Lower Mainstem Nooksack River Salmon Habitat Assessment

Final Report

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Contents

Introduction:

The Lower Nooksack River supports a diversity of salmonid species, including Endangered Species Act (ESA) listed Puget Sound Chinook *Oncorhynchus tshawytscha*, steelhead *O. mykiss*, and bull trout *Salvelinus confluentus* as well as all other anadromous salmonid species (coho *O.kisutch* , chum *O. keta*, pink *O. gorbuscha*, sockeye *O. nerka*, and cutthroat *O. clarkii*). Although the timing, duration, and uses vary among species, life histories, and life stages, the Lower Mainstem Nooksack River provides important rearing, migration, refuge, and spawning habitat for this diverse assemblage of salmonids (**Appendix A**). However, the quantity, quality, and connectivity of habitats within the Lower Mainstem Nooksack River have changed substantially relative to historical conditions (Collins and Sheikh 2004; Boyd et al. 2019).

This *Lower Mainstem Nooksack River Salmon Habitat Assessment* is part of a larger collaborative effort to develop an integrated floodplain management plan for the Nooksack River area to restore salmon habitat while reducing flood risk and management costs and supporting existing agricultural land uses within the floodplain. The primary objective of this habitat assessment was to describe the current and historic salmon habitat conditions in the Lower Mainstem Nooksack River study area. To achieve this objective, we relied on a combination of field surveys, previously collected habitat information, historical habitat reconstructions, and other available information on salmonid habitat use (e.g., distributions, timing, and densities).

Given that the Lower Mainstem Nooksack River integrates rain-dominated and snowmelt-dominated watersheds, the annual hydrograph can produce a highly variable, bi-modal flow distribution pattern with high flows occurring in November and December, frequent decreases in discharge during January, higher flows again during February through July, and summer low flow conditions in August and September (USGS gauges 12213100 and 12210700 measure discharge at Ferndale and Cedarville, Washington, respectively). Additionally, commonly occurring high flows (ca. 2-year recurrence event) can create widespread flooding within the study area. Because of this, it is critical to characterize habitats when winter flows create connectivity with refuge habitats for rearing juvenile fish. In addition, consistent with rearing needs of fish in the summer low flow conditions, it is critical to understand habitat extents and characteristics during that biologically important period for fish. Therefore, this assessment considered the seasonality of both river flows and salmon habitat use by describing current habitat conditions during both a summer low flow (≈1,450 cfs at Ferndale) and winter flow regime (≈5,000 cfs at Ferndale).

This assessment also compares current habitat conditions to historical reconstructions (circa 1880s) that represent conditions prior to development and conversion of the Lower Mainstem Nooksack River's floodplain and delta for agricultural and other purposes. Historical reconstructions rely on a variety of data sources and are inherently more generalized and lower resolution than surveys of current conditions. However, comparisons of current conditions to a historical condition can provide important context that will inform the development of restoration and conservation strategies by identifying the degree to which habitat types and quantities have changed over time.

To inform the analysis and interpretation of current and historical conditions, we compiled data on salmonid habitat use and timing by life histories and life stages (e.g., adult and juvenile). This information is important for developing recovery and conservation strategies for the study area, as it provides descriptive information on known habitat preferences and uses for nearly all the species and life stages of salmonids in the study area. In addition, we conducted an extensive literature review to compile juvenile salmonid density data by habitat type and season for all salmon species. These data were used to estimate juvenile Chinook salmon capacities by season and habitat type based on estimates of current and historical habitat availability. Juvenile Chinook salmon use the full range of habitats provided by the Lower Mainstem Nooksack River for rearing, refuge, and migration, and Chinook are a primary focal species given their ESA listing status. Salmon recovery and conservation strategies, and restoration strategies to support salmon recovery in general, often focus on listed species like Puget Sound Chinook. However, it is likely that strategies focused on Chinook salmon will benefit multiple salmon species, life histories, and life stages in the Nooksack River (UCSRB 2007), including other ESA-listed species that occur within the Nooksack River (e.g., steelhead and bull trout). Although we focus our assessment on juvenile Chinook salmon, we recognize that the data collected as part of this assessment can be used to evaluate habitat conditions and recovery or conservation strategies focused on other salmon species, life histories, or life stages (e.g., adults, spawners, or yearlings).

In this report, we present the methods used for each component of the assessment, current and historical habitat estimates, juvenile Chinook salmon rearing capacity estimates for historical and current conditions, and a discussion of next steps and applications. We provide both an overview of current and historical habitat conditions and capacities at the study area scale, as well as more detailed reach-scale results to support the development of reach-scale strategies. This report includes the following sections, and all figures, tables, and sections referenced therein are linked in the electronic version of this document (in-text links are in bold):

1. **Introduction:**
   This section provides an overview of the purpose, objectives, and approaches used in the assessment, and an outline of the report structure and what each section covers.
2. **Approach and Methods:**
   This section provides an overview of the study area and methods used for the habitat survey, historical reconstruction, habitat use and timing tables, and capacity analyses completed as part of this assessment.
3. **Results and Discussion:**
   This section provides a study area scale summary of current habitat conditions, comparisons to historical conditions, and subyearling Chinook rearing capacity. Results are organized by mainstem, floodplain, and estuary habitats to provide an overview of conditions and results at the study area scale. Summary figures and maps are included in this section while supporting tables and figures in Appendices are referenced in the text.
4. **Reach Conditions:**
   This section provides more detailed results at the reach scale. Current habitat conditions and comparisons to historical conditions are described in more detail. Summary figures and maps are included in this section while supporting tables and figures in Appendices are referenced in the text.
5. **Next Steps and Applications:**

This section provides an overview of next steps for the Lower Mainstem Nooksack River Salmon Habitat Assessment, and potential applications and limitations for the information presented in this assessment.

6. **References:**
   This section provides references for all sources cited in this assessment and the appendices included in the assessment.
7. **Appendices:**
   The appendices included in this assessment provide additional information on (**Appendix A**) fish habitat use, distribution, and periodicity; (**Appendix B**) current habitat survey methods and detailed summary tables, figures, and results; (**Appendix C**) detailed methods and results for the capacity analysis; and (**Appendix D**) reach strategies synthesis developed from the Lower Mainstem Nooksack River Salmon Habitat Assessment and the Geomorphic Assessment. Please note that WRIA 1 Salmon Recovery Staff Team members are developing the reach strategy synthesis as a separate document and tables and that these will be finalized subsequent to the delivery of this final report.

Approach and Methods:

Study Area:

The Lower Mainstem Nooksack River study area includes the Nooksack River, its floodplain, and associated floodplain tributaries, from the South Fork confluence (~RM 36.5) near Deming, downstream to Bellingham Bay and Lummi Bay (**Figure 1**). The study area boundaries were determined by the FEMA 100-year floodplain for the Nooksack River (2012). This assessment covers all four geomorphic reaches and sub-reaches (**Figure 2**), and reach breaks are consistent with the geomorphic assessment (Boyd et al. 2019). These reach breaks are based on dominant geomorphic conditions governing each reach, and it is a reasonable hypothesis that both available and potential habitat as well as fish use are naturally different among these reaches. National Hydrography Database and Washington Department of Fish and Wildlife hydrography extents were used to determine watercourses to survey.

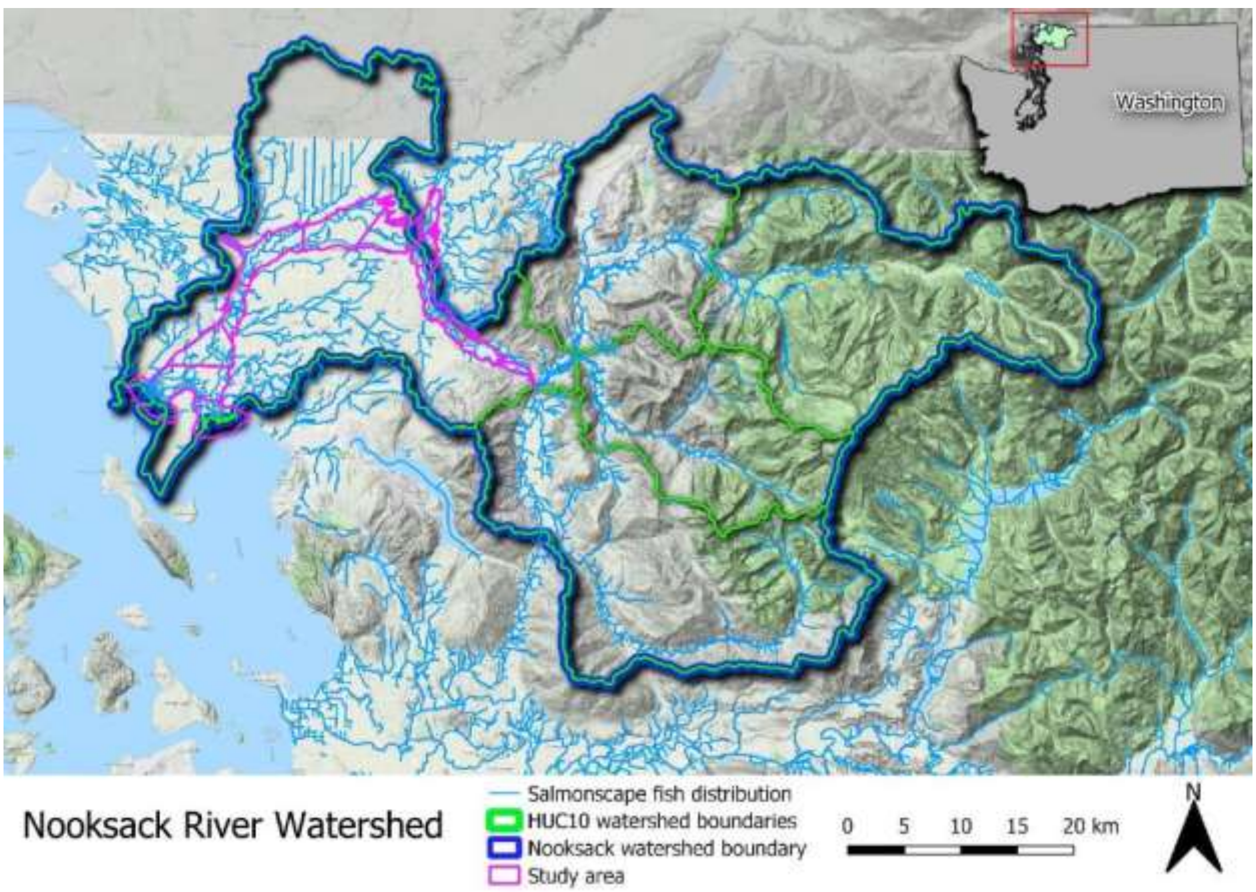

Figure 1: Overview of the Lower Mainstem Nooksack River Salmon Habitat Assessment study area within the Nooksack River watershed. Watershed boundaries shown are based on the USGS Watershed Boundary Dataset, which is a seamless watershed boundary layer with watersheds delineated as Hydrologic Units of increasing size. The 10th field Hydrologic Unit Code (HUC10) boundaries of subwatersheds composing the Nooksack River watershed are shown.

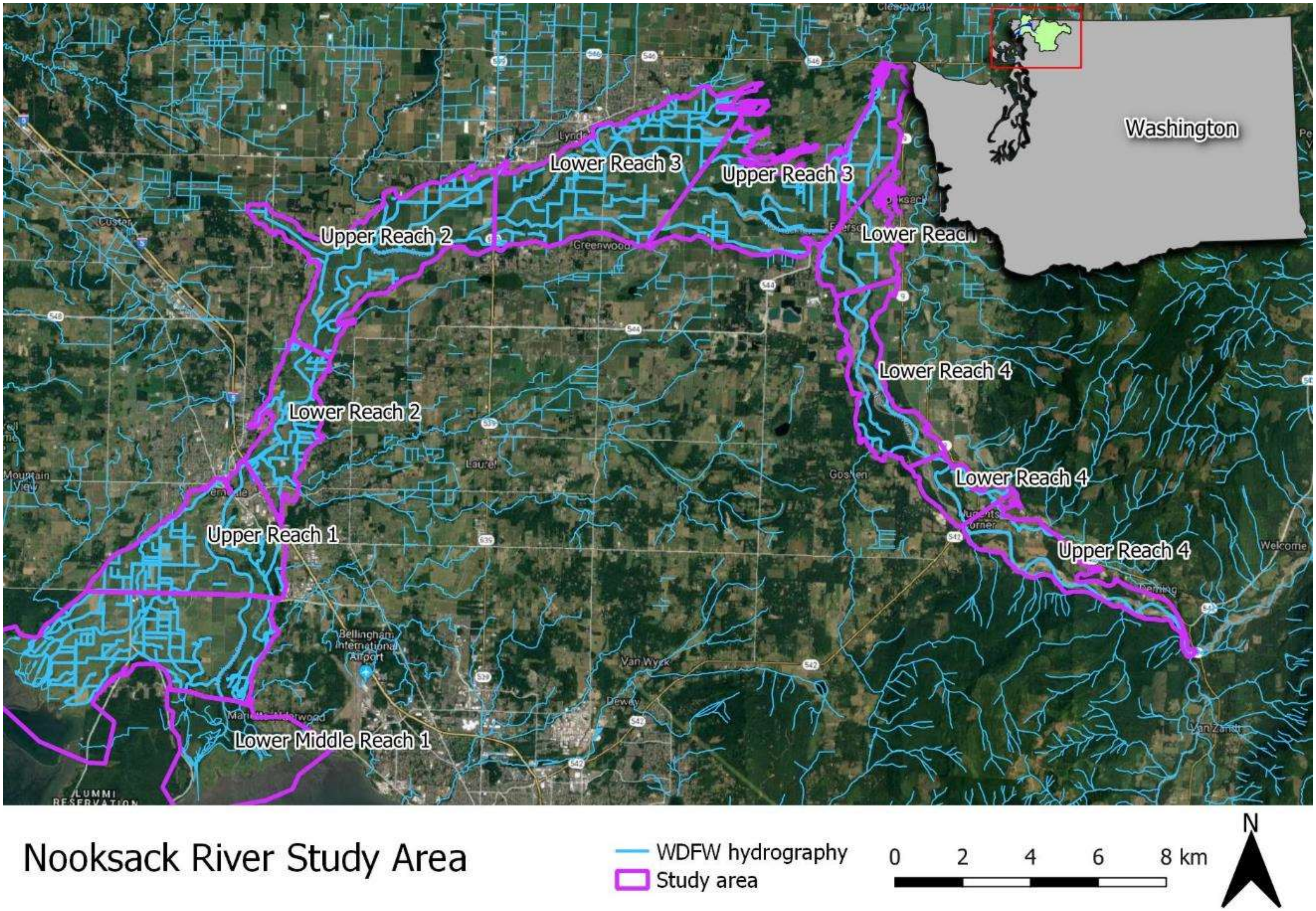

Figure 2: The Lower Mainstem Nooksack River Salmon Habitat Assessment study area and geomorphic reaches considered in this assessment.

Habitat Surveys:

Habitat surveys were completed by Cramer Fish Sciences (CFS) in order to capture summer low flow conditions and winter flow conditions. Our goal was to conduct mainstem and floodplain channel habitat surveys within the Lower Mainstem Nooksack River study area during typical winter flow conditions (ca. 5,000 cfs at Ferndale) and summer flow conditions (ca. 1,450 cfs at Ferndale) (**Figure 3**). Attempts were made to perform these surveys within their respective seasons (**Table 1**; **Figure 3**), but flow conditions were not conducive to this and thus summer low and winter flows were defined by discharge in cubic feet per second (cfs) as recorded at the Cedarville (USGS 12210700) and Ferndale (USGS 12213100) gages. Mainstem winter flow surveys were attempted when flows were above 4,000 cfs at Ferndale, and mainstem summer low flow surveys were performed when flows were below 3,000 cfs at Ferndale. Some mainstem winter surveys were performed when flows were below 4,000 cfs given an unseasonably dry winter and infrequency of flows above 4,000 cfs (**Table 1**). Winter flow surveys below the 4,000 cfs window at Ferndale were performed on lower reaches where braid and side-channel habitat was limited or absent, and thus the lower flows did not influence overall connectivity of secondary channel habitats.

Full mainstem habitat surveys (mainstem channels, braids, and side channels) were completed for both summer low flow conditions and winter flows. For tributary and floodplain habitats, winter surveys were performed in mid-late winter after rainfall had recharged the floodplain. Summer low flow floodplain surveys were conducted in October prior to fall rains. A full census of floodplain habitats was attempted during winter flows where access was permitted. During summer low flows, a subsampling effort was completed in order to estimate summer habitat capacity. Summer floodplain habitat estimates from validation surveys represent estimates of wetted habitat and do not represent direct measurement of connectivity to the mainstem. Methods for estimating summer habitat capacity are described in **Appendix B**.

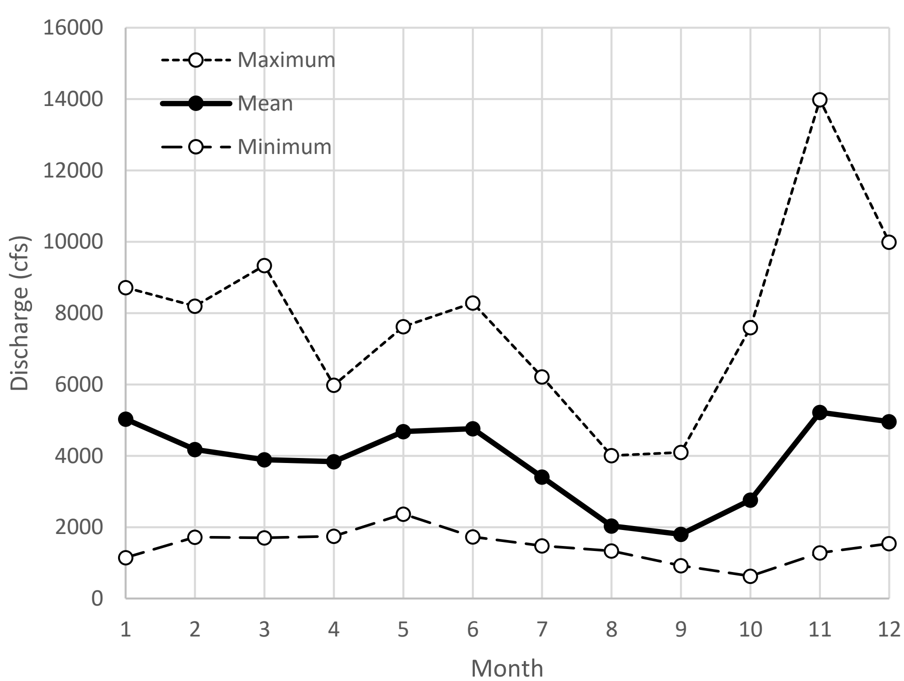

Figure 3: Monthly flows measured at the Ferndale gage (USGS 12213100) showing mean, maximum, and minimum monthly flows for the available period of record (1966-2019).

Table 1: Dates and average daily flows from the USGS Cedarville and Ferndale gages of summer low flow and winter flow surveys for mainstem and floodplain habitats.

Survey Type	Survey Date	Cedarville Flow (cfs)	Ferndale Flow (cfs)	Surveyed Habitats
Summer low flow	3/5/2018-3/7/2018	1,410-1,520	1,952-2,080	Mainstem
	10/1/2018-10/5/2018	1,501-2,473	1,403-1,948	Floodplain
Winter flow	3/7/2018-3/13/2018	1,390-4,190	1,952-3,418	Floodplain
	1/23/2019-1/24/2019	3,723-4,593	4,589-4,679	Mainstem
	4/6/2019	3,115	3,350	Mainstem, Floodplain
	4/20/2019	7,606	10,307	Mainstem
	5/13/2019-5/14/2019	2,752-3,175	3,135-3,605	Mainstem
	1/22/2019, 1/25/2019	2,358-2,976	2,499-3,438	Floodplain

The study included all mapped watercourses within the Nooksack 100-year FEMA floodplain (**Figure 2**). Surveys were grouped by mainstem, which incorporated all mainstem channels, braids, and side channels, and by floodplain habitats, which included tributaries and floodplain channels. All mainstem channels that were connected with surface water flow at the time of the survey were surveyed. Floodplain channels were surveyed where accessible. If crews were unable to access a section of floodplain channel, the channel was flagged as not surveyed and the reason was given. The lengths of floodplain habitat not surveyed were estimated in post processing in GIS using Washington Department of Fish and Wildlife (WDFW) regulatory hydrography data (WDFW regulatory layer) based on the mapped WDFW water course lengths for the unsurveyed areas and overall proportions of wetted and dry channels surveyed (see **Appendix B** for details).

Mainstem surveys were completed moving downstream by boat. For each mainstem habitat survey, GPS units were used to record tracks of the channel surveyed. Channel type was recorded as mainstem, braid, or side channel (Leopold and Wolman 1957). Habitat units were identified as pools (non-turbulent), riffles (fast-turbulent), or glides (fast non-turbulent) (Bisson et al. 1982; Beechie et al. 2005; CHaMP 2016). Pool type (e.g., plunge, scour, dam) and pool-forming feature were recorded for pool units (Bisson et al. 1982). Lengths and wetted widths were recorded in meters using a laser rangefinder. Subdominant units were recorded as a percentage of the total unit if the subdominant unit was at least one wetted width in length. The GPS coordinates of the top and the bottom of each dominant unit were recorded. Recorded data outputs are available in **Appendix B**.

In each habitat unit, stream shading, dominant riparian vegetation and height class, and edge type were visually estimated. Stream shading was recorded as the total percentage of channel wetted area covered by riparian vegetation. The dominant riparian vegetation class (e.g., coniferous, deciduous, grasses) and an estimate of the height (<3 m, 3-5 m, >5 m) in the area from the wetted edge to 10m inland as visible from the channel were recorded. For each riverbank of each unit, the percent of length occupied by each edge type at the wetted edge was estimated. Edge types were recorded as bank edge (natural or hydro-modified) or bar edge, bar edges were assumed to be naturally formed (Hayman et al. 1996). Hydro-modified banks were identified as banks where modifications were visually observed, such as levees, riprap, placed large woody debris, or pilings (**Figure 4**). If banks were modified but the modification could not be identified, they were categorized as "Hydro-modified unknown." For riprap, placed large woody debris, and pilings, bank type was recorded given the presence of these features, the quality of the features was not recorded. No banks with placed large woody debris were observed in the mainstem although some wood placement has occurred such as at the Everson overflow site. The lack of observation may be due to loss of the placed wood, the wood not being visible at the flow rate when sampled, or the active channel shifting away from the wood placement such that the habit mapping party did not observe the site. The width of slow water was recorded if present for each edge type. Slow water area was defined as present when a boundary between the edge type and mid-channel was visible as a current shear line. If no slow water was observed, a width of 1-m was applied in the analysis.

Figure 4: Examples of edge types observed in the Nooksack River mainstem. Top Left: natural bar edge on image left and natural bank edge on image right. Top Right: hydro-modified bank edge (riprap) on image right. Bottom Left: hydro-modified bank edge (levees) on image left. Bottom Right: hydro-modified bank edge (pilings).

For braids and mainstem channels, large wood jams were recorded if they were composed of three or more wood pieces 7.6 m in length by 0.3 m in diameter and were located within 10 m horizontal and 1 m vertical distance from the wetted channel edge (Leif et al. 2004). For each jam, the length and width were recorded as well as the percent of jam that was wetted.

For mainstem side channels, depths were recorded, where possible, along the thalweg at 25% and 75% of the habitat unit length. Dominant and subdominant substrate class was estimated for habitat units where possible. Depth and flow often prevented substrate and depth measurements, and no depth or substrate measurements were performed in mainstem or braid channels. Large wood jams were recorded in side channels if composed of five or more pieces of wood 1 m in length by 0.1 m in width (CHaMP 2016). In addition, the length and width of the jam in meters as well as the percent of jam that was wetted were recorded.

For tributary and floodplain habitats, a full census of habitats was attempted in winter flows but was limited by private property and difficulty of survey by vegetation and channel depth. Summer floodplain surveys were performed as a subset of winter surveys, and thus were limited to prioritized representative channels where access was allowed. Summer floodplain habitat was estimated by applying the ratio of wet to dry channel length and area observed in the summer subsampled channels. Wetland habitats were not directly surveyed in this assessment and estimates rely on supplemental data. The ratio of summer to winter wetland extent from Collins and Sheikh (2004) was used to estimate summer wetland habitat assuming the extent of mapped wetlands represent winter extents. Further details of how summer floodplain habitat was calculated are found in Appendix B. Surveyed channel types were recorded as mapped in the WDFW regulatory network as natural, hydro-modified natural, hydro-modified, diked, constructed, or wetland (WDFW regulatory layer). These designations were assigned as part of a WDFW habitat survey to designate stream types for agricultural use and were based off of SalmonScape, Washington Department of Natural Resources hydrography, and National Hydrography Dataset (Joel Ingram, WDFW, personal communication). Channels were labelled as tributaries for analysis based on connectivity to the mainstem, regardless of their WDFW regulatory classification. Habitat units were recorded using the same methods as described in the mainstem, and classified as a glide, pool, riffle, or ponded area unit. Ponded areas were defined as wetted units with no apparent flow. Lengths and wetted widths of units were recorded in meters. Depths were recorded at 25% and 50% of the unit length. Dominant and subdominant substrate was recorded for all units. Stream shading and dominant riparian vegetation class were recorded using mainstem methods. Edge type was also recorded using mainstem methods for each habitat unit and riverbank. Additionally, for each unit and riverbank, bank height was visually estimated as height of terrace above the wetted channel (<3 m, 3-5m, and >5m).

For tributary and floodplain habitats, individual large wood pieces were recorded according to Montgomery (2008) classifications (**Table 2**). All wood pieces encountered larger than 0.1 m in diameter by 1 m in length were recorded. The length and width of large wood jams (5+ pieces that were 0.1 m in diameter by 1 m in length) were recorded in meters (CHaMP 2016). The percent of the jam that was wetted was also recorded.

Table 2: Individual piece of wood size classifications adapted from Montgomery (2008) used for recording wood in floodplain habitats.

Wood length letter code and classes (meters)	Wood diameter numeric code and classes (meters)
(A) 0 to 1	(1) 0 to 0.1
(B) 1 to 2	(2) 0.1 to 0.2
(C) 2 to 4	(3) 0.2 to 2.4
(D) 4 to 8	(4) 0.4 to 0.8
(E) 8 to 16	(5) 0.8 to 1.6
(F) 16 to 32	(6) 1.6 to 3.2
(G) >32	(7) >3.2

Tributary and floodplain surveys were ended when the channel went dry, was too dangerous or difficult to survey, or was on private property and permission was not provided. The lengths and areas of unsurveyed floodplain habitats were estimated in GIS using survey data and WDFW hydrography. The WDFW hydrography was used to extract lengths by channel type not surveyed for each reach. The unsurveyed channel area was calculated using the average widths of surveyed units and estimated WDFW lengths. The average widths of surveyed floodplain habitat units were calculated at the reach and WDFW channel type strata. Areas and lengths of unsurveyed floodplain habitats were summarized at the reach and channel type level. Habitat unit type, riparian cover, stream shading, and large wood were not estimated for unsurveyed habitat extents, but our surveys covered a wide representation of the habitats and given the homogeneity of floodplain habitats are likely representative of unsurveyed habitats.

Historical Habitat:

Historical habitat conditions were derived from Collins and Sheikh (2004) reconstructions of habitat circa 1880, which approximately represent the study area prior to most development and conversion of the Lower Nooksack River, floodplain, and delta. These reconstructions cover the full extent of the Lower Nooksack Habitat Assessment study area and include estimates of floodplain habitats as well as distributaries and tidal wetlands connected to Lummi Bay that were more hydrologically connected during that historical period (**Figure 5**). Although the later reconstructions (after 1933) produced by Collins and Sheikh (2004) were based on aerial imagery provide both high and low flow habitat estimates, we used the 1880s reconstruction given that substantial development and alteration of the study area had already occurred prior to the 1933 and later reconstructions (Collins and Sheikh 2004; Boyd et al. 2019). In addition, the later reconstructions did not include floodplain and delta habitat estimates that could be used for comparisons to current habitat. However, use of the 1880s reconstruction to compare current and historical habitat required several assumptions and estimation of several components. The methods and assumptions used to estimate historical habitat for comparisons to current habitat and the capacity analysis are described in this section.

For estuary habitats, reconstructions were based on mapped distributary channel, large channel, and tidal wetland habitats in combination with estimated blind tidal channel areas for tidal wetlands. Allometric relationships were used to estimate blind tidal channel area from tidal wetland area. These estimates of blind tidal channel area were added as reported by Collins and Sheikh (2004) to the channel areas for larger channels that were derived from the mapped features produced by Collins and Sheikh (2004). Therefore, all maps of the estuary extent and features do not show the estimated blind tidal channel areas as these features were not directly mapped. However, estimates of total tidal channel area included in the summary tables include these estimated channel areas for the 1880s reconstruction.

Collins and Sheikh (2004) indicate that the historical 1880s reconstructions are based on survey measurements that most likely represented bankfull measurements for widths, although they note some possible inconsistencies in the reported measurements. We compared the 1880s reconstruction to 1933-1986 reconstructions to: (1) determine how the bankfull 1880s reconstruction compared to later high flow and low flow reconstructions, and (2) determine if consistent geomorphic relationships could be used to estimate habitat under different flow conditions (**Table 3**). Based on this comparison, the historical 1880s reconstructions from Collins and Sheikh (2004) appear to represent a high flow condition that is approximately 75% of the high flow conditions for later reconstructions (after 1933) from Collins and Sheikh (2004). Although habitat area estimates changed from year to year in the later reconstructions, there was a lack of a consistent trend and the standard deviation was less than 5% of the mean high flow habitat area (**Table 3**). Therefore, we assume that the 1880s reconstruction method produced habitat area estimates that represent high flow habitat area at approximately 75% of the bankfull high flow condition for the Collins and Sheikh (2004) high flow reconstructions for later years.

The 1880s reconstruction does not provide mapped seasonal reconstructions for mainstem, floodplain, and estuary habitats, aside from tabular estimates of seasonal wetland inundation. Despite increases in hydro-modification over time (Collins and Sheikh 2004; Boyd et al. 2019), the ratio of high flow to low flow perimeter was relatively stable over time (**Table 3**). Therefore, we used the mean ratio (0.67) of high flow to low flow channel edge from the 1933-1986 reconstructions to estimate low flow channel edge for the 1880s reconstruction. However, the 1880s reconstruction high flow condition is lower than the bankfull high flow condition represented in the 1933-1986 reconstructions as evidenced by lower channel area and higher perimeter lengths in the 1880 reconstruction compared to the later reconstructions (**Table 3**). Therefore, low flow estimates derived for the 1880s are potentially biased low given the high flow condition represents a flow that is likely lower than the 1933-1986 high flow reconstructions. Given these comparisons, we assume the 1880s reconstruction represents conditions most similar to our winter flow (≈5,000 cfs and less than bankfull condition), and that estimated low flow based on 1933-1986 reconstruction high flow: low flow ratios are most similar to a summer low flow condition.

The extent and connectivity of floodplain habitats (e.g., sloughs, tributaries, ponds, and wetlands) would likely change seasonally (e.g. winter verses summer) and are not captured by the spatial mapping products for the 1880s reconstruction. The Collins and Sheikh (2004) provides estimates of winter and summer wetland inundation area for a portion of the study area (Lower Reach 2 to Upper Reach 3) based on survey notes. We applied the ratio of summer to winter inundation area estimates in Collins and Sheikh (2004) to the mapped wetland areas to estimate summer and winter wetland extent for Upper Reach 1 through Upper Reach 4. This approach assumes that the mapped wetland areas are representative of maximum inundation extent that is assumed to most represent the winter flow condition, although documentation for the mapping products and the report do not specifically state this as the condition represented in the mapping products. For the estuary, assume seasonal changes in tidal delta habitats are minimal and primarily driven by tidal flooding and use the same mapped reconstructions of tidal wetland area for summer and winter condition.

Table 3: High flow (HF) and low flow (LF) channel area and perimeters derived from Collins and Sheikh (2004) reconstructions for 1933-1986. The ratios of HF:LF area and perimeters are shown for reference, which were used to evaluate geomorphic relationships between the LF and HF channel footprints within the study area over time. For comparison, the high flow area and perimeters for the 1880 reconstruction were 14,085,304 meters^2 and 400,892 meters, respectively.

Year	HF Area (meters^2)	HF Perimeter (meters)	LF Area (meters^2)	LF Perimeter (meters)	HF:LF Area Ratio	HF:LF Perimeter Ratio
1933	18,629,844	307,525	7,540,751	488,179	2.47	0.63
1938	18,704,065	294,089	6,213,466	415,142	3.01	0.71
1955	20,000,770	313,736	8,214,244	451,204	2.43	0.70
1966	19,280,592	343,088	9,387,680	528,840	2.05	0.65
1976	17,793,013	299,780	8,052,008	422,289	2.21	0.71
1986	17,930,763	345,832	9,037,132	526,846	1.98	0.66
Mean (1933-1986)	18,723,174	317,342	8,074,213	472,083	2.36	0.67
STDV (1933-1986)	830,079	22,059	1,133,091	50,274	0.37	0.03

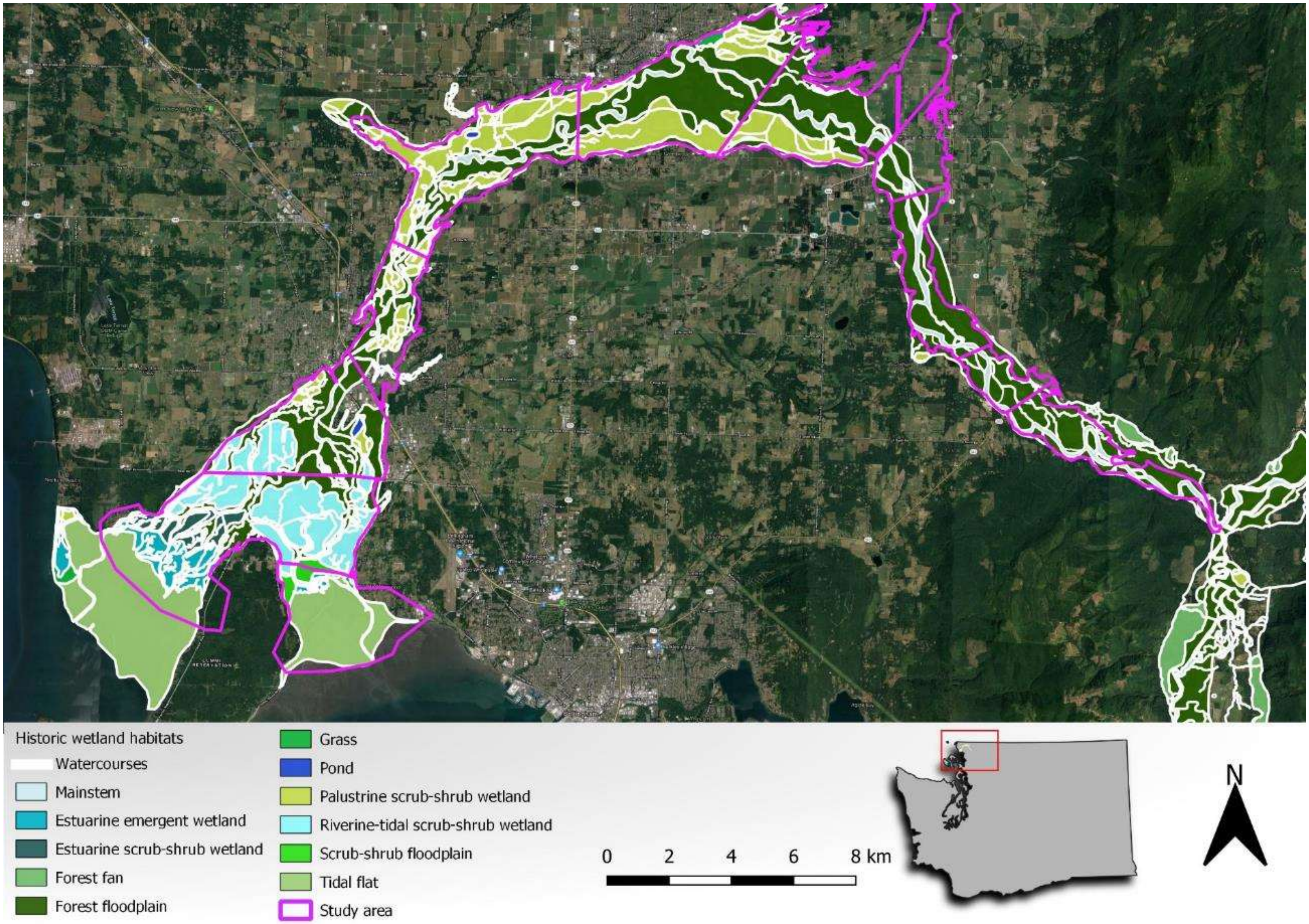

Figure 5: Historical reconstructions of habitat circa 1880 from Collins and Sheikh (2004) with reach boundaries for the study area.

Estimates of bar and bank edge habitat were also derived from the 1880s reconstruction, which support the capacity analyses using edge type information. An archived Army Corps of Engineers map obtained by Whatcom County provided mapped main channel features with bars for Middle Reach 1 through Upper Reach 3 during a summer low flow condition circa 1894 (**Figure 6**). This map was digitized by the Nooksack Tribe (Michael Maudlin, Nooksack Tribe, personal communication) to delineate bar edges based on the presence of mapped bar features and bank edges everywhere else.

Ratios of bar to bank edge from the 1894 ACOE map were then compared to ratios derived from the current surveys completed as part of this assessment (**Figure 7**). These ratios show an increasing bar to bank edge ratio from Middle Reach 1 through Lower Reach 3, and then a shift in the upper reaches to a higher ratio that is likely driven by the dominance of island braid channel morphology in the upper reaches. Given that the bar to bank edge ratios from the 1894 ACOE map was consistent with the results of our current assessment among the reaches (**Figure 7**), we used ratios derived from the current surveys under both winter flow and summer low flow surveys to estimate bar and bank edge habitat for the 1880s winter flow and summer low flow reconstructions, respectively.

Slow water edge habitat was also estimated for the 1880s reconstruction based on the results of the surveys completed as part of this assessment. Slow water edges measured during the surveys (see habitat survey methods) revealed that most slow water edges were 2-meters or less in width from the wetted edge (**Figure 8; Figure 9; Figure 10**). Natural bar edges do have higher average slow water edge width than both bank edge types observed during current surveys (**Figure 8**), but frequencies show that most slow water edge widths are less than 2 meters (**Figure 9; Figure 10**). Therefore, we assumed a fixed 2-meter width for slow water edges to estimate slow water edge area for the 1880s reconstructions.

Historical reconstructions of large wood debris or jams were not available for the lower Nooksack, although Collins and Sheikh (2004) describe many documented large debris jams, efforts to remove these debris jams, and extensive snag clearing operations. Historically documented jams include the Portage jam that was implicated in the redirection of flow to the Nooksack River and disconnection of the Lummi River, and several other large jams throughout the river. It is noted that wood jams were historically abundant in the Nooksack River prior to development and clearing of the floodplain, which likely contributed very large key pieces to the river. Although Collins and Sheikh (2004) provide estimates of snag removal, they note that these estimates cannot be used to estimate wood loading or abundance given that the efforts likely focused on deep channel areas. Furthermore, Collins and Sheikh (2004) note that the historical records of jams do not provide enough information to describe most jams or their effects on the river. Current surveys of habitat conditions included detailed surveys of wood jam cover area given that wood jams are positively associated with many aspects of fish use, and increased wood jam area is often associated with increased fish densities and habitat complexity (Montgomery et al. 2003). In the absence of historical reconstructions of wood jam area or loading, we used maximum wood jam cover areas observed among the reaches during current surveys as a conservative minimum estimate of wood cover area for mainstem and floodplain channel habitats for each reach. These estimates were only used to support the capacity analysis and should not be used to evaluate wood loading in the study area for other purposes.

Figure 6: Photo of archived 1894 ACOE map of the Nooksack River that included mapped bars.

Figure 7: Mapped bar to bank edge ratios from downstream to upstream from an 1894 ACOE map compared to ratios obtained from surveys completed during this assessment during summer low-flow and winter flow conditions. Dashed lines show ratios used to estimate bar and bank edge ratios within each reach for the 1880s reconstruction during summer low-flow and winter flow conditions.

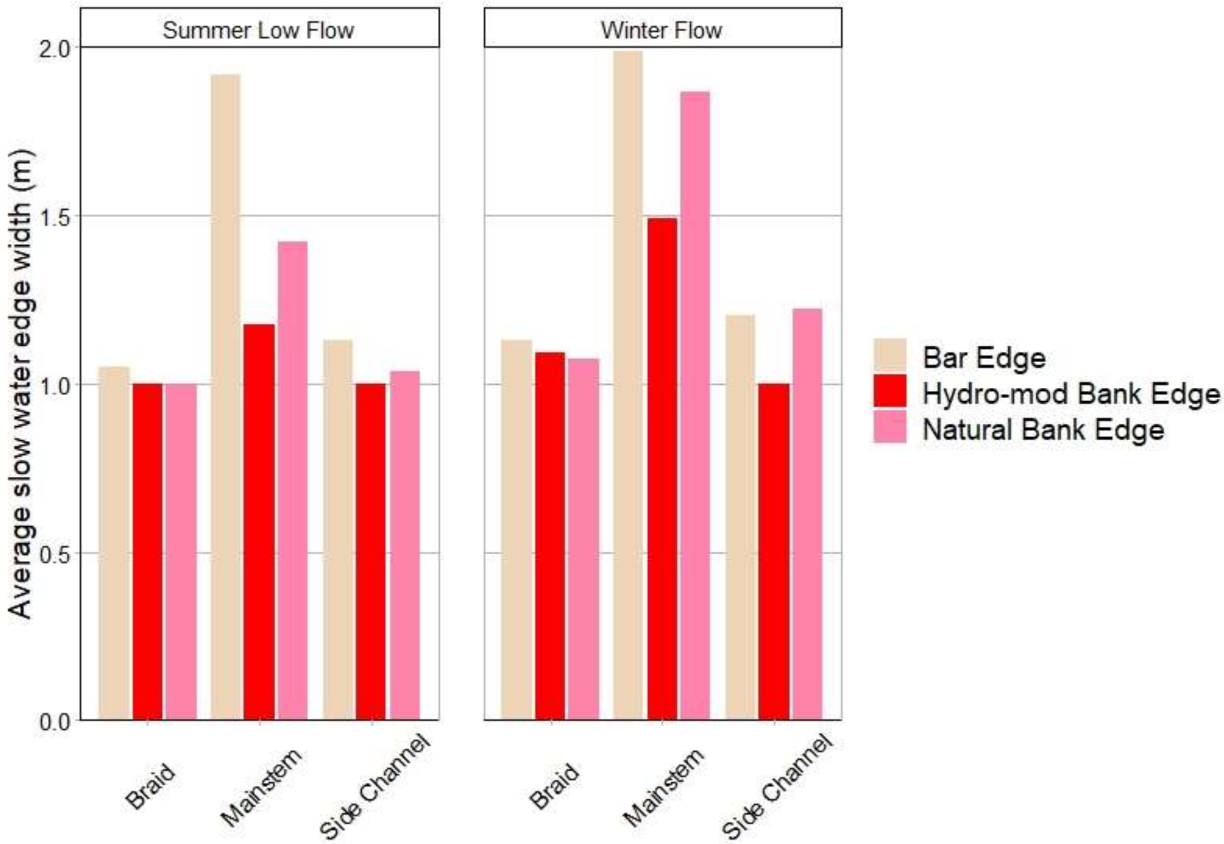

Figure 8: Average slow water edge width in meters by edge type, channel type, and season across reaches.

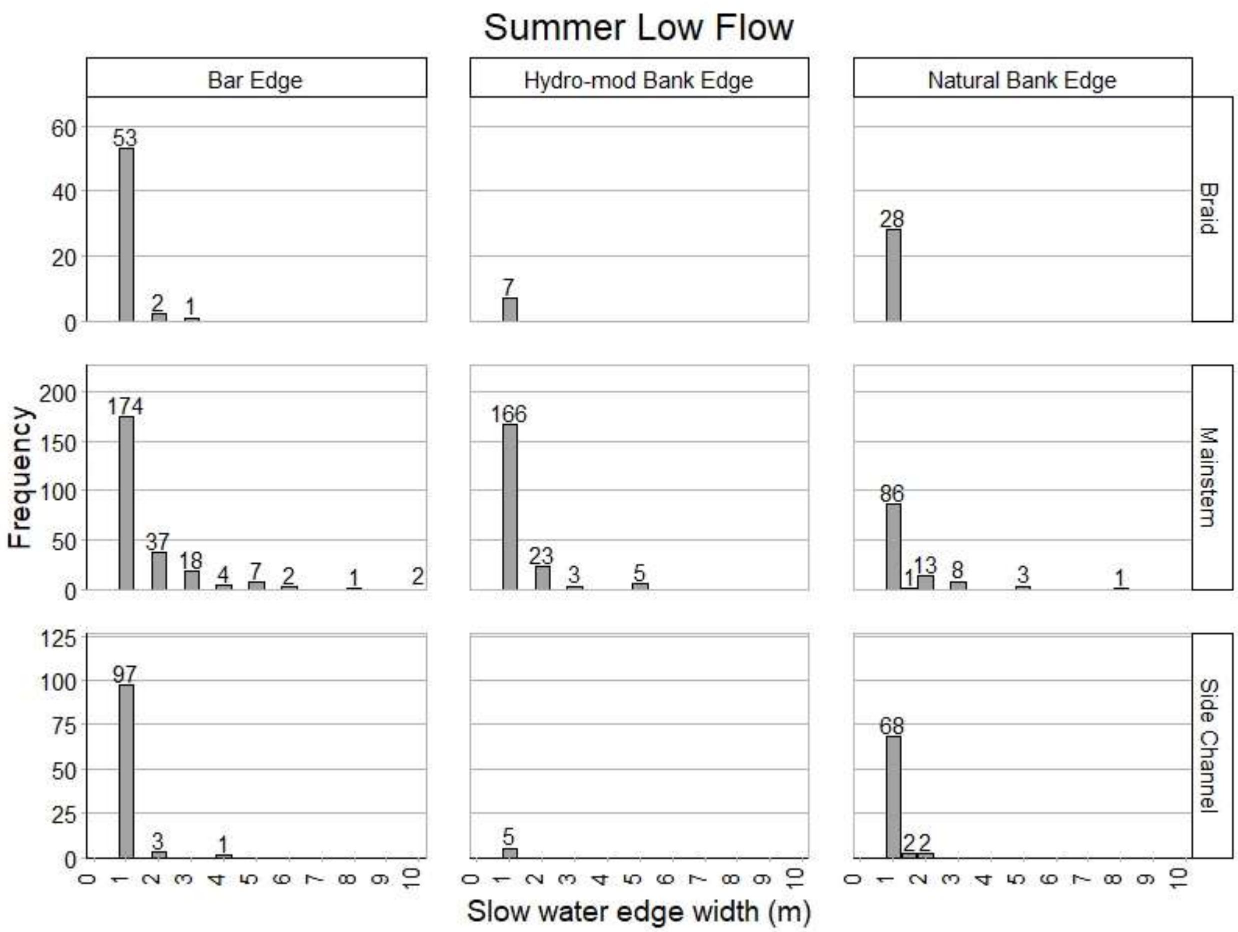

Figure 9: Frequency of slow water edge widths in meters measured during summer low flow habitat surveys completed during this assessment across mainstem, braid, and side channels.

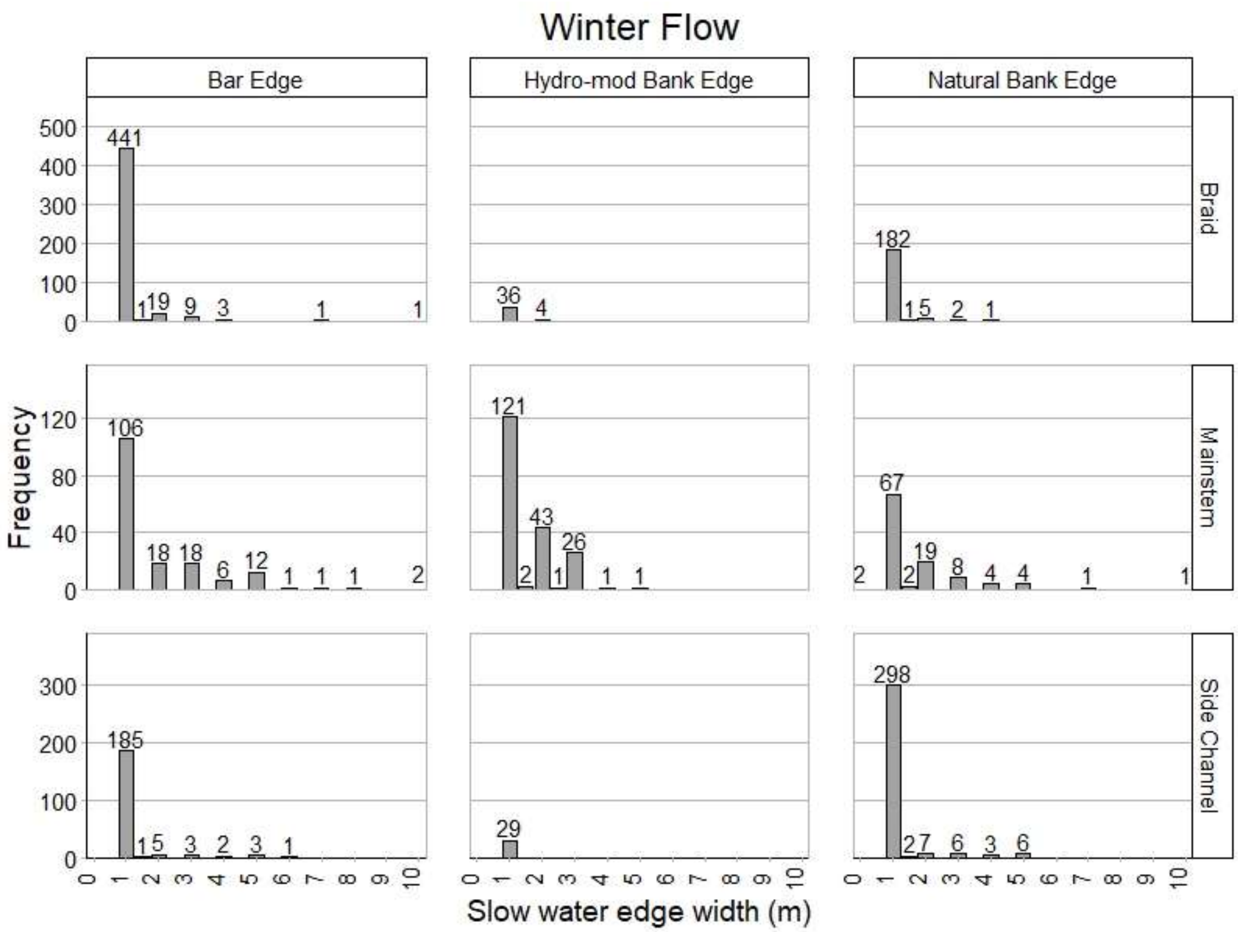

Figure 10: Frequency of slow water edge widths in meters measured during winter flow habitat surveys completed during this assessment across mainstem, braid, and side channels.

