October 20, 2024

Submitted by Columbia Land Trust and Cramer Fish Sciences

PROPOSAL FOR

PINE CREEK REACH 5 RESTORATION DESIGN IMPLEMENTATION

PACIFICORP LEWIS RIVER AQUATIC FUND

Columbia Land Trust

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Tyler Rockhill, Const./Eng. Oversight
Cramer Fish Sciences Restoration Engineer
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1. Project Title

Pine Creek Reach 5 Restoration Design Implementation

2. Requested Funding Amount

We are requesting consideration to fund our **$543,711** project through the Bull Trout Project Fund.

3. Project Manager

Project Manager
Ian Sinks, Columbia Land Trust Stewardship Director
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Construction/Engineering Oversight
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4. Identification of problem of problem or opportunity to be addressed

Based on feedback from the Bull Trout Working Group, Columbia Land Trust and Cramer Fish Sciences (CFS), Reach 5 is an opportunity to improve habitat conditions and learn without putting existing bull trout habitat use at significant risk.

Pine Creek is one of the most important bull trout spawning streams in the Lewis Basin, with some areas of high-quality habitat and others of degraded habitat due to both human (forestry) and natural (eruption of Mt. St. Helens) causes. There are multiple reaches in Pine Creek and its tributaries that are priorities for restoration for bull trout or steelhead and previous assessments have indicated the need to address limiting habitat conditions such as channel complexity (large wood, side channels), sediment, and riparian condition.

Columbia Land Trust and CFS previously collaborated to develop a comprehensive watershed assessment and restoration design for Pine Creek, focusing on Reaches 1, 2, 4, 5, and 6. This work included detailed analyses of the creek's hydrologic, geomorphic, and habitat characteristics, with the goal of increasing channel complexity and improving instream habitat for bull trout. Having completed this extensive planning and design phase, we now want to implement these carefully crafted restoration designs at Pine Creek Reach 5, as we are committed to seeing the project through from its conception to execution to enhance the creek's ecological function and support bull trout, as well as for salmon and steelhead.

5. BACKGROUND

Pine Creek is a major tributary to the North Fork Lewis River and provides important habitat for one of the three remaining spawning populations of the Endangered Species Act (ESA) listed Lewis River bull trout *Salvelinus confluentus,* as well as important habitat for steelhead *Oncorhynchus mykiss.* It is also utilized by listed coho salmon *O. kisutch* and spring Chinook salmon *O. tshawytscha*. The Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan indicates that Pine Creek is the number one area with the greatest current or potential production of bull trout in the upper North Fork Lewis Basin (LCFRB 2010). The plan states that bull trout may benefit from targeted riparian and stream channel restoration in the reaches of Pine Creek.

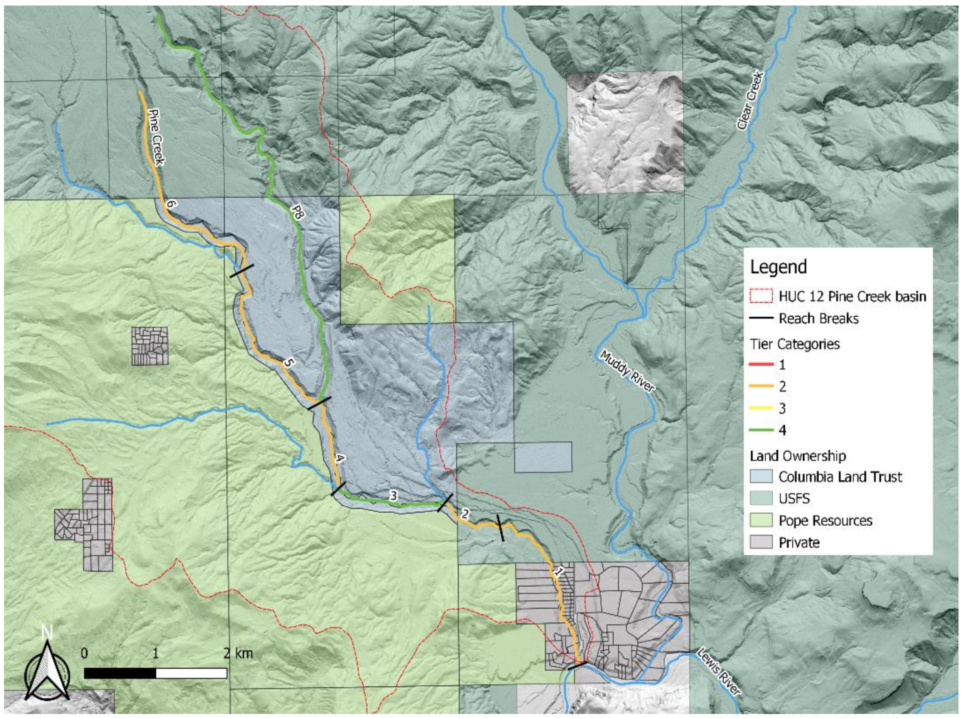

Figure 1. Map showing 100 m reaches, Tier category of each reach, and land ownership in the Pine Creek basin, WA.

Pine Creek drains approximately 68 km^2 and is mixed ownership by the U.S. Forest Service (USFS), private timberlands, as well as some private residential tracts in the lower reaches (Figure 1). Amid an upsurge of unchecked development in the mid-2000s, Columbia Land Trust collaborated with Pope Resources (a Washington-based timber company) and Skamania County to develop a comprehensive conservation effort to protect 20,000 acres around Swift Reservoir from development. Columbia Land Trust purchased 2,330 acres east of Pine Creek in 2013 and an additional 3,095 acres of contiguous forest land west of Pine Creek in 2014. Together, the two purchases protect most of the watershed from development. Columbia Land Trust is managing these lands to benefit bull trout, northern spotted owls, and gray wolves. The focus of management to date has been on moving the industrially managed forest to a natural, old growth forest structure benefiting these species.

There have been periodic assessments of the conditions in Pine Creek, including work by the USFS, U.S. Geological Survey (USGS), Washington Department of Fish and Wildlife (WDFW), and PacifiCorp, as well as ongoing spawner surveys by PacifiCorp. A watershed assessment in the 1990s by the USFS indicated concerns with peak flows due to young vegetation and high forest road density as well as mass wasting water quality concerns due to unstable and erodible sediments (USFWS 1995b, USFS 1996). More recent habitat surveys by the USGS in Pine Creek tributaries (P1 and P7) similarly showed very low levels of pool habitat, little to no large woody debris, and poor riparian condition (PacifiCorp 2016). Large woody debris concentrations in Pine Creek are low (<40 pieces per mile) and it also has low recruitment potential because of logging and the 1980 eruption of Mt. St. Helens. Additionally, resulting channel instability and migration have impeded mature conifer growth leading to a riparian corridor dominated by immature alders. EDT modeling efforts for Chinook salmon, soho salmon, and steelhead indicate that portions of Pine Creek are limited by habitat diversity (complexity/large wood) and sediment, while others, like P8, are key habitats (PacifiCorp 2016).

More recent work found that bull trout redds in the Pine Creek Basin were four times more likely to occur in reaches with complex channels (i.e., more than one channel with flowing water during base flow conditions) than reaches with only one main channel and redd occurrence was negatively related to stream depth. This suggests that habitat complexity and depth at the reach scale are important factors influencing bull trout spawning site selection within thermally suitable habitat (Lamperth et al. 2017). The study recommends restoration actions that increase channel complexity in the coldest accessible stream reaches within the basin. Recent spawner surveys suggest that with increasing numbers of bull trout, spawners are moving into lower quality areas to spawn.

According to SalmonPORT, Pine Creek Reach 1, 2, 4, 5, and 6 are Tier 2 priority reaches, have high potential as contributing reaches for winter steelhead, and are designated as a high or medium multi-species priority for several restoration needs as shown in Table 1.

Table 1. Multi-species (steelhead, spring Chinook Salmon, Coho Salmon) restoration needs for Pine Creek, as reported on SalmonPORT. H = high (red), M = medium (yellow), L = low (green). Table submitted with Columbia Land Trust and Cramer Fish Sciences' restoration design proposal.

	Pine Creek Reaches and Multi-Species Priority					
Restoration Needs	**1**	**2**	**3**	**4**	**5**	**6**
Off channel and side channel habitat	H	H	H	H	H	H
Riparian conditions & functions	H	H	H	H	H	H
Stream channel habitat structure & bank stability	H	H	H	H	H	H
Watershed conditions & hillslope processes	H	H	H	H	H	H
Floodplain function & channel migration processes	H	H	H	H	H	M
Instream flows	M	H	M	M	M	M
Access to blocked habitats	L	L	L	L	L	L
Regulated stream mgt. for habitat functions	L	L	L	L	L	L
Water quality	L	L	L	L	L	L

Although bull trout redds have been documented in Pine Creek, in 2014 Reach 1 and 4 had no documented redds, and Reach 3 had only one documented redd (Figure 2). In years of higher bull trout spawner abundance, such as 2021 and 2022, some redds have been documented in these reaches (PacifiCorp personal communication). Therefore, there is an opportunity to improve complexity in these reaches for the benefit of spawning bull trout as well as other species, while avoiding areas of currently high-quality bull trout spawning habitat. Other Pine Creek reaches and tributaries are listed as Tier 4 reaches in SalmonPORT (Pine Creek 3, P8), though they may also benefit from restoration.

Given the recently improved protection and ownership status of Pine Creek, the ongoing riparian and upland forest restoration, the priority reaches identified in SalmonPORT, and previous assessment work identifying limiting factors and bull trout habitat restoration opportunities, there was a unique opportunity to design holistic instream and riparian restoration in selected reaches of Pine Creek to benefit bull trout, as well as salmon and steelhead.

In 2023, Columbia Land Trust and CFS received funding from PacifiCorp and the Lewis River Aquatic Coordination Committee to complete a comprehensive assessment and restoration design for Pine Creek. The project included:

- Site investigation and baseline assessment.
- Development of permit ready designs and final construction plan for appropriate reaches.
- Photo documentation.
- Project management and coordination with the Aquatic Coordination Committee (ACC).

With input from the ACC and other interested parties, we complete the site investigation and assessment, identified priority reaches, developed preliminary designs, and are completing final designs and construction plans. Our detailed assessment and 15% Basis of Design Report (BOD) identified restoration opportunities in Reaches 1 through 6 of Pine Creek. Based on project stakeholder review comments, conceptual designs were progressed to 30% and final designs for Reach 5 of Pine Creek. The purpose of selecting Reach 5 was to minimize potential negative project impacts to spawning locations and allow for project monitoring to occur before progressing to further downstream reaches. We are currently completing the final designs and construction plans for Reach 5, with the intent to implement and complete construction of the project in 2025, should funding be available.

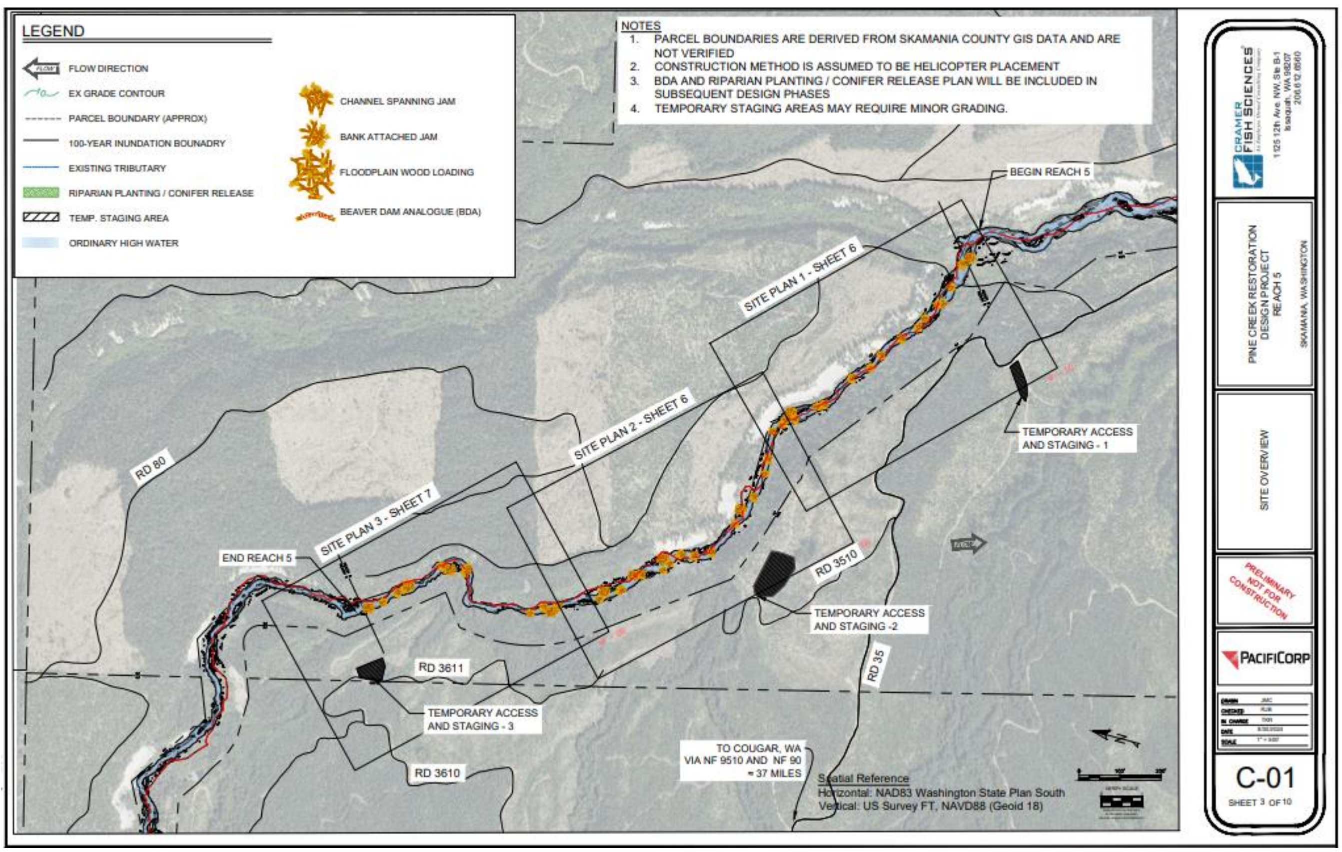

Figure 2. BOD report site overview sheet for plan sets for Reach 5 of Pine Creek.

6. PROJECT OBJECTIVES

The overall goal of the Pine Creek Reach 5 Implementation is to improve the project area's instream habitat complexity and riparian habitat to address key limiting factors. Specifically, we aim to:

- Improve habitat complexity in simplified reaches through large wood placement.
- Stabilize sediment to allow for riparian succession to mature conifer forest.
- Increase side channels and spawning habitat for bull trout and steelhead.
- Protect existing quality spawning habitat for bull trout and steelhead.
- Create resting areas for spawning adult bull trout and steelhead.
- Improve holding pools for juvenile bull trout and steelhead.
- Improve overwintering habitat for salmonids.
- Reduce or stabilize incision rates in areas with floodplain pockets.

Pine Creek Reach 5 has relatively low spawner density, areas of simple channel types, and lower use by spawning bull trout (Figure 2; Lamperth et al. 2017). Thus, our objective is to build out from Reach 6's stronghold of high-quality bull trout habitat to enhance habitat and benefit bull trout and steelhead recovery throughout the North Fork Lewis River. This will also ensure the protection of existing areas of high-quality bull trout spawning habitat in Pine Creek and address reach-specific limiting factors.

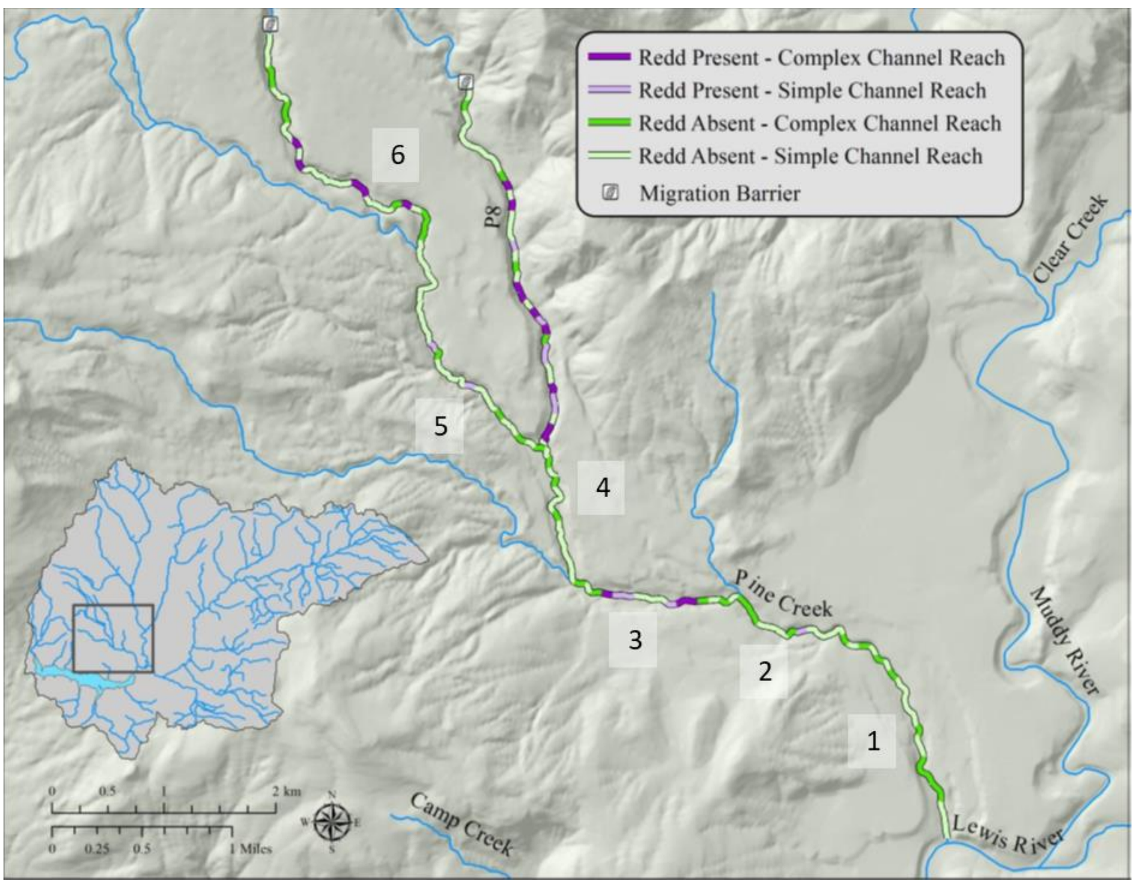

Figure 3. Map showing 100 m reaches by levels of bull trout redd occurrence and channel complexity in the Pine Creek basin, WA, from the Lewis River Bull Trout Habitat Restoration Project Identification Assessment (Lamperth et al. 2017).

7. TASKS

To meet the project objectives, Columbia Land Trust and CFS, hereafter referred to as "Project Team," will complete the following tasks, which are described in more detail in the Methods section below.

Task 1: Project Management

1.1: Pre-implementation meeting

The Project Team will attend a pre-construction meeting and site tour, bringing their technical expertise to discuss all aspects of project implementation. Engineers and restoration specialists will explain design elements, address questions, and ensure all parties understand project goals. This collaborative approach aims to set clear expectations for the project.

1.2: Management and coordination

This task will include time and resources for internal management among our team and project partners through the implementation's completion. We will facilitate a project kick-off meeting with the construction crew, PacifiCorp, the ACC, and interested parties prior to beginning the project. We also include periodic project update memos and invoices under this task.

1.3 Project close-out site visit

The Project Team will conduct a final site visit to assess the successful implementation of the restoration designs, which also marks the transition from the implementation phase to the monitoring and evaluation phase.

Task 2: Bid Documents

Working closely with PacifiCorp, we will draft bidding and contract documents, compiling all final design products along with bid submission instructions to create a complete package for project implementation.

Task 3: Construction Oversight

3.1: Site layout and staking

The Project Team will complete the construction site layout and staking, accurately translating design plans to on-ground markings.

3.2: Construction oversight

Our construction observation services include daily site visits, progress reports, and quality control checks. We will maintain communication with the construction team and PacifiCorp to address issues during implementation.

Task 4: Monitoring

We will provide photo documentation of habitat conditions at the project site before, during, and after project completion.

Task 5: Construction Implementation

This task includes the hiring of a construction contractor to complete the Pine Creek Reach Restoration Design.

8. Methods

The goal of this project is to implement our restoration design in Reach 5 of Pine Creek that aims to increase channel complexity and create instream habitat by facilitating pool formation, creating cover, and restoring natural fluvial and riparian processes. The design is intended to integrate forest management practices with design elements to improve habitat in the short term, as well as provide long term resiliency, incorporating the unique characteristics of this dynamic system.

Overall, implementing an appropriate treatment within Pine Creek will kick-start the recovery of instream fluvial processes while the uplands in the Pine Creek watershed continue to recover.

Task 1: Project Management

1.1: Pre-implementation meeting

Our team will coordinate closely with PacifiCorp, the ACC, and other interested parties to schedule and attend the pre-construction meeting and project site tour. We will bring our full technical expertise to this meeting, prepared to discuss all aspects of project implementation. Our engineers and restoration specialists will provide detailed explanations of design elements, address any questions or concerns from the construction team or interested parties, and ensure all parties have a clear understanding of project goals and expectations.

1.1: Management and coordination

This task will include time and resources for internal project management among our team and project partners through the implementation's completion. We also include periodic project update memos and invoices under this task.

1.3: Project close-out site visit

The Project Team will conduct a final site visit to assess the successful implementation of the restoration designs. This close-out visit will serve to evaluate the completed work, ensuring all elements of the design have been properly executed. Team members will observe the length of the implemented reach, comparing on-ground results with the original design plans, document newly created habitat features and channel modifications, assess the creek's initial response to the implemented changes, and identify any areas requiring additional attention. The visit will also provide an opportunity to discuss the project's outcomes and potential long-term monitoring plans. This site visit marks the transition from the implementation phase to the monitoring and evaluation phase, allowing the team to celebrate the project's completion while setting the stage for future assessment of its ecological impact.

Task 2: Bid Documents

We will incorporate comments from the 95% design into the final (100%) design construction plan, design report, and plan sheets. It is anticipated that minor design elements may change at this time. The final construction 100% design will be a bid-ready package that will include final plans, specifications, and estimates. A final update will be made to temporary access and staging, water management, work area isolation, fish bypass, erosion control and sediment, and monitoring and adaptive management plans, along with all required information to facilitate permitting, contracting, and the bid process. Having a monitoring and adaptive management plan in place before construction allows for data collection before construction if needed, as well as in the as-built condition. These data are critical to objective quantification of project benefits. The drawings will be finalized with the seal and stamp of the designer and delivered in digital format.

At this point, a scope for construction support can be developed to be included in the construction bid package. These elements can be subject to interpretation and/or vary based on construction conditions. Having the designer of record on-site during construction is beneficial for efficiency and project success.

We will work closely with PacifiCorp to draft bidding and contract documents for project implementation. All the final products from the design will be packaged together along with the requirements and directions for submitting a bid. The Project Team will solicit an invitation to bid on the project from qualified contractors.

Task 3: Construction Oversight

3.1: Site layout and staking

The Project Team will take full responsibility for the site layout and staking process. Our experienced field team will accurately translate the design plans to on-the-ground markings, ensuring precise implementation of all project elements. Throughout the implementation phase, we will maintain continuous availability via telephone to discuss any construction elements. We are accustomed to providing rapid, clear responses to field questions, helping to prevent delays and ensuring the project is constructed as designed. At this phase of the project, there is a wide range of construction activities that may require site layout and staking, leading to a high level of uncertainty in the scope and level of effort for this task. Since some design elements may require different levels of site layout, this estimate includes assumptions to allow for consistent comparison of proposals. This proposal assumes site layout and staking for engineered log jams, helicopter-placed wood, construction access and staging, and side channel alignment and slope staking for the Pine Creek project area. Since floodplain grading and other potential elements may vary too significantly for adequate comparison, these elements have not been included.

3.2: Construction oversight

Our team will work collaboratively with crews on-site to conduct observation services, which typically include daily site visits, regular progress reports, and quality control checks. We will maintain ongoing communication with the construction team and PacifiCorp to address any issues that arise during implementation. Similarly to site layout and staking, there is a wide range of construction activities that may require different levels of construction oversight, leading to a high level of uncertainty in the scope and level of effort for this task. We will provide construction oversight throughout the construction period. The estimated project cost includes time, materials, and travel. The Project Team will work with PacifiCorp and crews to determine an appropriate scope and level of effort once the designs are advanced enough to provide an accurate estimate of site layout and construction oversight. We look forward to determining a practical plan that evaluates critical elements that need engineering oversight and elements where oversight can rely on the extensive experience of our team. Implementation will occur during the in-water work window between July 16 and August 15.

Task 4: Monitoring

As per the National Marine Fisheries Service's Biological Opinion for Relicensing of the Lewis River Hydroelectric Projects, we will provide photo documentation of habitat conditions at the project site before, during, and after project completion. We have a team committed to the long-term conservation of this area and will continue to monitor and collaborate to ensure critical lessons are learned from this effort.

We will include general views and close-ups showing details of the project and project area, including pre- and post-construction. We will label each photo with the date, time, project name, photographer's name, and documentation of the subject activity. Photo points will be collected using a GIS app so that the point can be easily relocated, and the photo reproduced in subsequent years. The timing of photo collection is shown in the table below. Pre-construction monitoring and photo documentation were completed as part of our previous contract. As-built and post-construction photo documentation and monitoring will be done as part of construction.

Photo	Timing
1	Pre-construction
2	Post-construction as-built
3	Post one high flow
4	3 years after construction
5	5 years after construction

In addition, we will outline a detailed effectiveness monitoring plan based on previous effectiveness monitoring we designed for the Lewis River, western Washington, and the Columbia River Basin (Roni et al. 2020a, b; 2022). This plan leverages pilot studies we have underway using the latest remote sensing techniques to efficiently monitor floodplain, riparian, and large wood projects. These studies not only monitor the project's overall physical and biological effectiveness but also evaluate specific design elements to assist with adaptive management if needed. Based on the methods outlined in the monitoring plan we will collect required pre-project data during the design phase. This typically includes pre-project topo-bathymetric surveys, habitat surveys, and habitat suitability modeling. In addition, the long-term redd surveys will serve as additional biological monitoring of project success.

Task 5: Construction Implementation

The Project Team will lead the procurement of a contractor to perform the work outlined in the Pine Creek Reach 5 Restoration Design 100% final design bid package. We will select the most qualified, low bid contractor per our standard approach, which entails evaluating the firm's experience, approach, capacity, and cost as equal considerations. The contractor will be responsible for all work elements shown in the 100% final design, with our team providing support (detailed in Task 3). Implementation will occur during the in-water work window between July 16 and August 15.

9. SPECIFIC WORK PRODUCTS

Task 1: Project Management

- Status updates and project invoices (*provided throughout the life of the project*).

Task 2: Bid Documents

- Final 100% basis of design report, design plan sheets, specifications, and quantity estimates.
- Bid-ready documentation.

Task 3: Construction Oversight

- Site layout and staking according to Manual 18 and WSDOT Standard Specification standards.

Task 4: Monitoring

- Pre-project effectiveness monitoring data collection and brief report with photos and descriptions.
- Shapefiles and/or KMZ files of photo points with retained images.

Task 5: Construction Implementation

- Construction of the Pine Creek Reach 5 Restoration Design.
- As-built documentation.

10. PROJECT DURATION

This project will commence upon contract with PacifiCorp, expected in February 2025 (if funded). A detailed schedule for each task and deliverable is provided below. If the contract timeline does not allow for construction in July through August of 2025, it is possible that construction and most of the project budget will be delayed until 2026.

Task/Deliverable	Schedule
Task 1: Project Management	*Feb 2025 – Dec 2025*
1.1 Pre-Implementation Meeting	*Feb 2025*
1.2 Management and Coordination	*Feb 2025 – June 2026*
Project update memos	*Monthly*
Invoices	*Monthly*
1.3 Project close-out site visit	*August 2025*
Task 2: Bid Documents	*Feb 2025 – June 2025*
Task 3: Construction Oversight	*June 2025 – Aug 2025*
3.1 Site Layout and Staking	*June 2025*
3.2 Construction oversight	*July 2025 – Aug 2025*
Task 4: Monitoring	*Aug 2025 – Dec 2025*
4.1 As-built and post-construction photo documentation	*Aug 2025 – Dec 2025*
4.2 Reporting	*Aug 2025 – Dec 2025*
Task 5: Construction Implementation	*July 2025 – Aug 2025*

11. PERMITS AND AUTHORIZATIONS

All regulatory information needed to facilitate environmental compliance and permitting will be provided by the Project Team. We will submit the anticipated permits detailed below. The permitting process will begin by submitting a Joint Aquatic Resources Permit Application (JARPA) to relevant local, state, and federal agencies for review. At a minimum, we expect this project will require a Hydraulic Project Approval (HPA) from the WDFW, a 401 Water Quality Certification from the Washington Department of Ecology, an aquatic land use authorization from WADNR, and a County Shoreline Permit. Through the JARPA, we will apply for the Fish Habitat Enhancement Exemption which would expedite the permit process for the HPA, Shoreline Permit, and potentially the State Environmental Policy Act consultation, if a review is triggered. For any work occurring on USFS property, a NEPA consultation may be required unless the proposed actions fall under an existing programmatic. We do not expect a Section 404 or Section 10 permit from the Army Corps of Engineers (Corps) to be required; however, that will be at the discretion of the Corps representative.

We have successfully obtained these permits for many large wood additions, fish passage, and river restoration projects in Washington in a timely manner. Our preferred approach is to contact regulatory agencies early within a project's timeline to get them involved and help identify potential hurdles or constraints. Identifying concerns early allows us and our partners to address issues and incorporate solutions in the planning and design phases of a project. In our experience, regulatory agencies can be a strong supporter and ally if they feel engaged in the project.

Columbia Land Trust is the owner of the land used for access to the project site as well as the contracting agency for this project.

12. Matching Funds and In-kind Contributions

In-kind contributions may be sought during the bid solicitation process from the USFS or PacifiCorp for materials and/or time.

13. Peer Review of Proposal Project

It is anticipated that the Bull Trout Working Group will provide a third-party review of this proposed project. Contact: Jeremiah Doyle (jeremiah.doyle@pacificorp.com)

14. Budget

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	Projected Hours											
	Phil Roni	Tyler Rockhill	x	x	Columbia Land Trust							
	Principal Scientist	Project Manager I	Engineer I	Biologist	Natural Area Manager	Stewardship Director	$0	Labor Subtotal	Expenses			
Objectives and Tasks	$275	$171	$148	$121	$80	$110	$0		Equipment	Travel	Direct	Totals
Task 1 Project Management								$0				$0
Task 1.1 Pre-implementation meeting	4	8			8	8		$3,988		$1,250		$5,238
Task 1.2 Management and coordination	4	8			40	16		$7,428				$7,428
Task 1.3 Project close-out site visit	16	16			32	8		$10,576		$3,000		$13,576
Objective 1 Subtotal	24	32	0	0	80	32	0	$21,992	$0	$4,250	$0	$26,242
Task 2 Bid Documents								$0				$0
Task 2.1 Bid Documents	3	8	40		10	8		$9,793				$9,793
Objective 2 Subtotal	3	8	40	0	10	8	0	$9,793	$0	$0	$0	$9,793
Task 3 Construction Oversight								$0				$0
Task 3.1 Site layout and staking	4	8	36		36	8		$11,556		$3,200		$14,756
Task 3.2 Construction oversight	4	8	80		80	20		$22,908		$6,400		$29,308
Objective 3 Subtotal	8	16	116	0	116	28	0	$34,464	$0	$9,600	$0	$44,064
Task 4 Monitoring								$0				$0
Task 4.1 As-built and post-construction photo documentation	4			36	36	8		$9,216		$3,200		$12,416
Task 4.2 Reporting	4	8	20	24	24	8		$11,132				$11,132
Objective 4 Subtotal	8	8	20	60	60	16	0	$20,348	$0	$3,200	$0	$23,548
Task 5 Construction Implementation	**Rate**	**30% Design Quantity**	**Revised Quantity**									
Mobilization (LS)	LS	1									$20,000	$20,000
Erosion and Sediment Control (LS)	LS	1									$6,000	$6,000
Temporary Access and Staging (LS)	LS	1									$6,000	$6,000
Vegetation Management (LS)	LS	1									$2,000	$2,000
Helicopter Mobilization (LS)	LS	1									$25,000	$25,000
18-24" DBH x 30-40' logs w rootwad (EA)	485	312	109								$52,962	$52,962
Rock Collar with Cable (EA)	1,200	120	42								$50,400	$50,400
6-12" DBH x 20-30' Racking wood (EA)	175	360	126								$22,050	$22,050
Slash (CY)	30	624	218								$6,552	$6,552
Hauling and Decking (HR)	130	200	70								$9,100	$9,100
Helicopter fight time (HR)	12,000	53	20								$240,000	$240,000
												$0
												$0
Objective 5 Subtotal									$0	$0	$440,064	$440,064
Total Project Hours	43	64	176	60	266	84	0					
Total Project Costs	$11,825	$10,944	$26,048	$7,260	$21,280	$9,240	$0	$86,597	$0	####	$0	$543,711

15. PHOTO DOCUMENTATION

As per the National Marine Fisheries Service's Biological Opinion for Relicensing of the Lewis River Hydroelectric Projects, we will provide photo documentation of habitat conditions at the project site before, during, and after project completion. We will include general views and close-ups showing details of the project and project area, including pre- and post-construction. We will label each photo with the date, time, project name, photographer's name, and documentation of the subject activity. The timing of photo collection is shown in the table below. During and after photo documentation will be conducted when the project is implemented, it is anticipated that post high flow and 3-5 year after construction photos will be part of a separate contract.

Photo	Timing
1	Pre-construction
2	Post-construction as-built
3	Post one high flow
4	3 years after construction
5	5 years after construction

16. INSURANCE

ACORD

COLULAN-02 AHILL

CERTIFICATE OF LIABILITY INSURANCE

DATE (MM/DD/YYYY) 8/13/2024

THIS CERTIFICATE IS ISSUED AS A MATTER OF INFORMATION ONLY AND CONFERS NO RIGHTS UPON THE CERTIFICATE HOLDER. THIS CERTIFICATE DOES NOT AFFIRMATIVELY OR NEGATIVELY AMEND, EXTEND OR ALTER THE COVERAGE AFFORDED BY THE POLICIES BELOW. THIS CERTIFICATE OF INSURANCE DOES NOT CONSTITUTE A CONTRACT BETWEEN THE ISSUING INSURER(S), AUTHORIZED REPRESENTATIVE OR PRODUCER, AND THE CERTIFICATE HOLDER.

IMPORTANT: If the certificate holder is an ADDITIONAL INSURED, the policy(ies) must have ADDITIONAL INSURED provisions or be endorsed. If SUBROGATION IS WAIVED, subject to the terms and conditions of the policy, certain policies may require an endorsement. A statement on this certificate does not confer rights to the certificate holder in lieu of such endorsement(s).

PRODUCER Alliant Insurance Services, Inc. 4530 Walney Rd Ste 200 Chantilly, VA 20151-2285	CONTACT NAME: Anna Hill PHONE (A/C, No, Ext): (703) 397-0977 FAX (A/C, No): (703) 397-0995 E-MAIL ADDRESS:
	INSURER(S) AFFORDING COVERAGE — NAIC # INSURER A : Federal Insurance Company — 20281
INSURED Columbia Land Trust 850 Officers Row Vancouver, WA 98661	INSURER B : INSURER C : INSURER D : INSURER E : INSURER F :

COVERAGES CERTIFICATE NUMBER: REVISION NUMBER:

THIS IS TO CERTIFY THAT THE POLICIES OF INSURANCE LISTED BELOW HAVE BEEN ISSUED TO THE INSURED NAMED ABOVE FOR THE POLICY PERIOD INDICATED. NOTWITHSTANDING ANY REQUIREMENT, TERM OR CONDITION OF ANY CONTRACT OR OTHER DOCUMENT WITH RESPECT TO WHICH THIS CERTIFICATE MAY BE ISSUED OR MAY PERTAIN, THE INSURANCE AFFORDED BY THE POLICIES DESCRIBED HEREIN IS SUBJECT TO ALL THE TERMS, EXCLUSIONS AND CONDITIONS OF SUCH POLICIES. LIMITS SHOWN MAY HAVE BEEN REDUCED BY PAID CLAIMS.

INSR LTR	TYPE OF INSURANCE	ADDL INSD	SUBR WVD	POLICY NUMBER	POLICY EFF (MM/DD/YYYY)	POLICY EXP (MM/DD/YYYY)	LIMITS	
A	X COMMERCIAL GENERAL LIABILITY; CLAIMS-MADE X OCCUR; GEN'L AGGREGATE LIMIT APPLIES PER: X POLICY, PRO-JECT, LOC; OTHER:	X	X	35360414	7/1/2024	7/1/2025	EACH OCCURRENCE	$ 1,000,000
							DAMAGE TO RENTED PREMISES (Ea occurrence)	$ 1,000,000
							MED EXP (Any one person)	$ 10,000
							PERSONAL & ADV INJURY	$ 1,000,000
							GENERAL AGGREGATE	$ 2,000,000
							PRODUCTS - COMP/OP AGG	$ Included
								$
A	AUTOMOBILE LIABILITY; X ANY AUTO; OWNED AUTOS ONLY; SCHEDULED AUTOS; HIRED AUTOS ONLY; NON-OWNED AUTOS ONLY			73549694	7/1/2024	7/1/2025	COMBINED SINGLE LIMIT (Ea accident)	$ 1,000,000
							BODILY INJURY (Per person)	$
							BODILY INJURY (Per accident)	$
							PROPERTY DAMAGE (Per accident)	$
								$
A	X UMBRELLA LIAB X OCCUR; EXCESS LIAB CLAIMS-MADE; DED X RETENTION $ 10,000			93651879	7/1/2024	7/1/2025	EACH OCCURRENCE	$ 10,000,000
							AGGREGATE	$
							Aggregate	$ 10,000,000
A	WORKERS COMPENSATION AND EMPLOYERS' LIABILITY Y/N; ANY PROPRIETOR/PARTNER/EXECUTIVE OFFICER/MEMBER EXCLUDED? (Mandatory in NH); If yes, describe under DESCRIPTION OF OPERATIONS below	N/A		71742388	7/1/2024	7/1/2025	PER STATUTE / OTH-ER	
							E.L. EACH ACCIDENT	$ 1,000,000
							E.L. DISEASE - EA EMPLOYEE	$ 1,000,000
							E.L. DISEASE - POLICY LIMIT	$ 1,000,000

DESCRIPTION OF OPERATIONS / LOCATIONS / VEHICLES (ACORD 101, Additional Remarks Schedule, may be attached if more space is required)
Certificate Holder is included as an additional insured on the general liability as required by written contract. Waiver of Subrogation applies on General Liability in favor of Certificate holder.

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ACORD 25 (2016/03)

Client#: 188991 CRAMFISH

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PRODUCER
Propel Insurance
COM Middle Market
805 SW Broadway; Suite 2300
Portland, OR 97205-3363

CONTACT NAME: Jessica M Gordon
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INSURER(S) AFFORDING COVERAGE	NAIC #
INSURER A : Chubb Indemnity Insurance Company	12777
INSURER B : Federal Insurance Company	20281
INSURER C : Atlantic Specialty Insurance Company	27154
INSURER D : Ace American Insurance Company	22667
INSURER E : StarStone National Insurance	25496
INSURER F :	

INSURED
S. P. Cramer & Associates, Inc.
DBA Cramer Fish Sciences
7525 NE Ambassador Pl., Ste C
Portland, OR 97220

COVERAGES CERTIFICATE NUMBER: REVISION NUMBER:

THIS IS TO CERTIFY THAT THE POLICIES OF INSURANCE LISTED BELOW HAVE BEEN ISSUED TO THE INSURED NAMED ABOVE FOR THE POLICY PERIOD INDICATED. NOTWITHSTANDING ANY REQUIREMENT, TERM OR CONDITION OF ANY CONTRACT OR OTHER DOCUMENT WITH RESPECT TO WHICH THIS CERTIFICATE MAY BE ISSUED OR MAY PERTAIN, THE INSURANCE AFFORDED BY THE POLICIES DESCRIBED HEREIN IS SUBJECT TO ALL THE TERMS, EXCLUSIONS AND CONDITIONS OF SUCH POLICIES. LIMITS SHOWN MAY HAVE BEEN REDUCED BY PAID CLAIMS.

INSR LTR	TYPE OF INSURANCE	ADDL INSR	SUBR WVD	POLICY NUMBER	POLICY EFF (MM/DD/YYYY)	POLICY EXP (MM/DD/YYYY)	LIMITS	
A	X COMMERCIAL GENERAL LIABILITY	X	X	D02313704	06/18/2024	06/18/2025	EACH OCCURRENCE	$1,000,000
	CLAIMS-MADE [X] OCCUR						DAMAGE TO RENTED PREMISES (Ea occurrence)	$1,000,000
							MED EXP (Any one person)	$5,000
							PERSONAL & ADV INJURY	$1,000,000
	GEN'L AGGREGATE LIMIT APPLIES PER:						GENERAL AGGREGATE	$2,000,000
	[X] POLICY [ ] PRO-JECT [ ] LOC						PRODUCTS - COMP/OP AGG	$2,000,000
	OTHER:							$
A	AUTOMOBILE LIABILITY	X	X	73643003	06/18/2024	06/18/2025	COMBINED SINGLE LIMIT (Ea accident)	$1,000,000
	[X] ANY AUTO						BODILY INJURY (Per person)	$
	[ ] OWNED AUTOS ONLY [ ] SCHEDULED AUTOS						BODILY INJURY (Per accident)	$
	[X] HIRED AUTOS ONLY [X] NON-OWNED AUTOS ONLY						PROPERTY DAMAGE (Per accident)	$
								$
B	[X] UMBRELLA LIAB [X] OCCUR	X	X	56722818	06/18/2024	06/18/2025	EACH OCCURRENCE	$5,000,000
	EXCESS LIAB CLAIMS-MADE						AGGREGATE	$5,000,000
	DED [X] RETENTION $0							$
E	WORKERS COMPENSATION AND EMPLOYERS' LIABILITY Y/N; ANY PROPRIETOR/PARTNER/EXECUTIVE OFFICER/MEMBER EXCLUDED? [Y] (Mandatory in NH); If yes, describe under DESCRIPTION OF OPERATIONS below	N/A	X	T10241464	06/18/2024	06/18/2025	X PER STATUTE / OTH-ER	
							E.L. EACH ACCIDENT	$1,000,000
							E.L. DISEASE - EA EMPLOYEE	$1,000,000
							E.L. DISEASE - POLICY LIMIT	$1,000,000
C	Watercraft Liab			B5JH74533	06/18/2024	06/18/2025	$2,000,000	
D	Professional Liab			D02313091	06/18/2024	06/18/2025	$2,000,000 Occ/Agg	

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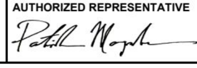

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17. APPENDIX A: 30% DESIGN

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PINE CREEK RESTORATION DESIGN

30% Basis of Design Report: Reach 5 Preliminary Design

Prepared for:

PacifiCorp

Pacific Power
Rocky Mountain Power
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Portland, OR 97232

Prepared by:

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An Employee Owned Consulting Company

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Report created: September 2024

1. EXECUTIVE SUMMARY

PacifiCorp owns the Merwin, Yale, and Swift No. 1 hydroelectric projects on the Lewis River in southwest Washington. Public Utility District No. 1 of Cowlitz County, Washington (Cowlitz PUD) owns the Swift No. 2 hydroelectric project, also located on the Lewis River. These projects are operated as a coordinated system. On November 30, 2004, the Lewis River Settlement Agreement (SA) established the Lewis River Aquatic Fund (Fund). On June 26, 2008, the Federal Energy Regulatory Commission acknowledged this fund as a stipulation of project operating licenses. The purpose of the Fund is to support resource protection measures via aquatic related projects (Projects) in the Lewis River basin. This project is one of the aquatic related projects funded, designed to meet each of the following priority objectives as specified in the project operating licenses and the SA: (1) Benefit to fish recovery throughout the North Fork Lewis River, with priority to federal ESA-listed species; (2) Support of the reintroduction of anadromous fish throughout the Basin; and (3) Enhancement to fish habitat in the Lewis River Basin, with priority given to the North Fork Lewis River.

Cramer Fish Sciences (CFS) and Columbia Land Trust (CLT) were retained by PacifiCorp to complete the Pine Creek Restoration Design Project. This project addresses all three priority objectives of the Lewis River Aquatic Fund including benefiting recovery of ESA listed species in the North Fork of the Lewis, supporting reintroduction of anadromous fish throughout the Basin, and enhancing fish habitat in the North Fork of Lewis Basin. It is also in alignment with and builds off the bull trout Habitat Restoration Identification Assessment (Lamperth et al. 2017).

