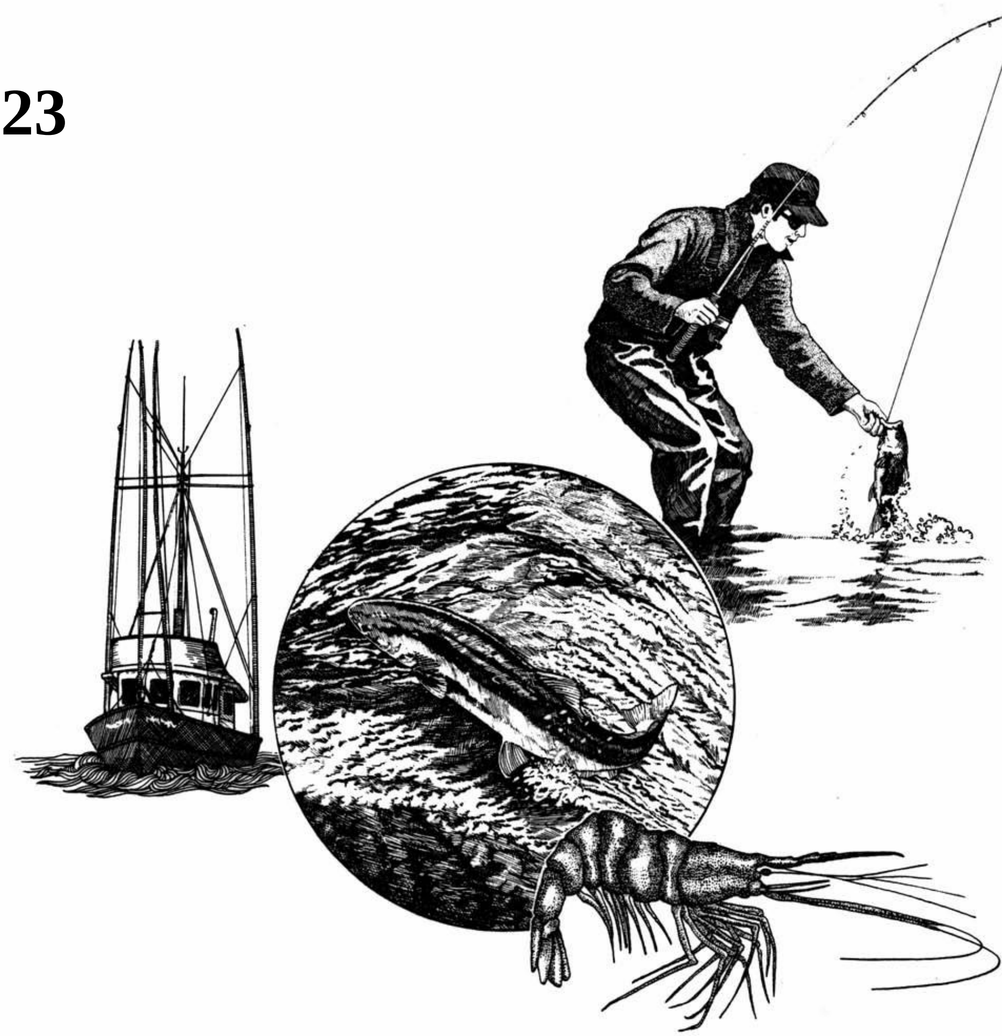
ODFW PROGRESS REPORT Series

2023



Oregon Department of Fish and Wildlife

2022- Monitoring Report for the Clackamas Focused Investment Partnership.

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Aquatic Inventories Program

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ABSTRACT

In 2022 the Oregon Department of Fish and Wildlife's Aquatic Inventories Program (AQI) and Unoccupied Aircraft System (UAS) operations continued to provide habitat restoration monitoring throughout the Clackamas River basin in support of the Clackamas Partnership Strategic Plan to improve and enhance the river and stream habitat for native fish and wildlife. ODFW used on-the-ground foot and boat surveys, snorkel surveys, a UAS, and Side Scan Sonar (SSS) to capture and describe habitat conditions at a watershed scale. In 2022 ODFW surveyed the Kingfisher Side Channel post-restoration and the three established control sites on the Lower Clackamas River. One control site and a pre-restoration site were established on Forest Service Land (USFS) above the North Fork Reservoir. UAS and physical habitat ground surveys were conducted between March and April to capture typical high-water conditions and available winter refuge habitat. We used UAS to capture stream conditions in September when flows were at their lowest point, and we snorkeled pool habitat from July through September to identify fish use and assemblage. Because the site data are paired, we analyzed the mean difference between pre-treatments and post-treatments to test each hypothesis at a *P*-value of 0.05 (two-sided test). Snorkel surveys revealed native fish in all sites.

Changes were observed in the Kingfisher Side Channel one year after restoration; fine sediments (silt and sand) decreased, while gravel and cobble increased. We also saw an increase in wood volume (m^3) and the number of key pieces (≥12 meters in length and 60cm in diameter). HabRate modeling indicated that surveyed habitats were generally fair for all life history types, with little change compared to previous years. By comparing metrics collected from pre- and post-restoration sites, control sites, and the mainstem Clackamas River, it will be possible to evaluate the effectiveness of restoration efforts in terms of habitat changes over time.

BACKGROUND

The Oregon Department of Fish and Wildlife's Aquatic Inventories Project (AQI) and Unoccupied Aircraft System (UAS) operations provide monitoring support for the Clackamas Focused Investment Partnership (FIP) to describe the quality and quantity of restored or improved habitats. Proposed restoration sites, control channels, and mainstem river surveys will be used to evaluate restoration influence and effectiveness at the individual site, reach, and basin scale. In Spring 2020, ground-based habitat surveys and Side Scan Sonar (SSS) surveys were conducted on the mainstem Clackamas River to establish a pre-restoration baseline and ground-based surveys on proposed restoration sites. Mainstem surveys will occur again after a six-year interval to document any habitat change associated with restoration treatment across defined reaches and within the basin. In 2021 ODFW surveyed eight individual sites; three post-restoration treatments, two proposed for upcoming restoration, and three control. UAS and physical habitat ground surveys were conducted to capture typical high-water conditions during the winter. At the end of the summer, we used UAS to capture the lowest water stream conditions and snorkel surveys to identify fish use and assemblage.

In 2022, habitat surveys were conducted within the Kingfisher restoration site, Four Control sites, and a pre-restoration site above the North Fork Reservoir, primarily in March following prescribed restoration efforts. UAS aerial surveys occurred in March, April, May, and September. Snorkel surveys were conducted in July, August, and September.

This report aims to provide a background for monitoring habitat and to describe the methods used to assess the varying habitat types. For each surveyed area, this report details (1) reach boundaries and general habitat characteristics, (2) channel area and depth profiles, (3) structure and complexity, and (4) general fish species composition. The data provided should be regarded as a baseline condition for control channels and primary river habitat for restoration activity.

METHODS

Ground Surveys

This report discusses findings from a survey design developed for both wadeable and non-wadeable habitat types. Due to the nature and size of the channels and habitat characteristics, AQI adhered to protocols Moore et al. (2007) developed within wadeable areas. Attributes collected and summarized at the reach level described channel morphology, substrate composition, instream wood, and fish species. The ground survey results described habitat quality through the HabRate model (Burke et al. 2010). The model generates habitat ratings (1-poor, 2-moderate, or 3-good) for each life stage of anadromous salmonids present in the Clackamas River basin (coho, steelhead, cutthroat trout, and Chinook salmon). Snorkel surveys assessed fish presence and adhered to methods described in Constable et al. (2012).

UAS Surveys

UAS surveys were used to supplement ground surveys and sonar data. Structure from Motion with Multi-View Stereo (SfM-MVS) reconstruction in Agisoft Metashape was used to create point clouds, Digital Elevation Models (DEM), and orthorectified photo mosaics. DEMs were made from the dense point cloud filtered to only ground points, which could sometimes provide topographic information when obscuring vegetation was present in the orthomosaic. Measurements and counts were made in Agisoft Metashape and ESRI ArcGIS Pro.

Side Scan Sonar

A Humminbird Helix 9 side imaging system was used to describe stream bed features within the USFS Upper Clackamas Sites. SonarTRX software (Leraand Engineering Incorporated, Honolulu, Hawaii, USA) was used to process the sonar imagery. The images were visually assessed within the bounds of individual pool habitat units to describe streambed features using a modified Wolman Pebble Count and adhered to methods described in Strickland et al. (2023).

Methods Comparison

We used R software (R Development Core Team 2006) for all analyses.
A simple linear regression was used to assess whether habitat area (m^2) from winter ground surveys differed from habitat area (m^2) generated from winter UAS survey imagery.

$$Y_i = \beta_0 + \beta_1 X_i + \varepsilon_i$$

We then used paired *t*-tests to describe whether a difference exists between winter habitat area derived from ground surveys and summer habitat area derived from UAS imagery.

A simple linear regression was used to assess wood volume (m^3) to describe whether a difference exists between ground-based wood counts and wood counts taken from UAS imagery in the Kingfisher side-channel following restoration.

Restoration Assessment

Paired t-tests were also used to assess differences between pre-restoration and post-treatment across habitat metrics; we analyzed the mean difference between treatment years to test each hypothesis at a *P*-value of 0.05 (two-sided test).

STUDY AREA

In 2022, the Kingfisher Side-Channel was surveyed following post-restoration work completed in 2021, and the three control sites, Upper, Middle, and Lower Control channels, which were established in 2020, were also surveyed (Figure 1).

A pre-restoration monitoring survey and a control site were established above the North Fork Reservoir of the Clackamas River on USFS land and surveyed in 2022 (Figure 1).

These USFS sites have been indefinitely put on hold due to the discoveries of culturally sensitive areas within the prescribed restoration sites. A new candidate site has been proposed but has yet to be finalized. The USFS control site will remain in place, and we will continue to use it as such in conjunction with a new proposed restoration location.

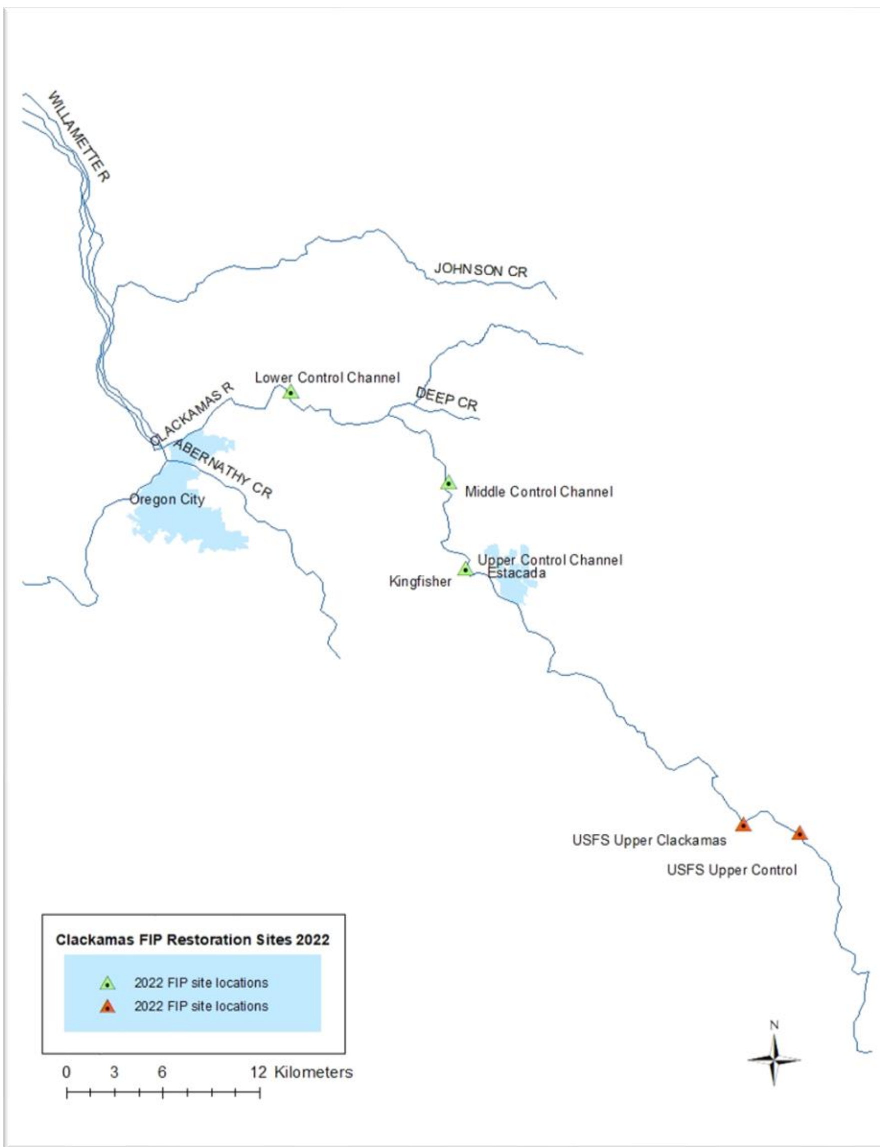

Figure 1. 2022 Clackamas FIP Sites.

Kingfisher Side-Channel

The Kingfisher Side-Channel is located on the west side of the Clackamas River main channel, immediately adjacent to the Upper Control Channel. Figures 2 and 3 show the Kingfisher Side-Channel during the winter and summer of 2022 following restoration work. The Kingfisher Side-Channel flows north 500 meters, begins approximately 400 meters downstream of the mouth of Dog Creek, and is accessed through Milo McIver State Park. The Kingfisher Side-Channel is constrained to its current channel location due to constraining terraces on either side of the channel. A valley width index (VWI) suggests the active channel could move 20 times between hillslope toes.

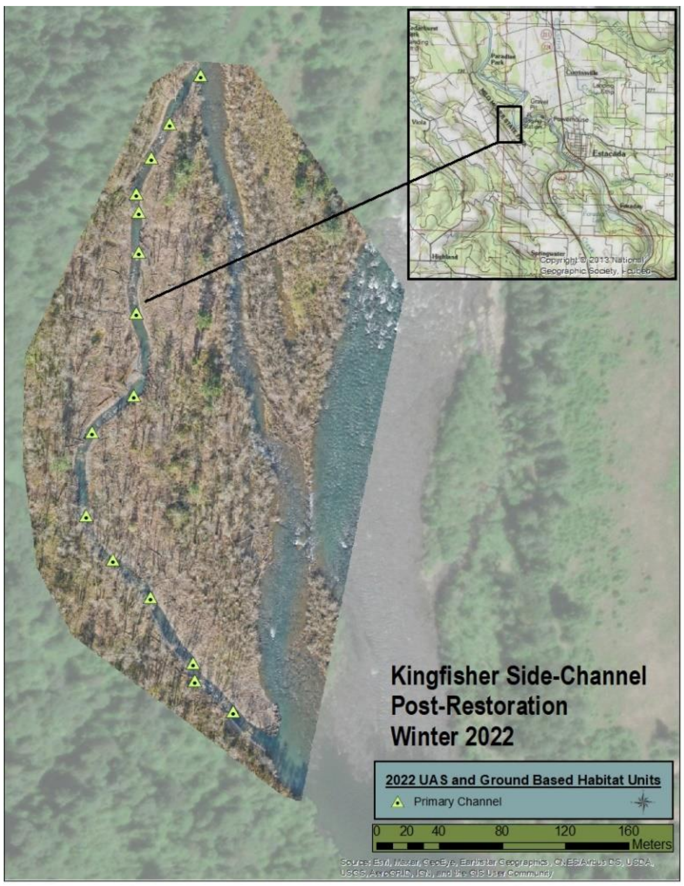

Figure 2. Kingfisher Side-Channel. Winter 2022 UAS imagery and ground-based survey points post-restoration.

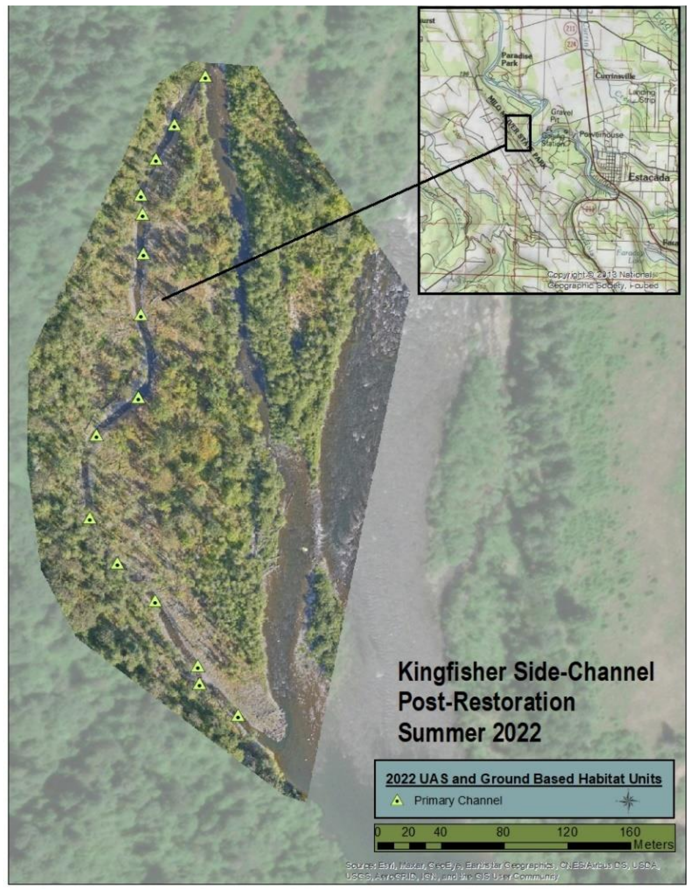

Figure 3. Kingfisher Side-Channel. Summer 2022 UAS imagery and ground-based survey points post-restoration.

