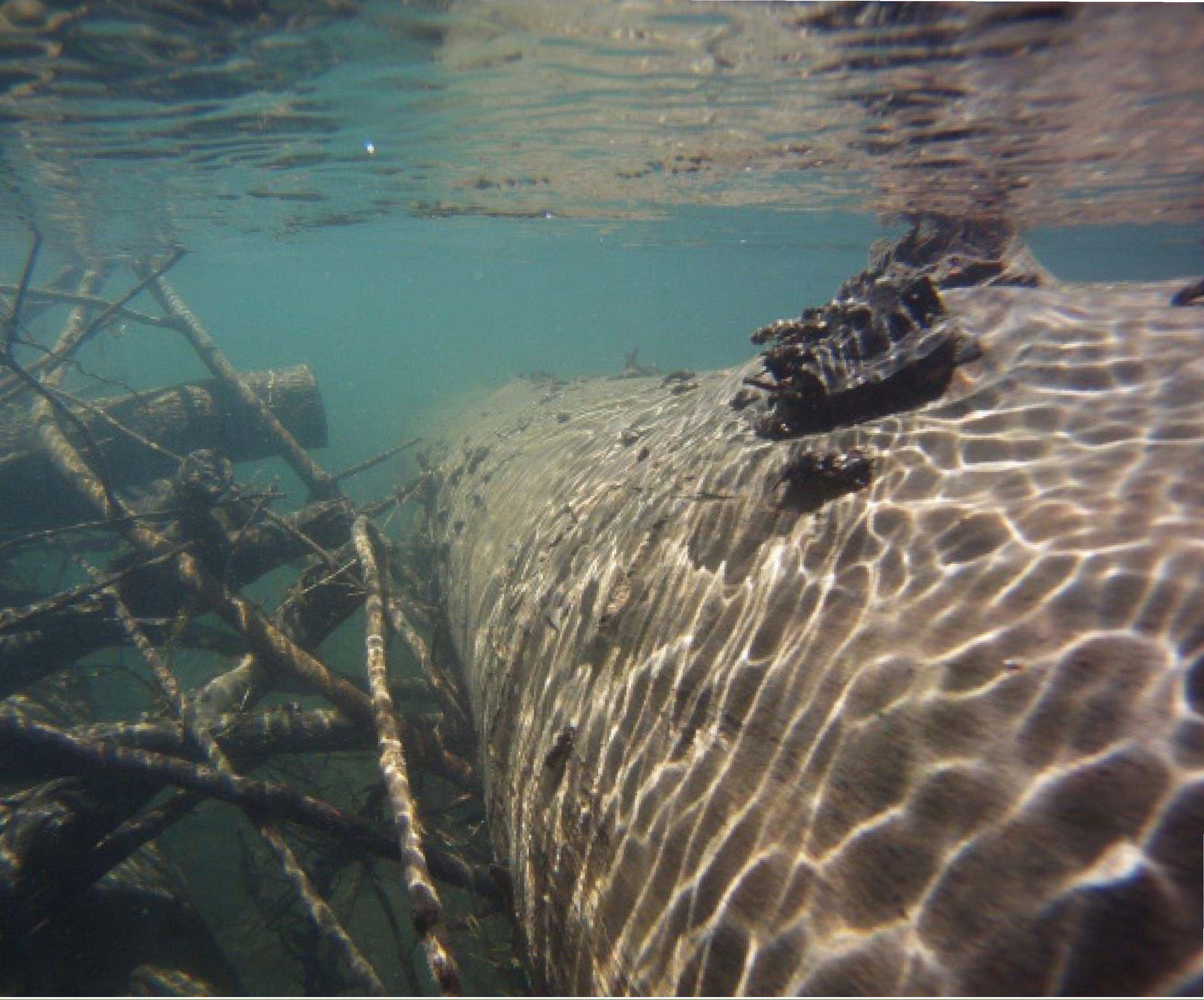

North Fork Lewis River
Haapa Fish Habitat Restoration Project
Final Design Report

PREPARED FOR
Lower Columbia Fish Enhancement Group

JUNE 2014

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Prepared for
Lower Columbia Fish Enhancement Group
12404 SE Evergreen Highway
Vancouver, WA 98683

Prepared By
Inter-Fluve, Inc.
501 Portway Ave, Suite 101
Hood River, OR 97031
(541) 386-9003

Table of Contents

1. Introduction

1.1 BACKGROUND

This report describes final design of restoration components for the Haapa site on the North Fork Lewis River. The purpose of this effort is to restore critical habitat for ESA-listed salmon and steelhead populations in a high priority reach of the North Fork Lewis River. The proposed project components have been developed to provide high-quality restoration opportunities for salmonids including fall Chinook, coho, steelhead, and chum. The project builds upon past and on-going restoration work in the lower Lewis River to address habitat limiting factors for high priority ESA-listed salmon and steelhead populations. Restoration of this area has been recommended as part of multiple previous reports including the LWD Study (Inter-Fluve et al., 2008) and the Lower Columbia Fish Recovery Board (LCFRB) habitat assessment (R2 Resource Consultants, 2004).

An inter-disciplinary oversight team has been convened to provide guidance throughout the design process, and to ensure that landowners and managers are involved throughout project development. The team consists of private landowners as well as representatives from Washington Department of Fish and Wildlife (WDFW), LCFRB, Clark County, PacifiCorp, Washington Department of Natural Resources (WDNR), Bonneville Power Administration (BPA), and other permitting and resource agencies. The oversight team met at the outset of the project on March 12, 2013 and will continue to meet intermittently during the design effort, as appropriate, to provide guidance and input into project designs.

1.2 PROJECT AREA

The Haapa Site is located on the North Fork Lewis River between river mile 13.8 and 15 in reach Lewis 5, a Tier 1 reach identified in the Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan (LCFRB, 2010). The site is adjacent to the Haapa Boat Ramp public river access points owned by Clark County and WDFW (see Figure 2). The project area encompasses the main channel and off-channel areas along the river-left (south) bank.

Aquatic habitat conditions within the project area have been impacted by a number of past and on-going human activities including historical clearing and snagging, historical gravel mining, residential development, blockage of large woody debris (LWD) transport due to the dams, and flow regulation. Project components aim to address critical habitat deficiencies while working within existing physical process constraints.

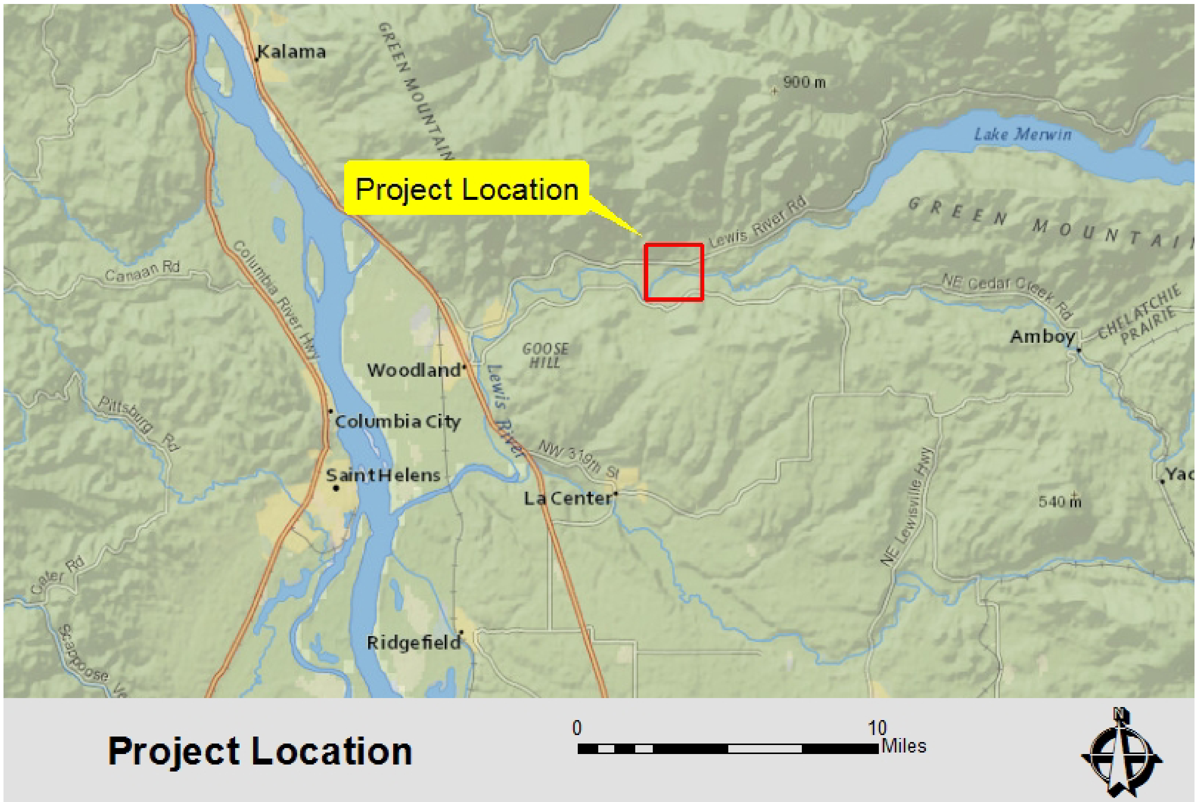


Figure 1. Project location on the lower North Fork Lewis River, downstream of Merwin Dam.

