Little Wind River

Phase 4 Habitat Enhancement

Preliminary Design Report

SUBMITTED TO
Lower Columbia Fish Recovery Board

February 7, 2017

Little Wind River
Phase 4 Habitat Enhancement
Preliminary Design Report

SUBMITTED TO
Lower Columbia Fish Recovery Board
2127 8th Avenue
Longview WA 98632

PREPARED BY
Inter-Fluve, Inc.
501 Portway Ave., Suite 101
Hood River, OR 97031

February 7, 2017

Table of Contents

1. Introduction

1.1 OVERVIEW

This report summarizes preliminary designs for aquatic habitat enhancement on the Little Wind River, a tributary to the Wind River near Carson, WA. The purpose of this project is to enhance habitat for ESA-listed Chinook salmon, coho salmon, chum salmon, and steelhead trout. The habitat objectives are to increase high quality spawning and rearing habitat by increasing channel complexity and improving floodplain and off-channel connectivity. This project builds on past habitat restoration work on the lower Little Wind River coordinated by the Underwood Conservation District. Although no formal effectiveness monitoring has occurred, observations by local biologists suggest that the past work has had a positive effect on local fish populations. This current effort begins at the upstream end of the previous work and continues upstream. This current effort is considered the fourth phase of habitat enhancement work on the Little Wind.

This report summarizes:

- Goals and objectives
- Site assessment
- Description of proposed project
- Conceptual designs
- Opinion of probable cost

1.2 BACKGROUND

This project was one of the top rated project opportunities identified in the Wind River Habitat Restoration Strategy (Strategy), which is currently in draft form (LCFRB 2017). This effort has been guided by the Wind River Work Group (WRWG), comprised of watershed stakeholders. As part of the Strategy, this project and another one on the middle Wind River have been taken forward to the Preliminary Design stage. Inter-Fluve, in cooperation with the Underwood Conservation District (UCD), has led the technical component of this design project, with guidance and support from the LCFRB and WRWG. Conceptual design alternatives were developed and presented to the WRWG to develop a preferred alternative for preliminary designs. The preliminary design process and products have been coordinated to meet the requirements outlined in SRFB Manual 18, Appendix D.

1.3 PROJECT AREA

The Little Wind River is a tributary to the Wind River in the Washington cascades range. The project area is located on private property and US Forest Service land approximately 2,000 feet upstream of the confluence with the Wind River and extends approximately 2,200 feet upstream (Figure 1). Forestry (logging and road building) is the dominant land use in the Little Wind watershed, with recreation and utility corridors also influencing stream processes. Past forestry practices have impacted streams in the watershed through timber harvest, wood removal, boulder removal, and the building of roads and bridges. This site is geomorphically dynamic with evidence of active gravel transport and bar development. Forest conditions are now dominated by early successional species with few conifers located near the channel margins.

