LARSEN CREEK PRELIMINARY DESIGN

Low-Tech Process-Based Restoration

Prepared for:

Chelan County Natural Resources Department

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INTRODUCTION

Chelan County Natural Resources Department in the state of Washington contracted Cramer Fish Sciences to complete a site survey and field-based low-tech process-based restoration (LTPBR) design for Larsen Creek in Chelan County, Washington (Figure 1). The Larsen Creek project area begins upstream of the recently improved stream crossing near its confluence with Peshastin Creek and continues until its connection with Sedge Meadows. In total, the project area is 1.10 river kilometers and spans two landowners: Freimuth and Chelan Resources LLC. The project was funded by the Washington State Department of Ecology.

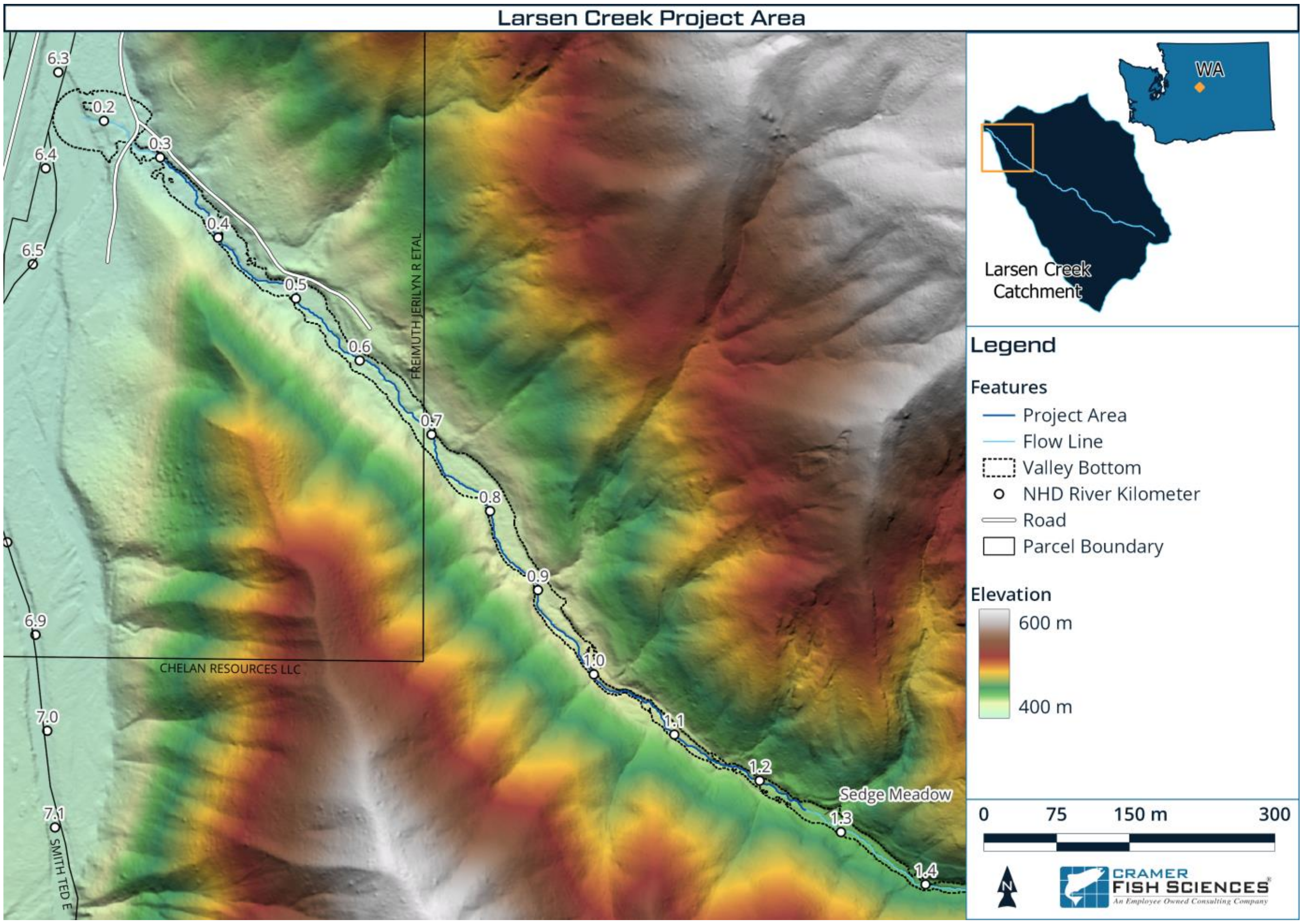

Figure 1. Overview map of the Bjork Creek project area.

The restoration design consists of two primary components: complexes and structures (e.g., Wheaton et al. 2019). Complexes represent short reaches that contain relatively consistent conditions and restoration opportunities. A complex consists of several structures that are designed to work together to achieve an overarching objective such as incision recovery or floodplain development. Structures are individual structural elements such as wood or boulders that influence the movement and retention of water and sediment. Each structure is designed to achieve local objectives such as pool creation, sediment sorting, or floodplain connection. As structures are designed, their contribution to other structures and the complex objective is considered. The LTPBR design on Larsen Creek consists of 4 post-assisted log structures (PALS), 10 leaky dams, 8 beaver dam analogs (BDA), and 19 post-assisted slash (PAS) areas.

Goals and Objectives

The stream reach for this project was chosen because it has high channel incision with the potential for alluvial water storage, which could help restore the streams flow and increase baseflows (CCNRD and NSD 2022). The streams and reaches for this project were chosen because they have the greatest potential for alluvial water storage (CCNRD and NSD 2022). The goal of this project is to increase the magnitude and duration of floodplain inundation and improve exchange between the hyporheic zone and surface flows to reduce stream temperature on Larsen Creek. The overall objective of this project is to survey conditions along Larsen Creek to develop alluvial water storage structures using low-tech process-based restoration principles (Wheaton et al. 2019). Complex objectives within the project are to retain water and sediment, recover channel incision, and increase floodplain connectivity. There will be a two-year implementation timeline for the Larsen Creek project. The downstream structures (RM 0.0 – 0.4; Complex 1 – 4) will be constructed in the first year and the upstream structures (RM 0.4 – 0.8; Copmlex 5 – 6) will be built in year two, allowing the downstream structures to capture and store sediment prior to installation of the upstream structures.

WATERSHED BACKGROUND

Land Cover

Although the Peshastin Creek watershed experienced mining since the 1980’s, it is unknown the extent of mining and land use alterations on Larsen Creek (USFS 1999). The aerial imagery from 1957–1990 is relatively similar (Figure 2 – Figure 3). Between 1990 and 2006 there was a lot of timber harvesting and road development throughout the catchment (Figure 3 – Figure 4). A severe wildfire occurred in 1994 and burned most of Larsen Creek catchment, subsequently salvage logging occurred (USFS 1999). Between 2013–2017 there was timber harvesting and road development in the northern part of the catchment (Figure 5–Figure 6). Between 2017 and 2019 there was timber harvesting in the southern portion of the basin, but the landscape is similar from 2019–2021 (Figure 6 – Figure 8). According to the National Land Cover Dataset (NLCD), evergreen forests is the most abundant landcover type, covering 55% of the catchment (Figure 9). The riparian habitat is a mixture of open canopy evergreen forest and shrub/scrub habitat. The area of shrub and scrub habitat makes up 24% of the catchment. Grassland and herbaceous habitat cover 14% of the catchment. Deciduous forest habitat makes up 3% of the catchment and mixed forests make up 1%. The remaining 2% is developed open spaces, which is primarily roads. All other habitat types make up <1% of the area of Larsen Creek catchment.

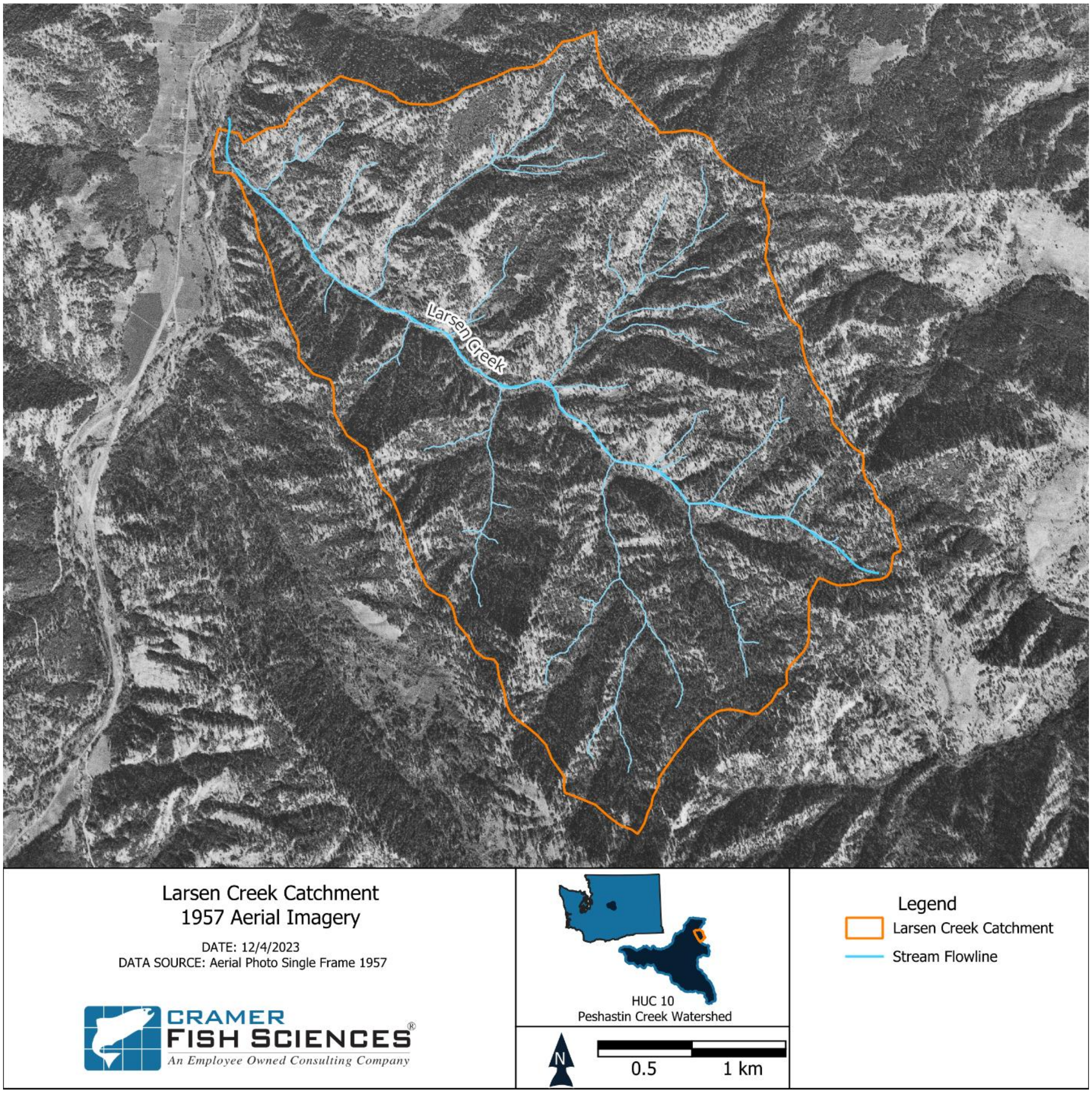

Figure 2. U.S. Geological Survey (USGS) Aerial Photo Single Frame imagery from 1957 for Larsen Creek catchment.

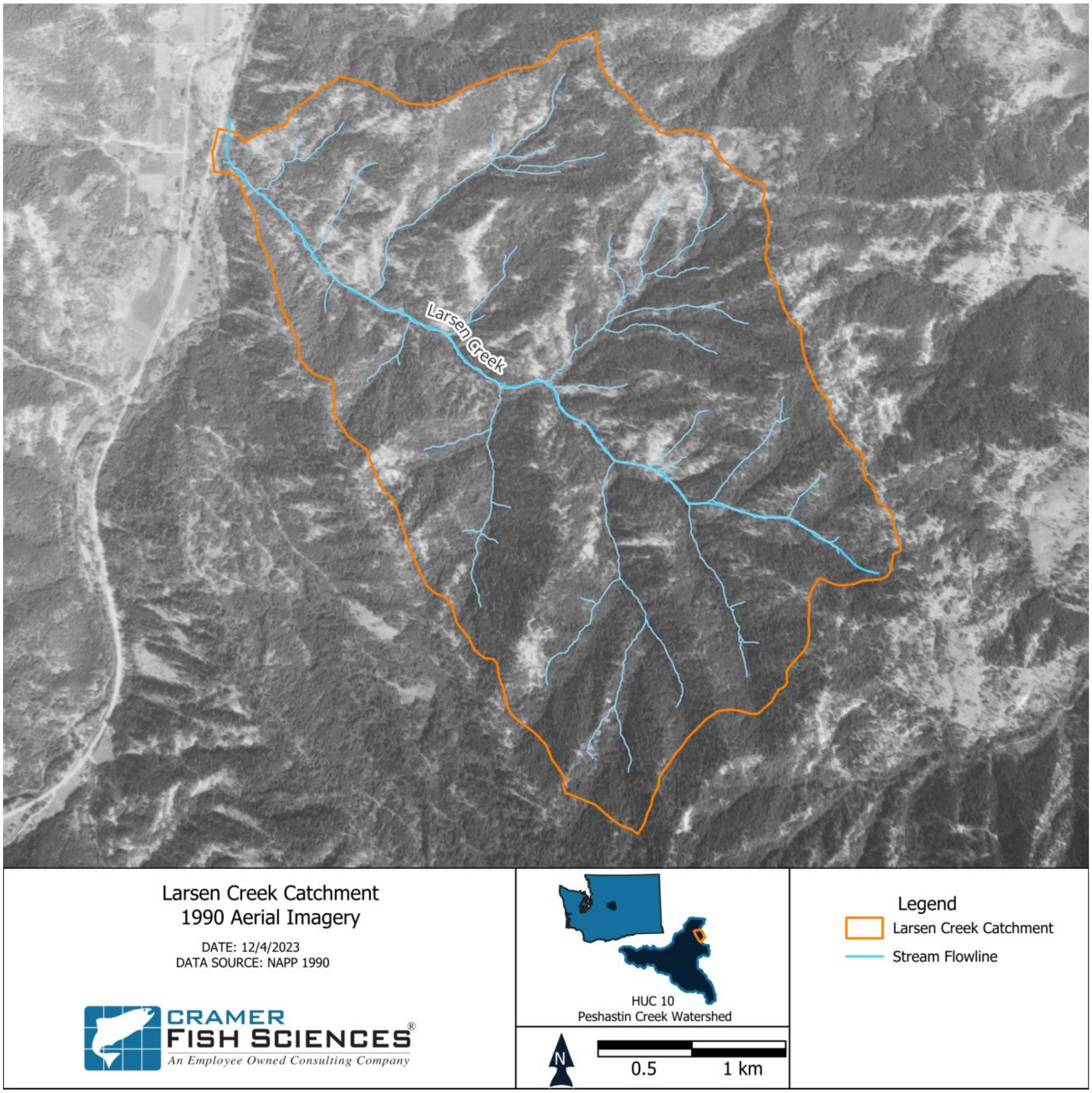

Figure 3. USGS National Aerial Photography Program (NAPP) imagery from 1990 for Larsen Creek catchment.

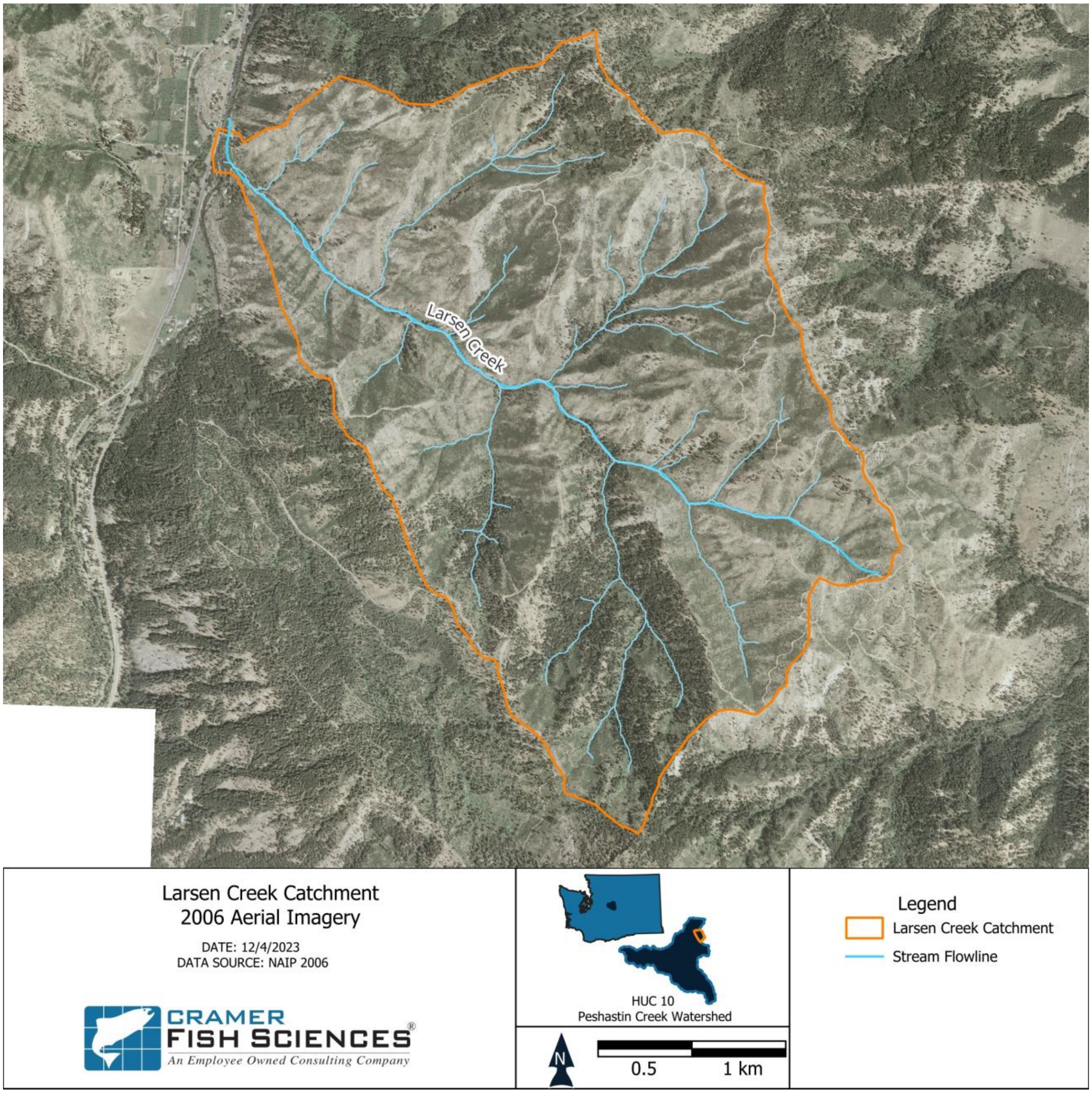

Figure 4. USGS National Agriculture Imagery Program (NAIP) imagery from 2006 for Larsen Creek catchment.

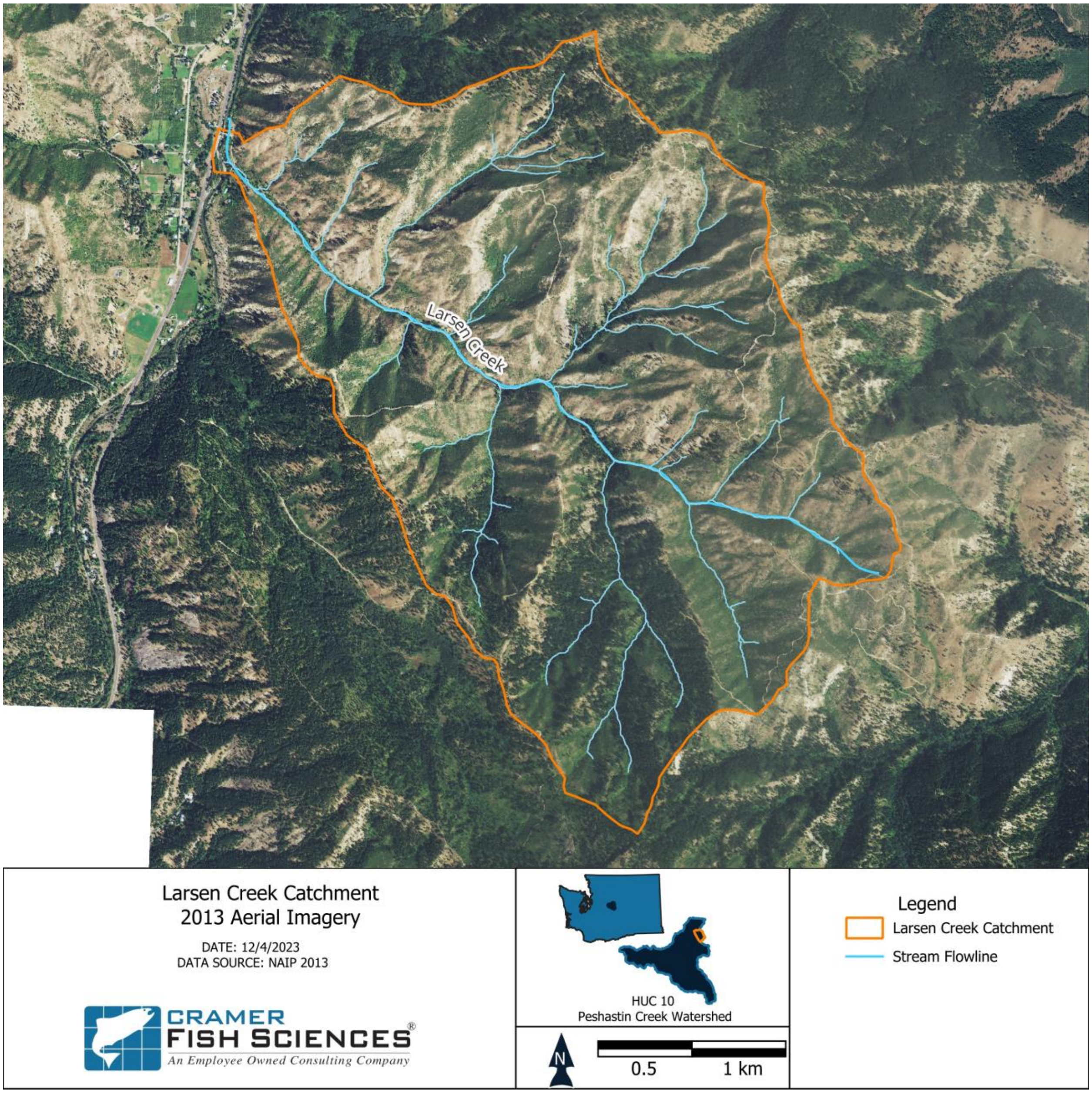

Figure 5. USGS NAIP imagery from 2013 for Larsen Creek catchment.