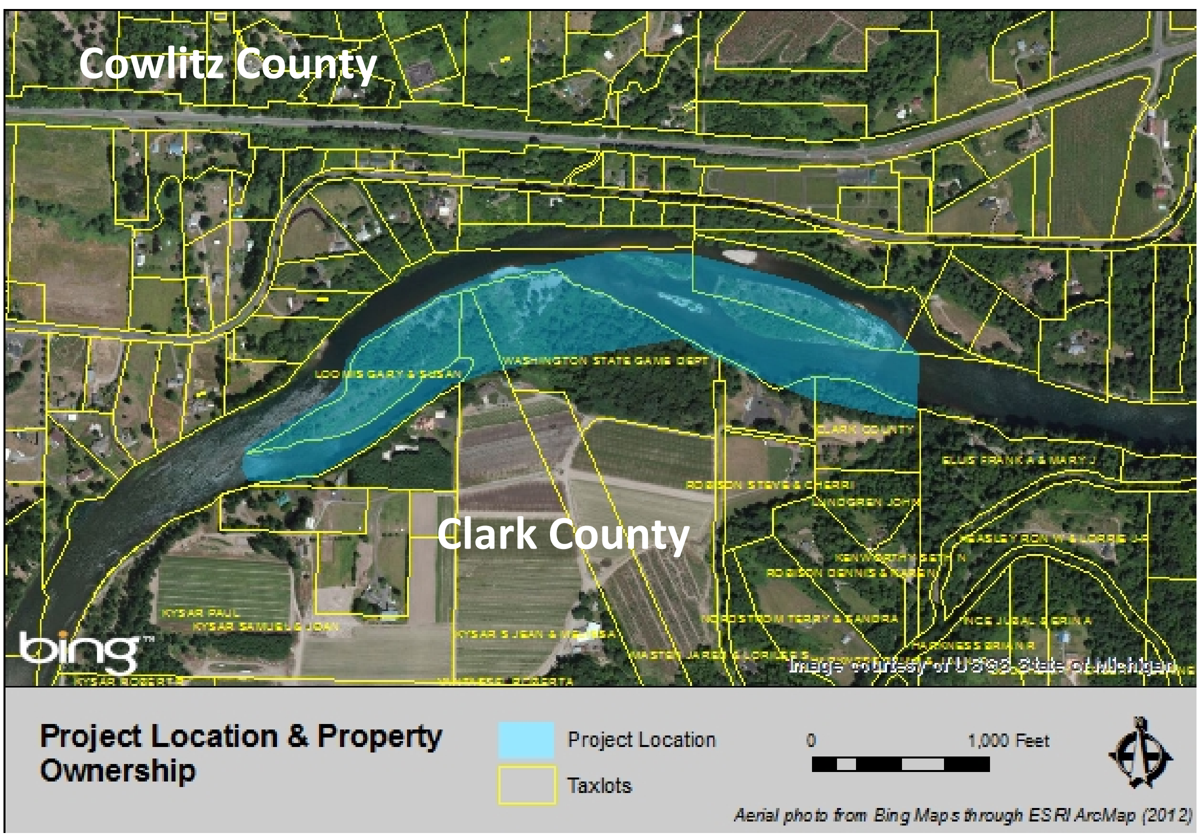


Figure 2. Project location and property boundaries; the river is the boundary between Clark and Cowlitz counties.

1.3 GOALS AND OBJECTIVES

The following goals and species-specific objectives have been developed for the project. These provide an overview of project intent. More specific project design criteria have also been developed and are presented in Section 3.1. The multi-faceted purpose of the design criteria is to further define project elements to ensure goals and objectives are achieved, so that constraints are adequately considered and addressed.

Project goals:

1) Increase channel complexity and velocity refuge along channel margins to benefit adult holding and juvenile rearing cover
2) Promote development of high quality complex pool habitat with wood cover to benefit adult holding and juvenile rearing cover
3) Create new and restore existing off-channel rearing and spawning habitat
4) Restore the native riparian plant community to provide long-term bank stability, stream shade, LWD recruitment, and nutrient exchange

Species-specific objectives:

- Chinook – Primary habitat objective is to increase the quantity and quality of shallow margin juvenile rearing habitat consisting of low depths and velocities along gently sloping gravel banks. Provide adult holding habitat in the form of mainstem cover. Addressing Chinook spawning is less a focus because most spawning occurs upstream; however, increasing the suitable depth, velocity, and substrate will yield some benefit to spawning.
- Chum – Increase off-channel chum spawning habitat. It is anticipated that this will primarily be addressed by a future WDFW groundwater-fed chum spawning channel; however, creating a flow-through side-channel may provide some opportunity for chum spawning and early rearing.
- Coho – Enhance off-channel juvenile rearing habitat quantity and quality via increased off-channel habitat area and increased cover and complexity in off-channel areas. Enhance mainstem cover habitat for juvenile rearing.
- Steelhead – Enhance main channel juvenile rearing habitat cover, spawning habitat, and adult holding cover.

2. Site Analysis

2.1 DATA COLLECTION EFFORTS

Restoration project components have been developed based on site visits, topographic survey, LiDAR analysis, geomorphic analysis, and hydraulic modeling. The data collection efforts, including a description of existing data used for the analysis, are described below.

2.1.1 Existing Data

LiDAR

Light Detection and Ranging (LiDAR) data are available for this area (US Army Corps of Engineers, 2009/2010). The data were used for geomorphic analysis and to supplement the topographic survey data collected at the site.

Aerial Photography

Aerial photography was acquired for years including 1938, 1968, 1973, 1981, 1989 and a current image. The photo record was used to evaluate trends in channel dynamics and planform. The aerial photography was also used to develop a history of human use in the vicinity of the project area.

Hydrologic Data

Hydrology data has been collected since the early 1900's at the location where the USGS currently operates station #14220500 Lewis River at Ariel, WA. Additional gage data from USGS Station #14222500 East Fork near Heisson was utilized to better estimate hydrology at the project site.

2.1.2 Data Collection

Site visits were conducted on multiple dates in 2013 for site reconnaissance and collection of topographic data. The Haapa project site was reviewed in detail on the ground and via jet boat in order to assess existing channel and floodplain conditions in preparation for detailed survey and design. Topographic surveys were conducted in June and July 2013. The surveys involved the collection bathymetry data as well as detailed topographic data of the floodplain on the valley left side. The mainstem bathymetry was collected using a Sonarmite single beam echosounder mounted to a jetboat and linked to GPS. The bathymetry and floodplain topography was collected with survey grade GPS and total station equipment. Data from the surveys was used for: 1) refinement of existing LiDAR data and provision of bathymetric data to support existing LiDAR ground surface data, 2) channel and floodplain cross-sections for hydraulic modeling of current and proposed restoration alternatives, and 3) creation of a grading plan and calculation of excavation quantities for off-channel creation alternatives.

Water Level and Temperature Monitoring

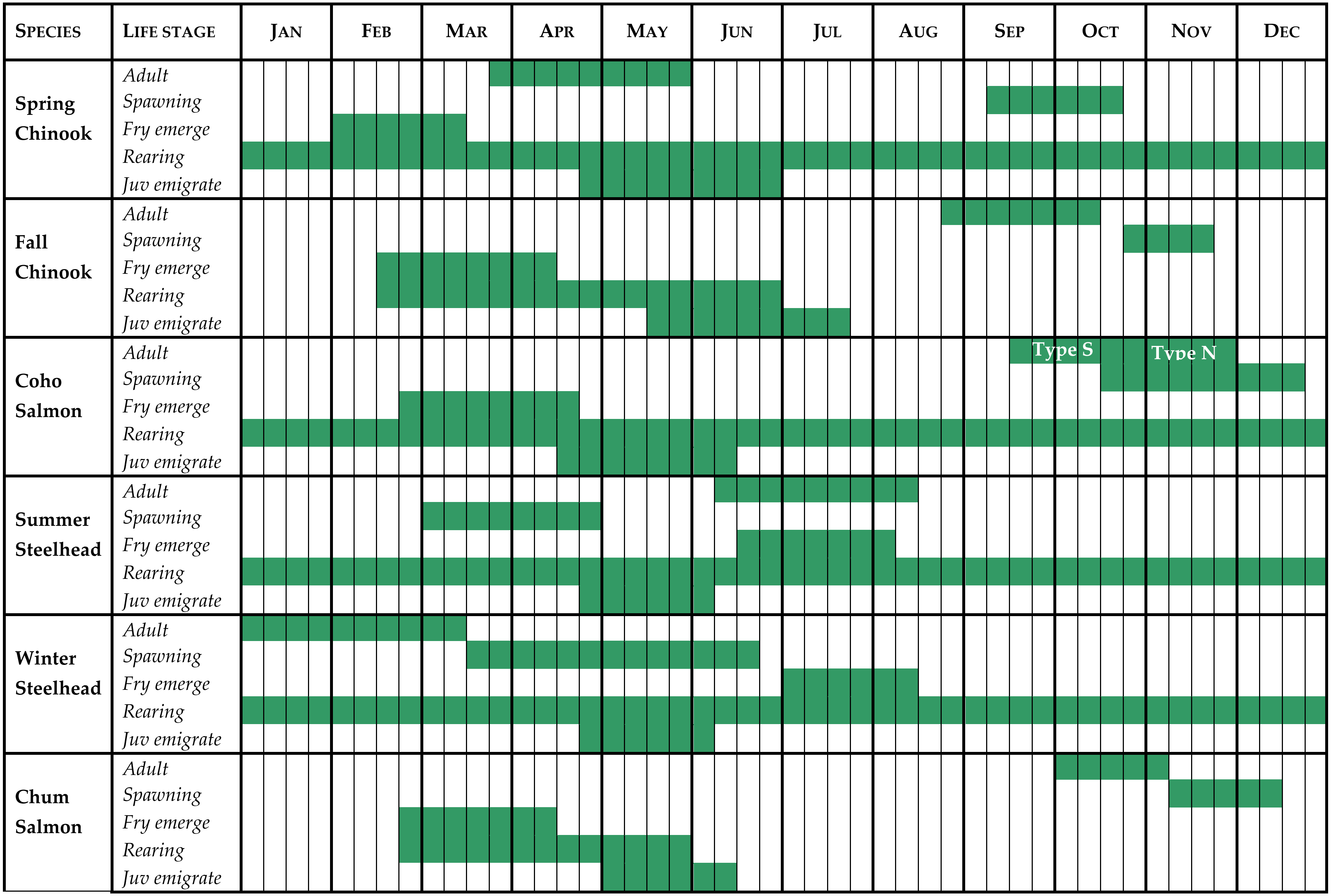
Surface and ground water monitoring instruments were deployed at the Haapa site in conjunction with a separate project. Monitoring stations utilized HOBO U20 water level data loggers. These loggers are used to monitor water levels via a pressure transducer. An additional station was deployed to collect atmospheric pressure, which is necessary for data processing in order to obtain accurate water level readings. These stations are intended to provide accurate water surface data for the reach (Figure 7). The U20 loggers also record water temperature, which will be useful for assessing temperature conditions as it relates to aquatic habitat quality.

2.2 EXISTING HABITAT CONDITIONS AND FISH USE

The Haapa project area extends along the river-left shoreline, floodplain and mid-channel islands from RM 13.8 to 15. The site includes an approximately mainstem, floodplain and off-channel habitat (Figure 2). A 3500 foot long floodplain is located between the main channel and an existing backwater area that extends for 1,500 feet along the left bank. The backwater is dominated by silt-bedded habitat with minimal structure to provide cover for fish. A flood overflow channel that connects the mainstem to the backwater across the floodplain and flows actively during moderate flood events. There are relic channels near the midpoint of the long valley-left floodplain. Native riparian vegetation is impaired and is affected by invasive species including Himalayan blackberry, scotch broom, and knotweed. The mainstem margin is generally composed of uniform habitat with little cover or complexity. An island complex in the mainstem provides a multi-thread channel system but aerial photo evidence indicates that this area had even greater channel complexity historically. It has likely been simplified through past gravel mining, hydro-regulation, and interruption of LWD delivery from the upper basin due to the hydro-system.