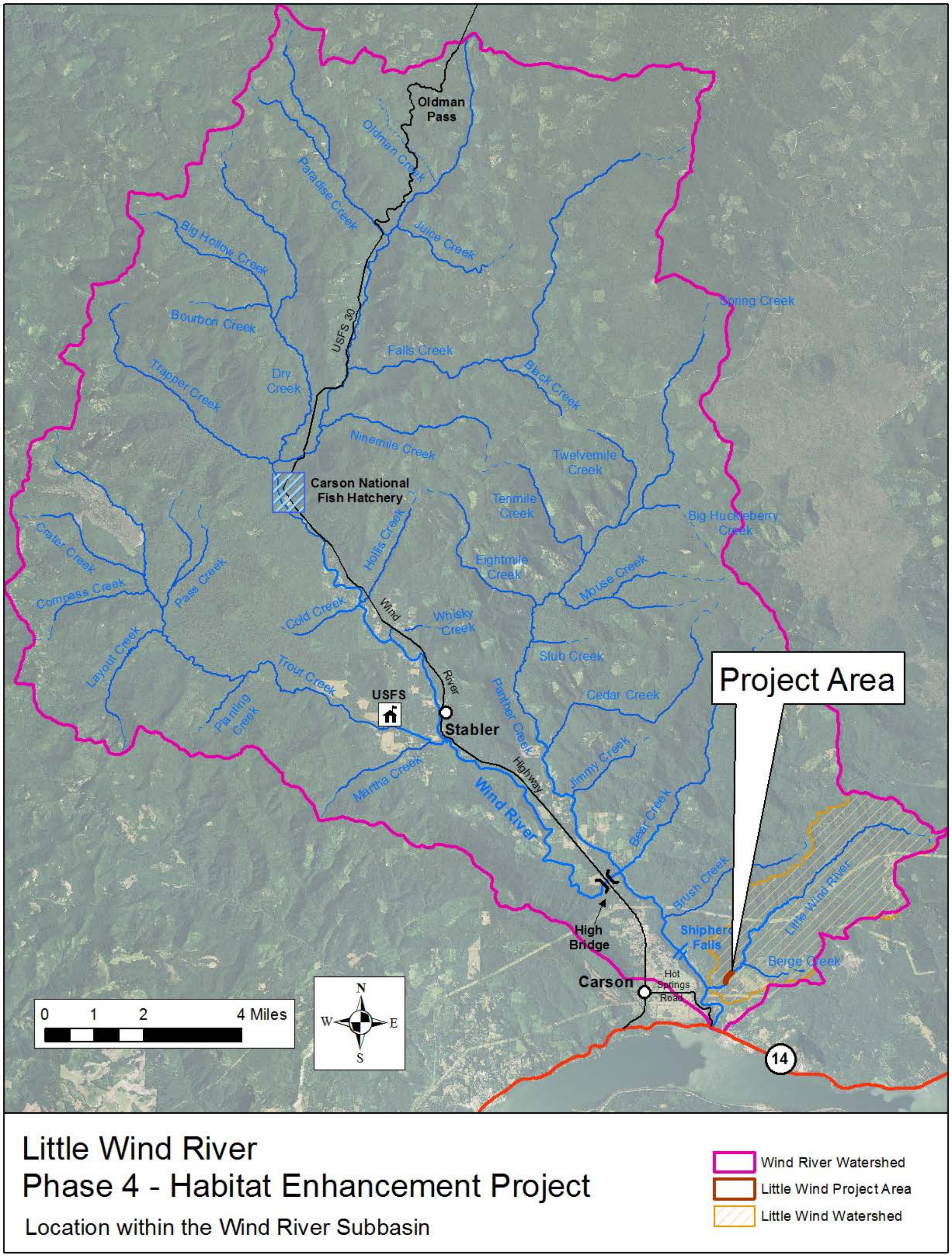

Figure 1. Little Wind River Project Location within Wind River Watershed.

1.4 GOALS AND OBJECTIVES

The Strategy identified a vision and suite of goals for restoration planning and implementation work throughout the Wind River subbasin. For this Little Wind restoration project, a subset of those goals applies. The goal for the Little Wind is to restore and enhance fish habitat and habitat-forming processes for multiple salmonid species. A suite of preliminary design objectives has been developed that fit within this goal. Preliminary design objectives have been categorized into geomorphic and habitat objectives, recognizing that they are interdependent and interrelated.

Habitat Objectives

- Increase the quantity and accessibility of juvenile rearing habitat for ESA listed species.
- Increase the amount of potential spawning habitat for ESA listed species.
- Off-channel habitat complexity – Increase the wetted area of off-channel habitat (either alcoves or flow through side-channels) at a range of flows.
- Pool frequency – Increase the number of pools per unit stream length over the reach. Design log jams and other project elements to encourage and maintain scour conditions and pool formation.
- Cover – Provide increased aerial extent of cover per unit stream length, primarily through the placement of large wood and log jams.
- Increase wood quantities to meet or exceed the NMFS standard for Western Cascades streams, which is 80 pieces per mile (>12 inches diameter; >35 feet long). This target meets or exceeds the reference quantities measured by Fox and Bolton (2007). Increase the frequency of log jams to emulate historical patterns and processes.
- Hydraulic refuge – Increase the area available for hydraulic refuge during high flow events. Accomplish this through increased stream channel structure (i.e. large wood) and increased off-channel habitat availability.
- Riparian conditions – Work closely with property owners and USFS to develop silvicultural prescriptions to thin riparian alder stands and establish conifer seedlings, providing long term wood supplies and ample shade for the project reach.
- Select installation methods that avoid or minimize negative impacts to target species, habitat, and vegetation.

