005). During July and August, 2001, average lengths of unmarked juveniles increased 5.5 mm over a 6-week period (Schroeder et al. 2001), evidence that juveniles of this species use the mainstem for rearing. The ODFW sampled areas downstream to San Salvador (RM 57) in 2002. Juvenile Chinook were abundant during late June, but numbers were smaller when the area was resampled in late July (Schroeder and Kenaston 2004). The decrease in numbers could have been the result of emigration from the Willamette River or a local shift in fish distribution into areas less accessible by beach seine (hypothetically, due to warmer temperatures).

Juvenile Chinook that ODFW has PIT-tagged in the lower Santiam River (RM 108) and in the main Willamette near Salem (RM 88) during late June have migrated past Willamette Falls (RM 27) by early July (Schroeder and Kenaston 2004). DNA micro-satellite analysis of fin tissues from samples of juvenile Chinook collected from the lower Santiam and from multiple points along the mainstem Willamette downstream in 2002 and 2003 showed these fish to be a mix of native spring Chinook and non-native fall Chinook, with the native fish substantially more abundant (Schroeder et al. 2005). Micro-satellite genetic analysis of fin tissues from 97-100% of juvenile Chinook sampled at Willamette Falls during 2003 and 2004 were native spring-run fish (Schroeder et al. 2005).

Sampling by ODFW along the lower Willamette, below Willamette Falls, during 2000 through 2003 showed juvenile Chinook to be present in each month sampled, though considerably more
abundant during the primary migration period in winter and spring (Friesen 2005). The fish were generally larger at the lower end of the river during periods of high abundance than they were at the upper end, suggesting that the fish were growing as they traveled downriver. Yearling Chinook smolts radio-tagged and tracked through the river below the Falls during 2001-2003 had median migration rates of 11.3 km/d and median residence times of 3.4 d (Friesen 2005). Knutsen and Ward (1991) report that Chinook smolts migrated downriver more often through Multnomah Channel than out the mouth of the Willamette River. Smolt migration rates were positively correlated with river flows (Friesen 2005).

**Population Viability**

The viability and current status of individual populations of UWR Chinook that use the mainstem Willamette was described in specific tributary baseline sections 4.2 Middle Fork Willamette, 4.3 McKenzie, 4.4 Calapooia, 4.5 South Santiam, and 4.6 North Santiam. Although large fish hatchery programs affected confidence in the available abundance estimates for natural-origin UWR Chinook for nearly 50 years, it has long been clear that the decline of these fish has been severe. Total (natural plus hatchery-origin) abundance of adults passing Willamette Falls remained relatively steady after the mid-1950s (ranging from approximately 20,000 to 70,000 fish), but this apparent stability depended on large returns of hatchery-origin fish and already reflected a substantial decline from peak abundances of perhaps more than 275,000 wild adults in the 1920s. Since 2001, as a consequence of improved fish marking and monitoring, estimates of the abundance of natural-origin UWR Chinook have reflected a high degree of confidence in the proportions of the annual runs into individual Willamette River tributaries that were composed of hatchery-origin fish.

Analyses of returns to spawning areas during 2002-2006, a period of relatively high marine survival, suggest an annual run of natural-origin UWR Chinook averaging about 5,000 adults above Willamette Falls (see previous sections), with most of these fish (with a possible exception in the McKenzie subbasin) unlikely to be more than a few generations removed from a fish hatchery. These hatchery-influenced natural returns represent only about 2% of the ESU’s historic abundance above the Falls. Below the Falls, returns of UWR Chinook to the Clackamas subbasin, where past hatchery programs replaced a historical run of LCR Chinook (see section 4.8.1), the abundance of natural-origin adults passing North Fork Dam averaged 2,644 during 2002-2004 (Schroeder et al. 2005).

The West Coast Salmon Biological Review Team (WCSBRT, cited as Good et al. 2005) expressed a strong concern that the majority of historical spawning habitat and approximately 30-40% of the habitat once used within the Willamette Basin by these fish is now inaccessible behind dams. The restriction of natural production to just a few areas, most of which now provide altered habitats, increases the ESU’s vulnerability to environmental variability and catastrophic events. Losses of local adaptation and genetic diversity through the mixing of hatchery stocks within the ESU represent further threats to viability.
4.10.2.2 UWR Steelhead

The same flow conditions at Willamette Falls that once limited access to all but spring-run Chinook salmon also provided an isolating mechanism for late-run winter steelhead. Fish belonging to populations of UWR Steelhead group of fish enter the Willamette beginning in January and February, but adults do not ascend to their spawning areas until late March or April (Dimick and Merryfield 1945). UWR Steelhead use the mainstem Willamette primarily as a migration corridor on their way to spawning and rearing habitat in the tributaries (ODFW 1990d; Fulton 1970). Spawning takes place from April to the first of June. The ODFW currently uses an artificial passage date at Willamette Falls, February 15th, to discriminate between native versus nonnative (i.e., naturalized Big Creek hatchery stock) winter steelhead (Kostow 1995).1

Emigration of native winter steelhead smolts past Willamette Falls begins in early April and extends through early June (Howell et al. 1985), with peak migration occurring in early to mid-May. Mean lengths of naturally-produced smolts sampled weekly at Willamette Falls (1976 through 1978) ranged from 170 mm to 220 mm. Larger smolts migrated significantly earlier than the smaller smolts (Buchanan et al. 1979).

Sampling by ODFW along the lower Willamette, below Willamette Falls, during 2000 through 2003 showed steelhead smolts to be present during winter and spring (Friesen 2005). The fish were generally larger at the lower end of the river than they were at the upper end, suggesting that the fish were growing as they traveled downriver. Smolts radio-tagged and tracked through the river below the Falls during 2001-2003 had median migration rates of 12.5 km/d and median residence times of 2.5 d (Friesen 2005).

As with Chinook, steelhead smolts migrated downriver more often through Multnomah Channel than out the mouth of the Willamette River (Knutsen and Ward 1991). Smolt migration rates were positively correlated with river flows (Friesen 2005).

Population Viability
The UWR steelhead ESU includes all naturally spawned populations of winter-run steelhead in the Willamette River in Oregon and its tributaries upstream from Willamette Falls to the Calapooia River (inclusive) (NMFS 1999b). It does not include any artificially propagated steelhead stocks that reside within the historical geographic range of the ESU. Hatchery summer steelheads occur in the Willamette Basin, but are an out-of-basin stock not included in the ESU.

The WCSBRT was encouraged by recent significant increases in returns of adult UWR steelhead (exceeding 10,000 total fish) in 2001 and 2002 for the UWR steelhead ESU. However, the recent five-year mean abundance remains low for an entire ESU (5,819 adults), and individual populations remain at low abundance. Long-term trends in abundance are negative for all populations in the ESU, reflecting a decade of consistently low returns during the 1990s. Short-term trends, buoyed by recent strong returns, are positive.

1 Stone (1878) reported that steelhead began arriving at the base of Willamette Falls around Christmas, but were most abundant in April. Additionally, the spawning peak was reported to be in May, with spawning complete by June.
About one-third of the ESU’s historically accessible spawning habitat is now blocked, but it remains relatively well-distributed spatially within accessible areas within each of its four natal subbasins (Good et al. 2005). The WCSBRT considered the relatively recent cessation of the early-winter-run hatchery program a positive sign for ESU diversity risk, but remained concerned that releases of non-native summer steelhead continue. The WCSBRT found moderate risks for each of the VSP categories.

4.10.2.3 LCR Chinook Salmon

Use of the lower Clackamas, below Willamette Falls, by LCR Chinook salmon is presumed to be relatively similar to that described for UWR Chinook except that upstream migrations of adults might occur during late summer and fall, while juvenile emigration would likely be restricted to sub-yearling fish rearing in and passing through the area during late winter, spring, and early summer.

Population Viability
Many populations within the LCR Chinook salmon ESU have exhibited pronounced increases in abundance and productivity in recent years, possibly due to improved ocean conditions. However, despite recent improvements, long-term trends in productivity are below replacement for the majority of populations in the ESU. Of the historical populations, 8 to 10 have been extirpated or nearly extirpated, including the population that once spawned in the Clackamas River and a few of the smaller Willamette tributaries below Willamette Falls.

The WCSBRT found moderately high risk for all VSP categories. High hatchery production poses genetic and ecological risks to the natural populations and complicates assessments of their performance. The WCSBRT also expressed concern over the introgression of out-of-ESU hatchery stocks.

4.10.2.4 LCR Steelhead

LCR steelhead from the Clackamas subbasin and nearby streams migrate upriver through the lower Willamette River as adults during winter and spring. They emigrate through the lower River as smolts during late winter and spring. Their behavior while in the lower Willamette is as described for UWR Steelhead.

Population Viability
The current status of this evolutionary group of populations was described earlier, in section 3.2.2.3 (Rangewide status, LCR steelhead), with additional detail on the Clackamas population provided in section 4.8.2, Clackamas subbasin baseline. The WCSBRT found moderate risks of extinction associated with the abundance, productivity, spatial structure, and diversity of the group’s component populations. Particular concerns included the impact on diversity or productivity of high proportions of hatchery-origin spawners in natural spawning areas and the potential for competitive displacement of native winter-run fish by the offspring of stray spawners from hatchery releases of nonnative hatchery summer steelhead.
4.10.2.5 LCR Coho Salmon

Juvenile coho are present in the lower Willamette below the Falls during winter and spring (Friesen 2005). They appear to grow while in the area. Radio-tagged and tracked coho smolts moved more slowly through the area than did chinook and steelhead smolts, having a median migration rate of 4.6 km/d and a median residence time of 8.7 km/d (Friesen 2005). Smolt migration rates were positively correlated with river flows (Friesen 2005).

Population Viability
The status of this ESU was described earlier in section 3.2.3.2 (Rangewide status, LCR coho salmon), with additional detail on the Clackamas population provided in section 4.8.2 (Clackamas subbasin baseline). There are only two extant populations in the LCR coho salmon ESU with appreciable natural productivity, one of which is the Clackamas population. An extreme loss of natural spawning populations, low abundance of extant populations, diminished diversity, fragmentation, and isolation of the remaining naturally produced fish, confer considerable risks on the ESU (Good et al. 2005). An exceptionally large hatchery program for coho in the lower Columbia continues to represent a threat to the genetic, ecological, and behavioral diversity of the extant natural populations. However, the hatchery stocks present in the lower Columbia collectively represent a significant portion of the LCR Coho ESU’s remaining genetic resources. The 21 hatchery stocks considered to be part of the ESU, if appropriately managed, may prove essential to the restoration of more widespread naturally spawning populations.

4.10.2.6 Limiting Factors & Threats to Recovery

Multiple conditions in the mainstem above Willamette Falls, or in the river corridor downstream of the Falls, unfavorably affect the status of ESA-listed populations of anadromous salmonids. These conditions have been summarized by ODFW (2007b) and are given in Table 4.10-1. Key limiting factors and threats to UWR Chinook and UWR steelhead from above-Falls populations, while in the mainstem above the Falls, include habitat impairments associated with flood control and land use, as well as Project-caused reductions in spring flows that elevate river temperatures and disease risks that the parasite Ceratomyxa shasta poses for steelhead smolts. Below Willamette Falls, anadromous salmonids using the lower Willamette and Columbia rivers are unfavorably influenced by multiple factors associated with USACE dams on both systems, by habitat degradation caused by the cumulative effects of varied land uses, competition with juvenile hatchery fish produced by programs funded by the USACE and others, predation, and toxic chemicals from agricultural, urban, and industrial practices.
Table 4.10-1  Key and secondary limiting factors and threats along the mainstem Willamette River to the recovery of UWR Chinook, UWR Steelhead, and fish from multiple ESA-listed populations of anadromous salmonids that might be found in the lower Willamette, below Willamette Falls (ODFW 2007b).

### Key threats and limiting factors

- **5a** Reduced macrodetrital inputs from near elimination of overbank events and the separation of the river from its floodplain.
- **5b** Increased microdetrital inputs due to reservoirs.
- **7h** Impaired fine sediment recruitment due to dam blockage.
- **8a** Impaired physical habitat from past and/or present land use practices.
- **10c** Reduced flows during spring reservoir filling result in increased water temperatures that lead to increased disease.
- **10f** Altered flows due to hydropower system that result in changes to estuarine habitat and plume conditions, impaired access to off-channel habitat, and impaired sediment transport.

### Secondary threats and limiting factors

- **4a** Competition with hatchery fish of all species.
- **6e** Predation by birds as a result of favorable habitat conditions for birds created by past and/or present land use activities.
- **8a** Impaired physical habitat from past and/or present land use practices.
- **9a** Elevated water temperatures from past and/or present land use practices resulting in decreased survival and/or growth.
- **9h** Toxicity due to agricultural practices.
- **9i** Toxicity due to urban and industrial practices.
- **9j** Elevated water temperatures due to reservoir heating.
- **10d** Reduced peak flows leading to decreased channel complexity and diversity of fish habitat by reducing channel movement that is important for recruitment of gravel and large wood, and maintaining varying seral stages of riparian vegetation. Lower peak flows also reduces scour and formation of pools.

<table>
<thead>
<tr>
<th>Threats</th>
<th>Species</th>
<th>Mainstem Willamette Above Falls (above-Falls populations)</th>
<th>Areas below Willamette Falls (all populations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvest</td>
<td>Chinook</td>
<td></td>
<td>Fingerling/Sub-yearling</td>
</tr>
<tr>
<td></td>
<td>Steelhead</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hatchery</td>
<td>Chinook</td>
<td></td>
<td>4a</td>
</tr>
<tr>
<td></td>
<td>Steelhead</td>
<td></td>
<td>4a</td>
</tr>
<tr>
<td>Hydropower/Flood Control</td>
<td>Chinook</td>
<td>10d</td>
<td>5a,5b,7h,10f</td>
</tr>
<tr>
<td></td>
<td>Steelhead</td>
<td>10c</td>
<td>10d</td>
</tr>
<tr>
<td>Landuse</td>
<td>Chinook</td>
<td>8a</td>
<td>5a</td>
</tr>
<tr>
<td></td>
<td>Steelhead</td>
<td>8a</td>
<td>5a</td>
</tr>
<tr>
<td>Introduced Species</td>
<td>Chinook</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Steelhead</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Black cells = key concerns; Gray cells = secondary concerns; Cross-hatched cells = no populations.
4.10.3 Environmental Conditions

4.10.3.1 Habitat Access

Safe and effective passage of adult anadromous salmonids up the Willamette River and of juvenile anadromous salmonids down the river are critical to the ability of these fish to complete their migratory life cycles. The general relationships between safe fish passage, access to historical habitat, and the habitat requirements of UWR Chinook salmon and steelhead are described in detail in Appendix E. Table 4.10-3 summarizes the status of safe passage and access to habitat in the mainstem Willamette River under the environmental baseline, which is described in more detail below.