Stream habitat surveys and other analyses conducted by R2 Resource Consultants (2004) documented the following impaired habitat conditions in this reach (Lewis 5): 1) loss of bar and connected side channel habitat, 2) poor shade condition ratings, 3) a lack of pools or pool tail-outs (0%), and 4) low large wood quantities (< 14 pieces per mile). Pool habitat, riparian shade, off-channel habitat, and LWD quantities were all in poor condition in this reach (reach Lewis 5) according to the 2004 habitat assessment commissioned by LCFRB (R2 Resource Consultants, 2004). Habitat unit composition was rated as 0% pool habitat, 48% riffle habitat, and 52% glide habitat. Very little LWD was observed in the reach. Similar results for LWD quantities were obtained as part of re-licensing studies (WTS-3 Relicensing Report, PacifiCorp, 2004a) and as part of the 2007 LWD assessment (Inter-Fluve et al., 2008), which observed only 3 "key" pieces throughout the entire 3-mile reach in which the project area is located.

A number of fish species utilize the lower Lewis River for portions of their life history. The ESA-listed salmonids that utilize the reach include Chinook salmon, coho salmon, chum salmon, steelhead, and bull trout, although bull trout use of this area is believed to be minimal. Life history periodicity for these species is included in Figure 4. Over the years, WDFW has conducted fish surveys in the lower Lewis, including spawning surveys as well as seining of juveniles for tagging. Steelhead and fall Chinook redds are frequently found in the vicinity of the project area. In addition, fall Chinook juveniles are regularly captured in seining sets conducted annually in the off-channel complex at the downstream end of the project area.


SPECIES
LIFE STAGE
JAN
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MAR
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MAY
JUN
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Spring Chinook
Fall Chinook
Coho Salmon
Summer Steelhead
Winter Steelhead
Chum Salmon
Adult
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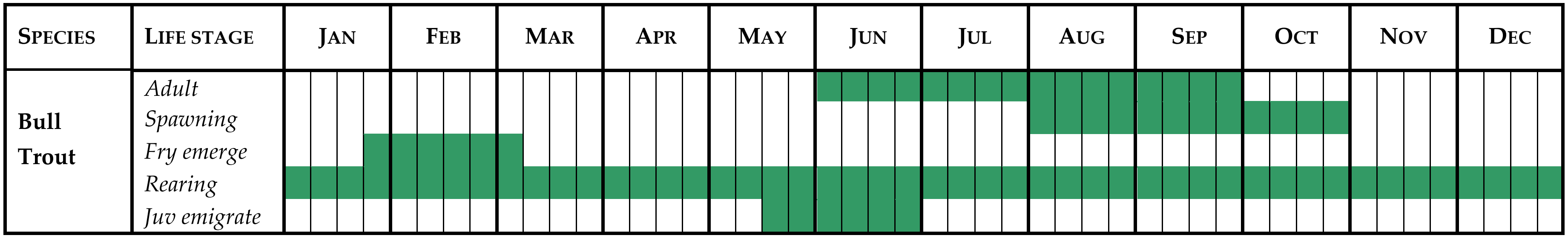

Figure 3. Life-stage periodicity for salmon, steelhead, and bull trout in the lower Lewis River.

2.3 VEGETATION & LWD

The overstory within the project area is dominated by black cottonwood (*Populus balsamnifera*), alders (*Alnus rubra*) and maples (*Acer macrophyllum*), with some Douglas fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), and Oregon ash (*Fraxinus latifolia*). Shrub understory includes salmonberry (*Rubus spectabilis*), snowberry (*Symphoricarpos albus*), nootka rose (*Rosa nutkana*), Himalayan blackberry (*Rubus discolor*). Red osier dogwood (*Cornus stolonifera*), alder, willow (*Salix spp*), cottonwood, and Douglas spirea (*Spiraea douglasii*) dominate the riparian zone.

Invasive species are a serious problem in the project area. Invasives include Scotch broom (*Cytisus scoparius)*, Himalayan blackberry, reed canary grass (*Phalaris arundinacea*), and Japanese knotweed (*Fallopia japonica*). Controlling invasive species and re-establishing a native vegetation community will be an important component of this project and will support long-term ecological processes and habitat formation.

Instream large woody debris very likely had a major role in this system historically, and would have been instrumental in creating complex multi-thread channels, frequent and deep pools, and abundant habitat cover (Inter-Fluve et al., 2008). Field investigations indicate that instream large woody debris is now scarce in the project area. The LWD study noted not only a lack of LWD quantities, but an almost non-existent supply of large wood pieces of the size necessary to self-anchor within the mainstem Lewis and initiate jam formation. This was attributed to blockage of wood transport by the dams, a lack of riparian trees of sufficient size, and channel modifications along the lower river. This condition has resulted in a reach of river that is almost completely devoid of complex habitat structure. The 2007 LWD study recommended installation of large woody debris structures along this segment of stream.

2.4 GEOMORPHOLOGY

2.4.1 Setting

The project reach is located just downstream the North Fork Lewis canyon reaches, which are confined by steep valley walls comprised of bedrock, glacial outwash, and Missoula Flood deposits. The transition out of the canyon reaches occurs at RM 15, where a broad alluvial terrace begins along the river-left bank. In the vicinity of the project site, the North Fork Lewis River flows through alluvial and terrace deposits. The site consists of a complex of mid-channel islands and a 3,500 foot long river-left floodplain area that contains mature relic channels and an existing large backwater channel. The active channel ranges from 500 to 1,200 feet wide in the project reach.

The section of river at the project site is multi-thread with a series of 3 riffles providing hydraulic controls. Stream gradient at the site is moderate at 0.24%. The active channel varies considerably between 500 and 1,200 feet in width. Streambed material is gravels and cobbles. The river-left terrace ranges from

15 to 20 feet above the low water surface. The river-right side of the channel is a tall vertical bank extending over 130 feet above the low water surface. The lower North Fork Lewis River has been impacted by historical clearing and snagging, gravel mining, residential development, blockage of large wood transport due to the dams, and flow regulation (Inter-Fluve et al 2008). These impacts have reduced wood loading, reduced channel complexity, reduced the development of side-channels and off-channels, and have reduced habitat-forming processes (e.g. floods) necessary for creating and maintaining complex habitats. A portion of the low floodplain is inundated relatively frequently (annually) and is the site of off-channel habitat restoration work detailed in Section 3. Reach hydraulics are discussed further in the Hydraulic Analysis section.

2.4.2 Historical Channel Adjustments

The channel and floodplain features in the vicinity of the project area has been dynamic over the air photo record, as a result of the complex interaction of direct modification of the channel, flood events and watershed scale changes resulting from the construction of upstream dams. Historical air photos and landowner reports indicate the presence of a large gravel mining operation at the Haapa Site in the 1950s. This site is also known as the "Haapa Crusher" site. Stream gravel extraction removed a significant amount of material and likely contributed to channel simplification and disconnection of off-channel habitat. The interruption of sediment transport processes caused by upstream impoundments may also affect channel complexity and availability of spawning and rearing habitat. The earliest aerial photos examined in this study (1938) show the active gravel mining going on in the vicinity of the current boat ramp location (see Figure 4). There is a split flow around a mid-channel vegetated island downstream of the bar. The next photo, from 1951, shows the vegetation maturing on the surfaces created by the gravel mining operation. These surfaces in the vicinity of the gravel mining operation were eroded by the November 1962 flood event, the 3rd largest flood on record (approximately a 20-year event). In the years following the 1962 flood, the air photo record shows deposition of bars and subsequent vegetation colonization. In the 1973 photo, the valley-left channel in the flow split around the island is filling in and slowly becoming more and more disconnected. The series of 3 distinct islands evolved to become the large 3,500- foot long floodplain surface seen in the 1989 and present photos. The trajectory of the channel and floodplain conditions seem to be the evolution of the downstream portion of the project area from multiple channels and distinct islands to a large, stable vegetated floodplain surface effectively narrowing the flow into a single channel. The stability of vegetation of the floodplain surface, reduced sediment supply, and altered hydrology may be causing some degradation where the river is narrowed into one channel. Future channel adjustments will be a function of hydrology (i.e. flooding), sediment dynamics and feedbacks with riparian processes.

Figure 4. Historical aerial photography for the project site, including years 1938, 1951, 1968, 1973, 1989, current.

Figure 4. continued (source: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community).

2.5 HYDROLOGY

2.5.1 Basin and Site Hydrology

The Lewis River encompasses a drainage area of 1,046 square miles. The headwaters of the Lewis are on Mount Adams, Mount St. Helens and their adjacent foothills. Basin hydrology is dominated by winter rains, but is driven by a combination of snow and glacier melt, rain, and groundwater flow. Major tributaries to the Lower Lewis include the East Fork Lewis, Johnson Creek, and Cedar Creek. Tidal influences extend up the Lower Lewis to approximately RM 11.

High flows occur in winter and spring as a result of rain and snowmelt. Occasional high flows occur in the fall as a result of heavy rains. An excedence plot developed from Ariel Gage flows over the past 10 years is provided in Figure 5.

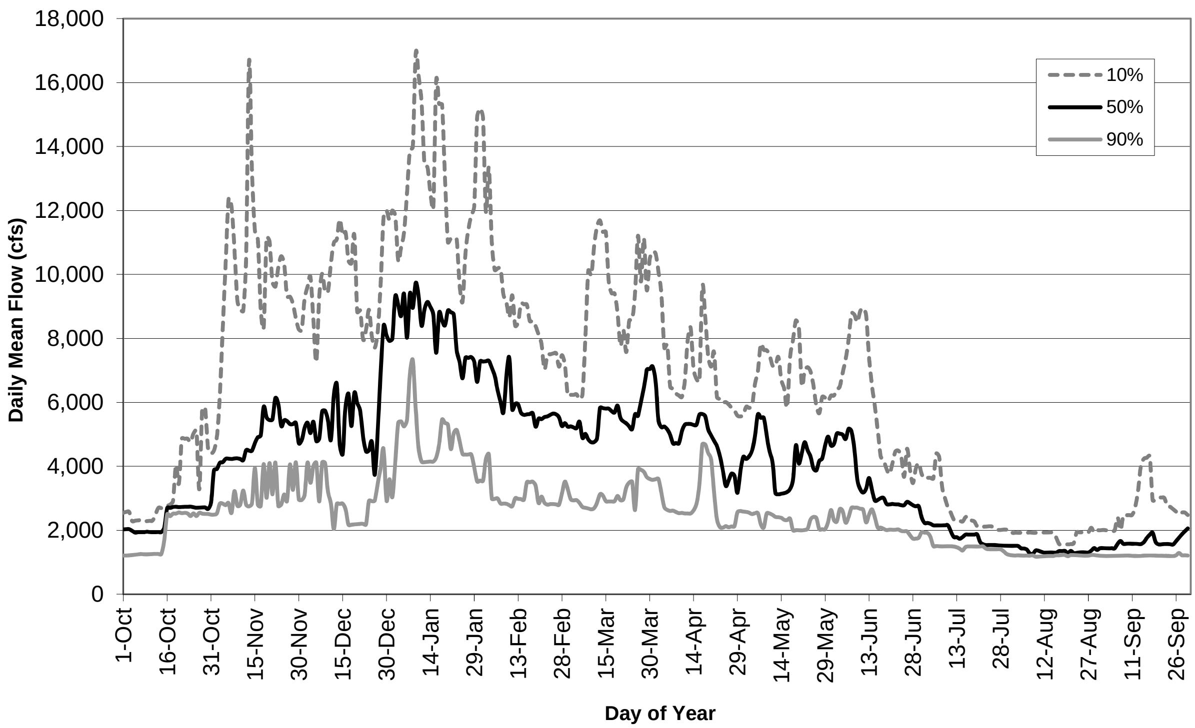

Figure 5. Hydrograph showing daily median flows and 10% and 90% excedences flows for the period 2002 to 2011 for USGS 14220500 Lewis River at Ariel, WA.