Upper Control Channel

The Upper Control Channel is located on the east side of the Clackamas River main channel, immediately adjacent to the Kingfisher Side Channel. Figures 4 and 5 show the Upper Control Channel during the winter and summer of 2022. The Upper Control Channel flows north 153 meters, begins approximately 400 meters downstream of the mouth of Dog Creek, and is accessed through Milo McIver State Park. The Upper Control Channel is primarily constrained to its current channel location due to a high constraining island terrace to the west and a steep hillslope to the east. These features limit the available lateral movement of the channel to 30 meters.

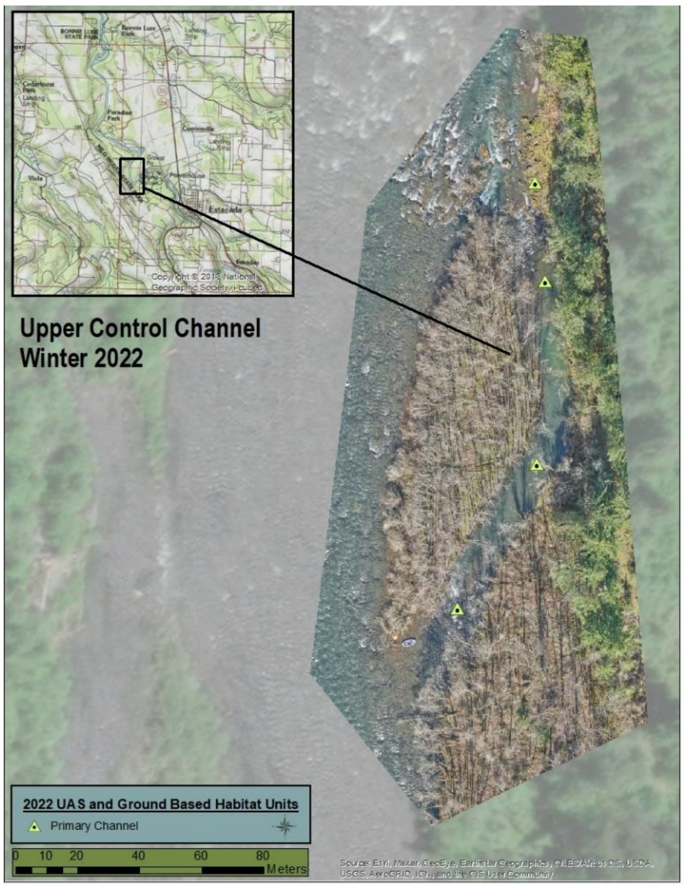

Figure 4. Upper Control Channel. Winter 2022 UAS imagery and ground-based survey points.

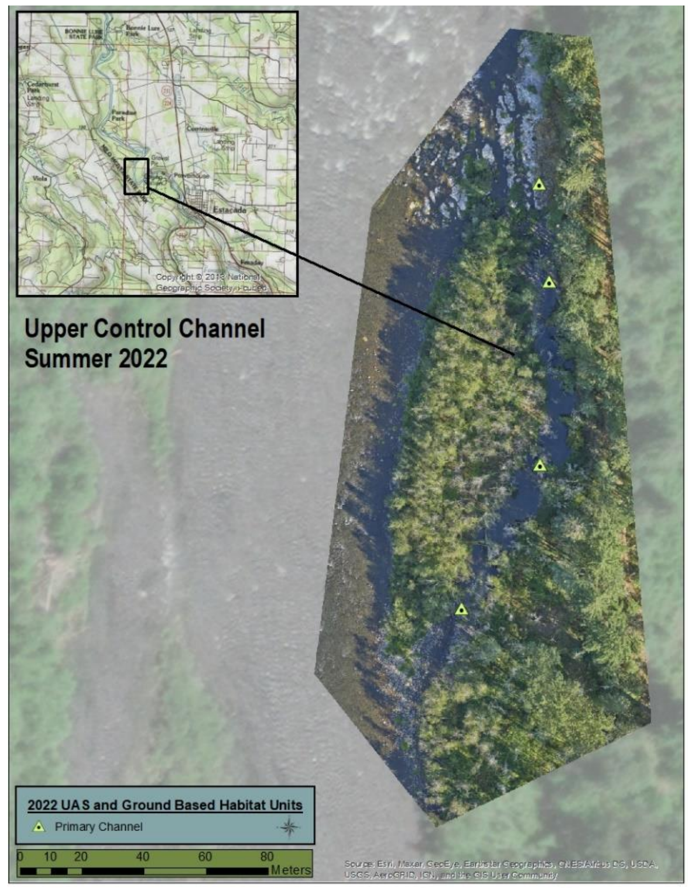

Figure 5. Upper Control Channel. Summer 2022 UAS imagery and ground-based survey points.

Middle Control Channel

The Middle Control Channel is located on the east side of the Clackamas River main channel and flows north 318 meters to form the southwest boundary of the Eagle Creek Complex. Figures 6 and 7 show the Middle Control Channel during the winter and summer of 2022. The Middle Control Channel flows entirely within Bonnie Lure State Recreation Area. Potential movement of the Middle Control Channel is restricted to 220 meters of movement between the main channel of the Clackamas River to the west and the hillslope to the east.

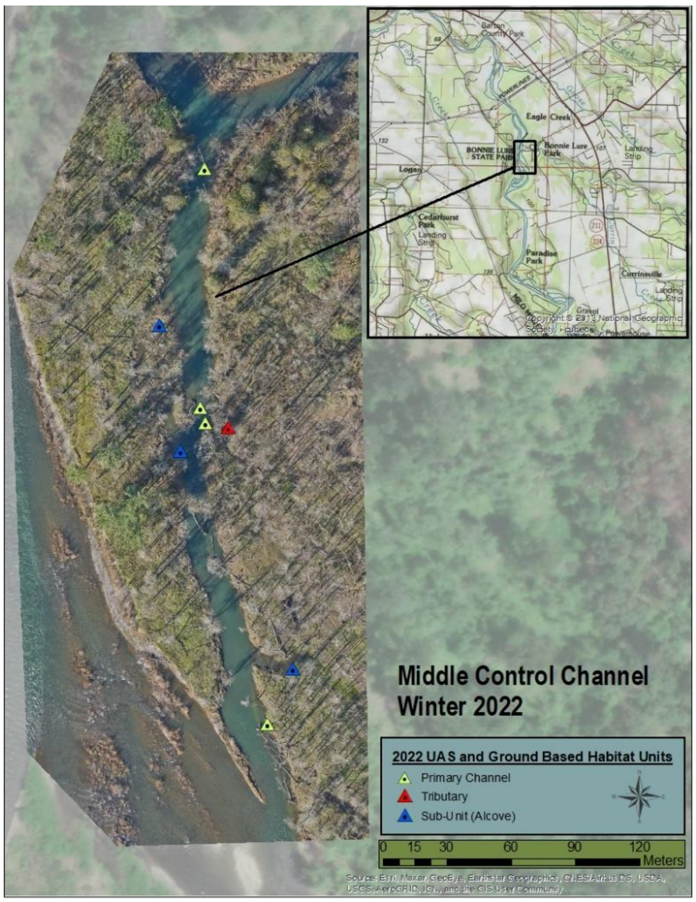

Figure 6. Middle Control Channel. Winter 2022 UAS imagery and ground-based survey points.

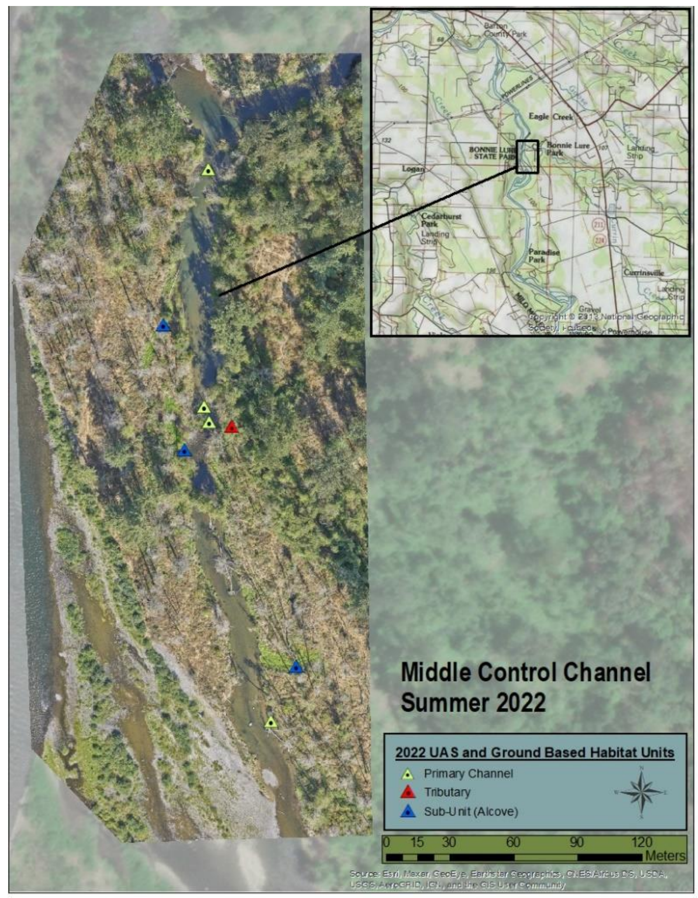

Figure 7. Middle Control Channel. Summer 2022 UAS imagery and ground-based survey points.

Lower Control Channel

The Lower Control Channel is located approximately 1 kilometer downstream of the Carver Bridge on the southwest side of the Clackamas River primary channel. Figures 8 and 9 show the Lower Control Channel during the winter and summer of 2022. Most of the Lower Control Channel flows northwest into a large alcove, while a single, small secondary channel flows northeast back to the Clackamas main channel. Potential movement of the Lower Control Channel is limited to 80 meters between a high constraining terrace on the west bank and the main channel of the Clackamas River.

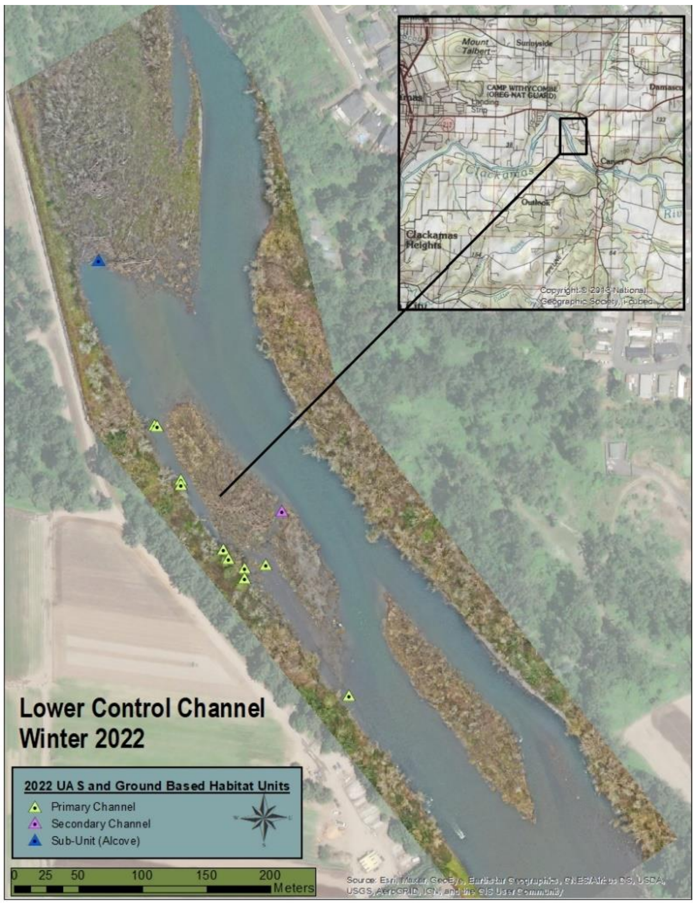

Figure 8. Lower Control Channel. Winter 2022 UAS imagery and ground-based survey points.

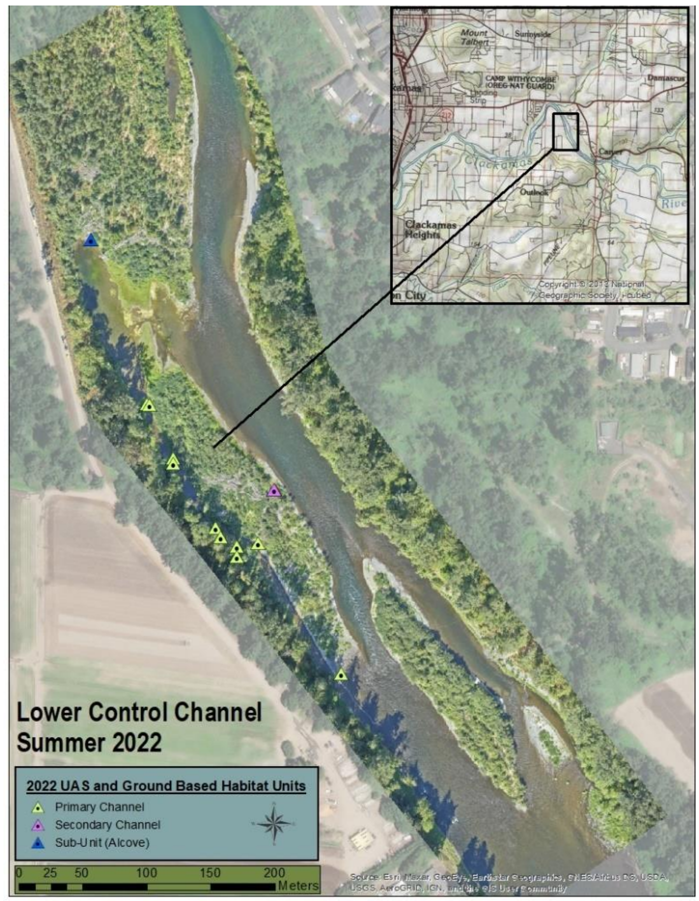

Figure 9. Lower Control Channel. Summer 2022 UAS imagery and ground-based survey points.

USFS Above Reservoir Control

The USFS Above Reservoir Control is located approximately 11.5 kilometers upstream of the Clackamas River North Fork Reservoir. Figure 10 shows the USFS Control during the spring of 2022. The USFS Above Reservoir Control makes up a 3-mile, 4.83 km reach that begins at Sun strip Campground and ends at Fish Creek. The Control Reach was surveyed downstream due to the large scale of the river. The Control reach flows northwest through a hillslope-constrained series of popular class 3 rapids. The Control reach is bisected by one named tributary: Roaring River, and several smaller seasonal runoff tributaries. Two secondary channels provide juvenile salmon refuge habitat. Potential movement of the USFS Above Reservoir Control is limited to 54 meters due to constraining hillslopes and Highway 224.

