Icicle Creek Reach Assessment & Restoration Strategy
Final Report

February 2026

PREPARED FOR
Yakama Nation Fisheries

PREPARED BY
Inter-Fluve, Inc.

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The authors of this report would like to thank the Upper Columbia Regional Technical Team (UCRTT), Washington Department of Ecology, and the Icicle Work Group (IWG) for their careful review and contributions to this report.

List of Abbreviations *List abbreviations in alphabetic order.*

DBH – Diameter at breast height
DSM – Digital Surface Model
ESA – Endangered Species Act
GC – Gravel Count
IID – Icicle Irrigation District
IPID – Icicle-Peshastin Irrigation District
IPCC – Intergovernmental Panel on Climate Change
LiDAR – Light Detection and Ranging
LNFH – Leavenworth National Fish Hatchery
LWM – Large Wood Material
NAIP – National Agriculture Imagery Program
NRCS – Natural Resources Conservation Service
PID – Peshastin Irrigation District
REI – Reach-Based Ecosystem Indicators
RM – River Mile
UCHRP – Upper Columbia Habitat Restoration Project (Yakama Nation)
UCRTT – Upper Columbia Regional Technical Team
UCSRB – Upper Columbia Salmon Recovery Board
USACE – United States Army Corps of Engineers
USBR – United States Bureau of Reclamation
USFWS – United States Fish and Wildlife Service
USGS – United States Geological Survey
WDOE – Washington Department of Ecology
WDNR – Washington Department of Natural Resources

1. Introduction

1.1 PROJECT OVERVIEW

This assessment evaluates aquatic habitat and watershed process conditions in the lower Icicle Creek watershed and identifies habitat restoration strategies. Icicle Creek is a tributary to the Wenatchee River and is located within the North Cascade Mountains in central Washington (Figure 1). Icicle Creek flows east-southeast and joins the Wenatchee River near the town of Leavenworth, Washington, approximately 25.6 river miles upstream of where the Wenatchee meets the Columbia River. The assessment area includes the lower 22.02 miles of the mainstem Icicle Creek.

Figure 1. Location of the Icicle Creek assessment area within the Icicle Creek watershed.

This reach assessment provides a technical foundation for understanding existing conditions of lower Icicle Creek and for identifying the areas that would benefit from restoration strategies to improve aquatic habitat and stream ecological functions. Conditions are assessed at both the assessment area scale and reach scale. The aim of this assessment is to identify areas for restoration actions that address factors limiting the productivity of native salmonids and to ensure that the identified actions fit within the appropriate geomorphic and ecological context of the river system. An emphasis is placed on understanding the underlying biological and physical processes at work and how human impacts have affected these processes and the habitat they support. Restoration measures focus on recovering, to the extent possible, the impaired processes. Additionally, areas of minimal human impact are identified to promote conservation of healthy fluvial process. Although the proposed restoration and conservation measures are expected to benefit a large suite of native aquatic and terrestrial species, there is a particular emphasis on recovery of Endangered Species Act (ESA) listed Upper-Columbia summer steelhead (*Oncorhynchus mykiss*), Upper-Columbia Spring Chinook (*Oncorhynchus tshawytscha*), and Columbia River Bull Trout (*Salvelinus confluentus*).

The report includes the following components:

- Assessment area characterization (Section 2): Summary evaluation of valley and basin-scale factors influencing aquatic habitat and stream geomorphic processes.
- Reach-scale characterization (Section 3): Inventory and analysis of habitat and geomorphic conditions at the reach and sub-reach scales.
- Stream habitat assessment (Appendix A): Aquatic habitat inventory at the reach-scale.
- Reach-Based Ecosystem Indicators (REI) analysis (Appendix B): Comparison of habitat conditions to established functional thresholds.
- Project Opportunities and Prioritization (Appendix C): A restoration strategy that compares “existing” conditions to “target” conditions at the reach-scale and the recommended restoration treatments that address habitat and ecological process limitations. Includes a list, summary description, and maps of specific potential project opportunities that would help to achieve the reach-scale restoration strategies and prioritizes the opportunities based on “existing” conditions to “target” condition potential combined with a cost to benefit ratio.
- Hydraulic Model (Appendix D): Preliminary-level 2-dimensional (2-D) hydraulic model of Reaches 1-20 of Icicle Creek built from hydrologic analysis and available LiDAR.

This framework allows for the identification of areas for restoration activities at discrete locations while considering broader scale physical, ecological, and anthropologic factors that influence the assessment area.

December 2025 Flood Event:

During finalization of this assessment report, a significant flood event occurred on Icicle Creek in December of 2025 related to an “atmospheric river” event that delivered high amounts or precipitation to parts of the Pacific Northwest experiencing warmer than usual conditions. The rain-on-snow event resulted in flood flows peaking on December 11, 2025. Preliminary data from the Icicle above Snow Creek gage (USGS 12458000) reports that Icicle Creek experienced at least a 2% annual exceedance probability (AEP) event (50-year recurrence interval). The Wenatchee River at Peshastin gage (USGS 12459000) suggests the Wenatchee River, approximately 9 miles downstream of the Icicle Creek confluence, experienced between a 1% and 0.5% (AEP) event (100-yr to 200-yr recurrence interval). In contrast, rivers just to the north, including the nearby Chiwawa and Entiat Rivers, had lower intensity floods, with a 50-20% AEP (2- to 5-yr) event on the Chiwawa (USGS 12456500) and less than a 50% AEP (2-yr) event on the Entiat (USGS 12452800), revealing the strong north-to-south gradient in rainfall intensity.

Events of this magnitude have the potential to significantly alter channel, floodplain, habitat, and infrastructure conditions. For these reasons, it is important for the reader to understand there may be changes within the Icicle Creek reach assessment area compared to the conditions documented in this report, which are based on pre-flood field surveys from the summers of 2024 and 2025. Regardless of potential changes, preliminary observations suggest the effects of the flood are unlikely to alter the overall habitat condition, REI analysis, restoration recommendations, or other broad conclusions made in the assessment.

Figure 2. Flooding on Icicle Creek at the Boulder Field area near river mile 6, December 11, 2025. (photo: Yakama Nation)

1.2 BACKGROUND

This project was completed on behalf of the Yakama Nation as part of their efforts to improve native aquatic fisheries within the Columbia River Basin through their Upper Columbia Habitat Restoration Project (UCHRP). The UCHRP works to achieve the objectives of the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSRB, 2007) and its associated Biological Strategy ((UCRTT, 2021)).

Assessment methods involved collecting field data and combining it with existing available information on Icicle Creek and the Wenatchee River watershed. The field procedures and data management for collecting new data was approved by the WA Department of Ecology through a Quality Assurance Project Plan (2024). Existing available information utilized in this assessment includes but is not limited to the Icicle Creek Boulder Field Fish Passage Assessment (Dominguez et al., 2013), Changing Streamflow in Icicle Creek (Mauger et al., 2017), the 2017 Lower Icicle Creek Reach Assessment River Mile 0.0 – 4.3 (Natural Systems Design, 2017), Seasonal Movements of Adult Fluvial Bull Trout and Redd Surveys in Icicle Creek (Nelson et al., 2011). This assessment builds on past efforts previously completed. New data collection and analysis performed as part of this effort includes a geomorphic assessment of the lower 22.02 river miles of the mainstem channel and its floodplain surfaces, as well as an aquatic habitat inventory, characterization of landforms and human impacts, and identification and prioritization of habitat restoration opportunities.

1.3 PURPOSE

The purpose of this assessment is to document aquatic habitat conditions and hydrologic, geomorphic, and ecological processes in the Icicle Creek and to present a comprehensive reach-based restoration strategy to address habitat limiting factors for salmon, steelhead, and bull trout. Evaluations used in this assessment include historical characterization, geomorphic assessment, hydraulic assessment, and an aquatic habitat inventory.

Specific goals and outcomes of this assessment include:

- Provide a comprehensive inventory and assessment of geomorphic and aquatic habitat existing conditions and trends
- Identify strategies and actions that address critical aquatic habitat impairments limiting the productivity of focal salmonid populations
- Identify strategies and actions that protect and restore the dynamic landscape processes that support sustainable riparian and salmonid habitat
- Present a prioritized list of recommended actions for implementation
- Provide a resource for coordinating efforts with local landowners, resource managers, and other stakeholders to accomplish habitat restoration goals.

2. Assessment Area Characterization

2.1 SETTING

Icicle Creek is a fifth-order stream located within the Upper Columbia River Basin in the central North Cascade Mountains of Washington State. It is the largest tributary drainage of the Wenatchee River watershed. Icicle Creek flows approximately 32.5 river miles (RM) from its headwaters at Josephine Lake in the Alpine Lakes Wilderness area, through a steep, bedrock-confined valley, southeast to its mouth in an unconfined valley at the Wenatchee River near the City of Leavenworth, WA. In these 32.5 miles, Icicle Creek falls over 3,000 feet.

Icicle Creek supports native salmonid populations; with most fish usage occurring downstream of river mile (RM) 4.6. The Leavenworth National Fish Hatchery (LNFH) Structure #5 at RM 3.15 serves as a seasonal fish barrier (USBR & USFWS, 2021;WDOE, 2019). Salmonids are also known to have natural limited passage through some of the canyon sections of Icicle Creek. See Section 2.2 for additional information.

This assessment focusses on the lower 22.02 miles of Icicle Creek. The assessment area is divided into 20 individual reaches to facilitate discussion of stream attributes and conditions. These reaches match the Upper Columbia Salmon Recovery Board (UCSRB) reaches, which were not changed as they were considered sufficient to represent geomorphic variability (UCSRB, 2021). Information on previous salmon habitat assessments and their comparison to this assessment can be found in Section 1.1 of Appendix A. Maintaining these established reaches also provide advantages for comparing existing and future reach-based studies. Reaches are numbered sequentially, with reach numbers increasing from downstream to upstream.

Although reach break locations remain the same, river mile values have been updated in the assessment to include the historical channel alignment near the hatchery, similar to historical USGS river miles, instead of using the hatchery canal as the mainstem channel. As a result, the length of Reach 3 increased to 1.28 miles, compared to the UCSRB Reach 3 length of approximately 0.8 miles. The river mile adjustment translates through all the reaches upstream of Reach 3. A comparison of the updated river miles used in this report and those used by UCSRB can be found in Table 1. The updated river miles are displayed in maps and referenced in the text of this assessment. Inter-Fluve is aware that as a result, the river miles used in this assessment will vary from other assessments and reports. However, the correction is important moving forward with restoration work and the correlation table is provided below as reference. A map of the assessment area with reach breaks and updated river miles is provided in Figure 3.

Icicle Creek watershed drains approximately 214 square miles of land, of which 87% is on public land (Okanogan-Wenatchee National Forest) including the Alpine Lakes Wilderness area (74%), although the Alpine Lakes Wilderness area is almost exclusively upstream of the assessment area. Private land ownership is limited to the lower six river miles of Icicle Creek and accounts for 13% of the basin (Figure 4).

Table 1. Updated river miles for this assessment compared to those used by UCSRB (UCSRB, 2021). Increased river mile length of Reach 3 is the result of using the historical channel, similar to USGS, instead of the hatchery canal as the defined mainstem channel. Other small variations in reach length are due to refinement of the centerline alignment.

Reach	Assessment Mileage		Assessment Length	UCSRB Mileage		UCSRB Length
	Start	End		Start	End	
1	0	1.24	1.24	0	1.27	1.27
2	1.24	3.02	1.78	1.27	3.0	1.73
3	3.02	4.3	1.28	3.0	3.8	0.8
4	4.3	5.05	0.75	3.8	4.5	0.7
5	5.05	6.27	1.22	4.5	5.65	1.15
6	6.27	7.15	0.88	5.65	6.55	0.9
7	7.15	8.63	1.48	6.55	8.0	1.45
8	8.63	9.63	1.0	8.0	8.9	0.9
9	9.63	10.24	0.61	8.9	9.5	0.6
10	10.24	11.36	1.12	9.5	10.6	1.1
11	11.36	11.92	0.56	10.6	11.2	0.6
12	11.92	12.5	0.58	11.2	11.75	0.55
13	12.5	12.84	0.34	11.75	12.1	0.35
14	12.84	14.75	1.91	12.1	14.0	1.9
15	14.75	16.63	1.88	14.0	15.7	1.7
16	16.63	17.24	0.61	15.7	16.5	0.8
17	17.24	18.74	1.5	16.5	17.8	1.3
18	18.74	19.18	0.44	17.8	18.45	0.65
19	19.18	21.11	1.93	18.45	20.2	1.75
20	21.11	22.02	0.91	20.2	21.15	0.95

Figure 3. Overview of the Icicle Creek assessment area.

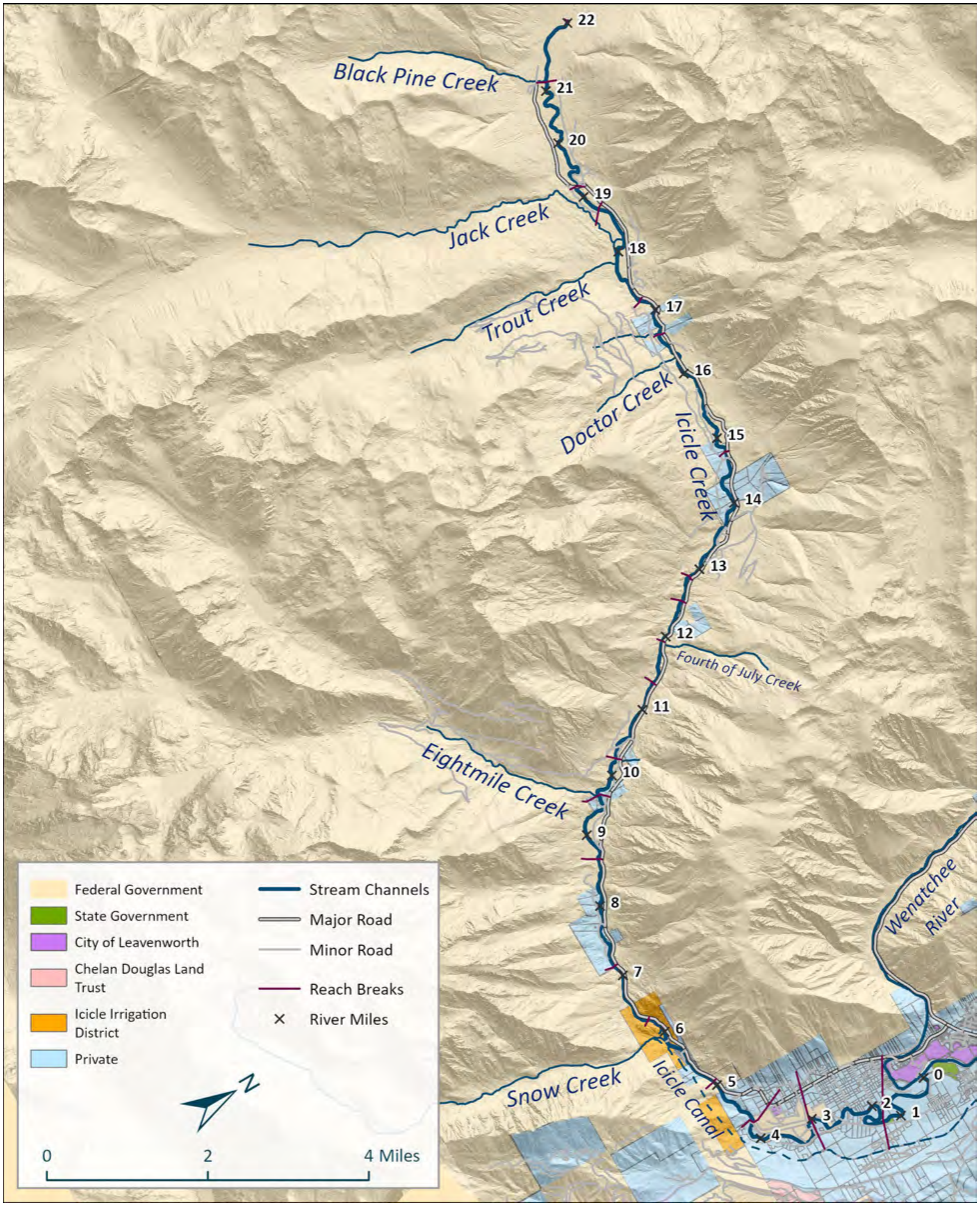

Figure 4. Land ownership in the Icicle Creek assessment area.

2.2 SALMONID USE AND STATUS

Icicle Creek currently supports anadromous runs of spring Chinook Salmon, Coho Salmon, steelhead trout, and Pacific Lamprey, and both resident and migratory bull trout (Carlson et al., 2004) Steelhead trout are classified as threatened (most recently classified in 2006) and Bull Trout are classified as threatened (listed in 1999). The Upper Columbia population of Spring Chinook Salmon in the Wenatchee Subbasin are classified as endangered (listed in 1999); however, most spring Chinook in Icicle Creek over the past several decades have been assumed to be Carson Stock hatchery fish from the Leavenworth National Fish Hatchery (LNFH), which are excluded from the listed population (National Oceanic and Atmospheric Administration (NOAA), 1999). Some Coho Salmon present in the watershed are part of Yakama Nation's Reintroduction Project (YNF & CRITFC, 2012) that began in 1996. Within the assessment area of Icicle Creek (RM 0-22.02), these salmon and trout species, along with Pacific Lamprey, are the primary focal species for restoration efforts by the Yakama Nation.

The LNFH located near RM 3 currently rears Spring Chinook and Coho Salmon which are released into Icicle Creek. From approximately 1940 to 2005, LNFH infrastructure and operations blocked fish passage year-round. Since 2006, operations at the upstream and downstream structures have been adjusted to improve fish passage and habitat conditions (Skalicky et al., 2013). Nevertheless, LNFH infrastructure still impacts both sediment transport and the migration of anadromous salmonids within Icicle Creek (Lorang & Aggett, 2005; Skalicky et al., 2013; USFWS, 2020). A more detailed discussion of the LNFH infrastructure and impacts to fish passage are provided in Section 2.5.3.

Upstream of the LNFH, the Icicle Creek boulder field is located at approximately RM 5.99 – 6.12. A 2013 assessment (Dominguez et al., 2013) evaluated fish passage and geomorphic conditions of the boulder field, including the extent of anthropogenic-related influence on the current fish passage through the boulder field. Dominguez et al. (2013) suggested that the natural geomorphic condition likely provided fish passage at only a limited range of flows, but road fill further constricted the channel and contributed to additional impediments to upstream fish passage through the boulder field section. Led by Trout Unlimited, a design for fish passage improvements was developed and implemented in 2020. The project constructed a step-pool channel and relocated a City of Leavenworth water pipe to reduce anthropogenic encroachment and improve passage through the boulder field under a range of flow conditions. It is assumed that salmonid passage is improved, allowing increased access to approximately 23 miles of mainstem habitat and dozens of miles of tributary habitat. A PIT tag array located upstream of the boulder field has detected some Chinook salmon passing the boulder field since 2021 (see description in 2.2.1).

An irrigation diversion structure located in the main channel near river mile 6.27 is not identified as a fish passage barrier by the Washington Department of Fish and Wildlife (WDFW, 2018).

2.2.1 Spring Chinook

Although the Upper Columbia population of Spring Chinook Salmon in the Wenatchee Subbasin are classified as endangered (listed in 1999), spring Chinook salmon residing in Icicle Creek over the past several decades have been assumed to be Carson Stock hatchery fish from the LNFH, which are excluded from the listed population (NOAA, 1999). Natural production is currently assumed to be limited due to the recent history of adult passage issues in the boulder field near RM 6 and by poor habitat conditions and warm summer water temperatures in potentially suitable spawning areas downstream of the LNFH (personal communication, Cory Kamphaus, Yakama Nation, June 2025). Recent improvements to passage at the boulder field do seem to have allowed some Spring Chinook to pass. Between 2021 and 2024, a PIT array data located upstream of the boulder field (Site Code ICU – Upper Icicle Creek) recorded a total of 17 Chinook, indicating some passage does occur. However, this represents only a small fraction of fish entering Icicle Creek. During the same period, the PIT array located 0.4km from the mouth of Icicle Creek (Site Code ICL – Lower Icicle Creek) recorded 3265 detections, and the PIT array (Site Code ICM – Middle Icicle Array) located downstream of the boulder field 4.35 miles from the mouth of Icicle Creek recorded 298 detections (DART, 2026).

Adult Chinook enter the Wenatchee River basin in May, and move into spawning areas, such as lower Icicle Creek. Spawning occurs late August through September (Chapman et al., 1995; Figure 5 and Figure 6). Eggs are very sensitive to changes in oxygen levels and percolation, both of which are affected by sediment deposition and siltation in the redd (Peven et al., 2004). Fry emerge in the spring, which typically coincides with the rising hydrograph. High water forces juvenile Chinook to seek backwater or margin areas with lower velocities, dense cover, and abundant food (Healy, 1991; Hillman & Miller, 1989; Quinn, 2005).

Age-1 parr utilize deeper pools with resting cover in mainstem habitats more than post-emergent individuals. Spring Chinook typically rear for one year in freshwater before out-migrating as yearlings. Out-migration typically begins in March (Healy, 1991; Peven et al., 2004).

Spring Chinook are reported in the lower six miles of Icicle Creek, though a majority currently spawn and rear below the LNFH near RM 3 (Figure 5; Carlson et al., 2004; WDFW, 2024). The Statewide Washington Integrated Fish Distribution (WDFW, 2026b) suggests Spring Chinook may potentially be present in the mainstem Icicle Creek throughout the entire study area, up to approximately RM 23. Rearing and spawning within Icicle Creek is largely driven by adults returning to the Leavenworth National Fish Hatchery, though some strays from elsewhere in the basin may be present (Andonaegui, 2001; Carlson et al., 2004; Peven, 2003). Between 1995 and 2021, surveys recorded 411 redds within the lower six miles of Icicle Creek, with specific counts of Spring Chinook redds only conducted from 2014 to 2016 (Upper Columbia Salmon Recovery Board, 2022a).

Summer Chinook are ESA listed but are also present in the Wenatchee basin. Summer Chinook primarily utilize the Wenatchee River, but have been observed spawning in the lower few miles of Icicle Creek (personal comm., C. Kamphaus, Yakama Nation, June 2025; Figure 5).

Figure 5. Summer and Spring Chinook redd locations. Source: Upper Columbia Salmon Recovery Board data portal, accessed November 13, 2024.

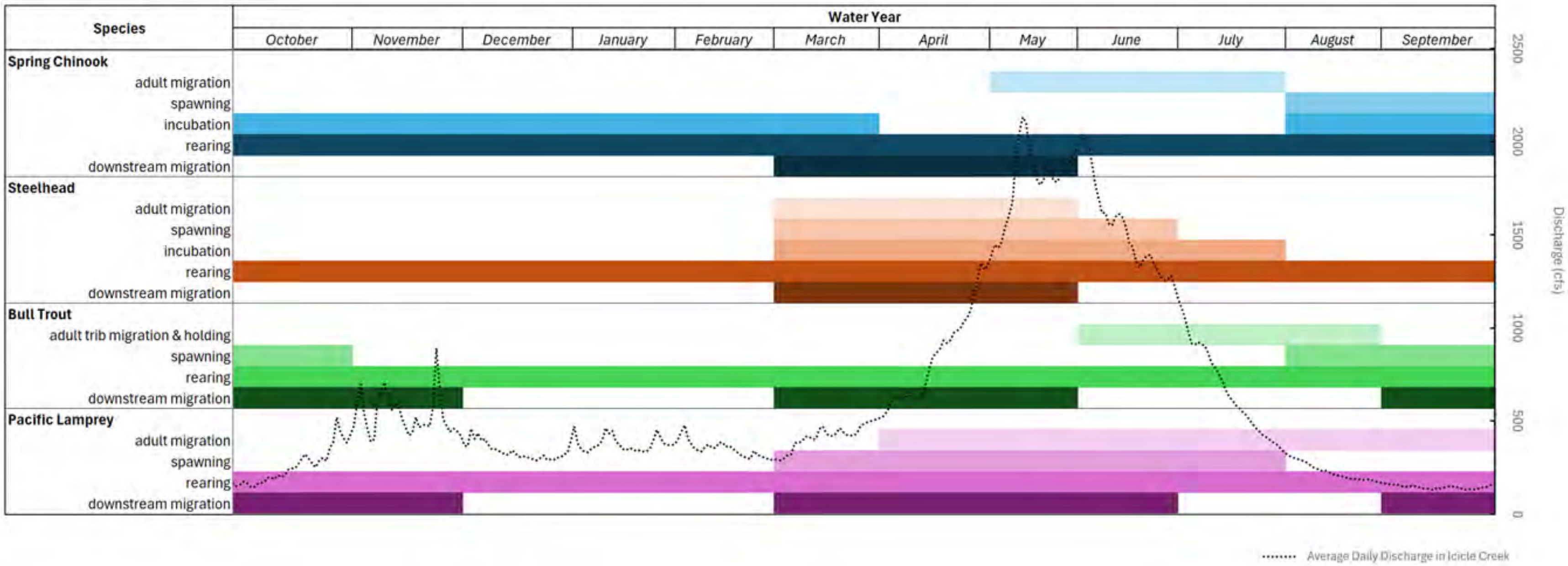

Figure 6. Summary of the life history timing of Spring Chinook, steelhead, Bull Trout, and Pacific Lamprey in Icicle Creek, overlaid on an annual hydrograph depicting mean daily discharge from the period 1993 - 2023 in the Icicle Creek USGS gage 124580000 near Leavenworth, WA (life history references cited in the species description sections 2.2.1 – 2.2.4).

2.2.2 Steelhead Trout

Upper Columbia River (UCR) steelhead trout were originally listed as endangered under the ESA in 1997 (NOAA, 1997) and later reclassified to threatened in 2006 (NOAA, 2006). The production of UCR steelhead is generally considered depressed and impacted by loss of habitat and downstream dams (Carlson et al., 2004). Lower Icicle Creek is considered a major spawning area for UCR steelhead (The Watershed Company, 2005).

These summer-run steelhead trout enter and ascend the Columbia River in June and July, arriving near their spawning grounds nine to eleven months prior to spawning (Figure 6 and Figure 7). Adult steelhead trout in the Upper Columbia typically overwinter in the mainstem Columbia, returning to the Wenatchee River sub-basin in the spring (March through May) of the following year prior to spawning (UCSRB, 2007). Egg survival is highly sensitive to intra-gravel flow and temperature (Peven et al., 2004) and is particularly sensitive to siltation earlier in the incubation period. Fry emerge from the redds six to ten weeks after spawning (Peven et al., 2004). The current distribution of steelhead upstream of the LNFH may have been impacted by the lack of passage upstream of this facility until 2006.

Age-0 juveniles spend their first year primarily in shallow riffle habitats, feeding on invertebrates and utilizing overhanging riparian vegetation and undercut banks for cover (Hillman & Miller, 1989; Moyle, 2002). Older juveniles prefer faster moving and deeper water, including large pools and runs over cobble and boulder substrate. Juvenile steelhead typically out-migrate between ages one and three, though some hold over and display a resident life history form (i.e., considered rainbow trout). Steelhead trout smolts typically begin migrating downstream from natal freshwater rivers in March (Carlson et al., 2004; Peven et al., 2004).

Summer steelhead trout spawning has been documented in Icicle Creek (WDFW, 2024). Steelhead are presumed to be present above the boulder field (RM 5.99 – 6.12), especially after the boulder field fish passage improvement project completed in 2020. However, limited data are available documenting presence, or upstream extent of steelhead in Icicle Creek, except for one single PIT tag detection recorded at the PIT array site upstream of the boulder field (Site Code ICU – Upper Icicle Creek) on June 19, 2015 (before the passage project improvement; DART, 2026). Between 2005 and 2020, surveys recorded 451 redds within the lower three miles of Icicle Creek (Figure 7; UCSRB, 2022b). From 2011 to 2025, 502 steelhead detections were recorded at the Lower Icicle Creek PIT array (Site Code ICL), and from 2015 – 2025, 49 steelhead detections were recorded at the Middle Icicle Creek PIT Array (Side Code ICM). This indicates the majority of steelhead use is within the downstream portions of the assessment area, but that individuals may be present in upstream reaches.

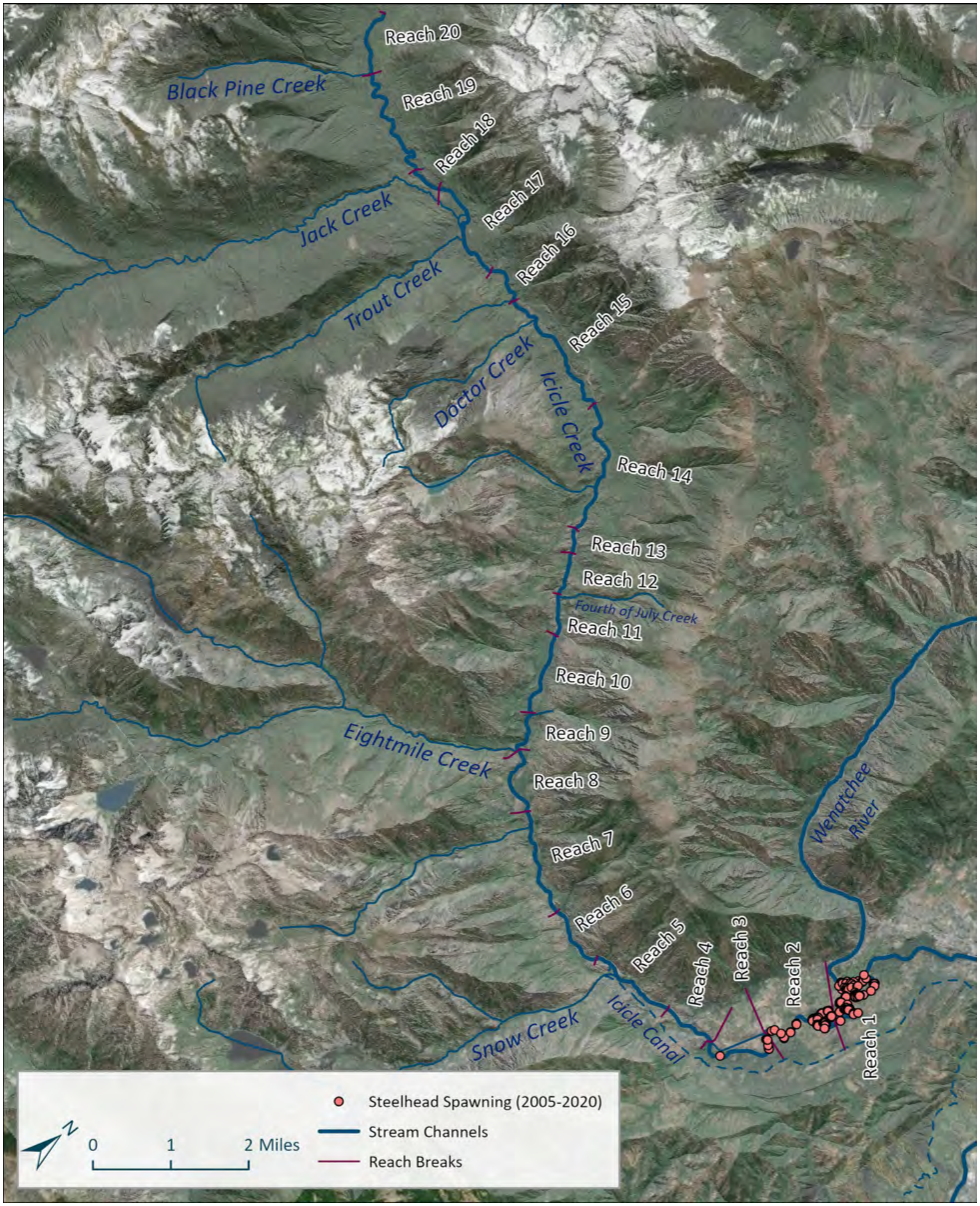

Figure 7. Steelhead trout redd locations. Source: Upper Columbia Salmon Recovery Board data portal - accessed November 13, 2024.

2.2.3 Bull Trout

Bull Trout were listed as threatened under the ESA in 1999 (USFWS, 1999). Bull Trout may exhibit both resident and migratory life-history strategies (B. E. Rieman & Mclntyre, 1993). Compared to other salmonids, Bull Trout have more specific habitat requirements that appear to significantly influence their distribution and abundance. Critical parameters include water temperature, cover, channel form and stability, valley form, spawning and rearing substrates, and migratory corridors (USFWS, 1999). The Icicle population of Bull Trout is considered an important local migratory population within the Upper Columbia Bull Trout Recovery Unit within the Wenatchee Core Area.

Bull Trout normally reach sexual maturity in 4 to 7 years and can live 12 or more years. Bull Trout in the Wenatchee River subbasin spawn from August through October (Figure 6) during periods of decreasing water temperatures (Carlson et al., 2004). Preferred spawning habitats are generally low gradient stream reaches, or in areas of loose, clean gravel in higher gradient streams (Fraley & Shepard, 1989), and where water temperatures are between 5 to 9° C (41 to 48° F) in late summer to early fall (Goetz, 1989). Spawning areas are often associated with cold-water springs, groundwater infiltration, and are typically the coldest systems in a given watershed (USFWS, 1999). Bull Trout egg incubation can last between 100–200 days, and juveniles remain in the substrate for a period after hatching. Fry normally emerge from the gravels early April through May, depending upon water temperatures and increasing stream flows (USFWS, 1999).

Non-migratory subpopulations of Bull Trout are known to spawn and rear in Icicle Creek, including within the assessment area (Figure 8). The resident Bull Trout populations complete their life cycles in tributary streams, such as French Creek and Jack Creek (Andonaegui, 2001), in which they spawn and rear (Figure 8). Within the assessment area, non-migratory subpopulations of Bull Trout have been recorded spawning and rearing, indicating it is a critical habitat for this threatened species (Carlson et al., 2004; Peven, 2003; WDFW, 2024).

Icicle Creek also hosts a migratory population of Bull Trout which is larger in size than the non-migratory subpopulation. Migratory-sized Bull Trout have been observed both upstream and downstream of the boulder field. Migratory-sized Bull Trout redds have been documented at least up to French Creek, upstream of the assessment area. Radio-tagged Bull Trout have been documented migrating to the Wenatchee (Nelson et al., 2011). This indicates that migratory Bull Trout are at least periodically present throughout the assessment area. The presence of migratory Bull Trout may have been reduced by the loss of fish passage at the LNFH until 2006.

Rearing Bull Trout have been observed in approximately the lower fifteen miles of Icicle Creek, while spawning areas begin around RM 15 and continue upstream past the end of the assessment area at RM 22.02 (WDFW, 2024). During 2010-2022 surveys, Bull Trout redds were reported in both French Creek and Jack Creek tributaries entering Icicle Creek within the assessment area near RM 22.7 and 18, respectively. A total of eleven redds in French Creek and one redd in Jack Creek were observed (Upper Columbia Salmon Recovery Board, 2023). Therefore, the majority of Bull Trout spawning appears to occur in the upper portion of the assessment area. However, during past snorkel surveys, small Bull Trout have been observed just upstream of the boulder field near RM 6.

Originally, it was unknown if these fish were resident fish from upstream or if they had ascended the boulder field falls (Nelson et al., 2011). The ability of Bull Trout to ascend these falls has likely improved following the Icicle Creek boulder field fish passage improvement project in 2020 (Dominguez et al., 2013).

eDNA data collected by the Range-Wide Bull Trout eDNA project have detected Bull Trout in Jack Creek, French Creek, and Leland Creek. Bull Trout were not detected within the Eightmile Creek basin or within the mainstem Icicle upstream of Jack Creek. The Icicle Creek mainstem downstream of Jack Creek (and through the entire assessment area) was not sampled (USFS, 2023).

Brook trout and Bull Trout hybridization is a concern in Icicle Creek (Nelson et al., 2011). Eastern brook trout were planted throughout eastern Washington beginning in the late 1800s, including in several locations in the Icicle Creek watershed in the early 1900s. They are believed to occur throughout the watershed, including within potential Bull Trout spawning areas. Hybridization with Bull Trout has been confirmed in the basin (Nelson et al., 2011). Hybridization with brook trout can lower the genetic fitness of native Bull Trout.

Bull Trout populations face ongoing threats that reduce habitat suitability and connectivity. Habitat fragmentation due to barriers, the expansion of non-native fishes, and the increasing impacts of climate change have all been identified as major challenges to Bull Trout populations. In the absence of enhanced conservation measures, these stressors are projected to lead to reduced resiliency in core areas and potential extirpation in vulnerable subpopulations, particularly under severe climate scenarios (USFWS, 2024). Conservation efforts targeted at habitat connectivity, cold-water preservation, and non-native species management remain essential to improving Bull Trout viability in the Icicle Creek watershed and throughout their listed range.

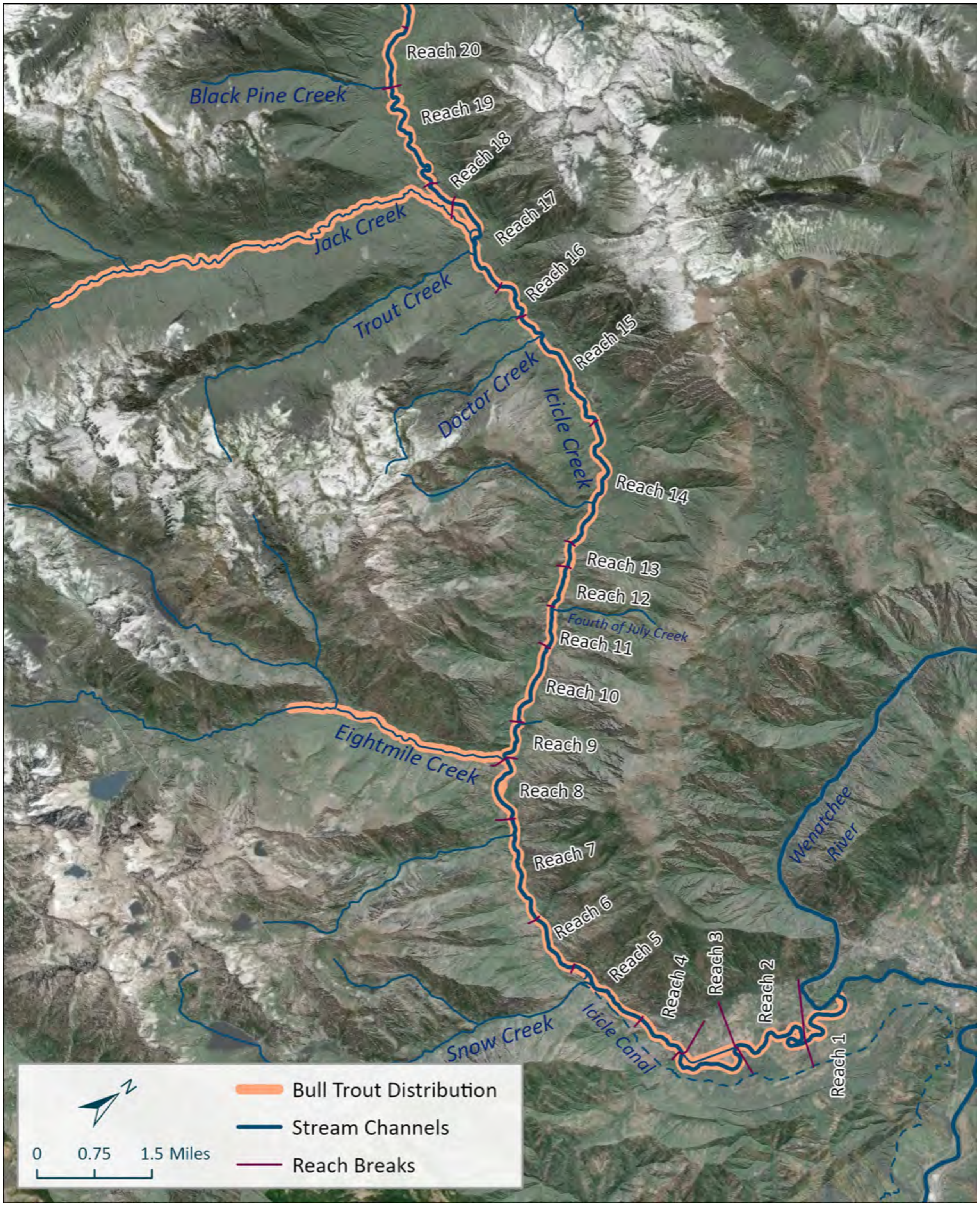

Figure 8. Bull trout distribution in Icicle Creek. Source: Upper Columbia Salmon Recovery Board data portal - accessed November 13, 2024.

2.2.4 Pacific Lamprey

Adult upstream migration of Pacific lamprey occurs from the late spring through fall in the Columbia River Basin, with peak passage occurring in the Upper Columbia at Rock Island Dam in late August (McIlraith et al., 2017; Figure 6). While there is some known information about Pacific lamprey in Icicle Creek, data remains quite limited. The U.S. Fish and Wildlife Service has observed Pacific lamprey redds in the Wenatchee River basin (USDA, 2011). Spawning generally occurs from March through July at temperatures between 10-15°C (Figure 6; USBR, 2017). Preferred spawning habitat is in low gradient runs and pool tail-outs. Hatching date varies according to water temperature and is typically around 15 days after spawning. Larval lampreys spend a short period of time (~15 days) in the redd after hatching before drifting downstream to suitable rearing habitats. Rearing habitat typically consists of low gradient areas with low water velocity, soft substrate, and organic material. Juveniles can rear in freshwater for up to seven years as they grow, during which time they filter feed on diatoms and suspended organic material. While in freshwater, juveniles undergo a transitional stage similar to smoltification in salmonids where they develop a large eye, a disk-shaped mouth, a silver body color, and begin preparing for the transition into saltwater. The transitional adults are termed “transformers” (or macrophthalmia). Downstream migration can occur in the late summer and fall, between July and October, or during high flows in late winter and early spring (USBR, 2017). Transformers may spend up to seven years in the ocean in a parasitic life stage, where they develop into adults before migrating to freshwater to spawn (WDFW, 2026a).

The historic distribution and behaviors of Pacific Lamprey in the Wenatchee subbasin is limited and may be confounded by the presence of river lamprey (BioAnalysts Inc., 2000). In the Wenatchee River, Pacific Lamprey were historically documented upstream of Tumwater Dam in Lake Wenatchee and the upper mainstem, and likely occupied the Chiwawa, White, and Little Wenatchee Rivers and Nason Creek (Grote & Lampman, 2024). In 1937, the Washington Department of Fisheries documented the collection of several lamprey in Icicle Creek that had been diverted from irrigation ditches (BioAnalysts Inc., 2000). However, electrofishing surveys from 2011-2016 indicated that Tumwater Dam (RM 49.6) was the upper limit of lamprey distribution in the Wenatchee River (Grote & Lampman, 2024). More recent survey efforts conducted between 2009 and 2017 to detect the presence of juvenile lamprey on Yakama Nation Ceded Lands found no juvenile lamprey within Icicle Creek (Beals & Lampman, 2018).

Starting in 2008, the Yakama Nation and USFWS have undertaken reintroduction of Pacific Lamprey under the Pacific Lamprey Project, which is actively working to restore populations within their historical habitat in the Wenatchee River Basin (Ortiz, 2021; Yakama Nation Fisheries, n.d.). From 2016 – 2025, a total of 3,796 lamprey were translocated by Yakama Nation and the Columbia River Inter-Tribal Fish Commission (CRITFC) into the Wenatchee Basin. The majority were translocated into the Upper Wenatchee (3,120), with additional placed in Lake Wenatchee and the Lower Wenatchee River. As a result of these translocation efforts, naturally produced lamprey have been documented above Tumwater Dam, and larval lamprey have again been found in Wenatchee tributaries (e.g., the Chiwawa River). Approximately 26 Pacific Lamprey were experimentally translocated into Icicle Creek in 2017; however, no existing data suggests that this translocation resulted in the establishment of a self-sustaining lamprey population within Icicle Creek (Grote & Lampman, 2024).

2.2.5 Other Species

Icicle Creek supports a range of other fish species, including Sockeye Salmon (*Oncorhynchus nerka*), Coho Salmon (*Oncorhynchus kisutch*), Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*), Mountain Whitefish (*Prosopium williamsoni*), and Suckers (*Catostomus sp*.). Coho Salmon in the watershed are part of Yakama Nation's Reintroduction Project (YNF & CRITFC, 2012) that began in 1996. The Reintroduction Program in the Upper Columbia has been successful, with adult returns high enough in 2009 and 2011 to allow opening a limited tribal and non-tribal fishery in Icicle Creek, the first in many decades (YNF & CRITFC, 2012).

Sockeye Salmon are frequently seen in Icicle Creek but in small numbers, however Icicle Creek is not known to be used for spawning or rearing. Sockeye Salmon primarily spawn in the White and Little Wenatchee Rivers while utilizing Lake Wenatchee as a rearing site (Carlson et al., 2004).

2.2.6 Stream Temperature

Stream temperatures are important for salmonid growth and survival. Stream temperatures are impaired in portions Icicle Creek. Sections of the assessment area (RM 0- RM 3, RM 6, RM 10.2 – RM 12) are listed on the Washington State 303(d) list as Category 4a impaired waterbodies for temperature. A temperature Total Maximum Daily Load (TMDL) technical study was completed by the Washington Department of Ecology in 2005 for the Upper Wenatchee watershed, including Icicle Creek (Cristea and Pelletier 2005); a temperature TMDL Water Quality Improvement Report was completed in 2007 (Anderson 2007).

Stream temperatures in Icicle Creek regularly exceed spawning and rearing thresholds and have approached salmonid lethal limits in some cases. Salmonids require stream temperatures within certain ranges depending on life stage. Temperatures that exceed those ranges can inhibit growth and survival. A threshold of 13°C for spawning and 15°C for rearing, holding, and migration are commonly used to assess impacts, and are what was used in the REI analysis as part of this assessment (see Appendix B for more details). Data reported by Richter and Kolmes (2005) suggest the lethal limit for salmonids is near 26°C, but above 24°C, mortality can occur with sufficient duration of exposure.

Measured and modeled temperatures reported in the TMDL study show that temperatures in Icicle Creek are cooler upstream and warmer in downstream reaches, with higher summertime stream temperatures in the historic channel adjacent to the LNFH due to low flows and modified hydraulic conditions (Cristea and Pelletier 2005). Temperature data from 2002 and 2003 were reported in the TMDL study and showed that max temperatures in 2002 near the mouth of Icicle Creek (RM 0.2) reached 20°C and the 7-day rolling average of the daily maximum temperature (7DAD-Max) exceeded 19°C. Sites further upstream (RM 2.3, 5.6, 5.9, 9.9, and 11.4) were cooler but still exceeded 17°C for daily max and 7DAD-Max in 2002 (Cristea and Pelletier 2005). The longest temperature record we were able to obtain for Icicle Creek is from the WDOE gage (#45B070) located at the downstream end of the Leavenworth National Fish Hatchery. This gauge has recorded stream temperatures for the past 14 years (since fall 2010). The 7DAD-Max was calculated from the data. The 7DAD-Max surpassed spawning (13°C) and rearing, holding, and migration (15°C) thresholds every year during the summer months (note, there is a data gap in August 2011) and the daily max reached 24.4°C in August 2012 (Figure 9).

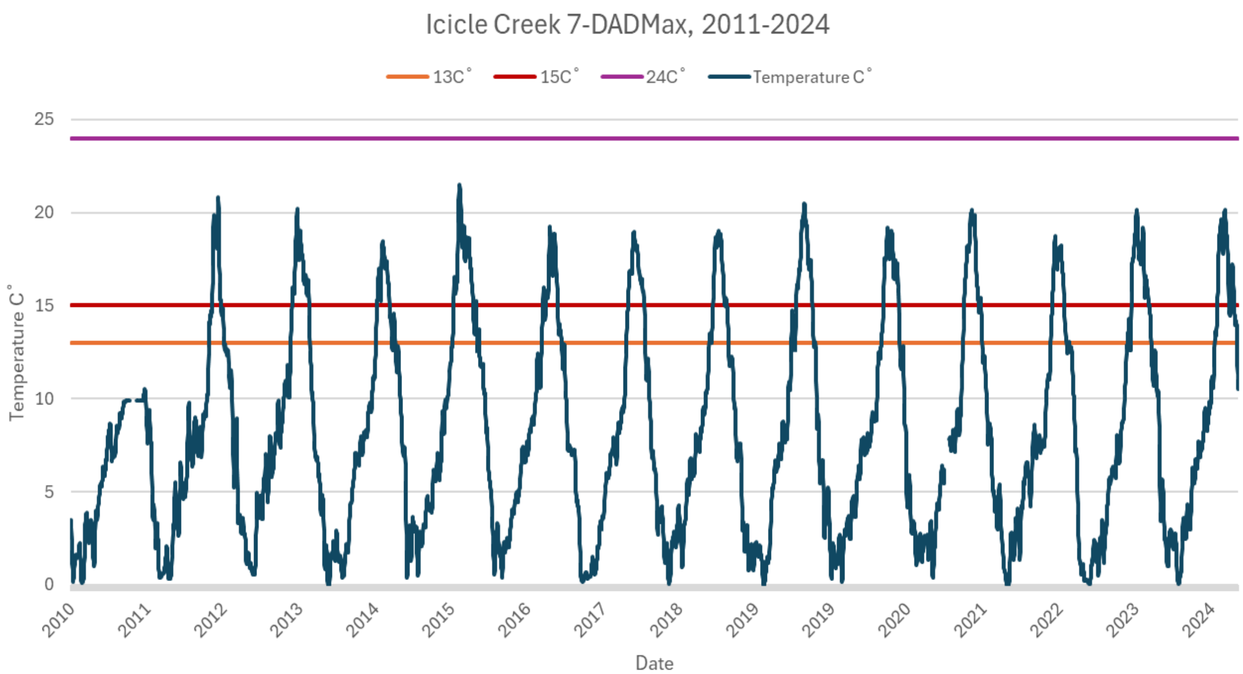

Figure 9. Graph shows 7DAD-Max from WDOE gage #45B070 (Icicle Creek near Leavenworth) from 2010-2024. The spawning threshold (13°C) and the rearing, holding, and migration threshold (15°C) are exceeded every year during the summer months (data gap in August 2011).

2.3 GEOLOGY AND SOILS

2.3.1 Geology

Icicle Creek is located on the eastern flank of Washington's North Cascade Range, which formed as the result of millions of years of crustal deformation and volcanism, followed by more recent periods of widespread regional glaciation (Tabor et al., 1987). The Icicle Creek watershed straddles the Ingalls Geologic Terrane, the Nason Geologic Terrane to the north, the Chiwaukum Graben, and the Mount Stuart Batholith, each of which represents a distinct series of geologic events and resulting surface deposits (Figure 10).

The Ingalls Terrane, which includes a portion of the middle Icicle Creek watershed consists of low- to high-grade metamorphic rock from the Late Jurassic Period (Mesozoic Era). These rocks, primarily include serpentine, serpentinized peridotite, and metaperidotite, derived from oceanic

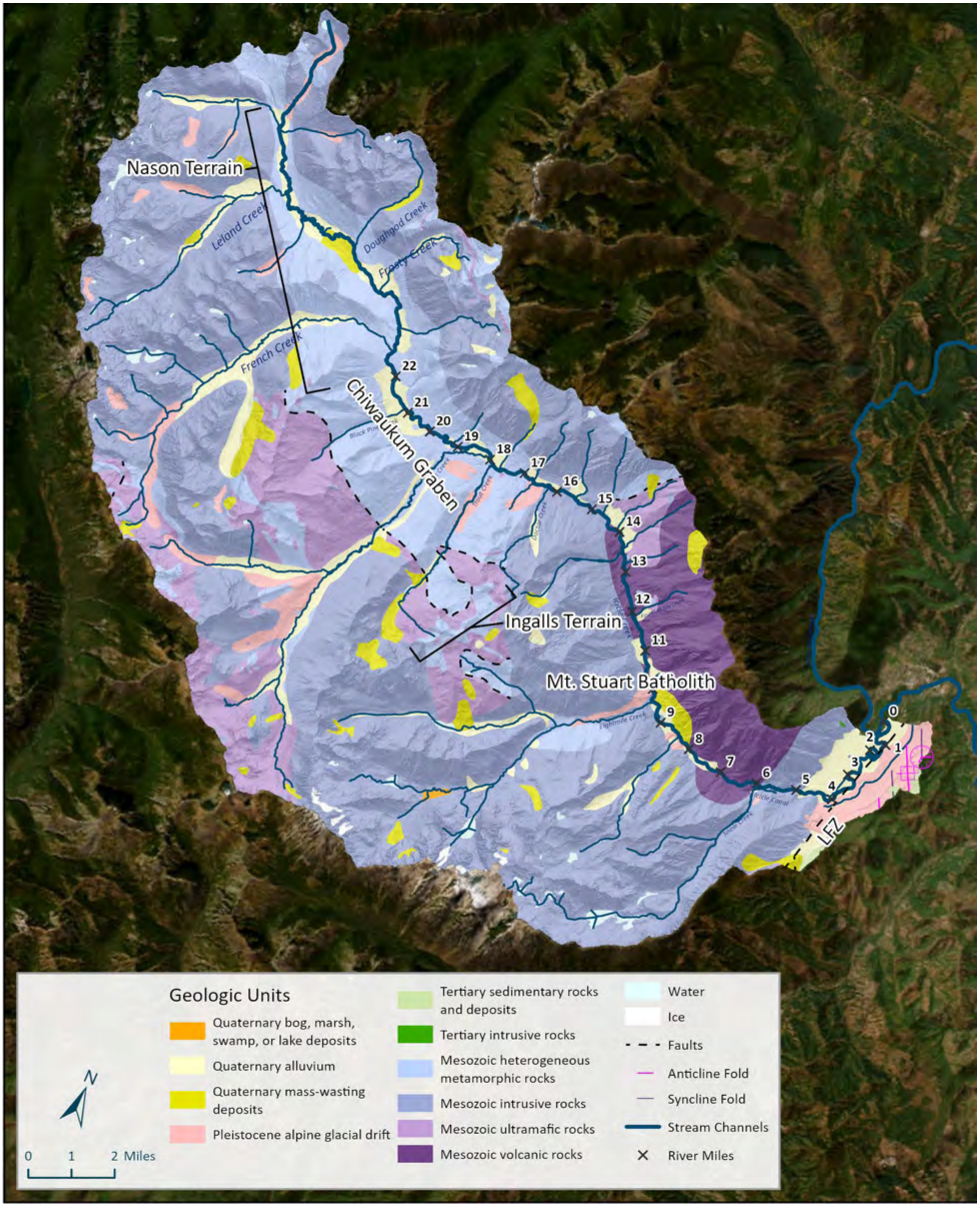

Figure 10. Surficial geology of the Icicle Creek watershed. Source: Washington Department of Natural Resources.

crust and island-arc deposits that were accreted to the North American continental plate through subduction at the continental margin. The Ingalls Terrane is separated from the Nason Terrane by a NW-SE trending thrust fault that is lifting the Ingalls Terrane above the Nason Terrane. The Nason Terrane encompasses a portion of the middle and upper Icicle Creek watershed and is primarily composed of high-grade metamorphic rocks from the Late Cretaceous Period (Late Mesozoic Era), with several Late Cretaceous igneous intrusions (Tabor et al., 1987).

The primary metamorphic rocks include the Chiwaukum Schist and Banded Gneiss formations, derived from fine-grained marine sedimentary rocks which underwent two episodes of regional metamorphism during the Late Cretaceous Period. The Ingalls and Nason Terranes are separated from the Chiwaukum Graben by the Leavenworth Fault Zone (LFZ), which trends approximately N-S through the Leavenworth, WA region. The Chiwaukum Graben includes a small portion of the Icicle Creek watershed near Leavenworth. It is topographically lower, younger, and consists of rocks that are generally more erodible than the Ingalls and Nason Terranes (Tabor et al., 1987). The Chumstick Formation, consisting of sedimentary deposits from the Cenozoic Era, is the most abundant feature of the Chiwaukum Graben. The Mount Stuart Batholith intruded the Ingalls and Nason Geologic Terranes during the Late Cretaceous Period. Tonalite and granodiorite deposits associated with the Mount Stuart Batholith make up most of the surface area of the Icicle Creek Watershed (Tabor et al., 1987). Rocks of the Icicle Creek watershed were uplifted beginning as early as 50 million years ago (Ma) during the Tertiary Period (66-2.6 Ma) as part of the regional period of uplift that resulted in the formation of the North Cascade Range.

2.3.2 Glaciation

Earth surface processes during the Quaternary Period (2.58 MA to present), including glaciation, landslides, and fluvial processes generated considerable amounts of unconsolidated sediments to the river, valley floors, and hillslope toes within the Icicle Creek watershed. Six major glacial cycles have been documented in the upper Wenatchee Basin between 12,500 and 165,000 years before present (Porter, 1976; Porter & Swanson, 2008; Stanton et al., 2019). Alpine glaciers originating at higher elevations in the North Cascade Range moved downslope, eroding considerable bedrock. Substantial glacial till and outwash deposits generated during glacial retreat are present within the Icicle Creek watershed, including the assessment area (Tabor et al., 1987). Moraines, including a terminal moraine dating back to ~165,000 years before present (ybp) suggest that glaciers extended from the headwaters of modern Icicle Creek drainage past the present-day town of Leavenworth. The end moraine associated with the Leavenworth glaciation suggests that the Icicle Creek Glacier was in retreat by approximately 24,000 years before present (Porter & Swanson, 1998). Remnants of terminal moraine deposits of two alpine glaciers sourced from west-side tributary drainages (Eightmile Creek and Rat Creek) extended into Icicle Creek between RM 7.1 – 9.1 – indicating localized glacial extension from the tributaries occurred post-glacial retreat from Icicle Valley along the mainstem of Icicle Creek. The moraine deposits associated with these tributaries continue to influence channel location in the valley and channel form of Icicle Creek, as well as remain local sources of sediment to the channel.

2.3.3 Soils

The soil units in the Icicle Creek watershed are varied. A significant portion of the hillslopes adjacent to the assessment area contain rock outcrops without significant soil accumulations. Where soil layers exist on the adjacent hillslopes they are derived either from erosion of the underlying bedrock, draped colluvial deposits and glacial till or drift, or/and aerial inputs of volcanic ash from Holocene eruptions of the Cascade volcanoes. The valley floor generally consists of soils derived from glacial till and glacial outwash, colluvial inputs from adjacent hillslopes, reworked alluvial deposits, and aerial inputs of volcanics from Holocene eruptions. Glacial outwash deposits contribute to soils downstream of RM 5 where the valley widens towards the town of Leavenworth, but do not generally contribute to soils within the narrow canyon upstream. A map of the soils in the assessment area, created from soils information from the Natural Resources Conservation Service, is provided in Figure 11.

Downstream of RM 5, the valley floor is broad, and valley bottom soils are dominated by low gradient (0-3%) floodplains and terraces composed of thick silt loam, sandy loam, and loamy sand derived from alluvium, and glacial till and outwash, with small amounts of loess and volcanic ash. Remnants of several terminal moraines created by the Icicle Creek Glacier (~165,000 – 24,000 ybp) are located within this broad valley near the confluence of the modern Icicle Creek and Wenatchee River. The soil in this region ranges from moderately well drained to well drained. Upstream of RM 5, the soil is generally well drained bouldery sandy loam derived from alluvial deposits, glacial till, colluvium from adjacent hillslopes, and volcanic ash. A pocket of somewhat poorly drained silt loam derived from alluvium and volcanic ash is located from ~RM 17.5-20.9.

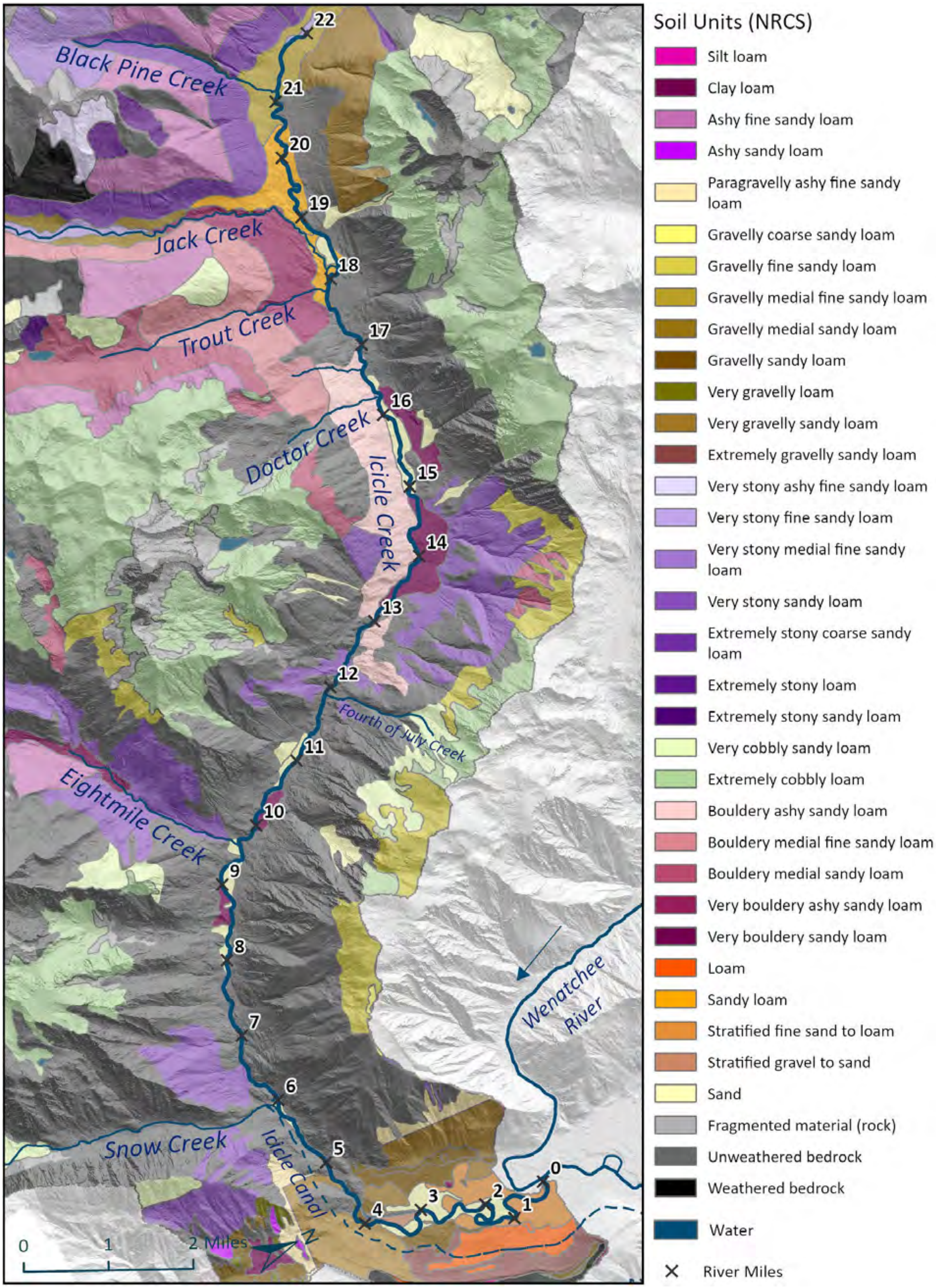

Figure 11. Soils of the Icicle Creek assessment area. Data from SSURGO, 2024

2.4 HISTORICAL FORMS AND PROCESSES

Historical conditions refer to those that existed before Euro-American settlement. These conditions represent environments to which native species, such as salmonids, were likely well-adapted before anadromous salmon populations declined due to settlement-related anthropogenic disturbances over the past two centuries. While full restoration to historical conditions is often impractical or inappropriate given modern infrastructure and existing hydro-geomorphic regimes, they serve as a valuable reference for understanding habitat and process evolution in this system and guiding restoration objectives. Although limited written records exist on Icicle Creek's conditions prior to Euro-American settlement, insights can be drawn from field observations, USGS records and maps, modern landforms, underlying geology, and glacial cycles. This section provides a brief summary of the presumed historical conditions within the Icicle Creek assessment area.

The Icicle Creek watershed supports a mixture of coniferous and deciduous forests (USFWS, 2006). However, following Euro-American settlement in the 1800s, the forests experienced subsequent series of degradation due to repeated timber harvest, clearing for development, fire suppression practices, and overgrazing (USFWS, 2006). Initially, logging and clearing for development removed old-growth forest cover and inputs. Fire suppression practices in 2nd growth forests have led to overcrowded undergrowth with an accumulation of dead wood. These practices decrease the possibility of large diameter tree growth. They also reduce forest patch heterogeneity, making the forests less resilient and more susceptible to large high severity fires or insect infestations.

In the past, the abundance of large old-growth conifers would have had a profound influence on river channel processes and morphology. Noted influences of effective large wood (old-growth) on river corridors include increased channel complexity and dynamism, enhanced floodplain connectivity, local sediment storage and retention, and increased availability of quality habitat for salmonids and other species (Abbe & Montgomery, 1996; Bilby, 1984; Cederholm et al., 1997; Wohl et al., 2019). Downed trees would have been stored within the channel as individual pieces or within large channel-spanning accumulations at a higher frequency than present (Fox & Bolton, 2007). Large old-growth trees have the capacity to span the channel in the assessment area as an individual piece, unlike the smaller second-growth forests that line most of the assessment area today. Historical old-growth riparian forests and the associated large in-channel wood and log jams would have prolonged and magnified the effects on geomorphic process (e.g. scour and deposition), floodplain connectivity, habitat complexity, hydraulic complexity, stream shade, nutrient contributions, soil stabilization, and floodplain moisture retention. It is assumed that prior to logging the historical channel through the Icicle Creek assessment area had a plentiful recruitment source of effective large wood occupying its floodplains, terraces, and hillslopes. The reduction in mature forest within the Icicle Creek corridor leads to decreased recruitment potential of effective wood to Icicle Creek, leading to decreased aquatic habitat complexity and forms.

Analysis of recent and historical aerial imagery and maps provides an opportunity to evaluate channel planform and location changes of Icicle Creek over the last 120 years. Much of the assessment area upstream of approximately RM 4.5 is naturally confined with no significant areas of channel change that could be discerned given the scale and quality of the historical aerial photos and maps. One exception is the channel adjustment that occurred near RM 16.3 as a result of the Doctor Creek debris slide, which is further discussed in the Reach 15 reach chapter (Section 3.15). In contrast, downstream of RM 4.5 significant changes to channel position have occurred over time. The location of mainstem Icicle Creek downstream of RM 4.5 was digitized from rectified US Geological Survey topographic map produced in 1901 (retrieved from TopoView (US Geological Survey (USGS), n.d.). The USGS 1901 channel location, though not expected to have channel form mapped in detail, is shown in relation to the modern channel in Figure 12. This comparison, in addition to the channel scars visible in the LiDAR hillshade, shows that the lower river has adjusted over time, including changes to the location of the confluence of Icicle Creek and the Wenatchee River.

It is presumed that during glacial retreat the channel expressed a braided form through the lower valley. A multi-threaded channel form likely precluded glacial outwash as vegetation established and an alluvial floodplain developed through sequences of partial stabilization that allowed for overbank deposition. The low gradient meandering channel would have naturally adjusted through meander scrolling and neck cut-off avulsions. Side channels and abandoned oxbows would have been common features. Since Euro-settlement, channel processes have been disrupted by development in the lower valley including forest clearing, structures and infrastructure, channel damming related to lumber production, agricultural uses, roadways, and the fish hatchery. Currently, the ability of the channel to naturally migrate has been mostly halted due to bank armoring and bridge constrictions.

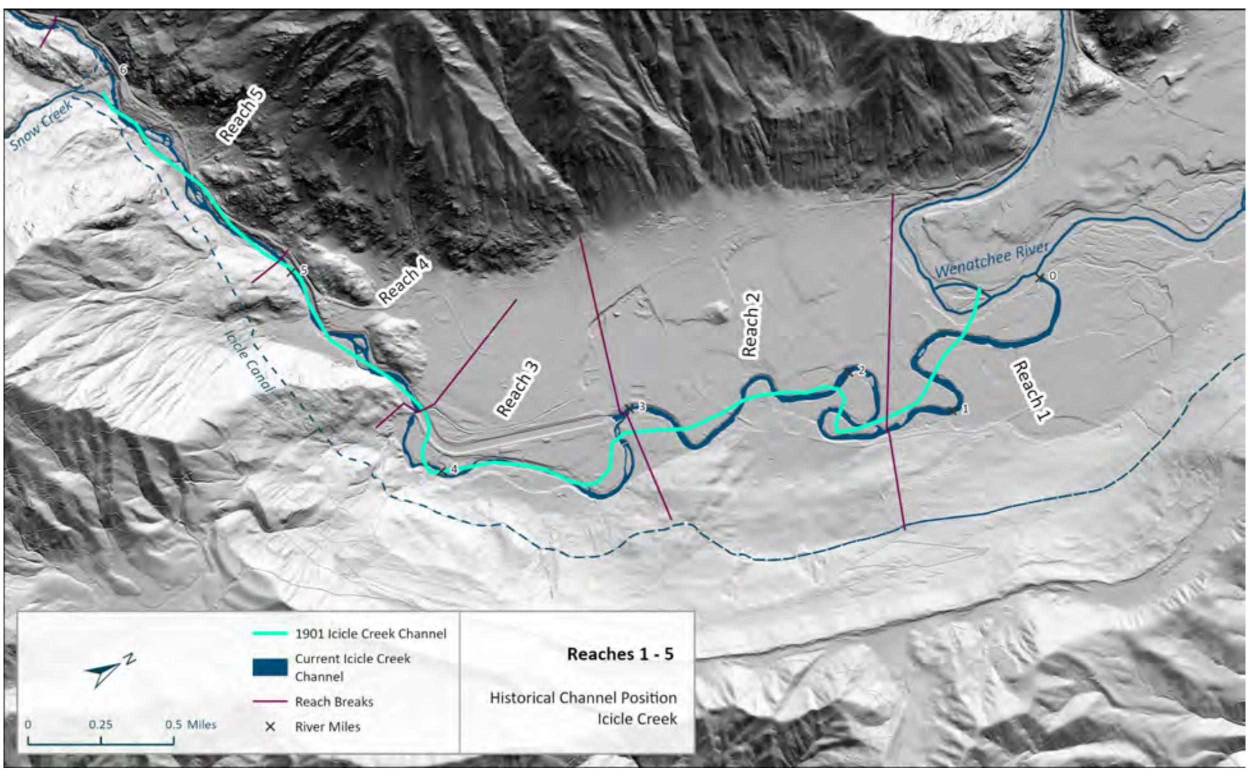

Figure 12. Reaches 1-5 showing the current channel alignment in the lower Icicle Valley compared to the 1901 channel alignment (centerline, digitized from the 1901 USGS map).

2.5 HUMAN IMPACTS

2.5.1 Indigenous History

The Wenatchee sub-basin region is the homeland of the Wenatchi people, self-identified as the *snpəsqʷáwsəxʷ* (P'Squosa or Pisquose) and *winátŝapam* (Beavert & Rigsby, 1975; Kinkade, 1981; Miller, 1998; Ray, 1933; Scheuerman, 1982). The P'Squosa lived along the Icicle, Wenatchee, and Columbia rivers throughout the year - fishing, hunting, and gathering berries. They had several villages at the present-day locations of Cashmere, Monitor, Leavenworth, and the Wenatchee-Columbia confluence. During the summer months, numerous Tribes would convene along Icicle Creek to fish for salmon, where the waters were once described to run red when the salmon were abundant (Beckham, 1995; Big Bull-Lewis, 2020; Mullan et al., 1992; Rader, 2024).

Following the 1855 treaty, 14 bands and tribes ceded over 11.5 million acres to the United States, including the lands in the Icicle Creek watershed (CCRITFC, 2025). After treaty negotiations, some of the Wenatchi remained in the area within tribal allotments, while others relocated to the Yakama Reservation or to the later established Confederated Tribes of the Colville Reservation (Miller 1998; Ruby and Brown 1986; Beavert and Rigsby 1975, Schuster 1998).

2.5.2 Euro-American Land Uses and Disturbances

Euro-American pioneer settlement at the confluence of Icicle Creek and the Wenatchee River began in the 1860s. By 1890 the site, once a salmon fishery for indigenous peoples, was converted into the trading post with a few homesteads the pioneers called Icicle Flats. Euro-settlement in the Icicle Creek watershed became permanent in the late 1800s, with trading, sheep herding, and mining among the earliest documented activities following the Treaty with the Yakama Nation and removal of the indigenous people. After rail construction, Icicle Flats was formally established as the town of Leavenworth in 1893. The Lamb-Davis Lumber Company then built a large sawmill on the banks of Wenatchee River in 1904 that included a dam at the south end of town on the Wenatchee River that also backwatered lower Icicle Creek. This initiated aggressive logging and timber extraction from the region, including the Icicle Creek watershed through the 1920s. Although timber extraction slowed in the 1930s, it continued for decades after. Conservation efforts expanded the Wenatchee National Forest in the 1980's and the Alpine Lakes Wilderness was established by Congress in 1976, which encompasses upper Icicle Creek starting near RM 21.

By 1912, agricultural practices expanded, and much of the lower basin was converted into orchards (The Watershed Company, 2005). In the 1960s, timber harvest became a significant resource again (Andonaegui, 2001; USFS, 1995). Roads were built to facilitate access for timber harvest, recreation, and development. As the roads progressed throughout the basin, residential and commercial development expanded across the floodplains of the lower reaches of Icicle. Expanding developments removed over 11% of the vegetation cover along lower Icicle Creek (Carlson et al., 2004). Recreational use also increased, leading to campground development and additional infrastructure. 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 that burned in the fire, which reached Icicle Creek above Snow Creek (Carlson et al., 2004).

The majority of the assessment area currently lies within the National Forest, and all stream reaches above RM 17 are publicly owned. Between RM 4 and 17, landownership in the assessment area alternates between private and National Forest. Human features in this area include homes, campsites, the Icicle Creek Road, numerous bridges, trails, and water diversion infrastructure. There are larger clusters of residences and RV campsites near RM 4.75 and between RM 5.5 and RM 5.75. In the lowest reaches, from RM 1 to RM 4, much of the land has been cleared for agriculture or development.

The Icicle Creek watershed has the highest recreational use of any watershed in the Wenatchee basin (Muir et al., 2023; Skalicky et al., 2013; USFS, 1995), with activities including kayaking, rock climbing, hiking, fishing, and camping. Six developed USFS campgrounds and numerous primitive sites are in the riparian zone (Chelan County, n.d.;Andonaegui, 2001).

2.5.3 Leavenworth National Fish Hatchery

The Leavenworth National Fish Hatchery (LNFH) was built between 1938 and 1940 along Icicle Creek and occupies approximately 160 acres. The hatchery was originally authorized by Congress in the 1930s as mitigation for fish losses resulting from the construction and operation of Grand Coulee Dam. The hatchery withdraws surface water from Icicle Creek at RM 5.05 and currently sources groundwater from on-site wells. The hatchery also receives supplemental summer water releases from Snow and Nada Lakes in the Alpine Lakes Wilderness Area (Snow Creek watershed). The water is used for fish production and is returned downstream of the hatchery to Icicle Creek at RM 2.95. The LNFH holds four water right certificates and two water right claims, allowing a maximum water withdrawal of 56.9 cubic feet per second (cfs) for fish rearing purposes (42 cfs of surface water rights and 14.9 cfs of groundwater withdraw rights) (Muir et al., 2023). Each year, the hatchery produces approximately 1.2 million juvenile spring Chinook Salmon and provides acclimation facilities for Coho Salmon. These salmon support commercial, sport, and tribal in-river and ocean fisheries (Skalicky et al., 2013).

The hatchery diversion channel (also referred to as the hatchery canal or bypass channel) is a 120-foot-wide artificial channel extending nearly 4,000 feet and lying to the west of the natural channel (also referred to as the historic channel). The diversion channel was originally built to divert water from the natural channel to facilitate using the natural channel for hatchery fish production (USFWS, 2009). The hatchery diversion channel is still in operation and is primarily used to recharge groundwater to feed groundwater wells that provide hatchery water. There is a water control structure (Structure 2) at the upstream end of the diversion channel to bifurcate and regulate flows between the natural channel and the diversion. There is a spillway at the downstream end of the diversion channel where it returns back to Icicle Creek (Figure 13). A series of small control structures (Structures 3, 4 and 5) were originally constructed within the natural channel to function as an instream hatchery and as holding ponds that were used to assist in capturing migrating anadromous salmon for hatchery broodstock. The hatchery was operated in-stream within the impoundments created by the small dams until the late 1970s, and seasonally, as recently as 2005. The instream hatchery was eventually abandoned and Structures 3 and 4 removed. Structures 2 and 5 remain within the channel (located at RM 4.3 and 3.15, respectively). Structure 5 is currently used for broodstock collection. The diversion channel remains dry during summer to allow unobstructed low flow into the natural Icicle Creek channel. The diversion channel is allowed to flood during spring and fall high flow events to prevent flooding of adjacent properties and to help groundwater well recharge (Skalicky et al., 2013; USFWS, 2020). Photos of the canal and the various structures are provided in Section 3.3 (Reach 3).

These modifications have altered fish passage and the natural hydrology and channel geomorphology of Icicle Creek and its floodplain in this area. From approximately 1940 to 2005, hatchery operations prioritized maintaining flows in the diversion channel, which blocked fish passage year-round and restricted flow into the natural channel. Since 2006, operations at the upstream and downstream structures have been adjusted to improve fish passage and habitat conditions (USFWS, 2009). (Skalicky et al., 2013). Nevertheless, Structures 2 and 5 still impact both sediment transport and the migration of anadromous salmonids (Lorang & Aggett, 2005; Skalicky et al., 2013; USFWS, 2020). Because of flow limitations at the upstream structure (Structure 2), the occurrence of channel-forming flows in the natural channel has been reduced, leading to an increase in undercut banks, vegetation encroachment, and fine sediment deposition (Lorang & Aggett, 2005; Skalicky et al., 2013). On the downstream end, between RM 3 and RM 3.1, hatchery return flow ponds are present along the left bank, along with multiple hatchery facility buildings, holding ponds, and an outfall. Riprap and rock spurs line sections of the left bank to protect the hatchery facility. Between the diversion channel and the natural channel, the spoils from the diversion channel excavation appear to have been placed into the former floodplain, disconnecting it from floodplain inundation. Upstream of the diversion channel, additional LNFH features include a pump and screen at RM 4.8, multiple fish arrays, armored banks with riprap, and an intake structure at approximately RM 5 with constructed drop structures.

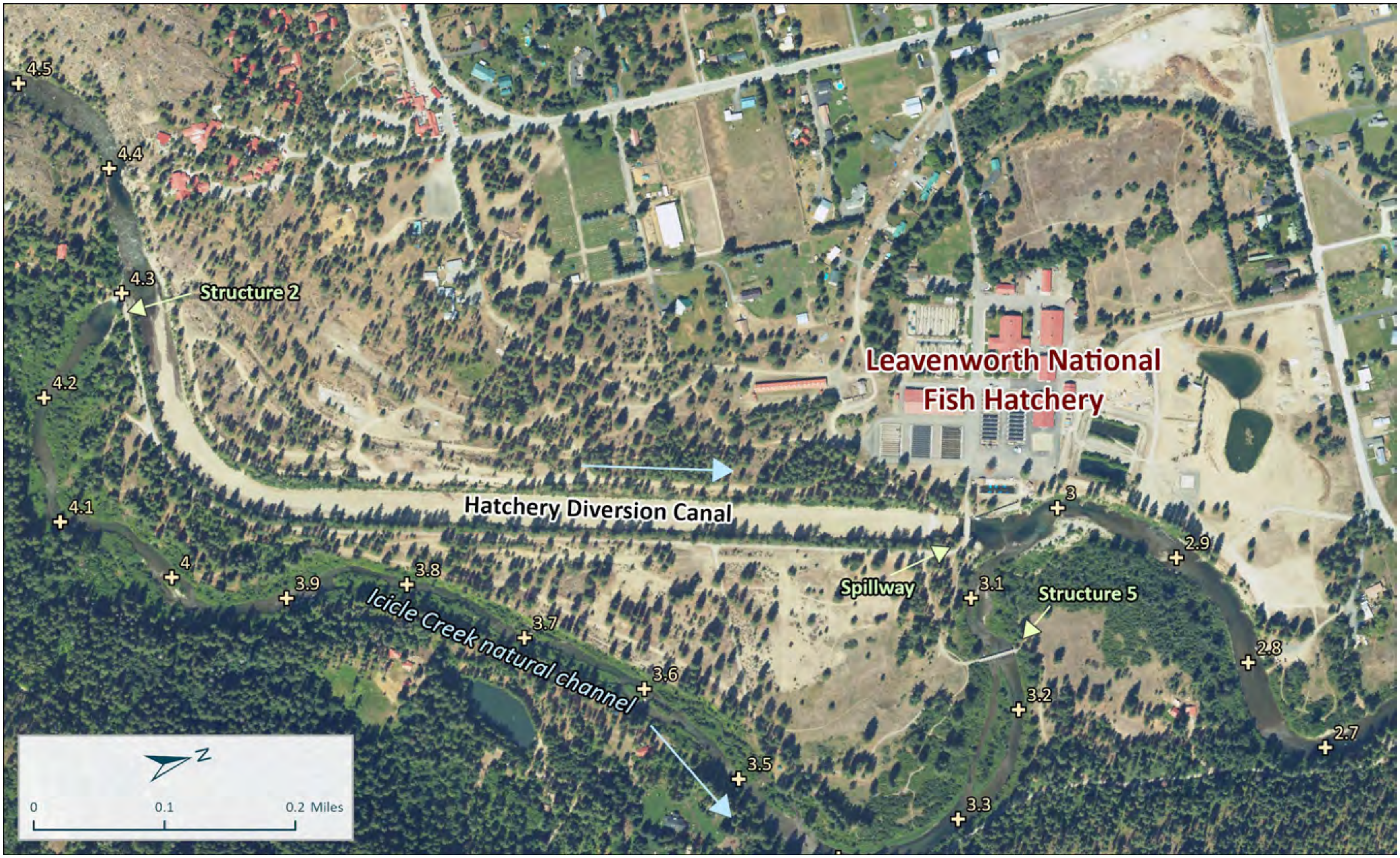

Figure 13. Map of Leavenworth National Fish Hatchery diversion canal and associated infrastructure.

2.6 HYDROLOGY AND CLIMATE

2.6.1 Basin Characteristics

The Icicle Creek watershed has a drainage area of approximately 212 square miles. The basin is bounded on the north by the Chiwaukum Mountains and on the south by the Wenatchee Mountains. The creek has its headwaters in the Alpine Lakes Wilderness. The main channel originates at Josephine Lake and flows approximately 32 miles south-southeast to join the Wenatchee River near Leavenworth. Elevations range from 9,370 to 1,100 feet above sea level with a mean basin elevation of 4,980 ft (USGS, 2022). The Icicle Creek watershed includes 102 lakes, 85 tributaries, and 14 glaciers. Tributaries that enter the Icicle Creek reach assessment project area include 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. Icicle Creek flows in a mostly confined, steep valley until the lowest 3 miles of river, where the floodplain expands as it enters the broad Wenatchee River valley. A map of the watershed is included as Figure 14.

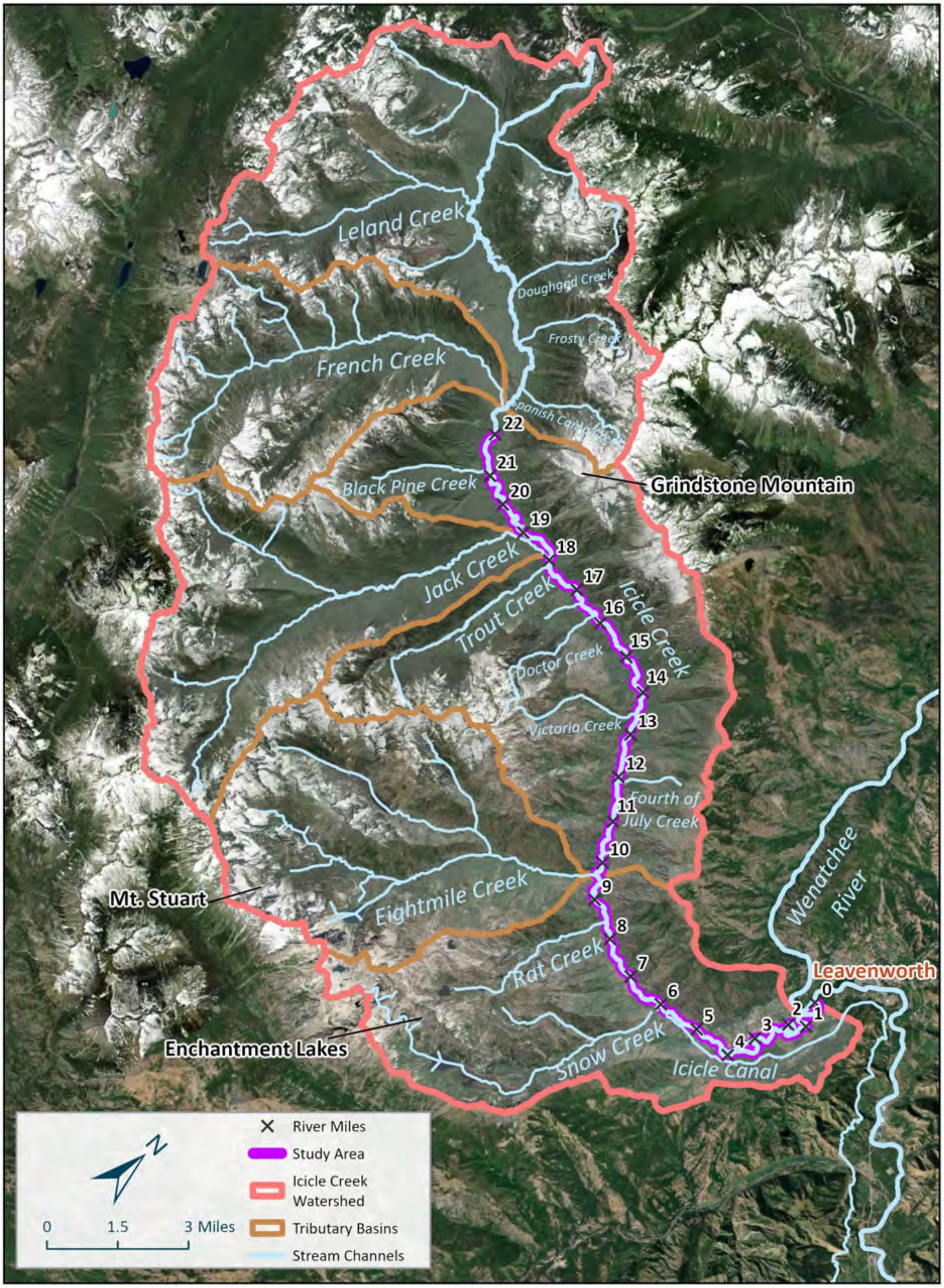

Figure 14. Map of the Icicle Creek watershed, primary tributaries, and tributary sub-watershed boundaries.

2.6.2 Climate

The Icicle Creek watershed is in the eastern rain shadow of the Cascade Mountain Range. The Cascade Mountain Range's precipitation is attributed to warm air from the Pacific Ocean rising and cooling as it flows east over the mountains, depositing heavy precipitation. The summers in the area are dry and warm while the winters are cool and wet (Figure 15). Most of the precipitation in the basin falls during the wet season between October and March. The high elevation headwaters receive considerably more precipitation than the mouth of Icicle Creek. Annually, the headwaters of Icicle Creek receive upwards of 82 inches of precipitation on average while the mouth of Icicle Creek receives an average of 21 inches (PRISM (Oregon State University), 2025).

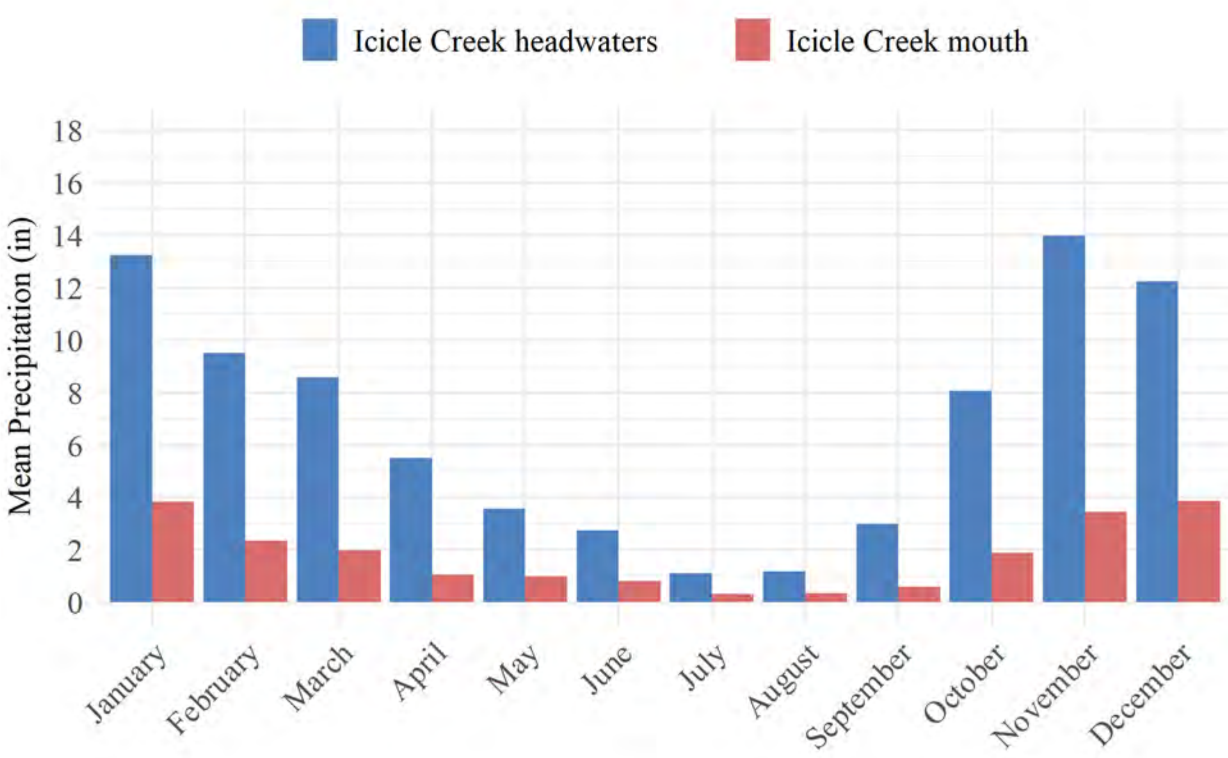

Figure 15. Average monthly precipitation in the Icicle Creek Watershed – headwaters and river mouth. Source: PRISM Climate Group, Oregon State University, 2025.

Air temperature differences between the mouth of Icicle Creek and its headwaters can exceed 10°F in summer months (Figure 16). Despite the absolute temperature difference between the two locations, the entire Icicle Creek Basin follows a similar climatological temperature pattern with warm summers and cool winters. The average air temperatures in the summer within the basin range from 49°F to 70°F. The winter has a much narrower range of 24°F to 33°F. The average monthly temperatures between the headwaters and the mouth of Icicle Creek are similar in December and January. The average monthly temperatures then diverge throughout the rest of the year, with the headwaters having consistently colder air temperatures than near the mouth of Icicle Creek from February to November (PRISM (Oregon State University), 2025).

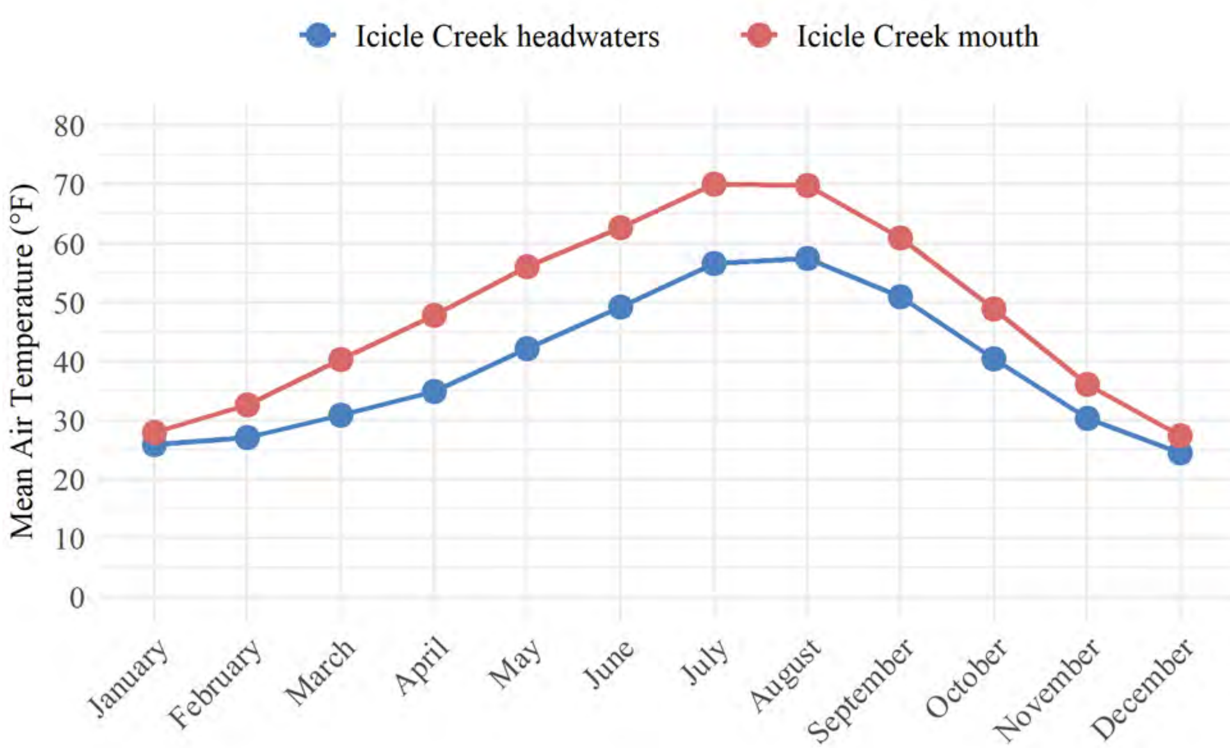

Figure 16. Average monthly temperature in the Icicle Creek watershed – headwaters and river mouth. Source: PRISM Climate Group, Oregon State University, 2025.

2.6.3 Available Streamflow Data

Two sets of long-term, publicly available stream discharge data are available for Icicle Creek from two gages located in the downstream region of the assessment area. A USGS gage located near RM 6.5 (Icicle Creek Above Snow Creek Near Leavenworth, WA, USGS 12458000) collected discharge data from 1936 to present and peak flow data back to 1912 (USGS, 2024). The Washington Department of Ecology gage collected flow and temperature data from 2007 to present at a site just downstream of the Leavenworth National Fish Hatchery near RM 2.2 (Icicle Cr. nr Leavenworth, Station 45B070) (WDOE, 2024). The USGS gage was utilized for hydrological analysis due to its longer period of record. The only qualification codes for the peak flows on record for the USGS gage are noting that the 1995 peak flow is an estimate, and the 1996 peak flow recorded was lower than the actual discharge value.

2.6.4 Seasonal Hydrology Patterns

Icicle Creek's annual hydrograph follows a typical pattern for east-slope Cascade Mountain streams, with larger discharges occurring in the late spring to early summer from snowmelt runoff and smaller precipitation-event driven peaks in late fall. Snowmelt is a primary contributor to Icicle Creek; it has been estimated that approximately 21% of summer flow during a hot and dry summer can originate from glacial melt (Mullan et al., 1992). The USGS gage (12458000) shows a relatively constant baseflow from August through September, with discharge increasing October to December, as fall and early winter rains produce discrete flow peaks (Figure 17). This is followed by generally lower flows in the winter from January through March, when most or all precipitation falls as snow. Snowmelt begins in spring when air temperatures start to warm. Figure 16 shows the daily flow statistics for the period of record, including the daily mean, 5% exceedance, and 95% exceedance as well as a monthly flow mean based on the last 20 years of flow data.

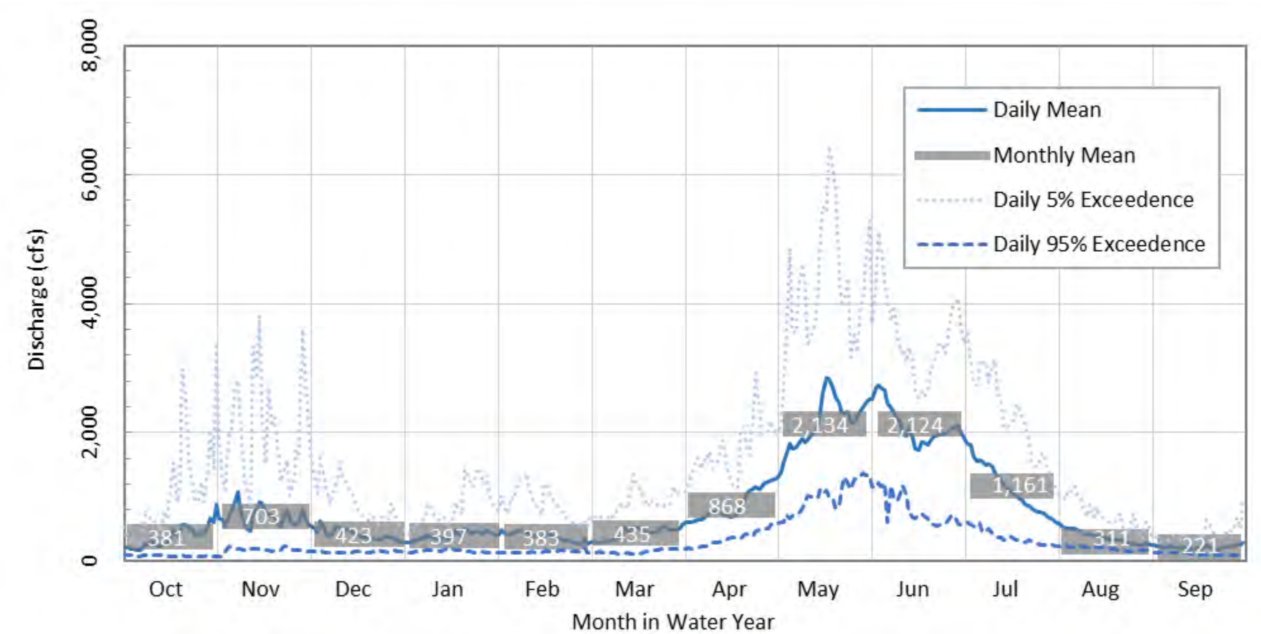

Figure 17. Daily flow statistics at Icicle Creek above Snow Creek near Leavenworth, WA (USGS gage 12458000) for water years 1993 through 2023 showing the daily average, 5% exceedance, and 95% exceedance discharge and monthly average discharge for the period of record.

2.6.5 Peak Flows

Peak flood event discharges reported at USGS gage 12458000 from 1912 to 2023 are displayed in Figure 18. Flood frequency estimates for Icicle Creek were calculated using the USGS gage (12458000) (instantaneous annual peak flow data) using a Log Pearson Type III flood frequency analysis for water years 1912 to 2023. The analysis was performed using the Bulletin 17C flood frequency analysis methods with the HEC-SSP software, using a weighted skew with a regional skew of -0.07 and a regional skew MSE of 0.18, following the guidelines in Mastin et al. (Mastin et al., 2017; USACE, 2023). The results are included in Table 2. The peak flow estimates closely resemble those reported in past studies, such as the Lower Icicle Creek 2017 assessment (Natural Systems Design, 2017), with slight changes likely attributable to this assessment using several additional years of data.

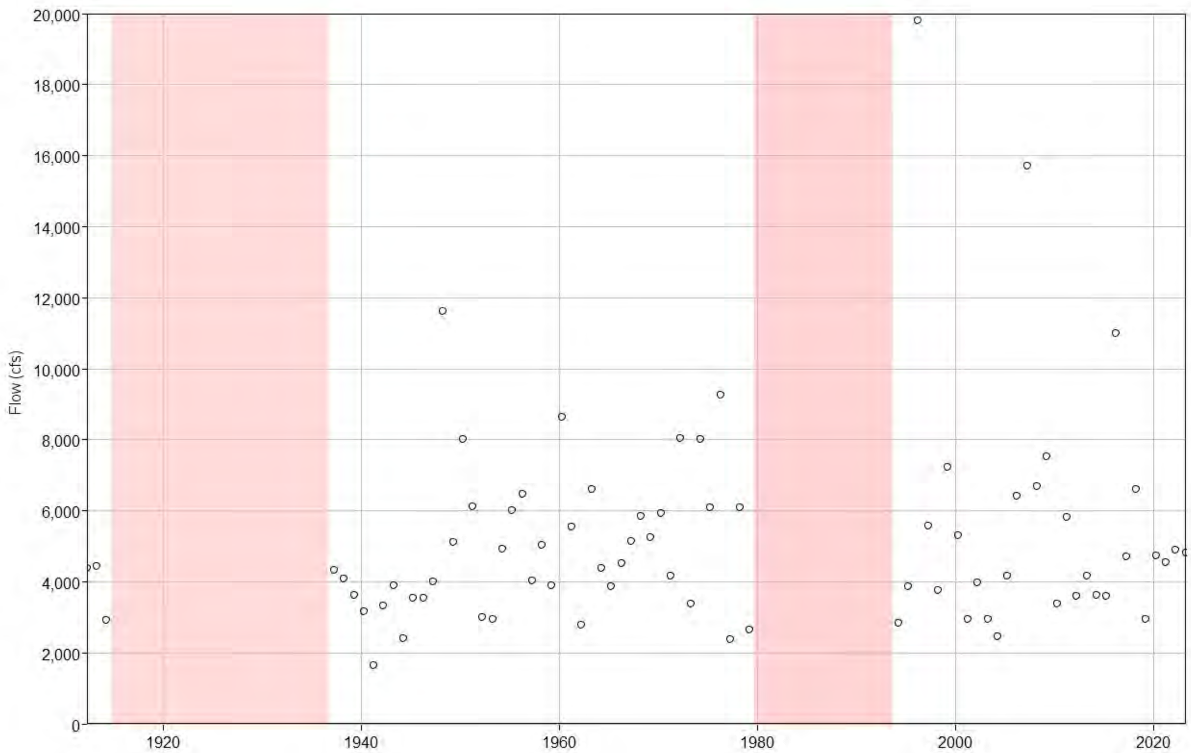

Figure 18. Peak flow history of USGS gage 12458000 from 1912 to 2023, with data missing from 1914-1936 and 1979-1993 highlighted in red.

Table 2. Icicle Creek flood frequency analysis results for the USGS gage 12458000 (USGS, 2024).

Flood Return Interval	Flood Flow (cfs)	5% Confidence Limit (cfs)	95% Confidence Limit (cfs)
2-Year	4539	4963	4164
5-Year	6663.5	7503	6033
10-Year	8285.4	9690.	7373
25-Year	10592.3	13241	9152
50-Year	12506.3	16576	10530
100-Year	14595.2	20598	11952

The flood frequency analysis results were then weighted to estimate peak flows for the upstream and downstream ends of the project area (RM 0 to 22). The Mastin et al. (2017) equation 11 for Region 2 in Washington was used to extrapolate the results to the top of the project area (RM 21) and the mouth of Icicle Creek (Table 3).