Geomorphic Objectives

- Design project elements that will be geomorphically sustainable given the current and future sediment load, land use, and large wood regime.
- Channel profile – Place large wood to encourage aggradation, which will lead to measureable changes in local bed slope and more variability in bed slope throughout the reach.
- Channel planform – Place large wood to increase lateral channel dynamics through increases in sinuosity, planform complexity, and the frequency of multi-thread channel segments.
- Bed material – Encourage the recruitment and retention of gravels and the decrease of the average diameter of bed material (D50) across the reach.

- Large wood and log jams – Use constructed log jams to aggrade sediment to more frequently engage side-channels and to enhance off-channel rearing habitat and increase sorting and retention of spawning sized substrate.
- Floodplain inundation – Design project elements to increase side-channel activation at a range of flows and floodplain inundation above the channel-forming flow (Q1-2).

2. Site Surveys

As part of the Restoration Strategy development, initial surveys were performed through this reach in the summer of 2016. These surveys documented habitat conditions and identified potential project opportunities. Once the project was selected for design, further surveys were performed to serve as the basis to develop a suite of conceptual restoration alternatives, identify key feasibility constraints, and identify access options to implement designs. The current condition of past restoration work in the downstream reach was also observed in order to understand stream channel response to inform the designs.

Topographic surveys were performed of the site in October 2016 using RTK GPS and total station survey to support design and hydraulic analysis. The area surveyed included approximately 2,200 feet of the Little Wind River upstream of the 2012 restoration project boundary. Surveys focused on collecting cross-sections of the channel, which were combined with LiDAR data in overbank areas for hydraulic analyses.

3. Site Conditions

3.1 OVERVIEW OF WATERSHED AND STREAM HABITAT CONDITIONS

The Little Wind watershed is primarily managed for commercial forestry and recreation. The US Forest Service manages approximately 85% of the watershed including a portion of the land within the project area. Private timber lands are located within the downstream portion of the project area. Past forest practices have impaired fish habitat by modifying stream flow, increasing fine sediment, and removing large conifers from the riparian zone.

The stream channel within the project reach is moderately confined and incised down to large, immobile substrate or bedrock. There is low large wood abundance, except where it has been artificially increased as part of past restoration work just downstream of the project area. The project reach consists of a mix of small to medium (0-12 in dbh) hardwood and coniferous forest in the valley bottom and medium-aged (8-24 in dbh) Douglas fir forest on the adjacent hillslopes. The valley-bottom forests are dominated by alder, with little undergrowth of conifers. Riparian conditions are affected by the natural gas pipeline corridor, which is regularly cleared of woody vegetation. There are several locations of mass wasting within the project reach, and these areas are generally related to past or on-going vegetation clearing.

In the habitat assessment performed as part of the Wind River Restoration Strategy, the reach that encompasses the project area was rated as either fair or poor for Pools, Large Wood, Off-Channel Habitat, and Fine Sediment.

3.2 GEOMORPHIC CONDITIONS

3.2.1 Historical geomorphic conditions

The geomorphic and habitat characteristics of the Little Wind River have changed dramatically since European settlement. Historically, mature conifers within the riparian zone provided a source of rot resistant large wood that fell within the narrow valley and provided channel grade control. Downed large wood reduced flow energy, increased the wetted width, provided channel complexity, and promoted floodplain connectivity. The historical channel was likely elevated above its current grade by a few feet.

3.2.2 Current geomorphic conditions

The streambed within the project site is armored with large cobble and boulder sized material and bedrock contacts are exposed at many locations. The channel has cut down to a base level of non-erodible sediments. Since vertical erosion is resisted by non-erodible sediments, lateral channel migration has produced landslides that are evident throughout the project reach. There is also evidence of active gravel transport, likely sourced from landslides, where gravel sized material has deposited along channel margins and mid-channel bars. Figure 2 displays finer grained bar deposits adjacent to large cobble located within the active channel bed. Forest conditions are now dominated by early successional species with few conifers located near the channel margins.