2.5.2 Hydro-regulation

Flows in the lower river are further influenced by flow regulation from the Lewis River hydro-system, which consists of 3 dams on the mainstem Lewis River: Swift Dam, Yale Dam, and Merwin Dam. The project site is located between RM 13.8 and 15, which is below the most downstream dam, Merwin Dam (RM 19.5). A USGS gage is located just downstream of the Merwin Dam at Ariel (Station #14220500).

PacifiCorp operates the hydrosystem to produce power, manage peak (flood) flows, and augment late summer flows for fish in accordance with license requirements. In the lower river, hydro-regulation has led to less variability in seasonal hydrology, including increasing summer and fall low flows and reducing the magnitude of floods (see Figure 6). The effect on peak flows varies depending on the size and timing of the event and the amount of available storage in the reservoirs. For the flood of February 1996, the PacifiCorp FLD-1 Study (PacifiCorp, 2004b) estimated that the flood, which registered 86,400 cfs on the Ariel Gage, would have registered 111,400 cfs without hydro-regulation.

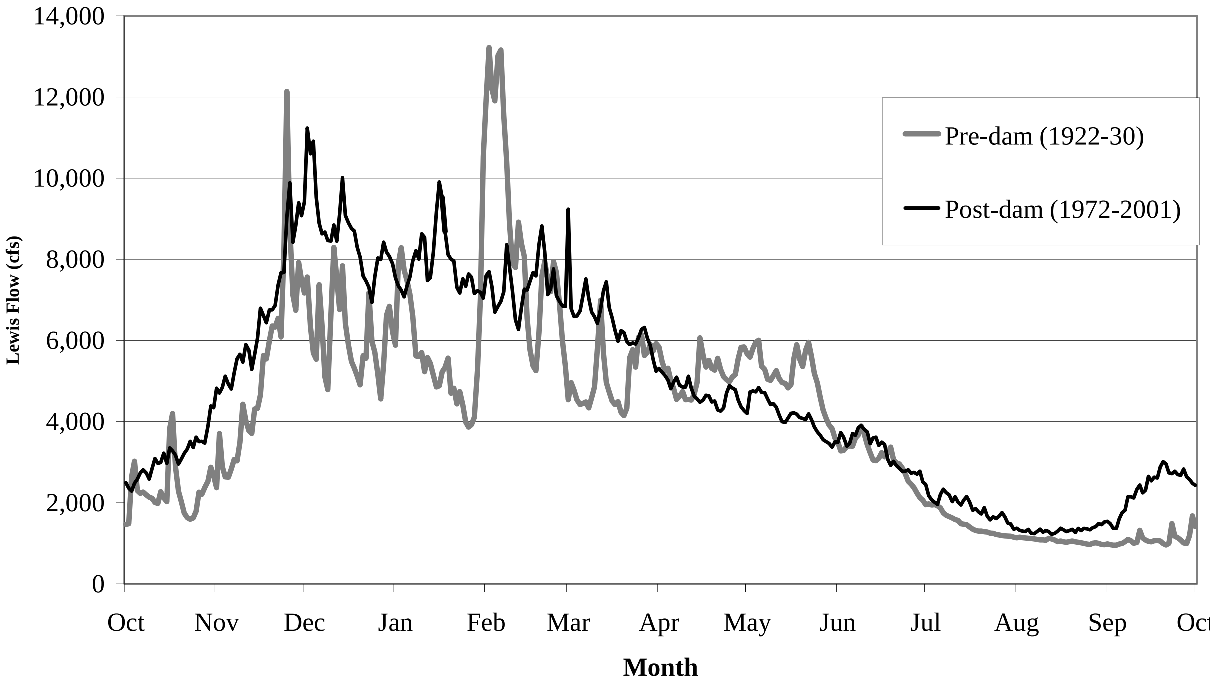

Figure 6. Lower Lewis River flow pre- and post-Merwin Dam (1931). Hydro-regulation has decreased flows in the spring and increased flows in the summer and fall. USGS Gage #14220500; Lewis River at Ariel, Wash.

2.5.3 Minimum flow requirements

PacifiCorp is required, as part of their hydropower license, to maintain minimum flows in the lower river below Merwin Dam for specific seasons in order to support key fish life-stages. Table 1 gives the flow requirements for each period. These requirements provide relatively reliable low-flow discharges for specific times of the year that are used to help guide the design of side-channel habitats.

Table 1. Minimum flow requirements for the lower river below Merwin Dam.

Time period	Minimum flow requirement (cfs)
July 31 through October 15	1,200
October 16 through October 31	2,500
November 1 through December	4,200
December 16 through March 1	2,000
March 2 through March 15	2,200
March 16 through March 30	2,500
March 31 through June 30	2,700
July 1 through July 10	2,300
July 11 through July 20	1,900
July 21 through July 30	1,500

2.5.4 Flood Frequency Analysis

Flood flow magnitudes were developed for various flood recurrence intervals to be input into hydraulic modeling and design calculations (Table 2). The 10-, 50-, and 100-year flood flow magnitudes were obtained from the Lewis River Hydroelectric Projects Flood Management Technical Report (FLD-1) (PacifiCorp 2004b) (Table 3). The flows for the scenario "regulated flows with 70,000 acre-feet dependable flood control storage" at Woodland, WA were utilized. Seventy thousand (70,000) acre-feet is the minimum flood storage space required among the three dams (Swift, Yale, and Merwin) between November 1 and April 1. These flows in Table x are conservative (i.e. higher) estimates of floods for the project site because Woodland is located downstream of the project site; however, there are no significant tributaries between the project site and Woodland.

The FLD-1 study did not provide 2-year event flows for Woodland, WA but provided 2-year event floods for the gage at Ariel for the scenario “regulated flows with actual historic flood control storage". Because a major tributary, Cedar Creek, enters the Lewis River between the Ariel gage and the project site (at approximately RM 15.7), the 2-year flood flow magnitude was corrected to account for Cedar Creek flow and other tributary flows between Ariel and the project site. Cedar Creek flow was calculated as 17% of flow at the East Fork Lewis gage near Heisson (USGS Station #14222500), which is consistent with the methods outlined in the FLD-1 Study. The remainder of the tributary flows between Ariel and the project site were calculated using the USGS regional regression equations (Sumioka et al. 1998). Cedar Creek and other tributary flows were added to the 2-year flows at Ariel in order to obtain the 2-year event flows for the project site.

Table 2. Recurrence interval flows used for the project area. These flows account for contributions from Cedar Creek and other tributaries between the Ariel gage and the project site as well as hydropower regulation.

Return Interval	Flow (cfs)
2-year	24,400
10-year	65,600
50-year	92,600
100-year	98,400

Table 3. Lewis River flood magnitude and frequency reproduced from PacifiCorp FLD-1 Study (PacifiCorp 2004b).

Location	Drainage Area (sq mi)	Flow Quantile (cfs) by Return Period (yrs)				
		2	10	50	100	500
Unregulated flows						
Near Ariel	731	42,000	71,900	99,100	111,000	140,000
Regulated flows with 70,000 acre-feet dependable flood control storage						
At Ariel	731	n/a	60,000	85,000	90,000	140,000
At Woodland	820	n/a	65,600	92,600	98,400	150,500
At mouth	1,046	n/a	85,400	119,400	128,200	187,600
Regulated flows with actual historic flood control storage						
At Ariel	731	22,000	60,000	n/a	n/a	n/a

Note: Analyses based on the period of record 1912-2000.

2.5.5 Flood History

The dates of large floods (i.e. greater than a 5-yr recurrence interval) were obtained from the gage data and these events were used to evaluate potential impacts on channel pattern and conditions observed from the aerial photo record. The top 15 floods over the period of record are included in Table 4.

The flood of record occurred in December 1933 (Water Year 1934), and was estimated at 129,000 cfs. Merwin Dam had been in place for less than two years at the time of the flood and did not provide any flood control storage for the event. The 1933 flood had a profound impact on channel morphology and spawning habitat in the lower Lewis River. This flood was considerably greater than the second largest flood, which occurred in February 1996. It is estimated that the 1996 flood would have been approximately 111,400 cfs in the absence of flow regulation (PacifiCorp 2004b). The most recent large flood was in January 2003 (49,300). Floods between 35,000 and 40,000 cfs occurred in November 2006, January 2009, and January 2011.

Table 4. Top 15 floods on the Lewis River from USGS Gage (Gage #14220500) at Ariel, WA. Flood volumes at the project area would be larger due to tributaries that enter the river between the USGS gage and the project site.

Event Rank	Water Year	Flow (cfs)	Event Rank	Water Year	Flow (cfs)
1	1934	129,000	9	1974	59,600
2	1996	86,400	10	1943	57,600
3	1963	75,500	11	1981	53,700
4	1978	71,900	12	1967	50,500
5	1947	67,300	13	2003	49,300
6	1976	64,500	14	1956	49,100
7	1928	62,600	15	1937	49,100
8	1938	61,500			

WATER LEVEL MONITORING

As a part of a project to identify potential chum spawning channels in the East and North Lewis, three piezometers for monitoring groundwater and one surface water monitoring station on the left bank of the main channel downstream of the boat ramp (Figure 7) at the Haapa site. Data was collected to cover a variety of flow conditions from 2011 – 2013. Depending on which components are selected to move into more detailed design and permitting, the water level monitoring data from the river station will be utilized to develop final designs.