Table 3. Icicle Creek estimated discharge for peak flood events based on weighted flood frequency analysis results for the WDOE Station 45K090 gage (WDOE, 2024).

Flood Return Interval	Icicle Creek Peak Discharge at RM 21 (cfs)	Icicle Creek Peak Discharge at mouth (cfs)
2-Year	1,900	4,960
5-Year	2,840	7,270
10-Year	3,570	9,030
25-Year	4,630	11,530
50-Year	5,520	13,600
100-Year	6,500	15,850

2.6.6 Water Withdrawals

There are four primary water users that divert flow from Icicle Creek: Icicle-Peshastin Irrigation District (IPID), the Cascade Orchard Irrigation Company (COIC), the City of Leavenworth, and the Leavenworth National Fish Hatchery (Skalicky et al., 2013; USFWS, 2009). The water rights of these entities are summarized below; however, the amount of actual diversion varies depending on water availability, water supply needs, and numerous operating agreements. These entities are also part of the Icicle Work Group (IWG), which is guided by the Icicle Strategy (WDOE, 2019), which strives to maintain target minimum instream flows in Icicle Creek while also meeting water supply needs. The IWG objectives are discussed further at the end of this section.

The IPID has a maximum water right of 117 cubic feet per second (cfs) from Icicle Creek (as long as senior water rights are met) via a dam and intake structure near RM 6.27 (Figure 19) (Anchor QEA, 2018). The IPID also holds water rights to multiple lakes within the Alpine Lakes Wilderness that are used to supplement flow in Icicle Creek to meet water supply needs (Anchor QEA, 2018). The COIC has a 11.9 cfs water right, with a diversion near RM 5 at the time of the survey (summer 2024). As of May 2025, the COIC diversion is located at RM 1.9 (personal communication, Ingrid Ekstrom, WA Department of Ecology, October 2025). The LNFH's water supply includes a 42 cfs surface water right, supplemented from late July to early October by releases from the Snow/Nada Lake system. The hatchery uses this surface water diversion and up to 14.9 cfs of groundwater pumped by seven wells (five in a shallow aquifer, one in a deep aquifer, and one in both – all wells are in sediment above bedrock) to supply water for hatchery operations (USFWS, 2009). Icicle Creek is also a primary water source for the City of Leavenworth, with a 6.2 cfs water right; 1.52 cfs water right with a priority date 1912, 1.50 cfs water right with a priority date June 20, 1960, and a primary instantaneous water right of 3.18 cfs which is not in addition to pre-existing rights; (Anchor QEA, 2018; Cowger & Cowger, 2018).

The Icicle Work Group was co-convened in 2012 by the Washington State Department of Ecology's Office of the Columbia River (OCR) and Chelan County Natural Resource Department to develop a collaborative strategy for water use among Icicle Creek water users and stakeholders (WDOE, 2019).

In response to the growing pressures of water demand, habitat degradation, and climate change in the Icicle Creek Subbasin, the IWG has developed the $82 million Icicle Strategy, a coordinated effort to ensure instream flow improvements, agricultural sustainability, and local domestic water supply through 2050 (WDOE, 2019). The strategy outlines a comprehensive suite of actions, including creek modifications for improved fish passage and habitat connectivity (Figure 20), residential water conservation projects in the Leavenworth area, automation of dam releases, restoration of Eightmile Lake to its historical and permitted storage elevation, and upgrades to the LNFH infrastructure to improve efficiency and fish welfare. Broader program elements include groundwater augmentation, pump exchange, modification and development of new water storage, expanded water markets, and tribal fisheries enhancement. These measures collectively aim to meet multiple goals: achieving 60 cfs in dry years and 100–250 cfs in average years for streamflow, ensuring 57 cfs of water diversion for LNFH operations, meeting Treaty and non-Treaty harvest obligations, securing 5,000 acre-feet for municipal/domestic use, enhancing aquatic and terrestrial habitats, and complying with state and federal regulations (WDOE, 2019).

Figure 19. Icicle Peshastin Irrigation Diversion at RM 6.27. (August 25, 2024)

Figure 20. Series of installed boulder steps at LNFH water intake structure at ~RM 5 (August 27, 2024).

2.6.7 Climate Change

Climate modeling in the Pacific Northwest predicts potential changes to streamflow in response to temperature changes and shifts in seasonal precipitation patterns. Climate change models have predicted a 3.2°F increase in annual temperature by the 2040s, and a 5.3°F increase by the 2080s in the region (Mote & Salathé, 2010). Predicted changes in precipitation vary by model but generally show trends towards wetter fall and winter seasons and drier summers (Mote & Salathé, 2010).

Seasonal shifts caused by overall warmer and drier conditions are expected to shift transitional (mixed rain and snow) and snow-dominated basins towards a rain-dominated regime. Tohver et al. (Tohver et al., (2014) used the Variable Infiltration Capacity hydrological model to simulate basin hydrological regimes under the A1B medium emissions and the B1 low emissions climate scenarios. Under these scenarios, the Wenatchee basin is predicted to remain a snow-dominated hydrological regime system through the 2020s but then shift to a transitional basin starting in the 2040s (Tohver et al., 2014). Transitional basins typically have elevated flows in the winter with peak rainfall and again in the spring with peak snowmelt, representing systems with mixed rain and snow dominance. These basins are projected to be the most sensitive to warming from climate change. Projected increases in winter precipitation are expected to cause more extensive flooding in basins such as the Wenatchee through the 2080s (Tohver et al., 2014). Warmer air temperatures combined with shifts in seasonal precipitation are predicted to result in earlier snowmelts, lower summer baseflows, and earlier peak flow timing. Warmer winter temperatures will result in more precipitation falling as rain instead of snow, lessening snowpacks that are essential for moderating stream temperature and regulating flow in spring and summer.

Several studies have been conducted on the Icicle Creek Basin's streamflow and stream temperature response to climate change. In a climate change vulnerability assessment conducted by (USFWS, 2022b), the authors projected similar changes to the Icicle Creek Basin that echoed those of the Wenatchee River Basin (Tohver et al., 2014). By the 2040s, mean monthly snowpack is projected to decrease for Icicle Creek by 35% and more precipitation is expected to fall as rain rather than snow (USFWS, 2022b). While the annual discharge for Icicle Creek is projected to remain stable, the shape of the hydrograph is expected to shift to higher flows in late fall and winter, lower runoff in June, and lower baseflows throughout the summer (USFWS, 2022b) Similar projections were made in previous work conducted by (Mauger et al., 2017). These authors used 5 different climate models to project monthly streamflow through the 2080s. The combination of higher air temperatures and lower snowpacks caused earlier and lower peak flows in the spring, higher flows in winter, and lower summer baseflows (Mauger et al., 2017). The consensus of these studies, along with the predictions for the Wenatchee Basin, demonstrates the importance of climate change consideration when discussing habitat and restoration efforts within Icicle Creek.

The National Climate Change Viewer (NCCV) is a USGS tool developed by Alder & Hostetler (Alder & Hostetler, 2021) for visualizing and graphing projected climate change impacts from the Climate Model Intercomparison Program (CMIP) across the conterminous United States. This tool downscales projections from 27 Global Climate Models (GCMs) to 6km spatial resolution that can be used to visualize specific climate change impacts in watersheds. The climate change impacts are organized by Shared Socioeconomic Pathways (SSPs). SSPs represent various human development potentials and their impact on the amount of radiative forcing, or warming, that is projected to occur. Radiative forcing occurs when the amount of energy entering our atmosphere is larger than the energy exiting our atmosphere. A larger, positive radiative forcing value signals more warming. The SSP scenarios serve as a baseline to compare how the climate is predicted to change based on various social, economic, and policy factors.

In the Wenatchee basin between 2025 - 2099, the climate models show an increase in mean temperature, a decrease in the amount of snow received, and an increase in late fall and winter precipitation in all SSPs (Figure 21, Figure 22, and Figure 23). The total amount of annual precipitation the basin receives is projected to change very little in the 2025 – 2099 timeframe, emphasizing seasonal and precipitation-type changes as the basin transitions from a snow-dominated to a transitional basin.

Changes to the dominant hydrological regime will have seasonal impacts on stream temperatures. Earlier peak flows from snowmelt and lower summer baseflows may increase the risk for summer water temperature exceedances for the salmonid and trout species that reside in Icicle Creek and its tributaries. The largest changes in precipitation seasonality are an increase in late fall and early winter precipitation. The hydrological and habitat changes are crucial to consider as the climate continues to change in and around Icicle Creek.

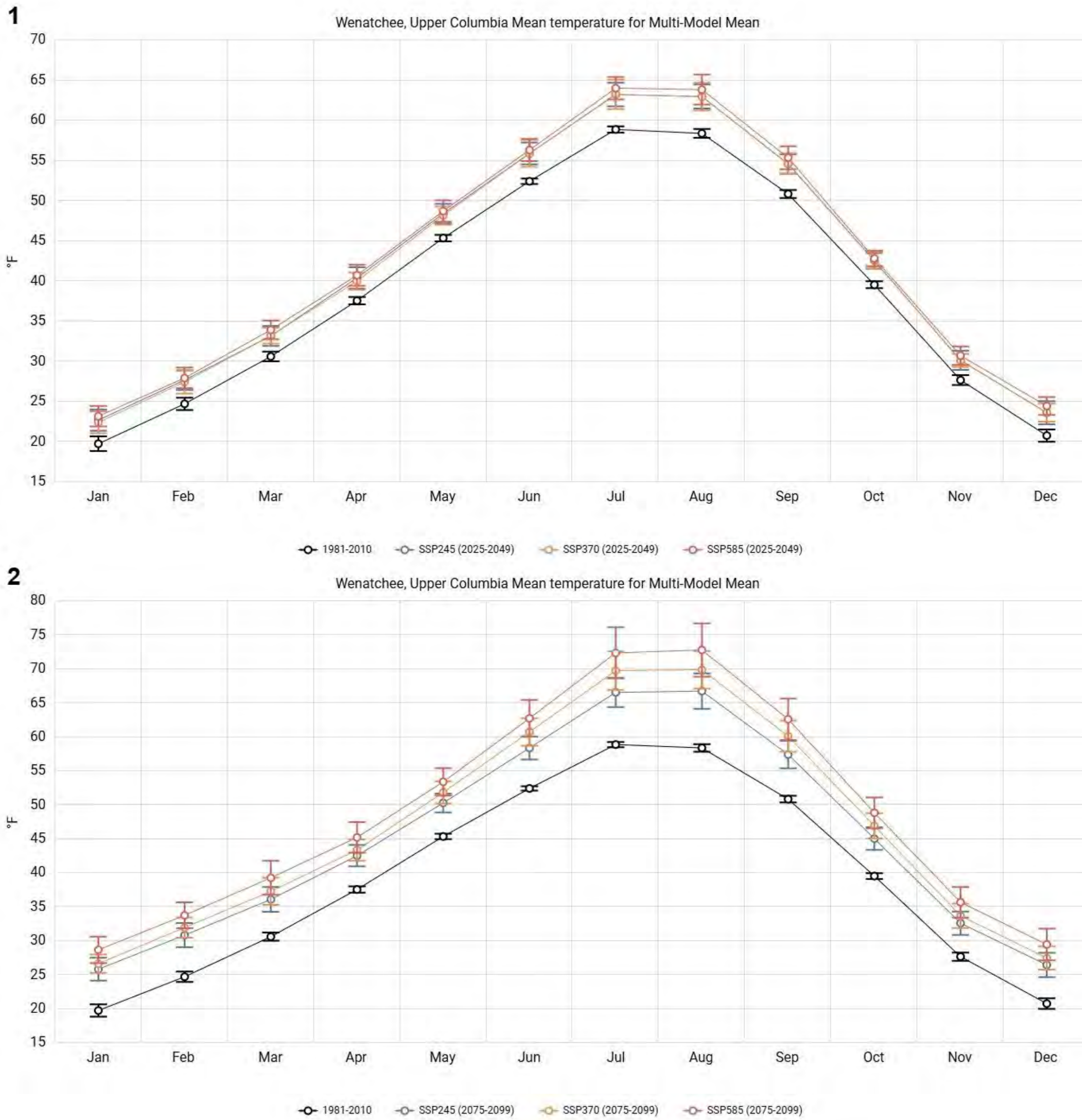

Figure 21. Climate change scenario graphs for the Wenatchee mean temperature. Source: Alder & Hostetler (2013), generated via USGS NCCV. The multi-model mean for mean temperature in the Wenatchee basin from 1) 2025 – 2049 and 2) 2075 – 2099. The three scenarios are the 3 Shared Socioeconomic Pathways. SSP245 represents a 'middle of the road' scenario with an additional 4.5W/m² of radiative forcing by 2100. SSP 370 represents an upper-middle scenario with an additional 7.0W/m² of radiative forcing by 2100. SSP585 represents the worst-case scenario akin to RCP 8.5 with an additional radiative forcing 8.5W/m² by 2100.

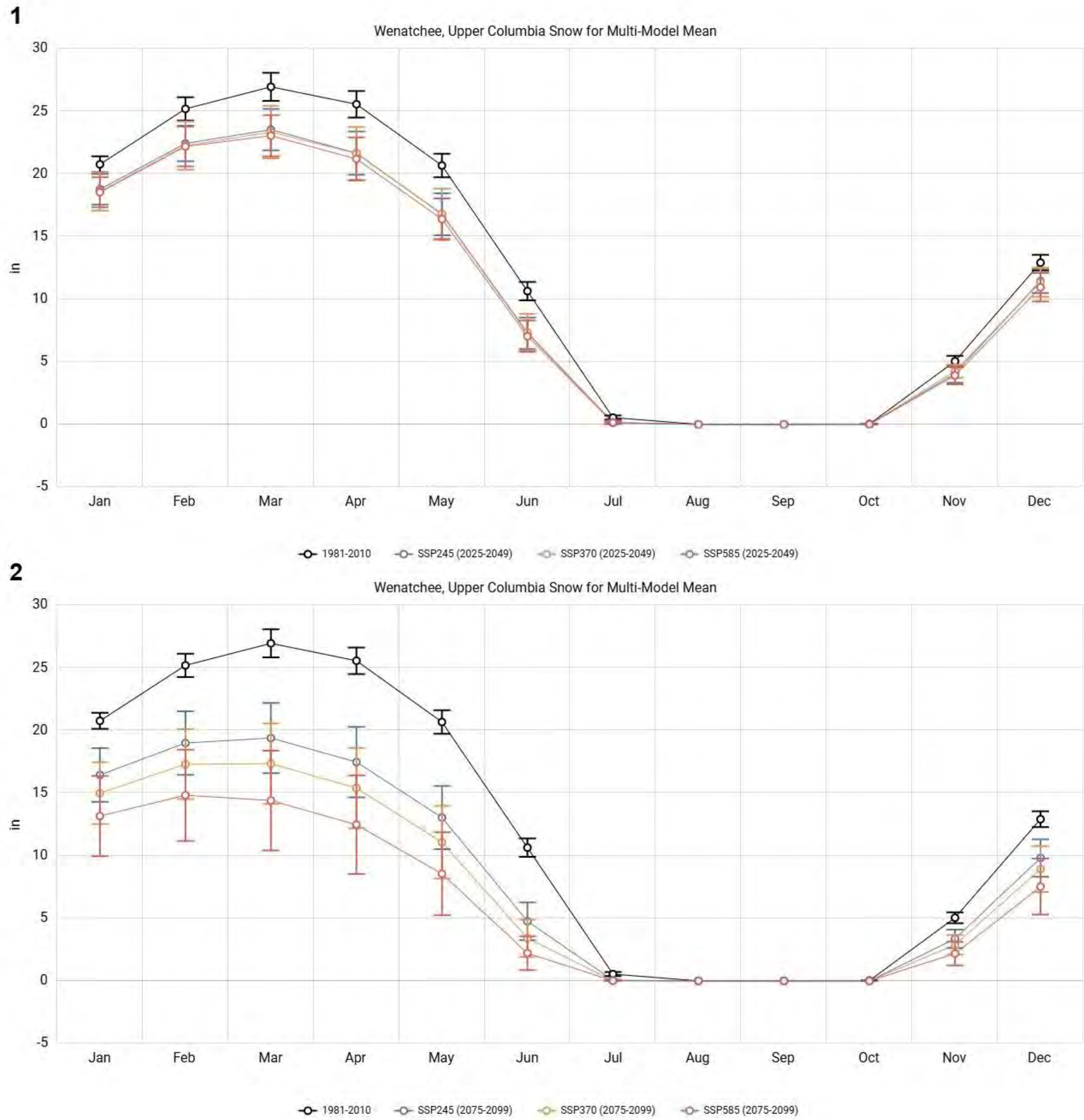

Figure 22. Climate change scenario graphs for the Wenatchee snow fall. Source: Alder & Hostetler (2013), generated via USGS NCCV. The multi-model mean for snow amount in the Wenatchee basin from 1) 2025 – 2049 and 2) 2075 – 2099. The three scenarios are the 3 Shared Socioeconomic Pathways. SSP245 represents a 'middle of the road' scenario with an additional 4.5W/m^2 of radiative forcing by 2100. SSP 370 represents an upper-middle scenario with an additional 7.0W/m^2 of radiative forcing by 2100. SSP585 represents the worst-case scenario akin to RCP 8.5 with an additional radiative forcing 8.5W/m^2 by 2100.

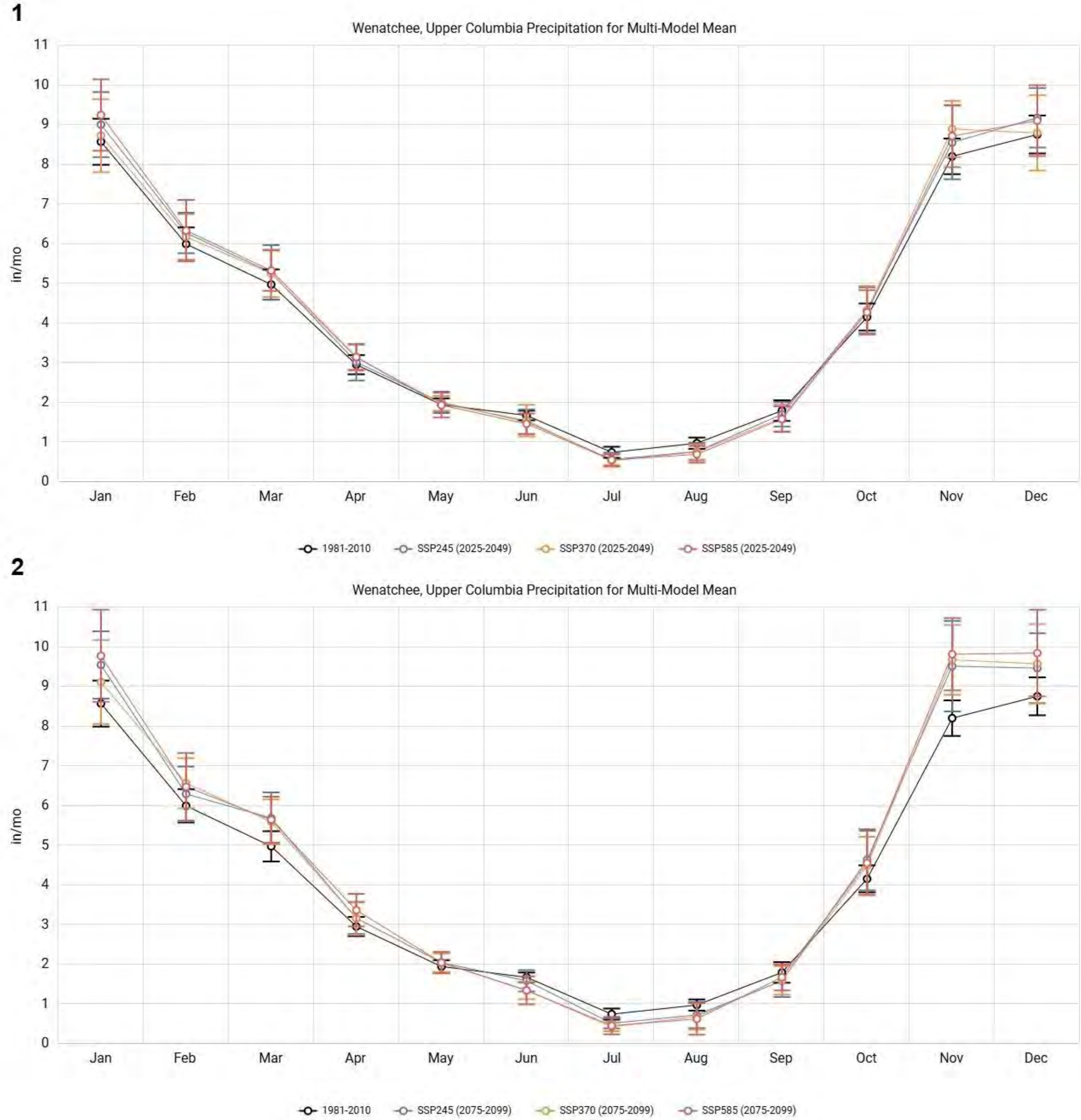

Figure 23. Climate change scenario graphs for the Wenatchee precipitation. Source: Alder & Hostetler (2013), generated via USGS NCCV. The multi-model mean for precipitation amount in the Wenatchee basin from 1) 2025 – 2049 and 2) 2075 – 2099. The three scenarios are the 3 Shared Socioeconomic Pathways. SSP245 represents a 'middle of the road' scenario with an additional 4.5W/m^2 of radiative forcing by 2100. SSP 370 represents an upper-middle scenario with an additional 7.0W/m^2 of radiative forcing by 2100. SSP585 represents the worst-case scenario akin to RCP 8.5 with an additional radiative forcing 8.5W/m^2 by 2100.

The climate change predictions from the modeling described above may already be occurring in the Icicle Creek Basin. The streamflow data available for Icicle Creek allow for some historical-to-current comparisons. Average monthly discharge from the USGS gage (Icicle Creek Above Snow Creek Near Leavenworth, WA - 12458000) from 1936 – 2024 is plotted in Figure 23 as averaged from 1937-1999 and 2000-2024. Peak mean monthly flows are shifted earlier from June to May since 2000, with the magnitude of monthly flows decreasing in the spring and summer (May to August) and increasing in the fall and winter (Nov to March) (Figure 24). The magnitude of annual peak flows have not noticeably changed since 2000 (Figure 25).

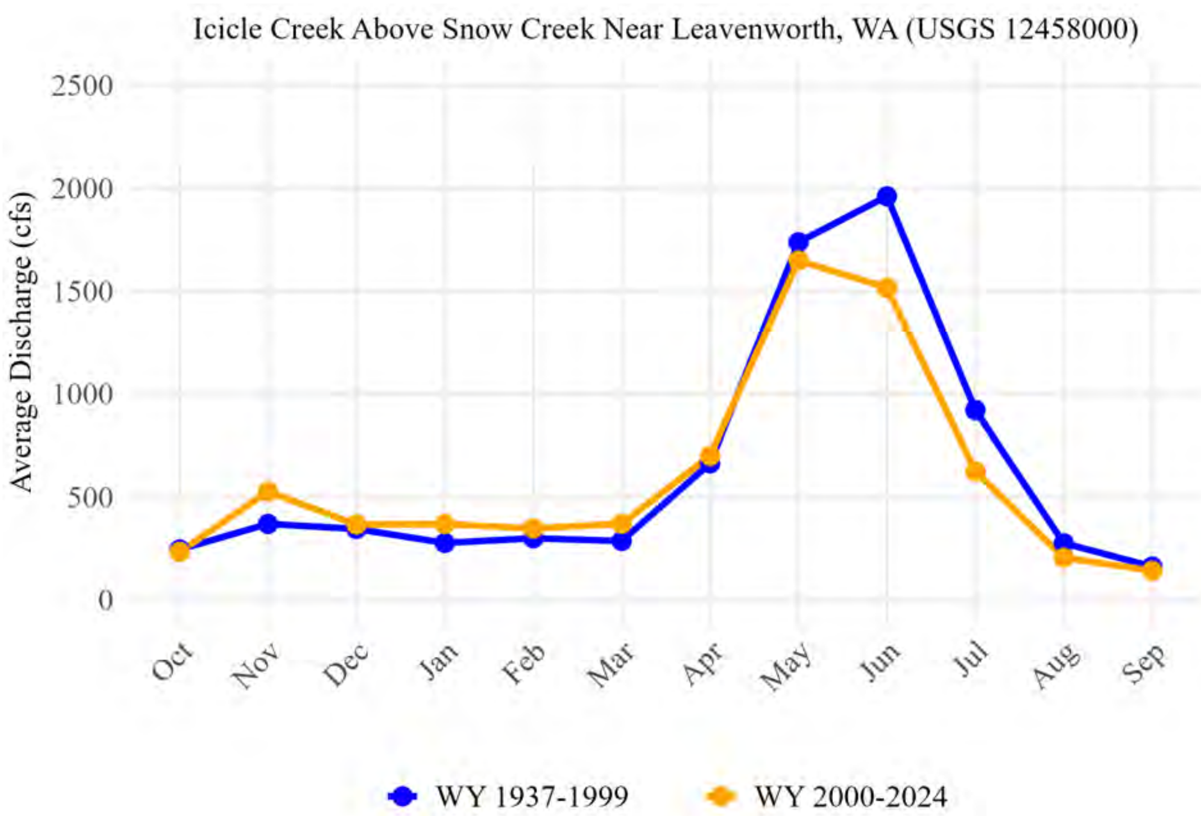

Figure 24. Comparison of mean monthly flows at the USGS gage (Icicle Creek Above Snow Creek Near Leavenworth, WA - 12458000)

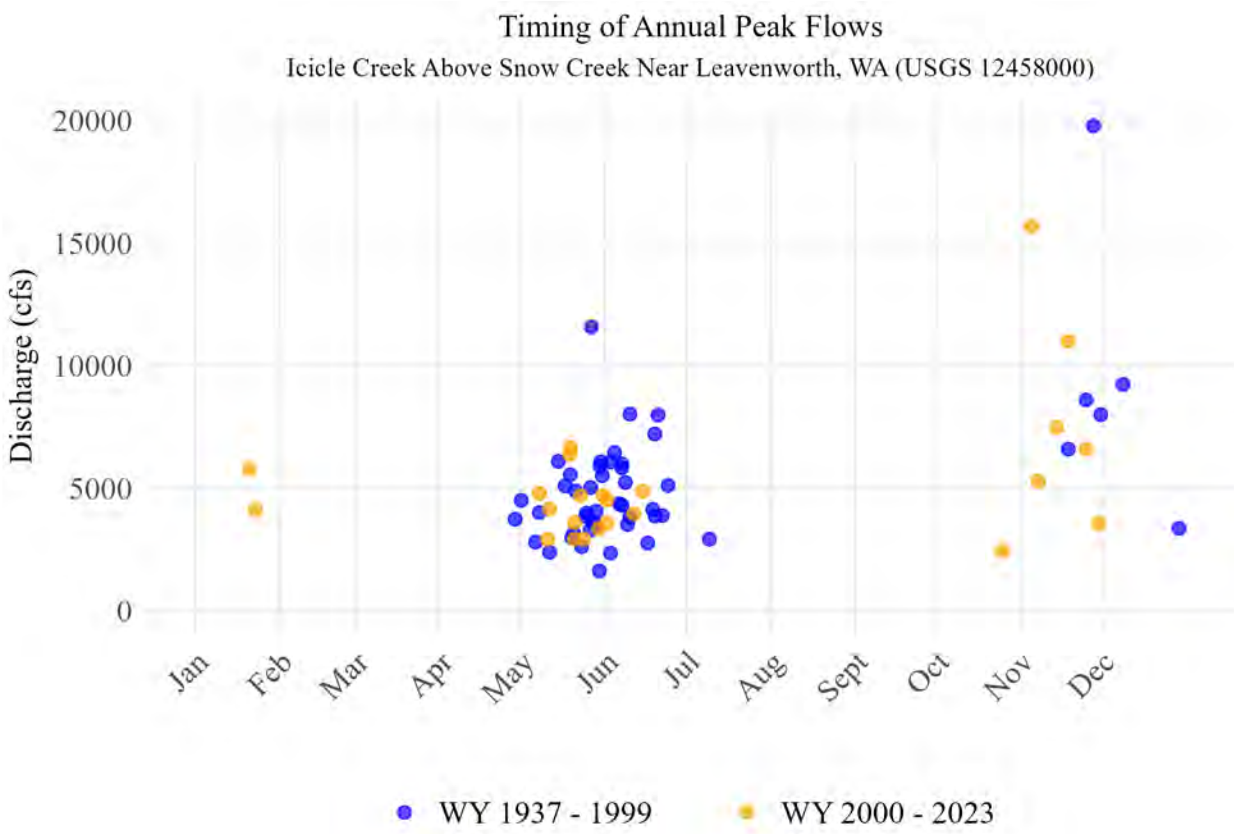

Figure 25. Annual peak flow timing and magnitude at the Icicle Creek Above Snow Creek Near Leavenworth, WA stream gage (USGS 12458000).

Despite the changes to the seasonal timing of flows, the mean annual discharge in the two periods (WY 1937 – 1999 & WY 2000 – 2024) remain similar. The mean annual flow for WY 1937 – 1999 is 618 cfs and the mean annual flow for WY 2000 – 2024 is 588 cfs. These similar annual flow averages support the previous predictions in the Wenatchee Basin and Icicle Creek that even though the timing and magnitude of flows will change with climate change, the overall mean annual flows are likely to remain the same. This finding further suggests that earlier snowmelt and shifts in precipitation type from snow to rain, driven by air temperature changes and overall changes in climate patterns, is a primary driver of the hydrological changes seen in Icicle Creek during recent decades.

It is reasonable to assume that high elevation basins, such as the Icicle Creek, would be exhibiting a greater response, thus far, to climate change, compared to lower elevation areas. These snowmelt-dominated systems are at the cusp of a transition to mixed rain and snow systems that exhibit both snowmelt and rain-dominated characteristics (Tohver et al., 2014). Rain events in the early season (late fall / early winter) in these high elevation basins often result in higher runoff compared to similar type events in later winter or spring due to a lower snowpack available to absorb the rainfall and buffer the runoff. This may be exacerbated by climate change-related impacts causing more precipitation falling as rain as opposed to snow, especially in the fall before there has been significant snow accumulation, which would be expected given the warming predicted by modeling (Figure 20). This is related to, and further exacerbated by, lower fall snowpack, which is also predicted by the modeling (Figure 21).

In summary, modeling predicts climate change effects on hydrologic processes in Icicle Creek and the Wenatchee Basin, including less snowpack, earlier and lower spring snowmelt peaks, elevated winter flows, and lower summer base flows (Alder & Hostetler, 2021; Mauger et al., 2017; Tohver et al., 2014; (USFWS), 2022a) Icicle Creek may be particularly susceptible to climate change impacts due to its high elevation and potential to transition from a snowmelt-dominated system to a rain and snowmelt-dominated system. The data suggest that Icicle Creek may already be experiencing some of these predicted transitions.

2.7 HYDRAULIC ANALYSIS

2.7.1 Hydraulic Analysis and Modeling

The hydraulic analysis for this assessment includes a preliminary 2-dimensional (2-D) hydraulic model for Reaches 1-20 of Icicle Creek. The model is also used to support the incipient motion sediment transport analysis described in Section 2.8.5. A more detailed description of the methods, analysis, and results of the hydraulic modeling can be found in Appendix D; a summary is provided here.

The preliminary-level model was developed for existing conditions for the study area using the estimated flood discharges described in Section 2.6.5. The model was developed in the U.S. Army Corps of Engineers HEC-RAS 6.5 software (USACE, 2024b), which computes hydraulic properties related to the physical processes governing water flow through natural rivers and other channels. Existing conditions were based on the most recent available LiDAR data, which varied by location in the study area and ranged from 2015 to 2020 (NV5 Geospatial, 2022; Quantumn Spatial, 2018).

The goal of this preliminary model is to assess the current channel and floodplain dynamics, as well as assess the impacts of flood flows (2, 5, 10, 25, 50, and 100-year flood events) on the existing landscape.

2.7.2 Model Results

Modeled velocities and depths for the 2-year, 25-year, and 100-year flood events show distinct trends across the Icicle Creek study area. In the downstream reaches (Reaches 1–3), where the valley is wide and there is greater floodplain interaction, channel velocities range from 4 to 6 ft/s during the 2-year event, increasing to 10 ft/s in localized areas at the 25-year and 100-year flows. Floodplain velocities remain below 2 ft/s, and depths increase from 8–10 feet at the 2-year event to 11–15 feet at the 100-year event. The hatchery diversion channel generally exhibits higher velocities but lower depths than the adjacent natural channel. In the steep, confined upstream reaches (Reaches 4–18), velocities are consistently higher, often exceeding 10 ft/s, with limited floodplain inundation. Some localized areas (e.g., Reaches 10 and Reach 15) exhibit lower velocities and minor floodplain activation. Further upstream (Reaches 19–20), where gradients are slightly lower and floodplains are more active, velocities range from 2 to 8 ft/s with greater floodplain inundation. Depths in these reaches increase from 4–6 feet at the 2-year event to 6–11 feet at the 100-year event, with localized areas reaching 20 feet depth.

2.7.3 Model Considerations

The model used in this assessment was developed for planning-level analysis. The hydraulic model was calibrated based on the geomorphology team's field observations (see Appendix D, Section 2.2.4). However, there are several key considerations in evaluating how much confidence can be put in the model results given the data utilized. First, the LiDAR used in the model terrain does not include channel bed (bathymetry) data, which limits the accuracy of model results. Instead of bathymetry, the LiDAR data is a representation of water surface elevation during the LiDAR flight, which therefore results in an underestimation of channel conveyance, as well as potential over estimation of floodplain inundation and shallower modeled channel depths compared to actual channel depths. For future project-scale modeling, channel bathymetric surveys are recommended. In addition, this model does not incorporate bridges in the project area or water control structures in and around the Leavenworth National Fish Hatchery. Surveying these structures or incorporating existing survey data (if available) is recommended to provide more detailed and accurate results around these structures for the next phase of modeling. Lastly, this model does not account for diversion of flows for agricultural, hatchery, and city use that take place in the downstream reaches of Icicle Creek, or other supplemental flows in and around this area, as these were not considered relevant for high flow events. Analysis of low flows in Icicle Creek will need to account for these diversions and inputs to better understand how they impact low flow hydraulic conditions.

2.8 GEOMORPHOLOGY

2.8.1 Overview and Methods

Icicle Creek extends 31.8 RM from its upstream most headwater source at Josephine Lake (4,695 ft elevation) located on the eastern side of the crest of the Cascade Range in the Alpine Lakes Wilderness, to the Wenatchee River near the town of Leavenworth, WA (~1,100 ft elevation). Developing a successful habitat restoration strategy requires an understanding of the geomorphic processes and trends of the modern channel, floodplain, and contributing hillslopes. This section provides an overview of the geomorphology of the watershed as well as a summary discussion of the primary geomorphic features of Icicle Creek from RM 0-22. The information presented here and in Section 3 is based on field-based survey observations (August 6-9, 12-19, and 25-31, 2024) combined with available digital and printed data and reports (as referenced). Staff Scientists (Geomorphologist, Hydrology, Ecologist) walked and/or floated each reach in the assessment area to characterize physical conditions and channel processes as well as identify restoration opportunities. Specific attention was paid to: 1) trends in channel incision and evolution, 2) substrate type, distribution, and sediment availability, 3) surface and subsurface flow interactions, 4) channel bank composition and migration patterns, 5) floodplain and habitat connectivity, 6) occurrence and influence of large woody material, 7) present function, quality, and diversity of vegetation, and 8) influence of past and current human structures and activities. The bed material was characterized by performing 26 pebble-count surveys (gravel counts) following the Wolman Pebble Count method (Wolman, 1954) and ocular observations on bedload composition. The pebble count method includes sampling and measuring a minimum of 100 separate pieces of sediment from a representative riffle crest or bar. Detailed discussions of geomorphic conditions and trends at the reach-scale are provided in Section 3, including sediment characterization. Table 4 includes a suite of metrics used to characterize each reach.

The mapped geomorphic surfaces of the assessment area are presented in Figure 26 and Figure 27. Mapped modern floodplain surfaces include low (inundated approximately once every 1-5 years), medium (5-20 years), and high (20-100+ years). Terraces include abandoned floodplains as well as glacial deposits and fan terraces that the mainstem channel is no longer able to inundate. The location of bedrock exposures in the bank or bed of the channel is also mapped. Geomorphic surface mapping was completed through a combination of field investigation and desk-top analysis. Surfaces were mapped as part of the geomorphology survey and with reference to LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications provided in many areas based on the survey. Reach-scale geomorphic-surface maps are provided for each reach in Section 3.

Table 4. Channel and Floodplain metrics for all reaches within the assessment area: based on habitat and geomorphic survey data and GIS analysis.

Metric	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
Length (miles)	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
River Mile	0-1.24	1.24-3.02	3.02-4.30	4.30-5.05	5.05-6.27	6.27-7.15	7.15-8.63	8.63-9.63	9.63-10.24	10.24-11.36	11.36-11.92	11.92-12.50	12.50-12.84	12.84-14.75	14.75-16.63	16.63-17.24	17.24-18.74	18.74-19.18	19.18-21.11	21.11-22.02
Stream Gradient (%)[1]	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%
Sinuosity[2]	1.67	1.90	1.10	1.05	1.05	1.01	1.03	1.06	1.04	1.05	1.02	1.03	1.02	1.01	1.10	1.10	1.15	1.00	1.18	1.15
Dominant Channel Habitat Unit Type	Pool	Pool	Pool	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Pool	Pool	Riffle	Riffle	Pool	Pool
Average Bankfull Width (ft)[3]	125.0	83	57	100	90	80	102	118	97	99	76	92	86	85	105	98	78	79	82	86
Confinement[4]	Unconfined	Unconfined	Partially Confined	Confined	Confined	Confined	Partially Confined	Partially Confined	Confined	Partially Confined	Confined	Confined	Confined	Confined	Partially Confined	Partially Confined	Partially & Confined	Confined	Unconfined	Partially Confined
Dominant Substrate[5]	Gravel	Gravel	Gravel	Cobble / Boulder	Boulder	Boulder	Boulder	Boulder / Cobble	Boulder / Cobble	Boulder / Cobble	Boulder	Boulder	Boulder	Boulder / Cobble	Cobble / Gravel	Cobble / Boulder	Boulder / Cobble	Cobble	Gravel	Cobble
% Pool Habitat[6]	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%	34.2%	29.9%	64.0%	16.4%
% Glide Habitat[6]	32.4%	6.0%	12.7%	0.0%	3.1%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%	4.8%	0.0%	2.6%	29.5%	12.7%	11.3%	1.5%	15.5%	18.1%
% Riffle Habitat[6]	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%	40.8%	61.9%	12.2%	65.4%
% Side Channel Habitat[6]	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%	8.8%	6.6%	8.3%	0.0%
% Other Habitat[6]	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%	4.9%	0.0%	0.0%	0.0%

[1] Stream gradient was calculated by dividing the difference of vertical distance by horizonal distance.
[2] Sinuosity was calculated by dividing channel length by valley length.
[3] The bankfull width was determined at evenly spaced intervals in the reach and then averaged.
[4] Confinement categories use the Washington Watershed Analysis Guidelines. Unconfined: Valley Width (VW) > 4 Channel Width (CW). Partially confined: 2 CW < VW < 4 CW. Confined: VW < 2 CW.
[5] The dominate substrate was determined using pebble counts. Reaches 4, 8,10,14, and 15 were averaged to get dominant substrate since individual results varied.
[6] The habitat area composition was determined by marking the start of each unit in the field following U.S. Forest Service (USFS) Level 2 protocol. GIS analysis included digitizing the habitat units using the starting points and aerial imagery and calculating total area and percentage of each habitat unit type.

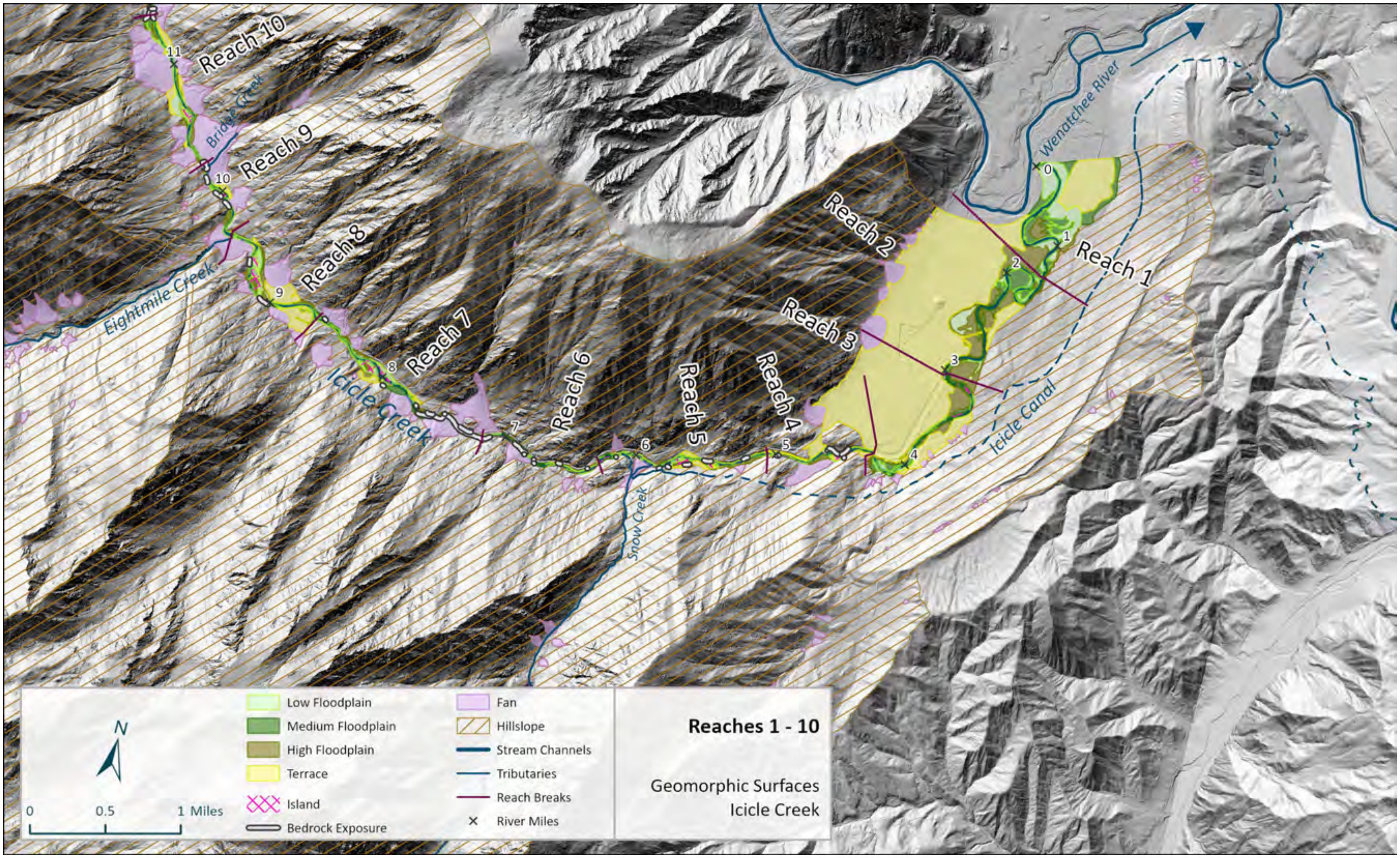

Figure 26. Map of geomorphic surfaces of Icicle Creek: Reaches 1-10.

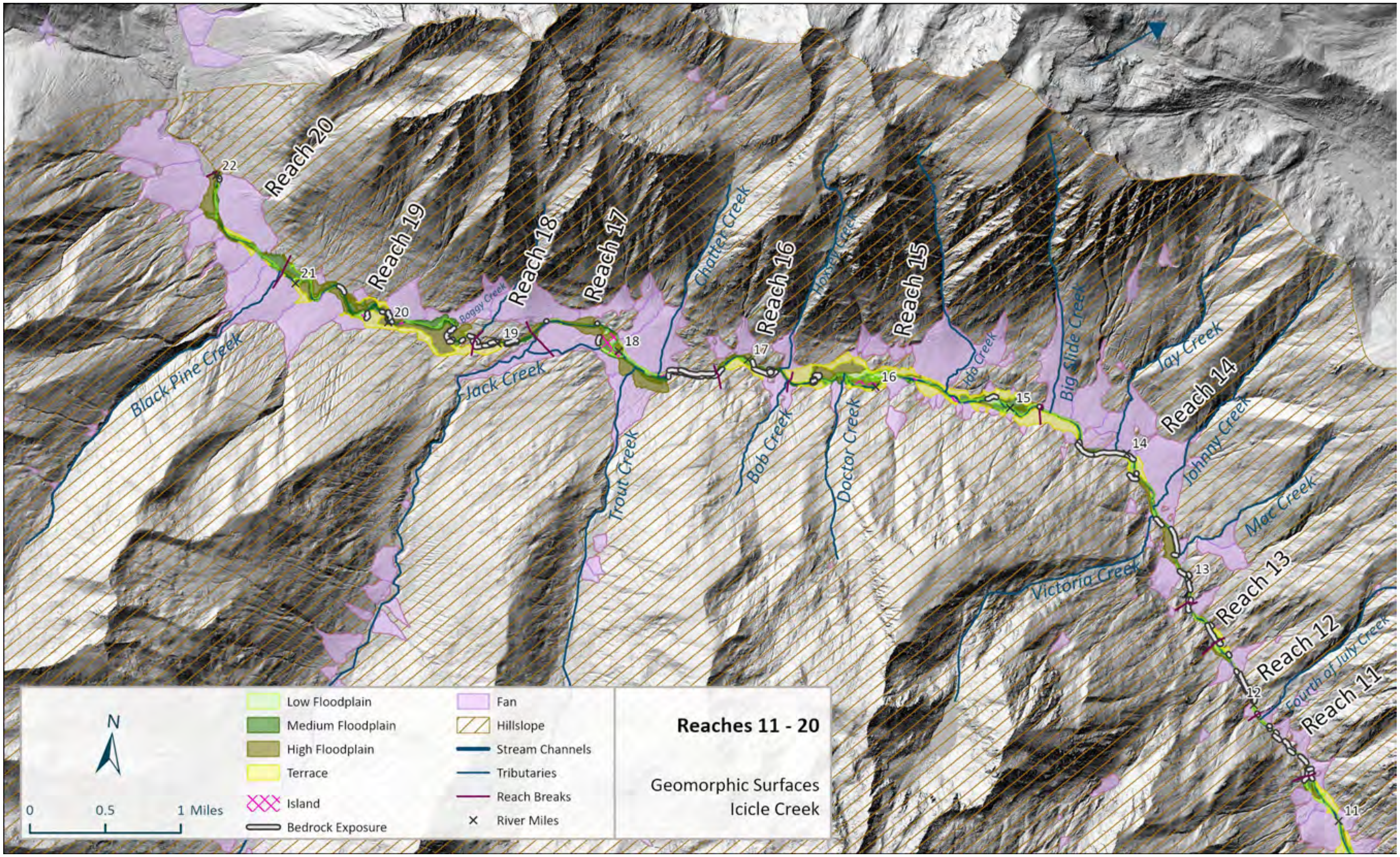

Figure 27. Map of geomorphic surfaces of Icicle Creek: Reaches 11-2

2.8.2 Hillslopes and Valley

Icicle Creek is nestled between glacially carved hillslopes and fans (debris and alluvial). The Icicle Creek Valley is high relief, with hillslopes adjacent to the assessment area rising to peaks and ridges several thousands of feet above the valley bottom. The valley bottom is the area at the base of and between the hillslopes in which the channel and its floodplain occupy. The steep hillslopes are vegetated with sparse conifer forests interspersed with bedrock outcrops (Figure 28). It contains sediments and soils derived from past glacial processes and deposits, reworked alluvium, hillslope colluvium, debris fans, and tributary inputs.

Figure 28. Icicle Creek "U"-shaped glacial valley form, looking upstream at RM 7.8. (August 26, 2024)

Ample hillslope to channel coupling provides sediment and some large wood contributions to the system. The steep hillslopes produce colluvium (landslide) and debris flow contributions that continue to supply material to the channel. Coupling is almost continuous along the confined reaches of the channel. In unconfined reaches, direct hillslope coupling to the channel is intermittent, occurring where the channel's path brings it into contact with the toe of a slope or debris fan. In several locations hillslope bedrock exposures contact the channel (Figure 29).

Figure 29. Bedrock hillslope, direct channel contact in Reach 18 looking upstream at RM 19.18 (August 8, 2024).

The presence of Icicle Road, set along and into the toe of the hillslopes and fans on the north side of the channel, both impedes and contributes to hillslope coupling with the channel and valley floor, depending on whether the road prism is cut into the hillside or built up off of it and armored.

The width of the modern valley floor in the assessment area ranges from approximately 100 feet to 1,000 feet in high/medium confined sections and up to 5,000 ft below RM 4 in lower Icicle Creek Valley. The valley floor in the most confined or canyon sections is often occupied primarily by the channel itself. Where valley width allows, floodplain and terrace surfaces occupy the valley along with the channel. However, substantial contributions to the valley floor from debris fans sourced from the hillslopes or alluvial/debris fans sourced from drainages and tributaries, and even glacial moraine deposits are important material contributors to the system. Hillslope and tributary contributions in the form of numerous landslides and debris flows throughout the assessment area have and will continue to influence river morphology and valley composition through sediment contribution and wood routing. Wildfires can lead to increased hillslope instability, resulting in sediment and wood inputs from hillslopes to channels. Evidence of recent and historical wildfires in the region highlights the need to consider the effects of wildfires in future management of the watershed.

2.8.3 Terraces, Floodplains, and Fans

Terraces are surfaces on the valley floor that the channel, under normal hydrologic regimes, is no longer able to inundate. Terraces within the assessment area are a mix of glacial deposits, glacial outwash, colluvium, fan deposits, or alluvium. The glacial outwash terraces formed when sediment and hydrological regimes shifted (decreased) after glacial retreat. Colluvium and fan deposits become terraces when their contributions extend into or across the valley, forcing the channel to flow over the contributions. Over time, the channel eventually erodes across and through or into valley-filling deposits to reestablish a consistent channel gradient, where possible. The remnant surfaces become abandoned terraces if and when the channel successfully erodes through the hillslope contributions. Modern alluvial terraces occur where historical floodplains are abandoned due to incision, often instigated by anthropogenic impacts or other causes for channel simplification or straightening.

The floodplains consist of a series of low (inundated approximately once every 1-5 years), medium (5-20 years), and high (20-100+ years) surfaces. Low floodplain surfaces are most common along the channel margins or in meandering channel sections on the insides of meander bends, extending off bars. Inundation results in relatively frequent sand deposits (accretion) on the surfaces of the low floodplains, where the vegetation is dominated by riparian forbs, shrubs, and small trees. On the higher, less frequently inundated floodplain surfaces, topsoil is usually more organic-rich and developed. The higher floodplain surfaces have potential to support establishment of larger trees which eventually are available for recruitment to Icicle Creek.

Alluvial tributary fans and debris fans sourced from the hillslopes are prevalent throughout the assessment area. The fans contribute material (sediment and large wood) to the floor of the valley and channel from the adjacent hillslopes on both sides of the valley. The fans range from presently active to stabilized with vegetation and/or established infrastructure. All appear to have the potential to be active or reactivated. Where the fan functions as a hillslope toe or terrace surface adjacent to the channel, it continues to have the potential to provide material to the channel over time.

2.8.4 Channel and Tributaries

Icicle Creek is a montane channel with confined, partially confined, and unconfined sections. Icicle Creek and its tributaries flow through glacially carved valleys with bedrock confined sections as well as depositional alluvial valley sections of varied widths. Tributary and hillslope contributions of sediment to the channel and valley floor are notable throughout the assessment area. The main tributaries within the assessment area include Black Pine Creek, Jack Creek, Trout Creek, Eightmile Creek, and Snow Creek, all of which are sourced from the western hillslope of the watershed. All the significant tributaries entering the assessment area are listed in Table 5.

Table 5. Primary tributaries within the assessment area and the river mile at which they join Icicle Creek.

Icicle Creek Tributary	River Mile (RM)
Snow Creek	6.00
Rat Creek	8.42
Lion Creek	9.13
Eightmile Creek	9.63
Bridge Creek	10.42
Fourth of July	11.85
Mac Creek	13.15
Victoria Creek	13.45
Johnny Creek	13.55
Jay Creek	14.15
Big Slide Creek	14.75
Ida Creek	15.45
Doctor Creek	16.35
Bob Creek	16.63
Hoxsey Creek	16.75
Chatter Creek	17.56
Trout Creek	17.86
Jack Creek	18.16
Boggy Creek	19.18
Black Pine Creek	21.11

Icicle Creek shifts from moderate-gradient upper reaches (Figure 30) to the steep canyon reaches in the mid sections (Figure 31), and then to the low-gradient downstream reaches (Figure 32). The variations in gradient are visually displayed with the longitudinal profile of the channel through the assessment area (Figure 33). The gravel-count results confirm gradient and hydraulic variability between reaches. The size-class percentiles (percent finer than) produced by the gravel counts are included in Table 6 and displayed as percent composition by substrate size class in Figure 34.

Figure 30. Example of moderate gradient cobble-dominated pool-riffle channel in Reach 16 at RM 16.8, looking downstream. (August 11, 2024)

Figure 31. Example of high-gradient, bedrock confined section – Reach 9 at RM 9.77, looking downstream. (August 13, 2024)

Figure 32. Example of unconfined low-gradient channel section in Reach 1 with point bar and floodplain development – Reach 1 at RM 0.16, looking downstream. (August 29, 2024)

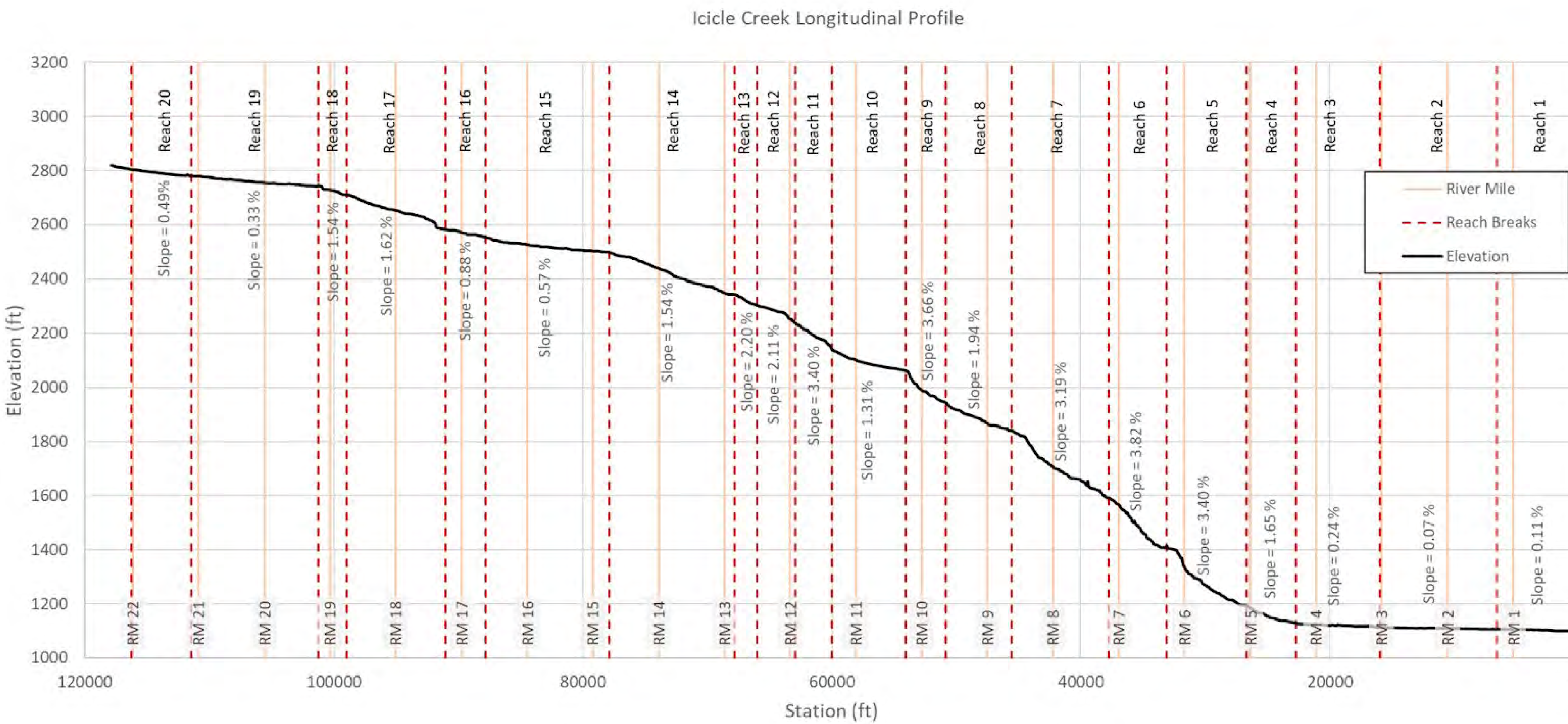

Figure 33. Icicle Creek longitudinal profile extracted from mainstem channel centerline digitized on 2020 LiDAR created by NV5 (2022).

Table 6. Bed material size (in mm) percentiles (percent finer than) for the 2-3 gravel counts completed per reach through the assessment area.

	GC26	GC25	GC24	GC23	GC22	GC21	GC20	GC19	GC18	GC17	GC16	GC15	GC14	GC13	GC12	GC11	GC10	GC9	GC8	GC7	GC6	GC5	GC4	GC3	GC2	GC1
	Reach 1		**Reach 2**		**Reach 3**	**Reach 4**		**Reach 8**		**Reach 9**	**Reach 10**		**Reach 12**	**Reach 14**		**Reach 15**		**Reach 16**		**Reach 17**		**Reach 19**			**Reach 20**	
Size Class (mm)	**Icicle Creek**																									
D5	13	4	3	8	5	19	30	12	3	8	5	35	1	4	2	9	1	7	50	23	8	9	17	8	19	2
D16	23	12	8	17	13	56	96	38	37	40	20	115	64	28	35	23	10	50	60	40	61	24	23	26	37	23
D50	55	39	31	32	39	180	275	123	256	165	73	330	205	95	180	60	125	135	105	90	205	57	57	63	80	80
D84	90	66	52	62	61	350	510	350	400	500	165	252	300+	300+	300+	110	300+	230	220	165	365	104	100	105	130	180
D95	125	90	64	90	80	512	724	590	550	580	205	650	300+	300+	300+	121	300+	300+	300+	240	425	128	140	145	190	300+

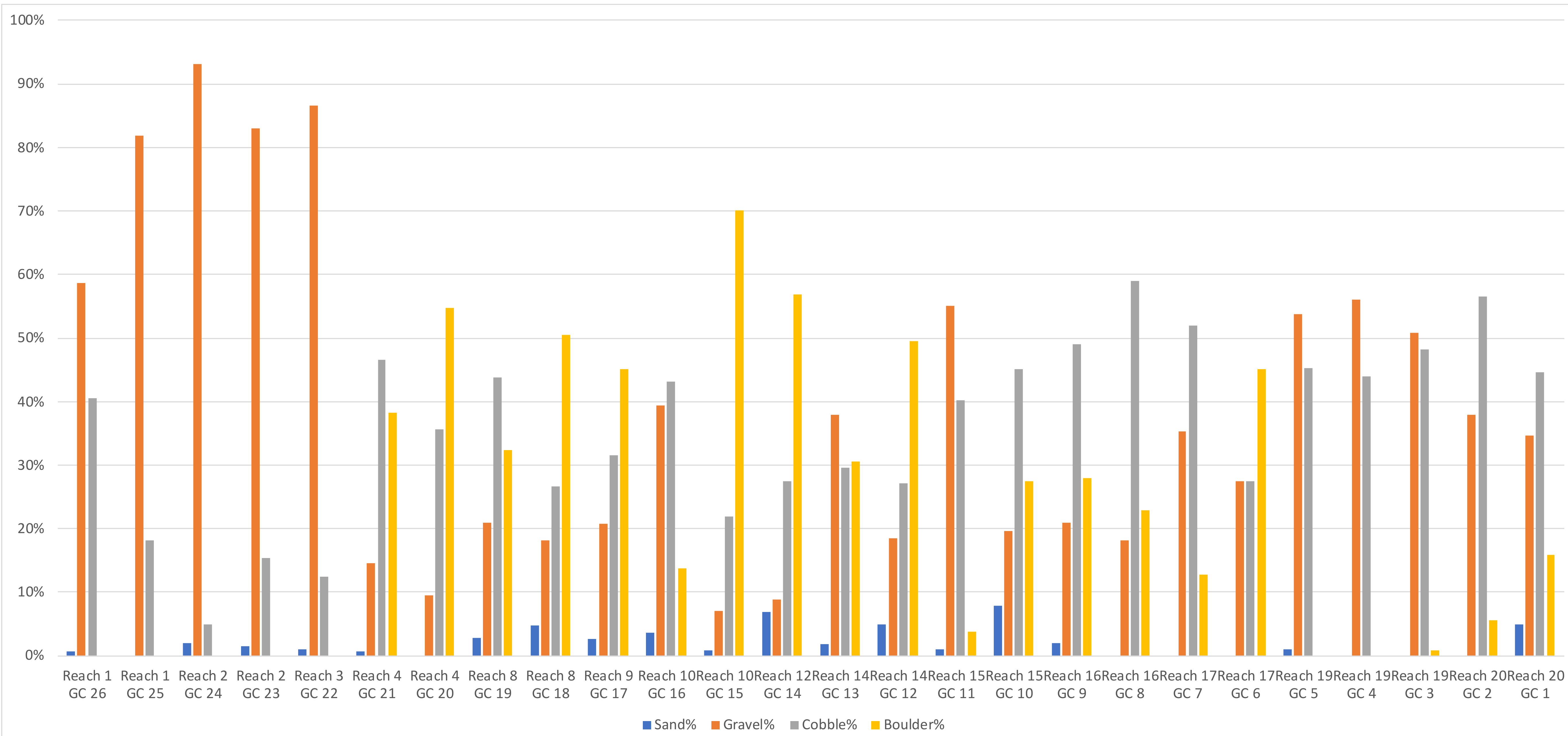

Figure 34. Substrate size class (sand, gravel, cobble, boulder) by percent counted at each pebble count (GC) location in the Icicle Creek assessment area (2024 survey)

The channel metrics resulting from this assessment for each reach are provided early in this section as Table 4. Reach-scale conditions are present in more detail in Section 3 of this report. In summary, the upper reaches (Reaches 14-20) have moderate gradients (0.33% - 1.62%) and range from unconfined to partially confined, and confined. In this segment of the channel, higher gradient is related to but does not correlate directly to confinement. Channel form is mostly single thread with straight (confined Reach 18) to low sinuosity. Occasional split flow routing around vegetated islands occurs where valley width allows. Pool-riffle morphology dominates and bedload is primarily gravels and cobbles. The middle reaches (Reaches 4-13) have higher gradients that range from 1.65% to 3.82%, except for Reach 10 at 1.31%. These reaches are confined or partially confined by the steep valley walls bedrock canyons. Pockets of less confined channel form occur, most notably in reaches 7, 8, and 9 where valley width intermittently exceed 1,000 feet. Split flow conditions around vegetated islands occur in the wider pockets but the channel is otherwise a single thread form of low sinuosity. Cobble-boulder riffle and step-pool morphologies with periodic cascades are the channel morphologies in these reaches. The dominant substrate is boulders and large cobbles. Relatively small patches of gravel occur in low velocity areas along the channel margin or behind very large boulders. The middle reaches (4-13) are generally considered transport reaches with only temporary retention of gravel or large wood. The channel in the downstream reaches (Reaches 1-3) meanders through a wide valley bottom with low gradients that range from 0.07% to 0.24%. The downstream reaches have a single-thread sinuous planform dominated by pool-riffle channel morphology, with pool habitat being most abundant. These reaches are unconfined and are dominated by gravels.

2.8.5 Sediment Mobility - Incipient Motion Hydraulics Analysis

An evaluation of potential sediment mobility in the Icicle Creek assessment area was conducted using the results of the preliminary Icicle Creek hydraulic model at the 2-year modeled flow event. Incipient motion analysis identifies the threshold between erosion (grain mobilization) and deposition for varied grain sizes, based on shear stress forces. Sediment or grains are transported when shear stress, the force of water acting on the sediment, is greater than the forces keeping the sediment in place. The amount of force required to initiate movement of a sediment particle or grain of a specific size is called critical shear stress (τ_c). If the shear stress generated by the force of water is greater than the forces holding the sediment in place, then the sediment grain has the potential to be mobilized and, if the water's shear stress is high enough, remain in transport. Conversely, if the flowing water's shear stress is less than that needed to initiate mobilization of the grain, the grain is not expected to mobilize. When upstream shear stress is sufficient to mobilize a grain, but downstream shear is insufficient, deposition of a mobilized grain is expected to occur in the downstream section – assuming the grain was available for mobilization in the upstream section. Incipient motion analysis does not estimate bedload transport volumes or sediment budgets. It identifies the point at which sediment particles of varied size are expected to mobilize in flowing water (specific shear) at a particle discharge.

2.8.5.1 Assumptions and Inputs

The shear stress results extracted from the preliminary existing conditions 2-D hydraulic model, at the estimated 2-yr flow, were used to examine probable sediment mobility using the Shields equation for incipient motion, as described in the *HEC-RAS 2D Sediment Technical Reference Manual Critical Thresholds for Transport and Erosion* (USACE, 2024a). The Shields equation and its variables are:

$$\tau_c = \theta^*(s-1)\rho g d*$$

where:

τ_c is the critical shear stress exerted on a grain by flowing water
θ^* is the dimensionless Shields parameter gravel − cobble rivers
s is the specific gravity of the grain
ρ is the density of water
g is the gravitational acceleration constant
$d*$ is the diameter of the grain size of interest

For the calculations, we used the constant values of g = 32.2 ft/s2, ρ = 62.4 lbs/ft3, and s = 2.65 (for granite and metamorphic rock).

This equation was rearranged to solve for grain size to identify where the modeled flow hydraulics of the 2-yr discharge reach critical shear and thus, potential to initiate grain mobilization.

$$d* = \frac{\tau_c}{\theta^*(s-1)\rho g}$$

For the purposes of this analysis, the required critical shear of grains (sand to boulder sized material) was added to the preliminary HEC-RAS hydraulic model as a calculated layer. A dimensionless Shields parameter of 0.047 was used based on professional judgment and previous studies on cobble and boulder channels (Julien, 2010; Wilcock, 2001)

2.8.5.2 Incipient Motion Considerations

Although this analysis is useful in identifying and predicting areas of potential or likely particle mobility or relative potential mobility from upstream to downstream, there are many limitations and uncertainties in the HEC-RAS model input data, HEC-RAS model capabilities. and the dimensionless parameter used in the Shields equation. In addition to selecting a representative value for the Shields parameter, incipient motion results are highly dependent on the variability and orientation of other grains on the bed of the channel. Sediment size variability and orientation is referred to as surface roughness, represented with a best-judgement selected Manning's n value in the model. Within HEC-RAS, shear stress is exponentially related to Manning's n. As a result, it can produce artificially high shear stress in areas at the contact point where the value of the roughness polygons change. The artificially high roughness areas are often not a good representation of the shear stress calculated for those locations (USACE, 2024c). For this analysis, the values of these parameters were informed by previous studies, field observations, and professional judgment. They were selected to represent general reach conditions instead of site-specific conditions. In practice, the values of the parameters will vary throughout the assessment area as the channel conditions change. Therefore, should more detailed questions about bed mobility arise for future design or sediment transport analysis, further investigations and analysis may be required to refine the results. However, this is a very useful analysis at the assessment-level to aid in identifying potential sediment transport versus sediment retention zones, based on flow hydraulics.

2.8.5.3 Results and Interpretation

The results of the incipient motion analysis for the estimated 2-yr discharge for the modeled shear stress are displayed in Figure 35 and Figure 36. The results are clipped to the modern active channel to display potential activation of bedload. The analysis results suggest that at the 2yr modeled flow the Icicle Creek study area has a varied sediment transport capacity that ranges from small gravel to boulder, depending on channel confinement and gradient. In the downstream lower gradient and unconfined sections (RM 4.2 – 0), the incipient motion analysis for the 2-yr modeled flow indicates capacity to transport gravel size fractions. The size fraction of gravel (large – small) decreases in a downstream trend, indicating that sediment aggradation (deposition) is expected downstream of RM 2.5. The partially confined and moderate gradient upstream section (RM 22.5 – 19) produced incipient motion analysis results for the 2-yr modeled flow that suggest capacity of the channel to mobilize gravel to cobble sized fraction material, in an alternating pattern. The areas with gravel or smaller sized fraction mobilization results are areas of bar development and sediment deposition. Downstream of RM 19, the dominant mobilized size fractions predicted in the analysis alternate between cobble and boulders, all the way to RM 4.2. This section of the channel is considered primarily transport dominant with areas of bar deposition occurring where reductions in confinement or gradient occur or massive boulders or islands provide localized pockets of hydraulic refuge. Filed observations concur that localized hydraulic refuge in the high-shear stress section occasionally produced boulder bars.

At the boundary where shear stress and grain size mobility potential decrease in a downstream trend, deposition of the larger grain fraction is expected to occur, assuming upstream sediment availability. The incipient motion analysis for the 2-yr modeled discharge suggests that the system, within the assessment area, has the capacity to deliver and mobilize overtime, small-fraction sized gravels from the upstream boundary to the downstream boundary. This indicates sediment connectivity through the assessment area. This characteristic also explains the presence of large, maintained gravel bars and bedforms in the very lower-gradient meandering downstream reaches of Icicle Creek. Field observations, representative pebble count data results, and reach-scale descriptions of the incipient motion analysis results are provided for each reach in Section 3.

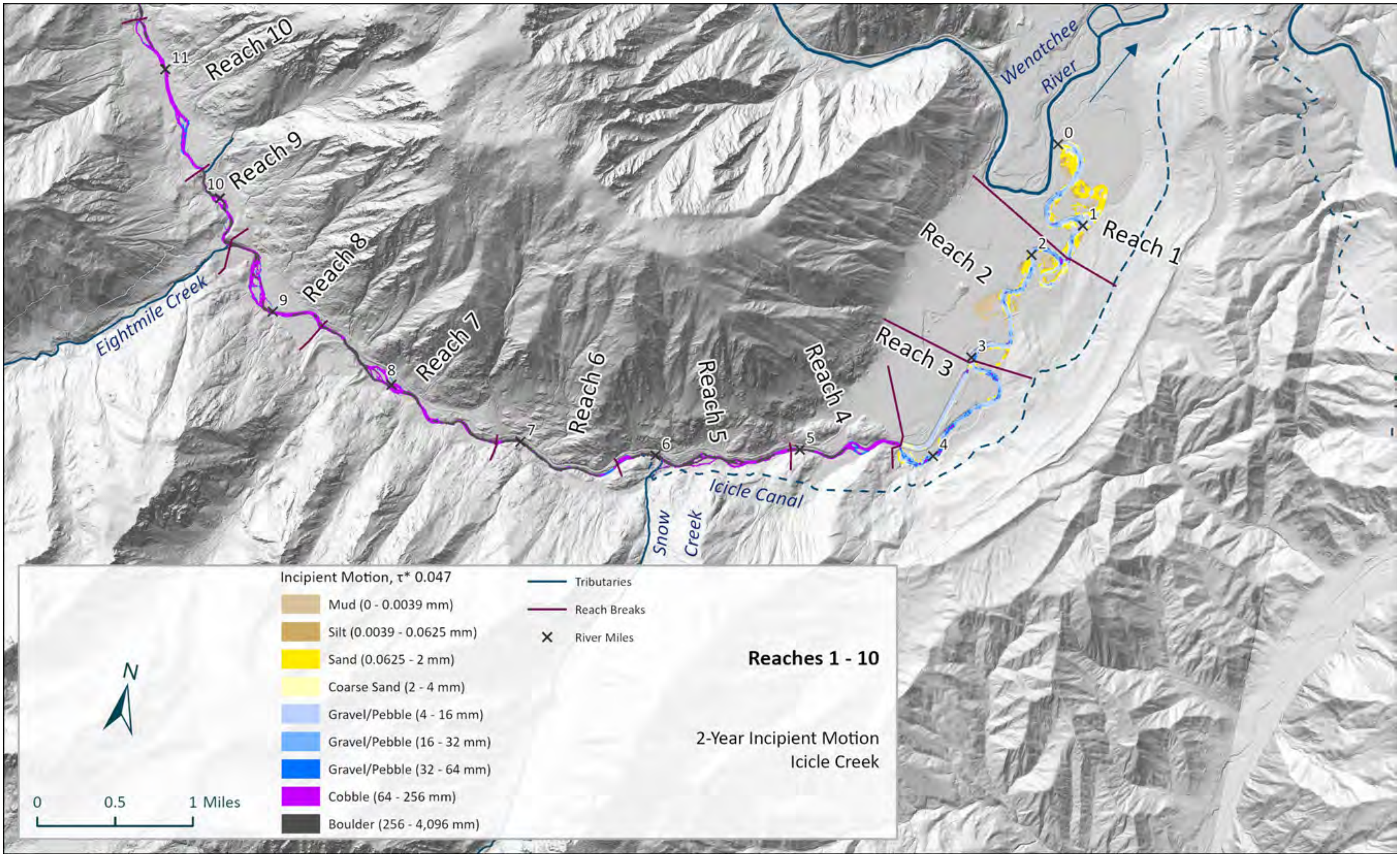

Figure 35. Incipient motion analysis map of estimated 2-year discharge modeled shear stress – Icicle Creek Reaches 1 - 10.

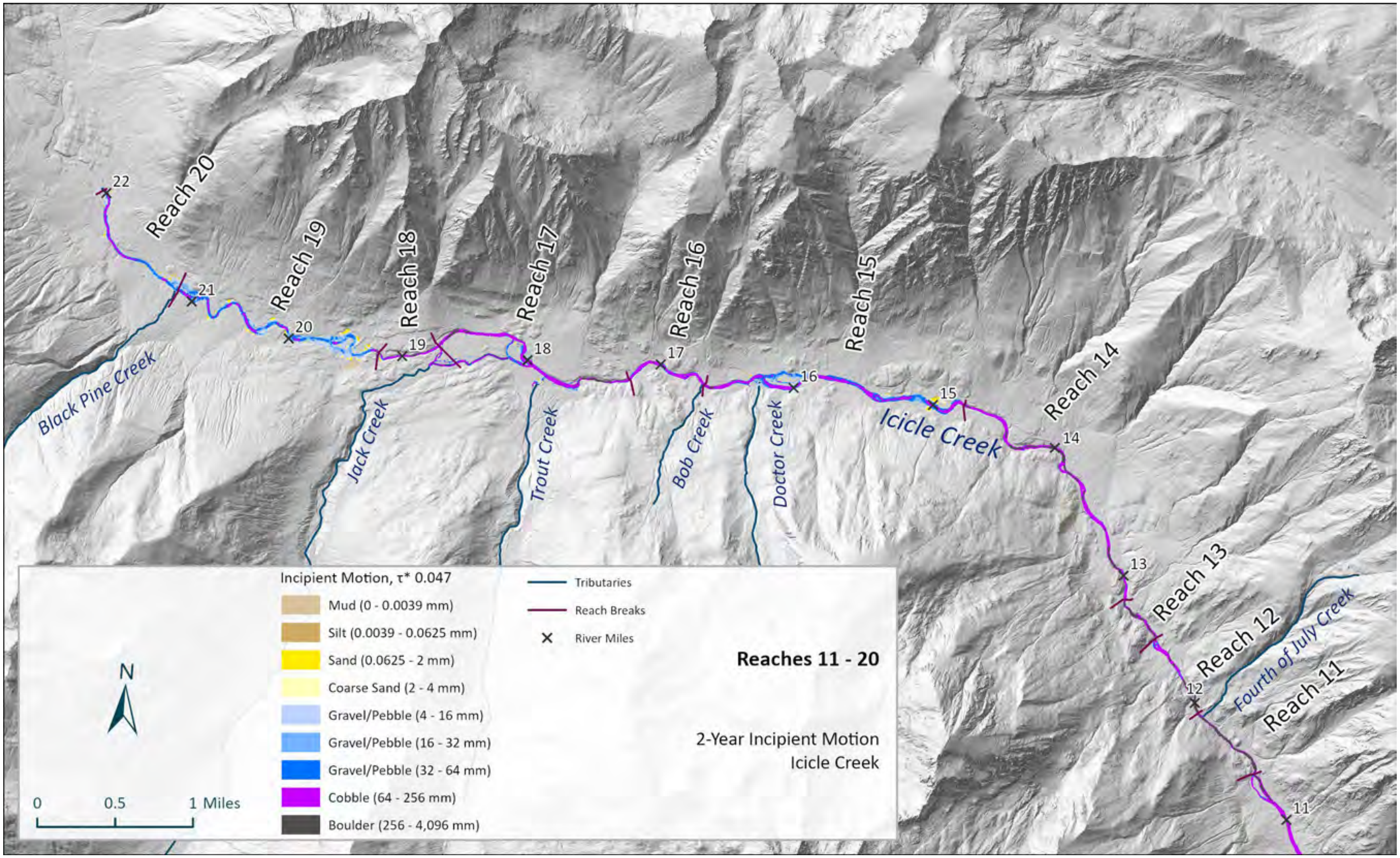

Figure 36. Incipient motion analysis map of estimated 2-year discharge modeled shear stress – Icicle Creek Reaches 10 – 20.

2.9 LARGE WOOD MATERIAL

Pieces of large wood (≥ 6 inches diameter) in a channel contribute nutrients, shade, and cover, and promote habitat complexity suitable for many riverine species (Langford et al., 2012). Medium and large sized woody material (≥12-in diameter and at least 35 feet long; ≥20-in diameter and at least 35 feet long, respectively) in a channel is expected to be able to influence local geomorphic process and increase channel complexity (Figure 37) by promoting scour and erosion related to the induced flow hydraulics associated with them and by redirecting or splitting flow pathways (Grabowski & Gurnell, 2016; Langford et al., 2012; Montgomery & Piégay, 2003). The quantity and quality of Large Woody Material (LWM) within a riverine system depends on the presence of mature or maturing forests, as well as the processes of recruitment such as infall from banks, debris flows or landslides off hillslopes, in-channel transport, etc. Tree size (length and diameter) compared to active channel width, channel form, and flow regimes control retention and accumulation patterns of the LWM in the channel.

Figure 37. Large wood jam in Icicle Creek (Reach 19) increasing channel complexity by promoting scour, sorting sediment, and promoting split-flow conditions at RM 20.31 (August 7, 2024).

LWM, including individual pieces and log jams, were counted during field surveys as part of the Habitat Assessment (See Appendix A) from July 29, 2024 -September 27, 2024. A total of 898 individual pieces of medium and large wood material (LWM) and 169 log jams (more than 3 pieces of LWM) were counted within the Icicle Creek assessment areas (Table 7). A summary of the data and a map of log jams and the distribution of large wood pieces recorded during the habitat survey is included in Figure 38 through Figure 42.

Table 7. Total counts of medium and large LWM (including individual pieces and pieces observed in jams), number of wood jams per reach, and LWM density (pieces per mile, includes individual pieces and pieces observed in jams) by reach in Icicle Creek.

Metric	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
Icicle Creek																				
Total Numbner of Medium and Large LWM	48	61	13	65	131	48	229	237	122	121	29	35	17	203	230	110	84	96	234	85
Total Number of Jams	3	4	1	6	14	4	16	14	9	7	5	5	4	10	15	13	13	1	22	3
Number of Medium and Large Pieces per mile	39	34	10	87	107	55	155	237	200	108	52	60	50	106	122	180	56	223	121	94

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 NMFS properly functioning conditions thresholds that are based on sizes exceeding the “medium” size class used in our study (≥12-in diameter and at least 35 feet long, from USFS Level 2 surveys). Their data showed that the 75th percentile wood loading was 67.45 pieces per mile for unmanaged streams in eastside forests. We chose the 75th percentile value to use as a comparison since this is believed to be a reasonable target to restore natural ranges across the landscape, which was also a recommendation from the Fox and Bolton study (2007). In Icicle Creek, the total of medium and large LWM per mile was evaluated against this threshold. Although medium and large LWM in Reaches 4, 5, 7-10, 14-17 and 19-20 exceeds 67.45 pieces per mile, the wood regime of Icicle Creek is nuanced, and this threshold alone is not sufficient to evaluate large wood or its potential geomorphic function within the assessment area. Large wood stability (capacity of LWM to be retained in a channel) can be an important driver of geomorphic processes and complexity. Compared to mobile wood entrained in the flow of the river, large wood that remains stable at flows capable of generating significant scour or transporting coarse sediments is more likely to drive complex habitat conditions through flow routing, sediment sorting, and racking of additional large wood. Large wood stability is a product of large wood piece size (basal diameter, log length) relative to channel size (bankfull width, depth); as channel size increases, so does the minimum large wood size required for large wood to remain stable (Abbe & Montgomery, 2003).

The majority of the live trees observed within the assessment area were second-growth. Removal of mature forests through logging diminished the availability of effective large wood capable of maintaining a complex and dynamic river corridor. Although several of the assessment reaches contain a relative abundance of large wood, it is generally lacking in “key” pieces – logs large enough to be retained in the channel and drive and maintain geomorphic processes. In many cases, the effective large wood is clustered within a small number of large jams or rafts, rather than distributed throughout the assessment area. Thus, while a few areas have high-quality large wood complexity, long portions of the assessment area are lacking in-channel large wood and the benefits it provides.

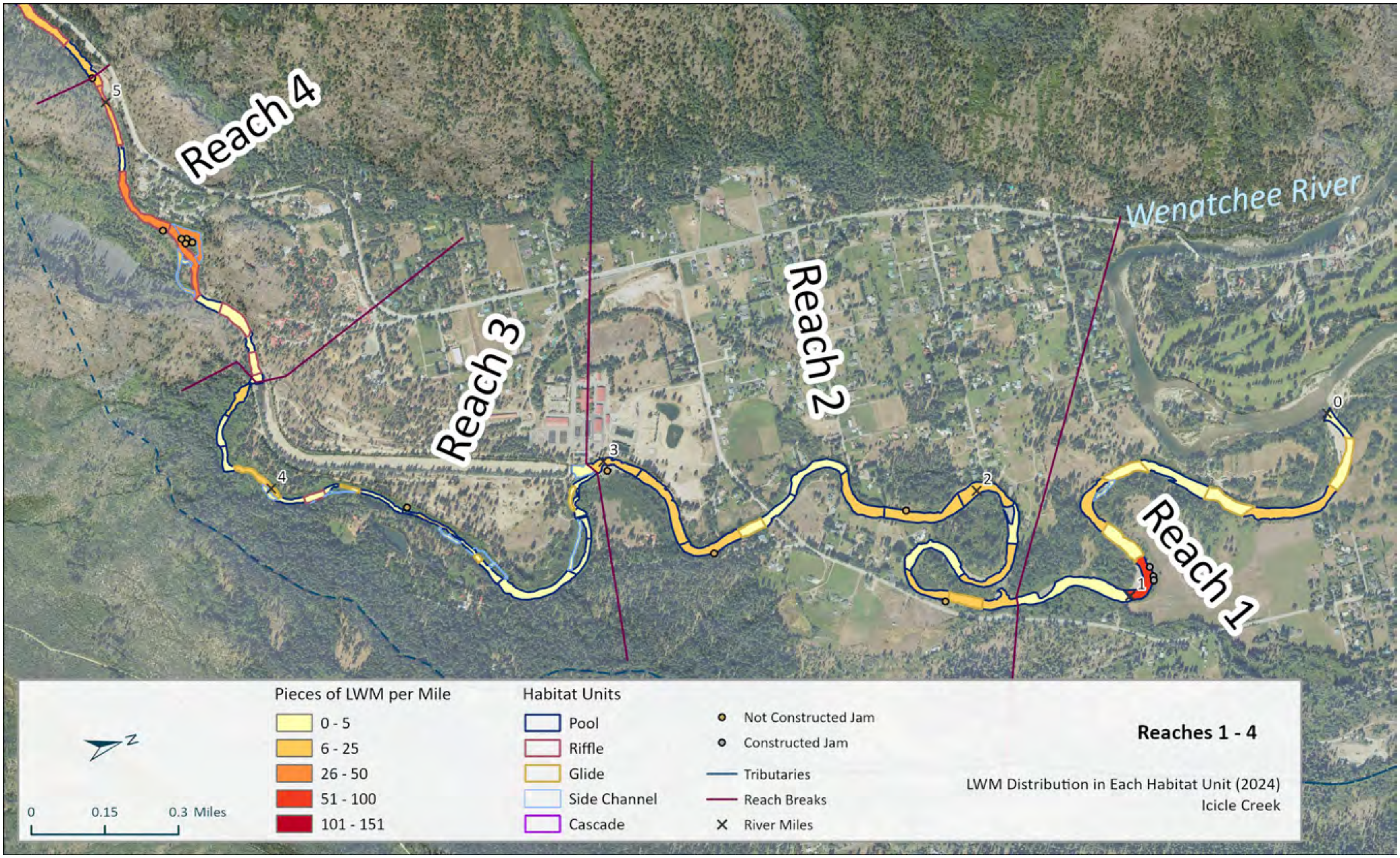

Figure 38. Map of LWM density per habitat unit (pieces per mile) in Reaches 1-4 recorded during the 2024 Habitat Survey of the Icicle Creek.

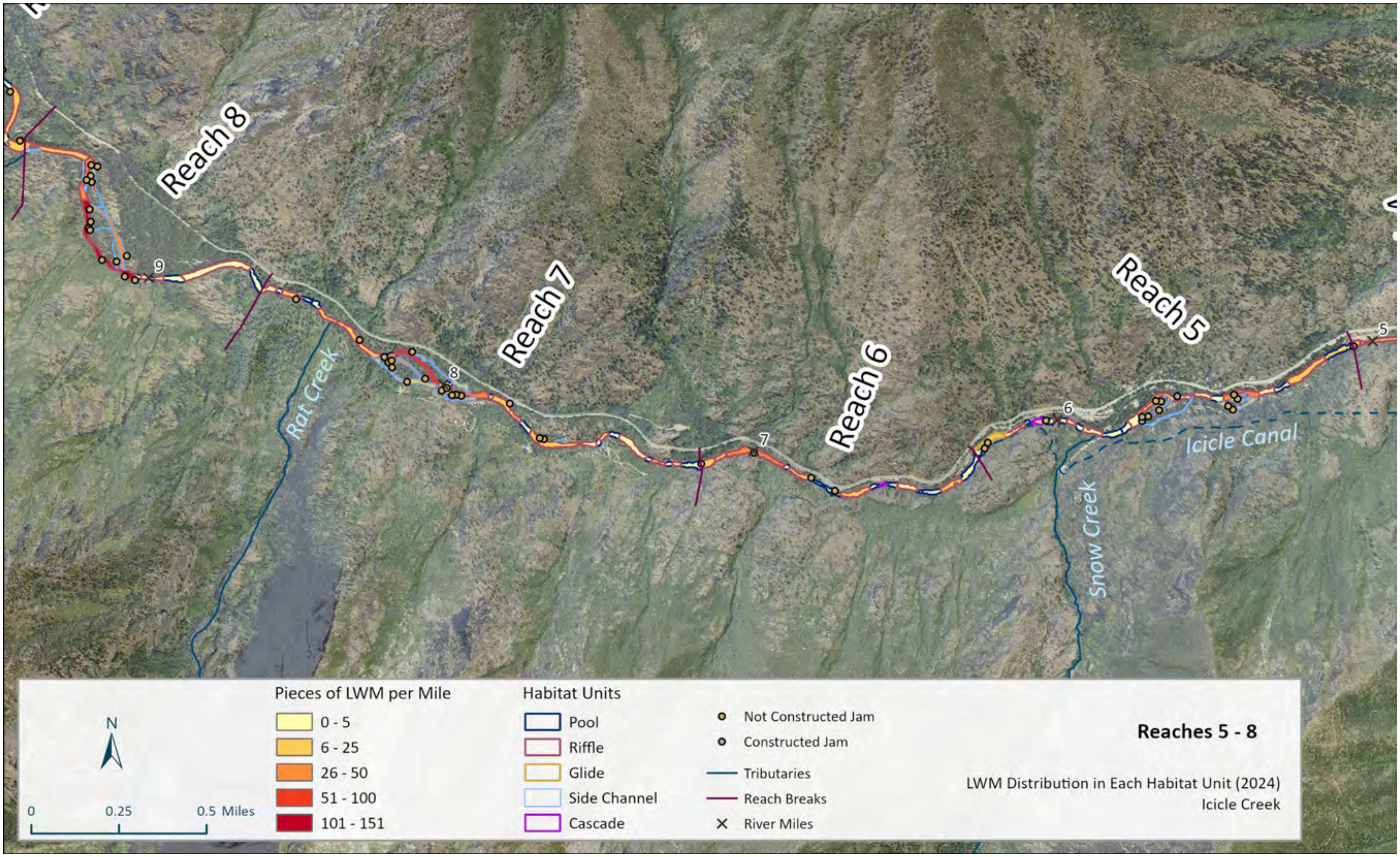

Figure 39. Map of LWM density per habitat unit (pieces per mile) in Reaches 5-8 recorded during the 2024 Habitat Survey of the Icicle Creek.

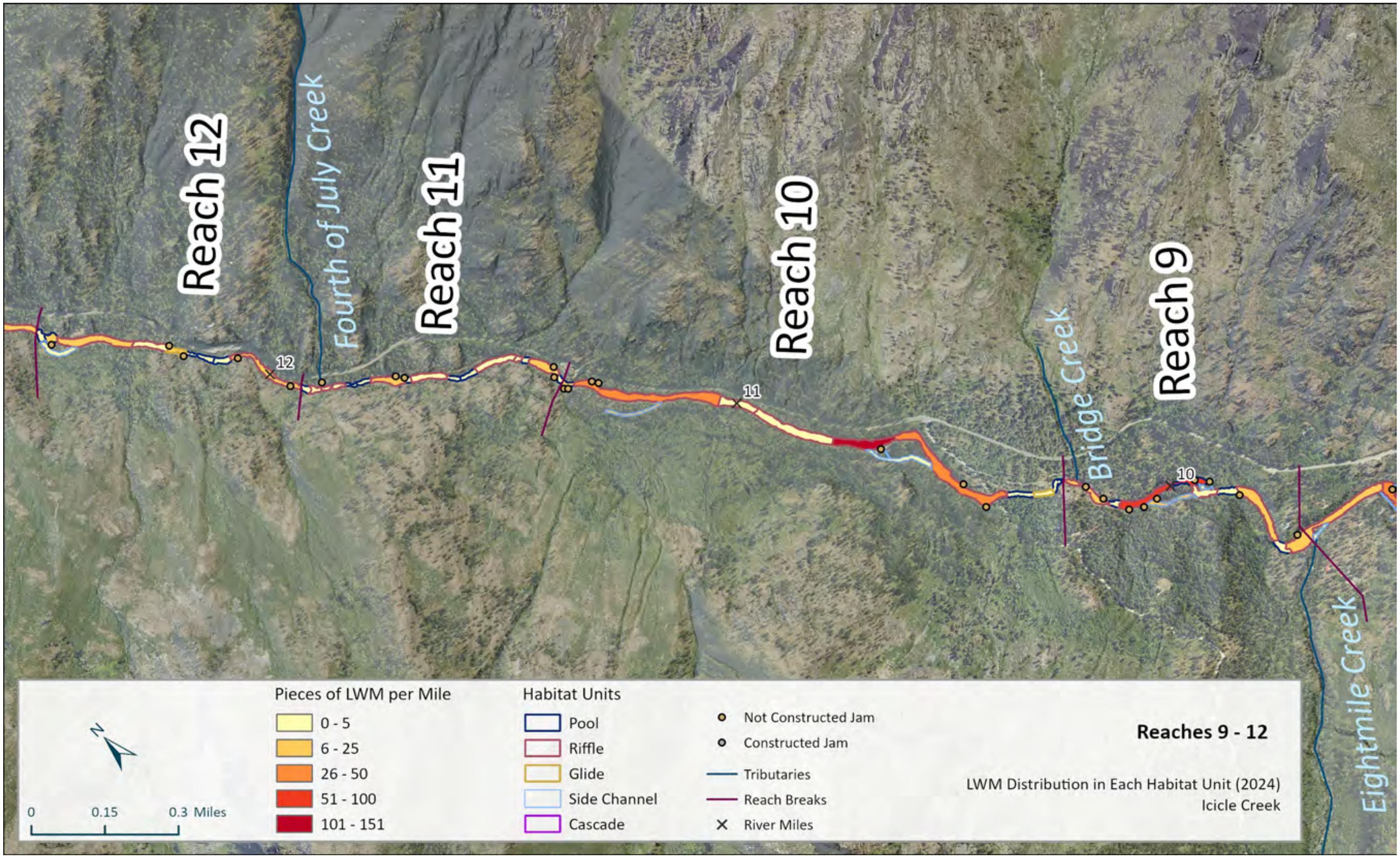

Figure 40. Map of LWM density per habitat unit (pieces per mile) in Reaches 9-12 recorded during the 2024 Habitat Survey of the Icicle Creek.

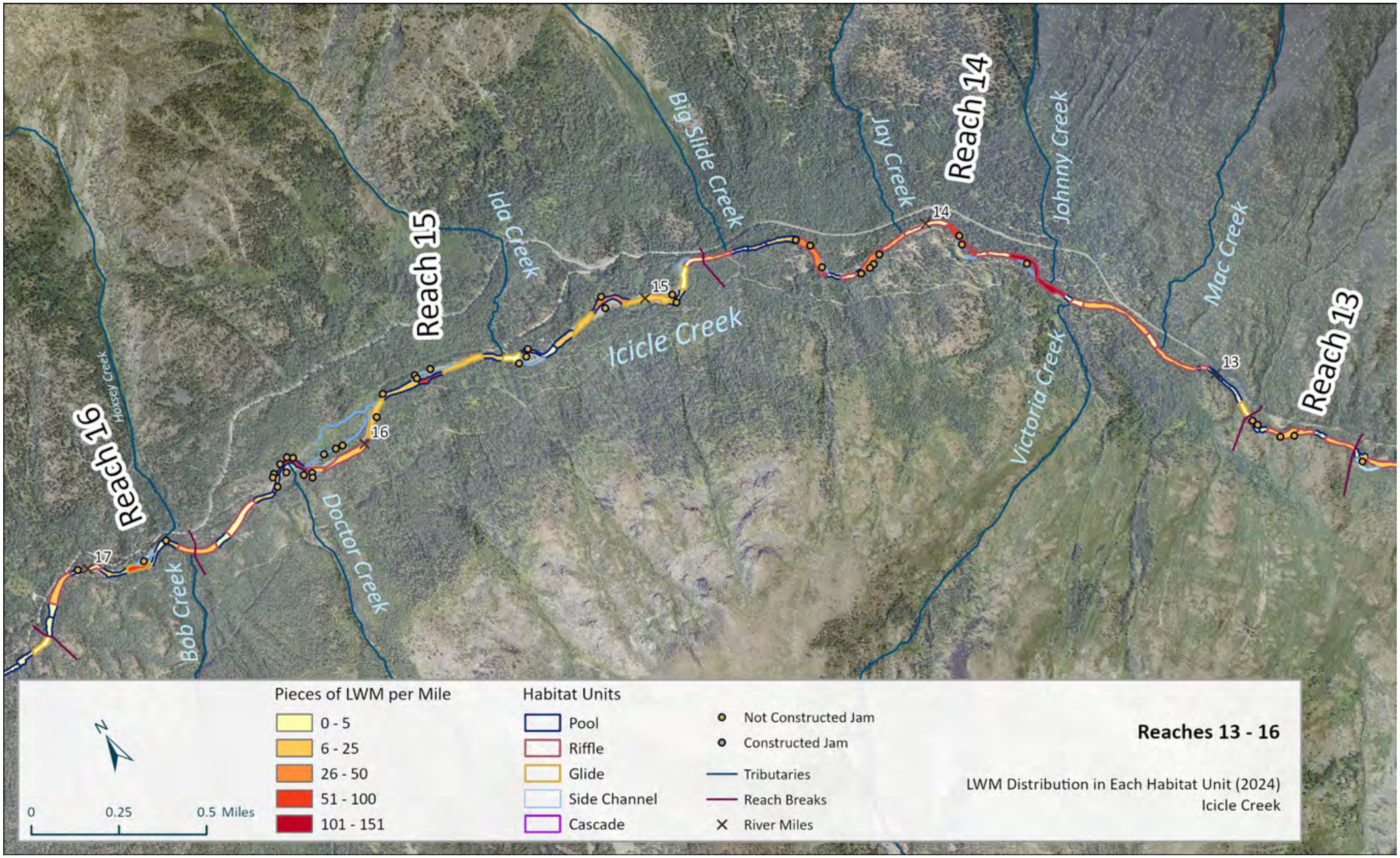

Figure 41. Map of LWM density per habitat unit (pieces per mile) in Reaches 13-16 recorded during the 2024 Habitat Survey of the Icicle Creek.

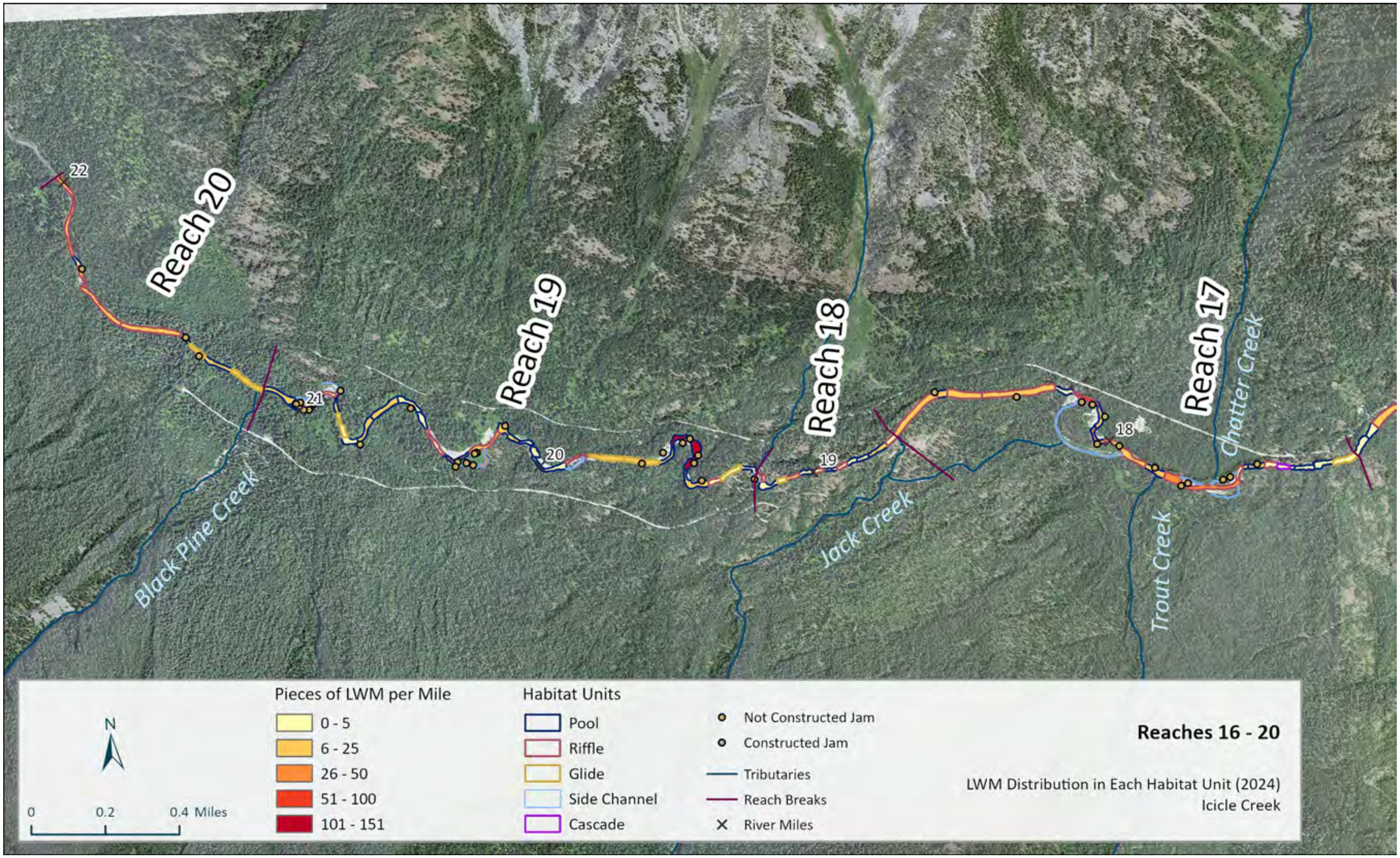

Figure 42. Map of LWM density per habitat unit (pieces per mile) in Reaches 17-20 recorded during the 2024 Habitat Survey of the Icicle Creek.

It is likely that the common practice of removing large wood from the channel was undertaken during periods of historical logging and more recently near existing infrastructure (recreational areas, bridges, riprap, homes, etc.). Additionally, the presence of roads likely restricts direct hillslope-to-channel inputs of trees at river-left contact points, and bank hardening restricts lateral migration in some areas that would otherwise generate large wood recruitment. Adding supplemental large wood in areas with appropriate flow hydraulics could improve both geomorphic and habitat complexity while floodplain forests mature.

2.10 VEGETATION

Within the assessment area, emergent, riparian, and upland vegetation classes were observed in the August 2024 field assessment. Vegetation classes typically corresponded to floodplain surfaces and modeled inundations. Low floodplains (with modeled inundations of approximately 1-5 years) were typically observed to contain emergent and riparian vegetation classes. Commonly observed vegetation on low floodplains included black cottonwood *(Popoulus trchocarpa),* willow species (including Sitka willow, *Salix sitchensis* and Scouler's willow, *Salix scouleriana*), red alder (*Alnus rubra),* red osier dogwood (*Cornus sericea)*, as well as Alaska yellow cedar (*Callitropsis nootkatensis)* and Western red cedar (*Thuja plicata).* Medium floodplains (inundations of approximately 5-20 years) were typically observed to contain riparian and transitional plant communities, with occasional upland vegetation presence. Species observed within medium floodplains included vine maple (*Acer circinatum),* bigleaf maple (*Acer macrophyllum*), black cottonwood *(Popoulus trchocarpa)*, Alaska yellow cedar (*Callitropsis nootkatensis),* Western red cedar (*Thuja plicata)*, and quaking aspen *(Populus tremuloides)*. High floodplain surfaces (with modeled inundations of approximately 20-100+ years) typically had a dominant vegetative cover of upland vegetation, with occasional riparian vegetation present in depressional areas. Terrace surfaces typically featured upland vegetation. Species observed within high floodplains and terraces included Western ponderosa pine (*Pinus ponderosa)*, Douglas fir (*Pseudotsuga menziesii)*, Western larch *(Larix occidentalis),* Engelmann spruce *(Picea engelmannii)*, Western white pine *(pinus monticola),* and mountain hemlock (*Tsuga mertensiana*). In addition to these general trends, hillslope aspect was observed to be a factor in vegetation community presence and absence.

