BJORK 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 Bjork Creek in Chelan County, Washington (Figure 1). The project area is located within Parcel Number 251821000050 on Bjork Creek about 1.5 river kilometers from its confluence with Eagle Creek. The project area and concept design are limited to this parcel and the land is owned by Chelan Resources LLC. The project was funded by Washington State Department of Ecology.

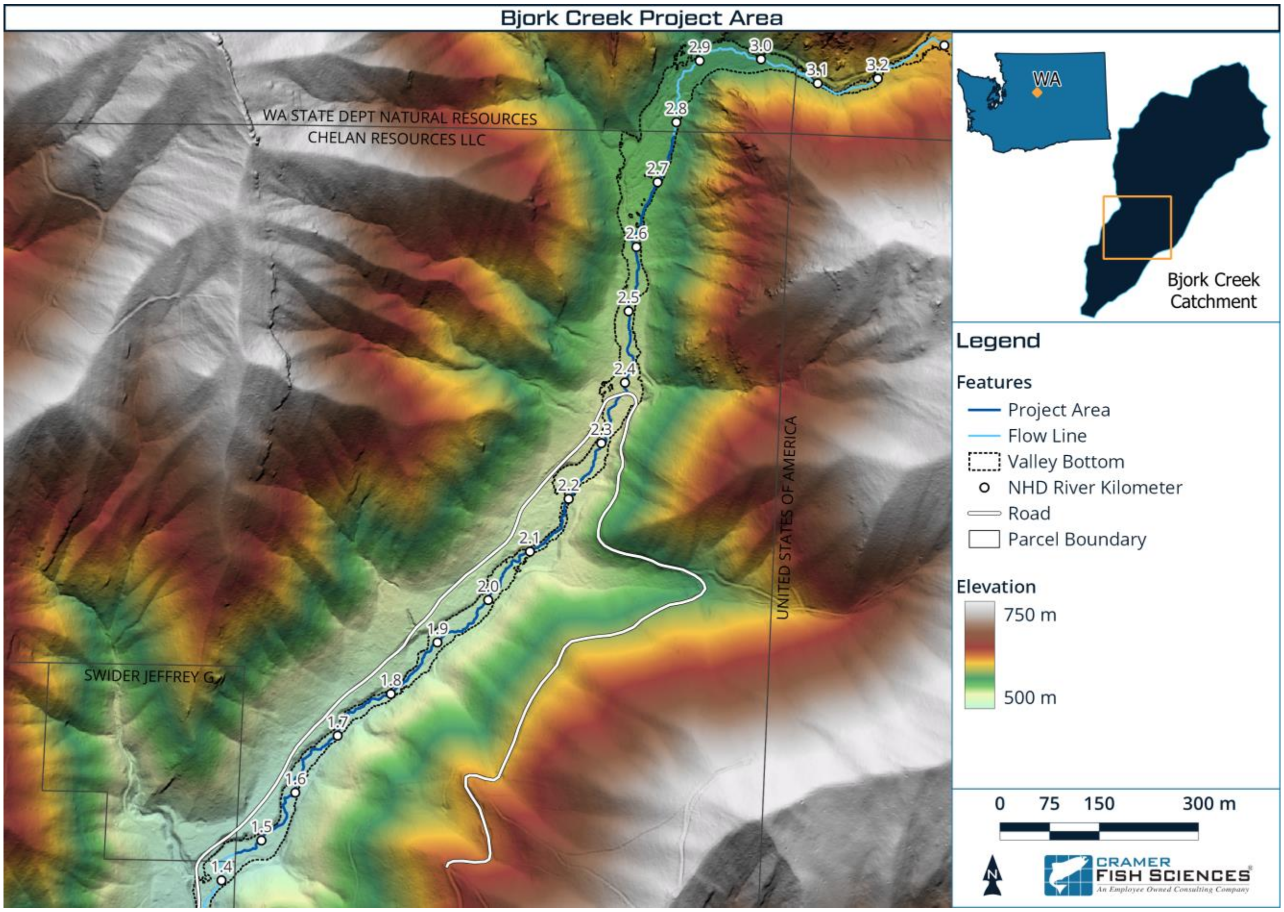

Figure 1. Overview map of the Bjork Creek project area.

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 increasing instream complexity. 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 Bjork Creek consists of 31 post-assisted log structures (PALS), 20 leaky dam structures, 17 beaver dam analogs (BDA), one direct fell opportunity, and 35 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 goal of this project is to design and construct alluvial water storage structures to increase the magnitude and duration of floodplain inundation and improve exchange between the hyporheic zone and surface flows on Bjork Creek. The overall objective of this project is to reduce stream temperature and retain water on the landscape. 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 Bjork Creek project. The downstream structures will be constructed in the first year (RM 0.9 – 1.4; Complex 1 – 8) and the upstream structures will be built in year two (RM 1.4 – 1.7; Complex 9 – 13), allowing the downstream structures to capture sediment prior to installation of the upstream structures.

WATERSHED BACKGROUND

Land Cover

According to the National Land Cover Dataset (NLCD), evergreen forest is the most abundant landcover type, which occurs on 43% of the catchment (Figure 2). The riparian habitat is a mixture of open canopy evergreen forest and shrub/scrub habitat. The area of shrub and scrub habitat covers 42% of the catchment. Grassland and herbaceous habitat cover 11% of the catchment. Developed open spaces, which is primarily roads, make up 2% of the catchment. The Chumstick Creek watershed has been logged several times beginning in the late 1800's–early 1900's, primarily removing large pine and Douglas-fir (USFS 1999). Although the aerial imagery is relatively similar throughout the years, logging could have occurred in Bjork Creek catchment prior to 1957. The aerial imagery from 1957 to 2011 shows that the tree canopy in the eastern part of the catchment becomes denser throughout the years (Figure 3 – Figure 6). Between 2011 and 2015 road development and tree removal occurred in the eastern part of the catchment (Figure 6 – Figure 8). In 2013, the Eagle Creek wildlife burned nearly 1,500 acres, including a large portion of the eastern hillslope along Bjork Creek. The burned portion of the basin was salvage logged the following year, along with an extensive harvest of the upper basin. Trees were harvested clear down to the headwater drainages that form Bjork Creek. Although these small drainages do not retain perennial surface flow, the extensive removal of vegetation has a direct impact on water and sediment transport during runoff events, especially in sandstone dominated systems. There were additional logging operations from 2015 and 2017 and by 2021 shrubs and seedlings within the eastern portion of the catchment are gaining a foothold (Figure 7 – Figure 9). Due to fire suppression throughout Chumstick Creek watershed, the tree species compostion has changed and the average stand is denser but tree diameter is smaller (USFS 1999).

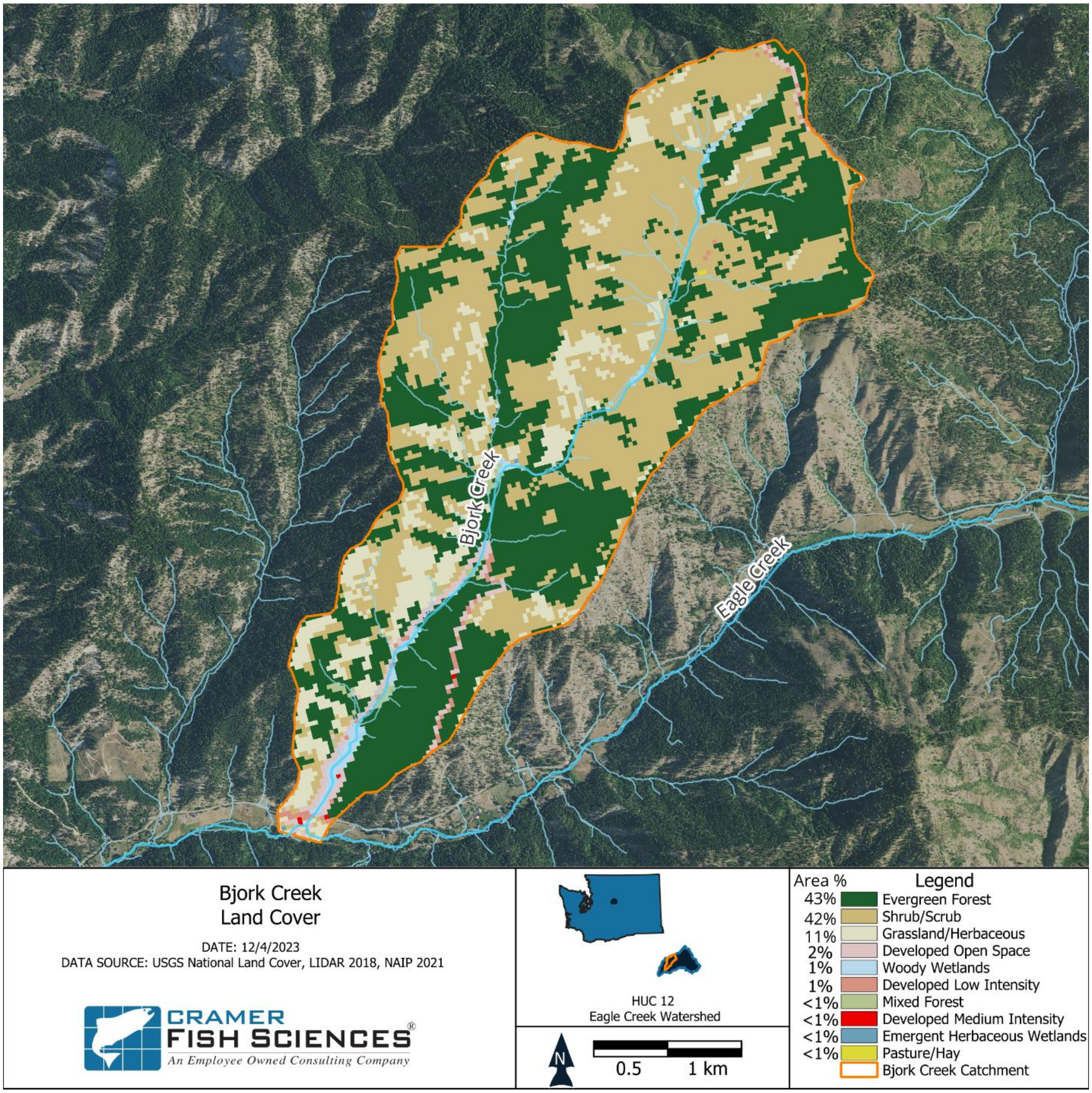

Figure 2. U.S. Geological Survey (USGS) National Land Cover for Bjork Creek catchment.

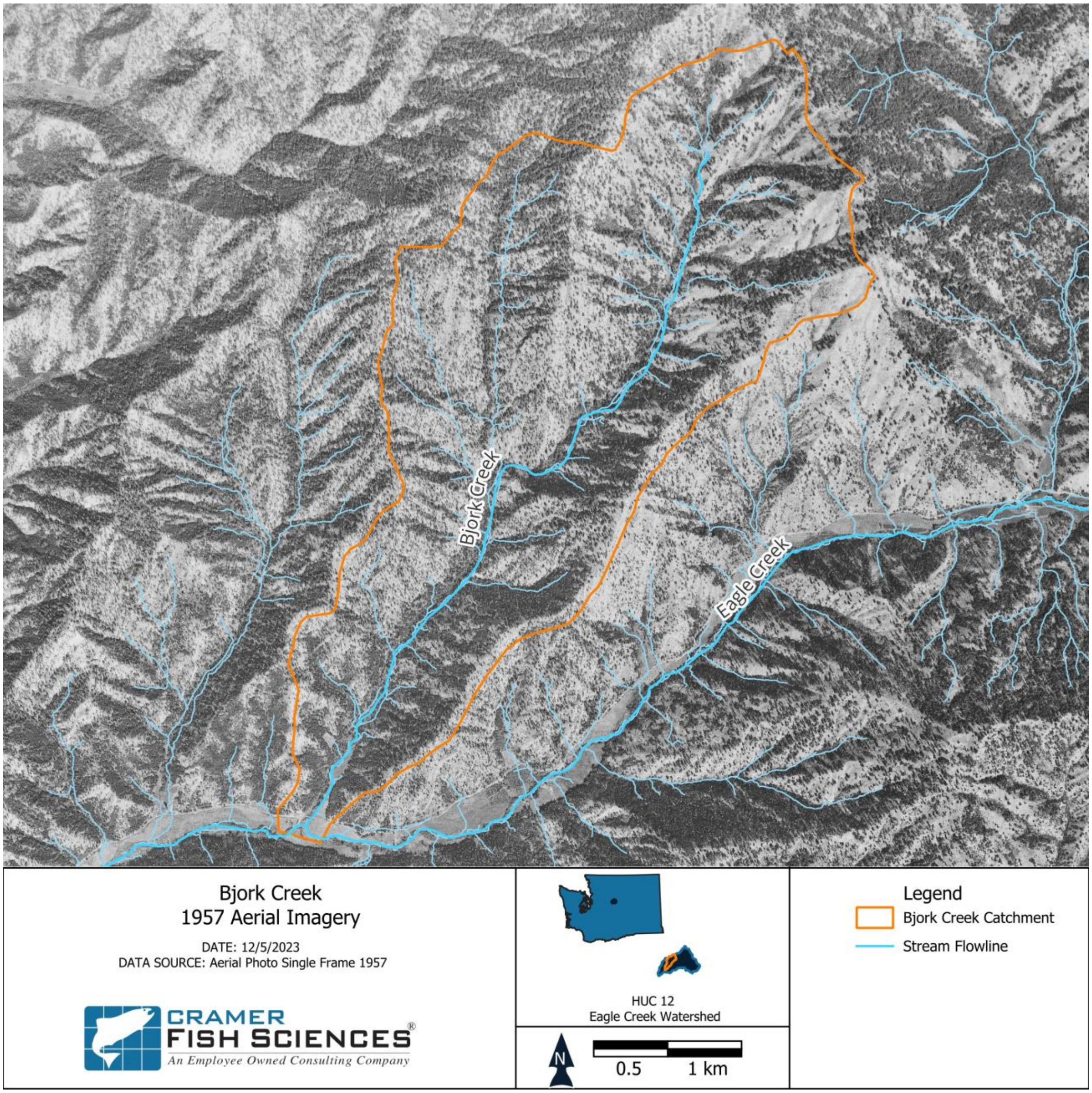

Figure 3. USGS Aerial Photo Single Frame imagery from 1957 for Bjork Creek catchment.

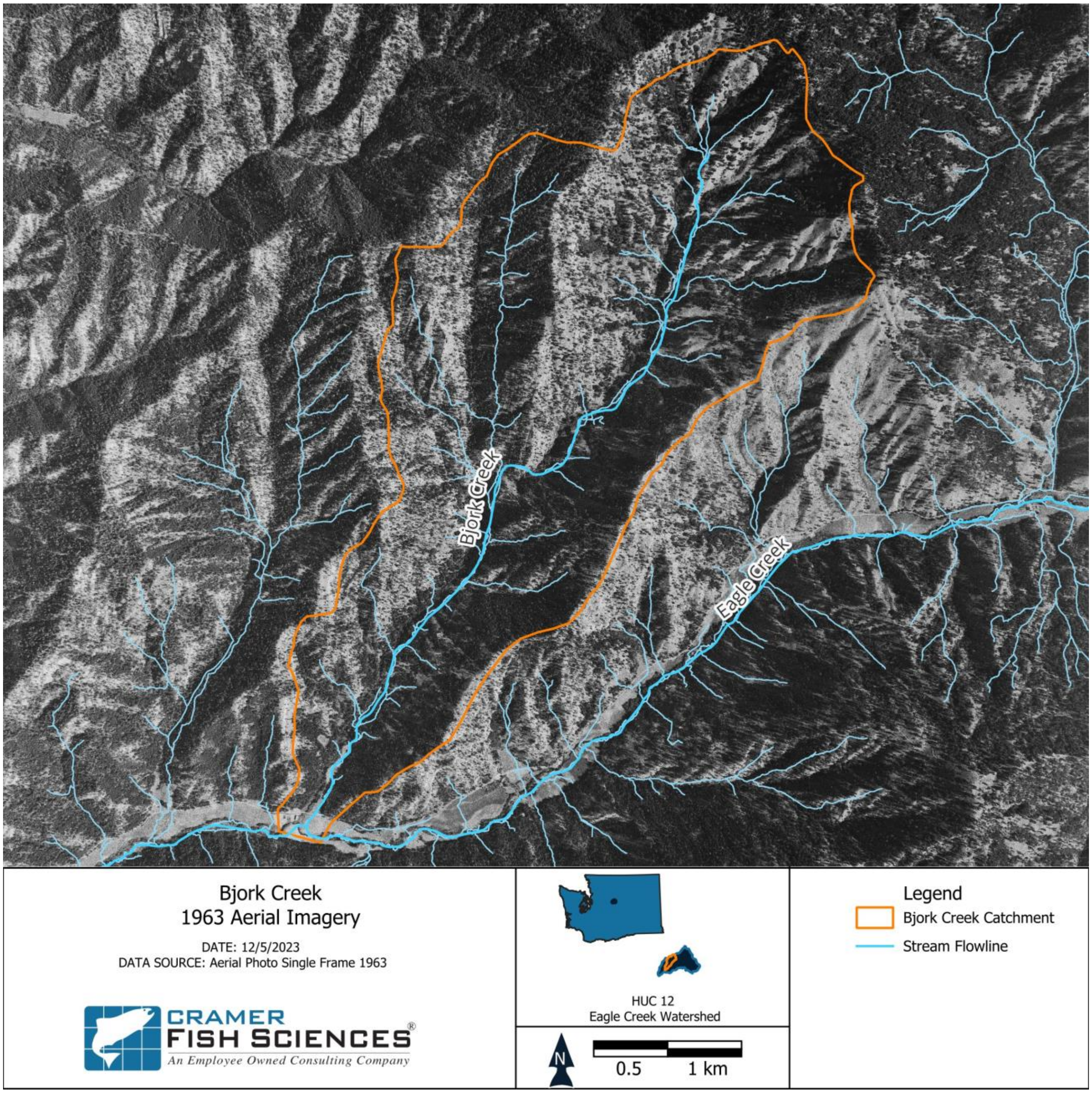

Figure 4. USGS Aerial Photo Single Frame imagery from 1963 for Bjork Creek catchment.

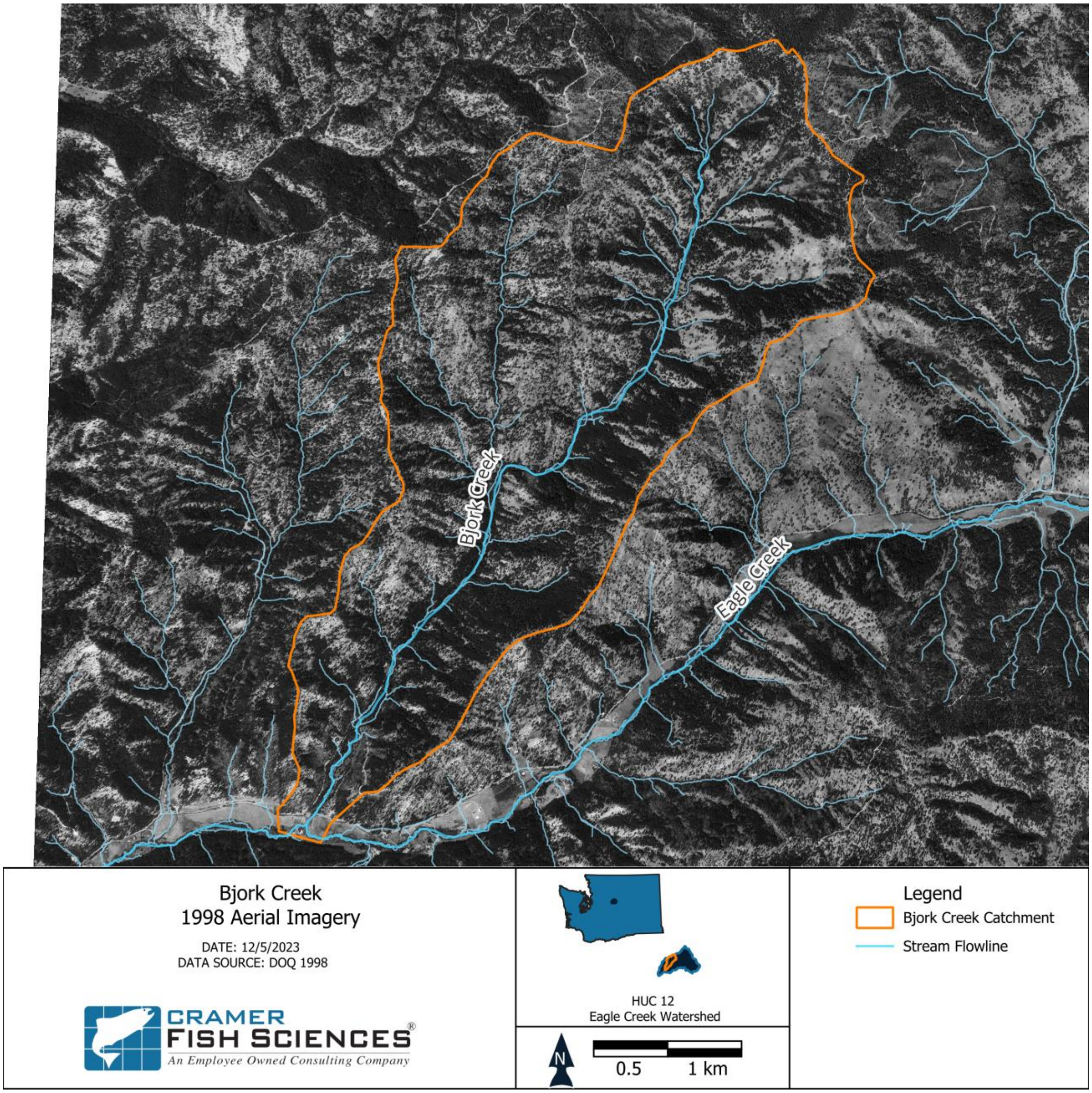

Figure 5. USGS Digital Orthophoto quadrangle (DOQ) aerial imagery from 1998 for Bjork Creek catchment.

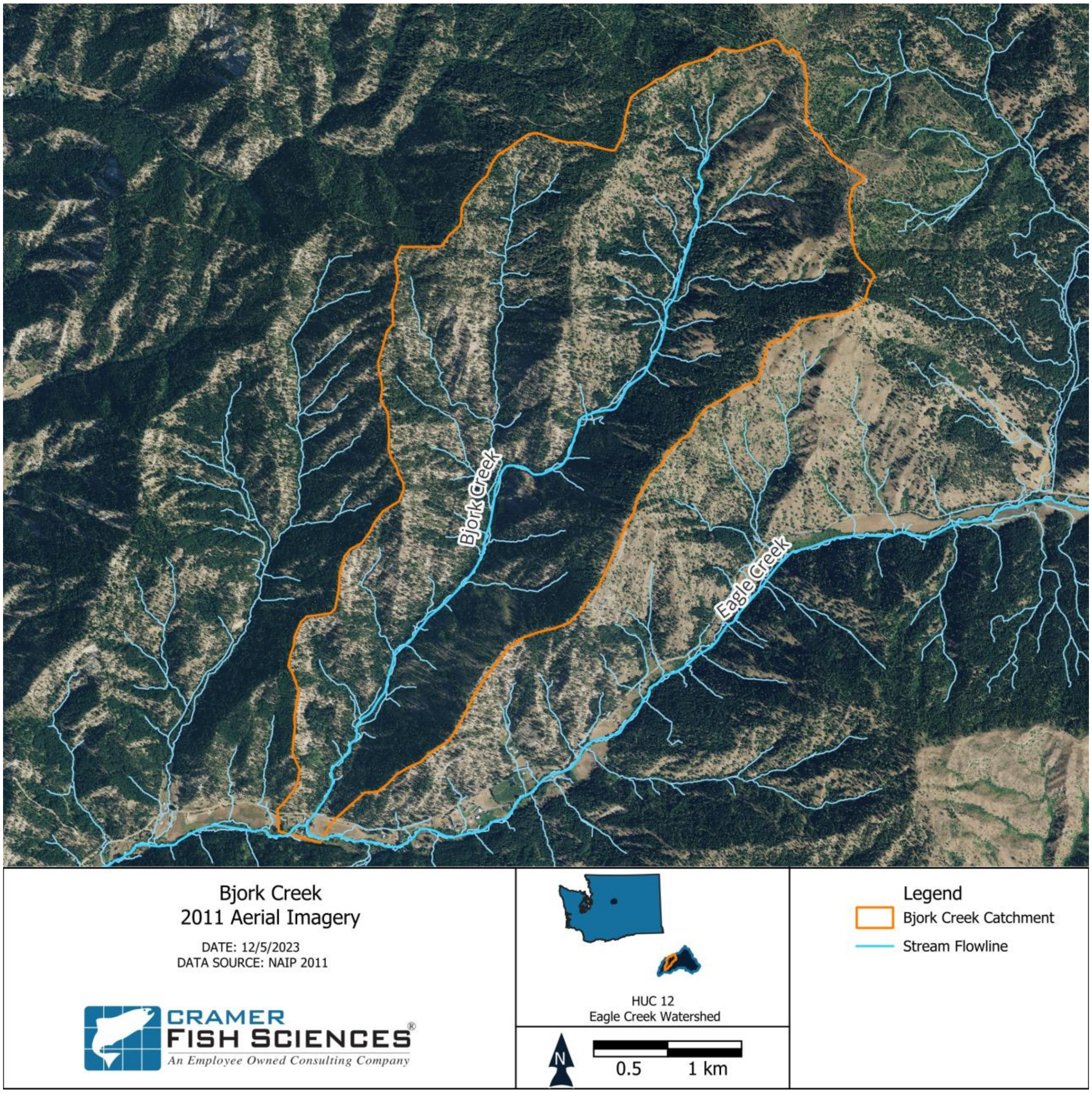

Figure 6. USGS National Agriculture Imagery Program (NAIP) aerial imagery from 2011 for Bjork Creek catchment.