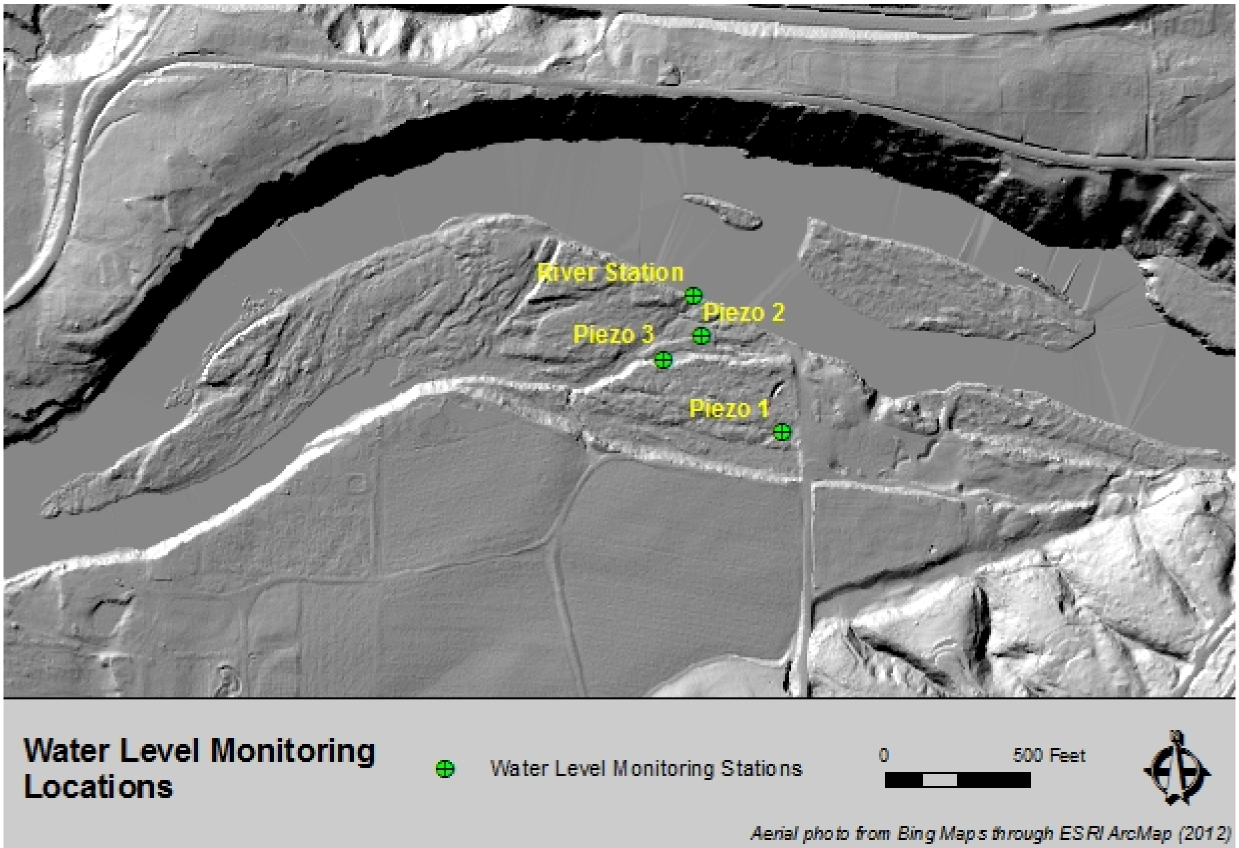

Figure 7. Map showing the locations of three piezometers and one surface water level monitoring locations instrumented with pressure transducers.

2.6 HYDRAULICS

The U.S. Army Corps of Engineer's 1-dimensional HEC-RAS (version 4.1.0) hydraulic modeling program was used to estimate hydraulic conditions in the Lewis River within the study area. HEC-RAS is a computer program that models the hydraulics of water flow through natural rivers and other channels. The program is one-dimensional, meaning that there is no direct modeling of the hydraulic effect of lateral cross section shape changes, bends, and other two- and three-dimensional aspects of flow. After project components are selected to move forward to permitting and final design, modeling efforts will be continued and refined. Additional modeling to support final design will include simulating proposed conditions.

2.6.1 Modeled Flows

Model conditions were run for low flows and flood recurrence flows. Lowest flow conditions were considered to be the minimum low flow requirements for Merwin Dam from July 31 through October 15 of 1200 cfs (Table 1). Average low flows throughout the year were considered to be the average annual 90th percentile flow of 2830 cfs (Figure 5). Flood flows were also modeled for the 1.01-, 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals (Table 2). A logarithmic regression equation was used to extrapolate flows for the 1.01- and 25-year recurrence intervals (10,199 cfs and 79,268 cfs, respectively).

2.6.2 Geometry

The existing conditions model is based on sixteen channel cross-sections generated from topographic site survey data collected between March and July 2013 (Figure 8). See topographic survey section above for more detailed information on data collection. One additional cross-section was added at the downstream end of the model from the NF Lewis River Mile 13.5 Habitat Restoration Project hydraulic model prepared by Inter-Fluve in 2011 (X-Section 1359.13). The RM 13.5 project is located 0.3 miles downstream. The additional cross-section was added to the Haapa model in order to set a rating curve as the downstream boundary condition (discussed in the next section).

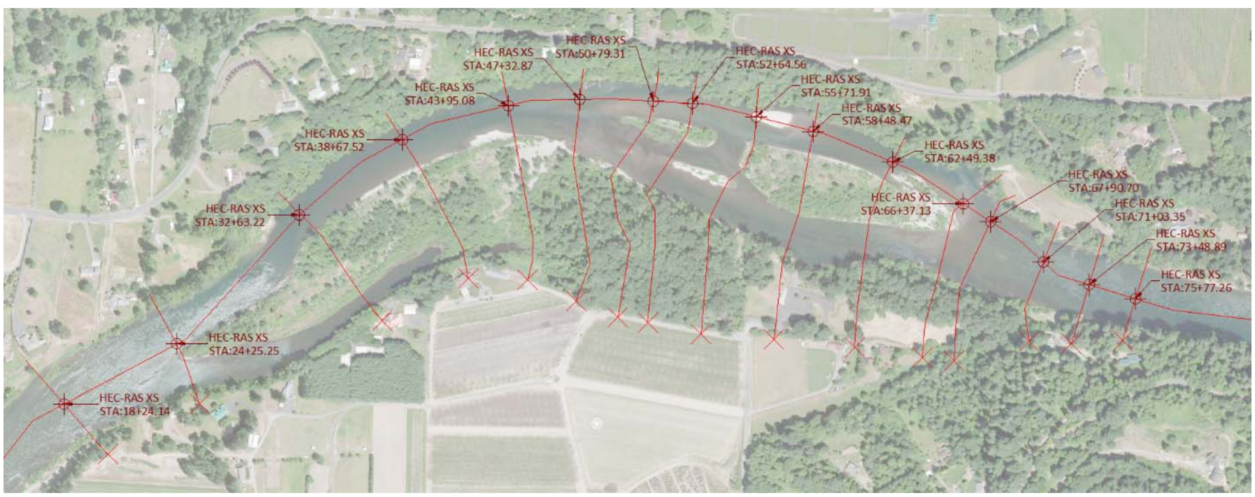

Figure 8. HEC-RAS cross-section locations.

2.6.3 Boundary Conditions

A mixed flow regime is assumed for the hydraulic model. A normal depth boundary condition (energy slope) is used at the upstream end of the model and is estimated as the average channel slope through the project reach. A rating curve is used for the downstream boundary condition based on output from the NF Lewis River Mile 13.5 Habitat Restoration Project hydraulic model. The stage and discharge HEC-RAS output for the most upstream cross-section from the most upstream cross-section of the RM 13.5 model was inputted as the downstream boundary condition for the Haapa model. The stage-discharge output included stage data for low flow through the 500-yr recurrence interval flood event.

2.6.4 Roughness

Manning's roughness coefficients are used by the model to calculate energy losses resulting from flow resistance caused by various channel bed materials, channel irregularities, and type and density of floodplain vegetation. For the existing conditions model, the following Manning's n values were used.

Table 5. Roughness values (Manning's 'n') used for existing conditions hydraulic modeling.

Main Channel	**n**
Cobble riverbed, minor variation in bedform, low sinuosity	0.05
Floodplain	
Riparian brush and trees, moderate irregularity of ground	0.08

2.7 SAFETY CONSIDERATIONS

A number of potential safety concerns have been and will continue to be considered as part of project design. These considerations primarily apply to the use of large wood, which can pose a potential risk to recreational river users. Safety considerations as part of design will follow recently developed protocols by the State of Washington and other groups (e.g. American Whitewater).

The restoration alternatives include placing wood structures (i.e. engineered log jams) along the main stem and as cover wood within existing or created off-channel habitats. The structures on the mainstem would be designed to provide habitat function while minimizing risk to river recreationists, and would be anchored as required to achieve stability at the design flow (to be determined).

In general, these guidelines are aligned with the standard approach taken by Inter-Fluve in design and placement of large wood. A number of considerations were included in the design to minimize risk consistent with the guidelines.

- This portion of the North Fork Lewis River is heavily utilized by motorized recreational river users for fishing, casual rafting, and swimming.
- As a design standard, all mainstem wood placements should have sufficient line of sight and navigable escape routes to be easily avoided by unskilled river users.
- Mainstem structures would be configured to shed objects floating along the river and thus minimize risk to recreationists. The optimal configuration for safety will be site dependent, but will commonly depend on flow orientation to the bank, bank height, depth of log submersion, line of sight, near bank velocity, near bank shear stress, and near bank depth.

- Mainstem structures will be designed for stability at the 100-yr flood with consideration given to buoyancy, depth of burial, cabling, and ballasting.
- Safety signage warning river users of the presence of log structures may be a viable component of safety measures given the traffic and skill level of many river users. This is consistent with recommendations by Andrus & Gessford (Skellenger & Bender, 2007); the River Safety Council; and the Washington State Department of Natural Resources.

3. Design Criteria and Restoration Components

3.1 DESIGN CRITERIA

Designs were developed with consideration of the restoration objectives and known constraints (Section 1.3), regulations, safety, and feasibility in mind. Design criteria have been developed to guide the design process and to ensure that project objectives are achieved and project constraints are understood and explicitly addressed. Design criteria are provided below within five sections: Geomorphic, Habitat, Engineering, Safety, and Feasibility. These design criteria will be revised and made to be more quantifiable once an alternative is selected.

1. Create a variety of complex habitat types to support all four ESA-listed anadromous salmonids at multiple life stages.
2. Chinook and chum are considered 'Primary' species in the Recovery Plan and these should be the primary focus of restoration. However, restoration work should target all ESA-species. Species-specific targets include the following. All of these may not necessarily be addressed due to site limitations and opportunities:
    a. Chinook – primary habitat objective is to increase the quantity and quality of shallow margin juvenile rearing habitat consisting of low depths and velocities along gently sloping gravel banks. Provide adult holding habitat in the form of mainstem cover. Addressing Chinook spawning is less a focus because most spawning occurs upstream; however, increasing the suitable depth, velocity, and substrate will yield some benefit to spawning.
    b. Chum – increase off-channel chum spawning habitat. It is anticipated that this will primarily be addressed by a future WDFW groundwater-fed chum spawning channel; however, creating a flow-through side-channel may provide some opportunity for chum spawning and early rearing.
    c. Coho – enhance off-channel juvenile rearing habitat quantity and quality via increased off-channel habitat area and increased cover and complexity in off-channel areas. Enhance mainstem cover habitat for juvenile rearing.

   d. Steelhead – enhance main channel juvenile rearing habitat cover, spawning habitat, and adult holding cover.