Habitat Use and Timing:

We compiled data on salmonid habitat use from existing literature and data to produce life history summaries of important species (**Appendix A**; **Table 28**), how fish use specific habitats (**Appendix A**; **Table 29**), and when fish could be expected to use respective habitats in the Lower Mainstem Nooksack River (**Appendix A**; **Table 30**). Summaries are also provided for various life histories and life stages. The timing of outmigrating juvenile fish was determined from specific information in published reports, including a recent study in the estuary that documented size at outmigration for juvenile salmonids (Beamer et al. 2016). Habitat types evaluated in this study were consistent with those defined for the WRIA 1 Salmonid Recovery Plan (2005). Many of these reports were previously identified by the Nooksack Tribe and were provided to us. We also included previous work from the North and South Fork Nooksack reach assessments and those in other literature sources, including those used in the Skagit Chinook Recovery Plan (Beamer et al. 2005). In some cases, specific habitat use and timing is not known. Identifying these data gaps is important to inform current and future studies that help define conditions for restoration planning.

Literature and studies reviewed included published studies, government reports, unpublished datasets, and other sources of information on the distributions and habitat requirements of:

- Early Chinook (North/Middle Forks; and South Fork) populations
- Fall Chinook
- Winter steelhead
- Summer steelhead
- Coho
- Chum
- Pink
- Sockeye
- Bull trout
- Cutthroat trout

We identified several important studies that specifically reported on the species, life history strategy, life stage, and ranges of habitat preferences for the ten focal groups of fish that are the focus of the Lower Mainstem Nooksack River. Most of the studies that we evaluated were focused on fish usage of edge habitats in the mainstem river and various habitats in the lower tributaries. Relatively few studies examined salmonid use of isolated or seasonally connected floodplain habitats. However, we were able to use some more general literature sources (e.g., Groot and Margolis 1998; Quinn 2005) to identify ranges of habitat preferences for species and life histories where they did not exist in literature specific to the Nooksack River system. In this way, we were able to identify known habitat preferences for nearly all the species and life stages of salmonids in the Lower Mainstem Nooksack River study area (**Appendix A**; **Table 29**). In addition, the Nooksack Tribal biologists updated the fish periodicity table that identifies specific habitat use by species by month. This table is specific to the Lower Nooksack SHA study area in most cases (**Appendix A**; **Table 30**). Data were organized according to species, life stage-specific behavior (e.g., migration, spawning, incubation, etc.), and timing. In addition, literature on other culturally important species in the Nooksack River, such as Salish sucker, Nooksack dace, and longfin smelt, was identified, although those species are not targeted in this study.

Capacity Analysis:

We used published and unpublished data on measured juvenile salmon densities by habitat type and season to estimate seasonal subyearling Chinook salmon rearing capacity for the Lower Mainstem Nooksack River study area. Given that habitat use varies among habitat types and by species, life stages, and season, we developed this capacity analysis to provide additional context for evaluating current habitat conditions. By considering the upper range of subyearling Chinook densities observed in different habitats at different seasons, we can evaluate habitat conditions with respect to their relative value to subyearling Chinook salmon. The capacity analysis completed as part of this assessment is described in detail in **Appendix C** and is only briefly described in this section.

We reviewed and compiled published and unpublished sources of juvenile salmon density for Pacific Salmon species in freshwater and estuary habitats across the range of Chinook salmon (Northern California to Alaska), but with an emphasis on north Puget Sound systems. It was important to consider data from other systems given that observed densities of subyearling Chinook salmon in the Nooksack are lower than the range of densities observed in similar habitats when all other systems are considered (**Appendix C ; Figure 179**).

Our synthesis considered only discrete density data for juvenile salmon that were in units of fish/m^2, or that were reported in such a way that values could be converted to fish/m^2 (e.g., reported catch per unit effort (CPUE) but net sizes were reported so that CPUE can be converted to an estimate of areal density). All qualifying data were classified by key habitat strata and sub-strata that were identified based on the availability of data and the habitats that could be quantified for both the historical reconstructions and current habitat assessments (**Table 4**).

Table 4: Habitat matrix used to summarize juvenile fish density data from data sources. These classifications represent a subset and aggregation of the classifications used in the database. See **Appendix C** for more details on available habitat types.

Strata	Sub Strata	Unit Type
Mainstem	Mainstem Channel	Hydro-modified Bank Edge
		Natural Bank Edge
		Side Channel and Braid
		Large Wood Jam
Floodplain	Secondary channel	Slough or tributary
	Pond and Wetland	Pond and Wetland
Estuary	Distributary	Estuarine Emergent Marsh (EEM)
		Estuarine Scrub Shrub (ESS)
		Forested Riverine Tidal (FRT)
	Tidal Channel	Estuarine Emergent Marsh (EEM)
		Estuarine Scrub Shrub (ESS)
		Forested Riverine Tidal (FRT)

Statistical summaries of all qualifying juvenile salmon density data were developed by habitat type, species, life stage, and season. Season was based on metrological season adjusted based on a typical juvenile salmon migration and river flow patterns as follows; winter occurring from December through march and representing winter flow conditions and the beginning of emergence and downstream migration pulse for juvenile salmonids, spring occurring from April through June and representing spring melt pulse flow conditions and the typical peak downstream migration pulse of juvenile salmonids, summer occurring from July through September and representing a low flow condition with little juvenile salmon migration, and fall occurring from October through November representing an increasing flow condition with little juvenile salmon migration (see **Figure 3** for flow patterns). Data were extracted by life stage and were aggregated to subyearling and yearling life stages only—no adult life stage data were considered or compiled in this review. We considered data for the following species: Chinook, coho, chum, pink, cutthroat, steelhead, and bull trout. No run type classifications were extracted or considered in this review, and only data for unmarked fish were considered where origin and marked status were reported. Where marked or proportions of hatchery origin fish were not reported, we assumed all fish were natural origin. Therefore, fish densities compiled in this literature review likely include some proportions of hatchery origin fish due to reporting detail and the possibility of unmarked hatchery origin fish being included in unmarked natural origin densities.

Statistical summaries are presented in **Appendix C** for all species and data compiled, although the capacity analysis completed as part of this assessment considers only subyearling Chinook salmon densities. Although our habitat surveys focused on a winter flow and summer low flow condition, we use our habitat estimates for these conditions in combination with seasonal subyearling Chinook densities to estimate seasonal capacities. We assume target winter conditions apply to winter and spring seasons, and that summer and fall are best described by our target summer low flow condition (**Figure 3**). To estimate rearing capacity, we used the upper third quartile of the distribution of subyearling Chinook density data (Q3 density) where sufficient data were available to estimate capacity by habitat type and season. The upper third quartile represents the upper range of densities that have been observed and therefore represents an approximate capacity for that habitat type and season.

By using the distribution of measured densities observed in other systems and regions, we can estimate rearing capacity based on the upper range of observed seasonal densities for different habitat types. This approach addresses the limited spatial and temporal extent of fish observations for the study area and potential biases of within system conditions that may influence observed rearing densities. Therefore, this approach will provide an estimate of potential rearing capacity based on the upper range of observed densities for given habitat types based on the habitat types themselves. Given that the density data represent mean seasonal densities, the capacity estimates based on the distribution of these means do not represent total juvenile production as they are not adjusted for rearing duration or timing. We also assume that the theoretical capacity derived from the Q3 densities are applicable to both current and historical conditions, and therefore we use the same data to estimate capacity for both conditions. However, it is possible that the distribution of densities observed in modern times are biased low due to a number of potential impacts and this may bias comparisons of current and historical capacities.

Results and Discussion:

Current Habitat Conditions:

Mainstem Habitats:

The Lower Mainstem Nooksack River is dominated by confined single-thread channel morphology in the lower reaches with braided and multithread channel forms occurring primarily in the upper reaches (**Figure 11**; **Figure 12**). In total, we surveyed 98.6 km of winter flow mainstem habitat and 66.3 km of summer low flow mainstem habitat from the Deming SR 9 bridge (RM 36.5) to Marine Drive (RM2) (**Table 5**). In winter flows, 37.6 km of mainstem habitat (38% of total channel length) was braid and side-channel habitats that were hydrologically connected to main channel flows (on upstream or downstream ends). Connected or hydrologically active braids and side channels only accounted for 10.3 km of summer low flow mainstem habitat, or 15% of total channel length. Connected braids and side channels were only observed in Reaches 3 and 4, and no braid or side-channel habitat was observed in Reaches 1 or 2 in either flow survey. However, no connected braid or side-channel habitat was observed in Lower Reach 3 or Upper Reach 4 in summer low flow surveys.

Edge length for mainstem habitats was dominated by hydro-modified edges (40% summer, 37% winter) and bar edges (40% summer, 35% winter) with relatively little natural bank edges (20% summer, 27% winter) (**Table 6**; **Figure 13**). Hydro-modifications observed included levees, riprap, pilings, and unknown modifications. Most of the hydro-modified bank edge length observed was associated with main channels of the mainstem, while braid and side channel edges were predominantly composed of bar and natural bank edges with hydro-modified bank edges accounting for less than 10% of edge length in both summer low flow and winter surveys (**Figure 11**). In summer low flow surveys, bar edges were the dominant edge type in both braids (65% of edge length) and side channels (51% of edge length). In winter surveys, bar edges were the dominant edge type in braid channels (65% of edge length) and natural bank edges were the dominant edge type for side channels (59% of edge length).

Slow water edge area (meters^2) is the portion of mainstem habitats most used by juvenile salmonids (Beamer et al. 2005), and our surveys indicate that slow water edge habitat area is higher during winter flow conditions compared to summer low flows (**Figure 14**). Most slow water edge habitat observed was associated with the main channel of the mainstem compared to side-channel and braid habitats (**Table 6**). In summer low flow surveys, most of the slow water edge area observed was associated with bar edges (48%), while in winter surveys hydro-modified bank edges contributed the most slow water edge habitat area (**Table 6**). This is likely due to the overall increase of hydro-modified bank edges associated with winter surveys and reduction in bar edge habitats with increasing flow.

Table 5: Total lengths of mainstem sureysfor summer low flow and winter flow conditions. Mainstem surveys represent a census and were not subsampled during summer low flow or winter flow flows. Mainstem channels refer to main channels of the mainstem, braid and side channels were surveyed where visibly hydrologically connected. Mainstem survey extents were the same in both seasons, differences in lengths reflect differences in sinuosity or connectivity due to flow.

		Summer Low Flow (meters)	Winter flow (meters)
Middle Reach 1	Mainstem	3,087	3,484
	Braid	-	-
	Side Channel	-	-
	Total	3,087	3,484
Upper Reach 1	Mainstem	6,716	5,745
	Braid	-	-
	Side Channel	-	-
	Total	6,716	5,745
Lower Reach 2	Mainstem	4,633	5,031
	Braid	-	-
	Side Channel	-	-
	Total	4,633	5,031
Upper Reach 2	Mainstem	7,999	10,177
	Braid	-	-
	Side Channel	-	-
	Total	7,999	10,177
Lower Reach 3	Mainstem	7,872	8,499
	Braid	-	390
	Side Channel	-	773
	Total	7,872	9,662
Upper Reach 3	Mainstem	5,165	6,391
	Braid	1,537	2,721
	Side Channel	-	2,086
	Total	6,702	11,198
Lower Reach 4	Mainstem	10,693	11,904
	Braid	1,527	12,987
	Side Channel	7,192	11,946
	Total	19,413	36,837
Upper Reach 4	Mainstem	9,830	9,801
	Braid	-	1,747
	Side Channel	-	4,918
	Total	9,830	16,466

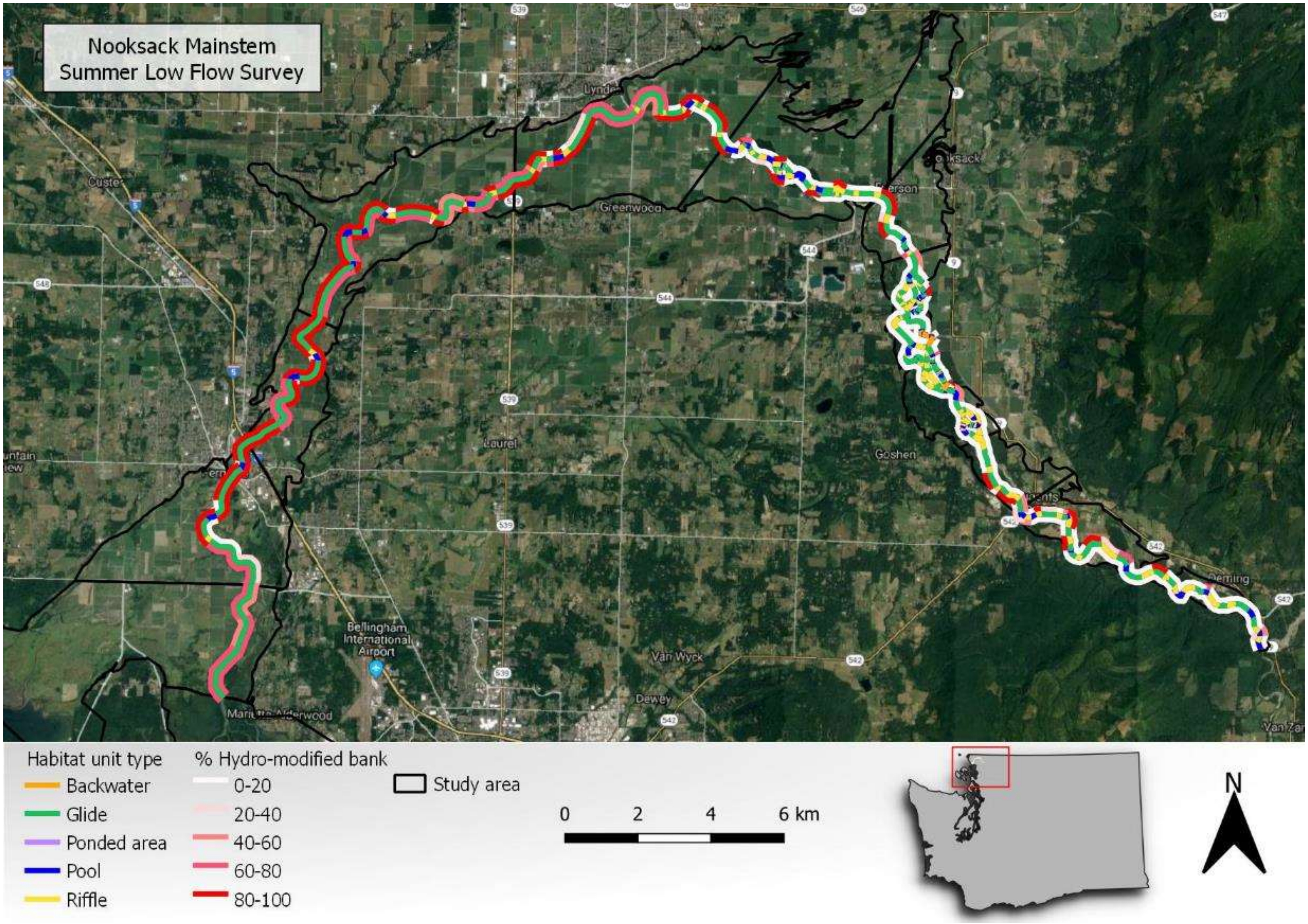

Figure 11: Nooksack mainstem habitat units and hydro-modified bank edges during summer low flow surveys. Percent hydro-modified banks are derived from field estimated proportions of edge type for each bank per habitat unit, and therefore specific edge types do not have start or stop points within each mapped unit. See **Appendix B** for more detailed reach-scale maps.

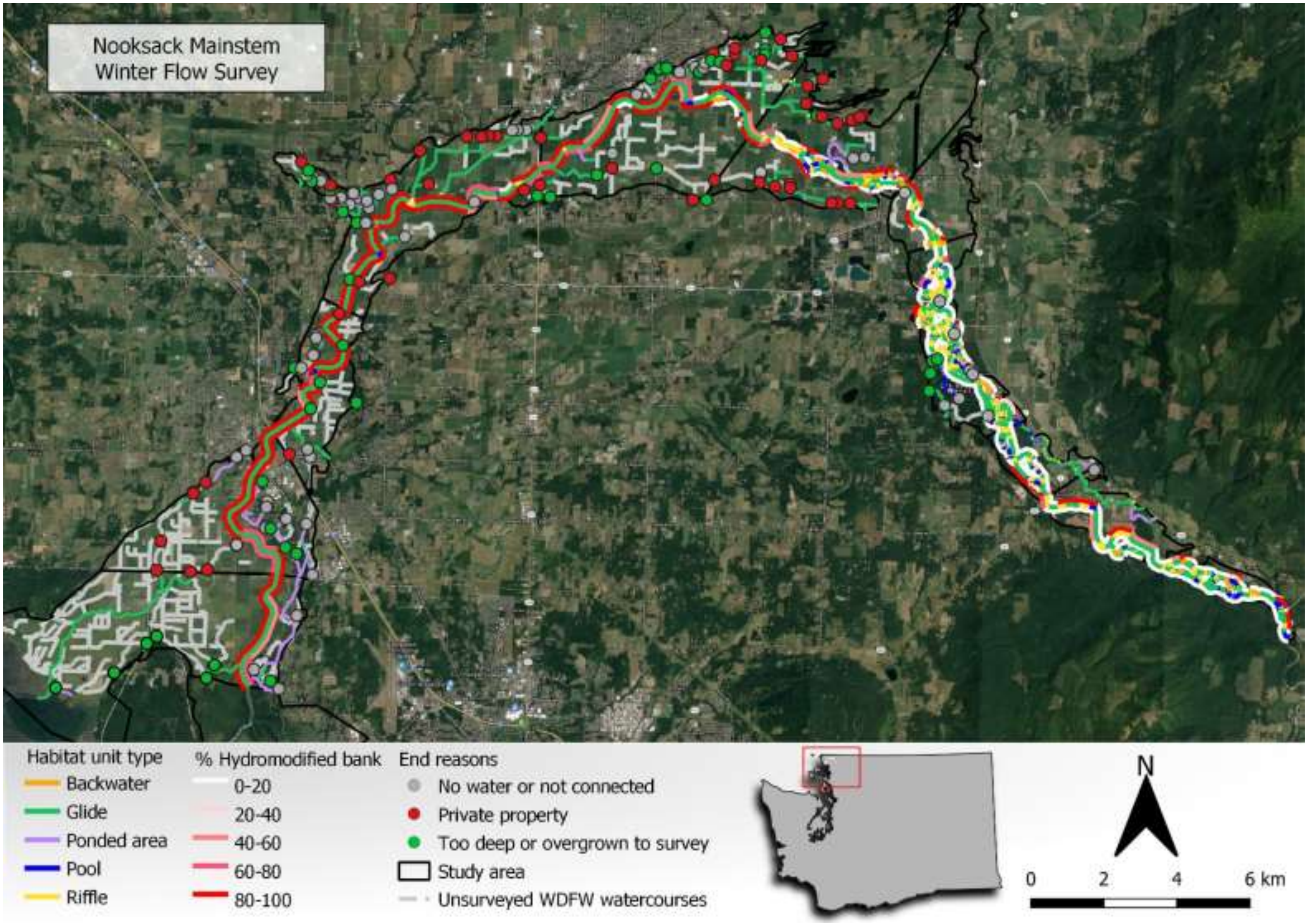

Figure 12: Nooksack mainstem habitat units and hydro-modified bank edges during winter flow surveys. Percent hydro-modified banks are derived from field estimated proportions of edge type for each bank per habitat unit, and therefore specific edge types do not have start or stop points within each mapped unit. See **Appendix B** for more detailed reach-scale maps.

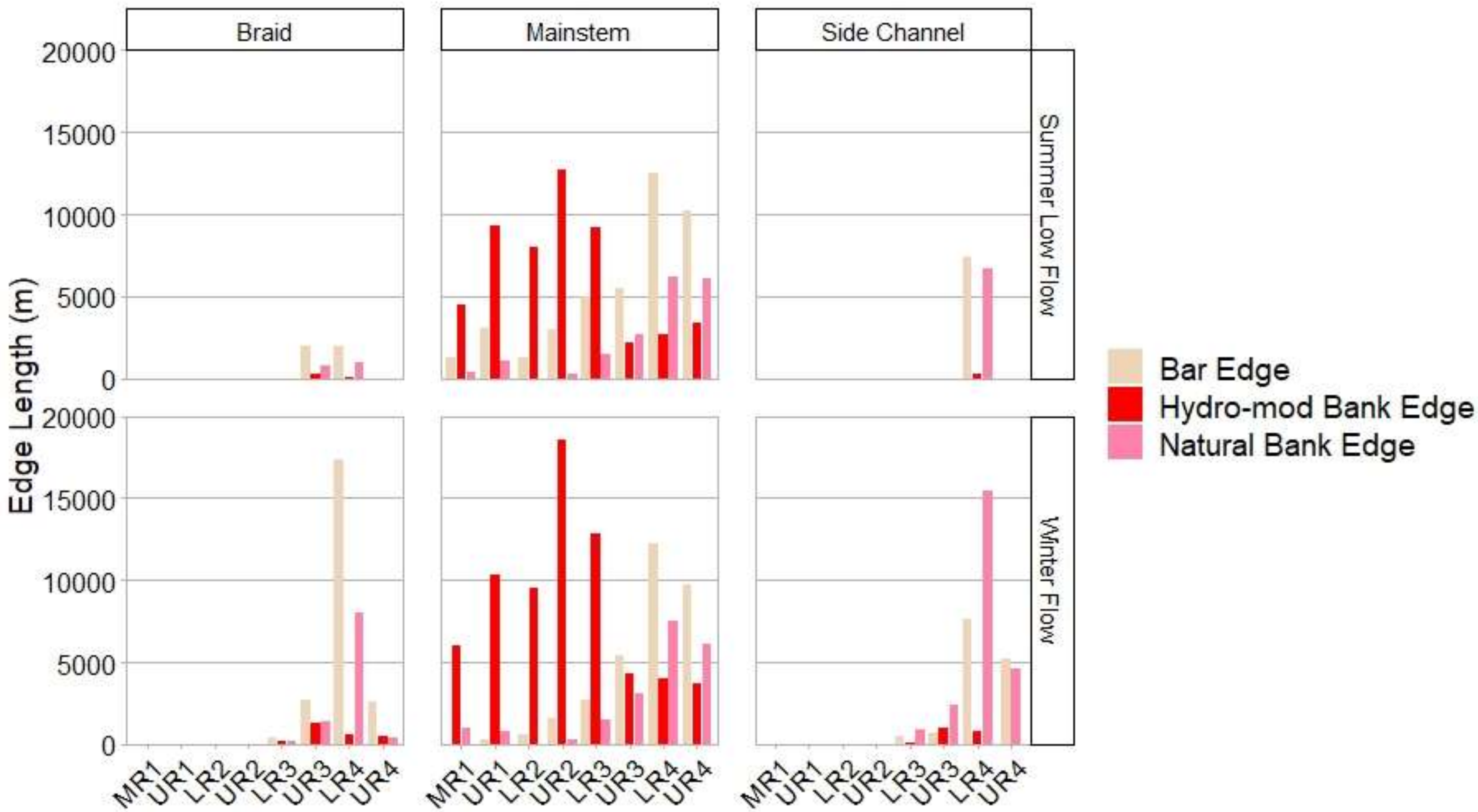

Figure 13: Bank edge type lengths (meters) by reach (LR = Lower Reach, MR = Middle Reach, and UR = Upper Reach) and channel type measured during summer low flow and winter flow surveys. Mainstem channels refer to main channels of the mainstem, braid and side channels were surveyed where visibly hydrologically connected. These summaries are based on census surveys of mainstem habitats for both flow periods and are not based on estimated data.

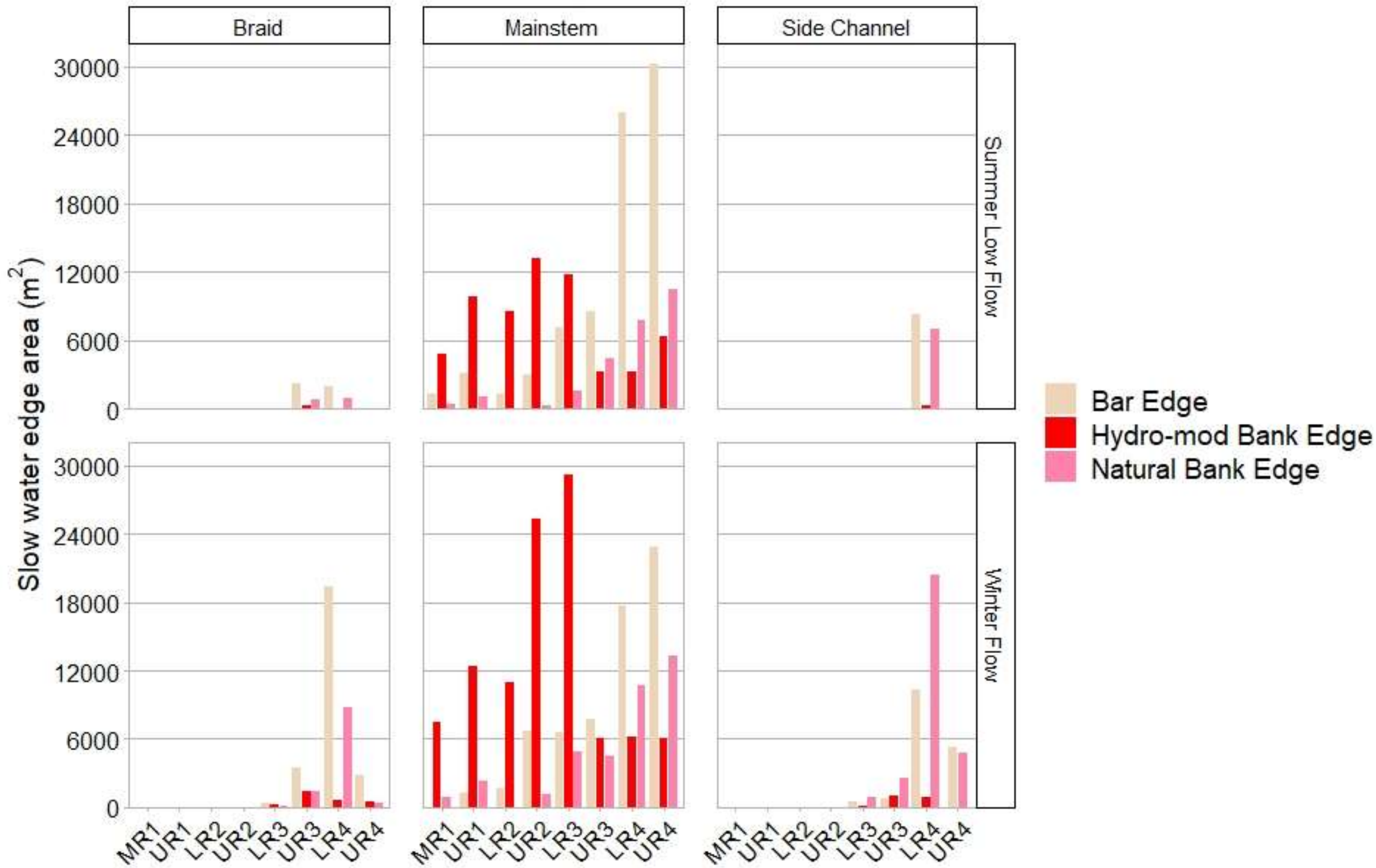

Figure 14: Bank edge type slow water areas (meters^2) by reach and channel type measured during summer low flow and winter flow surveys. Mainstem channels refer to main channels of the mainstem, braid and side channels were surveyed where visibly hydrologically connected. These summaries are based on census surveys of mainstem habitats for both flow periods and are not based on estimated data.

Table 6: Total lengths (meters) and slow water area (meters^2) for edge types for summer low flow and winter flow surveys of mainstem habitats. Mainstem channels refer to main channels of the mainstem, braid and side channels were surveyed where visibly hydrologically connected. These summaries are based on census surveys of mainstem habitats for both flow periods and are not based on estimated data.

		Summer Low Flow		Winter flow	
		Length (meters)	**Slow Water Area (meters^2)**	**Length (meters)**	**Slow Water Area (meters^2)**
Mainstem	Natural Bar Edge	41,912	80,480	32,500	64,546
	Natural Bank Edge	18,214	25,893	20,233	37,736
	Hydro-modified Bank Edge	51,864	61,017	69,331	103,553
	Total	111,990	167,389	122,064	205,835
Braid	Bar Edge	3,981	4,187	23,086	26,094
	Natural Bank Edge	1,792	1,792	10,050	10,794
	Hydro-modified Bank Edge	355	355	2,555	2,791
	Total	6,128	6,334	35,690	39,679
Side Channel	Bar Edge	7,356	8,303	14,031	16,921
	Natural Bank Edge	6,734	6,994	23,436	28,702
	Hydro-modified Bank Edge	295	295	1,980	1,980
	Total	14,385	15,592	39,447	47,602

Glides were the dominant habitat unit type observed in main channel, side-channel, and braid habitats during winter and summer low flow surveys (**Table 7**; **Figure 15**). In both winter and summer low flow surveys, glides comprised of 67 - 68% of total habitat length across all mainstem channel types (mainstem, side channel, and braid). However, glides were more predominant in main channel habitats compared to side-channel and braid habitats, with glides accounting for 80% of the total habitat surveyed in mainstem channels (**Figure 15**).

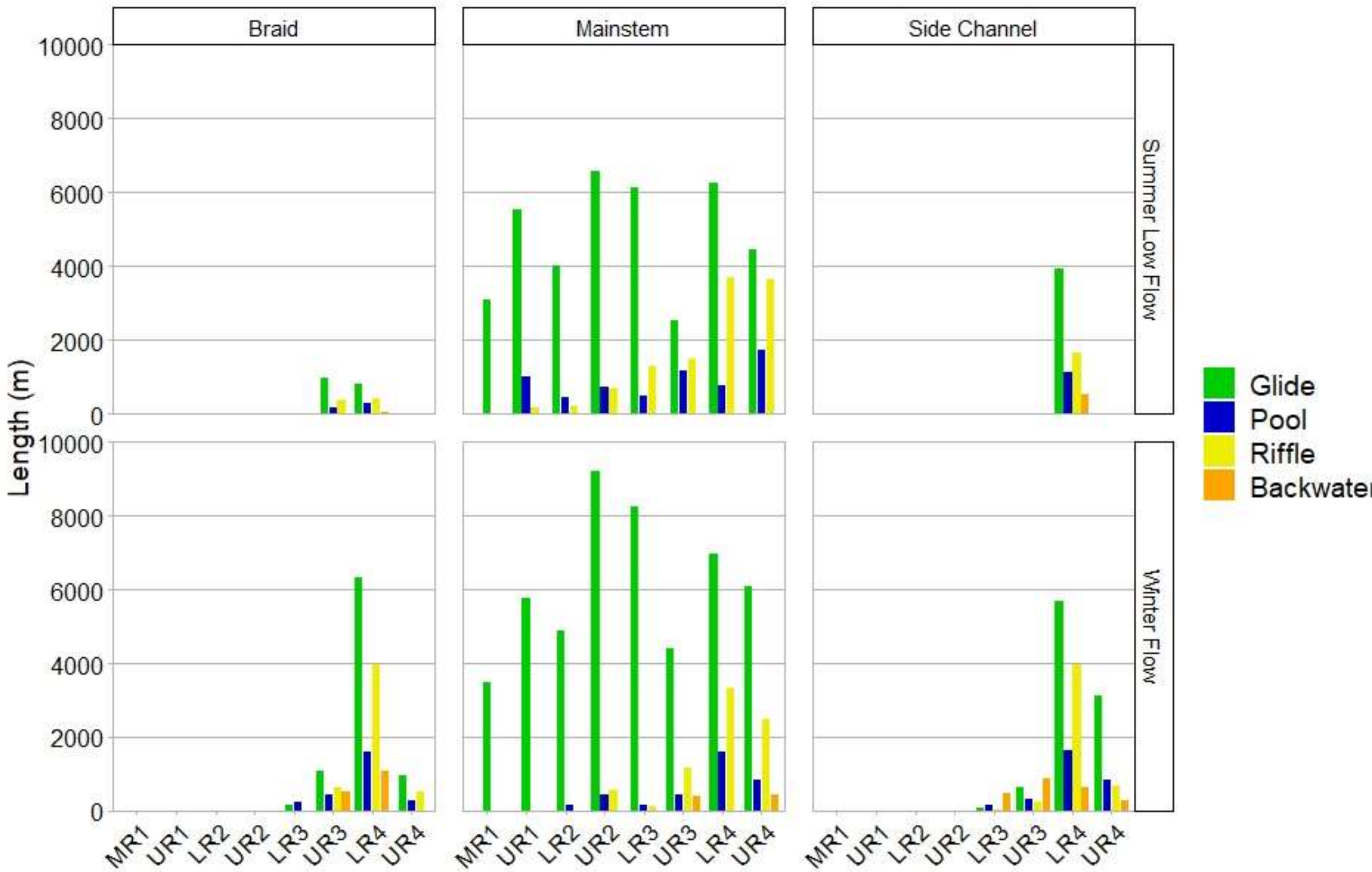

Figure 15: Habitat unit type lengths (meters) by reach and channel type measured during summer low flow and winter flow surveys. Mainstem channels refer to main channels of the mainstem, braid and side channels were surveyed where visibly hydrologically connected. These summaries are based on census surveys of mainstem habitats for both flow periods and are not based on estimated data

Table 7: Total length (meters) and area (meters^2) in habitat unit types for channel types for summer low flow and winter flow surveys of mainstem habitats. Mainstem channels refer to main channels of the mainstem, braid and side channels were surveyed where visibly hydrologically connected. These summaries are based on census surveys of mainstem habitats for both flow periods and are not based on estimated data.

		Summer Low Flow		Winter flow	
		Length (meters)	Area (meters^2)	Length (meters)	Area (meters^2)
Mainstem	Glide	38,546	2,394,164	48,979	3,444,311
	Pool	6,330	334,662	3,624	202,479
	Riffle	11,119	686,199	7,599	535,657
	Backwater	-	-	830	15,429
	Total	55,995	3,415,024	61,032	4,197,876
Braid	Glide	1,802	53,917	8,523	136,838
	Pool	462	11,453	2,549	44,025
	Riffle	775	22,250	5,169	85,473
	Backwater	25	113	1,603	24,589
	Total	3,064	87,732	17,845	290,925
Side Channel	Glide	3,908	93,506	9,530	201,949
	Pool	1,120	17,619	2,950	51,066
	Riffle	1,654	38,794	4,938	180,988
	Backwater	510	4,867	2,306	32,242
	Total	7,192	154,786	19,723	466,245

Pool habitats accounted for only 12% of combined mainstem channel habitat lengths during summer low flows (main channel, braid, and side channel combined). The proportion of pool habitat and total pool habitat unit length decreased in winter flow surveys as compared to summer for mainstem channel habitats (**Figure 15**). Pools accounting for just 9% of mainstem habitats lengths (mainstem, braid, and side channel combined) in winter flow surveys. Main channel of the mainstem pool habitat unit length in winter flows was reduced by 40% from summer low flow lengths. The proportion side channel and braid habitat length occupied by pools remained at about 15% between surveys, although total pool habitat length increased in side-channel and braid habitats in winter flow surveys relative to summer low flow surveys (**Table 7**; **Figure 15**). Pools were most frequent in Lower and Upper Reach 4 for both seasons and pool spacing was the lowest in Upper Reach 4 in winter flow surveys (**Table 8**). Backwater habitats were not observed in main channels of the mainstem in summer low flow surveys and accounted for less than 5% of habitat unit length for side-channel and braid habitats and 1% of overall mainstem channel length (main channel, braid, and side channel combined). During winter flows, both the total length and proportional length of backwater habitats increased although backwater habitat units accounted for less than 5% of the total combined mainstem channel length (main, braid, and side channel, combined) (**Table 7**; **Figure 15**).

Table 8: Pool counts and pool spacing (channel widths per pool), calculated according to Montgomery et al. (1995) for mainstem channel types for Summer Low Flow and Winter Flow surveys. Mainstem channels refer to main channels of the mainstem, braid and side channels were surveyed where visibly hydrologically connected.

		Summer Low Flow		Winter Flow	
		Pool Count	**Pool Spacing**	**Pool Count**	**Pool Spacing**
Middle Reach 1	Mainstem	0	-	0	-
	Braid	-	-	-	-
	Side Channel	-	-	-	-
Upper Reach 1	Mainstem	2	53.7	0	-
	Braid	-	-	-	-
	Side Channel	-	-	-	-
Lower Reach 2	Mainstem	2	54.5	1	87.5
	Braid	-	-	-	-
	Side Channel	-	-	-	-
Upper Reach 2	Mainstem	5	31.2	2	91.7
	Braid	-	-	-	-
	Side Channel	-	-	-	-
Lower Reach 3	Mainstem	2	92.1	1	107.6
	Braid	-	-	5	7.3
	Side Channel	-	-	4	24.9
Upper Reach 3	Mainstem	8	13.6	2	107.4
	Braid	2	25.4	9	26.3
	Side Channel	-	-	7	24.0
Lower Reach 4	Mainstem	7	32.3	7	33.3
	Braid	7	12.3	40	28.0
	Side Channel	22	22.6	32	25.4
Upper Reach 4	Mainstem	10	18.2	5	26.4
	Braid	-	-	4	27.5
	Side Channel	-	-	26	18.4

Given the large time frame over which our surveys occurred, canopy cover estimates do not likely accurately represent a winter and summer time frame. However, canopy cover was minimal in both winter flow and summer low flow surveys. Average canopy cover in main channels of the mainstem channels was less than 2% for both surveys. Average canopy cover was substantially higher in braid and side-channel units in winter flow surveys (12.4% and 11.6%, respectively), likely due to increased connectivity of shaded and overgrown channels and that surveys were completed as late as May to capture higher flows. Average canopy cover in braid and side channels in summer low flow surveys, which took place in March, was 2.4% and 3.1%, respectively.

Mainstem sediment was only recorded in side channels where depths and flows permitted visual assessment; water clarity, depths, and velocities throughout most of the mainstem habitats prevented rapid sediment assessment. During summer low flow surveys, side channels were only observed in Lower Reach 4, and substrates were dominated by gravel where substrates were visible. During winter flow surveys, substrates in Lower Reach 4 side channels were roughly equally composed of gravel, sand, and fines. Side channels observed in Upper Reach 4, Upper Reach 3, and Lower Reach 3 during winter flow surveys were dominated by fines. Although substrate composition, transport, and storage are important aspects of habitat formation and quality for salmon, detailed analyses and assessment of sediment and substrate were outside the scope of this assessment. More information on sediment and substrate for the Lower Mainstem Nooksack River study area can be found Anderson et al. (2019) and Boyd et al. (2019).

Large wood jams were observed throughout the mainstem survey extent except in Lower Reach 2 (**Figure 16**). Jams were more frequent and provided more wetted cover in winter surveys, which was not surprising given that higher flows led to increased channel length connected and increased channel width (**Table 9**). In summer low flow surveys, large wood was the most abundant and provided the largest area of wetted cover in main channels of the mainstem. In winter flow surveys, jams were most frequent in side channels but provided the most wetted cover in braided channels. Large wood jams were most abundant in the upper reaches of the Nooksack mainstem, with the most wood and wetted cover area being present in Lower Reach 4 in both seasons. Log jams in Upper Reach 3 and Lower and Upper Reach 4 accounted for approximately 93% of the total jams observed and provided 95% of the wetted cover in winter surveys and 93% of the cover in summer low flow surveys. Wood was lacking throughout the lower reaches. In both winter and summer low flow surveys, no qualifying wood jams were observed in Lower Reach 2. Given the presence of hydro-modified banks that constrain channel migration (an important mechanism for delivery of large wood) and the lack of canopy, there did not appear to be sufficient slow water area to collect and rack log jams along banks or sources of LWD provided from the riparian.

Table 9: Mainstem wood counts (meters) and wetted jam areas (meters^2) by channel type for summer low flow and winter flow surveys. Mainstem channels refer to main channels of the mainstem, braid and side channels were surveyed where visibly hydrologically connected.

		Summer Low Flow		Winter Flow	
		n	Wetted Jam Area (meters^2)	n	Wetted Jam Area (meters^2)
Mainstem	Glide	36	10,135	42	4,033
	Pool	11	3,449	10	590
	Riffle	23	4,317	21	1,807
	Backwater	-	-	1	430
	Total	70	17,901	74	6,860
Braid	Glide	5	1,565	32	7,392
	Pool	2	176	29	2,954
	Riffle	1	83	21	4,754
	Backwater	1	11	10	1,196
	Total	9	1,834	92	16,296

Side Channel	Glide	20	2,484	48	2,615
	Pool	14	1,069	30	3,009
	Riffle	7	608	28	2,154
	Backwater	0	0	9	2,880
	Total	41	4,161	115	10,657

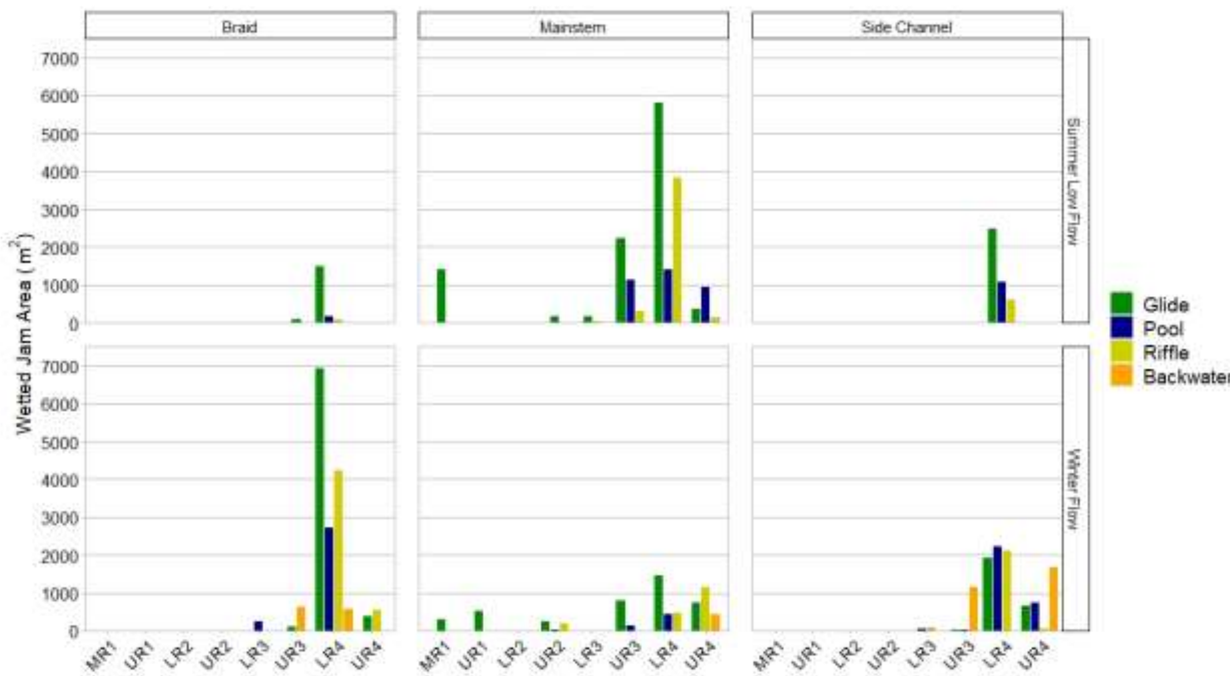

Figure 16: Wetted jam area (meters^2) for large woody debris jams by reach for summer low flow and winter flow surveys for mainstem, braids, and side channels. Mainstem channels refer to main channels of the mainstem, braid and side channels were surveyed where visibly hydrologically connected.

Floodplain Habitats:

Floodplain habitat in the Lower Mainstem Nooksack River study area was estimated to cover a total of 194.6 km in length, of which 85.8 km, or 44% of the total length, were surveyed in winter flows. Floodplain surveys were ended where the channel could not be accessed, most commonly due to overgrown vegetation or private property (**Figure 17**), and thus the remaining 108.7 km of watercourse length was estimated using the WDFW hydrography regulatory layer. Hydro-modified natural channels accounted for the majority of surveyed channel length, followed by tributaries (**Figure 18**). Most channels within the floodplain have a straightened appearance and primarily function as a drainage network for the floodplain, which is highly developed with agricultural land uses (**Figure 12**). Glides were the dominant habitat unit type across floodplain channels, making up 70% of the habitat unit types surveyed, followed by ponded areas at 24% (**Figure 18**). Pool and riffle units comprised only 4% and 2% of habitat units surveyed across the study area, respectively (**Figure 18**).

Figure 17: Example of an overgrown stream that was unable to be surveyed (left) and a stream that was not surveyed due to lack of private property access (right).

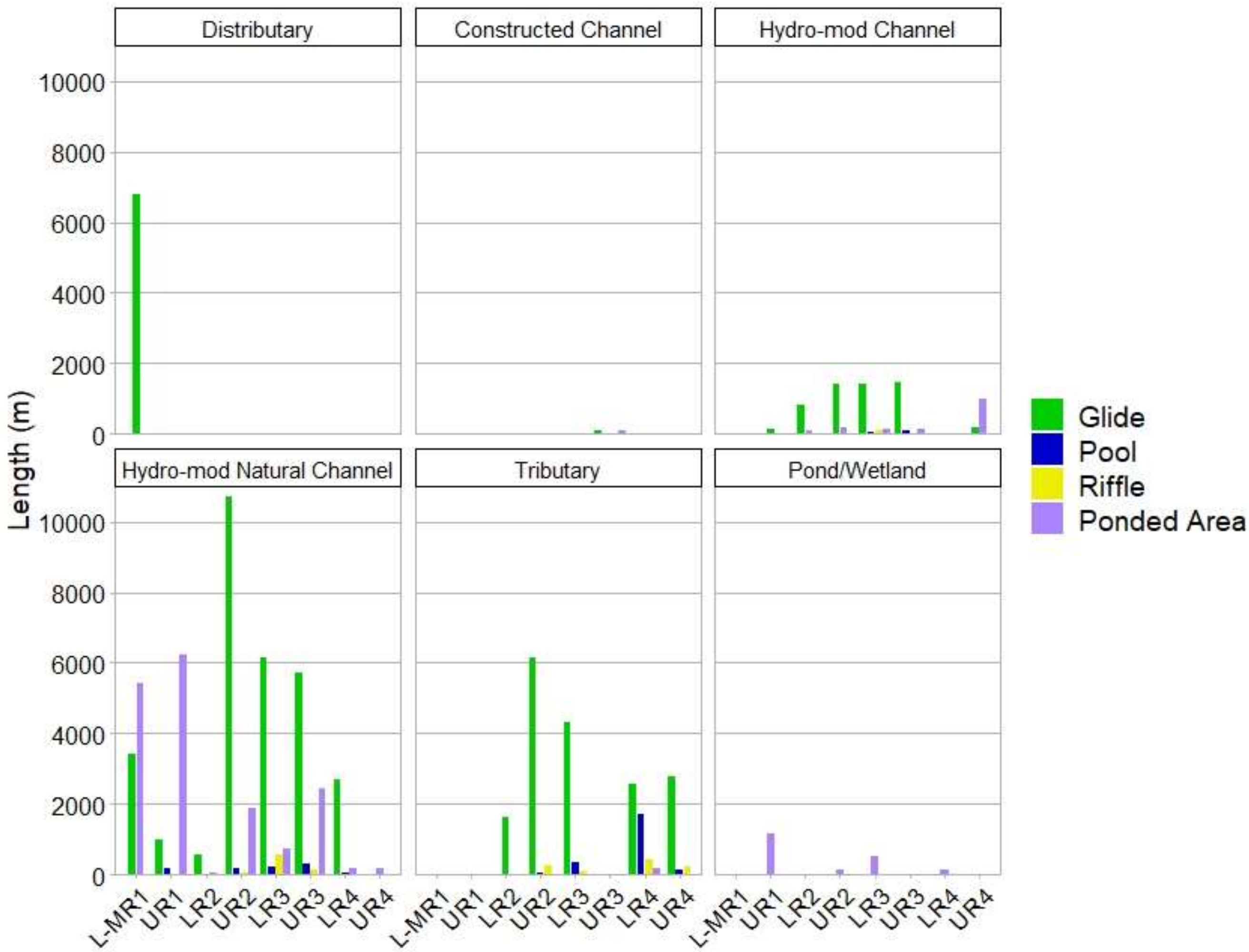

Figure 18: Lengths (meters) of floodplain channel types and habitat unit types by reach surveyed during winter flows.

Summer floodplain habitats were not surveyed extensively, and our estimates of summer low flow habitat rely on targeted validation surveys. Only 19% of the total floodplain habitat length as calculated from the WDFW regulatory layer, was surveyed in summer low flow surveys. These surveys indicate that total wetted floodplain habitat length is reduced by about 50% from winter to summer but varies with channel type (see **Appendix B** for detailed results from validation surveys). Validation surveys of channels that were wetted during winter flow surveys found that roughly 50% of hydro-modified natural channels were dry in summer surveys, 37% of tributary channels, 90% of hydro-modified channels, and 90% of constructed channels were dry during summer low flow conditions. A reduction in wetted habitat area was also observed in summer validation surveys, in terms of both dry channels and reduced wetted width. Total loss in wetted area was estimated to be 50% for hydro-modified natural channels, 69% for tributaries, and 84% for hydro-modified and constructed channels (**Figure 19**). Wetland habitats were estimated using the United States Fish and Wildlife Service (USFWS) National Wetlands Inventory data (NWI) wetlands layer (USFWS 2017), summer habitat reductions could not be calculated using CFS collected data, and thus Collins and Sheikh (2004) data were used to calculate summer wetland habitat. Collins and Sheikh estimated roughly 38% of habitat area wet in the winter was dry in the summer, which is comparable to our observed estimates which ranged from 40-60% (**Table 71**). Detailed methods for comparison are included in **Appendix B**.

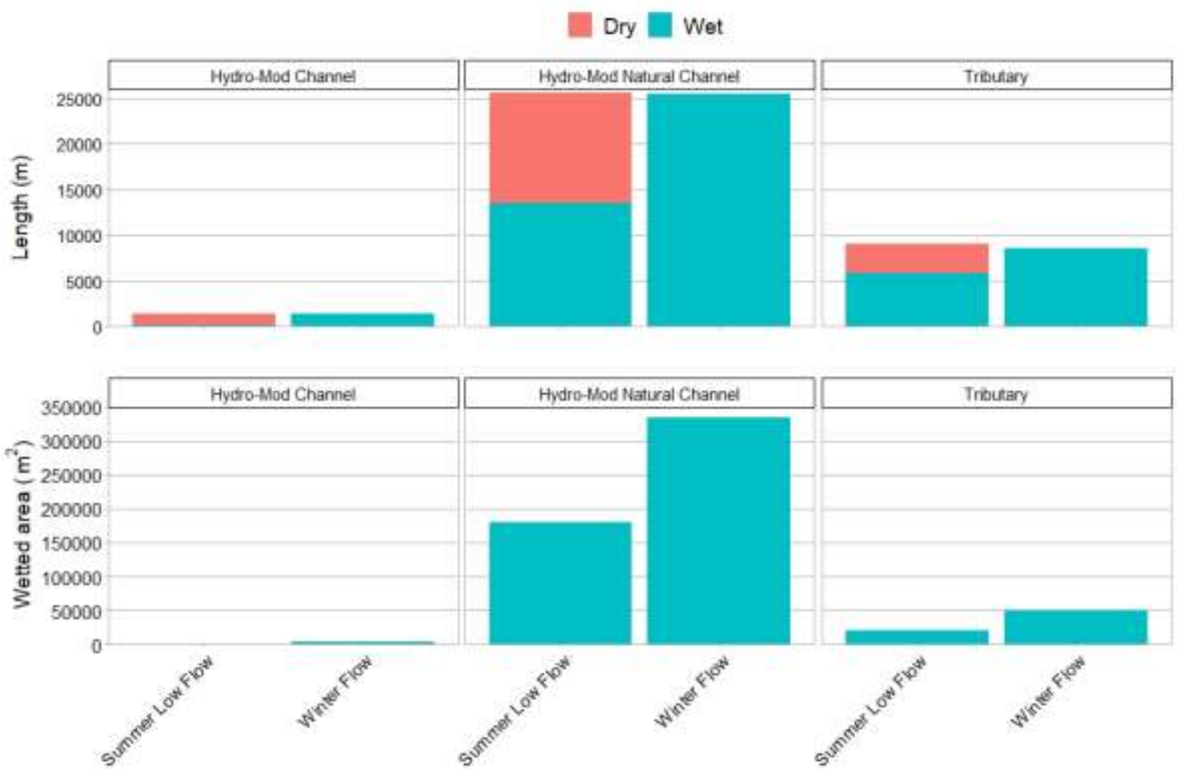

Figure 19: Lengths (meters) and areas (meters^2) of verification surveys performed in the same location during Summer Low Flow and Winter Flow conditions. Lengths of wet and dry channels are shown in meters.