The 15% basis of design report and appendices contain proposed conceptual alternatives for Pine Creek Reaches 1-6 and supporting documentation. The primary design elements proposed include large wood jams placed by helicopter due to the difficulty in accessing the Pine Creek floodplain. Proposed design elements are intended to address aquatic habitat limiting factors and provide a process-based restoration trajectory for the Pine Creek watershed. The basis of design report includes documentation that supports the proposed design including assessments of geomorphic, riparian, and habitat conditions as well as hydrologic and hydraulic analysis. An assessment of proposed design element risk and anticipated project regulatory requirements is included for planning purposes. The basis of design report and appendices is intended to meet the requirements of Recreation and Conservation Office (RCO) Manual 18 Design and Restoration Project guidelines and Pacific Northwest Region Aquatic Restoration Project Environmental Assessment Aquatic Restoration Biological Opinions (ARBO II).

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2. INTRODUCTION

Pine Creek is a major tributary to the North Fork (NF) Lewis River and provides important habitat for one of the three remaining spawning populations of ESA listed Lewis River bull trout *Salvelinus confluentus* as well as important habitat for steelhead *Oncorhynchus mykiss*. It is also utilized by listed coho salmon *O. kisutch* and spring Chinook salmon *O. tshawytscha*. The Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan indicates that Pine Creek is the number one area with the greatest current or potential production of bull trout in the upper NF Lewis Basin (LCFRB 2010). The plan states that bull trout may benefit from targeted riparian and stream channel restoration in reaches of Pine Creek.

There have been periodic assessments of the conditions in Pine Creek, including work by the United States Forest Service (USFS), U.S. Geological Survey (USGS), Washington Department of Fish and Wildlife (WDFW), and PacifiCorp as well as on going spawner surveys by PacifiCorp. A watershed assessment in the 1990s by the USFS indicated concerns with peak flows due to young vegetation and high forest road density as well as mass wasting water quality concerns due to unstable and erodible sediments (USFWS 1995b, USFS 1996). More recent habitat surveys by the USGS in Pine Creek tributaries (P1 and P7) similarly showed very low levels of pool habitat, little to no large woody debris (LWD), and poor riparian condition (PacifiCorp 2016). Large woody debris concentrations in Pine Creek are low (<40 pieces per mile) and it also has low recruitment potential because of logging and the 1980 eruption of Mt. St. Helens. Additionally, resulting channel instability and migration have impeded mature conifer growth, leading to a riparian corridor dominated by immature alders. EDT modeling efforts for Chinook, coho, and steelhead indicate that portions of Pine Creek are limited by habitat diversity (complexity/large wood) and sediment, while others, like P8, are key habitats (PacifiCorp 2016).

More recent work found that bull trout redds in the Pine Creek Basin were four times more likely to occur in reaches with complex channels (i.e., more than one channel with flowing water during base flow conditions) than reaches with only one main channel and redd occurrence was negatively related to stream depth (Lamperth et al. 2017). This suggests that habitat complexity and depth at the reach scale are important factors influencing bull trout spawning site selection within thermally suitable habitat (Lamperth et al. 2017). The study recommends restoration actions that increase channel complexity in the coldest accessible stream reaches within the basin. Recent spawner surveys suggest that with increasing numbers of bull trout, spawners are moving into lower quality areas to spawn.

Although bull trout redds have been documented thoughout much of Pine Creek, in 2014 Reach 1 and 4 had no documented redds and Reach 3 had only one documented redd. In years of higher bull trout spawner abundance, such as 2021 and 2022, some redds have been documented in these reaches (PacifiCorp pers. comm). Therefore, there is an opportunity to improve complexity in these reaches for the benefit of spawning bull trout as well as other species, while avoiding areas of currently high-quality bull trout spawning habitat. Other Pine Creek reaches and tributaries are listed as Tier 4 reaches in SalmonPORT (Pine Creek 3, P8), though they may also benefit from restoration.

According to SalmonPORT, Pine Creek Reaches 1, 2, 4, 5, and 6 are Tier 2 priority reaches, have high potential as contributing reaches for winter steelhead, and are designated as a high or medium multi-species priority for several restoration needs, as shown in Table 1.

Table 1. Multi-species (steelhead, spring Chinook salmon, coho salmon) restoration needs for Pine Creek, as reported on SalmonPORT. H = high (red), M = medium (yellow), L = low (green).

	Pine Creek Reaches and Multi-Species Priority					
Restoration Needs	**1**	**2**	**3**	**4**	**5**	**6**
Off channel and side channel habitat	H	H	H	H	H	H
Riparian conditions & functions	H	H	H	H	H	H
Stream channel habitat structure & bank stability	H	H	H	H	H	H
Watershed conditions & hillslope processes	H	H	H	H	H	H
Floodplain function & channel migration processes	H	H	H	H	H	M
Instream flows	M	H	M	M	M	M
Access to blocked habitats	L	L	L	L	L	L
Regulated stream mgt. for habitat functions	L	L	L	L	L	L
Water quality	L	L	L	L	L	L

Given the recently improved protection and ownership status of Pine Creek, the ongoing riparian and upland forest restoration, the priority reaches identified in SalmonPORT, and previous assessment work identifying limiting factors and bull trout habitat restoration opportunities, there is a unique opportunity to design holistic instream and riparian restoration in selected reaches of Pine Creek to benefit bull trout as well as salmon and steelhead.

3. PROJECT BACKGROUND

3.1 Project Location

Pine Creek is a tributary to the Upper NF Lewis River, flowing from the southwest flank of Mt. St. Helens into the NF Lewis immediately upstream on Swift Reservoir (Figure 1). Previous assessments of Pine Creek have developed reach breaks based on geomorphic and biological condition. There are 6 reaches in Pine Creek, which break at tributary junctions. Tributaries are labeled P1 through P10, from downstream to upstream. This assessment extends from the USFS property boundary in Reach 1 (at approximately River Mile (RM) 0.95) to the migration barrier in Reach 6 (approximately RM 7.54). The analysis portion of this assessment also includes the lower 0.95 RMs, but this section is not included in proposed designs because it is privately owned. This project excludes tributary reaches but includes opportunities within the valley bottom.

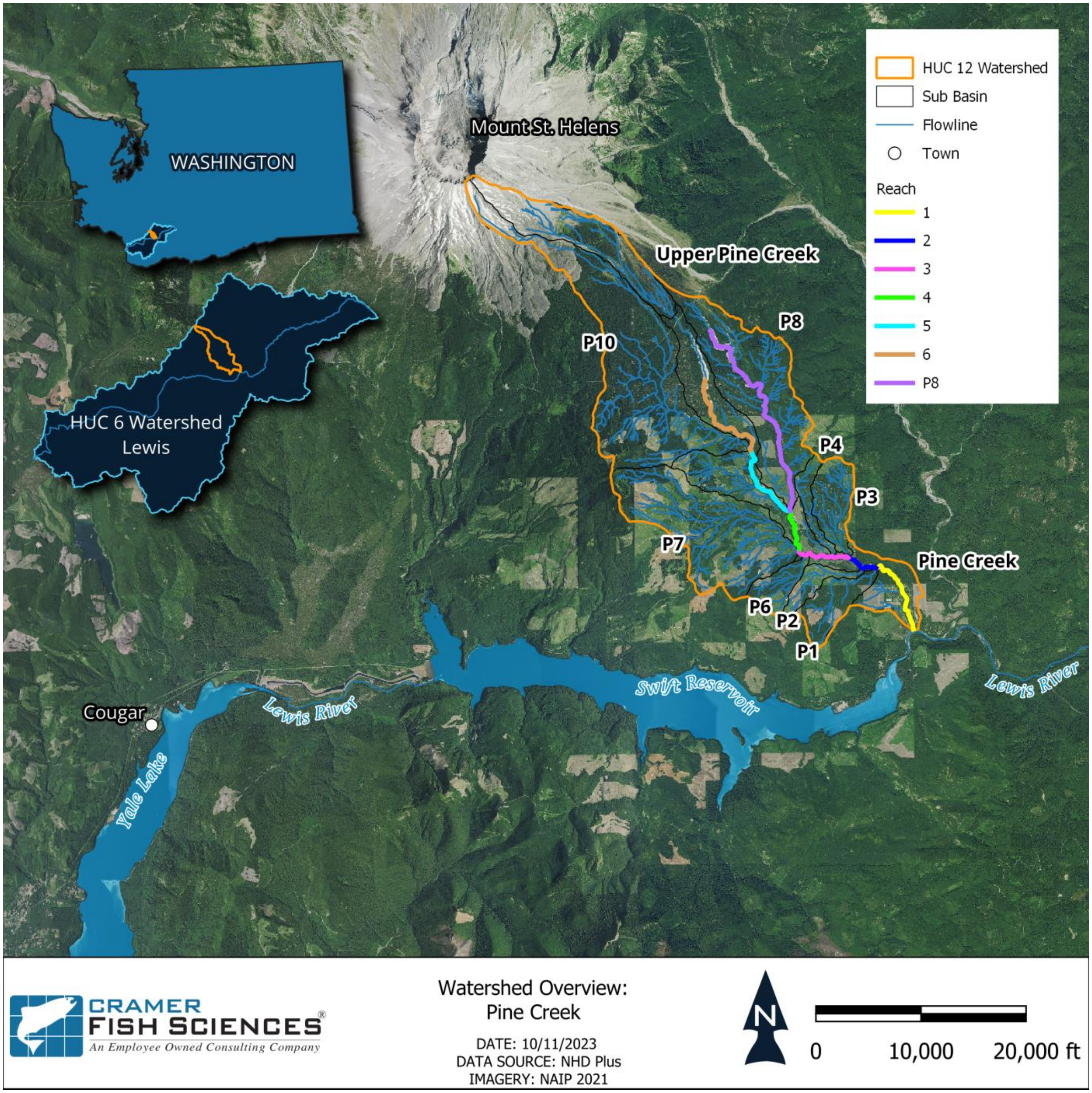

Figure 1. Overview map of the Pine Creek watershed and the surrounding area.

3.1.1 Goals, Objectives, and Constraints

Project goals, objectives, and constraints were developed using existing watershed basin planning documents, including the *Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* (LCFRB, 2010), *Lower Columbia Fish Recovery Board Climate Change and Habitat Priorities* (LCFRB, 2018), and *Lewis River bull trout Habitat Restoration Project Identification Assessment Final Report* (Lamperth et al. 2017). This section documents the merging of relevant goals from existing watershed plans with project-specific goals, assigning and generating quantitative objectives, and identifying project constraints.

Goals

The overall goal of the Pine Creek Restoration Design Project is to improve instream habitat complexity and riparian habitat in Pine Creek to address key limiting factors. Specifically, project goals aim to:

1. Improve habitat complexity in simplified reaches through large wood placement
2. Stabilize sediment to allow for riparian succession to mature conifer forest
3. Increase side channels and spawning habitat for bull trout, salmonids, and steelhead
4. Protect existing quality spawning habitat for bull trout, salmonids, and steelhead
5. Create resting areas for spawning adult bull trout, salmonids, and steelhead
6. Improve holding pools for juvenile bull trout, salmonids, and steelhead
7. Improve overwintering habitat for salmonids
8. Reduce or stabilize incision rates in areas with floodplain pockets

Objectives

The *Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* (LCFRB, 2010), *Lower Columbia Fish Recovery Board Climate Change and Habitat Priorities* (LCFRB, 2018), and -SalmonPORT list limiting factors, restoration needs and considerations, which are compiled below, reordered to highlight similarities:

Table 2. Limiting factors and restoration needs (LCFRM 2010, LCFRB 2018, SalmonPORT).

LCFRM 2010	LCFRB 2018	SalmonPORT
Habitat Diversity	Habitat Diversity	Off channel and side channel habitat
Habitat Connectivity	Cold Water Refugia	Riparian conditions & functions
Channel Stability		Stream channel habitat structure & bank stability
Riparian Function	High Quality Floodplain Habitat	Floodplain function & channel migration processes
Substrate and Sediment	Mature Riparian and Upland Forest	Watershed conditions & hillslope processes
Water Quality	Instream Flow	Instream flows

1. **Habitat diversity**: This project proposes to address limitations and restoration objectives for habitat diversity primarily through addressing the lack of instream woody material, homogeneous habitat units (especially pools and channel margin habitat), and restoring or preserving longitudinal, lateral, and vertical hydrologic connectivity to support a diversity of species and life histories.
2. **Habitat Connectivity:** There are no existing anthropogenic migration blockages within the project area, therefore this objective will focus on providing habitat connectivity resiliency by improving cold water refugia patches and habitat heterogeneity, allowing for habitats to be connected and accessible under varied flow and climatic conditions.
3. **Channel Stability:** The Mount St. Helens eruption and associated debris flows in Pine Creek, combined with watershed land use practices, have created conditions that are less stable

compared to historical conditions. This objective will focus on resiliency to bed and bank erosion as well as mass wasting events, improving the capacity to mitigate natural events.

4. **Riparian Function:** The Pine Creek riparian corridor is primarily composed of immature alder stands, therefore addressing this objective will focus on progressing riparian succession consistent with natural processes. Enhancing riparian succession will allow for increased bank and soil stability as well as wood recruitment into the future, establishing the processes to improve riparian function.
5. **Substrate and Sediment:** This project proposed to address limitations and restoration objectives for substrate and sediment through assessment of current geomorphic conditions and identification of process-based restoration actions that reduce excess fine sediment and provide substrate required for a diversity of species life histories.
6. **Water Quality:** This project proposes to address limiting factors related to water quality by enhancing floodplain connectivity to allow storage of fine sediment as well as assess and recommend actions to mitigate for altered streamflow regime. There is currently no existing instream flow water right on Pine Creek, this project does not address instream flow water rights.

Restoration design shall prioritize actions in the following order: 1) protect existing functional habitats and the processes that sustain them, 2) allow no further degradation of habitat or supporting processes, 3) re-connect isolated habitat, 4) restore watershed processes (ecosystem function), 5) restore habitat structure, and 6) create new habitat where it is not recoverable (LCFRB 2010).

Constraints

The unique opportunity to support bull trout, salmonid, and steelhead populations is not without constraints and challenges. These constraints will be further detailed throughout the report, but primary constraints include:

1. **Cost-effective and appropriately scaled restoration actions:** In order to benefit aquatic organisms and meet project goals, restoration actions must match the scale of the system, be cost-effective, and produce measurable results.
2. **Process-based design principles:** Restoration actions should follow process-based restoration design principles to allow for natural river dynamics and be appropriate for the system.
3. **Environmental regulations and impacts.** Project should meet environmental regulation requirements and minimize impacts to aquatic ecosystems, wetlands, flood risk, and additional factors.
4. **Infrastructure and property risk:** Project should not have a detrimental impact to infrastructure and private property.
5. **Construction limitations:** Site staging, access, procurement, and construction method should be cost effective and minimize impact.

4. SITE CHARACTERIZATION

4.1 Site History

Pine Creek drains approximately 26 mi^2 and is mixed ownership by the USFS, private timberlands, as well as some private residential tracts in the lower reaches (Figure 1). Amid an upsurge of unchecked development in the mid-2000s, Columbia Land Trust collaborated with Pope Resources (a Washington-based timber company) and Skamania County to develop a comprehensive conservation effort to protect 20,000 acres around Swift Reservoir from development that is held by DNR in a Forest Legacy Easement. The Columbia Land Trust owns 2,494 acres in fee title as well as 2,885 acres of conservation easement held in conservation easement. Together, the two parcels protect most of the watershed from development. The Columbia Land Trust is managing these lands to benefit bull trout, northern spotted owls, gray wolves, and other ESA listed species as well as for forest health and recreational opportunities. The focus of management to date has been on moving the industrially managed forest to a natural, old growth forest structure benefiting these species. This is accomplished through conservation-oriented timber thinning to enhance stand development and structural/compositional diversity, inter-planting with diverse trees and shrubs, installation of habitat features such as snags and downed woody debris, and weed control. Restoration and enhancement of riparian habitats has been identified as a priority need and opportunity for Land Trust land management. This project is directly supporting the achievement of this management goal in a comprehensive manner that limits potential detrimental impacts to existing bull trout habitat.

4.2 Watershed and Land Cover

Although the Pine Creek watershed consists of primarily evergreen forests, there has been frequent timber harvesting throughout the watershed since at least 1952 (Figure 2). According to the National Land Cover Database (NLCD), evergreen forest is the most abundant landcover type, ranging from 45–71% of the area, depending on the reach (Figure 4; Table 3). The upper portion of Reach 6, which is located at the base of Mt. St. Helens, consists of barren land where there is no soil or vegetation present. The earliest aerial imagery from 1952 shows that there was timber harvesting in portions of Reaches 3–6 (Appendix K). The 1994 aerial imagery shows the effects of the 1980 Mt. St. Helens eruption, which resulted in lahar deposition along the flow path (Appendix KFigure 48). In the upstream portion of Reach 6, there has been some vegetation colonization along the lahars; however, vegetation has not been able to colonize the lahars near Pine Creek where, according to the LIDAR data, there is a steeper change in elevation.

Additionally, the areas harvested in 1952 had mostly regrown and newly harvested areas were present throughout the basin by 1994. This pattern of continuous harvesting and regrowth continues through 2021, with concentrations varying by reach and year (Figure 49 - Figure 51). There is clear evidence of commercial stand thinning to improve forest habitats starting in 2015 and expanding in 2021. The area of shrub and scrub habitat ranges from 19–32% for Reaches 2–5 but Reaches 1 and 6 only have 7–9%. Grassland and herbaceous habitat area ranges from 11–29% for Reaches 1, 2, and 4 but Reaches 3, 5 and 6 only have 2–3%. The NLCD locations for shrub and scrub habitat correspond with the timber harvesting that occurred between 2006 and 2015, while the grassland and herbaceous habitat correspond with the timber harvesting that occurred between 2015 and 2021. Although there has been substantial harvesting throughout the basin, comparing the aerial imagery with LIDAR shows that it did not extend into the riparian corridor which is along the 30–60 m canyon walls.

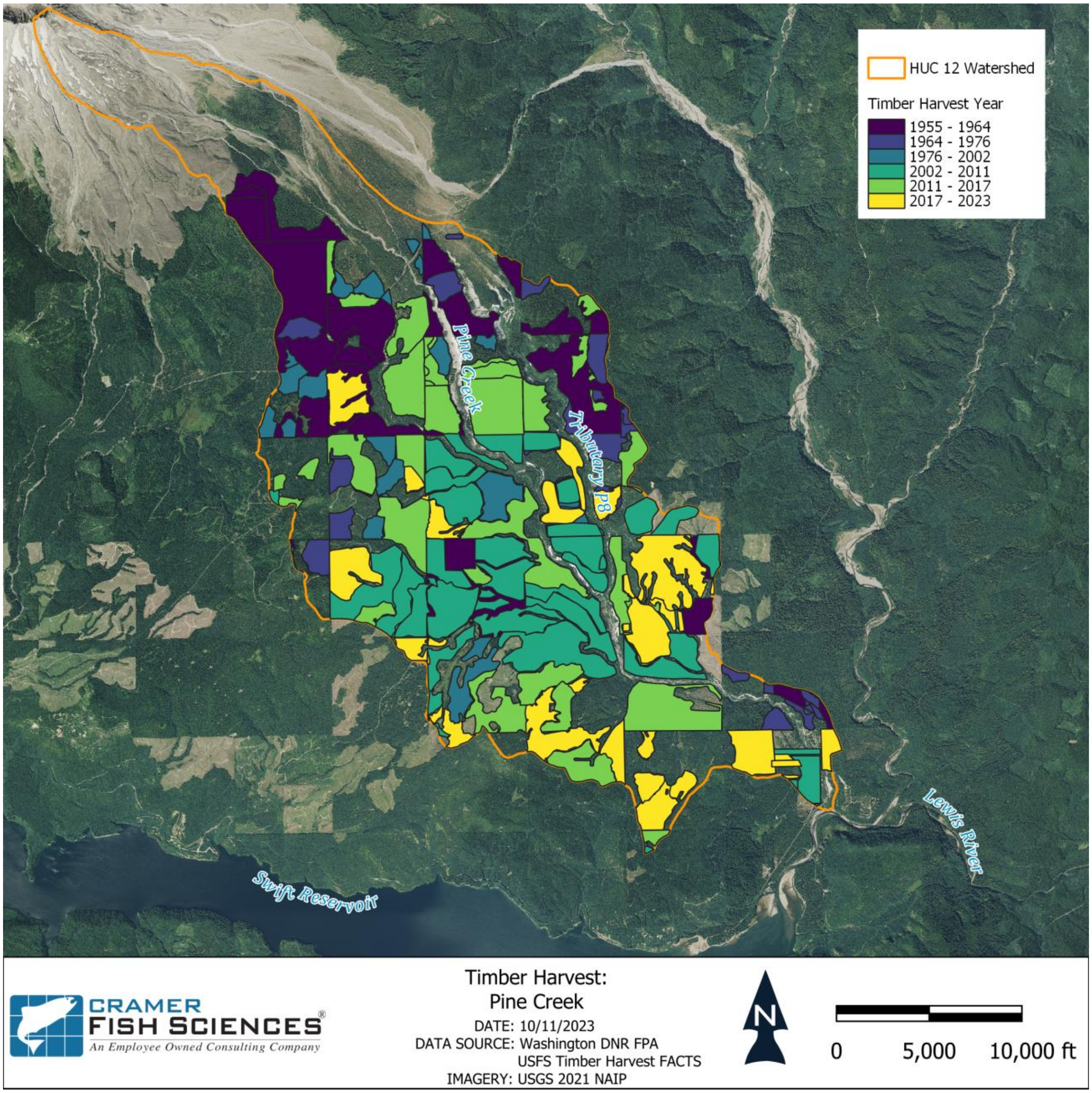

Figure 2. Map of recent years of timber harvest in the Pine Creek watershed.

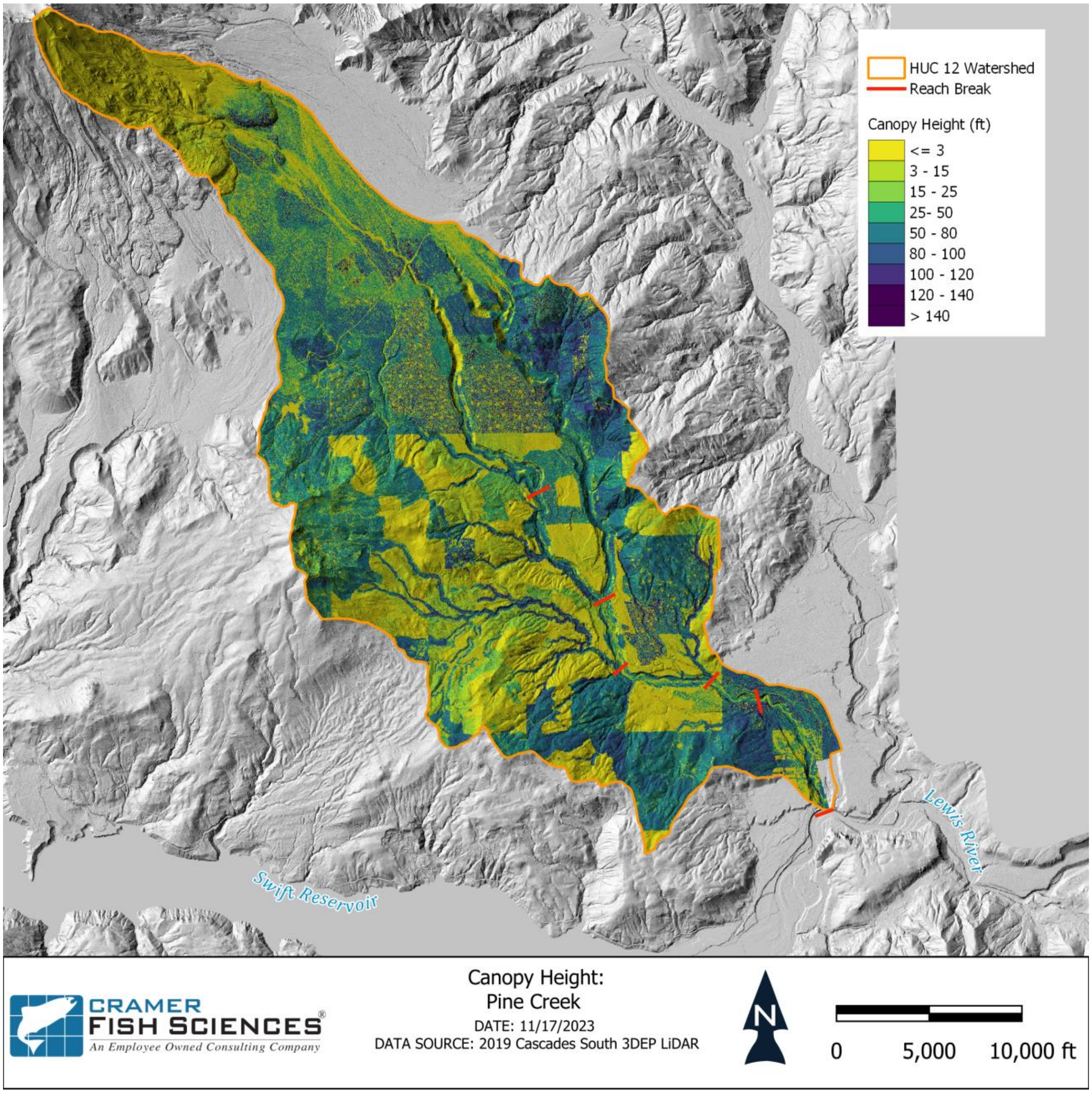

Figure 3. Map of canopy height in the Pine Creek watershed.

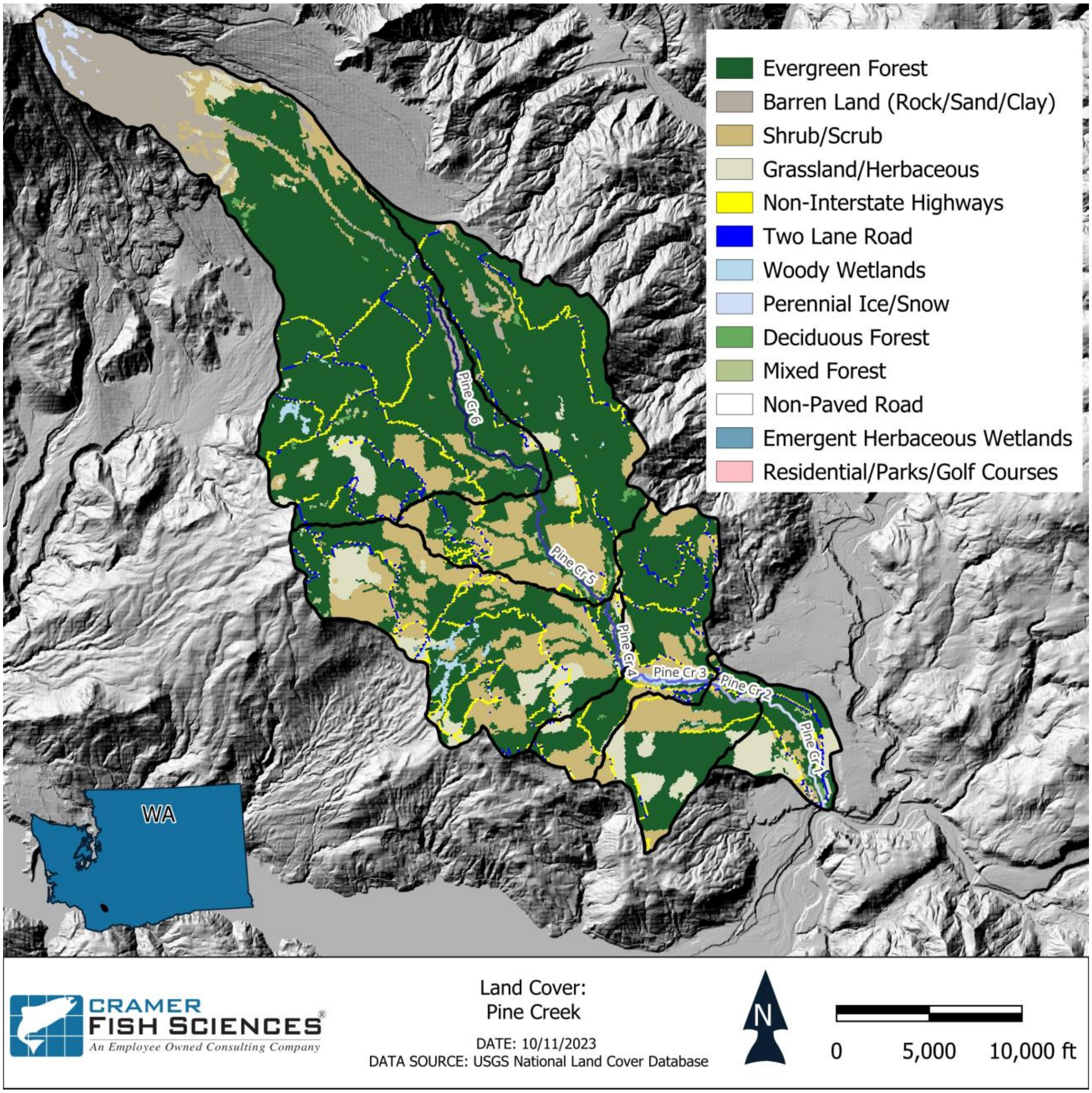

Figure 4. USGS National Land Cover for Pine Creek watershed.

Table 3. USGS National Land Cover percentage for six reaches along Pine Creek.

Land Cover Type	Reach 1	2	3	4	5	6
Evergreen Forest	49%	55%	61%	45%	71%	66%
Barren Land (Rock/Sand/Clay)	<1%	-	-	<1%	1%	16%
Shrub/Scrub	7%	22%	23%	32%	19%	9%
Grassland/Herbaceous	29%	16%	3%	11%	2%	3%
Non-Interstate Highway	4%	5%	6%	6%	4%	2%
Two Lane Road	6%	1%	4%	2%	2%	1%
Woody Wetlands	-	1%	3%	2%	<1%	<1%
Perennial Ice/Snow	-	-	-	-	-	1%
Deciduous Forest	2%	<1%	<1%	<1%	1%	<1%
Mixed Forest	1%	<1%	<1%	<1%	<1%	<1%
Non-Paved Road	1%	<1%	<1%	<1%	<1%	<1%
Emergent Herbaceous Wetlands	<1%	<1%	<1%	<1%	<1%	<1%
Residential/Parks/Golf Courses	<1%	<1%	<1%	<1%	<1%	<1%

4.3 Biological Assessment

Historically, the upper North Fork Lewis River subbasin supported large numbers of bull trout, spring-run Chinook salmon, coho salmon , and winter steelhead . However, populations have declined due to the construction of the Lewis River hydropower system, past forestry practices, and the eruption of Mt. St. Helens (LCFRB 2010). Lake Merwin was built in 1931 and has a 240 ft dam that prevents anadromous fish passage and blocks up to 80% of the historically available habitat in the upper Lewis River Basin. Yale Lake and Swift Reservoir were built upstream of Merwin Lake in 1953 and 1959, respectively, and directly inundate over 25 miles of historical stream habitat. Additionally, timber removal from past forestry practices has caused altered stream flow, increased sediment, and degraded riparian vegetation. The likely cause of increases in stream temperatures is channel widening caused by timber harvest combined with the vegetation loss from the 1980 Mt. St. Helens eruption. Pine Creek, which is one of only three tributaries to the Upper NF Lewis River subbasin where bull trout are known to spawn, experienced a 210% increase in stream widths between 1959 and 1989. Additionally, the natural recruitment potential of LWD has been reduced due to lingering effects of the 1980 Mt. St. Helens eruption and past logging practices (LCFRB 2010).

Bull trout were listed as federally threatened in 1999 due to declines in their distribution, abundance, and habitat (64 FR 58910; November 1, 1999). The Lewis River bull trout Recovery Team (LRBTRT) is a partnership between the U.S. Fish and Wildlife Service (USFWS), WDFW, PacifiCorp, USFS, USGS, the Lower Columbia Fish Recovery Board, and other groups that collaborate to determine research needs and recovery actions for bull trout in the Lewis River subbasin (Hudson et al. 2019). Substantial research has been conducted by the LRBTRT to understand system-specific life history patterns and population declines of bull trout in the Lewis River. Recent population estimates are between 250–500, which is lower than the USFWS minimum population target of 900 and has only been exceeded four times since 1994 (Lamperth et al., 2017). Currently, there is known spawning in two tributaries upstream of Swift Reservoir, Rush Creek, and Pine Creek. At present, the only known population of bull trout are adfluvial, where adults occupy Swift Reservoir and migrate to tributaries for spawning.

Juveniles will rear in the tributaries for approximately 0–3 years before migrating to the reservoir as adults. Prior to the hydropower system, there were likely populations of fluvial and anadromous forms of bull trout (LCFRB 2010).

Anadromous species, such as coho salmon, spring Chinook salmon, and steelhead occur within the subbasin, which are all federally listed under the endangered species act (64 FR 14308; March 24, 1999; 70 FR 37160; June 28, 2005; 71 FR 834; January 5, 2006; LCFRB 2010). The passage barrier from the hydropower systems caused anadromous salmonid populations to drastically decline in the NF Lewis Basin. The historic population of anadromous salmonids within the Lewis River basin was estimated to range from 7,500–85,000 (LCFRB 2010). However, after the construction of Merwin Dam, which created a passage barrier to optimal spawning habitats, their estimated populations decreased to 200–1,000 (LCFRB 2010). The Lewis River below Merwin Dam is identified as critical habitat for listed salmon and steelhead under the ESA (70 FR 52630). In addition, under the Magnuson-Stevens act, the Lewis River was designated as Essential Fish Habitat for Chinook and coho salmon by the Pacific Fisheries Management Council and NOAA (FERC 2008). As a result, the FERC approved settlement agreement for the new license for the NF Lewis River Hydroelectric Project required the reintroduction of anadromous salmonids by providing fish passage upstream of Merwin Dam and downstream of Swift No. 1 Dam (PacifiCorp 2018). The target species in the FERC 2008 settlement agreement are spring Chinook salmon, early run (S-Type) and late run (N-Type) coho salmon and winter steelhead (LCFRB 2010; PacifiCorp 2018).

Bull Trout Occurrence in the Project Area

The population of bull trout in the Lewis River is adfluvial, migrating from reservoirs to tributaries for spawning and juvenile rearing. bull trout spend most of the year foraging in Swift Reservoir until spawning migrations to Rush Creek, Pine Creek, or P8, a tributary of Pine Creek (CLT 2013, Lamperth et al. 2017). From 1994–2016, abundances of bull trout staging in Lewis River near the head of Swift Reservoir were estimated using a mark-recapture study and ranged from 101–753 with a maximum abundance in 2004 of 1,287 individuals (Hudson et al., 2019). Passive Integrated Transponders (PIT) tag surveys from 2011–2017 found that bull trout were using Pine Creek tributaries and Pine Creek more than Rush Creek for spawning and fish detections have declined in Rush Creek since 2013 (CLT 2013, Lamperth et al. 2017). Additionally, the effective number of bull trout breeders was calculated from 2013–2016 based on genetic tissue samples from age-0 bull trout. There was an average of 18.4 (15.5–21.7) breeders in Pine Creek (and P8) compared to an average of 15.4 (7.4–23) breeders in Rush Creek. Prior to spawning migrations, bull trout will stage at the upstream end of Swift Reservoir in the spring and begin migration in July or August (

Table 4). There have been no linkages found between timing of upstream spawning migrations and Lewis River discharge (Hudson et al., 2019). Spawning will occur between September and October and by November adults are returning to Swift Reservoir (Lamperth et al. 2017). Around mid-January to late February, bull trout fry emerge from gravel substrates and rear in the tributaries for up to three years before migrating downstream to Swift Reservoir in the spring (CLT 2013, Lamperth et al. 2017). bull trout will remain in Swift Reservoir until they become sexually mature at age 4–5 and begin their spawning migrations to the upstream tributaries (CLT 2013).

There have been numerous studies on bull trout spawning within the subbasin. Redd surveys have been conducted on Pine Creek from 2017–2022 and an average of 71.8 redds are documented annually (Figure 5; PacifiCorp Personal Communication 2023). Redd count surveys conducted in 2014 and 2017 consistently found more redds in P8 (46 and 42, respectively) than in Pine Creek (20 and 14, respectively; Lamperth et al. 2017; PacifiCorp 2018). Additionally, Doyle (2017) surveyed bull trout redds in P8 from 2008–2017 and found between 13–48 redds annually (Hudson et al., 2019). Habitat features in P8, such as reduced gradient and discharge, and increased tree canopy and LWD provide spawning and rearing habitat that is lacking in other Pine Creek tributaries (CLT 2013). bull trout redds are positively associated with complex channels (i.e., containing large wood and side channels) and negatively associated with stream depth (Figure 6; Lamperth et al. 2017). Their preferred spawning depth is 5.9–7.9 in. Additionally, bull trout are one of the most cold-water adapted salmonid species in North America and need 35.6–39.2 °F stream temperature for successful egg incubation (Lamperth et al., 2017; Hudson et al., 2019). Studies in the upper Lewis River Basin have shown that bull trout spawn and rear in the coldest available stream reaches, suggesting that temperature is a limiting factor for bull trout spawners in this system (Hudson et al. 2019). Spawning and rearing habitat could be improved by restoring floodplain connection and riparian vegetation, which could reduce stream temperatures, runoff rates, velocities, and sediment input (CLT 2013).

Table 4. Periodicity for bull trout life stages (blue) and adult spawning for non-target salmonid species (green) within project area.

Life Stage	J	F	M	A	M	J	J	A	S	O	N	D
Adult pre-migration staging[1]			X	X	X	X						
Adult spawning migration[1]							X	X				
Adult spawning[1]									X	X		
Adult adfluvial migration[1]											X	
Fry emergence[2]	X	X										
Juvenile adfluvial migration[1]			X	X	X	X						
Late form coho salmon[3]	X	X	X								X	X
Early form coho salmon[3]										X	X	
Spring Chinook salmon[3]								X	X			
Wild-origin winter steelhead[3, 4]			X	X	X	X						
Hatchery-origin winter steelhead[3, 4]												X
Adfluvial and fluvial cutthroat trout[3]		X	X	X	X	X						

[1]Lamperth et al. 2017; [2]CLT 2013; [3]LCFRB 2010; [4]PacifiCorp 2018

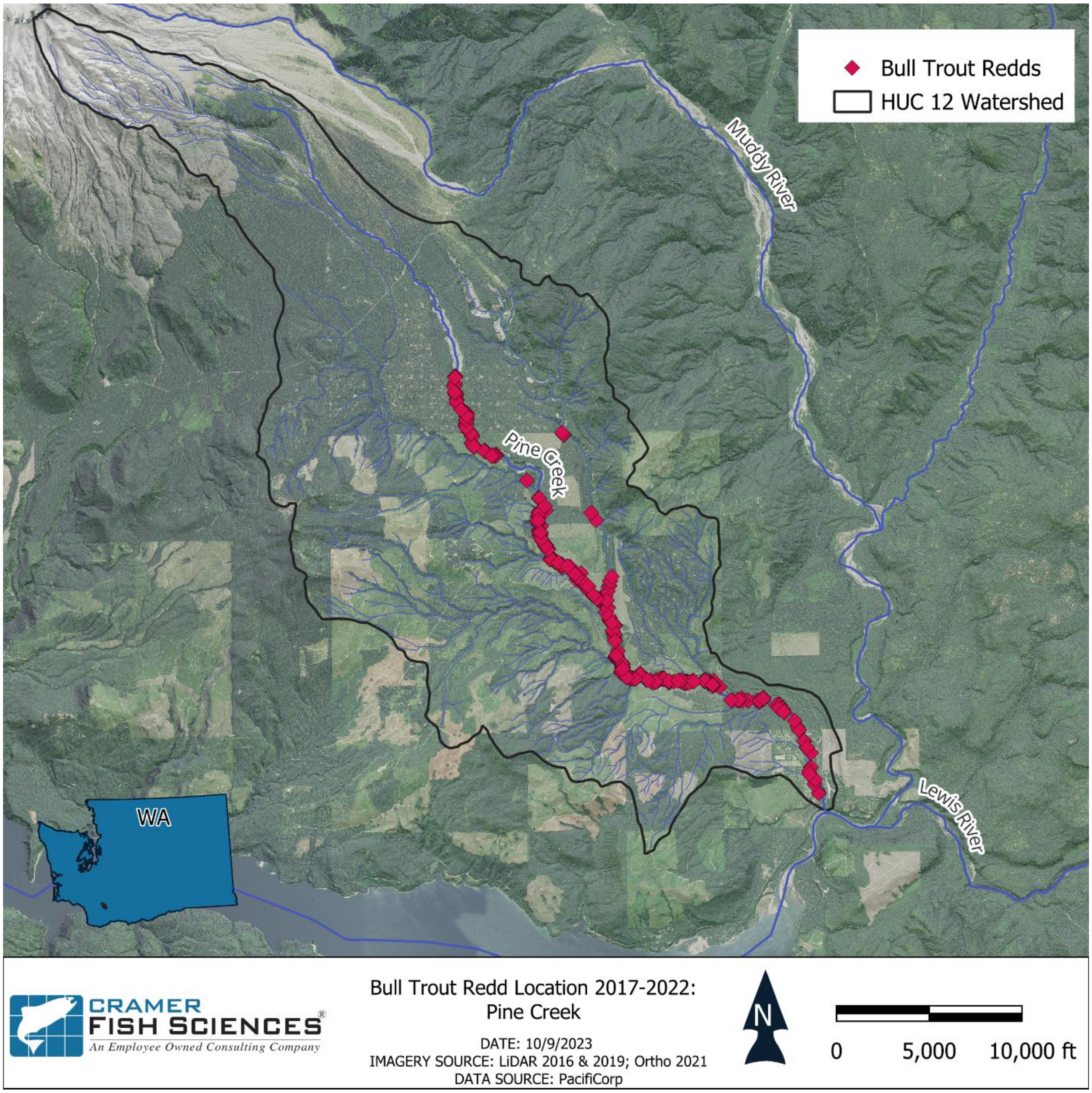

Figure 5. Location of bull trout redds sampled by PacifiCorp from 2017–2022 along Pine Creek.

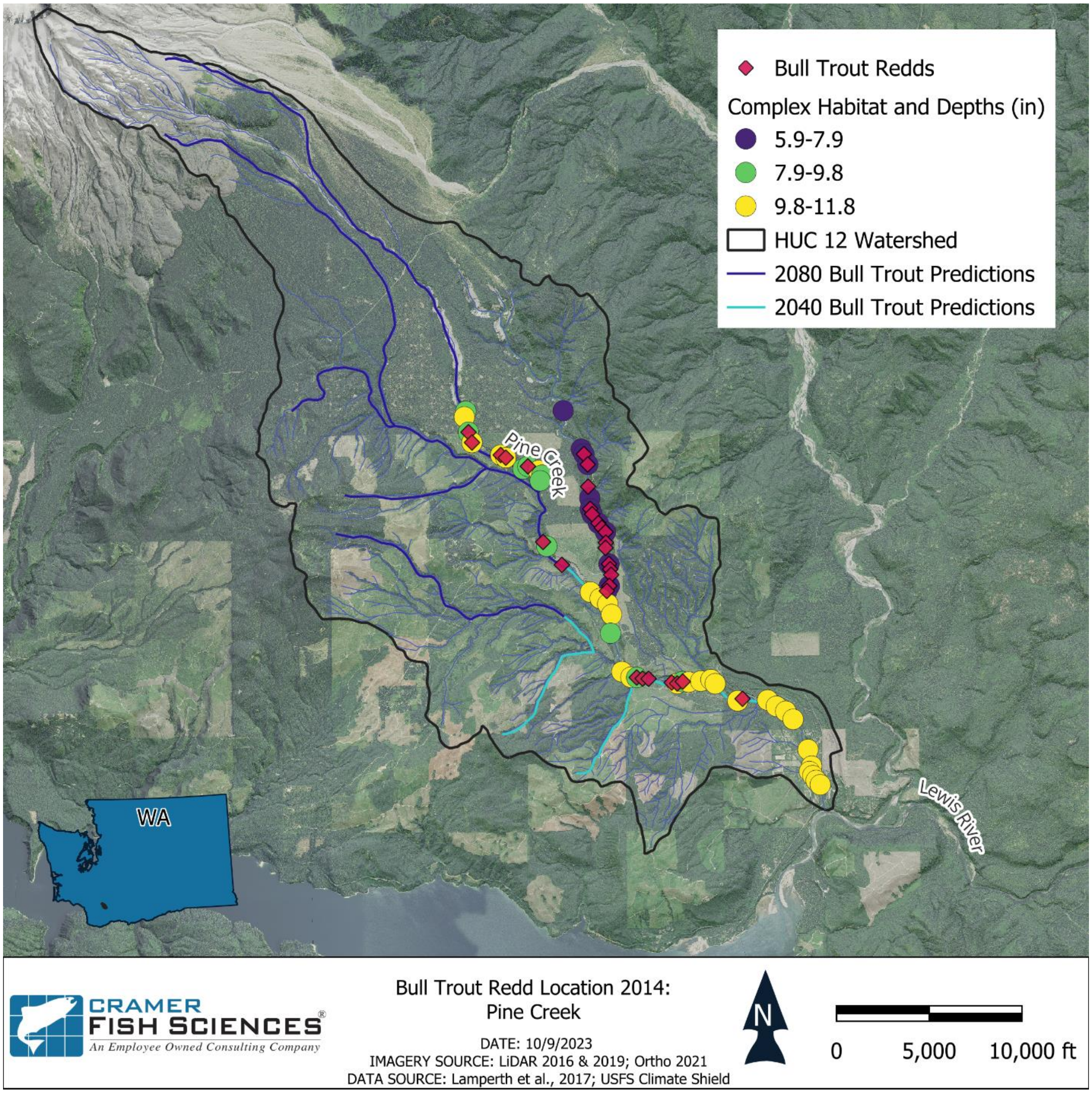

Figure 6. Locations of bull trout redds identified during PacifiCorp redd surveys in 2014 and habitat areas consisting of complex habitat (side channels and woody debris) and three ranges of shallow depths along Pine Creek and P8.