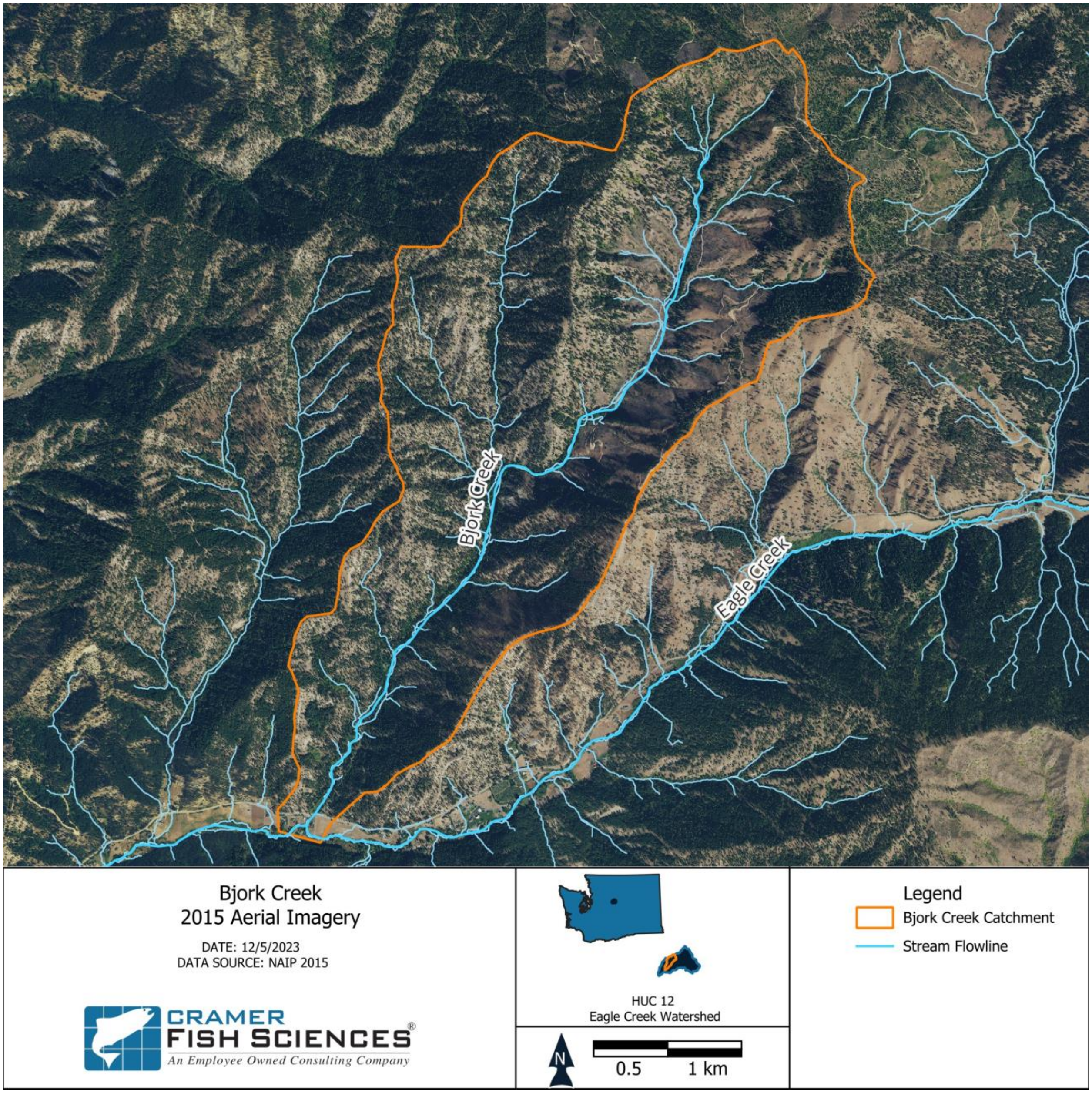

Figure 7. USGS NAIP aerial imagery from 2015 for Bjork Creek catchment.

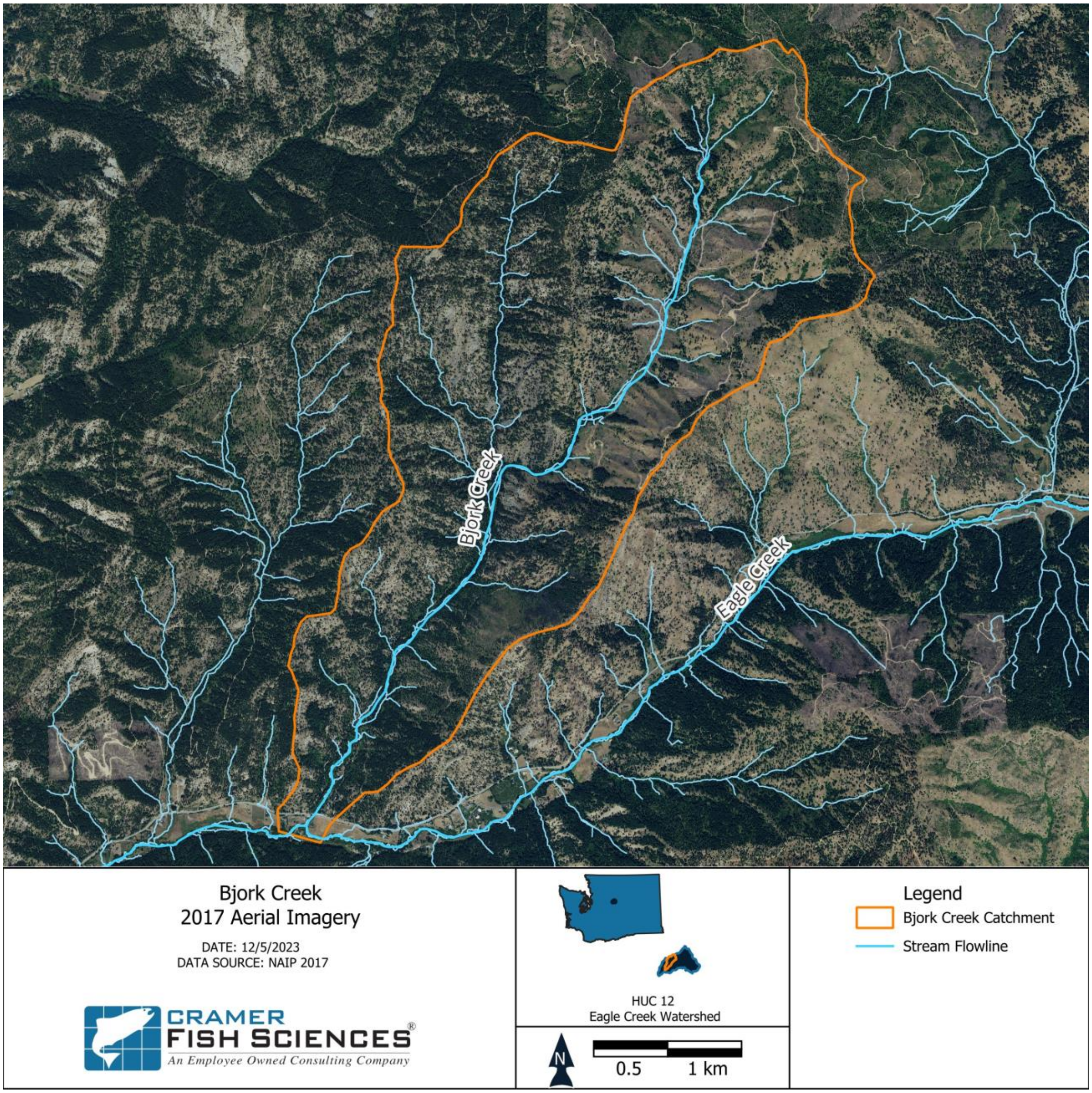

Figure 8. USGS NAIP aerial imagery from 2017 for Bjork Creek catchment.

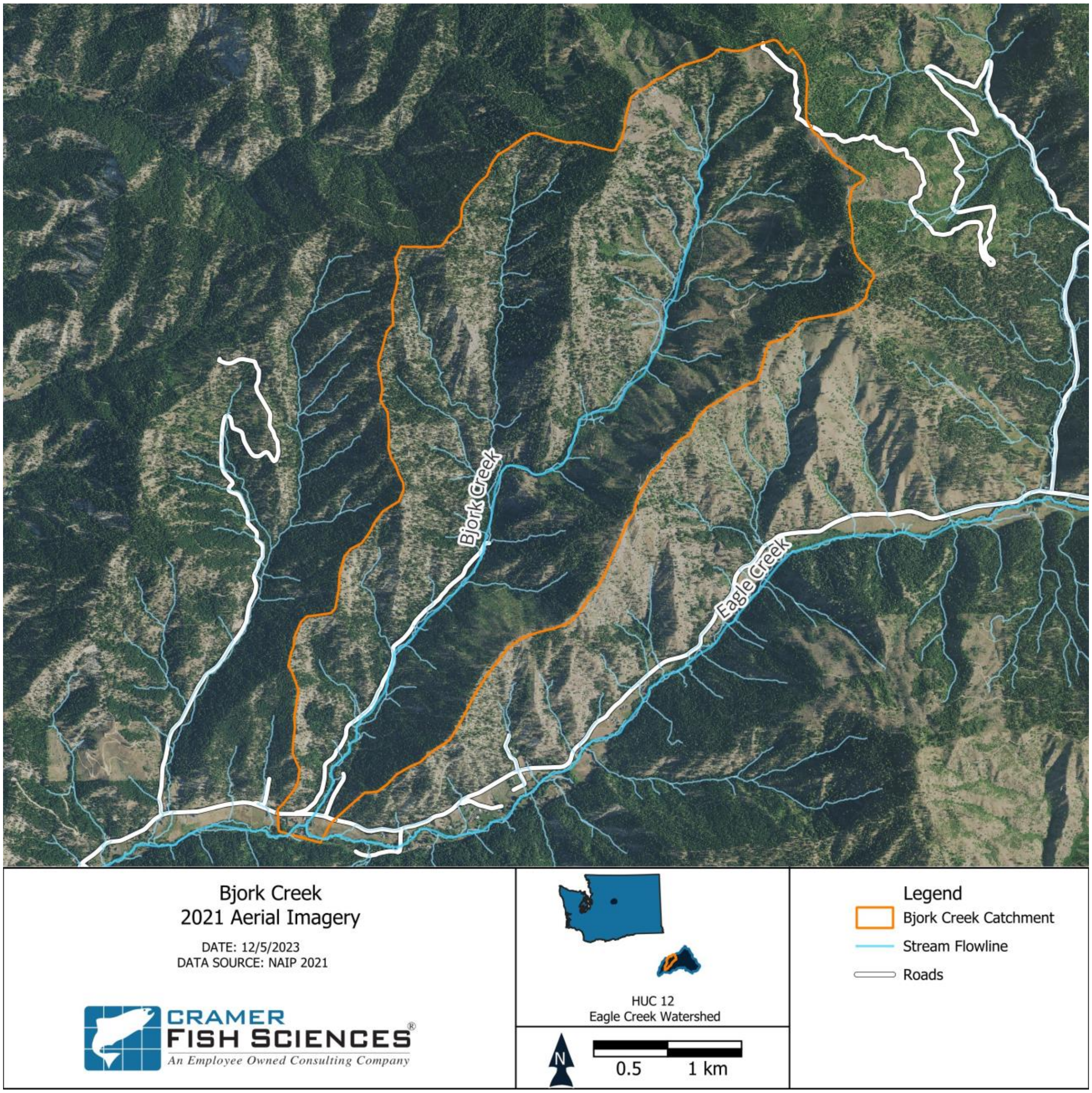

Figure 9. USGS NAIP aerial imagery from 2021 for Bjork Creek catchment.

Geology and Soils

Surficial geology within the Bjork Creek catchment is relatively simple, dominated primarily by continental sedimentary rocks. Continental sedimentary deposits or rocks and conglomerate sedimentary rocks from the Chumstick Formation make up 83% and 11% of the geology within the Bjork Creek catchment (Figure 10). The 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 5% 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. Swakane Biotite Gneiss makes up the remaining 2% of the catchment and is a metamorphic rock that is comprised of quartz, feldspar, and biotite (Gresens 1983).

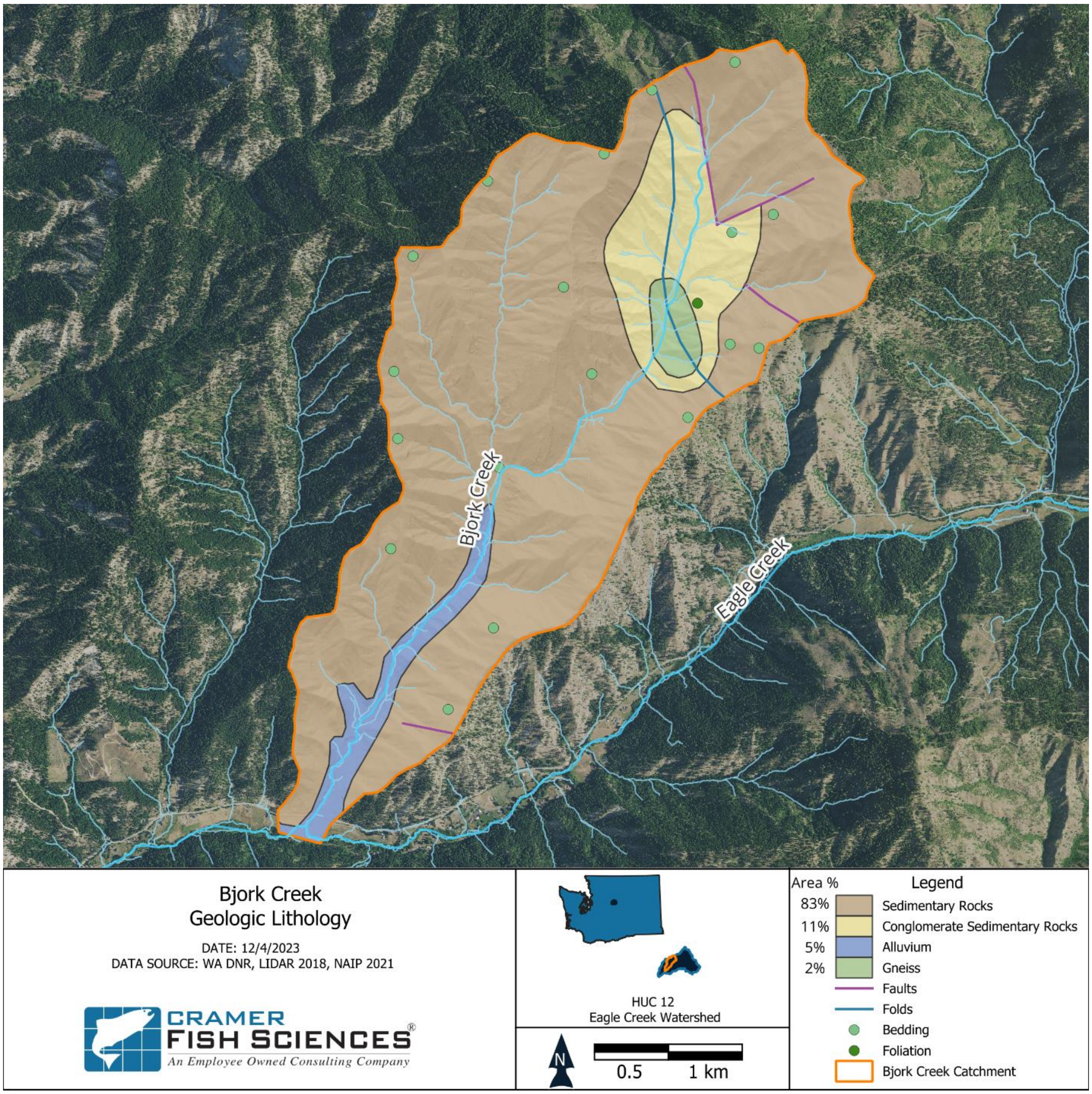

Figure 10. Washington Department of Natural Resources (WDNR) surface geology for Bjork Creek catchment.

The surface layer of Bjork Creek catchment is made of rock outcrops and a variety of soil types. Rock outcrops, which contain little to no soil and are large expanses of exposed sandstone, make up 56% of the catchment (Figure 11). Alfisols, primarily from the soil type Nard, make up 39% of the soil composition within Bjork Creek catchment. Nard is a well-draining soil 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). Nard soil horizons are dominated with ashy loam to a depth of 24 inches and clay loam between 24 and 60 inches (Soil Survey Staff 2023). Nard soils are primarily concentrated to the fluvial corridors of Bjork Creek, its tributaries, and ephemeral drainages, suggesting that runoff will transport fine soils from upstream to the project area. However, runoff will also transport sand and small gravels from the abundant sandstone outcrops as they weather. Andisols, which were developed from volcanic ash, pumice, cinders, and lava make up 2% of the catchment and are located along the riparian corridor of Bjork Creek. They are highly fertile, with unusually high water and nutrient holding capacity, which allow most plants to grow successfully (Soil Survey Staff 1999). Shaser, which is the dominant Andisol soil type in the catchment, has horizons dominated by ashy fine sandy loam to a depth of 9 inches, gravelly ashy loam between 9 and 18 inches, and very and extremely gravelly clay loam between 18 and 60 inches (Soil Survey Staff 2023). The project area is dominated by Andisols from the Shaser soil series and the effects on local riparian vegetation in the field are evident. Mollisols from the soil types Billyridge and Brisky make up 3% of the soil within the catchment. Billyridge is located downstream of the study site, along the riparian corridor and Brisky is negligible, at 1% located at the top of the catchment. Entisols make up <1% of the catchment and are located near the confluence with Eagle Creek and may be reflective of soil development in the Eagle Creek valley rather than deposition from Bjork Creek.

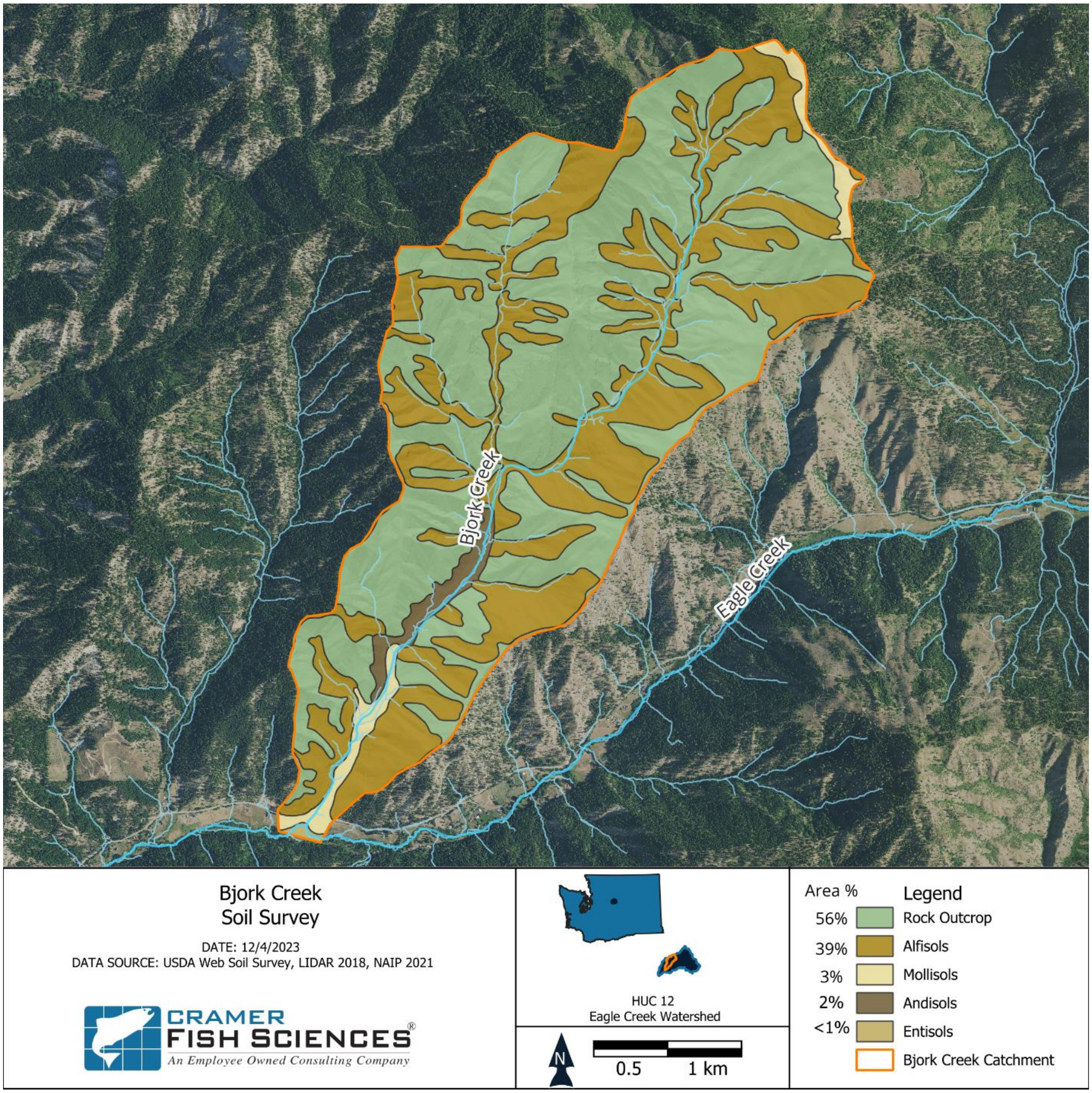

Figure 11. U.S. Department of Agriculture (USDA) Web Soil Survey for Bjork Creek catchment.

BIOLOGICAL ASSESSMENT

Land use alterations, such as roads, logging, development, grazing, and fire suppression throughout the Chumstick Creek watershed have resulted in degraded stream habitat (USFS 1999; Andonaegui 2001; NPCC 2004). Homesteading, railroad development, and logging began in the late 1800's–early 1900's (USFS 1999; NPCC 2004). In the 1930's the Civilian Conservation Corps began constructing roads throughout the watershed (USFS 1999). Many of the roads parallel stream channels, resulting in channel confinement, reduced access to the floodplain, altered riparian habitat, and increased sedimentation (Andonaegui 2001; NPCC

2004). There is a naturally high rate of fine sediment and sediment transportation in the Chumstick Creek watershed based on the geologic history, but it is exacerbated locally due to roads, degraded riparian habitat, and fire and grazing on hillslopes (USFS 1999; Andonaegui 2001). Increases in fine sediment can reduce salmonid spawning success and reduce macroinvertebrate populations and alter the composition of macroinvertebrate communities (USFS 1999; Andonaegui 2001; NPCC 2004). Additionally, streams discharge in the watershed have become lower and flashier due to the decreased infiltration capacity of compacted soil from roads, grazing, and timber harvesting (USFS 1999; Andonaegui 2001). Although there is some information about the past alterations in the watershed, there is limited site-specific information about Bjork Creek.

Due to the similarities of streams within the basin and the limited information on Bjork Creek, habitat characteristics and alterations are inferred based on information from Eagle Creek and Chumstick Creek. The dominant substrate for most streams in the Chumstick Creek watershed is sand with few substrates larger than small gravel (USFS 1999; Andonaegui 2001). Side channel and off-channel habitat is low for most streams throughout the watershed (USFS 1999). Bjork Creek is an intermittent stream that operates as a sediment transport zone, primarily delivering sands and small gravels transports sediment to Eagle Creek (USFS 1999; Andonaegui 2001). The altered riparian vegetation and high road density (6.28km/km^2) of Eagle Creek causes stream temperatures and peak flows to increase and reduces recruitment potential of large woody debris (USFS 1999). There is a TMDL listing on Eagle Creek just downstream of Bjork Creek for fecal coliform, ammonia, chloride, and pH (Listing 41249 2023; Listing 41536 2023; Listing 41696 2023; Listing 71471 2023). The high fecal coliform and degraded water quality is a result of livestock, private land development, and improper septic tanks (USFS 1999; Andonaegui et al. 2003).

There are many fish passage barriers throughout the watershed with varying levels of passability. In 1957 the North Road culvert was built at river km 0.45 on Chumstick Creek, which prevented upstream fish passage for most anadromous salmonids except during optimal flow conditions for steelhead (*Oncorhynchus mykiss irideus;* Andonaegui 2001; NPCC 2004; Schmidt 2014). Chumstick Creek watershed was identified as one of the most problematic watersheds for fish passage in the Wenatchee Basin (Andonaegui 2001; NPCC 2004). In 2009 the Chelan County Public Works Department replaced the North Road culvert with a 100% fish passable bridge (SRP Project 2023). Additionally, the Upper Chumstick Barrier Removal Project removed over 30 barriers from Chumstick Creek from 2001–2012, restoring fish passage for 15.77 river kms on Chumstick Creek (Schmidt 2014; SRP Project 2023). There are 9 culverts and 1 crossing that provide 0% fish passage throughout Eagle Creek watershed but they are all upstream of Bjork Creek. There are 21 culverts and one dam that are passable 33–67% of the time throughout Eagle Creek watershed. Three of these culverts are in Bjork Creek catchment and 7 are on Eagle Creek downstream of Bjork Creek. There are 15 crossings and 3 culverts on Eagle and Chumstick Creek that provide 100% fish passage downstream of Bjork Creek. There is 1 culvert on Bjork Creek that provides 100% fish passage. There is 1 crossing on Chumstick Creek downstream of Eagle Creek that has unknown fish passability. Although there has been substantial work to improve anadromous fish passage on Chumstick Creek, some fish passage barriers need to be addressed to restore passage throughout the watershed. Passage barriers reduce the diversity and quantity of available stream habitat and restrict access to spawning and rearing habitat for spawning salmonids (Sheer and Steel 2006).

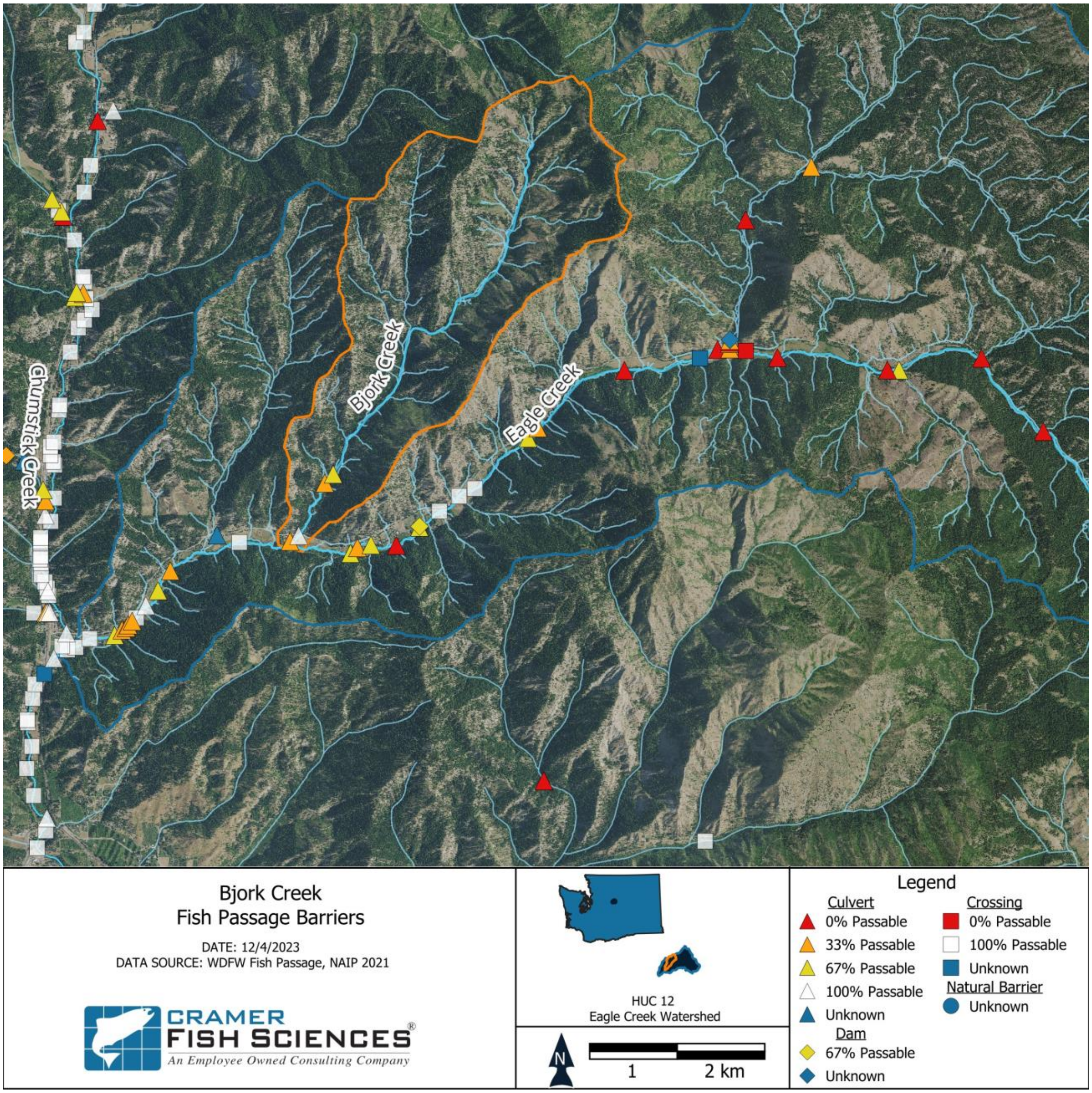

Figure 12. WDFW fish passage barriers throughout the Eagle Creek Watershed.