4.10.3.1.1 Willamette Falls as an Impediment or Barrier to Migration

Willamette Falls at Mile 26.6 is a bedrock sill that under natural conditions could be passed by upstream migrant salmon and steelhead only during winter and spring high flows. Opportunities for upstream fish passage at the Falls during less than high-flow conditions were then expanded by a series of early changes that included the construction of navigation locks in 1873 and of a crude rock fishway in the mid-1880s to early 1890s (ODFW 1990d). The effectiveness of the crude fishway was compromised, however, when subsequent hydropower development diverted flows away from its entrance to an area called the cul-de-sac, creating an area of false attraction for upstream migrants. A modern fish ladder completed in 1971 corrected the situation by providing entrances at several points around the falls area. Multiple additional improvements are now being made to correct upstream passage problems associated with specific features of the Willamette Falls Hydroelectric Project: the Sullivan Powerhouse, Blue Heron Powerhouse, and a low concrete dam at the top of the Falls. As part of Portland General Electric’s (PGE) new FERC license for this hydroelectric project (PGE 2004), continuous summer flow is provided to pools where adult fish can become stranded at the base of the Falls, Blue Heron Powerhouse was decommissioned to eliminate false-attraction of adults to its tailrace, and the existing ladder is being upgraded and better maintained.

Downstream passage conditions for salmonids migrating past Willamette Falls may rarely have been ideal under natural conditions, but were made less favorable when the site was developed for power production, beginning in 1891. At one point in the site’s developmental history, as many as 52 turbines were operated by several entities, each with the potential to cause high rates of injury and mortality to juvenile outmigrants. Massey (1967) estimated that during peak emigration (March through July), one-third of the downstream migrants passed through turbines at the Sullivan Plant. The Oregon State Game Commission measured mortality rates ranging from 7.7% to 100% for those juvenile Chinook salmon that passed through turbines at Willamette Falls in 1960 and 1961 (Thompson et al. 1966). Since then, all but 13 of the turbines have been removed, and PGE has installed an Eicher screen on the turbine that was found to pass the greatest percentage of fish. As mitigation for some of the project’s effects on anadromous fish, the FERC license includes the following improvements to downstream passage conditions:

- structural improvements to the Sullivan Powerhouse bypass system, including 2006 construction of a siphon bypass spillway at the downstream end of the forebay to pass juvenile fish around the turbines;
- permanent closure of the unscreened Blue Heron Powerhouse in 2003;
completion in 2007 of a Flow Control Structure at a low concrete dam atop the Falls, to direct over-falls flow toward safe fish landing areas; and

additional downstream passage improvements if needed to meet performance standards required by the new FERC license (PGE 2004). These standards include 98% smolt survival rates past the Sullivan Powerhouse, and 96% survival for emigrant fry.

4.10.3.1.2 Other Migration Impediments
Willamette Falls poses the only natural and artificial physical impediment to fish migration up or down the mainstem Willamette River. However, passage is no longer an impediment at the Falls due to passage improvements required in the FERC license and implemented by the licensee. Water quality conditions may at times affect the suitability of the river as a migration corridor. Such conditions are discussed in section 4.10.3.3.

4.10.3.2 Water Quantity/Hydrograph

The Willamette Project has changed the shape of the annual hydrograph of the Willamette River (Figures 4.10-2 A, B & C). A fraction of late-winter and spring runoff is now stored in reservoirs, reducing mainstem flows at those times of year, in order to augment flows in the summer and early fall. Late season flows remain low, but are higher now than they were prior to USACE dam construction. For example, the average annual 7-day low flow since completion of the Project has been almost twice that recorded in pre-project years.

The Willamette Project as a whole is operated to maintain year-round flows of at least 4,500-5,000 cfs in the Willamette River at its confluence with the Santiam River near Albany, Oregon and in excess of 6,000-7,000 cfs at Salem, Oregon. Maintaining such flows requires augmentation through reservoir drafting during August, September, and October in most years, and frequently requires augmentation in June and July as well. Since 2001, the Project has been managed with a greater emphasis on providing flows beneficial to ESA-listed salmonids, including efforts to hold minimum flows higher during spring through early fall to the degree feasible (see Figures 4.10-2 A, B & C and Table 2-8 in Chapter 2, Proposed Action). These recent efforts have enhanced minimum flows during the seasons identified relative to those that might have occurred without changes in Project operations.

The OWRD has issued permits for surface water withdrawals totaling 24,746 cfs for all uses throughout the Willamette basin. This is a maximum allowable diversion right and actual diversions are much lower at any particular time. Much of the diverted water is not consumed and returns to the river downstream from the point of diversion. Agricultural irrigation dates back to 1890 and is the largest water use in the basin, about 401,549 acre-feet per year (accounting for about 33% of total water use). Most of the early development took place near the cities of Portland, Salem, and Eugene, proceeding slowly through the first four decades of this century. About 1,000 acres were irrigated by 1911; 3,000 acres by 1920; 5,000 acres by 1930; and 27,000 acres by 1940. Since 1940, irrigation development has increased ten-fold. Total irrigated acreage in 1994 was between 240,000 and 290,000 acres, and water demands have increased accordingly (ten-fold) (OWRD 1999).
Before 1930, most of the water for irrigation came from surface sources but since then, there has been a growing reliance on groundwater. In 1990, the USGS estimated that 63% of water for irrigation in the basin came from surface sources and 37% from groundwater sources (OWRD 1999). Irrigated lands are distributed fairly evenly across the basin. Approximately 13% of the land that is irrigated with surface water sources is located in the region above Harrisburg, 24% in the upper mid-valley region above Albany, 32% in the lower mid-valley region above Salem, and 31% in the region below Salem (Table 4.10-2 A, B & C).

**Figures 4.10-2 A, B & C. Simulated discharge (cfs) of the Willamette River at Salem, Oregon under unregulated conditions (Unreg), with project operating criteria prior to 2000 (Pre-2000), and with project operating criteria after 2000 (Post-2000), depicting the 80th, 50th (median), and 20th percentile for each scenario.**

![Graph showing discharge simulations](image-url)
Figure 4.10-2 B

Figure 4.10-2 C
Water withdrawn anywhere from the Willamette Basin, whether in a tributary or on the mainstem affects flow in the mainstem Willamette River. In total, the USBR has issued 205 water service contracts for 59,231 acre-feet of water stored in Willamette Project reservoirs for irrigation (USACE 2007a). The largest contract provides for up to 9,625 acre-feet for the irrigation of 3,500 acres. Another five contracts individually serve more than 400 acres and provide for more than 1,000 acre-feet annually. The other 199 contracts currently in effect serve smaller numbers of acres and are almost all with individual water users. The amount of water actually used is less than the amount contracted (USACE 2007a).

As a subset of the entire USBR water contract program, on the mainstem Willamette itself there are a total of 49 long-term Reclamation water service contracts in effect on the mainstem for stored water from the Willamette Project. Cumulatively, these 49 contracts can withdraw a maximum of 10,971 acre-feet of stored water for irrigation.

The Willamette basin is home to over 2 million people, almost 70% of Oregon’s population. The Willamette River and its tributaries provide for substantial fraction of this population’s domestic and industrial water needs and the OWRD has issued water permits that total 2,737 cfs for municipal use from surface waters in the basin. The OWRD has also issued industrial uses water rights for diversions totaling 1,248 cfs and 13,691 cfs for hydropower.

Refilling the Willamette Project reservoirs during the late winter and spring (February through May) has reduced mainstem flows during the primary period of juvenile emigration from the system, adversely affecting migrating juvenile anadromous salmonids. ODFW (Mamoyac et al. 2000) has investigated the smolt-to-adult returns of Willamette basin winter steelhead and has determined that during years when average May flows fell below 15,000 cfs at Salem, Oregon, the number of recruits per spawner declined. These recruit per spawner data also corresponded to in-river temperature conditions above 14-15°C. Willamette River water temperatures during May tend to increase as flows decline. ODFW (Mamoyac et al. 2000) has identified Ceratomyxa shasta as the most likely causal agent for poor steelhead smolt-to-adult survival at low flows and

\[2\text{Most steelhead smolts migrate out of the Willamette system during March through June, with a peak in May. Spring Chinook juvenile migration timing in the basin tends to be more variable, with about half the annual outmigration taking place between February and June, peaking in May and half of the annual migration taking place between September and December, with a peak in late October.}\]
warm temperatures. The virulence of \( C. \ shasta \) to steelhead is known to increase at temperatures above 15°C. Flows below 15,000 cfs also tend to increase the disease’s virulence by contributing to warmer water temperatures. Also, as flows decrease, the average velocity decreases, particularly in large pools like the Newberg pool (a 45-mile stretch of deep, slow water between Willamette Falls and Wheatland Ferry north of Salem), thereby increasing smolt travel time and the duration of exposure to all causes of mortality in the river, including pathogens, toxins, and piscivorous fishes.

ODFW (Mamoyac et al. 2000) also investigated the relationship between flow and survival, although the data do suggest a positive correlation between survival and flow and a negative correlation between survival and temperature. Both Chinook and steelhead smolts have been found to migrate more slowly as flows decline in the lower Willamette below Willamette Falls (Freisen 2005), suggesting that durations of exposure to unfavorable conditions there may rise at the same time that the severity of such conditions increases.

Adult migrants can also be affected by reduced flows. At very low Willamette River flows (10,000 cfs and below) significant low-flow related passage delays have been observed at PGE’s Willamette Falls (T.W. Sullivan) hydropower project at Oregon City (Mamoyac et al. 2000), the most significant passage obstruction on the river. Passage time also increases as flows exceed 25,000 cfs at Willamette Falls, a condition that has been reduced by Willamette Project refill operations. At lower river flows and warmer temperatures adult spring Chinook salmon also tend to have a greater rate of pre-spawning mortality (Schreck et. al 1994). By reducing spring flows in the mainstem Willamette River the Willamette Project has complex and variable effects on adult salmonids. When natural Willamette River flows would otherwise exceed 25,000 cfs, spring storage operations at Willamette Project reservoirs may benefit spring Chinook salmon by reducing passage delays at Willamette Falls. At natural flow levels below 10,000 cfs, spring storage activity at Willamette Project reservoirs probably exacerbates passage delays at the Willamette Falls project and contributes to pre-spawning mortality in the river. In general, the period of poorest adult spring Chinook survival tends to occur after June 1 (Schreck et al. 1994), when the projects are usually passing inflow or augmenting flow.

Studies have shown that the mainstem Willamette River exhibits a fairly narrow period of optimal conditions for adult spring Chinook migration and survival to spawning areas (Schreck et al. 1994). Fish that pass Willamette Falls early in the season (April) tend to move slowly upstream, presumably due to cold water conditions, and may have difficulty maintaining their motivation to migrate. Some succumb. Mid-season migrants (May) move quickly upstream and reach holding areas in the spawning tributaries. Mid-season migrants survive well to the spawning tributaries. Late migrants (June) tend to move quickly to points near Salem and Albany where a substantial fraction remain and die. This general pattern varies with prevailing hydrologic and climatic conditions. In warmer, drier years the early migrants may behave like mid-season migrants and mid-season migrants may behave more like late season migrants. In wetter, cooler conditions, the behavior shifts toward that of early season migrants. These data suggest that reservoir filling during low water years may increase adult passage delays and contribute to pre-spawning mortality in the Willamette River. This effect appears to be small to negligible at river flows in excess of 10,000 cfs at Willamette Falls.
Aggregate water use in the basin has reduced streamflow, particularly during the summer irrigation season, potentially reducing the area suitable for rearing juvenile salmon and increasing adult passage delays, particularly during low water years.

Hydropower developments throughout the basin contribute to passage delays and passage mortality, and an array of water diversions diminishes flows and entrains juvenile fish. (Although the OWRD now requires that surface water diversions throughout the basin be screened to minimize fish entrainment, not all diversions are currently screened.)

The increase in late summer and early fall flows provided by USACE flow augmentation and reservoir drawdown operations probably benefits anadromous salmonids by increasing habitat area, reducing passage delays, and by improving water quality.

**Summary**

Human-caused alterations of the hydrologic regimes of the lower mainstem Willamette River and its principal tributaries have generally diminished flow-related habitat quantity and quality, and have reduced the numbers, productivity, and life history diversity (adult run timing and juvenile outmigrant strategies) of spring Chinook salmon and winter steelhead, and limited the production potential of accessible habitat in much of the basin.

Below Willamette Falls, the effect of project-related flow reductions during spring may be to incrementally increase exposures of juvenile salmonids to less than desirable conditions in that area by slowing their emigration rates.

### 4.10.3.2.1 Peak Flow Reduction

The 13-reservoir Willamette Project controls runoff from 27% of the Willamette Basin. Flood flows greater than 200,000 cfs were common at Albany, Oregon, prior to construction of the reservoir system (the recurrence interval was approximately 3.5 years; USACE 2000). The largest flow ever recorded at the Albany gauge (USGS Station No. 14174000) was 266,000 cfs on January 14, 1881, and larger, unrecorded floods were reported in 1861 and 1890. Between 1895 and 1941, the average annual maximum flow rate at Albany was over 106,000 cfs; floods were "flashy," building rapidly to a peak (USACE 1980). Since the USACE completed the flood control projects, the average annual maximum flow has been approximately 69,000 cfs. Operations have decreased the magnitude and frequency of extreme high flow events, and have increased the duration of moderate flows (22,000 to 45,000 cfs) and low flows (5,000 to 10,000 cfs).

Reductions in peak flows caused by USACE flood control operations have contributed to the loss of habitat complexity in the mainstem Willamette River by substantially reducing the magnitude of the channel-forming dominant discharge (i.e., the 1.5- to 2-year flood) and greatly extending the return intervals of larger floods. Over time, flood control tends to reduce channel complexity (e.g., reduces the frequency of side channels, and woody debris recruitment) and reduces the movement and recruitment of channel substrates. Side channels, backwaters, and instream woody debris accumulations have been shown to be important habitat features for rearing juvenile salmonids. Operation of USACE’s Willamette Project reservoirs is only partly responsible for the reduction in channel complexity noted in the mainstem Willamette River. Bank stabilization and channelization measures and land leveling and development in the basin...
have directly reduced channel complexity and associated juvenile salmon rearing habitat. These human-caused direct physical changes in the river’s complexity have been massive. For example, Benner and Sedell (1997) estimated that the total length of channel between Eugene and Albany has been reduced by 45% to 50% since 1850.