Additional Species Occurrence in the Lewis River Basin

There is less information about habitat use by other species in Pine Creek and P8 but there is some information about the fish community in Swift Reservoir and the upper Lewis River Basin. Annually, 20,000 pounds of Rainbow Trout (freshwater resident; *O. mykiss*) and 12,500 pounds of resident Kokanee salmon (*O. nerka*) are stocked for angling (PacifiCorp 2018; Al-Chokhachy et al. 2015). In the upper Lewis River Basin, there are naturally reproducing populations of Rainbow and Cutthroat trout (adfluvial and fluvial; *O. clarkii*), Mountain Whitefish (*Prosopium williamsonii*) and Largescale Sucker (*Catostomus macrocheilus*). There is limited information about Pacific Lamprey (*Entosphenus tridentatus*) in the upper Lewis Basin and passage is blocked upstream due to the hydropower systems

(LCFBR 2010). With the assistance of the trap-and-haul program, Chinook salmon, coho salmon and winter steelhead have been reintroduced above Swift Dam (PacifiCorp 2018). Trap-and-haul transportation for adults and juveniles began in 2012, transporting spawning adults from below Merwin Dam to above Swift Reservoir and transporting juveniles from Swift Reservoir downstream of Merwin Dam (Kock et al. 2021). In 2017, a total of 17,551 fish were captured in the Merwin Trap and of those 8,569 adult salmonids (1,110 spring Chinook, 6,813 coho, 592 winter steelhead, and 54 Cutthroat) were transported upstream (PacifiCorp 2018). As a result of the trap-and-haul program, the percentage of natural-origin early run coho salmon captured has increased from 7% in 2015 to 54% in 2017. Coho spawning season varies based on phenotype, with “late” forms spawning November–March, and “early” forms spawning from October–November (LCFRB 2010). Coho have been documented spawning throughout much of Pine Creek, while Chinook use of Pine Creek is more limited (Figure 7). Coho salmon redds were observed at Pine Creek (19.6 average) and P8 (2.4 average) from 2012–2022 (PacifiCorp Personal Communication 2023). Additionally, in 2017 juvenile coho salmon were found to occupy similar rearing habitats as juvenile bull trout during backpack electrofishing surveys (PacifiCorp 2018). These 2017 surveys found more juvenile coho salmon (282) captured in Pine Creek than juvenile bull trout (48); however, there were more juvenile bull trout (62) captured on P8 than juvenile coho salmon (28). Spring Chinook salmon spawning occurs in late August–September (LCFRB 2010). In 2022, redds were surveyed along Pine Creek (28 redds) and P8 (5 redds) (Figure 7; PacifiCorp Personal Communication 2023). Wild-origin winter steelhead spawning occurs in March–June; whereas, hatchery-origin winter steelhead from Chambers Creek spawn in December (LCFRB 2010; PacifiCorp 2018). Adfluvial and fluvial forms of Cutthroat Trout spawn from February–June. Rearing habitat was determined to be a limiting factor upstream of Swift Reservoir (CFS 2016). Improving instream habitat, reconnecting side channels and floodplain habitat, and restoring riparian areas could increase rearing habitat for steelhead, Chinook, and coho salmon (CFS 2016).

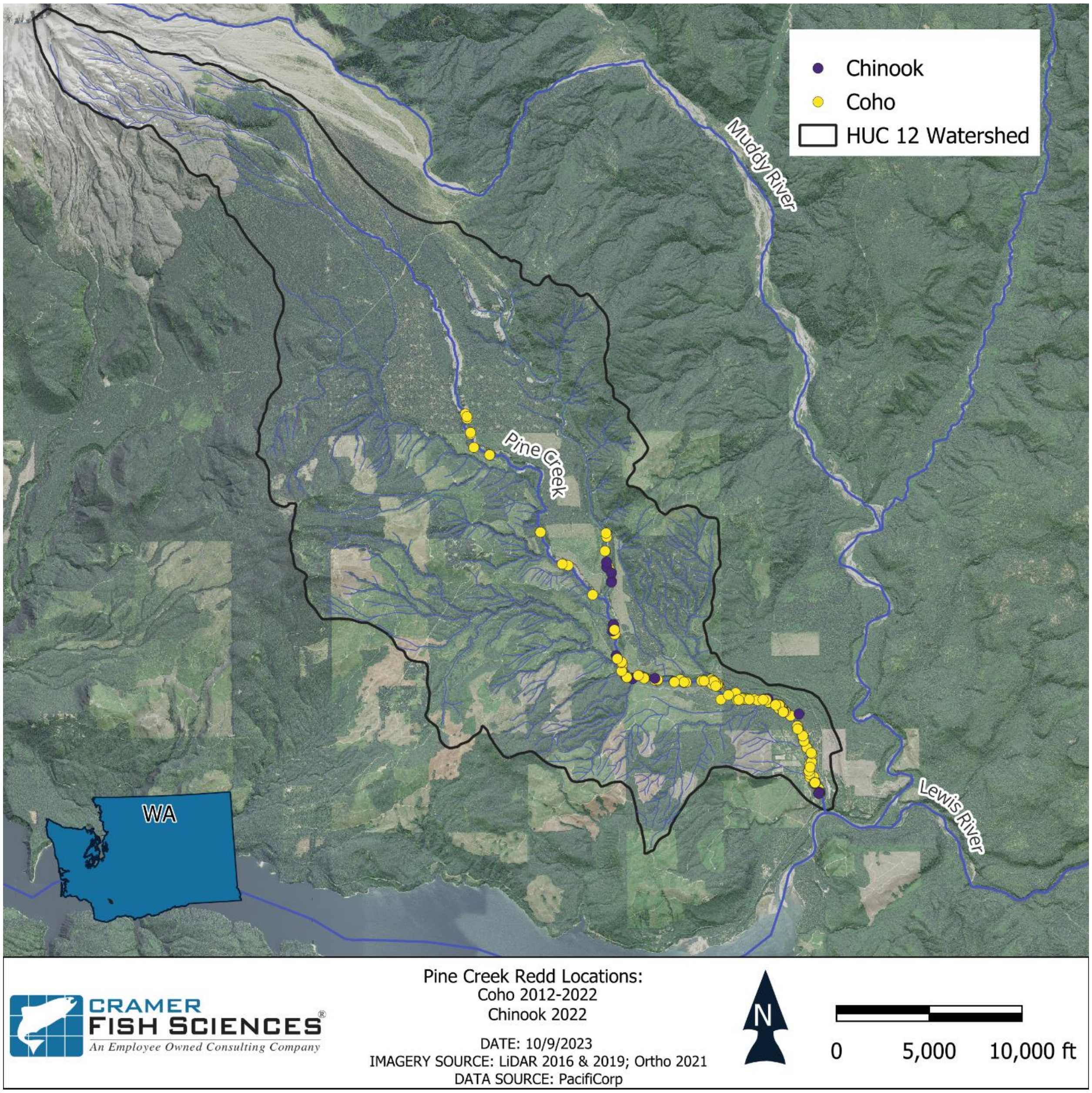

Figure 7. Location of Chinook and coho salmon redds sampled from 2012–2022 along Pine Creek and P8.

4.4 Riparian Condition

Riparian condition within Pine Creek varies widely from high in the watershed to low in the watershed. This diversity of riparian conditions results from a combination of climatic, hydrologic, and geomorphic factors that allow different species to establish and persist throughout succession in a regularly flooded and dynamic floodplain environment. Pine Creek's riparian condition and future restoration potential vary widely based on the same biophysical gradients that drive riparian processes across watersheds: climate, hydrology, sediment transport, and vegetation succession (Naiman and Decamps 1997). However, this riparian condition must be viewed not only through lateral (valley setting) and longitudinal perspectives (i.e. the river continuum; Vannote et al. 1980), but through the perspective of the 1980 upstream eruption of Mt. St. Helens that deposited mud flows and lahar debris across Pine

Creek and adjacent watersheds. This event reset many floodplains and forests to early-successional landscapes with immature, recolonizing forests on young parent soils (Kiilsgaard 1987), and forced the channel of Pine Creek to carve into the floodplain, lowering the channel elevation relative to the adjacent hillslopes.

The Pine Creek HUC12 watershed occupies a relatively small geographic area but occurs at the confluence of several hydrological, geomorphic, and ecological zones (classifications) that coarsely characterize the underlying riparian ecosystems and their potential. The Pine Creek watershed lies entirely within a single hydrologic landscape class (VwHMH; Leibowitz 2016), with a very wet climate, fall-winter precipitation seasonality, high aquifer permeability, montane terrain, and high soil permeability (Table 5). This hydrologic landscape class characterizes both the hydrology of Pine Creek and provides context as to what riparian species may grow within floodplains and riparian corridors based on hydrology and climate. Within the Pine Creek floodplain, the geomorphic potential for channel lateral mobility is relatively low within the vegetated portions of the mainstem and east fork. These segments are a combination of pool-riffle, step pool, and plane bed forms, many of which have lateral room for floodplain landforms and forest to develop (Figure 12, Figure 13).

Additionally, the surrounding forest matrix, which is a function of climate, geology, soils, and disturbance, controls what palette of species, including large wood contributing conifers (evergreens), can establish within floodplains and along Pine Creek's highly erosive riparian corridors. The EPA level 4 and level 3 EcoRegions (Omernik and Griffith 2014; Table 5) of Pine Creek are those, that in the absence of major landscape-scale fluvial and geomorphic disturbance, would otherwise grow closed canopy, conifer-dominated (evergreen-dominated) forests throughout most successional stages (Table 5; Figure 52). These upland conifer forests begin in the *Abies amabilis* and *Tsuga mertensiana* Zones (Franklin and Dyrness 1988), consisting of silver fir (*Abies amabilis*) and mountain hemlock (*Tsuga mertensiana*) during late successional stages. This forest zone also has a common sub-type dominated by *Alnus sinuata* in disturbance-prone areas like high-energy avalanche paths and ephemeral streams. Further downstream within the Pine Creek watershed, the *Abies amabilis* zone gives way to the *Tsuga heterophyyla* zone, which often originates as *Pseudotsuga menziesii* and *Alnus rubra* during secondary succession*,* and culminates in *Thuja plicata*, *Tsuga heterophylla*, and mixed *Abies* forest during late succession. Forests in these zones often give way to vertically and horizontally diverse stands of mixed fir, cedar, and hemlock as trees fall to the ground or into floodplains and active channels (Van Pelt 2007).

Franklin and Dyrness (1988) noted that even prior to the eruption of Mt. St. Helens, the mountain had a relatively low elevation tree line compared to other Cascade Mountain environments and hypothesized that this was a product of the recent origination of the volcanic cone and the resulting, well-drained soil conditions. These conditions allow many species that are not normally found at treeline to dominate the Mt. St. Helens sub-alpine forest community: *Pinus contorta, P. monticola, Pseudotstuga menziesii, Populus trichocarpa, Abies procera, and Tsuga heterophylla*. Following the eruption of Mt. St. Helens (1980), lahar deposits laid down ash and pumice in what is now the Pine Creek floodplain. It cannot be understated that the larger Pine Creek watershed's riparian forests, like many around Mt. St. Helens, are unique based on their volcanic history. This lahar and incision intersect with volcanic, well-drained soils, a large elevation gradient that co-occurs with a dramatic climate gradient, and startling differences in reach hydrogeomorphic properties based on stream lateral mobility (Figure 15).

Table 5. Summary of various landscape classifications that riparian condition corresponds within Pine Creek: EPA EcoRegions and hydrologic landscape classes.

Classification	Description	Notes
EPA EcoRegion - Level 4	Western Cascades Montane Highlands	Forests dominated by mid-elevation to sub-alpine conifers (*Abies sp.*, *Tsuga mertensiana*) in the upper watershed and cottonwood (*Populus balsamifera)*, western red cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*).
EPA EcoRegion - Level 3	Western Cascades Lowlands and Valleys	
Hydrologic Landscape Class	Very wet climate, fall-winter seasonality, high aquifer permeability, Montane terrain, high soil permeability (VwHMH)	This hydrologic classification synthesizes the climate, seasonality, terrain, and soils that generally correspond to Pine Creek's hydrology, geology, and soils.

Table 6. Forest types within the Pine Creek Watershed that correspond to riparian and fluvial processes (Franklin and Dyrness 1988).

Forest zone	Description	Notes
Tsuga heterophylla zone	The dominant forest type across the lowlands of western Washington and lower reaches of Pine Creek, this forest zone often colonizes as *Pseudotsuga menziesii*, *Alnus rubra*, and *Acer macrophyllum* before transitioning to later successional *Tsuga heterophylla, Abies grandis,* and *Thuja plicata*	At the watershed scale, this forest type can grow both species that can contribute instream large wood, as well as substantial shade. If succession is not restarted by disturbance or logging, there is substantial horizontal wood that is contributed to the forest floor and adjacent streams. This zone also includes *Populus balsamifera* (cottonwood) gallery forest along alluvial floodplains.
Abies amabilis zone	A temperate to sub-alpine forest type that can be dominated by *Abies amabilis* at late succession and mixes with *Tsuga heterophylla, Abies procera, Pinus monticola, Abies lasiocarpa,* and *Abies grandis* based on soils, hydrology, and overstory stand development.	This is a transitional zone between lowland forests of the *T. heterophylla* zone and *T. mertensiana* zone. While not a riparian forest type, this zone often has riparian ecosystems that reflect local topography and soils and the connectedness of the forest to hillslope and floodplain hydrologic processes.
Tsuga mertensiana zone	The wettest and coolest of the forest zones through which Pine Creek flows, this forest type is mostly high-elevation forest species (*Tsuga mertensiana, Abies*	The highest of the natural forest zones, this forest type is unique on Mount St. Helens due to the extensive pumice and poorly developed soils that reduce soil moisture and nutrients,

	lasiocarpa, Abies amabilis) with component high-elevation shrubs (*Alnus*, *Salix* sp.).	resulting in a lower forest tree line. This forest type is decoupled from the active channel along Pine Creek by channel incision through pumice and lahar deposits.

The Pine Creek watershed's vegetation is currently comprised of a variety of sparsely vegetated areas above treeline, and closed canopy and early-successional forest below tree line (Appendix K). Most forest canopy cover corresponds to land ownership, as it transitions from public land at higher elevations in the *Tsuga mertensiana* and *Abies amabilis* zones to private timber land within the more frequently logged *Tsuga heterophylla* zone (

Figure 2). Maps of LANDFIRE existing vegetation types (EVT) show that there are numerous recent clearcuts within the watershed that have not yet fully regenerated to closed canopy forest; many of these are classified as herbaceous vegetation types in LANDFIRE EVT, although they may be young forest (Figure 11). From the top of the watershed to the bottom, LANDFIRE EVT data also shows largely unvegetated areas that reflect the recent geomorphic and successional histories of the Mt. St. Helens eruption (geology presented in Table 7). Below these lahar areas the watershed vegetation consists primarily of forest cover in a range of successional stages due to floodplain evolution, industrial logging, or nearby human development (roads, cultivation, etc.). Because the upper portions of Pine Creek are heavily incised as the stream works through recently deposited volcanic material, the conifer-dominated forest matrix is disconnected from the early-successional alder- (*Alnus rubra*) dominated riparian fringe around the active channel and inset floodplain. In these areas, LANDFIRE EVT (2022) reflects the sparsely vegetated nature of the steep, coarse substrate hillslopes surrounding Pine Creek (Appendix K).

Within the Pine Creek riparian corridor, early-successional riparian forest comprised of *Alnus rubra*, *Salix* species, and other shrubs are common (Appendix K). Most inset floodplain surfaces within the upper portion of the floodplain are dominated by riparian shrubs (*Salix sp.)* and immature *Alnus rubra*. Much of the riparian corridor has a unique disturbance history from volcanic and fluvial processes, meaning that disturbance-prone riparian hardwood species predominate, and currently out-compete later successional, and longer-lived conifer species. There is a general lack of large wood contributing conifers immediately adjacent to the riparian corridor, with only 43% of canopy cover within 30 meters of the 2.5-year flood wetted channel being conifer species (Table 41). Much of this tall, conifer cover occurs low in Pine Creek and corresponds to confined or straight channel planforms (Appendix K).

Where perennial springs exist within the upper Pine Creek floodplain, there are diverse plant communities, although the later successional stages of these ecosystems may not result in increased conifer canopy. Groundwater and wetland areas that may contribute to instream flow and create perennially saturated soils should be identified in the field for restoration opportunities. These groundwater inputs and wetlands connect a variety of habitats for terrestrial and aquatic species, including amphibians.

4.5 Geology and Soils

Geology, soils, and geomorphic processes are strongly tied to the volcanic history of Mt. St. Helens. Historically, the Muddy River flowed down the Pine Creek valley but lahar flows from past eruptions created the valley walls that now separate the drainages (Crandell and Mullineaux 1973). Although there is a long history of Mt. St. Helens eruptions in the geologic record dating beyond 35,000 years, the lahar flows that separated Muddy and Pine creeks date between 2,500 and 450 years ago (Crandell and Mullineaux 1973). The most recent eruption in 1980 produced lahar flows down the Pine Creek valley as well. While the 1980 event essentially reset the channel, floodplain, and riparian conditions to a blank slate, the lahar-filled valley walls remained largely unchanged, aside from deep ash deposits. Volcaniclastic deposits or rocks are the primary geologic type throughout the Pine Creek watershed, with area percentages ranging from 12 – 81% (Figure 8; Table 7). Volcaniclastic deposits or rocks are fragmented volcanic rock, formed by volcanic processes, and are directly transported and deposited by explosive or effusive events including lahars during the Miocene through Oligocene epochs (~5.3—65.5 Ma; USGS 2016). The percentage of lahars occurring during the Holocene epoch (<11.7 ka), including the most recent eruption in 1980 (<11.7 ka), range from 2–14% depending on the reach. Andesite, which comprises 59%, 23%, and 41% of reach 2, 3, and 4, respectively, is an igneous rock that is formed when magma erupts onto the surface and crystalizes quickly. It is a fine-grained volcanic rock that is gray to black and is comprised of 52–63% silica. Basalt, which comprises 45% of reach 4, is a fine-grained igneous rock. It is a hard, black volcanic rock that contains 45–53% silica and is rich in iron and magnesium. The high abundance of large springs that emerge from the valley walls to form surface flows on Pine Creek are likely following lava tubes comprised of basalt. Moreover, the geology underlying the lahar-dominated landscape is primarily comprised of basalt and andesite flows deposited during the Oligocene through the Pleistoecene epochs (~11.7 ka—65.5 Ma). These deposits are exposed in areas in the southwest corner of the watershed and much of the alluvium in Pine Creek is derived from basalt and andesite. Pumice and other porous igneous rocks are also common among Pine Creek alluvium and have explicit implications for bedload transport given their lower specific gravity compared to solid rock.

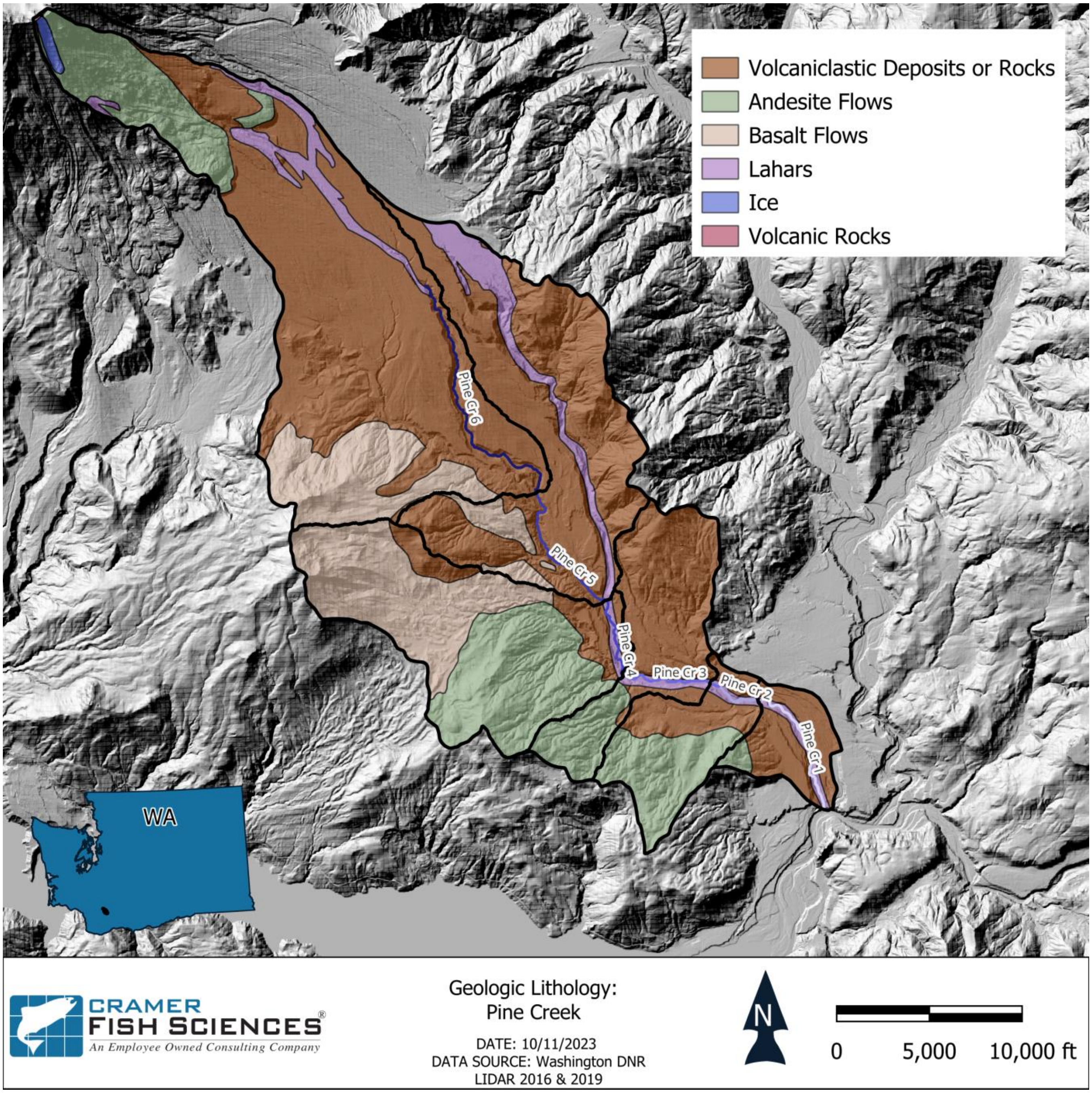

Figure 8. Washington DNR surface geology for Pine Creek watershed.

Table 7. Surficial geology percentage from Washington DNR for six reaches along Pine Creek.

	Reach					
Lithology	**1**	**2**	**3**	**4**	**5**	**6**
Volcaniclastic Deposits or Rocks	77%	37%	73%	12%	81%	65%
Andesite Flows	8%	59%	23%	41%	-	14%
Basalt Flows	-	-	-	45%	6%	15%
Lahars	14%	4%	4%	2%	12%	5%
Ice	-	-	-	-	-	1%
Volcanic Rocks	-	-	-	-	-	<1%

Pine Creek Reaches 1 – 5 are primarily comprised of andisol soils of the Lonestar series, which were developed from volcanic ash, pumice, cinders, and lava (Figure 9; Table 8; Soil Survey Staff 1999). These soils are highly fertile, with unusually high water and nutrient holding capacity, which allows most plants to grow successfully. The Lonestar soil series in the Pine Creek watershed are primarily sandy loam sourced from volcanic ash but contain a relatively high proportion of organic matter that increases erosion resistance. However, the Lonestar series is not immune to erosional processes, especially on steep slopes and areas with low vegetation cover. The Lonestar series is arguably the most relevant and important soil to restoration planning and land management in the Pine Creek watershed because of its spatial coverage and exposure to hillside erosion that delivers ash, sand, small gravels, and pumice to the valley bottom. The Wakepish soil series of the entisol order makes up 13% and 16% of Reaches 5 and 6, respectively, and is mostly bouldery sandy and gravely sandy soil. This soil type is typically sandy and shallow and usually occurs in areas with active erosion, along steep terrain or along floodplains that receive new deposits of alluvium at frequent intervals. The Wakepish series is most dominant at the base of Mt. St. Helens near the headwaters of Pine Creek but are also present in portions of Reaches 4 and 6. The large boulders included in the Wakepish series are highly functional structural elements in Reaches 4 and 6, creating long sections of rapids, cascades, and step-pool sequences. Within the valley bottom, the Wakepish series is also closely associated with rubbleland and rock outcrops. Spodosols of the Shoestring soil series make up 18% of Reach 6 and is a fine sandy loam soil. The upper portion of Reach 6 is comprised of 21% rubbleland and rock outcrop complexes, with little to no soil.

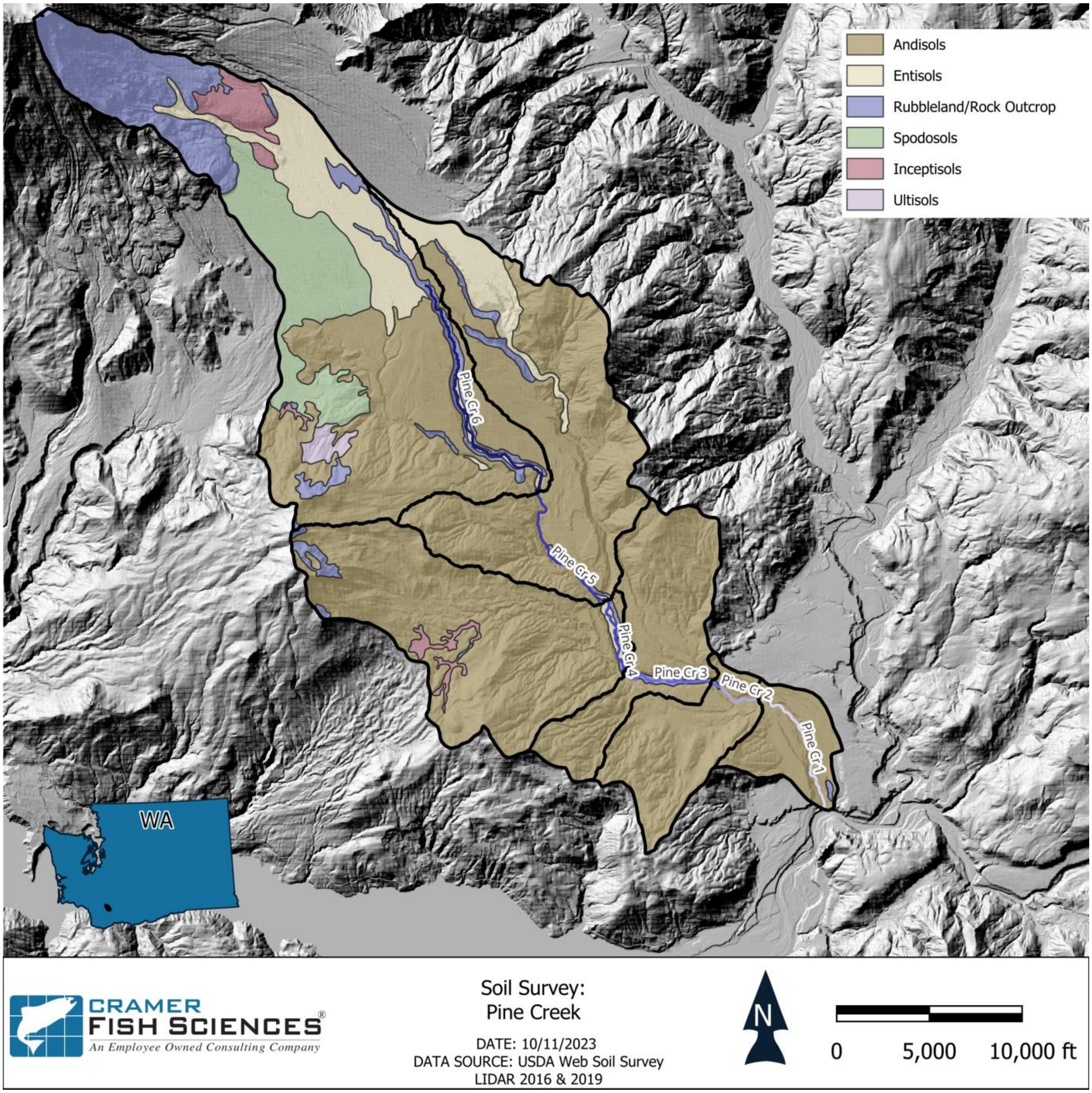

Figure 9. USDA Web Soil Survey for the Pine Creek watershed.

Table 8. Soil type percentage of USDA Web Soil Survey for six reaches along Pine Creek.

	Reach					
Soil Type	**1**	**2**	**3**	**4**	**5**	**6**
Andisols	99%	100%	97%	93%	84%	39%
Entisols	-	-	1%	1%	13%	16%
Rubbleland/Rock Outcrop	1%	<1%	2%	3%	3%	21%
Spodosols	-	-	-	-	-	18%
Inceptisols	-	-	-	3%	-	4%
Ultisols	-	-	-	-	-	1%

4.6 Geomorphic Assessment

We opted to use existing reach delineations used for regional planning to maintain consistency with past projects in the Pine Creek watershed. These reaches were delineated as part of the Ecosystem Diagnosis and Treatment (EDT) framework and are not explicit geomorphic reaches. Because they are based largely on tributary junctions, EDT reaches form a tractable geomorphic basis for restoration planning; however, EDT reach breaks do not always represent definitive transitions between reach types with distinct channel and floodplain characteristics or boundary conditions. Moreover, the character, behavior, and geomorphic trajectory of Pine Creek is ultimately predicated by the long-lasting impacts of lahar flows and other volcanic disturbances. Therefore, it is not surprising that the reaches exhibit similar characteristics relative to their upstream drainage area and position in the watershed (Table 9). To provide geomorphic guidance for restoration design planning in Pine Creek, we described geomorphic conditions and fluvial processes generally across the mainstem corridor and by reach.

Table 9. Physical characteristics of EDT reaches along the mainstem of Pine Creek.

Reach	Length (ft)	Drainage Area (mi^2)	Mean Bankfull Width (ft)	Mean Valley Bottom Width (ft)	Mean Slope (%)	Mean Sinuosity	Total Side Channel Length (ft)	Mean RCI
1	8,599	28.1	99.52	188.4	2.4	1.19	3,027	1.27
2	2,875	26.4	96.73	198.0	2.6	1.20	2,200	1.74
3	6,269	24.5	95.10	222.9	2.5	1.23	6,645	3.23
4	4,667	18.0	87.47	202.1	2.9	1.24	3,499	2.76
5	8,912	13.0	47.92	93.6	3.7	1.21	3,275	1.92
6	16,251	11.5	41.17	105.1	4.7	1.24	3,091	2.20

4.6.1 Channel and Floodplain Planform

The characteristics of the Pine Creek channel and floodplain are ultimately a product of volcanic activity that occurred over the last several millennia. Lahar flows from Mt. St. Helens delivered a tremendous amount of sediment dominated by gravel and sand. The existing channel and floodplain dissected the lahar deposits to create its contemporary valley bottom. Although it has been over 40 years since the last eruption, the prevalence of lahar flows provides a never-ending supply of mobile sediment as the channel continues to rework its margins in response to flood events. There are several locations with underlying and exposed bedrock that increase confinement locally as well as stretches of boulder deposits from ancient eruptions.

In its current condition, most of Pine Creek is a *wandering cobble/gravel bed* geomorphic reach type. Wandering cobble/gravel bed rivers have a moderate slope (<3%), low to moderate sinuosity (<1.3), a streambed dominated by gravel, and typically one or more active side channels (Brierley and Fryirs 2005). In Pine Creek, secondary channels are commonly found at varying elevations creating a mixture of perennial side channels and flood channels. Typical of wandering cobble/gravel bed reaches, surface flow access to secondary channels in Pine Creek may change year to year as the mainstem channel adjusts, and as sediment and wood are mobilized and deposited. Whole-sale avulsions are also a common response to flood events where the mainstem channel position swaps between defined channels separated by a stable bifurcation. Alternatively, as sediment and wood collect at a given point, the mainstem channel may avulse an entirely new flow path through the floodplain and remain relatively stable until more sediment and wood force a similar avulsion. The magnitude of change associated with avulsions in Pine Creek is largely dependent on vegetation in the floodplain. The valley bottom is heavily dominated by young alders whose roots can provide a lot of soil cohesion along channel margins. During our field survey, we observed several bifurcations forced by established alder clumps. In many cases, the alders captured sediment ramps and wood jams that locally increase stability and help maintain stable bifurcations. Ultimately, wandering cobble/gravel bed rivers like Pine Creek contain dynamic channels that create diverse topography throughout the valley bottom.

Although most of the reaches in Pine Creek exhibit relatively consistent behavior and responses to flood events, there is variability in local channel characteristics. The predicted historic channel types described by Beechie and Imaki (2014) highlights the differences among reaches in Pine Creek (Figure 10). Reach 6 was classified as a mixture of island-braided and braided channel types. In contrast, Reaches 1-5 were classified as dominantly confined and straight channel types (Figure 11). Because this classification system attempts to identify historic channel types based on large-scale remote sensing products, it does not perfectly describe local reach conditions. However, it is helpful for synthesizing large-scale physical controls that force variations in typical wandering cobble/gravel bed planforms. For example, several of the confined sections shown in Figure 10 point to exposed and shallow bedrock, large boulder deposits, and incision that force local confinement.

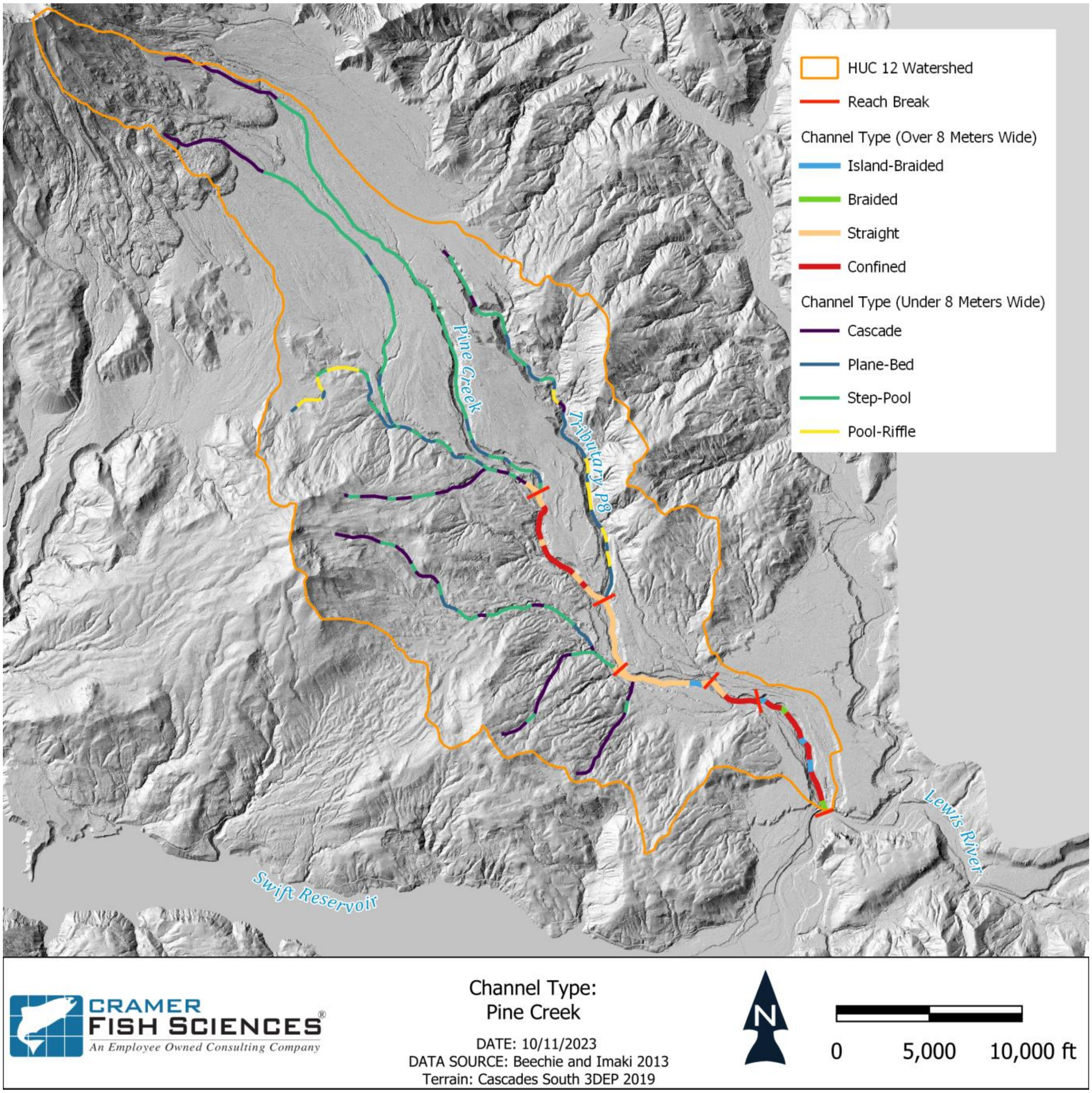

Figure 10. Map of channel types in the Pine Creek Watershed (Beechie and Imaki 2014).

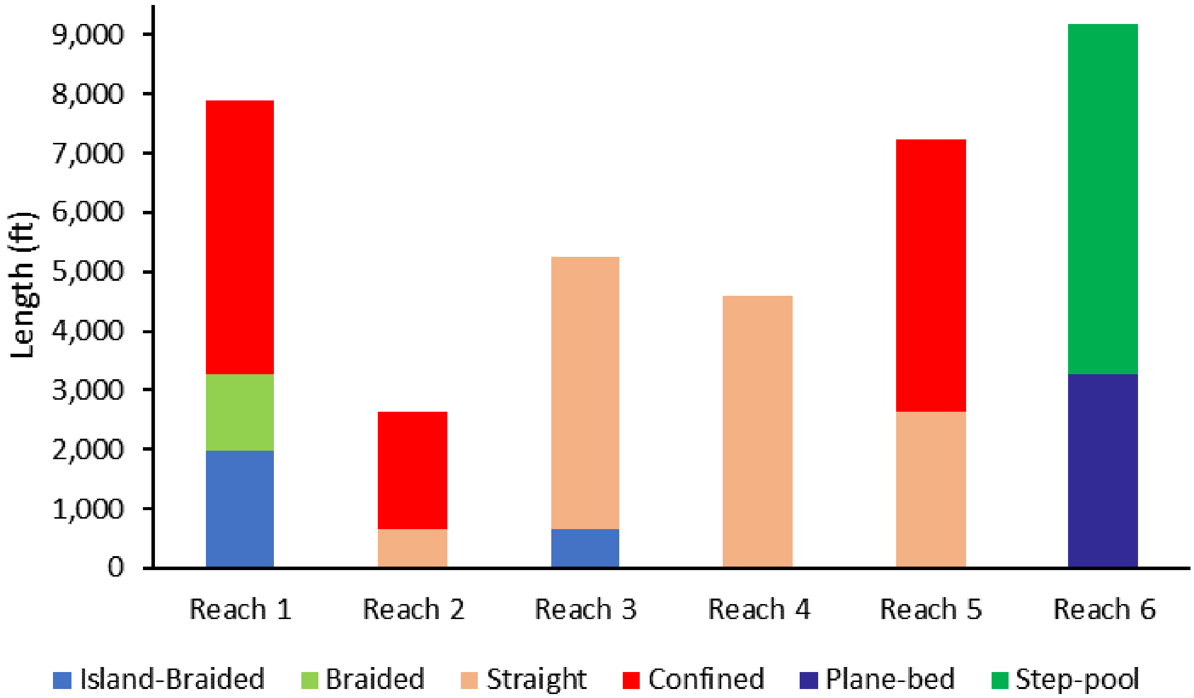

Figure 11. Distribution of dominant channel type lengths by reach in Pine Creek (Beechie and Imaki 2014).

The floodplain in Pine Creek is also best characterized within the context of lahar flows and the volcanic history of Mt. St. Helens. Floodplain sediments originated from lahar flows, but over time organic material and aeolian sediment was mixed in, and nitrogen-fixing vegetation like lupine and alder readily established. As pioneer vegetation grew, soil cohesion increased and helped create relatively stable locations that were resistant to erosion from Pine Creek flows. The current topography in the floodplain reflects the diversity of stable and unstable locations interacting with flood events. As such, natural boulder levees are very common and create linear features along channel margins and among the floodplain that are effective at restricting lateral channel migration. These areas tend to have older and larger trees (primarily alder), indicating they have been relatively stable through time. Wherever there is sufficient lateral accommodation space (i.e., wide valley bottom), multiple channels are common and regularly connect with incoming springs leading to wetland complexes and stable off-channel habitats. We identified areas with sufficient valley bottom width to support multi-threaded planforms to help guide restoration planning (Figure 12 and Figure 13). Wider areas have higher potential to retain large wood, maintain stable bifurcations, and sustain connected off-channel habitats for aquatic species. Similar areas were identified and described during our field survey and previous assessments of Pine Creek (e.g., Figure 14).

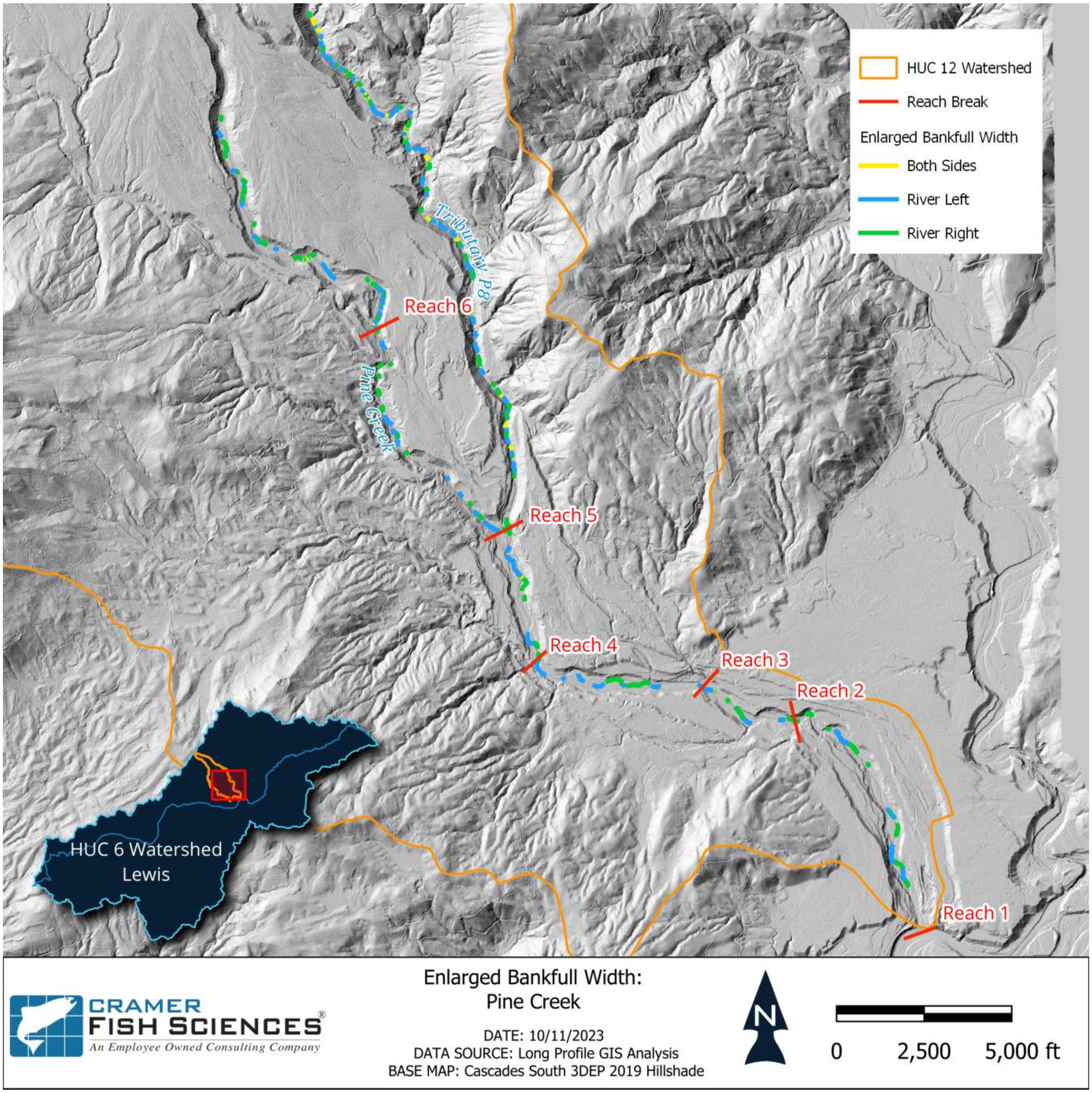

Figure 12. Map of locations on Pine Creek and Tributary P8 where the bankfull width is one standard deviation greater than the reach average bankfull width.