Figure 2. Mid-Channel Bar Formation

Approximately 2,200 feet of the Little Wind River are contained within the project site at an average gradient of 3.0%. The Little Wind River generally flows from the northeast to southwest through the project reach. It is primarily a single thread channel throughout the entire project reach except for three short split flow segments separated by mid-channel bars.

The downstream end of this project slightly overlaps the upstream end of the previous Little Wind restoration project. The previous phase Sta. 18+50 approximately corresponds to Sta. 0+00 for this Phase 4 project. Stationing references hereafter are referenced for the Phase 4 project and are depicted on the preliminary design drawings. A high flow channel inlet is located near Sta. 1+50 within a vegetated bar on river-left. This high flow channel extends downstream of the Phase 4 project and its outlet is located near the existing footbridge that crosses the channel. Previous phases log jams are located on the right bank near Sta. 0+00 and on the left bank near Sta. 1+00.

Another high flow channel is located on river-right between Sta. 4+00 to 1+00. The high flow channel is generally aligned along the valley toe within a vegetated bar and displays an alternating bar configuration. Naturally recruited pieces of large wood are located on the right and left channel margins near Sta. 3+50 as shown in Figure 3. The channel displays plane-bed characteristics despite the existence of large wood along the margins.

Figure 3. Existing Large Wood Located Near Sta. 3+50

The channel is very confined between Sta. 4+00 and 6+50 with little or no floodplain adjacent to the active channel margins. This section displays plane-bed channel characteristics as shown in Figure 4. The channel returns to an alternating bar configuration upstream of Sta. 6+50. A vegetated bar is located on river-left between Sta. 6+50 and 9+00 and a near vertical bank is located on river-right through this reach. Bedrock contacts were observed near Sta. 8+50 and an existing pool is present near Sta. 8+00. Figure 5 shows the existing pool near Sta. 8+00, the almost vertical bank located on river-right, and the vegetated bar on river-left.

Figure 4. Plane-bed Reach Between Sta. 4+00 and 6+50.

Figure 5. Pool Located Near Sta. 8+00.

The valley constricts near Sta. 8+50 and another alternating, vegetated bar is located on river-right between Sta. 8+50 and 11+00. This right bank bar is activated during flood flows and the channel through this reach is characterized as plane-bed with boulder/cobble substrate. An image of the plane-bed channel and vegetated bar near Sta. 10+00 is provided in Figure 6. A mid-channel bar splits low flow near Sta. 11+00, which is shown in Figure 2. A gas line crosses the Little Wind River near Sta. 11+25.

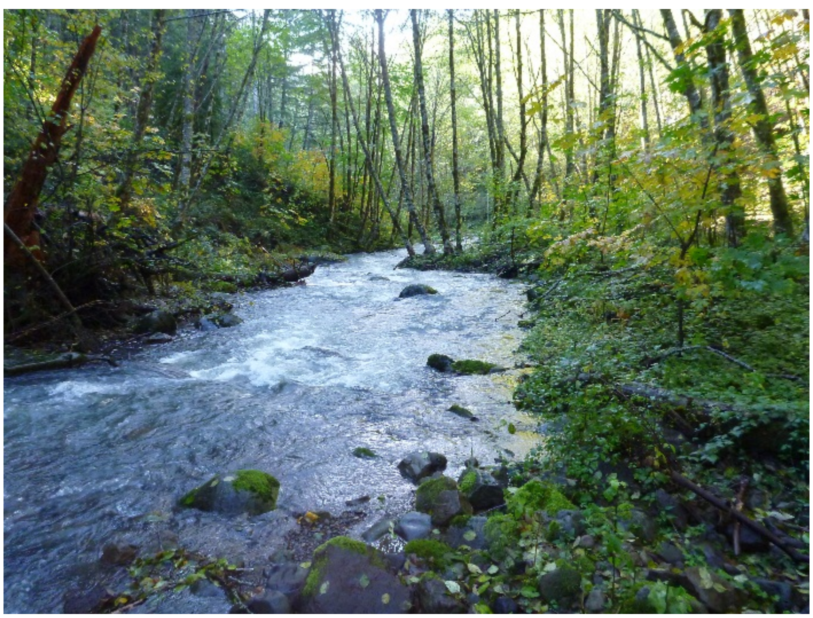

Figure 6. River-right, Vegetated Bar Near Sta. 10+00.