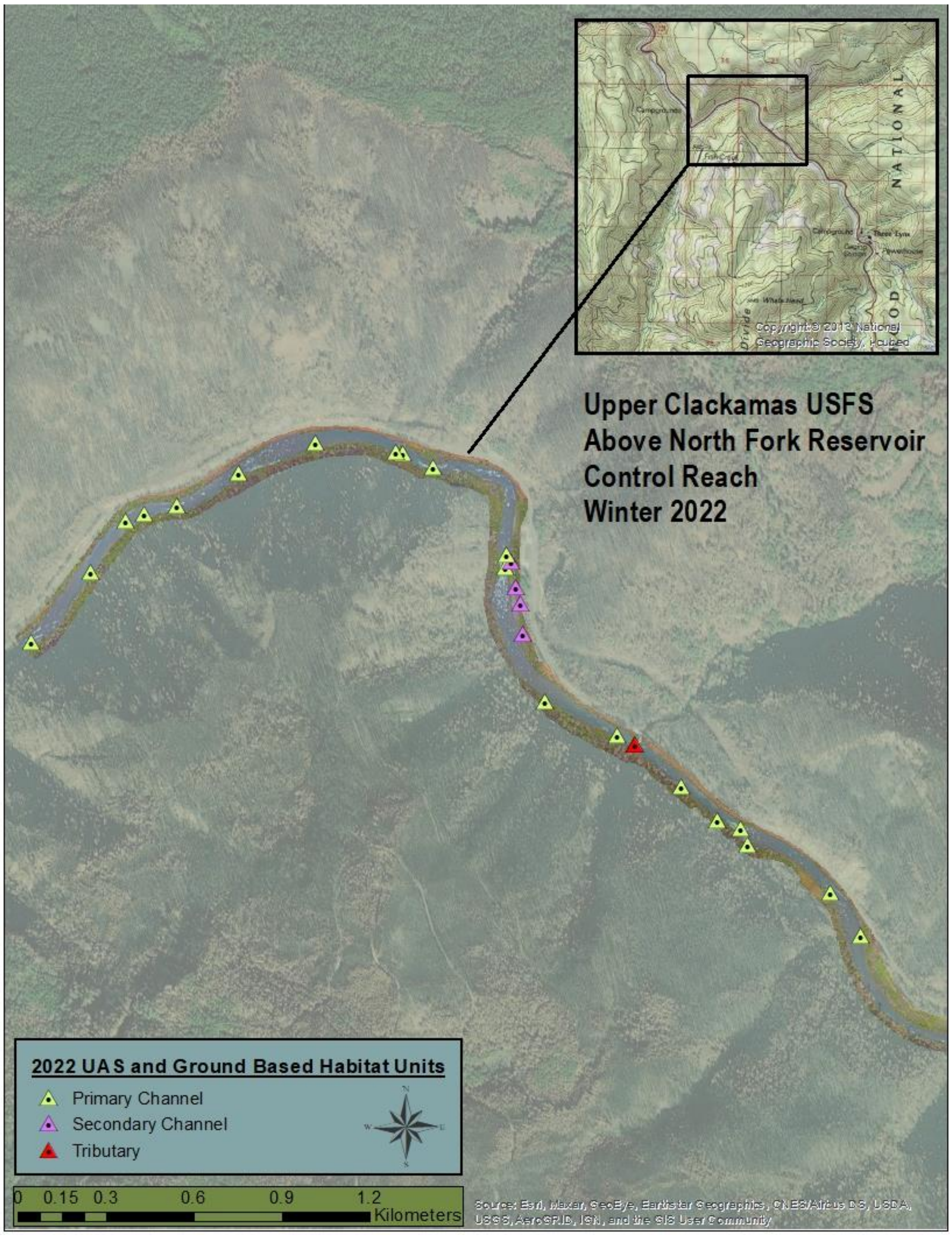

Figure 10. USFS Above Reservoir Control Summer 2022 UAS imagery and ground-based survey points.

USFS Upper Clackamas

The USFS Upper Clackamas is located approximately 7 kilometers upstream of the Clackamas River North Fork Reservoir. The USFS Upper Clackamas reach segment starts at Fish Creek and ends 10.15km downstream at Memaloose. Originally this reach was to end at the South Fork Clackamas River, but due to a lack of access points for rafts, the reach was shortened to end at Memaloose. Figure 11 shows the USFS Upper Clackamas during the winter of 2022. The USFS Upper Clackamas flows northwest and is constrained by hillslopes and Highway 224. Three named tributaries: Fish creek, Helion Creek, and Moore Creek, intersect and influence the reach. Six secondary channels provide in-stream channel diversity and potential juvenile salmon refuge habitat. Movement of the USFS Upper Clackamas channel is limited to 87 meters between a high constraining terrace and the surrounding hillslope.

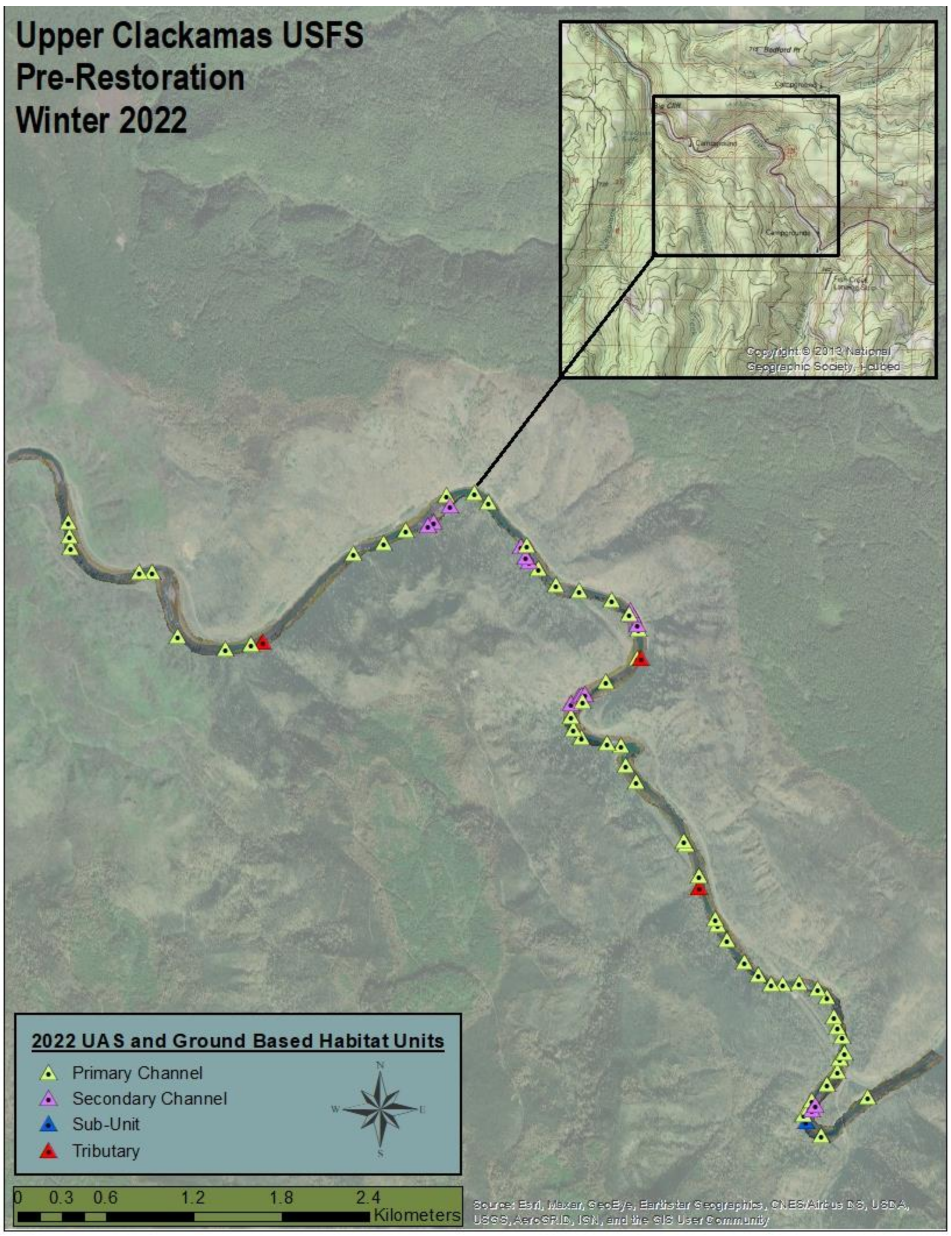

Figure 11. USFS Upper Clackamas 2022 UAS imagery and ground-based survey points.

RESULTS

Ground and UAS Surveys

Kingfisher Side-Channel

A UAS and a physical habitat survey was used to capture post-restoration winter flow conditions on March 7, 2022. The Kingfisher Side-Channel contained no secondary channel habitat (Table 1), but 32% of the primary channel consisted of scour pool habitat (Table 2). Large wood volume throughout the channel was 156 m^3, equivalent to 36.6 m^3 per 100 meters of primary channel length when standardized (Table 2). A total of 12 key pieces of wood were measured, which translates to an average of 2.8 pieces per 100 meters of primary length. The key pieces of wood measured were at least (≥ 12 m in length and ≥ 60 cm in diameter) (Table 2). Observed substrate types throughout the Kingfisher Side-Channel were composed of cobble (47%), gravels (27%), boulders (14%), and fine sediment (11%) (Table 3).

A UAS survey was conducted on September 20, 2022, to capture post-restoration summer conditions. The UAS images show distinct variations in habitat surface area between the summer and winter seasons following restoration efforts (Figures 2 and 3) (Table 9). UAS imagery shows that the newly constructed channel is completely inundated with water during expected winter flows (Figure 2). The UAS imagery shows that the new channel still flows freely during summer flows, with an expected loss of habitat surface area due to summer flow conditions. The tree canopy obscures a small portion of the observable surface area within several habitat units (Figure 3). The ground-filtered DEM layer aided in establishing channel boundaries when canopy cover obscured areas on the orthomosaic. An on-the-ground habitat survey provided details on the unit boundaries and depths and a secondary verification.

On August 3, 2022, an on-the-ground habitat and snorkel survey was conducted, during which 100% of the available pool habitat was snorkeled. Coho, steelhead, Chinook, dace, red-side shiners, and northern pike minnow were observed (Table 4).

The habitat rating of the Kingfisher Side-Channel was poor-moderate before restoration activity across salmonid life history types based on the HabRate model (Burke et al. 2010). Species-specific averages across life history types ranged from 1.2 (steelhead) to 1.75 (cutthroat trout). Following restoration activity, the habitat rating increased for Chinook and steelhead decreased slightly for coho, and remained the same for cutthroat trout. (Tables 5, 6, 7, 8).

Upper Control Channel

A UAS and physical habitat survey captured post-restoration winter flow conditions on March 7, 2022. (Table 9). The Upper Control Channel contained no secondary channel habitat (Table 1), and 29% of the primary channel was scour pool habitat (Table 2). Overall large wood volume throughout the channel was 2 m^3 or 1.5 m^3 per 100 meters of primary channel length when standardized (Table 2). No key pieces of wood (≥ 12 m in length and ≥ 60 cm in diameter) were measured. Observed substrate types throughout the Upper Control Channel were cobble (46%), gravel (18%), boulder (24%), bedrock (8%), and fine sediment (5%) (Table 3).

A UAS survey to capture summer flow conditions occurred on September 20, 2022. The UAS images show expected variations in habitat surface area between the summer and winter seasons (Figures 4 and 5) (Table 9). The Upper Control Channel has good connectivity to the Clackamas mainstem and, as a result, has minimal habitat loss between the winter and summer seasons. UAS imagery shows that the channel is completely inundated with water during expected winter flows (Figure 4). The UAS imagery shows a slight reduction in habitat surface area during summer flows. The summer tree canopy obscures much of the observable surface area (Figure 5). The ground-filtered DEM layer aided in establishing channel boundaries when canopy cover obscured areas on the orthomosaic. An on-the-ground habitat survey provided details on the unit boundaries and depths and a secondary verification.

On August 3, 2022, an on-the-ground habitat survey and a snorkel survey were conducted, and during the survey, 100% of the available pool habitat was snorkeled. Coho, Chinook, dace, red-side shiners, and northern pike minnow were observed (Table 4). The habitat rating of the Upper Control Channel was poor-moderate across salmonid life history types based on the HabRate model (Burke et al. 2010). Species-specific averages across life history types ranged from 1.25 (cutthroat trout) to 2.0 (Chinook). Habitat quality decreased slightly for Chinook, steelhead, and coho between 2020 and 2022 and remained the same for cutthroat (Tables 5, 6, 7, 8). A single large pool unit with good depth and undercut banks and the presence of cold-water seeps provided a thermal refuge during high summer temperatures.

Middle Control Channel

A UAS survey was conducted on March 7, 2022, to capture winter flow conditions. A physical habitat survey was conducted on March 8, 2022. Secondary channel habitat accounted for 400 m^2 of the Middle Control Channel (Table 1), and pools accounted for 44% of the habitat across all channel types (Table 2). Overall large wood volume throughout the channel was 34 m^3 or 11.6 m^3 per 100 meters of primary channel length when standardized (Table 2). No key pieces of wood (≥ 12 m in length and ≥ 60 cm in diameter) were measured. Observed substrate types throughout the Middle Control Channel were primarily composed of fine sediments (32%), gravel (33%), and cobble (34%) (Table 3).

A UAS survey occurred on September 20, 2022, to capture summer flow conditions. The UAS images show minor variations in habitat surface area between the summer and winter (Figures 6 and 7) (Table 9). The Middle Control Channel has good connectivity to the Clackamas mainstem, resulting in minimal habitat loss between the winter and summer seasons. UAS imagery shows that the channel is inundated with water during expected winter flows (Figure 6). Three slack water sub-units provide off-channel refuge from the fast water units of the primary channel, and a tributary enters from the east. UAS imagery shows the watered channel and drying of the three sub-units during summer flows (Figure 7). The UAS imagery also indicates that the tree canopy obscures some of the observable surface area and the tributary. An on-the-ground habitat survey verified the unit boundaries and the tributary location.

On August 3, 2022, an on-the-ground habitat survey and a snorkel survey were conducted, and 93% of the available pool habitat was snorkeled (Table 4). Observations included: Chinook, dace, red-side shiner, northern pikeminnow, and one sub-adult largemouth bass. The habitat rating of the Middle Control Channel was poor-moderate for salmonid use. Species-specific averages across life history types ranged from 1.3 (coho) to 2.0 (Chinook). Habitat quality remained the same across sampling years for nearly all species' life histories, with a slight increase for Chinook and a continued decrease for cutthroat trout (Tables 5, 6, 7, 8). This channel contains several alcoves, a tributary, and a long pool unit with wood structures. Recent fires have added to a decreased tree canopy.

Lower Control Channel

A UAS and physical habitat survey was used to capture post-restoration winter flow conditions on March 17, 2022, to capture winter flow conditions. An on-the-ground physical habitat survey to capture summer flow conditions occurred on July 12, 2022. The secondary channel habitat was dry during the sampling period of the Lower Control Channel (Table 1), and 85% of the channel was pool habitat (Table 2). Large wood volume throughout the channel was 124 m^3, equivalent to 44.4 m^3 per 100 meters of primary channel length when standardized (Table 2). A total of 4 key pieces of wood were measured, which translates to an average of 1.4 pieces per 100 meters of primary length. The key pieces of wood measured were at least (≥ 12 m in length and ≥ 60 cm in diameter) (Table 2). The Lower Control Channel habitat was primarily composed of cobble substrate (34%), gravel (11%), and fine sediments (51%) (Table 3).

A UAS survey to capture summer flow conditions occurred on September 20, 2022. The UAS images show distinct variations in habitat surface area between the summer and winter (Figures 8 and 9) (Table 9). The Lower Control Channel sits slightly higher than the wetted channel of the Clackamas mainstem. In typical winter flows, the channel is completely inundated with water (Figure 8). During summer flows, much of the mainstem flow is directed away from the control channel, reducing habitat surface area. This is most notable in the large alcove unit at the bottom end of the control channel and the secondary channel, which is nearly dry (Figure 9). During the summer UAS survey, the presence of the tree canopy made it challenging to observe distinct edge boundaries of several habitat units. The ground-filtered DEM layer aided in establishing channel boundaries when canopy cover obscured areas on the orthomosaic. An on-the-ground habitat survey provided details on the unit boundaries and depths and a secondary verification.

In the Lower Control Channel, UAS imagery shows that seasonal flows contribute to the available stream habitat surface area (Figures 8 and 9) (Table 9), and the primary and secondary channels are completely inundated with water during the winter flows (Figure 8). As shown in Figure 9, the primary and secondary channels are dramatically affected by the lack of flow during summer, and the available habitat surface area is significantly reduced.

On August 3, 2022, a snorkel survey was conducted, during which 100% of the available pool habitat was snorkeled (Table 4). Observations included: dace, shiner, northern pikeminnow, pumpkinseed sunfish, and one Chinook salmon. Good connectivity to the mainstem, overhead shade, available wood structure, and a large alcove continue to provide opportunities for rearing and refuge. The habitat rating of the Lower Control Channel was moderate-good for salmonid use across species life history types based on the HabRate model (Burke et al. 2010). Species-specific averages across life history types ranged from 1.3 (coho) to 2.0 (Chinook and steelhead). Habitat quality decreased slightly across sampling years for all salmonid life histories (Tables 5, 6, 7, 8), likely due to the survey timing occurring in the summer.

USFS Above Reservoir Control

A UAS survey occurred on May 4, 2022, to capture winter pre-restoration flow conditions (Figure 10). During summer flow conditions, an on-the-ground physical habitat survey occurred on August 10, 2022.
A Snorkel survey occurred on September 21, 2022.
A Sonar survey occurred on November 3, 2022.

Secondary channel habitat accounted for 658 meters or 4.4% of the USFS above Reservoir Control (Table 1), and pool habitat accounted for 20.0% across all channel types (Table 2). Overall large wood volume throughout the channel was 100 m^3 or 2.0 m^3 per 100 meters of primary channel length when standardized (Table 2). In addition, one key piece of wood (≥ 12 m in length and ≥ 60 cm diameter) was measured. The USFS Above Reservoir Control habitat was primarily composed of fine sediments (4%), with a mix of cobble (42%), boulders (34%,) and gravel (17%) (Table 3).

Establishing habitat breaks in a large river can be challenging while conducting on-the-ground surveys. The UAS images aided in determining the boundaries of each habitat unit. (Figure 10) (Table 9). UAS imagery shows the channel is completely inundated with water during expected winter flows (Figure 10)—the ground-filtered DEM layer aided in establishing channel boundaries when canopy cover obscured areas on the orthomosaic. An on-the-ground habitat survey was conducted and did provide details on the unit boundaries and depths and provided a secondary verification.