Fish Species Occurrence

Chumstick and Eagle Creek are the only systems with known populations of anadromous salmonids but there is limited fish community data for Chumstick Creek watershed (USFS 1999; Andonaegui 2001; NPCC 2004). Although Bjork Creek is thought to be a non-fish bearing stream (USFS 1999), species that occur in Eagle Creek could potentially use Bjork Creek. Prior to the barrier removal projects on Chumstick Creek salmonid species in the watershed were limited to rainbow trout (*O. mykiss*), inland redband trout (nonmigratory; *O. mykiss gairdneri*), and a few coastal steelhead (anadromous; *O. mykiss irideus*). Historically populations of coho salmon (*O. kisutch*) and spring Chinook salmon (*O. tshawytscha*) occupied streams in the watershed (USFS 1999; NPCC 2004). Before coho salmon were extirpated from Chumstick Creek watershed they were thought to be the most abundant salmonid in the system (USFS 1999; Andonaegui 2001). After the fish passage barriers were removed, a fish migration study from 2011–2013 on Chumstick Creek using Passive Integrative Transponder (PIT) tags and found that hatchery coho salmon, wild and hatchery summer steelhead, and spring Chinook salmon migrated upstream of the replaced North Road culvert (Table 1; Roumasset 2013). There is no evidence that bull trout (*Salvelinus confluentus*) use Chumstick Creek watershed and conditions are likely not suitable due to increased temperatures, fine sediment, and flows (Andonaegui 2001). Non-native rainbow trout and brook trout (*S. fontinalis*) have been introduced into Chumstick Creek watershed from 1931–1999 (USFS 1999; Andonaegui 2001; NPCC 2004).

Although spawning life history is unknown for salmonids in Chumstick Creek watershed, there is some known spawning information for the Wenatchee River basin. 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. Spring Chinook migrate from the ocean into Wenatchee River from May–July (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 and 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. Coho salmon migrate to the Wenatchee River in early September–late November for spawning (NPCC 2004).

Table 1. PIT tag study results of salmonid migrations into Chumstick Creek (Roumasset 2013).

Species	2011	2012	2013
Wild Summer Steelhead	37	26	14
Hatchery Summer Steelhead	46	33	17
Hatchery Coho	8	7	4
Wild Spring Chinook	3	2	2
Hatchery Spring Chinook	4	0	4

Table 2. Periodicity for salmonid species within Chumstick Creek, Eagle Creek, and the Wenatchee River.

Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Summer Steelhead prespawn migration[1]												
Summer Steelhead spawning[1]												
Summer Steelhead fry emergence[1]												
Spring Chinook prespawn migration[1]												
Spring Chinook spawning[1]												
Coho Salmon prespawn migration[2]												

[1]UCSRB 2007; [2]NPCC 2004

Limiting Factors

Habitat limitations for Bjork Creek, which is a tributary to Eagle Creek in the Chumstick Creek watershed are assumed to be similar to Eagle Creek and other streams in the watershed. Historically, streams in the watershed had meandering channels with beaver ponds, backwater, and side-channel habitat (Schmidt 2014). These conditions were particularly suitable for coho salmon rearing (USFS 1999). Land use alterations have resulted in channel incision with reduced riparain habitat, and floodplain connection. Which has resulted in limited large woody debris and few pool habitats in the channel. Additionally, the naturally high rate of sedimentaiton has been exacerbated. The instream flow has been altered with lower magnitude flows and a flashier flow regime. Restoration goals for Bjork Creek should include connecting the floodplain and creating off-channel and side-channel habitat. Additionally, restoration needs to improve the natural flow and sediment regime by slowing the transport of water and sediment, and restoring the riparian habitat, providing shade and large woody debris recruitment.

METHODS

Field Based Design

On September 13th, 2023, we conducted the field-based portion of the LTPBR design for the project area on Bjork Creek. We began about 0.5 kilometers upstream from the parcel boundary 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 (GGL) analysis results, and a 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, a channel-spanning PALS may be used to encourage overbank flows in areas with relatively low-lying floodplain. 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 13th, 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 provide 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 represents 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, max pool depth, pool head, and riffle crests would be used as sample locations. During our survey of Bjork 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 max pool depth, pool head, and riffle crest for each potential pool location.

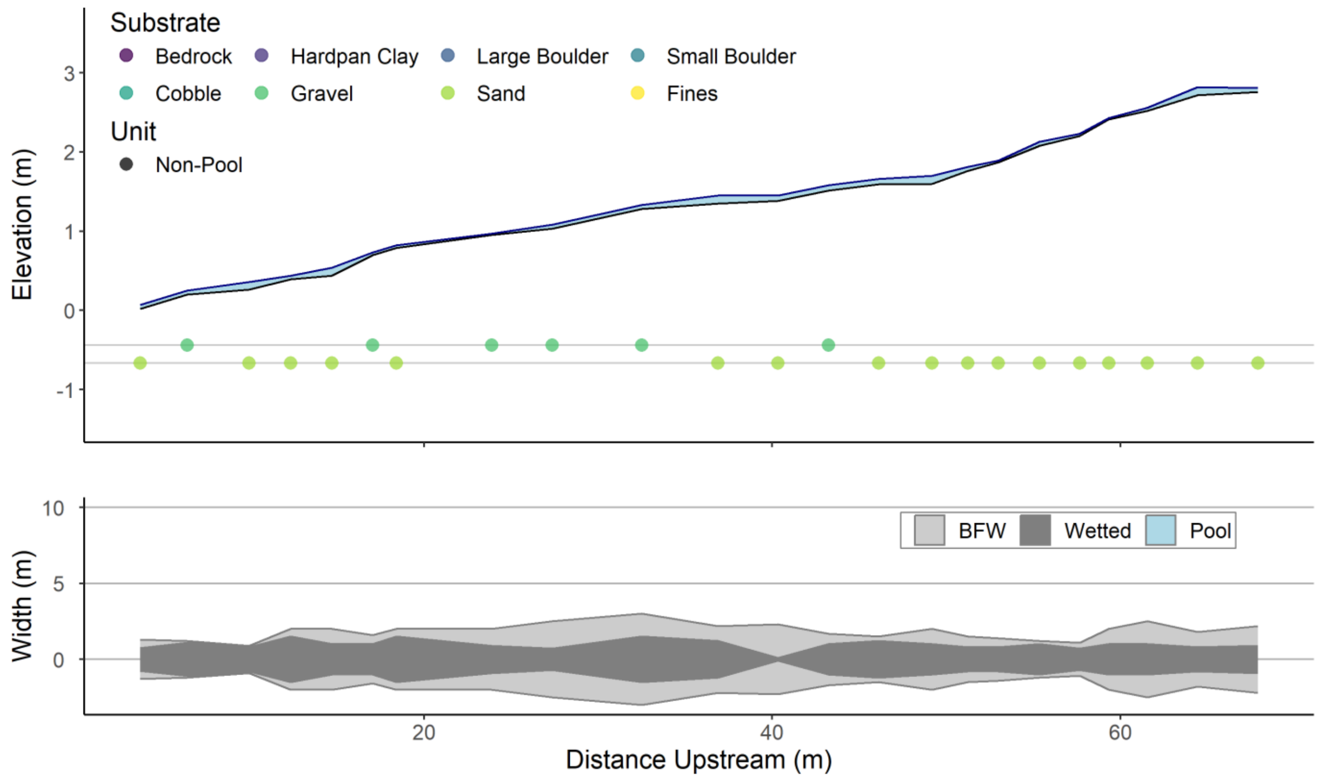

Figure 13. Long profile survey results in Complex 7 of Bjork Creek.

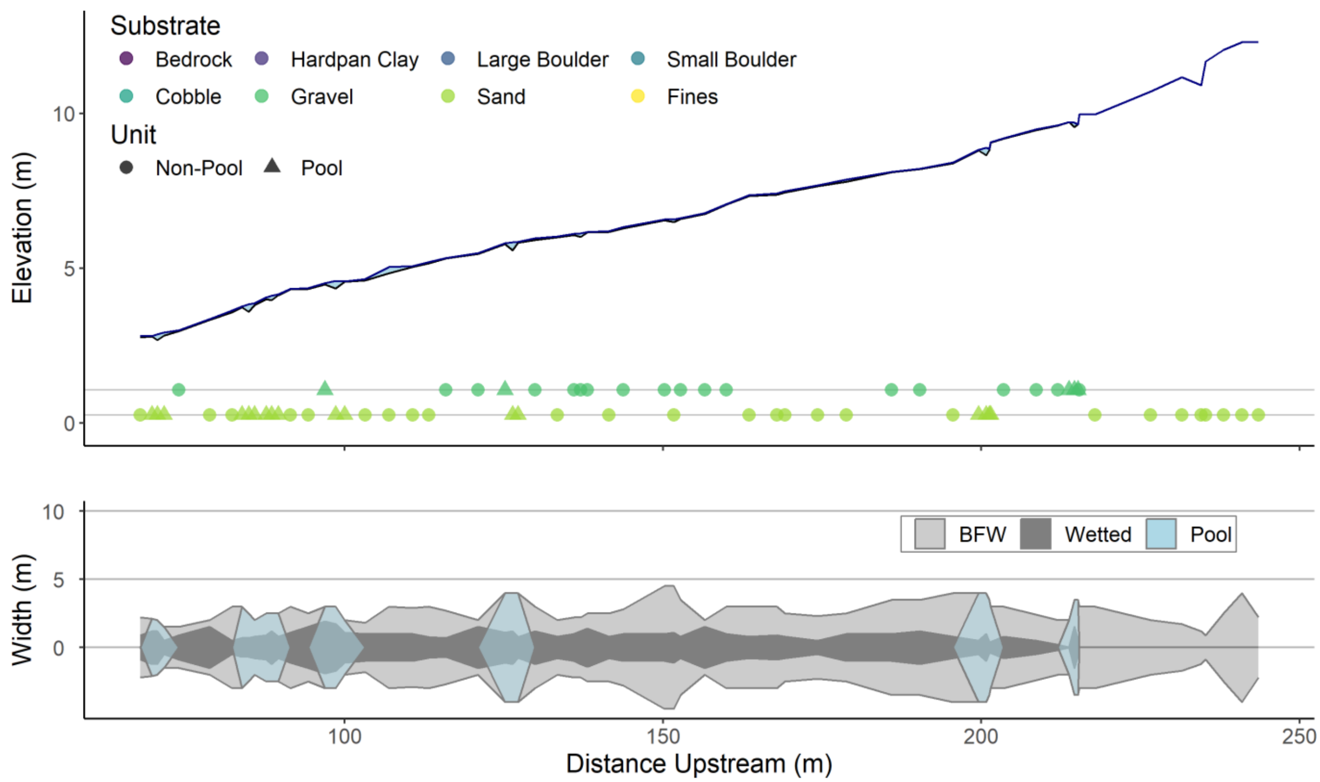

Figure 14. Long profile survey results in Complex 8 of Bjork Creek.

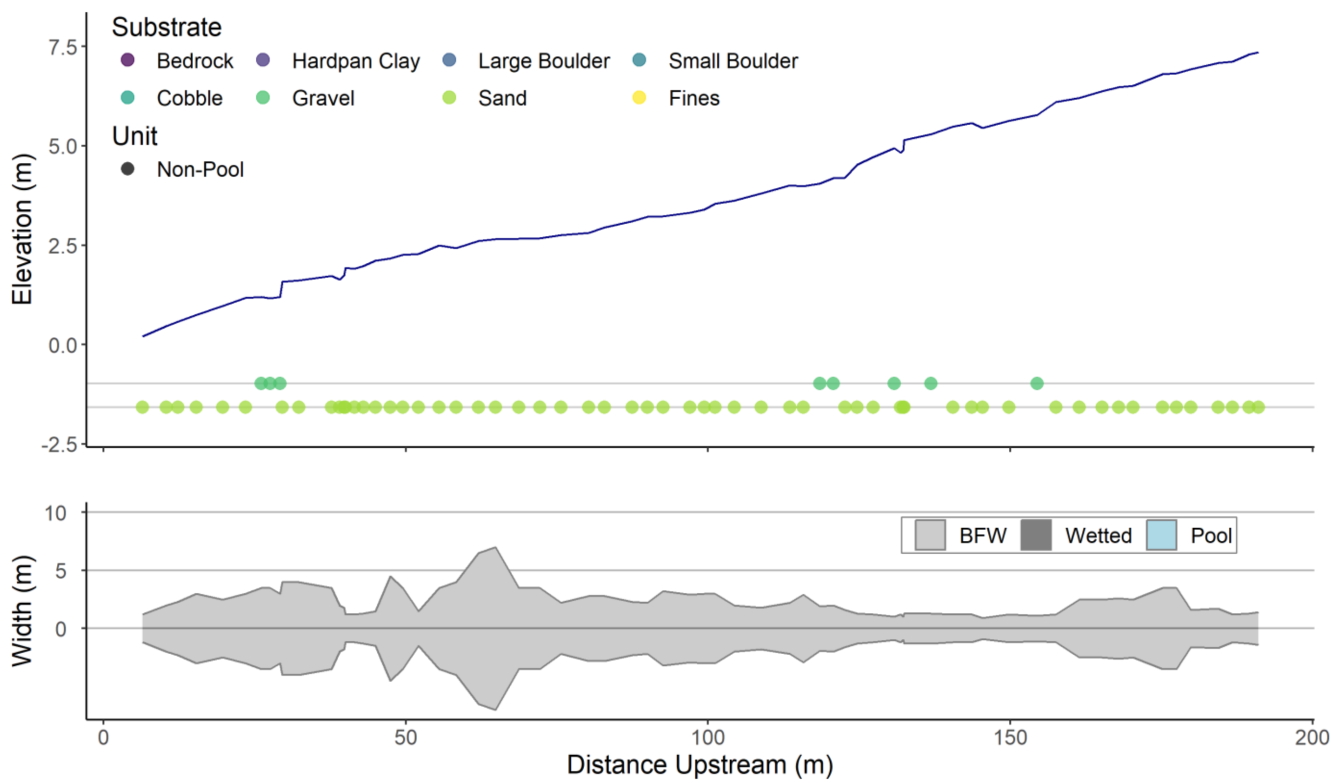

Figure 15. Long profile survey results in Complex 10 of Bjork Creek.

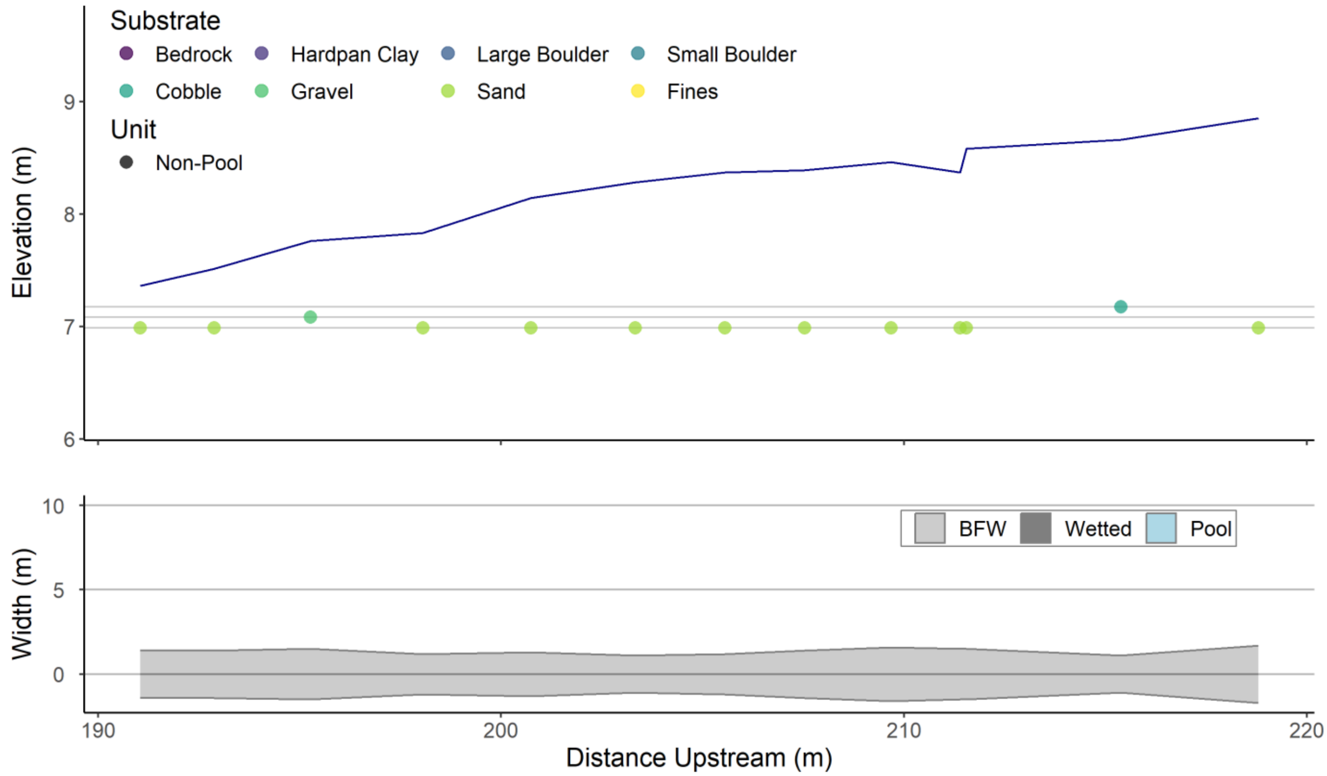

Figure 16. Long profile survey results in the downstream half of Complex 11 of Bjork Creek.

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 also used LiDAR from 2018 to complete analyses and generate models, including a flow accumulation model, a 1-meter resolution main channel flowline, GGL analysis, 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 18Figure 18). We also used the REM to generate bankfull and valley bottom polygons to provide additional lines of support for complex objectives. These GIS products were used for additional lines of support for structures placed in the field and used to generate a LTPBR design for the lower .5 kilometers of the project area.

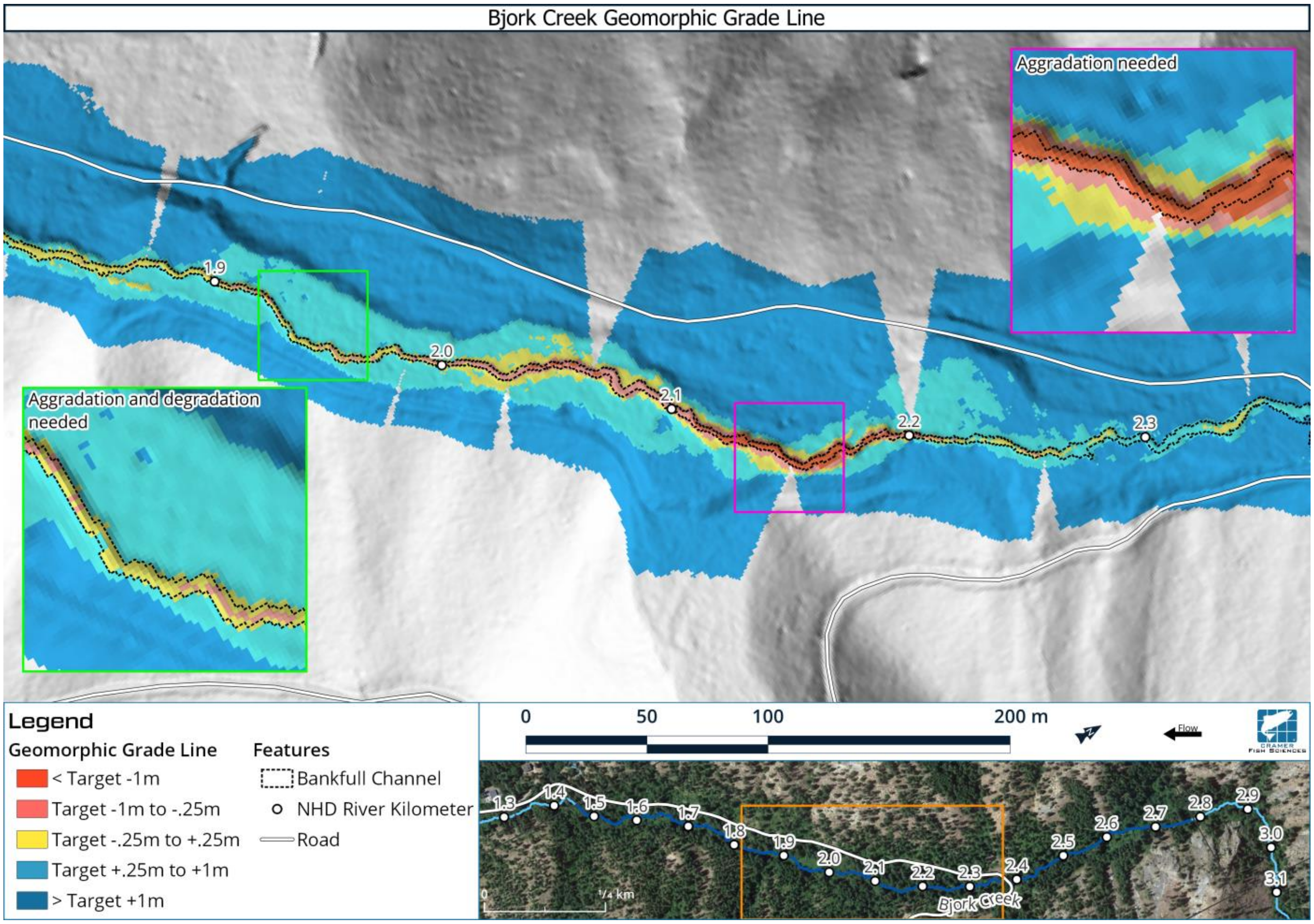

Figure 17. Example results of geomorphic grade-line analysis (GGL) available for the project area on Bjork Creek. GGL highlights areas of cut and fill in the floodplain needed to bring the channel closer to quasi-equilibrium along the valley grade line. Blue indicates areas where degradation (cut) is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

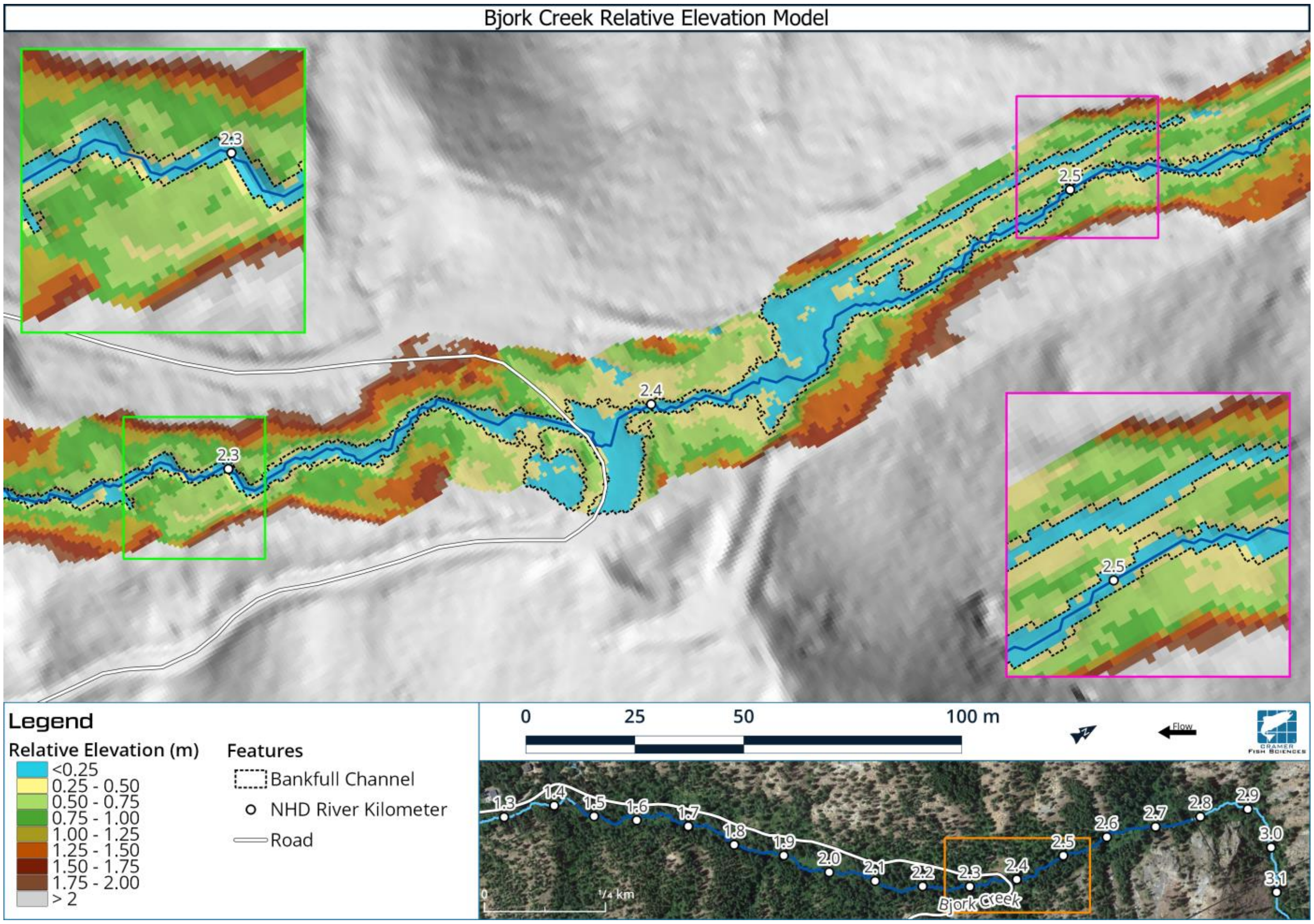

Figure 18. Example results from the Relative Elevation Model (REM) available for the project area on Bjork Creek. A REM highlights areas of low-lying floodplain and potential routes for reconnection.