3. Consider potential predation by invasive species or by salmonids on other salmonids (e.g. steelhead and coho predation on newly emerged chum)

4. Ensure that project elements do not increase erosion or flood impacts on the high bank on river-left (Kysar and Loomis property)

5. Do not increase erosion on river-right bank/valley wall, which has shown signs of instability in past floods.

6. Wood placements will need safety analysis including steps to minimize dangers (e.g. adequate line-of-site, signage). Complete the WDNR safety checklist.

7. Minimize the potential for sediment accumulation within the existing backwater and constructed side-channel

8. Apply appropriate re-vegetation and erosion control measures to control erosion following construction

9. Ensure adequate boat access to existing backwater area during and following construction

10. Consult with BPA on restrictions within transmission line corridor and adhere to those restrictions throughout design and construction.

11. Consult with Clark County Parks on potential issues or constraints for the components of the project adjacent to the Haapa Boat Launch.

3.2 DEVELOPMENT OF PROJECT COMPONENTS

Development of project components was driven by the draft design criteria, as well as regional and local restoration objectives. Each restoration alternative will be completed in tandem with riparian revegetation to promote the long-term recovery of the riparian community and large wood delivery processes. During the development of project designs, proposed alignment, habitat type, and channel complexity were the primary design elements considered. Specific assumptions were made regarding channel dimensions, large wood size, and access; these are described in the attached cost estimates. Upon selection of a preferred alternative(s), proposed conditions will be modeled as part of subsequent design efforts. Modeling will assess feasibility related to sediment transport, habitat accessibility, ballast requirements, and vertical and lateral channel dynamics. The below alternatives are not mutually exclusive and may be selected individually or combined.

3.3 DESCRIPTION OF PROJECT COMPONENTS

A total of seven restoration components were identified and evaluated in the preliminary design phase. Four of these components were selected to move into final design and permitting. Each component has the potential to be implemented individually or in combination with one or more additional component. The four components carried through final design were developed based on site investigations and analyses conducted as part of this effort, discussions with project stakeholders, and with reference to previous studies that included restoration recommendations for the area. The six components include: (detailed discussion of project components can be found in following sections).

Component 1 – Side Channel Construction

Component 2 – Backwater Channel Enhancement

Component 3 – Main Channel Margin LWD

Component 4 – Riparian Enhancement

3.3.1 Component 1 – Side Channel Construction

Component 1 includes the construction of a 1,350-foot long flow-through side channel through the valley left floodplain (see Figure 9). Component 1also includes a groundwater fed channel to provide additional habitat to fish utilizing the side channel. The proposed side-channel and groundwater channel will provide habitats that are no longer created due to past gravel removal, interruption of bedload transport, lack of large log jams, and associated feedbacks with channel processes. The inlet of the channel would be located near RM 14.4 with the outlet located at the head of the large existing backwater channel at the downstream end of the site. The inlet of the side channel has been designed to be active at the minimum flow of 1200 cfs, and includes grade control logs built into the bed. The side channel consists of a meandering planform with alternating lateral scour pools and margin LWD (see Figure 10). Channel dimensions include a channel bottom width of 16 feet average, a channel top width that varies from 20-50 feet, and approximately 3:1 side slopes. Cross-section dimensions would vary along the length of the channel. Lateral scour pools would be added along the outside of meander bends. Large wood placements would consist of accumulations/jams of approximately 4-7 pieces per structure to provide cover and complexity within pools and in other locations throughout the channel.

The side-channel would be expected to primarily support juvenile rearing and adult holding for ESA-listed Chinook and steelhead. There could also be limited spawning use of the channel. The channel would be designed to remain connected at low summer flows in order to provide year-round access for fish. Large wood additions are intended to provide diverse channel structure and form by increasing channel margin complexity and providing cover and holding areas for fish. The channel would provide summer-time juvenile rearing as well as over-wintering and flood refuge habitat.

Potential design considerations include whether there is adequate slope to move sediment through the channel as well as whether or not the native alluvium substrate is sufficiently stable to support side channel flows. The designs have been created with these concerns in mind, and a final channel slope, planform, and layout of floodplain roughness wood have been incorporated.

The effect of dynamic processes in the main channel and islands in the vicinity of the inlet could have important design consideration. Planform analysis indicates this area is relatively stable however it should be acknowledged that a large shift in the configuration of the split flows and islands could influence the grade control that would maintain flow into the side channel inlet.

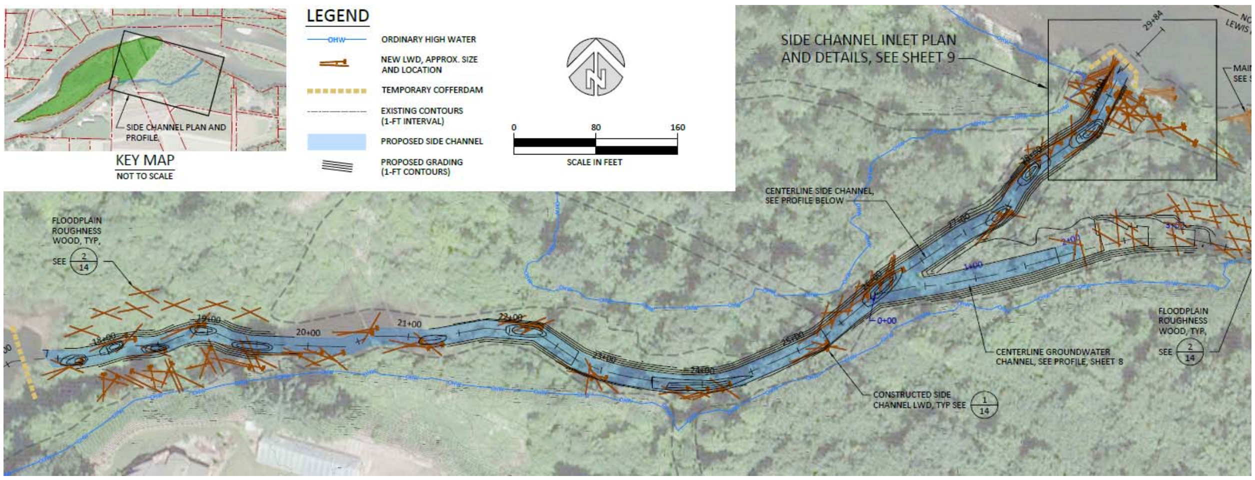

Figure 9. Plan view of Component 1 Side Channel Construction.

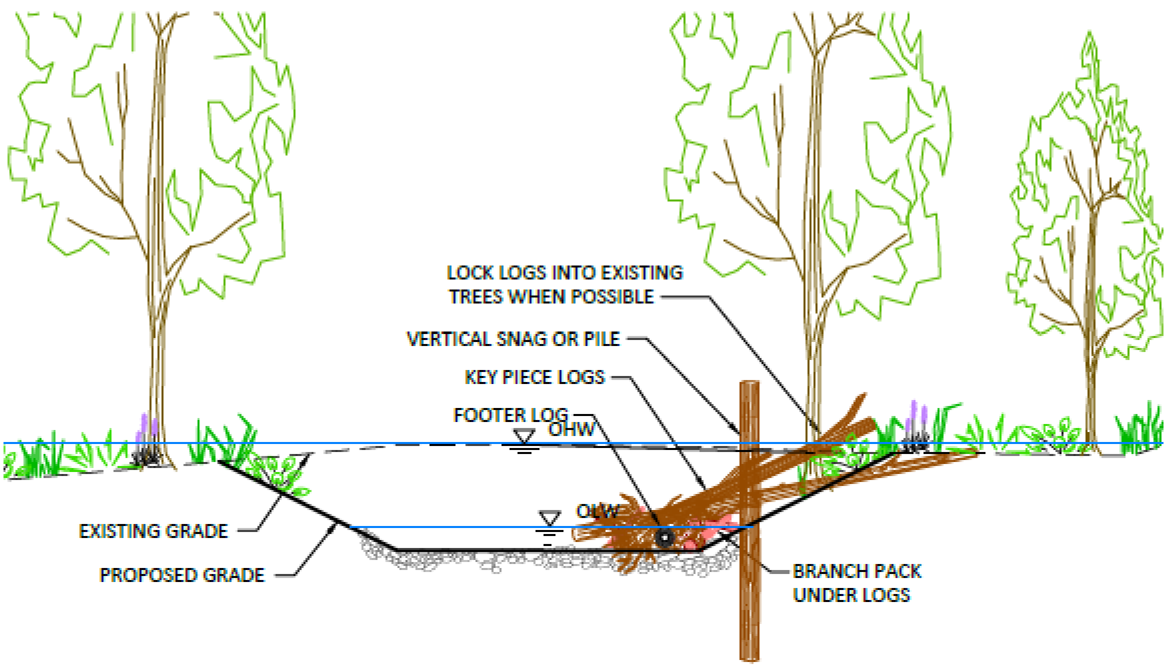

Figure 10. Typical section view showing margin LWD installed along the banks – relevant to Component 1 & 5.

3.3.2 Component 2 – Backwater Channel Enhancement

Component 2 includes the enhancement of a large existing 1,950 -foot long backwater channel below the left floodplain area (see Figure 11). Currently, the backwater is adjacent to a steep bank on the left side, and a gradual natural bank on the right side. Although existing conditions provide velocity refuge from the main channel, there is little cover in the backwater. The proposed enhancements in the backwater would increase the quality and diversity of juvenile rearing habitat over a variety of flow levels. The material excavated from Component 1 side channel construction would be placed along the north bank to create low elevation scrub-shrub environment. The complex of aquatic and wetland habitat would provide a mosaic of juvenile rearing habitat including low flow margin wood habitat and winter flood refuge habitat.

Large wood placements would consist of accumulations/jams of approximately 3 – 5 pieces per structure to provide cover and complexity to the existing habitat. There is fish access to this habitat year round, providing an opportunity to increase habitat conditions for both summer rearing and winter flood refuge. Habitat LWD placements are proposed along both the north and south sides of the backwater (see Figure 12). The side channel would be expected to primarily support juvenile rearing and adult holding for ESA-listed Chinook and steelhead. Large wood additions are intended to provide diverse channel structure and form by increasing channel margin complexity and providing cover and holding areas. The channel would provide summer-time juvenile rearing as well as over-wintering and flood refuge habitat.

Additionally, a simulated beaver dam is proposed for the upper end of that backwater channel (Figure 13). The beaver dam would help to trap sediment in a "sediment reservoir" in the upper end of the backwater channel. The beaver dam is composed of timber piles, slash and habitat logs woven together. Enhancement of the backwater area includes increasing the connectivity for fish access at lower flow periods and the addition of wood for complexity and cover. These enhancements would increase the availability of diverse low-flow rearing habitat that fluctuates with river levels. Large wood additions are intended to enhance channel structure and form, increase margin complexity, and create cover and holding pockets for fish.

