Woodward Creek Habitat Restoration Project Siting and Design Project

Final Report

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EXECUTIVE SUMMARY

This report documents the results of the Woodward Creek Restoration Project Siting and Design Study. The purpose of this project is to identify specific locations in and along Woodward Creek and its floodplain where fish and wildlife habitat restoration projects are needed and would feasible. The study area is the mainstem and its floodplain from the confluence with the Columbia River upstream to the limits of fish access (approximately River mile 4.0). The discussion includes the upper watershed and the major tributary (East Fork Woodward Creek) as appropriate. Woodward Creek is unique in the Lower Columbia Region in that the majority of the watershed is within public ownership and the potential opportunities for implementing restoration projects are very high. The primary landowners are the U.S. Forest Service and the State of Washington (Beacon Rock State Park).

This project builds upon the Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan (Recovery Plan) prepared by the Lower Columbia Fish Recovery Board (LCFRB) in 2004. The Recovery Plan identified several limiting factors in the Bonneville Tributaries subbasin: substrate/sediment; habitat diversity; channel stability; riparian function; and floodplain function. The Recovery Plan (LCFRB 2004) did not evaluate Woodward Creek using the Ecosystem Diagnosis and Treatment (EDT) model to help identify which reaches would be most adversely affected by further degradation and which reaches would provide the most fish benefits from restoration actions. As a result, in this study we have determined that Duncan Creek may be the most suitable comparable creek in the subbasin that was evaluated using EDT.

The LCFRB has also prepared a Six-Year Habitat Work Schedule (LCFRB 2007) that is frequently updated, with more specific restoration objectives to address the limiting factors in the subbasin. These include: 1) protect stream corridor structure and function; 2) protect hillslope processes; 3) restore floodplain function and channel migration processes in the lower reaches; 4) restore degraded hillslope processes; 5) restore access to habitat blocked by artificial barriers; 6) restore riparian conditions throughout the basin; 7) create/restore off-channel and side channel habitat; 8) restore degraded water quality; and 9) provide for adequate instream flows during critical periods. However, no site or reach-specific locations for these actions were identified. It is postulated that if these types of restoration actions are taken in Tier 1 and 2 reaches then significant gains can be made towards the recovery of salmonid populations. This study undertook an investigation and evaluation of potential locations to undertake the various types of restoration actions identified above. Because Woodward Creek has very good water quality and is already largely protected in public ownership, the primary objectives that this study addressed were items 3, 4, 5, 6, and 7.

The primary limitations on restoration in Woodward Creek are the high sediment load (both natural and human-facilitated) and the major infrastructure constraints located in the lower end of the creek.

Within the generally fish accessible study reach from River mile (RM) 4 to the confluence with the Columbia River there are seven distinct geomorphic reaches. The reaches were delineated based on the slope and channel morphology and major infrastructure which controls channel plan, profile and section, as identified during the September 2006 reconnaissance. The following geomorphic reaches are described herein from downstream to upstream.

- Reach 1 – RM 0.0 to 0.2 (Mouth to RR Crossing)
- Reach 2 – RM 0.2 to 0.5 (RR Crossing to SR 14)
- Reach 3 – RM 0.5 to 1.7 (SR 14 to E. Fk. Woodward Creek)
- Reach 4 – RM 1.7 to 2.0
- Reach 5 – RM 2.0 to 2.5
- Reach 6 – RM 2.5 to 3.0
- Reach 7 – RM 3.0 to 4.0

In Reach 1, historically, the creek would have meandered over the wider delta prior to diversion under the highway and railroad crossings and would have scoured its channel more frequently. Currently, the in-channel habitat is uniform except for where beavers periodically build dams and create pools.

Restoration opportunities in this reach include improving fish passage at the mouth, reconnecting a side channel in the floodplain to provide rearing habitat for juveniles and possible Chinook, coho and chum spawning habitat, roughening the floodplain to collect more sediment out of the main channel to help maintain the channel opening at the mouth, and riparian restoration. Until the sediment load is addressed in the reaches upstream of the railroad culvert, measures to improve the mouth for fish passage may only be successful in the short-term.

In Reach 2, channelization limits restoration opportunities in the short-term. The immediate problems are the constriction of the culvert and the deposition of sediment and debris at its upstream end. Wood or rock vanes could be placed upstream of the culvert to direct the channel in a more direct alignment into the culvert; although this would only provide temporary benefits. Control of sediment upstream of SR-14 and reconnection of the floodplain in Reach 2 will be the most effective and long-term opportunities to reduce sediment and debris deposition and allow the creek to migrate in a more natural alignment. One or more LWD jams could be placed immediately upstream of the SR-14 bridge to capture wood from Reach 3 before it reaches the bridge. In the long-term, removal or setback of the dike and Beacon Rock Moorage Road and reconnecting the creek to its floodplain would allow the channel to migrate without damaging infrastructure, thus creating off-channel and other habitats and providing a floodplain for sediment and debris deposition. These modifications would also increase the channel length and decrease the slope which, along with log jams create improved spawning habitat. If another road is eventually planned to connect potential future camping or other uses to the new road to the boat ramp, the road under the railroad could be abandoned and the culvert could be removed to allow the creek to flow through the railroad opening without a blockage. The railroad grade would still limit the channel width to 38 feet, the length would be very short and channel design features upstream would improve sediment transport through the crossing.

In Reach 3, the flow goes subsurface through portions of this reach in the coarse material. There is some wood in this reach in small clumps. There are few pools in this reach. The right bank for much of this reach is a high fractured basalt cliff. A dike has been placed at the end of this cliff to cut off the former right bank floodplain, and probable location of the historic main creek channel, and now diverts all flows towards the left bank and under the bridge at SR-14.

Reach 3 would be an excellent location to place additional wood and LWD jams. The wood could be used to protect the existing high quality side channel from sediment deposition and could also be used to trap sediment in the floodplain, and to create further spawning areas as well as providing scouring of pools and providing cover. Many juvenile fish (trout and coho) have been observed in the upper end of this reach. This reach also could benefit from the removal of non-native vegetation and plantings of native species. Removal of the dike along the right bank and reconnection of the floodplain would further trap sediments and provide the opportunity for the natural creation of off-channel habitats. This reach is easily accessible from SR-14 and an old road in the right bank floodplain. Because the dike currently protects the highway and bridge from erosion, a longer-term solution would be to widen the SR 14 bridge to 150 feet and reduce the need for the channel diversion dike and then provide protection for the road with rock set back closer to the roadway.

Reaches 4 through 7 are much less accessible and have largely intact riparian zones. In general, placement of LWD would likely be most beneficial to trap sediments and to keep these reaches connected to their floodplains. In the upper watershed it would be beneficial to investigate with the USFS if there are specific mass-wasting or road/culvert problems that could be fixed.

Projects were identified for each reach and then evaluated for their benefits to fish and wildlife and the certainty of success. Projects in Reaches 1, 2 and 3 rank most highly. Projects in Reach 2 will not be immediately implementable due to continued park planning, but may be feasible in 5 or more years.

Table of Contents

Table of Figures

Table of Tables

1. Introduction

Woodward Creek is one of the Bonneville Tributaries that together comprise one of seventeen major tributary watersheds to the Lower Columbia River in Southwestern Washington. These Bonneville tributaries include Hamilton, Hardy, Woodward, Duncan, Gibbons, and Lawton Creeks. These tributaries historically supported several anadromous fish species including: fall chinook, chum, and coho salmon, and winter steelhead and cutthroat trout. The salmon populations have declined dramatically in these tributaries and the Columbia Basin in general. As a result, several species and Evolutionary Significant Units (ESUs) of salmonids in the Columbia Basin were listed under the Endangered Species Act (ESA), including the Lower Columbia River ESUs of chinook, coho, and steelhead, and the Columbia River ESU of chum (all listed as Threatened, pursuant to the ESA).

The Lower Columbia Fish Recovery Board (LCFRB) and its partners and stakeholders in the Lower Columbia region developed the Lower Columbia Salmon Recovery Fish and Wildlife Subbasin Plan (hereafter called the Recovery Plan) in 2004 (LCFRB 2004). This plan included a technical assessment of conditions in each watershed within the overall Lower Columbia subbasin, an inventory of current and past efforts at habitat protection and restoration, and a management plan with goals, objectives and strategies for future actions to protect and recover fish and wildlife populations and their ecosystems. The Recovery Plan was adopted by NOAA Fisheries as an Interim Regional Recovery Plan in February 2006. The Recovery Plan and subsequent work plans developed by the LCFRB identified a number of protection and restoration goals and potential actions for the Bonneville Tributaries subbasin. However, those potential restoration actions did not include site-specific detail.

This report documents the results of a study intended to identify, rank, and conceptually design restoration projects at high priority locations in Woodward Creek and its floodplain. These projects will directly address limiting factors and high priority restoration needs identified in the Recovery Plan (LCFRB 2004). This study is not intended to be a monitoring plan or program, or a habitat assessment. The approach used in this study is to build on the previous work done in the Recovery Plan (LCFRB 2004); document restoration opportunities and constraints by reaches; identify specific project sites where restoration actions are appropriate; prioritize the projects based on physical, biological and engineering feasibility factors; and then provide conceptual designs and cost estimates for the highest ranked projects. The conceptual designs and cost estimates will be used as the basis for future grant applications and actions by the LCFRB and other entities in the watershed.

2. Woodward Creek Watershed Description

Woodward Creek is located on the steep southern slopes of the Columbia River Gorge in Washington State (**Figures 1 and 2**). It is an eight square mile watershed ranging in elevation from 0 to 3,314 feet. The creek is approximately 6 miles in length with seasonal and perennial tributaries totaling an additional 8 miles. Fish cannot access the majority of the stream miles because the gradient is too steep or natural impassable falls exist. Steelhead have been observed using the lower 3.5 miles of the creek and recently coho juveniles were found in large numbers at RM 3.0 (P. Barber, LCFEG)

The majority of the watershed is U.S. Forest Service timberlands or within Beacon Rock State Park; only a small portion of the watershed is privately owned residential. Stormwater runoff has likely increased somewhat due to the historic logging of old-growth forests and then partially returned to a normal hydrologic condition with the regrowth of the watershed to a mixed deciduous/coniferous mid-seral forest.

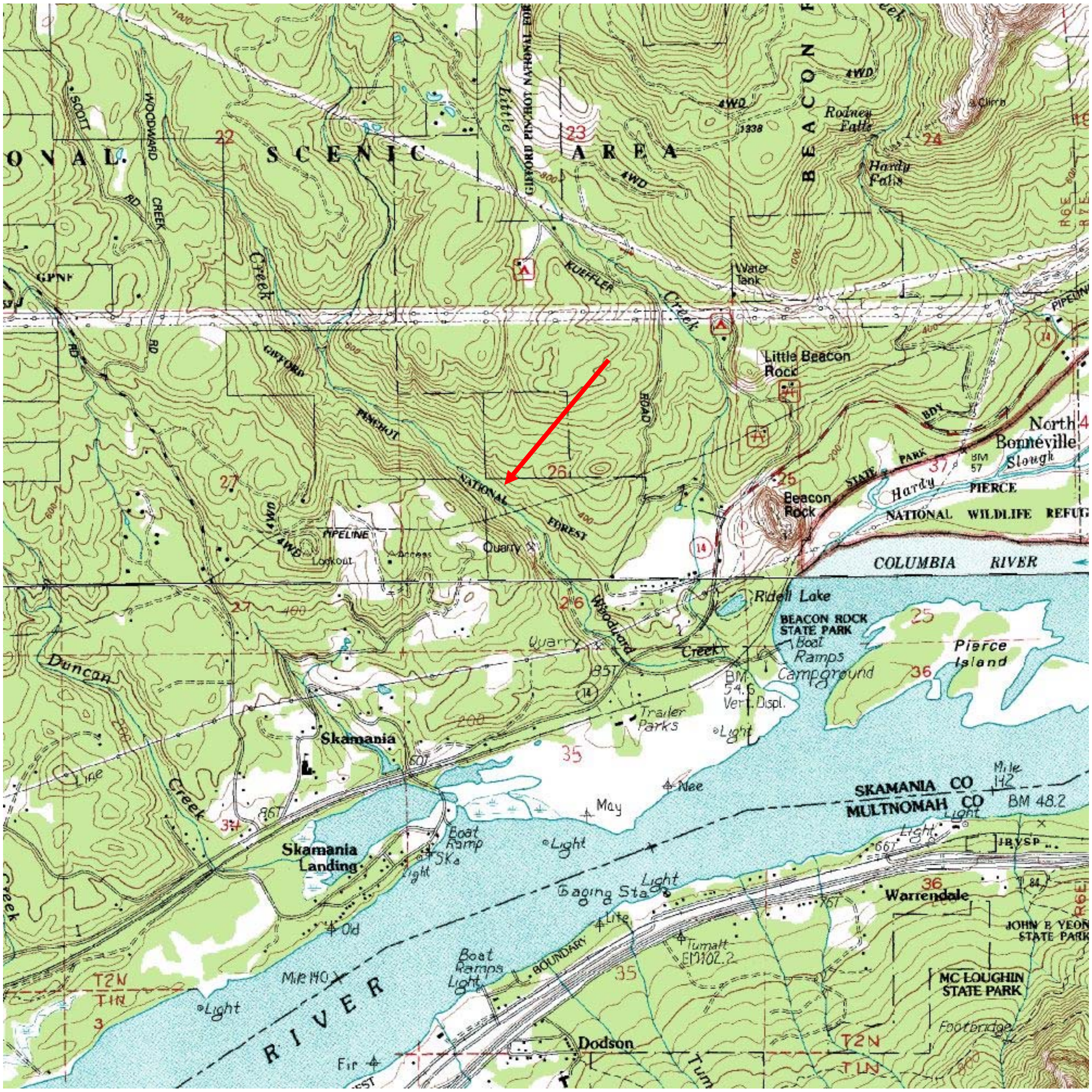


Figure 1. Woodward Creek Vicinity Map.

Figure 2. Aerial Photo from 2000 of Woodward Creek.

2.1 Geologic Setting

Woodward Creek arises from high basalt outcrops in the Columbia River Gorge. Weathered volcanic flows are the dominant features with both colluvial and alluvial deposits. The Missoula floods from the most recent continental glaciation (approximately 10,000 years BP) extensively scoured the Columbia Gorge and left basalt outcrops exposed. Periodic landslides deposit large quantities of boulders, cobbles, and finer sediments down the slopes of the gorge.

Alluvial deposition has occurred along the lower reaches of Woodward Creek. These deposits are primarily cobbles and large gravels, which do not appear to be readily transported by the Columbia River, and are thus continuing to build an alluvial fan with a gradient which extends several miles up the stream.

2.2 Channel Profile

The profile of Woodward Creek was evaluated from actual survey data in the lower 0.85 miles and USGS topographic maps upstream of RM 0.85 (**Figures 4 and 5**). Key features which affect the channel grade of Woodward Creek include:

- Mouth at Columbia River: Near the mouth of Woodward Creek the Columbia River water surface elevation fluctuates 14 feet on average, with the highest water levels occurring in June and the lowest in October. This creates a backwater in the lower 700 feet of Woodward Creek. High water for Woodward Creek occurs during November through February when the Columbia River is usually at a low to average water level; thus causing sediment to deposit near the mouth of the creek forming a delta. Fish passage becomes a problem at the mouth of Woodward Creek due to a steep drop over large cobble, when the Columbia River elevation at Bonneville Dam is below 10.0 feet. (USGS 2007)

Figure 3. Mouth of Woodard Creek when Columbia River elevation at Bonneville = 7.0 (September 2006). *Note the 3 to 4 foot steep drop which Woodard Creek cannot scour due to backwater.*

- Moorage Road to Columbia River: This reach has an average gradient of 1.7 to 2.3%. The channel is confined to the 35 foot width under the railroad crossing and Moorage Road. The most significant feature of this reach is the lack of bedload transport during flood flows, because the channel and culvert become blocked upstream of the railroad grade; the majority of the material is deposited as opposed to being transported to the delta downstream.