A snorkel survey was conducted on September 21, 2022, and 30% of the available pool habitat was snorkeled (Table 4). Observations included: adult chinook, steelhead, coho, cutthroat trout, dace, 0+ trout, and Mountain Whitefish.

USFS Upper Clackamas

A UAS survey occurred on April 15, 2022, to capture winter pre-restoration conditions. (Figure 11) During summer flow conditions, an on-the-ground physical habitat survey occurred on August 10, 2022.
A Snorkel survey occurred on September 21, 2022.
A Sonar survey occurred on November 3, 2022.

Secondary channel habitat accounted for 3.0% of the USFS Upper Clackamas (Table 1), and pool habitat accounted for 38% across all channel types (Table 2). Overall large wood volume throughout the channel was 511 m^3 or when standardized, 4.5 m^3 per 100 meters of primary channel length (Table 2). A total of 29 key pieces of wood were measured, which translates to an average of 0.3 pieces per 100 meters of primary length. The key pieces of wood measured were at least (≥ 12 m in length and ≥ 60 cm in diameter) (Table 2). The USFS Upper Clackamas habitat was primarily composed of fine sediments (15%), with a mix of cobble substrate (34%), boulders (31%,) and gravels (16%) (Table 3).

The UAS images aided in determining the boundaries of each habitat unit. (Figure 10) (Table 9). UAS imagery shows the channel is completely inundated with water during expected winter flows (Figure 11)—the ground-filtered DEM layer aided in establishing channel boundaries when canopy cover obscured areas on the orthomosaic. An on-the-ground habitat survey was conducted and did provide details on the unit boundaries and depths and provided a secondary verification.

A snorkel survey was conducted on September 21, 2022, and 32% of the available pool habitat was snorkeled (Table 4). Observations included: adult chinook, juvenile chinook, steelhead, coho, cutthroat trout, dace, 0+ trout, suckers, and Mountain Whitefish.

Table 1. Channel lengths and area across Clackamas Focused Investment Partnership survey locations during March and April of 2022 using Aquatic Inventory stream habitat survey methods described in Moore et al. (2007).

Site Location	Primary Channel Length (m)	Secondary Channel Length (m)	Primary Channel Area (m^2)	Secondary Channel Area (m^2)	Off-Channel Area (m^2)*
Kingfisher	426.0	0	2,763.0	0	0
Upper Control	155.0	0	2,261.0	0	0
Middle Control	295.0	75.0	4,705.0	400	375
Lower Control**	279.0	38	2,385.0	0	9,450
USFS Control	4,874	658	174,192	7,933	0
USFS Upper Clackamas	11,322	1,177	415,320	12,412	0

*Alcoves, Backwaters, and Isolated Pools. **Surveyed 7-12-2022, secondary channel dry at the time

Table 2. Physical habitat summary across Clackamas Focused Investment Partnership survey locations during March and April of 2022 using Aquatic Inventory stream habitat methods described in Moore et al. (2007).

Site Location	Pool Habitat (%)	Residual Pool Depth (m)	Riffle Depth (m)	Wood Volume (m^3)**	# Of Key Wood Pieces**
Kingfisher	32	0.70	0.63	36.6	2.8
Upper Control	29	1.35	0.70	1.5	0
Middle Control	44	0.65	0.60	11.6	0
Lower Control *	85	0.26*	0.20	44.4	1.4
USFS Control	20	3.27	1.09	2.0	0
USFS Upper Clackamas	38	1.63	0.78	4.5	0.3

*Surveyed 7-12-2022 summer, **Total/100m primary channel

Table 3. Description of streambed substrate within wetted channels across Clackamas Focused Investment Partnership survey locations during March and April of 2022 using Aquatic Inventory stream habitat survey methods described in Moore et al. (2007).

Site Location	% Fines*	% Gravel	% Cobble	% Boulder	% Bedrock
Kingfisher	11	27	47	14	0
Upper Control	6	18	47	20	9
Middle Control	32	33	34	0	0
Lower Control **	51	11	34	4	0
USFS Control	4	17	42	34	3
USFS Upper Clackamas	15	16	34	31	5

*Combined observed values of silt and sand; **Surveyed 7-12-2022 summer

Table 4. Results of snorkel surveys within pool habitats across Clackamas Focused Investment Partnership survey locations during July of 2022 using methods described in Constable et al. (2012).

Site Location	Pool Area (m^2)	Snorkeled Area (m^2)	Sum of Coho	Sum of Cutthroat	Sum of Steelhead	Sum of Chinook	Other Fish Observed
Kingfisher	876	876	2	0	1	16	Red-Side Shiners, Dace, NPM**
Upper Control	663	663	55	0	0	30	Dace, Red-side shiners, NPM**
Middle Control***	2,245	2,101	0	0	0	17	Dace, shiner, LB, NPM**
Lower Control***	8,768	8,768	0	0	0	1	Dace, shiner, NPM**
USFS Control	37,089	11,126	395	9	46	9*	Adult-Chinook, Dace, Mountain Whitefish,0+trout
USFS Upper Clackamas	161,941	51,821	225	33	214	215	Adult Chinook, Mountain Whitefish, Suckers, 0+trout

*Trout fry < 90 mm in fork length; **Northern Pikeminnow; ***Snorkeled an Alcove habitat unit type.

Table 5. HabRate (Burke et al. 2010) pre-and post-restoration life history ratings for Chinook salmon habitat across Clackamas FIP Kingfisher site and Control reaches

Chinook Salmon Habitat					
Stream	Year	Spawning to Emergence	0+ Summer	0+ Winter	Chinook Average
Kingfisher-(Pre)	2021	1	2	2	1.6
Kingfisher-(Post)	2022	2	2	2	2
Upper Control	2020	2	2	3	2.3
Upper Control	2021	2	2	2	2
Upper Control	2022	2	2	2	2
Middle Control	2020	1	2	2	1.6
Middle Control	2021	1	2	2	1.6
Middle Control	2022	1	3	2	2
Lower Control	2020	2	2	2	2
Lower Control	2021	3	2	2	2.3
Lower Control	2022	2	2	2	2

Table 6. HabRate (Burke et al. 2010) pre-and post-restoration life history ratings for steelhead habitat across Clackamas FIP Kingfisher site and Control reaches.

Steelhead Habitat							
Stream	Year	Spawning to Emergence	0+ Summer	0+ Winter	1+ Summer	1+ Winter	Steelhead Average
Kingfisher-(Pre)	2021	1	2	1	1	1	1.2
Kingfisher-(Post)	2022	2	2	2	2	2	2
Upper Control	2020	1	3	2	2	2	2
Upper Control	2021	2	2	2	2	2	2
Upper Control	2022	2	2	1	2	1	1.6
Middle Control	2020	1	2	2	2	2	1.8
Middle Control	2021	1	2	2	2	2	1.8
Middle Control	2022	1	2	2	2	2	1.8
Lower Control	2020	2	2	3	2	3	2.4
Lower Control	2021	2	2	3	2	3	2.4
Lower Control	2022	2	2	2	2	2	2

Table 7. HabRate (Burke et al. 2010) pre-and post-restoration life history ratings for coho salmon habitat across Clackamas FIP Kingfisher site and Control reaches.

Coho Habitat					
Stream	Year	Spawning to Emergence	0+ Summer	0+ Winter	Coho Average
Kingfisher-(Pre)	2021	1	2	2	1.6
Kingfisher-(Post)	2022	2	1	1	1.3
Upper Control	2020	1	3	1	1.6
Upper Control	2021	3	1	1	1.6
Upper Control	2022	1	1	1	1
Middle Control	2020	1	2	2	1.6
Middle Control	2021	1	2	2	1.6
Middle Control	2022	1	2	1	1.3
Lower Control	2020	2	2	2	2
Lower Control	2021	2	2	3	2.3
Lower Control	2022	2	1	1	1.3

Table 8. Habrate (Burke et al. 2010) pre-and post-restoration life history ratings for cutthroat trout habitat across Clackamas FIP Kingfisher site and Control reaches.

Cutthroat Habitat						
Stream	Year	Spawning to Emergence	0+ Summer	0+ Winter	1+ Summer	Cutthroat Average
Kingfisher-(Pre)	2021	1	2	2	2	1.75
Kingfisher-(Post)	2022	2	1	2	2	1.75
Upper Control	2020	1	1	1	2	1.25
Upper Control	2021	1	1	1	2	1.25
Upper Control	2022	1	1	1	2	1.25
Middle Control	2020	2	2	2	2	2
Middle Control	2021	1	2	2	2	1.75
Middle Control	2022	1	1	2	2	1.5
Lower Control	2020	2	3	2	2	2.25
Lower Control	2021	2	3	2	2	2.25
Lower Control	2022	2	1	2	2	1.75

Methods Comparison

We compared ground survey and UAS imagery results for habitat area (m^2) from all individual habitat units across sites and seasons where both methods occurred (Table 9).

Table 9. The surface area of ground surveys and UAS surveys between winter and summer (m^2).

Site Location	Ground-Based Winter Surface Area (m^2)	UAS Winter Surface Area (m^2)	UAS Summer Surface Area (m^2)
Kingfisher	2,763.00	3,110.76	2,304.10
Upper Control	2,261.00	2,282.33	1,407.30
Middle Control	5,016.00	4,010.00	4,611.47
Lower Control	11,809.00	11,470.00*	4,620.50*
USFS Control	180,983.00	192,783.30	NA
USFS Upper Clackamas	427,724.00	469,243.50	NA

*UAS View obscured by canopy cover on several units, We compared ground survey and UAS imagery results for wood volume (m^3) from the Kingfisher Side Channel following restoration. Results of a simple linear regression suggest the UAS imagery can be used to describe large wood volume adequately (Figure 12). The R^2 was 0.94 with a p-value less than 0.0005 (Table 10).

Table 10. Results of ground surveys and UAS survey comparison results for wood volume (m^3) in Kingfisher side channel

Residual DF	F-statistic	P-value	Adjusted R^2
3.219	206.1	<.0005	0.9491

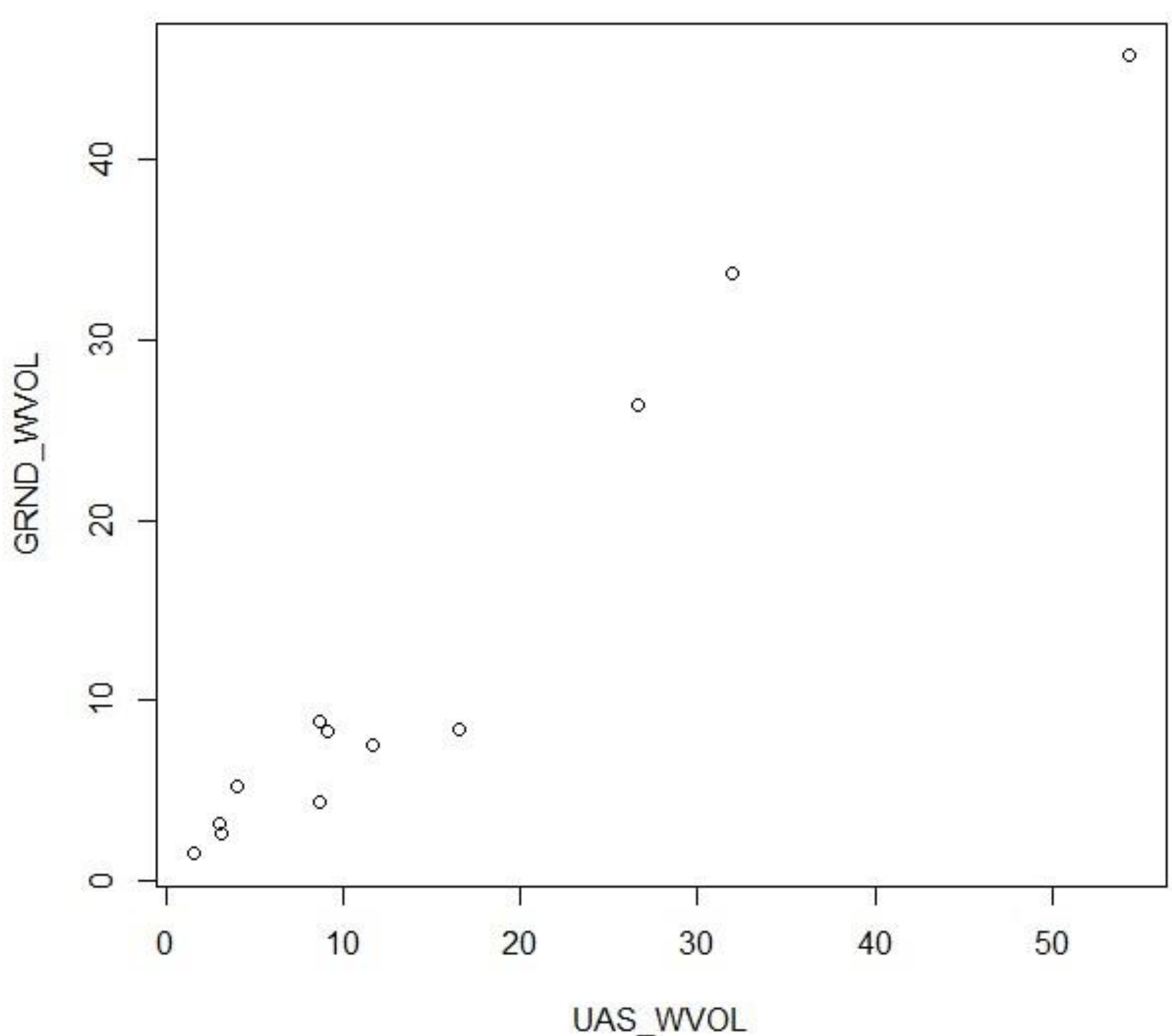

Figure 12. Results of a simple linear regression between ground survey and aerial imagery large wood volume (m^3)

We used paired *t*-tests to describe differences in winter habitat area (m^2) using ground surveys and summer habitat area (m^2) from UAS survey imagery. Differences were minimal across seasons for most sites (Table 11). Differences observed in the Upper Control and Middle Control (Figure 13) were likely attributed to sub-units drying out in the Middle Control between seasons, and high flows on the Upper Control during the winter ground surveys

Table 11. Paired *t*-test results assessing differences in habitat area (m^2) between winter ground surveys and summer UAS survey imagery results.

Site	t	df	Mean of Differences	P-value
Lower Control	1.094	4	1394.066	0.3354
Middle Control	3.1805	7	168.575	0.01548
Upper Control	7.6157	3	173.375	0.004699
Kingfisher	1.4985	13	25.57857	0.1579

The Middle Control and Upper Control had the most change in habitat area between winter and summer. Several alcove subunits in the Middle Control were fully inundated in winter and dry in summer, resulting in a loss of habitat area.

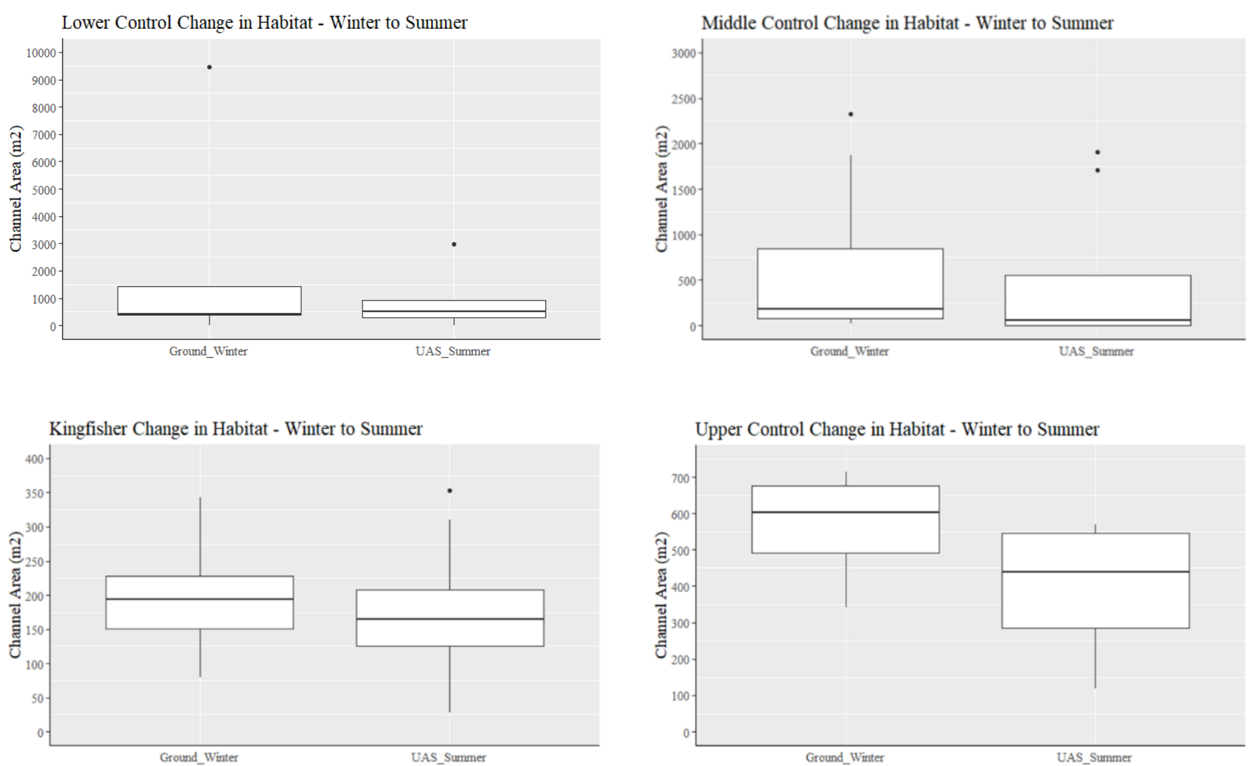

Figure 13. Box plots assessing differences in habitat area (m^2) between winter ground surveys and summer UAS survey imagery results.