Presence of emergent vegetation was used to characterize micro-habitat conditions such as hydraulics and hyporheic flows rather than denote a particular species presence or absence. Similarly, riparian vegetation was primarily noted in the context of geomorphic function, as well as habitat conditions such as shading. Upland vegetation conditions, such as forest composition and stand age and size class diversity, were assessed in the field and via desktop analysis. Upland forested area conditions were visually assessed for large wood recruitment potential from banks and hillslopes adjacent to Icicle Creek. Forest stem density was also ocularly assessed to identify where selective thinning would be beneficial for both forest health and used as a source of large wood in potential restoration projects. Fire regimes and fuel conditions were also noted in upland forests adjacent to Icicle Creek.

To support assessment of vegetation within the assessment area, a vegetation height analysis was completed for the assessment area using LiDAR data in ArcGIS Pro (Version 3.4.0). A raster layer that represents canopy height was created by calculating the difference between the LiDAR Digital Surface Model (DSM), which is the 'first return' data representing the top elevation of features, and the Digital Terrain Model (DTM), which is the bare earth elevation. Vegetation height analysis helps assess the existing vegetation biomass, habitat quality, post-disturbance regrowth, and large wood supply surrounding the river channel. Maps of the vegetation height analysis completed for the assessment area are provided for each reach in Section 3. Vegetation classes were developed based on field observations. Reach-scale maps and discussion are provided in Section 3. Assumed accuracy of this analysis is based on the reported point cloud testing completed by NV5 (2022) as part of the LiDAR processing, which is listed as meeting or exceeding the required accuracy (ACCz) of 19.6 cm at a 95% confidence level.

2.10.1 Fire Regime and Fire Suppression

Prior to Euro-American settlement, forest communities in the Icicle Creek watershed were largely composed of fire adapted species and underwent regular natural and human caused disturbances. With the implementation of fire suppression efforts in the Upper Wenatchee basin, forest composition and function have been altered. Beginning in the early 1900s, fire suppression practices were implemented to preserve timber for harvesting. Since the conclusion of intensive logging in the 1900s, forests within the basin have shifted toward a younger, multi-layered, denser condition, composed of less fire-tolerant species, with increases in crown and ladder fuels. The resulting modern forest is more prone to higher-intensity fires than were historically common. Prior to Euro-American settlement, the fire return interval for low intensity fires in upland dry forests was typically 20 years or less ((USFS, 2000).

Several large fires have occurred in the Icicle Creek watershed in recent years including the Icicle Complex in 2017 (8006 acres), the Square Lake Fire in 2003 (903 acres), the Icicle Fire in 2004 (697 acres), the Jack Creek Fire in 2008 (1058 acres), the Eight Mile Fire in 2010 (190 acres), the White Pine Fire in 2012 (61 acres), Cashmere Fire in 2012 (2792 acres), Cuitin Lake Fire in 2012 (309 acres), and the Jack Creek Fire in 2017 (4441 acres) (Mayfield et al., 2022). Fires within the watershed are caused by lightning and anthropogenic actions (human). Changes to the fire regime impact channel and floodplain processes in the Icicle Creek watershed through a reduction in available wood contributions to the channel and an increase in exposed destabilized hillslopes prone to contribute increased quantities of sediment the first few years post-fire.

2.11 AQUATIC HABITAT CONDITIONS

Habitat surveys using the U.S. Forest Service Region 6 Level II protocols were performed in the assessment area from July 19 to Sept 27, 2024. The full Icicle Creek Habitat Assessment (Appendix A) provides an inventory of the habitat conditions in the Icicle Creek study area. This section provides a summary of the findings. A summary of the habitat assessment results is included as Table 8.

From the upstream end of the assessment area near RM 22 to the confluence with the Wenatchee River, channel form and habitat types vary. The upper and middle portions of the study area have moderate to very-steep gradients and are relatively confined by bedrock and hillslopes. In contrast, Reaches 1 – 3 are located within the low-gradient and wide Icicle Creek Valley. At the mouth of the channel, backwater effects from the Wenatchee River influence flow dynamics and water depth in the downstream portion of lower Icicle Creek.

The proportion of pool habitat generally decreases moving upstream were gradient increases. Side channels were also more commonly observed in the lower portion of the study area, with the exception of less confined Reaches 15, 17, and 19 in the upper section. Substrate size increases with gradient, with gravels dominating substrate in Reach 1 – Reach 3. Boulder and cobble substrates were more common in the confined mid-section, and the upper section was dominated with cobble.

A total of 4,053 pieces of LWM, including 160 large wood jams, were observed during the 2024 survey through the assessment area. Large wood that provides habitat and cover for aquatic species was unevenly distributed. Reach 1 – Reach 3, Reach 6, and Reach 11 – Reach 13 did not meet criteria for sufficient large wood to support aquatic species habitats. Reach 8, however, had the most wood per mile of any reach with 385 pieces per mile, including wood in jams. Although large wood quantities may meet criteria to support aquatic species preferences in several of the reaches, the criteria do not consider the capacity of the wood to instigate or maintain geomorphic function in some of the more hydraulically dynamic reaches. For example, much of the large wood in the confined or partially confined reaches is racked on top of boulders, at the heads of island, or along the margin of the channel. Although it may provide some localized habitat uplift in these locations, large wood is often not in contact with the channel at low-flow conditions and not influencing geomorphic processes at high flows. Instead, the wood is arranged in these locations because of high-energy flow hydraulics and often only temporarily functionally, even when wedged or ballasted to boulders.

Riparian forests upstream of Reach 3 are composed primarily of ponderosa pines in the large trees size class category (21.0-31.9-inch diameter at breast height (dbh)). Understory vegetation is primarily shrub/seedling sized (1.0-4.9-inch dbh) and dominated by alder, willow, dogwood, and other woody-stemmed riparian shrubs.

Table 8. Summary of habitat assessment results. The habitat assessment is included as Appendix A.

Habitat Metric	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
Unit Composition																				
Pool	67%	91%	75%	28%	26%	32%	23%	10%	18%	6%	29%	19%	23%	19%	40%	46%	25%	30%	64%	16%
Riffle	32%	6%	13%	0%	3%	0%	0%	0%	0%	2%	0%	5%	0%	3%	29%	13%	4%	1%	16%	18%
Glide	0%	0%	3%	67%	50%	67%	66%	68%	70%	86%	71%	72%	77%	76%	21%	37%	61%	62%	12%	66%
Side Channel	1%	3%	9%	6%	18%	0%	11%	22%	12%	f6%	0%	4%	0%	3%	0%	4%	8%	7%	8%	0%
Cascade	0%	0%	0%	0%	3%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%	0%	0%
Substrate (% gravel)	70%	88%	87%	12%	--	--	--	20%	21%	23%	9%	--	--	28%	37%	20%	31%	--	54%	36%
Medium & Large LWM/Mile (includes jams)	39	34	10	87	107	55	155	237	200	108	52	60	44	106	148	98	79	144	127	81
Pools/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	4.6	15.4	10.3	3.2
No. Pools with Residual depth (6ft>D≥3ft	2	7	6	5	5	6	10	4	3	2	5	1	2	4	7	1	5	4	11	0
No. Pools with Residual depth D≥6ft	1	5	1	0	2	2	0	0	0	0	1	1	0	0	0	0	3	1	3	0
No. Side Channels	1	2	8	3	8	0	8	8	3	3	0	1	0	3	6	1	4	1	4	0
Riparian Conditions																				
Mature Trees	28%	0%	0%	0%	0%	0%	18%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	7%	0%
Large Trees	57%	73%	86%	100%	100%	0%	18%	100%	100%	63%	100%	50%	100%	56%	73%	83%	100%	69%	93%	100%
Small Trees	14%	0%	14%	0%	0%	80%	27%	0%	0%	25%	0%	50%	0%	44%	13%	17%	0%	15%	0%	0%
Sapling Pole	0%	0%	0%	0%	0%	0%	18%	0%	0%	0%	0%	0%	0%	0%	13%	0%	0%	8%	0%	0%
Shrub/Seedling	0%	0%	0%	0%	0%	20%	18%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Grassland/Forb	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%	8	0%	0%
Other	0%	18	0%	0%	0%	0%	0%	0%	0%	13%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

2.12 REACH-BASED ECOSYSTEM INDICATORS

A Reach-Based Ecosystem Indicators (REI) analysis was performed to support the reach assessment. The REI evaluates biological and physical conditions of a watershed in relation to regional standards and known habitat requirements for aquatic biota. The REI results include functional ratings for a range of attributes at the reach- and watershed-scale. 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. This assessment was informed by multiple surveys and analysis components of the assessment, including habitat surveys, geomorphology surveys, hydraulic modeling, sediment sampling and transport assessment, and with reference to remote sensing data and existing studies. The full REI analysis methods and results are provided in Appendix B. A summary of the results is provided as an overview in Table 9 and Table 10.

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. This is largely due to the presence of roads, residences and recreational facilities such as campgrounds. Riparian Vegetation condition indicators are predominantly rated At Risk or Unacceptable. Most Unacceptable ratings within the study area occurred due to 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. 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. Suitable spawning-sized substrates where natural channel form and stream power support the development of spawning areas occurred in all reaches.

Table 9. 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 10. Summary ratings for the Icicle 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 condition.

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.*

3. Reach-Scale Conditions

Reach-scale conditions of the Icicle Creek assessment area[1] are presented in the sections below. A map of the reach locations is included here for reference in Figure 43.

Figure 43. Map of reach breaks in the Icicle Creek assessment area (RM 0 -22.02).

[1] River mile values have been updated based on the centerline of the assessed reaches of Icicle Creek. A comparison of river miles used in this report and those used by UCSRB can be found in Table 1 (pg 13).

3.1 ICICLE CREEK REACH 1 (RM 0-1.24)

3.1.1 Overview

Reach 1 is 1.24 miles long and extends from the confluence with the Wenatchee River to RM 1.24. This reach has an average gradient of 0.11% and a sinuosity of 1.67. The dominant planform is single thread, and it is unconfined (Figure 44). Reach 1 is influenced by backwatering from the Wenatchee River at high flows. Likewise, the lower floodplains at the most downstream end of the reach are influenced by inundation from the Wenatchee River. There are several previous restoration projects throughout the reach. The low floodplain surfaces are typically vegetated with willows and cottonwood, and the higher floodplain surfaces are predominantly vegetated with ponderosa pine. Landownership is mostly private. There are opportunities for habitat restoration to support salmonid holding and rearing, with opportunities generally increasing as Icicle Creek approaches the confluence with the Wenatchee.

Figure 44. Representative photo of Icicle Creek in Reach 1 at RM 0.38 (August 29, 2024).

3.1.2 Channel and Floodplain Geomorphology

Table 11. Reach 1 metrics.

Reach 1												
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
1.24	0-1.24	0.11%	1.67	Pool	125.0	Unconfined	Gravel	66.4%	32.4%	0.0%	1.1%	0.0%

Reach one flows through the broad downstream portion of Icicle Creek Valley. The channel in Reach 1 is wide and low gradient with a sinuous meandering planform and a morphology of long pools and glides with occasional short riffles (Figure 46). The channel is over-widened and thus shallow during low-flow conditions at glides and riffles. Over-widening is suspected to be the result of riparian and floodplain forest removal from the banks, removal of large wood from the channel itself, and potentially historical impacts of exaggerated backwatering from the Lamb-Davis mill-dam once located downstream of the confluence with the Wenatchee. Reach 1 experiences backwatering from the Wenatchee River during high-flow events. During low-flow conditions the channel is wide and shallow at its mouth.

Bedrock contact is limited to one on river-right at the upstream end of the reach (RM 1.24), otherwise the channel is bordered by floodplains or terraces. Lateral processes (channel migration and bank erosion) are current active processes, however bank armoring in some locations has halted or impeded this process. Reach 1 contains several very large and deep pools up to approximately 20 feet deep, where salmon holding was observed during the 2024 survey (August 29, 2024). However, cover and complexity in the pools are often limited. Point bars are located at most meander bends. The bars are primarily gravel and cobble. Evidence of incision was noted in Reach 1, including cut banks that revealed gravel strata two feet higher than the tops of modern bars. In general, channel banks are high (4-10-ft) and relatively vertical. Bank stratigraphy was noted as 1-4 feet of gravel-cobble that fined upward to gravel, topped with coarse sand that fines up to sandy loam (Figure 45). In some locations, exposed banks reveal sands and sandy loam only, a signature of infilled paleo-meanders. Bank height and incision is presumed exaggerated to some extent in Reach 1 as a result of a period of impoundment behind the Lamb-Davis dam and related log drives in the early 1900's. Very large boulders, likely glacial erratics, were noted in the channel at RM 0.54 and 0.23, a reminder of past glacial extension (see Section 2.3.2).

Figure 45. Example of cut banks and impacted floodplain vegetation in Reach 1, near RM 0.67. (August 29. 2024)

There are no perennial or ephemeral tributaries to Icicle Creek in Reach 1. A disconnected historical meander scar near RM 0.4 hosts an oxbow wetland that, if reconnected via restoration efforts, has potential to provide off-channel habitat. Side channels currently activated only during flood events were noted near RM 0.5 on river-right and near RM 0.1 on river-left. Channel scars visible in the topography revealed in the LiDAR (NV5 2022) show a more sinuous historical planform to the channel than is expressed today as well as complex variability in the location and occupation of channels associated with the confluence of Icicle Creek and the Wenatchee River (Figure 46).

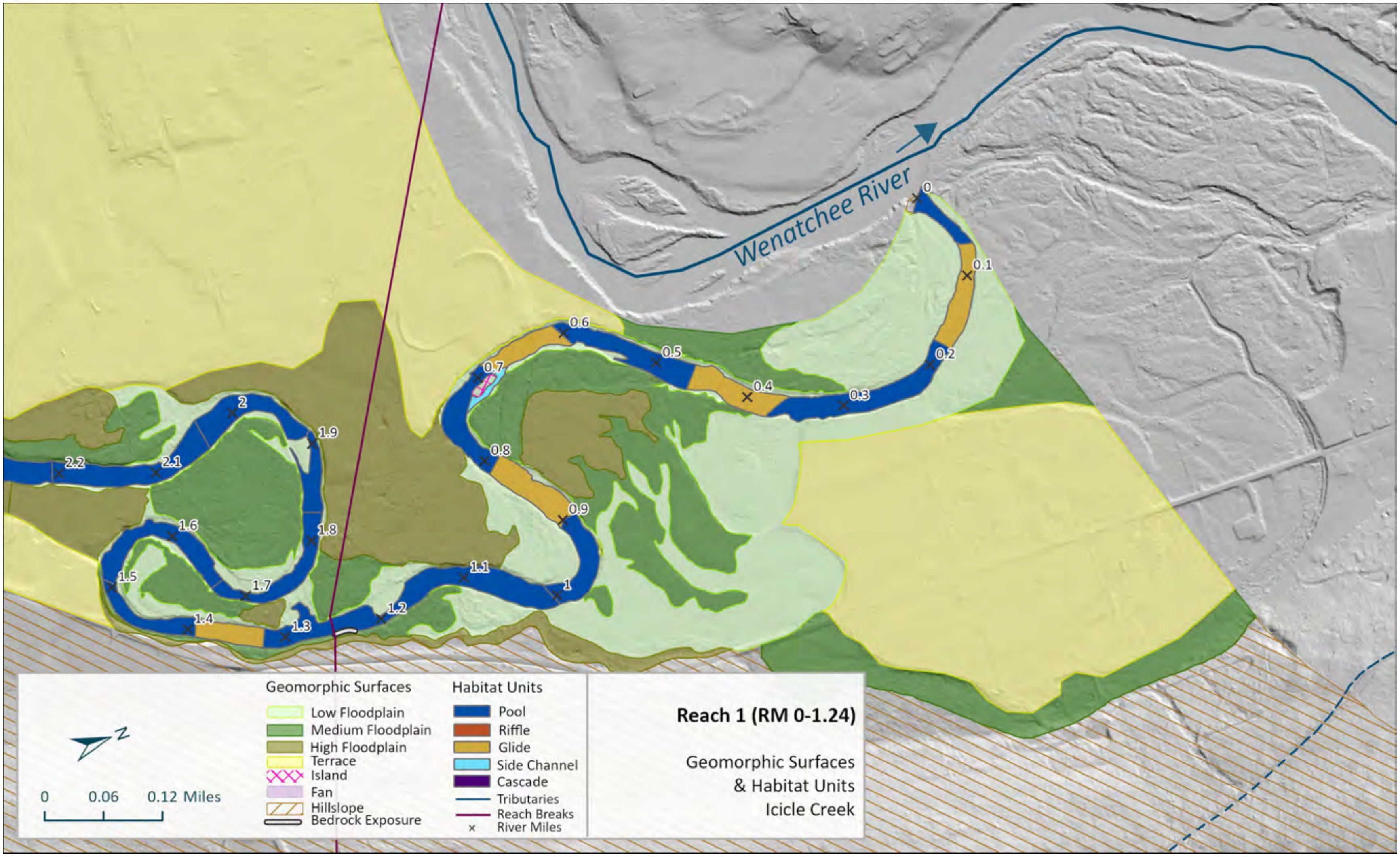

Figure 46. Reach 1: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

The geomorphic surfaces of the valley floor of Icicle Creek at Reach 1 are mapped (Figure 46) by estimated inundation frequency, vegetation, and observed evidence of inundation to indicate expected connectivity of the varied floodplain surfaces. Low floodplain (inundated ~1-5 yrs) and medium floodplain (inundated ~5-20 yrs) occupy most of the surfaces adjacent to the modern channel. High floodplain surfaces (inundated ~20-100+ yrs) and terraces (abandoned floodplain) border the channel where lateral processes are extending meander bends. Floodplain soils are mapped as stratified gravel to sand (Natural Resources Conservation Service, 2007).

Channel substrate in Reach 1 is primarily gravel, with small cobble and coarse sand (Figure 47). In areas of decreased flow energy (pools), the bed material is often coated in a layer of coarse sand.

Figure 47. Representative bedload composition atop bars at RM 0.88 (Right) and RM 0.12 (Left). (August 29, 2024)

Two Wolman Pebble Counts (Wolman, 1954) were conducted in Reach 1 on riffle crests. The median grain size (D50) of GC 25 at RM 0.87 was 39mm and of GC 26 at RM 0.6 was 55mm. The GC data is representative of the observed trend of a subtle reduction in bedload grain size from upstream to downstream in Reach 1. The pebble count data are included in Figure 48 of the Reach 1 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5). The analysis indicates that at the 2-year modeled discharge, the channel's shear stress is expected to mobilize gravel-sized material through the entire reach. At the margins of the channel and across inundated floodplain surfaces, sand is likely mobilized.

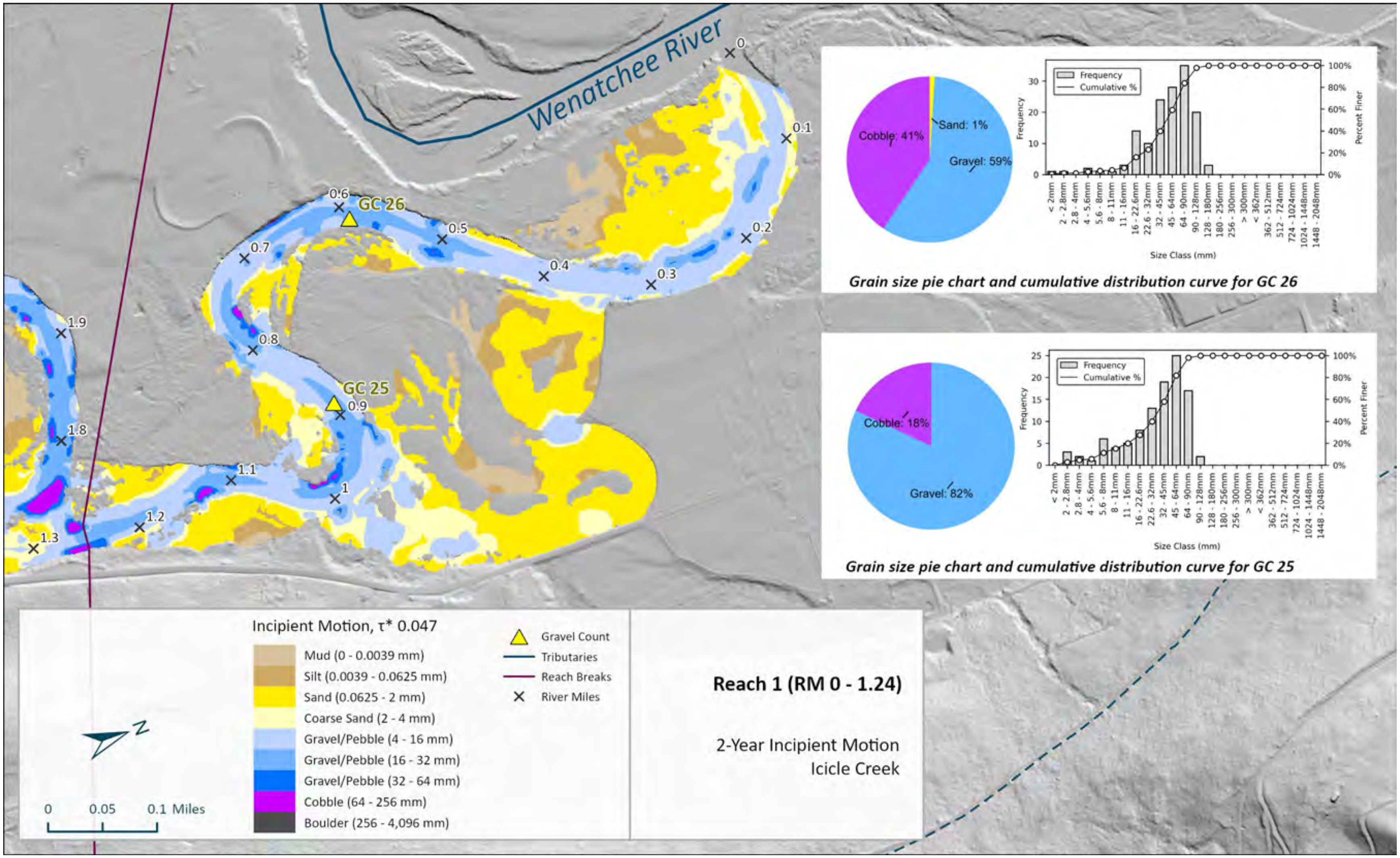

Figure 48. Reach 1: incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge). Includes location and grains size data of the GC 25 and GC 26 pebble counts (2024 survey).

3.1.3 Large Wood Material

The habitat survey conducted in summer 2024 recorded 56 individual pieces of large woody material (LWM) and 3 log jams (accumulation of >3 pieces of LWM) within the bankfull channel, for a compiled total of 125 observed pieces (Figure 49). Of the 56 individual pieces; 6 classified as large size class (>20-inches diameter and >35-feet long); and 14 as medium size class (12 to 20-inches diameter and at least 35-feet long). All 3 log jams in Reach 1 were constructed. They have multiple pieces of medium and large LWM and are effective at enhancing habitat. Reach 1 has 39 pieces of wood per mile (count includes medium and large LWM as individuals and in jams), which does not meet the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state ((Fox & Bolton, 2007); Appendix A). The limited abundance of large wood in this reach is likely due to historical removal of wood from the channel and adjacent lands. In its current conditions, the riparian zone in Reach 1 supports fewer large trees compared to upstream areas, reducing the immediate availability of wood for recruitment.

Effective large wood in Reach 1 plays a role in maintaining pool scour, providing quality rearing and migration habitat cover, and influencing localized sediment deposition and sorting. Large wood is recruited to Icicle Creek through lateral bank erosion. The three log jams (constructed) are associated with the "Icicle Creek Streambank Restoration Project 2022" located on river-right near RM 0.95 (Figure 49). These structures were installed behind failing riprap spurs and appear primarily designed for bank protection, showing limited evidence of pool scour. Nevertheless, they are actively racking wood, engaged during low flows, and two of the jams are promoting sediment sorting, which contributes to channel habitat complexity. Although large wood is currently sparse in Reach 1, existing channel processes suggest that the system would respond well to additional wood inputs, likely resulting in increased channel complexity and improved habitat availability.

Figure 49. Previously installed (constructed) large wood structures in Reach 1 at RM 0.94. (August 29, 2024).

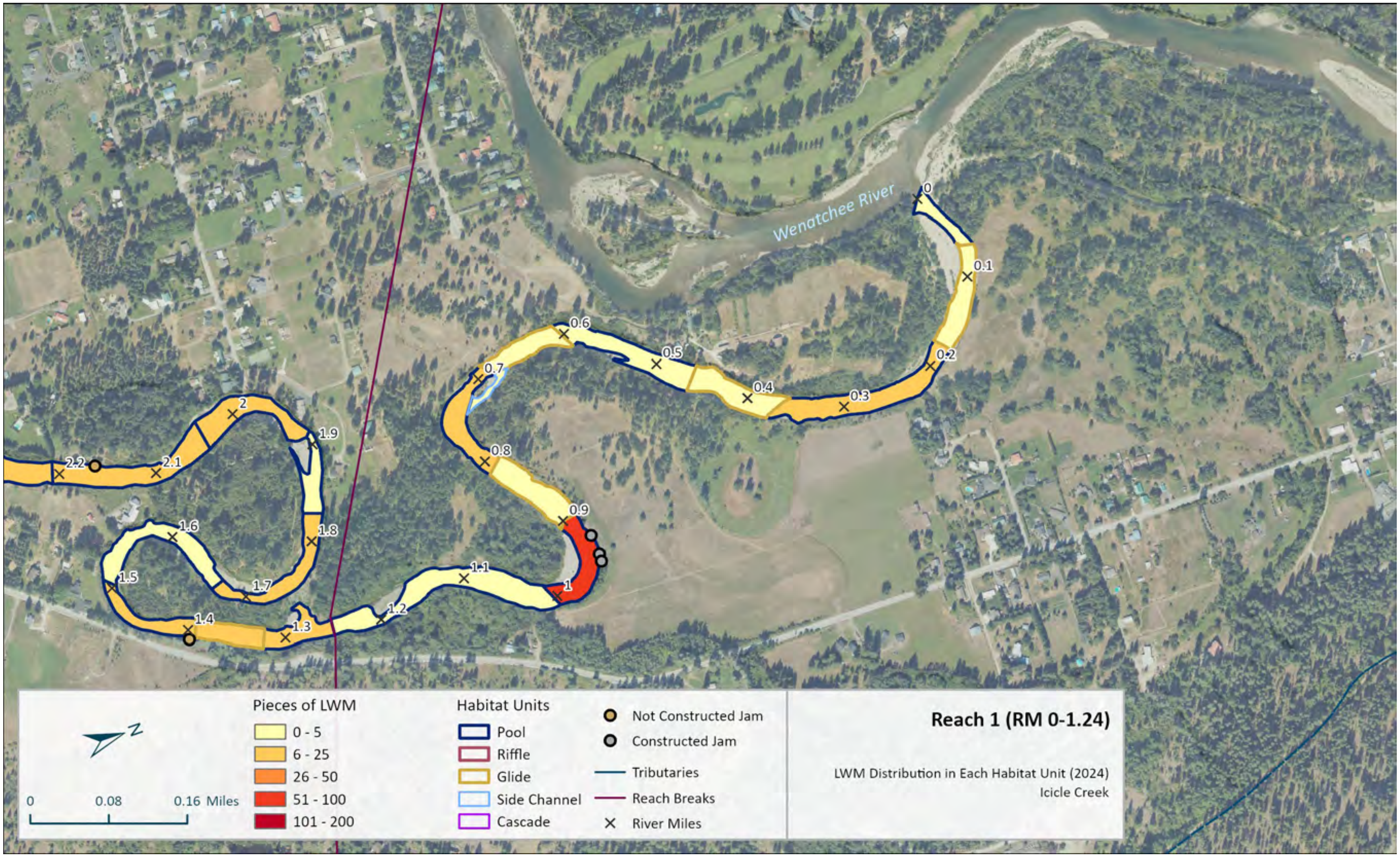

Figure 50. Reach 1: Large wood distribution map (pieces per mile per habitat unit) and surveyed habitat units (2024).

3.1.4 Vegetation

Riparian vegetation in Reach 1 alternates between forested and cleared. There are some large cottonwood stands but also many areas cleared for agriculture and rural residential development. Low floodplains and bars have a mix of aquatic vegetation, shrubs, and trees. There is abundant reed canary grass in many of the cleared areas (Figure 51). On medium floodplains, cottonwoods are common. High floodplains and terraces are dominated by pine, when an overstory exists at all.

There is disturbance to riparian vegetation cover and multiple sections of banks void of vegetation throughout the reach. Riparian successional processes including willow and cottonwood establishment have been impaired by bank armoring that halts lateral channel migration and sediment deposition required for seedling establishment.

The sporadic tree cover in Reach 1 provides limited availability for large wood recruitment. Large overstory trees are present in clusters around RM 0.2, 0.5, and 0.8, providing localized potential sources of large wood to the channel. A map showing vegetation heights is provided in Figure 52, with the aerial in Figure 53. The maps reveal the presence of large and very large trees along the banks and in portions of the floodplain but also many areas of low vegetation, narrow vegetated buffers, and cleared areas. The existing riparian vegetation provides very little stream shading due to the low incidence of large trees along a wide channel.

Figure 51. Floodplain vegetation with small cluster of cottonwood trees at RM 0.36 (August 16, 2024).

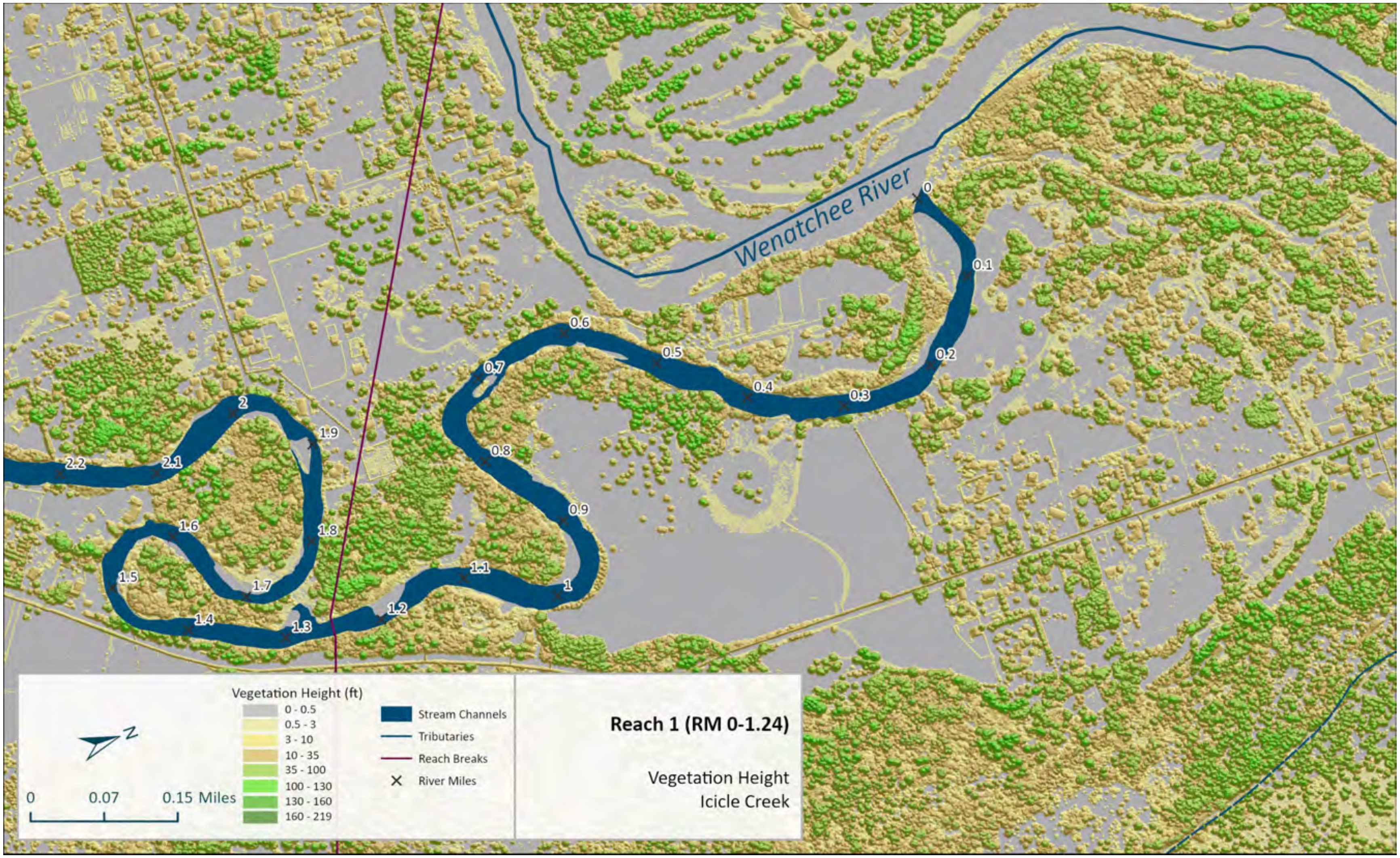

Figure 52. Reach 1: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 53. Reach 1: Map of aerial imagery for vegetation identification (ESRI 2023).

3.1.5 Human Alterations

Various anthropogenic features have influenced channel and floodplain processes, water quality, and habitat connectivity in the past 150 years. The Lamb-Davis Lumber Company dam (1904-1920's) on the Wentachee River near the confluence with Icicle Ceek backwatered the channel in lower Icicle Creek, including Reach 1. Related land clearing, sediment flux changes, floodplain inundation, and timber drives combined to scour and simplify lower Icicle Creek. A map of the modern anthropogenic features is provided in Figure 55. Two piped intake/discharge structures are located at RM 0.30 and RM 1.01. Each structure includes a generator and is fitted with a fish screen. The structure at RM 1.01 (Figure 54) appeared to be discharging water into Icicle Creek, despite appearing to be a pump intake with a fish screen. There are potential water quality concerns with discharges, although the origin of the discharge water was not known to the surveyors.

As discussed in Section 3.1.3, there are prior restoration efforts in Reach 1. At RM 0.94, large wood structures were installed behind a series of failing riprap spurs. These appear to be intended for bank stabilization and have limited geomorphic function. There was no observed scour pool development or large wood racking (Figure 50). Additionally, the adjacent banks lack riparian vegetation, further compromising bank stability and increasing erosion potential. In some locations, such as near RM 0.25, vegetation has been cleared for recreational purposes associated with residential properties (see Figure 56), exposing banks and reducing habitat quality.

Figure 54. Water intake structure in Reach 1, RM 1.01 in Icicle Creek (August 29, 2024).

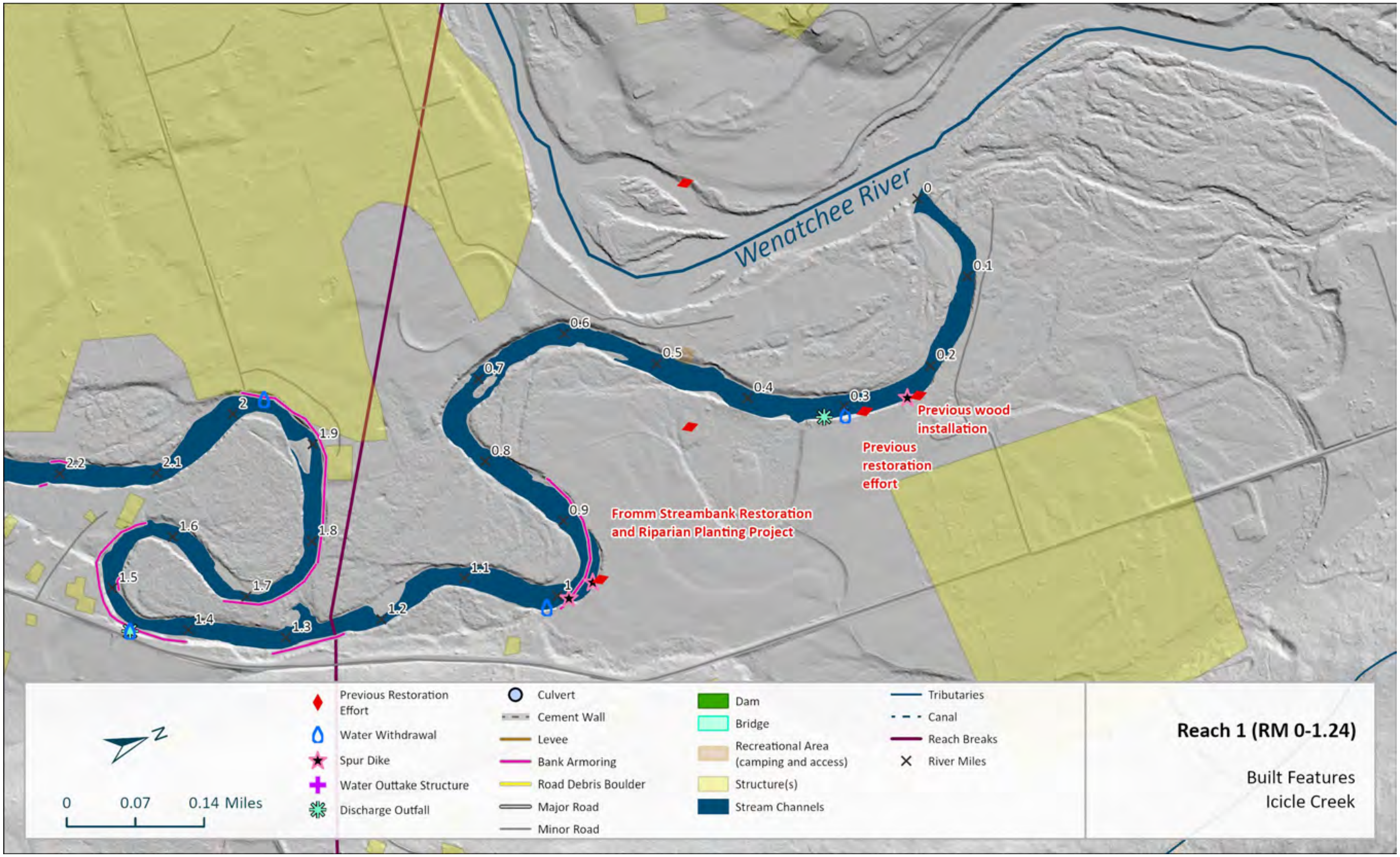

Figure 55. Reach 1: Mapped anthropogenic features (2024).

Figure 56. Bank erosion at home site in Reach 1, RM 0.25 (August 29, 2024).

Additional human infrastructure contributes to the degraded condition of the riparian zone. Near RM 0.32, electric utility wires and abandoned pipes are visible on the bank, suggesting past clearing or disturbance that has left the area devoid of stabilizing woody vegetation. From RM 0.93 to RM 1.0, three rock spurs are located along the river-right bank. These features are part of a broader stretch of riprap that extends upstream to RM 1.31 in Reach 2, forming a continuous hard-armored bank. While intended to protect infrastructure and control erosion, the riprap and rock spurs limit lateral channel migration and restrict floodplain connectivity. Two additional spurs at RM 0.24 are currently contributing to downstream bank erosion, likely indicating unintended geomorphic consequences from their installation.

There is significant human development throughout the reach, including multiple residential properties along both banks and the presence of East Leavenworth Road on river-right. Vegetation has been widely cleared throughout to accommodate structures and access, further limiting the natural dynamics of the stream. Despite these modifications, human alterations in Reach 1 are less constraining to natural processes than those in Reach 2.

3.1.6 Recommended Actions

This reach has significant habitat uplift potential given the impacts to the channel, riparian zone, and floodplain from residential and agricultural uses. However, it is also a challenging place to work given the many private parcels and adjacent infrastructure (e.g. roads and houses). There are abundant bank armoring, development, floodplain manipulations, and riparian clearing. This is also a popular recreational area for floating the river and thus several informal access points exist to accommodate the many river users during the summer. Potential project actions in Reach 1 are captured in the Eiszapfen Bach project. A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities)

There are multiple opportunities for creating off-channel habitat, both on the left and right-banks. These would occur via mainstem large wood jams, inlet jams, and excavation. The viability of some side-channels warrants additional survey and modeling to understand excavation requirements. Many of the banks are armored. Where possible, and where there are willing landowners, riprap could be removed and replaced with bank-buried log jams or augmented with wood complexity. The reach would also benefit from a variety of other large wood placement types, including bar apex jams to create split-flow and create/maintain vegetated islands, margin complexity wood, and general cover and complexity wood to improve overall salmonid rearing, holding, and refuge habitat.

There are many areas of cleared riparian and floodplain vegetation, much of which is associated with rural residential development. The objective would be to work with willing landowners to replant areas where possible, especially in areas that would provide shade and potential future wood recruitment to the channel.

There are also some important conservation measures to consider for this reach. Because of the high fish use and restoration potential of these reaches, any undeveloped parcels within riparian zones or floodplains in this reach should be viewed as high priority for protection, including the large inside bend of cleared pastureland between RM 0.4 and 1.0 (river-right).

3.2 ICICLE CREEK REACH 2 (RM 1.24-3.02)

3.2.1 Overview

Reach 2 is 1.78 miles long and extends RM 1.24 to the Leavenworth National Fish Hatchery (LNFH) spillway at RM 3.02. This channel is unconfined and has an average gradient of 0.07%, notably lower compared to upstream reaches. Planform is single-thread and sinuous meandering with a morphology dominated by extended deep pools occasionally separated with glides and short riffles. Although no prominent tributaries were noted, at RM 2.55 on river-left a floodplain drainage ditch was contributing surface water to the channel. There are significant anthropogenic impacts, including abundant bank armoring (Figure 57) and a confining bridge crossing. Vegetation on the low floodplain surfaces typically consists of willow and cottonwood. The higher floodplain surfaces are vegetated with ponderosa pine and other upland species. Landownership is mostly private.

Figure 57. Representative photo of Icicle Creek in Reach 2 at RM 1.76 (August 28, 2024).

3.2.2 Channel and Floodplain Geomorphology

Table 12. Reach 2 metrics.

Reach 2												
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
1.78	1.24-3.02	0.07%	1.90	Pool	83	Unconfined	Gravel	91.5%	6.0%	0.0%	2.5%	0.0%

Reach 2 flows through the east side of the broad lower Icicle Creek Valley. The channel is low gradient and meandering with a tortuous sinuosity in the downstream section. Channel morphology is deep long pools with glides and occasional short riffles (Figure 59). Pools appear to be maintained through meander flow hydraulics which were exaggerated by large boulders (exposed glacial erratics and riprap or cement bank armoring (Figure 58)). During the survey (August 2024), pools were being utilized by up-migrating salmon and spawning was observed on the few short riffles in the reach. Pools also offer potential for quality rearing habitat, if the prevalence of large wood at the pools is increased to provide cover and complexity. There are no perennial or ephemeral tributaries to Icicle Creek in Reach 2. Side channels, currently activated only during flood events, were noted near RM 2.75 and 2.3 on river-right.

Figure 58. Left: Boulder (glacial erratic) in foreground and riprap armored bank in the background near RM 2.34 Right: Channel bank at Low Floodplain with 3-ft of gravel topped with bank of sand and then loam at RM 1.92. (August 28, 2024)

Modern lateral processes are constricted at multiple locations via bank armoring and a bridge at RM 2.55. A bedrock hillslope toe contact at the downstream end of the reach also imposes a hard point along a reach that would otherwise laterally migrate across the wide valley floor. A meander neck-cut-off is underway at RM 1.77 to RM 1.33. Past efforts to reinforce the narrow floodplain with riprap boulders at the cut-off point probably delayed but have not deterred this process. Upstream bank armoring to protect private structures combined with the downstream bedrock contact have likely quickened and forced the neck-cut-off processes at what is a tortuous meander bend. Channel straightening and reduced sinuosity near the East Leavenworth Road bridge crossing (RM 2.55) add to the forced confinement of the channel in Reach 2. Evidence of incision was noted in Reach 2, including cut banks that revealed cobble-gravel strata two-three feet higher than the tops of modern bars. In general, channel banks are steep and high (4-12-ft) with a stratigraphy that fines up from cobble-gravel base to coarse sand topped with loam (Figure 58). Gravel bars topped with small cobbles and coarse sand occur at the inside of most meander bends.

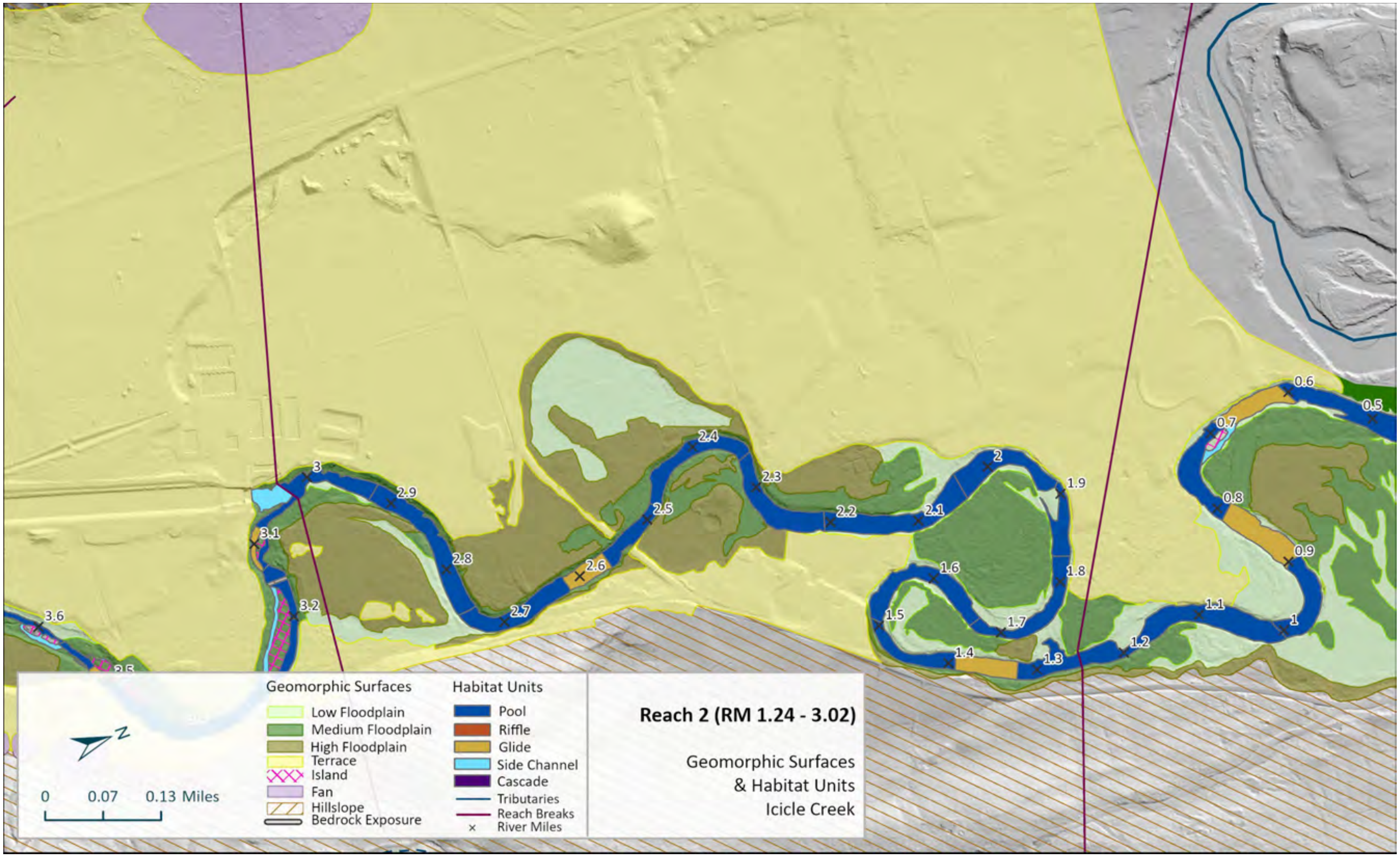

Figure 59. Reach 2: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

The geomorphic surfaces of the valley floor of Icicle Creek in Reach 2 by estimated inundation frequency, vegetation, and observed evidence of inundation to indicate expected connectivity of the varied floodplain surfaces. Low floodplain (inundated ~1-5 yrs), medium floodplain (inundated ~5-20 yrs), and high floodplain surfaces (inundated ~20-100+ yrs) occupy most of the surfaces adjacent to the modern channel. Terraces (abandoned floodplains) border the channel where lateral processes are extending meander bends. The prevalence of high floodplain and terrace surfaces is a product of bank armoring and road/bridge construction that reduces natural inundation potential. Floodplain soils in Reach 2 are mapped as para-gravelly ashy fine sandy loam and stratified gravel to sand (Natural Resources Conservation Service, 2007).

Channel substrate in Reach 2 is primarily gravel with some small cobble and sand. Point bars were located on the insides of most meander bends. The bars within this reach are primarily composed of gravel with fractions of pebbles and coarse sand (Figure 59).

Figure 60. Left: Representative bedload sediment on bars in Reach 2 at RM 1.66. Right: Example of sediment on bar in Reach 2 at RM 1.95. (August 28, 2024)

Two Wolman Pebble Counts (Wolman, 1954)) were conducted in Reach 2 on riffle crests. The median grain size (D50) of GC 23 at RM 2.75 was 32mm and of GC 24 at RM 2.08 was 31mm. The pebble count data are included in Figure 61 of the Reach 2 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5). The analysis indicates that at the 2-year modeled discharge, the channel’s shear stress is expected to mobilize gravel-sized material through the entire reach. At the margins of the channel and across bars sand is likely mobilized.

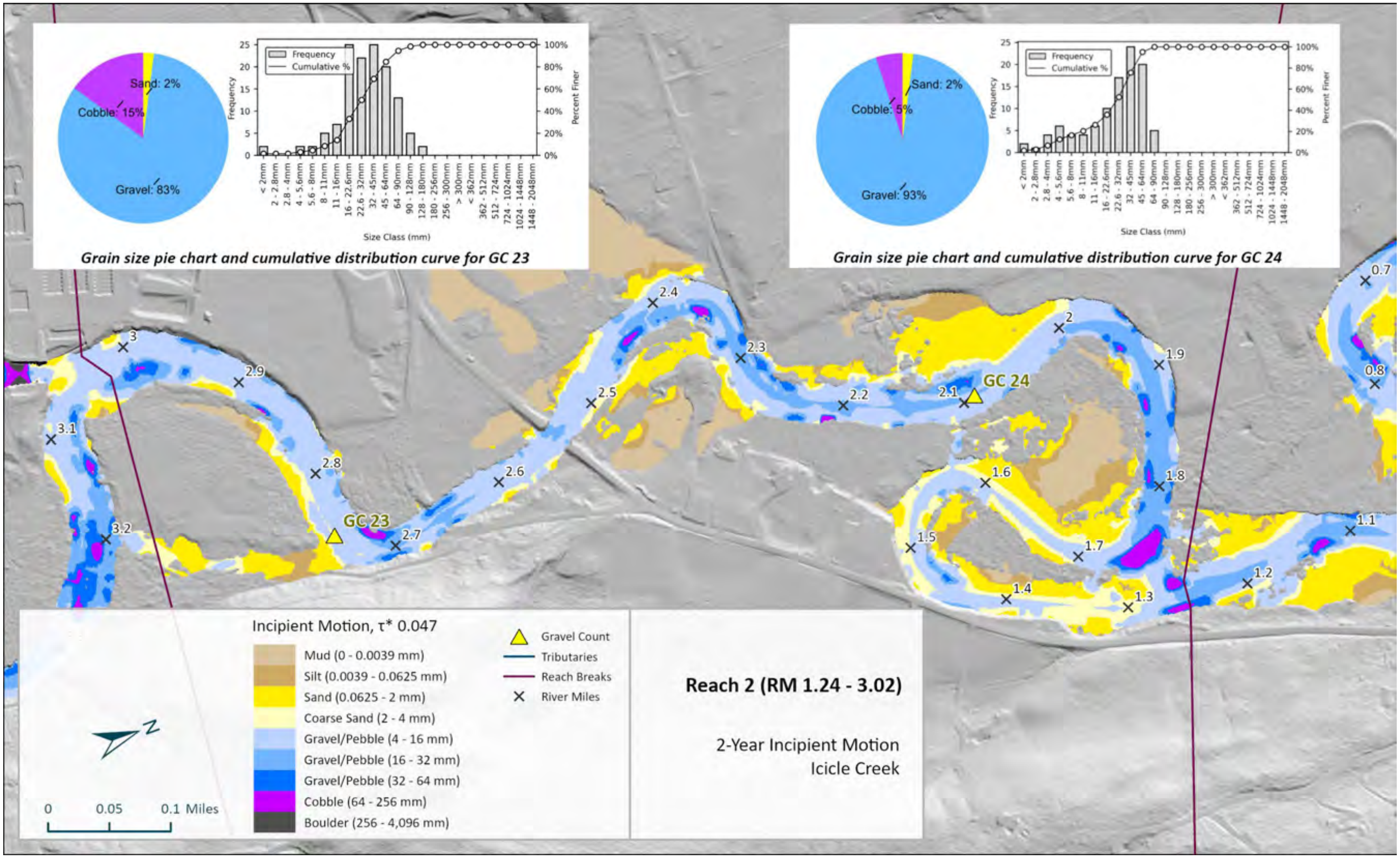

Figure 61. Reach 2: incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge). Includes location and grains size data of the GC 23 and GC 24 pebble counts (2024 survey).

3.2.3 Large Wood Material

The habitat survey conducted in summer 2024 recorded 106 individual pieces of large woody material (LWM) and four log jams (accumulation of >3 LWM) within the bankfull channel, for a compiled total of 142 observed pieces (Figure 63). Of the 106 individual pieces; 9 classified as large size class (>20-inches diameter and >35-feet long); and 36 as medium size class (12 to 20-inches diameter and at least 35-feet long). Of the four log jams in Reach 2, three jams have multiple pieces of medium and large LWM and thus are effective at adding channel complexity and uplifting habitat. Reach 2 has 34 pieces of wood per mile (count includes medium and large LWM as individuals and in jams), which does not meet the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state ((Fox & Bolton, 2007) Appendix A).

In Reach 2, the existing large wood plays a role in maintaining pool scour, influencing sediment deposition and sorting, and contributing to habitat complexity. For example, at RM 1.4, a few large wood pieces recruited from the adjacent hillslope (Figure 62) are promoting sediment sorting and deposition and enhancing channel habitat complexity.

Large wood recruitment in Reach 2 occurs through lateral bank erosion, where trees are present along the streambanks. Recruitment potential is limited by reduced lateral processes and vegetation clearing along the channel. Historical channel-clearing activities have left much of Reach 2 nearly devoid of large wood. The presence of wood in the channel may further be limited by removal activities at East Leavenworth Bridge (RM 2.54). Although large wood is currently sparse in Reach 1, existing channel processes suggest that the system would respond well to additional wood inputs, likely resulting in increased channel complexity and improved habitat availability.

Figure 62. Large wood recruited from the bank at RM 1.4 - promoting pool maintenance and habitat complexity. (August 28, 2024)

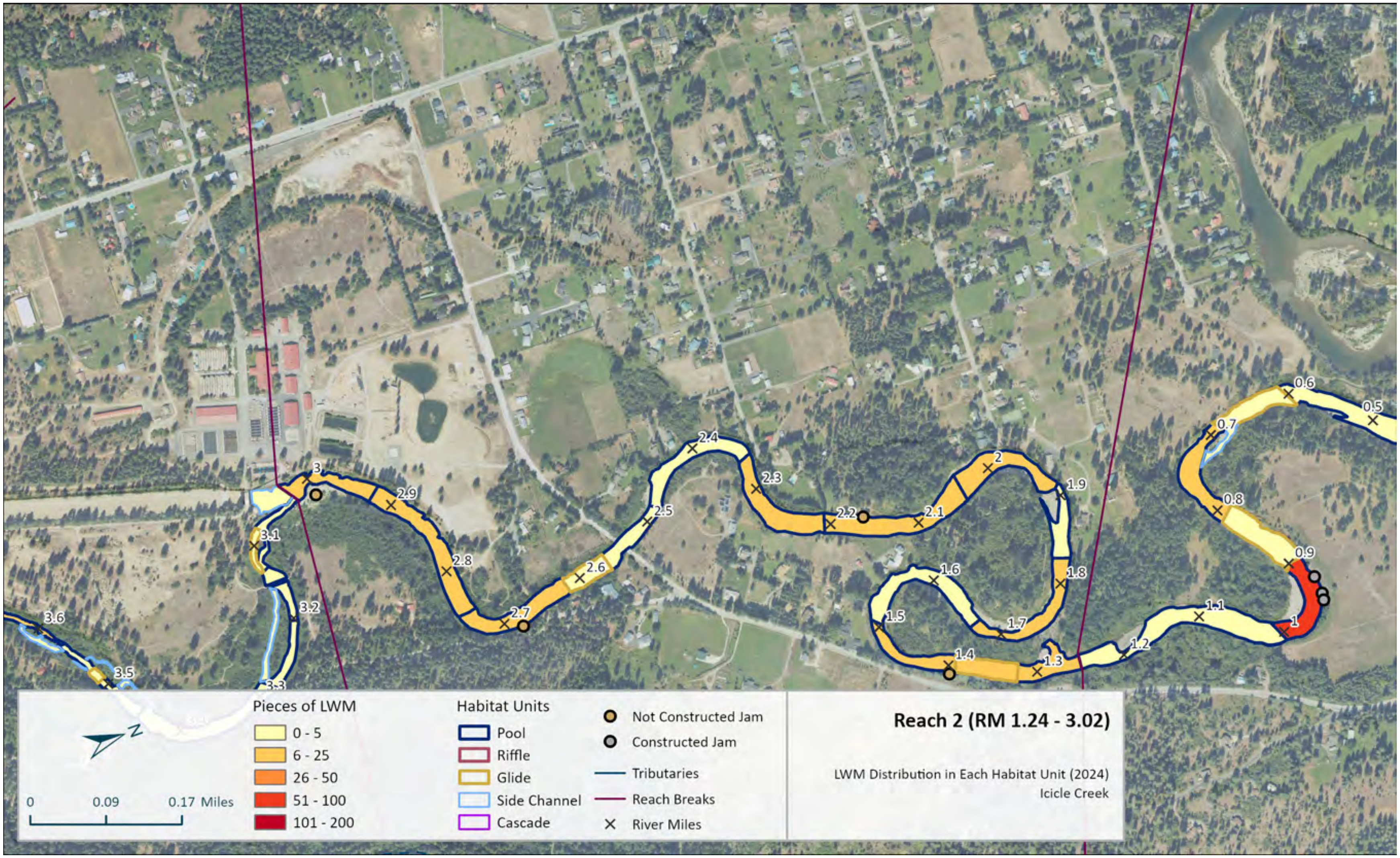

Figure 63. Reach 2: Large wood distribution (pieces per mile per habitat unit) map and surveyed habitat units (2024).

3.2.4 Vegetation

Vegetation conditions in Reach 2 vary, with significant human impacts to riparian and floodplain vegetation. Low floodplains and bars have sedges, willow, dogwood, and alder (Figure 64). However, in many locations, riparian successional processes including willow and cottonwood establishment have been impaired by bank armoring that halts lateral channel migration and sediment deposition required for seedling establishment. The abundance of reed canary grass further limits this process. On medium height floodplains, cottonwood is common where forested conditions remain intact. Many of the high floodplains and terraces are cleared; where they exist, they are dominated by ponderosa pine and other upland vegetation.

Figure 64. Riparian vegetation at RM 1.47 showing typical abundance of reed canary grass on bars with small trees and shrubs backed by alder, dogwood, and willow (August 2024).

The sporadic tree cover in Reach 2 provides limited availability for large wood recruitment. Large trees are present in some areas, providing localized potential sources of large wood to the channel. A map of vegetation heights is provided in Figure 65, with an aerial photo in Figure 66. The maps show the limited number of large and very large trees along the banks and across the floodplain. The existing riparian vegetation provides minimal stream shading in the reach due to lack of large trees along a wide channel. Rural residential development and roadways are the primary impacts, with impacts related to the fish hatchery at the upstream end on river-left.

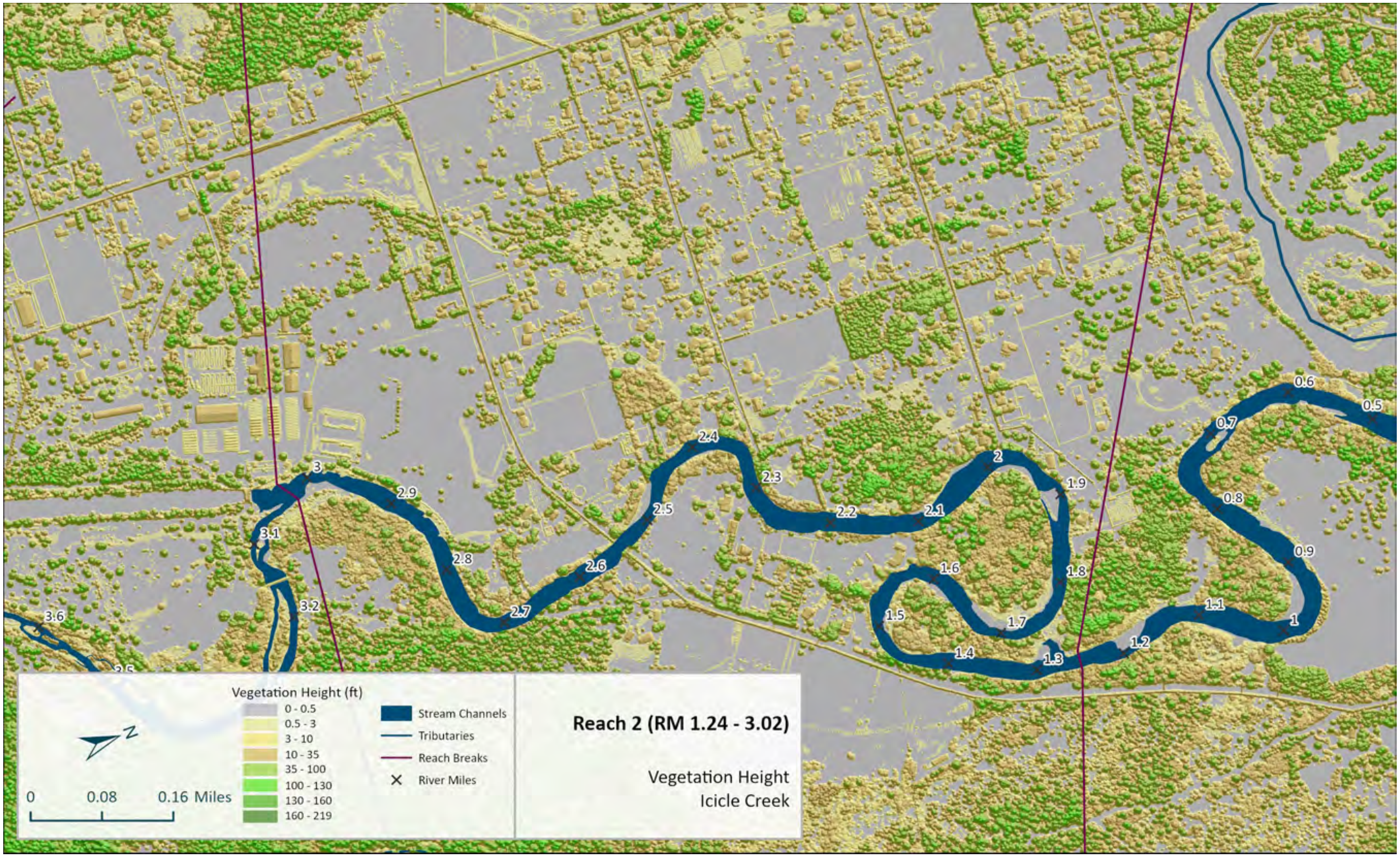

Figure 65. Reach 2: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 66. Reach 2: Map of aerial imagery for vegetation identification (ESRI 2023).

3.2.5 Human Alterations

Human alterations in Reach 2 significantly impact channel, riparian, and floodplain processes. The Lamb-Davis Lumber Company dam (1904-1920's) on the Wentatchee River near the confluence with Icicle Creek backwatered the channel in lower Icicle Creek, including the downstream portion of Reach 2. Related land clearing, sediment flux changes, floodplain inundation, and timber drives combined to scour and simplify lower Icicle Creek. A map of the modern anthropogenic features identified in Reach 2 is provided as Figure 67. Modern lateral movement of the channel is limited in Reach 2 due to extensive riprap armoring, bridge crossing confinement, and adjacent land development. Hard armoring is especially prevalent from approximately RM 1.1 in Reach 1 through RM 2.3. There is also armoring upstream associated with the Leavenworth Road crossing and the hatchery. Bank hardening reduces natural lateral channel processes and evolution, leading to over-widened and simplified sections of the river. Near the downstream end of the reach, there is riprap on the river-left bank, likely to attempt to prevent a neck cutoff of a prominent meander. Despite these actions, a cutoff is nevertheless very likely at this location, especially given that high flows connect through the avulsion path. The bank armoring and impacts to natural rates of channel migration have likely contributed to channel incision, reducing the frequency of floodplain inundation.

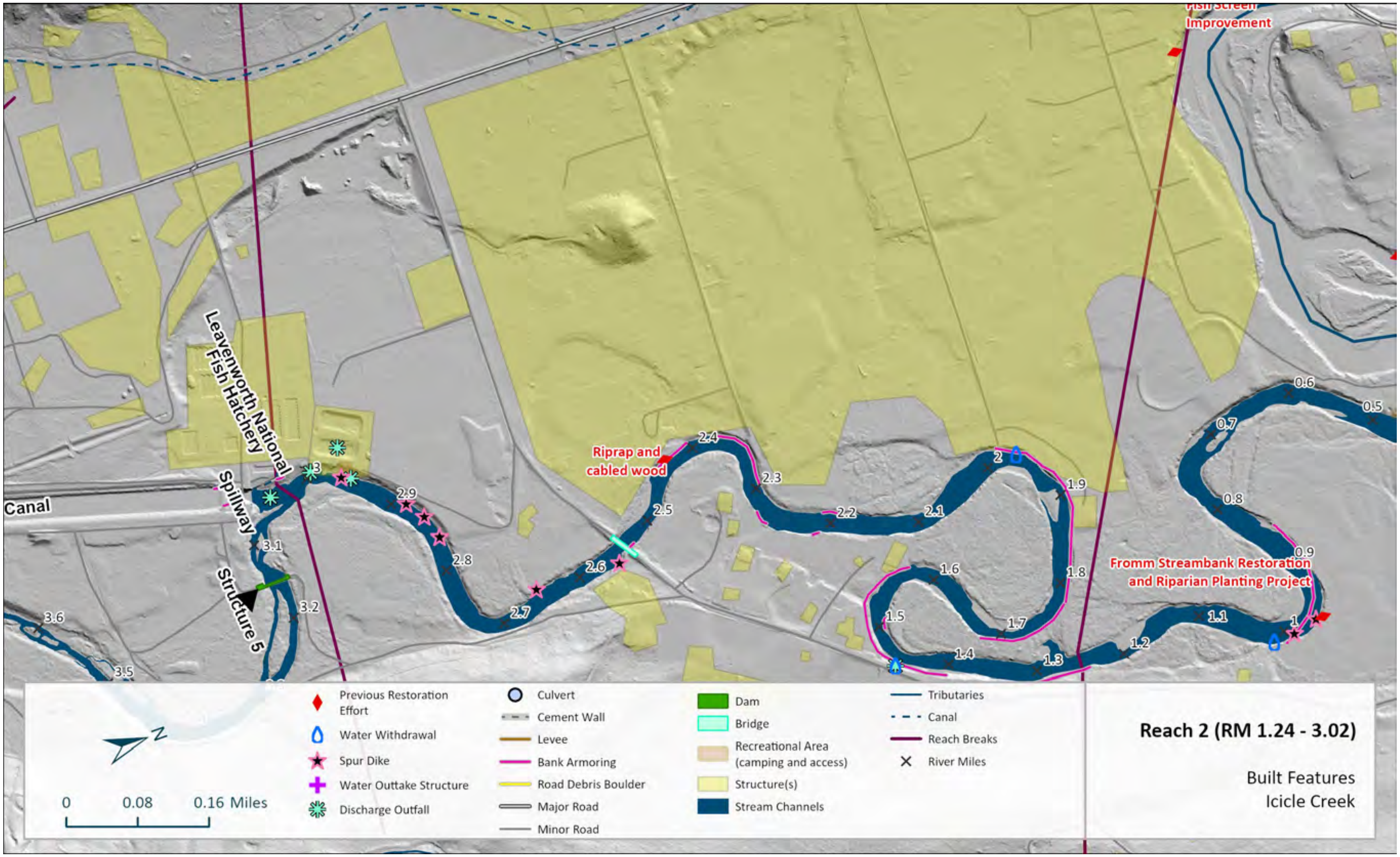

Figure 67. Reach 2: Mapped anthropogenic features (2024).

Throughout Reach 2, clearing associated with rural residential use has reduced riparian vegetation and the potential for large wood recruitment. The East Leavenworth Road bridge at RM 2.54 and its associated bank protection has confined Icicle Creek within a fixed path, further limiting floodplain connectivity, contributing to channel incision, and restricting lateral migration. Additional human-made features in Reach 2 include a retired water level gauge and associated infrastructure at RM 2.5 and a water withdrawal pump and pumphouse near RM 1.45 (Figure 68). At the upstream end of the reach near the hatchery, there are riprap spur dikes (groins) located along the river-left bank for bank protection.

Figure 68. Water withdrawal pump and pumphouse near RM 1.45 in Reach 2 of Icicle Creek (August 28, 2024).

There is additional infrastructure associated with the Leavenworth National Fish Hatchery (LNFH), which extends up into Reach 3 and includes buildings, raceways, ponds, roadways, parking areas, and various other hardened surfaces and cleared areas. There is an outfall near RM 2.95 and return flows from the hatchery area closer to RM 3.0. Near RM 2.9 through RM 3.0, there are tribal fishing platforms along the banks (Figure 69).

Figure 69. Tribal fishing platforms, riprap-lined banks and LNFH buildings and stockpile areas in Reach 2 of Icicle Creek near RM 3.0 on river left. (August 24, 2024)

3.2.6 Recommended Actions

Reach 2 has significant habitat uplift potential given the impacts to the channel, riparian zone, and floodplain from residential and agricultural uses. However, it is also a challenging place to work given the many private parcels and adjacent infrastructure (e.g. roads and houses). There is abundant bank armoring, development, floodplain manipulations, and riparian clearing. This is also a popular recreational area for floating the river with access points within the reach that serve river users during the summer.

Potential project actions in Reach 2 are captured in the Eiszapfen Bach project. There are a couple of opportunities for enhancing the connectivity of side-channels along the right bank RM 1.6 – 2.0. These would occur via mainstem large wood jams, inlet jams, and excavation. The viability of these warrants additional survey and modeling to understand excavation requirements. A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities)

Many of the channel banks are armored. Where possible, and where there are willing landowners, riprap could be removed and replaced with bank-buried log jams or augmented with wood complexity. The avulsion path near RM 1.7 was armored following a cutoff in 1972 but remains a potential avulsion pathway. From a habitat perspective, a cutoff here would provide a significant amount of off-channel rearing habitat. However, there may be landowner and social constraints to removing the armoring and allowing the cutoff to occur; but it’s very possible it could occur even if the armoring is not removed.

The rock spurs protecting portions of the hatchery complex at the upstream end of the reach on river-left already have some wood incorporated within them. However, they could be either fully replaced with bank-buried log jams or augmented with additional wood to provide additional cover and margin complexity.

The reach would benefit from a variety of other large wood placement types, including bar apex jams to create split-flow and create/maintain vegetated islands, margin complexity wood, and general cover and complexity wood to improve overall salmonid rearing, holding, and refuge habitat.

There are many areas of cleared riparian and floodplain vegetation, much of which is associated with rural residential development. The objective would be to work with willing landowners to replant areas where possible, especially in areas that would provide shade and potential future wood recruitment to the channel.

There are also some important conservation measures to consider for this reach. Because of the high fish use and restoration potential of these reaches, any undeveloped parcels within riparian zones or floodplains in this reach should be viewed as high priority for protection, including the large inside meander bend between RM 1.6 and 2.1 (river-right), and other undeveloped parcels.

3.3 ICICLE CREEK REACH 3 (RM 3.02-4.30)

3.3.1 Overview

Reach 3 is 1.28 river miles long through the natural channel and extends from the spillway at the downstream end of the Leavenworth National Fish Hatchery (LNFH) to the upstream end of the diversion canal near RM 4.3. The natural channel flows in the historical channel pathway, south of the diversion canal. A diversion dam (Structure 2) at the upstream end of the natural channel controls flow into the natural channel vs through the diversion canal. Another dam (Structure 5) located in the natural channel near the downstream end of the reach was once a fish barrier and used for fish collection for the hatchery. The natural channel has an average gradient of 0.24% and is partially confined due to the flow diversion structures and artificial confinement from floodplain fill associated with the hatchery diversion (Figure 70). Anthropogenic disturbance within this reach is significant due to development and land uses related to the hatchery, detailed in Section 3.3.5. Vegetation is mostly sparse on river-left due to historical fill and clearing and is impacted on river-right by rural residential development. Landownership is both private and LNFH property.

Figure 70. Representative photo of Icicle Creek in Reach 3 at RM 3.25. (August 30, 2024)

3.3.2 Channel and Floodplain Geomorphology

Table 13. Reach 3 metrics.

Reach 3												
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
1.28	3.02-4.30	0.24%	1.10	Pool	57	Partially Confined	Gravel	75.5%	12.7%	3.1%	8.8%	0.0%

The hatchery canal is a straight, constructed, riprap-lined and leveed flow route with no habitat complexity. The canal is currently wetted during high flow discharge, splitting discharge between the canal and the natural channel. At low-flow conditions, flow is currently routed though the natural channel. Since the natural channel does not receive full high and flood-flow discharge, channel-forming effects of high flows are muted. As a result, lateral processes are impeded, incoming sediment load is impeded, flushing flows that regenerate bars and maintain scour holes do not occur, and thus vegetation encroachment (reed canary grass) on the bars has occurred (Figure 71). Nevertheless, Reach 3 remains an important salmon spawning reach within the assessment area. Indicating that restoration efforts in Reach 3 have good potential to result in high level of uplift.

The channel and floodplain geomorphology described below pertains to the natural channel in Reach 3, not the diversion canal. The natural channel is low gradient with a very subtle meander planform that is single thread with side channels and islands at approximately RM 4, 3.84, 3.59, 3.49, and 3.28. It appears that between RM 3.5 and 3.8 the channel was artificially straightened during construction of the LNFH and banks reinforced to remain straight. For example, boulder spurs placed along the channel at RM 3.4 purposefully restrict lateral channel migration (Figure 71).

Figure 71. Left: boulder spurs to limit lateral processes at RM 3.4. Right: Vegetated (Reed Canary Grass) island and split-flow near RM 3.8 (looking upstream). (August 30, 2024)

Today, channel morphology is plane-bed and dominated by long pools of varied depths with intermittent glides and occasional short riffles (Figure 72). The extended deep pool at RM 3.16-3.45 is the result of flow management and grade control by the Structure 5 Dam at RM 3.16. At the most upstream end of the reach at RM 4.29, the Structure 2 Dam controls grade and modifies upstream and downstream hydraulics and flow routing. Both dams constrain lateral and vertical connectivity, impact flow hydraulics, and reduce floodplain development and inundation. Discussion of fish passage as it relates to these structures can be found in Appendix A.

Channel complexity is Reach 3 is limited to split flow conditions around small islands densely vegetated with reed canary grass and shrubs. In many locations, established vegetation on bars and banks provide overhang cover. Based on observed beaver activity and remnants of buried beaver dams observed in some of the islands, it is presumed that beaver activity initiated some of the split flow conditions found in the channel. Perennially connected side channels, though lacking in wood, offer rearing habitat opportunities.

There are no perennial tributaries to Icicle Creek in Reach 3. However, a spring fed constructed pond atop the adjacent river-right terrace near RM 3.7 does have a controlled over-flow ditch that flows off the hillslope and into the channel where remnant cement, wood, and steel footings of an historical crossing or dam remain in the channel. The channel has responded to the footings by developing side-channel flow around them.

The space available for floodplain development in Reach 3 has been altered by grading associated with the LNFH and construction of the diversion canal and dams. Spoils and fill used to construct the canal, and its associated levee, access roads, and dam structures encroach on the channel's historical floodplain and partially confine the natural channel to its current location. Grading (fill) across the floodplain along most of the river left section of this reach has changed surface elevations, decreasing connectivity potential between the floodplain and the channel, resulting in the surface now functioning as a terrace. Existing floodplains are limited to the area between the LNFH graded surfaces on river-left and the hillslope at the edge of the valley on river-right. Floodplain surfaces are discontinuous swaths of low floodplain (inundated ~1-5 yrs) and medium floodplain (inundated ~5-20 yrs) that border the channel and are backed, in some areas, by both natural and LNFH-created high floodplain surfaces (inundated ~20-100+ yrs). Floodplain soils in Reach 2 are mapped as paragravelly ashy fine sandy loam and bouldery medial fine sandy loam (Natural Resources Conservation Service, 2007).

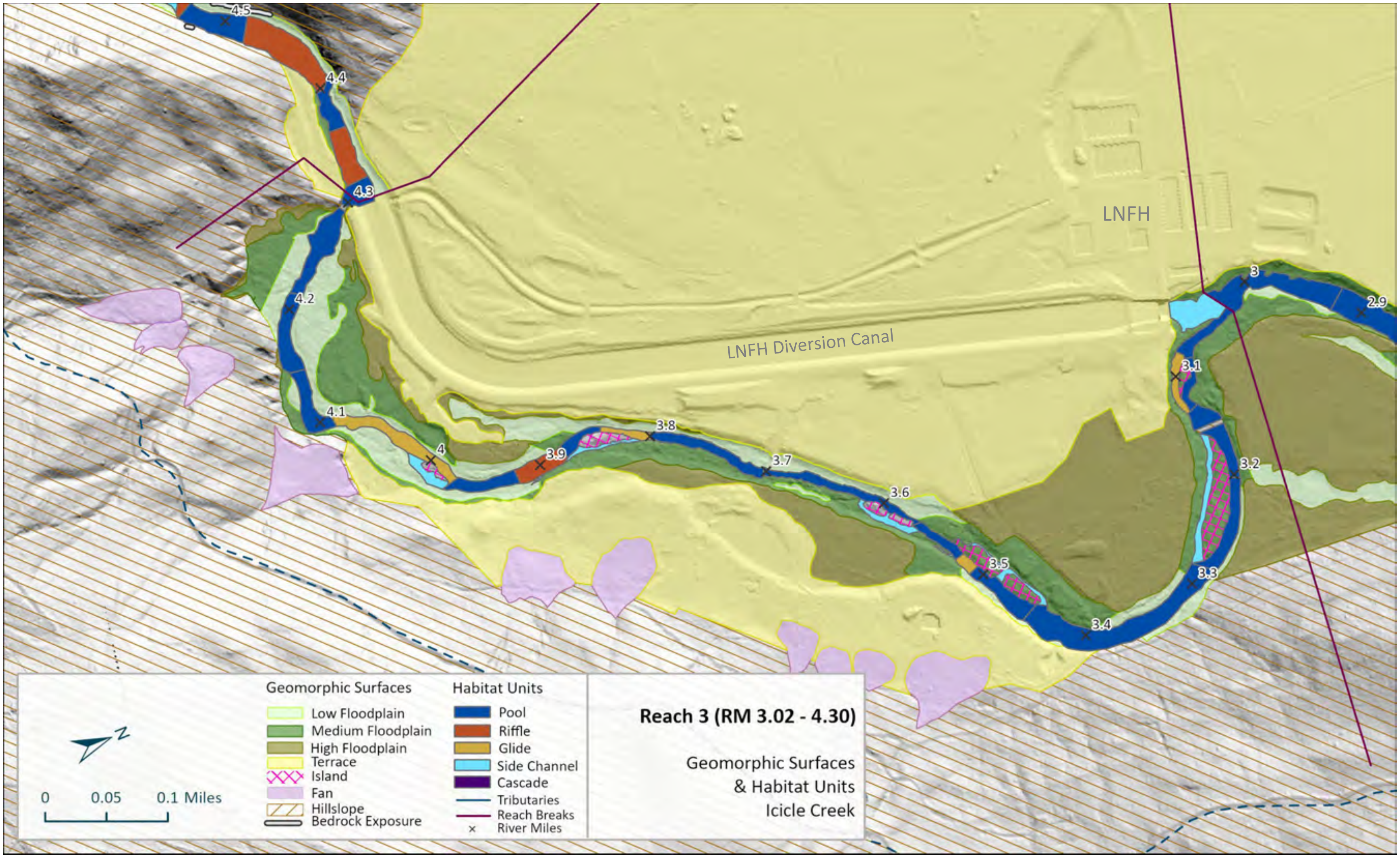

Figure 72. Reach 3: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

Channel substrate in Reach 3 is primarily composed of small gravels topped with coarse sand and fines. Boulder colluvium from the adjacent hillslope occurs at RM 3.9 but the boulders are currently stable due to reduced flow hydraulics through the reach. Where bars are unvegetated, they are composed of gravel with sparse small cobbles and coarse sands (Figure 73). Sediment supply in Reach 3 is limited by impediments to lateral migration and the restricted influx of material from upstream by Structure 2 and wash through at the hatchery canal.

Figure 73. Representative bedload sediment and bar composition in Reach 3, at RM 3.99. (August 30, 2024)

One Wolman Pebble Counts (Wolman, 1954) was conducted on a channel spanning riffle crest at RM 3.43 (GC 22). The median (D50) grain size at GC 22 was 39 mm. The presence of Dam 2 and Dam 5 impact sediment transport and hydraulics. The pebble count data are included in Figure 74 of the Reach 3 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5). The analysis indicates that at the 2-year modeled discharge, the channel's shear stress is expected to mobilize gravel-sized material through the entire reach with discontinuous small pockets of shear capable of mobilizing cobbles.

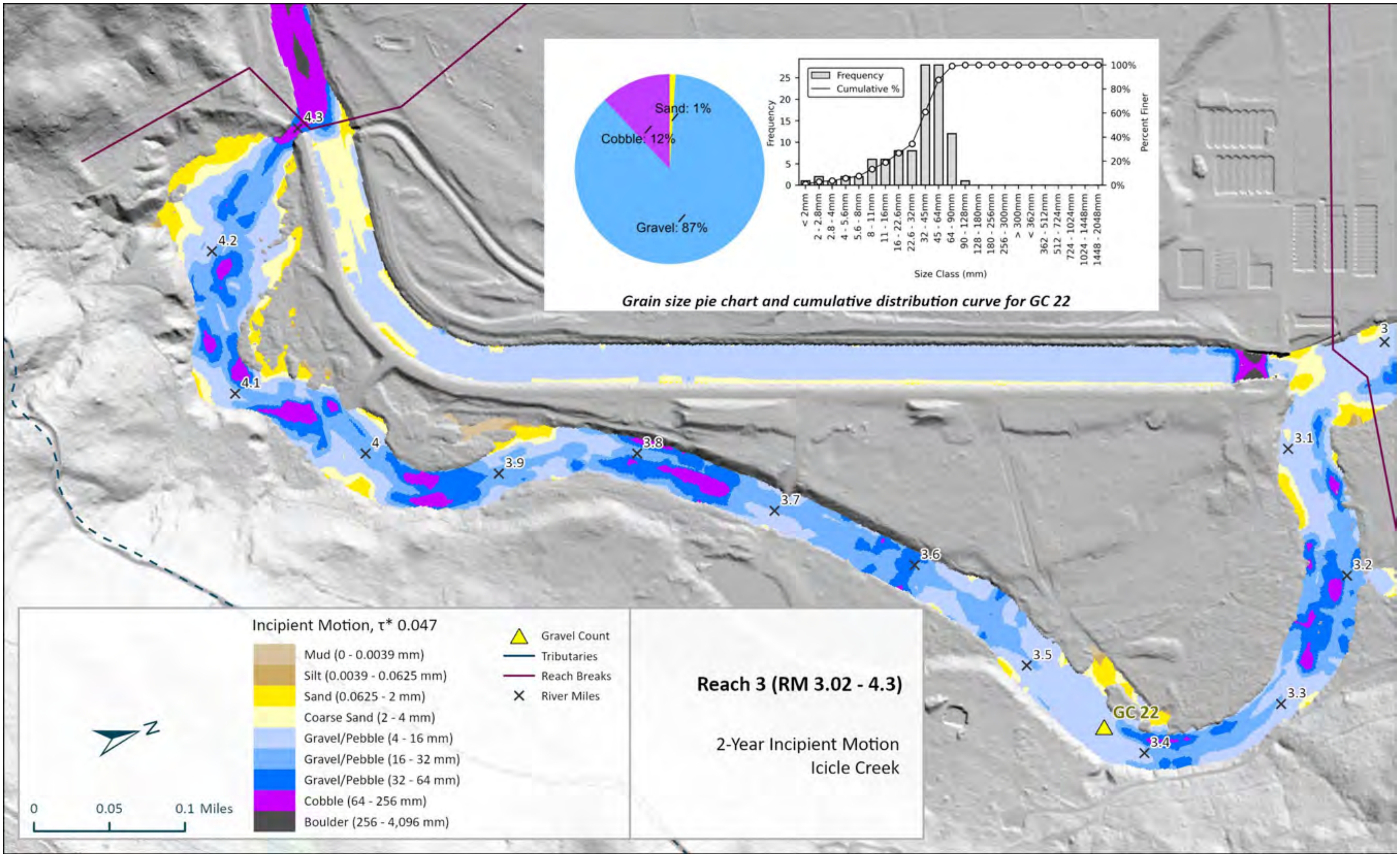

Figure 74. Reach 3: incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge). Includes location and grains size data of the GC 22 pebble count (2024 survey).

3.3.3 Large Wood Material

The habitat survey conducted in summer 2024 recorded 56 individual pieces of large woody material (LWM) and 1 log jam (accumulation of >3 LWM) within the bankfull channel, for a combined total of 61 observed pieces (Figure 74). Of the 56 individual pieces; 2 are classified as large size class (>20-inches diameter and >35-feet long); and 9 as medium size class (12 to 20-inches diameter and at least 35-feet long). The single log jam in Reach 3 has 1 piece of medium and 1 large LWM. Reach 3 has 10 pieces of wood per mile (count includes medium and large LWM as individuals and in jams), which does not meet the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state ((Fox & Bolton, 2007; Appendix A).

In Reach 3, effective large wood could play a key role in creating pool scour and influencing sediment deposition and sorting (Figure 75). However, this reach is largely devoid of wood. The limited abundance of large wood in Reach 3 is likely due to removal associated with infrastructure and minimal lateral function due to bank armoring and infrastructure. The addition of large wood to Reach 3 is expected to result in important habitat and geomorphic complexity uplift.

Figure 75. Single piece of medium-sized wood at RM 3.49 – instigating pool development, sediment sorting, and providing localized cover while also encouraging split-flow into a side channel. (August 30, 2024)

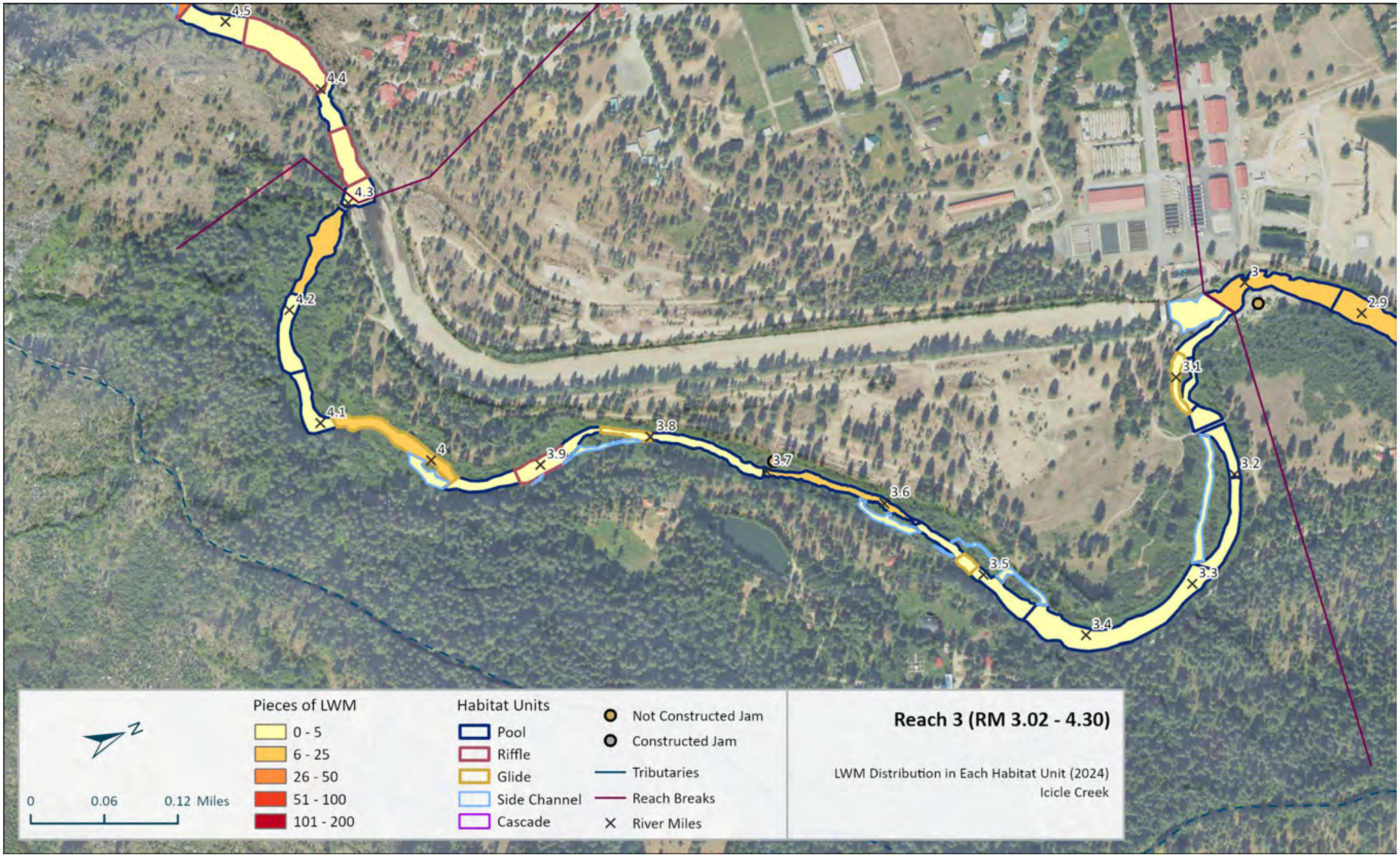

Figure 76. Reach 3: Large wood distribution map (pieces per mile per habitat unit) and surveyed habitat units (2024).

3.3.4 Vegetation

The vegetation in Reach 3 is heavily impacted by the hatchery infrastructure and operations. On river-left of the natural channel (between natural channel and diversion canal), woody vegetation is sparse due to historical fill and clearing. This area is also crisscrossed by dirt roads and trails, which impact vegetation establishment. The floodplain fill in this zone historically decimated the natural floodplain vegetation community and vegetation has not fully re-established. There has also been a shift from what was assumed to be historical riparian and floodplain species to more upland species. Currently, there is a scattered second-growth overstory dominated by ponderosa pine, with sagebrush scrub in the understory. Along the stream margin, there is a wetter, vegetated zone with riparian shrubs and trees including dogwood, alder, vine maple, willow, and cottonwood; however, the abundance of cottonwood and willow is assumed to be significantly less than would have existed historically prior to the impacts to the hydrology in the natural channel and to the lateral migration processes necessary for seedling establishment. There is also an abundance of reed canary grass, which is especially prevalent on channel margins and bars and is likely disrupting natural successional processes. Typical vegetation conditions in the reach are shown in Figure 77. The typical vegetation on the surface between the natural channel and hatchery channel is shown in Figure 78.

Figure 77. Riparian and upland vegetation in Reach 3, near RM 3.25. (August 2024)

Figure 78. Upland vegetation is present in filled portions of floodplain within the LNFH trail network near RM 3.1. (August 30, 2024)

Forest cover across portions of Reach 3 suggests there is limited availability of trees adjacent to the channel for large wood recruitment. Large overstory trees are present in clusters in Reach 3 at RM 3.3, 3.4, 3.5, 3.8, and 3.9-4.2. Although these trees may provide a localized source of large wood to the channel, the availability of large trees has been significantly reduced due to past harvest. This has also reduced stream shading throughout the reach. A map showing vegetation heights is provided in Figure 79, with an aerial map in Figure 80. The maps demonstrate the impacts to riparian vegetation, especially along the river-left bank in the former floodplain between the natural channel and the hatchery diversion channel.

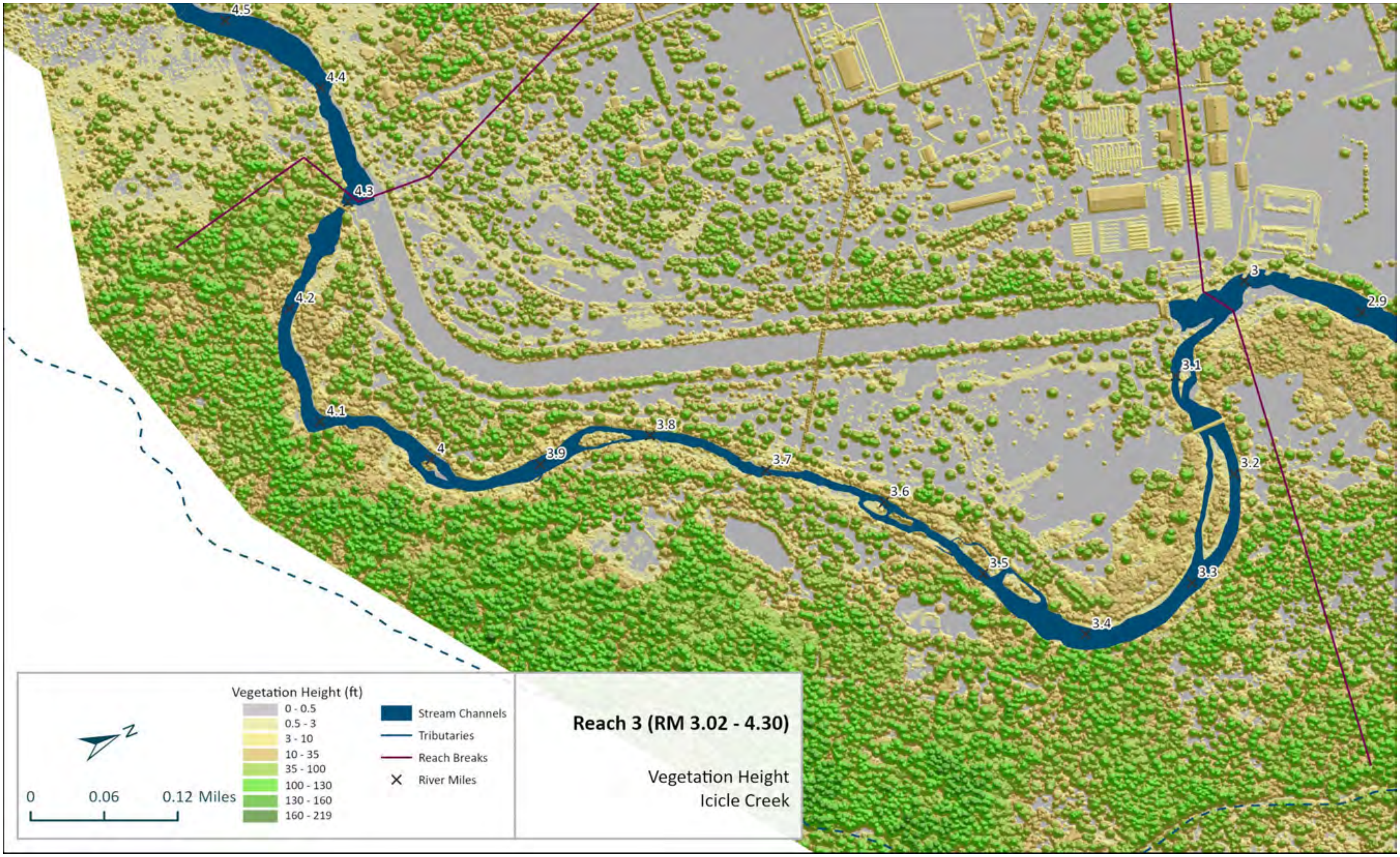

Figure 79. Reach 3: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 80. Reach 3: Map of aerial imagery for vegetation identification (ESRI 2023).

3.3.5 Human Alterations

Human alterations have heavily impacted channel, riparian, and floodplain conditions in Reach 3. A map identifying anthropogenic features is provided in Figure 82. Reach 3 has the most extensive human modification of any assessed reach in Icicle Creek. This reach includes the majority of the Leavenworth National Fish Hatchery (LNFH) infrastructure, including the artificial hatchery diversion channel and two dams (Structure 2 near RM 4.3 and Structure 5 near RM 3.15). See Section 2.5.3 for more information on the hatchery facility including the operation of the dams and the diversion channel. Previously, the natural channel in this reach contained two additional dams (Structures 3 and 4), which were removed in 2003. Structure 2 continues to be used to divert flows to the hatchery diversion channel for hatchery operations including well recharge (Figure 81).

Figure 81. Structure 2 at the upstream end of the hatchery diversion channel near RM 4.3 (August 27, 2024). Left: Downstream end of the dam, looking upstream. Right: upstream end of the dam, looking downstream with the diversion channel to the left (August 27, 2024).

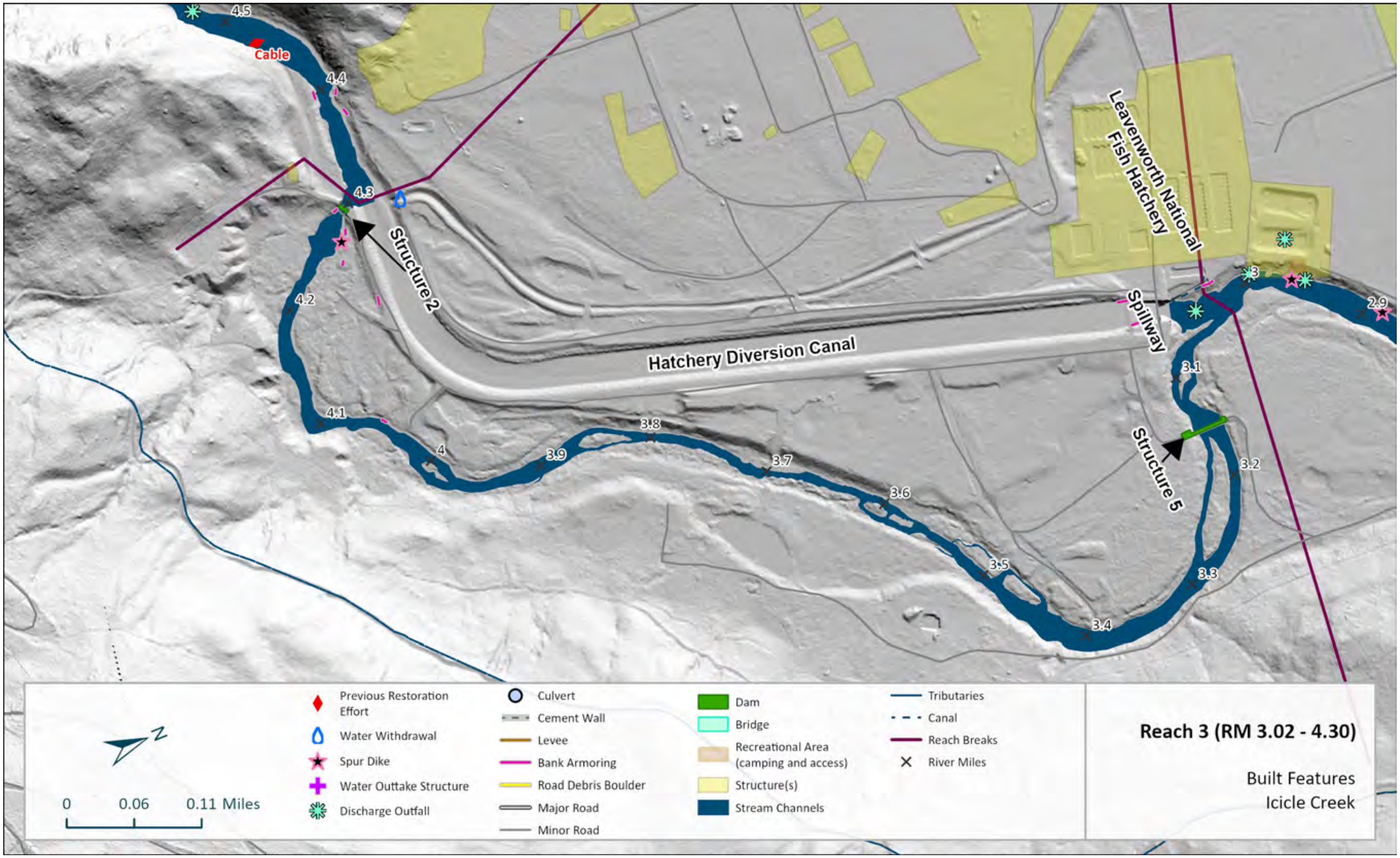

Figure 82. Reach 3: Mapped anthropogenic features (2024).

The construction of the LNFH and its diversion canal has affected floodplain connection, seasonal hydrology, flow hydraulics, and fish passage. The diversion channel extends from RM 4.3 to 3.1 and is located, at most, 1,200 feet from the natural channel. The diversion canal is a rectangular shaped channel with a grade control structure at the upstream end and a cement structure (spillway) at the downstream end (Figure 83). The diversion channel is 4,085 feet long (USFWS, 2020) and has been constructed with levees and related infrastructure to control flows. Prior operations focused on keeping flow in the hatchery canal. Since 2006, the gate at Structure 2 is generally kept open, providing flow to the natural channel. Flow is diverted periodically into the hatchery canal to recharge adjacent shallow wells (Figure 83). High flows occupy the diversion canal and the gates at Structure 2 can be operated to assist with flood control, including completely closing the gates to the natural channel to divert flows into the diversion canal (USFWS, 2009). Even when the gates at Structure 2 are completely closed, due to gate leakage and groundwater upwelling, the natural channel still has flow (USFWS, 2009).

Figure 83. Left: Hatchery Canal from downstream spillway looking upstream, near RM 3.08. Right: View from on top of the abandoned Wenatchee Canal spillway, looking across Icicle Creek to the upstream side of diversion dam – Structure 2. (August 27, 2024)

The diversion canal is typically dry during summer and winter months, with flows directed into the natural channel when not required for hatchery operations. Structure 5 at RM 3.15 currently functions as a fish trapping and counting facility (Figure 84), with blocking racks and slats that direct fish into side ladders for counting. During low-flow conditions this structure may act as a barrier to fish passage and visible wear on the concrete indicates aging infrastructure.