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. Much of the floodplain within the Bjork Creek project area is wider than two times the channel width but is perched above the channel or otherwise inaccessible to base flows. The results from the GGL confirm that much of the project area is deeply incised, with only ~300 meters of the channel above the geomorphic grade line (Figure 20). This section of aggraded channel can most likely be attributed to the presence of the road prism that crosses Bjork Creek. Therefore, many actions within the project area are expected to work toward the overall goal of attaining an equilibrium with the geomorphic grade line. Adding structural elements to each complex will help kick-start the recovery of hydrologic processes that create and maintain healthy river systems. There are many floodplain pockets throughout the project area that will help reduce water velocities and retain sediment (Figure 20). However, the greatest potential for floodplain connection is upstream of the Bjork Canyon Road prism. 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.

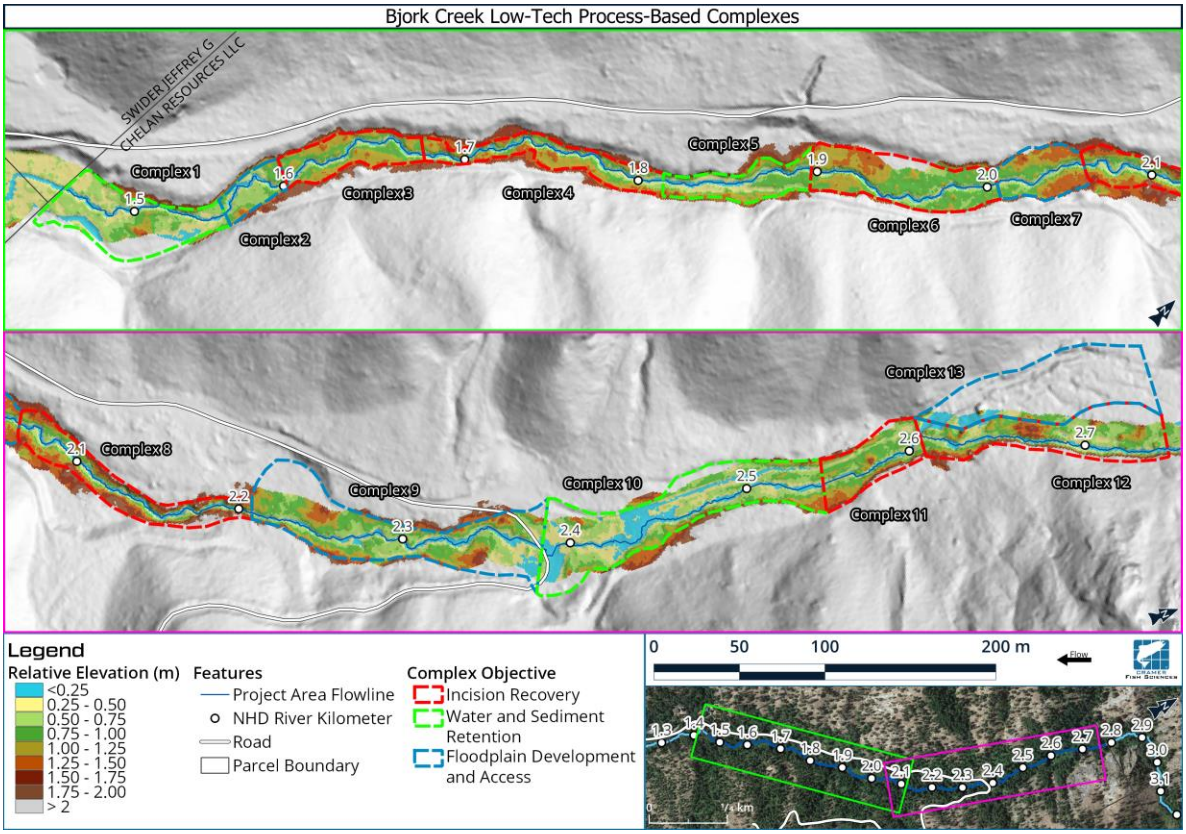

Figure 19. Locations of low-tech process-based complexes in Bjork Creek.

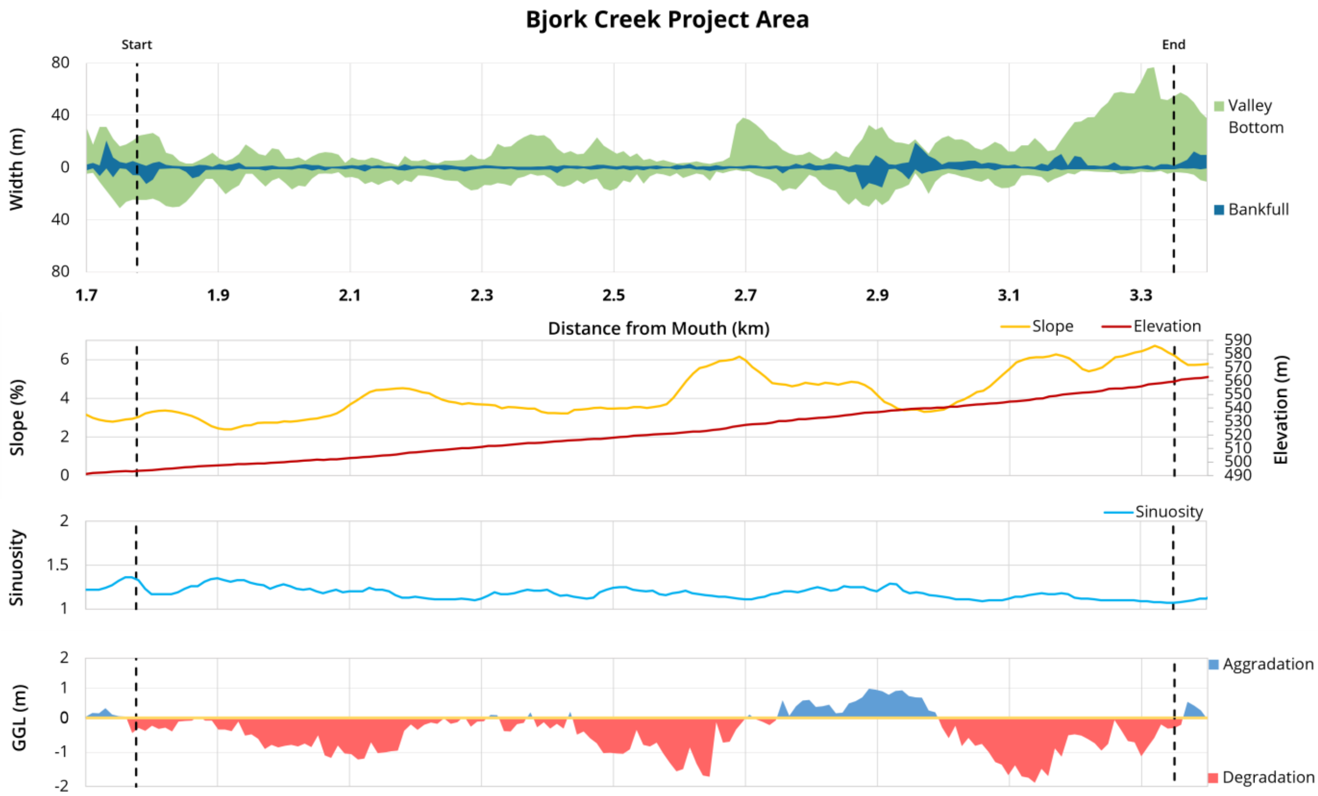

Figure 20. Long profile of geomorphic features and GGL results for the Bjork Creek project area.

Complex 1: Water and Sediment Retention

Complex 1 and all other complexes are located within Chelan Resources LLC property. Complex 1 focuses on water and sediment retention to take advantage of the low-lying floodplain that is more common here than in many upstream complexes. There are several opportunities for ponding and overbank flooding that could maintain the wide floodplain available in this complex or reactivate former channels. We recommend a focus on BDAs in this complex to pond water and hold back sediment to slow flows and prevent incision. Complex 1 has a significant amount of floodplain area that is in equilibrium with the geomorphic grade line and the channel is less than .5 meters incised (Figure 21). This near equilibrium in the lower half of the complex should be maintained. We also recommend installing PAS in the constricted section to build up the channel and widen the bankfull area.

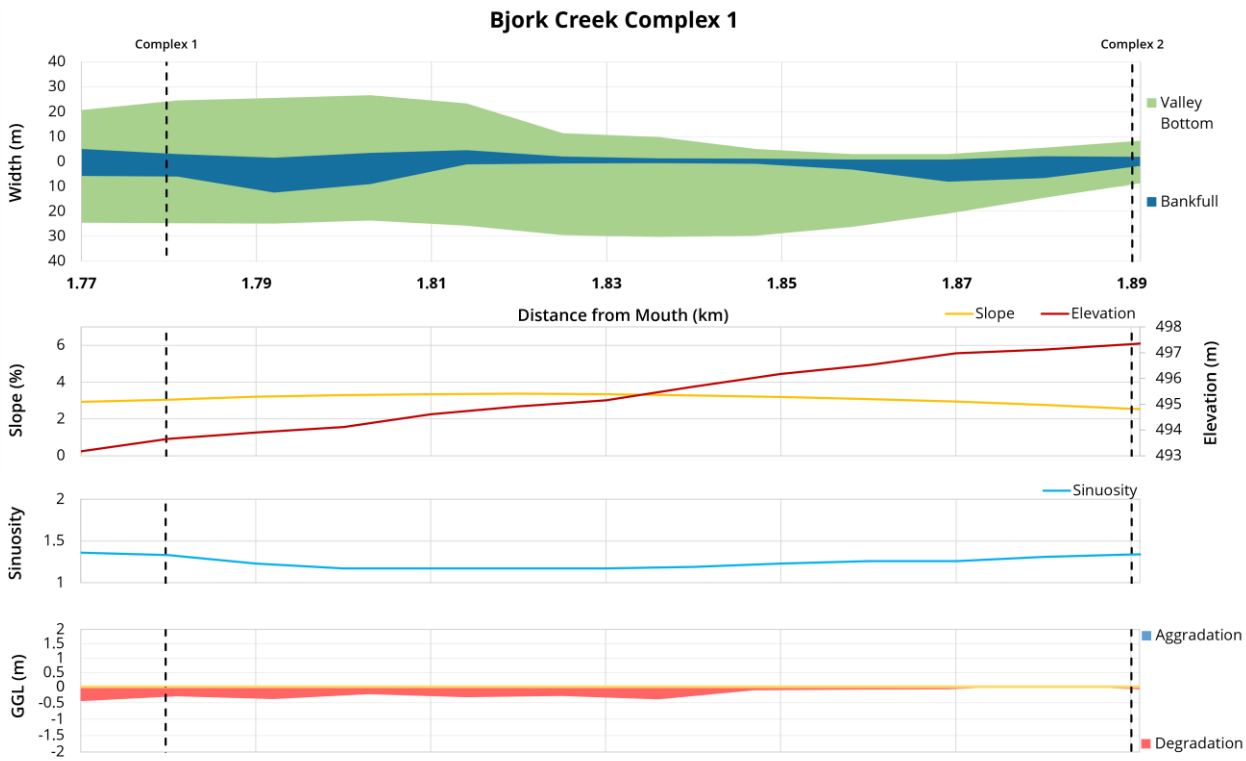

Figure 21. Long profile of geomorphic features and GGL results in Complex 1.

Complex 2: Floodplain Development and Access

Complex 2 focuses on floodplain development and access to halt incision and spread flows onto low lying floodplain. Complex 2 is not as incised as other locations in the project area. While it needs and would benefit from channel aggradation, the opportunity for floodplain development is significantly higher in this complex than other, more incised, locations. We recommend the use of both bank attached and channel spanning PALS in this complex that focus on access and development of the RL floodplain. Shunting flows away from the RR valley margin toward the RL floodplain will begin to widen the channel area and recruit sediment for the downstream Complex 1 that focuses on sediment retention. The channel in Complex 2 is less than .5 meters incised and many of the floodplain pockets are within the geomorphic grade line equilibrium (Figure 22). The RL floodplain is above the grade line but should move closer to equilibrium as access becomes available and process-based development takes place.

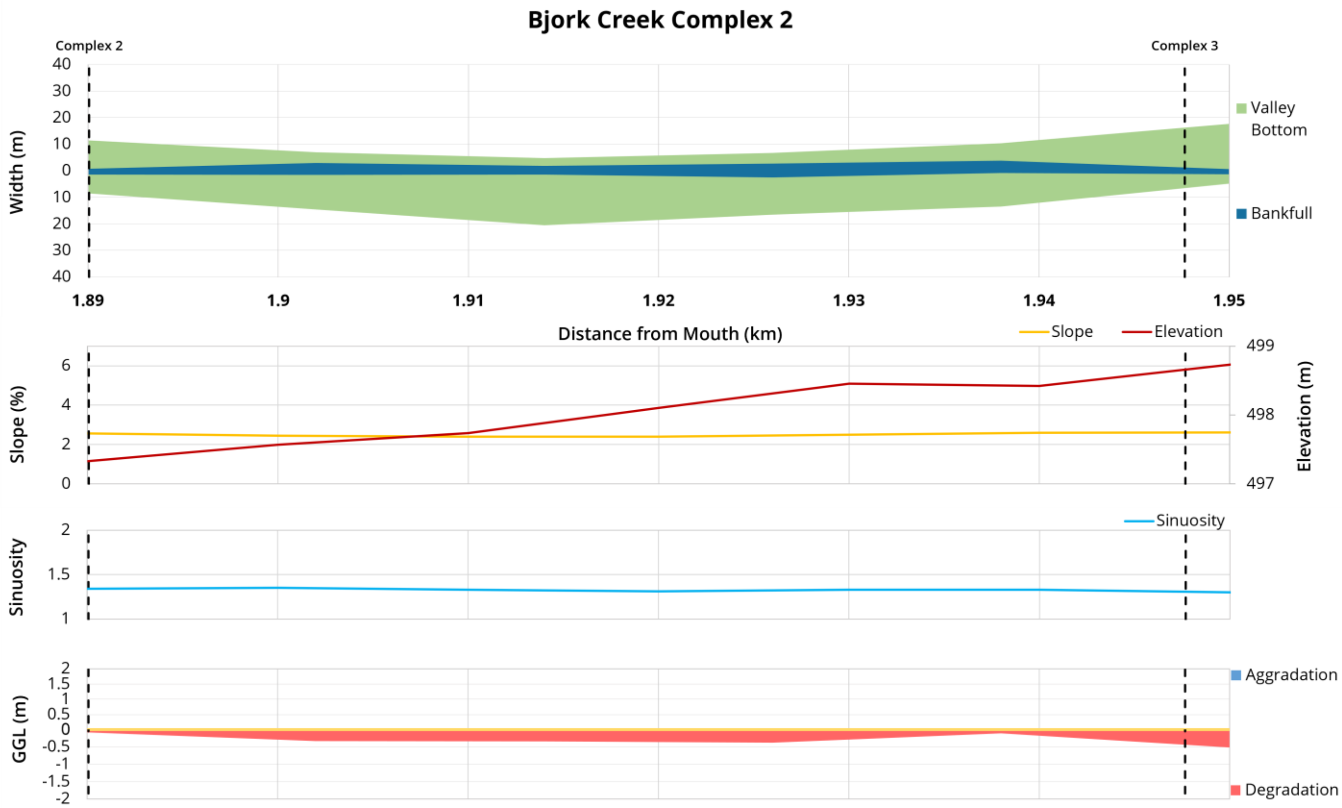

Figure 22. Long profile of geomorphic features and GGL results in Complex 2.

Complex 3: Incision Recovery

Complex 3 focuses on incision recovery due to its limited available floodplain. The channel in Complex 3 appears to have had the ability to move freely between the valley margins but is currently incised up to 1 meter below the geomorphic grade line. While some small floodplain pockets exist within a few meters of the bankfull channel, most of the floodplain beyond is above the geomorphic grade line and greater than 1 meter above the channel elevation. We recommend the use of PALS to progress the existing channel migrations and widen the channel. The channel in Complex 3 is not restricted to one side of the valley which will aid in widening the existing floodplain and allow for aggradation and incision recovery as flows spread out and slow down to allow for sediment deposition. The ~3% slope of Complex 3 is comparable to the slope of both complexes downstream (Figure 23), which provide an example of what is achievable for Complex 3. The most notable difference between Complex 3 and its downstream neighbors is the almost 1-meter incision of the channel that was identified in the field and is visible in the GGL results (Figure 23).

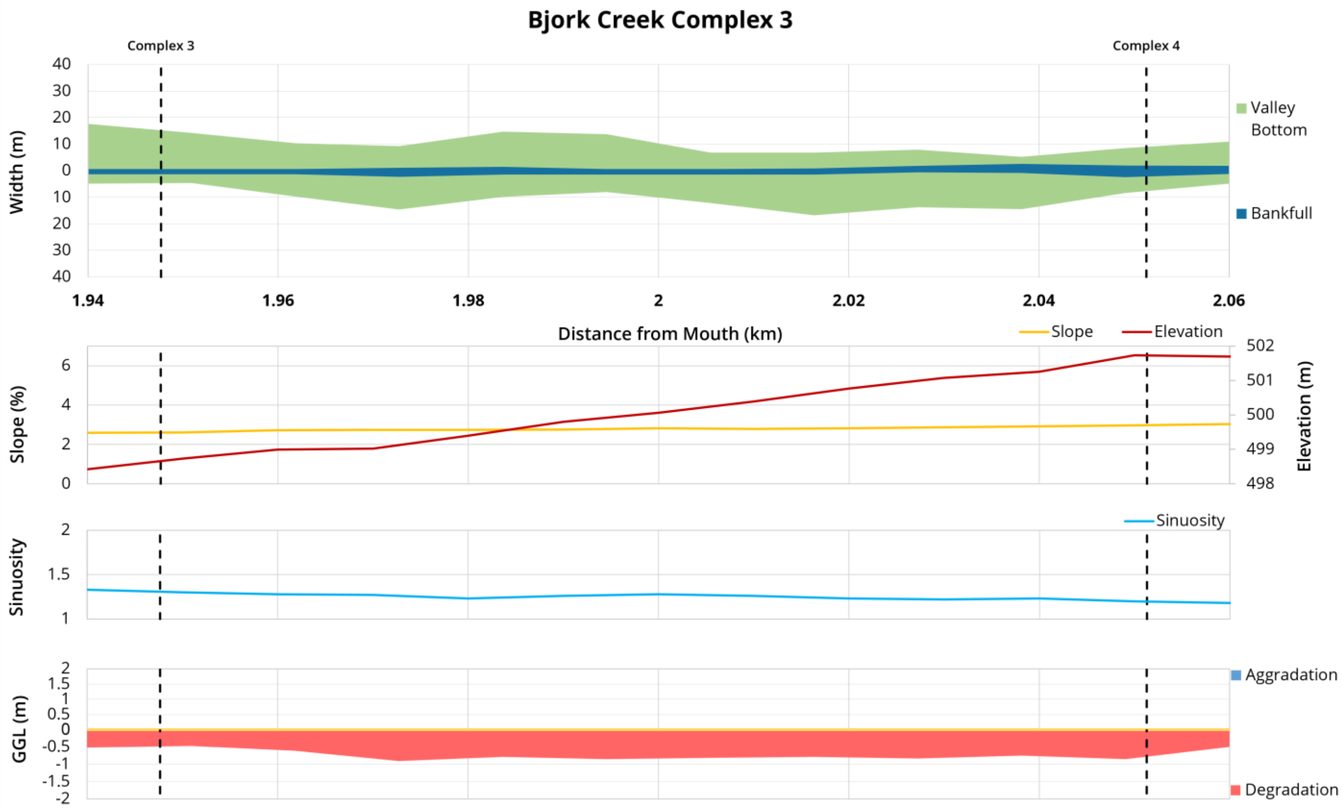

Figure 23. Long profile of geomorphic features and GGL results in Complex 3.

Complex 4: Incision Recovery

Complex 4 focuses on incision recovery. While both Complex 3 and 4 share the overall goal of incision recovery, the difference in valley width and channel slope constitutes a differing plan for individual structure goals. The opportunity in Complex 4 is limited until the channel can be aggraded. If the channel can be built up from its current state, there are several large floodplain areas that are in equilibrium with the geomorphic grade line. We recommend the use of PAS throughout the reach to slow flows, capture sediment, and back up water. The channel is incised more than 1 meter in many places throughout the complex (Figure 24). The use of PAS in this complex and throughout the project area will not only function as a tool for channel aggradation, but a method to increase the amount of wood in the system.

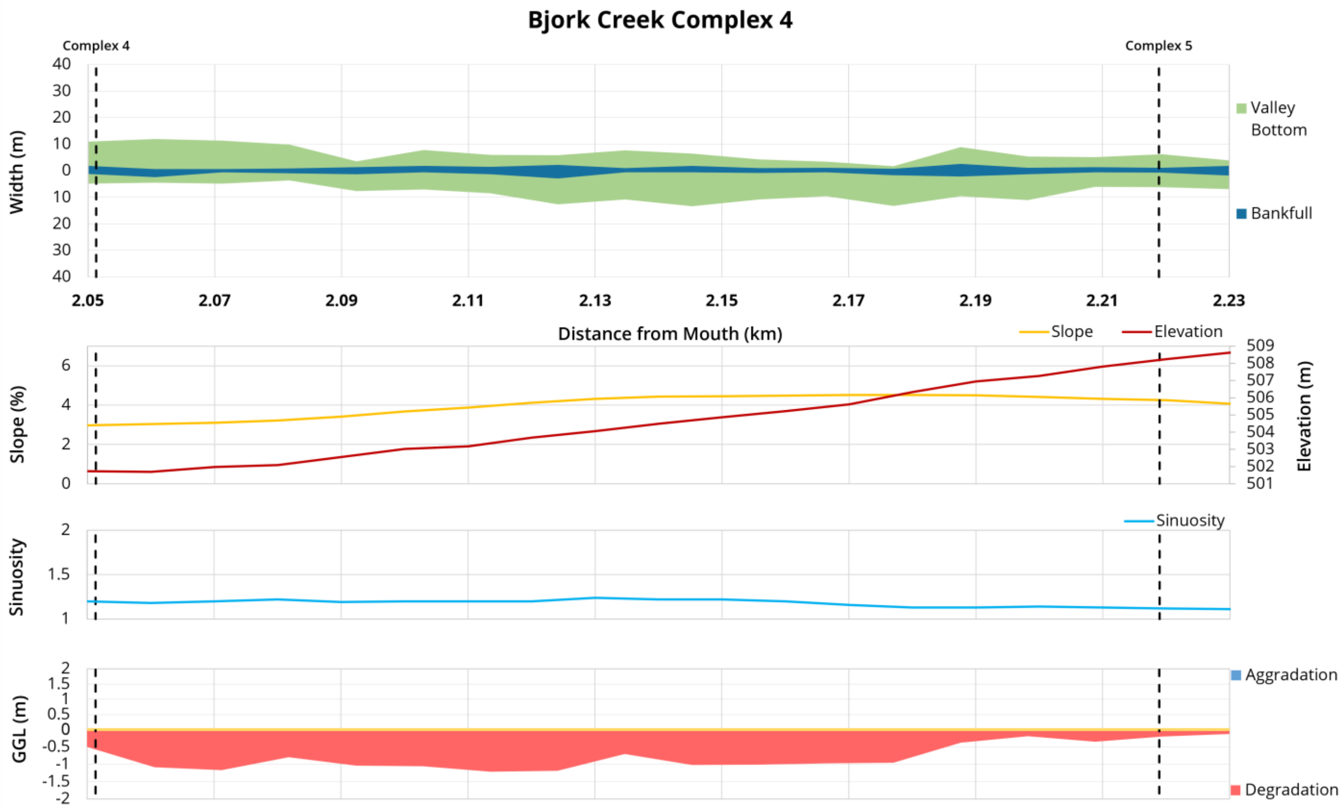

Figure 24. Long profile of geomorphic features and GGL results in Complex 4.

Complex 5: Water and Sediment Retention

Complex 5 focuses on water and sediment retention to take advantage of the accessible floodplain that spans most of the valley bottom. The presence of a relic channel on the RL side of the complex has left a wide and low floodplain that could provide an opportunity for water storage. We recommend the use of BDAs in this complex to capture water and sediment in the available floodplain. At the upper end of the complex, we recommend the use of PALS to widen the available floodplain and to work toward reconnecting flows with the relic channel. The GGL results for Complex 5 reveal that it is close to equilibrium with the geomorphic grade line. The channel is aggraded enough that a focus on water and sediment retention is most appropriate, unlike the upstream and downstream complexes.

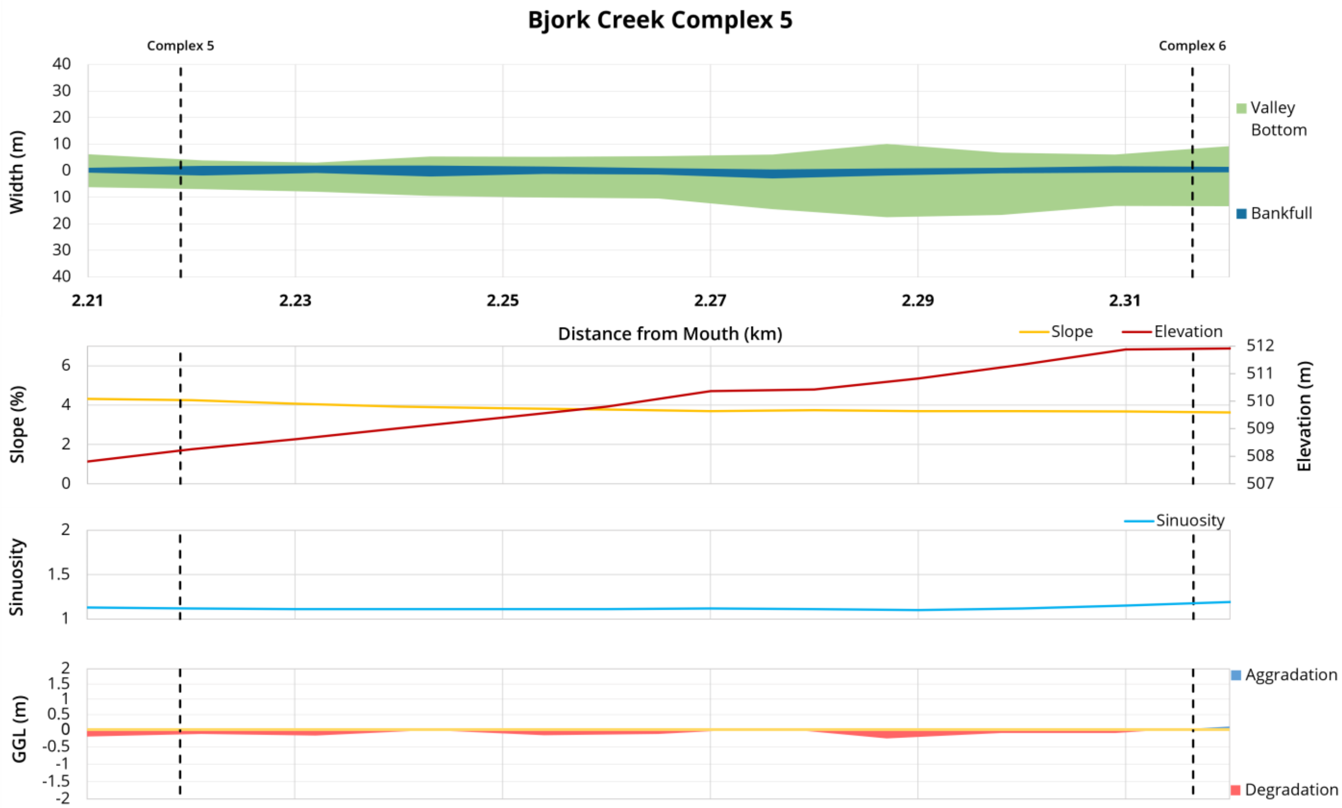

Figure 25. Long profile of geomorphic features and GGL results in Complex 5.

