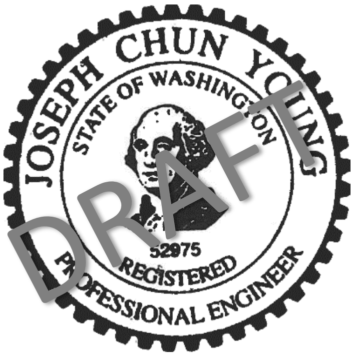
Lower Chiwaukum Creek Habitat Improvement Project
Basis of Design Report (30% Design)

For Cascade Fisheries
May 12, 2023



Applied Science & Engineering

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

BOD – Basis of Design

BPA – Bonneville Power Administration

CF – Cascade Fisheries

CFS – cubic feet per second

CWA – Clean Water Act

DTM – digital terrain model

FEMA – Federal Emergency Management Agency

GPDSR – General Project and Data Summary Requirements

HIP – Habitat Improvement Program

NHPA – National Historic Preservation Act

ODEQ – Oregon Department of Environmental Quality

ODFW – Oregon Department of Fish and Wildlife

ODSL – Oregon Department of State Lands

SHPO – State Historic Preservation Office

RRT – Restoration Review Team

SWCD – Soil and Water Conservation District

USACE – U.S. Army Corps of Engineers

USFS – U.S. Forest Service

WSEL – water surface elevation

1 INTRODUCTION

Rio Applied Science and Engineering (Rio ASE) has prepared this 30 Percent Basis of Design Report (report) for Cascade Fisheries. This report provides a summary of our findings pertaining to the existing conditions of Chiwaukum Creek located near Leavenworth, Washington, and an explanation of the design process, analyses, and outcomes for the proposed restoration design.

Rio ASE organized the following sections of this report to describe the project scope and design approach. This report is submitted to satisfy the 30 Percent design review. The conditions of the project reach are described in terms of processes that shaped the stream and associated ecosystem. This includes discussions on hydrology, hydraulics, habitat, and geomorphology. The evaluation and consideration of the site conditions provide the basis for the project stream and floodplain restoration design.

1.1 Project Responsible Parties

- The project sponsor is Cascade Fisheries and the project manager is Jason Lundgren, 509-476-3444.
- The design consultant is Rio ASE and the engineer of record is Joe Young, 208-484-4700.

1.2 Site Location

Chiwaukum Creek is a perennial stream in the upper Wenatchee River watershed in Chelan County, Washington. The project is located approximately 11 miles north of Leavenworth, Washington at the confluence with the Wenatchee River extending upstream on Chiwaukum Creek approximately 1.5 miles along the Tumwater Campground managed by the U.S. Forest Service (USFS).

Figure 1-1. Vicinity map.

2 PROJECT BACKGROUND

Cascade Fisheries has been actively working in concert with the USFS to improve aquatic habitat, floodplain connectivity, and decreased flood risk on Chiwaukum Creek so that the USFS can reopen the Tumwater Campground, which has been closed since 2015 due to risk of debris flows and flooding resulting from conditions created by the Chiwaukum Fire in 2014.

Chiwaukum Creek is an important perennial stream that provides cold water spawning and rearing habitat for ESA-listed species in the upper Wenatchee River watershed. Chiwaukum Creek has been negatively affected by roads (Highway 2 and other road networks), logging, and the Tumwater Campground. In general, these developments and activities have constrained habitat and habitat-forming processes in Chiwaukum Creek and adjacent floodplains, thereby resulting in reduced salmonid habitat quantity and quality. Despite these impacts, cold water from Chiwaukum Creek provides valuable summer thermal refuge for migrating Chinook Salmon in the otherwise temperature-limited Wenatchee River.

2.1 Environmental Setting

Chiwaukum Creek originates from Cup Lake in the Alpine Lakes Wilderness and drains into the Wenatchee River at Tumwater Campground. The total drainage area is approximately 48 square miles. The channel form is defined by a steep, confined, primarily step-pool channel morphology (Montgomery and Buffington, 1997). Step-pool channels are generally characterized by a high gradient, with a supply-limited sediment transport regime and a relatively high stream power that has also been confirmed in the watershed by past stream surveys (Raekes et al., 1993). As shown in Figure 2-1, the 1955 aerial photo reveals significant clearing on the left (eastern) side of lower Chiwaukum Creek. By 1966, roads associated with Tumwater Campground were built on the right (western) side of the creek and evidence of a flood and associated split flow is visible on the left (eastern) floodplain. In the 1960s, Tumwater Campground was constructed on the right (western) side of the creek in the floodplain, removing riparian vegetation, modifying existing side channels, and reducing the potential for floodplain activation during high flows.

The Chiwaukum Fire in July 2014 burned over 13,000 acres in the Chiwaukum Creek drainage. A handful of landslides have been mapped in the watershed, which have the potential to episodically deliver large volumes of sediment to the system. Likewise, following the 2014 Chiwaukum Creek fire, several small debris flows occurred (BAER 2014, and visible in 2015 aerial imagery). Most of these post-fire debris flows were small-scale, originating from cumulative hillslope runoff and erosion rather than deep-seated rotational mass-wasting. Regardless, based on aerial photo review, it appears that sediment from tributaries temporarily dammed the main-stem Chiwaukum in at least one location for a period of time.

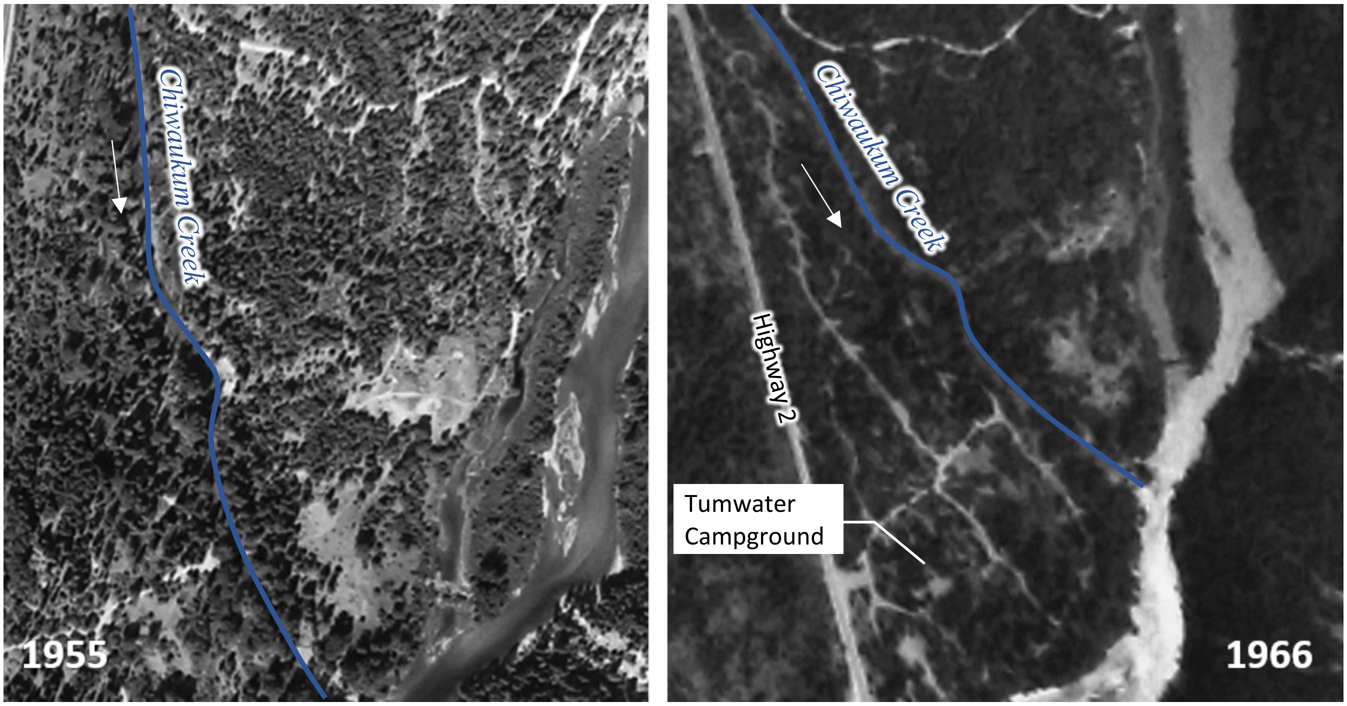

Figure 2-1. Historical aerial photography of Lower Chiwaukum Creek.

2.2 Project Goals and Objectives

The project is centered on two interconnected goals:

1) To restore and enhance spawning and rearing habitat for all species of salmonids in Lower Chiwaukum Creek and the adjacent Wenatchee River, and
2) To improve the Tumwater Campground layout to accommodate habitat restoration and mitigate flood risk to the extent practical.

To achieve these goals, the project has five main objectives:

1) Increase roughness and structure in Chiwaukum Creek, enabling increased water surface elevations for greater floodplain connection, side channel activation, sediment sorting and debris accumulation, habitat diversity, and channel dynamics supporting salmonid rearing and isolated spawning.
2) Improve adult holding habitat within Chiwaukum Creek by creating pools with cover.
3) Improve fish passage into Chiwaukum Creek by concentrating flow at strategic locations to promote scour pool formation at the confluence with the Wenatchee River where a steep and coarse alluvial bar/fan exists which is speculated to inhibit passage at low flows due to shallow water depth.
4) Improve holding habitat in the Wenatchee River by adding structure and cover within a known cold-water plume originating from the mouth of Chiwaukum Creek and extending downstream within the Wenatchee River.
5) Identify and decommission areas within the Tumwater Campground that have high flood risk and allow existing side channels in these areas to activate more frequently.

