Final Design and As-built Report

Asotin Creek Intensively Monitored Watershed Restoration Maintenance

Grant 17-1304

Charley Creek Beaver Dam Analogues

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EXECUTIVE SUMMARY

The Asotin Creek Intensively Monitored Watershed project (Asotin IMW) has been running since 2008 with the goal to test the effectiveness of low-tech process-based restoration structures at improving riverscape health and summer steelhead productivity. The project is coordinated by the Snake River Salmon Recovery Board and funded by the Pacific States Marine Fisheries Commission. This report summarizes the final design and as-built construction details for increasing wood densities in the Asotin IMW funded by RCO Grant 17-1304. Grant 17-1304 was originally developed to support monitoring and analysis efforts for the IMW, but was amended to focus more on maintenance and enhancement actions in the IMW treatment sections and updating enumeration of emigrating steelhead smolts, adult escapement, and smolts per spawner for each IMW stream and treatment and control section. Originally, we installed 654 post-assisted log structures (PALS) between 2012-2016 and have seen some positive geomorphic and fish population responses. As part of our adaptive management plan, we have conducted annual structure surveys and have thresholds that trigger the addition of more wood if the density in treatment sections does not remain high. We added additional wood to increase the treatment wood density in 2016, 2018, and 2020 based on the annual surveys. We increase wood density by adding more wood to structures that lost wood, rebuilding structures that were washed downstream, and other low-tech restoration approaches like harvesting trees on site or using grip-hoists to move downed wood into the stream. Surveys in spring 2020 and 2021 identified areas in each original treatment that could be enhanced with more wood. In this report, we document enhancing 131 structures with the addition of over 300 pieces of LWD and trees. Most of the material was added to the North Fork Asotin Creek using wood harvested onsite to rebuild or enhance 39 PALS. We also built 25 BDAs in Charley Creek and connected over 500 m of side-channels. We took advantage of abundant SWD that was available along South Fork from fire line construction and added brush and small trees to over 60 existing structures in South Fork Creek. This report includes the final restoration design and as-built descriptions of the methods, structure locations, construction actions, and a summary of analysis methods and estimates of steelhead smolt emigration and adult escapement from 2008-2020 for the IMW streams and treatment and control sections. Interpretation of the smolt and adult estimates will be presented in the IMW annual report for 2021 (SRFB Project 19-1545C). Costs of the two project elements were: Analysis = $12,045 and Restoration Maintenance and Enhancement = $44,018 for total of $56,063.

ACKNOWLEDGMENTS

The Asotin Intensively Monitored Watershed (IMW) is a collaborative multi-agency initiative sponsored by the Snake River Salmon Recovery Board (SRSRB). The SRSRB provides oversight and technical review of all the Asotin Creek IMW activities through support from the Regional Technical Team (RTT) and National Oceanic and Atmospheric Administration (NOAA) staff. The majority of the IMW takes place on the Asotin Wildlife Area managed by the Clarkston office of the Washington Department of Fish and Wildlife (WDFW) with portions of monitoring also occurring on the Pomeroy Ranger District, Umatilla National Forest, managed by the US Forest Service (USFS). Both the WDFW and USFS have supported the development and implementation of the Asotin IMW since its inception. Steve Martin (former director) and John Foltz (current director) of the Snake River Salmon Recovery Board have been supporters of the IMW and worked continually to help secure monitoring and restoration funds and coordinate between all the stakeholders – the IMW could not have been implemented without their commitment to the project. Keith Dublanica of the Washington State Recreation and Conservation Office (RCO) made sure contracts and funds were always secured to continue this long-term and complex project. Funding for the primary monitoring and reporting components of the IMW are provided and managed by Stephen Phillips, Pacific States Marine Fisheries Commission (PSMFC) and Greg Sieglitz, National Marine Fisheries Service (NMFS). Funding for restoration activities comes from PCSRF through the State of Washington's Salmon Recovery Funding Board (SRFB), BPA, Conservation Commission, USFS, and WDFW.

We are also grateful for support we receive from Ethan Crawford and Mike Herr of WDFW in the form of field staff and data from fish-in fish-out monitoring conducted by the Clarkston office, and Bonneville Power Administration (BPA) which supports WDFW's efforts to collect fish-in fish-out data in Asotin Creek. Bob Dice, the manager of the Clarkston Wildlife Office, has also provided the IMW with accommodation, transportation, and access since the start of the project. Megan Stewart of the Asotin County Conservation District, Brad Johnson of the Palouse Conservation District, and Dave Karl of the WDFW have also been an indispensable part of the IMW team, working with the local landowners and agencies to help secure access, operating permits, local support, and acting as sponsors for IMW funding. The Asotin County Public Utility Department has provided us with office space and storage for field gear. Del Groat (now retired) and Bill Dowdy of the USFS have provided generous donations of time and large wood for the restoration treatments and Billy Bowles, also with USFS, has helped with safety training for field crews. We also wish to thank the Koch and Thornton families for graciously providing us access to private property along Charley Creek (properties now owned by WDFW). Bruce Heiner, WDFW Habitat Engineer and Barry Sutherland, USDA Natural Resources Conservation Service (NRCS) Fluvial Geomorphologist (retired) provided comments on the earlier versions of the restoration plan. The following groups have provided direct support to the IMW in either goods or services: Avista Power, Clearwater Power, Collier Electric, Inland Metals Electric, TDS Telecom, WDFW, and USFS.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION AND SETTING

1.1 Background

The Asotin Intensively Monitored Watershed (IMW) Project is a long-term experiment to test the effectiveness of large wood additions at improving freshwater habitat and ultimately increasing freshwater production of ESA listed steelhead (Bennett et al. 2016). The Asotin IMW is part of a group of IMWs in the Pacific Northwest funded by federal and state agencies to provide critical information on stream restoration effectiveness and how restoration actions can be improved to maximize benefits to ESA listed salmon and steelhead. The Asotin IMW was initiated in 2008 in three tributaries of Asotin Creek: Charley Creek, North Fork, and South Fork Asotin Creeks (Figure 1). Pre-restoration monitoring of habitat and juvenile steelhead was conducted from 2008-2012 (Bennett and Bouwes 2009). From 2012-2016 restoration treatments were implemented on 14 km of stream where 654 post-assisted log structures (PALS) were installed in three different streams: Charley Creek (207 PALS), North Fork Asotin Creek (135 PALS), and South Fork Asotin Creek (312 PALS; Wheaton et al. 2012 ; Figure 2). We used grant 19-1499 to add large woody debris in 2020 to existing PALS, fell trees, and rebuild some PALS in Charley and South Fork Asotin Creek at locations where existing PALS lost wood or where existing PALS had moved from their original location. This report documents the restoration actions implemented on the three IMW study streams under grant 17-1304.

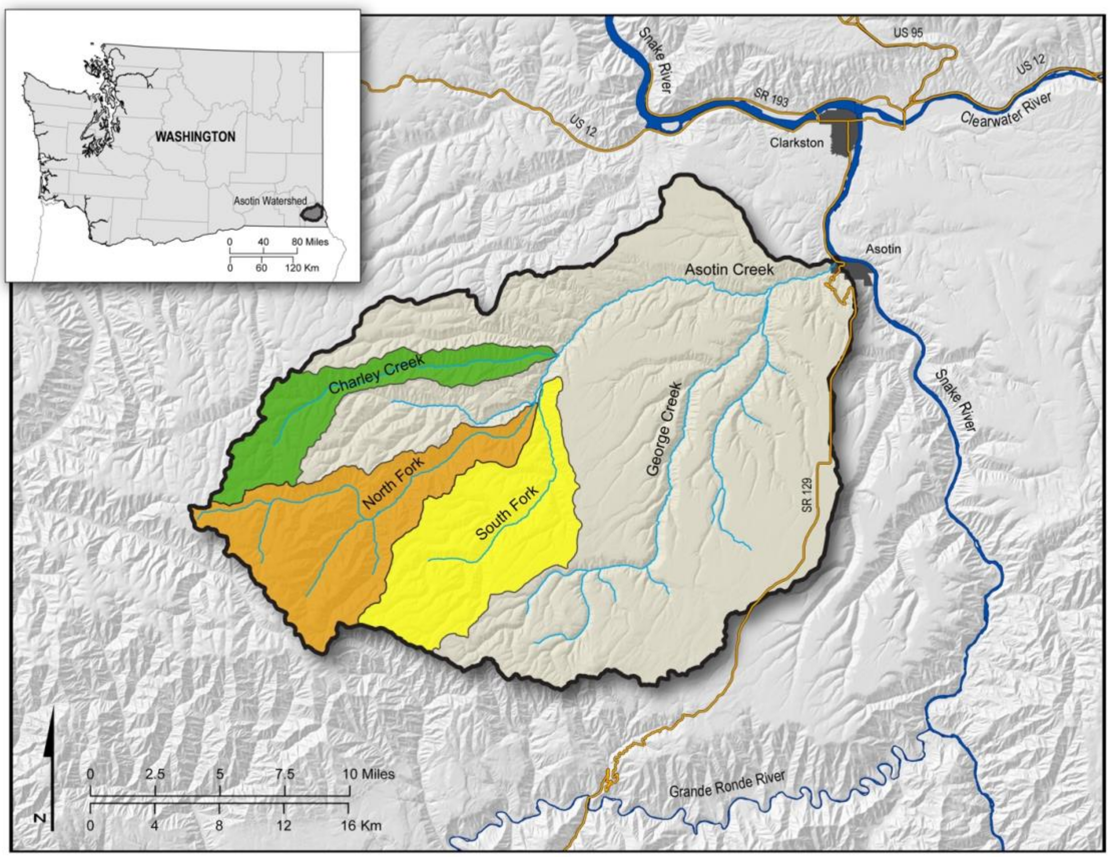

Figure 1. Asotin Creek watershed and Intensively Monitored Watershed area: Charley Creek (green), North Fork Asotin Creek (orange), and South Fork Asotin Creek (yellow). See Figure 2 for the experimental design (treatment and control areas) and fish and habitat monitoring layout.

1.2 Adaptive Management and Project Goals & Objectives

We developed the Asotin IMW using an adaptive management framework that explicitly called for the addition of more LWD if structures lose wood, move, or are not producing the desired results (Wheaton et al. 2012, Bouwes et al. 2016). Our annual surveys of PALS across the entire IMW study area suggest that more LWD will help continue to improve habitat conditions, potentially increase the fish response, and may lead to sustainable geomorphic processes and healthy riverscapes (Bennett et al. 2020). The goal of Project 17-1304 was originally to support monitoring activities for the IMW, but the grant was amended to support restoration actions. The goals of the restoration actions were to improve geomorphic condition, function, and habitat quality for rearing and spawning steelhead. Other species such as Chinook, bull trout and lamprey may benefit as well. The specific objectives were to increase

- large wood density in treatment sections of the IMW by 2-3 times the density of control reaches,
- occurrence of overbank flow by 25% across Asotin IMW project footprint by the year 2023 (i.e., increase the area of active floodplain),
- channel sinuosity by 0.1-0.3 (depending on the reach type) on average over the IMW project treatment footprint to reduce water velocities and support sediment aggradation to provide improved juvenile steelhead rearing habitat,
- total active channel length to valley length (measured as a ratio) across IMW project treatment footprint by 0.3-0.5 by 2023 year, and
- reconnect 1-4 side channels across in each treatment area of the IMW project treatment footprint by the year 2023.