Restoration Assessment – Kingfisher Side-Channel and Upper Control

Notable differences in habitat metrics were shown in the Kingfisher Side-Channel following restoration (Table 12.) We used paired *t*-tests to assess the Kingfisher Side-Channel and the Upper Control sites for pre-restoration treatment (2021) and post-treatment (2022) differences across habitat metrics described in Tables 1, 2, and 3. Across all habitat metrics, we observed significant differences between pre-treatment and post-treatment, most notably an increase in primary channel area, wood volume, and gravel and cobble substrates. Pool habitat and percentage fines decreased (Table 13). *P*-values ranged from 0.03741 to 0.9697.

Table 12. Differences between pre-restoration treatment and post-restoration treatment (2021-2022) across all habitat metrics in The Kingfisher Side-Channel.

Kingfisher Side-Channel Habitat Metrics	2021 Pre-Restoration	2022 Post-Restoration
Primary Channel Area (m^2)	3283.5	2762.6
Secondary Channel Area (m^2)	0	0
Off-Channel Area (m^2)	0	0
% Pool Habitat	82	31
Residual Pool Depth (m)	0.6	0.7
Riffle Depth (m)	0.18	0.6
Wood Volume (m^3)**	6.5	36.5
# Of Key Wood Pieces	1	12
% Fines*	47	11
% Gravel	14	26
% Cobble	23	47
% Boulder	14	14
% Bedrock	0	0

*Silt and Sand, ** Total/100m primary channel

Table 13. Paired *t*-tests assessing differences in The Kingfisher Side-Channel and Upper Control between pre-restoration treatment and post-restoration treatment (2021-2022) across all habitat metrics.

Habitat Metric	t	df	Mean of Differences	P-value
Primary Channel Area (m^2)	0.047628	1	26.05	0.9697
Secondary Channel Area (m^2)	NaN	1	0	NA
Off-Channel Area (m^2)*	NaN	1	0	NA
% Pool Habitat	-4.4108	1	-41.02	0.1419
Residual Pool Depth (m)	1.5556	1	0.14	0.3637
Riffle Depth (m)	17	1	0.425	0.03741
Wood Volume (m^3)	1.084	1	15.615	0.4744
# Of Key Wood Pieces	1	1	1.315	0.5
% Fines**	-1.1907	1	-19.79	0.4447
% Gravel	0.81569	1	5.665	0.5644
% Cobble	1.3376	1	13.985	0.4087
% Boulder	0.32308	1	0.315	0.8011
% Bedrock	-1	1	-0.18	0.5

*Alcoves, Backwaters, and Isolated Pools. **Combined observed values of silt and sand.

Restoration Assessment- Control Channels

We used paired *t*-tests to assess the Upper, Middle, and Lower Control sites for pre-restoration treatment (2021) and post-treatment (2022) differences across habitat metrics described in Tables 1, 2, and 3. Across all habitat metrics, we observed significant differences between pre-treatment and post-treatment notably an increase in primary channel area, pool habitat, fines, and boulder substrates. Secondary channel, off-channel area, and the percentage of cobble decreased (Table 14). *P*-values ranged from 0.1678 to 0.9272.

Table 14. Paired *t*-tests assessing differences in The Upper, Middle, and Lower Control sites between (2021-2022) across all habitat metrics.

Habitat Metric	t	df	Mean of Differences	P-value
Primary Channel Area (m^2)	0.28278	2	105.4	0.8039
Secondary Channel Area (m^2)	-1.0632	2	-3325.5	0.3991
Off-Channel Area (m^2)*	-0.81642	2	-453.6333	0.5
% Pool Habitat	1.2823	2	16.03645	0.3283
Residual Pool Depth (m)	0.63834	2	0.13	0.5886
Riffle Depth (m)	-1.7995	2	-0.2083333	0.2137
Wood Volume (m^3)	-1.1566	2	-8.570538	0.3669
# Of Key Wood Pieces	-1	2	-0.2003843	0.4226
% Fines**	1.924	2	4.217011	0.1942
% Gravel	-0.10327	2	-0.4436482	0.9272
% Cobble	-2.1224	2	-7.13901	0.1678
% Boulder	0.77808	2	3.244818	0.518
% Bedrock	1	2	0.1208285	0.4226

*Alcoves, Backwaters, and Isolated Pools. **Combined observed values of silt and sand.

Restoration Assessment-All Sites

Channel and pool features decreased post-treatment in the Kingfisher Side-Channel, although residual pool depth and riffle depth stayed the same or increased slightly across all sites (Figure 14). Wood volume increased within the Kingfisher restoration site as expected, and a slight increase in wood volume was shown in the Control sites. The number of key pieces of wood (≥ 12 m in length and 60 cm in diameter) increased within the Kingfisher site following restoration, and an increase was seen in the Lower Control Channel (Figure 15). Within stream bedload types, we observed a slight decrease in the percent of fines (silt and sand), an increase in gravel and cobble, and a reduction in the percent of boulders in the Kingfisher Side-Channel following restoration. The Control sites had relatively minor variations in bedload percentages (Figure 16).

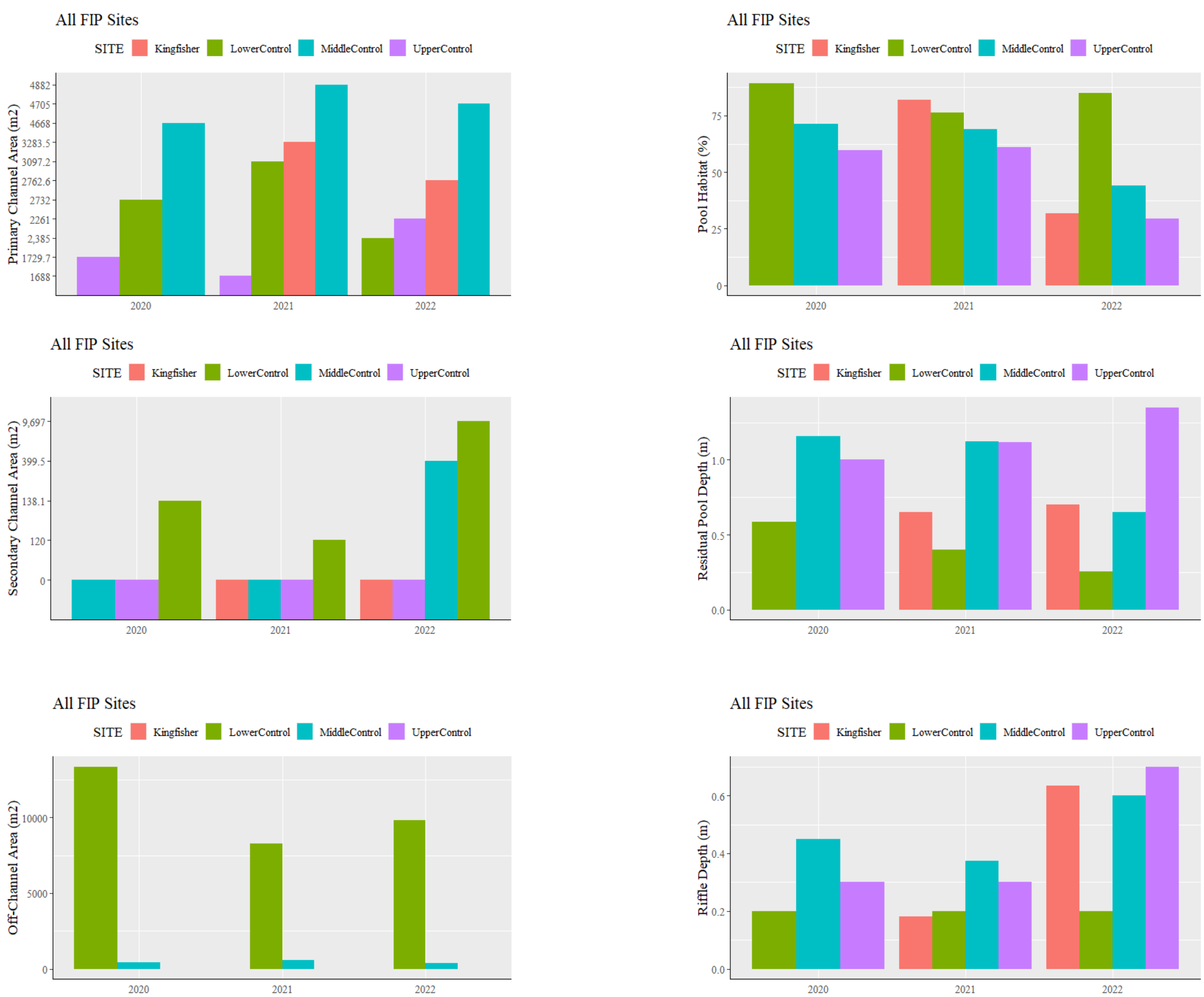

Figure 14. Bar plots describing differences between pre-restoration and post-restoration treatments across channel, pool, and riffle features of all 2022 FIP sites.

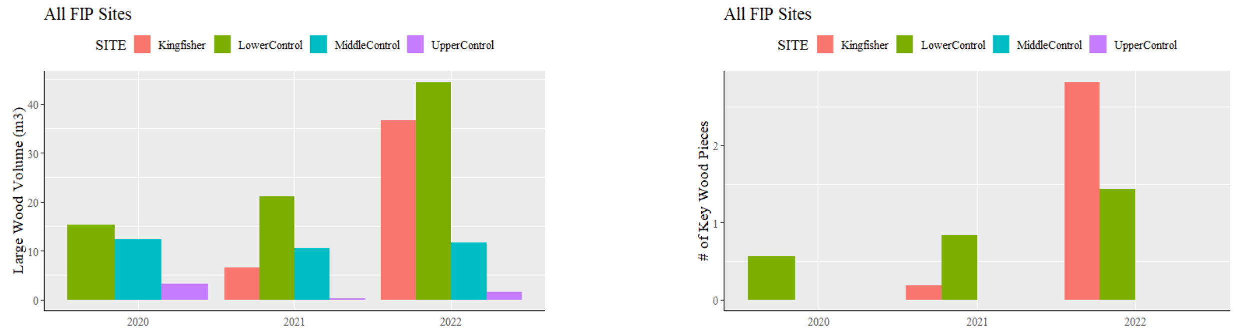

Figure 15. Bar plots describing differences between pre-restoration treatment and post-restoration treatment for wood volume (m3) and the number of key pieces of wood (≥ 12 m in length and 60 cm in diameter) Total/100m primary channel.

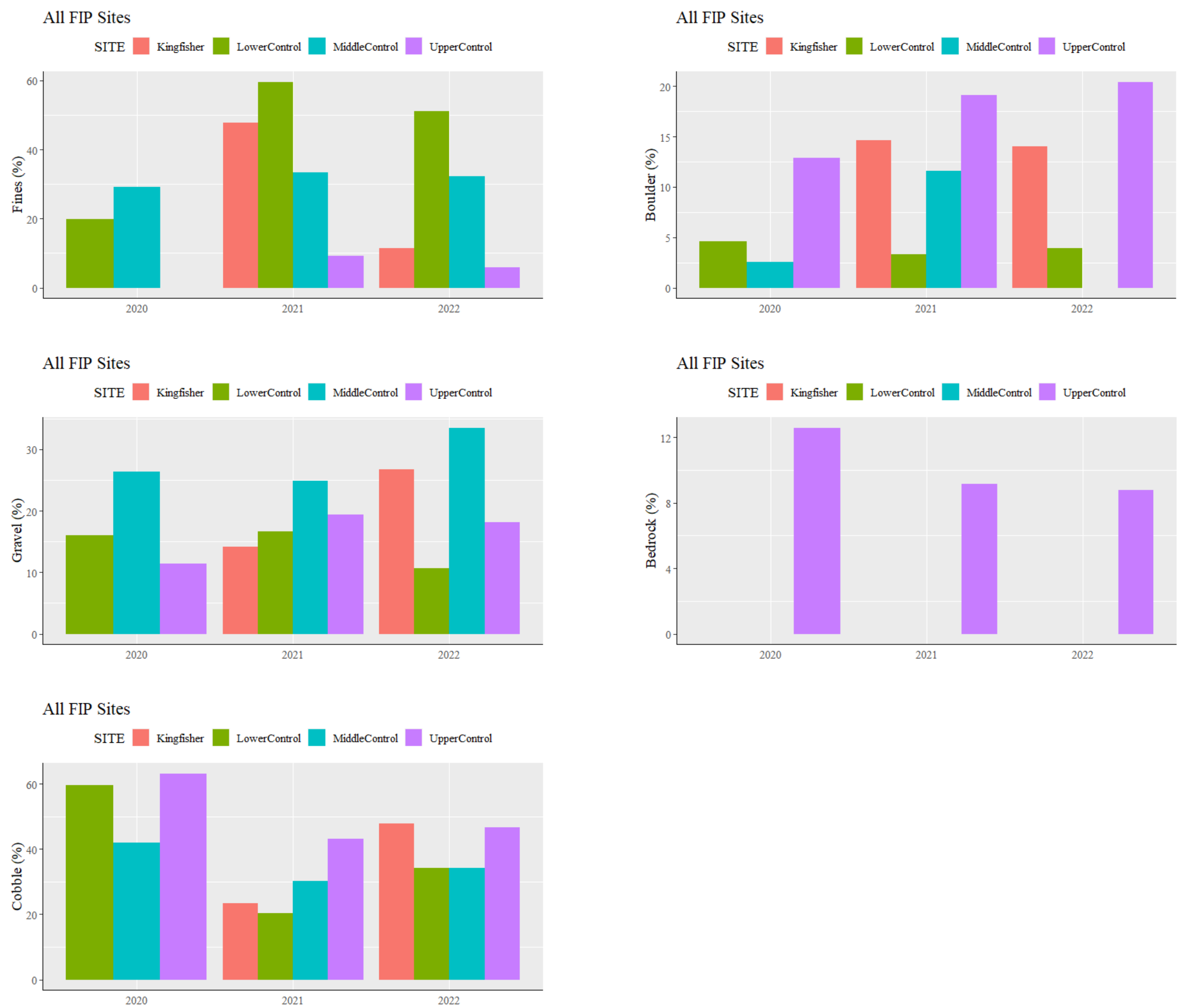

Figure 16. Bar plots describing differences between pre-restoration treatment and post-restoration treatment across bedload types.

Restoration Assessment-Kingfisher and Upper Control

The Upper Control experienced minor differences over three years, whereas the Kingfisher Side-Channel underwent significant changes after restoration efforts were implemented. The Kingfisher Side-Channel showed dramatic changes across fast water habitat metrics and pool habitat (Figure 17). Notably, the incorporation of new wood structures, along with the addition of gravel and cobble substrates, resulted in a considerable increase in these metrics (Figures 18, 19).