Canopy closure for floodplain channel habitats was generally low (23%), with estimated canopy closure being highest (26%) in hydro-modified natural channel units and lowest in constructed channel units (6%). Canopy closure was highest in Upper Reach 4 floodplain habitats where average channel cover was 54%. There were only 150 large wood jams observed in the floodplain channels, providing 3,874 m^2 of wetted cover. Large woody jams were most frequent in Lower Reach 4, where 36 were observed, providing 1,064 m^2 of cover.

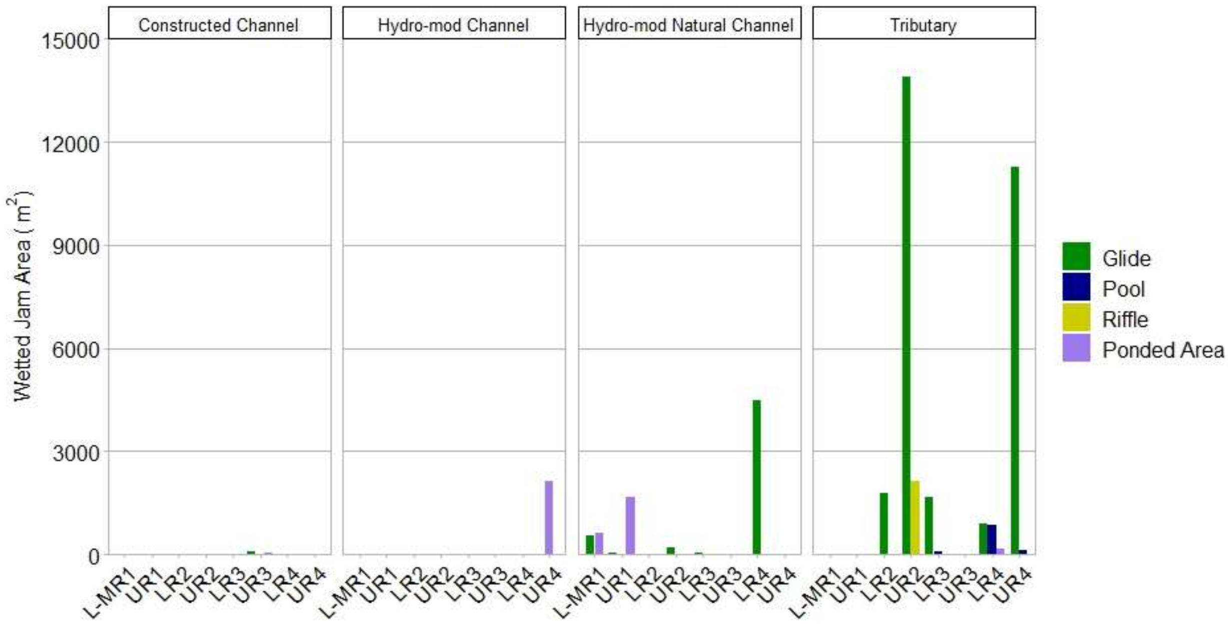

Figure 20: Wetted jam area (meters^2) for large woody debris jams by reach for winter flow surveys for constructed, hydro-modified, hydro-modified natural, and tributary channels.

Substrate in the floodplain channels were dominated by fines throughout the study area. Substrate estimates in constructed channels, distributaries, and pond and wetland habitats observed 100% dominance of fine sediment. Both hydro-modified channels and hydro-modified natural channels had over 80% fine sediment. Tributary channels had the highest diversity in sediment composition as compared to other channel types (**Figure 21**).

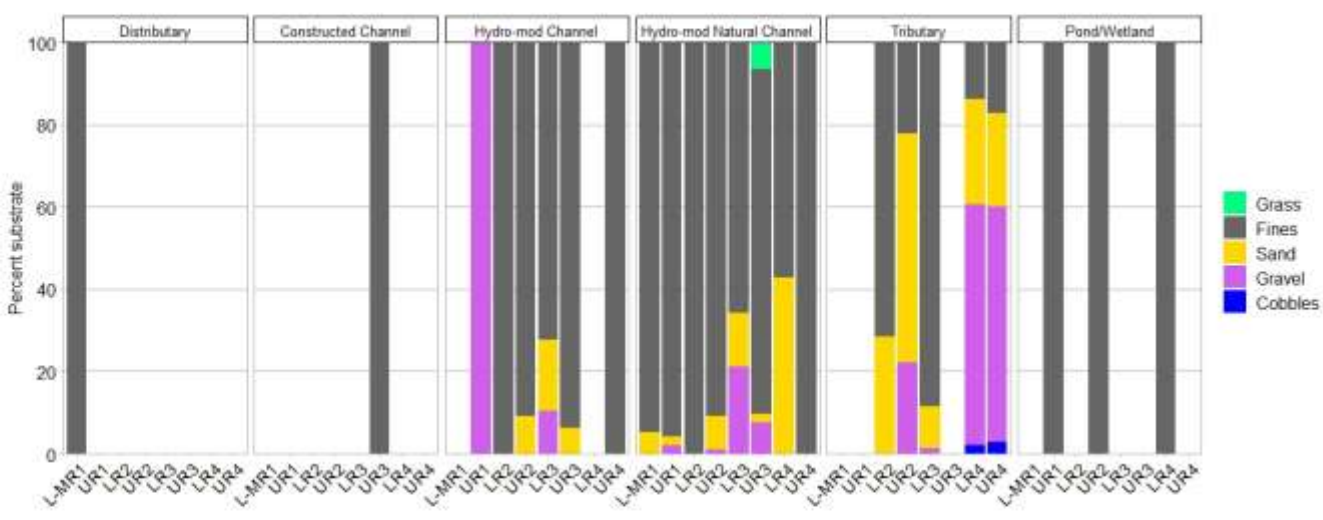

Figure 21: Percent of substrate observations by reach for floodplain channel types.

Estuary Habitats:

This assessment included only cursory surveys of estuary and delta habitats within the lower reaches of the study area. We rely on previous work to describe current conditions of estuary and tidally influenced habitats that represent conditions circa 2013 (Beamer et al. 2016). For this assessment, we only summarize distributary, tidal channels, and tidal marsh areas as reported in Beamer et al. (2016) to support comparisons to historical conditions and juvenile rearing capacity estimates (**Figure 22**). The mainstem Nooksack River and its distributaries account for most of the channel area in the estuary (65%), although considerable tidal channel habitat area was documented (35%) (**Figure 22**; **Figure 23**). Most estuary habitat is associated with the mainstem Nooksack River distributary and its delta draining into Bellingham Bay, while the Lummi Bay delta and its distributaries are less connected to the mainstem river (Beamer et al. 2016; Boyd et al. 2019) (**Table 31**; **Figure 22**; **Figure 91**). High sediment loading and concentration of flows through the mainstem distributaries have resulted in extensive progradation of the delta and growth of associated tidal marsh habitats in the Bellingham Bay delta (Beamer et al. 2016; Boyd et al. 2019). Most of the current tidal marsh habitats are associated with the mainstem Nooksack River distributary that drains into Bellingham Bay (78%), although tidal marsh habitats are associated with the other distributary and slough systems in the estuary. However, most of the geomorphic tidal delta footprint is disconnected from tidal flooding as a result of diking and land conversion (Beamer et al. 2016; Boyd et al. 2019), especially on the Lummi Bay distributary lobe of the delta (**Figure 23**).

Figure 22: Habitat areas in kilometers^2 for tidally influenced habitat areas for Lower and Middle Reach 1 as reported in Beamer et al. (2016) that represent current conditions circa 2013. These summaries do not include any habitat surveyed within these reaches as part of this assessment. Tidal channels include tidal and blind tidal channels that are not part of the distributary network. Habitat type codes are EEM = Estuarine Emergent Marsh, ESS = Estuarine Scrub-Shrub, and FRT = Forested Riverine Tidal.

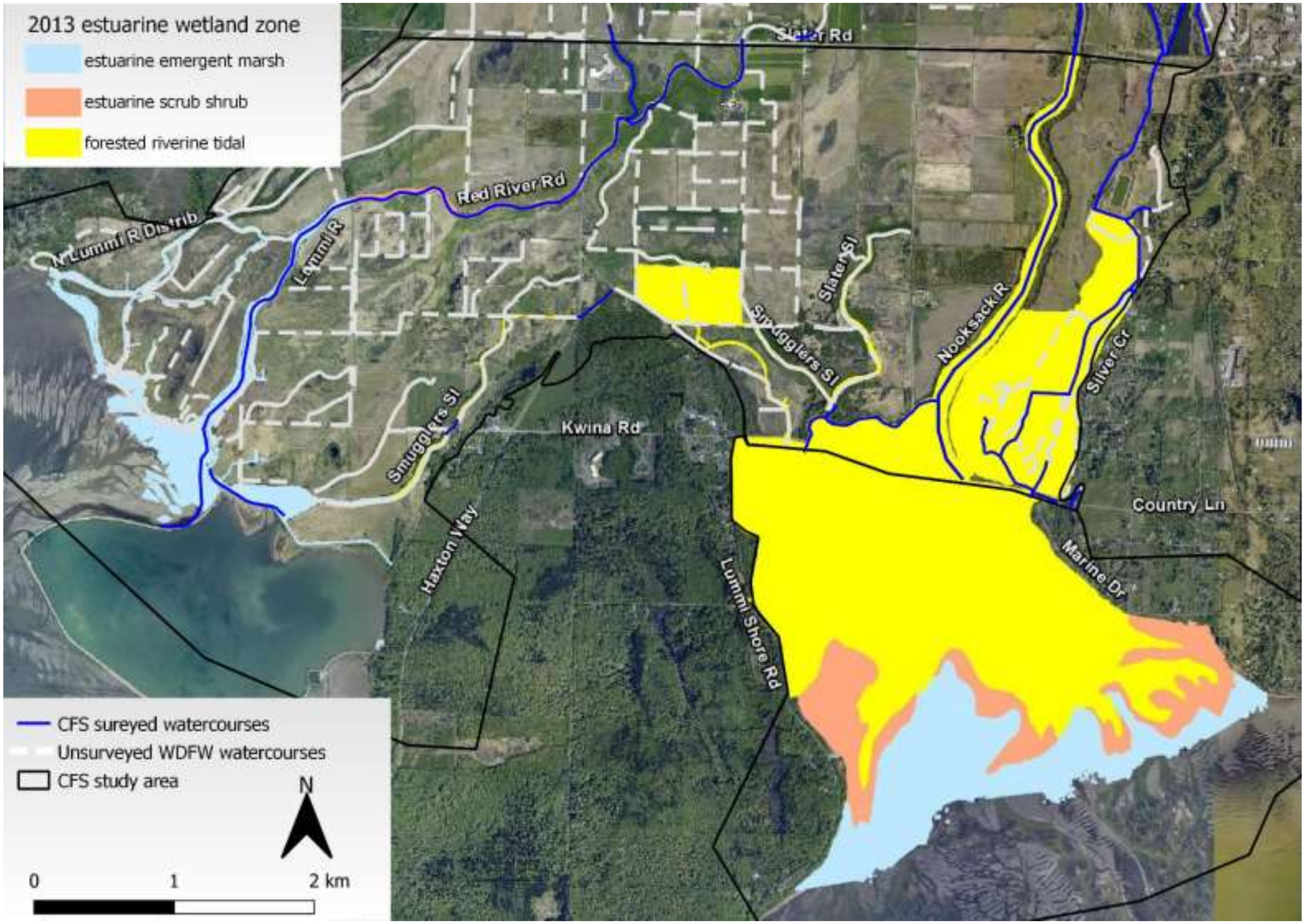

Figure 23: Map from Beamer et al. (2016) showing estuary habitat mapping extent and estuarine zones. Note: Map is taken directly from Beamer et al. 2016. and overlaid with channels surveyed during 2018-2019 CFS surveys and unsurveyed WDFW watercourses.

Historic and Current Habitat Comparisons:

Mainstem Habitats:

There has been an overall reduction of habitat for mainstem channels from historical reconstructions (**Figure 24**). Habitat loss for summer low flow conditions compared to historical reconstructions were most pronounced (**Figure 25**). Current mainstem edge lengths, including main channels of the mainstem, braids, and side channels, were reduced in summer low flows as compared to historic conditions. However, main channel habitat edge lengths were slightly higher under current conditions during winter flows compared to historical conditions (**Table 10**; **Figure 26**). Overall slow-water edge area was reduced for both flow periods in main channels of the mainstem as compared to historic conditions and in all reaches except Upper Reach 1 in winter flow surveys, where slow water area was slightly higher in present day surveys (**Table 10**; **Figure 27**).

In the mainstem summer low flow survey, including main channels of the mainstem and braids and side channels, all reaches except one experienced a loss in total channel length, and all reaches experienced reductions in total slow-water area in present day as compared to 1880s conditions (**Figure 25**). In the winter surveys, Upper Reach 1, Upper Reach 3, and both Lower and Upper Reach 4 were found to have increased total mainstem channel lengths, including main channels, braids, and side channels, as compared to 1880s estimates. This finding could be the result of our current survey resolution being higher than historical reconstructions rather than an actual increase in channel length relative to historical conditions. Increases in slow-water area in the winter flow surveys were only observed in Upper Reach 1 and Lower Reach 4 (**Figure 27**).

No braid or side-channel habitat was observed in the current surveys of Reaches 1 and 2, while historical reconstructions indicate that braid and side-channel habitats did occur in these reaches under a historical setting. The current lack of side-channel and braid habitats in these lower reaches is related to extensive hydromodification of bank edges and confinement of the channel to a single-thread channel system. Reductions in habitat with respect to historic conditions were also pronounced in summer low flow surveys, where braid and side-channel habitat were absent in Upper Reach 4, and side-channel habitat was lacking in Upper Reach 3. In winter surveys, there were increases in slow-water edge area and length observed for braid and side-channel habitat in Upper Reach 3, and Lower and Upper Reach 4 in present day surveys as compared to historic conditions. These increases may also be due to increased survey resolution for current surveys compared to historical reconstructions.

A large deviation from historic condition is the presence of hydro-modified banks in present day channels. No historic data were available for bank types for braids and side channels. In main channels of the mainstem, hydro-modified banks were observed in all reaches in present day surveys, while they were assumed to be completely absent in the 1880s. Hydro-modified banks accounted for a high proportion of total bank length in Reaches 1 and 2 and Lower Reach 3. Natural bank edge length and slow water area was less in present day surveys as compared to historic conditions across reaches and seasons. Additionally, there has been a loss of summer bar edge habitat length and area in present day surveys as compared to historic conditions. Winter bar edge habitat length and slow water area was comparable across reaches in present conditions as compared to estimates from historic reconstructions.

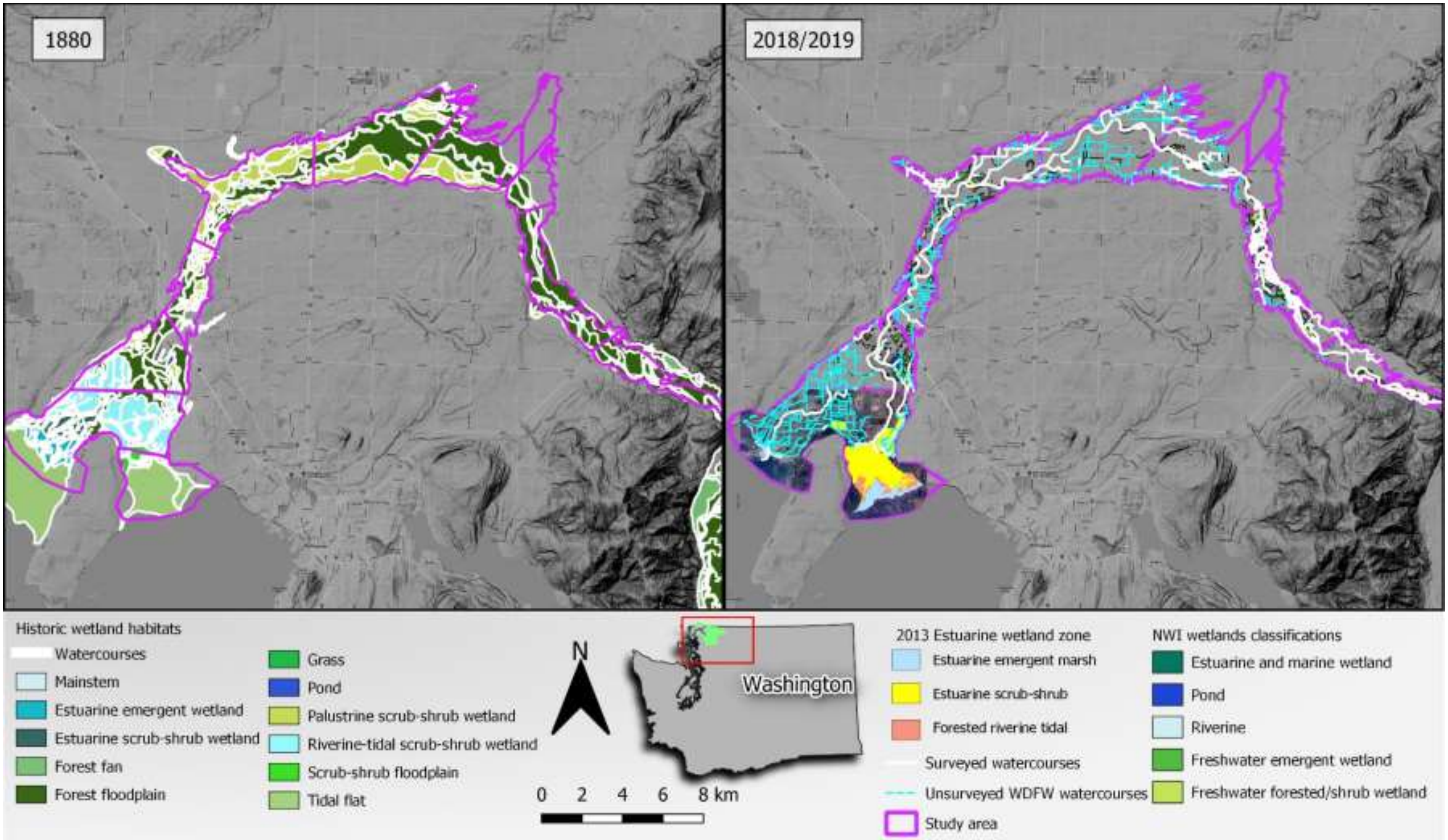

Figure 24: Map of current winter habitat and historical winter habitat extents (Collins and Sheikh) for the Lower Nooksack River study area. Surveyed watercourses and unsurveyed watercourses from current surveys are depicted, current wetland habitats are from the U.S. Fish and Wildlife Service National Wetlands Inventory (2017). See Reach Conditions section for reach scale maps for more detail.

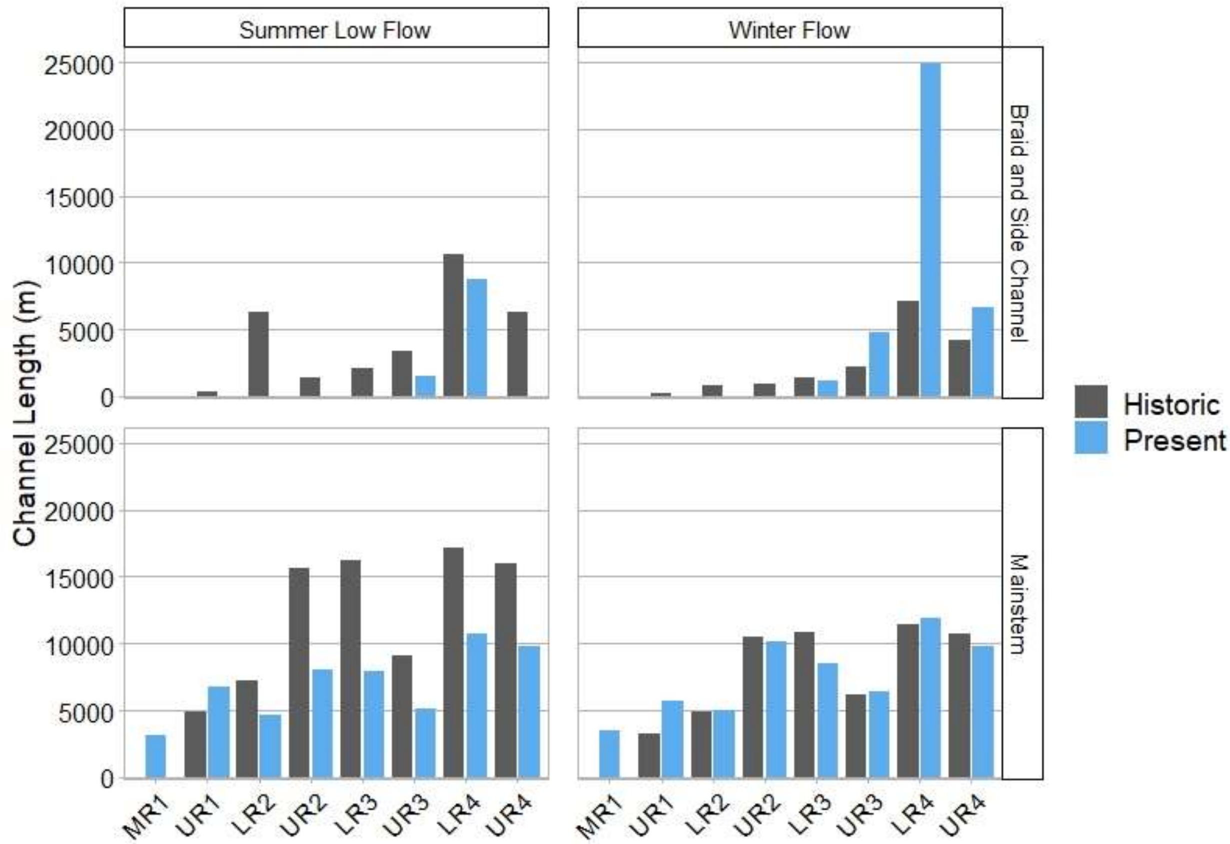

Figure 25: Channel lengths (meters) for braid and side-channel and mainstem habitats for historic versus present surveys. Mainstem channels refer to main channels of the mainstem.

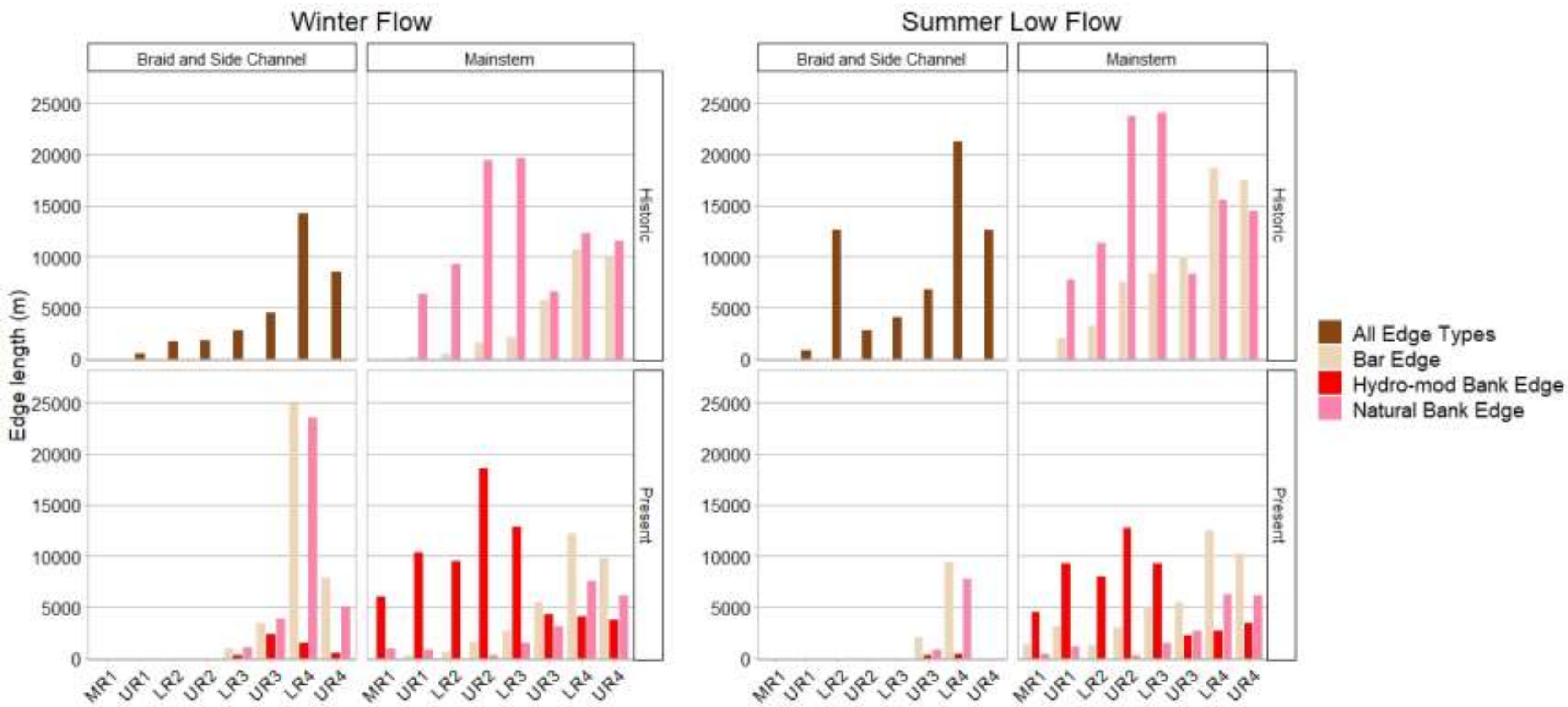

Figure 26: Edge lengths (meters) for mainstem and braid and side-channel habitats for historic and present-day estimates. Mainstem channels refer to main channels of the mainstem.

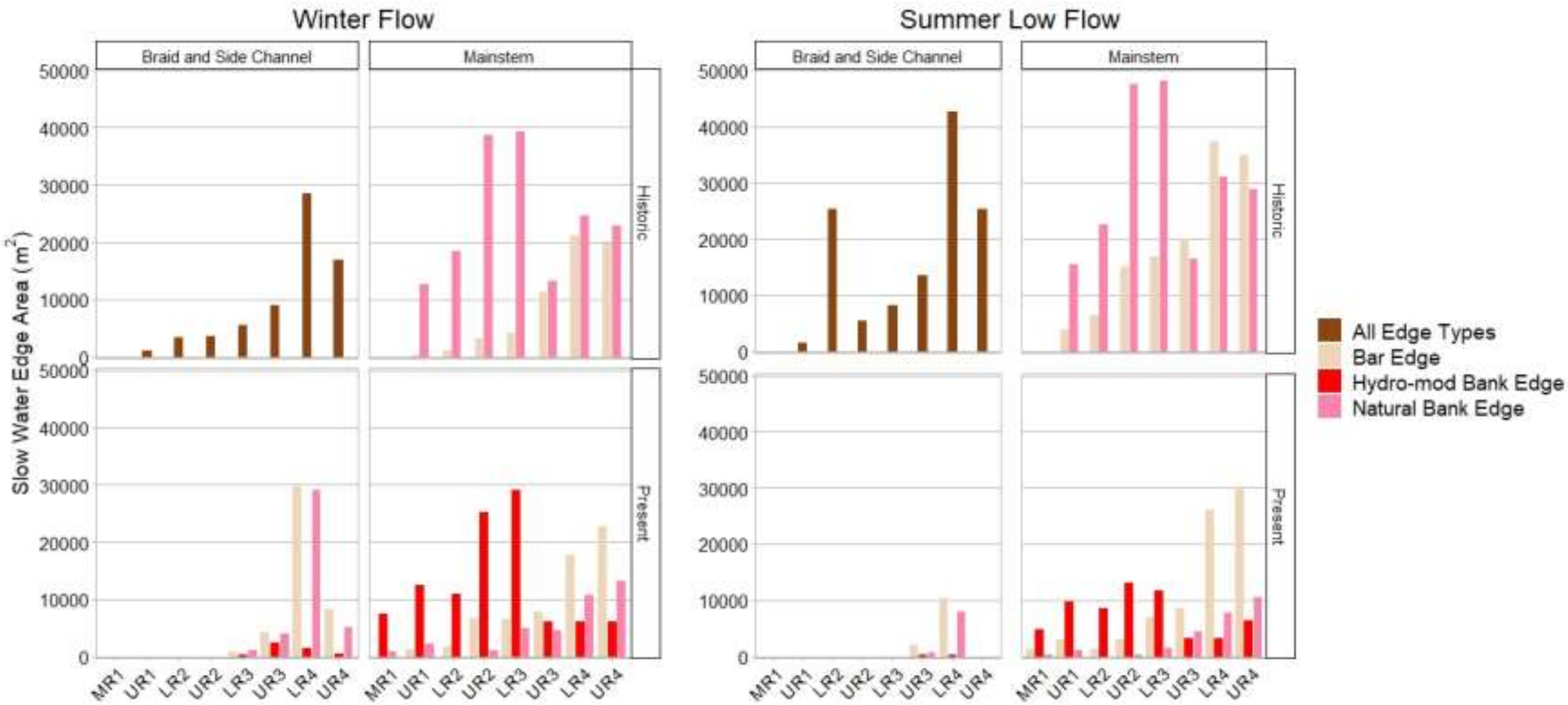

Figure 27: Slow water edge areas (meters^2) for mainstem and braid and side-channel habitats for historic and present-day estimates.

Table 10: Edge lengths (meters) and slow water habitat area (meters^2) in braid and side channels and mainstem channels in summer low flow and winter flows in historical reconstructions (circa 1880s) and present-day surveys. Mainstem channels refer to main channels of the mainstem.

			Braid and Side-Channel		Mainstem					
					Natural Bar		Hydro-modified Bank		Natural Bank	
			Slow Water Area (meters^2)	Edge Length (meters)	Slow Water Area (meters^2)	Edge Length (meters)	Slow Water Area (meters^2)	Edge Length (meters)	Slow Water Area (meters^2)	Edge Length (meters)
Upper Reach 1	Winter	Historic	1,062	531	354	177	0	0	12,644	6,322
		Present	0	0	1,254	301	12,406	10,374	2,326	815
	Summer	Historic	1,585	793	3,921	1,960	0	0	15,480	7,740
		Present	0	0	3,079	3,079	9,834	9,254	1,099	1,099
Lower Reach 2	Winter	Historic	3,383	1,692	1,007	503	0	0	18,492	9,246
		Present	0	0	1,724	554	10,906	9,508	0	0
	Summer	Historic	25,265	12,633	6,466	3,233	0	0	22,636	11,318
		Present	0	0	1,293	1,293	8,523	7,974	0	0
Upper Reach 2	Winter	Historic	3,654	1,827	3,141	1,570	0	0	38,833	19,417
		Present	0	0	6,762	1,580	25,274	18,518	1,137	256
	Summer	Historic	5,453	2,727	15,115	7,558	0	0	47,532	23,766
		Present	0	0	3,007	3,007	13,196	12,703	288	288
Lower Reach 3	Winter	Historic	5,494	2,747	4,219	2,109	0	0	39,317	19,659
		Present	2,382	2,326	6,557	2,672	29,134	12,846	4,921	1,481
	Summer	Historic	8,201	4,100	16,859	8,430	0	0	48,120	24,060
		Present	0	0	7,067	5,005	11,738	9,221	1,518	1,518
Upper Reach 3	Winter	Historic	9,031	4,515	11,358	5,679	0	0	13,153	6,577
		Present	10,751	9,615	7,759	5,436	6,095	4,262	4,477	3,084
	Summer	Historic	13,478	6,739	20,009	10,005	0	0	16,575	8,287
		Present	3,280	3,074	8,495	5,485	3,270	2,196	4,430	2,649
Lower Reach 4	Winter	Historic	28,533	14,267	21,240	10,620	0	0	24,596	12,298
		Present	60,268	49,865	17,697	12,208	6,189	4,056	10,685	7,545
	Summer	Historic	42,587	21,293	37,417	18,708	0	0	30,995	15,497
		Present	18,646	17,439	26,003	12,537	3,298	2,647	7,714	6,202
Upper Reach 4	Winter	Historic	16,928	8,464	19,851	9,926	0	0	22,989	11,494
		Present	13,881	13,331	22,794	9,750	6,020	3,748	13,241	6,104
	Summer	Historic	25,265	12,633	34,971	17,486	0	0	28,969	14,484
		Present	0	0	30,219	10,189	6,398	3,371	10,487	6,100
Total	Winter	Historic	68,085	34,042	61,169	30,585	0	0	170,025	85,012
		Present	87,281	75,137	64,546	32,500	103,553	69,331	37,736	20,233
	Summer	Historic	121,835	60,918	134,759	67,379	0	0	210,307	105,153
		Present	21,926	20,513	80,480	41,912	61,017	51,864	25,893	18,214

Floodplain Habitats:

Wetland habitat area was dramatically reduced in present day surveys as compared to historic (**Table 11; Figure 24**). Reductions in wetland habitat area were observed in all reaches except Lower and Upper Reach 4 where little historic wetland area was reported (**Table 11**; **Figure 28**). However, our current surveys suggests that slough and tributary habitat area and channel length have increased relative to historical conditions (**Table 11**; **Figure 28**; **Figure 29**). This finding could be the result of differences in survey resolution from historical reconstructions and current field surveys, and channelization and construction of drainage networks on the floodplain. Much like Collins and Sheikh (2004) suggested for tidal wetlands, reconstructed freshwater wetland areas likely contained channel networks that are not captured in the mapping of channel and wetland features for the 1880s condition. Therefore, changes in tributary and slough channel areas and length from historical estimates should be evaluated carefully given the potential underestimation of channel features in the historical reconstruction.

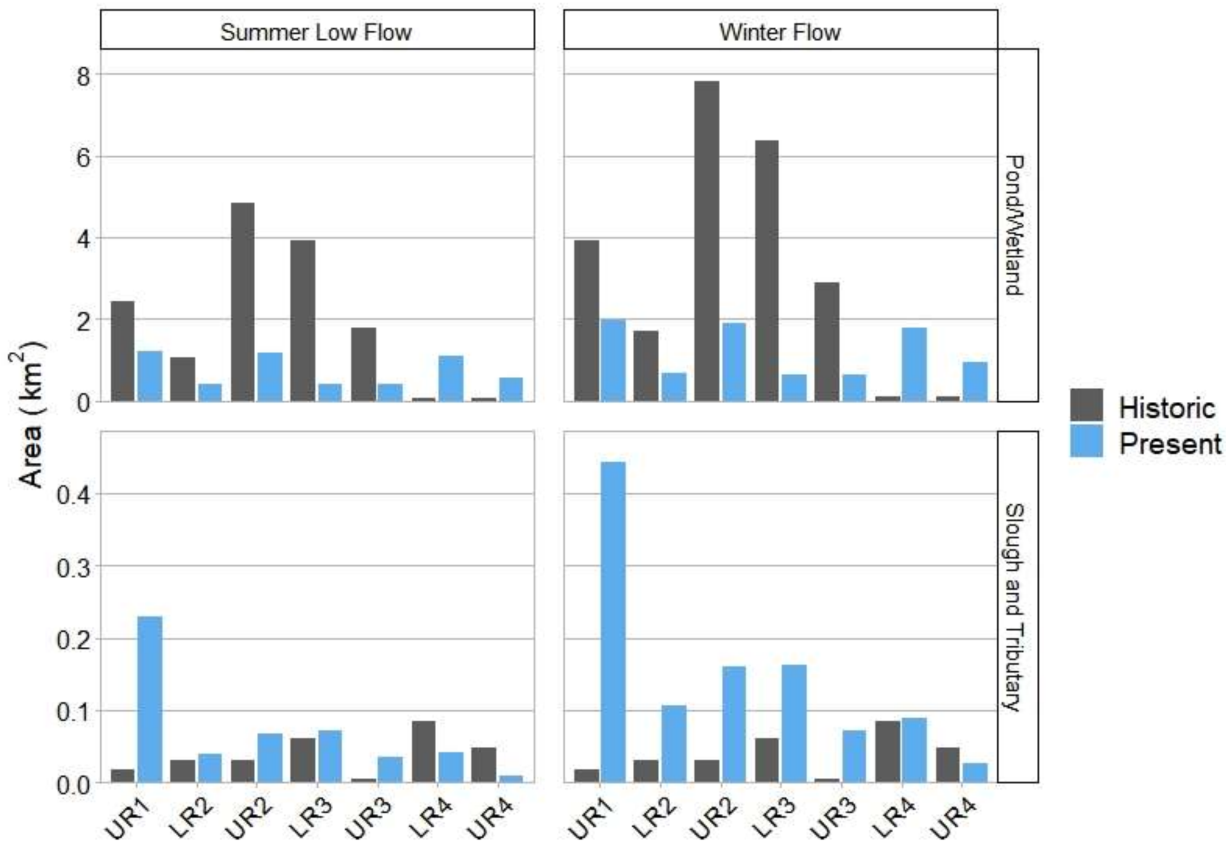

Figure 28: Channel areas (square kilometers) for pond/wetland and slough and tributary habitats for historic versus present surveys.

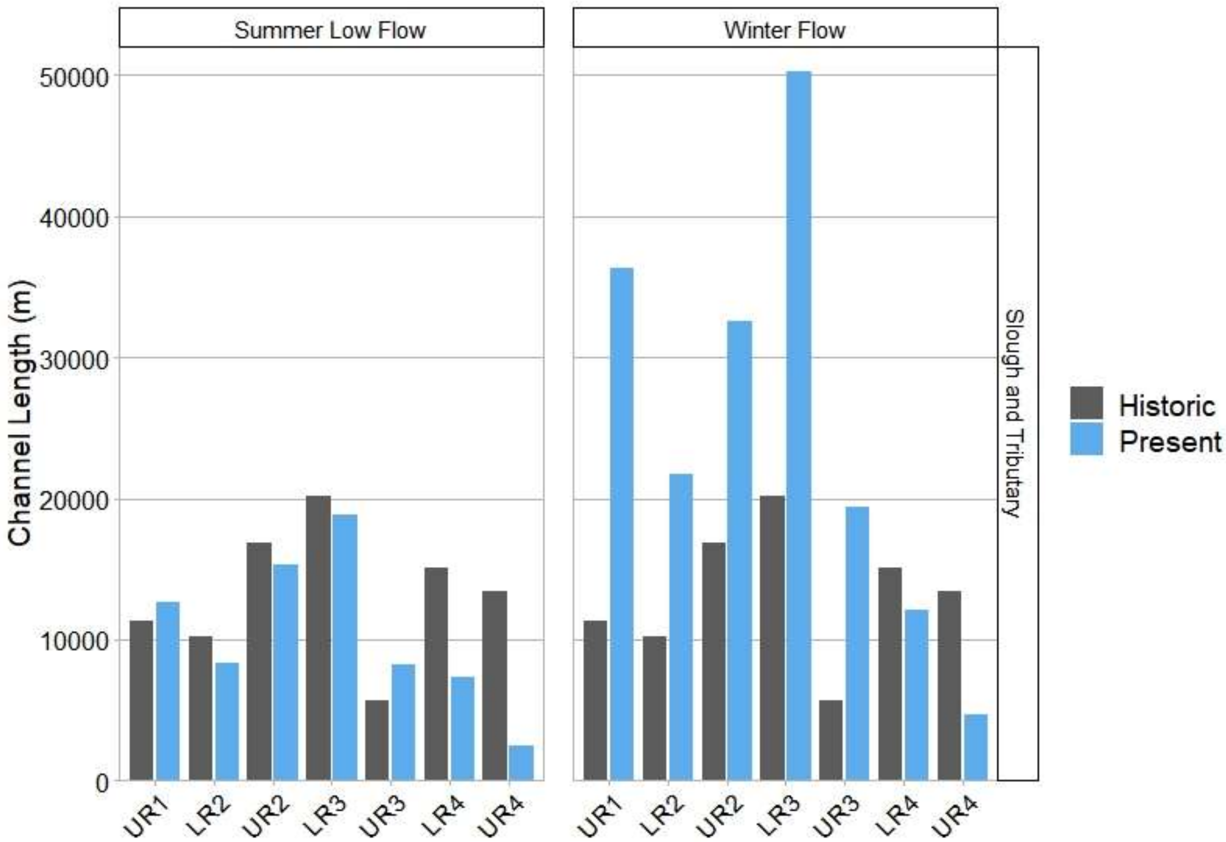

Figure 29: Channel lengths (meters) for slough and tributary habitats for historic versus present surveys. Channel lengths for were not reported for historic wetland habitat, so present surveys are not depicted in this figure.

Table 11: Lengths and areas in floodplain and wetland channels for 1880's historical reconstructions (assumed to be most representative of winter flow conditions) and present day surveys of winter flow and summer low flow conditions based on field surveys (Beamer et al. (2016) data used for Lower – Middle Reach 1 for both Lummi and Nooksack distributaries and associated wetlands and tidal channels; see **Figure 92** for extent).

			Historic		Present	
Reach	Flow	Channel Type	Area (meters^2)	Length (meters)	Area (meters^2)	Length (meters)
Lower – Middle Reach 1	NA	Tidal Channel and Distributary	1,468,089	NA	1,625,650	NA
		Wetland	14,836,709	NA	7,359,040	NA
		Total	16,304,798	NA	8,984,690	NA
Upper Reach 1	Winter	Slough and Tributary	17,871	11,268	441,980	36,284
		Pond/Wetland	3,922,661	NA	1,958,062	NA
		Total	3,940,532	11,268	2,400,042	36,284
	Summer	Slough and Tributary	17,871	11,268	228,485	12,642
		Pond/Wetland	2,426,191	NA	1,211,074	NA
		Total	2,444,062	11,268	1,439,559	12,642
Lower Reach 2	Winter	Slough and Tributary	30,919	10,230	106,584	21,768
		Pond/Wetland	1,692,929	NA	666,403	NA
		Total	1,723,848	10,230	772,987	21,768
	Summer	Slough and Tributary	30,919	10,230	39,413	8,290
		Pond/Wetland	1,047,088	NA	412,175	NA
		Total	1,078,007	10,230	451,588	8,290
Upper Reach 2	Winter	Slough and Tributary	30,404	16,900	161,369	32,580
		Pond/Wetland	7,818,466	NA	1,897,922	NA
		Total	7,848,870	16,900	2,059,291	32,580
	Summer	Slough and Tributary	30,404	16,900	67,307	15,299
		Pond/Wetland	4,835,772	NA	1,173,877	NA
		Total	4,866,176	16,900	1,241,184	15,299
Lower Reach 3	Winter	Slough and Tributary	61,405	20,217	162,217	50,247
		Pond/Wetland	6,355,107	NA	636,062	NA
		Total	6,416,512	20,217	798,279	50,247
	Summer	Slough and Tributary	61,405	20,217	70,875	18,821
		Pond/Wetland	3,930,675	NA	393,408	NA
		Total	3,992,080	20,217	464,283	18,821
Upper Reach 3	Winter	Slough and Tributary	5,689	5,689	72,636	19,371
		Pond/Wetland	2,883,063	NA	641,871	NA
		Total	2,888,752	5,689	714,507	19,371
	Summer	Slough and Tributary	5,689	5,689	35,580	8,280
		Pond/Wetland	1,783,193	NA	397,001	NA
		Total	1,788,882	5,689	432,581	8,280

Reach	Flow	Channel Type	Historic		Present	
			Area (meters^2)	Length (meters)	Area (meters^2)	Length (meters)
Lower Reach 4	Winter	Slough and Tributary	85,454	15,108	89,865	12,049
		Pond/Wetland	100,000	NA	1,800,055	NA
		Total	185,454	15,108	1,889,920	12,049
	Summer	Slough and Tributary	85,454	15,108	41,586	7,336
		Pond/Wetland	61,851	NA	1,113,346	NA
		Total	147,305	15,108	1,154,932	7,336
Upper Reach 4	Winter	Slough and Tributary	49,182	13,371	26,629	4,684
		Pond/Wetland	100,000	NA	927,518	NA
		Total	149,182	13,371	954,147	4,684
	Summer	Slough and Tributary	49,182	13,371	9,490	2,505
		Pond/Wetland	61,851	NA	573,676	NA
		Total	111,033	13,371	583,166	2,505

Estuary Habitats:

Compared to historical reconstructions, approximately 50% of tidal wetland habitat area has been lost in Lower-Middle Reach 1 (**Figure 30**). Most of the losses in tidal wetland habitat are associated with diversion of flow from the Lummi River distributary to the Nooksack River distributary, and disconnection of the geomorphic tidal delta floodplain due to diking and drainage (**Figure 31**). Although total distributary area has increased due to the concentration of flow into the Nooksack River distributary and progradation of the Nooksack River delta lobe, estimated total tidal channel area has decreased due to losses of tidal wetland habitat throughout the estuary (**Figure 30**). Losses of tidal channel habitat area were primarily associated with estuarine emergent marsh and estuarine scrub shrub marsh loses, while tidal channels associated with forested riverine tidal marshes increased relative to historical conditions (**Figure 30**). However, it should be noted that current surveys were limited by access and thus we relied on habitat areas that were calculated by previous surveys completed by Beamer et al. (2016) that represent conditions circa 2013.

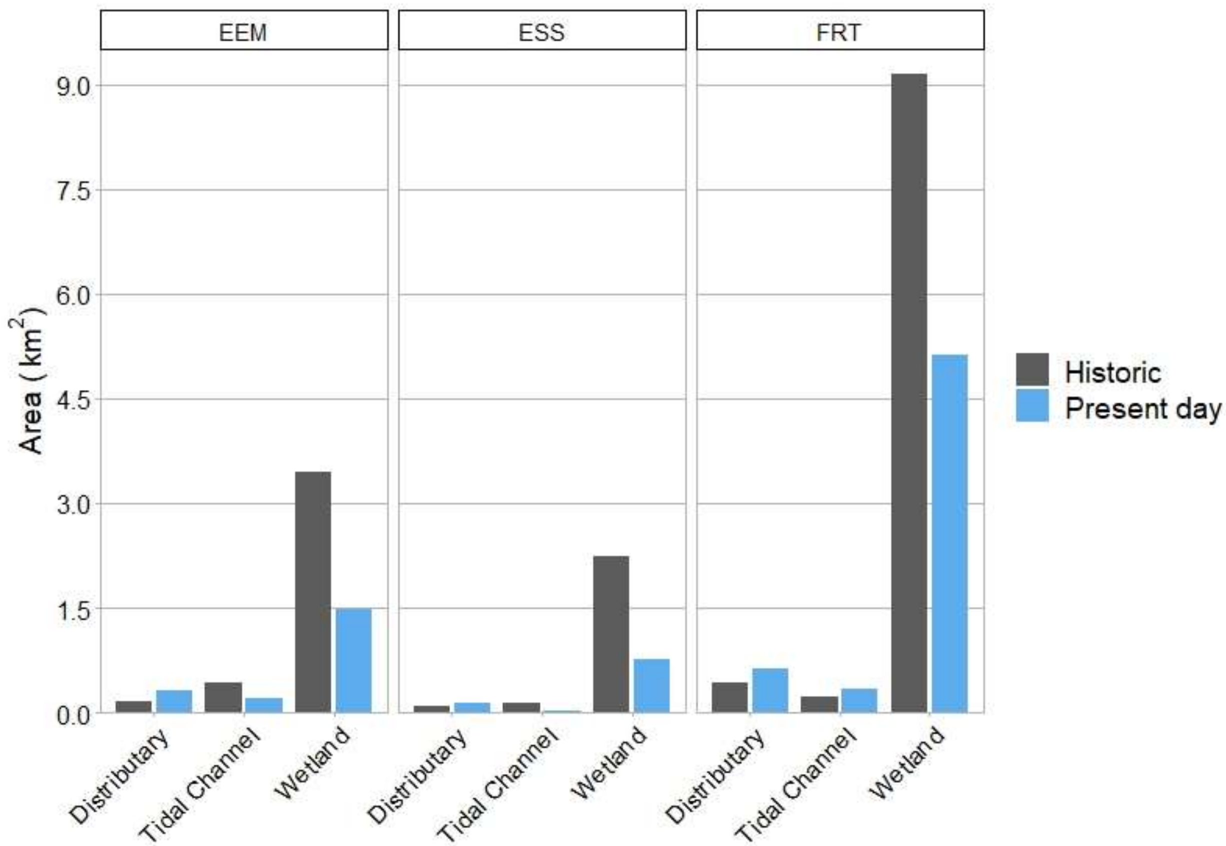

Figure 30: Comparison of present-day estuary habitat (circa 2013) mapped by Beamer et al. (2016) and historical reconstructions (circa 1880) from Collins and Sheikh (2004). Historical tidal channel area estimates include blind tidal channels and tributary habitats within the tidally influenced extent and estimates of blind tidal channel area from tidal wetland area to tidal channel area relationships from Collins and Sheikh (2004). Habitat type codes are EEM = Estuarine Emergent Marsh, ESS = Estuarine Scrub-Shrub, and FRT = Forested Riverine Tidal. See Table 31 for summaries of estuary habitat by geographic area within the delta.