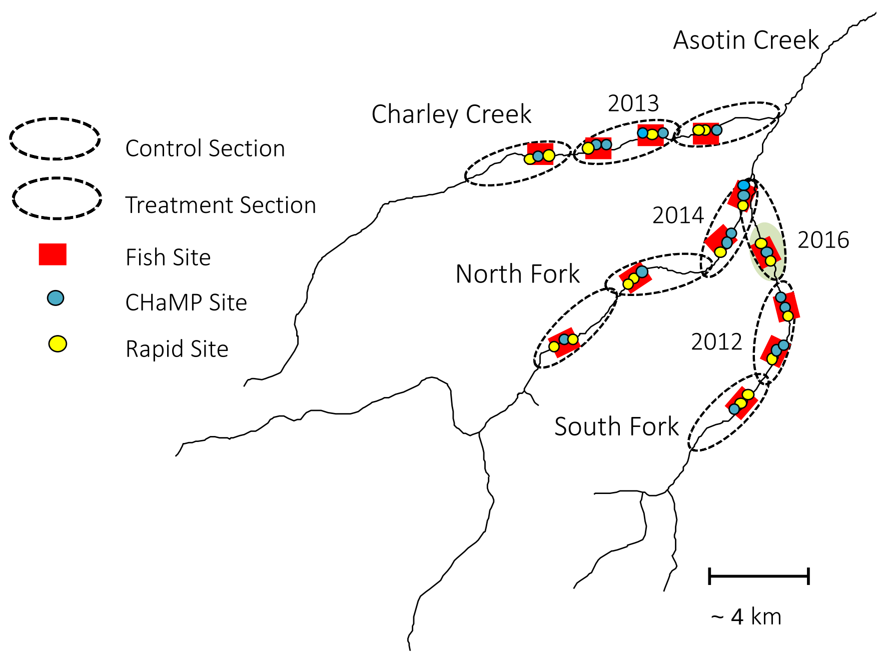

Figure 2. Experimental design and sample sites for juvenile steelhead PIT tagging and habitat surveys for the Asotin Creek IMW. Each study stream has three 4 km long sections. One section in each stream has been restored using post-assisted log structures (shaded green): South Fork (2012), Charley Creek (2013), and North Fork (2014). Additional section was restored in South Fork (lower section) in 2016 at part of the adaptive management plan. All other sections not colored are controls. Fish sites and habitat survey sites are nested within each section. CHaMP = Columbia Habitat Monitoring Protocol, Rapid = custom rapid habitat survey.

2 EXISTING CONDITIONS

Implementation of the Asotin Creek Model Watershed Plan starting in 1995 improved conditions in the uplands and led to extensive protection of much of the riparian areas in the watershed (ACCD 1995, 2004). The Model Watershed restoration actions lead to improved stream conditions by limiting sediment inputs from upland farming and initiated recovery of riparian areas. However, by the time the Asotin IMW was initiated in 2008 stream channels still lacked large woody debris, had low habitat complexity, were dominated by planar habitat, and were disconnected from their floodplains (SRSRB 2011).

The study streams differ in size, valley conditions, gradient, and flow characteristics. Charley Creek is steep and confined by numerous tributary fans and is dominated by spring flows and relatively stable flows (Table 1). North Fork is less confined and has the most potential floodplain, highest spring runoff and base flows, and is dominated by snow-melt. South Fork tends to have large but unpredictable spring flows and very low base flows. All three streams are in moderate geomorphic condition and are dominated by planar habitat, low LWD and pool frequencies, single thread channels, and had limited floodplain connection (Bennett et al. 2018). Since the implementation of PALS, habitat complexity has increased and we have documented increases in LWD, bar, and pool frequencies in treatment compared to control areas (Bennett et al. 2020). This has led to increases in fish abundance in treatment areas in all three study streams ranging from 128-745 juvenile steelhead/km compared to control areas. There is also evidence that self-sustaining geomorphic processes are being initiated by the PALS such as tree recruitment, erosion, and deposition. However, the channels in each of the study streams are still predominantly single thread and there is limited overbank flow and floodplain connection. The addition of more LWD to the treatment areas is expected to promote more overbank flow and floodplain connection and potentially increase the positive fish responses already documented.

Table 1. Basic watershed characteristics for the three Asotin Creek IMW study creeks.

Stream	Basin area (km^2)	Bankfull width (m)	Gradient (%)	Average annual discharge (cfs)	2 Year return interval* (cfs)
Charley	58	4.8	3.0	9.5	292
North Fork	165	9.8	1.7	60.0	674
South Fork	104	6.3	2.6	11.5	448

* data from USGS Stream Stats

3 PRELIMINARY DESIGN ALTERNATIVES

We developed PALS[1] specifically to test the low-tech process-based restoration approach within the Asotin IMW as an alternative to traditional restoration actions (Wheaton et al. 2019). PALS are installed by hand and all the wood is carried into the stream to limit the disturbance to recovering riparian habitat (Appendix A & B). We did not explore other engineering-based alternatives because the IMW is designed to test low-tech process-based restoration approaches. However, we did use other low-tech methods to increase wood densities in the treatment areas including adding wood to existing PALS, rebuilding PALS that have moved, falling subdominant trees on site and adding them to the treatment areas (Carah et al. 2014), and using grip-hoists to drag downed wood into the stream. We also constructed some beaver dam analogs (BDAs) in Charley Creek. Charley Creek has consistently had the smallest improvements in habitat and fish abundance, and we speculate that is because the stream power of Charley Creek is the smallest, which limits the effectiveness of wood structures to promote erosion and deposition. The intent of building BDAs in Charley Creek is to mimic beaver dams and force overbank flows during low flow conditions and connect it to historic side-channels and floodplain surfaces.

4 PREFERRED ALTERNATIVES

We describe the preferred alternatives for increasing wood and dam frequencies here. See the Appendix B for Design Drawings for more details on the preferred alternatives.

***Adding wood to existing PALS*:** Some PALS were present but lost wood. This happened when wood floated off the structure or when part of the structure was washed away (Figure 3). We added LWD to increase the size of some PALS, interlocking the wood into remaining posts or live trees. Wood was harvested on site from burned and unburned areas,[2] brush and small trees, and brush cleared along roads and trails during the fires.

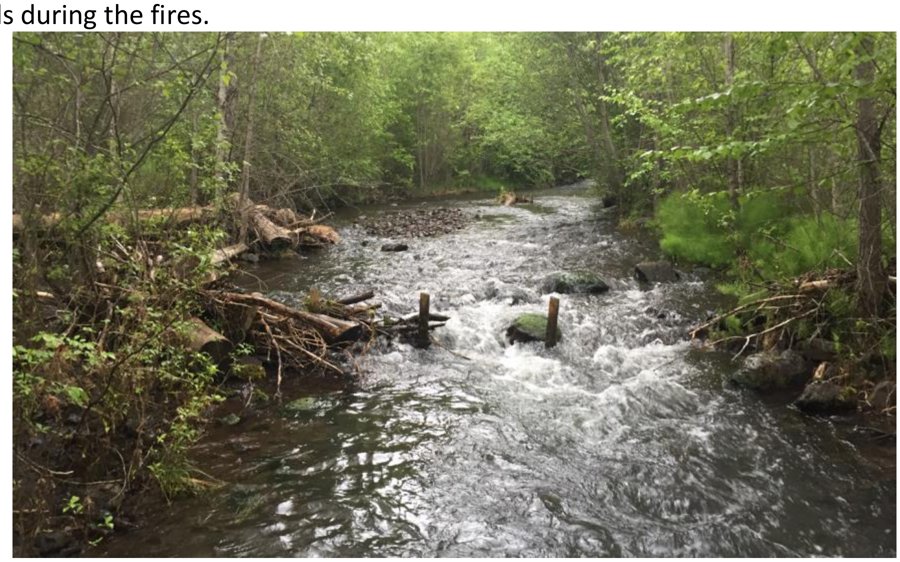

Figure 3. Example of a partly intact post-assisted log structure that was enhanced with the addition of more large woody debris.

[1] Note: Post-assisted log structures were originally referred to as Dynamic Woody Structures (Wheaton et al. 2012).

[2] Note: The Lick Creek and Green Ridge fires combined burned over 100,00 acres in Asotin Creek during the summer of 2021

***Rebuilding PALS*:** Some PALS have completely moved, reducing the wood density in treatment sections. Where it was logistically feasible to move the hydraulic post-driver to these locations, we rebuilt the PALS using onsite wood from burned areas and naturally downed wood (Figure 4).

Figure 4. Example of a post-assisted log structure that has washed downstream that could be rebuilt.

Cutting subdominant trees: The most efficient way to increase wood densities is to harvest wood on site along the riparian area (Figure 5). We have permission from the WDFW manager and forestry to cut subdominant conifers and alder in areas where the densities of trees are high. We have observed that alder is locking the stream in a single channel and harvesting some trees may help to allow the stream to begin to meander and interact with the floodplain more frequently.

Figure 5. Example of falling alders along North Fork Asotin Creek to increase wood density.

5 DESIGN CONSIDERATIONS AND PRELIMINARY ANALYSES

The original post-assisted log structures were designed in four basic configurations: bank-attached, mid-channel, channel spanning, and seeding. Each of these designs were developed to promote specific hydraulic and geomorphic responses. We have observed these responses during our annual IMW monitoring (Figure 6; Wheaton et al. 2012, Camp 2015, Wheaton et al. 2019, Bennett et al. 2020). Therefore, we usually maintained the original configuration of the structure when we added wood. However, some of the largest habitat responses were from channel spanning structures. If we did change the configuration of a structure, it was usually to establish a channel spanning PALS to promote larger habitat responses. When we added wood, the wood was placed to interlock with remaining posts or live trees at the site to secure the wood. When cutting trees, the trees were also interlocked with other trees, or where possible felled on existing structures to provide stability. We also added wooden posts to felled trees to increase their stability. We have noted from our extensive surveys of PALS that the high density of PALS tends to trap mobile wood, causing other PALS to increase in size and, in some cases, create new log jams (Figure 7).

Figure 6. Example of hydraulic and geomorphic diversity created by a channel spanning PALS on South Fork Asotin Creek. A large dam pool was created upstream, a plunge pool and gravel bar formed downstream, and overbank flow is being forced, connecting a portion of floodplain.

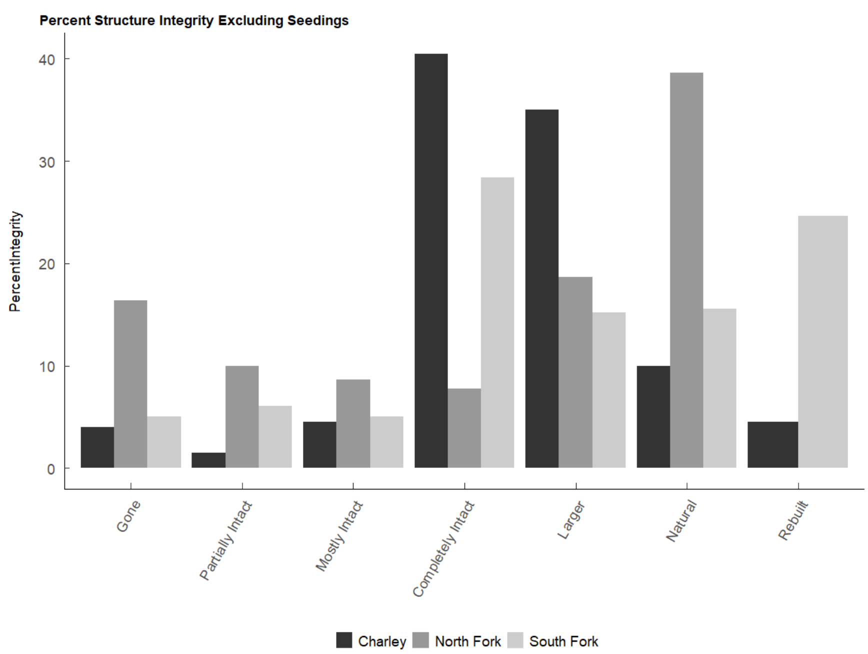

Figure 7. Percent of structures by category describing their integrity based on 2020 survey. Larger refers to structures that have increased 25% in volume due to wood accumulation and New refers to wood accumulations that have developed since the original restoration treatment from IMW wood, natural recruitment, or both (Total number of wood accumulations now = 732 in 14 km treatment area).