Complex 6: Incision Recovery

Complex 6 focuses on incision recovery to raise the channel and access the wide and flat floodplain. The floodplain in Complex 6 is continuous, wide, and flat but perched above the channel elevation by .5 to 1 meter throughout the upstream half. We recommend the use of PAS and PALS to capture sediment and shunt flows into potential floodplain areas. The lower end of the complex should focus on the use of PAS to build up the channel and widen the floodplain where the surrounding area is perched more than 1 meter above the channel elevation. This focus on the lower end of Complex 6 may have the added benefit of aiding in the reconnection of the Complex 5 relic channel. The GGL results in Complex 6 reveal that the channel bed is close to equilibrium with the geomorphic grade line (Figure 26) but the surrounding floodplain is consistently more than .25 meters above.

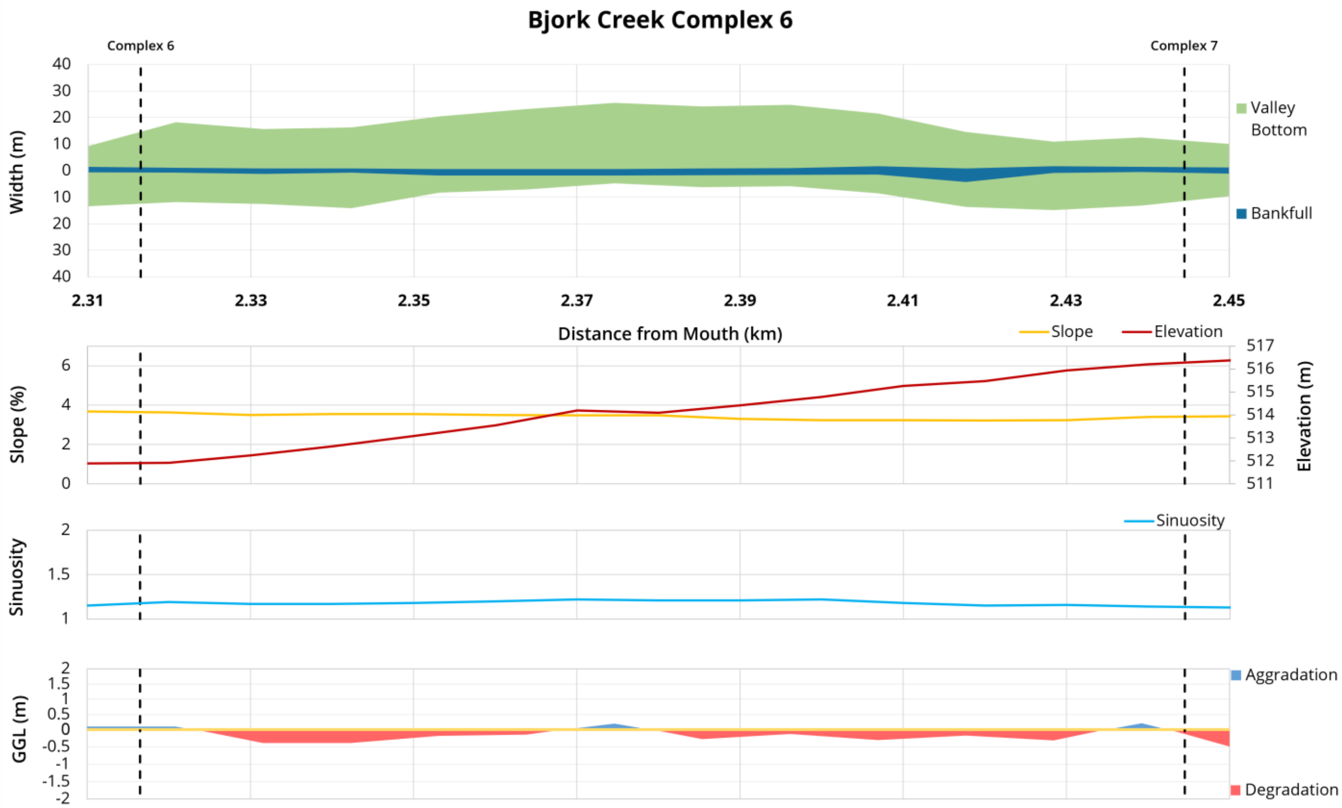

Figure 26. Long profile of geomorphic features and GGL results in Complex 6.

Complex 7: Floodplain Development and Access

Complex 7 focuses on floodplain development and access to capitalize on the existing floodplain pockets and widen areas that are not currently available to flows. Complex 7 has several opportunities to store water in the existing inset floodplain. We recommend the use of BDAs and PALS to inundate the inset floodplain and progress meanders. At the upper end of the complex, where the channel is more incised, we recommend the use of leaky dams to erode the banks, widen the channel, and act as a grade control. The GGL results confirm that the downstream end is incised .5 meters below the geomorphic grade line, while the upstream end is incised greater than 1 meter below (Figure 18). The GGL results also reveal that large pockets of floodplain are in equilibrium.

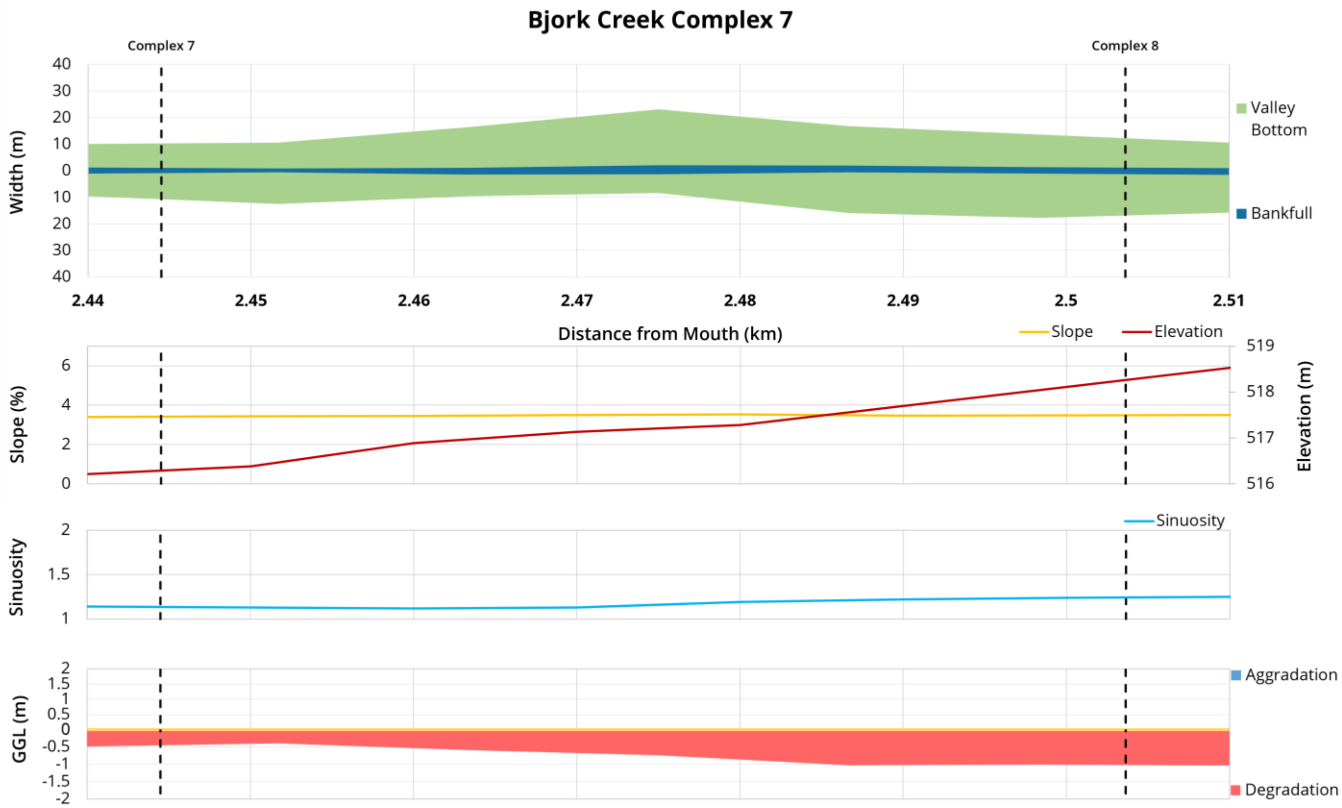

Figure 27. Long profile of geomorphic features and GGL results in Complex 7.

Complex 8: Incision Recovery

Complex 8 focuses on incision recovery to combat the effects caused by the steep and narrow section of the creek. In the upstream half of the complex, the creek is confined by the valley margins and the slope of the channel shifts from below 4% up to 6% (Figure 28). Opportunities in Complex 8 are currently limited to small floodplain pockets within a few meters of the bankfull channel. We recommend the use of leaky dams and PAS in this complex to capture floodplain pockets, recruit wood, and act as a grade control. The GGL results confirm that the channel is incised more than 1 meter below the geomorphic grade line throughout the complex and will require long term incision recovery to access the wider floodplain at the downstream end of the complex.

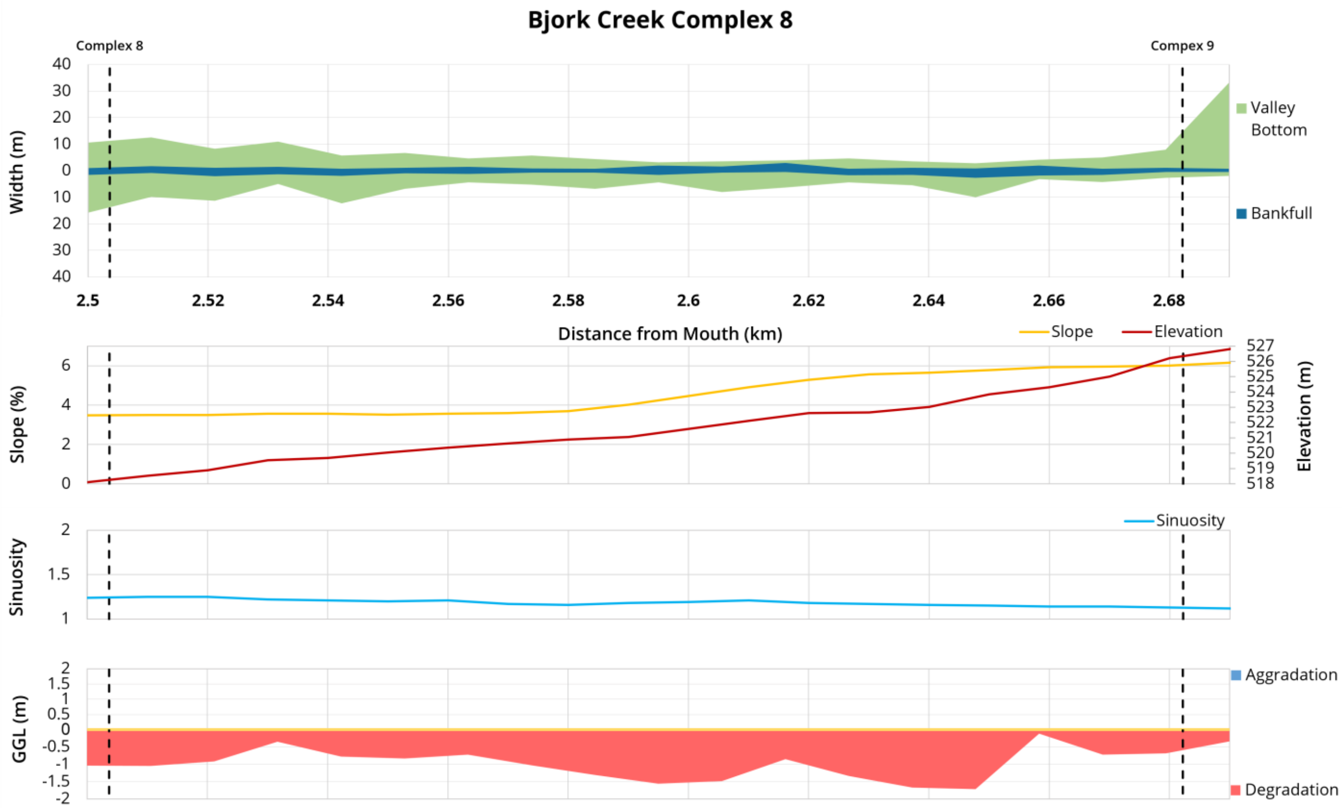

Figure 28. Long profile of geomorphic features and GGL results in Complex 8.

Complex 9: Floodplain Development and Access

Complex 9 is located immediately downstream of the road crossing. Complex 9 focuses on floodplain development and access. The floodplain in Complex 9 is much wider than the downstream Complex 8 and has potential for current and future inundation. We do not recommend any structures within 75 meters downstream of the road crossing to ensure that no unplanned damage takes place. There are many floodplain pockets in this complex that sit less than .75 meters above the channel. We recommend the use of leaky dams and BDAs to plug up the channel and push flows onto the floodplain. GGL results reveal that the channel in Complex 9 is generally in equilibrium with the geomorphic grade line. With the channel at a suitable elevation in relation to the grade line, it would be most beneficial to begin developing the floodplain through increased access and inundation.

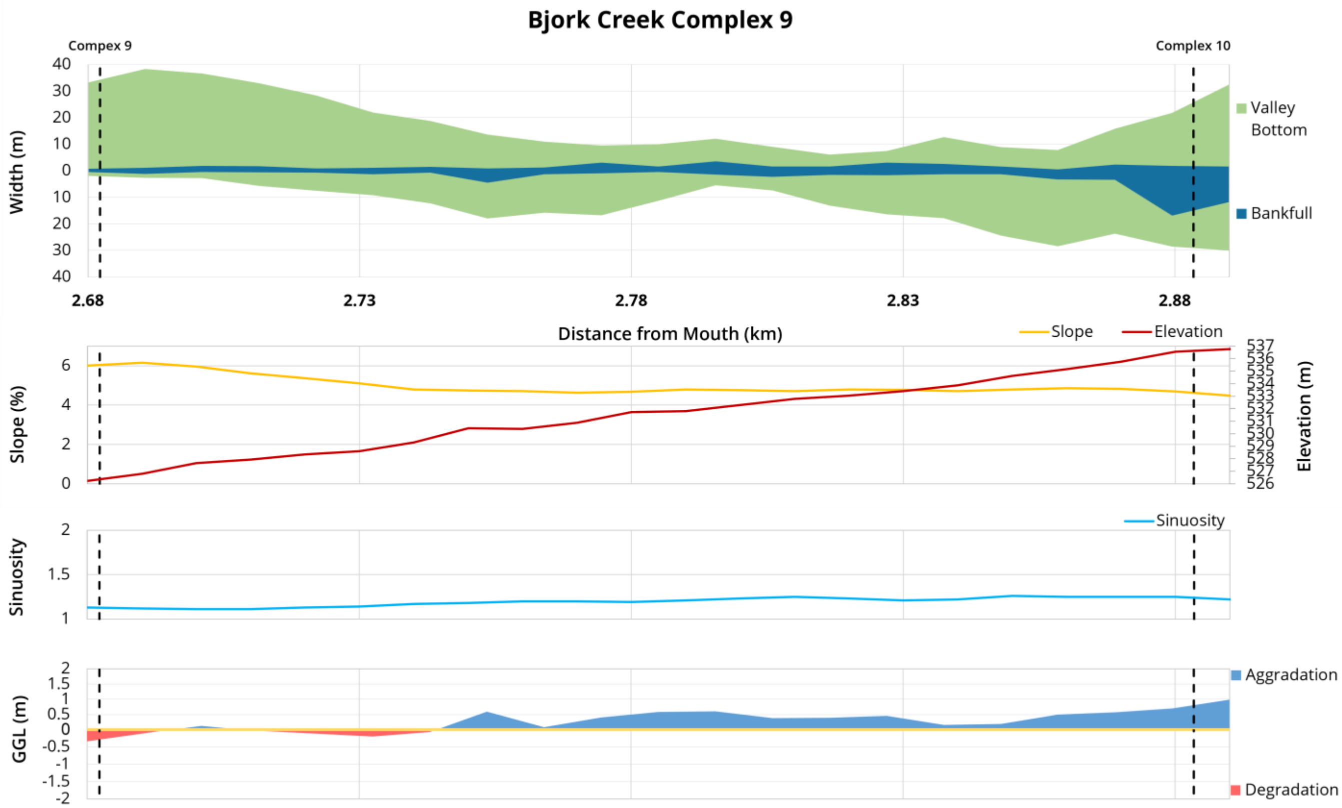

Figure 29. Long profile of geomorphic features and GGL results in Complex 9.

Complex 10: Water and Sediment Retention

Complex 10 focuses on water and sediment retention to utilize the available floodplain that has reclaimed an abandoned road. The floodplain in Complex 10 is relatively flat, both in person and confirmed by the REM (Figure 42). The location on the RR floodplain where a road used to exist has become a channel and is at a similar relative elevation as the main channel. We recommend the use of leaky dams and BDAs to flood the low-lying floodplain. The use of these structures will work to store water and sediment as well as force flows onto the floodplain and into the many small channels and lows spots. The downstream end of Complex 10 is aggraded when compared to the rest of the project area, which can largely be attributed to the road crossing at its downstream boundary. While the downstream end is aggraded, the upstream end of Complex 10 is degraded significantly (Figure 30) and several small headcuts are present. The use of leaky dams and BDAs will aid in headcut arrest when paired with PAS.

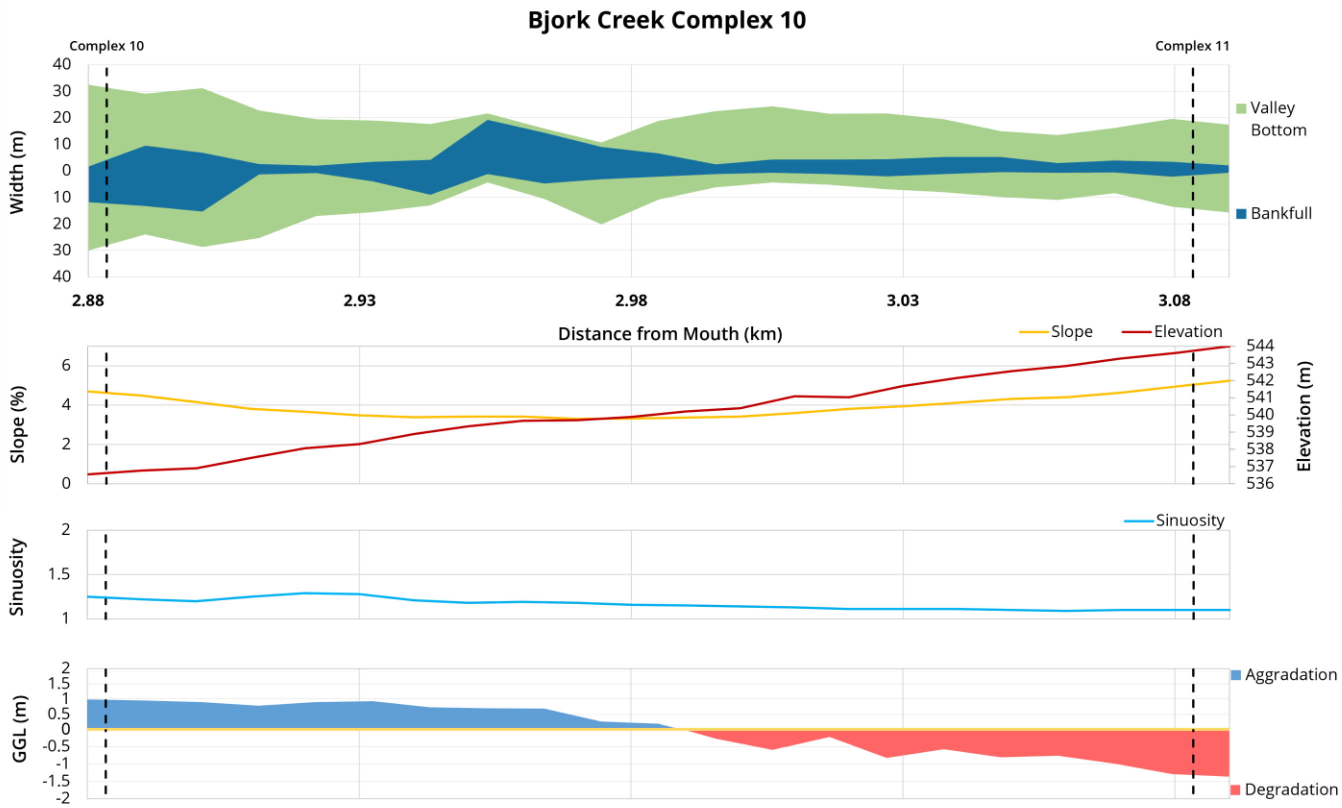

Figure 30. Long profile of geomorphic features and GGL results in Complex 10.

Complex 11: Incision Recovery

Complex 11 focuses on incision recovery as it contains the most degraded location in the project area, based on GGL results (Figure 31). The channel of Bjork creek in this complex is deep and narrow, resembling a ditch. Unlike other portions of the project area, almost the entire floodplain has been identified by the GGL as degraded more than .25 meters. We recommend the use of leaky dams and PAS to slow flows and plug the channel to force flows onto the inset floodplain.

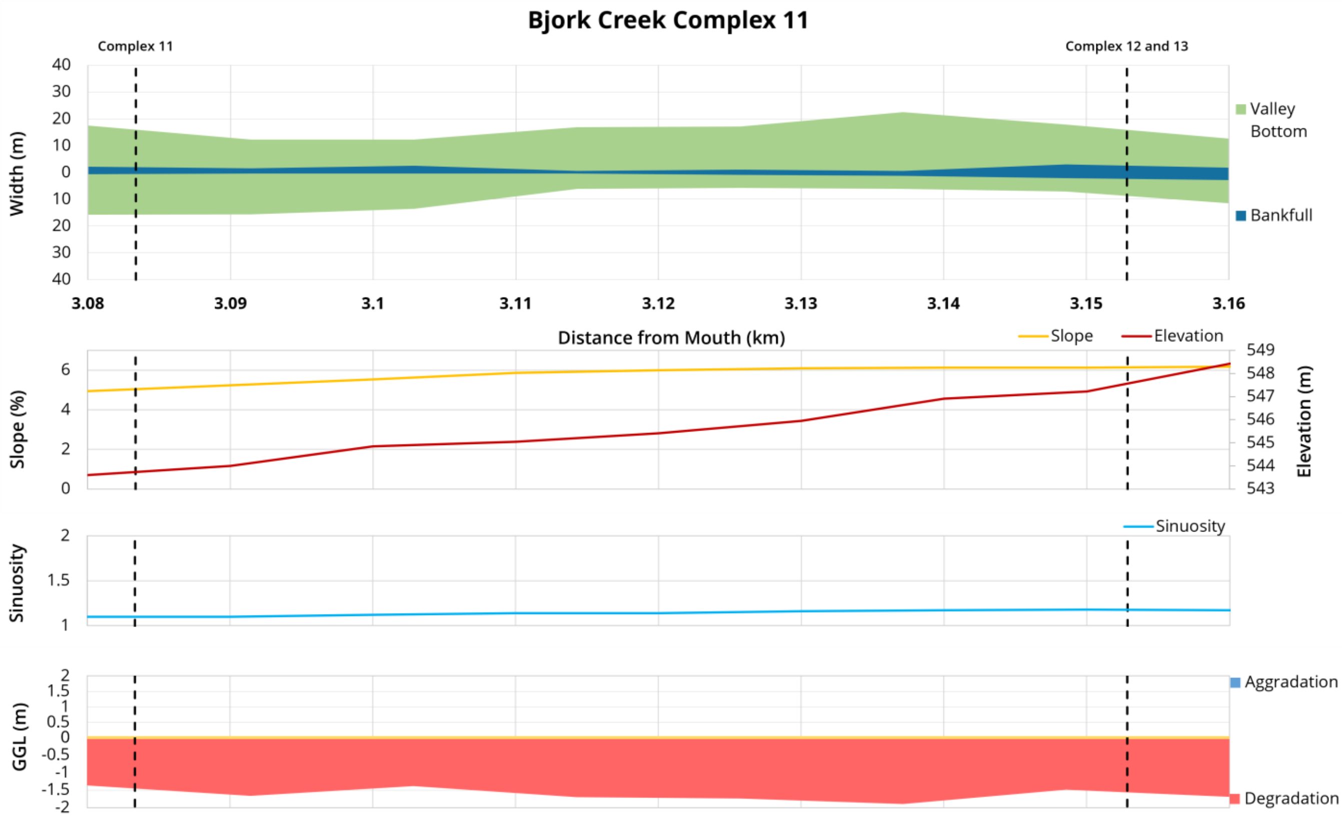

Figure 31. Long profile of geomorphic features and GGL results in Complex 11.

Complex 12: Incision Recovery

Complex 12 focuses on incision recovery. Complex 12 and 13 are both in the same longitudinal location along Bjork Creek, however Complex 12 encompasses the main channel on the East side of the valley and Complex 13 encompasses the tributary flow on the West side of the valley. Complex 12 contains several floodplain pockets but is degraded between .5 and 1 meter along its length (Figure 32). We recommend the use of PAS and PALS to slow flows, capture sediment, and force water up onto the floodplain. Complex 12 and 13 should, in time, work together to develop the wide floodplain that is available between them. Structures placed in Complex 12 should be placed to encourage flows away from the valley margins, so the whole valley bottom can eventually be utilized.

