Icicle Creek Reach Assessment

Appendix A | Habitat Assessment

Icicle Creek (RM 0 – 22.02)

February 2026

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1 Introduction & Background

Icicle Creek originates from Josephine Lake in the Alpine Lakes Wilderness on the eastern side of the North Cascade Mountains in central Washington. It is approximately 32.75 river miles long and flows east-southeast through the foothills and joins the Wenatchee River near the town of Leavenworth. Icicle Creek is the largest tributary drainage of the Wenatchee River.

The Yakama Nation identified the lower 22.02 miles of Icicle Creek for assessment and potential restoration efforts for native salmon and trout populations. This Icicle Creek Habitat Assessment was completed on behalf of the Yakama Nation as part of their efforts to assess and improve Threatened and Endangered salmon and trout habitat within the Columbia River Basin. As part of the assessment process, Inter-Fluve conducted this salmonid habitat survey of Icicle Creek between July 29th and September 26th, 2024. Habitat survey crews started at RM 0 (confluence with the Wenatchee River) and worked upstream to RM 22.02 (0.9 miles from the end of U.S. Forest Service [USFS] Forest Road [FR] 7609). River miles (RM) were based on those available from the Upper Columbia Salmon Recovery Board (UCSRB) but were modified to include the historical channel alignment located at the Leavenworth National Fish Hatchery (LNFH).

The assessment was divided into 20 distinct geomorphic reaches. Reach breaks used for the Icicle Creek habitat assessment were based on the Upper Columbia Salmon Recovery Board reach boundaries, with some modifications (Upper Columbia Spatial Framework, 2021). Due to the modifications made to river miles to include the historical channel alignment near the hatchery, the length of Reach 3 increased (approximately 1.28 miles, compared to the UCSRB Reach 3 length of approximately 0.8 miles). As a result of the river miles adjustment in Reach 3, upstream reaches start and stop at different river miles than the UCSRB reaches. The updated river miles are referenced in maps provided below and Inter-Fluve recognizes that the river miles used in this assessment will vary from other completed assessments and reports. A comparison of river miles used in this report and those used by UCSRB can be found in Table 1 of Section 2.1 in the Main Report. Field surveys followed the USFS Stream Inventory Handbook: Level I & II, Pacific Northwest Region (USFS, 2020). A flow rate of 191 cubic feet per second (cfs) was measured in the field at RM 8.3 on July 30th, 2.9 miles upstream from the USGS River Gauge #12458000 above Snow Creek. A flow rate of 188 cfs was measured at the same location of the USGS River Gauge on July 30th, 2024 (USGS, 2024). Insignificant precipitation was received over the survey period and stream flow was not otherwise measured as part of this survey.

The objective of this Habitat Assessment is to characterize the habitat quantity and quality for salmonid species native to Icicle Creek by quantifying in-channel morphologic features, characterizing riparian conditions, and identifying anthropogenic features influencing aquatic habitat. This information is used to inform potential restoration and conservation actions and will provide a baseline for evaluating future habitat trends and measuring the effectiveness of restoration efforts to improve the quantity and quality of available habitat within the study area.

1.1 COMPARISON TO PREVIOUS SALMON HABITAT ASSESSMENTS

Stream habitat surveys have been previously completed in lower Icicle Creek between the mouth and RM 3 by The Watershed Company (2005) for the Icicle Valley Chapter of Trout Unlimited, between the mouth

and RM 4.3 by Natural Systems Design for Chelan County Natural Resources (Natural Systems Design, 2017), and between RM 0 and RM 30.2 by Cramer Fish Studies (Camp et al. 2023). A brief summary of the results from these surveys is provided below.

Other studies conducted on Icicle Creek include:

- Fish passage assessment in Icicle Creek's Boulder Field (approx. RM 5.6; Dominguez et al. 2013),
- Reach Geomorphic, Hydraulic and Habitat Assessment (RM 3 – RM 4.5; Katz et al., 2023),
- Streamflow study (Mauger et al. 2017),
- Bull Trout and Redd survey (Nelson et al. 2009), and
- Biomass assessment for the Leavenworth National Fish Hatchery (Leavenworth National Fish Hatchery, 2006).

1.1.1 2005 Reach Assessment Summary

The Watershed Company conducted a Reach Level Assessment in 2005 on lower Icicle Creek (RM 0 – 3) for the Icicle Valley Chapter of Trout Unlimited. The Watershed Company followed Rosgen (1996) and Rosgen (2001) methodologies to quantity large woody debris (LWM), streambank vegetation (riparian vegetation), and stream bed gravel. Rosgen (1996, 2001) methods include classifying stream reaches based on geomorphic qualities. The study measured the average channel gradient for the first three miles as 0.17% compared to an estimate of 0.09% by Inter-Fluve in 2025. The Watershed Company study intended to compare lower Icicle Creek to a reference river system, in this case the lower White River. Riparian vegetation was based on density (i.e., bare, forbs only, annual grass with forbs, perennial grass, rhizomatous grasses, low brush, high brush, combination grass/brush, deciduous with brush/grass understory, perennial overstory, wetland vegetation community), while Inter-Fluve identified species and size class. Wood debris was also measured based on density of channel blockage from floatable material (i.e., leaves, needles, small limbs to "dams" of larger material occupying 30-50% of the active channel cross section). Individual pieces of LWM were not identified in the Watershed Company's study. Due to the highly different methods of data classification, the 2005 study results cannot be readily compared.

1.1.2 2017 Reach Assessment Summary

A reach assessment and habitat survey was performed on the lower 3 miles of Icicle Creek in 2016 by Natural Systems Designs (NSD) for Chelan County Natural Resources Department (CCNRD) (Natural Systems Design, 2017). The survey followed USFS Levell II Stream Inventory protocol, with modifications, and was conducted in September 2016.

Habitat unit composition at the time of the 2016 survey recorded pool habitat as the dominant habitat type (46%) in the CCNRD study area (RM 0-3), followed by riffle (44%) and glide (10%) habitat types. In comparison, the Inter-Fluve habitat survey (2024) recorded a higher proportion of pool habitat (84%), followed by glide (14%), then side channels (2%), and riffles only comprised 1% of the habitat area in the same river miles (0-3). NSD identified 22 pools and measured pool spacing at 7 pools per mile in 2016. Inter-Fluve identified 19 pools and measured pool spacing at 6.3 pools per mile. Although there are notable discrepancies in reported pool and riffle composition between the two surveys, we do not believe

these are indicative of major channel changes since 2016. This is based on the geomorphology assessment, which did not identify significant changes to channel planform or longitudinal profile. Assuming the same protocols were applied to both habitat surveys, the discrepancies are assumed to be related to different flow conditions at the time of surveys and/or different interpretations or biases of the different survey teams.

For LWM, the methods used by NSD (2016) and Inter-Fluve (2024) differed. The 2016 surveys used procedures from the Washington Salmon Recovery Funding Board whereas the 2024 surveys used the USFS Level II protocols. The 2016 surveys used a smaller size threshold for qualifying pieces (>5 feet in length and >4 inches diameter) compared to the 2024 surveys (>20 feet in length and >6 inches diameter). In addition, for pieces embedded in the bank or partially within the bankfull channel, the 2016 surveys only counted the piece if the exposed portion of the piece within the bankfull channel cross-section met the minimum size criteria. In the USFS protocol, if any portion of the piece is within the bankfull channel cross-section then the piece is counted. In the 2024 surveys, pieces of wood within jams were counted if they met the size criteria. It was not clear if wood in jams was recorded in the 2016 surveys. A total of 119 LWM pieces were recorded by NSD in 2016. In comparison, Inter-Fluve recorded 267 LWM pieces in this same section of channel. It is expected that over 8 years, there could be changes to LWM quantities in these reaches due to the large channel that is capable of readily transporting LWM, and these numbers are potentially reflecting a positive trend of increasing wood abundance. There were also additions of wood as part of habitat restoration work at a project site near RM 0.93, which accounts for approximately 69 pieces. Drawing definitive conclusions with respect to trends is challenging, however, due to the use of different survey methodologies which would be expected to result in different wood tallies.

1.1.3 2023 Habitat Assessment and Reach Characterization Summary

A rapid habitat assessment was completed on Icicle Creek by Cramer Fish Sciences (henceforth, Cramer) in September 2023 for CCNRD (Camp et al., 2023). The Cramer surveys were performed to support the Columbia Habitat Prioritization Tool (UCRTT, 2022). The surveys had similar but slightly different objectives, spatial extents, and methods compared to this reach assessment.

A "rapid habitat assessment" field protocol was developed for Cramer's assessment. This was based on the USFS Level II Stream Inventory protocol but did not include the full suite of Level II measurements. Cramer's field data collection also had a slightly different spatial extent. The survey did not include RM 3 to RM 9.63, from the Leavenworth National Fish Hatchery to Eight Mile Creek (Inter-Fluve Reaches 3-8), and their surveys extended further upstream than the Inter-Fluve surveys. Cramer categorized Icicle Creek into three reach groups – Lower reaches (Lower 01, Lower 02; RM 0 – RM 3), middle reaches (Middle 01 to Middle 10; RM 9.63 – RM 22.72), and upper reaches (Upper 01 to Upper 05; RM 22.72 – RM 30.2). The Inter-Fluve survey ended 0.7 miles downstream of the upstream end of Cramer Middle 10, below French Creek (RM 22).

Average wetted and bankfull widths recorded in the Lower Reaches (Inter-Fluve Reach 1 and Reach 2), downstream of the Leavenworth National Fish Hatchery, were similar across both the Cramer and Inter-Fluve assessments, with average wetted widths of 100.6 feet (Cramer) and 96 feet (Inter-Fluve) and average bankfull widths of 118.4 feet (Cramer) and 120 feet (Inter-Fluve). Similarly minor differences

were present in the wetted and bankfull widths recorded for the middle reaches (Inter-Fluve Reach 9 to Reach 20).

LWM survey methods were similar for the Cramer and Inter-Fluve assessments, with the exception of LWM size classes and log jams. Cramer's wood counts included LWM pieces with estimated lengths greater than 35 feet and diameters greater than 12 inches (i.e., medium size class or larger in the USFS Level II protocol). Cramer did not record LWM in the small size class (length >20 feet and diameter >6 inches), whereas Inter-Fluve did record small size LWM. With respect to jams, Cramer's assessment used a threshold of 10 or more qualifying pieces, whereas Inter-Fluve used a threshold of 3 or more qualifying pieces. In both assessments, jam locations, instream function, recruitment potential, and recruitment sources for LWM were documented. For the lower reaches (RM 0-3), Cramer recorded 62 pieces and three jams, whereas Inter-Fluve recorded 65 pieces (Medium or larger, for comparison) and 7 jams. These total numbers are similar, and jam number differences are not comparable due to different jam criteria. For the middle reaches, a direct comparison is challenging due to a slightly different upstream boundary to this segment (RM 22.72 in Cramer survey and RM 22 in Inter-Fluve survey). The Cramer total was 628 pieces, whereas the Inter-Fluve total was 847 pieces. The reason for the differences between these two surveys is uncertain. It potentially reflects a real change in wood numbers; however, a net gain of over 200 pieces is unlikely given the lack of a significant flow event (based on gage records) between the two survey periods. It more likely represents different field survey techniques. The Cramer survey was described as a "rapid habitat assessment protocol" and was performed "primarily via foot" (Camp et al., 2023), whereas the 2024 survey followed the full USFS Level II protocol, which included surveyors walking all reaches and recording detailed habitat attributes, including wood, at the habitat unit scale.

Methods for recording pool habitat types also differed between the Cramer and Inter-Fluve surveys. Both assessments followed the USFS Levell II protocol, but Cramer used the PacFish InFish Biological Opinion (PIBO) Monitoring Program pool qualifier definition to identify pools, which states "a pool must span 50% of the wetted channel width and have maximum depth of at least 1.5 times greater than the pool tail depth". The USFS Level II protocol delineates a slow water habitat (pool) as having "little/no surface gradient, a hydraulic control, and a residual pool depth" (USFS, 2020) and does not include the relationship between the maximum depth and pool tail crest depth. The average number of pools recorded by Cramer in the lower reaches (RM 0-3) was 5.5 pools per mile compared to 6 pools per mile recorded by Inter-Fluve. In the middle reaches, Cramer recorded 23.2 pools per mile and Inter-Fluve recorded 8.2 pools per mile. These discrepancies are assumed to be due to the use of different pool criteria, as opposed to channel changes, which did not measurably change between survey years (2023 versus 2024).

2 Methods

The Icicle Creek study area (RM 0 – 22.02) was subdivided into 20 distinct reaches based primarily on geomorphic indicators. The 20 reach delineations were used for both the habitat reach assessment as well as the geomorphic reach assessment and restoration strategy as documented in Section 3 of the main report and Appendix C.

The habitat assessment employed the methods outlined in the US Forest Service Stream Inventory Handbook: Level I & II, Pacific Northwest Region, Version 2.20 (USFS, 2020). The "Eastside Forest

Option" protocol, which includes data categorizations for large wood and riparian vegetation specific to ecosystems east of the Cascade Crest, was used. All protocols were followed when safe and most of the suggested forest inventory options were applied in the survey. Due to unsafe conditions within the stream channel, surveyors estimated some instream measurement from the bank; more details are in Section 4 in this Appendix. Adaptions to the USFS Eastside protocol were made for this survey. Those adaptations include:

- All reach and habitat unit lengths were measured in GIS from GPS data recorded in the field. Habitat units were delineated by survey points collected with a Juniper Systems Geode unit (sub-foot accuracy).
- Floodplain width was calculated using LiDAR and 2D hydraulic modeling results.
- Field data was collected digitally, using an iPad and ESRI Field Maps software. The Special Case field data was collected using a printed copy of the Special Case form.

At all channel units, surveyors performed an ocular estimate of wetted width and at n^{th} units performed a measured wetted width using a laser rangefinder to calibrate their ocular estimate. A bankfull measurement was performed at the first three fast water channel units (riffle or glide) per reach when safe, and then at every n^{th} unit after. The n^{th} channel unit (riffle, pool, glide) measurement frequency applied in the field for data collected was 20%, or every 5th unit, for both fast- and slow-water channel unit types. If fewer than three fast-water units were encountered in a reach, bankfull measurements were collected at slow water units instead. The length of anthropogenically-induced unstable banks was recorded for both the left and right channel banks in all units. Water depths for all habitat units were measured using a graduated stadia rod carried by the observer, or estimated if depths or velocities exceeded the wading ability of the observer. Water temperature and stream flow measurements were recorded for tributaries when safely accessible. Water temperatures were taken for the tributary and in the main channel upstream of tributary influence and downstream of tributary confluence.

For riparian vegetation measurements, the riparian corridor can be defined as either a single 100-feet wide zone or two adjacent riparian zones (inner and outer zones) totaling 100 feet in width (USFS, 2020). For this assessment, one single 100-feet wide riparian zone was designated for the Icicle Creek study area. Survey methods dictate defining a dominant size class of vegetation type within the riparian corridor (e.g. small tree, shrubs), then defining the dominant species observed in the overstory and understory. Survey protocol differed from the USFS protocol by collecting dominant overstory class and species, and a dominant understory species within the 100-feet wide riparian zone in addition to class size (USFS, 2020).

Gravel counts were performed as part of the geomorphic survey to characterize the size distribution of bedload sediment. In total, 26 gravel counts were completed. Two gravel counts were completed in each of the reaches, except for Reach 3, Reach 9 and Reach 12, where only one gravel count was completed due to concerns of surveyor safety or lack of channel bed complexity. Three gravel counts were completed in Reach 19. Reaches 5, 6, 7, 11, 13 and 18 did not have a gravel count completed due to safety reasons. Gravel count locations were selected as representative of the general character of the reach.

For this habitat survey, side channels were defined as naturally wetted flow paths connected to the mainstem channel at their upstream and downstream ends at low flow. Side channel units were

identified when the main channel split to form a stable island with soil or fine sediment accumulations and with established vegetation older than 2 to 3 years. Each side channel was determined to be predominantly fast-water or slow-water unit type. Total lengths of the side channels were recorded using GPS following the same protocols used for main channel unit delineation. If the entire side channel was not wet at the time of survey, the length of the wetted portion of the side channel was estimated. This report provides data based on total side channel lengths, unless otherwise noted.

LWM was counted in the mainstem and side channels following the size class characterizations for "Eastside" forests. Tallies of small (> 6 in. diameter, >20 feet long), Medium (>12 in. diameter, > 35 feet long) and Large (>20 in. diameter, >35 feet long) pieces of LWM were completed for each reach. A log jam was classified as a group of three or more pieces of qualifying size (meets the size requirements above) in contact with one another and with at least one piece within bankfull. For the log jam count in the habitat survey, both a within bankfull count (number of pieces within bankfull) and total count was performed (number of pieces within and outside of bankfull). The within bankfull count was used for this report. Geomorphic function of the jam, as well as whether the jam was of natural origin or constructed as a part of habitat enhancement efforts in the basin, was also noted. More information on the jams can be found in Section 2.9 of the main report.

3 Summary of Results

This section summarizes the results for all 20 reaches surveyed in Icicle Creek between July 27th to September 29th, 2024, from RM 0 (confluence with the Wenatchee River) to RM 22.02 (study area extent). Detailed reach summaries with reach-specific results are included in Section 4 of this report.

3.1 CHANNEL MORPHOLOGY

Within the assessment area, the channel morphology of Icicle Creek can be divided into three distinct segments. The downstream reaches (Reaches 1-3) are located within the wide Lower Icicle Creek valley and have relatively low channel gradients, on average less than 0.3%. These reaches have low natural confinement from hillslopes and alluvial fans. Meander scars provide evidence of historical lateral migration. Infrastructure, the Leavenworth National Fish Hatchery and residential areas are present on the floodplains and terraces within these lower reaches.

In contrast to the downstream reaches, the middle reaches (Reach 4 – Reach 14) exhibit an increase in the level of hillslope and alluvial fan confinement, with bedrock outcrops present. The channel alternates between confined and partially confined through these reaches. The slope gradient in Reaches 4 to Reach 14 is significantly higher than the downstream reaches. In the confined reaches (Reach 5, Reach 6, Reach 9, and Reach 11- Reach 13), the channel exhibits a lower sinuosity than reaches that are partially confined (Reach 7, Reach 8, Reach 10 and Reach 14). In the partially confined reaches, more LWM was recorded and large boulder split flow into multi-threaded channel created pockets for sediment accumulation and supporting vegetated islands. In the uppermost reaches of the study area (Reach 15 -Reach 20), the channel is single-thread and relatively straight. Side channels are minimal due to presence of terraces, alluvial fans and hillslopes. A summary table for channel morphology metrics recording in Icicle Creek during the 2024 field habitat surveys is found in Table 2.

Table 2. Icicle Creek bankfull width results from habitat assessment.

Bankfull Widths (feet)																				
	Reach 1	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**	**Reach 7**	**Reach 8**	**Reach 9**	**Reach 10**	**Reach 11**	**Reach 12**	**Reach 13**	**Reach 14**	**Reach 15**	**Reach 16**	**Reach 17**	**Reach 18**	**Reach 19**	**Reach 20**
Max	130	120	70	120	90	110	120	119	99	114	80	102	87	92	117	102	80	98	95	95
Min	120	20	40	80	90	50	90	116	94	75	72	80	84	72	92	93	75	60	69	81
Mean	125	83	57	100	90	80	102	118	97	99	76	92	86	85	105	98	78	79	82	86
St Dev	7.1	55	15	28	0	42	16	2	4	21	4	10	2	9	11	6	4	14	13	7
Flood Prone Widths (feet)																				
	Reach 1	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**	**Reach 7**	**Reach 8**	**Reach 9**	**Reach 10**	**Reach 11**	**Reach 12**	**Reach 13**	**Reach 14**	**Reach 15**	**Reach 16**	**Reach 17**	**Reach 18**	**Reach 19**	**Reach 20**
Max	2077	336	280	190	219	141	110	362	150	171	104	113	121	110	505	172	210	83	366	439
Min	1190	260	152	190	108	110	100	147	142	99	75	88	99	88	109	140	93	72	288	95
Mean	1634	298	204	190	161	126	105	255	146	145	91	103	110	101	217	156	148	76	326	215
St Dev	627	38	55	0	45	16	4	108	4	33	12	10	11	8	166	16	49	5	32	136
Bankfull Depths (feet)																				
	Reach 1	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**	**Reach 7**	**Reach 8**	**Reach 9**	**Reach 10**	**Reach 11**	**Reach 12**	**Reach 13**	**Reach 14**	**Reach 15**	**Reach 16**	**Reach 17**	**Reach 18**	**Reach 19**	**Reach 20**
Max	6.1	6.3	5.6	10.8	8.5	11.1	10.2	8.1	7.2	6.3	8.8	7.5	6.4	7.2	6.4	7.5	8.2	6.5	6.8	5.7
Min	2.6	3.2	0.5	3.3	2	1.5	2	1.8	1.3	1.9	0.5	0.5	1.4	1.6	0.2	1.6	1.6	1.8	2.4	0.6
Mean	4.5	5.4	4.3	8.1	6.3	6.7	5.3	5	4.6	4.5	5.7	5.1	4.5	5.1	4.8	4.5	5.2	4.1	4.8	4.2
St Dev	1	0.8	1.4	1.9	1.9	3.1	2.3	1.9	1.6	1.1	2.1	1.6	1.1	1.3	1.4	1.5	2.3	1	1.3	1

3.2 HABITAT UNIT COMPOSITION

Within the surveyed area, riffles and pools are the dominant habitat type, comprising 48.6% and 36%, respectively of the total area of the channel. Glides comprise 8.6%, side channels comprise 6.5%, and cascades comprise 0.3% of the total aquatic habitat area (Figure 1 and Figure 2). A single cascade unit was recorded in Reaches 5, 6 and 17. Reach 2 maintains the highest percentage of pool habitat at 91% and Reach 10 the lowest at nearly 6%. Side channel habitat area was comparatively low across the study area with no side channel habitat in Reaches 6, 11, 13, 15, and 20. The reach with the highest percentage of side channel habitat was Reach 8 at 22%. Reach 3 consisted of the natural channel and an artificial hatchery diversion channel for the Leavenworth National Fish Hatchery. More information on the Leavenworth National Fish Hatchery can be found in Section 2.5.3 of the main report. The diversion channel is only wet at high flows and is controlled via an inlet structure at the upstream end. A greater proportion of fast water units was present in Reaches 4 - 18 compared to Reaches 1 – 3.

The mean residual pool depth ranged from 2.4 feet (lowest; Reach 16) to 7 feet (highest; Reach 17). Overall, the mean residual pool depth across all reaches was 4.4 feet (Figure 3). The deepest pools were found in Reaches 1, 17, 18 and 20 where a pool was estimated to be 15 feet or greater. Several reaches had high numbers of deep pools (residual pool depth > 3 feet), including Reach 19, Reach 2 and Reach 4. Notably, Reach 4 had the highest percentage of pools greater than six feet (100%). Overall, the pools in Reach 3 were the shallowest. A summary of all data recorded is provided in Table 53 in Section 4.21 of this Appendix.

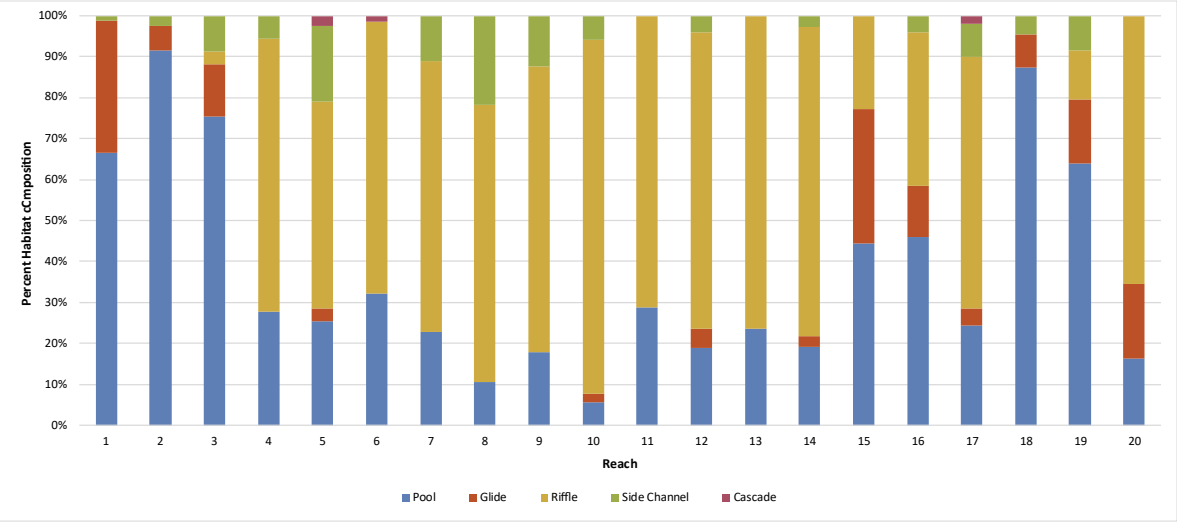


Figure 1. Figure illustrates habitat unit composition (as a percentage of total area) for each of the 20 reaches.

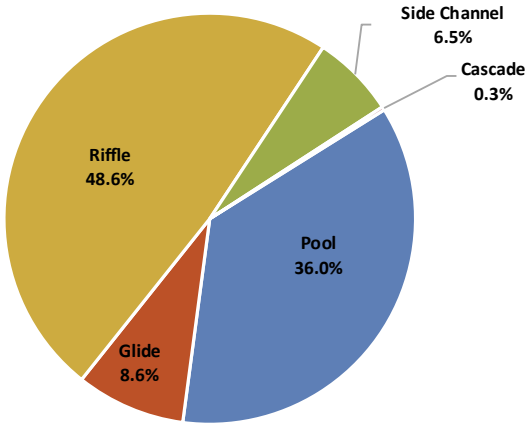


Figure 2. Figure illustrates the habitat unit composition for the entire study area.

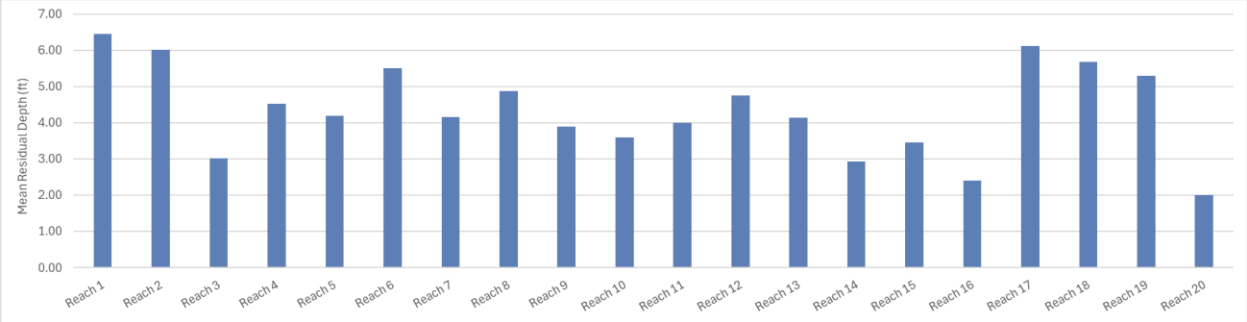


Figure 3. Mean residual pool depth for Icicle Creek.

3.3 SIDE CHANNEL HABITAT

Overall side channel habitat throughout the surveyed area accounts for approximately 7% of the surface habitat area. In total, 63 side channel units exist, averaging three side channels per mile of stream. The side channels average 423 feet in length and 23 feet in width (wetted width). The total side channel length throughout all reaches is 5.05 miles. The side channels contain a total of 655 pieces of Large Woody Material (LWM).

3.4 LARGE WOODY MATERIAL (LWM)

A total of 4,071 pieces of LWM were counted in the study area averaging 185 pieces per mile; 46% were small LWM pieces with diameters between 6 and 12 inches and lengths greater than 20 feet, 37% were medium LWM pieces with diameters between 12 and 20 inches and lengths greater than 30 feet, and 17% were large LWM pieces with diameters over 20 inches and lengths greater than 30 feet. Of all the reaches in the Icicle Creek study area, Reach 8 had the highest amount of LWM recorded, including 237 pieces of medium and large LWM per mile (Figure 4). Reach 3 maintained the least LWM per mile with only 10 pieces of medium and large LWM pieces per mile and 48 total pieces of LWM per mile. A total of 169 log jams was recorded in the study area; to classify as a jam, at least three qualifying pieces of LWM was required.

Fox and Bolton (Fox and Bolton 2007) conducted instream large wood surveys in unmanaged streams across Washington State to help understand natural wood loading conditions. As part of their study, they

compared their data to the National Marine Fisheries Service (NMFS) properly functioning conditions threshold (1996) that are based on sizes exceeding the "medium" size class used by the USFS in the Level 2 survey protocols (2020; ≥12 in diameter and at least 35 ft long). The Fox and Bolton (Fox and Bolton 2007) 75th percentile of wood loading was 67.45 pieces per mile for unmanaged streams in eastside forests. For this Icicle Creek Reach Assessment, we chose the 75th percentile value to use as a comparison to observed conditions in Icicle Creek, since this is believed to be a reasonable target for restoration of natural wood loading ranges across the landscape by Fox and Bolton (Fox and Bolton 2007). Therefore, the "adequate" threshold for LWM in Icicle Creek is > 67.45 pieces per mile of medium and large size class wood, with additional woody debris available for long-term recruitment. There are 31 pieces of large LWM pieces per mile average across the whole study area. There are 69 pieces of medium LWM pieces per mile across the whole study area. Reach 1, Reach 2, Reach 3, Reach 6, Reach 11, Reach 12, Reach 13, and Reach 18 however, do not maintain "adequate" threshold for LWM; Reach 3 having only 10 pieces of medium and large LWM per mile.

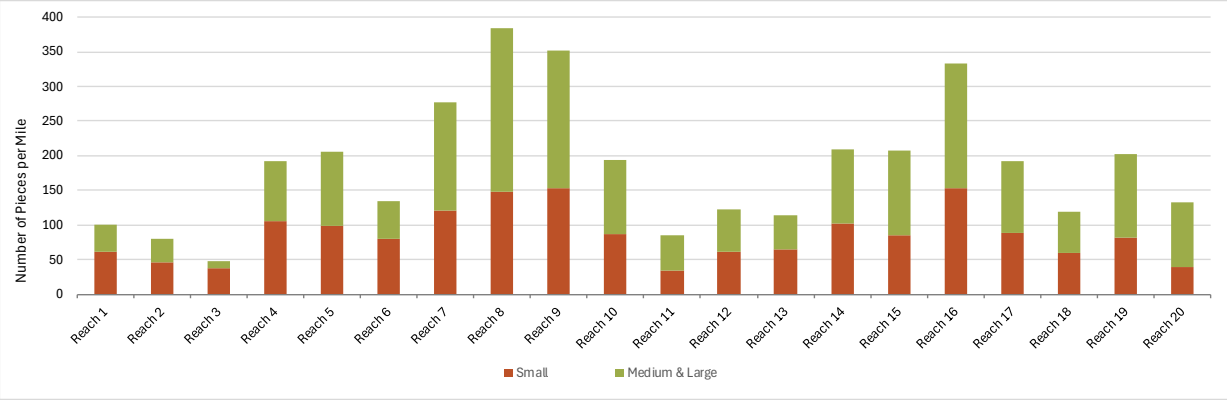


Figure 4. Summary of LWM pieces per mile recorded in each Icicle Creek reach during the 2024 surveys, classified by small size class LWM and Medium and Large combined size classes of LWM.

3.5 SUBSTRATE & FINE SEDIMENT

Substrate characterization is based on 26 gravel counts completed in Icicle Creek. In Reaches 5 - Reach 7, Reach 11, Reach 13, and Reach 18, gravel counts were not performed due to lack of available substrate and safety of the survey crew. Gravel counts were performed starting from the upstream extent of the study area and moving downstream; the first gravel count (GC1) was completed in Reach 20 and the last gravel count (GC26) in Reach 1. When possible, two gravel counts were completed in each of the respective reaches, at representative riffle crests or bars. However, In Reach 3, Reach 9, and Reach 11 only one count was performed and in Reach 19 three counts were conducted.

Sediment type is classified by the B-axis diameter of the clasts sampled according to the Wentworth grain size scale (fines = <2 mm, gravel = 2.1–64 mm, cobble = 64.1–256 mm, boulder = >256.1 mm; Wentworth, 1922). In Icicle Creek the dominant substrate classification was gravel, followed by cobble, boulder and then sand (Figure 5). Reaches 1-3 are the least confined with lowest slope gradient, with gravels and cobble substrates observed. Reaches 4-14 are more confined, with steeper channel gradients and consistently larger sediment observed, including large proportions of boulders present. The upper reaches (Reach 15-20) include a mix of gravels, cobbles, and boulders, reflecting the variable channel conditions within those reaches.

The percentage of fine substrate is less than 10% throughout the assessment area (with the highest percentage occurring at 8% in Reach 15 GC 11). Fine substrate can be harmful to salmonid survival in high concentrations at spawning grounds by limiting the flow of dissolved oxygen and nutrients, but the low percentage poses minimal risk to aquatic habitat quality. Additionally, larger substrate, such as boulders, is less optimal for spawning purposes as it is too large to be moved easily during redd construction. However, in higher velocity areas, boulders can provide refuge for smaller substate leading to accumulation of small islands and bars of gravel and cobble which can be beneficial for habitat and spawning.

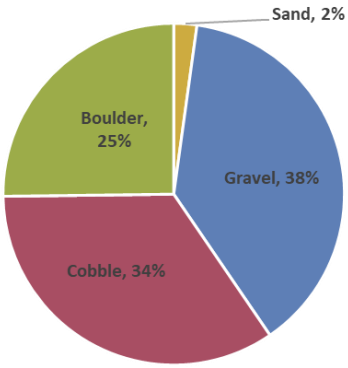


Figure 5. Gravel count size classification averaged for all reaches. Gravel was the dominant classification.

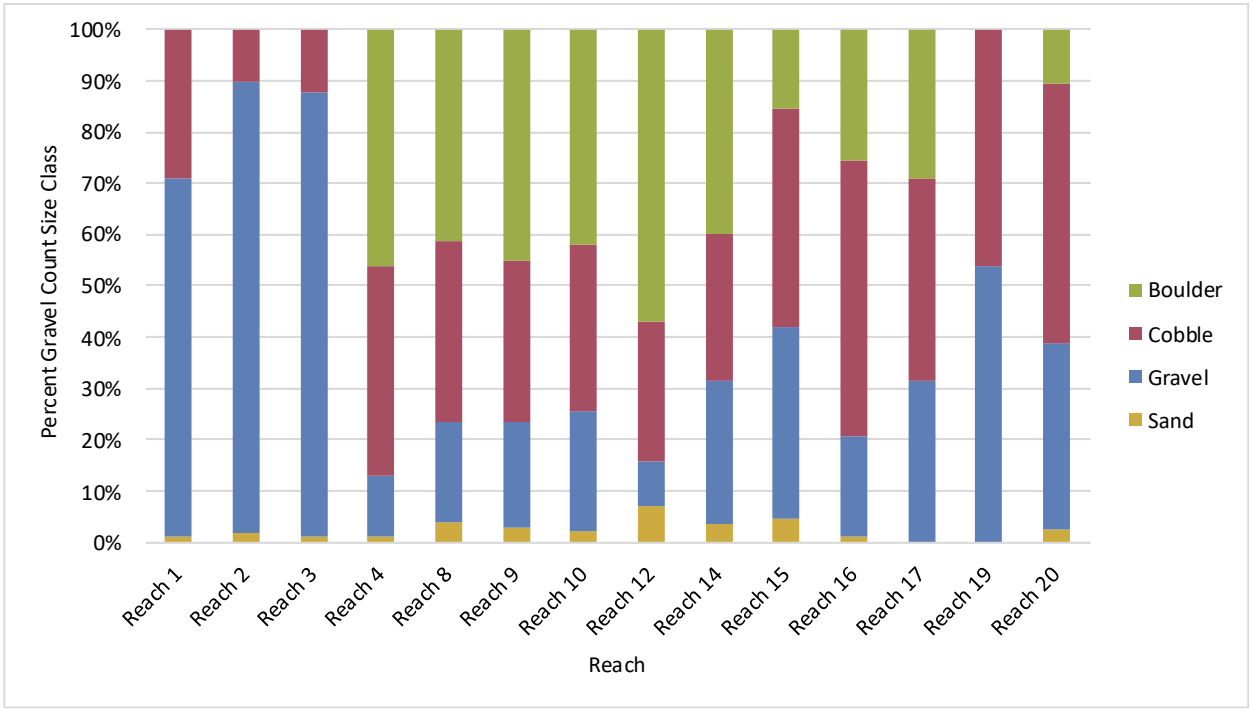


Figure 6. Combined average gravel count size classification by reach for al reaches based on the number of gravel counts observed for each reach.

3.6 BANK INSTABILITY

Throughout the Icicle Creek study area, irrigation infrastructure, residential development, roads, bridges, channel bank armoring, campgrounds and other anthropogenic features are present. Many of these land use modifications have resulted in channel entrenchment, geomorphic simplification, and riparian/floodplain vegetation clearing and alterations. The extent of human-induced bank erosion and/or instability on both the left and right banks of each channel unit and side channel unit were documented during the 2024 field assessment. While there are some bank erosion processes occurring throughout the project area in all reaches, the habitat team did not directly identify any sources of the human-induced erosion.

Unstable banks were found to be relatively more frequent throughout the downstream reaches (Reach 1 to Reach 6) compared to the upper reaches. Reach 2 remains the most affected by human-altered banks; a result of the river flowing through the housing developments of Leavenworth and the presence of the Leavenworth National Fish Hatchery. Riprap and other bank armoring were extensive in Reaches 4, Reach 5 and Reach 6, where Icicle Road (USFS Road 7600) runs parallel to the river-left bank. Bank armoring, decreased riparian vegetation, and bank stability are impacted in Reach 5 as a result of the Leavenworth Irrigation District Road and the irrigation canal. Bridges, riprap and residential homes impact channel banks in Reach 7. Forest service campgrounds and trails are present along the banks in Reach 10 and Reach 17. Fewer roads and more public lands in the upper reaches reduced the occurrence of anthropogenically-induced bank instability.

3.7 FISH PASSAGE BARRIERS

Anthropogenic structures within the mainstem Icicle Creek channel occur in Reach 3, Reach 4 and Reach 5. There are two channel-spanning structures located in the natural channel of Reach 3; a dam (Structure 5) on the downstream end of the reach (RM 2.95; Figure 7) and a diversion at the upstream end of the reach (RM 4.8). In Reach 4, the Icicle-Peshastin Irrigation Canal (RM 5.05) extends from the river-right bank halfway across the Icicle Creek channel. At the time of survey (August 27th, 2024), approximately 0.7 feet of water was flowing over the top of the concrete structure. The channel on river-left at this location does not have a structure present and consists of a riffle/cascade feature with boulder substrates. Downstream of the structure is a constructed step-pool feature intended to aid fish passage over the submerged concrete. This structure is not recorded as a fish passage barrier according to WDFW (2025).

A water diversion structure, maintained by the Icicle-Peshastin Irrigation District and City of Leavenworth, is located at the upstream end of Reach 5 (RM 6.27). It is a channel-spanning diversion, diverting water into the Leavenworth Irrigation Canal that flows into the town of Leavenworth, WA (Figure 8). The diversion is approximately three feet high with additional 0.5 feet tall wooden planks.

Figure 7. Photo of the dam located on the downstream end of Reach 3 within the historical channel.

Figure 8. Channel spanning diversion at the upstream end of Reach 5.

3.8 RIPARIAN CORRIDOR

Riparian vegetation was surveyed at select habitat units, including n^{th} units and when a dramatic change in riparian vegetation between units was observed by the survey crew. In total, 149 units had observations of riparian vegetation recorded. Across the study area, the dominant (72%) overstory

riparian vegetation size was Large Tree (21.0-31.9- inch diameter at breast height [dbh]). Small Tree (9.0-20.9-inch dbh) was the second most dominant at 15% of the total observations. Sapling Pole (5.0-8.9-inch dbh) and Mature Trees (5.0-8.9-inch dbh) each composed 3% of the measured units, while Shrub/Seedling (1.0 -4.9-inch dbh) and Other comprised 2% of the units. "Other" overstory species class in the study area include burned trees. Only 1% of the recorded units were classified as No Vegetation within the riparian corridor (Figure 9).

The dominant overstory species were Ponderosa and Jeffrey pine, composing 42% of all measured habitat units. A positive identification of Jeffrey Pine was observed within 100 feet of Icicle Creek. Douglas fir and Western red cedar composed 21% and 20%, respectively, of measured habitat units. Cottonwood (9%), Other/Unknown (4%), Quaking Aspen (2%) and Alder (1%) composed the remaining units (Figure 10).

The dominant understory riparian vegetation size class is Shrub/Seedling, recorded in 87% of the units, followed by Grassland/Forb (6%), No Vegetation (4%), Sapling Pole (2%) and Small Tree (1%; Figure 11). The dominant understory riparian vegetation species was Alder (57%), followed by Dogwood (19%). Unknown/Other and Willow equally composed 9% of measured habitat units. The remaining measured riparian understory units consisted of Cottonwood (3%), Vine/Douglas maple (2%), and Cedar (1%; Figure 12).

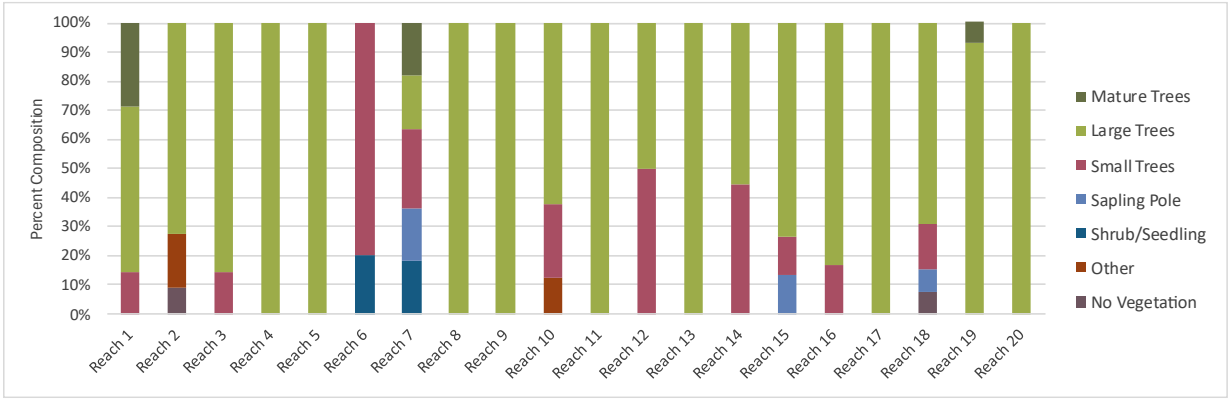


Figure 9. Percent composition of the dominant overstory size class for all units in which vegetation surveys were performed.

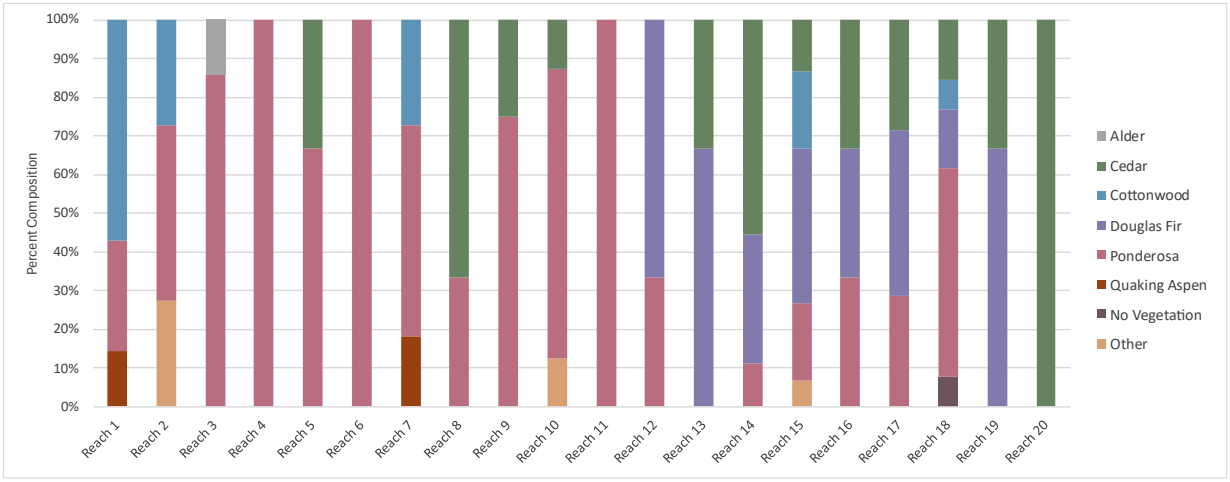


Figure 10. Percent composition of the dominant overstory species for all units in which vegetation surveys were performed.

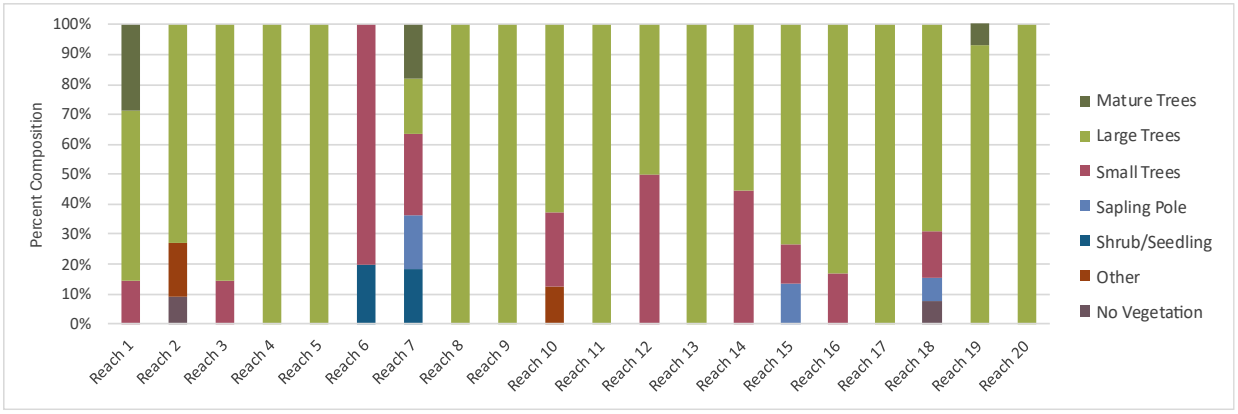


Figure 11. Percent composition of the dominant understory size class for all units in which vegetation surveys were performed.

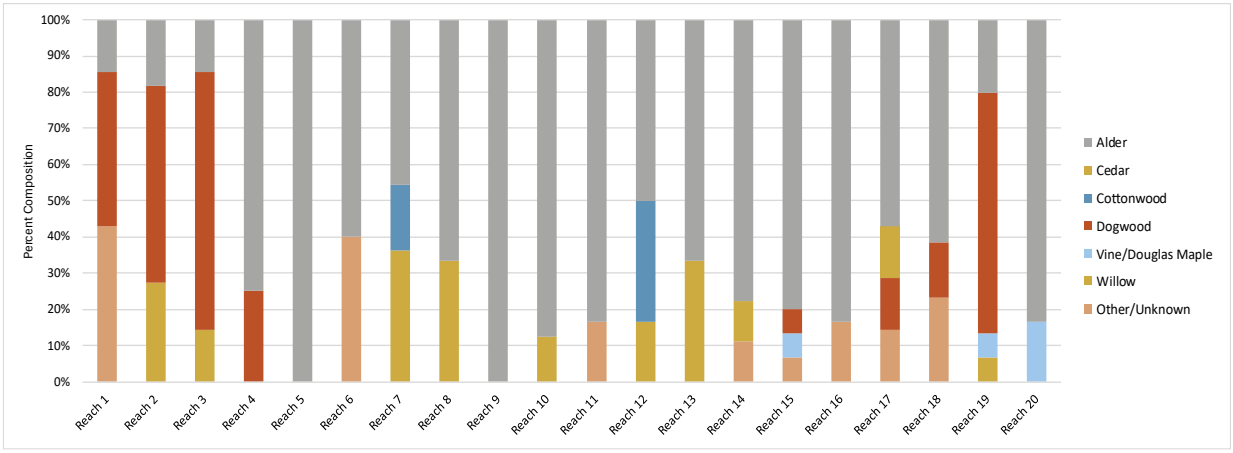


Figure 12. Percent composition of the dominant understory species for all units in which vegetation surveys were performed.

4 Stream Habitat Reach Reports

4.1 REACH 1

Location: River mile 0 – 1.24
Total length: 1.24 miles
Survey date: August 13 - 14, 2024

Figure 13. Representative photo of Reach 1.

4.1.1 Habitat Unit Composition

Reach 1 was 1.24 miles long and has the third largest proportion of pool habitat area of all the reaches (67%), compared to the study area average of 38.5%. The remainder of the habitat area is comprised of glides (32%) and side channels (1%; Figure 14 and Figure 15). Reach 1 has a stream gradient of 0.11%, less than the study area average of 1.7%. The channel and floodplains of Reach 1 are frequently used by the public and residential land uses are widespread. This reach starts at the confluence with the Wenatchee River near the town of Leavenworth, WA.

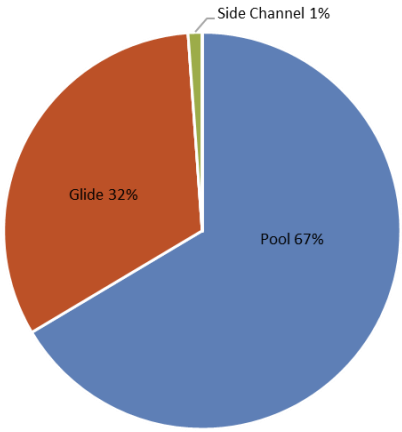


Figure 14. Stream habitat unit area composition for Reach 1.

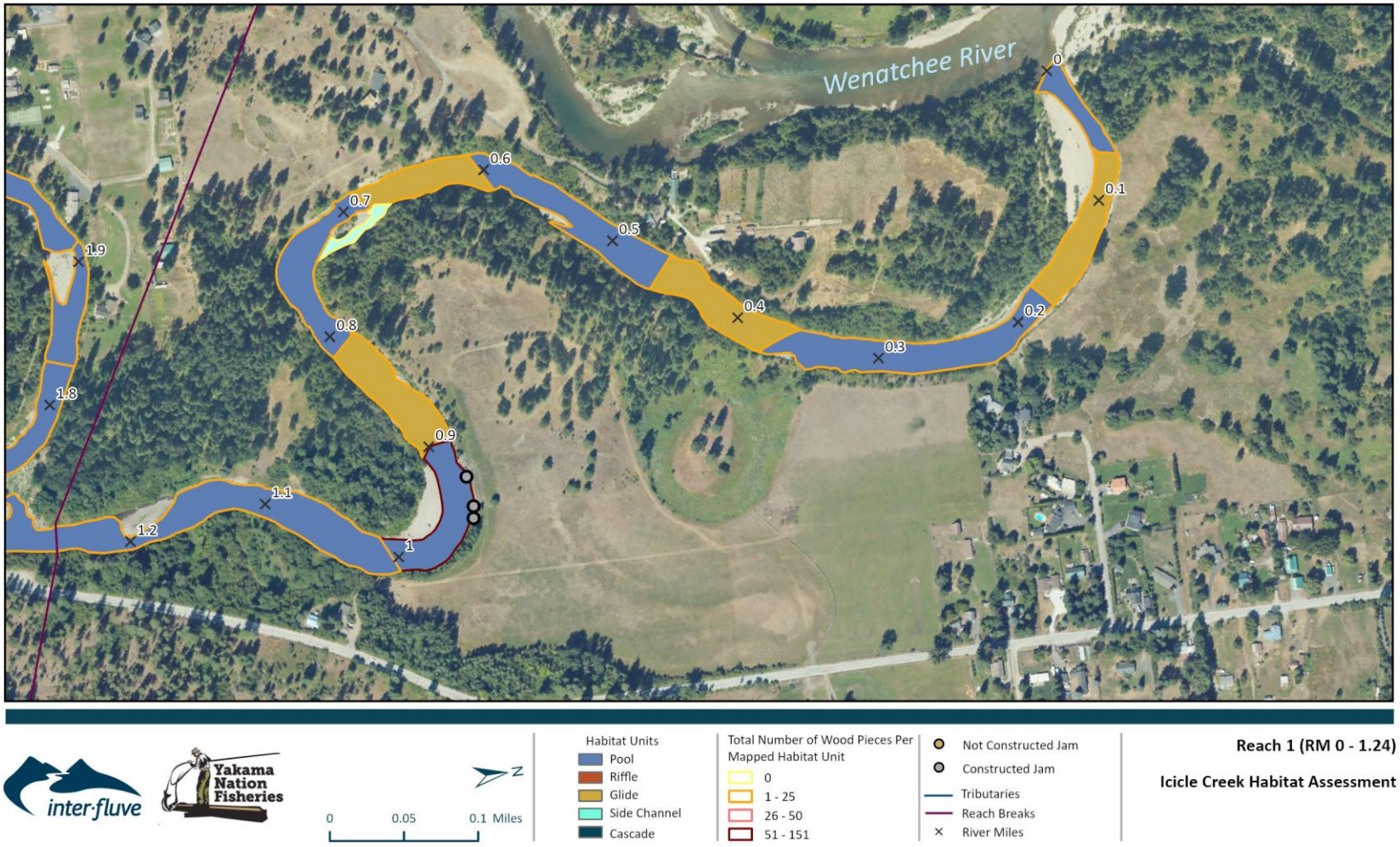


Figure 15. Map of the habitat unit composition and LWM in Reach 1 of Icicle Creek. LWM count includes pieces in jams.

4.1.2 Pools

Pool was the most common habitat type recorded in Reach 1, composing 67% of the habitat unit surface area. A total of five pools were recorded within the reach, averaging four pools per mile compared to the study area average of seven pools per mile. Of the five pools, 40% of pools measured a residual pool depth less than three feet. Another 50% of pools measured a residual pool depth between three feet and six feet, while the remaining 20% measured a residual pool depth greater than six feet. The average residual depth of pools in Reach 1 was 6.5 feet but ranged from 0.5 feet to 18 feet, compared to the study area average of 4.4 feet.

4.1.3 Side Channel Habitat

Only one side channel was observed in Reach 1 with a length of 265 feet. The slow-water side channel contained no LWM (Table 3).

Table 3. Side channels observed in Reach 1.

Location	Length (ft)	Dominant Unit Type	Wood Count	Jam Count	Wood Count in Jams
Side 1	265	Slow	0	0	0
Total	*265*		*0*	*0*	*0*

4.1.4 Large Woody Material

A total of 125 pieces of LWM were recorded in Reach 1, which includes individual pieces and pieces recorded in jams. LWM frequency within the reach is approximately 101 pieces of LWM per mile, with 39 of those pieces per mile being Medium and Large LWM. Three wood jams were observed, containing 69 pieces of LWM (Table 4).

Table 4. LWM quantities in Reach 1.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Individual Pieces	36	14	6	56
Number of Individual Pieces per Mile	29	16		45
Number of Total Pieces per Mile (including pieces in jams)	62	39		101
Number of Jams	3			
Number of Jams per Mile	2			
Estimated Wood Count in Jams	69			

4.1.5 Substrate & Fine Sediment

Two gravel counts were performed in Reach 1, with a combined average of 70% gravel, 29% cobbles and 1% sand (Figure 16). The first gravel count (GC26) was performed at a channel spanning riffle crest near RM 0.60 and the second (GC25) was at a performed at a riffle crest near RM 0.90. Cumulative distribution curves and grain size class of the gravel counts completed in Reach 1 are provided in Figure 17, Figure 18, and Table 5.

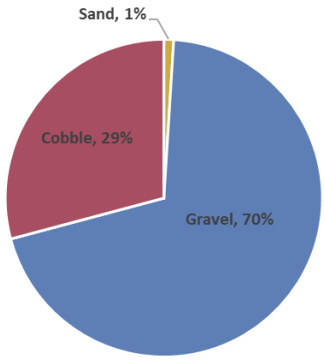


Figure 16. Combined percent sediment composition from the two gravel counts (GC 26 and GC 25) performed in Reach 1.

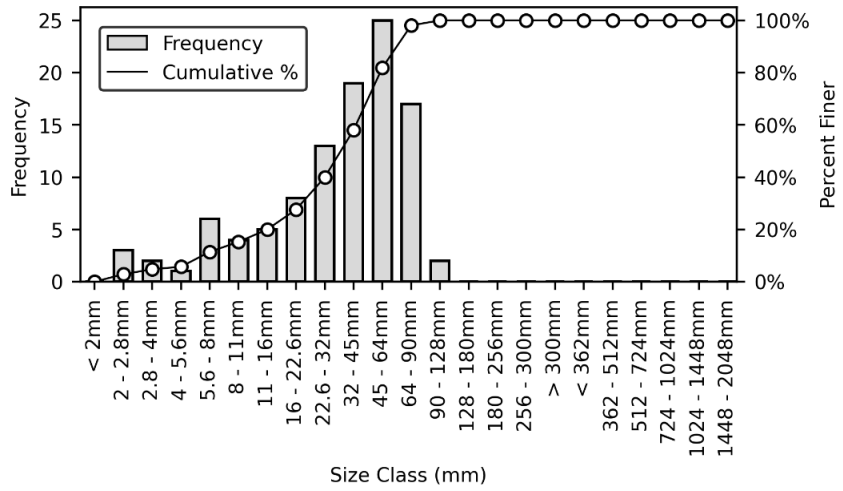


Figure 17. Cumulative distribution curve for GC 26.

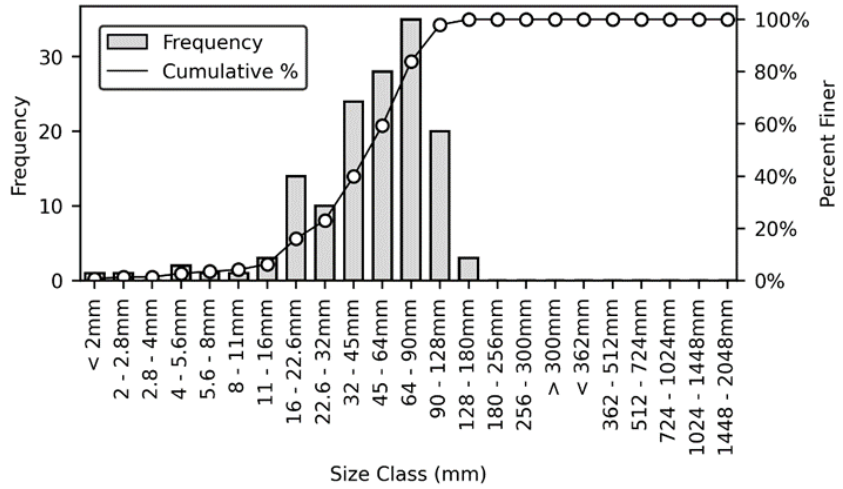


Figure 18. Cumulative distribution curve for GC25.

Table 5. Grain size class for GC 26 and GC 25 (assumed linear interpolation).

Size Class	GC26 *Size percent finer than (mm)*	GC25 *Size percent finer than (mm)*
D5	13	4
D16	23	12
D50	55	39
D84	90	66
D95	125	90

4.1.6 Riparian Corridor

A total of seven ocular assessments of riparian observations were recorded in Reach 1. The dominant overstory size class recorded was Large Trees (57%; 21-31.9-inch dbh), followed by Mature Trees (29%; >32-inch dbh) and Small Trees (14%; 9.0 – 20.9-inch dbh). The dominant overstory species were Cottonwood (57%), followed by Ponderosa pine (29%) and Quaking Aspen (14%; Figure 19). The dominant riparian understory size classes were Grassland/Forb (57%) and Shrub/Seedling (43%; 1.0 – 4.9-inch dbh). The understory species were recorded as primarily Dogwood (43%) and Other/Unknown (43%), and the remaining 14% as Alder (Figure 20). The Other/Unknown classification in this reach consisted of non-native species used in residential areas.

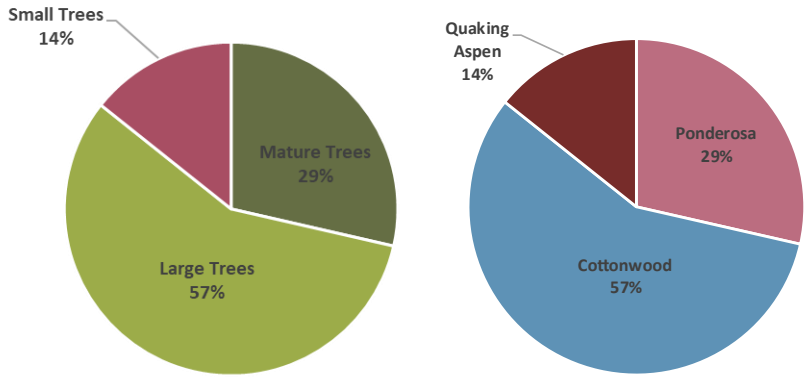


Figure 19. Dominant overstory riparian vegetation class and species, based on seven units surveyed, within 100 feet of Icicle Creek by ocular estimate.

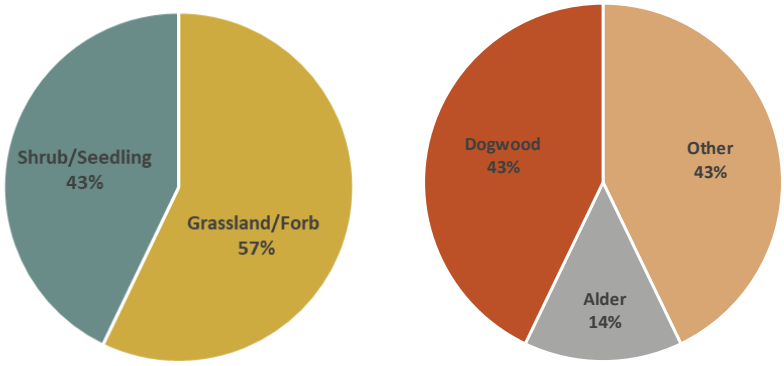


Figure 20.Dominant understory riparian vegetation class and species, based on seven units surveyed, within 100 feet of Icicle Creek by ocular estimate.

4.2 REACH 2

Location: River mile 1.24 – 3.02
Total length: 1.78
Survey Date: August 14 - 15, 2024

Figure 21. Representative photo of Reach 2.

4.2.1 Habitat Unit Composition

Reach 2 is the third longest reach in the study area at 1.78 miles. Reach 2 had the largest proportion of pool habitat area of all the reaches (91.5%). The remaining 8.5% of the habitat area is composed of glides (6%) and side channels (2.5%; Figure 22 - Figure 23). The stream gradient in Reach 2 is 0.07%. Reach 2 ends at the Leavenworth National Fish Hatchery.

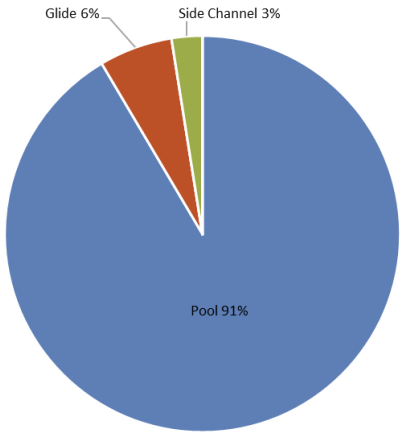


Figure 22. Stream habitat unit area composition for Reach 2.

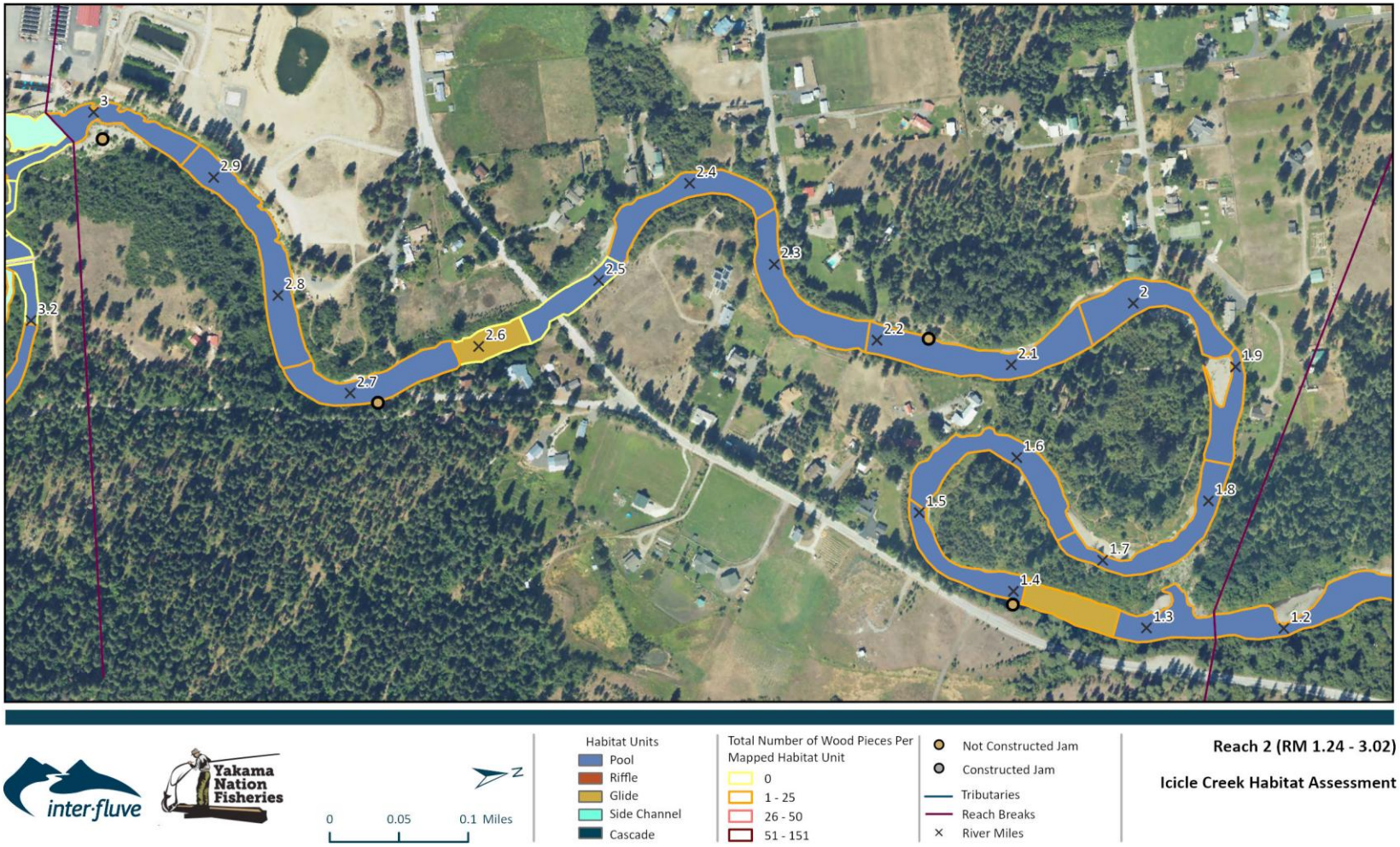


Figure 23. Map of the habitat unit composition and LWM in Reach 2 of Icicle Creek. LWM count includes individual pieces in jams.

4.2.2 Pools

A total of 14 pools were identified in Reach 2, averaging eight pools per mile. Of the 14 pools, 14% of pools had residual depths less than three feet, 50% had residual depths between three feet and six feet, and 36% of pools had residual depths greater than six feet. The average residual pool depth was six feet for Reach 2.

4.2.3 Side Channel Habitat

One side channel was present in Reach 2 and was 216 feet in length. The side channel was primarily slow-water at the time of survey. No LWM was observed in the side channel (Table 6).

Table 6. Side channels observed in Reach 2.

Location	Length (ft)	Dominant Unit Type	Wood Count	Jam Count	Wood Count in Jams
Side 2	216	Slow	0	0	0
Total	*216*		*0*	*0*	*0*

4.2.4 Large Woody Material

A total of 142 pieces of LWM was identified in Reach 2. This total includes individual pieces and pieces recorded in jams. LWM averaged 80 pieces per mile, and of that, 34 pieces of medium and large LWM combined per mile (Table 7). Of the total number of pieces, 36 pieces were counted in wood jams. Four jams were recorded in Reach 2, averaging two jams per mile.

Table 7. LWM quantities in Reach 2.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20in x 35 ft)	Total
Number of Individual Pieces	61	36	9	106
Number of Individual Pieces per Mile	34	25		60
Number of Total Pieces per Mile (including pieces in jams)	46	34		80
Number of Jams	4			
Number of Jams per Mile	2			
Estimated Wood Count in Jams	36			

4.2.5 Substrate & Fine Sediment

Two gravel counts were performed in Reach 2, with a combined average of 88% gravel, 10% cobble and 2% sand (Figure 24). GC24, the first gravel count, was conducted in a riffle crest at RM 2.09 and the second gravel count (GC23) was conducted in a channel spanning riffle crest near RM 2.77. Both cumulative distribution and grain size class can be found in Figure 25- Figure 26 and Table 8.

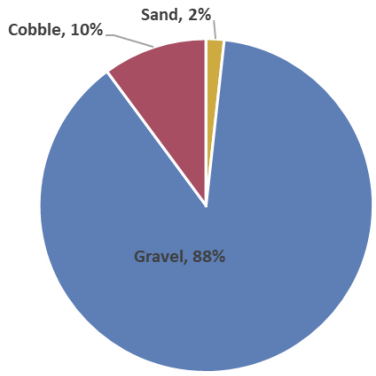


Figure 24. Combined percent sediment composition from the two gravel counts (GC24 and GC 23) performed in Reach 2.

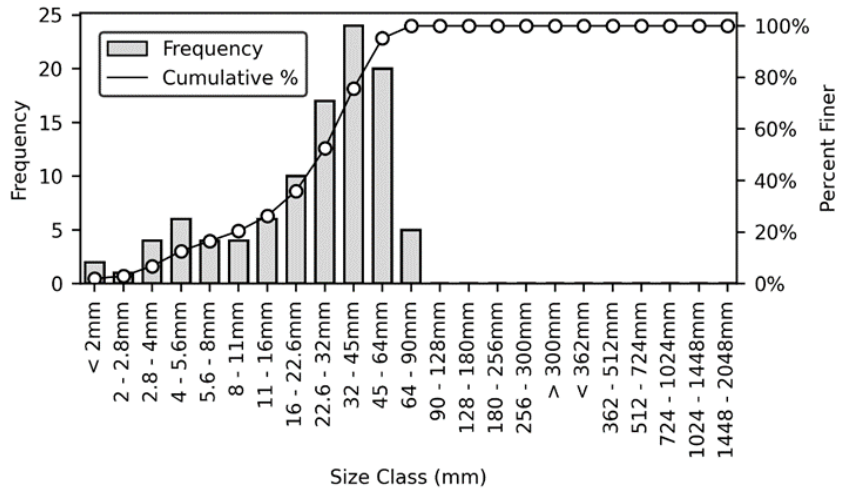


Figure 25. Cumulative distribution curve for GC24.

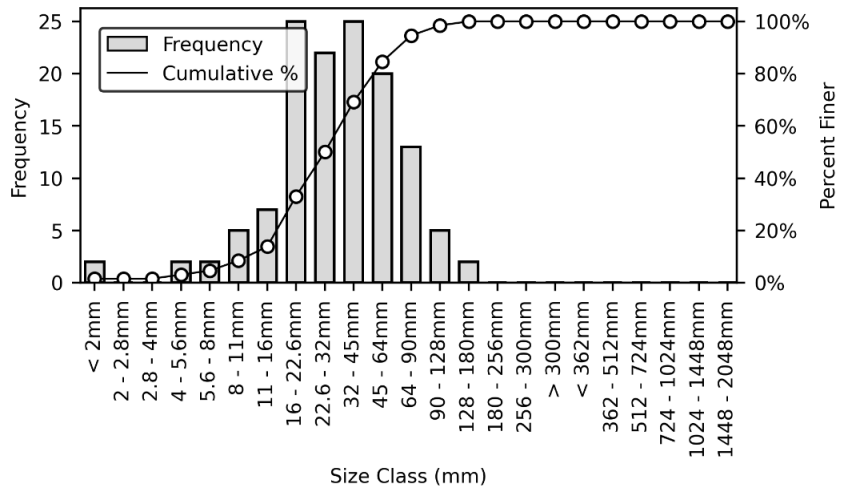


Figure 26. Cumulative distribution curve for GC23.

Table 8. Grain size class for GC24 and GC23 (assumed linear interpolation).

Size Class	GC24 Size percent finer than (mm)	GC23 Size percent finer than (mm)
D5	3	8
D16	8	17
D50	31	32
D84	52	62
D95	64	90

4.2.6 Riparian Corridor

Eleven channel units in Reach 2 included ocular assessment of riparian vegetation. The dominant overstory consisted of 75% Large Trees (21.0 - 31.9-inch dbh), 18% Other, and 9% No Vegetation. Ponderosa pine comprised 46% of the dominant overstory species, while Cottonwood and Other/Unknown were each recorded in 27% of measured units (Figure 27). The Other size class and species in Reach 2 were non-native species observed on residential properties. The dominant understory size class was recorded as 91% Shrub/Seedling (1.0 - 4.9-inch dbh) and 9% Grassland/Forb, with Dogwood as the dominant understory species (55%), followed by Willow (27%) and Alder (14%; Figure *28*).

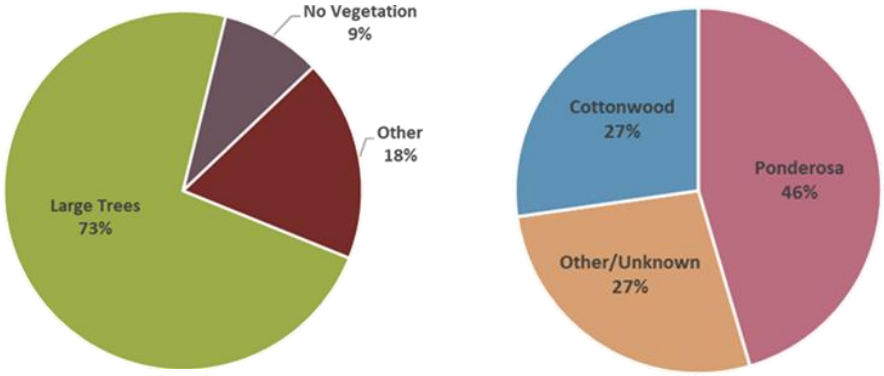


Figure 27. Dominant overstory riparian vegetation class and species, based on eleven units surveyed, within 100 feet of Icicle Creek by ocular estimate.