4.10.3.2.2 Altered Flow Effects on Spawning Success
The mainstem Willamette is generally not used for spawning by UWR Chinook or UWR Steelhead, although occasional use by spawning UWR Chinook has been reported for areas near the confluence of the McKenzie or farther upriver. Effects of USASCE-induced changes in mainstem flows during fall and winter on egg survival when Chinook redds are constructed in these areas are unknown, but any decreases in survival are likely to be small or negligible due to the attenuation of such changes with increasing distance from dams. Reductions in mainstem peak flows may increase egg survival in these areas by reducing risks of redd scour.

4.10.3.2.3 Flow Fluctuations, Entrapment & Stranding
Due to the distance from the projects, contributions from uncontrolled tributaries, and the attenuating effects of channel storage, rapid discharge fluctuations at the various Willamette Project dams are unlikely to result in rapid discharge fluctuations in the mainstem Willamette River. Thus the potential for project operations to cause stranding of juvenile salmonids in the mainstem Willamette River is very small.

4.10.3.3 Water Quality
Water quality conditions in the mainstem Willamette have improved noticeably from the severely poor conditions that prevailed along much of the river in the early to mid-1900s, when un- or little treated municipal and industrial wastes were discharged directly into the river. Recent trends in an integrated water quality index (the OWQI3) have generally been positive, though water quality during some months remains less than good along the mainstem as far upstream as Albany (at Mile 119.3) and poor from Newberg (Mile 48.6) down to the mouth (Cude 1996a, 1996b, 1996c). Despite the problems that remain, however, water quality conditions in the river place less severe constraints on sensitive fishes like UWR Chinook and UWR Steelhead than they did in the 1930s or 40s, a time when the Willamette Basin was producing well over an order of magnitude more wild UWR Chinook than it does at present. For example, Hughes and Gammon (1987) compared the results of historical and more recent longitudinal surveys of the river and concluded that there had been marked improvements in fish community quality since 1945.

The general relationships between water quality and the habitat requirements of UWR Chinook salmon and steelhead are described in Appendix E. Table 4.10-3 summarizes water quality conditions in the mainstem Willamette River under the environmental baseline, and which are described in more detail below.

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3 The Oregon Water Quality Index (OWQI) incorporates quantitative information on the following water quality constituents: temperature, nutrients (phosphorous and nitrogen), biochemical oxygen demand, dissolved oxygen, total solids, *E. coli* bacteria, and pH.
4.10.3.3.1. Water Temperature

The mainstem Willamette River exceeds Oregon temperature criteria intended to protect its value as salmonid habitat (ODEQ 2006a). From the confluence of the Middle and Coast forks (at Mile 187) downriver to Newberg (Mile 50.6), temperatures greater than criteria for salmonid rearing and migration habitat (18°C) are common from as early as mid-June to as late as mid-September, and those exceeding the standard for salmon spawning (13°C) have been recorded in the fall (ODEQ 2006a). From Newberg to the mouth, the Willamette exceeds a temperature standard established to maintain suitable migration conditions for salmon and steelhead (20°C) from as early as mid June to as late as mid-September (ODEQ 2006a). The frequency and magnitude of these temperature exceedences are partly a consequence of natural processes and conditions, but they also reflect man-caused changes within the river basin (ODEQ 2006a). Temperatures in the mainstem Willamette have been influenced by a variety of land and water uses, changes in channel morphology related to past USACE effort to simplify and stabilize the river itself, riparian alterations associated with development and flood control, and altered temperature and discharge patterns immediately below USACE dams on the river’s tributaries (ODEQ 2006a).

Willamette Project flood-control reservoirs have an influence on water temperatures in the mainstem Willamette related to release temperatures, discharge volumes, and distance downriver (ODEQ 2006a). The reservoirs store late winter and spring runoff, and then release it to augment streamflows during the dry months of summer and early fall. Consequent reductions in spring flows in the Willamette’s tributaries can lead to early warming of the mainstem and may lead to increased losses of emigrant steelhead smolts to the native parasite C. shasta (which becomes more virulent above 15°C) (ODFW 2007b). Greater than natural flows of cold water released from the deep, thermally stratified reservoirs during summer months may in some cases be too cold for optimal salmon growth immediately below the dams (ODEQ 2006a), but also reduces temperatures lower in the tributaries and the mainstem Willamette (USACE 1982), to the potential benefit of salmonids in those areas.

Thermal stratification in the reservoirs then breaks down in late summer or early fall, causing the temperature of released water to be warmer than natural as reservoirs are drawn down to increase flood storage capacity in the fall. The increased temperatures during fall can be too warm to fully support salmonid spawning and egg incubation (ODEQ 2006a; ODFW 2007b). The degree to which mainstem Willamette temperatures are elevated at this time of year is greatest in the upper river (ODEQ 2006a), where evidence of salmon spawning has been observed. Warmer than natural river temperatures during fall can result in elevated egg mortality, accelerated development of incubating Chinook salmon eggs, and premature fry emergence from the spawning gravels. Chinook fry that emerge too early tend to experience poorer river conditions, and thus are likely to have lower survival rates than they would have if egg development had followed a more natural pattern.

The USACE has long recognized the potential for Willamette Project reservoirs to have adverse thermal effects on salmonids using river reaches below its dams at certain times of year. In 2004, Cougar Dam on the South Fork McKenzie was fitted with a multi-level intake that allows for selective withdrawal of water from various reservoir depths and better matching of outflow to inflow temperatures. USACE operations will continue to have seasonally unfavorable thermal effects on ESA-listed salmon downriver from other flood-control dams until additional selective withdrawal structures or their equivalent are installed.
**Summary**

Temperatures in the mainstem Willamette River have been altered by a variety of man-caused changes in the drainage basin, including the operation of Willamette Project reservoirs and USACE modifications to the river channel. The mainstem is kept cooler by USACE flow augmentation during summer but is warmer than normal in the late summer and fall. The direct thermal effects of reservoir operations may be beneficial to salmonids in the Willamette during summer, but less than favorable for emigrating steelhead smolts during spring (when temperatures in years of low runoff may be warmer due to reduced spring flows) and are clearly unfavorable for any UWR Chinook that may spawn in river segments near the McKenzie River confluence or farther upriver. Degraded riparian conditions that are partly a consequence of flood control efforts have tended to warm the mainstem during spring and summer, and channel simplification by the USACE has likely reduced thermal heterogeneity and the availability of cool thermal refugia important to salmonids when mainstem temperatures are warm.

4.10.3.3.2. Dissolved Oxygen

Depressed concentrations of dissolved oxygen were common in the lower mainstem Willamette River during the first half of the 20th century as a consequence of serious water quality problems caused by little-regulated urban and industrial development. Human and industrial wastes were being discharged into waterways (Fish and Wagner 1950), creating problems that were pronounced in the mainstem from Newberg to the mouth (USACE 1982). Below Willamette Falls, high levels of bacterial decomposition and respiration caused dissolved oxygen concentrations to drop below 5 mg/l during August (Fish and Wagner 1950), creating an “oxygen block”. This “oxygen block” precluded fish migrations, including those of species now listed under the ESA. Passage generally occurred when dissolved oxygen concentrations were greater than about 3.5 to 5 mg/l (Alabaster 1988). The river’s water pollution and dissolved oxygen problems were eventually minimized by treating domestic and oxygen-consuming industrial wastes (reducing oxygen demand in the river by about 30%), and by augmenting flows and reducing peak temperatures through management of Willamette Project reservoirs (USACE 1982).

Despite improvements, available data suggest that dissolved oxygen concentrations in portions of the mainstem Willamette are at times falling below ODEQ numerical criteria intended to protect beneficial uses that include salmonid rearing and spawning. Results of a dissolved oxygen study described by Pogue and Anderson (1995) indicate that dissolved oxygen fell below 90% saturation (an ODEQ criterion established to protect salmonid habitat) in the mainstem Willamette River from RM 151 to 141.6 (just above Peoria, Oregon) during the summer rearing period. The lowered dissolved oxygen concentrations were probably the result of respiration by periphyton (attached algae). The ODEQ’s 2004/2006 Integrated Report database indicates that dissolved oxygen levels in the mainstem Willamette River between RM 54.8 (mouth of the Yamhill River) and RM 186.5 (the confluence of the Coast and Middle forks) have also fallen below numerical criteria intended to protect spawning salmonids or their incubating eggs from

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4 “The major pollution of the Willamette and its tributaries [in 1951] is caused by the discharge of raw sewage from 473,650 people, treated sewage from 45,500, wastes from 6 pulp mills and a variety of other industrial plants. The total organic wastes discharged from all municipal sources of pollution have a total population equivalent of 953,800. Fifty-six industries are known to be discharging organic wastes directly to the water courses with a population equivalent of 2,963,750” (Federal Security Agency 1951).
October 15 through May 15. These lower dissolved oxygen levels, while below the criteria, are not much lower.

Given the locations and seasons of the documented exceedances of ODEQ criteria, dissolved oxygen concentrations in the mainstem might at times be having small effects on juvenile UWR Chinook rearing in the mainstem during summer and on the survival to fry emergence of any UWR Chinook eggs deposited in the upper mainstem.

Flow augmentation from Project reservoirs and basin-wide secondary sewage treatment increased dissolved oxygen levels in the mainstem Willamette River and have contributed to positive changes in the native fish communities found in the mainstem Willamette. Compared to observations made in 1945, the river currently supports increased numbers of fish species that are relatively sensitive to low dissolved oxygen levels (Hughes and Gammon 1987).

**Summary**

Pollution-related dissolved oxygen problems in the mainstem Willamette River have been substantially reduced from those in the early 20th century, due in part to the construction and operation of Willamette Project reservoirs and in part to treating waste water. Fish communities in the river have responded to this improvement, though dissolved oxygen levels in the river remain less than optimal at some locations and in some seasons.

### 4.10.3.3.3 Total Dissolved Gas

There is no information indicating that total dissolved gas concentrations in the mainstem Willamette River have exceeded 110% of saturation.

### 4.10.3.3.4 Nutrients

The ODEQ’s 2004/2006 Integrated Report database does not indicate that the mainstem Willamette River is water quality limited due to nutrient loadings.

### 4.10.3.3.5 Turbidity

The ODEQ’s 2004/2006 Integrated Report database does not indicate that the mainstem Willamette River is water quality limited due to turbidity.

### 4.10.3.3.6 Toxics

Numerous organic pesticides are present in Willamette Basin streams, and some of these pesticides are present at concentrations that approach criteria for the protection of human or ecological health (Anderson et al. 1996). The Willamette Pesticides Project (Phase III), a cooperative effort between the USGS and the ODEQ, studied a representative set of 16 small streams that each drained approximately 10 square miles of primarily agricultural land (Anderson et al. 1996). Four sites draining primarily urban land were also included, to provide a comparison between agricultural and urban land uses. Water-quality samples were taken five times between April and November, 1996, twice coinciding with spring storms, once during the summer low flow period, and twice during fall storms. Basinwide, a total of 36 pesticides (29 herbicides and 7 insecticides) were detected that could find their way into the Willamette River. The five most frequently detected compounds were the herbicides atrazine (99% of samples), desethylatrazine (93%), simazine (85%), metolachlor (85%), and diuron (73%). Although the transport of contaminants to streams is related to discharge and the amount of runoff,
correlations between discharge and pesticide concentration were poor (Anderson et al. 1996). In general, pesticide concentrations were greater in smaller than in larger tributary streams (Anderson et al. 1996).

Bacterial contamination is an intermittent problem along the mainstem Willamette during periods of elevated runoff from fall through spring (ODEQ 2006a). However, concerns related to this contamination focus primarily on the protection of human health and any effects of the elevated bacteria levels on salmonids are unclear. Combined sewer overflows (CSOs) during fall through spring remain a particular human health concern in and below the Portland metropolitan area (ODEQ 2006a). Portland’s CSOs are not known to have a major effect on UWR Chinook or UWR Steelhead, but are being addressed by $1.4 billion changes in infrastructure that will better isolate the remaining 35% of the city’s sewage treatment system influenced by stormwater runoff (Portland 2007).

The ODEQ’s 2004/2006 Integrated database indicates the following exceedences of water quality criteria for the protection of anadromous fish:

- DDT - 2 out of 7 water column samples at RM 12.7 exceeded the criterion of 0.000024 pg/L
- Polynuclear aromatic hydrocarbons (PAH) - at RM 6 the 35-day average concentration of 52,900 pg/L exceeded the criterion of 2,800 pg/L

**Summary**

Available data suggest that small streams draining agricultural lands in the Willamette Basin, such as those valley floor tributaries that are sometimes used as over-wintering areas by juvenile UWR Chinook, may contain one or more organic pesticides at levels approaching those of environmental concern. Below Willamette Falls, concentrations of DDT and of PAH measured in the mainstem Willamette have exceeded criteria established to protect anadromous fish.

### 4.10.3.4 Physical Habitat Characteristics

The general relationships between natural processes that create and maintain complex stream channels, and the habitat requirements of UWR Chinook salmon and steelhead, are described in Appendix E. Many of these processes within the Willamette Basin have been substantially altered by human actions, including the construction and operation of USACE dams, historical alterations to the Willamette River channel, and varied landuses both in upland areas and on the floor of the Willamette Valley. Table 4.10-3 summarizes the status of key habitat components along the Willamette mainstem under the environmental baseline, which is described in more detail below.

**Substrate**

Substrate conditions at various points along the mainstem Willamette reflect a combination of natural landscape-level processes, adjacent topographic features, and the cumulative effects of man-caused changes in the surrounding watershed. Fine-textured sediments predominate below Newberg and particularly below Willamette Falls, due to low channel gradients. Gravel is mined extensively from the river for navigational, commercial, and private purposes. The Division of State Lands permitted extraction of close to 60 million cubic yards from the mainstem between 1967 and 1994 (OWRRI 1995). Many commercial operations extract gravel from the river’s
floodplain, and private and commercial operations also remove gravel from bars exposed by low summer flows.