A spring flow in May 2020 of ~ 600 cfs was recorded in Asotin Creek just below the confluence of North Fork and South Fork that likely washed some PALS downstream. A survey in June of 2020 was conducted to determine potential locations for adding wood or rebuilding some PALS. We identified 156 PALS sites and ranked the sites as high priority for wood enhancement/rebuilding if they were near our fish and habitat sampling sites. We re-surveyed the treatment areas in 2021 to confirm which sites still needed enhancement and observed that the North Fork treatment area had lost more structures. We therefore decided to focus on replacing or enhancing PALS in the North Fork. We also decided that we would add BDAs to Charley Creek to see if we could force over-bank flow during summer and fall low-flow conditions. Lastly, due to the high volumes of small trees and brush cut along South Fork to enhance a fire line, we decided to add most of the slash to the treatment section to enhance existing structures.

6 PERMITTING AND STAKEHOLDER CONSULTATION

We secured the required HPA to conduct addition of wood to PALS or constructions of new PALS (attached to PRISM), we have cultural surveys completed for all three IMW streams (attached to PRISM). We also secured permits from the US Army Corp of Engineers to construct BDAs and previously had HPA permits to build PALS. All restoration actions were discussed with WDFW staff that manage the Asotin Creek Wildlife Area where the IMW is located.

7 FINAL DESIGN DRAWINGS AND INFRASTRUCTURE

See Figure 1 & 2 for project locations and experimental design for the Asotin Creek IMW. Figure 8 shows the property boundaries of the IMW study area which is entirely owned by WDFW and USFS, the monitoring sites for fish and habitat, locations of existing and intact PALS, and structures that were enhanced with more wood. There is no infrastructure other than primitive roads, wood was staged along the stream and carried by hand to the enhancement locations. Fill material was only used to construct BDAs on Charley Creek. See Appendix B for structure design drawings.

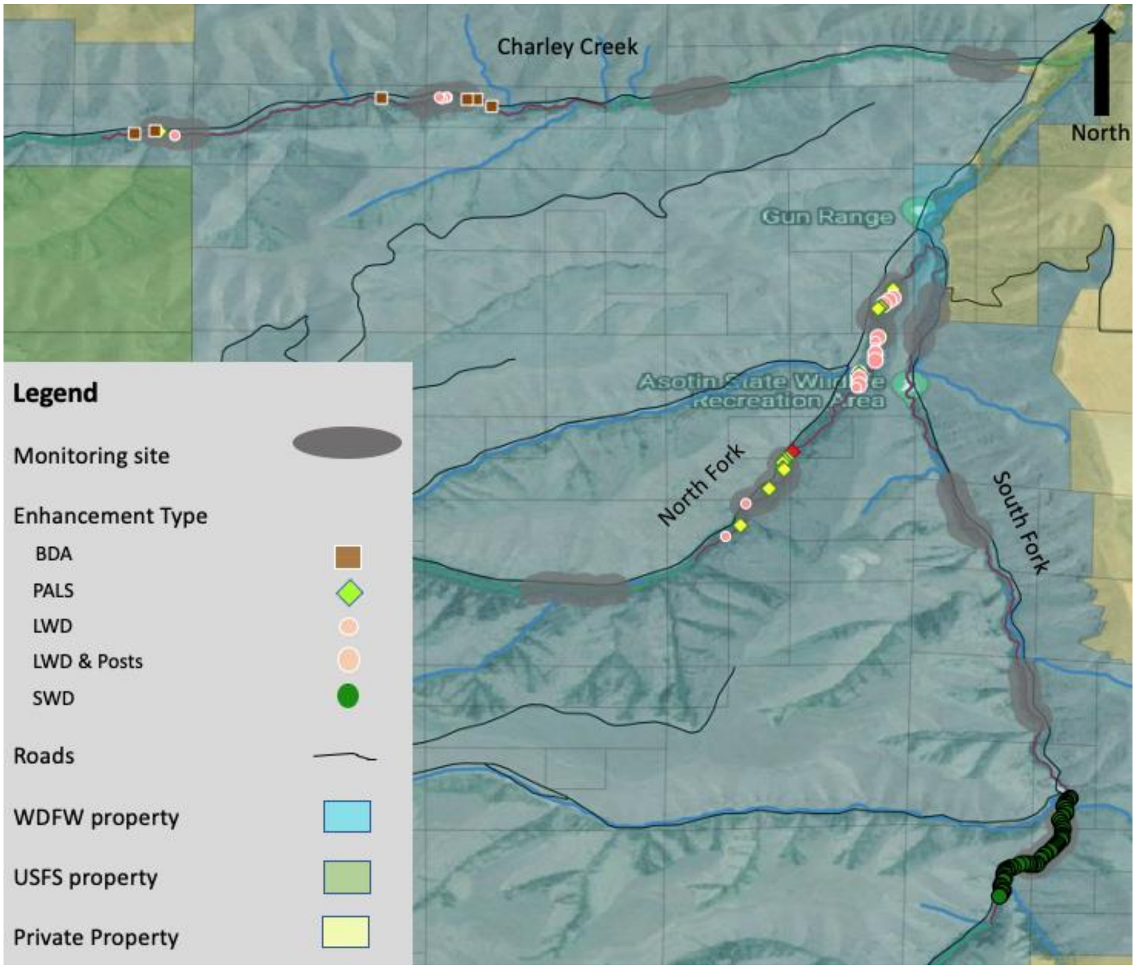

Figure 8. As-built construction locations and actions for increasing wood density in Asotin Creek IMW. Map also includes existing fish and habitat monitoring sites, access roads, and property boundaries. The construction actions included beaver dam analogues (BDA), post-assisted log structures (PALS), large wood added to existing structures (LWD), and existing structures being enhanced with LWD and posts. See Appendix C for list of all construction actions and GPS locations.

8 AS-BUILT CONSTRUCTION QUANTITIES AND CONSTRUCTION COSTS

We identified 156 sites where enhancement could be implemented in the preliminary design report in 2020 (see SRFB project 19-1499). In 2020, we focused on enhancing structures in South Fork Creek due to WDFW being unable to complete a cultural resource consultation on North Fork Creek and lack of a permit to build BDAs in Charley Creek. In 2021, we received cultural clearance to work in North Fork Creek and a permit to construct BDAs in Charley Creek, and therefore, focused maintenance and enhancement in both creeks. We also took advantage of a large amount of brush that was available due to the construction of fire lines that cut brush bordering access trails along South Fork Creek to fight the Lick Creek fire. In total, we constructed 25 BDAs, 18 PALS, added LWD and/or posts to 22 existing PALS, and added brush/small woody debris to 66 PALS (Figure 8, Table 2, Appendix C).

In Charley Creek, we built six new BDAs and converted one existing channel-spanning PALS into a BDA to force the reconnection of side-channels and floodplain (Figure 9). We also built 19 more small BDAs in the reconnected side-channels to force more floodplain connection, create pools, and increase side-channel complexity (Figure 10). We reconnected seven side-channels totaling approximately 550 m in length. We also constructed one new channel-spanning PALS and added more LWD.

In North Fork Creek, we rebuilt 17 PALS and enhanced 22 existing PALS by adding LWD (6) or LWD and posts (11; Figure 11). No side-channels or floodplain were connected by these enhancements during low flow, but we anticipate increased floodplain connection at higher flows and will monitor these sites in spring 2022. We added SWD to 66 PALS in South Fork Creek due to its availability after fire line construction. In total, we added 320 pieces of LWD consisting of felled trees and downed burned trees to 60 structures (4.9 LWD/structure) in the three streams. Most of the pieces of wood were medium to large diameter alder (6-12”), and small diameter (3-6”) water birch and ponderosa pine that were relatively long (15-40’). The budget for this project was $45,000.

Table 2. Summary of as-built enhancement actions by stream and type. All actions were conducted in the October 2021. See Figure 2 and Appendix C for locations of enhancement. Existing treatment sections were enhanced by building beaver dam analogues (BDAs), channel spanning post-assisted log structure (CS_PALS), MID-channel post-assisted log structure (MID_PALS), adding large woody debris (LWD), or adding LWD and posts to existing structures.

	Enhancement Type						
Stream	**BDA**	**CS_PALS**	**MID_PALS**	**LWD**	**LWD & Posts**	**SWD**	**Total**
Charley	25	1					26
North Fork		15	2	11	11		39
South Fork						66	66
Total	**25**	**16**	**2**	**11**	**11**	**66**	**131**

Figure 9. Example of a primary and secondary beaver dam analogue on the mainstem of Charley Creek viewed from downstream (left) and the mainstem and reconnected side-channel viewed from upstream (right).

Figure 10. Examples of a newly connected side-channels in Charley Creek with a series of small beaver dam analogues to create pools and spread water across floodplain.

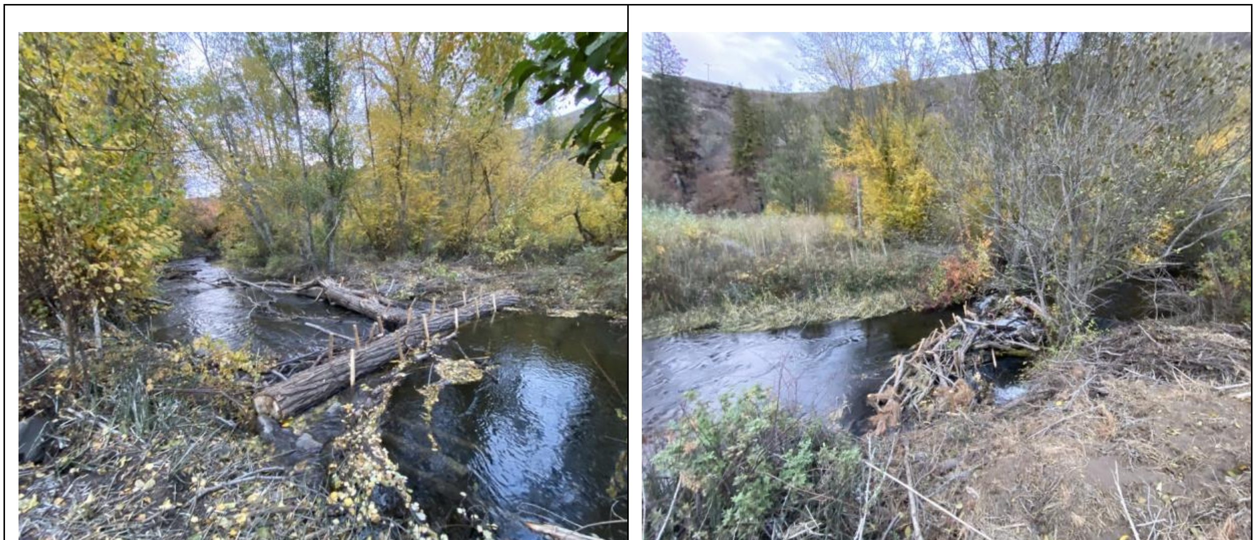

Figure 11. Example of a new post-assisted log structure (left) and the addition of a LWD and posts added to an existing PALS (right) to increase channel complexity, promote increased overbank flow frequency and floodplain connection on the North Fork.