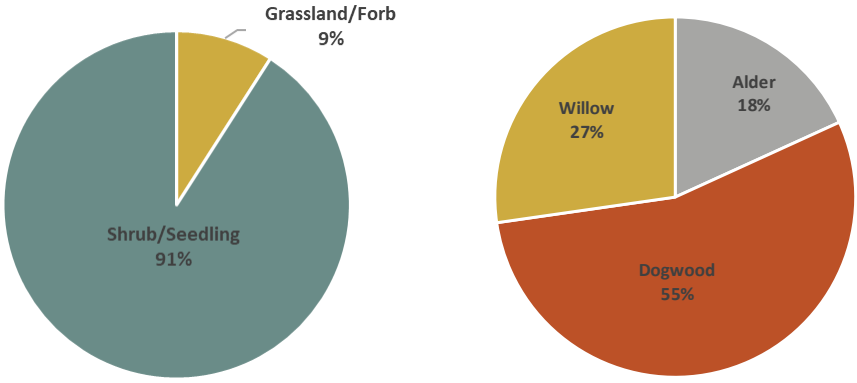


***Figure** 28. Dominant understory riparian vegetation class and species, based on eleven surveyed units, within 100 feet of Icicle Creek by ocular estimate.*

4.3 REACH 3

Location: River mile 3.02 – 4.3
Total length: 1.28 miles
Survey Date: August 15 - 16, 2024

Figure 29. Representative photo of Reach 3.

4.3.1 Habitat Unit Composition

Reach 3 is the natural channel of Icicle Creek that flows parallel to the Leavenworth National Fish Hatchery diversion channel. This channel is 1.28 miles long and has a stream gradient of approximately 0.24%. Habitat unit composition within the reach was 75% pools, 13% glides, 3% riffle and 9% side channel (Figure 30 and Figure 31).

Two anthropogenic structures were observed in this reach – Structure 5 at the downstream end (RM 2.95) and Structure 2 at the upstream end (RM 4.8). Structure 2 located at the upstream end of Reach 3; the water surface level drops approximately 5 feet from upstream to the downstream end of the structure. Structure 2 narrows the river from a wetted width of 110 to 20 feet and functions to control the flow into/out of the natural channel and hatchery diversion channel.

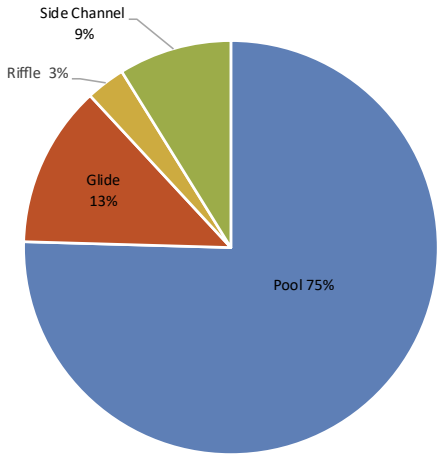


Figure 30. Stream habitat unit area composition of Reach 3.

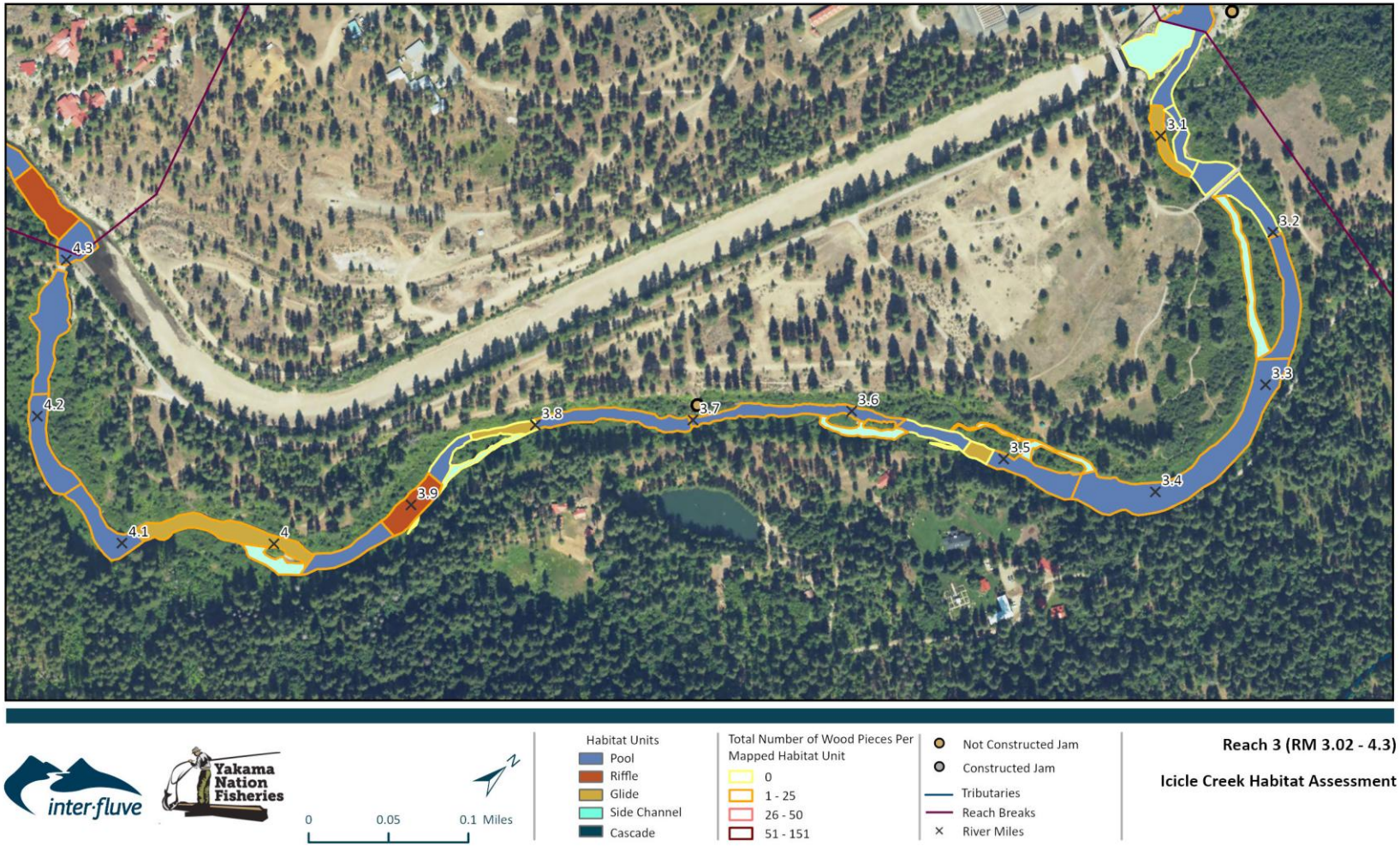


Figure 31. Map of the habitat unit composition and LWM in Reach 3 of Icicle Creek. LWM count includes pieces in jams.

4.3.2 Pools

A total of 15 pools were identified in Reach 5, averaging 12 pools per mile and comprising 75% of the total habitat area in the reach. The average residual pool depth was three feet. Residual pool depths ranged from 1.5 feet to 7.1 feet. Of the 15 pools, eight pools (40%) had a residual depth less than three feet, six pools (50%) had residual pool depths between three and six ft, and one pool (10%) had a residual depth greater than six feet.

4.3.3 Side Channel Habitat

Eight side channels were identified in Reach 3 (Table 9) comprising 9% of the total habitat area. All side channel units were recorded as predominately slow-water at the time of the survey. The total length of all eight channels is 2,053 feet, averaging 257 feet in length. A total of eight small pieces of LWM were observed in the side channels. No jams were recorded in side channels.

Table 9. Side channels observed in Reach 3.

Location	Length (ft)	Dominant Unit Type	Wood Count	Jam Count	Wood Count in Jams
Side 3	554	Slow	2	0	0
Side 4	275	Slow	1	0	0
Side 5	290	Slow	2	0	0
Side 6	95	Slow	0	0	0
Side 7	293	Slow	2	0	0
Side 8	281	Slow	0	0	0
Side 9	64	Slow	0	0	0
Side 10	201	Slow	1	0	0
Total	*2,053*		*8*	*0*	*0*

4.3.4 Large Woody Material

A total of 61 pieces of LWM pieces were recorded in Reach 3. This total includes individual pieces and pieces recorded in jams. LWM frequency within the reach is approximately 48 pieces of LWM per mile, with 10 of those pieces per mile being Medium and Large LWM. There was one jam observed in Reach 3. A total of five LWM pieces were observed in the jam (Table 10).

Table 10. LWM quantities in Reach 3.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20in x 35 ft)	Total
Number of Individual Pieces	45	9	2	56
Number of Individual Pieces per Mile	35	9		44
Number of Total Pieces per Mile (including pieces in jams)	38	10		48
Number of Jams	1			
Number of Jams per Mile	2			
Estimated Wood Count in Jams	5			

4.3.5 Substrate & Fine Sediment

One gravel count (GC22) was conducted in Reach 3 at an irregular riffle crest near RM 3.44. The irregularity in the location is due to the surveyor avoiding active redds in the reach. The composition of the count was predominantly gravel (87%), followed by cobbles (12%) and sand (1%; Figure 32). The distribution and grain size class can be found in Figure 33 and Table 11.

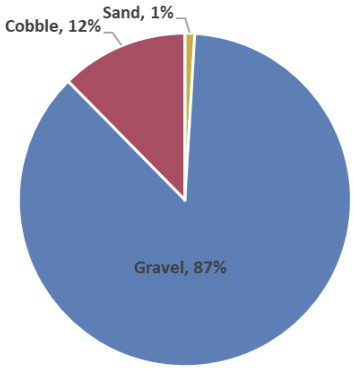


Figure 32. Percent of sediment composition from the gravel count (GC22) performed in Reach 3.

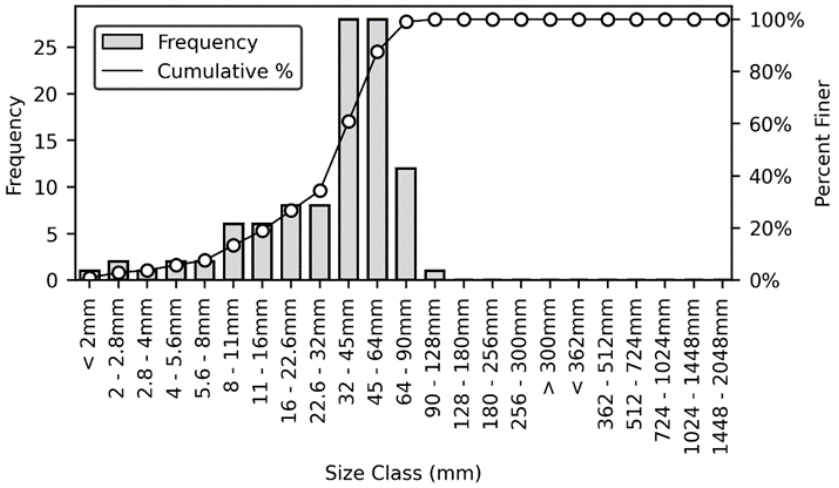


Figure 33. Cumulative distribution curve for GC22.

Table 11. Grain size class for GC22 (assumed linear interpolation).

	GC22
Size Class	*Size percent finer than (mm)*
D5	5
D16	13
D50	39
D84	61
D95	80

4.3.6 Riparian Corridor

Seven channel units in Reach 3 included ocular assessment of riparian vegetation. The overstory was primarily Large Trees (86%; 21.0 - 31.9-inch dbh) with the remaining units observed as Small Trees (14%; 9.0 - 20.9-inch dbh). Changes to the riparian vegetation within 100 feet of Icicle Creek were noted in Reach

3, resulting from the Leavenworth National Fish Hatchery. The dominant overstory species was Ponderosa pine (86%), followed by Alder (14%; Figure 34). The dominant understory was recorded as entirely the Shrub/Seedling (100%) size class. The dominant understory species was Dogwood (72%), followed by Willow and Alder each with 14% (Figure 35).

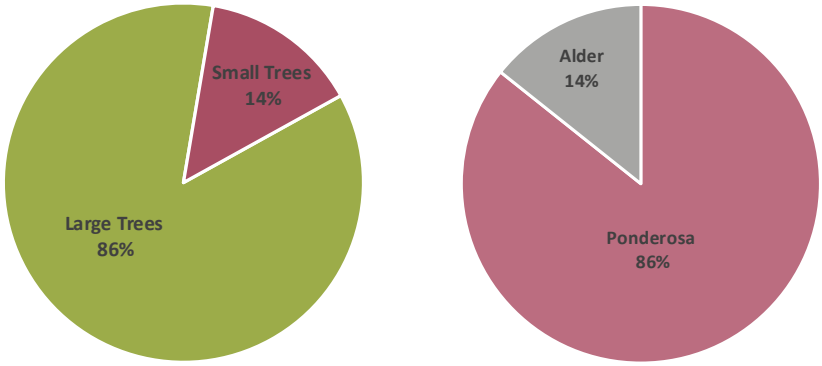


Figure 34. Dominant overstory riparian vegetation class and species, based on seven units surveyed, within 100 feet of Icicle River by ocular estimate.

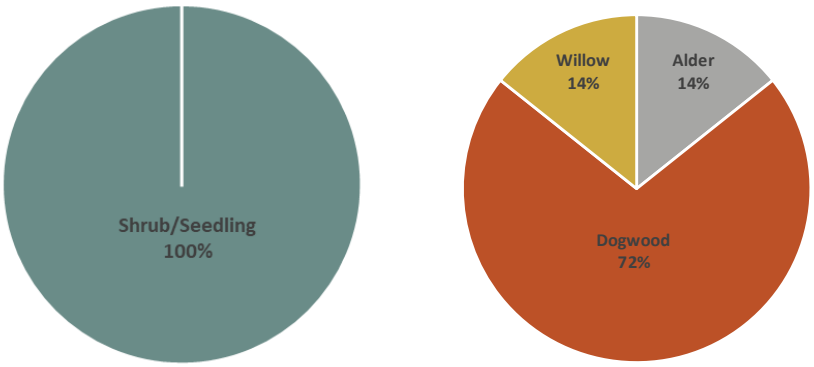


Figure 35. Dominant understory riparian vegetation class and species, based on seven units surveyed, within 100 feet of Icicle River by ocular estimate.

4.4 REACH 4

Location: River mile 4.3 – 5.05
Total length: 0.75 miles
Survey Date: August 26 – 27, 2024

Figure 36. Representative photo of Reach 4. Habitat is dominated by riffle units.

4.4.1 Habitat Unit Composition

Reach 4 begins at the upstream end of the Leavenworth National Fish Hatchery diversion channel and Structure 2, approximately 0.75 miles in length. This reach marks an increase in riffle habitat, composing 66% of the total reach area. Pool habitat was 28% of the total reach area, followed by side channel habitat (6%; Figure 37). Channel gradient through Reach 4 is 1.65%, marking a substantial departure from the lower gradient Reaches 1-3. Reach 4 ends at a water diversion canal (RM 5.05) for the LNFH and the Cascade Orchard Irrigation District[1]. A project sponsored by the Bureau of Reclamation to replace and modernize the water intake while creating a roughened channel and fishway (WDOE, 2019; WDFW, 2025). Photos of the diversion are included below (Figure 39 and Figure 40).

[1] As of May 2025, the Cascade Orchard Irrigation District diversion is located at RM 1.9 (WDOE, 2019; personal communication, Ingrid Ekstrom, WA Department of Ecology, October 2025).

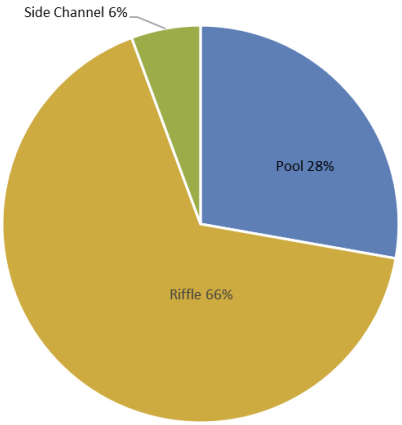


Figure 37. Stream habitat unit area composition of Reach 4.

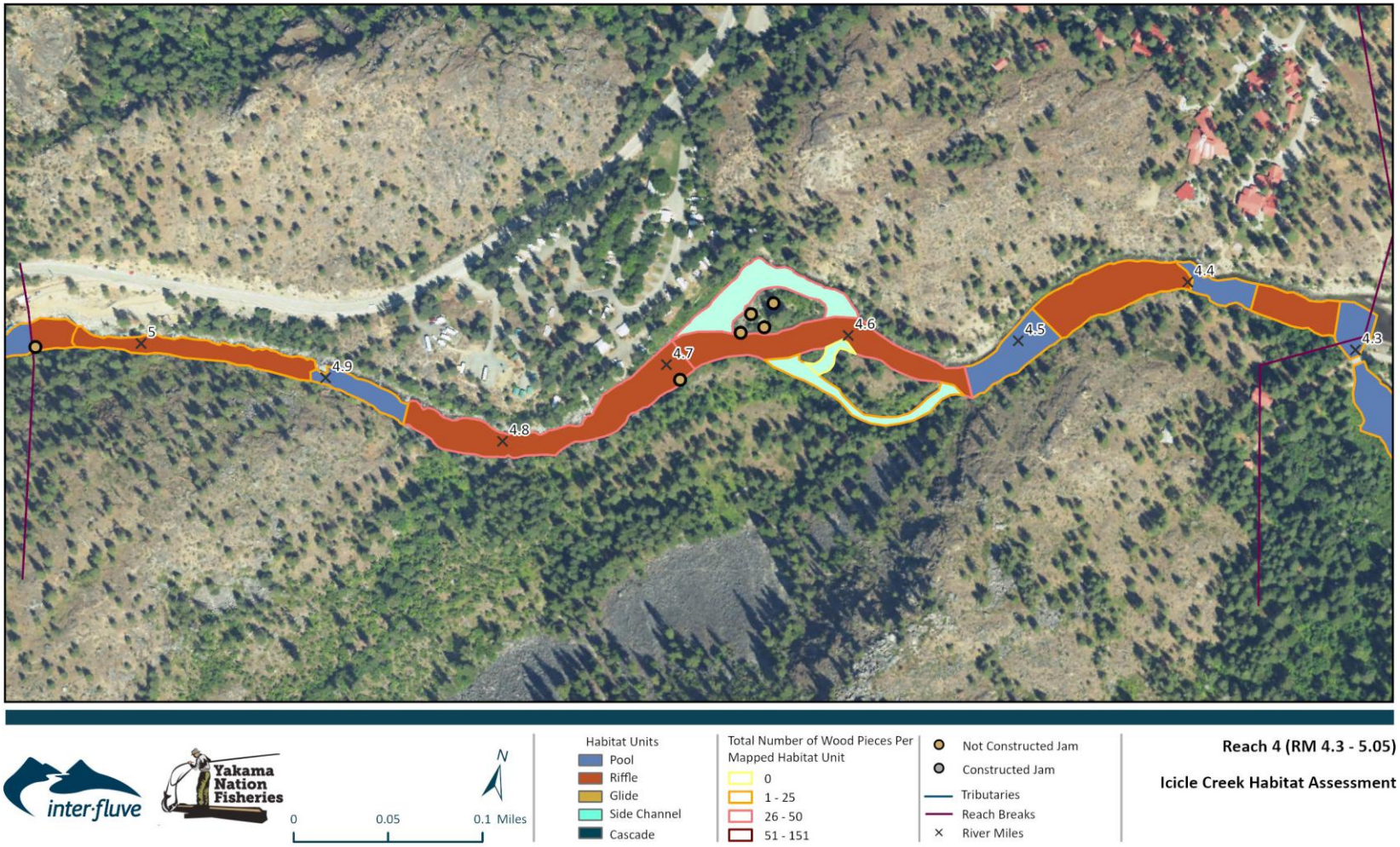


Figure 38. Map of the habitat unit composition and LWM in Reach 4. LWM count includes pieces in jams.

Figure 39. Photo of the fishway looking upstream at the surface water intake for the LNFH and Cascade Orchard Irrigation District[1].

[1] As of May 2025, the Cascade Orchard Irrigation District diversion is located at RM 1.9 (WDOE,2019; personal communication, Ingrid Ekstrom, WA Department of Ecology, October 2025).

Figure 40. Photo of the LNFH and Cascade Orchard Irrigation District[1] surface water intake project completed by the USBR (WDOE, 2019)

4.4.2 Pools

Reach 4 had five total pools, all of which had a residual pool depth between three and six feet. Residual pool depths ranged from 3.5 feet to 5.5 feet, with an average of 4.5 feet (compared to the 4.4 feet for the study area average). The mean pool spacing for this reach was eight pools per mile, less than the study area average of seven pools per mile.

4.4.3 Side Channel Habitat

Three side channels were observed in Reach 4, with a total combined length of approximately 1,135 ft. One side channel was predominantly fast water (e.g., riffle and glide habitat within the side channel), while the other two were predominantly slow water at the time of the survey. A total of 39 pieces of LWM and two jams with an estimated 25 pieces of LWM were observed in the three side channels (Table 12).

[1] As of May 2025, the Cascade Orchard Irrigation District Diversion is located at RM 1.9 (WDOE,2019; personal communication, Ingrid Ekstrom, WA Department of Ecology, October 2025).

Table 12. Side channels observed in Reach 4.

Location	Length (ft)	Dominant Unit Type	Wood Count	Jam Count	Wood Count in Jams
Side 11	561	Slow	9	0	0
Side 12	471	Slow	5	2	25
Side 13	104	Fast	0	0	0
Total	*1,135*		*14*	*0*	*0*

4.4.4 Large Woody Material

Reach 4 had a total of 144 pieces of LWM observed. This total includes individual pieces and pieces recorded in jams. Of the total, 62 (43%) pieces of LWM were observed in wood jams. Surveyors observed six wood jams in Reach 4, equating to eight jams per mile. There were 192 pieces of LWM per mile, with 87 being medium and large LWM (Table 13).

Table 13. LWM quantities in Reach 4.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20in x 35 ft)	Total
Number of Individual Pieces	52	22	8	82
Number of Individual Pieces per Mile	69	40		109
Number of Total Pieces per Mile (including pieces in jams)	105	87		192
Number of Jams	6			
Number of Jams per Mile	4			
Estimated Wood Count in Jams	62			

4.4.5 Substrate & Fine Sediment

Two gravel counts were performed in Reach 4, with a combined average of 46% boulder, 41% cobbles, 12% gravel and 1% sand (Figure 41). The two gravel counts, GC21 and GC20, were conducted at riffle crests at RM 4.47 and RM 4.68, respectively. The distribution and grain size class can be found in Figure 42 -Figure 43 and Table 14.

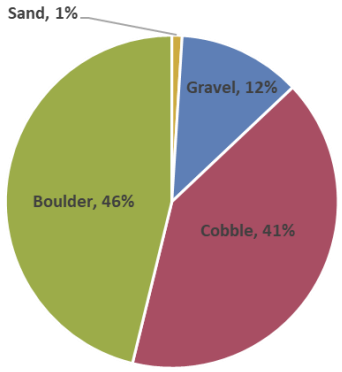


Figure 41. Combined percent sediment composition from the two gravel counts (GC21 and GC20) performed in Reach 4.

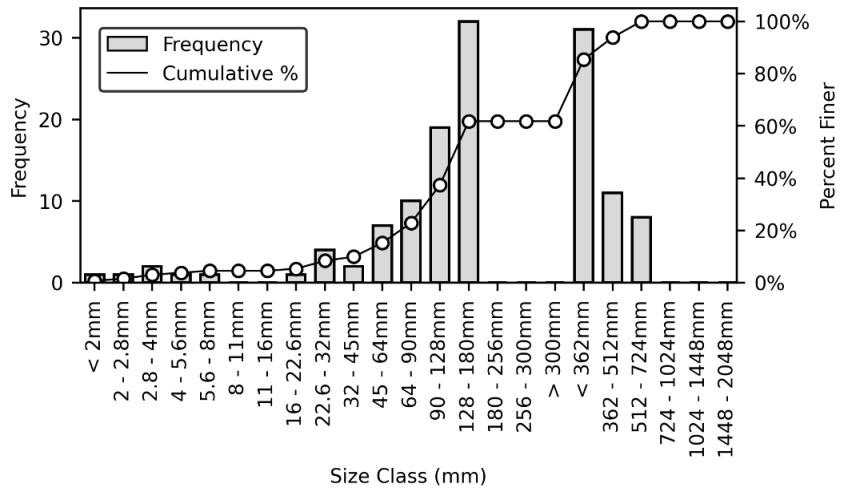


Figure 42. Cumulative distribution curve for GC21.

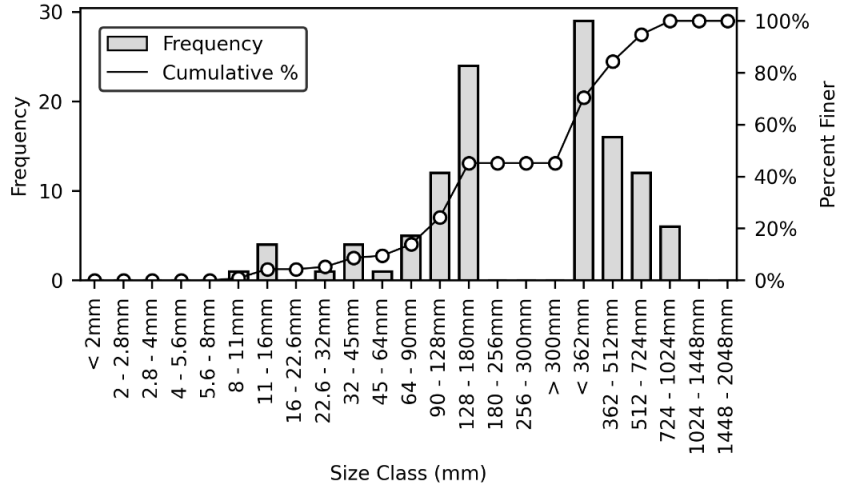


Figure 43. Cumulative distribution curve for GC20.

Table 14. Grain size class for GC21 and GC20 (assumed linear interpolation).

Size Class	GC21 *Size percent finer than (mm)*	GC20 *Size percent finer than (mm)*
D5	19	30
D16	65	96
D50	180	275
D84	350	510
D95	512	724

4.4.6 Riparian Corridor

Four channel units included ocular assessment of riparian vegetation in Reach 4. The overstory was dominated (100%) by Large Trees (21.0 - 31.9-inch dbh), with all units documented as Ponderosa pine (Figure 44). The understory was dominated (100%) by the Shrub/Seedling (1.0 - 4.9-inch dbh) size class and consisted of Alder (75%) and Dogwood species (25%; Figure 45).

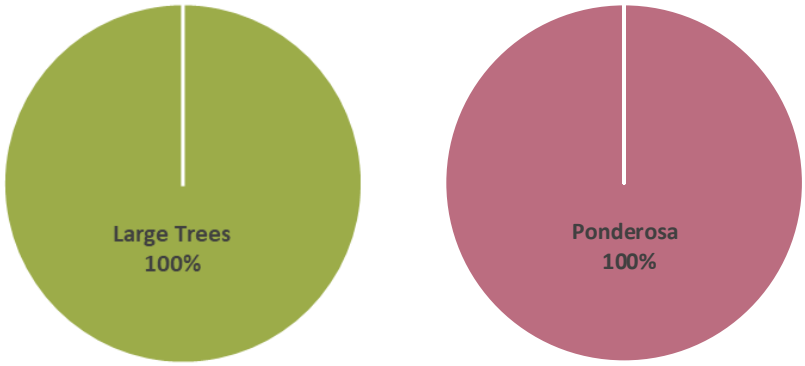


Figure 44. Dominant overstory riparian vegetation class and species within 100 feet of Icicle Creek, based on four units surveyed by ocular estimate.

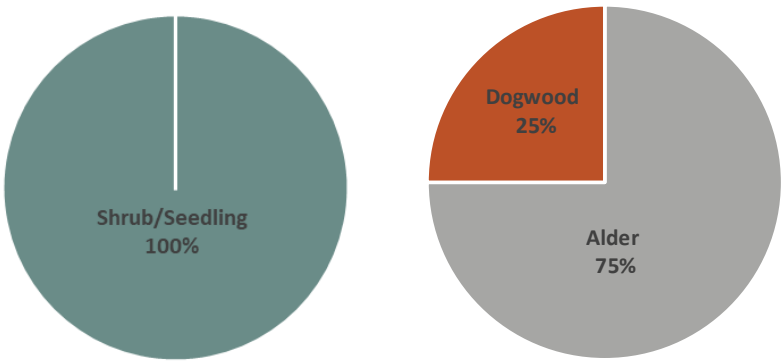


Figure 45. Dominant understory riparian vegetation species, based on four units surveyed, within 100 feet of Icicle Creek by ocular estimate.

4.5 REACH 5

Location: River mile 5.05 – 6.27
Total length: 1.22 miles
Survey Date: August 27 – 29, 2024

Figure 46. Representative photo of Reach 5. Habitat is dominated by riffle units

4.5.1 Habitat Unit Composition

Reach 5 consists predominantly of riffle units, which account for 50% of the habitat area recorded. Pool units were the second most prevalent with 26% of the habitat area. Side channels composed 18% of Reach 5's habitat unit area, one glide channel unit composed 3% of the habitat unit area and one cascade unit accounted for the remaining 3% (Figure 47). Reach 5 was 1.22 miles long with a channel gradient of 3.4%; almost double the gradient of Reach 4. The majority of left bank, where Icicle Road (FR 7600) follows the river and residential homes reside, is armored with riprap. Much of the reach was not wadable for the habitat survey crew due to the confined, steep nature of the channel, and data is based on ocular estimates from the crew walking along the banks.

At the upstream end of Reach 5 is the Icicle-Peshastin Irrigation Canal and City of Leavenworth diversion structure (WDFW, 2025; Figure 48). The diversion included a 3-foot-tall concrete dam with an additional

one-half foot of wooden planks to increase height. The structure has been modified to improve fish pass but may still act as a barrier during a subset of flows.

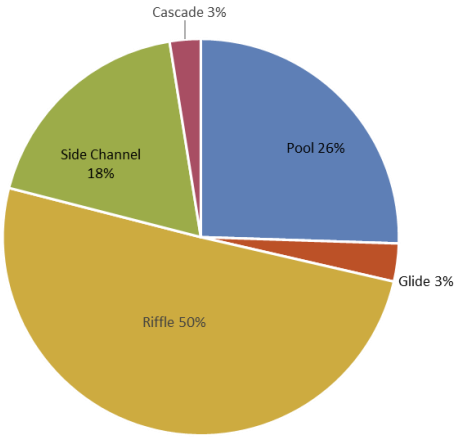


Figure 47. Stream habitat unit area composition for Reach 5.

Figure 48. Water diversion structure located at the upstream end of Reach 5.

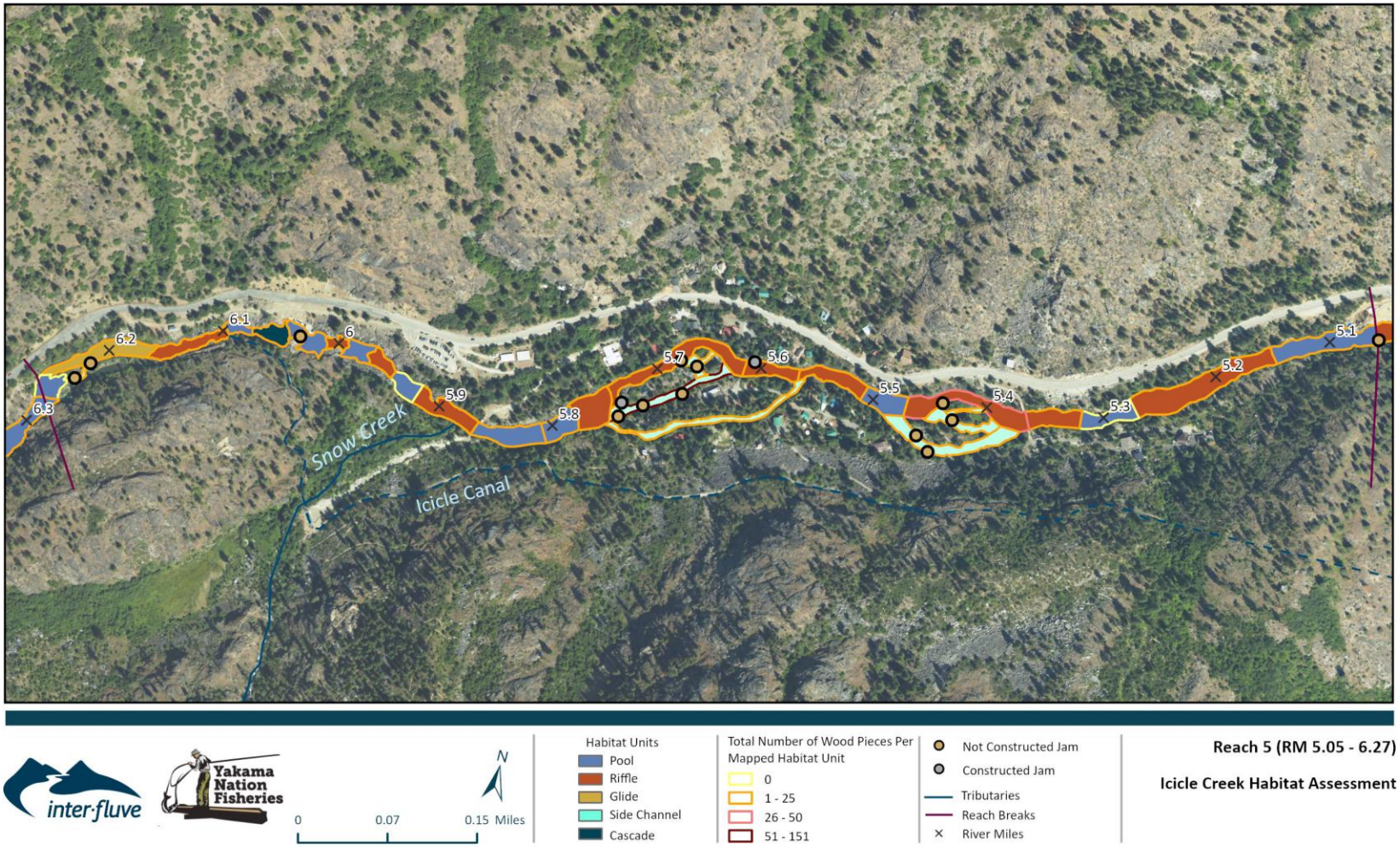


Figure 49. Map of the habitat unit composition and LWM in Reach 5 of Icicle Creek. LWM count includes pieces in jams.

4.5.2 Pools

A total of 9 pools were observed in Reach 5, which equates to approximately seven pools per mile. Two pools (22%) had residual pool depths less than three feet and five pools (56%) had residual depths between three and six feet. Two pools (22%) had a residual depth of six feet or more. Residual pool depths ranged from a low of 1.6 feet to a high of 7.5 feet, with a residual pool depth average of 4.2 feet (slightly less than the study area average of 4.4 feet).

4.5.3 Side Channel Habitat

Reach 5 had eight side channels recorded. All side channels were recorded as primarily fast water (e.g., riffle and glide habitat within the side channels). The total combined length of the side channels in Reach 5 was 2,814 feet. There were 36 LWM pieces observed in the side channels and nine jams with 101 pieces of LWM recorded (Table 15).

Table 15. Side channels observed in Reach 5.

Location	Length (ft)	Dominant Unit Type	Wood Count	Jam Count	Wood Count in Jams
Side 14	605	Fast	12	2	11
Side 15	304	Fast	3	1	12
Side 16	165	Fast	9	0	0
Side 17	935	Fast	2	0	0
Side 18	568	Fast	7	3	56
Side 19	98	Fast	2	2	4
Side 20	78	Fast	0	1	18
Side 21	61	Fast	1	0	0
Total	*2,814*		*36*	*9*	*101*

4.5.4 Large Woody Material

A total of 252 pieces of LWM were recorded in Reach 5. This total includes individual pieces and pieces recorded in jams. LWM frequency within the reach is approximately 207 pieces of LWM per mile, with 107 of those pieces per mile being Medium and Large LWM. Fourteen jams were observed in this reach, yielding 11 jams per mile. The jams contained approximately 143 pieces of LWM, about 57% of LWM in the entire reach (Table 16).

Table 16. LWM quantities in Reach 5.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20in x 35 ft)	Total
Number of Individual Pieces	56	38	15	109
Number of Individual Pieces per Mile	46	43		89
Number of Total Pieces per Mile (including pieces in jams)	99	107		207
Number of Jams	14			
Number of Jams per Mile	11			
Estimated Wood Count in Jams	143			

4.5.5 Substrate & Fine Sediment

No gravel counts were performed in Reach 5. Conditions were not appropriate or safe to complete a gravel count. Substrate was dominated by boulders.

4.5.6 Riparian Corridor

Three channel units in Reach 5 included ocular assessment of riparian vegetation. Large Trees (21.0 - 31.9-inch dbh) were the dominant overstory size class (100%). Ponderosa pine was the dominant overstory species, accounting for 67% of units. Cedar was also observed as an overstory species (33%; Figure 50). The dominant understory was comprised of entirely Shrub/Seedling vegetation size classes, with Alder as the primary understory species (Figure 51).

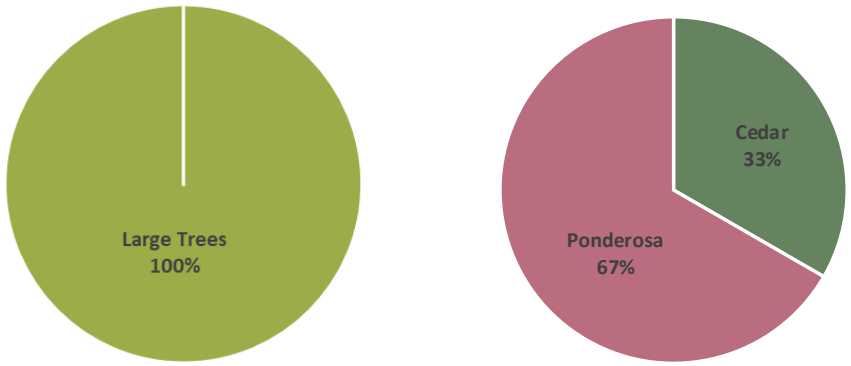


Figure 50. Dominant overstory riparian vegetation class and species, based on three nth units surveyed, within 100 feet of Icicle Creek by ocular estimate.

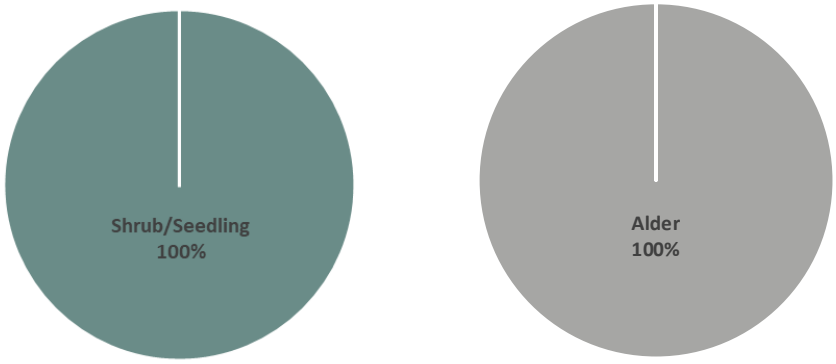


Figure 51. Dominant understory riparian vegetation class and species, based on three nth units surveyed, within 100 feet of Icicle Creek by ocular estimate.

4.6 REACH 6

Location: River mile 6.27 – 7.15
Total length: 0.88 miles
Survey Date: August 29 – 30, 2024

Figure 52. Representative photo of Reach 6. The habitat was dominated by riffles.

4.6.1 Habitat Unit Composition

Reach 6 was 0.88 miles long and the channel gradient was 3.82%, the steepest within the study area (study area average is 1.7%). The dominant habitat type was riffle, making up 67% of the total reach area. Pool habitat was the second most common habitat type within Reach 6, consisting of 32% of the study area habitat, followed by cascade (1%; Figure 53). One cascade unit was identified in Reach 6. The cascade (Figure 54) was located in the boulder field assessed by Dominguez et al. (2013). The entire left bank, where Icicle Road (FR 7600) follows the river, was armored with riprap. Much of the reach was not wadable for the habitat survey crew due to the confined, steep nature of the channel, and data is based on ocular assessment by the crew walking along the banks.

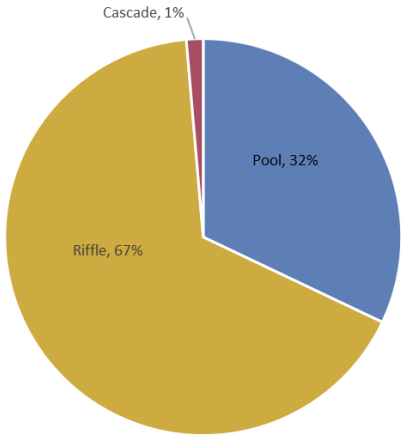


Figure 53. Stream habitat unit area composition of Reach 6.

Figure 54. Cascade units identified in Reach 6.

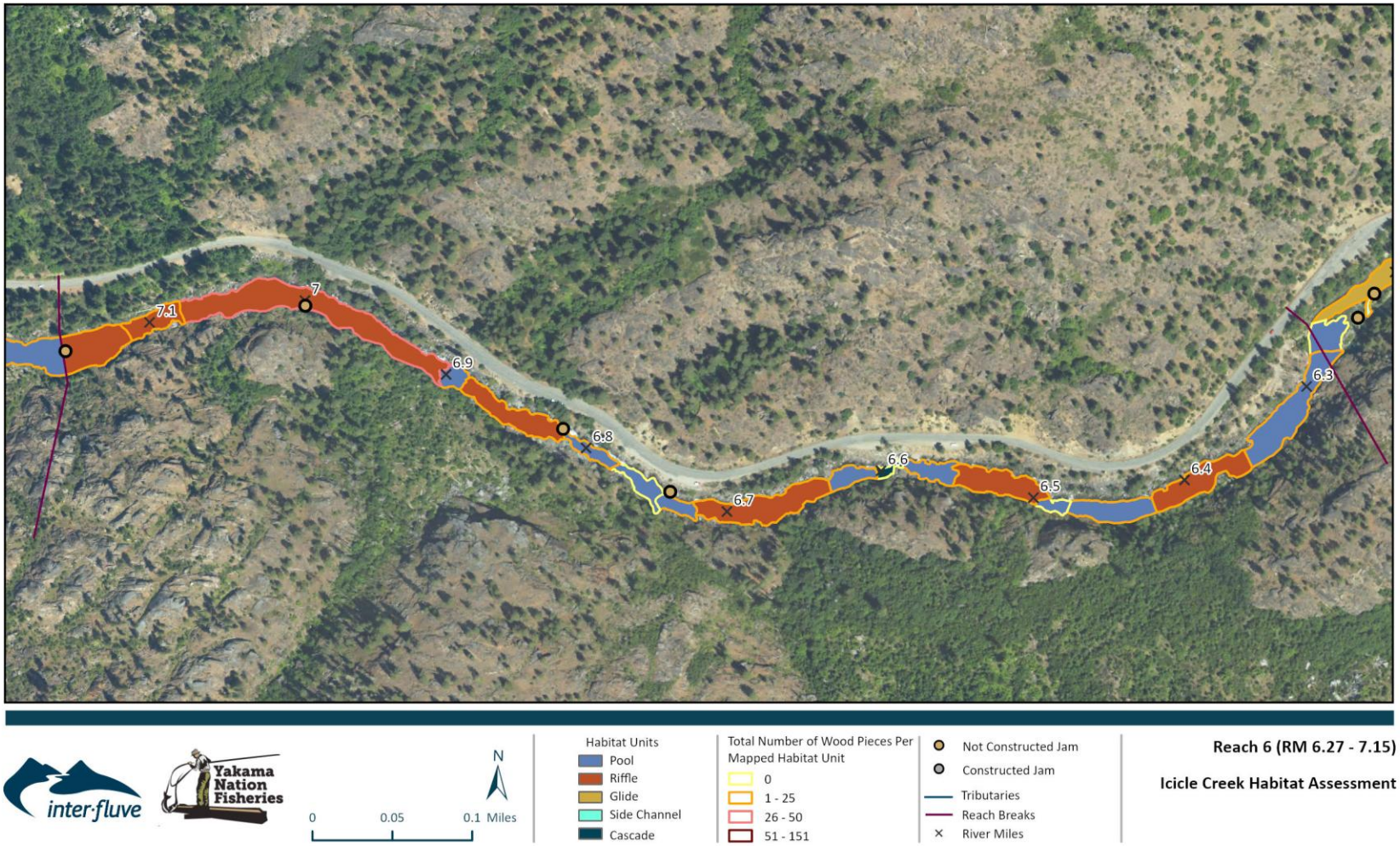


Figure 55. Map of the habitat unit composition and LWM in Reach 6 of Icicle Creek. LWM count includes pieces in jams.

4.6.2 Pools

Reach 6 had nine pools observed. Mean pool spacing for this reach was ten pools per mile, compared to the study area average pool spacing of seven pools per mile. Average residual depth of the pools was 5.5 ft and ranged from 2.3 ft to 14.7 ft. Of the nine pools, one pool (11%) had a residual pool depth less than three feet, four pools (67%) had a residual pool depth between three and six feet, and five pools (22%) has residual pool depths greater than or equal to six feet.

4.6.3 Side Channel Habitat

No side channels were observed in Reach 6.

4.6.4 Large Woody Material

One hundred-eighteen pieces of LWM were recorded in Reach 6. This total includes individual pieces and pieces recorded in jams. LWM frequency within the reach is approximately 134 pieces of LWM per mile, with 55 of those pieces per mile being Medium and Large LWM. Four jams were recorded within Reach 6 and contained an estimated 29 pieces of LWM or 25% of the total LWM pieces within the reach (Table 17).

Table 17. LWM quantities in Reach 6.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20in x 35 ft)	Total
Number of Individual Pieces	53	27	9	89
Number of Individual Pieces per Mile	60	41		101
Number of Total Pieces per Mile (including pieces in jams)	80	55		134
Number of Jams	4			
Number of Jams per Mile	5			
Estimated Wood Count in Jams	29			

4.6.5 Substrate & Fine Sediment

No gravel counts were performed in Reach 5. Conditions were not appropriate or safe to complete a gravel count. Substrate was dominated by boulders.

4.6.6 Riparian Corridor

Six channel units in Reach 6 included ocular assessment of riparian vegetation. The dominant overstory observed was Small Trees (80%; 9.0 - 20.9-inch dbh). Shrub/Seedling (20%; 1.0 - 4.9-inch dbh) composed the remaining overstory. Ponderosa pine was the dominant overstory species for all surveyed units (100%; Figure 56). The dominant understory in Reach 6 was Shrub/Seedling (60%; 1.0 - 4.9-inch dbh) and Grassland/Forb (40%). Alder (60%) and Other (40%) were the dominant understory species observed (Figure 57). Other understory species observed included grasslands and mosses, a classification outside the scope of the survey. Evidence of historical wildfires (e.g., burned trunks) was also noted on trees within the Reach 6 riparian zone.

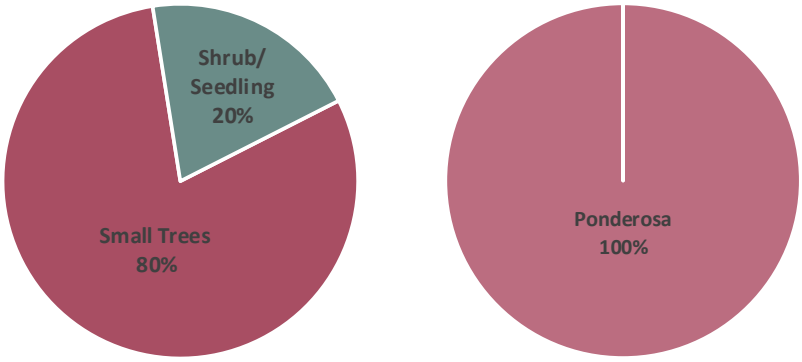


Figure 56.Dominant overstory riparian vegetation class and species, based on six units surveyed, within 100 feet of Icicle Creek by ocular estimate.

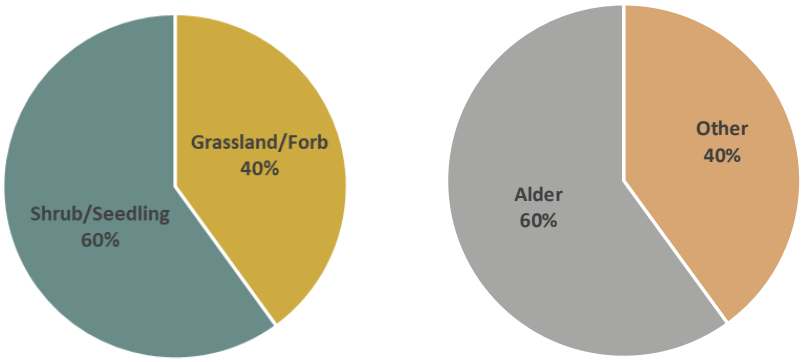


Figure 57. Dominant understory riparian vegetation class and species, based on six units surveyed, within 100 feet of Icicle Creek by ocular estimate.

4.7 REACH 7

Location: River mile 7.15 – 8.63
Total length: 1.48 miles
Survey Date: August 30 – 31, 2024

Figure 58. Representative photo of Reach 7. The habitat was dominated by riffles.

4.7.1 Habitat Unit Composition

Reach 7 was 1.48 miles long and continues the trend of predominantly fast water unit channel composition and higher stream gradients. Reach 7 is predominantly riffles (66%), followed by pools (23%) and side channels (11%; Figure 59). The stream gradient of this reach is 3.19%, which is steeper than than the study area average of 1.7%. Much of the reach was not wadable for the habitat survey crew due to the confined, steep nature of the channel, and data is based on ocular estimates from the crew walking along the banks.

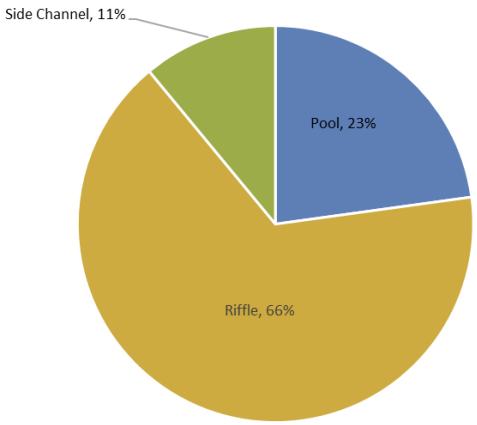


Figure 59. Stream habitat unit area composition of Reach 7.

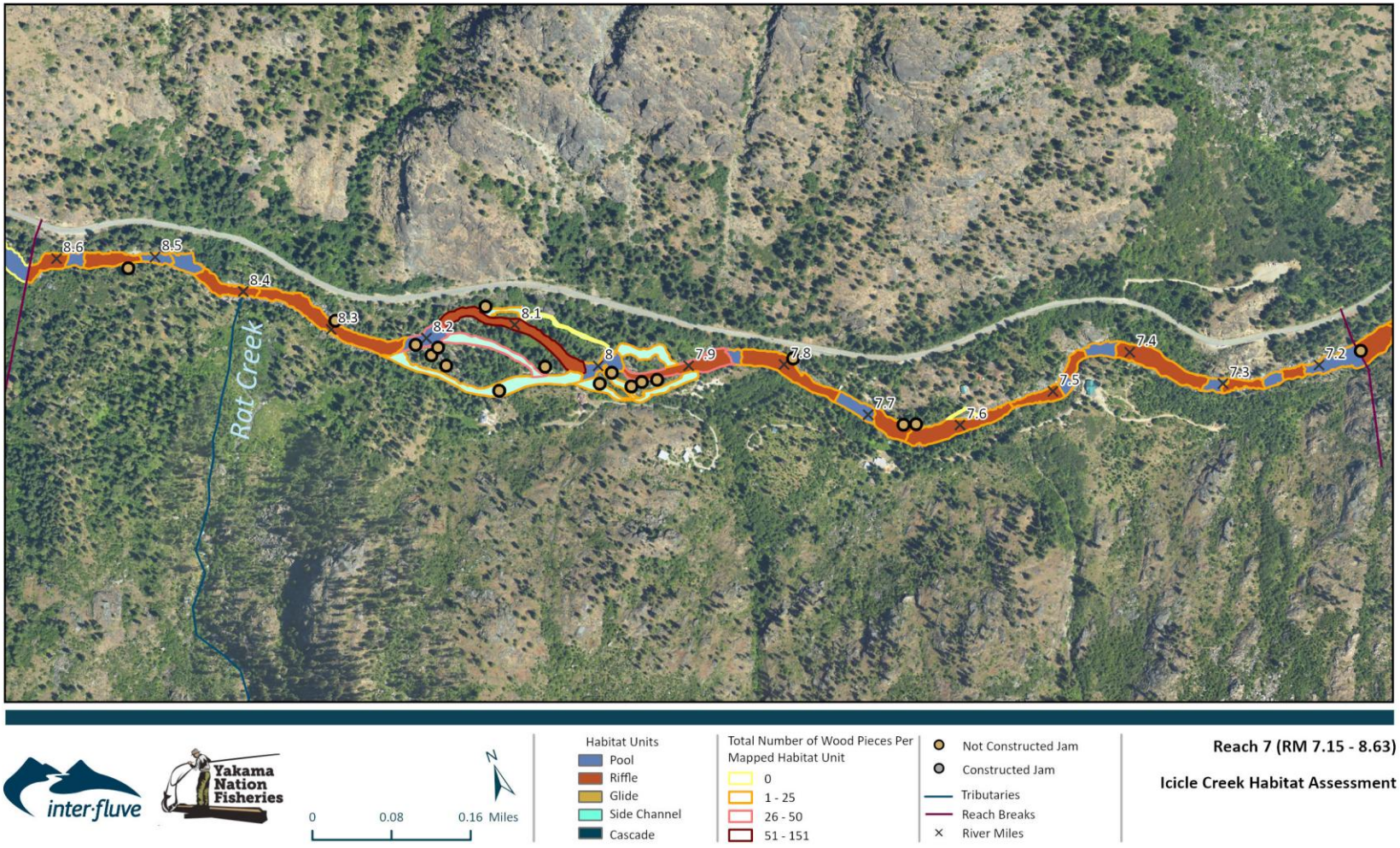


Figure 60. Map of the habitat unit composition and LWM in Icicle Creek in Reach 7. LWM count includes pieces in jams.

4.7.2 Pools

Twelve pool units were observed in Reach 7. Of those, eight pools (67%) had a residual depth between three and six feet, while four pools (33%) had a residual depth greater than six feet. Residual depth averaged 4.2 feet and ranged from 2.3 feet to 6 feet. Mean pool spacing in Reach 7 was eight pools per mile, greater than the average of seven pools per mile for the study area.

4.7.3 Side Channel Habitat

Reach 7 had eight recorded side channels. Of the eight side channels, only one side channel was dominated by slow water. The other seven side channels were dominated by fast water (e.g., riffle and glide habitat within the side channels). The total length of all the side channels in Reach 7 is 3,759 ft. A total of 96 pieces of LWM was recorded in the side channels. Seven jams were observed in the side channels and contained approximately 74 LWM pieces (Table 18).

Table 18. Side Channels observed in Reach 7.

Location	Length (ft)	Dominant Unit Type	Wood Count	Jam Count	Wood Count in Jams
Side 22	185	Fast	0	0	0
Side 23	634	Fast	6	2	16
Side 24	238	Slow	0	1	5
Side 25	330	Fast	10	0	0
Side 26	519	Fast	0	0	0
Side 27	1,044	Fast	6	2	14
Side 28	562	Fast	3	1	26
Side 29	246	Fast	7	1	13
Total	*3,759*		*32*	*7*	*74*

4.7.4 Large Woody Material

A total of 409 pieces of LWM was recorded in Reach 7. This total includes individual pieces and pieces recorded in jams. LWM frequency within the reach is approximately 276 pieces of LWM per mile, with 155 of those pieces per mile being Medium and Large LWM. Sixteen jams were recorded in Reach 7 containing 48% of LWM within the reach (Table 19).

Table 19. LWM quantities in Reach 7.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20in x 35 ft)	Total
Number of Individual Pieces	78	65	69	212
Number of Individual Pieces per Mile	53	91		143
Number of Total Pieces per Mile (including pieces in jams)	122	155		276
Number of Jams	16			
Number of Jams per Mile	11			
Estimated Wood Count in Jams	197			

4.7.5 Substrate & Fine Sediment

No gravel counts were performed in Reach 5. Conditions were not appropriate or safe to complete a gravel count. Substrate was dominated by boulders.

4.7.6 Riparian Corridor

Eleven channel units in Reach 7 included ocular assessment of riparian vegetation conditions. The dominant overstory in Reach 7 was Small Trees (28%; 9.0 - 20.9-inch dbh) followed by Shrub/Seedling (18%; 1.0 - 4.9-inch dbh), Sapling/Pole (18%; 5.0 - 8.9-inch dbh), Large Trees (18%; 21.0 - 31.9-inch dbh) and Mature Trees (18%; > 32-inch dbh). The dominant overstory species was Ponderosa pine (55%) followed by Cottonwood (27%), then Quaking Aspen (18%; Figure 61). The primary understory size class observed was Shrub/Seedling (82%; 1.0 - 4.9-inch dbh) and Sapling/Pole (18%; 5.0 - 8.9-inch dbh). Alder (46%) is the dominant understory species in Reach 7, followed by Willow (36%), then Cottonwood (18%; Figure 62).

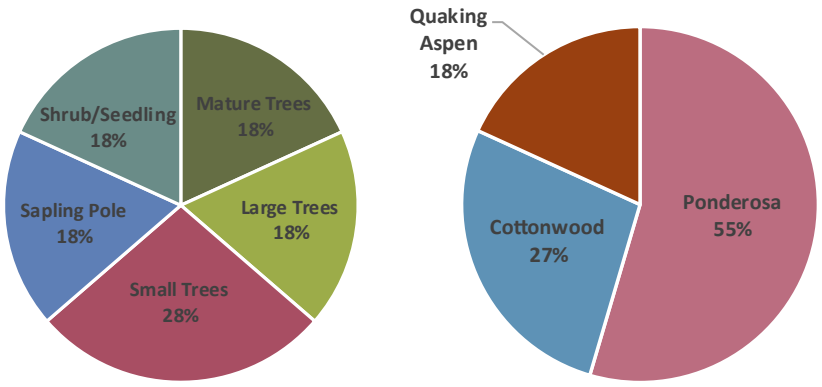


Figure 61. Dominant overstory riparian vegetation class and species, based on 11 units surveyed, within 100 feet of Icicle Creek by ocular estimate.

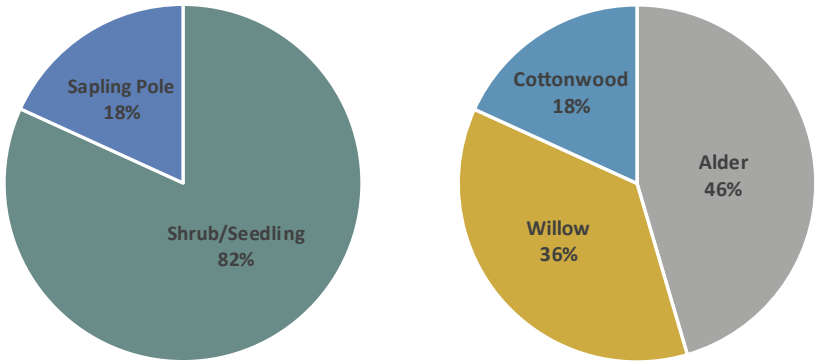


Figure 62. Dominant understory riparian vegetation class and species, based on 11 units surveyed, within 100 feet of Icicle Creek by ocular estimate.

4.8 REACH 8

Location: River mile 8.63 – 9.63
Total length: 1.0 miles
Survey Date: July 30, August 31 – September 1, 2024

Figure 63. Representative photo of Reach 8 of Icicle Creek. The habitat was dominated by riffles.

4.8.1 Habitat Unit Composition

Reach 8 is 1.0 miles long and had primarily riffle habitat unit types (68%). The second most prevalent unit type was side channels (22%), with pool units composing the remaining 10% of habitat area (Figure 64). Reach 8 had the most LWM observed within the study area. Channel gradient decreased to 1.94% from the steeper reaches just downstream. Much of the reach was not wadable for the habitat survey crew due to the confined, steep nature of the channel, and data is based on ocular estimates from the crew walking along the banks.

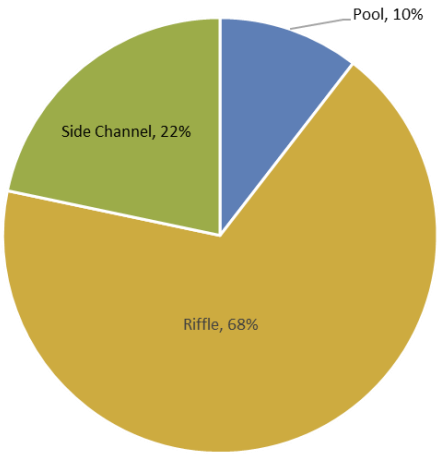


Figure 64. Stream habitat unit area composition of Reach 8.

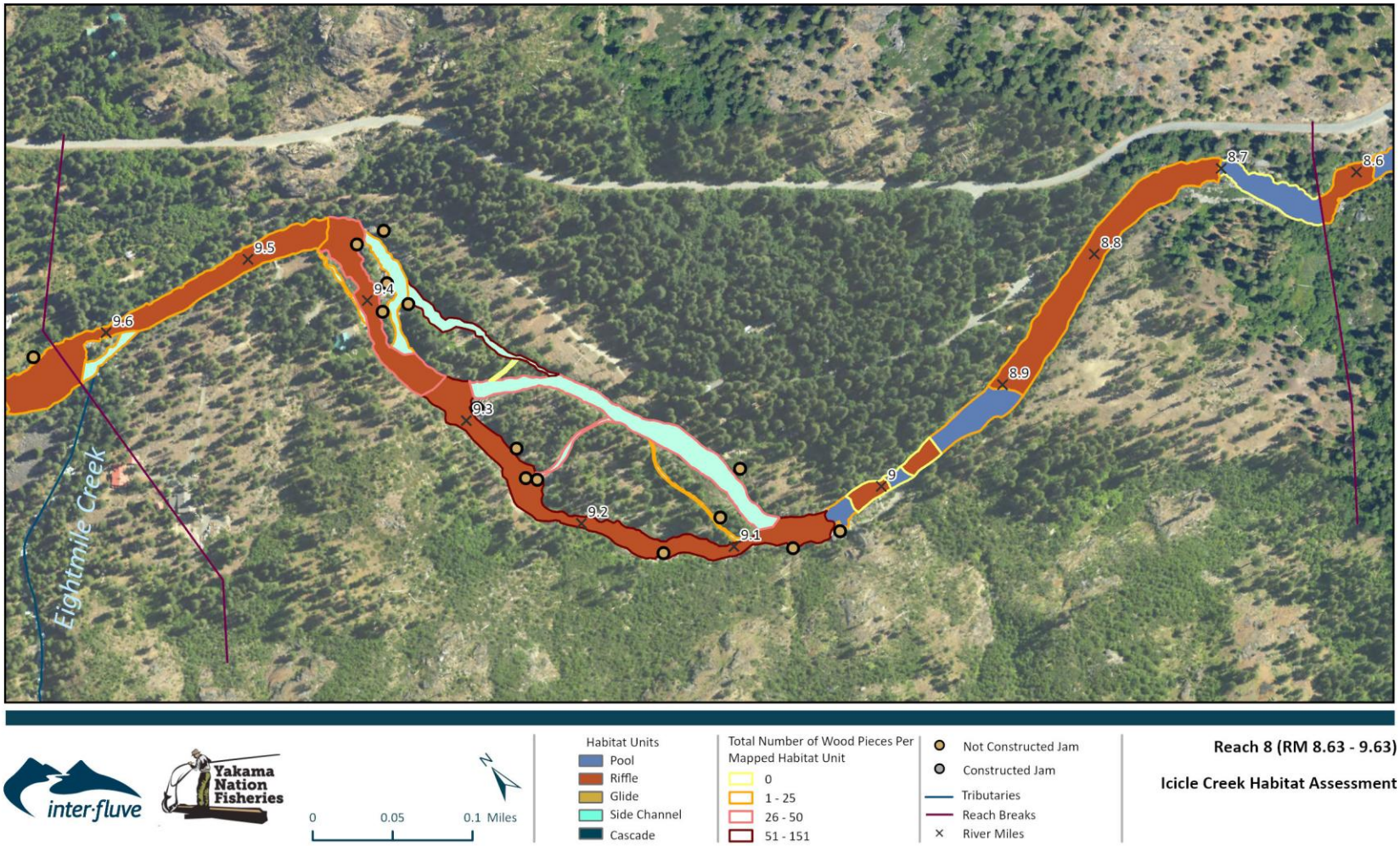


Figure 65. Map of the habitat unit composition and LWM in Reach 8 of Icicle Creek. LWM count includes pieces in jams.

4.8.2 Pools

Reach 8 had four total pools, all of which had a residual depth greater than or equal to six feet. The average residual pool depth in Reach 8 was 4.9 feet and ranged from 4.2 feet to six feet. The mean pool spacing for the reach was four pools per mile, less than the study area average of seven pools per mile.

4.8.3 Side Channel Habitat

Eight side channels were surveyed in Reach 8 with a total channel length of 3,527 feet. A majority of the side channels were fast water (e.g., riffle and glide habitat within the side channels), while two of the eight side channels were predominantly slow water. A total of 41 individual LWM pieces were recorded in the side channels and five jams were observed with an estimated 133 pieces of LWM present within the jams (Table 20).

Table 20. Side Channels observed in Reach 8.

Location	Length (ft)	Dominant Unit Type	Wood Count	Jam Count	Wood Count in Jams
Side 30	1,152	Fast	20	1	12
Side 31	319	Slow	9	1	1
Side 32	566	Slow	2	1	45
Side 33	107	Fast	0	1	71
Side 34	468	Fast	0	0	0
Side 35	443	Fast	6	1	4
Side 36	273	Fast	1	0	0
Side 37	201	Fast	3	0	0
Total	*3,527*		*41*	*5*	*133*

4.8.4 Large Woody Material

A total of 385 pieces of LWM were recorded in Reach 8. This total includes individual pieces and pieces recorded in jams. LWM frequency within the reach is approximately 385 pieces of LWM per mile, with 237 of those pieces per mile being Medium and Large LWM. Fourteen jams were recorded in Reach 8 containing 77% of LWM within the reach (Table 21).

Table 21. LWM quantities in Reach 8.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20in x 35 ft)	Total
Number of Individual Pieces	39	41	9	89
Number of Individual Pieces per Mile	39	50		89
Number of Total Pieces per Mile (including pieces in jams)	148	237		385
Number of Jams	14			
Number of Jams per Mile	14			
Estimated Wood Count in Jams	296			

4.8.5 Substrate & Fine Sediment

Two gravel counts were conducted in Reach 8, and the combined average of the two counts had boulder (41%), followed by cobble (35%), gravel (20%) and sand (4%; Figure 66). The first gravel count, GC18, was

conducted at a riffle crest near RM 8.91 and the second gravel count, GC19, was conducted at a riffle crest upstream of a flow split near RM 9.32. The distribution and grain size class can be found in Figure 67-Figure 68 and Table 22.

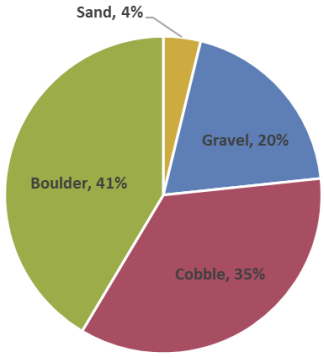


Figure 66. Percent sediment composition from two gravel counts (GC19 and GC18) performed in Reach 8.

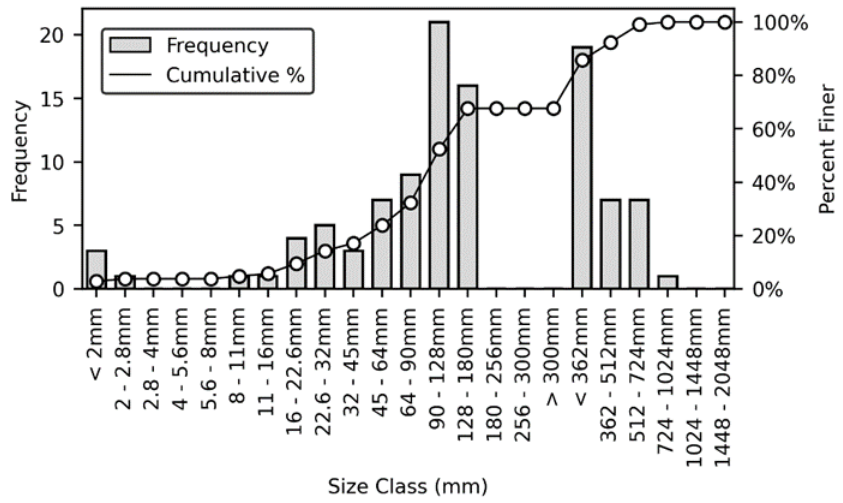


Figure 67. Cumulative distribution curve for GC19.

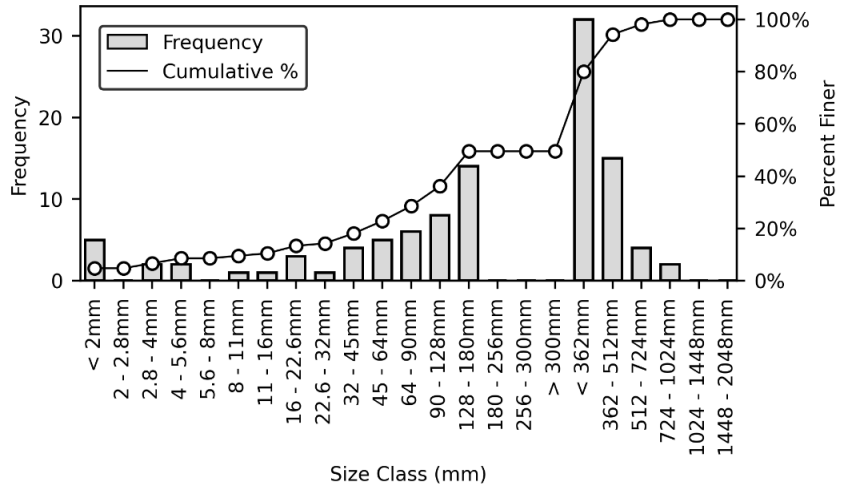


Figure 68. Cumulative distribution curve for GC18.

Table 22. Grain size class for GC19 and GC18 (assumed linear interpolation).

Size Class	GC19 *Size percent finer than (mm)*	GC18 *Size percent finer than (mm)*
D5	12	3
D16	38	37
D50	123	256
D84	350	400
D95	590	550

4.8.6 Riparian Corridor

Three channel units in Reach 8 included ocular assessment of riparian vegetation. The overstory consisted entirely of Large Trees (21.0 - 31.9-inch dbh), which were documented as Cedar (67%) and Ponderosa pine (33%; Figure 69). The understory was entirely Shrub/Seedling (1.0 - 4.9-inch dbh) size classes, which were primarily Alder (67%) and Willow (33%) species (Figure 70).

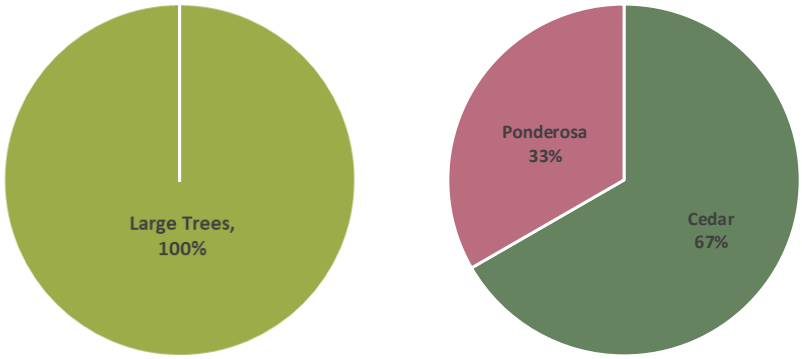


Figure 69. Dominant overstory riparian vegetation class and species, based on three surveyed units, within 100 feet of Icicle Creek by ocular estimate.

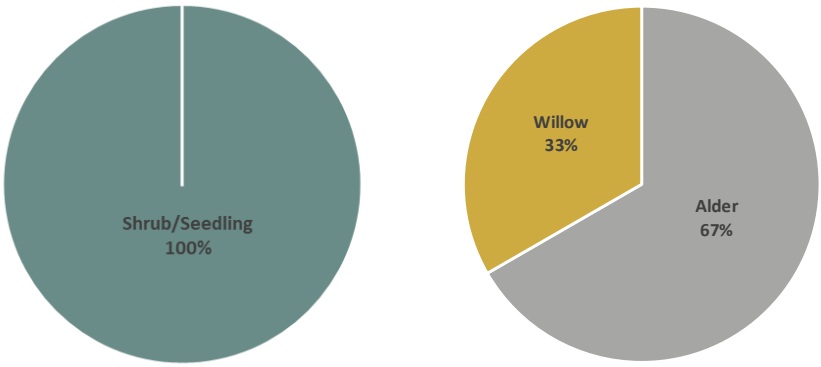


Figure 70. Dominant understory riparian vegetation class and species, based on three surveyed units, within 100 feet of Icicle Creek by ocular estimate.

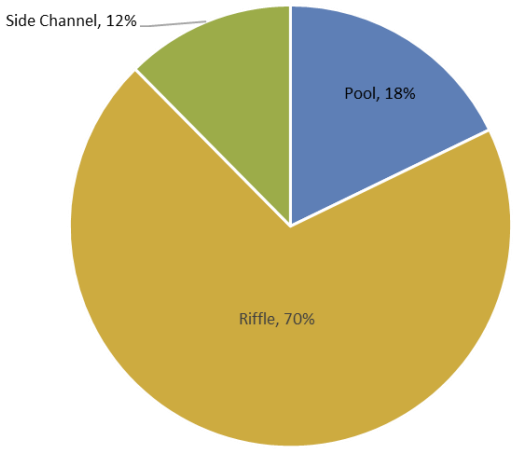
4.9 REACH 9

Location: River mile 9.63 – 10.24
Total length: 0.61 miles
Survey Date: September 9 – 10, 2024

Figure 71. Representative photo of Reach 9 in Icicle Creek. The habitat was dominated by riffles.

4.9.1 Habitat Unit Composition

Reach 9 was approximately 0.61 miles long and was primarily riffles (70%), followed by pools (18%) and side channels (12%; Figure 72). Reach 9 has a substantial increase in channel gradient from Reach 8, with an average of 3.7% for the reach. Reach 9 starts at Eight Mile Creek and ends at large bedrock outcrop on the right bank. Several units within the reach were not wadable for the habitat survey crew due to the confined, steep nature of the channel, and data is based on ocular estimates from the crew walking along the banks.



Figu ition for Reach 9.