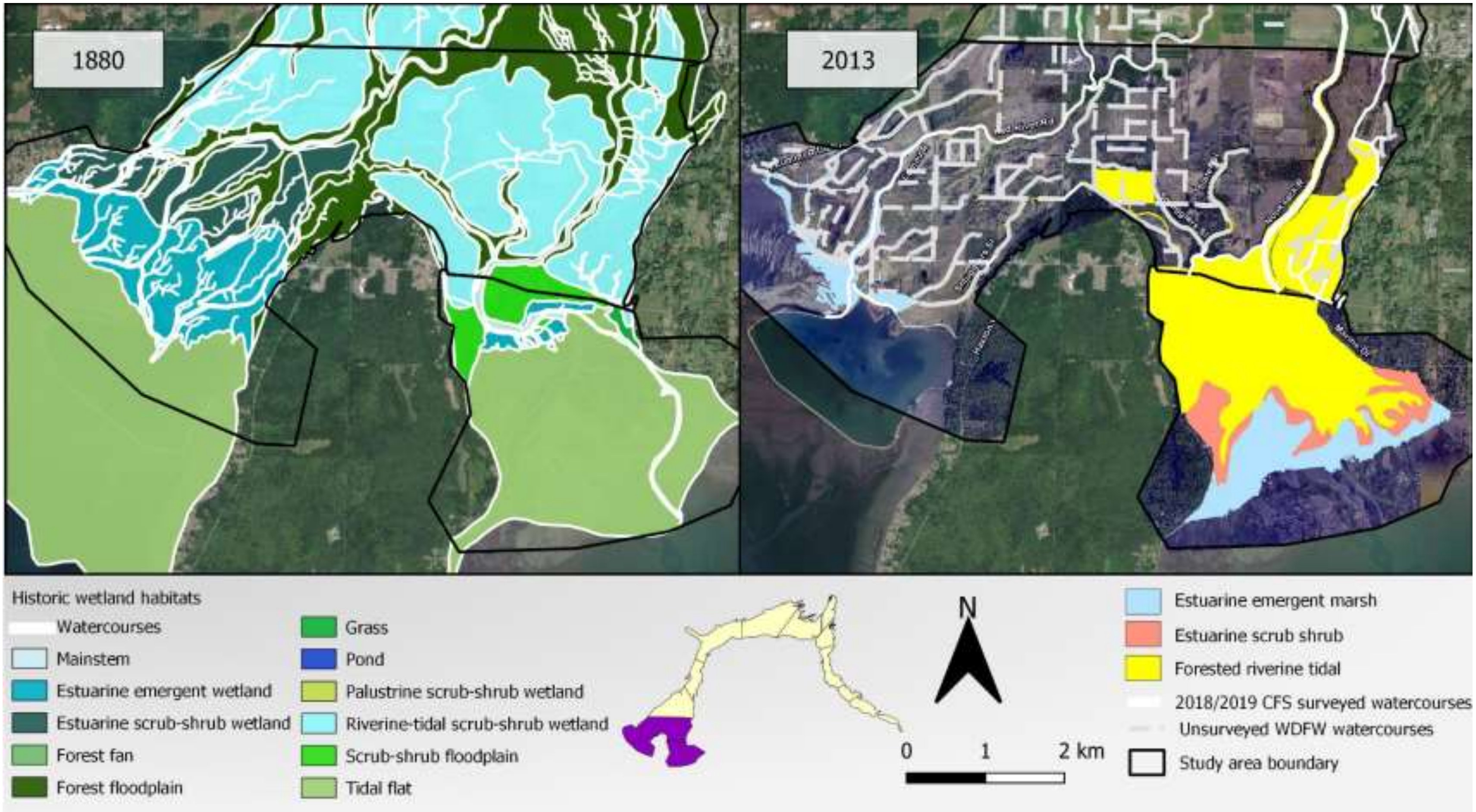

Figure 31: Map of current winter habitat and historical winter habitat extents (Collins and Sheikh) for Lower-Middle Reach 1. Current tidal wetland and estuarine habitats are from Beamer et al. (2016) reports from surveys completed in 2013. Watercourses surveyed by CFS in winter flows in 2018/2019 are also shown.

Capacity Analysis:

This section provides an overview of the capacity analysis results for subyearling Chinook salmon rearing capacity in the Lower Mainstem Nooksack River study area. We focused on subyearling Chinook for this analysis in consultation with the WRIA 1 Salmon Recovery Staff Team given that Chinook are a focal ESA listed species for recovery, subyearling Chinook salmon life histories rely on Lower Mainstem Nooksack River habitats, and subyearling Chinook salmon were the most well represented species in the juvenile salmon density data compiled for the capacity analysis. Although yearling life histories account for approximately 30% of the adult returns to the Nooksack River (Treva Coe, Nooksack Tribe, personal communication), available data did not support estimates of yearling rearing capacities that could be used to compare current and historical habitats to support development of restoration and conservation strategies for the study area.

We developed capacity estimates for winter, spring, and summer seasons to capture the primary rearing and migration patterns of juvenile Chinook life histories (data for fall were too limited to support estimates). However, it should be noted that subyearling density data compiled for this capacity analysis may include fish that ultimately express a yearling life history given that reported seasonal subyearling densities do not account for individuals that may ultimately overwinter and express a yearling life history. More detailed results and methods descriptions for the capacity analysis are provided in **Appendix C**. Therefore, subyearling densities likely represent an overestimate given that some portion of the cohort may adopt a yearling life history.

Furthermore, given the assumptions and estimations required to complete the capacity analysis, we recommend discussing rearing capacities in thousands of fish and do not recommend using the exact estimates (although these are provided in **Appendix C**). In addition, it is important to note that the capacity estimates are primarily based on 75th percentile (Q3, or third quartile) of densities observed in certain habitat types by season across a range of systems and do not account for rearing duration. Therefore, these rearing capacity estimates represent an upper range of mean seasonal abundance that could be expected for a given habitat type within each season. This provides a common currency to compare habitat quantities and types under current conditions, compared to historical reconstructions, and ultimately with different restoration strategies.

Subyearling Chinook Rearing Capacity:

Estimated total current subyearling Chinook rearing capacities are significantly lower than estimates based on historical reconstructions of habitat (**Figure 32**). Seasonal rearing capacity estimates with all reaches combined are 43-58% of estimated historical rearing capacity based on historical reconstructions. There are several factors contributing to differences between current and historical estimates of rearing including:

1. Prevalence of hydro-modified bank edges and the associated reduction in preferred cover types,
2. Simplification of the mainstem channel network and resultant reduction in braid and side-channel habitats,
3. Differences in spatial resolution between current surveys and historical reconstructions,
4. Resolution differences between historical and current estimates of floodplain wetland and pond estimations,

5. Resolution differences between historical and current estimates of floodplain slough and tributary habitats, and
6. Progradation of the Nooksack River delta and disconnection of the Lummi River delta.

The compiled juvenile salmon density data indicate Q3 densities for subyearling Chinook are up to 2.6 times higher along natural bank edges compared to hydro-modified bank edges (**Table 78**). Current habitat surveys revealed that approximately 40% of the mainstem channel length has hydro-modified bank edges (40% summer low flow and 37% winter flow). This significantly reduces rearing capacity for the Lower Mainstem Nooksack River study area. Conversion of hydro-modified bank edges to natural bank edges increases estimated current subyearling Chinook rearing capacities by an average of 3.2x (1.1 to 11.9x) among reach and seasonal estimates (**Figure 33**). The biggest difference in potential rearing capacity associated with hydro-modified bank edges occur from Upper Reach 1 to Lower Reach 3 where the proportions of hydro-modified bank edge length are the greatest.

Differences in current braid and side-channel habitat compared to historical reconstructions also account for loss of current spring subyearling rearing capacities in mainstem habitats that have become simplified compared to historical conditions. Estimated losses of side and braid channel slow-water edge habitat area relative to historical reconstructions were noted in all reaches except Upper Reach 3 and Lower Reach 4 (**Table 10**). The estimated reduction in side and braid channel slow-water edge habitat area account for a reduction in estimated rearing capacity of 84,000 and 6,000 fewer subyearlings during the spring and summer, respectively, for reaches where losses in slow-water edge habitat area from historic to current conditions occurred.

Current surveys suggest that more braid and side-channel habitats occur in Upper Reach 3 and Lower Reach 4 during winter flows compared to historical reconstructions (**Table 10**). These increases translate to an estimated increased rearing capacity of approximately 10,000 subyearlings in Upper Reach 3 and 188,000 subyearlings in Lower Reach 4 compared to historical conditions. However, we note that extensive braid and side channel complexes were mapped during current surveys of winter flows in Lower Reach 4, and we do not feel that the historical reconstructions can capture the level of detail that our current surveys were capable of mapping. Therefore, it is possible that some of the estimated increase in rearing capacity associated with braid and side-channel habitats in Lower Reach 4 is influenced by the survey resolution.

This difference in resolution between current and historical mapping also potentially affects mainstem edge habitat classifications across the study area. Bar edge habitats were estimated for historical conditions based on available mapping data, but it is likely that the bar edges depicted in the historical maps are lower resolution than what would be mapped during a field survey like that used in our assessment. Our literature review and juvenile salmon density data synthesis shows that natural bank edges have up to 6.5 times higher Q3 densities than bar edges among seasons (**Table 78**). Therefore, under representation of bar edge habitat during historical conditions and commensurate over representation of natural bank edge habitat could inflate historical subyearling Chinook rearing capacities.

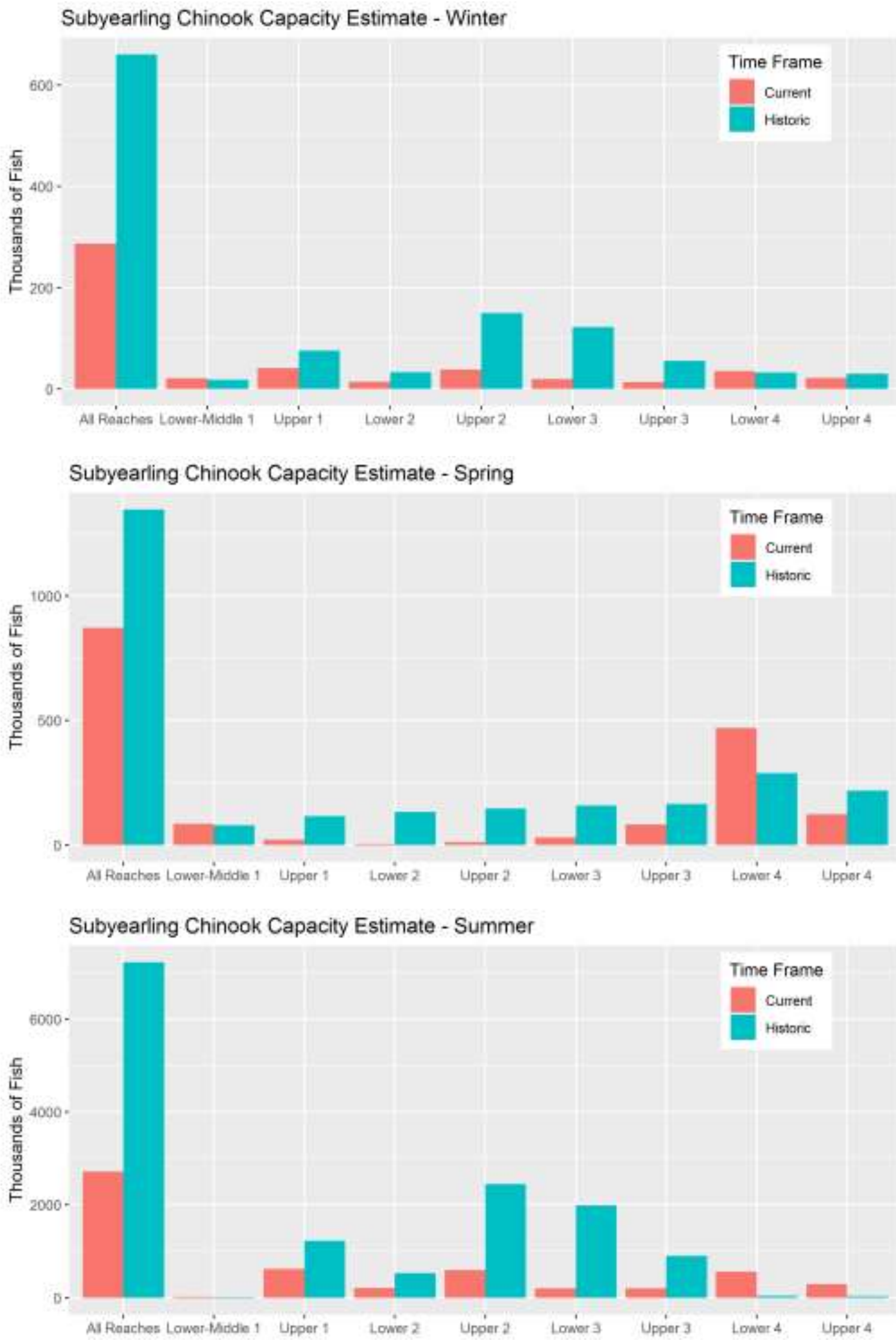

Figure 32: Estimated rearing capacity for subyearling Chinook salmon by reach and season (winter – top, spring – middle, and summer – bottom) for current habitat and historical reconstruction estimates. Values represent the 75th percentile of mean seasonal density for all habitat types combined for each reach and season, except for floodplain pond and wetland habitats that are based on the 25th percentile of mean winter density for pond and wetland habitats. See **Table 79** for values and **Appendix C** for more information.

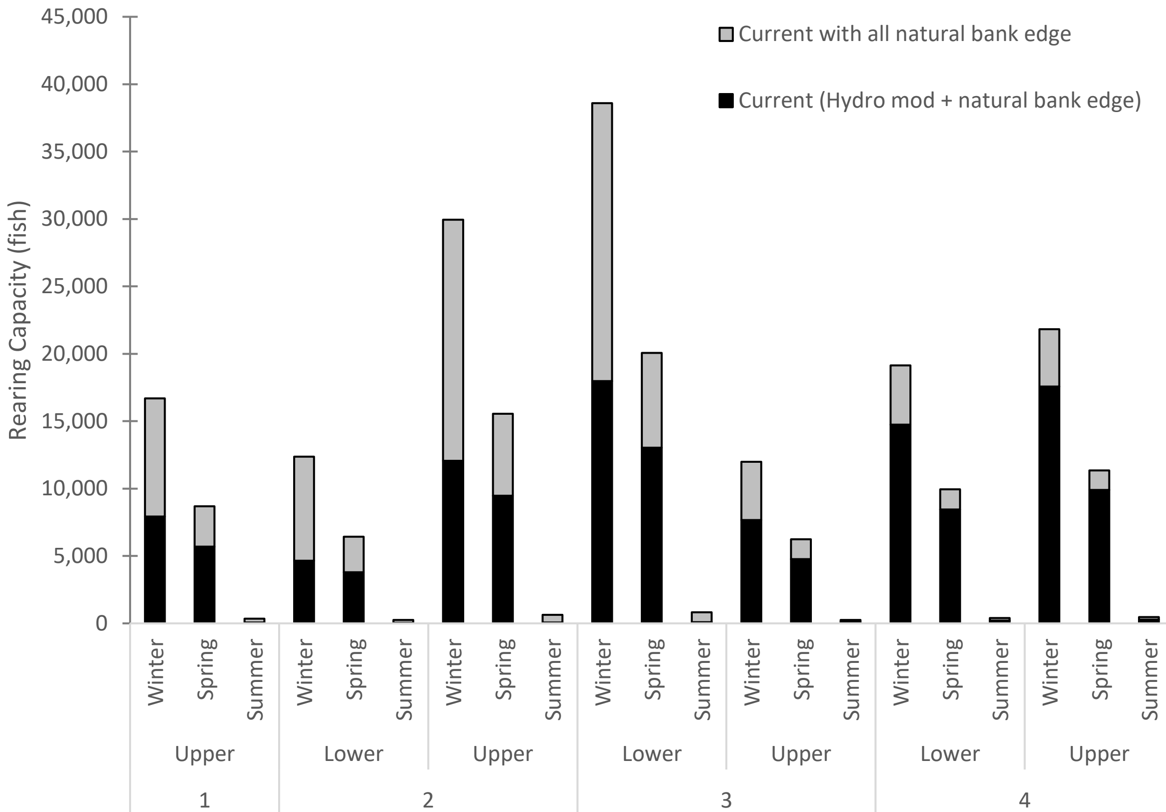

Figure 33: Current subyearling Chinook capacity estimates with hydro-modified bank edge and natural bank edge mainstem habitat compared to capacity estimates. Stack bars indicate estimated current rearing capacity with current distribution of hydro-modified and natural bank edge habitat (black bar) and how much the estimated rearing capacity would increase if all bank edge habitat were converted from hydro-modified bank edge to natural bank edge habitat (grey bar).

Although subyearling Chinook densities in mainstem habitats are lower in the summer than winter or spring (**Table 78**), estimated channel edge areas were higher under low flow conditions compared to winter flows for the historical reconstructions. This is the result of historical reconstructions showing bankfull spanning conditions for the high flow condition that simplify the edge network compared to a low flow period which produces more channel features that are separated by islands or bars and therefore have more edge habitats. In contrast, our current surveys indicated that edge habitat area was greater during winter flow conditions (**Table 10**) , which suggests that high flows created more activated channel units that were still separated by islands rather than bankfull spanning flow conditions with minimal islands. This highlights another limitation of comparing our higher resolution field survey data to historical reconstructions that simplify habitat conditions and comparisons of summer rearing capacity to historical conditions should be used cautiously.

Capacities for floodplain habitats were highly influenced by wetland habitat estimates. In addition, data for juvenile salmon densities in pond and wetland habitats were relatively limited and considerably higher that other habitats (**Appendix C**). The higher relative density values for pond and wetland habitats may be the result of sampling biases in channel or ponded areas with high fish densities (e.g., fish cannot be easily sampled across marsh surfaces and marsh surfaces may not contain standing water that would support fish use). Furthermore, we rely on historical reconstructions for historical wetland extent and supplemental data for current wetland extents and do not have estimates of what portions of these habitats are accessible or usable to subyearling Chinook salmon. To address this issue, we use the lower 25th percentile (Q1 density) for winter pond and wetland habitats (0.02 fish/m^2) in floodplains to estimate capacities for subyearling Chinook. This provides a conservative estimate based on the seasonal estimate with the most data (**Appendix C**) that assumes not all wetland and pond habitats are accessible or usable to juvenile Chinook salmon.

Losses in pond and wetland habitats are estimated to have occurred in all reaches except Lower and Upper Reach 4 (**Figure 28**). Assuming a low-density rearing capacity as described above, estimated losses in pond and wetland habitat relative to current conditions account for a reduction in winter and spring rearing capacity of approximately 274,000 subyearlings for winter and spring during winter flow conditions across all reaches, and 170,000 subyearlings during summer low flow. In Lower and Upper Reach 4 where current estimates suggest an increase in pond and wetland habitat relative to historical reconstructions, winter and spring rearing capacity is approximately 48,000 subyearlings higher than historical reconstructions, and 30,000 subyearlings higher during summer low flow conditions. However, apparent increases in pond and wetland habitat area relative to historical conditions in Reach 4, and associated increases in estimated subyearling rearing capacities, could be related to differences in mapping resolution between historical reconstructions and supplemental data used to estimate pond and wetland habitat for current conditions. This is combination with the fact that our approach for estimating rearing capacities for pond and wetland habitats does not account for habitat accessibility and usability (e.g., connectivity of channel networks and access to impoundments), suggests that estimated rearing capacities for pond and wetland habitats from this assessment should be used with caution when comparing reaches under current and historical conditions. More detailed and focused surveys of pond and wetland habitat and survey of literature would be needed to support better analysis of rearing capacities for pond and wetland habitats in the study area.

Our current surveys suggest increases in floodplain channel area relative to historical conditions in nearly all reaches (**Table 79**), which also contribute to an increase in estimated subyearling Chinook rearing capacities. The estimated increase in floodplain channel area relative to historical reconstructions is associated with an increase in rearing capacity of approximately 7,000 and 31,000 subyearlings in the winter and spring during winter flow conditions, and 8,000 subyearlings during summer low flow conditions. However, the estimated increase in floodplain channel habitat compared to historical conditions, and commensurate increases in estimated rearing capacity, may be the result of differences in spatial resolution and accuracy between field surveys of current conditions and historical reconstructions. The current floodplain channel network is composed mostly of hydro-modified natural and constructed channels that are relatively small, and historical reconstructions appears to have mapped only the larger slough and tributary channel systems that may have occurred in the historical floodplains. Therefore, comparisons of rearing capacity based on current and historical floodplain channel habitat should be considered carefully.

Current estimates of subyearling rearing capacity can be used without comparison to historical conditions to inform evaluation of current habitat restoration or conservation strategies. However, many of these floodplain channels are highly modified or constructed channels that function more as a drainage network than off-channel rearing habitat for juvenile salmon (**Figure 34**). Current capacity estimates are based on the upper range of fish densities observed in floodplain slough and tributary habitats and are not likely representative of the current capacities for these habitats in the floodplain where conditions may limit habitat quality. In addition, the floodplain mapping only considers hydrological connectivity and summer habitat area was estimated from subsampling during summer low flow periods. Therefore, it is likely that a portion of the quantified winter flow and summer low flow floodplain channel habitats are not accessible to fish and this may also result in an overestimate of subyearling rearing capacity in floodplain channel habitats.

Figure 34: Impaired ditch with poor fish habitat.

The capacity analysis also suggests that subyearling rearing capacities in the estuary (Lower-Middle Reach 1) have increased relative to historical reconstructions (**Figure 32**), despite substantial loss of estuary habitat area based on current estimates (**Figure 31**). The estimated increase in subyearling rearing capacity is driven primarily by an estimated increase in distributary channel area relative to historical reconstructions (**Figure 30**). The estimated increase in distributary area is associated with reduced connectivity of the Lummi River distributary, concentration of flow into the Nooksack River distributary, and subsequent progradation of the Nooksack River delta lobe (Collins and Sheikh 2004; Beamer et al. 2016; Boyd et al. 2019). The estimated increase in distributary channel area accounts for an increase in estuary rearing capacity of approximately 7,000 and 26,000 subyearlings in the winter and spring, respectively, and 9,000 subyearlings during the summer. However, current habitat estimates suggests that estimated tidal channel area has reduced substantially relative to historical reconstructions (**Figure 30**), and this is likely associated with a reduction in overall tidal wetland habitat area (Collins and Sheikh 2004; Beamer et al. 2016; Boyd et al. 2019). Current estimates of habitat from Beamer et al. (2016) suggest that 50% of tidal wetland habitats have been lost relative to historical reconstructions from Collins and Sheikh (2004). The estimated loss of tidal channel area accounts for an estimated loss of estuary rearing capacity of approximately 3,000 and 19,000 subyearlings in the winter and spring, respectively, and 1,000 subyearlings during the summer. However, these losses are outweighed by the estimated increase in rearing capacity associated with the increase in distributary channel area.

This estimated increase in estuary rearing capacity is the result of rearing capacity estimates being applied to channel areas only (total distributary channel area), which will bias the estimated rearing capacities high given that juvenile salmonids will preferentially use edge habitats in larger distributary and tidal channels (Beamer et al. 2005). In addition, the estimated rearing capacities for this assessment are relatively simplistic and do not account for rearing duration or period or the functional benefits of adjacent and connected tidal wetland marshes that may influence rearing capacities in the current estuary. However, recent research has produced more detailed estimates of rearing capacity for the Nooksack River estuary that incorporate density dependence, rearing duration, and additional edge habitat information (Correigh Greene, NOAA NWFSC, personal communication). Preliminary estimates from that work suggests that current rearing capacity for the Nooksack River estuary system is approximately 350,000 – 715,000 based on 90-95th percentiles of predicted weekly capacities, 25-week rearing season, and a 4-week rearing duration (Correigh Greene, NOAA NWFSC, personal communication). In comparison, our simplified approach to estimating subyearling rearing capacities yields a total estimated rearing capacity of approximately 127,000 subyearlings based on the 75th percentile of mean seasonal densities and total distributary and tidal channel surface area (as compared to edge habitat area used to derive the other estimates).

Given that fish density data and the resulting capacity estimates are log normally distributed, the simplified subyearling rearing capacity estimates developed in this assessment for the estuary appear to generally agree with the independent estimates. This is encouraging and provides support for the approach used in this assessment given that the intent is to provide a common metric for which current and historical habitat information can be compared to develop reach-based restoration and conservation strategies. However, we recommend reviewing and possibly integrating the more detailed rearing capacity estimates for the estuary when they become available given the limitations of the estimates for estuary habitat generated in this assessment, and possibly implementing more detailed field surveys of estuary habitat to improve estuary habitat and rearing capacity estimates.

Reach Conditions:

This section provides more detailed information on current habitat conditions within each reach based on field surveys completed as part of this assessment, and comparisons of current habitat conditions to historical reconstructions. Tables and figures referenced in this section can be found in **Appendix B.** Additional survey data attributes and information are contained within the survey database (see **Appendix B** for more information on the attributes collected during field surveys).

Reach: Lower – Middle Reach 1

Current Habitat Conditions:

Survey extent was limited within Lower and Middle Reach 1 during this assessment and did not include most of the Nooksack River delta complex below Marine Drive or many of the hydro-modified water courses within the larger delta area (**Figure 93**). The full extent of the Nooksack main channel of the mainstem was surveyed, but floodplain, tidal channels, and other distributaries (e.g., Lummi River) were only subsampled and represented only 24% of mapped water courses within these reaches. To summarize floodplain and distributary habitat capacity within these reaches, we rely on previous habitat assessment data reported in Beamer et al. (2016). These data provide areal estimates of channel features (e.g., distributary, tidal channel, and marsh features within each estuarine zone) for the whole reach based on remote sensing that we used to describe current habitat quantity and conditions circa 2013 in these reaches (**Table 31**; **Figure 92**). Most of the current estuary habitat area is associated with the Nooksack River distributary followed by the Silver Creek, Lummi River, and Smugglers Slough areas within the delta (**Table 31**; **Figure 92**; **Figure 91**). However, substantial areas of the current estuary habitat are hydrologically muted and fish passage and migration pathways are potentially impacted as noted by Beamer et al. (2016).

We also report the results from our surveyed watercourses even though these represent a subsample of the Lower and Middle Reach 1, which represent 24% of the mapped water courses in these reaches. Given our limited survey extent in this reach, these summaries are presented to describe current habitat qualities for surveyed reaches only and are not used to describe conditions throughout the reach or to derive capacity estimates.

Surveys in the Nooksack mainstem covered the full length of the mainstem Nooksack River channel in this reach, approximately 3,000 meters, in the lower Nooksack River between Slater Road and Marine Drive (**Table 32**). Banks were dominated by hydro-modified bank edges, including levees, pilings, and riprap edges (**Figure 93**; **Figure 96**). In summer low flow surveys, natural bar edges made up 20% of the edge length surveyed. No bar edges were observed in winter surveys. Slow water edge habitat overall was greater in winter flow surveys. Glides were the only habitat unit type observed in both summer low flow and winter surveys (**Figure 93**; **Figure 94**). Canopy cover was less than 2% in both surveys. Large wood was minimal in the mainstem of this reach, only three large wood jams were observed. Cover provided by large wood jams was greater in summer low flow than winter surveys, which could have been due to submersion at higher flows or wash out (**Table 33**).

Floodplain habitat surveys were performed in the Nooksack River delta, slough habitat, and Lummi distributary floodplain in hydro-modified natural channels and distributary (Lummi) channels (**Table 34**). A substantial number of watercourses were not surveyed as part of this effort due to time, difficulty or danger of survey, and access constraints. Distributary habitats in this reach were fully surveyed, but for hydro-modified natural channels, approximately 80% of the channel length was not surveyed. The only habitat unit types observed in both distributaries and hydro-modified natural channels were glides and ponded areas, but glides were dominant (**Figure 97**). Much of the floodplain habitat was tidally influenced, and habitat depths and widths were dependent on this (**Figure 98**).

Percent canopy cover averaged 16% for distributary and 19% for hydro-modified natural channels (**Table 34**). The percent canopy cover for hydro-modified natural channels was likely an underestimate as channels with dense overstory cover, such as blackberry or willows, were not surveyed due to difficulty of wading. Large wood jams were only observed in hydro-modified natural channels and covered 610 m^2 of wetted channel in the survey extent. Fine sediment was dominant across channel types. Summer validation surveys performed found numerous dry channel units across distributary and hydro-modified natural channel units, specifically in the upper Lummi river and Slater ditch above Slater road and in the Smugglers slough complex (**Figure 95**).

Current versus Historical Conditions:

Compared to historical reconstructions, approximately 50% of tidal wetland habitat area has been lost in Lower-middle Reach 1 (**Figure 35**). Most of the losses in tidal wetland habitat are associated with diversion of flow from the Lummi River distributary to the Nooksack River distributary, and disconnection of the geomorphic tidal delta floodplain due to diking and drainage (**Figure 36**). Although total distributary area has increased due to the concentration of flow into the Nooksack River distributary and progradation of the Nooksack River delta lobe, estimated total tidal channel area has decreased due to losses of tidal wetland habitat throughout the estuary (**Figure 35**). Losses of tidal channel habitat area were primarily associated with estuarine emergent marsh and estuarine scrub shrub marsh loses, while tidal channels associated with forested riverine tidal marshes increased relative to historical conditions (**Figure 35**). However, it should be noted that current surveys were limited by access and thus we relied on habitat areas that were calculated by previous surveys completed by Beamer et al. (2016) that represent conditions circa 2013.

Summary:

Although current surveys were limited in this reach, historical reconstructions and available data for current conditions indicate that substantial losses of tidal wetland habitat have occurred and tidal connectivity to channel and wetland habitats are impaired (Beamer et al. 2016; Boyd et al. 2019). Most losses in estuary habitat were associated with disconnection of the Lummi Distributary and reduced tidal connectivity and conversion of tidal marsh habitat in the geomorphic tidal delta floodplain (**Figure 36**). In channels that were surveyed, banks were dominated by hydro-modified bank edges and channels (**Table 12**). Habitat generally lacked complexity with glides dominating the surveyed extent, although this would be expected in a low gradient delta reach (**Table 13**). However, these represent a very small subsample of mapped water courses and additional surveys should be completed to improve evaluation of current habitat conditions in this reach.

Table 12: Summary results for mainstem surveys for Middle Reach 1, W=Winter flow, S= Summer Low Flow. Change from historic condition refers to the difference in slow water area for mainstem channels and braid and side channels from 1880s data to present. The shading indicates a negative deviation from the study area average for each value. For the change from historic conditions, green indicates an increase in habitat area and red indicates a loss in habitat area. For the percent of total channel length, red indicates mainstem values being above average and braid and side channel values being below average. For the percent of edge length in hydro-modified bank and percent length in glides red indicates a reach value above the study area average and green indicates a reach value below the study area average. For the number of pools, the percent length in pools, the number of jams, and the wetted jam area, red indicates a reach value below average and green indicates a reach value above average. Study area averages are also reported.

		Change from Historic Condition		% of Total Channel Length		% Edge Length in Hydro-modified Bank		% Length in Glides		# Pools		% Length in Pools		# LWD Jams		Wetted LWD Jam Area (m2)	
		W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Middle Reach 1	Mainstem	NA	NA	100	100	86	73	100	100	0	0	0	0	3	3	305	1400
	Braid & Side Channel	NA	NA	0	0	-	-	-	-	-	-	-	-	-	-	-	-
Study Area Average	Mainstem	NA	NA	80	92	63	52	84	73	3	5	6	12	5	5	429	1193
	Braid & Side Channel	NA	NA	20	8	11	6	42	59	32	16	20	14	9	6	1225	749

Table 13: Summary results for floodplain surveys for Middle Reach 1. The shading indicates a negative deviation from the study area average for each value. For the percent length in glides red indicates a reach value above the study area average and green indicates a reach value below the study area average. For the number of pools, the percent length in pools, the number of jams, and the wetted jam area, red indicates a reach value below average and green indicates a reach value above average. Study area averages are also reported.

		% of Total Channel Length	% Length Unsurveyed	% Length in Glides	# Pools	% Length in Pools	# LWD Jams	Wetted LWD Jam Area (m2)
Middle Reach 1	Hydro-modified natural channel	57	66	100	0	0	19	610
	Distributary	43	0	39	0	0	0	0
	Hydro-modified channel	-	-	-	-	-	-	-
	Wetland	-	NA	NA	NA	NA	-	-
	Constructed Channel	-	100	-	-	-	-	-
Study Area Average	Hydro-modified natural channel	50	59	67	8	2	9	245
	Tributary	36	4	88	15	12	14	400
	Hydro-modified channel	11	0	77	4	4	3	13
	Wetland	2	NA	NA	NA	NA	0	0
	Constructed Channel	0.2	100	49	1	3	10	135

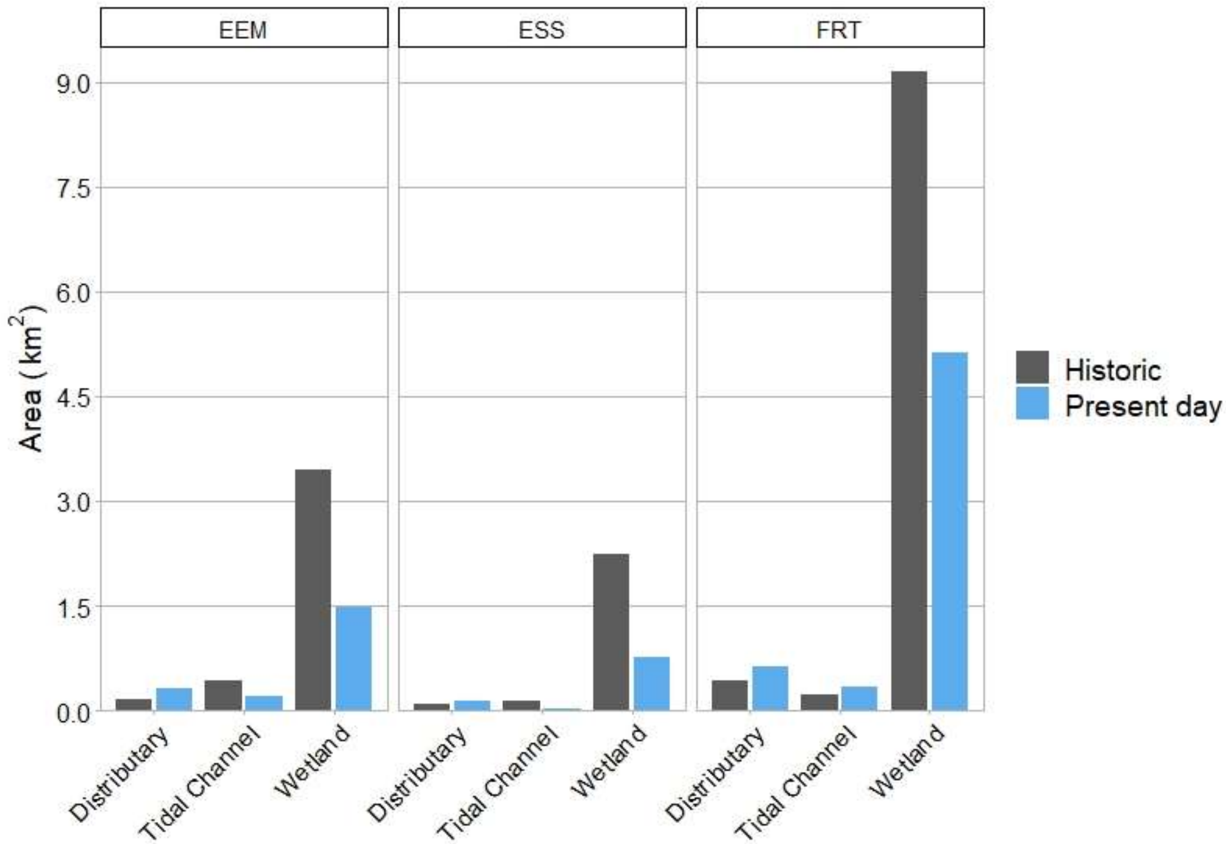

Figure 35: Comparison of present-day estuary habitat (circa 2013) mapped by Beamer et al. (2016) and historical reconstructions (circa 1880) from Collins and Sheikh (2004). Historical tidal channel area estimates include blind tidal channels and tributary habitats within the tidally influenced extent and estimates of blind tidal channel area from tidal wetland area to tidal channel area relationships from Collins and Sheikh (2004). Habitat type codes are EEM = Estuarine Emergent Marsh, ESS = Estuarine Scrub-Shrub, and FRT = Forested Riverine Tidal.

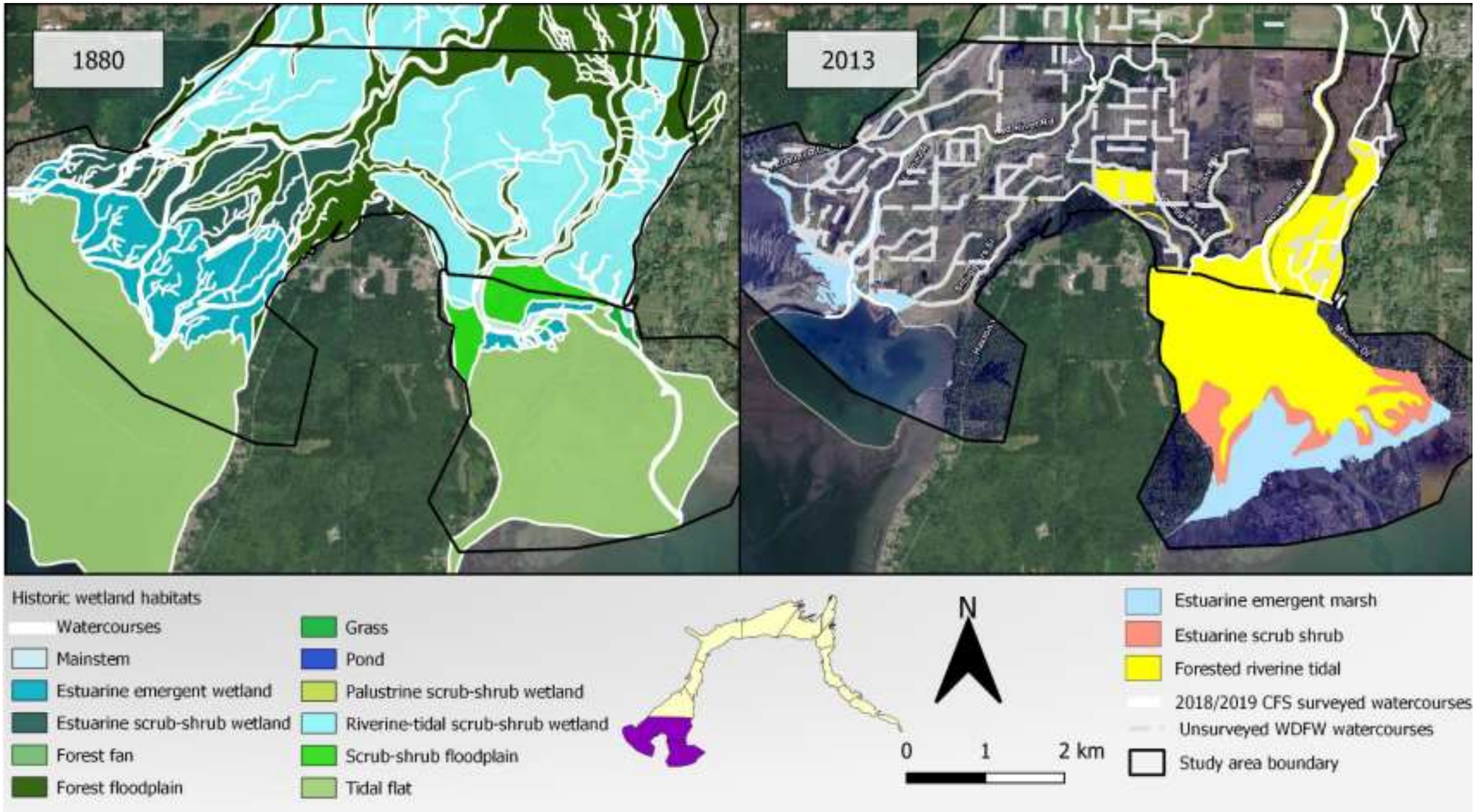

Figure 36: Map of current winter habitat and historical winter habitat extents (Collins and Sheikh) for Lower-Middle Reach 1. Current tidal wetland and estuarine habitats are from Beamer et al. (2016) reports from surveys completed in 2013. Watercourses surveyed by CFS in winter flows in 2018/2019 are also shown.

Reach: Upper Reach 1

Current Mainstem Habitat Conditions:

The mainstem surveys of Upper Reach 1 found a single-thread, confined channel, with no braid or side-channel habitat (**Table 36**). Hydro-modified banks were the dominant edge type in both winter and summer low flow surveys (**Figure 100; Figure 101**). Hydro-modified bank edge length was recorded as a percentage of total edge length at the unit scale. Hydro-modified banks observed included levees, pilings, riprap, and unknown modifications. The percent of overall edge length made up by hydro-modified banks was less in summer low flow surveys than winter surveys. In summer low flow surveys, natural bar edges accounted for 23% of edge length, while hydro-modified bank edges made up 69%, and natural bank edges made up 8%. In winter flow surveys, bar edge length was substantially reduced given higher flows. Hydro-modified banks made up 90% of the edge length, while bar edges accounted for 3% and natural bank edges made up 7% of the length. Slow water edge habitat area for bar edges was greater in summer low flows than winter flows (**Figure 103**). Total slow water edge habitat and overall habitat area were both higher in winter than summer low flow surveys (**Table 36**).

Habitat unit diversity was low for both summer low flow and winter flow surveys. In Upper Reach 1, glide, pool, and riffle units were observed in summer low flow mainstem surveys (**Figure 101**; **Figure 104**), while glides were the only observed habitat unit type in winter flow surveys (**Figure 100**; **Figure 105**). In summer low flow surveys, for both habitat area and length, glides accounted for 83%, pools consisted of 15%, and riffles made up the remaining 2%. Large wood jam formed scour pools accounted for all pools observed. Cover was lacking from both canopy and large woody debris. Percent canopy cover was higher in summer low flow than winter surveys but was minimal in both surveys. Deciduous species were the dominant canopy providing class. Large wood was lacking throughout the mainstem channel in this reach. Seven large wood jams were observed in winter surveys covering 525 m^2 of wetted channel. No wood in the wetted channel was observed in summer low flow surveys.

Current Floodplain Habitat Conditions:

Floodplain surveys in Upper Reach 1 consisted of hydro-modified natural, hydro-modified channels, and wetland channel types, with the majority of habitat length being hydro-modified natural channels and habitat area being wetland (**Table 38**). Floodplain access was limited in this reach due to private property, and only 8.7 km of 37.4 km, or 23%, of total channel length was surveyed (WDFW regulatory network) (**Figure 101**; **Figure 102**;). This reach included Hovander Park, which included a large wetland habitat. Of wetland habitat area, 98% was estimated using the NWI data (USFWS 2017) due to difficulty in ground surveying. Constructed channels were not surveyed, but lengths were estimated from the WDFW regulatory stream network (WDFW regulatory layer). Of the total reported hydro-modified natural channel length, 62% was estimated from the WDFW regulatory stream network.

Floodplain channels were dominated by ponded area habitat units, with ponded areas accounting for 84% of hydro-modified natural channel habitat units and 100% of wetland habitat units (**Figure 105**). For hydro-modified natural channels, glide habitat made up 13%, pool habitat made up 2%, and riffle habitat made up 1% of surveyed channel length. Glides were the only habitat unit types observed in hydro-modified channels. Percent canopy cover was highest in surveyed wetland channels at 39% but was also high in hydro-modified natural channels at 20%, followed by hydro-modified channels at 15% (**Table 38**). Large wood jams were only observed in hydro-modified natural channels and were infrequent. Substrate in hydro-modified natural channels and wetland channels was dominated by fines. Gravel was the dominant substrate in hydro-modified channels.

All channels surveyed in the winter floodplain survey extent that were revisited in summer low flow surveys were dry (**Figure 102**). Summer floodplain habitat was estimated from validation surveys across the study area (**Appendix B**), with estimates indicating that a large portion of the floodplain channels wetted during winter surveys are dry in the summer (**Table 39**). Summer habitat surveys in this reach were performed in Schell Ditch and on the Lummi River distributary.

Current versus Historical Conditions:

Floodplain wetland habitat has been dramatically reduced from historic conditions to present (**Figure 37**) and no side-channel or braid habitat was observed in current surveys of Upper Reach 1 (**Table 40**; **Figure 38**) compared to historical reconstructions that show the presence of some side channel and braid habitat in this reach (**Table 40**). Additionally, for both summer and winter surveys, mainstem edges in 2018/2019 surveys were dominated by hydro-modified bank edge, whereas natural bank edge was dominant in historic estimates (**Figure 38**). Slow water edge habitat area overall was less than historic values in summer low flow surveys, but was greater in current than historic winter flow surveys (**Table 40**).

Bar edge lengths were greater for present day surveys in both summer and winter than historic estimates (**Figure 38**). However, for summer low flow surveys, there was more slow water edge area in bar habitat in historic estimates than present day surveys. Winter flow surveys found greater slow water edge habitat area for bar edges in current than historic estimates (**Figure 37**; **Figure 38**). Current mainstem and secondary channels are also substantially more confined than historically (**Figure 37**) and wetland and floodplain habitat dramatically decreased, while slough and tributary channel length increased (**Table 40**).

Summary:

Although historic reconstructions suggest naturally low channel complexity in this reach with few secondary mainstem channels (braids and side channels), our surveys revealed a lack of mainstem channel complexity with no braid or side-channel habitats observed (**Table 14**). Lack of mainstem channel complexity and prevalence of hydro-modified bank edges are the primary conditions impairing mainstem habitat quality in this reach. The single-thread mainstem channel in this reach had bank edges that were 90% hydro-modified. Habitat unit diversity was also low, and comparatively little large woody debris and log jams were observed in this reach. Low floodplain connectivity and modification of floodplain channels also impact this reach, and a large portion of the floodplain channels surveyed in the winter floodplain survey extent are likely dry during summer low flows (**Table 15**).

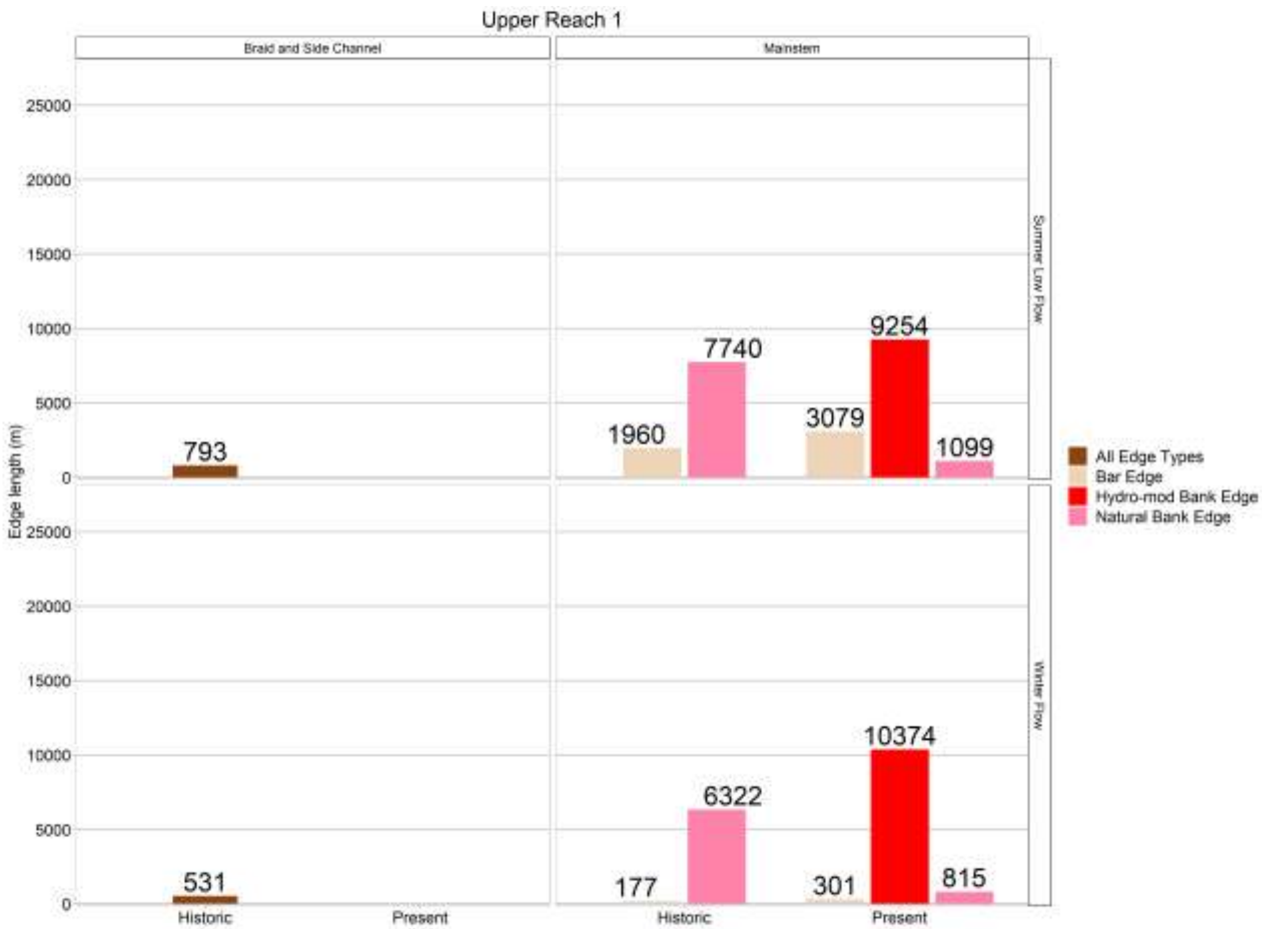

Figure 37: Edge lengths of bank types for summer low flow and winter flow conditions for historic versus present data. Edge type data for historic braid and side-channel habitats were not available. No braid or side-channel habitat was observed in Upper Reach 1.

Figure 38: Slow water edge areas (meters^2) of bank types for summer low flow and winter flow conditions for historic versus present data. Edge type data for historic braid and side-channel habitats were not available. No braid or side-channel habitat was observed in Upper Reach 1.

Table 14: Summary results for mainstem surveys for Upper Reach 1, W=Winter flow, S= Summer Low Flow. Change from historic condition refers to the difference in slow water area for mainstem channels and braid and side channels from 1880s data to present. The shading indicates a negative deviation from the study area average for each value. For the change from historic conditions, green indicates an increase in habitat area and red indicates a loss in habitat area. For the percent of total channel length, red indicates mainstem values being above average and braid and side channel values being below average. For the percent of edge length in hydro-modified bank and percent length in glides red indicates a reach value above the study area average and green indicates a reach value below the study area average. For the number of pools, the percent length in pools, the number of jams, and the wetted jam area, red indicates a reach value below average and green indicates a reach value above average. Study area averages are also reported.

		Change from Historic Condition		% of Total Channel Length		% Edge Length in Hydro-modified Bank		% Length in Glides		Pool Count		% Length in Pools		LWD Count		Wetted LWD Jam Area (m2)	
		W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Upper Reach 1	Mainstem	2988	-5389	100	100	90	69	100	83	0	2	0	15	7	0	525	0
	Braid & Side Channel	-1062	-1585	0	0	-	-	-	-	-	-	-	-	-	-	-	-
Study area average	Mainstem	NA	NA	80	92	63	52	84	73	3	5	6	12	5	5	429	1193
	Braid & Side Channel	NA	NA	20	8	11	6	42	59	32	16	20	14	9	6	1225	749

Table 15: Summary results for floodplain surveys for Upper Reach 1. The shading indicates a negative deviation from the study area average for each value. For the percent length in glides red indicates a reach value above the study area average and green indicates a reach value below the study area average. For the number of pools, the percent length in pools, the number of jams, and the wetted jam area, red indicates a reach value below average and green indicates a reach value above average. Study area averages are also reported.