Complex 13: Floodplain Development and Access

Complex 13 focuses on floodplain development and access. Both Complex 13 and 12 are both in the same longitudinal location along Bjork Creek, however Complex 13 encompasses the tributary flow on the West side of the valley (Figure 32). The channel in Complex 13 is about .5 meters lower than the main channel. Similar to Complex 12 and the main channel, Complex 13 and the tributary channel are incised. The upper end of Complex 13 has the most opportunity for floodplain access, while the lower end will take more time to develop through process-based restoration efforts. The focus of structures in this complex should be to move flows away from the valley margin and develop any low-lying areas. We recommend the use of PALS in Complex 13 to shunt flows away from the valley margin and to force flows toward the center of the valley. Complex 13 and Complex 12 should work together to develop the floodplain in the center of the valley.

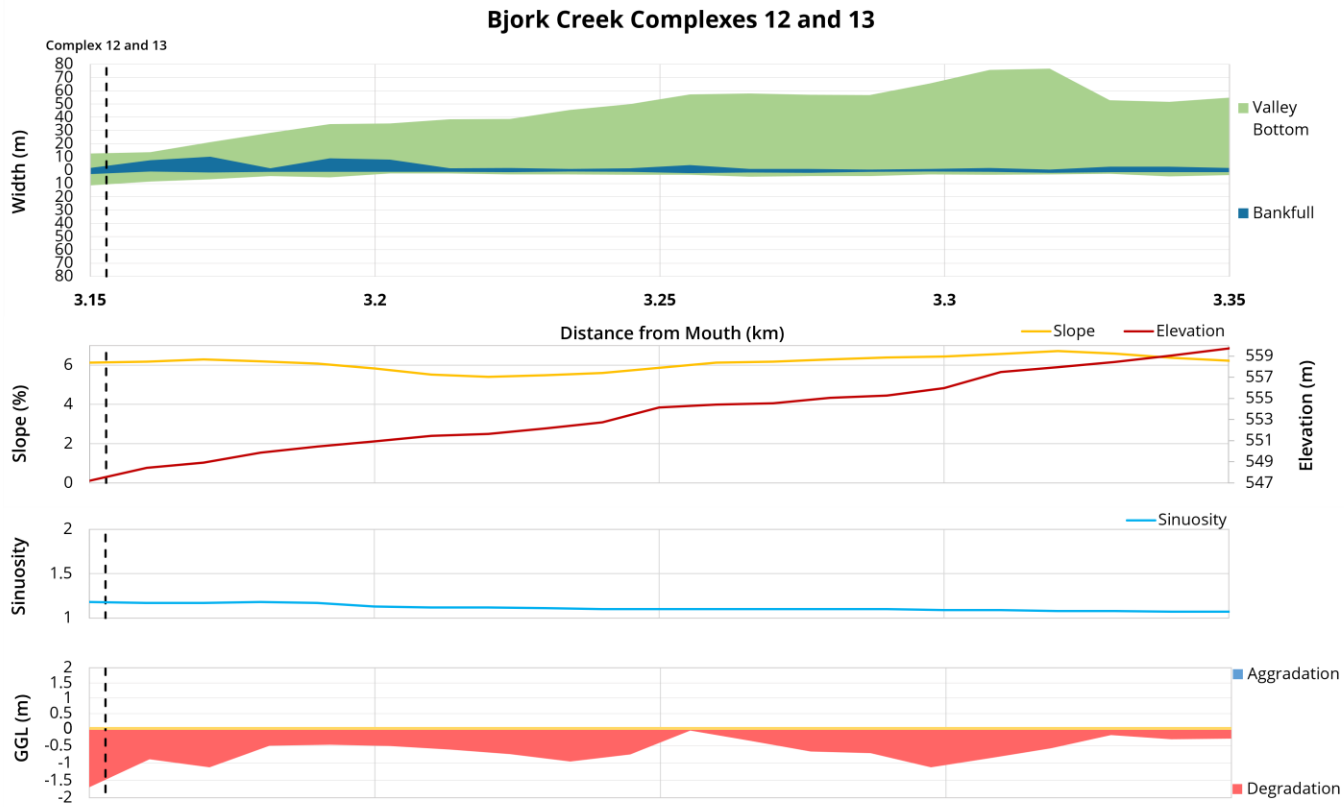

Figure 32. Long profile of geomorphic features and GGL results in Complex 12 & 13

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 19. 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 69 structures and 35 PAS areas were designed for the Bjork 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 954 posts (2-inch diameter, 6-foot long).

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

Structure Type	Material Type	Fill Quantity (yds^3)
PALS	Wood	27.24
PALS	Posts	1.4
BDA	Weave	14.51
BDA	Posts	1.14
BDA	Local sediment	2.55
PAS	Slash	39.8
PAS	Posts	2.18
Leaky Dam	Wood	10.6
Leaky Dam	Posts	0.68

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

Material Type	Fill Quantity (yds^3)
Wood	37.85
Posts	5.4
Slash	39.8
Weave	14.51
Local Sediment	2.55

In each figure below, the project flowline represents the lowest point of the current channel based on available LiDAR (2018), and structures are displayed as PALS, BDAs, leaky dam, direct fell, or PAS (Figure 33 - Figure 44). 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.

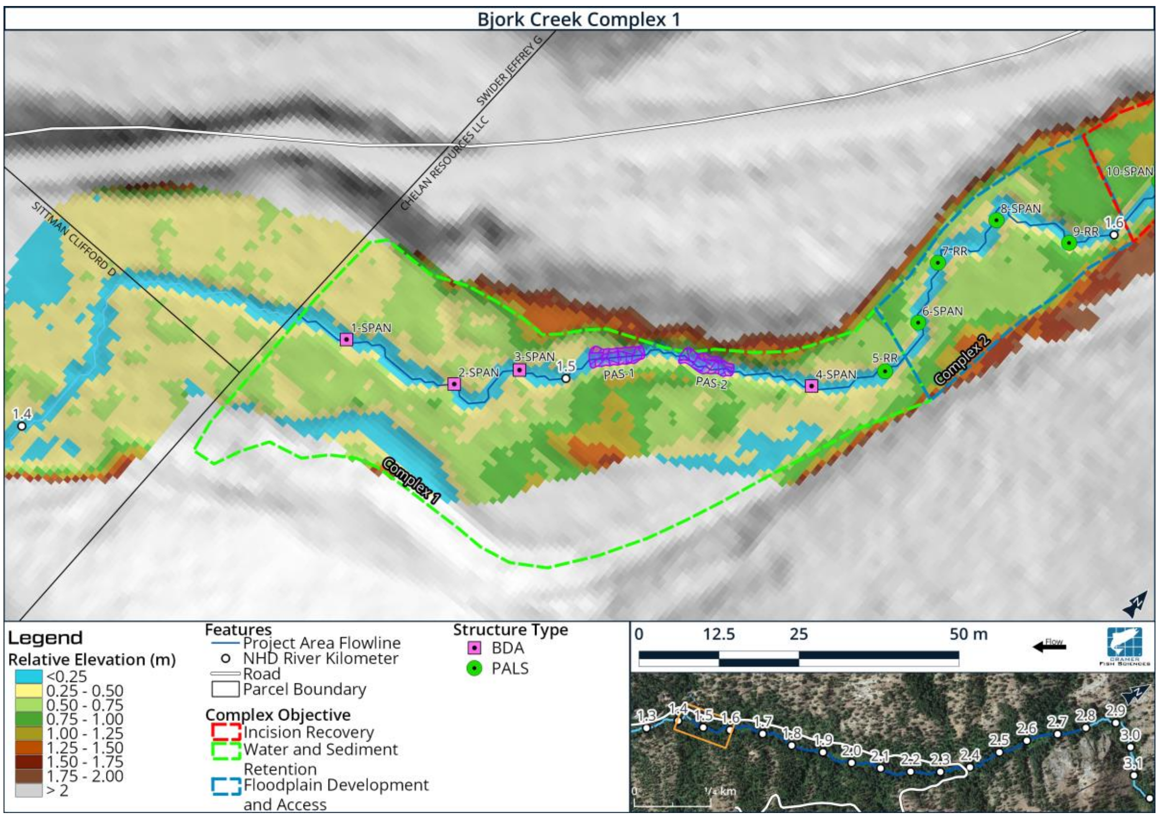

Figure 33. Location and type of low-tech structures within Complex 1 on Bjork Creek.

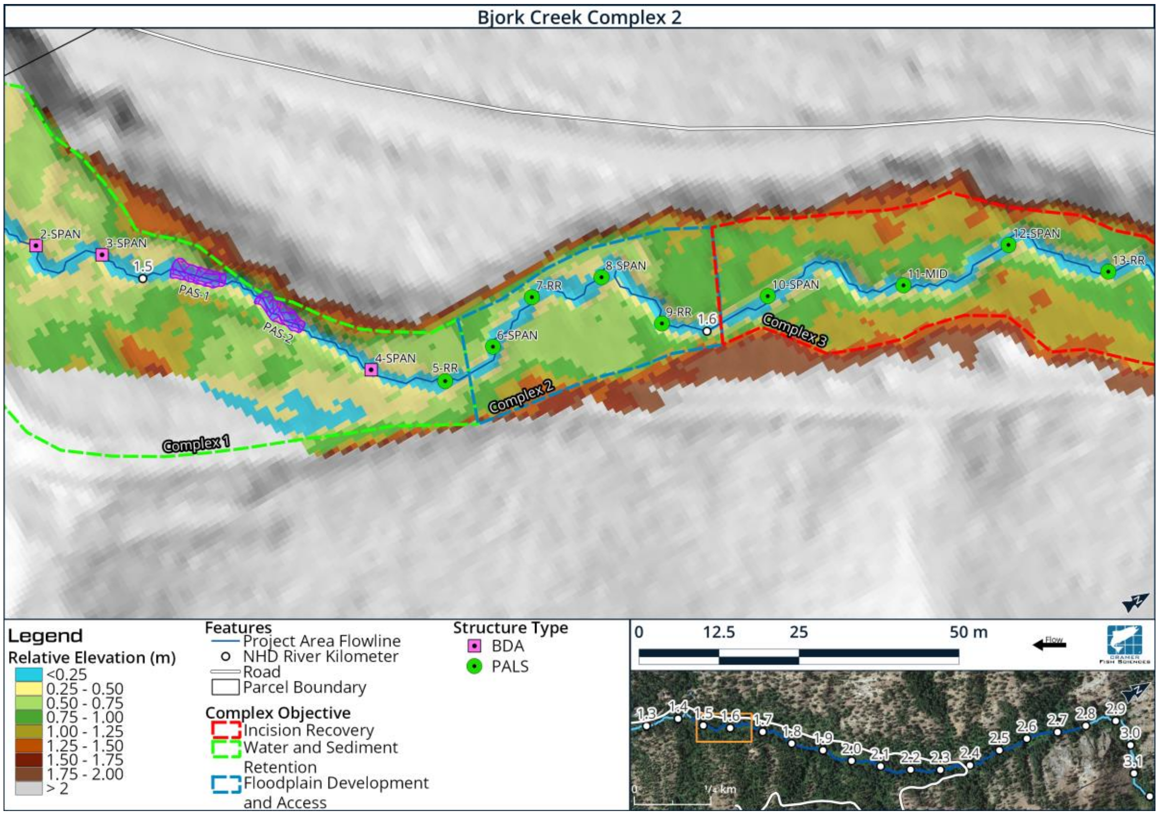

Figure 34. Location and type of low-tech structures within Complex 2 on Bjork Creek.

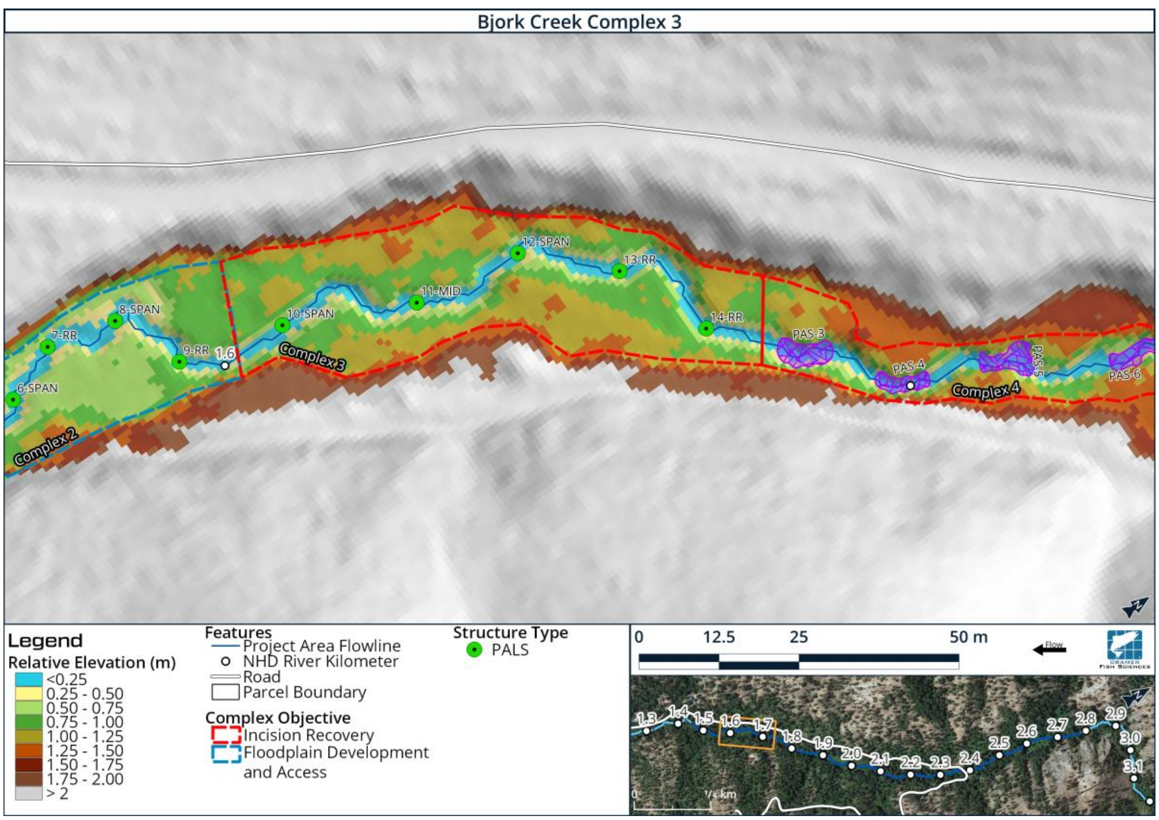

Figure 35. Location and type of low-tech structures within Complex 3 on Bjork Creek.

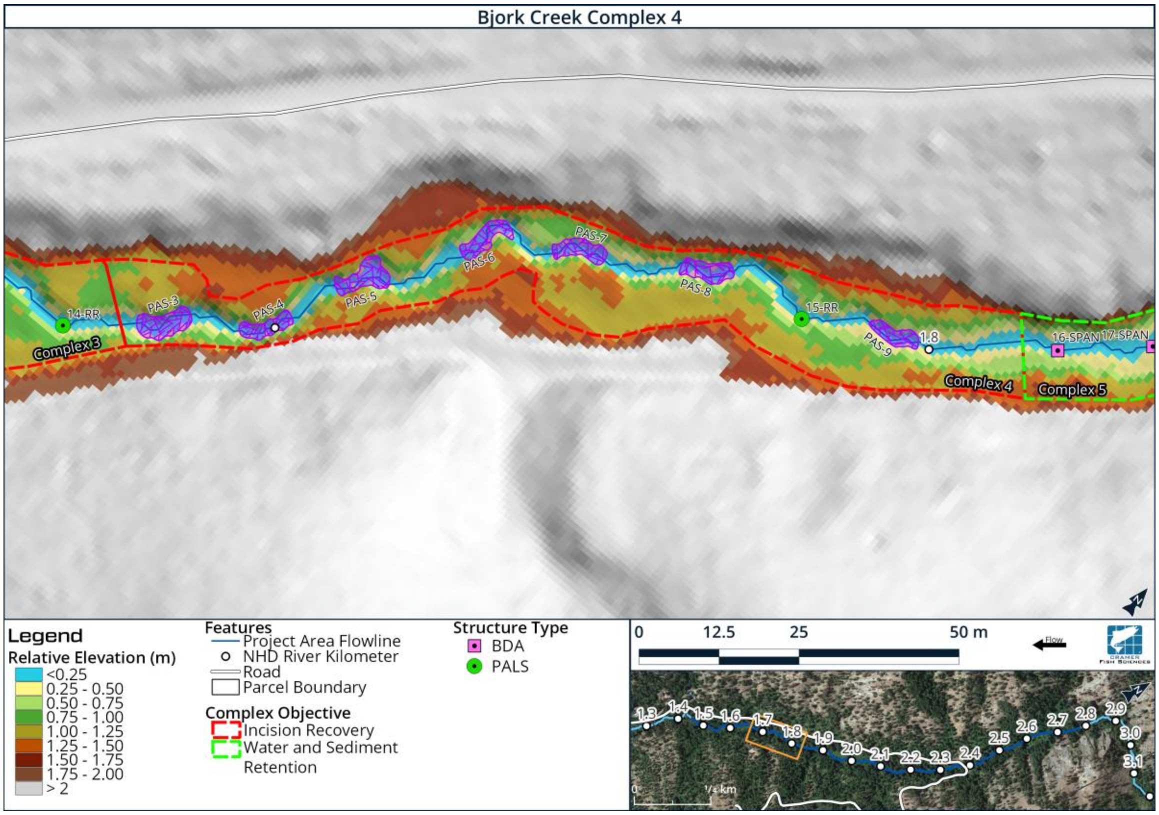

Figure 36. Location and type of low-tech structures within Complex 4 on Bjork Creek.

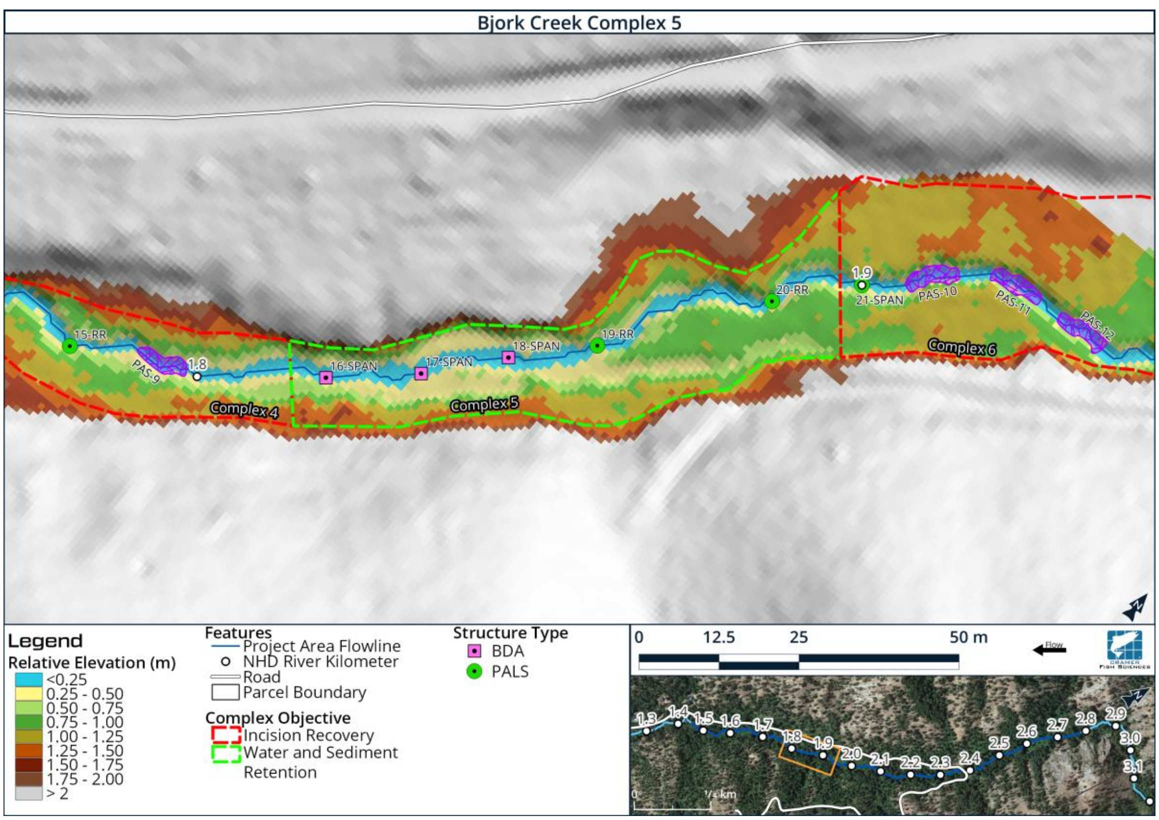

Figure 37. Location and type of low-tech structures within Complex 5 on Bjork Creek.

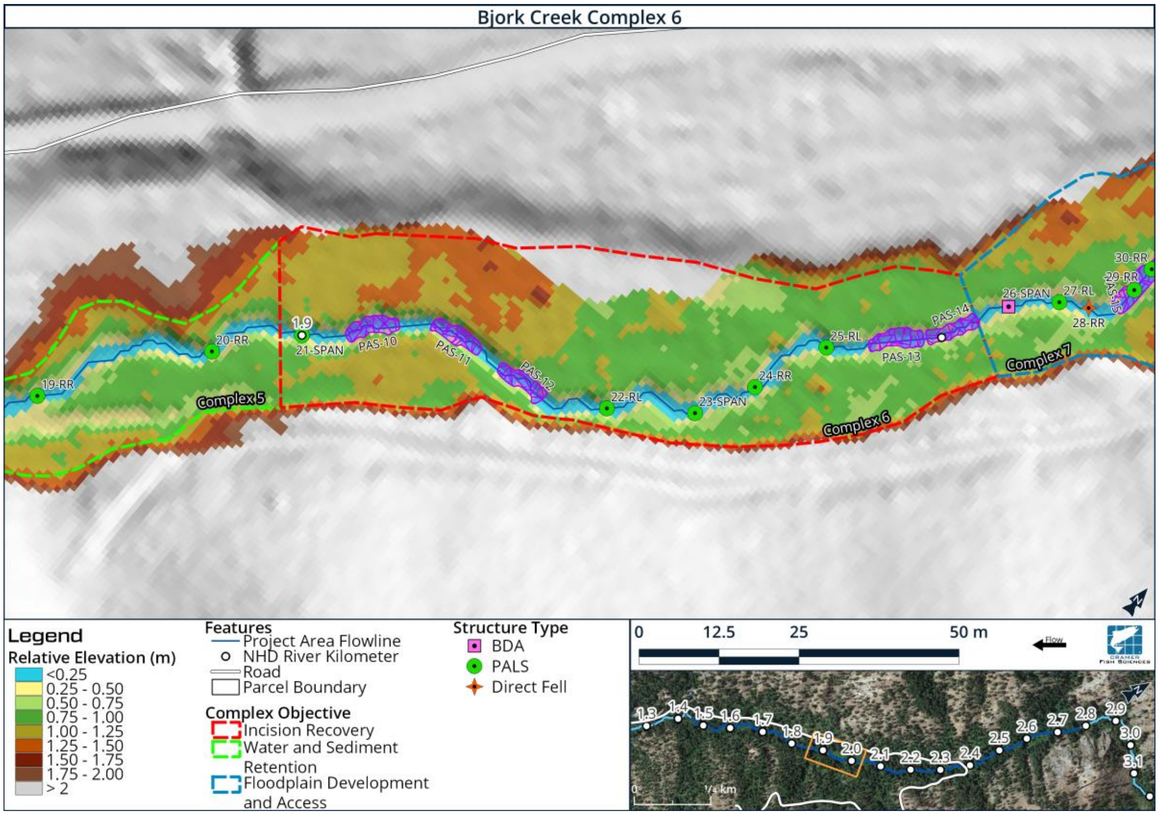

Figure 38. Location and type of low-tech structures within Complex 6 on Bjork Creek.

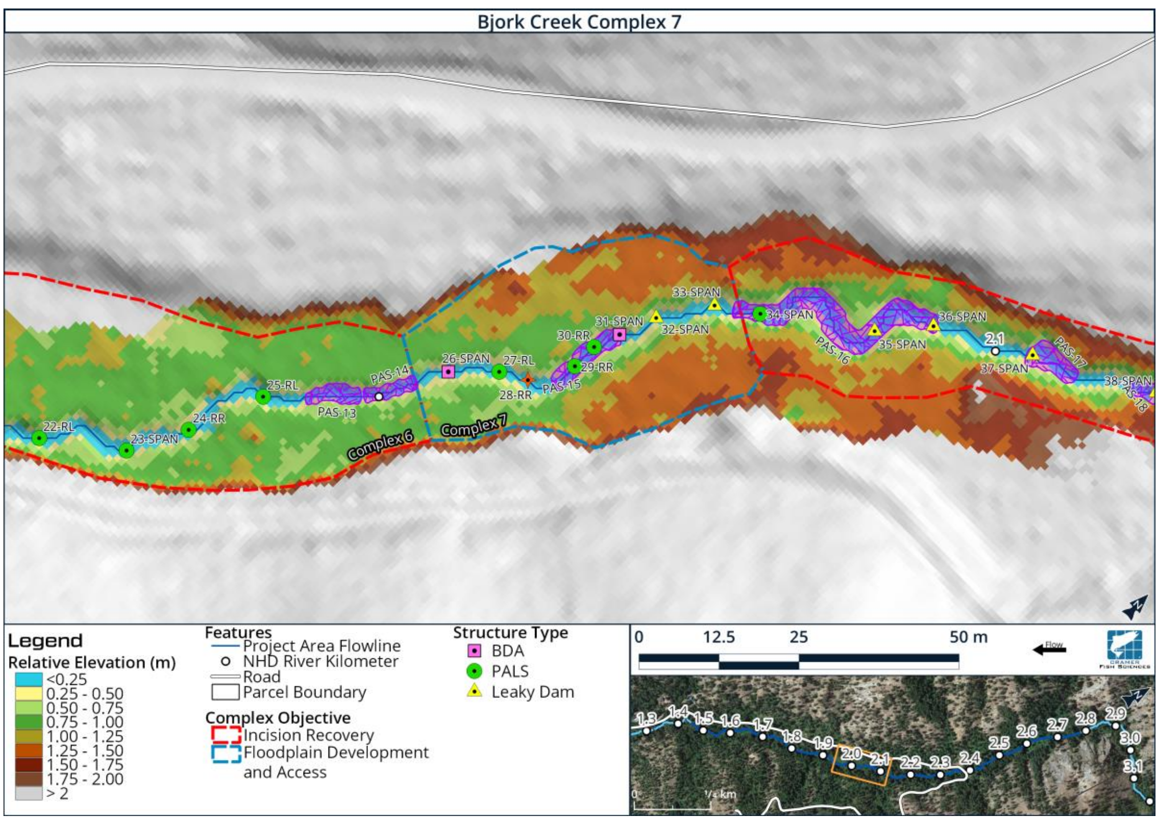

Figure 39. Location and type of low-tech structures within Complex 7 on Bjork Creek.