Replace with Field Photo

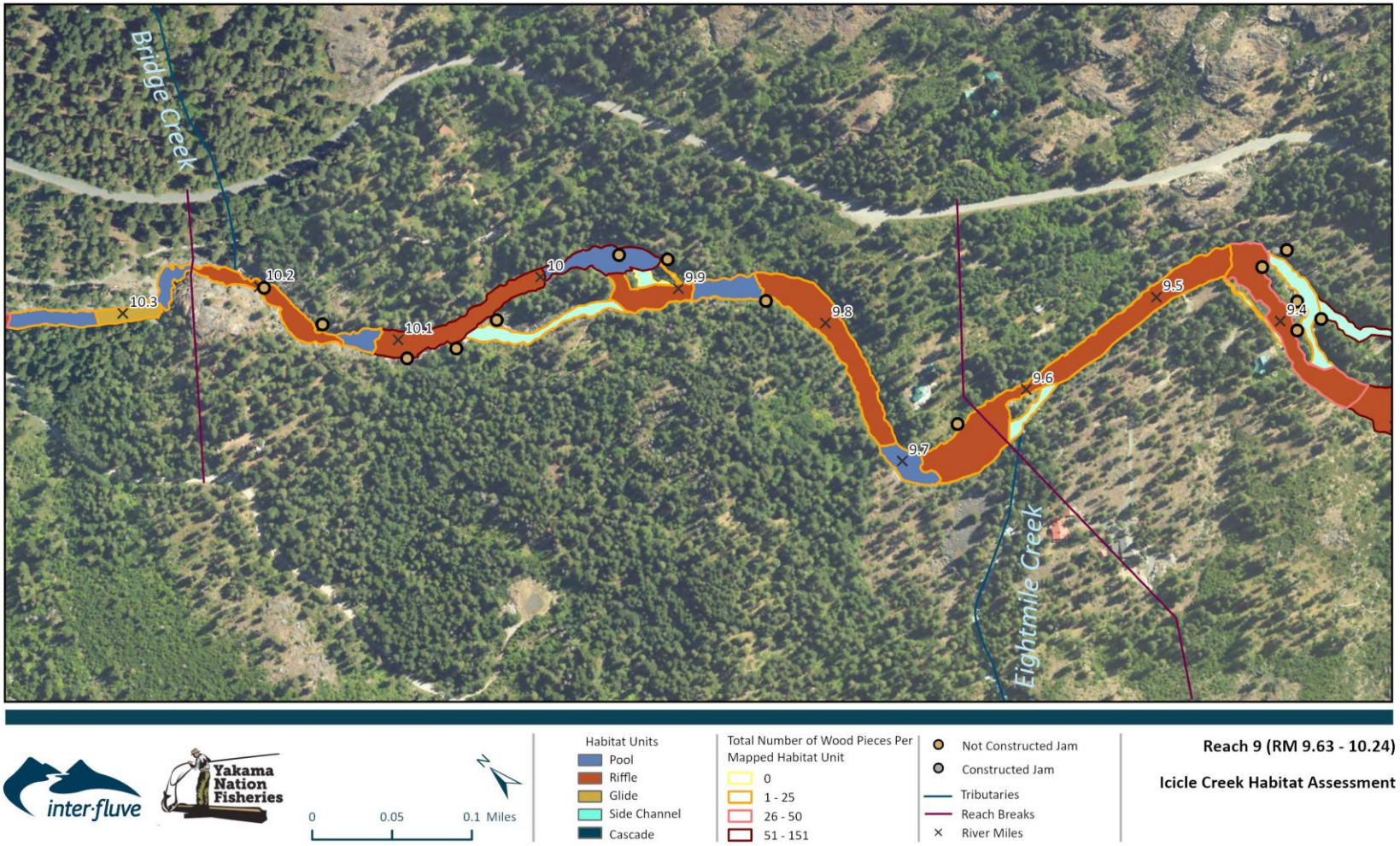


Figure 73. Map of the habitat unit composition and LWM in Reach 9 of Icicle Creek. LWM count includes pieces in jams.

4.9.2 Pools

A total of four pools were recorded in Reach 9, equivalent to seven pools per mile. The average residual depth of the pools was 3.9 feet, compared to the study area average of 4.4 feet. Residual pool depth ranged from 1.2 feet to 5.2 feet. Of the four pools, 25% had residual pool depths less than three feet and 75% of pools had residual pool depths between three and six feet.

4.9.3 Side Channel Habitat

In Reach 9, three side channels were observed and had a total channel length of 666 feet. Two of the side channels were relatively short (less than 100 feet) while one was over 500 feet long. All three side channels were predominantly fast water types (e.g., riffle and glide habitat within the side channels). A total of seven individual pieces of LWM were found in the three side channels. One jam was recorded with 13 total pieces of LWM (Table 23).

Table 23. Side Channels observed in Reach 9.

Location	Length (ft)	Dominant Unit Type	Wood Count	Jam Count	Wood Count in Jams
Side 38	95	Fast	0	0	0
Side 39	55	Fast	0	0	0
Side 40	517	Fast	7	0	0
Total	*666*		*7*	*0*	*0*

4.9.4 Large Woody Material

A total of 215 pieces of LWM were recorded in Reach 9. This total includes individual pieces and pieces recorded in jams. LWM frequency within the reach is approximately 352 pieces of LWM per mile, with 200 of those pieces per mile being Medium and Large LWM. Nine jams were recorded in Reach 9 containing 67% of LWM within in the reach (Table 24).

Table 24. LWM quantities in Reach 9.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20in x 35 ft)	Total
Number of Individual Pieces	35	31	5	71
Number of Individual Pieces per Mile	57	59		116
Number of Total Pieces per Mile (including pieces in jams)	152	200		352
Number of Jams	9			
Number of Jams per Mile	15			
Estimated Wood Count in Jams	144			

4.9.5 Substrate & Fine Sediment

One gravel count (GC17) was conducted in Reach 9. The dominant substrate in the gravel count was recorded as 45% boulder, 32% cobble, 21% gravel and 3% sand (Figure 74). The gravel count was conducted at a riffle crest at RM 9.84. The distribution and grain size class can be found in Figure 75 and Table 25.

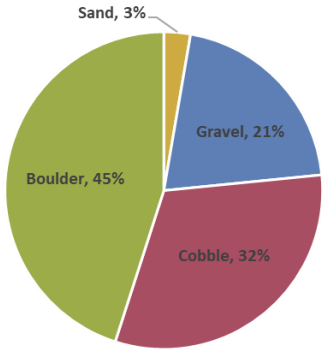


Figure 74. Percent sediment composition from the gravel count (GC17) performed in Reach 9.

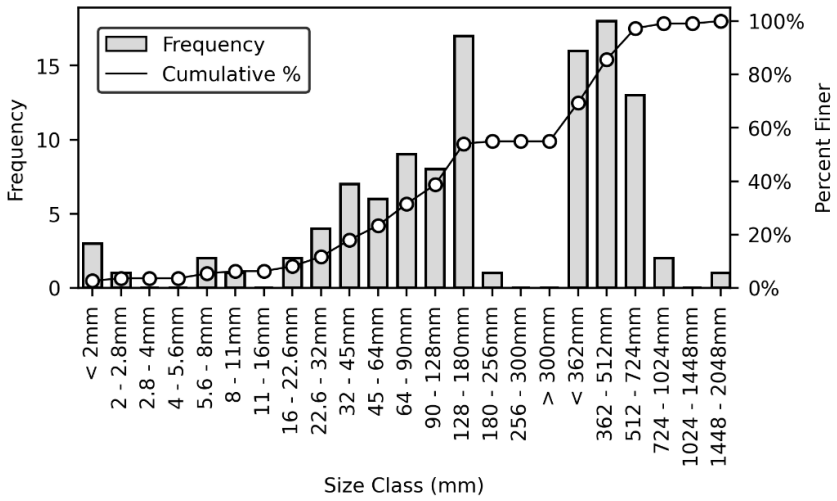


Figure 75. Cumulative distribution curve for GC17.

Table 25. Grain size class for GC17 (assumed linear interpolation).

	GC17
Size Class	*Size percent finer than (mm)*
D5	8
D16	40
D50	165
D84	500
D95	680

4.9.6 Riparian Corridor

Based on four ocular assessments of riparian vegetation in Reach 9, the dominant overstory size class was Large Trees (100%; 21 - 31.9-inch dbh). Ponderosa pine was the dominant overstory species (75%), with Cedar recorded for the other 25% of overstory species (Figure 76). The dominant understory size class was recorded as entirely Alder in the Shrub/Seedling size class (1.0 - 4.9-inch dbh; Figure 77).

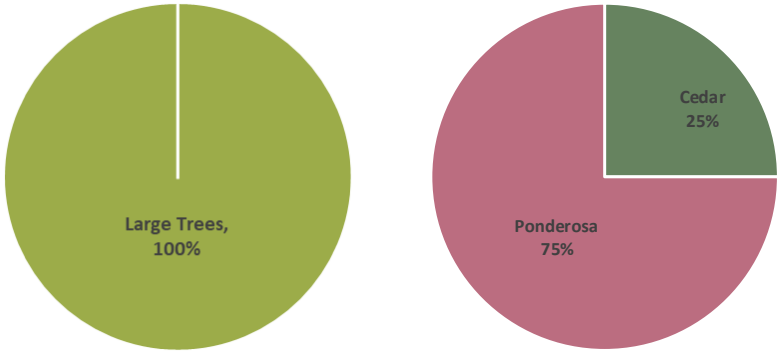


Figure 76. Dominant overstory riparian vegetation class and species, based on four surveyed units, within 100 feet of Icicle Creek by ocular estimate.

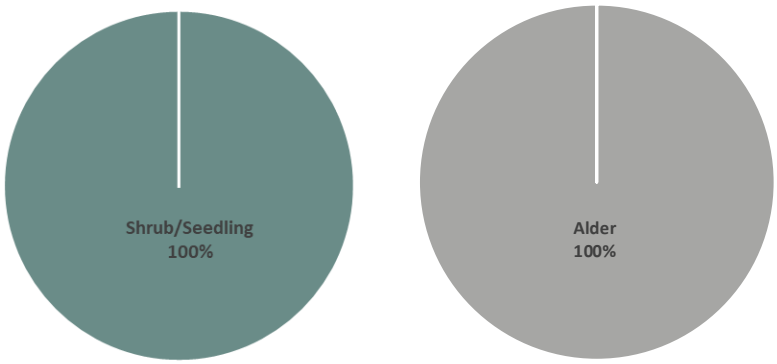


Figure 77. Dominant understory riparian vegetation class and species, based on four surveyed units, within 100 feet of Icicle Creek by ocular estimate.

4.10 REACH 10

Location: River mile 10.24 – 11.36
Total length: 1.12 miles
Survey Date: September 10, 2024

Figure 78. Representative photo of Reach 10 in Icicle Creek. Habitat is dominated by riffles.

4.10.1 Habitat Unit Composition

Reach 10 was 1.12 miles long and had the greatest percentage of fast water unit types within the entire study area, almost entirely riffle (86%) or glide (2%) habitat units. Side channels and pool units equally comprised 6% of the channel unit area (Figure 79). Channel gradient in this reach was 1.31%, a substantial decrease from the previous unit. Much of the left bank contained campgrounds managed by the U.S. Forest Service, dispersed camping, and road pull-offs.

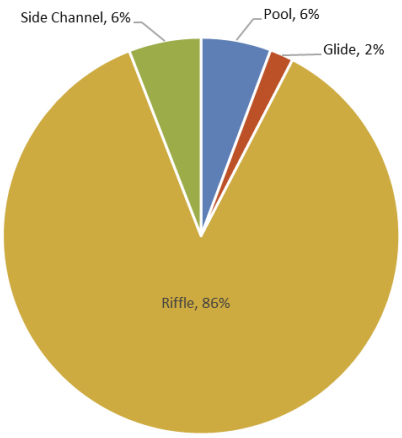


Figure 79. Stream habitat unit area composition of Reach 10.

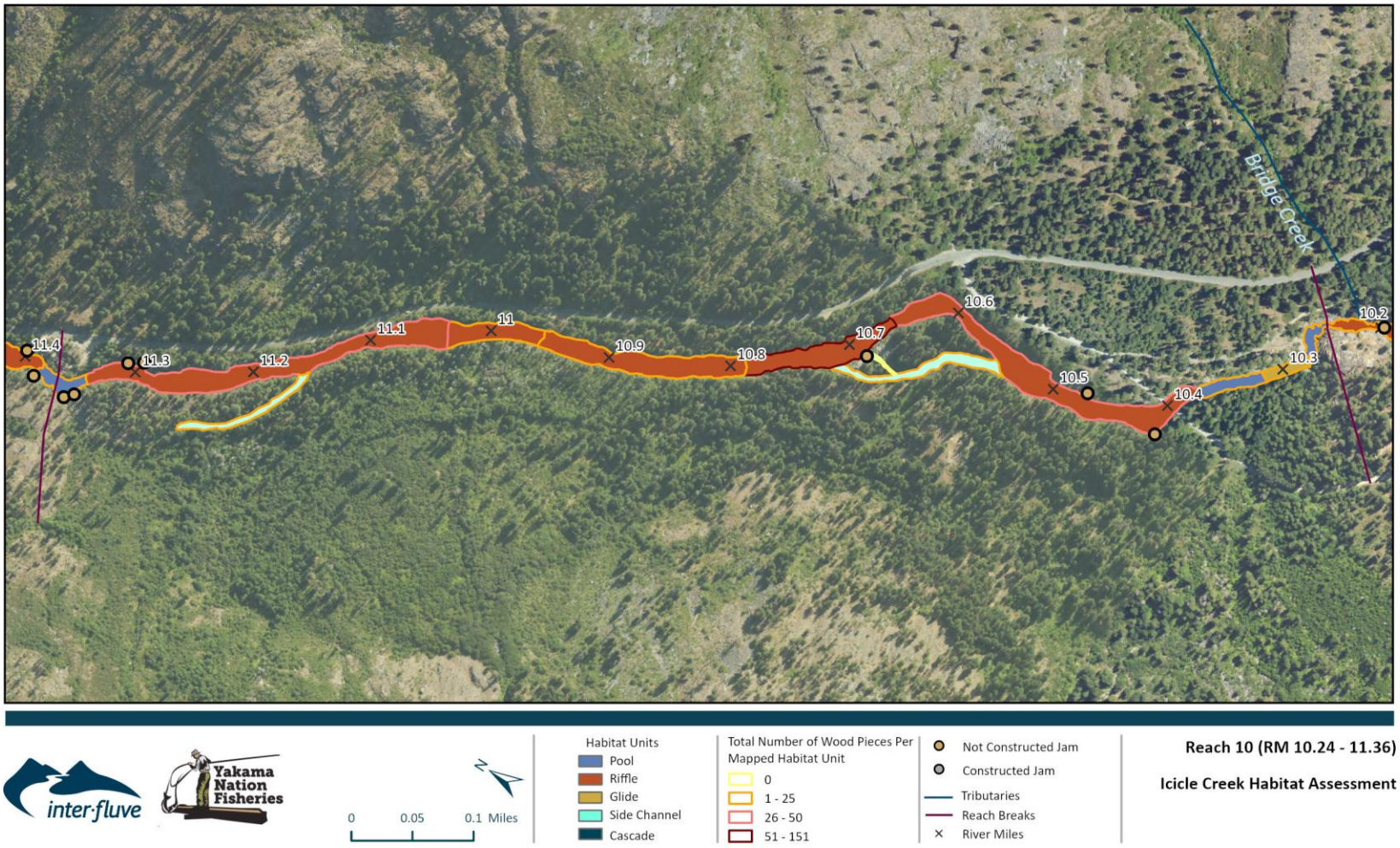


Figure 80. Map of the habitat unit composition and LWM in Reach 10 of Icicle Creek. LWM count includes pieces in jams.

4.10.2 Pools

Three pool units were observed in Reach 10. Of those pools, 33% had a residual depth less than three feet and 67% had a residual pool depth between three feet and six feet. Residual pool depths ranged from 1.8 feet to 4.6 feet and averaged approximately 3.6 feet. Mean pool spacing in Reach 10 was three pools per mile, substantially lower than the study area average of seven pools per mile.

4.10.3 Side Channel Habitat

Three side channels were observed in Reach 10. Two of the three side channels were fast water, and one was slow water. A total of ten individual LWM pieces were recorded in the side channels. One jam was observed with 17 pieces of LWM (Table 26).

Table 26. Side channels observed in Reach 10.

Location	Length (ft)	Dominant Unit Type	Wood Count	Jam Count	Wood Count in Jams
Side 41	732	Fast	2	0	0
Side 42	162	Fast	0	0	0
Side 43	620	Slow	8	1	0
Total	*1,513*		*10*	*1*	*17*

4.10.4 Large Woody Material

A total of 218 pieces of LWM were recorded in Reach 10. This total includes individual pieces and pieces recorded in jams. LWM frequency within the reach is approximately 195 pieces of LWM per mile, with 108 of those pieces per mile being Medium and Large LWM. Seven jams were observed in the reach, which equates to six jams per mile. Jams contained 72% of the total LWM pieces recorded in the reach (Table 27).

Table 27. LWM quantities in Reach 10.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20in x 35 ft)	Total
Number of Individual Pieces	32	20	8	60
Number of Individual Pieces per Mile	29	25		54
Number of Total Pieces per Mile (including pieces in jams)	87	108		495
Number of Jams	7			
Number of Jams per Mile	6			
Estimated Wood Count in Jams	158			

4.10.5 Substrate & Fine Sediment

Two gravel counts were performed in Reach 10, with a combined average of 42% boulder, 33% cobble, 23% gravel and 2% fines (Figure 81). The first gravel count, GC16, was conducted within a riffle at RM 10.46 and the second gravel count, GC15, was conducted at a riffle crest at RM 11.05. The distribution and grain size class can be found in Figure 82– Figure 83 and Table 28.

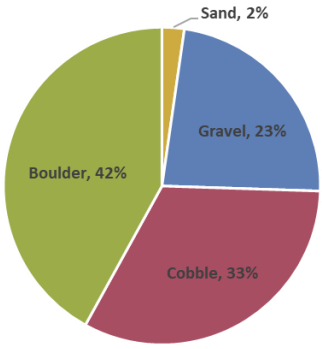


Figure 81. Combined percent sediment composition from the gravel counts (GC16 and GC15) performed in Reach 10.

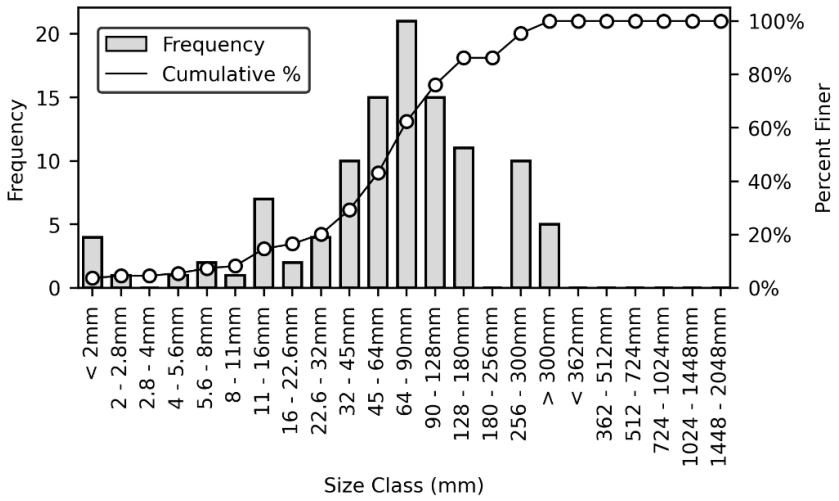


Figure 82. Cumulative distribution curve for GC16.

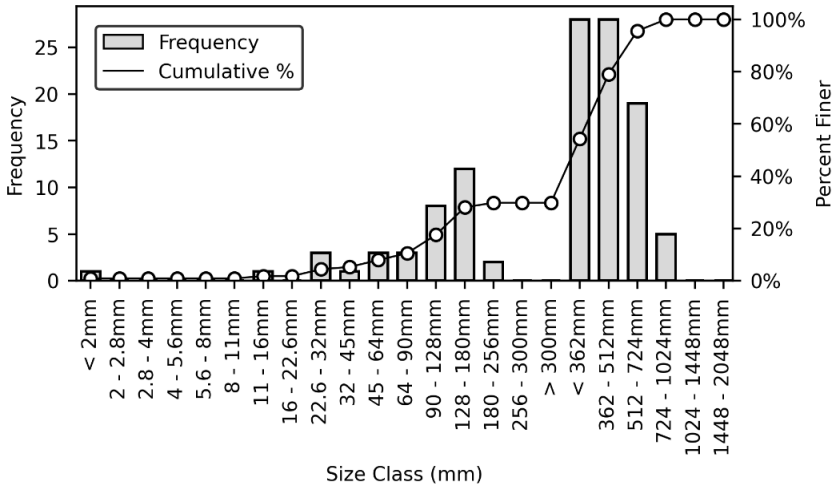


Figure 83. Cumulative distribution curve for GC15.

Table 28. Grain size class for GC16 and GC15 (assumed linear interpolation).

Size Class	GC16 *Size percent finer than (mm)*	GC15 *Size percent finer than (mm)*
D5	5	35
D16	20	115
D50	73	330
D84	165	525
D95	205	650

4.10.6 Riparian Corridor

Based on seven ocular assessments of riparian vegetation in Reach 10, the dominant overstory was Large Trees (62%; 21 - 31.9-inch dbh), followed by Small Trees (25%; 9.0 - 20.9-inch dbh) then by Other (13%). The dominant overstory species in Reach 10 was Ponderosa pine (75%), followed by Cedar (12%) and Other/Unknown (13%; Figure 84). The Other size class and Other/Unknown species in Reach 10 is due to a fire scar, in which the overstory was charred dead trees. The dominant understory size class was Shrub/Seedling (87%; 1.0 - 4.9-inch dbh) followed by Small Tree (13%). The dominant understory species in Reach 10 was Alder (87%) and Willow (13%; Figure 85).

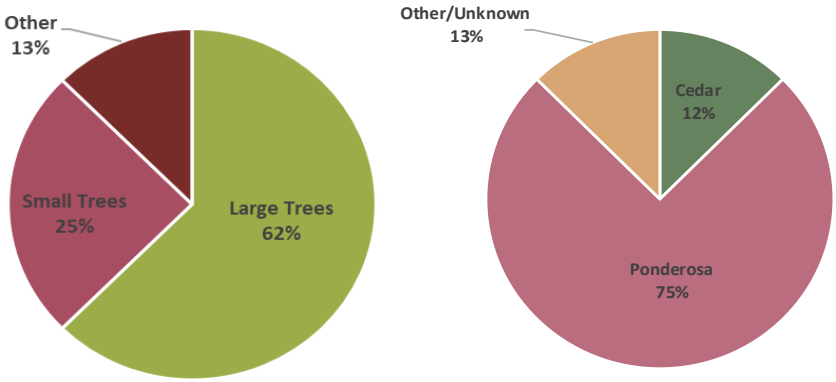


Figure 84. Dominant overstory riparian vegetation class and species, based on seven surveyed units, within 100 feet of Icicle Creek by ocular estimate.

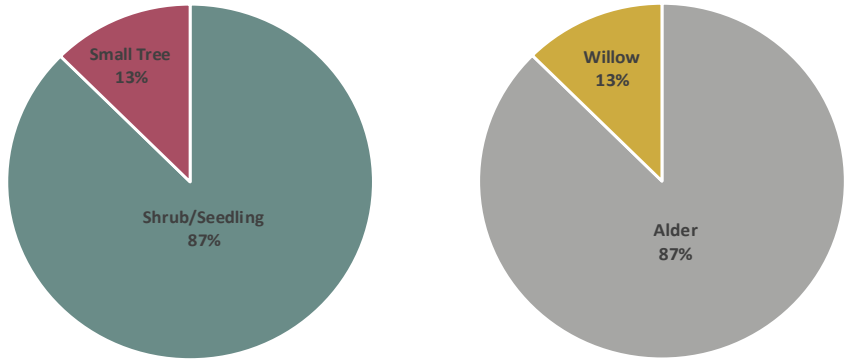


Figure 85. Dominant understory vegetation class and species, based on seven surveyed units, within 100 feet of Icicle Creek by ocular estimate.

4.11 REACH 11

Location: River mile 11.36 – 11.92
Total length: 0.56 miles
Survey Date: September 10 – 11, 2024

Figure 86. Representative photo of Reach 11. Habitat is dominated by riffles.

4.11.1 Habitat Unit Composition

Reach 11 was dominated by riffles, composing 71% of the habitat unit area. Pools comprised the remaining 29% (Figure 87). The reach is 0.56 miles long and has a channel gradient of 3.4%, an increase from the previous reach. The right bank on the downstream channel units within Reach 11 was reinforced by riprap and the left bank had intermittent bedrock exposure. Much of the reach was not wadable for the habitat survey crew due to the confined, steep nature of the channel, and data is based on ocular estimates from the crew walking along the banks.

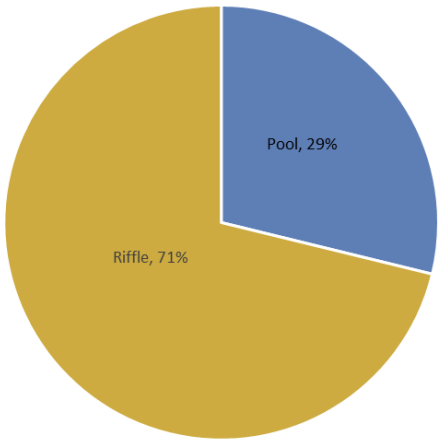


Figure 87. Stream habitat unit area composition of Reach 11.

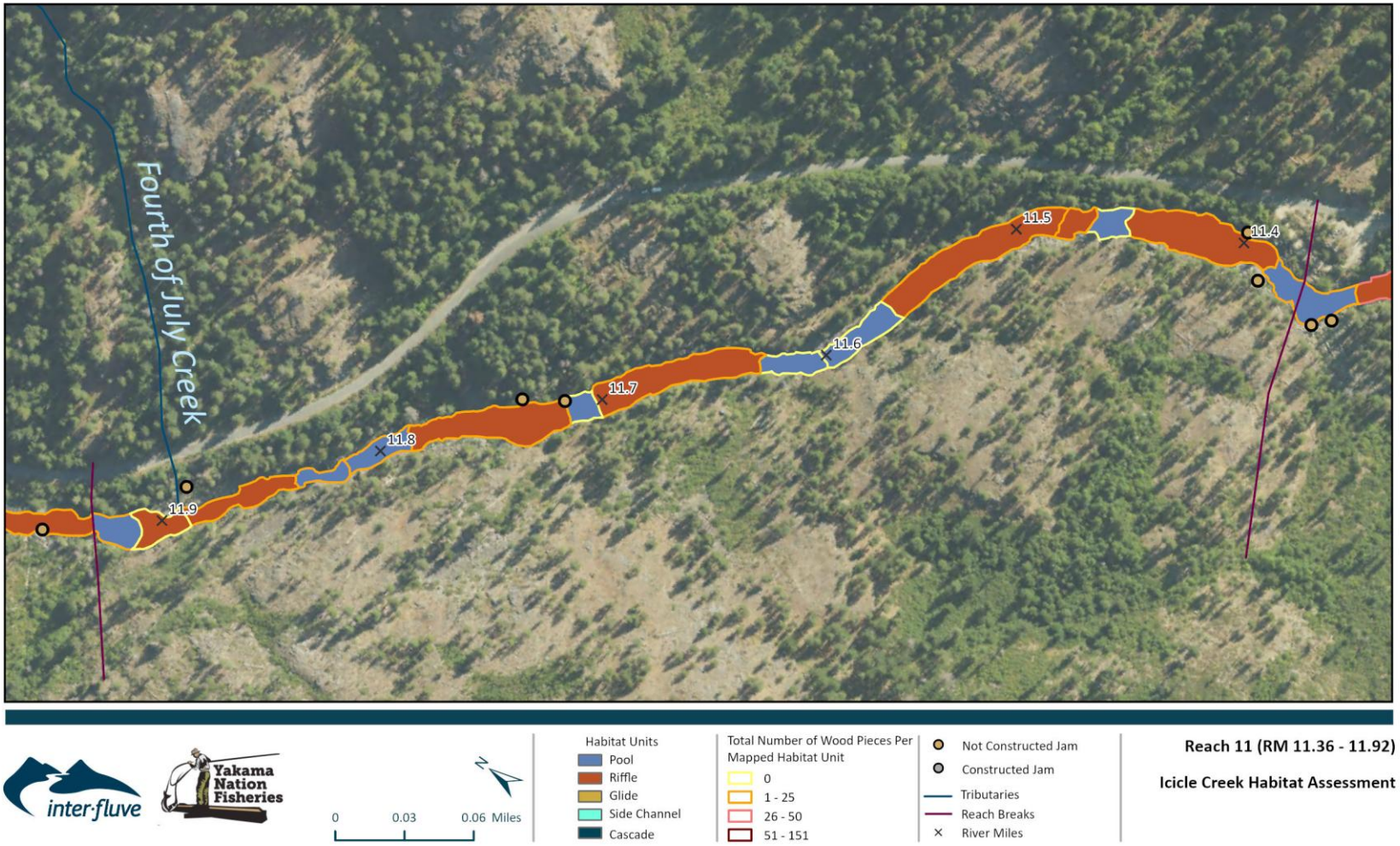


Figure 88. Map of the habitat unit composition and LWM in Reach 11 of Icicle Creek. LWM count includes pieces in jams.

4.11.2 Pools

Eight pool units were observed in Reach 11. Of those eight pools, 63% had a residual depth between three feet and six feet, while 25% had a residual depth less than three feet and 12% had a residual depth greater than six feet. Residual depth ranged from 2.2 feet to 6.5 feet, and averaged approximately four feet, only slightly less than the study area average of 4.4 feet. Mean pool spacing in Reach 11 was 14 pools per mile, more than the study area average of seven pools per mile.

4.11.3 Side Channel Habitat

No side channels were observed in Reach 11.

4.11.4 Large Woody Material

A total of 48 pieces of LWM was recorded in Reach 11. This includes individual pieces and pieces recorded in jams. LWM frequency within the reach is approximately 86 pieces of LWM per mile, with 52 of those pieces per mile being Medium and Large LWM. Five jams were observed in Reach 11 containing 35% of LWM within the reach (Table 29).

Table 29. Large Wood Material quantities in Reach 11.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20in x 35 ft)	Total
Number of Individual Pieces	14	11	6	31
Number of Individual Pieces per Mile	25	30		55
Number of Total Pieces per Mile (including pieces in jams)	34	52		86
Number of Jams	5			
Number of Jams per Mile	9			
Estimated Wood Count in Jams	17			

4.11.5 Substrate & Fine Sediment

No gravel counts were performed in Reach 11. Conditions were not appropriate or safe to complete a gravel count. Substrate was dominated by boulders.

4.11.6 Riparian Corridor

Based on six ocular assessments of riparian vegetation in Reach 11, the dominant overstory class and species was Large Tree (100%; 21 - 31.9-inch dbh) and Ponderosa (100%; Figure 89). The dominant understory size was split between Shub/Seedling (83%; 1.0 - 4.9-inch dbh) and Grassland/Forb (17%). The dominant understory species in Reach 11 was Alder (87%) and Other (13%; Figure 90). The Other species in the understory was recorded as a grass.

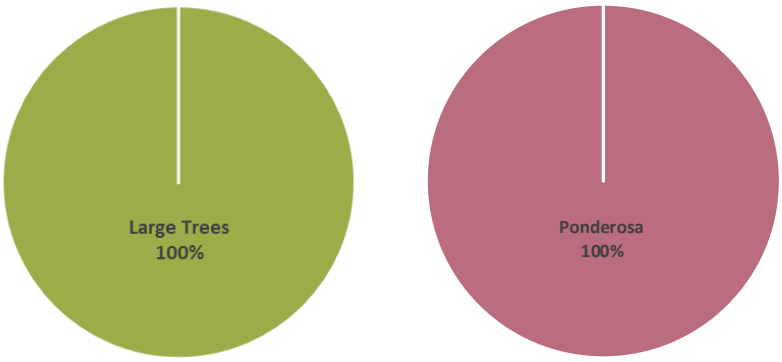


Figure 89. Dominant overstory riparian vegetation class and species, based on six surveyed units, within 100 feet of Icicle Creek by ocular estimate.

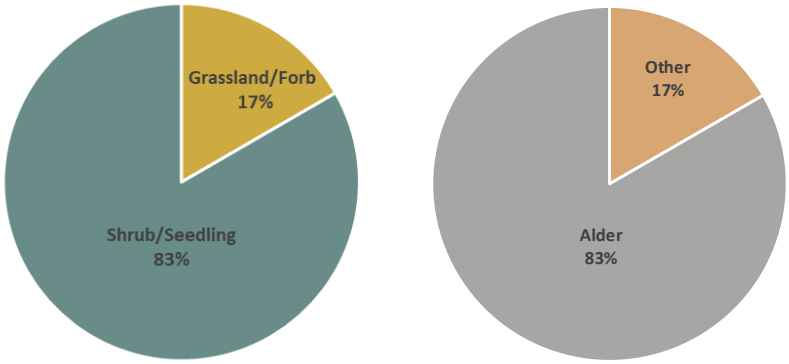


Figure 90. Dominant understory riparian vegetation class and species, based on six surveyed units, within 100 feet of Icicle Creek by ocular estimate.

4.12 REACH 12

Location: River mile 11.92 – 12.5
Total length: 0.58 miles
Survey Date: September 11 – 12, 2024

Figure 91. Representative photo of Reach 12. Habitat was dominated by riffles.

4.12.1 Habitat Unit Composition

Reach 12 was 0.58 miles long and dominated by riffles (72%), a continuing trend moving upstream in Icicle Creek. Pools (19%) were the second most prevalent habitat unit type, followed by glide (4%), then side channels (4%;Figure 92). Channel gradient in Reach 12 begins to decrease moving upstream from the three previous reaches, measuring an average of 2.11%. The left bank in Reach 12 was reinforced with riprap due to road infrastructure. U.S. Forest Service campsites are located on the left banks in the upstream channel units of Reach 12.

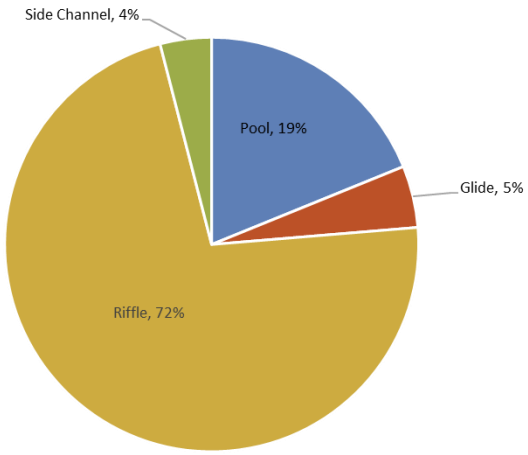


Figure 92. Stream habitat unit area composition for Reach 12.

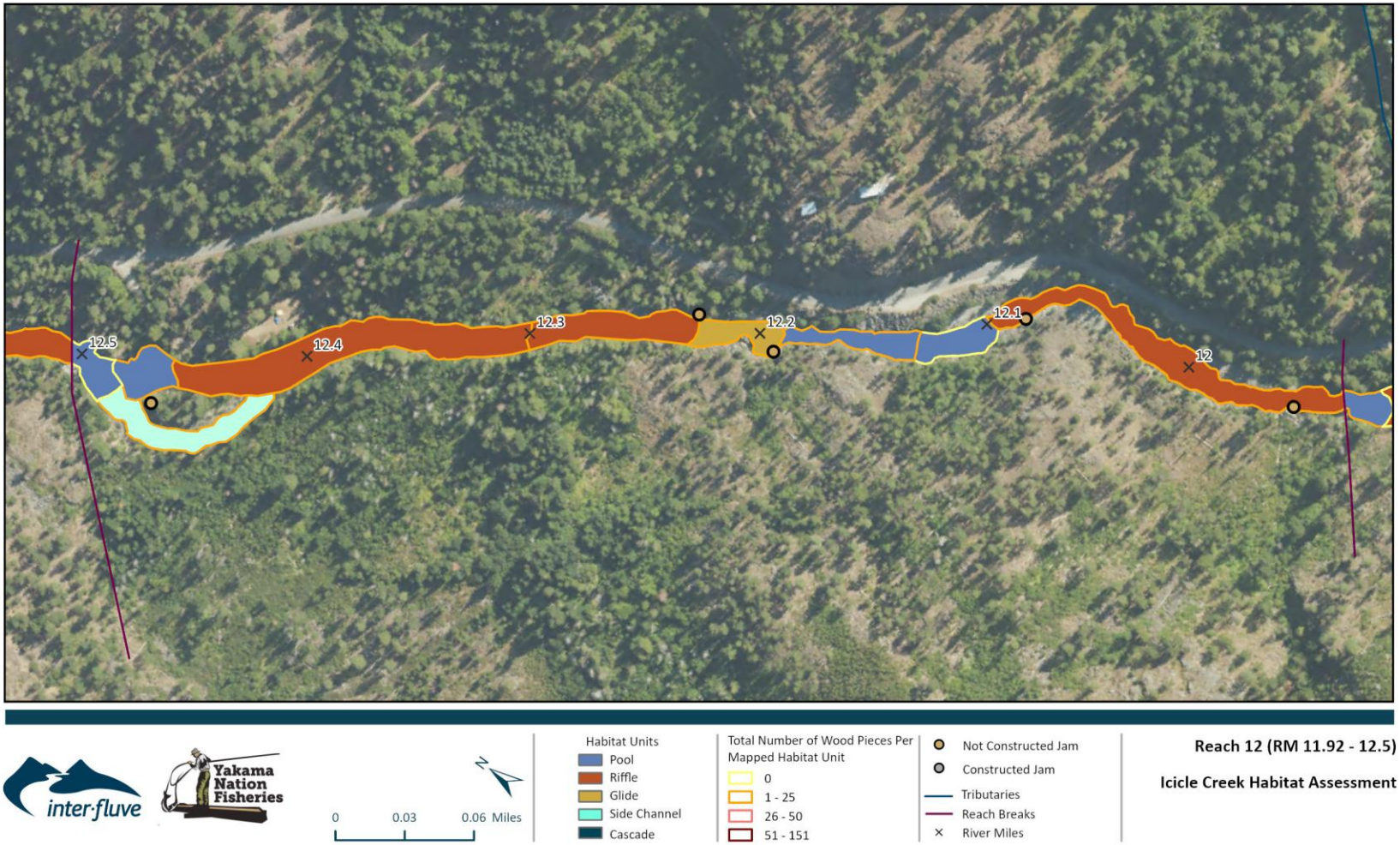


Figure 93. Map of the habitat unit composition and LWM in Reach 12 of Icicle Creek. LWM count includes pieces in jams.

4.12.2 Pools

Reach 12 recorded four pool units. Mean pool spacing for this reach was seven pools per mile, equal to the the study area average. Two of the four pools observed had residual depth less than three feet. One of pools (25%) had residual depth between three feet and six feet. The remaining 25% of pools had a residual depth greater than six feet. Residual depth in reach 12 ranged from 2.6 feet to 8.8 feet and averaged 4.8, slightly greater than the study area average of 4.4 feet.

4.12.3 Side Channel Habitat

One side channel was observed in Reach 12 with a channel length of 411 feet. No jams were observed in the reach and one piece of LWM was recorded (Table 30).

Table 30. Side channels observed in Reach 12.

Location	Length (ft)	Dominant Unit Type	Wood Count	Jam Count	Wood Count in Jams
Side 44	411	Slow	1	0	0
Total	*411*		*1*	*0*	*0*

4.12.4 Large Woody Material

A total of 71 pieces of LWM were recorded in Reach 12. This total includes individual pieces and pieces recorded in jams. LWM frequency within the reach is approximately 122 pieces of LWM per mile, with 60 of those pieces per mile being Medium and Large LWM. There were five jams observed in Reach 12, which contained a 59% of the total pieces (Table 32).

Table 31. LWM quantities in Reach 12.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Individual Pieces	18	8	4	30
Number of Individual Pieces per Mile	31	21		52
Number of Total Pieces per Mile (including pieces in jams)	62	60		122
Number of Jams	5			
Number of Jams per Mile	9			
Estimated Wood Count in Jams	41			

4.12.5 Substrate & Fine Sediment

One gravel count was conducted in Reach 12, and the dominant substrate was recorded as 57% boulder, 27% cobbles, 9% gravel and 7% sand (Figure 94). The gravel count, GC14, was conducted in a riffle near RM 12.39. The distribution and grain size class can be found in Figure 95 and Table 32.

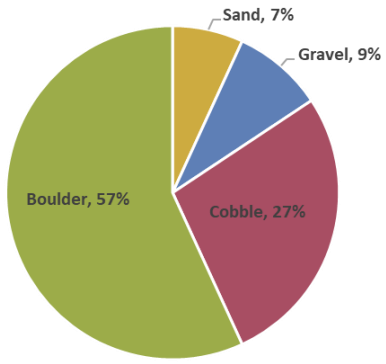


Figure 94. Percent sediment composition from the gravel count (GC14) performed in Reach 11.

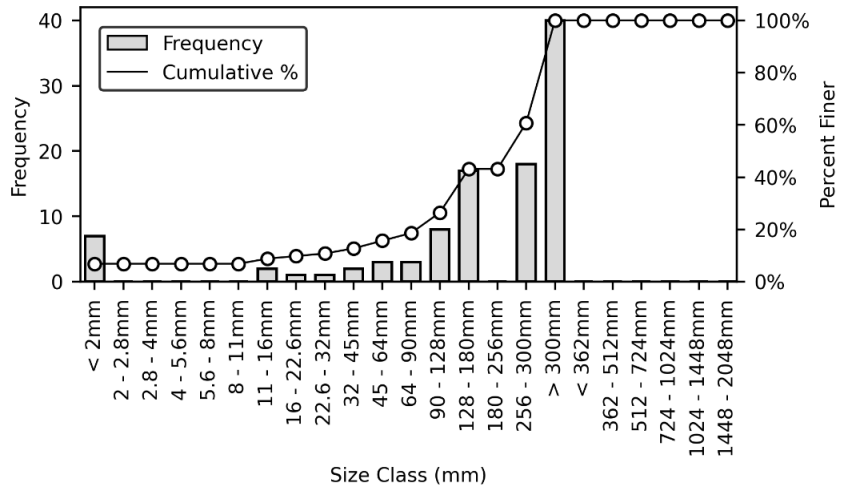


Figure 95. Cumulative distribution curve for GC14.

Table 32. Grain size classes for GC14 (assumed linear interpolation)

	GC14
Size Class	*Size percent finer than (mm)*
D5	1
D16	64
D50	205
D84	300+
D95	300+

4.12.6 Riparian Corridor

Six channel units in Reach 12 included ocular assessment of riparian vegetation. From those observations, Reach 12 was equally dominated by Small Trees (50%; 9.0 - 20.9-inch dbh) and Large Trees (50%; 21 - 31.9-inch dbh). Douglas fir was the dominant overstory species in 67% of units and Ponderosa pine the other 33% (Figure 96). The dominant understory was Shrub/Seedling (1.0 - 4.9-inch dbh) in 83% of units, and Sapling/Pole in the other 17% (5.0-8.9-inch dbh). Alder (50%) was the dominant understory species in Reach 12. Cottonwood (33%) and Willow (17%; Figure 97) consisted of the remaining observed units.

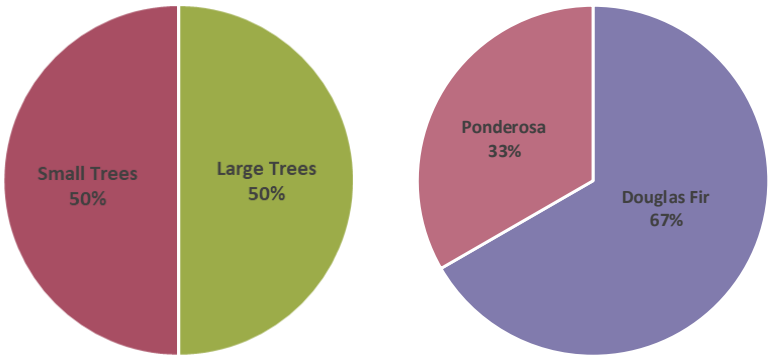


Figure 96. Dominant overstory riparian vegetation class and species, based on six surveyed units, within 100 feet of Icicle Creek by ocular estimate.

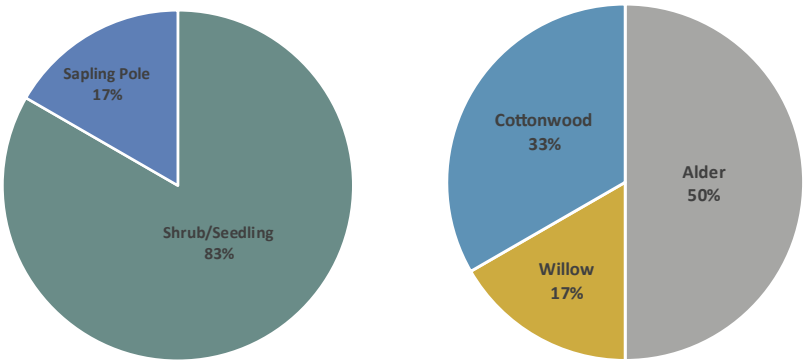


Figure 97. Dominant understory riparian vegetation class and species, based on six surveyed units, within 100 feet of Icicle Creek by ocular estimate.

4.13 REACH 13

Location: River mile 12.5 – 12.84
Total length: 0.34 miles
Survey Date: September 12, 2024

Figure 98. Representative photo of Reach 13. Habitat was dominated by riffles.

4.13.1 Habitat Unit Composition

Reach 13 is the shortest reach in the study area with a channel length of 0.34 miles. Riffles were the dominant habitat type, consisting of 77% of the unit area. Pools comprised the remaining 23% (Figure 99). Channel gradient maintained a similar slope to the previous unit at 2.20%.

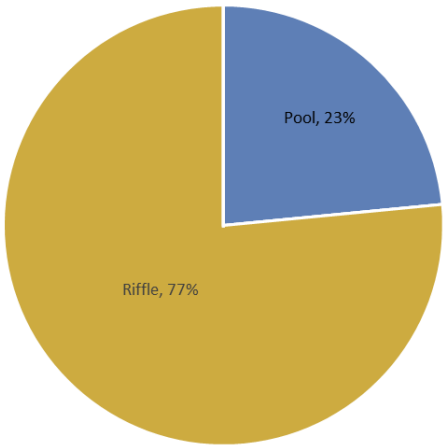


Figure 99. Stream habitat unit area composition of Reach 13.

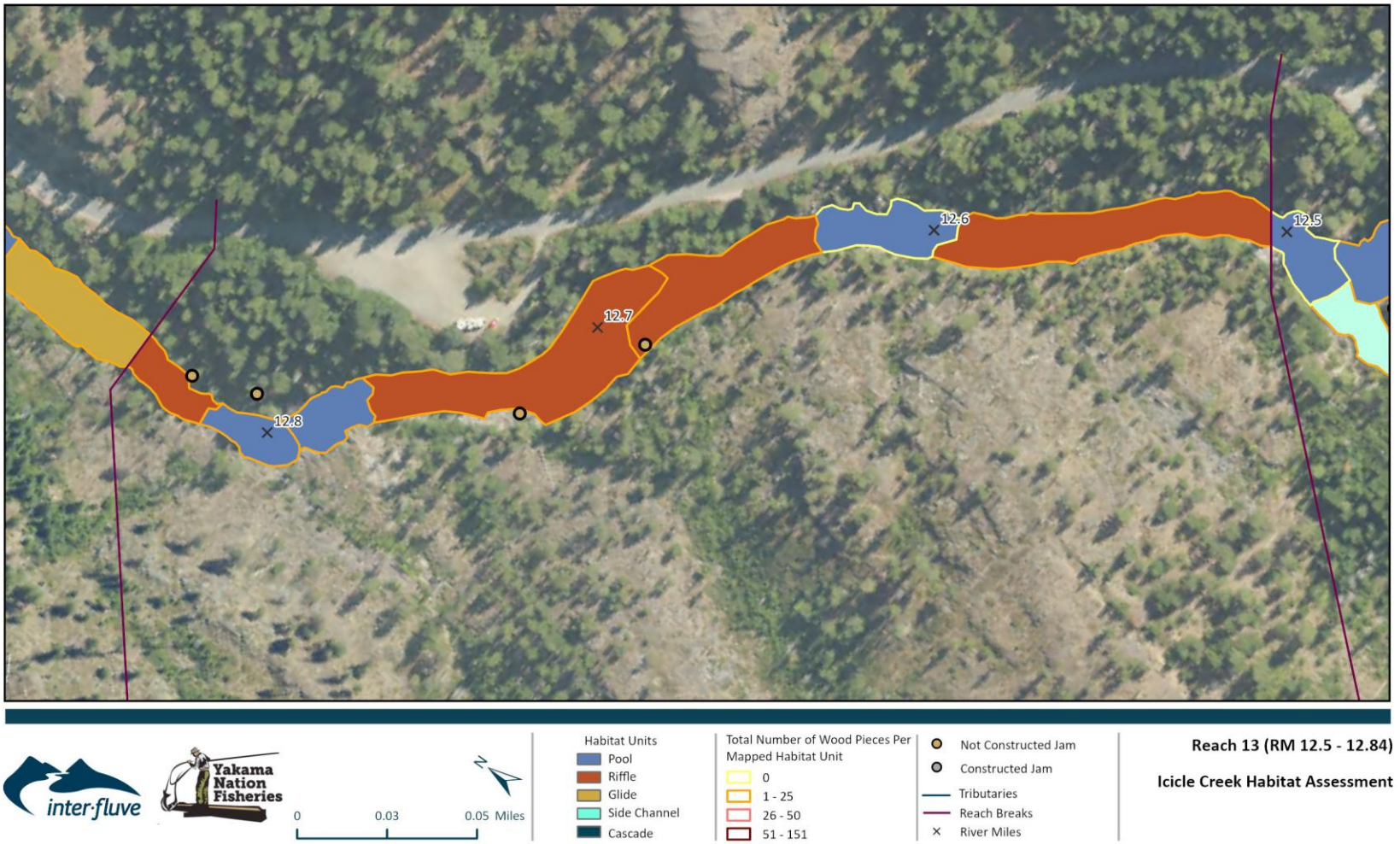


Figure 100. Map of the habitat unit composition and LWM in Reach 13 of Icicle Creek. LWM count includes pieces in jams.

4.13.2 Pools

Three pools were observed in Reach 13. Two pools (67%) had a residual depth between three feet and six feet, and the other pool (33%) had a residual depth greater than six feet. The average residual depth for Reach 13 was 4.13 feet, ranging from 2.4 feet to 6.0 feet. Pool frequency was approximately nine pools per mile. Pool frequency for the entire study averaged seven pools per mile.

4.13.3 Side Channel Habitat

No side channels were observed in Reach 13.

4.13.4 Large Woody Material

Thirty-five pieces of LWM were recorded in Reach 13, yielding 103 pieces per mile and 44 Medium and Large pieces per mile. The total number of pieces include individual pieces and pieces recorded in jams. A total of four jams were observed in this reach, containing 37% of the total wood count (Table 33).

Table 33. LWM quantities in Reach 13.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Individual Pieces	14	7	1	22
Number of Individual Pieces per Mile	41	24		65
Number of Total Pieces per Mile (including pieces in jams)	59	44		103
Number of Jams	4			
Number of Jams per Mile	12			
Estimated Wood Count in Jams	13			

4.13.5 Substrate & Fine Sediment

No gravel counts were performed in Reach 13.

4.13.6 Riparian Corridor

Three channel units in Reach 13 included ocular assessment of riparian vegetation. The dominant overstory in Reach 13 was Large Trees (100%; 21.0 - 31.9-inch dbh), with Douglas fir (67%) and Cedar (33%) as the primary species observed (Figure 101). The dominant understory was in the Shrub/Seedling (100%; 1.0 - 4.9-inch dbh) size class, with Alder recorded in 67% of units and Willow in the remaining 33% (Figure 102).

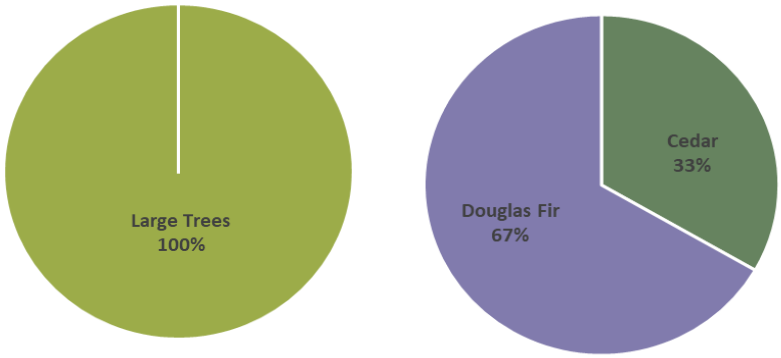


Figure 101. Dominant overstory riparian vegetation class and species, based on three surveyed units, within 100 feet of Icicle Creek by ocular estimate.

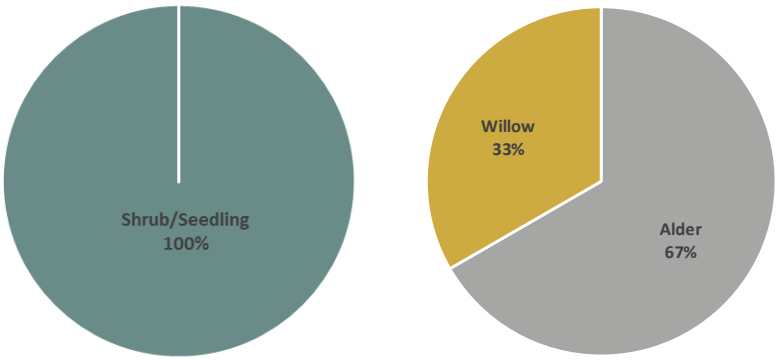


Figure 102. Dominant understory riparian vegetation class and species, based on three units surveyed, within 100 feet of Icicle Creek by ocular estimate.

4.14 REACH 14

Location: River mile 12.84 – 14.75
Total length: 1.91 miles
Survey Date: September 12 – 13, 2024

Figure 103. Representative photo of Reach 14. Habitat is dominated by riffles.

4.14.1 Habitat Unit Composition

Reach 14 is 1.91 miles long and had aquatic habitats predominantly composed of riffles (75%). Pools were the second most common habitat type making up 19% of the reach. Side channels and glide habitat types equally compose 3% of the aquatic habitat area, making up the remaining 6% (Figure 104). Channel gradient decreases to 1.54% and marks the transition away from the steep terrain in the previous nine reaches.

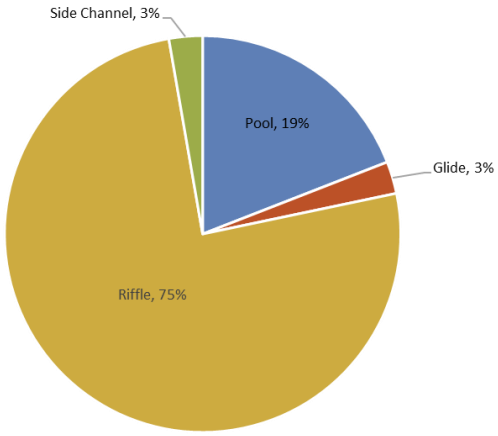


Figure 104.Stream habitat unit area composition for Reach 14.

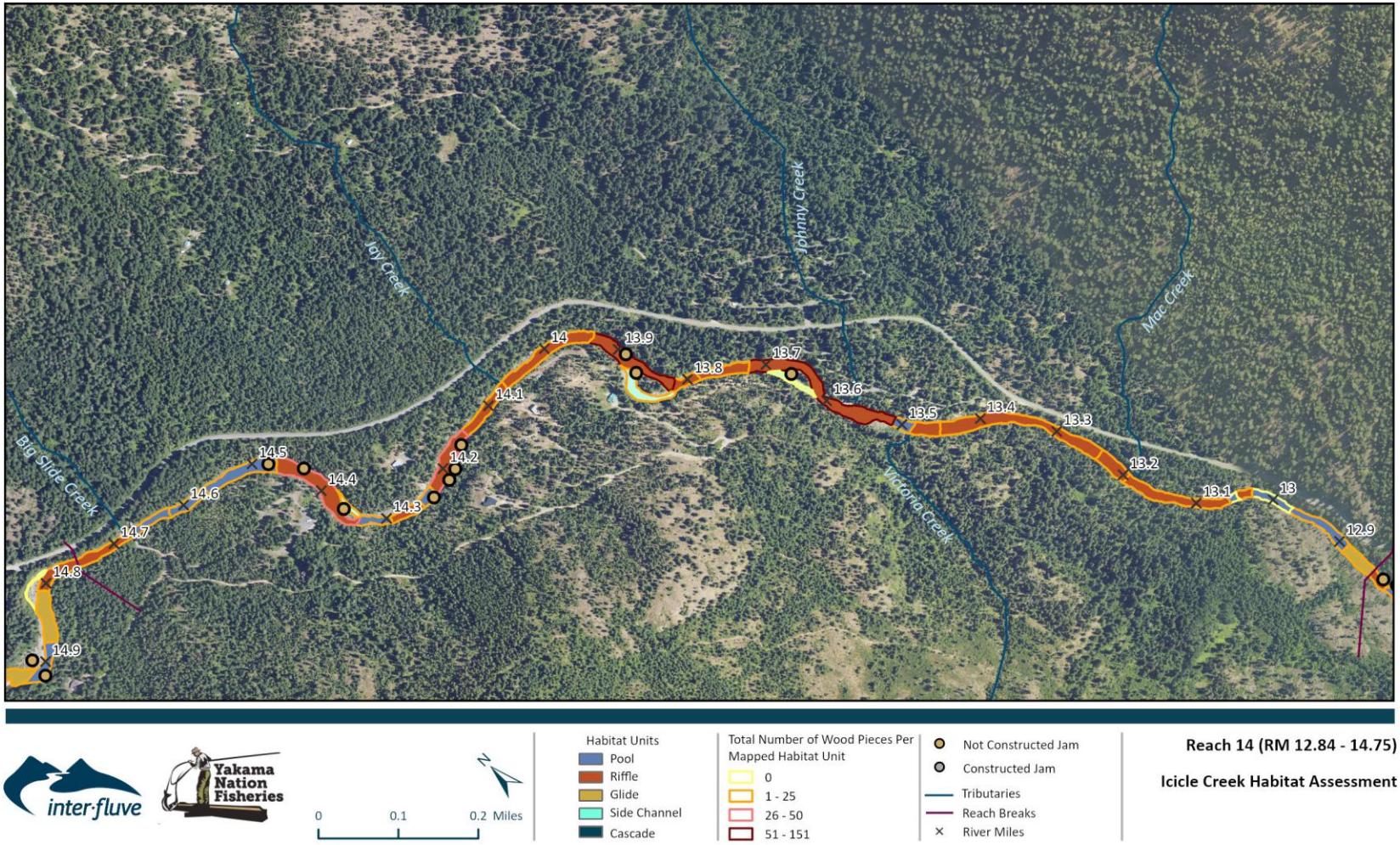


Figure 105. Map of the habitat unit composition and LWM in Reach 14 of Icicle Creek. LWM count includes pieces in jams.

4.14.2 Pools

Reach 14 had a total of nine pools recorded. Mean pool spacing in this reach was five pools per mile, compared to the study area average of seven pools per mile. Five pools (56%) had a residual depth less than three feet, and the remaining four pools (44%) had a residual depth between three and six feet. Average residual depth was 2.9 feet, ranging from 1.7 feet to 4.2 feet. The mean residual depth for the study area was 4.4 feet.

4.14.3 Side Channel Habitat

Three side channels were observed in Reach 14 and had a total channel length of 892 feet. All side channels were observed as predominantly fast water. Within the side channel, 13 pieces of LWM were recorded. No jams were observed in the side channels (Table 34).

Table 34. Side channels observed in Reach 14.

Location	Length (ft)	Dominant Unit Type	Wood Count	Jam Count	Wood Count in Jams
Side 45	293	Fast	0	0	0
Side 46	436	Fast	13	0	0
Side 47	162	Fast	3	0	0
Total	*2892*		*16*	*0*	*0*

4.14.4 Large Woody Material

A total of 399 pieces of LWM were recorded in Reach 14. This total includes individual pieces and pieces recorded in jams. LWM frequency within the reach is approximately 209 pieces of LWM per mile, with 106 of those pieces per mile being Medium and Large LWM. Of the 399 total pieces, 60% were observed in jams. Ten jams were observed in the reach; jam frequency averaged five jams per mile (Table 35).

Table 35. LWM quantities in Reach 14.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Individual Pieces	85	52	22	159
Number of Individual Pieces per Mile	45	39		83
Number of Total Pieces per Mile (including pieces in jams)	103	106		209
Number of Jams	10			
Number of Jams per Mile	5			
Estimated Wood Count in Jams	240			

4.14.5 Substrate & Fine Sediment

Two gravel counts were performed in Reach 14, with a combined average of 40% boulder, 28% cobbles, 28% gravel, and 3% sand (Figure 106). The first gravel count, GC13, was conducted within a riffle crest at RM 12.9. The second gravel count, GC12, was conducted within a riffle at RM 13.43. The distribution and grain size class can be found in Figure 107 – Figure 108 and Table 36.

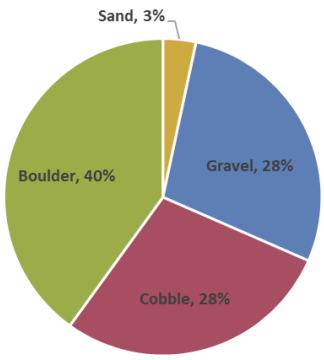


Figure 106. Combined sediment composition from the two gravel counts (GC13 and GC12) performed in Reach 14.

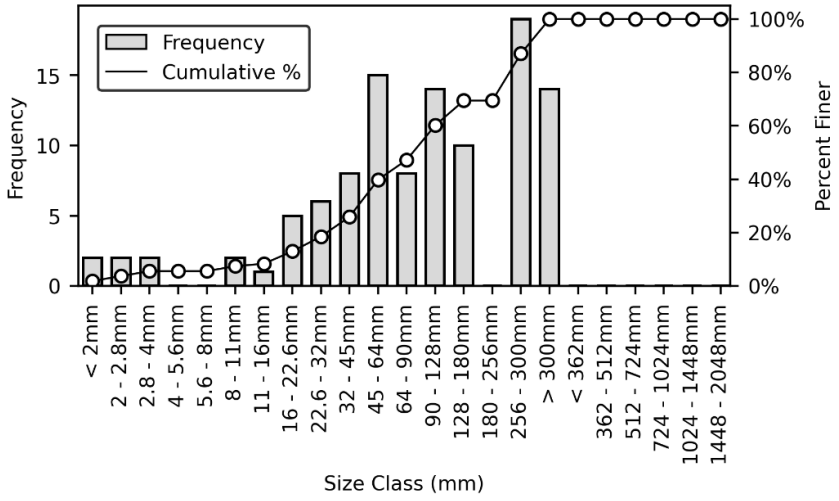


Figure 107. Cumulative distribution curve for GC13.

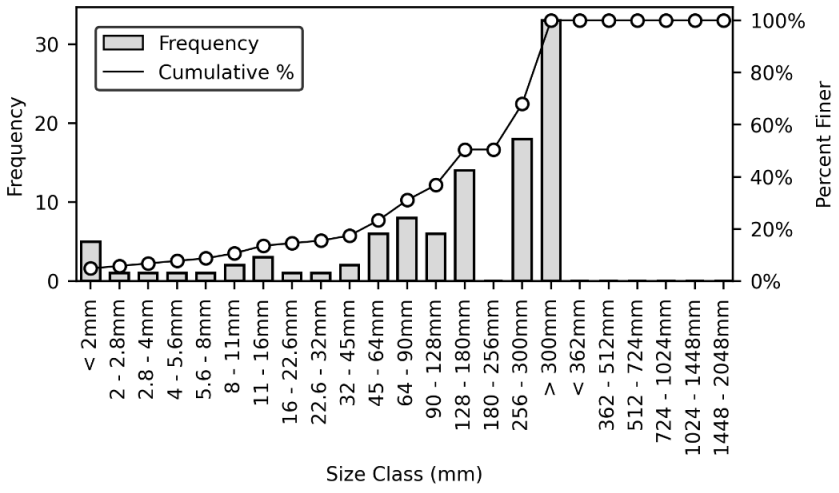


Figure 108. Cumulative distribution curve for GC12.

Table 36. Grain size class for GC13 and GC12 (assumed linear interpolation).

	GC13	GC12
Size Class	*Size percent finer than (mm)*	*Size percent finer than (mm)*
D5	4	2
D16	28	35
D50	95	180
D84	300+	300+
D95	300+	300+

4.14.6 Riparian Corridor

Seven of the channel units in Reach 13 included ocular assessment for riparian vegetation. Large Trees (21.0 - 31.9-inch dbh) were recorded in 56% of the measured units, followed by Small Trees (9.0 - 20.9-inch dbh) in 44% of measured units. Cedar composed 56% of the total measured units as the dominant overstory species. Douglas Fir (33%) and Ponderosa/Jeffrey Pine (11%) make up the remaining dominant overstory species observations (Figure 109). The dominant understory in Reach 14 was recorded as Shrub/Seedling (1.0 - 4.9-inch dbh) in 89% of the measured survey units. No Vegetation was recorded in the remaining 11% of units. Alder was the dominant species with 78% of measured units, followed by Willow and Other at 11% each of measured units (Figure 110).

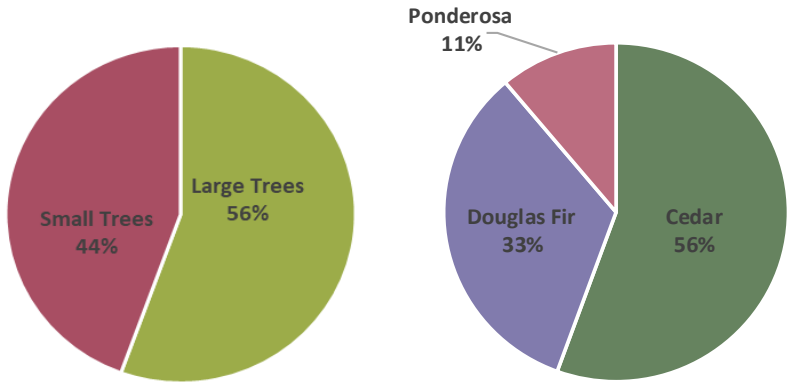


Figure 109. Dominant overstory riparian vegetation class and species, based on seven surveyed units, within 100 feet of Icicle Creek by ocular estimate.

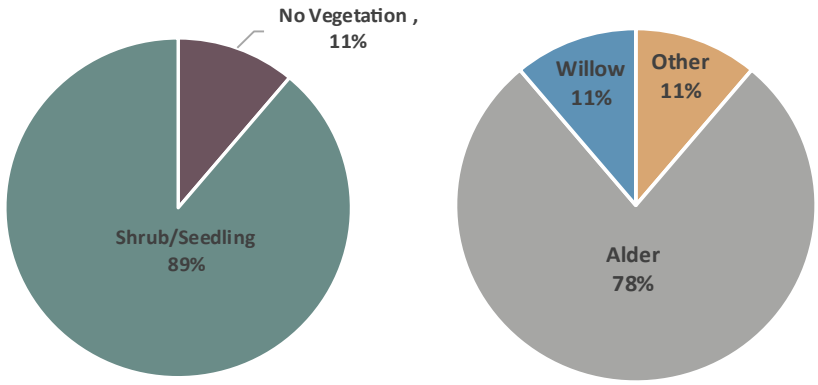


Figure 110. Dominant understory riparian vegetation class and size, based on seven surveyed units, within 100 feet of Icicle Creek by ocular estimate.

4.15 REACH 15

Location: River mile 14.75 – 16.63
Total length: 1.88 miles
Survey Date: September 13 – 14, 2024

Figure 111. Representative photo of Reach 15. Habitat was dominated by riffles.

4.15.1 Habitat Unit Composition

In Reach 15, riffle units are no longer the dominant aquatic habitat type. This reach was 1.89 miles long and channel gradient decreases to 0.54%, almost 1% less than the previous unit. Reach 15 is dominated by pools, comprising 40% of the habitat area. Glides consist of 29% and riffles 21% of the total habitat area. Side channels compose the remaining 10% of the aquatic habitat in Reach 15 (Figure 112).

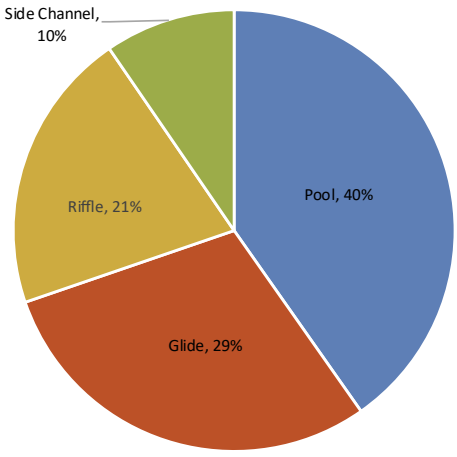


Figure 112. Stream habitat unit area composition of Reach 15.

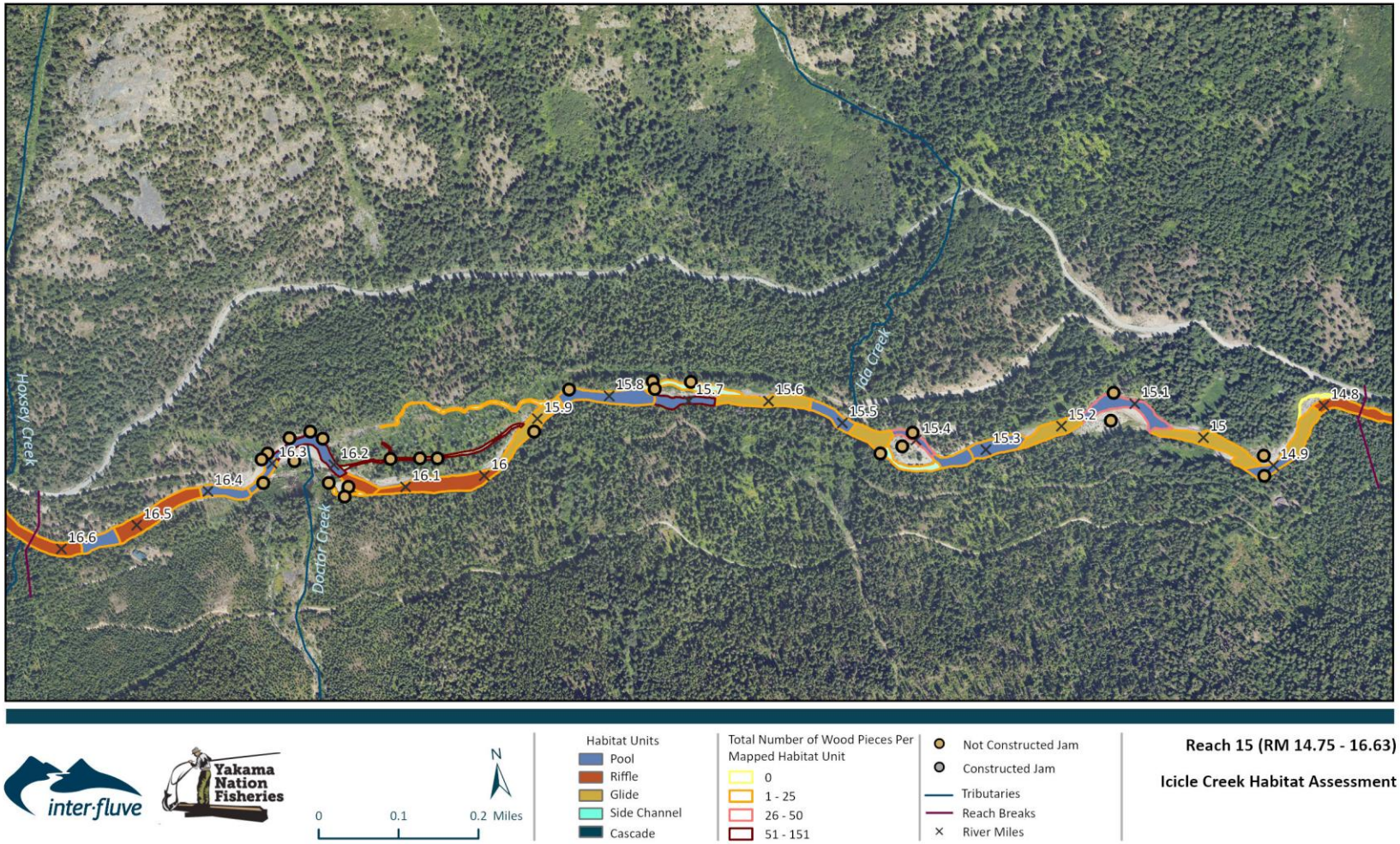


Figure 113. Map of the habitat unit composition and LWM in Reach 15 of Icicle Creek. LWM count includes pieces in jams.

4.15.2 Pools

Twelve pools were recorded in Reach 15 with an average residual depth of 3.5 feet. Residual depth ranged from 2.3 feet to 5.2 feet. Of the twelve pools, 42% had residual depths less than three feet and 58% of pools had residual depths between three feet and six feet. Pool frequency in Reach 15 was approximately six pools per mile, less than the study area average of seven pools per mile.

4.15.3 Side Channel Habitat

In Reach 15, a total of six side channels were observed with a total channel length of 4,387 feet. Five of the side channels were observed to be predominantly slow water units and one side channel was observed as predominantly fast water. A total of 53 individual pieces of LWM were observed in the side channels. Eight wood jams with 49 pieces of LWM were observed (Table 37).

Table 37. Side channels observed in Reach 15.

Location	Length (ft)	Dominant Unit Type	Wood Count	Jam Count	Wood Count in Jams
Side 48	328	Slow	0	0	0
Side 49	428	Fast	3	1	5
Side 50	598	Slow	6	2	7
Side 51	1247	Slow	7	0	0
Side 52	1263	Slow	37	3	24
Side 53	523	Slow	0	2	13
Total	*4,387*		*53*	*8*	*49*

4.15.4 Large Woody Material

A total of 487 pieces of LWM were recorded in Reach 15, the most LWM in the study area (Table 38). This total includes individual pieces and pieces recorded in jams. LWM frequency within the reach is approximately 258 LWM pieces per mile, with 148 of those pieces per mile being Medium and Large LWM. Twenty-five jams were observed within Reach 15, which is roughly 13 jams per mile. Jams contained 56% of the total LWM wood count. Reach 15 contained the highest number of jams in the study area.

Table 38. LWM quantities in Reach 15.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Individual Pieces	100	83	23	206
Number of Individual Pieces per Mile	53	56		109
Number of Total Pieces per Mile (including pieces in jams)	110	148		258
Number of Jams	25			
Number of Jams per Mile	13			
Estimated Wood Count in Jams	281			

4.15.5 Substrate & Fine Sediment

Two gravel counts were performed in Reach 15, with a combined average of 43% cobble, 37% gravel, 16% boulder and 4% sand (Figure 114). The first gravel count, GC11, was conducted in a riffle extending from a gravel bar at RM 14.94. The second gravel count, GC10, was conducted at a riffle near RM 16.23. The distribution and grain size class can be found in Figure 115 – Figure 116 and Table 39.

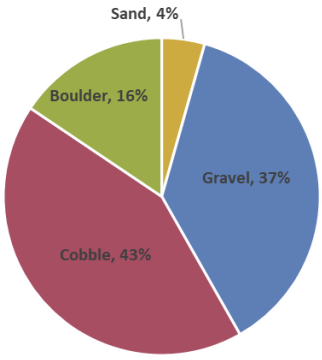


Figure 114. Combined percent sediment composition from the two gravel counts (GC11 and GC10) performed in Reach 15.