Figure 12. Example of small woody debris (SWD) along South Fork Asotin Creek Road cleared to improve a fire line (left) and an existing PALS that was enhanced with the SWD (right).

9 SUMMARY ANALYSIS OF STEELHEAD SMOLT ENUMERATION AND ADULT ESCAPEMENT

We used part of the funding from project 17-1304 to summarize total number of steelhead smolts emigrating from the IMW streams, as well as the adult escapement. We used these estimates to calculate smolts per spawner. In this section, we briefly describe the methods we used to calculate smolt and adult estimates and provide summary graphics of the data analysis. We will provide further interpretation of these summary data in the upcoming annual report for the Asotin IMW (SRFB project 19-1545).

9.1 Analysis Methods for Smolt Emigration and Adult Escapement

We estimated the total number of steelhead smolts leaving the IMW tributaries as a measure of freshwater tributary productivity. We refer to these fish as smolts but recognize they can be a mixture of juveniles (i.e., pre-smolts) and smolts (i.e., migrants heading to the ocean). Previous IMW reports have noted that many migrants leaving the tributaries may spend several months to more than a year in the mainstem Asotin Creek before migrating to the Snake River. Therefore, the best assessment of the effectiveness of LWD treatments may be the productivity as measured by fish leaving the tributaries as the fish that spend time rearing in the mainstem may be influenced by habitat in the mainstem. The following steps were used to estimate productivity (see Figure 1 & 2 for references to streams, sections, and sample sites, and ptagis.org for locations and configurations of PIT tag interrogation sites):

- estimate the total number of IMW tags detected leaving the tributaries (Charley, North Fork, South Fork)
- calculate the efficiency of each instream PIT tag array allowing us to expand the number of tag detections to an estimate of all tagged fish leaving each tributary
- calculate the abundance of juvenile steelhead in each IMW tributary using our summer and fall PIT tagging mark/recapture surveys at fish sites (completed 2008-2020) and expand these estimates up to the section and stream scale

- estimate the tagged to untagged ratio at each section (4 km long experimental unit), each year using the formula (New Tags)/(Abundance)
- estimate the total number of smolts that left the IMW tributaries (Charley, North Fork, and South Fork) using the tagged/untagged ratio and the array efficiency
  (Array Detections/Detection Efficiency)/(New Tags/Abundance) assuming:
  - the survival rate for tagged and untagged fish is equal and tagged and untagged fish migrate at same rate
  - New Tagged Fish/Abundance is calculated at each site each year (and season)
- Above analysis is done for each age class, each year to determine brood year (migration year – age at migration)
- To determine the relative productivity of each study creek, we used estimates of adult escapement from detections of PIT tagged adults counts from each creek and estimates of juvenile abundance and migrants to calculate the number of smolts produced per adult female.

9.2 Analysis Summary for Smolt Emigration and Adult Escapement

We have now developed a workflow and set of R code to estimate juvenile steelhead emigration and adult escapement from the Asotin IMW streams. In future analysis we will develop confidence intervals around these estimates. Here we present estimates of juvenile steelhead abundance, smolt emigration (total and by age class), adult escapement, and smolts/female by stream and year, or brood year (Appendix D). Year refers to the tagging year estimates were made. For example, juvenile abundance by year reflects the total population of fish $\geq$70 mm within each stream over 12 km study area for the year fish were captured and tagged. Brood year refers to the year fish hatched or the year the female that produced a fish spawned. Brood year is used to estimate how many fish survived and then emigrated as smolts from all the adult females that spawned each year. It takes several years of counting smolt emigration to account for all the smolts from a particular brood year because steelhead emigrate from age 0 to at least age 5; therefore, estimates for early years (<2009) and later years (>2018) are incomplete, though later years can be filled in with more sampling.

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APPENDIX A. PHOTOS OF TYPICAL POST-ASSISTED LOG STRUCTURE

Figure 13. Post-restoration conditions in South Fork Asotin Creek – channel spanning post-assisted log structure forcing overbank flow (during receding high flow) and ponding water upstream of the structure.

Figure 14. Post -restoration conditions in Charley Creek – bank attached post-assisted log structure forcing flow against river left bank, creating eddy pool downstream, and forcing overbank flow and forming upstream and downstream bars on river right.

Figure 15. Post -restoration conditions in North Fork Asotin Creek – mid-channel post assisted log structure splitting flow and creating downstream mid-channel bar.

APPENDIX B. DRAWINGS OF TYPICAL LOW-TECH STRUCTURE TYPES

Beaver dam analogue – for ponding water at low flow and reconnecting side-channels and floodplain

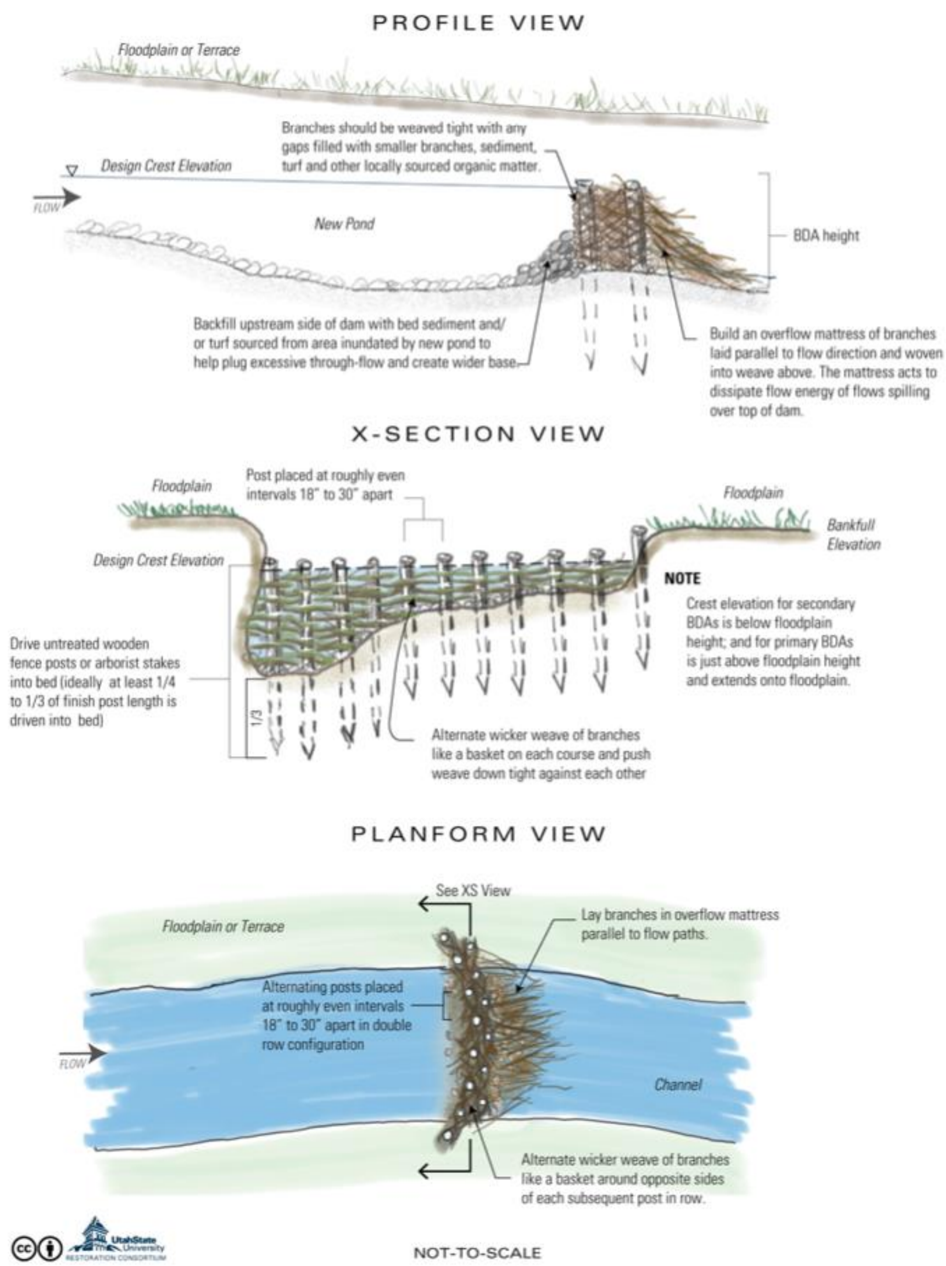


Figure 16. Typical drawing sketches of a beaver dam analogue intended to cause ponding, overbank flow, and aggradation.