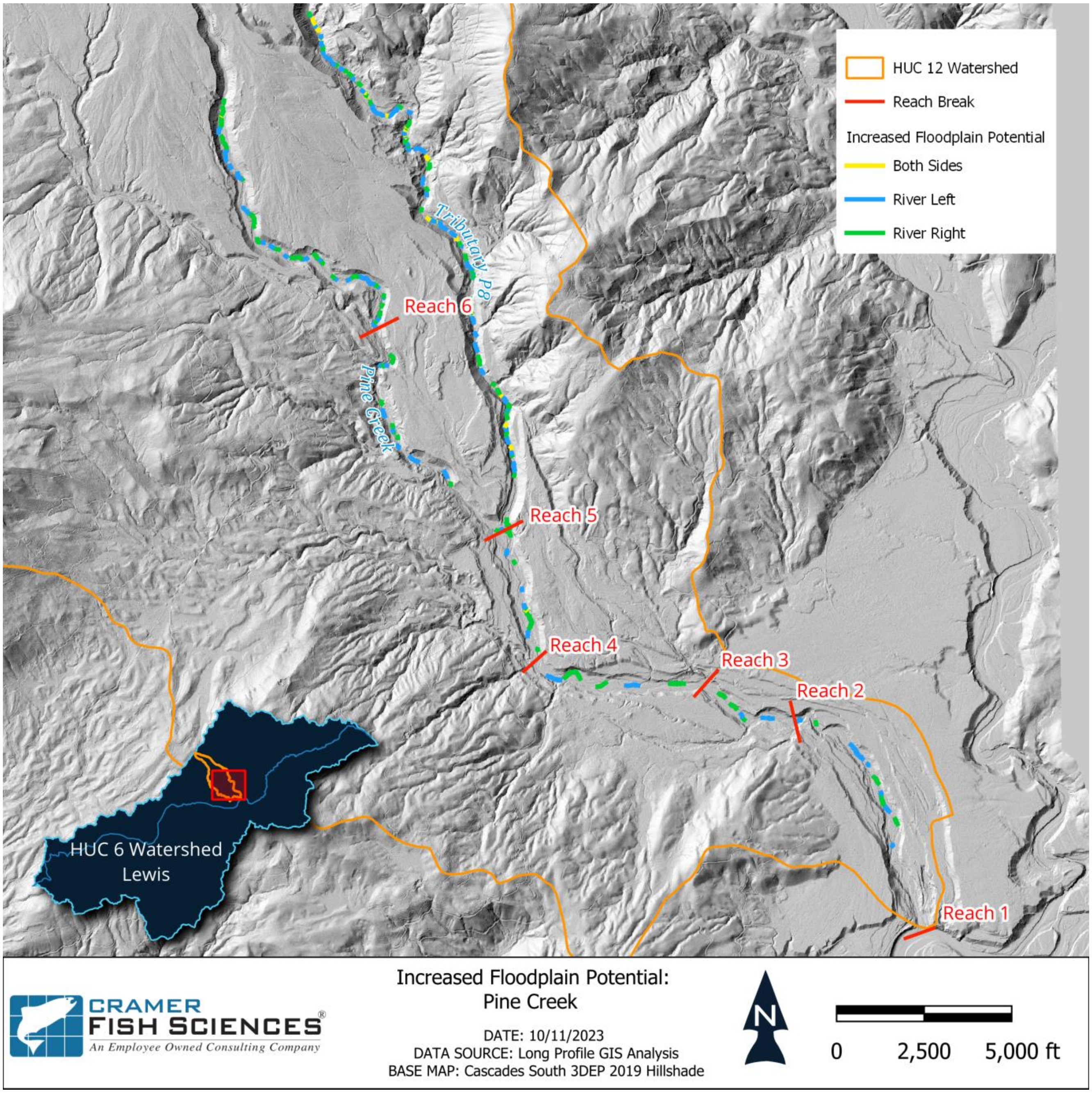

Figure 13. Map of locations on Pine Creek and Tributary P8 where the difference between the valley bottom width and bankfull width is greater than two bankfull widths.

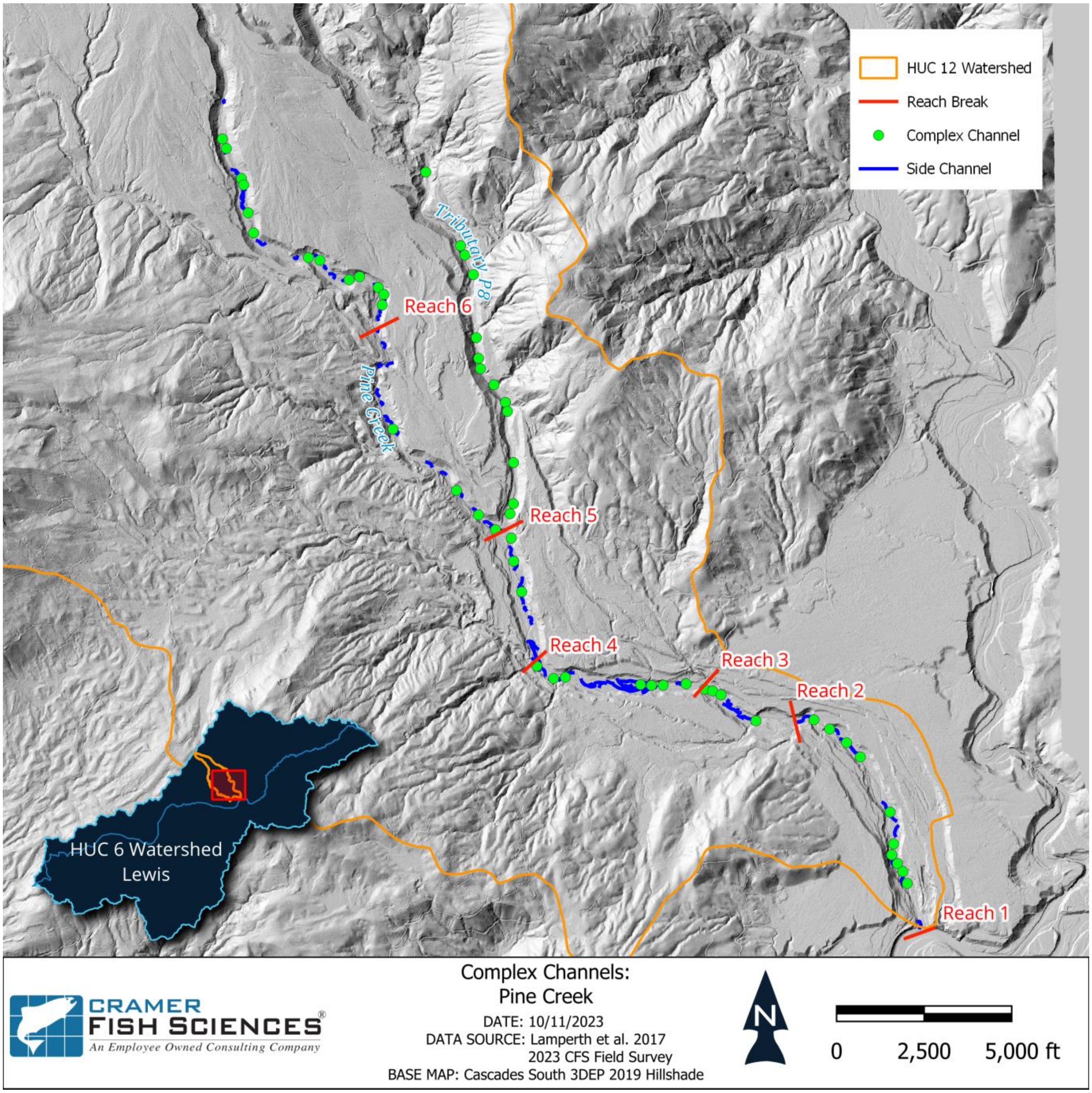

Figure 14. Map of complex channels and side channels of Pine Creek and Tributary P8 referenced from field data and Lamperth et al. 2017.

4.6.2 Longitudinal Patterns and Substrate

We calculated a suite of channel and watershed metrics at 50-100 m intervals continuously throughout the mainstem of Pine Creek to help characterize longitudinal patterns. We calculated bankfull channel width, valley bottom width, channel slope, elevation, sinuosity, stream power, and drainage area to create a continuous longitudinal profile overlayed with reach breaks and major tributary confluences (Figure 15). The bankfull and valley bottom widths are relatively narrow in Reach 5 and 6 and increase two to four times downstream of the confluence with tributary P8. Fluctuations in bankfull width are generally correlated with valley bottom width. The channel slope is relatively high, remaining above 2%

for most of the mainstem and increases upstream of Reach 5. There is a large spike in slope near the upstream extent of Reach 5 where bedrock from the Marbel Mountain basalt flows is shallow and exposed. Sinuosity fluctuates with valley bottom width but remains relatively low which is typical of wandering cobble/gravel bed rivers. Pine Creek accommodates energy from high flows through the creation of secondary channels and avulsions, rather than developing full meanders. As expected, stream power correlates with changes in gradient and confinement; however, there is a noticeable decrease upstream of the confluence with tributary P10 in Reach 6.

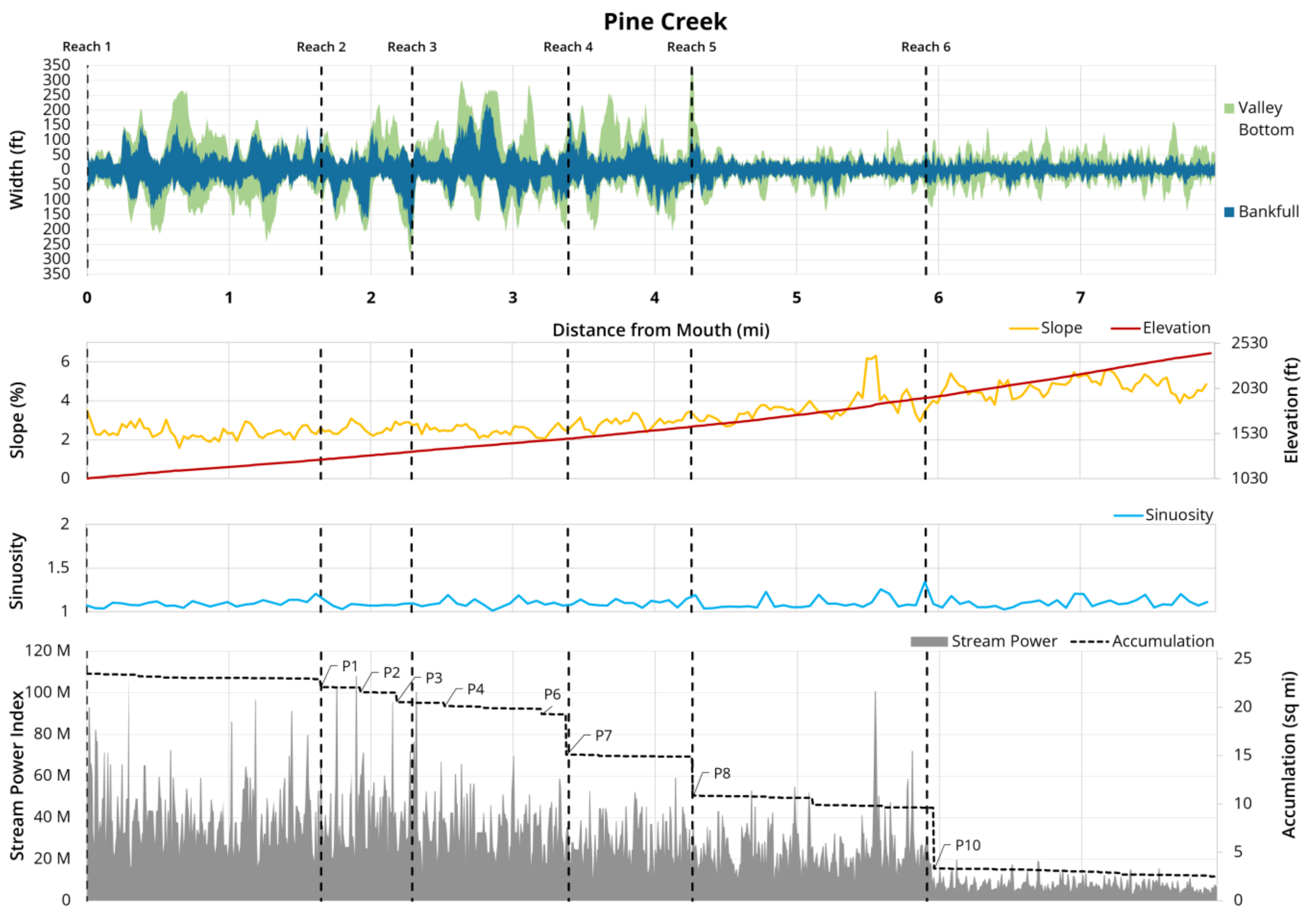

Figure 15. Stacked longitudinal profile of Pine Creek including bankfull width, valley bottom width, channel slope, elevation, sinuosity, stream power, drainage area, reach breaks, and tributaries.

Streambed substrate in Pine Creek is dominated by cobble and gravel; however, there are longitudinal patterns worth considering for restoration planning (Figure 16). The confined portion near the boundary between Reach 5 and Reach 6 contains shallow and exposed bedrock from the Marble Mountain basalt flows. Boulders remain the dominant substrate through most of Reach 5. There is another section of exposed bedrock at the boundary between Reach 1 and Reach 2 where tertiary andesite flows impose a brief stretch of high confinement. To support previous assessments, we completed ocular surveys of dominant substrate during site visits in 2023 (Figure 17). Tributary P8 contains a higher proportion of gravel than the mainstem reaches and is a notable stronghold for bull trout. Although fine sediment was rarely the dominant substrate, fines and sand are prevalent throughout the system because they are a large component of lahar flow deposits. Because of this embeddedness is a potential issue in areas with low velocity; however, substrate in riffles and rapids was generally unembedded during our site visits.

Another consideration for substrate within Pine Creek is the difference in rock density among bed load sediments. Eruptions of Mt. St. Helens throughout history have contained basalt, andesite, and dacite in various forms. Most eruptions with lava flows occurred during the Castle Creek eruptive period (2,500 – 1,700 ka) and formed what we see today as the modern volcano. However, most eruptions produced large amounts of tephra and pumice during pyroclastic blasts that were deposited over the surrounding region. Therefore, the primary sources of bedload substrate are hard igneous rocks from basalt, andesite, and dacite and pyroclastic deposits with a range of vascularity (e.g., pumice). Although basalt, andesite, and dacite rocks can be vascular, they are much denser and heavier than pumice. This is an important consideration for restoration planning because the specific gravity varies greatly among these rock types, meaning that rocks like pumice will be much easier for Pine Creek to transport. We did not specifically characterize the composition of rock densities in Pine Creek; however, we observed a large range from pumice that floats on the water surface to pumice that slowly sinks in water and is easily suspended, in addition to the other hard volcanic rocks. If local sediment is ever used as ballast to build structural elements, the specific gravity of those sediments must be accounted for. There are variations in specific gravity in rock types depending on its formation and porosity, but the specific gravity for basalt, andesite, and dacite ranges from 2.5 – 3.0 and pumice ranges from 0.8 – 2.0 (values <1 allow pumice to float on water).

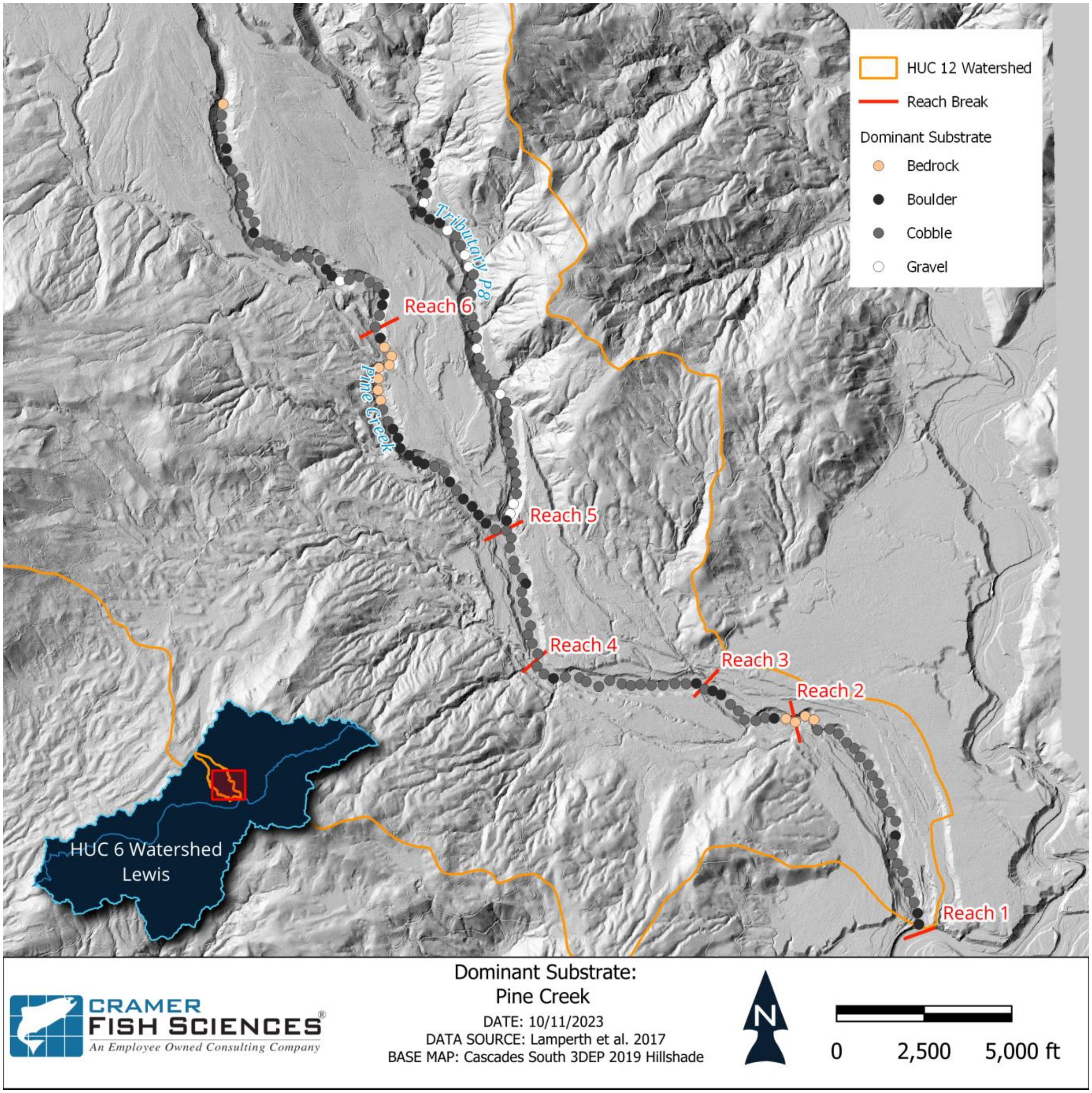

Figure 16. Map of dominant substrate types in Pine Creek, referenced from Lamperth et al. 2017.

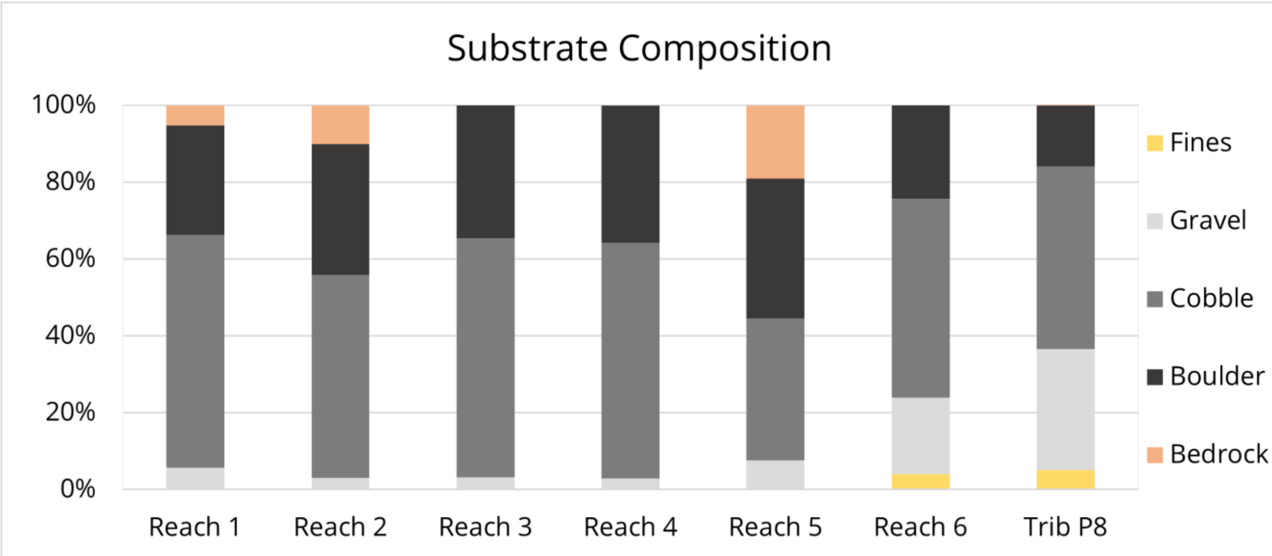

Figure 17. Graph of dominant substrate composition by reach observed during site visits in 2023.

4.6.3 Reach Descriptions

4.6.3.1 Reach 1

Reach 1 begins at Pine Creek's confluence with the Lewis River about 0.5 miles upstream of Swift Reservoir. Pine Creek flows under a bridge crossing for National Forest Development Road 25 about 400 feet upstream of the Lewis River confluence. The bridge height and span are sufficient and does not restrict the conveyance of water, sediment, or wood; however, the abutments potentially inhibit the channel from widening if Pine Creek's alluvial fan were to expand. Upstream of the bridge, the channel and valley bottom widen and there are areas for the creek to access its floodplain and maintain secondary channels (Figure 18). The channel is mostly straight with a few arrested meanders that have maintained chute-cutoffs for decades. Boulders are the primary structural element in Reach 1 that help maintain grade and support bar and secondary channel development. There are few large, deep pools in Reach 1, but pocket pools are common, especially in areas with higher boulder density. The channel and valley bottom constrict again near the upstream end of Reach 1 as the channel passes through tertiary andesite flows. Although this constriction imposes a sinuous appearance, the channel is merely following the valley. There are no major tributaries that enter Reach 1, but the upstream extent is at the confluence with tributary P1. LWD density is low and very few pieces were recruited recently. Existing key pieces are predominantly conifers and tend to be perched along channel margins. However, buried key pieces are common throughout the floodplain and appear to help maintain the grade of secondary channels.

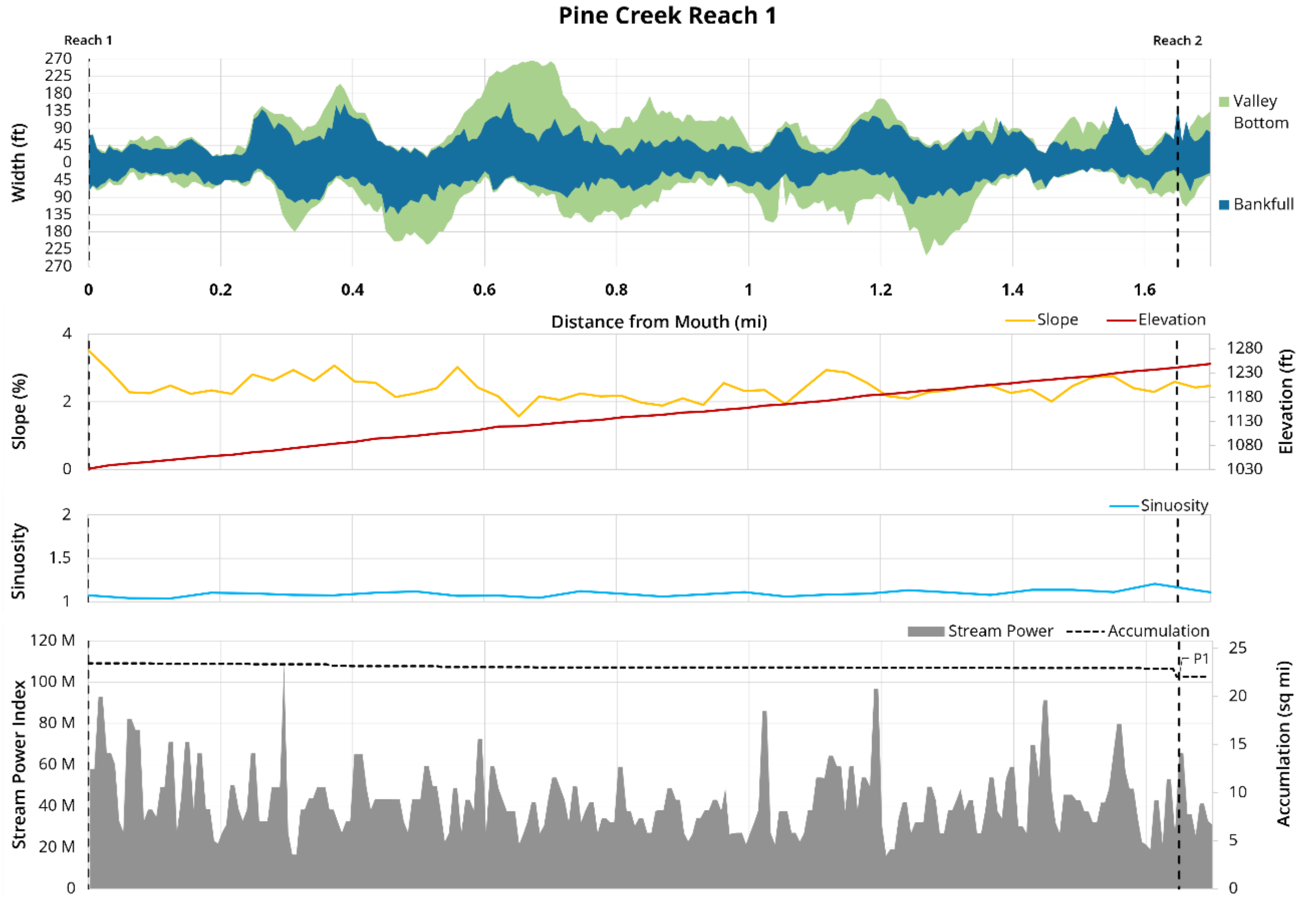

Figure 18. Stacked long profile of Pine Creek Reach 1 including bankfull width, valley bottom width, channel slope, elevation, sinuosity, stream power, drainage area, reach breaks, and tributaries.

4.6.3.2 Reach 2

Reach 2 begins at Pine Creek's confluence with tributary P1, just upstream of a constriction point forced by tertiary andesite flows and is the shortest reach in the project area. The channel runs along the valley margin, swapping from river right to river left upstream of tributary P2, and has created cutbanks that have high potential to recruit LWD as they continue to erode. Natural boulder berms and levees are common and limit lateral floodplain access. The valley bottom width is relatively narrow, and the banks are high, but there are a few access points to flood channels that were created by LWD jam breaches that created enough force to erode through the natural levees. The channel is steep and generally transitions between riffles and rapids with boulder ribs acting as grade control separating channel units. Most pools are forced by conglomerations of boulders and tend to be relatively deep but short. Engineered log jams (ELJ) installed during a previous restoration effort are damaged but many are still intact. Reach 2 ends near the confluence with tributary P3. The confluence with P3 is topographically diverse and appears to be well protected from erosive flows on Pine Creek, giving it high potential for maintaining high quality off-channel habitat.

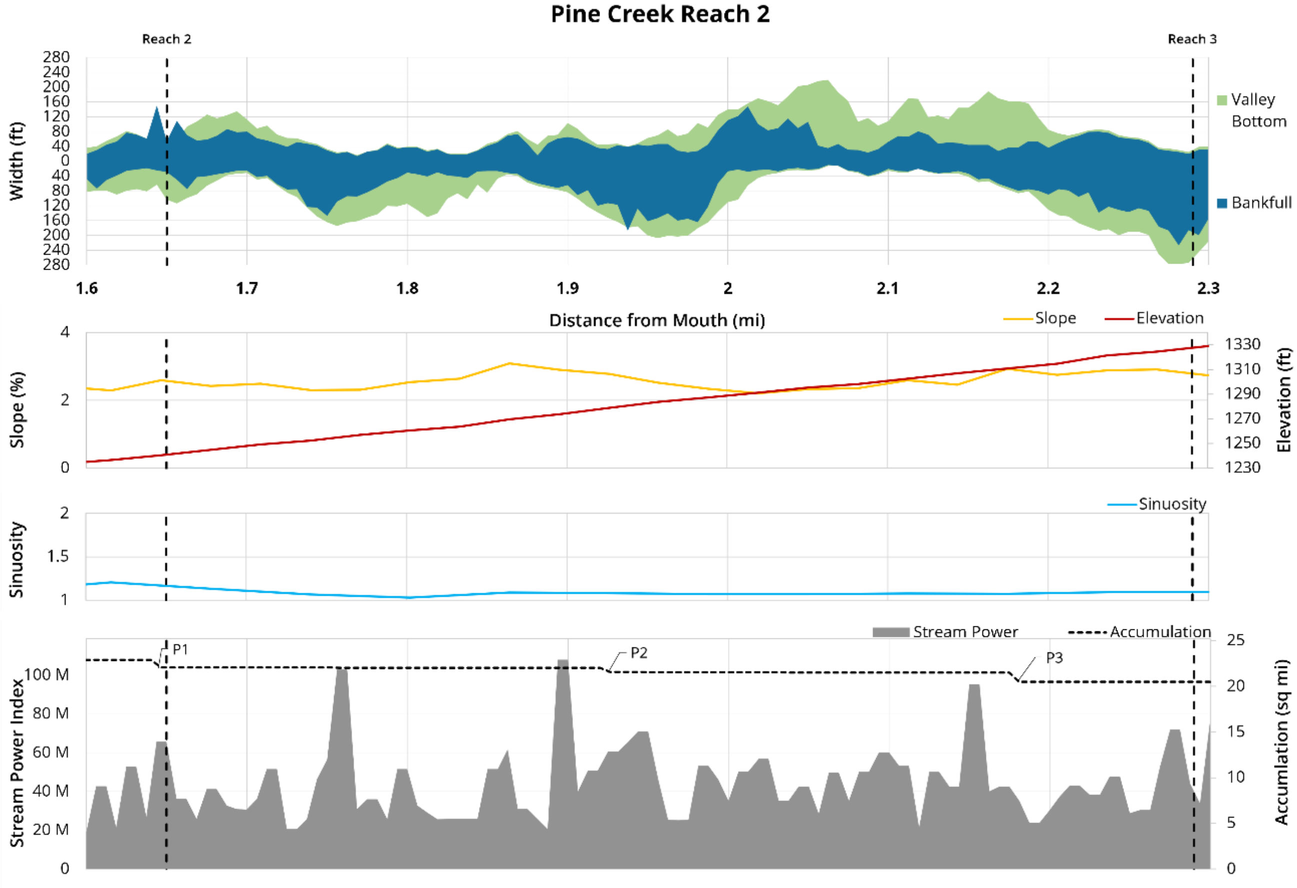

Figure 19. Stacked long profile of Pine Creek Reach 2 including bankfull width, valley bottom width, channel slope, elevation, sinuosity, stream power, drainage area, reach breaks, and tributaries.

4.6.3.3 Reach 3

Reach 3 begins at the confluence with tributary P3. For the first 0.25 miles, the channel is very straight and maintains a slope >2% (Figure 20). The channel is incised 6–10 feet through this section, leaving relic channel scars perched on a Holocene terrace along river right. Upstream of this location near the confluence with tributary P4, the channel is not incised and is well connected to the floodplain. There is ample evidence of floodplain inundation that left deposits of sediment and wood, including recent avulsions forced by LWD jam breaches. Despite evidence of recent LWD jam breaches, Reach 3 has the lowest density of LWD in the project area as much of the remaining wood is perched on the floodplain. While this does little for habitat in the mainstem, the prevalence of wood in the floodplain has created high quality off-channel habitats. In the mainstem, boulders are the dominant pool-forcing mechanism. Natural boulder berms and levees are still prevalent but are discontinuous and have clearly been reworked during recent flood events. Upstream of the confluence with tributary P6, the valley bottom narrows, but there are still multiple secondary channels as the mainstem runs along the valley margin on river right. Reach 3 ends near the confluence with tributary P7.

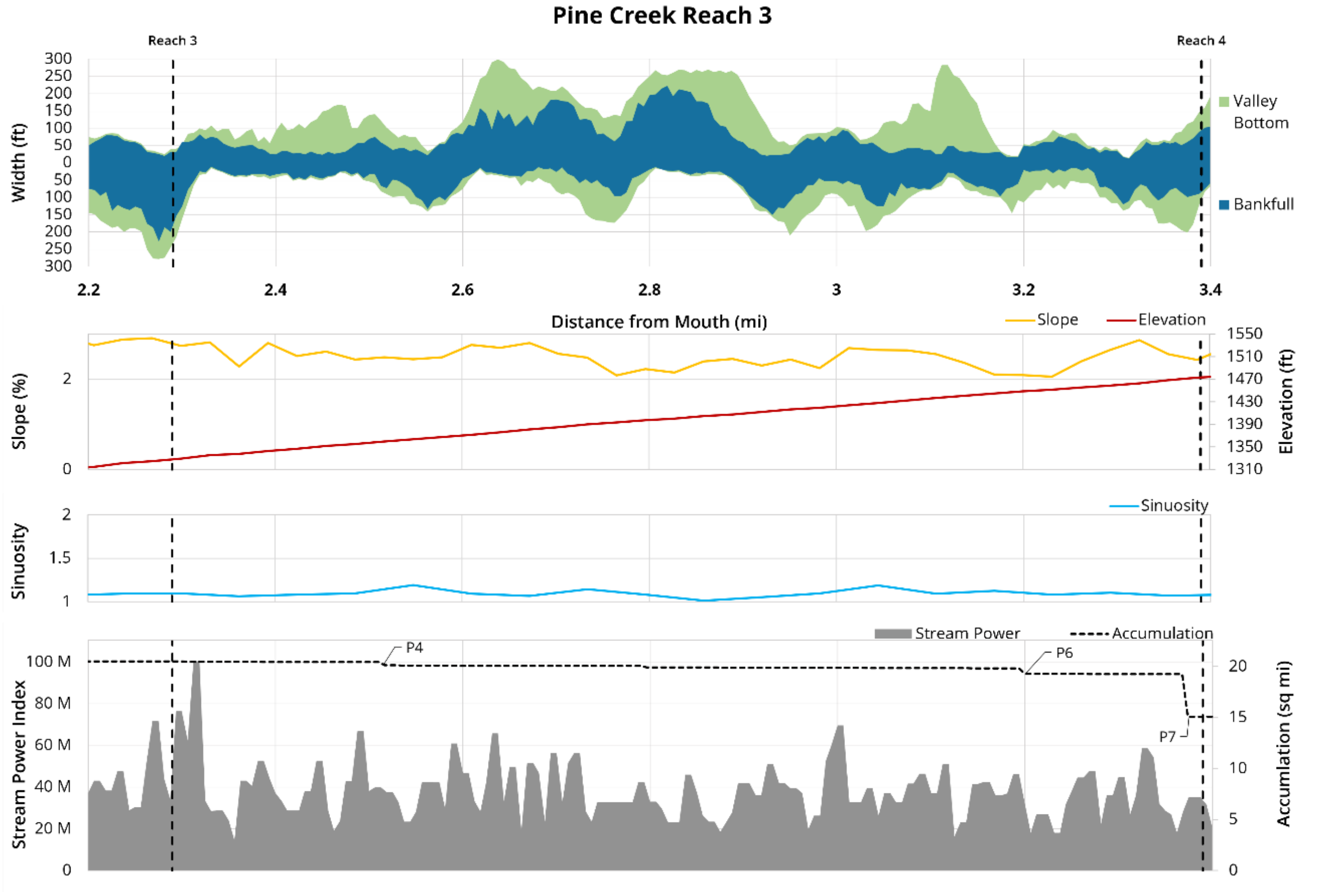

Figure 20. Stacked long profile of Pine Creek Reach 3 including bankfull width, valley bottom width, channel slope, elevation, sinuosity, stream power, drainage area, reach breaks, and tributaries.

4.6.3.4 Reach 4

Reach 4 begins near the confluence with tributary P7. At this point, Pine Creek makes a sharp turn to the north, briefly moving away from the andesite flows on river right. The channel slope remains >2% and gradient breaks in the streambed are often tied to large boulder ribs (Figure 21). Although the impact of lahar flows is prevalent throughout all of Pine Creek, the channel begins directly interacting with lahar-dominated valley slopes in Reach 4. The valley bottom is consistent with downstream reaches, in that it is well developed, vegetated, and even compacted in many places. However, as the channel runs against the valley walls, it rapidly recruits lahar sediment as it erodes. Given the extensive depth of the lahar flows, there is very little lateral expansion of the valley bottom, but the sediment contribution is significant. Even during base flows, we observed crumbling hillsides as the flows ran along the toe of the valley wall. There is evidence of recent incision up to 10 feet that has left Holocene terraces on river right, primarily in the middle section of Reach 4. The channel banks in this section are heavily armored by large boulders. There is a wide diversity of off-channel habitats in this reach that appear to be largely driven by beaver activity. Beavers are highly unlikely to build dams across the mainstem, but they are active and there are relic dams in the floodplain. LWD density is low and the majority of existing LWD pieces are old and decaying. Reach 4 ends near the confluence with tributary P8.

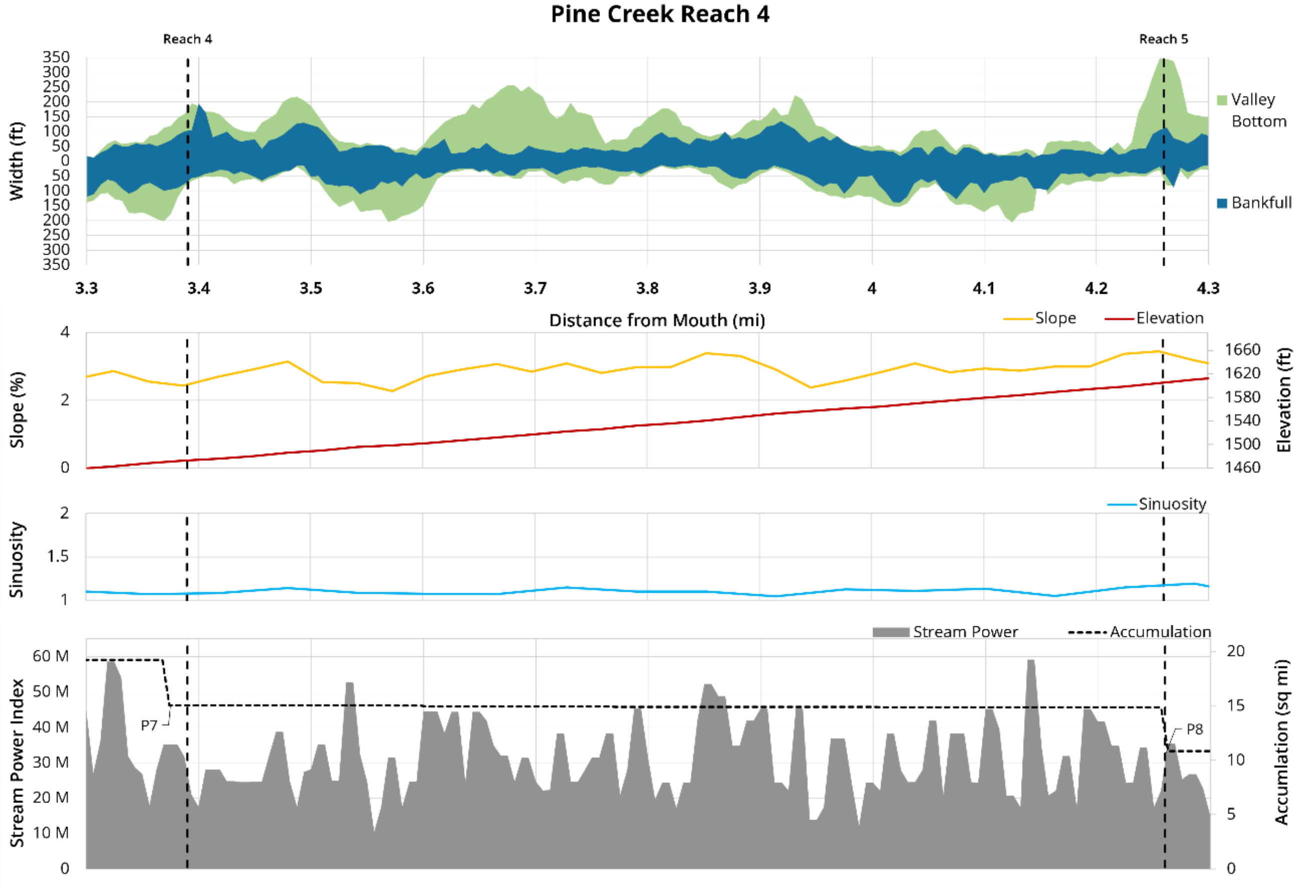

Figure 21. Stacked long profile of Pine Creek Reach 4 including bankfull width, valley bottom width, channel slope, elevation, sinuosity, stream power, drainage area, reach breaks, and tributaries.

4.6.3.5 Reach 5

Reach 5 begins near the confluence with tributary P8 and the character of the Pine Creek changes drastically. The valley bottom width is much narrower than downstream reaches, and in some places does not extend beyond the bankfull channel (i.e., confinement greatly increases; Figure 22). Sediment delivered from P8 creates a patch of high topographic diversity that propagates upstream for about 1,000 ft before entering a highly confined valley setting. Despite the high confinement, there are several short secondary channels that are forced by stable bifurcations. LWD density increases in Reach 5 compared to downstream reaches but is still very low. Similar to downstream reaches, most of the existing LWD is old and decaying, but helps maintain split flow paths and contributes to sediment aggradation. Small LWD jams often form at the head of bars and are clearly contributing to the development and maintenance of secondary channels and braids. Given the high confinement, the channel is often interacting with a valley wall and recruiting lahar sediments throughout the year. Near the upstream extent of Reach 5, bedrock from the Marble Mountain basalt flows is exposed and has a direct impact on the planform and future trajectory of the channel. Reach 5 ends near the confluence with tributary P10.

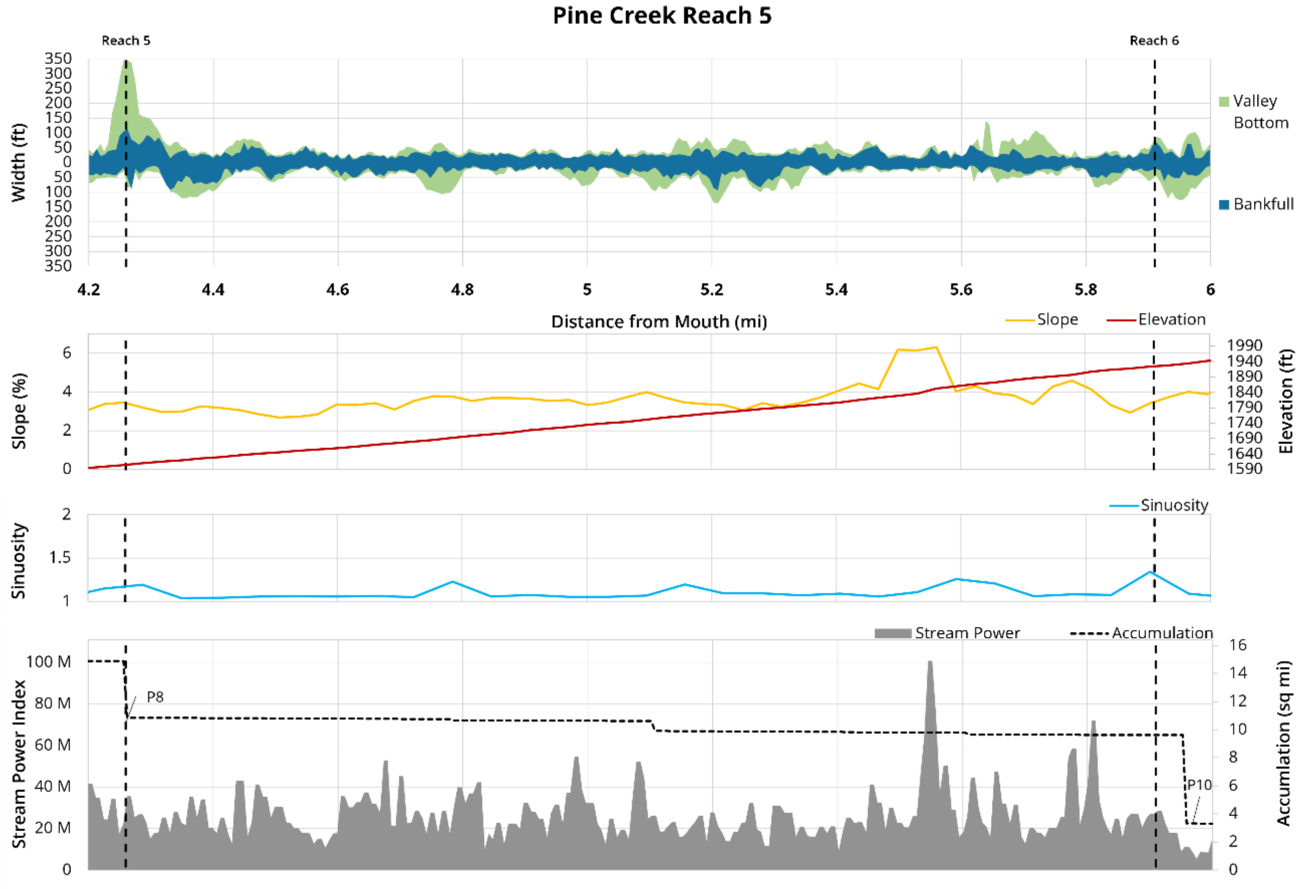

Figure 22. Stacked long profile of Pine Creek Reach 5 including bankfull width, valley bottom width, channel slope, elevation, sinuosity, stream power, drainage area, reach breaks, and tributaries.