Project objectives will be achieved by three key proposed actions:

1) Install large woody debris structures within Chiwaukum Creek to achieve Objectives 1, 2, and 3.
2) Install large woody debris structures within the Wenatchee River to achieve Objective 4.
3) Remove campground amenities including asphalt roads, campsites, and utilities in the low-lying floodplain areas at the downstream portion of the campground and excavate channels at existing road crossings to allow activation of existing high-flow side channels to achieve Objective 5.

3 EXISTING CONDITIONS

3.1 Hydrology

The Chiwaukum Creek watershed is approximately 48 square miles starting at an elevation of 8,070 ft down to the confluence with the Wenatchee River at 1,670 ft. The watershed is heavily forested (77% forest) and relatively steep (84% of the watershed area over 30% slopes) with large, burned areas from historic fires (the most recent and largest in 2014).

3.1.1 Annual Peak Flows

Flood recurrence intervals in Chiwaukum Creek were estimated using regression equations adapted from U.S. Geological Survey (USGS) StreamStats based on drainage area and annual precipitation averages. Gages used to develop the regression equations include Icicle Creek (12458000), Stehekin River (12451000), Railroad Creek (12451500), Twisp River (12448998), White River (12454000), Chiwawa River (12456500), Wenatchee River (12455000 and 12457000), Methow River (12447383), Chewuch River (12448000), and Andrews Creek (12447390). These gages were selected based on similar location and/or drainage areas. Area and precipitation exponents were determined by a best fit curve. Estimated recurrence interval flows for Chiwaukum Creek are summarized in Table 3-1.

Table 3-1. Chiwaukum Creek Percent Exceedance and Recurrence Interval Flows

Percent Exceedance	Recurrence Interval (yrs)	Chiwaukum Creek Flow (cfs)
99.5%	1.005	598
99.0%	1.01	652
95.0%	1.05	825
90.0%	1.1	943
80.0%	1.25	1,111
66.7%	1.5	1,294
50.0%	2	1,536
42.9%	2.33	1,621
20.0%	5	2,067
10.0%	10	2,399
4.0%	25	2,857
2.0%	50	3,225
1.0%	100	3,608
0.5%	200	3,939
0.2%	500	4,446

The project area's proximity to the confluence with the Wenatchee River suggests that the project site has the potential to be influenced by a backwater effect at high flows, especially if a high flow in Chiwaukum Creek occurs during high water on the Wenatchee. Data from the Wenatchee River near Plain (12457000) gage, and a downstream gage near Peshastin (12459000) were used to estimate recurrence interval flows upstream of Chiwaukum Creek. The Wenatchee at Plain gage? has a drainage area of 597 square miles and the gage at Peshastin has a drainage area of 1,000 square miles, while the drainage area in the Wenatchee immediately upstream of Chiwaukum Creek is 616 square miles. Recurrence intervals at the gaged sites were calculated using

PeakFQ, which implements the Bulletin 17C procedures for flood-frequency analysis to calculate the Pearson Type III distribution of annual flood peaks. Flood recurrence intervals in the Wenatchee at Chiwaukum Creek were then estimated by averaging a linear interpolation based on drainage area between the Wenatchee River at Plain and the Wenatchee River at Peshastin for a given recurrence interval (Table 3-2). While it is likely that the Wenatchee will experience high flows within the same time period as Chiwaukum Creek, it is unlikely that the two will peak at the same time due to the difference in drainage area and basin characteristics. For hydraulic modeling purposes, a given recurrence interval in Chiwaukum Creek was modeled with the corresponding recurrence interval flow in the Wenatchee River. This approach is expected to overestimate the potential backwater influence of the Wenatchee River.

Table 3-2. Wenatchee River Recurrence Intervals Upstream of Confluence with Chiwaukum Creek

Percent Exceedance	Recurrence Interval (yrs)	Chiwaukum Creek Flow (cfs)
99.5%	1.005	5,567
99.0%	1.01	5,848
95.0%	1.05	7,053
90.0%	1.1	7,831
80.0%	1.25	8,937
66.7%	1.5	10,161
50.0%	2	11,691
42.9%	2.33	12,410
20.0%	5	15,623
10.0%	10	18,331
4.0%	25	21,902
2.0%	50	24,651
1.0%	100	27,480
0.5%	200	30,430
0.2%	500	34,520

3.1.2 Seasonal Flows

Monthly exceedance values were not estimated but may be developed in a future design iteration if it is determined that evaluating hydraulic conditions during low flows (for example at important juvenile rearing periods and/or adult migration periods) is needed to address project goals and objectives.

3.2 Geomorphology

The project reach is located on a valley-confined alluvial fan. Alluvial fans are depositional features frequently formed by a series of episodic debris flow deposits at the mouth of a confined valley where flows are allowed to spread out resulting in less sediment transport competency initiating deposition. The alluvial fan within the project area is believed to have formed many hundreds (if not thousands) of years ago evident by the size and structure of trees growing on its surface. The slope in the project reach also reduces from an average of 5.5% immediately upstream of Skinny Creek to an average of 2.4% on the fan surface contributing to its depositional character relative to upstream reaches. Alluvial fan deposition generally includes episodic/short-term deposition of a broad range of grain sizes followed by periodic/long-term winnowing of fine sediment (i.e. incision into the fan surface), frequently resulting in armored and incised channels.

Long-term winnowing of finer material has left behind an incised and heavily armored channel with a veneer of fluvially transported bedload covering portions of the streambed and floodplain. The bedform is primarily plane bed with occasional forced pools associated with large flow obstructions (LWD and/or bedrock) creating localized pool scour, gravel deposition, and bank erosion. Infrequent large floods overtop the banks in places resulting in floodplain sand deposition, small natural levees, and side-channel formation.

Human actions have reduced the small amount of floodplain access otherwise available on the alluvial fan, especially on the right bank in the campground, but possibly on the left bank where a small levee persists. These features (along with natural substrate armor, few pools, and lack of LWD) limit the habitat available to salmonids that would otherwise use the project area including: adult salmonid spawning; juvenile salmonid rearing in the main stem, side channels, and off-channel areas; and adult and juvenile salmonids seeking temperature refugia from the Wenatchee.

Sediment delivery in the project area is summarized as follows:

- Frequent/Periodic – fluvial sand and gravel deposition locally associated with in-stream structure
- Infrequent/Episodic – alluvial sand, gravel, cobble, boulder deposition from debris flows (the coarsest material is commonly pushed to the front and periphery (boulder front) of the debris flow creating natural levees and armored banks along the margin of the debris flow)

Bank conditions:

- Valley/bedrock confined in places (primarily upper reach, left bank)
- Boulder armor with mature riparian and forest vegetation/roots

Frequently mobilized bedload is primarily gravel (D50 of 58.6 millimeters), determined via pebble count, while the dominant streambed substrate is composed primarily of cobble and gravel (determined via field observation and ocular estimates). The estimated channel bed gradation (estimated by from photographs) is consistent with field observations. A summary of pebble count data is presented in Table 3-3.

Table 3-3. Bedload Pebble Count Particle Size Distribution

Particle Size	**D15**	**D35**	**D50**	**D84**	**D95**
Distribution (mm)	29.9	48.7	58.6	93.7	119.3
Distribution (in)	1.2	1.9	2.3	3.7	4.7

Field observations and soil reports for the area suggest 1-2 feet of relatively coarse material (cobbles/boulder) overlies more fine material (sand/gravel) throughout the floodplain within the project reach (see Figure 3-1 and Table 3-4). It is likely that both relatively coarse and relatively fine materials are interbedded at varying depths and locations throughout the alluvial fan surface within the project area representing debris flow deposits (coarse) and floodplain deposits (fine) respectively.

Figure 3-1. USDA web soil survey map.

Table 3-4. NRCS Custom Soil Report for the Floodplain within the Project Area

ID	Unit	Desc	Surface Horizon
1	Aeric fluvaquents	Nearly level	0 to 8 inches: silt loam 8 to 27 inches: silt loam 27 to 36 inches: sandy loam 36 to 60 inches: sand
148	Kladnick cobbly fine sandy loam	0 to 8% slopes	0 to 14 inches: cobbly ashy fine sandy loam 14 to 21 inches: very gravelly loamy sand 21 to 60 inches: extremely cobbly sand

Table 3-4. NRCS Custom Soil Report for the Floodplain within the Project Area

ID	Unit	Desc	Surface Horizon
187	Mippon very boulder loam	0 to 3% slopes	0 to 6 inches: very boulder loamy sand 6 to 18 inches: very cobbly loamy sand 18 to 60 inches: extremely cobbly loamy sand
201	Nard sandy loam	30 to 60% slopes	0 to 7 inches: ashy sandy loam 7 to 27 inches: ashy sandy loam 27 to 67 inches: loam

Source: https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx (accessed June 8, 2021)

The Chiwaukum Creek sediment regime is a derivative of source and transport mechanisms at work in the watershed. Although mountain glaciers were prevalent across the northern Cascade Mountains during the last ice age, there is very little mapped glacial alluvium within the Chiwaukum Creek watershed (Tabor et al. 1987). Most of the surficial geology within the watershed is exposed bedrock or bedrock overlain by relatively thin soils with minimal alluvial deposition in the valley bottoms derived from local landslides, debris flows, and stream processes. Sediment sources contributing to Chiwaukum Creek are determined to be largely derived from local hillslope processes such as surficial runoff (sheet flow, rills, and gullies) and mass-wasting (landslides, debris flows, slumps, etc.). Small-scale reworking of instream alluvium likely occurs in highly localized areas on an episodic basis, but the steep, confined shape of the valley does not permit significant alluvial sediment accumulation, storage, and remobilization.