There is a high flow channel near the valley wall and a vegetated bar on river-right between Sta. 11+50 and 13.50. Exposed gravel was observed in the high flow channel suggesting annual inundation. The valley constricts close to Sta. 13+80 and a mid-channel, vegetated bar is located between Sta. 14+00 and 14+60 (Figure 7). There is another plane-bed reach with little flood prone area along the channel margins between Sta. 15+00 and 18+00. This section includes a higher right bank terrace between Sta. 16+00 and 18+00. An existing piece of large wood is present on the right bank near Sta. 17+50 (Figure 8).

Figure 7. Valley Constriction and Upstream Mid-Channel Bar Near Sta. 14+00.

Figure 8. Plane-bed Reach, Sta. 15+00 to 18+00.

A channel constriction resulting from a near vertical bank located on river-left and an existing woody debris deposit on river-right is located near Sta. 18+00. There is a short split flow segment between Sta. 18+00 and 20+00 where a vegetated mid-channel bar creates flow separation (Figure 9).

The upstream end of the project reach (Figure 10) expands from an upstream valley-wide constriction where there is little to no active floodplain. The floodplain expands to a densely vegetated bar on river-right and an active slide area on river-left. The active slide area around Sta. 20+00 to 22+00 has contributed several large trees to the stream channel that have captured and sorted gravels and created a more sinuous channel through this segment.

Figure 9. Split Flow near Sta. 18+00.

Figure 10. Valley-Wide Constriction Near at Sta. 23+00.

4. Hydrology & Hydraulics

4.1 HYDROLOGY

4.1.1 Hydrologic Setting

The Little Wind River is a tributary to the Wind River, with a watershed area of 9.1 square miles upstream of the project site. The Little Wind River watershed extends from an elevation of approximately 2,400 feet above sea level at its headwaters to 90 feet at the confluence with the Wind River. The project area ranges from approximately 140 to 200 feet in elevation. The watershed receives 69 inches of rain annually on average. Snowfall is light due to mild winters and the relatively low elevation of this watershed, and rain on snow events do occasionally occur.

4.1.2 Peak Flow Analysis

A hydrologic analysis of the Little Wind River was conducted in order to estimate the magnitude of peak flow events for several standard recurrence intervals (2-, 10-, 25-, 50-, and 100-year). A standard method of peak flow estimation for a range of recurrence intervals is regional regression curves that estimate stream discharge for several recurrence intervals based on multiple basin characteristics. The USGS StreamStats web interface was utilized to determine basin characteristics and to compute the regression curves. Washington StreamStats uses the regression equations developed by Mastin et al. (2016). Using the StreamStats program, a downstream flow point was located at the downstream extent of the project site. Peak flow estimates were generated for several recurrence intervals (Table 1).

Table 1. USGS StreamStats Regional Regression calculations for the Little Wind River at the downstream end of the project site. Basin area is 9.11 square miles.

	Recurrence Interval				
	2-year	**10-year**	**25-year**	**50-year**	**100-year**
Flow (cfs)	373	681	855	989	1,130

4.2 HYDRAULICS

The U.S. Army Corps of Engineers Hydraulic Engineering Center River Analysis System (HEC-RAS 5.0.3) was used for hydraulic modeling. HEC-RAS was used to perform hydraulic computations including estimates of water surface elevations, lateral inundation extent at a cross-section, velocity, and shear stress for discharge values under existing and proposed conditions.

4.2.1 River Geometry

Existing conditions model geometry was developed using topographic data obtained through surveys completed in October, 2016 combined with LiDAR of the greater area. Hydraulic cross-sections were surveyed perpendicular to the primary flow vector across hydraulic controls such as riffle crests. Out of channel data was collected as lines of points along major slope breaks, or as gridded points covering larger areas of ground. Survey data were supplemented with 2015 LiDAR data (DOGAMI 2016) laterally from surveyed cross section extents. The LiDAR and survey data were post-processed in AutoCAD to create a 3-dimensional surface of site topography as the basis for the HEC-RAS river geometry.