4.6.3.6 Reach 6

Reach 6 begins near the confluence with tributary P10. The channel and valley bottom have more accommodation space and thus are wider than Reach 5 as the channel moves away from the Marble Mountain basalt flows (Figure 23). Channel slope within Reach 6 increases to >4% as Pine Creek extends into the expanse lahara deposits at the base of Mt. St. Helens. In Reach 6, Pine Creek is dominantly single-threaded, but the floodplain is well connected throughout. Secondary channels do exist; however, wetland complexes created by incoming springs, and lateral off-channel habitats are more common than well-defined secondary channels. Given the high gradient, existing secondary channels are maintained through stable bifurcations that are forced by a combination of LWD racking and large-clast sediment deposits. The entirety of Reach 6 is a high-energy system, and the stability of its planform is heavily dependent on living vegetation (primarily alder roots), boulder deposits, and LWD jams. Springs emerging from the base of the lahar deposits are common and extensive throughout the reach. The surface flows that create Pine Creek literally emerge as springs from the base of Mt. St. Helens along the base of the lahar deposits. Reach 6 ends at the upstream extent of these massive springs. Pine Creek's valley transitions from zero surface water and a sterile landscape of lahara deposits to 100+ cfs and well-developed geomorphic morphologies over the length of 100 meters as springs emerge.

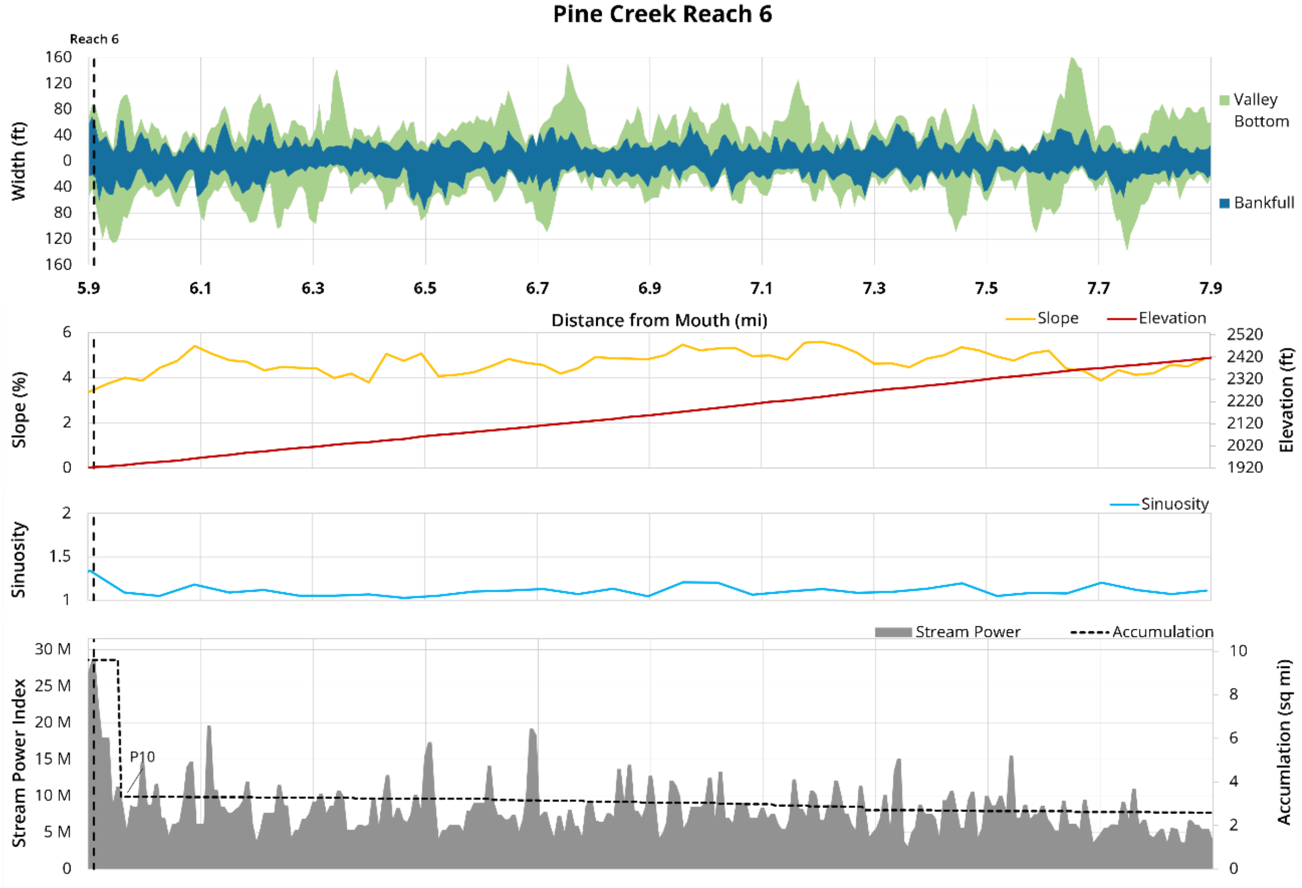

Figure 23. Stacked long profile of Pine Creek Reach 6 including bankfull width, valley bottom width, channel slope, elevation, sinuosity, stream power, drainage area, reach breaks, and tributaries.

4.6.4 Geomorphic Interpretation

The geomorphic evolution and trajectory of Pine Creek is heavily dictated by the volcanic history of Mt. St. Helens which must be considered during restoration planning. Most recently, the 1980 eruption created lahar flows and extensive flooding that effectively removed all vegetation and LWD from the valley bottom and reset the valley bottom topography. As the creek responded to subsequent floods, newly created channels became more defined. Pioneer vegetation quickly occupied the open spaces and nitrogen-fixing species like alder, lupine, and clover are still dominant within the floodplain. Alder is still the dominant canopy species and plays a large role in channel stability throughout the drainage. Even though alder trees can live up to 70 years, many only live 40-50 years at which point they can be recruited to the channel as LWD. By this time, channels become more stable, and soils in the floodplain are more developed and contain sufficient nutrients for secondary succession species like conifers. There have been periods in Pine Creek's history where this full process took place and large conifers created significant log jams that helped create a mix of stable bifurcations and dynamic habitats. Currently, the existing stands of alder trees are 40 years old at most, but many appear to be <15 years old. Therefore, Pine Creek is still in the early phases of this cyclical response to the 1980 eruption. Our primary recommendation from a geomorphic perspective is to expedite Pine Creek's trajectory by adding a high density of LWD. Rather than wait for natural wood recruitment processes to reach culmination, adding LWD now will give the creek the tools it needs to create dynamic habitats while floodplain vegetation continues to progress to secondary succession. Placing unsecured LWD will also allow the river to transport pieces and form wood jams naturally. This tactic will set the stage for Pine Creek to evolve as it would if we jumped forward in time 100 – 150 years when large trees finally reach the end of their lifespan.

4.7 Hydrologic Assessment

4.7.1 Watershed Overview

Pine Creek is a tributary to the Upper NF Lewis River, flowing from the southwest flank of Mount St. Helens into the NF Lewis immediately upstream on Swift Reservoir (Figure 24). Most the upper watershed is within the Gifford Pinchot National Forest, the middle watershed area is a mix of private industrial forest ownership and Columbia Land Trust land, and the lower watershed is a mix of National Forest, private timber, Columbia Land Trust, and private parcels.

Approximately 70% of the basin is forested, with 67% tree canopy cover. Most of these forests are managed as timber lands. The forests in the upper watershed were denuded by the 1980 eruption of Mt. St. Helens. Additionally, stand replacing fires such as the Yocult Burn in 1902 have occurred periodically within the basin (notably in 1927 and 1929) and had lasting impacts on hydrology, sediment and soil conditions, and riparian vegetation (LCFRB 2010).

The Pine Creek watershed has also been heavily impacted by the eruption of Mt. St. Helens. The upper portion of the watershed was denuded of trees and covered by a layer of volcanic ash (Figure 25). Additionally, a volcanic debris flow (lahars) was triggered by the eruption of Mt. St. Helens that flowed down the Muddy-Pine fan, reaching speeds of up to 30 meters per second and depositing randomly sorted particles up to small boulder size, up to 2.5 meters deep (Pierson 1985). The impacts of Mt. St. Helens have continuing effects on the Pine Creek watershed; however, streamflow from impacted basins increased by only a few percent for a period of up to 10 years (Major and Marks 2006).

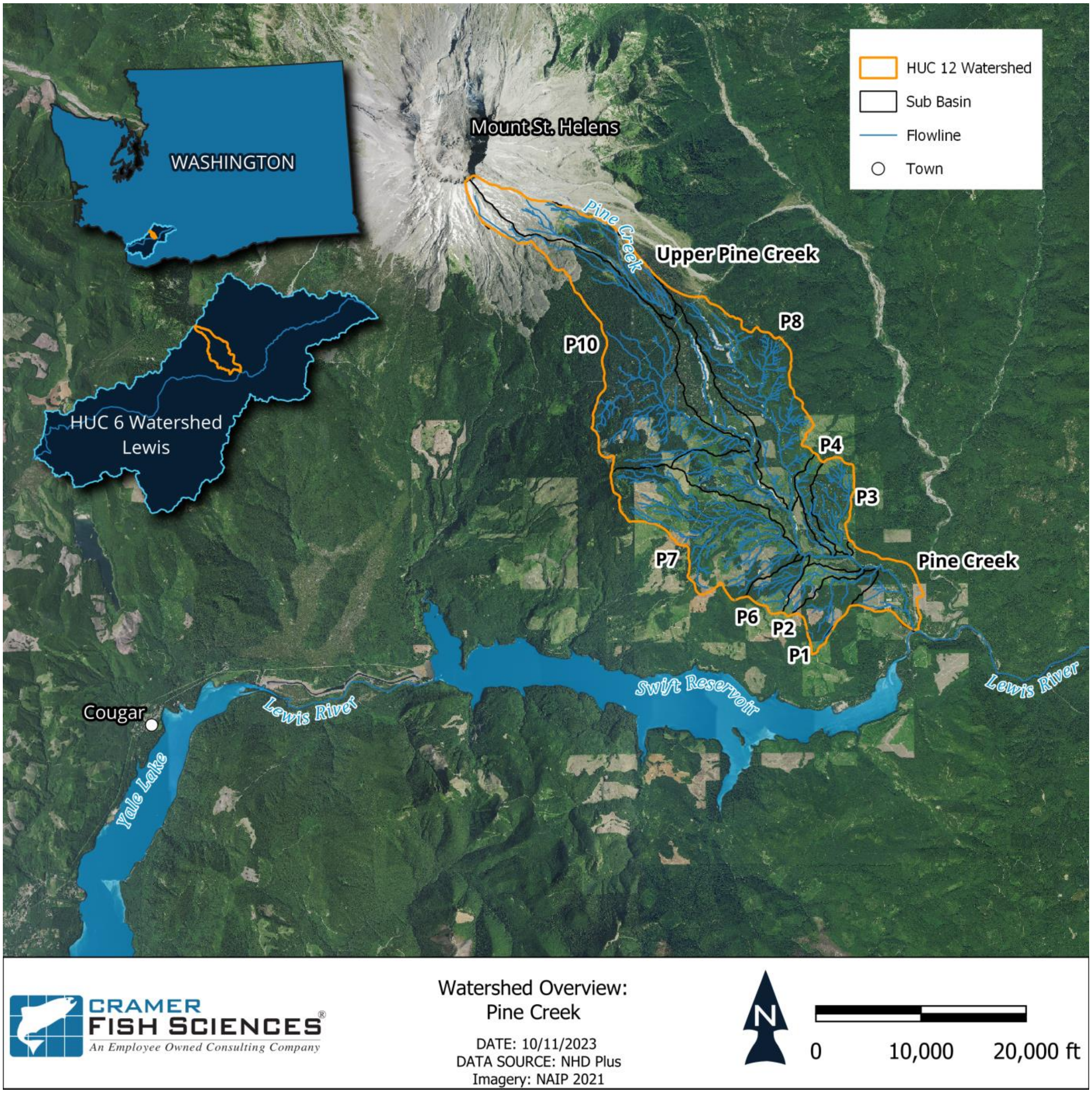

Figure 24. Overview map of the Pine Creek watershed and the surrounding area.

Figure 25. Photograph of the upper Pine Creek watershed taken in 2009 by David Anderson.

Pine Creek is classified as a VwHMH hydrologic landscape, indicating very wet, fall or winter season dominated, high aquifer and soil permeability, mountainous basin (Liebowitz et a. 2016). Peak streamflow on Pine Creek exhibits a bimodal distribution between precipitation events in the winter (including rain-on-snow events) and snowmelt in the spring (Figure 26). Spring recession and summer baseflow are influenced by winter snowpack and then transition to primarily groundwater in the summer and early fall. The influence of groundwater is significant in Pine Creek, it is presumed that the highly permeable volcanic lithology provides elevated groundwater contribution, especially in the upper basin. This unique hydrology supplies the cold, consistent streamflow that is critical to bull trout habitat. An example of the mid-basin springs can be seen in Figure 27. Spring runoff is consistent, decreasing throughout the summer until fall pulse events occur. The timing and magnitude of fall pulse storms play a significant role in annual low flow; variability of these events accounts for the large flow variability in September and October.

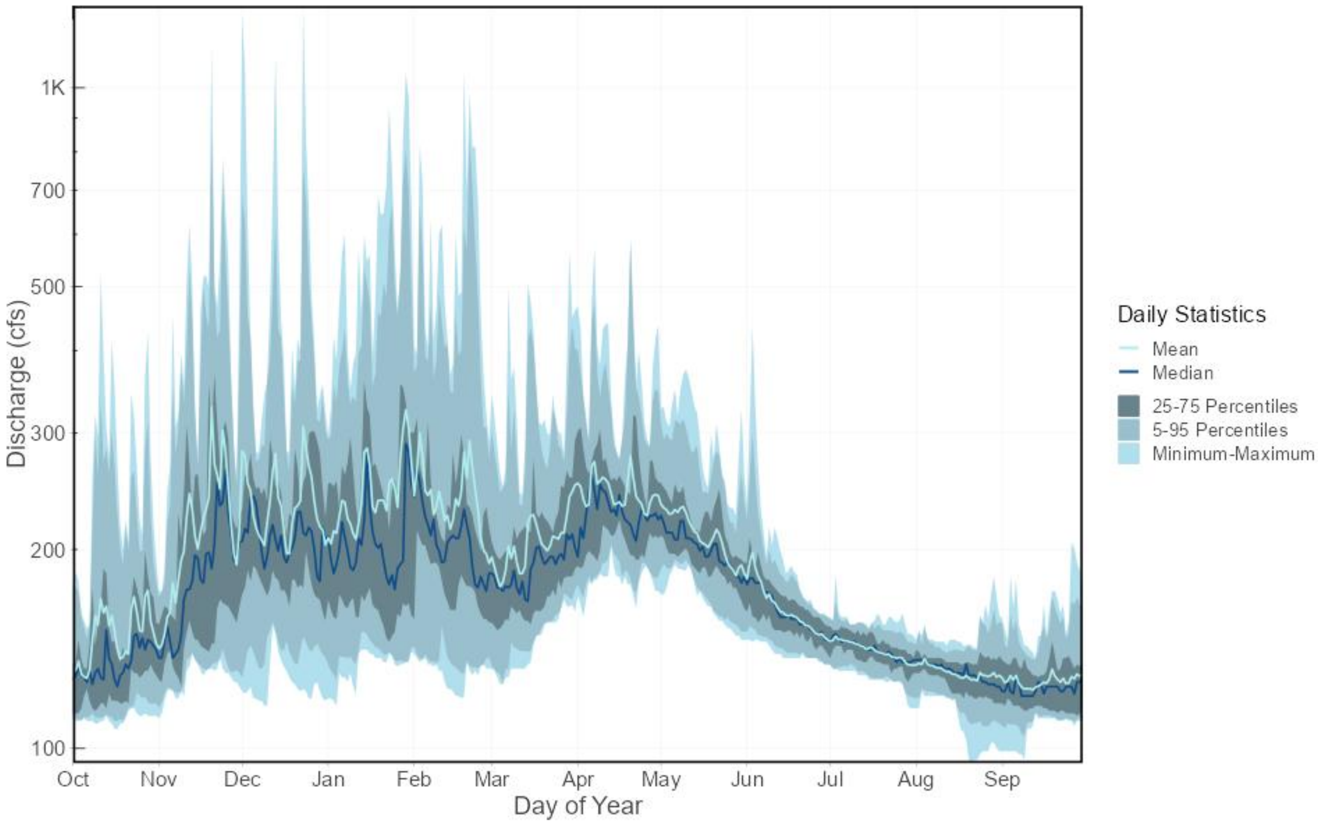

Figure 26. Mean annual hydrograph for USGS Gage 14216800 Pine Creek near Cougar, WA

Figure 27. Example photographs of springs associated with forested hillsides in the headwaters during the summer.

4.7.2 Hydrologic Data

We completed three types of hydrologic analysis to support this design—flood frequency, flow duration, and climate change impacts assessments. All hydrologic analyses rely on available gage records supplemented with regional regression equations, where required (Table 10). Primarily, the historic record from gage 14216800 Pine Creek Near Cougar, WA provides the longest continuous record of streamflow in Pine Creek. Adjacent basin gages 14216500 Muddy River below Clear Creek and 1421600 Lewis River above Muddy River were used for long-term comparisons.

Table 10. Summary of available streamflow gage data on Pine Creek and adjacent relevant basins.

Gage Number	Gage Name	Drainage Area [sq. mi.]	Period of Record	Number of Years
14216800	Pine Creek Near Cougar, WA	21.55	09/30/1957 - 09/28/1970	13
14216900	Pine Creek at Mouth Near Cougar, WA	26	09/30/1981 - 09/28/1984	3
14216500	Muddy River below Clear Creek near Cougar, WA	131	09/30/1927 - Current	57
14216000	Lewis River above Muddy River near Cougar, WA	227	08/31/1927 - Current	36
14222500	East Fork Lewis River near Heisson, WA	125	10/01/1929 - Current	92

4.7.3 Flow Duration Analysis

We completed a flow duration analysis using the methodology from Granato et al. (2017) to support the assessment and design, which determines the percentage of time that a given flow value is equaled or exceeded. This assessment helps determine the frequency of lower magnitude flows that can be ecologically relevant for aquatic species and geomorphic processes (Table 11 and

Figure 28). Flow duration exhibits a strong groundwater and snowmelt signature, with relatively consistent flows throughout the year and relatively high summer baseflows relative to basin size. This is a critical element contributing to the high-quality bull trout habitat in Pine Creek. Additionally consistent streamflow contributes to a unique and robust riparian forest with dense grasses and a low depth to groundwater.

Table 11. Results of the flow duration analysis for the project location.

Percent of Time Exceedance (%)	Pine Creek Discharge (cfs)
99	132.7
95	140.0
90	148.4
80	161.7
50	199.1
20	277.5
10	341.4
5	417.0
2	555.1
1	690.8

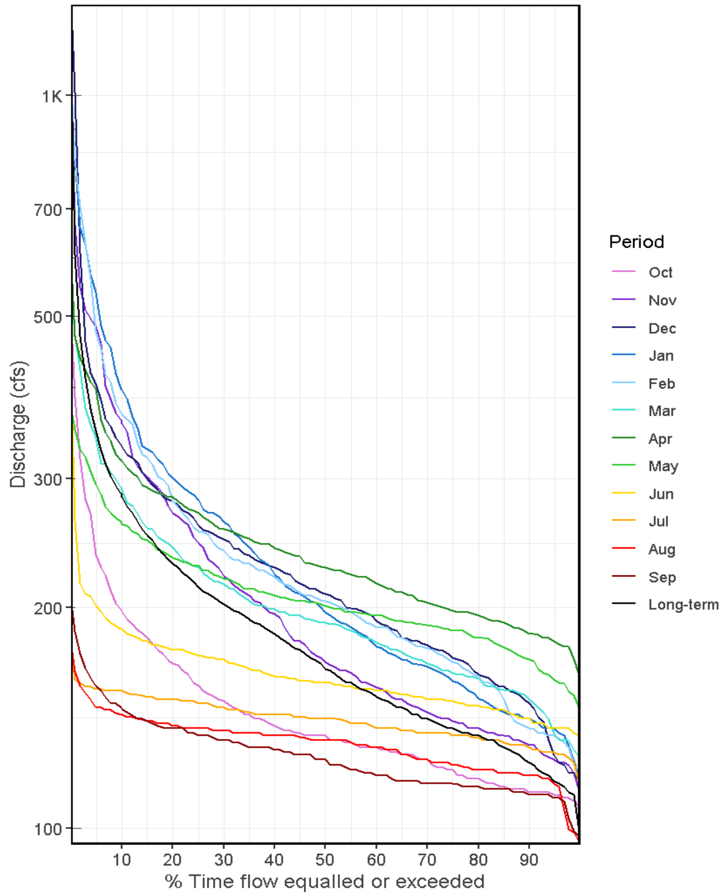

Figure 28. Graphical representation of flow duration analysis, separated by month and aggregated over the year for gage 14216800 Pine Creek near Cougar, WA.

4.7.4 Flood Frequency Analysis

We assessed the peak discharges at flood recurrence intervals using the Bulletin 17C methodology (England et al. 2018) and compared to results from weighted regional regression equations (StreamStats, USGS 2019). The basin area scaling approach from Mastin et al. (2016) was applied to flood frequency estimates at the Pine Creek near Cougar, WA to scale results to the subbasins within the project area. Results from the flood frequency analysis (Table 12) compare results from Bulletin 17C method and Streamstats. Streamstats results are shown to typically overestimate peak discharge relative to the Bulletin 17C methodology, this is likely due to the unique soils and geologic conditions of the watershed, as well as the influence of groundwater. Though the flood frequency analysis utilizes only pre-eruption record, these results are preferred for this study. Flood frequency results are used to assess risk, determine restoration action stability, and analyze floodplain connectivity, among other objectives.

Table 12. Summary of select flood frequency results for the project area.

Location	Drainage Area (sq. mi.)	Analysis Years	Recurrence Interval	Bulletin 17C Peak Discharge (cfs)	StreamStats Peak Discharge (cfs)
Pine Creek at confluence with NF Lewis River	26	13	500	3746.3	7430
			200	3273.2	6580
			100	2934.3	6250
			50	2609.7	5650
			25	2296.1	5110
			10	1892.8	4450
			5	1588.1	3800
			2	1152.6	2970
			1.5	982.2	
			1.2	820.1	
			1.01	524.0	

4.7.5 Flood History

The recent and historic impacts of flood hysteresis within a watershed are critical to consider due to their influence on current channel morphology and trajectory. For Pine Creek, it is important to understand the interaction between the Mt. St. Helens eruption and flood events. The Mt. St. Helens eruption destroyed the upper watershed hillslope forest. The resulting debris flow eroded and scoured the channel valley, and post-eruption ash and debris flow material was deposited on top (Mark and Majors 2006). This event reset many of the fluvial and watershed processes in Pine Creek. Since the eruption, the most significant flood event occurred in February 1996, which is one of the highest recorded events in the period of record for the Lewis River basin. The February 1996 event occurred on a landscape that was still recovering from the eruption, leading to increased rates of channel migration, widening, and scour. Given the poorly sorted sediment within Pine Creek, sediment transport was likely elevated during this event, scouring away smaller sediment classes including spawning gravels. This event also likely resulted in impacts to riparian vegetation, specifically primary successional species such as alder that were recolonizing after the eruption. Though subsequent events were not captured by the Pine Creek gage, it is assumed that significant events in 2006, 2015, and 2009 (listed in order of magnitude) also impacted Pine Creek along with moderate recent events in 2020 and 2021. Flood events are critical for channel forming processes to occur and influenced the post-eruption trajectory of Pine Creek, but also have impacts on current habitat conditions.

4.7.6 Impact of Mt. St. Helens Eruption on Hydrology

A study by Mark and Major (2006) evaluated the hydrologic response to the eruption of Mt. St. Helens (Figure 29), specifically peak flow response. Although peak flow is only one aspect of ecologically and geomorphically relevant flows, this study lends insight into the hydrologic processes occurring in the post-eruption landscape. Mark and Majors (2006) concluded that increases in peak flows were observable, but strongly seasonal and transient, typically affecting fall and winter flows for a period of up to 5 years. The primary mechanism for the change was identified as hillslope hydrology. The reduction in vegetation reduced the proportion of interception and evapotranspiration, additionally lahar deposits (present in the Pine Creek watershed) reduced surface infiltration. Secondarily, the lahar flows in the Pine-Muddy simplified channel complexity, but also deposited large substrate. The reduction in channel complexity was likely mediated by the coarsening of the substrate.

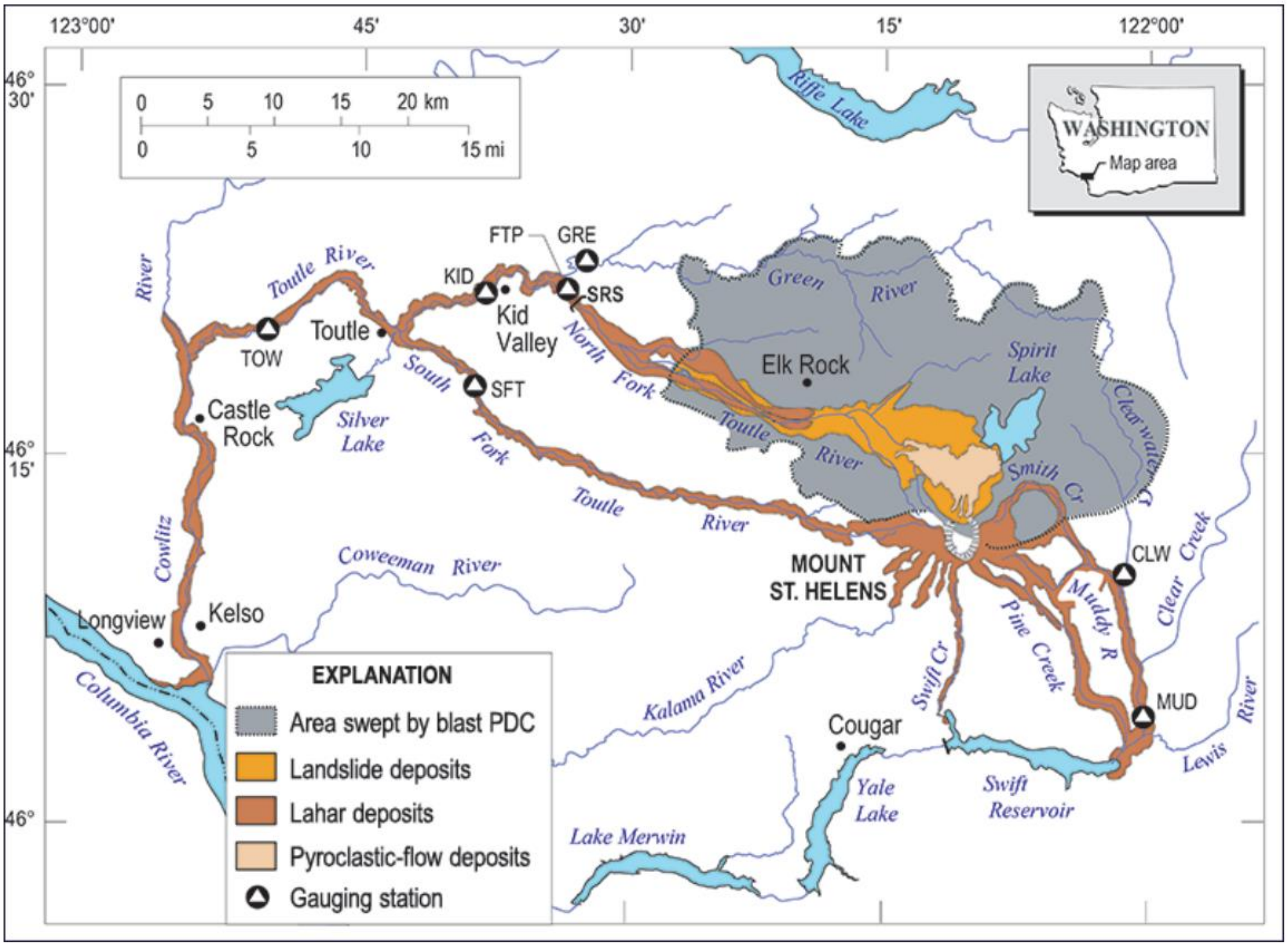

Figure 29. Map showing the distribution of different deposits following the 1980 Mt. St. Helens eruption (The distribution of tephra fall is not shown). Locations of U.S. Geological Survey (USGS) stream and sediment gauges (e.g., TOW; see Figure 2 for other names and abbreviations) are also shown. Abbreviations are SRS = sediment-retention structure; PDC =pyroclastic density current. Reprinted from Major, Crisafulli, and Swanson (2020).

We compared the hydrology between basins with varying degrees of impact from the Mt. St. Helens eruption to assess if significant hydrologic responses were still identifiable in the time since the eruption. The East Fork of the Lewis River (14222500) was used as a control basin because the relative impact of the Mt. St. Helens eruption was negligible. We considered the Muddy River below Clear Creek (14216500) the impacted basin, a reasonable analogy to Pine Creek, but with the gage restored post-eruption. Four flow metrics were used to compare pre- and post-eruption hydrologic conditions: maximum 1-day flow, mean daily flow, median daily flow, and 7-day minimum flow. Comparing results for the maximum daily flow, the conclusions from Mark and Major (2006) can be observed in relatively high peak discharges in the Muddy River without coincident wet years in the East Fork Lewis River. However, the period of elevated peak flows appears to have returned to baseline. Mean and median flow show no substantial differences pre- and post-eruption comparing the two gages. The 7-day minimum flow on the Muddy River does appear to be decreasing over time, with a jump associated with the Mt. St. Helens eruption; however, the East Fork Lewis minimum flows are declining as well, indicating a potential climatic forcing element. Additionally, we ran a Mann Whitney test for the Muddy River below Clear Creek (14216500) gage peak flow record and results showed no significant nonstationary, indicating that the impacts of Mt. St. Helens were too short to be statistically significant relative to other climatic trends and conditions. Overall, results from Mark and Majors (2006) appear consistent with the gage comparison, and the impacts of climate change obscure direct impacts of the Mt. St Helens eruption.

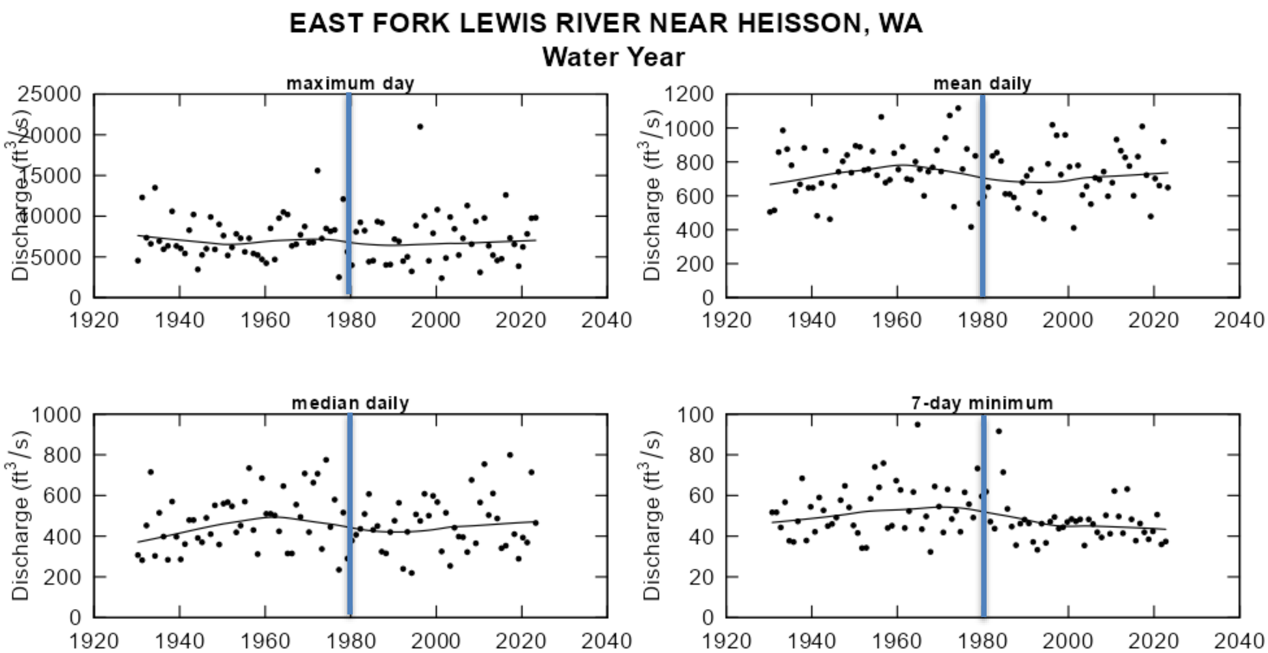

Figure 30. Comparison of maximum 1-day flow, mean daily flow, median daily flow, and 7-day minimum flow for the East Fork Lewis River near Heisson, WA gage. The blue lines indicates the Mt. St. Helens eruption.

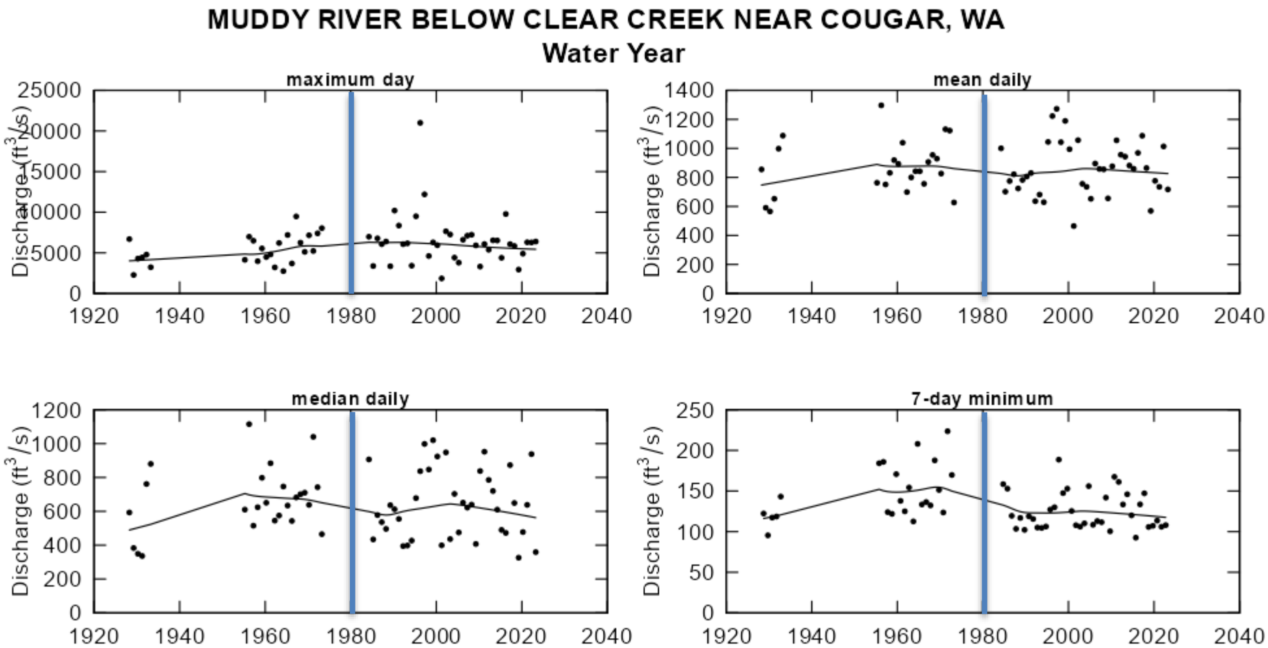

Figure 31. Comparison of maximum 1-day flow, mean daily flow, median daily flow, and 7-day minimum flow for the Muddy River below Clear Creek near Cougar, WA gage. The blue lines indicates the Mt. St. Helens eruption.

4.7.7 Climate Change

The final component of the hydrologic assessment incorporated projected climate change impacts. Generally, climate change is predicted to alter seasonality of precipitation in the Upper Lewis River watershed causing increased frequency and magnitude of winter events and lower more extreme summer low flows (LCFRB, 2018). Additionally, extreme precipitation events (Salathe et al. 2014 and Mauger et al. 2018) and shifting hydrologic regime from snowmelt to rainfall and rain-on-snow are likely to lead to increased frequency and magnitude of flood events. Stream temperatures are expected to increase during summer low flow season. However, due to the high proportion of cold groundwater contribution, Pine Creek has the potential to serve as a thermal refugia within the Upper Lewis basin. We used data from Hamlet et al. (2013) to evaluate streamflow changes for the Upper Lewis River (Table 13). The general trends for the Upper Lewis basin are consistent with previous findings (LCFRB, 2018), but may be less applicable to the Pine Creek watershed due to the unique geologic and climatic conditions, particularly for summer low flow projections. Extreme winter flood events are more likely to occur on Pine Creek in the form of atmospheric rivers and/or rain-on-snow events. Providing a resilient stream corridor to buffer aquatic species from climate impacts includes providing flood refugia in the form of off channel habitat, channel roughness elements to retain fine sediment and gravels, and protecting and enhancing riparian vegetation to prevent excess channel widening and provide shading. Changes in peak flow used in hydraulic modeling, structure stability, and risk assessment are shown in Table 14.

Table 13. Streamflow change projections from Hamlet et al. (2013) for climate scenario A1B.

	2020-2040	2040-2060	2060-2080	2080 - 2100
O	3%	-6%	0%	8%
N	8%	23%	9%	22%
D	14%	33%	44%	46%
J	17%	44%	31%	59%
F	20%	26%	34%	46%
M	20%	13%	19%	17%
A	0%	-1%	-5%	-12%
M	-19%	-34%	-42%	-50%
J	-36%	-53%	-67%	-71%
J	-51%	-67%	-74%	-76%
A	-34%	-45%	-55%	-51%
S	-17%	-30%	-35%	-22%

Table 14. Summary of select flood frequency results for the project area and projected peak discharge values based on Chedwiggen et al. (2017) climate change projections.

Location	Drainage Area (sq. mi.)	Analysis Years	Recurrence Interval (Years)	Current Peak Discharge (cfs)	2080 Peak Discharge (cfs) Low Scenario (RCP 4.5)	2080 Peak Discharge (cfs) High Scenario (RCP 8.5)
Pine Creek at confluence with NF Lewis River	26	13	500	3746.3	4720.3	5169.9
			100	2934.3	3755.9	4049.3
			10	1892.8	2422.8	2612.1
			2	1152.6	1475.3	1590.6

4.8 Hydraulic Modeling and Analysis

We created a one-dimensional (1D) and a two-dimensional (2D) hydrodynamic model for the entire Pine Creek project area. These models solve the Saint-Venants Equations for depth-averaged hydraulic properties such as depth, velocity, and shear stress. We used the to answer specific questions and inform design elements, develop project goals and metrics, and assess risk. Both models were constructed in HEC-RAS v6.4.1 developed by the United States Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (HEC-RAS), developed by the Hydrologic Engineering Center (USACE 2022).

4.8.1 Model Domain

The model domain for the 1D and 2D models are equivalent; both models extend longitudinally from the confluence with the NF Lewis River at the downstream end to the upstream end of the project area (upstream extent of fish accessibility). Both models extend laterally from valley wall to valley wall, spanning beyond the 100-year flood extents. The model does not significantly extend upstream at tributary junctions. The model domain is shown in Figure 32.

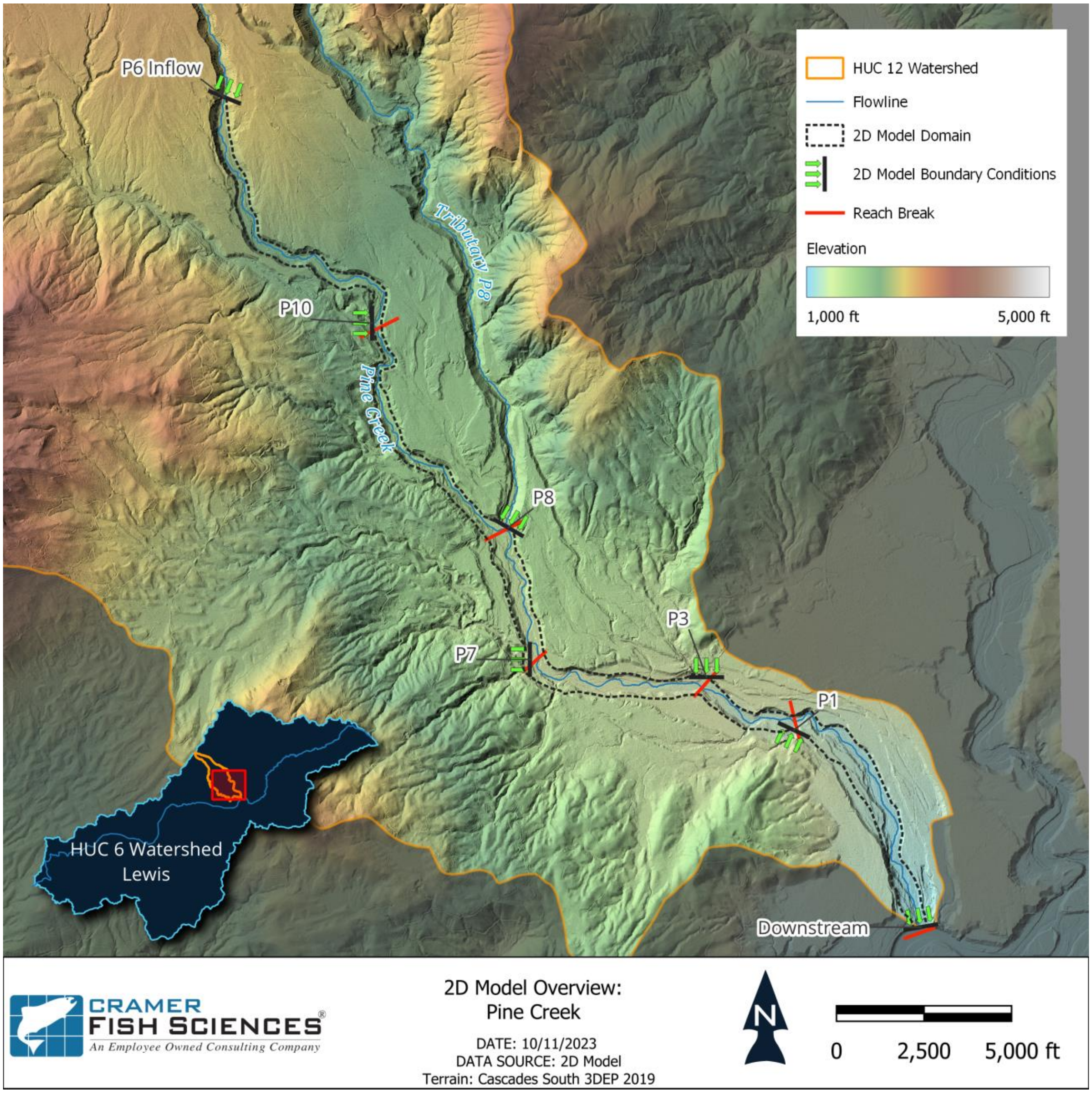

Figure 32. Hydraulic model domain.