Figure* 84. *Structure 5 in Reach 3 near RM 3.15 (August 24, 2024). Left: view of upstream side of structure from river-left. Right: View of downstream side of Structure 5 from river-left with blocking racks and fish ladder at the far end at the river-right bank.

A constructed pond at RM 3.7 on river right was contributing surface flow to Icicle Creek (natural channel) at the time of the August 2024 survey. The overflow channel from the pond to Icicle Creek is controlled with board dams. The overflow channel falls into Icicle Creek from atop the terrace the pond is located on and is not considered accessible by fish. The pond looked like it was sourced from a spring and has aerated oxygenators in it. The overflow water entering Icicle Creek from the pond was cool. These surface water contributions enter the channel at the upstream end of an established side channel that initiates behind historical cement bridge footings.

Between the diversion and natural channels lies the historical floodplain, which now contains maintained roads and trails, active and abandoned utility poles and wires, levees with spoils piles, surface grading, and a public wildlife viewing blind. Between RM 3.1 and 4.3 the natural channel has been further manipulated to support downstream bypassing, flow control, and historical routing for hatchery operations. Hard armoring composed of riprap and spurs is present throughout this section of the natural channel. There is evidence of a historical dam structure near RM 3.9. At the upstream end of the hatchery infrastructure, on the river left bank of the diversion channel, there is an abandoned spillway from the historical Wenatchee Canal at RM 4.3 (Figure 83). This canal was constructed to deliver water from the Wenatchee River to Icicle Creek to help with water supply associated with hatchey operations and the Icicle Peshastin Irrigation Canal. The canal was abandoned after only a few years of operation (Rieman, 2014).

3.3.6 Recommended Actions

Some of the largest habitat and river process uplift potential in the study area is located in Reach 3. The greatest uplift would occur via an aggressive approach to re-naturalize the river, riparian zone, and floodplain in this reach, which has been heavily impacted by the hatchery diversion canal and other related hatchery operations and past uses. The most aggressive approach would be to remove the hatchery canal, spillway, and dam Structures 2 and 5 that affect fish passage in the reach. This would be combined with removal of fill and regrading the area between the canal and the natural channel to re-create a connected and re-vegetated floodplain. It's possible that groundwater recharge of wells to the west of the canal could continue to be achieved via a side-channel that would carry water through portions of the former canal footprint during key periods. This warrants further analysis to fully understand feasibility and design approach. Less aggressive alternatives include leaving the canal but removing the dams and floodplain fill. At the very least, and as a component of any alternative, the natural channel could be loaded with large wood to drive lateral dynamics, encourage split flows and island development, and to provide overall habitat cover and complexity. It is acknowledged that the IWG is currently considering restoration options, including sediment management, for the historical channel in this reach and that project planning will need to coordinate closely with the IWG and on-going efforts.

Any work that is done at this site needs to consider the continued use of the site by the tribes for fishing. This includes maintaining the large pool downstream of the modern spillway (or something comparable nearby) as it is an important and productive tribal fishing location. Other fishing access in general in this vicinity would need to be maintained. A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities)

3.4 ICICLE CREEK REACH 4 (RM 4.30 – 5.05)

3.4.1 Overview

Reach 4 is 0.75 miles long and extends from the upstream end of the LNFH diversion canal at RM 4.30 to the LNFH diversion and intake structure at RM 5.05. At the time of the survey, Cascade Orchard Irrigation District diversion and intake structure was located at RM 5.05 but in May 2025 it was moved downstream to RM 1.09 (personal communication with Ingrid Ekstrom, Department of Ecology). The reach has an average gradient of 1.65% and is mostly confined. Channel form is single thread except for a split-flow section near RM 4.6. Hillslope and bedrock contacts with the channel are common. A characteristic photo is provided in Figure 85. The morphology alternates between boulder step-pool and boulder dominated riffle-pool. Vegetation is naturally sparse on the bedrock hillslopes with scattered ponderosa pine. The few lower floodplain surfaces have willow, dogwood and cottonwood. Human disturbance is significant, with the Icicle River RV Park along the left bank, the Icicle Road on river-left at the upstream end, and a diversion structure and associated bank protection along the left bank at the upstream end. Landownership is private along most of the reach with National Forest land at the upstream end of the reach. Adult salmon were observed spawning and holding in the reach during the survey near RM 4.8 in late August 2024.

Figure 85. Representative photo of Icicle Creek in Reach 4 at RM 4.53 (August 27, 2024).

3.4.2 Channel and Floodplain Geomorphology

Table 14. Reach 4 metrics.

Reach 4												
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
0.75	4.30-5.05	1.65%	1.05	Riffle	100	Confined	Cobble / Boulder	27.8%	0.0%	66.6%	5.6%	0.0%

In Reach 4 the channel has a moderate reach-averaged gradient. However, the upstream portion of the reach is steeper and more confined than the downstream portion. Between RM 4.9 – 5.05 the channel is confined with hillslope colluvium and bedrock on river-right and a riprap constructed and/or reinforced bank on river-left that extends to RM 4.6. The large boulder riprap bank on river-left is associated with both irrigation withdrawal and piping as well as the Icicle River RV Park. In the steeper section, the channel alternates between boulder step-pool and boulder riffle-pool (Figure 86). Large to massive boulder colluvium and periodic exposures of bedrock notably increase roughness and define grade in this section. Near RM 4.9 confinement reduces, gradient reduces, and morphology shifts to boulder riffle-pool for the remainder of the reach (Figure 86). Side channel split-flow around forested islands occur between RM 4.55 – 4.7, with bedrock present in the bed of the channel at RM 4.61 in the river-left side channel. Formation of the islands, bars, and floodplains in the mid-section are related to the reduced stream-energy compared to upstream. At the downstream end of the reach the final pool deep and backwatered by Structure 2 and LNFH diversion canal.

Figure 86. Left: Confined boulder-step and boulder riffle at RM 4.96, looking upstream. Right: Boulder riffle at RM 4.72, looking downstream. (August 27, 2024)

Narrow discontinuous strips of low (inundated ~ 1-5 yrs) and medium (inundated ~5-20 yrs) floodplains occur along the margins of the channel where space allows. Otherwise, surfaces are mapped as confining terraces, fans, or hillslopes (Figure 87). The vegetated islands at mid-reach are associated with a band of medium floodplain on river-left. A floodplain cutbank at RM 4.6 reveals that floodplain composition is a matrix of cobble to coarse sand. There are no tributaries to Icicle Creek in Reach 4.

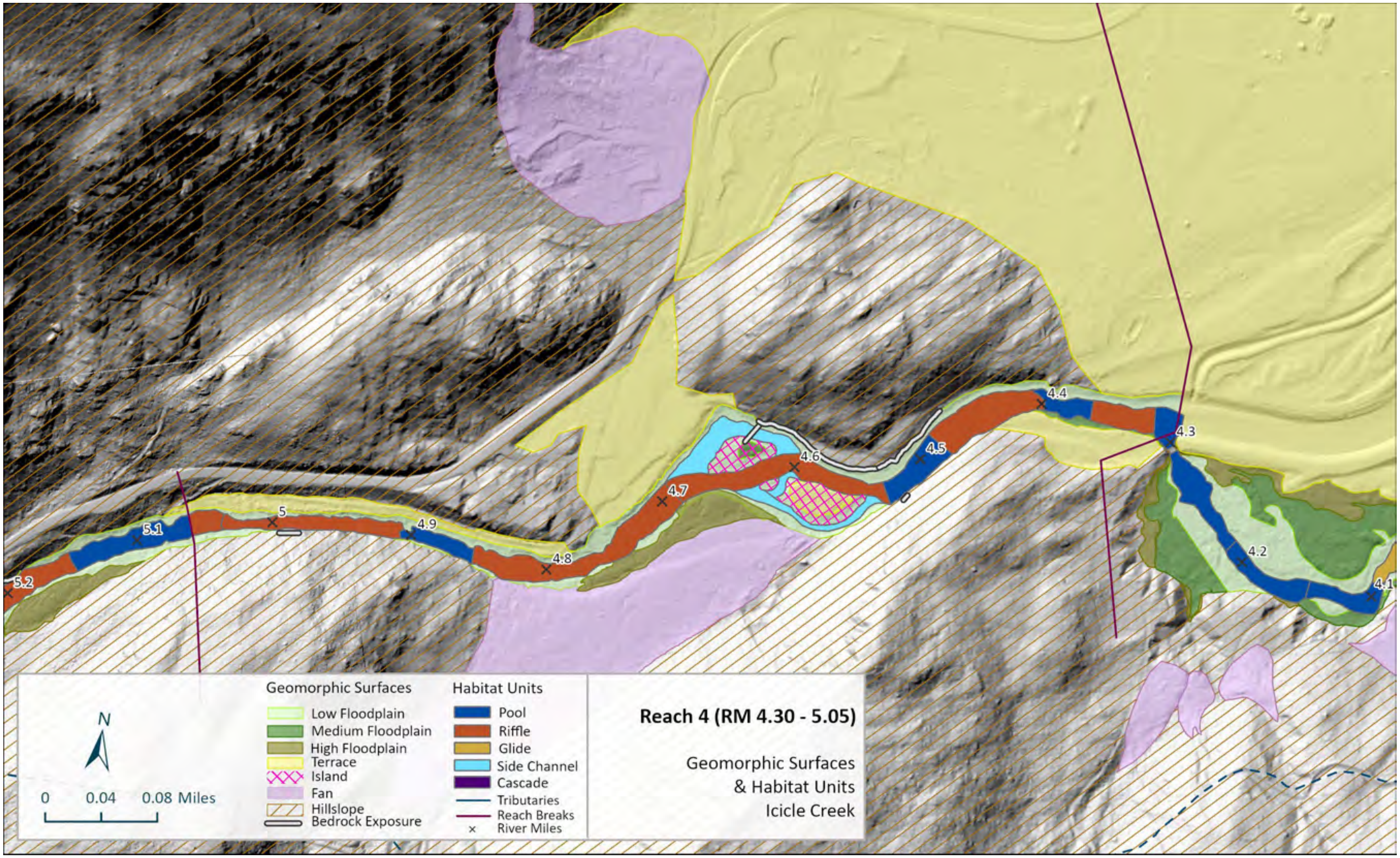

Figure 87. Reach 4: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

Channel substrate in Reach 4 is dominated by boulders with cobbles. Gravel and occasionally sand occur in areas with reduced flow hydraulics such as pool tail outs, bar tops, behind large boulders, and along the channel margin (Figure 88). Bars are present in the mid-reach split-flow section only. Sediment is sourced from hillslope and fan contributions and delivered into Reach 4 from upstream, as well as laterally eroded from the island floodplains.

Figure 88. Boulder-cobble bar with coarse sand at downstream end of split-flow island at RM 4.53. (August 27, 2024)

Two Wolman Pebble Counts (Wolman, 1954) were conducted in Reach 4 on riffle crests. The median grain size (D50) of GC 20 at RM 4.66 was 275mm and of GC 21 at RM 4.48 was 180mm. The pebble count data are included in Figure 89 of the Reach 4 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5). The analysis indicates that at the 2-year modeled discharge, the channel's shear stress is expected to mobilize boulder-sized material through the upstream half of the reach and cobble-sized material in the downstream half. The reduced shear stress in the lower half of the reach is reflected in the development of floodplains and split-flow conditions within the available space on the valley floor.

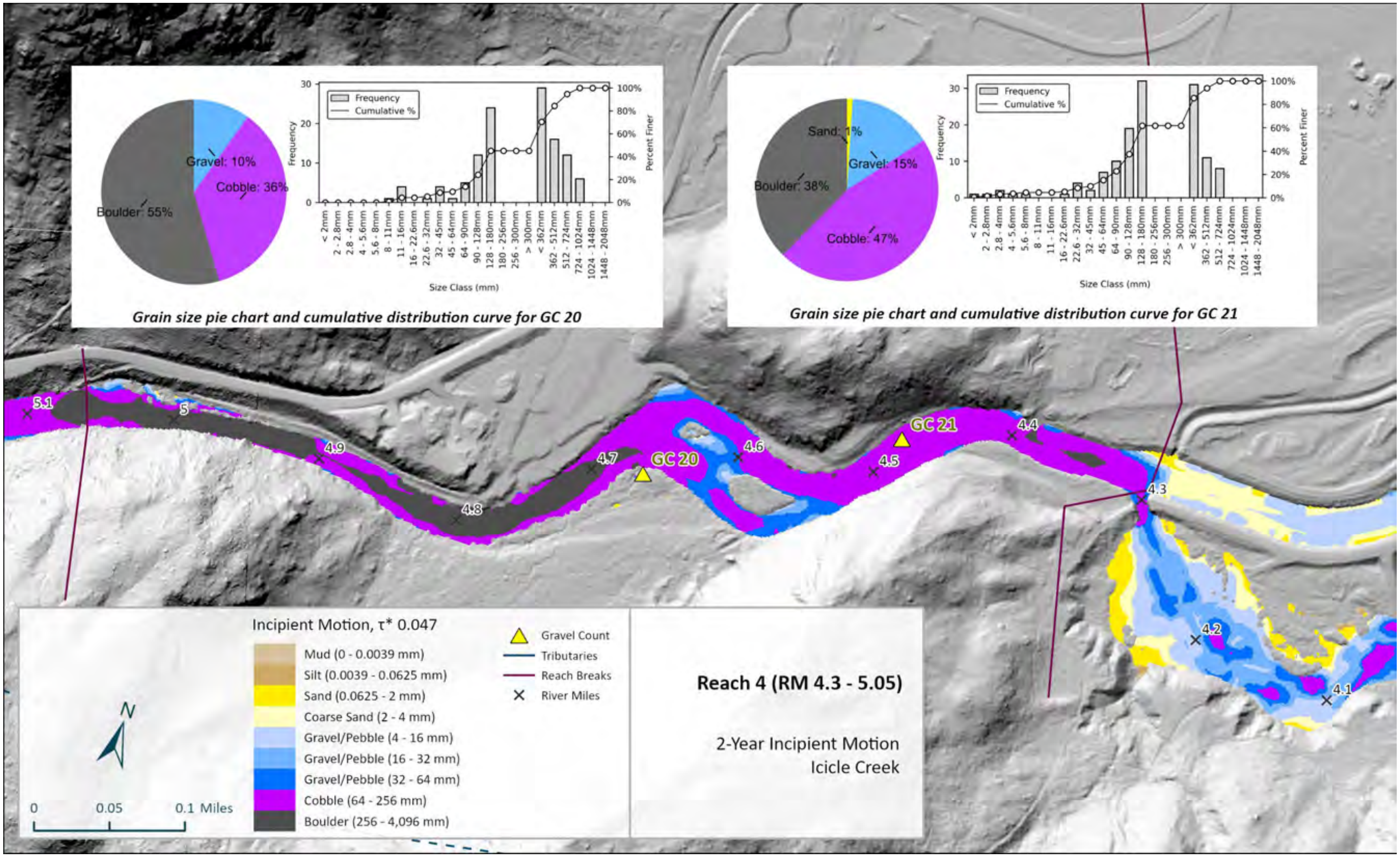

Figure 89. Reach 4: incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge). Includes location and grains size data of the GC 20 and GC 21 pebble counts (2024 survey).

3.4.3 Large Wood Material

The habitat survey conducted in summer 2024 recorded 82 individual pieces of large woody material (LWM) and 6 log jams (accumulation of >3 LWM) within the bankfull channel, for a combined total of 144 observed pieces (Figure 90). Of the 82 individual pieces; 8 classified as large size class (>20-inches diameter and >35-feet long); and 22 as medium size class (12 to 20-inches diameter and at least 35-feet long). All 6 log jams in Reach 4 have multiple pieces of medium and large LWM. Reach 4 has 87 pieces of wood per mile (count includes medium and large LWM as individuals and in jams), which does meet the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state ((Fox & Bolton, 2007; Appendix A). However, none of the wood observed at the time of assessment was within the wetted channel, indicating that the river tends towards moving wood within this reach, rather than wood acting as a geomorphic driver.

The large wood in Reach 4 is racked on boulders, or the front of islands and bar tops. Racked LWM often is not in contact with the channel at low-flow conditions. However, some of the LWM jams provide habitat uplift, especially in the split-flow section of the reach.

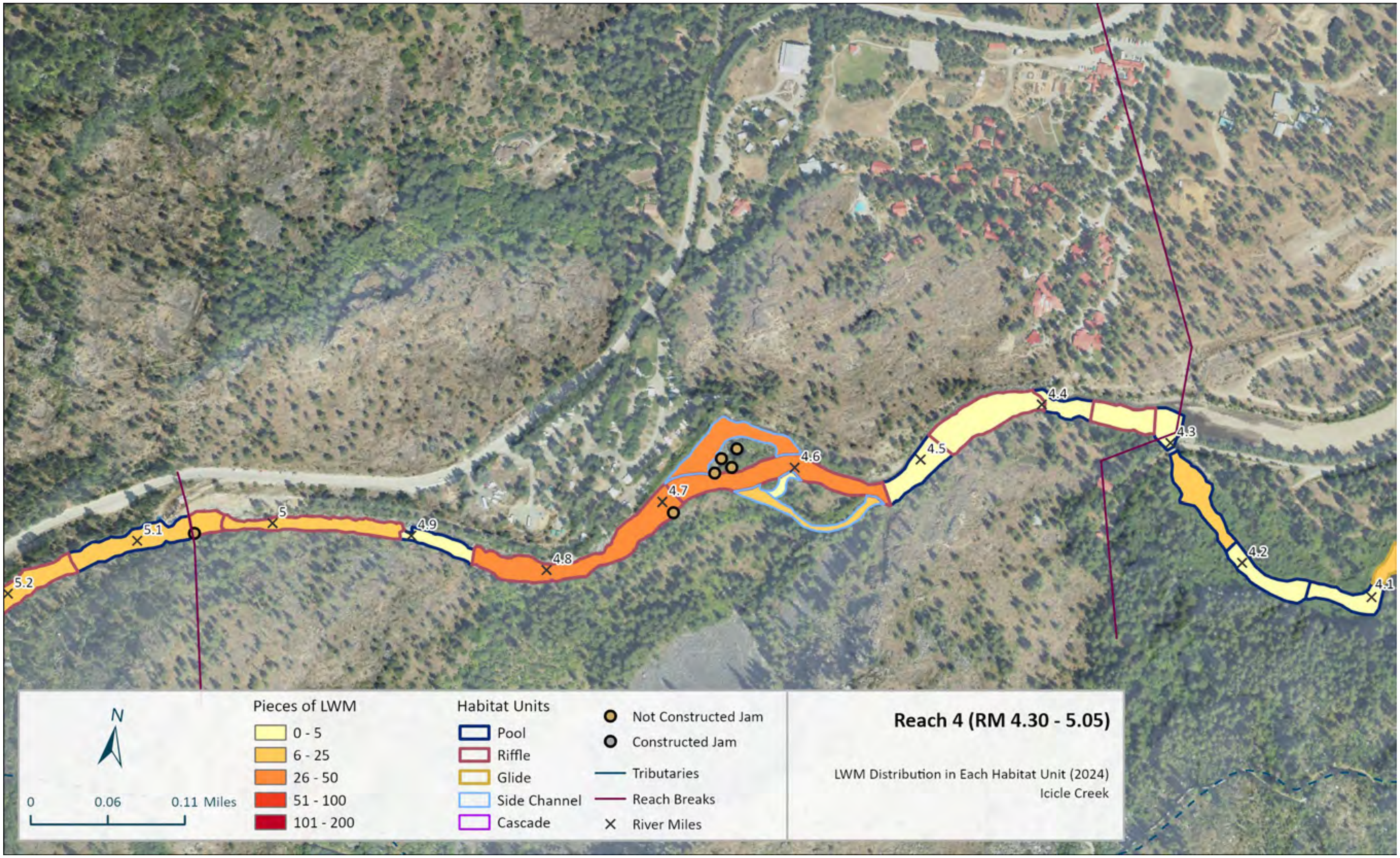

Figure 90. Reach 4: Large wood distribution (pieces per mile per habitat unit) map and surveyed habitat units (2024).

3.4.4 Vegetation

Riparian vegetation in Reach 4 is naturally sparse on the bedrock hillslopes, with scattered ponderosa pine of various age classes and narrow bands of riparian shrubs (alder and dogwood) and small trees (pine and cedar) along the stream margin. The fan surface on river-right midway through the reach is more heavily vegetated and is also dominated by ponderosa pine along its higher surface. The riparian zone here is wider and more densely vegetated with willows, dogwood, alder, with some cottonwood and cedar. Vegetation on river-left at the upstream half of the reach is heavily impacted by the RV Park, the road, and the diversion infrastructure and access road. Reed canary grass occupies many low surfaces. Typical conditions are shown in Figure 90. Large overstory trees are present in clusters of Reach 4 around RM 4.4 and at RM 4.65. Other than those, there is relatively little in the way of large riparian trees available for instream recruitment. A map showing vegetation height is provided in Figure 92, with an aerial in Figure 93. The map reveals the presence of only few large and very large trees along the banks and across the floodplain. The riparian vegetation provides limited stream shading across the reach due to a wide channel and smaller trees. Exceptions include the river-right side channel at RM 4.6 and at the upstream end where large trees are capable of providing shade to the narrower confined channel.

Figure 91. Typical channel and vegetation conditions in Reach 4 near RM 4.5 (August 2024).

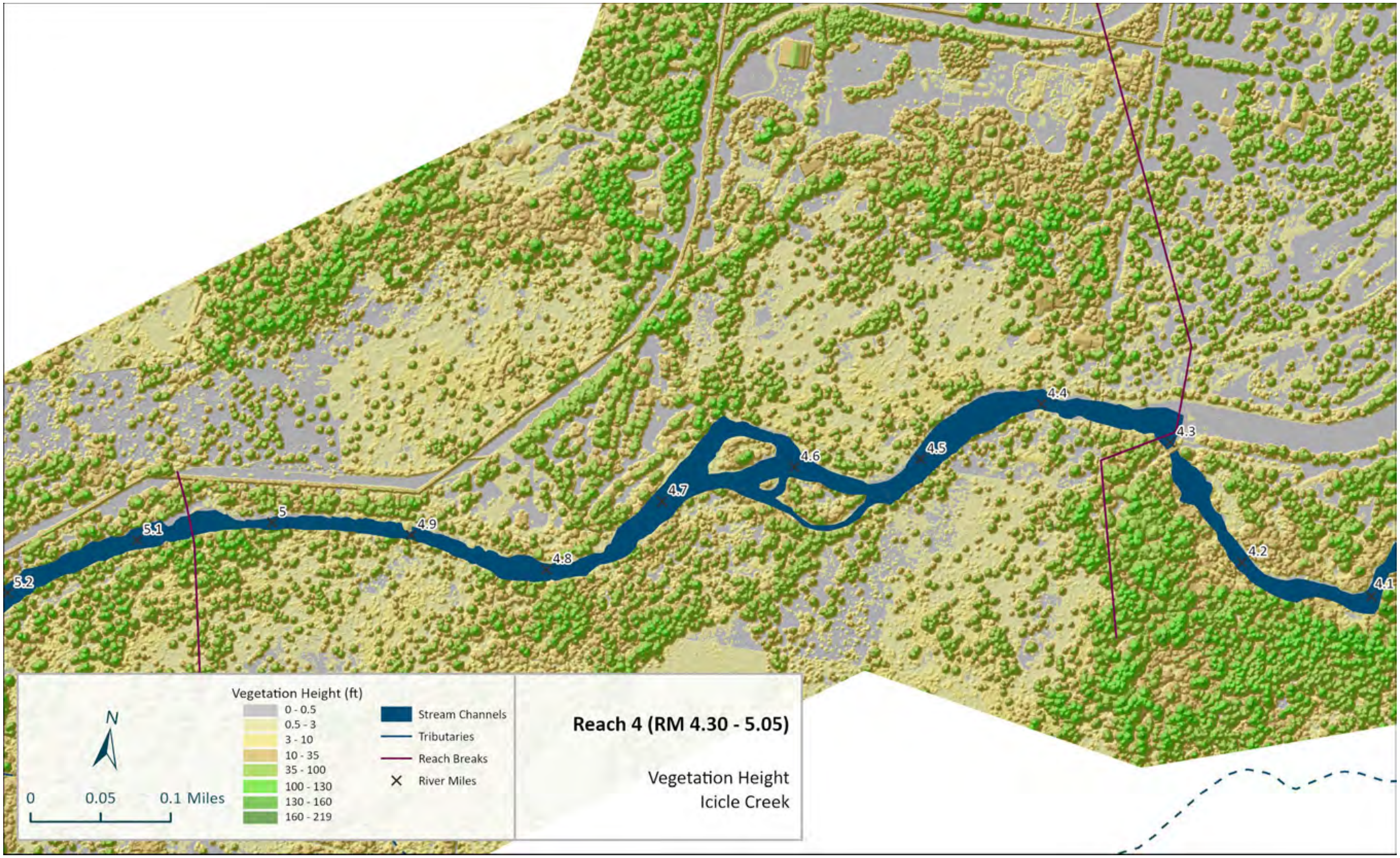

Figure 92. Reach 4: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 93. Reach 4: Map of aerial imagery for vegetation identification (ESRI 2023).

3.4.5 Human Alterations

Anthropogenic features in Reach 4 are mapped in Figure 95. The features with the largest impacts on habitat and stream processes are the RV Park midway through the reach and the water diversion at the upstream end. The water intake is a combined intake for the Cascade Orchard Irrigation District and the LNFH (Figure 94) and is located at approximately RM 5.05. The Cascade Orchard Irrigation District holds water rights for 12.4 cfs during the irrigation season (approximately May 1 to October 1) and the LNFH is permitted to divert up to a total of 56.9 cfs (42 cfs of surface water rights and 14.9 cfs of groundwater withdraw rights) (Muir et al., 2023). As of May 2025, the COIC diversion moved to RM 1.9 (personal communication, Ingrid Ekstrom, Wa. Department of Ecology, October 2025)

The diversion and intake have been recently updated to replace/reconfigure a former low-head dam. The new structure includes a constructed boulder step-pool channel set within low banks constructed as roughened channels that accommodate higher flows. This configuration holds grade at the top end for the diversion intake located along the river-left bank. The pipeline runs downstream parallel to the channel buried in an armored floodplain bench. The pipeline extends downstream through the RV park as a 24-inch steel pipe resting on concrete footings (Figure 96). There is a fish screen and return channel to Icicle Creek near RM 4.75 (Figure 97). Due to this diversion, the left bank is armored with large boulder riprap from RM 5.0 to 4.77, which impairs natural lateral channel dynamics, riparian vegetation establishment, and channel margin habitat.

Figure 94. Cascade Orchard Irrigation District and the LNFH shared diversion and intake structure at RM 5.05 (August 27, 2024).

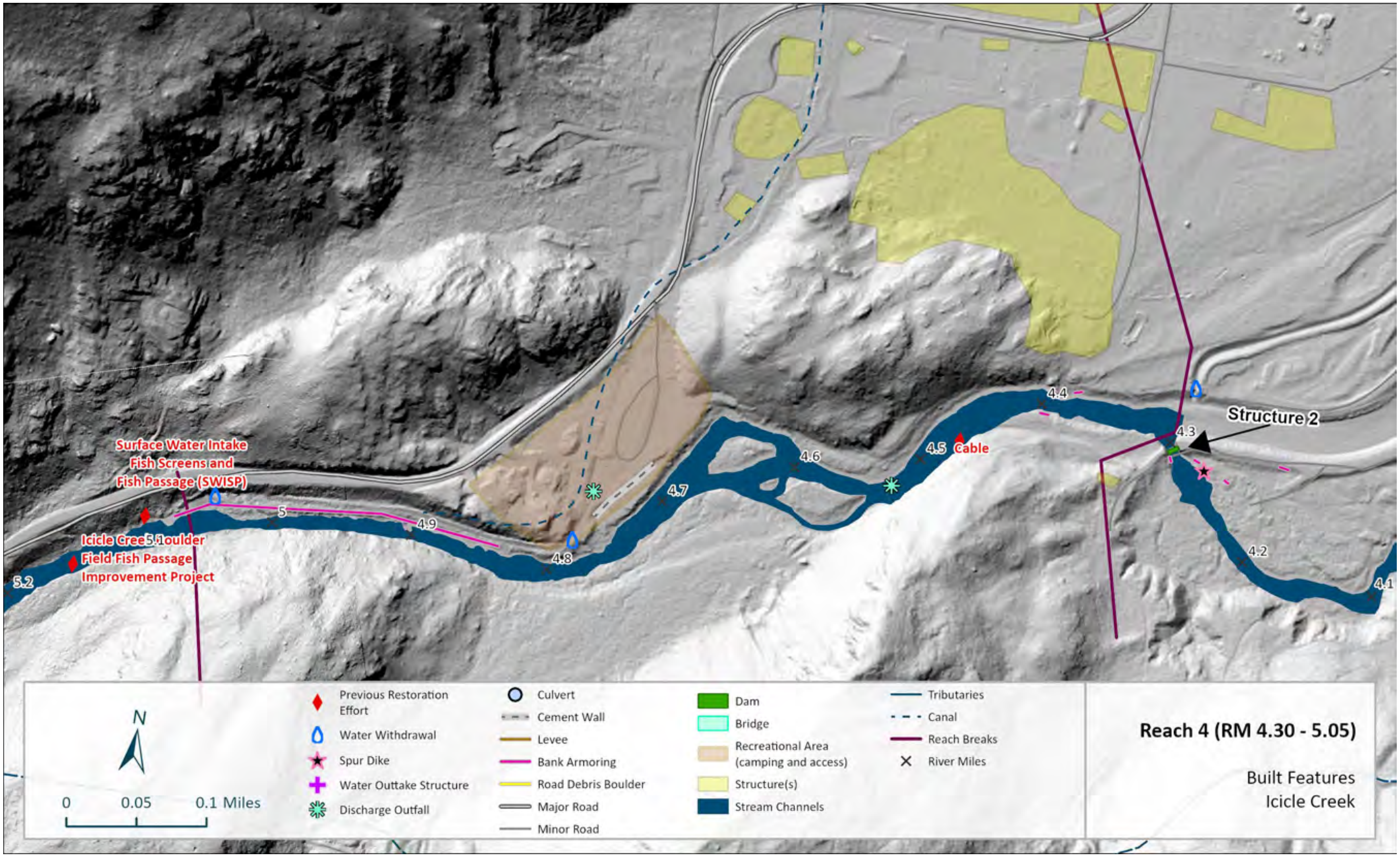

Figure 95. Reach 4: Mapped anthropogenic features (2024).

Figure 96. The 24-inch steel pipe running through the Icicle Creek RV Park in Reach 4 at RM 4.73 (August 27, 2024). Right: Possibly a surge tank or other related pipeline structure at RM 4.78 (August 27, 2024).

Figure 97. Left :Fish screen and Right: return channel near RM 4.75 (August 27, 2024).

From RM 4.64 to 4.89 lies the Icicle River RV Park, a developed area that occupies much of the available floodplain and terrace surface. This area has been modified with concrete landings, armored retaining walls along the channel, paved areas, vegetation clearing, and is at least seasonally occupied by RVs and small mobile homes.

There are no obvious human features downstream of the RV Park until near RM 4.4 where there are structures (restaurant, cabins) up on the left hillslope, with some remnant concrete structures along the left bank at a bedrock outcrop. These have relatively little effect on the channel today. Between RM 4.34 and 4.35, there were several instream fish arrays.

3.4.6 Recommended Actions

Reach 4 has limited restoration opportunity given the confined and moderately steep channel and adjacent infrastructure including the road, a diversion point, a pipe buried next to the river, the RV Park, and residences. There are nevertheless a few areas where large apex log jams could enhance lateral dynamics and help create or maintain split flow conditions and vegetated islands. Other habitat wood could be placed in existing pools and glides for cover and complexity. There is one area on river-right midway through the reach where side-channel connectivity could be enhanced, but access would be challenging. There are numerous riparian areas with cleared or partially-cleared vegetation where replanting of trees would benefit long term shade and wood recruitment; most of these would require cooperation from willing private landowners. A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities)

3.5 ICICLE CREEK REACH 5 (RM 5.05 – 6.27)

3.5.1 Overview

Reach 5 is 1.22 miles long and extends from RM 5.05 to 6.27 at the Icicle-Peshastin Irrigation Canal diversion structure on one side of the channel and the City of Leavenworth diversion on the opposite side. The channel is confined although it expresses split-flow conditions around boulder islands in two sections. The average channel gradient in Reach 5 is 3.4% with step-pool, boulder-dominated riffle-pool, and boulder cascade morphology (Figure 98). Riparian vegetation is naturally sparse on the bedrock hillslopes and highly affected by various human uses throughout the reach. Human alterations are significant and include diversion structures, residential development, multiple bridges, and recreational infrastructure. Icicle Creek Road parallels the channel on river-left and occupies the adjacent bank in several locations. Landownership is largely private with some Wenatchee National Forest land near the downstream end and Peshastin-Icicle Irrigation District property in much of the upstream portion of the reach.

Figure 98. Representative photo of boulder riffle in Reach 5 near RM 5.38 and contributing hillslope boulder colluvium. (August 26, 2024)

3.5.2 Channel and Floodplain Geomorphology

Table 15. Reach 5 metrics.

Reach 5												
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
1.22	5.05-6.27	3.40%	1.05	Riffle	90	Confined	Boulder	25.5%	3.1%	50.4%	18.5%	2.5%

In Reach 5 the channel is relatively high gradient and single thread in form, except in the middle section between RM 5.36-5.78 where split-flow channel form occurs (Figure 99). The multi-threaded section has slightly reduced gradient, increased valley floor width, and increased channel complexity. Although the mid-reach section has split-flow form, minimal lateral channel processes are underway due to the boulder composition of the island. Adjacent hillslopes provide colluvial boulders and debris material that influence channel form. Otherwise, the channel is confined by fans, terraces, and hillslope that include bedrock exposures and boulder talus draped slopes. Channel morphology varies from boulder step-pool, boulder riffle-pool, and boulder cascade, depending on gradient, width of confinement, and composition of hillslope contributed boulders (Figure 100). Colluvial boulders in Reach 5 range from large to massive. The Icicle “Boulder Field,” a long, steep, confined boulder cascade, is reported to affect fish passage near RM 6.05. However, the large boulders sourced from adjacent hillslopes produce localized areas of complexity around stable features in the channel that maintain pools, rack large wood, and split flow. Habitat and geomorphic complexity in this reach is maintained by the size and distribution of large -massive boulders.

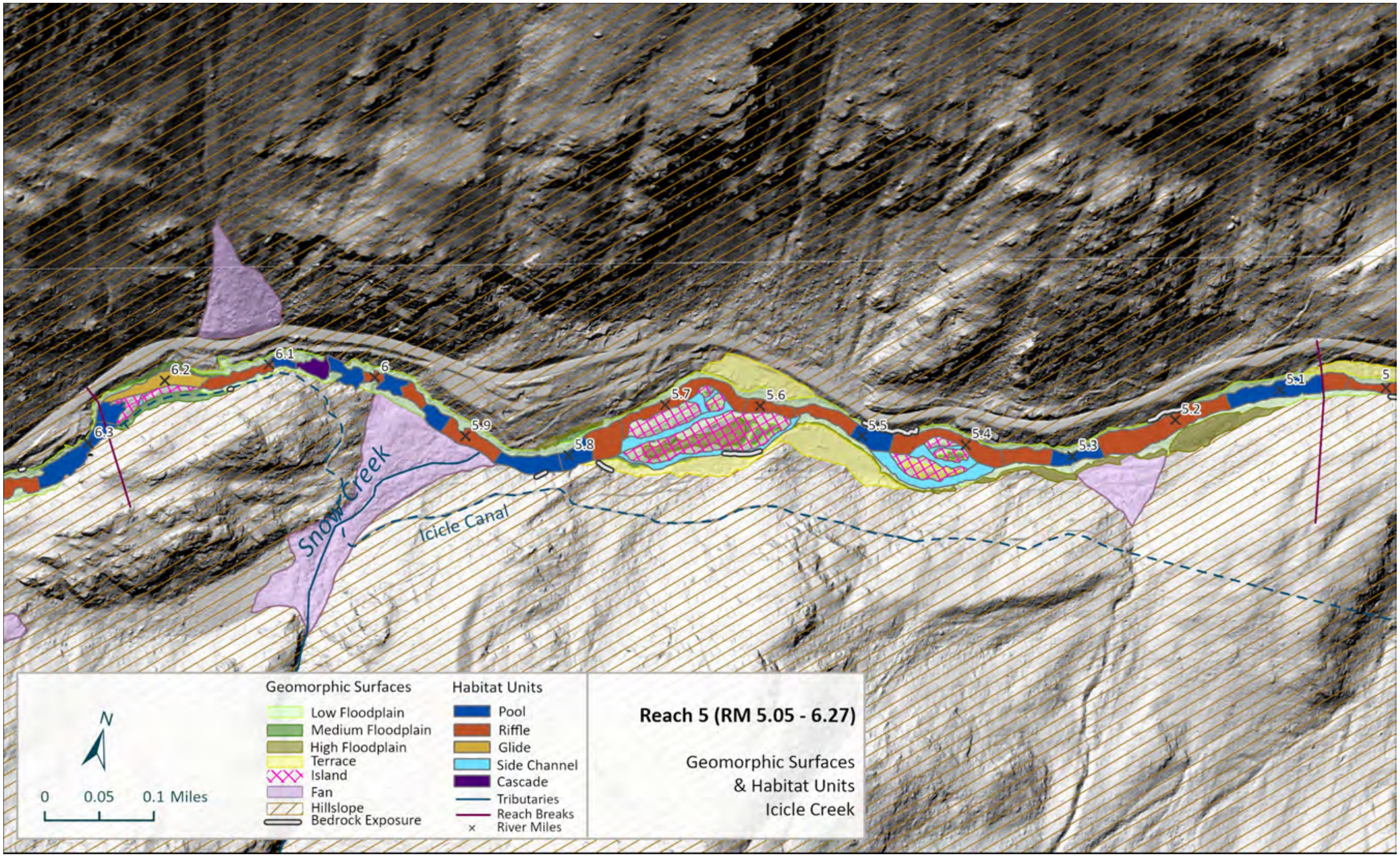

Figure 99. Reach 5: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

Figure 100. Left: Icicle Creek "Boulder Field" near RM 6.05. Right: Boulder-riffle at downstream end of split-flow section at RM 5.36. (August 6, 2024)

Snow Creek and its alluvial fan join Icicle Creek on river-right near RM 6. Snow Creek contributes surface water and sediment to the channel. Floodplains in Reach 5 are narrow discontinuous strips or mid-channel islands that support riparian vegetation and forests on the valley floor. Floodplains are composed of flood-event deposited alluvial boulders and cobbles and/or sets of accumulated hillslope colluvium that vegetation is establishing on. The mid-channel island surfaces are also composed of boulders and debris, relatively stable, and vegetated with conifer forests. Terrace surfaces occur on both sides of the valley floor in Reach 5 near RM 5.6.

Channel substrate in Reach 5 is primarily composed of large to massive boulders with pockets of cobbles and occasionally gravel present at the channel margins or behind boulders (Figure 117). The large to massive boulders provide hydraulic variability/refuge and localized pools that comprise the in-channel complexity that is available in Reach 5. Sediment in Reach 5 is primarily sourced from the adjacent hillslopes and contributing fans and tributaries. Limited bedload is currently transported into the reach because of the extended backwater pool created immediately upstream of Reach 5 by the Icicle Irrigation Diversion structure.

Figure* 101*. Boulder dominated substrate near RM 5.7 (August 26, 2024).

No appropriate locations were identified in Reach 5 to complete a Wolman Pebble Count (Wolman, 1954)Incipient motion hydraulic analysis (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5) suggests that at the 2-year modeled discharge, the channel's shear stress is capable of mobilizing boulder-sized material through much of the reach (Figure 102), including in the split-flow sections. The only exceptions are short sections near RM 5.15, 5.35, and 6.2 and two of the side channels where cobble-sized material is expected to mobilize.

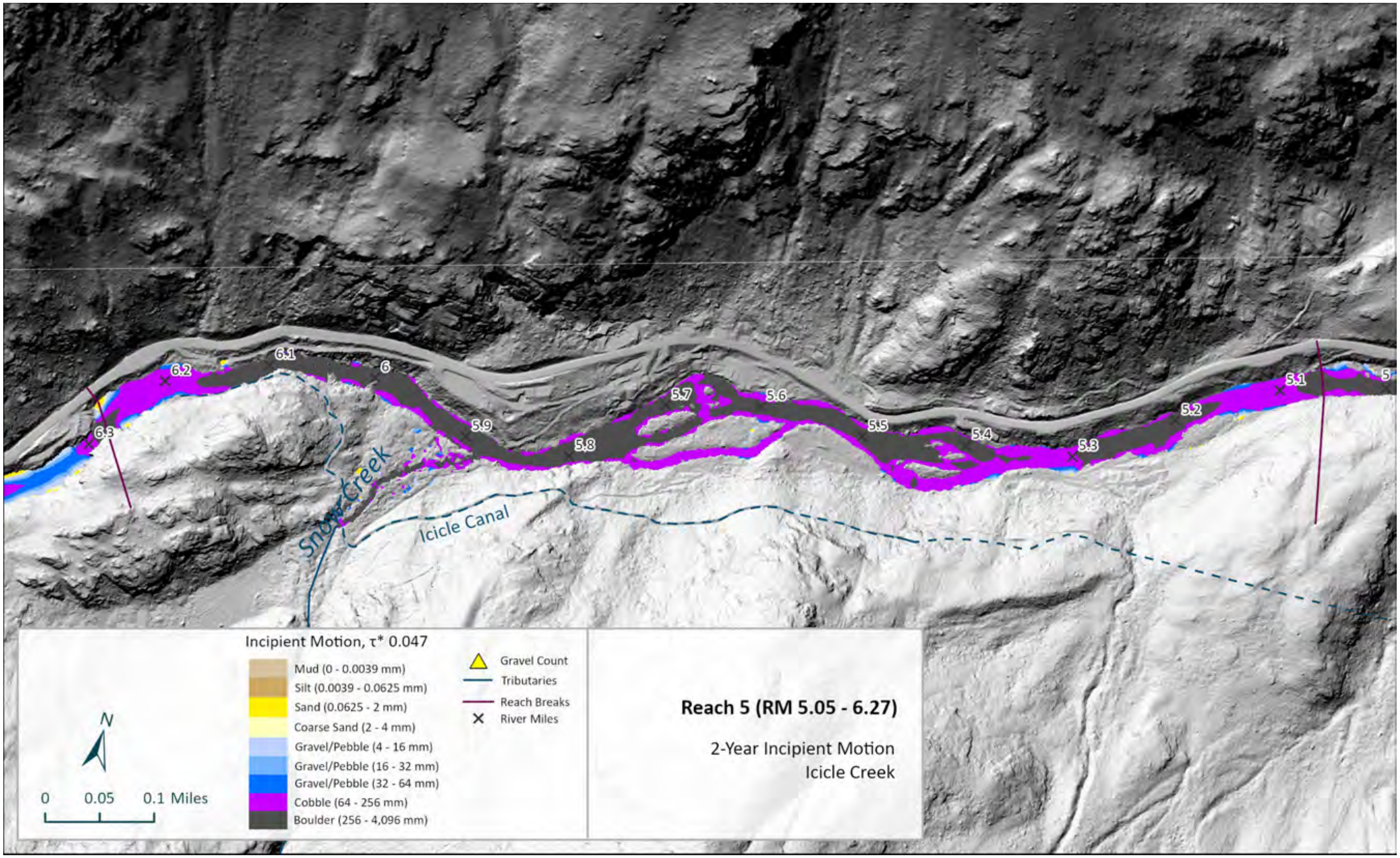

Figure 102. Reach 5: incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge).

3.5.3 Large Wood Material

The habitat survey conducted in summer 2024 recorded 109 individual pieces of large woody material (LWM) and 14 log jams (accumulation of >3 LWM) within the bankfull channel, for a compiled total of 252 observed pieces (Figure 104). Of the 109 individual pieces; 15 classified as large size class (>20-inches diameter and >35-feet long); and 38 as medium size class (12 to 20-inches diameter and at least 35-feet long). All 14 log jams in Reach 5 have multiple pieces of medium and large LWM. Reach 5 has 107 pieces of wood per mile (count includes medium and large LWM as individuals and in jams), which does meet the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state (Fox & Bolton, 2007; Appendix A). However, the high shear stress produced in the reach does not allow for retention of LWM. Large wood does not influence geomorphic processes in this reach. The wood that is present is usually draped along the channel margins or temporarily racked atop boulders or bedrock.

Most of the existing LWM in Reach 5 is racked on boulders, the front of islands, or discarded along the channel margin – with limited interaction with the channel during low-flow conditions. While the presence of large wood can enhance local aquatic habitat conditions, the high stream energy produced in Reach 5 limits the influence LWM has on geomorphic processes. A LW jam racked on boulders at the head of an island at RM 5.74 (Figure 103) does contributes cover to enhance habitat complexity of the boulder-created pools. Recruitment of large wood in Reach 5 is from infall off adjacent hillslopes or islands. The quantity and potential future recruitment of large wood in Reach 5 may be limited by past and ongoing removal activities, particularly at and upstream of bridge crossing and near home development.

Figure 103. Wood jam in Reach 5 at RM 5.74 (August 26, 2024).

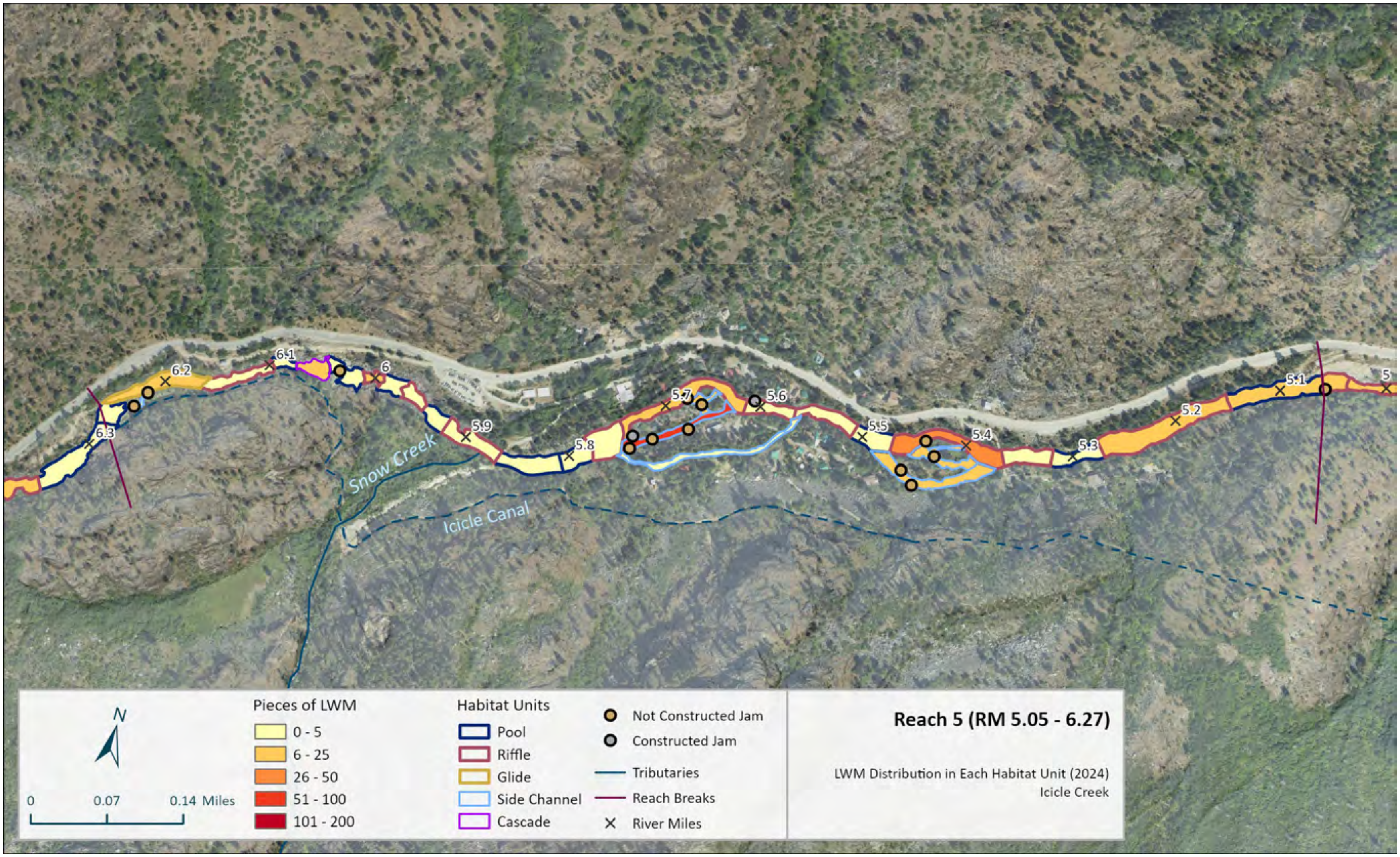

Figure 104. Reach 5: Large wood distribution (pieces per mile per habitat unit) map and surveyed habitat units (2024).

3.5.4 Vegetation

The density, size, and composition of riparian vegetation vary considerably along the reach depending on confinement, substrate, and human impacts. The vegetated riparian buffer is narrow along hillslope contacts and sparse in areas dominated by bedrock. Some riparian areas along the roadway on river-left are completely devoid of vegetation due to the road, bank armoring, and side-cast material, especially at the upstream end. A wide denser vegetated buffer does occur along the right margin at the Snow Creek fan. Large trees and riparian shrubs are generally present elsewhere although they are heavily impacted by residential and other development. The overstory tends to be dominated by ponderosa pine, with many western red cedars and some cottonwoods along channel margins, and occasional Douglas fir and quaking aspen. The understory is mostly willow, alder, dogwood, and maple. Willows grow along the channel margins and are occasionally located among instream boulder clusters. See Figure 105 for an example photo. Most of the trees appeared to have a maximum age of approximately 80 years, with occasionally larger trees. There are large trees available for potential recruitment to the river via infall, since lateral processes are confined.

A map showing vegetation heights is provided as Figure 106, with an aerial in Figure 107. Although there are large trees, they rarely exceed 130 feet tall, and much of the riparian is dominated by shrubs or is cleared. Many of the larger trees do provide shading to the channel, especially in confined sections or along smaller side channels where canopy cover is most effective.

Figure 105. Typical mix of riparian vegetation, where buffers exist, in Reach 5 (RM 5.6, August 2024).

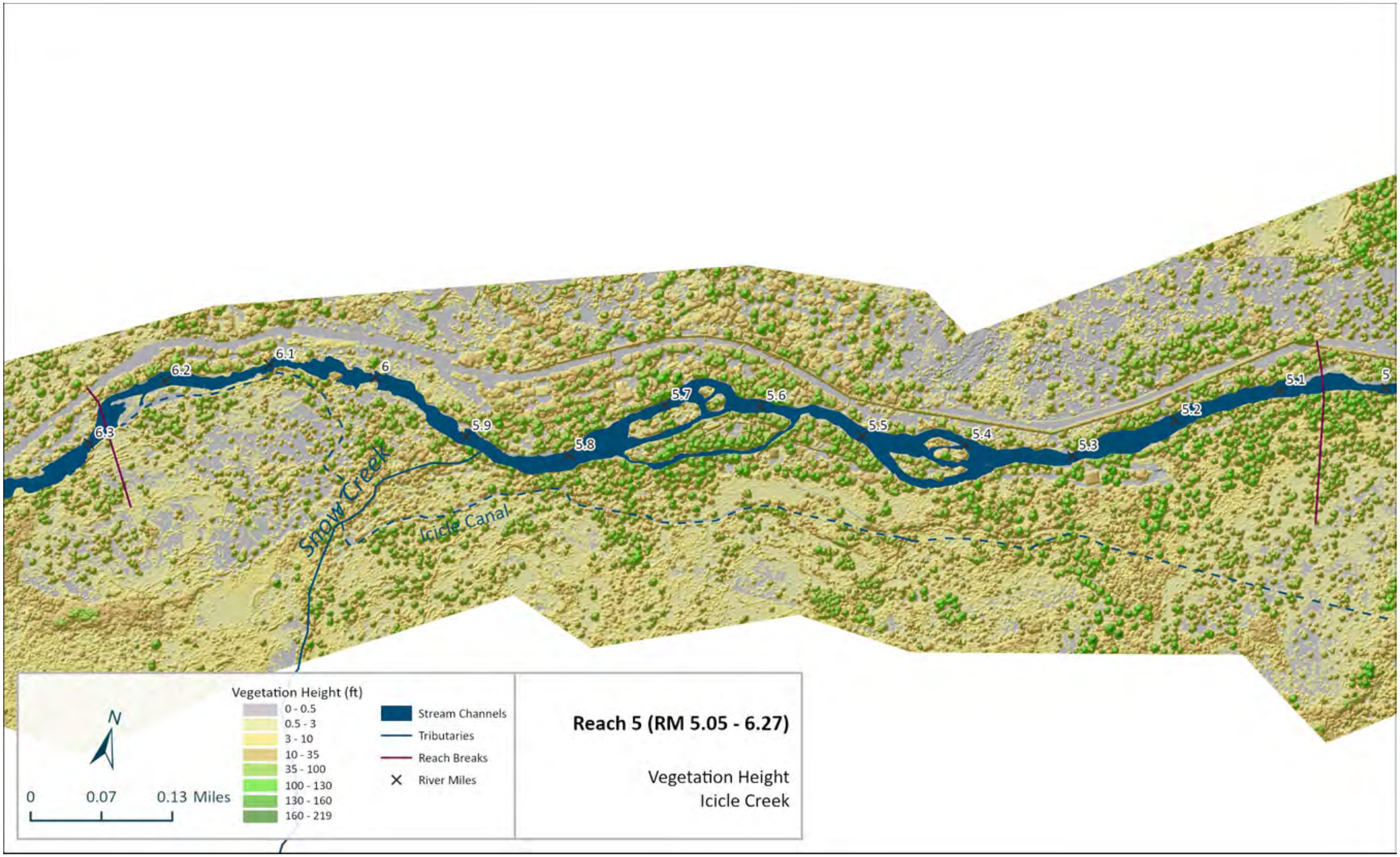

Figure 106. Reach 5: Map of vegetation height classification analysis (LiDAR – based analysis).

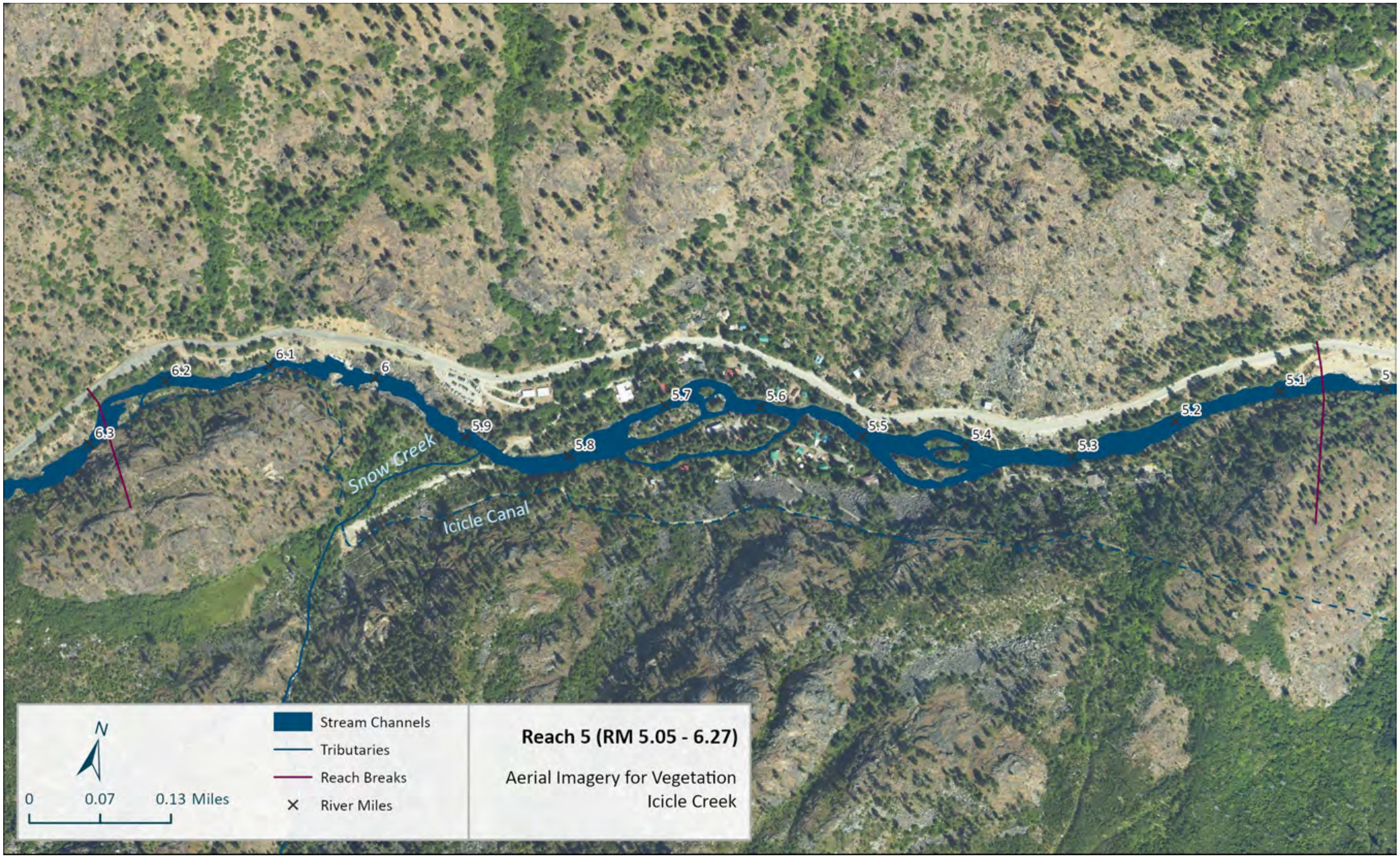

Figure 107. Reach 5: Map of aerial imagery for vegetation identification (ESRI 2023).

3.5.5 Human Alterations

Human alterations in Reach 5 impact channel processes, floodplain connectivity, and water quality. A map of anthropogenic features identified in this reach is provided in Figure 108.

Reach 5 is bordered by numerous private residences with homes situated along the banks and on islands throughout the downstream half of the reach. Some of the structures are very close (e.g. within 20 feet) to the channel, with numerous outdoor living and recreation areas on the channel banks. There are 2 road bridges across the main channel used to access private property on the south side of the river, including at RMs 5.37 and 5.62. There are 3 additional vehicle access bridges across side-channels. The bridge at RM 5.62 has center pillars in the main channel (Figure 109). At least one of the side-channel bridges also has center footing supports. Due to natural confinement, the bridges have relatively little impact on lateral channel migration, although there are localized impacts to the narrow floodplain bench at a couple of the bridges and the armoring associated with the footings (and bridge structures themselves) impairs channel margin habitat and riparian vegetation.

Near RM 5.9, the Snow Lakes Trailhead parking lot is located above the channel on river left. This area includes a trail and light vehicle bridge across the river at RM 5.86, public toilets, and stormwater catchment ponds. The left bank is dominated by boulders from RM 5.7 to RM 6.15, most of it comprised of either riprap or side-cast boulders from the road cut, impairing riparian vegetation and channel margin habitat.

The boulder field is a very steep boulder cascade section of channel extending from approximately the Snow Creek Trail parking area near RM 5.95 up to past the irrigation canal access bridge to approximately RM 6.15. This section of steep channel has long been a concern for fish passage, where high velocity flow with narrow, steep drops and boulder sieves affects upstream passage. In 2022, a project was performed to break up boulders and re-arrange a portion of the boulder field to improve passage conditions, primarily along the river-left bank near RM 6.05.

From RM 6.10 to 6.27, the City of Leavenworth and the Icicle Peshastin Irrigation District (IPID) have water diversion infrastructure (Figure 110). IPID diverts approximately 117 cfs, while the City diverts approximately 6.2 cfs (Kaputa, 2025). At RM 6.13, the IPID facility sits atop large boulder riprap and includes an abandoned steel well casing and a 12-inch steel pipe discharging into Icicle Creek on river left. At RM 6.15, an embedded historical wooden pipe with steel banding is visible, while across the river on the right bank is the irrigation ditch spillway and a raised cement canal with steel gates. The low-head concrete diversion dam for the irrigation canal at RM 6.27 is 3-4 feet high and there is a headgate structure at the top of the canal, which lies against a bedrock wall (Figure 111). There is a screen and fish return approximately 500 feet down the canal. There was a PIT tag antenna array in the channel in this area near RM 6.15.

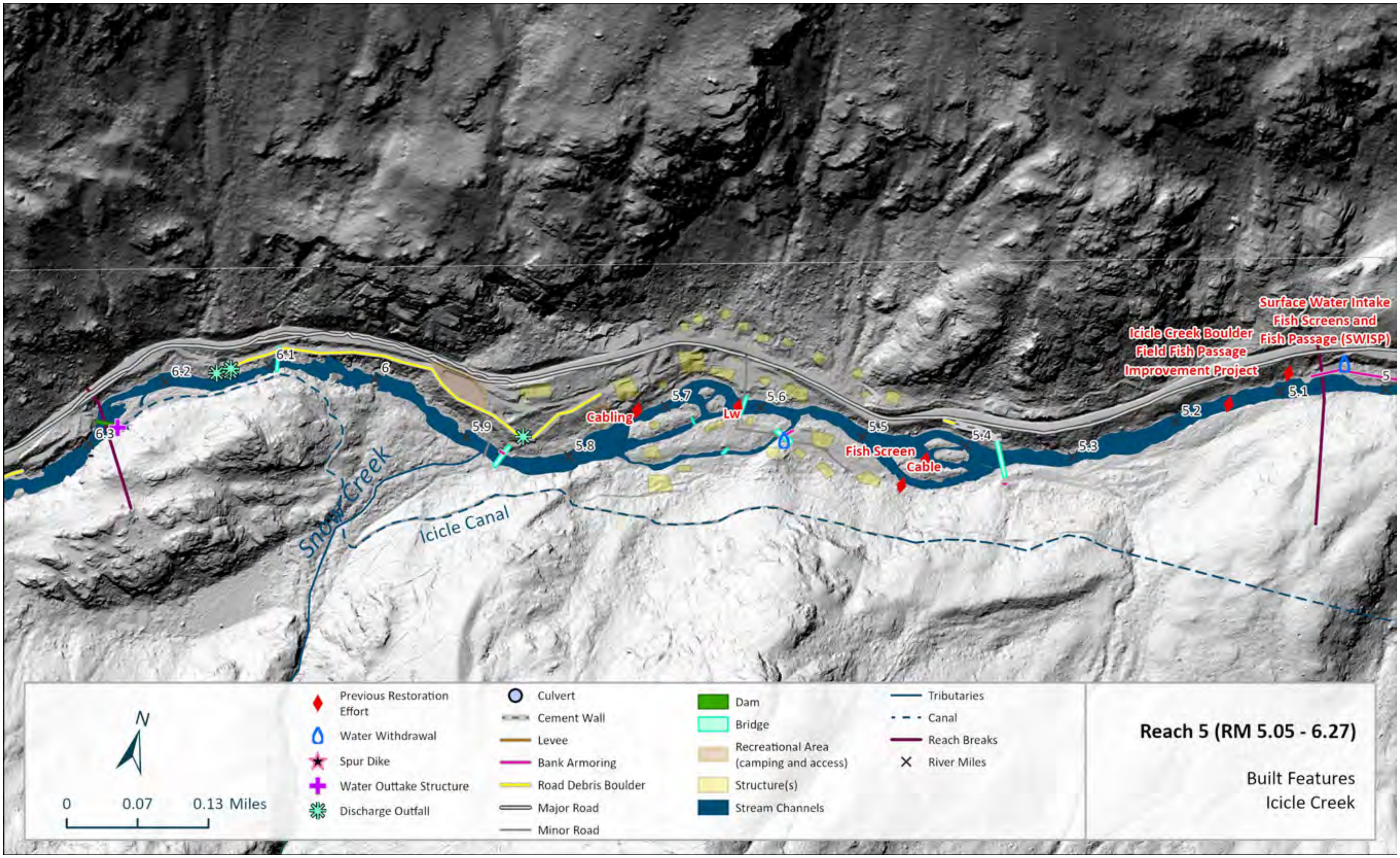

Figure 108. Reach 5: Mapped anthropogenic features (2024).

Figure 109. Bridge at RM 5.62. (August 25, 2024)

Figure 110. Icicle Peshastin Irrigation Canal on river-right and access bridge, near RM 6.14. (August 25, 2024)

Figure 111. Diversion structure for the Icicle Peshastin Irrigation Canal near RM 6.3. (August 2024)

3.5.6 Recommended Actions

There is minimal restoration potential in Reach 5 given the steep and confined channel. At the very downstream end of the reach (RM 5.1 - 5.4) there are a couple of pools that could benefit from large wood additions. RM 5.4 to 6.2 is a steep boulder-bed step-pool channel. Opportunities for large wood additions are limited here. There are occasional pools and side-channels where large wood could be added for cover and complexity; braced against large boulders, large trees, or extending down the bank. At the upstream end of the reach is the low head diversion dam for the Icicle-Peshastin Canal. This structure could be revised to include a roughened channel (constructed riffle) to improve fish passage, while maintaining the bed elevation of the hydraulic control for the diversion.

There are challenges with restoration access and potential impacts to surrounding recreational uses that may complicate restoration in this reach, including the proximity of cabins, two residential bridges, recreational infrastructure (bridge, trail parking), and the Icicle-Peshastin irrigation diversion. A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities)

3.6 ICICLE CREEK REACH 6 (RM 6.27 – 7.15)

3.6.1 Overview

Reach 6 is 0.88 miles long and extends from the Peshastin-Icicle Irrigation Diversion at RM 6.27 upstream to RM 7.15. This is a confined reach with a steep gradient of 3.82% (Figure 112). Icicle River Road runs close along the river-left bank for the entirety of the reach, with multiple occurrences of armoring along the bank and impacts to riparian vegetation. The channel is mostly a boulder step-pool channel and likely used by fish primarily as a migration corridor or for transient adult holding or juvenile rearing in the pools and pocket water eddies created by boulders. There are numerous bedrock contacts and a short bedrock canyon at the downstream end. Landownership is comprised of Peshastin-Icicle Irrigation District at the downstream end of the reach and the Wenatchee National Forest throughout the remainder of the reach.

Figure 112. Representative photo of Reach 6 at RM 7.09 (August 25, 2024).

3.6.2 Channel and Floodplain Geomorphology

Table 16. Reach 6 metrics.

Reach 6												
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
0.88	6.27-7.15	3.82%	1.01	Riffle	80	Confined	Boulder	32.1%	0.0%	66.6%	0.0%	1.4%

Reach 6 displays the highest channel gradient in the assessment area. This reach is considered completely confined by hillslopes, including bedrock bank exposures, and fans (Figure 116). Confinement and hillslope coupling are exaggerated by boulders generated while constructing the Icicle Creek Road into the hillside on river-left. The road-cut boulders were discarded down the bank on river-left in several locations or purposefully stacked as riprap for bank armoring in select locations (Figure 113). The banks of the channel in Reach 6 are steep coupled hillslopes. Channel morphology alternates between boulder and bedrock steppe-pool and boulder cascading riffles. Bedrock controlled cascades occur at RM 6.69 and 6.7. Discussion of fish passage along the boulder cascades is included in the Habitat Assessment (Appendix A). The downstream 0.1 mile is an extended pool in a canyon, which is backwatered by the downstream canal diversion dam.

Figure 113. Boulder cascades with riprap armored bank (river left) at RM 6.59. (August 25, 2024)

There are two unnamed ephemeral tributaries to Icicle Creek in Reach 6. The tributaries join Icicle Creek on river-right at RM 6.90 and on river-left at RM 7.10. Although they are listed an ephemeral, both tributaries were providing surface water flow to Icicle Creek at the time of this assessments survey (August 2024). Floodplains in Reach 6, where they occur, are narrow discontinuous strips along the channel margin composed of flood-event deposited alluvial boulders and cobbles and/or narrows sets of accumulated hillslope colluvium that vegetation can establish on.

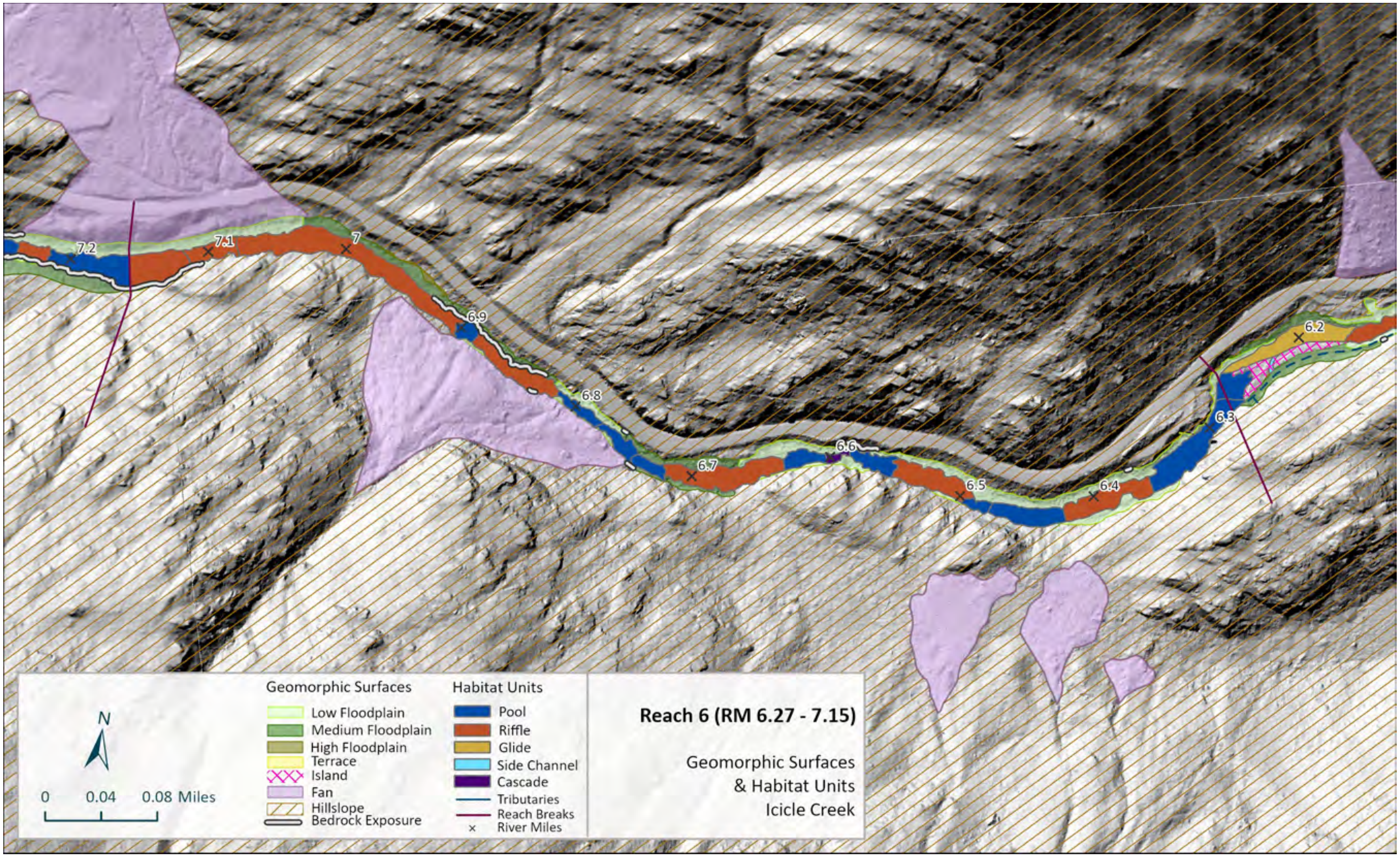

Figure 114. Reach 6: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

Channel substrate in Reach 6 is primarily composed of large to massive boulders with pockets of cobbles and occasionally gravel present at the channel margins or behind boulders (Figure 115). The large to massive boulders provide hydraulic variability/refuge and localized pools that comprise the in-channel complexity that is available in Reach 6. Sediment in Reach 7 is transported via the channel from upstream as well as sourced from the adjacent hillslopes and fans.

Figure 115. Example of boulder-dominated bedload with small pockets of cobble and gravel at the top of the channel margin behind large very large boulders at RM 6.9. (August 25, 2024)

No appropriate locations were identified in Reach 6 to complete a Wolman Pebble Count (Wolman, 1954)Incipient motion hydraulic analysis (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5) suggests that at the 2-year modeled discharge, the channel's shear stress is capable of mobilizing boulder-sized material through much of the reach (Figure 116). The only exception is the downstream backwater created pool at the downstream end of the reach located behind the Peshastin-Icicle Irrigation Diversion at RM 6.27.

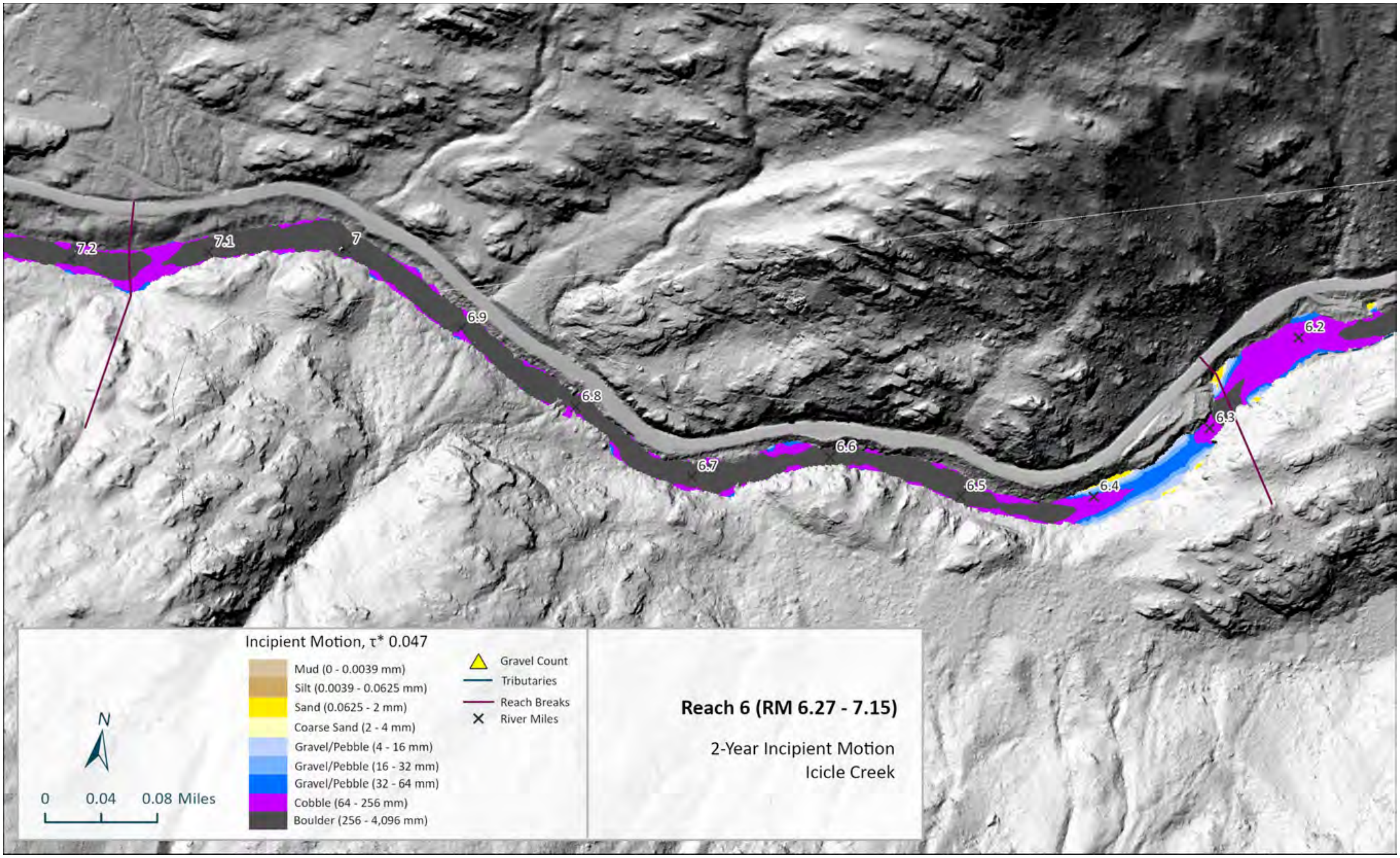

Figure 116. Reach 6: incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge).

3.6.3 Large Wood Material

The habitat survey conducted in summer 2024 recorded 89 individual pieces of large woody material (LWM) and 4 log jams (accumulation of >3 LWM) within the bankfull channel, for a total of 118 observed individual pieces and pieces in jams (Figure 118). Of the 89 individual pieces; 9 classified as large size class (>20-inches diameter and >35-feet long); and 27 as medium size class (12 to 20-inches diameter and at least 35-feet long). All 4 log jams in Reach 6 have multiple pieces of medium and large LWM. Reach 6 has 55 pieces of wood per mile (count includes medium and large LWM as individuals and in jams), which does not meet the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state (Fox & Bolton, 2007; Appendix A). However, the high shear stress produced in the reach does not allow for retention of LWM. Large wood does not influence geomorphic processes in this reach. The wood that is present is usually draped along the channel margins or temporarily racked atop boulders or bedrock.

The role of large woody material in Reach 6 is minimal. Most of the existing LWM is racked on or wedged into boulders and discarded along the channel margin (Figure 117). While the presence of large wood can enhance local aquatic habitat conditions, the high stream energy produced in Reach 6 limits the influence LWM has on geomorphic processes. Habitat and geomorphic complexity in this reach is maintained by the size and distribution of large -massive boulders.

Figure 117. LWM wedged into massive boulders and discarded along the channel margin near RM 6.8. (August 25, 2024)

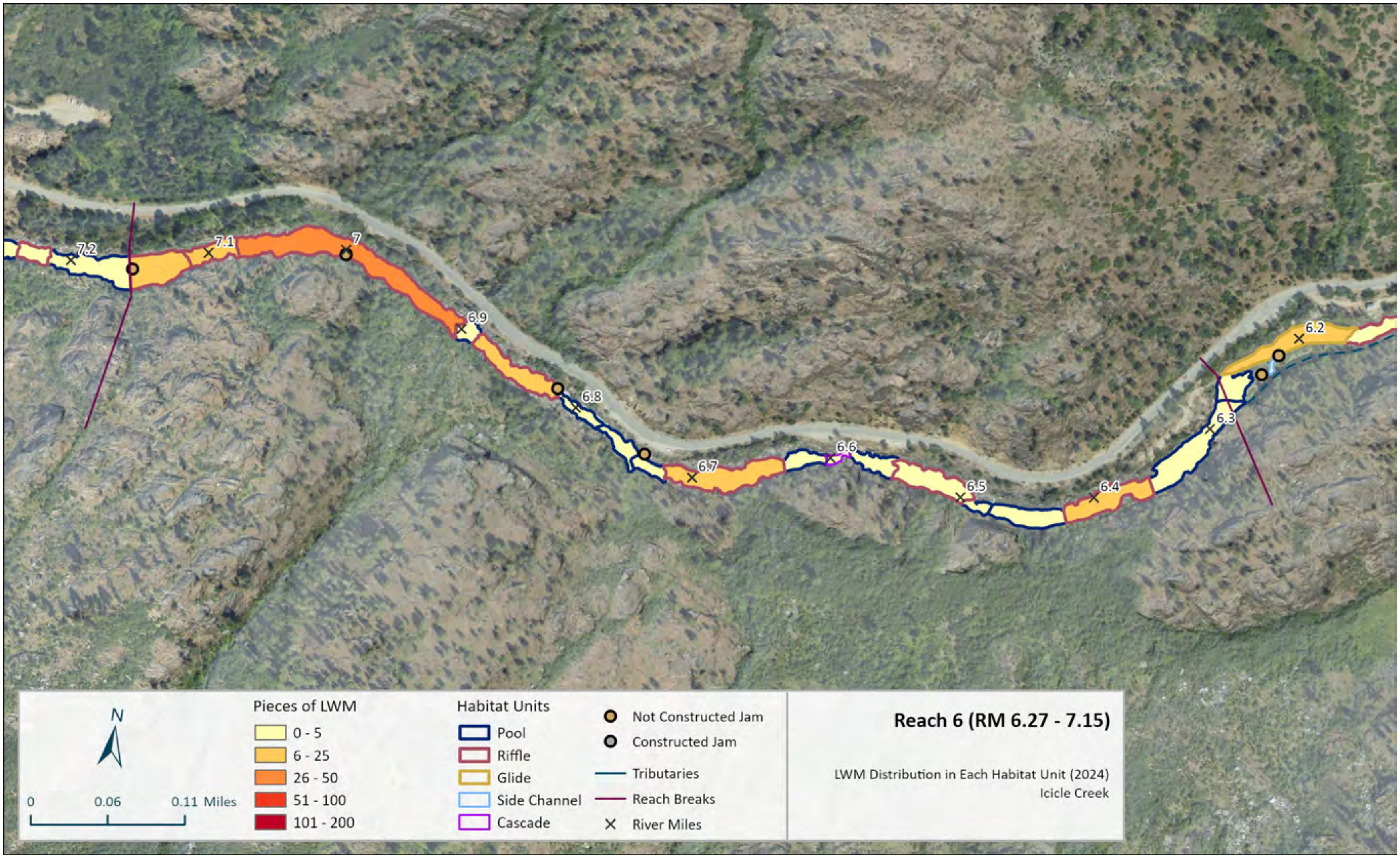

Figure 118. Reach 6: Large wood distribution (pieces per mile per habitat unit) map and surveyed habitat units (2024).

3.6.4 Vegetation

Riparian vegetation is impacted on river-left by the roadway. As a result, only young sparse or absent vegetation occurs due to the armoring and what are assumed to be large side-cast boulders from road construction. On river-right, vegetation is naturally sparse on the bedrock-dominated hillslopes although there is generally at least a narrow band of shrubs and trees along the channel margin and atop the occasional low floodplain benches interspersed between bedrock or steep alluvial fan contacts. The overstory, where it exists, is dominated by ponderosa pine, with some cedar. The understory is dominated by alder, with willows and dogwoods along the occasional low, narrow bars (Figure 119).

Clusters of large trees were noted during the surveys on the river-right bank at RM 6.4, 6.5, and 6.8, and on the left bank from RM 6.95 to 7.15. The tall right-bank trees do provide some shading to the channel. Large wood recruitment to the channel would primarily only occur via natural tree fall or during very large floods, as on-going bank erosion and channel migration is not occurring in this reach. A map showing the vegetation height size class distribution in Reach 6 is provided as Figure 120, along with the air photo map in Figure 121. The map shows the occasional clusters of larger trees but also demonstrates the overall sparse vegetation coverage dominated by smaller trees, shrubs, and grasses.

Figure 119. Representative vegetative conditions in Reach 6, at RM 6.77. (August 25, 2024)

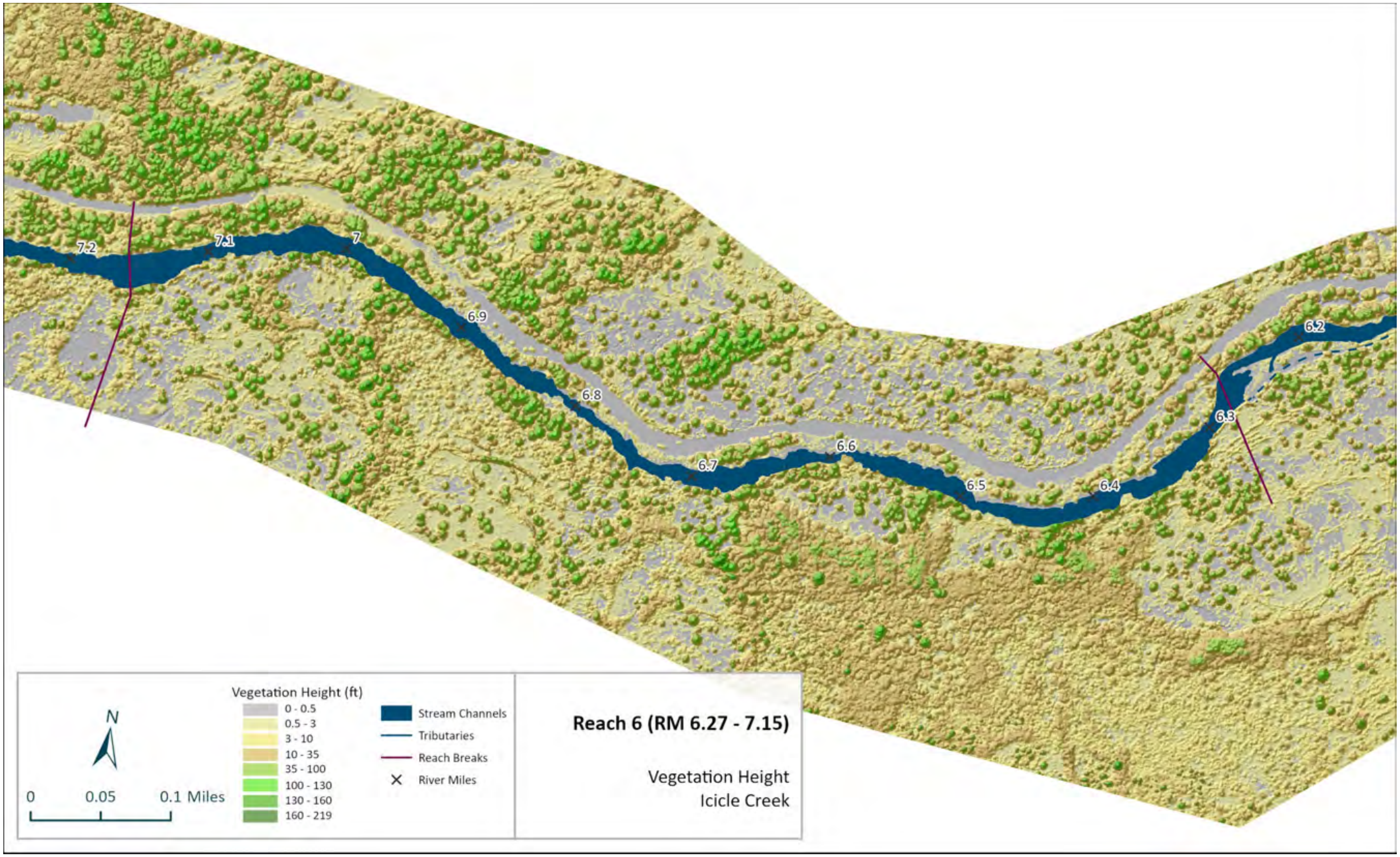

Figure 120. Reach 6: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 121. Reach 6: Map of aerial imagery for vegetation identification (ESRI 2023).

3.6.5 Human Alterations

A map of the anthropogenic features identified in this reach is provided in Figure 123. The most prominent human impact in Reach 6 is the presence of Icicle Road, which runs along the river left bank. Construction of the road has resulted in extensive deposition of road debris (boulders, rocks, and stacked riprap reinforced with cement) along nearly the entire left bank. This has limited the establishment of a vegetated riparian buffer along much of the left bank. At RM 6.82, there is a culvert beneath Icicle Road that conveys a small tributary underneath the roadway. This culvert consists of a 1.5-foot corrugated metal pipe that discharges downslope into Icicle Creek (Figure 124). Additionally, at RM 6.48, a U.S. Geological Survey (USGS) gaging station is located along the bank, along with its associated housing structure on cement footings and the cable crossing infrastructure (Figure 122).

Figure 122. Left: Culvert transferring tributary water under Icicle Road, discharging into Icicle Creek at RM 6.82/ Right: USGS gage station and housing located at RM 6.48. (August 25, 2024)

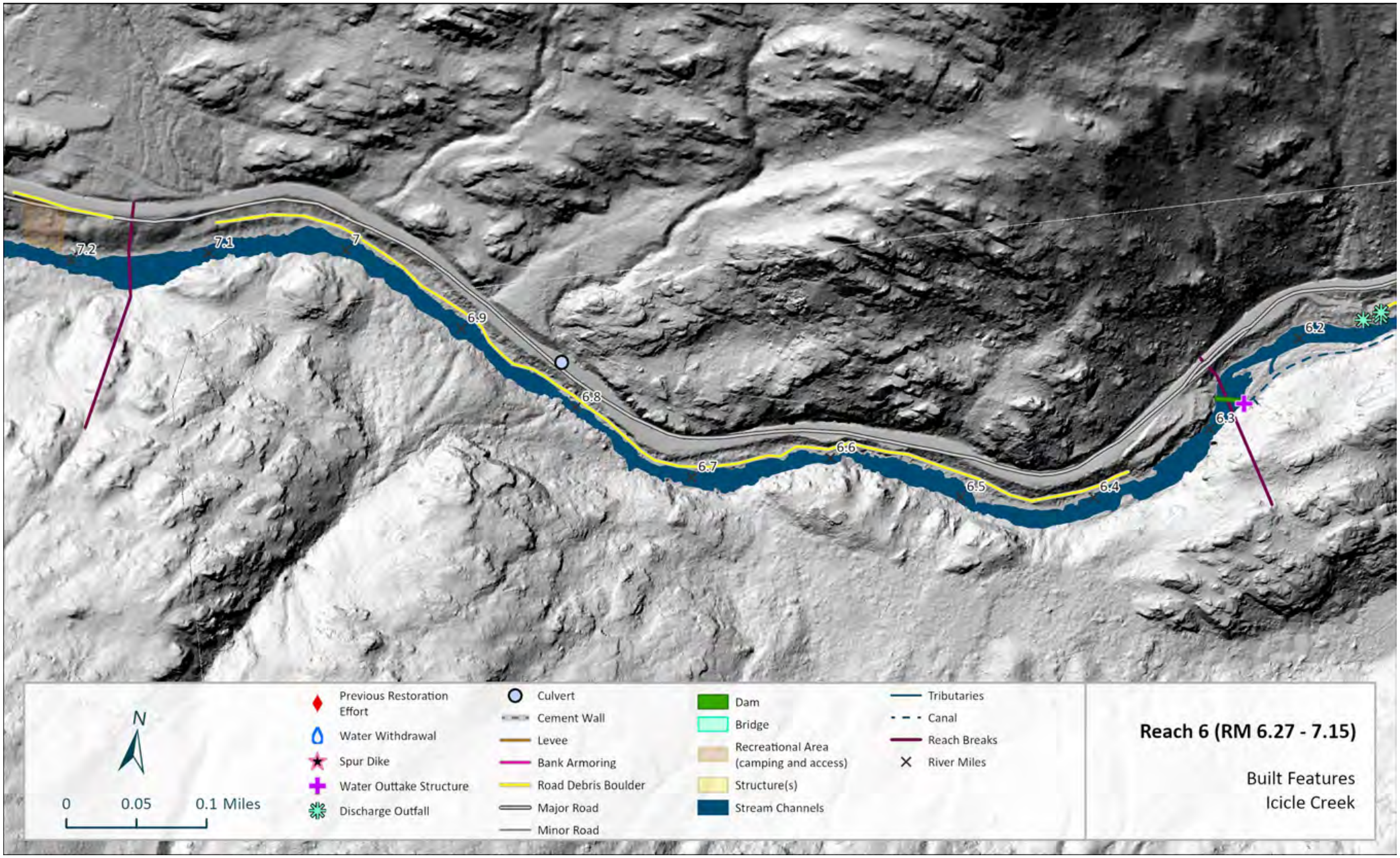

Figure 123. Reach 6: Mapped anthropogenic features (2024).

3.6.6 Recommended Actions

There is very little restoration potential in Reach 6 given the steep, confined, high stream-energy channel and the directly adjacent road. At the very downstream end, just upstream of the Icicle-Peshastin irrigation diversion dam, large wood could be added to the pool above the dam, but this is a bedrock-confined section where anchoring wood would be challenging. Replacement of the diversion structure with a roughened channel could improve passage, as discussed for Reach 5. A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities).

Otherwise, the remainder of Reach 6 is a steep boulder-bed step-pool channel where opportunities for restoration are limited. There are occasional pools where large wood could be added for cover and complexity; braced against large boulders, large trees, or extending down the bank; but wood will create very little geomorphic response due to high energy, and anchoring would be a challenge. It is expected that large wood additions to this reach will be temporary, depending on frequency of large floods. The river-left bank is directly adjacent to Icicle Road, with either riprap and/or road debris boulders covering the slopes, in some cases with very little riparian vegetation. Enhancing channel margin habitat could occur along these banks using large wood, with the caveats mentioned above regarding large wood in this steep section. Addressing the effects of the riprap/roadcut boulders would be impractical with the road remaining in its current location, so this action is not called out as a project. Similarly, meaningful riparian restoration along these banks would also be challenging due to the large boulder/debris material.

3.7 ICICLE CREEK REACH 7 (RM 7.15-8.63)

3.7.1 Overview

Reach 7 is 1.48 miles long and extends from RM 7.15 to RM 8.63, at the upstream end of the Rat Creek moraine. This is a steep, mostly confined reach, with an average gradient of 3.19%. The channel is boulder-dominated riffle-pool or step-pool in morphology (Figure 124). The less confined section at mid-reach has split-flow channels around forested islands. Bedrock confinement occurs in the downstream third of the reach, while fans and moraine deposits confine the upstream third. Riparian vegetation conditions are mostly intact, with occasional clearing associated with roads and residential development. Icicle Creek Road is mostly situated high on the left hillslope but occasionally abuts the channel. Other human impacts include private residences, a bridge, camping, and other recreational areas. Landownership is mostly private, with Wenatchee National Forest lands located along portions of the river-left bank.

Figure 124. Representative photo of Reach 7 at RM 7.55 with bedrock confinement on river-left. (August 15, 2024)

3.7.2 Channel and Floodplain Geomorphology

Table 17. Reach 7 metrics.

Reach 7												
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Partially Confined	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
1.48	7.15-8.63	3.19%	1.03	Riffle	102	Confined	Boulder	22.8%	0.0%	66.2%	11.0%	0.0%

In Reach 7 the channel is relatively high gradient and single thread in form, except between RM 7.9-8.2 where multi-threaded channel form occurs. The multi-threaded section occurs where gradient is reduced, space on the valley floor allows, and abundant sediment inputs from the Rat Creek Moraine has and continues to provide sediment to the channel immediately upstream to maintain channel and habitat complexity. Otherwise, the channel is confined at the upstream end (RM 8.3 – 8.63) by remnants of the Rat Creek Moraine on river-left and hillslope and toes on river-right (Figure 127). Downstream from RM 7.9 channel confinement is forced by fans and hillslope toes that include extended bedrock exposures along the river-left site. At RM 7.3, both banks are confined by bedrock as the channel flows through a relatively narrow canyon section. Channel morphology is dominated by boulder riffle-pool sequences that shift to sets of boulder steps and cascades with pools in the higher gradient sections (Figure 125). In portions of the reach, massive boulders sourced from adjacent hillslopes or delivered to the valley floor in the past by the Rat Creek glacier produce localized areas of complexity around stable features in the channel that maintain pools, rack large wood, and split flow (Figure 126).

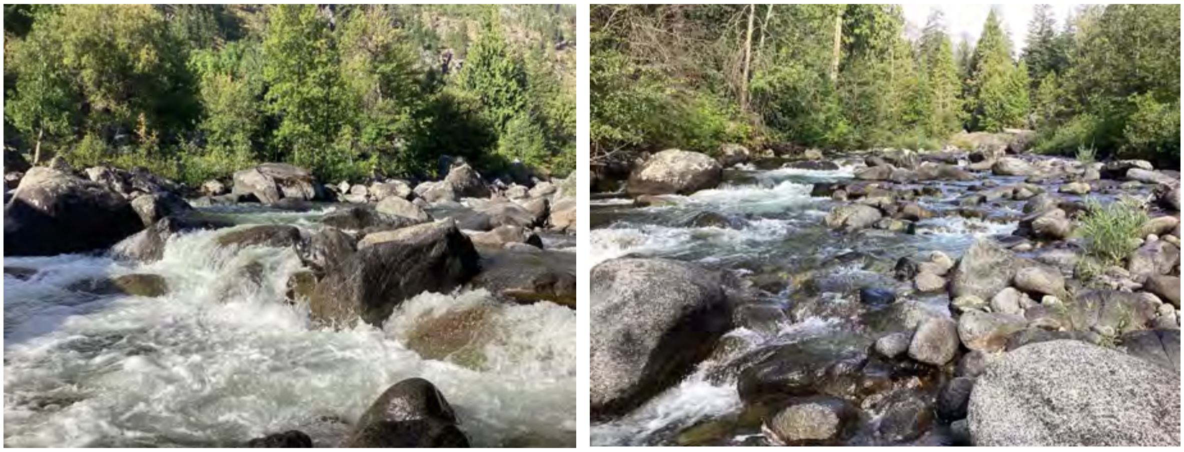

Figure 125. Left: Boulder step-pool morphology near RM 7.49. Right: Boulder riffle-pool morphology near RM 8.1. (August 16, 2024)

Figure 126. Hillslope colluvium boulders sourced from river-left side of the valley, maintain pool habitat at RM 7.86. (August 16, 2024)

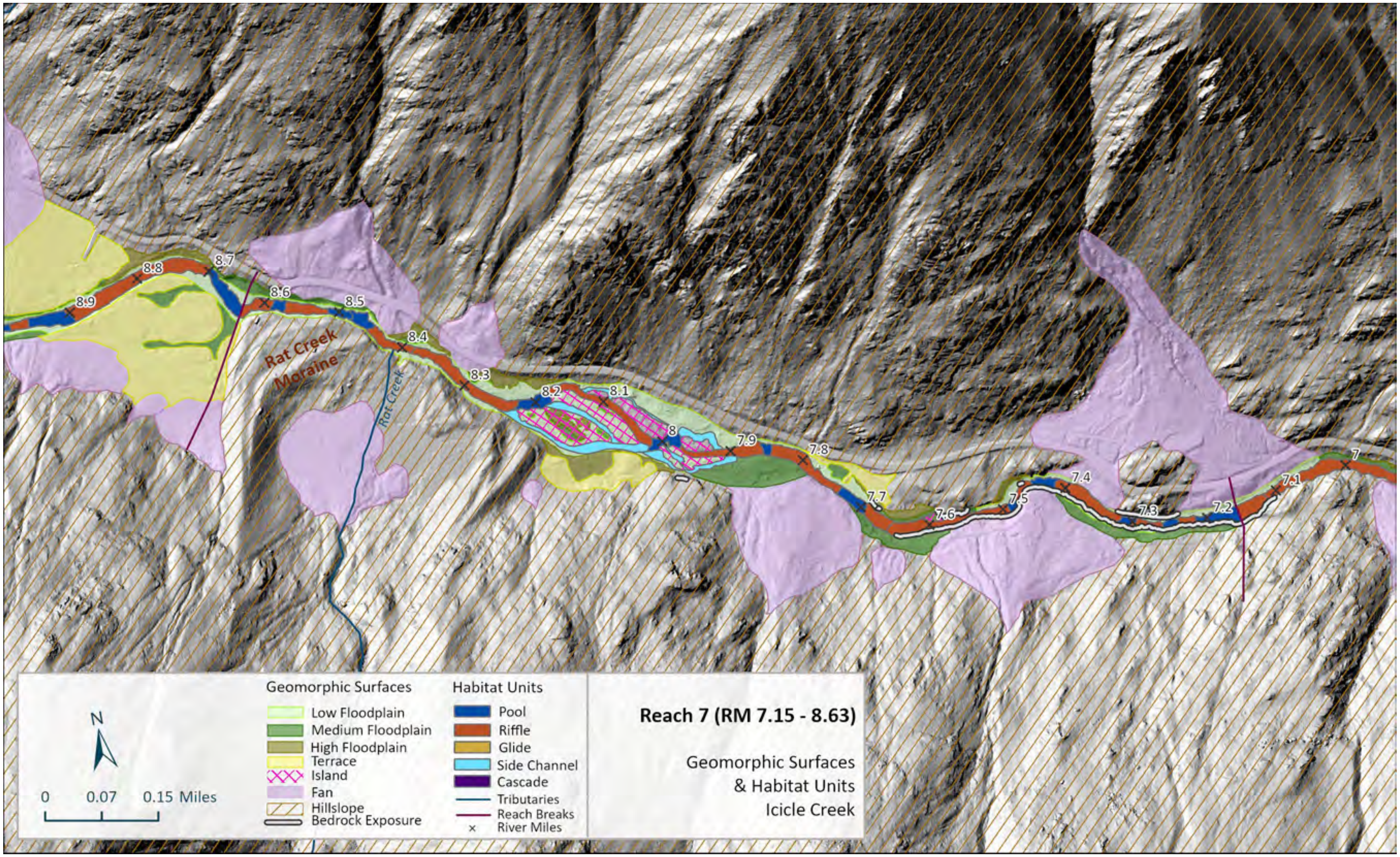

Figure 127. Reach 7: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

Rat Creek is the one perennial tributary to Icicle Creek in Reach 7. Rat Creek flows over remnants of the Rat Creek terminal moraine to reach Icicle Creek via at least two outlets. On Rat Creek, upstream of the moraine and downstream of the Rat Creek alluvial fan is a low-gradient, high-complexity, well-vegetated tributary channel that could offer high-quality off-channel habitat to the mainstem.

The floodplains in Reach 7 are inset below fan, hillslope, moraine, and terrace surfaces (Figure 127). Low floodplains (inundated ~1-5 yrs) occur as a narrow band along the channel throughout much of the reach where bedrock bank do not occur and as island floodplain surfaces between RM 7.9 – 8.2. Medium floodplains (inundated ~5-20 yrs) are more prominent downstream of RM 7.9, occupying available valley floor between the channel and adjacent hillslopes and fans. High floodplains (inundated ~ 20-100+ years) occur as discontinuous pockets. Floodplains are composed of cobbles and boulders topped with gravel/sand.

Channel substrate in Reach 7 is primarily composed of boulders with cobbles. In the mid-section where gradients are reduced and flow is split, gravel and sometimes sand are also present at the margins of the channel, behind massive boulders, and as floodplain deposits. Sediment in Reach 7 is transported via the channel from upstream as well as sourced from the adjacent fans and hillslopes, including the Rat Creek Moraine at the upstream end of the reach (Figure 128).

Figure 128. Cut bank contributions at the toe of the Rat Creek Moraine near RM 8.4. (August 16, 2024)

No appropriate locations were identified in Reach 7 to complete a Wolman Pebble Count (Wolman, 1954). Incipient motion hydraulic analysis (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5) suggests that at the 2-year modeled discharge, the channel's shear stress is capable of mobilizing boulder-sized material through much of the reach (Figure 129). In the mid-reach section where split flow occurs, cobbles are the maximum grain size expected to mobilize in the side channels while the mainstem through this section is expected to mobilize boulders, similar to the confined sections of the reach. Reach 7 is considered a high-energy sediment transport reach.