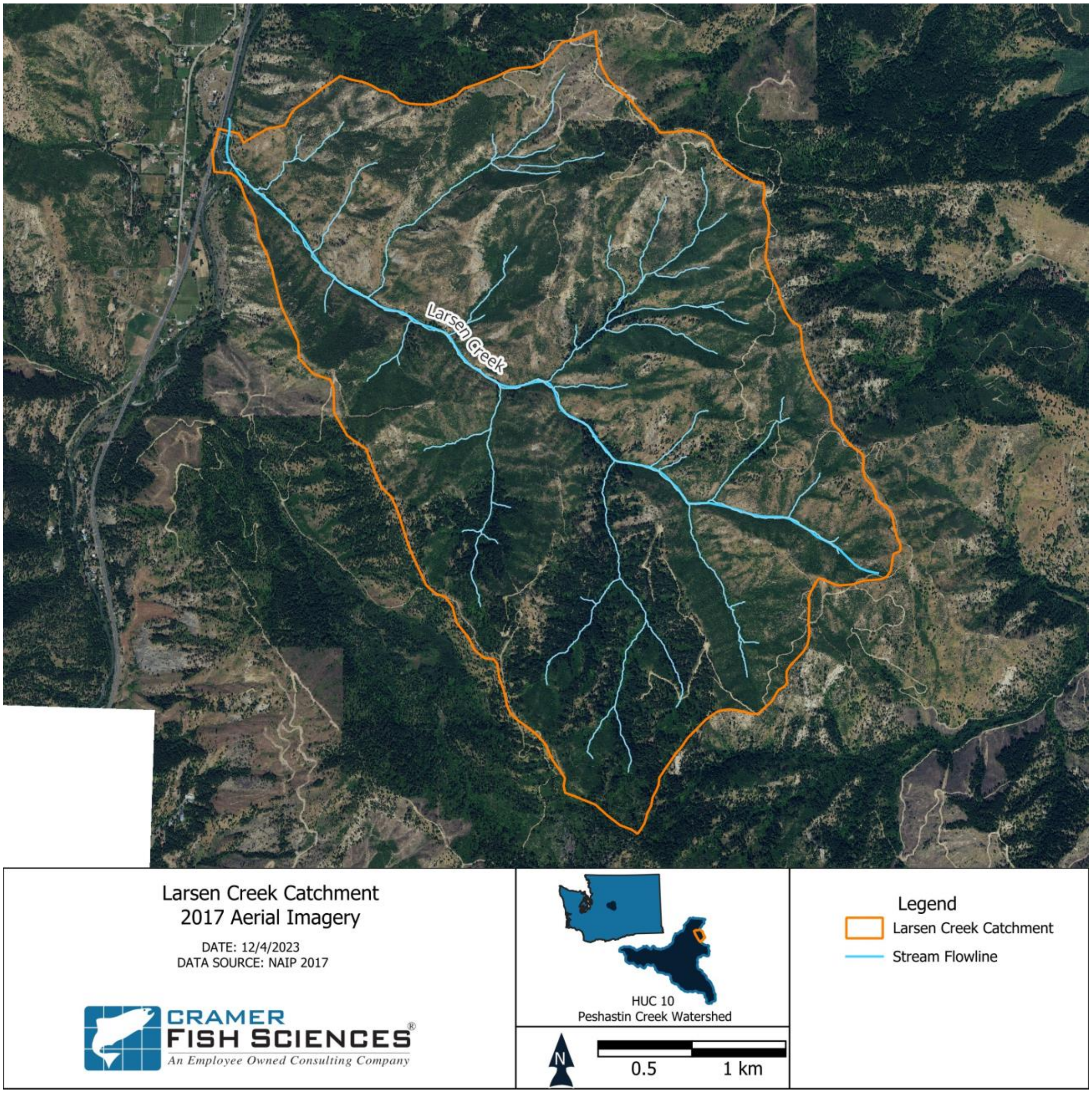

Figure 6. USGS NAIP imagery from 2017 for Larsen Creek catchment.

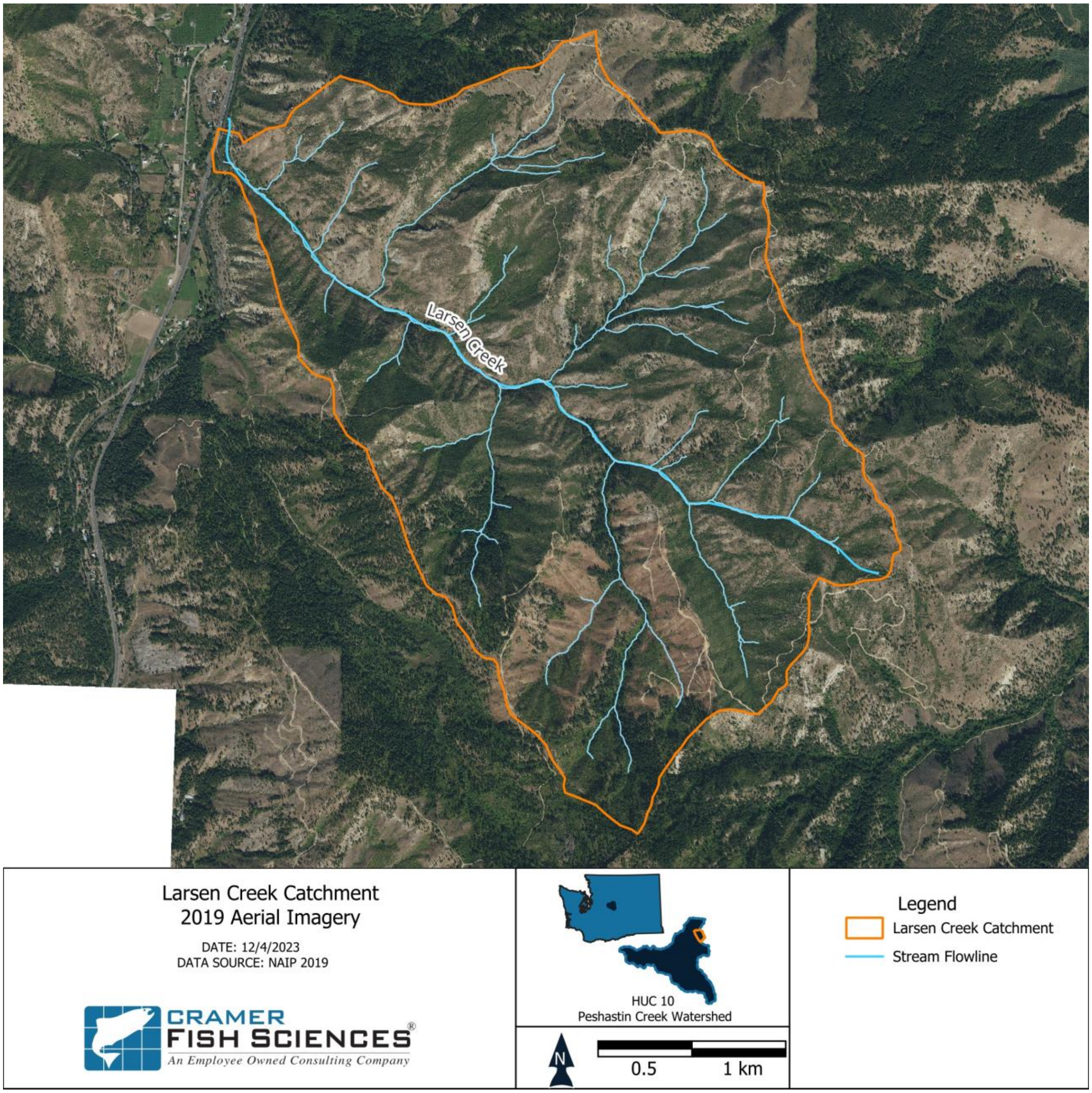

Figure 7. USGS NAIP imagery from 2019 for Larsen Creek catchment.

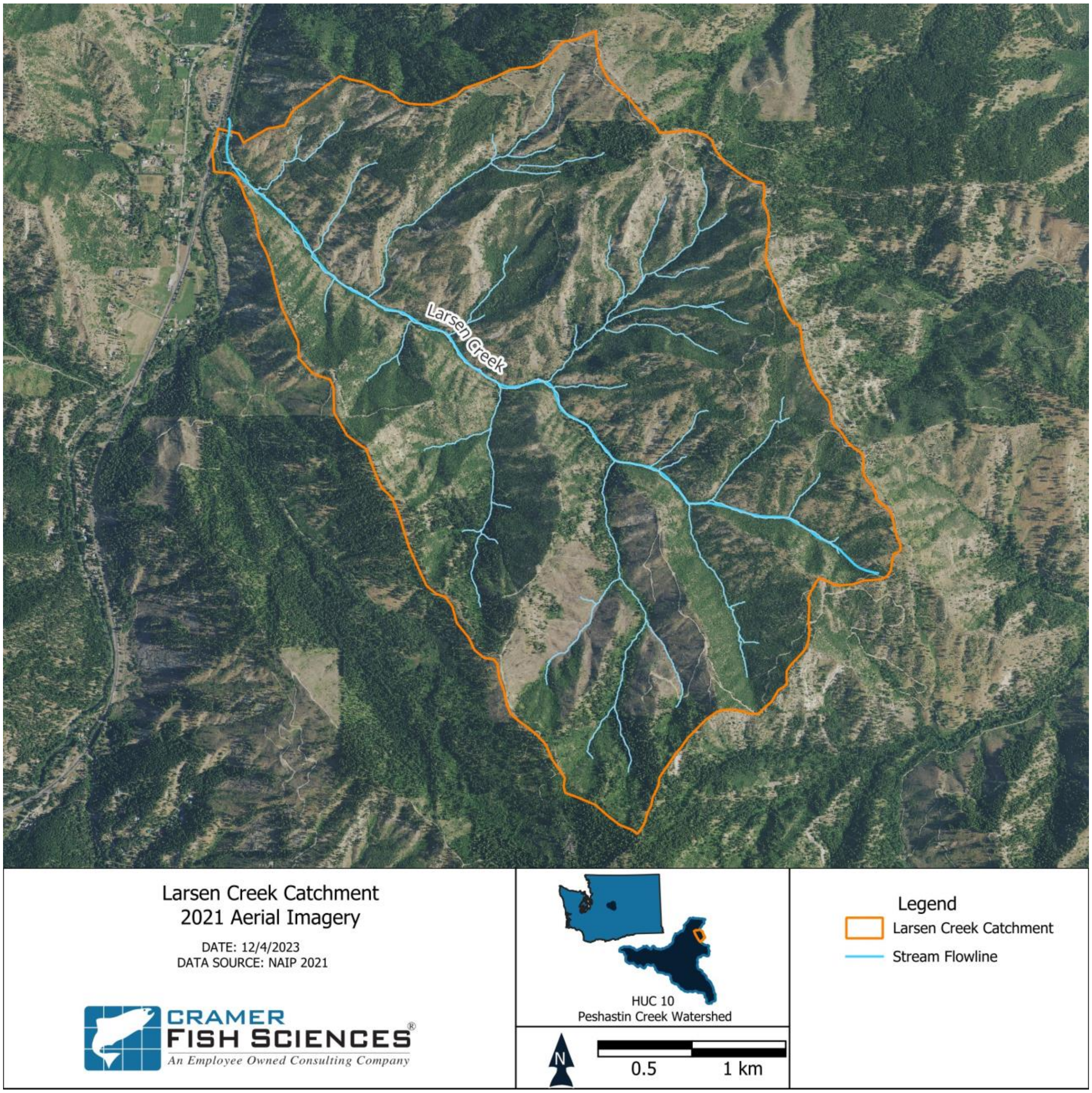

Figure 8. USGS NAIP imagery from 2021 for Larsen Creek catchment.

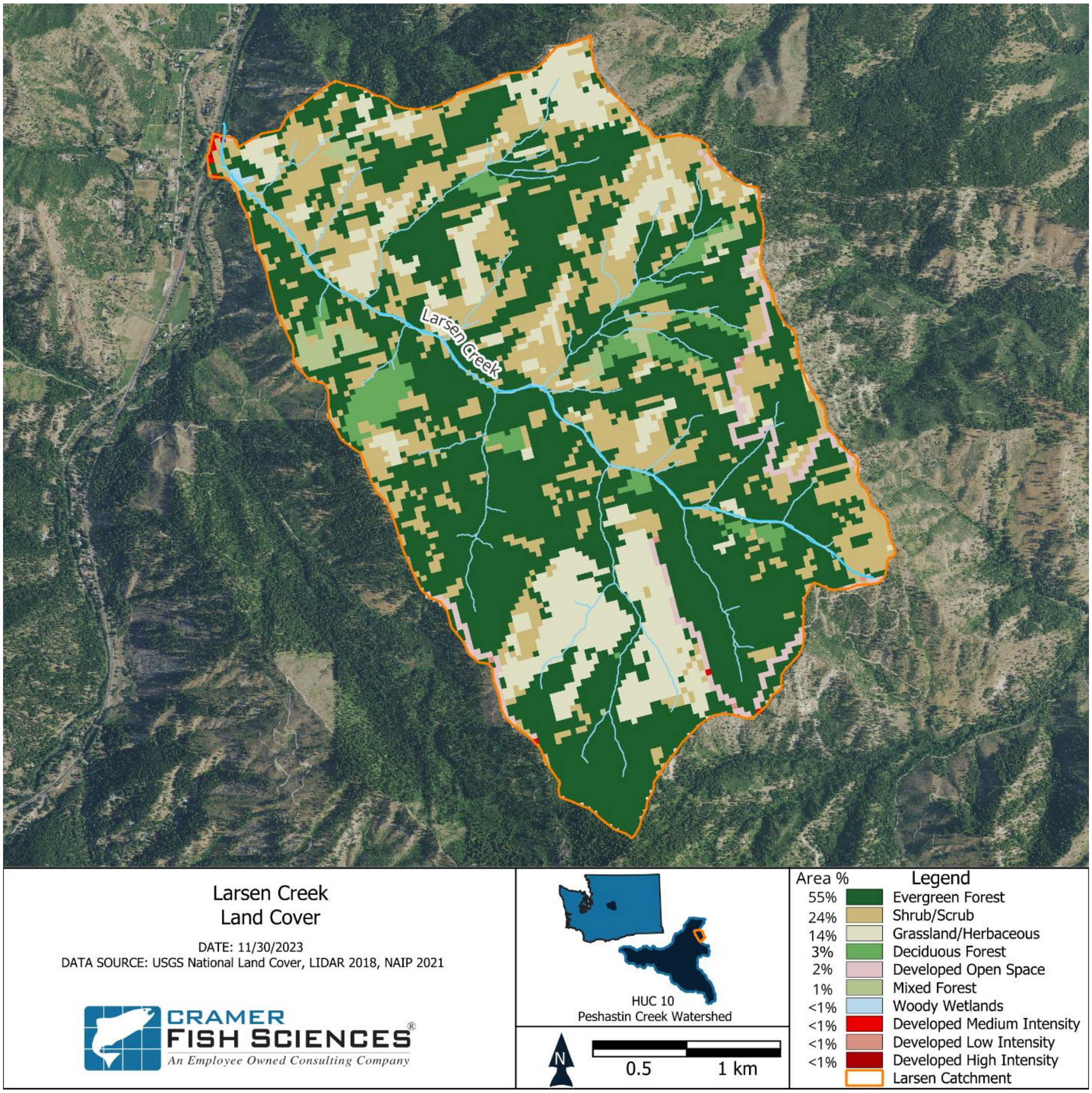

Figure 9. USGS National Land Cover for Larsen Creek catchment.

Geology and Soils

Surficial geology within the Larsen Creek catchment is relatively simple, dominated primarily by continental sedimentary rocks. Sedimentary deposits or rocks of the Chumstick Formation make up 88% of the geology within Larsen Creek catchment (Figure 10). Chumstick Formation is whitish to buff-gray and mostly consists of fine to medium grain feldspathic sandstone and pebbly sandstone of fluvial origin (Gresens et al., 1981). Formed approximately 45 mya, the Chumstick Formation was created through fluvial and lacustrine deposits during a period of high tectonic activity in the region (Evans 1991a, 1991b). The resulting landscape is dominated by exposed rocky outcrops, and shallow soils with greater soil depth concentrated within small ephemeral drainages. Alluvium makes up 7% of the catchment, which is a general term for unconsolidated silt, sand, and gravel deposited in recent geologic time by streams (Huntting et al., 1961). The project area is almost entirely within the alluvium geology layer and is reflected on the ground as mostly silt, sand, and small gravel pockets that make up the substrate and soils within the channel and floodplain. Mass-wasting deposits make up 5% of the catchment. These are deposits from fallen rock and soil that occur when a slope is too steep to remain stable with existing material and conditions (NPS 2019). The natural high rate of surface erosion of sandstone is increased due to mass wasting and can lead to high sedimentation in the watershed. Mafic intrusive rocks comprise <1% of the area from the Camas Land Diabase Formation. Intrusive igneous rocks solidify from magma within the earth and are characterized by large crystal sizes due to slow cooling rates (NPS 2022). Mafic is a dark colored igneous rock that has high magnesium and iron and low silica. Specifically, the Camas Land Diabase Formation consists of dark colored diabase with lesser gabbro (Easterbrook and Macdonald 2017).

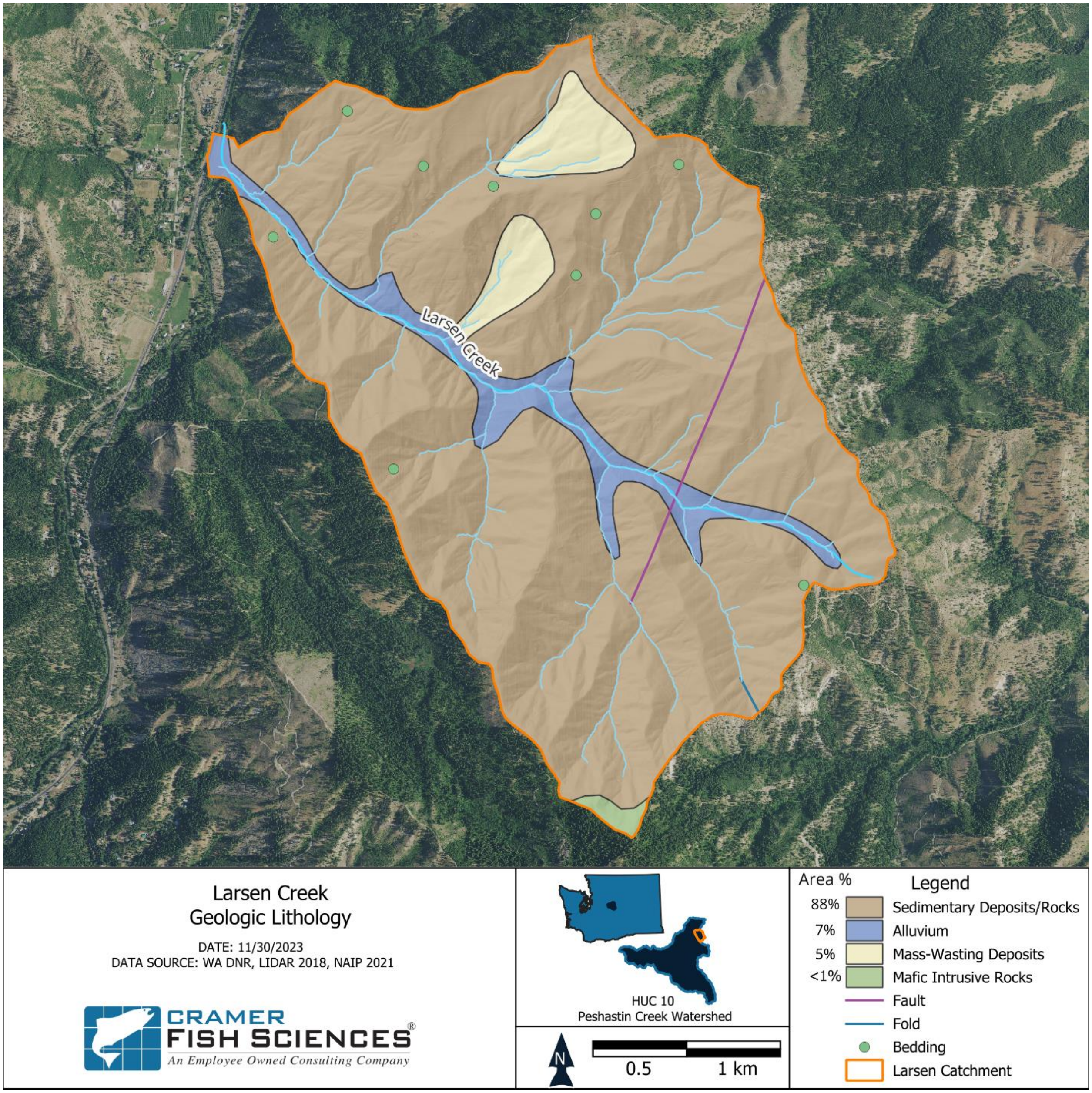

Figure 10. Washington Department of Natural Resources (WDNR) surface geology for Larsen Creek catchment.

The surface layer of Larsen Creek catchment is made of rock outcrops and a variety of soil types. Alfisols make up 57% of the soil composition within Larsen Creek catchment (Figure 11). The Alfisol soil types (Cle Elum, Nard, and Varelum) are well draining soils from the suborder group Xeralfs, which has a xeric soil moisture regime and are typically associated with coniferous forests in cool moist climates (Soil Survey Staff 1999). Cle Elum and Nard both make up about 45% of the Alfisol soil types in the catchment. Cle Elum soil horizons within the catchment are dominated by loam to a depth of 14 inches, sandy clay loam between 14 and 29 inches, and clay loam between 29 and 36 inches (Soil Survey Staff 2023). Whereas Nard soil horizons are dominated with ashy loam to a depth of 24 inches and clay loam between 24 and 60 inches. Rock outcrops, which contain little to no soil and are large expanses of exposed sandstone, make up

23% of the catchment. Inceptisols, from the Blag soil type, make up 20% of the soil composition. Blag are shallow, well drained soils that have a soil horizon dominated by gravelly sandy loam to a depth of 16 inches (Soil Survey Staff 2023). The remaining <1% of soil within the catchment is Mollisols from the soil type Mippon and is located near the confluence with Peshastin Creek and is unlikely to influence the project area.

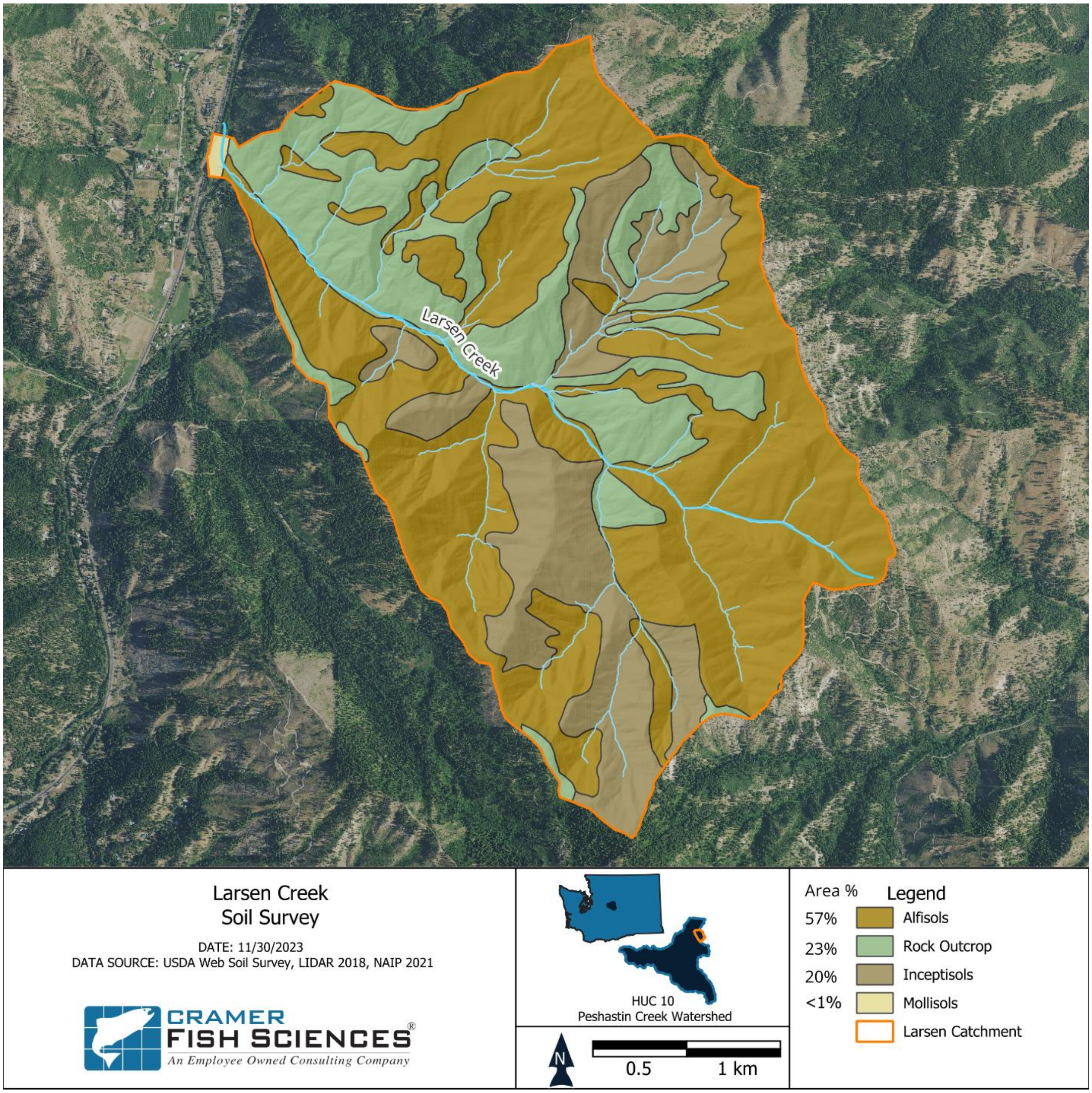

Figure 11. U.S. Department of Agriculture (USDA) Web Soil Survey for Larsen Creek catchment.