		% of Total Channel Length	% Length Unsurveyed	% Length in Glides	# Pools	% Length in Pools	# LWD Jams	Wetted LWD Jam Area (m2)
Upper Reach 1	Hydro-modified natural channel	85	62	13	6	2	11	737
	Tributary	-	-	-	-	-	-	-
	Hydro-modified channel	2	0	100	0	0	0	0
	Wetland	13	NA	NA	NA	NA	0	0
	Constructed Channel	-	100	-	-	-	-	-
Study Area Average	Hydro-modified natural channel	50	59	67	8	2	9	245
	Tributary	36	4	88	15	12	14	400
	Hydro-modified channel	11	0	77	4	4	3	13
	Wetland	2	NA	NA	NA	NA	0	0
	Constructed Channel	0.2	100	49	1	3	10	135

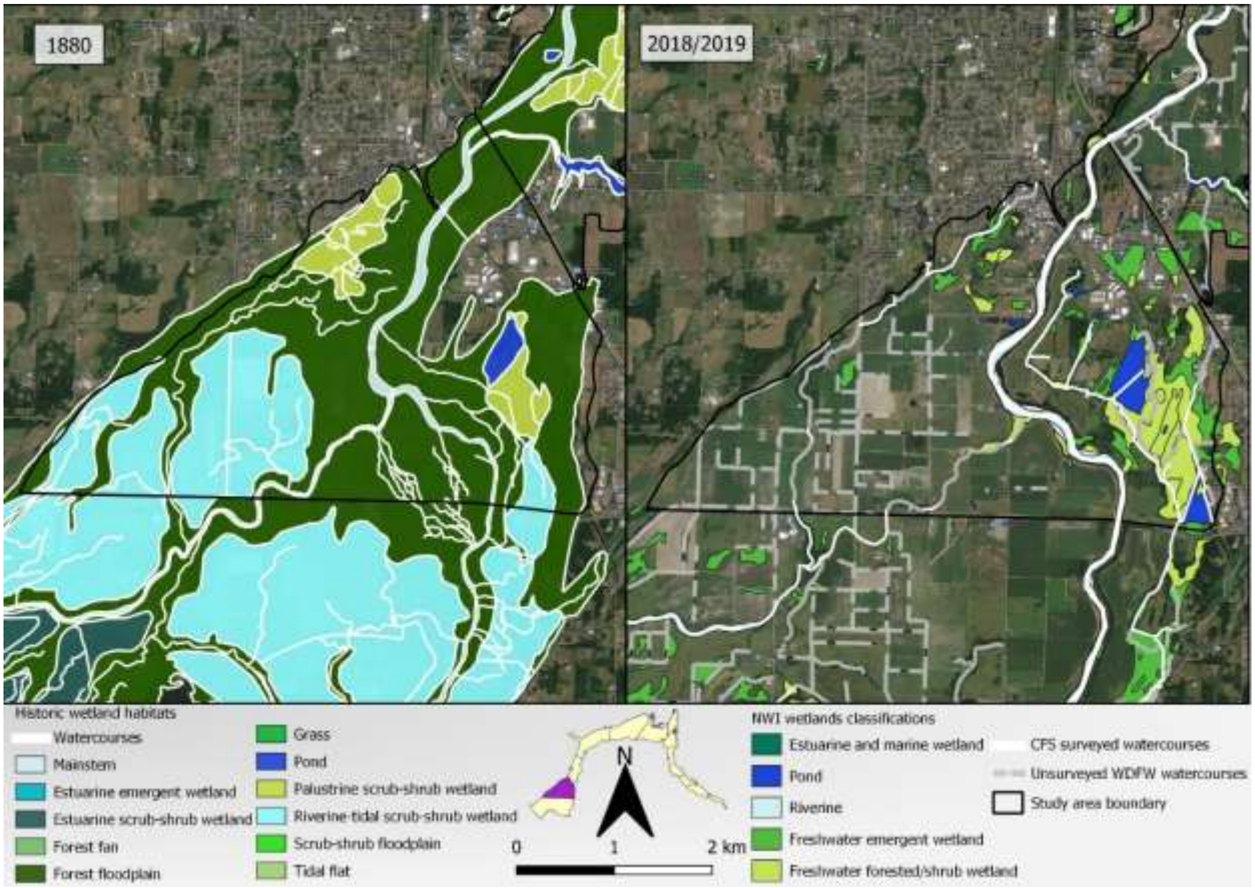

Figure 39: Map of current winter habitat and historical winter habitat extents (Collins and Sheikh) for Upper Reach 1. Surveyed watercourses and unsurveyed watercourses from current surveys are depicted, current wetland habitats are from the U.S. Fish and Wildlife Service National Wetlands Inventory (2017).

Reach: Lower Reach 2

Current Mainstem Habitat Conditions:

The mainstem of Lower Reach 2 was made up of only single-thread confined channel. No braid or side-channel habitat was observed in summer low flow or winter flow surveys (**Table 41**). Hydro-modified banks were dominant in this reach and accounted for 94% and 86% of the reach bank length in winter and summer low flow surveys, respectively (**Figure 109**; **Figure 110**). Bar edge made up 6% and 14% of the edge length in winter and summer low flow surveys, respectively. No natural banks were observed in Lower Reach 2 in either season. Hydro-modifications of edges in this reach included levees, placed riprap, and pilings (**Figure 112**). Hydro-modified banks made up of 86% of slow water edge habitat in winter flows and 87% of slow water edge habitat in summer low flows. Slow water edge habitat area was greater in winter flow than summer low flow surveys for both bar and hydro-modified bank edges, even though total bar edge length was less in winter flow surveys (**Figure 112**).

Glides were the dominant habitat unit type in both length and total area observed in mainstem surveys in both winter flow and summer low flow surveys (**Figure 113**). In winter flow surveys, glides accounted for 96% of habitat unit length and total area, while pools made up the remaining 3% (**Figure 109**). In summer low flow surveys, glides accounted for 86% of the length and area, while pools accounted for 10% of the length and 8% of the area, and riffles accounted for 4% of the length and 6% of the area (**Figure 110**). All pools observed in both seasons were scour pools. In winter flow surveys 100% of pools were formed by large woody jams, while in summer low flow both rip rap (50% of pools) and large wood jams (50% of pools) were attributed as the pool forming feature (**Figure 114**). Deciduous species were the dominant riparian canopy cover in both summer low flow and winter flows. Percent canopy cover was higher in summer low flow surveys (2.1%) than winter surveys (1.4%) (**Table 42**). No qualifying large wood jams were observed in the mainstem in this reach.

Current Floodplain Habitat Conditions:

Floodplain surveys in this reach were limited by access overall and only a small portion of habitats were surveyed (14% of floodplain channel length surveyed), while the remainder was estimated using the WDFW regulatory hydrography layer (**Figure 109**; **Figure 110**). Floodplain habitat in this reach was predominantly made up of hydro-modified natural channels, with some tributary habitat and hydro-modified channels surveyed (**Table 43**). However, 95% of the hydro-modified natural channel length was estimated using the WDFW regulatory stream network (WDFW regulatory layer). Tenmile Creek, which flows through Barrett Lake before entering the Nooksack, was the only tributary in this reach surveyed in our winter flow surveys. No constructed channels were surveyed due to private property restrictions, but length and area estimates calculated from the WDFW regulatory stream network show they contribute a substantial portion of habitat. Dry habitat units were observed in this reach in winter habitat surveys. No summer validation surveys were performed in this reach, summer habitat lengths were calculated using winter habitat lengths and areas in addition to the ratio of wet to dry units (**Appendix B**).

Glides were the dominant habitat unit across surveyed floodplain channel types (**Figure 115**). Tributaries were made up of 100% glide habitat units. Hydro-modified natural channels had the highest habitat variety, with glides, pools, and ponded area habitat units observed, however, glides accounted for 94% of the habitat unit length, while ponded areas accounted for 80% of the unit area overall (**Table 43**). All pools observed were scour pools formed by LWD (**Figure 116**). Hydro-modified channels also had glide and ponded area units and were made up of 90% glide unit length and 79% glide unit area and 10% of pond unit length and 21% of pond unit area.

Percent canopy cover was higher in floodplain than in mainstem channels, and was the highest in hydro-modified channels, followed by hydro-modified natural channels, and tributary channels (**Table 43**). Percent canopy cover was reported from winter values and would be assumed to be higher in summer surveys after leaf-out. Large wood was scarce in floodplain habitats in this reach, with only three jams being observed across the reach and 40 m^2 of wetted cover provided. Substrate was dominated by fine sediment across channel types.

Current versus Historical Conditions:

Floodplain habitat has been dramatically reduced from historic conditions to present (**Figure 40**; **Figure 42**) and no side-channel or braid habitat was observed in current surveys of Lower Reach 2 (**Table 45**; **Figure 41**) compared to historical reconstructions that show the presence of secondary channels in this reach (**Table 45**). Additionally, for both summer and winter surveys, mainstem edges in 2018/2019 surveys were dominated by hydro-modified bank edge, whereas natural bank edge was dominant in historic estimates (**Figure 41**). Slow water edge habitat area overall was also less than historic values (**Figure 42**).

For winter surveys, bar edge lengths in current surveys were comparable to historic estimates, and there was slightly more slow water edge area observed in current surveys. However, for summer surveys, current bar edge length and bar edge slow water area were substantially less than historic estimates (**Figure 41**; **Figure 118**; **Figure 42**). Current mainstem and secondary channels are also substantially more confined than historically (**Figure 40**), and wetland and floodplain habitat dramatically decreased.

Summary:

Historic reconstructions also suggest naturally low mainstem channel complexity in this reach compared to the upper reaches, with relatively little side channel and braid habitat. However, our surveys revealed no braid or side-channel habitats observed in this reach (**Table 16**). Lack of mainstem channel complexity and prevalence of hydro-modified bank edges are also the primary conditions impairing mainstem habitat quality in this reach. The mainstem channel in this reach is a single-thread confined channel with no braid or side-channel habitat observed during the surveys, with most of the bank edge being hydro-modified. Habitat unit diversity was low, and comparatively little large woody debris and log jams were observed. Low floodplain connectivity and modification of floodplain channels also impact this reach, and a large portion of the floodplain channels surveyed in the winter floodplain survey extent are likely dry during summer low flows (**Table 17**).

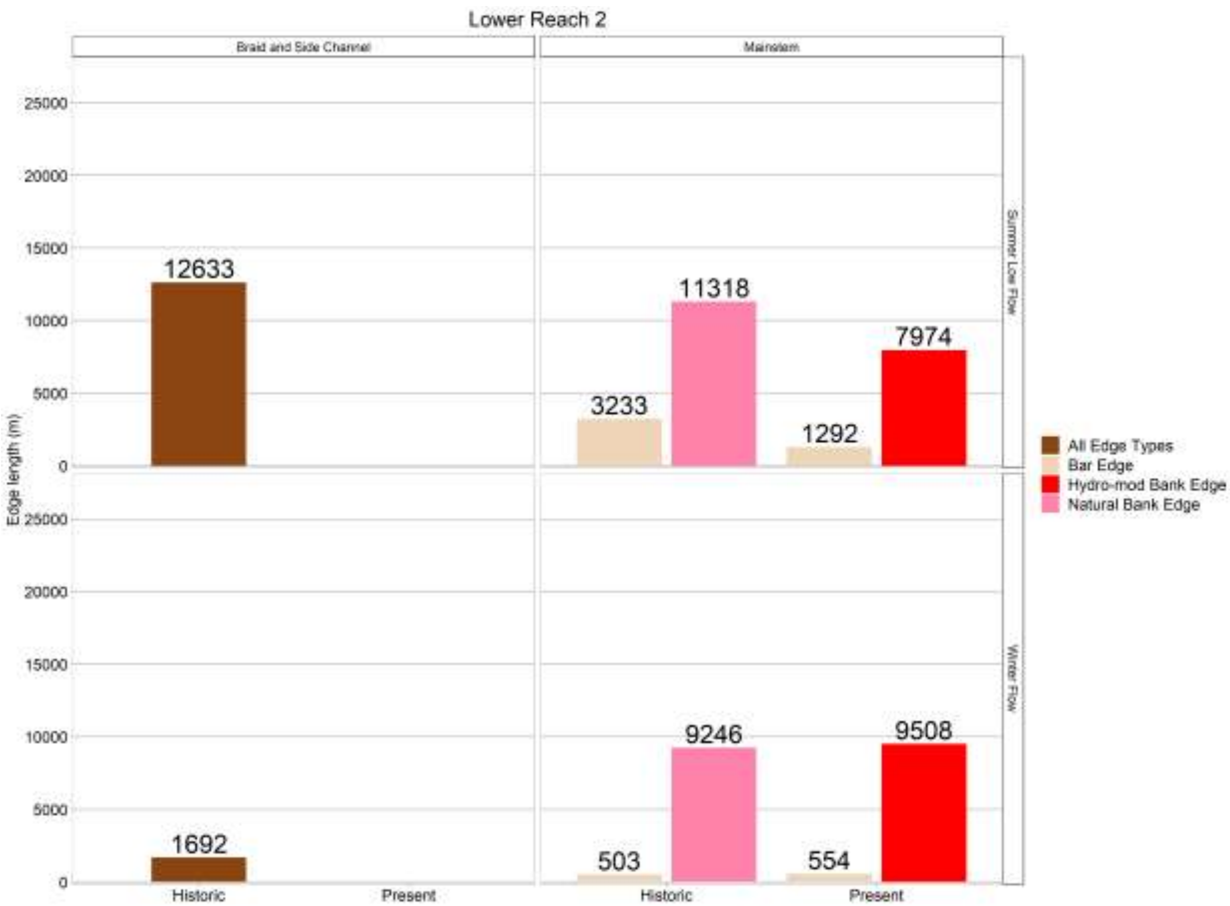

Figure 40: Edge lengths (meters) of bank types for summer low flow and winter flow conditions for historic versus present data. Edge type data for historic braid and side-channel habitats were not available. No braid or side-channel habitat was observed in Lower Reach 2.

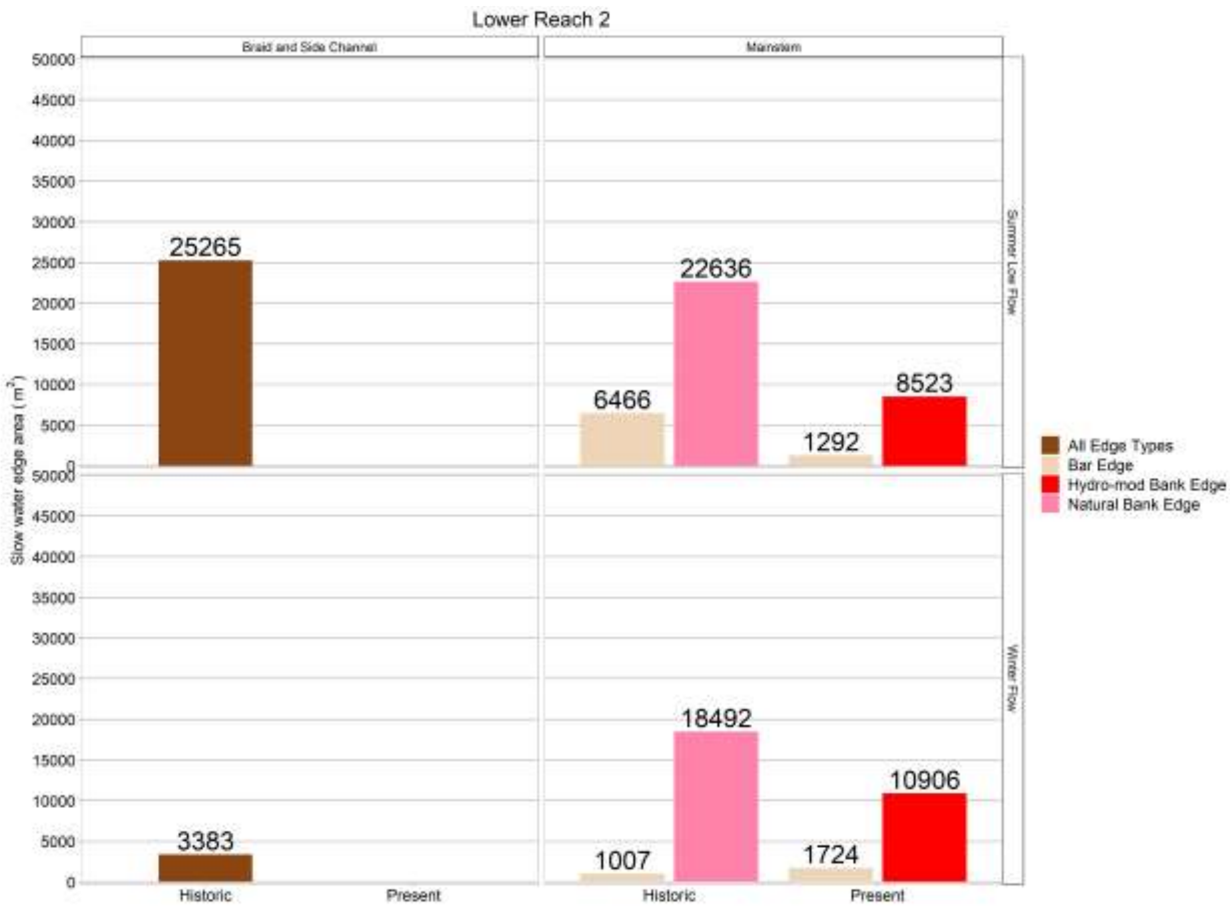

Figure 41: Slow water edge area (meters^2) for bank types for summer low flow and winter flow conditions for historic versus present data. Edge type data for historic braid and side-channel habitats were not available. No braid or side-channel habitat was observed in Lower Reach 2.

Table 16: Summary results for mainstem surveys for Lower Reach 2, W=Winter flow, S= Summer Low Flow. Change from historic condition refers to the difference in slow water area for mainstem channels and braid and side channels from 1880s data to present. The shading indicates a negative deviation from the study area average for each value. For the change from historic conditions, green indicates an increase in habitat area and red indicates a loss in habitat area. For the percent of total channel length, red indicates mainstem values being above average and braid and side channel values being below average. For the percent of edge length in hydro-modified bank and percent length in glides red indicates a reach value above the study area average and green indicates a reach value below the study area average. For the number of pools, the percent length in pools, the number of jams, and the wetted jam area, red indicates a reach value below average and green indicates a reach value above average. Study area averages are also reported.

		Change from Historic Condition		% of Total Channel Length		% Edge Length in Hydro-modified Bank		% Length in Glides		Pool Count		% Length in Pools		LWD Count		Wetted LWD Jam Area (m2)	
		W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Lower Reach 2	Mainstem	-6872	-19286	100	100	94	86	97	86	1	2	3	10	0	0	0	0
	Braid & Side Channel	-3383	-25265	0	0	-	-	-	-	-	-	-	-	-	-	-	-
Study area average	Mainstem	NA	NA	80	92	63	52	84	73	3	5	6	12	5	5	429	1193
	Braid & Side Channel	NA	NA	20	8	11	6	42	59	32	16	20	14	9	6	1225	749

Table 17: Summary results for floodplain surveys for Lower Reach 2. The shading indicates a negative deviation from the study area average for each value. For the percent length in glides red indicates a reach value above the study area average and green indicates a reach value below the study area average. For the number of pools, the percent length in pools, the number of jams, and the wetted jam area, red indicates a reach value below average and green indicates a reach value above average. Study area averages are also reported.

		% of Total Channel Length	% Length Unsurveyed	% Length in Glides	# Pools	% Length in Pools	# LWD Jams	Wetted LWD Jam Area (m2)
Lower Reach 2	Hydro-modified natural channel	20	95	94	1	1	2	13
	Tributary	52	0	100	0	0	1	27
	Hydro-modified channel	28	0	90	0	0	0	0
	Wetland	-	NA	NA	NA	NA	-	-
	Constructed Channel	-	100	-	-	-	-	-
Study Area Average	Hydro-modified natural channel	50	59	67	8	2	9	245
	Tributary	36	4	88	15	12	14	400
	Hydro-modified channel	11	0	77	4	4	3	13
	Wetland	2	NA	NA	NA	NA	0	0
	Constructed Channel	0.2	100	49	1	3	10	135

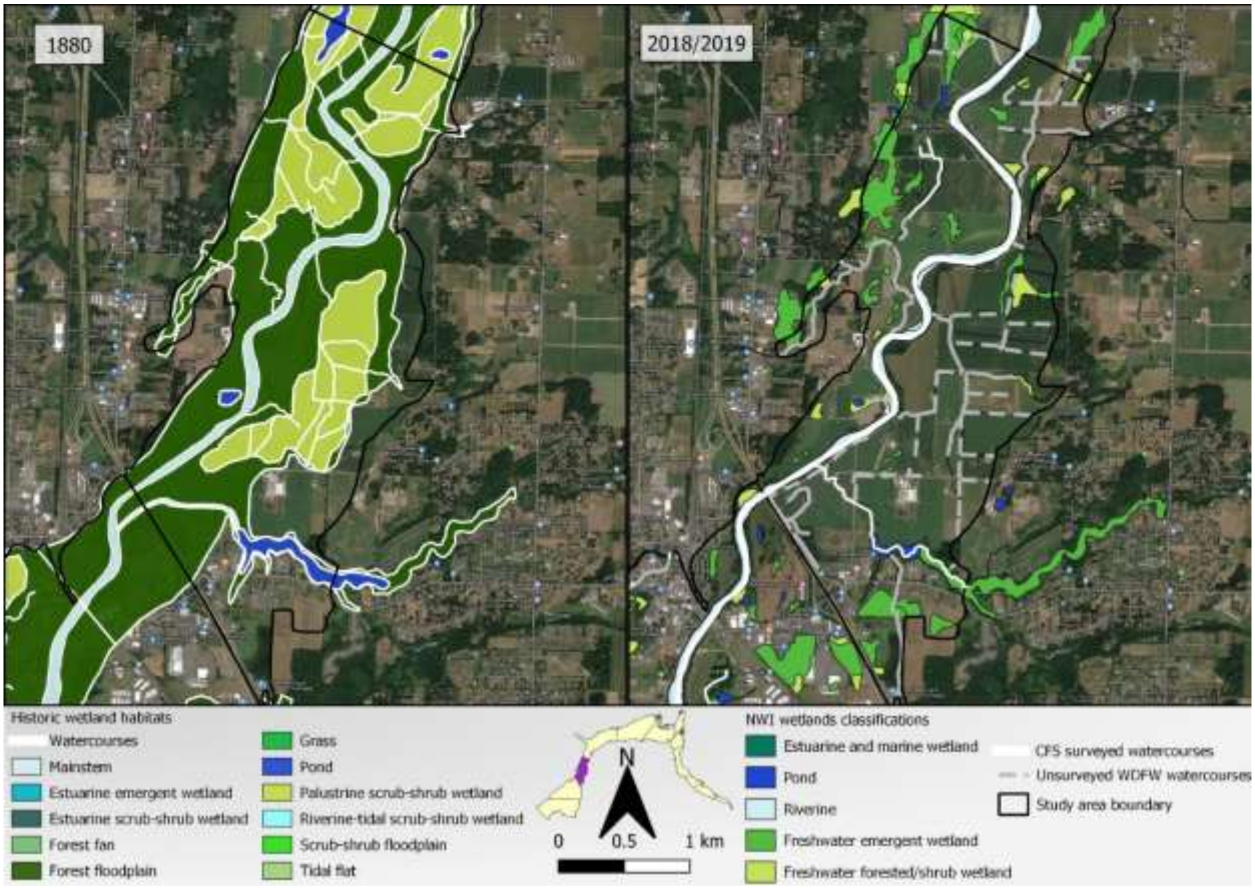

Figure 42: Map of current winter habitat and historical winter habitat extents (Collins and Sheikh) for Lower Reach 2. Surveyed watercourses and unsurveyed watercourses from current surveys are depicted, current wetland habitats are from the NWI (USFWS 2017).

Reach: Upper Reach 2

Current Mainstem Habitat Conditions:

The mainstem of Upper Reach 2 consisted of all single-thread channel. No braid or side-channel habitat was observed in summer low flow or winter flow surveys. Edge length was dominated by hydro-modified bank in both winter flow surveys and summer low flow (91% and 79%, respectively) (**Figure 120**; **Figure 121**), with bar edge habitat accounting for 8% (winter) to 19% (summer) of habitat. Leveed hydro-modified bank edges were the dominant mainstem edge types by length, with bar edge, natural bank edge, pilings, and unknown modifications only composing a small proportion of edge length (**Figure 123**). Hydro-modified bank edges accounted for 80% of the slow water edge habitat area in summer low flow surveys and 76% of the slow water edge habitat area in winter flows, with bar habitat accounting for 18% (summer) and 20% (winter), and natural bank making up only 1.3% (summer) and 3.4% (winter) (**Table 46**). While bar edges accounted for more length in summer low flow surveys, slow water bar edge habitat area was greater in winter flow surveys. There was more total habitat area as well as slow water edge habitat area in winter flow surveys than summer low flow surveys.

Summer low flow surveys had greater habitat diversity with 82% glide, 9% scour pool, and 9% riffle habitat length, while winter flow surveys found 90% glide habitat, 4% scour pool, and 6% riffle habitat length (**Figure 120**; **Figure 121**; **Figure 124**). In summer low flow surveys rip rap and LWD were identified as the pool forming features, while in winter surveys 100% of pools were formed by river bends (**Figure 125**). Percent canopy cover was minimal in both summer (1.4%) and winter (1.2%), but slightly less in winter (**Table 47**). Deciduous species were the dominant canopy providing class. More large wood jams were observed within the activated channel in the winter flow surveys than summer low flow, and resulted in a higher area of wetted cover (**Table 47**).

Current Floodplain Habitat Conditions:

Floodplain habitat in Upper Reach 2 was composed primarily of hydro-modified natural channel and tributary habitat (**Table 48**). Habitat lengths were estimated for 31% of hydro-modified natural channel lengths and 100% of constructed channel length. Tributary and hydro-modified channel lengths were fully surveyed in this reach (**Figure 120**). Fishtrap Creek and Bertrand Creek are both substantial tributaries that drain into the Nooksack River within Upper Reach 2. In Upper Reach 2, summer validation surveys were only performed as a representative subset of winter surveys in the lower portion of Bertrand Creek (**Figure 121**; **Figure 122**), a tributary with active flow. Bertrand Creek was selected for summer validation surveys due to accessibility on Whatcom County property. Summer floodplain habitat was estimated from validation surveys across the study area (**Appendix B**)**.** with estimates indicating that a large portion of the wetted floodplain channels during winter surveys are dry in the summer (**Table 49**). Although the validation surveys on tributary channels found active flow, we were only able to survey 500 m of channel length, therefor given the limited extent, we used the average ratio of wet to dry channel length for tributaries across the study area as a whole to estimate summer tributary channel length as 68% of the winter channel length.

Glides accounted for the majority of habitat units in tributary reaches at 85% of the length and 96% of area. Glides were also the dominant habitat type for hydro-modified channels and hydro-modified natural channels (**Figure 126**). Dammed pools, plunge pools, and scour pools were observed in hydro-modified natural channels, while scour pools were the only pool type observed in tributaries (**Figure 127**). Beaver dams were the primary pool forming feature in hydro-modified natural channels, while river bends were the primary pool forming feature in tributary channels. Percent canopy cover in floodplain habitats was greater than in mainstem habitats, with hydro-modified natural, hydro-modified, and wetland channels all having greater than 30% riparian canopy cover and tributary channels having 15% (**Table 48**). Large wood was minimal across channel types. Tributary channels had the greatest area of wetted channel covered by log jams, while log jams were the most frequent in hydro-modified natural channels. Fines were the dominant substrate in all channel types except tributaries, which were dominated by sand (**Table 48**).

Current versus Historical Conditions:

Floodplain habitat has been dramatically reduced from historic conditions to present (**Figure 43**; **Figure 45**) and no side-channel or braid habitat was observed in current surveys of Upper Reach 2 (**Table 50**; **Figure 44**) compared to historical reconstructions that show the presence of secondary channels in this reach (**Figure 43**). Additionally, for both summer and winter surveys, mainstem edges in 2018/2019 surveys were dominated by hydro-modified bank edge, whereas natural bank edge was dominant in historic estimates (**Figure 44**). Slow water edge habitat area overall was also less than historic values (**Figure 130**).

For winter surveys, bar edge lengths were similar, and there was more slow water edge area observed in current surveys than historical estimates. However, for summer surveys, current bar edge length and bar edge slow water area were substantially less than historic estimates (**Figure 44**; **Figure 45**). Current mainstem and secondary channels are also substantially more confined than historically (**Figure 43**) and wetland and floodplain habitat has dramatically decreased.

Summary:

Historic reconstructions also suggest naturally low channel complexity in this reach, but our surveys revealed a reduction of mainstem channel complexity relative to historic conditions (**Table 18**). Lack of mainstem channel complexity and prevalence of hydro-modified bank edges are the primary conditions impairing mainstem habitat quality in this reach. The current mainstem surveys in this reach found a single-thread confined channel with no braid or side-channel habitat and a high percentage of bank edge hydro-modified. Habitat unit diversity was low, but a moderate amount of large woody debris and log jams were observed in this reach. Low floodplain connectivity and modification of floodplain channels also impact this reach, and a large portion of the floodplain channels surveyed in the winter floodplain survey extent are likely dry during summer low flows (**Table 19**).

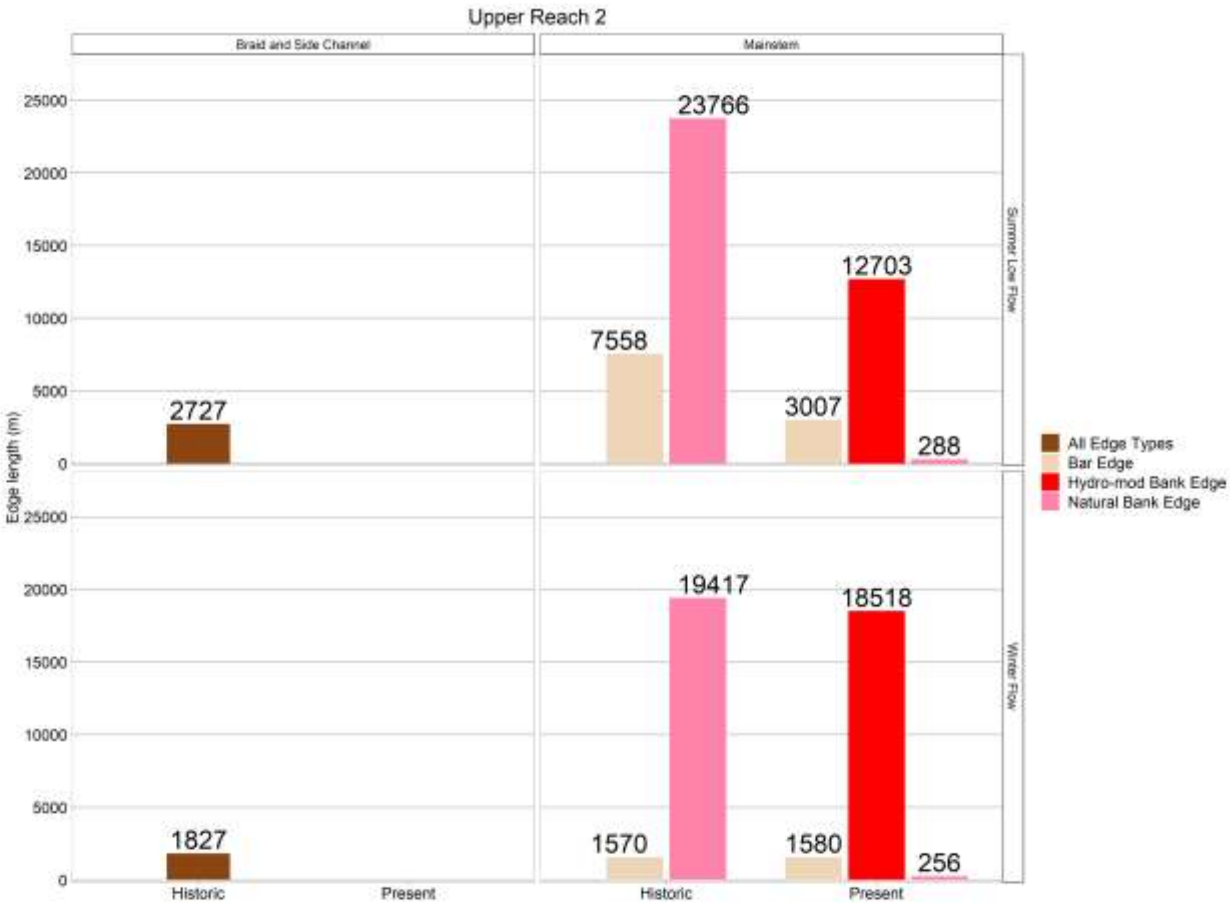

Figure 43: Edge lengths (meters) of bank types for summer low flow and winter flow conditions for historic versus present data. Edge type data for historic braid and side-channel habitats were not available. No braid or side-channel habitat was observed in Upper Reach 2.

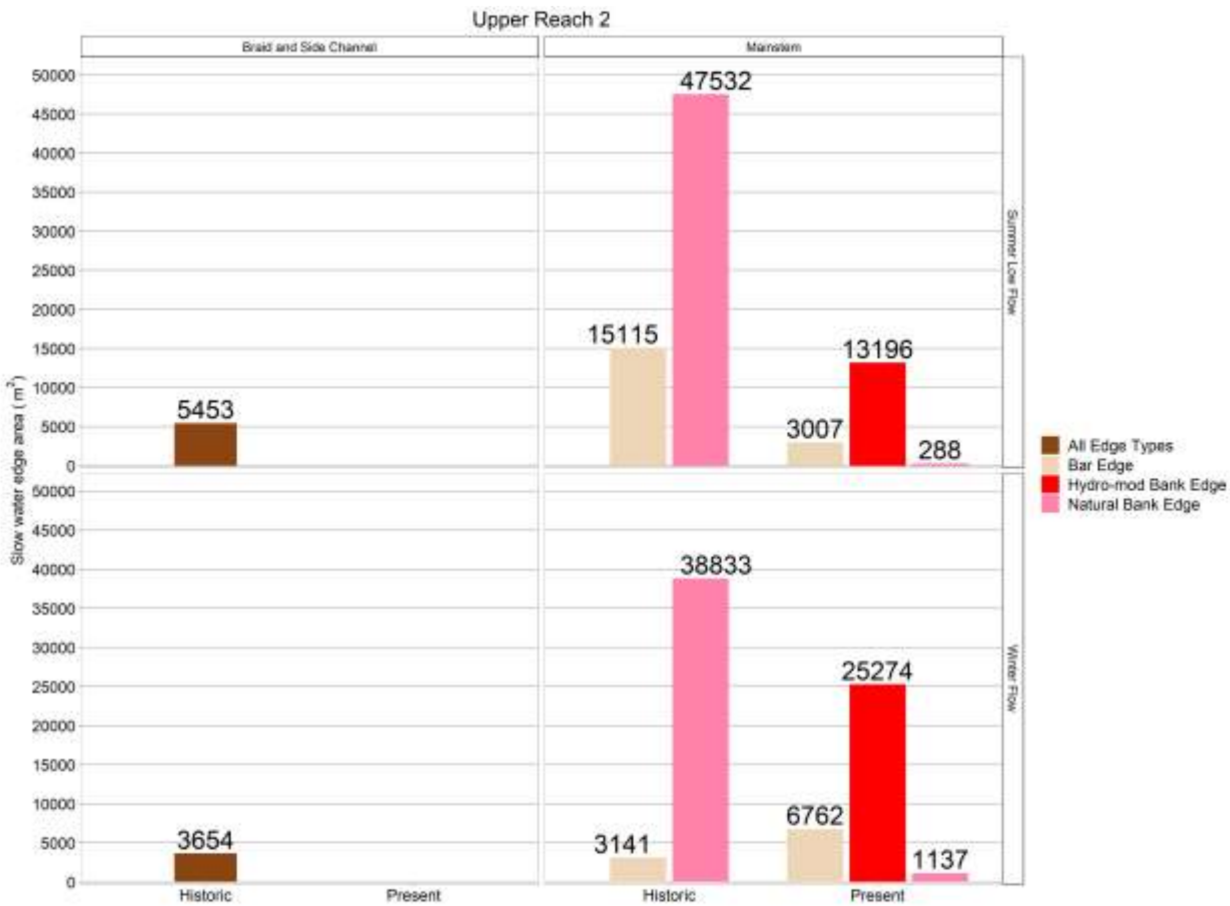

Figure 44: Slow water edge area (meters^2) for bank types for summer low flow and winter flow conditions for historic versus present data. Edge type data for historic braid and side-channel habitats were not available. No braid or side-channel habitat was observed in Upper Reach 2.

Table 18: Summary results for mainstem surveys for Upper Reach 2, W=Winter flow, S= Summer Low Flow. Change from historic condition refers to the difference in slow water area for mainstem channels and braid and side channels from 1880s data to present. The shading indicates a negative deviation from the study area average for each value. For the change from historic conditions, green indicates an increase in habitat area and red indicates a loss in habitat area. For the percent of total channel length, red indicates mainstem values being above average and braid and side channel values being below average. For the percent of edge length in hydro-modified bank and percent length in glides red indicates a reach value above the study area average and green indicates a reach value below the study area average. For the number of pools, the percent length in pools, the number of jams, and the wetted jam area, red indicates a reach value below average and green indicates a reach value above average. Study area averages are also reported.

		Change from Historic Condition		% of Total Channel Length		% Edge Length in Hydro-modified Bank		% Length in Glides		Pool Count		% Length in Pools		LWD Count		Wetted LWD Jam Area (m2)	
		W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Upper Reach 2	Mainstem	-8801	-46156	100	100	91	79	90	82	2	5	4	9	6	1	439	175
	Braid & Side Channel	-3654	-5453	0	0	-	-	-	-	-	-	-	-	-	-	-	-
Study area average	Mainstem	NA	NA	80	92	63	52	84	73	3	5	6	12	5	5	429	1193
	Braid & Side Channel	NA	NA	20	8	11	6	42	59	32	16	20	14	9	6	1225	749

Table 19: Summary results for floodplain surveys for Upper Reach 2. The shading indicates a negative deviation from the study area average for each value. For the percent length in glides red indicates a reach value above the study area average and green indicates a reach value below the study area average. For the number of pools, the percent length in pools, the number of jams, and the wetted jam area, red indicates a reach value below average and green indicates a reach value above average. Study area averages are also reported.

		% of Total Channel Length	% Length Unsurveyed	% Length in Glides	# Pools	% Length in Pools	# LWD Jams	Wetted LWD Jam Area (m2)
Upper Reach 2	Hydro-modified natural channel	61	31	83	11	1	16	146
	Tributary	31	0	95	1	0.5	11	600
	Hydro-modified channel	8	0	89	0	0	0	0
	Wetland	1	NA	NA	NA	NA	0	0
	Constructed Channel	-	100	-	-	-	-	-
Study Area Average	Hydro-modified natural channel	50	59	67	8	2	9	245
	Tributary	36	4	88	15	12	14	400
	Hydro-modified channel	11	0	77	4	4	3	13
	Wetland	2	NA	NA	NA	NA	0	0
	Constructed Channel	0.2	100	49	1	3	10	135

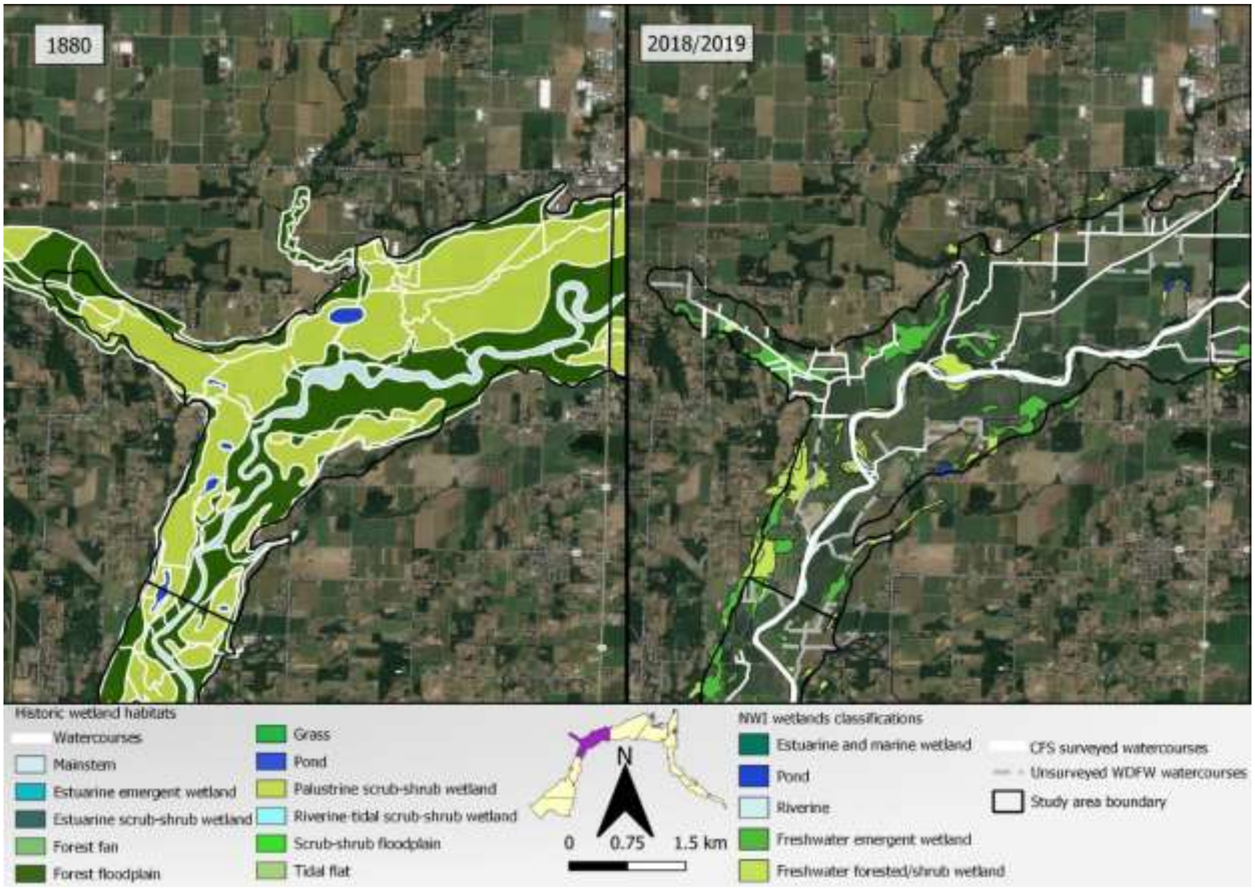

Figure 45: Map of current winter habitat and historical winter habitat extents (Collins and Sheikh) for Upper Reach 2. Surveyed watercourses and unsurveyed watercourses from current surveys are depicted, current wetland habitats are from the NWI (USFWS 2017).

Reach: Lower Reach 3

Current Mainstem Habitat Conditions:

Lower Reach 3 was composed of only mainstem channel types in summer low flow surveys, but winter surveys observed both braid and side channel connectivity, although in low proportion of the total length of channel surveyed (4% and 8%, respectively) (**Table 51**). For main channels of the mainstem, edges were dominated by hydro-modified banks in winter flow surveys and summer low flow surveys (76% and 59%, respectively) (**Figure 131**; **Figure 132**). Levees and riprap were the most commonly observed hydro-modifications (**Figure 134**). Hydro-modified banks were present in both braid and side channels, but edge length was dominated by bar edge and natural bank edge, respectively. Slow water edge area was substantially greater in winter flow surveys across edge types but was greatest in hydro-modified bank edges across channel types in both survey periods.

Total habitat area was also greater in winter flow surveys in main channels of the mainstem, as well as side channels and braids, which were lacking in summer low flow surveys (**Table 51; Figure 131**; **Figure 132**). In main channels of the mainstem, glide, scour pool, and riffle habitats were observed in both winter flow and summer low flow surveys, however, pools and riffles were infrequent in winter flow surveys, with only one unit of each being observed (**Table 51; Figure 135**). There were two scour pools and nine riffles observed in summer low flow surveys. Glides and pools were the only habitats observed in braided channels in winter surveys. In side channels in winter flow surveys, backwater units accounting for the majority of habitat length and area surveyed (63% and 67%, respectively) (**Figure 135**). Large wood jams were the most frequently observed pool forming feature, however in the mainstem in winter flow surveys, river bends also accounted for pool formation (**Figure 136**). Slow water edge area was greatest in glide units for both surveys.

Mainstem canopy cover was minimal in both summer low flow and winter flow surveys, but was slightly higher in summer low flow (1.9% and 1.4%, respectively) (**Table 52**). Deciduous species were the dominant canopy cover across surveys and channel types. In winter flow surveys, cover was substantially greater in braid and side channels than the mainstem. Reported values for winter flow canopy cover for braid and side channels are likely higher than would exist in true winter conditions given that surveys were completed in May when springtime growth had commenced. Large wood jam cover and abundance was minimal in both surveys. Only four log jams were observed in summer low flow surveys in mainstem channels covering 180 m^2 of wetted channel. In winter flow surveys, no log jams were found in main channels of the mainstem, however, four jams were observed in braid and side channel units covering 352 m^2 of wetted channel. Fine sediment was dominant in all side channel observations.

Current Floodplain Habitat Conditions:

Lower Reach 3 has extensive floodplain habitat and includes Kamm Creek, Mormon Ditch, and Scott Ditch. Hydro-modified natural channels account for most of the habitat length in this reach, followed by constructed channels and tributaries (**Table 53**). Private property drastically limited floodplain surveys in this reach, and only 29% of total floodplain channel length was surveyed (**Figure 131**). Hydro-modified natural channels accounted for the majority of surveyed channel length and area, although approximately 70% of total length and area were estimated using the WDFW regulatory stream network (WDFW regulatory layer). Summer validation surveys were performed on the lower sections of Kamm Creek, Scott Ditch, and an adjacent channel (**Figure 132**; **Figure 133**). Kamm Creek and Scott Ditch both had active flow, while the adjacent channel was found to be dry. It is estimated that a large portion of hydro-modified natural, hydro-modified, and constructed channels would be dry in summer surveys (**Appendix B; Table 54**). Glides were the dominant habitat unit type for all surveyed channels (**Figure 137**). Dammed pools, scour pools and trench pools were found in this reach with culverts, LWD, and bedrock accounting for the majority of pool forming features (**Figure 138**). Wetland habitat was estimated to account for the largest habitat area for floodplain habitats. Canopy cover was the greater in tributary channels (20%), than hydro-modified natural channels (13%) and hydro-modified channels (8%) (**Table 53**). Canopy cover was primarily made up of deciduous species. Blackberry, reed canary grass, and willows were abundant riparian species covering banks. Wood was most abundant in tributary channels in both jam number, wetted area covered, and total number of individual pieces observed. Fine sediment was dominant across channel types, with less than 20% of observations finding gravel or sand.

Current versus Historical Conditions:

A reduction in total available habitat has occurred from the 1880's condition to present day in Lower Reach 3, especially summer low flow habitat (**Table 55**; **Figure 48**). In winter flow surveys, main channel of the mainstem lengths and slow water area were only slightly less than historic conditions (**Figure 97**). Braid and side channel lengths were also similar, however slow water area was substantially less than historic conditions. In summer low flow surveys, no braid or side-channel habitat was observed which was a large departure from historic conditions. Summer low flow channel length and slow water area were also greatly reduced (**Figure 98**). Hydro-modified bank edges dominate present edge length and slow water area, which is a departure from historic conditions where edges were dominated by natural banks.

For floodplain habitats, estimated wetland habitat area was dramatically less than historic conditions (**Figure 139**). Slough and tributary habitat area increased in present day surveys as compared to historic conditions, however length of slough and tributary habitats was less in summer low flow surveys than winter flow surveys due to the large length of channels that are dry in summer.

Summary:

Historic reconstructions suggest naturally low channel complexity in this reach, however, our surveys indicate that only a small amount of braid and side-channel habitat is active in this reach during present-day winter flows and no secondary channels are active in summer low flow surveys (**Table 20**). Lack of mainstem channel complexity and prevalence of hydro-modified bank edges are also the primary conditions impairing mainstem habitat quality in this reach. The mainstem in this reach is a single-thread confined channel with little or no braid or side-channel habitat observed during the winter flow and summer low flow surveys, respectively, and with most of the bank edge being hydro-modified. Habitat unit diversity was low and large woody debris and log jam abundance were also low in this reach. Low floodplain connectivity and modification of floodplain channels also impact this reach, and a large portion of the floodplain channels surveyed in the winter floodplain survey extent are likely dry during summer low flow (**Table 21**).

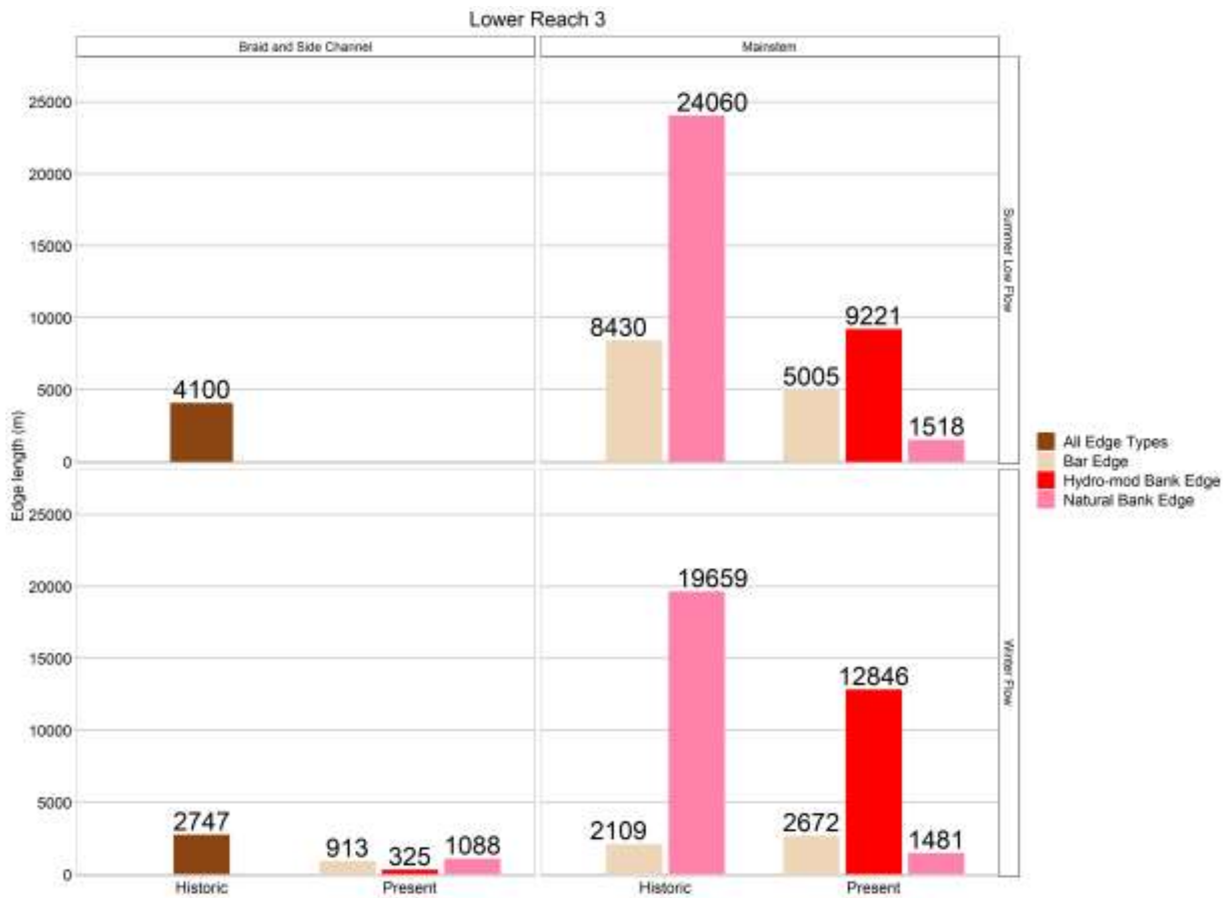

Figure 46: Edge lengths (meters) of bank types for summer low flow and winter flow conditions for historic versus present data For Lower Reach 3. Edge type data for historic braid and side-channel habitats were not available.