**Large Woody Debris**
Historically, many segments of the Willamette River were filled with snags (large wood) and fallen trees “too numerous to count” (Reports of Secretary of War 1875, in Sedell and Froggatt 1984). The USACE observed that a primary source of these snags was that trees toppled into the river from its banks during floods and were transported downstream (Benner and Sedell 1997). The snags often formed large jams and rafts of logs that created or cut off side channels, diverted flow, and formed gravel bars (Sedell and Froggatt 1984). All of these functions would have favored the creation and maintenance of complex, high-quality salmonid habitat. For many years the USACE attempted to clear the Willamette River channel of large wood. Between 1870 and 1950, over 69,000 snags and overhanging trees were removed from the river, 90% of which were removed from highly complex channels found between Albany and Eugene (Sedell and Froggatt 1984). Inputs of large wood to the mainstem Willamette have been reduced by extensive riparian alterations along the river and in many tributary subbasins, as well as by elimination of wood delivery from watershed areas above dams. While no data quantifying large wood abundance is available for the present-day mainstem Willamette, the river no longer contains volumes of wood approaching those described by the USACE in 1875 surveys.

**Channel Complexity, Off-channel Habitat & Floodplain Connectivity**
Prior to development, complex channel features important to salmonids were created and maintained along the mainstem Willamette by the dynamic behavior of uncontrolled river processes including floods, gravel movement, large wood recruitment, erosion and sediment deposition (Hulse et al. 2002). Development of the Willamette Valley has modified these processes through flood control (with 13 major USACE dams), channel stabilization (by removing wood and constructing revetments), removal of large patches of riparian forest and their potential as wood sources, and gravel mining. The result has been channel simplification and reductions in the quantity and quality of key salmonid habitats: side channels, alcoves, and aquatic features on the river’s floodplain (Hulse et al. 2002). These changes may also have had unfavorable effects on river temperatures, by increasing surfaces exposed to solar radiation (ODEQ 2006a) and by reducing important thermal refugia associated hyporheic exchange (Fernauld et al. 2001; ODEQ 2006a).

The historical Willamette River channel was very complex, frequently recruited and transported large wood, and dynamically changed its course in high-flow events unless constrained by adjacent topography. Beginning in the mid-1800s, however, efforts were made to improve the river for navigation, and the first federal program to improve the navigability of the Willamette began in 1870. The USACE removed large woody debris (as noted earlier) and began confining the river to fewer channels by dredging the main channel and blocking side channels (Benner and Sedell 1997). Over time, the USACE installed over 46 miles of revetments along the river and private entities constructed an additional 50 miles of such structures to maintain navigation, prevent riverbank erosion, or both. Combined, 25% of the mainstem Willamette has now been revetted on one or both sides. This understates the effect of these structures, however, because revetments are typically constructed along dynamic sections of river. Approximately 65% of all meander bends along the mainstem Willamette, those segments of the river most likely to change under natural conditions, have been stabilized with revetments (Hulse et al. 2002).
Flood control has exacerbated the loss of channel length and complexity caused along the Willamette by direct modifications like revetments, intentional channel blockages, and gravel removals because most changes in channel form occur during high flow events. Diminished high flows have reduced the river’s access to its floodplain and the large wood still present in remaining patches of riparian forest. USACE dams now regulate about 65% of flow in the Willamette River at Harrisburg, and approximately 27% of runoff from the entire Willamette Basin passes through flood control reservoirs (USACE 1989a).

The mainstem Willamette River is today relatively simple and static compared to the complex, dynamic system present prior to development. During the period from 1850 to 1995, the total area of river channels and islands decreased from 41,000 acres to less than 23,000 acres and the total length of all channels decreased from 355 miles to 264 miles (Hulse et al. 2002). More than one half of the area of small floodplain tributaries and more than one-third of the alcoves and sloughs were lost by 1995 (Hulse et al. 2002). About half of these reductions in habitat complexity occurred between 1934 and 1995, a period influenced by the construction and operation of all 13 USACE flood control dams in the basin, and floodplain development that occurred after dam construction.

Losses of islands, alcoves and side channels, combined with extensive revetments, have reduced hyporheic (subsurface hydraulic) connectivity within the Willamette River. Fernauld et al. (2001) show that hyporheic flow can enter alcoves that are separated from the main river channel by 200 m gravel bars, and can have a strong influence on conditions in off-channel habitats. During the hottest time of the day during summer, the upper-most portion of some alcoves was 3.6 to 9°F cooler than the main channel, most likely due to water emerging into the head of the alcove after flowing hyporheically (Hulse et al. 2002). Hyporheic connectivity is dependent on fresh, unconsolidated gravel, which has become limited in the upper Willamette River. Revetments directly prevent hyporheic connectivity (Fernauld et al. 2001), but also indirectly, as revetments hinder migration of the channel that is necessary for loose gravel to deposit and create conditions conducive to hyporheic flow.

Changes in habitat complexity, off-channel habitats, and floodplain connectivity have not been uniform along the Willamette. They have been pronounced along naturally unconfined river segments, particularly upriver from Albany (Figure 4.10-3), and more subtle where the river channel is naturally constrained by local topography, particularly below Newburg. This pattern would suggest that the mainstem rearing habitats of Chinook populations that spawn in tributary subbasins upriver from Albany, and particularly the McKenzie and Middle Fork Willamette spring Chinook, have been most affected by simplification of the mainstem Willamette.

Although significant seasonally high-quality rearing habitat still exists in some segments of the Willamette above Albany, what remains is a fraction of that once present. Though still the most complex section of the river, the Willamette above Albany has experienced a 45% reduction in active channel length, from 210 to 115 miles, since 1850 (Hulse et al. 2002). Also since 1850, the total area of islands and active channels within this river section has decreased from around 25,000 acres to about 8,000 acres. Approximately 70-80% of the island and side channel area, and 40% of the alcove area, were lost above Albany during this same period, with about half the loss occurring after 1932 (Hulse et al. 2002).
Figure 4.10-3 Changes in Willamette River channels in the Harrisburg area, upriver from Albany, between 1850 and 1995 (Hulse et al. 2002).
Riparian Reserves & Disturbance History
The general relationships between riparian vegetation, floodplain function, and the habitat requirements of UWR Chinook salmon and steelhead are described in Appendix E. Table 4.10-3 summarizes the status of riparian vegetation and floodplain function in the mainstem Willamette River under the environmental baseline, which is described in more detail below.

Pre-settlement vegetation along the Willamette River consisted primarily of bottomland forests containing black cottonwood, Oregon ash, Douglas fir, ponderosa pine, big-leaf maple, willow, and alder (Johannessen et al. 1970). The lateral extent of these forests depended on the width of the floodplain, but along reaches of the Willamette above Albany, they generally extended one to two miles on either side of the river. Bottomland forest near the confluence of the Santiam and Willamette rivers was approximately seven miles wide (Towle 1982). In 1850, hardwood forests bordered 68% the 276 river miles of channels length between Ross Island (below Willamette Falls) and Eugene, while mixed and coniferous forests were found along 21% of the river’s length (Hulse et al. 2002).

In an intensive effort to improve the Willamette for navigation, the USACE cleared at least 31,450 trees from the banks of the Willamette from Albany to Eugene between 1870 and 1915, and cut additional wood to fuel steamboats used for clearing snags from the river. Larger-scale clearing of the Willamette’s riparian forests began just before 1900, when softwoods were floated in rafts to paper mills in Oregon City (Nash 1904). By 1895, more than half of the bottomland hardwood forests had been converted to agriculture. Forests then continued to be cleared for agriculture well into the 20th century (Towle 1982) as large-scale irrigation systems became available and flood protection afforded by the newly-constructed Willamette Project reduced the risk of farming in the floodplain.

By 1990, riparian land uses were varied along the Willamette and had frequently altered or removed vegetation adjacent to the river. USACE characterizations of riparian vegetation while reconnoitering the river from a boat in 1850, 1895, 1932, and 1990, provide an indication of the changes that have taken place. Their accounts revealed that the greatest losses of forest have occurred along the Willamette River above Albany, where historically hardwood forests comprised 88% of streamside vegetation. As of 1990, 40% of the riverside area above Albany was occupied by agriculture and 9% by urban areas. Along the Willamette River from Albany to Newberg, agricultural and urban areas now border 40% of the river, where historically this area consisted of primarily hardwood forests interspersed with native grassland and mixed forests. Below Newberg, where almost 60% of the river passed through coniferous and mixed riparian forests in 1870, 50% of the riparian corridor had been converted to urban development or agricultural land.

Although substantially reduced in area and often in vigor, patches of cottonwood-dominated forest remain along the Willamette, particularly in those areas where they were once most extensive: along naturally unconstrained channels between Eugene and Newberg. Many of these patches started years ago as young trees that established themselves on exposed alluvial and floodplain surfaces after floods. Such natural establishment of these forests has been diminished by flood control.
During qualitative surveys of the river during 1995 and 1996, Dykaar and Wigington (2000) found few young cottonwoods and expressed concern that present levels of establishment are not sufficient to sustain riparian forests even at their presently diminished extent. This is something of substantial concern since cottonwoods are the bottomland species whose boles are large enough to make them important in providing big wood to the river. As cottonwood forests mature their understories fill with shade-tolerant species such as Oregon ash and big-leaf maple (Fierke 2002). Then, as they reach and pass maturity, live cottonwood trees and snags can serve as a source of in-channel wood if recruited to the river through channel migration or over-bank flooding. However, without the continued natural establishment of young cottonwoods that occurs with channel migration and overbank floods, existing cottonwoods near the river may senesce without replacement, leaving hardwood forests that are less capable of contributing big wood to the river. An additional concern is that non-native plant species, such as Himalayan blackberry and reed canarygrass, have invaded many riparian forests along the river and may hinder even the development of native understory species (Fierke 2002).

Land clearing for agricultural and urban development, construction of revetments, flood control, and invasive species have reduced the extent and health of riverside forests along the mainstem Willamette. This has contributed to reductions in the quantity and quality of rearing habitats for the river’s juvenile salmonids by reducing inputs of wood to river’s primary and secondary channels, limiting the complexity of available aquatic habitats, and contributing to elevated river temperatures by reducing levels of shade. Current riparian communities are far less capable than the historical floodplain forests at supplying valuable nutrients and organic matter during flood pulses, enhancing food sources for macro-invertebrates, and providing slow-water refugia for fish during flood events.

**Summary**

The installation of revetments, reduced magnitude and frequency of floods, direct channel modifications, development, reduced floodplain forest, reduced amounts of large wood, and gravel mining have significantly diminished both the quantity and quality of anadromous salmonid habitat in the mainstem Willamette River. Resultant decreases in channel complexity may have reduced thermal heterogeneity important to any remaining adult Chinook migrating up the river after water temperatures have risen to sub-optimal levels during late spring or summer. Reduced complexity has also affected the abundance and quality of mainstem summer rearing and/or over-wintering habitat for juvenile Chinook spawned in the river’s tributaries. Such habitat includes woody debris jams, side channels, alcoves, areas of lowered velocity along channel margins, summer-time thermal refugia, and quiescent winter refugia on floodplains and in the lower-most reaches of valley floor tributaries.

**4.10.4 Hatchery Programs**

Interactions with hatchery fish exert key adverse effects on all UWR Chinook populations above Willamette Falls and two of four UWR Steelhead populations. The key threat to Chinook occurs at the adult spawner stage in the tributaries when hatchery fish interbreed with wild fish, and may reduce their fitness (productivity) through genetic introgression. Key threats to native steelhead occur at several juvenile life stages (competitive interactions) as well as at the adult spawner stage.
4.10.5 Fisheries

Chinook
UWR Chinook salmon returning to the Willamette River have supported many commercial and recreational fisheries, which contributed to their decline. Intentional harvest of natural-origin spring Chinook was, until recently, permitted. However, a Fisheries Management and Evaluation Plan that specifies a new harvest regime for wild UWR Chinook has been approved by NMFS under the ESA. Harvest management now focuses on using identifiable marks (fin clips) and selective fisheries to protect natural-origin stocks, with a cap of 15% for fishing-related mortality. The result has been a reduction in fishing-related mortality of wild fish to levels below the cap, and in the range of 8-12% (Figure 4.10-4, ODFW 2008c). Selective fisheries are helping to conserve the wild population while allowing harvest of more abundant adult hatchery-origin Chinook that were released as smolts into the Willamette’s tributaries.

![Graph showing harvest rates of wild UWR Chinook](image)

*Figure 4.10-4 Harvest rates of wild UWR Chinook in freshwater commercial and sport fisheries. Data from ODFW (2008c).*

Steelhead
Fishing-related mortality of wild UWR Steelhead is held to low levels by selective fisheries that allow harvest only of hatchery-origin steelhead marked with a clipped adipose fin. Chilcote (2007) estimates that recent levels of incidental mortality on these populations have averaged 7%.

4.10.6 Status of PCEs of Designated Critical Habitat and Factors Affecting Those PCEs along the Mainstem Willamette

Although the WLCTRT (2003) found no evidence of a historical demographically independent population of UWR Chinook or UWR Steelhead that spawned primarily in the mainstem Willamette, NMFS designated the river as Critical Habitat because of its importance as both a migratory corridor and juvenile rearing area for populations in the river’s tributaries (NMFS...
NMFS
Willamette Project Biological Opinion

2005g). The mainstem Willamette River passes through three different subbasins, within each of which Critical Habitat has been identified by NMFS (2005d). The Lower Willamette subbasin includes the mainstem from its confluence with the Columbia River to Willamette Falls (RM 0.0 to RM 26.6). The Middle Willamette subbasin includes the mainstem from Willamette Falls upriver to the confluence of the Luckiamute River (RM 26.6 to RM 107.5). The Upper Willamette subbasin includes the mainstem from the Luckiamute River confluence up to the confluence of the Middle and Coast forks of the Willamette (RM 107.5 to RM 187.0). NMFS determined that the following occupied areas of habitat associated with the mainstem Willamette River contain PCEs (as described below) for UWR Chinook salmon ESU and UWR steelhead (NMFS 2005g):

UWR Chinook salmon in the Upper Willamette Subbasin, excluding Westside Tributaries (see section 4.9) and the Calapooia system (section 4.4)

- There are 0 miles of PCEs for spawning/rearing, 79.9 miles for rearing/migration, and 0 miles for migration/presence in the Upper Willamette Subbasin. Areas included are the mainstem Willamette, its floodplain, and small floodplain tributaries.
- The upper mainstem Willamette is an important rearing area and migration route for UWR Chinook, but the watersheds within which it is embedded were given a low rating.
- Bank protection measures in the mainstem Willamette associated with USACE activities total 175,387 linear feet (33.2 miles) between RM 111.1 and RM 182.6, with 66,559 feet (12.6 miles) on the right bank, and 108,828 feet (20.6 miles) on the left bank (USACE 2000).