BIOLOGICAL ASSESSMENT

Activities such as timber harvest, roads, mining, irrigation diversions, and urban development have affected fish habitat in the lower Peshastin watershed. Mining in Peshastin watershed began around 1860 with the discovery of gold, and was expanded to quartz in 1874 (USFS 1999; Andonaegui 2001). There have also been reports of silver, copper, nickel, iron, chromite, zinc, lead, tungsten, mercury, and arsenic in the watershed. Placer mining was extensive throughout Peshastin Creek, which affected sedimentation, substrate changes, woody debris, and riparian vegetation (USFS 1999). The road density for the lower Peshastin watershed is 3.0 km of roads/km^2 which is lower than the road density for the entire Peshastin watershed at 3.9 km of roads/km^2 (USFS 1999; USFS 2003). The land use impacts across streams within the lower Peshastin watershed is not well known (USFS 1999).

Although frequent, low intensity fires were a natural component of the Peshastin watershed and can help maintain the evergreen forest community, high intensity fires have caused portions of the watershed to be severely burned (USFS 1999). Larsen Creek, an intermittent stream in the lower Peshastin watershed, was impacted during a severe fire in 1994. The catchment was subsequently salvage logged due to the fire damage. The effects of the fire decreased the water quality. Sedimentation and temperature increased due to tree removal especially in the riparian area. In 2003, the downstream section of Larsen Creek was included on the state’s 303(d) list of impaired waters due to water quality violations for temperature (Schneider and Anderson 2007; WA WQA 2023). Additionally, there was a mass failure in the watershed which transported a large amount of sediment into Peshastin Creek during a winter flood in 1996. Reduced riparian vegetation limits the availability of wood recruitment into the stream which resulted in reduced fish habitat and large woody debris. Larson Creek, regardless of fire impacts, is a high sediment transport stream. High flow events in the headwaters of Larsen Creek scour the stream and transport debris and fine sediment that were temporarily stored in the catchment. Additionally, there is a lack of large woody debris in Larsen Creek due to the high transport capacity of the system. A survey conducted in Larsen Creek determined that the dominant substrate was sand and that there were only 4 pieces of large wood per 1.6 km (Table 1).

Table 1. USFS 1999 Larsen Creek survey results.

Variable	Survey Results
Avg Bankfull Width (m)	2.96
Pool/Riffle Ratio	12.5:86.5
Dominant Substate	Sand
Subdominant Substrate	Cobble
LWD/1.6 km	4

Although there are many fish passage barriers throughout the Peshastin watershed, most of the barriers are located upstream of Larsen Creek catchment (Figure 12). However, the Peshastin Irrigation District (PID) diversion is located downstream. There are 16 dams and diversions throughout the Peshastin watershed but only 3 downstream of Larsen Creek with one of them being the PID diversion. The PID diversion was built in 1898 and can act as a barrier for migrating salmonids (Andonaegui 2001; NPCC 2004). The PID diverts up to 1.4 cms from

Peshastin Creek during late summer and can cause discharges to drop below 0.28 cms (Anchor QEA 2012). An instream flow analysis determined that migrating fish need 0.79–1.16 cms for adequate passage, which causes the PID diversions to be specifically limiting for summer and fall fish spawning migrations when flows are lowest (Andonaegui 2001; NPCC 2004; Anchor QEA 2012). A feasibility study is currently underway to assess options for improving instream flows below the PID diversion (Anchor QEA 2012). Although there are 95 culverts, 33 road crossings, and 12 natural barriers in the Peshastin watershed, these structures are either upstream or do not act as fish passage barriers to Larsen Creek. The downstream crossing on Larsen Creek was a fish passage barrier until it was modified in 2018 and it is now considered 100% passable.

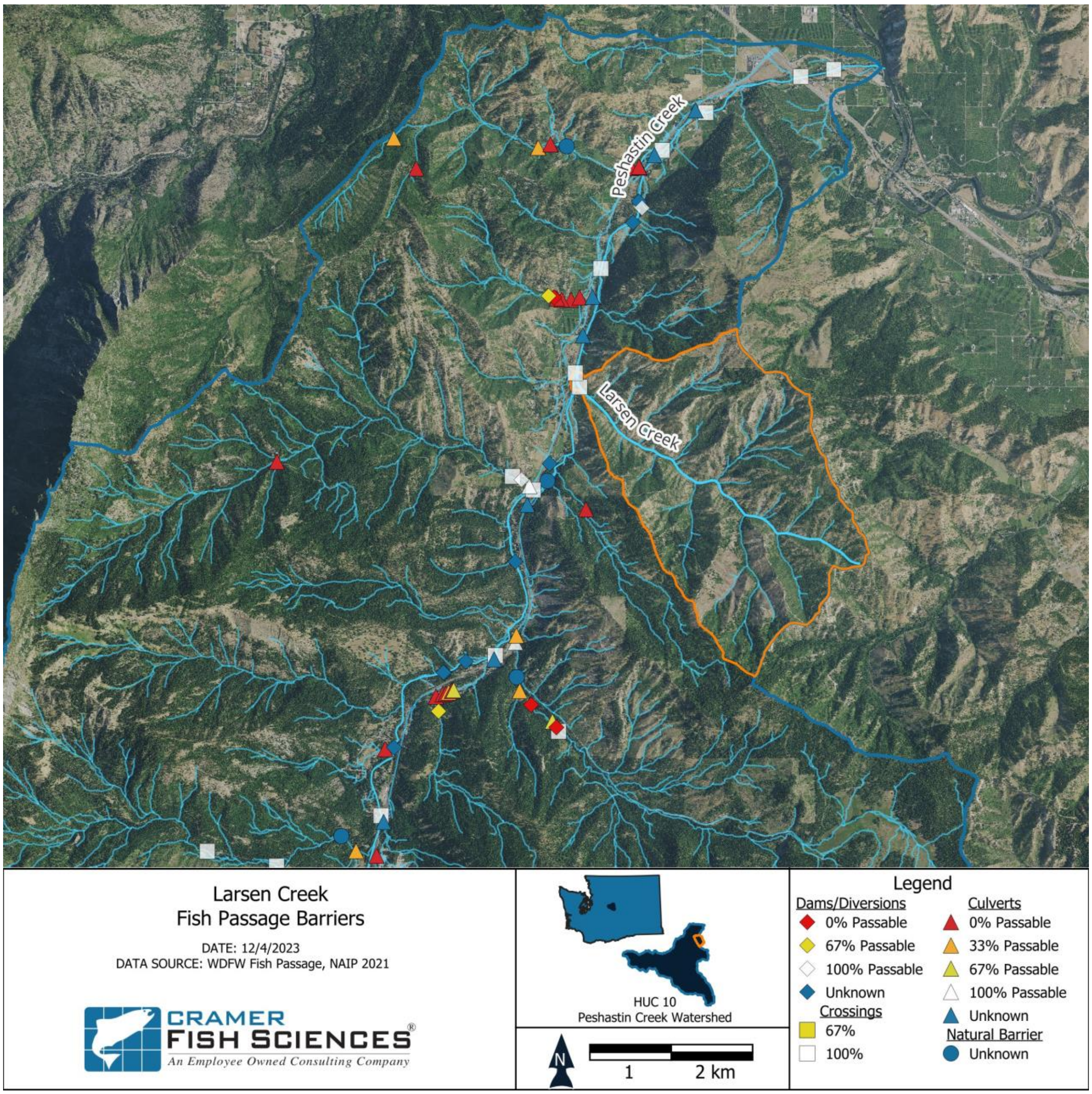

Figure 12. Washington Department of Fish and Wildlife (WDFW) fish passage barriers within Larsen Creek Catchment.

Steelhead Occurrence in Project Area

There is limited information about the fish community in Larsen Creek but there is some information about the fish community in Peshastin Creek. Peshastin Creek has populations of rainbow trout (*Oncorhynchus mykiss*), redband trout (nonmigratory; *O. mykiss gairdneri*), and summer steelhead (anadromous; *O. mykiss irideus*). The Upper Columbia steelhead was listed as endangered in 1999 but was changed to threatened in 2009 (74 FR 42605). According to the Upper Columbia Salmon Recovery Board (UCSRB 2007), Peshastin Creek is a major spawning area for summer steelhead and redds have been observed throughout the watershed. The UCSRB was established to restore salmonid populations and is a partnership among Chelan, Douglas, and Okanogan counties, the Yakama Nation, and Colville Confederated Tribes. The UCSRB designated Peshastin Creek a Category 2 watershed with 3 significant subbasins including the lower Peshastin. From 1949–1999, there were 12 million rainbow trout (nonanadromous; *O. mykiss*) and summer steelhead from 15 different origins introduced within the Columbia River basin, including in Peshastin Creek until 1990 (USFS 1999). Based on a passive integrated transponder (PIT) tag study by Waterhouse et al., (2020) there was a mean estimate of 150 wild summer steelhead that migrated to Peshastin Creek in 2016 for spawning. Spawning surveys in the Wenatchee basin by WDFW from 2004 – 2012 found that 12.2% of redds were surveyed in Peshastin Creek, with the majority between RM 3 – 6.5 (Juelson and Soden 2012). Historically, rainbow trout within Peshastin Creek were all inland redband trout and coastal steelhead (USFS 1999). Introduced non-native steelhead are a threat to the native redband trout, which have drastically declined due to hatchery introgression, hybridization, fishing pressure, and loss of habitat (USFS 1999). Steelhead migrate to the Wenatchee River between July–October and reside there or in reservoirs until the following spring (Table 2; USFS 1999; UCSRB 2007). Some individuals will spawn in the Wenatchee River and others will migrate to smaller tributaries for spawning between March–June. Fry emergence depends on water temperature but occurs from late spring–August. Juveniles will spend 1–3 years rearing in freshwater before migrating to the ocean where they will stay for 1–2 years until returning to freshwater for spawning.

Additional Species Occurrence in Larsen Creek

Spring Chinook salmon (*O. tshawytscha*), bull trout (*Salvelinus confluentus*), westslope cutthroat trout (*O. clarkia lewisi*), sculpins (*Cottus* spp), dace (*Rhinichthys* spp), whitefish (*Prosopium* spp), and redside shiners (*Richardsonius balteatus*) use the lower Peshastin subbasin and could possibly use Larsen Creek (USFS 1999; NPCC 2004; UCSRB 2007). The Upper Columbia spring Chinook salmon was listed as endangered and bull trout was listed as threatened in 1999 (64 FR 14308; 64 FR 58910). Peshastin Creek is a minor spawning stream for spring Chinook salmon and from 2001–2005 the USFWS and Yakama Nation stocked adult spring Chinook into Peshastin Creek (UCSRB 2007). In 2004, there were 66,395 subyearling spring Chinook estimated in Peshastin Creek but few yearling Chinook captured, indicating that Peshastin Creek does not have quality over wintering habitat (Cooper and Mallas 2004). All three forms of bull trout (resident, fluvial, adfluvial) occur in the Wenatchee River and could possibly occur in the Peshastin watershed (UCSRB 2007). A small population of stream-resident bull trout occur in two tributaries of Peshastin Creek (i.e., Ingalls and Ettienne Creeks) and mostly use the mainstem for migration (USFWS 2002). Bull trout could use other tributaries in the watershed opportunistically depending on temperature for overwintering and rearing (Juelson and Soden

2012). Westslope cutthroat trout compete with the high abundance of rainbow trout in the lower Peshastin which could push their population farther upstream in the Peshastin watershed. Additionally, the decreased water quality could reduce or prevent populations of bull trout, spring Chinook salmon, and westslope cutthroat trout from occupying Larsen Creek. Coho salmon were thought to be extirpated from the Peshastin Creek watershed after the 1940's, but spawning was documented in the lower Peshastin Creek in 2003 (USFS 1999; NPCC 2004). Pacific lamprey (*Lampetra tridentata*) have been observed in the lower Wenatchee River and could possibly occupy portions of the lower Peshastin Creek (NPCC 2004). Additionally, invasive brook trout (*S. fontinalis*) have been observed in Peshastin Creek (Andonaegui 2001).

Although spawning is unknown for salmonids in Larsen Creek, there is some known spawning information for the Wenatchee River basin. Spring Chinook migrate from the ocean into Wenatchee River from May–July (Table 2; USFS 1999; UCSRB 2007). Some individuals spawn in the Wenatchee River in August but most migrate to tributaries to spawn in September. Their eggs will hatch December–January, fry will emerge late March–early May. Juveniles will rear for 1–2 years before migrating to the ocean in late fall or the following spring and will return to freshwater for spawning after 2–3 years in the ocean. Resident bull trout will complete their entire life cycle in their natal stream, whereas migrating bull trout will spawn in streams and juveniles will rear there until they migrate to either a lake (adfluvial) or a mainstem river (fluvial). Bull trout will typically migrate upstream for spawning from July–September and will spawn from September–early November (USFS 1999; UCSRB 2007). Juveniles will migrate downstream after 2–3 years and will reach sexual maturity in 4–7 years. Westslope cutthroat trout have three life history strategies, individuals can either migrate from lakes to streams, from larger rivers to tributaries, or be non-migratory. Individuals that migrate from lakes to streams for spawning will spawn March–July (USFS 1999). Juveniles will spend 2–3 years in the stream before migrating to the lake and will become sexually mature after 1–3 years in the lake. Migratory river fish that spawn in tributaries will usually return to the mainstem river shortly after spawning. Coho salmon migrate to the Wenatchee River in early September–late November for spawning (NPCC 2004).

Table 2. Periodicity for steelhead and other salmonids within Peshastin River basin and the Wenatchee River.

Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Summer Steelhead prespawn migration[1,2]							■	■	■	■		
Summer Steelhead spawning[1,2]			■	■	■	■						
Summer Steelhead fry emergence[1,2]					■	■	■	■				
Spring Chinook prespawn migration[1,2]					■	■	■					
Spring Chinook spawning[1,2]								■	■			
Bull Trout prespawn Migration[1,2]							■	■	■			
Bull Trout Spawning[1,2]									■	■	■	
Westslope Cutthroat Trout (adfluvial) spawning[1]			■	■	■	■	■					
Coho Salmon prespawn migration[3]									■	■	■	

[1]USFS 1999; [2]UCSRB 2007; [3]NPCC 2004

Limiting Factors

Although there is limited information about Larsen Creek, some habitat limitations are known. The natural high sediment transport rates throughout Larsen Creek catchment were exaserbated by the affects of the 1994 fire. The reduction in trees and vegetation throughout the catchment has increased the runoff and sedimentation rates of Larsen Creek. Sedimentation in Larsen Creek will continue to be a problem unless structural elements are constructed to slow sediment transport. Additionally, the lack of riparian vegetation and trees throughout the catchment cause increased stream temperature. The impaired water quality, such as high temperatures and sediment in Larsen Creek could act as a migration barrier for many salmonid species like spring Chinook salmon, bull trout and westslope cutthroat trout (USFS 1999). The PID diversion located downstream also reduces migration for late summer and early fall spawning salmonids (USFS 1999; Andonaegui 2001). Due to the high transport capacity of the system and the loss of trees in the catchment, there is minimal large woody debris in the stream channel. Restoration projects to restore Larsen Creek habitat and salmonid populations need to reduce sedimentation and restore the riparian vegetation to provide stream shading and improve future large wood recruitment (Andonaegui 2001; NPCC 2004; UCSRB 2007).

METHODS

Field Based Design

On September 14th, 2023, we conducted the field-based portion of the LTPBR design for the project area on Larsen Creek. We began upstream of the bridge on the Freimuth property and designed structures while moving upstream. We used the GIS Touch app on a tablet with a Bluetooth map grade GPS to mark and describe structure locations. GIS Touch also contained base layers for imagery, topography, the stream network, Geomorphic Grade Line analysis (GGL) results, and the Relative Elevation Model (REM) to aid the design process.

Structure locations were chosen based on opportunities to improve local site conditions, improve fluvial processes, and contribute to complex objectives. Structure types were chosen based on the hydraulic and geomorphic modifications needed to target the opportunity (see Appendix A for typical structure schematics). For example, a BDA may be used where the channel slope is low, and the floodplain is accessible. Alternatively, PAS may be used to capture sediment and aggrade an incised channel. Each structure location was attributed with the structure type, general description, objective, and an estimate of materials (wood and posts) needed for construction. Because BDAs create a ponded area upstream, they are best used in areas where the floodplain is accessible to inundate as much area as possible. When conditions are suitable, BDAs are also a great tool for trapping sediment to rapidly aggrade stream channels.

Long Profile Survey

During the field-based design, on September 14th, 2023 we also completed several long profile surveys to capture streambed gradient, recording elevation at each inflection point. The long profile data gathered in the field was used to supplement remote sensing data and provided additional insight into fluvial processes at a finer scale than the current LiDAR can provide. At each point, bankfull width, wetted width, depth (if wetted), stream bed elevation, channel unit (if wetted), presence of large wood, and dominant substrate were recorded. The profile follows along the deepest portion of the stream, yielding a two-dimensional longitudinal profile of streambed elevation and bankfull width (Figure 13 - Figure 16).

Typically, in addition to inflection points, maximum pool depth, pool head, and riffle crests would be used as sample locations. During our survey of Larsen Creek, much of the surveyed channel length was dry and pools were not present, however we created points at locations we estimated would be the maximum pool depth, pool head, and riffle crest for each potential pool location.

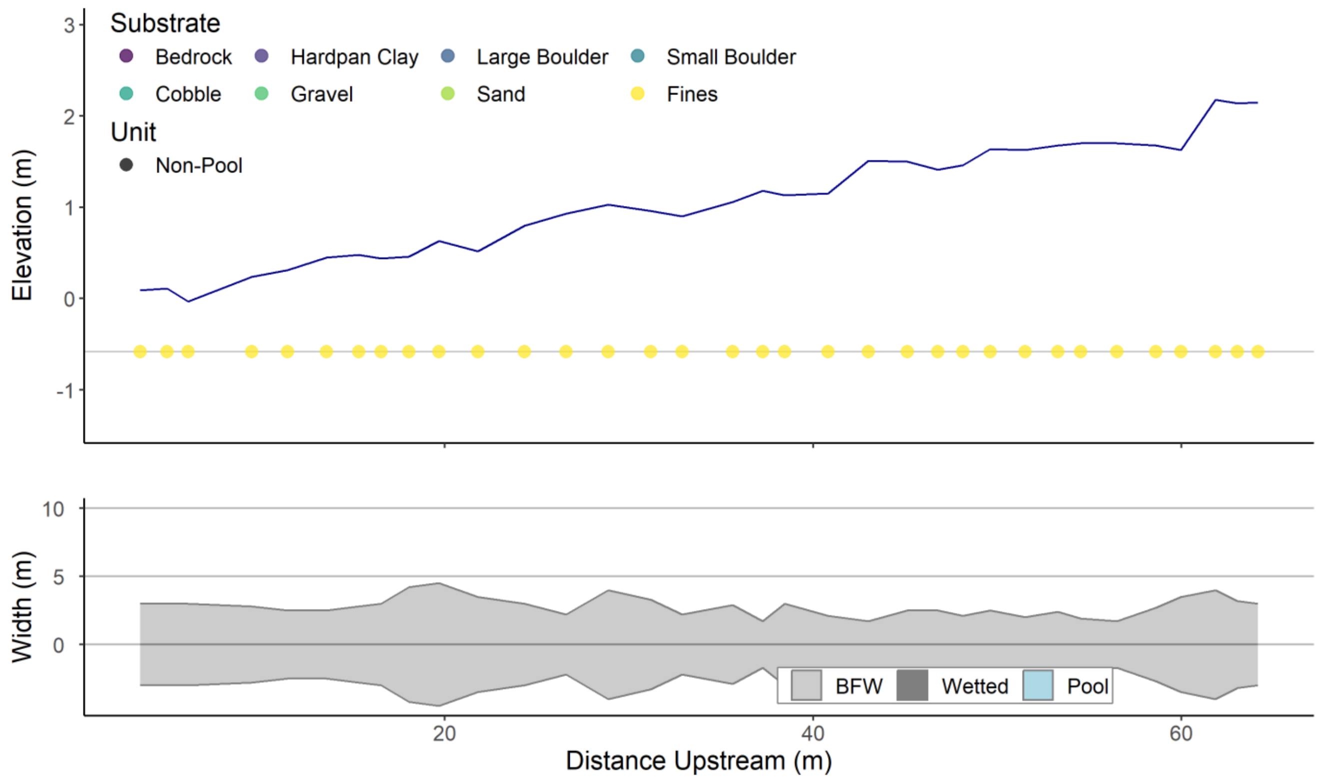

Figure 13. Long profile survey results in Complex 1 of Larsen Creek.

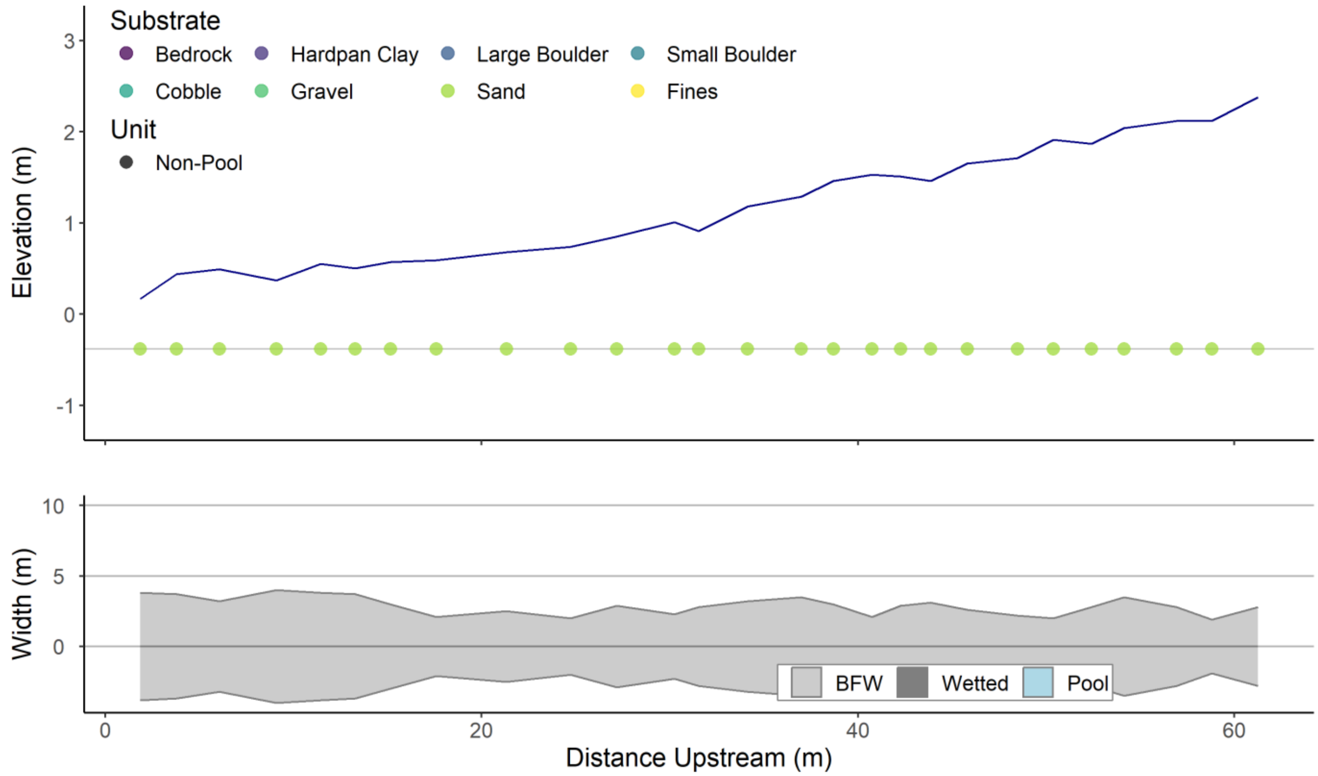

Figure 14. Long profile survey results in Complex 2 of Larsen Creek.