Bank Attached Post-assisted log structure (PALS) – for widening the channel

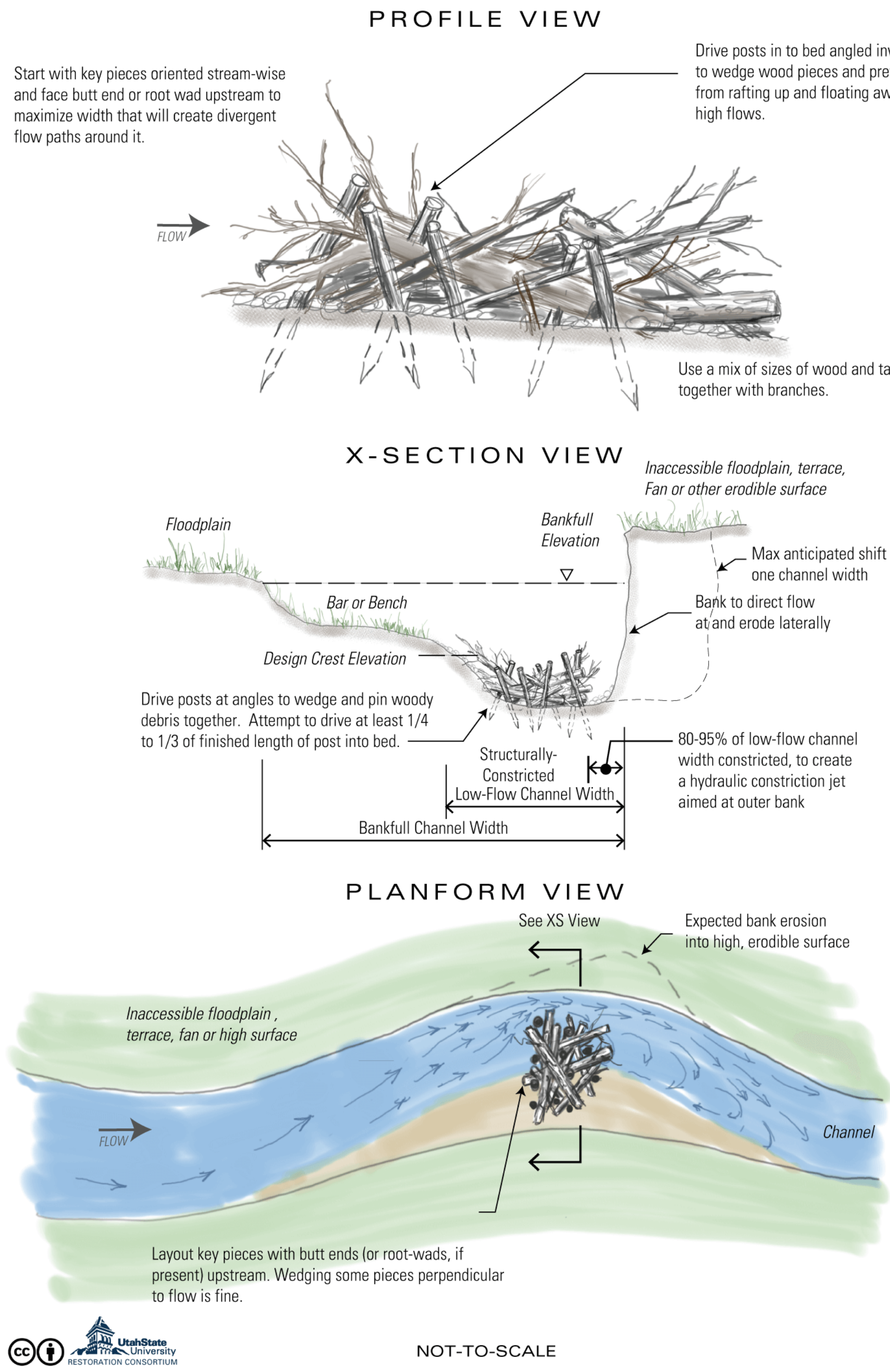


Figure 17. Typical drawing sketches of a bank-attached PALS intended to cause lateral channel migration through deposition of material on point and diagonal bars and erosion of high bank features.

Bank Attached Post-assisted log structure (PALS) – for scouring pools

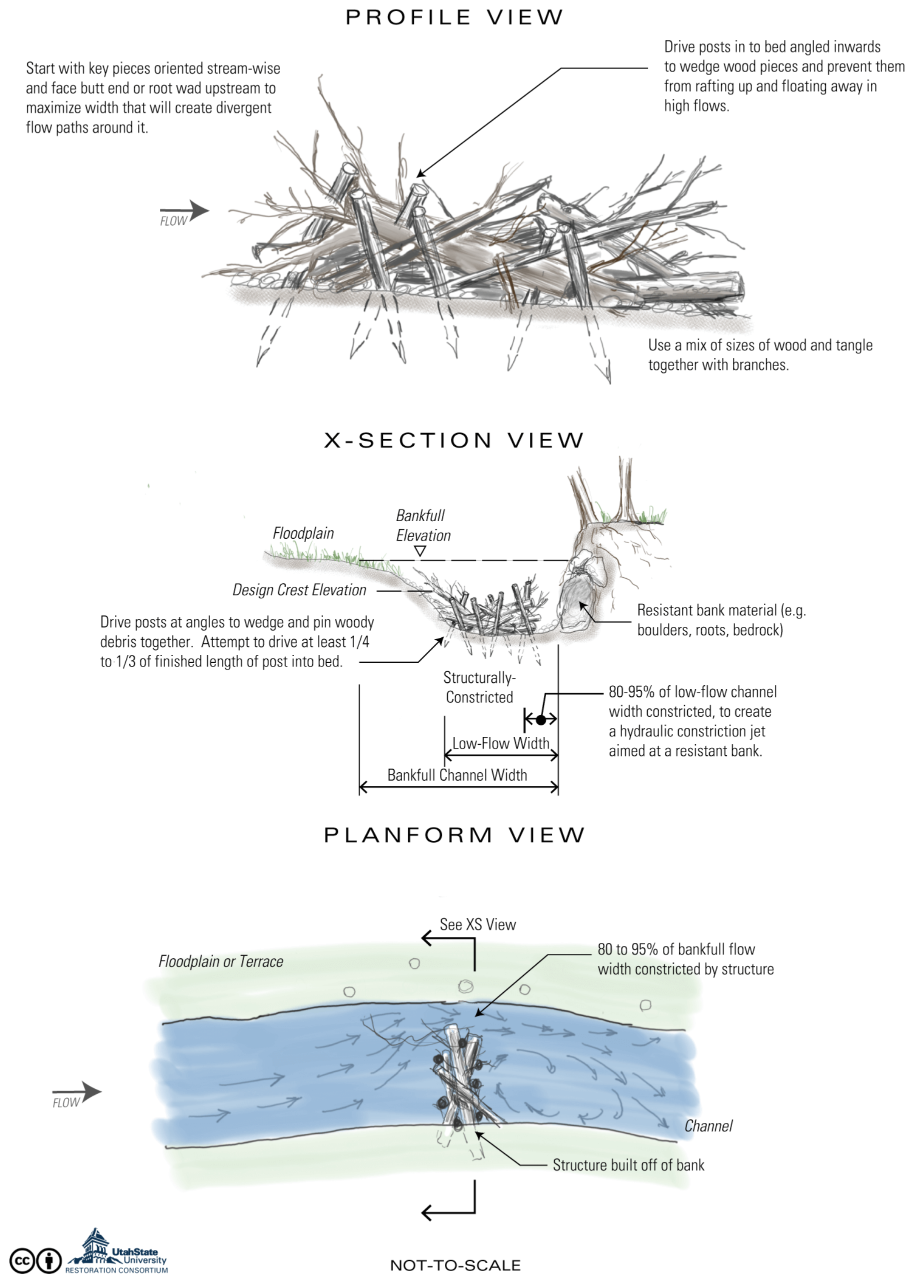


Figure 18. Typical drawings of a mid-channel PALS designed to induce channel complexity, encourage mid-channel deposition, and encourage channel avulsion.

Mid-channel Post-assisted log structure (PALS) – for splitting flow

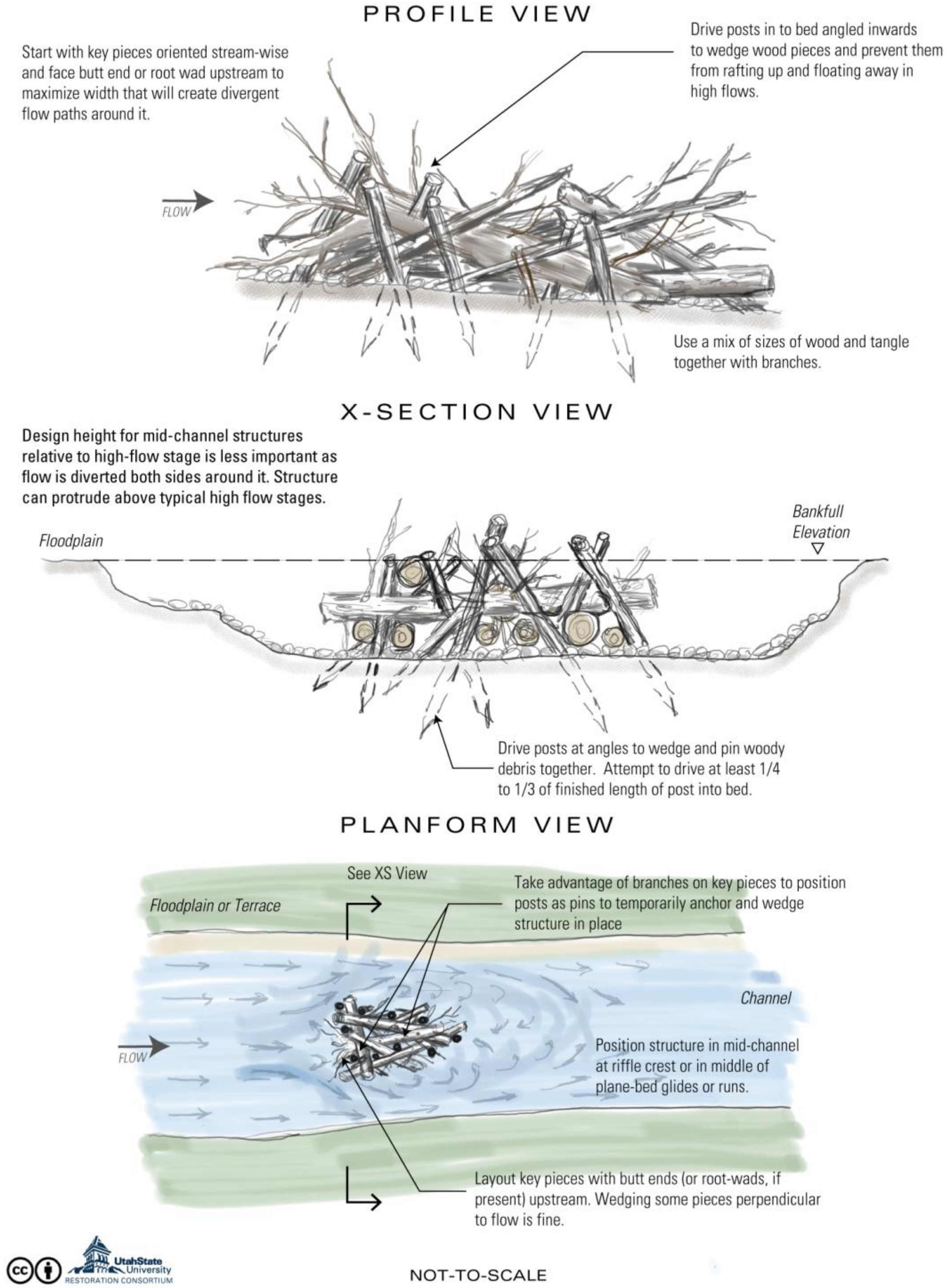


Figure 19. Typical drawings of a mid-channel PALS designed to split flow, increase channel complexity, encourage mid-channel deposition, and encourage overbank flow.