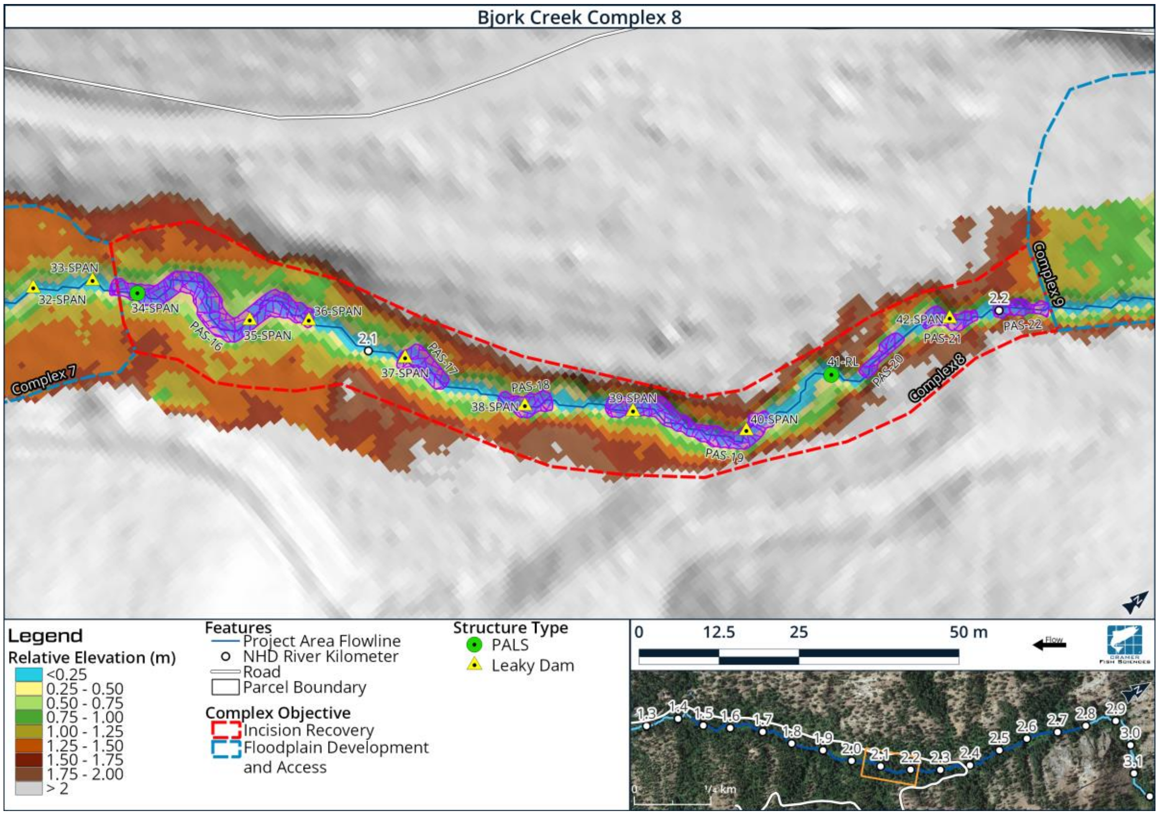

Figure 40. Location and type of low-tech structures within Complex 8 on Bjork Creek.

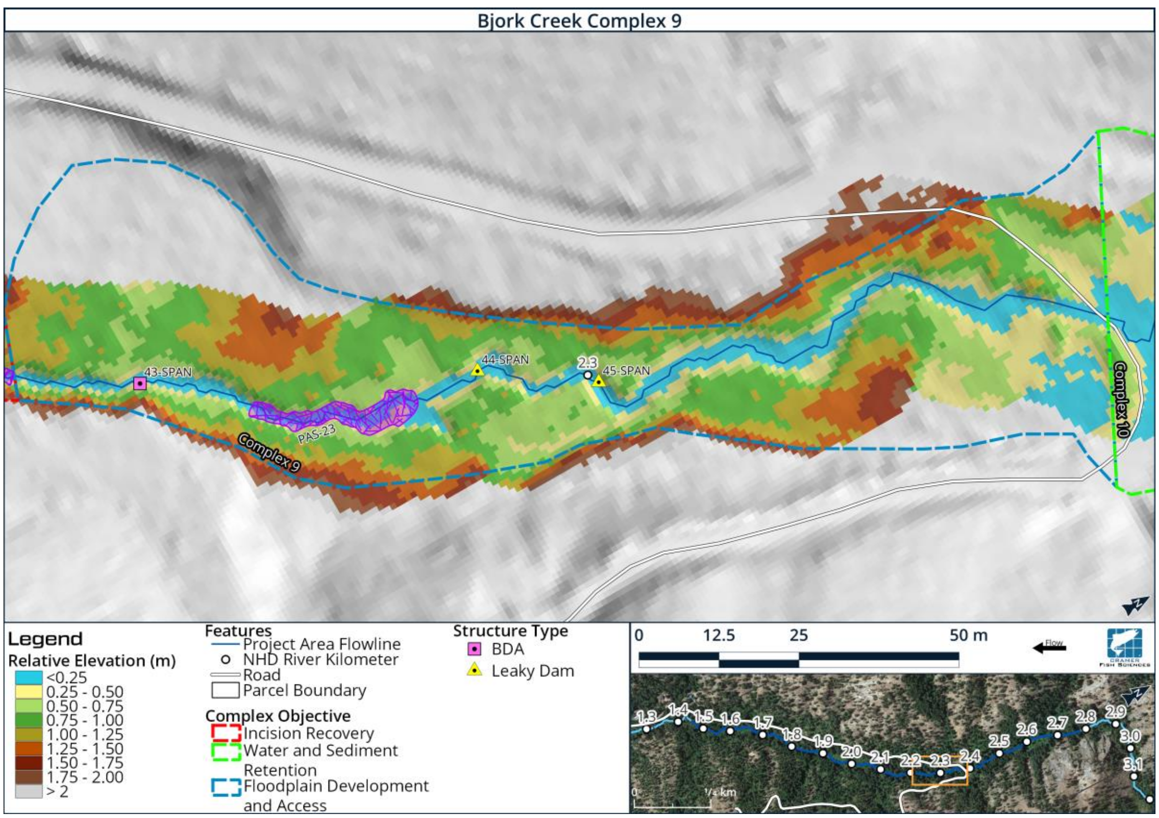

Figure 41. Location and type of low-tech structures within Complex 9 on Bjork Creek.

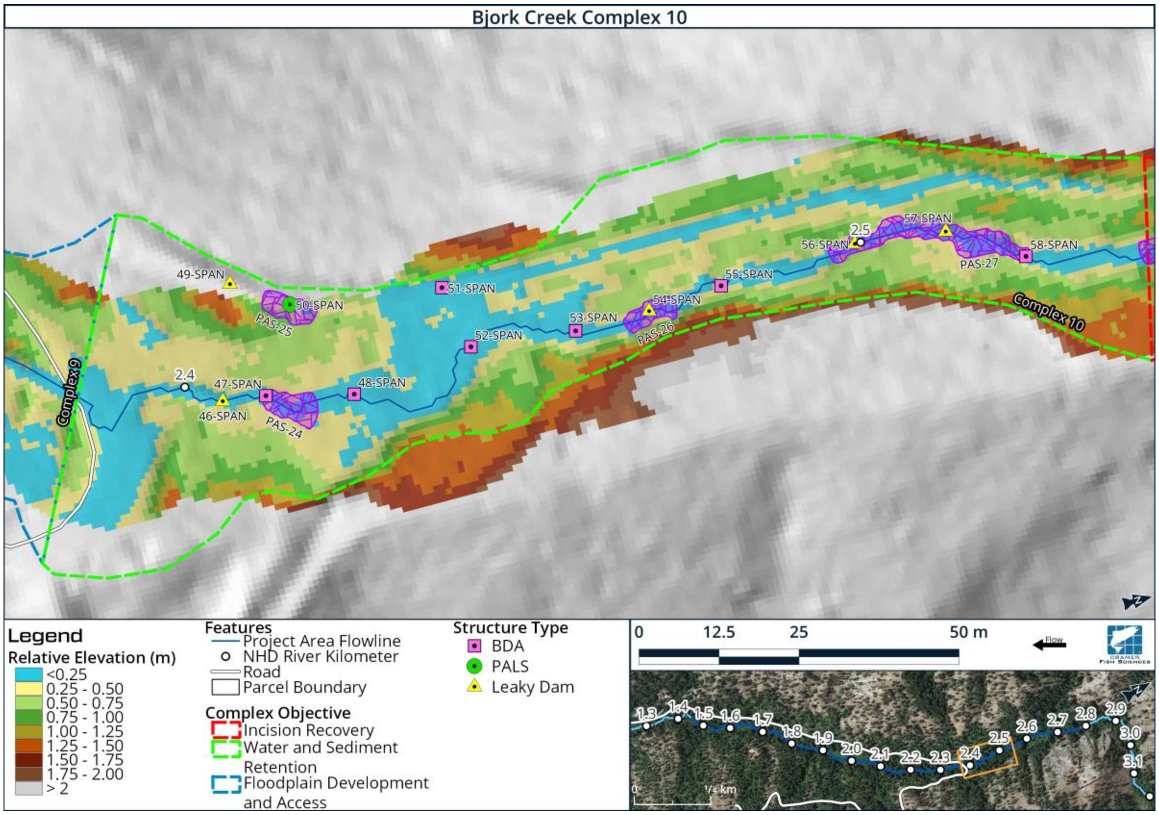

Figure 42. Location and type of low-tech structures within Complex 10 on Bjork Creek.

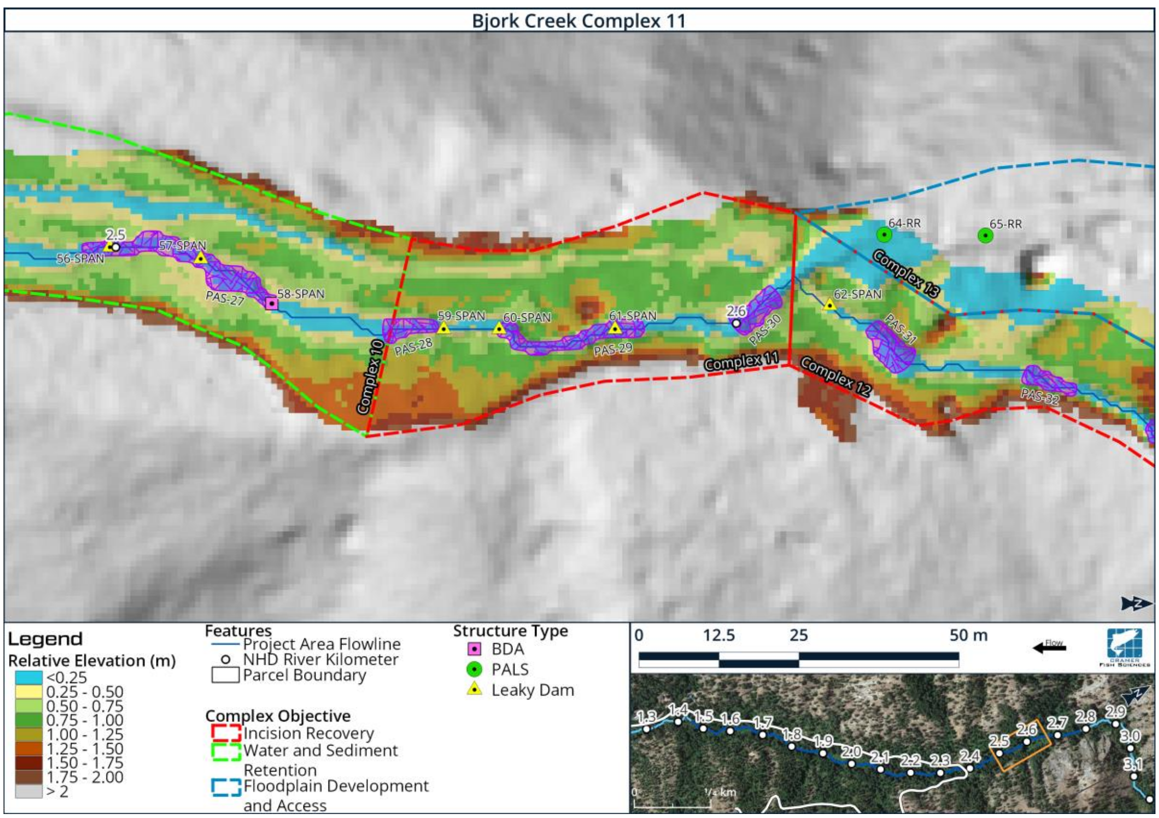

Figure 43. Location and type of low-tech structures within Complex 11 on Bjork Creek.

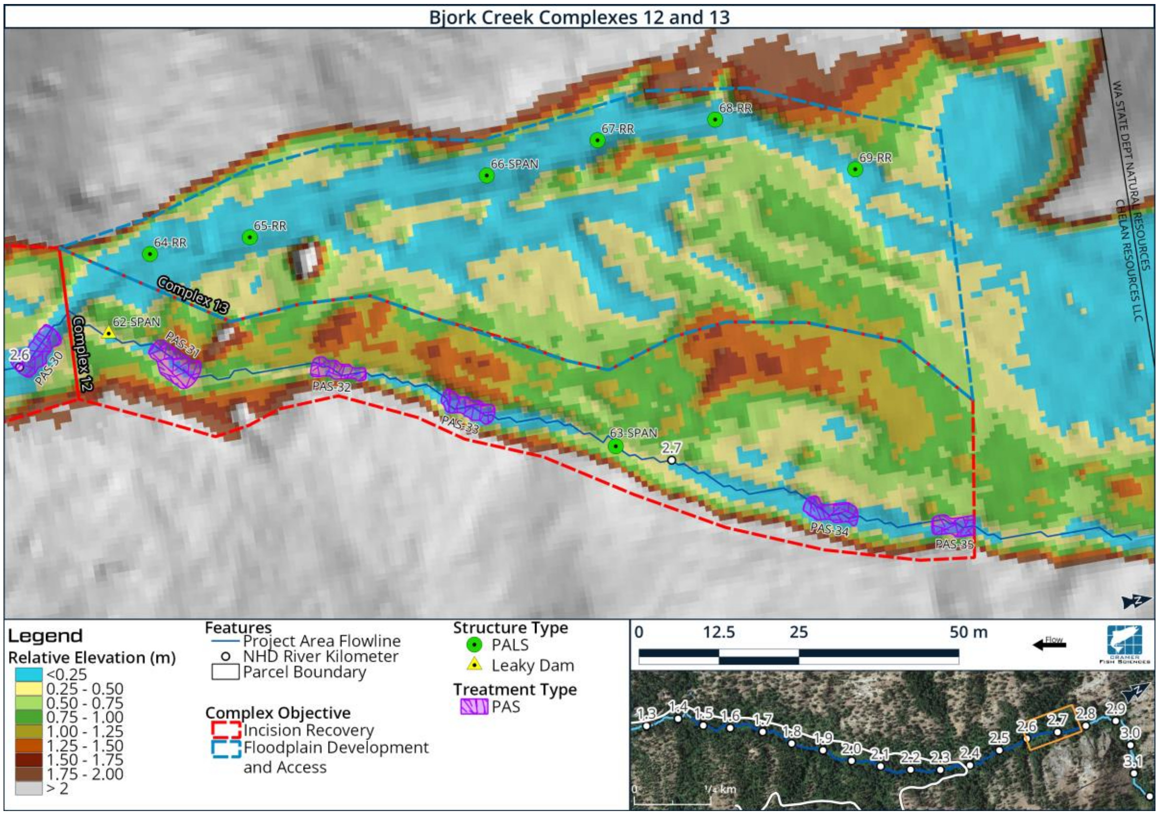

Figure 44. Location and type of low-tech structures within Complexes 12 and 13 on Bjork Creek.

Table 5. Description, expected number of posts and wood, bank attachment, objectives, and location of low-tech structures in Complexes 1-13 on Bjork Creek. RL = river left, RR = river right

Complex	ID	Type	Description	# of Posts	Wood Count	Attachment	Objectives	Lat	Long
1	1	BDA	Slow flows and force water onto floodplain.	11	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.647435	-120.600916
1	2	BDA	Slow flows and spread water onto floodplain.	7	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.647484	-120.600685
1	3	BDA	BDA to slow flow in wide and low area.	9	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.647558	-120.600600
1	4	BDA	BDA to capture floodplain pocket and overflow into floodplain on RL. Potential for overflow to increase activation of downstream backwaters.	9	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.647805	-120.600114
1	5	PALS	Continue widening meander toward RL.	7	5	RR	Pool Development, Sediment Sourcing, Meander Progression	47.647888	-120.600017
2	6	PALS	Channel spanning PALS to force overbank flooding. Perpendicular to flow.	10	8	SPAN	Channel Widening, Floodplain Connection	47.647970	-120.600029
2	7	PALS	Bank attached PALS to move flows toward RL floodplain.	7	5	RR	Pool Development, Sediment Sourcing	47.648052	-120.600078
2	8	PALS	Tie PALS into curve of bank to support a structure that could widen the creek into the RL floodplain.	10	8	SPAN	Channel Widening, Floodplain Connection	47.648151	-120.600042
2	9	PALS	Force flows into RL bank to widen channel into floodplain.	7	5	RR	Pool Development, Sediment Sourcing, Channel Widening	47.648192	-120.599896
3	10	PALS	Channel spanning PALS to extend channel toward RR. Angle toward RR inset floodplain.	10	7	SPAN	Channel Widening, Floodplain Connection	47.648340	-120.599835
3	11	PALS	Mid channel PALS to promote complexity in straight section of channel. Erode channel on both sides.	7	5	MID	Channel Widening, Floodplain Connection	47.648513	-120.599714
3	12	PALS	Channel spanning PALS to widen channel in narrow location. Angle toward RL.	10	7	SPAN	Channel Widening, Floodplain Connection	47.648669	-120.599677
3	13	PALS	Expand meander into RL floodplain.	7	5	RR	Pool Development, Sediment Sourcing, Meander Progression	47.648772	-120.599526

Complex	ID	Type	Description	# of Posts	Wood Count	Attachment	Objectives	Lat	Long
3	14	PALS	PALS to carve out inset floodplain on RL of channel.	7	5	RR	Pool Development, Sediment Sourcing	47.648826	-120.599325
4	15	PALS	Structure on RR to force flows into RL bank and widen channel.	7	5	RR	Pool Development, Sediment Sourcing, Channel Widening	47.649501	-120.598158
5	16	BDA	BDA to take advantage of small floodplain area Upstream.	12	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.649699	-120.597708
5	17	BDA	BDA to force water onto floodplain.	13	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.649789	-120.597562
5	18	BDA	BDA to back flows into floodplain pocket and overflow into low lying side channel.	12	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.649886	-120.597444
5	19	PALS	PALS to move flows into low lying floodplain on RL and deflect direct flows from downstream BDA.	7	7	RR	Pool Development, Sediment Sourcing, Channel Widening	47.649979	-120.597319
5	20	PALS	Extend channel meander into RL bank. Long term to capture low lying area on RL.	7	5	RR	Pool Development, Sediment Sourcing	47.650185	-120.597100
6	21	PALS	Channel spanning PALS directed toward RL.	10	7	SPAN	Channel Widening, Floodplain Connection	47.650283	-120.596979
6	22	PALS	PALS to initiate a meander in straight stretch of creek and erode RR bank.	7	5	RL	Pool Development, Sediment Sourcing, Meander Progression	47.650481	-120.596396
6	23	PALS	Channel Spanning PALS to slow flows and widen channel. Perpendicular to flow.	10	7	SPAN	Channel Widening, Floodplain Connection	47.650555	-120.596249
6	24	PALS	Extend meander toward the RL bank. Erode RL bank.	7	5	RR	Pool Development, Sediment Sourcing, Meander Progression	47.650638	-120.596188
6	25	PALS	Take advantage of small directional change to widen meander with PALS.	7	5	RL	Pool Development, Sediment Sourcing, Meander Progression	47.650745	-120.596128
7	26	BDA	BDA to plug channel.	9	0	SPAN	Pond, Sediment Storing	47.650954	-120.595892
7	27	PALS	Erode RR bank.	7	5	RL	Pool Development, Sediment Sourcing, Meander Progression	47.651004	-120.595817

Complex	ID	Type	Description	# of Posts	Wood Count	Attachment	Objectives	Lat	Long
7	28	Direct fell	Fall dead maple tree downstream towards PALS.	0	0	RR	Pool Development, Sediment Sourcing, Floodplain Connection	47.651024	-120.595763
7	29	PALS	Erode RL bank. Add slash to structure.	7	5	RR	Pool Development, Sediment Sourcing, Meander Progression	47.651085	-120.595714
7	30	PALS	Erode RL bank. Incorporate a lot of slash.	7	5	RR	Pool Development, Sediment Sourcing, Meander Progression	47.651123	-120.595715
7	31	BDA	Build attached to alder clump on RR. Small inset floodplain to capture upstream.	9	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.651161	-120.595695
7	32	Leaky dam	Plug up channel at downstream end of confined section. Key logs into banks. Pond from BDA downstream will help with erosion.	5	3	SPAN	Pond, Sediment Storing	47.651214	-120.595666
7	33	Leaky dam	Plug up channel where roots are acting as grade control in the channel.	5	3	SPAN	Pond, Sediment Storing	47.651284	-120.595599
8	34	PALS	Plug up channel with slash and wood. Small bench on RR to build onto and capture during floods.	10	10	SPAN	Sediment Sourcing, Floodplain Connection	47.651321	-120.595519
8	35	Leaky dam	Plug up channel here. Slash as described in downstream structure continues around this leaky dam and upstream for another 10m or so. Capture floodplain bench on RR. Build vertical 60-70cm.	5	3	SPAN	Pond, Sediment Storing, Floodplain Connection	47.651418	-120.595326
8	36	Leaky dam	Plug up channel upstream of S curve. Back up water through straight section.	5	3	SPAN	Pond, Sediment Storing	47.651481	-120.595246
8	37	Leaky dam	Plug up channel near base of maple tree on RR. Capture small floodplain pocket on RR.	5	3	SPAN	Pool Development, Sediment Storing, Floodplain Connection	47.651551	-120.595058
8	38	Leaky dam	Plug up channel. Key logs into bed and bank. Surround with slash to build up vertical. Capture floodplain pockets upstream. Build 60-70cm vertical.	5	3	SPAN	Pool Development, Sediment Storing	47.651637	-120.594822
8	39	Leaky dam	Plug up channel just downstream of gradient drop and add slash around structure through the small meander bend.	5	3	SPAN	Pool Development, Sediment Storing	47.651749	-120.594669

Complex	ID	Type	Description	# of Posts	Wood Count	Attachment	Objectives	Lat	Long
8	40	Leaky dam	Key pieces into bank and hillside. Plug up channel to capture spring input. Build 70cm vertical. Surround with slash.	5	3	SPAN	Pool Development, Sediment Storing	47.651854	-120.594487
8	41	PALS	Erode RR bank to increase undercut and eventually recruit maple trees on bank. RL bank is low but not much space for connection.	7	5	RL	Sediment Sourcing	47.651996	-120.594463
8	42	Leaky dam	Plug up channel. Key logs into bed and bank. Add slash and seeding throughout.	5	3	SPAN	Pool Development, Sediment Storing	47.652174	-120.594394
9	43	BDA	Try to get ponding out onto floodplain and around large cottonwood downstream on RR. Crest height about 70cm.	12	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.652440	-120.594135
9	44	Leaky dam	Plug channel. Key logs into bank and bed. Push water towards RL into floodplain pocket.	5	3	SPAN	Pool Development, Sediment Storing, Floodplain Connection	47.652860	-120.593807
9	45	Leaky dam	Plug up channel. Key wood into bed and banks. Place just upstream of small meander.	5	3	SPAN	Pool Development, Sediment Storing	47.653000	-120.593661
10	46	Leaky dam	Plug channel. Key logs into bed and bank. Integrate local wood on the banks.	5	3	SPAN	Pool Development, Sediment Storing, Floodplain Connection	47.653861	-120.593164
10	47	BDA	Big BDA near base of maple tree on RR. Push flows to floodplain on RL. Crest height around 70cm.	13	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.653921	-120.593152
10	48	BDA	Big span BDA to spread flows out as much as possible. Capture at least two flow paths. Crest height around 50-60cm. Key into large cottonwood on RL.	13	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.654042	-120.593107
10	49	Leaky dam	Add near downstream end of old road ditch to store water. Build 60-70cm vertical.	5	3	SPAN	Pool Development, Sediment Storing	47.653913	-120.593395
10	50	PALS	Add wood and slash, secure with posts. Key in some wood pieces into bed and bank to arrest headcut. Source cobbles to place in bowl for scour protection.	10	8	SPAN	Sediment Storing, Headcut Arrest	47.653987	-120.593322
10	51	BDA	Capture confluence of road ditch and overflow from main stem.	13	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.654199	-120.593274
10	52	BDA	Large span BDA. Crest height around 70cm. Push flows towards overflow channel to old road ditch.	16	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.654217	-120.593140
10	53	BDA	Large span BDA to access floodplain on RR. Attach to cottonwood on RL. Crest height around 60cm.	17	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.654365	-120.593116

Complex	ID	Type	Description	# of Posts	Wood Count	Attachment	Objectives	Lat	Long
10	54	Leaky dam	Plug channel. Key into existing boulder on RR. Crest height around 70cm. Cover with slash and additional wood for a long structure.	5	3	SPAN	Pool Development, Sediment Storing	47.654472	-120.593116
10	55	BDA	Key into grand fir on RR. Crest height around 60cm. Raise water to connect floodplain upstream.	13	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.654579	-120.593128
10	56	Leaky dam	Plug up channel near root drop. May need a lot of slash to plug it up because roots will be in the way of trying to key pieces into the bed and bank.	5	3	SPAN	Pool Development, Sediment Storing, Headcut Arrest	47.654776	-120.593141
10	57	Leaky dam	Key into grand for on RR. Plug up channel. Fill with slash upstream and downstream. Add posts throughout to hold everything in. Slash to span about 20m of channel length with Leaky Dam in the middle. Add slash and wood to small headcut about 10m upstream.	25	15	SPAN	Pool Development, Sediment Storing, Headcut Arrest	47.654904	-120.593117
10	58	BDA	5m downstream of large grand fir on RL. Channel narrows here but widens upstream starting at the fir. Place among mock orange patch and use clippings for weave. Crest height about 70cm.	13	0	SPAN	Pond, Sediment Storing, Floodplain Connection	47.655004	-120.593024
11	59	Leaky dam	Plug up channel. Key logs into bed and bank just downstream of existing boulders and Doug fir on RR. Plenty of wood nearby on the banks or fell nearby snag. Crest height around 60cm.	5	3	SPAN	Pool Development, Sediment Storing	47.655245	-120.592971
11	60	Leaky dam	Key into bed and banks. Add nearby boulders if possible. Capture potential overflow from RR channel.	5	3	SPAN	Pool Development, Sediment Storing	47.655323	-120.592971
11	61	Leaky dam	Within slash and wood zone of the downstream structure. Plug up channel. Key wood into bed and banks. Crest height around 70cm.	5	3	SPAN	Pool Development, Sediment Storing	47.655486	-120.592972
12	62	Leaky dam	Plug up channel. Key wood into bed and banks. Tie into roots of large maple on RL. Extend into floodplain pocket on RR. RL is around 1m high, but roots make nice hard point. Crest height around 70cm.	5	3	SPAN	Pool Development, Sediment Storing, Floodplain Connection	47.655788	-120.593021
12	63	PALS	Channel spanning PALS to plug up channel and shunt flows toward RR to access floodplain.	10	8	SPAN	Channel Widening, Floodplain Connection	47.656463	-120.592608
13	64	PALS	Bank attached PALS to shunt flows toward inset floodplain.	7	5	RR	Pool Development, Sediment Sourcing	47.655865	-120.593169