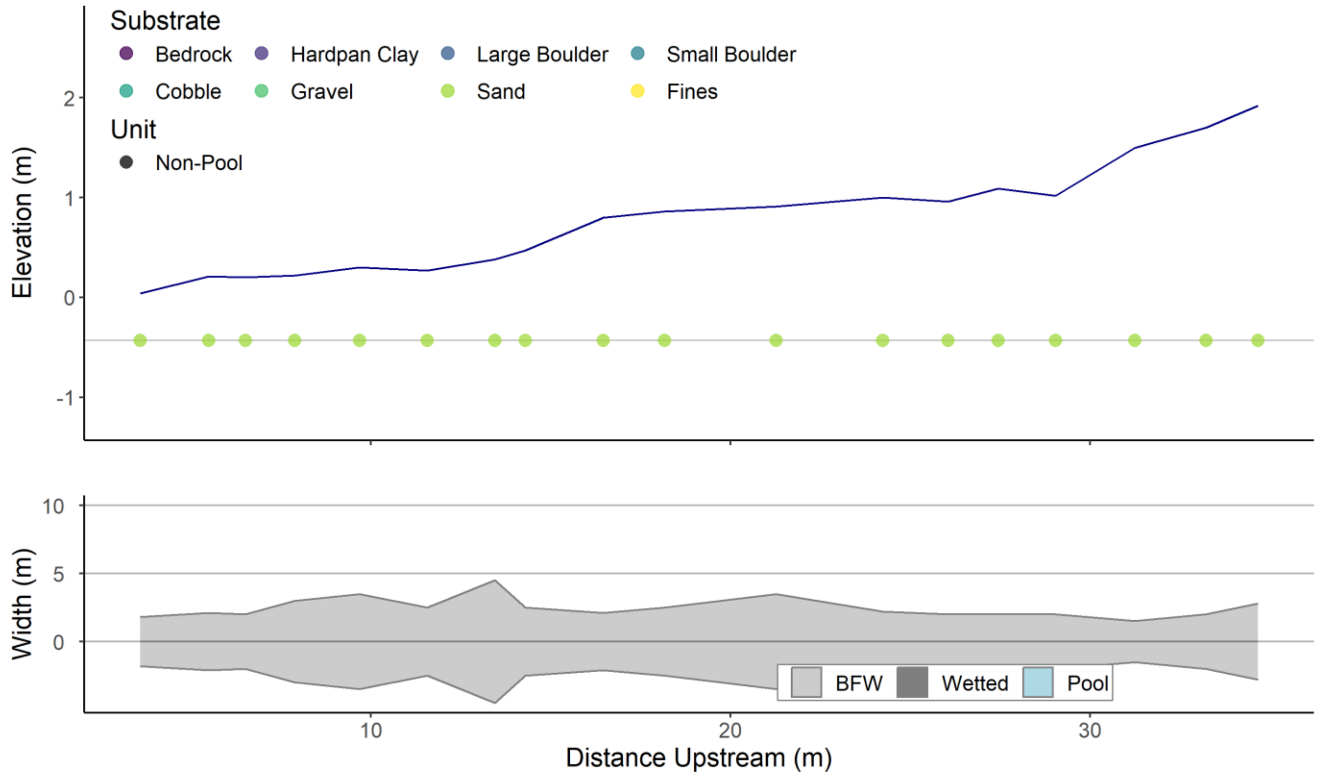

Figure 15. Long profile survey results in Complex 3 of Larsen Creek.

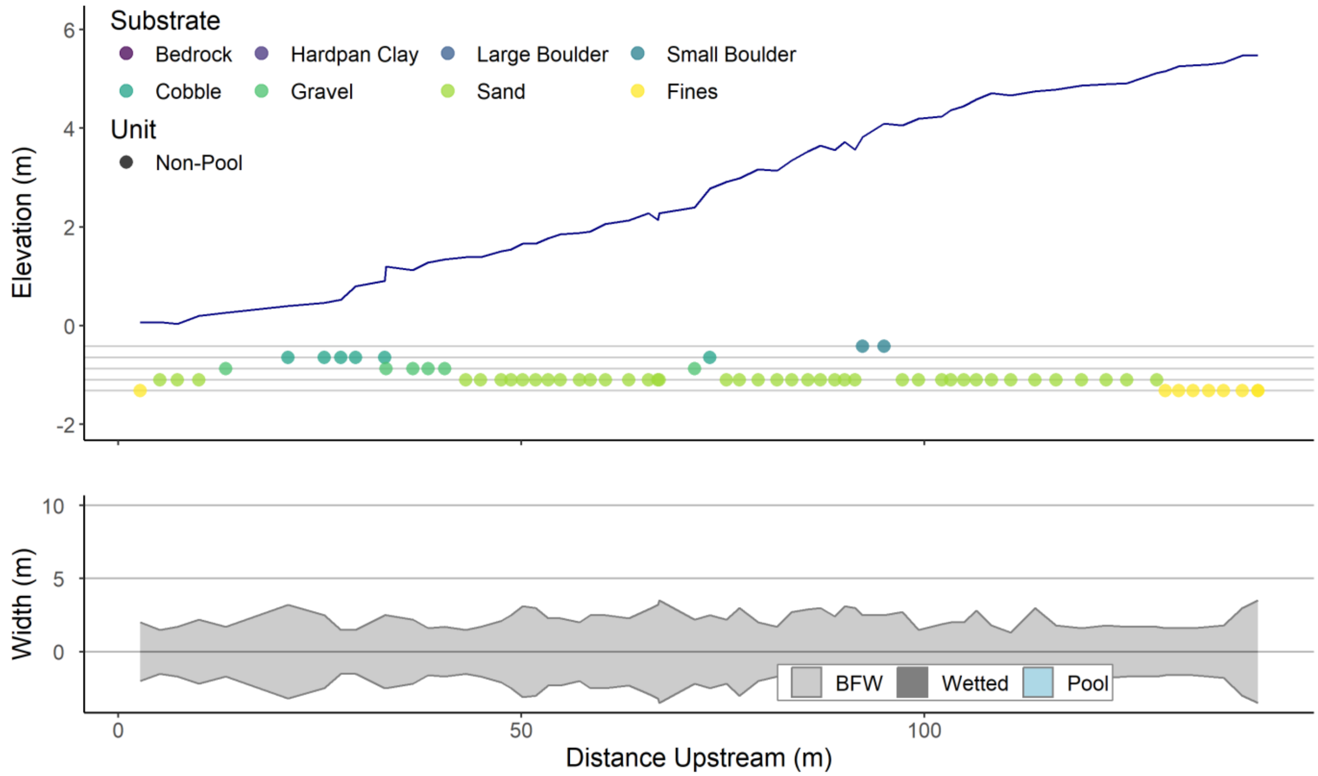

Figure 16. Long profile survey results in Complex 5 of Larsen Creek.

GIS Based Design

LTPBR designs are primarily conducted in the field to ensure the design is suited to current and local site conditions. However, GIS data and analysis can be used to inform a LTPBR design by providing high level information that is difficult to glean while in the field. To aid in the planning and design process, we first reviewed information and GIS data sources available from the Washington State Department of Natural Resources, Chelan County, and other public sources. We used LiDAR from 2018 to complete analyses and generate models, including a flow accumulation model, a 1-meter resolution main channel flowline, GGL results, and a REM. We used the GGL results to determine the magnitude of channel incision within the floodplain (Figure 17). We used the REM to highlight areas with low-lying floodplain and inform structure location and function (Figure 18). We also used the REM to generate bankfull and valley bottom polygons to provide additional lines of support for complex objectives.

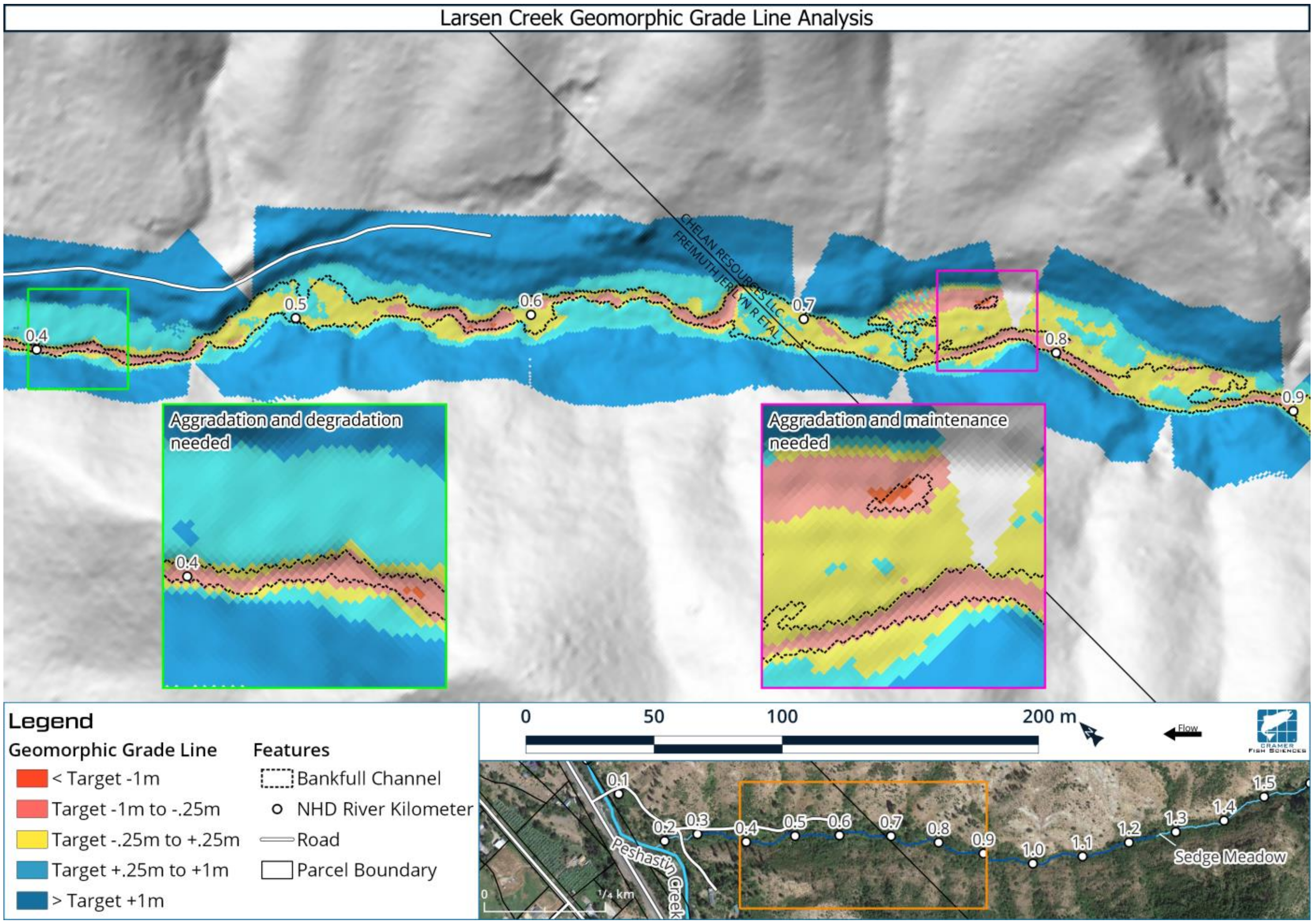

Figure 17. Example results of geomorphic grade line analysis (GGL) available for the project area on Larsen Creek. GGL highlights areas of cut and fill in the floodplain needed to bring the channel closer to quasi-equilibrium along the valley grade line. Blue indicates areas where degradation (cut) is needed and red indicates areas where aggradation (fill) is needed.

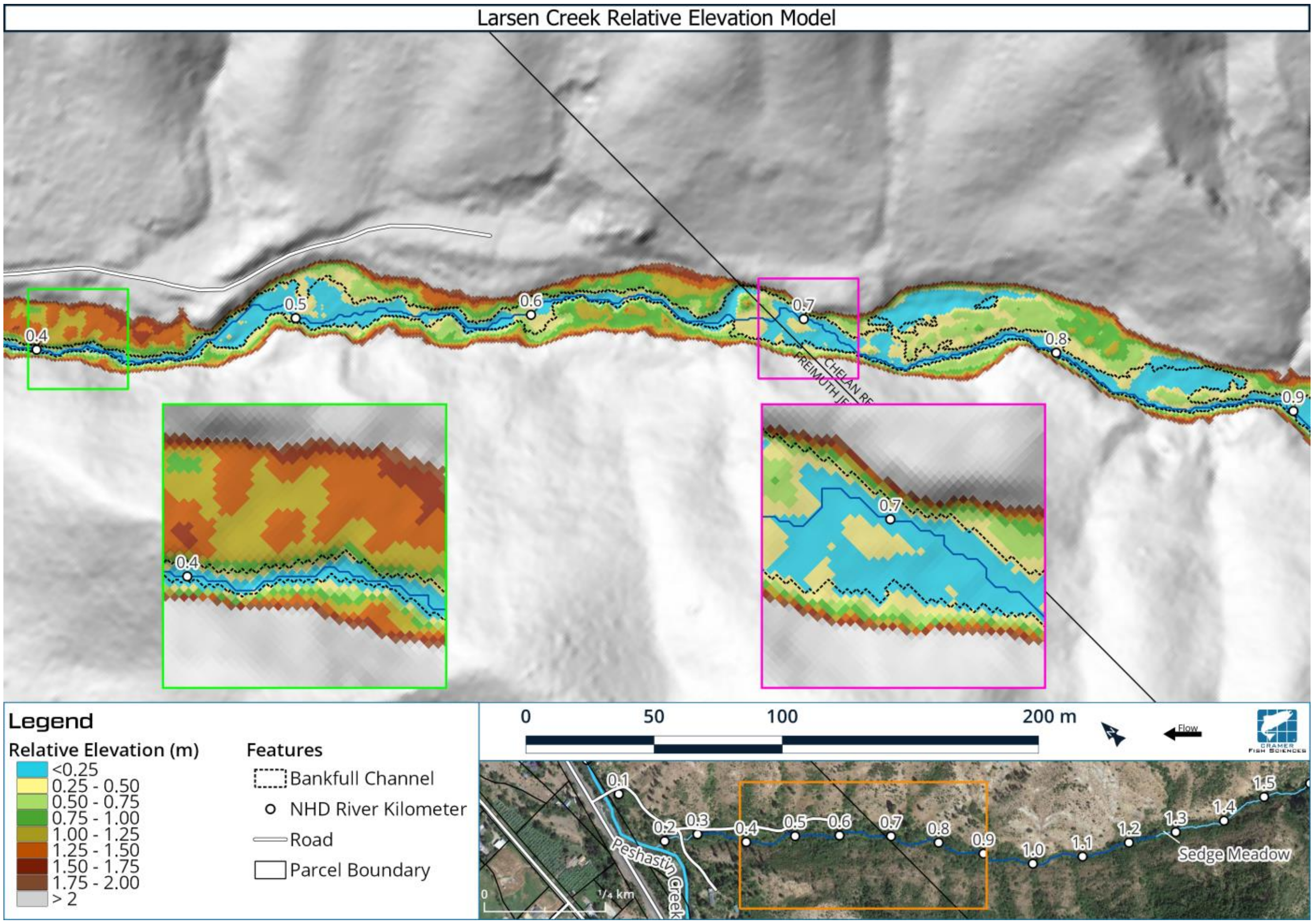

Figure 18. Example results from the Relative Elevation Model (REM) available for the project area on Larsen Creek. A REM highlights areas of low-lying floodplain and potential routes for reconnection.

COMPLEX OBJECTIVES

Every complex was assigned an overarching objective based on local site conditions and opportunities. We assigned a general objective to each complex: floodplain development and access, water and sediment retention, or incision recovery (Figure 19). Most complexes are expected to achieve more than one objective (e.g., structural elements usually increase complexity); therefore, the assigned objective represents the primary expected outcome of the treatment within that complex.

The Larsen Creek project area contains a variety of incision depths and floodplain widths. Most of the channel is incised and disconnected from the floodplain. The results from the GGL show that approximately 60% of the channel is incised more than 0.25 meters. While much of the channel is incised, many floodplain areas are in equilibrium with the GGL and will provide opportunities for ponding and lateral movement of flows. The GGL results within the sedge meadow near RM 0.8 reveal that both the channel and floodplain are above the geomorphic grade line by more than one meter. Quaternary mass wasting events in the headwaters of a small ephemeral tributary delivered fine and sandy sediment to Larsen Creek and contributed to the aggradation seen in the sedge meadow. Using the sedge meadow as a reference for what is desired and achievable in Larsen Creek, aggradation of the channel and floodplain should be the focus for much of the project area. Therefore, many actions within the project area are expected to work toward the overall goal of attaining an equilibrium with the geomorphic grade line through aggradation. Adding structural elements to each complex will help kick-start the recovery of hydrologic processes that create and maintain healthy river systems. A planting plan should be developed and implemented to support the objectives of each complex and take advantage of the expected increase in channel migration, water retention, and infiltration.

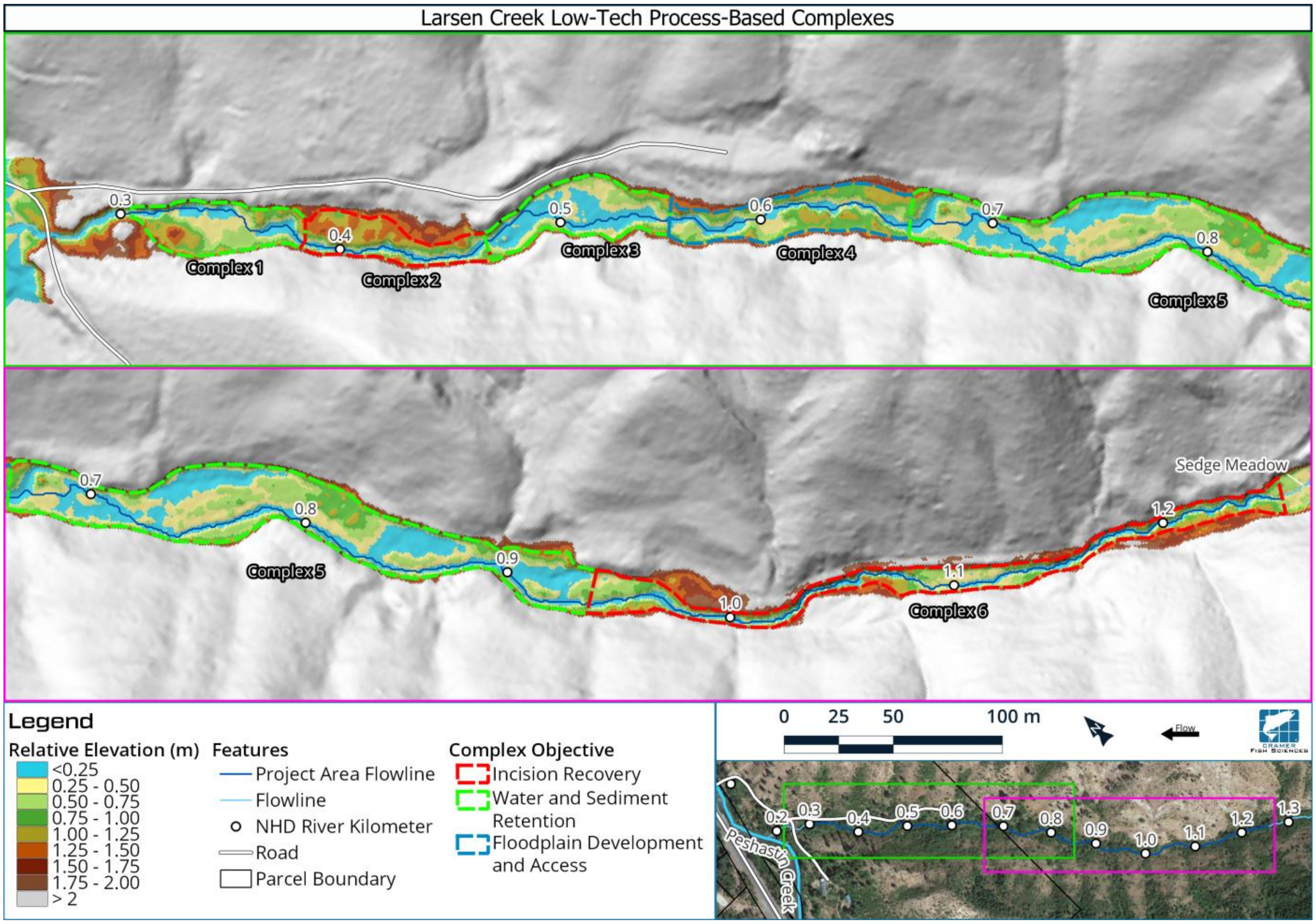

Figure 19. Locations of low-tech process-based complexes in Larsen Creek.

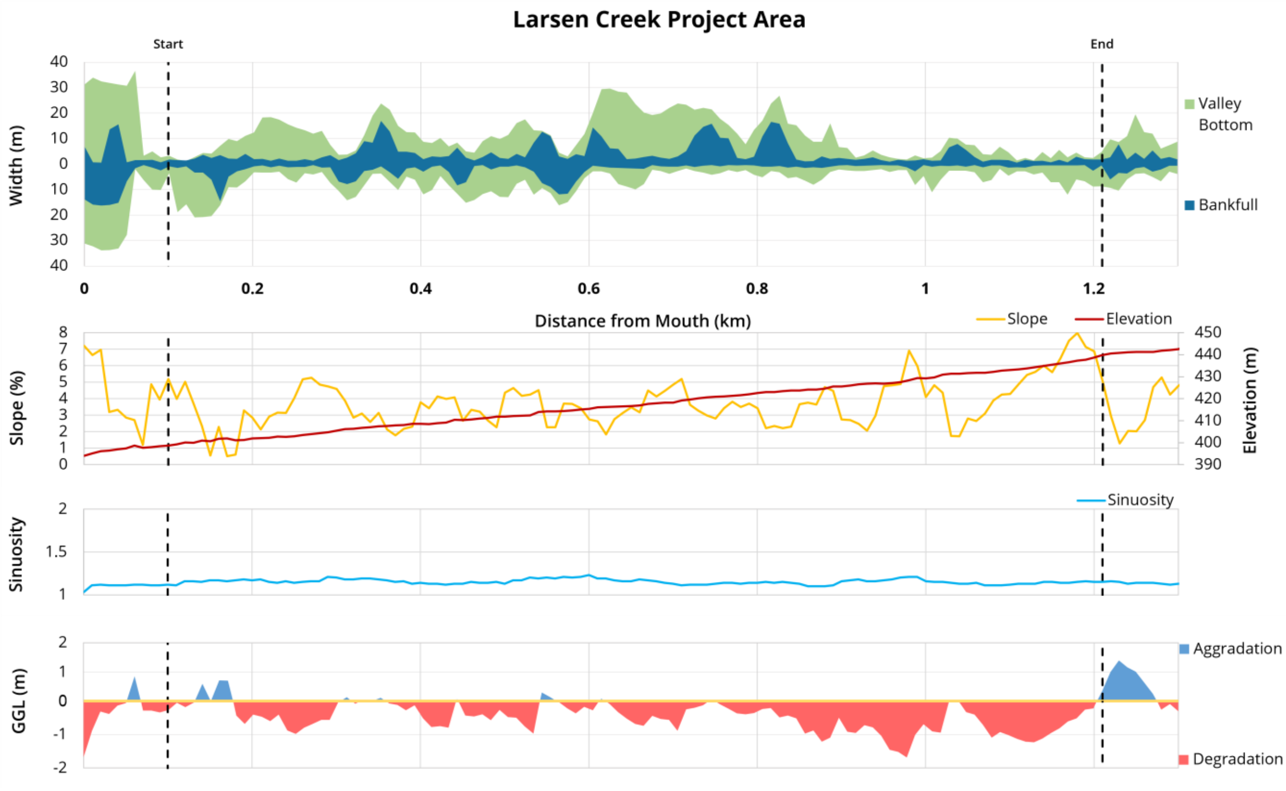

Figure 20. Long profile of geomorphic features and GGL results for the Larsen Creek project area.