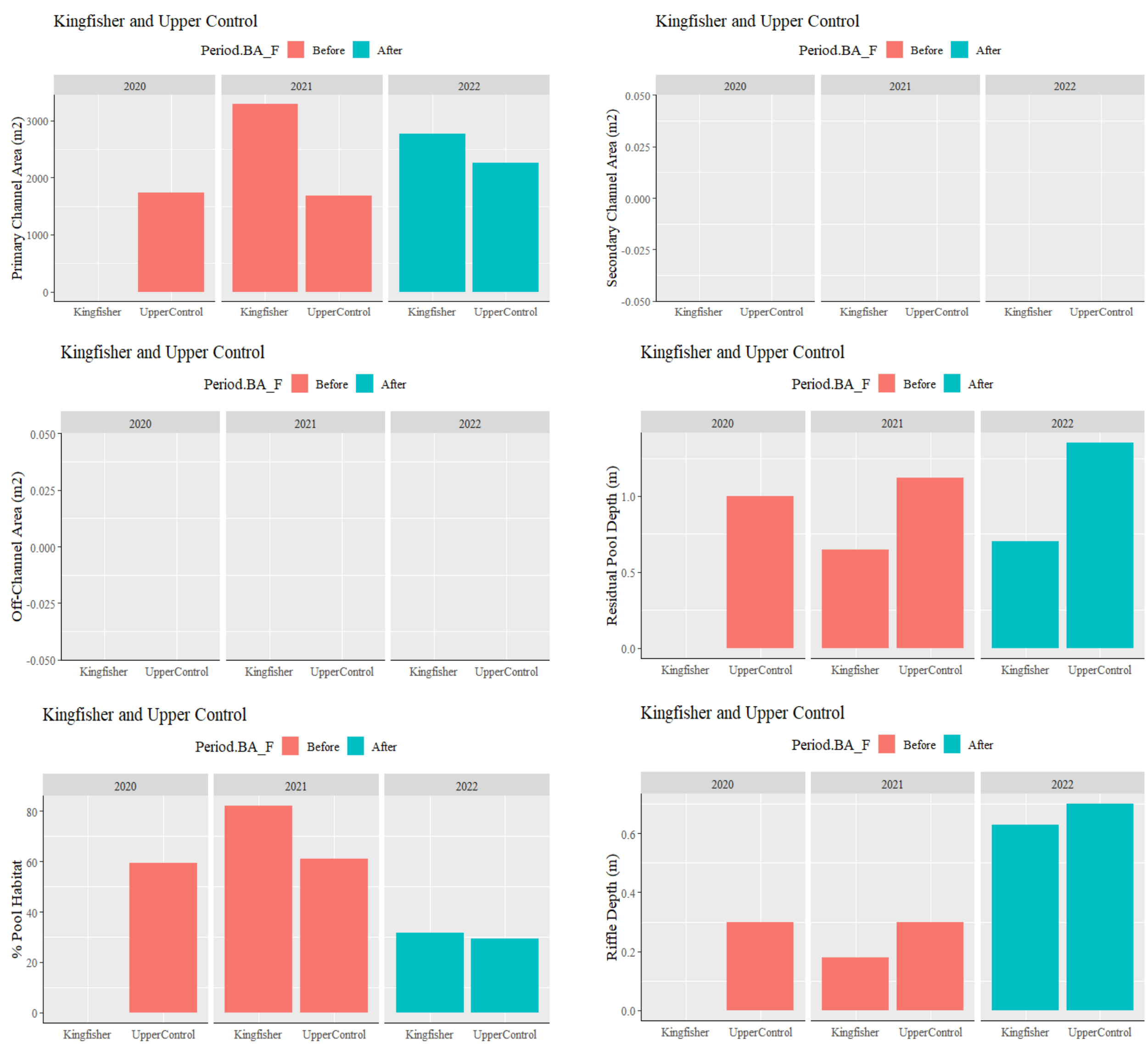

Figure 17. Bar plots describing differences between pre-restoration and post-restoration treatments across channel, pool, and riffle features of the Kingfisher Side-Channel and the Upper Control.

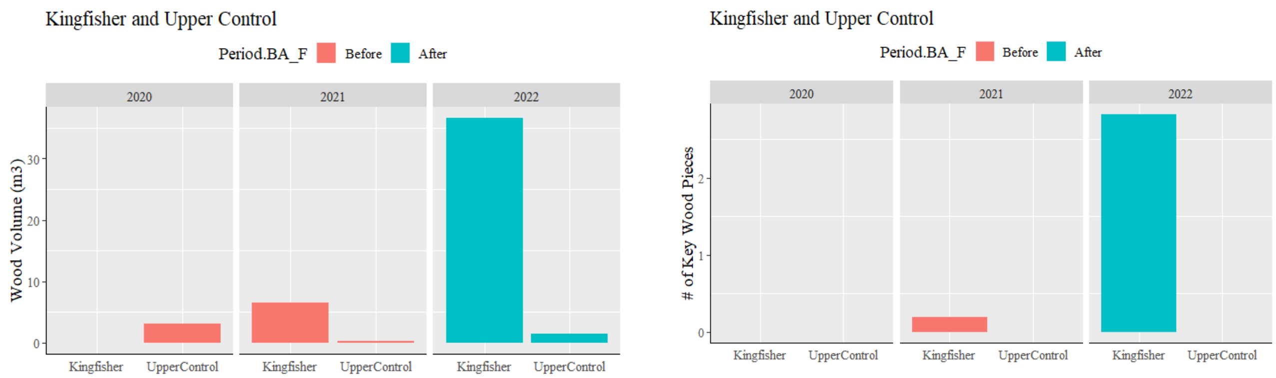

Figure 18. Bar plots describing differences between pre-restoration and post-restoration wood volume and the number of key wood pieces (total/ 100m primary channel) of the Kingfisher Side-Channel and the Upper Control.

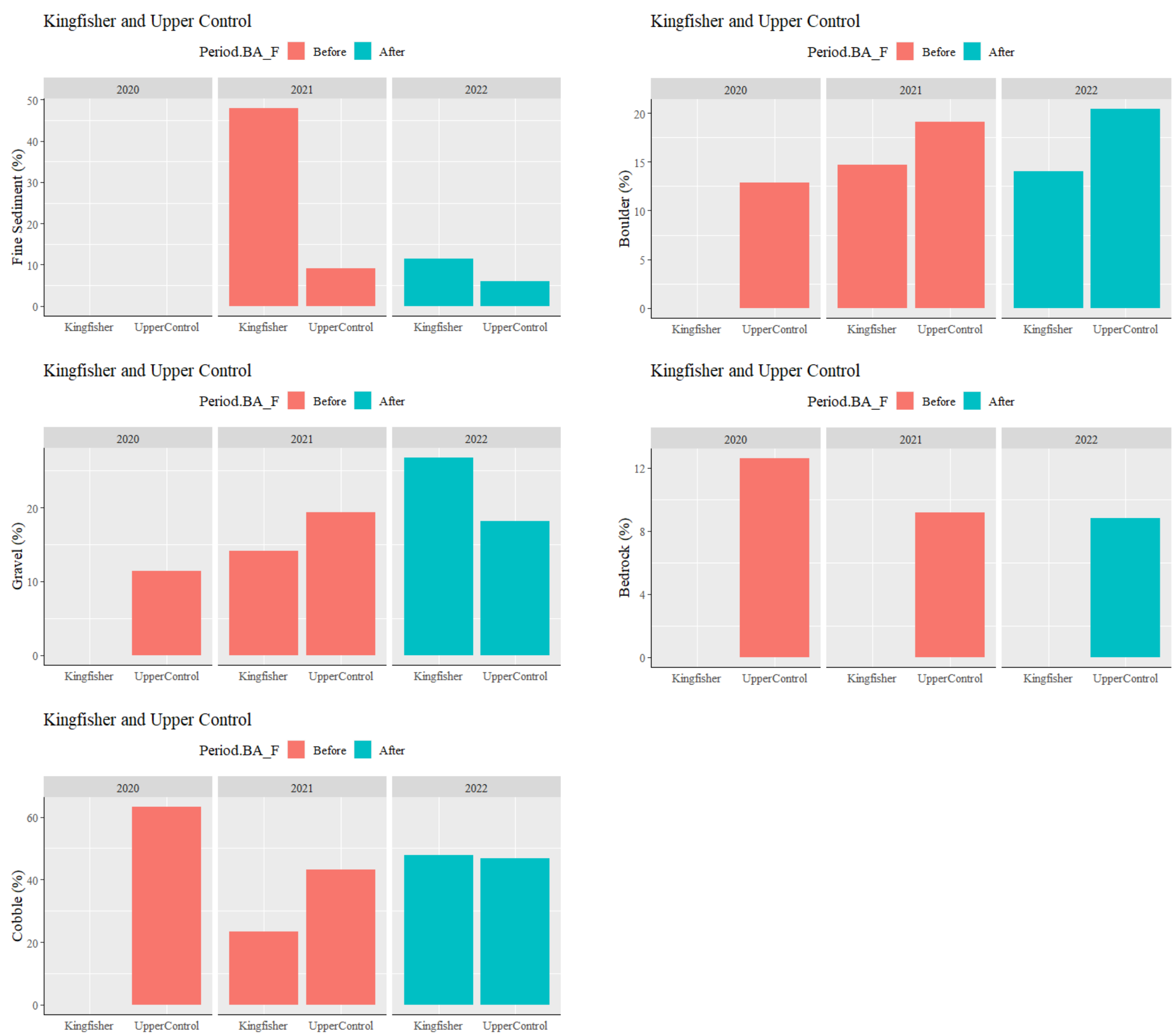

Figure 19. Bar plots describing differences between pre-restoration and post-restoration bedload percentages of the Kingfisher Side-Channel and the Upper Control.

Restoration Assessment – Kingfisher

Across channel and pool features within the Kingfisher Side-Channel, there were observable differences between year one and year two of the FIP monitoring effort (Figure 20).

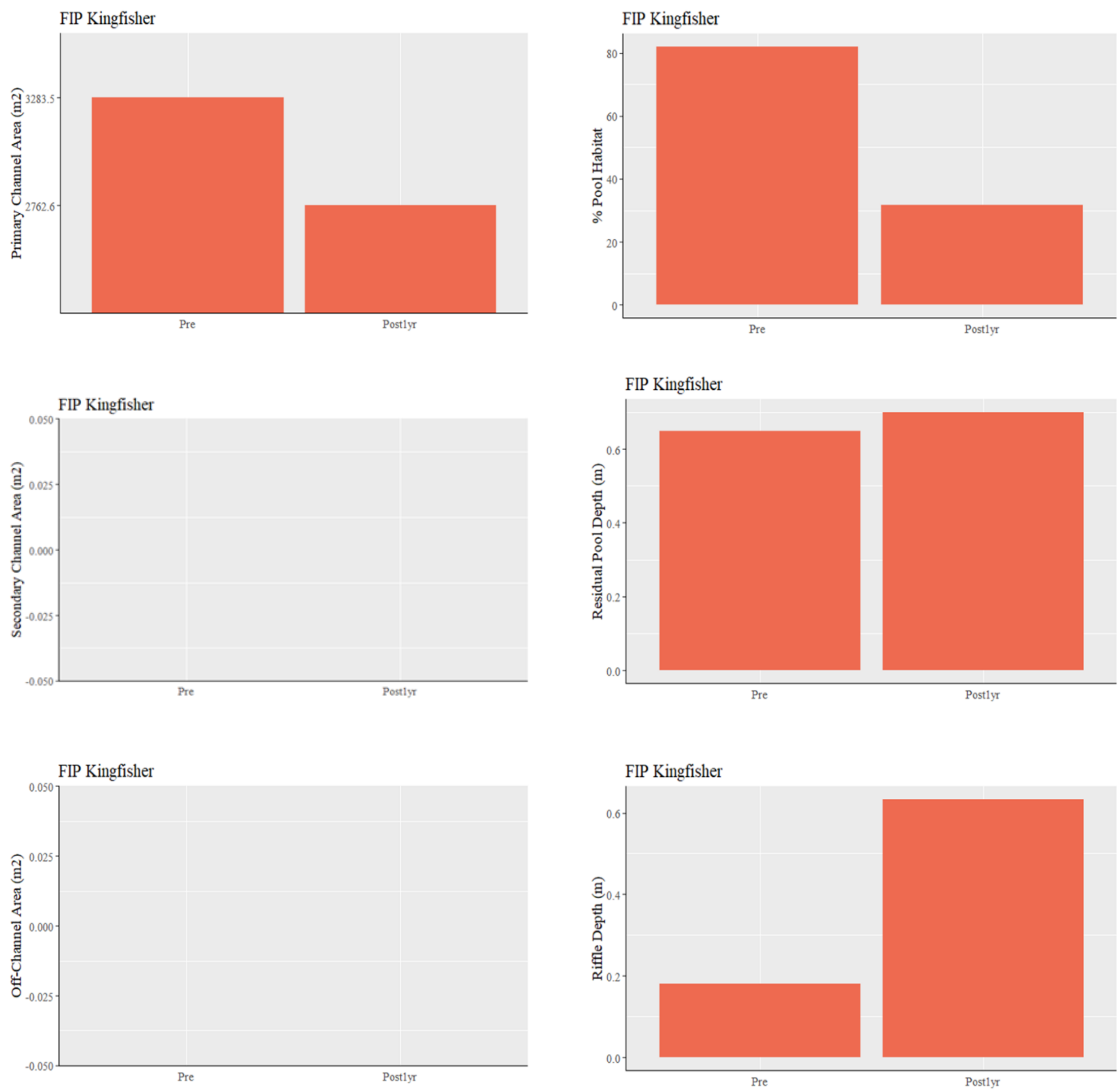

Figure 20. Bar plots describing differences between pre-restoration and post-restoration treatments across channel and pool features of the Kingfisher Side-Channel.

Wood volume (m^3) and the number of key wood pieces noticeably increased from year one to year two following restoration activities in Kingfisher Side-Channel (Figure 21).

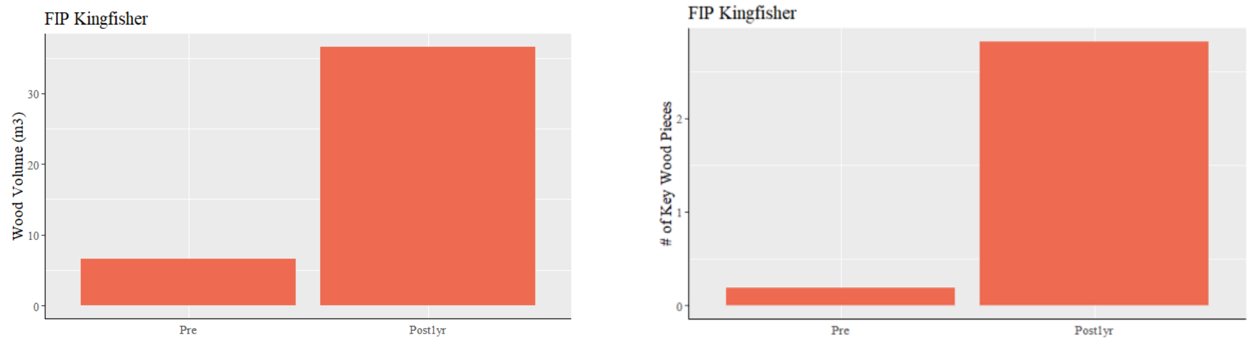

Figure 21. Bar plots describing differences between pre-restoration and post-restoration wood volume and the number of key wood pieces (total/ 100m primary channel) of the Kingfisher Side-Channel.

Differences were observed across bedload types within the Kingfisher Side-Channel (Figure 22). The percentage of fines (sand and silt) and boulders decreased while the percentage of gravel and cobble increased following restoration activity within Kingfisher Side-Channel.

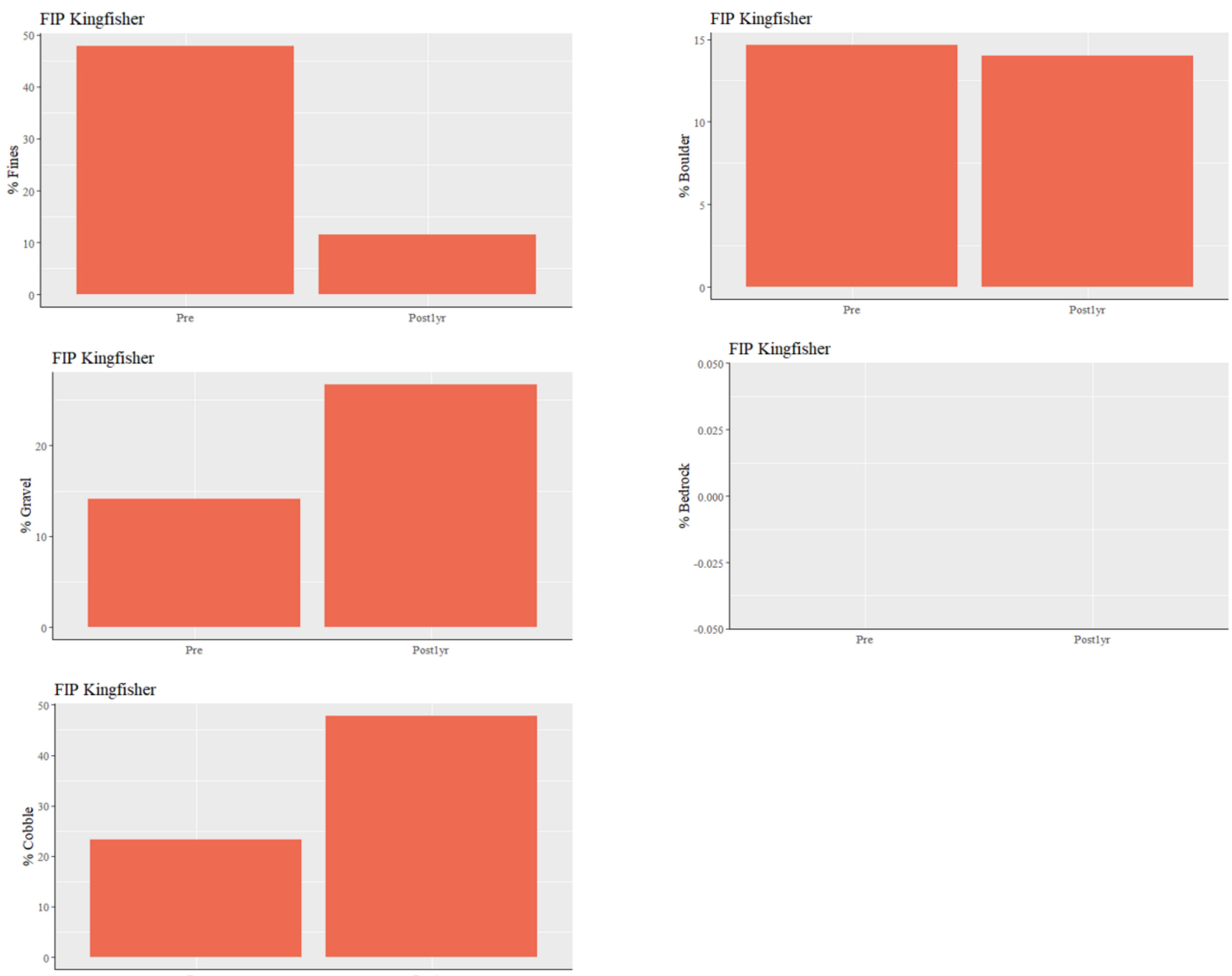

Figure 22. Bar plots describing differences between pre-restoration and post-restoration treatments across bedload percentages of the Kingfisher Side-Channel.