- Moorage Road to SR-14: This reach is 1700 feet long with a gradient from 1.9 to 2.3%. The channel shape and profile is controlled by the dike on the right bank, backwater and sediment deposition from the channel upstream of the Moorage Road culvert and the SR 14 Bridge opening (40 feet wide with vertical walls). During flood flows, the bridge opening under SR 14 is a very efficient channel cross section (narrow and deep). Sediment is easily transported through this site and deposits downstream where the channel is blocked by the Moorage Road culvert.

- Upstream of SR-14: In this reach the floodplain is reduced from over 300 feet wide to 40 feet at the highway bridge. The constriction causes a significant backwater at flood flows and the transport of bedload is blocked resulting in deposition and formation of a steep (7%) channel immediately upstream of the bridge. Upstream of this point the channel floodplain widens and the gradient increases to 2.8 to 3.7%.

- RM 0.8 to 1.7: The channel steepens to 5 to 7%, but due to the wide floodplain actual channel slope is much less. Much of the gradient is controlled by small waterfalls and cascades (3 to 6 feet in height) which do not block fish passage for adult salmon and steelhead but control the channel profile and create opportunities for spawning.

- RM 1.7 to 2.7: The gradient steepens to 8 to 12%. Grade is controlled by the steep valley walls, small cascades and cobble and boulder size bed material size.

- Above RM 2.7: The gradient steepens to 15 to 20%.

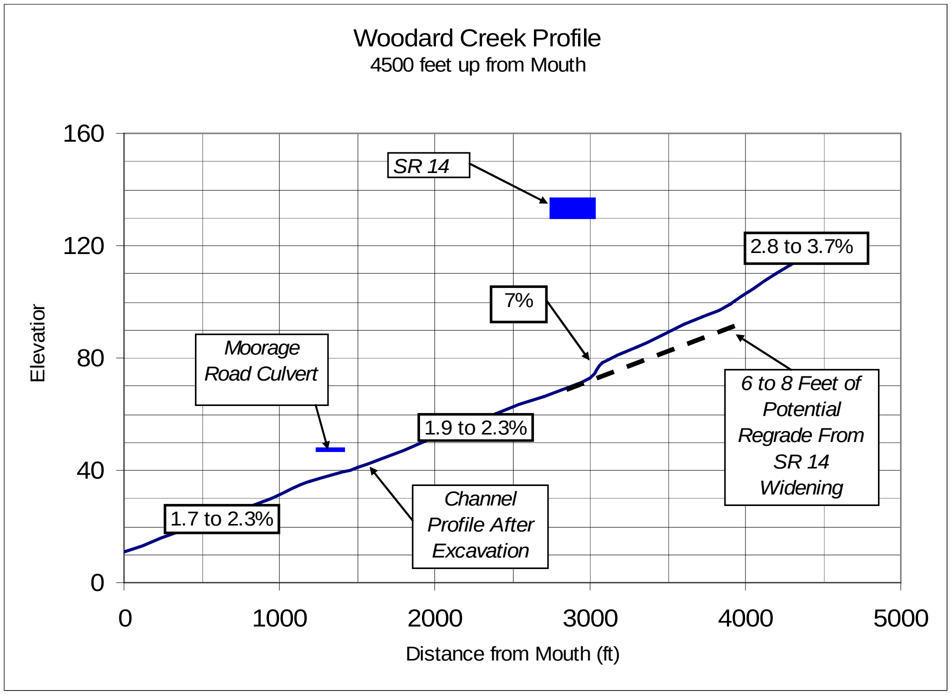


Figure 4. Profile of Woodward Creek from Mouth to RM 0.85 Based on Survey Data. (*Upstream of this point, the gradient is estimated from USGS quads.)*

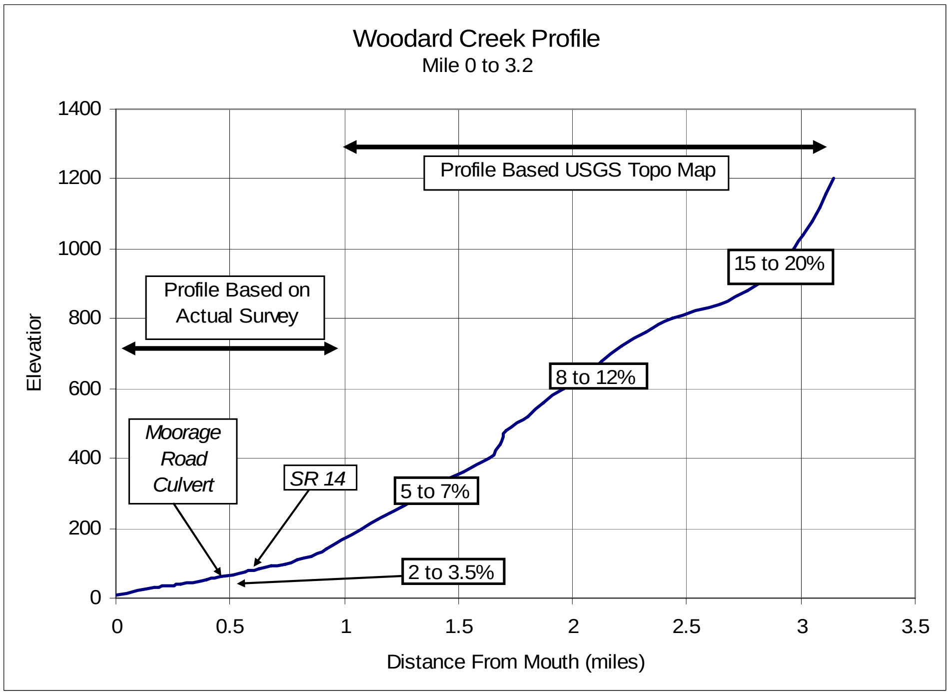


Figure 5. Profile of Woodward Creek from Mouth to RM 3.2 (*based on actual survey data to RM 0.85 and on USGS quads upstream of RM 0.85*).

2.3 Climate and Precipitation

The Columbia River Gorge has typically cool, wet winters and warm, dry summers. Temperatures can vary significantly during the winter months depending on whether the prevailing winds are from the mild west side or from the colder east side. Freezing and thawing cycles are frequent. Precipitation averages around 70 inches annually at Skamania, and is higher at the higher elevations in the watershed. Flooding occurs on Woodward Creek following heavy rainfall events. The 2-year 24-hour storm event exceeds 4 inches in the upper watershed.

2.4 Hydrology

Woodward Creek hydrology was calculated from two sources; 1) Culvert Design Flows for Fish Passage and Structural Safety in East Cascade and Blue Mountain Streams, Orsborn 2002, and 2) Flood Frequencies in Washington, USGS, 1998. Based on a drainage area of 6.9 square miles and an average annual precipitation of 80 inches per year the following flows (in cubic feet per second {cfs}) were calculated. The LCFEG has installed a stream gage just downstream of the Moorage Road. Low flows for the summer of 2007 varied from 3 to 7 cfs.

Characteristic Flow	Orsborn Model	USGS Model
Mean Annual	23 cfs	
Two Year Peak Flood Flow	380 cfs	390 cfs
25 Year Peak Flood Flow	740 cfs	830 cfs
100 Year Peak Flood Flow	920 cfs	1077 cfs

2.5 Vegetation

The natural vegetation of the western Columbia Gorge is Douglas fir and western hemlock climax forest (Franklin & Dyrness 1988). It is likely that most of the Woodward Creek watershed was historically covered with dense forest, except where occasional landslides removed the vegetation. The remnant large cedars along the creek indicate that the floodplain may have been dominated by large cedars.

Currently, the majority of the watershed is still in forest, albeit in early to mid seral stages, with the dominant tree species now Douglas fir and red alder. In the floodplain, the existing vegetation is alder and cedar, with vine maple, willows, salmonberry, Himalayan blackberry, devil's club, and red osier dogwood in the understory or in non-forested patches. Cottonwood are present along the lowest reach (delta). Non-native species such as Himalayan blackberry and reed canary grass are dominant in some areas downstream of the East Fork Woodward Creek confluence.

Figure 6. Upper East Fork Woodward Creek (alder dominated).

2.6 Fish Distribution

The focal species in the Bonneville Tributaries basin include federally listed salmonid species: fall chinook (threatened), chum (threatened), coho (threatened), and winter steelhead (threatened). Other species of interest in the Bonneville Tributaries basin include coastal cutthroat trout and Pacific lamprey. It is likely that fall chinook and chum are naturally produced, whereas the coho and steelhead stocks may be a mixture of hatchery strays and naturally produced fish.

In the Recovery Plan (LCFRB 2004), coho and winter steelhead were the only species identified as using Woodward Creek. It was known that both coho and steelhead had been found in the past up to the confluence of East Fork Woodward Creek (RM 1.7), with potential use further upstream. Both early and late stock coho may be present in Woodward Creek. Chum have been observed on the delta of Woodward Creek, and anecdotally by Beacon Rock park staff below the SR-14 bridge (E. Plunkett, pers. comm. August 2007).

The Lower Columbia Fish Enhancement Group (LCFEG) has undertaken spawner surveys since December 2005, and has documented adult steelhead and redds up to RM 3.5 on the mainstem. The East Fork enters the mainstem at RM 1.7 and is likely to be accessible and provide good steelhead spawning for at least 1 mile. Adult coho and chinook and redds have been observed downstream of SR-14. The coho observed have been mixed hatchery and naturally spawned fish. Juvenile coho have been observed upstream of SR-14 (P. Powers, pers. comm. August 2007). From the spawner surveys it is evident that coho, chinook, and steelhead all utilize lower Woodward Creek (see Table 1, below). Over 200 coho were observed by Ty Fugate in September 2006 before formal spawning surveys began in October 2006.

A large deltaic gravel deposit is present at the mouth of Woodward Creek and can be a fish passage barrier during low flows in the Columbia River (primarily during August through November, but can also be a barrier in April and May for winter steelhead if Columbia River flows are ramped down for reservoir refilling). This barrier limits the numbers of chinook and early stock coho that can enter Woodward Creek, and is a limiting factor to salmon production in the watershed.

Table 1. Spawner surveys in Woodward Creek (from LCFEG data)

Date	Species	Location of survey	Redds	Adults	Jacks	Total # Fish
12/3/05	Coho	Hwy 14 to mouth	2	1	0	7
12/10/05	Coho	Hwy 14 to mouth	1	0	0	3
12/17/05	Coho	Hwy 14 to mouth	0	0	0	2
12/23/05	Coho	Hwy 14 to mouth	0	0	0	1
12/31/05	Coho	Hwy 14 to mouth	0	0	0	1
1/7/06	Coho	Hwy 14 to mouth	0	0	0	3
4/4/06	Steelhead	Woodard Bridge crossing - mouth	1	0	0	0
4/1106	Steelhead	Woodard, Hwy 14 Bridge - upstream 1.4 miles	2	2	0	2
4/18/06	Steelhead	Woodard Bridge crossing - mouth	5	0	0	0
4/22/06	Steelhead	Woodard Bridge crossing - upstream .5 mile	4	2	0	2
4/25/06	Steelhead	Woodard Bridge - Upstream 1 mile	5	2	0	2
5/2/06	Steelhead	E.F. Woodard Bridge - Main stem mouth	0	0	0	0
11/1/06	Coho	Hwy 14 Bridge - mouth	1	1	0	8
11/7/06	Coho	Hwy 14 Bridge - mouth	0	0	0	0
11/14/06	Coho/Chin	Hwy 14 Bridge - mouth	0	0	1	7
11/22/06	Coho	Hwy 14 Bridge - mouth	0	0	0	7
12/1/06	Coho	Hwy 14 Bridge - mouth	0	1	0	3
12/1/06	Coho	Hwy 14 Bridge - upstream to .5 mile	0	0	0	0
12/6/06	Coho	Hwy 14 Bridge - mouth	0	0	0	1
12/21/06	Coho	Hwy 14 Bridge - mouth	0	0	0	0
1/15/07	Coho	Hwy 14 Bridge - mouth	0	0	0	0
1/26/07	Coho	Hwy 14 Bridge - mouth	0	0	0	0

2.7 Limiting Factors in Basin

The Recovery Plan (LCFRB 2004) identified several limiting factors in the Bonneville Tributaries basin including: substrate/sediment; habitat diversity; channel stability; riparian function; and floodplain function. The key priority actions and programs that were also identified in the Recovery Plan are:

1. Provide adequate water flows in Bonneville Dam tailrace for downstream habitats;
2. Restore floodplain function, riparian function and stream habitat diversity;
3. Manage growth and development to protect watershed processes and habitat conditions;
4. Manage forest lands to protect and restore watershed processes;
5. Restore passage at culverts and other artificial barriers;
6. Address immediate risks with short-term habitat fixes;
7. Align hatchery priorities with conservation objectives;
8. Manage fishery impacts so they do not impede progress towards recovery;
9. Reduce out-of-subbasin impacts so that the benefits of in-basin actions can be realized.

In the Recovery Plan (LCFRB 2004), limiting factors and the productivity/abundance/diversity of fish populations were evaluated using both the Ecosystem Diagnosis and Treatment (EDT) model (Mobrand Biometrics 1999) and an Integrated Watershed Assessment (IWA). The EDT model relates physical habitat and biological conditions in a watershed to fish performance at each life history stage. Habitat features are described on a reach level and then related to life-stage specific survival. The IWA evaluates the condition of key watershed processes that can directly or indirectly affect habitat conditions and thus focal fish species. The IWA model is particularly useful in identifying limiting factors in the watershed and their root causes, and potential management measures to address the limiting factors. Woodward Creek was not included in the EDT analysis and thus is not explicitly considered in the recovery needs of the salmonid species in the Recovery Plan (LCFRB 2004). The Woodward Creek watershed is lumped with the Hardy Creek watershed in the IWA. For the purposes of this study, we have considered Woodward Creek to be roughly equivalent to Duncan Creek, which was evaluated in the EDT and IWA analyses. The similarity is due to the relative size of the two creeks; although Duncan Creek goes dry in most years during the low flow period (August-September), whereas Woodward Creek does not typically go dry.

3. Woodward Creek Reach Description

The geomorphology and channel form of Woodward Creek is a function of current and historical landform and geologic structural controls and inputs; basin-scale land use and vegetation characteristics; and climatic, hydrologic and sedimentary inputs to the river. The cumulative effects of inputs and responses over time contribute to the current forms and processes occurring along the creek, which are ultimately linked to a variety of habitats and functions. Understanding the geomorphologic processes of the major reaches is an important step in evaluating potential habitat restoration opportunities for Woodward Creek.

Within the generally fish accessible study reach from River mile (RM) 4 to the confluence with the Columbia River there are seven distinct geomorphic reaches. The reaches were delineated based on the slope and channel morphology and major infrastructure which controls channel plan, profile and section, as identified during the September 2006 reconnaissance. The following geomorphic reaches are described herein from downstream to upstream.

- Reach 1 – RM 0.0 to 0.2 (Mouth to RR Crossing)
- Reach 2 – RM 0.2 to 0.5 (RR Crossing to SR 14)
- Reach 3 – RM 0.5 to 1.7 (SR 14 to E. Fk. Woodward Creek)
- Reach 4 – RM 1.7 to 2.0
- Reach 5 – RM 2.0 to 2.5
- Reach 6 – RM 2.5 to 3.0
- Reach 7 – RM 3.0 to 4.0

3.1 Reach 1

This reach extends from the mouth of Woodward Creek at the Columbia River up to the railroad crossing and culvert. This reach is low-medium gradient (2%) and the lower portion is a natural deposition zone (alluvial fan), particularly when Columbia River flows are high. The substrate is dominated by large cobbles and some gravels. This reach is too short to develop side channel habitat, has one main channel with two abandoned channels and evidence of additional braiding closer to the Columbia River. The delta gets scoured by Columbia River flows that leave a 3 to 4 foot drop off of the delta into the Columbia River at low flows[1]. Fish passage is prevented during low flows and likely delays entry for coho and may reduce the overall numbers of fish spawning in Woodward Creek. This may also reduce the potential for chum use of the lower creek. The passage problems are most evident during August-October and in April/May when the reservoirs are being filled on the Columbia.