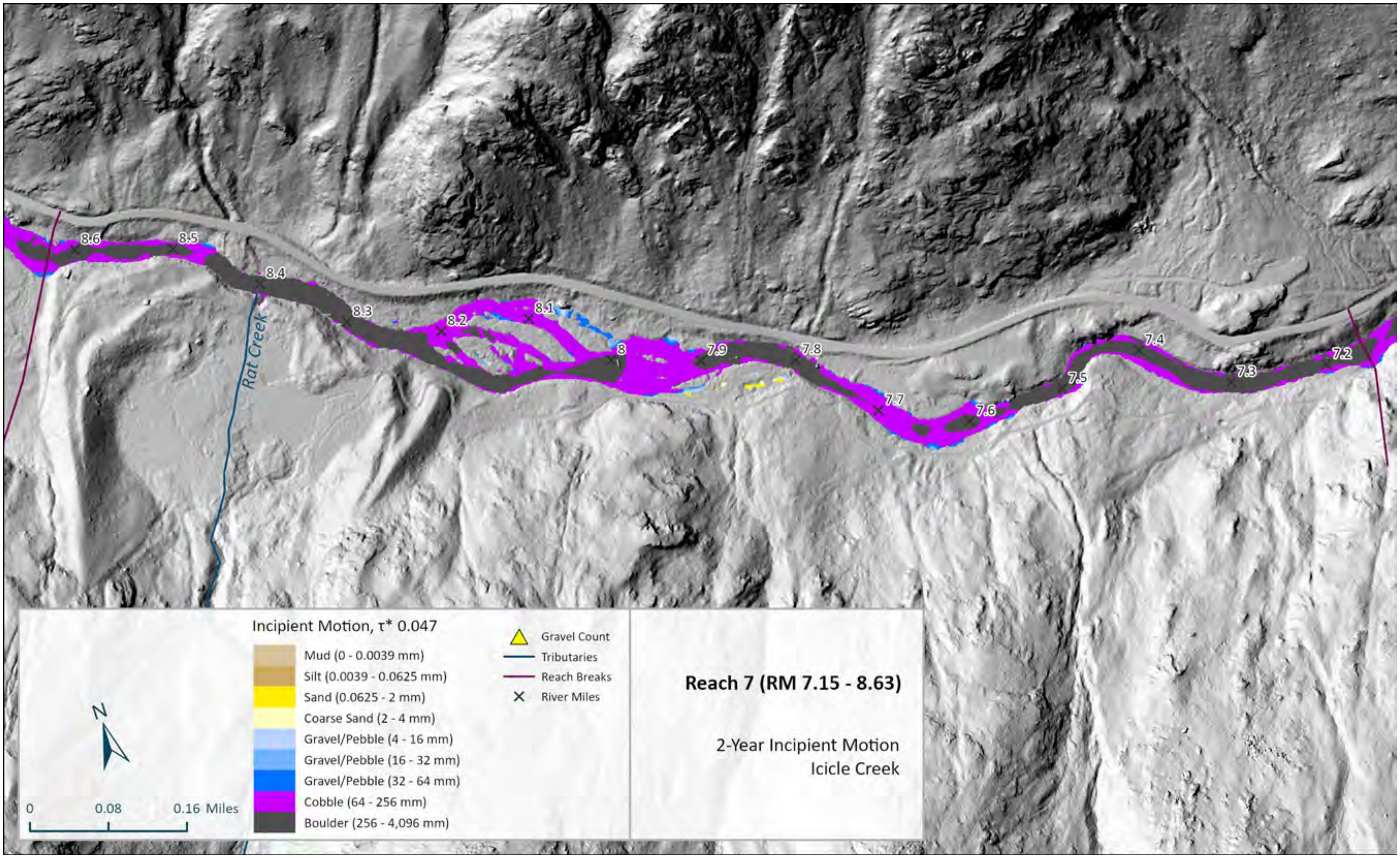

Figure 129. Reach 7: incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge).

3.7.3 Large Wood Material

The habitat survey conducted in summer 2024 recorded 212 individual pieces of large woody material (LWM) and 16 log jams (accumulation of >3 LWM) within the bankfull channel, for a combined total of 409 observed pieces (Figure 131). Of the 212 pieces; 69 classified as large size class (>20-inches diameter and >35-feet long); and 65 as medium size class (12 to 20-inches diameter and at least 35-feet long). Of the 16 log jams in Reach 7, 15 have multiple pieces of medium and large LWM. Reach 7 has 155 pieces of wood per mile (count includes medium and large LWM as individuals and in jams), which meets the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state (Fox & Bolton, 2007; Appendix A).

Most of the large wood (LWM) in Reach 7 is racked on boulders, the front of islands, or the margins on the channel. Racked or wedged on the top of boulders, LWM often is not in contact with the channel at low-flow conditions. However, some of the large wood jams do provide habitat uplift, especially in the split-flow section of the reach. For example, a LWM jam racked onto the head of a small island at RM 8.18 (Figure 130) contributes to flow divergence around the island. While the presence of large wood can enhance local aquatic habitat conditions it generally lacks the size, anchoring, and strategic placement needed to drive significant geomorphic change in Reach 7. Additionally, there is a lack of old-growth forest along the channel so potential to recruit key-log (24-36-inche diameter whole trees) for long-term jam function is limited and much of the existing LWM is considered temporary.

Figure 130. Log jam with racking wood in Reach 7 at RM 8.18 (August 16, 2024).

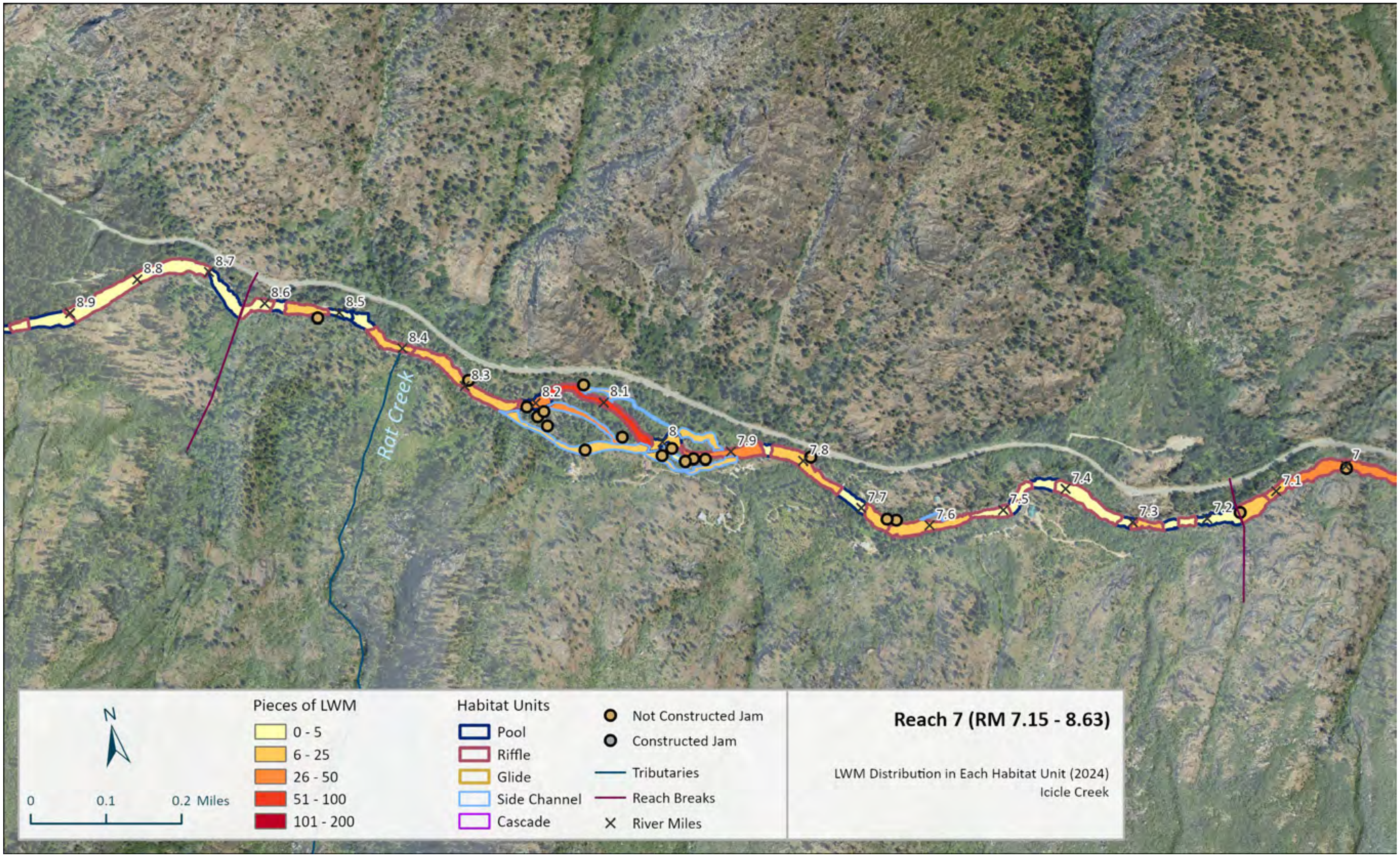

Figure 131. Reach 7: Large wood distribution (pieces per mile per habitat unit) map and surveyed habitat units (2024).

3.7.4 Vegetation

Reach 7 has mostly intact vegetated riparian zones with occasional impacts from the road and residences. The vegetation is naturally sparse and patchy given the confined nature of the channel and the frequency of bedrock. The overstory tree heights are variable, with some large trees present for much of the reach from RM 8.2 to 8.55. Most of the overstory is dominated by ponderosa pine, with lesser amounts of cedar, cottonwood, fir, and aspen. The shrub and small tree understory are mostly alder, willow, and cottonwood. Typical conditions are shown in Figure 132. Several areas with tall right-bank trees do provide some shading to the channel. Large wood recruitment to the channel would primarily only occur via natural tree fall or during very large floods, as on-going bank erosion and channel migration is limited due to the natural confinement.

A map showing vegetation heights is provided in Figure 133, with an aerial map in Figure 134. The map shows some large trees scattered throughout the riparian, with many large trees on the islands in the split-flow section of the channel.

Figure 132. Representative vegetative conditions in Reach 7, near RM 7.7. (August 16, 2024)

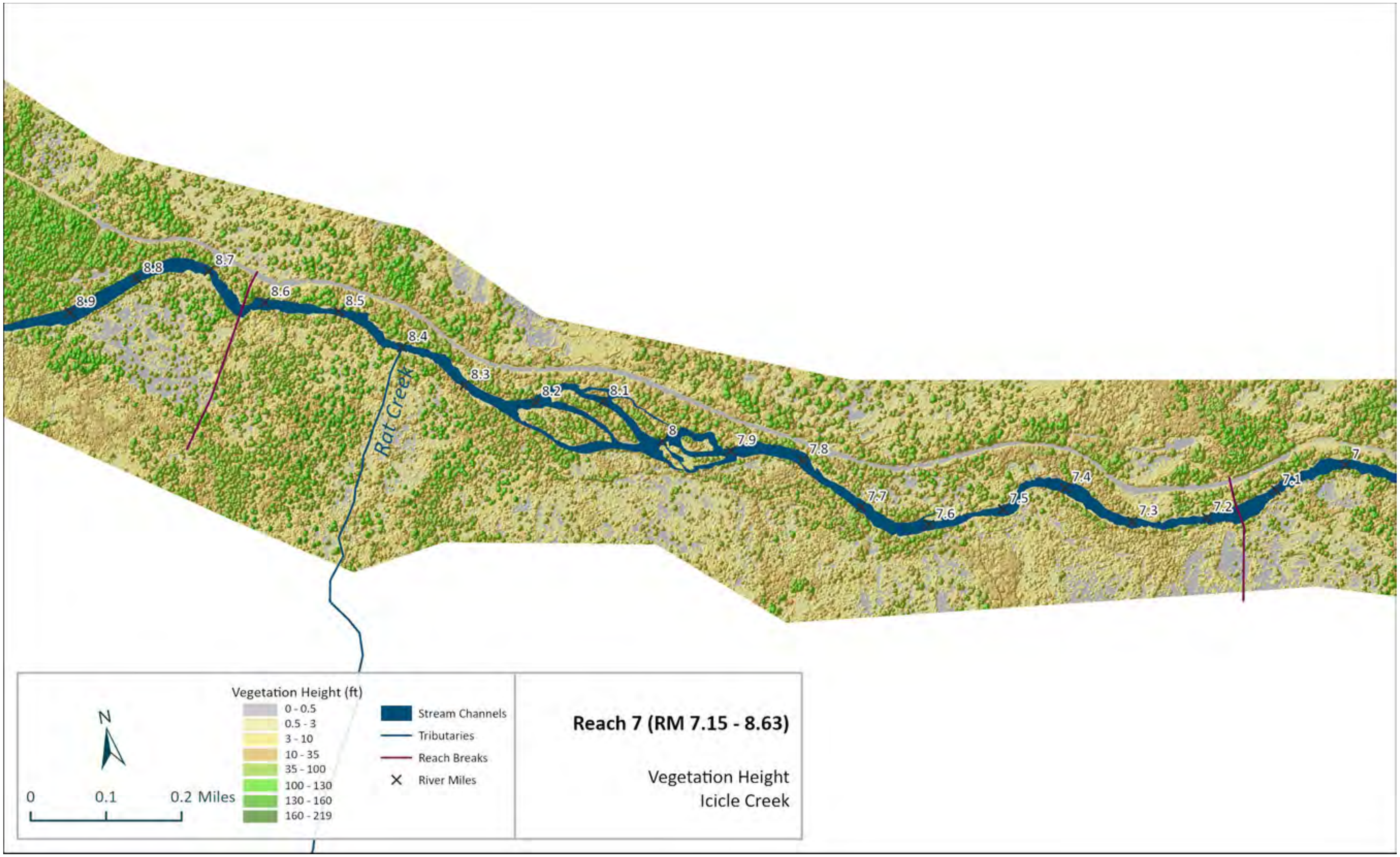

Figure 133. Reach 7: Map of vegetation height classification analysis (LiDAR – based analysis).

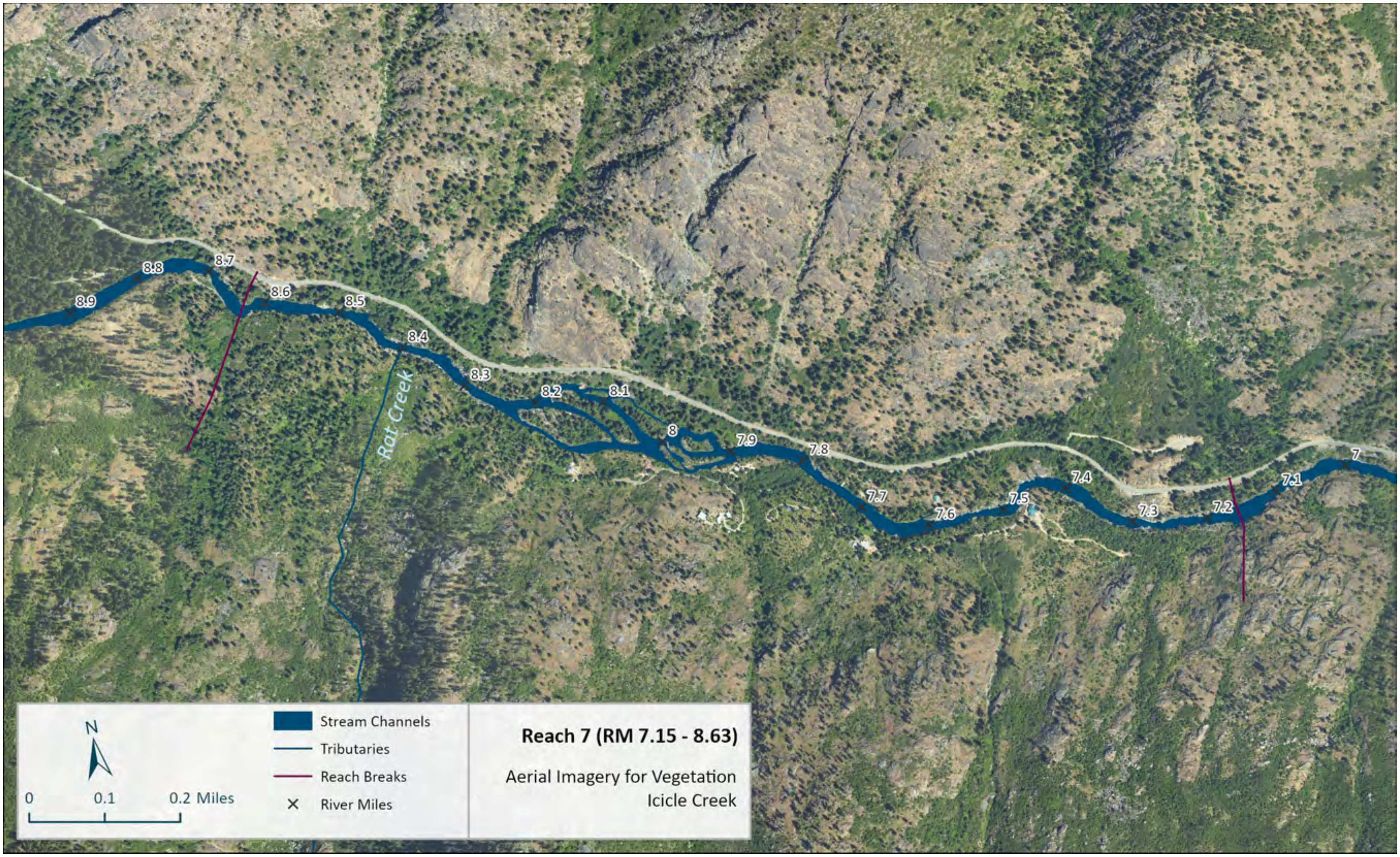

Figure 134. Reach 7: Map of aerial imagery for vegetation identification (ESRI 2023).

3.7.5 Human Alterations

Human alterations in Reach 7 affect main channel, off-channel, floodplain, and riparian processes. A map highlighting the anthropogenic features is provided in Figure 136. Several private residences are located along river-right, some close to the channel. There are several cleared bank areas associated with residences. Between RM 7.23 and 7.27, there is a dispersed camping and rock-climbing area along the river-left bank. At RM 7.58 and 8.12 there were pumps drawing water from Icicle Creek, assumed for private use (Figure 135). At RM 7.74, the Icicle Creek Lane bridge and associated bank protection affects channel margin and riparian habitat. There are several locations of bank armoring. At RM 7.95, on the right bank, there is riprap and a levee along West Icicle Creek Lane Road. Spur dikes have also been constructed in this area, extending into the floodplain and blocking the entrance to a side channel, limiting off-channel and floodplain connectivity (Figure 136).

Figure 135. Left: Pump withdrawal at RM 7.58 (August 28, 2024). Right: Spur dikes in a side channel at RM 7.95 (August 16, 2024).

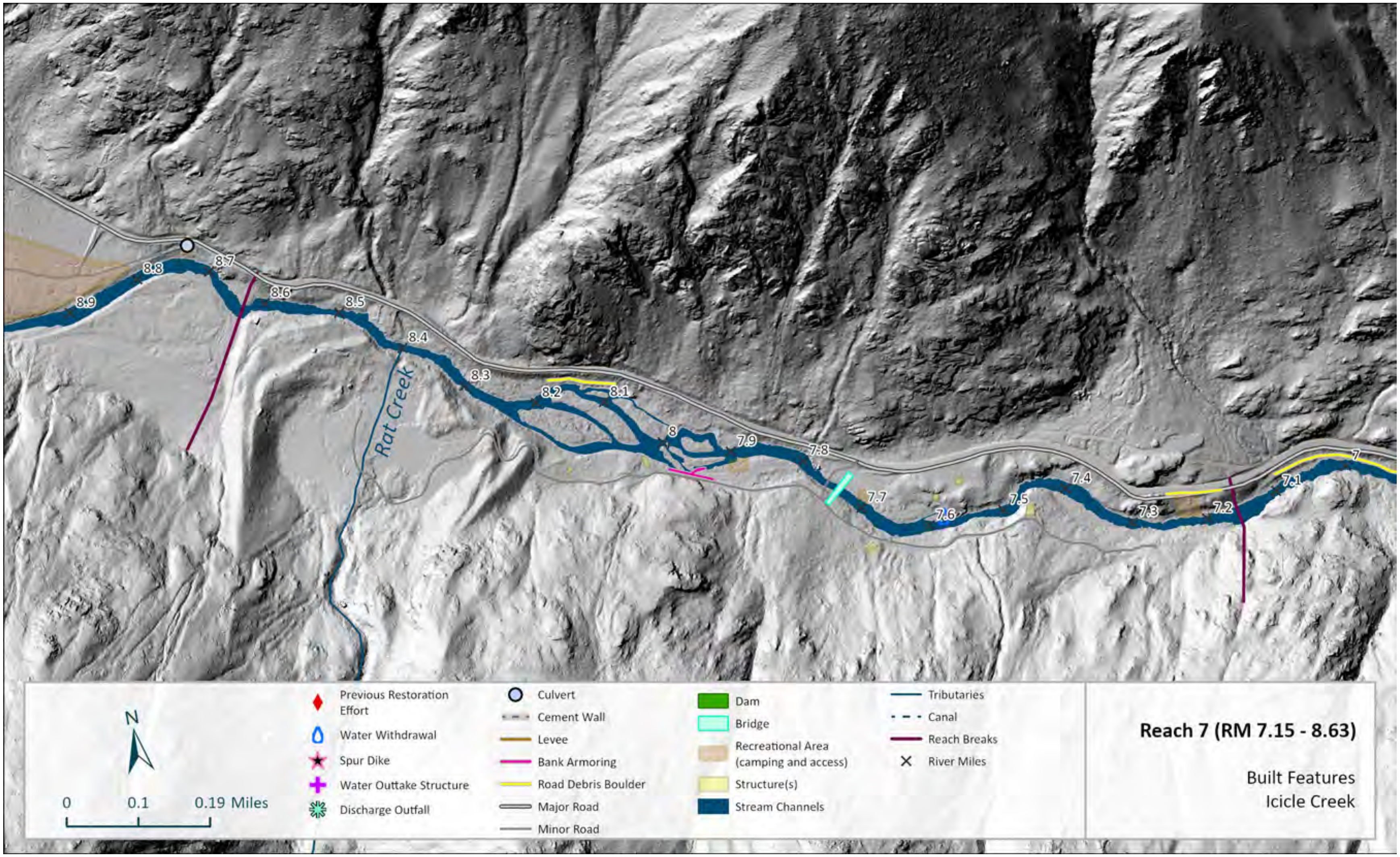

Figure 136. Reach 7: Mapped anthropogenic features (2024).

3.7.6 Recommended Actions

The middle section of Reach 7 has the greatest potential for restoration (“Trident” project) in the reach although restoration opportunities in the reach overall are relatively limited. Downstream of RM 7.6 and upstream of RM 8.1 are mostly steep boulder-bed step-pool channels with little opportunities for restoration. Some of the pools would benefit from LW for habitat cover and complexity, but wood will create very little geomorphic response due to high energy, and anchoring would be a challenge. Nevertheless, there are numerous pools with large boulders where large wood could be braced or wedged between boulders and may have better longevity. 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 and limited (or no) access on opposite (south) bank.

From RM 7.6 - 7.8 is a short lower gradient section where there is better potential for large wood placements for cover and complexity but also for geomorphic functions including gravel capture and pool scour. There are a few large pools on river-left from RM 7.9 to 8.1 that would benefit from large wood cover. 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 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. There may be some residential structure conflicts, but these may be temporary seasonal structures. A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities).

3.8 ICICLE CREEK REACH 8 (RM 8.63-9.63)

3.8.1 Overview

Reach 8 is 1 mile long and extends from RM 8.63 to the confluence with Eightmile Creek at RM 9.63. The channel has an average gradient of 1.94% and a morphology that is dominated by boulder-cobble riffles (Figure 137). The channel is considered partially confined because from RM 9 – 9.45 split-flow conditions and functional wide floodplains exist within an otherwise very confined reach. Modern anthropogenic impacts include the US Forest Service Eightmile Campground, bridge crossings, homes, and other recreational areas. Riparian and floodplain vegetation is generally intact, minus clearing associated with recreational uses and residences. Landownership is both Wenatchee National Forest and private lands at the upstream end of the reach accessed by a bridge across the river.

Figure 137. Representative photo of Reach 8 at RM 8.97. (August 15, 2024)

3.8.2 Channel and Floodplain Geomorphology

Table 18. Reach 8 metrics.

Reach 8												
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
1	8.63-9.63	1.94%	1.06	Riffle	118	Partially Confined	Boulder / Cobble	10.5%	0.0%	67.8%	21.7%	0.0%

The channel in Reach 8 is partially confined and has an intermediate reach gradient of 1.94%, which is notably less steep than the reaches up and downstream (Figure 139). The steeper upstream section of Reach 8 from RM 9.54-9.63 is a mix of boulder step-pool, boulder cascade, and boulder riffle channel morphology (Figure 138). Downstream of RM 9.54, channel gradient is reduced and morphology transitions to extended boulder riffles and then, near RM 9.26, transitions again to a boulder-cobble riffle with pools. In the less confined section of the reach (RM 9-9.45) the channel shifts from single-thread to a multi-threaded form with side channel and floodplain islands (Figure 140). The multiple side channels in the unconfined section range from perennially wetted and connected to the mainstem channel to seasonally dry side channels that wet up during high-flows.

The side channel that runs through the Eightmile campground near RM 9.2 appears to have been purposefully disconnected to avoid seasonal high flows through the campground area. Eightmile Creek joins Icicle Creek at the upstream end of Reach 8, contributing perennial surface water discharge and seasonal sediment inputs. Reworked glacial deposits and modern Eightmile Creek alluvial fan contributions have and continue to provide sediment to the channel, supporting downstream floodplain and split-flow conditions. Another tributary enters the valley floor near RM 9.2, but after passing under Icicle Road at a culvert, it flows through a straight constructed canal through the Eightmile campground area before reaching Icicle Creek.

Figure 138. Boulder cascade morphology at RM 9.63. (August 15, 2024)

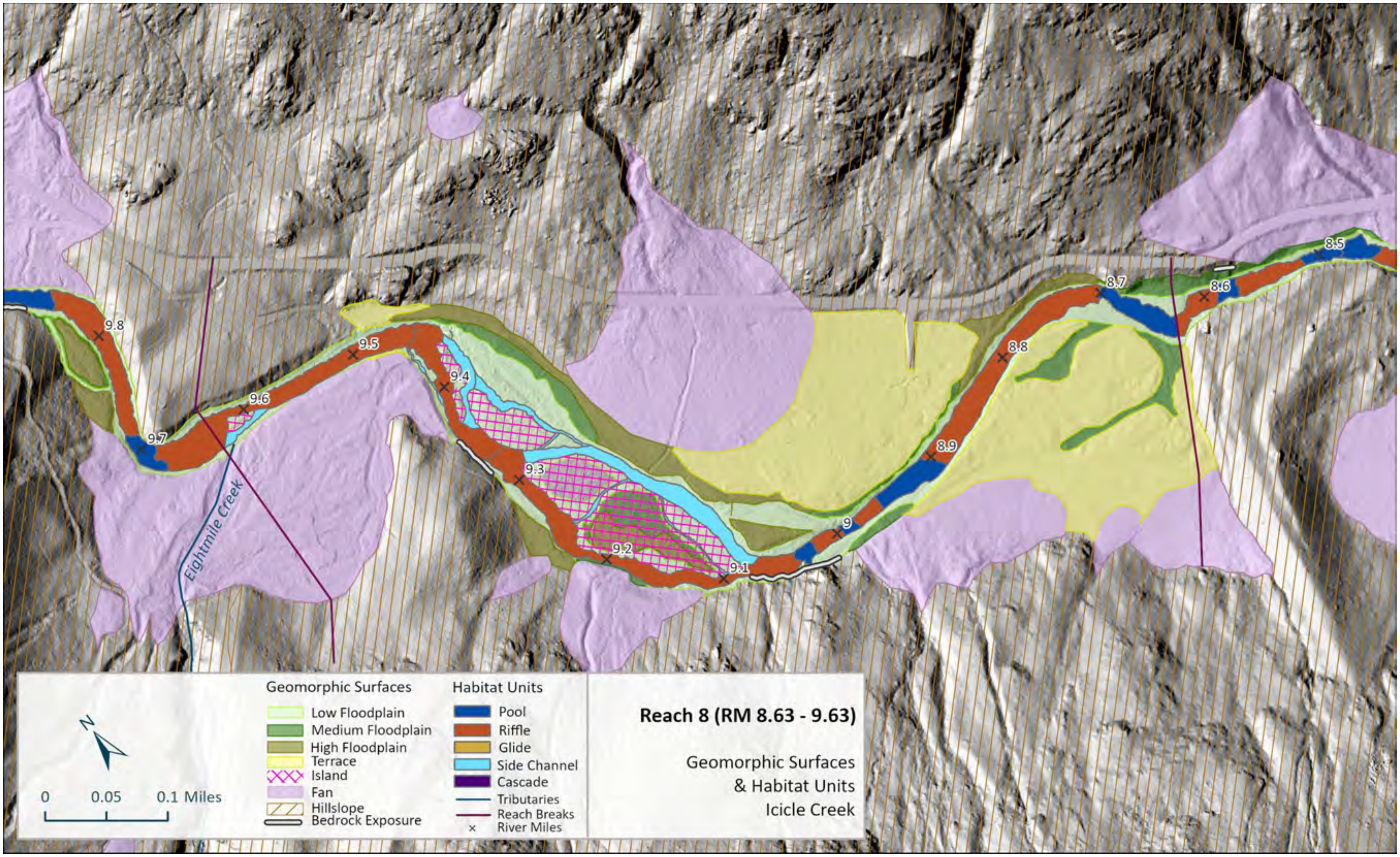

Figure 139. Reach 8: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

The floodplains in Reach 8 are inset below fan, hillslope, and terrace surfaces. Bedrock hillslope contacts near RM 9.05 and 9.35 impose channel confinement on river-right. Low floodplains (inundated ~1-5 yrs) occur as a narrow band along the channel throughout much of the reach and as island floodplain surfaces between RM 9-9.45. The low floodplains host riparian trees and shrubs in Reach 8. Medium floodplains (inundated ~5-20 yrs) and high floodplains (inundated ~ 20-100+ years) occur as discontinuous strips between the low floodplains and terraces and fans. Floodplains are composed of cobbles and boulders topped with gravel/sand and developing soil. Development of the terraces in the lower half of the reach is likely related to historical valley blockage by the Rat Creek Moraine located at the downstream end of the Reach 8.

Channel substrate in Reach 8 is primarily composed of boulders with cobbles. Gravel and sometimes sand are also present at the margins of the channel or behind large boulders. Sediment in Reach 8 is transported in from upstream as well as sourced from the adjacent fans and hillslopes. The floodplain areas represent a stored sediment source within the reach. Where they occur, bars are primarily composed of cobble, with smaller fractions of boulders and gravel present, and are vegetated with willow and other riparian species (Figure 140).

Figure 140. Boulder-cobble substrate in Reach 8 at RM 9.8. (August 15, 2025).

Two Wolman Pebble Counts (Wolman, 1954) were conducted in Reach 8 along riffle crests. Counts were performed upstream of split flow conditions on the mainstem channel to avoid the sorting influence of split flow conditions. The median grain size (D50) of GC 18 at RM 9.32 was 256mm and for GC 19 at RM 8.9 was 123mm. The pebble count data are included in Figure 141 of the Reach 8 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5). The analysis indicates that at the 2-year modeled discharge, the channel’s shear stress is expected to mobilize cobble-sized material through the entirety of the reach. Boulder-sized material is expected to mobilize in the upstream confined section (RM 9.4-9.63), as well as patches throughout the reach.

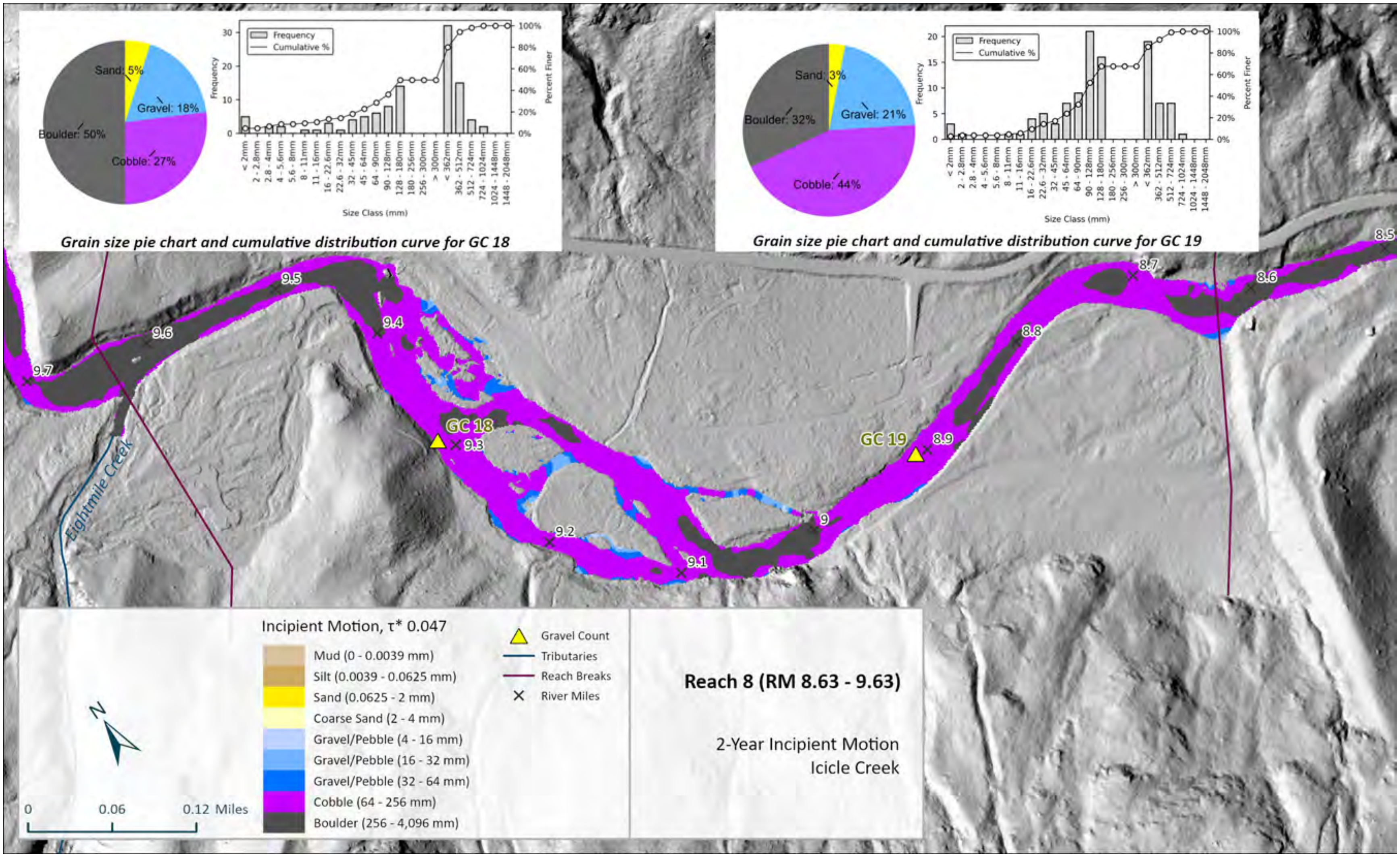

Figure 141. Reach 8: incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge). Includes location and grains size data of the GC 18 and 19 pebble counts (2024 survey).

3.8.3 Large Wood Material

The habitat survey conducted in summer 2024 recorded 89 individual pieces of large woody material (LWM) and 14 log jams (accumulation of >3 LWM) within the bankfull channel, for a combined total of 385 observed pieces (Figure 143). Of the 89 individual pieces; 9 classified as large size class (>20-inches diameter and >35-feet long); and 41 as medium size class (12 to 20-inches diameter and at least 35-feet long). All 14 log jams in Reach 8 have multiple pieces of medium and large LWM. Reach 8 has 237 pieces of wood per mile (count includes medium and large LWM as individuals and in jams), which meets the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state (Fox & Bolton, 2007; Appendix A). However, LWM distribution is not consistent through the reach and the unconfined middle section of the reach where split-flow conditions occur is more likely than the confined sections to recruit and retain LWM to support complexity. Several of the jams are not connected to the channel during low-flow conditions.

Most of the large wood in Reach 8 is racked on boulders, the front of islands, or the margins on the channel. Though racked on features, they do provide geomorphic process and habitat uplift. For example, at RM 9.04 a large wood jam racked against a set of boulders provides cover to a scour pool (important habitat feature) formed between the boulders (Figure 142). At RM 9.27 a large apex jam racked at the upstream end of an island supports maintenance of the island, the split-flow condition it creates, and the forest and riparian vegetation established on the island (Figure 142). And, at RM 9.38 a channel-spanning log jam at the inlet of an important side channel captures gravel and debris, providing localized reduced hydraulics and abundant cover. Large wood was also noted atop floodplains. Several logs and LWM accumulations lack key anchoring logs of sufficient size (24–36-inch diameter), contact with the streambed, or ballasting to banks – making them susceptible to mobilization during high flows. Large wood abundance in Reach 8 may be limited by past wood removal activities.

Figure 142. Left: Boulder racked jam at RM 9.04 – providing cover to scour pool between boulders. Right: Large apex jam rack at head of island at RM 9.27 – not in contact with the channel at low flows. (August 15, 2024)

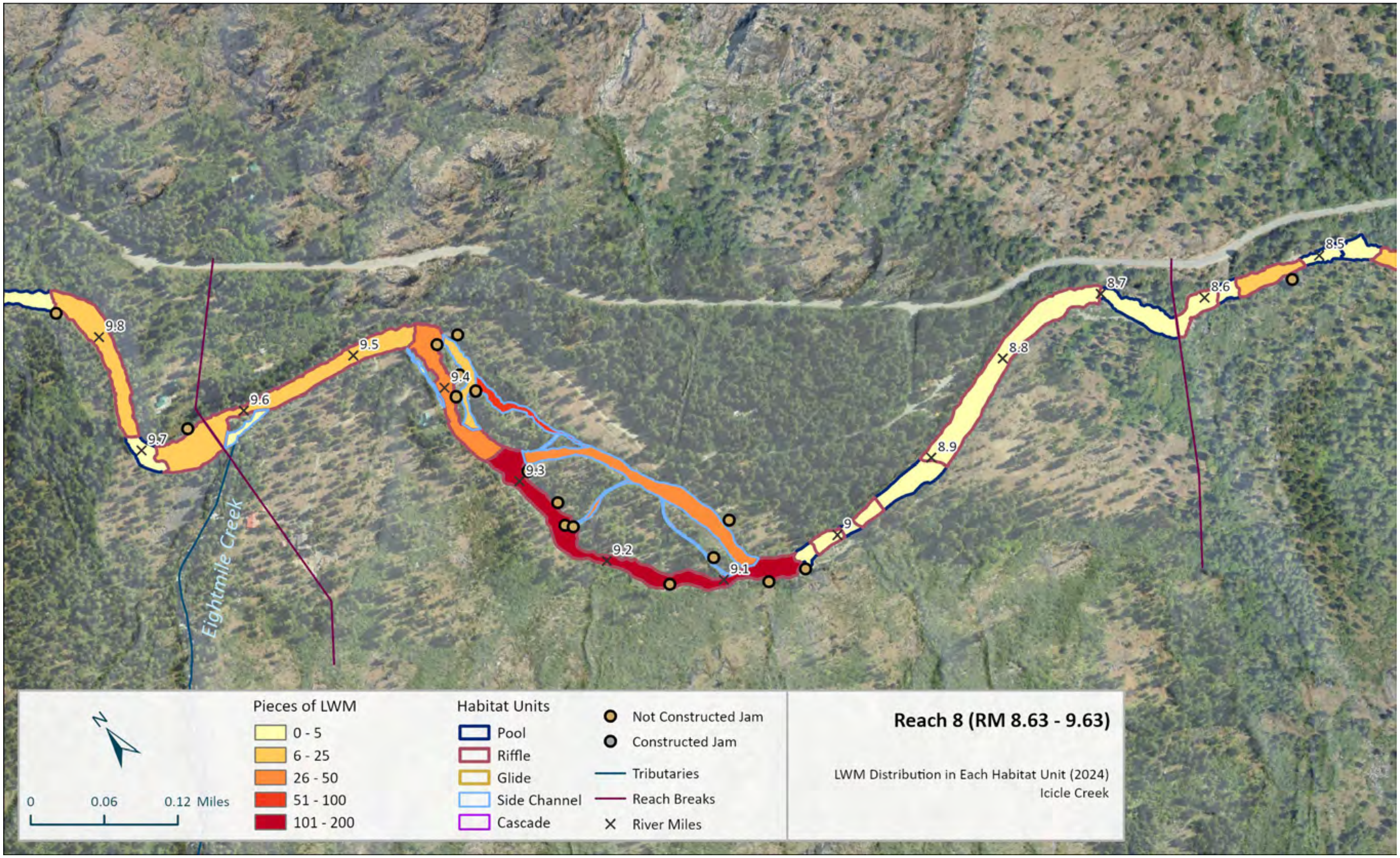

Figure 143. Reach 8: Large wood distribution (pieces per mile per habitat unit) maps and surveyed habitat units (2024).

3.8.4 Vegetation

Reach 8 has mostly intact vegetated riparian zones. Impacts to the vegetation are associated with the campground, residences, recreational areas, and past fire-affected areas. The vegetation is naturally sparse and patchy given the confined nature of the channel and the frequency of bedrock. The overstory tree heights are variable, with some large trees present, mostly on river-left, especially from RM 8.6 to 8.7, around RM 8.9, and from RM 9 to 9.2. River-right is bordered by a moderately-steep bedrock-dominated hillslope dominated by grasses, shrubs, and small trees. Much of the right bank area shows signs of past fire, which is associated with the modern young vegetation community. The overstory, where it exists in the reach, is generally dominated by either ponderosa pine or cedar, depending on location, with lesser amounts of cottonwood and fir. The shrub and small tree understory is mostly alder and willow. Willows were observed ranging from approximately 2 to 15 years old, and cottonwood ranging from 5 to 15 years. Typical conditions are shown in Figure 144. There is very little shading to the river provided by the tree canopy due to a lack of large trees on the right (southern) bank. Large wood recruitment to the channel would primarily occur via natural tree fall or during very large floods, as on-going bank erosion and channel migration is limited due to natural confinement.

Figure 144. Representative vegetative conditions in Reach 8, RM 9.13 (August 2024).

A map showing vegetation heights is provided in Figure 145, with an aerial map in Figure 146. The map shows occasional large trees, mostly on the left bank within the campground area.

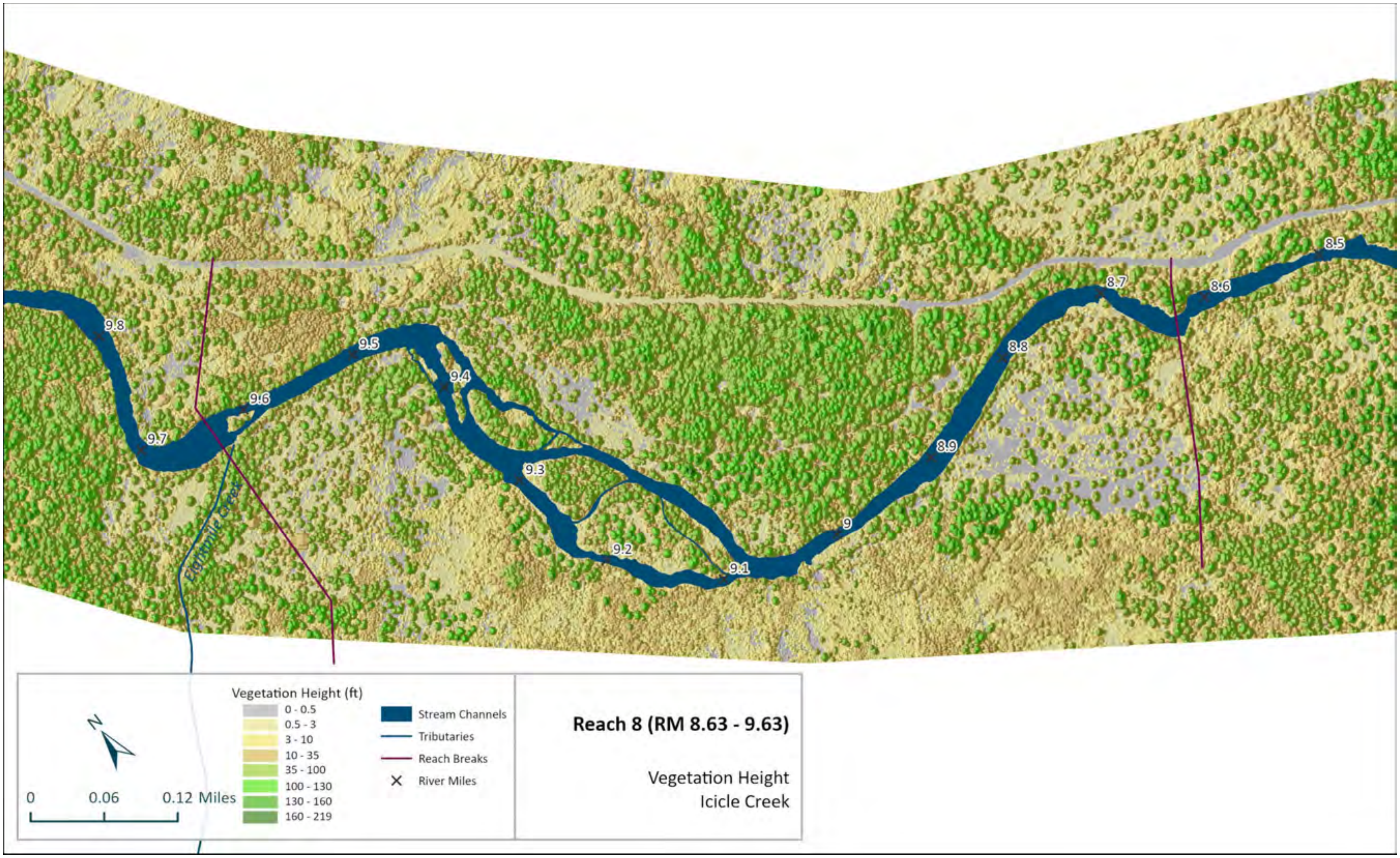

Figure 145. Reach 8: Map of vegetation height classification analysis (LiDAR – based analysis).

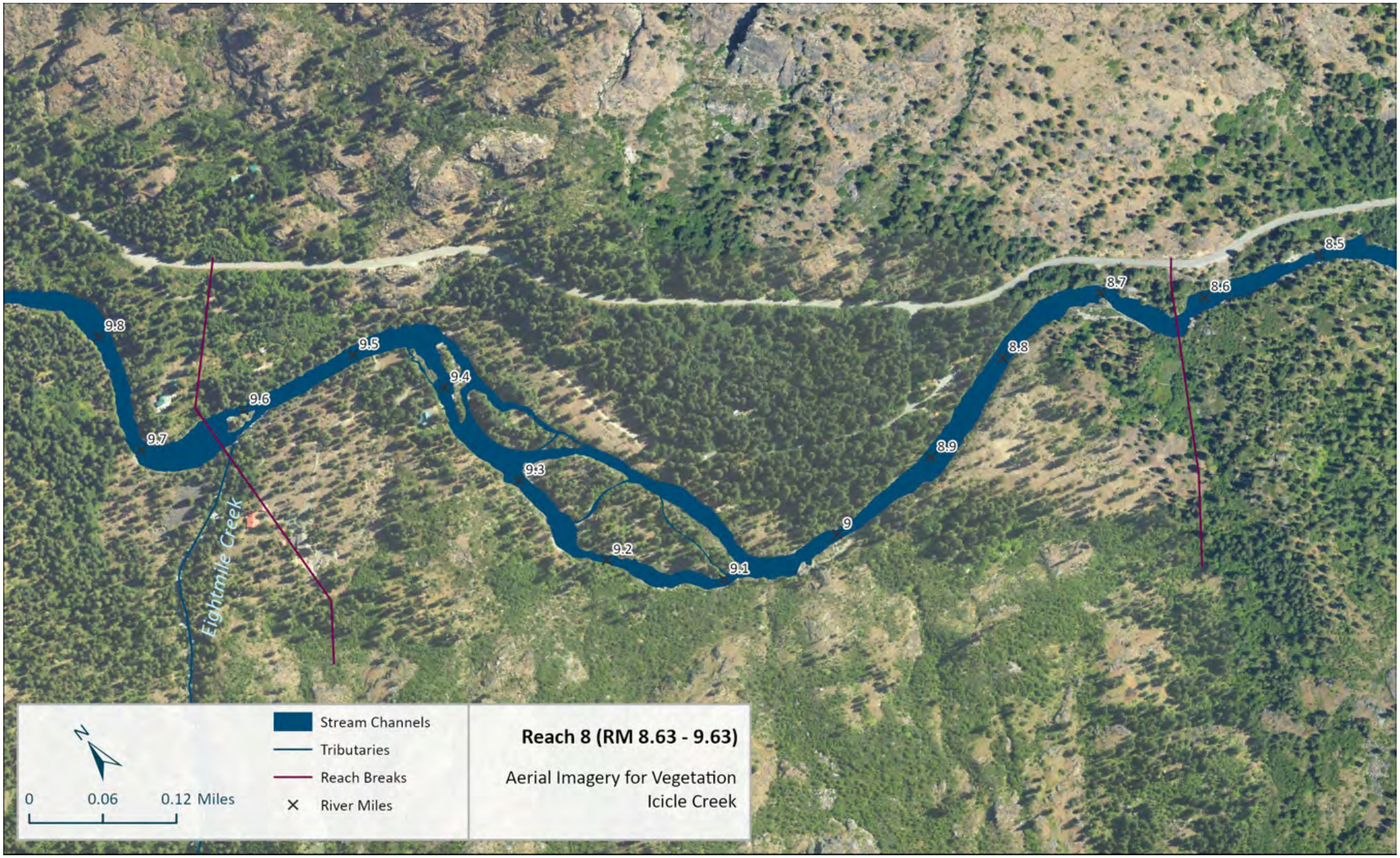

Figure 146. Reach 8: Map of aerial imagery for vegetation identification (ESRI 2023).

3.8.5 Human Alterations

Human alterations in Reach 8 impact channel, riparian, and off-channel conditions. A map showing the anthropogenic features identified in this reach is provided as Figure 147. The largest human impact is the US Forest Service Eightmile Campground on the river-left bank from RM 8.8 to near 9.3. The impacts associated with the campground include cleared riparian zones and the construction of small hand-built rock dams across sections of the channel (Figure 148), which can affect fish movements. There are also numerous dispersed camping and rock-climbing areas, with associated trails and vegetation impacts, particularly on the left bank near RM 8.7 and 9.45. The area just upstream of the campground, along the entrance road, is also cleared, near RM 9.35.

In addition to recreational impacts, several private residences are located throughout Reach 8. At RM 9.48, the Mountaineer Creek Lane Bridge and associated bank protection features impact channel margin habitat and riparian vegetation (Figure 149). Houses along the right bank at the upstream end of the reach impact riparian vegetation.

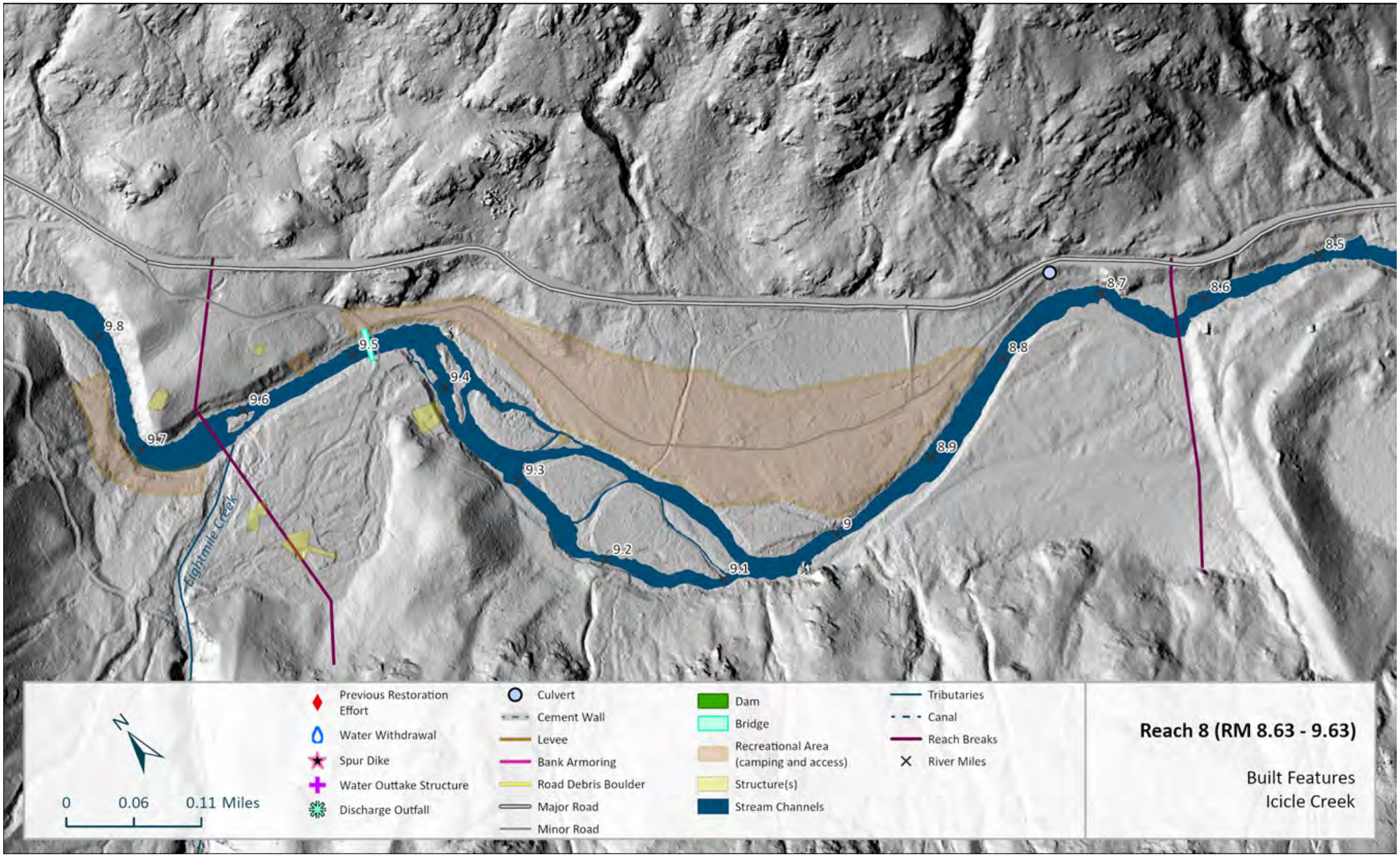

Figure 147. Reach 8: Mapped anthropogenic features (2024).


Figure 148. Anthropogenically created potential seasonal fish barriers. Left: Hand-built rock dams near camping area at RM 9.13 (August 15, 2024). Right: Anthropogenic pools created by hand-moving rocks and small boulders at RM 8.85. (August 15, 2024).

Figure 149. Mountaineer Creek Lane Bridge at RM 9.48 of Reach 8 (August 15, 2024).

3.8.6 Recommended Actions

Restoration opportunities in Reach 8 include side/off-channel enhancement, riparian replanting, and large wood additions. At the downstream end of the reach, there are a few lower floodplain depressions set within the glacial outwash terrace up-valley from the Rat Creek Moraine on river-right. These depressions may offer opportunities for side-channel connections, groundwater-fed channels, and/or alcoves. Further assessment will be required to understand the availability of groundwater and the amount of excavation that would be required. There is a high-flow side-channel on river-left in Eightmile Campground where connectivity could be increased via excavation and wood placements, but conflicts with the campground uses could prove challenging. There are cleared areas at the upstream end of the campground on river-left that could be replanted to create a more robust forested riparian buffer. There are opportunities for large wood placements throughout the reach. Most of these are within low-to-moderate gradient sections where large wood extending from the banks and secured tight to the bed would collect gravels, provide cover, and create hydraulic complexity. Boulder ballast may be required to achieve a reasonable degree of stability and longevity of placements given high energy. The split-flow sections provide good opportunity for wood placements, given the reduced stream energy. These actions are mapped as part of the Eightmile Project. A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities).

3.9 ICICLE CREEK REACH 9 (RM 9.63 – 10.24)

3.9.1 Overview

Reach 9 is 0.61 miles long and extends from Eightmile Creek at RM 9.63 to RM 10.24. This is a steep and relatively confined reach with an average gradient of 3.66%. The channel is dominated by boulder cascades and boulder or boulder/cobble riffles separated by deep pools (Figure 150). The US Forest Service Bridge Creek Campground is located along the river-left bank in the upstream portion of the reach. Recreational uses are the greatest modern anthropogenic impact in Reach 9, albeit limited, and riparian vegetation conditions are largely intact. Landownership is primarily Wenatchee National Forest with some private lands and residential development at the downstream end of the reach on river-left.


Figure 150. Left: Representative photo of boulder-cobble riffle at RM 9.85. Right: Representative photo of boulder-cascade at RM 10.2. (August 15, 2024)

3.9.2 Channel and Floodplain Geomorphology

Table 19. Reach 9 metrics.

Reach 9												
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
0.61	9.63-10.24	3.66%	1.04	Riffle	97	Confined	Boulder / Cobble	17.8%	0.0%	69.8%	12.4%	0.0%

The channel in Reach 9 is a relatively high gradient and mostly confined. Exposed bedrock along the river-right side of the valley floor are intermittent but important confinement points in the reach. Split-flow side channels occur between RM 9.9-10.5 around a hillslope island and immediately downstream from the island. Split-flow conditions offer some channel complexity in this relatively high energy reach, but the island does impose some confinement to both flow routes (Figure 151). Even were confinement between fans (alluvial and debris), hillslopes, and terraces is lessened, and floodplains occur near RM 9.8 and 10, the channel morphology of boulder riffle or boulder cascades to pool remains. Bridge Creek is a perennial tributary with its confluence to Icicle Creek at RM 10.23, on river-left. The Eightmile Creek alluvial fan bounds the area on river-left from RM 9.63-9.73. Additional unnamed ephemeral tributaries and their fans also contribute sediment and seasonal discharge to the channel and valley floor at RM 9.9 on river-left and at RM 10.1 on river-right.

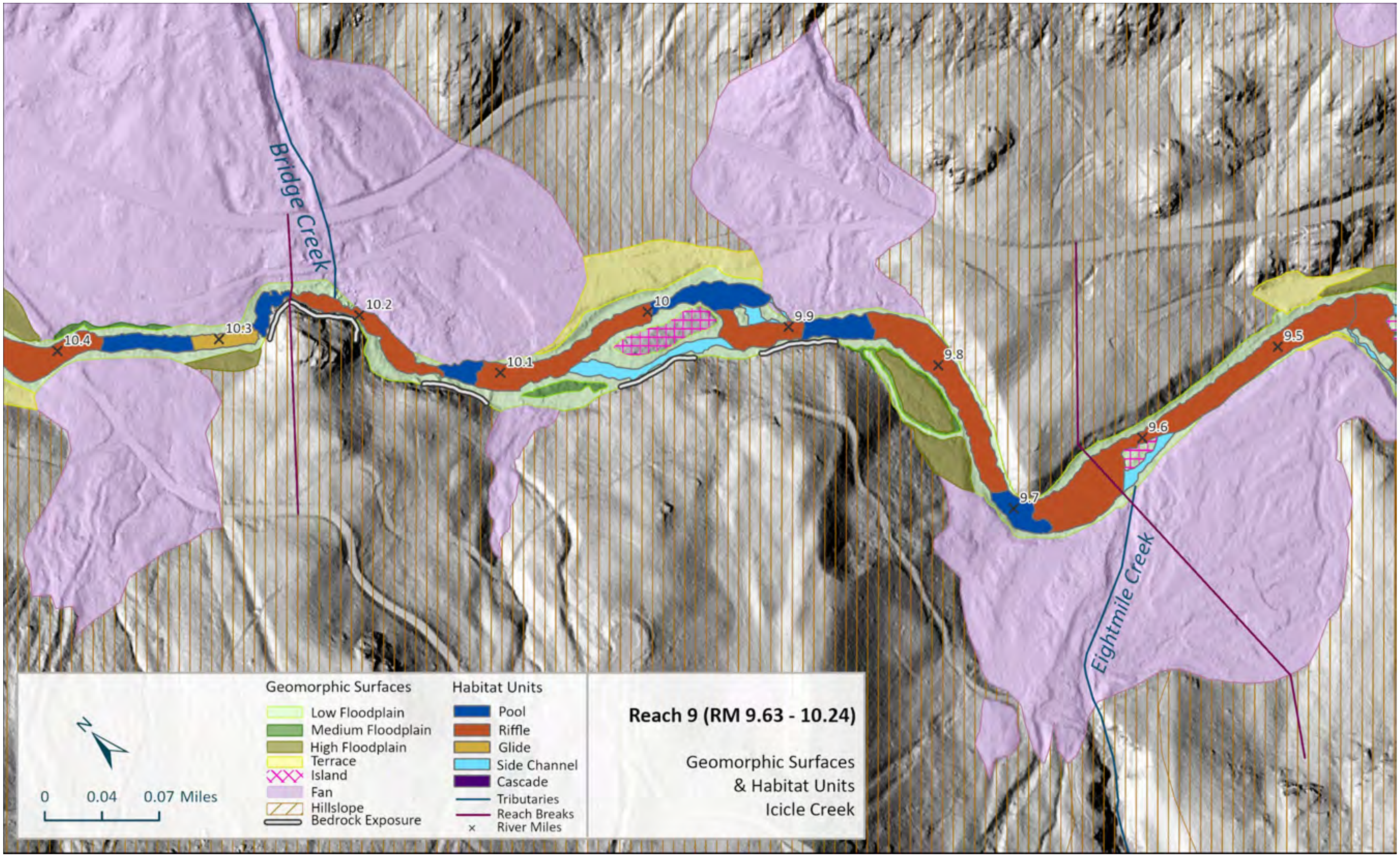

Figure 151. Reach 9: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

The floodplains that occur in Reach 9 are inset below fan and terrace surfaces where valley floor space allows. Low floodplains (inundated ~1-5 yrs) occur as a strip along the channel throughout much of the reach, providing a narrow band for riparian vegetation to establish. Medium floodplains (inundated ~5-20 yrs) are sparse, but high floodplain (inundated ~20-100+ yrs) surfaces occur at RM 9.8 and 10.3. The floodplain at RM 9.8 is composed of reworked boulders sourced from an historical landslide off the adjacent hillslope on river-right (Figure 152). The hillslope that the landslide originated from is a moraine created by an historical alpine glacier that once occupied what is now named Eightmile Creek drainage (Tabor et al., 1987).

Figure 152. Fluvially reworked landslide boulders on floodplain and large flood-event flow route on river-right near RM 9.8. (August 15, 2024)

Channel substrate in Reach 9 is primarily composed of boulders with cobbles. Gravel and sometimes sand are also present at the margins of the channel, but rare in this reach (Figure 153). Sediment in Reach 9 is transported in from upstream as well as sourced from the adjacent fans and hillslopes. The floodplain areas represent a stored sediment source within the reach.

Figure 153. Channel margin boulder bar with gravel and coarse sand in the lee of the boulders at RM 9.89. (August 15, 2024)

One Wolman Pebble Count (Wolman, 1954) was conducted in Reach 9 on a riffle crest located at RM 9.85 (GC 17). The median grain size (D50) of GC 17 was 165 mm. The pebble count data are included in Figure 156 of the Reach 9 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5). The analysis indicates that at the 2-year modeled discharge, the channel's shear stress is expected to mobilize boulder-sized material though most of this high-energy reach (Figure 154). The only exception is associated with the split flow conditions at RM 9.85 and RM 10 where cobble-sized material is expected to mobilize. Compared to the upstream and downstream shear, deposition of boulder-cobble substrate and channel margins bars exposed at low-flow conditions are expected. Reach 9 is considered a transport reach.

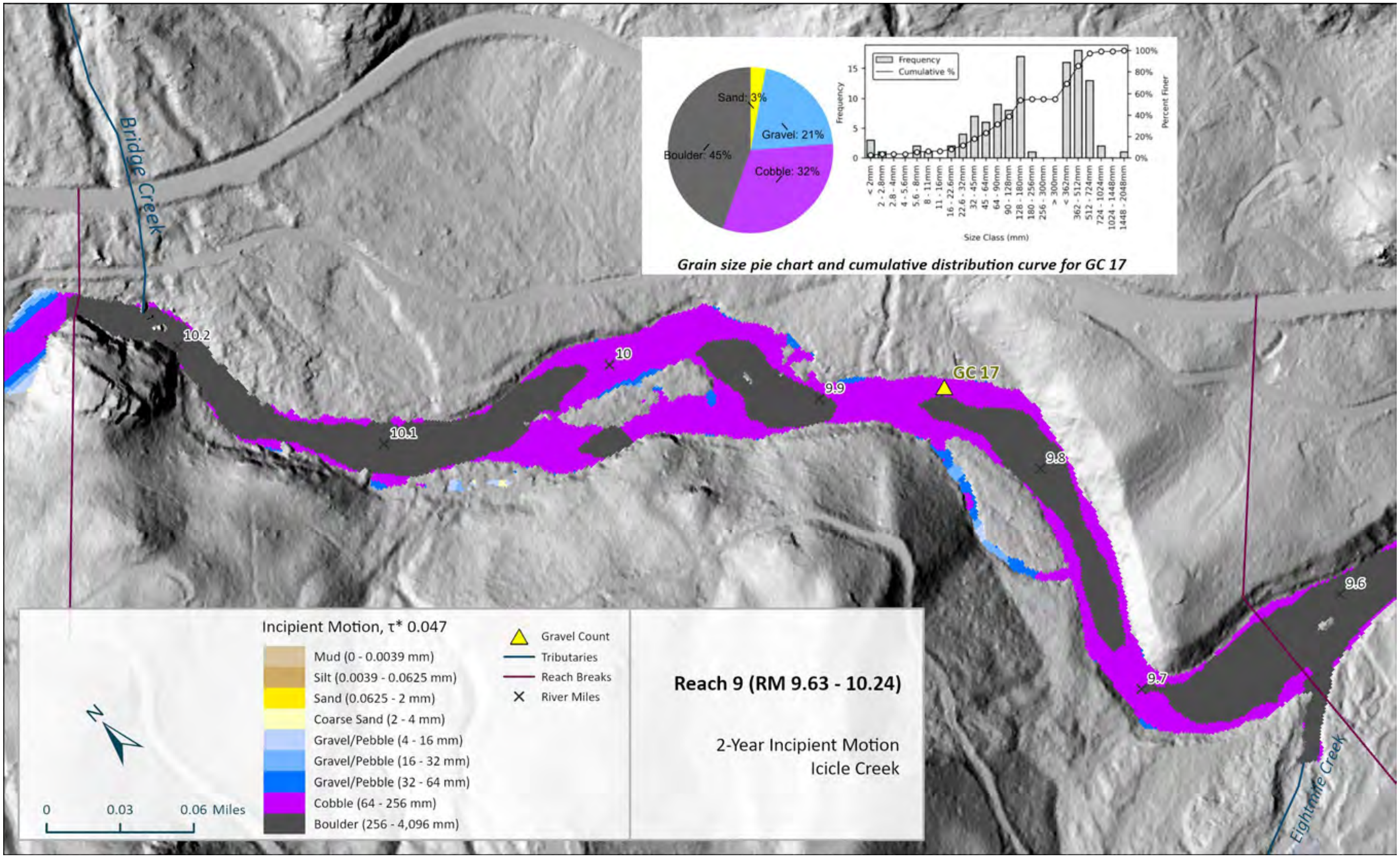

Figure 154. Reach 9: incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge). Includes location and grains size data of the GC 17 pebble count (2024 survey).

3.9.3 Large Wood Material

The habitat survey conducted in summer 2024 recorded 71 individual pieces of large woody material (LWM) and 9 log jams (accumulation of >3 LWM) within the bankfull channel, totaling 215 observed pieces (Figure 156). Of the 71 individual pieces; 5 classified as large size class (>20-inches diameter and >35-feet long); and 31 as medium size class (12 to 20-inches diameter and at least 35-feet long). All 9 log jams in Reach 9 have multiple pieces of medium and large LWM. Reach 9 has 200 pieces of wood per mile (count includes medium and large LWM as individuals and in jams), which meets the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state (Fox & Bolton, 2007; Appendix A). However, the distribution of LWM is uneven throughout the reach and several of the jams are not connected to the channel during low-flow conditions.

Much of the LWM counted during the 2024 survey was located along the margins of the channel or racked on islands. In addition, while large wood is present in the reach, some of the accumulations lack anchoring by key logs, making them more likely to be mobilized during high flows. However, few of the large jams are influencing geomorphic processes. For example, the LW at RM 9.91 that maintains a scour pool. However, the large LW jam at RM 9.95 (Figure 155), though large in size, is racked along the channel bank and influences minimal geomorphic processes in the channel. Recruitment of LWM to Icicle Creek in Reach 9 primarily occurs through in-fall of trees from the bank. The large jam at RM 9.95 looks to be related to avulsion.

Figure 155. Wood jam on Reach 9 at RM 9.95. (August 14, 2024)

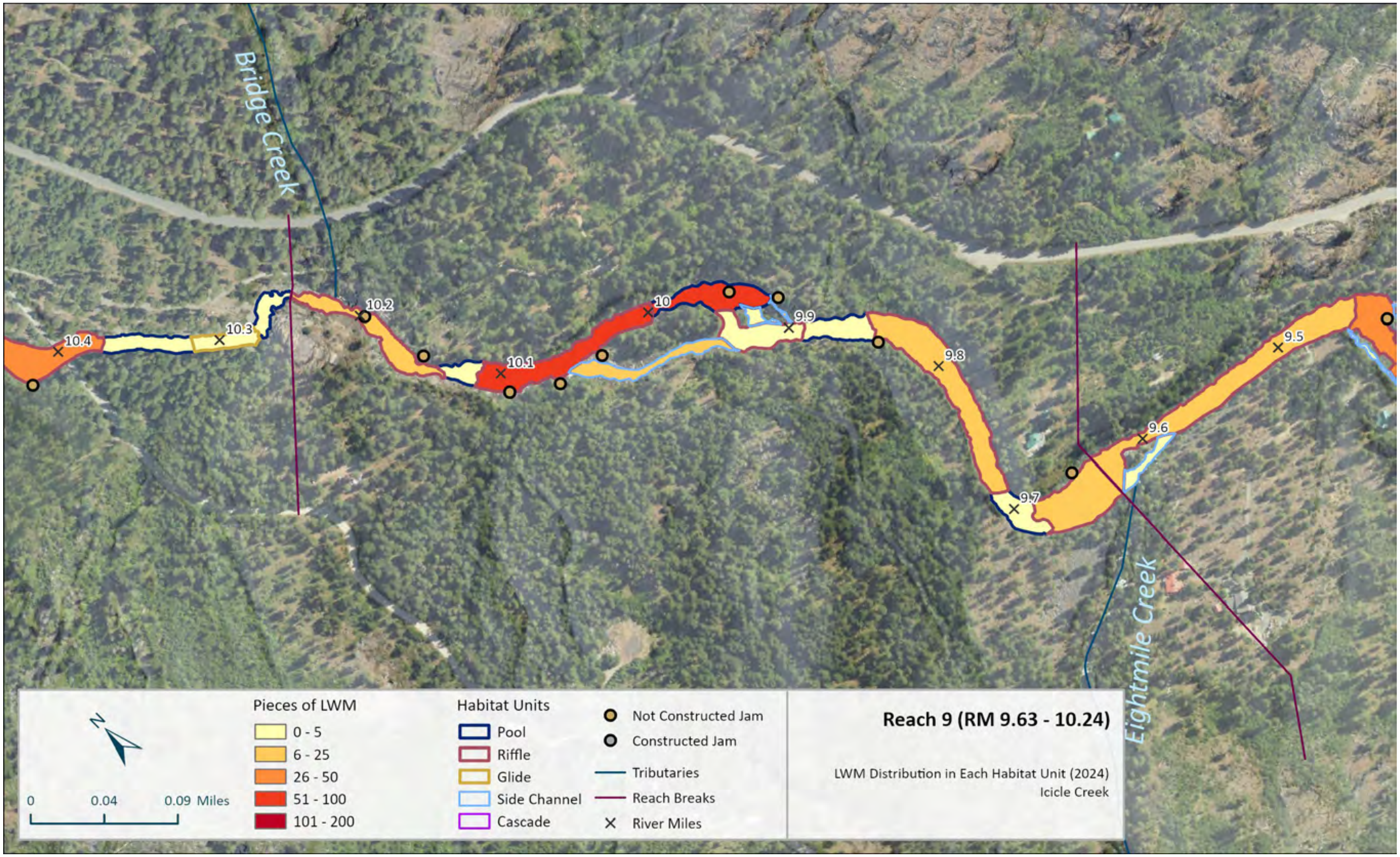

Figure 156. Reach 9: Large wood distribution (pieces per mile per habitat unit) map and surveyed habitat units (2024).

3.9.4 Vegetation

Reach 9 has intact riparian vegetation with minor impacts from the campground, residences, and dispersed recreation. At the upstream end on river-right, there is a large bedrock outcrop that is naturally void of vegetation. Along the left bank, there are minor impacts to vegetation from the Bridge Creek group campground area and dispersed camping areas downstream. At the downstream end of the reach, there is a small floodplain area on the right bank that is well-vegetated. Private land and a house high on the glacial terrace have minor impacts to riparian conditions related to a stairway and trail to the river.

The overstory is dominated by large trees, especially from RM 9.68 to 9.8 and RM 9.85 to 10.24. The dominant overstory species is ponderosa pine, with cedar, cottonwood, fir, and spruce also present. The shrub understory is mostly alder, with willows lining channel margins and in-channel boulder clusters in many areas. Vine maple and dogwood are also common in the understory. There is some shading to the river provided by large trees along the river-right (southern) bank. Large wood recruitment to the channel would primarily occur via natural tree fall or during very large floods, as on-going bank erosion and channel migration is limited due to the natural confinement. A representative photo of riparian vegetation conditions is included in Figure 157.

A map showing vegetation heights is provided in Figure 158, with an aerial map in Figure 159. The map shows the relative abundance of large trees throughout the reach.

Figure 157. Representative vegetative conditions in Reach 9, RM 10.03 (August 2024).

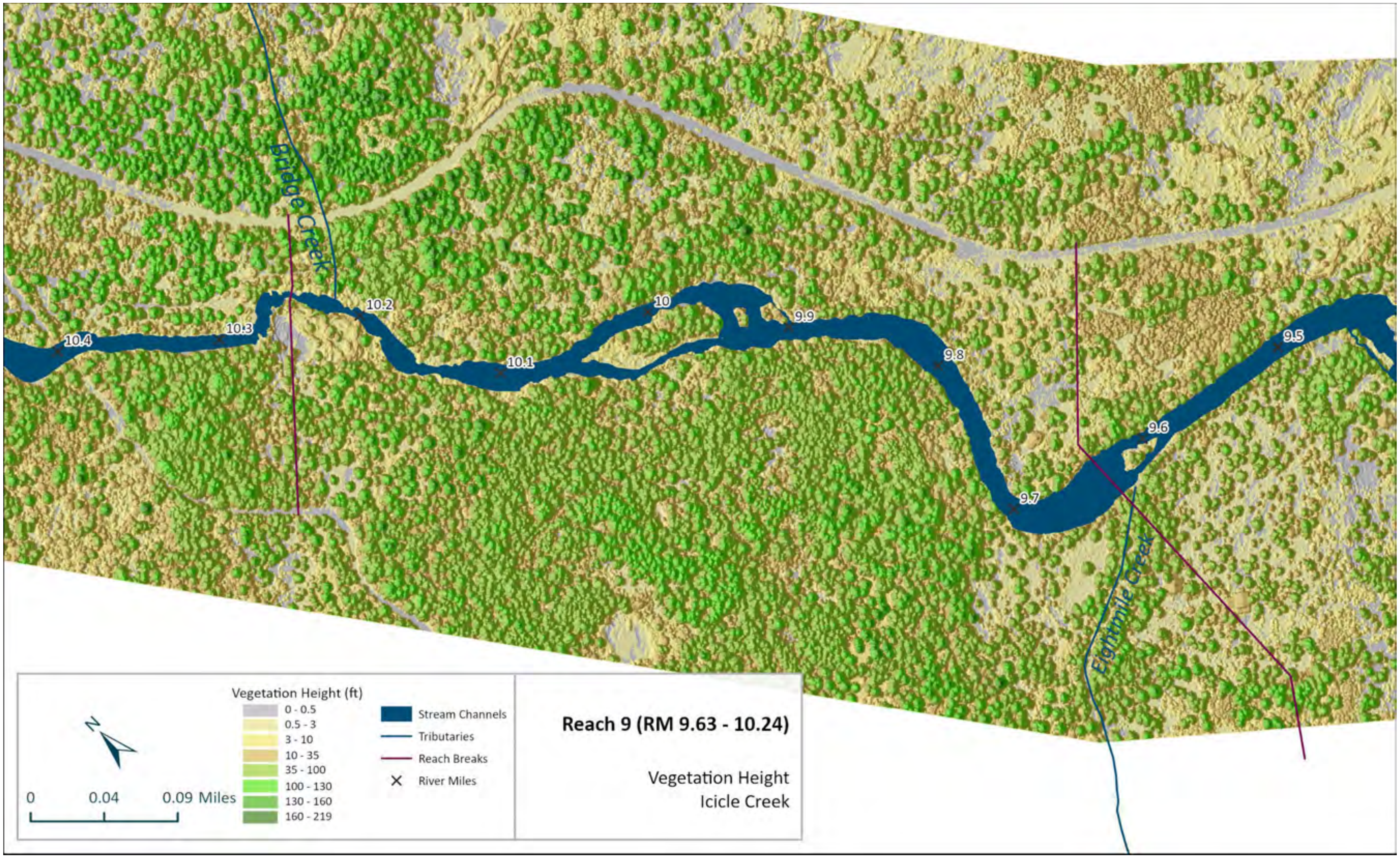

Figure 158. Reach 9: Map of vegetation height classification analysis (LiDAR – based analysis).

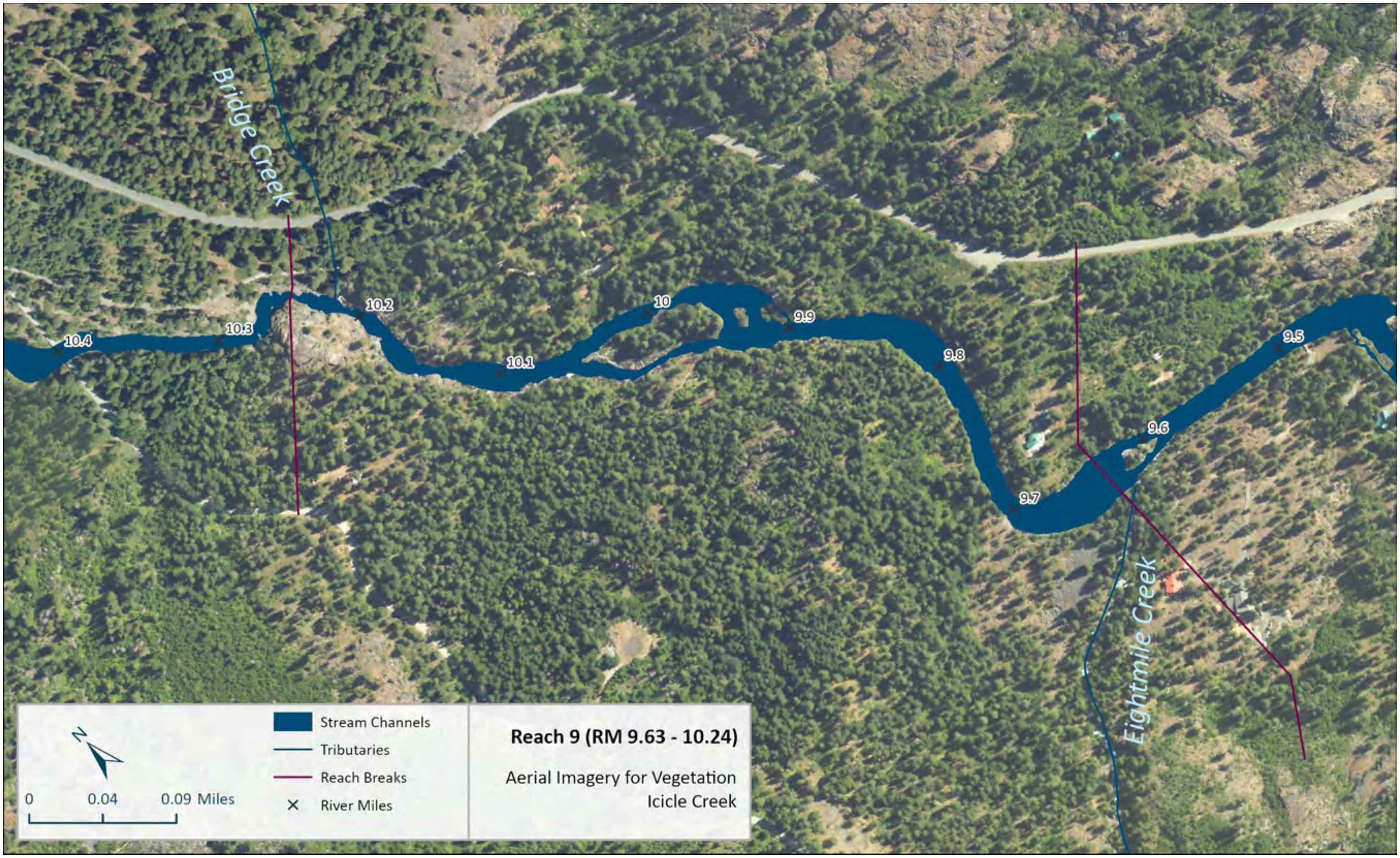

Figure 159. Reach 9: Map of aerial imagery for vegetation identification (ESRI 2023).

3.9.5 Human Alterations

Human features within Reach 9 are mapped in Figure 161. Human impacts are limited to the Bridge Creek Campground (group sites), dispersed recreational and camping use, and minor impact related to residential development. On river left at approximately RM 10.22, there is the Bridge Creek Campground group camping area (the remainder of the campground extends upstream into Reach 10). Although there are camping areas and associated trails that have affected vegetation, the overall impact is minimal. Near RM 9.7 on river right, there is a dispersed camping area with cleared riparian vegetation. At RM 9.72, there is a long private staircase extending down to the river (Figure 160). There are some impacts to vegetation in this area, but relatively minor. Additional modifications include a 48-inch corrugated metal pipe culvert at RM 10.21, as well as two adjacent 20-inch corrugated metal pipe culverts at RM 10.2. These culverts direct runoff and contribute seasonal surface water flow to Icicle Creek. One culvert appears to function as an inlet and the other as an outlet. These structures are likely associated with the Bridge Creek Campground and the Forest Service Road 7601-111.

Figure 160. Staircase leading from a private house to Icicle Creek on river-left bank in Reach 9 at RM 9.72. (August 15, 2024)

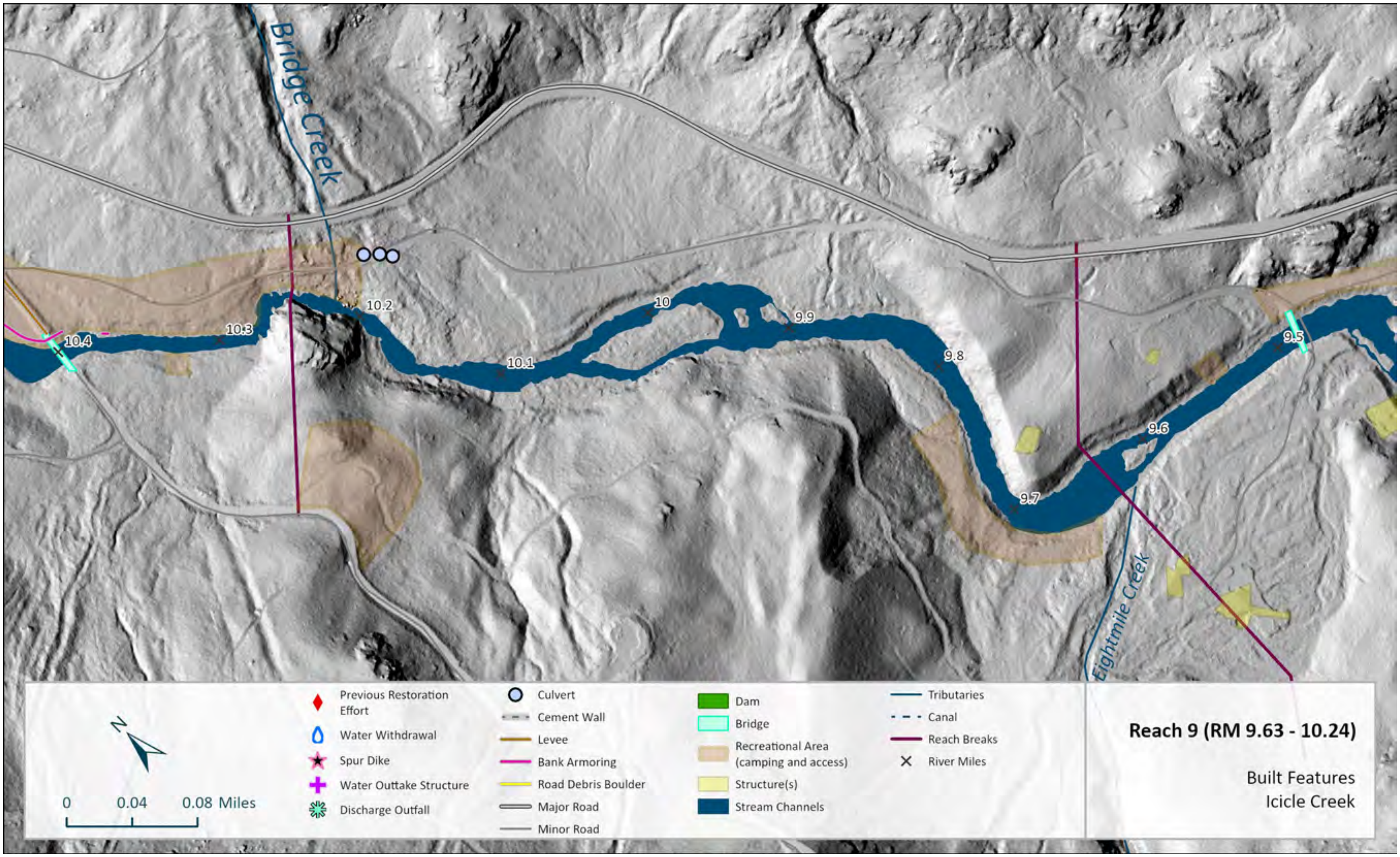

Figure 161. Reach 9: Mapped anthropogenic features (2024).

3.9.6 Recommended Actions

Reach 9 has little opportunity for restoration work and the restoration opportunities that do exist have challenging access. There is a disconnected side-channel on river-right that starts near RM 9.85. The inlet may have been filled. Connectivity could be enhanced via inlet excavation, but there is a steep hillside from the old road grade above it, thus access may be challenging. This is also an area of past landslides from the adjacent steep hillside, which would need to be taken into consideration with respect to potential influence on restoration actions. There has been cleared riparian vegetation at the downstream end on river-right just upstream of the Eightmile Creek confluence associated with dispersed recreation. This area would benefit from riparian plantings to reestablish a robust forested riparian buffer. A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities).

3.10 ICICLE CREEK REACH 10 (RM 10.24 – 11.36)

3.10.1 Overview

Reach 10 is 1.12 miles long and extends from RM 10.24 to 11.36. This channel has an average gradient of 1.31% and is partially confined. In areas with available space and floodplain, split flow conditions occur. Otherwise, channel form is single-thread and relatively straight with a boulder-riffle dominated channel type (Figure 162). Vegetation is well established throughout the reach except where anthropogenic uses occur. Icicle River Road runs relatively parallel to the channel on the adjacent river-left hillslope and Eightmile Road (USFS Rd 7601) traverses the lower river-left floodplain with a bridge crossing over the mainstem channel near RM 10.4. The Bridge Creek Campground also occupies the toe of the Bridge Creek fan on the river-left side of the channel. These features impair riparian vegetation conditions. Except for one private landowner on the hillside at the downstream end of Reach 10, landownership is otherwise within the Wenachee National Forest.

Figure 162. Representative photo of Reach 10 at RM 10.85. (August 14, 2024)

3.10.2 Channel and Floodplain Geomorphology

Table 20. Reach 10 metrics.

Reach 10												
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
1.12	10.24-11.36	1.31%	1.05	Riffle	99	Partially Confined	Boulder / Cobble	5.7%	1.9%	86.5%	5.9%	0.0%

The channel in Reach 10 follows a moderate reach-gradient of 1.31%, notable lower than the upstream and downstream reaches. Sections of the reach from RM 10.45 – 10.8 and RM 11.15-11.35 have floodplain development and split-flow channel conditions around islands to occur (Figure 164). The split-flow areas offer zones of habitat complexity. The remainder of the reach is confined by fans (alluvial and debris), terraces, and bedrock hillslope toes. Channel morphology is limited to an extended boulder and large-cobble riffle, except at the upstream and downstream ends where pools and a glide form in the most confined sections of the reach (RM 11.3-11.35 and RM 10.24-10.37). An unnamed ephemeral channel was noted as providing surface water to Icicle Creek during the 2024 survey (August) on river-left at RM 11.30. A groundwater fed side channel that meets the mainstem on river-right at RM 11.15 was also connected via surface water during the survey. Sources of groundwater contributions of ~1cfs or less were noted at RM 11.34, 10.96, and 10.79.

The floodplains in Reach 10 are inset below fan and terrace surfaces. Low floodplains (inundated ~1-5 yrs) occur as a narrow strip along the channel throughout much of the reach and as a wide well-vegetated surface on river-right near RM 10.7. Medium floodplains (inundated ~5-20 yrs) and high floodplain (inundated ~20-100+ yrs) are discontinuous and flank low floodplains with varied widths. Floodplains are composed of cobbles and boulders topped with gravel/sand and developing soils. Banks of the channel also contact cut fan toes and hillslopes (Figure 163).

Figure 163. Icicle Creek at RM 11. Low floodplain on right side of photo and cut fan toe on left side of the photo. (August 14, 2024)

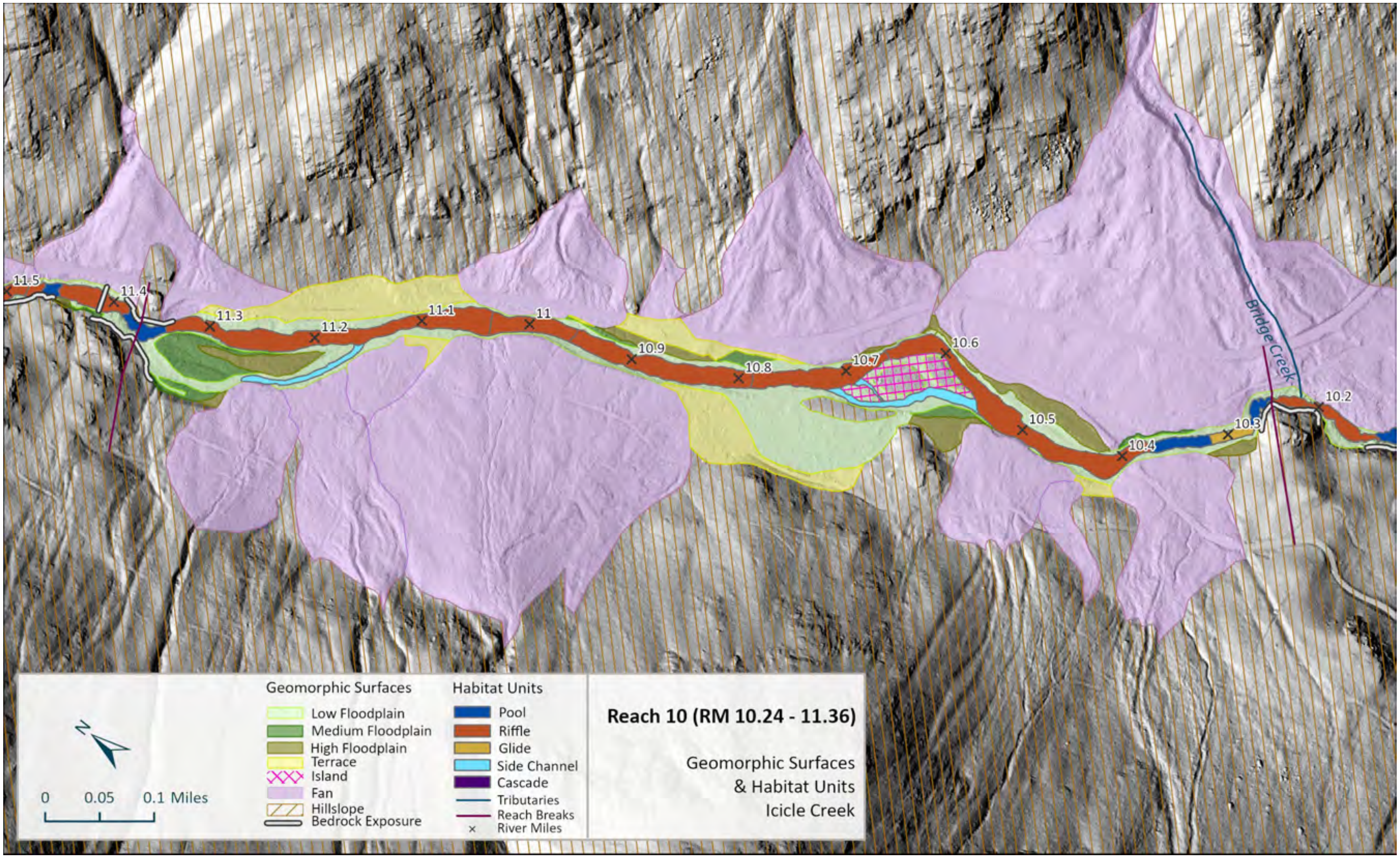

Figure 164. Reach 10: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

Channel substrate in Reach 10 is primarily composed of boulders and cobbles with gravel and sometimes sand also present at the margins or in areas of reduced flow hydraulics (behind boulders, etc.) (Figure 165). Cobbles and gravel are more prevalent in the downstream section of the reach and in areas with split-flow conditions. Sediment in Reach 10 is transported in from upstream as well as sourced from the adjacent fans and hillslopes. The floodplain areas represent a stored sediment source within the reach.

Figure 165. Example of channel margin sediment at RM 10 – gravel and sand retained within boulders. (August 14, 2024)

Two Wolman Pebble Counts (Wolman, 1954) were conducted in Reach 10 on riffle crests. The median grain size (D50) of GC 16 at RM 10.47 was 73 mm and of GC 15 at RM 11.05 was 330mm. The pebble count data are included in Figure 166 of the Reach 10 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5). The analysis indicates that at the 2-year modeled discharge, the channel's shear stress is expected to mobilize cobble sized material throughout the reach, including at the split-flow areas. Mobilization of boulders is expected to occur in the mainstem channel between RM 11.08-11.36 and in the thalweg of the channel near RM 11. Reduced shear stress along the margins of the channel downstream of RM 10.6 reveal only gravel-sized material mobilization is expected there.

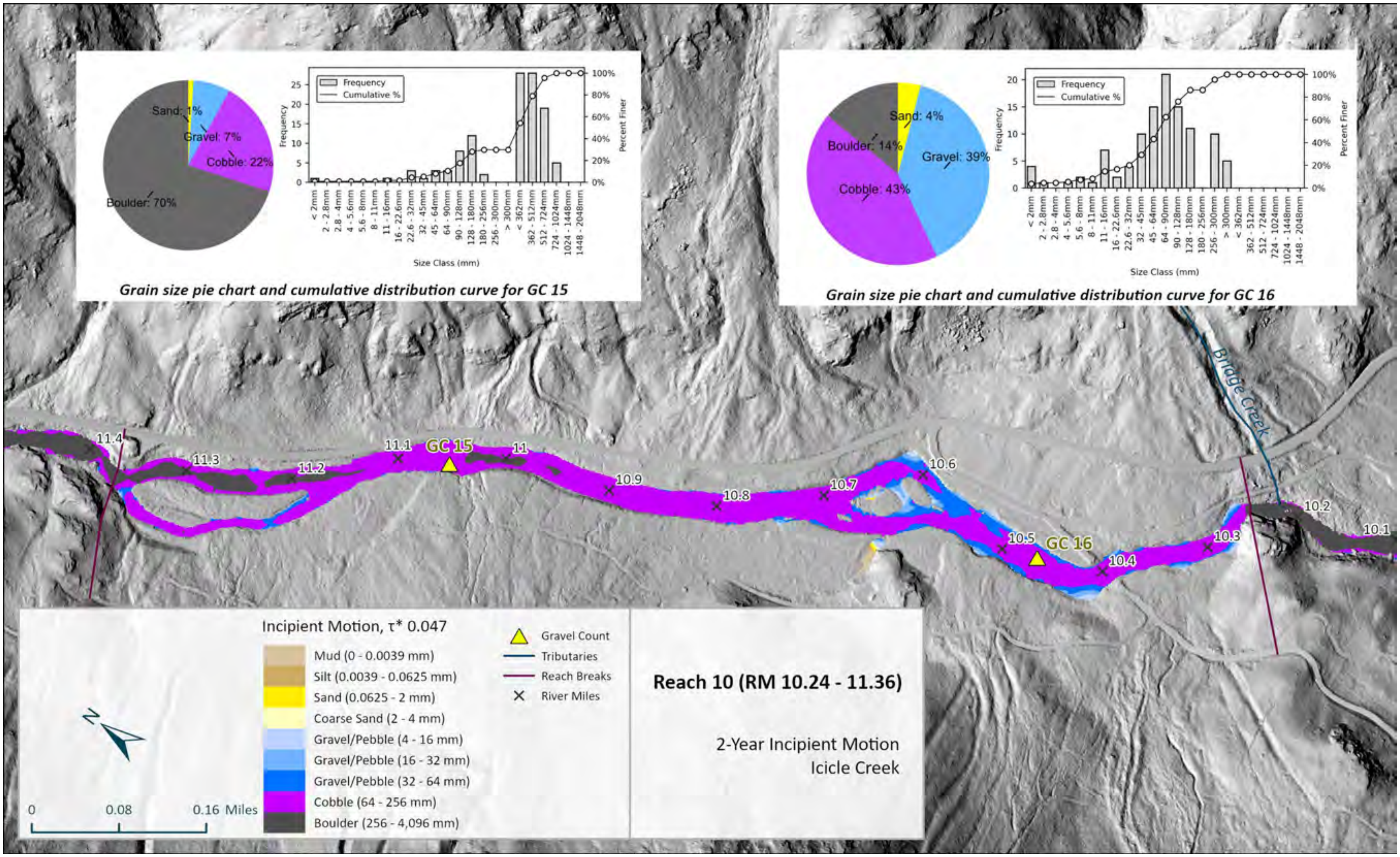

Figure 166. Reach 10: incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge). Includes location and grains size data of the GC 15 and GC 16 pebble counts (2024 survey).

3.10.3 Large Wood Material

The habitat survey conducted in summer 2024 recorded 60 individual pieces of large woody material (LWM) and 7 log jams (accumulation of >3 LWM) within the bankfull channel, totaling 218 observed pieces. Figure 168 is a map of the surveyed large wood in Reach 10. Of the 60 individual pieces; 8 classified as large size class (>20-inches diameter and >35-feet long); and 20 as medium size class (12 to 20-inches diameter and at least 35-feet long). All 7 log jams in Reach 10 have multiple pieces of medium and large LWM. Reach 10 has 108 pieces of wood per mile (count includes medium and large LWM as individuals and in jams), which meets the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state (Fox & Bolton, 2007; Appendix A). However, large wood distribution is varied and several of the jams are not connected to the channel during low-flow conditions.

Accumulations of LWM were found at RM 11.3 and RM 11.35 and a notable racked jam at the head of an island near RM 10.71 (Figure 167). The jam at RM 10.71 enhances habitat diversity and supports key geomorphic processes such as flow splitting, sediment sorting, upstream bedload aggregation, and the formation of vegetated bars downstream. While large wood is present in the reach, some of the accumulations lack anchoring by key logs making them more likely to be mobilized during high flows. The large wood in Reach 10 is also likely limited by past wood removal activities at the Eightmile Forest Service 7601 Road bridge (RM 10.4) and campground.

Figure 167. Left: Large wood jam at RM 11.3 (August 14, 2024). Right: Wood racking at the head of an island at RM 10.71. (August 14, 2024)

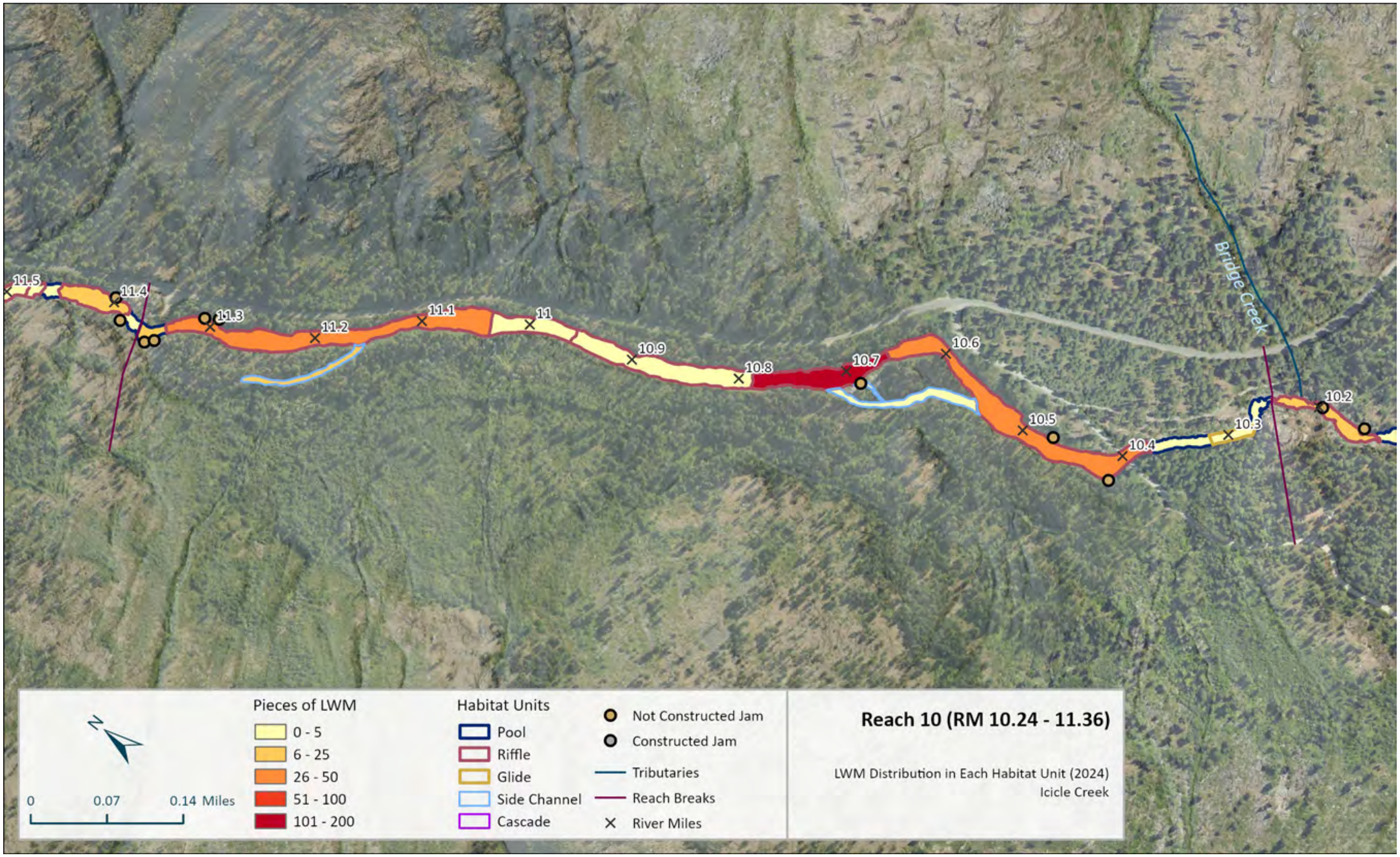

Figure 168. Reach 10: Large wood distribution (pieces per mile per habitat unit) map and surveyed habitat units (2024).