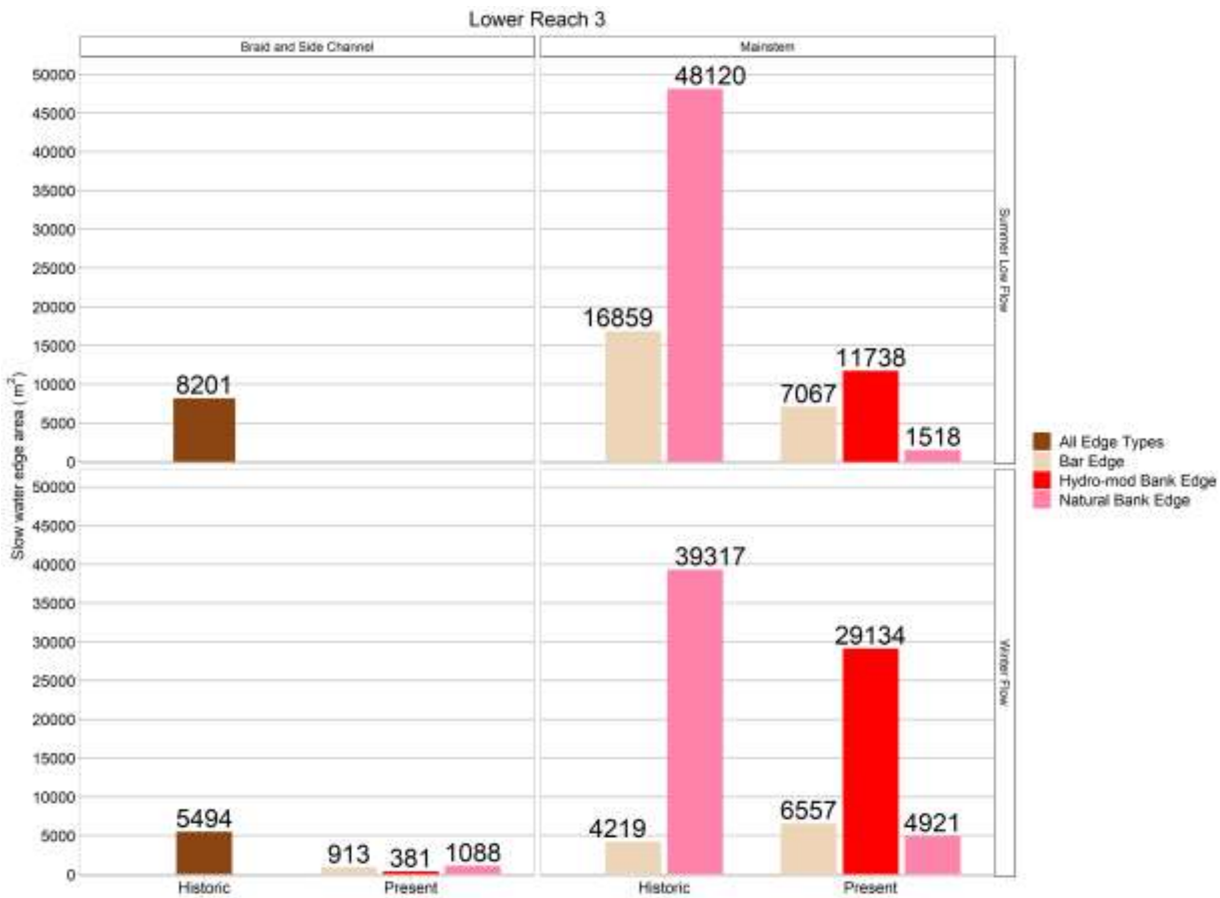

Figure 47: Slow water edge area (meters^2) for bank types for summer low flow and winter flow conditions for historic versus present data. Edge type data for historic braid and side-channel habitats were not available.

Table 20: Summary results for mainstem surveys for Lower Reach 3, W=Winter flow, S= Summer Low Flow. Change from historic condition refers to the difference in slow water area for mainstem channels and braid and side channels from 1880s data to present. The shading indicates a negative deviation from the study area average for each value. For the change from historic conditions, green indicates an increase in habitat area and red indicates a loss in habitat area. For the percent of total channel length, red indicates mainstem values being above average and braid and side channel values being below average. For the percent of edge length in hydro-modified bank and percent length in glides red indicates a reach value above the study area average and green indicates a reach value below the study area average. For the number of pools, the percent length in pools, the number of jams, and the wetted jam area, red indicates a reach value below average and green indicates a reach value above average. Study area averages are also reported.

		Change from Historic Condition		% of Total Channel Length		% Edge Length in Hydro-modified Bank		% Length in Glides		Pool Count		% Length in Pools		LWD Count		Wetted LWD Jam Area (m2)	
		W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Lower Reach 3	Mainstem	-2924	-44656	88	100	76	59	97	78	1	2	2	6	0	4	0	181
	Braid & Side Channel	-3112	-8201	12	0	14	-	21	-	9	-	33	-	4	-	352	-
Study area average	Mainstem	NA	NA	80	92	63	52	84	73	3	5	6	12	5	5	429	1193
	Braid & Side Channel	NA	NA	20	8	11	6	42	59	32	16	20	14	9	6	1225	749

Table 21: Summary results for floodplain surveys for Lower Reach 3. The shading indicates a negative deviation from the study area average for each value. For the percent length in glides red indicates a reach value above the study area average and green indicates a reach value below the study area average. For the number of pools, the percent length in pools, the number of jams, and the wetted jam area, red indicates a reach value below average and green indicates a reach value above average. Study area averages are also reported.

		% of Total Channel Length	% Length Unsurveyed	% Length in Glides	# Pools	% Length in Pools	# LWD Jams	Wetted LWD Jam Area (m2)
Lower Reach 3	Hydro-modified natural channel	52	68	81	9	3	6	18
	Tributary	33	0	91	18	7	16	277
	Hydro-modified channel	12	0	84	5	2	5	15
	Wetland	4	NA	NA	NA	NA	0	0
	Constructed Channel	-	100	-	-	-	-	-
Study Area Average	Hydro-modified natural channel	50	59	67	8	2	9	245
	Tributary	36	4	88	15	12	14	400
	Hydro-modified channel	11	0	77	4	4	3	13
	Wetland	2	NA	NA	NA	NA	0	0
	Constructed Channel	0.2	100	49	1	3	10	135

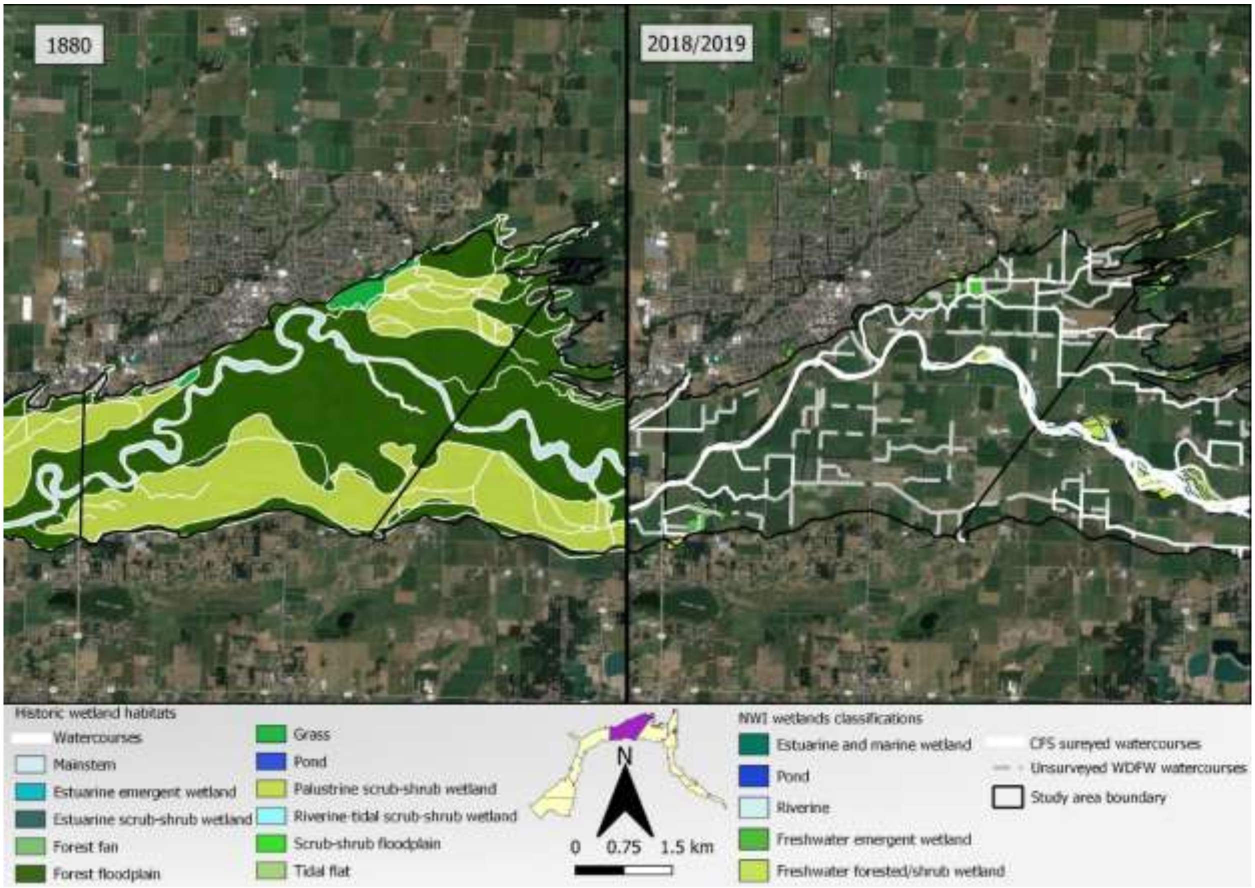

Figure 48: Map of current winter habitat and historical winter habitat extents (Collins and Sheikh) for Lower Reach 3. Surveyed watercourses and unsurveyed watercourses from current surveys are depicted, current wetland habitats are from the from the NWI (USFWS 2017).

Reach: Upper Reach 3

Current Mainstem Habitat Conditions:

In winter flows, Upper Reach 3 mainstem channel length was composed of 57% main channels, 24% braids, and 19% side channels (**Table 56; Figure 142**). In summer low flow surveys, main channels of the mainstem made up 77% of mainstem channel length, braids accounted for 23%, and no side channel length was observed (**Figure 143**). In winter flow surveys and summer low flow surveys, bar edges were the most abundant edge type in both length and slow water area overall, in both main and braided channels. Natural bank edges accounted for the most length of side channels in winter low flow surveys. Hydro-modified bank edges accounted for only 29% of mainstem edge length overall in winter flow surveys and only 19% in summer low flow surveys. Hydro-modifications observed included levees, riprap, and unknown modifications (**Figure 145**). Slow water area overall was greater in winter flow surveys across channel types and edge types.

Glides were the dominant habitat unit type across channel types and surveys in both length, overall area, and slow water area. In winter flows, glides, pools, riffles, and backwater units were observed. In summer low flow surveys, no backwater units were observed in mainstem or braided channels. Pools were the least frequent habitat type and accounted for only 11% of winter flow habitat length and 20% summer low flow habitat length across mainstem channel types (main, braid, and side channels) (**Figure 146**). Dammed pools, plunge pools, and scour pools were observed in this reach, with large woody debris and river bends being the primary pool forming features (**Figure 147**). Canopy cover was greater in winter flow surveys than summer low flow, likely due winter flow surveys being completed in May for this reach, while summer low flow surveys were completed in March (**Table 57**). Average mainstem cover in summer low flow surveys was 1.6% for main channels and 2.8% for braids. Main channel cover for winter surveys was 4.1% and average braid and side-channel cover was 17% and 16%, respectively. Many of the connected braid and side channels were in dense, vegetated bars and thus canopy cover was greater. In both summer and winter surveys, riparian bank vegetation was predominantly deciduous or lacking. Large wood jams were more abundant in this reach than reaches further downstream. In summer low flow surveys, mainstem jam count and wetted cover was highest in main channels (**Table 57**). Only one wood jam was observed in summer low braided channels and only provided 85 m^2 of wetted cover. In winter flow surveys, wood jams were observed in main channels, braids, and side channels. Wetted wood jam cover area was the highest in side channels.

Current Floodplain Habitat Conditions:

Floodplain surveys in this reach included the upper extents of Mormon Ditch and Scott Ditch (**Figure 142**). The lower extents of Mormon Ditch and Scott Ditch found in Lower Reach 3 were classified as tributaries, however given their confined and ditched nature in Upper Reach 3, the WDFW regulatory layer classification of hydro-modified natural channel was used and they were not included in the tributary habitat estimates. All hydro-modified channels, 80% of hydro-modified natural, and 15% of constructed channels were surveyed as part of winter flow surveys, or 54% of total floodplain channel length. Wetland floodplain habitats were estimated using the NWI layer (USFWS 2017). Private property prevented surveying the remaining habitats, but lengths were estimated using WDFW hydrography (WDFW regulatory layer). Of the surveyed habitats, hydro-modified natural channels accounted for the majority of habitat unit length and area surveyed (**Table 58**). Hydro-modified and constructed channels accounted for a relatively small amount of channel habitat compared to further downstream reaches. Glide habitat units were the most abundant in length across all channel types (**Figure 148**). In hydro-modified natural channels, ponded area units made up the greatest total area, as well 40% of the habitat length surveyed. Overall, pools and riffles made up less than 4% of total floodplain habitat length. Dammed pools, plunge pools, scour pools, and trench pools were observed in this reach. Not all pool forming features were able to be identified but large woody debris jams, culverts, and beaver dams were all documented as pool forming features (**Figure 149**). Average percent canopy cover was highest in hydro-modified natural channels (18%), followed by hydro-modified channels (10%), and constructed channels (6%). Grasses were the most frequent canopy vegetation, followed by deciduous species. Riparian bank vegetation was made up of blackberry, reed canary grasses and other grasses, willow, and other deciduous species. Qualifying large wood jams and pieces were only observed in hydro-modified natural and constructed channels (**Table 58**). Large wood was lacking in this reach, total wetted wood cover for jams for Upper Reach 3 was only 265 m^2. Sediment was dominated by fines across channel types, with minimal amounts of sand and gravel.

Summer floodplain validation surveys were performed in a large section if this reach and found a large portion of channel length to be dry (**Figure 143**; **Figure 144**). It is estimated that floodplain habitat is dramatically reduced in the summer (**Appendix B; Table 59**).

Current versus Historical Conditions:

Total mainstem channel length has dramatically decreased in both winter flow and summer low surveys from historic conditions to present surveys (**Table 60**). Edge lengths of main channel units and braids and side channels have decreased for summer low flow surveys (**Figure 49**). For winter flow surveys, lengths of main channel, side-channel, and braid habitat have increased (**Figure 51**). No hydro-modified bank edge was reported in historic surveys. Natural bank edge habitat has been reduced when compared to historic surveys and hydro-modified banks were in present day surveys. Bar edge length was substantially less than the 1880's data in summer low flow surveys but was only slightly less for winter flow surveys. Summer low flow low water edge area for all edge types and channels was reduced as compared to 1880's surveys (**Figure 50**). In winter flow surveys, braid and side channel slow water area was slightly increased as compared to historic data, but main channel slow water area was reduced.

For floodplain habitats, present-day surveys found wetland areas were substantially less than historically, however slough and tributary lengths and areas were greater than historic values for both summer low flow and winter flow conditions (**Figure 150**).

Summary:

The 2018/2019 surveys suggest mainstem habitat complexity during winter flows is currently higher in this reach than historical conditions, with our surveys showing a large increase in braid and side-channel length coupled with a slight increase in main channel length compared to historical conditions (**Table 22**). However, the apparent increase in braid and side-channel habitats in this reach could be the result of increased survey resolution biasing current survey estimates compared to historically reconstructed mainstem channel networks. Although braid channels remained activated during summer low flows, side channels did not, and overall summer low flow habitat area for main channel and braid and side channel was reduced relative to historic conditions. Hydro-modified bank edges were present in this reach but are less prevalent than natural bank edges and bar edges. Large wood and jams were prevalent in this reach, and habitat unit diversity was high compared to the lower reaches. Low floodplain connectivity and modification of floodplain channels also impact this reach, although fewer floodplain channels were hydro-modified or constructed compared to lower reaches. Like the other reaches, our validation surveys suggest that significant portions of the floodplain channel network become dry during summer low flows in this reach (**Table 23**).

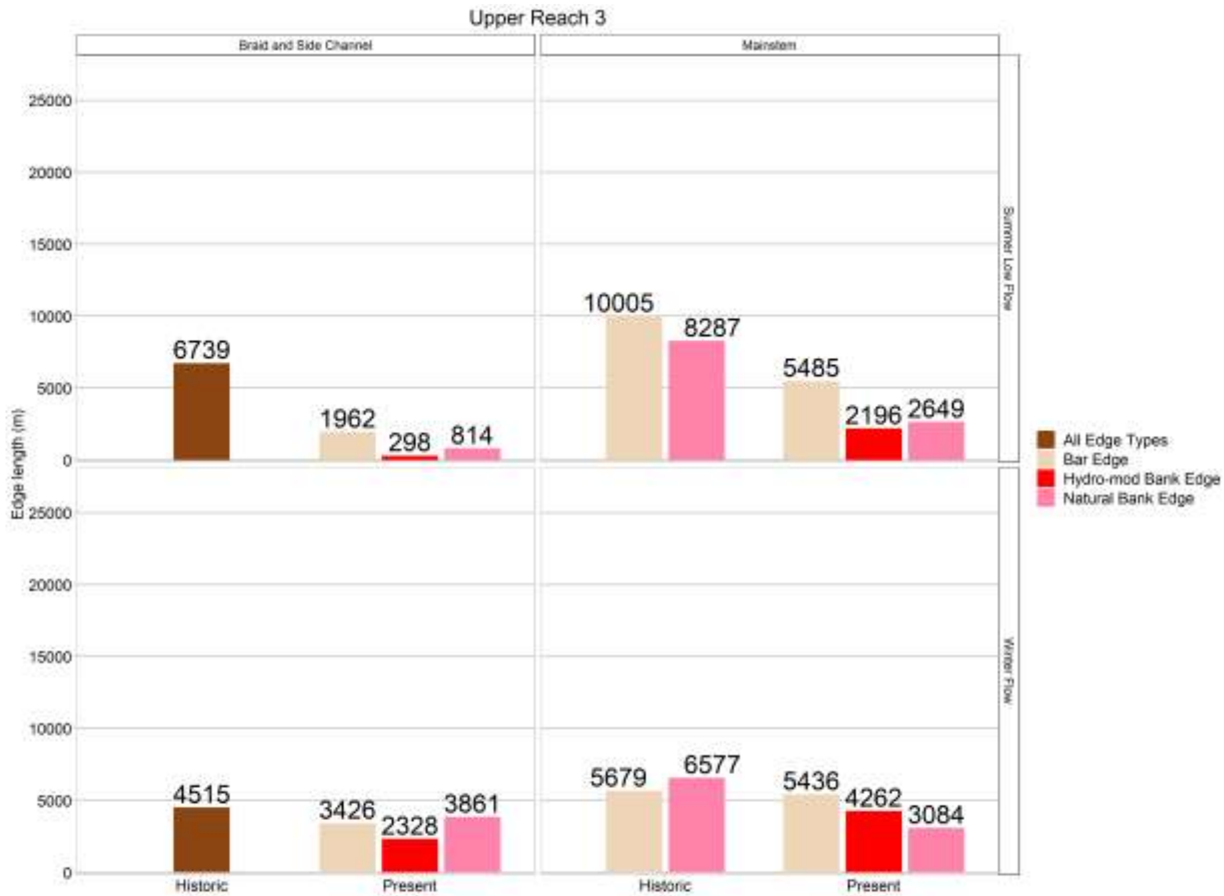

Figure 49: Edge lengths (meters) of bank types for summer low flow and winter flow conditions for historic versus present data for Upper Reach 3. Edge type data for historic braid and side-channel habitats were not available.

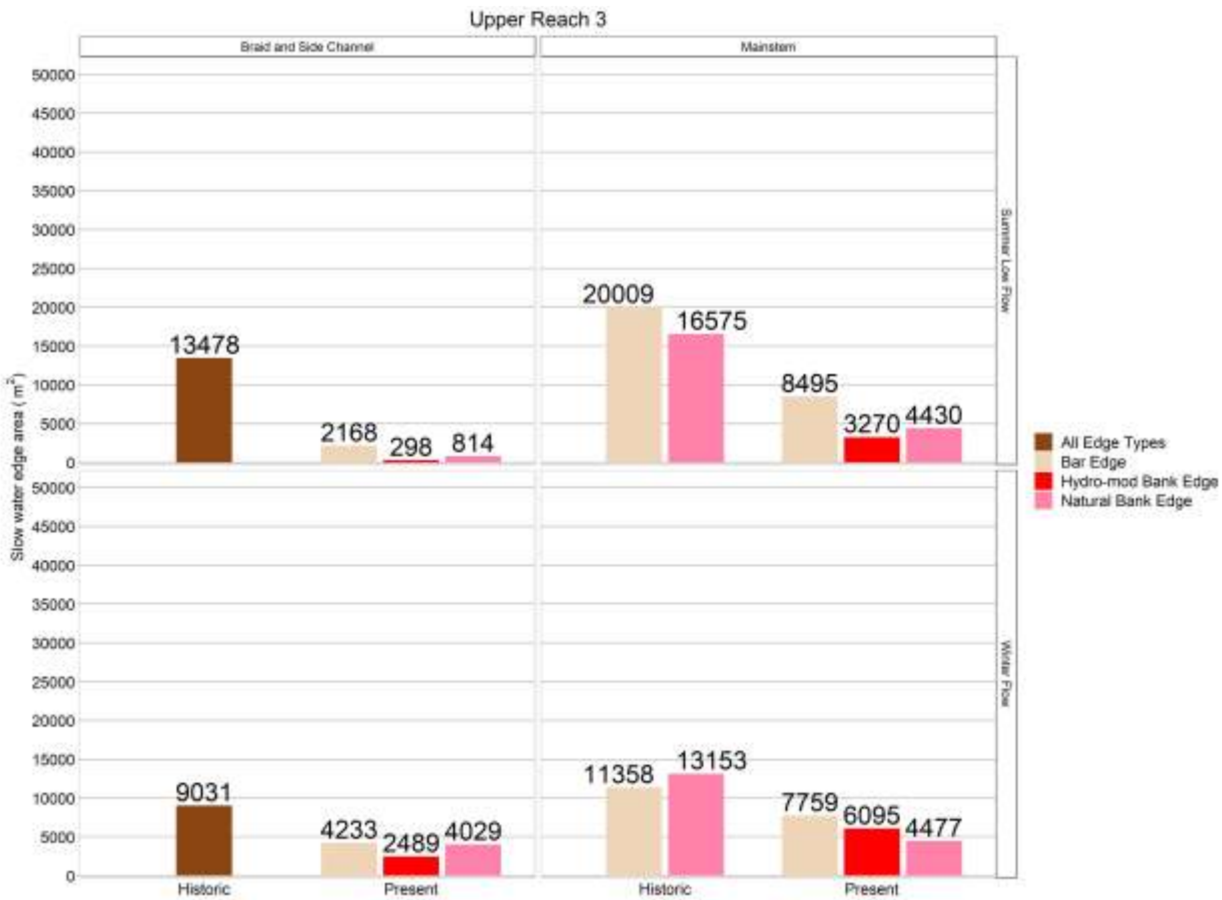

Figure 50: Slow water edge area (meters²) for bank types for summer low flow and winter flow conditions for historic versus present data. Edge type data for historic braid and side-channel habitats were not available.

Table 22: Summary results for mainstem surveys for Upper Reach 3, W=Winter flow, S= Summer Low Flow. Change from historic condition refers to the difference in slow water area for mainstem channels and braid and side channels from 1880s data to present. The shading indicates a negative deviation from the study area average for each value. For the change from historic conditions, green indicates an increase in habitat area and red indicates a loss in habitat area. For the percent of total channel length, red indicates mainstem values being above average and braid and side channel values being below average. For the percent of edge length in hydro-modified bank and percent length in glides red indicates a reach value above the study area average and green indicates a reach value below the study area average. For the number of pools, the percent length in pools, the number of jams, and the wetted jam area, red indicates a reach value below average and green indicates a reach value above average. Study area averages are also reported.

		Change from Historic Condition		% of Total Channel Length		% Edge Length in Hydro-modified Bank		% Length in Glides		Pool Count		% Length in Pools		LWD Count		Wetted LWD Jam Area (m2)	
		W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Upper Reach 3	Mainstem	-6180	-20389	57	77	33	21	69	49	2	8	7	23	7	11	941	3661
	Braid & Side Channel	1720	-10198	43	23	24	10	36	64	16	2	16	12	8	1	1902	85
Study area average	Mainstem	NA	NA	80	92	63	52	84	73	3	5	6	12	5	5	429	1193
	Braid & Side Channel	NA	NA	20	8	11	6	42	59	32	16	20	14	9	6	1225	749

Table 23: Summary results for floodplain surveys for Upper Reach 3. The shading indicates a negative deviation from the study area average for each value. For the percent length in glides red indicates a reach value above the study area average and green indicates a reach value below the study area average. For the number of pools, the percent length in pools, the number of jams, and the wetted jam area, red indicates a reach value below average and green indicates a reach value above average. Study area averages are also reported.

		% of Total Channel Length	% Length Unsurveyed	% Length in Glides	# Pools	% Length in Pools	# LWD Jams	Wetted LWD Jam Area (m2)
Upper Reach 3	Hydro-modified natural channel	82	40	67	16	4	1	1
	Tributary	-	-	-	-	-	-	-
	Hydro-modified channel	16	0	86	3	5	0	0
	Wetland	-	NA	NA	NA	NA	-	-
	Constructed Channel	2	100	49	1	3	10	135
Study Area Average	Hydro-modified natural channel	50	59	67	8	2	9	245
	Tributary	36	4	88	15	12	14	400
	Hydro-modified channel	11	0	77	4	4	3	13
	Wetland	2	NA	NA	NA	NA	0	0
	Constructed Channel	0.2	100	49	1	3	10	135

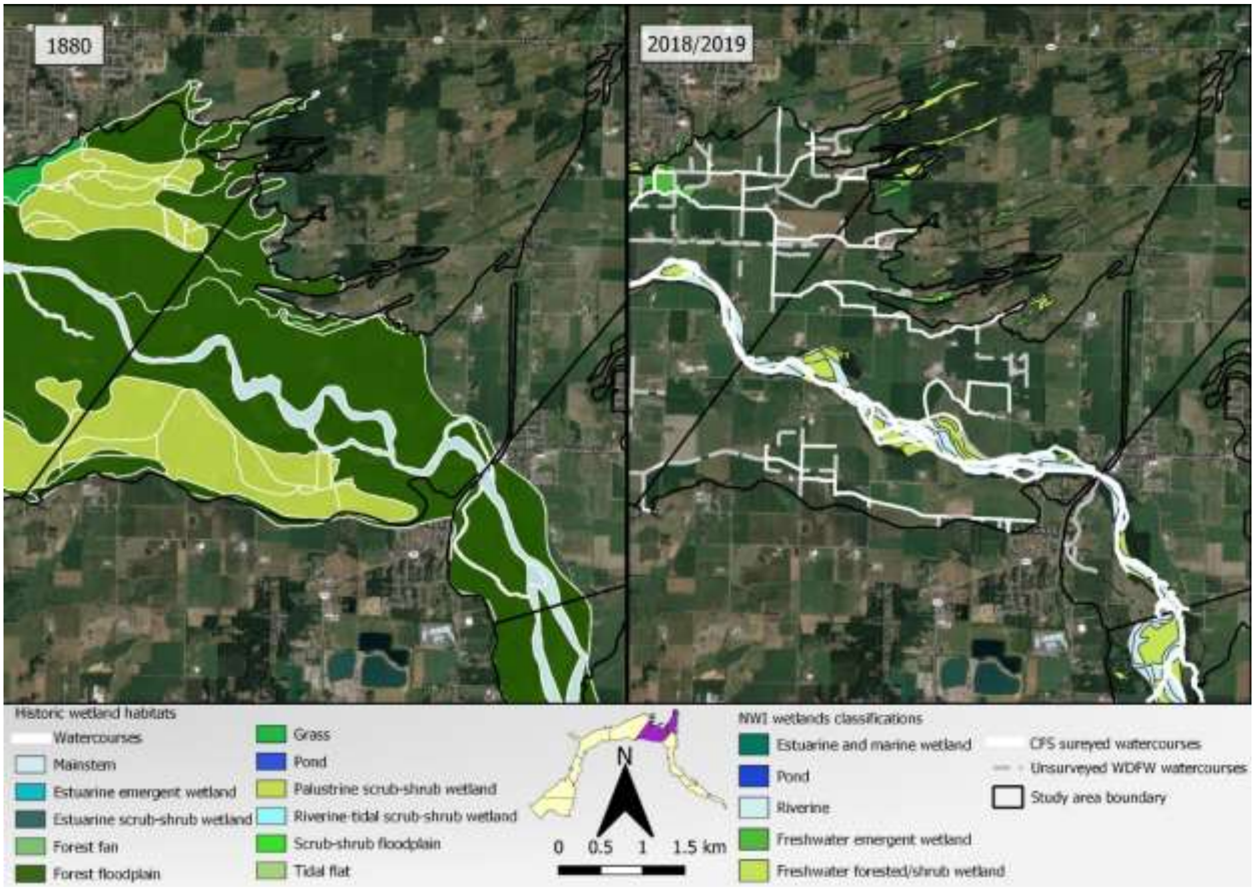

Figure 51: Map of current winter habitat and historical winter habitat extents (Collins and Sheikh) for Upper Reach 3. Surveyed watercourses and unsurveyed watercourses from current surveys are depicted, current wetland habitats are from the NWI (USFWS 2017).

Reach: Lower Reach 4

Current Mainstem Habitat Conditions:

Lower Reach 4 was the largest reach and spanned from Nugent's Corner to Everson. Lower Reach 4 has a wide and relatively unconfined floodplain and had the most braid and side-channel habitat in both summer low flow and winter flow surveys (**Table 61**). In winter flow surveys, main, braid, and side-channel channel types were observed in roughly equal proportions. Lower Reach 4 was the only reach where side-channel habitats were connected in summer low flow surveys, however the proportion of braid and side-channel habitat was substantially less in summer low flow than winter flow, with the main channel of the mainstem accounting for 55% of the channel length surveyed and 76% of the channel area. Edges were predominantly composed of natural bar edges in main and braid channels for both summer low flow and winter flow surveys (**Figure 153**; **Figure 154**). Side channel banks were made up of predominantly natural bank edges for summer low flow and winter flow surveys. Hydro-modified banks were infrequent in this reach and accounted for only 17% of winter flow and 12% of summer low flow edge length for main channels of the mainstem and less than 3% of braid and side channel edge length for both surveys. Hydro-modifications observed included levees, pilings, deflectors, riprap, and unknown modifications (**Figure 156**). Riprap banks were the most commonly observed hydro-modification. Slow water edge area was greatest for bar edges for all channels for all seasons, with the exception of winter flow side channels where natural bank edges had the most slow-water edge habitat area.

Glides accounted for the most habitat length and area for mainstem and braid channels across surveys (**Figure 157**). In winter flow side channels, glide units made up the most length, but accounted for less habitat unit area than riffle units. Relative proportion of habitat units were similar across channel types and seasons (**Figure 157**). Pools habitats were relatively infrequent in this reach but contributed a larger length and area in winter flow surveys across channel types. Pool units accounted for 13% of the habitat length surveyed in winter flow surveys and 11% of the summer length surveyed. Backwater pools, dammed pools, plunge pools, and scour pools were observed in this reach. Large wood jams accounted for most of the pool forming features, but river bends, dolos, confluences, and rip rap also contributed to pool formation (**Figure 158**). In both summer low flow and winter flow surveys, backwater units were present in braids and side channels, but not in main channels of the mainstem. Average percent canopy closure was higher in winter low flow than summer flow surveys due to the winter flow surveys being completed in May. Average main channel canopy closure was less than 2% for both seasons (**Table 62**). Braid and side channels had higher canopy closure than mainstem channels and were higher in winter flow surveys than summer low flow (9% and 14% winter, and 2% and 3% in summer, respectively). Deciduous species were the most dominant canopy species, although many units had no canopy cover. Many units did not have riparian vegetation, but when riparian species were present, deciduous species were the most abundant. Knotweed was prevalent throughout this reach in throughout all mainstem channel types. Large wood jams were observed in main channel, braid, and side channels in both seasons. In winter flow surveys, braids contained the highest number of jams and had the largest area of wetted cover. Main channel jams were the most abundant and provided the most wetted cover in summer low flows. In winter flows, sand was the predominant substrate documented in side channels, followed by fines and gravel. Gravel was the dominant substrate in summer low flow side channel surveys.

Current Floodplain Habitat Conditions:

Floodplain habitat in Lower Reach 4 was composed of primarily tributary habitats (**Table 63**). Smith Creek and Anderson Creek are major tributaries that enter the Nooksack River in this reach (**Figure 153**). All of Smith Creek present in Lower Reach 4 was surveyed, but a limited section of Anderson Creek was surveyed due to dense vegetation preventing access. There were no hydro-modified or constructed channels present in this reach. Sixty-five percent of total floodplain channel length was surveyed as part of the winter flow surveys. Glides accounted for the most habitat unit length across and within each of the channel types. In tributary channels, pools accounted for 35% of the habitat length, but 50% of the surveyed habitat area. Riffle units were infrequent in Lower Reach 4 and were only seen in tributary channels. All pools observed in hydro-modified natural channels were scour pools formed by LWD jams, while in tributary surveys documented beaver dam, plunge, and scour pools formed by sediment, river bends, LWD, and rip rap (**Figure 160**). Average canopy cover in hydro-modified channels was roughly 40%, while average tributary canopy cover was around 7%. Blackberry, deciduous species, willows, grasses, reed canary grass, and conifers were all present as riparian vegetation. Deciduous species were the dominant canopy providing vegetation. Riparian conifers were observed more frequently in this reach than those downstream. Fines were the dominant substrate in hydro-modified natural and wetland channels. Fines and gravel were predominant in tributaries, followed by sand. Dense vegetation was the biggest limiting factor for surveys in this reach and prevented access in a large section of the Anderson Creek drainage. Two channels mapped in WDFW hydrography were dry at access points, but given the inability to access due to dense vegetation and private property, they were assumed to have wetted channels elsewhere in their extent and were included in estimates (**Figure 154**). Summer validation surveys were performed in the lower wetted section of Smith Creek (**Figure 155**). Validation surveys were not performed in Anderson Creek given the difficulty of access, but the presence of dry channels in summer low flow conditions was estimated to reduce overall habitat length and area compared to winter flow conditions (**Table 64**).

Current versus Historical Conditions:

Overall, Lower Reach 4 did not see a huge decrease in habitat when compared to historic conditions relative to other reaches. Increases in winter flow habitat were observed in Lower Reach 4 when compared to historic condition in edge length and braid and side-channel habitat length and slow water area (**Table 65; Figure 52**; **Figure 53**). However, this apparent increase relative to historical conditions could be the result of increased survey resolution rather than an actual increase in channel complexity and length. Summer low flow habitats decreased when compared to historic condition in slow water area, edge length, and braid and side-channel habitat. For both seasons, hydro-modified bank edges were present, which was a deviation from historic conditions (**Figure 54**).

For winter low flow surveys, there was a decrease in length of slough and tributary habitat, but an increase in overall area (**Figure 161**). Summer low flow surveys found a decrease in both length and area for slough and tributary habitats when compared to historic conditions due to the large number of channels estimated to be dry in summer conditions.

Summary:

This reach was the most complex mainstem reach surveyed within the study area, with the most braid and side-channel habitat in both summer low flow and winter flow surveys (**Table 24**). Mainstem habitat complexity and habitat unit diversity were generally high, and hydro-modified bank edges were relatively infrequent. Knotweed was prevalent throughout this reach in main channels, braids, and side channels. Large wood jams and large woody debris were observed throughout mainstem, braid, and side channels in both seasons in this reach. The floodplain for this reach is predominantly tributary habitat with no hydro-modified or constructed channels present in this reach (**Table 25**). Our surveys suggest summer low flow conditions reduce the floodplain channel network in this reach, but to a lesser extent than estimated for other reaches.

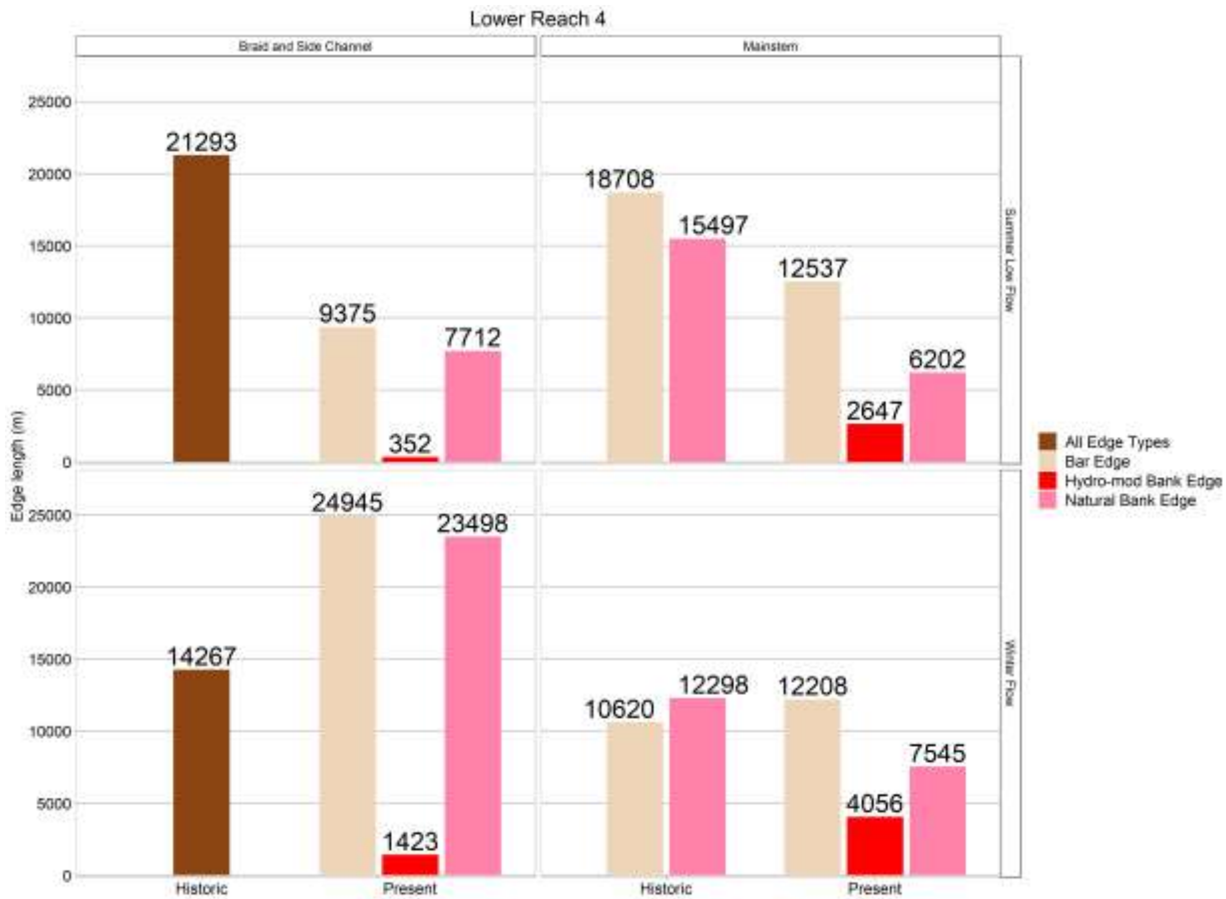

Figure 52: Edge lengths (meters) of bank types for summer low flow and winter flow conditions for historic versus present data for Upper Reach 4. Edge type data for historic braid and side-channel habitats were not available.

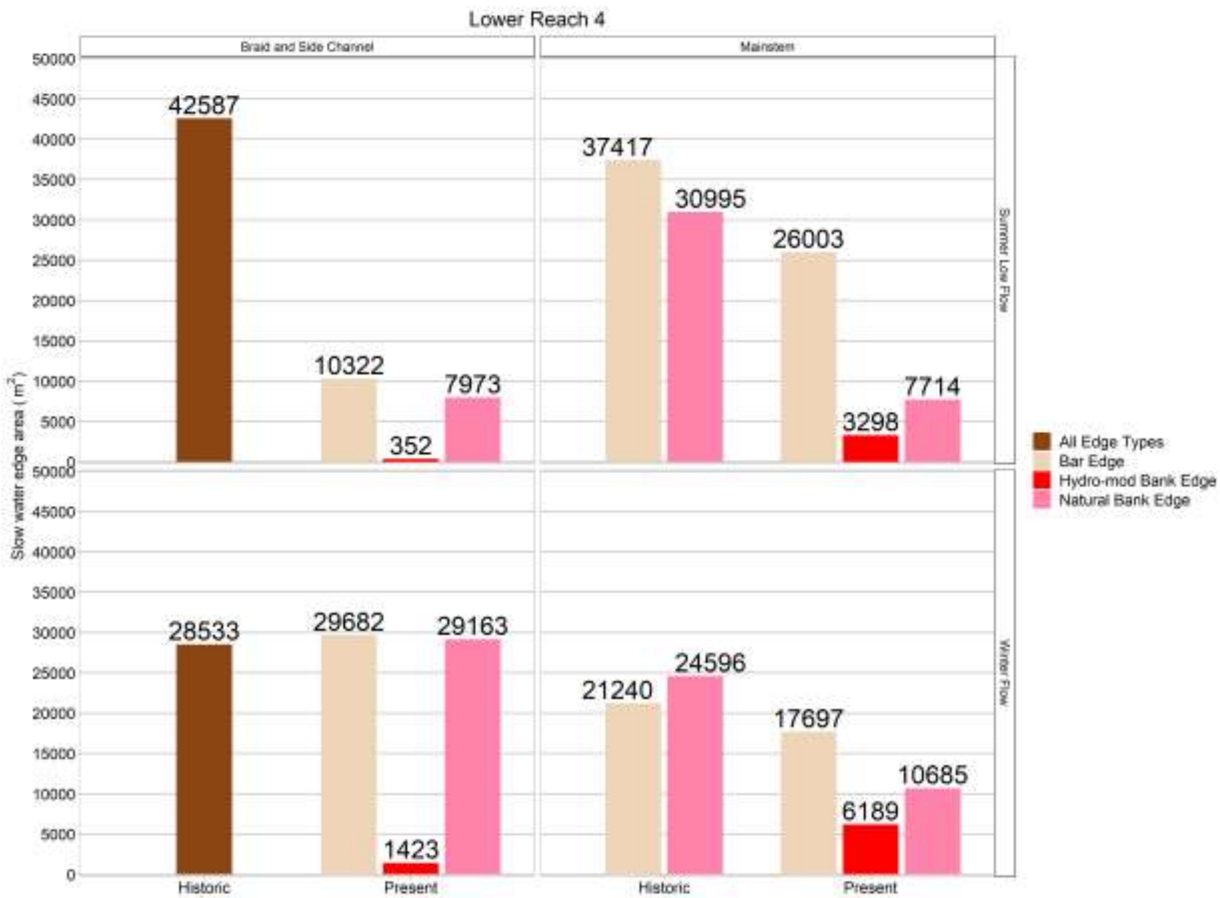

Figure 53: Slow water edge area (meters²) for bank types for summer low flow and winter flow conditions for historic versus present data for Upper Reach 3. Edge type data for historic braid and side-channel habitats were not available.

Table 24: Summary results for mainstem surveys for Lower Reach 4, W=Winter flow, S= Summer Low Flow. Change from historic condition refers to the difference in slow water area for mainstem channels and braid and side channels from 1880s data to present. The shading indicates a negative deviation from the study area average for each value. For the change from historic conditions, green indicates an increase in habitat area and red indicates a loss in habitat area. For the percent of total channel length, red indicates mainstem values being above average and braid and side channel values being below average. For the percent of edge length in hydro-modified bank and percent length in glides red indicates a reach value above the study area average and green indicates a reach value below the study area average. For the number of pools, the percent length in pools, the number of jams, and the wetted jam area, red indicates a reach value below average and green indicates a reach value above average. Study area averages are also reported.

		Change from Historic Condition		% of Total Channel Length		% Edge Length in Hydro-modified Bank		% Length in Glides		Pool Count		% Length in Pools		LWD Count		Wetted LWD Jam Area (m2)	
		W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Lower Reach 4	Mainstem	-11265	-31397	32	55	17	12	59	59	7	7	14	7	39	42	2329	11039
	Braid & Side Channel	31735	-23941	68	45	3	2	48	54	72	29	13	16	142	49	20686	5910
Study area average	Mainstem	NA	NA	80	92	63	52	84	73	3	5	6	12	5	5	429	1193
	Braid & Side Channel	NA	NA	20	8	11	6	42	59	32	16	20	14	9	6	1225	749

Table 25: Summary results for floodplain surveys for Lower Reach 4. The shading indicates a negative deviation from the study area average for each value. For the percent length in glides red indicates a reach value above the study area average and green indicates a reach value below the study area average. For the number of pools, the percent length in pools, the number of jams, and the wetted jam area, red indicates a reach value below average and green indicates a reach value above average. Study area averages are also reported.

		% of Total Channel Length	% Length Unsurveyed	% Length in Glides	# Pools	% Length in Pools	# LWD Jams	Wetted LWD Jam Area (m2)
Lower Reach 4	Hydro-modified natural channel	37	48	92	3	2	10	188
	Tributary	62	25	52	35	35	26	875
	Hydro-modified channel	-	-	-	-	-	-	-
	Wetland	1	NA	NA	NA	NA	0	0
	Constructed Channel	-	-	-	-	-	-	-
Study Area Average	Hydro-modified natural channel	50	59	67	8	2	9	245
	Tributary	36	4	88	15	12	14	400
	Hydro-modified channel	11	0	77	4	4	3	13
	Wetland	2	NA	NA	NA	NA	0	0
	Constructed Channel	0.2	100	49	1	3	10	135

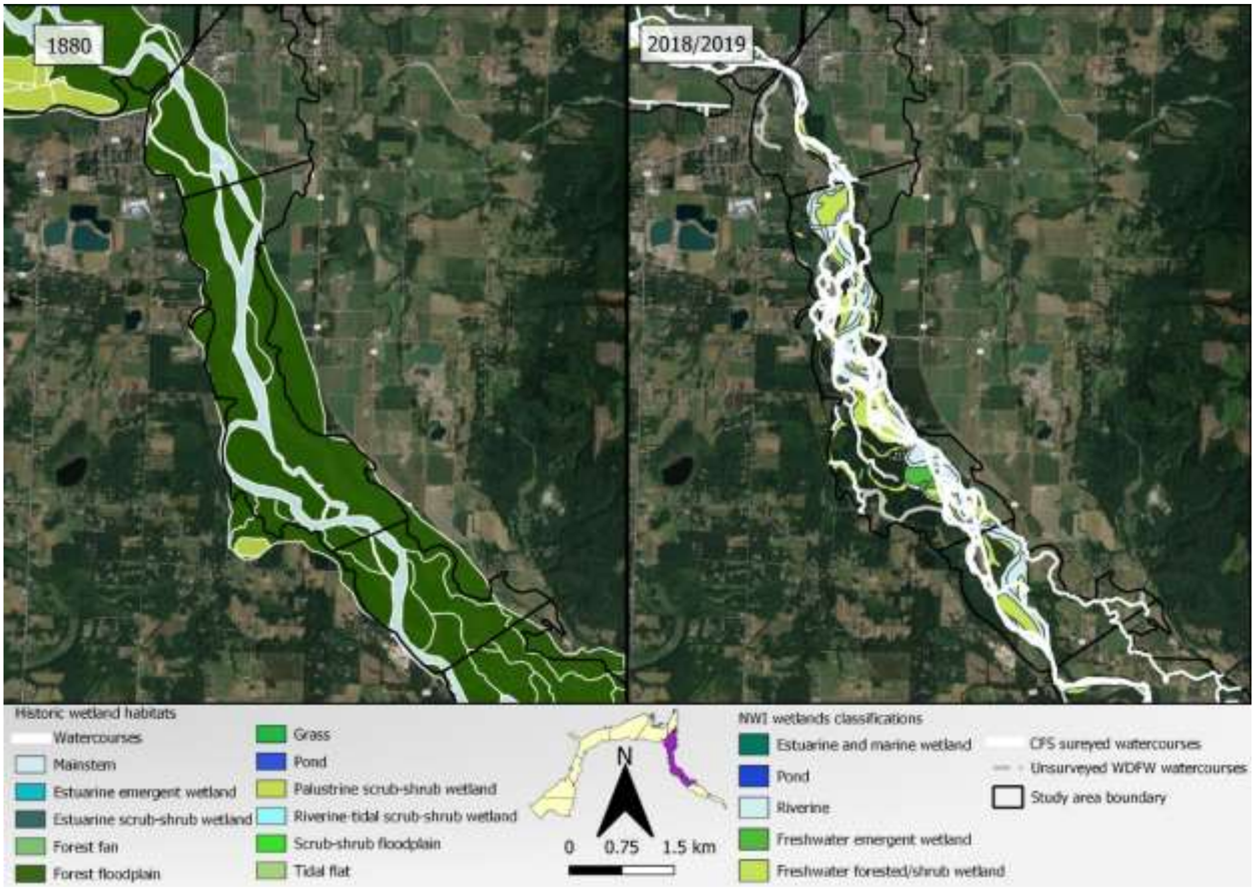

Figure 54: Map of current winter habitat and historical winter habitat extents (Collins and Sheikh) for Lower Reach 4. Surveyed watercourses and unsurveyed watercourses from current surveys are depicted, current wetland habitats are from the NWI (USFWS 2017).

Reach: Upper Reach 4

Current Mainstem Habitat Conditions:

Upper Reach 4 spans from the confluence of the North and South Fork of the Nooksack River to Nugent's Corner. The surrounding area experiences moderate development and minimal main channel confinement relative to downstream reaches. In winter flows, braids and side channels were observed throughout the reach, however, in summer low flow conditions, braid and side-channel habitats were not connected (**Figure 164**; **Figure 165**). In winter surveys, braids and side channels made up 11% and 30%, respectively, of the total channel length surveyed (**Table 66**). Total habitat area as well as slow water area were both greater in winter flow surveys overall, however for main channels of the mainstem, total slow water area was greater in summer low flow surveys.