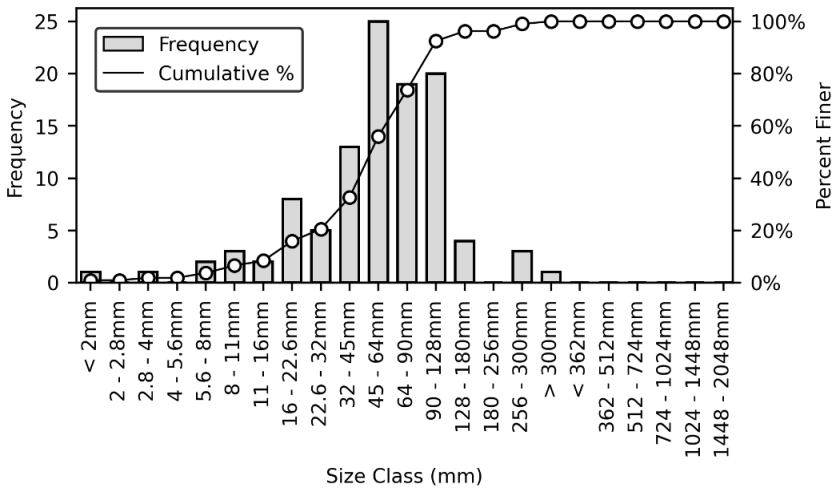


Figure 115. Cumulative distribution curve for GC11.

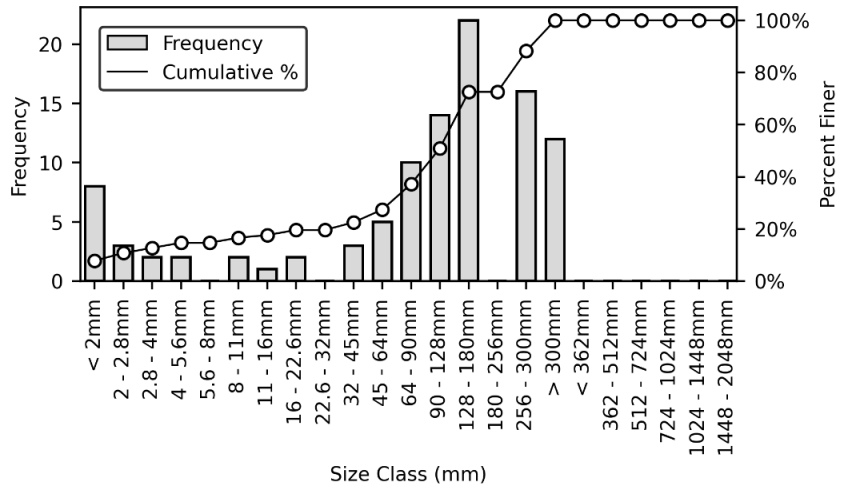


Figure 116. Cumulative distribution curve for GC10.

Table 39. Grain size for GC11 and GC10 (assumed linear interpolation).

	GC11	GC10
Size Class	*Size percent finer than (mm)*	*Size percent finer than (mm)*
D5	9	1
D16	23	10
D50	60	125
D84	110	300+
D95	121	300+

4.15.6 Riparian Corridor

Thirteen channel units in Reach 15 included ocular assessment of riparian vegetation. The dominant overstory was Large Trees (21.0 - 31.9-inch dbh) which was recorded in 73% of measured units. Small Trees (14%; 9.0 - 20.9-inch dbh) and Sapling/Pole (13%; 5.0 - 8.9-inch dbh) composed the remaining units. The overstory species in this reach were diverse; Douglas fir was the most frequently observed at 40% of measured units, followed by Ponderosa pine (20%) and Cottonwood (20%). The remaining units were recorded as Cedar (13%) and Other/Unknown (7%; Figure 117). The dominant understory was nearly all recorded as Shrub/Seedling (1.0 - 4.9-inch dbh), observed in 93% of units, while Grassland/Forb composed the remaining 7%. The dominant understory species in Reach 15 was Alder (80%) followed by Dogwood and Vine/Douglas maple (both 7%), with Other recorded in the remaining 6% of units (Figure 118). The Other understory species in Reach 15 includes various grass species.

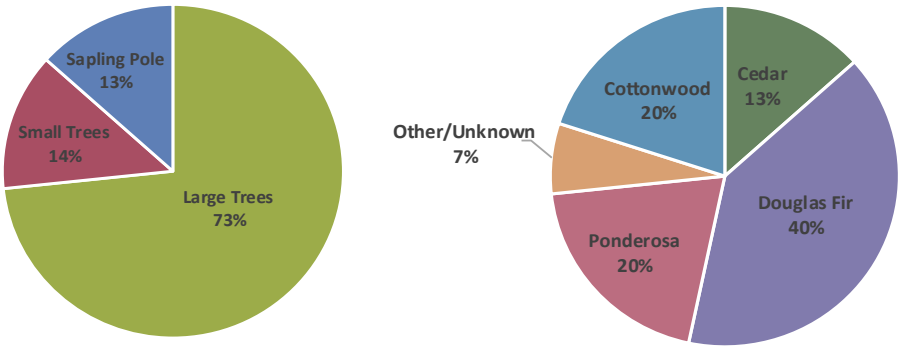


Figure 117. Dominant overstory riparian vegetation, based on 13 surveyed units, within 100 feet of Icicle Creek by ocular estimate.

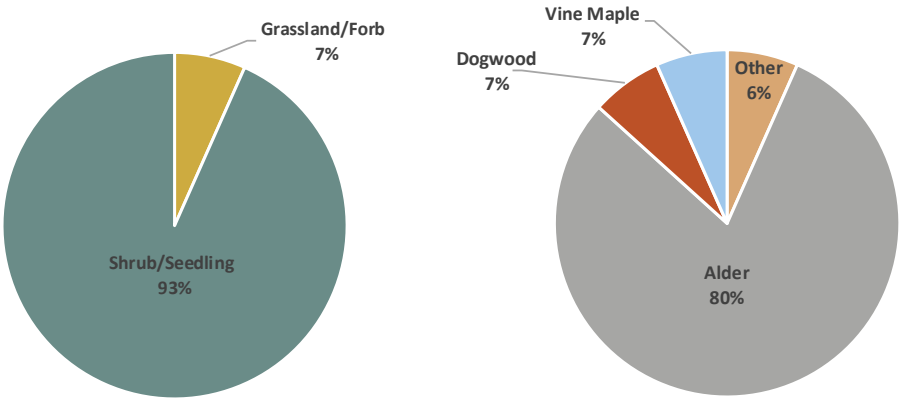


Figure 118. Dominant understory riparian vegetation class and species, based on 13 surveyed units, within 100 feet of Icicle Creek by ocular estimate.

4.16 REACH 16

Location: River mile 16.63 – 17.24
Total length: 0.61 miles
Survey Date: September 14 – 15, 2024

Figure 119. Representative photo of Reach 16. Habitat was dominated by pools.

4.16.1 Habitat Unit Composition

Reach 16 spans 0.61 miles. Pools were the dominant habitat type, consisting of 46% of the total area. Riffles were the second most common habitat type with 37% in the reach, followed by glides (13%) and side channels (4%) (Figure 120). Reach 16 had a stream gradient of 0.88%.

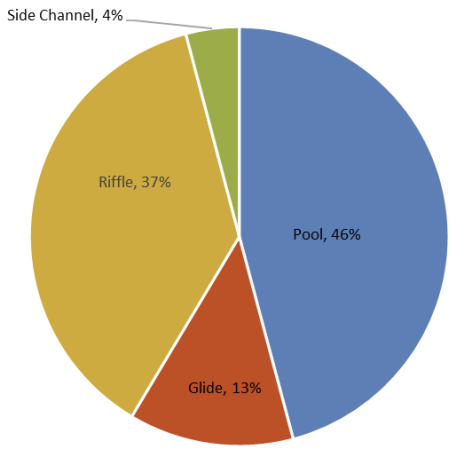


Figure 120. Stream habitat unit area composition of Reach 16.

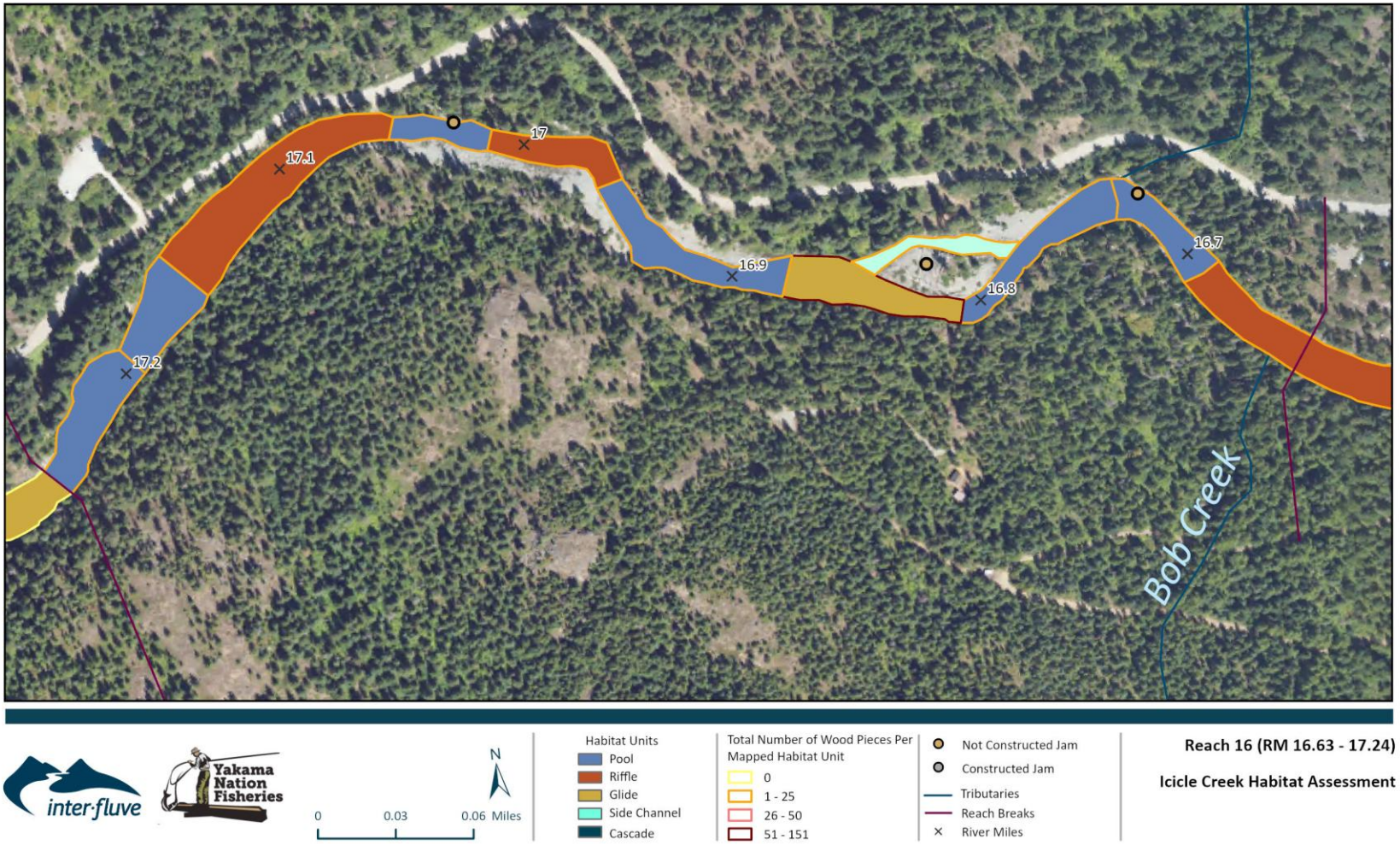


Figure 121. Map of the habitat unit composition and LWM in Reach 16 of Icicle Creek. LWM count includes pieces in jams.

4.16.2 Pools

Reach 16 had a total of six pools, with 83% of those pools having a residual depth less than three feet. The remaining 17% of pools had a residual depth between three feet and six feet. Residual depth averaged 2.4 feet (compared to the study area average of 4.4 feet) and ranged between 1.5 feet to 3.5 feet. The mean pool spacing for this reach was ten pools per mile, greater than the study area average of seven pools per mile.

4.16.3 Side Channel Habitat

One side channel was observed in Reach 16 with a total channel length of 316 feet. The side channel was predominantly slow water. One pieces of LWM was recorded and no jams were observed (Table 40).

Table 40. Side channels observed in Reach 16.

Location	Length (ft)	Dominant Unit Type	Wood Count	Jam Count	Wood Count in Jams
Side 54	316	Slow	1	0	0
Total	*316*		*1*	*0*	*0*

4.16.4 Large Woody Material

A total of 192 pieces of LWM were recorded in Reach 16. This total includes individual pieces and pieces recorded in jams. LWM frequency within the reach is approximately 175 pieces of LWM per mile, with 98 of those pieces per mile being Medium and Large LWM. Of total amount of pieces, 80% were recorded in the 13 observed jams in the reach (Table 41).

Table 41. LWM quantities in Reach 16.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Individual Pieces	19	15	4	38
Number of Individual Pieces per Mile	31	31		62
Number of Total Pieces per Mile (including pieces in jams)	77	98		175
Number of Jams	3			
Number of Jams per Mile	5			
Estimated Wood Count in Jams	69			

4.16.5 Substrate & Fine Sediment

Two gravel counts were performed in Reach 15, with a combined average of 54% cobble, 25% boulder, 20% gravel, and 1% sand (Figure 122). The first gravel count, GC9, was conducted in a riffle crest at RM 16.74 and the second gravel count, GC8, was conducted at a pool tail crest at RM 16.85. The distribution and grain size class can be found in Figure 123 – Figure 124 and Table 42.

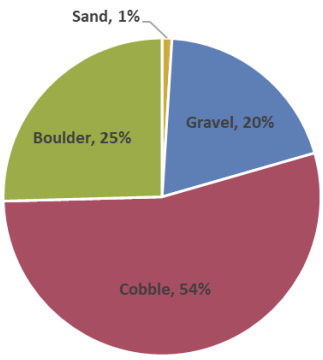


Figure 122. Combined percent sediment composition from the two gravel counts (GC9 and GC8) performed in Reach 16.

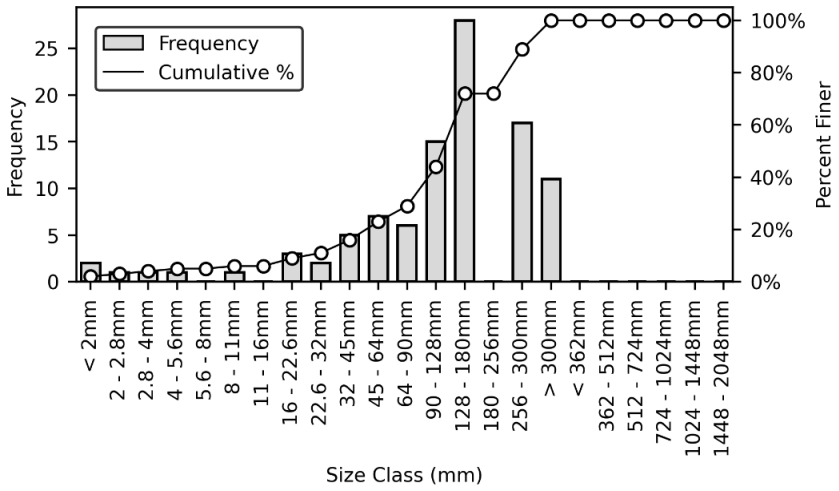


Figure 123. Cumulative distribution curve for GC9

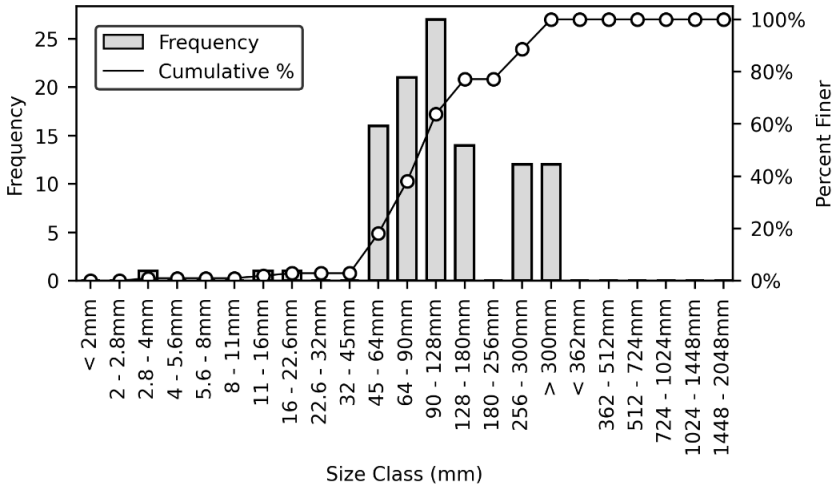


Figure 124. Cumulative distribution curve for GC8.

Table 42. Grain size class for GC9 and GC8 (assumed linear interpolation).

Size Class	GC9 Size percent finer than (mm)	GC8 Size percent finer than (mm)
D5	7	50
D16	50	60
D50	135	105
D84	230	220
D95	300+	300+

4.16.6 Riparian Corridor

Six channel units included ocular assessment of riparian vegetation in Reach 16. The dominant overstory class size was Large Trees (83%; 21.0 - 31.9-inch dbh), followed by Small Trees (17%; 9.0 - 20.9-inch dbh). The dominant overstory species in the reach were observed to be Cedar (34%), Douglas fir (33%) and Ponderosa pine (33%; Figure 125). The dominant understory size in Reach 16 was Shrub/Seedling (83%; 1.0 - 4.9-inch dbh). No Vegetation was recorded for the remaining 17% of units. The dominant understory species was Alder (83%) followed by Other (17%; Figure ***126***). Understory species recorded as Other in Reach 16 were in units with the No Vegetation size class.

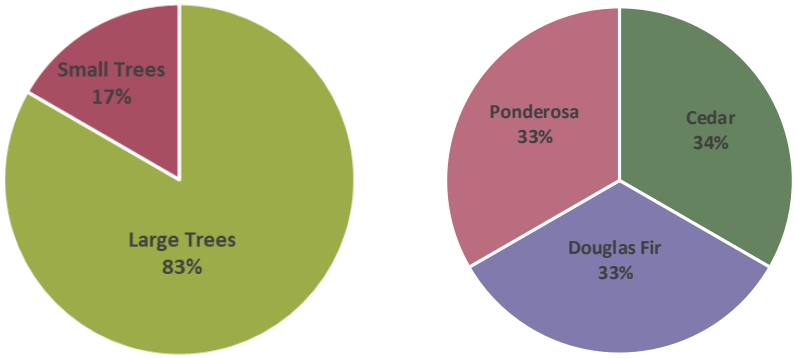


Figure 125. Dominant overstory riparian vegetation class and species, based on six surveyed units, within 100 feet of Icicle Creek by ocular estimate.

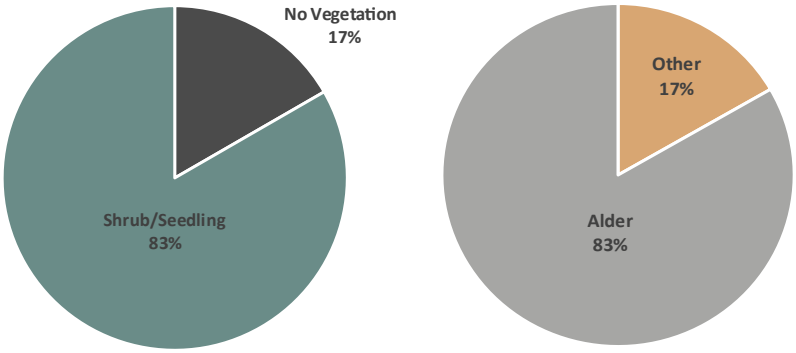


Figure** 126**. Dominant understory riparian vegetation class and species, based on six surveyed units, within 100 feet of Icicle Creek by ocular estimate.

4.17 REACH 17

Location: River mile 17.24 – 18.74
Total length: 1.5 miles
Survey Date: September 15, September 23 – 24, 2024

Figure 127. Representative photo of Reach 17 in Icicle Creek. Habitat is dominated by riffles

4.17.1 Habitat Unit Composition

In Reach 17, riffles were the dominant habitat unit type consisting of 61% of the aquatic habitat area. Pools comprise the second most dominant habitat unit type with 25%, followed by side channels (8%), glides (4%) and cascades (2%) (Figure 128 and Figure 130). One cascade was recorded in Reach 17 (Figure 129). Reach 17 was approximately 1.5 miles long with a gradient of 1.19%. Portions of Reach 17 flow through a bedrock gorge. U.S. Forest Service maintains trails that follow the upstream extent of the reach on the right bank. A pedestrian bridge crosses at RM 18.2 and overlooks the cascade and gorge. Much of the reach was not wadable for the habitat survey crew due to the confined, steep nature of the channel, and data is based on ocular estimates from the crew walking along the banks.

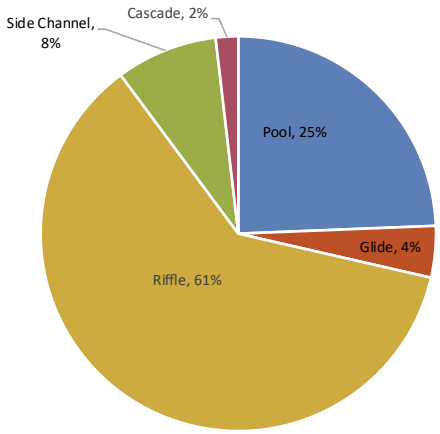


Figure 128. Stream habitat unit area composition of Reach 17.

Figure 129. Photo of the cascade in Reach 17 taken from the pedestrian bridge crossing Icicle Creek, looking upstream.

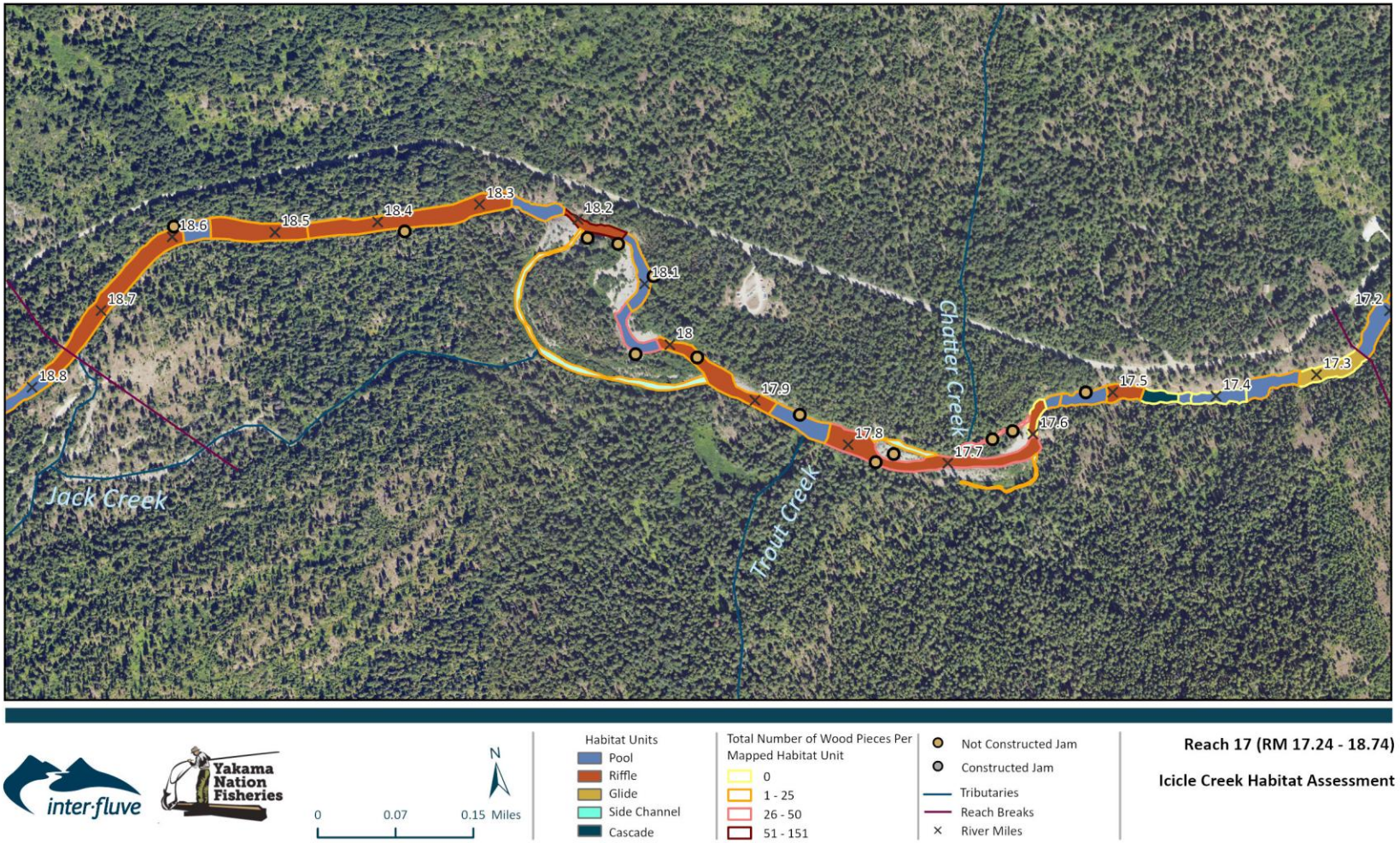


Figure 130. Map of the habitat unit composition and LWM in Reach 18 of Icicle Creek. LWM count includes pieces in jams.

4.17.2 Pools

Ten pools were observed in Reach 17 equating to a mean pool spacing of four pools per mile. Average residual depth was 6.1 feet. Residual depth of 20% of units is less than three feet. Fifty percent of pools have a residual depth between three and six feet, and the remaining 30% had a residual depth greater than or equal to six feet.

4.17.3 Side Channel Habitat

In Reach 17, four side channels were observed with a channel length of 2,956 feet. Three of the side channels are predominantly fast water units and the fourth is predominantly slow water. Twenty-six pieces of LWM were recorded in the side channels. Two jams were observed in the side channels with a LWM wood count of 20 pieces of wood (Table 43).

Table 43. Side channels observed in Reach 17.

Location	Length (ft)	Dominant Unit Type	Wood Count	Jam Count	Wood Count in Jams
Side 55	424	Fast	8	2	20
Side 56	524	Slow	4	0	0
Side 57	316	Fast	1	0	0
Side 58	1,692	Fast	13	0	0
Total	*2,956*		*26*	*2*	*20*

4.17.4 Large Woody Material

A total of 287 pieces of LWM were recorded in Reach 17. This total includes individual pieces and pieces recorded in jams. LWM frequency within the reach is approximately 191 pieces of LWM per mile, with 103 of those pieces per mile being Medium and Large LWM (Table 44). Of the total pieces, 54% were recorded in the 13 observed jams in the reach.

Table 44. LWM quantities in Reach 17.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Individual Pieces	69	42	22	133
Number of Individual Pieces per Mile	46	43		89
Number of Total Pieces per Mile (including pieces in jams)	88	103		191
Number of Jams	13			
Number of Jams per Mile	9			
Estimated Wood Count in Jams	154			

4.17.5 Substrate & Fine Sediment

Two gravel counts were performed in Reach 17, with a combined average of 40% cobbles, 29% boulder, and 31% gravel (Figure 131). The first gravel counts, GC7, was conducted in a riffle crest adjacent to a vegetation gravel bar at RM 18.08 and the second gravel count, GC6, was conducted in a boulder bar located river right at RM 18.59. The distribution and grain size class can be found in Figure 132 – Figure 133 and Table 45.

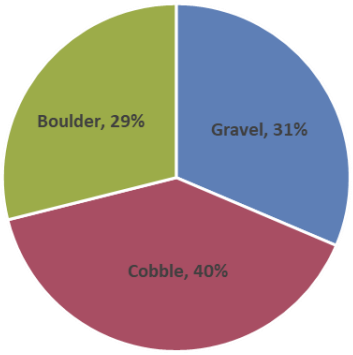


Figure 131. Combined percent sediment composition from the two gravel counts (GC7 and GC6) performed in Reach 17.

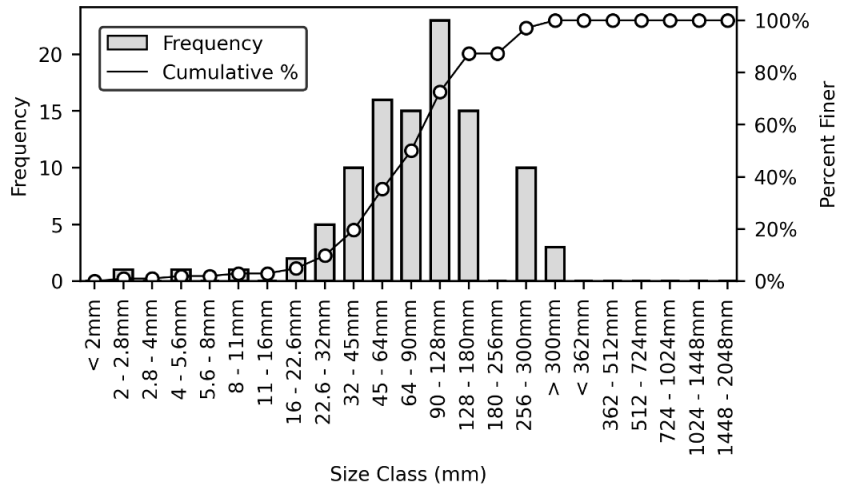


Figure 132. Cumulative distribution curve for GC6.

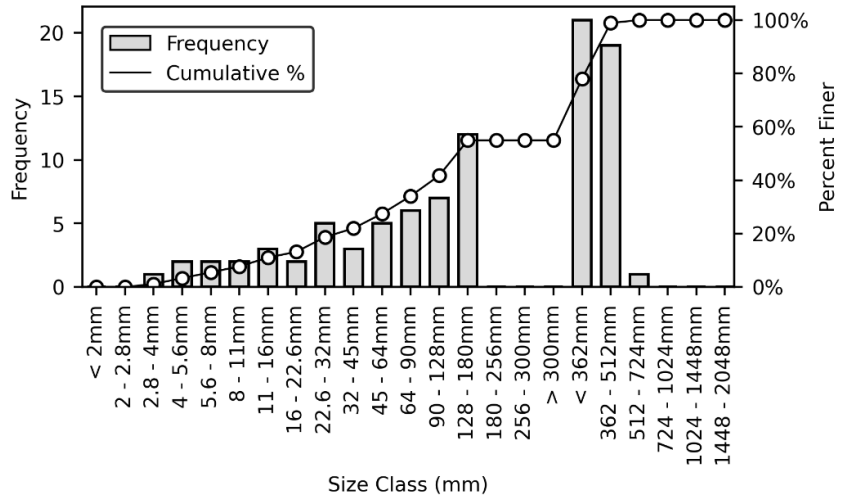


Figure 133. Cumulative distribution curve for GC7.

Table 45. Grain size class for GC7 and GC6 (assumed linear interpolation).

Size Class	GC7 Size percent finer than (mm)	GC6 Size percent finer than (mm)
D5	23	8
D16	40	43
D50	90	205
D84	165	365
D95	240	425

4.17.6 Riparian Corridor

Fourteen channel units in Reach 17 included ocular assessment of riparian vegetation. The dominant overstory size class was Large Trees (86%; 21.0 - 31.9-inch dbh), followed by Small Trees (14%; 9.0 - 20.9-inch dbh; Figure ***134***). Ponderosa pine is the dominant overstory species, comprising 36% of units. Douglas fir was recorded in 29% of the units, followed by Cedar (28%) and Cottonwood (7%; Figure ***134***). The dominant understory size class in Reach 17 was Shrub/Seedling (1.0 - 4.9-inch dbh) composing 86% of units, followed by No Vegetation in the remaining 14%. The understory vegetation species included Alder (57%), Dogwood (22%), Cedar (7%), and Other (14%; Figure ***135***). The Other understory species classification in Reach 17 was recorded for units with No Vegetation size class.

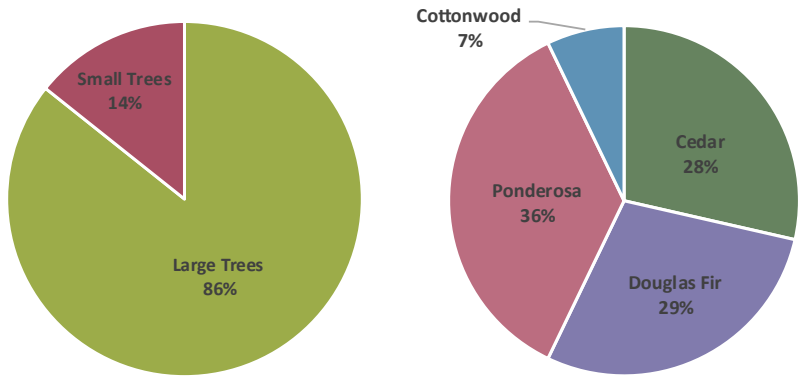


Figure 134***. Dominant overstory riparian vegetation class and species, based on 14 surveyed units, within 100 feet of Icicle Creek by ocular estimate.***

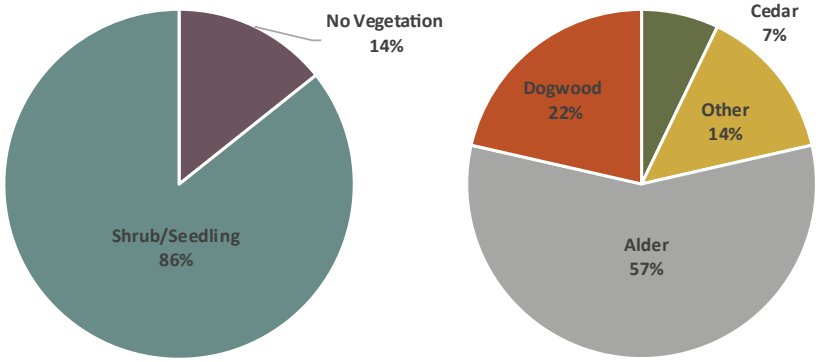


Figure 135***. Dominant understory riparian vegetation class and species, based on 14 surveyed units, within 100 feet of Icicle Creek by ocular estimate.***

4.18 REACH 18

Location: River mile 18.74 – 19.18
Total length: 0.44 miles
Survey Date: September 24 – 25, 2024

Figure 136. Representative photo of Reach 18 in Icicle Creek. Habitat was dominated by riffles.

4.18.1 Habitat Unit Composition

Reach 18 was 0.44 miles long. The stream gradient was approximately 1.54%. This reach was predominantly composed of riffles (62%), which was an increase in riffle composition compared to the previous unit. Pools were the second dominant habitat type composing 30% of the aquatic habitat area, followed by side channels (7%) then glides (1%) (Figure 137). Some of the reach was not wadable for the habitat survey crew due to the confined, steep nature of the channel, and data is based on ocular estimates from the crew walking along the banks.

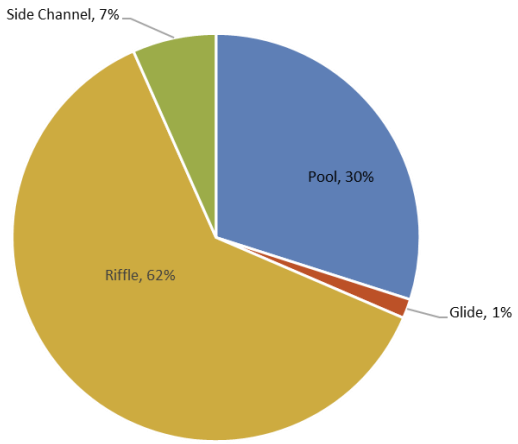


Figure 137. Stream habitat unit area composition of Reach 18.

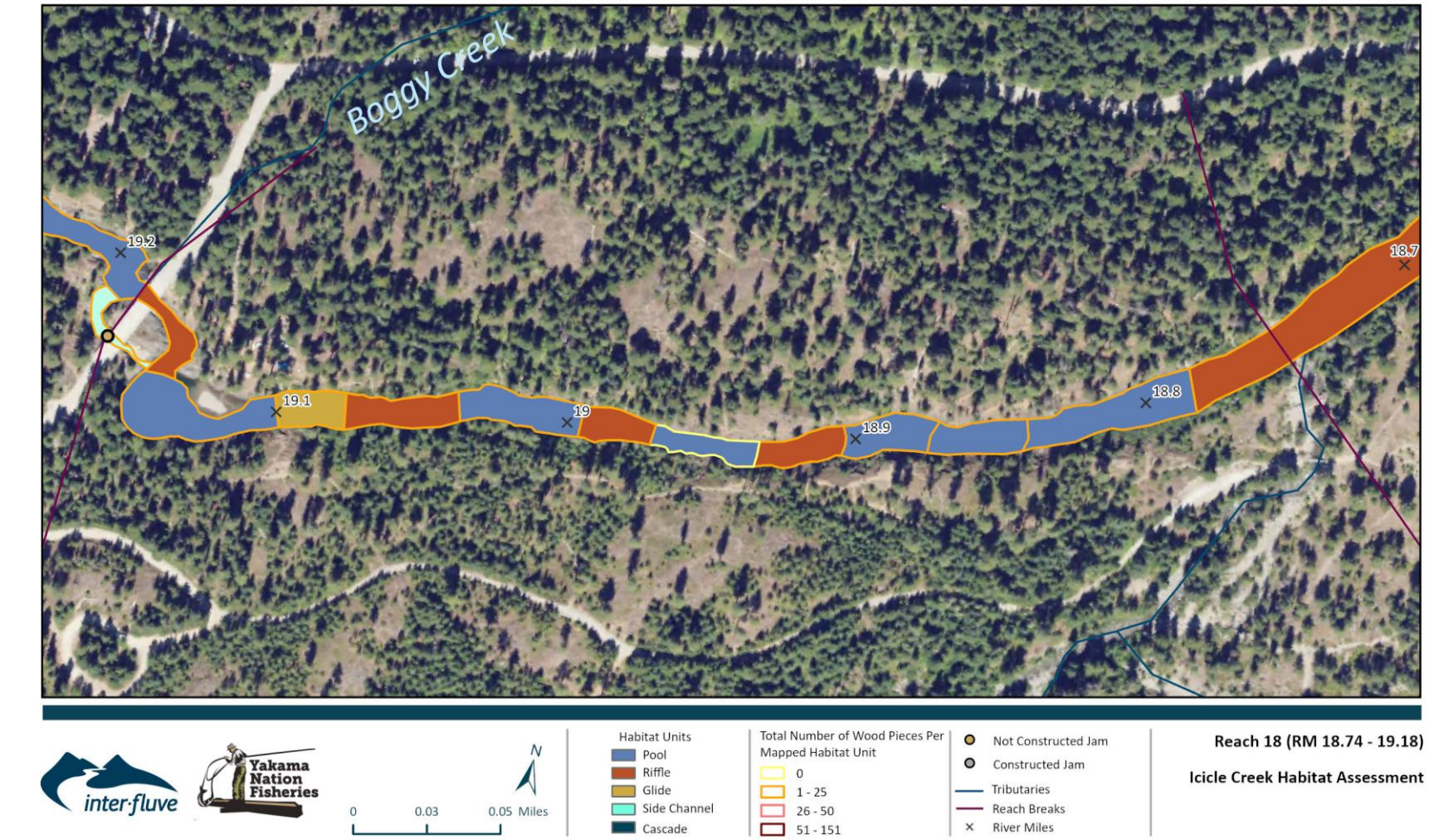


Figure 138. Map of the habitat unit composition and LWM in Reach 18 of Icicle Creek. LWM count includes pieces in jams.

4.18.2 Pools

Reach 18 had a total of six pools. Seventeen percent of pools had a residual depth greater than six feet. Sixty-seven percent of the pools had a residual depth between three feet and six feet, while the remaining 17% had less than three feet of residual depth. Residual depth in Reach 18 ranged from 2.3 feet to 18.5 feet, with an average of 5.7 feet (compared to the 4.4 feet for the study area average). The mean pool spacing for this reach was 14 pools per mile, higher than the study area average of seven pools per mile.

4.18.3 Side Channel Habitat

One side channel was measured in Reach 18 with a total channel length of 191 feet. The side channel was observed as predominantly slow. One jam was observed in the side channels with an estimated wood count of 18 LWM (Table 46).

Table 46. Side channels observed in Reach 18.

Location	Length (ft)	Dominant Unit Type	Wood Count	Jam Count	Wood Count in Jams
Side 59	191	Slow	1	1	18
Total	*191*		*1*	*1*	*18*

4.18.4 Large Woody Material

A total of 111 pieces of LWM was recorded in Reach 18. This total includes individual pieces and pieces recorded in jams. LWM frequency within the reach is approximately 258 pieces of LWM per mile, with 114 of those pieces per mile being Medium and Large LWM. One jam was observed in the reach, consisting of 16% of the total wood count (Table 47).

Table 47. LWM quantities in Reach 18.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Individual Pieces	40	40	13	93
Number of Individual Pieces per Mile	93	123		216
Number of Total Pieces per Mile (including pieces in jams)	114	114		258
Number of Jams	1			
Number of Jams per Mile	2			
Estimated Wood Count in Jams	18			

4.18.5 Substrate & Fine Sediment

No gravel counts were performed in Reach 18. Conditions were not appropriate or safe to complete a gravel count. Substrate was dominated by boulders.

4.18.6 Riparian Corridor

Six channel units in Reach 18 included ocular assessment of riparian vegetation. The dominant overstory class was Large Trees (21.0 - 31.9-inch dbh) composing 67% of the measured units. The second most dominant size class was No Vegetation (17%), followed by Sapling/Pole (8%; 9.0 - 20.9-inch dbh; Figure 139). Ponderosa was the dominant overstory species, present in67% of the measured units.

Other/Unknown species (17%) was observed in units where No Vegetation Size class recorded. Douglas Fir was the next most dominant overstory species (16%) in Reach 18. The dominant understory size in Reach 18 was 67% Shrub/Seedling (1.0 - 4.9-inch dbh), followed by No Vegetation for 23% of the surveyed units. The dominant species for the understory was Alder (62%) and Other (33%) (Figure 140). The Other understory species classification in Reach 18 was recorded in channel units with No Vegetation size class.

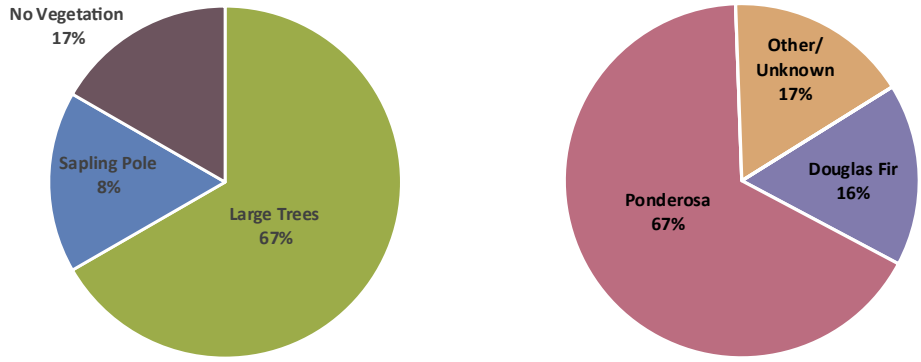


Figure 139. Dominant overstory riparian vegetation class and species, based on six surveyed unit, within 100 feet of Icicle Creek by ocular estimate.

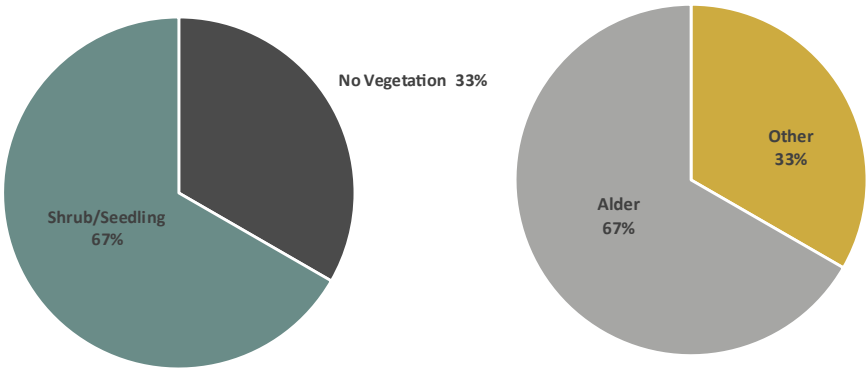


Figure 140. Dominant understory riparian vegetation class and species, based on six surveyed units, within 100 feet of Icicle Creek by ocular estimate.

4.19 REACH 19

Location: River mile 19.18 – 21.11
Total length: 1.93 miles
Survey Date: September 25 – 26, 2024

Figure 141. Representative photo of Reach 19 in Icicle Creek. Habitat was dominated by riffles

4.19.1 Habitat Unit Composition

Reach 19 spans 1.93 miles. Pools were the dominant habitat type in Reach 19, consisting of 64% of the total aquatic habitat area. This is followed by glides (16%), riffles (12%), and side channels (8%; Figure 142 and Figure 143) This reach delineates the steep, turbulent habitats observed in the downstream reaches. Stream gradient in Reach 19 was 0.33%. The reach ends within the Alpine Lakes Wilderness.

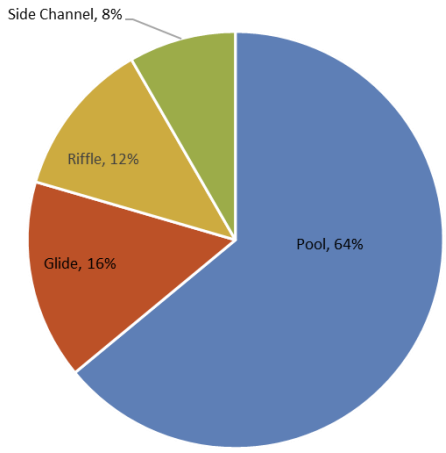


Figure 142. Stream habitat unit area composition of Reach 19.

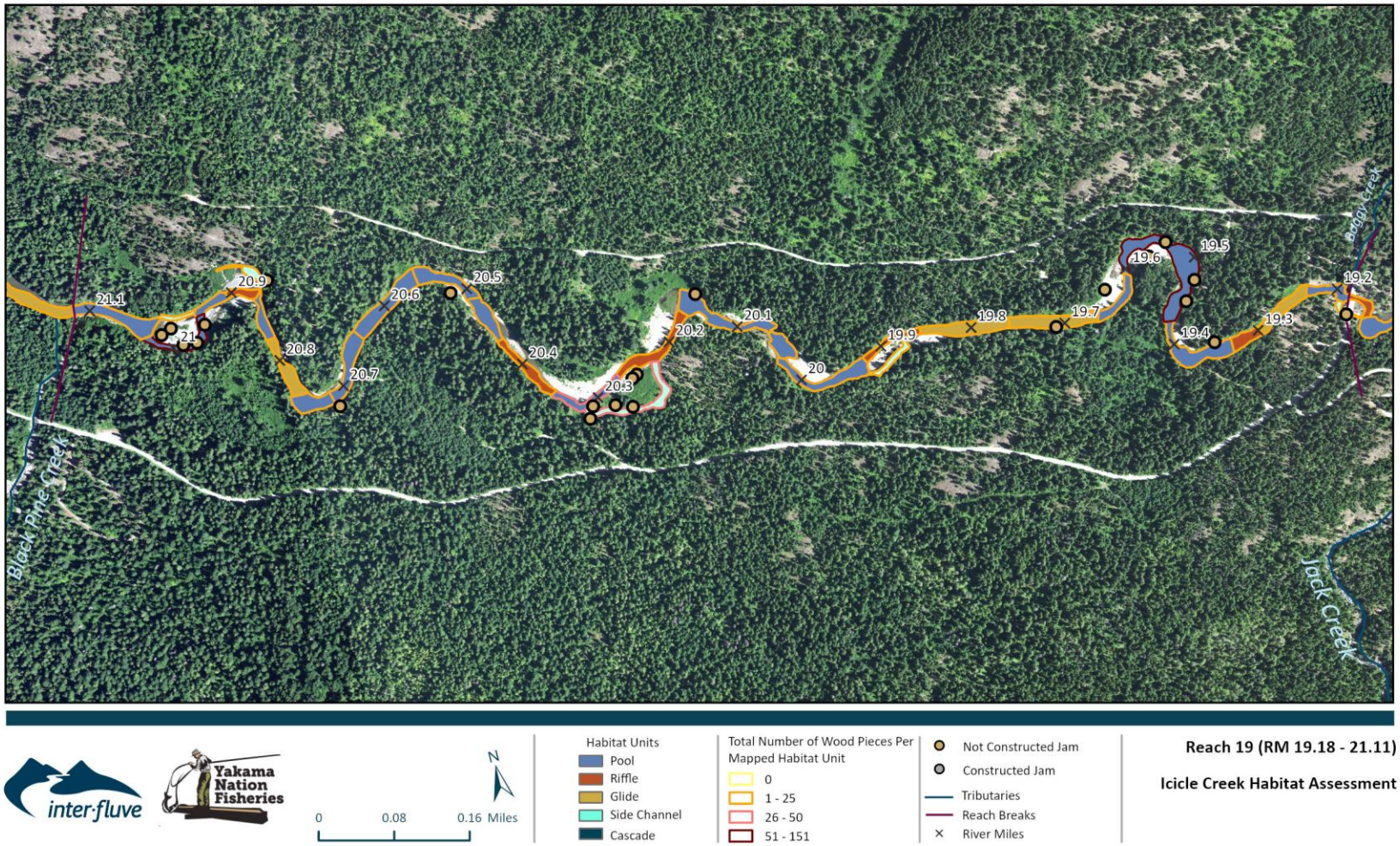


Figure 143. Map of the habitat unit composition and LWM in Reach 19 of Icicle Creek. LWM count includes pieces in jams.

4.19.2 Pools

Reach 19 had a total of 18 pools. Three pools (17%) had a residual depth greater than or equal to six feet. A majority of the pools (61%, n = 11) had a residual depth between three feet and six feet, while the remaining 22% were shallower than three feet of residual depth. Residual depth in Reach 19 ranged from 2.1 feet to 18.9 feet, with an average of 5.3 feet. The mean pool spacing for this reach was 14 pools per mile, higher than the study area average of seven pools per mile.

4.19.3 Side Channel Habitat

Four side channels were identified in Reach 19 and the total channel length was 1,543 feet. All side channels were observed as predominantly slow water units. A total of 14 individual pieces of LWM were recorded. Three jams were observed and had a total LWM wood count of 21 LWM (Table 48).

Table 48. Side channels observed in Reach 19.

Location	Length (ft)	Dominant Unit Type	Wood Count	Jam Count	Wood Count in Jams
Side 60	324	Slow	2	0	0
Side 61	685	Slow	8	3	21
Side 62	328	Slow	2	0	0
Side 63	205	Slow	2	0	0
Total	*1,543*		*14*	*3*	*21*

4.19.4 Large Woody Material

A total of 413 pieces of LWM were recorded in Reach 19, the second most of any reach in the study area. This total includes individual pieces and pieces in jams. LWM frequency was approximately 213 pieces of LWM per mile, with 127 of those pieces per mile being Medium and Large LWM. A total of 22 jams were observed within the reach which contained 67% of the total wood count (Table 49).

Table 49. LWM quantities in Reach 19.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Individual Pieces	59	55	23	137
Number of Individual Pieces per Mile	30	40		71
Number of Total Pieces per Mile (including pieces in jams)	86	127		213
Number of Jams	22			
Number of Jams per Mile	11			
Estimated Wood Count in Jams	276			

4.19.5 Substrate & Fine Sediment

Three gravel counts were performed in Reach 19, with a combined average of 54% gravel and 46% cobbles (Figure 144). The first gravel count, GC 5, was conducted at RM 19.66 in a riffle crest at the upstream end of a point bar. The second and third gravel counts, GC 4 and GC 3, were conducted at RM 20.13 and RM 20.83, respectively, in riffle crests. The distribution and grain size class can be found in Figure 145– Figure 146 and Table 50.

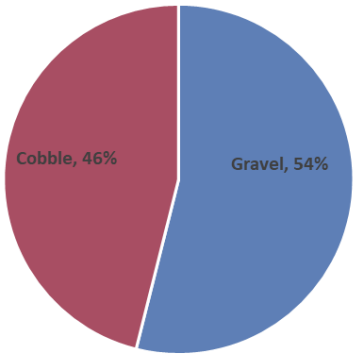


Figure 144. Combined sediment composition from the three gravel counts (GC5, GC4, and GC3) performed in Reach 19.

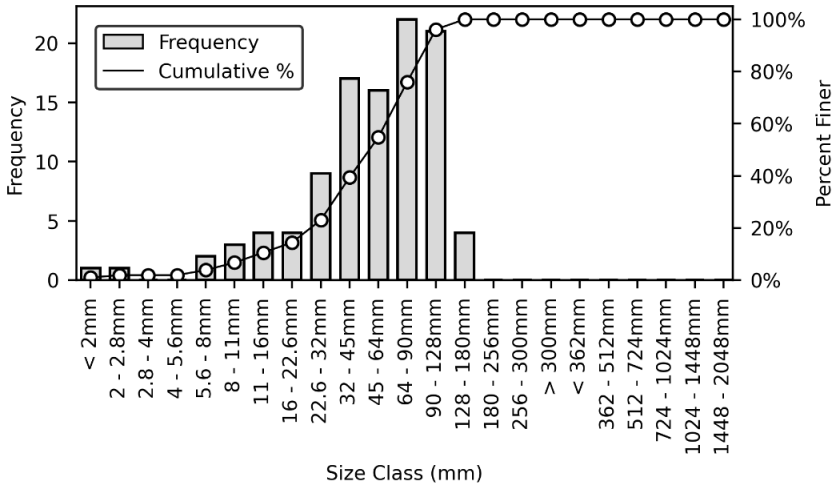


Figure 145. Cumulative distribution curve for GC5.

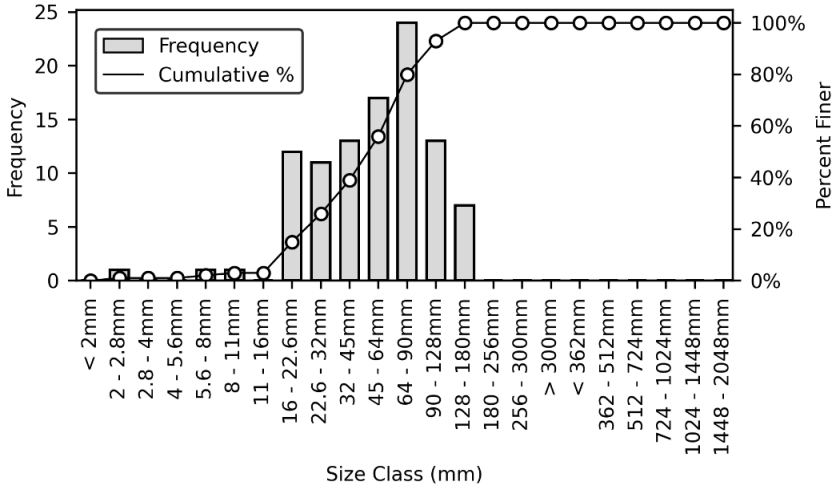


Figure 146. Cumulative distribution for GC4.

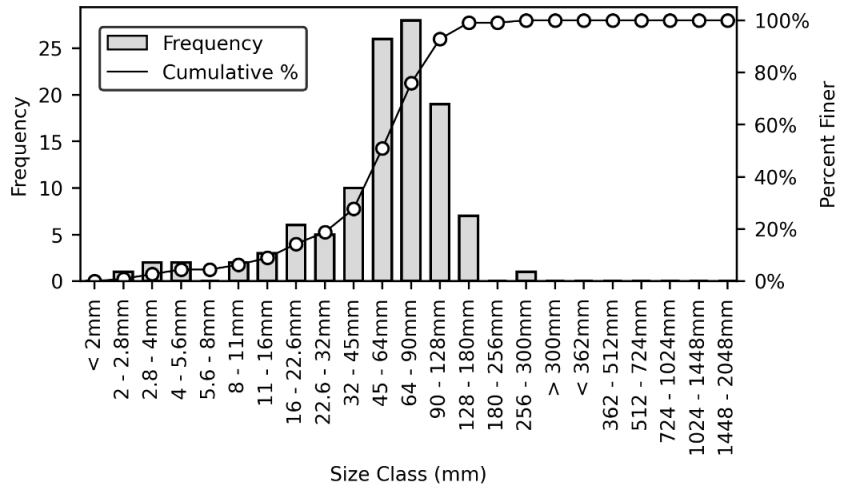


Figure 147. Cumulative distribution curve for GC3.

Table 50. Grain size class for GC5, GC4 and GC3 (assumed linear interpolation).

	GC5	GC4	GC3
Size Class	*Size percent finer than (mm)*	*Size percent finer than (mm)*	*Size percent finer than (mm)*
D5	9	17	9
D16	24	23	26
D50	57	57	63
D84	104	100	105
D95	128	140	145

4.19.6 Riparian Corridor

Fifteen channel units in Reach 19 included ocular assessment of riparian vegetation. The dominant overstory size class in Reach 19 was 93% Large Trees (21.0 - 31.9-inch dbh). The remaining 7% of overstory units recorded was in the Mature Tree (> 32-inch dbh) size class. The dominant species was composed of Douglas fir (67%) and Cedar (33%; Figure 148). The understory was dominated (100%) by Shrub/Seedling (1.0 -4.9-inch dbh) and largely consisted of Dogwood (67%; Figure 148). The remaining understory species composition was Alder (20%), Willow (7%) and Vine/Douglas maple (6%; Figure 149).

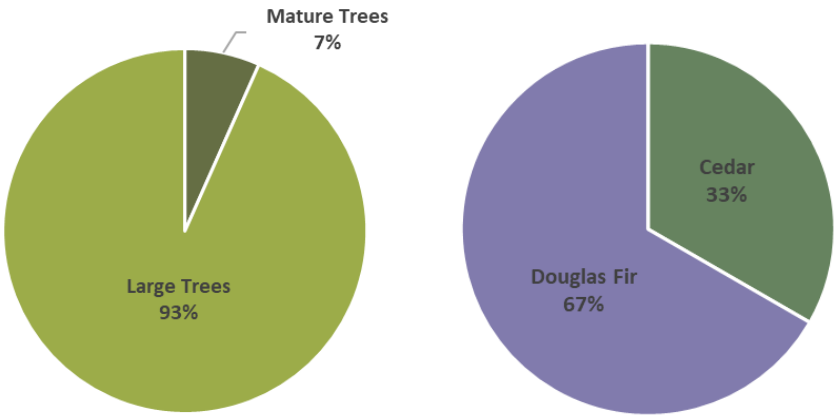


Figure 148. Dominant overstory riparian vegetation class and species, based on 15 surveyed units, within 100 feet of Icicle Creek by ocular estimate.

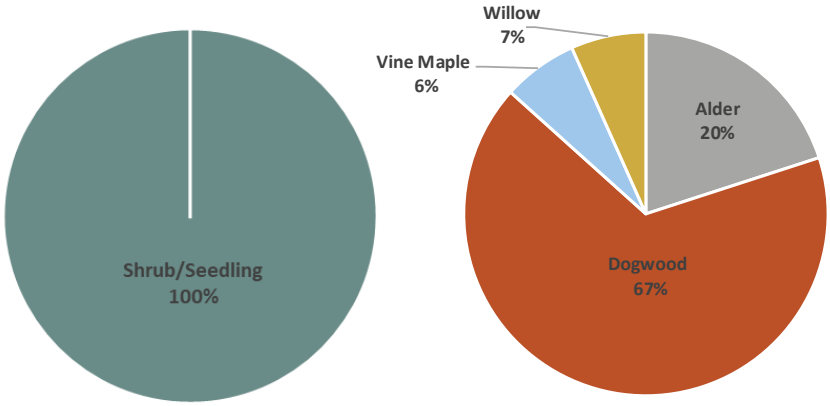


Figure 149. Dominant understory riparian vegetation class and species, based on 15 surveyed units, within 100 feet of Icicle Creek by ocular estimate.

4.20 REACH 20

Location: River mile 21.11 – 22.02
Total length: 0.91 miles
Survey Date: September 26, 2024

Figure 150. Representative photo of Reach 20 in Icicle Creek. Habitat was dominated by riffles

4.20.1 Habitat Unit Composition

Reach 20 was 0.9 miles long and composed predominantly of fast water units. Riffles composed 66% of the habitat area. Glides (18%) were the second most dominant habitat, followed by pools (16%; Figure 151). The final reach in the study area had a stream gradient of 0.49%. This reach is located exclusively within the Alpine Lakes Wilderness.

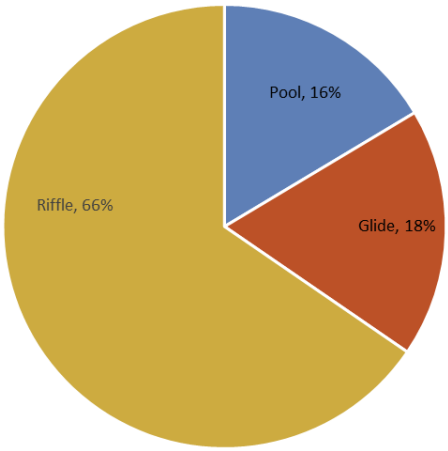


Figure 151. Stream habitat unit area composition of Reach 20.

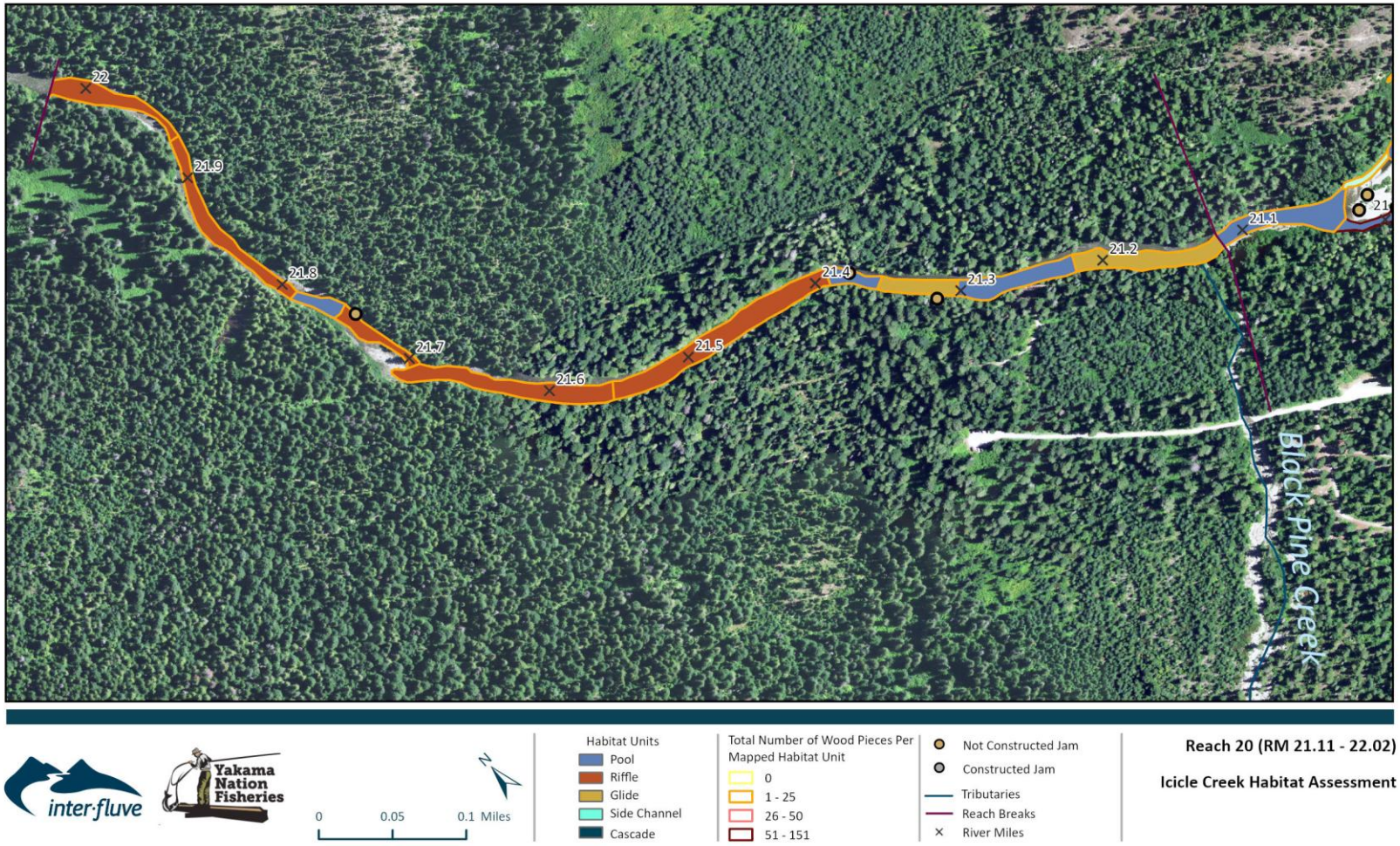


Figure 152. Map of the habitat unit composition and LWM in Reach 20 of Icicle Creek. LWM count includes pieces in jams.

4.20.2 Pools

Three pools were observed in Reach 20, which corresponds to 3.3 pools per mile. All of the pools within the reach (100%) have residual depths less than three feet. Residual pool depth ranged from a low of 1.8 feet to a high of 2.2 feet, the shortest range among all reaches in the study area. The average residual depth for Reach 20 was 2.0 feet.

4.20.3 Side Channel Habitat

No side channels were observed in Reach 20.

4.20.4 Large Woody Material

A total of 100 pieces of LWM were recorded in Reach 20 (Table 51). This total includes individual pieces and pieces recorded in jams. LWM frequency within the reach is approximately 111 pieces of LWM per mile, with 81 of those pieces per mile being Medium and Large LWM. There were three observed jams in Reach 20, which contained an estimated 21 pieces of LWM or 21% of the total amount of LWM pieces.

Table 51. LWM quantities in Reach 20.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Individual Pieces	20	46	13	79
Number of Individual Pieces per Mile	22	66		88
Number of Total Pieces per Mile (including pieces in jams)	30	81		111
Number of Jams	3			
Number of Jams per Mile	3			
Estimated Wood Count in Jams	21			

4.20.5 Substrate & Fine Sediment

Two gravel counts were performed in Reach 20, with a combined average of 51% cobbles, 36% gravel, 11% boulder, and 2% sand (Figure 153). The first gravel count, GC2, was conducted at RM 21.4 in a riffle crest. The second gravel count, GC1, was conducted at RM 21.73 in a riffle crest adjacent to a gravel bar. The distribution and grain size class can be found in Figure 154 – Figure 155 and Table 52.

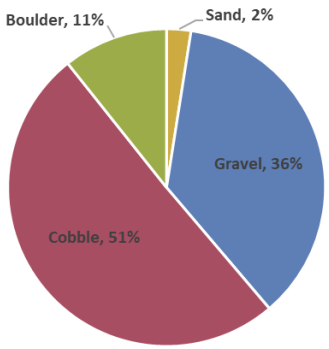


Figure 153. Combined sediment composition from the two gravel counts (GC2 and GC1) performed in Reach 20.

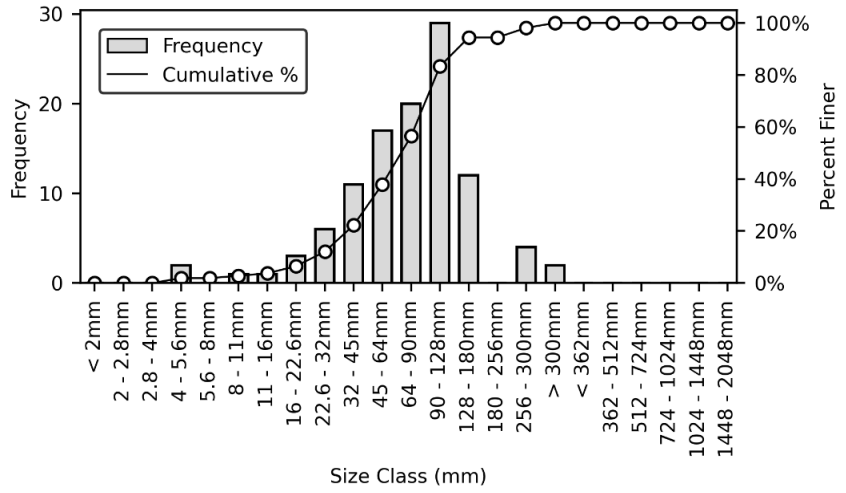


Figure 154. Cumulative distribution curve for GC2.

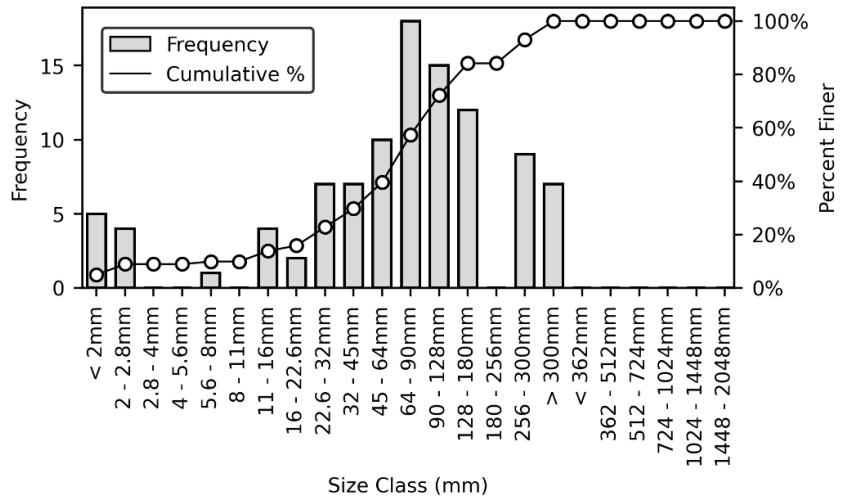


Figure 155. Cumulative distribution curve for GC1.

Table 52. Grain size class for GC2 and GC1 (assumed linear interpolation).

	GC2	GC1
Size Class	*Size percent finer than (mm)*	*Size percent finer than (mm)*
D5	19	2
D16	37	23
D50	80	80
D84	130	180
D95	190	300+

4.20.6 Riparian Corridor

Based on five nth units surveyed in Reach 20, the dominant (100%) overstory class and species was Large Trees (21.0 - 31.9-inch dbh) that were 100% Cedar (Figure 156). The dominant understory in Reach 20 was Shrub/Seedling (100%; 1.0 -4.9-inch dbh). The dominant understory species was Alder that composed of 83% of units, followed by Vine/Douglas maple that composed the remaining 17% of units (Figure 157).

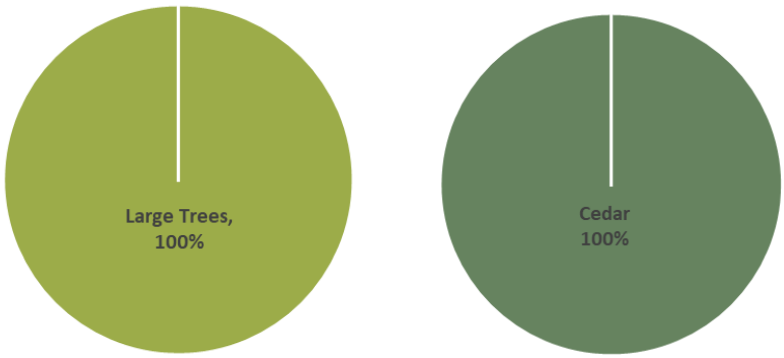


Figure 156.Dominant overstory riparian vegetation class and species, based on five nth units surveyed, within 100 feet of Icicle Creek by ocular estimate.

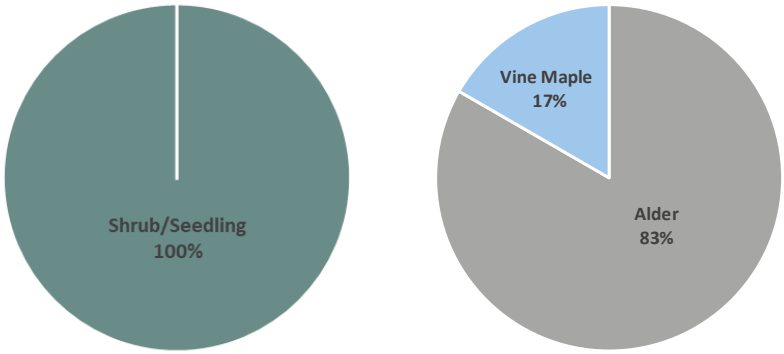


Figure 157. Dominant understory riparian vegetation class and species, based on five nth units, within 100 feet of Icicle Creek by ocular estimate.

4.21 SUMMARY DATA

Table 53. Summary table of all the data collected in the 2024 Habitat Assessment for all the mainstem reaches in the Icicle Creek study area.