Channel Spanning Post-assisted log structure (PALS) – for aggrading channel, creating plunge pool, and forcing overbank flow

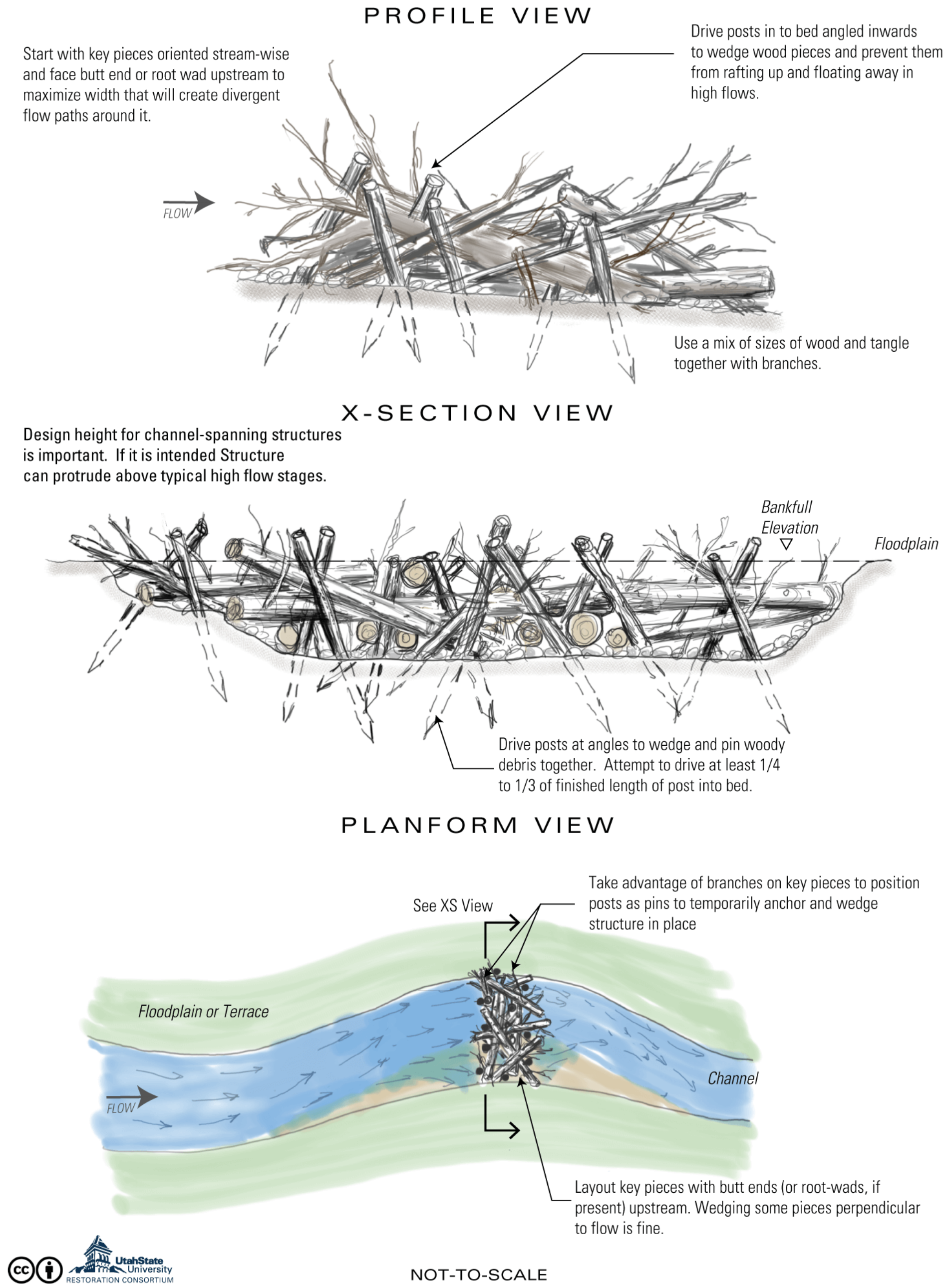


Figure 20. Typical drawings of a channel spanning PALS designed to trap sediment, increase channel complexity, force overbank flow, plunge pools, and induce avulsions.

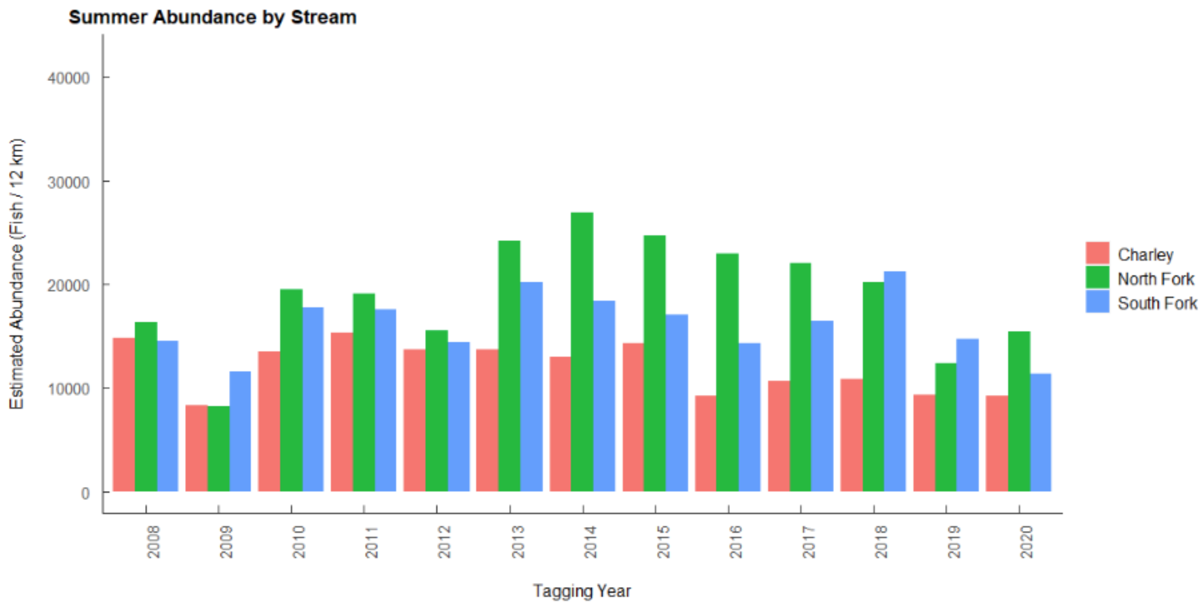
APPENDIX C. DESIGN SUMMARY FOR EACH STRUCTURE DESCRIBING HOW MUCH WOOD WAS ADDED, ENHANCEMENT TYPE, IF A SIDE-CHANNEL WAS CONNECTED, AND GPS LOCATION. ENHANCEMENT TYPES ARE: LWD & POSTS – STRUCTURE REBUILT WITH POST-DRIVER AND MORE LWD; LWD – WOOD OR TREES ADDED TO EXISTING STRUCTURE; PALS TYPE – CS = CHANNEL SPANNING, BA = BANK ATTACHED, MID = MID CHANNEL. SEE FIGURE 2 FOR LOCATION OF TREATMENT SECTIONS. STRUCTURE COUNT* - 1 = TOTAL NUMBER OF STRUCTURES ON MAINSTEM; >1 = NUMBER OF STRUCTURES ON MAINSTEM AND SIDE-CHANNELS.

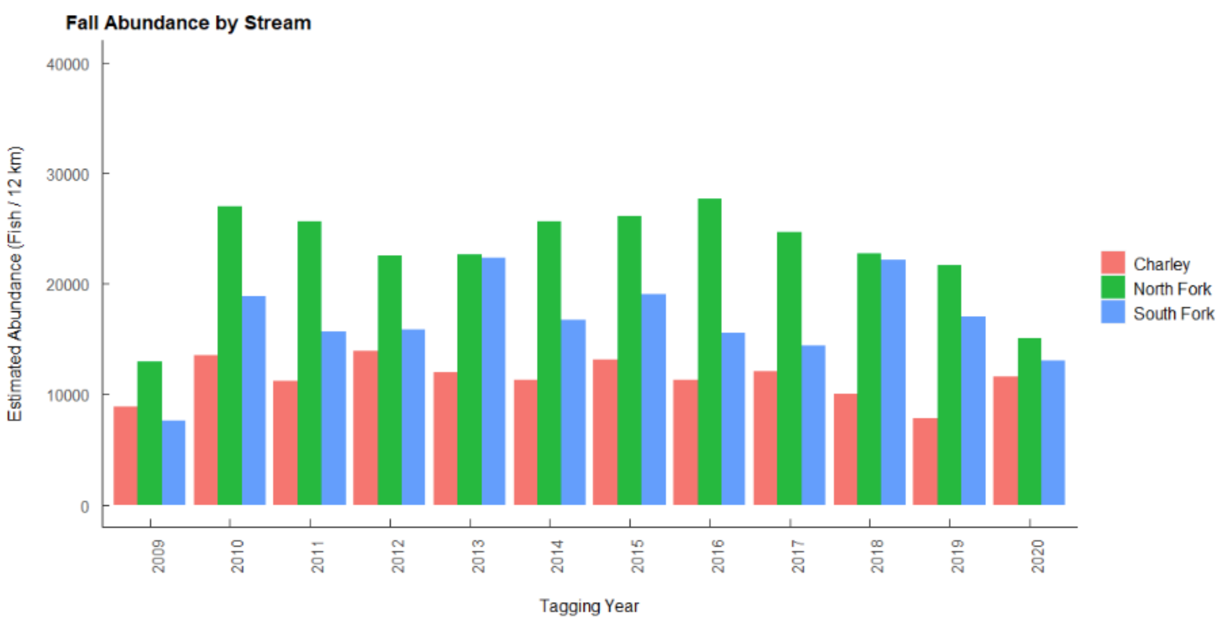
Section	Structure Number	Enhancement Type	LWD & Tree Count	SWD Count	Structure Count*	Side-channel Connection	Side-channel Length (m)	Latitude	Longitude
CC-S2	228	BDA		30	2	yes	60	46.284677	-117.330414
CC-S2	232.1	BDA		20	3	yes	75	46.285272	-117.331766
CC-S2	234	BDA	8	15	1	yes	250	46.285258	-117.332512
CC-S2	234.1	BDA	10	30	5	yes	250	46.285258	-117.332512
CC-S2	241	LWD	3	5	1			46.285424	-117.334298
CC-S2	242	LWD	8	5	1			46.285421	-117.334479
CC-S2	243	LWD	4	10	1			46.285343	-117.334753
CC-S2	244	LWD	2	0	1			46.285350	-117.334977
CC-S2	265	BDA	5	25	3	yes	50	46.285286	-117.340089
CC-S2	349	LWD	3	5	1			46.282080	-117.358271
CC-S2	350	BDA	5	20	6	yes	60	46.282080	-117.358271
CC-S2	358.1	CS_PALS	5	25	1	no		46.282375	-117.359545
CC-S2	361.1	BDA		20	4	yes	30	46.282435	-117.359986
CC-S2	370	BDA		10	2			46.282236	-117.361775
NF-S1	418	CS_PALS	6	30	2			46.268560	-117.295174
NF-S1	421	LWD & Posts	10	25	3			46.267837	-117.295175
NF-S1	423	LWD & Posts	5	10	1			46.267583	-117.295572
NF-S1	425	MID_PALS	12	15	1			46.267160	-117.296019
NF-S1	425.1	LWD & Posts	5	5	1			46.267160	-117.296019
NF-S1	427	CS_PALS	10	10	1			46.266996	-117.296296
NF-S1	429	CS_PALS	12	10	1			46.266839	-117.296502
NF-S1	429.1	CS_PALS	8	10	1			46.266839	-117.296510
NF-S1	439	CS_PALS	10	20	1			46.264500	-117.296273
NF-S1	440	LWD & Posts	8	10	1			46.264279	-117.296441
NF-S1	442.1	LWD	6	5	1			46.264008	-117.296765
NF-S1	443	LWD	8	15	1			46.263358	-117.296727
NF-S1	444	LWD & Posts	8	15	1			46.262846	-117.296707
NF-S1	447	LWD & Posts	8	15	1			46.262308	-117.296708
NF-S1	454	LWD	10	30	1			46.261296	-117.298018
NF-S1	455	LWD & Posts	12	10	1			46.261082	-117.298123