Sediment transport in this reach is affected by the culvert under Moorage Road. In the summer of 2007, 5000 cubic yards of material was removed from the channel upstream of Moorage Road. This material deposited during the November 2006 flood.

Historically, the creek would have meandered over the wider delta prior to diversion under the highway and RR crossings and would have scoured its channel more frequently. Currently, the in-channel habitat is uniform except for where beavers periodically build dams and create pools.

Restoration opportunities in this reach include improving fish passage at the mouth, reconnecting a side channel in the floodplain to provide rearing habitat for juveniles and possible Chinook, coho and chum spawning habitat, roughening the floodplain to collect more sediment out of the main channel to help maintain the channel opening at the mouth, and riparian restoration. Until the sediment load is addressed in the reaches upstream of the railroad culvert, measures to improve the mouth for fish passage may only be successful in the short-term.

Figure 7. Mouth of Woodward Creek during Low Flows in Columbia River (September 2006).

[1] High flows on Woodward Creek in November-December 2006 scoured the creek channel out to the Columbia River and temporarily provided an accessible channel for fish passage. During years when there are no high flows on Woodward Creek, or when high flows correspond to high flows in the Columbia, sediment deposits in the Woodward Creek channel and reduces fish accessibility.

3.2 Reach 2

This reach extends from the railroad crossing up to the bridge at SR-14. This reach is highly channelized between the left naturally high bank and a dike along Moorage Road on the right bank. The SR-14 bridge opening is about 40 feet in width, which is about half the width of the channel in the upstream Reach 3. The channel was directed to this left side of the floodplain more than 60 years ago. The upper portion of the reach transports sediment quite effectively, whereas the lower portion of the reach widens out somewhat at the end of the dike and also has to enter the culvert at an angle. The widened channel and debris deposition at the culvert has caused sediment deposition in the 200 feet or so upstream of the culvert. During the flood in November 2006, the sediment build-up caused the creek to jump out of the channel and flow down Beacon Rock Moorage Road. The culvert and channel are a maintenance problem for the Park, and the debris may block fish passage after large depositional events. This reach is dominated by large cobble and has essentially no pools or other habitat diversity. The riparian zone is in fairly good condition with mature trees and good canopy cover except near the confluence of Little Creek (RM 0.25) and in the immediate vicinity of the culvert where frequent maintenance occurs.

The channelization of this reach limits restoration opportunities in the short-term. The immediate problems are the constriction of the culvert and the deposition of sediment and debris at its upstream end. One or more wood or rock vanes could be placed upstream of the culvert to direct the channel in a more direct alignment into the culvert; although this would only provide temporary benefits. Control of sediment upstream of SR-14 and reconnection of the floodplain in Reach 2 will be the most effective and long-term opportunities to reduce sediment and debris deposition and allow the creek to migrate in a more natural alignment. One or more LWD jams could be placed immediately upstream of the SR-14 bridge to capture wood from Reach 3 before it reaches the bridge. In the long-term, removal or setback of the dike and Beacon Rock Moorage Road and reconnecting the creek to its floodplain would allow the channel to migrate without damaging infrastructure, thus creating off-channel and other habitats and providing a floodplain for sediment and debris deposition. These modifications would also increase the channel length and decrease the slope which, along with log jams create improved spawning habitat. If another road is eventually planned to connect potential future camping or other uses to the new road to the boat ramp, the road under the railroad could be abandoned and the culvert could be removed to allow the creek to flow through the railroad opening without a blockage. The railroad grade would still limit the channel width to 38 feet, the length would be very short and channel design features upstream would improve sediment transport through the crossing.

Figure 8. Reach 2, Typical Uniform Channel.

Figure 9. Railroad Culvert and Roadway after 2006 High Flows (January 2007).

3.3 Reach 3

This reach extends from the SR-14 bridge up to the confluence with the East Fork Woodward Creek. This is a higher gradient reach (generally 2-5% slope, except immediately upstream of the SR-14 bridge) with a wide floodplain area up to several hundred feet wide. This reach is a depositional area and has received a large quantity of sediment in recent years. The channel has braided and created islands and side-channels. The riparian zone is of fairly good quality although most of the trees are young (less than 30 years) and there are a number of non-native species such as blackberries and reed canary grass. The substrate is dominated by large cobbles and gravel with a few smaller boulders. The lack of channel structure can be seen throughout Reach 3 (**Figure 10**). After the November 2006 flood, several large trees fell in the creek and blocked the channel and redistributed sediment (**Figure 11**). As the creek formed around these trees, pool and riffle habitat was created and steelhead were actually observed spawning.

The flow goes subsurface through portions of this reach in the coarse material. There is some wood in this reach in small clumps. There are few pools in this reach. The right bank for much of this reach is a high fractured basalt cliff. A dike has been placed at the end of this cliff to cut off the former right bank floodplain, and probable location of the historic main creek channel, and now diverts all flows towards the left bank and under the bridge at SR-14.

This reach would be an excellent location to place additional wood and LWD jams. The wood could be used to protect the existing high quality side-channel from sediment deposition and could also be used to trap sediment in the floodplain, and to create further spawning areas as well as providing scouring of pools and providing cover. Many juvenile fish (trout and coho) have been observed in the upper end of this reach. This reach also could benefit from the removal of non-native vegetation and plantings of native species. Removal of the dike along the right bank and reconnection of the floodplain would further trap sediments and provide the opportunity for the natural creation of off-channel habitats. This reach is easily accessible from SR-14 and an old road in the right bank floodplain. Because the dike currently protects the highway and bridge from erosion, a longer-term solution would be to widen the SR 14 bridge to 150 feet and reduce the need for the channel diversion dike and then provide protection for the road with rock set back closer to the roadway.

Figure 10. Reach 3; Typical Wider Floodplain Section before November 2006 Flood.

Figure 11. Reach 3, After November 2006 Flood.

3.4 Reach 4

This reach extends from the confluence with East Fork Woodward Creek up to RM 2.0. This reach is within a narrow ravine and has two bedrock outcrop falls of 6 to 8 feet in height. The left bank is eroding at the powerline crossing and the right bank is eroding near the bedrock falls (**Figure 12**). These slides are contributing gravel, cobbles, and clay to the channel. Some of the eroding banks are dominated by red clays, while others are a compressed conglomerate of silts and cobbles. The channel substrate is dominated by cobbles and boulders and bedrock. The wetted width varies significantly in this reach from 10 to 20 feet depending on the presence of large boulders. The powerline is a dominant feature in this reach and has caused the removal of a significant amount of riparian vegetation, and invasion by non-native species such as Himalayan blackberry. Recent observations at the power line crossing indicate that coho and steelhead may spawn extensively in upper end of Reach 3 and also in Reach 4. Significant numbers of juvenile coho salmon were observed in August 2007 both upstream and downstream of the powerline crossing.

Potential access by construction equipment is feasible at the powerline crossing, but is limited above the bedrock falls in this reach. It may be possible to trap some of the sediment eroding off the steep banks by placing wood structures at the toe of the banks to accumulate the material. It is likely not feasible to prevent the slides because they are occurring all along the face of the slope in highly weathered volcanic material, and are not due to timber harvest or other human caused activities. There are also revegetation opportunities with willows and other native shrubs in the powerline area as long as trees are not planted under the powerlines.

Figure 12 Eroding Bank Near Downstream End of Reach 4

3.5 Reach 5

This reach extends about ½ mile in length from about RM 2.0 to 2.5. The gradient increases in this reach (~11%) with several boulder drops of 6 to 8 feet in height. The boulders in this reach are large, with some up to 6 feet in diameter (**Figure 13**). There are small pocket floodplain areas in this reach, typically only on one side of the channel that may reach up to 100 feet in width for a short distance. The wetted width during low flow averaged about 13-15 feet and the bankfull width is about 40 feet. A slide is present in this reach contributing compacted clays and other fine materials to the channel. This slide has temporarily filled in the channel for up to 1000 feet downstream. The riparian and floodplain vegetation is primarily alder and cedar approximately 20-30 years old, although there are remnant large cedars up to 6 feet in diameter or greater and the riparian zone generally provides 100% canopy cover. There are scattered individual pieces of wood in this reach and a couple of channel spanning jams. The large boulders and wood trap some gravels and steelhead have been observed spawning in this reach by the LCFEG.

This reach is high gradient and has limited construction accessibility. Placement of wood upstream in Reach 6 may slowly contribute additional wood to this reach which would help trap sediment and promote the formation of scour pools. Additionally, wood could potentially be placed in this reach via helicopter. There are no other feasible restoration opportunities.

Figure 13. Reach 5; Typical Boulder Section.

3.6 Reach 6

This reach extends for about ½ mile from RM 2.5 to 3.0 and the Woodward Creek Road bridge is approximately in the middle of this reach. This reach is lower gradient (less than 5%) and is dominated by large cobbles with some boulders. The wetted channel width during low flows averaged about 18-20 feet; the bankfull width is 30-32 feet. There is an approximately 100 foot wide floodplain in this reach and then 30-50 foot high ravine side slopes. The US Forest Service (USFS) installed log weirs in this reach in the 1990s, likely to prevent or reduce channel incision and/or to trap sediment coming down the channel (there is an eroding bluff at the upper powerline crossing in this reach). It appears from the tags at the structures that about 25 of these weirs were installed. Only about 7-8 of them are still visible. Some of the weirs may have been buried and others have been undermined and were likely transported downstream. The weirs that remain in place are effectively trapping gravel and also creating scour pools, and more importantly keeping the channel connected to the floodplain. It appears that the channel may have been incised in the 1980s perhaps as a result of timber harvest and/or high flows in the upper watershed. However, since then, either as a result of the weirs or from recent large sediment inputs, the channel has filled back in. The riparian vegetation shows signs of burial in some locations. The riparian and floodplain vegetation is primarily alder and cedar approximately 20-30 years old, although there are remnant large cedars 4 feet in diameter or greater. Canopy cover is 100% throughout most of the reach. There is a natural log jam near the downstream end of this reach (**Figure 14**). Boulders and wood trap small patches of gravel in this reach that provide spawning habitat; they also create scour pools and large numbers of juvenile trout were observed in the few pools in this reach during the September 2006 reconnaissance.

The primary limitations with this section of the creek are the limited areas of spawning gravel and rearing habitat. The placement of additional wood in this reach would trap spawning gravel and create additional scour pools and cover, which would likely increase the carrying capacity and production of steelhead from this reach. Flows are steady year-round in this reach and water temperatures are low. This reach could provide high quality spawning and rearing habitat for steelhead and resident trout near the upper end of accessibility in the creek. It is unlikely that coho can access this reach due to the large drops towards the downstream end of this reach.

Figure 14. Reach 6, Showing Channel Spanning Logs.

3.7 Reach 7

This reach extends from approximately RM 3.0 to 4.0. It is a very high gradient reach dominated by boulder cascades, typically 15% slope or greater. From the limited observations made in this reach, the ravine is typically fairly narrow with limited floodplain. The riparian zone provides nearly 100% canopy cover and some inputs of woody debris. This reach is likely transporting cobbles, gravels and some boulders that come from upstream slopes and slumps or slides off the ravine slopes. There are limited habitat restoration options due to the high gradient nature of this reach and limited accessibility. The placement of wood via helicopter could help reduce the rate of sediment transport. This reach is the upstream end of fish access to Woodward Creek with an impassable falls.

4. Restoration Site Identification and Prioritization

4.1 Initial Restoration Needs and Opportunities

Beacon Rock State Park staff and the LCFEG have been collecting information and developing restoration ideas over the past few years based on previously identified sediment deposition problems, fish passage problems at the delta, and the overall need to identify potential chum spawning areas associated with the deltas of tributaries to the Columbia River. Initial ideas included investigating the feasibility of creating a groundwater-fed chum spawning channel in the floodplain of Reach 1, evaluating the potential for reducing sediment loads into Reaches 1 and 2 and evaluation of the railroad culvert to determine if it is a fish passage barrier.

From these initial ideas, several tasks were proposed to collect more information and identify further restoration opportunities and constraints:

- Install piezometers or excavate pits to determine feasibility of creating a groundwater-fed channel in Reach 1
- Conduct surveys of the floodplain and channel up to SR-14 to identify options for dealing with sediment deposition upstream of the RR culvert
- Conduct a watershed reconnaissance trip with biologists and geomorphologists to identify watershed processes and restoration opportunities.
- Develop a list of projects
- Prioritize projects
- Develop conceptual designs for high priority projects to move forward with grant applications

4.2 Watershed Reconnaissance

A field restoration site reconnaissance was conducted in September 2006 to identify watershed conditions and processes and develop reach-based restoration opportunities and constraints. The portion of the watershed accessible to fish was walked from approximately RM 4 to the confluence with the Columbia River by a team of biologists and engineers/geomorphologists from the LCFEG, Anchor Environmental, and Tetra Tech, Inc. This reconnaissance led to the descriptions provided by reach in Section 3, above. A site visit memo was developed based on the reconnaissance and is included as Appendix A. Additionally, the upper watershed has been observed by the same staff on various occasions. From these watershed reconnaissance trips a project list was developed to consider all potential restoration options.

4.3 Initial Identification of Project Opportunities

Table 2. Project Opportunities and Constraints List

Reach	Potential Projects	Constraints
Upper Watershed	Identify and control sediment sources	There are many small dispersed sediment sources, including eroding culverts, road embankments, and natural landslides. Recommend obtaining any info from USFS on mass wasting or road/culvert conditions.
Upper Watershed	Encourage transition to mature forested conditions	USFS lands were harvested approximately 30-40 years ago, most areas now have dense alder stands and some Douglas fir stands.
Reach 7	Add wood to slow sediment transport	Difficult to access due to ravine conditions and only road is ½ mile downstream. Wood may not stay in reach long.
Reach 6	Add wood to capture spawning gravels, keep creek connected to floodplain, and provide scour of pools and cover.	Do not want to disturb high quality riparian, so access may be only possible from upper end.
Reach 5	Add wood to slow sediment transport	Difficult to access due to ravine conditions and only road is more than ½ mile upstream. Wood may not stay in reach long.
Reach 4	Reduce sediment supply	Difficult to stop entire banks from sliding due to natural groundwater and weathering processes. Could place wood at toe of slope to accumulate sediment and slow its transport into the creek. Also, potential for some revegetation for stabilization.
Reach 3	Add wood and LWD jams to reduce sediment transport; create pool habitat and sort spawning gravels; protect high quality side channels from sediment.	Access is good to this site. November 2006 flood deposited some large wood which could be re-oriented as stable logjams inexpensively
Reach 3	Riparian restoration	Need to remove non-native species and revegetate.
Reach 3	Remove dike and reconnect floodplain area on right bank	Historic channel likely further west. Need to protect SR-14 with setback levee or revetment. May be long-term opportunity to widen bridge opening.
Reach 2	Place LWD jams (debris catchers) in upper portion of reach to prevent clogging of culvert downstream.	Limited fish benefits. This effort would provide better habitat benefits in Reach 3.
Reach 2	Remove debris and sediment wedge upstream of culvert and realign creek to enter culvert at more favorable angle.	Limited fish benefits.
Reach 2	Remove dike along right bank and reconnect floodplain	Current residential uses of floodplain. Eventually road may be abandoned and site connected to new park entrance road. Not able to quickly accomplish this project. Would remove high quality riparian zone by removing dike.
Reach 2	Remove road crossing and culvert under RR, allow creek to use RR similar to SR-14 bridge upstream.	Currently residential access on road. Eventually road may be abandoned, may be possible to remove in future.
Reach 1	Create/restore side channel that is semi-protected to provide rearing and spawning habitat	High sediment load may still fill in channel even with protection. Sediment deposition may be alleviated by proximity of side-channel inlet

		to road crossing and high velocities.
Reach 1	Improve fish passage at outlet by realigning main channel and roughening floodplain to encourage scouring flows in main channel.	High sediment load may still fill in channel. Large, well designed wood/ rock structures could alleviate sediment deposition locally.
Reach 1	Riparian and floodplain restoration	Plantings limited by Columbia River elevations; heavy beaver use.