Restoration Assessment – Upper Control Channel

Across channel and pool features within the Upper Control Channel, minor observable differences existed between years of the FIP monitoring effort. The pool habitat dropped, and riffle depth increased (Figure 23).

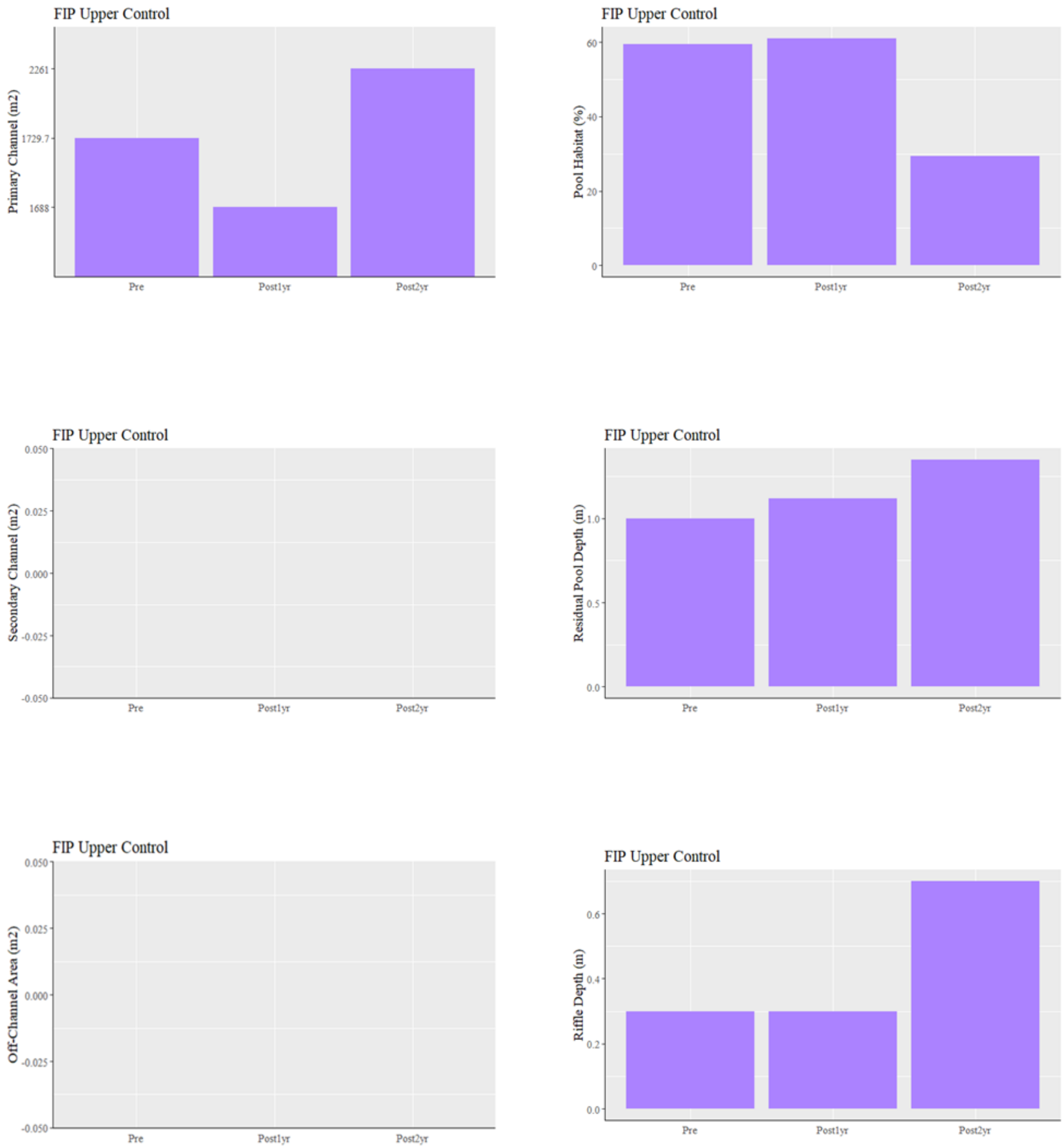

Figure 23. Bar plots describing differences between year one, year two, and year three of the FIP monitoring effort across channel and pool features within the Upper Control Channel.

Wood volume (m^3) noticeably fluctuated over the three-year monitoring cycle, and key pieces of wood remained absent across years in the Upper Control Channel (Figure 24).

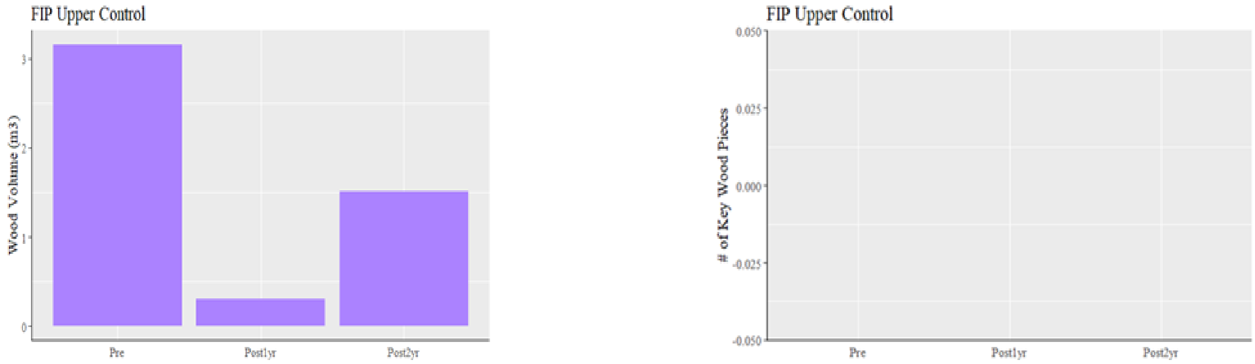

Figure 24. Bar plots for the Upper Control Channel describing differences between year one, year two, and year three year of the FIP monitoring effort for wood volume (m^3) and the number of key pieces of wood (≥ 12 m in length and 60 cm in diameter) (total/ 100m primary channel).

Differences were observed across bedload types within the Upper Control Channel (Figure 25). The percentage of fines (sand and silt), gravel, and bedrock decreased while the percentage of cobble and boulder increased.

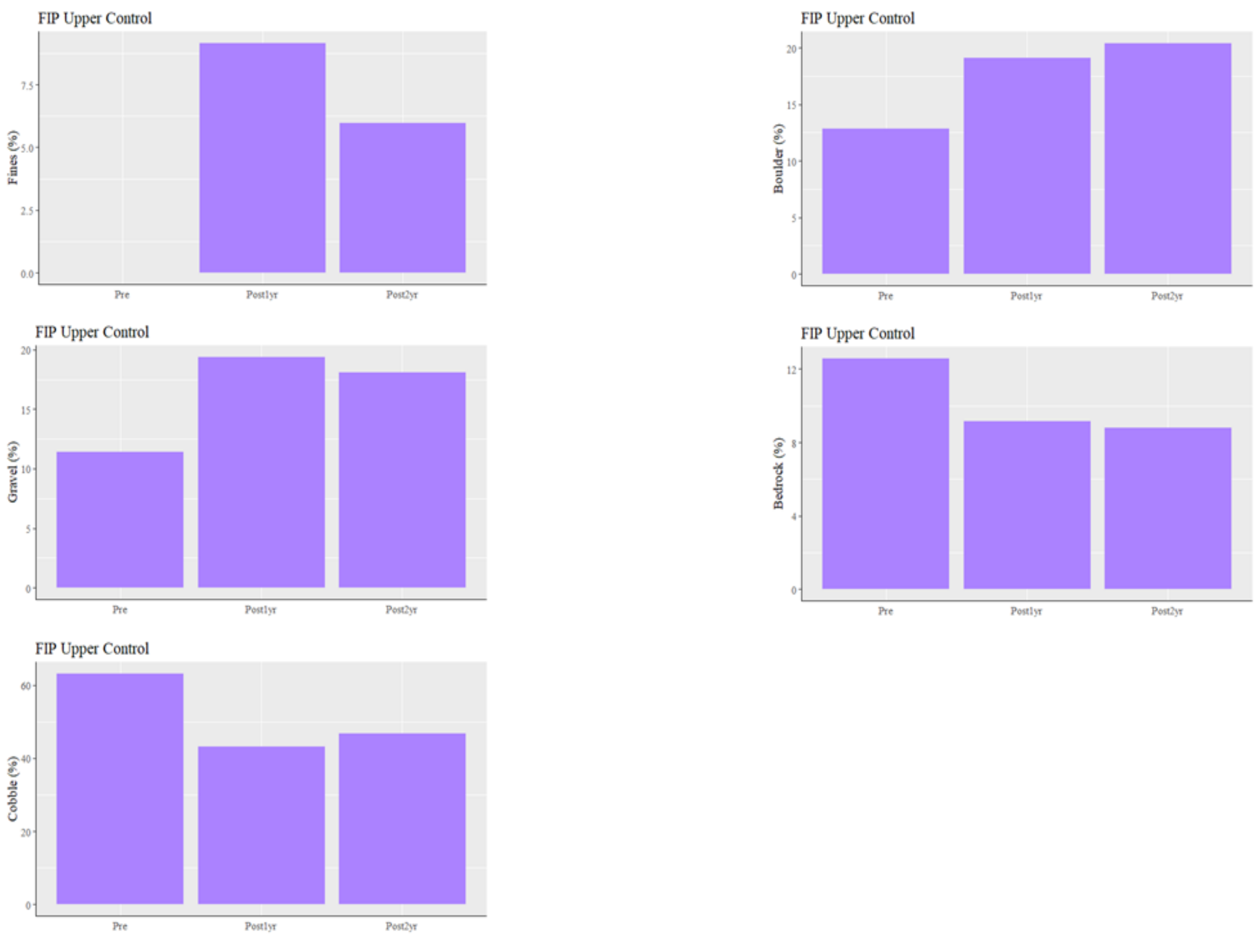

Figure 25. Bar plots for the Upper Control Channel describing differences between three years of monitoring effort across bedload types.

Restoration Assessment – Middle Control Channel

Across channel and pool features within the Middle Control Channel, differences were minimal between years of the FIP monitoring effort (Figure 26). Off-channel habitat (alcoves, backwaters, and isolated pools) decreased slightly, while riffle depth increased somewhat.

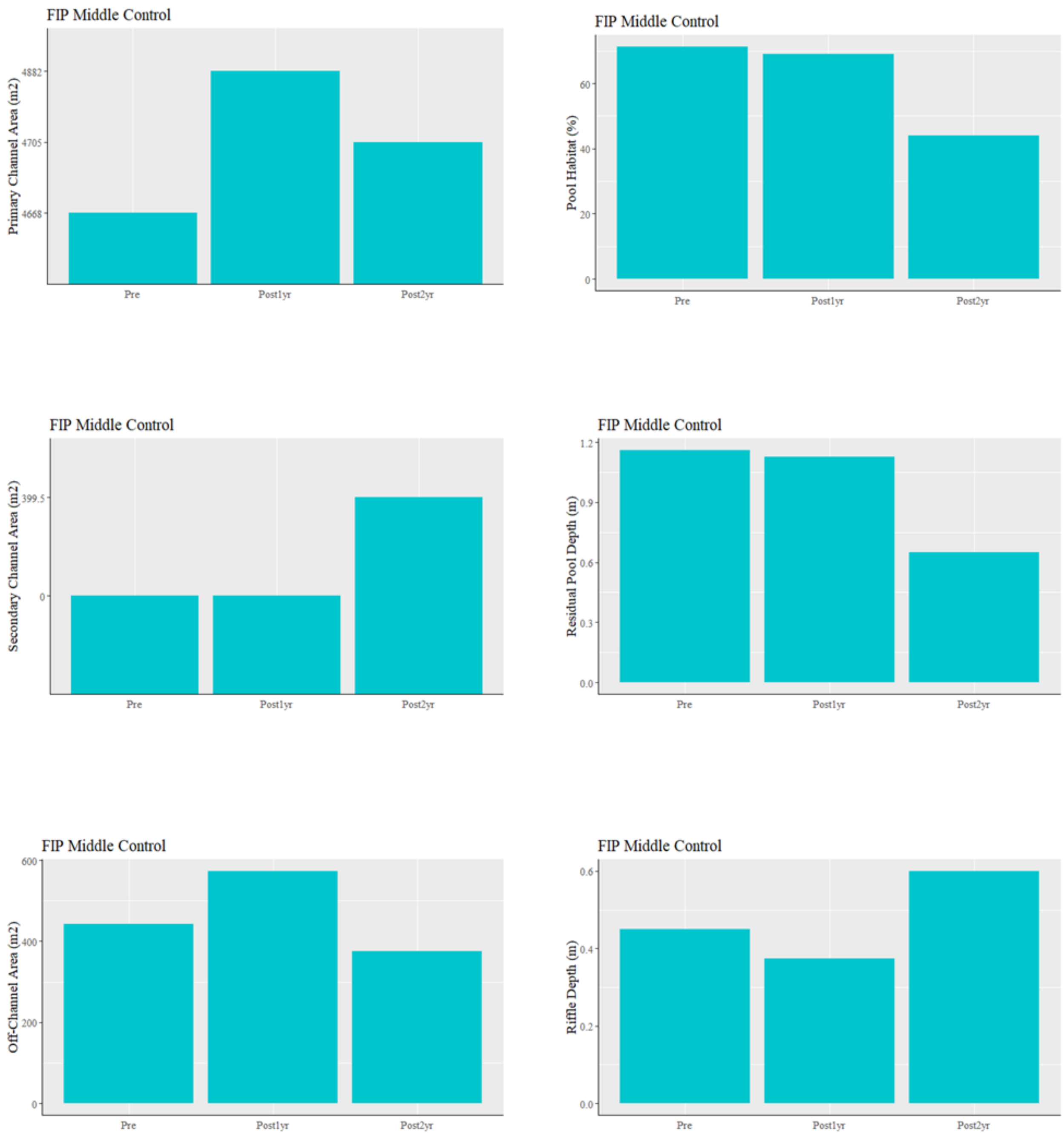

Figure 26. Bar plots describing differences between three years of the FIP monitoring effort across channel and pool features within the Middle Control Channel.

Wood volume (m^3) shifted slightly across years. Key pieces of wood remained absent across years in the Middle Control Channel (Figure 27).

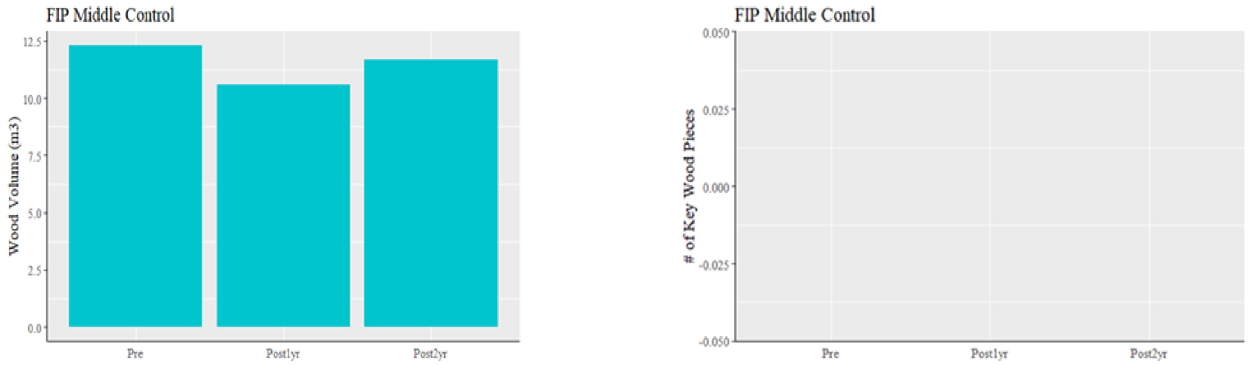

Figure 27. Bar plots for the Middle Control Channel describing differences between year one, year two, and year three of the FIP monitoring effort for wood volume (m^3) and the number of key pieces of wood (≥ 12 m in length and 60 cm in diameter) (total/ 100m primary channel).