As sediment enters the stream system from the adjacent hillslopes, fluvial processes sort the sediment based on transport competency and capacity. Sediment transport competency refers to the size of sediment that could be mobilized according to the magnitude of discharge (i.e., incipient motion), while transport capacity refers to the volume of sediment that could be mobilized according to the magnitude and duration of discharge. Most of the Chiwaukum Creek drainage consists of steep, narrow, confined headwater streams that are generally classified as supply-limited (i.e., transport reaches). These streams are typically bedrock-controlled and heavily armored with boulders and cobbles with only localized and thin deposits of finer sand and gravel (Raekes et al. 2014). While small volumes of hillslope erosion may supply sediment transport processes on an annual basis, the majority of sediment likely is derived infrequently via large-scale, episodic surface runoff and mass-wasting following disturbances such as wildfire and large hydrologic events (heavy rain, snowmelt, and floods). These larger, episodic events deliver pulses of generally poorly graded sediment to the system. Depending on the magnitude and duration of the event, sediment may be mobilized to the banks of a tributary channel, to the main stem of the Chiwaukum, or all the way to the mouth of the Chiwaukum and/or into the Wenatchee River.

3.3 Fish Use and Habitat Availability

Very little fish use and habitat data were discovered for Chiwaukum Creek. A fisheries resource assessment was completed by USFS as part of the burned area emergency response in the aftermath of the Chiwaukum Fire. Chiwaukum Creek has active spawning and rearing habitat for Chinook Salmon, Steelhead, and fluvial Bull Trout in the lower 2 miles below a barrier (USFS 2014). Cold-water salmonids are known anecdotally to preferentially occupy a cold water plume created where the Chiwaukum River flows into the warmer Wentachee River during the summer.

Species of interest consist of the following:

- Chinook salmon (Oncorhynchus tshawytscha) life stages present within the project area
    - Adult holding (pre-spawn) occurs in spring and summer
    - Adult spawning: late summer
    - Egg incubation: fall and winter

    - Parr: summer
    - Pre-smolt: winter
    - Smolt: spring
- Steelhead (Oncorhynchus mykiss) life stages within the project area
    - Adult spawning: spring
    - Juvenile rearing: year-round
- Bull Trout (Salvelinus confluentus) life stages within the project area
    - Adults: fluvial and resident use year round
    - Juveniles: fluvial and resident use year round
    - No adfluvial populations

3.4 Riparian Conditions and Wetlands

The floodplain is largely occupied by mature forest with large coniferous (Douglas fir, western red cedar, and grand fir) and deciduous (cottonwood) trees along with dense understory brush (dogwood, hawthorn, vine maple, and alder). Large portions of the floodplain have been cleared for the campground facilities on river right and historically on river left for unknown reasons; these have been largely reestablished by immature vegetation. A formal wetland resource inventory has not been conducted. If required, a formal wetland delineation will be completed at a later time. According to the US Fish and Wildlife Service National Wetland Inventory database (USFWS, 2019), forested/shrub and emergent wetland types existing within the project reach as shown in Figure 3-2.

Figure 3-2. Existing wetlands on Lower Chiwaukum (from USFWS NWI).

4 DESIGN DEVELOPMENT

The restoration plan for the project reach integrates elements of restoring processes for improved river-floodplain function and rehabilitation and enhancement of habitat for all life stages of Chinook salmon and steelhead. Applying this strategy is intended to improve habitat complexity.

4.1 Proposed Project Elements

The design team collaborations and interpretations of the current environmental setting have helped identify specific restoration actions for the project reach. These actions are listed below and depicted in the Drawings (Appendix A):

- Addition of large wood habitat structures (numerous types) to promote in-channel complexity, force hydraulic response (scour, deposition, split flow, floodplain connection, sediment sorting, and overall hydraulic diversity), and provide concealment cover for juvenile and adult salmonids.
- Removal of campground amenities including asphalt roads (berms) and associated fill, campsites, and utilities from high flood risk areas.
- Revegetation by means of planting and seeding native species within the riparian zone and transplanting local vegetation harvested near the project site (if possible). Existing mature vegetation will be preserved or if disturbance is unavoidable, will be used as floodplain roughness and/or incorporated into proposed wood structures.
- Excavation of pilot channels within the Tumwater Campground to provide continuity to existing downstream side channels within the floodplain (these features are labeled as “potential channel excavations” in the Drawings (Appendix A).

The project elements categorized into the Habitat Improvement Program (HIP) work element, category, risk level, and performance/sustainability criteria are listed in Table 4-1. See the Monitoring and Adaptive Management Plan (Appendix C; to be developed in a future design phase) for more information on performance, sustainability, and monitoring criteria. All project elements are designed by a professional engineer licensed in the State of Washington.

Table 4-1. HIP Work Elements and Performance/Sustainability Criteria

Work Element	HIP Category	HIP Risk Level	Performance/Sustainability Criteria
Improve Secondary Channel and Wetland Habitats	2a	TBD	Secondary side channels that become activated shall be self-sustaining and transport fine sediment (to be verified by hydraulic modeling). Increase LWD in secondary channels for improved habitat. Secondary channels shall not pose a high risk to the public safety and property.
Remove Existing Berms	2b	TBD	Excavated channels and floodplains through existing campground roads/berms shall be designed to withstand expected hydraulic conditions and pedestrian traffic. Provide short-term stability along banks to allow for fully vegetated banks within 3 years. Road/berm removal shall not result in a high risk to the public and property at all flows.
Install Habitat-Forming Natural Material Instream	2d	TBD	Provide for self-sustaining scour pool(s) with cover and hydraulic variability at the structure to promote gravel sorting and retention. Structures shall be designed to be stable, appear

Table 4-1. HIP Work Elements and Performance/Sustainability Criteria

Work Element	HIP Category	HIP Risk Level	Performance/Sustainability Criteria
Structures (Large Wood, Boulders, and Spawning Gravel)			natural to the extent practical, and not pose a high risk to the public and property.
Plant Riparian Vegetation	2e	TBD	Utilize live stakes and containerized plants to create a higher level of survivability to expedite growth to mature vegetation heights in addition to native seed mixes.
Reconstruct Channel	2f	TBD	New channels (and the existing relic side channels that become activated) shall be self-sustaining and transport fine sediment (to be verified by hydraulic modeling). Points of diversions shall be appropriately located and include bank structure to effectively split flow and decrease the potential for side channel inlets to become clogged. Channels shall not pose a high risk to the public and property.
Overall Project Risk	TBD		

4.2 Limiting Factors

Limiting factors addressed by the project are listed below:

- Habitat Quantity: Habitat Quantity – Competition
  - Floodplain connectivity and LWD are directly addressed by the objectives of this project.
- Riparian Condition: Riparian Vegetation
  - The project is expected to sustain or improve existing riparian vegetation.
- Peripheral and Transitional Habitats: Floodplain Condition
  - Development of the side channels and increased floodplain connection will improve peripheral and transitional habitats.
  - This project will activate relic side channels at annual flow events thereby improving floodplain connectivity. Also, this project includes excavation of new pilot channels which activate at near annual flow events.
- Channel Structure and Form: Bed and Channel Form
  - Log structures proposed within Chiwaukum Creek and side channels will improve channel complexity and long-term channel form.
  - Log structures within Chiwaukum Creek near the confluence with the Wenatchee River are designed to promote scour at flows less than the annual flow event with the goal of mobilizing sediment and improving fish passage at lower flows.
  - Log/boulder structures in the Wenatchee River are designed to provide scour pools with cover for improved holding conditions for fish seeking temperature refuge during summer and winter.
- Sediment Conditions: Increased Sediment Quantity
  - Wood structures are designed to provide hydraulic variability thereby promoting scour and deposition/retention of gravels.
- Water Quality: Temperature
  - Wood structures on Chiwaukum Creek and the Wenatchee River are designed to promote hydraulic variability and scour pools to provide isolated microhabitat and are strategically located to take advantage of a known cold-water plume providing thermal refuge for fish.

4.3 Scientific Basis: Literature Review

A key component of the design approach, including detailed habitat structure designs, aims to maintain and maximize the cold-water plume at the Lower Chiwaukum confluence with the Wenatchee River. To ensure that the designs are grounded by a solid scientific foundation, we reviewed the literature on cold-water plumes at confluences and hyporheic exchange associated with logjams. While not exhaustive, the following highlights the most current knowledge basis of our designs.

Guidelines and recommendations of practical examples of how thermal refugia may be protected or enhanced are somewhat limited, due in part, to the rapid evolution of the science (Isaak and Young, CJFAS in press). For example, Torgerson et al., (2012) developed a primer for state, tribal and federal fisheries and watershed managers that illustrates how to identify cold-water refuges for salmonids. Management approaches to protect and enhance thermal refugia may help salmonids survive warmer summers (Fullerton et al., 2018; Torgerson et al., 2021), especially where climate change is expected to have the greatest impact onstream temperatures (Battin et al., 2007; Beechie et al., 2023).

As one of several potential thermal refugia management strategies, Kurylyk et al. (2014) suggest the construction of channel deflectors at confluences to preserve cold-water plumes and limit mixing with mainstem waters. Their discussion of this strategy, however, comes with several important caveats. Most notably, in the context of the Lower Chiwaukum project design approach outlined in this report, the authors caution the potential adverse effects of scour and bank erosion and recognized ecological uncertainties, such as a lack of knowledge on how structures may influence salmonid behavior to seek and find thermal refugia. To enhance the spatial extent of existing cold-water plumes, they point to strategies that increase or create more cover and riparian shade, which is further supported by several others (Cristea and Burges, 2010; Ebersole et al., 2015; Wang et al., 2020). Such strategies are also likely to reduce harvest mortality risks of fish staging in thermal refugia (i.e., Keefer et al., 2009). We also caution against possible unintended consequences of this technique whereby a large eddy may form in the lee of the deflection structure significantly increasing the potential for mixing of the cold water with the mainstem water.