3.10.4 Vegetation

Riparian vegetation on river-left is impacted by the Icicle Creek Road, which was constructed along the river-left bank for a large portion of the channel in Reach 10. The Bridge Creek Campground and nearby dispersed camping and recreation areas impact riparian vegetation at the downstream end, mainly in river-left. The vegetation on river-right is largely undisturbed except for past fire impacts and an area of floodplain with cleared areas and dispersed camping near RM 10.7 – 10.8.

The overstory is dominated by large trees, especially from RM 10.24 to 10.98, RM 11.03 to 11.18, and RM 11.25 to 11.36. The dominant overstory species is ponderosa pine, with cedar, cottonwood, fir, and aspen also present. The shrub understory is mostly alder, with willows lining channel margins in many areas. Vine maple, oceanspray, and dogwood are also common in the understory. There is some shading to the river provided by large trees along the river-right bank. Large wood recruitment to the channel would primarily occur via natural tree fall or during very large floods, as on-going bank erosion and channel migration is limited due to natural confinement. A representative photo of riparian vegetation conditions is included in Figure 169.

A map showing vegetation heights is provided in Figure 170, with an aerial map in Figure 171. The map shows the relative abundance of large trees throughout the reach.

Figure 169. Representative vegetative conditions in Reach 10, near RM 10.95 (August 2024).

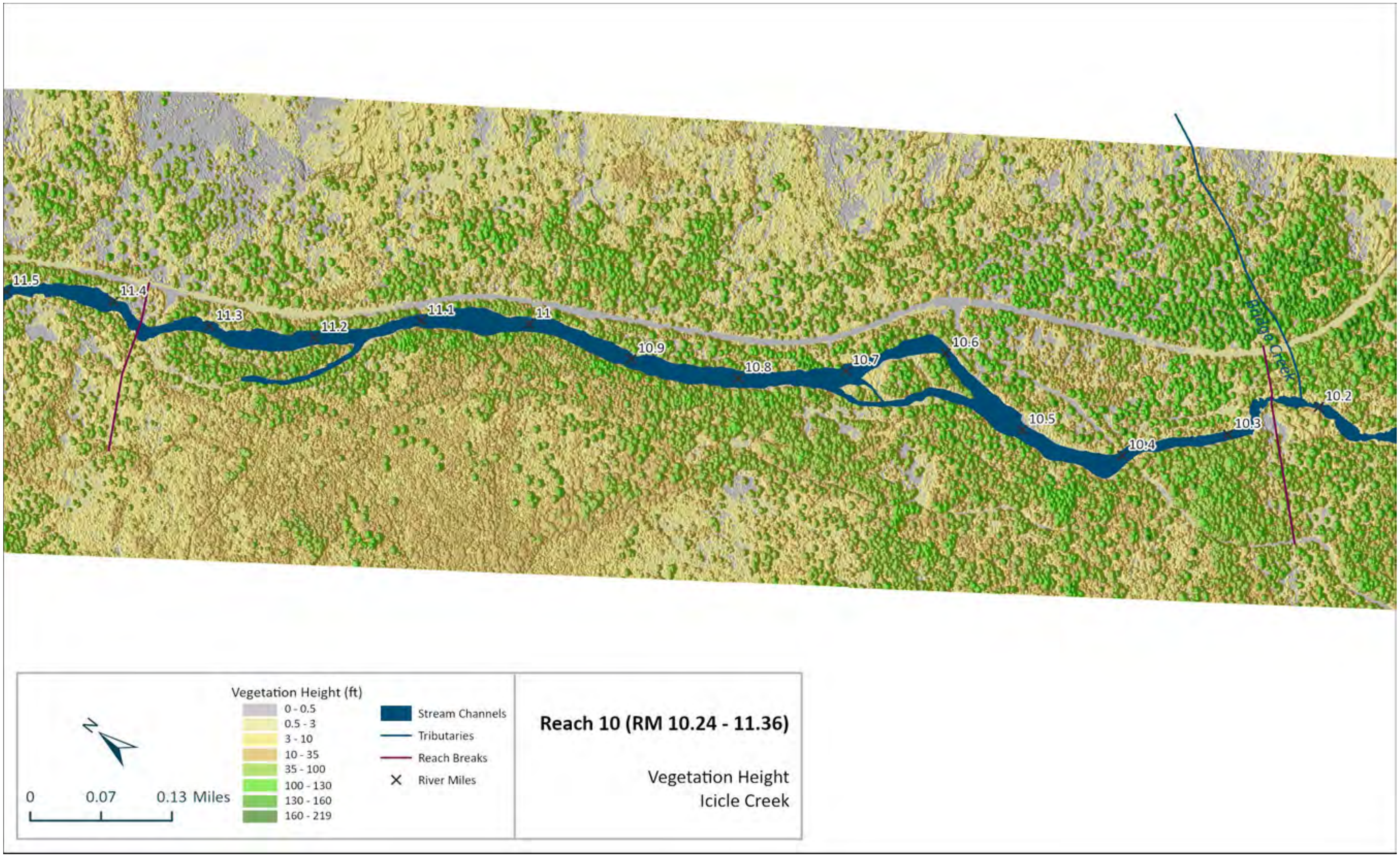

Figure 170. Reach 10: Map of vegetation height classification analysis (LiDAR – based analysis).

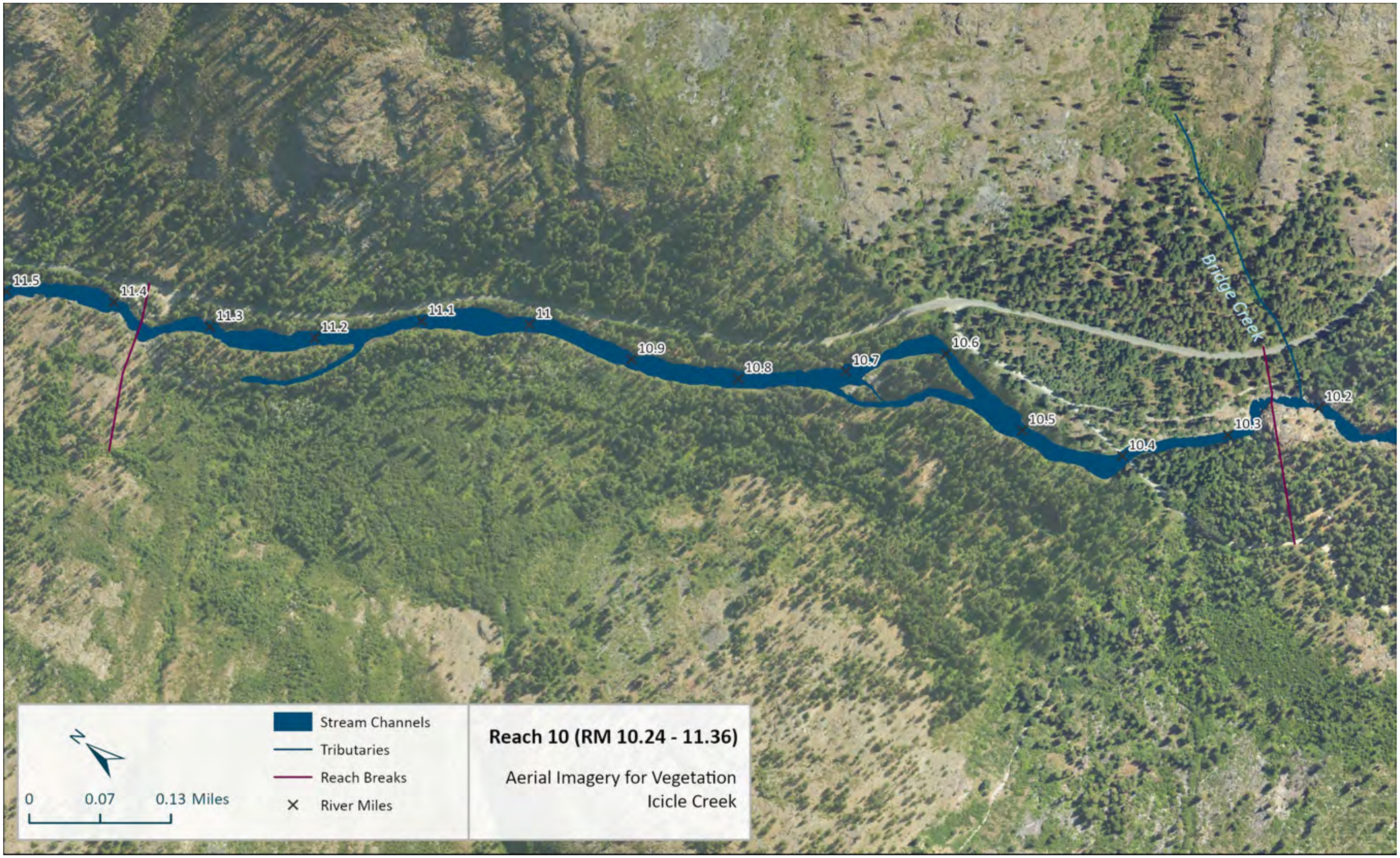

Figure 171. Reach 10: Map of aerial imagery for vegetation identification (ESRI 2023).

3.10.5 Human Alterations

A map of human features is provided in Figure 172. The Icicle Creek Road runs along most of the reach on river-left, impacting riparian conditions and providing easy river access. At the downstream end on river-left is the Bridge Creek Campground and dispersed recreation areas in the vicinity (Figure 173). The Eightmile Forest Service Road 7601 bridge crosses near RM 10.4 and has a concrete and steel structure (Figure 174). The associated bridge abutments and banks are heavily armored with riprap that extends upstream on river-left. The bridge approach serves as a levee bisecting the river-left floodplain. The bridge and levee restrict lateral channel migration and floodplain connectivity. Dispersed camping and associated foot trails continue upstream along the riverbanks on both sides of the river. In several locations, hand-built rock dams were observed during the survey, with potential temporary effects on fish movement. In the river-right floodplain from RM 10.7 – 10.8, there appears to be the remnants of former development, potentially a former campground that includes remnants of a levee, cleared areas, a concrete pad, and a picnic table. There are currently rough trails and dispersed camping in this area. In the floodplain in this area there were what are assumed to be shallow groundwater monitoring stations (PVC standpipes) and a river level monitoring station (PVC standpipe) along the channel bank near RM 10.72 (Figure 175).

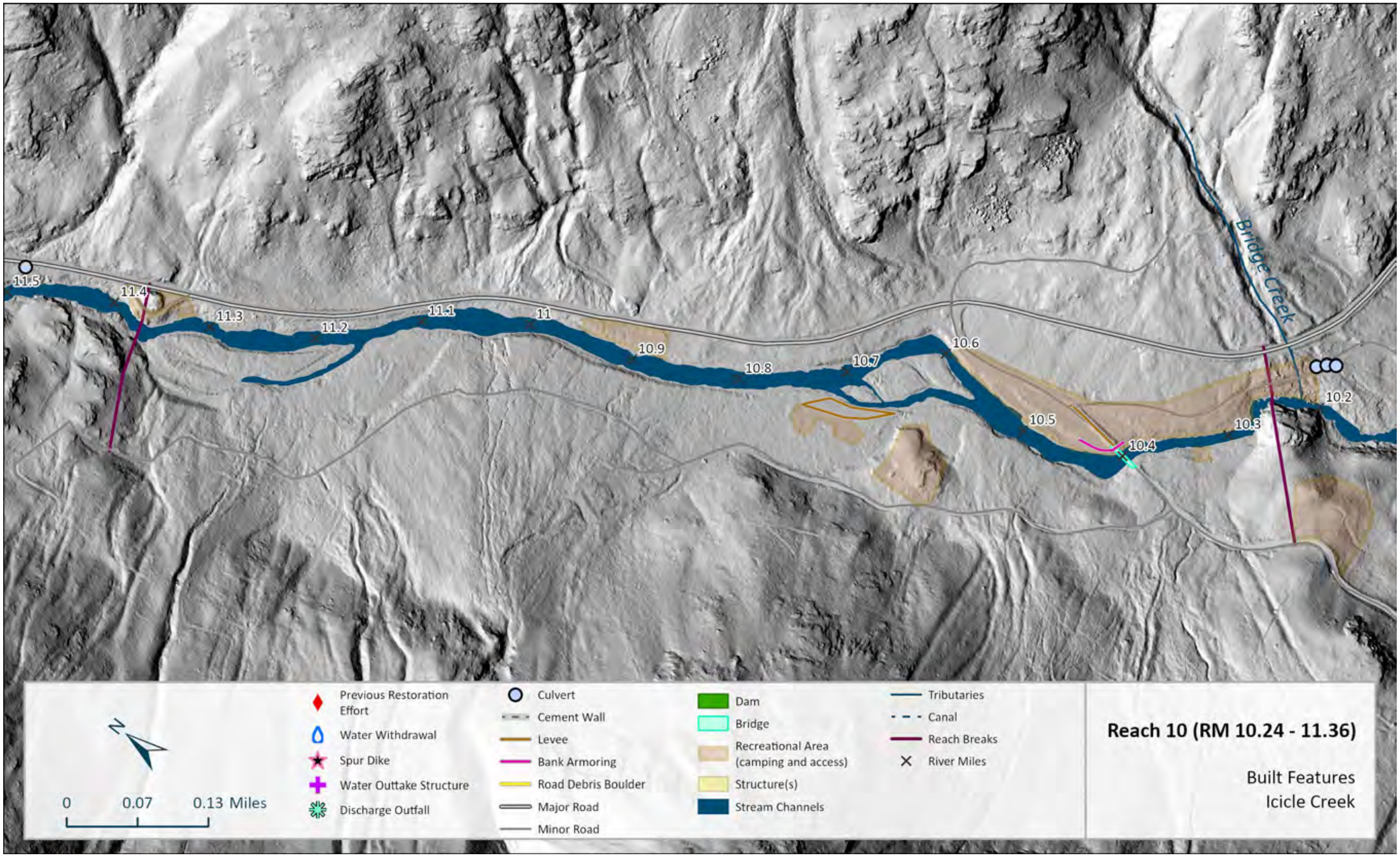

Figure 172. Reach 10: Mapped anthropogenic features (2024).

Figure 173. Looking across at the Bridge Creek Campground on river-left from the downstream end of the reach. (August 14, 2024)

Figure 174. Eightmile Road bridge (FR 7601) near RM 10.4. (August 2024)

Figure 175. River (left) and presumed floodplain groundwater level monitoring station (right) on river-right near RM 10.72. (August 14, 2024)

3.10.6 Recommended Actions

Reach 10 has some good restoration opportunities. The Eightmile Project encompasses this reach. This reach may be particularly important for restoration given that it is a relatively low gradient reach bounded by long higher gradient sections upstream and downstream where slow-water rearing habitat and off-channel habitats are more naturally limited. There are also some legacy human features that could be modified to restore floodplain processes. The primary feature is a levee in the river-right floodplain near RM 10.7 that could be removed to enhance floodplain connectivity. There may also be opportunities in this larger river-right floodplain for creating off-channel or side-channel features in old channel scars. Groundwater monitoring stations in this area suggest that others may already be investigating restoration potential in this area. There are also a concrete pad and other areas of fill (former campground?) that could be removed in this floodplain.

There are opportunities for enhancing riparian conditions on river-left along the Bridge Creek Campground where recreational activities have disturbed the riparian zone, but these actions will be challenged by the continued campground uses. There are numerous low gradient plane bed 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. Wood placements are possible along the campground but may conflict with recreational uses. A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities).

3.11 ICICLE CREEK REACH 11 (RM 11.36 – 11.92)

3.11.1 Overview

Reach 11 is 0.56 miles long and extends from RM 11.36 to RM 11.92 at the upstream end of the Fourth of July Creek alluvial fan. This is a steep reach with an average gradient of 3.40%. The channel is confined and single-thread in form. Boulder-riffle and boulder or pool sequences define the channel unit type (Figure 176). Icicle River Road runs parallel to the channel on the adjacent river-left hillslope. There is a dispersed recreation area on the left bank at the downstream end. The reach lies entirely within the Wenatchee National Forest.

Figure 176. Representative photo of boulder riffle in Reach 11 at RM 11.65 (August 14, 2024).

3.11.2 Channel and Floodplain Geomorphology

Table 21. Reach 11 metrics.

Reach 11												
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
0.56	11.36-11.92	3.40%	1.02	Riffle	76	Confined	Boulder	28.8%	0.0%	71.2%	0.0%	0.0%

The channel in Reach 11 is relatively high gradient and confined. Confinement is forced by fans (alluvial and debris) extending into the valley floor along the river-left side and hillslope confinement on river-right (Figure 178). Bedrock exposures along the bank occur on both sides of the channel and in the bed of channel at RM 11.41 (Figure 177). The channel displays a boulder riffle-pool type sequence that includes periodic boulder-steps and a bedrock/boulder step at RM 11.41. Fourth of July Creek joins Icicle Creek on river-left at RM 11.9. Habitat complexity in Reach 11 is associated with the tributary confluence and very small pockets of refugia associated with large boulders that produce localized scour, cover, or reduced hydraulics. Floodplains in Reach 11 are limited to narrow discontinuous bands along the margin of the channel, where vegetation establishment can occur.

Figure 177. Boulder/bedrock step at RM 11.41. Bedrock is exposed in bank and bed of channel. (August 14, 2024)

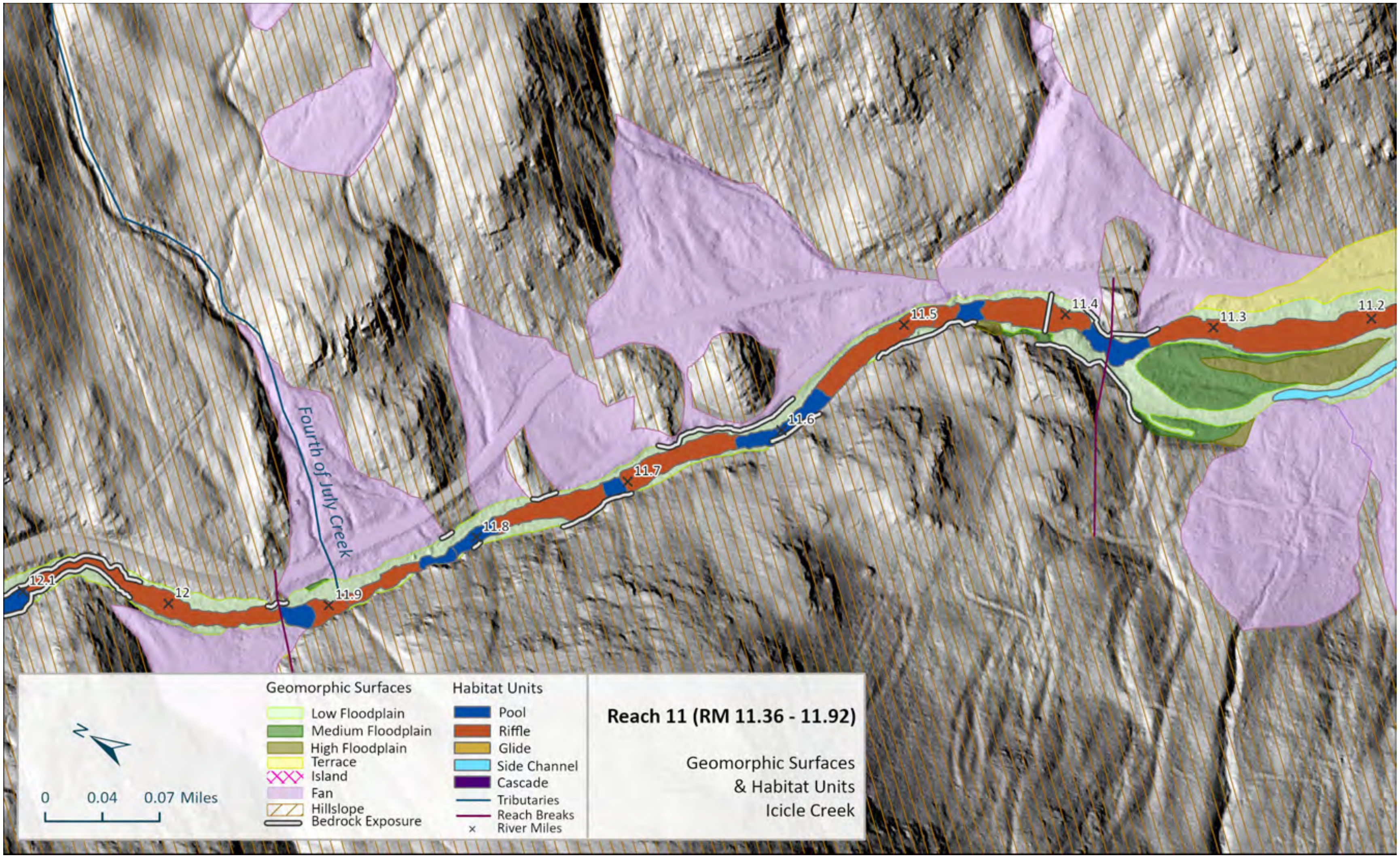

Figure 178. Reach 11: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

Channel substrate in Reach 11 is primarily composed of boulder and cobble. Only small fractions of gravel or coarse sand were observed draped along the margin of the active channel or in small areas of reduced hydraulics behind large boulders along the margin of the channel. Colluvium from adjacent confining hillslopes is a primary source of sediment in Reach 11, including large to massive boulders (Figure 179).

Figure 179. Example of hillslope-contributed colluvium that includes large boulders mixed with bedload at RM 11.88. (August 14, 2024)

No appropriate locations were identified in Reach 11 to complete a Wolman Pebble Count (Wolman, 1954) Incipient motion hydraulic analysis (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5) suggests that at the 2-year modeled discharge, the channel's shear stress is capable of mobilizing boulder-sized material through the reach (Figure 180). Reach 11 is considered a high-energy sediment transport reach. Sediment in this reach is sourced from upstream contributions transported into Reach 11, as well as hillslope colluvium and debris fan inputs.

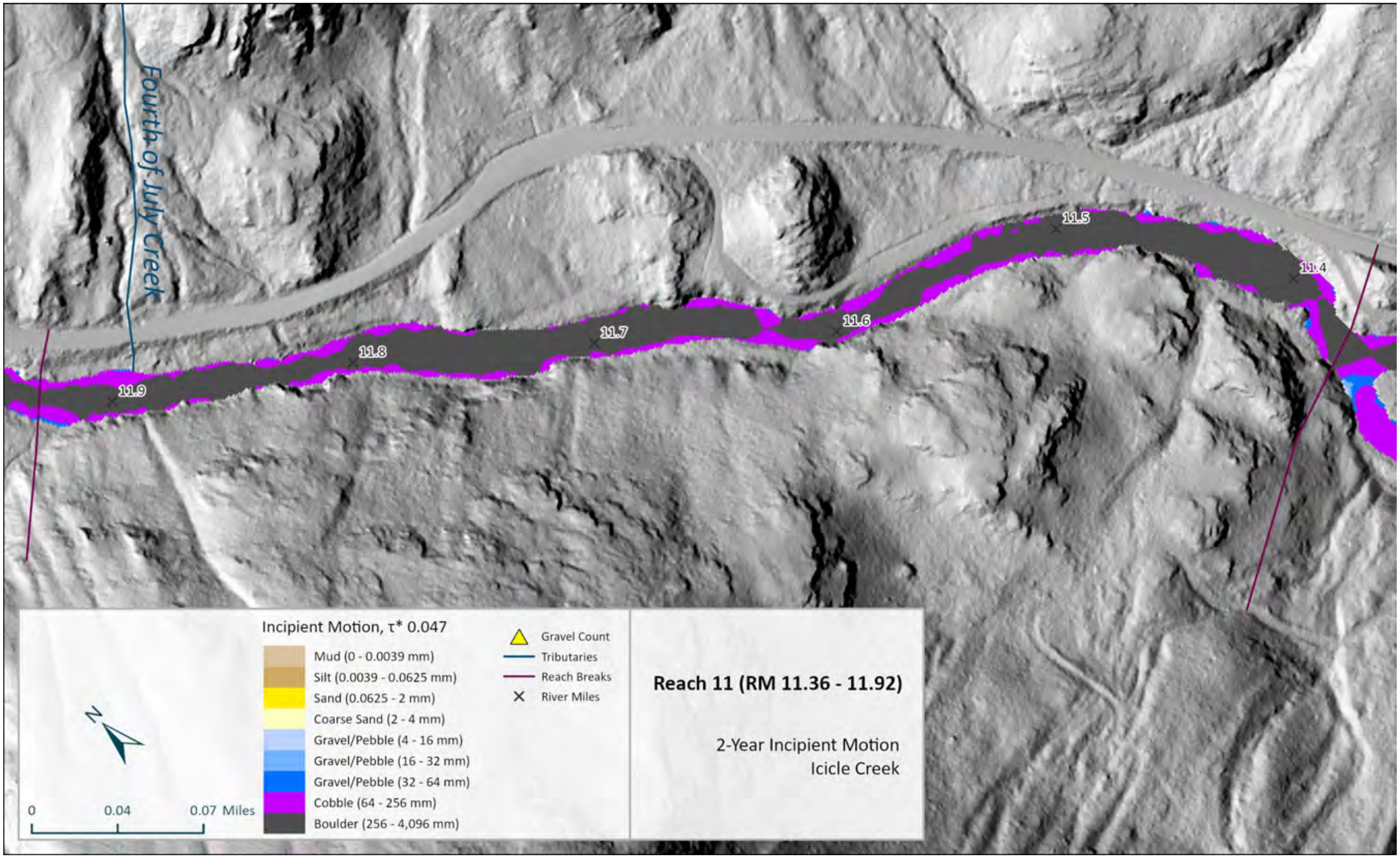

Figure 180. Reach 11: incipient motion analysis results map (estimated grain size mobility at the 2-year modeled discharge).

3.11.3 Large Wood Material

The habitat survey conducted in summer 2024 recorded 31 individual pieces of large woody material (LWM) and 5 log jams (accumulation of >3 LWM) within the bankfull channel, with a combined total of 48 observed pieces. Figure 182 is a map of the surveyed large wood in Reach 11. Of the 31 individual pieces; 17 pieces are considered medium and large LWM; 6 classified as large size class (>20-inches diameter and >35-feet long); and 11 as medium size class (12 to 20-inches diameter and at least 35-feet long). All 5 log jams in Reach 11 have multiple pieces of medium and large. Reach 11 has 52 pieces of wood per mile (count includes medium and large LWM as individuals and in jams), which does not meet the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state (Fox & Bolton, 2007; Appendix A). However, the high shear stress produced in the reach does not allow for retention of LWM. As a result, LWM currently does not influence geomorphic processes in this reach. The wood that is present is usually draped along the channel margins (Figure 181) or temporarily racked atop boulders or bedrock.

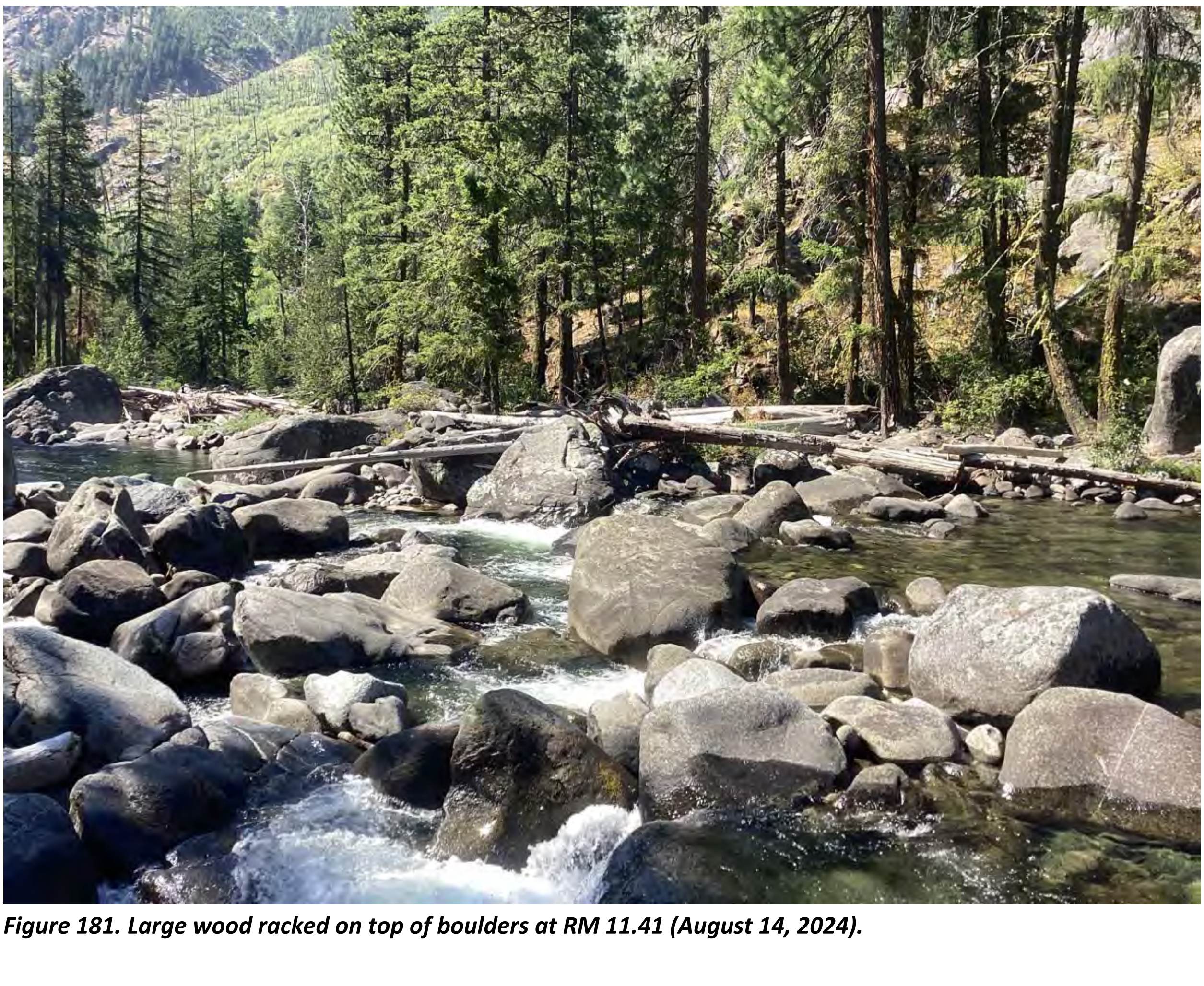

Figure 181. Large wood racked on top of boulders at RM 11.41 (August 14, 2024).

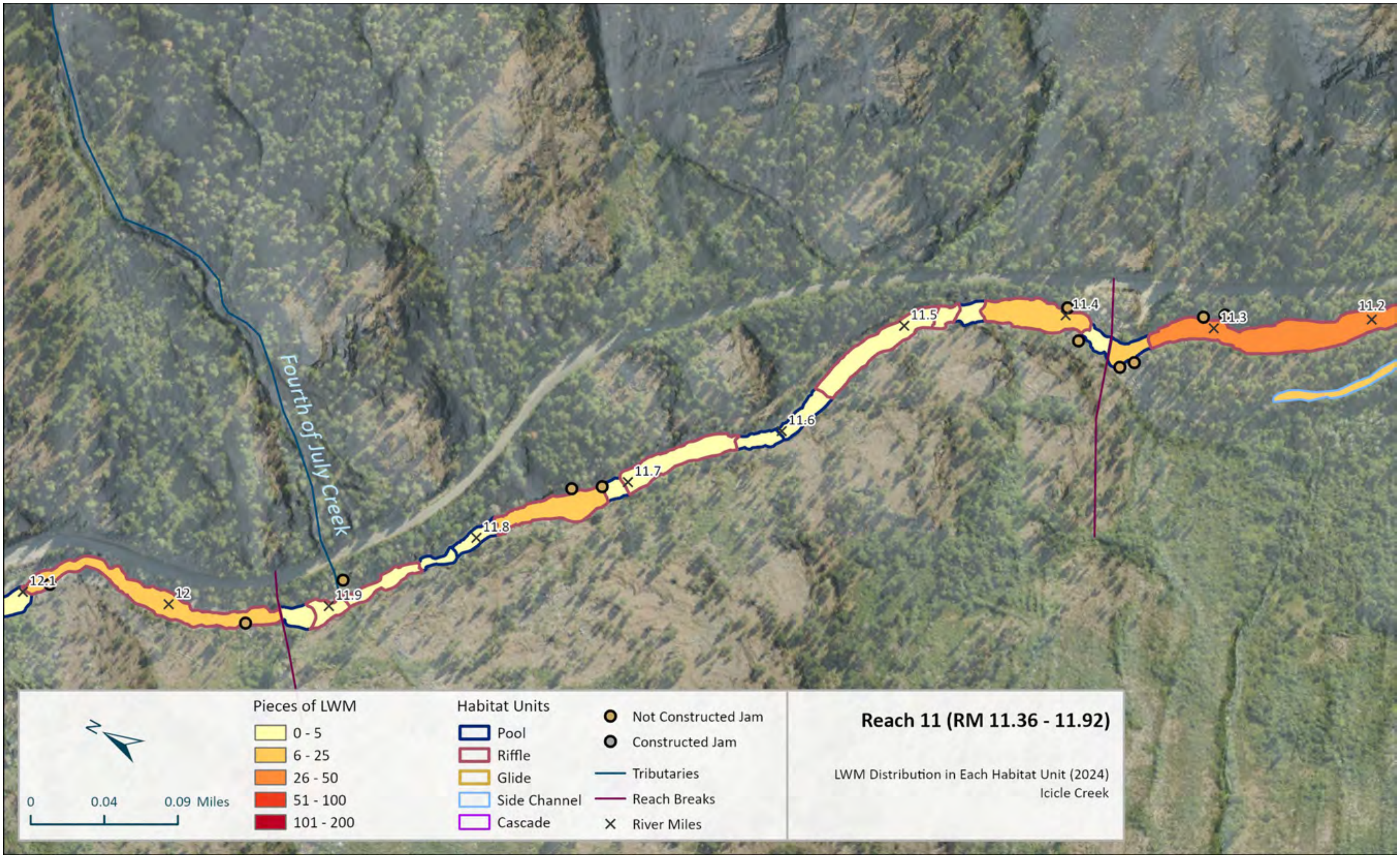

Figure 182. Reach 11: Large wood distribution (pieces per mile per habitat unit) map and surveyed habitat units (2024).

3.11.4 Vegetation

The riparian vegetation is naturally sparse due to hillslope bedrock composition and steep slopes with shallow soil (Figure 183). There are subtle impacts to hillslope and riparian vegetation due to Icicle Road, and dispersed recreation use on river-left at the downstream end. Otherwise, there are relatively few human impacts to riparian vegetation. The overstory, where it exists, is dominated by large trees, especially from RM 11.36 to 11.63 and from RM 11.7 to 11.92. The dominant overstory species is ponderosa pine, with cedar, cottonwood, and fir also present. The shrub understory is mostly alder, with willows lining channel margins in many areas. Dogwood, vine maple, serviceberry, rose, and yampah were also observed in the understory. There is some shading to the river provided by large trees along the river-right bank. Large wood recruitment to the channel would primarily occur via natural tree fall or during very large floods. A map showing vegetation heights is provided in Figure 184, with an aerial map in Figure 185.

Figure 183. Representative vegetative conditions in Reach 11, near RM 11.53 (August 2024).

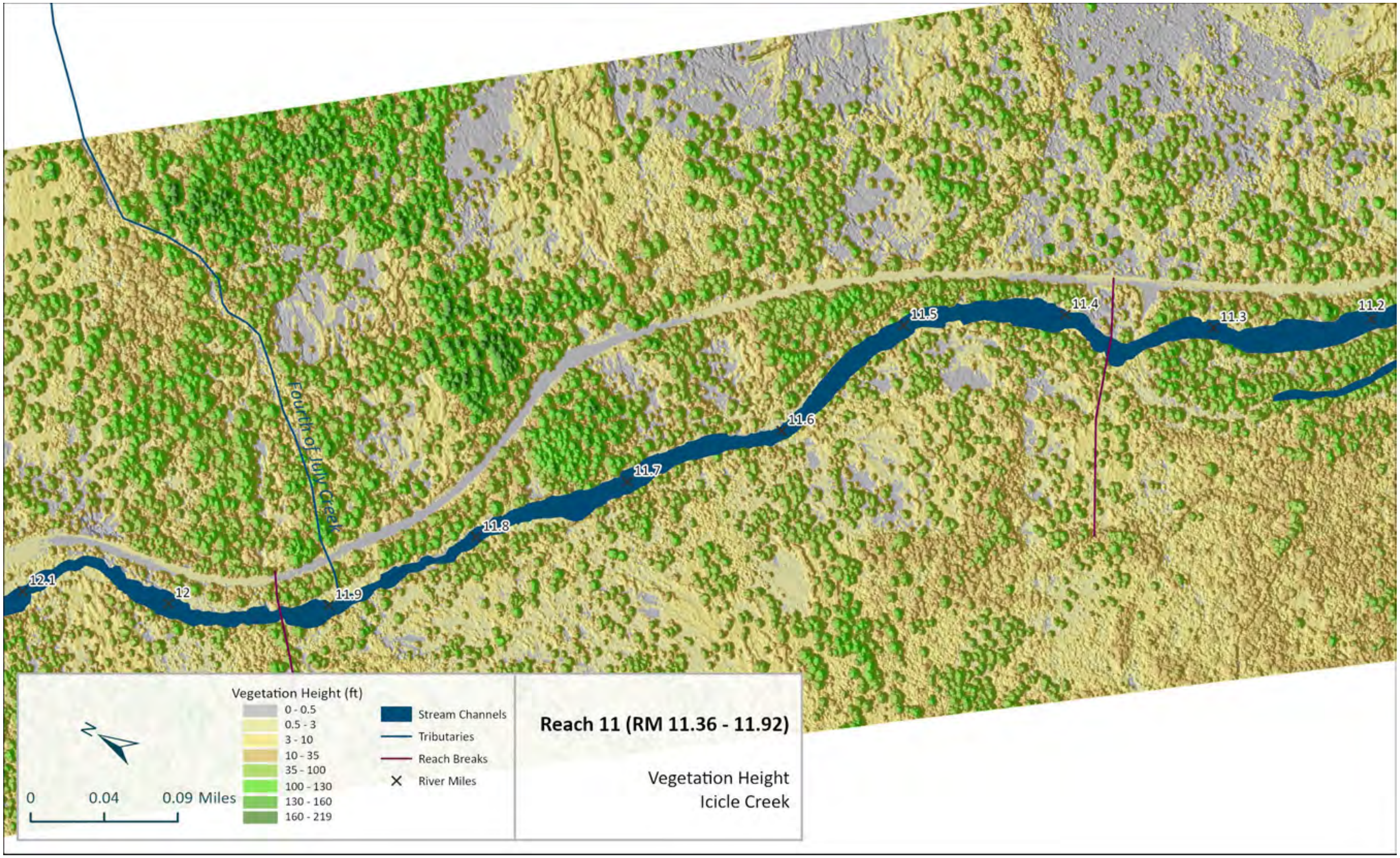

Figure 184. Reach 11: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 185. Reach 11: Map of aerial imagery for vegetation identification (ESRI 2023).

3.11.5 Human Alterations

Human alterations in Reach 11 are shown in Figure 187. There are relatively few human impacts to the reach. Icicle Road lies mostly high on the river-left bank and impacts riparian vegetation only at the upstream and downstream ends of the reach. Road debris was identified at RM 11.39, RM 11.5, and RM 11.81. The debris slightly increases channel confinement. There is an abandoned road, the former Icicle Creek Road, which runs from RM 11.65 down to approximately RM 11.45, portions of which have been converted into a trail. There is a dispersed recreation area at the downstream end river-left with vegetation impacts. There are two culverts under Icicle Creek Road; one is a 24-inch corrugated metal pipe on an ephemeral creek near RM 11.48 and the second is at Fourth of July Creek near RM 11.89 (Figure 186). The culverts are inadequate for accommodating debris flows.

Figure 186. Fourth of July Creek culvert under Icicle Creek Road at RM 11.89. (August 14, 2024)

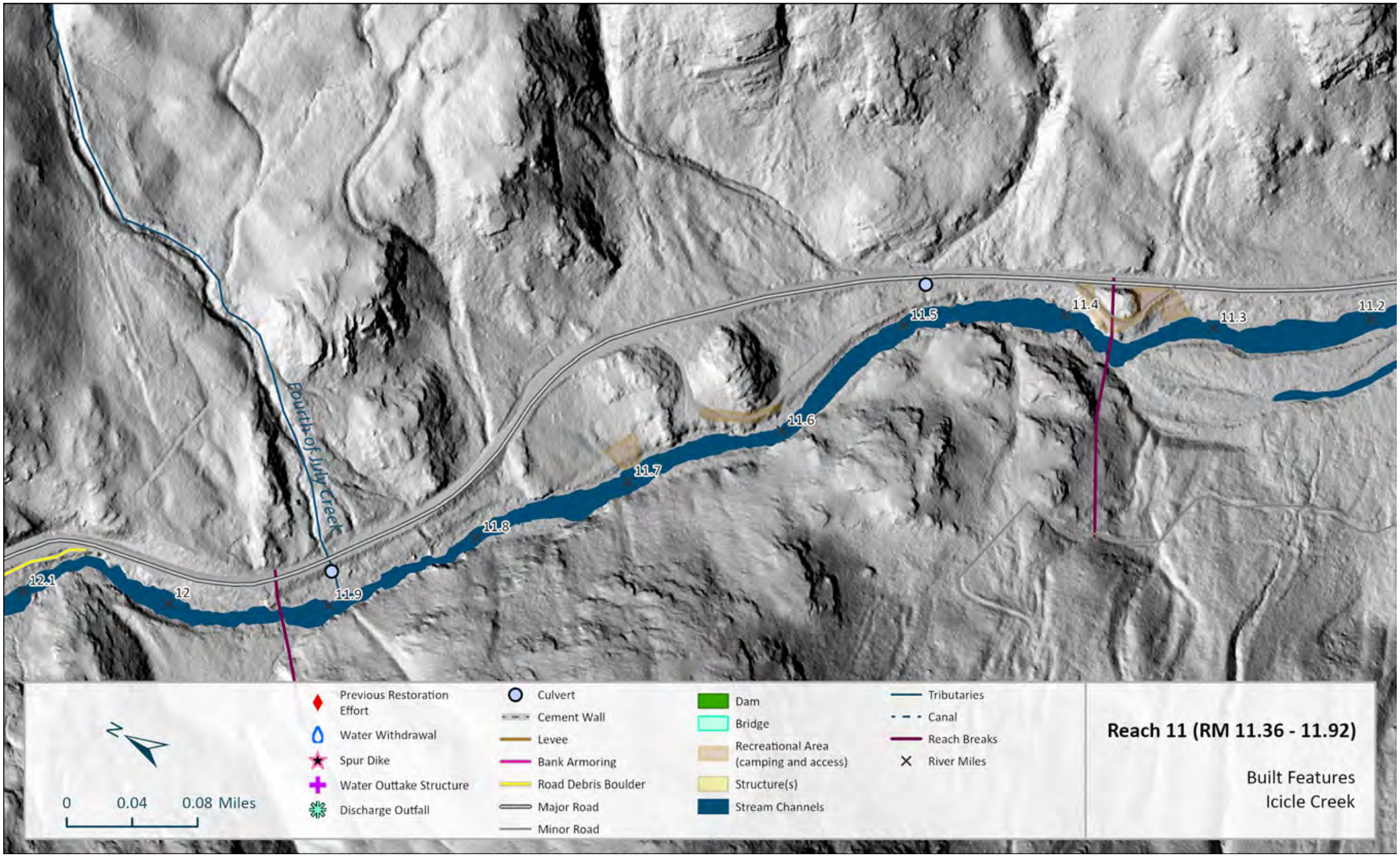

Figure 187. Reach 11: Mapped anthropogenic features (2024).

3.11.6 Recommended Actions

There is very little restoration potential in Reach 11 given the steep and confined channel. The reach is mostly a steep boulder-bed step-pool channel where opportunities for restoration are limited and access would be challenging. There are occasional pools where large wood could be added for cover and complexity; braced against large boulders, large trees, or extending down the bank; but wood will create very little geomorphic response due to high energy, and anchoring would be a challenge. No projects are mapped for this reach. A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities).

3.12 ICICLE CREEK REACH 12 (RM 11.92 – 12.50)

3.12.1 Overview

Reach 12 is 0.58 miles long and extends from RM 11.92 to RM 12.50. The reach has an overall moderately steep gradient at 2.11%. With the exception of split flow around a vegetated island at RM 12.45, the channel is single-thread in form. The upstream portion of the reach has a slightly lower gradient with marginal floodplains and is dominated by extended boulder-cobble riffles (Figure 188). The downstream half of the reach is confined with an increased gradient and extended boulder riffles and boulder or bedrock steps. (Figure 189). Human alterations in Reach 12 include the Icicle Road cut into the hillslope on river-left as well as dispersed camping and recreational areas. The reach lies entirely within the Wenatchee National Forest.

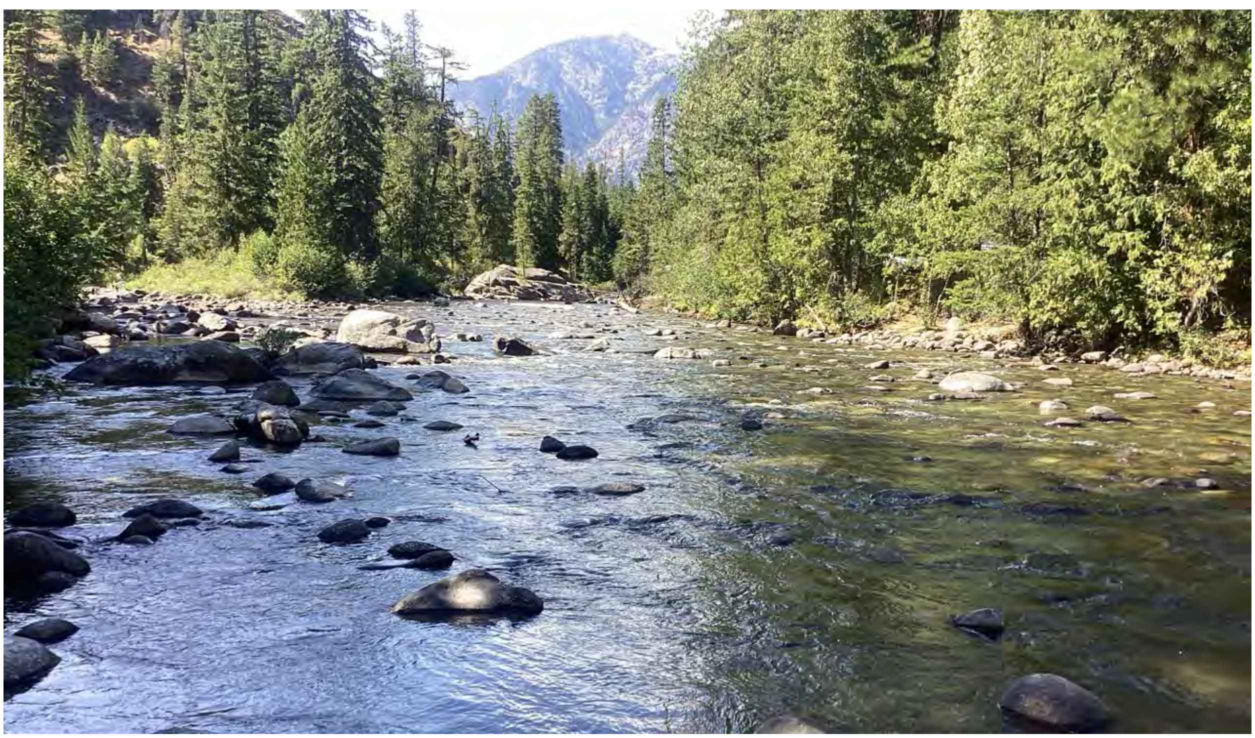

Figure 188. Representative photo upstream section of Reach 12 near RM 12.35 (August 13, 2024).

Figure 189. Representative photo in steep downstream section of the reach near RM 12.05 (August 2024).

3.12.2 Channel and Floodplain Geomorphology

Table 22. Reach 12 metrics.

Reach 12												
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
0.58	11.92-12.50	2.11%	1.03	Riffle	92	Confined	Boulder	18.9%	4.8%	72.3%	4.0%	0.0%

The channel in Reach 12 ranges from moderate gradient in the upstream section (RM 12.1-12.5) to high gradient in the downstream section (RM 11.92-12.1), resulting in a reach average gradient of 2.11%. Variation in gradient and confinement in this reach produces variation in channel substrate, presence of floodplain, and channel unit types. Upstream of RM 12.4, reduced confinement allows for the development of floodplain and terrace surfaces, as well as split flow conditions around a vegetated island. Downstream of RM 12.4 the channel is confined via fans (debris and alluvial) and bedrock hillslopes (Figure 190). One unnamed ephemeral tributary from a broad fan surface at RM 12.32 on river-right seasonally feeds Icicle Creek.

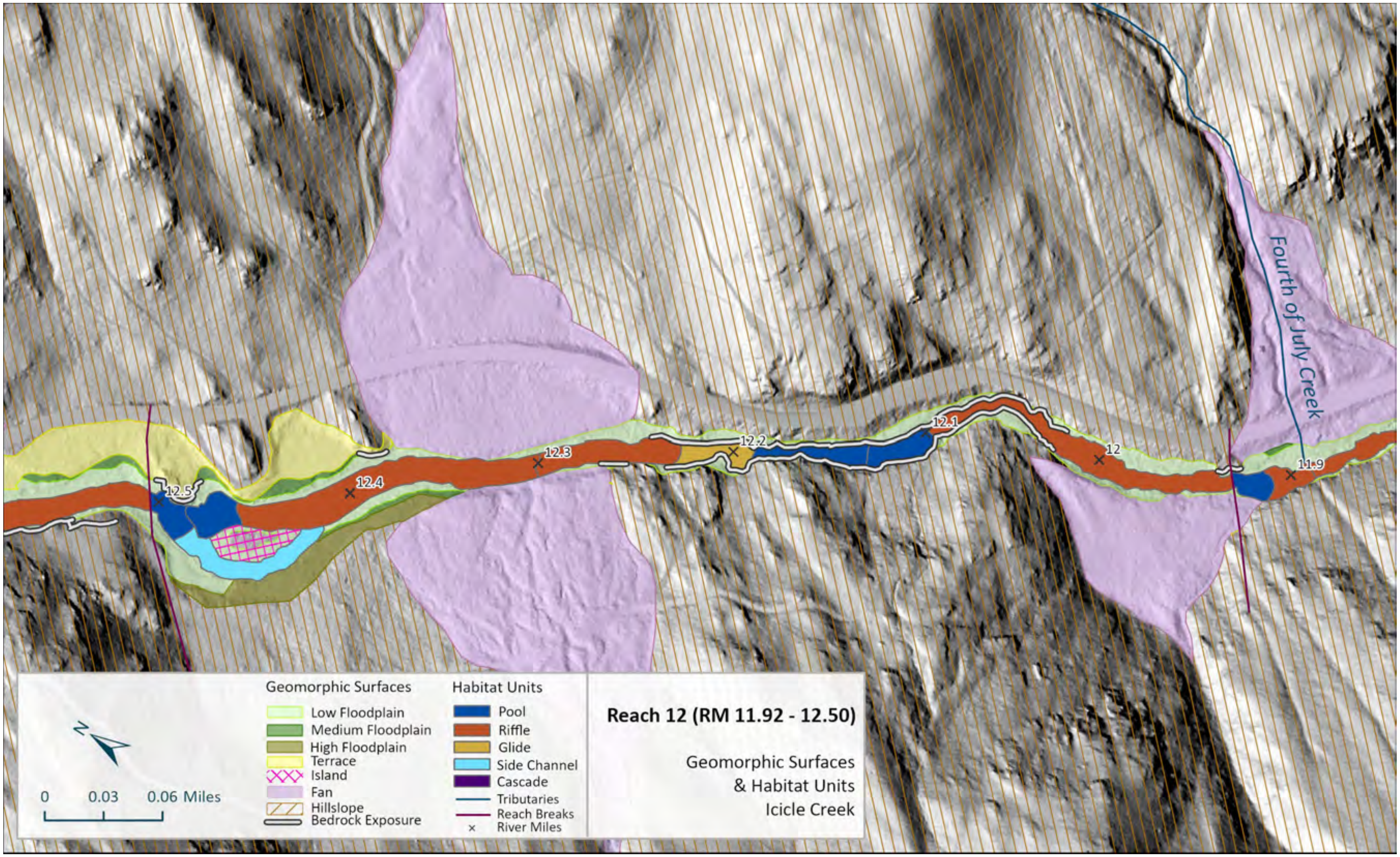

Figure 190. Reach 12: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

The channel in Reach 12 displays riffle-pool sequencing with extended boulder riffles that shift to extended cascading boulder riffles or boulder/bedrock steps in the downstream steeper sections. Bedrock imposes a channel grade control at RM 12.09 that creates a low-flow extended pool upstream of it (Figure 191).

Figure 191. Left: In-channel bedrock grade control at RM12.08. Right: extended pool and glide upstream of grade control at RM 12.2. (August 13, 2024)

Channel substrate in Reach 12 includes bedrock, boulders, and cobbles. Bars composed of cobble and sometimes gravel exist in pockets of reduced energy along the channel margins or behind large boulders (Figure 192). Sediment in this reach is sourced from upstream contributions transported from Reach 13, as well as hillslope colluvium and debris fan inputs.

Figure 192. Boulder-cobble substrate with cobble-gravel bar at the margin at RM 12.24. (August 13, 2024)

One Wolman Pebble Counts (Wolman, 1954)was conducted in Reach 12 on a riffle crest located at RM 12.39 (GC 14). The median grain size (D50) of GC 14 was 205 mm (Figure 193). The pebble count data are included in Figure 194 of the Reach 12 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5). The analysis indicates that at the 2-year modeled discharge, the channel's shear stress is expected to mobilize cobble sized material through the upstream section (RM 12.25-12.5). Considering the modeled shear in Reach 13 predicts boulder-sized material transport into Reach 12, the upper section of Reach 12 likely experiences some deposition of imported bedload. Modeled shear increases slightly downstream to include patches of boulder mobilization (RM 12.18-25). Downstream RM 12.18 the incipient motion analysis predicts boulder-sized mobilization capacity. The downstream sections of Reach 12 are considered transport sections.

Figure 193. Boulder, cobble, and gravel at channel margin of GC 14 at RM 12.39. (August 13, 2024)

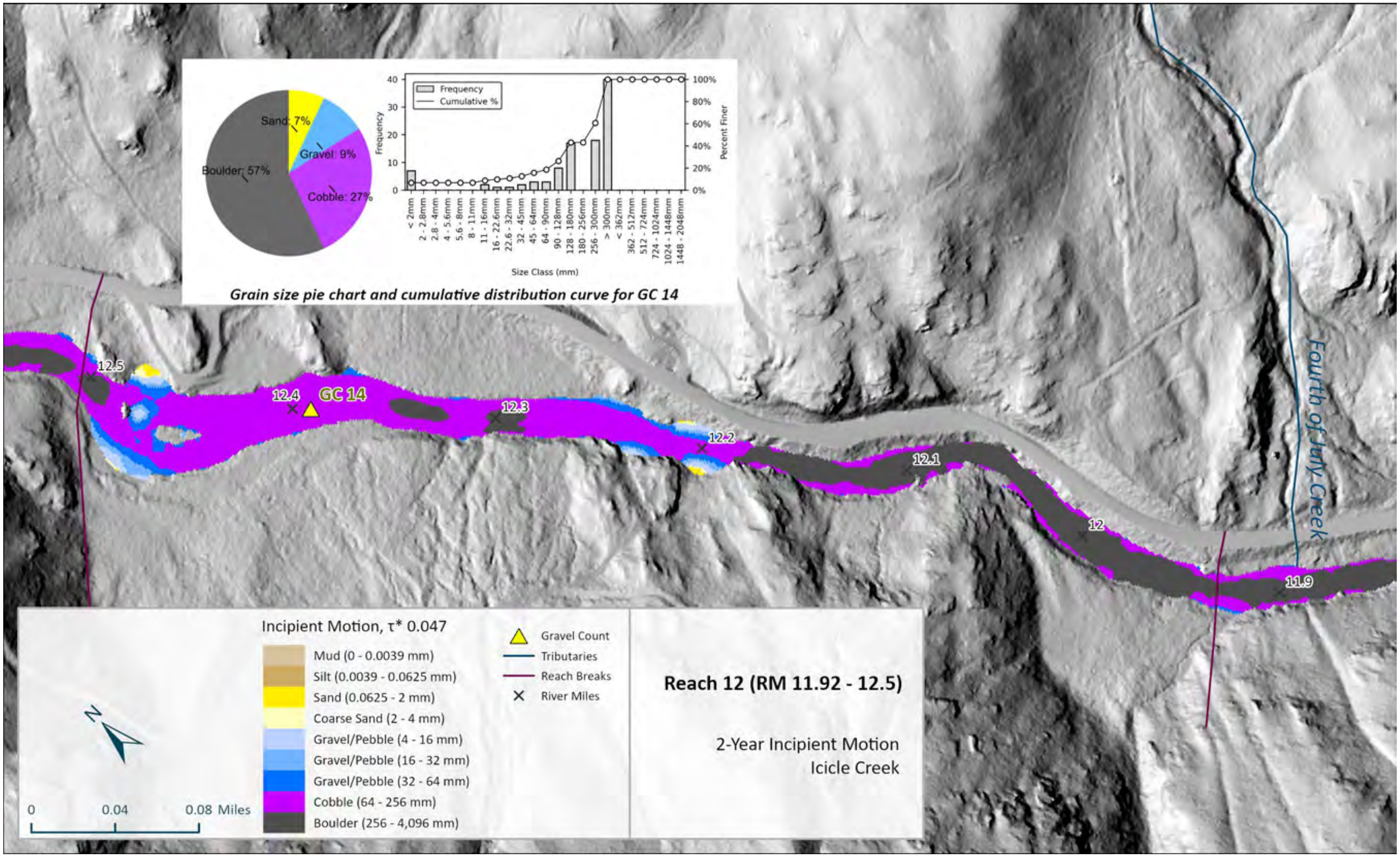

Figure 194. Reach 12: incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge). Includes location and grains size data of the GC 14 pebble count (2024 survey).

Channel confinement results in limited area for floodplain development in Reach 12. Narrow bands of riparian vegetation occupy discontinuous strips of marginal low floodplain (inundated ~1-5 yrs) throughout the reach (Figure 195). Floodplains do occur at RM 12.32-12.5 as stepped bands of low and medium floodplain (inundated ~5-20 yrs) and high floodplains (inundated 20-100+yrs) surfaces. The river-left edge of this area is bound by terraces (abandoned surface). The stepped pattern reveals the process of channel downcutting. The floodplain soils are described as silt loam (Natural Resources Conservation Service, 2007)

Figure 195. Discontinuous narrow low floodplain with riparian vegetation at RM 12.47. (August 13, 2024)

3.12.3 Large Wood Material

The habitat survey conducted in summer 2024 recorded 30 individual pieces of large woody material (LWM) and 5 log jams (accumulation of >3 LWM) within the bankfull channel, for a combined total of 71 observed pieces (Figure 197). Of the 30 individual pieces; 12 pieces are considered medium and large LWM; 4 classified as large size class (>20-inches diameter and >35-feet long); and 8 as medium size class (12 to 20-inches diameter and at least 35-feet long). Of the 5 log jams in Reach 12, 4 have multiple pieces of medium and large LWM. Reach 12 has 60 pieces of wood per mile (count includes medium and large LWM as individuals and in jams), which does not meet the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state (Fox & Bolton, 2007; Appendix A). However, the high shear stress produced in Reach 13 because of its gradient and confinement limits the retention of LWM. As a result, LWM currently does not influence geomorphic processes in this reach. However, the high shear stress produced in Reach 13 because of its gradient and confinement often does not allow for retention of LWM. As a result, LWM currently does not influence geomorphic processes in this reach. The wood that is present is usually draped along the channel margins or temporarily racked atop boulders or bedrock.

The wood that is present in Reach 12 is usually draped along the channel margins or temporarily racked on boulders or bedrock - not interacting with the channel at low-flow conditions (Figure 196). While some large wood and jams are present in the reach, most are considered temporary and likely to be mobilized during high flow or flood events. However, large wood loading near RM 12.4, where floodplain and split-flow conditions occur, could be beneficial for habitat uplift.

Figure 196. Wood jam racked atop boulders at RM 11.96 (August 14, 2024)

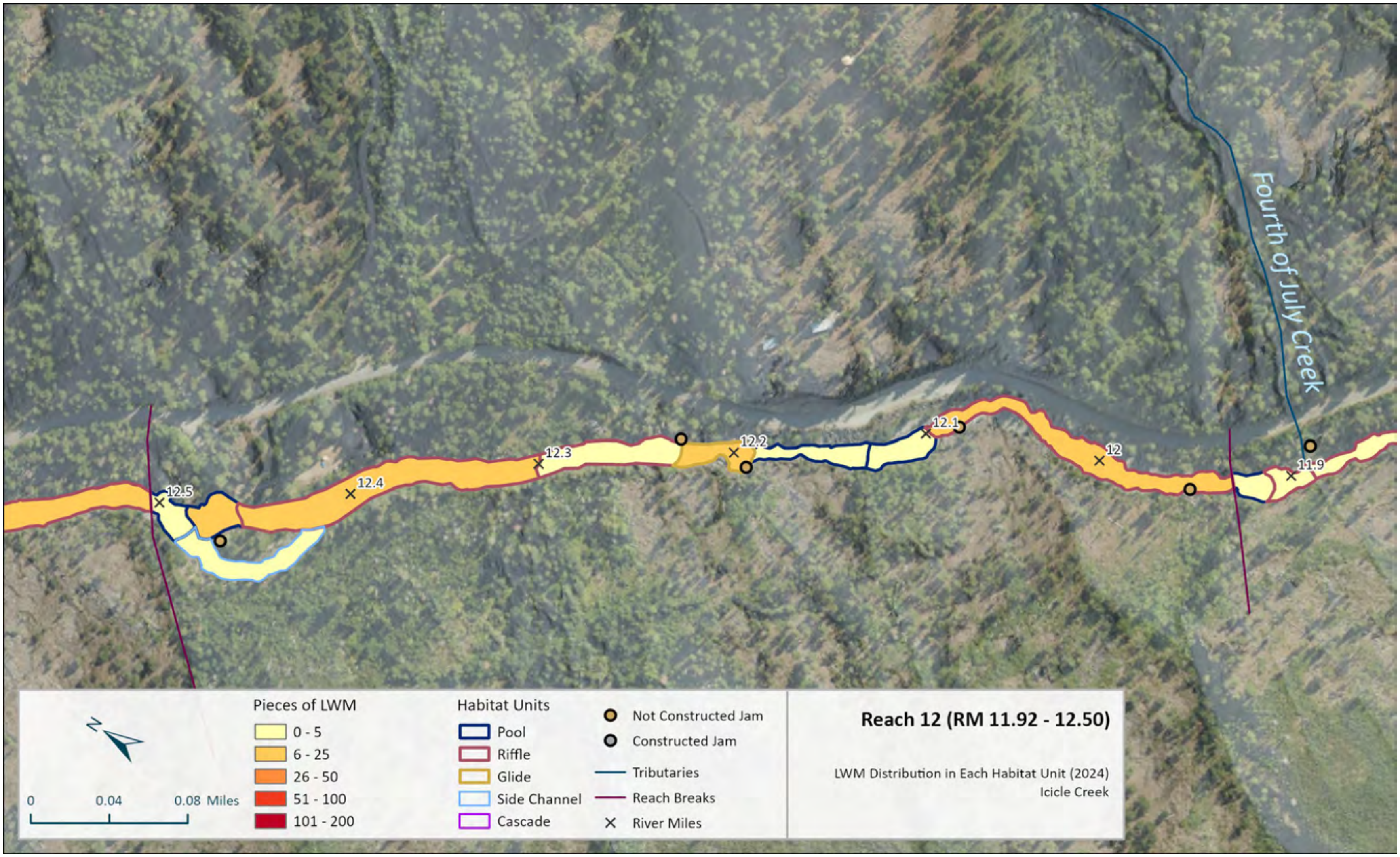

Figure 197. Reach 12: Large wood distribution (pieces per mile per habitat unit) map and surveyed habitat units (2024).

3.12.4 Vegetation

The riparian vegetation is patchy throughout the reach with dense forested riparian zones at tributary fan contacts, sparse vegetation at bedrock hillslope contacts, and no vegetation where the road abuts the channel at the downstream end on river-left. There is also impact to riparian vegetation at the upstream end on river-left associated with a dispersed camping and recreational area. The overstory, where it exists, is dominated by large or small trees depending on location. Groups of large trees were observed from RM 12 to 12.1 (right bank), and from RM 12.3 to 12.5 (left bank). The dominant overstory species are ponderosa pine and fir, with cedar and cottonwood also present. The understory is mostly alder, willow, cottonwood, and rose. There is some shading to the river provided by large trees along the river-right bank, but it is intermittent. Large wood recruitment to the channel primarily occurs via natural tree fall or during very large floods since channel migration is limited due to natural confinement. A representative photo of riparian vegetation conditions is included in Figure 198. A map showing vegetation heights is provided in Figure 199, with an aerial map in Figure 200.

Figure 198. Representative vegetative conditions in Reach 12 at RM 12.34.

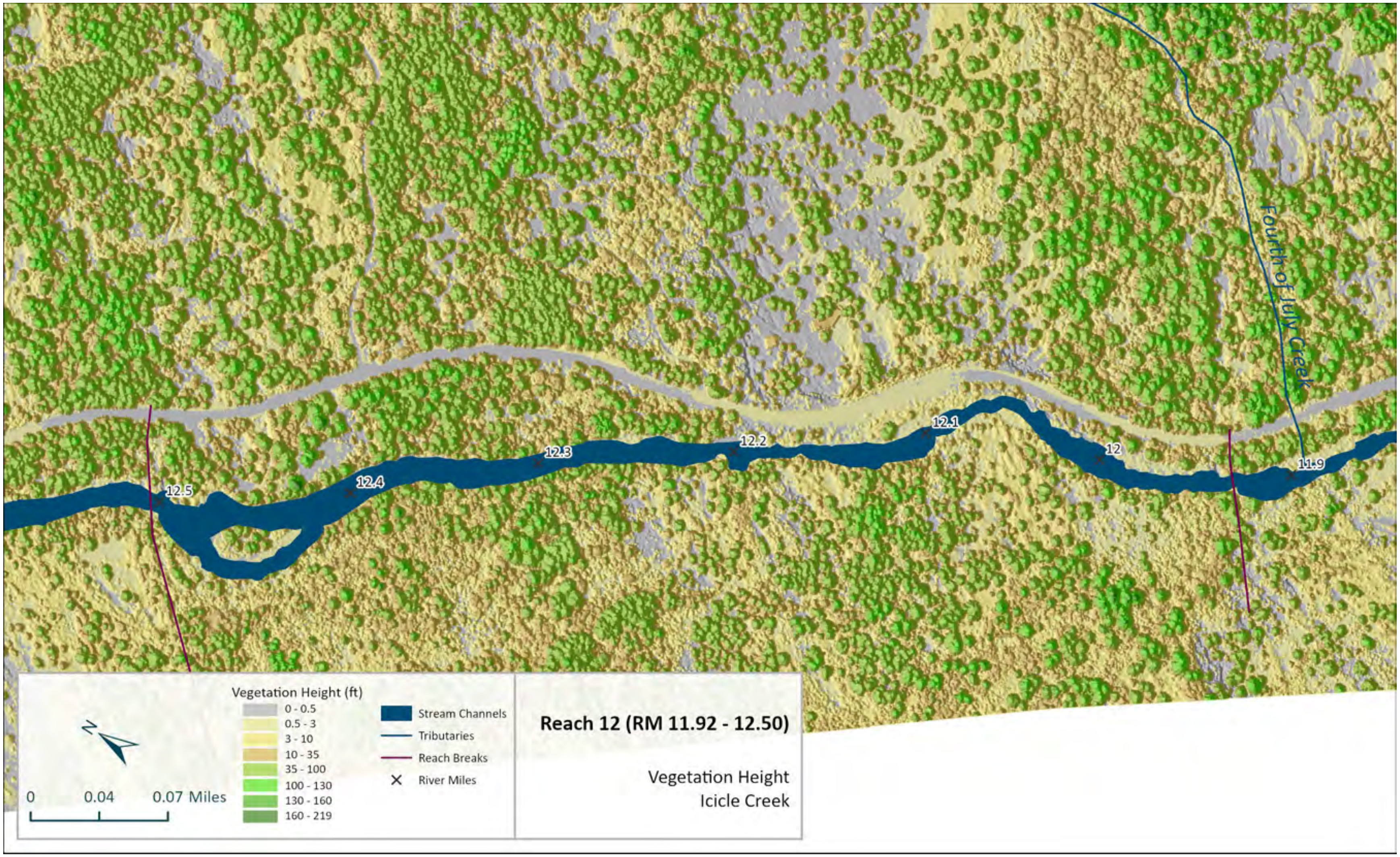

Figure 199. Reach 12: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 200. Reach 12: Map of aerial imagery for vegetation identification (ESRI 2023).

3.12.5 Human Alteration

There are minimal anthropogenic impacts in the reach. The road abuts the channel on river-left at the downstream end of the reach, with impacts to riparian vegetation and channel margin habitat due to side cast boulders and armoring (Figure 201). From RM 12.40 to the upstream end of the reach on river-left is a recreational area with some removal of vegetation, but it has relatively little impact on stream habitat. A map showing the human alteration in Reach 12 is included in Figure 202.

Figure 201. Side-cast road debris boulders on river left at RM 12.13. (August 13, 2024)

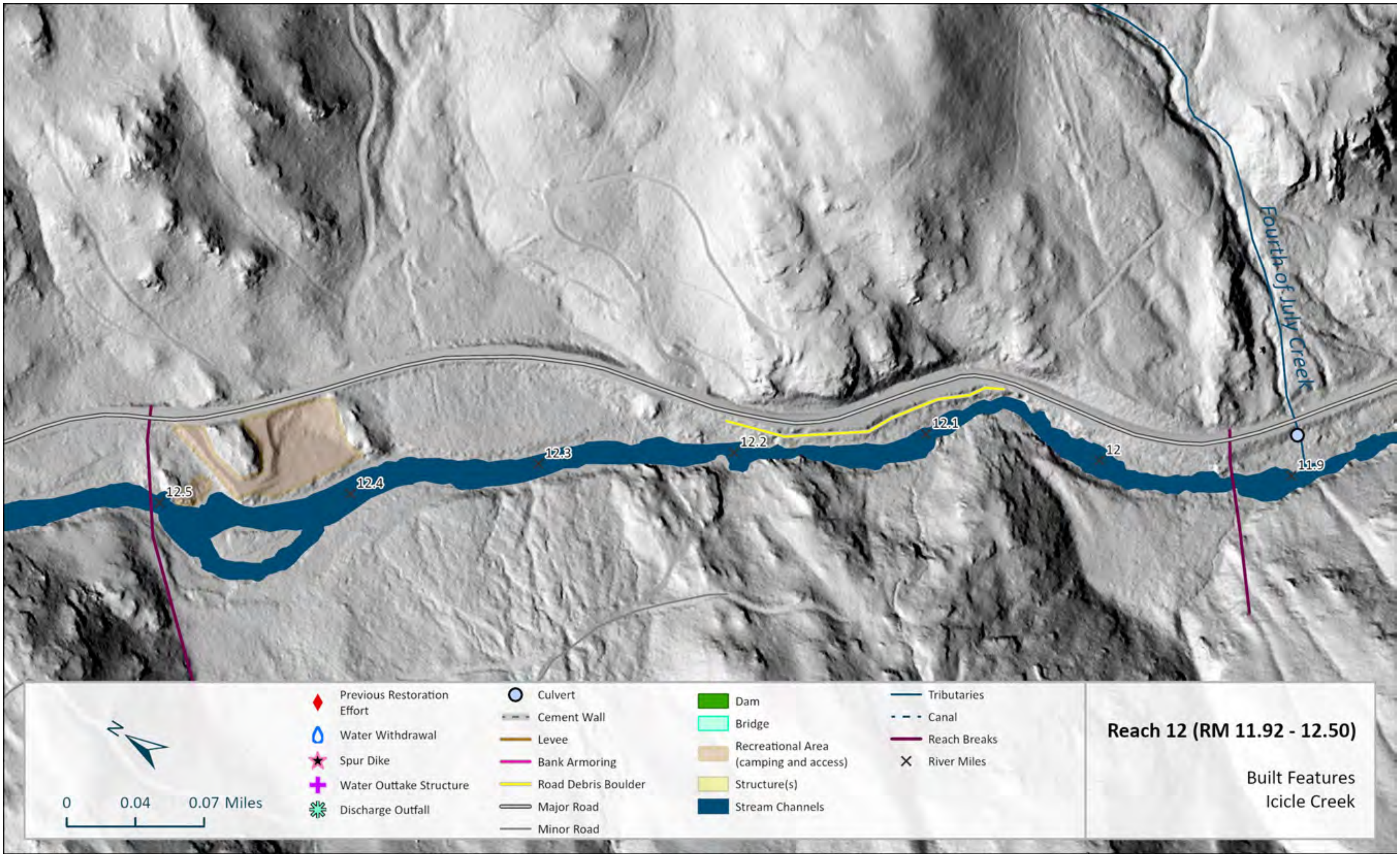

Figure 202. Reach 12: Mapped anthropogenic features (2024).

3.12.6 Recommended Actions

There is limited restoration potential in Reach 12 given the steep and confined channel dynmics. Downstream of RM 12.2, the reach is mostly a steep boulder-bed step-pool channel where opportunities for restoration are very limited. There are occasional pools where large wood could be added for cover and complexity; braced against large boulders, large trees, or extending down the bank; but wood will create very little geomorphic response due to high energy, and anchoring would be a challenge. The river-left bank is directly adjacent to Icicle Road, with either riprap and/or road debris boulders covering the slopes, in some cases with very little riparian vegetation. Enhancing channel margin habitat could occur along these banks using large wood, with the caveats mentioned above regarding large wood in this steep section. Addressing the effects of the riprap/roadcut boulders would be impractical with the road remaining in its current location, so this action is not called out as a project. Similarly, meaningful riparian restoration along these banks would also be challenging due to the large boulder/debris material. No projects were identified for this area.

The remainder of Reach 12 (upstream of RM 12.2) 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. Boulder ballast may be necessary to anchor wood placements. There is a short split-flow section at the upstream end of the reach with a large pool at the upstream end of the main channel. Wood loading could occur for cover in the pool and in the side-channel, where stream energy is less and wood placements could occur with less anchoring. These actions at the upstream end of the reach are included in the Johnny Victoria project. A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities).

3.13 ICICLE CREEK REACH 13 (RM 12.50 – 12.84)

3.13.1 Overview

Reach 13 is a short reach at 0.34 miles long. It extends from RM 12.50 to RM 12.84. The reach has an average gradient of 2.20%. It is confined and is mostly comprised of long boulder riffles (Figure 203). There are numerous bedrock contacts. The road and dispersed recreation impose impacts along river-left. The riparian vegetation is generally intact, except for minor impacts in the recreation use areas. The reach is entirely within the Wenatchee National Forest.

Figure 203. Representative photo of Reach 13 at RM 12.53 (August 13, 2024).

3.13.2 Channel and Floodplain Geomorphology

Table 23. Reach 13 metrics.

Reach 13												
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
0.34	12.50-12.84	2.20%	1.02	Riffle	86	Confined	Boulder	23.5%	0.0%	76.5%	0.0%	0.0%

The channel in Reach 13 is a moderate-high gradient confined channel with single-thread planform (Figure 205). Icicle Creek is laterally confined by a fan terrace on river-left between RM 12.7 – 12.84. Otherwise, confinement is controlled by relatively steep hillslopes and bedrock contacts on the banks and bed of the channel. From RM 12.6 – 12.5 along the river-left side are stepped floodplain surface but the bedrock exposure on the opposite side currently holds the channel along that side of the valley wall. The channel displays riffle-pool sequencing composed of boulders. There are no tributaries to Icicle Creek at Reach 13.

Confinement and increased stream power result in limited floodplain area in much of Reach 13. A narrow band of riparian vegetation occupies a strip of marginal low floodplain (inundated ~1-5 yrs) at the toe of the confining slopes (Figure 204), except where bedrock occurs. Floodplains do occur on river-left at RM 12.5 – 12.6 that step from bands of low and medium alluvial floodplain (inundated ~5-20 yrs) surfaces to terrace (abandoned). The stepped pattern reveals the process of channel downcutting.

Figure 204. Narrow marginal floodplain with riparian vegetation at RM 12.84. (August 13, 2024)

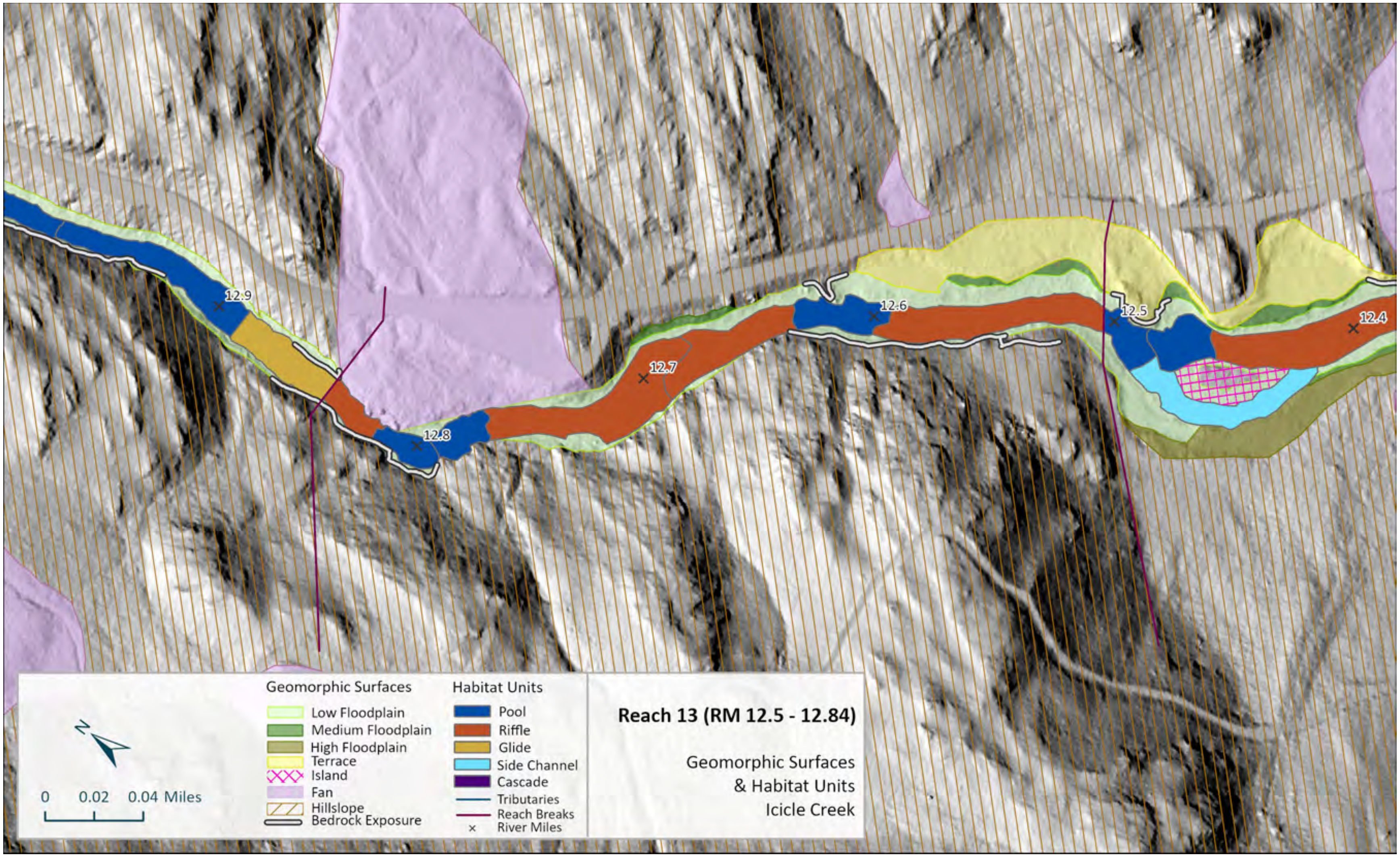

Figure 205. Reach 13: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

The bedload sediment in Reach 13 is primarily boulder with cobbles. The channel's banks are mostly steep and often composed of boulder colluvium or bedrock (Figure 206). Smaller cobbles and sometimes gravel were observed in very small pockets behind large boulders in areas of hydraulic relief or draped at the margin of the channel's seasonal high-flow elevation. In low-flow conditions, boulder-cobble bars and banks are exposed.

Figure 206. Boulder-cobble channel substrate and bank composition (bedrock and boulder) at RM 12.82. (August 13, 2024)

No appropriate locations were identified in Reach 13 to complete a Wolman Pebble Count (Wolman, 1954) Incipient motion hydraulic analysis (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5) suggests that at the 2-year modeled discharge, the channel's shear stress is capable of mobilizing boulder-sized material through most of the reach (Figure 207). Reach 13 is considered a sediment transport reach. Sediment in this reach is sourced from upstream contributions transported into Reach 13, as well as hillslope colluvium and debris fan inputs.

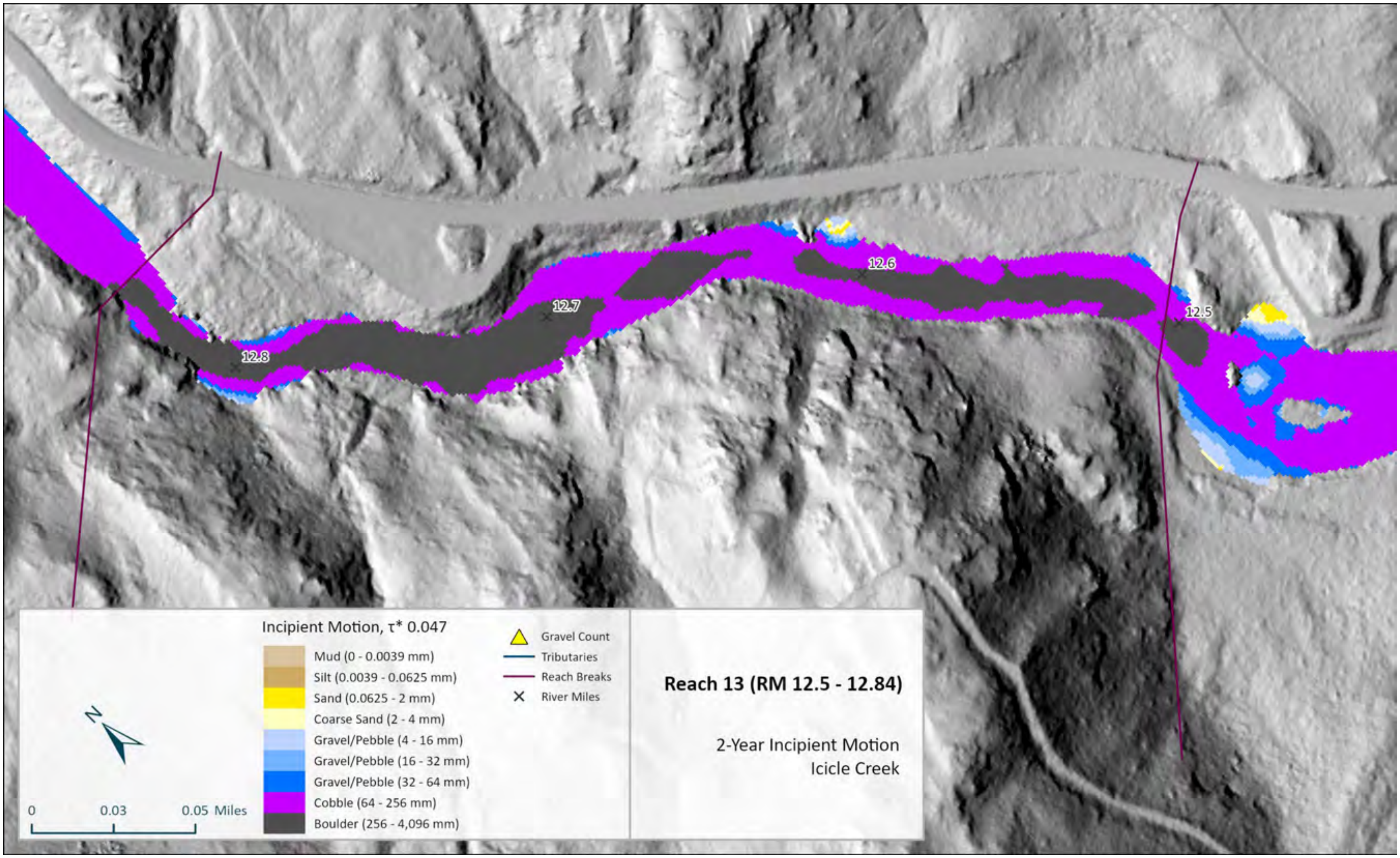

Figure 207. Reach 13: incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge).

3.13.3 Large Wood Material

The habitat survey conducted in summer 2024 recorded 22 individual pieces of large wood material (LWM) and 4 log jams (accumulation of >3 LWM) within the bankfull channel, for a combined total of 35 observed pieces (Figure 209). Of the 22 individual pieces; 8 pieces are considered medium and large LWM; 1 classified as large size class (>20-inches diameter and >35-feet long); and 7 as medium size class (12 to 20-inches diameter and at least 35-feet long). All 4 log jams in Reach 13 have multiple pieces of medium or large LWM. Reach 13 has 44 pieces of wood per mile (count includes medium and large LWM as individuals and in jams), which does not meet the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state (Fox & Bolton, 2007; Appendix A). However, the high shear stress produced in Reach 13 because of its gradient and confinement often does not allow for retention of LWM. As a result, LWM currently does not influence geomorphic processes in this reach. The wood that is present is usually draped along the channel margins (Figure 208) or temporarily racked atop boulders or bedrock.

Figure 208. Margin-draped large wood at RM 12.87. (August 13, 2024)

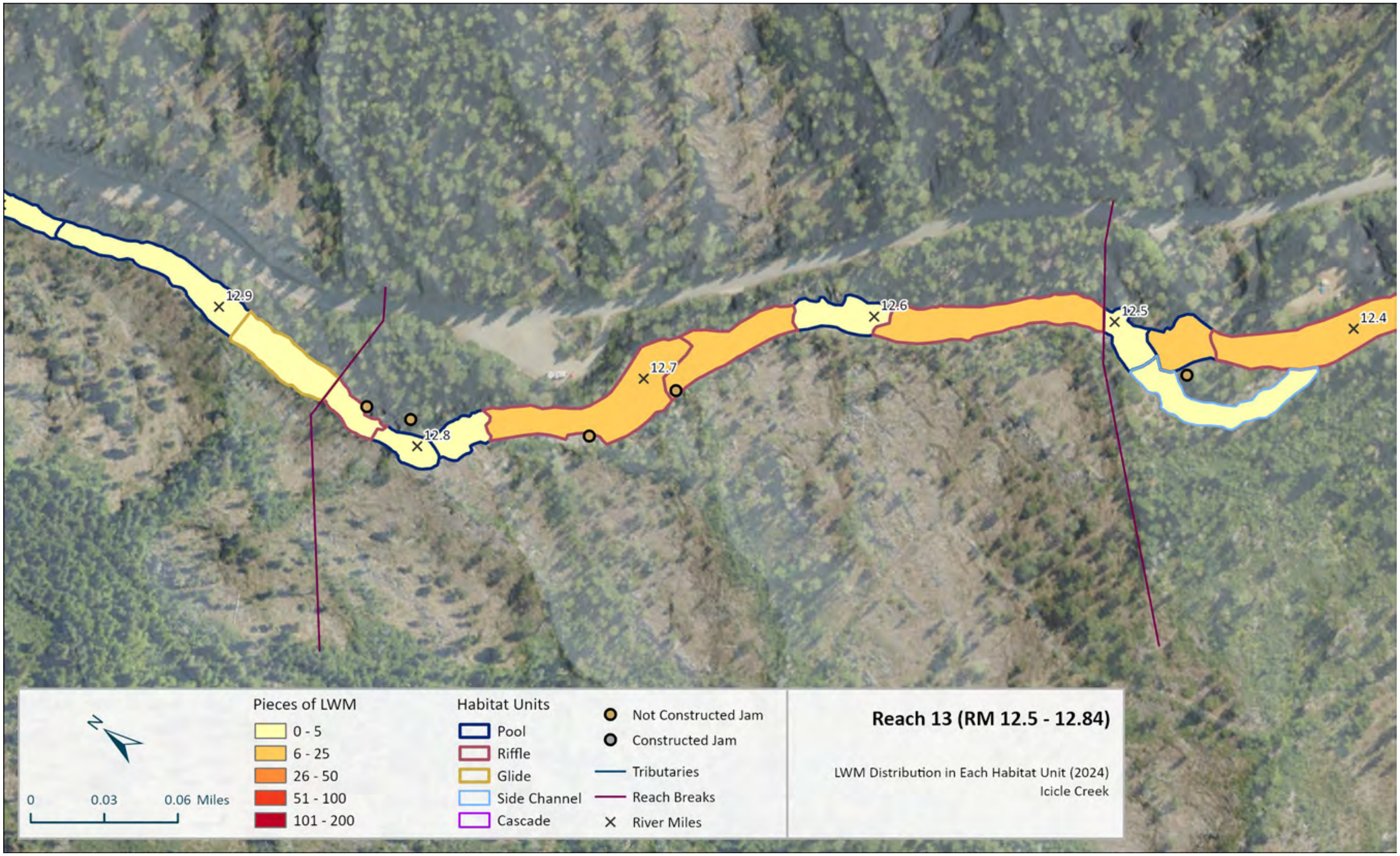

Figure 209. Reach 13: Large wood distribution (pieces per mile per habitat unit) map and surveyed habitat units (2024).

3.13.4 Vegetation

The riparian vegetation on the right adjacent hillslope is naturally sparse due to the common occurrence of bedrock outcrops. Vegetation on the river-left confining hillslopes is more dense but sections of it are impacted by the road and dispersed recreation areas. The overstory, where it exists, is dominated by large trees, primarily Douglas fir and cedar, with some ponderosa pine and cottonwood. The largest trees were observed on river-left from RM 12.55 to 12.65 and from RM 12.78 to 12.82. The understory is dominated by alder and willows, with lesser amounts of vine maple, dogwood, and rose. There is some shading provided to the river by large trees along the river-right bank, but it is limited due to the sparse tree cover. Large wood recruitment to the channel would primarily occur via natural tree fall. A representative photo of riparian vegetation conditions is included in Figure 210. A map showing vegetation height is provided in Figure 211, with an aerial map in Figure 212.

Figure 210. Representative vegetative conditions in Reach 13, near RM 12.53. (August 2024)

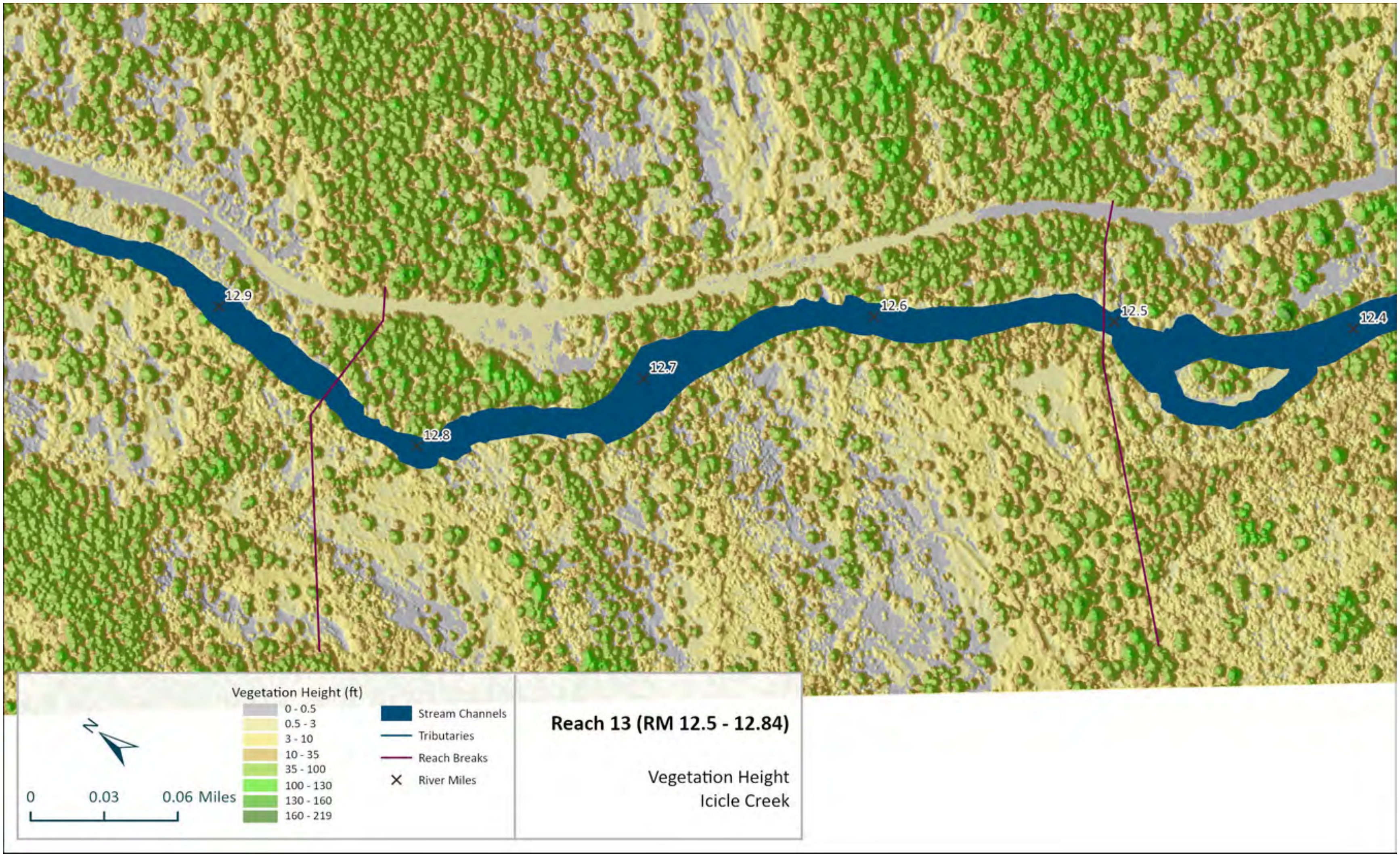

Figure 211. Reach 13: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 212. Reach 13: Map of aerial imagery for vegetation identification (ESRI 2023).

3.13.5 Human Alterations

Reach 13 is primarily affected by the road and dispersed camping and recreational access areas on river left. There are side-cast road debris boulders along the banks and in the channel on river-left midway through the reach, likely slightly increasing channel confinement (Figure 213). Dispersed campsites are located on river-left at RM 12.6 and 12.8, and trails are located at RM 12.58 and 12.75. A map of anthropogenic features is included in Figure 214.

Figure 213. Side-cast road-debris boulders on river left at RM 12.68. (August 13, 2024)

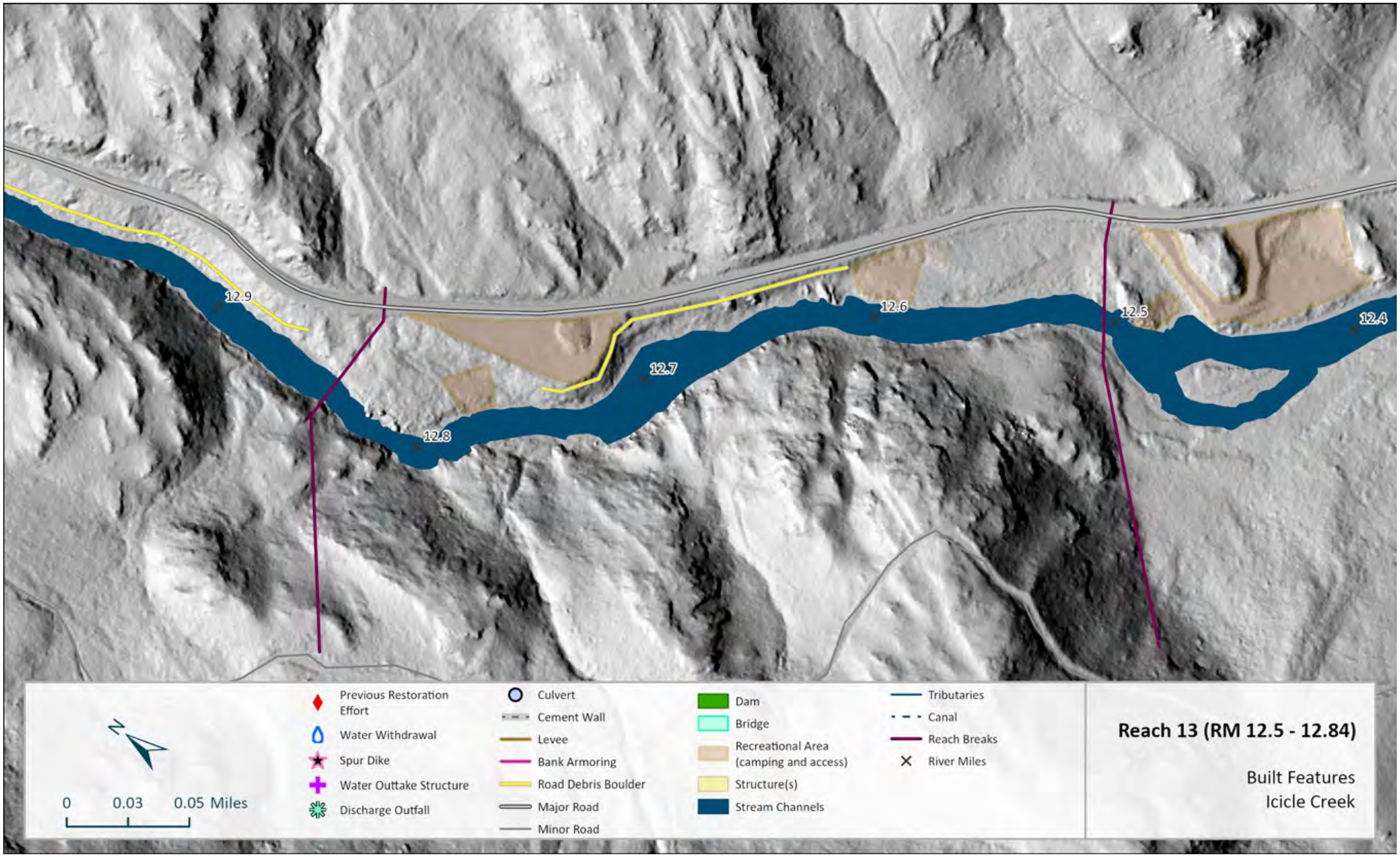

Figure 214. Reach 13: Mapped anthropogenic features (2024).

3.13.6 Recommended Actions

There is very little restoration potential in Reach 13 given the steep and confined channel. The reach is mostly a steep boulder-bed step-pool or boulder riffle channel where opportunities for restoration are limited and access would be challenging. There are occasional pools where large wood could be added for cover and complexity; braced against large boulders, large trees, or extending down the bank; but wood will create very little geomorphic response due to high energy, and anchoring would be a challenge. Only one location for potential wood cover placement in a pool is identified for this reach as part of the Johnny Victoria project. A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities).

3.14 ICICLE CREEK REACH 14 (RM 12.84 – 14.75)

3.14.1 Overview

Reach 14 is 1.91 miles long, extending from RM 12.84 to RM 14.75. The average channel gradient is 1.54%. The reach is confined by fan terraces, hillslope toes, and bedrock - with only narrow discontinuous strips of floodplain along the channel (Figure 215). The channel type is riffle dominated with long sections of small boulder and large cobble riffles separated by pools. There is a largely intact forested riparian buffer along the adjacent surfaces, but vegetation has been cleared or thinned in proximity to campgrounds, residential development, and the roadway. Landownership is mostly private in the upstream half of the reach and Wenatchee National Forest in the downstream half.

Figure 215. Representative photo of Reach 14 at RM 13.15 (August 13, 2024).

3.14.2 Channel and Floodplain Geomorphology

Table 24. Reach 14 metrics.

Reach 14												
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
1.91	12.84-14.75	1.54%	1.01	Riffle	85	Confined	Boulder / Cobble	19.1%	2.6%	75.6%	2.7%	0.0%

The channel in Reach 14 is primarily single-thread planform with very short split flow conditions at RM 14.35, 13.85, and 13.68. Split flow is around vegetated islands at the two downstream locations and a partially vegetated mid-channel bar at the upstream location (Figure 216). Split flow conditions and narrow discontinuous floodplains border the channel where space allows between the confining hillslopes that border the remainder of the reach. Confining banks include hillslopes of bedrock, debris fans and alluvial terraces that are often 6-30+ feet higher than the bed of the channel. The confining hillslopes periodically contribute colluvium, debris, and alluvium to the channel. If large enough in size to remain stable during high-energy flood events, boulders provide localized and generally stable points of hydraulic refuge in a reach with relatively low complexity.