Reach	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	All
Reach Mileage Boundaries	1.24	1.78	1.28	0.75	1.22	0.88	1.48	1	0.61	1.12	0.56	0.58	0.34	1.91	1.89	0.61	1.5	0.43	1.94	0.9	22.02
Stream Gradient (%)	0.11	0.07	0.24	1.65	3.40	3.82	3.19	1.94	3.66	1.31	3.40	2.11	2.20	1.54	0.57	0.88	1.62	1.54	0.33	0.49	1.70
Wetted Width (ft)																					
Pool																					
Mean	92	101	61	82	54	37	67	65	58	52	53	56	58	58	71	63	49	52	61	58	62
Median	90	100	60	70	50	40	60	65	55	50	55	43	55	55	70	58	50	45	50	55	59
St. Dev	22	15	27	24	8	12	14	5	15	2	10	25	8	10	18	22	10	23	23	8	15
Glide																					
Mean	78	105	45	0	20	0	0	0	0	50	0	50	0	75	88	80	0	60	58	65	41
Median	75	105	45	0	20	0	0	0	0	50	0	50	0	75	88	80	0	60	58	65	41
St. Dev	22	15	11	0	0	0	0	0	0	0	0	0	0	0	24	0	0	0	3	5	4
Riffle																					
Mean	0	0	60	67	52	49	64	72	75	91	67	68	59	68	70	73	57	48	42	62	57
Median	0	0	60	60	50	50	60	70	75	90	70	70	68	70	70	70	55	50	35	65	57
St. Dev	0	0	0	21	11	9	15	12	26	2	10	6	17	9	7	16	14	10	19	6	11
Side Channel																					
Mean	20	130	15	18	18	0	16	26	38	17	0	20	0	32	20	30	14	20	33	0	23
Median	20	130	18	20	18	0	18	25	55	20	0	20	0	30	18	30	15	20	35	0	24
St. Dev	0	0	9	2	6	0	8	19	25	8	0	0	0	2	12	0	2	0	11	0	5
Water Depth (ft)																					
Pool Maximum Depth																					
Mean	7.9	7.4	3.9	5.5	5.5	7.0	6.0	7.5	5.8	5.6	5.9	6.8	6.3	5.0	4.6	3.8	7.5	7.6	6.1	2.7	5.9
Median	6.5	7.5	3.5	5.5	5.0	7.0	5.5	7.5	6.5	6.5	6.0	6.0	6.0	5.0	4.5	3.9	5.4	5.6	5.0	2.8	5.6
St. Dev	6.3	2.8	1.3	1.0	1.2	3.2	1.4	0.4	1.9	1.6	1.1	2.0	1.2	0.8	1.1	0.3	5.2	5.6	3.8	0.1	2.1
Pool Residual Depth																					
Mean	6.5	6.0	3.0	4.5	4.2	5.5	4.1	4.9	3.9	3.6	4.0	4.7	4.1	2.9	3.5	2.4	6.1	5.7	5.3	2.0	4.4
Median	5.4	5.4	2.6	4.3	4.0	5.0	4.0	4.6	4.6	4.4	3.9	3.8	4.0	2.8	3.4	2.5	4.1	4.3	4.4	2.0	4
St. Dev	6.2	3.0	1.3	0.8	1.8	3.5	1.2	0.7	1.6	1.3	1.2	2.5	1.5	0.9	1.0	0.6	5.1	4.4	3.7	0.2	2.1
Riffle/Glide Average Depth																					

Reach	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	All
Mean	1.6	1.3	1.6	2.0	3.0	3.2	3.1	2.2	2.3	1.6	2.6	2.0	2.0	2.1	1.6	1.8	2.0	2.0	1.4	1.4	2.0
Median	1.4	1.3	1.4	2.3	3.0	3.0	3.0	2.1	2.2	1.6	2.5	2.0	2.0	2.2	1.5	1.8	1.8	1.7	1.4	1.3	2.0
St. Dev	0.65	0.75	0.65	0.50	0.96	0.41	0.81	0.42	0.42	0.32	0.27	0.33	0.43	0.36	0.35	0.57	0.78	0.8	0.30	0.30	0.5
Bankfull Characteristics																					
Width (ft)																					
Mean	125	83	57	100	90	80	102	118	97	99	76	92	86	85	105	98	83	72	82	86	90.8
Median	80	100	55	65	50	40	60	70	60	90	60	55	65	65	70	62.5	80	66	50	62.5	63
St. Dev	7	55	15	28	0	42	16	2	4	21	4	10	2	9	11	6	8	13	13	7	13.5
Average Depth (ft)																					
Maximum depth	6.1	6.3	5.6	10.8	n=0	n=0	6.6	8.1	7.2	6.3	8.8	7.5	6.4	7.2	6.4	7.5	8.2	5.0	6.8	5.7	7.1
Minimum Depth	3.5	4.0	0.8	6.3	n=0	n=0	3.0	0.0	2.9	3.0	0.5	2.8	3.2	3.6	2.5	1.6	1.6	2.2	2.4	2.5	2.6
Mean	4.5	5.4	4.3	8.1	n=0	n=0	4.5	5.0	4.6	4.5	5.7	5.1	4.5	5.1	4.8	4.5	4.6	3.9	4.8	4.2	4.9
St. Dev	1.0	0.8	1.4	1.9	n=0	n=0	1.2	1.9	1.6	1.1	2.1	1.6	1.1	1.3	1.4	1.5	1.8	0.8	1.3	1.0	1.4
Maximum Depth (ft)																					
Mean	4.5	5.4	4.3	8.1	n=0	n=0	4.5	5.0	4.6	4.5	5.7	5.1	4.5	5.1	4.8	4.5	8.2	5.0	4.8	4.2	4.9
St. Dev	1.0	0.8	1.4	1.9	n=0	n=0	1.2	1.9	1.6	1.1	2.1	1.6	1.1	1.3	1.4	1.5	1.8	0.8	1.3	1.0	1.4
Width: Depth Ratio																					
Mean	27.9	15.5	13.2	12.4	n=0	n=0	22.5	23.3	21.0	22.0	13.3	18.0	19.1	16.8	21.8	21.7	17.0	20.3	17.0	20.4	18.4
Flood Prone Width (ft)																					
Mean	1634	298	204	190	161	126	105	255	146	145	91	103	110	101	217	156	148	76	326	215	240
Median	1633	298	181	190	155	125.5	106	254.5	146	166	93	106	110	102	127.5	156	130	73	323	162.5	232
St. Dev	627	54	67	n=0	56	22	5	152	6	40	15	11	16	9	192	23	55	6	39	157	300
Habitat Area																					
Pool (%)	66.4	91.5	75.5	27.8	25.5	32.1	22.8	10.5	17.8	5.7	28.8	18.9	23.5	19.1	40.3	45.9	25	87	64.0	16.4	41.0
Glide (%)	32.4	6.0	12.7	0.0	3.1	0.0	0.0	0.0	0.	1.9	0.0	4.8	0.0	2.6	29.5	12.7	4	8	15.5	18.1	9.1
Riffle (%)	0.0	0.0	3.1	66.6	50.4	66.6	66.2	67.8	69.8	86.5	71.2	72.3	76.5	75.6	20.7	37.3	61	0	12.2	65.4	42.7
Side Channel (%)	1.1	2.5	8.8	5.6	18.5	0.0	11.0	21.7	12.4	5.9	0.0	4.0	0.0	2.7	0.0	4.1	8	5	8.3	0	6.1
Cascade (%)	0.0	0.0	0.0	0.0	2.5	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2	0	0	0	0.2
Pools																					
Pools per Mile	3.9	8.1	18.8	7.1	7.8	10.0	8.3	4.4	6.7	2.7	13.3	7.3	8.6	4.7	7.1	7.5	6.7	14	10.3	3.2	7.2

Reach	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	All
Residual Depth (% of pools)																					
pools < 3ft	40%	14%	53%	0%	22%	11%	17%	0%	25%	33%	25%	50%	33%	56%	42%	83%	20%	17%	22%	100%	30.82 %
Pools 3-6 ft	40%	50%	40%	100%	56%	67%	83%	100%	75%	67%	63%	25%	67%	44%	58%	17%	50%	67%	61%	0%	56.60 %
Pool 6< ft	20%	36%	7%	0%	22%	22%	0%	0%	0%	0%	13%	25%	0%	0%	0%	0%	30%	17%	17%	0%	12.58 %
Riffle: Pool Ratio	0	0	0	1	1	1	1	2	1	11	1	1	1	2	0	1	0.8	0.8	0	2	1.3
Mean Pool Spacing (Bankfull channel widths per pool)	8.5	9.1	8.1	10.3	6.5	6.5	6.4	11.2	8.4	19.9	4.6	8.2	7.0	13.1	7.9	5.5	10.2	4.8	7.0	18.6	9.1
Large Woody Material																					
Total Number of LWM Pieces (Individual + Jams)																					
Total	125	142	61	144	252	118	413	385	215	218	48	71	35	399	487	107	209	111	413	100	4053
Large (20in by 35ft)	12	4	1	8	18	0	31	59	25	25	3	9	1	40	60	16	33	4	64	9	422
Medium (12in by 35ft)	16	12	1	27	60	12	65	128	61	68	9	14	6	89	114	25	58	5	104	5	879
Large and Medium	28	16	2	35	78	12	96	187	86	93	12	23	7	129	174	41	91	9	168	14	1301
Small (6in by 20ft)	41	20	3	27	65	17	105	109	58	65	5	18	6	111	107	28	63	9	108	7	972
Number of LWM Pieces/Mile (Individual + Jams)																					
Total	101	80	48	192	207	134	279	385	352	195	86	122	103	209	258	175	139	258	213	111	184
Large (20in by 35ft)	15	7	2	35	78	12	96	187	86	93	12	23	7	129	174	41	91	9	168	14	31
Medium (12in by 35ft)	24	27	8	65	80	44	88	169	151	79	36	38	38	74	104	66	51	105	82	57	69
Large and Medium	39	34	10	87	107	55	155	237	200	108	52	60	44	106	148	98	79	144	127	81	100
Small (6in by 20ft)	62	48	38	105	99	80	124	148	152	87	34	62	59	103	110	77	61	114	86	30	84
Jams																					
Total Jams per reach	3	4	1	6	14	4	17	14	9	7	5	5	4	10	25	3	13	1	22	3	170
Unstable Banks																					
Total Unstable Banks (% of total Bank)	81%	55%	23%	42%	51%	99%	40%	9%	6%	10%	59%	39%	54%	15%	15%	28%	5%	13%	5%	14%	33%
Substrate																					
Total																					

Reach	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	All
% Sand	1%	2%	1%	1%	N/A	N/A	N/A	4%	3%	2%	7%	N/A	N/A	3%	4%	1%	0%	N/A	0%	2%	2%
% Gravel	70%	88%	87%	12%	N/A	N/A	N/A	20%	21%	23%	9%	N/A	N/A	28%	37%	20%	31%	N/A	54%	36%	38%
% Cobble	29%	10%	12%	41%	N/A	N/A	N/A	35%	32%	33%	29%	N/A	N/A	28%	43%	54%	40%	N/A	46%	51%	34%
% Boulder	0%	0%	0%	46%	N/A	N/A	N/A	41%	45%	42%	57%	N/A	N/A	40%	16%	25%	29%	N/A	0%	11%	25%
Vegetation (% of sampled units in 100-ft-wide zone average between both banks)																					
Dominant Overstory Class																					
Mature Trees	29%	0%	0%	0%	0%	0%	18%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	7%	0%	3%
Large Trees	57%	73%	86%	100%	100%	0%	18%	100%	100%	63%	100%	50%	100%	56%	73%	83%	86%	0%	93%	100%	72%
Small Trees	14%	0%	14%	0%	0%	80%	27%	0%	0%	25%	0%	50%	0%	44%	13%	17%	14%	0%	0%	0%	15%
Sapling Pole	0%	0%	0%	0%	0%	0%	18%	0%	0%	0%	0%	0%	0%	0%	13%	0%	0%	0%	0%	0%	3%
Shrub/Seedling	0%	0%	0%	0%	0%	20%	18%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	86%	0%	0%	2%
Grassland/Forb	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
No Vegetation	0%	9%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	14%	0%	0%	1%
Other	0%	18%	0%	0%	0%	0%	0%	0%	0%	13%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%
Overstory Species Composition																					
Cedar	0%	0%	0%	0%	33%	0%	0%	67%	25%	13%	0%	0%	33%	56%	13%	33%	28%	0%	33%	100%	20%
Douglas Fir	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	67%	67%	33%	40%	33%	29%	16%	67%	0%	21%
Ponderosa Pine	29%	45%	86%	100%	67%	100%	55%	33%	75%	75%	100%	33%	0%	11%	20%	33%	36%	67%	0%	0%	42%
Other/Uknown	0%	27%	0%	0%	0%	0%	0%	0%	0%	13%	0%	0%	0%	0%	7%	0%	0%	17%	0%	0%	3%
Alder	0%	0%	14%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%
Cottonwood	57%	27%	0%	0%	0%	0%	27%	0%	0%	0%	0%	0%	0%	0%	20%	0%	7%	0%	0%	0%	9%
Quaking Aspen	14%	0%	0%	0%	0%	0%	18%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%
Dominant Understory Species																					
Grassland/Forb	57%	9%	0%	0%	0%	40%	0%	0%	0%	0%	17%	0%	0%	0%	7%	0%	0%	0%	0%	0%	6%
No Vegetation	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	11%	0%	17%	14%	33%	0%	0%	4%
Other	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Shrub/Seedling	43%	91%	100%	100%	100%	60%	82%	100%	100%	88%	83%	83%	100%	89%	93%	83%	86%	67%	100%	100%	2%
Sapling Pole	0%	0%	0%	0%	0%	0%	18%	0%	0%	0%	0%	17%	0%	0%	0%	0%	0%	0%	0%	0%	87%
Small Tree	0%	0%	0%	0%	0%	0%	0%	0%	0%	13%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%
Understory Species Composition																					
Cedar	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	7%	0%	0%	0%	1%
Other	43%	0%	0%	0%	0%	40%	0%	0%	0%	0%	17%	0%	0%	11%	7%	17%	14%	33%	0%	0%	9%

Reach	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	All
Alder	14%	18%	14%	75%	100%	60%	45%	67%	100%	88%	83%	50%	67%	78%	80%	83%	57%	67%	20%	83%	57%
Dogwood	43%	55%	71%	25%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	7%	0%	22%	0%	67%	0%	3%
Cottonwood	0%	0%	0%	0%	0%	0%	18%	0%	0%	0%	0%	33%	0%	0%	0%	0%	0%	0%	0%	0%	19%
Vine/Douglas Maple	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	7%	0%	0%	0%	7%	17%	2%
Willow	0%	27%	14%	0%	0%	0%	36%	33%	0%	13%	0%	17%	33%	11%	0%	0%	0%	0%	7%	0%	9%

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Icicle Creek Reach Assessment

Appendix B | Reach-Based Ecosystem Indicators (REI)

Icicle Creek (RM 0 – 22.02)

February 2026

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1 Introduction

1.1 BACKGROUND

The Reach-based Ecosystem Indicators (REI) provide a consistent means of evaluating biological and physical conditions of a watershed in relation to regional standards and known habitat requirements for aquatic biota. These indicators, along with other scientific evaluations, describe the current quality of stream biophysical conditions and can help inform restoration targets and actions. The REI indicators used in this assessment are adaptations from previous efforts including the National Marine Fisheries Service matrix of pathways and indicators (NMFS, 1996) and the U.S. Fish and Wildlife Service matrix of pathways for eastside streams (USFWS, 1998).

The REI evaluation for Icicle Creek was conducted using field data, observations, previous studies, and available data for the study area. In particular, the rankings were developed based on 1) quantitative inventory information from the Habitat Assessment performed as part of the Reach Assessment using U.S. Forest Service (2020) protocols, 2) assessment of geomorphic patterns and processes and how they have deviated, if at all, from historical conditions, and 3) analysis of existing watershed assessments and data (e.g. available GIS data). Functional ratings include Adequate, At Risk, or Unacceptable. The REI analysis helps to summarize habitat impairments and to distill the impairments down to a consistent value that can be compared among reaches. The REI results help to inform the identification of recommended restoration measures in the Restoration Strategy (Appendix C). They are also used in the project prioritization framework, where existing conditions are rated and compared to target conditions (typically equivalent to an REI Adequate rating) to determine project priorities.

1.2 SUMMARY OF RESULTS

At the watershed scale, REI ratings for Icicle Creek ranged from Unacceptable to Adequate. Watershed-scale impairments are primarily related to historical or ongoing anthropogenic disturbance to the watershed. Fish passage impediments in the mainstem of Icicle Creek were observed in Reaches 3 – Reach 5 and were largely related to LNFH current or historical infrastructure. Across all reaches, the most impaired indicators occurred in the Riparian Vegetation and Habitat Quality categories. High-quality riparian vegetation conditions that support aquatic ecosystem processes, such as mature, old-growth trees in the riparian zone that offer channel shading and contribute large wood to the channel are limited within the study area, largely due to the presence of roads, residences and recreational facilities such as campgrounds. Riparian Vegetation condition indicators predominantly rated At Risk or Unacceptable. Most Unacceptable ratings within the study area occurred in Disturbance (Human); Reach 20 was the only reach in the study area to rate Adequate. Habitat Quality indicators ranged from Adequate to Unacceptable with most Unacceptable ratings occurring in the Large Woody Material (LWM) and Pool Quantity/Quality Indicators. The middle and upper reaches offer relatively little high-quality, deep pool habitat. Off-channel habitat is intermittently available within the study area, with Unacceptable or At Risk ratings in more of the lower reaches due to anthropogenic impacts to the channel and floodplains. Suitable spawning-sized substrates where natural channel form and stream power support the development of spawning areas occurred in all reaches. Geomorphic channel conditions, documented in the Channel Dynamics Pathway and Indicators, are relatively stable within the project area, with Reach 3 having the only Unacceptable rating for Bank Stability/Channel Migration.

Table 1. Summary ratings for the Icicle Creek reach assessment (Reach 1 – Reach 10). Ratings are color-coded, with green shading for Adequate condition, yellow for At Risk condition, and red for Unacceptable condition.

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
Habitat Access	Physical Barriers	Main Channel Barriers	Adequate	Adequate	At Risk	At Risk	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
Habitat Quality	Substrate	Dominant Substrate/ Fine Sediment	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	At Risk	Adequate
	LWM	Pieces per Mile at Bankfull	Unacceptable	Unacceptable	Unacceptable	Adequate*	Adequate*	Unacceptable	Adequate*	Adequate*	Adequate*	Adequate
	Pools	Pool Frequency and Quality, Presence of Large Pools	Adequate	Adequate	Adequate	Unacceptable	At Risk	At Risk	At Risk	Unacceptable	At Risk	At Risk
	Off-Channel Habitat	Connectivity with Main Channel	At Risk	Unacceptable	At Risk	At Risk	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
Riparian Vegetation	Condition	Structure	At Risk	At Risk	At Risk	At Risk	At Risk	Unacceptable	Unacceptable	At Risk	At Risk	At Risk
		Disturbance (Human)	At Risk	Unacceptable	Unacceptable	At Risk	Unacceptable	Unacceptable	Unacceptable	Unacceptable	At Risk	Unacceptable
		Canopy Cover	Unacceptable	At Risk	At Risk	At Risk	At Risk	Unacceptable	At Risk	Adequate	Adequate	Adequate
Channel	Dynamics	Floodplain Connectivity	Adequate	At Risk	Unacceptable	At Risk	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
		Bank Stability/ Channel Migration	At Risk	At Risk	Unacceptable	At Risk	At Risk	Adequate	Adequate	Adequate	Adequate	Adequate
		Vertical Channel Stability	Adequate	At Risk	At Risk	At Risk	Adequate	Adequate	Adequate	At Risk	Adequate	Adequate

**Although the LWM maybe be adequate from a habitat/cover perspective, this indicator does not consider the geomorphic function of LWM. An asterisk is indicated in the LWM reach rating where the rating would potentially be lowered if geomorphic function of LWM was taken into account.*

Table 2. Summary ratings for the Icicle Creek reach assessment (Reach 11 – Reach 20). Ratings are color-coded, with green shading for Adequate condition, yellow for At Risk condition, and red for Unacceptable.

ay	General Indicators	Specific Indicators	Reach 11	Reach 12	Reach 13	Reach 14	Reach 15	Reach 16	Reach 17	Reach 18	Reach 19	Reach 20
ccess	Physical Barriers	Main Channel Barriers	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
Habitat Quality	Substrate	Dominant Substrate/ Fine Sediment	Adequate	Adequate	Adequate	Adequate	At Risk	At Risk	At Risk	Adequate	Adequate	At Risk
	LWM	Pieces per Mile at Bankfull	Unacceptable	Unacceptable	Adequate*	Adequate*	Adequate*	Adequate*	Adequate*	Unacceptable	Adequate*	Adequate
	Pools	Pool Frequency and Quality, Presence of Large Pools	At Risk	At Risk	At Risk	At Risk	At Risk	Unacceptable	Unacceptable	Adequate	Unacceptable	Unacceptable
	Off-Channel Habitat	Connectivity with Main Channel	Adequate	Adequate	Adequate	At Risk	Adequate	At Risk	At Risk	Adequate	At Risk	Unacceptable
Riparian Vegetation	Condition	Structure	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	Adequate
		Disturbance (Human)	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	At Risk	At Risk	At Risk	Adequate
		Canopy Cover	At Risk	At Risk	At Risk	At Risk	At Risk	Unacceptable	Unacceptable	Unacceptable	At Risk	At Risk
Channel	Dynamics	Floodplain Connectivity	Adequate	Adequate	Adequate	Adequate	At Risk	At Risk	At Risk	Adequate	At Risk	At Risk
		Bank Stability/ Channel Migration	Adequate	Adequate	Adequate	Adequate	At Risk	Adequate	At Risk	Adequate	At Risk	At Risk
		Vertical Channel Stability	Adequate	Adequate	Adequate	Adequate	At Risk	Adequate	At Risk	At Risk	Adequate	At Risk

**Although the LWM maybe be adequate from a habitat/cover perspective, this indicator does not consider the geomorphic function of LWM. An asterisk is indicated in the LWM reach rating where the rating would potentially be lowered if geomorphic function of LWM was taken into account.*

2 Metrics & Indicators

2.1 WATERSHED-SCALE METRICS

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Watershed Scale					
Watershed Condition	Drainage Network and Hydrologically Impaired Surfaces	Increase in Drainage Network/ Hydrologically Impaired Surfaces	Zero or minimal increases in the drainage network that is correlated with human caused disturbances. Hydrologically impaired surfaces in watershed total <8%. Road density <1 mile/miles^2.	Low to moderate increase in the drainage network correlated with human caused disturbances. Hydrologically impaired surfaces in watershed total between 8 and 14.9%. Road density 1-2.4 miles/miles^2.	Substantial increase in the drainage network correlated with human caused disturbances. Hydrologically impaired surfaces in watershed total >15%. Road density ≥2.5 miles/miles^2.
	Disturbance Regime	Natural/Human Caused	Environmental disturbance is short-lived; predictable hydrograph, high-quality habitat and watershed complexity providing refuge and rearing space for all life stages or multiple life-history forms. Natural processes are stable.	Localized events of hillslope contributions, avulsion, lateral migrations, minor bed incision, or wildfires. Resiliency of habitat to recover from environmental disturbances is moderate.	Frequent flood or drought producing highly variable and unpredictable flows, hillslope contributions, avulsion, lateral migrations, minor to major bed incision (head cuts), or wildfires throughout a majority of the watershed. The channel is simplified, providing little hydraulic complexity in the form of pools or side channels. Natural processes are unstable.
Flow/Hydrology	Streamflow	Alterations to Peak/Base Flows	Magnitude, timing, duration, and frequency of peak flows within a watershed are not altered relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.	Some evidence of altered magnitude, timing, duration and/or frequency of peak flows relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.	Pronounced changes in magnitude, timing, duration and/or frequency of peak flows relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.
Water Quality	Temperature	7-day average maximum temperatures	**Bull Trout:** incubation 2 - 5°C rearing 4 - 12°C spawning 4 - 9°C **Other salmonids:** spawning <13°C rearing <15°C holding & migration <15°C And, temperatures do not exceed 15°C in areas used by adults during migration (no thermal barriers)	**Bull Trout:** incubation <2 or 6°C rearing <4 or 13 - 15°C spawning <4 or 10°C **Other salmonids:** spawning 14-15.5°C rearing <14 – 17.5°C holding & migration <14 – 17.5°C And, temperatures in areas used by adults during migration sometimes exceed 15°C	**Bull Trout:** incubation <1 or >6°C rearing >15°C spawning <4 or >10°C **Other salmonids:** spawning >15.5°C rearing >17.5°C holding & migration >17.5°C And, temperatures in areas used by adults during migration regularly exceed 15°C (thermal barriers present)

2.2 REACH-SCALE METRICS

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Reach Scale					
Habitat Access	Physical Barriers	Main Channel Barriers	No man-made barriers present in the mainstem that limit upstream or downstream migration at any flow.	Man-made barriers are present in the mainstem that have the potential to prevent or inhibit upstream or downstream migration at a subset of flows.	Man-made barriers present in the mainstem that prevent upstream or downstream migration at multiple or all flows.
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	Gravels or small cobbles make up >50% of the bed materials where natural channel form and stream power support development of spawning areas, with ≤12% of substrates <5.6 mm in spawning gravel.	Gravels or small cobbles make up 30-50% of the bed materials where natural channel form and stream power support the development of spawning areas, with 12-20% of substrates <5.6 mm in spawning gravel.	Gravels or small cobbles make up <30% of the bed materials where natural channel form and stream power support the development of spawning areas, with >20% of substrates <5.6 mm in spawning gravel.
	LWM	Pieces per Mile at Bankfull	67.5 pieces of medium or large wood (M+L)/mile, based on the 75th percentile values for unmanaged streams in eastside forests from Fox and Bolton (2007). Qualifying pieces are the “Medium” and “Large” size large woody material (LWM) based on USFS (2020) size classifications. USFS Stream Inventory protocol (2020) large woody material criteria, under the Eastside Forests criteria: Medium = diameter > 12 in, length > 35 ft Large = diameter > 20 in, length > 35 ft In addition to a minimum of 67.5 pieces of medium or large wood/mile, an adequate rating also indicates the LWM are well-distributed throughout the reach and there are sources of woody debris available for long-term recruitment within the reach.	Current levels are able to maintain the minimum requirements for an "adequate" rating, but potential sources for long-term woody debris recruitment, as determined by the Riparian Structure reach metrics, are lacking in order to maintain these current levels or wood is not well-distributed throughout the reach.	Current levels are not meeting the minimum requirements for an “adequate” rating, and potential source of woody debris for long-term recruitment are lacking or wood is not well-distributed throughout the reach.

<table>
<tr><th>Pathway</th><th>General Indicators</th><th>Specific Indicators</th><th>Adequate Condition</th><th>At Risk Condition</th><th>Unacceptable Risk Condition</th></tr>
<tr><td rowspan="5">Riparian Vegetation</td><td>Pools</td><td>Pool Frequency and Quality; presence of large pools.</td><td>Pool frequency: Number of pools/mile for a given bankfull width (BFW) equal or exceed NMFS (1996) criteria (below). For channels with bankfull >100 ft, minimum number of pools/mile were extrapolated based on relationship between BFW and pools/mile in NMFS (1996) criteria.
Bankfull width:
<table><tr><td>25-50</td><td>26</td><td>pools/mile</td></tr><tr><td>51-75</td><td>23</td><td>pools/mile</td></tr><tr><td>76-100</td><td>18</td><td>pools/mile</td></tr><tr><td>101-130</td><td>15</td><td>pools/mile</td></tr><tr><td>131-140</td><td>14</td><td>pools/mile</td></tr></table>In addition, at least 50% of the total pools must be large pools with >1 m (3 ft) of residual depth and good fish cover.</td><td>Pool frequency meets or almost meets the values for the "adequate" rating, but pools have inadequate cover/temperature and/or there has been a moderate reduction of pool volume by fine sediment. Reaches have between 20-50% large pools present with good fish cover.</td><td>Pool frequency does not meet the pools/mile metric given in the “adequate” rating. Reaches have <20% large pools (>1 m deep). Pools also have inadequate cover/temperature and/or there has been a major reduction of pool volume by fine sediment.</td></tr>
<tr><td>Off-Channel Habitat and Refugia</td><td>Connectivity with Main Channel</td><td>Reach has side channels and/or groundwater fed tributaries. Aquatic refugia such as backwaters, alcoves, large boulder eddies exist within the reach. Well-vegetated floodplains with healthy riparian community are inundated on a 1-2-year recurrence frequency. No man-made barriers that prevent access to off-channel areas.</td><td>Reach provides some aquatic off-channel and refugia features but access varies or is at risk of disconnection due to human impacts or man-made barriers. Floodplains along the off-channel habitat are well-vegetated with inundation recurrence of 2-5-years.</td><td>Reach provides no or only minimal off-channel refugia. Floodplains are disconnected and riparian vegetation has been altered.</td></tr>
<tr><td rowspan="3">Condition</td><td>Structure</td><td>>80% large trees (>21” DBH; USFS, 2020) in the riparian zone (defined as a 100ft buffer along each bank) based on habitat assessment data, as well as no visual evidence of human impacts on vegetations (e.g. logging or residential/agricultural clearing) in the floodplain.</td><td>50-80% large trees (>21” DBH; USFS, 2020) in the riparian zone (defined as a 100ft buffer along each bank) based on habitat assessment data, as well as a moderate amount of visual evidence of human impacts on vegetation (e.g. logging or residential/agricultural clearing) in the floodplain.</td><td><50% large trees (>21” DBH; USFS, 2020) in the riparian zone (defined as a 100ft buffer along each bank) based on habitat assessment data, as well as moderate-high visual evidence of human impacts on vegetation (e.g. logging or residential/agricultural clearing) in the floodplain.</td></tr>
<tr><td>Disturbance (Human)</td><td><20% disturbance (e.g. agriculture and grazing, residential, roads, etc.) and <2 mile/miles^2 road density in the 200-foot channel buffer.</td><td>20-50% disturbance (e.g. agriculture and grazing, residential, roads, etc.) and 2-3 miles/miles^2 road density in the 200-foot channel buffer zone.</td><td>>50% disturbance (e.g. agriculture and grazing, residential, roads, etc.) and >3 miles/miles^2 road density in the in the 200-foot channel buffer zone.</td></tr>
<tr><td>Canopy Cover</td><td>Canopy cover provides high level of channel shading relative to likely natural condition, based on the number of shaded daylight hours on the summer solstice according to publicly available map tool Shademap (https://shademap.app/). In addition, a high proportion of large trees (height > 100 feet) and little or no anthropogenic clearing or disturbance are present within 100-feet of the channel bank.</td><td>Canopy cover provides moderate level of channel shading, based on the number of shaded daylight hours on the summer solstice. In addition, a moderate proportion of large trees (height > 100 feet) and some anthropogenic clearing or disturbance is present within 100-feet of the channel bank.</td><td>Canopy cover provides low level of channel shading, based on the number of shaded daylight hours on the summer solstice. In addition, a small proportion of large trees (height > 100 feet) and substantial anthropogenic clearing or disturbance are present within 100-feet of the channel bank.</td></tr>
</table>

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Channel	Dynamics	Floodplain Connectivity	Floodplain areas are hydrologically linked to main channel within the context of the local process domain; overbank flows occur and maintain wetland functions, and riparian vegetation. Naturally confined channels are considered adequate.	Reduced linkage of floodplains and riparian areas to main channel in reaches with historically strong connectivity; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of floodplain soil accumulations and riparian vegetation/succession.	Severe reduction in hydrologic connectivity between off-channel, floodplain, and riparian areas relative to historical connectivity; riparian vegetation/ succession is altered significantly.
		Bank Stability/Channel Migration	Channel is migrating at or near natural rates within the geomorphic construct of the reach.	Channel migration is occurring at a faster or slower rate relative to natural rates, but significant change in channel width or planform is not detectable; large woody debris is still being recruited.	Little or no channel migration is occurring because of human actions preventing reworking of the floodplain and large woody debris recruitment; or channel migration is occurring at an accelerated rate such that channel width has at least doubled, possibly resulting in a channel planform change, and sediment supply has noticeably increased from bank erosion.
		Vertical Channel Stability	No measurable trend of aggradation or incision beyond the natural geomorphic processes of the reach.	Measurable trend of aggradation or incision that has the potential to, but has not yet caused, disconnection of the floodplain or a visible change in channel planform (e.g. single thread to braided.)	Enough incision or human infrastructure has occurred that the floodplain and off-channel habitat areas have been disconnected from the main channel; or enough aggradation has occurred to create a visible change in channel planform (e.g. single thread to braided.)

3 REI Ratings

This section discusses the results for each indicator, rated at either the watershed-scale or reach-scale for all reaches.

3.1 WATERSHED-SCALE RATINGS

General Characteristics	General Indicators	Specific Indicators	Rating	Discussion
Watershed Scale				
Watershed Condition	Drainage Network and Hydrologically Impaired Surfaces	Increase in Drainage Network/ Hydrologically Impaired Surfaces	Adequate	Hydrologically impaired surfaces (roads, parking lots, and buildings) in the watershed were calculated using the 2010 Statewide Landuse GIS dataset (Washington Department of Ecology, 2010). Parcels were classified as "hydrologically impaired" or "Not hydrologically impaired" for the watershed based on landuse codes in the dataset. Hydrologically impaired parcel polygon areas were summed and compared to the total watershed area, as determined using the StreamStats online mapper application (U.S. Geological Survey, 2024). The average percentage of hydrologically impaired surfaces for the entire contributing watershed was 1.3%. Road density was calculated using Washington state Department of Natural Resources roads GIS datasets, as well as visual interpretation of lidar and aerial photos (WADNR Active Roads, 2017). Total length of roads in the Icicle Creek watershed was calculated and compared to the total watershed area. The watershed road density is 0.6 miles of road per square mile of watershed. The Icicle River watershed is relatively undeveloped, with most of the impaired surfaces in the valley bottom and in the downstream portion of the study area near the town of Leavenworth (Reach 4 and below). There is some development in the upstream reaches, and often the roads and structures are immediately adjacent to the river. Overall, road density and percentage of impaired surfaces is low, therefore this indicator receives an Adequate condition.
	Disturbance Regime	Natural/Human Caused	At Risk	This disturbance history rating reflects historical accounts of riparian and hillslope timber harvest, fire suppression, beaver trapping, mining, agriculture and roads and residential development. These human-caused disturbances have historical and on-going impacts on the watershed and have altered the natural disturbance cycles. Fire suppression policies altered the natural fire regimes. In 1994, a major forest fire burned 12% of the watershed in the lower subbasin, followed in 1999 by a landslide originating from a slope burned in the fire, which reached Icicle Creek above Snow Creek (Carlson et al., 2004). Agricultural practices expanded by 1912 and much of the lower basin was converted into orchards (The Watershed Company, 2005). Timber harvest became a significant resource in the 1960s. Roads were built to facilitate access for timber harvest, recreation, and development. The removal of old growth conifers for timber harvest in the hillslopes and valley bottom has resulted in a lack of LWM that has significant influence on channel processes and morphology, as well as diminished amount of shade, nutrient contribution, and floodplain moisture retention. Large trees surveyed in the riparian zone within the study area have been observed as 2nd growth. Residential and commercial development expanded in the 20th century, removing over 11% of the vegetative cover along the lower Icicle Creek (Carlson et al., 2004). The Icicle Creek watershed has the highest recreational use of any watershed in the Wenatchee basin, with activities including kayaking, rock climbing, hiking, fishing, and camping (USFS, 1999; Andonaegui, 2001). Water from Icicle Creek is used by the City of Leavenworth, rural Chelan County residents, the Cascade Orchards Irrigation Company (COIC), Icicle Peshastin Irrigation District (IPID), and the Leavenworth National Fish Hatchery (LNFH) (Forsgren Associates, 2014; WDOE, 2019; USFWS, 2022; USFWS, 2009). In consideration of these factors, the watershed receives an At Risk rating for disturbance.
Flow/Hydrology	Streamflow	Alterations to Peak/Base Flows	At Risk	The hydrology of the Icicle Creek watershed is driven by snowmelt and precipitation. Peak flows occur in the spring from snowmelt runoff, often with a secondary peak in the late fall from precipitation. Gage data is available from the USGS Icicle Creek Above Snow Creek Near Leavenworth gage (#12458000) located at RM 11.2, upstream of major diversions. The period of record is from 1936-present. In a comparison between decades 1993 – 2003, 2004 – 2013 and 2014 – 2023, more recent data shows earlier timing in peak flow events occurring in April to June, and higher discharge events in the fall. This aligns with predictions from regional climate change models, which estimated an increased proportion of the precipitation would fall as rain rather than snow throughout the water year, and that the timing and magnitude of peak flow will change. In addition to the observed change in fall discharge patterns and timing of peak flow which are related to global/regional effects for climate change, hydrologic alterations at the watershed-scale are also present. Several diversion dams are present, largely in the lower reaches of Icicle Creek, to support water use by the City of Leavenworth, rural Chelan County residents, the Cascade Orchards Irrigation Company (COIC), Icicle Peshastin Irrigation District (IPID), and the Leavenworth National Fish Hatchery (LNFH). Therefore, the watershed receives an At Risk Rating.
Water Quality	Temperature	Daily maximum and 7-day mean daily maximum temperatures	Unacceptable	Recent water temperature data exists from a Washington Dept of Ecology gage (Gage #45B070, data from 2011-2024). Temperature data was evaluated for the period 2011-2024. Over the course of the 13-year period, the 7-DADMax exceeded 15°C 12 out of the 13 years. Between 2011-2024, the 7-DADMax was exceeded roughly every year. Water temperatures over 15 °C most regularly occurred in August. The duration of water temperatures over 15 °C lasted for an average of 51 days. For these reasons, this indicator receives an Unacceptable rating.

3.2 REACH-SCALE RATINGS – REACH 1 - REACH 10

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
Habitat Access	Physical Barriers	Main Channel Barriers	Adequate There were no anthropogenic barriers in the main channel.	Adequate There were no anthropogenic barriers in the main channel.	At Risk Two anthropogenic barriers are present in the mainstem. A dam located at Rm 2.95 has potential to inhibit upstream and downstream migration at extreme low flow events. The hatchery channel Dam 2 at RM 4.8 known to prevent fish passage seasonally, when managed by LNFH.	At Risk One anthropogenic barrier is present in the mainstem. The diversion located at the upstream end of the reach, RM 5.05, has been modified to improve fish passage but may still act as a barrier during a subset of flows.	At Risk One anthropogenic barrier is present in the mainstem. A diversion structure located at Rm 6.27 may inhibit fish migration at a subset of flows.	Adequate There were no anthropogenic barriers in the main channel. Fish passage through the boulder field within the reach has been studied by Dominguez et al., 2013 and may limit upstream passage at a subset of flows. Modifications to the boulder field have been made to improve passage.	Adequate There were no anthropogenic barriers in the main channel.	Adequate There were no anthropogenic barriers in the main channel.	Adequate There were no anthropogenic barriers in the main channel.	Adequate There were no anthropogenic barriers in the main channel.
Habitat Quality	Substrate	Dominant Substrate/ Fine Sediment	Adequate Dominant substrate: Gravel (4-64mm) At pebble count GC 26, 59% of substrate was gravel. At pebble count GC 25, 83% of the sampled substrate was gravel. The combined average between the two counts showed 5% of substrates are <5.6 mm.	Adequate Dominant substrate: Gravel (4-64mm) At pebble count GC 24, 95% of substrate was gravel. At pebble count GC 23, 83% of the sampled substrate was gravel. The combined average between the two counts showed 1% of substrates are <5.6 mm.	Adequate Dominant substrate: Gravel (4-64mm) At pebble count GC 22, 87% of substrate was gravel. The count showed 1% of substrates are <5.6 mm.	Adequate Dominant substrate: Cobble (64.1-256mm) and Boulder At pebble count GC 21, 15% of substrate was gravel. At pebble count GC 20, 10% of the sampled substrate was gravel. The combined average between the two gravel counts showed 4% of substrates are <5.6 mm.	Adequate Dominant substrate: Boulder (>256.1mm) and cobble (64.1-256mm) No gravel counts were performed in this Reach.	Adequate Dominant substrate: Boulder (>256.1mm) No gravel counts were performed in this Reach.	Adequate Dominant substrate: Boulder (>256.1mm) and cobble (64.1-256mm) No gravel counts were performed in this Reach.	Adequate Dominant substrate: Boulder (>256.1mm) and cobble (64.1-256mm) At pebble count GC 19, 21% of substrate was gravel. At pebble count GC 18, 18% of the sampled substrate was gravel. The combined average between the two counts showed 3% of substrates are <5.6 mm. Substrates are appropriate to geomorphic context of the reach.	At Risk Dominant substrate: Boulder (>256.1mm) and cobble (64.1-256mm) At pebble count GC 17, 21% of substrate was gravel. The count showed 15% of substrates are <5.6 mm.	Adequate Dominant substrate: Boulder (>256.1mm) and cobble (64.1-256mm) At pebble count GC 16, 39% of substrate was gravel. At pebble count GC 15, 7% of the sampled substrate was gravel. The combined average between the two counts showed 4% of substrates are <5.6 mm. Substrates are appropriate to geomorphic context of the reach.

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
Habitat Quality	LWM	Pieces per Mile at Bankfull	Unacceptable	Unacceptable	Unacceptable	Adequate*	Adequate*	Unacceptable	Adequate*	Adequate*	Adequate*	Adequate*
			M+L pieces/mi = 39 Percent in Jams = 22% Does not meet the minimum criteria of 67.5 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams, and there are extremely limited potential sources of woody debris for long-term recruitment due to anthropogenic land-use modifications.	M+L pieces/mi = 34 Percent in Jams = 11% Does not meet the minimum criteria of 67.5 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams, but there are extremely limited potential sources of woody debris for long-term recruitment due to anthropogenic land-use modifications.	M+L pieces/mi = 10 Percent in Jams = 3% Does not meet the minimum criteria of 67.5 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams and there are limited potential sources of woody debris for long- and recruitment due to anthropogenic land-use modifications.	M+L pieces/mi = 87 Percent in Jams = 24% Meets the minimum criteria of 67.5 pieces of M+L wood per mile Less than 50% of M+L wood is within jams and there are limited potential sources of woody debris for long-term recruitment within the reach.	M+L pieces/mi = 107 Percent in Jams = 31% Meets the minimum criteria of 67.5 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams and there are limited potential sources of woody debris for long- term recruitment within the reach.	M+L pieces/mi = 55 Percent in Jams = 10% Does not meet the minimum criteria of 67.5 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams and there are limited potential sources of woody debris for long-term recruitment within the reach.	M+L pieces/mi = 155 Percent in Jams = 23% Meets the minimum criteria of 67.5 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams, though there are some potential sources of woody debris available for long- term recruitment within the reach.	M+L pieces/mi = 237 Percent in Jams = 49% Meets the minimum criteria of 67.5 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams and there are some potential sources of woody debris available for long-term recruitment within the reach.	M+L pieces/mi = 200 Percent in Jams = 40% Meets the minimum criteria of 67.5 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams and there are some potential sources of woody debris available for long-term recruitment within the reach.	M+L pieces/mi = 108 Percent in Jams = 43% Meets the minimum criteria of 67.5 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams, though there are some potential sources of woody debris available for long-term recruitment within the reach.

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
Habitat Quality	Pools	Pool Frequency and Quality; Presence of large pools.	Adequate	Adequate	Adequate	Unacceptable	At Risk	At Risk	At Risk	Unacceptable	At Risk	At Risk
			Total Pools = 5 Pools/mi = 4 Pools ≥ 3 ft = 3 (60%) Pools ≥ 6 ft = 1 (20%) Avg residual pool depth: 6.5 ft Cover: Low Reach is affected by backwatering from Wenatchee River and is dominated by pools. Though pool frequency criteria are not met for bankfull width (average BFW = 125, requires 15 pools/mile), the pools are large and deep. Overhanging cover and LWM is relatively minimal.	Total Pools = 14 Pools/mi = 8 Pools ≥ 3 ft = 12 (86%) Pools ≥ 6 ft = 5 (36%) Avg residual pool depth: 6.0 ft Cover: Low Though pool frequency criteria are not met for bankfull width (average BFW = 115, requires 15 pools/mile), reach is almost entirely pool habitat. Pools are large and deep. Overhanging cover is low, though there is LWM present.	Total Pools = 15 Pools/mi = 12 Pools ≥ 3 ft = 7 (47%) Pools ≥ 6 ft = 1 (7%) Avg residual pool depth: 3.0 ft Cover: Low Though pool frequency criteria are not met for bankfull width (average BFW = 57, requires 23 pools/mile), reach is almost entirely pool habitat. Pool residual depths are highly variable with low amount of vegetative cover and LWM.	Total Pools = 5 Pools/mi = 7 Pools ≥ 3 ft = 5 (100%) Pools ≥ 6 ft= 0 (0%) Avg residual pool depth: 4.5 ft Cover: Low Does not meet the pool frequency criteria for bankfull width (average BFW = 100, requires 18 pools/mile). Limited availability of vegetative cover and LWM.	Total Pools = 9 Pools/mi = 7 Pools ≥ 3 ft = 7 (78%) Pools ≥ 6 ft= 2 (22%) Avg residual pool depth: 4.2 ft Cover: Low - Moderate Does not meet the pool frequency criteria for bankfull width (average BFW = 90, requires 18 pools/mile), however, natural conditions (steep slope and bedrock confinement) limit formation of pools that met survey criteria. Additional smaller pool habitat is likely present, and pools that were recorded were relatively deep and LWM and cover moderately available.	Total Pools = 9 Pools/mi = 10 Pools ≥ 3 ft = 8 (89%) Pools ≥ 6 ft = 2 (22%) Avg residual pool depth: 5.5 ft Cover: Low Does not meet the pool frequency criteria for bankfull width (average BFW = 80, requires 18 pools/mile), however, natural conditions (steep slope and bedrock confinement) limit formation of pools that met survey criteria. Additional smaller pool habitat is likely present, and pools that were recorded were relatively deep. Vegetative cover is moderate, but very little LWM is present.	Total Pools = 12 Pools/mi = 8 Pools ≥ 3 ft = 10 (83%) Pools ≥ 6 ft = 0 (0%) Avg residual pool depth: 4.1 ft Cover: Moderate Does not meet the pool frequency criteria for bankfull width (average BFW = 102, requires 15 pools/mile). LWM and cover moderately available where pools are present.	Total Pools = 4 Pools/mi = 4 Pools ≥ 3 ft = 4 (100%) Pools ≥ 6 ft = 0 (0%) Avg residual pool depth: 4.9 ft Cover: Moderate Does not meet the pool frequency criteria for bankfull width (average BFW = 118, requires 15 pools/mile), though pools are deep. Vegetative cover and LWM are relatively available.	Total Pools = 4 Pools/mi = 7 Pools ≥ 3 ft = 3 (75%) Pools ≥ 6 ft = 0 (0%) Avg residual pool depth: 3.9 ft Cover: Moderate Does not meet the pool frequency criteria for bankfull width (average BFW = 97, requires 18 pools/mile), however, natural conditions (steep slope and bedrock confinement) limit formation of pools that met survey criteria. Additional smaller pool habitat is likely present, and pools that were recorded were relatively deep. Vegetative cover and LWM are moderately available.	Total Pools = 3 Pools/mi = 3 Pools ≥ 3 ft = 2 (67%) Pools ≥ 6 ft= 0 (0%) Avg residual pool depth: 3.6 ft Cover: Moderate - High Does not meet the pool frequency criteria for bankfull width (average BFW = 99, requires 18 pools/mile), however, natural conditions (steep slope and bedrock confinement) limit formation of pools that met survey criteria. Additional smaller pool habitat is likely present. LWM and cover are relatively available.

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
Habitat Quality	Off-Channel Habitat and Refugia	Connectivity with Main Channel	At Risk	Unacceptable	At Risk	At Risk	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
			Total SC = 1 Fast water = 0 Slow water = 1 Very little off-channel habitat exists that is connected at a variety of flows; however, floodplains are hydraulically connected at a greater range of flows than other reaches. Some confinement still occurs from human impacts.	Total SC = 1 Fast water = 1 Slow water = 0 Very little off-channel habitat exists. Floodplains have been disconnected by incision and human structures, as determined by field observations and hydraulic modeling.	Total SC = 8 Fast water = 0 Slow water = 8 The reach has side-channel habitats that are connected at a range of flows. However, a large portion of the historical floodplain is anthropogenically disconnected or has other impacts (levees, roads, fill, canal).	Total SC = 3 Fast water = 1 Slow water = 2 Some off-channel habitat exists that is connected at a range of flows. Available floodplains are marginally hydraulically connected to the channel.	Total SC = 8 Fast water = 8 Slow water = 0 A moderate amount of off-channel habitat exists within the reach, and floodplains are hydraulically well connected to the channel.	Total SC = 0 Minimal off channel habitat exists; however, natural conditions (steep slope and bedrock confinement) limit the natural potential for off-channel habitat to be present.	Total SC = 8 Fast water = 7 Slow water = 1 A moderate amount of off-channel habitat exists within the reach, and floodplains are hydraulically well connected to the channel.	Total SC = 8 Fast water = 6 Slow water = 2 A moderate amount of off-channel habitat exists within the reach, and floodplains are hydraulically well connected to the channel.	Total SC = 3 Fast water = 3 Slow water = 0 Minimal off channel habitat exists; however, natural conditions (steep slope and bedrock confinement) limit the natural potential for off-channel habitat to be present. Where geomorphically available, floodplains are hydraulically well-connected to the channel	Total SC = 3 Fast water = 2 Slow water = 1 Minimal off channel habitat exists; however, natural conditions (steep slope and bedrock confinement) limit the natural potential for off-channel habitat to be present.

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
Riparian Vegetation	Condition	Structure	At Risk	At Risk	At Risk	At Risk	At Risk	Unacceptable	Unacceptable	At Risk	At Risk	At Risk
			The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 57% Large Tree, 29% Mature Tree and 14% Small Tree. Reach has visual evidence of human disturbance that has reduced the width of the riparian buffer and impacted stand age and structural complexity in many areas of this reach as determined by field estimates, tree height data, or aerial photographs.	The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 73% Large Tree, 9% No Vegetation and 18% Other. Other is this reach was non-native vegetation in residential areas. Reach has some visual evidence of human disturbance that has reduced the width of the riparian buffer and impacted stand age and structural complexity in many areas of this reach as determined by field estimates, tree height data, or aerial photographs.	The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 86% Large Tree and 14% Small Tree. Reach has some visual evidence of human disturbance that has reduced the width of the riparian buffer and impacted stand age and structural complexity in many areas of this reach as determined by field estimates, tree height data, or aerial photographs.	The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 100% Large Tree. Reach has some visual evidence of human disturbance that has reduced the width of the riparian buffer and impacted stand age and structural complexity in many areas of this reach, as determined by field estimates, tree height data, or aerial photographs.	The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 100% Large Tree. Reach has visual evidence of human disturbance that has reduced the width of the riparian buffer and impacted stand age and structural complexity in many areas of this reach, as determined by field estimates, tree height data, or aerial photographs.	The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 80% Small Tree and 20% Shrub/ Seedling. Reach has some visual evidence of human disturbance that has reduced the width of the riparian buffer and impacted stand age and structural complexity in many areas of this reach, as determined by field estimates, tree height data, or aerial photographs.	The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 28% Small Tree, 18% Large Tree, 18% Mature Tree, 18% Sapling/Pole and 18% Shrub/ Seedling. Reach has some visual evidence of human disturbance that has reduced the width of the riparian buffer and impacted stand age and structural complexity in many areas of this reach as determined by field estimates, tree height data, or aerial photographs.	The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 100% Large Tree. Reach has some human disturbance that has reduced the width of the riparian buffer and impacted stand age and structural complexity in many areas of this reach, as determined by field estimates, tree height data, or aerial photographs.	The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 100% Large Tree. Reach has some visual evidence of human disturbance that has reduced the width of the riparian buffer and impacted stand age and structural complexity in many areas of this reach, as determined by field estimates, tree height data, or aerial photographs.	The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 62% Large Tree, 25% Small Tree and 13% Other. Other category recorded dead, burned trees as the overstory. Reach has some visual evidence of human disturbance that has reduced the width of the riparian buffer and impacted stand age and structural complexity in many areas of this reach, as determined by field estimates, tree height data, or aerial photographs.
		Disturbance (Human)	At Risk	Unacceptable	Unacceptable	At Risk	Unacceptable	Unacceptable	Unacceptable	Unacceptable	At Risk	Unacceptable
			4.1% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 4.6 miles/miles^2 road density in the 200-foot riparian buffer zone.	20.5% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 8.1 miles/miles^2 road density in the 200-foot riparian buffer zone.	21.1% disturbance in the 200-foot buffer zone (e.g. LNFH, residential, roads, etc.) and 10.6 miles/miles^2 road density in the 200-foot riparian buffer zone.	11.1% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 4.8 miles/miles^2 road density in the 200-foot riparian buffer zone.	16.1% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 22.5 miles/miles^2 road density in the 200-foot riparian buffer zone.	9.0% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 13.4 miles/miles^2 road density in the 200-foot riparian buffer zone.	9.6% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 15.6 miles/miles^2 road density in the 200-foot riparian buffer zone.	4.4% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 8.2 miles/miles^2 road density in the 200-foot riparian buffer zone.	2.2% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 4.2 miles/miles^2 road density in the 200-foot riparian buffer zone.	7.3% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 13.8 miles/miles^2 road density in the 200-foot riparian buffer zone.

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
Riparian Vegetation	Condition	Canopy Cover	Unacceptable	At Risk	At Risk	At Risk	At Risk	Unacceptable	At Risk	Adequate	Adequate	Adequate
			Reach average of 2.9 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Large trees within the 100-foot riparian buffer are present, but disturbance or clearing within the 100-foot buffer were observed likely reducing shading potential in reach.	Reach average of 3.2 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Large trees within the 100-foot riparian buffer are present, but disturbance or clearing within the 100-foot buffer were observed likely reducing shading potential in reach.	Reach average of 3.7 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Large trees within the 100-foot riparian buffer are present, but disturbance or clearing within the 100-foot buffer were observed likely reducing shading potential in reach.	Reach average of 3.1 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Large trees within the 100-foot riparian buffer are present, but disturbance or clearing within the 100-foot buffer were observed likely reducing shading potential in reach.	Reach average of 3.2 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Large trees within the 100-foot riparian buffer are present, but disturbance or clearing within the 100-foot buffer were observed likely reducing shading potential in reach.	Reach average of 2.7 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Few large trees are present within the 100-foot riparian buffer. Some disturbance or clearing within the 100-foot buffer has likely further reduced shading potential in reach.	Reach average of 3.7 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Few large trees are present within the 100-foot riparian buffer. Some disturbance or clearing within the 100-foot buffer has likely further reduced shading potential in reach.	Reach average of 5.2 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Large trees within the 100-foot riparian buffer are present and limited disturbance or clearing is evident within the riparian buffer.	Reach average of 5.9 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Large trees within the 100-foot riparian buffer are present and limited disturbance or clearing is evident within the riparian buffer.	Reach average of 5.8 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Large trees within the 100-foot riparian buffer are present, though some disturbance or clearing is evident within the riparian buffer.

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10
Channel	Dynamics	Floodplain Connectivity	Adequate	At Risk	Unacceptable	At Risk	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
			Connectivity to the existing modern floodplain is currently adequate.	Road crossing bridge at mid-reach imposes confinement and associated floodplain disconnection that will continue.	Constructed levees, canal, terraces, and flow control structures limit connectivity to historical floodplain.	Infrastructure and development, including structure confinement at the downstream end, impose continued confinement and reduces potential floodplain connectivity.	Naturally confined reach. Where valley width allows, narrow functional floodplains and islands exist, and connectivity is maintained.	Naturally confined reach. Where valley width allows, narrow functional floodplains and islands exist, and connectivity is maintained.	Naturally confined reach. Where valley width allows, functional floodplains and islands exist, connectivity is maintained.	Naturally partially confined reach. Where valley width allows, functional floodplains and islands exist, connectivity is maintained.	Naturally confined reach. Where valley width allows, functional floodplains and islands exist, connectivity is maintained.	Naturally confined reach. Where valley width allows, functional floodplains and islands exist, connectivity is maintained.
		Bank Stability/ Channel Migration	At Risk	At Risk	Unacceptable	At Risk	At Risk	Adequate	Adequate	Adequate	Adequate	Adequate
			Channel has reduced rate of lateral migration in portions of the reach as a result of anthropogenic confinement (bank armoring).	Channel has reduced rate of lateral migration as a result of anthropogenic confinement and development.	Anthropogenic influences have notably decreased lateral processes.	Channel has reduced rate of lateral migration as a result of anthropogenic confinement and infrastructure.	Channel has reduced rate of lateral migration as a result of anthropogenic confinement and infrastructure.	Channel is laterally migrating at or near natural rates within the geomorphic construct of the reach.	Channel is laterally migrating at or near natural rates within the geomorphic construct of the reach.	Channel is laterally migrating at or near natural rates within the geomorphic construct of the reach.	Channel is laterally migrating at or near natural rates within the geomorphic construct of the reach.	Channel is laterally migrating at or near natural rates within the geomorphic construct of the reach.
		Vertical Channel Stability	Adequate	At Risk	At Risk	At Risk	Adequate	Adequate	Adequate	At Risk	Adequate	Adequate
			No measurable trend of aggradation or incision beyond the natural geomorphic processes of the reach.	Trends of continued incision associated with anthropogenic confinement and development.	Altered hydrology reduces flow hydraulics and channel dynamics.	Trends of continued incision associated with anthropogenic confinement and development.	No measurable trend in incision or aggradation beyond natural geomorphic processes was observed in the reach.	No measurable trend in incision or aggradation beyond natural geomorphic processes was observed in the reach.	No measurable trend in incision or aggradation beyond natural geomorphic processes was observed in the reach.	Localized trend of incision and channel widening at upstream end of the reach.	No measurable trend in incision or aggradation beyond natural geomorphic processes was observed in the reach.	No measurable trend in incision or aggradation beyond natural geomorphic processes was observed in the reach.

Although LWM may be adequate from a habitat/cover perspective, this does not consider the geomorphic function of the LWM, which may be lacking.

3.3 REACH-SCALE RATINGS – REACH 11 – REACH 20

Pathway	General Indicators	Specific Indicators	Reach 11	Reach 12	Reach 13	Reach 14	Reach 15	Reach 16	Reach 17	Reach 18	Reach 19	Reach 20
Habitat Access	Physical Barriers	Main Channel Barriers	Adequate There were no anthropogenic barriers in the main channel.	Adequate There were no anthropogenic barriers in the main channel.	Adequate There were no anthropogenic barriers in the main channel.	Adequate There were no anthropogenic barriers in the main channel.	Adequate There were no anthropogenic barriers in the main channel.	Adequate There were no anthropogenic barriers in the main channel.	Adequate There were no anthropogenic barriers in the main channel.	Adequate There were no anthropogenic barriers in the main channel.	Adequate There were no anthropogenic barriers in the main channel.	Adequate There were no anthropogenic barriers in the main channel.
Habitat Quality	Substrate	Dominant Substrate/ Fine Sediment	Adequate Dominant substrate: Boulder (>256.1mm) No gravel counts were performed in this reach.	Adequate Dominant substrate: Boulder (>256.1mm) At pebble count GC 14, 9% of substrate was gravel and 27% was cobble. 8% of substrates are <5.6 mm	Adequate Dominant substrate: Boulder (>256.1mm) and cobble (64.1-256mm) No gravel counts were performed in this Reach.	Adequate Dominant substrate: Boulder (>256.1mm) and cobble (64.1-256mm) At pebble count GC 13, 38% of substrate was gravel and 30% was cobble. At pebble count GC 12, 18% of the sampled substrate was gravel and 27% was cobble. The combined average between the two counts showed 4% of substrates are <5.6 mm.	At Risk Dominant substrate: Cobble (64.1-256mm) and Gravel (4-64mm) At pebble count GC 11, 55% of substrate was gravel and 40% was cobble. At pebble count GC 10, 20% of the sampled substrate was gravel and 45% was cobble. The combined average between the two counts showed 5% of substrates are <5.6 mm.	At Risk Dominant substrate: Cobble (64.1-256mm) At pebble count GC 9, 21% of substrate was gravel. At pebble count GC 8, 18% of the sampled substrate was gravel. The combined average between the two counts showed 6% of substrates are <5.6 mm.	At Risk Dominant substrate: Boulder (>256.1mm) and cobble (64.1-256mm) At pebble count GC 7, 35% of substrate was gravel and 52% was cobble. At pebble count GC 6, 27% of the sampled substrate was gravel and 27% was cobble. The combined average between the two counts showed 2% of substrates are <5.6 mm.	Adequate Dominant substrate: Cobble (64.1-256mm) No gravel counts were performed in this reach.	Adequate Dominant substrate: Gravel (4-64mm) At pebble count GC 5, 54% of substrate was gravel. At pebble count GC 4, 56% of the sampled substrate was gravel. At pebble count GC 3, 51% of the sampled substrate was gravel. The combined average between the three counts showed 7% of substrates are <5.6 mm.	At Risk Dominant substrate: Cobble (64.1-256mm) At pebble count GC 2, 38% of substrate was gravel. At pebble count GC 1, 35% of the sampled substrate was gravel. The combined average between the two counts showed 4% of substrates are <5.6 mm.

Pathway	General Indicators	Specific Indicators	Reach 11	Reach 12	Reach 13	Reach 14	Reach 15	Reach 16	Reach 17	Reach 18	Reach 19	Reach 20
Habitat Quality	LWM	Pieces per Mile at Bankfull	Unacceptable	Unacceptable	Unacceptable	Adequate*	Adequate*	Adequate*	Adequate*	Unacceptable	Adequate*	Adequate*
			M+L pieces/mi = 52 Percent in Jams = 25% Does not meet the minimum criteria of 67.5 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams and there are some potential sources of woody debris for long- and recruitment.	M+L pieces/mi = 60 Percent in Jams = 32% Does not meet the minimum criteria of 67.5 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams and there are some potential sources of woody debris for long- term recruitment within the reach.	M+L pieces/mi = 50 Percent in Jams = 18% Does not meet the minimum criteria of 67.45 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams, and there are limited potential sources woody debris for long-term recruitment.	M+L pieces/mi = 106 Percent in Jams = 32% Does not meet the minimum criteria of 67.5 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams, and there are some potential sources of woody debris for long-term recruitment within the reach.	M+L pieces/mi = 122 Percent in Jams = 32% Meets the minimum criteria of 67.5 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams, and there are potential sources of woody debris for long-term recruitment within the reach.	M+L pieces/mi = 180 Percent in Jams = 45% Meets the minimum criteria of 67.5 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams and there are potential sources of woody debris for long-term recruitment within the reach.	M+L pieces/mi = 103 Percent in Jams = 32% Meets the minimum criteria of 67.5 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams and there are potential sources of woody debris for long- term recruitment within the reach.	M+L pieces/mi = 58 Percent in Jams = 18% Does not meet the minimum criteria of 67.5 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams and there are some potential sources of woody debris for long- term recruitment within the reach.	M+L pieces/mi = 121 Percent in Jams = 40% Meets the minimum criteria of 67.5 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams and there are potential sources of woody debris for long- term recruitment within the reach.	M+L pieces/mi = 94 Percent in Jams = 20% Meets the minimum criteria of 67.5 pieces of M+L wood per mile. Less than 50% of M+L wood is within jams and there are potential sources of woody debris for long- term recruitment within the reach.

Pathway	General Indicators	Specific Indicators	Reach 11	Reach 12	Reach 13	Reach 14	Reach 15	Reach 16	Reach 17	Reach 18	Reach 19	Reach 20
Habitat Quality	Pools	Pool Frequency and Quality; Presence of large pools.	At Risk Total Pools = 8 Pools/mi = 14 Pools ≥ 3 ft = 6 (75%) Pools ≥ 6 ft = 1 (13%) Avg residual pool depth: 4.0 ft Cover: Low Does not meet the pool frequency criteria for bankfull width (average BFW = 76, requires 18 pools/mile), however, natural conditions (steep slope and bedrock confinement) limit formation of pools that met survey criteria. Additional smaller pool habitat is likely present. Vegetative cover for the pools is relatively low.	At Risk Total Pools = 4 Pools/mi = 7 Pools ≥ 3 ft = 2 (50%) Pools ≥ 6 ft = 1 (25%) Avg residual pool depth: 4.7 ft Cover: Low - Moderate Does not meet the pool frequency criteria for bankfull width (average BFW = 92, requires 18 pools/mile), however, natural conditions (steep slope and bedrock confinement) limit formation of pools that met survey criteria. Additional smaller pool habitat is likely present, and pools that were recorded were relatively deep. Vegetative cover is moderately available, but LWM is limited.	At Risk Total Pools = 3 Pools/mi = 9 Pools ≥ 3 ft = 2 (67%) Pools ≥ 6 ft = 0 (0%) Avg residual pool depth: 4.1 ft Cover: Low Does not meet the pool frequency criteria for bankfull width (average BFW = 86, requires 18 pools/mile), however, natural conditions (steep slope and bedrock confinement) limit formation of pools that met survey criteria. Additional smaller pool habitat is likely present, and pools that were recorded were relatively deep. Availability of cover in the reach is low.	At Risk Total Pools = 9 Pools/mi = 5 Pools ≥ 3 ft = 4 (44%) Pools ≥ 6 ft = 0 (0%) Avg residual pool depth: 2.9 ft Cover: Low - Moderate Does not meet the pool frequency criteria for bankfull width (average BFW = 85, requires 18 pools/mile), however, natural conditions (steep slope and bedrock confinement) limit formation of pools that met survey criteria. Additional smaller pool habitat is likely present. Pools residual depths are relatively low and availability of cover in the reach is low.	At Risk Total Pools = 12 Pools/mi = 6 Pools ≥ 3 ft = 7 (58%) Pools ≥ 6 ft = 0 (0%) Avg residual pool depth: 3.5 ft Cover: Moderate Does not meet the pool frequency criteria for bankfull width (average BFW = 105, requires 15 pools/mile). Cover from riparian vegetation and LWM is relatively available.	Unacceptable Total Pools = 6 Pools/mi = 10 Pools ≥ 3 ft = 1 (17%) Pools ≥ 6 ft = 0 (0%) Avg residual pool depth: 2.4 ft Cover: Low - Moderate Does not meet the pool frequency criteria for bankfull width (average BFW = 98, requires 18 pools/mile). Pool residual depths are relatively low. Vegetative cover is moderately available, but LWM is limited.	Unacceptable Total Pools = 6 Pools/mi = 4 Pools ≥ 3 ft = 4 (67%) Pools ≥ 6 ft = 2 (33%) Avg residual pool depth: 7.0 ft Cover: Moderate - High Does not meet the pool frequency criteria for bankfull width (average BFW = 78, requires 18 pools/mile). LWM and cover relatively available.	Adequate Total Pools = 10 Pools/mi = 23 Pools ≥ 3 ft = 9 (90%) Pools ≥ 6 ft = 2 (20%) Avg residual pool depth: 5.7 ft Cover: Low Meets the pool frequency criteria for bankfull width (average BFW = 79, requires 18 pools/mile). Pools within the reach are large, however LWM and cover are relatively low.	Unacceptable Total Pools = 18 Pools/mi = 9 Pools ≥ 3 ft = 14 (78%) Pools ≥ 6 ft = 3 (17%) Avg residual pool depth: 5.3 ft Cover: Moderate – High Does not meet the pool frequency criteria for bankfull width (average BFW = 82, requires 18 pools/mile), though pools are deep. Availability of cover in the pool is moderate to high.	Unacceptable Total Pools = 3 Pools/mi = 3 Pools ≥ 3 ft = 0 (0%) Pools ≥ 0 ft= 0 (0%) Avg residual pool depth: 2.0 ft Cover: Moderate Does not meet the pool frequency criteria for bankfull width (average BFW = 86, requires 18 pools/mile). Pools residual depths are relatively low, though LWM and cover are moderately available.

Pathway	General Indicators	Specific Indicators	Reach 11	Reach 12	Reach 13	Reach 14	Reach 15	Reach 16	Reach 17	Reach 18	Reach 19	Reach 20
Habitat Quality	Off-Channel Habitat and Refugia	Connectivity with Main Channel	Adequate	Adequate	Adequate	At Risk	Adequate	At Risk	At Risk	Adequate	At Risk	Unacceptable
			Total SC = 0 Natural conditions (steep slope and bedrock confinement) limit the potential for off-channel habitat forming. Minimal constriction from human impacts are present in the reach.	Total SC = 1 Fast water = 1 Slow water = 0 Natural conditions (steep slope and bedrock confinement) limit the potential for off-channel habitat forming. Minimal constriction from human impacts are present in the reach.	Total SC = 0 Natural conditions (steep slope and bedrock confinement) limit the potential for off-channel habitat forming. Minimal constriction from human impacts are present in the reach.	Total SC = 3 Fast water = 3 Slow water = 0 Natural conditions (steep slope and bedrock confinement) limit the potential for off-channel habitat forming. Where available, floodplains are hydraulically connected at a slightly greater range of flows but constricted by high incision rates and human impacts (Highway 2).	Total SC = 6 Fast water = 1 Slow water = 5 A moderate amount of off-channel habitat exists that is connected at a variety of flows. Available floodplains are somewhat connected to the channel. Entrenched sections have the potential to reduce connectivity of other sections.	Total SC = 1 Fast water = 0 Slow water = 1 Very little off-channel habitat exists that is connected at a variety of flows. Floodplains are hydraulically connected at a greater range of flows than other reaches, though some confinement still occurs from human impacts. Downstream entrenchment has potential to continue to impact floodplain connectivity.	Total SC = 3 Fast water = 2 Slow water = 1 Very little off-channel habitat exists. Where available in this naturally partially confined reach, floodplains are hydraulically connected at a greater range of flows than other reaches.	Total SC = 2 Fast water = 1 Slow water = 1 Minimal off channel habitat exists; however, natural conditions (steep slope and bedrock confinement) limit the potential for off-channel habitat forming. Minimal constriction from human impacts are present in the reach.	Total SC = 4 Fast water = 0 Slow water = 4 Some off-channel habitat exists that is connected at a variety of flows, natural confinement that limits the potential for off-channel habitats. Available floodplains are hydraulically well connected to the channel.	Total SC = 0 Reach is lacking off-channel habitats that are connected at a high range of flows. Where valley width allows, floodplains and islands exist.

Pathway	General Indicators	Specific Indicators	Reach 11	Reach 12	Reach 13	Reach 14	Reach 15	Reach 16	Reach 17	Reach 18	Reach 19	Reach 20
Riparian Vegetation	Condition	Structure	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	Adequate
			The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 100% large tree. Reach has some visual evidence of human disturbance that has reduced the width of the riparian buffer and impacted stand age and structural complexity in many areas of this reach as determined by field estimates, tree height data, or aerial photographs.	The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 50% large tree and 50% small trees. Reach has some visual evidence of human disturbance that has reduced the width of the riparian buffer and impacted stand age and structural complexity in many areas of this reach as determined by field estimates, tree height data, or aerial photographs.	The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 100% large tree. Reach has some visual evidence of human disturbance that has reduced the width of the riparian buffer and impacted stand age and structural complexity in many areas of this reach as determined by field estimates, tree height data, or aerial photographs.	The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 56% large tree and 44% small tree. Reach has some visual evidence of human disturbance that has reduced the width of the riparian buffer and impacted stand age and structural complexity in many areas of this reach, as determined by field estimates, tree height data, or aerial photographs.	The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 73% large tree, 14% small tree, and 13% sapling pole. Reach has visual evidence of human disturbance that has reduced the width of the riparian buffer and impacted stand age and structural complexity in many areas of this reach, as determined by field estimates, tree height data, or aerial photographs.	The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 83% large tree and 17% small tree. Reach has some visual evidence of human disturbance that has reduced the width of the riparian buffer and impacted stand age and structural complexity in many areas of this reach, as determined by field estimates, tree height data, or aerial photographs.	The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 100% large tree. Reach has some visual evidence of human disturbance that has reduced the width of the riparian buffer and impacted stand age and structural complexity in many areas of this reach as determined by field estimates, tree height data, or aerial photographs.	The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 69% large tree, 15% small tree, 8% sapling pole and 8% no vegetation. Reach has visual evidence of human disturbance that that impacted the riparian buffer as determined by field estimates, tree height data, or aerial photographs.	The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 93% large tree and 7% mature tree. Reach has some visual evidence of human disturbance that has reduced the width of the riparian buffer and impacted stand age and structural complexity in many areas of this reach, as determined by field estimates, tree height data, or aerial photographs.	The riparian canopy overstory composition within the 100-foot riparian buffer was recorded as 100% large tree. Reach has very little visual evidence of human disturbance that that impacted the riparian buffer as determined by field estimates, tree height data, or aerial photographs.
		Disturbance (Human)	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	At Risk	At Risk	At Risk	Adequate
			6.9% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 13.2 miles/miles^2 road density in the 200-foot riparian buffer zone.	6.3% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 9.5 miles/miles^2 road density in the 200-foot riparian buffer zone.	8.0% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 12.1 miles/miles^2 road density in the 200-foot riparian buffer zone.	5.8% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 10.4 miles/miles^2 road density in the 200-foot riparian buffer zone.	4.2% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 8.5 miles/miles^2 road density in the 200-foot riparian buffer zone.	7.2% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 12.6 miles/miles^2 road density in the 200-foot riparian buffer zone.	2.6% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 4.6 miles/miles^2 road density in the 200-foot riparian buffer zone.	2.6% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 7.9 miles/miles^2 road density in the 200-foot riparian buffer zone.	2.5% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 5.2 miles/miles^2 road density in the 200-foot riparian buffer zone.	0% disturbance in the 200-foot buffer zone (e.g. residential, roads, etc.) and 0.0 miles/miles^2 road density in the 200-foot riparian buffer zone.

Pathway	General Indicators	Specific Indicators	Reach 11	Reach 12	Reach 13	Reach 14	Reach 15	Reach 16	Reach 17	Reach 18	Reach 19	Reach 20
Riparian Vegetation	Condition	Canopy Cover	At Risk	At Risk	At Risk	At Risk	At Risk	Unacceptable	Unacceptable	Unacceptable	At Risk	At Risk
			Reach average of 5.4 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Large trees within the 100-foot riparian buffer are present, but disturbance or clearing within the 100-foot buffer were observed likely reducing shading potential in reach.	Reach average of 5.2 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Large trees within the 100-foot riparian buffer are present, but disturbance or clearing within the 100-foot buffer were observed likely reducing shading potential in reach.	Reach average of 5.1 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Large trees within the 100-foot riparian buffer are present, but disturbance or clearing within the 100-foot buffer were observed likely reducing shading potential in reach.	Reach average of 4.1 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Large trees within the 100-foot riparian buffer are present, but disturbance or clearing within the 100-foot buffer were observed likely reducing shading potential in reach.	Reach average of 3.0 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Large trees within the 100-foot riparian buffer are present, but disturbance or clearing within the 100-foot buffer were observed likely reducing shading potential in reach.	Reach average of 2.7 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Large trees are present within the 100-foot riparian buffer in some locations, but disturbance or clearing within the 100-foot buffer were observed likely reducing shading potential in reach.	Reach average of 2.8 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Large trees within the 100-foot riparian buffer are present, but disturbance or clearing within the 100-foot buffer were observed likely reducing shading potential in reach.	Reach average of 2.5 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Large trees within the 100-foot riparian buffer are present, but disturbance or clearing within the 100-foot buffer were observed likely reducing shading potential in reach.	Reach average of 2.5 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Large trees within the 100-foot riparian buffer are present, and little disturbance or clearing within the 100-foot buffer were observed.	Reach average of 3.6 hours shaded during daylight hours on the summer solstice, determined from the weighted average of raster data from the shademap tool for each reach. Large trees within the 100-foot riparian buffer are present, and little disturbance or clearing within the 100-foot buffer were observed.

Pathway	General Indicators	Specific Indicators	Reach 11	Reach 12	Reach 13	Reach 14	Reach 15	Reach 16	Reach 17	Reach 18	Reach 19	Reach 20
Channel	Dynamics	Floodplain Connectivity	Adequate	Adequate	Adequate	Adequate	At Risk	At Risk	At Risk	Adequate	At Risk	At Risk
			Naturally confined reach. Where valley width allows, narrow functional floodplains and islands exist, and connectivity is maintained.	Naturally confined reach. Where valley width allows, narrow functional floodplains and islands exist, and connectivity is maintained.	Naturally confined reach. Where valley width allows, narrow functional floodplains and islands exist, and connectivity is maintained.	Naturally confined reach. Where valley width allows, narrow functional floodplains and islands exist, and connectivity is maintained.	Floodplain connectivity varies in the reach. Entrenched sections have the potential to reduce connectivity of other sections.	Naturally confined to partially confined reach. Where valley width allows, floodplains and islands exist. Downstream entrenchment has potential to impact floodplain connectivity.	Naturally confined to partially confined reach. Where valley width allows, floodplains and islands exist. Downstream and upstream entrenchment has potential to impact floodplain connectivity.	Naturally confined reach. Where valley width allows, narrow functional floodplains and islands exist, and connectivity is maintained.	Partially confined reach. Where valley width allows, floodplains and islands exist. Simplification from lack of functional large wood has potential to continue to reduce floodplain connectivity.	Partially confined reach. Where valley width allows, floodplains and islands exist. Simplification from lack of functional large wood has potential to continue to reduce floodplain connectivity.
Channel	Dynamics	Bank Stability/ Channel Migration	Adequate	Adequate	Adequate	Adequate	At Risk	Adequate	At Risk	Adequate	At Risk	At Risk
			Channel is laterally migrating at or near natural rates within the geomorphic construct of the reach.	Channel is laterally migrating at or near natural rates within the geomorphic construct of the reach.	Channel is laterally migrating at or near natural rates within the geomorphic construct of the reach.	Channel is laterally migrating at or near natural rates within the geomorphic construct of the reach.	Channel has reduced rate of lateral migration where trend of entrenchment occurs due to loss of channel complexity.	Channel is laterally migrating near natural rates within the geomorphic construct of the reach.	Channel has reduced rate of lateral migration where trend of entrenchment occurs due to loss of channel complexity.	Channel is laterally migrating at or near natural rates within the geomorphic construct of the reach	Channel has reduced rate of lateral migration where trend of entrenchment occurs due to loss of channel complexity.	Channel has reduced rate of lateral migration where trend of entrenchment occurs due to loss of channel complexity.
Channel	Dynamics	Vertical Channel Stability	Adequate	Adequate	Adequate	Adequate	At Risk	Adequate	At Risk	At Risk	Adequate	At Risk
			No measurable trend in incision or aggradation beyond natural geomorphic processes was observed in the reach.	No measurable trend in incision or aggradation beyond natural geomorphic processes was observed in the reach.	No measurable trend in incision or aggradation beyond natural geomorphic processes was observed in the reach.	No measurable trend in incision or aggradation beyond natural geomorphic processes was observed in the reach.	Subtle trend of incision due to loss of complexity (lack of effective large wood).	No measurable trend in incision or aggradation beyond natural geomorphic processes was observed in the reach.	Trend of incision due to loss of complexity (lack of effective large wood).	Subtle trend of incision due to loss of complexity (lack of effective large wood).	No measurable trend in incision or aggradation beyond natural geomorphic processes was observed in the reach.	Subtle trend of incision due to loss of complexity (lack of effective large wood).