In the development of appropriate design strategies, it is also important to recognize existing uncertainties associated with fish mobility and variable coping strategies for handling summer temperatures in mainstem rivers (Armstrong et al., 2021; Barrett and Armstrong, 2022). Mixing of cold water at confluences has potential benefits for annual growth and adaptive capacity to offset the energetic costs of thermoregulation (Brewitt et al., 2017).

Generally agreed upon definitions for thermal refuge are lacking because of dependence on the thermal preferences and timing of different life stages for different fish species present in a particular river and the relative flow conditions and relative temperature differences in mainstem and tributary (Wang et al., 2020; Saadi et al., 2021). Additionally, recent confusion exits in the literature regarding the differences between thermal refuge and climate refugia (Isaak and Young, CJFAS in press).

Nonetheless, current consensus on best practices of restoration treatments for increasing the spatial extent of cold-water plumes centers on creating, enhancing, or maintaining shade and cover in the vicinity of cold-water tributary sources (Wang et al., 2020). Design approaches that increase shade and cover are likely to be particularly effective for offsetting increased stream temperatures in recently burned watersheds (Swartz and Warren, 2023).

Wood structures are generally assumed to promote hyporheic exchange flow (Wondzell et al., 2009), and offer another potential thermal refugia management strategy (Kurylyk et al., 2014). However, the actual effectiveness in decreasing water temperatures is heavily dependent on structure placement and the degree to which such structures drive flow into the hyporheic zone (Clark et al., 2021). Indeed, channel-spanning structures may be the most effective (Clark eta L., 2021), but not always appropriate considering design constraints such as recreational use (Wohl et al., 2016).

Increasing floodplain habitat connectivity and riparian shade are among the most robust restoration actions that are expected to increase salmonid population resilience (Beechie et al., 2023). By increasing floodplain connectivity in the Lower Chiwaukum reach and providing additional cover and complexity along the margins of the Wenatchee through the installation of large wood habitat structures (i.e., HS-5 and HS-6 described in the Drawings), the design approach outlined here, is well supported by the most current scientific understanding as reported in the peer-reviewed literature. Adding additional structure to the bank of the Wenatchee River upstream of the Chiwaukum confluence may not increase the size of the existing thermal plume and could reduce the effect of the cold-water plume by creating an eddy which could increase mixing of Wenatchee and Chiwaukum waters. As stated above, we believe enhancing the fish holding characteristics of the existing cold-water plume by providing cover and shade (and the potential for scour pool development) along the Wenatchee riverbank adjacent the existing cold-water plume yields the greatest likelihood of maximizing the thermal benefit at this location.

4.4 Alternatives Assessment and Selection

Prior to finalizing the conceptual design (15% Design), concept alternatives were developed and vetted with Cascade Fisheries, U.S. Fish and Wildlife, and the Forest Service. A description of alternatives/concepts that were excluded from the 15% Design are as follows:

- Alternative 1 – Add large woody debris and engineered log jams to the existing channel; no change to the adjacent campground.
- Alternative 2 – Add large woody debris and engineered log jams to the existing channel and perform floodplain excavation to reconnect existing high-flow channels and/or increase side channel inundation frequency; this alternative included necessary modifications to low-lying areas of the adjacent campground to address flood and channel migration risk.
  - Selected by stakeholders as the preferred alternative.
  - Refined during the 15% Design to include reduced disturbance/excavation on the left floodplain and greater side channel connection on the right floodplain.
- Alternative 3 – Add large woody debris and engineered log jams to the existing channel and perform significant floodplain excavation to reconnect large areas of the existing/abandoned floodplain on both the right and left banks; this alternative included increased modifications to low-lying areas of the adjacent campground to address flood and channel migration risk.

The proposed project elements shown in the Drawings (Appendix A) were selected based on stakeholder feedback on the 15% Design and multiple iterations of the 30% Design. Additionally, the design team qualitatively assessed all project elements in the 15% and 30% Designs relative to hydraulic performance and habitat quality (through 2D hydraulic modeling), risk to public safety and property (through 2D hydraulic modeling), disturbance/impacts to existing vegetation, cost, and constructability. Table X includes a list of changes and associated rationale that occurred after the 15% Design.

Table 4-2. Design Element Assessment Summary

Feature Description	Action	Rationale
Left-bank, high-flow, pilot channels (formerly located at STA 27+00, 30+00, and 31+50) including associated	Removed from Draft 30% Design	Intended to improve floodplain and side channel activation however based on initial hydraulic model results, the design team concluded the habitat gained for the cost did not outweigh the impacts to existing vegetation and potential for adverse impacts to the existing downstream Wenatchee River side channel. Also,

Table 4-2. Design Element Assessment Summary

Feature Description	Action	Rationale
wood structures and temporary bridge		splitting flow away from the mainstem Chiwaukum Creek reduces scour potential at the bar/fan features at the mouth of Chiwaukum Creek which is speculated to inhibit passage at low flows due to shallow water depth.
Wood structures at STA 30+00 and 31+50	Added to Final 30% Design	Added to help force connectivity on left floodplain.
Increased the number of felled trees (HS-1B structures)	Added to Final 30% Design	Based on stakeholder feedback.
Incorporated additional trees and added excavated scour pool to HS-5 structures to improve holding habitat and constrict flow to increase scour potential of the existing bar/fan	Added to Final 30% Design	Proposed conditions hydraulic model results for the Draft 30% Design indicate a reduction in velocity therefore additional key members were added to force a constriction to promote scour pool development and improve pool longevity.
Incorporated additional trees and added excavated scour pool to HS-6 structures to improve holding habitat	Added to Final 30% Design	Based on stakeholder feedback.
Temporary construction access routes	Modified at Final 30% Design	Modified to avoid mature vegetation observed in the LiDAR (highest hits) data.

Additional assessment/evaluation and design refinements of wood structures will occur in a future design phase to ensure each structure performs as expected to optimize scour potential, reduce public safety, and maximize habitat value. Additional structure(s) may be considered and evaluated in the area immediately upstream of the mouth of Chiwaukum Creek to optimize hydraulic conditions/reduce mixing of Wenatchee River water with the goal of improving the Chiwaukum Creek cold-water plume. And, the proposed project elements in the 30% Design may be eliminated or modified in a future design iteration based on future stakeholder feedback and continued evaluation of performance against the project goals and objectives.

5 HYDRAULIC MODELING AND ANALYSIS

The purpose of the existing and proposed conditions two-dimensional (2D) hydraulic models are as follows:

- Determine the hydraulic conditions (inundation extent, depth, velocity, shear stress, and water surface elevation) to evaluate in-stream habitat conditions and floodplain connectivity at the project-scale.
- Provide the basis for comparison with the proposed conditions hydraulic model to ensure project objectives are being met.

The 2D hydraulic models were developed using the U.S. Army Corps of Engineers (USACE) Hydraulic Engineering Center's River Analysis System (HEC-RAS), version 6.3.1. Development of any 2D hydraulic model requires a terrain surface, delineation of the model domain, designation of hydraulic roughness (Manning's n values), creation of the model mesh, and designation of boundary conditions specifying the inflow(s) hydrology and conditions for outflow(s). Each of these major components of the hydraulic model are discussed in greater detail in subsequent sections.

5.1 Data Used

Data used to develop the two-dimensional (2D) hydraulic model includes topography and bathymetry, aerial imagery, and hydrology, which is discussed in subsequent sections.

5.1.1 Topography and Bathymetry

Topographic and bathymetric information used to create existing and proposed ground surfaces (terrains) for use in the hydraulic model and for design includes the following data sources:

- 2022 Green LiDAR data collected for the Bureau of Reclamation of the Pacific Northwest (USBR), by Quantum Spatial (2022) obtained online from the Cascade Fisheries in raster format having a cell size of 3.0 feet. The coordinate system of the dataset is Washington State Plane, North Zone, with linear unit in survey feet. The vertical datum is NAVD 88 (Geoid 18). The spatial extent of this survey covered the entire Wenatchee River and Chiwaukum Creek project reach.
- 2015 LiDAR data collected for Oregon LiDAR Consortium (OLC) Chelan FEMA study, by Quantum Spatial (2015) obtained online from the Washington State Department of Natural Resources LiDAR Portal in raster format having a cell size of 1 meter. The coordinate system of the dataset is Transverse Mercator (UTM) 10 North, with linear unit in meters. The vertical datum is NAVD 88 (Geoid 12A). The spatial extent of this survey covered the entire Wenatchee River and Chiwaukum Creek project reach.
- Bathymetric cross section surveys were performed by U.S. Bureau of Reclamation in April 2020 and Rio ASE in September 2020. Approximately thirty cross sections were surveyed in the existing channel within the project reach and five in existing side channels. The cross-section survey was used to validate the LiDAR datasets to localized site conditions.

5.1.2 Aerial Imagery

- 2022 Bing Maps, as shown in the construction drawings (Appendix A) imagery accessed through AutoCAD Civil 3D streaming service provided improved spatial reference to features and landmarks within the project reach. Aerial imagery was also used to determine land use, vegetation type, condition, and density for estimating Manning's n values used in the hydraulic model. Determination of Manning's n values are discussed in detail in a subsequent section.
- 2021 high-resolution drone imagery collected by Cascadia Conservation District in May 2021 obtained from Cascade Fisheries. The imagery was used to provide improved spatial reference to features and landmarks within the project reach and to determine land use, vegetation type, condition, and density

for estimating Manning's n values used in the hydraulic model. Determination of Manning's n values are discussed in detail in a subsequent section.