4.2.2 Model Discharges

Only peak flows were modeled for preliminary project design. These flows include discharge estimates for the following recurrence interval floods: 2-, 10-, 25-, 50-, and 100-year. The discharges and methods for estimating them are presented in Section 4.1.2.

4.2.3 Manning's Roughness Coefficients and Boundary Conditions

Hydraulic roughness for the three reaches was determined based on several contributing factors including the shape of the channel and degree meander, obstructions within the channel, the type and size of bed material, and vegetation (Arcement and Schneider 1989). Existing conditions modeled roughness coefficient values generally correspond to the values are displayed in Table 2.

Table 2. Manning values for existing conditions HEC-RAS modeling.

Modeled feature	Mannings Value
Left Bank Floodplain	0.10
In-channel	0.07
Right bank floodplain	0.010

Proposed conditions log jams were modeled as blocked obstructions. The blocked obstruction generally included raising the channel bed 24 inches where channel spanning log jams are anticipated to aggrade gravel, and at lateral channel margins where proposed log jams are anticipated to obstruct flow. Channel roughness was kept the same for existing and proposed conditions. The existing channel conditions include a highly irregular bed due to the presence of randomly located large boulders. Proposed conditions will include more irregularity imposed by proposed log jams, but less irregularity where gravel deposits, reducing the irregularity associated with randomly spaced boulders. In areas where extensive floodplain wood placements are proposed, roughness values were generally increased to a value of 0.12.

4.2.4 Model Results

Model results were used to understand the existing hydraulic conditions operating at the site and to predict the effects of the proposed project. The results are also used to help inform the potential for movement of placed elements (e.g. large wood and log jams), the potential risk to infrastructure or property, and any measures that may need to be taken to address this risk.

Model results indicate that under existing conditions, most of the flow is contained within the bankfull channel at the 2-YR recurrence interval flow. Under proposed conditions, there is greater floodplain inundation at low to moderately-sized floods, suggesting that the project will help to reconnect the floodplain and re-activate side-channels and floodplain habitat features. Additional detailed survey and modeling may be required as part of the final design phase depending on final specific log jam construction methods, locations, and configurations.

5. Alternatives Evaluation

At the concept stage, two alternatives were considered; these included construction of the project using ground-based machinery and construction of the project using a helicopter-based approach. Basic information (pros, cons, etc) and drawings were provided for these approaches and they were discussed with the WRWG and project landowners in the fall of 2016.

One of the primary considerations in the alternatives evaluation was site access. Using a ground-based approach is feasible but challenging. If the site were accessed from the downstream end, near the upper end of the previous project, there would likely need to be at least 10 stream channel crossings developed for an excavator to access the length of the site and to deliver logs throughout the site. There would also be impacts to riparian vegetation associated with the access routes. There are potentially other access routes into the stream valley, including old grown-over forest roads and the natural gas pipeline, but these are not straightforward as they traverse challenging terrain, have their own suite of impacts to existing vegetation, and have potential landowner and infrastructure constraints. Using ground-based machinery does open up other potential options for log jam placement and channel work, including the option of performing work very similar to the previous work on the lower reaches, which not only included log jam construction but also included digging scour pools, creating riffles, and placing spawning gravels.

In contrast, the helicopter approach allows for the placement of large whole trees. Placing larger trees, combined with hand-felling of site trees, reduces the need for artificial anchoring, reduces impacts during construction, and in many ways allows for a more streamlined, quicker, and possibly more cost effective approach. The types of jams that can be constructed using the helicopter approach also help to directly achieve the habitat and geomorphic objectives of the project, which are focused primarily on complexity and floodplain/off-channel habitat reconnection. For these reasons, the WRWG, as well as the primary landowners at the site, selected the helicopter approach to advance forward to Preliminary Design.