Differences were minimal across bedload types within the Middle Control Channel (Figure 28). The percentage of boulders increased significantly, and the percentage of gravel increased during the sampling period.

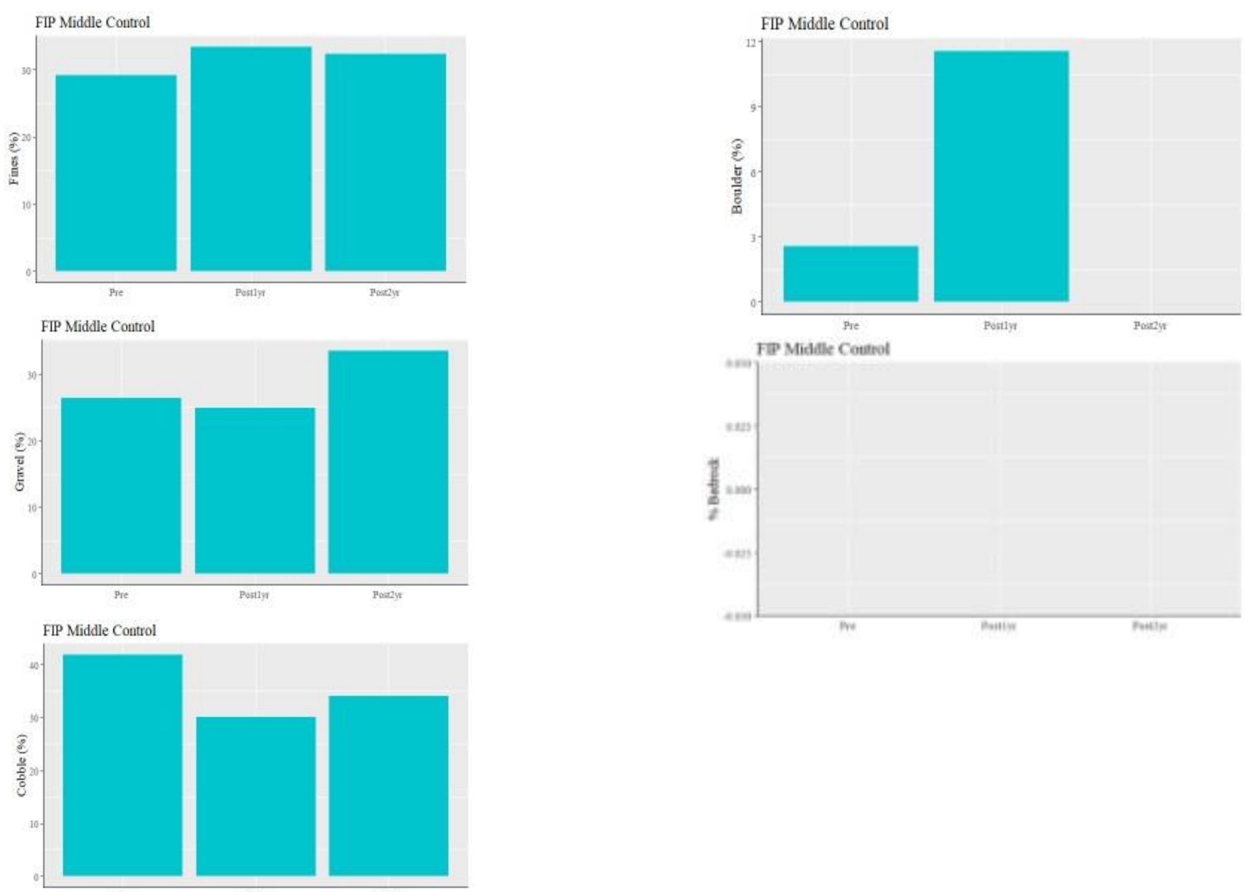

Figure 28. Bar plots for the Middle Control Channel describing differences between year one, year two and year three of monitoring effort across bedload types.

Restoration Assessment – Lower Control Channel

Differences were minimal across channel and pool features within the Lower Control Channel between years of the FIP monitoring effort (Figure 29). The off-channel habitat (alcoves, backwaters, and isolated pools) increased slightly, and the residual pool depth decreased.

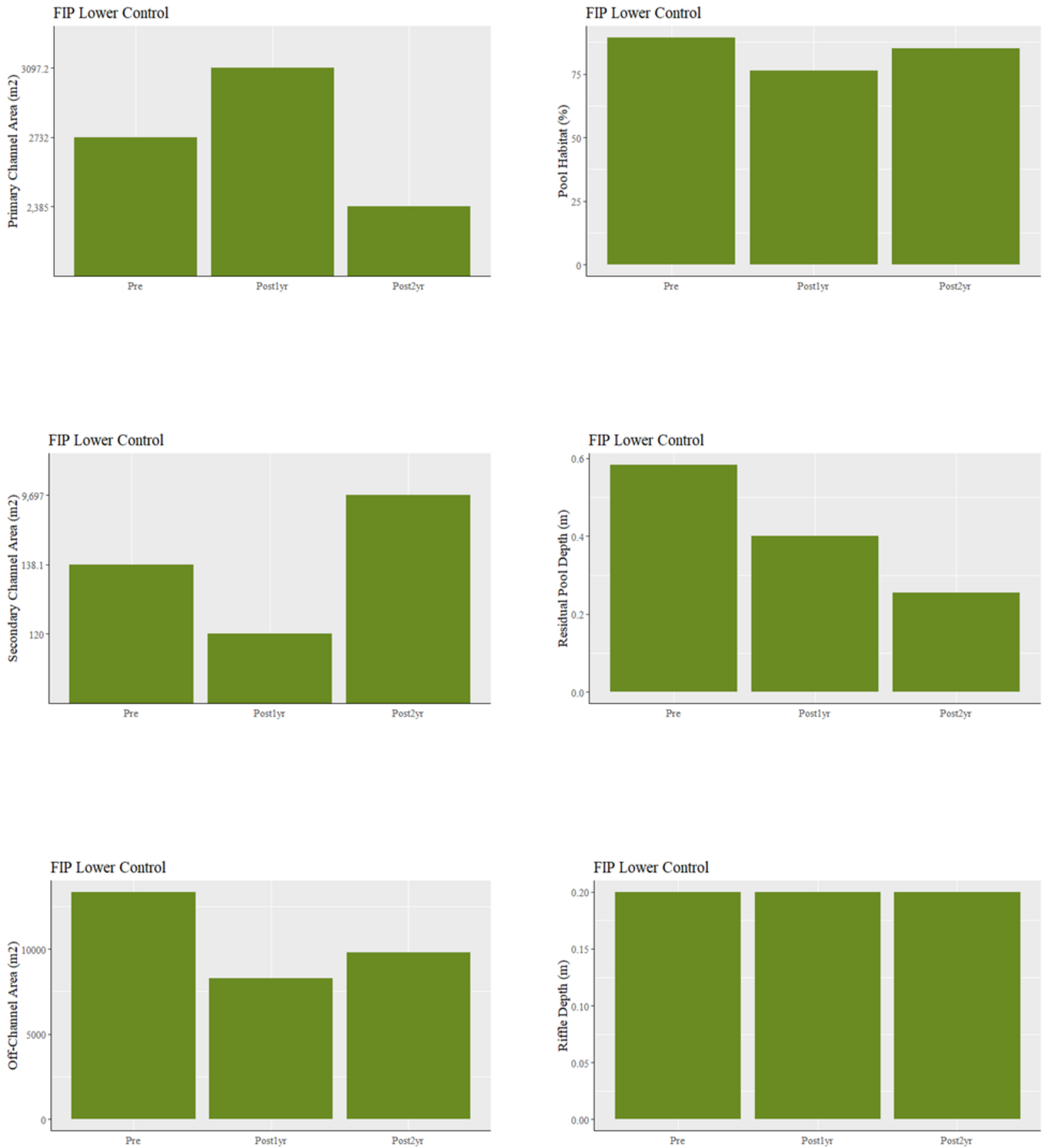

Figure 29. Bar plots describing differences between year one, year two and year three of the FIP monitoring effort across channel and pool features within the Lower Control Channel.

Both wood volume (m^3) and key pieces of wood increased from year one, year two, and year three in the Lower Control Channel (Figure 30).

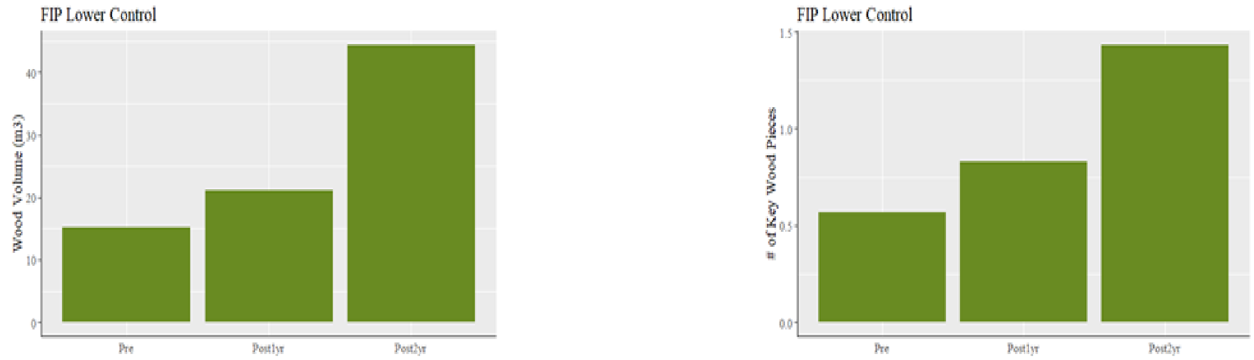

Figure 30. Bar plots for the Lower Control Channel describing differences between year one, year two and year three of the FIP monitoring effort for wood volume (m^3) and the number of key pieces of wood (≥ 12 m in length and 60 cm in diameter) (total/ 100m primary channel).

Across bedload types within the Lower Control Channel, the percent gravel and cobble showed the most significant shifts between years of the monitoring effort. In contrast, the percent of bedrock remained absent (Figure 31).

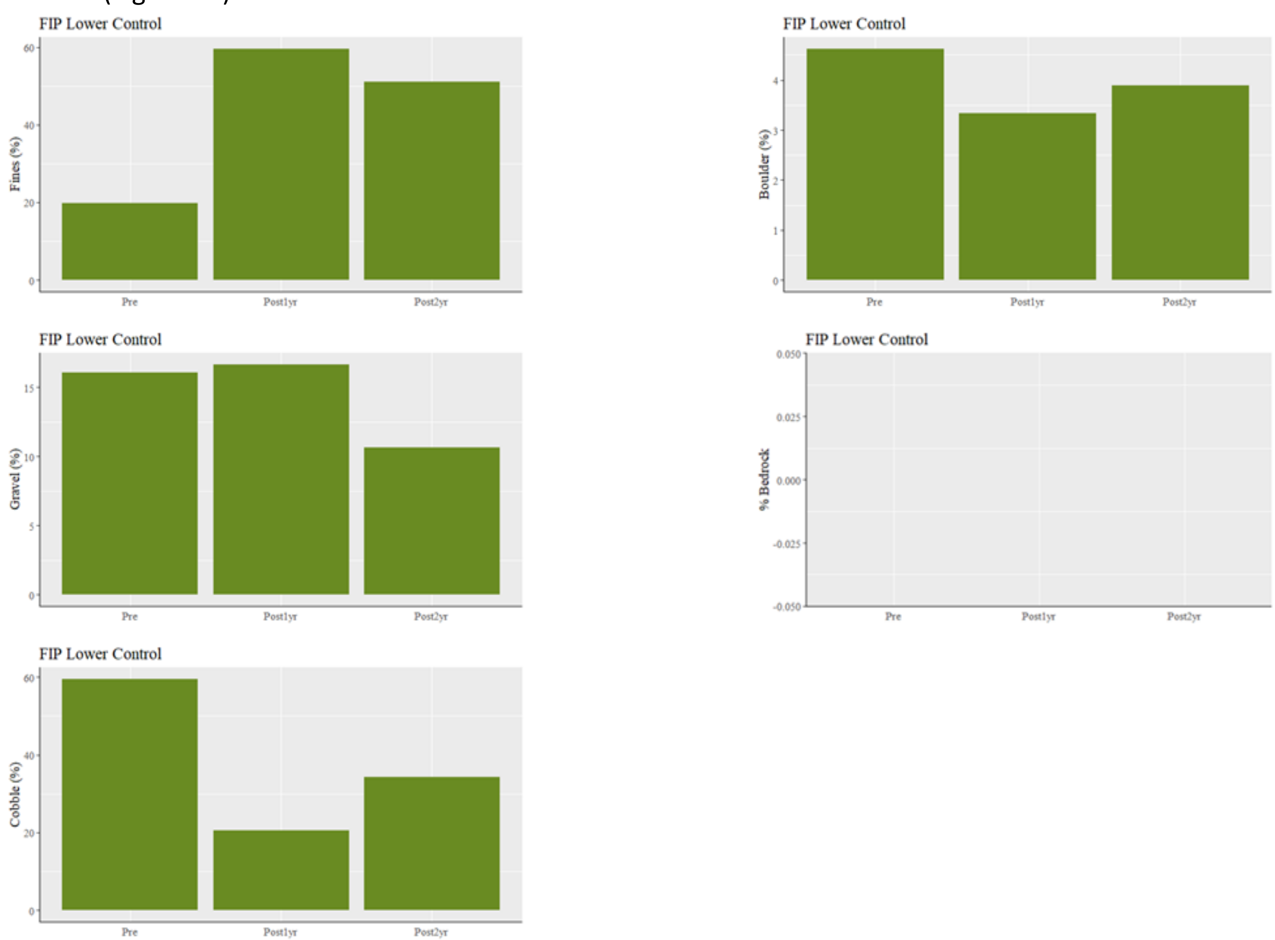

Figure 31. Bar plots for the Lower Control Channel describing differences between year one, year two, and year three of monitoring effort across bedload types.

DISCUSSION

Ongoing restoration efforts to improve habitat conditions are taking place in the Clackamas River Basin. This report outlines the protocols that will be used to compare and evaluate the changes in habitat resulting from these efforts. The monitoring program will utilize both the AQI Program and UAS operations, with a specific emphasis on sites that are scheduled for upcoming restoration work. Baseline data will be collected before restoration, and a follow-up evaluation will be conducted one year after the restoration work is completed. Additionally, select sites will be re-surveyed over multiple years to track the long-term impact of the restoration efforts.

When assessing one-year post-treatment results, the Kingfisher Side-Channel showed differences across habitat attributes. The observations made at the site suggested positive outcomes of the restoration efforts, with several desired differences observed. One such difference was a marked increase in the percentage of gravel and cobble substrates. The most dramatic improvements were seen in the overall wood volume and the number of key pieces of wood in the side channel, which increased following the restoration. The structures added during restoration are expected to remain in the site areas for longer periods due to strategic bolstering and pinning of large wood pieces within the active channel banks. Five-year post-restoration surveys will likely reflect these efforts, and we anticipate an overall increase in wood accumulation. The increase in riffle depth could be explained by the channelization and increase in fast water units created during the restoration process and reconnection to the mainstem Clackamas after restoration activity. Additionally, we saw a decrease in pool habitats along with a decrease in percentage fines.

Kingfisher Side-Channel

After restoration, the Kingfisher Side-Channel experienced desired alterations in its habitat characteristics. The primary channel area and pool habitat saw a noticeable reduction due to the channelization and increased flow volume resulting from the restoration work. To improve the habitat conditions, gravel, and cobble substrates were introduced as part of the restoration effort. In addition, large wood structures and strategically placed wood pieces were added to enhance the habitat quality further.

Upper Control Channel

Compared to the previous year, 2022 showed a slight upsurge in wood volume. However, there was an overall decrease in wood volume over the past three years. This reduction in wood volume (measured in cubic meters) may have been caused by partial inundation of the site during high flows, which prevented wood pieces from remaining in place due to the active channel size and a lack of key pieces. Differences in the fine, gravel, and cobble substrates can be attributed to the high winter flows and minimal structure, which allowed for the movement of bedload types during the winter season.

Middle Control Channel

An increase in secondary channel habitat was due to higher flows increasing the output of the small, connected tributary. Pool habitat decreased due to the margins of fast water units being enlarged by the higher flows. Although only slight variations were observed between the sampling years, it is worth noting that the Middle Control Channel is directly connected to the mainstem Clackamas River. As a result, during periods of high flows, bedload types and wood pieces are likely to be displaced and replaced.

Lower Control Channel

The rise in wood volume in the Lower Control Channel resulted from the increased flow, which pushed sizeable wood pieces into the alcove at the head of the side channel. Notably, a large wood jam in the alcove is accumulating many wood pieces. However, the decrease in primary and secondary areas is a consequence of low to dry seasonal flow, which contrasts with previous seasons.

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