5.2 Model Development

The project reach consists of approximately 3,800 feet of Chiwaukum Creek from the US Highway 2 overpass to the confluence with the Wenatchee River and boarders the Tumwater campground. The existing conditions 2D hydraulic model upstream extent begins at the US Highway 2 overpass on Chiwaukum Creek, approximately 700 feet upstream of the start of the project reach and extends to the confluence with the Wenatchee River. Within the Wenatchee River, the downstream boundary is located below the US Highway 2 overpass and extends approximately 4,800 feet upstream of the confluence with Chiwaukum Creek. Therefore, the model domain extends well upstream and downstream of the project reach to ensure accurate flow and inundation conditions at the start and end of the project reach, including any backwater influence of the Wenatchee River confluence.

5.2.1 Terrain

Rio ASE created a composite existing conditions terrain surface using AutoCAD Civil 3D by pasting the topographic and bathymetric datasets listed in 5.1.1 in the order of priority as listed. The 2022 Green LiDAR was utilized for bathymetric and near floodplain topographic information and the 2015 LiDAR was used for more expansive floodplain topography. The datasets were overlaid to create an AutoCAD Civil 3D surface in the North American Datum of 1983 (NAD 83), Washington State Plane North, U.S. Foot, coordinate system. The dataset vertical datum is the North American Vertical Datum of 1988 (NAVD 88). Both LiDAR datasets were validated against the site survey. Local control points and data points located across the site indicated elevation discrepancy on hard surfaces, such as asphalt for example, of an average of 0.31-ft and 0.32-ft for the 2015 and 2022 LiDAR datasets respectively. Both datasets were lowered by the reported average elevation discrepancy prior to merging. The resulting composite terrain surface was exported in *.tiff file format with a cell size of 1-foot and converted to a terrain within HEC-RAS. The composite existing condition terrain surface was used for hydraulic modeling as well as for conceptual design. Proposed conditions surface modeling was completed within AutoCAD Civil 3D, exported, and merged to create a composite terrain within HEC-RAS to inform post project hydraulic results.

5.2.2 Hydraulic Roughness

High-resolution drone imagery was used to generate hydraulic roughness mapping for the full model domain. Using the aerial imagery as reference, polygons were digitized based on channel and vegetation type and other identifiable features listed in Table 5-1. A Manning's n value for the channel was assigned based on engineering judgement and the existing conditions model was calibrated to observed water surface elevations during the September 17, 2020, topographic survey at a measured discharge of approximately 13 cfs. Calibration was achieved through manipulation of channel roughness values and a Manning's n value of 0.05 was selected for the channel bed in Chiwaukum Creek. The same value was applied to the Wenatchee River. Model simulations for each recurrence interval flow use a constant channel bed roughness value. This approach is expected to overpredict flooding because the roughness value was determined at low flow and because roughness values typically decrease with increasing flow. To reflect the impacts of channel bed roughness during high-flow events more accurately, future modeling efforts will utilize reduction factors. Manning's n values for areas outside of the channel were selected based on engineering judgement and are constant regardless of the simulated flow, since overbank flow only occurs when flows are near or greater than bankfull. The selected Manning's n values in Table 5-1 are also consistent with published values in Chow (1959).

Table 5-1. Hydraulic Model Manning's n Values

Description	Low Flow Manning's n
Wenatchee River	0.05
Chiwaukum Creek	0.05
Large Woody Debris	0.30
Floodplain Forest (medium density)	0.10
Islands	0.10

5.2.3 Computational Mesh

The USACE's HEC-RAS 2D program uses a finite-volume solution scheme, which allows for use of a structured or unstructured computational mesh. This means that the computational mesh can be a mixture of 3- to 8-sided cells. The existing and proposed conditions hydraulic model uses a structured and unstructured mesh that contains variable mesh cell sizes ranging from 20-ft spacing to 4-ft spacing. Generally, the model mesh within floodplain areas that have a low topographic complexity use a nominal grid mesh (square cells) with a resolution of 20 feet by 20 feet. Channels or areas with high topographic complexity use a much finer mesh with variable-sided computational cells. For Chiwaukum Creek, the model mesh contains at least 6 mesh cells representing the channel bottom and 1 mesh cells representing the channel banks throughout the modeled reach. For side channels, the model mesh contains at least 2 mesh cells representing the channel bottom and 1 mesh cell representing the channel banks. For the mainstem Wenatchee River, the model mesh contains at least 12 mesh cells representing the channel bottom and 2 mesh cells representing the channel banks throughout the modeled reach. To improve model accuracy and efficiency, breaklines were included to enforce cell size and to align the edges of mesh cells at locations of topographic change. These locations include the top of existing and proposed banks, toe of slopes, centerline or thalweg of channels, top of roads, riffle crests, and any other areas requiring a more detailed mesh or where more complex hydraulic conditions are expected to occur.

5.2.4 Boundary Conditions

Boundary conditions designated within the model specify the flow rate(s) for flow entering the model (inflow) and conditions or flow rates leaving the model (outflow). The following are boundary conditions defined in the existing and proposed conditions hydraulic model:

- Upstream Chiwaukum Boundary (Inflow)
- Upstream Wenatchee River Boundary (Inflow)
- Downstream Wenatchee River Boundary (Normal Depth)

The upstream inflow boundary flow rates are different for each model run. Peak flow rates used for each model run at the upstream boundaries are presented in Table 3-1 and Table 3-2. The downstream outflow boundary is set to normal depth and therefore uses the Manning's equation to compute normal depth at each computational mesh cell along the boundary, assuming an energy slope of 0.005 ft/ft which is equal to the reach slope within 200 feet upstream and downstream of the model boundary.

5.2.5 Computational Method and Options

The existing and proposed conditions 2D hydraulic models were run using both the diffusion wave (DW) and shallow water equation (SWE) computational engines. The SWE set uses full Saint-Venant momentum equations. For all model runs, separate DW and SWE plans are created and are named with a "DW" for diffusion wave or "FM" for full momentum in the plan file. Each DW model run saves a restart file at the end of the model simulation, which is then used as the initial condition for the SWE model simulation. All model runs are performed using unsteady state boundary conditions and use a fixed time step; computational interval (time step) for DW model runs were 0.5 seconds and time steps for SWE model runs were 0.3 seconds. All other computation options and tolerances utilize HEC-RAS default settings.

5.3 Hydraulic Model Results

Appendix B includes two-dimensional hydraulic model results (depth and velocity) for existing conditions and proposed conditions at various recurrence interval flows. Proposed conditions include Chiwaukum Creek and Wenatchee River wood habitat structures as well as focused floodplain excavation and potential channel excavations. Associated pilot channel on river left of Chiwaukum Creek have been removed through design iteration and stakeholder feedback.

5.3.1 Existing Conditions Model Results

Interpretations of the existing conditions model results are summarized as follows:

- Inundation extent (and water surface elevations relative to existing bank heights) within the upper half of the project reach indicate Chiwaukum Creek is moderately connected to the floodplain at the 1.5-year flow event. The lower half is largely disconnected.
- High flow channels on the left floodplain are activated at the 5-year flow event.
- The lower portion of the left floodplain becomes inundated/backwatered by the Wenatchee River at the 1.5-yr flow (Figure 1 of Appendix B). This area will continue to be a depositional zone.
- The project reach is confined resulting in a lack of floodplain connectivity and exhibits a homogenous channel that provides little quantity and quality habitat value to juvenile and adult salmonids.
- There are approximately 10 pools within the project reach.
- Depth, velocity, and shear stress results indicate a lack of hydraulic variability throughout the project reach at all flows.

5.3.2 Proposed Conditions Model Results

Interpretations of the existing conditions model results are summarized as follows:

- At the 1.5-year flow, the optional high-flow channels on the right floodplain are activated and improve floodplain connectivity at all flow events; however, the effect diminishes as flows increase up to the 50-year flow.
- A gain in inundated/backwater is observed in the lower portion of the left floodplain adjacent to the Wenatchee River at the 1.5-yr flow (Figure 1 of Appendix B) due to proposed wood structures within the mainstem. This area will continue to be a depositional zone.
- Inundation extent at the 100-year flow is similar to that of existing conditions therefore the proposed condition is not expected to significantly increase flood risk.
- Velocity results at the 1.5-year flow (Figure 2 of Appendix B) show a narrowed band of increased velocities and depths around proposed habitat structures on Chiwaukum Creek near the mouth. The structures appear to have changed flow conditions from a sweeping right flow path into the Wenatchee to a near perpendicular intersection with slightly reduced velocities in the mainstem Wenatchee. These findings suggest that improved scour potential in Chiwaukum Creek near the mouth.
- Histograms of depth and velocity for existing and proposed conditions at the 1.5-year flow are shown in Figure 5-1 and Figure 5-2. Each cell (y-axis) represents an inundated cell (1’x1’) within the existing and proposed conditions model). The charts indicate the following compared to existing conditions:
    - Floodplain activation/inundation has increased by 1.5 acres, primarily due to the optional high-flow channels on the right floodplain.
    - Figure 5-1 shows an increase in the quantity of cells with depths ranging from 0 to approximately 3.2 feet. The quantity of cells having depths greater than 3.2 feet did not change significantly. The

increase in the quantity of wetted cells less than 3.2 feet is primarily due to the increased floodplain activation associated with optional high-flow channels, as well as increased depths associated with the constricting of Chiwaukum Creek immediately upstream of the confluence.