4.8.2 Topographic and Bathymetric Data

The topographic and bathymetric data for both models is the same and is primarily comprised of LiDAR datasets. The QSI (2019) LiDAR (flown in 2018) was used for most of the project area, except a small floodplain and upland portion of Reach 1, for which QSI (2017) LiDAR (flow in 2016) was utilized. It should be noted that LiDAR was also flown for most of the project area (Atlantic, 2020) in 2017; however, this flight occurred during leaf-on conditions resulting in reduced point density and non-vegetated accuracy relative to other LiDAR flights.

We supplemented LiDAR datasets with bathymetric terrain generated from datasets produced by the Lamperth et al. (2017) study and validated by an RTK survey (Section 4). The mean depth for each 100-meter reach was applied to the wetted extent of the channel to “burn in” the bathymetric channel terrain. We applied a normal distribution +/- one standard deviation to the mean depth at a three-foot grid spacing to account for the variability of the bathymetry. This technique allows for a more accurate representation of the bathymetric variability compared to using traditional survey methods or green LiDAR (due to turbulence).

4.8.3 Model Geometry

The 1D model consists of cross sections with approximately 100 foot spacing, utilizing the topographic and bathymetric terrain data described above. The cross section is a 1D representation of the terrain, hydraulic roughness, and flow path conditions. We computed the 1D model using a mixed flow regime, allowing for subcritical and supercritical flow, which is appropriate given the hydraulic drops present in the project area.

The 2D model consists of a continuous mesh, with a resolution of 6-foot cells in the main channel and 20-foot cells in the floodplain and overbank areas. Higher mesh resolution is required in the main channel to capture relatively more rapid changes in depth, velocity, and shear stress compared to floodplain and overbank areas, which typically exhibit more consistent hydraulic conditions. We computed the 2D model using the diffusion wave equation, with a time step that resulted in Courant condition values below threshold value of 3.

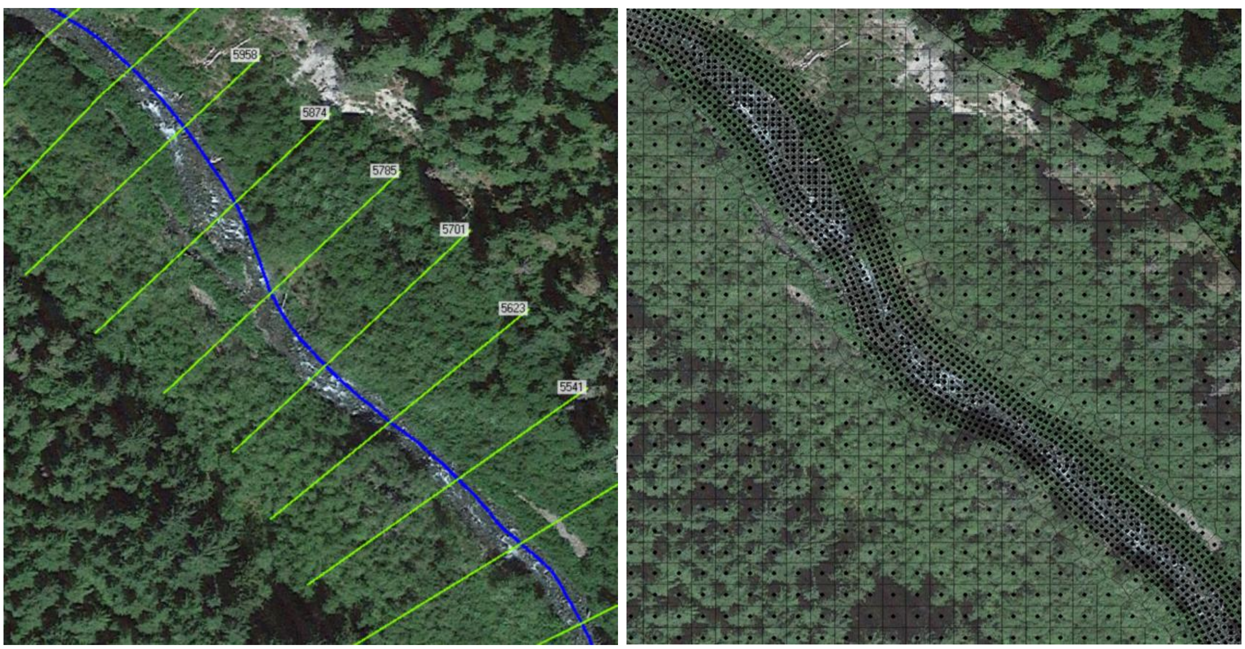

Figure 33. Hydraulic model geometry for 1D (left) and 2D (right).

4.8.4 Hydraulic Roughness

Hydraulic roughness is a representation of the amount of frictional resistance water experiences when passing over channel or land features and is generally due to (1) drag from sediment grains on the bed surface (grain roughness); (2) bed, bank, vegetation, and large wood undulations creating pressure drag (form roughness), (3) sediment transport derived drag (Griffiths 1987), and (4) resistance associated with hydraulic jumps, turbulence, and wave drag, especially in high gradient channels (Yochum 2018).

We calculated hydraulic roughness on a reach basis using the flow resistance coefficient estimation tool (Yochum 2018). The tool utilizes multiple approaches (tabular guidance, photographic guidance, and quantitative equations) to recommend a hydraulic roughness coefficient (Manning's n). The variables used in the computation, as well as final main channel roughness values are shown in Table 15.

Table 15. Variables that were used to estimate hydraulic roughness and the final hydraulic roughness values in each reach of Pine Creek.

Reach	Stream Channel Slope (ft/ft)	D_{50} (mm)	D_{84} (mm)	Hydraulic Radius (ft)	Mean Flow Depth (ft)	Mean Thalweg Depth (ft)	Main Channel Manning's n value (unitless)
1	0.024	59.4	125.5	34.06	1.08	1.81	0.059
2	0.025	59.4	125.5	38.09	1.07	1.75	0.064
3	0.025	60.2	163.1	36.88	0.96	1.72	0.066
4	0.029	55.2	143.3	33.63	0.94	1.65	0.070
5	0.037	55.2	143.3	28.62	1.01	1.67	0.060
6	0.049	55.2	143.3	26.03	0.78	1.42	0.075

We determined hydraulic roughness spatial distribution and values for overbank, floodplain, and upland areas based on NLCD (NLCD, 2021) coverage and literature values. Hydraulic roughness values are shown in Table 16.

Table 16. Summary of Manning's n hydraulic roughness values for overbank, floodplain, and upland areas, based on NLCD land cover types.

NLCD land cover Type	Manning's n Hydraulic Roughness Value
Barren Land Rock-Sand-Clay	0.03
Perennial Ice-Snow	0.04
Open Water	0.05
Evergreen Forest	0.15
Grassland-Herbaceous	0.04
Shrub-Scrub	0.05
Developed, High Intensity	0.15
Deciduous Forest	0.1
Developed, Open Space	0.035
Developed, Medium Intensity	0.12
Developed, Low Intensity	0.08
Mixed Forest	0.12
Woody Wetlands	0.08
Emergent Herbaceous Wetlands	0.045
Pasture-Hay	0.045

4.8.5 Boundary Conditions

Boundary conditions represent locations of flow change in the hydraulic model as well as define the hydraulic properties of flow leaving the model domain. For these models, flow change locations occur at Pine Creek reach breaks, and downstream boundary condition is the confluence with the NF Lewis River. The downstream boundary condition is a substantial length away from the project area such that modeling assumptions at the boundary condition do not impact the project area. Because the private portion of Reach 1 is not included in the study area, transient hydraulic interaction with the NF Lewis River was not considered for this study.

We determined inflow values at boundary conditions based on the results of the hydrologic analysis (Section 4.6.4). We ran the hydraulic model at ecologically relevant exceedance intervals as well as typical recurrence interval flows (2-, 10-, 25-, 50-, 100-year as well as 100-year + climate change).

4.8.6 Model Results

We used the results from the hydraulic models to assess the existing hydraulic properties of each reach within Pine Creek, as well as inform the design process. We used the 1D hydraulic model to assess average hydraulic conditions in the main channel as well as the floodplain/overbank for each reach. The 2D model was used to identify opportunities for floodplain connectivity, assess the benefit of restoration actions, and identify project risks.

4.8.6.1 Existing Condition Model Results

We used the 1D hydraulic model to characterize reach-averaged hydraulic properties. First, we synthesized hydraulic characteristics for key ecological flows corresponding to typical conditions during spawning and rearing. Spawning flows are relatively consistent year to year; however, rearing flows are represented by an average condition, though a wide range of variability is possible. Reach-averaged spawning and rearing hydraulic properties are shown in Table 17. In general, as slope increases with increasing elevation, flow depth decreases and velocity increases.

Table 17. Reach-average hydraulic properties for spawning (90% exceedance interval) and rearing (25% exceedance interval) conditions.

Reach	Main Channel Flow Depth (ft)		Floodplain Flow Depth (ft)		Main Channel Velocity (ft/s)		Floodplain Velocity (ft/s)		Main Channel Shear Stress (lb/ft^2)		Floodplain Shear Stress (lb/ft^2)	
	Spawning	Rearing	Spawning	Rearing	Spawning	Rearing	Spawning	Rearing	Spawning	Rearing	Spawning	Rearing
1	1.08	1.67	0.05	0.34	3.36	4.37	0.21	1.16	1.79	2.61	0.1	0.51
2	1.07	1.66	0.04	0.33	3.49	4.59	0.27	1.41	1.9	2.87	0.1	0.56
3	0.96	1.47	0.03	0.28	3.52	4.53	0.2	1.31	1.82	2.6	0.07	0.48
4	0.94	1.38	0.07	0.28	3.36	4.26	0.42	1.51	2.02	2.8	0.16	0.58
5	1.01	1.49	0.05	0.28	3.88	4.94	0.28	1.3	2.48	3.54	0.13	0.62
6	0.78	1.07	0.04	0.17	3.86	4.62	0.3	1.17	2.51	3.28	0.19	0.51

We also synthesized model results for flows relevant to geomorphology, channel processes, and project risk, including the 2-year, 10-year, and 100-year flows. These types of flow conditions are likely to be related to fall/winter rain or rain on snow events as well as spring runoff hydrologic conditions. Flood flow results typically follow a similar pattern as ecologically relevant flows, with lower reaches averaging higher flow depth than higher reaches. However, velocities for the 2- year and greater flows do not vary as much by reach (except for Reach 6 in the upper watershed). Additionally, Reach 5 is an exception to the trend. Because of the relatively confined nature of the reach, there are fewer floodplain areas, a narrower and swifter main channel, and less sinuosity. Reach-average hydraulic properties for flood recurrence interval conditions are shown in Table 18.

Reach	Main Channel Flow Depth (ft)			Floodplain Flow Depth (ft)			Main Channel Velocity (ft/s)			Floodplain Velocity (ft/s)			Main Channel Shear Stress (lb/ft^2)			Floodplain Shear Stress (lb/ft^2)		
	2-yr	10-yr	100-yr	2-yr	10-yr	100-yr	2-yr	10-yr	100-yr	2-yr	10-yr	100-yr	2-yr	10-yr	100-yr	2-yr	10-yr	100-yr
1	3.59	4.63	5.71	1.24	1.67	2.20	6.96	8.13	9.23	2.40	2.77	3.19	5.25	6.67	8.06	1.71	2.23	2.93
2	3.46	4.33	5.28	1.20	1.65	2.16	7.18	8.37	9.36	3.43	4.29	5.19	5.53	7.02	8.18	1.83	2.59	3.22
3	2.95	3.73	4.52	1.01	1.35	1.77	6.90	7.99	8.99	3.00	3.66	4.24	4.84	6.00	7.04	1.60	2.12	2.69
4	2.52	3.15	3.84	0.83	1.15	1.54	6.18	7.21	8.15	3.20	4.03	4.56	4.95	6.16	7.31	1.67	2.29	2.79
5	2.52	3.32	4.21	0.81	1.20	1.68	6.94	8.19	9.42	2.58	3.17	3.74	5.99	7.60	9.27	1.84	2.62	3.52
6	1.30	1.70	2.13	0.30	0.50	0.72	5.23	6.22	7.15	1.64	2.34	2.97	3.97	5.24	6.49	0.86	1.49	2.15

We used the 2D hydraulic model to identify potential side channel and floodplain connection areas, priority sites for restoration actions, unique hydraulic features, and potential project risk locations. An example of a potential floodplain connection that we identified using the 2D model is shown in Figure 34. Activating the example side channel area during spawning and rearing flow conditions would meet project goals and objectives. An example of a unique hydraulic feature is shown in Figure 35, which highlights a portion of Reach 5 where the channel is confined by bedrock and lahar features creating a potential partial barrier to passage under certain flow conditions. Model results indicate instantaneous slope up to 10%, main channel velocities of approximately 8 ft/s, and relatively shallow depths for a prolonged distance.

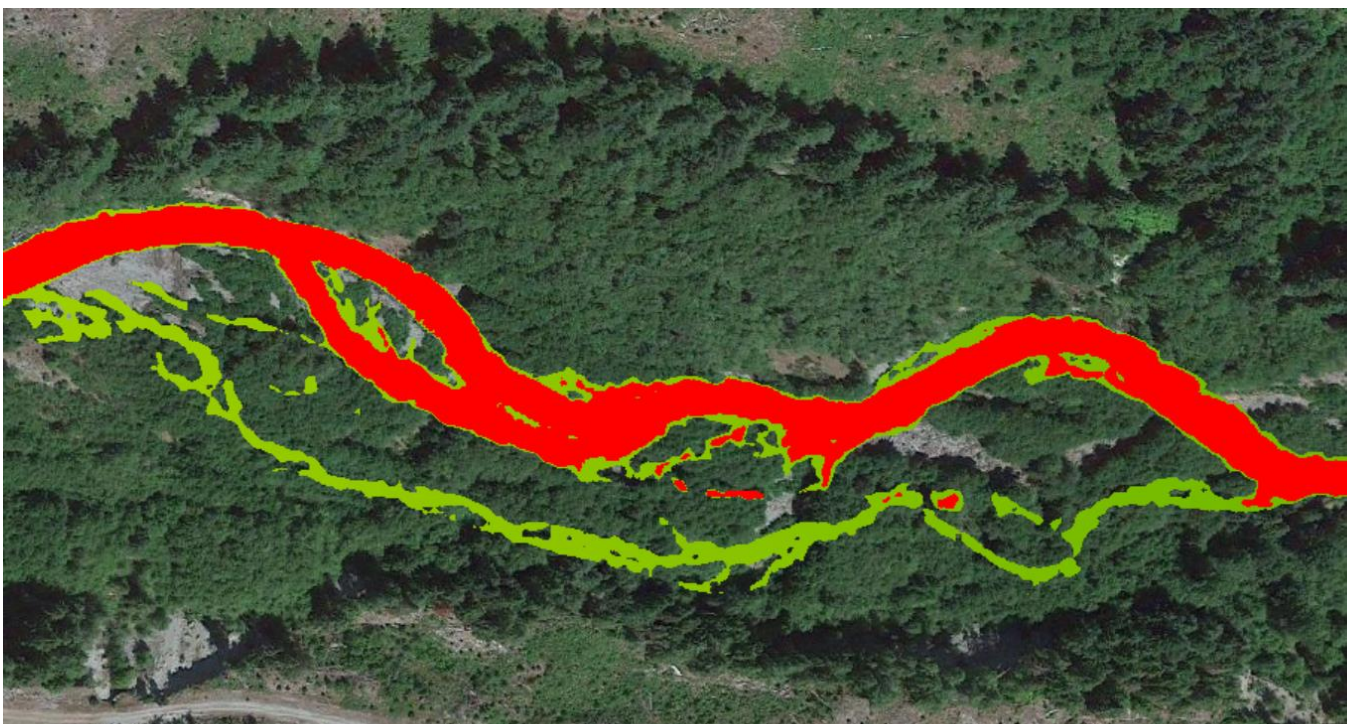

Figure 34. Wetted perimeter during baseflow conditions (red) compared to 50% exceedance interval conditions (green) with a side channel area that could potentially be activated utilizing restoration actions.

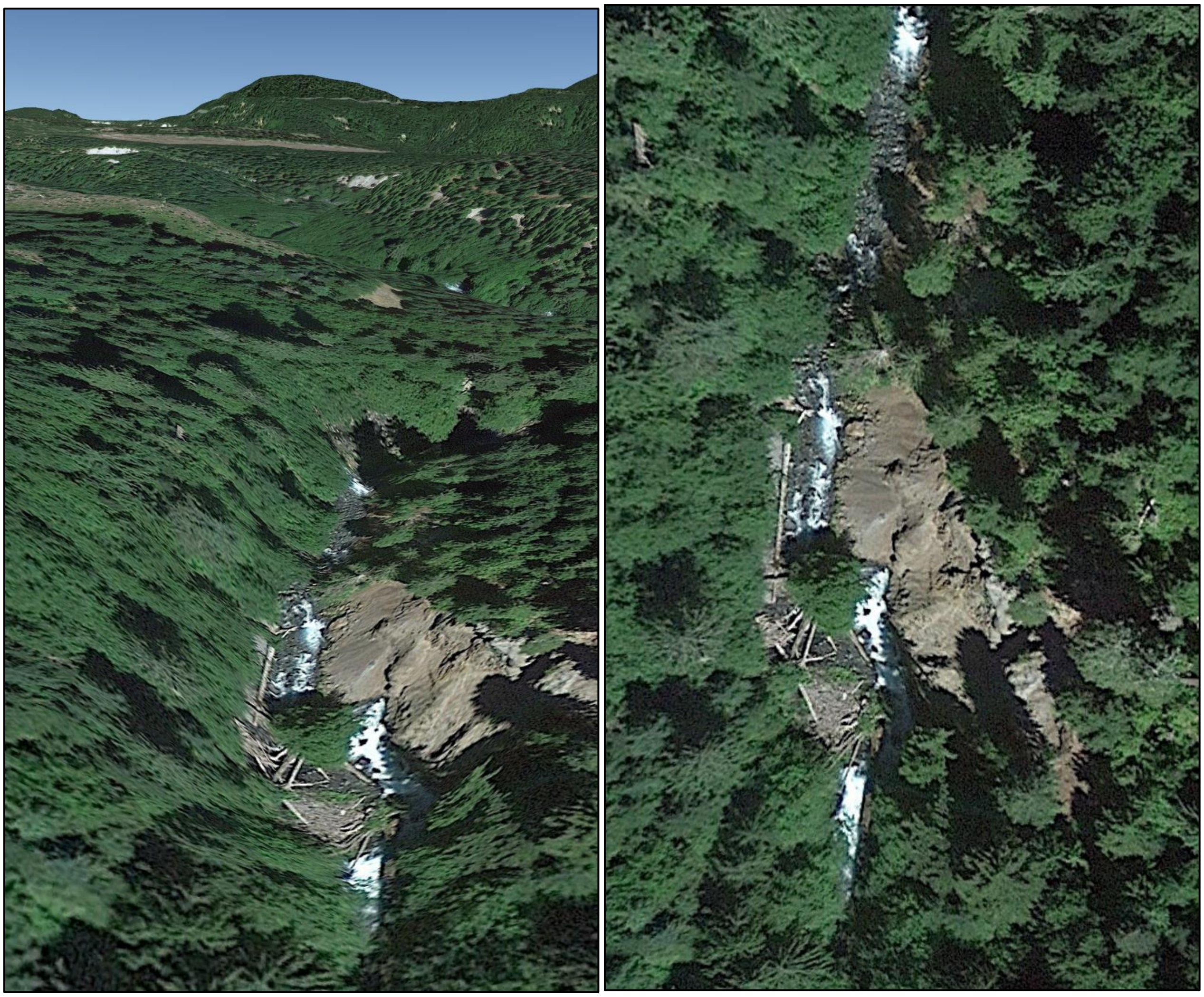

Figure 35. Oblique (left) and plan (right) view of potential partial barrier in Pine Creek Reach 5.

4.8.6.2 Proposed Condition Model Results

We have not completed the proposed conditions modeling for the 30% design phase but will include it in the Final design phase.

4.8.7 Assumptions and Limitations

Modeling dynamic river systems includes both implicit and explicit assumptions and limitations. This section documents some of the primary assumptions and limitations. Riverine systems are inherently dynamic, and this project heavily relies on LiDAR data products, which are recent but not current. As a result, discrepancies between modeled and current conditions are likely, yet the hydraulic characteristics are expected to remain similar. Both models assume that the channel bed is fixed, meaning that it does not change in response to flow and sediment transport, as would be expected to occur under natural flow conditions. Additionally, the models are not calibrated or validated. Calibration and/or validation will require additional field data collection beyond the scope of this project. However, the level of model detail is within generally accepted practices in the field of river restoration for the level of project risk.

5. DESIGN DEVELOPMENT

5.1 Design Goals and Objectives

Project goals, objectives, and constraints were developed from existing watershed basin planning documents, including the *Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* (LCFRB, 2010), *Lower Columbia Fish Recovery Board Climate Change and Habitat Priorities* (LCFRB, 2018), and *Lewis River bull trout Habitat Restoration Project Identification Assessment Final Report* (Lamperth et al. 2017). This section documents the merging of relevant goals from existing watershed plans with project-specific goals, assigning and generating quantitative objectives, and identifying project constraints.

The overall goal of the Pine Creek Restoration Design Project is to improve instream habitat complexity and riparian habitat in Pine Creek to address key limiting factors. Specifically, project goals aim to:

1. Improve habitat complexity in simplified reaches through large wood placement
2. Stabilize sediment to allow for riparian succession to mature conifer forest
3. Increase side channels and spawning habitat for bull trout, salmonids, and steelhead
4. Protect existing quality spawning habitat for bull trout, salmonids, and steelhead
5. Create resting areas for spawning adult bull trout, salmonids, and steelhead
6. Improve holding pools for juvenile bull trout, salmonids, and steelhead
7. Improve overwintering habitat for salmonids
8. Reduce or stabilize incision rates in areas with floodplain pockets

The Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan (LCFRB, 2010), Lower Columbia Fish Recovery Board Climate Change and Habitat Priorities (LCFRB, 2018), and - SalmonPORT list limiting factors, restoration needs and considerations, which are compiled below, reordered to highlight similarities:

Table 19. Limiting factors and restoration needs (LCFRM 2010, LCFRB 2018, SalmonPORT)

LCFRM 2010	LCFRB 2018	SalmonPORT
Habitat Diversity	Habitat Diversity	Off channel and side channel habitat
Habitat Connectivity	Cold Water Refugia	Riparian conditions & functions
Channel Stability		Stream channel habitat structure & bank stability
Riparian Function	High Quality Floodplain Habitat	Floodplain function & channel migration processes
Substrate and Sediment	Mature Riparian and Upland Forest	Watershed conditions & hillslope processes
Water Quality	Instream Flow	Instream flows

5.2 Design Background

Prior work was completed by the USFS on Pine Creek to improve spawning and rearing habitat for bull trout. In 2012 the Gifford Pinchot National Forest obtained funds from PacfiCorp and Cowlitz Public

Utilities District to make improvements within portions of the creek located on US Forest Service Land. The effort consisted of installing fifteen (15) large wood structures in Reaches 1, 2, and 3; most of the structures were installed in Reach 2 (Figure 36).

The goals of the restoration efforts described here are largely similar to those outlined in the USFS report. One main difference is that the USFS effort focused on the use of large wood to improve and increase mainstem habitat, whereas the work described herein will seek to not only improve mainstem habitat, but expand habitat into floodplain and side-channels, as well.

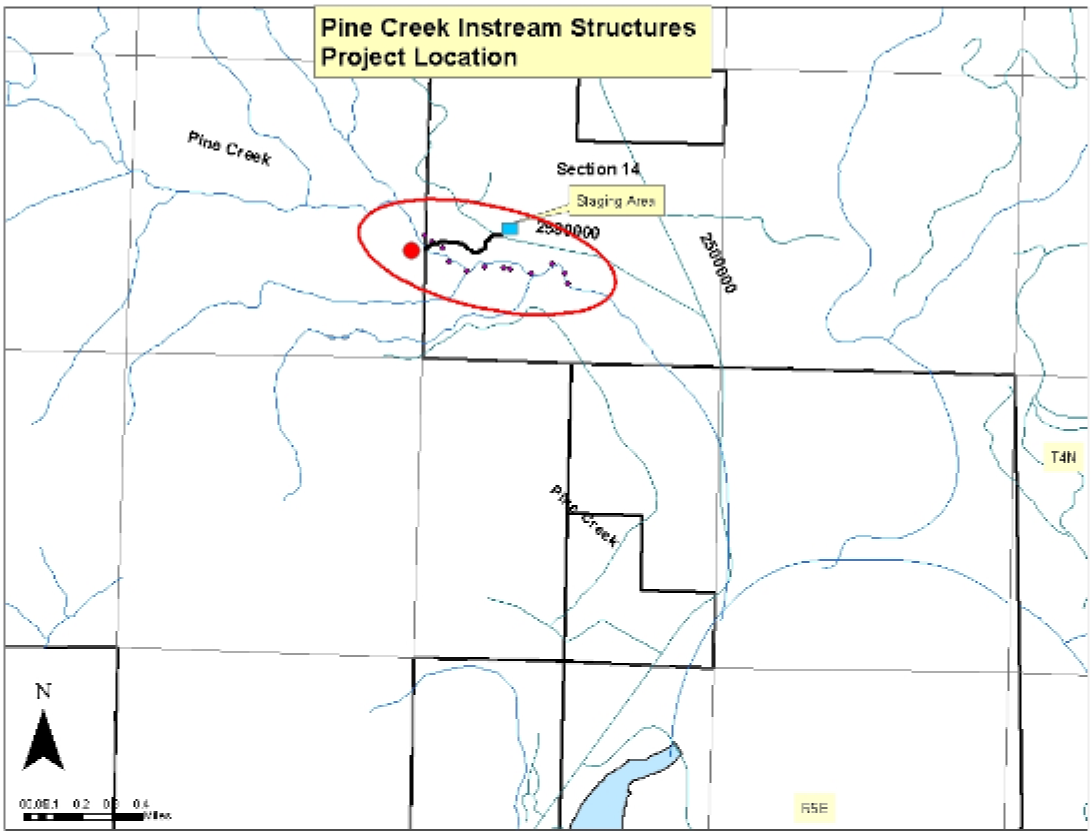

Figure 36. Pine Creek instream structures project location. Figure obtained from the Pine Creek Instream Habitat Restoration Monitoring Report (USFS 2013).

During the geomorphic assessment, the field crew was able to locate several of the existing structures (Figure 36, Figure 37). While no monitoring report was completed to assess the impact of the structures after their installation, the structures that were located appeared to have benefited the mainstem either by aggrading course sediment or creating additional refugia in the form of scour pools or woody debris racks.

Figure 37. Photos of Structure 13 as labeled in the USFS report; the photo on the left was included in the 2013 report, and the photo on the right was taken by CFS field staff in August of 2023.

5.3 Design Elements

We determined design element type, size, and location based on project goals and objectives while maintaining element construction feasibility. Proposed locations of design elements are shown in Appendix A.

Fox (2003) investigated the distribution of large wood group sizes according to bankfull width classification. For streams with a bankfull width of less than 5 meters, log jams primarily consisted of single logs and secondarily of jams with 2 or 3-4 pieces, with a median of 2 pieces per jam. For streams with a bankfull width between 5 and 10 meters, jams primarily consisted of 21-50 pieces with roughly equivalent distribution of other jam sizes and a median of 10 pieces per jam. Fox (2003) also examined the large wood jam distribution based on the percent occupying specific zones of the stream corridor. Zone 1 is the wetted low-flow channel, Zone 2 is above the wetted low-flow channel but below the horizontal axis of the bankfull channel, Zone 3 is above the high-flow channel but within the vertical confines of bankfull, and Zone 4 is laterally beyond the bankfull width. For streams that have a bankfull width between 5 and 10 meters and contain jams consisting of more than 10 pieces of large wood, approximately 30% of the large wood by volume is found in both Zone 1 and Zone 2. This is followed by 21% in Zone 3, and 14% in Zone 4.This indicates that large wood volume decreases with increasing distance from the low flow channel.

Abbe and Montgomery (2003) studied the characteristics of wood jams in the Queets River watershed and discovered that in high gradient streams, large wood jams accounted for an average of 43% of the elevation loss within a channel reach. They also found that the median angle of logs in these jams was 53 degrees relative to the direction of the stream.. In high gradient systems, various types of wood jams were observed, including bank attached, oblique log steps, valley-spanning and valley-confined jams, flow deflection jams, debris flows, jams at the bankfull bench (floodplain), and bar apex jams. However, wood rafts and meander jams were deemed unsuitable for environments like Pine Creek. The density of jams in basins the size of Pine Creek, which range between 7.5 and 68 square kilometers, varied from 0.2 to 60 jams per kilometer, averaging 13.3 jams per kilometer (Figure 38). A study by May and Gresswell (2003) in a similar basin suggested that windthrow is the most likely primary mechanism for wood input, followed by bank erosion, natural tree mortality, and slope instability.

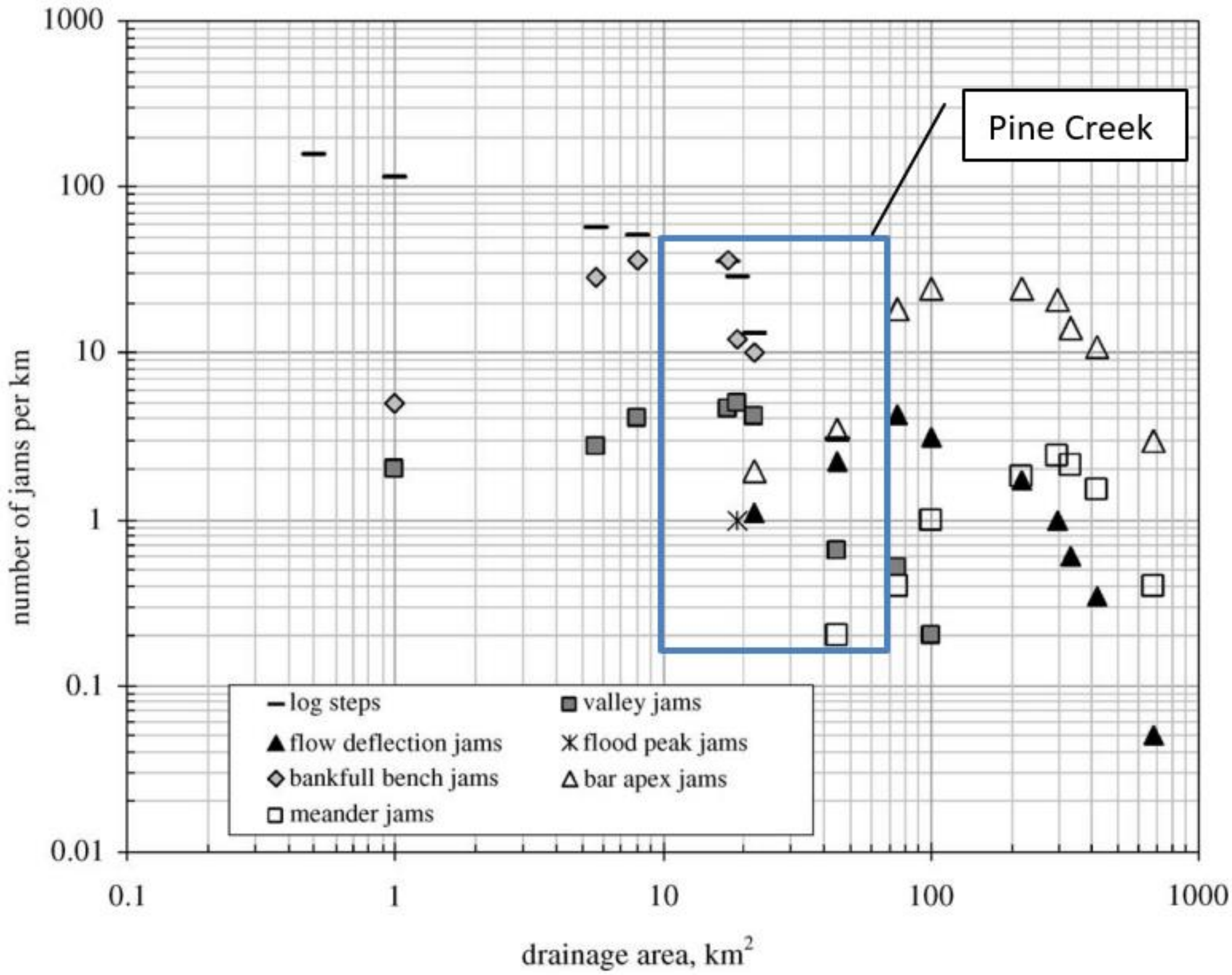

Figure 38. Variation in frequency of wood debris accumulation types for the Queets River (reprinted from Abbe and Montgomery (2003)) with range of Pine Creek watershed characteristics.

Based on the existing literature, pre-disturbance large wood conditions in Pine Creek likely consisted of bank attached and channel spanning jams, and secondarily contain large wood and apex jams (mostly lower down in the system) in the floodplain. Large wood jams had an average spacing of 13.3 jams/km or approximately 1 jam per 200 feet of channel length. Jams contained between 21 and 50 pieces, with 10 on average. Most of the wood volume (at least 65%) should be contained within the bankfull channel. We designed the proposed large wood jams to mimic characteristics of wood jams that were likely present in Pine Creek.

Channel Spanning Jams are designed to mimic jams consisting of key pieces with roots attached that spanned the channel. These serve as a core for accumulating more wood and forming a stable jam. ELJs are designed to aggrade native alluvium upstream of the jam, providing a diversity of substrate sizes to facilitate spawning and rearing. This structure is designed to sustain a downstream pool through scour and erosion. This jam is intended to influence reach-scale sediment function to reconnect the floodplain and raise the groundwater table locally. Key pieces are supplemented by racking wood and slash to reduce porosity. Channel Spanning Jams are designed to be active at all flows and stable to the 10-year recurrence interval flow event.

Apex Jams are designed to split the flow between multiple paths and are typically located at the upstream end of a bar or where bar formation is likely to occur. The split flow allows for hydraulic and habitat diversity in different flow paths. At high flows, the structure will drive bank erosion and increase inundation of the floodplain and side channels. The ELJ is primarily comprised of large wood key pieces, racking material, and slash as well as habitat boulder ballast and timber piles, as needed. Racking pieces will be placed within the interior space of the jam to decrease porosity and increase the total area of wood in direct contact with the streambed. These structures will be constructed primarily at secondary channel junctions, where the channel is over widened, and where braid-development processes are active. Apex Jams are designed to be active at moderate flows and stable to the 10-year recurrence interval flow event.

Bank Attached Jams aim to mimic jams that start with trees tipping into the channel due to windthrow or erosion, which then gather more key pieces and debris. Racking pieces will be placed within the interior space of the jam to decrease porosity and increase the total area of wood in direct contact with the streambed. These structures will be used to enhance existing quality habitat, create new quality habitat, shunt flows towards accessible floodplain, and trap and sort sediment as they interact with flood flows. Bank attached jams are designed to be active at moderate flows and stable to the 10-year recurrence interval flow event.

Floodplain Wood Loading is designed to emulate mature riparian forest conditions on low floodplains. These structures primarily consist of unballasted large wood in low-risk areas with relatively low depths and velocities to achieve the required stability. This element is designed to rack mobile wood, create diverse hydraulic conditions in the floodplain, and provide resilience during flood events. Floodplain Wood Loading is designed to be active at moderate flood flows and be stable to the 10-year recurrence interval flow event.

Beaver Dam Analogues (BDAs) and Post-Assisted Log Structures (PALS) are designed to emulate observed beaver dams and will be built by driving non-treated wood fence posts at alternating angles to secure wood pieces to the streambed. Posts will be driven a minimum of 2.5 feet into the stream bed and banks. The crest height will not exceed the bankfull elevation. A minimum of seven posts will be used per structure, but there is no prescribed limit. Posts will be added until all wood pieces are secured to the rest of the structure, the streambed, or the bank. These structures will be focused on out-of-channel areas within the floodplain, primarily with flood channels. The addition of floodplain roughness elements in this design are expected to reduce water velocity, increase fine sediment deposition, and support establishment of riparian vegetation in the floodplain. BDAs and PALS are designed to be active at a variety of flow conditions and are not designed to stability criteria.

Guidelines and best practices from The *Large Wood National Manual* (USBR and USACE 2015) combined with Fox and Bolton (2007) were used to determine the spacing and layout of the proposed design elements to meet project goals and objectives. Fox and Bolton (2007) determined instream large wood quantities and volumes based on geomorphology, forest zones, and disturbance regimes to set targets for wood loading relative to unmanaged basins with similar characteristics. Table 20 compares the proposed design metrics to the reference metrics from Fox and Bolton (2007).

Table 20. Comparison of proposed design element (all tiers) and Fox and Bolton (2007) reference large wood density.

Reach	Bankfull Width (ft)	Reach Length (ft)	Target Key Pieces	Proposed Key Pieces	Target Total Pieces	Proposed Total Pieces	Target Volume [yd^3]	Proposed Volume [yd^3]	Target Number of Jams	Proposed Number of Jams
1	99.52	3,415[1]	42	217	656	651	1348	1953	14	29
2	96.73	2,875	35	273	552	819	1135	2407	12	37
3	95.10	6,269	76	502	1204	1506	2475	4426	25	70
4	87.47	4,667	57	372	896	1116	1843	3348	19	52
5	47.92	8,912	299	357	1712	1125	3518	1492	36	50
6	41.17	10,590[1]	355	350	2034	975	4181	1410	43	47

1. Note: only the portion of the reach within the project area

Restoration actions across all tiers either meet or surpass most metrics for large wood, thereby improving aquatic habitat quality and supplying a source of large wood to maintain conditions into the future as the wood decays and moves over time. Tier 1 restoration elements are highly suited to the stream conditions and have a low probability of impacting existing redd locations. Tier 2 restoration elements are moderately suited for the geomorphic, hydraulic, and/or riparian conditions and may have slight impacts on existing redd locations. Tier 3 items are the least suited to the geomorphic, hydraulic, and/or riparian conditions and tend to have potential impacts to existing redd locations. Appendix A includes a detailed plan showing the location and layout of proposed restoration elements.

5.4 15% Conceptual Design Overview

5.4.1 Reach 1 (RM 1.0 – 1.6)

The Reach 1 project area includes the upper ~ 0.6 miles of Reach 1. Access and landownership are primarily USFS. Reach 1 contains multiple high priority side channel and floodplain areas but is predominantly a single thread meandering channel. Reach 1 is close to private land parcels and maintains relatively high stream power; therefore, this reach presents the highest potential impact to public safety and property relative to other reaches. The proposed conceptual design includes a distribution of design elements, but relatively fewer apex jams due to the single thread planform.

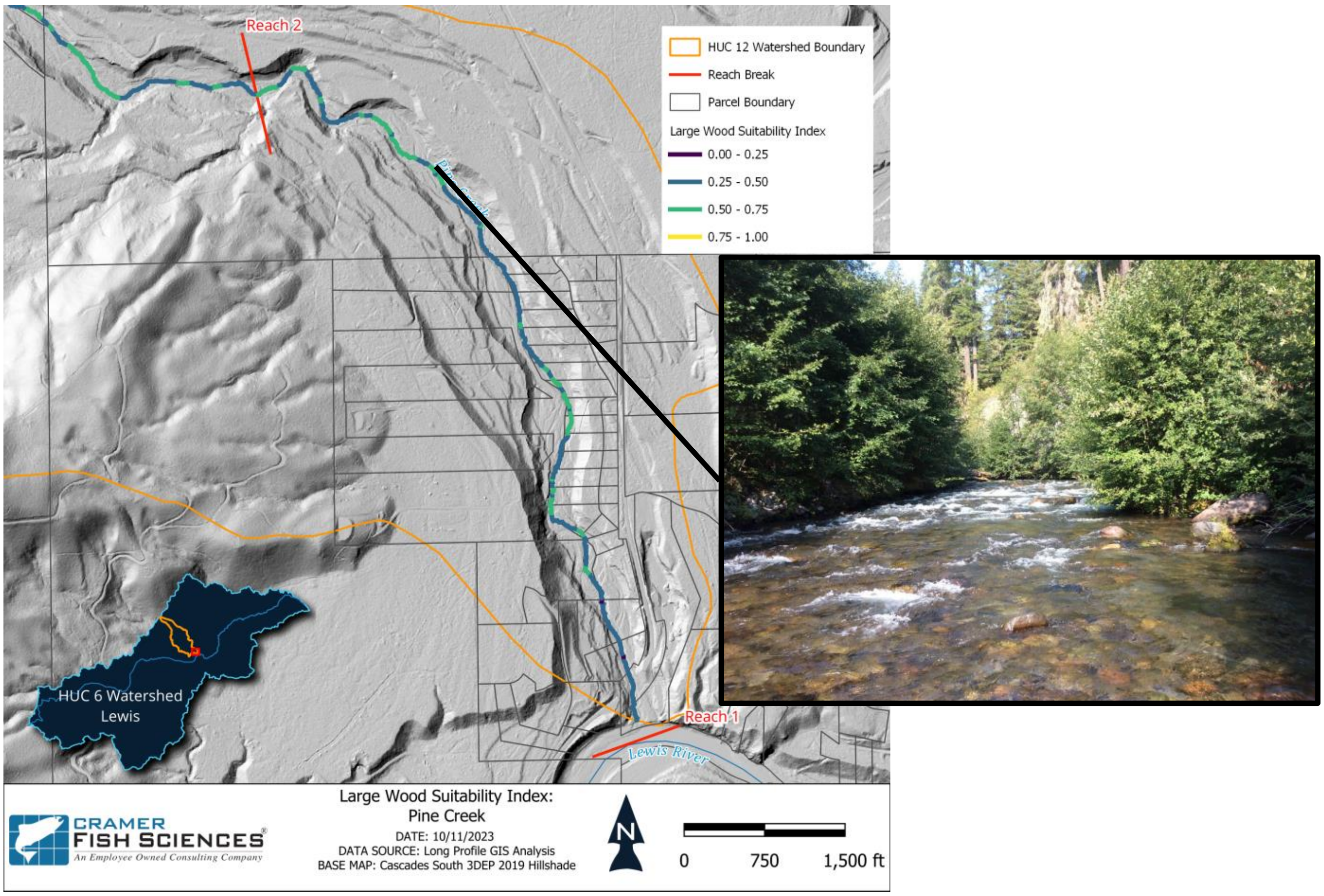

Figure 39. Map of project areas within Reach 1 (left) and photo of Reach 1 (inset).

Table 21. Project area characteristic for Reach 1.

Length (ft)	Stream Slope (ft/ft)	Dominant Substrate	Bankfull Width (ft)	Valley Bottom Width (ft)
8,599	2.4	Cobble	99.52	188.4

Table 22. Restoration design elements Reach 1.

Element Type	Tier I	Tier II	Tier III	Total
Channel Spanning	5	2	2	9
Apex Jam	2	1	0	3
Bank Attached Jam	3	3	3	9
Floodplain Wood Loading	2	3	3	8

5.4.2 Reach 2 (RM 1.6 – 2.2)

Reach 2 mainly lies on property owned by the USFS and CLT, accessible through USFS parcels. Despite being the shortest reach, it has numerous high-priority restoration areas, resulting in a relatively high density of proposed restoration elements within Reach 2.Channel planform, slope, and confinement are varied within Reach 2, leading to a wide applicability of restoration elements. Reach 2 features several side channels and open bars disconnected from the active channel, offering opportunities to enhance connectivity through restoration actions.