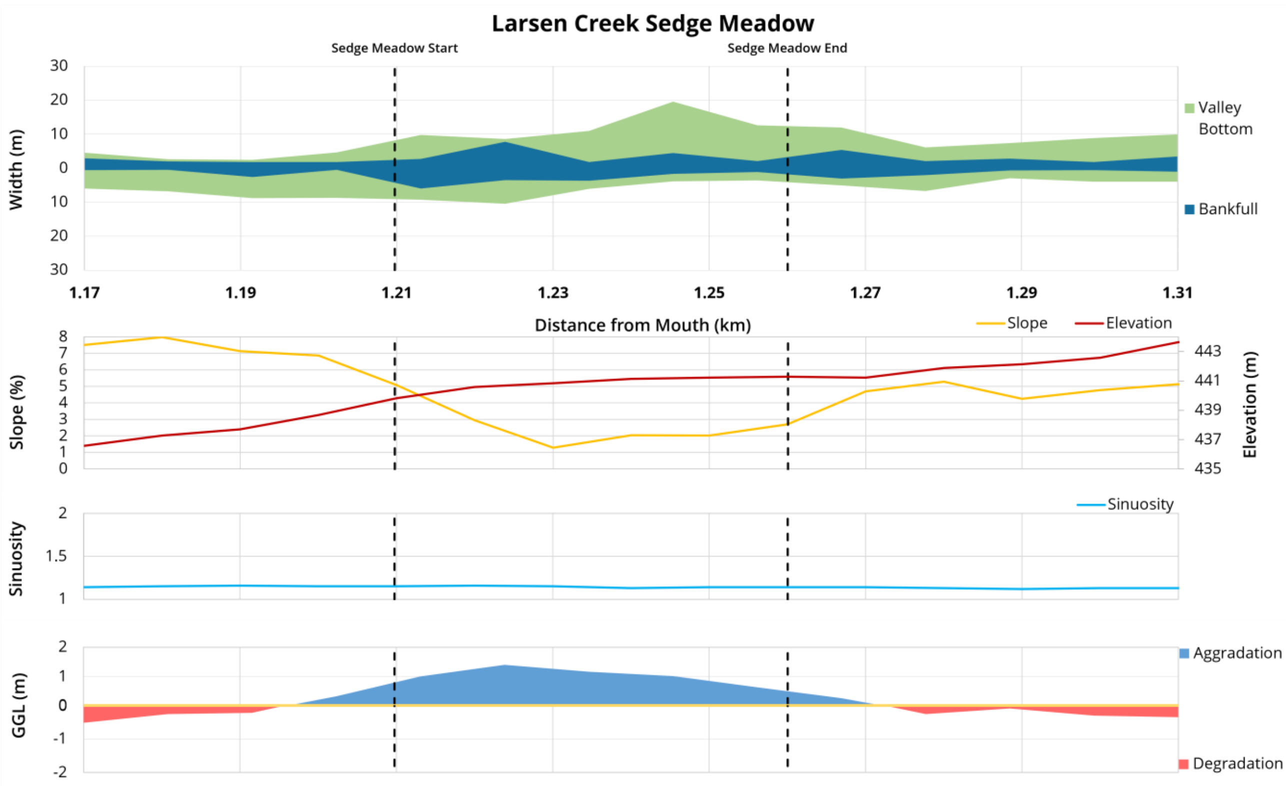

Figure 21. Long profile of geomorphic features and GGL results for Sedge Meadow on Larsen Creek.

Complex 1: Water and Sediment Retention

Complex 1 focuses on water and sediment retention. The center of Complex 1 contains an area of floodplain less than 0.5 meters above the channel. The channel in Complex 1 is incised at its upper and lower end but has aggraded in the center, providing opportunity for ponding. Complex 1 is well suited to target water and sediment retention since its channel maintains equilibrium with the geomorphic grade line along much of its length (Figure 22). We recommend BDAs and leaky dams as the main structures in this complex to inundate existing floodplain and capture sediment. We also recommend the installation of PAS throughout future ponded areas and overtop leaky dams to aid in sediment storing and slowing flows. The combination of these structures will develop pools and store sediment to continue aggradation and increase alluvial water storage.

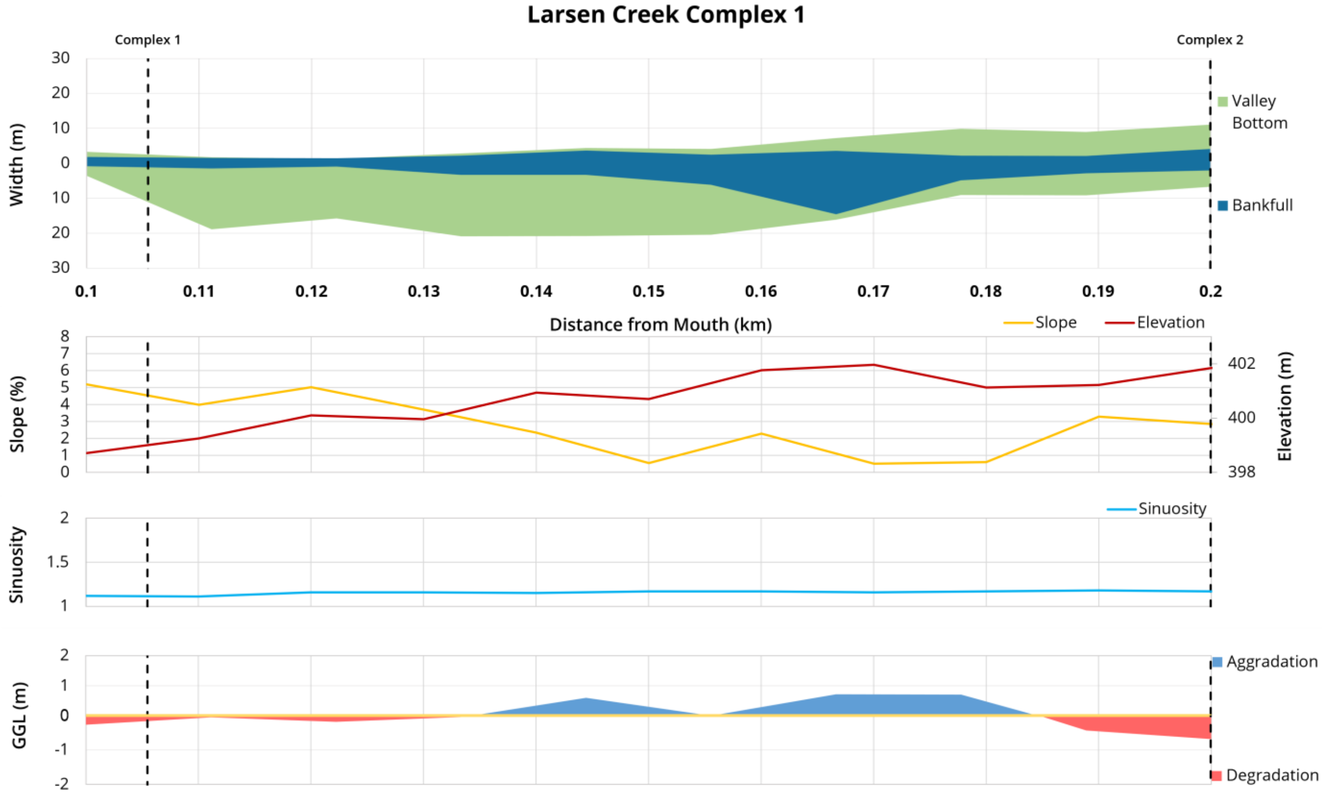

Figure 22. Long profile of geomorphic features and GGL results in Complex 1.

Complex 2: Incision Recovery

Complex 2 focuses on incision recovery. Based on field measurements and the REM, most of the floodplain in Complex 2 is situated more than 1 meter above the channel elevation, leaving little opportunity for immediate activation. The GGL results also show that the channel is consistently incised more than 0.25 meters below the geomorphic grade line (Figure 23). We recommend the installation of PAS throughout the complex to bolster existing debris piles and plug the channel. Long and continuous installations of PAS will aim to halt further incision and capture sediment to increase the streambed elevation. At the downstream end of Complex 2, the channel slope nears 2% and increases up to 5% in the upstream half. Using Sedge Meadows as a goal, the slope and level of aggradation of Sedge Meadows and Complex 2 differ greatly (Figure 21 &Figure 23). This comparison supports our recommend focus on incision recovery through streambed aggradation.

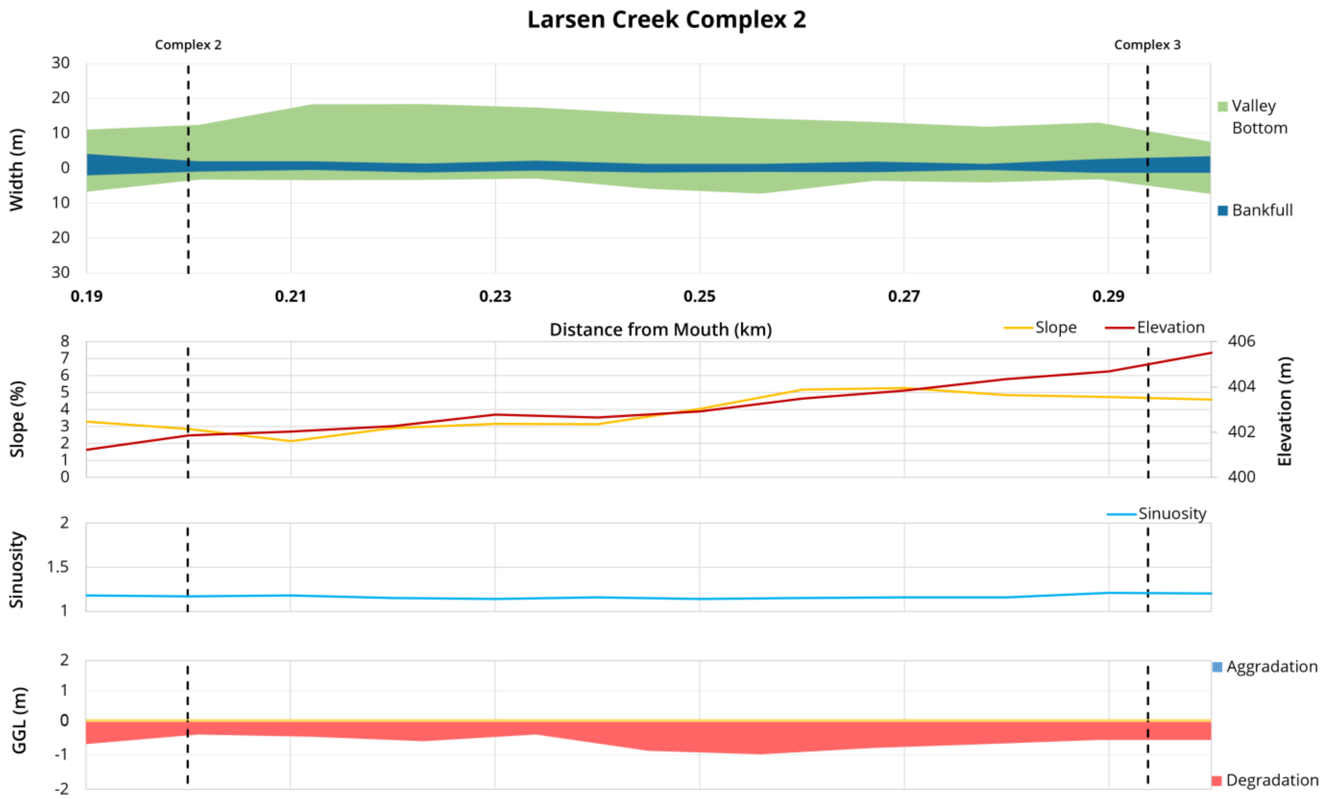

Figure 23. Long profile of geomorphic features and GGL results in Complex 2.

Complex 3: Water and Sediment Retention

Complex 3 focuses on water and sediment retention. During our survey of Larsen Creek, the channel in Complex 3 was often difficult to define. Regular flows likely spread laterally across the available and low-lying floodplain in many locations. The channel slope in this complex is near 3% and the channel and floodplain have attained equilibrium with the geomorphic grade line (Figure 24). The accessible floodplain and the lateral flows are likely attributable to this equilibrium. We recommend the use of BDAs as the dominant structure in Complex 3 to pond water and improve the connection with the eastern channel. Creating a series of ponds through Complex 3, in both the eastern and western channels, will promote lateral flows and work to improve the connection between both sides of the floodplain.

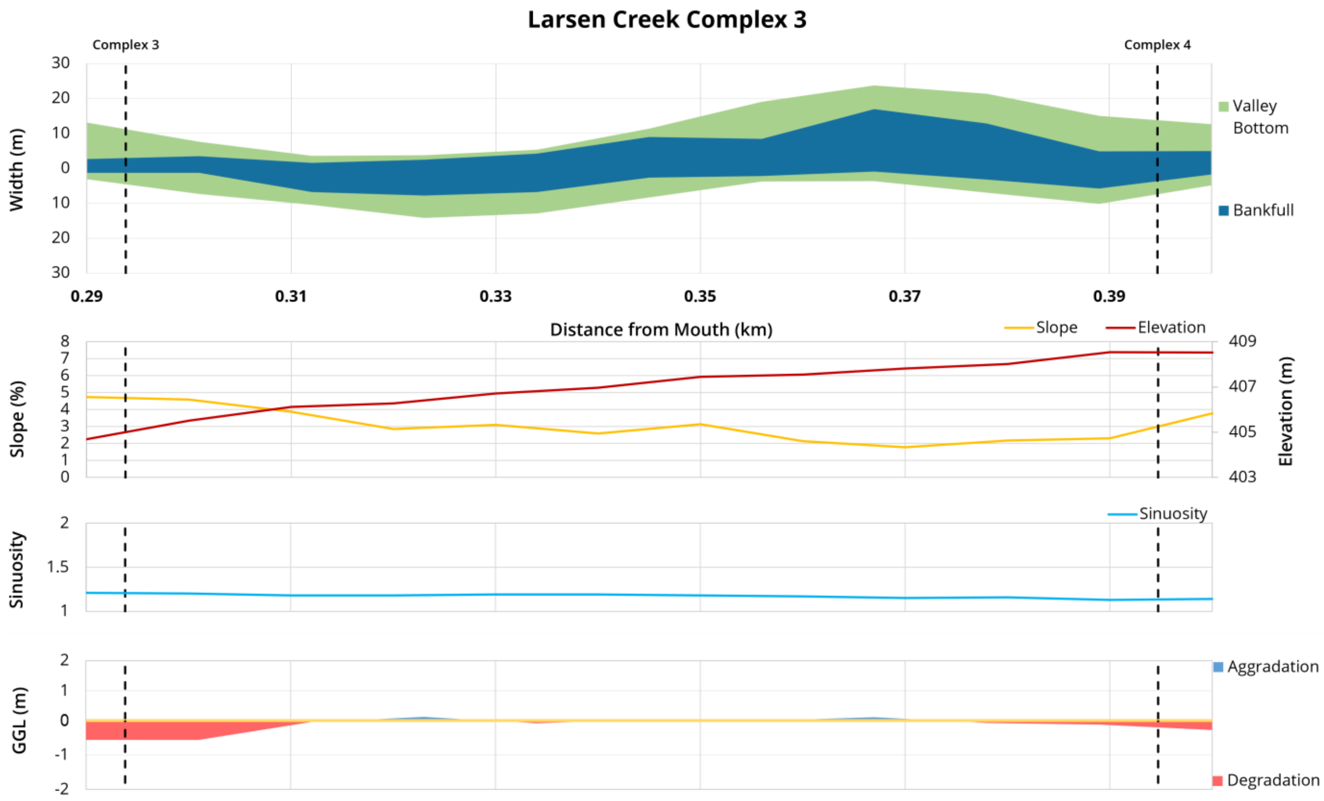

Figure 24. Long profile of geomorphic features and GGL results in Complex 3.

Complex 4: Floodplain Development and Access

Complex 4 focuses on floodplain development and access. While much of the channel in Complex 4 is incised (Figure 25), there are many opportunities to widen the channel and progress existing small meanders. There are several locations where headcuts are present that are potentially accelerating downstream degradation. We recommend the installation of PAS throughout Complex 4 to address several objectives. Depending on location, the PAS areas will progress existing meanders, widen the channel, arrest headcuts, and aggrade the channel. Areas upstream of headcuts often provide opportunities to force flows toward the bank to widen the channel and recruit sediment for downstream restoration efforts. Areas downstream of headcuts have little opportunity for floodplain development and should focus on arresting the headcut and aggrading the channel.

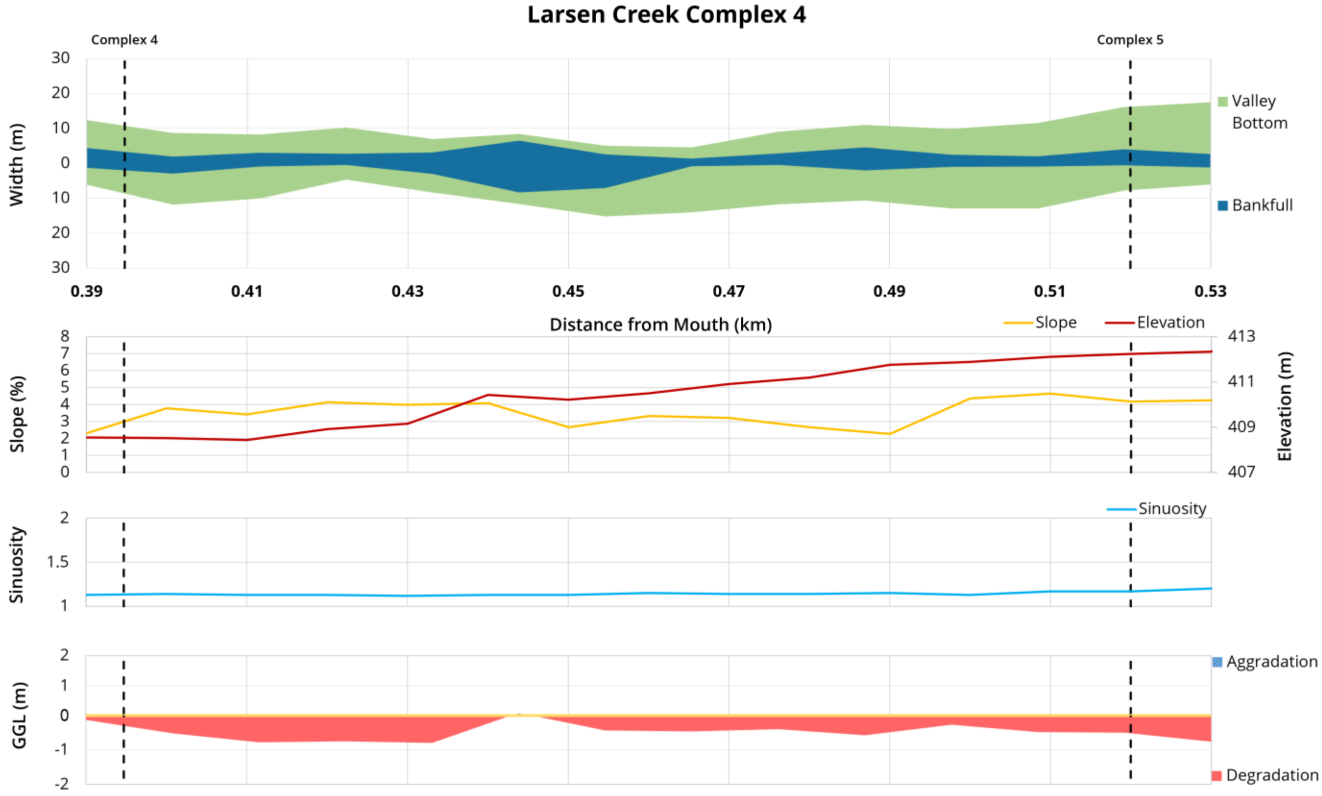

Figure 25. Long profile of geomorphic features and GGL results in Complex 4.

Complex 5: Water and Sediment Retention

Complex 5 focuses on water and sediment retention. Complex 5 contains large areas of floodplain that are in equilibrium with the geomorphic grade line. While much of the channel in Complex 5 is incised (Figure 26), the locations where the channel is in equilibrium with the geomorphic grade line provide an opportunity for water storage using leaky dams and BDAs to capture the floodplain that is also in equilibrium. The placement of these leaky dams and BDAs was confirmed using the GGL results. For areas in need of aggradation, we recommend the combination of PAS and leaky dams to slow flows and aggrade the channel to eventually provide more access to the expansive floodplain in Complex 5.

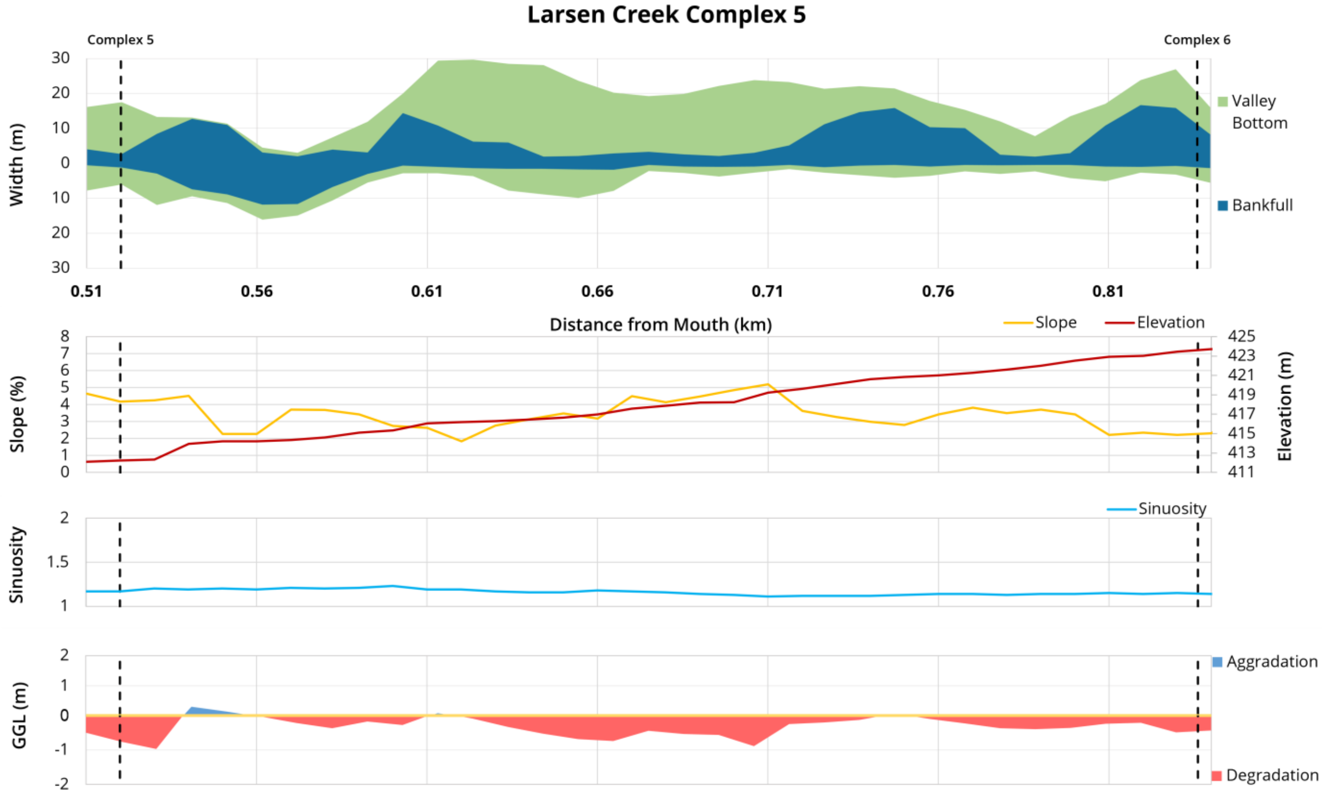

Figure 26. Long profile of geomorphic features and GGL results in Complex 5.