Although LWM may be adequate from a habitat/cover perspective, this does not consider the geomorphic function of the LWM, which may be lacking.

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Icicle Creek Reach Assessment

Appendix C| Restoration Strategy

February 2026

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1 Restoration Strategy

1.1 INTRODUCTION

The Restoration Strategy uses field surveys, inventories, and analyses performed in the Reach Assessment and accompanying appendices (Appendix A: Habitat Assessment and Appendix B: Reach-based Ecosystem Indicators), as the technical basis for identifying and prioritizing restoration actions. This framework of developing a restoration strategy provides a direct linkage between the technical analyses, identified limiting factors, and the actions that are moved forward towards implementation. The restoration objectives (targets) are used to guide the development of appropriate restoration action types for the assessment area. The Reach-Scale Restoration Strategies (Section 1.4) present summarized and compiled information in table format for the reaches. Conceptual maps and descriptions of the project opportunities are presented in Section 1.4.1. Project ranking in Section 3, lays out the targets, benefits, and costs scoring involved in prioritizing project opportunities for the restoration strategies.

1.2 RESTORATION OBJECTIVES

Restoration objectives were developed for multiple ecological attributes, including instream habitat, geomorphologic processes, and riparian function. These objectives are presented as restoration targets. They are made to be as quantifiable as possible at this stage of analysis. These target conditions are compared to existing conditions from the Reach Assessment. This highlights habitat deficiencies and the "gap" that needs to be filled to recover habitat.

Target conditions were developed using the Reach-based Ecosystem Indicators (REI) targets (see Appendix B) as well as reference to site conditions and inference from local and regional studies. See the Assessment Report and Appendix B for more information on the REI analysis.

1.3 ACTION TYPES

Recommended actions are categorized here into five action types. There are four restoration action types plus a conservation action. We use the term 'restoration' as a broad catch-all for the actions; however, we acknowledge that many of the actions are not restoration in the true sense of the word and would be more appropriately labeled as "enhancement" or "creation." We consider true restoration actions to be those that address root causes of impairments in an effort to return the system close to its naturally functioning state. This is often not achievable, or advisable, due to existing changes to the underlying processes or to process impairments that are unlikely to change, such as a significant piece of infrastructure. An example of a true restoration project would be a project that fully removes a levee, returns the channel to its historical form, and replants the valley floor to restore natural floodplain inundation patterns. Enhancement measures are those that improve or rehabilitate habitat to the extent possible given impaired processes and anthropogenic constraints. Placement of large wood in an existing pool to provide cover is an example of habitat enhancement. Creation projects are those that create new habitat where it is currently lacking or that will not be created on its own in a reasonable timeframe given existing impairment. The excavation

of a new side-channel where one did not exist already is an example of a creation project. Action types are often combined, and each project typically incorporates numerous action types. The five action types are described below.

1. Riparian Restoration

Riparian restoration projects are recommended in areas where native riparian vegetation communities have been impacted by historical or current anthropogenic activities such that riparian function and connection with the stream are compromised. In the Icicle Creek assessment area, large sections of the floodplain vegetation were logged in the past and the forests are still recovering. Near some private property, campgrounds, and infrastructure, riparian vegetation has been cleared or impacted for homes/buildings, agricultural purposes, roads and trails, or crossings. Restoration actions are focused on restoring native riparian vegetation communities to reestablish natural stream stability, stream shading, nutrient exchange, ecologic diversity, long-term large wood recruitment, and wildfire resilience. Riparian restoration may also include the development or enhancement of wetlands or riparian function along off-channel features. Even though it is not always explicitly stated, riparian restoration is a recommended component of most restoration actions, particularly within the disturbance limits of the action.

Examples:

- Replanting a riparian buffer area with native vegetation.
- Controlling invasive species within the riparian zone.
- Placing willow or cottonwood baffles on bars to encourage vegetated island development.

2. Enhance Channel Complexity

Channel complexity enhancement actions are aimed at increasing quantity or improving the quality of existing channel habitat and geomorphology. This type of action is designed to improve the geomorphic complexity of the system, which in turn supports instream aquatic habitat conditions and builds system resiliency. Sections of the Icicle Creek assessment area lack geomorphic and habitat complexity as a result of historical logging, floodplain grading, channel manipulations, and channel clearing practices. Due to the removal of old-growth trees, many of the riparian and floodplain forests lack sufficiently sized trees to act as "key-logs" capable of influencing and maintaining channel complexity. Where sufficient large wood jams do occur, geomorphic complexity and habitat function are notably increased. The Enhance Channel Complexity strategy includes a broad range of large wood installation types of varied sizes and purposes. Enhance Channel Complexity is recommended in the mainstem channel, side channels, and off-channel habitat. The recommendations include broad treatment types as well as site-specific actions. For example, log placement may be recommended in a field-identified existing pool to provide salmonid hiding cover. In contrast, several thousand feet of the channel may be identified as appropriate for large wood loading. The structural elements (e.g. large wood) included in these actions are placed in areas where they would naturally accumulate and be maintained by stream hydrology and geomorphology. These actions can exhibit a wide range of intended functions, from helping to

restore reach-scale geomorphic processes (e.g., apex jams to create multi-thread channel conditions) to simply adding structural cover and other habitat complexity features (e.g., adding large wood to an existing pool).

Examples:

- Installation of individual large wood pieces or jams for cover, pool scour, sediment sorting, and hydraulic complexity (e.g., high flow refuge for rearing juvenile fish).
- Installation of apex jam to promote scour, sediment retention, and split-flow conditions to support mid-channel bar/island development or side-channel initiation.

3. Side and Off-Channel Habitat Creation or Enhancement

Off-channel habitat creation or enhancement projects are identified in areas where there is the potential to increase the quantity, quality, or connectivity of off-channel habitat (i.e. alcoves, side channels, floodplain wetlands). Off-channel habitat features provide important rearing and refugia areas for juvenile salmonids, including high flow refugia, temperature refugia, and highly productive feeding areas. These projects may include the activation of existing habitat areas that have been disconnected via channel incision or floodplain alterations. In other cases, off-channel areas can be created via excavation and construction of features such as side channels or alcoves. Off-Channel Habitat Creation or Enhancement is often paired with Enhance Channel Complexity actions.

Examples:

- Increase the degree of connectivity (i.e. for surface flow and fish passage) of an existing off-channel area such as a floodplain oxbow wetland for juvenile feeding, flood refuge, or thermal refuge.
- Create new mainstem-connected side channel or off-channel habitat via excavation.
- Enhance conditions in new or created off-channel habitat.

4. Floodplain and Channel Migration Zone (CMZ) Reconnection

Floodplain and CMZ connectivity actions are those that increase the frequency, duration, or extent of hydrologic connection between the mainstem channel and the floodplain or that re-establish natural channel migration processes. Floodplain connectivity projects are identified in areas where there is the potential to increase the quantity or frequency of floodplain inundation, most notably where floodplains have been disconnected via channel incision/straightening, channel bypass or diversions, anthropogenic confinement such as undersized bridges or levees, or floodplain modifications that inhibit connectivity such as road prisms or hardened banks. CMZ reconnection projects include projects that restore the natural lateral adjustment process to a channel. Floodplain and CMZ reconnection strategies include a broad range of potential project types, including floodplain grading to create hydraulic connectivity, inset floodplains, or wetlands; as well as removal of constructed levees or armoring to reengage existing floodplain surfaces (or oxbows) and

to restore channel migration processes. It may also require grading to reactivate or reconnect abandoned channel sections or flow routes, especially those resulting from anthropogenic manipulations.

Examples:

- Remove or modify levees, bank armor, roads, or bridges to reestablish natural floodplain inundation and channel migration processes.
- Raise the bed or promote aggradation of an incised channel.
- Create multi-threaded channel corridor with valley-wide hydraulic connectivity.

6. Conservation

Conservation actions include such things as land acquisitions, easements, or other measures that provide enduring protection for channels, riparian zones, and floodplains. These are only identified where it complements restoration actions or where there is believed to be specific future risk of impairment. Most of the assessment area upstream of RM 6.6 is within the Okanogan-Wenatchee National Forest, with intermittent clusters of private parcels along the river corridor. Many of the private parcels have vacation homes and most of them are located on the hillslopes above the river, and not within the floodplain. Working with landowners to perform riparian revegetation would have benefits in some areas. Downstream of RM 6.6 is mostly privately owned, with the exception of the Leavenworth National Fish Hatchery in Reach 3. There is also a large parcel owned by the Icicle Irrigation District near the Snow Creek confluence (and Icicle-Peshastin Canal diversion area). The lower two reaches (RM 0-3) are dominated by private lands and this is where most of the conservation opportunities are located. Conservation measures in these areas would help to prevent additional development, including parcels without homes yet, and would also help facilitate restoration actions with willing and interested landowners. Because these parcels are on the floodplain and/or within the historical channel migration zone of the river, portions of nearly all of these private lands could be considered targets for conservation. However, existing county-level shorelines, critical areas, and floodplain regulations apply to many of these parcels and, in theory, provide some level of conservation protection already.

This assessment does not include any type of land-use analysis such as looking at zoning patterns or the adequacy of local regulations. Due to these uncertainties, conservation actions are not identified broadly for private lands. Instead, this assessment identifies conservation actions in the following situations: 1) private lands with high restoration value, where long-term protection of the land would complement restoration actions, and 2) where site or other observations indicate there are impending encroachments or development potential, such as land clearing, road building, land subdivision, or undeveloped properties advertised for sale.

1.4 REACH-SCALE RESTORATION STRATEGIES

Restoration strategies for each reach are provided below. The reach-scale restoration strategies identify existing ecologic/geomorphic conditions, project objectives and recovery potential, a list of potential projects, and recommended restoration action types. The ecological function (Low, Moderate, or High) of each reach is characterized by the ratings that resulted from the REI (see Appendix B). The trajectory (decline, same, improve) is determined by evaluation of the modern geomorphic trends, related existing habitat conditions, and continued limitations such as infrastructure and land-use (see the Reach Assessment Report and Habitat Assessment Appendix A). The recovery potential (Low, Moderate, and High) is based on the potential for the site to recover functioning habitat and processes with implementation of restoration actions. The recovery potential rating considers known limitations to recovery that are unlikely to be eliminated with or without implementation of this restoration strategy, such as the presence of transportation and residential infrastructure.

1.4.1 Reaches 1 – 2 Restoration Strategy

Overall ecological function	**Low**
	Rating is based on the Reach Assessment evaluations of habitat, geomorphology, hydrology, hydraulics, and vegetation. Six of 11 REI metrics in Reach 1 and eight of 11 REI metrics in Reach 2 are at risk or unacceptable. Significant impairment of channel and riparian function due to riparian vegetation clearing, lost or reduced habitat complexity, lack of large wood in the channel, and limited off-channel habitat.
Trajectory if no action taken	**Decline**
	Continued degradation due to persistent anthropogenic impacts on floodplain surfaces and large wood processes, including the effects of channel incision, bank armoring, riparian vegetation clearing, and anthropogenic development. Predominately private landownership may increase potential for ecological decline trajectory without intervention.
Recovery potential	**Moderate**
	Projects address lack of large in-channel structure but have limited impact on recovery of root causes due to effects of reach-wide incision related to floodplain and CMZ lateral constrictions that are assumed to remain.
Restoration objectives	**Target conditions in Table 1**
	Bring existing conditions to target conditions (multiple habitat and geomorphic attributes), where possible, for the metrics identified in Table 1 below. To the extent possible at this stage of planning, the targets are presented as measurable quantities.
Action Types	**Riparian Restoration** **Enhance Channel Complexity** **Side and Off-Channel Habitat Creation or Enhancement** **Floodplain and CMZ Connectivity** **Conservation**
	Actions include enhancement/improvement of channel complexity via large wood placements. Where possible given existing infrastructure, modification of anthropogenic features, such as bank riprap, would improve channel condition and floodplain connectivity. Excavation of side channel or oxbow/alcove inlets would increase available, accessible off-channel habitat areas in a relatively high fish-use portion of Icicle Creek. Revegetation within the riparian zone of cleared areas would improve long-term riparian conditions.
Project Areas & Prioritization	**Eiszapfen Bach** **Hatchery**
	The potential to improve the quantity and quality of available habitat in Reaches 1 and 2 is moderate, and primarily includes large wood addition, targeted side channel inlet excavation, and replacement of bank armoring with more naturalized bank protection features that include large wood structures. Existing private land uses and infrastructure limit recovery potential in Reaches 1 and 2, though acquisition and protection of parcels as they become available would improve potential outcomes. Riparian restoration where banks have been cleared can support long-term recovery of large wood processes. If needed, the projects could be phased or divided into multiple smaller projects.

Table 1. Reaches 1 – 2 Restoration Objectives, Action Types, and Projects.

Attribute	Existing Condition (from assessment)	Target Condition [REI – Adequate Rating]	Action Type	Project
Habitat Quality	Gravels present and the presence of fine sediments is moderate in both reaches. 39 and 34 pieces of medium or large LW per mile for Reach 1 and Reach 2, respectively. Pool habitat is extensive, and pools are deep but have limited cover/complexity. Only 2 side channels (qualified according to Level 2 protocols) are present.	Gravels or small cobbles make up >50% of the bed materials in spawning areas and ≤12%fines/sand (<6 mm) in spawning gravel. At least 67.45 pieces/mile of large wood and sources for LW recruitment. Due to backwater effect from Wenatchee River, pool frequency is not considered in Target Conditions. Pools should be deep and have good fish cover and cool water. Contains side or off-channel refugia.	Side and Off-Channel Habitat Creation or Enhancement Enhance Channel Complexity Floodplain and CMZ Connectivity	Eiszapfen Bach Hatchery
Riparian Condition	Riparian areas in Reaches 1 and 2 are highly disturbed and modified, with riparian clearing, infrastructure or other human land uses present within the riparian zone resulting in 57% Large Tree cover in Reach 1 and 73% Large Tree in Reach 2. Reach 2 has more riparian disturbance (20.5%) and road density (8.1 mi/mi^2). Both reaches have low thermal shading of the channel.	At least a 200-ft riparian buffer with: > 80% large trees, or consistent with potential native community < 20% riparian disturbance (human); high proportion of daylight hours with thermal shading over channel; and <2 mile/miles^2 road density.	Riparian Restoration Floodplain and CMZ Connectivity Conservation	Eiszapfen Bach Hatchery
Channel Dynamics	Floodplain disconnection is widespread, with reduced rates of lateral migration due to bank armoring. Some incision and confinement in Reach 2 due to road crossing and anthropogenic development.	Floodplain areas are hydrologically linked to main channel within the context of the local process domain. Channel is migrating at or near natural rates within the geomorphic construct of the reach. No measurable trend of aggradation or incision beyond the natural geomorphic processes of the reach.	Floodplain and CMZ Connectivity Enhance Channel Complexity Conservation	Eiszapfen Bach Hatchery

1.4.2 Reach 3 Restoration Strategy

Overall ecological function	**Low**
	Rating is based on the Reach Assessment evaluations of habitat, geomorphology, hydrology, hydraulics, and vegetation. 9 of 11 REI metrics are at risk or unacceptable. Impairment of channel and riparian function due to the LNFH and associated infrastructure, including dams, roads, diversions, canals, levees, and riparian vegetation clearing have resulted in fish passage issues, minimal habitat complexity, a lack of large wood in the channel, and limited natural geomorphic processes.
Trajectory if no action taken	**Decline**
	Continued degradation due to persistent anthropogenic impacts to floodplain and channel, riparian zone, and large wood processes are assumed if no action is taken, primarily due to the presence of the LNFH and related infrastructure and water delivery systems.
Recovery potential	**Moderate - High**
	The hatchery project has some of the greatest uplift potential of any project in the assessment area due to the level of impairment and the magnitude of enhancement that could be achieved with comprehensive restoration treatments. Projects address simplification of aquatic habitats by removing or modifying infrastructure. Project addresses the lack of large in-channel structure, side-channel/off-channel habitat, floodplain connectivity, riparian conditions, and fish passage issues. Recovery potential decreases if the LNFH canal infrastructure remains in place.
Restoration objectives	**Target conditions in Table 2**
	Bring existing conditions to target conditions (multiple habitat and geomorphic attributes), where possible, for the metrics identified in Table 1 below. To the extent possible at this stage of planning, the targets are presented as measurable quantities.
Action Types	**Riparian Restoration** **Enhance Channel Complexity** **Side and Off-Channel Habitat Creation or Enhancement** **Floodplain and CMZ Connectivity** **Conservation**
	Actions include Removal and/or modification of LNFH canal and related features, such as graded surfaces, riprap, and flow diversions to reestablish the historical channel, floodplain connectivity, and channel dynamics for notably uplifted aquatic habitat in a potentially high spawning zone. Habitat enhancements include increased channel complexity via large wood placements and improved fish passage via roughened channel features. Regrade to functional floodplain. Establish side channels and revegetate area to improve long-term riparian conditions.
Project Areas & Prioritization	**Hatchery**
	The potential to improve the quantity and quality of available habitat in Reach 3 is moderate – high. Treatment alternatives are varied and range from installation of large wood in the existing historical channel to removal of existing flow diversion canal and its associated in-channel structures. The most uplift potential exists when the treatments are combined. Potential restoration work downstream of Structure #5 could occur relatively independent of what occurs upstream. Riparian revegetation throughout would improve long-term riparian and large wood processes. If the existing infrastructure cannot be removed or modified, it will limit recovery potential in Reach 3.

Table 2. Reach 3 Restoration Objectives, Action Types, and Projects.

Attribute	Existing Condition (from assessment)	Target Condition [REI – Adequate Rating]	Action Type	Project
Habitat Quality	Gravels present with relatively limited amounts of fines. Only 10 pieces of medium or large LW per mile. Pool habitat is extensive, and pools are deep but have limited cover/complexity. Limited side channel habitats are available.	Gravels or small cobbles make up >50% of the bed materials in spawning areas and ≤12%fines/sand (<6 mm) in spawning gravel. At least 67.45 pieces/mile of large wood and sources for LW recruitment. Meets the pool frequency criteria for bankfull width of 18 pools/mile, and pools should be deep and have good fish cover and cool water. Contains side or off-channel refugia.	Enhance Channel Complexity Side and Off-Channel Habitat Creation or Enhancement Floodplain and CMZ Connectivity	Hatchery
Riparian Condition	Where riparian trees are present, they are 86% large trees; 21.1% of the riparian zone is disturbed; 3.7 hours of shade during summer solstice (moderate thermal shading); and 10.6 mile/miles^2 road density within 200-ft riparian buffer.	At least a 200-ft riparian buffer with: > 80% large trees, or consistent with potential native community < 20% riparian disturbance (human); high proportion of daylight hours with thermal shading over channel; and <2 mile/miles^2 road density	Riparian Restoration Floodplain and CMZ Connectivity	Hatchery
Channel Dynamics	Constructed levees, canal, terraces, and flow control structures currently limit connectivity to floodplain and impair habitat conditions. Anthropogenic influences have notably decreased lateral processes, and altered hydrology reduces flow hydraulics and channel dynamics.	Floodplain areas are hydrologically linked to main channel within the context of the local process domain. Channel is migrating at or near natural rates within the geomorphic construct of the reach. No measurable trend of aggradation or incision beyond the natural geomorphic processes of the reach	Floodplain and CMZ Connectivity Enhance Channel Complexity Side and Off-Channel Habitat Creation or Enhancement	Hatchery

1.4.3 Reaches 4 – 9 Restoration Strategy

Overall ecological function	**Moderate**
	Rating is based on the Reach Assessment evaluations of habitat, geomorphology, hydrology, hydraulics, and vegetation. Though Reach 4 is one of the most impacted reaches with 9 of 11 REI metrics at risk or unacceptable, Reaches 7 – 9 are less impacted due to the naturally confined channel conditions, all with 4 of 11 REI metrics at risk or unacceptable. Reach 5 has 6 of 11 and Reach 6 has 5 of 11 REI metrics at risk or unacceptable, indicating moderate impairment to ecological function. Some disturbance to riparian vegetation and loss of habitat complexity with very limited off-channel habitat in these naturally confined reaches.
Trajectory if no action taken	**Maintain**
	Effects of historical and ongoing degradation will remain due to anthropogenic impacts that have resulted in primarily altered riparian and large wood processes. Possible long-term natural recovery of riparian condition due to mix of private and federally-owned land, though high recreational use in these reaches may limit that recovery.
Recovery potential	**Low-Moderate**
	Projects address lack of large in-channel structure but have limited impact on recovery of root causes due to naturally confined channel condition in a majority of Reaches 4 – 9. Campgrounds and roads/bridges are assumed to remain.
Restoration objectives	**Target conditions in Table 3**
	Bring existing conditions to target conditions (multiple habitat and geomorphic attributes), where possible, for the metrics identified in Table 3 below. To the extent possible at this stage of planning, the targets are presented as measurable quantities.
Action Types	**Riparian Restoration** **Enhance Channel Complexity** **Floodplain and CMZ Connectivity** **Side and Off-Channel Habitat Creation or Enhancement**
	Actions include enhancement/improvement of channel complexity via large wood placements. The most promising places for wood treatments are in Reach 4 and the lower portion of Reach 5, the upper portion of Reach 7, and Reaches 8 and 9, where channel confinement is reduced. Activation of side channel features where floodplains exist would increase available, accessible refugia habitat for fish migrating or rearing in these reaches. No project opportunities are proposed in Reach 6. Revegetation and fuels management on the banks and hillslopes could improve long-term riparian and large wood recruitment processes in these reaches.
Project Areas & Prioritization	**Tunnel** **Trident** **Eightmile**
	The potential to improve the quantity and quality of available habitat in Reaches 4 – 9 is limited due to the geomorphic site conditions.. Treatments are primarily focused on large wood additions and some riparian restoration. A few opportunities exist for side channel activation where low floodplain surfaces are present. All three project areas are complimentary to each other and together would provide the greatest potential for uplift in Reaches 4 – 9 but would also provide habitat and function benefits if completed independently.

Table 3. Reaches 4 – 9 Restoration Objectives, Action Types, and Projects.

Attribute	Existing Condition (from assessment)	Target Condition [REI – Adequate Rating]	Action Type	Project
Habitat Quality	Substrate dominated by boulders/cobbles but gravels present with low fines in all reaches except Reach 9, which had only 21% gravels. Pieces of medium or large LW per mile exceeded the threshold in all reaches except Reach 6. However, the LW provides low to marginal influence on geomorphic processes. Pools/mile did not meet pool frequency criteria in any of the reaches, though that is a function of the relatively steep boulder step-pool channel type that is not being adequately included in the USFS survey protocols. Pool shade/cover was low to moderate. Side channels are present in all reaches except Reach 6.	Gravels or small cobbles make up >50% of the bed materials in spawning areas and ≤12%fines/sand (<6 mm) in spawning gravel. At least 67.45 pieces/mile of large wood; adequate sources for LW recruitment; and wood is providing geomorphic function. Pool frequency of 18 pools/mile for Reaches 4, 5, 6, and 9 and pool frequency of 15 pools/mile for Reaches 7 and 8. ≥50% of pools ≥1m (3ft) deep and good fish cover and cool water. Contains side or off-channel refugia.	Enhance Channel Complexity Floodplain and CMZ Connectivity Side and Off-Channel Habitat Creation or Enhancement	Tunnel Trident Eightmile
Riparian Condition	Riparian overstory consists of 100% large trees in Reaches 4, 5, 8 and 9, but does not meet criteria in Reaches 6 and 7. Nevertheless, past logging has reduced the size and availability of effective large wood for all reaches. Riparian zone disturbance is high and does not meet Adequate rating criteria in all reaches, and low-moderate thermal shading is available (shading increases in Reaches 8 and 9).	At least a 200-ft riparian buffer with: > 80% large trees, or consistent with potential native community < 20% riparian disturbance (human); high proportion of daylight hours with thermal shading over channel; and <2 mile/miles^2 road density.	Riparian Restoration	Tunnel Trident Eightmile
Channel Dynamics	Most of these reaches are naturally confined. Channel dynamics are impaired in Reach 7, where a riprap spur blocks connectivity to a side-channel and low floodplain area. There are also instances of fill in side-channel inlets in reaches 8 and 9. Where valley width allows, narrow functional floodplains and islands exist, and connectivity is generally maintained.	Floodplain areas are hydrologically linked to main channel within the context of the local process domain. Channel is migrating at or near natural rates within the geomorphic construct of the reach. No measurable trend of aggradation or incision beyond the natural geomorphic processes of the reach.	Floodplain and CMZ Connectivity Enhance Channel Complexity Side and Off-Channel Habitat Creation or Enhancement	Trident Eightmile

1.4.4 Reach 10 Restoration Strategy

Overall ecological function	**Low-Moderate**
	Rating is based on the Reach Assessment evaluations of habitat, geomorphology, hydrology, hydraulics, and vegetation. Three of 11 REI metrics are at risk or unacceptable. Some impairment of channel and floodplain function due to channel modification and floodplain disconnection and riparian vegetation clearing, resulting in reduced habitat complexity and loss of large wood in the channel.
Trajectory if no action taken	**Maintain**
	Continued impairment due to persistent anthropogenic impacts to floodplain/channel migration zone, riparian conditions, and large wood processes. Possible long-term recovery of riparian conditions due to federal land ownership, though high-use recreational activities within the reach may limit that recovery.
Recovery potential	**Moderate-High**
	Moderate-High potential for recovery, assuming Bridge Creek Campground and associated infrastructure remain on the landscape. Levee removal and off-channel work on river-right near RM 10.7 has good potential to create high quality habitat. The reach has potential to provide improved and important migratory refugia and rearing habitat between the more confined and higher gradient reaches upstream and downstream of it.
Restoration objectives	**Target conditions in Table 4**
	Bring existing conditions to target conditions (multiple habitat and geomorphic attributes), where possible, for the metrics identified in Table 4 below. To the extent possible at this stage of planning, the targets are presented as measurable quantities.
Action Types	**Riparian Restoration** **Enhance Channel Complexity** **Side and Off-Channel Habitat Creation or Enhancement** **Floodplain and CMZ Connectivity**
	Actions include enhancement/improvement of channel complexity via large wood placements. Removal of levee and fill (associated with decommissioned campground) on river-right may increase floodplain and off-channel refugia potential. Reconnection and maintenance of side channels to increase availability and diversity of aquatic habitat. Revegetation of open bank areas would improve long-term riparian conditions.
Project Areas & Prioritization	**Bridge Creek**
	The potential to improve the quantity and quality of available habitat in Reach 10 is moderate-high. If all channel and floodplain treatment actions are implemented jointly, notable improvements are possible. However, existing campground and bridge infrastructure limit recovery potential in Reach 10.

Table 4. Reach 10 Restoration Objectives, Action Types, and Projects.

Attribute	Existing Condition (from assessment)	Target Condition [REI – Adequate Rating]	Action Type	Project
Habitat Quality	Substrate is primarily boulder-dominated, with some gravels present (39% and 17% in the two pebble counts) and little fines. 108 pieces of medium or large LW per mile. However, the LW provides low to marginal influence on geomorphic processes in the confined sections. Only 3 pools per mile with 67% pools > 1m (3ft) and moderate to high pool shade/cover. Three side channels present.	Gravels or small cobbles make up >50% of the bed materials in spawning areas and ≤12% fines/sand (<6 mm) in spawning gravel. At least 67.45 pieces/mile of large wood and sources for LW recruitment. Pool frequency of 18/mile with ≥50% of pools ≥1m (3ft) deep and good fish cover and cool water. Contains side or off-channel refugia.	Enhance Channel Complexity Side and Off-Channel Habitat Creation or Enhancement Floodplain and CMZ Connectivity	Bridge Creek
Riparian Condition	Riparian overstory consists of 62% large trees; 7.3% of the riparian zone is disturbed; 5.8 hours of shade during summer solstice (moderate thermal shading); and 13.8 mile/miles^2 road density within 200-ft riparian buffer. Past logging and modern clearing for recreation has reduced the size and availability of effective large wood contributions. The campground significantly affects riparian conditions in the lower portion of the reach.	At least a 200-ft riparian buffer with: > 80% large trees, or consistent with potential native community < 20% riparian disturbance (human); high proportion of daylight hours with thermal shading over channel; and <2 mile/miles^2 road density	Riparian Restoration	Bridge Creek
Channel Dynamics	Channel is naturally partially confined, with two sections, one at the upstream end and one at the downstream end, that provide available floodplain and channel complexity. The downstream unconfined section does seem to be impaired and limited by a river-right levee near RM 10.7.	Floodplain areas are hydrologically linked to main channel within the context of the local process domain. Channel is migrating at or near natural rates within the geomorphic construct of the reach. No measurable trend of aggradation or incision beyond the natural geomorphic processes of the reach	Floodplain and CMZ Connectivity Enhance Channel Complexity Side and Off-Channel Habitat Creation or Enhancement	Bridge Creek

1.4.5 Reaches 11 – 14 Restoration Strategy

Overall ecological function	**Moderate**
	Rating is based on the Reach Assessment evaluations of habitat, geomorphology, hydrology, hydraulics, and vegetation. Five of 11 REI metrics are at risk or unacceptable in all Reaches 11 – 14. Some impairment of channel habitat and function due to roads and campgrounds, bank armoring, and riparian vegetation clearing has reduced habitat complexity.
Trajectory if no action taken	**Maintain**
	The combined reaches are mostly moderately steep and confined with boulder riffles and step-pool sections. Some degradation due to persistent anthropogenic impacts from roads and recreational uses is likely, but some long-term recovery of riparian conditions is possible due to federal landownership.
Recovery potential	**Low - Moderate**
	Large wood addition would increase habitat complexity but not necessarily address the reduced short-term large wood supply. Assuming the road remains in place, the potential for recovery of riparian processes and channel margin complexity is limited.
Restoration objectives	**Target conditions in Table 5**
	Bring existing conditions to target conditions (multiple habitat and geomorphic attributes), where possible, for the metrics identified in Table 5 below. To the extent possible at this stage of planning, the targets are presented as measurable quantities.
Action Types	**Riparian Restoration** **Enhance Channel Complexity**
	Actions primarily include enhancement/improvement of channel complexity via large wood placements. Targeted revegetation may improve localized long-term riparian conditions.
Project Areas & Prioritization	**Johnny Victoria**
	The potential to improve the quantity and quality of available habitat in Reaches 11-14 is low-moderate due to the relatively steep and confined nature of the channel.

Table 5. Reaches 11 – 14 Restoration Objectives, Action Types, and Projects.

Attribute	Existing Condition (from assessment)	Target Condition [REI – Adequate Rating]	Action Type	Project
Habitat Quality	All reaches meet Adequate ratings for substrate, because reaches are naturally boulder-cobble dominant and do not geomorphically support spawning areas. Small pockets of gravels and few fines are present in the reaches. Only Reach 14 meets the large wood criteria for pieces of medium and large LW per mile, all other reaches were rated as Unacceptable. The LW that is present usually provides low to marginal influence on geomorphic processes. Most reaches did not meet the pool frequency criteria, however, natural conditions (steep slope and bedrock confinement) limit formation of pools that met survey criteria. Pool cover was generally low overall. Side channels were relatively limited.	Gravels or small cobbles make up >50% of the bed materials in spawning areas and ≤12% fines/sand (<6 mm) in spawning gravel. At least 67.45 pieces/mile of large wood and sources for LW recruitment. Pool frequency of 18/mile with ≥50% of pools ≥1m (3ft) deep and good fish cover and cool water. Contains side or off-channel refugia.	Enhance Channel Complexity	Johnny Victoria
Riparian Condition	Riparian overstory consists of primarily large trees but not all reaches met the Adequate criteria. Past logging and roads have reduced the size and availability of effective large wood contributions. Up to 8% of the riparian zone was disturbed (Reach 13). Moderate channel shading is available in these reaches, and between 9.5 – 13.2 mile/miles^2 road density within 200-ft riparian buffer. The proximity of the roadway affects riparian conditions in numerous locations.	At least a 200-ft riparian buffer with: > 80% large trees, or consistent with potential native community < 20% riparian disturbance (human); high proportion of daylight hours with thermal shading over channel; and <2 mile/miles^2 road density	Riparian Restoration	Johnny Victoria
Channel Dynamics	Where valley width allows, narrow functional floodplains and islands exist, and connectivity is maintained. Channel is laterally migrating at natural or near natural rates (mostly naturally confined) and no measurable trend in incision or aggradation (beyond natural geomorphic processes) was observed.	Floodplain areas are hydrologically linked to main channel within the context of the local process domain. Channel is migrating at or near natural rates within the geomorphic construct of the reach. No measurable trend of aggradation or incision beyond the natural geomorphic processes of the reach	Enhance Channel Complexity	Johnny Victoria

1.4.6 Reaches 15 – 20 Restoration Strategy

Overall ecological function	**Low**
	Rating is based on the Reach Assessment evaluations of habitat, geomorphology, hydrology, hydraulics, and vegetation. Reach 17 and Reach 15 are more impacted reaches, with 9 out of 11 and 8 out of 11 REI metrics at risk or unacceptable, respectively. Reaches 14 and 18 had 5 out of 11 REI metrics at risk or unacceptable, and Reaches 16, 19, and 20 each had 7 of 11 REI metrics at risk or unacceptable. Impairment of channel habitat complexity, limited off-channel habitat, and disturbance to riparian vegetation are the primary impairments.
Trajectory if no action taken	**Maintain or Improve**
	Effects of degradation due to anthropogenic impacts to floodplain, channel migration and incision, riparian, and large wood processes continue, but recovery over the long term may be possible due to a more responsive channel type in these reaches compared to downstream. Possible long-term recovery of riparian condition, especially in the upper reaches.
Recovery potential	**Moderate - High**
	Significant available opportunities for improving aquatic habitat conditions via large wood addition and off-channel habitat reconnection. Projects address the lack of large in-channel structure and the processes that create and maintain it over the long-term.
Restoration objectives	**Target conditions in Table 6**
	Bring existing conditions to target conditions (multiple habitat and geomorphic attributes), where possible, for the metrics identified in Table 6 below. To the extent possible at this stage of planning, the targets are presented as measurable quantities.
Action Types	**Riparian Restoration** **Enhance Channel Complexity** **Side and Off-Channel Habitat Creation or Enhancement** **Floodplain and CMZ Connectivity**
	Actions include enhancement/improvement of channel complexity via large wood placements. Includes removal or modification of defunct anthropogenic features (i.e. old road fill and armoring in Reach 15) to improve floodplain connectivity. Excavation of side channels would increase available, accessible off-channel habitat or floodplain wetland areas. Revegetation of open areas and fuels reduction treatments in Reaches 17, 18 and 19 would support improved long-term riparian conditions. Upstream of the wilderness boundary in Reach 20 would require hand-felling or other non-machine constructed wood loading actions.
Project Areas & Prioritization	**Ida** **Doctor** **Jack** **Boggy Black Pine**
	The potential to improve the quantity and quality of available habitat in Reaches 15 – 20 is moderate-high. If all channel and floodplain treatment actions are implemented, substantial improvements are possible. All Reach 15 – 20 project areas are complimentary to each other but would still provide habitat and function benefits if completed independently.

Table 6. Reaches 15 – 20 Restoration Objectives, Action Types, and Projects.

Attribute	Existing Condition (from assessment)	Target Condition [REI – Adequate Rating]	Action Type	Project
Habitat Quality	Most reaches do not meet Adequate rating for substrate, though there are some gravels present in the reaches and low fines. Reach 18 is the only reach that did not meet the large wood criteria for pieces of medium and large LW per mile. However, Reach 18 is primarily bedrock confined and was also the only reach to meet the pools/mi criteria. Pool depths were highly variable across the reaches. Pool cover was moderate overall. Side channels were relatively limited, though present where the channel was less confined.	Gravels or small cobbles make up >50% of the bed materials in spawning areas and ≤12% fines/sand (<6 mm) in spawning gravel. At least 67.45 pieces/mile of large wood and sources for LW recruitment. Pool frequency of 15/mile (Reach 15) or 18/mile (Reaches 16 – 20) with ≥50% of pools ≥1m (3ft) deep and good fish cover and cool water. Contains side or off-channel refugia.	Enhance Channel Complexity Side and Off-Channel Habitat Creation or Enhancement Floodplain and CMZ Connectivity	Ida Doctor Jack Boggy Black Pine
Riparian Condition	Riparian overstory consists of primarily large trees, with between 2.5-7.2% of the riparian zone disturbed in Reaches 15 – 19. Little evidence of riparian disturbance is present in Reach 20. Less channel shading is available in these reaches compared to the more confined downstream reaches, and between 0 – 12.6 mile/miles^2 road density within 200-ft riparian buffer (Reach 20 = 0 mi/mi^2, Reach 16 = 12.6 mi/mi^2). Most riparian impacts are relatively minor and are related to campgrounds and recreational areas.	At least a 200-ft riparian buffer with: > 80% large trees, or consistent with potential native community < 20% riparian disturbance (human); high proportion of daylight hours with thermal shading over channel; and <2 mile/miles^2 road density	Riparian Restoration Floodplain and CMZ Connectivity	Ida Doctor Jack Boggy Black Pine
Channel Dynamics	There are currently active channel dynamics occurring in Reach 15 due to the Doctor Creek slide. Connected floodplains and off-channel habitats occur where channels are naturally unconfined. There are a few anthropogenic features that affect channel processes.	Floodplain areas are hydrologically linked to main channel within the context of the local process domain. Channel is migrating at or near natural rates within the geomorphic construct of the reach. No measurable trend of aggradation or incision beyond the natural geomorphic processes of the reach	Floodplain and CMZ Connectivity Enhance Channel Complexity Side and Off-Channel Habitat Creation or Enhancement	Ida Doctor Jack Boggy Black Pine

2 Project Opportunities

2.1 PROJECT IDENTIFICATION AND EVALUATION APPROACH

Projects were identified through field surveys and analysis performed in the Reach Assessment. A map of the project areas is provided in Figure 1. Project elements were identified that are believed to best achieve target conditions and address fish habitat limiting factors. The projects represent an initial first step; it is expected that projects will be modified once project-specific surveys, analysis, and stakeholder coordination are performed. Project descriptions and maps are provided below. Project prioritization was performed to rank the projects into three priority tiers. Prioritization occurred by subjecting the projects to a set of scoring criteria. These criteria are based on several factors, including how well projects address the "gap" between existing and target conditions, species use/potential use of the area, and whether or not projects address root causes of impairments. Projects are also given a relative cost score estimate and feasibility designation in order to provide a relative cost perspective in project selection and planning. A description of the scoring methods and guidance is provided at the end of this document (Section 3.2).

2.2 PROJECT OPPORTUNITIES OVERVIEW

A total of 11 project areas were identified. An effort was made to identify project boundaries that group similar actions or that address similar reach-scale conditions; however, in many cases the selection of boundaries was qualitative, but a necessary means to divide up the study area into distinct projects that can be evaluated and ranked. Actual project extents for projects that are brought forward for implementation are likely to change depending on factors such as funding, landowner cooperation, schedule, phasing, etc. Areas where there are believed to be very few restoration opportunities are not included in the project maps.

A summary of the prioritization results is included in Table 7. The projects in the table are ranked by the Benefit-to-Cost score. The highest ranked projects are spread throughout the Icicle Creek Reach Assessment area. The Bridge Creek Project is located in a relatively unconfined reach bordered by mostly confined reaches up- and downstream. As such, it has the potential to provide important migratory and rearing refuge in an otherwise very high energy section of the assessment area. The Doctor and Ida projects also provide good opportunities for habitat uplift upstream of an extended confined section. The Hatchery Project in Reach 3 has tremendous habitat and geomorphic function uplift potential; however, costs could be relatively high and feasibility is more challenging so it does not rank as well from a benefit-to-cost perspective. These ranking results should be considered draft results and open to adjustment by technical teams and potential project sponsors depending on evolving circumstances and collaboration opportunities. In particular, the emphasis on total benefit versus cost-benefit may depend on funding levels or other considerations.

Table 7. Summary results of project prioritization. The full matrix is presented in Section 3.1.

Tiers	Project Name	Reach	Downstream RM	Upstream RM	Total Length (mi)	Total Benefit Score	Cost Score	Benefit-to-Cost Score	Feasibility Designation
Tier 1	Bridge Creek	10	10.30	11.40	1.10	6.5	2	3.3	High
	Doctor	15,16	15.80	17.20	1.40	6.5	2	3.3	High
	Hatchery	2,3	2.70	4.40	1.70	11	3.5	3.1	Moderate
	Eightmile	8,9	8.60	9.90	1.30	5.5	2	2.8	Moderate-High
	Ida	15	14.80	15.80	1.00	5.5	2	2.8	High
Tier 2	Tunnel	4,5	4.40	5.40	1.00	4.5	2	2.3	Moderate
	Trident	7	7.55	8.30	0.75	4.5	2	2.3	Moderate-High
	Jack	17,18	17.60	19.20	1.60	4.5	2	2.3	High
	Eiszapfen Bach	1,2	0.00	2.70	2.70	6.5	3	2.2	Low-Moderate
Tier 3	Boggy Black Pine	19,20	19.20	22.00	2.80	4	3	1.3	Moderate-High
	Johnny Victoria	12,13,14	12.20	14.70	2.50	3	3	1.0	Moderate-High

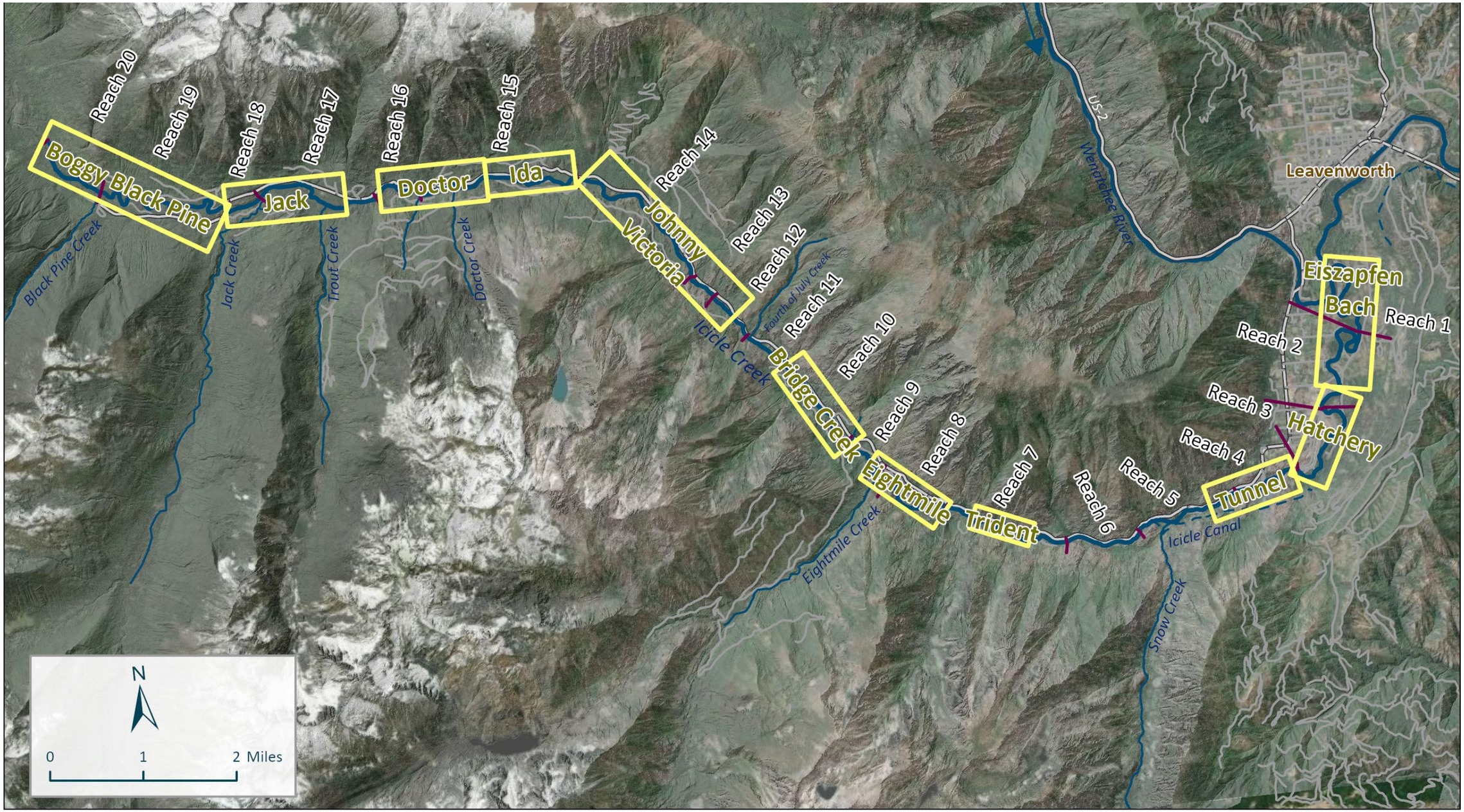


Figure 1. Overview map of project area locations and names

2.3 PROJECT DESCRIPTIONS

This table describes project opportunities by project area within the Icicle Creek Assessment area. Concept maps of the project opportunities are included below the table.

Reach	River Miles	Project Name	Project Description
1-2	0 – 2.7	*Eiszapfen Bach*	This project area has a lot of habitat uplift potential, including to the channel, riparian zone, and floodplain. Existing conditions are affected by impacts associated with residential and agricultural uses as well as historical impacts. The many private parcels and adjacent infrastructure (e.g. roads and houses) do pose challenges to restoration work. There is abundant bank armoring, development, floodplain manipulations, and riparian clearing. This is also a popular recreational area for river users with access points within the project area. There are many areas of cleared riparian and floodplain vegetation, much of it associated with rural residential development. Riparian replanting areas are identified on the project map for areas with cleared riparian vegetation within approximately 200 feet of the channel and where not bisected by development or roads. It is acknowledged that many of these areas are private lawns where revegetation may be unlikely. Some small bank revegetation projects are underway or planned that do overlap with, and thus support, this restoration prescription. The objective would be to work with willing landowners to replant / reestablish riparian vegetation where possible, especially in areas that would provide shade and potential future wood recruitment to the channel. There are some larger cleared areas that could benefit greatly from revegetation efforts, such as the river-right bank from RM 0.8 – 1.0 where there is no substantial development. Riparian revegetation is especially important given the active meander scrolling in this area (somewhat mitigated by existing bank treatments). There are numerous places where bank armoring protects houses or other structures. Property acquisitions would be a consideration and would allow removal of armoring, but widespread property acquisitions and removal of structures are believed to be impractical and overly costly in these reaches. In lieu of acquisitions, in some of the locations with armoring, where hydraulics allow, the hard armoring (mostly riprap) could be removed and replaced with bank-buried large wood structures that would enhance margin complexity, cover, and pool scour but would still provide bank some degree of protection. In other locations some (e.g. toe protection) or all of the existing riprap could remain but could be augmented with large wood to improve habitat conditions. Near RM 0.9 along the channel are rock spurs and failed large boulder riprap in the channel that could be removed. A set of large wood structures have been placed along the bank near RM 1 for bank protection but these could be augmented with additional complexity wood. The downstream portion of the bank is untreated; jams could be placed here to moderate erosion, combined with riparian revegetation. Numerous pools, glides, and alcoves throughout the project area would benefit from wood placements for habitat cover and complexity. At RM 1.3/1.7 a partial neck cutoff occurred in 1972 and action was taken to repair the cutoff and restore the previous alignment using hard armoring. This site is nevertheless still potentially at risk of a cutoff during a large flood. There is riprap armoring along the left-bank on the upstream side and a headcut scour hole on the downstream side. Although there would be some loss in sinuosity, a cutoff here may not significantly impair habitat and may create split-flow conditions for a while and eventually transition to an abandoned oxbow connected to the channel as off-channel habitat. This area is low gradient, and so significant upstream channel adjustment may not be a risk; however, this should be further evaluated prior to performing restoration work. The riprap armoring along the upstream side could be removed and replaced with channel-margin cover wood. The avulsion path should be revegetated and treated with large wood for floodplain roughness to mimic a forested condition. Large wood could be added to the headcut scour pool to provide habitat cover and also some degree of erosion resistance. These treatments would remove the hard armoring but provide some replacement of erosion resistance and bank strength to allow the channel evolution to occur at a more natural pace. There are a few places where the connectivity of existing floodplain swales could be increased or where new side-channels or off-channel features (e.g. alcoves or floodplain wetlands) could be created to both add complexity and reduce flow hydraulics along the outside of meander bends during flood events. Potential locations are located on the insides of large meander bends between RMs 0.5 and 2.0. Further analysis is required to understand excavation requirements and the potential for mainstem log jams to help activate these areas. **Conservation**: Although this project area is one of the most developed within the assessment area, there are still large undeveloped parcels or portions of parcels that could potentially be further developed. Because of the high fish use (migration and rearing) and restoration potential of these reaches, any undeveloped parcels within riparian zones or floodplains in this area should be viewed as high priority for protection. The large forested inside meander bends from 0.5 to 2.0 are relatively well-functioning and warrant protection of existing conditions at the least. The large cleared inside meander bend/floodplain on river-right between RM 0.3 and 1.0 has been heavily impacted but would benefit from protections that would prevent new development and would allow for vegetative and habitat restoration actions.

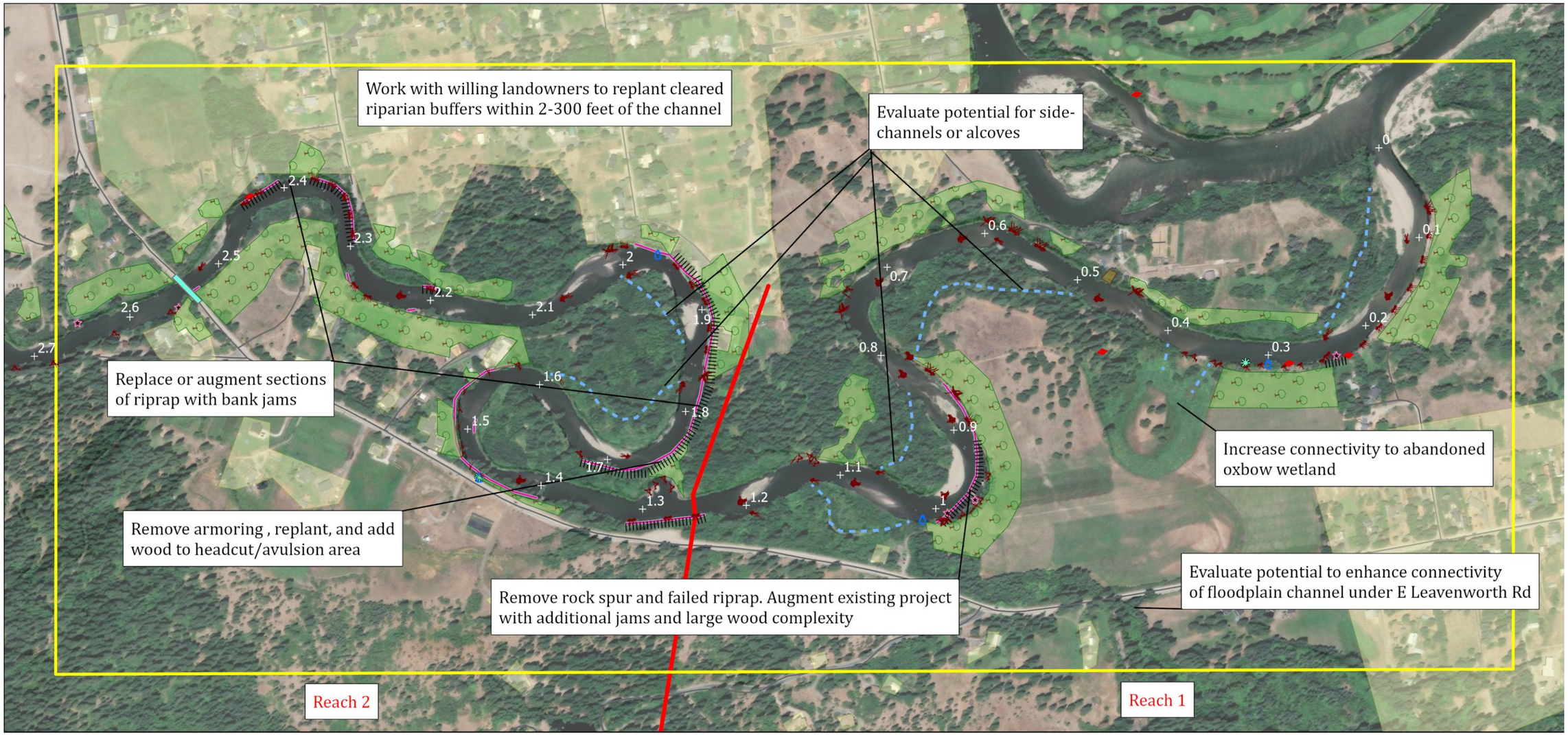
Reach	River Miles	Project Name	Project Description
3	2.7 – 4.3	*Hatchery*	The hatchery project has some of the greatest uplift potential of any project in the assessment area for the channel, riparian zone, and floodplain reconnection. Some of the actions described and mapped in this strategy may require potential changes to the fish collection system and an alternate location/means for flow monitoring through the site. It is acknowledged that modifications to these systems would require close coordination with the hatchery and other various parties, and would require significant planning, design, and construction costs to make sure multiple objectives are achieved. A range of different restoration options are described below. The most comprehensive alternative at this site with the most ecologic and geomorphic uplift includes removing the hatchery diversion canal, the downstream canal spillway, and both dam structures #2 and #5 as well as the remnant pieces of structures #3 and #4. The dam Structure #2 location would be converted to a flow monitoring station. The fish trapping function at dam Structure #5 would be replaced at an appropriate location, ideally with a seasonally operated structure that allows for the free movement of fish and bed sediments throughout most of the year. In the currently leveed and graded area between the left (west) side of the existing canal and the natural channel, anthropogenic fill and features would be removed and grading performed to recreate a connected floodplain with diverse topography able to support a variety of ecologically beneficial conditions such as riparian zone, potentially wetlands, and floodplains of varied inundation frequencies. New side-channel(s) through the re-created floodplain would provide quality off-channel habitat and floodplain/groundwater recharge, including design to support groundwater recharge of the existing wells used by the hatchery. An alcove that extends deep pool habitat at the downstream end of the project could also provide additional quality off-channel habitat refuge and rearing. A constructed riffle at the upstream end of the project area may be required to maintain channel grade for side channel activation. The addition of large wood in the mainstem channel and newly created side channel(s) would add cover and complexity. The long-term sustainability of this scenario would, like all projects, require further evaluation, modeling, and analysis. The area would be revegetated with native vegetation communities. This is the alternative that is portrayed in the project map later in this section. This alternative has feasibility challenges and associated high costs due to the infrastructure modifications and grading that would be required. There are also challenges associated with fulfilling multiple goals and objectives at this site, including water management. Other alternatives include: moderate uplift = keeping the canal but removing one or both mainstem dams (Structures #2 and #5) and replacing #2 with a roughened channel and #5 with another fish collection system if needed, or minimal uplift = keeping the canal and the dams and only adding large wood structures to the existing natural channel. This action has the most feasibility of the alternatives. Potential restoration work downstream of Structure #5 could occur relatively independent of what occurs upstream. There are currently rock spurs with a few pieces of large wood, providing minimal ecological benefit along the river-left bank downstream of the spillway (canal return). These spurs could be replaced or enhanced with habitat- enhancing large wood jams, improving margin complexity and cover habitat. Riparian areas could be planted with more robust native vegetation. A small island complex on river-right just downstream of Structure #5 could be enhanced with apex jams and complexity wood to help maintain and increase split flows, scour pools, and trap and sort gravels and sediments. The size and depth of the large pool at the spillway would need to be maintained as this is an important and productive tribal fishing area. Fishing access in general in this vicinity would need to be maintained. **Conservation**: Most of this project area is National Fish Hatchery land except for a couple of parcels that may be necessary to perform restoration actions, depending on the scale of the restoration. The primary parcel that would allow for the larger site restoration effort that may be beneficial to acquire is the private parcel at the upstream end between the canal and the natural channel. The other parcel is on the right-bank at the downstream end. In lieu of acquisition, cooperation from these landowners may be necessary to accomplish certain restoration actions.
4-5	4.4 – 5.4	*Tunnel*	Between RM 4.4 – 4.7 the channel geomorphology provides opportunity to enhance habitat with the addition of large wood at island apexes and within existing side channels. The private property on both sides of the channel will require access permissions. An established RV park and the related armored bank limit action that would notably alter inundation patterns here. However, riparian restoration along the front of the RV park, as well as other cleared areas would benefit long-term function. Upstream of RM 4.7, the channel is relatively steep, boulder-dominated, and confined by hillslopes and extended sections of riprap armoring along a pipeline. There are numerous pools with large boulders where large wood could be braced or wedged between boulders to provide habitat cover and complexity. However, wood would create only minor geomorphic response and should be considered relatively temporary. Wood could also be braced against standing riparian trees in some locations or extended into pools from high banks. Access would be challenging due to steep banks down from roadway or lack of access on opposite (south) bank.

Reach	River Miles	Project Name	Project Description
7	7.6 – 8.3	*Trident*	From RM 7.6 - 7.8 the channel is lower gradient and there is potential for large wood placements and retention for cover and complexity, as well as for geomorphic functions including gravel capture and pool scour. Placement of large wood is an option in specific locations where flow hydraulics and existing boulder or bank ballasting provide structural support. The large pools on river-left from RM 7.9 to 8.1 would benefit from the addition of large wood as cover and complexity. However, access and conflict with recreation (swimming) could be challenging. On river-right near RM 7.95 is a private roadway that is armored along the channel and also a riprap spur that blocks the entrance to a short side-channel (~300 ft long). This spur could be removed to re-activate the side channel for high-flow refuge and added quality habitat. There may be some residential structure conflicts, but these may be temporary seasonal structures.
8-9	8.65 – 9.9	*Eightmile*	There is a channel scar depression river-right set within the downstream portion of the terrace upstream of the Rat Creek Moraine near RM 8.7-8.8. There may be the potential to connect this as a side-channel or as a groundwater-fed channel. Survey and analysis is required to understand the amount of excavation that would be required. There is a floodplain on river right near RM 9.8 developing on the remnants of landslide debris contributions. Enhancement of the existing high-flow side channel with an inlet jam (RM 9.86) could promote additional floodplain connectivity and development. Access could be challenging. There is a side-channel through the campground that starts on river-left near RM 9.1 that has been disconnected at the inlet except for very high flows. Connectivity could be enhanced via inlet excavation. There is a lot of campground-related recreational use in this area that would make this challenging. There are several areas noted in the map where placed large wood could provide cover and complexity to existing pools. There are other areas, such as in the split-flow section RM 9.1-9.3 and downstream that are low gradient planebed sections that are dominated by small boulders and cobbles. Wood structures that extend from the banks and sit tight to the channel could be effective at trapping and sorting sediments including spawning gravels. In many areas, banks are low and structures may be able to be ballasted by stacking wood above high flow levels. Boulder ballast may also be necessary to anchor wood placements. The split-flow sections around the island provide a good opportunity for wood placements given the lower energy than the single-thread sections.
10	10.4 – 11.3	*Bridge Creek*	In the river-right floodplain from ~RM 10.7-10.8 there is a levee, fill, cleared areas, a concrete pad, and other features that suggest the decommissioning of a campground or other prior use of this area. Groundwater monitoring stations (PVC standpipes) were observed in this area, suggesting that investigations regarding the restoration potential of this area are underway. There are channel scar depressions in this floodplain, and potential for connected side-channels or groundwater-fed channels in this area, pending further investigation. Preliminary modeling suggests this surface gets wetted at the 25-year event and likely more frequently. There are numerous low gradient planebed sections that are dominated by small boulders and cobbles. Wood structures that extend from the banks and sit tight to the channel could be effective at trapping and sorting sediments including spawning gravels. In many areas, banks are low and structures may be able to be ballasted by stacking wood above high flow levels, including mid-channel apex-type structures meant to split flows. Boulder ballast may also be necessary to anchor wood placements. Large wood structures could be placed downstream of the Eightmile Bridge, similar to upstream of the bridge. However, this area runs along campsites at Bridge Creek Campground and there is heavy recreational use. Structures were therefore not depicted on the map for this section.
12-14	12.2 – 14.7	*Johnny Victoria*	This is a long project area, extending 3.4 miles from RM 11.4 to 14.8 and comprising all of reaches 11-14. These are moderate-to-high gradient (1.5-4%) channels and mostly confined. The channels are dominated by small boulders and cobbles, much of it planebed, with a few step-pool sections. The reaches are lacking in large wood but the high energy makes it challenging for wood restoration. There are two primary types of potential wood installations that were identified: There are numerous low gradient planebed sections that are dominated by small boulders and cobbles. Wood structures that extend from the banks and sit tight to the channel could be effective at trapping and sorting sediments including spawning gravels. In many areas, banks are low and structures may be able to be ballasted by stacking wood above high flow levels, including mid-channel apex-type structures meant to split flows. Boulder ballast may also be necessary to anchor wood placements. Cover and complexity wood in pools, including in some of the larger step-pools and especially in a few longer pools that lack complexity, such as near RM 12.9. There may be numerous other potential sites for cover and complexity treatments that could take advantage of easier access and willing landowners. Not all of the potential sites were identified for wood treatment in the project map.

Reach	River Miles	Project Name	Project Description
15	14.85 – 15.8	*Ida*	This is a low gradient section with restoration opportunities associated with campground infrastructure, side-channel connectivity, and large wood additions to encourage geomorphic processes and habitat complexity. At the upstream portion of the project area, the road has been relocated far up the river-left hillslope, opening up restoration opportunities. At the upstream end on river-left is the former road alignment with at least one area with remnant armoring that could be removed, plus opportunities to enhance vegetation conditions on the former roadbed. At Ida Creek Campground on river-left, there is riprap and a berm/fill that could be removed to enhance connectivity of the downstream floodplain. In the downstream portion, from RM 14.85 to 15.2, there may be opportunities to enhance or create side-channel and backbar channels on both sides of the river using log jams to divert water and select excavation in the floodplain. Bar apex and bank jams throughout most of the project area could be used to create split-flow conditions, encourage sediment/gravel deposition, direct flow into banks to recruit trees, and sustain existing or create new mid-channel islands. Other wood placements can be used to enhance cover and complexity in existing pools and glides.
15-16	15.85 – 17.2	*Doctor*	Similar to downstream (Ida Project), this is a low gradient section with significant restoration opportunities, including removing human fill and features and working with existing dynamic processes to enhance complexity and habitat. The road has been relocated far up the river-left hillslope, opening up restoration opportunities. A groundwater-level observation tube was observed on site during the field survey, indicating that evaluation for potential restoration efforts are underway. At the upstream end of the abandoned road alignment, there is old fill associated with the road and other activities in the floodplain. This fill could be removed and a new side-channel alignment may be possible in an old meander scar in the left-bank floodplain (RM 16.3-16.5), pending further analysis of required excavation quantities. There is impaired riparian vegetation throughout this floodplain related to the old road and dispersed recreational uses. Replanting would help to restore the forested riparian and floodplain vegetation community. At the Doctor Creek slide area (~RM 16.1-16.4), there are still active dynamics occurring since the 2008 slide that washed out the road, changed the channel path, and activated new side channels. Wood additions could be used to work with these dynamics, including apex and bank jams downstream of the slide location to capture wood that originated from the slide and jams to better activate existing side-channels that are only wetted during higher flows. Bar apex and bank jams throughout most of the project area could be used to create split-flow conditions, encourage sediment/gravel deposition, direct flow into banks to recruit trees, and sustain existing or create new mid-channel islands. Other wood placements can be used to enhance cover and complexity in existing pools and glides.
17-18	17.7 – 19.1	*Jack*	The upstream portion (RM 18.8 to 19.2) is a confined bedrock canyon. There is little work to be done in the channel through this section but there has been past clearing of riparian trees on the river-right bank through here where revegetation work would benefit long-term shade and wood recruitment. Downstream of the canyon to RM 18.2 is a moderate gradient planebed section that is dominated by small boulders and cobbles. Wood structures that extend from the banks and sit tight to the channel could be effective at trapping and sorting sediments including spawning gravels. In many areas, banks are low and structures may be able to be ballasted by stacking wood above high flow levels, including occasional mid-channel apex-type structures meant to split flows. Boulder ballast may also be necessary to anchor wood placements. Downstream of RM 18.2 is lower gradient with more pool-riffle morphology with higher complexity including active channel splitting around a large forested island complex. There are numerous existing large wood jams. Additional large wood could be used to build off of these existing processes, including bar apex jams to create split-flow conditions, encourage sediment/gravel deposition, direct flow into banks to recruit trees, and sustain existing or create new mid-channel islands. Other wood placements can be used to enhance cover and complexity in existing pools and glides.

Reach	River Miles	Project Name	Project Description
19-20	19.2 – 22	*Boggy Black Pine*	This project area is a low gradient (<0.5%) pool-riffle channel with relatively abundant existing large wood, log jams, and complex habitats supported by active lateral channel dynamics. However, much of the wood is smaller than needed to act as key pieces and is relatively mobile. Adding log jams throughout the project area would help trap and retain large wood moving through the system and would build off of existing conditions to even further improve habitat and channel complexity. Constructed log jams throughout most of the project area could be used to create/maintain split-flow conditions, direct flow into side-channels, and encourage gravel deposition. There are some older tree stands, including some pockets of old growth, where jams could direct flow into banks to recruit trees. Other wood placements can be used to enhance cover and complexity in existing pools and glides. There is an area of potential fill on river-right near RM 19.35, where an old road/trail accesses the river. According to the hydraulic model, this fill obstructs the continuity of floodplain flow on this surface. This needs further investigation to understand the origin of the material, but if it is fill, then its removal would help to reconnect this surface. Construction access is challenging throughout the reach, especially upstream of the end of the roads (located on both sides but set back from channel) near RM 21.3. Upstream of RM 21.6 is within the Alpine Lakes Wilderness, which significantly limits access options. The treatment types vary depending on these access constraints. The work located in the wilderness may need to include felling of riparian trees with hand tools, or helicopter wood loading, if allowed. Downstream of the wilderness boundary, occasional access routes are possible from the roads on either side of the channel, but there would be impacts to riparian and floodplain vegetation. Helicopter placements and felling of streamside trees may also be a viable option. At the downstream end river-right there is a dispersed camping area where there has been past clearing of riparian trees; revegetation work would benefit long-term shade and wood recruitment.

2.4 PROJECT MAPS



Icicle Creek Reach Assessment

Project Opportunities

Eiszapfen Bach

N

0 0.1 0.2 Miles

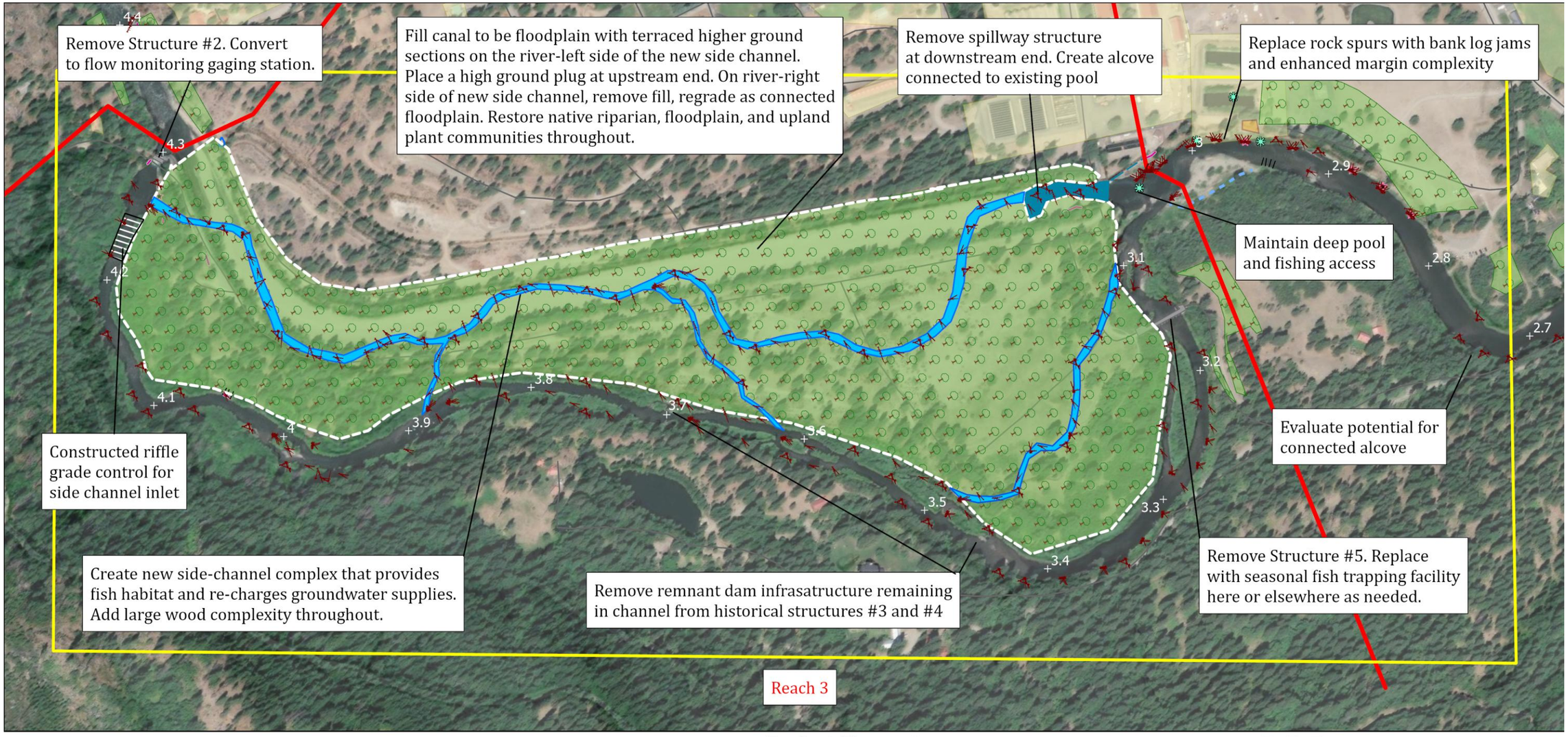
Project Elements

- Side Channel Activation
- Remove or Modify Armoring
- Fill Removal
- Riparian Restoration
- Individual logs
- Complexity jams
- Whole trees
- Apex jams
- Bank jams

These are preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.

Built Features

- Water Withdrawals
- Spur Dikes
- Municipal Water Outtake Structure
- Discharge Outfalls
- Culverts
- Previous Restoration Effort
- Roads
- Cement Wall
- Levee
- Bank Armoring
- Road Debris Boulders
- Canals
- Recreational Areas
- Structures
- Bridges
- Dams



Icicle Creek Reach Assessment

Project Opportunities

Hatchery

N

0 0.1 0.2 Miles

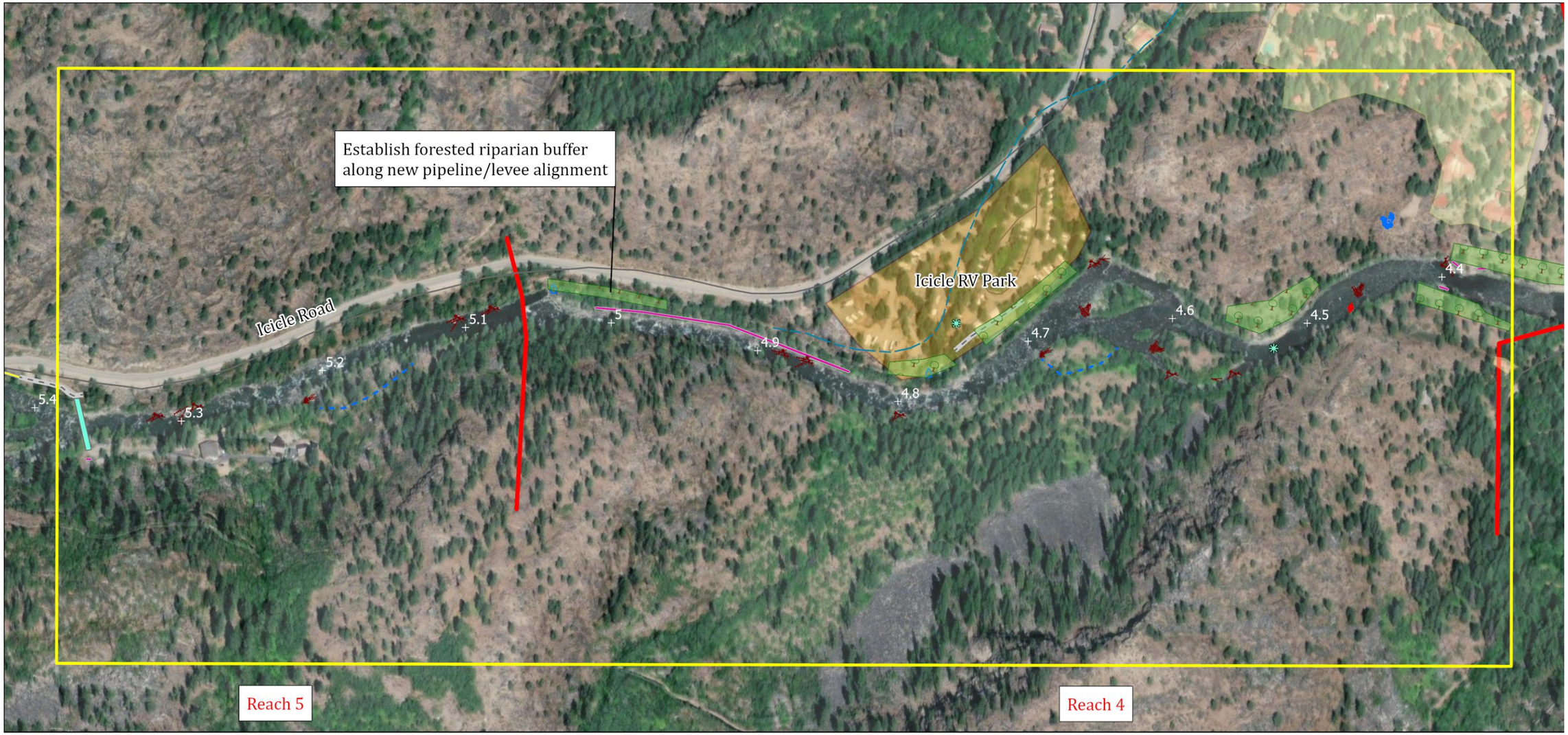
Project Elements

- Side Channel Activation
- Remove or Modify Armoring
- Fill Removal
- Riparian Restoration
- Individual logs
- Complexity jams
- Whole trees
- Apex jams
- Bank jams

These are preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.