This project opportunity list was discussed at a meeting with Beacon Rock State Park staff in February 2007 to ensure that constraints on park management and uses were incorporated into the constraints analysis and to help the prioritization, below, on what can be accomplished in the near term versus the long term.

4.4 Groundwater and Sediment Investigations

To assess the channel hydraulics, bedload transport capacity and overall channel stability two cross sections were measured in Reach 2. Sediment size was assessed using pebble counts in Reaches 1 and 2. In addition, grain size distributions were analyzed for three soil samples from the proposed Reach 1 side channel area.

Reach 2 can best be described as a transitional plane bed reach (Montgomery and Buffington 1998) with a generally featureless gravel/cobble bed (**Figure 15**). The upper section of Reach 2 is confined and the lower reach unconfined. This transition, the proximity of Moorage Road and the bridge downstream is the reason sediment builds up here during a channel threshold disturbing event. Herein is a key opportunity for habitat restoration via the installation of LWD and by reducing the channel confinement to transition the current reach from a plane bed to a pool/riffle type channel, thus providing improved fish habitat features.

Figure 15. Channel in Vicinity of Moorage Road. *Left, looking upstream; right, looking downstream into Reach 1 (September 2006).*

The survey data was collected before the November 6, 2006 flood event. This flood was significant enough to modify the channel profile and cross section in several locations. Although, due to the proximity to infrastructure (i.e. Moorage Road, culverts and dikes in Reach 2) the post flood channel configuration, after the channel was excavated, was not significantly different in slope and width because the excavation was intended to return the channel to a configuration to flow through and within existing structures.

One section upstream of the Moorage Road was analyzed using Flowmaster to estimate the relationships between discharge, velocity and depth. **Figure 16** shows a mean channel velocity of 9 feet per second (fps) at the 100 year flood of 1100 cfs. The reach slope is 0.023 ft/ft. **Figure 17** shows how depth varies with discharge. These velocity and depths are typical of Reaches 1 and 2, because channel width and slope are similar.

Figure 16. Woodward Creek Reach 2: Velocity and Discharge Rating.

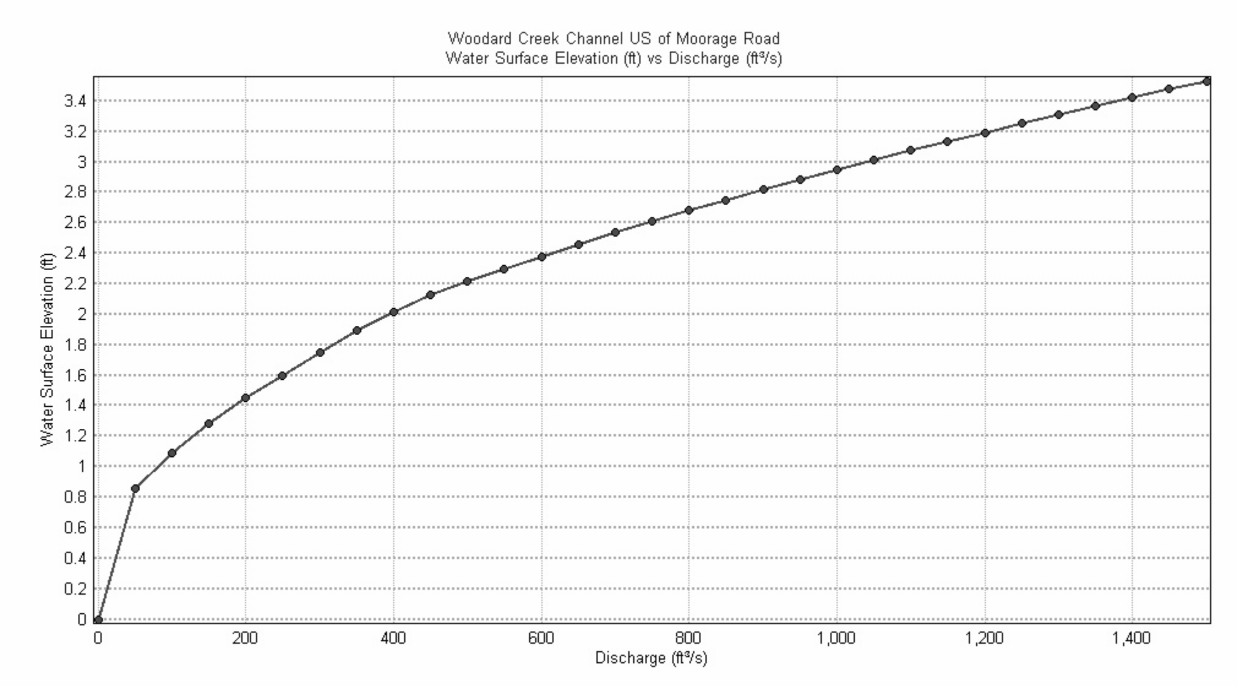


Figure 17. Woodward Creek Reach 2: Depth and Discharge Rating.

A critical shear stress analysis was then done using two equations (Bathurst, J.C. 1978), and (Norman, J.M. 1975).

The critical shear stress is defined as the shear stress required to cause movement of a particle of a given size. Using the above mentioned equations yields the following results for channel stability in Reach 2.

Flood Frequency	Discharge (cfs)	Stable D_{50} Size (inches)
2	380	3.2
25	830	5.1
100	1100	6.0

Pebble counts from Reach 1 and Reach 2 are shown in **Figure 18**. The D_{50} value for Reach 2 varies between 4 and 6 inches. Comparing these values to the critical threshold values calculated for Reach 2, shows that the Reach 2 channel may become unstable around the 10 to 20 year flood event. This result seems reasonable based on past experience with the frequency of bed load transport in the channel as described by Washington State Parks staff.

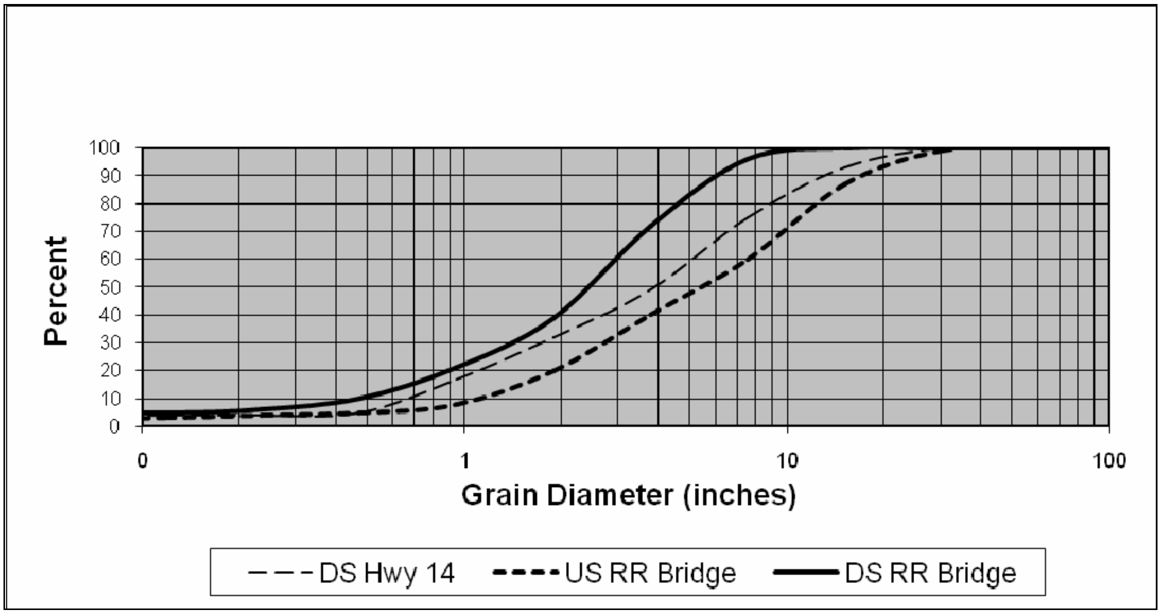


Figure 18. Grain Size Distribution from Pebble Counts in Reaches 1 and 2.

Test pits were dug in three locations of the proposed side channel in Reach 1. The locations are shown in **Figure 19**. Initially the plan was to explore the potential for groundwater, either seepage or hyporheic flow from Woodward Creek or from other isolated sources which may be within the floodplain. No groundwater was found, but three soil samples were taken (**Figures 20 and 21**). The soil sample results are shown in the table below. Sieve analysis was completed by Geotechnical Testing Laboratory in Olympia, WA. Soil samples were taken from a depth of 2 to5 feet below the surface layer.

	Percent Passing		
US Sieve Size	Upper	Middle	Lower
6"			
4"	100		
2"	96	100	100
1"	84	80	93.4
1/2"	73	58	85.2
#4	52	33	80
#30	17	11	71
#200	2.9	1.8	45

The material can best be classified as well to poorly graded silty sand and gravel. Soils in the lower test pit were much smaller in grain size compared to the upper test areas which included more gravel. The most important finding from the test excavations was the absence of groundwater, and the presence of fine grained materials which could support a surface fed side channel restoration project. Grain size distribution for the excavated samples were much smaller than as determined from the pebble counts in the adjacent channel (1/2 to 1 inch compared to 5 inches) for the d_{84} size. This clearly shows the shallow overall depth of the alluvial flood plain material.

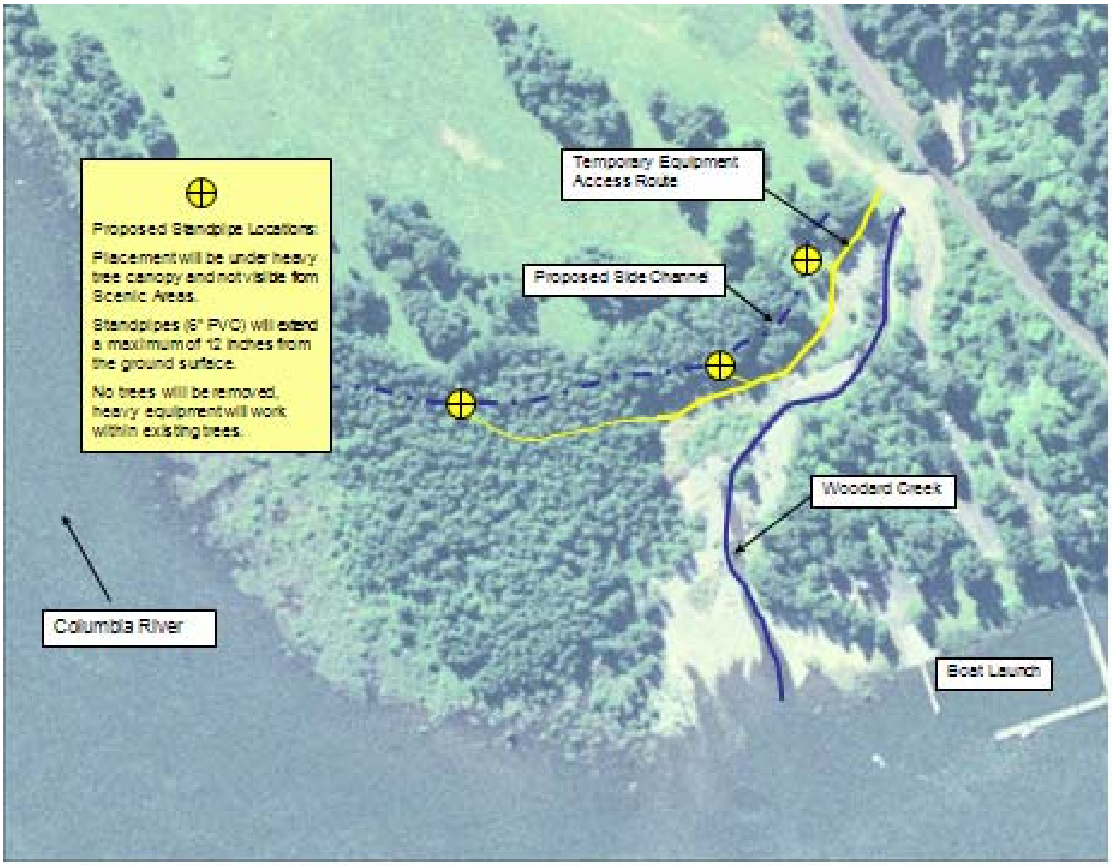


Figure 19. Locations of Test Excavations in Reach 1.

Figure 20. Typical Test Dig Layout in Proposed Side Channel Area.

Figure 21. Excavation (typical) 8 to 10 Feet below Ground Surface.

4.5 Recovery Plan Priorities

As stated previously, Woodward Creek was not explicitly included in the EDT analysis as part of the Recovery Plan (LCFRB 2004). Woodward and Hardy Creeks were analyzed together in the Integrated Watershed Assessment (IWA). Both Woodward and Hardy Creeks are primarily within either Beacon Rock State Park or the Gifford-Pinchot National Forest. Woodward Creek has a larger watershed area, due to its major tributaries, and is not nearly as steep as Hardy Creek. Thus, for the purposes of this evaluation, we will instead consider Duncan Creek to be more roughly equivalent to Woodward Creek based on size and channel characteristics, although Duncan Creek goes dry periodically during low flow periods (August-September). Also, Woodward Creek does not outlet through a lake, thus the Duncan Lake reach is not at all comparable to Woodward Creek.

The Duncan Creek reaches have been rated as Tier 1 and 2 as shown in the table below. Because Duncan Creek does go dry periodically, its Tier 2 rating may be lower than what Woodward Creek should be rated.

Table 3. Subbasin Reach and Restoration Priorities

Reach	*Woodward Equivalent*	*Species*	*EDT Tier*	*Stream Channel Habitat*	*Off-channel Habitat*	*Floodplain Function*	*Riparian Conditions*	*Instream Flows*	*Hillslope Processes*
Duncan 2	Woodward 4-7	Winter steelhead – M Coho – L	2	H	H	M	M	H	M
Duncan 1	Woodward 1,2,3	Coho – H Winter steelhead – L	1	H	H	H	M	H	H

The IWA rated the Hardy/Woodward Creeks combined watershed as impaired for hydrology at both the localized and watershed scale. Sediment and riparian functions are moderately impaired. Hydrology is tending to improve over time as it has been more than 20 years since the watershed was logged. Most of the watershed is now covered with mid-seral stage forest, both deciduous and coniferous. There are numerous small to large sediment sources in the Woodward Creek watershed. Erosion from logging roads and culvert failures are continuing to contribute fine sediments to the creek. This situation will likely slowly improve over time. The riparian condition of Woodward Creek is improving, and in many reaches of the creek the conditions are good. The most degraded sections are along the lower creek from the lower powerline crossing (RM 1.8) down to the mouth.

In Woodward Creek, the fish species that have been observed utilizing the system are fall chinook, coho, and winter steelhead[2]. Chum may occasionally be present. The following paragraphs summarize the critical life stages and required habitats from the Recovery Plan (LCFRB 2004) and Habitat Work Schedule (LCFRB 2007) that would be most beneficial to restore in the Woodward Creek watershed.

The most critical life history stage for fall chinook in the Bonneville Tributaries subbasin is spawning adults and the greatest limiting factors are high temperatures and lack of key habitat. Woodward Creek does not have high water temperatures, but lacks stable spawning habitat for chinook in the lower two reaches. Spawning habitat will be the most important habitat type to restore for Chinook salmon.

The most critical life history stage for coho is 0-age summer rearing and the greatest limiting factors are high temperatures, hatchery competition, flows, food, and habitat diversity. Woodward Creek does not have high water temperatures or competition from hatchery stocks in the juvenile rearing stage. Instream flows, primarily subsurface flows, are a problem in Woodward Creek during the summer. It is unclear whether prey resources are a limiting factor in Woodward Creek. Habitat diversity, particularly the lack of pools and cover, are limiting factors for coho rearing. A complete lack of ponded or slow moving, off-channel rearing habitat is a major limiting factor. Instream flows, off-channel rearing and in-stream habitat diversity will be the most important habitat elements to restore for coho salmon.