Complex	ID	Type	Description	# of Posts	Wood Count	Attachment	Objectives	Lat	Long
13	65	PALS	Continue eroding RL bank.	7	5	RR	Pool Development, Sediment Sourcing	47.656007	-120.593167
13	66	PALS	Channel spanning PALS to shunt flows into low lying floodplain on RL.	10	8	SPAN	Channel Widening, Floodplain Connection	47.656350	-120.593209
13	67	PALS	Bank attached PALS to shunt flows away from valley margins.	7	5	RR	Pool Development, Sediment Sourcing	47.656512	-120.593241
13	68	PALS	Bank attached PALS to shunt flows away from valley margin.	7	5	RR	Pool Development, Sediment Sourcing	47.656680	-120.593242
13	69	PALS	Widen channel toward valley center.	7	5	RR	Pool Development, Sediment Sourcing, Channel Widening	47.656861	-120.593089

Table 6. Description, expected volume of slash, and location of post assisted slash (PAS) in Complexes 1-13 on Bjork 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 channel in narrow location.	8	0.43	47.647633	-120.600503	47.647688	-120.600421
1	2	PAS	Plug channel in narrow location.	7	0.79	47.647719	-120.600363	47.647749	-120.600257
4	3	PAS	Plug channel and recruit sediment.	10	0.88	47.648895	-120.599211	47.648953	-120.599136
4	4	PAS	Build up incised location.	7	0.70	47.648980	-120.599037	47.649041	-120.598970
4	5	PAS	PAS to back up water and widen channel.	9	0.78	47.649114	-120.598943	47.649165	-120.598861
4	6	PAS	Plug channel and slow flows.	8	1.02	47.649262	-120.598778	47.649336	-120.598744
4	7	PAS	Posts and slash to slow flows and build up channel.	7	0.59	47.649346	-120.598641	47.649386	-120.598550
4	8	PAS	Posts and slash to slow flows and build up channel.	8	0.66	47.649454	-120.598422	47.649491	-120.598330
4	9	PAS	Post assisted slash and wood to plug up channel.	6	0.66	47.649559	-120.598045	47.649582	-120.597941
6	10	PAS	Plug channel and recruit sediment. Aid in slowing flows for DS BDA.	7	0.55	47.650323	-120.596908	47.650381	-120.596835
6	11	PAS	Plug channel and slow flows.	7	0.49	47.650413	-120.596787	47.650432	-120.596675
6	12	PAS	Plug up channel and build up sediment.	7	0.53	47.650423	-120.596621	47.650432	-120.596511
6	13	PAS	Plug up straight Channel.	7	0.56	47.650787	-120.596065	47.650842	-120.595984
6	14	PAS	Plug up straight portion of channel.	6	0.45	47.650845	-120.595980	47.650912	-120.595921
7	15	PAS	Heavy slash added to PALS.	12	0.89	47.651046	-120.595714	47.651160	-120.595697
8	16	PAS	Plug up channel with slash and wood. Add unsecured wood pieces through meander curves starting at root ball to about 20m upstream. Cover channel with slash and add pieces within and on top. Jam pieces into bank oriented to shunt flows into undercuts.	40	3.62	47.651294	-120.595560	47.651485	-120.595239
8	17	PAS	Add unsecured wood and slash. Key into live maple on RR bank directly upstream of previous leaky dam structure.	10	1.09	47.651545	-120.595068	47.651569	-120.594959
8	18	PAS	Surround leaky dam with slash to build up vertical.	8	0.75	47.651617	-120.594871	47.651672	-120.594795
8	19	PAS	Add slash and wood through bend and over top of leaky dam. Surround leaky dams with slash.	26	2.86	47.651724	-120.594714	47.651892	-120.594475
8	20	PAS	Add slash to plug up channel at pinch point. May blow out around and recruit trees and sediment. Short term will be clogged and create ponding upstream. Use	6	0.91	47.652030	-120.594414	47.652107	-120.594426

			local boulders as ballast.						
8	21	PAS	Surround leaky dam with slash.	7	0.58	47.652139	-120.594421	47.652206	-120.594360
8	22	PAS	Add slash downstream of pinch point. Fill plunge pool with slash and wood. Jam wood pieces into undercuts on both sides.	6	1.32	47.652229	-120.594350	47.652291	-120.594281
9	23	PAS	Add slash and wood to existing slash pile. Shove wood into undercuts. Plug up channel. Will be supported by BDA downstream.	28	4.24	47.652562	-120.593979	47.652767	-120.593819
10	24	PAS	Fill hole with slash and wood and secure with posts. Secure some logs to existing wood with posts to arrest headcut.	11	0.80	47.653922	-120.593151	47.653988	-120.593115
10	25	PAS	Add wood and slash and secure with posts. Key some wood pieces into bed and bank to arrest headcut. Source cobbles to place in bowl for scour protection.	10	0.86	47.653953	-120.593349	47.654020	-120.593291
10	26	PAS	Cover leaky dam with slash and wood to extend the structure.	9	0.70	47.654434	-120.593104	47.654511	-120.593104
10	27	PAS	Use slash to aid the leaky dam in plugging the channel. Roots will make it difficult to key pieces into the bed and bank. Surround leaky dams with slash.	31	2.92	47.654738	-120.593129	47.655006	-120.593021
11	28	PAS	Buck two of the downed trees to bring pieces back into the channel. Leave at least two intact on top to hold jam together. Fill area with slash. Potentially fell nearby snag. Ultimately fill hole under downed trees to plug channel.	8	0.94	47.655161	-120.592959	47.655238	-120.592971
11	29	PAS	Add slash and wood secured by posts. Creek is surrounded by thimbleberry and looks like a ditch. Surround leaky dams with slash.	18	1.64	47.655321	-120.592971	47.655527	-120.592975
11	30	PAS	Buck up large cottonwood and place rounds in the channel surrounded by slash. Plug up the channel. Cottonwood is 50cm ebb.	11	1.75	47.655649	-120.592984	47.655711	-120.593053
12	31	PAS	Build up channel elevation by adding slash.	11	1.09	47.655847	-120.592982	47.655901	-120.592899
12	32	PAS	Build up channel elevation in very narrow location.	7	1.25	47.656063	-120.592887	47.656135	-120.592849
12	33	PAS	Build up channel elevation.	8	0.76	47.656235	-120.592774	47.656301	-120.592713
12	34	PAS	Plug channel and recruit sediment by adding slash.	8	0.92	47.656715	-120.592430	47.656781	-120.592378
12	35	PAS	Scattered slash to plug channel and recruit sediment.	7	0.84	47.656882	-120.592341	47.656940	-120.592317

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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.

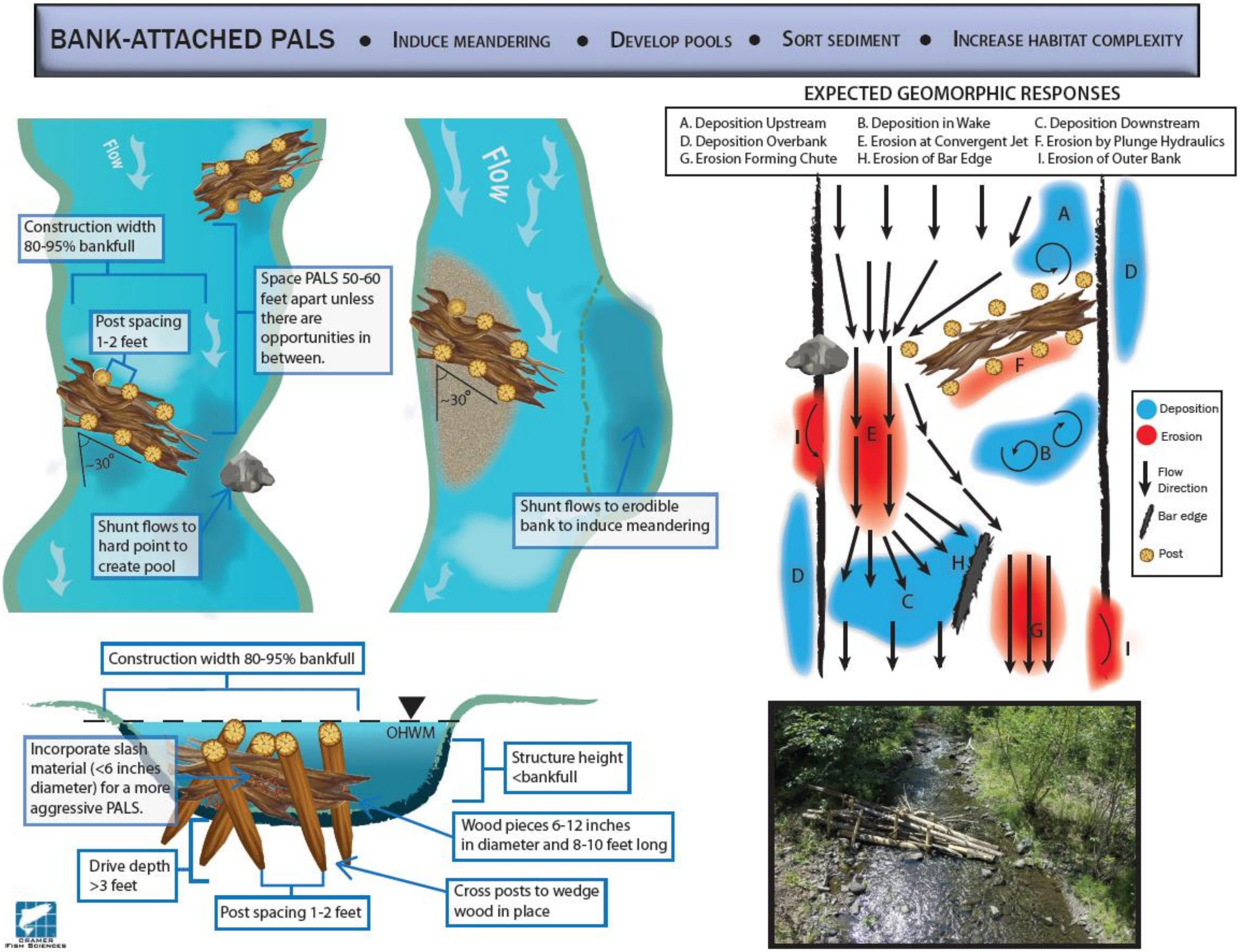

Figure 45. Typical structure schematic for a bank-attached post assisted log structure used to force a constriction jet.

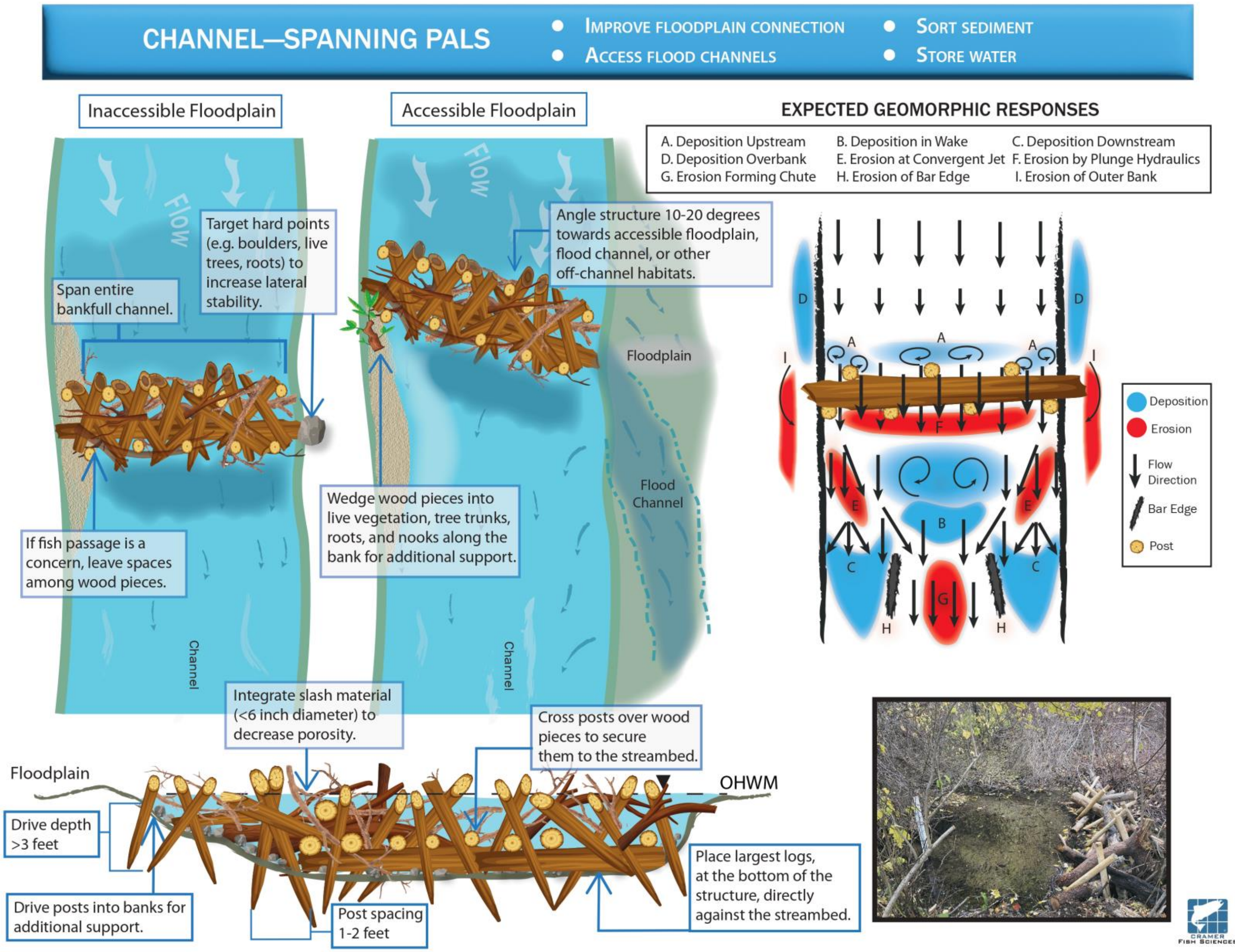

Figure 46. Typical structure schematics for a channel-spanning post assisted log structure used to promote overbank flows, retain water and sediment, and increase complexity.

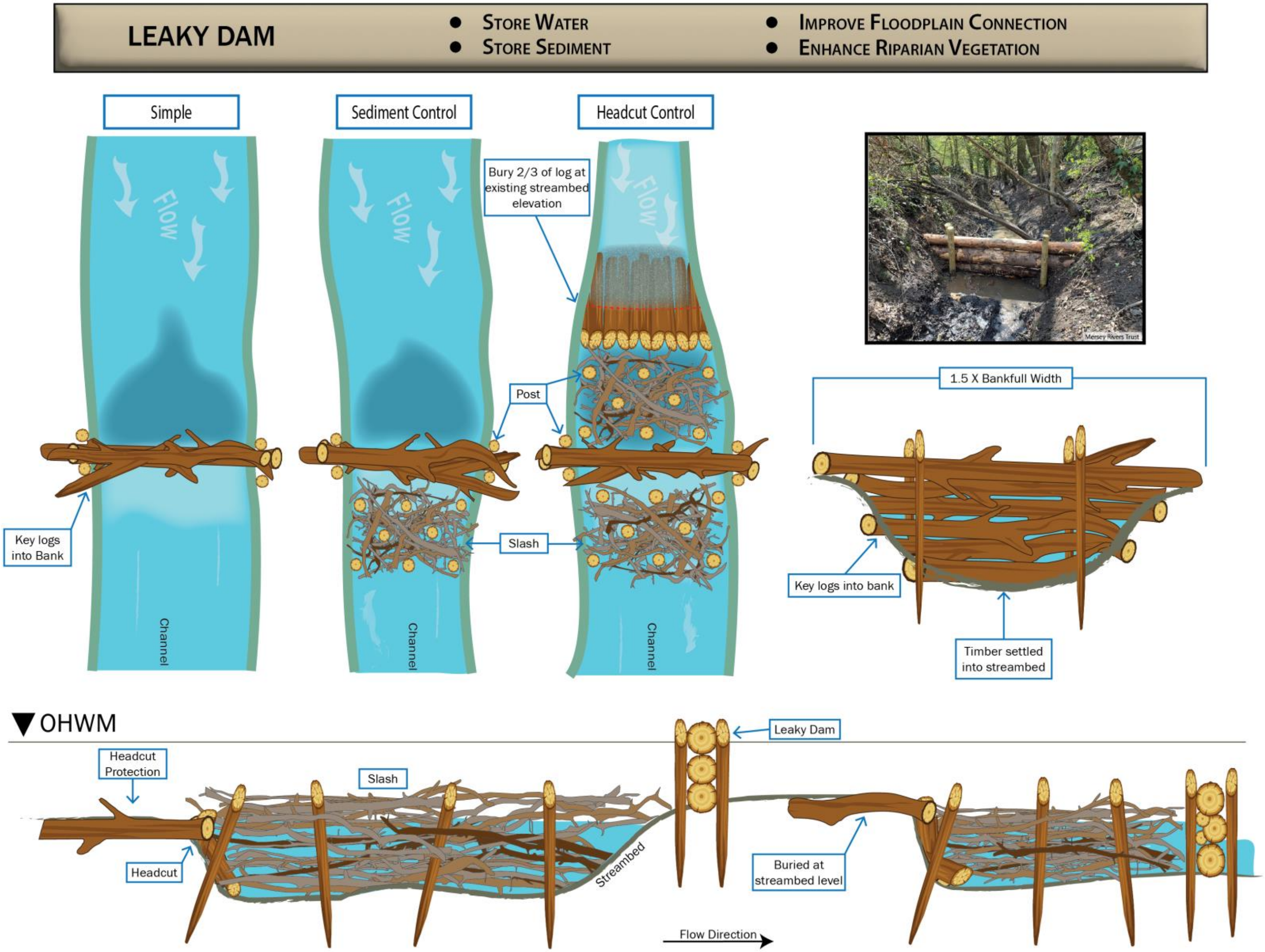

Figure 47. Typical structure schematic for a leaky dam.

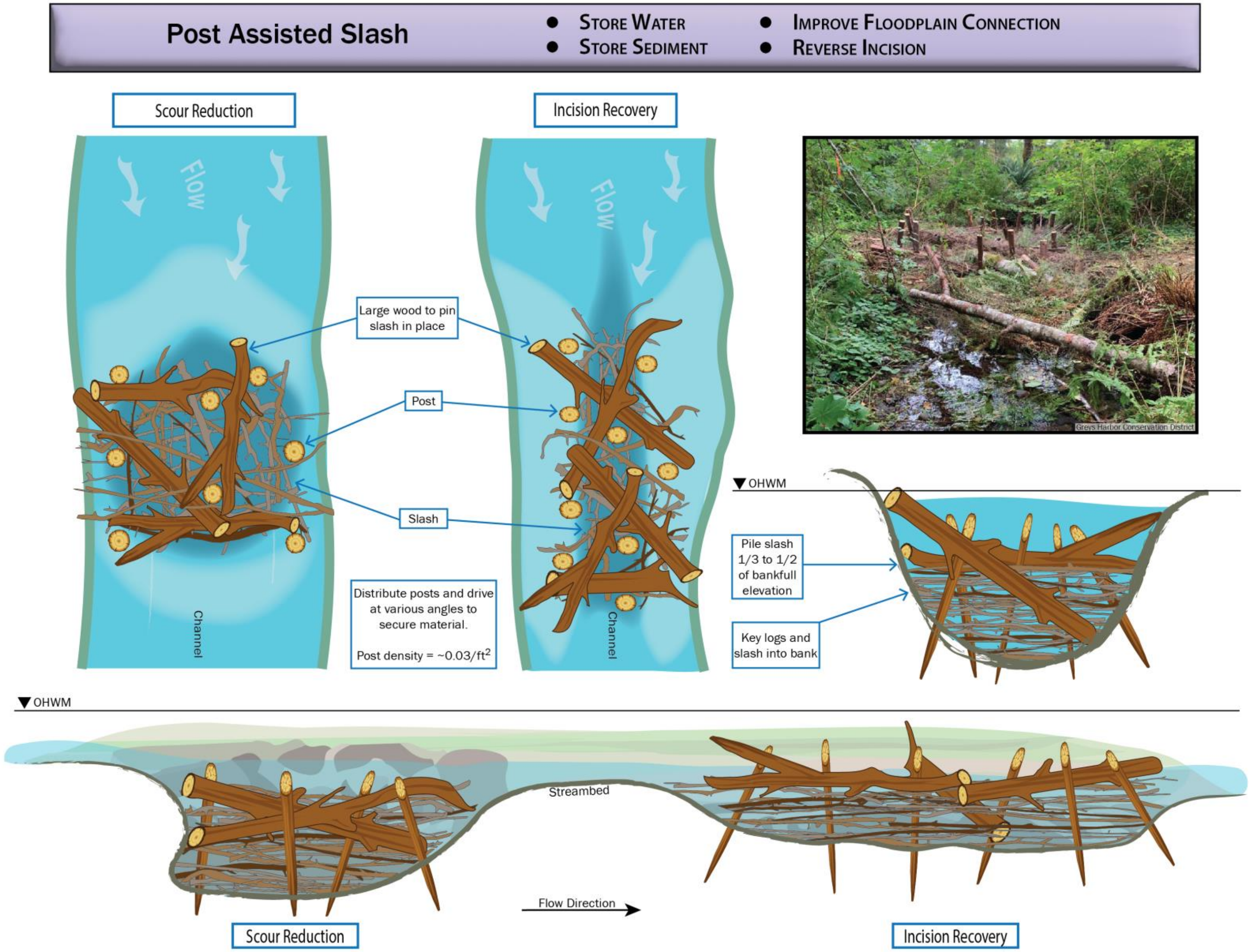

Figure 48. Typical structure schematic for a post assisted slash (PAS) area.

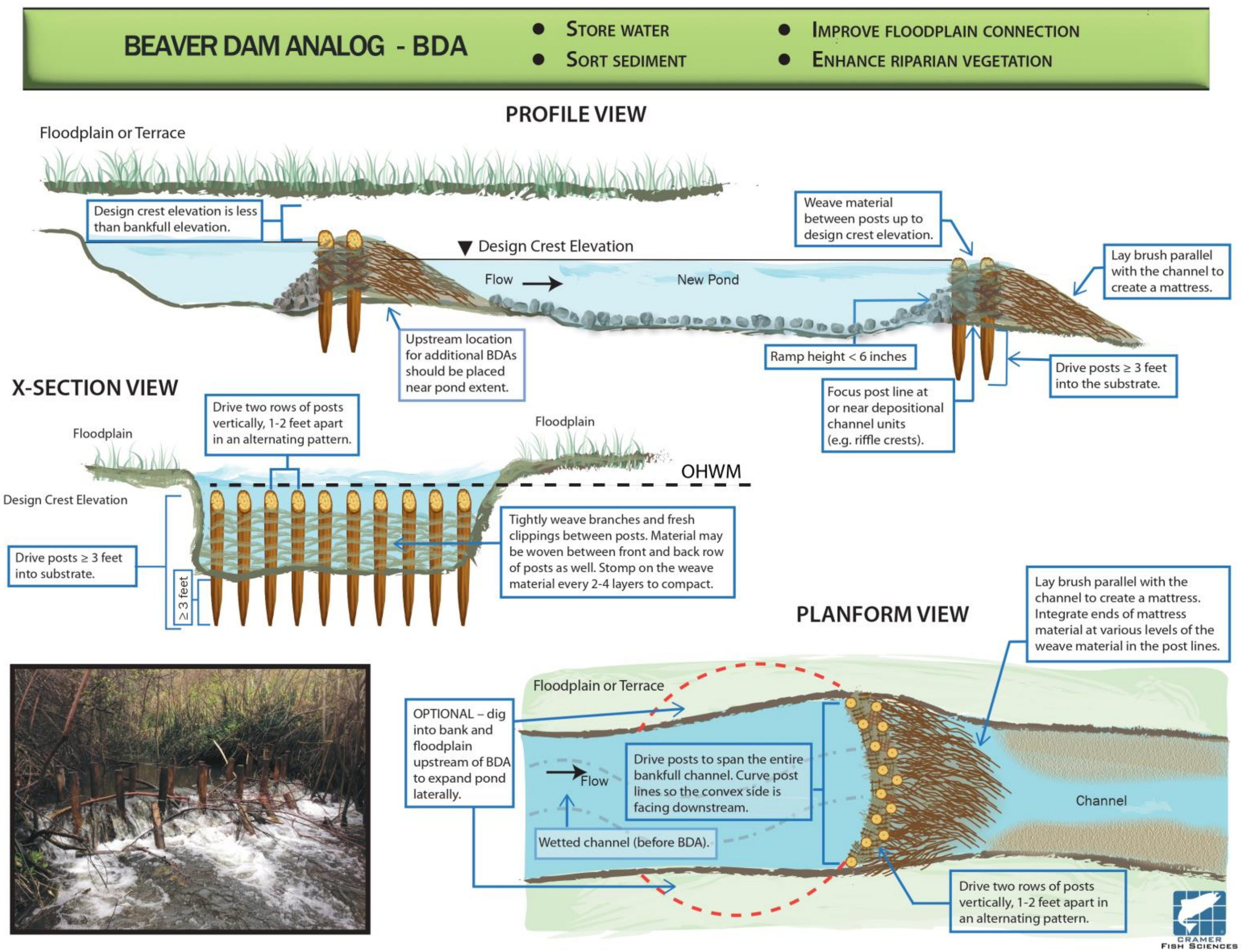

Figure 49. Typical structure schematics for a beaver dam analog (BDA) used to pond water, retain sediment, and promote overbank flows.

APPENDIX B: ACCESS AND STAGING AREAS