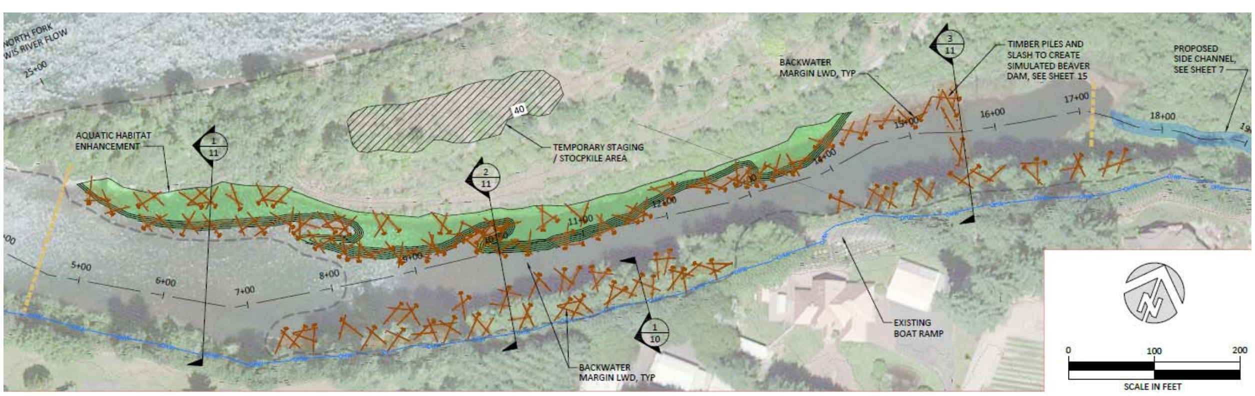

Figure 11. Component 2 Backwater Channel Enhancement.

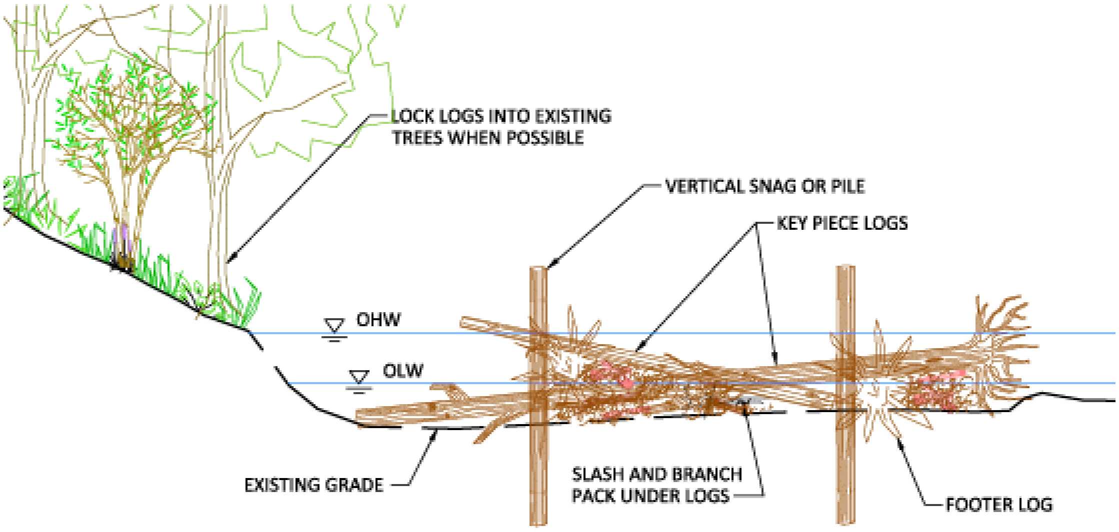

Figure 12. Typical section view of backwater enhancement LWD.

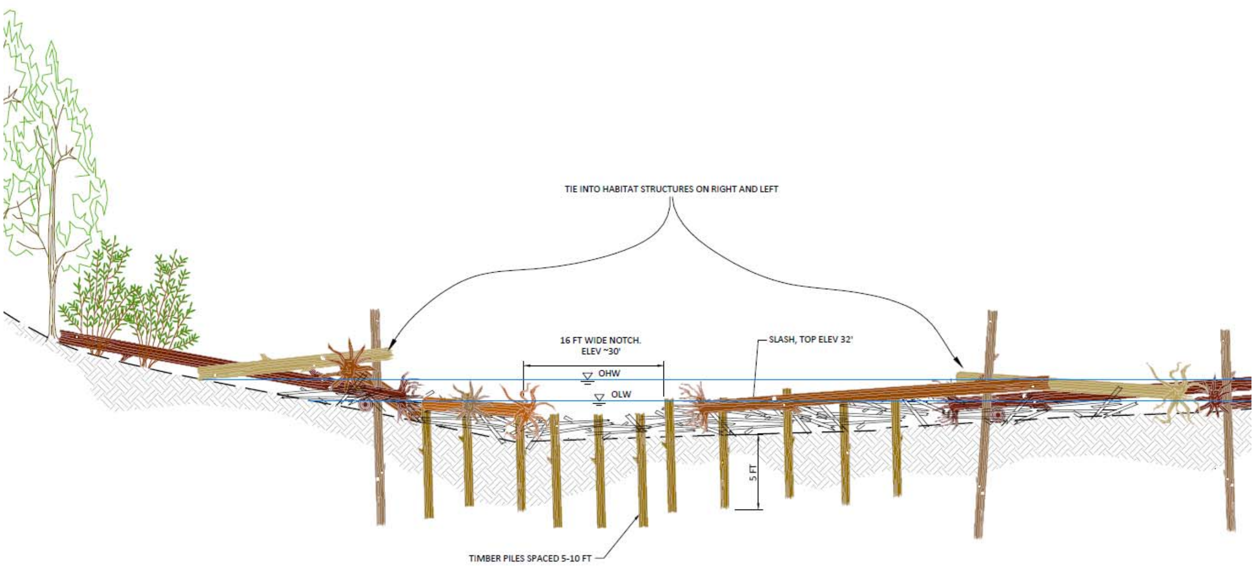

Figure 13. Section view of the proposed simulated beaver dam in the upper end of the backwater channel.

3.3.3 Component 3 – Main Channel Margin LWD

Component 3 includes margin wood enhancements increasing the amount of margin cover habitat in the mainstem (see Figure 14). As described in previous sections, historical modifications to both aquatic and upland habitats have reduced the delivery of large wood to the North Fork Lewis River. The margin LWD placements have been designed to provide habitat complexity and provide suitable rearing habitat during low flow that would historically been provided by naturally occurring LWD in the system. Furthermore, proposed LWD margin wood placement locations have been selected to avoid existing shallow shoreline high quality juvenile Chinook rearing habitat, and in consideration of recreational boat traffic in the river. The margin LWD component also includes the treatment of a section of eroding streambank downstream of the boat ramp. Treating this section of bank includes some regarding, wood placements and riparian plantings to provide stability and improve fish habitat. The proposed bank treatment would restore a native riparian community and address the sediment and erosion issues associated with the current condition.

Figure 14. Plan view showing a portion of Component 3 Main Channel Margin LWD.

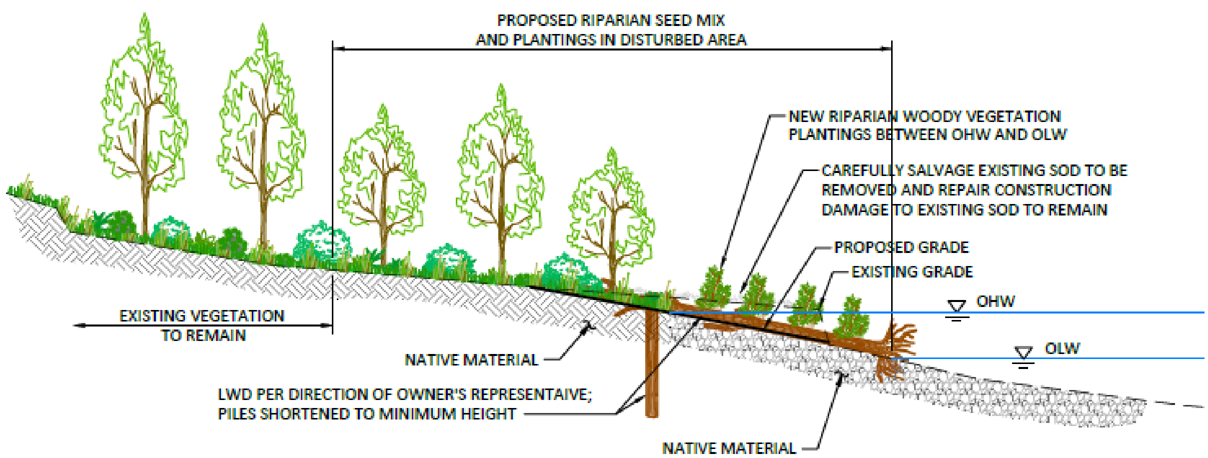

Figure 15. Typical section of Component 7 bank regarding.

3.3.4 Component 4 – Riparian Enhancement & Floodplain Roughness

Component 4 includes the restoration of more than six acres of the western portion of the floodplain (see Figure 18). This component includes both the biological elements and habitat structure through the placement of floodplain roughness wood. This portion of the floodplain is composed of a mixed community of native species and exotic invasive species. Figure 17 provides representative photos of the site, demonstrating the presence of non-native species such as Himalayan blackberry, scotch broom, and knotweed. Riparian plantings will enhance long-term riparian functions including shade, wood recruitment, and stability. Riparian restoration will occur in areas currently dominated by invasive species and within the disturbance limits of the project to ensure that disturbed areas are revegetated with native species. Riparian restoration will include removal of invasive species and planting of native riparian vegetation that is appropriate for the site. A specific, multi-year riparian restoration and maintenance plan will be developed in conjunction with the development of monitoring and performance criteria with regulatory agencies during permitting.. Maintenance of the mitigation work area will be critical to the suppression of invasive species. Reed canarygrass, Scotch broom, and giant knotweed will be the focus of maintenance procedures. Removal and offsite disposal of all infested soils is recommended. Reed canarygrass shall be suppressed through herbicide application as water levels allow, once in the spring, once in late summer prior to seed set, and once in the fall before the grass collapses. Scotch broom will be removed by hand or by mechanical means. Resprouts will be removed by hand for the duration of the monitoring period. Japanese knotweed shall be controlled through excavation and removal from the site. Regrowth will be controlled by herbicide injection or by foliar application.