Complex 6: Incision Recovery

Complex 6 focuses on incision recovery. The channel in Complex 6 is deeply incised in many locations. The channel is most incised in the confined location where an alluvial fan from tributary deposits has pinned Larsen Creek against the western valley margin. The channel in this confined section is more than 2 meters incised, based on our survey of Larsen Creek. Outside of this confined area, the channel is incised in locations where the valley bottom should be accessible to the creek, based on REM and GGL results. We recommend the installation of PAS throughout Complex 6 to plug up the channel and begin building up the stream bed elevation. We also recommend the use of a leaky dam to capture a pocket of floodplain near the center of the complex where the channel and floodplain are in equilibrium with the geomorphic grade line (Figure 27). Complex 6 ends at the downstream extent of the sedge meadow near RM 0.8.

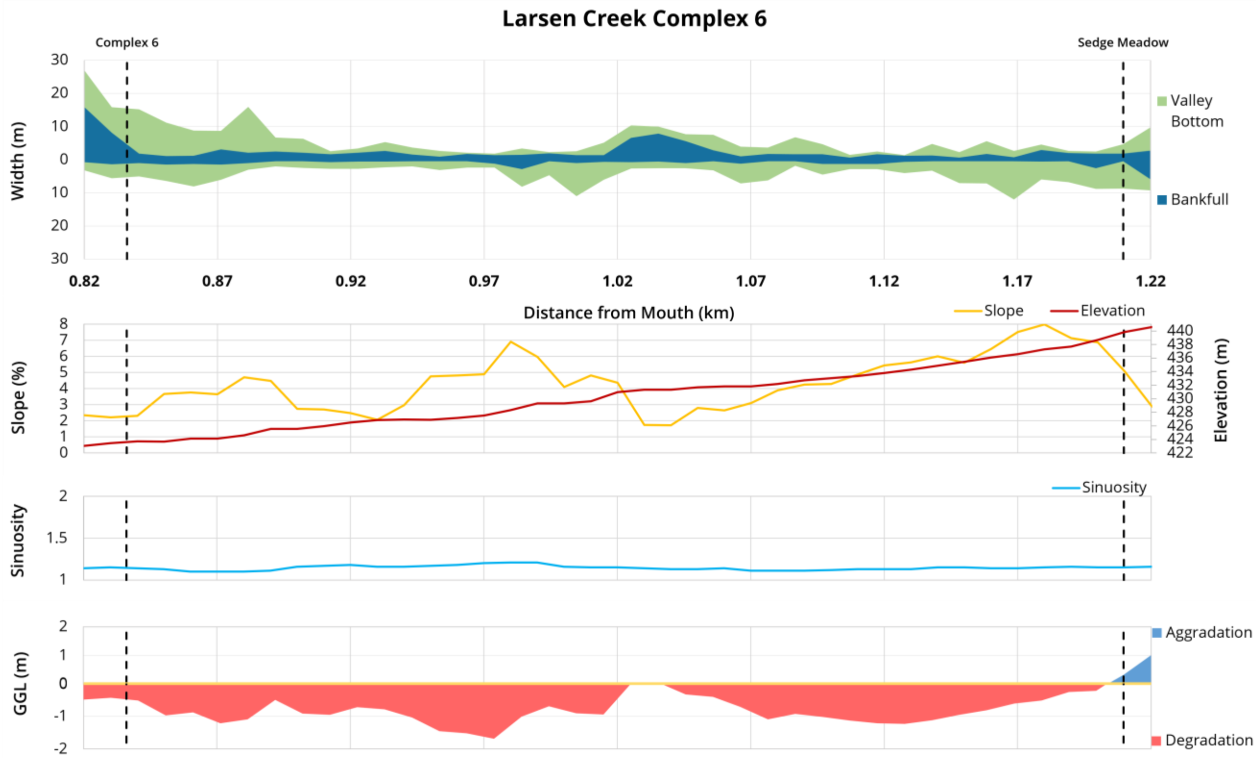

Figure 27. Long profile of geomorphic features and GGL results in Complex 6.

STRUCTURE DESIGN

Each complex is composed of several structures that are designed to work in concert to achieve the complex objective. The number of structures and PAS areas in a single complex ranges from 4 to 14. The number of structures and PAS areas per complex depends on the length and width of the complex, the opportunities available, and the primary objective. A total of 22 structures and 19 PAS areas were designed for the Larsen Creek project area. An estimate of fill volume for wood, posts, slash, weaving material, and hand-excavated sediment is provided in Table 3 and Table 4. We estimate this project will require 637 posts (2-inch diameter, 6-foot long).

Table 3. Fill quantities by structure type and material type for proposed structures in Larsen Creek.

Structure Type	Material Type	Fill Quantity (yds^3)
PALS	Wood	5.2
PALS	Posts	0.2
BDA	Weave	6.5
BDA	Posts	0.7
BDA	Local sediment	1.2
PAS	Slash	76.4
PAS	Posts	2.4
Leaky Dam	Wood	4.4
Leaky Dam	Posts	0.3

Table 4. Fill quantities in cubic yards by material type for proposed structures in Larsen Creek.

Material Type	Fill Quantity (yds^3)
Wood	9.6
Posts	3.6
Slash	76.4
Weave	6.5
Local Sediment	1.2

In each figure below, the project flowline represents the lowest point of the current channel (2018), and structures are displayed as PALS, BDA, leaky dam, or PAS (Figure 28 - Figure 36). Table 5 provides the details needed to stage and build each structure as well as each structure's objective. Table 6 provides the details needed to stage and install each PAS area.

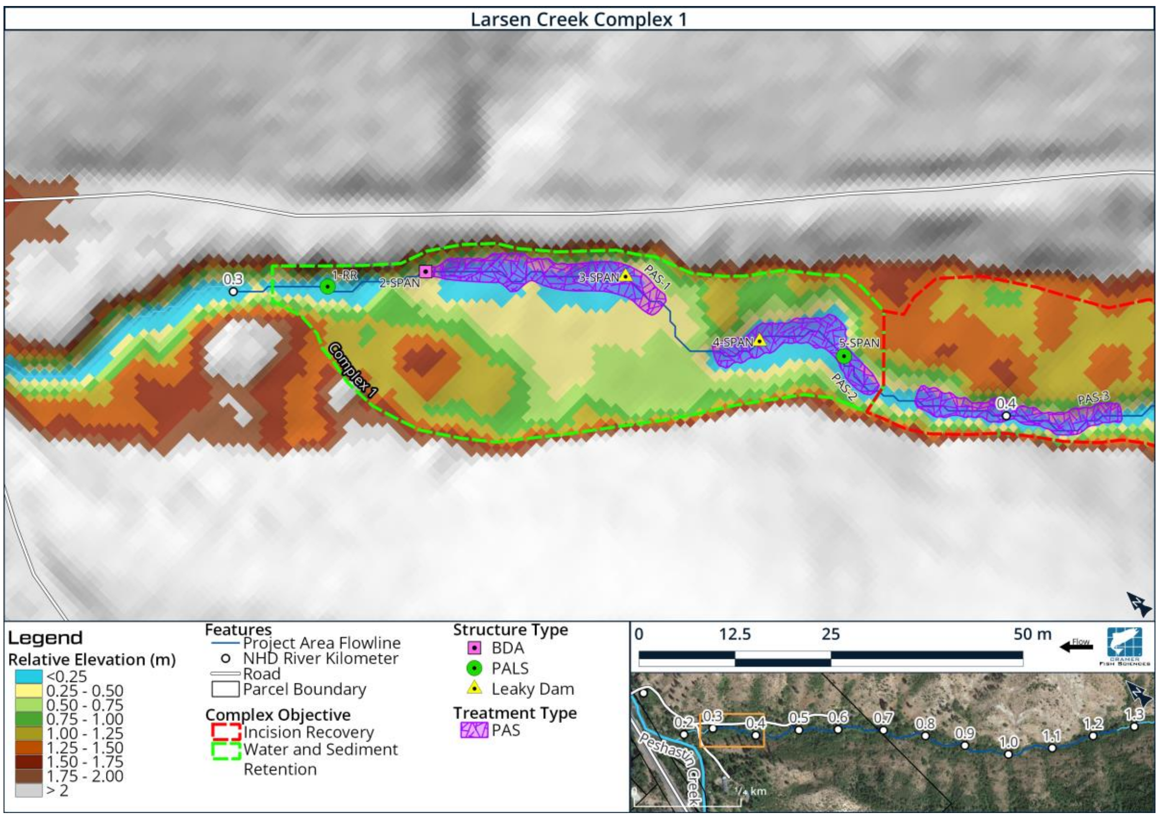

Figure 28. Location and type of low-tech structures within Complex 1 on Larsen Creek.

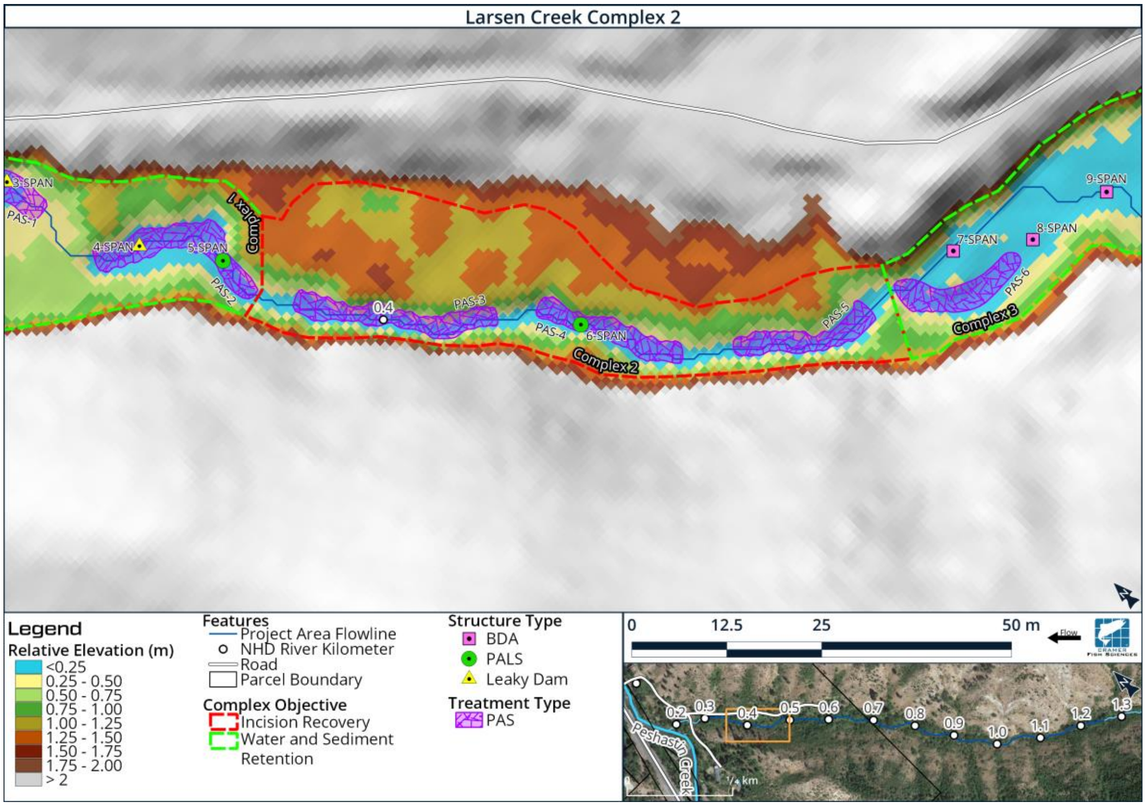

Figure 29. Location and type of low-tech structures within Complex 2 on Larsen Creek.

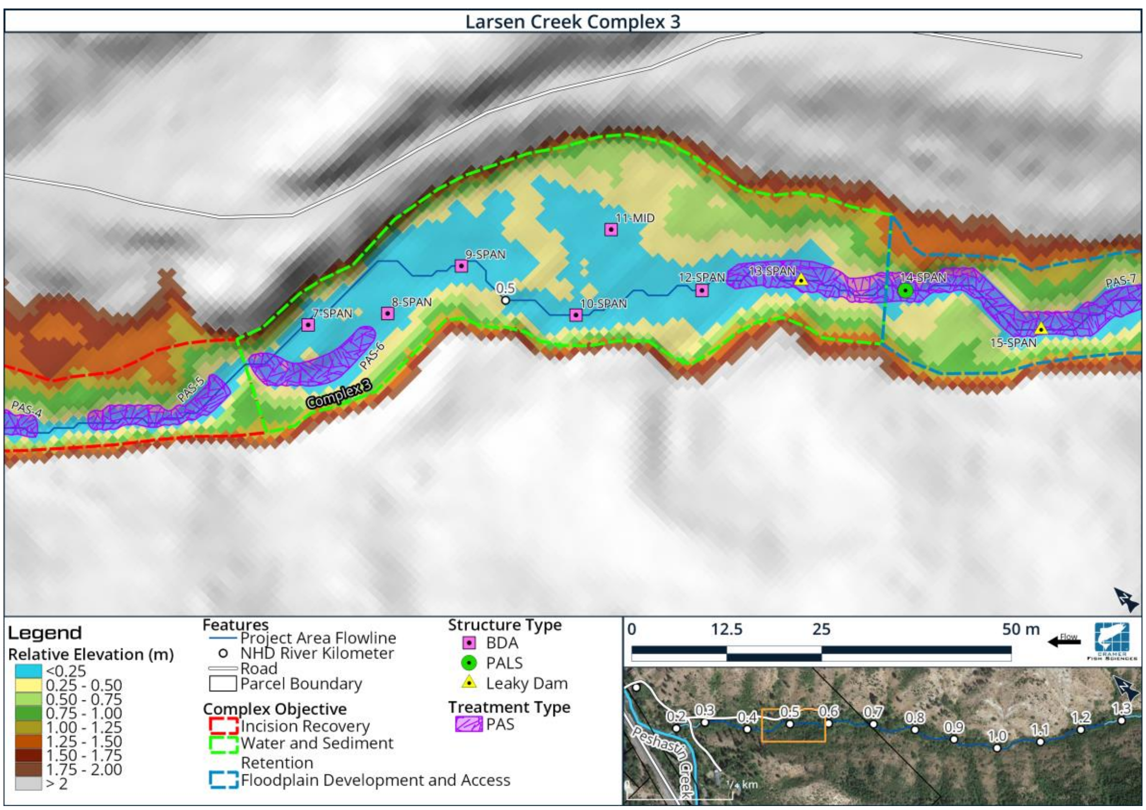

Figure 30. Location and type of low-tech structures within Complex 3 on Larsen Creek.

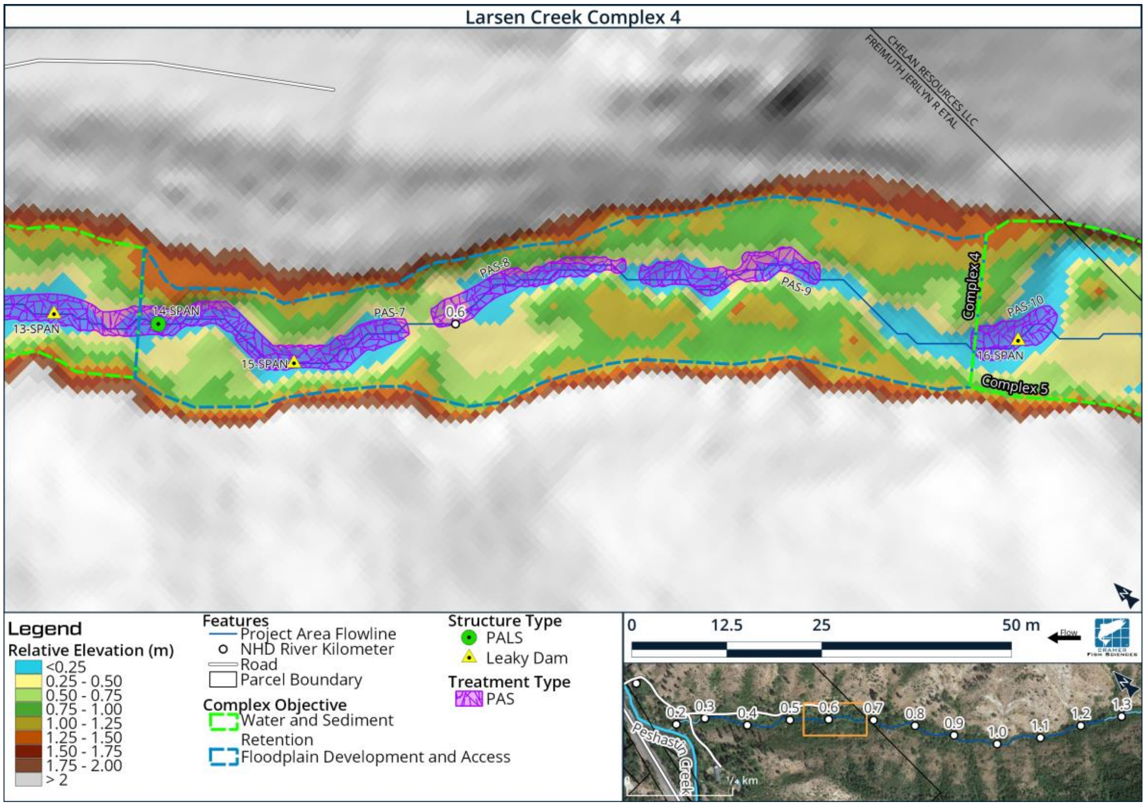

Figure 31. Location and type of low-tech structures within Complex 4 on Larsen Creek.

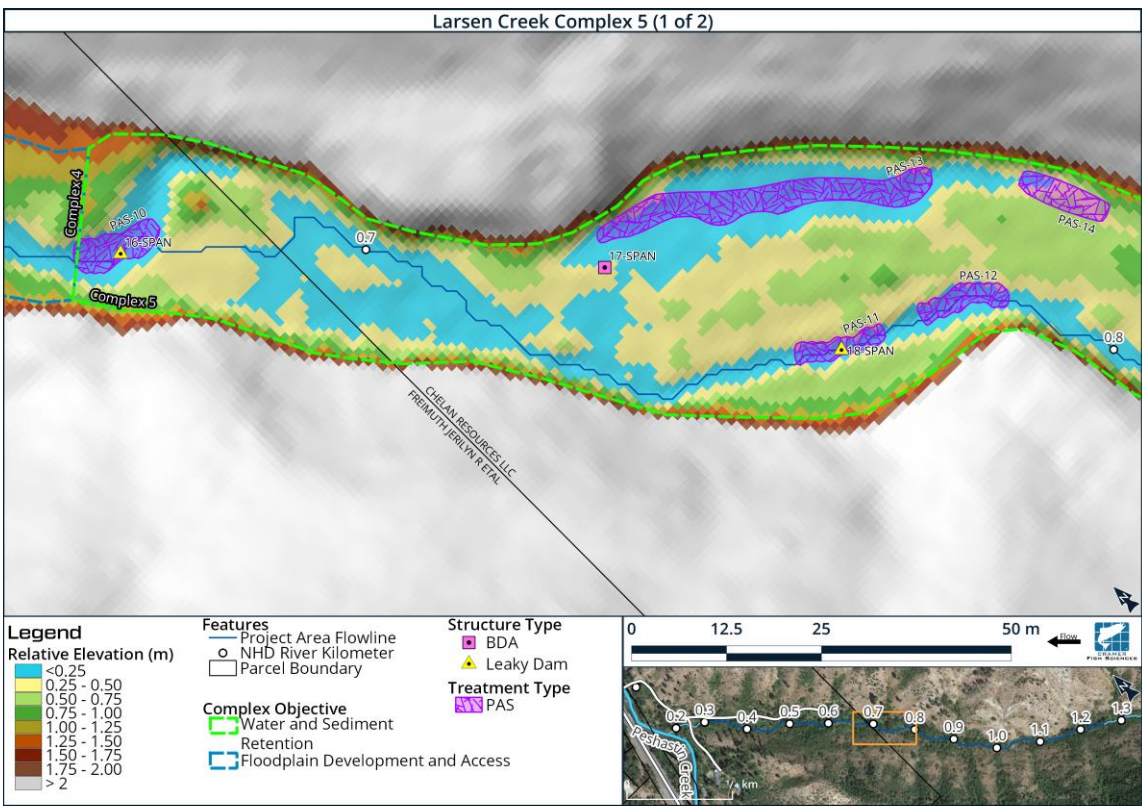

Figure 32. Location and type of low-tech structures within Complex 5 on Larsen Creek (1 of 2).

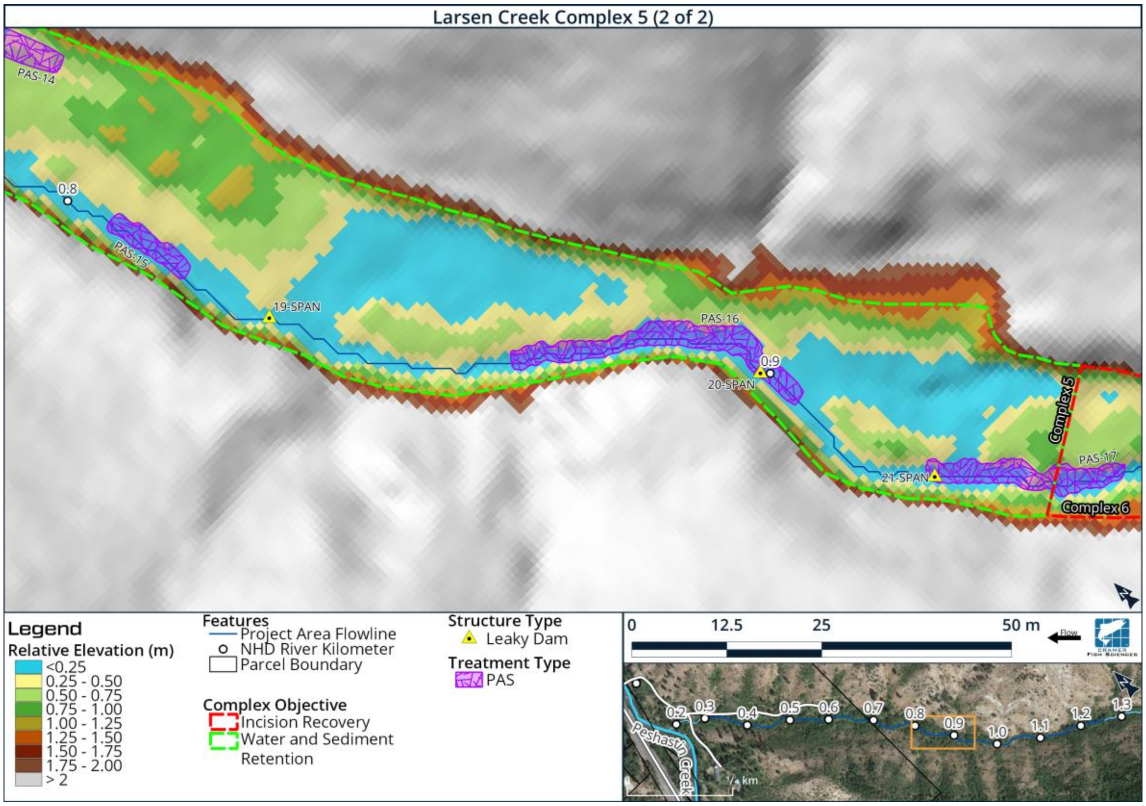

Figure 33. Location and type of low-tech structures within Complex 5 on Larsen Creek (2 of 2).