6. Project Design

6.1 PRELIMINARY DESIGN CRITERIA

As set of preliminary design criteria have been developed to guide the preliminary design process and to ensure that project objectives are achieved and project constraints understood and explicitly addressed. Development of this design is based upon: 1) Wind River Work Group vision and goals for habitat work, 2) additional information obtained from site surveys, and 3) coordination and communication with stakeholders. It is anticipated that these design criteria will continue to be refined throughout the final design phase. Preliminary design criteria are provided below – by necessity and intention, there is some overlap with the geomorphic and habitat objectives stated earlier in this report:

- Place large wood structures in locations where floodplain and side-channel activation is maximized, including the upstream end of existing floodplain surfaces and just downstream of potential floodplain flow paths.
- Size structures to increase side-channel activation at a range of flows and floodplain inundation above the channel-forming flow (Q1-2).
- Design resilient project conditions that will withstand the predicted hydraulic effects of flood events.
- Design structures to have one to four coniferous logs with minimum 24” diameter and 70 feet in length to build grade, enhance lateral channel dynamics, and activate floodplains and side-channels.
- Utilize whole trees where possible to maximize stability, habitat, and complexity. Whole trees have a high probability of being caught within the existing floodplain forest if mobilized during a large flood.
- Design structures to have nine to twelve smaller diameter logs, up to 18” DBH, placed in the streambed to retain sediment over the existing substrate.
- Utilize logs that have intact rootwads that provide stability and create complex pool habitat.
- Place slash within and at upstream face of jams to seal jams and enhance the flow obstruction component of the jams.
- Increase wood quantities to meet or exceed the NMFS standard for Western Cascades streams, which is 80 pieces per mile (>12 inches diameter; >35 feet long).
- Increase hydraulic roughness in the floodplain to reduce the potential for new channels to re-incise into the floodplain.
- We assume that boat use in the project reach is insignificant or non-existent

6.2 DESCRIPTION AND BENEFITS OF PROPOSED FEATURES

The proposed project consists of large wood installations utilizing a combination of helicopter log placements and a ground-based hand crew. Wood placements will consist of structures ranging in size from a few to over a dozen pieces of wood of different sizes. These structures will primarily be located in the main channel at strategic locations to initiate floodplain and side-channel activation, but will also include wood that extends into the overbank and floodplain areas. In general, there is a layering concept to structure construction. The first layer is composed of smaller riparian deciduous trees such as alders that are felled into the channel on-site by hand crews. This will be accomplished using chainsaw winches, grip hoists, come-alongs, etc. Only a portion of the riparian deciduous trees will be used in order to leave adequate shade, nutrients, and bank stability. Next, the helicopter will place larger trees, with a target minimum size of approximately 24 inches diameter and 70 feet long. Ideally these are whole trees or at least with some branches intact, and to the extent possible, with attached rootwads. The final layer includes placement of slash or smaller trees on top, within, and on the upstream face of the structure, which would likely occur using a combination of helicopter placements and hand-crew placements. In general, the large pieces dropped by helicopter provide stability to the structure, while the smaller material adds complexity and helps “seal” the structure to enhance the hydraulic effects of the structure. Using this construction approach is intended to minimize both cost and disturbance to the streambed and riparian zone.

Adding key pieces of large wood and log jam structures will create instream structure and habitat complexity that mimics the historical conditions to which local fish populations have adapted. Logs placed in the channel will be both on the channel margins and span the channel to slow water, promote sediment aggradation, and create habitat. Log structures are expected to trap gravel and gradually raise the channel grade to address existing incision and floodplain disconnection. The structures will create multiple flow paths where there is now just one. There are several opportunities for activating and re-connecting off-channel habitat including wall-based channels, backwater alcoves, and flow-through side-channels so that they are more frequently inundated and accessible to fish.

Log placements will also extend into and throughout the floodplain. Floodplain logs will increase floodplain roughness to emulate historical conditions and will help to control for the potential for future channel incision should the channel avulse and change course into the floodplain.

The log placements are anticipated to resemble log jams placed in Cameron Creek in 2016, as shown in Figure 11 below.

Figure 11. Helicopter placed log structure in Cameron Creek, tributary to Abernathy Creek, southwest WA, 2016.

The preliminary strategy is to acquire logs from private lands near the area as well as from the margins of the gas pipeline corridor within private and federal lands adjacent to the site. Preliminary discussions have taken place with landowners and the pipeline, but more coordination will be necessary with landowners and Williams Pipeline in the final design stage to manage pipeline safety/encroachment agreement needs during project construction.