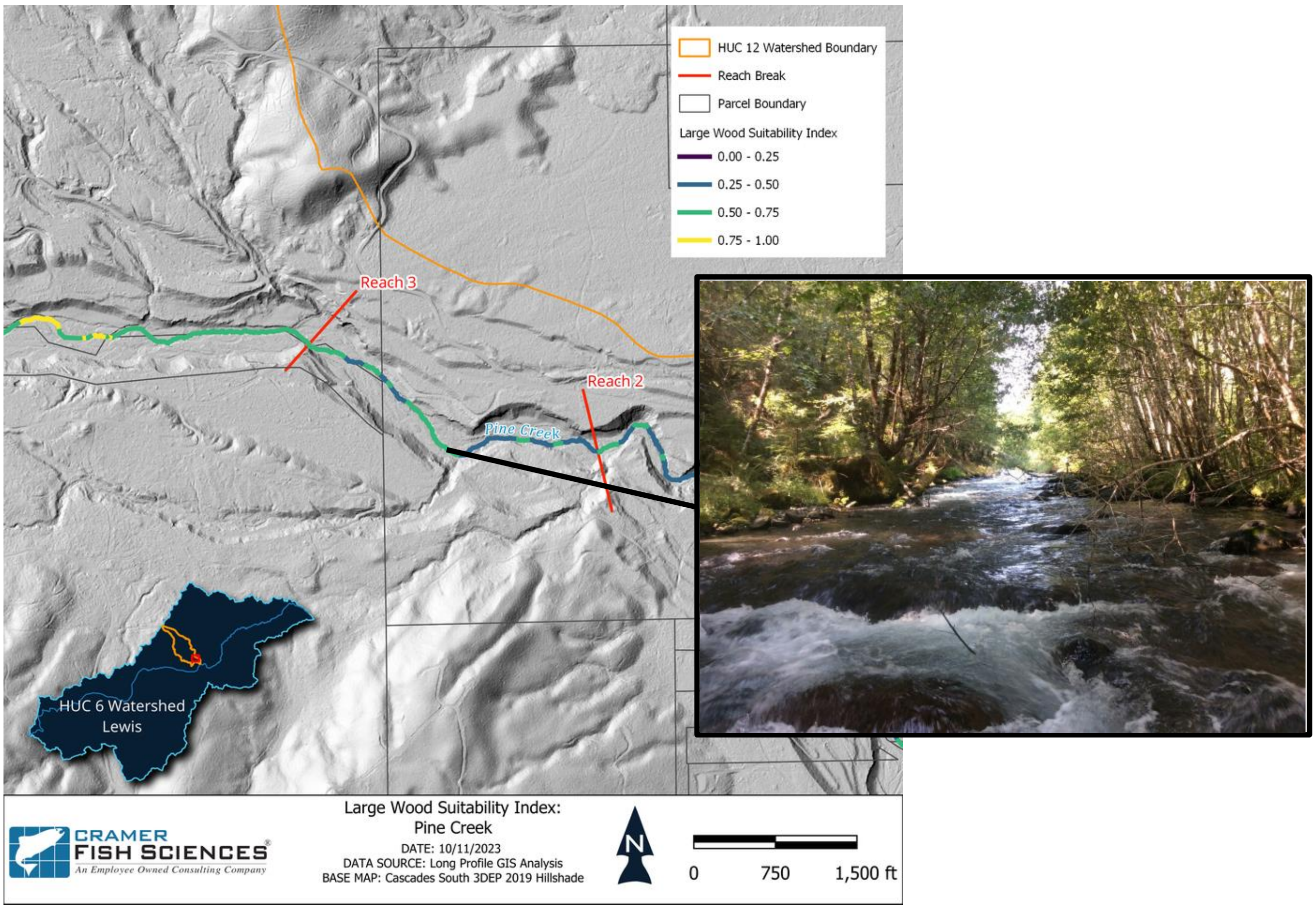

Figure 40. Map of project areas within Reach 2 (left) and photo of Reach 2 (inset).

Table 23. Project area characteristic for Reach 2.

Length (ft)	Stream Slope (ft/ft)	Dominant Substrate	Bankfull Width (ft)	Valley Bottom Width (ft)
2,875	2.6	Cobble	96.73	198.0

Table 24 Restoration design elements Reach 2.

Element Type	Tier I	Tier II	Tier III	Total
Channel Spanning	4	2	3	9
Apex Jam	4	2	1	7
Bank Attached Jam	4	3	2	9
Floodplain Wood Loading	6	4	2	12

5.4.3 Reach 3 (RM 2.2 – 3.3)

Reach 3 is located entirely within CLT property, with access through CLT and USFS parcels. Reach 3 is the only reach within the project limits that was rated as a Tier 4 (lowest tier) priority reach (SalmonPort); however, restoration needs received the same ratings as all adjacent reaches. Reach 3 contains the highest density of redd locations and a high density of quality spawning and rearing habitat relative to adjacent reaches. However, Reach 3 has a relative lack of large wood and mature riparian forest and could benefit from restoration actions. Additionally, the relatively low slope of reach is likely to act as a sink for any wood transported from upstream reaches. The lower stream power, decreased confinement, and sediment source from P8 have likely contributed to a faster improvement in Reach 3 compared to adjacent reaches and can serve as an analogue for restoration potential.

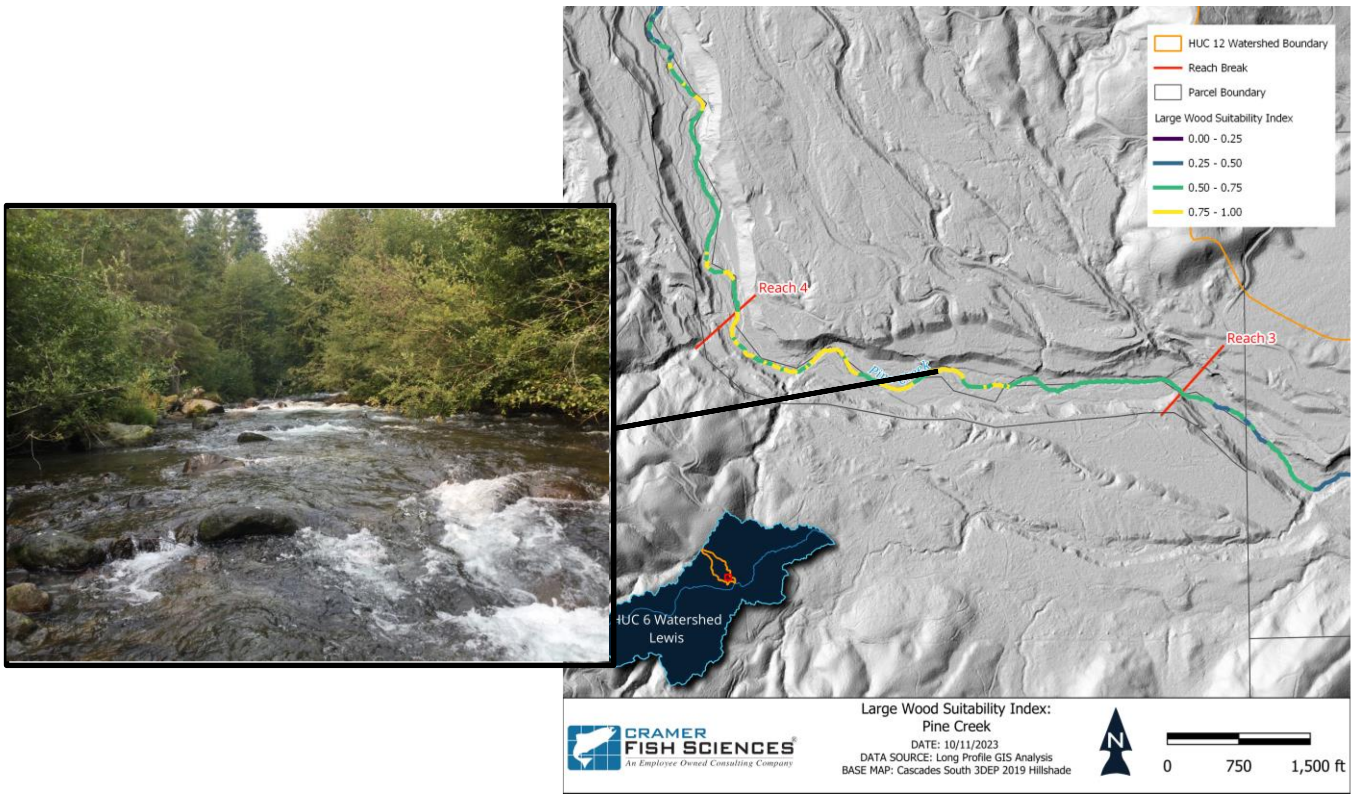

Figure 41. Map of project areas within Reach 3 (right) and photo of Reach 3(inset).

Table 25 Project area characteristic for Reach 3.

Length (ft)	Stream Slope (ft/ft)	Dominant Substrate	Bankfull Width (ft)	Valley Bottom Width (ft)
6,269	2.5	Cobble	95.10	222.9

Table 26 Restoration design elements Reach 3.

Element Type	Tier I	Tier II	Tier III	Total
Channel Spanning	8	6	2	16
Apex Jam	5	7	4	16
Bank Attached Jam	12	6	3	21
Floodplain Wood Loading	9	6	2	17

5.4.4 Reach 4 (RM 3.3 – 4.3)

Reach 4 is located entirely within CLT property, with access through CLT and USFS parcels. Reach 4 alternates between steep, confined reaches with bedrock often visible, and less confined reaches with accessible floodplain areas. Restoration actions proposed in this reach target less confined reaches with more suitable hydraulic conditions for large wood placements and avoid steeper, confined areas. Helicopter access for Reach 4 will likely be more difficult relative to other areas due to a narrower floodplain and more canopy cover. Upstream of P8, the baseflow wetted width of Pine Creek decreases slightly and the channel becomes more single thread. If large wood placed in Reaches 4, 5, and 6 is mobilized, the large wood will likely be redeposited due to existing vegetation along the streambank.

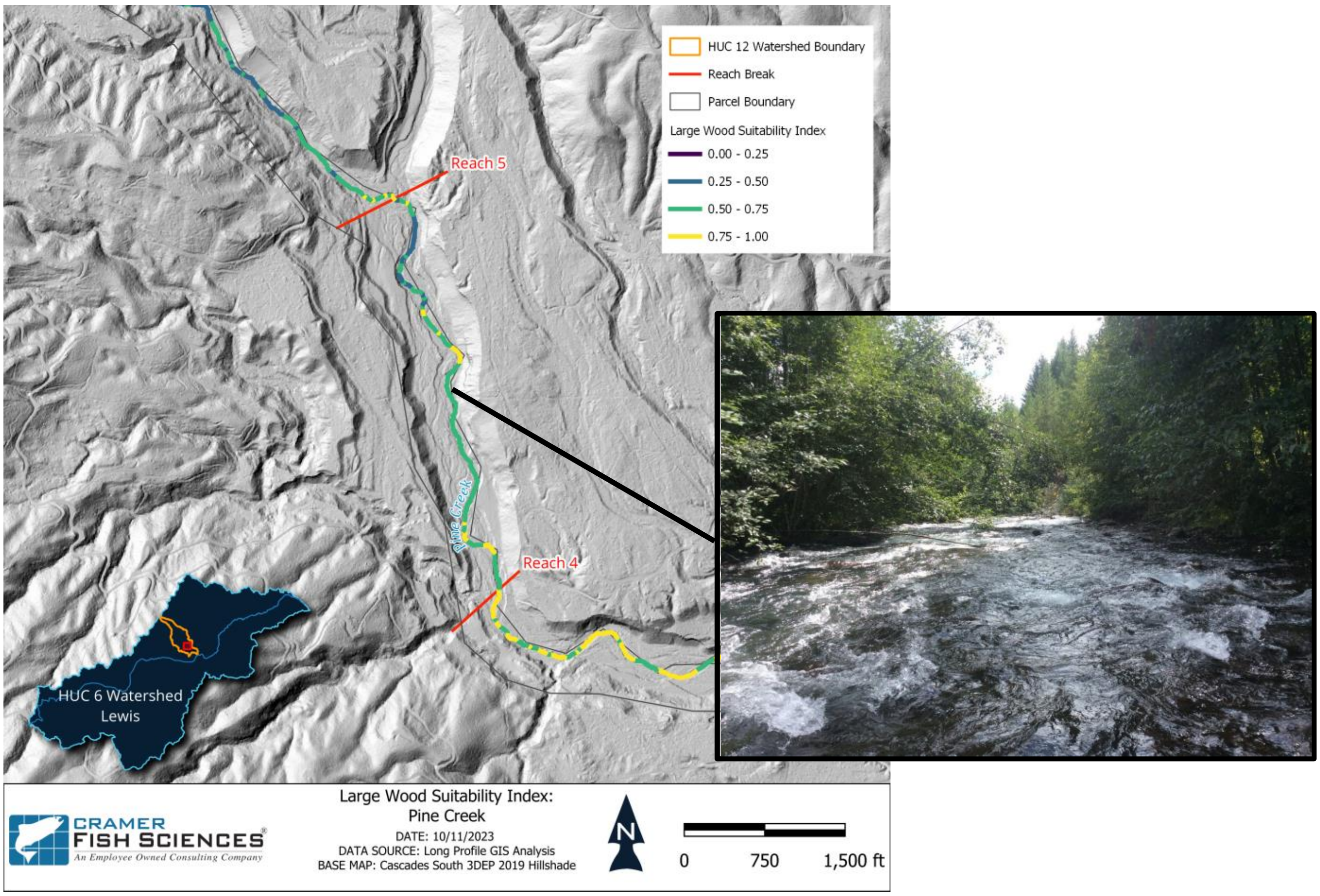

Figure 42. Map of project areas within Reach 4 (left) and photo of Reach 4 (inset).

Table 27. Project area characteristic for Reach 4.

Length (ft)	Stream Slope (ft/ft)	Dominant Substrate	Bankfull Width (ft)	Valley Bottom Width (ft)
4,667	2.9	Cobble	87.47	202.1

Table 28. Restoration design elements Reach 4.

Element Type	Tier I	Tier II	Tier III	Total
Channel Spanning	5	5	2	12
Apex Jam	7	5	3	15
Bank Attached Jam	7	5	1	13
Floodplain Wood Loading	7	4	1	12

5.4.5 Reach 5 (RM 4.3 – 5.9)

Reach 5 is located entirely within CLT property, with access through CLT and USFS parcels. Reach 5 is like Reach 4 in that there are alternating confined reaches separated by floodplain pockets. Similarly, restoration actions focus on less confined sections where habitat uplift is more feasible. Reach 5 contains multiple pinch points with steep, bedrock sections which are likely to break up key pieces rather than transport intact large wood. Reach 5 is steeper than Reach 4, but also contains more slope variation. Sections of boulder step-pools are unlikely to have a significant response to large wood placement, but targeting areas with potential side channel and floodplain connectivity can still create habitat characteristics that are typically lacking in Reach 5.

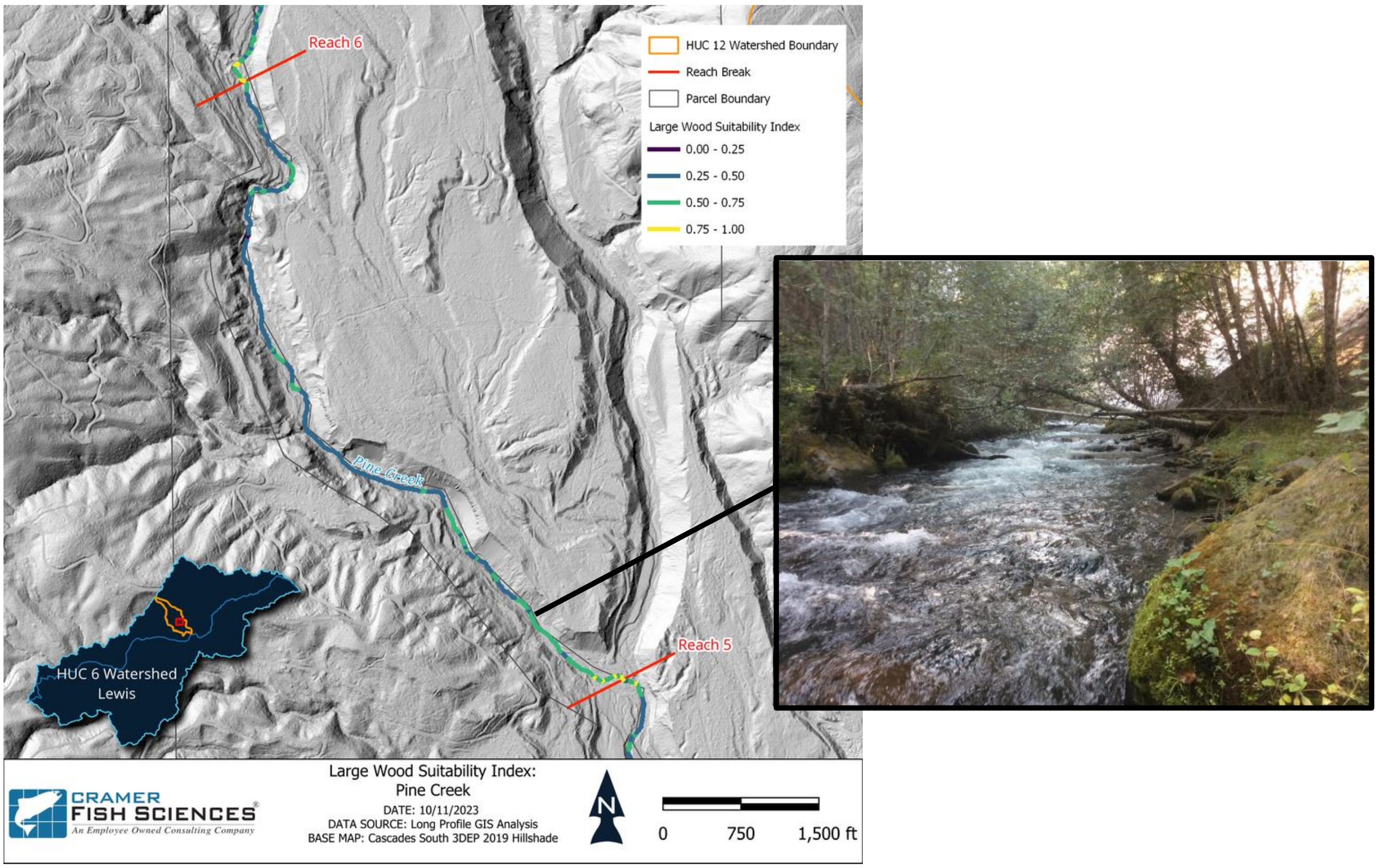

Figure 43. Map of project areas within Reach 5 (left) and photo of Reach 5(inset).

Table 29. Project area characteristic for Reach 5.

Length (ft)	Stream Slope (ft/ft)	Dominant Substrate	Bankfull Width (ft)	Valley Bottom Width (ft)
8,912	3.7	Boulder	47.92	93.6

Table 30. Restoration design elements Reach 5.

Element Type	Tier I	Tier II	Tier III	Total
Channel Spanning	9	7	5	21
Apex Jam	3	2	0	5
Bank Attached Jam	8	4	3	15
Floodplain Wood Loading	4	3	2	9

5.4.6 Reach 6 (RM 5.9 – 8.0)

The lower portion of Reach 6 is located on CLT land and accessed primarily through USFS and CLT parcels. The upper portion of Reach 6 is located on USFS land and primarily accessed through USFS parcels. The average slope of Reach 6 is greater than adjacent reaches and is influenced by the upper and lower portions the reach. The middle section of Reach 6 presents significant opportunities for restorations actions. Although observed redd densities are lower in Reach 6 than in Reaches 1-3, Reach 6 has more unconfined sections with suitable complex habitat compared to the upper portion of Reach 5. Restoration actions proposed in Reach 6 focus on unconfined sections where floodplain connectivity and channel complexity can be augmented. Furthermore, improving floodplain connectivity and groundwater recharge in the upstream portions of the watershed are likely to have benefits further downstream later into the summer/fall low flow season.

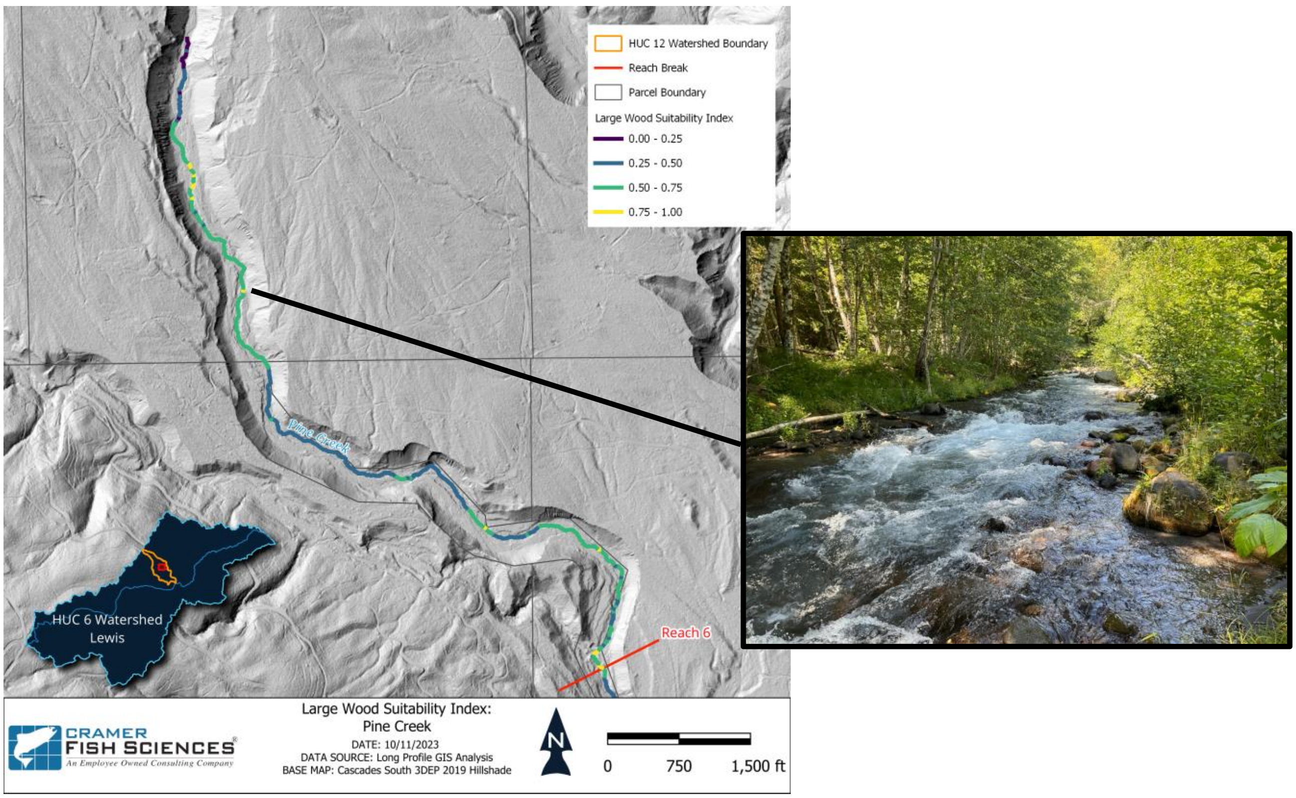

Figure 44. Map of project areas within Reach 6 (left) and photo of Reach 6 (inset).

Table 31. Project area characteristic for Reach 6.

Length (ft)	Stream Slope (ft/ft)	Dominant Substrate	Bankfull Width (ft)	Valley Bottom Width (ft)
16,251	4.7	Cobble/Gravel	26.0	105.1

Table 32. Restoration design elements Reach 6.

Element Type	Tier I	Tier II	Tier III	Total
Channel Spanning	7	6	3	16
Apex Jam	5	0	1	6
Bank Attached Jam	7	4	4	15
Floodplain Wood Loading	6	3	1	10

5.5 30% Preliminary Design

5.5.1 Reach 5 Preliminary Design

Based on project stakeholder review comments (Appendix F), 15% conceptual designs were progressed to 30% Preliminary designs for Tiers 1-3 for Reach 5 of Pine Creek (Appendix A). The purpose of selecting this reach was to minimize potential negative project impacts to spawning locations and allow for project monitoring to occur before progressing to further downstream reaches. Engineering design has progressed, including ELJ stability calculations (Appendix D) and the cost estimate for the proposed design has been refined (Appendix C).

5.5.2 Implementation Schedule Recommendations

The proposed design includes a strategy to address limiting factors through feasible restoration actions for approximately 8 river miles, which presents significant challenges related to construction funding, implementation, and monitoring logistics. Therefore, we recommend a phased restoration strategy to monitor the impacts of restoration implementation and inform future actions. The recommended course of action is to construct Tiers 1, 2, and 3 for Reach 5 and monitor for 2 years to establish the benefits and effects of restoration implementation. Then implement Reaches 1 and 2 if the restoration actions are meeting project objectives in Reach 5. Reaches 3 and 4 are lower tier restoration priority within the NF Lewis River watershed, but spawning and rearing habitat could improve through additions of large wood. Therefore, construction would occur later, once sufficient evidence has been collected that supports the efficacy of restoration actions and without negative impacts on spawning conditions. Furthermore, despite Reach 6 having some of the highest spawning potential, its location in the watershed has limits its use by fish. Consequently, this reach is proposed for construction later in the cycle. Once all Tier 1 and 2 restoration actions have been implemented, Tier 3 actions can be constructed if monitoring data supports that action. Table 33 shows a tabular representation of this proposed course of action; however, this is only one of multiple potential implementation sequences.

Table 33. Sequence recommendations for implementation of restoration actions.

Reach	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6+
Reach 1			C - 1,2	M	M	C - 3
Reach 2			C - 1,2	M	M	C - 3
Reach 3					C-1,2	M
Reach 4			M	M	C-1,2	M
Reach 5	C - 1,2,3	M	M	M	M	M
Reach 6					C	C - 1,2,3

C - X = Construct Tier X, M = Monitoring,

5.6 Design Elements Risk Assessment

Project Risks were categorized into public safety risk and property damage risks following frameworks and concepts from *The Large Wood National Manual* (USBR and USACE 2015), *Large Woody Material - Risk Based Design Guidelines* (Knutson and Fealko 2014) and *Stream Habitat Restoration Guidelines* (WDFW 2012). This risk assessment, in combination with discussions with the project sponsor, is used to determine factors of safety, acceptable construction methods, and design flows for the project.

5.6.1 Public Safety Risk

The public safety risk assessment compares the characteristics of the users with the impact of the restoration actions. At this phase, we used conceptual restoration actions to represent the structure characteristics. Later design modifications may alter the structure characteristic risks. Table 34, Table 35, and Figure 45. Public safety risk matrix summarize the public safety risk.

Table 34. Summary of reach-user characteristics.

Reach-User Characteristic	Rating	Rationale
Frequency of Use	2	Low usage throughout the project area; the main area of use is at the confluence with Lewis River roughly 0.9 miles downstream of the nearest project reach.
Skill Level	3	Considering how remote the Project reaches are, it is assumed that anyone seeking access for recreation would be of a high skill level.
Access	1	Low; access to most of the Project area is through gated roads on working timberland. A small portion of the project area is accessible from the confluence with the Lewis River and forest service roads off of NFD 25.
Child Presence	1	Unknown, but presumed low child presence.
Average	1.8	Low overall reach-user risk, however, uncertainty is high.

Table 35. Summary of structure characteristics.

Structure Characteristic	Rating	Rationale
Active Channel	4	While ELJs are proposed in the active channel, the potential for these structures to cause excessive channel migration is limited by the fact that the Project area is confined within a well-defined ravine.
Outside of Bend	5	In all conceptual alternatives, ELJs are proposed on the outside of bends
Strainer Potential	7	Strainer potential varies by alternative, but the average potential is moderately high.
Egress Potential	7	The size of the bed material, the steep local channel slope in some reaches, and the nature of the flow could make it difficult to avoid ELJs in some areas of the Project.
Sight Distance	6	Meander bends limit sight distance.
Depth x Velocity	8	During primary use season, the depth and velocity prevent wading.

Average	6.2	Moderate overall structure risk, however, structure characteristics may change at later design phases.

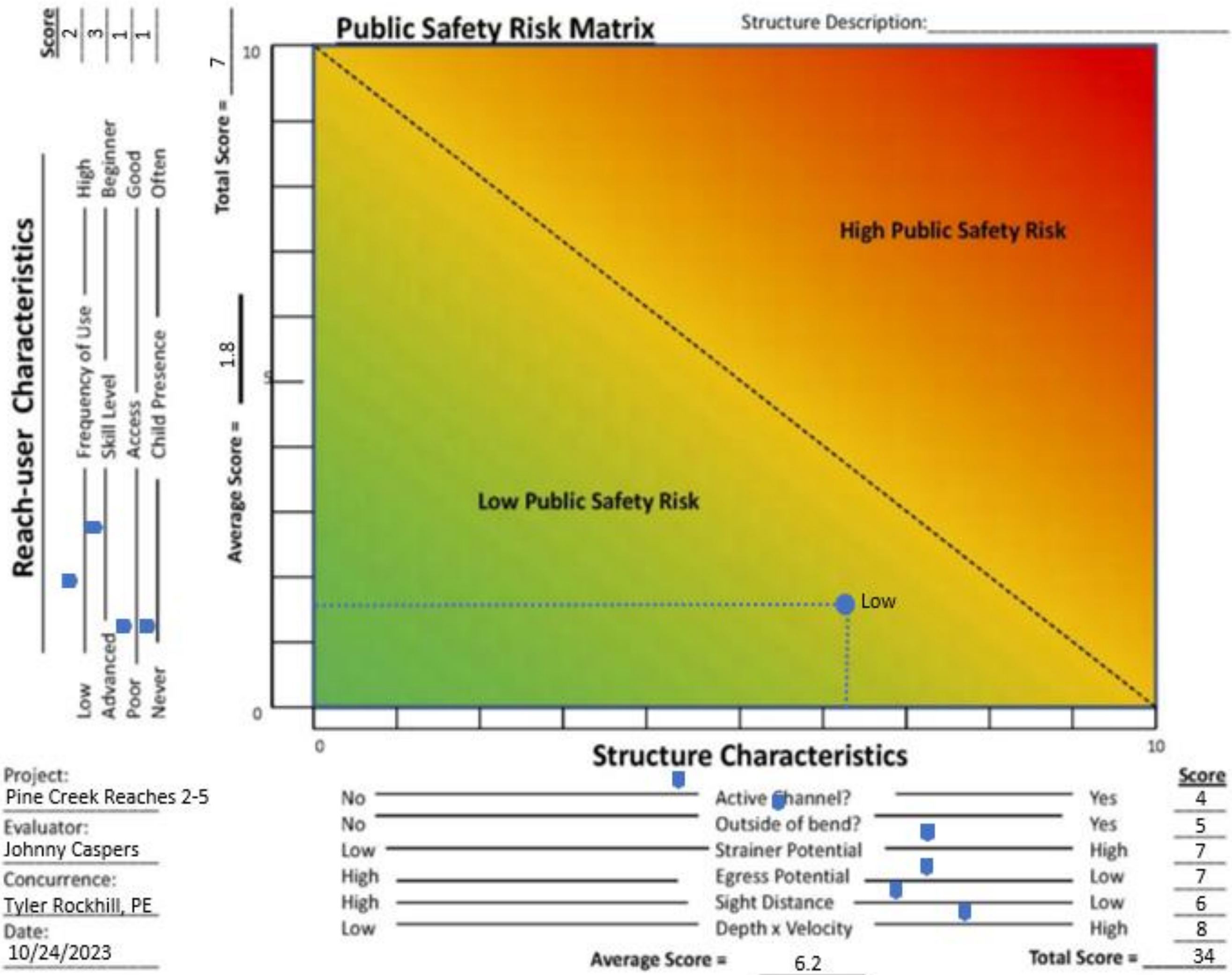

Figure 45. Public safety risk matrix.

5.6.2 Property Damage Risk

The property damage risk assessment compares the stream response potential to the project characteristics to evaluate the risk to private and public infrastructure and private land. Property damage risks are primarily driven by the risk to the NFD 25 bridge located in Reach 1; however, the height of the bridge soffit above the channel and the location of the abutments on the floodplain are such that the overall risk to the bridge is low. Dynamic conditions are expected and desirable within response reaches in this type of geomorphic and hydrologic setting. Table 36, Table 37, and Figure summarize the property damage risk.

Table 36. Summary of property/project characteristics.

Property / Project Characteristic	Rating	Rationale
In-Channel Structures	1	No in-channel structures.
Floodplain Structures	2	Two abutments for NFD 25 bridge in Reach 1.
Land Use	1	Most of the national forest and CLT land with a portion of Reach 1 owned by private landowners.
Average	1.3	Project risk is primarily to National Forest Road 25 infrastructure (bridge abutments in floodplain)

Table 37. Summary of stream response potential characteristics.

Stream Response Potential	Rating	Rationale
Stream Type	2	Low sensitivity due to presence of bedrock and steep channel slope.
Riparian Corridor	5	Riparian corridor is discontinuous and alternates between areas with floodplain and channel-confining bedrock.
Bed Scour	3	Streambed is primarily gravel/cobble, D_{50} = 58 mm.
Hydrologic Regime	6	Hydrologic regime is rain-on-snow dominated.
Bank Erosion	5	The lahar deposit hillsides are highly erodible, but do not pose a threat to any existing structures.
Average	4.2	Stream Response Potential is moderate.

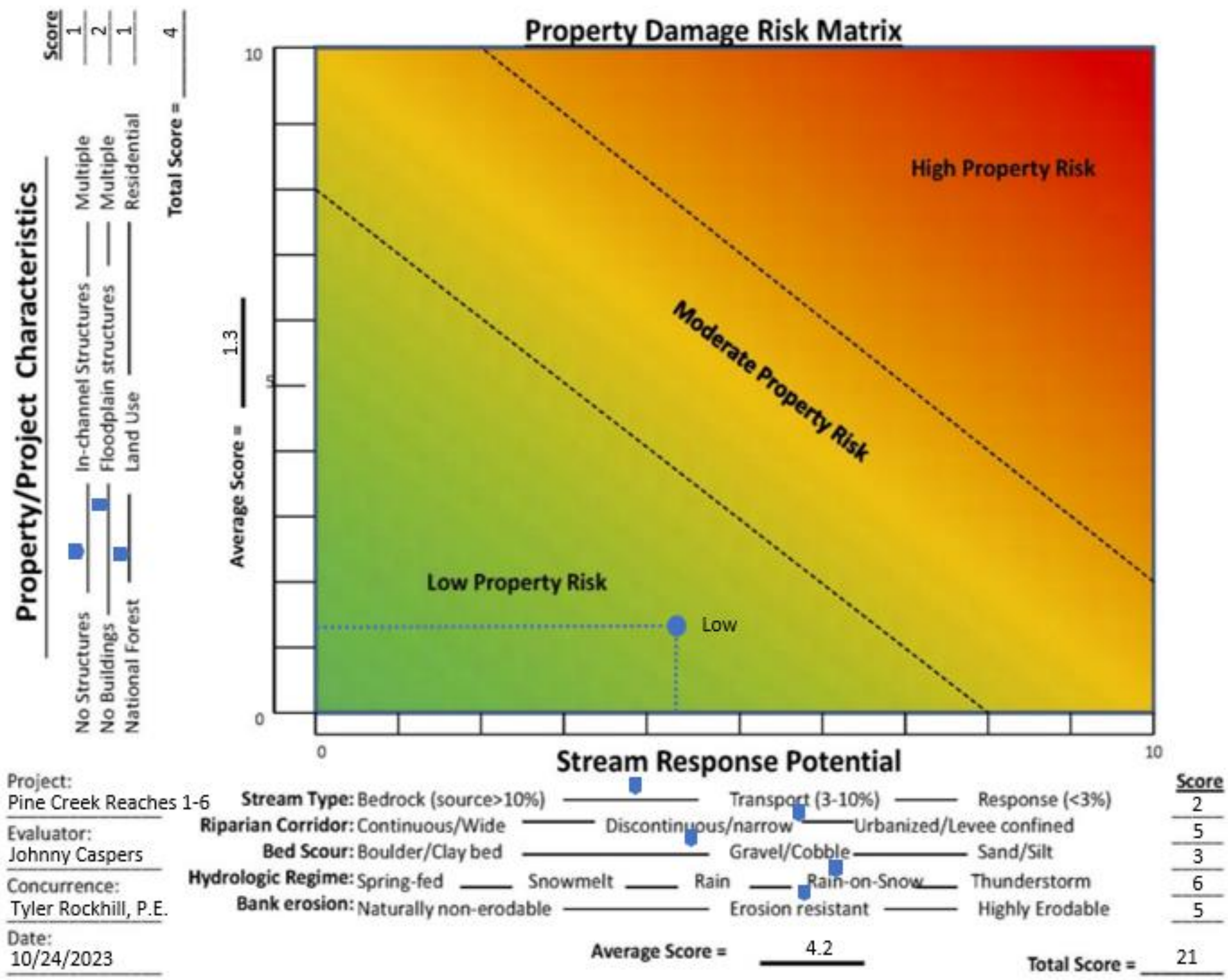

Figure 46. Property damage risk matrix.

5.6.3 Factor of Safety and Design Flow

We used the project risk assessment to inform the factor of safety and design flow following guidance from the *Large Wood National Manual* (USBR and USACE 2015) and Section 6.4.1 of *Large Woody Material – Risk Based Design Guidelines* (Knutson and Fealko, 2014). Factors of safety represent the ratio of resisting forces to driving forces on restoration elements and serve to accommodate levels of uncertainty in the design. Based on the information outlined in this report, a 10-year recurrence interval is recommended as the design discharge with the corresponding factors of safety shown in Table 15. This assessment will be further refined in later phases of the design to include additional factors such as racking, scour, and channel migration.

Table 15. Minimum recommended factors of safety (Knutson and Fealko, 2014). The recommended factor of safety is outlined in orange.

Public Safety Risk	Property Damage Risk	Stability Design Flow Criteria	$FOS_{sliding}$	$FOS_{bouyancy}$	$FOS_{rotation}$ $FOS_{overturning}$
High	High	100-year	1.75	2.0	1.75
High	Moderate	50-year	1.5	1.75	1.5
High	Low	25-year	1.5	1.75	1.5
Low	High	100-year	1.75	2.0	1.75
Low	Moderate	25-year	1.5	1.75	1.5
Low	Low	10-year	1.25	1.5	1.25

5.6.4 Engineered Log Jam Stability

Buoyancy / Vertical Stability

The factor of safety for buoyancy is assessed through vertical stability analysis. Vertical stability includes buoyancy as the primary driving force, derived from the submerged portion of the structure. The secondary driving force is fluid lift, which is generated by flow acceleration above and below a solid object; however, this component is typically negligible relative to buoyancy. Resisting forces are primarily resisting vertical forces derived from ballast mechanisms, including alluvium ballast, boulders, unsubmerged logs, and vertical piles. Vertical piles must be connected to the structure to provide vertical stability. Force provided by the vertical piles is dependent on construction method and substrate characteristics, as well as number, size, and orientation/location of piles. The factor of safety for buoyancy is defined as the ratio between the sum of vertical resisting forces and the sum of vertical driving forces.

Sliding / Horizontal Stability

The factor of safety for sliding is assessed through horizontal stability analysis. Horizontal stability includes fluid drag as the primary driving force, derived from the force generated by the inertia of the fluid on the structure. Fluid drag is largely dependent on the cross-sectional area of the structure normal to flow, and velocity. The primary resisting force is frictional resistance force, derived from the interaction between the channel bed and structure. To experience friction, the structure must be vertically stable, otherwise there is no contact with the bed and is largely a function of the internal angle of friction for the bed sediment and the vertical force. Driving forces can also include hydrostatic force (if there is a water surface elevation difference between the upstream and downstream side of the structure), passive forces (interaction with native materials behind the structure), ice loading, and impact force. The factor of safety for sliding is defined as the ratio between the sum of horizontal resisting forces and the sum of horizontal driving forces.

Scour, Racking, Overturning/Rotation, and Other Factors

In addition to buoyancy and sliding, multiple factors can influence the overall stability of a structure either directly or indirectly. The foremost factor is scour, which can undercut a structure and undermine stability. Additional factors include racking of additional natural material, which can increase the effective buoyant force of the structure, and impact from other structures or natural logs that are being transported downstream. In addition, some structures should be assessed for moment factor of safety, analyzing the risk for overturning or rotation. This affects some structure types more than others and is originated by asymmetric loading which causes a moment force around a moment center. For structures in high-risk areas or specific rational, log decay and resistance to erosion may also be considered for structures. Applicable additional factors mentioned in this section will be included in subsequent design phases.

Results

Engineered log jams were assessed for stability at the design discharge (10-year recurrence interval) based on applicable guideline, such as *The Large Wood National Manual* (USBR and ERDC 2015), *Large Woody Material – Risk Based Design Guidelines* (Knutson and Fealko 2014) and *Stream Habitat Restoration Guidelines* (WDFW 2012) combined with institutional knowledge, profession judgement, and best practices. At the preliminary design stage, additional factors such as scour, impact, and racking wood were not included in stability calculations and will be assessed at future design phases. A summary of ELJ stability results is shown in

Table 38.

Table 38. Summary engineered log jam stability assessment including ballast mechanism and achieved factors of safety.

Large Wood Structure Type	Ballast Mechanism	Buoyancy FOS (1.5 Required)	Sliding FOS (1.25 Required)
Channel Spanning ELJ	Rock Collar	1.70	1.63
Bank Attached ELJ	Rock Collar	2.05	3.02
Floodplain ELJ	Self-Ballasted	N/A	N/A
BDA/PALS	N/A	N/A	N/A

5.6.5 Ecological Risk

In addition to public safety and property damage risk, proposed project actions also have ecological risks. The primary ecological risks include risk associated with no action and risk to ESA listed species because of proposed actions, specifically aquatic and avian species. The risks associated with no action are significant. Risks include predicted changes in meteorological conditions associated with climate change, changes to watershed land cover characteristics, and changes to the current geomorphic and riparian condition and trajectory. Given the relatively immature riparian forest and hydraulic conditions, it is possible that mature riparian development will continue to be delayed due to increasingly frequent high magnitude storm events, causing a persistence of current conditions. Habitat conditions without intervention are lacking critical elements that support survival and persistence of bull trout.

There are also risks to ESA listed species within the project, primarily bull trout and northern spotted owl. For bull trout, the addition of large wood can disturb habitat conditions in the short term as the channel morphology adjusts. For avian species, the disturbance of proposed large wood placement by helicopters will cause disturbance and/or harassment from noise. Risks to aquatic species are mitigated by avoiding persistent and/or high density redd locations and implementing construction during the fish window (July 16 – August 15) when adult bull trout are unlikely to be present in the system. Risks to avian species will be further assessed in later design phases, but preliminary mitigation measures are shown in Table 39 and Table 40.

Table 39. Disturbance, disruption (harass), and/or physical injury (harm) distance thresholds for northern spotted owls during the nesting season (March 1 to September 30). Distances are to a known occupied spotted owl nest tree or suitable nest trees in unsurveyed nesting habitat (ARBO II)

Disturbance Source	Disturbance Distances During the Breeding Period[1] (Mar 1 - Sep 30)	Disruption Distances During The Critical Breeding Period[1, 4] (Mar 1 - Jul 15) (Mar 1 - Jul 7 ONCPP)[5]	Disruption Distances During the Late Breeding Period[1] (Jul 16-Sep 30) (Jul 8 - Sep 30 ONCPP)
Use of chain saws	440 yards (0.25 mile)	65 yards	0 yards
Heavy equipment	440 yards (0.25 mile)	35 yards	0 yards
Tree climbing	440 yards (0.25 mile)	35 yards	0 yards
Burning	440 yards (0.25 mile)	440 yards (0.25 mile)	0 yards
Use of type I helicopter[2]	880 yards (0.5 mile)	440 yards (0.25 mile)	440 yards (0.25 mile)
Use of type II, III or IV helicopter[3]	440 yards (0.25 mile)	120 yards	0 yards
Use of fixed-wing aircraft	440 yards (0.25 mile)	120 yards	0 yards
Pile driving	440 yards (0.25 mile)	60 yards	0 yards

1. Noise disturbance and disruption distances were developed from a sound threshold. Estimates of distances at which incidental take of murrelets and spotted owls due to harassment are anticipated from sound-generating, forest-management activities in Olympic National Forest). Smoke disturbance and disruption distances are based on a U.S. Fish and Wildlife Service white paper (USFWS 2008. Observations of Smoke Effects on Northern Spotted Owls. Compiled by J. Thrailkill, Oregon Department of Fish and Wildlife).
2. Type I helicopters seat at least 16 people and have a minimum capacity of 5,000 lbs. Both a CH 47 (Chinook) and UH 60 (Blackhawk) are Type I helicopters. Kmax helicopters are considered “other” for the purposes of disturbance. Sound readings from Kmax helicopter logging on the Olympic NF registered 86 dB at 150 yards (Piper. 2006. Pers. comm. Sound Measurements for Harris Timber Sale, Olympic National Forest).
3. All other helicopters (including Kmax).
4. Dates may vary slightly depending on site-specific conditions.
5. ONCPP= Oregon North Coast Planning Province

Table 40. Distance and time periods for marbled murrelet habitat (from ARBO II).

Disturbance Source	Disturbance Distances During the Breeding Period[1] (Apr 1 – Sep 15)	Disruption Distances During The Critical Breeding Period[1,4] (Apr 1 – Aug 5)	Disruption Distances During the Late Breeding Period[1] with Daily Timing Restrictions,* Unless Noted Otherwise (Aug 6-Sep 15)
Road repair such as culvert replacement	440 yards (0.25 mile)	100 yards	0 yards
Use of chain saws	440 yards (0.25 mile)	100 yards	0 yards
Heavy equipment	440 yards (0.25 mile)	100 yards	0 yards
Tree climbing	440 yards (0.25 mile)	100 yards	0 yards
Burning	440 yards (0.25 mile)	440 yards (0.25 mile)	0 yards
Use of type I helicopter[2]	880 yards (0.5 mile)	440 yards (0.25 mile)	440 yards (0.25 mile)
Use of type II, III or IV helicopter[3]	440 yards (0.25 mile)	120 yards	0 yards
Use of fixed-wing aircraft	440 yards (0.25 mile)	120 yards	0 yards
Pile driving	440 yards (0.25 mile)	100 yards	0 yards

* Activities would not begin until 2 hours after sunrise and ending 2 hours before sunset.