[2] This is in contrast to the EDT listing fish species presence in Duncan Lake and Creek as chum, coho, and winter steelhead.

The most critical life history stages for winter steelhead are egg incubation and 0-age summer rearing, and the greatest limiting factors are sediment, flows, and temperature. Woodward Creek transports a significant amount of sediment through all reaches. Stable gravel beds for egg incubation are in limited supply and likely limit production. Slowing the rate of sediment transport and trapping of gravels for spawning beds will be the most important habitat element to restore for steelhead. Reduction of subsurface flows and an increase in habitat diversity is also important.

4.6 Project Screening and Prioritization

When prioritizing restoration projects it is important to keep in mind that there are different approaches that can be taken to restoration and the most appropriate approach will vary depending on the adjacent land uses and geomorphology of the study area. It may make most sense to preserve habitats on publicly owned lands or higher up in the watershed where less development may have occurred. Watershed and land use management may be most appropriate in areas where future development or other activities (i.e. timber harvest) are expected.

4.6.1 Restoration Approaches

<u>Conservation and Protection</u>
The most sustainable approach in river restoration is protecting existing river systems, their natural processes and subsequent functioning habitats. This typically involves acquiring and dedicating conservation easements or channel migration/floodplain zones, especially in critical areas that have extremely valuable habitat benefits, persistent flooding problems and/or the potential for significant channel migration.

<u>Watershed and Land Use Management</u>
With historical and future growth and development of the human population, it is inevitable that conservation easements and full protection of aquatic and riverine resources are not feasible. Therefore, land use planning and management is the next best approach in river and fish habitat restoration. Proper management of development, growth and land use practices throughout a watershed can protect vital downstream aquatic resources. Some examples include:

- Floodplain and critical area management and regulation in urbanizing areas.
- Management of industries such as mining, forestry and agriculture to minimize tree removal, road construction, and/or provision of adequate buffers along streams.
- Stormwater management and planning to maintain natural hydrology in developing areas.

<u>Process Based Restoration</u>
Process based river restoration focuses on restoring physical, biological and chemical processes and the connective linkages that can be lost due to anthropogenic influences. Disruption and loss of hydrologic connectivity can result in habitat fragmentation and loss of ecological connectivity, linkages and fish habitat functions. There are a range of processed based restoration feature types and actions that can mitigate or restore functioning processes within the river that can ultimately improve fish habitat. Engineered solutions may be required, but the underlying approach is based

on restoring processes and not fixing localized symptoms, such as sediment filling up a culvert. The following are a few examples of processed based restoration.

- Riparian plantings in along river banks and floodplains to contribute wood and nutrients to the stream system.
- Decommissioning and removal of structures that block fish passage or otherwise disrupt natural hydrology and/or sediment and wood transport.
- Levee removal or setback to restore floodplain hydrologic and ecological processes.
- Simple construction and installation of large wood structures and/or side channel reconnection projects that simulate historic habitats or features.

<u>Engineered and Constructed Restoration</u>
Engineered and constructed restoration involves physical manipulation of the river and floodplain to promote, enhance or augment river processes related to fish habitat conditions. Typically, restoration features of this scale and type involve some type of installation of a hydraulic structure or channel manipulation to a desired condition. Engineering analysis and design is needed to support construction of the planned structures. These engineered features can often attain results immediately after construction. However there is a higher risk of not being sustainable over the long term. A few examples that fall within this category are summarized herein.

- Permanent installation and major construction of rock or large wood debris using ballasting or anchoring systems to create fish habitat.
- Reconnection or reconfiguration of the river channel and floodplain side channels, backwater and wetlands using excavation and/or dredging techniques.
- Bioengineering bank enhancement to minimize bank stabilization activities.

4.6.2 Project List

Because the majority of the watershed is currently within public ownership, it is generally already protected from further development. Beacon Rock State Park recently acquired the resort in the floodplain of Reach 2 and will be developing management plans for this area. Over time, the structures will be removed, and the area will be primarily utilized for camping and boat launching. There may be opportunities to remove Moorage Road. This will improve habitat conditions in the floodplain over time. This process will take a few years and is a constraint on actions that can be taken in the short term in Reach 2. The remaining restoration opportunities identified initially are either process-based or engineering-based. In general, the primary approach is to take actions that will promote better functioning of natural processes because the high natural sediment load would likely pose a risk to engineered restoration actions. In situations where an engineered solution is required due to adjacent infrastructure or to create a specific habitat type that might not naturally occur for a long time period, the design may require future maintenance.

A specific list of projects was developed for the Woodward Creek watershed. This list is shown in Table 4.

Table 4. Project List

Project ID	Project Type/Title	Description
W-UWA	Place Large Woody Debris (LWD), Upper Watershed	Place unanchored LWD into upper watershed downstream of road crossings to simulate and supplement natural wood recruitment and functioning due to mid-seral status of riparian and hillslope forests. Primary goal is to slow down sediment transport rate.
W-7A	Place LWD, Reach 7	Place unanchored LWD into Reach 7 to simulate and supplement natural wood recruitment. Two goals in this reach, to slow down sediment transport rate and create pools and cover for fish rearing and holding.
W-6A	Place LWD, Reach 6	Place unanchored LWD into Reach 6 to simulate and supplement natural wood recruitment. Three goals in this reach, to slow down sediment transport rate, keep creek connected to floodplain and trap gravels, create pools and cover for fish spawning and rearing.
W-5A	Place LWD, Reach 5	Place unanchored LWD into Reach 5 to simulate and supplement natural wood recruitment. Two goals in this reach, to slow down sediment transport rate and create pools and cover for fish rearing and holding.
W-4A	Place LWD, Reach 4	Place unanchored LWD into Reach 4 to simulate and supplement natural wood recruitment. Two goals in this reach, to slow down sediment transport rate and create pools and cover for fish rearing and holding.
W-3A	Place LWD jams in Reach 3	Construct several LWD jams in Reach 3 to simulate natural debris deposition zone as creek comes out of confined reaches into depositional reach. Two goals in this reach, to slow down sediment transport rate, and trap spawning gravels and create pools/cover for fish spawning and rearing.
W-3B	Riparian restoration, Reach 3	Restore riparian zone where degraded from utility crossings and invasion of non-native species.
W-3C	Protect and enhance side channels and spring fed areas, Reach 3	Protect existing high quality side channel and spring fed area by placing LWD jam at entrance, additional wood in channel, and riparian restoration as needed.
W-3D	Remove dike and restore floodplain, Reach 3	Remove right bank dike that cuts off floodplain area upstream of SR-14. Protect road as necessary, remove non-native species and revegetate with native riparian species. Primary goal is to reconnect creek to its floodplain for additional channel migration, side-channel formation, wood recruitment, and sediment deposition and storage.
W-2A	Place debris catchers and realign stream at culvert, Reach 2	Install wood or other devices to capture small woody debris in upper portion of Reach 2. Realign lower end of creek to divert flow more directly into culvert and reduce sediment and debris buildup. Remove existing sediment wedge as necessary. This project will provide minor fish benefits because it will create more habitat diversity within the channel and also provide slightly improved fish passage at the culvert. The primary goal is to reduce maintenance at the culvert.
W-2B	Remove dike and restore floodplain, Reach 2	Remove right bank dike and roadway and reconnect floodplain area. Protect infrastructure as necessary, remove non-native species and densely vegetate with

Table 4. Project List		
Project ID	**Project Type/Title**	**Description**
		native riparian species. Primary goal is to connect creek to its floodplain for additional channel migration, side-channel formation, wood recruitment, and sediment deposition.
W-2C	Remove culvert and roadway at RR crossing, Reach 2	Remove culvert and road through undercrossing at RR. Primary goal is to allow creek maximum width and depth at RR crossing to reduce sediment buildup and eliminate any fish passage concerns. This project would also reduce the amount on instream excavation and protect existing habitat.
W-1A	Restore/create protected side channel, Reach 1	Restore historic side-channel to west of main channel downstream of RR crossing. Create a protected entrance to allow low flows and a maximum flow into side-channel to prevent creek from avulsing into side-channel, and to minimize sediment deposition. Restore riparian zone and enhance side-channel with wood, etc. Primary goal is to provide rearing habitat for juveniles of all species and potential chinook spawning habitat.
W-1B	Realign creek mouth and enhance/roughen floodplain, Reach 1	Move creek mouth to a point further east on the delta to minimize the drop from the creek into the Columbia when Columbia flows are low. Roughen the floodplain by placing wood or boulders and planting vegetation as appropriate for river levels. Two main goals are to provide fish passage during low flows and to promote sediment deposition in the floodplain, while confining the scouring flows to the main channel.

5. Restoration Project Prioritized List

The projects identified above, in Table 4, were then evaluated and ranked according to their potential benefits to fish. The ranking process used by the SRFB and the LCFRB was used. This ranking process is based on two key components: 1) the importance of the fish populations, key life history stages, and associated limiting factors targeted by the project; and 2) the extent to which a project will address the targeted limiting factors.

A total fish benefit score is derived from adding a population/reach score to the restoration score. The population/reach score results from the EDT reach tier rankings, the number of anadromous fish species/populations present in a reach and the classification of each of the fish populations (primary, contributing, or stabilizing) to the overall recovery plan. The restoration score results from the number of limiting factors that a project will address, the priority of the limiting factors in the recovery plan, the size of the project or the area that will benefit from a project, and the effectiveness of the project in addressing the limiting factor on the reach scale. The projects are then ranked based on their total benefit score.

The ranked list is shown in Table 5, below. The details of the scoring and rationale are provided in Appendix B.

Table 5. Woodward Creek Restoration Projects Ranked Based on Benefits to Fish							
Project ID	Project Name	Pop/ Reach Score	PAR Score	Total Score	Benefit Ranking	Certainty of Success	Overall Priority Grouping
W-1A	Restore/create protected side channel, Reach 1	10.00	12.00	22.00	H	H	1
W-3C	Protect/enhance side channel, Reach 3	10.00	12.00	22.00	H	H	1
W-2B	Remove dike/floodplain reconnection, Reach 2	10.00	28.00	38.00	H	M	2
W-3A	Construct LWD jams, Reach 3	10.00	14.00	24.00	H	M	2
W-3B	Riparian restoration, Reach 3	10.00	4.00	14.00	M	H	3
W-2C	Remove culvert and road at RR, Reach 2	10.00	8.00	18.00	M	M	4
W-1B	Realign creek mouth, enhance floodplain, Reach 1	10.00	7.00	17.00	M	M	4
W-4A	Place LWD, Reach 4	9.00	7.00	16.00	M	M	4
W-5A	Place LWD, Reach 5	9.00	7.00	16.00	M	M	4
W-6A	Place LWD, Reach 6	9.00	7.00	16.00	M	M	4
W-7A	Place LWD, Reach 7	9.00	7.00	16.00	M	M	4
W-3D	Remove dike/floodplain reconnection, Reach 3	10.00	4.00	14.00	M	M	4
W-UW	Place LWD in Upper Watershed	9.00	7.00	16.00	M	L	5
W-2A	Debris catchers, stream realign, Reach 2	10.00	0.30	10.30	L	M	5

6. Concept Designs

From the top 5 projects identified in Table 5, above, one project is not really feasible in the near-term. Project W-2B cannot be implemented in the near-term due to the need of the Park to develop a plan to relocate the residents and develop the site according to the recreational funding that was used for the site acquisition. This may include the removal of Beacon Moorage Road and thus the potential to setback or remove the dike along Woodward Creek, but a lot of planning will need to take place in the near-term. The projects in Reach 3 will significantly benefit Reaches 1 and 2 by trapping sediment.

Projects W-1A, W-3A, and W-3C are feasible in the near-term because of a willing landowner (State Parks), and projects W-3A and W-3C will address some of the upstream sediment issues that could dramatically enhance conditions in Reaches 1 and 2 and lead to further work downstream. These projects were developed as conceptual designs and are described and shown below. Project W-3B could be included in the implementation of projects W-3A and W-3C, but was not detailed out at this time.

6.1 Project W-1A, Side-Channel Reach 1

The proposed side-channel will create 1000 feet of floodplain side channel habitat and add habitat features to the mainstem of Woodward Creek to create pools and improve fish passage. The new side channel will create 8000 feet^2 of new habitat. The channel is approximately 1000 feet long by 8 feet wide. The channel consists of 80 feet of a 6% sloped roughened boulder/cobble channel at the upstream end, 200 feet of step pool habitat formed by log drop structures and 720 feet of a 1% sloped pool/riffle channel with LWD. This will function as a natural/active side channel which incorporates natural features found in active side channels such as LWD and log jams at the entrance to regulate flood flows into the channel, a steep drop into the side channel controlled by river cobble and boulders, seepage from a trenched drain constructed into the floodplain, and LWD in the channel which will help sort spawning gravel and create pools. These concepts and features are described in the Stream Habitat Restoration Guidelines (Saldi-Caromile, K., *et al*. 2004) under the side channel technique.

The right bank of Woodward Creek in the side channel area is above the 100-year flood elevation (at 1100 cfs). To protect the side channel from excessive sediment deposition and create habitat in the mainstem of Woodward Creek, 4 to 6 log vane structures will be added to the creek. These structures will force a channel thalweg to develop which will direct scour away from the banks and create step/pool habitat along the right bank. The gradient in this reach is 2 to 3%. Two rock weirs will be added to the channel to control the channel profile. The upper rock weir will be placed at an elevation 0.5 feet above the side channel elevation so at low flows access and egress into Woodward Creek will be through the side channel. The lower rock weir structure will provide grade control to backwater the constructed seepage trench which is a backup supply of flow to the channel if the channel becomes plugged with wood or sediment.

Other features include: 1) a flood protection berm on the right bank of the new channel to prevent flood waters from entering the upper end of the channel. Currently flood waters overtop Moorage Road, flow into the parking lot and enter back into the floodplain at the upstream end, 2) a constructed log jam at the entrance to the left bank overflow channel (towards the boat ramp) to keep Woodward Creek in its current main channel, 3) boulder clusters in the lower reaches of both Woodard Creek and the new side channel to serve as anchor points for the channel and maintain a thalweg for fish passage when the Columbia River is low in the fall. There are already several vegetated berms in the floodplain on the right bank which would direct overbank flows away from the side channel.