6.3 ENGINEERING AND STABILITY CONSIDERATIONS

The length of large wood and the use of whole trees with intact rootwads is a primary consideration for stability for this project. Stability will rely on large wood size classified as key pieces as defined by Fox and Bolton (2007), and referenced in the Washington State Stream Habitat Restoration Guidelines (Cramer 2012). The design will also utilize smaller wood size classifications that are anticipated to be pinned down or trapped by larger key pieces. This design acknowledges that wood may move from its placed location, but will not travel far downstream to create an infrastructure problem based on channel widths and large wood length with intact rootwads.

The key piece criteria provides a minimum volume, diameter, and length based on average bankfull width. The preliminary design assumes that the 2-year recurrence interval flow top-width represents bankfull width. Using the 2-year recurrence interval flow top-width assumption, bankfull width was found to be just under 50 feet (15 meters). For a 10 to 15 meter bankfull width, minimum key piece volume is 6.0 cubic meters (7.8 cubic yards), which also corresponds to a minimum diameter of 2 feet and minimum length of 70 feet. The minimum key piece criteria produces a weight that is very close to the maximum payload capacity of 10,000 pounds of a dual rotor Vertol helicopter. It is not likely that enough wood can be sourced that is over the minimum key piece criteria yet still under the Vertol payload capacity. Thus, a Chinook dual rotor helicopter with a payload capacity of 26,000 has been assumed for design implementation. Preliminary investigations and past experience suggest that the equipment and materials needed for this project are reasonable to achieve, but the approach will depend upon the project sponsor's ability to effectively secure these.

6.4 OPINION OF PROBABLE COST

Costs associated with construction, permitting, and design services for the Little Wind River project have been developed with assumptions for helicopter operations and ground-based operations as shown on the drawings. The cost opinion is provided in Table 3.

Table 3. Opinion of Probable Cost.

Preferred Alternative					
Assumes wood stockpiled near the construction site and placed with helicopter.					
Construction oversight expenses not included					
Assumes revegetation stock/effort completed by Sponsor					
Location	**Item**	**Unit**	**Qty**	**Unit Cost**	**Total**
Site-wide	Mobilization	LS	1	$30,000	$30,000
Helicopter Wood Placements	Helicopter placed logs	LS	1	$81,000	$81,000
	Owner cost to provide Douglas-fir key piece	EA	60	$1,200	$72,000
Hand Crew Wood Placements	Small diameter wood	EA	100	$400	$40,000
	Slash	CY	200	$50	$10,000
	Construction subtotal				**$233,000**
	State Sales Tax (7.7%)				**$17,941**
	Construction cost				**$250,941**
	Permitting				**$20,000**
	Final Design				**$25,000**
	Construction Oversight				**$15,000**
				Total	**$310,941**

7. References

Arcement, G.J. and V.R. Schneider. 1989. Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains. U.S. Geological Survey Water-Supply Paper 2339.

Cramer, Michelle L. (managing editor). 2012. Stream Habitat Restoration Guidelines. Co-published by the Washington Departments of Fish and Wildlife, Natural Resources, Transportation and Ecology, Washington State Recreation and Conservation Office, Puget Sound Partnership, and the U.S. Fish and Wildlife Service. Olympia, Washington.

Fox, M.J. and S.M. Bolton. 2007. A regional and geomorphic reference for quantities and volumes of instream wood in unmanaged forested basins of Washington State. North American Journal of Fisheries Management 27:342-359.

Mastin, M.C., C.P. Konrad, A.G. Veilleux, and A.E. Tecca. 2016. Magnitude, frequency, and trends of floods at gaged and ungaged sites in Washington, based on data through water year 2014 (ver 1.1, October 2016): U.S. Geological Survey Scientific Investigations Report 2016 - 5118, 70 p.

Oregon Department of Geology and Mineral Industries (DOGAMI). 2016. 2015 LiDAR dataset for the Wind River subbasin obtained from DOGAMI fall of 2016.

Schuett-Hames, D.A., J. Pleus, M. Ward, M. Fox, and J. Light. 1999. TFW Monitoring Program Method Manual for the Large Woody Debris Survey. Prepared for the Washington State Department of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-004. DNR #106.