  - Figure 5-2 shows an increase in the quantity of cells with velocities ranging from 0 to approximately 4 feet per second (fps) and a reduction in the number of cells with velocities greater than 4 fps to approximately 8.4 fps. In general, the results indicate slower water, less fast water, and higher velocity variability (higher standard of deviation) which typically translates to increased habitat quantity and quality.

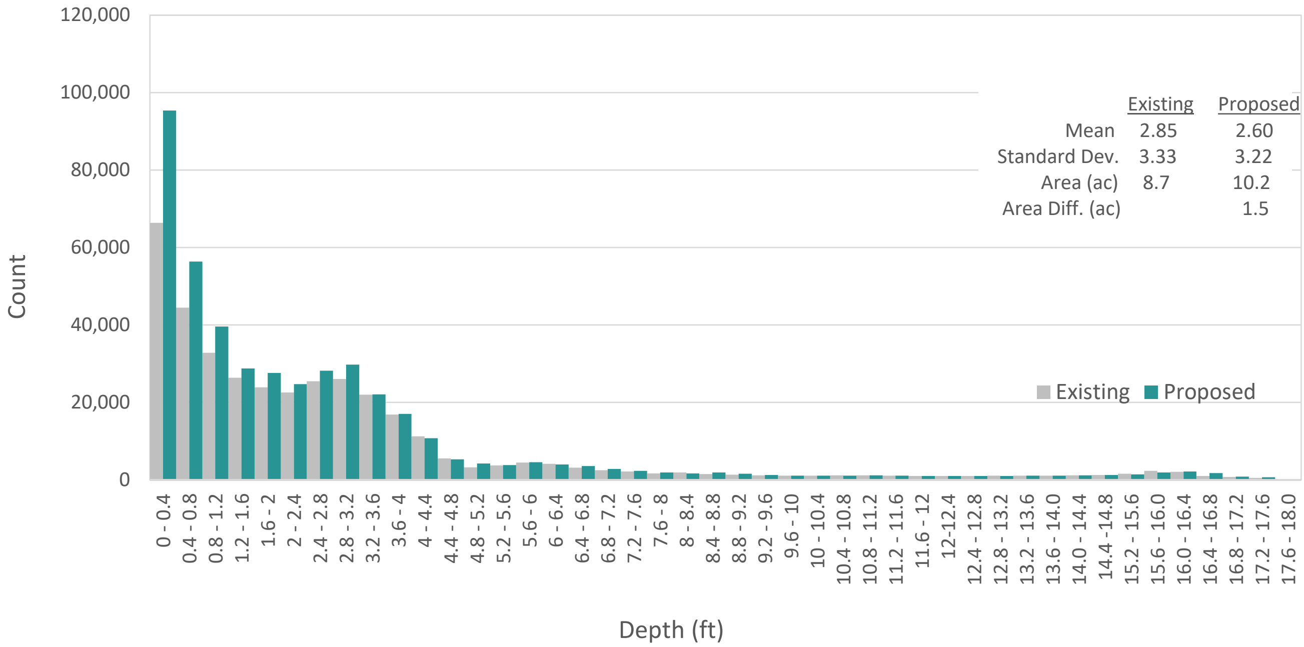

Figure 5-1. Depth histogram at the 1.5-year flow.

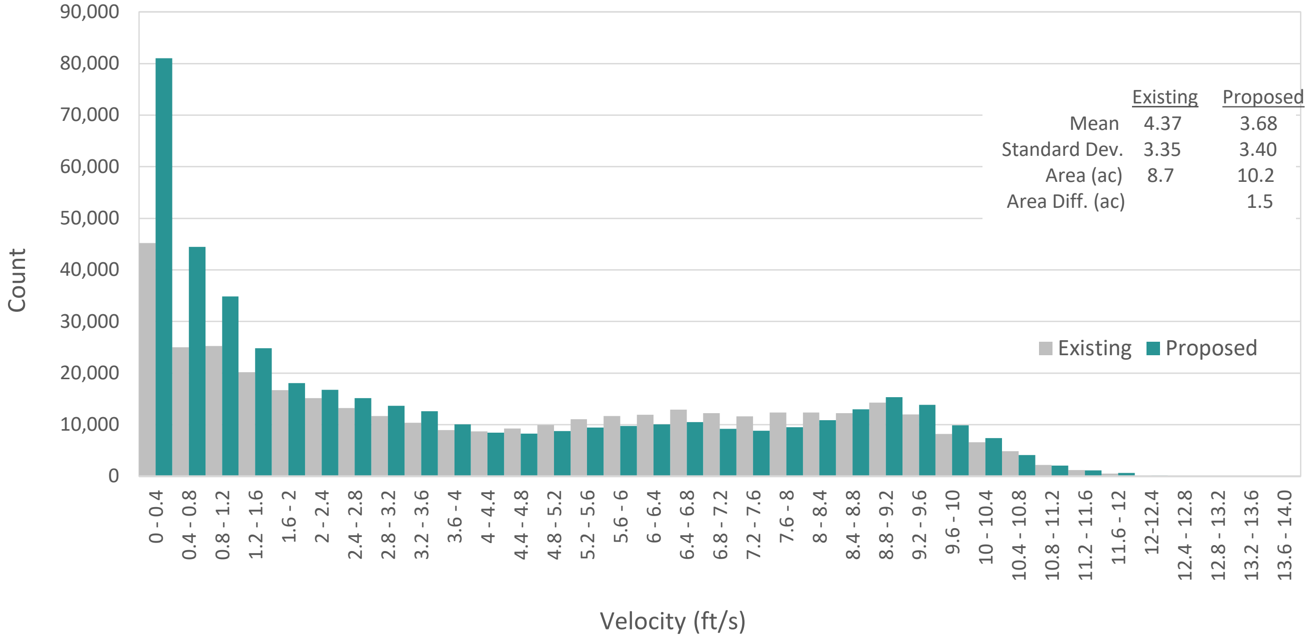

Figure 5-2. Velocity histogram at the 1.5-year flow.

6 LARGE WOODY MATERIAL STABILITY ANALYSIS

6.1 Large Woody Materials Risk Assessment and Design Factors of Safety

Large woody material structures are proposed in Chiwaukum Creek and secondary side channels and floodplain areas to provide roughness and habitat throughout the project area. Large wood structures are also proposed for the mainstem Wenatchee River. There are 5 different types of proposed wood structures. These structures will consist of key log members that act as the skeleton of the structure. The structure will then be completed with the addition of racking logs and slash material. These structures are intended to emulate natural log jams.

Rio ASE analyzed perceived risk associated with large woody material using the Large Woody Materials–Risk Based Design Guidelines (Knutson and Fealko 2014). The risk analysis for the project area estimates a high risk to public safety and a moderate risk to property damage. Public safety is considered high mainly due to relatively high recreational use in the summer and proximity to the campground. Moderate risk is associated with the presence of campground infrastructure, however most of it is located outside of the 100-year floodplain extents. These scorings can be seen in Figure 6-1 and are meant to be representative of the numerous structures proposed throughout the project reach.

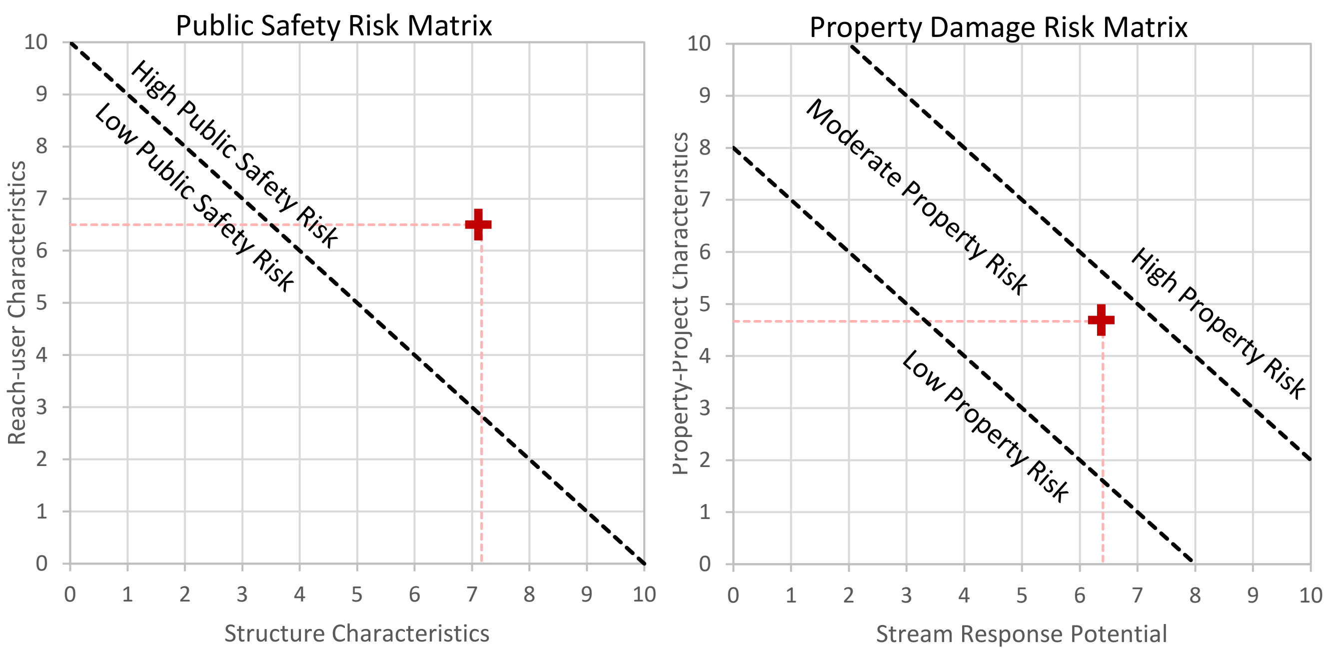

Figure 6-1. Risk evaluations for public safety and property damage.