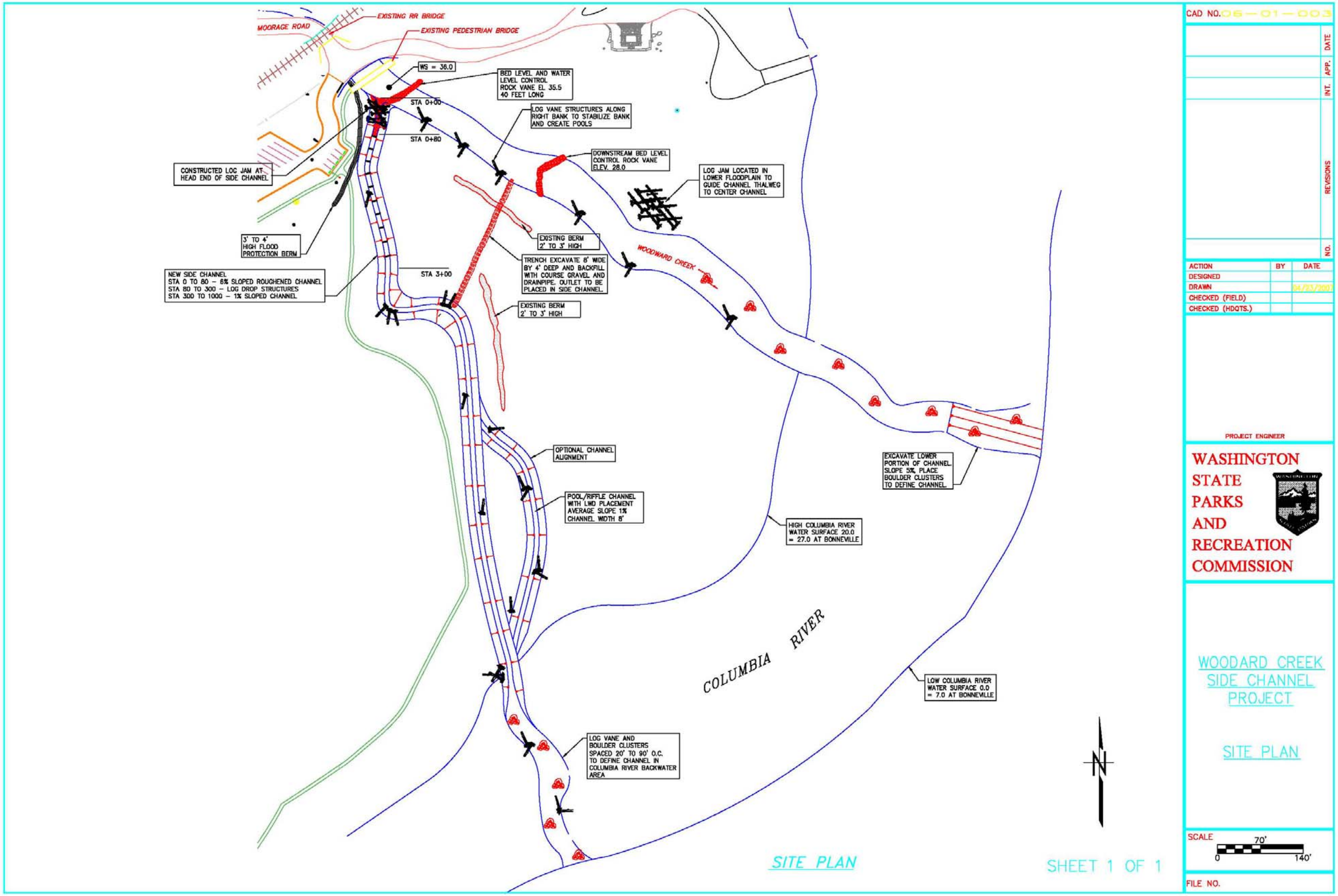


Figure 22. Project W-1A Concept Layout.

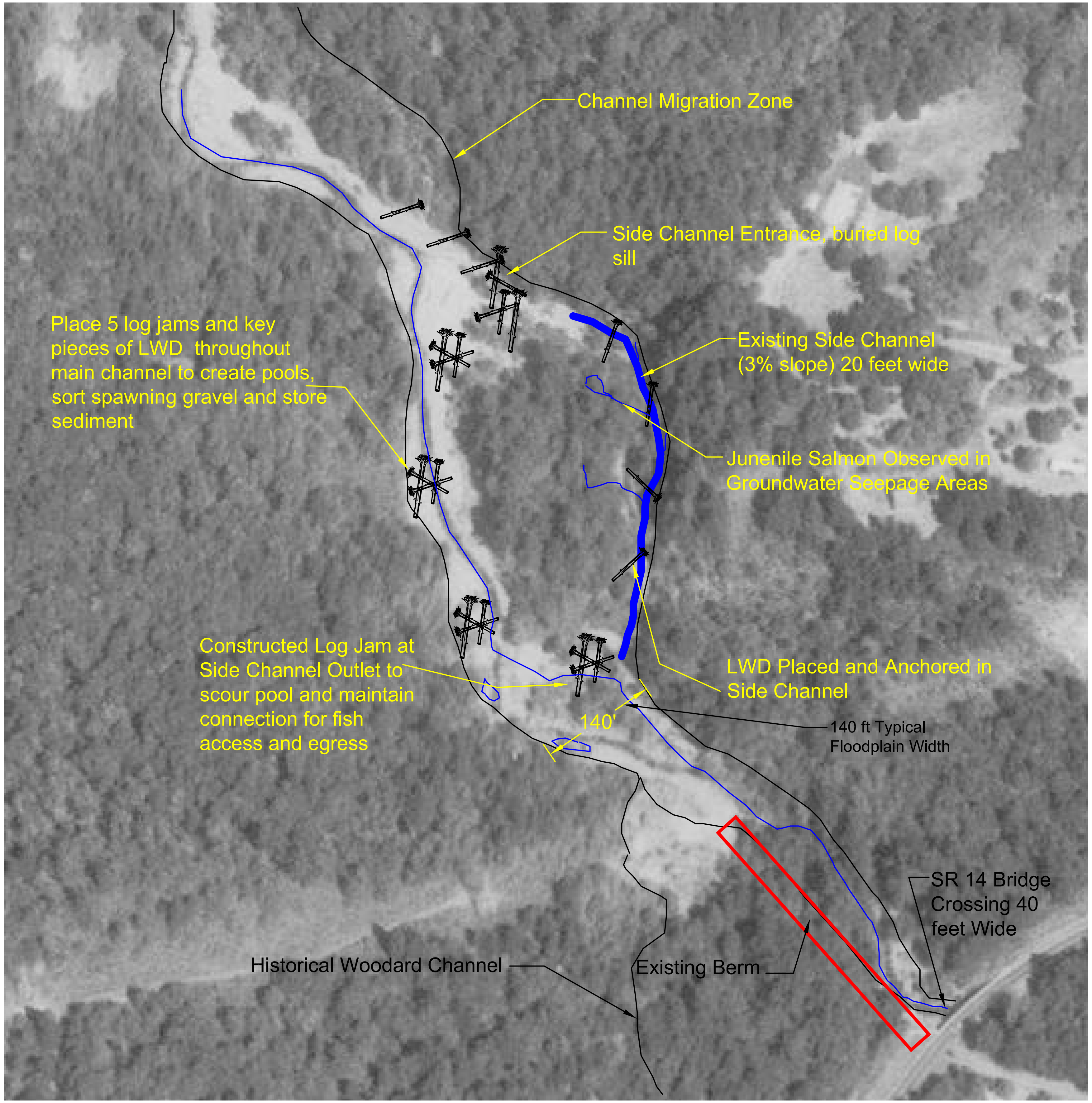
6.2 LWD Placement, Reach 3

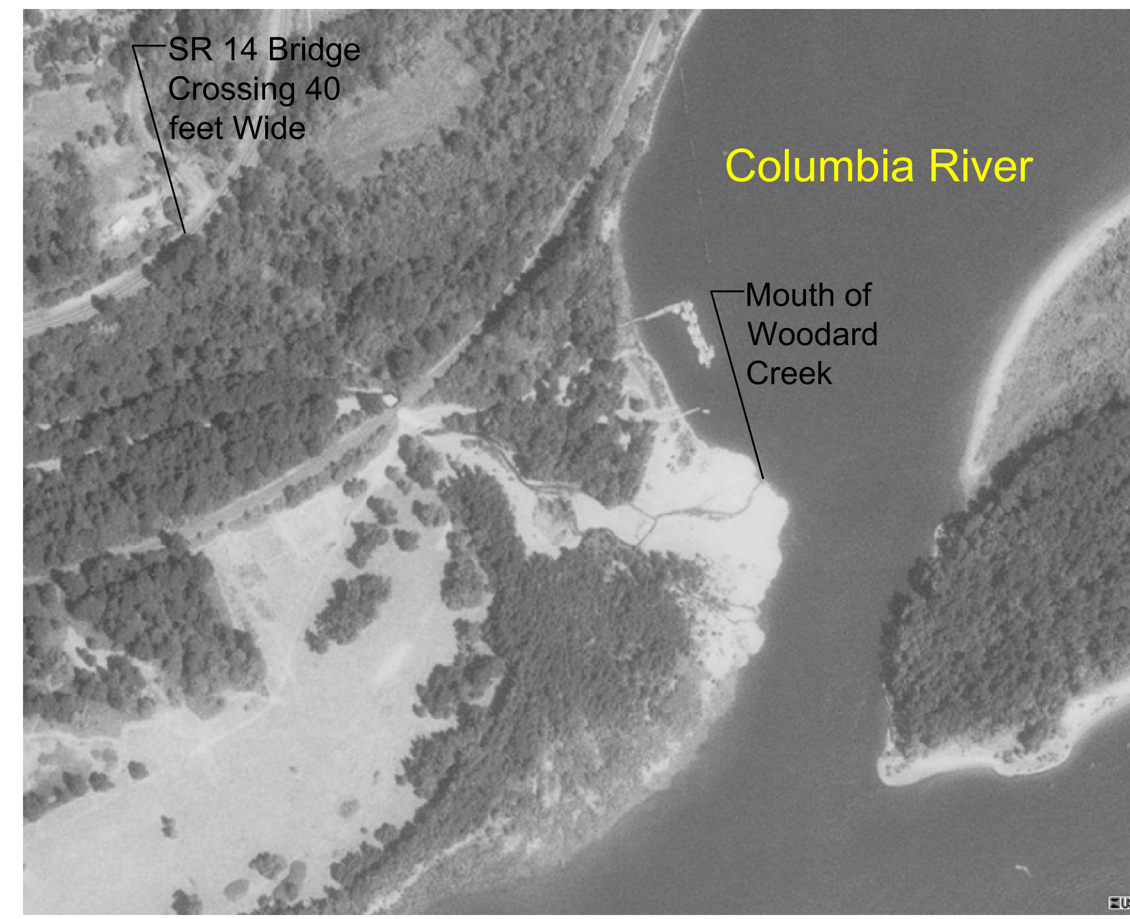
These proposed projects, W-3A and W-3C, will place constructed log jams in the main channel to trap and stabilize sediment, and protect the existing high quality spring fed side-channel habitat in Reach 3. Three log jams are proposed in the main channel to trap and store sediment, and promote scour pools and cover. Additional log jams could be placed to extend the project for another 1000 feet or so upstream or downstream. This will likely also help prevent the flow from going subsurface by accumulating fine sediments as well as spawning sized gravels and cobbles.

Two engineered log jams are proposed at the inlet and outlet of the side-channel to both deflect flows (and high sediment loads) away from the channel and to promote the scour of the opening and outlet of the side-channel. The channel would be excavated to intercept groundwater and additional wood would be placed and anchored in the side-channel to provide cover. An existing groundwater channel is present at the upper end of Reach 3 that would be used as a template to enhance this side channel.

The risk with the placement of wood in any of the reaches is that the sediment load may still be so high that the structures would eventually get buried (similar to the USFS log weirs upstream). However, in the near to mid-term, these structures will likely trap moderate to significant quantities of sediment and help to stabilize the downstream reaches. The benefits to Reaches 1 and 2 should be very high from trapping sediment in Reach 3. Additionally, large numbers of coho juveniles have been observed in pools in this reach and the provision of additional spawning beds and pools as a result of placement of wood should significantly expand the potential production of fish from this reach.

Woodard Creek Above SR 14





Lower Portion of Woodard Creek

LOWER COLUMBIA FISH ENHANCEMENT GROUP

Woodard Creek Reach 3
Conceptual Design - Log Jam Placement

DESIGNED BY:
DRAWN BY:
CHECKED BY:
APPROVED BY:
FILE:
DATE:

2000 Aerial Photo of Site

SHEET NO. 1

OF 1

7. Conclusions and Recommendations

The assessment of potential habitat restoration projects conducted in this study identified the majority of floodplain, off-channel and side-channel, channel migration, and stream channel habitat restoration that can possibly be done in the fish accessible portion of Woodward Creek. A few riparian restoration measures were identified; however, additional riparian restoration actions could be identified on the Forest Service lands upstream. This assessment generally evaluated water quality, instream flows, watershed conditions and hillslope processes. Water quality is not generally a problem in Woodward Creek. The measures identified in Reaches 1 and 3 will begin to address the instream flow problem (subsurface flows). Watershed conditions and hillslope processes are somewhat degraded and there is the potential to reduce sediment inputs from forest roads and culverts in the upper watershed and accelerate the transition to a mature forested condition through plantings of conifers. However, the watershed is naturally prone to landslides and it is likely that sediment inputs will continue to be periodically high.

The projects identified in this assessment will address critical limiting factors for salmonids in Woodward Creek, including habitat diversity, key habitats, and channel stability. The restoration of floodplain and side-channel habitats, placement of wood and log jams, and riparian restoration will significantly improve habitat diversity in the mainstem and restore many of the key habitats that historically existed and provided channel stability as well as spawning, rearing, and refuge habitats. This will improve egg incubation, fry colonization, 0-age summer and winter rearing, 1-age summer rearing, pre-spawning holding, migration, and spawning habitats. However, the regulation of Columbia River elevations will continue to affect Reach 1 and prevent the natural formation of channels on the alluvial fan.

Implementation of the projects identified in this assessment will likely take many years and should be accomplished in a phased approach, to restore the highest priority sites first and then move down the list from high to moderate to low fish benefit. Fortunately, the majority of the watershed is in public ownership and the two major entities, State Parks and the Forest Service are very interested in restoration; although some areas are subject to restrictions for various planned uses. The culvert under the railroad crossing does not appear to be a fish passage barrier, except perhaps when debris blocks the culvert. However, the size of the culvert significantly constrains the stream channel and causes the sediment deposition problems. An evaluation of the potential removal of this culvert should be undertaken as part of the park master planning process.

The implementation of the projects identified in this assessment will address the majority of the limiting factors in the watershed and restore small but viable salmonid populations to Woodward Creek.

8. References

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APPENDIX A
SEPTEMBER 2006 SITE RECONNAISSANCE MEMO

Watershed Reconnaissance Summary
Woodward Creek, Skamania County, Washington
9/25/06
Tetra Tech, Inc.

GENERAL

This section provides the background to the Woodward Creek site visit and general observations for the portion of Woodward Creek observed by the study team. The site visit was performed on 9/25/06 and involved walking approximately the lower 2.5-3 miles of Woodward Creek. The reconnaissance was conducted by Pete Barber and Nello Picinich, Lower Columbia Fish Enhancement Group; Pat Powers, Anchor Environmental; and Bill Fullerton and Merri Martz, Tetra Tech. The reconnaissance started at the bridge on Woodward Creek Road. The project team walked approximately ½ mile upstream of the bridge and then returned and walked downstream to the Columbia River. The purpose of the reconnaissance was twofold; first to observe the general conditions in Woodward Creek above the potential project area to develop an understanding of the processes and conditions providing sediment supply to the project area and secondly to observe fish habitat restoration needs and opportunities that would function within the larger watershed context.

1. Woodward Creek is a small watershed (approximately 5000 acres; 7.8 square miles) that arises in the upper slopes of the Columbia River Gorge and flows for approximately 5.5 miles to the Columbia River. The major tributary is the East Fork Woodward Creek that is approximately 5 miles in length. The watershed is primarily in public ownership, either the Gifford Pinchot National Forest or Beacon Rock State Park.
2. The Columbia River Gorge is dominated by volcanic flows and is highly incised from prehistoric glacial flood events. Woodward Creek and other tributaries to the Columbia River fall steeply through weathered volcanic outcrops and transport high sediment loads to the Columbia River.
3. On a reach basis (several hundred feet or more) the average channel gradient varies considerably throughout the observed portion of Woodward Creek. The "flatter" reaches typically range between 3 to 6 percent, except in the area of the Highway 14 crossing where the slope reduces to about 2 percent and then further to about 1 percent toward the Columbia River confluence. In some areas the gradient exceeds 15 percent. The range of slopes is distributed throughout the creek and appears to be largely determined by local geologic conditions that control the level of confinement by hillsides, the delivery of coarse boulders from adjacent hillsides, and underlying bed rock control. Within a reach, there may be considerable variation in local slope. This is particularly true of the steeper reaches where the large boulders create a series of drops and pools. In the flatter reaches, the gradient is much more uniform with a lack of complexity in the bed profile in many areas.
4. Actual exposure of bedrock in the bed was only observed at one location; a falls of about 8 vertical feet upstream of the East Fork confluence. Exposure of bedrock on the slopes of the valley at or near the channel level is more frequent in several areas. The largest in linear extent are in the intermittent areas below the falls to near a pipeline crossing about 3,000 feet upstream of Highway 14.