UWR Chinook salmon in the Middle Willamette Subbasin

- There are 0 miles of PCEs for spawning/rearing, 158.3 miles for rearing/migration, and 0 miles for migration/presence in the Middle Willamette Subbasin. This subbasin includes habitat within the mainstem and multiple small tributaries.
- All watersheds evaluated in the Middle Willamette River subbasin were assigned a low rating.
- Bank protection measures associated with USACE activities total 71,469 linear feet (13.5 miles) between RM 59.6 and RM 104.7, with 37,201 feet (7.04 miles) on the right bank, and 34,268 (6.5 miles) on the left bank (USACE 2000).

UWR Chinook salmon in the Lower Willamette Subbasin

- There are 0 miles of PCEs for spawning/rearing, 46.5 miles for rearing/migration, and 0 miles for migration/presence in the Lower Willamette Subbasin. This subbasin includes the mainstem Willamette and the following tributaries: Johnson Creek, Scappoose Creek, and the Columbia River Slough.
- All 3 watersheds were assigned a high rating because rearing and migration through these areas are considered highly essential for ESU conservation. (NMFS 2005g).

UWR Steelhead in the Upper Willamette Subbasin, excluding Westside Tributaries and the Calapoioa system

- There are 0 miles of PCEs for spawning / rearing, 12 miles for rearing/migration, and 0 miles for migration/presence in the Upper Willamette Subbasin. This includes mainstem habitat between the Calapooia and Luckiamute confluences.
The watershed within which the segment of the mainstem noted above is embedded was assigned a medium rating.

Bank protection measures in the Mainstem Willamette associated with USACE activities total 175,387 linear feet (33.2 miles) between RM 111.1 and RM 182.6, with 66,559 feet (12.6 miles) on the right bank, and 108,828 feet (20.6 miles) on the left bank (USACE 2000). Some of these altered banks are upriver from the habitat designated as critical for UWR Steelhead.

**UWR Steelhead in the Middle Willamette Subbasin**

- There are 35.8 miles of PCEs for spawning / rearing, 140.7 miles for rearing/migration, and 0 miles for migration/presence in the Middle Willamette Subbasin. This subbasin includes the mainstem Willamette and several small tributaries.
- Within the 4 watersheds evaluated in the Middle Willamette River subbasin, all 4 were assigned a low rating.
- Bank protection measures associated with USACE activities total 71,469 linear feet (13.5 miles) between RM 59.6 and RM 104.7, with 37,201 feet (7.04 miles) on the right bank, and 34,268 (6.5 miles) on the left bank (USACE 2000).

**UWR Steelhead in the Lower Willamette Subbasin**

- There are 0 miles of PCEs for spawning / rearing, 46.5 miles for rearing/migration, and 0 miles for migration/presence in the Lower Willamette Subbasin. This subbasin includes the mainstem Willamette and the following tributaries: Johnson Creek, Scappoose Creek, and the Columbia River Slough.
- All 3 watersheds were assigned a high rating because rearing and migration through these areas are considered highly essential for ESU conservation.

NMFS (2005g) identified the key management activities that affect the PCEs identified above. These activities include agriculture, channel modifications/diking, road building and maintenance, urbanization, and wetland loss and removal.

Table 4.10-3 summarizes the condition of PCEs associated with the mainstem Willamette River. Many of the habitat indicators are not in a condition suitable for salmon and steelhead conservation. In most instances, this is the result of past or ongoing operations of the Willamette Project, USACE alterations of the river channel, or the cumulative effects of other human activities (e.g., development, agriculture, and logging).
### Table 4.10-3 Critical habitat primary constituent elements (PCEs) and associated pathways, indicators, current conditions, and limiting factors for ESA-listed anadromous salmonids in the Mainstem Willamette River under the environmental baseline.

<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
<th>Limiting Factors</th>
</tr>
</thead>
</table>
| Freshwater migration corridors | Habitat Access | Physical Barriers | *Willamette Falls as a Barrier to Migration*  
Willamette Falls (RM 26.6) is a natural barrier that has always restricted fish passage during low flows; however, constructed ladders have likely improved passage during low flow periods.  
Navigation locks built in 1873 allowed some upstream fish passage; first crude rock fishway built at Willamette Falls in mid-1880s to early 1890s  
Falls developed for hydroelectric production in 1891 with as many as 52 turbines in operation at one time; juvenile Chinook turbine mortality rates are 7.7%-100%  
Sullivan Plant was closed during the downstream migration in the mid-1970s and 1980s; with structural improvements to the bypass in 1991, Sullivan Plant operates year round.  
Currently, downstream passage survival is above 90% through the Sullivan Plant and anticipated to be at least than 97% over the Willamette Falls Dam. | Natural condition  
Privately owned navigation lock  
Private hydroelectric development |
### Freshwater Spawning Sites

<table>
<thead>
<tr>
<th>PCE</th>
<th>Pathway</th>
<th>Indicator</th>
<th>Condition</th>
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### Freshwater Rearing

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# Willamette Project Biological Opinion

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<td>Freshwater rearing</td>
<td>Water Quality</td>
<td>Freshwater migration corridors</td>
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<td>Freshwater rearing</td>
<td>Water Quality</td>
<td>Freshwater migration corridors</td>
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<td>Limiting Factors</td>
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<td>Water Quality</td>
<td>Total Dissolved Gas (TDG)</td>
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<td>Habitat Elements</td>
<td>Substrate</td>
<td>USACE reservoirs trap sediment and large wood from headwaters</td>
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<td>Freshwater migration corridors</td>
<td>Habitat Elements</td>
<td>Large Woody Debris</td>
<td>USACE operates flood control dams to reduce the magnitude and frequency of peak flows</td>
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<td></td>
<td></td>
<td>Lack of large wood in main channel and side channels</td>
<td>USACE and private revetments</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>USACE channel straightening</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Extensive in-stream and floodplain gravel mining</td>
<td></td>
</tr>
<tr>
<td>PCE</td>
<td>Pathway</td>
<td>Indicator</td>
<td>Condition</td>
<td>Limiting Factors</td>
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<td>-----------------</td>
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<tr>
<td></td>
<td>Freshwater rearing sites</td>
<td>Habitat Elements</td>
<td>Pool Frequency and Quality</td>
<td>Simplification of the river channel has resulted in losses of pools and pool quality</td>
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<td></td>
<td>Freshwater spawning sites</td>
<td>Habitat Elements</td>
<td>Off-channel Habitat</td>
<td>Major losses of channel complexity, side channels, backwaters, and other features of importance to salmonids as a consequence of stream cleaning, construction of revetments, flood-control, altered riparian vegetation, reduced inputs of large wood, and floodplain development.</td>
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<tr>
<td></td>
<td>Freshwater spawning sites</td>
<td>Channel Conditions and Dynamics</td>
<td>Width/Depth Ratio</td>
<td>The river is less dynamic and has fewer multi-threaded channels due to historical alterations, construction of revetments, flood-control, altered riparian vegetation, reduced inputs of sediment and large wood, and floodplain development.</td>
</tr>
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### Limiting Factors

<table>
<thead>
<tr>
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<tr>
<td></td>
<td>Freshwater spawning sites</td>
<td>Streambank Condition</td>
<td>46 miles of USACE revetments and 50 miles of private revetments along the mainstem Willamette prevent lateral channel migration</td>
<td>USACE operates flood control dams to reduce the magnitude and frequency of peak flows</td>
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<td></td>
<td>Freshwater rearing</td>
<td>Channel Conditions and Dynamics</td>
<td>65% of outer bends of meanders revetted</td>
<td>USACE reservoirs trap sediment and large wood from headwaters</td>
</tr>
<tr>
<td></td>
<td>Freshwater migration corridors</td>
<td>Channel Conditions and Dynamics</td>
<td>Channel length in 1990 reduced to only 20%-30% of channel length in 1850</td>
<td>USACE channel straightening</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Channel Conditions and Dynamics</td>
<td>Alcove and island area reduced to 20%-30% of that present in 1850</td>
<td>USACE and private revetments</td>
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<tr>
<td></td>
<td></td>
<td>Channel Conditions and Dynamics</td>
<td>River channel form does not change frequently, and new islands and gravel bars seldom form</td>
<td>USACE removes large wood from reservoirs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Floodplain Connectivity</td>
<td>Floodplain is not frequently inundated, with less over-bank flow and side channel connectivity</td>
<td>Development of floodplain land</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Floodplain Connectivity</td>
<td>Reduced nutrient exchange, reduced sediment exchange, reduced flood refugia for fish, and reduced establishment of new riparian forests</td>
<td>USACE blockage of side channels and channelization for navigation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Floodplain Connectivity</td>
<td>USACE operation of flood control dams reduces the magnitude and frequency of peak flows</td>
<td>USACE and private revetments</td>
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<td>Floodplain Connectivity</td>
<td></td>
<td>Levees</td>
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<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Watershed Conditions</td>
<td>Prairie and oak savanna habitat is rare within the Willamette Valley foothills</td>
<td>Conversion to agricultural, urban, residential, industrial, and rural uses</td>
</tr>
<tr>
<td></td>
<td>Freshwater migration corridors</td>
<td></td>
<td>Lower watershed contains extensive agricultural, urban, and residential development</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Agriculture and development constitute almost 60% of the Willamette Valley lowland vegetation</td>
<td></td>
</tr>
<tr>
<td>Freshwater spawning sites</td>
<td>Freshwater rearing</td>
<td>Watershed Conditions</td>
<td>Area of riparian forest along the mainstem Willamette in 1990 is 75-90% less than in 1850</td>
<td>Clearing for navigation, agriculture, or development</td>
</tr>
<tr>
<td></td>
<td>Freshwater migration corridors</td>
<td></td>
<td>Many remaining patches of floodplain forest are interspersed with agriculture</td>
<td>USACE and private revetments</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Low large wood recruitment potential</td>
<td>USACE operation of flood control dams alters the hydrologic regime</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Few continuous large patches of riparian forest</td>
<td>Timber harvest</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Riparian Reserves</td>
<td>Many forests contain non-native Himalayan blackberry and reed canary grass that hinder development of young cottonwood forests.</td>
<td>Conversion to agricultural, urban, residential, industrial, and rural uses</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Prairie and oak savanna habitat is rare within the Willamette Valley foothills</td>
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</table>
Section 4.11
Lower Columbia River, Estuary & Coastal Ocean Baseline
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4.11 LOWER COLUMBIA RIVER, ESTUARY, & COASTAL OCEAN

The Columbia River is the largest in the Pacific Northwest and the fourth largest in the United States. At its confluence with the Willamette River near Portland, Oregon, the river carries an average annual flow of about 190,000 cfs. The Willamette River contributes another 34,000 cfs, about 15 percent of total Columbia River flow.

All 13 listed species of ESA-listed Columbia River basin salmonids (see Table 3-1) occupy the lower Columbia River during some portion of their life cycle, primarily during their juvenile and adult migrations. The estuary is also occupied by the southern DPS of North American green sturgeon (*Acipenser medirostris*), which is listed as threatened. Southern Resident killer whales are found throughout the coastal waters off Washington, Oregon, and Vancouver Island and are known to travel as far south as central California and as far north as the Queen Charlotte Islands, British Columbia. Southern Residents are highly mobile and can travel up to 86 miles (160 km) in a single day (Erickson 1978; Baird 2000). To date, there is no evidence that Southern Residents travel further than 50 km offshore (Ford et al. 2005).

Recent investigations using Interior Columbia Basin Chinook and steelhead have shown that juvenile salmon survival below Bonneville Dam is a strong determinant of year-class strength. Several known factors contribute to this effect, including bird, fish, and pinniped predation and near-shore ocean characteristics. The latter are presumed to be related to the influence of ocean conditions on the availability of prey and as habitat for marine predators at the time of ocean entry.
Habitat in the lower Columbia River, estuary, and plume has been affected over the past 60 years by water development, including operations at mainstem Columbia River hydrosystem projects and by operations at the multipurpose storage projects both in the upper Columbia and Willamette basin. With the loss of low velocity, shallow water habitats, the mainstem reach of the lower Columbia River has been reduced primarily to a single channel. The river has been cut
off from the tidal floodplain by dikes, revetments, and flood control operations, off-channel habitat features have been eliminated or disconnected from the main channel, and the amount of large woody debris in the mainstem has been greatly reduced. Much of the remaining habitat continues to be affected by flow fluctuations associated with reservoir water management for flood control, irrigation, and other purposes.

Large multipurpose storage projects, developed in both Canada and the United States, have altered the seasonal runoff pattern and volume of flow into the estuary. Recent model studies indicate that the volume and timing of water and sediment delivery to the estuary have changed since the late 1880s due to hydrosystem operation, even after the effects of climate change and irrigation withdrawals are taken into account (Bottom et al. 2000). Compared with the 1880s, current operations:

- Deliver more water to the estuary during winter (October through April) and less water during spring and summer
- Reduce the peak spring freshet by more than 40% and reduce total freshet-season flow volume by about 30%
- Lengthen the period of the freshet and move the peak flow earlier (by pre-releasing stored water for flood control, a need heightened by recent global climate change)
- Greatly increase fall-winter minimum flows

In addition, model studies indicate that the hydrosystem and climate change together have decreased suspended particulate matter to the lower river and estuary by about 40% (as measured at Vancouver, Washington) and have reduced fine sediment transport by 50% or more. Over-bank flow events, important to habitat diversity, have become rare—partly because flow management and irrigation withdrawals prevent high flows and in part because diking and revetments have increased the “bankfull” flow level (from about 643,000 to 857,000 cfs). The dynamics of estuarine habitat have changed in other ways relative to flow. The availability of shallow (between 4-in and 6.5-ft depth), low-velocity (less than 1 ft/s) habitat now appears to decrease at a steeper rate with increasing flow than during the 1880s, and the estuary’s absorption capacity for increasing water depth with increasing flow appears to have declined.