These guidelines recommend a design flow event equal to or greater than the 50-year peak flood and factors of safety of 1.8 for buoyancy and 1.5 for sliding and rotation. However, the selected design flow will be the 100-year with factors of safety for buoyance, and sliding and rotation of 1.8 and 1.8, respectively.

6.2 Large Wood Stability Analysis

This analysis will be completed in a future design iteration.

6.3 Large Wood Scour Analysis

This analysis will be completed in a future design iteration.

7 CONSTRUCTION

Rio ASE considered HIP IV General Aquatic Conservation Measures when completing the project design. We included HIP Conservation Measures, with more detail, as notes in the Design Drawings attached in Appendix A for ease of reference by the construction contractor. The following is a summary of the project's compliance with the general conservation measures.

7.1 General Aquatic and Construction Conservation Measures

- **Climate change**: Climate change was considered in the design. Primary features that address climate change scenarios (runoff timing, lower flows, increased temperature) include side channels, wetlands, and shallow groundwater storage. In addition to these, there will be increased floodplain connectivity and wetland habitat, which should also enhance shallow groundwater storage and subsequent surface water/groundwater connectivity in warmer months and low-flow conditions.
- **Timing of in-water work**: The approved in-water work window is currently ________ to _______ of the following year.
- **Site layout and flagging**: The construction contractor will be required to stake all major project elements for approval by the contracting officer or engineer prior to construction and adhere to vertical and horizontal tolerances in accordance with the Specifications (to be developed in a future design phase).
- **Temporary access roads and paths**: Temporary access routes are shown in the Drawings (Appendix A). The construction contractor will not be allowed to deviate from the designated routes unless approved by the contracting officer or engineer.
- **Temporary stream crossings**: Temporary stream crossings are shown in the Drawings (Appendix A). The construction contractor will not be allowed to deviate from the crossing locations unless approved by the contracting officer or engineer.
- **Staging, storage, and stockpile areas**: Proposed staging and stockpile areas throughout the project area are shown in the Drawings (Appendix A). The construction contractor will not be allowed to deviate from these areas unless approved by the contracting officer or engineer.
- **Equipment**: Equipment necessary to complete the project likely will include dozers, excavators, loaders, and a variety of service vehicles. We included HIP General Conservation and Implementation Measures as notes in the Drawings (Appendix A), and those notes indicate biodegradable lubricants are required for work below the OHWM.
- **Erosion control**: HIP General Aquatic Conservation Measures in the Drawings (Appendix A). Those include erosion control measures for temporary erosion controls, sediment barriers restricting loads to the stream, soil stabilization measures and emergency erosion controls. Our scope does not include preparation of a project specific storm water pollution prevention plan (SWPPP).
- **Dust abatement**: General Conservation and Implementation Measures in the Drawings (Appendix A). Those include recommendations regarding work scheduling, dust stabilization measures (water only), spill containment and a restriction on petroleum-based stabilization products.
- **Spill prevention, control, and counter measures**: HIP General Conservation and Implementation Measures are included in the Drawings (Appendix A). Those include directing the contractor to keep a list of hazardous materials, written procedures for notification of environmental response, spill containment kits, worker training and storage of waste liquids. Our scope does not include preparation of a project specific SWPPP.
- **Invasive species control**: HIP General Conservation and Implementation Measures are included in the Drawings (Appendix A). Those include directing the contractor to power wash all vehicles, inspecting in-water equipment and a restriction on felt-soled wading boots. Our scope does not include preparation of a project specific invasive species control plan.

7.2 Project Disturbance Extent

The areal extent of disturbance is shown in Drawings (Appendix A). Table 7-1 and Table 7-2 summarize project impacts.

Table 7-1. Summary of Materials Discharged below OHWM or Wetlands

Disturbance Type	Quantity (cubic yards)
Native Alluvium	TBD
Wood	TBD
Boulders	TBD
Total	TBD

Note: Temporary impacts not included are temporary cofferdams and temporary excavation and backfill for wood habitat structures.

Table 7-2. Summary of Impacts to Waters of the U.S. or Wetlands

Type	Acre (acres)	Quantity (cubic yards)
Alluvium Backfill for Wood Structures	TBD	TBD
Temporary Access Road Clearing	TBD	TBD
Scour Pool Excavation for Wood Structures	TBD	TBD
Wood and Boulders	TBD	TBD
Total	TBD	TBD

Note: Temporary impacts not included are temporary cofferdams and temporary excavation and backfill for wood habitat structures.

All existing roads used as temporary construction access routes will be restored to equal or better condition. Disturbed areas will be scarified back to natural unconsolidated densities and will be planted and/or seeded. Planting and seeding requirements will be included in the Drawings (Appendix A) in a future design phase.

8 LIMITATIONS

Some clients, design professionals, and contractors may not recognize that stream and river engineering analysis and design practices are less exact than other engineering and natural science disciplines. Such misunderstandings can create unrealistic expectations, sometimes leading to disappointments, claims, and disputes. Rio ASE includes these explanatory "limitations" provisions in our reports to help reduce such risks. Please confer with Rio ASE if you are unclear how these "Report Limitations and Guidelines" apply to your project or site.

8.1 Design Purposes, Persons, and Projects

This report has been prepared for the Client and their authorized agents and regulatory agencies for use on the Project(s) specifically designed in the report. The information contained herein is not applicable to other sites or projects.

Rio ASE structures its services to meet the specific needs of its clients. No party other than the Client may rely on the product of our services unless we agree to such reliance in advance and in writing. Within the limitations of the agreed scope of services for the Project and its schedule and budget, our services have been executed in accordance with our Agreement and generally accepted practices in this area at the time this report was prepared. We do not authorize, and will not be responsible for, the use of this report for any purposes or projects other than those identified in the report.

8.2 Design Factors

This report has been prepared solely for this Project and Client. Rio ASE considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless Rio ASE specifically indicates otherwise, it is important not to rely on this report if it was:

1) Not prepared for you,
2) Not prepared for your project,
3) Not prepared for the specific site, or
4) Completed before project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

1) The function of the proposed design and/or structure
2) Elevation, configuration, location, or orientation of the proposed structures
3) Composition of the design team, or
4) Project ownership.

If changes occur after the date of this report, Rio ASE cannot be responsible for any consequences of such changes in relation to this report unless we have been given the opportunity to review our interpretations and recommendations in the context of such changes. Based on that review, we can provide written modifications or confirmation, as appropriate.

8.3 Conditions Can Change

This report is based on conditions that existed at the time the study/design was performed. The findings and conclusions of this report may be affected by the passage of time, by man-made events such as construction on or adjacent to the site, new information or technology that becomes available subsequent to the report date, or by natural evens such as floods, earthquakes, slope instability, stream flow fluctuations or stream channel fluctuations. If more than a few months have passed since issuance of our report or work product, or if any of the described events may have occurred, please contact Rio ASE before applying this report for its intended purpose so that we may evaluate whether changed conditions affect the continued reliability or applicability of our conclusions and recommendations.

Any designs associated with this report may need to be adjusted in the field during construction in order to meet the specific-site conditions and intended function. Rio ASE cannot assume responsibility for the recommendations in this report if unexpected conditions are encountered during construction. We recommend that you allow sufficient monitoring and consultation by Rio ASE during construction to confirm that the conditions encountered are consistent with those indicated in the report, to provide recommendations for design changes if the conditions revealed during the work differ from those anticipated, and to evaluate whether construction activities are completed in accordance with our recommendations.

8.4 Report Misinterpretation

Misinterpretation of this report can result in costly problems. Rio ASE can help reduce the risks of misinterpretation by conferring with appropriate stakeholders after submitting the report, participating in pre-bid and preconstruction conferences, and providing construction observation.

To help reduce the risk of problems, we recommend giving contractors the complete report, including these "Report Limitations and Guidelines." When providing the report, we recommend that you preface it with a clearly written letter of transmittal that:

1) Advises contractors that the report was not prepared for purposes of bid development and that its accuracy is limited, and
2) Encourages contractors to confer with Rio ASE and/or to conduct additional study to obtain the specific types of information they need or prefer.

8.5 Hazards of Instream Habitat Structures

Instream habitat structures ("Structures") create potential hazards, including, but not limited to:

1) Persons falling from the Structures and associated injury or death,
2) Collisions of recreational users and their watercraft with the Structures, and associated risk of injury, and damage of the watercraft,
3) Mobilization of a portion or all of the Structures during high water flow conditions and related damage to downstream persons and property,
4) Flooding,
5) Erosion, and
6) Channel avulsion.

In some cases, instream habitat structures are only intended to be temporary, providing temporary stabilization while riparian vegetation becomes established or while stream/river processes stabilize. This gradual deterioration with age and vulnerability to major flood events make the risks with temporary Structures inherently greater with their increasing age.

Rio ASE strongly recommends that the Client appropriately address safety concerns, including but not limited to warning construction workers of hazards associated with working in or near deep and fast-moving water and on steep, slippery, and unstable slopes. In addition, signs should be placed along the enhanced stream reaches in prominent locations to warn third parties, such as nearby residents and recreational users, of the potential hazards noted above.

8.6 Channel Response is Unpredictable

In general, rivers and streams are dynamic and unpredictable. Any predictions regarding future channel evolution and/or response either stated or implied in this report or associated design(s) shall be considered an estimate based on professional judgment given the data available and conditions that existed at the time the study/design was performed. Channel evolution and/or response may include but is not limited to erosion, deposition, channel migration, avulsion, flooding, and sediment and debris transport. Channel evolution and/or response is inevitable, and it should not be assumed that any condition whether natural or constructed will persist unchanged indefinitely in a riverine environment.