5. Due to Woodward Creek's steep gradient and surrounding geology, the creek bed is dominated by coarse material ranging from large cobbles (5 to 10 inches) to large boulders up to six feet in diameter. The presence of small cobble (2.5 to 5 inch material) and coarse gravels (0.5 to 2.5 inches) is primarily limited to isolated pockets where local hydraulic conditions allow the material to be retained. These locations are typically in the shadow of boulders, small pools, behind LWD and in areas where the flow changes direction and small bars form. There appeared to be a significant amount of gravel in the floodplain deposits starting near the pipeline crossing previously mentioned and down to the Highway 14 crossing.
6. The creek bed has recently (past several decades) experienced areas of aggradation and incision. As with the channel gradient and bed material, these areas are localized and there is no distinct spatial pattern or trend to the changes in bed response. This is likely at least partially a function of the sporadic nature of transport of the bed material resulting from the formation of boulder dams that retain bed load when multiple boulders form a blockage and the release of bed material when these boulders shift. In addition the coarse bed load moves in waves or slugs and only moves short distance during most events. Thus it takes a years for an input of coarse sediment to move through the system.

SPECIFIC OBSERVATIONS AND NOTES

This section presents observations at specific locations in the observed portion of Woodward Creek. The observations are presented in upstream to downstream order starting about 0.5 miles above the bridge crossing and progressing downstream to the Columbia River confluence.

1. At the upstream limit of the reconnaissance, a steep reach of 15 percent or more that contains large boulders and a series of drops and pools starts (Photo 1).
2. Below the upstream limit to the Woodward Creek Road bridge, the channel is contained within a ravine with bank slopes approximately 40-50 feet high. Narrow floodplain areas are present in some locations, and in other locations the bedrock or large boulders confine the creek to a narrow channel. The gradient is typically on the order of 5 percent. Some pools exists in areas where large boulders are present. There is a small area of bed rock outcrop along the right bank about 100 feet below the upstream limit of the reconnaissance (Photo 2).
3. The riparian vegetation is dominated by red alder (*Alnus rubra*) approximately 20-30 years in age. There are remnant large cedar (*Thuja plicata*) up to 48 inches in diameter, as well as younger cedar of 12 to 18 inches in diameter. Photo 3 shows a typical portion of this reach of Woodward Creek. The understory includes vine maple (*Acer circinatum*), Himalayan blackberry (*Rubus procerus*), salmonberry (*Rubus spectabilis*), stink currant (*Ribes bracteosum*), devil's club (*Oplopanax horridus*), red osier dogwood (*Cornus stolonifera*), Cooley hedgenettle (*Stachys cooleyae*), and water parsley (*Oenanthe sarmentosa*). The canopy cover is 100% in most locations.
4. A measurement of wetted width and bankfull width approximately 150 feet upstream of the bridge was 18 feet and 30 feet, respectively. Photo 4 shows the creek in the area of the width measurements.
5. The USFS installed log weirs and deflectors both upstream and downstream of the bridge in 1997, estimated to have been about 25 such structures (Photo 5 and 6). Only about 8 are

obviously remaining in place. Some may have been buried, whereas other have likely been dislodged and moved downstream. The coarse sediment load is very high with some locations showing evidence of burial of trees and log structures. Other locations show evidence of channel incision (weir was suspended about 1 to 2 feet above water level) and several trees have fallen due to undermining. The first grouping of log structures occurs within the flattest portion of Woodward Creek above the Woodward Creek Road bridge. This approximately 1,000 foot section of Woodward Creek has an average gradient of about 3 percent. The gradient continues at about 5 percent for another 1,000 feet. This 3 to 5 percent gradient area is considered the second reach.

6. About 2,000 feet below the bridge, the channel becomes steeper and more confined. Additionally, large boulders become more frequent and dominate the bed (Photos 7 and 8). The gradient in this third reach ranges from 7 to 11 percent.
7. Within the third reach two additional log structures were observed. There were tags identifying these structures as # 22 and #23. Structure 23 is shown in Photo 9.
8. Within the third reach, the local gradient varies. In the flatter portions, the bed material is generally cobbles and small boulders. In the steeper portions, large boulders become more frequent. The flatter portions typically have a wider channel. Photo 10 shows one of the flatter portions of the third reach. In some of theses flatter areas of the third reach, as well as in portions of the second reach there are locations where there is an approximately 100 foot wide floodplain.
9. There are some larger cedars, including one approximately 6 feet in diameter in the second and third reaches. There is natural LWD present in single logs and clumps, and a couple of LWD jams that span the channel (Photo 11). However, in the 2.5 miles there are approximately 100 pieces, which would average out to 40 pieces per mile. This is much less than what is considered properly functioning for coastal streams (80 pieces/mile), but may be within the realm of natural variation for the Columbia Gorge.
10. Near the middle powerline crossing, the valley walls become steeper and the stream becomes more confined. This is considered the fourth reach. The creek flows through a narrow canyon for approximately ½ mile that is dominated in many areas by large boulder (greater than 4 feet in diameter) and cascades and step pools (Photo 14). There are intermittent areas of exposed bedrock on either side of the creek. The channel steepens up to 20 percent in some locations, though there are also areas of this reach with a gradient of 6 to 10 percent .
11. At the middle powerline crossing, the left bank bluff is eroding (approximately 30 foot high bluff) and appears to be comprised primarily of stony clay loam or clay loam.
12. Wetted width generally varies from 10 to 20 feet, where boulders constrain the flow, the bankfull width would be equal to the wetted width.
13. At the confluence of the East Fork tributary, the right bank is bedrock of highly fractured basalt entablature (Photo 15), likely corresponding to the Steever-Rock outcrop soil association that also becomes much more prevalent further downstream of the East Fork confluence (Photo 16). Just upstream of the East Fork confluence, the basalt outcrops in the bed and creates a falls with about 6 feet of drop (Photo 17)
14. The channel and floodplain widen out approximately 3,500 feet below the powerline crossing and there is evidence of braiding and cobble bar deposition in many locations. The gradient in this reach lessens ranging from 3 to 5 percent. The large boulders in excess of three feet become infrequent and there are more frequent areas of coarse gravel and small cobble, though the bed is still largely dominated by large cobbles and small boulders (Photo 18). This

is considered the fifth reach. The creek flow goes subsurface in many locations and then discharges back into the channel (Photo 19). This reach continues downstream for abut 4,000 feet to the Highway 14 bridge. Tree cover is much less in this reach, likely because of the more frequent disturbance from sediment erosion/deposition.

15. The Highway 14 bridge does not appear to constrain the channel, it is 40 feet wide, similar to many locations upstream in the bedrock outcrop areas (fourth reach). The bridge was placed at a natural constriction in the stream corridor formed by a high terrace on the right bank and valley wall near the left bank (Photo 20).
16. Downstream of Highway 14, the creek has been moved from its original location to the east, and a rock berm is present along the right bank adjacent to Beacon Rock Moorage Road. This is the sixth reach and it has an average gradient of 2 percent over its approximately 2,000 foot length.
17. The bed profile through the sixth reach is very uniform and the channel is extremely straight (Photo 21). The bed is dominated by large cobbles and small boulders, though small cobbles and gravel are present on the surface between the coarser bed material.
18. The straightening of the creek would increase the channel slope; however, this may have been offset by relocating the channel to the east and sending it on a less direct path to the Columbia River. Downstream of the Highway 14 bridge, the channel is flowing across an alluvial fan created by Woodward Creek and superimposed on the historic floodplain of the Columbia River.
19. This reach of the creek may transport sediment more efficiently than the historic channel crossing the alluvial fan because of the artificial confinement. However, when the channel takes a 90 degree bend and enters the Beacon Rock Moorage Road culvert, some of the bed load is deposited (Photo 22 and Photo 23).
20. The seventh and final reach starts below the Beacon Rock Moorage Road culvert and continues downstream for approximately 2,000 feet. The gradient in this reach averages about 1 percent based on the USGS maps. The bed material in the reach starts as coarse cobble and boulders (Photo 24), but decreases to have some areas with significant gravels and small cobbles (Reach 25) as the gradient decreases. This is a natural deposition zone and there is evidence of extensive braiding and channel changes. Large deposits of cobble and gravels are present (Photo 26). The channel changes based on the presence of LWD, channel aggradation/bars or other features that may block one channel and cause it to divert to another channel. There are several small beaver dams that have recently been constructed in the lower creek and are forming nice pools (Photo 27). The creek flow goes partially or completely subsurface in some locations where the bed material is very coarse. At the date of the visit the Columbia River was quite low and there was a definite drop from Woodward Creek into the Columbia with partial subsurface flows that was not passable by salmonids (Photo 28).

INITIAL CONCLUSIONS AND RECOMMENDATIONS

This section presents initial conclusions and recommendations based on the site visit. These will likely be expanded and may change as the project team reviews more information and conduct additional analysis.

1. The coarse sediment load, cobbles and boulders, appears to be significant throughout Woodward Creek. There are multiple sources of sediment from eroding banks, steep hillsides, and weathered rock outcrops. The larger sized material, particularly the boulders likely only move in significant flow events.
2. It is expected that the Creek transports significant moderate quantities of smaller cobbles and gravel, but these are supplied at a lower rate than the energy of the flow can potentially transport, so very little of this material, which represents spawning sized material, is retained in the bed. In other words, gravel and small cobble is transported through the system as fast as it is supplied. It is only stored in the channel in localized areas where hydraulic conditions are less severe. These areas include around LWD, shadows nears larger boulders, tail out of scour pools, and in zones of flow separation.
3. The amount of LWD could be increased in the upper portion of the creek visited to provide some localized capture of sediment and sorting that could provide spawning habitat. However, it is unlikely that the placement of LWD would provide a significant reduction in the overall volume of sediment moving downstream. Additionally, there are many locations where numerous large boulders provide opportunity for retaining gravels, but only limited amounts of gravels have been retained in these areas.
4. The bed of the braided section below the pipeline crossing is comprised of fairly uniform material. Because of the uniformity and mobility of this material, it has a fairly high porosity. As a result, low flows infiltrate rapidly and the entire flow becomes subsurface in several locations. Placement of wood in this reach might help trap finer sediments and fill in the voids to reduce the subsurface flow.
5. The sediment deposition at the culvert under Beacon Rock Moorage Road and the Railroad is caused by the channel flattening out at this location and could be exacerbated by the alignment of the culvert which causes the flow to take an abrupt 90 degree turn. During large flood flows, there may also be a backwater at the culvert entrance that causes material to deposit immediately upstream of the culvert. The reach between the culvert and Highway 14 has been confined and may have been steepened (without knowing the original location of the creek it is not certain whether the slope has been increased by straightening since it is possible that moving the creek to the edge of the fan caused it to take a less direct route to the Columbia). The confinement of the flow and the possible steepening of the gradient from the realignment has likely resulted in Woodward Creek more efficiently conveying coarse bed load across the upper portion of the alluvial fan and to the culvert.
6. Significant deposition of coarse material on the delta at the confluence with the Columbia causes flows to go subsurface and there is a drop from the delta into the Columbia River. Both conditions seasonally create a fish passage barrier. If sediment is transported more effectively through the culvert by the use of groins or other structures, it will increase deposition on the delta. Therefore, this could possibly increase the fish passage problems at the delta and should be considered and investigated if such an alternative is considered.
7. An option for the culvert problems could be to realign the creek back to its original channel. Need to determine where culvert under RR is and if it would go through private property. Depending on the size and condition of the old culvert, this could reduce sedimentation problems at the RR crossing. This would require probably a significant amount of excavation to send the creek back into old channels that have partially filled

in, but would allow reconnections and possible groundwater flow into multiple channels, including potential chum channels.

8. Another option for the culvert would be to keep the current culvert location, but create a more sinuous channel along the general path of the current alignment. In addition, the channel should be configured to have a floodplain. This option would also require significant earthwork. Under this alternative, sediment would be deposited in the reach between Highway 14 and the culvert. The need to eventually perform maintenance on this channel and the long term sustainability would need to be investigated.
9. In evaluating alternatives, consideration should be given to potentially abandoning the road and culvert at the RR crossing. If the new access road is currently being installed, does that 100-150 feet of roadway need to remain in place or is that the only potential crossing point of the RR?
10. In evaluating plans it must be kept in mind that the area below the Highway 14 Bridge to the Columbia River is an alluvial fan. It is a natural depositional environment because the gradient of Woodward Creek decreases dramatically and the confining influence of the surrounding hillsides disappears. Therefore, it would be difficult to create a system that would pass the entire coarse bed load to the Columbia River. If such a system could be created, it would lost likely be extremely unnatural (example – concrete channel).

Photo 1 – Looking upstream into downstream end of steep (> 15%) boulder drop/cascade and pool reach at upstream limit of the reconnaissance

Photo 2 – Bedrock outcrop along right bank about 100 feet downstream of recon limits

Photo 3 – Typical portion of Woodward Creek upstream of bridge, this area has experienced deposition with large cedar growing at current bed level (photo is upstream view)

Photo 4 – Large fallen cedar spanning creek near area where channel was measured with wetted topwidth of 18' and bankfull topwidth of 30 feet (Note: such LWD is scarce in Woodward Creek)

Photo 5 – Deflector log structure right bank and cabled rootwad on left bank immediately below Woodward Creek Road bridge

Photo 6 – Looking upstream at a series of alternating (left bank then right bank) log deflectors about 1,000 feet downstream of bridge, bed may have degraded and left structures perched.

Photo 7 – Looking downstream into start of steeper more confined reach of Woodward Creek with gradient of 7 to 11 percent (about 2,000 feet downstream of bridge)

Photo 8 – Area dominated by larger boulders in the 7 to 11 percent gradient reach, channel is confined to about 20 to 25 feet by hillsides

Photo 9 - Looking upstream at structure #23 (ID based on metal tag on adjacent tree), this was the downstream most structure identified, some small gravel present between boulders

Photo 10 – Wider (approximately 40 foot wide channel) and flatter area within 7 to 11 percent gradient reach, bed is smaller boulders and cobbles with some gravels, channel steepens up several hundred feet upstream and downstream

Photo 11 – Channel spanning log jam in the third reach

Photo 12 – Six foot diameter cedar growing at bed level in the third reach, some gravels deposited upstream and in bar downstream

Photo 13 – Three foot boulder drop in 11 percent portion of third reach

Photo 14 – Steep boulder dominated portion of the fourth reach

Photo 15 – Bedrock on right bank near east fork confluence

Photo 16 – Bedrock on left bank near downstream end of fourth reach

Photo 17 – Bedrock falls just above East Fork confluence, fourth reach

Photo 18 – Wider, lower gradient channel with floodplain, typical of the fifth reach

Photo 19 – Looking upstream into split flow reach as water reappears from loose gravel and cobble bed. Flow goes subsurface for several 100 feet upstream of this location in both sides of the split flow. Note eroding left bank, floodplain in this reach has significant gravel deposits.

Photo 20 -- Looking upstream at Highway 14 Bridge

Photo 21 – Typical straight channel with uniform profile between Highway 14 and Beacon Rock Moorage Road culvert. Bed material is mostly large cobble and small boulder with some gravel and small cobble.

Photo 22 – Upstream side of Beacon Rock Moorage Road culvert crossing. Some bed load is depositing at the upstream end and possibly within the culvert.

Photo 23 – View into Beacon Rock Moorage Road culvert from the downstream side

Photo 24 – Looking downstream from Beacon Rock Moorage Road culvert into the seventh reach, bed is primarily coarse cobble with some small boulders

Photo 25 – The bed is primarily large gravel and small cobble in this area several hundred feet above the Columbia River confluence. A beaver dam creates the pool in the foreground of the photo. Banks are comprised largely of gravels and cobbles with sand.

Photo 26 – Large area of gravel and cobble deposition near the Columbia River confluence. This area is currently abandoned by the channel at low flow, but experienced flow last winter.

Photo 27 – Small beaver dams and ponds several hundred feet upstream of the Columbia River Confluence

Photo 28 – Depositional area at the confluence with the Columbia River. Channel becomes steeper as it is influenced by removal of material by the Columbia River as well as interaction of varying deposition zones dependent on the stage of the Columbia River. Flow also disappears in the loosely deposited gravels and cobbles. This condition creates problems for fish passage.