Depending on the season and river flow, the Columbia River plume may extend hundreds of miles into the Pacific Ocean. The plume appears to be an important habitat for juvenile salmonids, particularly during the first month or two of ocean residence. Ongoing studies show that nutrient concentrations in the plume are similar to those associated with upwelled nearshore waters, thus the plume may provide an important nutrient source for juvenile salmonids and other species. Coho salmon appear to have a preference for low salinity surface waters, as the abundance and distribution of juveniles are higher and more concentrated in the Columbia River plume compared to adjacent, more saline waters (Jay 2002). What is not known is how Columbia River flows affect the structure of the plume during outmigration periods, and whether critical threshold flows are needed. Ongoing research is documenting important relationships between juvenile salmon growth and survival during this stage of their life history (Casillas 2002).
4.11.1.1 Predator/Prey Interactions in the Lower Columbia River, Estuary & Coastal Ocean

4.11.1.1.1 Piscivorous Birds
Increasing populations of piscivorous birds (primarily Caspian terns and double-crested cormorants), nesting on islands in the Columbia River estuary, have annually consumed millions of migrating juvenile salmonids (Roby et al. 1998; IMST 1998; Johnson et al. 1999). Anthropogenic changes in the Columbia River Basin appear to have facilitated increases in populations of these colonial waterbirds (Roby et al. 1998). Until 1999, the largest recorded colony of Caspian terns in the world (Roby et al. 1998) occupied an island created by dredging and maintaining a navigation channel in the Columbia River estuary. The terns fed on large numbers of migrating juvenile salmon and steelhead as they moved through the estuary (Table 1 in NMFS 2002). The Corps began to move the tern colony to a naturally-formed island in the lower estuary (East Sand Island) in 1999 in an effort to reduce the number of juvenile salmonids consumed. This strategy has worked, reducing the number of smolts consumed per year from greater than 12 to approximately 5.4 million. Under the RPA for the 2008 FCRPS Biological Opinion (NMFS 2008a), the Action Agencies are relocating the tern colony to sites outside the Columbia River estuary by 2010, which is expected to reduce predation rates even further. However, the double-crested cormorant colony has increased in size in the last decade and these predators now consume as many smolts as the terns. Under the FCRPS RPA, the Action Agencies will also develop a management plan for double-crested cormorants, although implementation is uncertain.

4.11.1.1.2 Northern Pikeminnow
Although northern pikeminnow (*Ptychocheilus oregonensis*) is a native species that is a natural predator of juvenile salmonids, development of the Columbia River hydropower system has likely increased levels of predation. Northern pikeminnow predation throughout the Columbia and Snake Rivers was indexed in 1990-1993 based on electrofishing catch rates of predators and the occurrence of salmonids in predator stomachs relative to estimates in John Day Reservoir (Ward et al. 1995). Northern pikeminnow abundance was estimated to total 1.8 million, and daily consumption rates averaged 0.06 salmonids per predator (Beamesderfer et al. 1996).

Beamesderfer et al. (1996) estimates that over 16 million total salmonids were consumed annually in the mainstem Columbia and Snake Rivers prior to initiation of the Northern Pikeminnow Management Program (NPMP see below). Total system-wide impacts are concentrated in the lower Columbia River from The Dalles Reservoir downstream, where approximately 13 million of the 16.4 million total salmonids are estimated to have been consumed by northern pikeminnow. This estimated predation loss is 8% of the approximately 200 million hatchery and wild juvenile salmonid migrants in the system.

**Northern Pikeminnow Management Program (NPMP)**
Predator control fisheries have been implemented in the Columbia Basin since 1990 to harvest northern pikeminnow with an annual exploitation rate goal of 10-20%, needed to obtain up to a 50% reduction in smolts consumed by pikeminnow (Rieman et al. 1991). The NPMP is a multi-year, ongoing effort funded by BPA to reduce piscivorous predation on juvenile salmon, primarily through public, angler-driven, system-wide removals of predator-sized northern pikeminnow. From 1991 to 1996, three fisheries (sport-reward, dam angling, and gill net) harvested approximately 1.1 million
northern pikeminnows greater than or equal to 250 mm fork length. Total exploitation averaged 12.0% (range: 8.1 to 15.5%) for 1991 to 1996 (Section 6.2.7.1 in NMFS 2000b).

Since the program’s inception in 1990, the NPMP’s monetary incentive to harvest northern pikeminnow has motivated sports fishermen to remove over two million northern pikeminnow throughout the system. This has reduced predation mortality by an estimated 25% (Friesen and Ward 1999), which is estimated to equate to approximately 4 million fewer juvenile salmonids consumed by pikeminnow each year. Currently, the annual harvest rate ranges approximately between 8 and 16% of the northern pikeminnow that qualify in size but has averaged approximately 12% in the last number of years. In 2001 and again in 2004, BPA increased the reward, which led to increases in both catch and exploitation. Under the 2008 FCRPS RPA (NMFS 2008a), the expanded Northern Pikeminnow (Ptychocheilus oregonensis)-Management Program will continue for ten years, which will benefit all 13 salmonid species.

### 4.11.1.2 Water Quantity/Hydrograph

Based on a review of available streamflow data, the Willamette River provides about 4 to 29% (averaging approximately 15%) of total average monthly Columbia River flow at Portland, Oregon (Table 4.11-1). The Willamette River’s total contribution is highest during fall and winter and lowest during summer.

#### Table 4.11-1  Average monthly flows in the Columbia and Willamette rivers and the percent contribution of the latter to total Columbia River flow.

<table>
<thead>
<tr>
<th>Month</th>
<th>Columbia River above Willamette River Confluence (cfs)¹</th>
<th>Willamette River at Portland (cfs)²</th>
<th>Columbia River below Willamette River Confluence (cfs)</th>
<th>Willamette River % of Columbia River Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>195973</td>
<td>68539</td>
<td>264512</td>
<td>25.9%</td>
</tr>
<tr>
<td>February</td>
<td>185478</td>
<td>62136</td>
<td>247614</td>
<td>25.1%</td>
</tr>
<tr>
<td>March</td>
<td>184371</td>
<td>51143</td>
<td>235514</td>
<td>21.7%</td>
</tr>
<tr>
<td>April</td>
<td>233297</td>
<td>41326</td>
<td>274623</td>
<td>15.0%</td>
</tr>
<tr>
<td>May</td>
<td>297903</td>
<td>30253</td>
<td>328156</td>
<td>9.2%</td>
</tr>
<tr>
<td>June</td>
<td>312666</td>
<td>18562</td>
<td>331228</td>
<td>5.6%</td>
</tr>
<tr>
<td>July</td>
<td>213825</td>
<td>8791</td>
<td>222616</td>
<td>3.9%</td>
</tr>
<tr>
<td>August</td>
<td>150469</td>
<td>6110</td>
<td>156579</td>
<td>3.9%</td>
</tr>
<tr>
<td>September</td>
<td>106569</td>
<td>6475</td>
<td>113044</td>
<td>5.7%</td>
</tr>
<tr>
<td>October</td>
<td>114821</td>
<td>11148</td>
<td>125969</td>
<td>8.8%</td>
</tr>
<tr>
<td>November</td>
<td>137257</td>
<td>37408</td>
<td>174665</td>
<td>21.4%</td>
</tr>
<tr>
<td>December</td>
<td>159528</td>
<td>64318</td>
<td>223846</td>
<td>28.7%</td>
</tr>
</tbody>
</table>
Notes:
1. Combined average monthly flow from simulated Federal Columbia River Power System operations under the 2008 biological opinion and twice the monthly average flow of the Sandy River below Bull Run River, USGS Station No. 14142500 (72-year period of record [1911-1966 and 1985-2000]).
2. Simulated monthly average Willamette River discharge based on a 70-year simulation of current operations.

Willamette Project operations have affected flow in the lower Columbia River in three ways (Figure 4.11-2):

- Flow in the Columbia River downstream from its confluence with the Willamette River has increased during summer (July and August), when water is released from Project reservoirs to maintain water quality in the Willamette, and has increased by a larger amount during fall (September through November), when project reservoirs are evacuated to provide storage space for fall and winter floods.
- Flow in the Columbia has decreased by a small amount during late-winter through spring (February through May), when water is stored in Project reservoirs, to bring them back up to summer elevations.
- Flow in the Columbia has decreased episodically during fall and winter, when peak flows generated by storms or rain-on-snow are stored in Project reservoirs (i.e., to reduce the risk of downstream flooding), followed by increases, as the stored water is released to provide storage for future flood events.

![Graph showing simulated monthly average Willamette River discharge](image)

**Figure 4.11-2** Simulated monthly average Willamette River discharge at Oregon City, Oregon before (unregulated) and after (regulated) construction of the 13 USACE multipurpose dams. Source: Donner 2008.
During February through May, Willamette Project operations have modified (i.e., decreased) average monthly flows in the lower Columbia River by less than 3% or less compared to the pre-project period (Table 4.11-2). Average project effects are larger (flows increased by up to 5%) in September through December, the natural low flow season in the lower Columbia River.

Table 4.11-2  Average monthly Columbia River flows and the estimated change in discharge caused by Willamette Project operations, measured at Portland below the mouth of the Willamette River.

<table>
<thead>
<tr>
<th>Month</th>
<th>Columbia River Flow below Mouth of Willamette River (cfs)</th>
<th>Change in Willamette River Flow Caused by Willamette Project Operations (cfs)</th>
<th>Effect of Willamette Project Operations on Columbia River Flows (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>264,512</td>
<td>384</td>
<td>0.15%</td>
</tr>
<tr>
<td>February</td>
<td>247,614</td>
<td>-7,215</td>
<td>-2.91%</td>
</tr>
<tr>
<td>March</td>
<td>235,514</td>
<td>-6,648</td>
<td>-2.82%</td>
</tr>
<tr>
<td>April</td>
<td>274,623</td>
<td>-4,739</td>
<td>-1.73%</td>
</tr>
<tr>
<td>May</td>
<td>328,156</td>
<td>-1,974</td>
<td>-0.60%</td>
</tr>
<tr>
<td>June</td>
<td>331,228</td>
<td>326</td>
<td>0.10%</td>
</tr>
<tr>
<td>July</td>
<td>222,616</td>
<td>991</td>
<td>0.45%</td>
</tr>
<tr>
<td>August</td>
<td>156,579</td>
<td>2,929</td>
<td>1.87%</td>
</tr>
<tr>
<td>September</td>
<td>113,044</td>
<td>5,357</td>
<td>4.74%</td>
</tr>
<tr>
<td>October</td>
<td>125,969</td>
<td>5,860</td>
<td>4.65%</td>
</tr>
<tr>
<td>November</td>
<td>174,665</td>
<td>4,500</td>
<td>2.58%</td>
</tr>
<tr>
<td>December</td>
<td>223,846</td>
<td>121</td>
<td>0.05%</td>
</tr>
</tbody>
</table>

Notes:  
1  Effects of past project operations are derived from operations simulation over a 70-year record. Source: Donner 2008.

The Willamette Project’s relative influence on Columbia River flows diminish in a downstream direction as other tributaries, especially the Cowlitz and Lewis Rivers, contribute additional flow. Estimating flow at the mouth of the Columbia River near Astoria, Oregon, as the flow immediately downstream from the Willamette-Columbia confluence plus flows in the Lewis and Cowlitz rivers plus 10% for local accretion, past Willamette Project operations have modified Columbia River flows by an average of about 2% (Table 4.11-3).
Table 4.11-3  Average monthly Columbia River flows and the estimated change in discharge caused by Willamette Project operations, measured at Quincy, Oregon (USGS Gage 14246900)

<table>
<thead>
<tr>
<th>Month</th>
<th>Columbia River Flow below Mouth of Willamette River (cfs)</th>
<th>Cowlitz and Lewis and Local Tributary Contributions (cfs)</th>
<th>Columbia River Total Flow at Mouth (cfs)</th>
<th>Change in Willamette River Flow Caused by Willamette Project Operations¹ (cfs)</th>
<th>Effect of Willamette Project Operations on Lower Columbia River Flows</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>264512</td>
<td>23879</td>
<td>288391</td>
<td>384</td>
<td>0.13%</td>
</tr>
<tr>
<td>February</td>
<td>247614</td>
<td>22193</td>
<td>269807</td>
<td>-7215</td>
<td>-2.67%</td>
</tr>
<tr>
<td>March</td>
<td>235514</td>
<td>18593</td>
<td>254107</td>
<td>-6648</td>
<td>-2.62%</td>
</tr>
<tr>
<td>April</td>
<td>274623</td>
<td>17159</td>
<td>291782</td>
<td>-4739</td>
<td>-1.62%</td>
</tr>
<tr>
<td>May</td>
<td>328156</td>
<td>17261</td>
<td>345417</td>
<td>-1974</td>
<td>-0.57%</td>
</tr>
<tr>
<td>June</td>
<td>331228</td>
<td>14736</td>
<td>345964</td>
<td>326</td>
<td>0.09%</td>
</tr>
<tr>
<td>July</td>
<td>222616</td>
<td>8139</td>
<td>230755</td>
<td>991</td>
<td>0.43%</td>
</tr>
<tr>
<td>August</td>
<td>156579</td>
<td>4655</td>
<td>161234</td>
<td>2929</td>
<td>1.82%</td>
</tr>
<tr>
<td>September</td>
<td>113044</td>
<td>5141</td>
<td>118185</td>
<td>5357</td>
<td>4.53%</td>
</tr>
<tr>
<td>October</td>
<td>125969</td>
<td>8578</td>
<td>134547</td>
<td>5860</td>
<td>4.36%</td>
</tr>
<tr>
<td>November</td>
<td>174665</td>
<td>18913</td>
<td>193579</td>
<td>4500</td>
<td>2.32%</td>
</tr>
<tr>
<td>December</td>
<td>223846</td>
<td>25777</td>
<td>249624</td>
<td>121</td>
<td>0.05%</td>
</tr>
</tbody>
</table>

Note:  The hydrologic effects of the Project were estimated by comparing hydrologic records before and after the Project was developed. Because post-development conditions were somewhat wetter (due to increased precipitation) than pre-development conditions, the apparent increase in fall and early winter flows at the Quincy gage (e.g., December flows increased by 8.2%) may be over-estimated.

The Columbia River is highly developed for water use, hydropower production, and navigation. Lower Columbia River flows have been altered by operations at storage reservoirs located upstream from the mouth of the Willamette. With a combined active storage of about 50 Maf, these upstream reservoirs profoundly affect the seasonal hydrology of the Columbia River. Many of these reservoirs are drafted during the fall and winter to provide downstream flood protection and to generate energy during the high-load winter months (October through March), thereby increasing flows in the lower Columbia River (Figure 4.11-3). Refilling these reservoirs during the spring substantially decreases spring flows in the lower Columbia. Although a substantial amount of consumptive water use occurs during the summer months, this effect is largely offset by reservoir drafting to serve that demand. Combining the effects of operations...
upstream from the mouth of the Willamette with those of Willamette Project reservoirs, flows in the lower Columbia River have increased (i.e., compared to the predevelopment period) by 9% to 51% during September through March (Table 4.11-4). Flows have been reduced by 4% to 41% from April through August.¹

Figure 4.11-3 Simulated mean monthly Columbia River flows at Bonneville Dam under current conditions and flows that would have occurred without water development (natural). Source: Current - HYDSIM model run FRIII07Final2008BiOp, Natural – USBR 1998.