8.7 Monitoring and Maintenance

In some designs, Rio ASE may have excluded piles, anchors, chains, cables, reinforcing bars, bolts and similar fasteners from woody habitat structures with the intent of mimicking naturally occurring instream wood structures. In other designs Rio ASE may have included such fasteners in woody habitat structures, if considered appropriate. While Rio ASE designs structures to be relatively stable during flood events, some movement of these structures is expected. We recommend that the Client implement appropriate monitoring and maintenance procedures to minimize potential adverse impacts at or near areas of concern, and consider replacing, adjusting and/or removing damaged, malfunctioning, or deteriorated components of structures.

8.8 Construction Site Safety

Our recommendations are not intended to direct the construction contractor’s procedures, means, methods, schedule, or management of the work site during construction of any project associated with this report. The construction contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and adjacent properties.

9 REFERENCES

BAER (Burned Area Emergency Response). 2014. BAER Analysis Briefing: Chiwaukum Creek Fire 09/08/2014. Accessed online 12/18/19: http://centralwashingtonfirerecovery.info/2014/wp-content/uploads/2014/08/ChiwaukumBriefing.pdf

Battin, J., M. W. Wiley, M. H. Ruckelshaus, R. N. Palmer, E. Korb, K. K. Bartz, and H. Imaki. 2007. "Projected Impacts of Climate Change on Salmon Habitat Restoration." Proceedings of the National Academy of Sciences 104: 6720–5.

Beechie, T.J., C. Fogel, C. Nicol, J. Jorgensen, B. Timpane-Padgham, and P. Kiffney. (2023). How Does Habitat Restoration Influence Resilience of Salmon Populations to Climate Change? *Ecosphere* 14(2): e4402. https://doi.org/ 10.1002/ecs2.4402

Berenbrock, Charles. 2002. "Estimating the Magnitude of Peak Flows at Selected Recurrence Intervals for Streams in Idaho," U.S. Geological Survey Water Resources Investigations Report 02-4170.

Brewitt, K. S., Danner, E. M., & Moore, J. W. (2017). Hot eats and cool creeks: Juvenile Pacific salmonids use mainstem prey while in thermal refuges. *Canadian Journal of Fisheries and Aquatic Sciences*, 74, 1588–1602.

Castro, J. M. and P. L. Jackson. 2001. "Bankfull Discharge Recurrence Intervals and Regional Hydraulic Geometry Relationships: Patterns in the Pacific Northwest, USA." in the Journal of the American Water Resources Association. 37 (5): 1248–1262.

Chow, V.T. 1959. Open-channel hydraulics: New York, McGraw-Hill, 680 p.

Clark, C., Krall, M., Roni, P., & Ceder, K. (2021). Reach-scale stream temperature response to large wood placement. *Restoration Ecology*, *29*(7), e13433.

Cristea, N. C. and S. J. Burges. (2010). An assessment of the current and future thermal regimes of 791 three streams located in the Wenatchee River basin, Washington State: some implications for 792 regional river basin systems. *Climatic Change* 102:493-520.

Ebersole JL, Wigington PJ, Leibowitz SG, Comeleo RL, Sickle JV (2015) Predicting the occurrence of cold-water patches at intermittent and ephemeral tributary confluences with warm rivers. *Freshwater Science* 34:111–124.

Fullerton, A.H.; Torgersen, C.E.; Lawler, J.J.; Steel, E.A.; Ebersole, J.L.; Lee, S.Y. (2018) Longitudinal thermal heterogeneity in rivers and refugia for cold water species: Effects of scale and climate change. *Aquatic Science*, 80, 1–15.

Keefer, M. L., C. A. Peery, and B. High. (2009). Behavioral thermoregulation and associated mortality trade-offs in migrating adult steelhead (Oncorhynchus mykiss): variability among sympatric populations. *Canadian Journal of Fisheries and Aquatic Sciences* 66, 1734–1747.

Kurylyk, B. L., Macquarrie, K. T. B., Linnansaari, T., Cunjak, R. A., & Curry, R. A. (2014). Preserving, augmenting, and creating cold-water thermal refugia in rivers: Concepts derived from research on the Miramichi River, New Brunswick (Canada). *Ecohydrology*, 8(6), 1095–1108.Montgomery, D.R., and J.M. Buffington. 1997. "Channel-reach morphology in mountain drainage basins." *GSA Bulletin*. 109(5).

Raekes, C., M. Rickel, and S. Brakensiek. 1993. Chiwaukum Creek Stream Survey Report. Survey Dates July 8 – August 5, 1993.

Saadi, A. M., Msilini, A., Charron, C., St-Hilaire, A., & Ouarda, T. B. M. J. (2022). Estimation of the area of potential thermal refuges using generalized additive models and multivariate adaptive regression splines: A case study from the Ste-Marguerite River. *River Research and Applications*, 38(1), 23–35.

Swartz A, Warren DR (2023) Wildfire in western Oregon increases stream temperatures, benthic biofilms and juvenile coastal cutthroat trout size and densities with mixed effects on adult trout and coastal giant salamanders. *Canadian Journal of Fisheries and Aquatic Sciences*, 00: 1–14 dx.doi.org/10.1139/cjfas-2022-0053

Tabor, R. W., V. A. Frizzel, Jr., J. T. Whetten, R. B. Waitt, D. A. Swanson, G. R. Byerly, D. B. Booth, M. J. Hetherington, and R. E. Zartman. 1987. Geologic Map of the Chelan 30-Minute by 60-Minute Quadrangle, Washington. Department of the Interior. U.S. Geological Survey. Miscellaneous Investigations Series. Map 1-1661.

Torgersen, C. E., Ebersole, J. L. & Keenan, D. M. (2012). Primer for identifying cold-water refuges to protect and restore thermal diversity in riverine landscapes. EPA 910-C-12-001, U.S. Environmental Protection Agency, Seattle, Washington, USA. https://pubs.er.usgs.gov/publication/70037945.

Torgersen, C. E., Le Pichon, C., Fullerton, A. H., Dugdale, S. J., Duda, J. J., Giovannini, F., et al. (2021). Riverscape approaches in practice: Perspectives and applications. *Biological Reviews*, 97(2), 481–504.

UCRTT (Upper Columbia Regional Technical Team). 2017. A biological Strategy to Protect and Restore Salmonid Habitat in the Upper Columbia Region (Draft). Chelan County, Washington.

UCSRB (Upper Columbia Salmon Recovery Board). 2007. Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan. August 2007. Appendix G: Identification of primary limiting factors and threats, objectives, and habitat actions for each listed species within each subbasin. Accessed online 12/2/19: https://www.ucsrb.org/mdocuments-library/plans/

USBR (U.S. Bureau of Reclamation). 2014. Pacific Northwest Region Resource and Technical Services—Large Woody Material Risk Based Design Guidelines. U.S. Bureau of Reclamation, Pacific Northwest Region, Boise, Idaho.

USGS (U.S. Geological Survey). 1982. "Guidelines for Determining Flood Flow Frequency Bulletin." #17B of the Hydrology Subcommittee.

USGS (U.S. Geological Survey). 2016. Streamstats. https://water.usgs.gov/osw/streamstats

USWRC (U.S. Department of the Interior. United States Water Resources Council). 1981 Guidelines for Determining Flood Flow Frequency. Bulletin #17B of the Hydrology Committee.

WADOE (Washington State Department of Ecology) 2020. River and Stream Flow Monitoring. Chiwaukum Cr. Nr mouth (ID 45G060). Accessed online 12/2/19: https://fortress.wa.gov/ecy/eap/flows/station.asp?sta=45G060&historical=true

WADOE and Watershed Sciences (Washington State Department of Ecology and Watershed Sciences, LLC). 2012. Aerial Surveys in the Wenatchee River Basin – Thermal Infrared and Color Videography. Made available from the Cascade Columbia Fisheries Enhancement Group (Cascade Fisheries) Salmon Recovery Funding Board 2019 funding request for: Restore Lower Chiwaukum Creek – Phase 1 (#19-1472)

Wang T, Kelson SJ, Greer G, Thompson SE, Carlson SM. (2020), Tributary confluences are dynamic thermal refuges for a juvenile salmonid in a warming river network. *River Research Applications,* 36:1076–1086. https://doi. org/10.1002/rra.3634

Wohl, Ellen, Brian P. Bledsoe, Kurt D. Fausch, Natalie Kramer, Kevin R. Bestgen, and Michael N. Gooseff, (2016), Management of Large Wood in Streams: An Overview and Proposed Framework for Hazard Evaluation. Journal of the American Water Resources Association (JAWRA) 52(2): 315-335.

Wondzell, S. M., J. LaNier, R. Haggerty, R. D. Woodsmith, and R. T. Edwards (2009), Changes in hyporheic exchange flow following experimental wood removal in a small, low-gradient stream, Water Resour. Res., 45, W05406, doi:10.1029/2008WR007214.

APPENDIX A DESIGN DRAWINGS

- Drawings provided as a standalone document (PDF file).

APPENDIX B HYDRAULIC ANALYSIS

- 2D hydraulic model results for existing and proposed conditions.
- LWD Risk Matrix Evaluation (to be completed in a future design phase).
- LWD stability calculations (to be completed in a future design phase).

APPENDIX C ADAPTIVE MANAGEMENT PLAN

- To be completed in a future design phase.

APPENDIX D CONSTRUCTION QUANTITIES AND COST ESTIMATE

- Quantities and cost estimate provided as a standalone document (PDF file).

APPENDIX E DESIGN REVIEW COMMENT TRACKING

- To be completed in a future design phase.