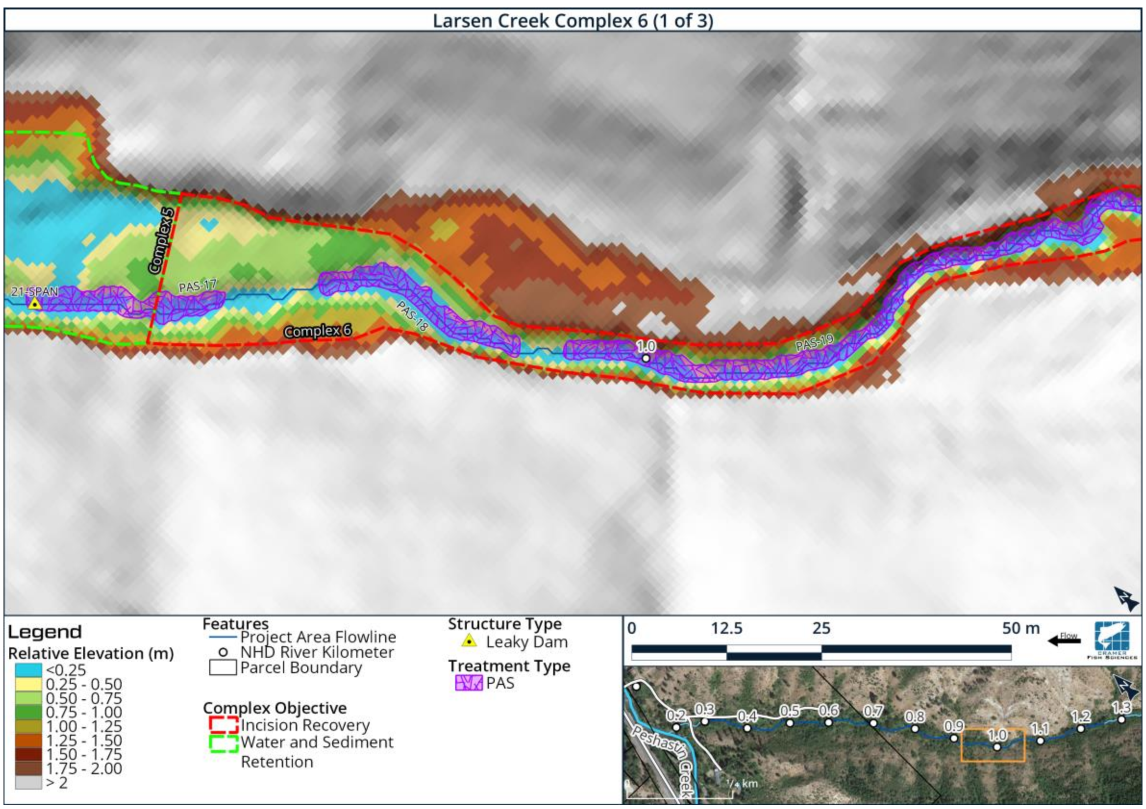

Figure 34. Location and type of low-tech structures within Complex 6 on Larsen Creek (1 of 3).

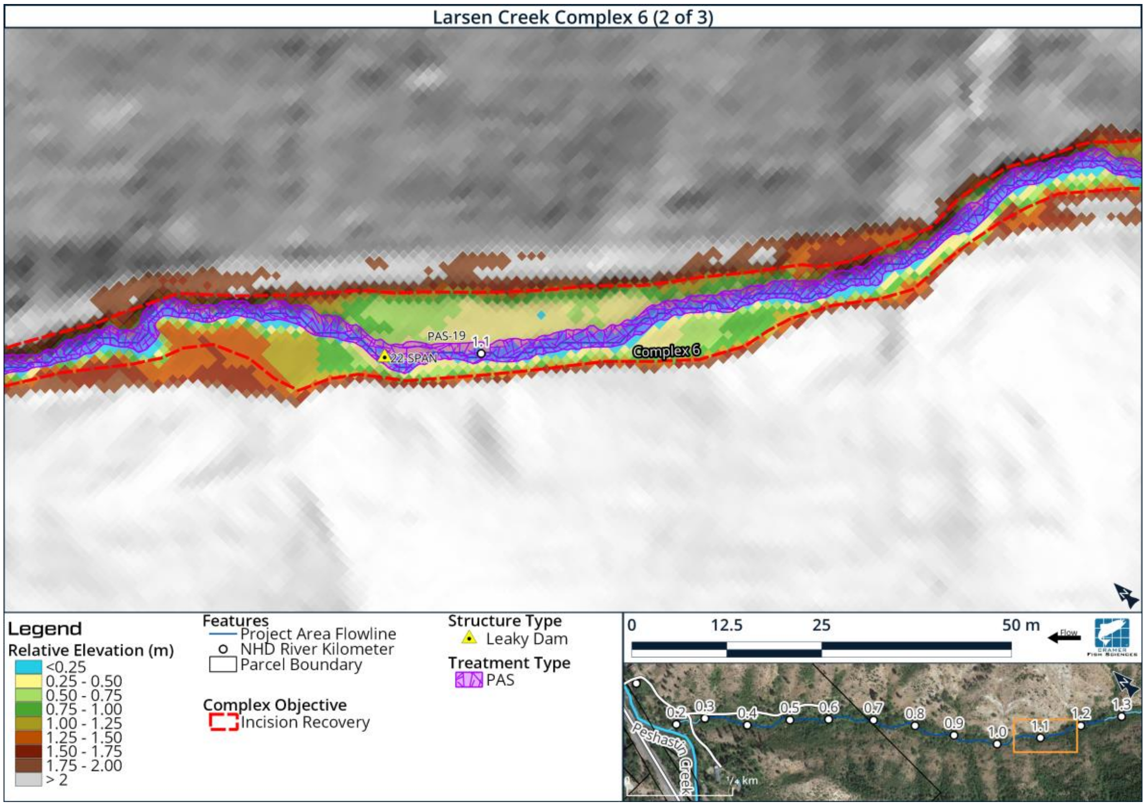

Figure 35. Location and type of low-tech structures within Complex 6 on Larsen Creek (2 of 3).

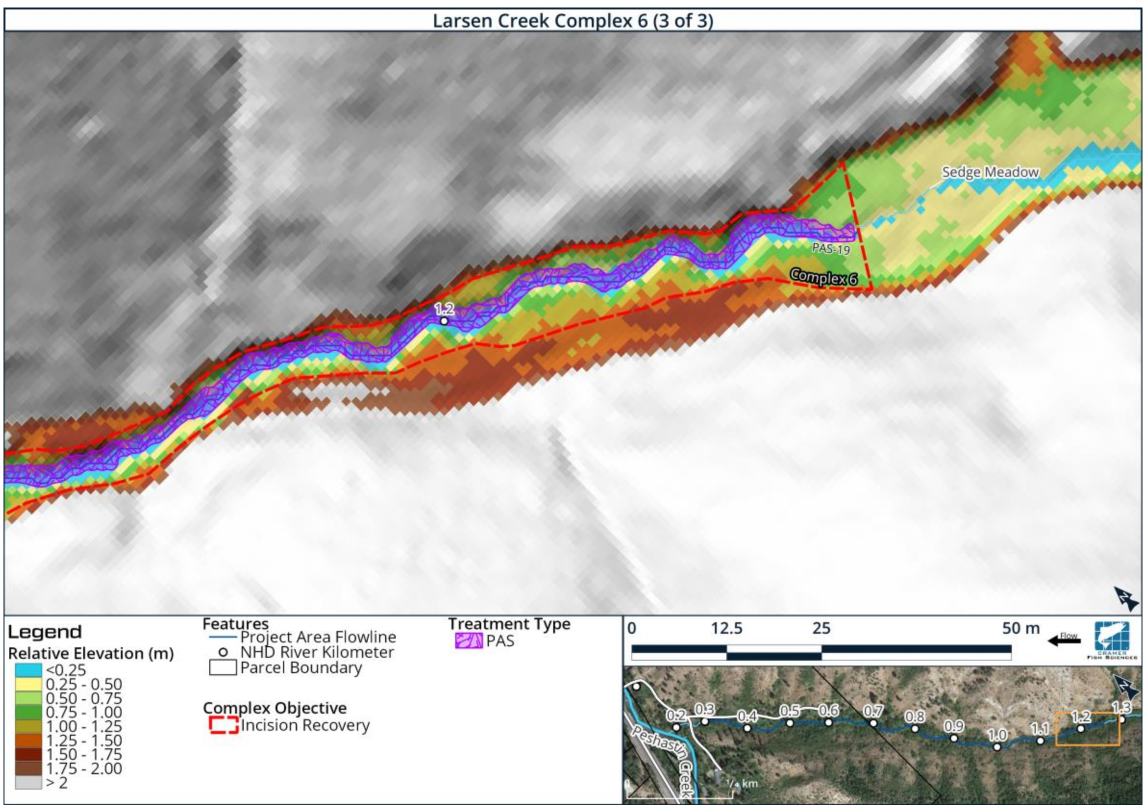

Figure 36. Location and type of low-tech structures within Complex 6 on Larsen Creek (3 of 3).

Table 5. Description, expected number of posts and wood, bank attachment, objectives, and location of low-tech structures in Complexes 1-6 on Larsen Creek. RL = river left, RR = river right

Complex	ID	Type	Description	# of Posts	Wood Count	Attachment	Objectives	Lat	Long
1	1	PALS	Add wood to RR side of existing root war. Leave open on RL side as relief valve. Pound posts around to secure. Act as catcher's mitt for upstream structures.	7	7	RR	Pool Development, Sediment Sourcing	47.521827	-120.623334
1	2	BDA	Span opening where channel widens. Curve BDA around widened area so banks can support sides of structure. Clip nearby cottonwood for some of the weave.	9	0	SPAN	Pond, Sediment Storing	47.521759	-120.623196
1	3	Leaky Dam	Plug up channel. Key pieces into bed and banks. Cover with slash. Secure with posts. Build about 70cm vertical.	5	3	SPAN	Pool Development, Sediment Storing	47.521589	-120.622957
1	4	Leaky Dam	Plug up channel. Key logs into bed and bank. Cover with slash and secure with posts. Build to 70cm vertical.	5	3	SPAN	Pool Development, Sediment Storing	47.521425	-120.622872
1	5	PALS	Add more slash and wood to existing debris pile. Secure with posts. Extend upstream and downstream covering 10-15m. Be sure to cover headcut upstream.	10	10	SPAN	Pool Development, Sediment Storing, Headcut Arrest	47.521343	-120.622787
2	6	PALS	Plug up channel with slash and wood for 10-15m. Key logs into willow on RR. Work around existing logs and slash. Dig up boulders if needed and place on top of ballast.	10	8	SPAN	Pool Development, Sediment Storing	47.520990	-120.622422
3	7	BDA	RR channel. Crest height about 80cm. Build near downstream end of floodplain pocket within gap of shrubs.	9	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.520740	-120.621870
3	8	BDA	RL channel. Attempt BDA if posts will drive, otherwise leaky dam. Pond water to improve connection into RR channel. Crest height around 70cm. May need to carve down access to RR channel a little bit.	10	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.520683	-120.621758
3	9	BDA	Build near willow clumps upstream of root drop. Make sure mattress extends downstream 5+ m to cover root drop. Ponding from downstream BDA should reach root drop for additional protection.	16	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.520661	-120.621607

Complex	ID	Type	Description	# of Posts	Wood Count	Attachment	Objectives	Lat	Long
3	10	BDA	Channel mostly disappears, likely sheet flow across floodplain surface with a couple small divots. Capture far RL channel before it goes back into dogwood patch. Single line wicker weave. Crest height around 60cm.	13	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.520524	-120.621526
3	11	BDA	Single line wicker weave. Near center of floodplain area with small channel visible. Build wide to spread flows laterally. Ponding will be limited without banks to hold in water. Crest height around 50cm.	26	0	MID	Pond, Sediment Storing, Floodplain Connection	47.520567	-120.621377
3	12	BDA	Single line wicker weave. Crest height around 40cm.	24	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.520440	-120.621340
3	13	Leaky Dam	Plug up channel with existing wood and slash. Add more to extend up and down 10-15m, be sure to cover root drop upstream. Key logs into bed and bank. Connect RL floodplain. Build crest to about 60cm.	5	3	SPAN	Pool Development, Sediment Storing, Floodplain Connection, Headcut Arrest	47.520365	-120.621205
4	14	PALS	Plug channel with wood and slash using alder clump on RL as hard point. Wedge wood into alder. Secure with posts. Key bottom log into stream bed.	10	10	SPAN	Pool Development, Sediment Storing	47.520269	-120.621088
4	15	Leaky Dam	Add to existing wood jam. Build leaky dam downstream of existing jam near alder clump. Key logs into bed and banks. Add more slash and wood and tie into existing jam. Build about 70cm vertical.	5	3	SPAN	Pool Development, Sediment Storing, Headcut Arrest	47.520123	-120.620968
5	16	Leaky Dam	Plug up channel with wood and slash. Key logs into bed and bank. Build at brief wide spot to store water. Build to about 70cm vertical.	5	3	SPAN	Pool Development, Sediment Storing	47.519536	-120.620044
5	17	BDA	BDA to create pond in flat area.	17	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.519120	-120.619461
5	18	Leaky Dam	For RL channel. Plug up channel. Key in logs into bed and bank cover with slash.	5	3	SPAN	Pool Development, Sediment Storing	47.518853	-120.619270
5	19	Leaky Dam	Plug up channel. Key logs into bed and bank. Build 70cm vertical.	5	3	SPAN	Sediment Storing, Floodplain Connection	47.518359	-120.618827
5	20	Leaky Dam	Plug up channel. Key logs into bed and bank. Cover with slash, including slash from downstream PAS. Build to 70cm vertical.	5	3	SPAN	Sediment Storing, Floodplain Connection	47.517902	-120.618287

Complex	ID	Type	Description	# of Posts	Wood Count	Attachment	Objectives	Lat	Long
5	21	Leaky Dam	Plug up channel near existing small jam. Key logs into bed and bank. Add slash up and down for 15m. Secure with posts.	5	3	SPAN	Pool Development, Sediment Storing	47.517669	-120.618199
6	22	Leaky Dam	Leaky dam to capture low floodplain.	5	3	SPAN	Sediment Storing, Floodplain Connection	47.516632	-120.616529

Table 6. Description, expected volume of slash, and location of post assisted slash (PAS) in Complexes 1-6 on Larsen Creek. DS = Downstream, US = Upstream

Complex	ID	Type	Description	# of Posts	Slash Volume (yd^3)	DS Lat	DS Long	US Lat	US Long
1	1	PAS	Plug up channel under overhanging vegetation with wood and slash. Secure with posts. Wedge slash between available live trees. Add wood and slash to existing debris piles. Extend slash into dogwood thicket. Cover leaky dam with slash.	32	4.77	47.521759	-120.623196	47.521535	-120.622945
1	2	PAS	Add slash and wood to existing debris piles. Secure with posts. Ensure headcut is included. Cover leaky dam with slash and wood. Roll existing cottonwood into channel. Dig out RL side and roll log into middle of channel. May need to buck a portion of cottonwood but try to keep as large as possible.	22	1.62	47.521455	-120.622940	47.521288	-120.622790
2	3	PAS	Add wood and slash to plug up channel. Integrate with large cottonwood from downstream. Build around large boulder in channel. Attempt to roll boulder into center of the channel. Key wood pieces into the boulder	19	2.55	47.521247	-120.622754	47.521064	-120.622520
2	4	PAS	Plug channel with slash and wood. Key logs into willow on RR. Work around existing logs and slash. Dig up boulders if needed and place on top as ballast.	15	1.65	47.521039	-120.622458	47.520876	-120.622339
2	5	PAS	Add wood and slash to existing debris piles. Add cottonwood logs on RL bank. Key logs into willow on RR.	14	1.52	47.520841	-120.622263	47.520760	-120.622046
3	6	PAS	In the RL channel, add slash and wood underneath live vegetation. Plug up the channel and use live vegetation. Pin logs to ground to back up water. Add posts if possible.	17	2.31	47.520755	-120.621990	47.520676	-120.621795
4	7	PAS	Plug channel with wood and slash near existing debris piles. Key logs into live trees and shrubs on the bank. Fill holes with wood and slash. Add cobble to bowl if possible to reduce further down cutting	56	6.91	47.520426	-120.621296	47.520062	-120.620780

			and top with wood and slash. Extend some logs above banks. Key logs into bed and banks.						
4	8	PAS	Plug channel with wood and slash. Wedge wood into live trees and into undercuts. Angle major pieces and pieces on the bed toward RL to advance undercut scour. Goal is to widen the channel and bring in sediment. Wedge slash and wood under giant cottonwood.	20	1.75	47.520037	-120.620744	47.519926	-120.620452
4	9	PAS	Use all the big cottonwood pieces on the banks to fill the channel. Plug up hole under big boulders with wood and slash.	20	3.90	47.519903	-120.620436	47.519754	-120.620215
5	10	PAS	Plug channel with wood and slash. Cover leaky dam with wood and slash.	14	2.60	47.519568	-120.620110	47.519509	-120.619990
5	11	PAS	Cover leaky dam with wood and slash.	8	0.58	47.518879	-120.619341	47.518830	-120.619196
5	12	PAS	Fill hole with wood and slash. Buck up old cottonwood and integrate. Place large logs in “V” shape to help secure slash.	10	0.61	47.518809	-120.619132	47.518754	-120.619003
5	13	PAS	Add a lot of wood and slash in RR side channel. Wedge wood between live vegetation.	46	5.96	47.519153	-120.619430	47.518875	-120.618873
5	14	PAS	Roll in wood from hill slope, sourced from slash piles. Scatter throughout RR side channel for future recruitment.	12	1.91	47.518845	-120.618840	47.518746	-120.618769
5	15	PAS	Add slash and wood to existing jam to plug up channel. Build up to 80cm vertical.	9	1.26	47.518572	-120.618908	47.518464	-120.618883
5	16	PAS	Add wood and slash to the channel. Buck up big cottonwood log and roll into channel with slash placed underneath. Cover leaky dam with wood and slash.	31	3.07	47.518117	-120.618582	47.517847	-120.618275
5	17	PAS	Plug up channel near existing jam. Add slash near leaky dam and cover leaky dam with slash.	20	2.52	47.517676	-120.618208	47.517515	-120.617958
6	18	PAS	Plug up channel with wood and slash. Add more slash and wood to existing debris piles. Buck large cottonwoods and drop them in on top of slash, keeping pieces as long as possible. Source additional large cottonwood logs from surrounding floodplain.	21	2.23	47.517448	-120.617822	47.517224	-120.617660

			Buck spanning cottonwood logs upstream as well. Cover with slash.						
6	19	PAS	Channel is greatly incised. Fill with wood and slash. Continue filling the channel with wood and slash throughout. Cover leaky dam with wood and slash. Add 3 posts every 20 meters to act as hard points and capture mobile slash.	40	28.30	47.517185	-120.617604	47.515857	-120.614622

REFERENCES CITED

Anchor QEA. 2012. Peshastin Irrigation District Pump Exchange Project. Prepared for Washington State Department of Ecology and Chelan County Natural Resources Department.

Andonaegui, C. 2001. Salmon, steelhead and bull trout habitat limiting factors for the Wenatchee subbasin (water Resource inventory area 45) and portions of WRIA 40 within Chelan County (Squilchuck, Stemilt and Colockum drainages). Final Report November 2001. WA State Conservation Commission.

Chelan County Natural Resource Department (CCNRD) and Natural Systems Design (NSD). 2022. Alluvial Water Storage Restoration in the Wenatchee Basin: Synthesis of Approach, Results, and Applications, 2017-2021. A report prepared for Washington State Department of Commerce, Grant Agreement No. CD19-96619-091. June 30, 2022.

Cooper, M. and S. Mallas. 2004. Peshastin Creek Smolt Monitoring Program, Annual Report 2004. U.S. Fish and Wildlife Service, Mid-Columbia River Fishery Resource Office, Leavenworth, WA.

Easterbrook, M.A., and J.H. Jr. Macdonald. 2017. Mineral chemistry of the camas land diabase, Central Cascades, Washington: a sill within the Eocene chumstick formation. Presented at The Geological Society of America annual meeting, Seattle, Washington, USA. https://gsa.confex.com/gsa/2017AM/webprogram/Paper301296.html

Forest Service (USFS). 1999. Peshastin Watershed Assessment. Wenatchee National Forest.

Forest Service (USFS). 2003. Okanogan and Wenatchee National Forests Road Analysis: Wenatchee Sub-Basin. Leavenworth Ranger District

Gresens, R.L., C.W. Naeser, and J.W. Whetten. 1981. Stratigraphy and age of the Chumstick and Wenatchee Formations; Tertiary fluvial and lacustrine rocks, Chiwaukum graben, Washington. Geological Society of America Bulletin 92:841 – 876.

Huntting, M.T., Bennett, W.A.G., Livingston, V.E.Jr., and Moen, W.S. 1961. Geologic Map of Washington: Washington Division of Mines and Geology, scale 1:500,000.

Juelson, J. and J. Soden. 2012. Memorandum: ESA Listed Fish Use in Peshastin Creek-Wenatchee Subbasin, Upper Columbia Region.

National Parks Service. 2019. Erosion: Mass Wasting. Accessed at URL: https://www.nps.gov/subjects/erosion/mass-wasting.htm

National Parks Service. 2020. Geology: Sedimentary Rocks. Accessed at URL: https://www.nps.gov/subjects/geology/sedimentary.htm

National Parks Service. 2022. Geology: Igneous Rocks. Accessed at URL: https://www.nps.gov/subjects/geology/igneous.htm

Northwest Power and Conservation Council (NPCC). 2004. Wenatchee Subbasin Plan. Prepared for the Northwest Power and Conservation Council. Lead organizations: Chelan County and the Yakama Nation.

Powers, P., M. Helstab, and S. Niezgoda. 2018. A process-based approach to restoring depositional river valleys to Stage 0, an anastomosing channel network. River Research and Applications.

Sheer M.B. and E.A. Steel. 2006. Lost watersheds: barriers, aquatic habitat connectivity, and salmon persistence in the Willamette and Lower Columbia River basins. Transactions of the American Fisheries Society 135: 1654–1669.

Schneider D., and R. Anderson. 2007. Wenatchee River Watershed Temperature Total Maximum Daily Load. Water Quality Improvement Report. Washington State Department of Ecology. Water Quality Program.

Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd edition. Natural Resources Conservation Service. U.S. Department of Agriculture Handbook 436.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Official Soil Series Descriptions. Available online. Accessed December 1 2023.

Upper Columbia Salmon Recovery Board (UCSRB). 2007. Upper Columbia spring Chinook salmon, steelhead, and bull trout recovery plan: Upper Columbia Salmon Recovery Board, Wenatchee, Washington, 300 pp. Web site: http://www.ucsrb.com/plan.asp

U.S. Fish and Wildlife Service (USFWS). 2002. Chapter 22, Upper Columbia Recovery Unity, Washington. 113 p. In: U.S. Fish and Wildlife Service. Bull Trout (Salvelinus confluentus) Draft Recovery Plan. Portland, Oregon.

U.S. Fish and Wildlife Service, "Endangered and Threatened Species; Threatened Status for Three Chinook Salmon Evolutionarily Significant Units (ESUs) in Washington and Oregon, and Endangered Status for One Chinook Salmon ESU in Washington" Federal Register 64, no. 56 (March 24, 1999). https://www.govinfo.gov/content/pkg/FR-1999-03-24/pdf/99-6815.pdf

U.S. Fish and Wildlife Service, "Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for Bull Trout in the Coterminous United States," Federal Register 64, no. 210 (November 1, 1999). https://www.govinfo.gov/content/pkg/FR-1999-11-01/pdf/99-28295.pdf

U.S. Fish and Wildlife Service, "Listing Endangered and Threatened Species: Change in Status for the Upper Columbia River Steelhead Distinct Population Segment" Federal Register 74, no. 162 (August 24, 2009). https://www.govinfo.gov/content/pkg/FR-2009-08-24/pdf/E9-20315.pdf

Waterhouse, L., J. White, K. See, A. Murdoch, and B. X. Semmens. 2020. A Bayesian nested patch occupancy model to estimate steelhead movement and abundance. Ecological Applications 30(8): e02202. 10.1002/eap.2202

Washington State Water Quality Assessment. Listing ID: 42982. Department of Ecology. State of Washington.