1. See note 1 in table 3 above.
2. See note 2 table 3 above.
3. All other helicopters (including Kmax). Dates may vary slightly depending on site-specific conditions.
4. Standard 14 from ARBO II requires daily timing restrictions* during the entire breeding period, when adjacent to suitable habitat and potential nesting structure for projects (see standard 14 for exemptions).

a. NSO1: To reduce adverse effects to spotted owl, projects will not generally occur during the critical breeding period, generally between March 1 – July 15, but may vary by location (July 7 for the Oregon North Coast Planning Province) if there is an active known owl site, predicted owl site (as determined through an approved modeling process), RPO (Reference Point Owl) and/or occupied habitat within the disruption distance of the project area. Projects should (a) be delayed until after the critical breeding season (unless action involves Type I helicopters, which extend critical nesting window to September 30); (b) delayed until it is determined that young are not present. ii. iii. iv. v. vi.
b. NSO2: The unit wildlife biologist may extend the restricted season based on site-specific information (such as a late or recycle nesting attempt).
c. NSO3: Table 9 shows disruption distances applicable to the equipment types proposed in the ARBO II. These distances can be locally altered based on current information.
d. NSO4: No activity within this BO will cause adverse effects to spotted owl critical habitat when analyzed against the appropriate local scale as determined by the unit wildlife biologist.
e. NSO5: For LW projects follow project design as outlined within section 22. e.
f. NSO6: No hovering or lifting within 500 feet of the ground within occupied spotted owl habitat during the critical breeding season by ICS Type I or II helicopters would occur as part of any proposed action addressed by this assessment.

5.7 Environmental Compliance and Permitting

5.7.1 Introduction

A review of environmental compliance and permitting associated with the project is provided in this section. All applicable environmental compliance, regulatory permits, and official authorizations shall be obtained by the contracting agency before construction.

5.7.2 National Environmental Policy Act (NEPA) Compliance

National Environmental Policy Act of 1969 (42 U.S.C 4321-4347) applies whenever an action is: proposed on federal lands; requires passage across federal lands; to be funded – either entirely or in part – by the federal government; or affects the air or water quality that is regulated by federal law. The Bureau of Indian Affairs (BIA) is primary federal entity responsible for ensuring the compliance of the National Environmental Policy Act (NEPA) for projects and activities affecting the environment on Indian trust lands.

At this phase of the project, it is assumed that actions proposed by this project will require NEPA compliance.

5.7.3 Cultural Resources, NHPA Section 106 Consultation

Section 106 of the National Historic Preservation Act (NHPA) requires that each federal agency identify and assess the effects its actions may have on historic resources. After an undertaking is identified, consultation is initiated between the federal agency, the State Historic Preservation Officer (SHPO) or Tribal Historic Preservation Officer (THPO), and other consulting parties including but not limited to the ACHP, certified local governments, and members of the general public with an economic, social or cultural interest in the project.

At this phase of the project, it is assumed that Section 106 of the NHPA will be applicable.

5.7.4 US Army Corps Section 404 / Nationwide 27 and Section 10

Section 404 of the Clean Water Act (CWA) (Code of Federal Regulations, Title 33, Chapter 26, Subchapter 4, Section 1344) establishes a program to regulate the discharge of dredged or fill material into waters of the United States, including wetlands. Activities in waters of the United States regulated under this program include fill for development, water resource projects, infrastructure development, and mining projects. Section 404 requires a permit before dredged or fill material may be discharged into waters of the United States unless the activity is exempt from Section 404 regulation. The permit applicants must show that they have avoided, minimized, and compensated for any impacts to the aquatic environment4. The permit is reviewed by USACE or an approved State/Tribal 404 (g) Program under a public interest review and the environmental criteria set by the EPA.

Section 10 of the Rivers and Harbors Act of 1899 requires authorization from the Secretary of the Army, acting through the Corps of Engineers, for the construction of any structure in or over any navigable water of the United States. Structures or work outside the limits defined for navigable waters of the United States require a Section 10 permit if the structure or work affects the course, location, or condition of the water body. The law applies to any dredging or disposal of dredged materials, excavation, filling, rechannelization, or any other modification of a navigable water of the United States.

The Nationwide Permit 27 Aquatic Habitat Restoration, Enhancement, and Establishment Activities (Sections 10 and 404) regulates activities in waters of the United States associated with the restoration, enhancement, and establishment of tidal and non-tidal wetlands and riparian areas, the restoration and enhancement of non-tidal streams and other non-tidal open waters, and the rehabilitation or enhancement of tidal streams, tidal wetlands, and tidal open waters, provided those activities result in net increases in aquatic resource functions and services.

At this phase of the project, it is assumed that section 404 of the Clean Water Act and section 10 of the Rivers and Harbors Act of 1899 and Nationwide Permit 27 will be required for this project and will be filed under JARPA.

5.7.5 Endangered Species Act, Section 7 Consultation

The Endangered Species Act (16 U.S.C. §1531 et seq. 1973) requires federal agencies, in consultation with the U.S. Fish and Wildlife Service and/or the NOAA Fisheries Service, to ensure that actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of designated critical habitat of such species. The law also prohibits any action that causes "taking" of any listed species of endangered fish or wildlife. Likewise, import, export, interstate, and foreign commerce of listed species are all generally prohibited.

At this phase of the project, it is assumed that consultation with National Marine Fisheries Service (NMFS) and USFWS for threatened and endangered species will be completed for this project through the SEPA and/or ARBO II process.

5.7.6 Joint Aquatic Resources Permit Application (JARPA)

For projects in Washington State, multiple regulatory permits can be filed together under JARPA including:

<u>Federal</u>
U.S. Army Corps of Engineers (Corps): Section 10 and Section 404 (Corps Permits FAQ)
U.S. Coast Guard: Private Aids to Navigation (PATON)
<u>State</u>
Washington Department of Ecology: 401 Water Quality Certification
Washington Department of Fish and Wildlife: Hydraulic Project Approval (HPA FAQ)
Washington Department of Natural Resources: Aquatic Use Authorization
<u>Local</u>
Shoreline Substantial Development Permit
Shoreline Conditional Use Permit
Shoreline Variance
Shoreline Exemption

At this phase of the project, it is assumed that the JAPRA application will be used for this project.

5.7.7 State Permits

<u>Washington Department of Ecology: 401 Water Quality Certification.</u>

Passed by Congress in 1972, the federal Clean Water Act grants states and Tribal governments the authority to review and approve, condition, or deny proposed projects, actions, and activities directly affecting waters of the United States. In Washington, Ecology is the certifying authority and is responsible for issuance of Section 401 water quality certifications. Tribal governments and the EPA also have this authority on Tribal and nonstate lands.

At this phase of the project, it is assumed that a 401 Water Quality Certification will be required for this project and will be filed under JARPA.

<u>Washington Department of Fish and Wildlife: Hydraulic Project Approval (HPA).</u>

Washington State law (RCW 77.55) requires people planning hydraulic projects in or near state waters to get a Hydraulic Project Approval (HPA) from the Washington Department of Fish and Wildlife (WDFW). This includes most marine and fresh waters. An HPA ensures that construction is done in a manner that protects fish and their aquatic habitats.

At this phase of the project, it is assumed that an HPA will be required for this project and will be filed under JARPA.

<u>Washington Department of Natural Resources: Aquatic Use Authorization.</u>

Projects taking place on or over state-owned aquatic lands require an authorization from DNR. DNR is the landlord of state-owned aquatic lands and has proprietary authority. In an effort to minimize project proponents obtaining regulatory permits before they have contacted DNR, regulatory staff need to confirm applicants have received acknowledgement from DNR before processing permits for aquatic land use.

At this phase of the project, it is assumed that an aquatic use authorization will be required for this project and will be filed under JARPA.

<u>Washington State Department of Transportation: General Permit</u>

This General Permit applies to all Work being constructed by the permit on WSDOT right-of-way that is owned by or under WSDOT jurisdiction and includes all Work that will be WSDOT's responsibility to maintain when the Work is completed and accepted by WSDOT. (RCW 47.24.020 City Streets as part of State Highways.)

At this phase of the project, it is assumed that temporary access road construction will not require a general permit for work occurring within WSDOT right-of-way.

5.7.8 Tribal Permits

At this phase of the project, no proposed actions occur on lands owned by a tribal nation, therefore relevant permits are not applicable.

5.7.9 Local/County Permits

At this phase of the project, it is assumed that the local and county permits will be required for this project and will be filed under JARPA.

5.8 Construction

This section will be completed during the Final Design phase.

- Materials and Quantities
- Site Access, Staging, and Sequencing
- Work Area Isolation and Dewatering
- Erosion and Pollution Control Plan
- Site Reclamation and Restoration Plan
- Schedule

6. LIMITATIONS

Dynamic river systems include both implicit and explicit assumptions and limitations. This document reports some of the primary assumptions and limitations. Riverine systems are inherently dynamic, and this project relies substantially on LiDAR data products, which are recent but not current. Therefore, discrepancies between modeled and current conditions are likely; however, the hydraulic characteristics are likely to remain similar. However, the level of model detail is within accepted best practices in the field of river restoration for the level of project risk.

7. MONTORING AND ADAPTIVE MANAGEMENT

This section will be completed at the Final design phase.

7.1 Introduction

7.2 Existing Monitoring Protocols

7.3 Project Effectiveness Monitoring Plan

7.4 Project Review Team Triggers

7.5 Monitoring Frequency, Timing, and Duration

7.5.1 Baseline Survey

7.5.2 As-built Survey

7.5.3 Monitoring Site Layout

7.5.4 Post-Bankfull Event Survey

7.5.5 Future Survey (related to flow event)

7.6 Monitoring Technique Protocols

7.6.1 Photo Documentation and Visual Inspection

7.6.2 Longitudinal Profile

7.6.3 Habitat Survey

7.6.4 Survival Plots

7.6.5 Channel and Floodplain Cross-sections

7.6.6 Fish Passage

7.7 Data Storage and Analysis

7.8 Monitoring Quality Assurance Plan

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APPENDIX A: 30% PRELIMINARY PLANS

APPENDIX B: 30% PRELIMINARY ENGINEER'S CONSTRUCTION COST ESTIMATE AND QUANTITIES

APPENDIX C: DRAFT CONSTRUCTION TECHNICAL SPECIFICATIONS

This section was intentionally left blank and will be completed at Final Design.

APPENDIX D: STABILITY CALCULATIONS

APPENDIX E: HYDRAULIC MODELING RESULTS

This section was intentionally left blank and will be completed at Final design.

APPENDIX F: PROJECT REVIEW COMMENTS

APPENDIX G: LANDOWNER ACKNOWLEDGEMENT AND FORMS

APPENDIX H: CONSTRUCTION PERMITS

This section was intentionally left blank and will be completed at Final Design.

APPENDIX I: AS-BUILT DRAWINGS AND DOCUMENTATION

This section was intentionally left blank and will be completed after construction.

APPENDIX J: PROJECT MONITORING PLAN

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APPENDIX K: PROJECT MAPS AND ADDENDUM

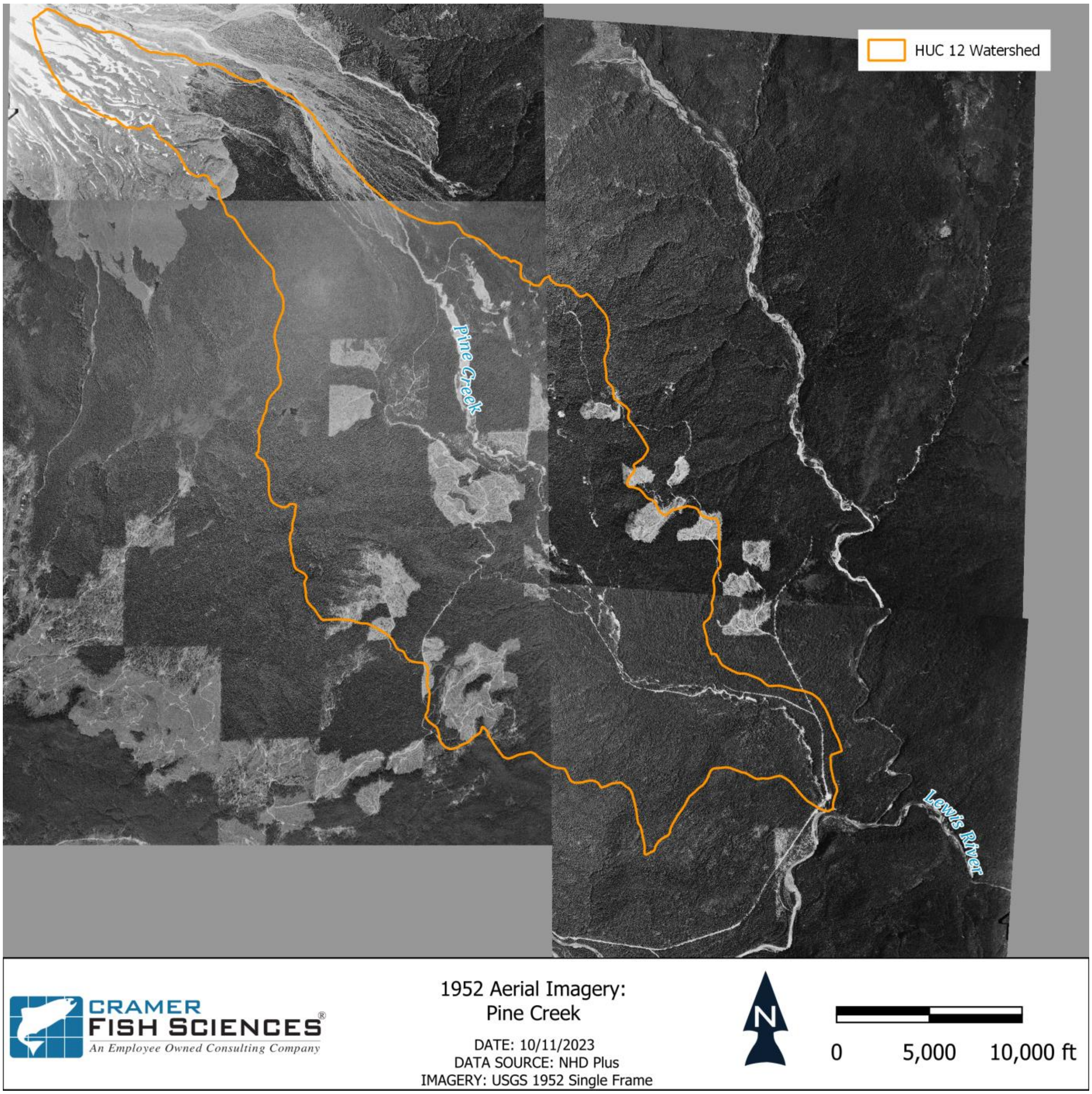

Figure 47. USGS Aerial Photo Single Frame imagery from 1952 for the Pine Creek watershed

Figure 48. USGS Digital Orthophoto Quadrangle (DOQ) imagery from 1994 for the Pine Creek watershed.

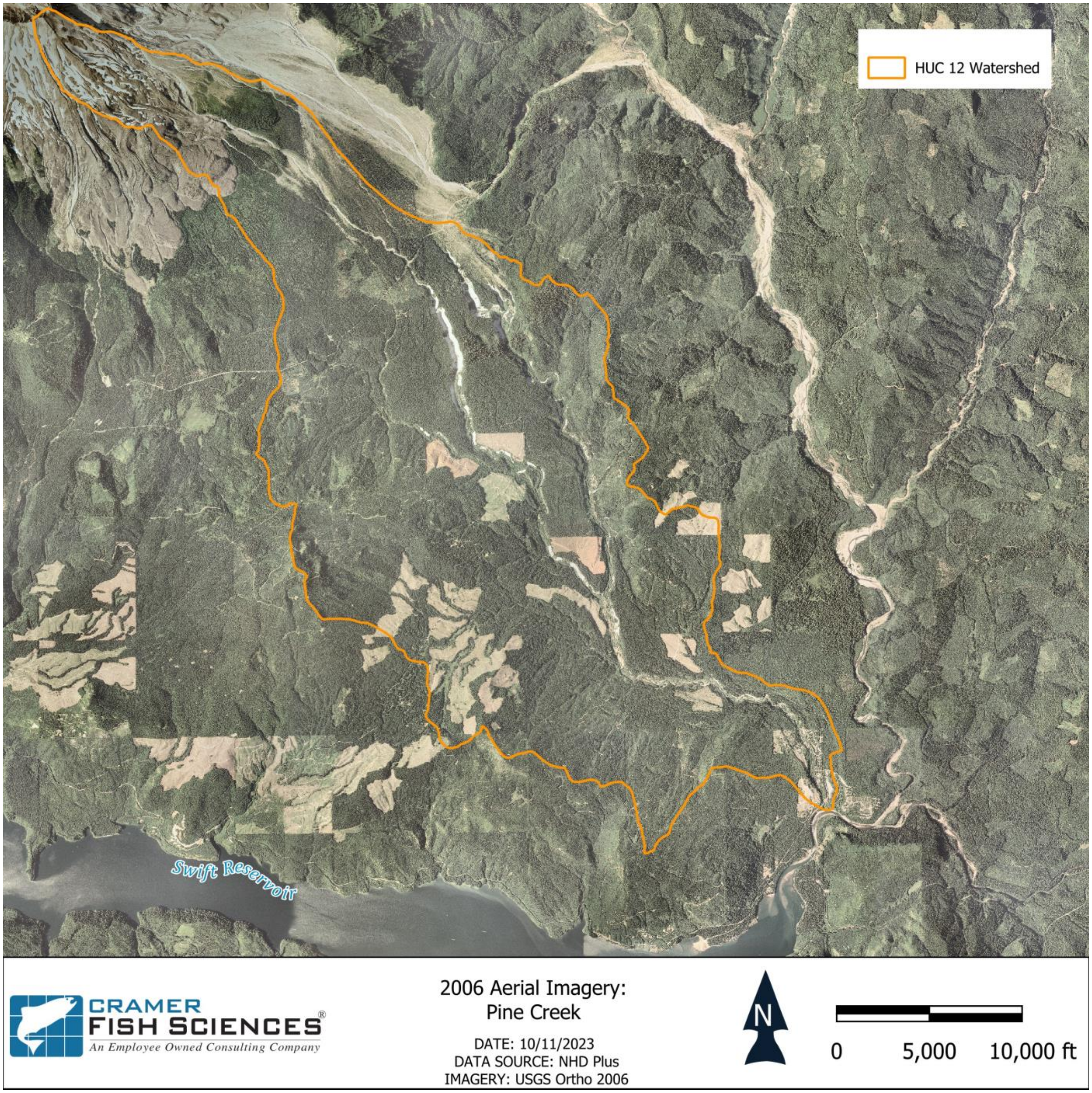

Figure 49. USGS High Resolution Orthoimagery (HRO) from 2006 for the Pine Creek watershed.

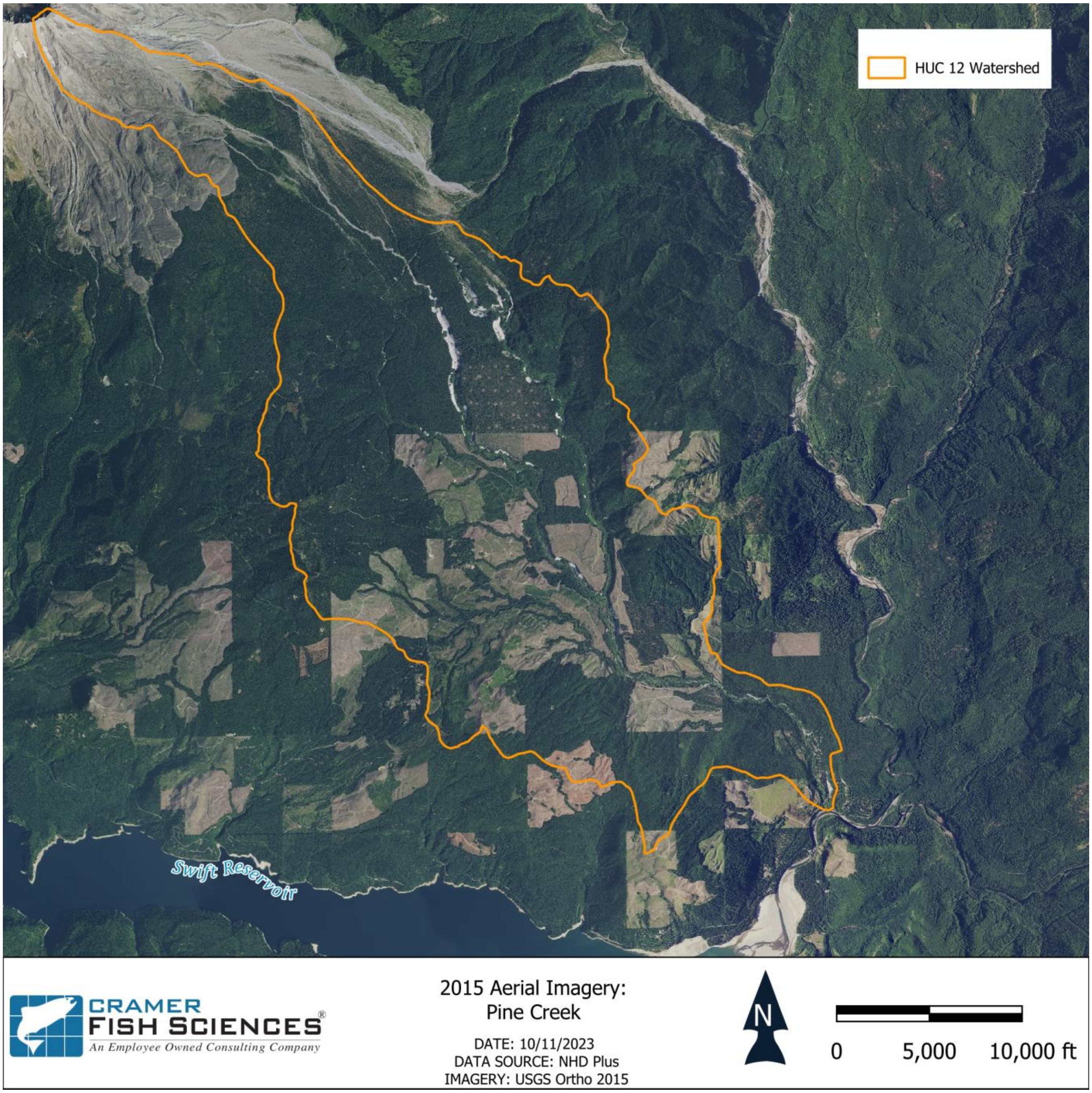

Figure 50. USGS High Resolution Orthoimagery (HRO) from 2015 for the Pine Creek watershed.

Figure 51. USGS National Agriculture Imagery Program (NAIP) imagery from 2021 for Pine Creek watershed.

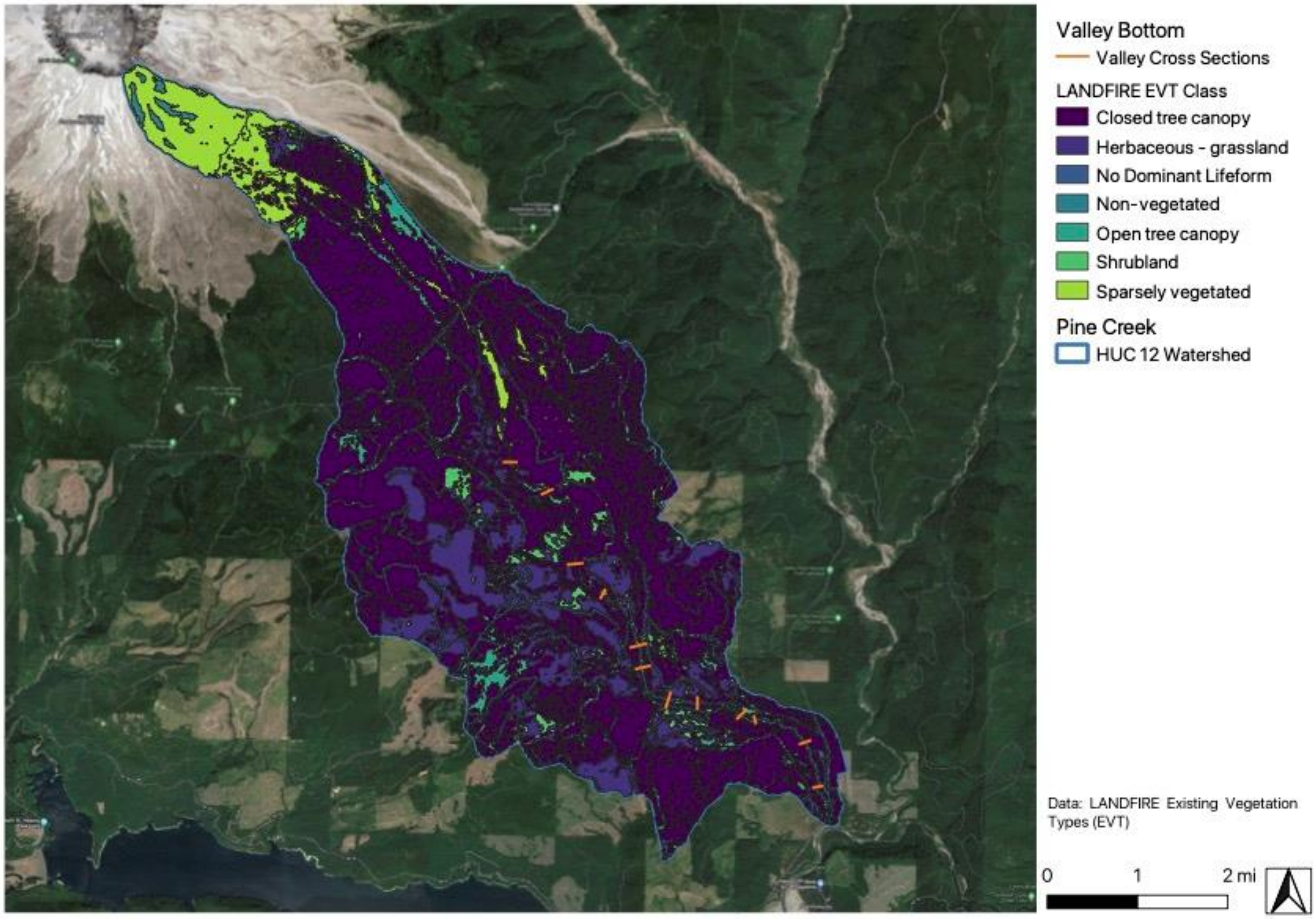

Figure 52.The watershed wide LANDFIRE EVT (2022) classes within Pine Creek. Note that vegetation is predominantly forest cover below treeline, with some open human use and a wide variety of successional stages that correspond to forestry activity, roads, and the evolution of Pine Creek and associated stream corridors.

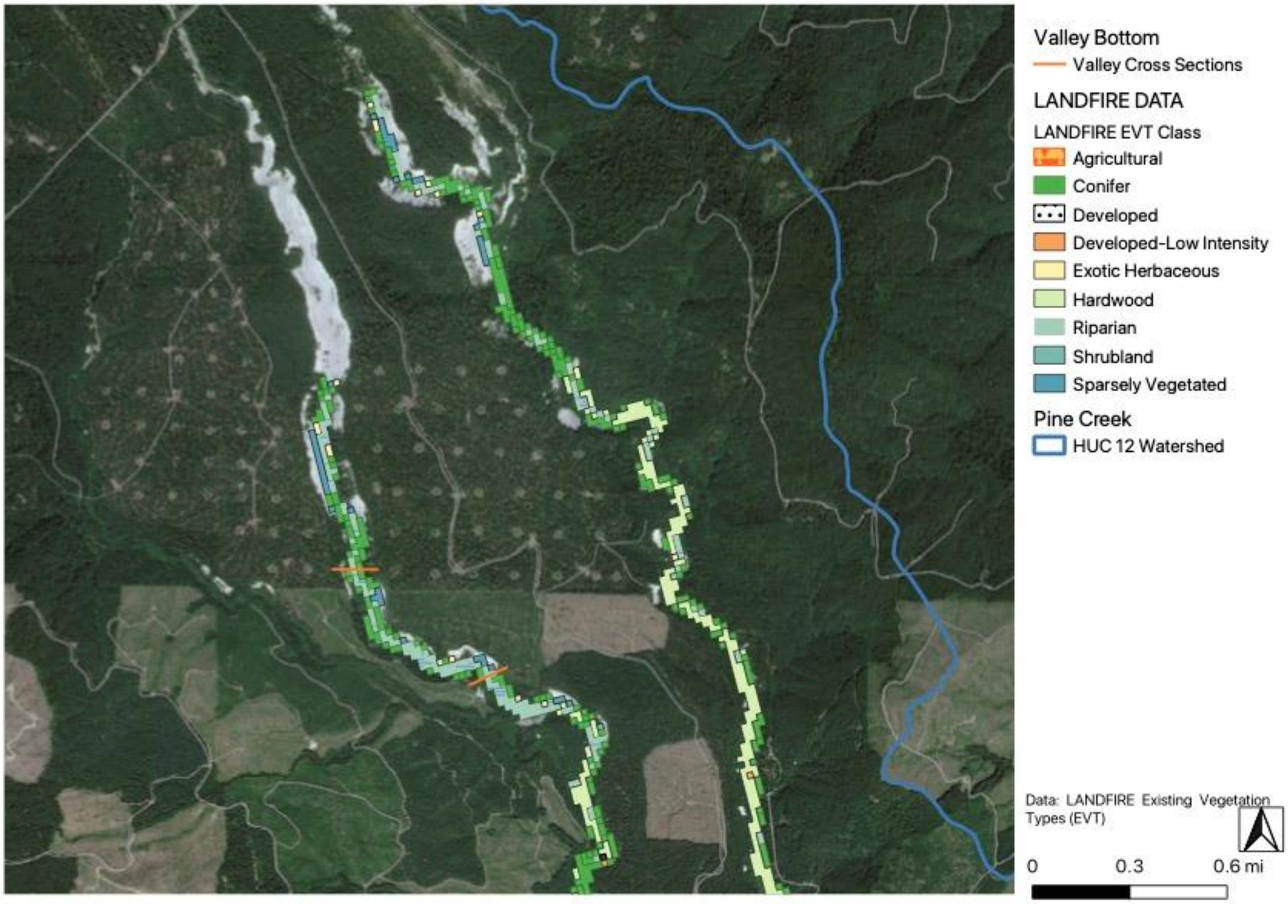

Figure 53. LANDFIRE Existing Vegetation Type - Riparian Physical Vegetation Classes surrounding Upper Pine Creek. Note that the Riparian PVC is comprised of the *North Pacific Lowland Riparian Forest, Temperate Pacific Freshwater Emergent Marsh*, *North Pacific Montane Riparian Woodland*, *North Pacific Montane Riparian Shrubland* vegetation types. LANDFIRE cells are 30m grid cells buffering the channel within the modeled 2.5-year flood.

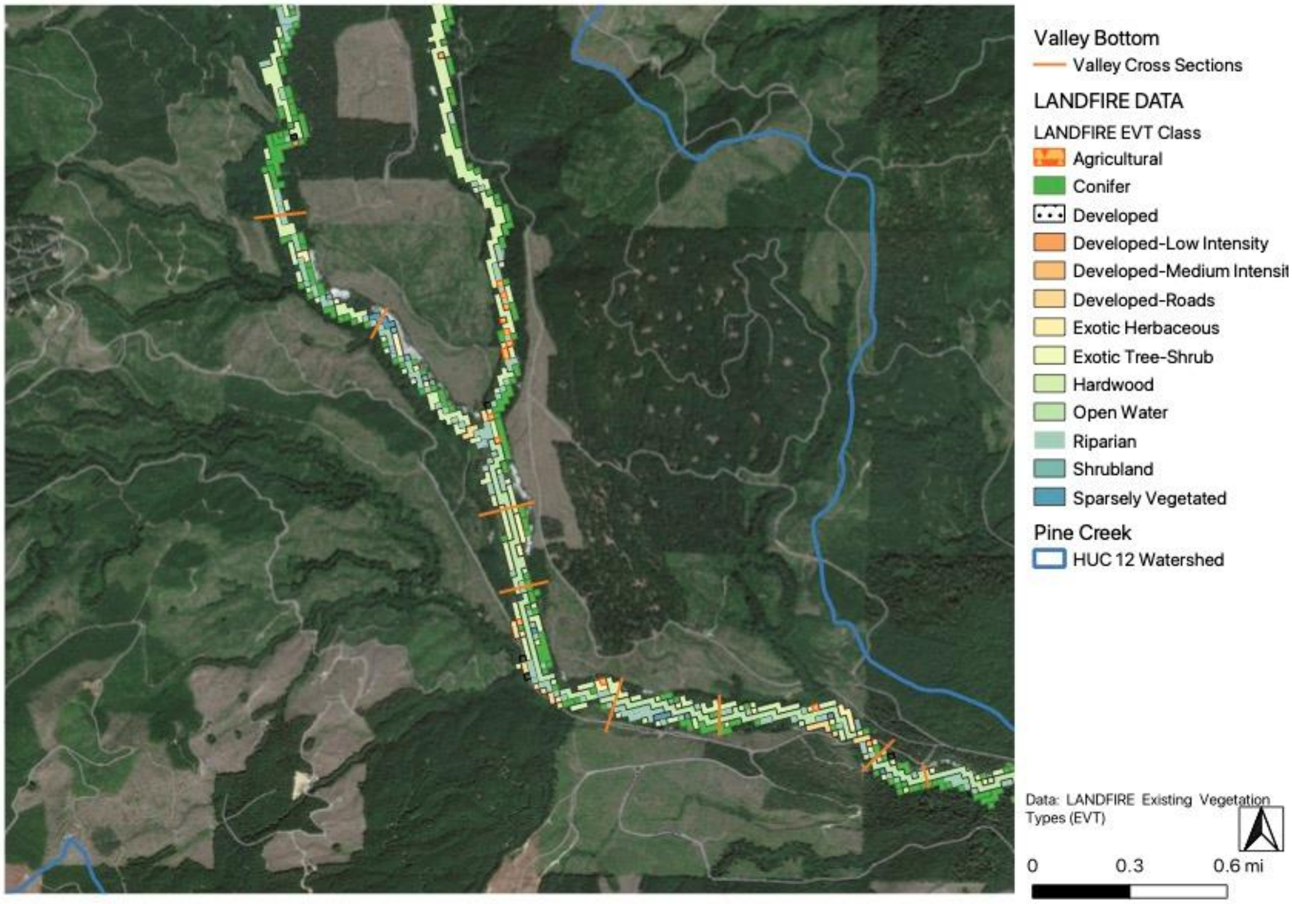

Figure 54. LANDFIRE Existing Vegetation Type - Riparian Physical Vegetation Classes surrounding the confluence of Pine Creek and East Fork Pine Creek. Note that the Riparian PVC is comprised of the *North Pacific Lowland Riparian Forest, Temperate Pacific Freshwater Emergent Marsh*, *North Pacific Montane Riparian Woodland*, *North Pacific Montane Riparian Shrubland* vegetation types. LANDFIRE cells are 30m grid cells buffering the channel within the modeled 2.5-year flood.

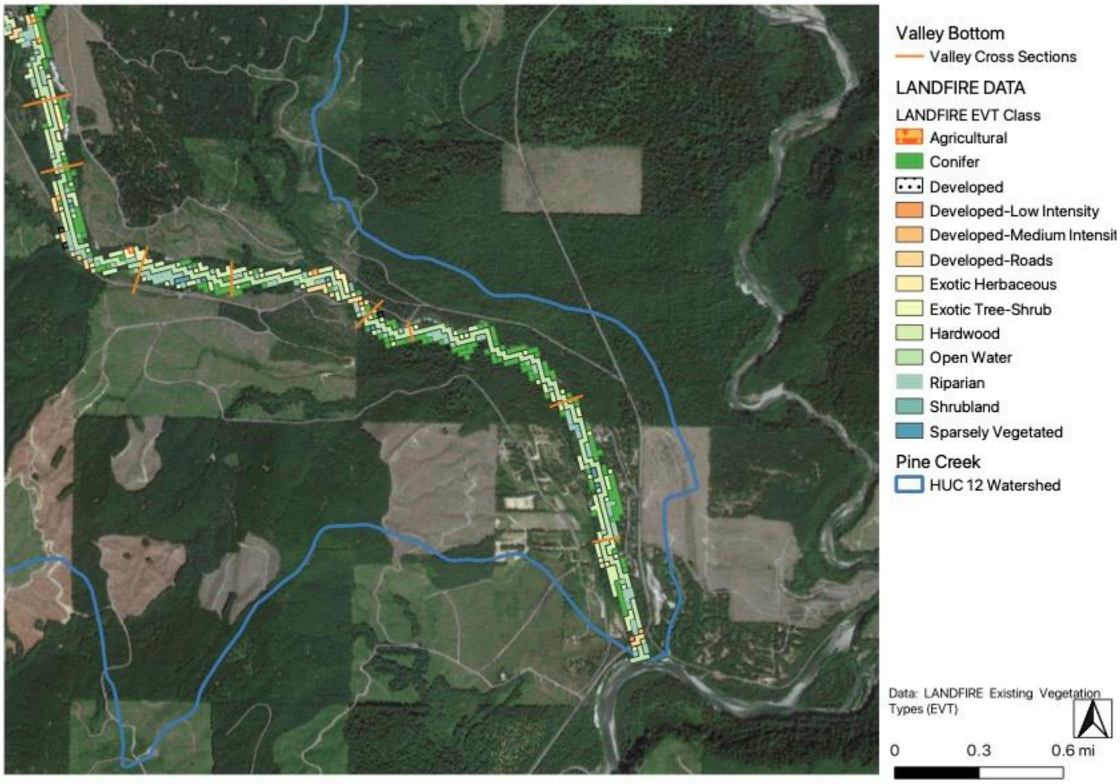

Figure 55. LANDFIRE Existing Vegetation Type - Riparian Physical Vegetation Classes surrounding lower Pine Creek. Note that the Riparian PVC is comprised of the *North Pacific Lowland Riparian Forest, Temperate Pacific Freshwater Emergent Marsh*, *North Pacific Montane Riparian Woodland*, *North Pacific Montane Riparian Shrubland* vegetation types. LANDFIRE cells are 30m grid cells buffering the channel within the modeled 2.5-year flood.

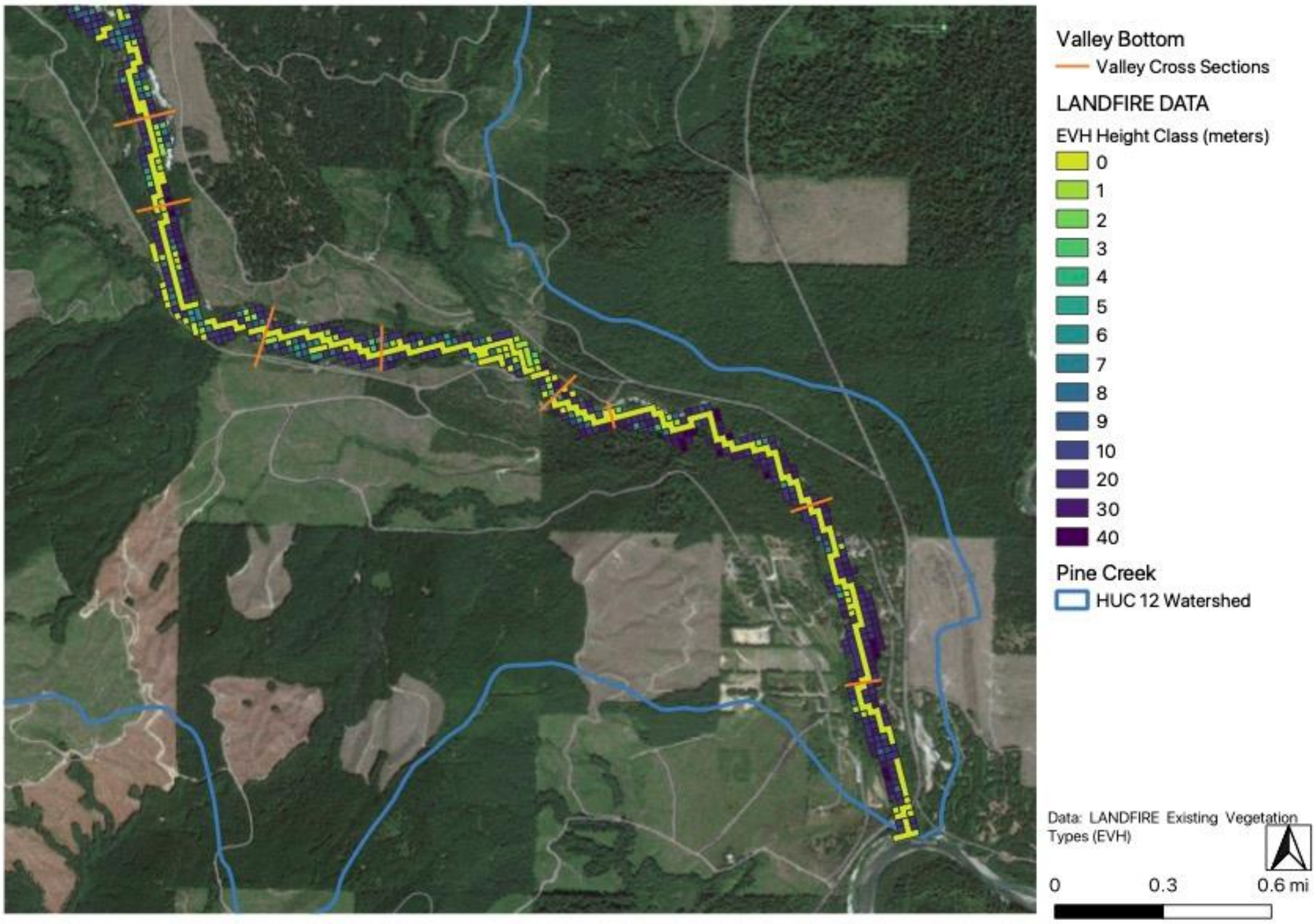

Figure 56. LANDFIRE Existing Vegetation Height for lower Pine Creek shows that much of the lower floodplain is dominated by taller trees, primarily where conifers occur within 30m of the floodplain.

Table 41. Summary of LANDFIRE Existing Vegetation Type and Physical Class cells within 30m of the modeled 2.5-year floodplain around Pine Creek. Each cell is 30x30 m and corresponds to 0.222 acres. Note that the dominant EVT cover is conifer (61%), riparian (23%), and hardwood (18%).

LANDFIRE Existing Vegetation Type Name	Riparian	Conifer	Hardwood	Shrubland	Exotic Herbaceous	Exotic Tree-Shrub	Sparsely Vegetated	Agricultural	Developed-Roads	Developed	Developed-Low Intensity	Developed-Medium Intensity
Developed-Low Intensity	0	0	0	0	0	0	0	0	0	0	2	0
Developed-Medium Intensity	0	0	0	0	0	0	0	0	0	0	0	2
Developed-Roads	0	0	0	0	0	0	0	0	14	0	0	0
North Pacific Broadleaf Landslide Forest	0	0	116	0	0	0	0	0	0	0	0	0
North Pacific Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest	0	50	0	0	0	0	0	0	0	0	0	0
North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest	0	126	0	0	0	0	0	0	0	0	0	0
North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest	0	56	0	0	0	0	0	0	0	0	0	0
North Pacific Mesic Western Hemlock-Silver Fir Forest	0	44	0	0	0	0	0	0	0	0	0	0
North Pacific Montane Massive Bedrock-Cliff and Talus	0	0	0	0	0	0	25	0	0	0	0	0
North Pacific Montane Shrubland	0	0	0	9	0	0	0	0	0	0	0	0
Southern Vancouverian Lowland Ruderal Grassland	0	0	0	0	34	0	0	0	0	0	0	0
Southern Vancouverian Lowland Ruderal Shrubland	0	0	0	0	0	3	0	0	0	0	0	0

Western Cool Temperate Bush fruit and berries	0	0	0	0	0	0	0	1	0	0	0	0
Western Cool Temperate Orchard	0	0	0	0	0	0	0	2	0	0	0	0
Western Cool Temperate Pasture and Hayland	0	0	0	0	0	0	0	10	0	0	0	0
Western Cool Temperate Urban Deciduous Forest	0	0	0	0	0	0	0	0	0	1	0	0
Western Cool Temperate Urban Evergreen Forest	0	0	0	0	0	0	0	0	0	4	0	0
North Pacific Montane Riparian Shrubland	1	0	0	0	0	0	0	0	0	0	0	0
North Pacific Montane Riparian Woodland	4	0	0	0	0	0	0	0	0	0	0	0
Temperate Pacific Freshwater Emergent Marsh	21	0	0	0	0	0	0	0	0	0	0	0
North Pacific Lowland Riparian Forest	121	0	0	0	0	0	0	0	0	0	0	0
Total Cells	147	276	116	9	34	3	25	13	14	5	2	2
Total Acres	32.69	61.38	25.80	2.00	7.56	0.67	5.56	2.89	3.11	1.11	0.44	0.44
Proportion of buffered floodplain	0.23	0.43	0.18	0.01	0.05	0.00	0.04	0.02	0.02	0.01	0.00	0.00