Built Features

- Water Withdrawals
- Spur Dikes
- Municipal Water Outtake Structure
- Discharge Outfalls
- Culverts
- Previous Restoration Effort
- Roads
- Cement Wall
- Levee
- Bank Armoring
- Road Debris Boulders
- Canals
- Recreational Areas
- Structures
- Bridges
- Dams



Icicle Creek Reach Assessment

Project Opportunities

Tunnel

N

0 0.1 0.2 Miles

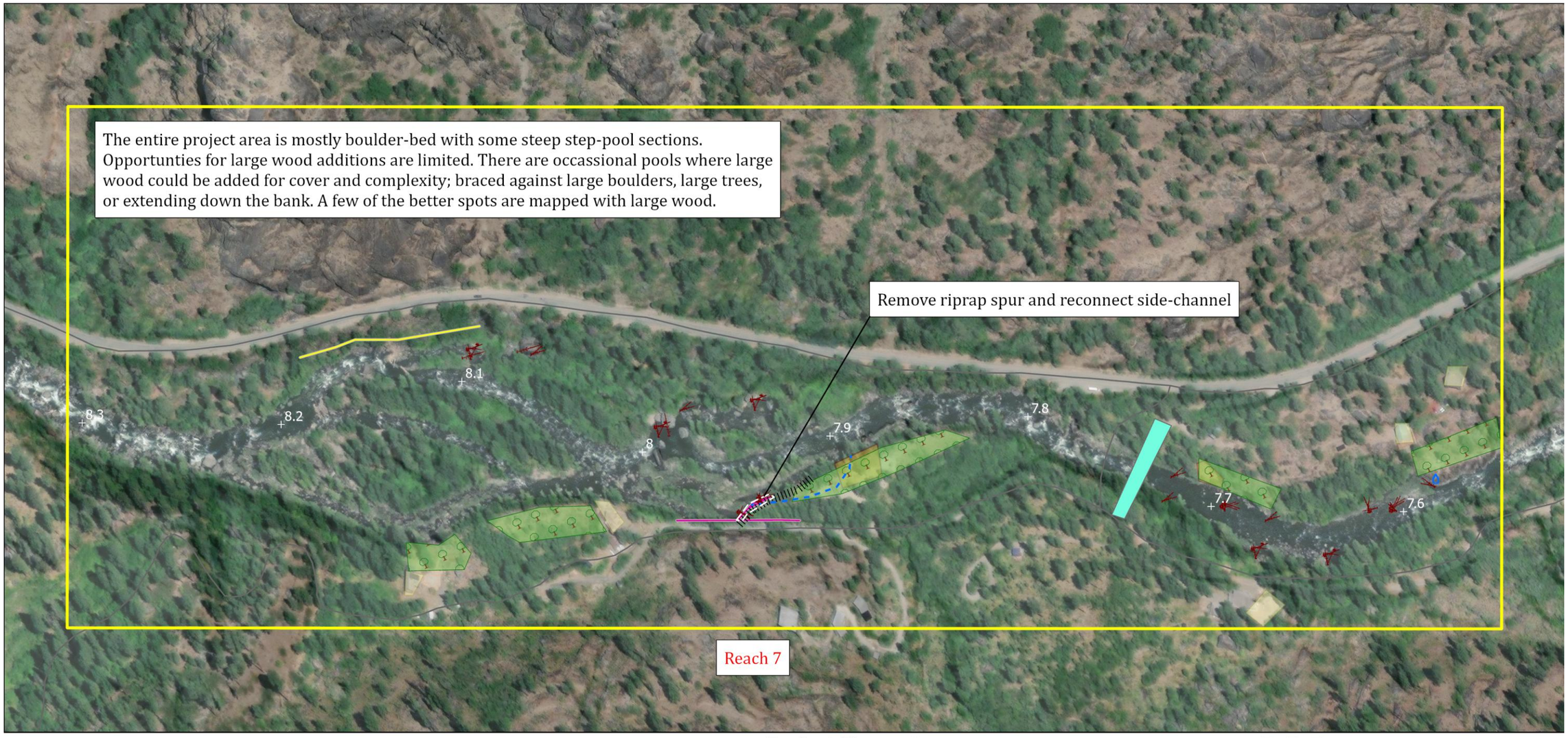
Project Elements

- Side Channel Activation
- Remove or Modify Armoring
- Fill Removal
- Riparian Restoration
- Individual logs
- Complexity jams
- Whole trees
- Apex jams
- Bank jams

These are preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.

Built Features

- Water Withdrawals
- Spur Dikes
- Municipal Water Outtake Structure
- Discharge Outfalls
- Culverts
- Previous Restoration Effort
- Roads
- Cement Wall
- Levee
- Bank Armoring
- Road Debris Boulders
- Canals
- Recreational Areas
- Structures
- Bridges
- Dams



Icicle Creek Reach Assessment

Project Opportunities

Trident

N

0 0.1 0.2 Miles

Project Elements

- Side Channel Activation
- Remove or Modify Armoring
- Fill Removal
- Riparian Restoration
- Individual logs
- Complexity jams
- Whole trees
- Apex jams
- Bank jams

These are preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.

Built Features

- Water Withdrawals
- Spur Dikes
- Municipal Water Outtake Structure
- Discharge Outfalls
- Culverts
- Previous Restoration Effort
- Roads
- Cement Wall
- Levee
- Bank Armoring
- Road Debris Boulders
- Canals
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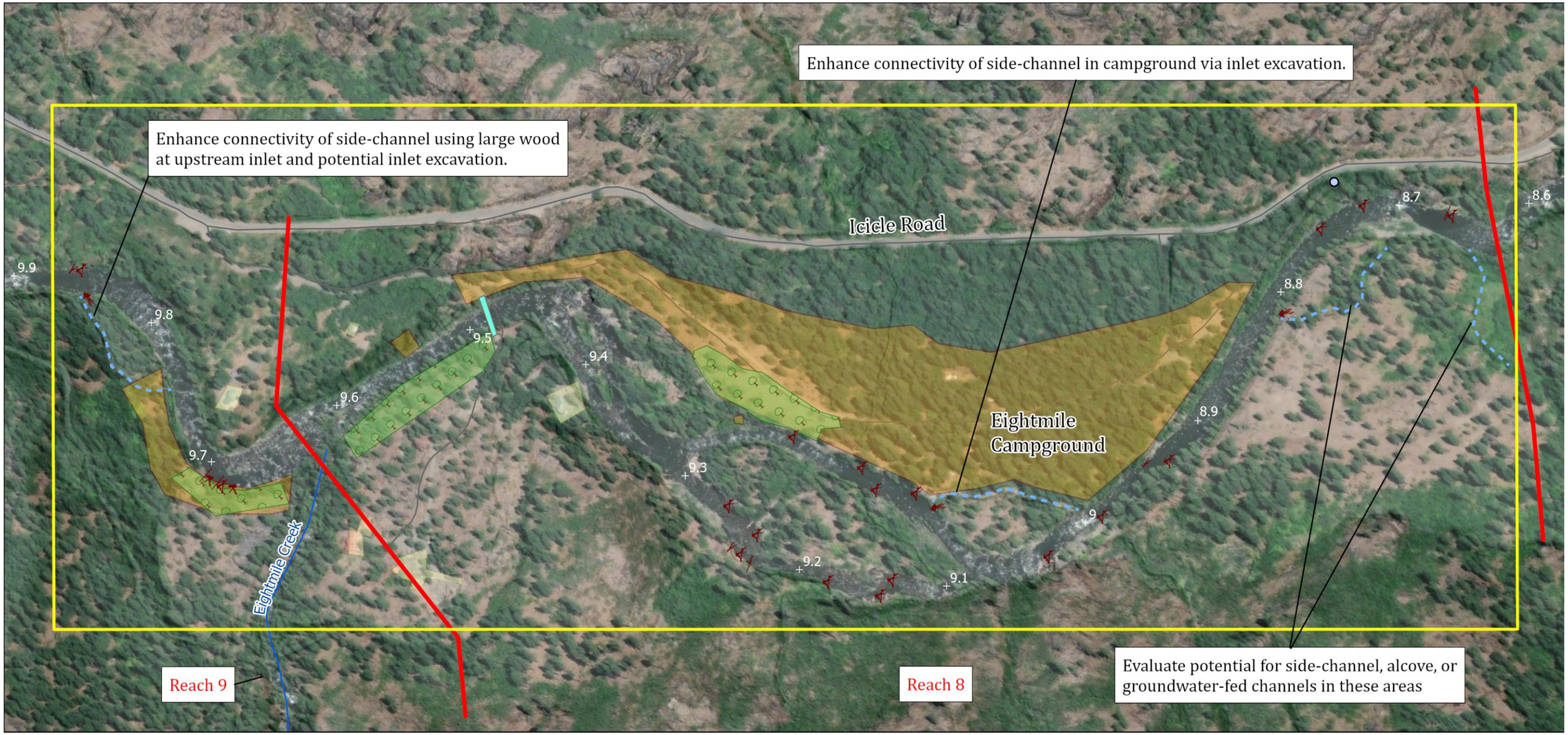

Icicle Creek Reach Assessment

Project Opportunities

Eightmile

N

0 0.1 0.2 Miles

Project Elements

- Side Channel Activation
- Remove or Modify Armoring
- Fill Removal
- Riparian Restoration
- Individual logs
- Complexity jams
- Whole trees
- Apex jams
- Bank jams

These are preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.

Built Features

- Water Withdrawals
- Spur Dikes
- Municipal Water Outtake Structure
- Discharge Outfalls
- Culverts
- Previous Restoration Effort
- Roads
- Cement Wall
- Levee
- Bank Armoring
- Road Debris Boulders
- Canals
- Recreational Areas
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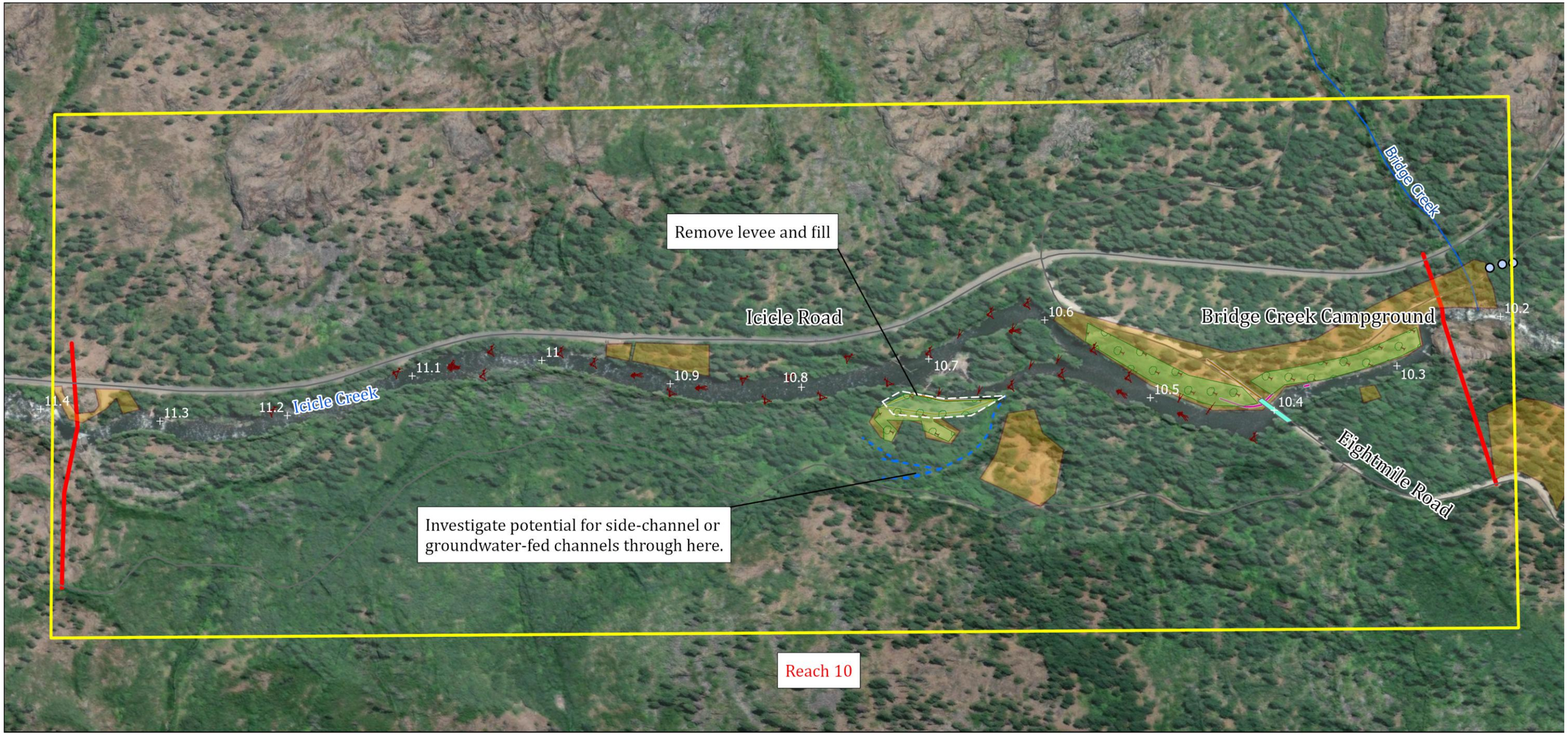
- Dams



Icicle Creek Reach Assessment

Project Opportunities

Bridge Creek

N

0 0.1 0.2 Miles

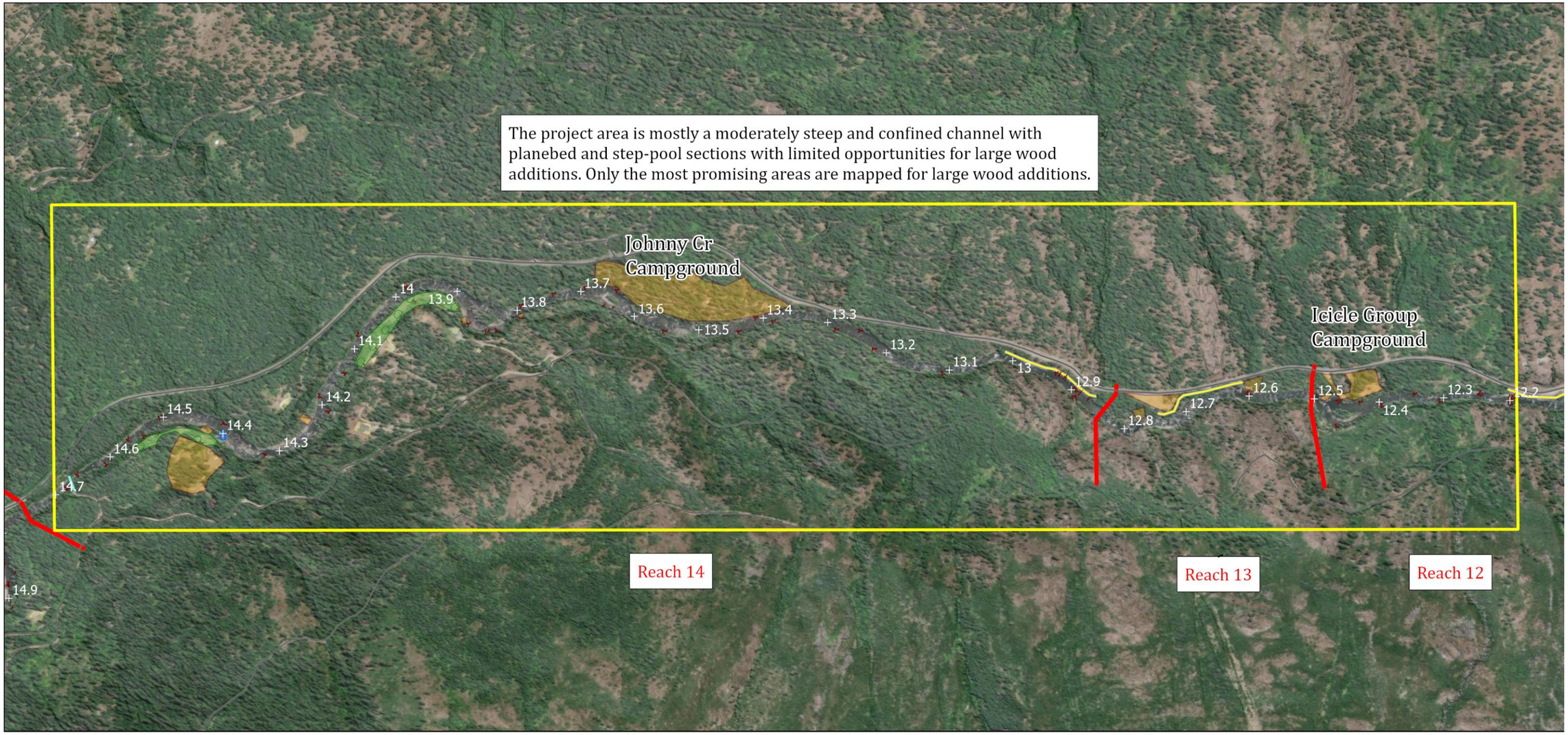
Project Elements

- Side Channel Activation
- Remove or Modify Armoring
- Fill Removal
- Riparian Restoration
- Individual logs
- Complexity jams
- Whole trees
- Apex jams
- Bank jams

These are preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.

Built Features

- Water Withdrawals
- Spur Dikes
- Municipal Water Outtake Structure
- Discharge Outfalls
- Culverts
- Previous Restoration Effort
- Roads
- Cement Wall
- Levee
- Bank Armoring
- Road Debris Boulders
- Canals
- Recreational Areas
- Structures
- Bridges
- Dams



Icicle Creek Reach Assessment

Project Opportunities

Johnny Victoria

N

0 0.1 0.2 Miles

Project Elements

- Side Channel Activation
- Remove or Modify Armoring
- Fill Removal
- Riparian Restoration
- Individual logs
- Complexity jams
- Whole trees
- Apex jams
- Bank jams

These are preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.

Built Features

- Water Withdrawals
- Spur Dikes
- Municipal Water Outtake Structure
- Discharge Outfalls
- Culverts
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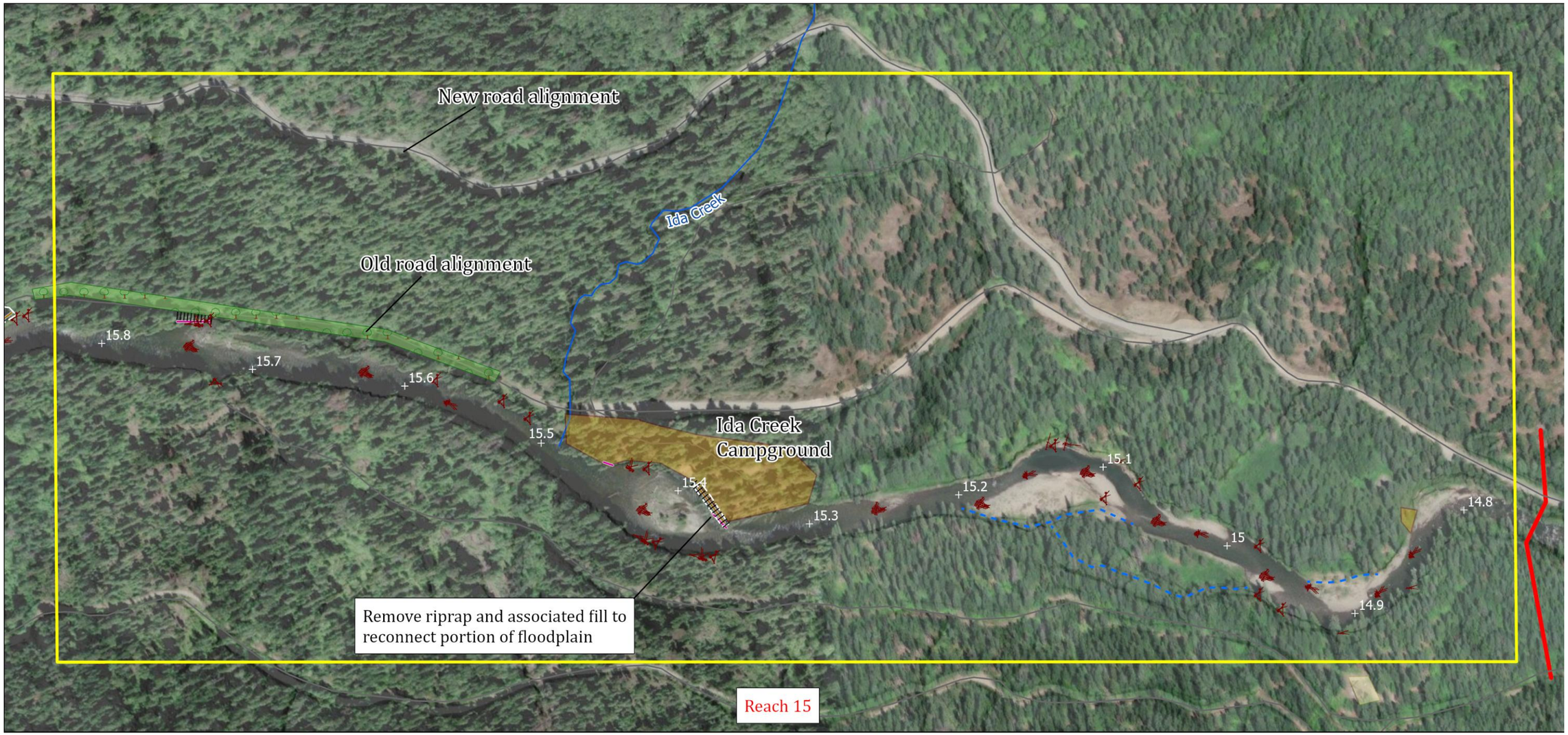

Icicle Creek Reach Assessment

Project Opportunities

Ida

N

0 0.1 0.2 Miles

Project Elements

- Side Channel Activation
- Remove or Modify Armoring
- Fill Removal
- Riparian Restoration
- Individual logs
- Complexity jams
- Whole trees
- Apex jams
- Bank jams

These are preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.

Built Features

- Water Withdrawals
- Spur Dikes
- Municipal Water Outtake Structure
- Discharge Outfalls
- Culverts
- Previous Restoration Effort
- Roads
- Cement Wall
- Levee
- Bank Armoring
- Road Debris Boulders
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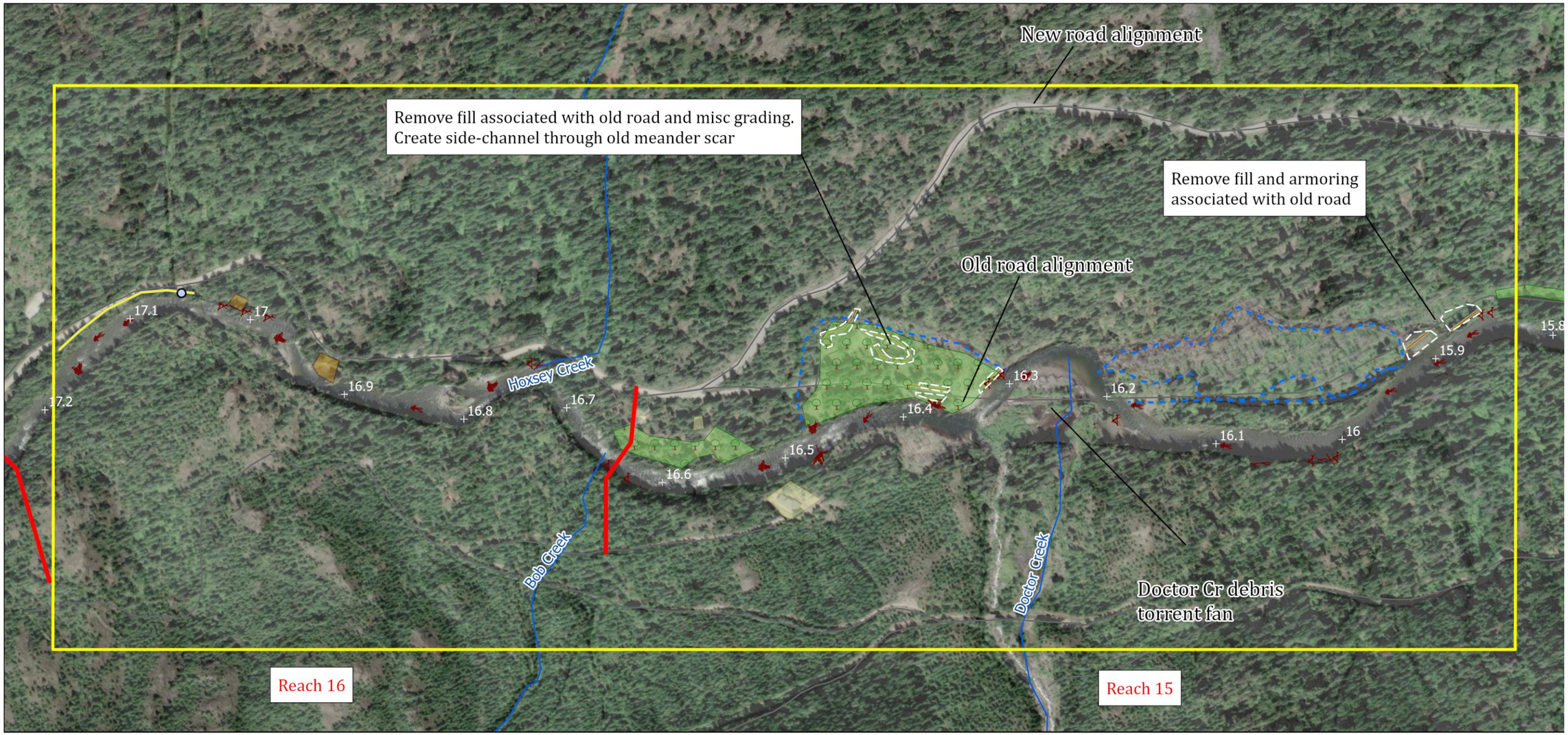

Icicle Creek Reach Assessment

Project Opportunities

Doctor

N

0 0.1 0.2 Miles

Project Elements

- Side Channel Activation
- Remove or Modify Armoring
- Fill Removal
- Riparian Restoration
- Individual logs
- Complexity jams
- Whole trees
- Apex jams
- Bank jams

These are preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.

Built Features

- Water Withdrawals
- Spur Dikes
- Municipal Water Outtake Structure
- Discharge Outfalls
- Culverts
- Previous Restoration Effort
- Roads
- Cement Wall
- Levee
- Bank Armoring
- Road Debris Boulders
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- Bridges
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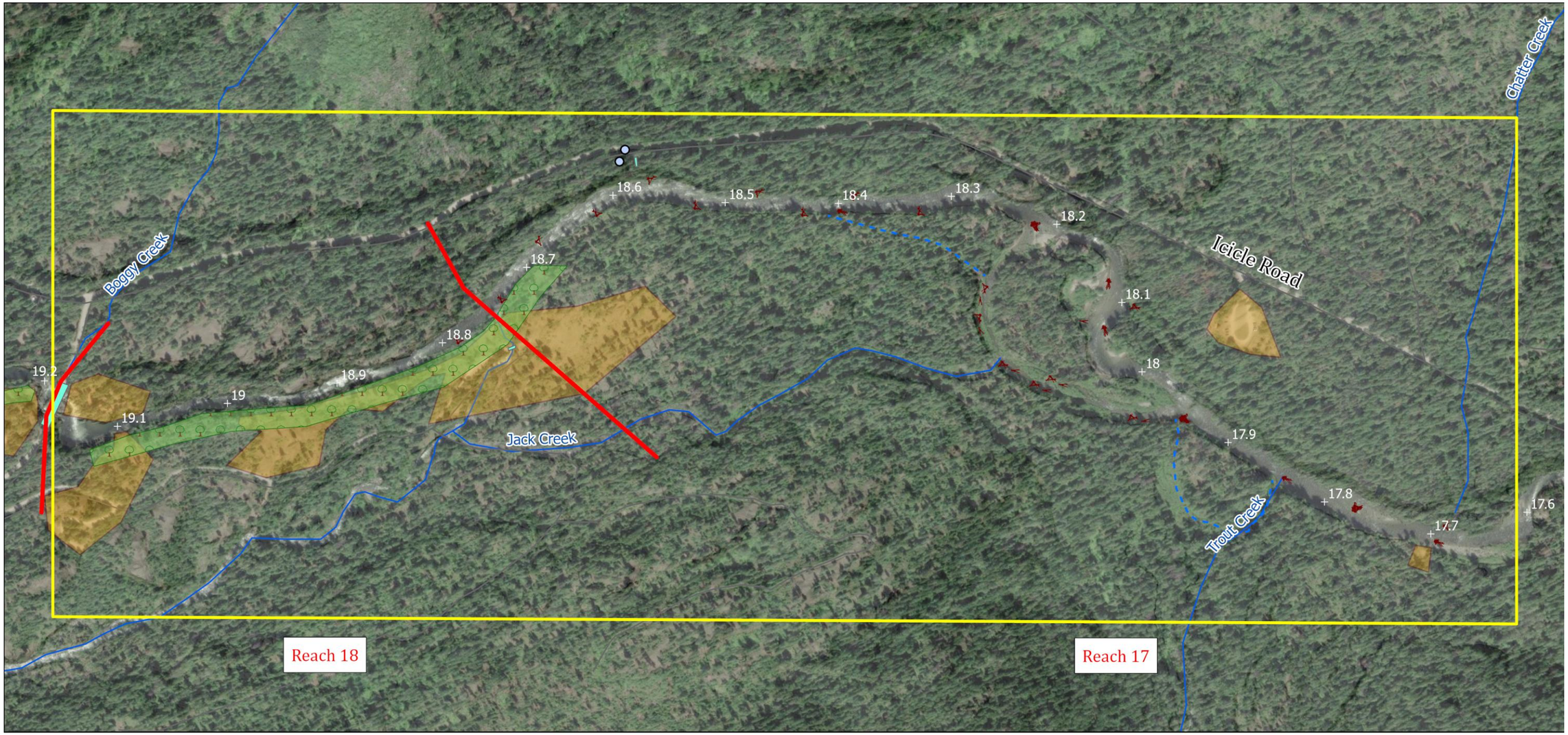

Icicle Creek Reach Assessment

Project Opportunities

Jack

N

0 0.1 0.2 Miles

Project Elements

- Side Channel Activation
- Remove or Modify Armoring
- Fill Removal
- Riparian Restoration
- Individual logs
- Complexity jams
- Whole trees
- Apex jams
- Bank jams

These are preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.

Built Features

- Water Withdrawals
- Spur Dikes
- Municipal Water Outtake Structure
- Discharge Outfalls
- Culverts
- Previous Restoration Effort
- Roads
- Cement Wall
- Levee
- Bank Armoring
- Road Debris Boulders
- Canals
- Recreational Areas
- Structures
- Bridges
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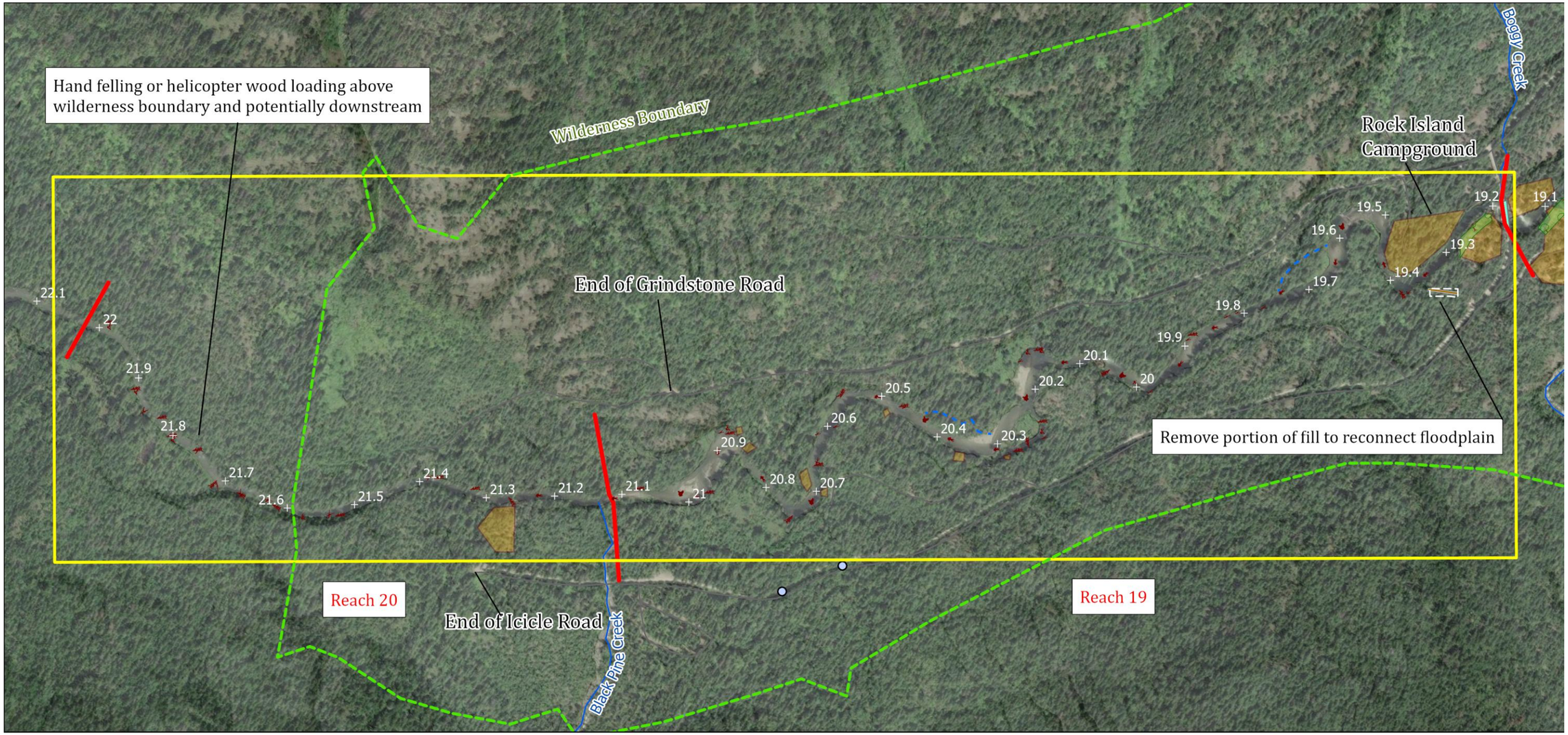

Icicle Creek Reach Assessment

Project Opportunities

Boggy Black Pine

N

Miles

0 0.1 0.2

Project Elements

- Side Channel Activation
- Remove or Modify Armoring
- Fill Removal
- Riparian Restoration
- Individual logs
- Complexity jams
- Whole trees
- Apex jams
- Bank jams

These are preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations.

Built Features

- Water Withdrawals
- Spur Dikes
- Municipal Water Outtake Structure
- Discharge Outfalls
- Culverts
- Previous Restoration Effort
- Roads
- Cement Wall
- Levee
- Bank Armoring
- Road Debris Boulders
- Canals
- Recreational Areas
- Structures
- Bridges
- Dams

3 Project Prioritization and Ranking

3.1 PRIORITIZATION MATRIX

Project Area						Benefit Score									Cost Score	Cost Benefit	Feasibility Designation	
						Restoration Gap Analysis				Existing and Potential Fish Use		Root Causes		Total Benefit Score				
Tiers	Project Name	Reach	Downstream RM	Upstream RM	Total Length (mi)	Existing Condition (1-7)	Achievable Target (1-7)	Final Gap Score (Target - Existing) (0-6)	Rationale/ assumption	Score (1-3)	Rationale/ assumption	Score (1-3)	Rationale/ assumption		Cost Score	Benefit-to-Cost Score	Feasibility Designation	Rationale/ assumption
Tier 1	Bridge Creek	10	10.30	11.40	1.10	4.5	6	1.5	Some impairment of channel and floodplain function due to channel modification and floodplain disconnection and riparian vegetation clearing, resulting in reduced habitat complexity and loss of large wood in the channel. Recovery is relatively high especially river-right levee and off-channel potential; less so at Bridge Creek campground assuming bridge and campground remain.	2.5	Above boulder field (limits passage for some species). Less confined and lower gradient than up and downstream with some potential off-channel habitat. Could be important stepping-stone habitat within otherwise canyon section.	2.5	Removal of river-left levee, and riparian restoration, would address root causes. Large wood supplementation would not address the processes that create and maintain it over time. Side-channel creation in river-left floodplain would partially address root causes.	6.5	2	3.3	High	No major constraints. National Forest
	Doctor	15,16	15.80	17.20	1.40	4.5	6	1.5	Project area is impacted by fill/berms associated with prior uses, the old road bed and related impacts to riparian veg, some residential impacts, and lack of large wood in channel. Area has the potential for signifcant improvement given that much of the human infrastructure has been removed. Doctor Cr slide is creating healthy dynamism that can be built upon for high quality off-channel habitat and floodplain connections.	2.5	Above boulder field (limits passage for some species). Low gradient with floodplains, with some existing and abundant potential off-channel habitat.	2.5	Removal of fill and armoring and riparian work addresses root causes. Large wood work does not address the processes that create and maintain LW over the long-term.	6.5	2	3.3	High	Mostly public land. Road mostly far from channel so few impacts to existing infrastructure
	Hatchery	2,3	2.70	4.40	1.70	1	6	5	Impairment of channel and riparian function due to the LNFH and associated infrastructure, including dams, roads, diversions, canals, levees, and riparian vegetation clearing have resulted in fish passage issues, minimal habitat complexity, a lack of large wood in the channel, and limited natural geomorphic processes. However, the hatchery project has some of the greatest uplift potential of any project in the study area due to the level of impairment and the magnitude of enhancement that could be achieved with comprehensive restoration treatments.	3	Reach is highly used by multiple species in the downstream portion, but dams block passage upstream. Potential use is very high.	3	The primary root causes of impairments (canal,dams, fill) would be removed/addressed as part of the project, assuming the more aggressive is approach is taken.	11	3.5	3.1	Moderate	Would require significant commitment from LNFH and funders.
	Eightmile	8,9	8.60	9.90	1.30	4.5	6	1.5	The primary impacts are riparian and recreational disturbances, a couple of side-channel disconnections, and lack of large wood. Impacts are limited due to partial confinement and moderate gradient.	1.5	Above boulder field (limits passage for some species), partially confined and moderately steep, but some side-channel and potential off-channel habitat compared to upstream and downstream.	2.5	Removal of side-channel inlet fill, and riparian restoration, would address root causes. Large wood supplementation would not address the processes that create and maintain it over time.	5.5	2	2.8	Moderate-High	Mix of private and public lands.
	Ida	15	14.80	15.80	1.00	5	5.5	0.5	Project area is impacted by fill associated with the campground, the old road bed and related impacts to riparian veg, and lack of large wood in channel. Area has the potential for signifcant improvement given that much of the human infrastructure has been removed, though campground and road is expected to still remain at downstream end.	2.5	Above boulder field (limits passage for some species). Low gradient with floodplains, with some existing and potential off-channel habitat.	2.5	Removal of riprap spur (and fill) and riparian work addresses root causes. Large wood work does not address the processes that create and maintain LW over the long-term.	5.5	2	2.8	High	Mostly public land

Project Area						Benefit Score									Cost Score		Cost Benefit	Feasibility Designation	
						Restoration Gap Analysis				Existing and Potential Fish Use		Root Causes							
Tiers	Project Name	Reach	Downstream RM	Upstream RM	Total Length (mi)	Existing Condition (1-7)	Achievable Target (1-7)	Final Gap Score (Target - Existing) (0-6)	Rationale/ assumption	Score (1-3)	Rationale/ assumption	Score (1-3)	Rationale/ assumption	Total Benefit Score	Cost Score (1-4)	Rationale/ assumption	Benefit-to-Cost Score	Feasibility Designation	Rationale/ assumption
Tier 2	Tunnel	4,5	4.40	5.40	1.00	5	6	1	The primary impacts are the diversion, riparian disturbance, and a lack of large wood, but the departure from historical conditions is lower due to the natural confinement and high gradient of the channel.	2.5	Current fish use is affected by the hatchery dams and diversions downstream, but potential fish use for multiple species is high since this is still below the boulder field, which limits the degree of passage for some speecies. However, the steep gradient and confinement limits fish use overall.	1	Addresses lack of large in-channel structure but does not address the processes that create and maintain it over the long-term. Riparian work addresses root causes.	4.5	2	Good access. No major constraints	2.3	Moderate	Access is challenging due to confinement (canyon) and some private lands.
	Trident	7	7.55	8.30	0.75	5	6	1	The primary impacts are riparian disturbance, a lack of large wood, and a riprap spur that is blocking a side channel inlet; but the departure from historical conditions is lower due to the natural confinement and high gradient of the channel.	1	Above boulder field (limits passage for some species) and mostly confined and steep, limiting fish use	2.5	Removal of riprap spur and riparian restoration would address root causes. Large wood supplementation would not address the processes that create and maintain it over time.	4.5	2	Generally good access, especially for riprap spur removal and riparian work.	2.3	Moderate-High	Mix of private and public lands.
	Jack	17,18	17.60	19.20	1.60	5	6	1	Project area has relarively few impacts. Primary impacts are from riparian clearing, recreational impacts on riparian areas, and loss of large wood. There is the potential for relatively high functioning conditions in project area.	2.5	Above boulder field (limits passage for some species). Low gradient with floodplains, with some existing and potential off-channel habitat.	1	Project is primarily addition of large wood. This work benefits instream habitat but does not address the processes that create and maintain LW over the long-term.	4.5	2	Good access. No major constraints	2.3	High	Mostly public land
	Eiszapfen Bach	1,2	0.00	2.70	2.70	2	4.5	2.5	Significant impairment of channel and riparian function due to riparian vegetation clearing, lost or reduced habitat complexity, lack of large wood in the channel, and limited off-channel habitat. Achievable target is moderate-to-high, decremented due to unlikelihood of widespread acquisitions that would be required for full recovery.	3	Reach is highly used for spawning and rearing for multiple species and the project would increase quality of in-channel aquatic habitat as well as expand quantity / access to off-channel habitat.	1	Addresses lack of large in-channel structure and lack of off-channel connections in some locations, but does not address the processes that create and maintain these over the long-term (wood recruitment, greater floodplain connectivity).	6.5	3	Large jams that restore habitat plus protect homes are expensive. Alternative of property acquisitions is very expensive.	2.2	Low-Moderate	Many private parcels and structures. High recreational use.
Tier 3	Boggy Black Pine	19,20	19.20	22.00	2.80	6	6.5	0.5	Project area has relarively few impacts. Primary impacts are from past logging and loss of instream large wood. There is the potential for relatively high functioning conditions in project area, especially given wilderness in upper portion.	2.5	Above boulder field (limits passage for some species). Low gradient with floodplains, with some existing and potential off-channel habitat.	1	Project is primarily addition of large wood. This work benefits instream habitat but does not address the processes that create and maintain LW over the long-term.	4	3	Some access challenges due to lack of roads and wilderness in upstream portion	1.3	Moderate-High	Public land but feasibility somewhat affected by wilderness.
	Johnny Victoria	12,13,14	12.20	14.70	2.50	5	6	1	The primary impacts are riparian disturbance, a lack of large wood, and riprap/road debris boulders along Icicle Road; but the departure from historical conditions is lower due to the natural confinement and high gradient of the channel.	1	Above boulder field (limits passage for some species) and mostly confined and steep, limiting fish use	1	Addresses lack of large in-channel structure but does not address the processes that create and maintain it over the long-term. Riparian work addresses root causes, but it's limited.	3	3	Challenging access in steep canyon.	1.0	Moderate-High	Mostly public land but disturbance to banks and riparian zones may not be worth impact.

3.2 PROJECT RANKING METHODS

Step 1: **Benefit Score**: Projects are scored according to 3 benefit categories, which include a "recovery gap" category and 2 additional categories. Scores for each category are summed to obtain the ***Benefit Score***.

Step 2: **Cost Score**: Projects are given a ***Cost Score***, which reflects the overall *relative cost* for the project based on techniques, access, and construction feasibility issues.

Step 3: **Benefit-to-Cost Score**: Total benefit score (sum of all 4 benefit scores) is divided by the cost score to obtain the ***Benefit-to-Cost Score***.

Step 4: **Feasibility Designation:** Projects are given a ***Feasibility Designation*** based on the overall likely feasibility of being able to implement the project within a 10-year timeframe.

Benefit Score

The Benefit Score includes the summation of scores from 3 categories. These include the Recovery Gap score (0-6 points), the Fish Use score (1-3 points), and the Root Causes score (1-3 points). The guidelines for scoring are provided below.

Recovery Gap

Existing Condition Rating (1-7)

1 – Very low ecosystem function and habitat quality. Highly altered systems.
2 – Low ecosystem function and habitat quality.
3 – Low-to-moderate ecosystem function and habitat quality.
4 – Moderate ecosystem function and habitat quality.
5 – Moderate-to-high ecosystem function and habitat quality.
6 – High ecosystem function and habitat quality.
7 – Very high level of natural ecosystem function and habitat quality. Pristine, unaltered systems.

Achievable Condition Rating (1-7)

These ratings use the same categories as above but reflect the future potential recovery trajectory. This is a rating of what can realistically be achieved given past and on-going impacts and constraints of land use, infrastructure, social acceptance, and ownership. Ratings should reflect an "optimistic potential scenario" in order to not discount large potential changes.

Final Gap Score (0-6)

This is simply the achievable condition rating minus the existing condition rating. This represents the gap that can be filled between existing and target conditions through restoration measures.

Fish Use

3 – High existing or potential productivity area for spawning or rearing for multiple species
2 – Moderate existing or potential productivity area for one or more species
1 – Low existing or potential productivity area for one or two species

Root Causes

3 – Restoration of root causes and key physical processes that create and maintain habitat over time
2 – Partial restoration of root causes
1 – Primarily a structurally-focused restoration strategy that doesn't significantly address underlying causes

Cost Score

The cost score reflects the relative cost for the project based on techniques, access, and feasibility issues. This is a relative cost, not an absolute cost, so the scale of the project is NOT factored into this score. The cost score ranges from 1 to 3, with 1 reflecting relatively lower cost projects. The following guidelines/examples can help to determine the cost score.

4 – High relative cost

- Requires high-cost techniques or materials (e.g., highly engineered log jams, extensive channel shaping, water crossings or bridges)
- Deep excavation or long-distance hauling of spoils
- Entails construction of additional new flood control or bank erosion features (e.g. set-back levees or buried rip-rap)
- Intensive de-watering requirements
- Limited, difficult, or remote access

2-3 – Moderate relative cost

- Uses moderate cost techniques (e.g. typical log jam structures)
- Moderate excavation and hauling distance of spoils
- Typical planting or invasive weed control
- Moderate access conditions
- Standard or no de-watering requirements

1 – Low relative cost

- Uses low cost techniques (e.g. non-ballasted log placements)
- Minimal excavation and hauling distance of spoils
- Little to no planting or weed control
- Easy access conditions
- No de-watering required
- Availability of free materials or volunteer labor

Benefit-to-Cost Score

The benefit-to-cost score is simply the benefit score divided by the cost score. This is a relative value used to compare project benefits.

Feasibility Designation

The feasibility designation is the overall likely feasibility of being able to implement the project within a 10-year timeframe. This is based on landownership, as well as economic, regulatory, political, social, permitting, or other considerations that are known to impact the feasibility of conducting projects within a reasonable timeframe. The feasibility designation is not used as part of the project scoring because feasibility issues may change over time and it is desirable to evaluate project benefits independent of feasibility. The designations include the following:

High feasibility

- No known feasibility issues.
- One or two landowners; or landowner(s) has already indicated willingness

Moderate feasibility

- There are potential feasibility constraints that could affect the likelihood of project implementation within a 10-year timeframe
- Three to five landowners; or there is reason to believe landowner(s) would grant permission

Unlikely feasibility

- There are known feasibility constraints that would be expected to limit the ability to implement the project within a 10-year timeframe
- More than five landowners: or there is reason to believe landowner(s) would not grant permission

Icicle Creek Reach Assessment

Appendix D | Hydraulic Model

Icicle Creek RM 0 – 22

February 2026

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1 Introduction

A hydraulic analysis of the lower 22 river miles (RMs) of Icicle Creek was conducted as part of the Icicle Creek Reach Assessment and Restoration Strategy. This analysis includes a preliminary-level 2-dimensional (2-D) hydraulic model of Reaches 1-20 of Icicle Creek. The hydraulic model is used to understand general hydraulic characteristics of the stream at a range of high flows, including stream energy (e.g. velocity), floodplain inundation patterns, and the effects of human and natural features on streamflow patterns. Model results were used to support various components of the reach assessment, including geomorphological characterization, sediment transport analysis, assignment of Reach-Based Ecosystem Indicator (REI) ratings, and project identification.

2 Hydraulic Model Methodology

The hydraulic model was developed in the U.S. Army Corps of Engineers HEC-RAS 6.5 software (USACE, 2024b), which can compute hydraulic properties related to the physical processes governing water flow through natural rivers and other channels. Characteristics of Icicle Creek, such as the regions of high sinuosity and a wide and complex floodplain in the lower 4 miles of the creek, make it a good candidate for a 2-D model as such features are difficult to accurately model using a 1-dimensional model. The model was developed for existing conditions to assess the current channel and floodplain dynamics, as well as to assess the impacts of a range of flows on the landscape. This document describes parameterization, assumptions, and set-up of the hydraulic model. Results are depicted and described in Section 3.

2.1 MODEL SETUP

2.1.1 Model Terrain

A digital terrain model (DTM) was created using publicly available LiDAR data of the project area. Available LiDAR datasets were available from 2015, 2018, and 2020 (NV5 Geospatial, 2022; Quantum Spatial, 2016, 2019). We utilized the most recent and high-resolution data where available for the model terrain except for a vegetated island near RM 19.25, where upon review our geomorphology team observed that the 2020 LiDAR appeared to be artificially elevated due to dense vegetation; to address this, the 2018 LiDAR was used in this location as it was believed to better represent the bare ground elevation. None of the LiDAR datasets captured ground elevations below water, leaving considerable data gaps of the bathymetry of the river channels, or any areas that were wetted during the LiDAR flights. The effect of these data gaps on the modeling would be greatest in the lower reaches of Icicle Creek where the channel is deeper, with many large pools. As a result, the model is likely to underestimate the depth and conveyance of Icicle Creek; although at large flood events, the effects of these data gaps may be relatively minor. Overall, the model results were generally consistent with indicators of inundation observed by geomorphologists during site surveys and the model is believed to adequately represent flooding conditions at a resolution and scale sufficient to support the purposes of the reach assessment. Future project design-level modeling will require more detailed survey data, including bathymetry of the channel.

2.1.2 Model Domain and Geometry

The model domain extends from approximately RM 22 just upstream of the end of Forest Road NF-7609 (and the Icicle Creek Trailhead) to downstream of the confluence with the Wenatchee River near the city of Leavenworth (Figure 1). The computational mesh consists of grid cells ranging from 10-100 feet, with the smallest grid cells utilized to provide higher resolution results closer to the channel and terrain features of interest (Figure 2). To save hours to days of run time, channel cell size ranged between 12x12 and 25x25 ft, while much of the floodplain is made up of 50x50 ft cells. Larger cells on the floodplain can sometimes result in overestimation of flow inundation if cells span across high ground areas that would in reality be a flow barrier. Breaklines were added along topographic high points to align cell faces along high ground to improve the representation of the underlying terrain and to limit this "leaking" effect, but there can still be some overestimation of floodplain inundation in some areas. The Leavenworth National Fish Hatchery is located near RM 3 and the hatchery diversion canal is located between RM 3 and 4; the canal diverts much of the Icicle Creek flow from the natural channel at this location (USFWS, 2024). This man-made channel was represented in the model by adding breaklines and computation points into the computational mesh in order to capture flow perpendicular and parallel to the channel, prevent leakage out of the channel walls, and to mitigate water surface elevation errors along the steep spillway dam. Breaklines are also added along the channel to force cell alignment perpendicular to flow, improving efficiency and accuracy.

2.1.3 Bridges and Water Control Structures

Although there are several bridges that cross Icicle Creek within the assessment area, bridge surveys were not performed and therefore no bridges were included in the model. Most of the bridges are high and likely have relatively minor or insignificant effects at the reach-scale at the flows used in the model. The LiDAR captures the lateral constriction at bridge locations. However, the deck and any pilings would not be represented in the model, which may underrepresent any local backwatering that occurs at these crossings. Also, the lack of channel bathymetry data in the model will underrepresent the conveyance of the channels through these crossings. Water control structures in the project area were deemed to be adequately represented by the LiDAR-based model terrain for this preliminary analysis. The complexity of how the Leavenworth National Fish Hatchery and its water control structures are managed (in Reach 3 of this assessment) is outside of the scope of this model. Therefore, the hydraulic characteristics around the hatchery will vary from the results reported here based on specific structure configurations and their management. Future design-level modeling should include surveys of bridges and water control structures, especially those associated with irrigation diversions and the Leavenworth National Fish Hatchery.

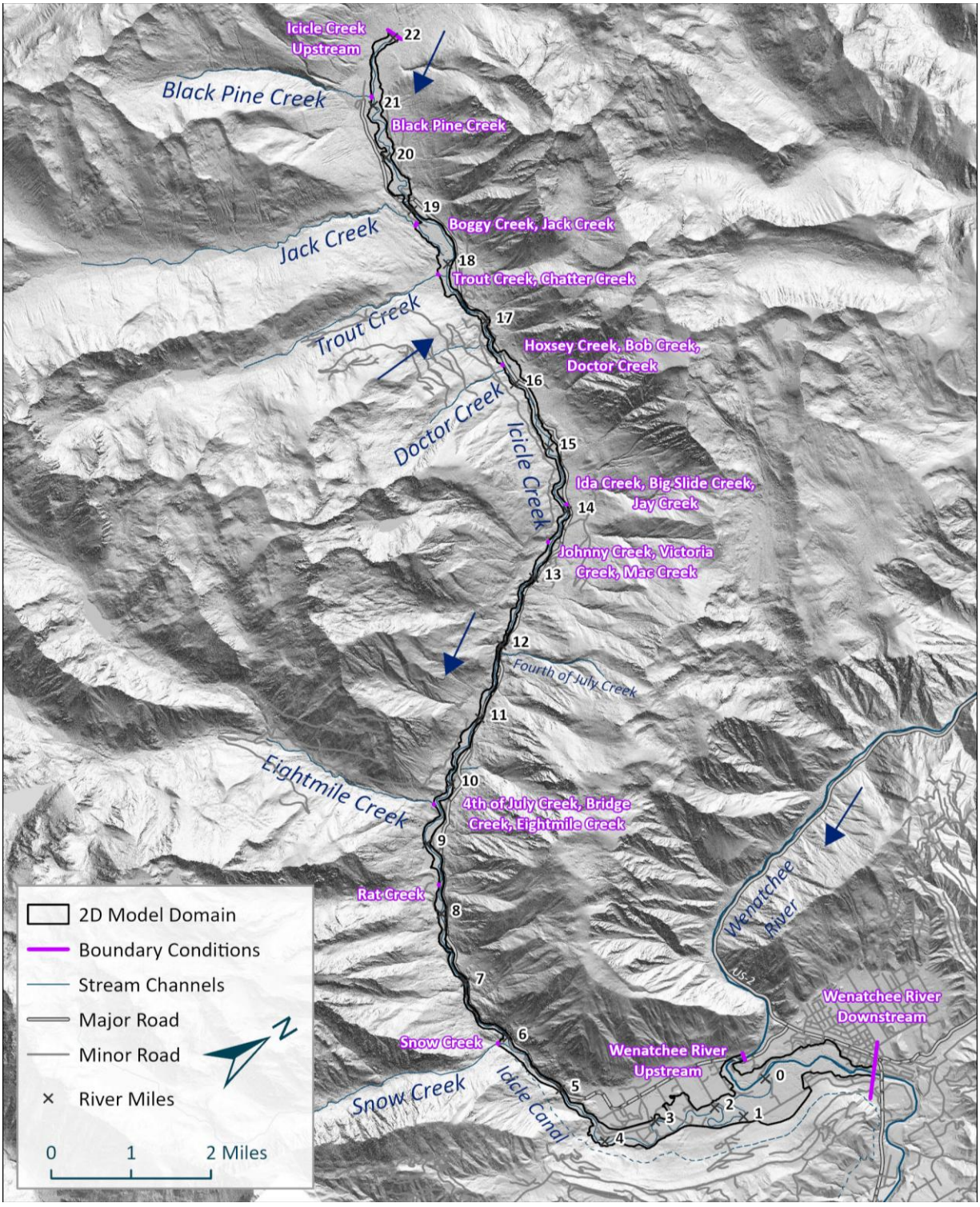

Figure 1. Terrain map of Icicle Creek showing tributaries included in the model, flow input locations, and model external boundary conditions. Blue arrows indicate the general direction of flow inputs.

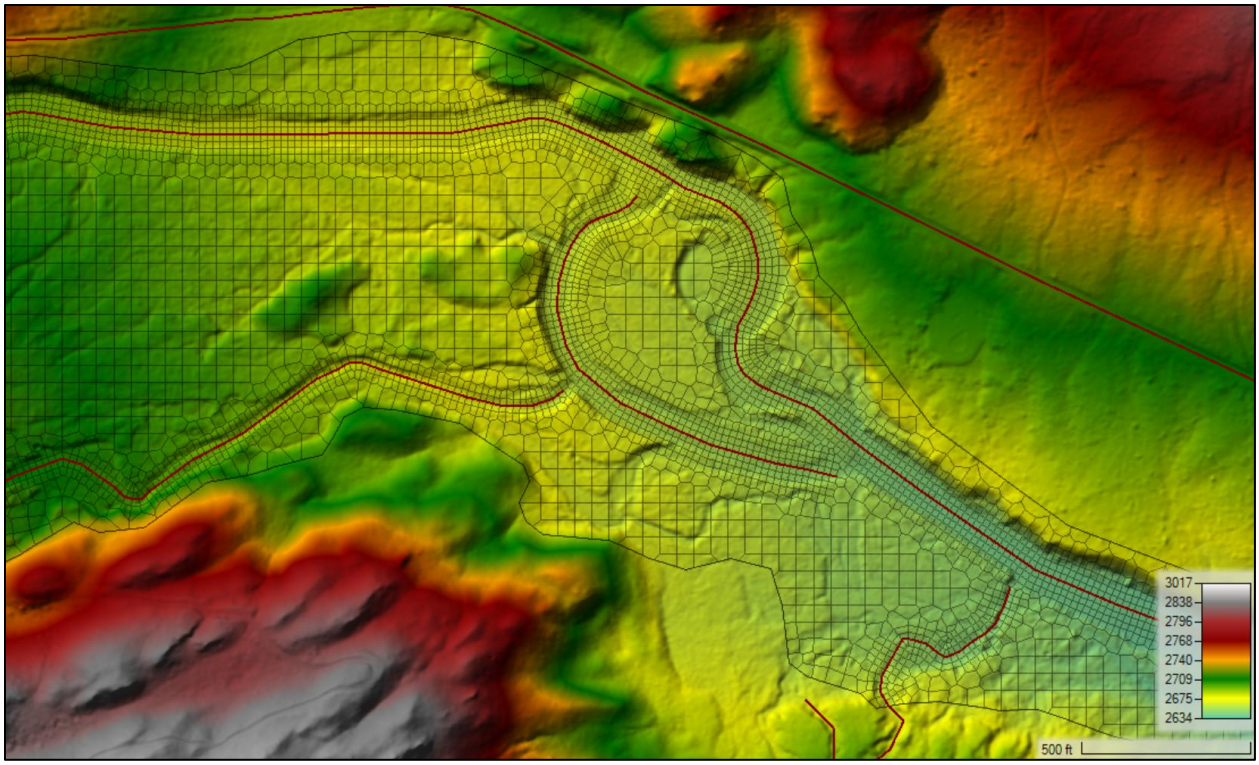

Figure 2. Example cell size at the upstream end of the model. Cells near the channel are 12 to 25 ft in width. The outer floodplain cells are 50 ft. Breaklines (seen in red) are enforced along the channels and roads.

2.2 MODEL INPUTS

2.2.1 Model Roughness

A spatially varying Manning's n layer was developed using ArcGIS tools to represent hydraulic roughness throughout the model domain. The roughness layer was developed using a vegetation height layer created by subtracting the LiDAR bare ground layer (DTM) from the LiDAR first return layer (Digital Surface Model) and reclassifying these data to approximate vegetation densities based on observations of vegetation communities surrounding Icicle Creek that would represent different Manning's n values. These data were supplemented with hand-digitized polygons representing creek and river channels, prevalent roads, and developed areas around Leavenworth, WA near the downstream boundary of the model. Hydraulic roughness coefficients and their associated classifications are provided in Table 1. Channel roughness coefficients range from 0.06 where the channel is steep and dominated by boulders to 0.025 at the downstream end where the gradient is low and the bed is comprised of fine substrate. During field surveys, the hatchery diversion canal was observed to be comprised of gravel or partially paved and was assigned a roughness of 0.02. Floodplain roughness coefficients range from 0.03 to 0.12. Roughness values were determined through a combination of resources including the NLCD Land Cover types (USACE, 2024a), USGS and HEC-RAS roughness value recommendations (USACE, 2025; USGS, 1967), and professional judgment considering channel substrate type and floodplain and upland vegetation characteristics.

Table 1. Roughness coefficients (Manning's n values) used in the model.

Area Description	Roughness Coefficient (Manning's n Value)
Upper Icicle Creek Channel	0.06
Icicle Creek Channel Beside Hatchery	0.03
Lower Icicle Creek Channel	0.025
Wenatchee River	0.03
Tributary Channels	0.07
Hatchery Channel	0.02
Developed Areas	0.1
Road Surfaces	0.05
Bare Ground (<0.5 ft)	0.03
Vegetation Height 0.5-4 ft	0.07
Vegetation Height 4-12 ft	0.1
Vegetation Height 12-25 ft	0.12
Vegetation Height 25-60 ft	0.095
Vegetation Height 60+ ft	0.085

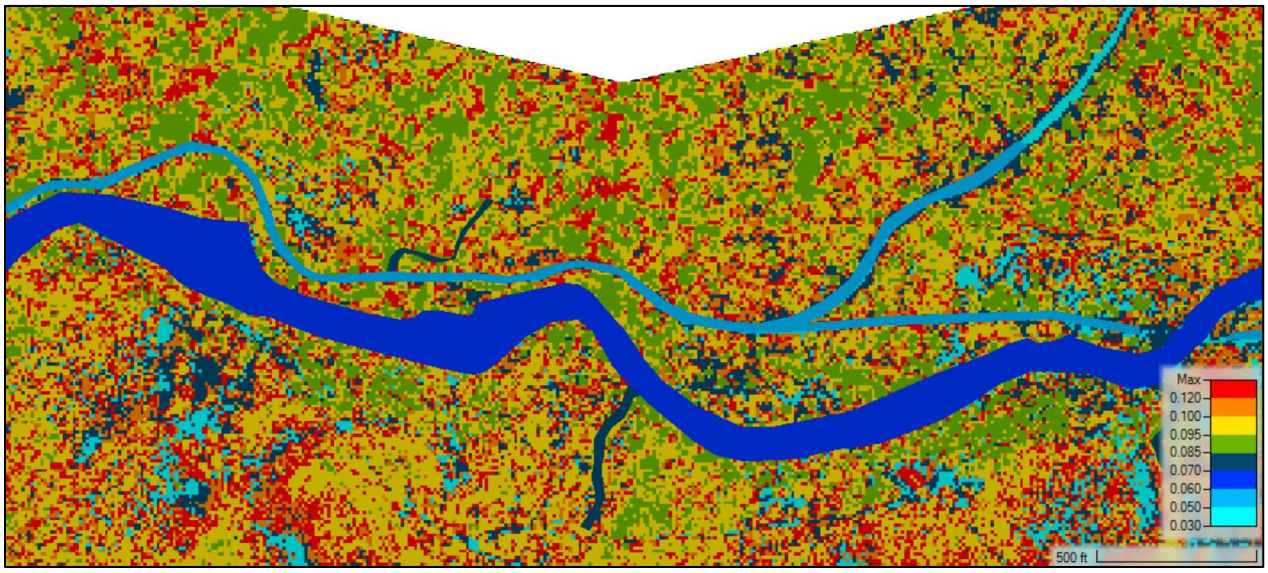

Figure 3. Roughness values assigned to the existing conditions Icicle Creek model.

2.2.2 Model Hydrology

Icicle Creek hydrology was estimated using the Icicle Creek above Snow Creek gage near Leavenworth, WA (USGS gage 12458000) (USGS, 2024a). The gage has a period of record from May 1912 to present, with data gaps from 1915 to 1936 and 1980 to 1993. All peak flows available were used to complete a Log Pearson Type 3 (USGS Bulletin 17C) peak flow analysis in HEC-SSP (USACE, 2023). The 17C analysis was conducted using a weighted skew, with a regional skew of -

0.07 and a regional skew MSE of 0.18, as suggested by Mastin et al. (2017). The Mastin et al. (2017) equation 11 for Region 2 in Washington was used to obtain flow estimates for the top of the project area and the mouth of Icicle Creek using a basin-area weighted conversion from the gage data. (Table 2).

Nineteen tributaries to Icicle Creek were identified within the model domain: Black Pine Creek, Boggy Creek, Jack Creek, Trout Creek, Chatter Creek, Bob Creek, Hoxsey Creek, Doctor Creek, Ida Creek, Big Slide Creek, Jay Creek, Johny Creek, Victoria Creek, Mac Creek, 4th of July Creek, Bridge Creek, Eightmile Creek, Rat Creek, and Snow Creek. Portions of some tributaries were deemed to be poorly represented in the LiDAR and not adequate for modeling. This included areas where the lack of bathymetry resulted in no clear channel for a given tributary or where roads crossed the channel and there was no documented culvert or bridge. To streamline the hydrology and resolve these problem areas, tributaries were clumped into nine inflow boundary conditions in a representative distribution of inputs along the hydraulic model. The drainage area for each of these clumped model inputs was calculated as the difference between the drainage area of Icicle Creek directly below the downstream-most tributary confluence and the drainage area of the previous upstream input included in the model (calculated using the same method). Drainage areas were interpolated using StreamStats (USGS, 2022). The difference in flows between the top and bottom of the project area, calculated using Mastin et al. (2017) equation 11, was divided among the tributary boundary conditions based on drainage area (see Table 2).

A portion of the Wenatchee River was included in the model to account for interactions between the Wenatchee River and Icicle Creek in the downstream portion of the assessment area, including backwatering from the Wenatchee into Icicle Creek during high-flow events. A gage on the Wenatchee River a couple of miles upstream of the Icicle Creek confluence (USGS 12457000) was utilized to estimate the peak flows of the Wenatchee upstream of Icicle Creek (USGS, 2024b). This gage provides peak flow data from 1911 to the present (with data missing between 1930 and 1931, and 1980 to 1989), which were used to run a peak flow analysis and basin-area correction using the same methods as described previously for Icicle Creek (Table 2).

Table 2. Modeled flow events for the White River and tributaries used in hydraulic modeling.

Flow Event	Icicle Creek Upstream Discharge	Black Pine Creek	Boggy Creek and Jack Creek	Trout Creek and Chatter Creek	Bob Creek, Hoxsey Creek, and Doctor Creek	Ida Creek, Big Slide Creek, and Jay Creek	Johny Creek, Victoria Creek, and Mac Creek	4th of July Creek, Bridge Creek, and Eightmile Creek	Rat Creek	Snow Creek	Wenatchee River
2 - year	1,900	170	790	110	110	160	110	980	170	370	13,580
5 - year	2,840	250	1,150	160	160	230	160	1,420	240	530	17,990
10 - year	3,570	300	1,410	190	190	280	190	1,740	290	650	20,980
25 - year	4,630	380	1,780	240	240	350	240	2,200	370	820	24,850
50 - year	5,520	440	2,090	280	280	410	280	2,570	430	960	27,810
100 - year	6,500	510	2,420	330	330	470	320	2,980	500	1,120	30,840

2.2.3 Model Boundary Conditions

The hydraulic model was used to evaluate existing conditions at flow events ranging from the 2-year to the 100-year flow event (Table 2). These flows are incorporated into synthetic quasi-steady state hydrographs with periods of steady flow (at the discharges of interest and other intermediate discharges) connected by smooth transition periods to create a stair-step-like pattern. The timing of all flows (Icicle Creek, its tributaries, and the Wenatchee River) are assumed to be simultaneous, which provides conservative (high) results with respect to flooding. A representative quasi-steady flow hydrograph is depicted in Figure 4. The periods of steady flow allow the model to come to a quasi-steady state condition, which facilitates the interpretation of hydraulics at specific discharges. In some cases, allowing the model to reach a steady state during large flood events may overestimate flooding results, as floodplain storage throughout the model domain must reach capacity for the outflow of the model to reach steady-state conditions. This may not occur during actual floods, especially short-duration events. Regardless, the conservative nature of this approach was deemed appropriate for this preliminary-level model.

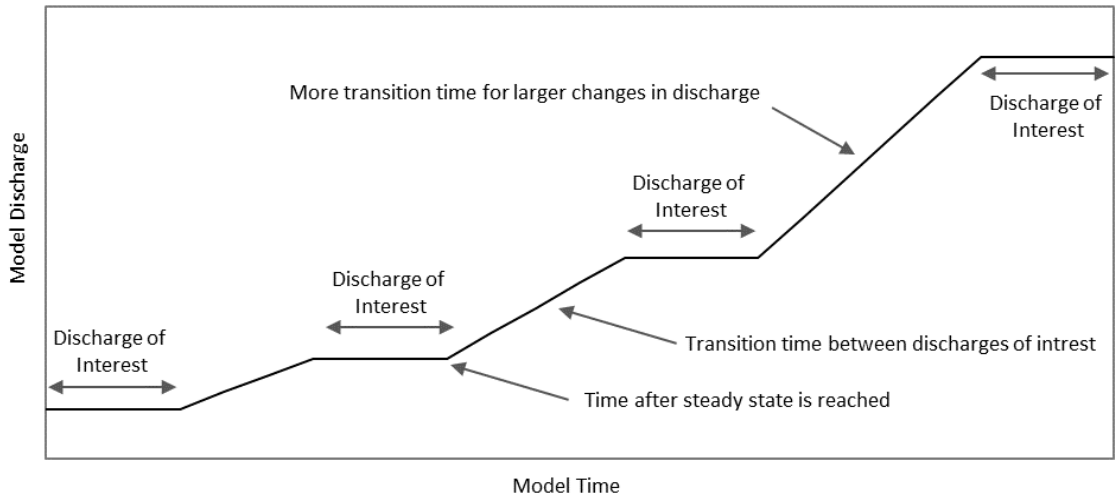

Figure 4. Demonstrative quasi-steady flow model input hydrograph.

The upstream boundary condition was set to the Icicle Creek Upstream Discharge in Table 2, with an energy grade (EG) slope of 0.002 based on the terrain at the location of the upstream boundary

condition. Each of the tributary inputs (grouped as listed in Table 2) were added to the model as external boundary conditions with their own hydrograph and energy slopes estimated based on the channel bed slope from the LiDAR-based terrain. In addition, a portion of the Wenatchee River was included in the downstream end of the model to account for interactions between the Wenatchee River and Icicle Creek. On the Wenatchee River upstream of the Icicle Creek confluence, an external boundary condition was added with input for the Wenatchee River. Downstream of the Icicle Creek confluence, the downstream boundary condition of the model was added as a normal depth boundary condition with a friction slope of 0.005.

2.2.4 Model Calibration

Model calibration was performed to the extent possible and within reasonable limits given the limited data available for model development and the limited data available for calibration. Data limitations were primarily related to lack of accurate channel bathymetry (i.e., use of non-bathymetric LiDAR) and lack of tributary inflow data. Despite these limitations, efforts were made to calibrate the model based on evidence of bankfull flow and floodplain inundation observed by the geomorphology team during the field assessment. These observations included bankfull channel indicators, debris lines, extent of overbank floodplain deposits, and vegetation patterns. Repeated adjustments were made to the model mesh and roughness until model results reasonably reflected the field observations. Calibration was most challenging in the downstream three reaches due to larger channel depths (compared to the steeper upstream reaches), which are not represented accurately by the LiDAR. More information on potential depth errors in the model in these lower reaches is discussed in Section 3.2.

Model results were compared to the stage readings at the USGS gaging station (USGS #12458000) near RM 6.5 to assess model accuracy at this location. This was performed by creating a high flow rating curve from the gage data using flows that had “fair” and “good” quality ratings. Modeled WSEs were shown to exceed those predicted by the rating curve by about 2 feet at the 2-year event and about 0.3 feet at the 100-year event. The greater discrepancy at the 2-year event is attributed to lack of low flow channel bathymetry in the LiDAR data. Only non-bathymetric LiDAR data were available for this assessment. These data do not capture ground elevations below water, and so the data essentially represent the water surface elevation during the LiDAR flight as opposed to the bathymetry of the channel. Even though in this case the LiDAR data were collected at relatively low flows (~331 cfs), this nevertheless equates to potentially a few feet of depth at the time of the LiDAR flight (331 cfs equates to ~3.73 ft at the gage), which is a significant portion of the channel that is not represented in the model. For these reasons, the discrepancies between modeled WSEs and actual WSEs are expected to be most pronounced in deeper channel areas, like those that occur in the lower 3 reaches, and at lower flows, where a higher percentage of the flow is contained in the low-flow portion of the channel.

3 Summary of Hydraulic Model Results

A summary of model results and output figures/maps are provided below. Although a wide range of flows were simulated in the model (2, 5, 10, 25, 50, and 100-year flood events), for clarity and simplicity we focus here on the 2-year, 25-year, and 100-year results.

3.1 MODELED VELOCITY RESULTS

Modeled velocities for the 2-year, 25-year, and 100-year flood velocity results are displayed in Figures 5-13.

In reaches 1 and 2, the valley is wide and Icicle Creek is highly sinuous as it flows toward the Wenatchee River downstream of the hatchery canal starting at RM 3. The gradient is low and model result show low velocities here compared to most of the remainder of the assessment area. There is also much more available floodplain. In-channel velocities range from 4 to 6 ft/s during the 2-year flow event, with average floodplain velocities less than 0.5 ft/s (Figure 5). Channel and floodplain velocities increase at the 25-year flow, with channel velocities spiking to 10 ft/s near RM 2, and floodplain average velocities increasing to 0.5-2 ft/s (Figure 8). The 100-year results show portions of the channel exceeding 10 ft/s velocity, but most of the channel with velocities are between 4 and 8 ft/s, with floodplain inundation crossing the road on river right and velocities increasing slightly across the valley floor (Figure 11).