APPENDIX B
FISH BENEFIT SCORING ASSUMPTIONS

Project ID	Project Description	Reach/Population									Restoration						Total Benefit
		Affected Reaches	Tier		Species	Pop Class		SRP		Reach/Pop Score	Restoration Type	Restoration Ranking		Habitat Units	Effectiveness Factor	Restoration Score	
W-UW	Place LWD	Upper Watershed	2	5	WS	P	3	M	2	5	Stream channel habitat structure	H	3	2	0.5	3	
					CO	P	3	L	1	4	Floodplain function / channel migration processes	M	2	2	1	4	
										9						7	16.00
W-7A	Place LWD	Reach 7	2	5	WS	P	3	M	2	5	Stream channel habitat structure	H	3	2	0.5	3	
					CO	P	3	L	1	4	Floodplain function and channel migration processes	M	2	2	1	4	
										9						7	16.00
W-6A	Place LWD	Reach 6	2	5	WS	P	3	M	2	5	Stream channel habitat structure	H	3	2	0.5	3	
					CO	P	3	L	1	4	Floodplain function and channel migration processes	M	2	2	1	4	
										9						7	16.00
W-5A	Place LWD	Reach 5	2	5	WS	P	3	M	2	5	Stream channel habitat structure	H	3	2	0.5	3	
					CO	P	3	L	1	4	Floodplain function and channel migration processes	M	2	2	1	4	
										9						7	16.00
W-4A	Place LWD	Reach 4	2	5	WS	P	3	M	2	5	Stream channel habitat structure	H	3	2	0.5	3	
					CO	P	3	L	1	4	Floodplain function and channel migration processes	M	2	2	1	4	
										9						7	16.00
W-3A	LWD jams	Reach 3	1	8	WS	P	3	L	1	4	Stream channel habitat structure	H	3	4	0.5	6	
					CO	P	3	H	3	6	Floodplain function and channel migration processes	M	2	4	1	8	
										10						14	24.00
W-3B	Riparian restoration	Reach 3	1	8	WS	P	3	L	1	4	Riparian conditions and function	M	2	2	1	4	
					CO	P	3	H	3	6							
										10						4	14.00
W-3C	Protect side-channel	Reach 3	1	8	WS	P	3	L	1	4	Off-channel and side channel habitat	H	3	4	1	12	
					CO	P	3	H	3	6							
										10						12	22.00
W-3D	Floodplain reconnection	Reach 3	1	8	WS	P	3	L	1	4	Floodplain function and channel migration processes	M	2	2	1	4	
					CO	P	3	H	3	6							
										10						4	14.00
W-2A	Place debris catchers and realign stream at culvert	Reach 2	1	8	WS	P	3	L	1	4	Stream channel habitat structure	H	3	1	0.1	0.3	
					CO	P	3	H	3	6							
										10						0.3	10.30
W-2B	Remove dike and reconnect floodplain	Reach 2	1	8	WS	P	3	L	1	4	Floodplain function and channel migration processes	H	3	4	1	12	
					CO	P	3	H	3	6	Stream channel habitat structure	H	3	4	1	12	
											Riparian conditions and function	M	2	2	1	4	
										10						28	38.00
W-2C	Remove culvert and road crossing	Reach 2	1	8	WS	P	3	L	1	4	Stream channel habitat structure	H	3	2	1	6	
					CO	P	3	H	3	6	Floodplain function and channel migration processes	H	1	2	1	2	
										10						8	18.00
W-1A	Restore/create protected side-channel	Reach 1	1	8	WS	P	3	L	1	4	Stream channel habitat structure	H	3	2	1	6	
					CO	P	3	H	3	6	Off-channel and side channel habitat	H	3	2	1	6	
										10						12	22.00
W-1B	Realign creek mouth and roughen floodplain with wood and riparian plantings	Reach 1	1	8	WS	P	3	L	1	4	Riparian conditions and function	M	2	2	1	4	
					CO	P	3	H	3	6	Stream channel habitat structure	H	3	2	0.5	3	
										10						7	17.00

W-UW

- Reach: Upper Watershed, upstream of salmonid access. Considered comparable to Duncan Reach 2 (Tier 2).
- Populations: Winter steelhead (P), coho (P)
- Project would place unanchored LWD in two or more locations in the upper watershed, where accessible, such as downstream of USFS road crossings. Estimated that 1000 feet of stream would be enhanced to approximately natural or properly functioning levels of LWD.
- Review of proposed benefits:
    - LWD would improve stream channel habitat structure by providing cover, reducing sediment transport rate, promoting pool scour, and by providing hydraulic diversity.
    - LWD would help keep creek connected to its floodplain by preventing or reducing channel incision.
- Current habitat conditions are moderately degraded due to past timber harvesting (loss of wood recruitment) and roads (sediment input). Riparian and upland forest is regrowing (approximately 30 years) with alder and Douglas fir forest.
- Effectiveness was based on assumptions:
    - LWD will provide approximately 50% effective improvement in stream channel habitat structure and bank stability conditions by providing natural or properly functioning conditions (PFC; NOAA 1996)[3] wood volumes. Will not address slope stability or sediment inputs.
    - LWD will keep the creek effectively connected to its floodplain for treated reach.

W-7A

- Reach 7, estimated as equivalent to Duncan Reach 2 (Tier 2).
- Population: Winter steelhead (P), coho (P)
- Project would place unanchored LWD in Reach 7, upstream of Woodward Creek Road bridge. Estimate that 1000 feet of stream would be enhanced to approximately natural or properly functioning levels of LWD.
- Review of proposed benefits:
    - LWD would improve stream channel habitat structure by providing cover, reducing sediment transport rate, promoting pool scour, and by providing hydraulic diversity.
    - LWD would help keep creek connected to its floodplain by preventing or reducing channel incision.
- Current habitat conditions are moderately degraded due to past timber harvesting (loss of wood recruitment) and roads (sediment input). Riparian and upland forest is regrowing (approximately 30 years) with alder and Douglas fir forest.
- Effectiveness was based on assumptions:

[3] Properly functioning conditions have been estimated by NOAA in their August 1996 document "Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Watershed Scale." Properly functioning conditions were based on documentation of physical parameters and habitat conditions in relatively pristine streams in the Pacific Northwest and wood is estimated at 80 pieces/mile.

    - LWD will provide approximately 50% improvement in stream channel habitat structure and bank stability conditions by providing natural or PFC wood volumes. Will not address slope stability or sediment inputs.
    - LWD will effectively (100%) keep treated reach connected to its floodplain.

<u>W-6A</u>

- Reach 6, estimated as equivalent to Duncan Reach 2 (Tier 2).
- Population: Winter steelhead (P), coho (P)
- Project would place unanchored LWD in Reach 6, downstream of Woodward Creek Road bridge. Estimate that 1000 feet of stream would be enhanced to approximately natural or properly functioning levels of LWD.
- Review of proposed benefits:
    - LWD would improve stream channel habitat structure by providing cover, reducing sediment transport rate, promoting pool scour, and by providing hydraulic diversity.
    - LWD would help keep creek connected to its floodplain by preventing or reducing channel incision.
- Current habitat conditions are moderately degraded due to past timber harvesting (loss of wood recruitment) and roads (sediment input). Riparian and upland forest is regrowing (approximately 30 years) with alder and Douglas fir forest.
- Effectiveness was based on assumptions:
    - LWD will provide approximately 50% improvement in stream channel habitat structure and bank stability conditions by providing natural or PFC wood volumes. Will not address slope stability or sediment inputs.
    - LWD will effectively (100%) keep treated reach connected to its floodplain.

<u>W-5A</u>

- Reach 5, estimated as equivalent to Duncan Reach 2 (Tier 2).
- Population: Winter steelhead (P), coho (P)
- Project would place unanchored LWD in Reach 5; potentially by access via Woodward Creek Road. Estimate that 1000 feet of stream would be enhanced to approximately natural or properly functioning levels of LWD.
- Review of proposed benefits:
    - LWD would improve stream channel habitat structure by providing cover, reducing sediment transport rate, promoting pool scour, and by providing hydraulic diversity.
    - LWD would help keep creek connected to its floodplain by preventing or reducing channel incision.
- Current habitat conditions are moderately degraded due to past timber harvesting (loss of wood recruitment) and roads (sediment input). Riparian and upland forest is regrowing (approximately 30 years) with alder and Douglas fir forest.
- Effectiveness was based on assumptions:

    - LWD will provide approximately 50% improvement in stream channel habitat structure and bank stability conditions by providing natural or PFC wood volumes. Will not address slope stability or sediment inputs.
    - LWD will effectively (100%) keep treated reach connected to its floodplain.

W-4A

- Reach 4, estimated as equivalent to Duncan Reach 2 (Tier 2).
- Population: Winter steelhead (P), coho (P)
- Project would place unanchored LWD in Reach 4, upstream of powerline crossing. Estimate that 1000 feet of stream would be enhanced to approximately natural or properly functioning levels of LWD.
- Review of proposed benefits:
    - LWD would improve stream channel habitat structure by providing cover, reducing sediment transport rate, promoting pool scour, and by providing hydraulic diversity.
    - LWD would help keep creek connected to its floodplain by preventing or reducing channel incision.
- Current habitat conditions are moderately degraded due to past timber harvesting (loss of wood recruitment) and roads (sediment input). Riparian and upland forest is regrowing (approximately 30 years) with alder and Douglas fir forest.
- Effectiveness was based on assumptions:
    - LWD will provide approximately 50% improvement in stream channel habitat structure and bank stability conditions by providing natural or PFC wood volumes. Will not address slope stability or sediment inputs.
    - LWD will effectively (100%) keep treated reach connected to its floodplain.

W-3A

- Reach 3, estimated as equivalent to Duncan Reach 1 (Tier 1).
- Populations: Winter steelhead (P), coho (P).
- Project would place constructed LWD jams in Reach 3. Access would be from SR-14 and floodplain. Estimate that 2000 feet of stream would be enhanced to approximately natural or properly functioning levels of LWD.
- Review of proposed benefits:
    - LWD jams would improve stream channel habitat structure by providing cover, reducing sediment transport rate, promoting pool scour, and by providing hydraulic diversity. Some jams could be placed at toe of eroding slope to capture sediment before it is entrained in channel, thus further reducing sediment transport rate.
    - LWD would help keep creek connected to its floodplain by preventing or reducing channel incision.
- Current habitat conditions are moderately degraded due to past timber harvesting (loss of wood recruitment) and roads (sediment input). Riparian and upland forest is regrowing (approximately 30 years) with alder and Douglas fir forest.
- Effectiveness was based on assumptions:

- LWD will provide approximately 50% improvement in stream channel habitat structure and bank stability conditions by providing natural or PFC wood volumes. Will not address slope stability, but will likely reduce sediment inputs also into Reaches 1 and 2.
- LWD will effectively (100%) keep treated reach connected to its floodplain.

<u>W-3B</u>

- Reach 3, estimated as equivalent to Duncan Reach 1 (Tier 1).
- Populations: Winter steelhead (P), coho (P).
- Project would restore riparian zone in Reach 5 (approximately 1000 feet).
- Review of proposed benefits:
  - Restore riparian along 1000 feet, both sides, of stream.
- Effectiveness was based on assumptions:
  - 1000 feet of length effectively restored to maximum riparian width possible, both sides.

<u>W-3C</u>

- Reach 3, estimated as equivalent to Duncan Reach 1 (Tier 1).
- Populations: Winter steelhead (P), coho (P).
- Project would protect and enhance existing high quality side channel.
- Review of proposed benefits:
  - Protect and enhance 2000 feet of side-channel.
- Effectiveness was based on assumptions:
  - The 2000-foot' length is four HUs, includes riparian, fish passage and LWD, assumed 100% effective for proposed HUs

<u>W-3D</u>

- Reach 3, estimated as equivalent to Duncan Reach 1 (Tier 1).
- Populations: Winter steelhead (P), coho (P).
- Project would remove dike along right bank and reconnect floodplain
- Review of proposed benefits:
  - Reconnect floodplain along approximately 1000 feet
- Effectiveness was based on assumptions:
  - 1000 feet of floodplain connection is 2 HUs, assume 100% effective

<u>W-2A</u>

- Reach 2, estimated as equivalent to Duncan Reach 1 (Tier 1).
- Populations: Winter steelhead (P), coho (P).
- Project would place wood debris catchers and realign the stream to enter the railroad culvert at a better angle (to prevent sediment deposition).

- Review of proposed benefits:
    - LWD would provided stream channel habitat structure and cover.
- Effectiveness was based on assumptions:
    - LWD will provide approximately 10% improvement in stream channel habitat structure and bank stability conditions by providing natural wood volumes in a short section. Will not address slope stability, but may slightly reduce sediment inputs.

<u>W-2B</u>

- Reach 2, estimated as equivalent to Duncan Reach 1 (Tier 1).
- Populations: Winter steelhead (P), coho (P).
- Project would remove the dike along the right bank and reconnect the floodplain area to allow natural channel migration on the upper end of the alluvial fan. Riparian restoration and placement of LWD would be included.
- Review of proposed benefits:
    - Removing dike will allow natural floodplain function and channel migration
    - Natural channel migration will allow formation of high quality stream channel habitats and structure; placement of LWD will supplement in the near-term.
    - Riparian zone would be restored along 2000 feet.
- Effectiveness was based on assumptions:
    - Restore channel migration along 2000 feet of channel is 4 HUs, assume 100% effective
    - LWD will provide approximately 50% improvement in stream channel habitat structure and bank stability conditions by providing natural or PFC wood volumes. Will not address slope stability, but may slightly reduce sediment inputs.
    - Will restore riparian zone along 2000 feet of stream length to 150 feet or maximum possible (on left steep slope).

<u>W-2C</u>

- Reach 2, estimated as equivalent to Duncan Reach 1 (Tier 1).
- Populations: Winter steelhead (P), coho (P).
- Project would remove culvert and road crossing under railroad embankment to allow full development of stream profile without plugging.
- Would eliminate frequent excavation in channel and stranding of adult and juvenile fish from flood flows.
- Review of proposed benefits:
    - Removal of road and culvert would allow increased channel migration and connections to floodplain.
    - Removal of road and culvert would remove the majority of channel confinement and allow natural stream channel habitat structure.
- Effectiveness was based on assumptions:
    - Removal of culvert would open up approximately 1000 feet of channel to natural channel migration, floodplain connection and habitat structure.

W-1A

- Reach 1, estimated as equivalent to Duncan Reach 1 (Tier 1).
- Populations: Winter steelhead (P), coho (P).
- Project would create/restore a protected side-channel in lowest reach of river to provide chinook spawning habitat and juvenile salmonid rearing habitat. Placement of LWD and riparian restoration would also occur.
- Review of proposed benefits:
  - Reduced gradient (1%) will provide improved spawning and rearing
  - LWD would provide stream channel habitat and structure
  - Restoration of approximately 2000 feet of riparian along side-channel
- Creation/restoration of side-channel that is currently disconnected.
- Effectiveness was based on assumptions:
  - LWD will provide approximately 50% improvement in stream channel habitat structure and bank stability conditions by providing natural or PFC wood volumes.
  - The 2000-foot length enhanced channel is 100% effective, includes fish passage, LWD, and riparian

W-1B

- Reach 1, estimated as equivalent to Duncan Reach 1 (Tier 1).
- Populations: Winter steelhead (P), coho (P).
- Project would realign main Woodward Creek channel at mouth, place LWD in floodplain to provide roughness for sediment trapping, place rock or wood to channelize lower end of channel to reduce sediment deposition in lower end.
- Review of proposed benefits:
  - LWD jams would improve stream channel habitat structure by providing cover, promoting pool scour, and by providing hydraulic diversity.
  - LWD would help keep creek flowing with greater velocity in main channel.
  - Riparian restoration along 1000 feet of channel.
- Effectiveness was based on assumptions:
  - LWD will provide approximately 50% improvement in stream channel habitat structure and bank stability conditions by providing natural or PFC wood volumes. Will not address slope stability, but may slightly reduce sediment inputs.
  - The entire length of the reach would have riparian restoration.