In both surveys, bar edges made up the majority of length and slow water area across channel types. Hydro-modified banks were relatively minimal overall and accounted for approximately 19% and 17% of main channel of the mainstem edge length for winter flow and summer low flow surveys, respectively. Hydro-modified banks were infrequent in braid (13% of total channel length) channels and not observed in side channels in winter flow surveys. Hydro-modifications observed included levees, riprap, and pilings (**Figure 167**). Glides were the dominant habitat unit in both winter flow and summer low flow surveys across channel types, followed by riffle units (**Figure 168**). Riffle made up a higher proportion of total length surveyed in summer low flow surveys. Backwater units were only observed in winter flow surveys in main and side channels. All pools observed in this reach were scour pools; pool forming features included river bends, large wood jams, rip rap, bedrock, and confluences (**Figure 169**). Average canopy closure was similar in main channel units between winter flow (1.6%) and summer low flow surveys (1.5%) (**Table 67**). Winter flow surveys were completed in this reach in January and therefore represent the winter riparian condition. Average canopy cover during winter flow surveys was higher in braids (5%) and side channels (3.1%) than main channels. Deciduous species were the dominant canopy cover followed by conifers. Rocks (e.g., bare ground) were the most common riparian cover, followed by deciduous and coniferous species. Large wood jams were present throughout this reach. Large wood jams were most abundant and provided the most cover in winter flow side channels. Large wood jams were more abundant in main channels and overall in winter flow surveys compared to summer low flow. Fine sediment was dominant in winter flow side channels. Flow prevented sediment measures in other channels.

Current Floodplain Habitat Conditions:

Floodplain habitat in Upper Reach 4 included Smith Creek and its contributing channels. Tributary channels contributed most of the channel length surveyed in this reach, followed by hydro-modified channels, and hydro-modified natural channels (**Table 68**). Hydro-modified natural channels were estimated where private property prevented access. No wetland areas were surveyed in this reach, but wetland habitat was estimated using the NWI wetlands layer (USFWS 2017). All existing tributary and hydro-modified channels were surveyed as part of our effort. Overall, 94% of the floodplain channel length was surveyed. Tributary channels were dominated by glide habitat and pools and riffles were minimal (**Figure 170**). For hydro-modified natural channels, ponded units were the only observed habitats. In hydro-modified channels, both glides and ponded areas were observed. Both scour pools and dammed pools were observed in tributary channels in Upper Reach 4, LWD and boulders were the primary pool forming features (**Figure 171**). Average percent canopy cover was high in Upper Reach 4, especially in hydro-modified natural channels (**Table 68**). Deciduous species were the dominant canopy cover. Blackberry was the most frequently observed dominant riparian bank cover, but deciduous species, including willows, conifers, and grasses were also observed. Gravel was the dominant substrate in tributary channels, but fines were dominant in both hydro-modified natural and hydro-modified channels. Summer validation surveys found a large portion of Smith Creek to be dry (**Figure 166**). The ratio of dry to wet channel length was used to estimated summer habitat length and area. It is estimated that tributary, hydro-modified natural channel, and hydro-modified channel area would be roughly half in summer flows (**Table 69**).

Current versus Historical Conditions:

In Upper Reach 4, current edge length and slow water area overall are less than 1880's values for main channels of the mainstem (**Table 70**). These values are only slightly less in winter flows, but differences are more substantial in summer low flow surveys. In winter flow surveys, braid and side channel lengths are slightly higher in present day surveys, but slow water area is slightly less than historic values (**Figure 57**). The 1880's data show braids and side channels provided a large amount of habitat in summer low flow surveys, which has been dramatically reduced compared to present day, where no braids or side channels were observed. No hydro-modified bank edges were assumed for the historical condition but were observed in current surveys in both seasons for a substantial portion of the main channel. In historic and present summer low flow surveys, bar edges accounted for the majority of slow water area and edge length (**Figure 103**; **Figure 56**).

Present day floodplain habitat areas and lengths are less than historical values for slough and tributary habitats for both seasons (**Figure 55**). Pond and wetland habitats were not historically estimated to occur in this reach which is a deviation from current estimates of 927,518 m^2 of pond and wetland habitat.

Summary:

This reach has moderate mainstem habitat complexity with abundant side channel and braid habitat during winter flow conditions, but these habitats do not appear to maintain connectivity during summer low flow conditions (**Table 26**). Edges of mainstem channels were dominated by bar edges with relatively little hydro-modified bank edges observed within this reach. Large wood jams and large woody debris were abundant and observed throughout mainstem, braid, and side channels in both seasons in this reach. The floodplain for this reach is predominantly tributary habitat with some hydro-modified and constructed channels present in this reach (**Table 27**). Our surveys suggest summer low flow conditions may reduce the floodplain channel network in this reach by about 50% of the winter flow extent.

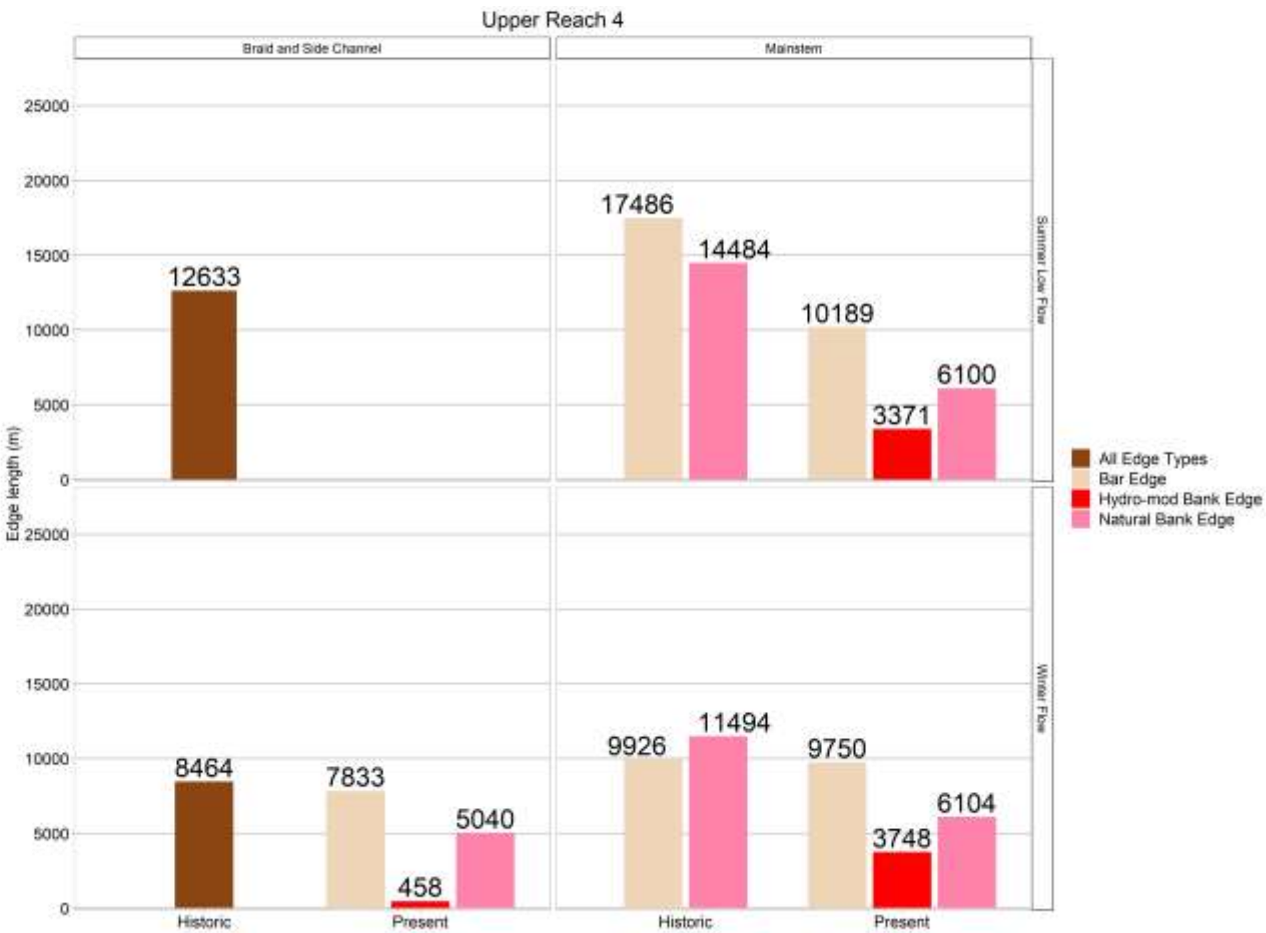

Figure 55: Edge lengths (meters) of bank types for summer low flow and winter flow conditions for historic versus present data for Upper Reach 4. Edge type data for historic braid and side-channel habitats were not available.

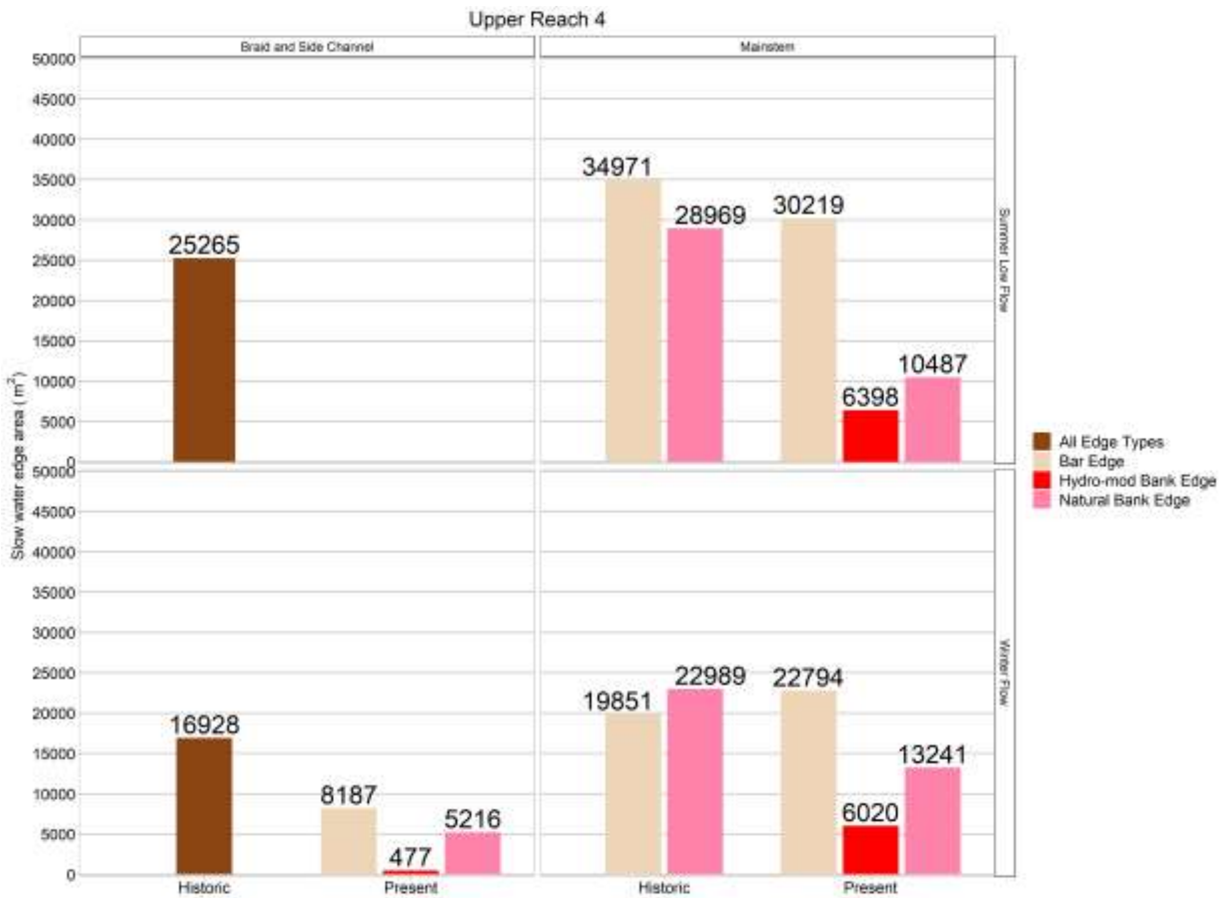

Figure 56: Slow water edge area (meters^2) for bank types for summer low flow and winter flow conditions for historic versus present data. Edge type data for historic braid and side-channel habitats were not available.

Table 26: Summary results for mainstem surveys for Upper Reach 4, W=Winter flow, S= Summer Low Flow. Change from historic condition refers to the difference in slow water area for mainstem channels and braid and side channels from 1880s data to present. The shading indicates a negative deviation from the study area average for each value. For the change from historic conditions, green indicates an increase in habitat area and red indicates a loss in habitat area. For the percent of total channel length, red indicates mainstem values being above average and braid and side channel values being below average. For the percent of edge length in hydro-modified bank and percent length in glides red indicates a reach value above the study area average and green indicates a reach value below the study area average. For the number of pools, the percent length in pools, the number of jams, and the wetted jam area, red indicates a reach value below average and green indicates a reach value above average. Study area averages are also reported.

		Change from Historic Condition		% Total Channel Length		% Edge Length in Hydro-modified Bank		% Length in Glides		Pool Count		% Length in Pools		LWD Count		Wetted LWD Jam Area (m2)	
		W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
Upper Reach 4	Mainstem	-785	-16836	60	100	19	17	62	45	5	10	8	18	12	9	2321	1445
	Braid & Side Channel	-3047	-25265	40	0	3	-	61	-	30	-	17	-	53	-	4012	-
Study area average	Mainstem	NA	NA	80	92	63	52	84	73	3	5	6	12	5	5	429	1193
	Braid & Side Channel	NA	NA	20	8	11	6	42	59	32	16	20	14	9	6	1225	749

Table 27: Summary results for floodplain surveys for Upper Reach 4. The shading indicates a negative deviation from the study area average for each value. For the percent length in glides red indicates a reach value above the study area average and green indicates a reach value below the study area average. For the number of pools, the percent length in pools, the number of jams, and the wetted jam area, red indicates a reach value below average and green indicates a reach value above average. Study area averages are also reported.

		% of Total Channel Length	% Length Unsurveyed	% Length in Glides	# Pools	% Length in Pools	# LWD Jams	Wetted LWD Jam Area (m2)
Upper Reach 4	Hydro-modified natural channel	4	64	0	0	0	0	0
	Tributary	71	0	89	5	4	15	219
	Hydro-modified channel	26	0	14	0	0	1	12
	Wetland	-	NA	NA	NA	NA	-	-
	Constructed Channel	-	-	-	-	-	-	-
Study Area Average	Hydro-modified natural channel	50	59	67	8	2	9	245
	Tributary	36	4	88	15	12	14	400
	Hydro-modified channel	11	0	77	4	4	3	13
	Wetland	2	NA	NA	NA	NA	0	0
	Constructed Channel	0.2	100	49	1	3	10	135

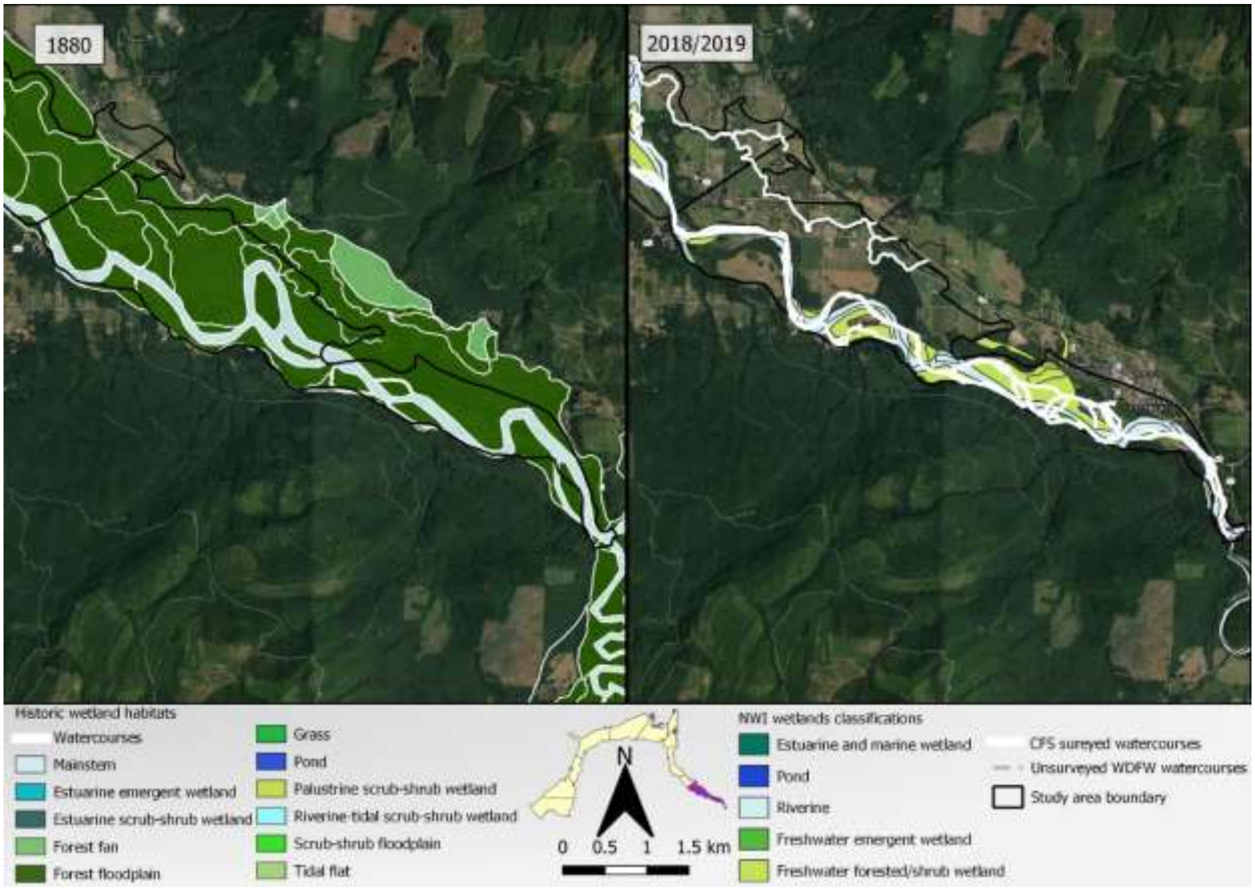

Figure 57: Map of current winter habitat and historical winter habitat extents (Collins and Sheikh) for Upper Reach 4. Surveyed watercourses and unsurveyed watercourses from current surveys are depicted, current wetland habitats are from the NWI (USFWS 2017).

Next Steps and Applications:

This Lower Mainstem Nooksack River Salmon Habitat Assessment is part of a larger collaborative effort to develop an integrated management plan for the Nooksack River to restore salmon habitat while reducing flood risk and management cost and supporting existing land uses within the floodplain. The information presented in this assessment supports this larger effort by providing information on current habitat conditions, historical conditions, and estimated rearing capacities for subyearling Chinook salmon (a primary focal species for the study area) that support the development of reach scale strategies. These reach scale strategies will be developed by synthesizing the information developed in this assessment with the geomorphic assessment (Boyd et al. 2019) to identify and prioritize strategies within each reach.

Understanding the current condition of habitat (both quantity and quality) is an important component to developing reach scale strategies for an integrated management plan. The information presented in this assessment describes the current composition and extent of mainstem, floodplain, and estuary habitats during flow and seasonal periods relevant to juvenile salmonid rearing and migration (winter flow and summer low flow periods) within each reach of the study area. This information can be used to identify where key habitats occur or are lacking in the landscape and to what degree they have been modified from historic conditions. The assessment and survey methods focused on subyearling Chinook salmon habitat preferences and requirements, and therefore provides habitat information (e.g., slow-water edge habitat area and mainstem bank condition) relevant to this focal species for the study area. However, it is likely that strategies focused on Chinook salmon will benefit multiple salmon species, life histories, and life stages in the Nooksack River (UCSRB 2007), including other ESA-listed species that occur within the Nooksack River (e.g., steelhead and bull trout).

This assessment also compares current habitat to reconstructions of historical habitat (circa 1880). Comparisons to historical conditions can provide useful context for evaluating the types and extent of habitat loss within the landscape based on current conditions. These comparisons can inform the development of reach-based strategies by defining target conditions so long as current conditions, processes, and limitations are considered. However, comparisons to historical conditions are often complicated by the differences in resolution between historical reconstructions and surveys of current habitat. In this assessment, we rely on well-documented and detailed reconstructions of habitat that represent historic conditions prior to most development of the landscape (Collins and Sheikh 2004). However, these reconstructions do not provide the same level of detail as our current surveys and estimation of certain habitat components (e.g., seasonal changes in mainstem and floodplain habitats) required assumptions and rely on generalized data that may limit the utility of certain comparisons to historical conditions. Therefore, we have attempted to identify these potential uncertainties in this assessment so that the historical information and context can be used appropriately in developing reach-scale strategies for the study area.

Floodplain wetland and pond habitat estimates and comparisons to historical conditions are also limited in this assessment. We rely on supplemental data and the historical reconstructions to quantify the extent of current and historical wetland extents, and these data do not provide sufficient detail to determine the extent of wetland habitat that are accessible or usable during different flow or seasonal conditions. In this assessment, we apply a fixed ratio of summer to winter inundation area to estimate winter and summer wetland habitat for all reaches based on data provided by the historical reconstructions. These fixed estimates combined with no information on hydrological connectivity, and therefore fish accessibility, may limit the comparisons of current and historical conditions among reaches. Future field surveys could target current wetland habitat to determine the extent of accessible and usable habitat under key flow and seasonal periods, which would improve the assessment and development of reach-based strategies for current conditions.

We also developed rearing capacity estimates for subyearling Chinook salmon for mainstem, floodplain, and estuary habitats within the study area to support the development of reach-based strategies. By synthesizing density information from a broad range of systems, we have developed seasonal estimates of rearing capacity that represent the upper range of juvenile densities that would be expected to use certain habitats within the study area. This approach is useful in that it is not influenced by the current depressed status of Nooksack River Chinook populations, and it allows both current and historical habitat estimates to be compared using a common currency that integrates habitat use and preferences patterns for a key focal species. By using the upper range of observed densities associated with different habitat types, we estimate rearing capacities for reaches and habitats within these reaches. However, the synthesized density information can also be used to evaluate restoration strategies by allowing projects to be prioritized or considered with respect to potential fish capacity rather than just habitat quantity alone.

Although this assessment focused on subyearling Chinook capacities, we synthesized and summarized density data for the range of salmon species and juvenile life stages that rely on the Lower Mainstem Nooksack River (**Appendix C**). We attempted to develop rearing capacity estimates for yearling Chinook salmon given that yearling life histories contribute to approximately 30% of the returning adults in the Nooksack River (Treva Coe, Nooksack Tribe, personal communication). However, available data did not support estimates of yearling rearing capacities that could be used to compare current and historical habitats to support development of restoration and conservation strategies for the study area. Continued development of data and refinement of habitat estimates would support development of yearling rearing capacity estimates. For both yearling Chinook and other juvenile salmon species and life stages for which data were compiled but not used to estimate rearing capacities in this assessment, we recommend that sample sizes be considered to determine the degree to which juvenile density data can be used to support rearing capacity estimates or development of reach restoration and conservation strategies.

Furthermore, this assessment and the subyearling Chinook rearing capacity analysis do not directly address habitat conditions that impact adult life stages (e.g., migration corridors, holding habitats, and spawning habitats). The results of the habitat surveys provide a number of attributes that could be used to support evaluation of potential adult habitats, but the surveys completed as part of this assessment did not specifically target habitat attributes that would provide information to support detailed evaluation of adult habitat (e.g., mainstem habitat substrate and depths). Furthermore, our literature review focused on juvenile salmon densities and the compiled data do not include similar information on adult densities. Therefore, additional work would be needed to integrate adult life stages into the Lower Mainstem Nooksack River habitat assessment and development of strategies for the integrated management plan.

Given that we relied on other data sources for estuary habitat estimates (Beamer et al. 2006), estimates of current habitat could be improved through a similar field survey effort of estuary habitat as was completed as part of this assessment for mainstem and floodplain habitats. Although we did manage to survey portions of Lower Reach 1 and Middle Reach 1, these surveys were not comprehensive and information on that effort are presented for informational purposes only. Our assessment relies on previous assessments and do not represent the same temporal period (e.g., 2013 vs. 2018-2019) and may reflect and integrate differences in survey methodology and assumptions into estimates of current habitat extent and rearing capacity.

Our habitat survey approach was based on hydrological connectivity that produced an assessment of hydrologically activated habitats (or connected habitats). Our assessment results do not integrate fish passage or barriers (e.g., culverts or flood gates) and this assessment currently assume all hydrologically connected habitats are physically accessible for estimates of habitat quantity and rearing capacity. Integration of fish passage barrier information would help refine estimates of current habitat quality and rearing capacities based on accessibility. In addition, some habitats were not surveyed due to accessibility (e.g., private property or overgrown water courses). We used survey information to estimate hydrological connectivity based on observed channel conditions (e.g., wet and dry channels), but these are estimates and could be refined through additional field survey efforts. We did explore using hydrodynamic model outputs to refine estimates of connectivity, but outputs from these models are only available at 5,000 cfs and higher flow events and provide little detail on connectivity of habitats at lower flows.

Finally, it is worth noting that no fish measurements were made during the surveys completed as part of this assessment. Therefore, fish use and distributions are assumed based on supplemental data and hydrological connectivity as described above. We recommend development and implementation of targeted field surveys to evaluate fish use and distribution within the study area. A number of approaches could be used to develop a better understanding of what fish species use different habitats (e.g., eDNA, electroshocking, seining, etc.), which can provide refined information on fish distribution patterns within the study area.

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Appendix A:
Fish Habitat Use, Distribution, and Periodicity

Final Report

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Appendix A provides detail on habitat use and timing and fish distributions that were developed in the Phase 1 memo for the Lower Mainstem Nooksack River Assessment. The information presented in this appendix are not field verified and information (e.g., fish presence or habitat uses) are assumed based on available data.

The Statewide Integrated Fish Distribution (SWIFD) data is an important GIS dataset that provides documented, modeled, presumed, and potential geographic distributions for Lower Mainstem Nooksack River focal species and their habitat use (NWIFC 2017). Habitat use is recorded as presence, spawning, or rearing. Although salmon species distribution has been mapped throughout the study area, the distribution of life stages has not been systematically mapped for each species. Therefore, the designation of "Presence" in SWIFD data may indicate the presence of multiple life stages and the distribution extent is not necessarily reflective of the current and changing extent of fluvial habitats within the study area (e.g., side channels and braids). Therefore, SWIFD data can provide an estimate of distributions of species and this is summarized for habitat types and species in **Table 28**.

Another important GIS dataset is the WDFW regulatory stream network. These data designate streams in the Lower Mainstem Nooksack River as natural, hydro-modified natural, hydro-modified, diked, constructed, or wetland. We attributed the SWIFD data with the Washington Department of Fish and Wildlife (WDFW) regulatory stream network GIS layer to quantify lengths of habitat for a given stream designation. These stream network layers have significant overlap, but discrepancies do exist. To correct for this, we buffered the WDFW stream network to overlap with the SWIFD data, then intersected the layers in GIS.

Some assumptions were presented in the modeled GIS data sources (NWIFC 2017) compared to other literature sources and other reported sources of fish distributions (Nooksack Tribe, personal communication 2017) that should be validated and corrected through field sampling, although this was not completed as part of this assessment. For some species of salmonids, there is some disagreement among managers in the drainage about the spatial extent, timing, and the life stages of fish that use these habitats. However, these differences are mainly associated with select life stage and habitat usage and not with overall expected distributions of fish. For the most part, existing depictions of fish distributions are consistent with expectations from the literature. With that said, this represents one of the most important data gaps in our knowledge of fish habitat quantity and quality, and the timing of use for focal fish species. Our field surveys worked to address these gaps as best as possible. Maps of fish distributions for known species of salmonids in the Lower Mainstem Nooksack River study area are provided in this appendix.

We identified several important studies that specifically reported on the species, life history strategy, life stage, and ranges of habitat preferences for the ten focal groups of fish that are the focus of the Lower Mainstem Nooksack River study area. Most of the studies that we evaluated were focused on fish usage of edge habitats in the mainstem river and various habitats in the lower tributaries. Relatively few studies examined salmonid use of isolated or seasonally connected floodplain habitats. However, we were able to use some more general literature sources (e.g., Groot and Margolis 1998; Quinn 2005) to identify ranges of habitat preferences for species and life histories where they did not exist in literature specific to the Nooksack River system. In this way, we were able to identify known habitat preferences for nearly all the species and life stages of salmonids in the study area (**Table 29**; **Table 30**). In addition, the Nooksack Tribal biologists updated the fish periodicity table that identifies specific habitat use by species by month. This table is specific to the Lower Nooksack study area in most cases (**Table 30**). Data were organized according to species, life stage-specific behavior (e.g., migration, spawning, incubation, etc.), and timing. In addition, literature on other culturally important species in the Nooksack River, such as Salish sucker, Nooksack dace, and longfin smelt, was identified although those species were not targeted in this study.

Fish Distribution by Water Type:

Table 28: Species and life stage distribution by WDFW water type classification in the WDFW in the Lower Nooksack Salmon Habitat Assessment area floodplain. Habitat lengths derived from overlap of SWIFD fish distribution (NWIFC 2017) with WDFW regulatory water type layer. Please note that, while species distribution has been mapped in the study area, distribution of life stages has not been systematically mapped for each species. "Presence" therefore may indicate presence of multiple life stages. SWIFD fish distribution is updated periodically. NA values indicate SWIFD segments that do not overlap with WDFW regulatory segments or where there was no WDFW classification.

Species	Distribution Type	Use Type	Habitat Length (kilometers) by Water Type Classification					
			Constructed	Diked	Mod Natural	Natural	Wetland	NA
Spring Chinook	Documented	Presence	-	-	0.48	-	-	42.81
		Rearing	-	-	1.45	-	-	18.02
Fall Chinook	Documented	Presence	1.45	0.16	21.89	1.45	-	13.68
		Rearing	0.48	-	9.98	0.03	-	6.12
		Spawning	-	-	1.93	-	-	55.36
	Modeled	Presence	-	-	0.16	-	-	0.32
	Potential	Presence	0.16	-	10.30	-	-	0.16
	Presumed	Presence	-	-	1.61	-	0.32	3.38
Winter steelhead	Documented	Presence	0.48	-	15.45	1.61	0.48	16.42
		Rearing	-	-	0.97	-	-	1.13
		Spawning	-	-	6.76	-	-	51.50
	Modeled	Presence	20.76	1.45	60.35	-	0.97	14.48
	Presumed	Presence	0.16	-	9.98	-	-	0.16
Summer steelhead	Documented	Presence	-	-	4.18	1.61	-	59.38
Coho	Documented	Presence	2.41	1.45	42.97	1.61	0.97	15.77
		Rearing	0.64	-	9.66	-	0.32	63.25
	Modeled	Presence	19.79	0.16	32.99	-	0.16	5.79
	Presumed	Presence	0.03	-	10.30	-	-	0.48
Fall Chum	Documented	Presence	1.45	0.16	23.34	1.61	0.32	77.89
	Modeled	Presence	22.05	1.29	70.17	1.61	1.13	5.79
Odd year Pink	Documented	Presence	-	-	1.29	-	-	57.61
		Rearing	-	-	1.29	-	-	8.85
		Spawning	-	-	0.16	-	-	-
	Modeled	Presence	0.03	-	6.12	3.06	-	0.64
Sockeye	Documented	Presence	0.64	0.16	8.85	-	-	13.52
		Rearing	-	-	1.93	-	-	59.55
Bull trout	Documented	Presence	-	0.02	1.45	0.03	-	7.24
		Rearing	-	-	1.93	-	-	58.90
	Modeled	Presence	20.12	0.16	35.57	-	0.16	5.95
	Presumed	Presence	2.41	1.45	53.91	3.06	1.29	12.87
Resident Coastal Cutthroat trout	Documented	Presence	1.93	0.16	49.25	1.61	1.13	78.37
	Modeled	Presence	22.37	1.29	37.98	1.61	0.32	4.67
	Presumed	Presence	0.32	-	7.56	-	-	1.61
Rainbow trout	Documented	Presence	0.64	0.16	9.82	-	-	71.45

Fish Habitat Use Table:

Table 29: Summary of select literature describing the timing of salmonid habitat use for the Lower Nooksack River and floodplain ecosystem. The table is organized to present species, life history, age, and life stage. Ranges of specific habitat types and conditions, as well as geomorphic channel types known to be used (MS = Mainstem, SC = side channel, FP = floodplain, Trib = tributary) are also presented. Finally, the literature sources used in these determinations are presented by their source region, indicating if the study was specific to the Nooksack River, Puget Sound in general, or other regions. Preferred habitat types and ranges that are presented in bold italics are from literature identifying Lower Nooksack habitats specifically. Some cases of habitat usage documented but unable to assign race, such as Coe 2004 documenting Chinook mainstem use, are assumed for all Chinook races (i.e. juvenile Chinook caught in beach seines and documented floodplain usage, however, unable to designate as NF/MS early vs SF early vs late).

Species	Life History	Life Stage		Preferred Habitat Types and Ranges Bolded & italicized: Habitat usage of documented fish species and race for Nooksack mainstem or mainstem habitats from sources 1, 2, 3, 6, & 7.	Channel Types 1: Known; 2; Presumed; 3: Unknown; X: To be determined								Source Region (Y: Yes, Blank: No)			Sources
		Age	**Stage**		**MS-MS**	**MS-Braid**	**MS-SC**	**FP-SC**	**FP-Trib**	**FP-Constructed**	**FP-Pond**	**FP-Wetland**	**Nooksack**	**Puget Sound**	**Other**	
Chinook	Spring/Summer - NF/MF Early	Adult	Upstream migration / holding	Holding for long periods, same pool for 2-4 weeks.	1								Y			1
		Adult	Spawning	NF & MF, depth ≥ 24 cm, velocity ≈ 30-91 cm/s, substrate ≈ 1.3-10.2 cm.									Y		Y	1,3
		Incubation	Intragravel development	Temperature < 16 C, emergence > 100 days, gravel 4-6 weeks.									Y		Y	1
		0	Rearing	***Increasing depth & velocity w/ growth, shallow margins, gravel bars, back eddies,*** undercut banks, LWD, small & clear water, temperature ≈ 5-11 C, floodplain tributaries, ***mainstem, mainstem tributaries, off-channel habitats***, velocity ≤ 12 cm/s, rubble - finer substrates than steelhead, ***depth ≈ 0.7 m***.	X	X	X	X	X		X	X	Y		Y	1,3,5,6
		0	Outmigration	~71% population subyearling, mainstem, margins, nightly migrations, Nooksack tidal delta peak March/May.									Y			3,6,8
		1+	Rearing	~29% population stream-type, pool heads, channel edges, LWD, ***depth & velocity > 0+ preference,*** cobble substrate, out of tributaries & into mainstems, ***mainstem,*** pool & glides, margins, tail ends of lateral scour pools, pools, runs, riffles, ***lower velocity in winter, depth ≈ 1.07 m.***	X	X	X						Y		Y	3,5,6
		1+	Outmigration	Mainstem, margins, nightly migrations, peak in April.	1								Y		Y	3,4
	Spring/Summer - SF Early	Adult	Upstream migration / holding	Holding for long periods, same pool for 2-4 weeks, deep pools, cover, undercut banks, LWD.	1								Y			3
		Adult	Spawning	SF, ~2-3 weeks later peak in spawning compared to NF/MF, depth ≥ 24 cm, velocity ≈ 30-91 cm/s, substrate ≈ 1.3-10.2 cm.									Y		Y	1,3

Species	Life History	Life Stage		Preferred Habitat Types and Ranges Bolded & italicized: Habitat usage of documented fish species and race for Nooksack mainstem or mainstem habitats from sources 1, 2, 3, 6, & 7.	Channel Types 1: Known; 2; Presumed; 3: Unknown; X: To be determined								Source Region (Y: Yes, Blank: No)			Sources
		Age	Stage		MS-MS	MS-Braid	MS-SC	FP-SC	FP-Trib	FP-Constructed	FP-Pond	FP-Wetland	Nooksack	Puget Sound	Other	
		Incubation	Intragravel development	Temperature < 16 C, emergence > 100 days, gravel 4-6 weeks.									Y		Y	1
		0	Rearing	***Increasing depth & velocity w/ growth, shallow margins, gravel bars, back eddies,*** undercut banks, LWD, small & clear water, temperature ≈ 5-11 C, floodplain tributaries, ***mainstem, mainstem tributaries, off-channel habitats***, velocity ≤ 12 cm/s, rubble - finer substrates than steelhead, ***depth ≈ 0.7 m***.	X	X	X	X	X		X	X	Y		Y	1,3,5,6
		0	Outmigration	~62% population subyearling, mainstem, margins, nightly migrations, Nooksack tidal delta peak March/May.	1								Y			3,6,8
		1+	Rearing	~38% population stream-type, pool heads, channel edges, LWD, ***depth & velocity > 0+ preference,*** floodplain tributaries, cobble substrate, out of tributaries & into mainstems, ***mainstem,*** pool & glides, margins, tail ends of lateral scour pools and glides, ***lower velocity in winter, depth ≈ 1.07 m.***	X	X	X	X	X				Y		Y	3,5,6
		1+	Outmigration	Mainstem, margins, nightly migrations, peak in April.									Y		Y	3,4
	Fall - Late	Adult	Upstream migration / holding													
		Adult	Spawning	Depth ≥ 24 cm, velocity ≈ 30-91 cm/s, substrate ≈ 1.3-10.2 cm, ***mainstem, mainstem tributaries,*** all forks, and tributaries.	X				X				Y		Y	1,6,7
		Incubation	Intragravel development	Temperature < 16 C, emergence > 100 days, gravel 4-6 weeks.									Y		Y	1
		Fry <55mm	Rearing	***Increasing depth & velocity w/ growth, shallow margins, gravel bars, back eddies,*** undercut banks, LWD, small & clear water, temperature ≈ 5-11 C, floodplain tributaries, ***mainstem, mainstem tributaries, off-channel habitats***, velocity ≤ 12 cm/s, rubble - finer substrates than steelhead, ***depth ≈ 0.7 m***.	X	X	X	X	X		X	X	Y		Y	1,3,5,6

Species	Life History	Life Stage		Preferred Habitat Types and Ranges Bolded & italicized: Habitat usage of documented fish species and race for Nooksack mainstem or mainstem habitats from sources 1, 2, 3, 6, & 7.	Channel Types 1: Known; 2; Presumed; 3: Unknown; X: To be determined								Source Region (Y: Yes, Blank: No)			Sources
		Age	Stage		MS-MS	MS-Braid	MS-SC	FP-SC	FP-Trib	FP-Constructed	FP-Pond	FP-Wetland	Nooksack	Puget Sound	Other	
		Juvenile	Rearing	Pool heads, channel edges, LWD, ***depth & velocity > 0+ preference,*** cobble substrate, out of tributaries & into mainstems, ***mainstem,*** pool & glides, margins, tail ends of lateral scour pools and glides, ***lower velocity in winter, depth ≈ 1.07 m***.	X	X	X	X					Y		Y	3,5,6
		Juvenile	Outmigration	Mainstem, margins, nightly migrations, peak in April.									Y		Y	3,4
Coho		Adult	Upstream migration / holding													
		Adult	Spawning	Ground water seepage, temperature ≈ 0.8-13 C, gravel bars, riffles, forks, ***mainstem,*** mainstem ***tributaries,*** depth ≥ 18 cm, velocity ≈ 30-90 cm/s, substrate ≈ 11.3-10.2 cm, stream width < 1 m, substrate < 15 cm.	X				X				Y		Y	1,5,7
		Incubation	Intragravel development	Require clean loose gravel, nighttime emergence, longer emergence time w/ high fine sediments.											Y	5
		Fry <55mm	Rearing	Low velocity, pools, riffles, tributaries, sloughs, wetlands, side channels, small & shaded creeks, substrate, LWD.									Y		Y	1,5
		Juvenile	Rearing	Velocity ≈ 10-30 cm/s, depth ≈ 30-70 cm, slow & deep pools, LWD, roots, undercut banks, spring-fed ponds.											Y	4,5
		Juvenile	Outmigration	Peak outmigration in May, nocturnal, smolt length ≈ 100-130 mm.											Y	4
Chum	SF/Mainstem $^{\psi}$	Adult	Upstream migration / holding	Poor ability to pass barriers.											Y	5
		Adult	Spawning	Forks, ***mainstem, mainstem tributaries,*** side channels, depth ≥ 18 cm, substrate ≈ 1.3-10.2 cm, velocity ≈ 21.3-83.8 cm/sec, upwelling locations.									Y		Y	1,5,7
		Incubation	Intragravel development													
		Fry		No freshwater rearing.									Y			1
		Juvenile	Outmigration	Days - weeks after emergence, ***length≤ 50-65 mm caught in mainstem screw trap.***	X								Y			1
Pink	Odd year	Adult	Upstream migration / holding													
		Adult	Spawning	< 50 km of river mouth, tributaries to all forks, ***side channels to mainstem,*** depth ≥ 15 cm, velocity ≈ 21-101 cm/s, shallow pools & riffles, substrate ≈ 1.3-10.2 cm, temperature < 16 C.	X	X	X	X					Y			1
		Incubation	Intragravel development	Free of large amounts of silt.											Y	5

Species	Life History	Life Stage		Preferred Habitat Types and Ranges Bolded & italicized: Habitat usage of documented fish species and race for Nooksack mainstem or mainstem habitats from sources 1, 2, 3, 6, & 7.	Channel Types 1: Known; 2; Presumed; 3: Unknown; X: To be determined								Source Region (Y: Yes, Blank: No)			Sources
		Age	**Stage**		**MS-MS**	**MS-Braid**	**MS-SC**	**FP-SC**	**FP-Trib**	**FP-Constructed**	**FP-Pond**	**FP-Wetland**	**Nooksack**	**Puget Sound**	**Other**	
		Fry		No freshwater rearing.									Y			1
		Juvenile	Outmigration	Shortly after emergence, nocturnal outmigrations, fastest flowing water.									Y		Y	1,4
Sockeye	Stream type	Adult	Upstream migration / holding													
		Adult	Spawning	Depth ≥ 15 cm, velocity ≈ 21-101 cm/s, substrate ≈ 1.3-10.2 cm, NF & SF, upwelling locations.									Y			1
		Incubation	Intragravel development	100-200 days.											Y	5
		Fry/Juvenile	Rearing	1-2 years, off-channel, low velocity habitats.									Y			1
		Juvenile	Outmigration	Age 1 smolt length ≈ 60-90 mm, nocturnal outmigrations peak in May.											Y	4
Steelhead	Summer	Adult	Upstream migration	Further upstream than winter race.									Y			1
		Adult	Holding	Deep pools.									Y			1
		Adult	Spawning	Depth ≥ 24 cm, velocities ≈ 40-91 cm/s, substrate ≈ 0.6-10.2 cm.									Y			1
		Adult	Outmigration	Few outmigrants relative to mortality rate.									Y			1
		Incubation	Intragravel development	4-7 weeks.									Y			1
		Fry <~55mm														
		Juvenile	Rearing	1-4 years, deeper water as they grow.									Y			1
		Juvenile	Outmigration	Peak outmigration in May.											Y	4
	Winter ψ - Mainstem/NF, MF, SF	Adult	Upstream Migration													
		Adult	Holding													
		Adult	Spawning	Depth ≥ 24 cm, velocities ≈ 40-91 cm/s, substrate ≈ 0.6-10.2 cm.									Y			1
		Adult	Outmigration	Few outmigrants relative to mortality rate.									Y			1
		Incubation	Intragravel development	4-7 weeks.									Y			1
		Fry <~55mm														
		Juvenile	Rearing	1-4 years, deeper water as they grow.									Y			1
		Juvenile	Outmigration	Peak outmigration in May.											Y	4

Species	Life History	Life Stage: Age	Life Stage: Stage	Preferred Habitat Types and Ranges Bolded & italicized: Habitat usage of documented fish species and race for Nooksack mainstem or mainstem habitats from sources 1, 2, 3, 6, & 7.	Channel Types (1: Known; 2; Presumed; 3: Unknown; X: To be determined): MS-MS	MS-Braid	MS-SC	FP-SC	FP-Trib	FP-Constructed	FP-Pond	FP-Wetland	Source Region (Y: Yes, Blank: No): Nooksack	Puget Sound	Other	Sources
Coastal Cutthroat trout	Anadromous	Adult	Upstream migration													
		Adult	Holding													
		Adult	Spawning	Higher contribution of repeat spawners relative to steelhead, higher fecundity in repeat spawning females, riffles, depth ≈ 15-45 cm, velocity < 0.3 m/s, substrate ≈ pea-size gravel.									Y			1
		Adult	Outmigration	Some stay in freshwater for 1 year prior to outmigrating again.									Y			1
		Incubation	Intragravel development	6-7 weeks.									Y			1
		Fry <~55mm		Channel margins, backwaters, pools, riffles, glides, depth ≈ 10-50 cm, greatest proportion using 20 cm depth.									Y		Y	1,4
		Juvenile	Rearing	1-6 years, pools, log jams, undercut banks, migrate upstream & downstream, depth ≈ 10-80 cm, greatest proportion using 40 cm depth, shallow margins.									Y		Y	1,4
		Juvenile	Outmigration													
Bull trout / Dolly Varden	Anadromous	Adult	Upstream migration													
		Subadult	Upstream migration	Often other than natal stream, floodplain habitats, south fork, mainstem, mainstem tributaries.									Y	Y		1,2
		Subadult	Overwinter foraging	Mainstem and all 3 forks, ***mainstem side channel/tributaries.***			X	X	X				Y			2,3
		Adult	Holding	Deep pools, floodplain habitats, temperature ≤ 13-15 C, ***mainstem side channel/tributaries.***			X	X	X				Y	Y		1,2,3
		Adult	Spawning	5-7 years at maturation, temperatures < 10 C, tributaries & streams, low gradient, loose gravel, cold ground water, Nooksack NF, MF, & SF.									Y	Y		1,2
		Adult	Outmigration	1-2 m deep pools/runs.									Y			1
		Incubation	Intragravel development	Temperature ≈ 2-4 C optimal, incubation ≈ 100-145 days, emergence ≈ 200 days.									Y		Y	1,2
		Fry <~55mm		Large substrate, side channels, margins, pools & cover, backwaters.									Y			1
		Juvenile	Rearing	Natal stream ≈ 2 years residence time, 1-4 years rearing period, temperature ≈ 8-10 C optimal, side channels, margins, pools & cover.									Y	Y		1,2
		Juvenile	Outmigration	***Lower mainstem early April - mid July***	X	X							Y			2

Sources 1: Anchor 2001. 2: U.S. Fish and Wildlife Service 2004. 3: WRIA 1 2005 + Appendix C. 4: Quinn 2005. 5: Groot & Margolis 1998. 6: Coe 2004.7: NSEA Spawner Survey 2010. 8: Beamer et al. 2016

Table 29 was created using the best available data at the time of submission. There is on-going work to document fish habitat uses within the Nooksack river and the table may be updated accordingly.

Fish Periodicity Table:

Table 30: Salmonid periodicity table that identifies specific habitat use by species and month used. Data include species, race, life stage, age, and behavior. Green boxes indicate months of the year when respective life stage is likely to be found in the broader Nooksack Watershed; green boxes with "MS" indicate months of the year when life stage is likely to be found in the Lower Nooksack Salmon Habitat Assessment study area; blue boxes indicate CFS suggested changes to periodicity table that have not been verified by citation or otherwise.

Species	Life History	Life Stage													
		Age	Stage	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Chinook	Spring/Summer - NF/MF Early	Adult	Upstream migration / holding		MS	MS	MS	MS	MS	MS	MS	MS			
		Adult	Spawning												
		Incubation	Intragravel development												
		0	Rearing	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
		0	Outmigration	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	
		1+	Rearing	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
		1+	Outmigration	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
	Spring/Summer - SF Early	Adult	Upstream migration / holding		????	????	MS	MS	MS	MS	MS	MS			
		Adult	Spawning												
		Incubation	Intragravel development												
		0	Rearing	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
		0	Outmigration	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	
		1+	Rearing	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	
		1+	Outmigration	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
	Fall - Late	Adult	Upstream migration / holding						????/MS	MS	MS	MS	MS	MS	????/MS
		Adult	Spawning									MS	MS	MS	????/MS
		Incubation	Intragravel development	MS	MS	MS	MS					MS	MS	MS	MS
		Fry <55mm	Rearing	MS	MS	MS	MS	MS	MS						
		Juvenile	Rearing	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
		Juvenile	Outmigration		MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	
Coho		Adult	Upstream migration / holding	MS						MS	MS	MS	MS	MS	MS
		Adult	Spawning	MS	????								MS	MS	MS
		Incubation	Intragravel development	MS	MS	MS							MS	MS	MS
		Fry <55mm	Rearing		MS	MS	MS	MS	MS						
		Juvenile	Rearing	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
		Juvenile	Outmigration			MS	MS	MS	MS	MS					
Chum	SF/Mainstem [ψ]	Adult	Upstream migration / holding	MS	MS						MS	MS	MS	MS	MS
		Adult	Spawning	MS	MS								MS	MS	MS
		Incubation	Intragravel development	MS	MS	MS	MS						MS	MS	MS
		Fry			MS	MS	MS	MS	MS	MS					
		Juvenile	Outmigration		MS	MS	MS	MS	MS	MS					
Pink	Odd year	Adult	Upstream migration / holding						????/MS	MS	MS	MS	MS		
		Adult	Spawning								MS	MS	MS		
		Incubation	Intragravel development	MS	MS	MS	MS	MS			MS	MS	MS	MS	MS
		Fry		MS	MS	MS	MS	MS	MS						MS
		Juvenile	Outmigration	MS	MS	MS	MS	MS	MS						
Sockeye	Stream type	Adult	Upstream migration / holding				MS	MS	MS	MS	MS	MS	MS	MS	
		Adult	Spawning												
		Incubation	Intragravel development												
		Fry/Juvenile	Rearing	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
		Juvenile	Outmigration			MS	MS	MS	MS	MS					

Species	Life History	Life Stage		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
		Age	Stage												
Steelhead	Summer	Adult	Upstream migration				MS	MS	MS	MS	MS	MS	MS		
		Adult	Holding				MS	MS	MS	MS	MS	MS	MS		
		Adult	Spawning												
		Adult	Outmigration		MS	MS	MS	MS							
		Incubation	Intragravel development												
		Fry <~55mm													
		Juvenile	Rearing	MS?	MS?	MS?	MS?	MS?	MS?	MS?	MS?	MS?	MS?	MS?	MS?
		Juvenile	Outmigration		MS	MS	MS	MS	MS	MS	MS				
	Winter ψ - Mainstem/NF, MF, SF	Adult	Upstream Migration	MS	MS	MS	MS	MS	MS					MS	MS
		Adult	Holding												
		Adult	Spawning			MS	MS	MS	MS						
		Adult	Outmigration	MS	MS	MS	MS	MS	MS	MS					MS
		Incubation	Intragravel development			MS	MS	MS	MS	MS					
		Fry <~55mm		MS		MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
		Juvenile	Rearing	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
		Juvenile	Outmigration		MS	MS	MS	MS	MS	MS	MS				
Coastal Cutthroat trout	Anadromous	Adult	Upstream migration	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
		Adult	Holding	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
		Adult	Spawning	MS	MS	MS	MS	MS	MS	MS					
		Adult	Outmigration	MS	MS	MS	MS	MS	MS						
		Incubation	Intragravel development	MS	MS	MS	MS	MS	MS	MS	MS	MS			
		Fry <~55mm		MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
		Juvenile	Rearing	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS	MS
		Juvenile	Outmigration		MS	MS	MS	MS	MS	MS	MS				
Bull trout	Anadromous	Adult	Upstream migration					MS	MS	MS	MS	MS			
		Subadult	Upstream migration								MS	MS	MS	MS	
		Subadult	Overwinter foraging	MS	MS	MS	MS	MS			MS	MS	MS	MS	MS
		Adult	Holding												
		Adult	Spawning												
		Adult	Outmigration	MS	MS	MS	MS	MS	MS	MS					
		Incubation	Intragravel development												
		Fry <~55mm													
		Juvenile	Rearing	MS*	MS*	MS*	MS*	MS*	MS*	MS*	MS*	MS*	MS*	MS*	MS*
		Juvenile	Outmigration			MS	MS	MS	MS	MS	????/MS				

Legend:

	Months in which the species life stage occurs in WRIA 1.
????	Months in which there is a question whether the species life stage occurs in WRIA 1.
MS	Months in which the species life stage occurs in WRIA 1 **AND** species life stage is known or presumed to be use lower Nooksack and floodplain
	Proposed updates to periodicity (need citations)

* Applies to later rearing (1+ and older)

Fish Distribution Maps:

These maps show the current known and presumed historic distributions of salmonid fish in the Lower Mainstem Nooksack River study area. Maps included in this appendix provide details for fish distributions by each of the three reaches defined for the study. Lower Nooksack River Reach 1 encompasses the delta region from I-5 down to Bellingham Bay. Reach 2-3A captures the largely single-thread section of the lower mainstem from just upstream of Lynden down to I-5. Reach 3B-4 covers the laterally dynamic section of the river and floodplain from the forks at Deming down to just above Lynden. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). Please note that, while species distribution has been mapped in the study area, distribution of life stages has not been systematically mapped for each species. "Presence" therefore may indicate presence of multiple life stages. Statewide integrated fish distribution (SWIFD) fish distribution is updated periodically.