Five perennial tributaries flow into Icicle Creek in Reach 14. Victoria Creek enters from river-right at RM 13.47. The confluences of the remaining four creeks are on river-left at RM 13.2 (Mac Creek), Johnny Creek at RM 13.55, Jay Creek at RM 14.17, and Big Slide Creek at RM 14.78. The alluvial and debris fans associated with the river-left tributaries are well-developed, especially in comparison to the size of the tributaries. Icicle Road traverses the toe of the river-left fans, confining the location of the fan's tributary to culvert crossings in the roadway and thus likely impeding sediment delivery to the channel.

Reach 14 contains narrow discontinuous strips of low floodplain surfaces (inundated ~1-5 yrs) and medium floodplain (inundated ~5-20 yrs) surfaces and high floodplains (inundated 20-100+yrs) surfaces. Low floodplains surfaces are usually vegetated with mixed riparian vegetation while medium and high floodplain surfaces host conifer-dominated forests. Floodplains are composed of either reworked cobble-boulder alluvium or hillslope toes eroded to stable boulders and/or cobble surfaces. The surfaces are topped with either overbank coarse sands and gravel or mass-wasted hillslope debris that support vegetation establishment.

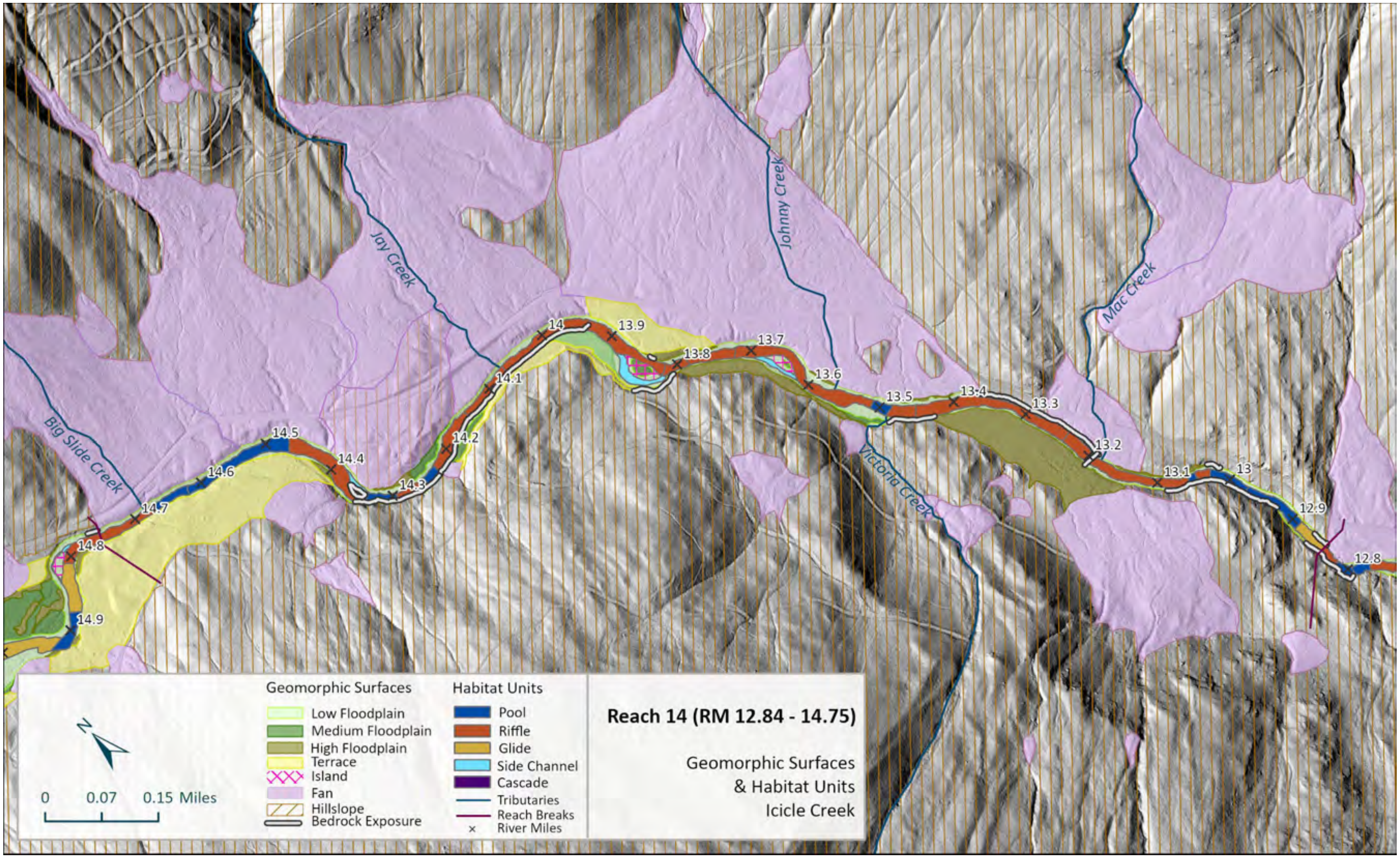

Figure 216. Reach 14: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

Channel substrate in Reach 14 is primarily composed of boulder and cobble sized material with some gravel and coarse sand present in situ between or behind boulders or as overbank deposits on narrow floodplains (Figure 217). Hillslope contributions of weathered bedrock or terrace slopes provide additional sediment sources to the channel that range from fines to large colluvial boulders.

Figure 217. Left: Boulder-cobble bar at RM 13.82. Right: Hillslope colluvium contributions to Icicle Creek at RM 12.98. (August 13, 2024)

Two Wolman Pebble Counts (Wolman, 1954) were conducted in Reach 14 at boulder riffle crests. The median grain size (D50) of GC 13 at RM 12.9 was 95mm and for GC 12 at RM 13.42 the median grain size (D50) was 180mm. The pebble count data are included in Figure 218 of the Reach 14 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5). The analysis indicates that at the 2-year modeled discharge, the channel's shear stress is expected to mobilize cobble sized through the entirety of the reach and boulder-sized materials in patches throughout the reach.

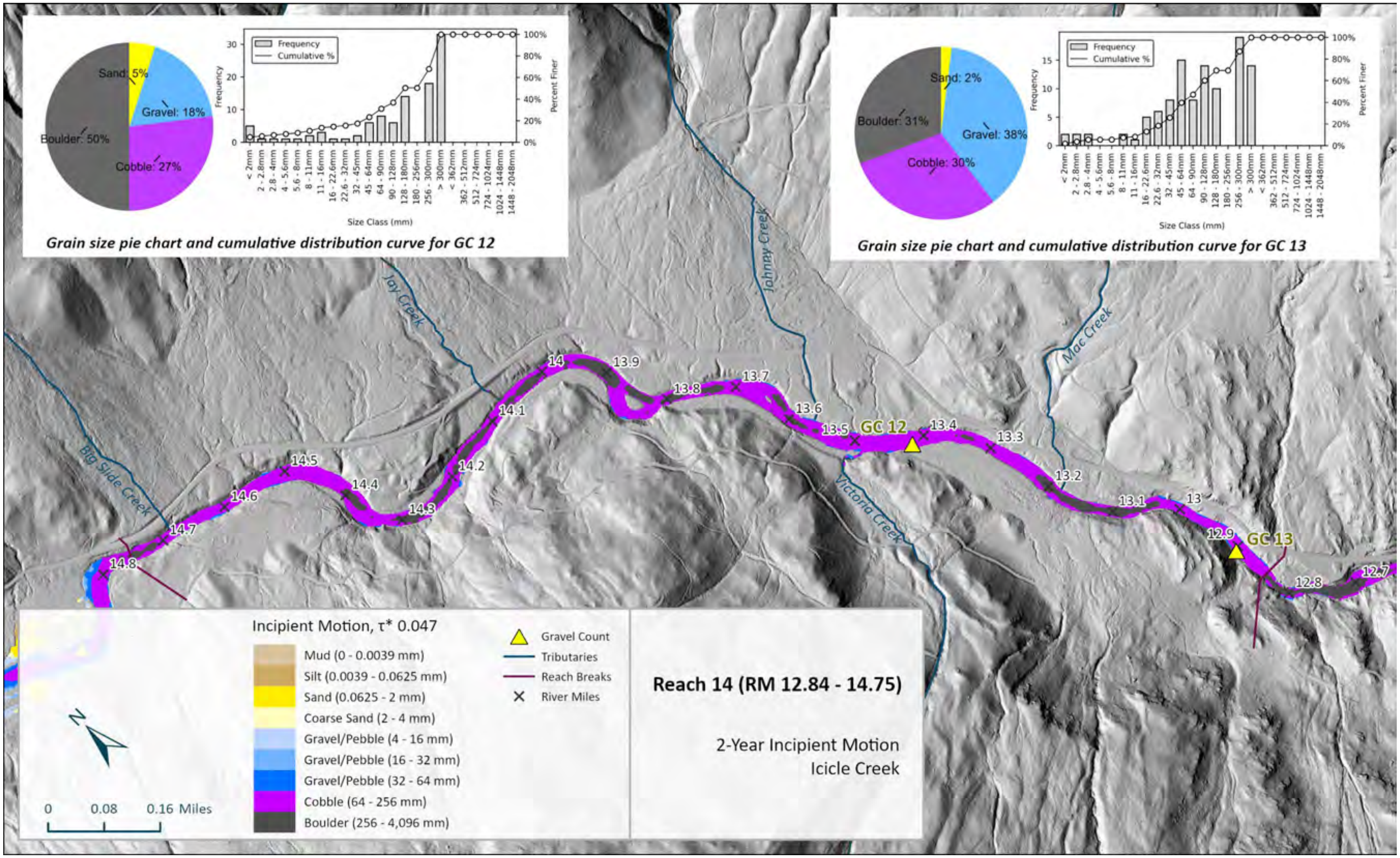

Figure 218. Reach 14: incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge). Includes location and grains size data of the GC 12 and GC 13 pebble counts (2024 survey).

3.14.3 Large Wood Material

The habitat survey conducted in summer 2024 recorded 159 individual pieces of large woody material (LWM) and 10 log jams (accumulation of >3 LWM) within the bankfull channel, for a combined total of 399 observed pieces (Figure 220). Of the 159 individual pieces, 74 pieces are considered medium and large LWM; 22 classified as large size class (>20-inches diameter and >35-feet long); and 52 as medium size class (12 to 20-inches diameter and at least 35-feet long). All 10 log jams in Reach 14 have multiple pieces medium and large LWM and thus are effective at influencing the channel complexity and being habitat forming structures. Reach 14 has 106 pieces of wood per mile (count includes medium and large LWM as individuals and in jams), which meets the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state (Fox & Bolton, 2007; Appendix A).

While Reach 14 contains a relatively high amount of wood, much of it does not interact with the channel. As shown in Figure 219, large wood jams at RM 13.66 and RM 13.86 are representative of the reach and remain disengaged from low flows which offer limited habitat value. Several islands within Reach 14, including those at RM 13.68, 13.89, and 14.36, accumulate wood at their upstream ends. However, due to the boulder-bed nature of the channel, wood in this reach generally has limited effectiveness in creating scour. Although large wood is present, some accumulations are not anchored by key logs or secured to the streambed or banks, making them temporary and likely to mobilize during higher flows.


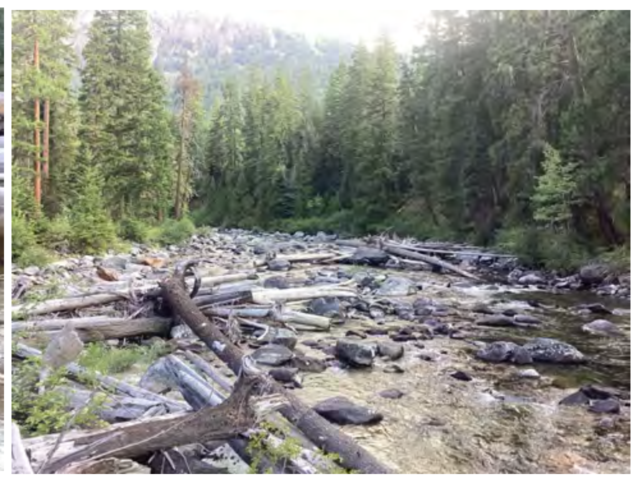

Figure 219. Typical large wood jams in Reach 14 where the majority of the wood is not interacting with the active channel. Left: Jam located at RM 13.66 (August 13, 2024). Right: Jam located at RM 13.86 (August 13, 2024).

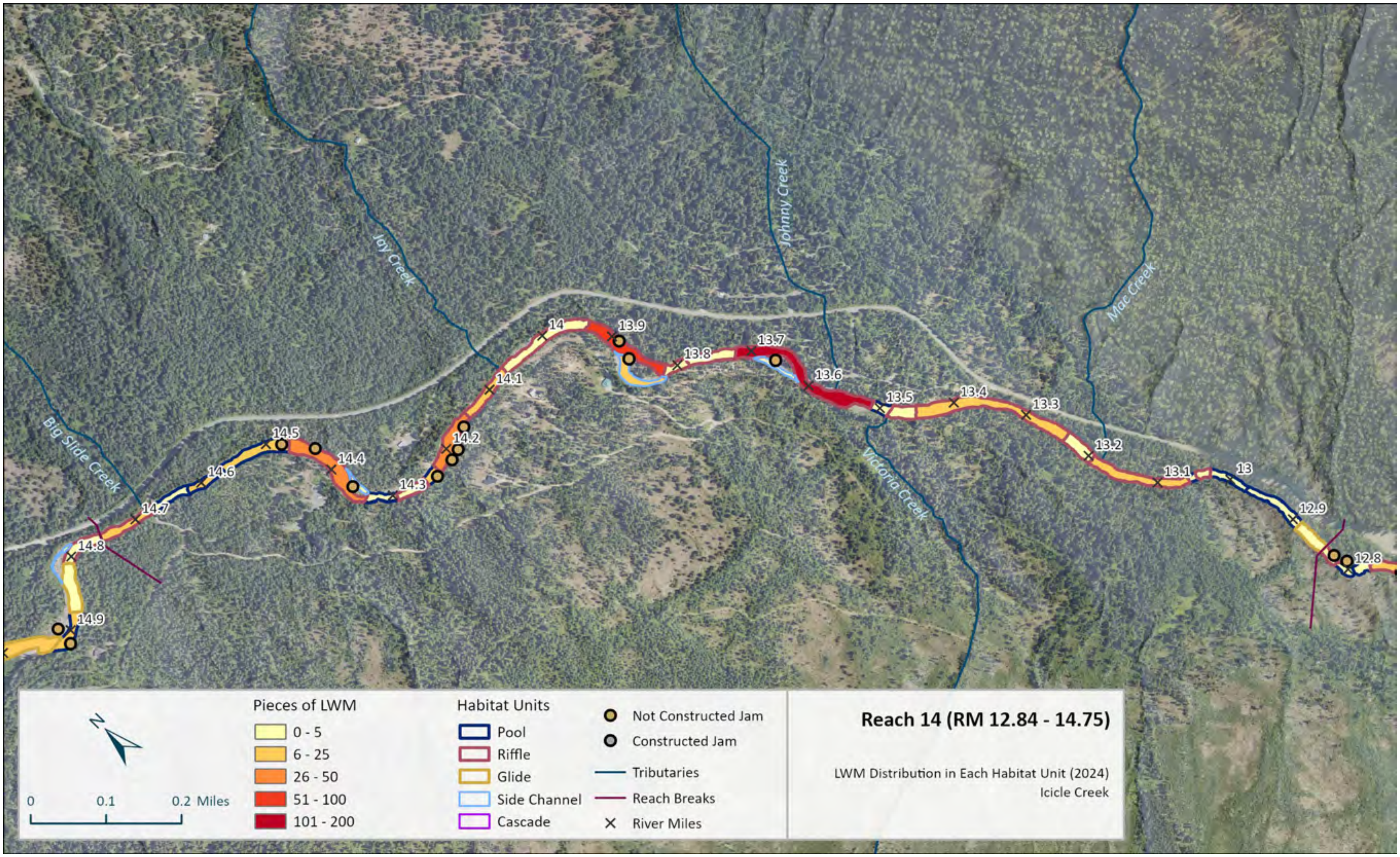

Figure 220. Reach 14: Large wood distribution (pieces per mile per habitat unit) map and surveyed habitat units (2024).

3.14.4 Vegetation

The riparian vegetation in Reach 14 is relatively well established, with some impacts from the roadway, campground, and private residences. The riparian zones include a mix of woody-stemmed shrubs and small trees in the near-channel low floodplains and bars, including rushes, willow, alder, cedar and cottonwood (Figure 221). The overstory is comprised of Douglas fir, ponderosa pine, cedar, and cottonwood. The understory is dominated by alder, vine maple, dogwood, and willow. Historical timber harvest has occurred on the river right hillslopes decreasing size and age of the overstory in the middle portion of the reach. Vegetation clearing associated with the Lower Johnny Creek campground and trails has also impacted riparian conditions on river left.

Riparian tree cover in Reach 14 provides moderate availability for large wood recruitment, though key piece recruitment may be more limited. Large trees are present throughout the reach, but only sporadic clusters of very tall trees adjacent to the channel are available near RMs 13.2, 13.7, 14.3, and 14.7. A map showing the vegetation heights in Reach 14 is provided as Figure 222, with an aerial in Figure 223. The existing riparian vegetation provides some stream shading from the large trees along the river-right bank.

Figure 221. Representative vegetative conditions in Reach 14, figure captured at RM 13.19 (August 13, 2024).

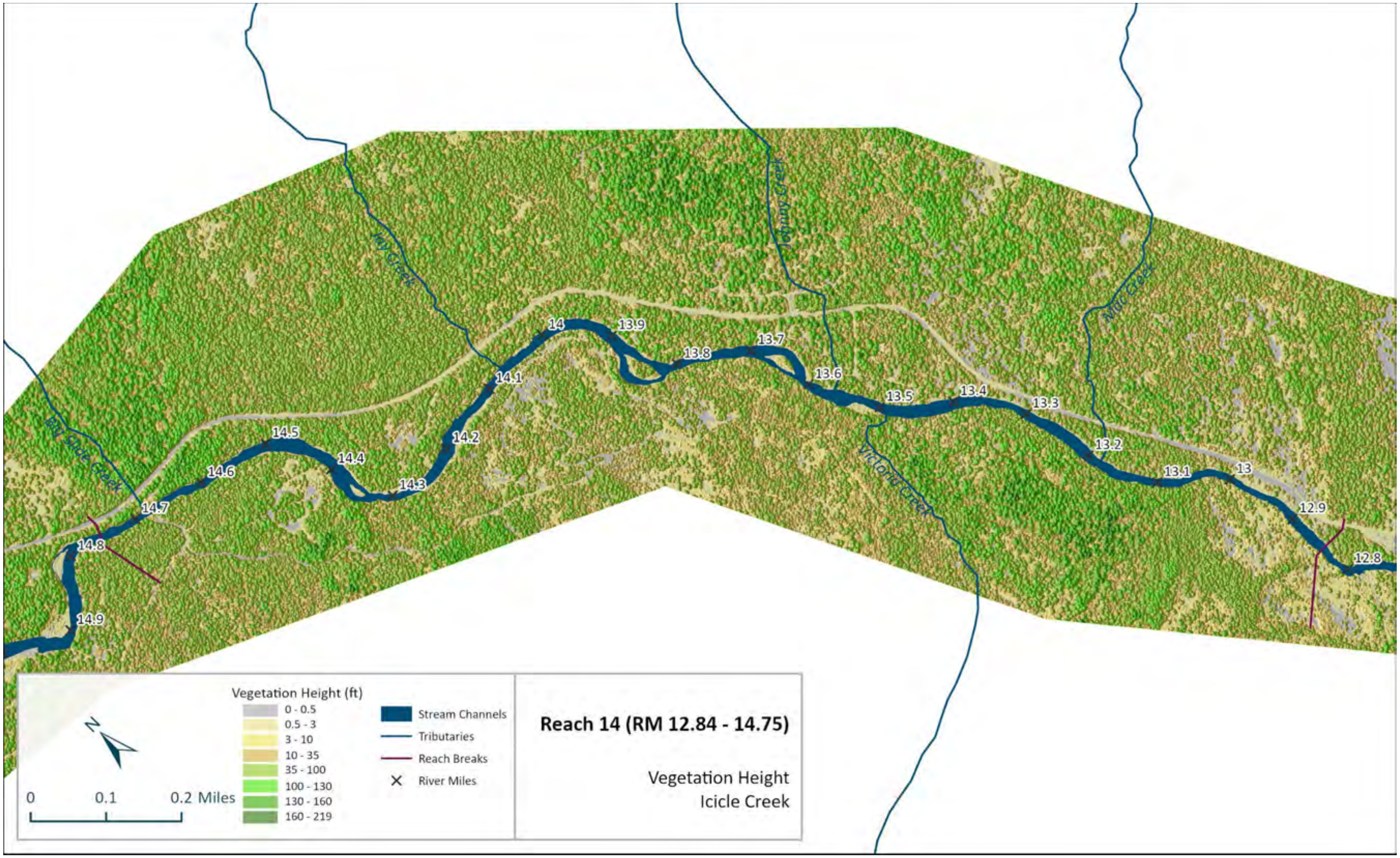

Figure 222. Reach 14: Map of vegetation height classification analysis (LiDAR – based analysis).

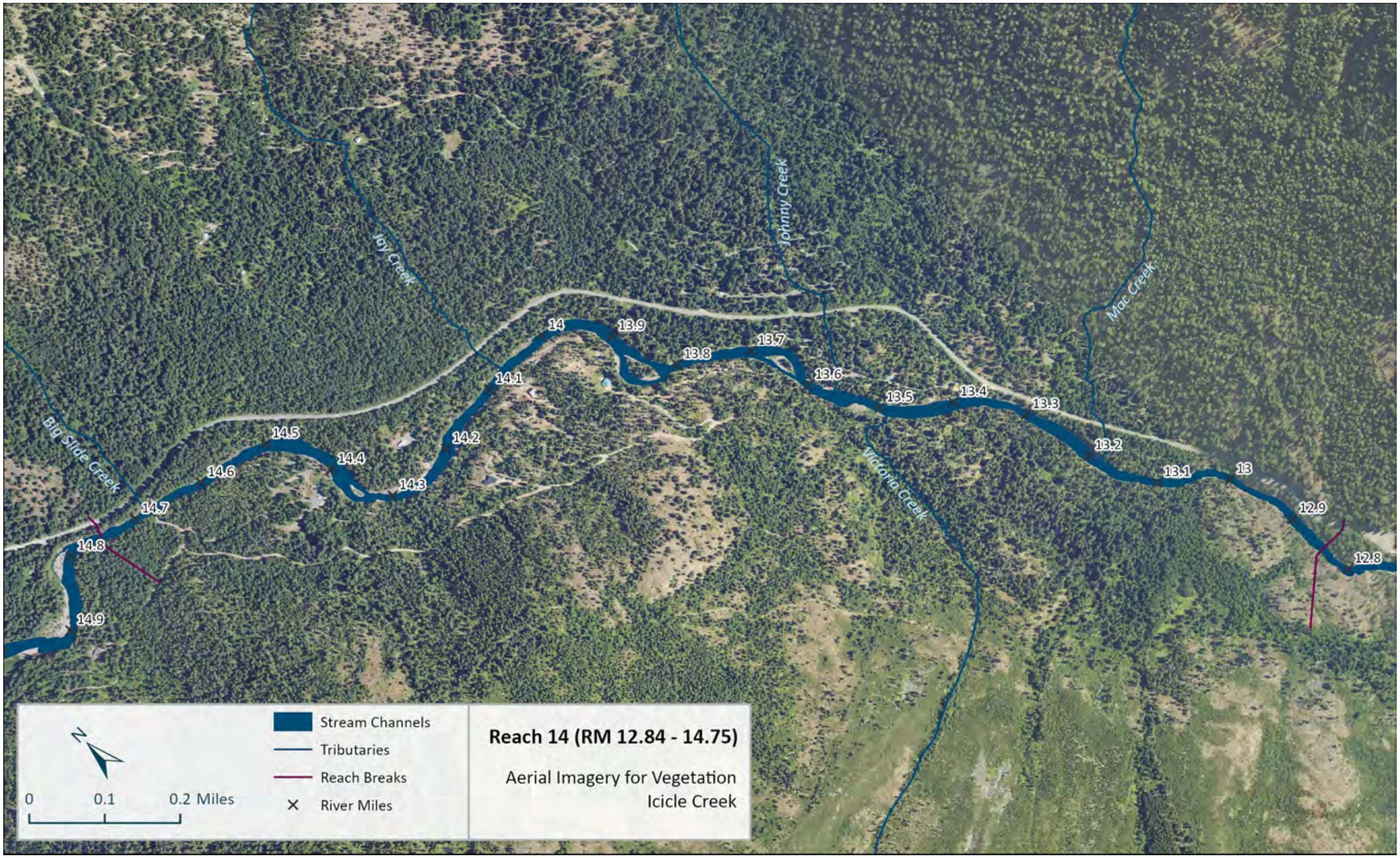

Figure 223. Reach 14: Map of aerial imagery for vegetation identification (ESRI 2023).

3.14.5 Human Alterations

Human alterations in Reach 14 are mostly a mixture of road impacts, public campground, dispersed recreation, and private residences. The US Forest Service's Johnny Creek Campground is located from approximately RM 13.4 to 13.6 on river left. There are relatively minor impacts to riparian vegetation at the campground. The road abuts the channel at the downstream end of the reach on river-left, with impacts to channel margin habitat and riparian vegetation (Figure 224). There are private residences/cabins along the upstream half of the reach, mostly on river-right but also some on river-left. These areas have cleared areas and recreational access points to the river with impacts on riparian vegetation. There is a bridge near the upstream end of the reach near RM 14.7 (Figure 225). A map of the anthropogenic features identified in Reach 14 is provided as Figure 226.

Figure 224. View downstream near RM 12.9. Roadcut side-cast boulders on river-left bank affect riparian conditions (August 2024).

Figure 225. Bridge crossing at RM 14.7.(August 12, 2024)

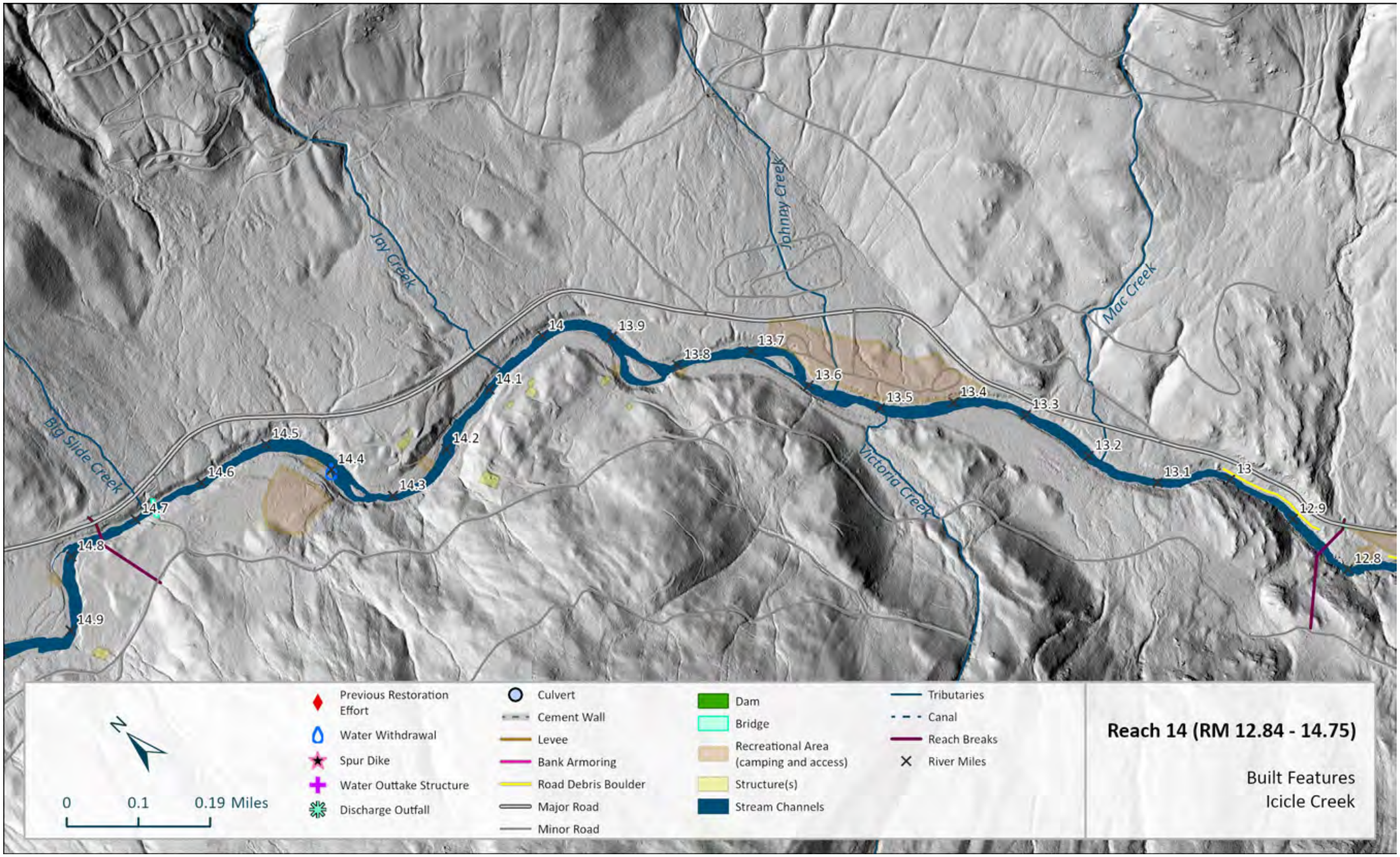

Figure 226. Reach 14: Mapped anthropogenic features (2024).

3.14.6 Recommended Actions

There is limited restoration potential in Reach 14 given the moderately steep and confined channel. The reach is mostly a small boulder or cobble dominated channel where opportunities for restoration are limited. Wood structures that extend from the banks and sit tight to the channel could be effective at trapping and sorting sediments including spawning gravels. Boulder ballast may be necessary to anchor wood placements. These types of wood structure placements are identified throughout this reach as part of the Johnny Victoria project. A few of the larger pools are also identified for large wood cover and complexity treatments, although access and anchoring may be challenging for some locations. A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities).

3.15 REACH 15 (RM 14.75 – 16.63)

3.15.1 Overview

Reach 15 is 1.88 miles long and extends from RM 14.75 to the Bob Creek confluence at RM 16.63. Compared to downstream reaches, the reach is relatively low gradient, less confined overall, and has more available off-channel habitat and floodplain area compared to adjacent reaches (Figure 227). Portions of the reach express high complexity with split flows, side channels, islands, and well-inundated low floodplain surfaces. In addition, significant accumulations of LWM influence channel dynamics in portions of Reach 15. Low floodplain surfaces are typically vegetated with shrubs and small trees, while higher floodplain surfaces are vegetated with conifers. The road is located far from the channel to the north and was relocated there following a debris slide in Doctor Creek (river-right tributary) in May 2008 that resulted in washing out and flooding the previous road. Fill and grading associated with the old road alignment is still present close to the channel along most of the reach length on river left. Other human alterations to the channel and floodplain in Reach 15 include built structures, active and former roads, and recreational uses including campsites, trails, and channel bank modifications (armoring). The reach is mostly within the National Forest, with private lands located at the upstream and downstream ends.

Figure 227. Representative photo of Reach 15 at RM 15.18 (August 14, 2024).

3.15.2 Channel and Floodplain Geomorphology

Table 25. Reach 15 metrics.

Reach 15												
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
1.89	14.75-16.63	0.57%	1.10	Pool	105	Partially Confined	Cobble / Gravel	40.3%	29.5%	20.7%	0.0%	0.0%

The channel in Reach 15 is relatively low gradient, expressing riffle-pool and riffle-glide habitat types. The reach is considered partially confined because the available area occupied by the channel and floodplain ranges from unconfined, to confined by fan and alluvial terraces (RM 16.5-16.63 and RM 15.5-15.8). Where space allows, multiple flow paths that include perennial and high-flow side channels that extend around islands off the low-sinuosity mainstem channel (Figure 228). In addition to Bob Creek at the upstream end of Reach 15, Ida Creek (RM 15.5) and Doctor Creek (RM 16.3) are perennial tributaries to Icicle Creek.

In the unconfined sections of Reach 15, wide floodplains host side channels and mixed forests. In the terrace/fan confined sections very narrow discontinuous strips of floodplain flank the channel. The low (inundated ~1-5 yrs) and medium (inundated ~5-20 yrs) floodplains occupy the greater portion of the unconfined sections. The wide high floodplain surfaces (inundated ~20-100+ yrs) between RM 16.1-16.5 and the narrow strips elsewhere in the reach indicate historical sequence(s) of aggradation in the valley followed by downcutting. Aggradation periods are likely instigated by hillslope fan contributions to the valley floor and channel. Floodplain composition is generally gravel-cobble with a base boulder topped with sandy loam of varied depths (0.5 – 4 ft) and a thin layer of organic soil on top (Figure 229). The floodplains are mapped in the geomorphic surfaces map in Figure 228.

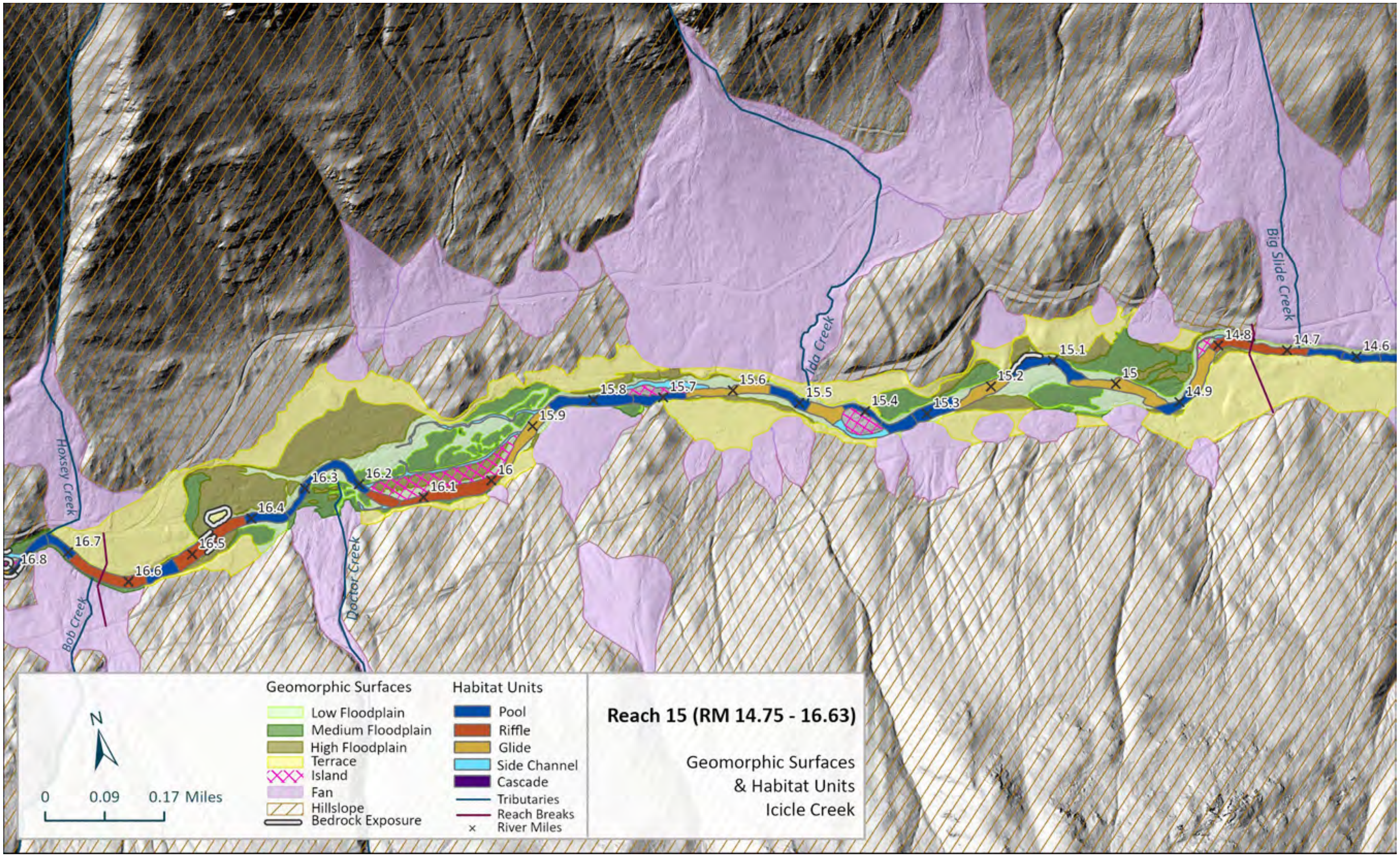

Figure 228. Reach 15: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

Figure 229. Example of high floodplain cut bank at RM 14.9 with boulder-cobble-gravel base. (August 11, 2024)

Geomorphic and habitat complexity in portions of this reach is relatively diverse. Complexity includes floodplain wetlands, localized active lateral processes and floodplain development, plentiful off-channel/side channel habitat, and large wood recruitment. Modern contributions of sediment and large wood from floodplains, tributaries, and hillslopes influence current geomorphic trends and complexity. A debris flow in 2008 down Doctor Creek, sourced upslope off a skid path created during previous logging activities, initiated the delivery of sediment and debris to the mainstem channel that has yet to stabilize 15 years later. The creation of a new Doctor Creek debris/alluvial fan at its mouth not only delivered a large amount of material into the valley, but it also pushed the mainstem river to the left (north) side of the valley. As a result, Icicle Road was washed out and had to be moved north and upslope to the location it is found at today. Shifting the channel north also meant that the forested floodplain across from Doctor Creek became occupied by the channel, creating flow paths and drowning the forest that once grew on that floodplain and thus generating additional wood and debris to the channel. As the forest regenerates after the logging impacts in the Doctor Creek watershed, hillslope stability is expected to increase. Today, the mainstem channel meanders around the toe of the active Doctor Creek alluvial fan. Side channels and wetlands related to system response and evolution to the debris flow(s) still exist on the nearby floodplain and downstream. A set of historical photos from 2006 (pre-debris flow), 2009 (post debris-flow initiation), 2011 (fan development), and 2023 (modern conditions) are provided in Figure 228. This modern example of the influence of periodic fan contributions to the channel is useful in understanding channel form and responses in the upper reaches of the assessment area.

Figure 230. Set of aerial imagery (2006, 2009, 2011, and 2023) of the Doctor Creek post-logging debris flow(s) (initiated in 2008) at RM 16.3 and related tributary fan and channel evolution. (Google Earth imagery)

Channel substrate in Reach 15 is primarily cobble with gravel and some boulders. Cobble-gravel bars are located on the inside of meander bends, laterally along the channel margins and as mid-channel bars at low-flow conditions (Figure 231). The ratio of cobbles and boulders increases in the more confined sections of the reach. Coarse sand and pebble substrate were noted at the downstream end of bars or along side channels or other areas of reduced flow velocities.

Figure 231. Sediment on bar at RM 15. (August 11, 2024)

Two Wolman Pebble Counts (Wolman, 1954) were conducted in Reach 15 at riffle crests. The median grain size (D50) of GC 11 at RM 14.94 was 160mm and for GC 10 at RM 16.22 the median grain size (D50) was 125 mm. The pebble count data are included in Figure 232 of the Reach 15 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5). The analysis indicates that at the 2-year modeled discharge, the channel's shear stress is expected to mobilize cobble sized or smaller material through most of the reach, except near RM 15.1 where gravel-sized material is the largest expected grain size to be mobilized at the modeled flow. The scale of the model results depicts the diversity of shear stress through the reach with side channels and bars expressing shear stress for smaller grain fractions such as gravel and coarse sand mobilization. Compared to Reach 16 upstream, transport capacity at the modeled two-year flow is lower in Reach 15. In addition to slope and tributary sediment contributions, the reduced shear in 15 compared to upstream promotes sediment accumulation, temporary storage, and floodplain development.

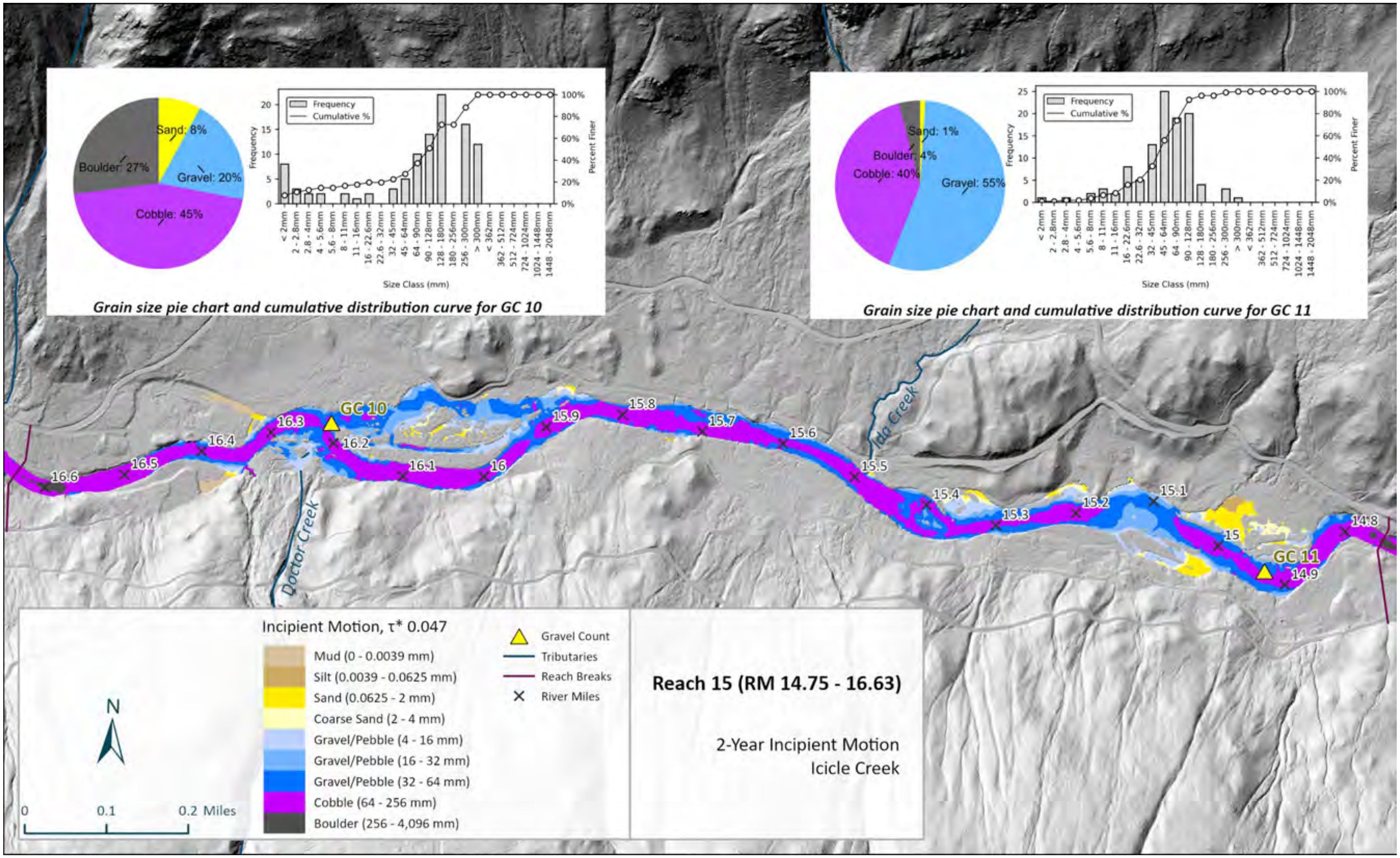

Figure 232. Reach 15: incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge). Includes location and grains size data of the GC 10 and GC 11 pebble counts (2024 survey).

3.15.3 Large Wood Material

The habitat survey conducted in summer 2024 recorded 206 individual pieces of large woody material (LWM) and 25 log jams (accumulation of >3 LWM) within the bankfull channel, for a combined total of 487 observed pieces. Figure 234 is a map of the surveyed large wood in Reach 15. Of the 206 individual pieces; 106 pieces are considered medium and large LWM; 23 classified as large size class (>20-inches diameter and >35-feet long); and 83 as medium size class (12 to 20-inches diameter and at least 35-feet long). All 15 log jams (3 or more pieces) in Reach 15 have multiple pieces of medium and large LWM. Reach 15 has 258 pieces of wood per mile (count includes medium and large LWM as individuals and in jams), which meets the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state (Fox & Bolton, 2007; Appendix A).

Large wood inputs occur through recruitment along eroding banks or reactivated vegetated floodplains, and debris fan contributions. Several large wood and jams (3+ pieces of large wood) are influencing channel processes, and some are enhancing habitat quality, while others temporarily rest at the margins or atop bars providing little geomorphic or habitat function. Those that do interact with the channel, especially in the unconfined sections, influence and maintain pool scour, sediment sorting, and provide habitat cover (Figure 233). Some of the large wood jams and pieces are not anchored by key logs or attached to the banks, making them likely to mobilize during higher flows.

Figure 233. Large wood jam maintaining scour pool with cover along the bank at RM 15.9. (August 11, 2024)

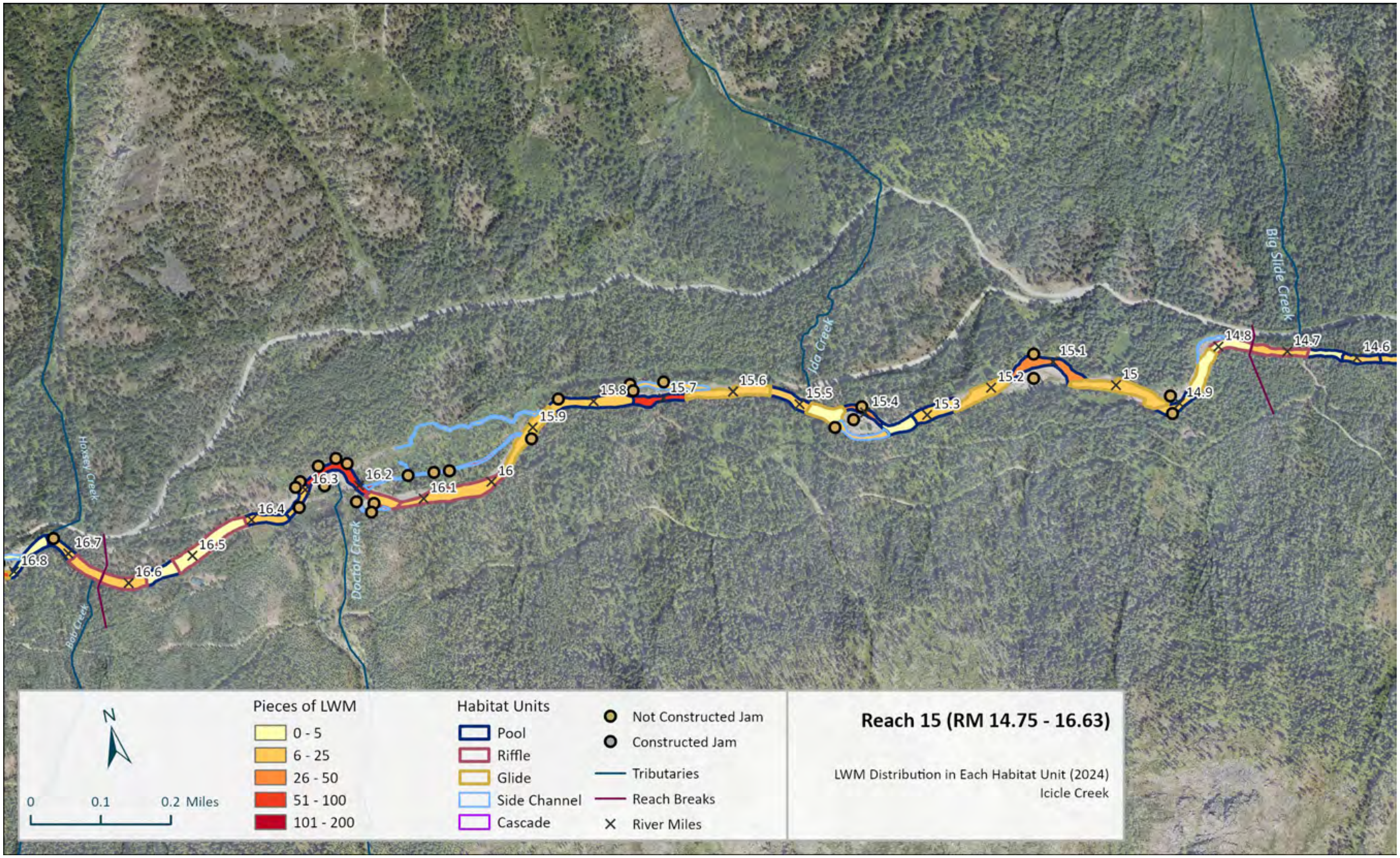

Figure 234. Reach 15: Large wood distribution (pieces per mile per habitat unit) map and surveyed habitat units map (2024).

3.15.4 Vegetation

Riparian vegetation and buffers in Reach 15 are mostly intact with some impacts from current and former roads, a campground, past timber harvest, and a debris slide. The former Icicle Creek Road alignment runs parallel and close to the channel along river-left through most of the upstream portion of the reach. At the upstream end, this alignment has compacted soils and vegetation has been slow to recover. It is recovering quicker in downstream areas but vegetation on the old corridor is young. There are also impacts to vegetation river-left near RM 15.4-15.5 at the Ida Creek Campground. The river-left floodplain from 16.3 to 16.4 has many cleared areas, some associated with past grading in the area (excavation and various spoils piles and berms). This area has also been used as a dispersed camping area. Other areas with cleared riparian vegetation include campsites and picnic areas at RM 14.8 and RM 15.5 and at a residential area river-right at RM 16.6. Tree size and stand age is impacted in the upper portion of Reach 15 from timber harvest activities on the river-right hillslopes.

Low floodplain surfaces typically had cottonwood, cedar, alder, and dogwood, with willows on bars (Figure 236). Higher floodplains, terraces, and hillslopes were dominated by large conifers, including Douglas fir, ponderosa pine and cedar. Forest cover across portions of Reach 15 suggests there is availability of trees adjacent to the channel for large wood recruitment. A map showing vegetation heights is included in Figure 238, with an aerial in Figure 239. The map reveals the presence of large and very large trees along the banks and across the floodplain. The existing riparian vegetation provides moderate stream shading from larger trees along the river-right (southern) bank.

The Doctor Creek debris flows that initiated in May 2008 impacted floodplain and riparian vegetation upstream and downstream of the Doctor Creek confluence at RM 16.25 (river-right). The slide debris appears to have backwatered a portion of Icicle Creek upstream, resulting in mortality of a low floodplain forest on river-right just upstream of the confluence and of channel margin trees on river-left upstream of the confluence. Multiple species appear to have been affected including fir, cedar, and cottonwood (Figure 236). Similarly, downstream of the confluence, on river-left, there is tree mortality and a transition in vegetation conditions due to the increased activation of the river-left floodplain (RM 15.9 – 16.25) because of the debris flows (Figure 237).

Figure 235. Representative vegetative conditions in Reach 15, near RM 14.8 (August 2024).

Figure 236. View downstream at tree mortality on river-right upstream of Doctor Creek slide near RM 16.4 (August 2024).

Figure 237. View down valley in left-bank floodplain near RM 16.22. This floodplain received increased activation following the Doctor Creek slide (May 2008) and has experienced tree mortality and a shift in the vegetation community to more riparian shrubs.

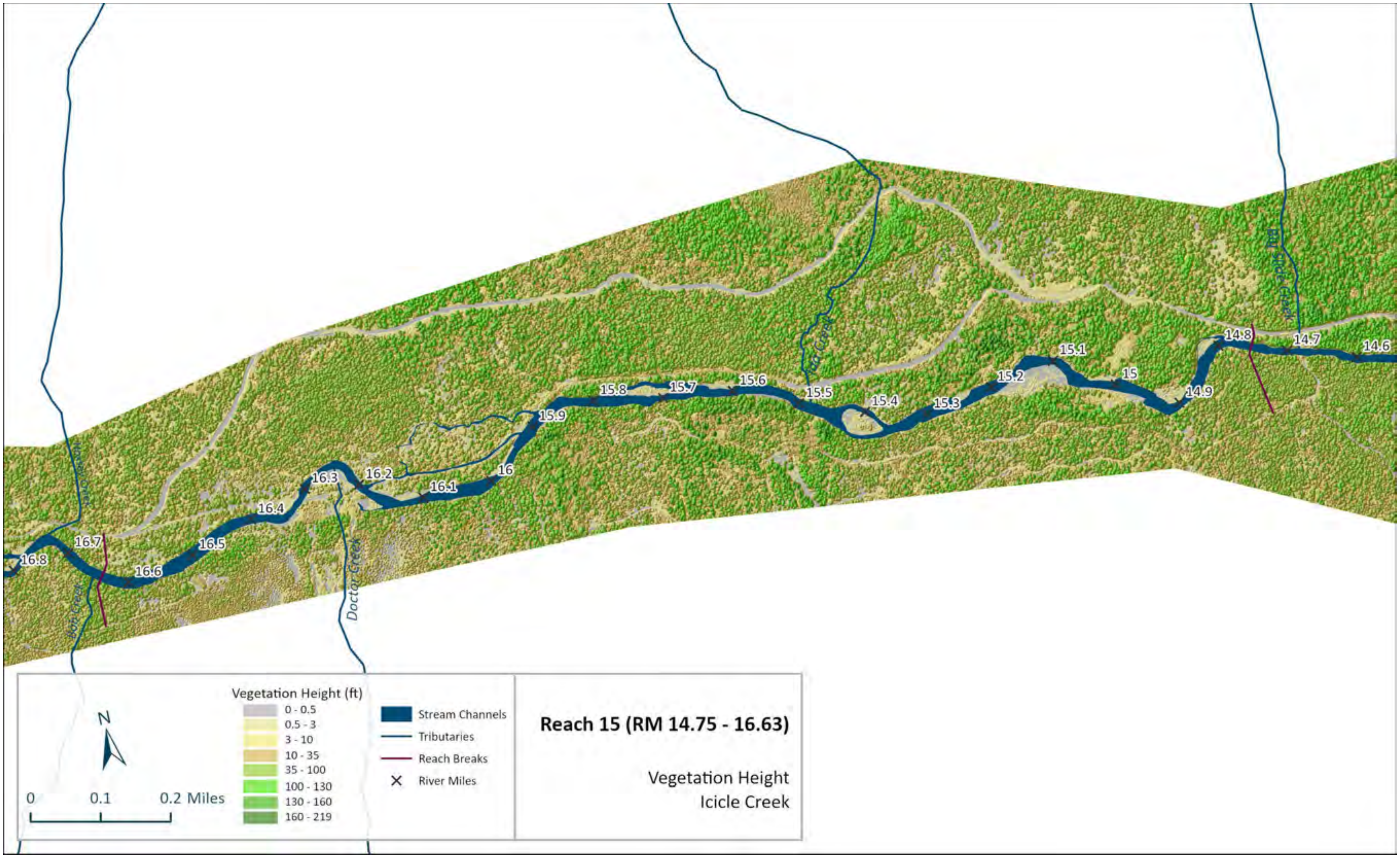

Figure 238. Reach 15: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 239. Reach 15: Map of aerial imagery for vegetation identification (ESRI 2023).

3.15.5 Human Alterations

A map of anthropogenic features is provided in Figure 243. The greatest impacts in the reach are associated with the former road alignment and the Ida Creek Campground. Much of the river-left channel margin and riparian zone is impacted by the former road, which was washed out due to the Doctor Creek slide in May 2008 and was replaced with a new road (circa 2010) further up the river-left hillslope. The former road and associated features continue to affect channel, riparian, and floodplain processes from RM 15.5 to 16.5. These impacts include remaining road fill and compaction, berms, cleared areas, placed boulders, and riprap (Figure 240). There is also riprap, cleared riparian vegetation, and hand-built rock dams near associated with Ida Creek Campground on river-left RM 15.35 to 15.5. In the river-left floodplain from RM 16.3 to 16.5 there is grading, clearing, the old roadbed, and dispersed camping both north and south of the old road. The grading may be related to past gravel mining for road construction and was likely a pull-out area off the old road for dispersed camping. The grading affects floodplain connectivity and vegetation recovery. There is a water monitoring station (PVC and staff gauge attached to T-post on river-left at RM 15.92 (Figure 241). There are houses/structures near the channel at the upstream end of the reach on both sides. The house on river-left is located on a terrace, while the one on river-right is on the hillslope.

Figure 240. Placed boulders associated with former Icicle Creek Road, river-left RM 15.88 (August 2024).

Figure 241. Water monitoring station at RM 15.92 (August 2024).

Figure 242. Cleared riparian area river-left near RM 16.46 (August 2024).

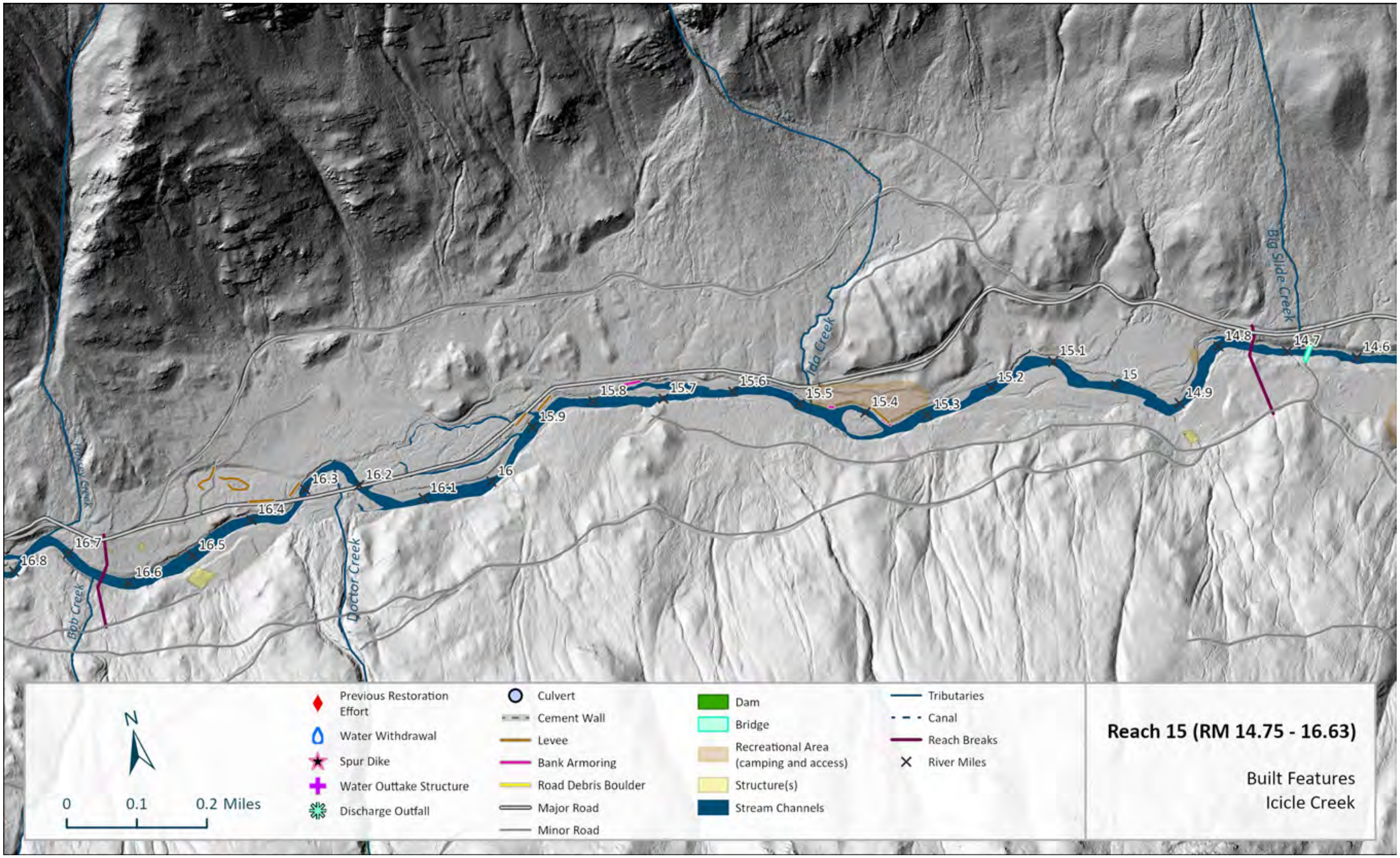

Figure 243. Reach 15: Mapped anthropogenic features (2024).

3.15.6 Recommended Actions

Reach 15 has some of the greatest potential restoration opportunities in the study area. This is due to legacy human features that are affecting floodplain connectivity but could be modified, plus some dynamic processes associated with the Doctor Creek debris slide that restoration actions could work with. The Doctor and Ida projects are located within this reach. A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities).

At the Ida Creek Campground on river-left near RM 15.4, there is a berm, fill, and riprap that could be removed to enhance connectivity of the floodplain. Downstream of this, there are 2-3 opportunities to enhance the connectivity of side-channels via mainstem large wood loading and excavation. The mainstem channel in this downstream half of the reach would also greatly benefit from large wood placements including bar apex log jams to split flows and help create or maintain vegetated islands. Other complexity wood in pools would provide rearing cover.

Midway through the reach, the old (now abandoned) road is located adjacent to the channel on river left. There is occasional armoring associated with this road that could be removed, with bar apex jams and margin wood added throughout. The old road alignment could benefit from replanting conifers.

At the upstream end of the reach, fill could be removed, located to the north of the abandoned road on river left. A side-channel could potentially be constructed through this floodplain. If a flow-through connection is not possible, an alcove connection at the downstream end may be feasible. Grading in the floodplain could increase flood inundation frequency. 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. Downstream of the slide, the river-left floodplain has become more activated with overbank flows. Restoration work, including mainstem wood loading and select excavation could work with these existing processes to further activate left-bank side-channels and increase floodplain connectivity. There are a couple areas of old fill that could be removed at the downstream end of this surface to enhance floodplain connection, left bank near RM 15.9. The mainstem channel in this upstream half of the reach would also greatly benefit from large wood placements including bar apex log jams to split flows and help create or maintain vegetated islands. Other complexity wood in pools would provide rearing cover.

3.16 REACH 16 (RM 16.63 – 17.24)

3.16.1 Overview

Reach 16 is 0.61 miles in length and extends from the confluence of Bob Creek at RM 16.63 to RM 17.24. The reach has an average gradient of 0.88%. It is partially confined by hillslope, terrace, and debris fans but inset bands of functioning floodplains along 0.4 miles of the channel in the middle section provide for some sinuosity development (Figure 244). The channel is primarily single thread in form with one short split flow around a small bedrock island at RM 16.8. There are numerous bedrock exposures in the banks and bed of the channel. Riparian vegetation and buffers are mostly intact, though naturally sparse on bedrock hillslope areas. Vegetation cover is also reduced along the roadway on river-left and by residential development at the downstream end on river-left. Landownership is a mix of private and National Forest.

Figure 244. Representative photo of Reach 16 at RM 16.94. Bedrock hillslope confinement on river right and well-vegetated floodplain on river-left. (August 11, 2024)

3.16.2 Channel and Floodplain Geomorphology

Table 26. Reach 16 metrics.

Reach 16												
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
0.61	16.63-17.24	0.88%	1.10	Pool	98	Partially Confined	Cobble / Boulder	45.9%	12.7%	37.3%	4.1%	0.0%

Although partially confined, the channel in Reach 16 is relatively low in gradient. Confinement via terraces and bedrock hillslopes vary in width and location, providing for the development of inset floodplains in the mid 0.4 miles of the reach (Figure 246). Channel form is single-thread with one split flow side-channel around a bedrock island near RM 16.8. Channel type is pool-riffle with a dominant substrate of cobble and boulder. Two tributaries contribute sediment and discharge to the mainstem channel. Hoxsey Creek joins on river-left near RM 16.75 and Bob Creek joins near the downstream reach boundary at RM 17.24 on river-right. Geomorphic and habitat complexity are moderate to low. Scour pools are maintained with many of the bedrock bank contacts, however few of the pools have adequate cover (Figure 245).

Figure 245. Scour pool at bedrock bank contact at RM 16.76 (August 11, 2024).

The floodplains in Reach 16 are inset below fan and hillslope terraces and most occur as discontinuous strips along the channel that alternate with confining hillslopes. Low floodplains (inundated ~1-5 yrs) occur as narrow strips along portions of the channel with establishing riparian vegetation. Near RM 17, low floodplain surfaces occur on both sides of the channel. Medium floodplains (inundated ~5-20 yrs) flank the low floodplains and range in width and distribution. High floodplain surfaces (inundated ~20-100+ yrs) edge the medium and low floodplains with minimal contact points along the channel. Floodplains are composed of cobbles and boulders topped with developing soils.

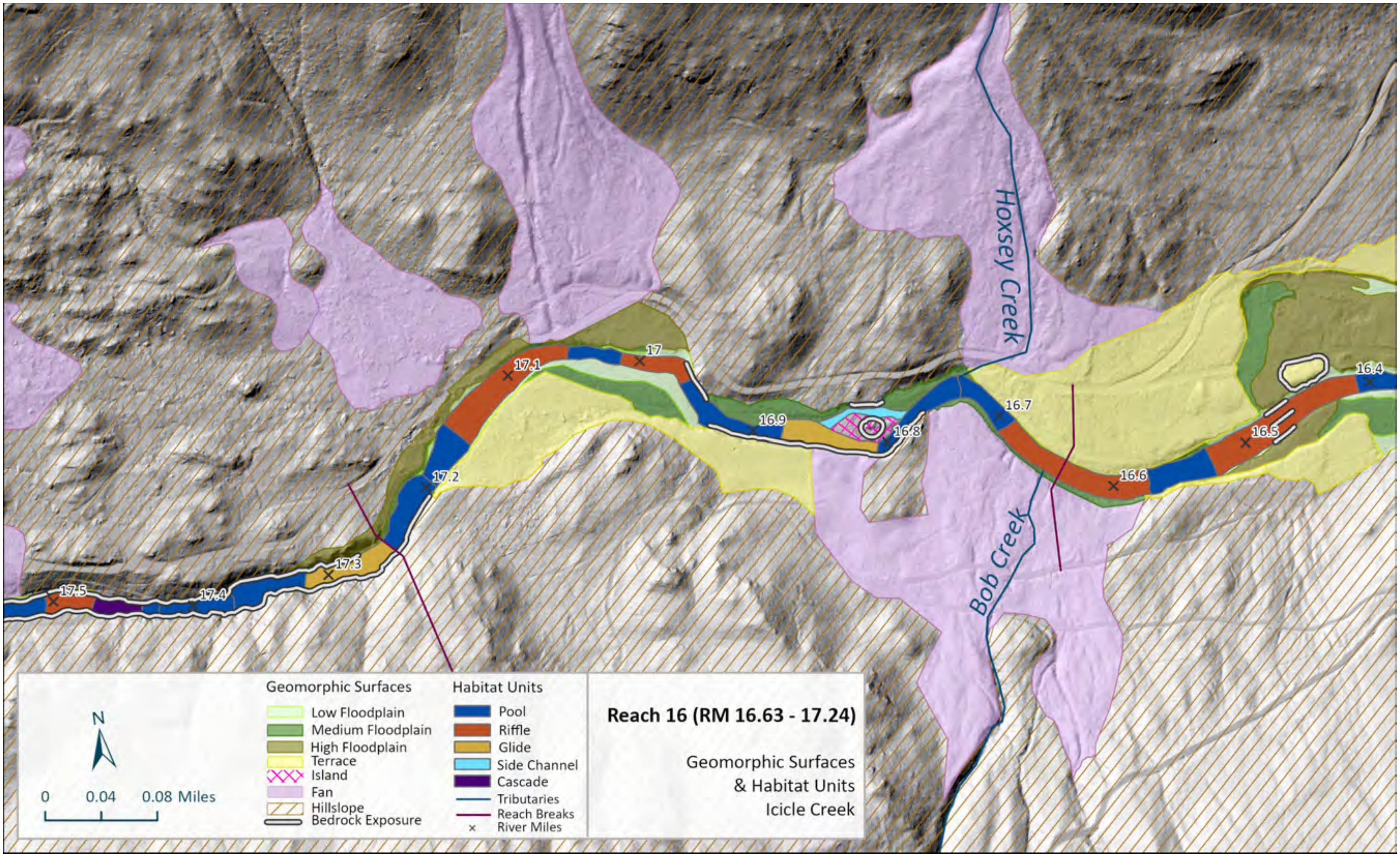

Figure 246. Reach 16: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

Channel substrate in Reach 16 is dominated by cobble, with fractions of boulder and gravel. One established point bar occurs at the meander near RM 16.96. Otherwise, cobble-boulder bar development occurs along the margins of the channel, exposed during low-flow conditions (Figure 247). Gravels and coarse sands are retained behind boulders, draped on low floodplain surfaces and other small areas of hydraulic refuge. Sediment is sourced primarily from adjacent hillslopes and fan contributions. Additional material is transported into Reach 16 via the channel from upstream.

Figure 247. Lateral cobble-boulder bar at RM 17.24 (August 11, 2024).

Two Wolman Pebble Counts (Wolman, 1954) were conducted in Reach 16. The median grain size (D50) of GC 9 at RM 16.74 along a riffle crest was 135mm and for GC 8 at RM 16.84 atop a lateral bar the median grain size (D50) was 105 mm. The pebble count data are included in Figure 248 of the Reach 16 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5). The analysis indicates that at the 2-year modeled discharge, the channel's shear stress is expected to mobilize cobble-sized material through the entirety of the reach. Small patches with increased shear near RM 17.05 and 16.69 indicate a model shear capable of mobilizing boulders.

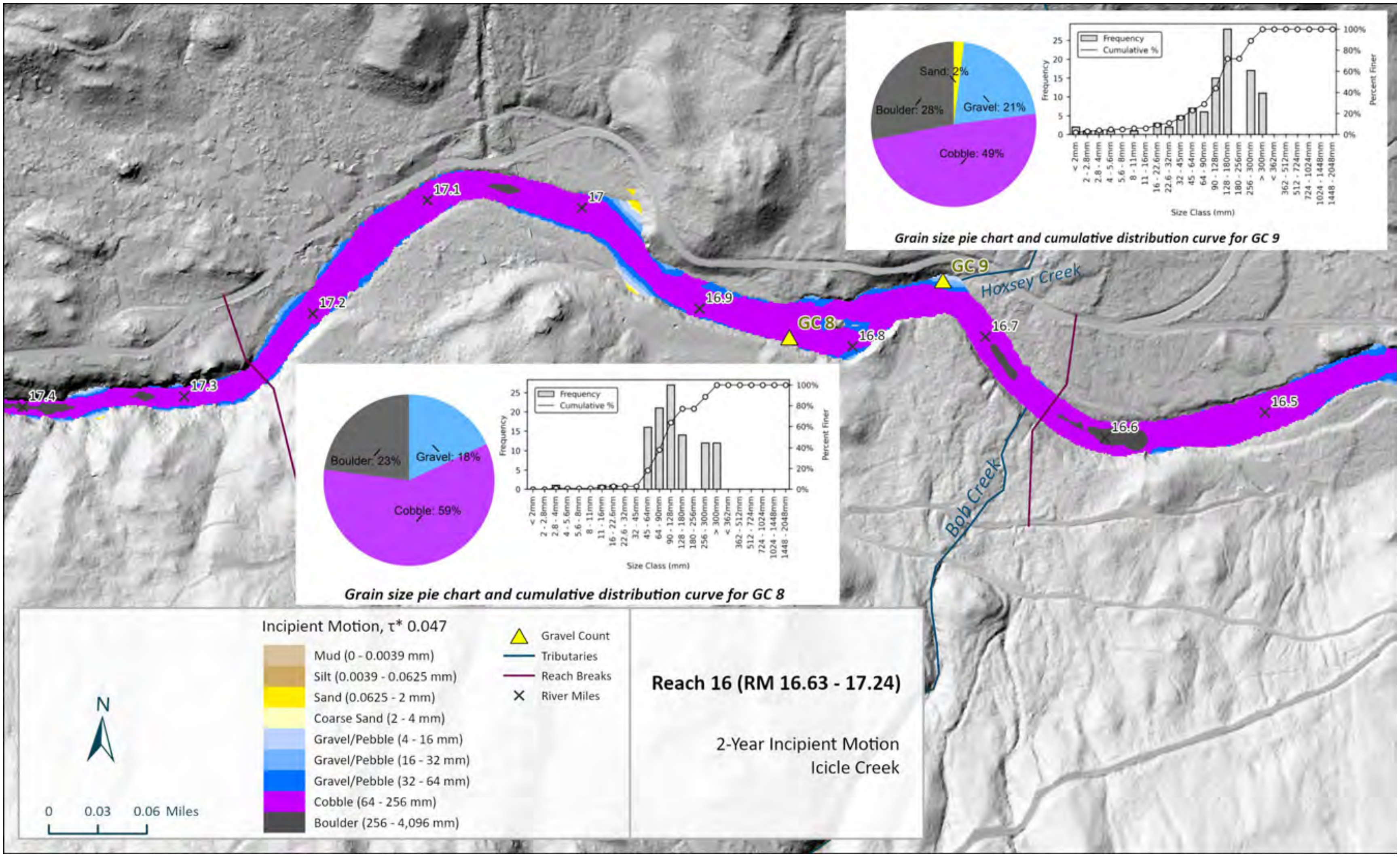

Figure 248. Reach 16: incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge). Includes location and grains size data of the GC 8 and GC 9 pebble counts (2024 survey).

3.16.3 Large Wood Material

The habitat survey conducted in summer 2024 recorded 38 individual pieces of large woody material (LWM) and 3 log jams (accumulation of >3 LWM) within the bankfull channel, for a combined total of 107 observed pieces (Figure 250). Of the 38 individual pieces; 4 are classified as large size class (>20-inches diameter and >35-feet long); and 15 as medium size class (12 to 20-inches diameter and at least 35-feet long). All 3 log jams in Reach 16 have multiple pieces of medium and large LWM. Reach 16 has 98 pieces of wood per mile (count includes medium and large LWM as individuals and in jams), which meets the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state (Fox & Bolton, 2007; Appendix A).

Large wood in Reach 16 plays a minor role in geomorphic function. Instead, it contributes to habitat quality by adding cover and nutrients to the channel where it occurs. The largest jam in the reach is found racked at the upstream end of the bedrock/boulder island at RM 16.83 (Figure 249). The island's position maintains the jam with continued racking of wood. It is mostly perched above the channel during low-flow conditions but continues to provide habitat cover during higher flow conditions. While large wood is present throughout Reach 16, several of the accumulations are not anchored by key logs or securely attached to the streambed or banks, rendering them temporary and likely to mobilize during high flow events. Recruitment occurs from the adjacent channel margins and hillslopes.

Figure 249. Large wood apex jam racking on head of island at RM 16.83. (August 11, 2024)

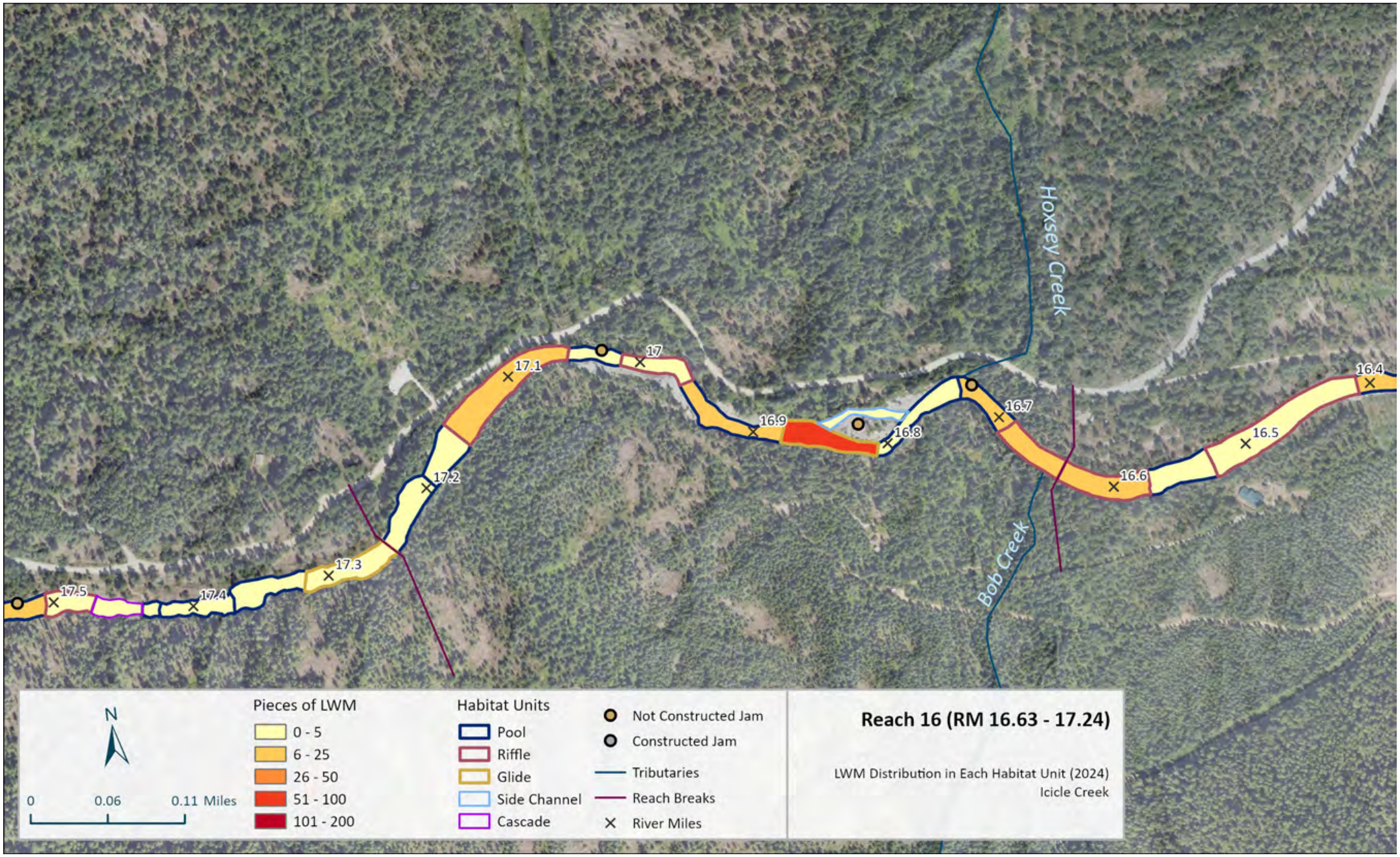

Figure 250. Reach 16: Large wood distribution (pieces per mile per habitat unit) map and surveyed habitat units (2024).

3.16.4 Vegetation

Riparian vegetation in Reach 16 is mostly intact with some clearing associated with the Icicle Creek Road on river-left in a few locations where the road is close to the channel (RM 16.75, 17.05-17.15). There has also been some clearing associated with residential development at the downstream end on river-left near RM 16.65. Vegetation is naturally sparse on the bedrock or debris fan hillslopes and denser where a narrow floodplain exists. There is a vegetated island at RM 16.8 with pine trees estimated to be 40 years or older. Low floodplains and bars have a mix of rushes and grasses and woody-stemmed plants, including alder, willow, and dogwood. The overstory is Douglas fir, ponderosa pine, cedar, and cottonwood. Higher surfaces are forested with conifer overstory dominant. Vegetation has been influenced by wildfire and by debris flows from the steep northern hillslope drainages. Typical conditions are shown in Figure 251.

Tree cover in Reach 16 suggests there is some availability for large wood recruitment. Large overstory trees are especially present in clusters near RM 16.5, 16.7, and 17.2, providing localized sources of large wood to the channel. The proximity of Icicle Creek Road to the channel limits potential for large wood recruitment in some portions of the reach. A map showing the vegetation heights is provided in Figure 252, with an aerial in Figure 253. The existing riparian vegetation provides the greatest amount of stream shading in the confined portions of the reach where vegetation overhangs the active channel more regularly.

Figure 251. Representative vegetative conditions in Reach 16, near RM 17.15 (August 2024).

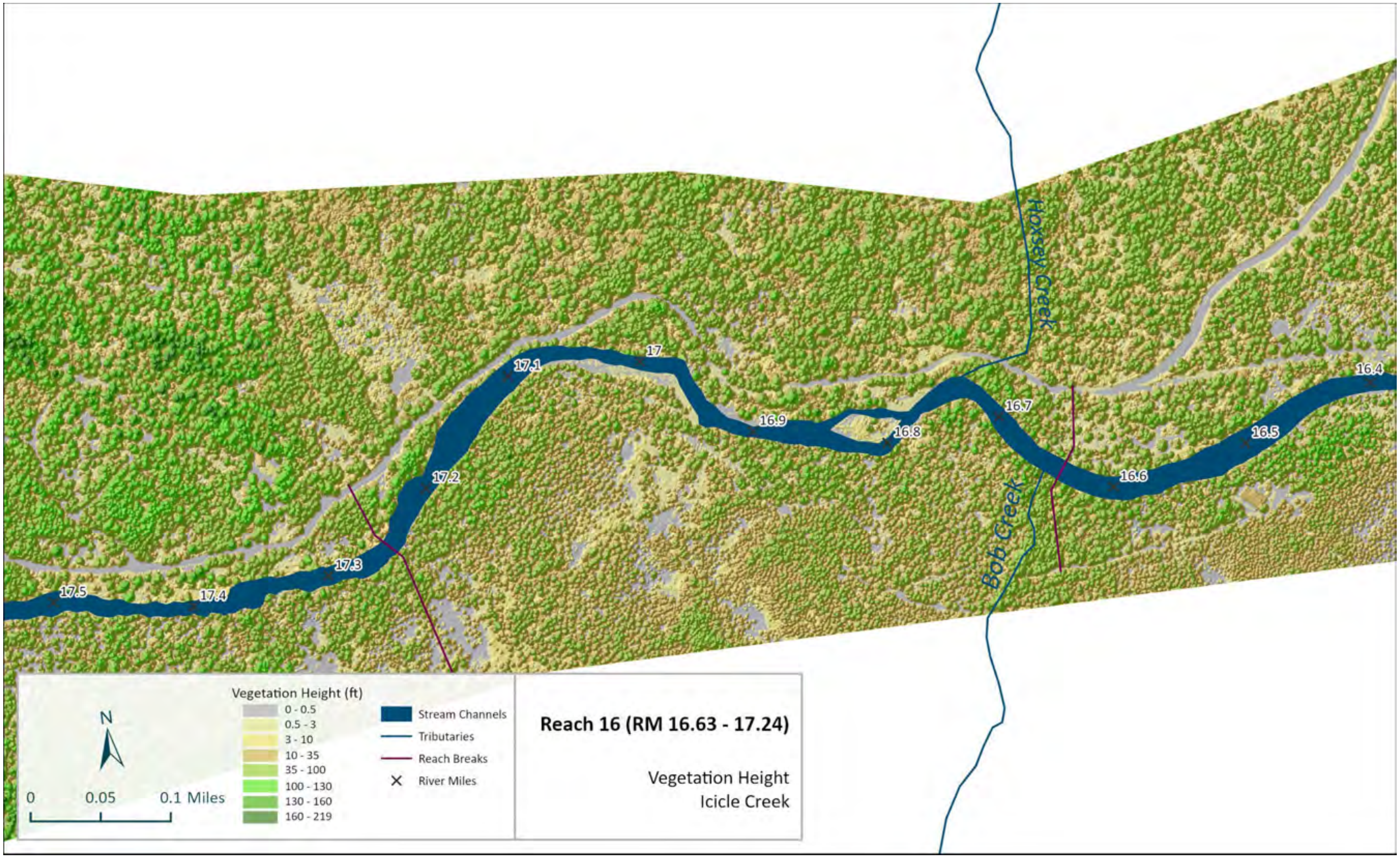

Figure 252. Reach 16: Map of vegetation height classification analysis (LiDAR – based analysis).

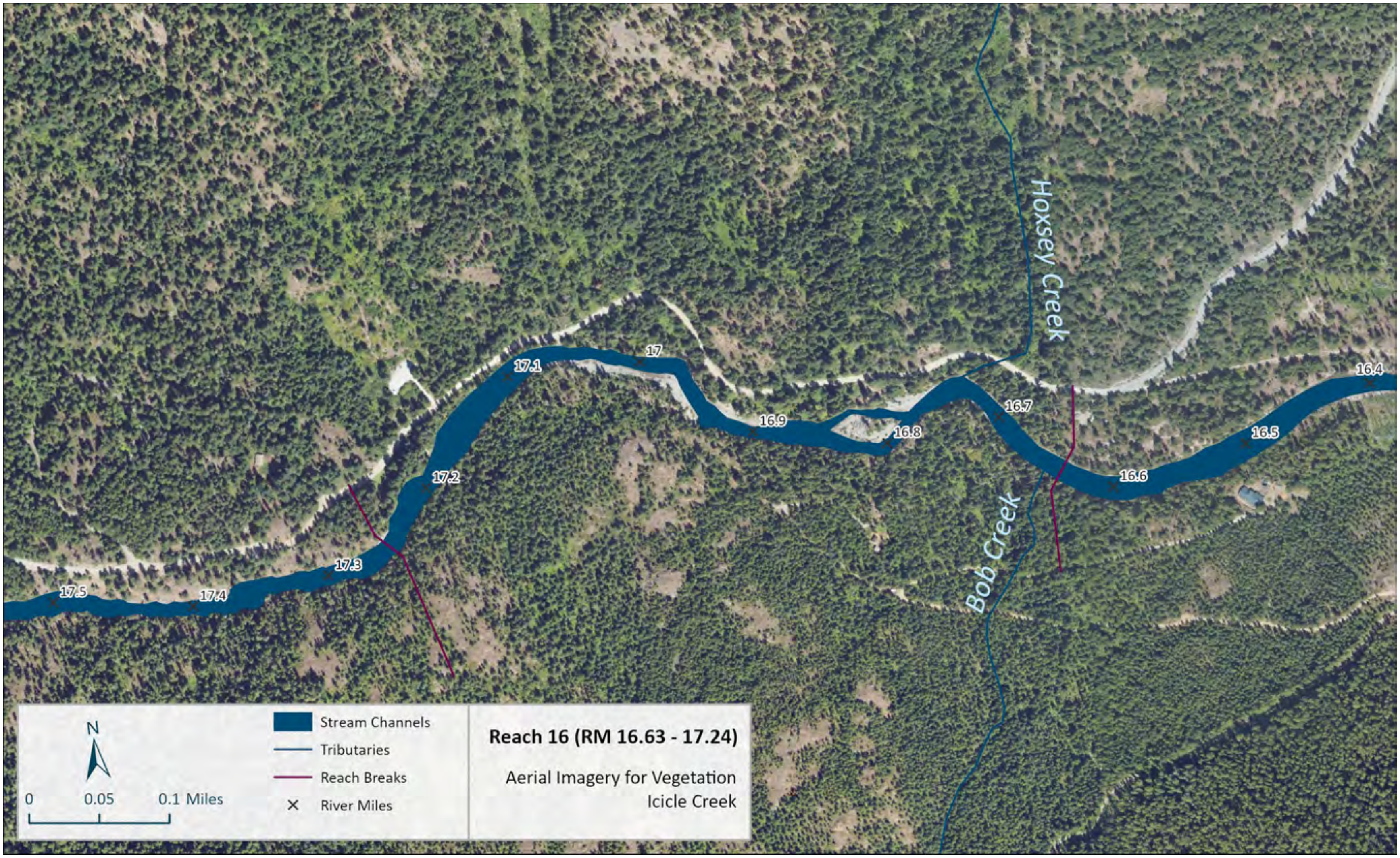

Figure 253. Reach 16: Map of aerial imagery for vegetation identification (ESRI 2023).

3.16.5 Human Alterations

Human alterations in Reach 16 are relatively minor and include the Icicle Creek Road on river-left, dispersed camping, and some residential development. There is armoring associated with the road near RM 17.1 (Figure 254) that has an impact on riparian vegetation and channel margin habitat but very little impact to channel migration due to the natural hillslope contact. There is a road culvert at RM 17.06, very likely inadequate to pass large flows or debris flows. There is minor clearing associated with residential development at the downstream end near RM 16.65. There are some camping (river-left RM 16.95 and 17.01) and parking (RM 16.8) areas which have also contributed to removal of vegetation. A map of the anthropogenic features is provided in Figure 255.

Figure 254. Road impacts river-left near RM 17.1.

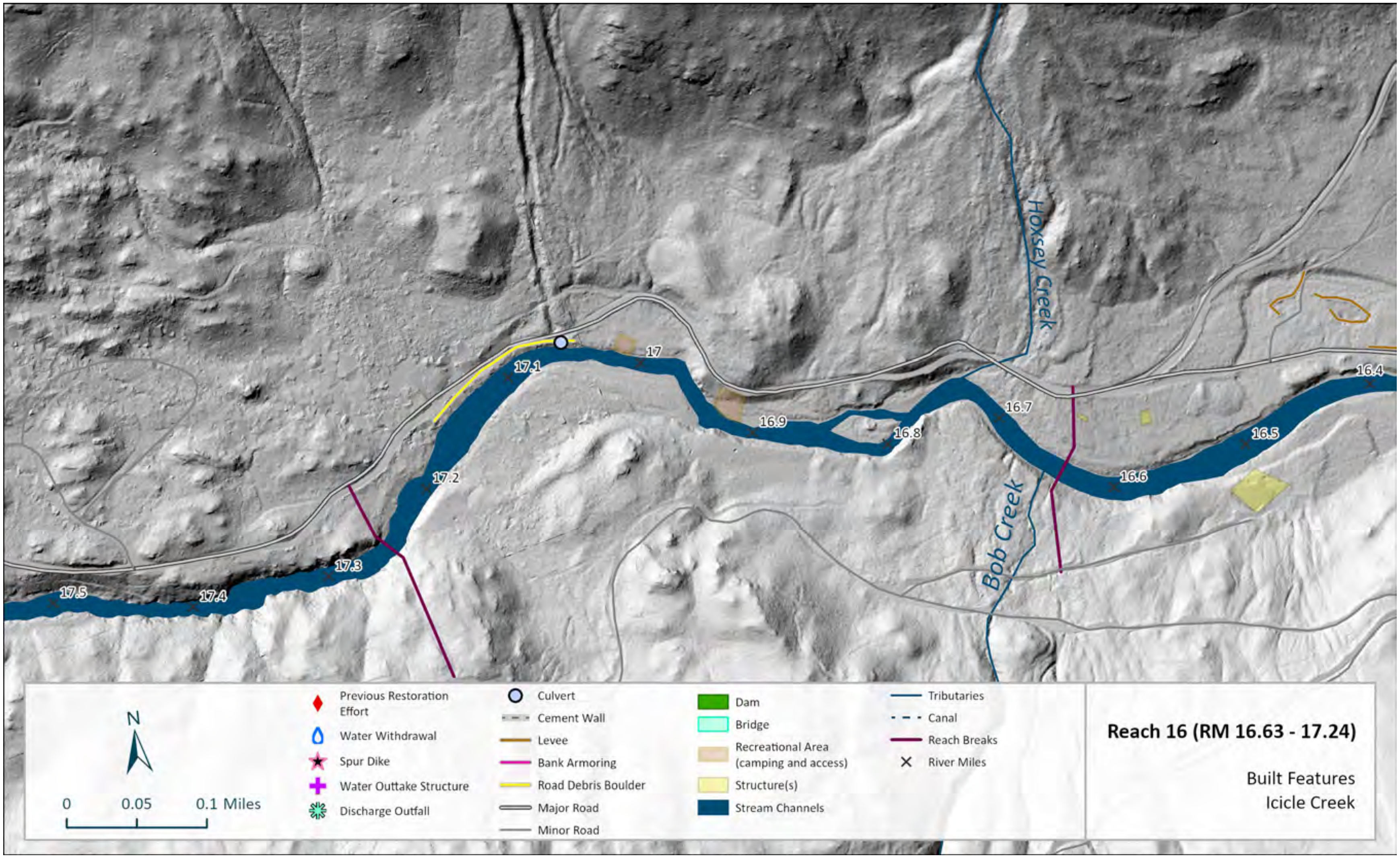

Figure 255. Reach 16: Mapped anthropogenic features (2024).

3.16.6 Recommended Actions

Restoration opportunities in Reach 16 include large wood placements to enhance channel dynamism and complexity. Multiple bar apex jams would split flows and help create or maintain vegetated islands. Other complexity wood in pools would provide rearing cover. Actions in Reach 16 are captured in the Doctor project. A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities).

3.17 REACH 17 (RM 17.24 – 18.74)

3.17.1 Overview

Reach 17 is 1.5 miles long and extends from RM 17.24 to RM 18.74 at the Jack Creek alluvial fan on river left. The reach has an average gradient of 1.62%. The reach is comprised of two different subsections: 1) the confined Icicle Gorge at RM 17.24 – 17.6, and 2) the partially confined and lower gradient upstream reach along toe of Jack and Trout Creek alluvial fans on river-right and a set of debris fan terraces and landslide contributions on river-left at RM 17.6 – 18.74. The reach is characterized overall as partially confined to confined because of the variation in the two subsections. There are split flow conditions around vegetated islands at RM 17.65, 17.75, and 8.3. The channel is otherwise single thread. Jack Creek flows through multiple distributary channels across its fan and joins Icicle Creek on river-right at RM 18.74 and again at RM 18.1. Trout Creek joins Icicle on river-right near RM 17.84. Channel type is boulder and bedrock step-pool in the gorge section and boulder dominated pool-riffle in the upstream section (Figure 256). Riparian and floodplain vegetation is relatively established with some clearing on river-right along the top of the Jack Creek alluvial fan. Human alterations to the channel and floodplain are localized and related to recreational uses including campsites, trails, access roads, and associated infrastructure. Reach 17 is located entirely within the Wenatchee National Forest.

Figure 256. Representative photos of the Icicle Creek Gorge near RM 17.4 (left) and an upstream boulder-dominated extended riffle near RM 18.3 (August 2024).

3.17.2 Channel and Floodplain Geomorphology

Table 27. Reach 17 metrics.

Reach 17													
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
1.5	17.24-18.74	1.62%	1.15	Riffle	78	Partially & Confined	Boulder / Cobble	34.2%	11.3%	40.8%	8.8%	4.9%

The channel in Reach 17 follows a moderate gradient except for a steep bedrock grade step in Icicle Canyon at approximately RM 17.4 (see channel longitudinal profile: Figure 33). The canyon sub-section (RM 17.24 – 17.6) is bedrock confined single-thread in form while the upstream sub-section (RM 17.6-18.74) is partially confined by active alluvial fans on river left and contributing debris fans and landslide contributions on river right. The sediment contributions received from the fans produce increased complexity compared to the upstream and downstream river sections. The sediment contributions include boulders which offer some localized complexity in wide plane-bed channel units. The section includes perennial (wetted) and high-flow (dry) side channels around vegetated islands and cobble-boulder bars.

Three perennial tributaries meet Icicle Creek in Reach 17 – Jack, Trout, and Chatter Creeks. The largest tributary, Jack Creek, currently enters the mainstem channel via distributary fan channels on river-right at RM 18.1 and 18.74. Based on historical imagery, logging in the Jack Creek drainage prior to 1985 increased activation of sediment across the fan and into the Icicle Creek. Although forest regeneration is underway in the drainage, Jack Creek remains, though an active contributor of both discharge and sediment to Icicle Creek. Hyporheic groundwater contributions at multiple locations along the toe of the Jack Creek fan were observed during the survey. Trout Creek meets Icicle Creek at RM 17.84 after flowing over its own alluvial fan. Chatter Creek is a small tributary that joins Icicle Creek on river-left at RM 17.76 after navigating across its drainage's debris fan. Geomorphic and habitat complexity varies in Reach 17. Downstream of RM 17.6 in the bedrock canyon sub-section, complexity is low, and the channel is considered a sediment transport reach. Upstream of RM 17.6, off-channel habitat, scour pool, and bars are associated with side channels, tributary confluences, and large wood. The potential to increase channel complexity and function in Reach 17 is good.

No floodplain surfaces occur in the downstream canyon sub-section of the reach. Upstream of the canyon section, low floodplain surfaces (inundated ~1-5 yrs) occur as disconnected pockets where vegetation is established on previously active bars. Medium floodplain (inundated ~5-20 yrs) surfaces occur as narrow discontinuous strips primarily associated with side or high-flow channels. High floodplain surfaces (inundated >20 yrs) occupy larger surface areas, including across the toes of re-worked alluvial fans. With the exception of very large flood events, the toes of the fans restrict lateral erosion. Floodplains are composed of boulder and cobble with gravel (Figure 257). The floodplains are mapped in the geomorphic surfaces map in (Figure 258).

Figure 257. Floodplain composition of Jack Creek alluvial fan at side-channel outlet near RM 18.06. (August 9, 2024.

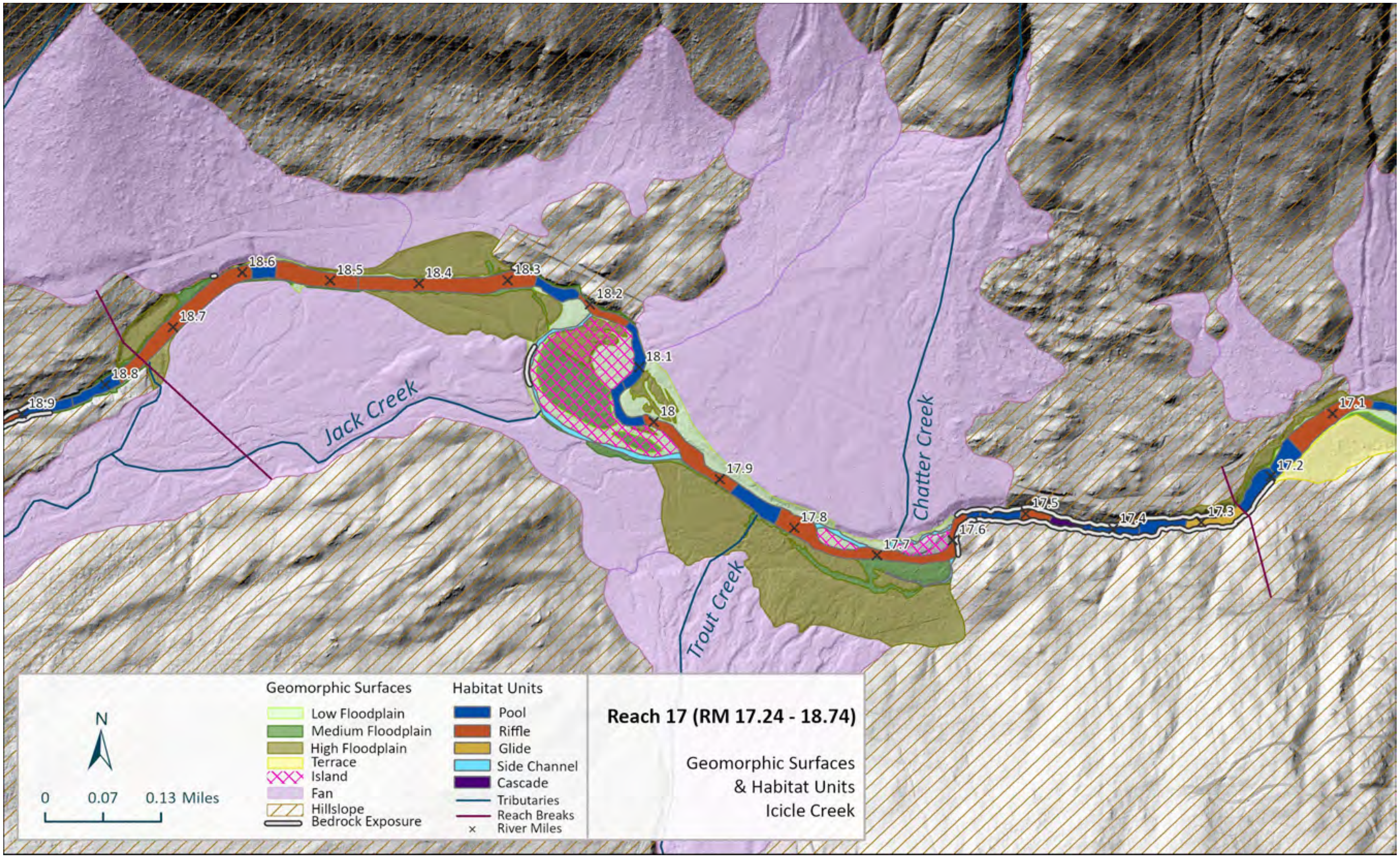

Figure 258. Reach 17: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

Excluding the bedrock sub-reach of Icicle Canyon, mainstem channel substrate in Reach 17 is primarily boulders and cobble with gravel on bars or in pockets of hydraulic refuge. Bars occur along the inside of meander bends and as lateral bars in straight sections (Figure 259). Side-channel substrate was observed to have pockets of gravel and sand within a cobble-boulder substrate due to lower stream power conditions compared to the mainstem channel.

Figure 259. Boulder-cobble lateral bar at RM 17.91 (August 9, 2024).

Two Wolman Pebble Counts (Wolman, 1954) were conducted in Reach 17. The median grain size (D50) at GC 7 at RM 18.08 along a riffle crest was 90mm; at GC 6 at RM 18.6 atop a lateral boulder bar the median grain size (D50) was 205mm. The pebble count data are included in Figure 260 of the Reach 17 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5). The analysis indicates that at the 2-year modeled discharge, the channel's shear stress is expected to mobilize at least cobble-sized material in the upstream subsection (RM 17.6 – 18.74) and boulder sized material in the downstream canyon section (RM 17.24-17.6). Reduced stream energy in the side channels indicate gravel to cobble mobilization during the 2-yr modeled discharge.