Floodplain Roughness

Component 4 includes the installation of floodplain roughness LWD in order to influence geomorphic and biological processes. Floodplain roughness LWD will provide winter refuge habitat for salmonids during flood flows (see Figure 16). Additionally, the proposed roughness elements will interact with the movement of water and sediment to encourage riparian processes on the floodplain. The riparian plantings will be implemented in a way that will benefit from the effects of the floodplain roughness LWD. Roughness LWD may provide some protection from high flows and encourage fine sediment deposition and provide a boost to pedogenesis on the floodplain.

Figure 16. Installation of floodplain roughness LWD on the Cowlitz River (Inter-Fluve).

Invasive species treatment

Invasive species are a serious problem in the project area. Controlling invasives and re-establishing a native vegetation community will be an important component of this project and will support long-term ecological processes and habitat formation. Invasives present at that site include Scotch broom (*Cytisus scoparius)*, Himalayan blackberry, reed canary grass (*Phalaris arundinacea*), and Japanese knotweed (*Fallopia japonica*) (Figure 17). Removal of invasive species will require several years of effort and continued maintenance. Because the area is used frequently by the community, seeds of invasive plants will likely continue to enter the site via visitors' shoes and clothing. In addition, Japanese knotweed and reed canary grass are present in other parts of the Lewis River and these species are likely to arrive in the area from upstream sources. Finally, the BPA transmission corridor is subject to regular maintenance program and there are limitations to what activities can occur in this part of the project area. It will be necessary to work closely with the agency to ensure the planting and invasive species control efforts are compatible with BPA's operations and maintenance. Initial discussions with BPA suggest that any plantings in the transmission line corridor would need to be a maximum of 10 feet tall. To control invasives on the site various options are available, but an integrated management strategy is recommended which includes mechanical and chemical treatments timed to coincide with appropriate growing seasons, heavy mulch and dense replanting and closely monitored and maintained sites.

Scotch Broom

Scotch broom is present throughout a large portion of the project area. It occupies lower elevation areas with gravel cobble dominated substrate as well as a higher terrace area with more developed soil and conifers. Scotch broom seed bank can be viable for 5 to 60 years and seeds are easily dispersed by soil disturbance so frequent, ongoing control and minimizing soil disturbance is essential. Shade will reduce competitiveness of Scotch broom, so it will be important to replant the area with native species. Scotch broom can be removed mechanically with a weed wrench, or for plants with stems larger than 2 inches cutting and stump treating may be necessary. For the mechanical treatments, moist soils support effective removal, so spring and fall are ideal times of year. Post treatment, replace any disturbed soil and provide a thick layer (3-4") of mulch.

Himalayan blackberry

Himalayan blackberry is present in patches at the site. In areas where it is present it can be treated with fall spraying after seed set while foliage is still green, approximately late August to October. Alternatively stems can be cut and stump treated in late spring. Post treatment actions should include thick woody mulch and dense plantings of natives which form thickets, including nootka rose, salmonberry and snowberry.

Knotweed

Japanese knotweed is of special concern along the North Fork Lewis River. It has been the focus of a multi-year treatment effort in Clark County. At the site it is not yet widespread, but this plant grows aggressively and is a risk to floodplain and aquatic habitat. It forms a deep, dense rhizomatous mat.

Knottweed can reproduce through seeds and vegetatively. Dispersal of any plant part either through natural processes (e.g., flooding) or human caused processes (e.g., earth moving) can form new plant colonies. Control is primarily accomplished through herbicide application either by injection of the chemical into the stem, or foliar spraying over multiple years. Appropriate disposal of all plant parts is essential as each node of the plant is able to produce roots and new plants. Treatment includes foliar spraying or injection mid-summer through fall. Sites should be monitored in late spring for new populations.

Reed canary grass

Reed canary grass is present in patches at the site that are seasonally inundated. Shading can reduce vigor of reed canary grass and will be necessary for long term control. The location of the Component 1 side channel includes a fairly substantial reed canary grass infestation. Excavated material which contains reed canary grass should be removed from the site and this area will be replanted with native vegetation. Replanting with woody shrubs (e.g., willows) and competitive sedges and bulrushes after construction will help increase native plant diversity in the area.

Reed canary grass is also present in smaller patches at the site including the fringe around the existing backwater (zone 9) and in a small low area to the northeast of the site (zone 3). These areas could benefit from a late season spray treatment before replanting in the spring, however, the reed canary grass in these areas appears to be fairly contained and monitoring these areas may be the best approach at this time.

Maintenance

Woody species survivorship that falls below target performance standards will be replaced during the earliest appropriate planting period, typically in early spring. Should woody species experience heavy losses due to herbivory by beaver or other species, exclusion fences should be considered where appropriate. Exclusion fences should not be installed in areas prone to frequent sweeping flood flows. Fencing should be constructed of hardware cloth at least 3 feet in height, and be installed around the perimeter of planted areas.

Monitoring

Monitoring for the project area will be designed to follow the persistence, vitality, and development trends of planted vegetation and weedy species maintenance within the project area. Baseline conditions for monitoring comparison will be established in a comprehensive as-built description of wetland areas. Mitigation performance standards and specific monitoring requirements will be developed in conjunction with the regulatory agencies during the permitting process.

Figure 17. Invasive species present on site. A) Scotch broom in treatment zone 6, B) blackberry in treatment zone 1 and 2, C) knotweed present along the edge of treatment zones 8 and 9, D) reed canary grass along the Component 1 channel alignment.

Vegetation Treatment Zones

Existing vegetation zones and proposed steps for riparian enhancement and invasive species removal are detailed in Table 6. More detailed construction specifications and plant lists and quantities can be found in the Final Design drawings. Additionally, a detailed monitoring and maintenance plan will be developed in coordination with the regulatory agencies.

Table 6. Description of vegetation treatment zones.

Zone	Existing Condition	Treatment
1	Native shrubs and invasive blackberry	• Spot treat blackberry (and knotweed if present) • Prep site • Replant with native shrubs (e.g., nookta rose, snowberry)
2	Native shrub and herbaceous plants, pockets of Scotch broom, blackberry and knotweed, sandy soils, drier area.	• Remove Scotch broom, blackberry, knotweed • Prep site • Replant with upland native shrubs (e.g., snowberry, nootka rose), opportunity for conifers
3	Low, backwater area with native shrubs and reed canary grass	• If reed canary grass treatment is desired, spray or mow to inhibit growth • Replant with FACW plants (e.g., willow, dogwood, spirea)
4	Small terrace with mature firs and cedars and snowberry, sword fern. Scotch broom present. Sandy soils	• Remove Scotch broom • Prep site • Replant with upland native shrubs (e.g., snowberry, alder)
5	Evidence of high-flow paths, cottonwood overstory, minimal understory. Soils mostly sandy but variable from gravel/cobble to sandy loam.	• Treat any invasive species (minimal observed in this area)
6	Poorly developed soils, fairly open riparian area with Scotch broom	• Remove Scotch broom • Prep site • Replant (e.g., willows, dogwood, cottonwood)
7	Partially within BPA right of way, some soil development. Dense stands of Scotch broom throughout most of this zone.	• Remove Scotch broom and treat blackberry and knotweed if present • Prep site • Replant with upland/FACW shrubs (e.g., snowberry, nootka rose, oceanspray)
8	Cottonwood/alder overstory, mixed understory with natives and some invasives (blackberry, knotweed patches). Fairly well developed soils. Doug fir present.	• Treat blackberry and knotweed • Prep site • Replant with upland/FACW shrubs and trees (e.g., snowberry, nootka rose, ocean spray, alder, hawthorn), conifers likely will do well here.
9	Backwater shoreline. Mostly native shrubs (e.g., willow, dogwood) with a fringe of reed	• Monitor for reed canary grass or other invasive species (e.g., knotweed)

	canary grass. Minimal understory. Seasonally inundated. Some beaver activity.	expansion into this area. • Spot treat any knotweed present
10	Riparian buffer, including areas of BPA right of way. Poorly developed soils. Some willow, dogwood, alder present along shoreline. Scotch broom present.	• Remove Scotch broom • Prep site • Plant riparian area with cuttings (e.g., willow, dogwood)
11	Minimal soils present, primarily gravel/cobble. Few cottonwood in overstory. Scotch broom present.	• Remove Scotch broom.

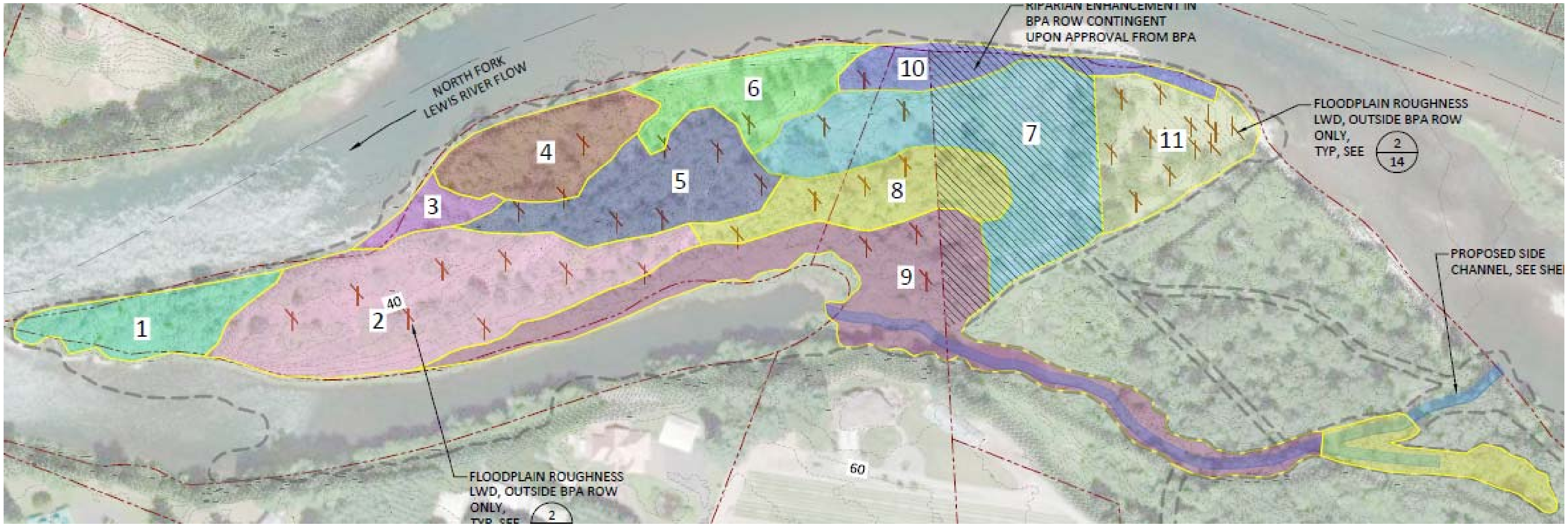

Figure 18. Component 4 Riparian Enhancement, note BPA right of way crosses this component. Note Table 6. Description of vegetation treatment zones.

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