Wheaton, J., S. Bennett, N. Bouwes, J. Maestas, and S. Shahverdian. 2019. Low-Tech Process-Based Restoration of Riverscapes: Design Manual. Page 286. Utah State University Restoration Consortium, Logan, UT.

APPENDIX A: TYPICAL STRUCTURE SCHEMATICS

The following section provides typical structure schematics for PALS, BDAs, leaky dams, and PAS areas. These schematics are meant to be used as a general guide when building structures to meet a general objective. Structures may be modified in the field during construction to fit local site conditions and optimize effectiveness. The number of posts and wood used, structure orientation and angle, structure type, height, width constriction, and location may all be adjusted during construction. Site conditions may also force alterations in the typical structure schematics. For example, boulders or bedrock may make driving posts impossible at the original location.

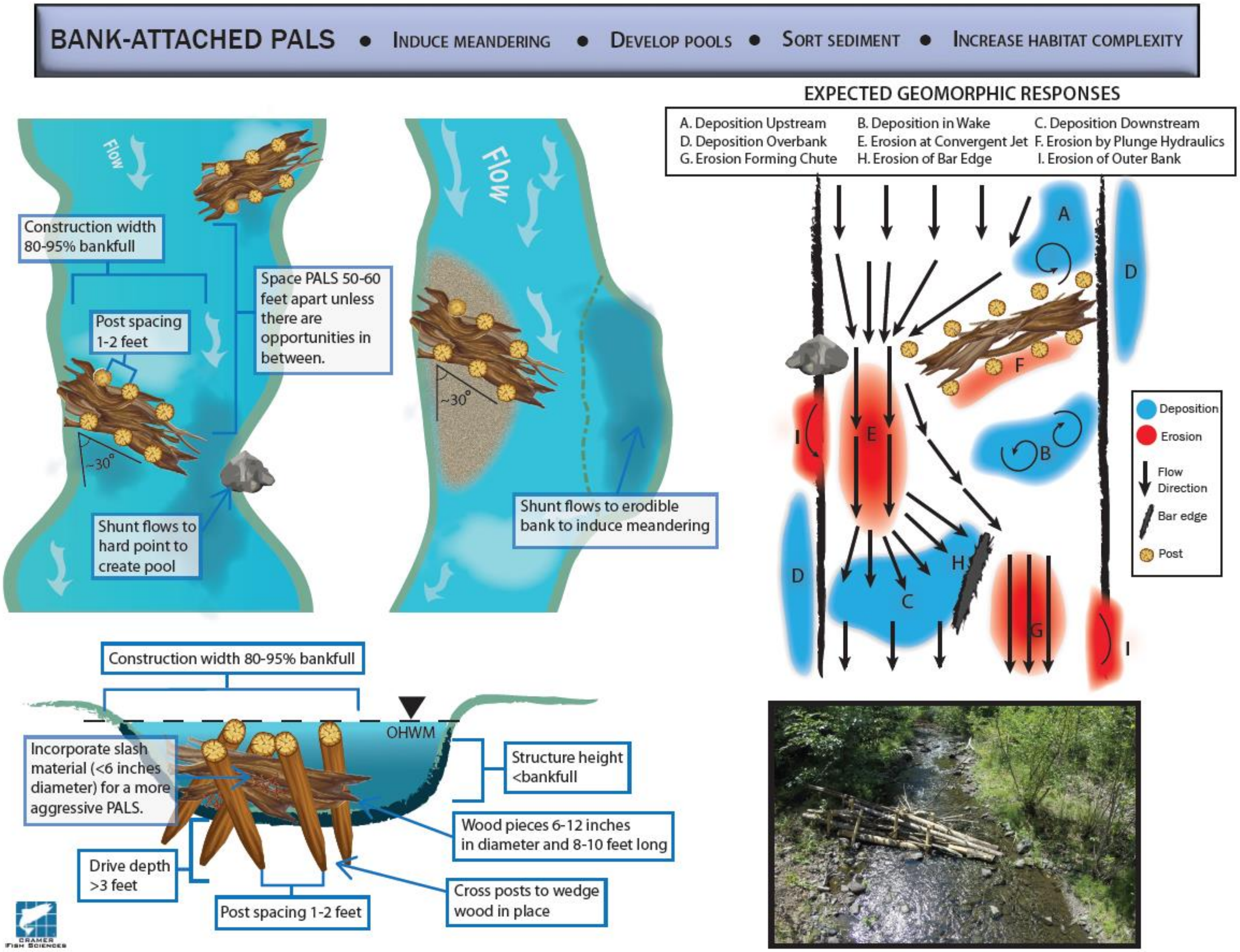

Figure 37. Typical structure schematic for a bank-attached post assisted log structure used to force a constriction jet.

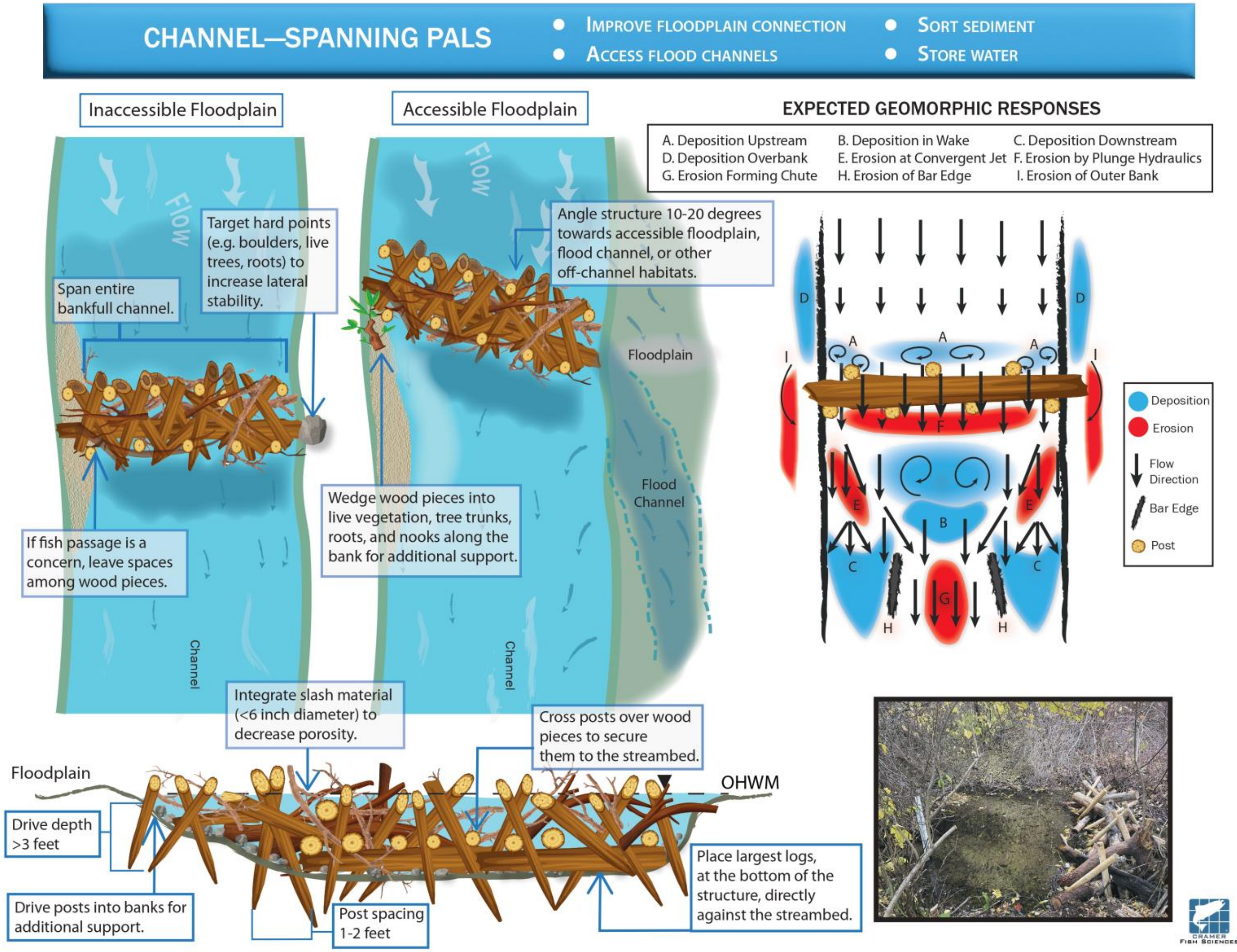

Figure 38. Typical structure schematics for a channel-spanning post assisted log structure used to promote overbank flows, retain water and sediment, and increase complexity.

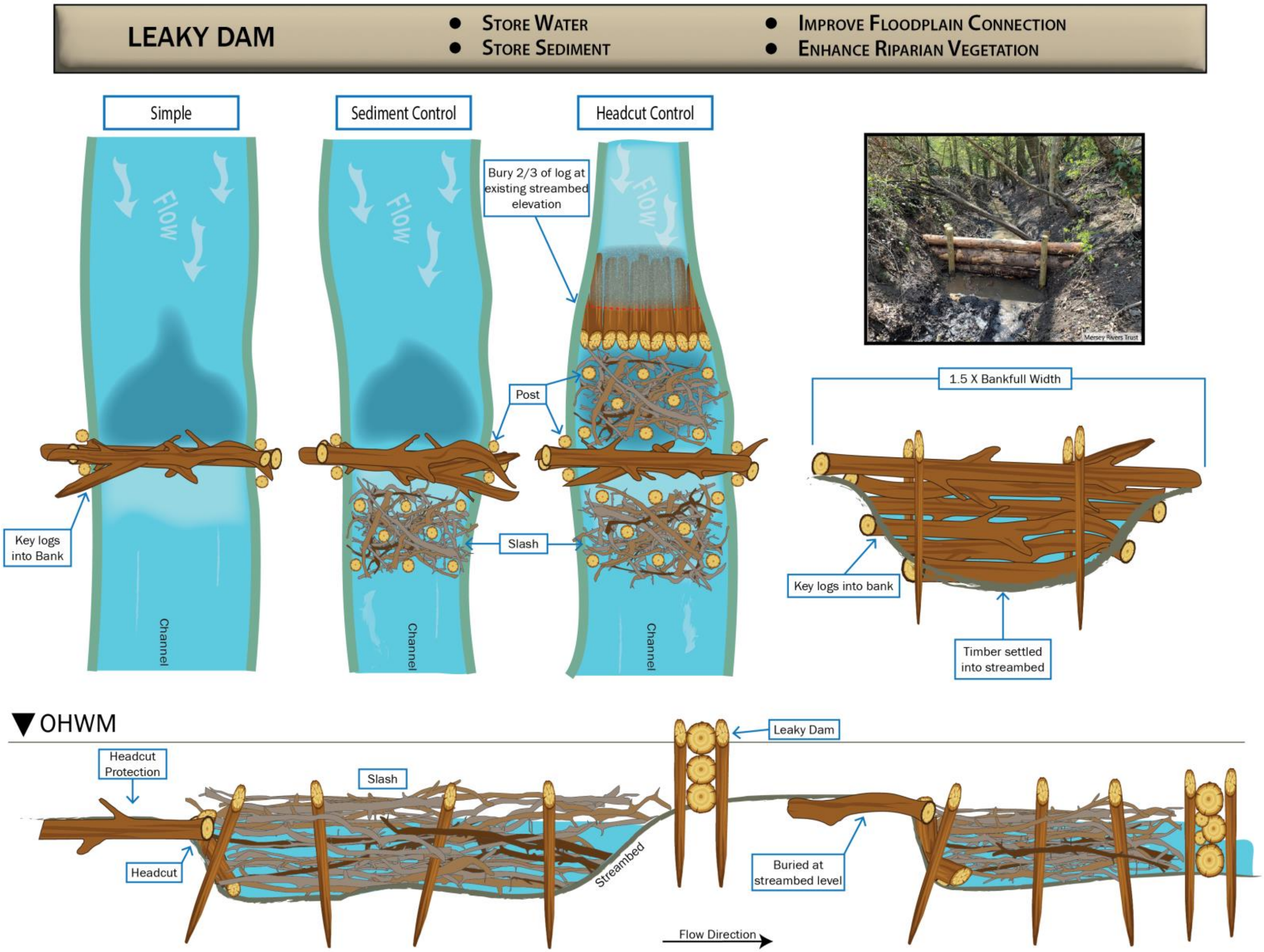

Figure 39. Typical structure schematic for a leaky dam.

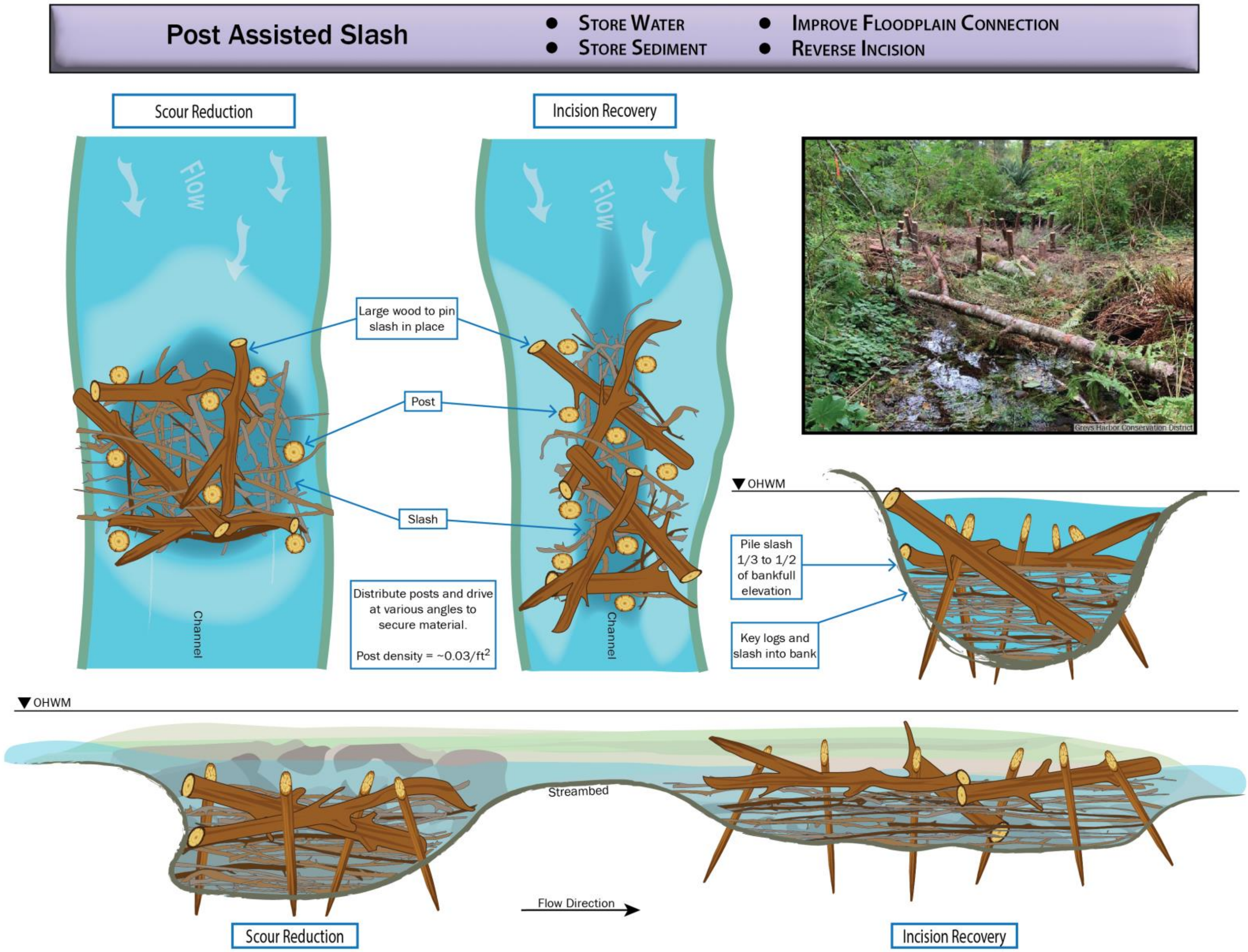

Figure 40. Typical structure schematic for a post assisted slash (PAS) area.

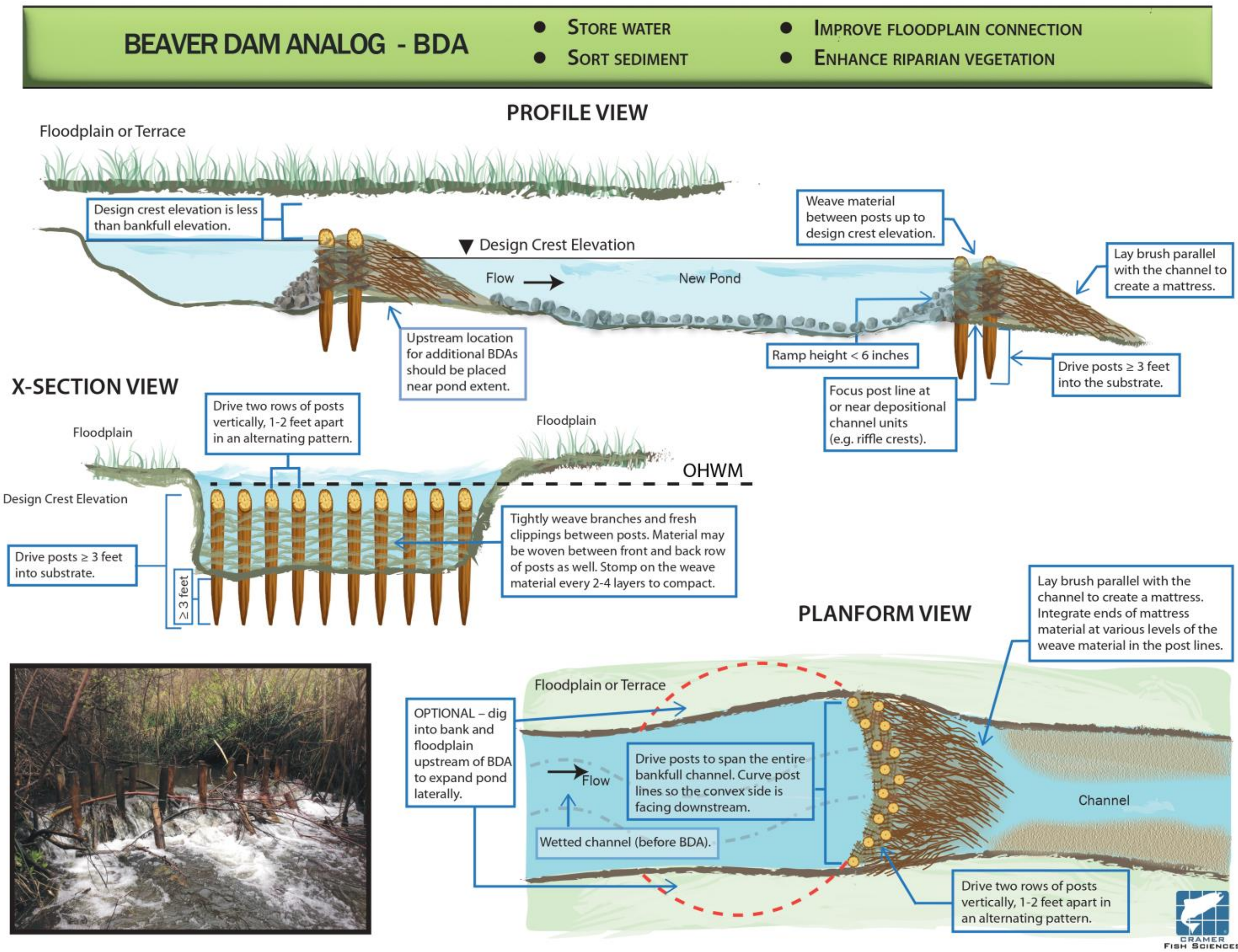

Figure 41. Typical structure schematics for a beaver dam analog (BDA) used to pond water, retain sediment, and promote overbank flows.

APPENDIX B: ACCESS AND STAGING AREAS

The access route provided in Figure 42 will be finalized in the field when contruction materials are staged. For the ATV access route, we plan to reoccupy the existing ATV trail.

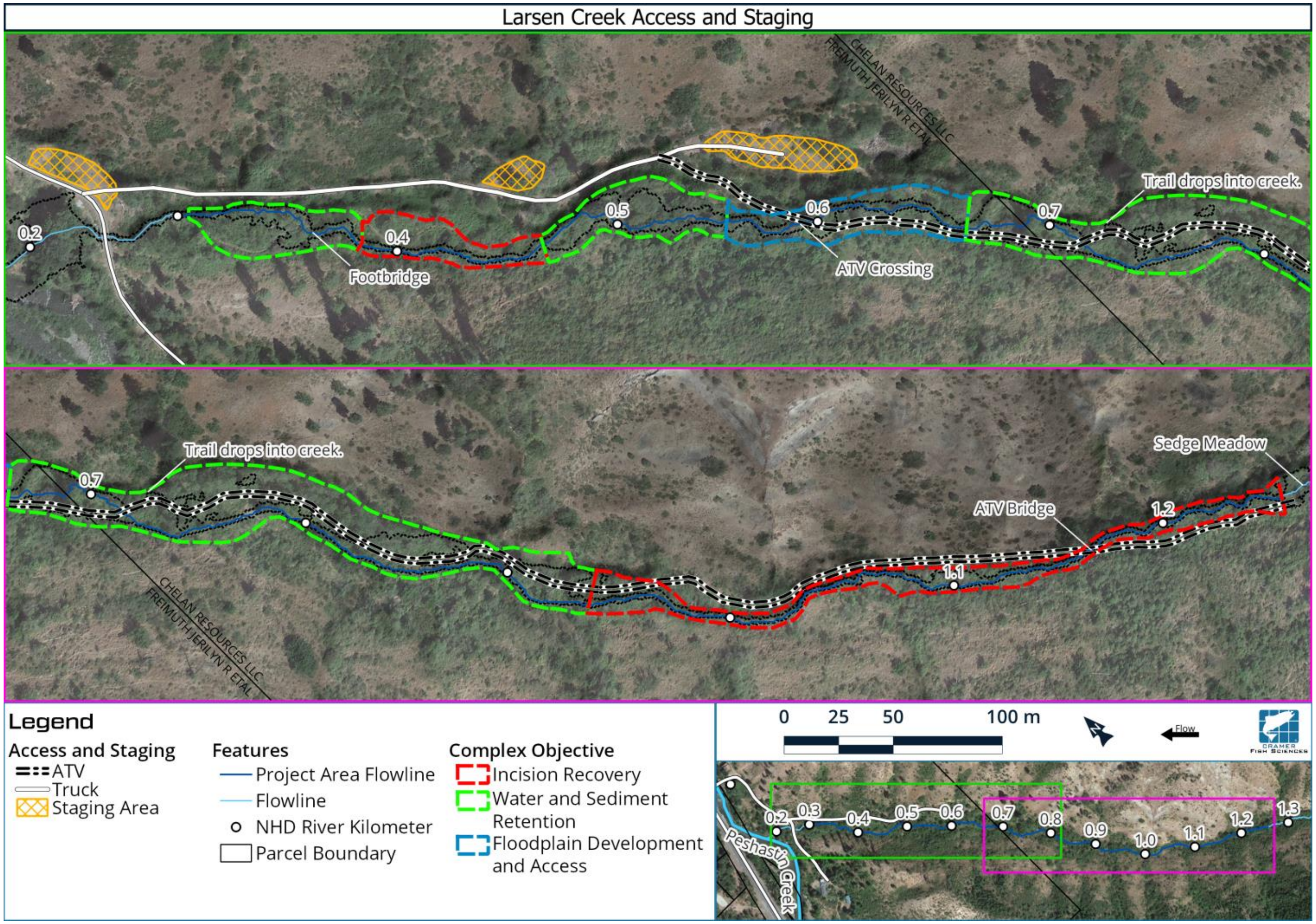

Figure 42. Access and Staging map of Larsen Creek project area.