¹ Individual year effects may be greater or less than these long-term averages.
Table 4.11-4  Comparison of mean monthly Columbia River discharge downstream from the Willamette River confluence under pre-development and current conditions

<table>
<thead>
<tr>
<th>Month</th>
<th>Pre-development Columbia River Flow (cfs)</th>
<th>Current Columbia River Flow (cfs)</th>
<th>Change in Columbia River Flow Since Development (cfs)</th>
<th>% Change in Columbia River Flows</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>175013</td>
<td>264977</td>
<td>89964</td>
<td>51%</td>
</tr>
<tr>
<td>February</td>
<td>174969</td>
<td>237641</td>
<td>62672</td>
<td>36%</td>
</tr>
<tr>
<td>March</td>
<td>185753</td>
<td>222675</td>
<td>36922</td>
<td>20%</td>
</tr>
<tr>
<td>April</td>
<td>278989</td>
<td>268892</td>
<td>-10097</td>
<td>-4%</td>
</tr>
<tr>
<td>May</td>
<td>485934</td>
<td>327869</td>
<td>-158065</td>
<td>-33%</td>
</tr>
<tr>
<td>June</td>
<td>567728</td>
<td>336423</td>
<td>-231305</td>
<td>-41%</td>
</tr>
<tr>
<td>July</td>
<td>344655</td>
<td>229930</td>
<td>-114724</td>
<td>-33%</td>
</tr>
<tr>
<td>August</td>
<td>179536</td>
<td>167970</td>
<td>-11566</td>
<td>-6%</td>
</tr>
<tr>
<td>September</td>
<td>111849</td>
<td>121915</td>
<td>10067</td>
<td>9%</td>
</tr>
<tr>
<td>October</td>
<td>100591</td>
<td>132353</td>
<td>31762</td>
<td>32%</td>
</tr>
<tr>
<td>November</td>
<td>134723</td>
<td>176836</td>
<td>42112</td>
<td>31%</td>
</tr>
<tr>
<td>December</td>
<td>171302</td>
<td>221437</td>
<td>50136</td>
<td>29%</td>
</tr>
</tbody>
</table>

Note:
Data are from several sources. Pre-development flows are the sum of simulated pre-development Columbia River flows at Bonneville Dam for the period of record from 1929 to 1978 (USBR 1999), two times Sandy River flows from 1910 to 2000 (USGS Station No. 14142500), simulated Willamette River flows at Portland, Oregon from 1937 to 2004, and Clackamas River flows (USGS Station No.14211010). Current flows are the sum of simulated flows under the current level of development and with current operations at Bonneville Dam from 1929 through 1998, two times Sandy River flows for the period of record 1910 through 2000 (USGS Station No. 14142500), simulated Willamette River flows at Portland, Oregon from 1937 to 2004, and Clackamas River flows (USGS Station No.14211010).

The effects of these changes in the hydrologic environment on anadromous fish are discussed below.

### 4.11.1.3 Water Quality

Water quality characteristics of the lower Columbia River are affected by an array of land and water use developments. Water quality characteristics of particular concern are: water temperature, turbidity, total dissolved gas, and chemical pollutants.
**Water Temperature**

Water development influences water temperatures through storage, diversion, and irrigation return flows. These changes in water temperatures have significant implications for anadromous fish survival.

Comparisons of long term temperature monitoring in the migration corridor before and after impoundment reveal a fundamental change in the thermal regime of the Columbia River. Using historical flows and environmental records for the 35 year period from 1960 to 1995, one recent study compared water temperature records in the lower Snake River with and without the federal mainstem dams (Perkins and Richmond 2001). There are three notable differences between the current temperature regime and the temperature regime of the unimpounded Columbia River:

- Maximum summer water temperatures have been reduced slightly,
- Water temperature variability has decreased, and
- Post-impoundment water temperatures stay cooler longer into the spring and warmer later into the fall. (This latter phenomenon is termed thermal inertia, see Section 4.1.1.3)

**Biological Effects**

High water temperatures stress all life stages of anadromous fish, increase the risk of disease and mortality, affect toxicological responses to pollutants, and can cause migrating adult salmon to stop or delay their migrations. Warm water temperatures also increase the metabolic demands and thus the foraging rates of predatory fish, thereby increasing consumption of smolts. Though the duration and magnitude of high water temperatures in the migration corridor is generally less under current, developed conditions than prior to water development, some juvenile fish are exposed to these conditions for a longer period of time due to the substantial increase in travel time caused by FCRPS and Upper Snake operations (NMFS 2008b).

Global warming has increased average annual Columbia Basin air temperatures by about 1 degree C over the past century and water temperatures have been affected similarly (ISAB 2007). The influence of this and other large-scale environmental variations are discussed in Section 4.1.

**Turbidity**

Flow regulation and the settling of particulates in upstream reservoirs reduce turbidity in the lower Columbia River. Reduced turbidity can increase predator success through improved prey detection, increasing the susceptibility smolts to predation. Predation is a substantial contributor to juvenile salmon mortality throughout the Columbia River migration corridor.

**Total Dissolved Gas**

Spill at mainstem dams can cause downstream waters to become supersaturated with dissolved atmospheric gasses. Supersaturated total dissolved gas (TDG) conditions can cause gas bubble trauma (GBT) in adult and juvenile salmonids resulting in injury or death. Biological monitoring shows that the incidence of GBT in both migrating smolts and adults remains between 1 and 2% when TDG concentrations in the portion of the water column occupied by migrating fish do not exceed 120% of saturation. When those levels are exceeded, there is a corresponding increase in the incidence of signs of GBT symptoms.
High TDG conditions diminish with time and in a downstream direction from the point of creation. TDG conditions in the lower Columbia River are strongly affected by operations at hydroelectric projects on the Columbia River, principally Bonneville Dam, whereas operation of the Willamette Project has negligible effect on TDG conditions in this part of the action area. Since the late 1980s, substantial efforts have been made to limit the magnitude and duration of adverse TDG conditions in the lower Columbia River migratory corridor and additional measures will be taken during the next ten years to address TDG (NMFS 2008a).

**Pollutants**

Background or ambient levels of pollutants in inflows carry cumulative loads from upstream areas in variable and generally unknown amounts. Industrial and municipal wastes from the Portland-Vancouver metro areas affect the lower river and estuary. Highly developed agricultural areas of the basin also deliver fertilizer, herbicide, and pesticide residues to the river.

Current environmental conditions in the Columbia River estuary indicate the presence of contaminants in the food chain of juvenile salmonids including DDT, PCBs, and polyaromatic hydrocarbons (PAH) (NMFS 2001). This data also indicates that juvenile salmonids in the Columbia River estuary have contaminant body burdens in the range where sublethal effects can occur. The sources of exposure are not clear but may be widespread. Several pesticides and heavy metal contaminants have been sampled in Columbia River sediments (ODEQ 2007). In field studies, juvenile salmon from sites in the Pacific Northwest have demonstrated immunosuppression, reduced disease resistance, and reduced growth rates due to contaminant exposure during their period of estuarine residence (Arkoosh et al. 1991, 1994, 1998; Varanasi et al. 1993; Casillas et al. 1995a, 1995b, 1998a).

**4.11.1.4 Physical Habitat Characteristics**

Prior to extensive dam development, spring runoff brought colder, more turbid water and an array of sediments and large woody debris to the lower Columbia River. Today, much of the river’s sediment and large wood is trapped in its headwater reservoirs. These characteristics affect both water quality conditions and physical channel characteristics, both of which affect habitat quality. It is known that the Columbia River estuary contained a larger island complex, more shoreline marshes, and large rafts of woody debris prior to development. In part, these habitat characteristics have been purposely altered (e.g., dredging and snag removal to facilitate navigation) and in part these changes are the result of changes in suspended sediment, turbidity, large woody debris, and stream flows associated with land and water development activities higher in the watershed. The estuary functions as an important transition environment, where smolts have the opportunity to gradually adapt to salt water, and as a nursery ground, smolts may feed and grow to sizes that may increase their chances of surviving in the ocean (Reimers 1973; Simenstad et al. 1982; Thorpe 1994). Juvenile salmon are found in the estuary all months of the year as different species, size classes, and life-history types move downstream from multiple upstream sources. Ocean-type Chinook migrants could depend entirely on the estuary for nursery habitats Healey (1982). Chum salmon, which rear in estuaries for several weeks, have been classified as the second most estuarine-dependent species.

The movements of juvenile salmon and their patterns of habitat use within estuaries are size related. Chinook and chum salmon subyearlings (fry) usually occupy shallow, nearshore
habitats, including salt marshes, tidal creeks, and intertidal flats (Levy and Northcote 1982; Myers and Horton 1982; Simenstad et al. 1982; Levings et al. 1986). As subyearlings grow to fingerling and smolt stages, their distribution typically shifts toward deeper habitats farther from the shoreline (Healey 1982; Myers and Horton 1982). In the Columbia River estuary, McCabe et al. (1986) reported that subyearling Chinook in shallow intertidal habitats were smaller than subyearlings captured in deeper offshore areas. Large yearling migrants, on the other hand, may spend relatively little time in shallow-water habitat (Bottom et al. 1984). Thus, the occurrence of small subyearling salmon, including those life-history types that stay in the estuary for the longest periods, may be closely linked to the availability of certain shallow-water habitats.

Historical habitat changes may have reduced the benefit that anadromous salmonids, particularly rearing juveniles, derive from the estuary. The estuarine food webs that support these fish are apparently detritus-based, and in the Columbia estuary, the detritus-based food web has diminished in response to development. Macrodetritus derived from emergent marsh vegetation has undergone a dramatic reduction due to the loss of shallow water habitat. The loss of those production areas reduced emergent plant production by approximately 82%. Prior to development, the biomass of organisms that feed on the macrodetritus would have been 12 times the current biomass. Since those organisms are prominent prey of juvenile salmonids, it is reasonable to assume that a reduction in the food web supported by macrodetritus has had a negative effect on the anadromous salmonids (ISG 1996).

In summary, historical changes in peripheral wetland habitats, shape of the river's bottom, and flows of the Columbia River estuary have altered basic estuarine processes and conditions such as sediment transport, detrital input, and the trophic pathways that support salmon. Such changes also have affected the availability of shallow water, off-channel rearing areas that may be particularly important to small subyearling salmon with estuarine-rearing life histories. However, the specifics of salmonid ecology in the Columbia River estuary are poorly understood. Much of what is assumed about the estuarine requirements of Columbia River salmon is derived from research in much smaller Northwest estuaries, where ecological processes differ substantially from this large river-dominated system. Furthermore, available estimates of estuarine habitat change are restricted to the lower estuary below Puget Island (Thomas 1983) and exclude the tidal floodplain upriver to Bonneville Dam, which has also been extensively modified. Efforts to quantify habitat change or assess the benefits of estuary restoration to Columbia River salmon are limited by the lack of baseline information about modern and historical spatial distributions of habitats and food-web linkages.

Recent projects that have protected or restored riparian areas and breached or lowered dikes and levees in the tidally influenced zone of the estuary (between Bonneville Dam and approximately RM 40) have improved the functioning of the juvenile migration corridor and of rearing habitat for ocean-type Chinook and chum salmon. The FCRPS Action Agencies recently implemented 18 estuary habitat projects that removed passage barriers, providing access to good quality habitat and will implement 44 more in just the first three years of executing the FCRPS RPA (NMFS 2008). These actions, and others that will be implemented under the FCRPS RPA, will protect and restore riparian areas, protect remaining high quality off-channel habitat, breach or lower dikes and levees to improve access to off-channel habitat, and reduce noxious weeds.
Habitat conditions in the estuary are therefore expected to improve as a result of the next 10 years of effort.

4.11.2 Hatchery Effects

Information and analysis on the effects of past and ongoing hatchery factors on the current status of ESA protected salmon and steelhead of the Columbia Basin is provided in NMFS 2004, NMFS 2006, and in NMFS 2007 (NMFS 2004b; NMFS 2006a; NMFS 2008a).

The history or evolution of hatcheries is an important factor in analyzing their past and ongoing effects. The first hatcheries, beginning in the late 19th century, provided additional fish for harvest purposes on top of large relatively healthy salmon and steelhead populations. As development of the Columbia Basin proceeded (e.g., construction of the FCRPS between 1939 and 1975), the role of hatcheries shifted to replacing losses in fish production attributable to habitat degradation and reduced salmon and steelhead survival. National Fish Hatcheries in the upper Columbia for example produce salmon and steelhead for areas blocked by federal dams (approximately 50% of the production area for upper Columbia Chinook salmon and steelhead was blocked and remains inaccessible) while federally funded hatchery programs in the Snake River are expected to replace losses of fall Chinook salmon from inundation of their spawning habitat and from reduced survival during their migration to and from the ocean because of the four Lower Snake River federal projects. The scope and level of hatchery production increased greatly during this period as impacts from development and the requirement for mitigation increased. A new role for hatcheries emerged during the 1980s and 1990s after populations declined to unprecedented low levels. Because tools were needed to help conserve salmon and steelhead resources, some hatchery programs changed their goals and practices and whole new programs were implemented including substantial new research to assess the efficacy of artificial propagation as a tool to promote conservation. Today, because nearly 90% of the Chinook salmon and steelhead habitat originally available in the Columbia Basin has been lost or degraded (Brannon et al. 2002), fish produced by hatcheries comprise the vast majority of the annual returns to the basin (CBFWA 1990). There would be few if any fish returning to many areas of the Columbia Basin and little or no tribal, public or commercial fishing opportunity without hatcheries.