NF-S1	455.1	CS_PALS	10		1			46.261082	-117.298129
NF-S1	456	LWD & Posts	10	10	1			46.260784	-117.298208
NF-S1	458	LWD & Posts	15		1			46.260192	-117.298148
NF-S1	460	LWD	30		1			46.259889	-117.298350
NF-S1	487.1	MID_PALS	6	10	1	yes	30	46.254273	-117.303970
NF-S1	489	CS_PALS	5	10	1			46.253668	-117.304514
NF-S1	489.1	CS_PALS	3	5	1			46.253668	-117.304519
NF-S1	490	CS_PALS	10	15	1			46.253510	-117.304762
NF-S1	491	CS_PALS	12	20	1			46.253325	-117.304899
NF-S1	493	CS_PALS	6	15	1			46.252873	-117.304850
NF-S1	494.1	CS_PALS	5	10	1			46.252740	-117.304779
NF-S1	503.1	CS_PALS	8	10	1			46.251091	-117.306109
NF-S1	509	LWD	2		1			46.249710	-117.308039
NF-S1	514	CS_PALS	4	30	1			46.247852	-117.308515
NF-S1	518	LWD	3		1			46.246798	-117.309941
SF-S2	115	SWD		5	1			46.223928	-117.279549
SF-S2	116	SWD		5	1			46.223717	-117.279742
SF-S2	117	SWD		5	1			46.223579	-117.279917
SF-S2	118	SWD		5	1			46.223474	-117.279936
SF-S2	119	SWD		5	1			46.223349	-117.280015
SF-S2	120	SWD		5	1			46.223234	-117.280123
SF-S2	121	SWD		5	1			46.223179	-117.280182
SF-S2	122	SWD		5	1			46.222980	-117.280029
SF-S2	123	SWD		5	1			46.222809	-117.279985
SF-S2	124	SWD		5	1			46.222512	-117.279976
SF-S2	125	SWD		5	1			46.222297	-117.280189
SF-S2	126	SWD		5	1			46.222204	-117.280315
SF-S2	127	SWD		5	1			46.221980	-117.280555
SF-S2	128	SWD		5	1			46.221702	-117.280398
SF-S2	129	SWD		5	1			46.221446	-117.280323
SF-S2	130	SWD		5	1			46.221221	-117.280304
SF-S2	131	SWD		5	1			46.221125	-117.280216
SF-S2	132	SWD		5	1			46.220838	-117.280310
SF-S2	133	SWD		5	1			46.220674	-117.280376
SF-S2	134	SWD		5	1			46.220514	-117.280376
SF-S2	135	SWD		5	1			46.220410	-117.280375
SF-S2	136	SWD		5	1			46.220250	-117.280372
SF-S2	137	SWD		5	1			46.220116	-117.280473
SF-S2	138	SWD		5	1			46.219892	-117.280733
SF-S2	139	SWD		5	1			46.219847	-117.280825
SF-S2	140	SWD		5	1			46.219738	-117.280931
SF-S2	141	SWD		5	1			46.219593	-117.281036
SF-S2	142	SWD		5	1			46.219462	-117.281108

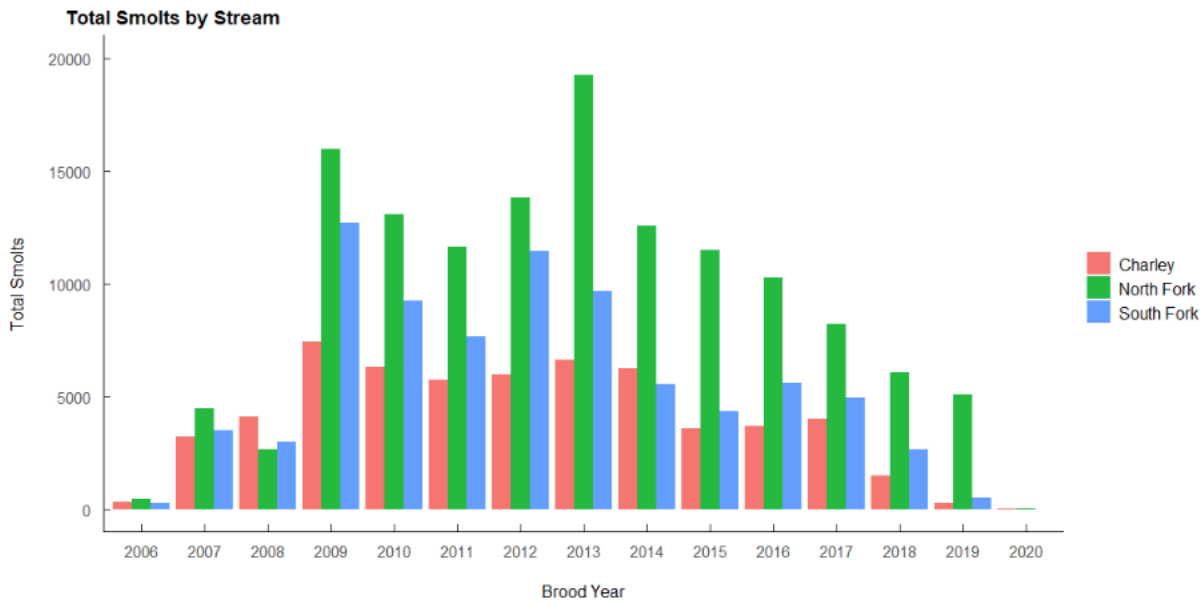
SF-S2	143	SWD	5	1	46.219325	-117.281275
SF-S2	144	SWD	5	1	46.219249	-117.281425
SF-S2	145	SWD	5	1	46.218945	-117.281712
SF-S2	146	SWD	5	1	46.218866	-117.281829
SF-S2	147	SWD	5	1	46.218825	-117.281848
SF-S2	148	SWD	5	1	46.218627	-117.282134
SF-S2	149	SWD	5	1	46.218539	-117.282223
SF-S2	150	SWD	5	1	46.218172	-117.282475
SF-S2	151	SWD	5	1	46.218043	-117.282635
SF-S2	152	SWD	5	1	46.217993	-117.282883
SF-S2	153	SWD	5	1	46.218010	-117.283089
SF-S2	154	SWD	5	1	46.218038	-117.283189
SF-S2	155	SWD	5	1	46.218068	-117.283329
SF-S2	156	SWD	5	1	46.218106	-117.283577
SF-S2	157	SWD	5	1	46.218106	-117.283751
SF-S2	158	SWD	5	1	46.217997	-117.284175
SF-S2	159	SWD	5	1	46.217785	-117.284649
SF-S2	160	SWD	5	1	46.217715	-117.284835
SF-S2	161	SWD	5	1	46.217602	-117.285059
SF-S2	162	SWD	5	1	46.217543	-117.285111
SF-S2	163	SWD	5	1	46.217491	-117.285295
SF-S2	164	SWD	5	1	46.217416	-117.285370
SF-S2	165	SWD	5	1	46.217315	-117.285372
SF-S2	166	SWD	5	1	46.217216	-117.285418
SF-S2	167	SWD	5	1	46.217132	-117.285397
SF-S2	168	SWD	5	1	46.216985	-117.285411
SF-S2	169	SWD	5	1	46.216866	-117.285384
SF-S2	170	SWD	5	1	46.216726	-117.285413
SF-S2	171	SWD	5	1	46.216569	-117.285498
SF-S2	172	SWD	5	1	46.216261	-117.285684
SF-S2	173	SWD	5	1	46.216119	-117.285652
SF-S2	174	SWD	5	1	46.216041	-117.285602
SF-S2	175	SWD	5	1	46.215876	-117.285535
SF-S2	176	SWD	5	1	46.215736	-117.285497
SF-S2	177	SWD	5	1	46.215648	-117.285567
SF-S2	178	SWD	5	1	46.215580	-117.285608
SF-S2	179	SWD	5	1	46.215365	-117.285756
SF-S2	180	SWD	5	1	46.215275	-117.285774

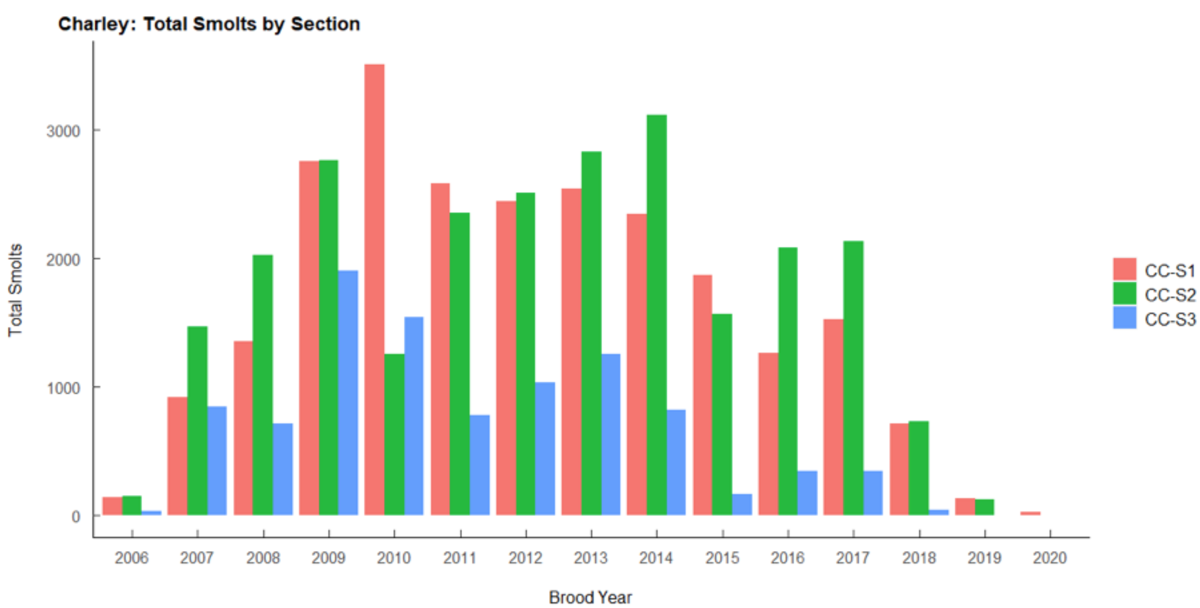
APPENDIX D – ESTIMATES OF JUVENILE STEELHEAD ABUNDANCE, SMOLT EMIGRATION (TOTAL AND BY AGE CLASS), ADULT ESCAPEMENT, AND SMOLTS/FEMALE BY STREAM AND YEAR, OR BROOD YEAR.