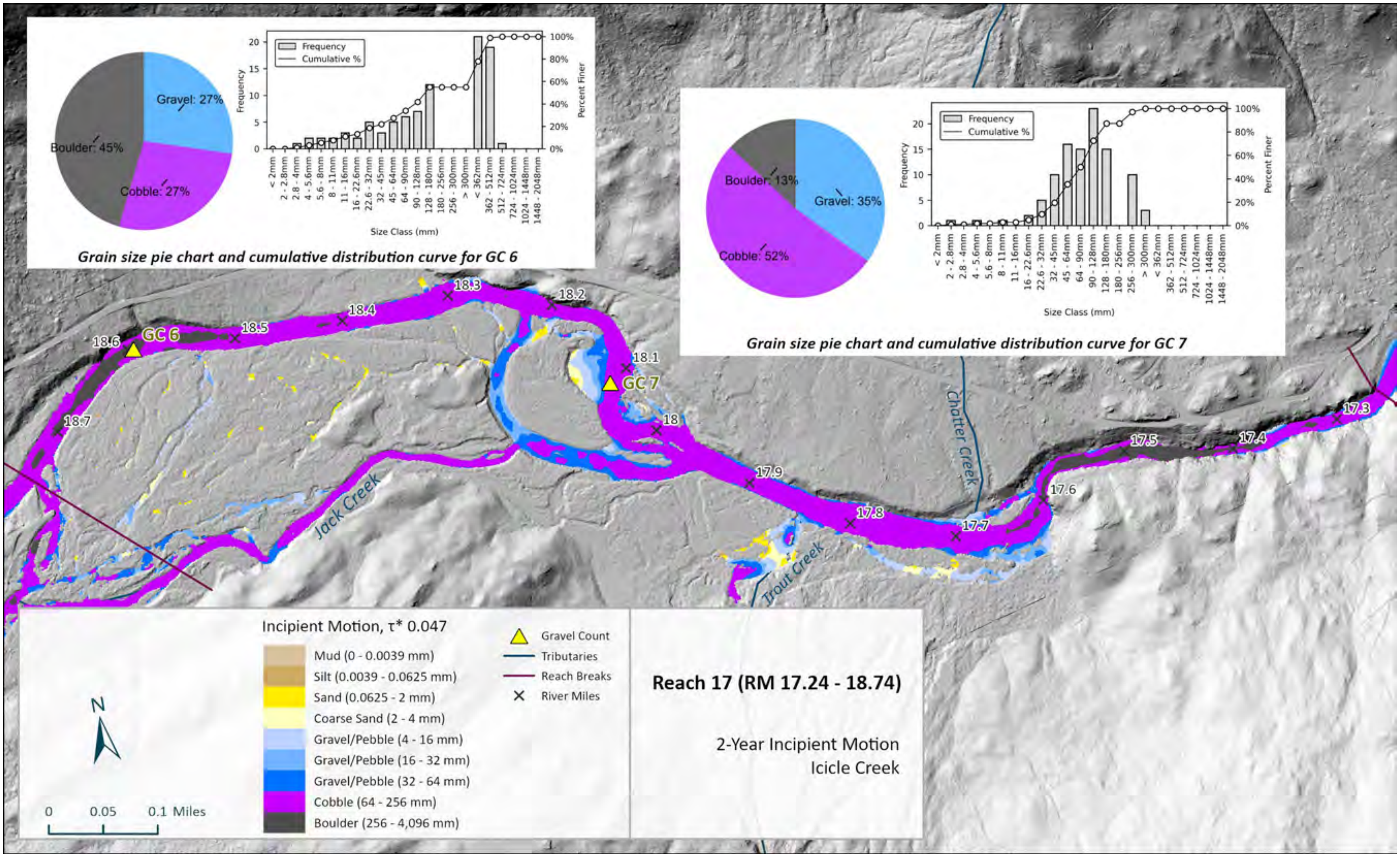

Figure 260. Reach 17: incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge). Includes location and grains size data of the GC 6 and GC7 pebble counts.

In addition to material transported into Reach 17 from upstream, the alluvial and debris fans in the Reach also contribute sediment and occasionally large wood to the channel. Hillslope colluvium in the bedrock confined sections are predominantly boulders and slabs. High floodplains and terrace surfaces with moderate to infrequent inundation comprise the majority of floodplain surfaces across the entire reach (Figure 257). Boulder fans along river-right confine lateral erosion with the exception of very large events. This reach contains narrow strips of disconnected or infrequently activated floodplain along the channel, with a narrow strip of low active floodplain also present.

3.17.3 Large Wood Material

The habitat survey conducted in summer 2024 recorded 133 individual pieces of large woody material (LWM) and 13 log jams (accumulation of >3 LWM) within the bankfull channel, for a combined total of 287 observed pieces. Figure 261 is a map of the surveyed large wood in Reach 17. Of the 133 individual pieces; 22 classified as large size class (>20-inches diameter and >35-feet long); and 42 as medium size class (12 to 20-inches diameter and at least 35-feet long). All 13 log jams in Reach 17 have multiple pieces of medium and large LWM. Reach 17 has 103 pieces of wood per mile (count includes medium and large LWM as individuals and in jams), which meets the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state (Fox & Bolton, 2007; Appendix A).

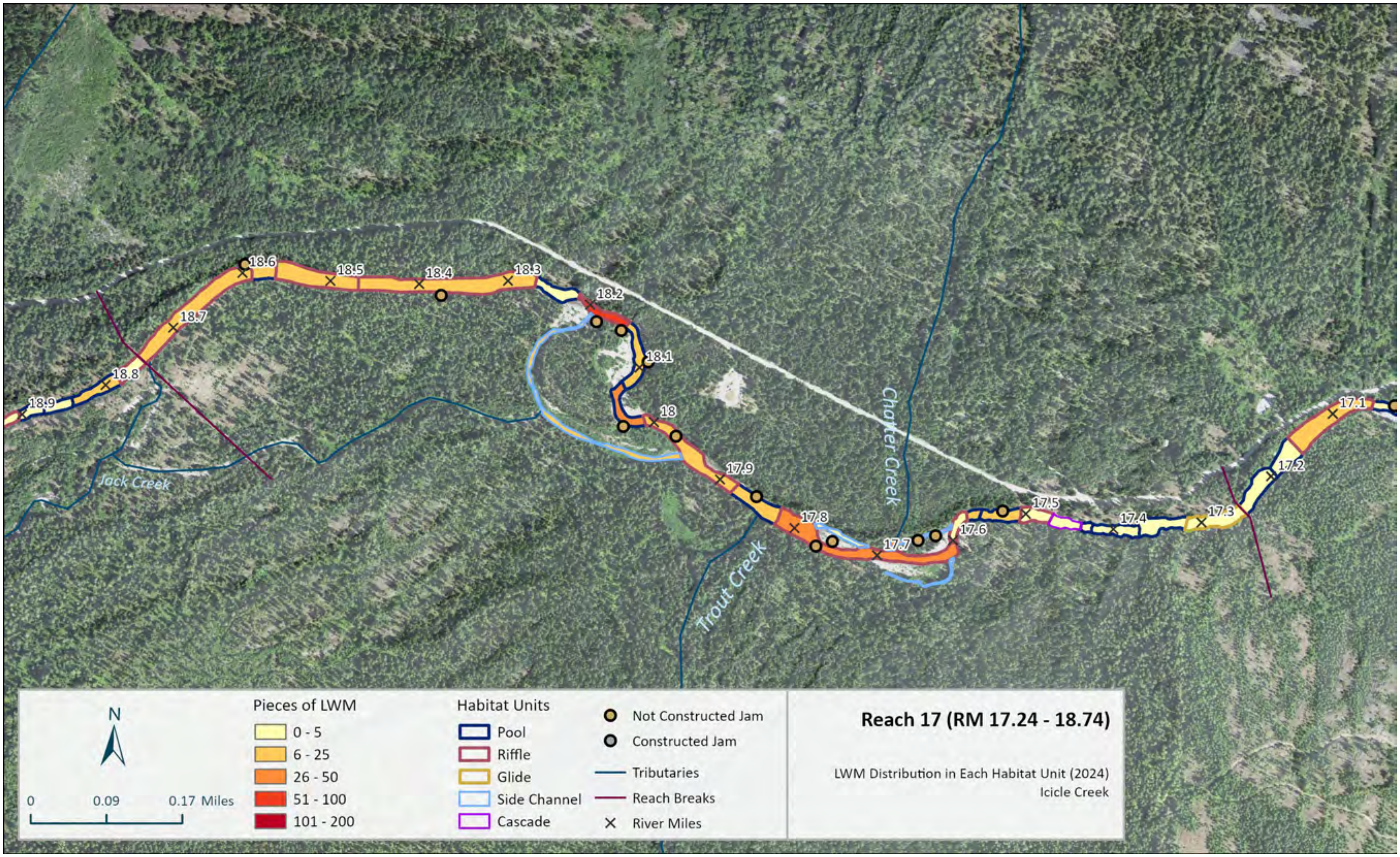

Figure 261. Reach 17: Large wood distribution (pieces per mile per habitat unit) map and surveyed habitat units (2024).

Several of the jams in Reach 17 were observed interacting with the channel and effectively maintaining scour pools and split flow conditions, as well as promoting floodplain development – thus effectively influencing channel and habitat complexity (Figure 262). These jams provide analog examples for effective large wood. Pieces and jams of large wood were also observed atop bars or banks, producing limited to no interaction with the channel. Modern LW recruitment is primarily through previous channel avulsion and some modern lateral bank erosion. While large wood is present throughout this reach, some accumulations are not anchored by key logs or secured to the streambed or banks, making them temporary features that are likely to mobilize during higher flows. Where large wood is present, channel complexity is greater. Despite the presence of large wood throughout Reach 17, some log accumulations do not contain key logs (>20-inches diameter). These jams are considered temporary and are expected to mobilize during higher flow events.

Figure 262. Large wood jam maintaining scour and side channel outlet near RM 18.03 (August 9, 2024).

3.17.4 Vegetation

Riparian vegetation in Reach 17 is mostly intact, with minor impacts related to recreational use. At the downstream end, there is naturally sparse vegetation in the bedrock gorge. Vegetation on the north side is further impacted by the established trail and by a network of dispersed user trails.

There is riparian and floodplain vegetation clearing near an access road on river-right at the upstream end of the reach near RM 18.7 (Figure 263). The vegetation on the Jack Creek alluvial fan is second growth forest cover, with high stem densities and smaller trees. Otherwise, the overstory canopy is generally dominated by large trees including ponderosa pine, Douglas fir, cedar, and cottonwood. Low floodplains typically supported alder, dogwood, vine maple, cottonwood, and cedar, with willows on bars and channel margins. Figure 264 provides an example of riparian and floodplain vegetation in the upstream portion of the reach.

Forest cover across much of Reach 17 suggests there is an availability of trees adjacent to the channel for large wood recruitment. Moderately sized overstory trees are present throughout a large portion of Reach 17, and clusters of taller trees are scattered throughout the reach. A map showing vegetation heights is provided in Figure 265, with an aerial in Figure 266. Stream shading from riparian vegetation is relatively high given the tall trees along the river-right (southern) bank.

Figure 263. Second-growth vegetation on Jack Creek alluvial fan near RM 18.72. (August 2024)

Figure 264. Riparian vegetation and condition near RM 18.7. (August 2024)

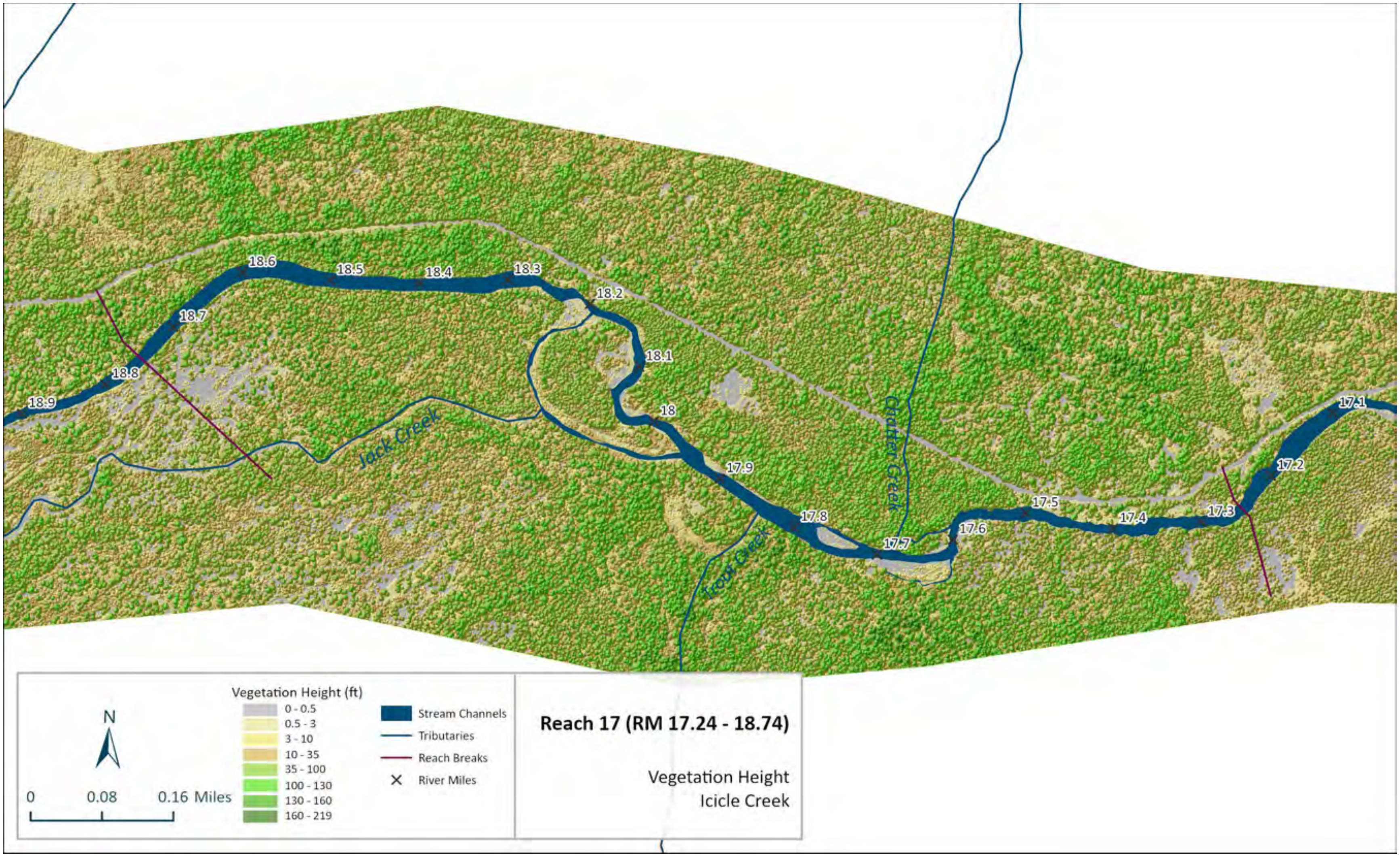

Figure 265. Reach 17: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 266. Reach 17: Map of aerial imagery for vegetation identification (ESRI 2023).

3.17.5 Human Alterations

Human alterations to the channel and floodplain are relatively minor and primarily related to the Icicle Creek Road and to recreational uses including trails, access roads, and dispersed camping areas. Human features are mapped in Figure 268. The road is located out of the active floodplain on river-left and has only very limited impacts where it lies close to the channel due to being located on the hillslope. There are culverts across the road that are inadequate to transmit debris flows from the steep northern hillside. There are a few campsites along the creek including the Chatter Creek Campground and the associated road, which forms a loop at RM 17.46. Impacts to the channel are limited due to the bedrock hillslope and because the camping area is located to the north of the road; however, trails and recreational access have some impacts on riparian vegetation. There is a footbridge at the gorge near RM 17.43 but it is high, the footings are tied to bedrock, and there is very little impact on the channel. There are additional footbridges across tributaries along the trail that follows the river on river-left (Figure 267). There is an access road on river-right at the upstream end of the reach near RM 18.75 and some dispersed camping in the area.

Figure 267. Footbridge across Icicle Creek at RM 17.43 (left) and footbridge across a tributary near RM 18.53 (right). (August 2024)

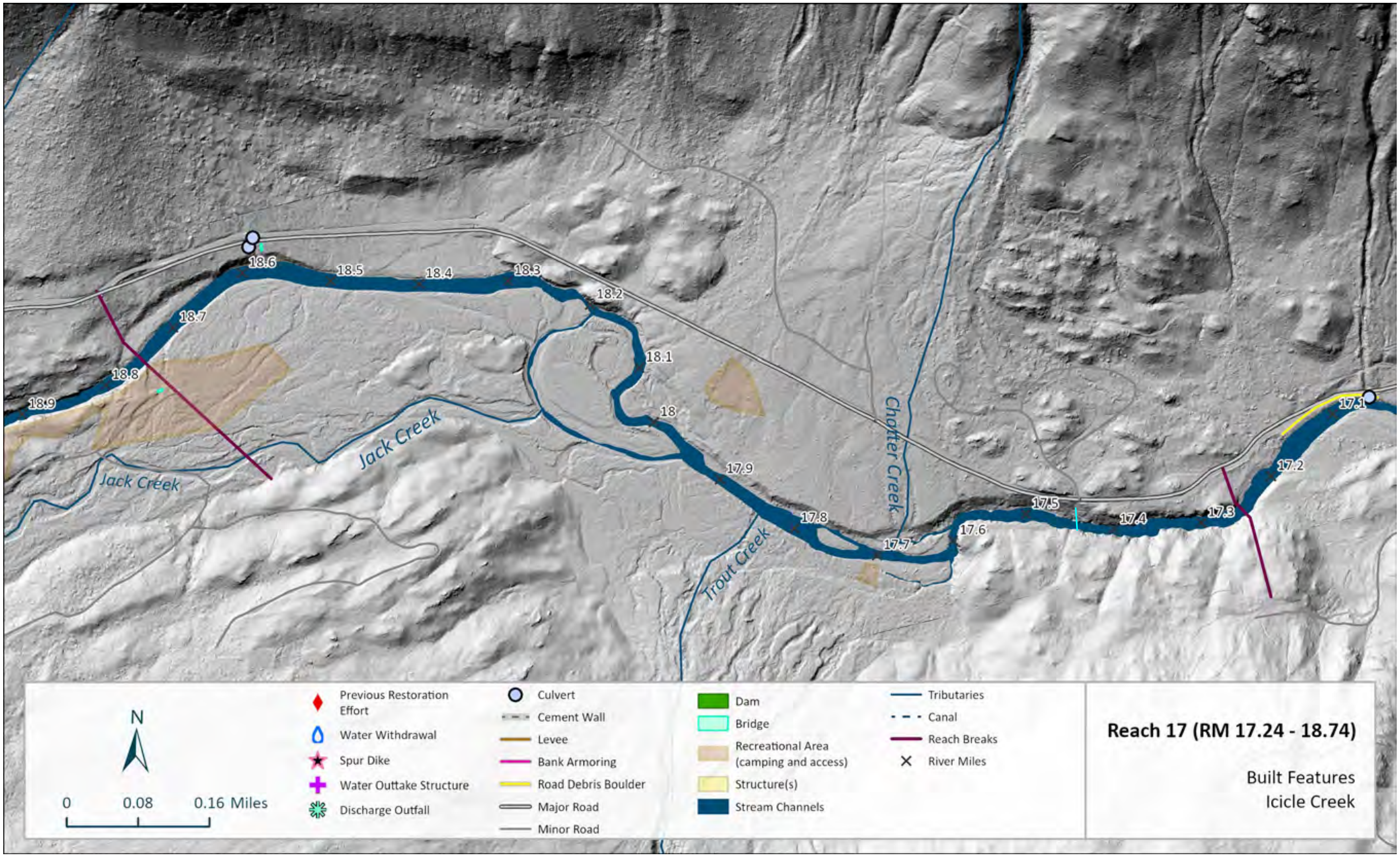

Figure 268. Reach 17: Mapped anthropogenic features (2024).

3.17.6 Recommended Actions

There are good restoration opportunities in the middle and upper portions of Reach 17, but nothing to do in the downstream canyon section below RM 17.6. Upstream of this, especially between RM 17.6 and 18.2, multiple bar apex jams would split flows and help create or maintain vegetated islands. Other complexity wood in pools would provide rearing cover. Upstream of RM 18.4 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 some areas in the reach, log jams could be used to drive bank erosion to recruit large riparian trees.

There is a prominent split-flow section around a vegetated island at RM 18-18.2. The right-bank side-channel could be loaded with wood for cover and complexity. There are a couple locations where side-channels could potentially be activated along the right-bank via mainstem wood and excavation.

The riparian zones are well-vegetated, but with some dense stands with significant understory and ladder fuels. Fuel management including thinning and prescribed burns may help to support and sustain mature fire-resistance riparian stands.

A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities).

3.18 REACH 18 (RM 18.74 – 19.18)

3.18.1 Overview

Reach 18 is 0.44 miles in length, occupying a bedrock-confined reach between RM 18.74-19.18. The National Forest Road 1609 bridge crosses the channel at the upstream end over “Rock Island.” The channel is confined with an average gradient of 1.54% (Figure 269). Except for split flow around the bedrock boulder island at the upstream end, the channel is single thread. The river-right hillsides host second-growth forests, but forest cover is naturally sparse on both sides due to growing conditions produced by thin soil-mantled bedrock. Anthropogenic impacts in the reach are limited to past logging and recreational uses such as campsites, trails, and swimming access. Reach 18 is located entirely within the Wenatchee National Forest.

Figure 269. Representative photo of Reach 18 at RM 18.87 (August 8, 2024).

3.18.2 Channel and Floodplain Geomorphology

Table 28. Reach 18 metrics.

Reach 18													
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
0.43	18.74-19.18	1.54%	1.01	Riffle	79	Confined	Cobble	29.9%	1.5%	61.9%	6.6%	0.0%

The channel in Reach 18 is single thread and confined. Channel type is boulder step-pool to boulder riffle-pool with one short glide. Bedrock and hillslope contacts along the channel's banks maintain channel form (Figure 271). Periodic bedrock exposures in the bed of the channel and colluvial boulder contributions from the hillslopes provide grade control to the reach (Figure 270). The boulders provide pockets of habitat complexity and refugia where they create localized hydraulic relief and pools. Encroaching debris fans off the river-left hillslopes dress the underlying bedrock strath terrace the channel has, over time, incised into its modern position of confinement. No identified tributaries contribute to Icicle Creek in Reach 18.

Figure 270. Bedrock confined channel at RM 19. (August 8, 2024)

Confinement and increased stream power result in basically no low floodplain (inundated ~1-5 yrs) surfaces in Reach 18. Medium floodplain (inundated ~5-20 yrs) surfaces occur occasionally as very narrow small pockets along the margin of the channel. High floodplain surfaces (20-100+yrs) are mapped where the channel has cut, including strath erosion, or deposited material on confining adjacent hillslopes (Figure 271). Most of the narrow valley floor is otherwise occupied by hillslope or bedrock terraces.

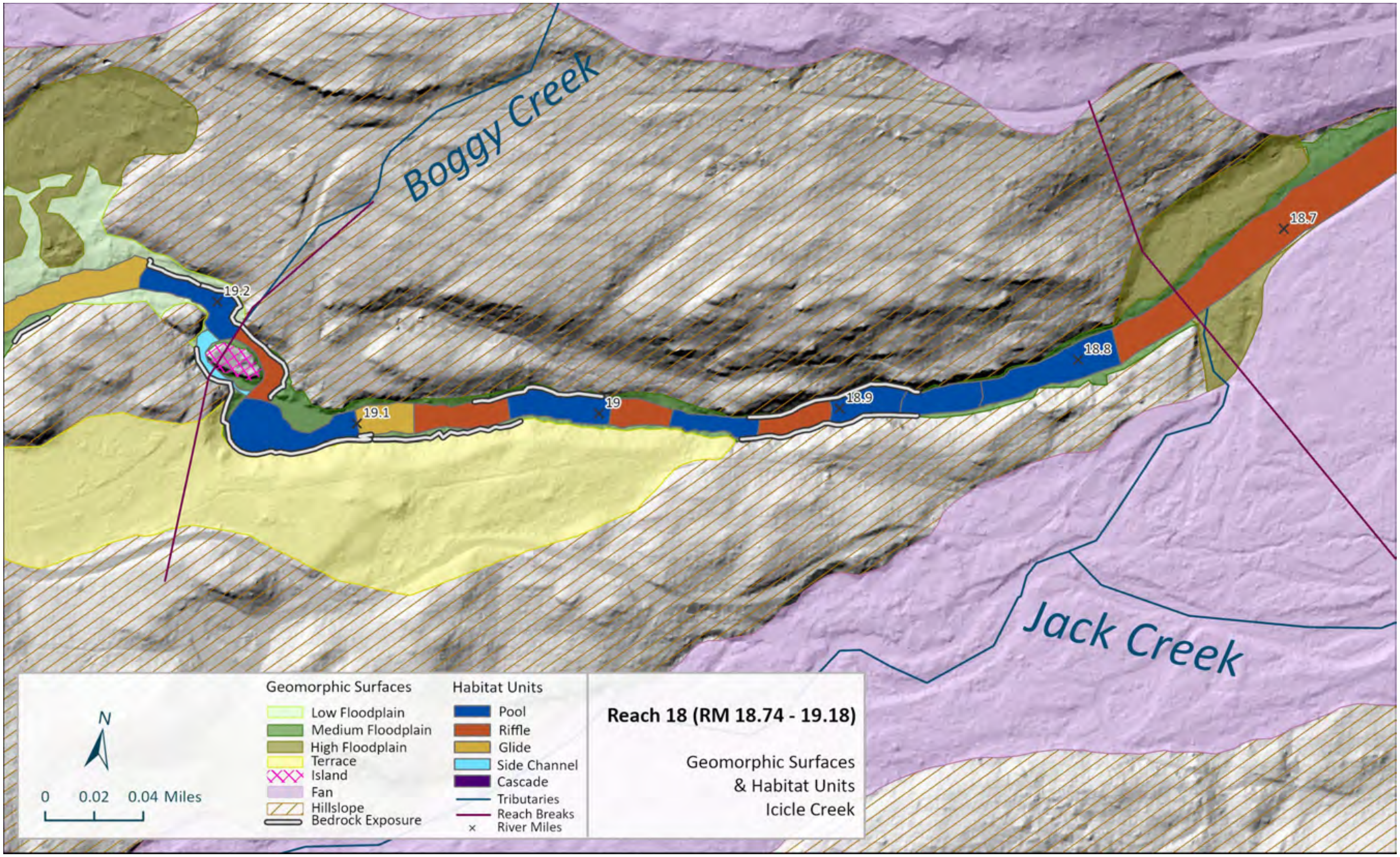

Figure 271. Reach 18: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

Substrate in Reach 18 is primarily composed of boulder and cobbles. Gravel and small cobbles collect at the margins or in proximity to large boulders that create zones of hydraulic relief (Figure 272). Colluvial contributions from the confining walls vary in size and composition, including very large boulders that are stable, even at large flood events. Sediment in Reach 18 is sourced from a combination of material imported via the channel from upstream reaches and locally contributed hillslope fan material or colluvium.

Figure 272. Boulder-cobble bedload in Reach 18 at ~ RM 19. (August 8, 2024)

No appropriate locations were identified in Reach 18 to complete a Wolman Pebble Count (Wolman, 1954)Incipient motion hydraulic analysis (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5) suggests that at the 2-year modeled discharge, the channel's shear stress is capable of mobilizing cobble through the entire reach, with potential to mobilize boulder-sized material between at the upstream end, where the channel funnels into confined reach (RM 19.18) and in a middle section near RM 18.9 (Figure 273). Reach 18 is considered a sediment transport reach.

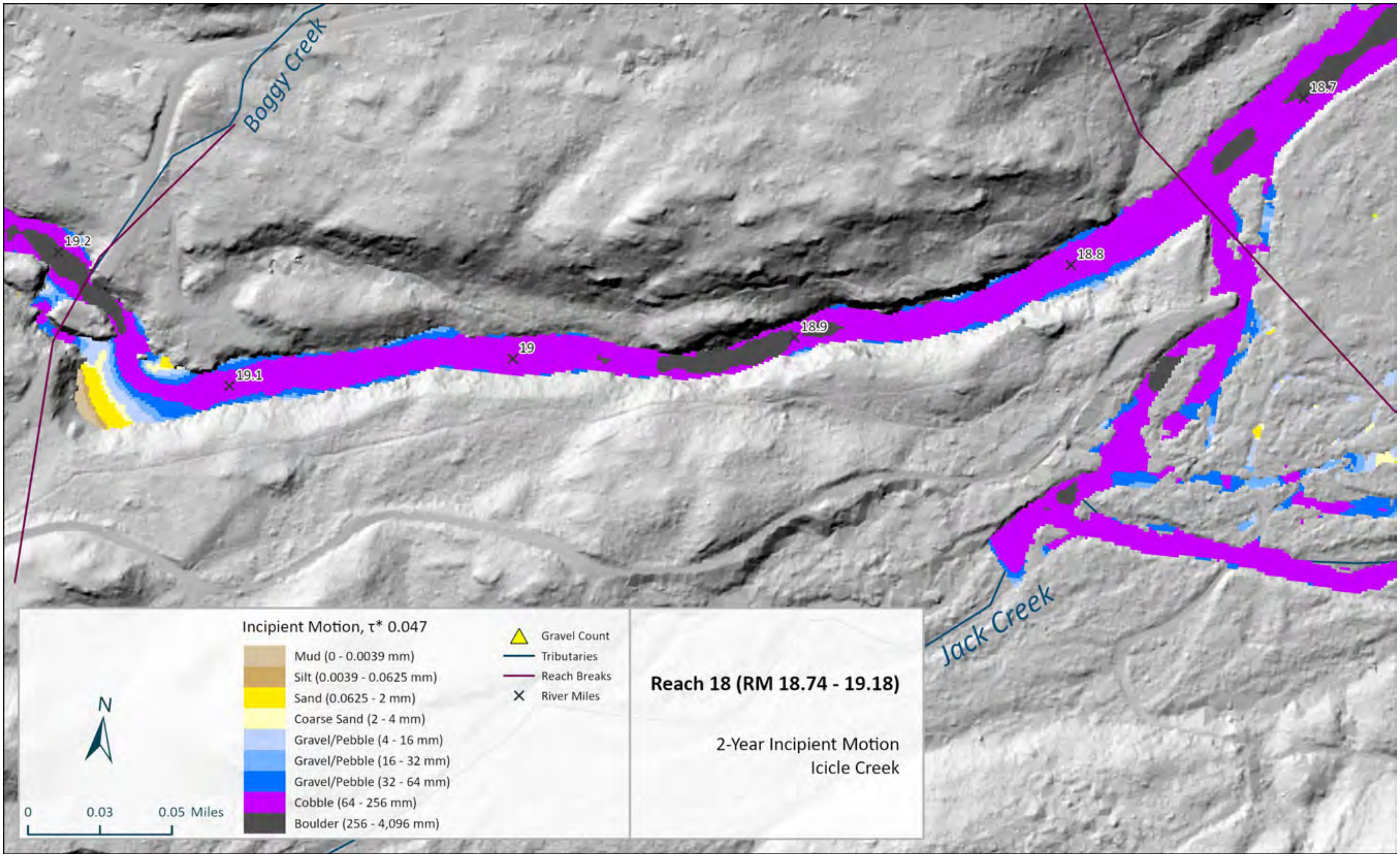

Figure 273. Reach 18 incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge).

Confinement and increased stream power result in basically no low floodplain (inundated ~1-5 yrs) surfaces in Reach 18. Medium floodplain (inundated ~5-20 yrs) surfaces occur occasionally as very narrow small pockets along the margin of the channel. High floodplain surfaces (20-100+yrs) are mapped where the channel has cut, including strath erosion, or deposited material on confining adjacent hillslopes (Figure 271). Most of the narrow valley floor is otherwise occupied by hillslope or bedrock terraces.

3.18.3 Large Wood Material

The habitat survey conducted in summer 2024 (Appendix A) recorded 93 individual pieces of large woody material (LWM) and 1 log jam (accumulation of >3 LWM) within the bankfull channel of Reach 18, combined for a total of 111 observed pieces (Figure 275). Of the 93 individual pieces; 40 are classified as large size class (>20-inches diameter and >35-feet long); 13 as medium size class (12 to 20-inches diameter and at least 35-feet long). Reach 18 has 144 pieces of wood per mile (count includes medium and large LWM as individuals and in jams), which does meet the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state (Fox & Bolton, 2007; Appendix A).

Most of this wood is located within the one "glide" habitat unit mapped in the reach near RM 18.88. The LWM that is present is mostly stored temporarily at the channel margins or atop boulders where it has limited interaction with the channel at normal flow conditions. The single log jam in Reach 18 is located in the side channel at the upstream end of the reach at RM 19.18 (Figure 274). The jam has multiple pieces of medium and large LWM. Large wood is ineffective at influencing geomorphic complexity in Reach 18.

Figure 274. Log jam in the side channel at RM 19.18. (August 8, 2024)

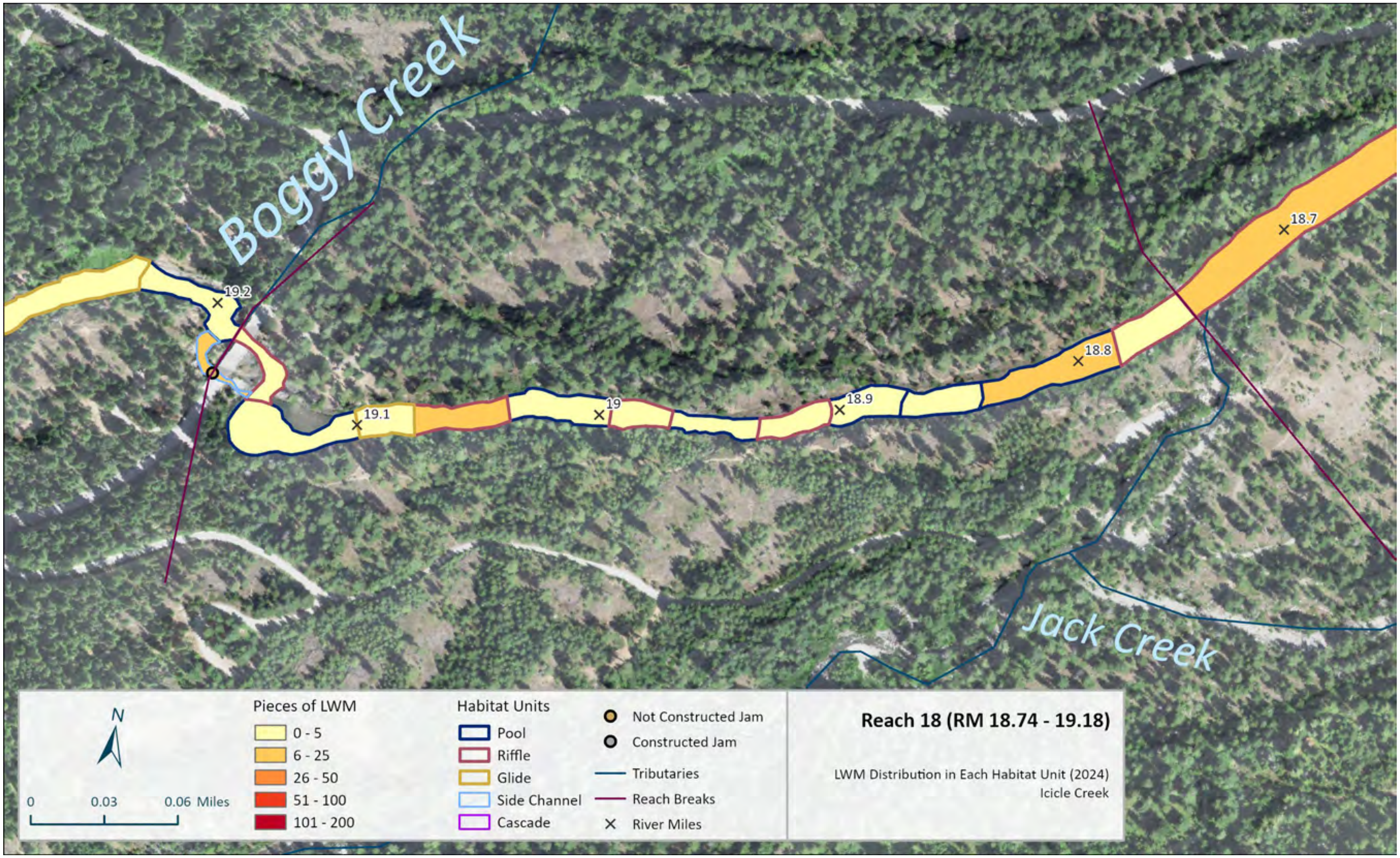

Figure 275. Reach 18: Large wood distribution (pieces per mile per habitat unit) map and surveyed habitat units (2024).

3.18.4 Vegetation

The riparian corridor in Reach 18 is narrow and represented as discontinuous strips where hillslope or side-margin deposits provide areas for vegetation to establish. Vegetation is relatively sparsely forested on the bedrock hillslopes confining the channel. The river-right (south) side appears to have had the forests harvested in the last 30 years. The trees on river-left (north) side are larger and more established but also second growth. Some clearing associated with recreational uses was observed during the surveys, primarily at the upstream end around the Rock Island Campground and access/dispersed camping areas across the river. The overstory, where it exists, is comprised of ponderosa pine, cedar, fir, and spruce. The understory is dominated by alder and willow, with lesser amounts of maple, dogwood, cottonwood, serviceberry, rose, and ceanothus. Large woody material recruitment to the channel occurs via natural tree fall of the hillslope or if a very large flood event extends further than usual up the confined banks to recruit vegetation. Even though the forests are smaller on the river-right (south) side of the channel, stream shading occurs as a result of the inset canyon and its aspect. Vegetation conditions in Reach 18 are represented in Figure 276.

Figure 276. Representative vegetative conditions in Reach 18, near RM 19.03 looking upstream. (August 2024)

The vegetation height analysis map (Figure 277) shows the variation in tree size between the river-left and river-right sides of the channel, as well as the relatively smaller size of the second growth forests in Reach 18 compared to the patches of larger trees upstream in Reach 19. The reduced forest density in Reach 18 compared to Reach 19 is also visible in the aerial shown in Figure 278.

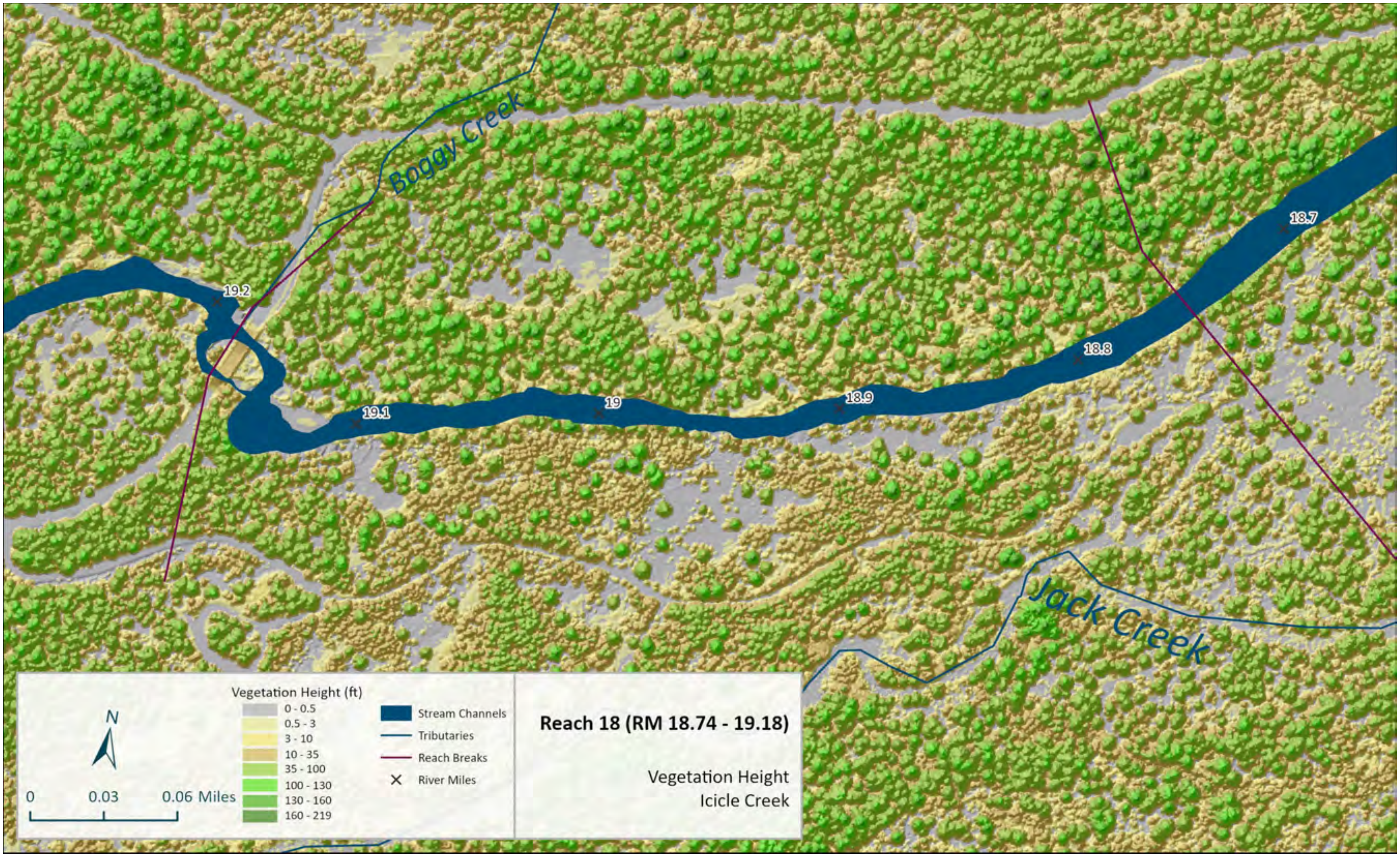

Figure 277. Reach 18: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 278. Reach 18: Map of aerial imagery for vegetation identification (ESRI 2023).

3.18.5 Human Alterations

Human alterations include the bridge at the upstream end, dispersed camping and trails, and past timber harvest. The alterations have a relatively minor impact on the channel due to the bedrock confinement. The bridge spans high above the channel and is anchored to bedrock (Figure 279). There is high recreation use and human alteration to vegetation associated with the Rock Island Campground on river-left and the Jack Trout Trailhead on river-right. A footbridge over lower Jack Creek is technically on the creek's fan within Reach 18, but the impacts it imposes on Jack Creek are related to contributions and processes at the downstream end of the fan in Reach 17. Past timber harvest and a recreational access trail on river-right have impacts to vegetation in this area, with reductions in stream shade and large wood inputs. A map of the anthropogenic features identified in Reach 18 is provided as Figure 280.

Figure 279. Concrete bridge (NFS Road 1609) at RM 19.18, upstream reach break. (August 15, 2024)

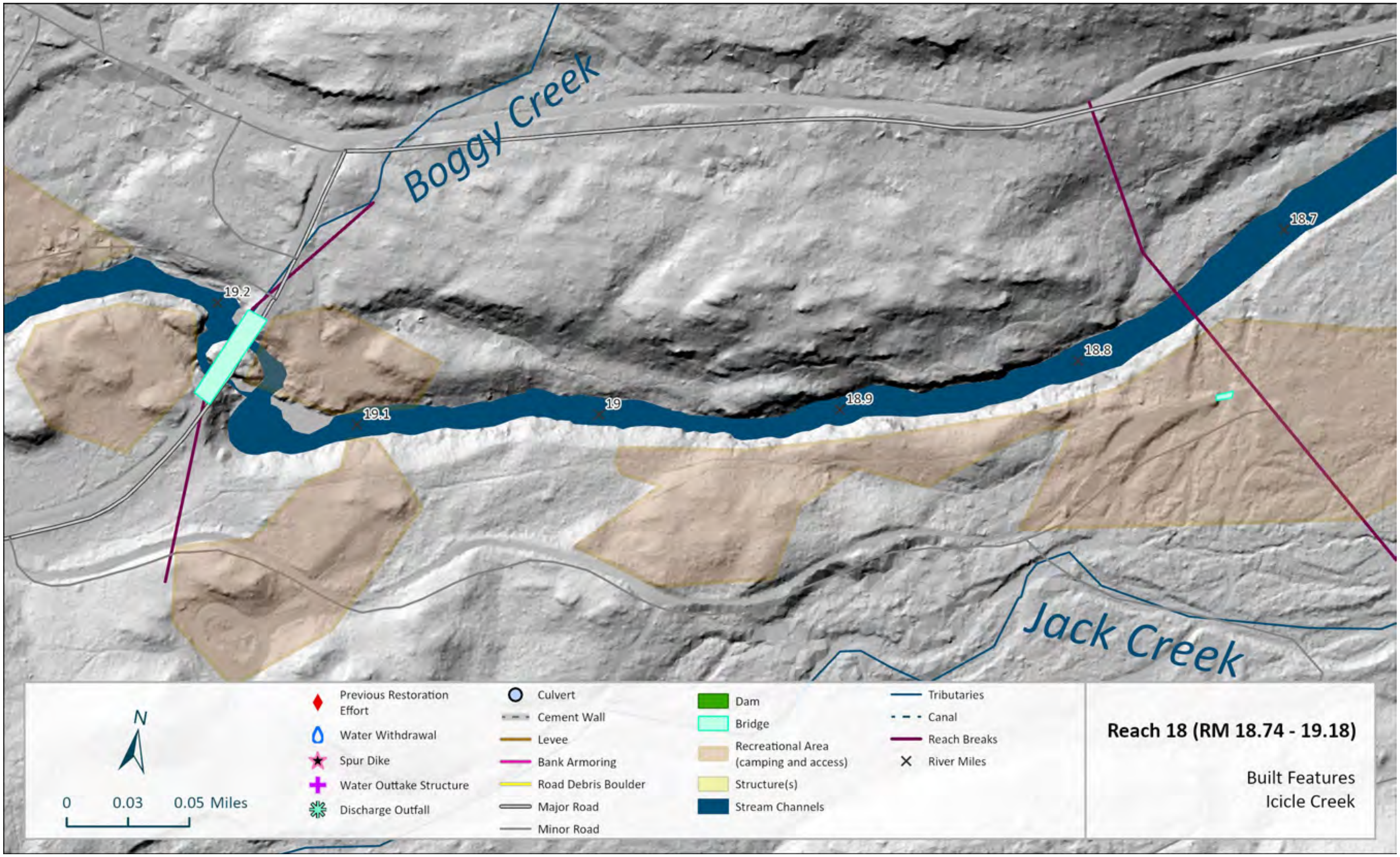

Figure 280. Reach 18: Mapped anthropogenic features (2024).

3.18.6 Recommended Actions

Reach 18 is a short, bedrock-confined reach with very little opportunity for in-channel restoration work. The riparian zone on the south (river-right) side has been impacted by past harvest and has not fully revegetated. Inter-planting conifers along the high bank would create more shade and large wood recruitment over the long term. A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities).

3.19 REACH 19 (RM 19.18 – 21.11)

3.19.1 Overview

Reach 19 is 1.93 miles long and extends from the Rock Island Bridge at RM 19.18 to RM 21.11 at the Black Pine Creek confluence (river-right). This reach has a moderate gradient of 0.33%, lower in gradient than Reach 18 downstream and Reach 20 upstream. It is considered an unconfined reach with a channel sinuosity of 1.18. The channel type is pool-riffle throughout, with a few split flow sections and gravel-cobble bars (Figure 281). Alluvial and debris fans influence channel form through the reach and contribute sediment to the reach. Anthropogenic impacts are limited and associated with historical logging impacts and modern recreational uses that include access roads. Reach 19 is located entirely within the Wenatchee National Forest.

Figure 281. Representative photo of Reach 19 at RM 19.33 (August 8, 2024).

3.19.2 Channel and Floodplain Geomorphology

Table 29. Reach 19 metrics.

Reach 19												
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
1.94	19.18-21.11	0.33%	1.18	Pool	82	Unconfined	Gravel	64.0%	15.5%	12.2%	8.3%	0.0%

Icicle Creek in Reach 19 is considered unconfined. The channel is of moderate gradient and moderate sinuosity (Figure 283). In addition to debris and alluvial fan contributions to the valley floor, bedrock contacts on alternating sides of the valley floor influence channel location to produce an often valley-spanning meander form. Split flow conditions produce side channels around islands that provide geomorphic complexity at RM 19.9, 20.28, and 21. A substantial alcove connected to the channel on river left at RM 20.89 receives groundwater-initiated contributions from the upstream floodplain. Hyporheic processes were also observed at the downstream end of bars. Channel type is pool-riffle glide with irregular distribution of pools and extended glides in straight less complex sections of the reach.

Black Pine Creek is the primary contributing tributary to the reach where it meets the channel at the upstream reach boundary. Smaller, but also perennial, Boggy Creek enters on river-left at RM 19.18. Five additional unnamed ephemeral tributaries enter the Icicle Creek at RM 19.80, at RM 20.18, at RM 20.90, and at RM 21.01, on river-left, and at RM 20.70 on river-right.

Geomorphic and habitat complexity varies in Reach 19. Floodplain connectivity, maintained scour pools, and active bar maintenance are associated with the presence of large wood accumulations and active lateral channel migration. Lateral processes produce both wood recruitment and sediment to the channel. The potential to increase channel complexity and function in Reach 19 is high. Low floodplain (inundated ~1-5 yrs) and medium floodplain (inundated ~5-20 yrs) surfaces occupy a good portion of available valley floor not otherwise occupied by fan toes. The wide floodplains provided increased ecological functions and diversity, including evidence of active beaver use. High floodplain surfaces (inundated ~20-100+ yrs) edge the medium and low floodplains with minimal contact points along the channel. Floodplains are composed of cobble, gravel, and sand topped with developing soils (Figure 282). The floodplains are mapped in the geomorphic surfaces map in Figure 283.

Figure 282. Flood plain: gravel, cobble, and sand with loam soil on river right at RM 19.53. (August 7, 2024)

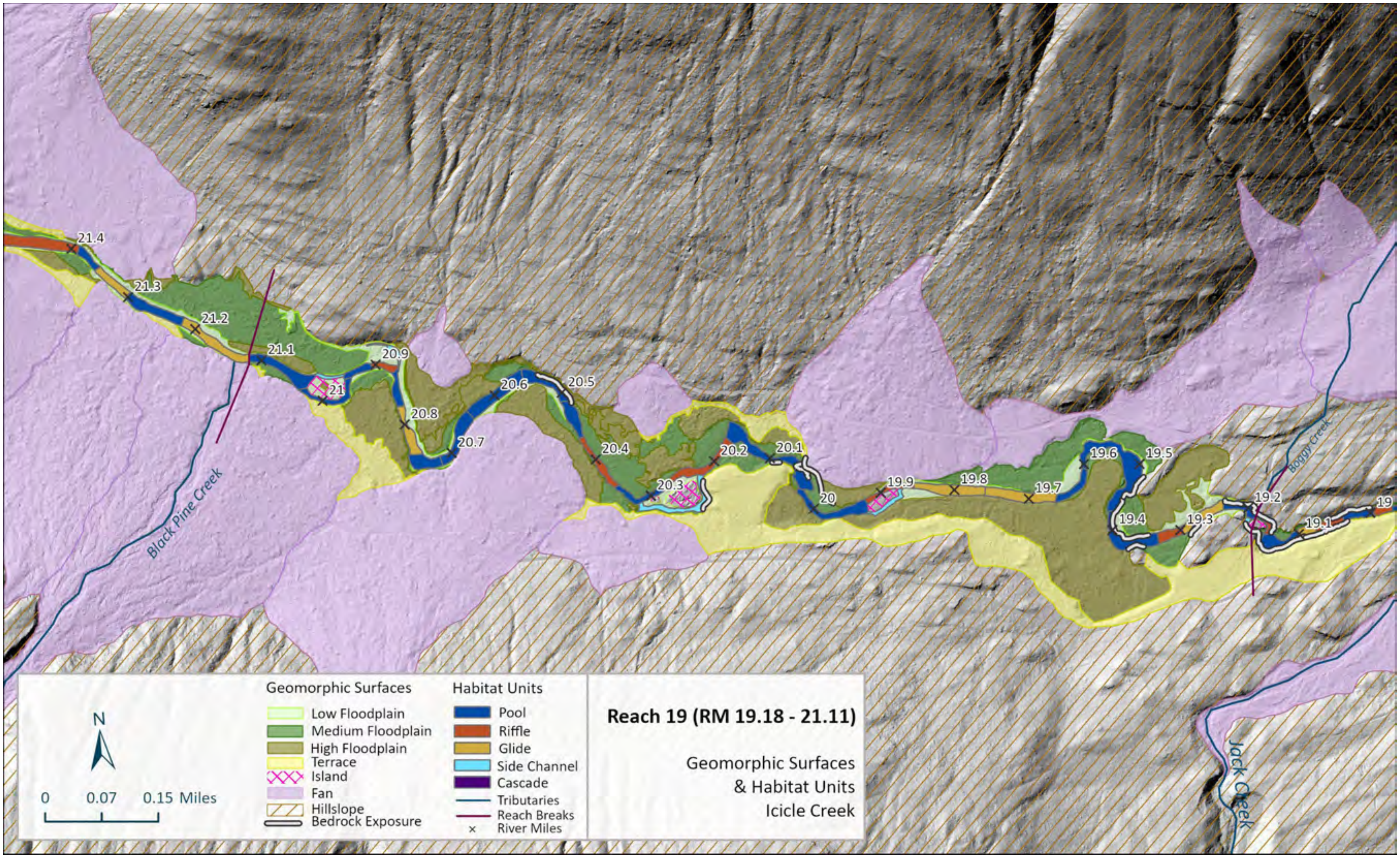

Figure 283. Reach 19: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

Channel substrate in Reach 19 is primarily gravel and cobble. Point bars are located on the insides of all meander bends. Cobble composes the dominant bedload through the riffles and glides but gravel is dominant on the bars (Figure 284). Sand was notes accumulating in pockets of reduced hydraulics such as pool tail-outs behind boulders or backwater features.

Figure 284. Example of representative bar composition, at RM 19.42. (August 7, 2024)

Three Wolman Pebble Counts (Wolman, 1954) were conducted on riffle crests that extended across the upstream portion of point bars. The median grain size (D50) at GC 03 at RM 20.81 was 63mm; at GC 04 at RM 20.11 was 57mm; and at GC 05 at RM 19.65 was 57mm. The pebble count data are included in Figure 285 of the Reach 19 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5). The analysis indicates that at the 2-year modeled discharge, the channel's shear stress is diverse, representing a pool-riffle-glide channel type (cobble to gravel) with active bar maintenance. Small gravels and sands are activated from channel margins, bar tops, and off-channel areas.

Sediment in Reach 19 is sourced from a combination of material imported via the channel from upstream reaches and tributaries as well as locally generated material temporarily stored in floodplains or bars. Adjacent hillslopes, bedrock banks, debris fans, and terraces provide mixed grain-size material, including large boulders and colluvium that, when large enough, are relatively stable in the channel and thus able to produce localized complexity.

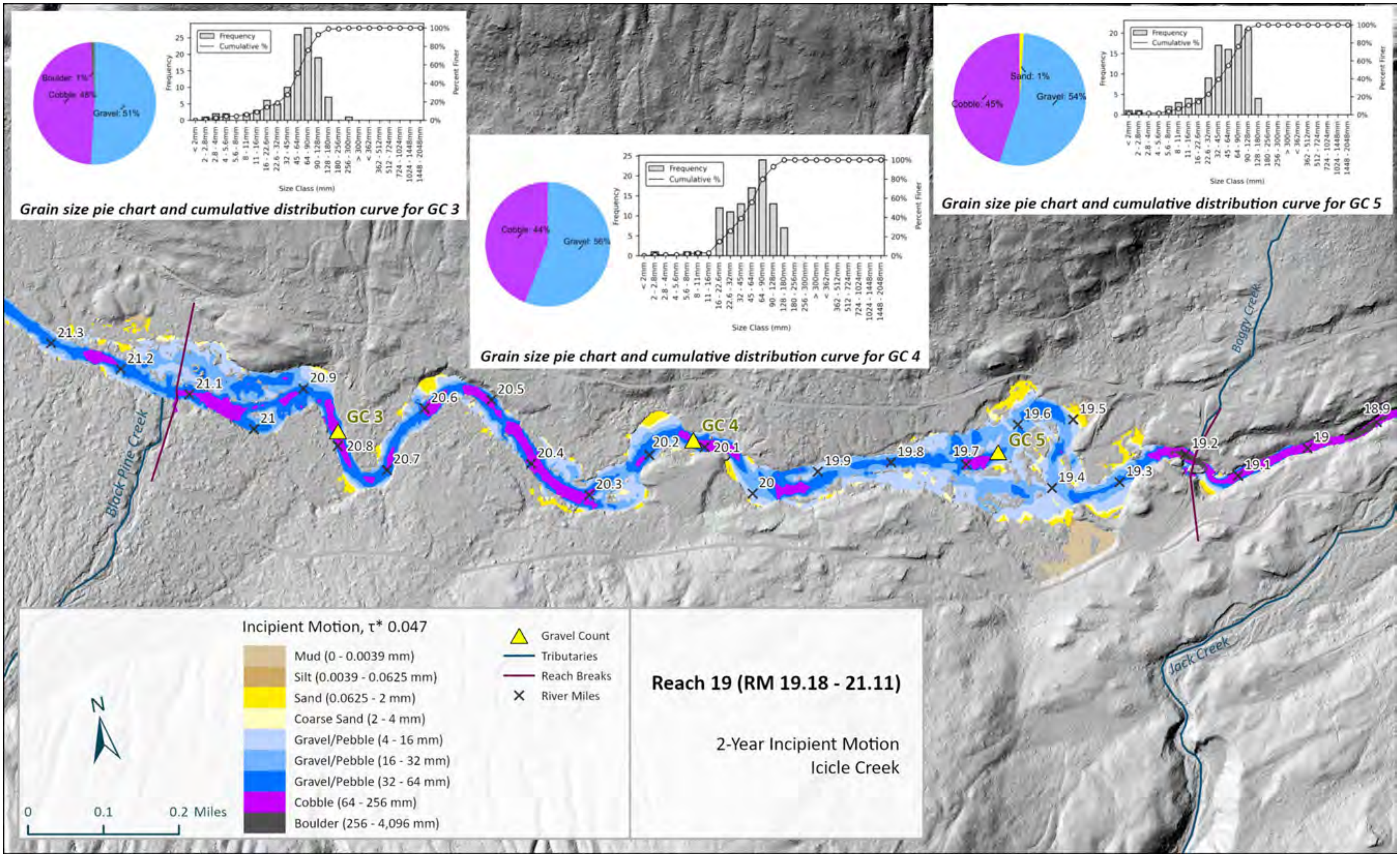

Figure 285. Reach 19: incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge). Includes location and grains size data of the GC 3, GC 4, and GC 5 pebble counts.

3.19.3 Large Wood Material

The habitat survey conducted in summer 2024 (Appendix A) recorded 137 individual pieces of large woody material (LWM) and 22 log jams (accumulation of >3 LWM) within the bankfull channel, combined for a total of 413 observed pieces (Figure 286). Of the 137 individual pieces; 23 are classified as large size class (>20-inches diameter and >35-feet long); and 55 as medium size class (12 to 20-inches diameter and at least 35-feet long). Reach 19 had 127 pieces of medium or large wood per mile (count includes medium and large LWM as individuals and in jams), which meets the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state (Fox & Bolton, 2007; Appendix A). The key pieces of LWM that provide stability to jams in Reach 19 were observed to have a diameter (dbh) of at least 20-inches. All 22 log jams in Reach 19 have multiple pieces of medium and large LWM. The jams were effective at influencing the channel complexity and performing as habitat forming structures. Reach 19 contains the second highest quantities of large wood counted in the 2024 survey, compared to other reaches in the assessment area, with 413 total pieces – combining individual logs and those that form log jams.

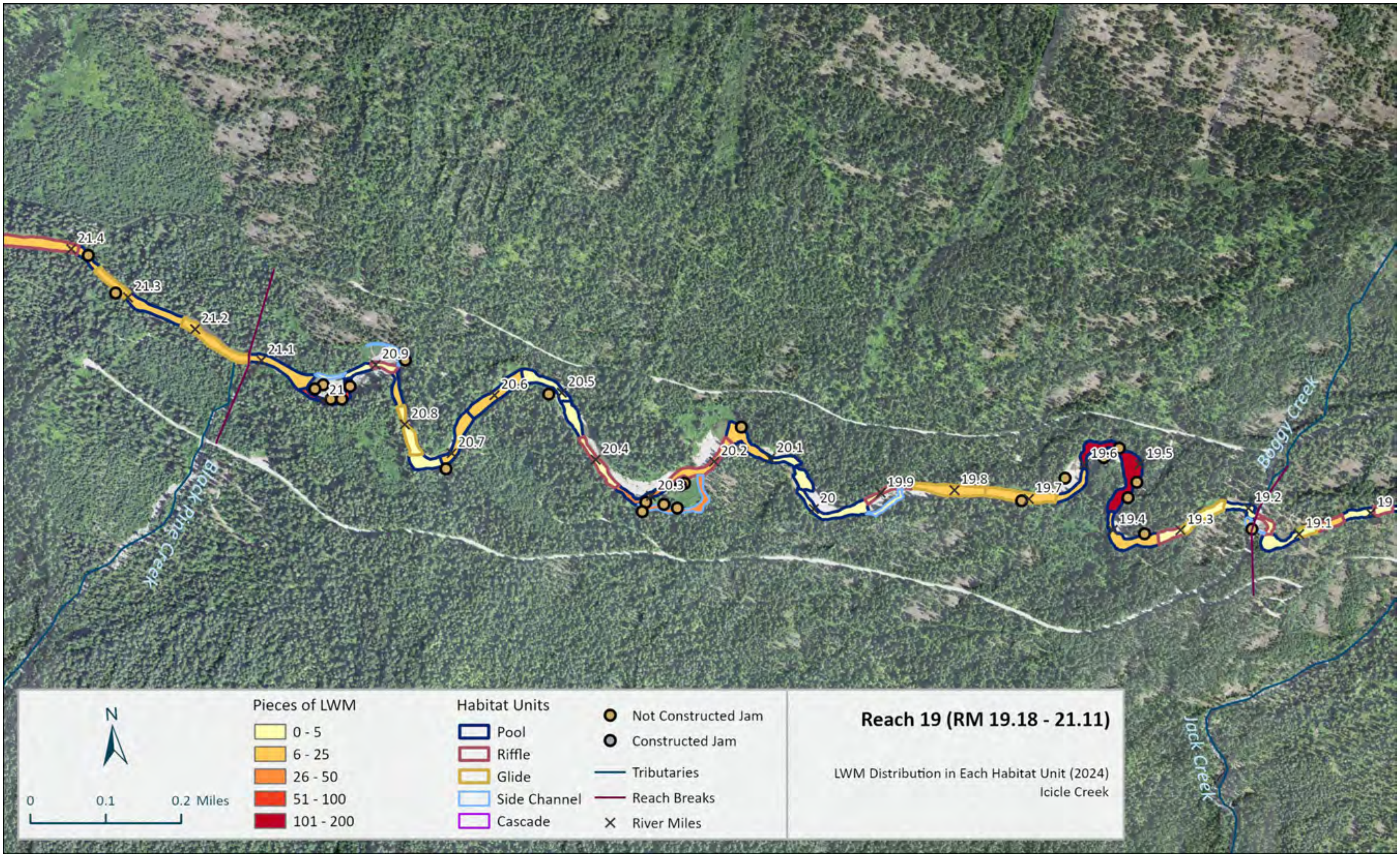

Figure 286. Reach 19: Large wood distribution (pieces per mile per habitat unit) map and surveyed habitat units (2024)..

Effective large wood in Reach 19 generates and maintains pool scour, as well as sediment deposition and sorting (Figure 287). The LWM in Reach 19 is recruited from the adjacent floodplain surfaces and occasionally where hillslope or fans contact the channel. Current wood recruitment is obtained through lateral bank erosion and thus density of wood in the channel is highest where lateral processes are or were currently active. Where large wood is present, channel complexity is greater, including side channels and scour pools, and floodplain connectivity and surface area is greatest. Despite the presence of large wood throughout Reach 19, some log accumulations do not contain key logs or bank attachment. These loosely positioned jams are considered temporary and are expected to mobilize during higher flow events.

Figure 287. Channel spanning large wood jam at RM 19.55. (August 8, 2024)

3.19.4 Vegetation

Vegetation on low floodplains and bars in Reach 19 is commonly dominated by dogwood, alder, vine maple, and willow. The bars are capable of recolonizing when disturbance is limited with sedges, rushes, and willow. The overstory is dominated by large and matures trees including Douglas fir, grand fir, cedar, and spruce (Figure 288). The high floodplain and terrace (fan) surfaces host conifer forests. The riparian and floodplain vegetation are mature and established in Reach 19. Anthropogenic impacts are limited to clearing related to formal and dispersed camping areas, trails, and access roads. Most of these impacts occur at the downstream end of the reach near the Rock Island Campground.

Figure 288. Representative floodplain and bar vegetation in Reach 19, at RM 19.55 (August 7, 2024).

There is relatively high potential for future large wood recruitment by the channel due to plentiful mature trees on floodplains where lateral channel processes are occurring. The vegetation height analysis map (Figure 289) classifies large overstory trees adjacent to the channel throughout a majority of the reach. The distribution of large tree overstory is also visible in the aerial image of Reach 19 (Figure 290). In addition to being a source for large wood recruitment, the existing vegetation provides shade and nutrients to the channel.

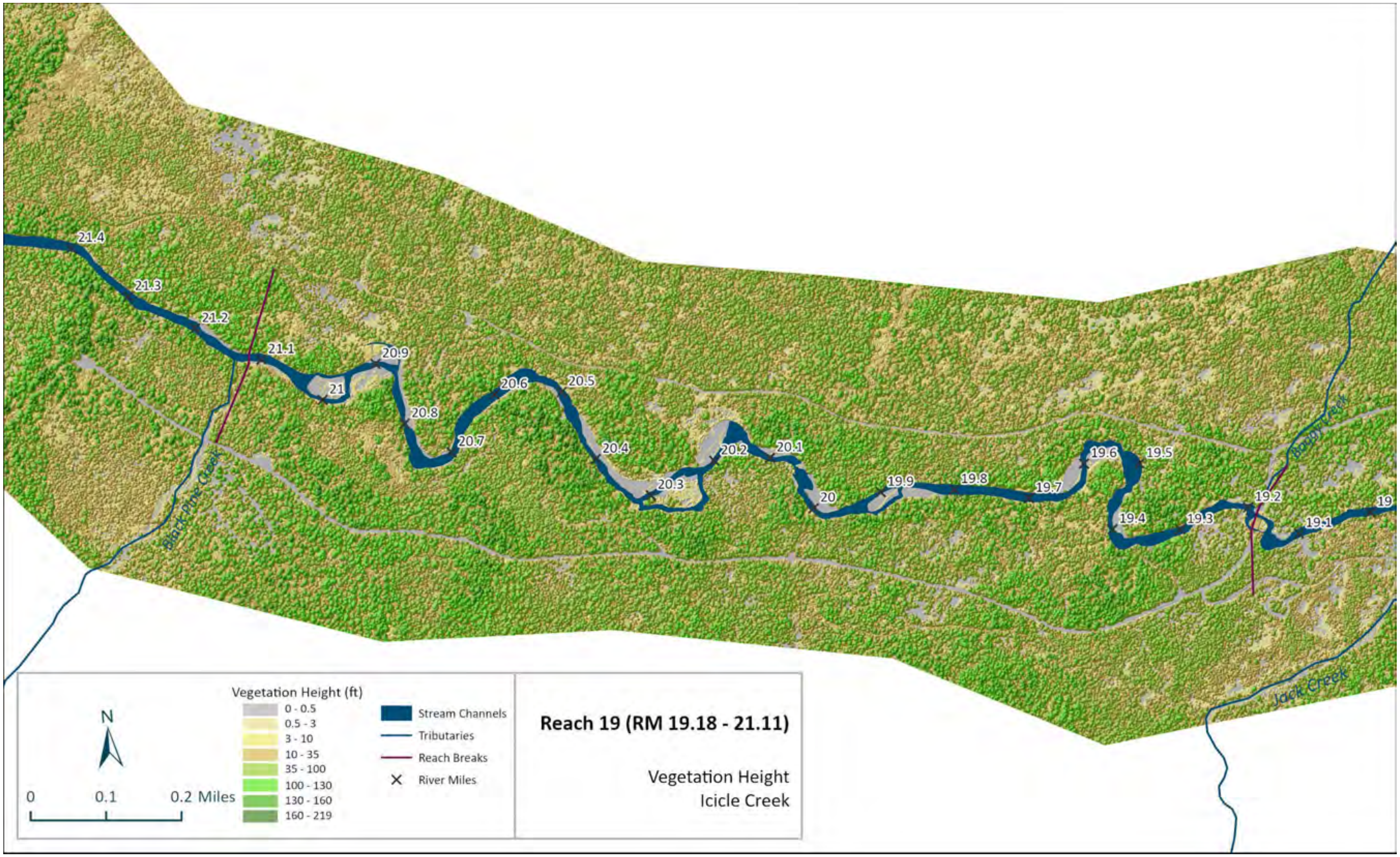

Figure 289. Reach 19: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 290. Reach 19: Map of aerial imagery for vegetation identification (ESRI 2023).

3.19.5 Human Alterations

Human alterations in Reach 19 are relatively few and have a minor impact on reach function. The bridge at the downstream end has minor impact on the channel due to the natural bedrock confinement. Camping and dispersed recreational use at the downstream end, on both side of the creek, have minor impacts to riparian vegetation. There are several other dispersed campsites in the floodplain, which have caused limited vegetation disturbance along the channel; including at RM, 20.28, 20.35, 20.49, 20.69, and 20.85) (e.g. Figure 291). There are gravel and dirt roads and trails connecting these campgrounds to the two roads which run parallel to Icicle Creek on both river-left (Grindstone Forest Service 7609 Rd) and river-right (Icicle Creek Road - FR 7600), which also have impacts on vegetation. There are two culverts along NF 7600 Rd located at RM 20.9 and 20.72 which are likely inadequate to convey large floods or debris flows. Past logging in isolated areas affects stand age and riparian tree heights in some areas. A map of the anthropogenic features is provided in Figure 292.

Figure 291. Cleared access road and campground at RM 20.3 (August 2024).

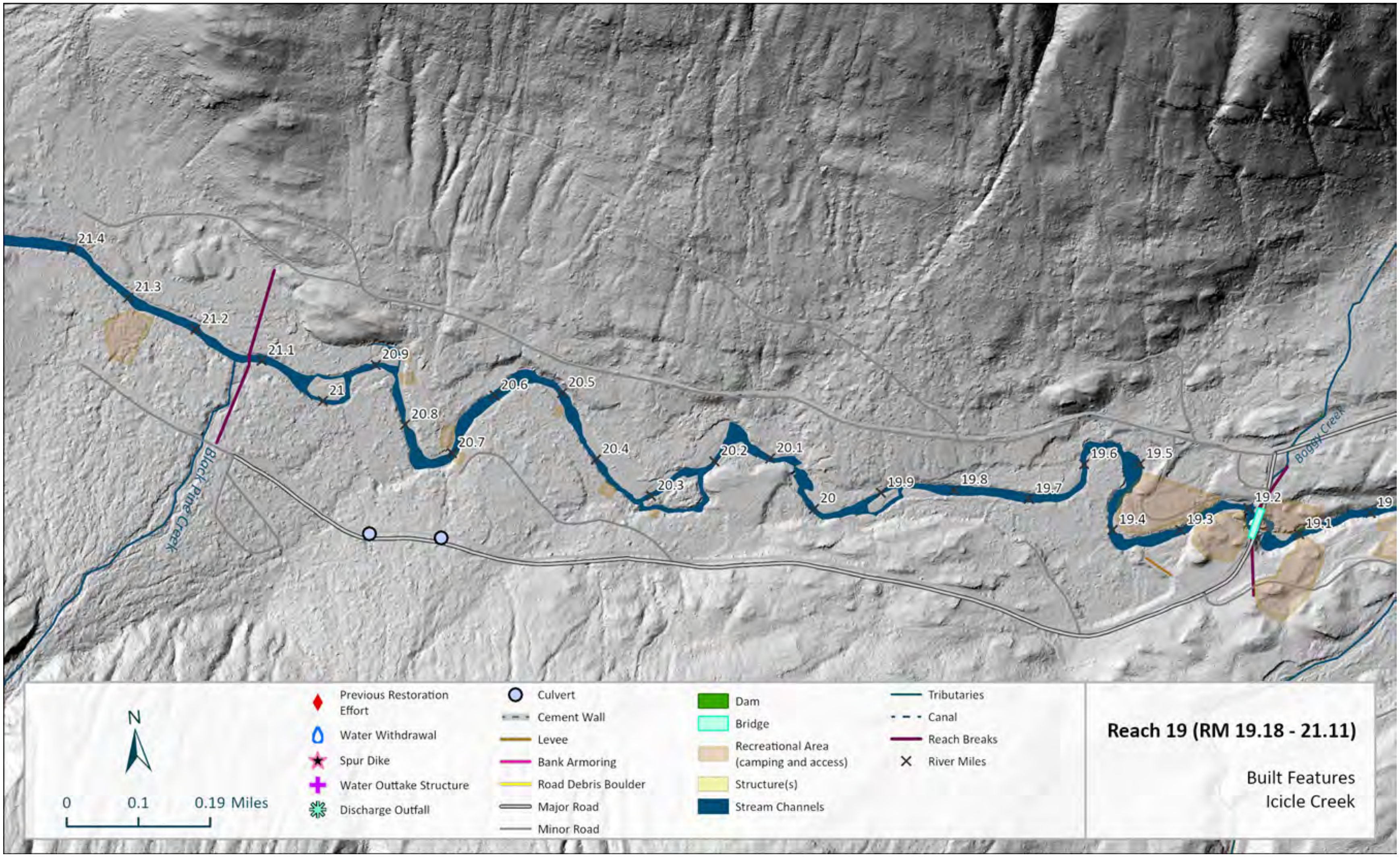

Figure 292. Reach 19: Mapped anthropogenic features.

3.19.6 Recommended Actions

Reach 19 is relatively well-functioning. However, there are nevertheless beneficial restoration actions that would work with the existing conditions to provide meaningful habitat improvements. The primary recommended treatment includes bar apex jams to split flows and help create or maintain vegetated islands. Other complexity wood in pools and along margins would enhance rearing cover and velocity refuge. In some areas in the reach, log jams could be used to drive bank erosion to recruit large riparian trees. There are a couple of locations where wood and excavation could be used to enhance side-channel and floodplain connectivity. Access can be obtained from roads on both sides of the channel.

The riparian zones are well-vegetated, but with some dense stands with significant understory and ladder fuels. Fuel management including thinning and prescribed burns may help to support and sustain mature fire-resistance riparian stands.

A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities).

3.20 REACH 20 (RM 21.11 -22.02)

3.20.1 Overview

Reach 20 is 0.92 miles long and extends from RM 21.11 to the upstream end of the assessment area at RM 22.02. This reach has a moderate gradient of 0.5%, and a sinuosity of 1.15. The dominant morphology is single-thread and unconfined (Figure 293). The average bankfull width for Reach 20 is estimated to be approximately 86 feet (estimated using 2023 NAIP following the Habitat Assessment). Most of the floodplain surfaces in the valley are mapped as high floodplains. Vegetation on the low floodplain surfaces typically consists of dogwood, willow, cedar, and alder. The higher floodplain surfaces are vegetated with coniferous tree species, predominantly ponderosa pine. Human alterations to the channel and floodplain in Reach 20 primarily include road development, historical logging impacts, and modern recreational uses.

Figure 293. Representative photo of Reach 20 at RM 21.5 (August 6, 2024).

3.20.2 Channel and Floodplain Geomorphology

Table 30. Reach 20 metrics.

Reach 20												
Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
0.9	21.11-22.02	0.5%	1.15	Pool	86	Partially Confined	Cobble	16.4%	18.1%	65.4%	0	0

The channel in Reach 20 is of low-moderate gradient and low sinuosity. Planform is single thread with a subtle meander that is organized around debris and tributary fan contributions to the valley floor that partially confine the channel (Figure 294). Inset below the fan surfaces are bands of floodplains (low-medium-high) created by the channel reworking and adjusting in response to what are likely episodic sediment contributions received from the fans. The modern channel shifts from riffle-pool in the upstream section of the reach to glide-pool in the downstream section. The riffles are long (extended) and alternate with short pool sections. The Habitat Assessment (See Appendix A) recorded 65.4% of the channel's habitat unit type as riffle, 18.1% as glide, and just 16.4% as pool. No side channels or attached off-channel habitat unit types were identified during the survey. Black

Pine Creek is a major tributary to Icicle Creek. It currently meets the channel on river right at the downstream reach boundary (RM 21.11) after flowing across its alluvial fan. Three additional unnamed intermittent tributaries seasonally discharge to Icicle Creek at RM 21.31, at RM 21.71, and at RM 21.95 in the Spring.

The channel in Reach 20 currently has limited geomorphic complexity except in the few locations where effective large wood occurs, near RM 21.3 and 21.4. The lack of complexity is due to a lack of channel-influencing large wood and potentially a relatively modern reduction of sediment inputs sourced from upstream and the fans. Simplification includes a trend toward gradually reduced floodplain connectivity. Subtle sequences of scrolls on medium and high floodplain surfaces suggest periods of lateral migration and floodplain development, historically. However, review of historical aerial imagery indicates that the location of the channel has changed very little since 1957 (the earliest photo-set available).

Low floodplain (inundated ~1-5 yrs) and medium floodplain (inundated ~5-20 yrs) surfaces occur as layered narrow bands along the channel. A wide functional medium-class floodplain does occur on river left downstream of RM 21.3, correlating to the presence of the channel spanning log structures at its upstream end. A wide high floodplain (inundated ~20-100+ yrs) surface at the upstream end and narrow strips at the back side of the low and medium floodplain surfaces indicate the current trend of gradual reduced floodplain connectivity through incision. Floodplains are composed of cobble and gravely sand topped with developing soils. The floodplains are mapped in the geomorphic surfaces map in (Figure 294). Debris and alluvial fan deposits have mixed compositions that often include boulder-sized material as well as fines and debris. When a fan deposit extends across the valley floor, the channel is forced to go over or around it in response. Reach 20 reveals a channel that has likely eroded multiple times through episodic fan contributions to readjust its gradient and channel form.

The primary source of bedload material in Reach 20 is a combination of material imported from upstream as well as episodic or periodic fan deposits and reactivation of temporarily stored bar material. Lateral bank erosion is currently a minor sediment source, more functional in the downstream portion of the reach. Lateral processes are currently related mostly to channel widening. Debris fan contributions at bank contact points are mixed in size, including angular boulders that are likely mobilized infrequently

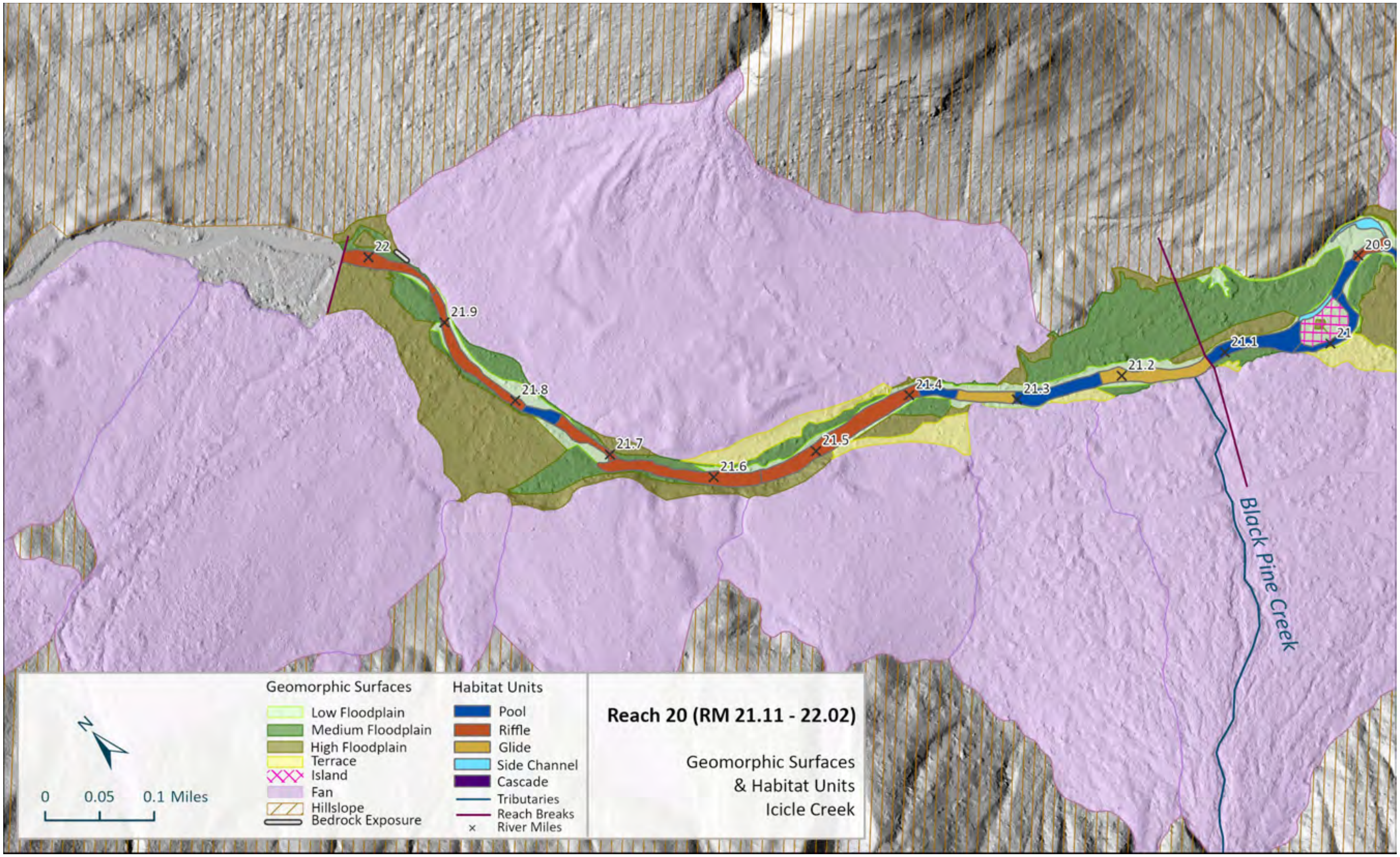

Figure 294. Reach 20: Geomorphic surfaces and habitat units map. Habitat units were mapped as part of the stream habitat survey. Surfaces were mapped as part of the geomorphology survey and with reference to field observations, LiDAR, aerial photos, relative elevation mapping, and hydraulic model results. Mapped alluvial fans from the Alluvial Fan Inventory of Chelan County, WA (Mickelson et al. 2024) were also used, with modifications based on the survey and other information from this assessment.

Although the reach is low-moderate gradient, it appears to currently be functioning as a transport reach. Gravel retention in the channel and as bars was observed only where effective channel-spanning large wood jams occur and occasionally in small pockets behind large boulders. Besides the few bar accumulations related to the two spanning log jams, bar development is limited to lateral cobble bars with small boulders and gravels that periodically occur along the channel margins (Figure 295).

Figure 295. Bar surface composition at RM 21.90 (August 6, 2024).

Two Wolman Pebble Counts (Wolman, 1954) were conducted in Reach 20. One gravel count was completed at a riffle crest at RM 21.4 (GC 2) and the other at a riffle and bar crest at RM 21.73 (GC 1). The median grain size (D50) at both GC 1 and GC 2 was 80mm (cobble). Additional ocular observations recorded throughout the reach confirm that bedload and bar sediment composition are dominated by cobbles, with smaller fractions of gravel, coarse sand, and boulders. The pebble count data are included in Figure 296 of the Reach 20 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.8.5). The analysis indicates that at the 2-year modeled discharge, the channel's shear stress is expected to be capable of mobilizing material cobble-sized or smaller from RM 22 – 21.45, in a homogenous pattern that further confirms channel simplification. Downstream of 21.45, where the first gravel and large wood accumulations occur even though channel gradient remain consistent, the 2-yr modeled shear stress reduces transport capacity primarily to coarse gravels with increased floodplain connectivity. Providing an analog of uplift potential in Reach 20 if additional effective large wood was contributed to the channel.

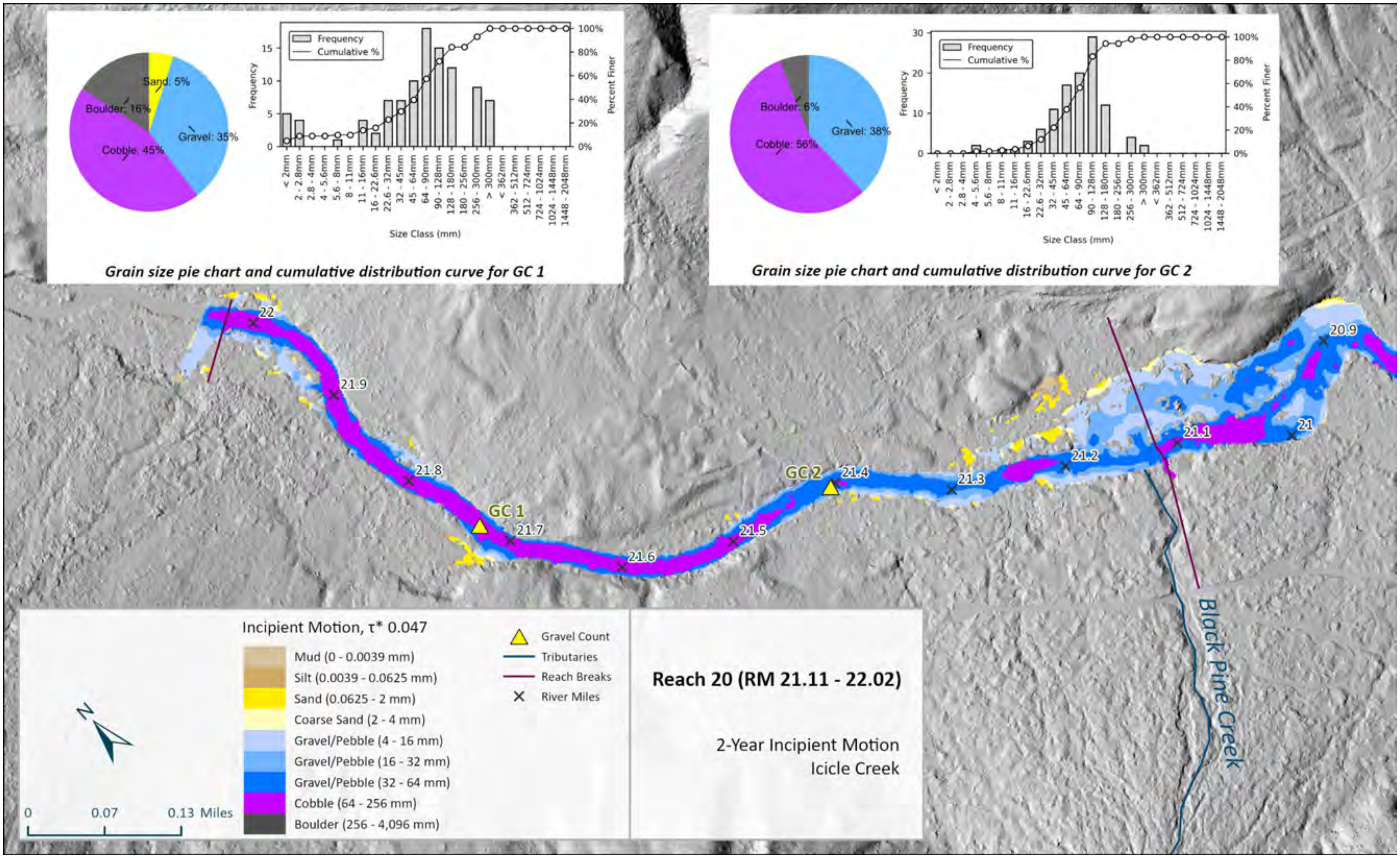

Figure 296. Reach 20: incipient motion analysis results map (estimated grains size mobility at the 2-year modeled discharge). Includes location and grains size data of the GC 1 and GC 2 pebble counts.

3.20.3 Large Wood Material

The habitat survey conducted in summer 2024 recorded 79 individual pieces of large woody material (LWM) and 3 log jams (accumulation of >3 LWM) within the bankfull channel, combined for a total of 100 observed pieces (Figure 298). Of the 79 individual pieces; 13 were classified as large-size class (>20-inches diameter and >35-feet long); and 46 as medium size class (12 to 20-inches diameter and at least 35-feet long). Reach 20 had 111 pieces of medium or large wood per mile (count includes medium and large LWM as individuals and in jams), which meets the 75th percentile value of 67.45 pieces per mile for unmanaged eastside streams in Washington state (Fox & Bolton, 2007; Appendix A). However, the key pieces of LWM that provide stability to jams in Reach 20 were observed to have a diameter (dhb) of at least 24-inches (large-sized). The three log jams in Reach 20 have multiple pieces of medium and large LWM in addition to key logs and were effectively influencing localized channel complexity and acting as habitat forming structures. The remainder of the LWM in the reach was positioned along the margins and banks, imposing minor localized complexity.

Effective LWM in Reach 20 generates local pool scour as well as sediment deposition and sorting, and support floodplain connectivity (Figure 298). The LWM in Reach 20 is recruited from the adjacent floodplain and fan terrace surfaces. The forested adjacent surfaces provide good future large wood recruitment potential, if lateral processes are instigated, including pockets of old-growth forest with sufficiently sized trees to act as key-logs in jams.

Figure 297. Channel-spanning LWM jam in Reach 20 at RM 21.4 with >24" dbh key logs effectively influencing and maintaining geomorphic complexity. (August 6, 2024)

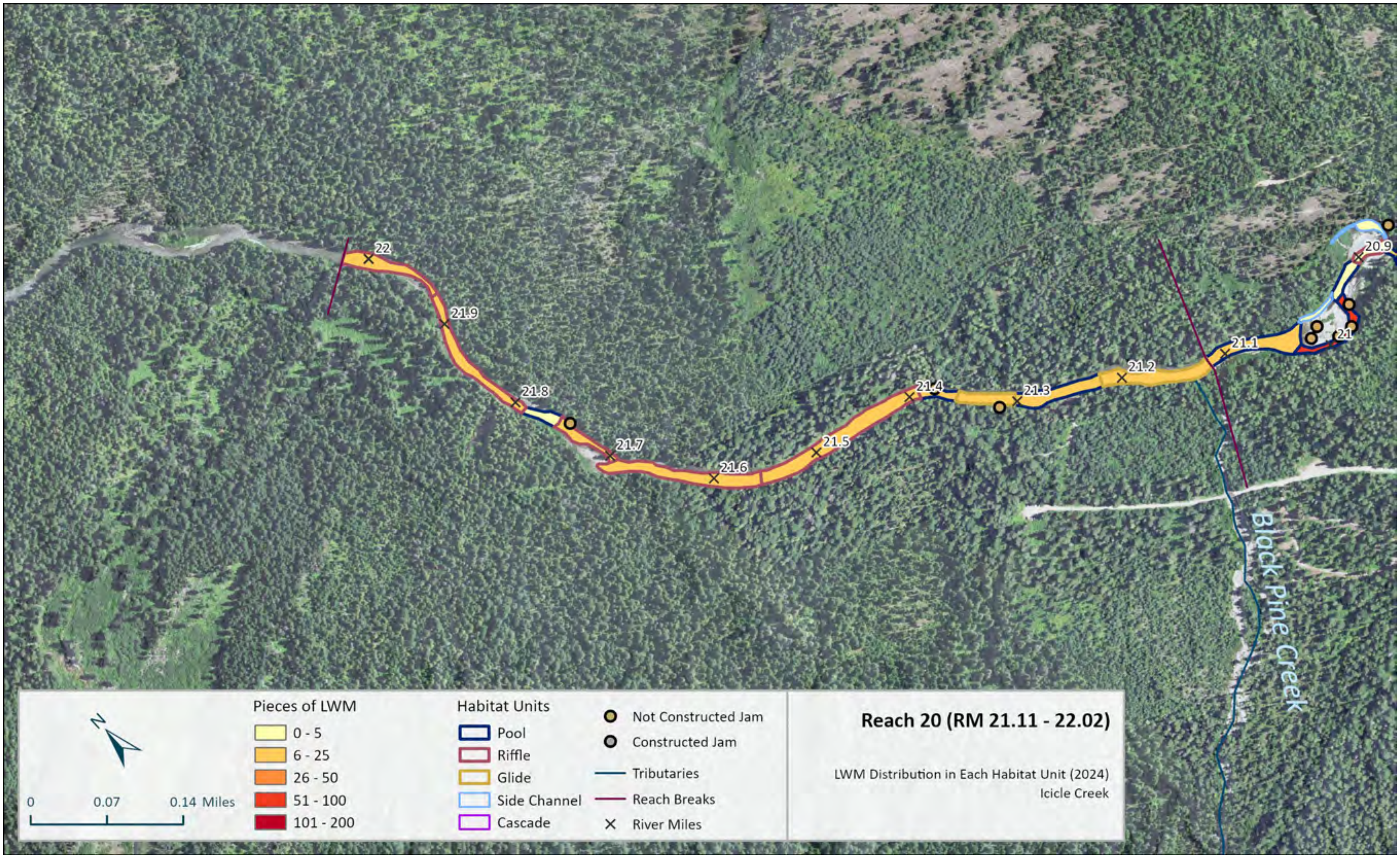

Figure 298. Reach 20: Large wood distribution (pieces per mile per habitat unit) map and surveyed habitat units (2024).

3.20.4 Vegetation

Vegetation on low floodplains and bars is commonly willow with some observations of mint, sedges and forbs, along with a mixed overstory of dogwood, alder, cedar, cottonwood. Where dense, the riparian shrubs and trees provide root-strength that aids bank stability. The medium floodplains are often vegetated with alder and vine maple with an overstory of Douglas firs and cedar. The high floodplain and terrace (fan) surfaces host conifer forests comprised primarily of second-growth trees with remnant pockets of old-growth (Figure 299).

Figure 299. Example of pocket of old-growth forest on adjacent river-right floodplain at RM 21.71 (August 6, 2024).

The vegetation height analysis map (Figure 300) reveals the pockets of old-growth sized trees along the banks of the channel located on river-right from ~ RM 21.2 to 21.4, on both side of the channel from ~21.5 to 21.6, and river-right from ~RM 21.75-22. Otherwise, the forests adjacent to the channel in Reach 20 are second-growth forests. The variations in forest regeneration maturity are also visible in the aerial image of Reach 20 (Figure 301). The existing vegetation does provide shading, nutrients, and woody material to the channel.

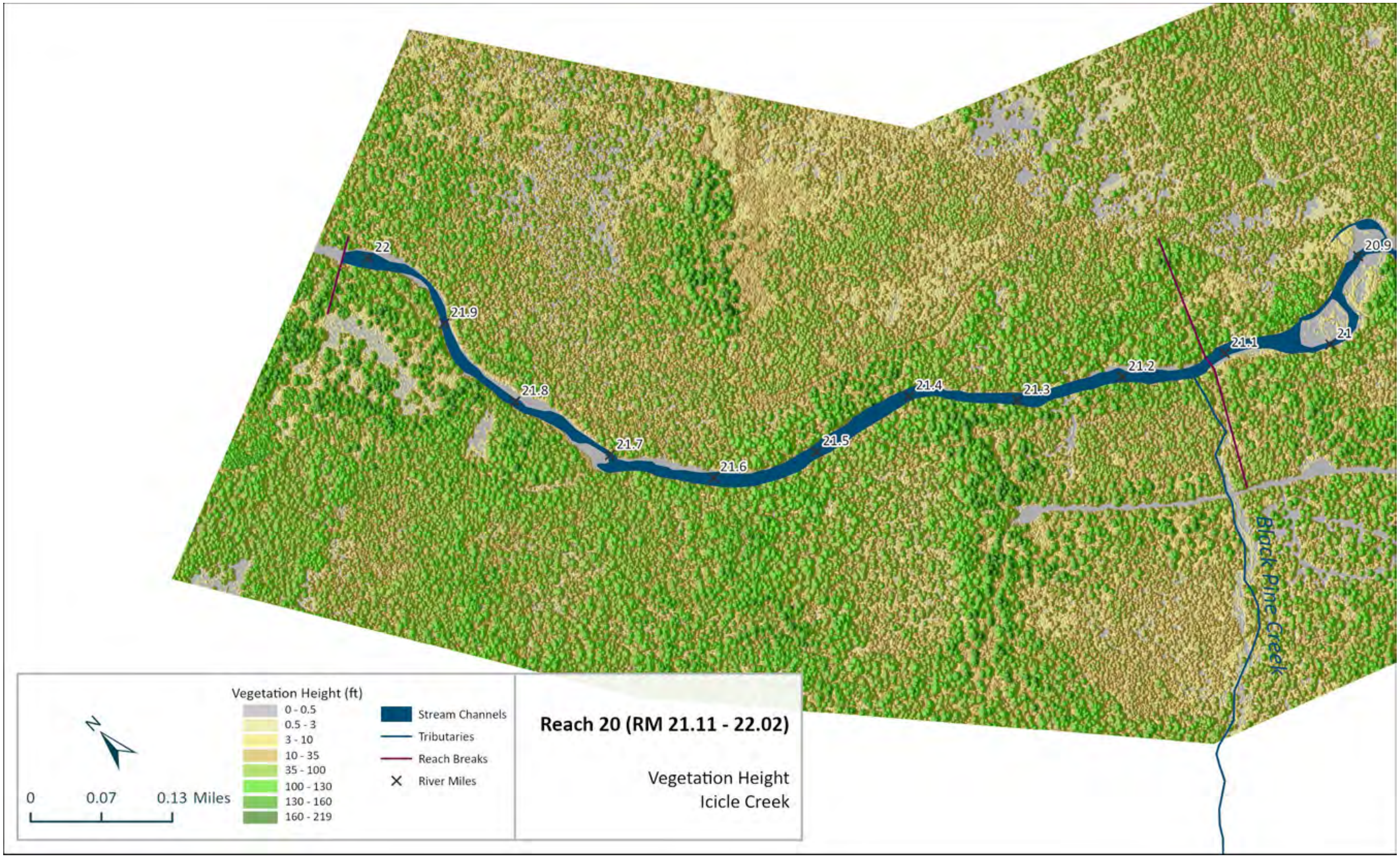

Figure 300. Reach 20: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 301. Reach 20: Map of aerial imagery for vegetation identification (ESRI 2023).

3.20.5 Human Alterations

Human alterations in Reach 20 are minimal and there are no anthropogenic built features interacting with the channel. Human alterations are limited, in part, due to the upper half (upstream of approximately RM 21.6) of this reach lying within the Alpine Lakes Wilderness. The Icicle Creek Trail head is located on the hillslope approximately 500 ft from the creek on river-right (Figure 302) and a trail leads down to Icicle Creek at RM 21.25. There are informal campsites located near the trailhead with informal trails that connect them to each other and the creek. Vegetation clearing has occurred in the access roads, trails, and campgrounds. The Icicle Creek Road (Forest Service Road NF 7600) runs along the hillslope adjacent to the creek on river right, until it ends at RM 21.3 – near the wilderness boundary. Forest Service Road NF 7609 accesses the river-left hillslopes at about 250 feet from the creek, also generally perpendicular to the channel, until it ends at RM 21.41 (Figure 303).

Figure 302. Icicle Creek Trailhead at RM 21.27 on river-right hillslope at end of Forest Service Road 7600.

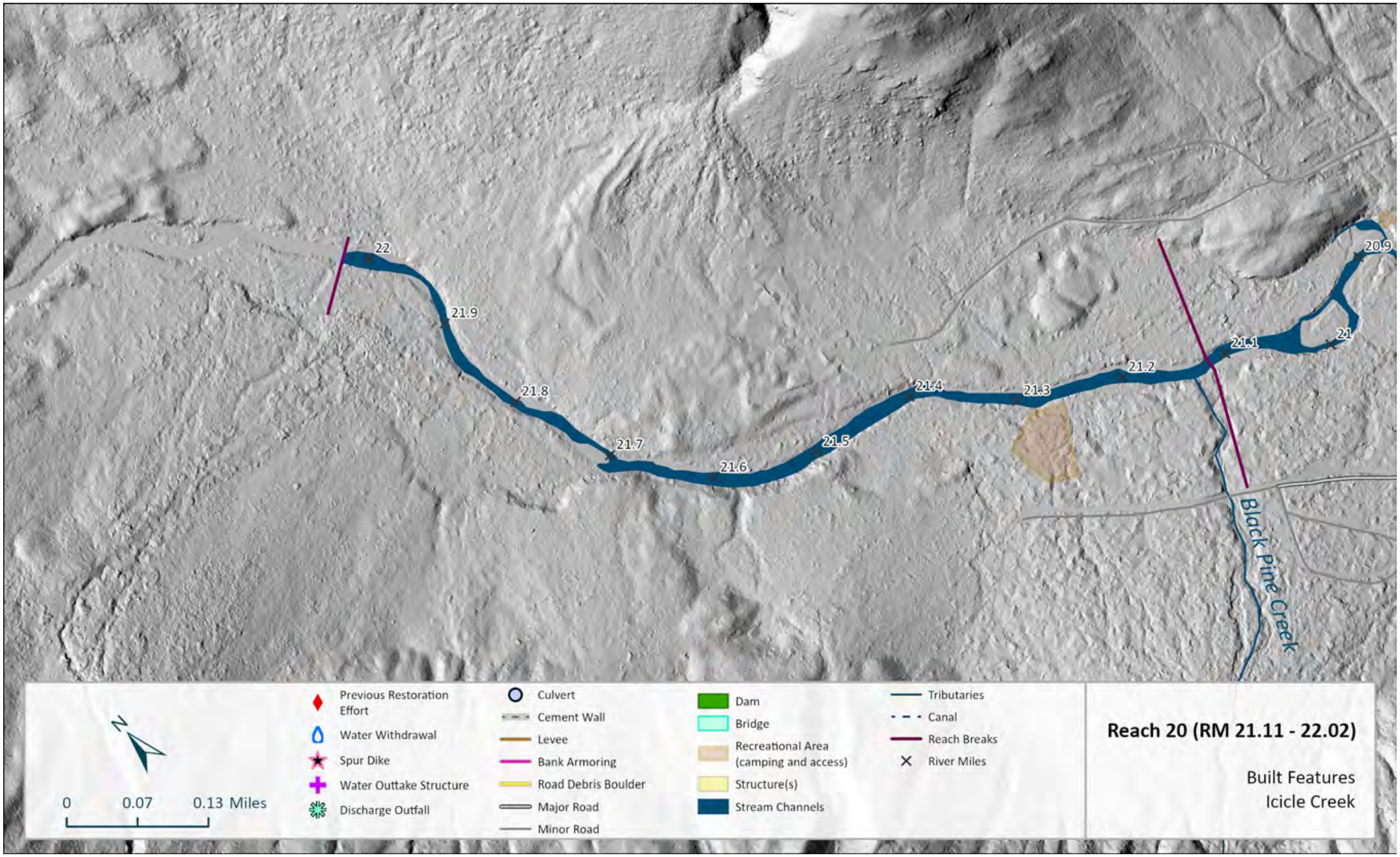

Figure 303. Reach 20: Mapped anthropogenic features (2024).

3.20.6 Recommended Actions

Reach 20 is relatively well-functioning. However, there are nevertheless beneficial restoration actions that would work with the existing conditions to provide meaningful habitat improvements. However, access is challenging except for in the lowest 0.2 miles where road access on the right side hillslope is available to RM 21.3. The upstream 0.4 miles is in wilderness, significantly limiting construction options. For this reason, the most effective treatments in this reach are likely to include helicopter wood placements and/or hand felling of large riparian conifers into the channel. Some machine-based work could occur in the downstream-most portion outside of the wilderness boundary, but there would be significant riparian vegetation impacts (to establish access from existing road) for only a short treatment segment. Helicopter placed or hand-felling or pulling in of trees could occur throughout the reach, as riparian stands are relatively mature. Whole tree placements would be preferred, targeting lower energy areas and using existing riparian trees or topographic features for bracing trees to withstand high flows.

The riparian zones are well-vegetated, but with some dense stands with significant understory and ladder fuels. Fuel management including thinning and prescribed burns may help to support and sustain mature fire-resistance riparian stands.

A map and more detailed descriptions of project opportunities are provided in Appendix C (Project Opportunities).

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