Hatchery programs are mitigation for factors limiting salmon and steelhead survival. The nearly two hundred programs that operate in the Columbia Basin are mitigation for Federal and public and private utilities projects. NMFS 2004 evaluates hatchery effects at two levels: at the population level and at the ESU or DPS level. For programs in the Interior Columbia (upstream from Bonneville Dam), NMFS 2006 developed with input provided by members of the Hatchery and Harvest Workgroup of the FCRPS collaboration; (1) summarized the major factors limiting salmon and steelhead recovery at the population scale, (2) provided an inventory of existing hatchery programs including their funding source(s) and the status of their regulatory compliance under the ESA and under the National Environmental Policy Act (NEPA), (3) summarized the effects on salmon and steelhead viability from current hatchery operations, and (4) identified new opportunities or changes in hatchery programs likely to benefit population viability. As a follow-up to this report, NMFS developed guidance for determining hatchery effects, including a general assessment of hatchery programs in the upper Columbia and Snake River Basin, and presented this paper and results to the Hatchery and Harvest Workgroup and to the Policy Workgroup in August of 2006. NMFS received comments and made edits to this paper to provide updated guidance.
During the last one hundred or more years, artificial propagation has become an integral and necessary component in the management and conservation of salmon and steelhead and genetic resources that represent the ecological and genetic diversity of a species (these can reside in fish spawned in a hatchery as well as in fish spawned in the wild) (Hard et al. 1992; NMFS 2005c). Hatchery programs can preserve the raw materials (i.e., genetic resources) that ESU and DPS conservation depends on and buy time until the factors limiting salmon and steelhead viability are addressed. In absence of hatchery programs like this, genetic resources important to ESU or steelhead DPS survival and recovery would disappear at an accelerated rate or be lost altogether. In this role, hatchery programs can reduce the risk of extirpation, and thereby mitigate the immediacy of an ESU’s extinction risk (NMFS 2005c). In absence of hatchery programs like this, genetic resources important to ESU or steelhead DPS survival and recovery would disappear at an accelerated rate or be lost altogether. Hatchery programs that only conserve genetic resources however “do not substantially reduce the extinction risk of the ESU in the foreseeable future” or long-term (NMFS 2005d). Accordingly, “Hatcheries are not a proven technology for achieving sustained increases in adult production” (NRC 1995), and the long-term effects of hatchery supplementation remain untested (Araki et al. 2007a).

Captive-broodstock and safety-net programs, including some hatchery supplementation programs, function to preserve genetic resources. In general, these hatchery programs increase the number and spatial distribution of naturally spawning fish (i.e., F1 hatchery-origin fish) but increased NOF viability cannot be attributed to the program. For example, hatchery programs can serve an important conservation role when habitat conditions in freshwater depress juvenile survival, or when access to spawning and rearing habitat is blocked. “The fitness of the naturally spawning population, its productivity, and the numbers of adult salmon returning to the watershed, ultimately must depend on the natural habitat, not on the output of the hatchery” (HSRG 2004). Under circumstances like these and in the short-term, the demographic risks of extinction exceed genetic and ecological risks to NOF from hatchery supplementation. Benefits like this should be considered transitory or short-term and do not contribute to survival rate changes necessary to meet ICTRT abundance and productivity viability criteria (ICTRT 2007).

Hatchery actions designed to benefit salmon and steelhead viability sometimes produce only limited positive results. One potential reason for this is that other factors (i.e., limiting factors and threats) can offset or out-weigh the benefits from hatchery actions. For example, in Puget Sound, eight Chinook salmon hatchery programs are specifically implemented to preserve native populations in their natal watersheds “where habitat needed to sustain the populations naturally at viable levels has been lost or degraded” (NMFS 2005d). These hatchery programs deserve credit for helping “to preserve remaining genetic diversity, and likely have prevented the loss of several populations” (NMFS 2005d). Until, however, the factors limiting salmon and steelhead productivity are addressed, the full benefit (i.e., potential contributions to increased viability) of hatchery actions designed to benefit salmon and steelhead viability may not be realized.

In general, there are two options for hatchery programs to increase viability. They can reduce or eliminate hatchery impacts that reduce NOF survival, and second, they can be affirmatively used as a conservation tool to benefit recovery. In both cases, a net increase in viability (i.e., NOF abundance, productivity, spatial distribution, and diversity) is partially or wholly attributable to hatchery actions. For example, steps to control hatchery fish straying or to ensure that adult and juvenile fish passage is not impeded by hatchery facilities are actions that qualify under this category (i.e., they reduce
hatchery impacts). Helping fish to re-colonize their former range and become self-sustaining using hatchery–origin fish also would qualify for credit.

Under the RPA (Action 39) in the 2008 FCRPS Biological Opinion, the Action Agencies will continue funding hatcheries as well as adopt programmatic criteria for funding decisions on hatchery mitigation programs for the FCRPS that incorporate BMPs. NMFS will consult on the operation of existing or new programs when Hatchery and Genetic Management Plans (HGMPs) are updated by hatchery operators with the Action Agencies as cooperating agencies. For the lower Columbia, new HGMPs must be submitted to NMFS and ESA consultations initiated by July 2009 and consultations must be completed by January 2010. Subject to subsequent hatchery specific ESA § 7(a)(2) consultation, implementation of BMPs in NMFS-approved HGMPs are expected to: 1) integrate hatchery mitigation and conservation objectives, 2) preserve genetic resources, and 3) accelerate trends toward recovery as limiting factors and threats are addressed and natural productivity increases. These benefits, however, are not relied upon for this consultation pending completion of the future consultations.

4.11.3 Fisheries

For thousands of years, Native Americans have fished for salmon and steelhead, as well as other species, in the tributaries and mainstem of the Columbia River for ceremonial, subsistence, and economic purposes. A wide variety of gears and methods were used, including hoop and dip nets at cascades such as Celilo and Willamette Falls; to spears, weirs, and traps (usually in smaller streams and headwater areas). Commercial fishing developed rapidly with the arrival of European settlers and the advent of canning technologies in the late 1800s. The development of non-Indian fisheries began circa 1830, and by 1861 commercial fishing was an important economic activity. The four Columbia River “Stevens” Treaty Tribes (the Nez Perce, Umatilla, and Warm Springs Tribes, and the Yakama Indian Nation) entered into treaties with the United States in 1855. In exchange for the Indians relinquishing their interest in certain lands, the treaties reserved to the Tribes "exclusive" on-reservation rights and the right to take "fish at all usual and accustomed places in common with citizens of the United States" outside the reservations on the Columbia River and major tributaries.

Treaty Indian fishing rights in the Columbia Basin are under the continuing jurisdiction of the U.S. District Court for the District of Oregon in the case of United States v. Oregon, No. 68-513 (D. Oregon, continuing jurisdiction case filed in 1968). The parties to United States v. Oregon are the United States acting through the Department of the Interior (U.S. Fish and Wildlife Service and Bureau of Indian Affairs) and Department of Commerce (NOAA), the Warm Springs, Umatilla, Nez Perce, Yakama, and Shoshone-Bannock Tribes, and the states of Oregon, Washington, and Idaho.

In United States v. Oregon, the court affirmed that the treaties reserved for the Tribes’ 50% of the harvestable surplus of fish destined to pass through their usual and accustomed fishing areas. In at least a half-dozen published opinions and several unpublished opinions in United States v. Oregon, as well as dozens of rulings in the parallel case in United States v. Washington (interpreting the same treaty language for Tribes in the Puget Sound area), the courts have established a large body of case law setting forth the fundamental principles of treaty rights and the permissible limits of conservation regulation of treaty fisheries.
Table 4.11-5 displays the most recent modification to the *U.S. v. Oregon* agreement as of May 2008. As displayed below, the 2008-2017 Management Agreement concluded that the harvest elements of the Management Agreement for upriver Chinook, sockeye, steelhead, coho and white sturgeon remain in effect through December 2017. As has been the case with prior agreements, the current agreement is subject to ESA Section 7 consultation by NMFS that was completed in May 2008 (NMFS 2008c).

### 4.11.4 Status of Designated Critical Habitat in the Lower Columbia River and Estuary

The critical habitat that NMFS designated for each of 12 species of salmon and steelhead includes the lower Columbia River below the confluence of the Willamette and the estuary. These areas are essential to conservation because without them juveniles cannot reach the ocean in a timely manner and use the variety of habitats to avoid predators, compete successfully for forage organisms, and complete the behavioral and physiological changes needed for life in the ocean. Similarly, these features are essential to the conservation of adults because they provide resources needed to make the physiological transition to fresh water, migrate upstream, avoid predators, and develop to maturity upon reaching spawning areas.

Factors that have limited the functioning and conservation value of PCEs in the estuary are:

- Changes in the estuary that have increased the number of avian predators [*Caspian terns and double-crested cormorants*]
- Diking and reduced peak spring flows have eliminated much of the shallow water, low velocity habitat [*agriculture and other development in riparian areas; FCRPS and Upper Snake water management*]

The FCRPS Action Agencies and other Federal and non-Federal entities have taken actions in recent years to improve the functioning of these PCEs and will continue to take actions under the RPA in the 2008 FCRPS Biological Opinion. For example, the safe passage of juvenile salmonids improved beginning in 1999 when Caspian terns were relocated from Rice to East Sand Island, and relocation of terns to sites outside the Columbia basin will be completed by 2010. The double-crested cormorant colony, which has grown during that period, will be addressed by a management plan. Projects that have protected or restored riparian areas and breached or lowered dikes and levees in the tidally influenced zone of the estuary (between Bonneville Dam and approximately RM 40) have improved the functioning of the juvenile migration corridor. The FCRPS Action Agencies recently implemented 18 estuary habitat projects that removed passage barriers, providing access to good quality habitat and will implement 44 more in just the first three years of executing the FCRPS RPA (NMFS 2008a).

These actions, and others that will be implemented under the FCRPS RPA, will protect and restore riparian areas, protect remaining high quality off-channel habitat, breach or lower dikes and levees to improve access to off-channel habitat, and reduce noxious weeds. The PCEs safe passage, water quality, cover/shelter, and forage will be enhanced. Projects that improve estuarine habitat will have long-term beneficial effects at the project scale. Adverse effects to PCEs during construction are expected to be minor, occur only at the project scale, and persist.

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2 Habitat requirements and adult use of the estuary are unknown (Fresh et al. 2005).
for a short-time (no more than a few weeks and typically less). The positive effects on the functioning of PCEs and the conservation value of critical habitat will be long-term.

Table 4.11-5 Expected incidental take of listed salmonids for non-Treaty and treaty Indian Fisheries under the 2008 U.S. v Oregon Agreement expressed in terms of harvest rates unless otherwise indicated.

<table>
<thead>
<tr>
<th>ESUs</th>
<th>Total Expected Take (%)</th>
<th>Treaty Indian (%)</th>
<th>Non-Indian (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snake River Fall Chinook Salmon</td>
<td>17.9-32.2 1</td>
<td>11.6-23.0 1</td>
<td>5.9-9.0 1</td>
</tr>
<tr>
<td>Snake River Spring/Summer Chinook Salmon</td>
<td>7.0 - 14.6 2</td>
<td>5.8-12.5 2</td>
<td>1.2-2.1 2</td>
</tr>
<tr>
<td>Lower Columbia River Chinook Salmon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring Component</td>
<td>0.2-2.0</td>
<td>0</td>
<td>0.2-2.0</td>
</tr>
<tr>
<td>Tule Component (LRH13 stock)</td>
<td>7.7-14.9 3</td>
<td>0</td>
<td>7.7-14.9 3</td>
</tr>
<tr>
<td>Bright Component (LRW14 stock)</td>
<td>6.0-18.8 3</td>
<td>0</td>
<td>6.0-18.8 3</td>
</tr>
<tr>
<td>Upper Willamette River Spring Chinook Salmon</td>
<td>5.0-11.0 4</td>
<td>0</td>
<td>5.0-11.0 4</td>
</tr>
<tr>
<td>Snake River Basin Steelhead</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-Run Component</td>
<td>na 5</td>
<td>4.1-12.4 6</td>
<td>0.9-1.7</td>
</tr>
<tr>
<td>B-Run Component</td>
<td>14-21.8 7</td>
<td>13-20 7</td>
<td>1.0-1.8 7</td>
</tr>
<tr>
<td>Lower Columbia River Steelhead</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Winter component</td>
<td>na 5</td>
<td>&lt;1.4-6.9 8,9</td>
<td>0.2-1.0 3</td>
</tr>
<tr>
<td>Summer component</td>
<td>na 5</td>
<td>&lt;4.1-12.4 6,8</td>
<td>0.2-0.4 3</td>
</tr>
<tr>
<td>Upper Willamette River Steelhead</td>
<td>na 5</td>
<td>0</td>
<td>0.2-1.0 3</td>
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<tr>
<td>Middle Columbia River Steelhead</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter component</td>
<td>na 5</td>
<td>1.4-6.9 9</td>
<td>0.2-1.0 3</td>
</tr>
<tr>
<td>Summer component</td>
<td>na 5</td>
<td>4.1-12.4 5</td>
<td>0.9-1.7</td>
</tr>
<tr>
<td>Upper Columbia River Spring Chinook Salmon</td>
<td>7.0-14.6 2</td>
<td>5.8-12.5 2</td>
<td>1.2-2.1 2</td>
</tr>
<tr>
<td>Columbia River Chum Salmon</td>
<td>1.6</td>
<td>0</td>
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<tr>
<td>Upper Columbia River Steelhead</td>
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<td>Natural-origin Component</td>
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<td>4.1-12.4 6</td>
<td>0.9-1.7</td>
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<td>Hatchery Component</td>
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<td>3.8-9.2 10</td>
<td>7.6-11.2</td>
</tr>
<tr>
<td>Snake River Sockeye Salmon</td>
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<td>2.8-6.1 10</td>
<td>0.0-1.0 10</td>
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<td>Lower Columbia Coho Salmon</td>
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<td>0</td>
<td>13.3-24.3 11</td>
</tr>
<tr>
<td>Research, Monitoring, and Evaluation</td>
<td>0.1-0.5 12</td>
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<td></td>
</tr>
</tbody>
</table>

Notes:
Fisheries are normally managed in season with buffers and other conservative management measures that typically result in impacts being less than allowed ESA limits.

Allowed take for spring Chinook, fall Chinook, B-steelhead, sockeye, and coho varies by run size.

Ranges represent recent year averages.

Steelhead harvest rates assume equal harvest rates on any DPS present in fishery.

Footnotes:
1. Range based on 1999-2007 average under fixed harvest rate schedule. Expected impacts may increase under new abundance based management.
2. Range based on 2001-2007 average for treaty and non-treaty fisheries. Treaty spring Chinook harvest impacts on listed fish can be higher than river mouth run size harvest rates, because of changing hatchery/wild proportions between the river mouth and Bonneville Dam. Future expected impacts may be higher if run sizes indicate use of upper end of harvest rate schedule.
4. Range of harvest rate for Columbia River mainstem fisheries only.
5. Steelhead impacts are not additive, because of different methods of calculating harvest rates.
9. Expected impact for above Bonneville portion of ESU only. Impacts on entire ESU will be lower winter season harvest rates are based on catch in Bonneville Pool divided by Bonneville Dam count of winter steelhead. Tributary impacts not included.
12. Includes research, monitoring and evaluation that is currently in place. For Chinook and coho ESU’s, the range is 0.1-0.5% for each ESU. For steelhead DPS’ and sockeye and chum ESU’s the range is 0.1-0.3% for each DPS.
13. Lower Columbia River hatchery origin (LRH)
14. Lower Columbia River non-hatchery origin (LRW)