Reach 3 is also low gradient with a wide valley, but it is confined by the Leavenworth National Fish Hatchery diversion canal located on river left from RM 3 to 4. A portion of Icicle Creek's flow is diverted through this straight concrete and gravel channel, where simulated velocities are higher than the adjacent natural channel. A dam structure, "Structure 2", regulates flow between the hatchery diversion channel (canal) and the historical (natural) channel via gates that when closed direct flow into the diversion channel. However, Structure 2 is represented in the LiDAR-based model only by the abutments of the structure, not including the adjustable gates and bridge deck (as discussed in Section 2.1.3), therefore the amount of flow diverted to the hatchery diversion channel is likely being underestimated. At the 2-year flow, channel velocities in the natural channel and hatchery canal are between 2 and 6 ft/s, spiking to over 10 ft/s where flow in the natural channel is confined by water crossing and control structures downstream of the hatchery canal (near RM 4.25) and at the water control structure where flow leaves the hatchery canal and returns to Icicle Creek (near RM 3) (Figure 5). At the 25-year flow, velocities in the natural channel increase slightly, reaching 8 ft/s in some sections, while most of the hatchery canal increases to 6 to 8 ft/s (Figure 8). These velocities continue to increase at the 100-year flow, with small spikes up to 10 ft/s in the natural channel, and much of the hatchery canal reaching 8 to 10 ft/s (Figure 11). Floodplain inundation is limited in this reach by the hatchery canal on river left and the hillslopes on river right, with some activation near RM 4 and near RM 3 at higher flows, with velocities generally less than 1 ft/s.

In the upstream portion of the project area, Icicle Creek flows through a steep and confined valley. A dramatic increase in gradient and channel confinement distinguished Reaches 4 to 18 from these lower reaches. The steep gradient coupled with the confined channel and greater prevalence of cobbles and boulders in this part of the study area results in much more turbulent and high velocity flows. At the 2-year flow, the in-channel velocities generally span from 6 to 10 ft/s, though often exceed 10 ft/s in steep sections (Figure 5 to 7). For the 25-year and 100-year flows, velocities in these reaches generally exceed 10 ft/s (Figure 8 to 11). Floodplains are limited in these reaches. There are two key areas that stand out from this trend, a small portion of Reach 10 (near RM 10.5) and Reach 15. These areas have lower gradient than upstream and downstream areas, with floodplain inundation occurring at the 25-year and 100-year flows, and velocities generally between 4 and 8 ft/s, not exceeding 10 ft/s.

Upstream of this steep section, reaches 19 and 20 have slightly lower gradients and are less confined than the downstream canyon reaches, resulting in lower channel velocities and more floodplain inundation. At the 2-year flow, channel velocities range from 2 to 6 ft/s and small areas of floodplain inundation have velocities from <0.05 to 2 ft/s (Figure 7). Channel velocities increase to 2 to 8 ft/s at the 25-year flow and there is more floodplain inundation, with velocities between 1 to 2 ft/s (Figure 10). Velocities continue to increase at the 100-year flow, ranging from 4 to 8 ft/s in channel with some small areas between 8 to 10 ft/s, and 0.5 to 4 ft/s modeled in the floodplain (Figure 13).

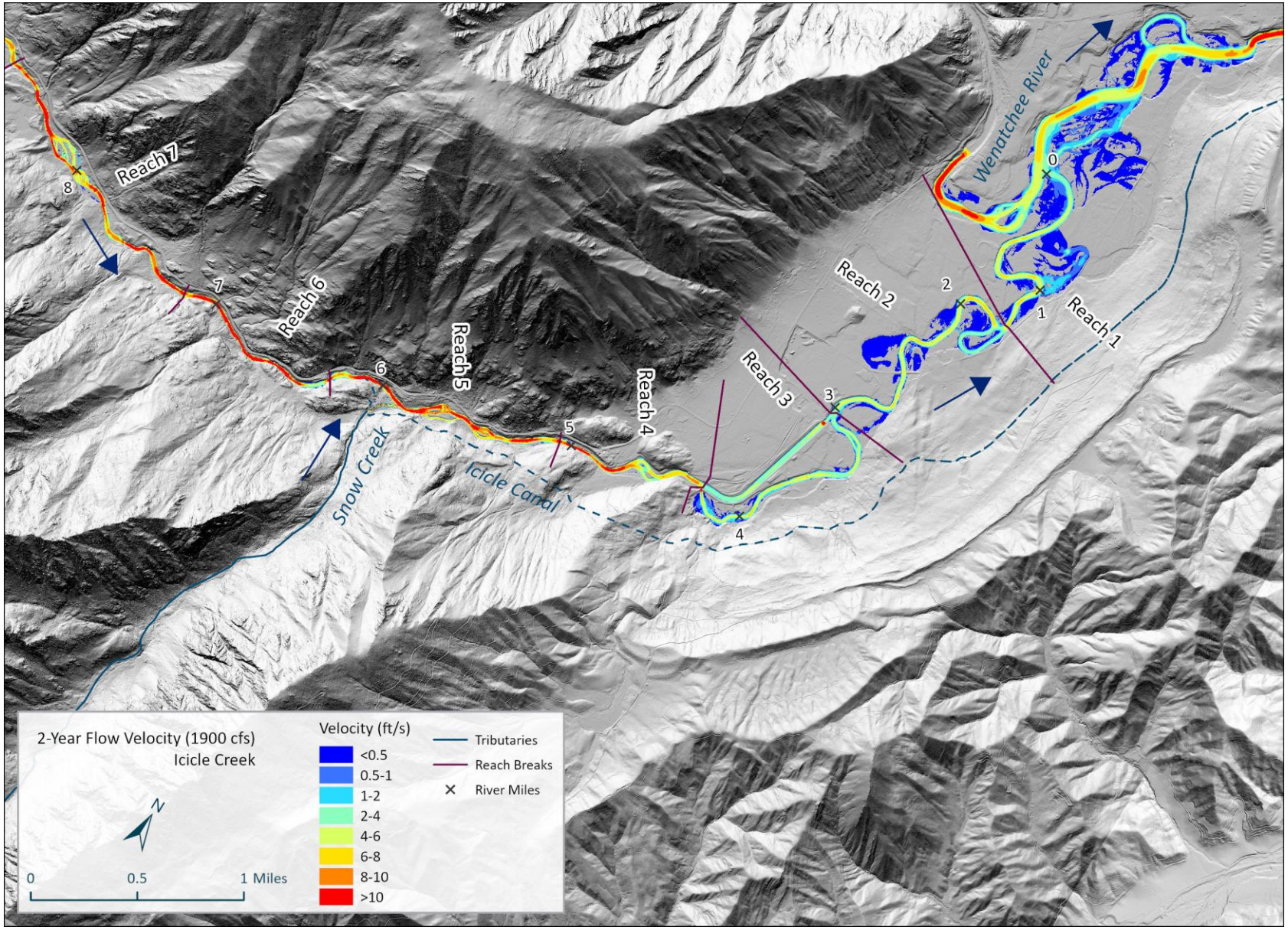

Figure 5. Modeled 2-year flood velocity for Reaches 1 to 7, labeled with flow input at the upstream end of the model.

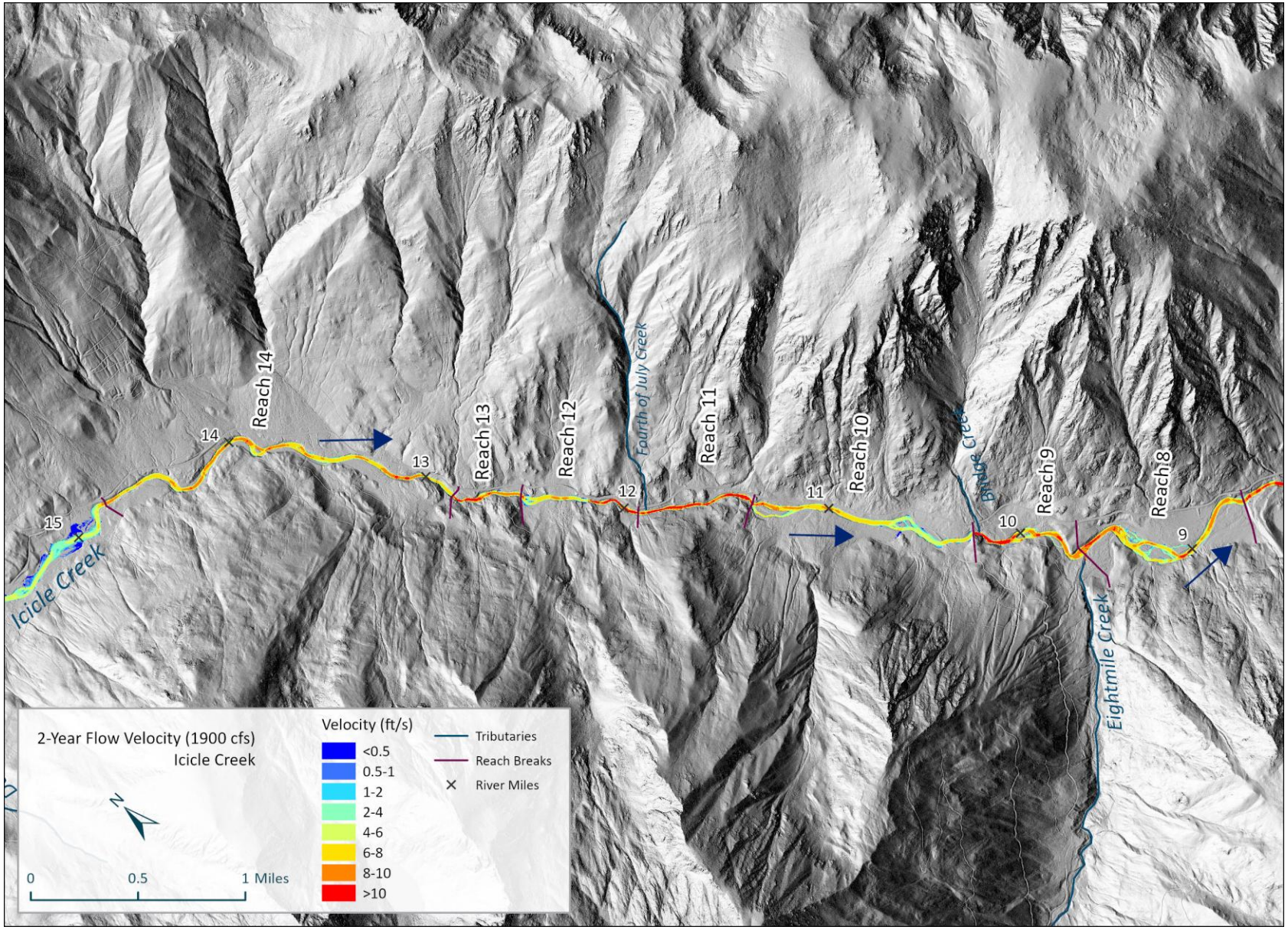

Figure 6. Modeled 2-year flood velocity for Reaches 8 to 14, labeled with flow input at the upstream end of the model.

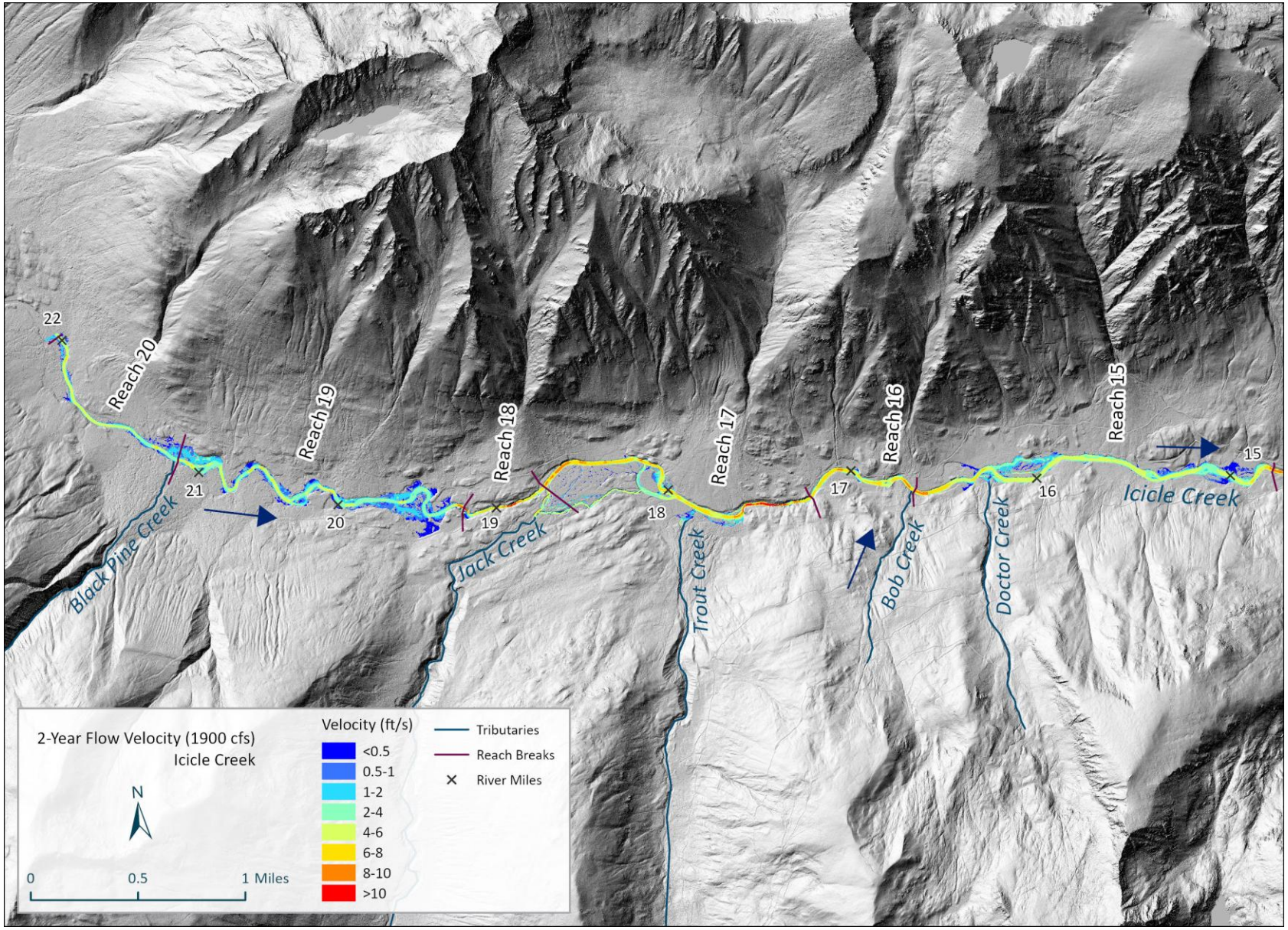

Figure 7. Modeled 2-year flood velocity for Reaches 15 to 20, labeled with flow input at the upstream end of the model.

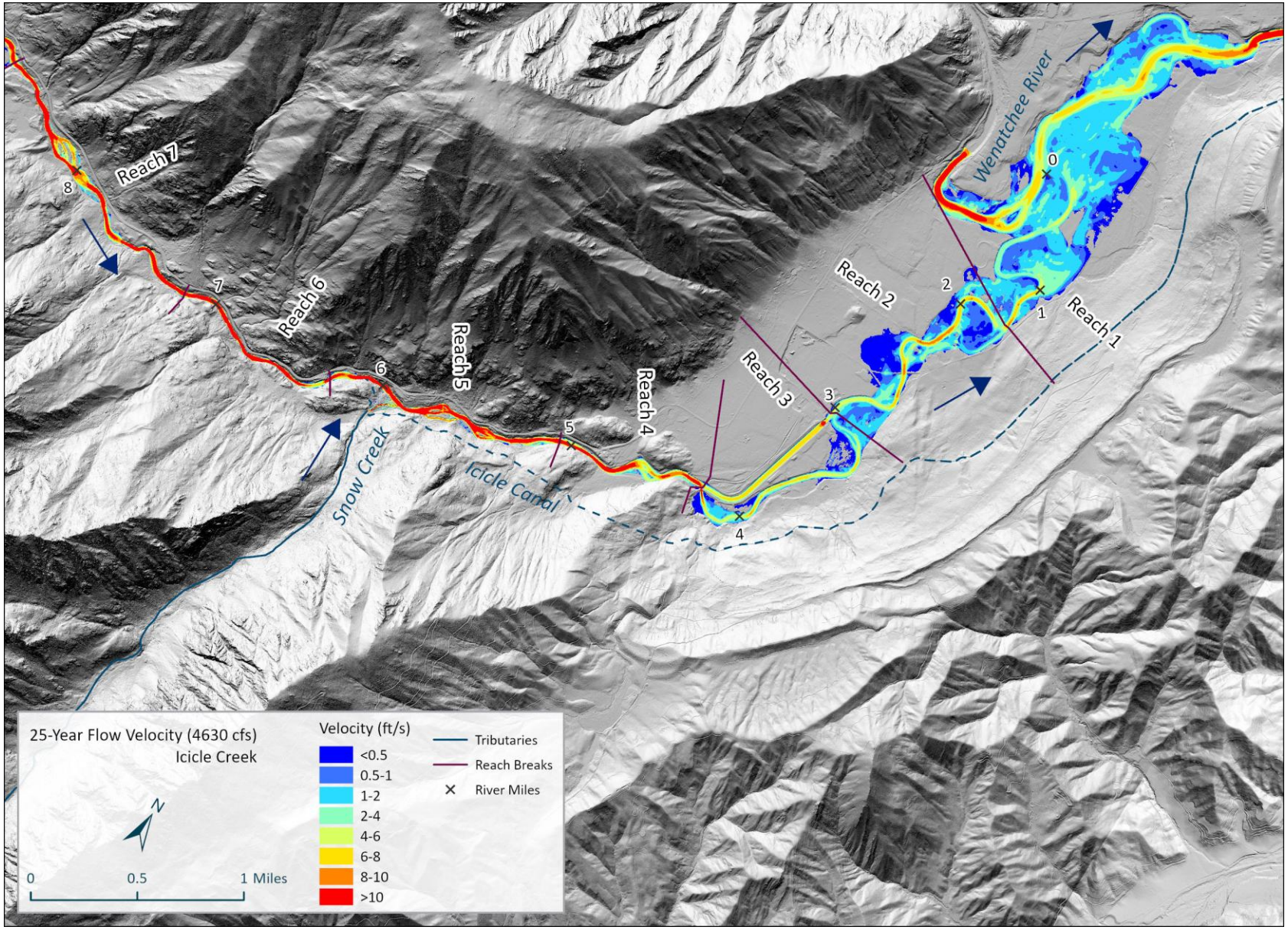

Figure 8. Modeled 25-year flood velocity for Reaches 1 to 7, labeled with flow input at the upstream end of the model.

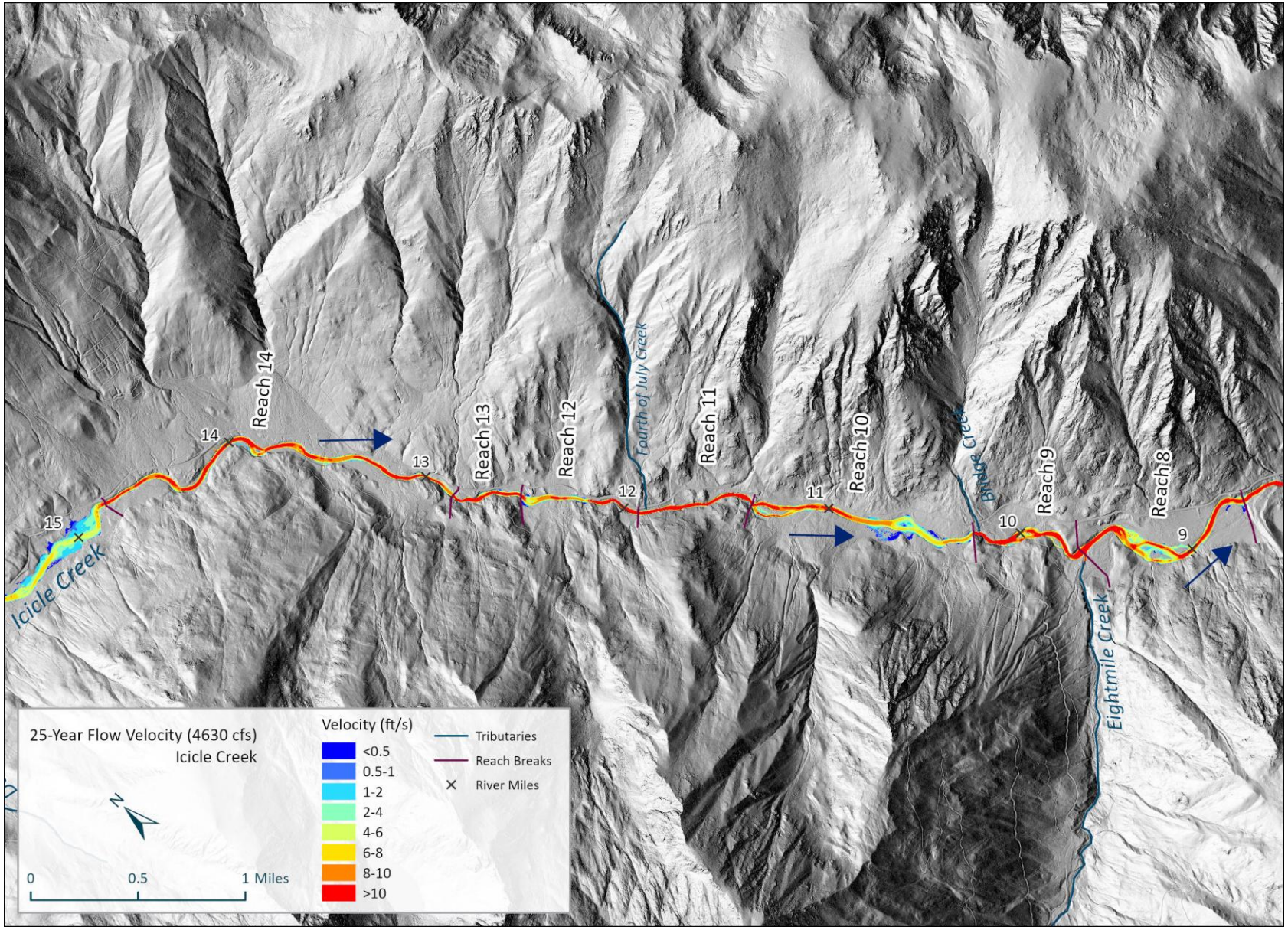

Figure 9. Modeled 25-year flood velocity for Reaches 8 to 14, labeled with flow input at the upstream end of the model.

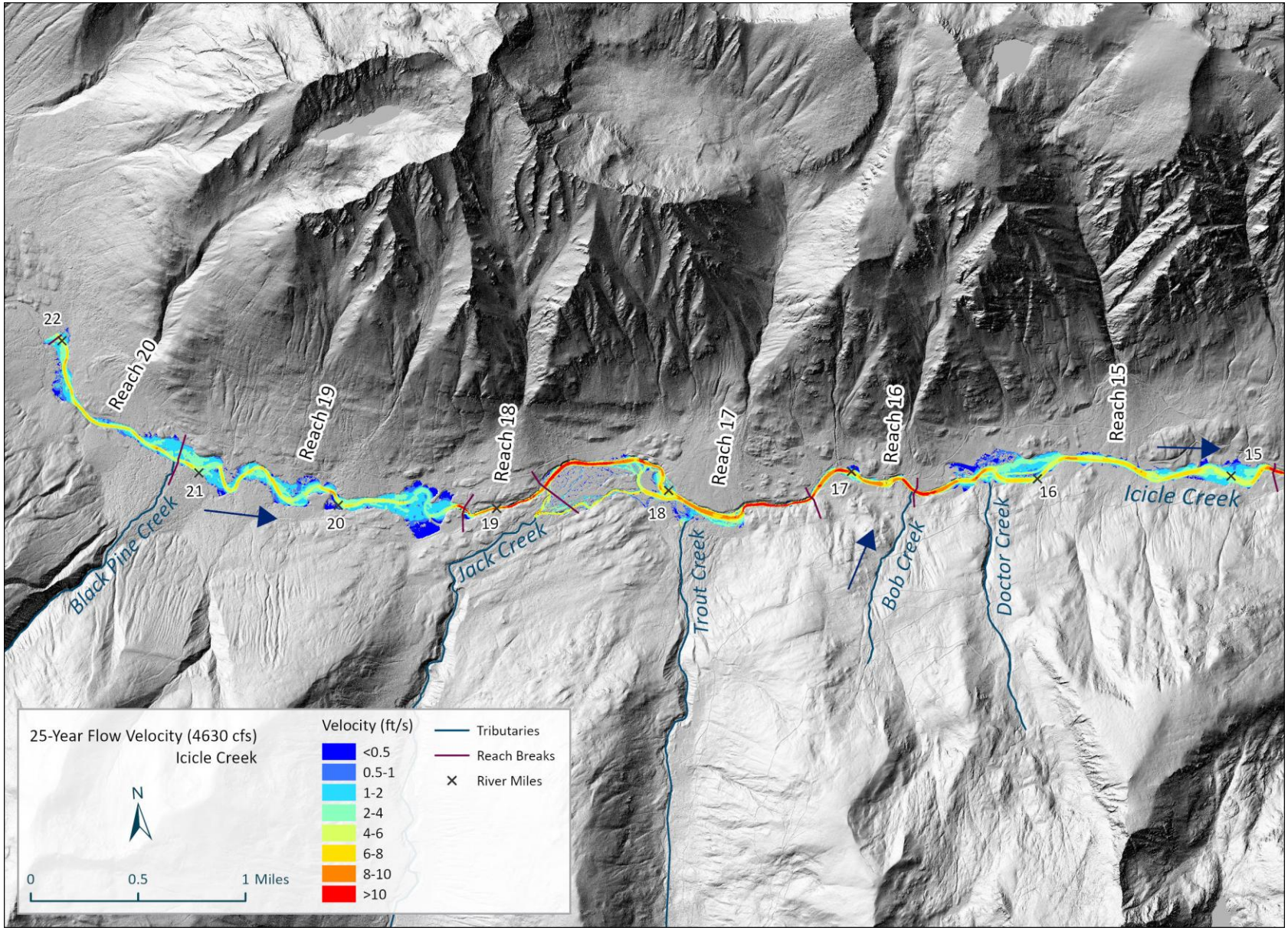

Figure 10. Modeled 25-year flood velocity for Reaches 15 to 20, labeled with flow input at the upstream end of the model.

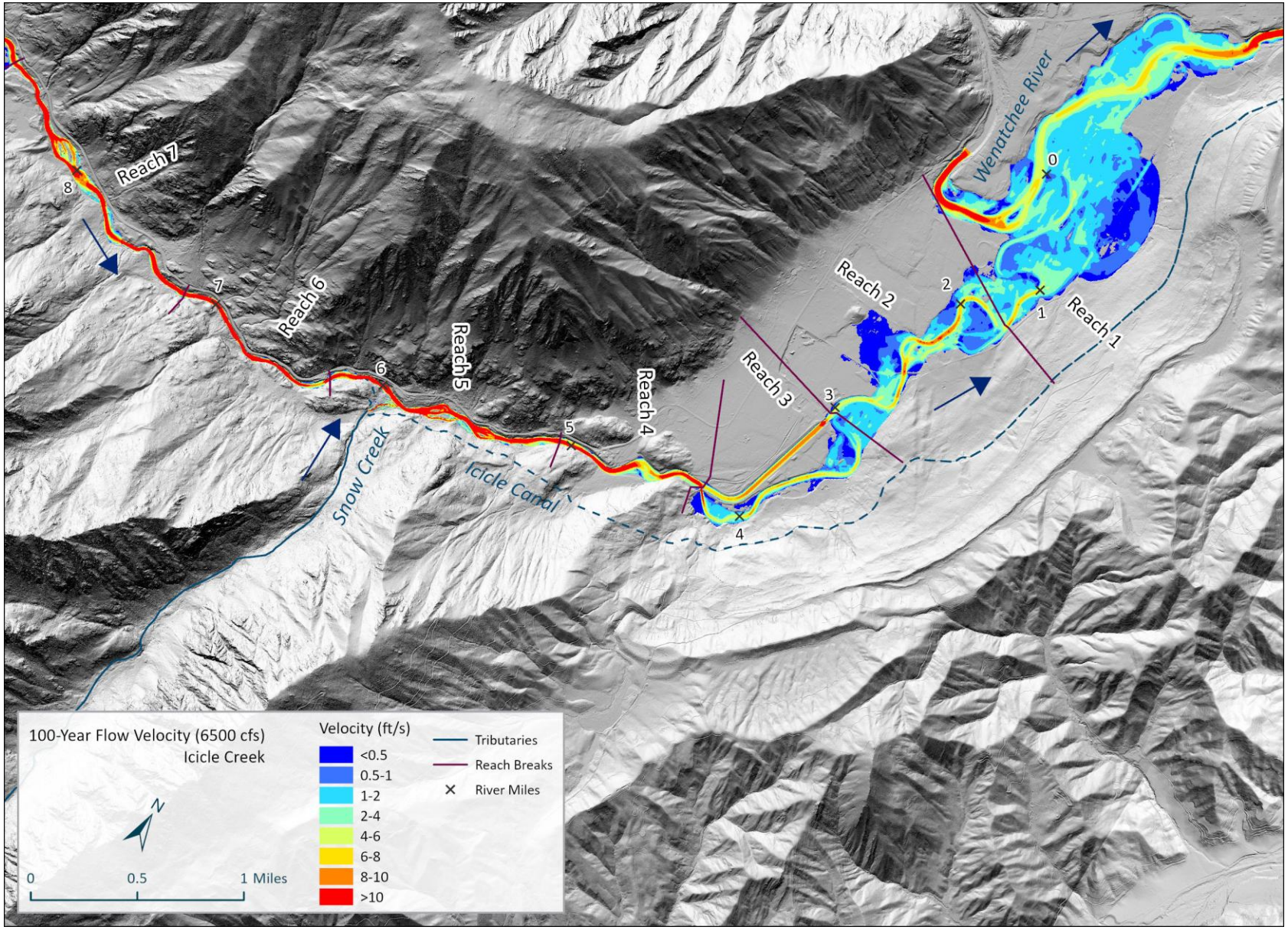

Figure 11. Modeled 100-year flood velocity for Reaches 1 to 7, labeled with flow input at the upstream end of the model.

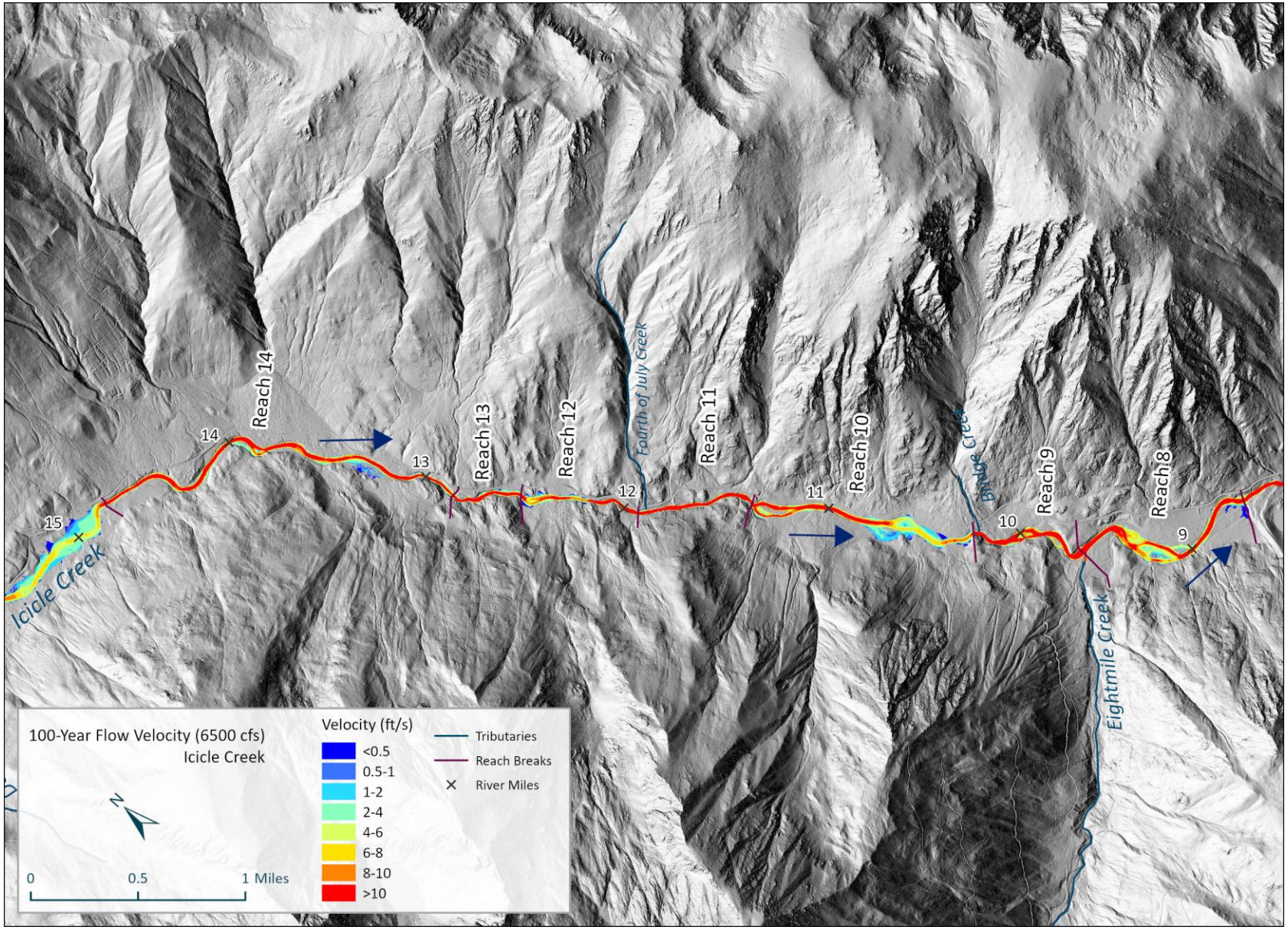

Figure 12. Modeled 100-year flood velocity for Reaches 8 to 14, labeled with flow input at the upstream end of the model.

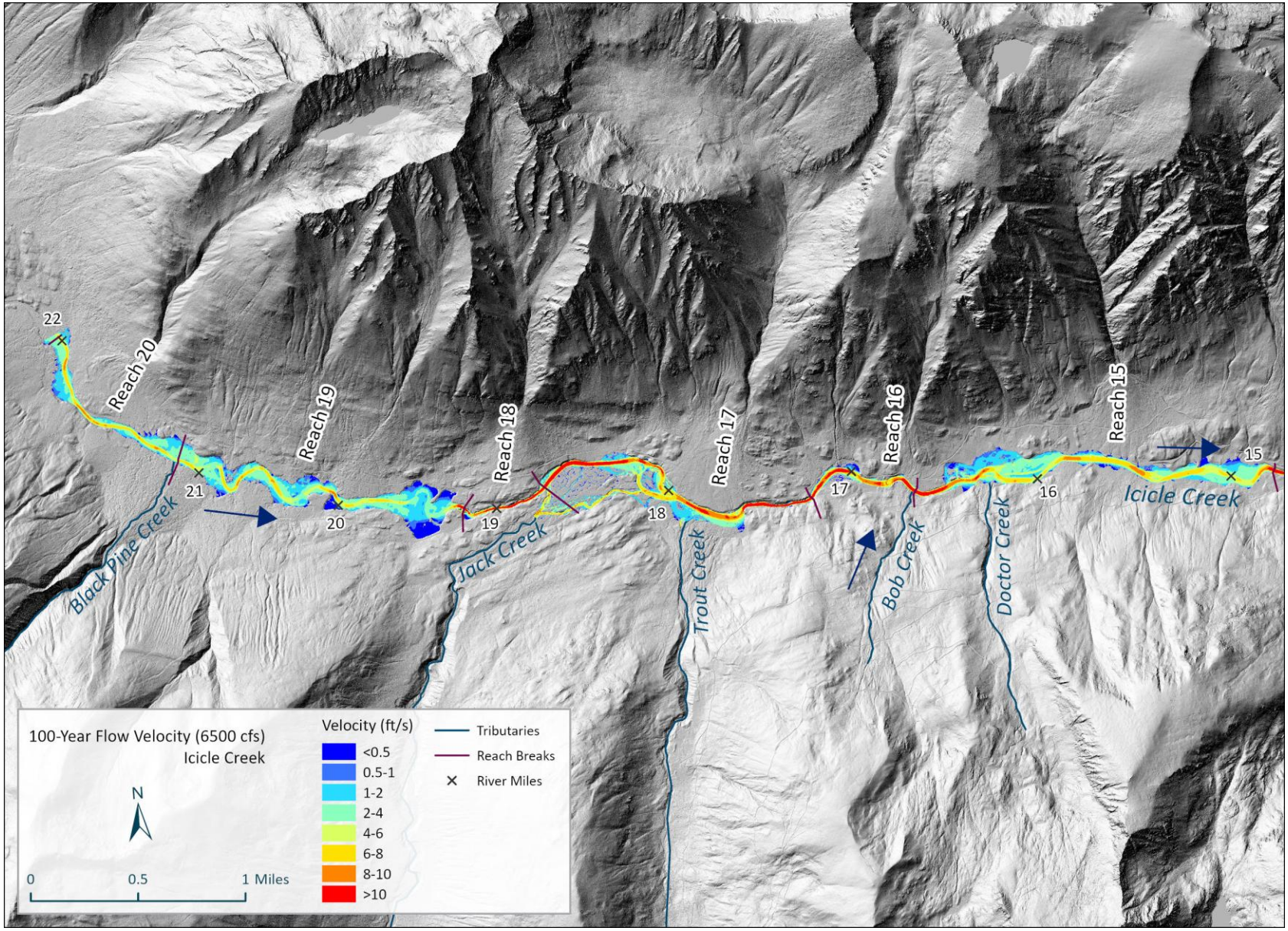

Figure 13. Modeled 100-year flood velocity for Reaches 15 to 20, labeled with flow input at the upstream end of the model.

3.2 MODELED DEPTH RESULTS

Modeled depths at the 2-year, 25-year, and 100-year floods are included below in Figures 14-22. As previously described, The LiDAR used in the model terrain does not include bathymetry, which means there is error and uncertainty in the channel conveyance and model depths, and an overall underestimation of depths and conveyance. For reference, the habitat surveys recorded residual pool depths of between 0.5 and 18 feet in the lower three reaches of the assessment area, depths that would not be captured by the LiDAR. The model is believed to be more accurate in upstream reaches due to shallower channels at hydraulic controls (e.g., riffle crests). Despite these caveats, the model is nevertheless believed to provide useful information on relative depths and conveyance at the reach-scale and for comparing conditions among reaches and across flow levels.

In the portion of the assessment area around Leavenworth (Reaches 1 to 3), channel depths for the 2-year flow range from 8 to 10 feet, while floodplain depths vary from 0.5 to 4 feet (Figure 14). As flows increase to the 25-year event, channel depths exceed 10 feet, ranging from 10 to 12 feet, and floodplain depths increase to between 2 and 6 feet (Figure 17). For the 100-year flow event, downstream channel depths further increase to 11 to 15 feet, with floodplain depths ranging from 2 to 8 feet (Figure 20). The model results show that the hatchery canal experiences lower depths than the natural channel beside it, which can be 2 to 4 feet deeper (Figure 14, 17, and 20). Structure 5 (a low bridge with gates crossing the historic channel) is not explicitly represented in the model (see section 2.1.3). Therefore, the model would not fully represent backwatering effects caused by the structure. Floodplain inundation in the downstream area increases with large flow events and appears to result in the road on river right being overtopped between RM 0 and 1.

In the upstream section of the assessment area (Reaches 4 to 20), water depths for the 2-year flow generally range from 4 to 6 feet, with occasional deep pockets reaching 8 to 12 feet (Figure 14 to 16). For the 25-year flow, depths increase to 6 to 10 feet, with some isolated pockets reaching 12 to 18 feet (Figure 17 to 19). During the 100-year flow event, depths further increase, ranging from 6 to 11 feet, with the deepest pockets extending to 15 to 20 feet (Figure 20 to 22).

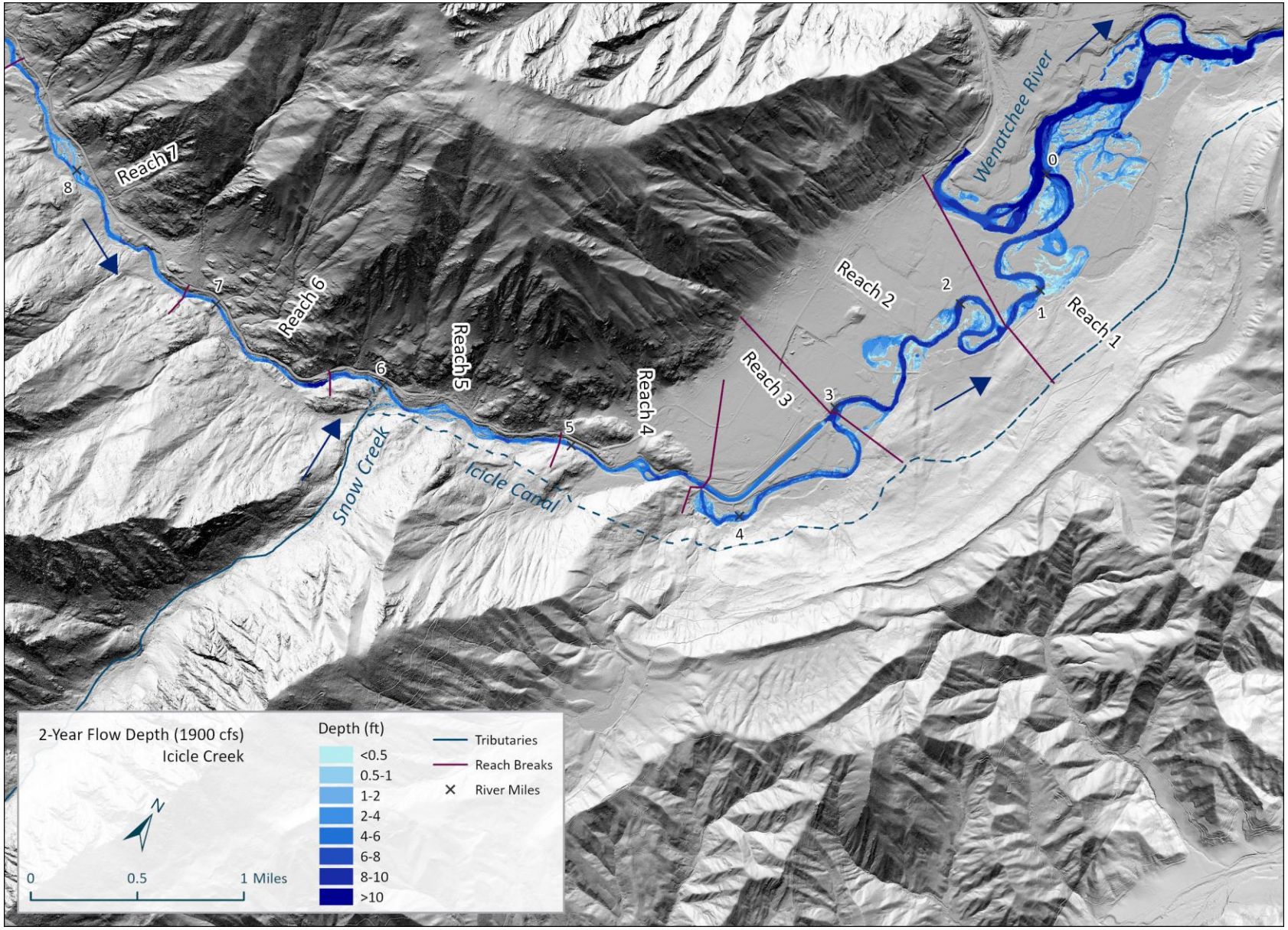

Figure 14. Modeled 2-year flood depth for Reaches 1 to 7, labeled with flow input at the upstream end of the model.

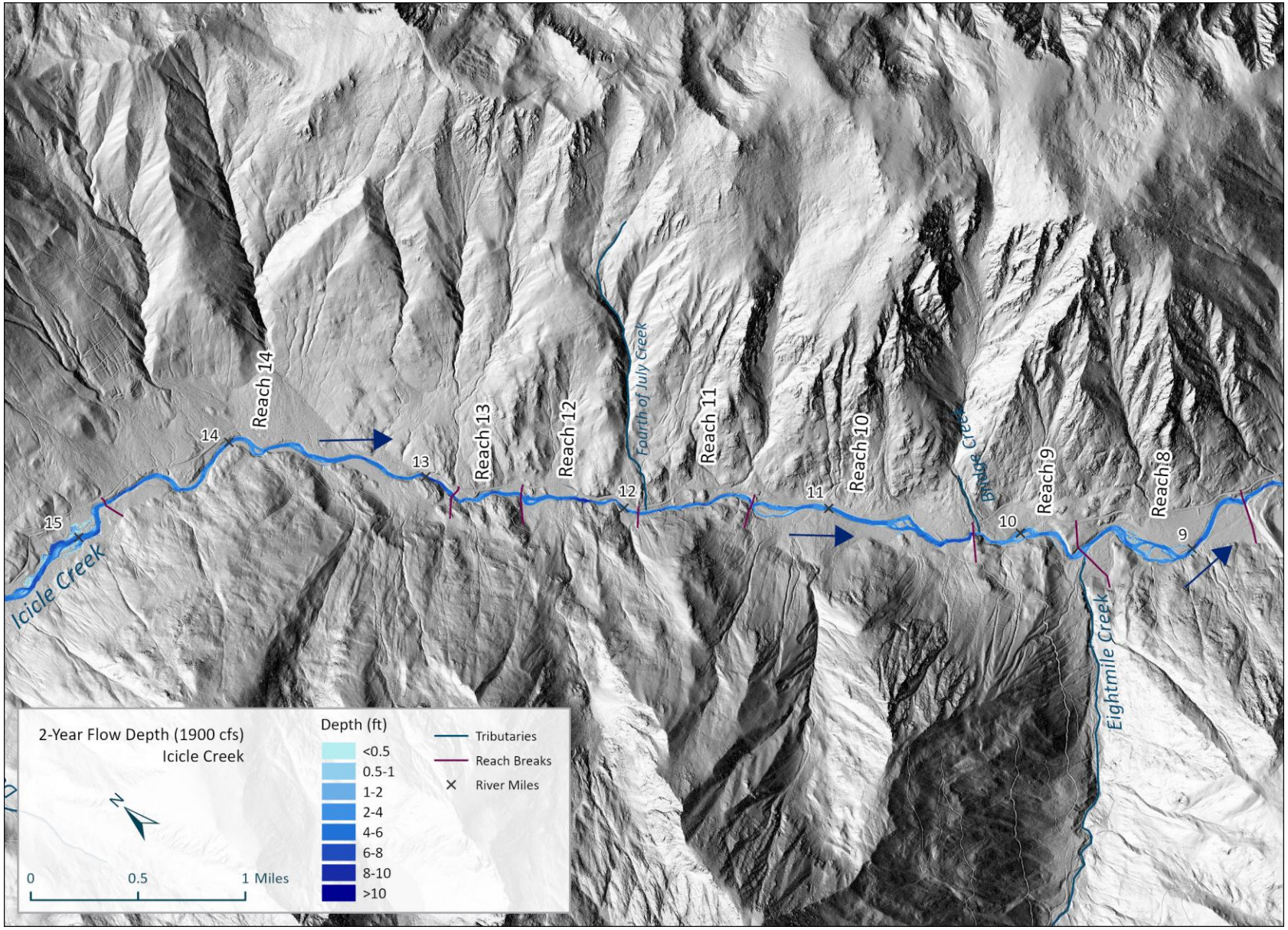

Figure 15. Modeled 2-year flood depth for Reaches 8 to 14, labeled with flow input at the upstream end of the model.

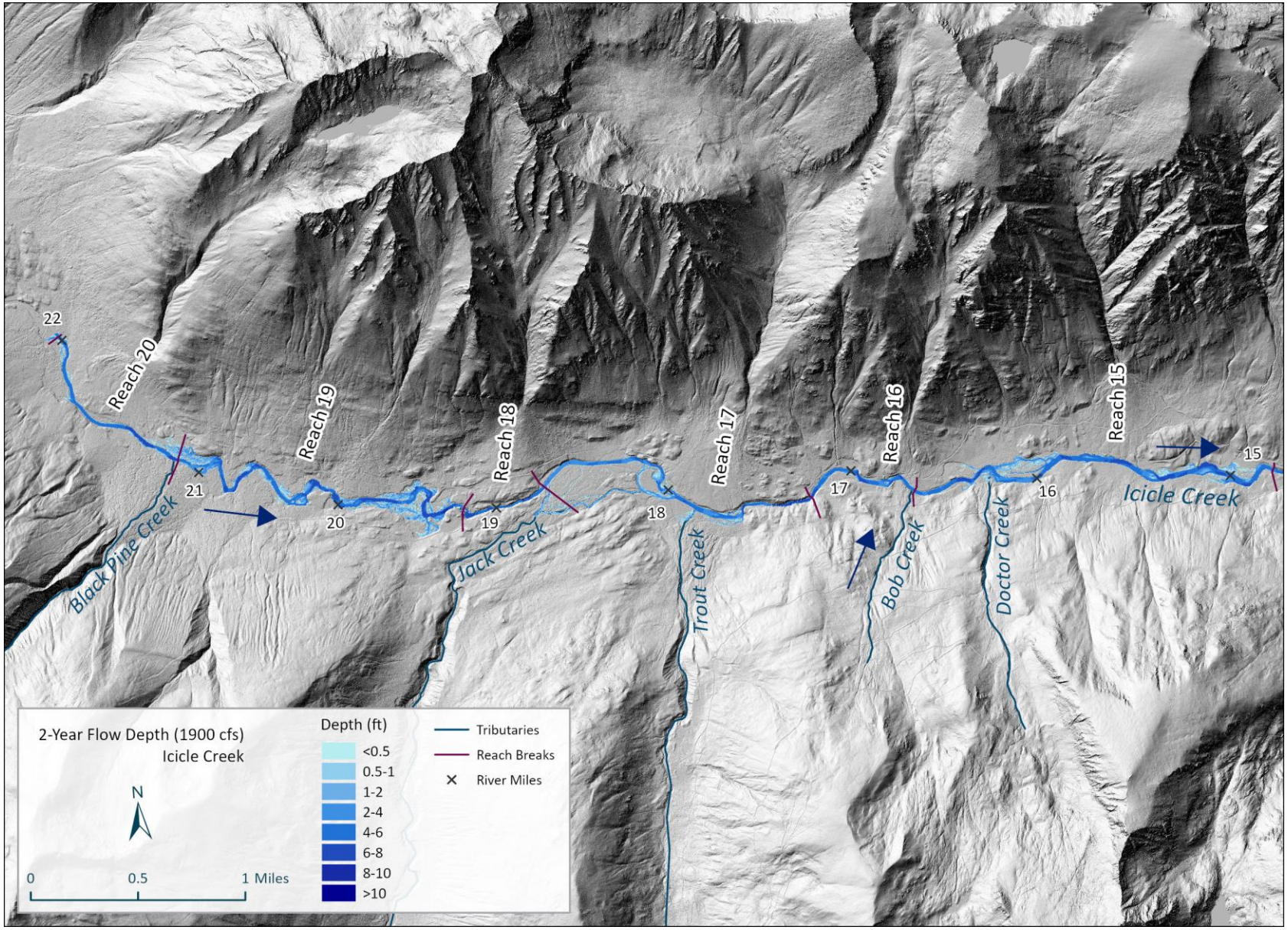

Figure 16. Modeled 2-year flood depth for Reaches 15 to 20, labeled with flow input at the upstream end of the model.

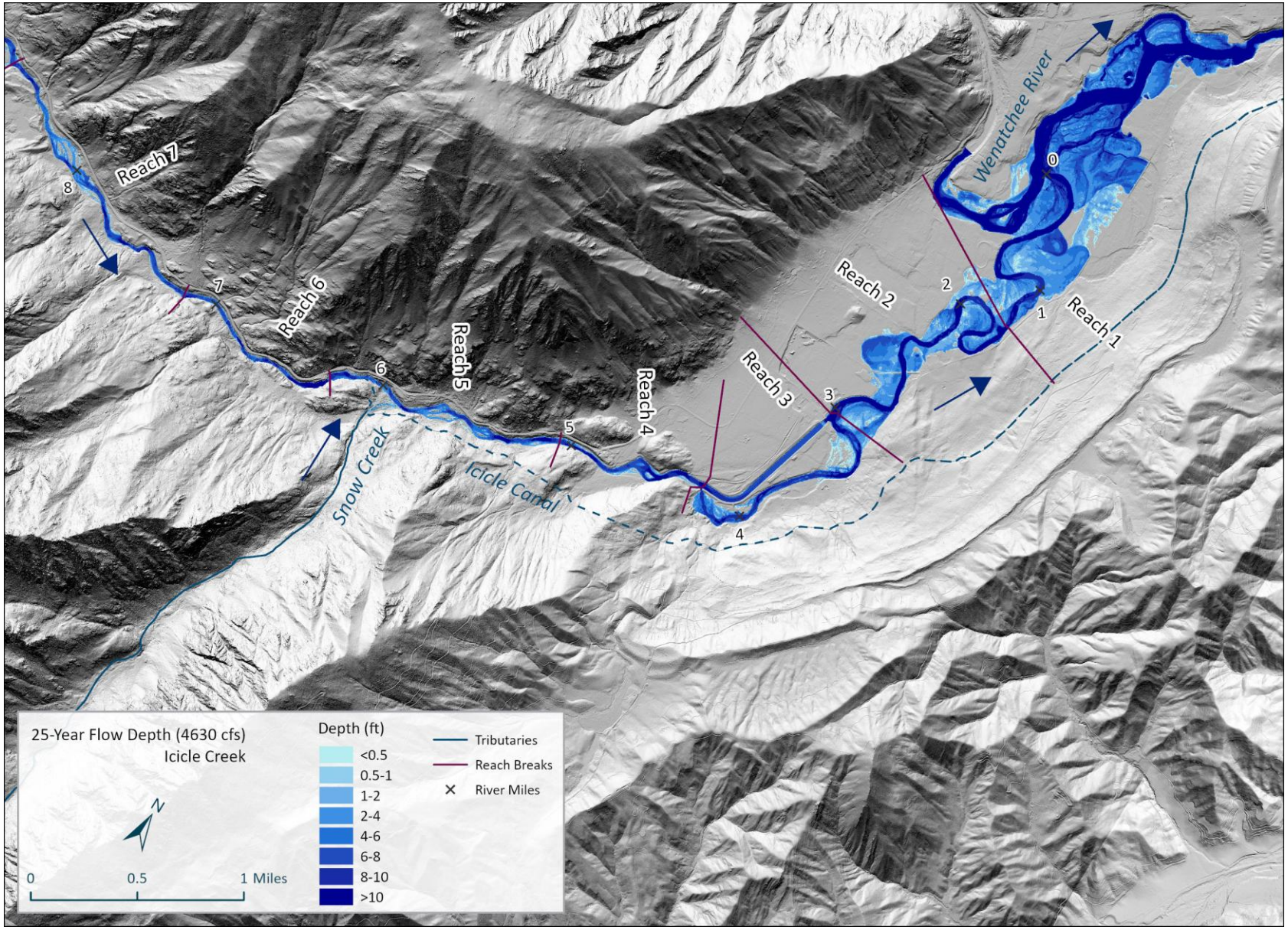

Figure 17. Modeled 25-year flood depth for Reaches 1 to 7, labeled with flow input at the upstream end of the model.

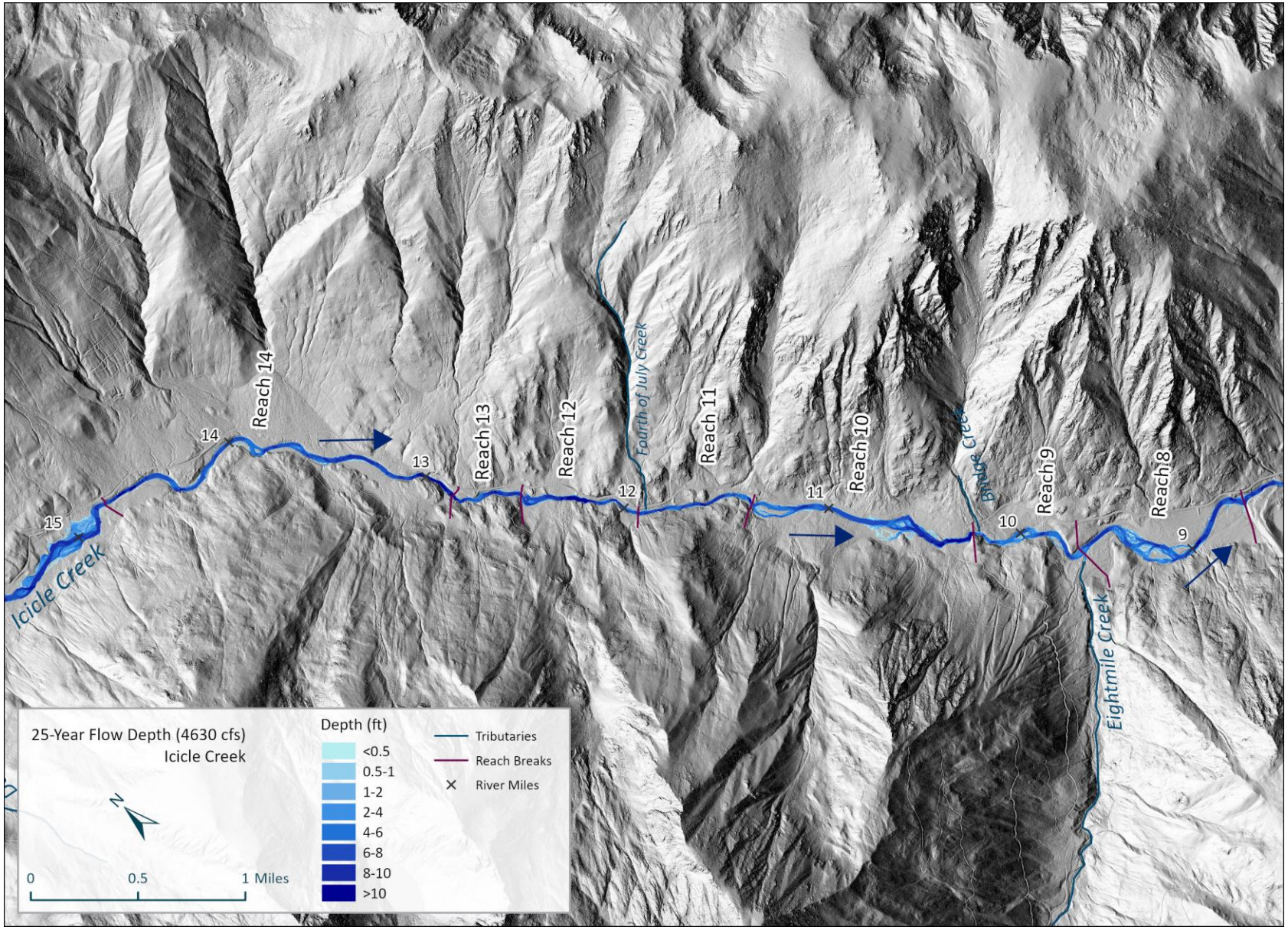

Figure 18. Modeled 25-year flood depth for Reaches 8 to 14, labeled with flow input at the upstream end of the model.

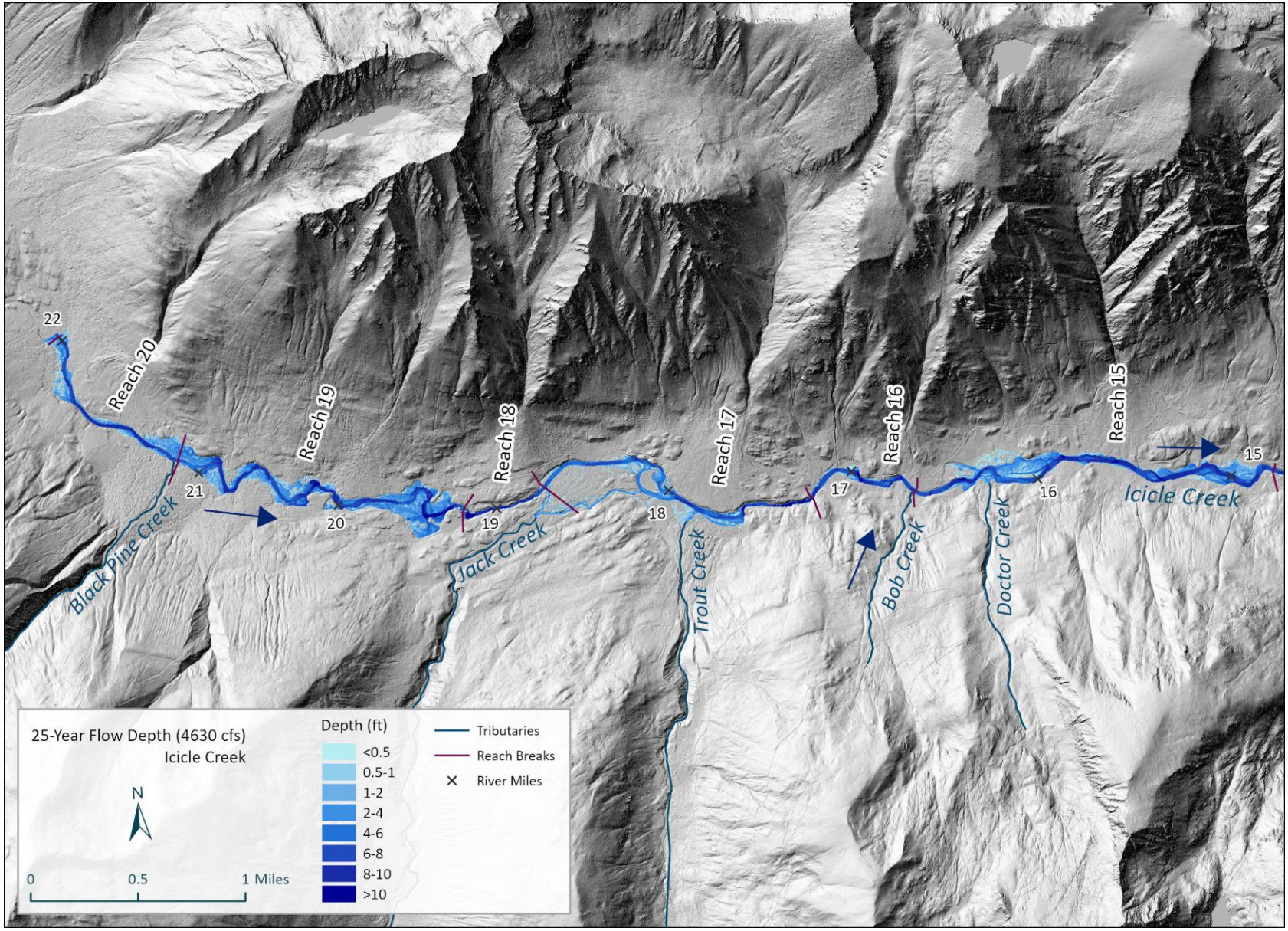

Figure 19. Modeled 25-year flood depth for Reaches 15 to 20, labeled with flow input at the upstream end of the model.

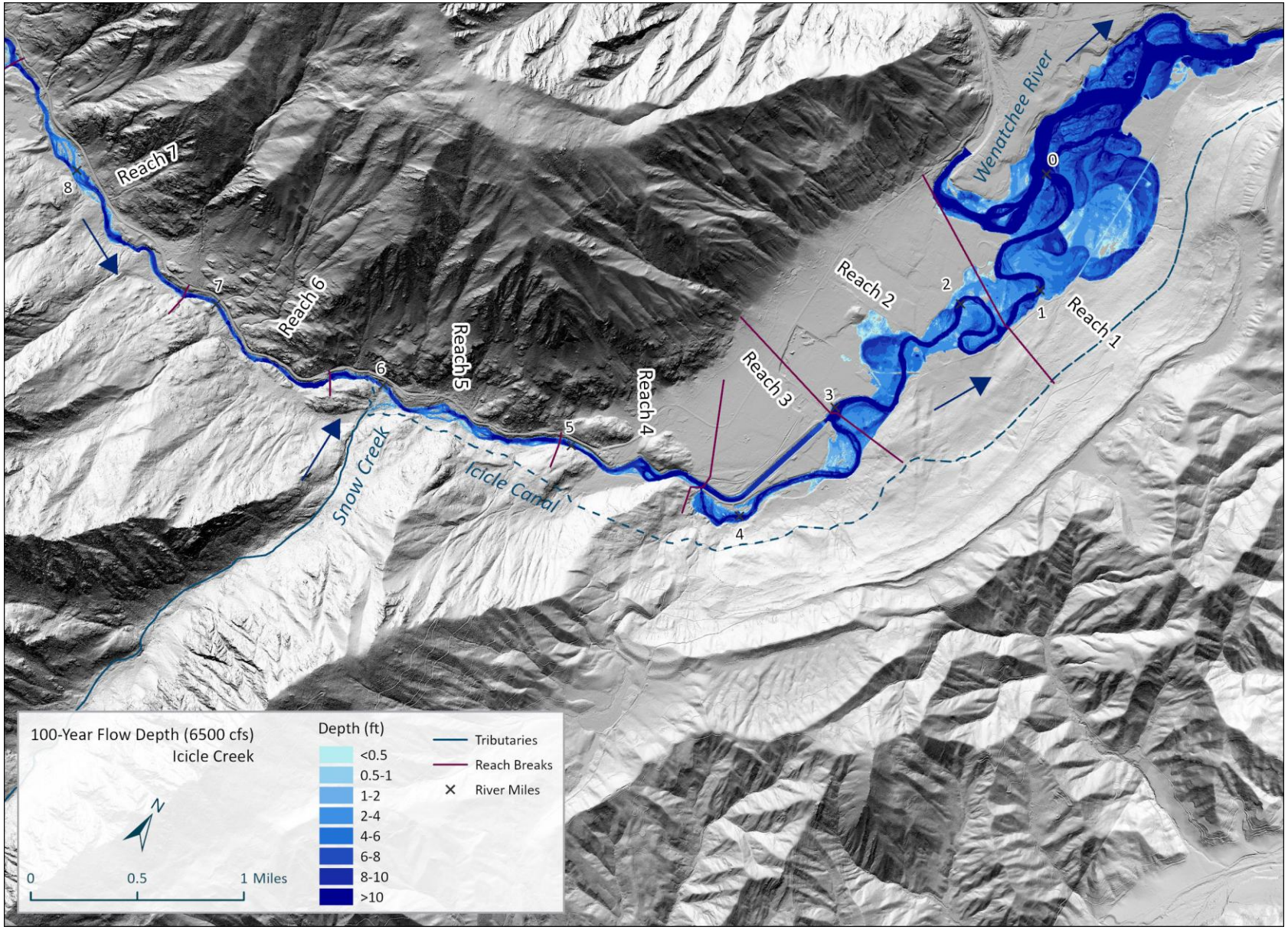

Figure 20. Modeled 100-year flood depth for Reaches 1 to 7, labeled with flow input at the upstream end of the model.

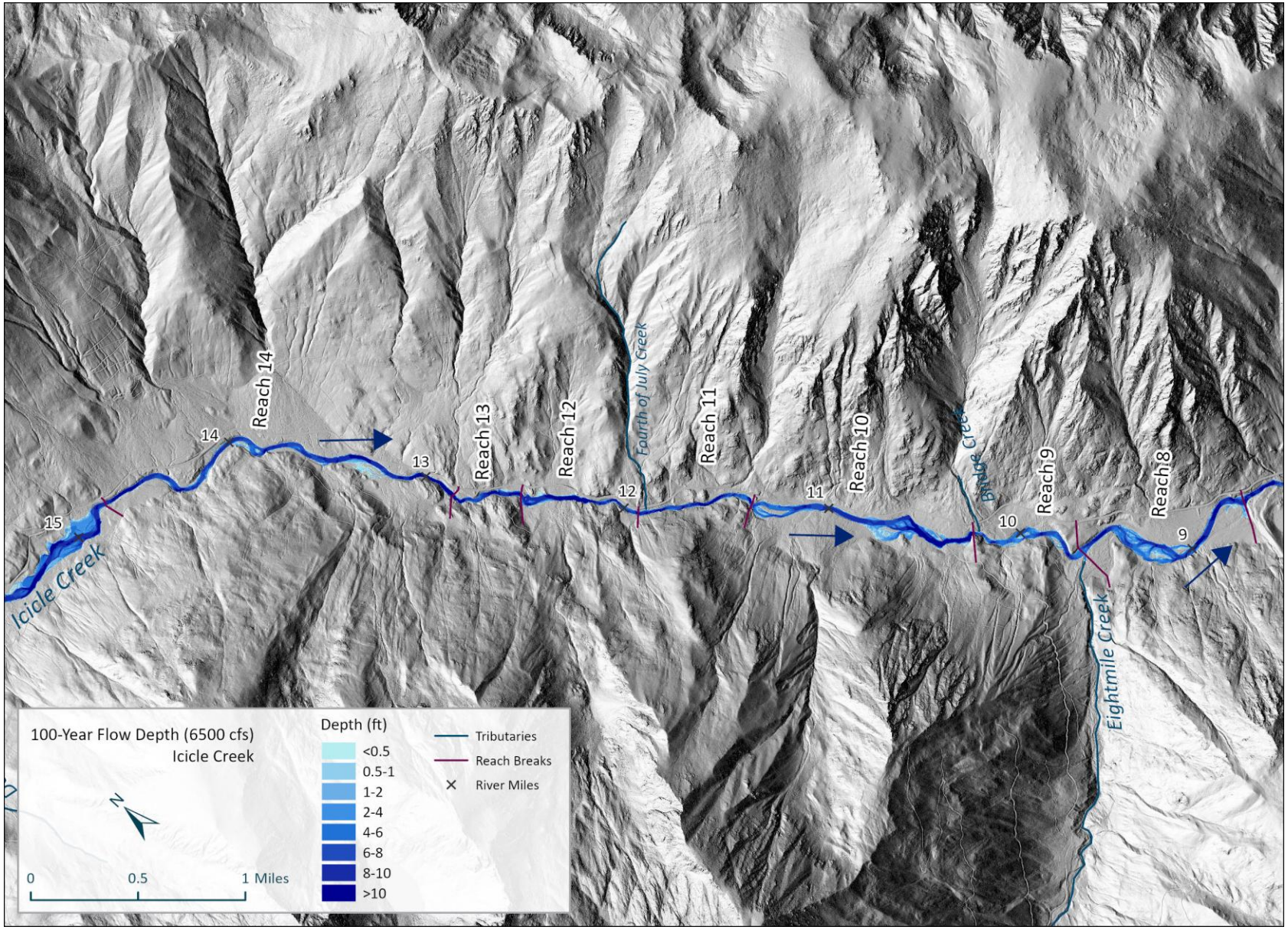

Figure 21. Modeled 100-year flood depth for Reaches 8 to 14, labeled with flow input at the upstream end of the model.

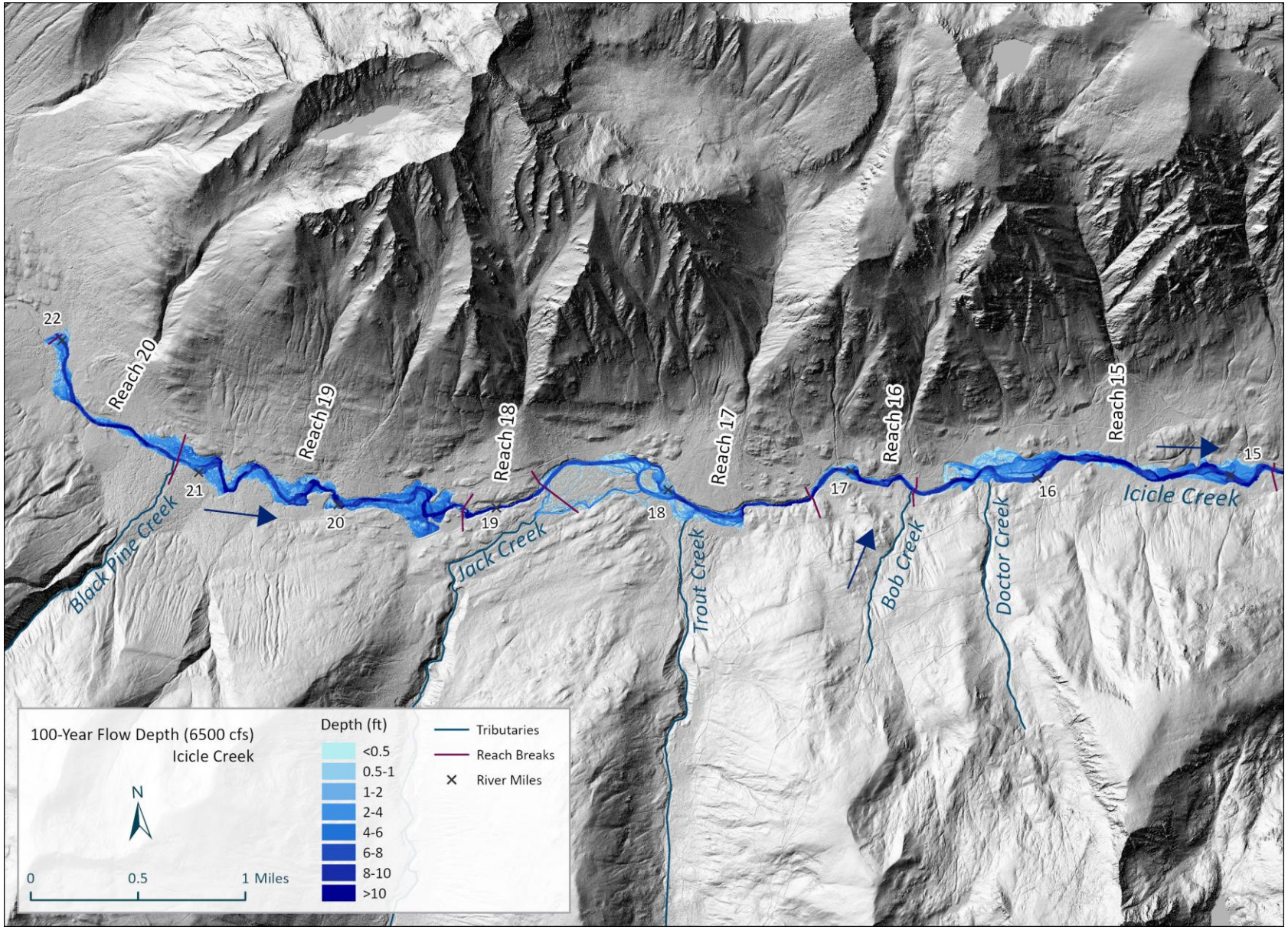

Figure 22. Modeled 100-year flood depth for Reaches 15 to 20, labeled with flow input at the upstream end of the model.

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USGS. (2024b). *USGS Surface-Water data for Washington*. USGS 12457000 WENATCHEE RIVER AT PLAIN, WA.