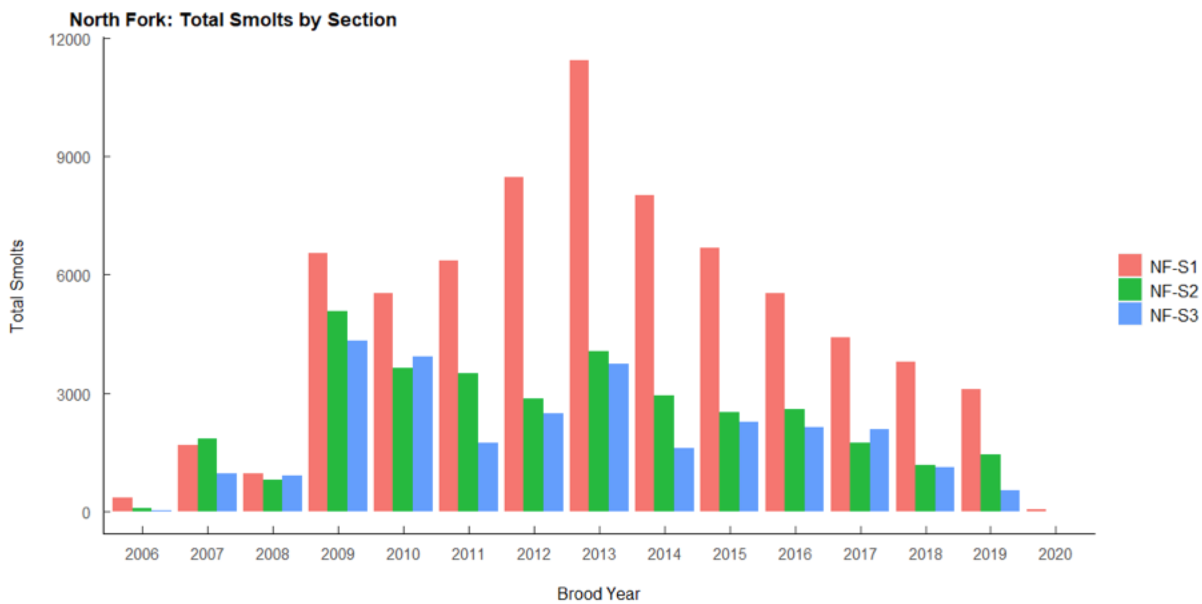


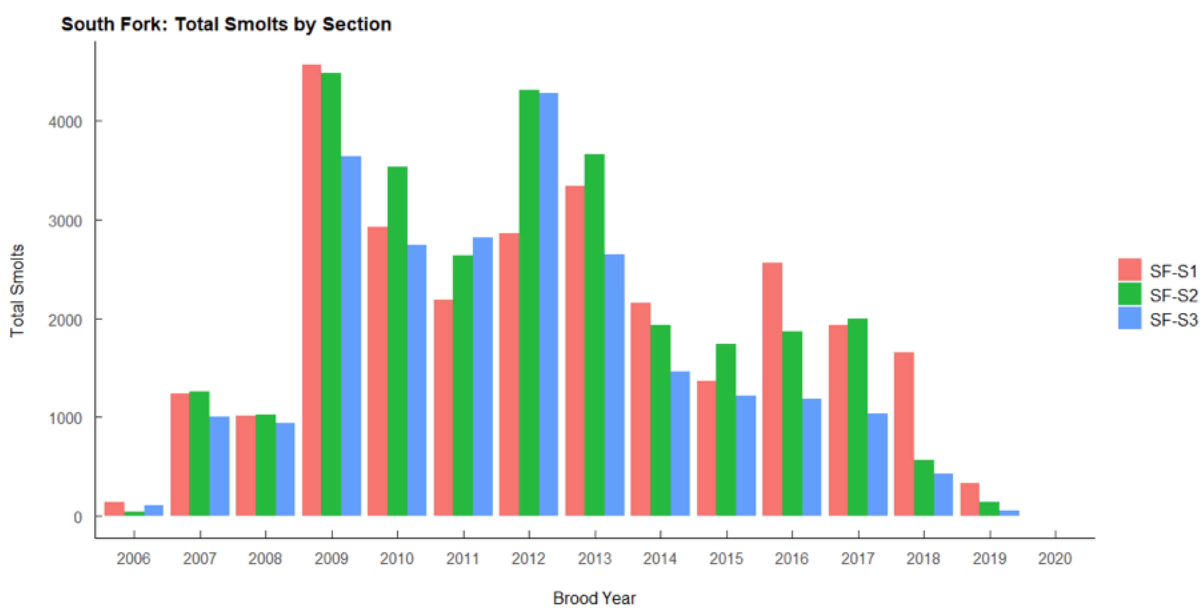


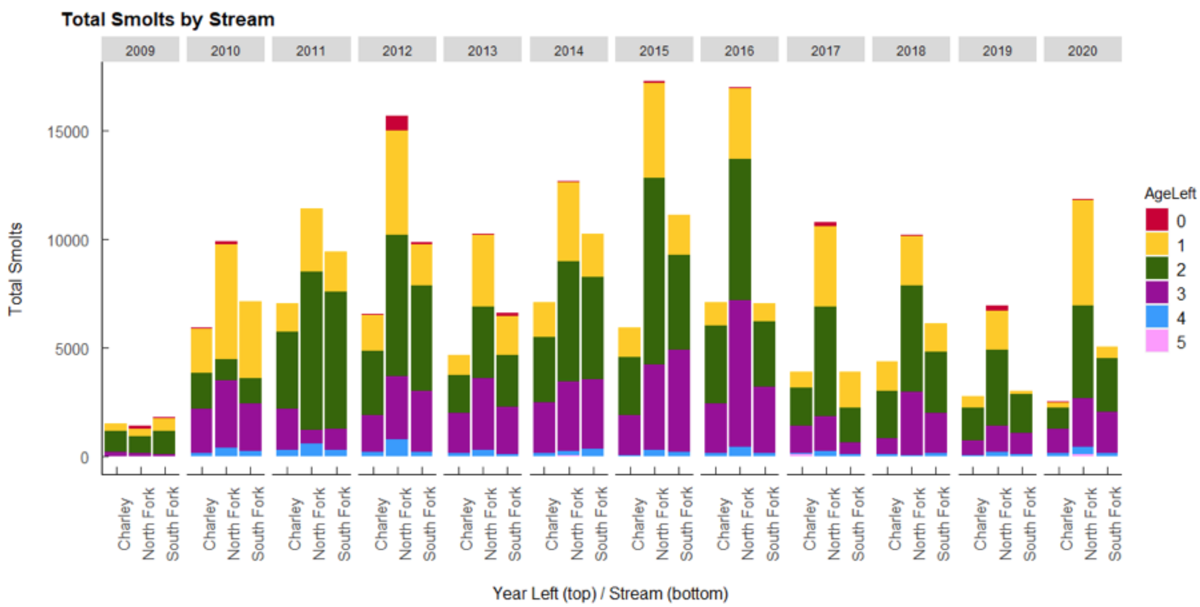
Eco Logical Research

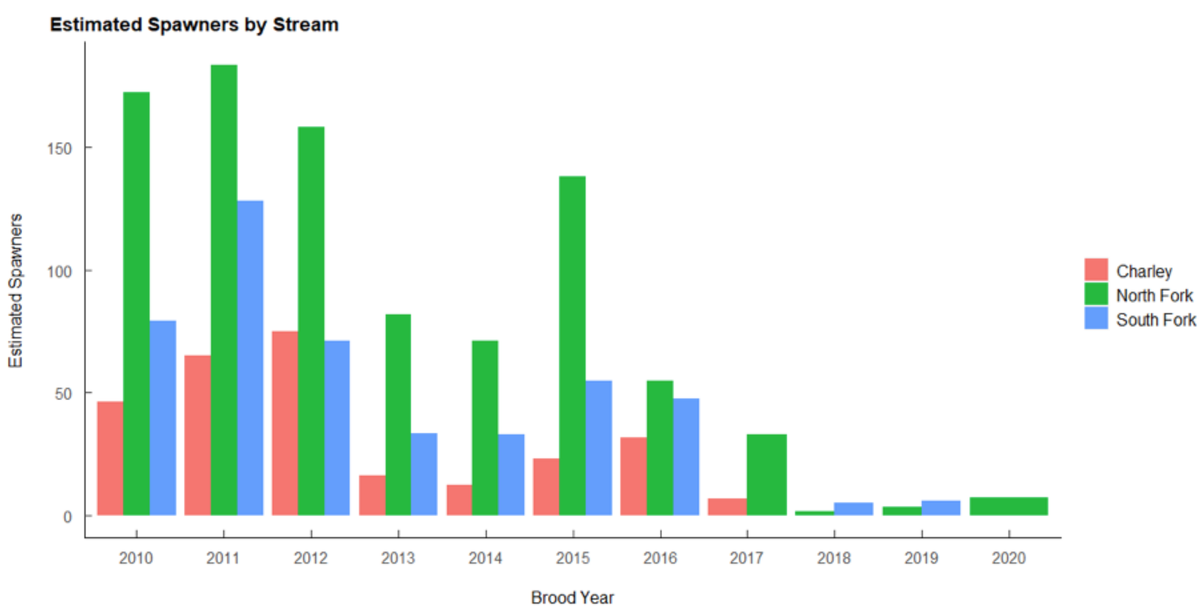

Total Smolts by Stream
20000
15000
10000
5000
0
Total Smolts
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Brood Year
Charley
North Fork
South Fork

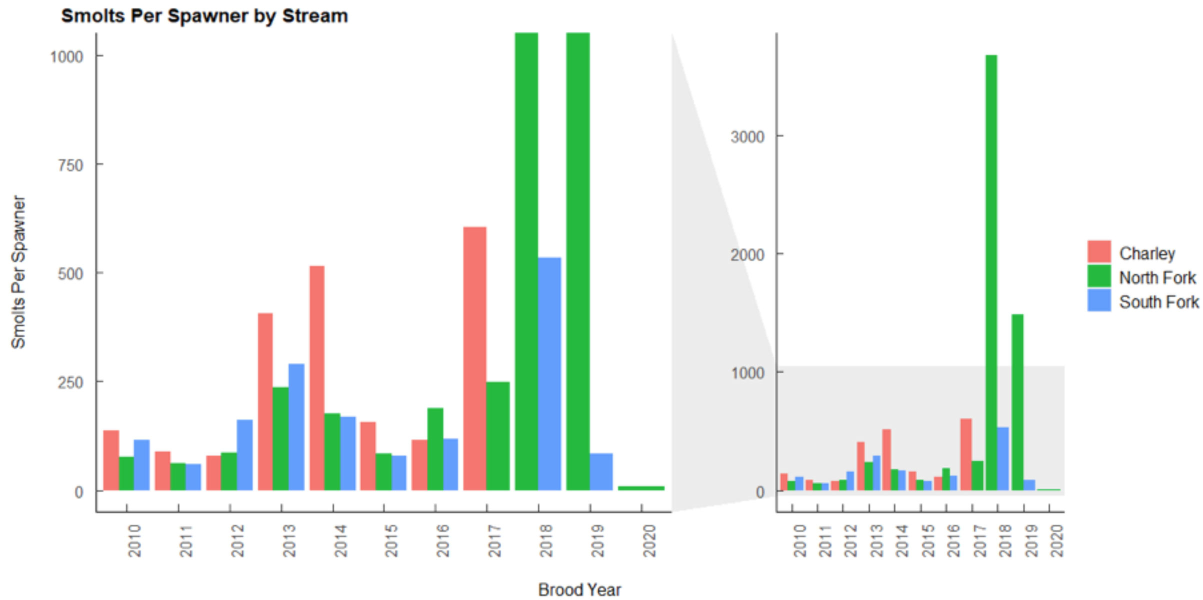

Charley: Total Smolts by Section
3000
2000
1000
0
Total Smolts
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Brood Year
CC-S1
CC-S2
CC-S3


North Fork: Total Smolts by Section
Total Smolts
12000
9000
6000
3000
0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Brood Year
NF-S1
NF-S2
NF-S3


South Fork: Total Smolts by Section
Total Smolts
4000
3000
2000
1000
0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Brood Year
SF-S1
SF-S2
SF-S3


Total Smolts by Stream
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Total Smolts
15000
10000
5000
0
AgeLeft
0
1
2
3
4
5
Charley
North Fork
South Fork
Year Left (top) / Stream (bottom)


Estimated Spawners by Stream
Estimated Spawners
150
100
50
0
Charley
North Fork
South Fork
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Brood Year


Smolts Per Spawner by Stream
Smolts Per Spawner
1000
750
500
250
0
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Brood Year
3000
2000
1000
0
Charley
North Fork
South Fork