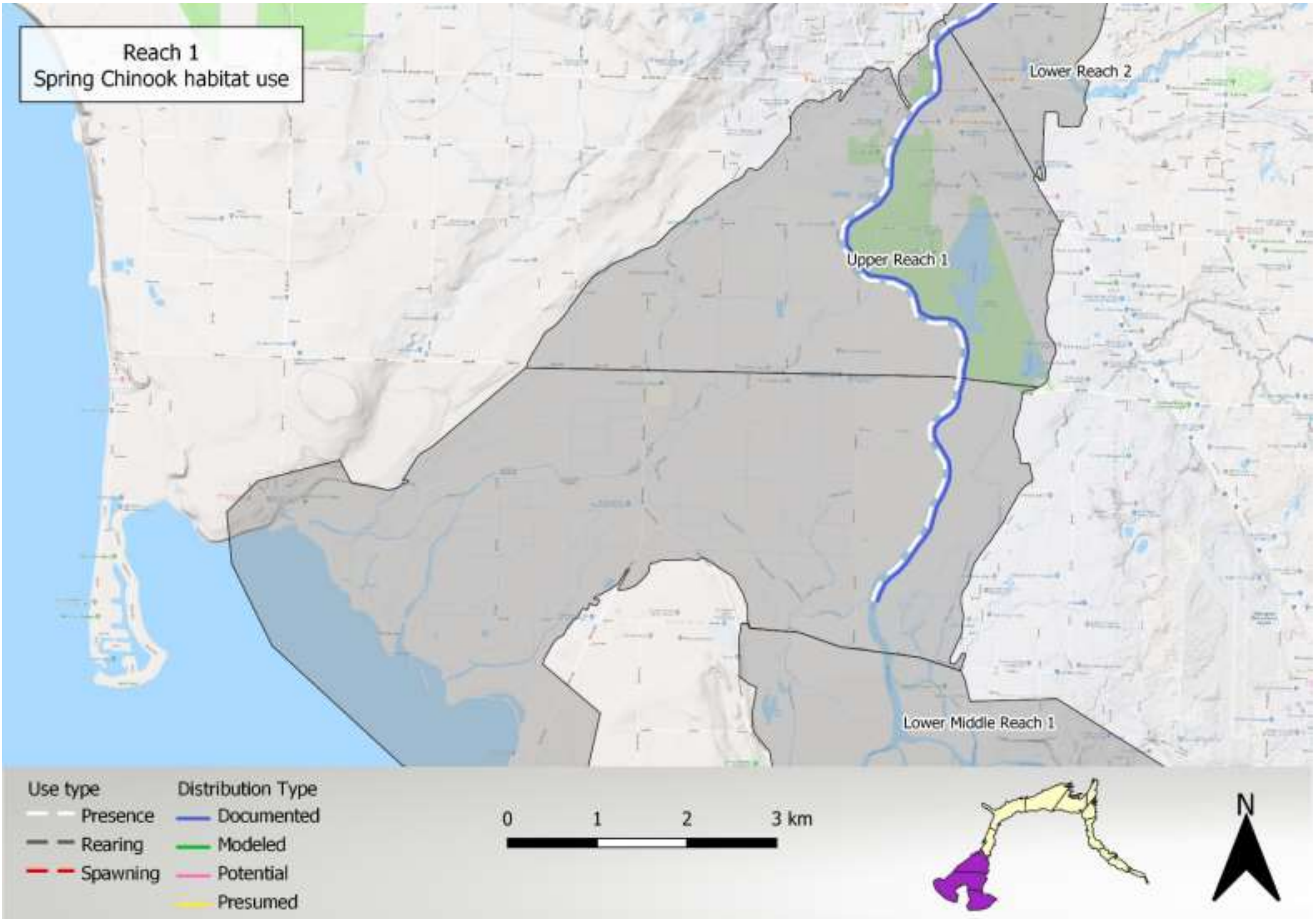

Figure 58: Statewide Integrated Fish Distribution for spring Chinook in Reach 1. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

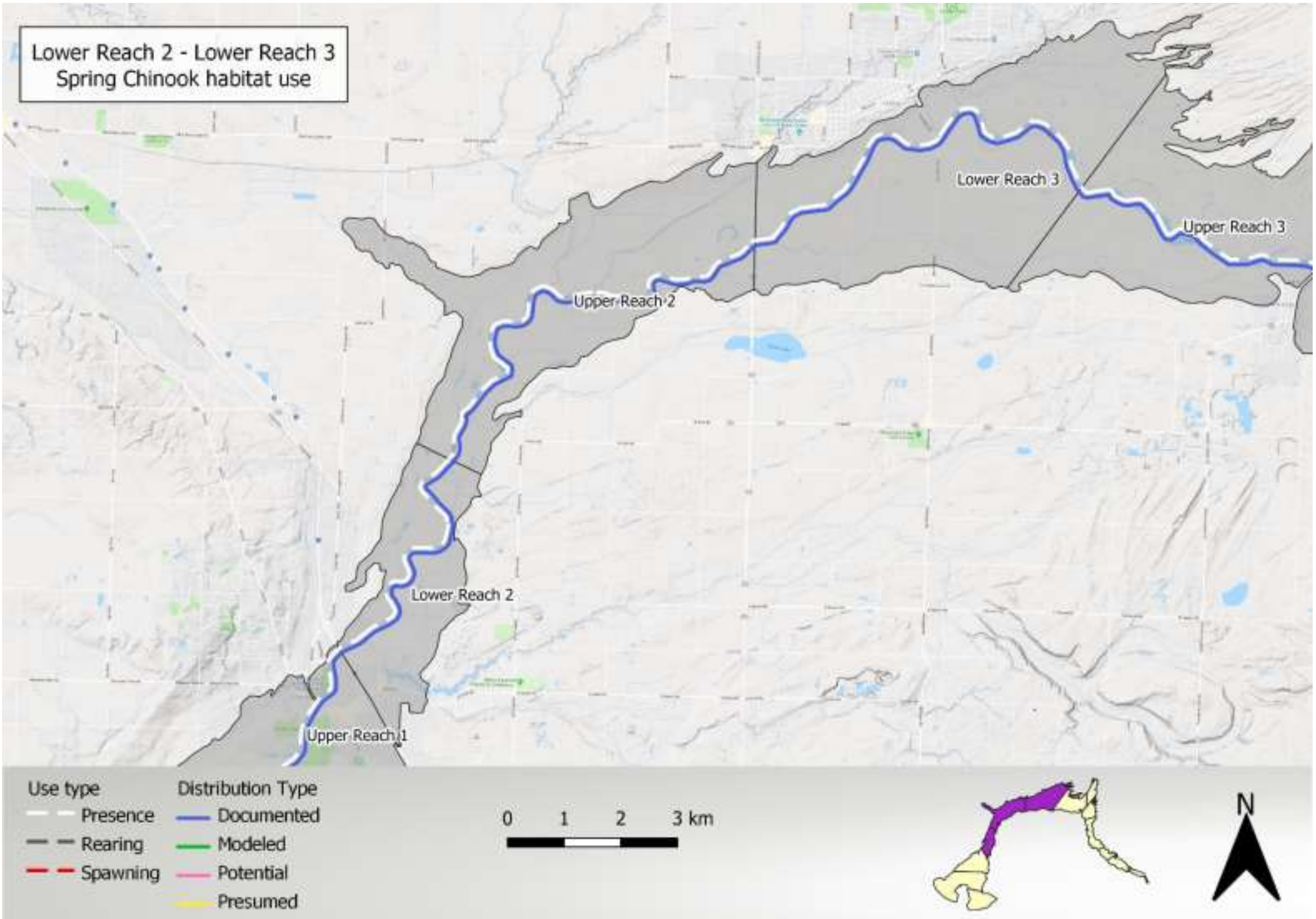

Figure 59: Statewide Integrated Fish Distribution for spring Chinook in Reach 2 and Lower Reach 3. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

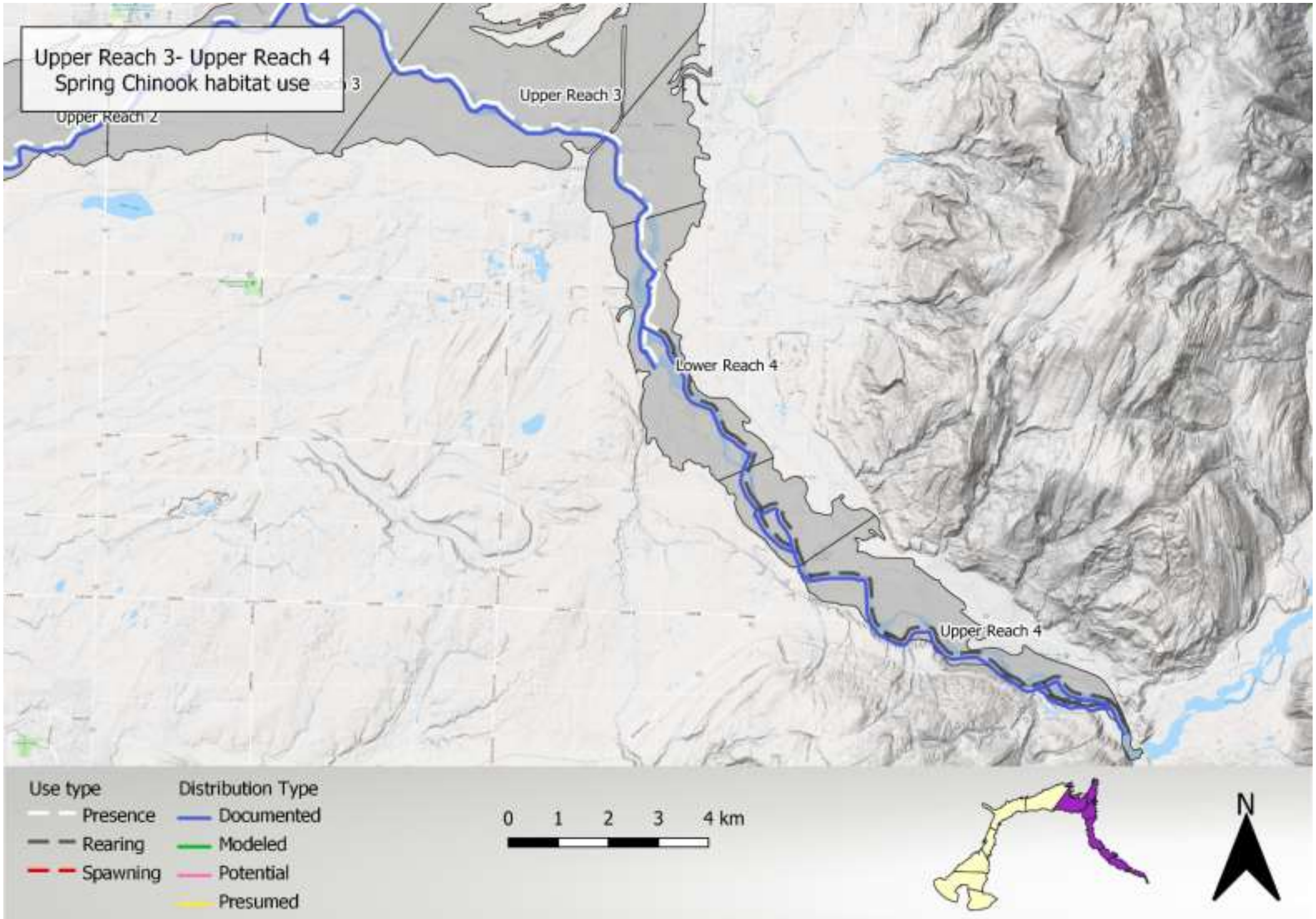

Figure 60: Statewide Integrated Fish Distribution for spring Chinook in Upper Reach 3 and Reach 4. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

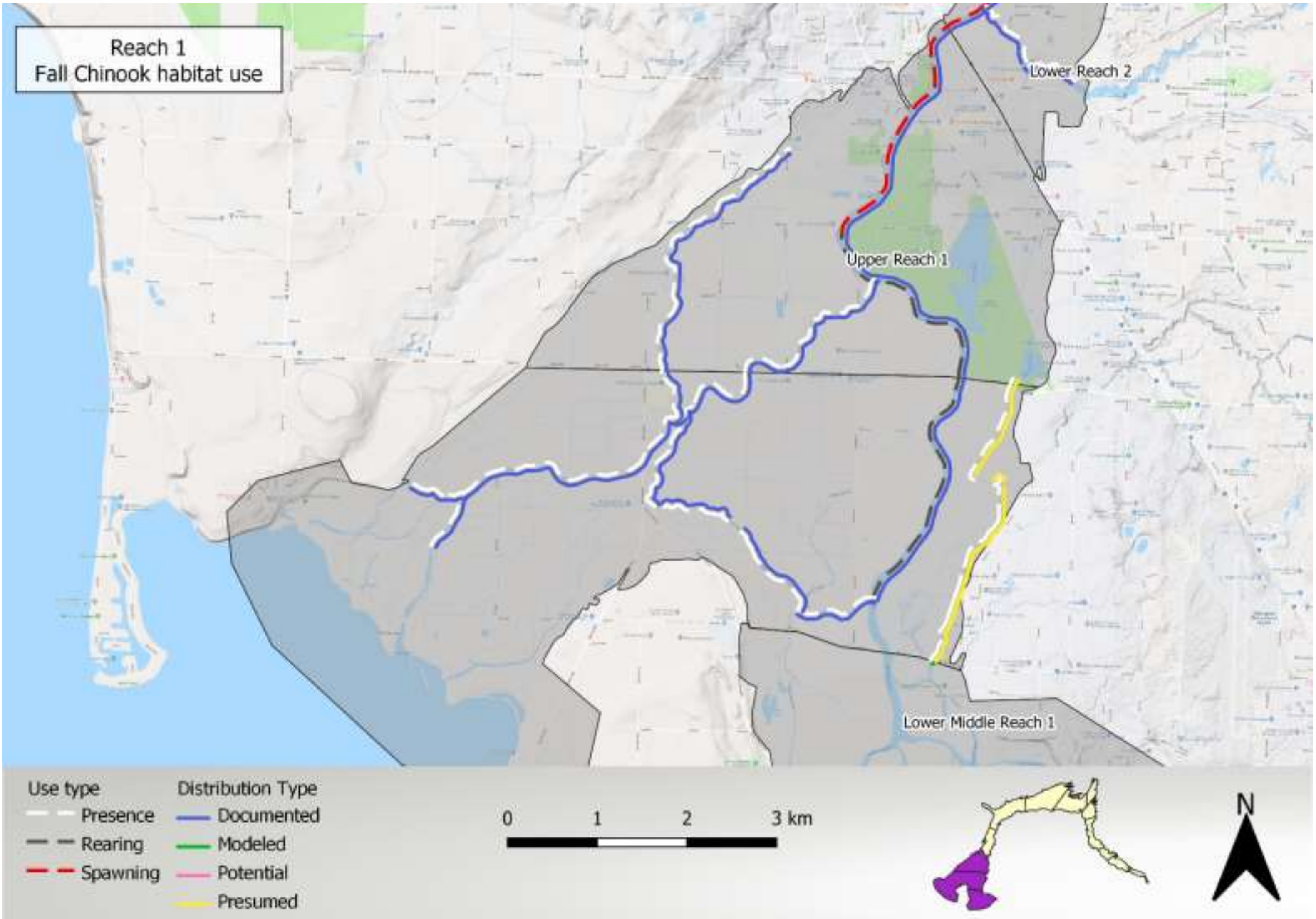

Figure 61: Statewide Integrated Fish Distribution for fall Chinook in Reach 1. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

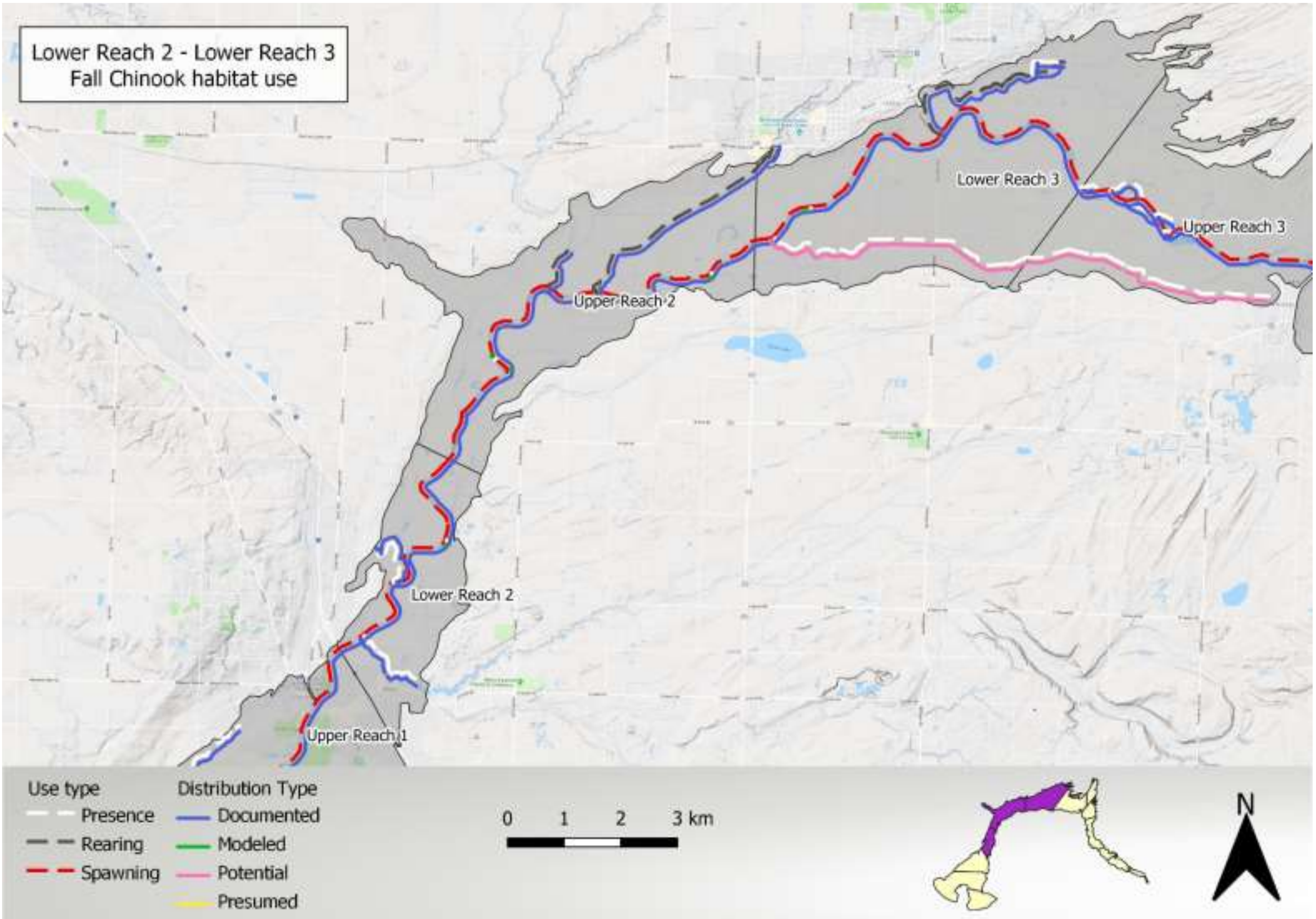

Figure 62: Statewide Integrated Fish Distribution for fall Chinook in Reach 2 and Lower Reach 3. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

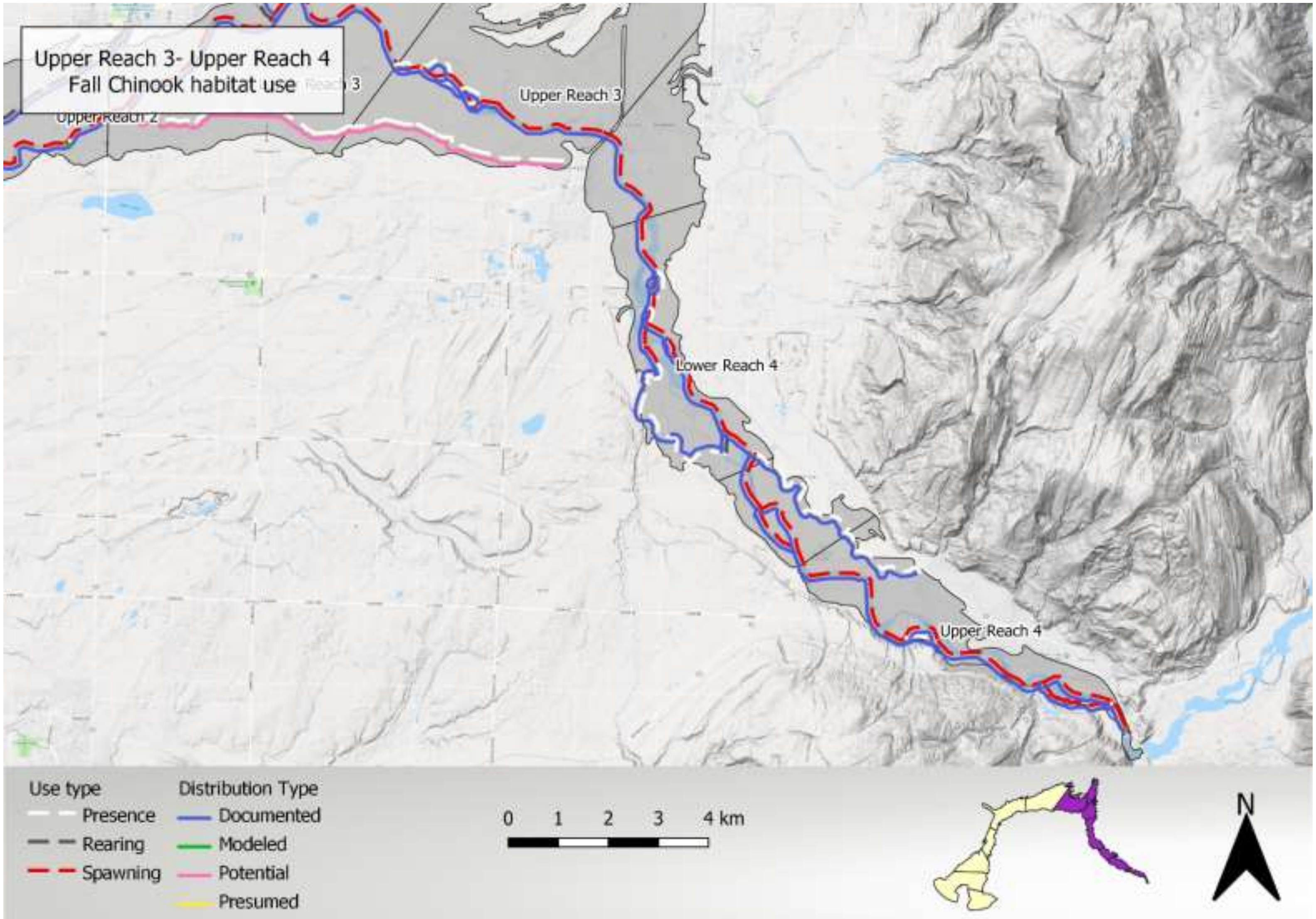

Figure 63: Statewide Integrated Fish Distribution for fall Chinook in Upper Reach 3 and Reach 4. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

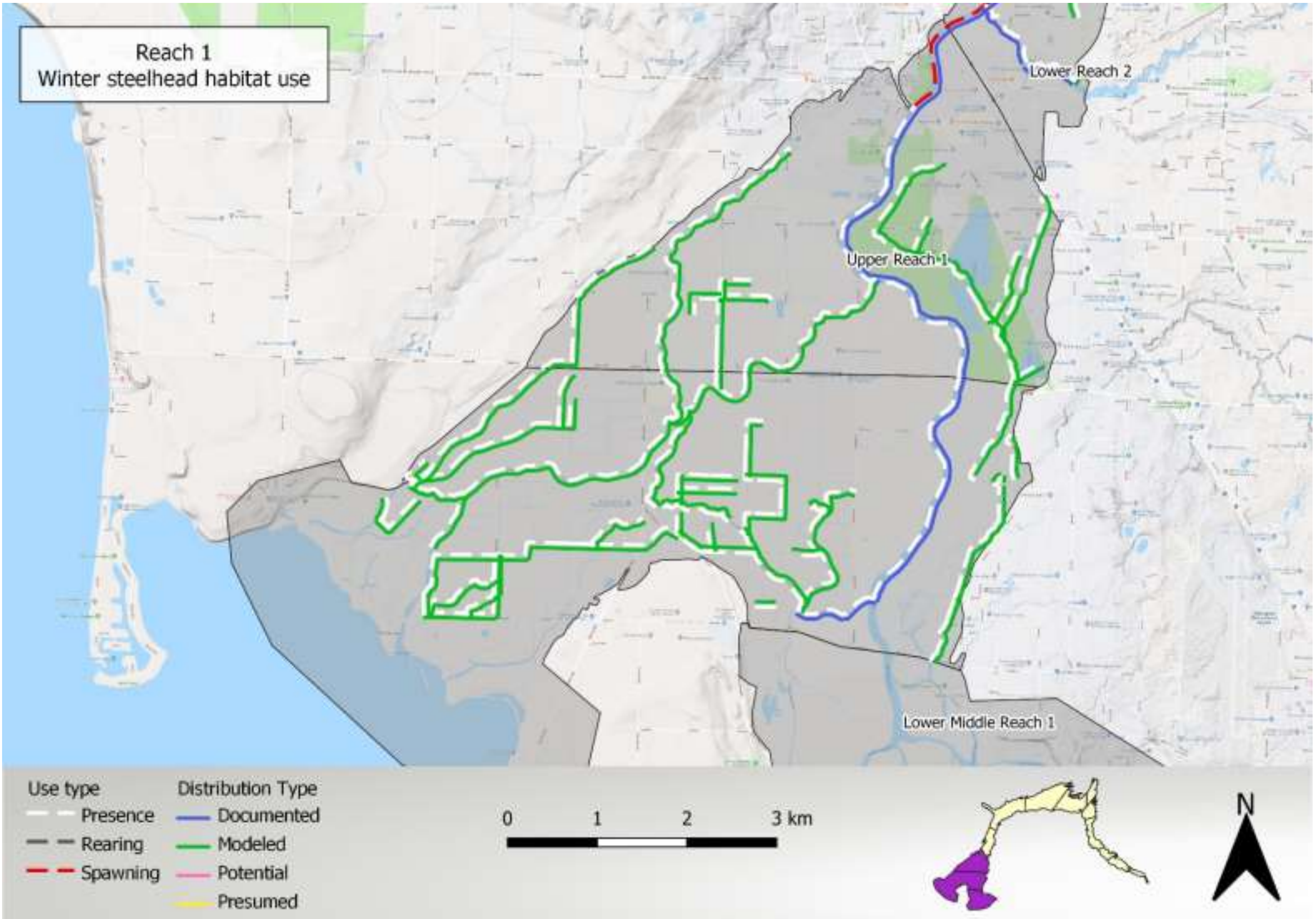

Figure 64: Statewide Integrated Fish Distribution for winter steelhead in Reach 1. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

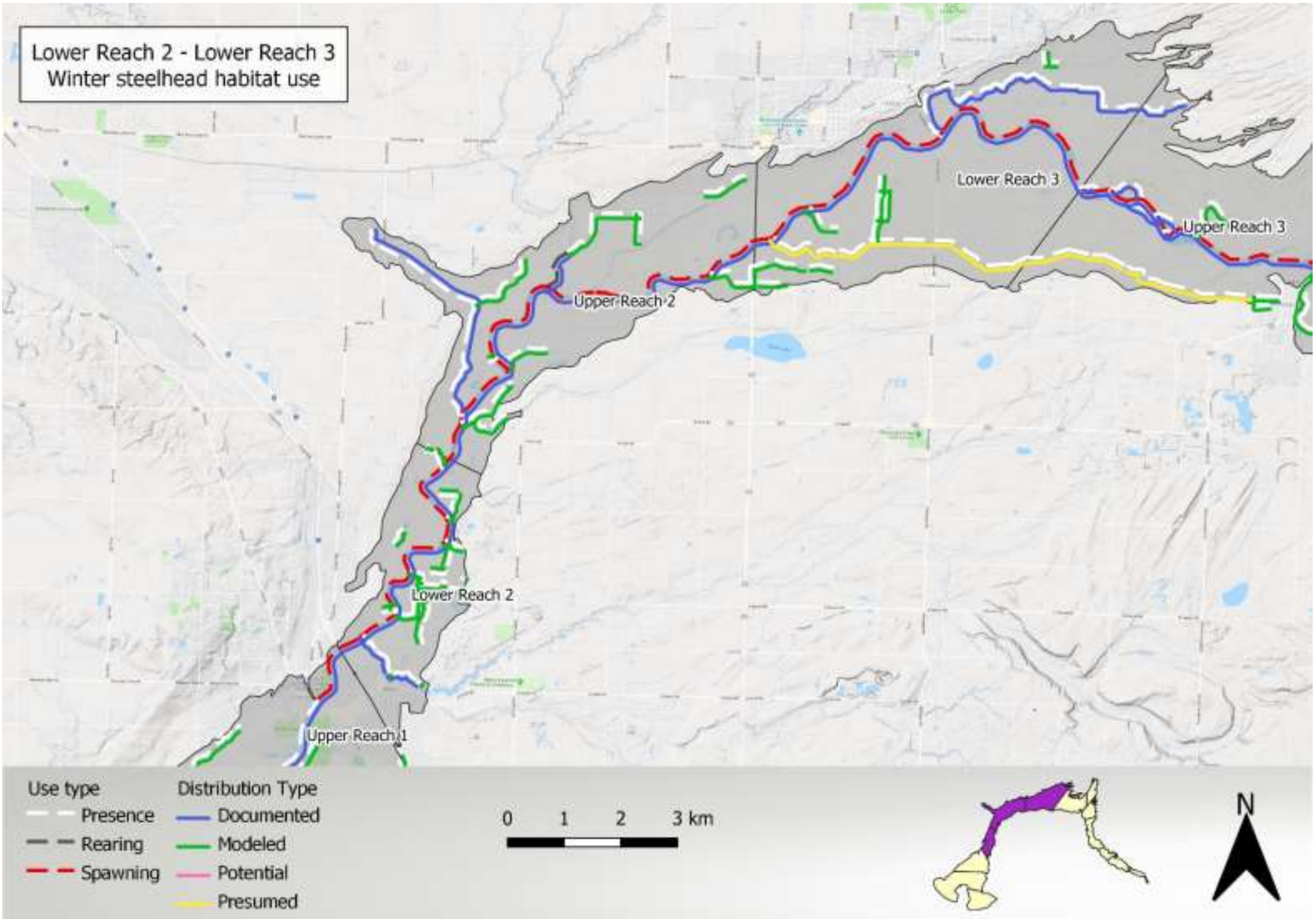

Figure 65: Statewide Integrated Fish Distribution for winter steelhead in Reach 2 and Lower Reach 3. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

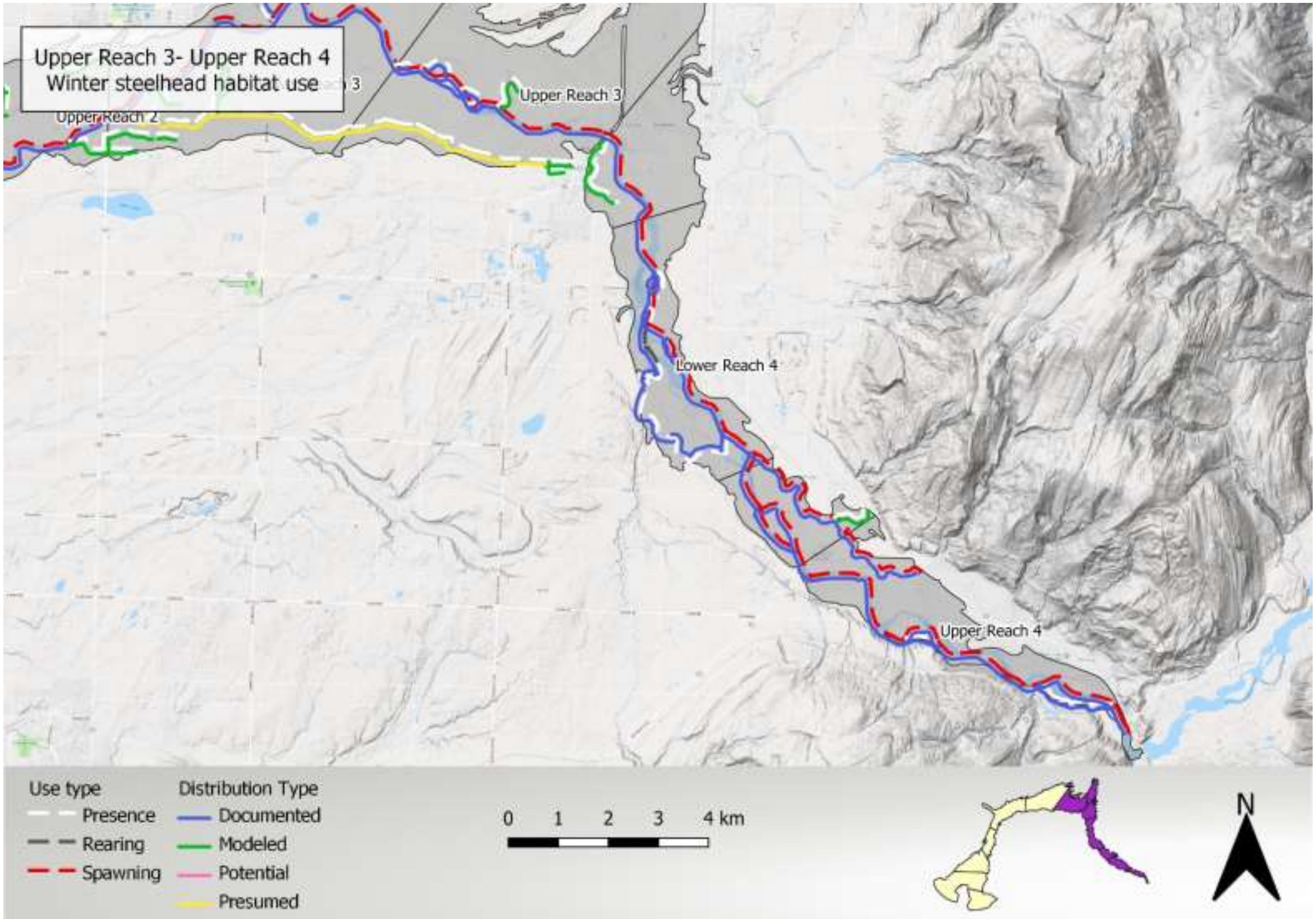

Figure 66: Statewide Integrated Fish Distribution for winter steelhead in Upper Reach 3 and Reach 4. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

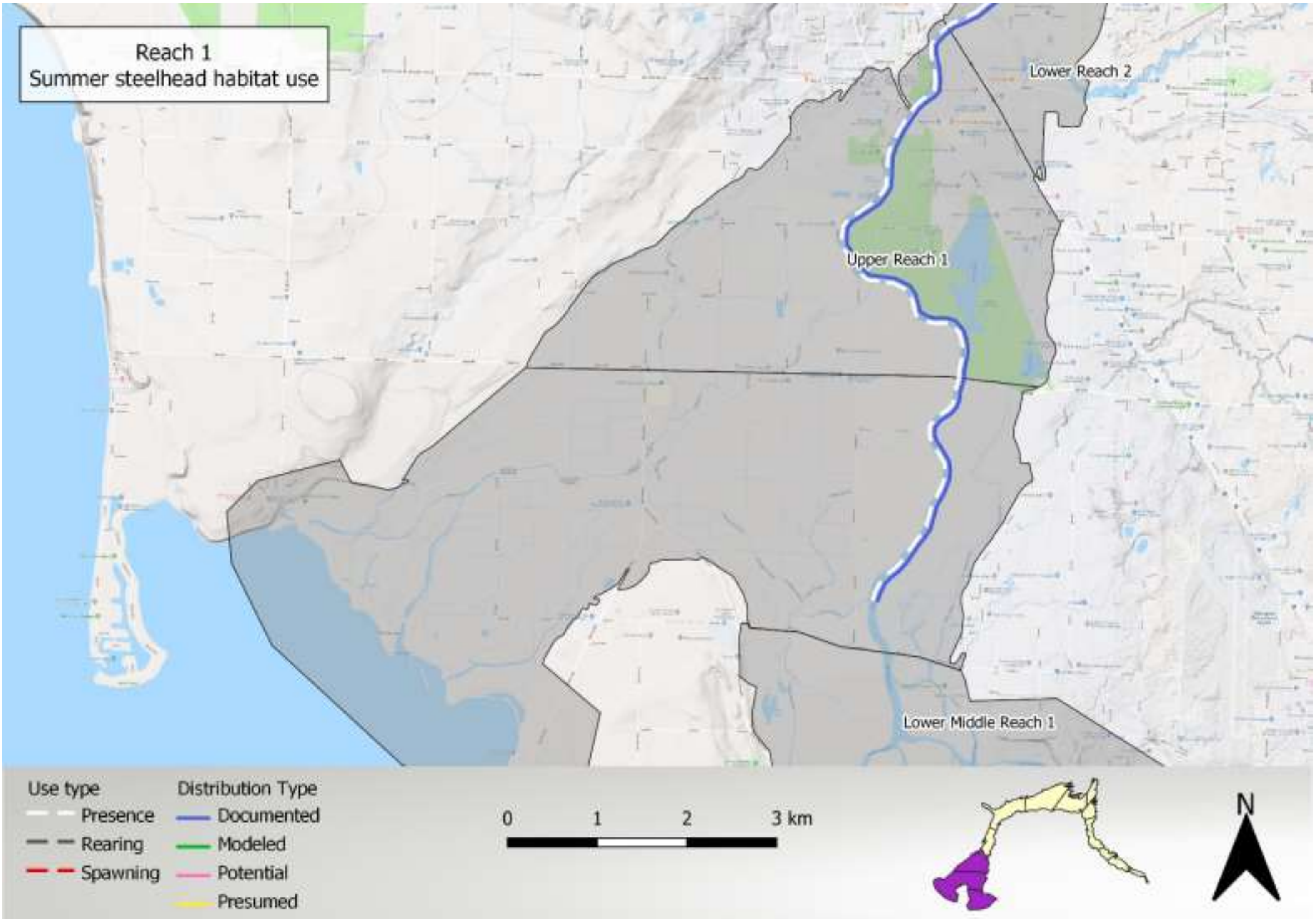

Figure 67: Statewide Integrated Fish Distribution for summer steelhead in Reach 1. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

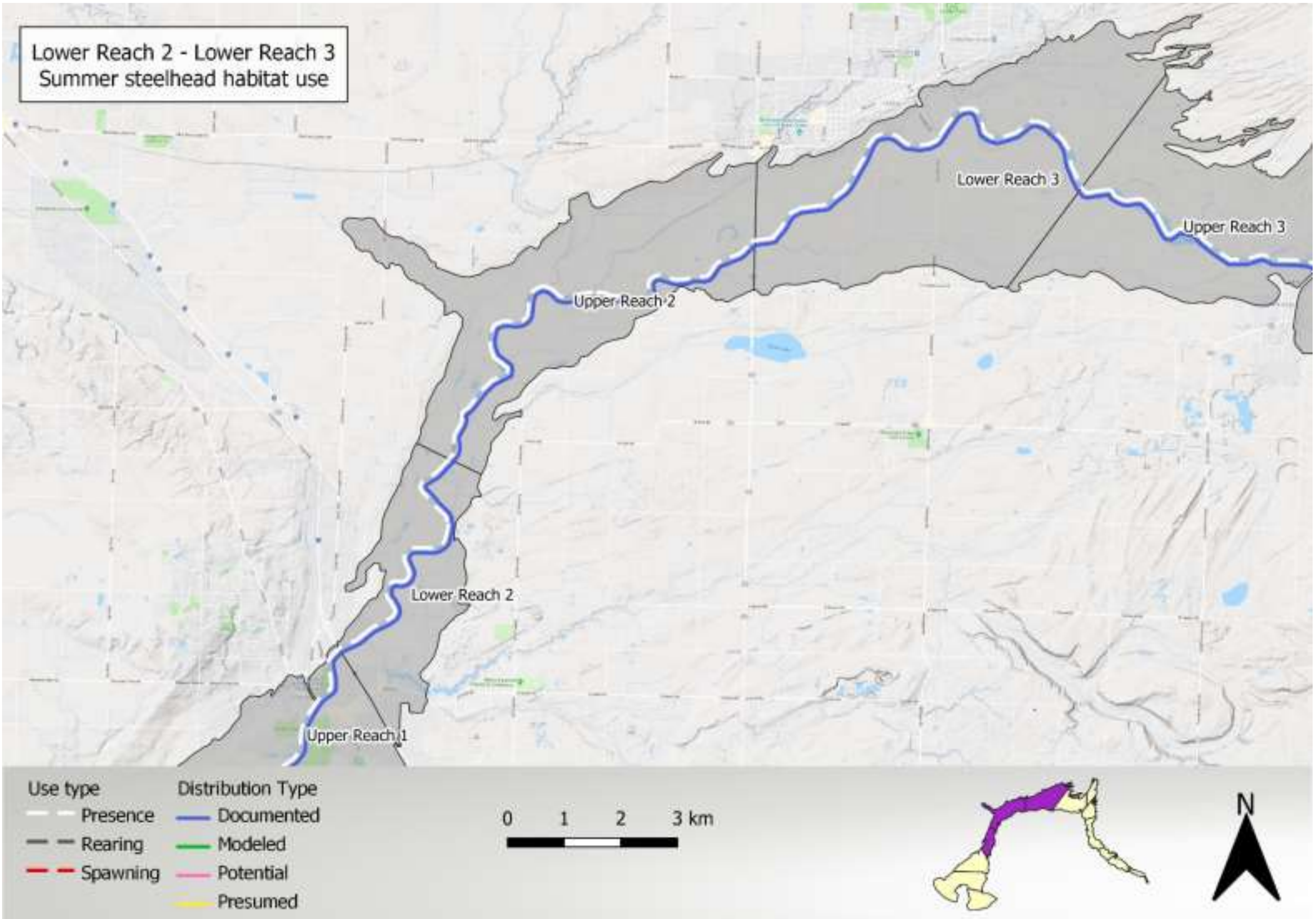

Figure 68: Statewide Integrated Fish Distribution for summer steelhead in Reach 2 and Lower Reach 3. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

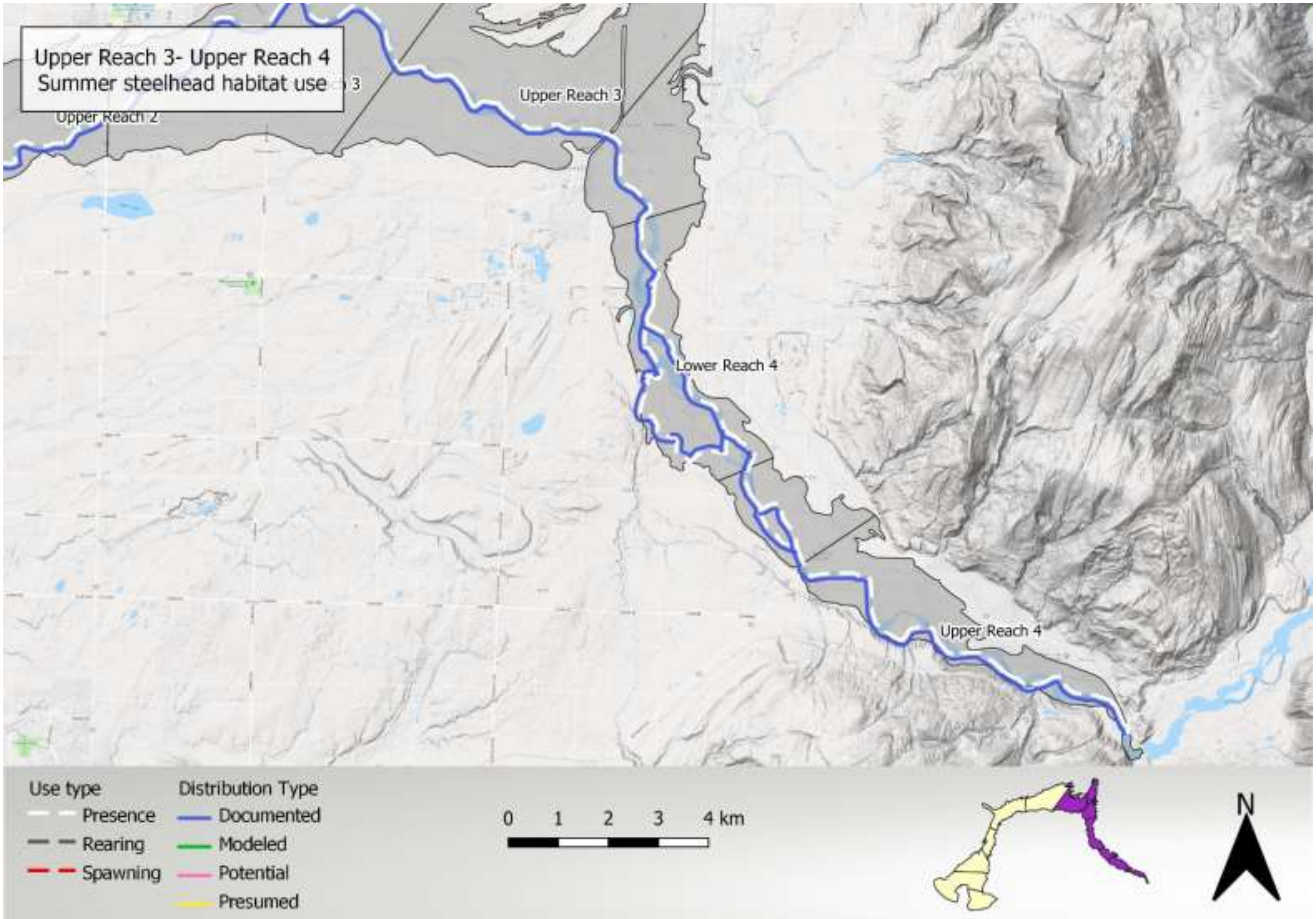

Figure 69: Statewide Integrated Fish Distribution for summer steelhead in Upper Reach 3 and Reach 4. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

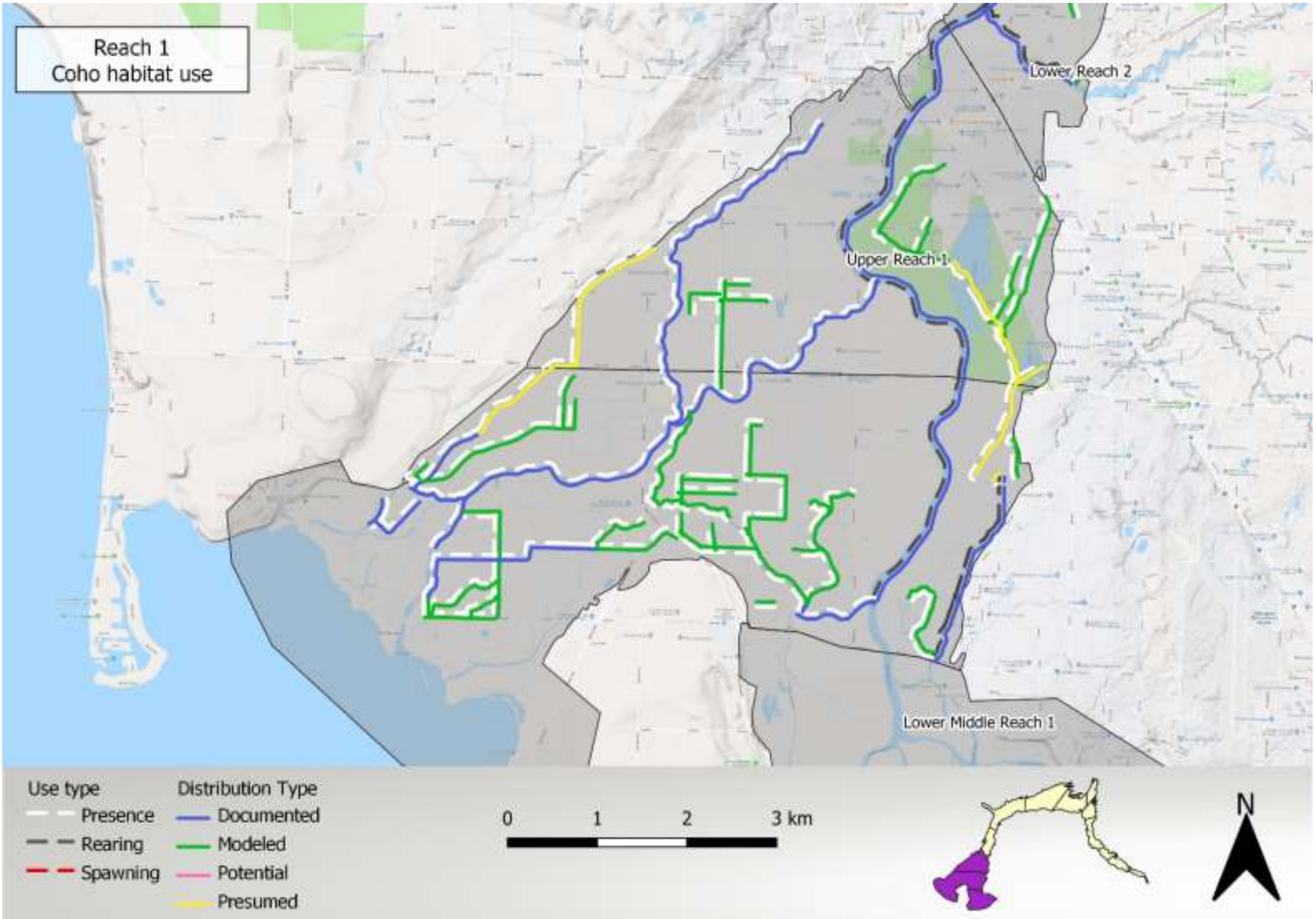

Figure 70: Statewide Integrated Fish Distribution for coho in Reach 1. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

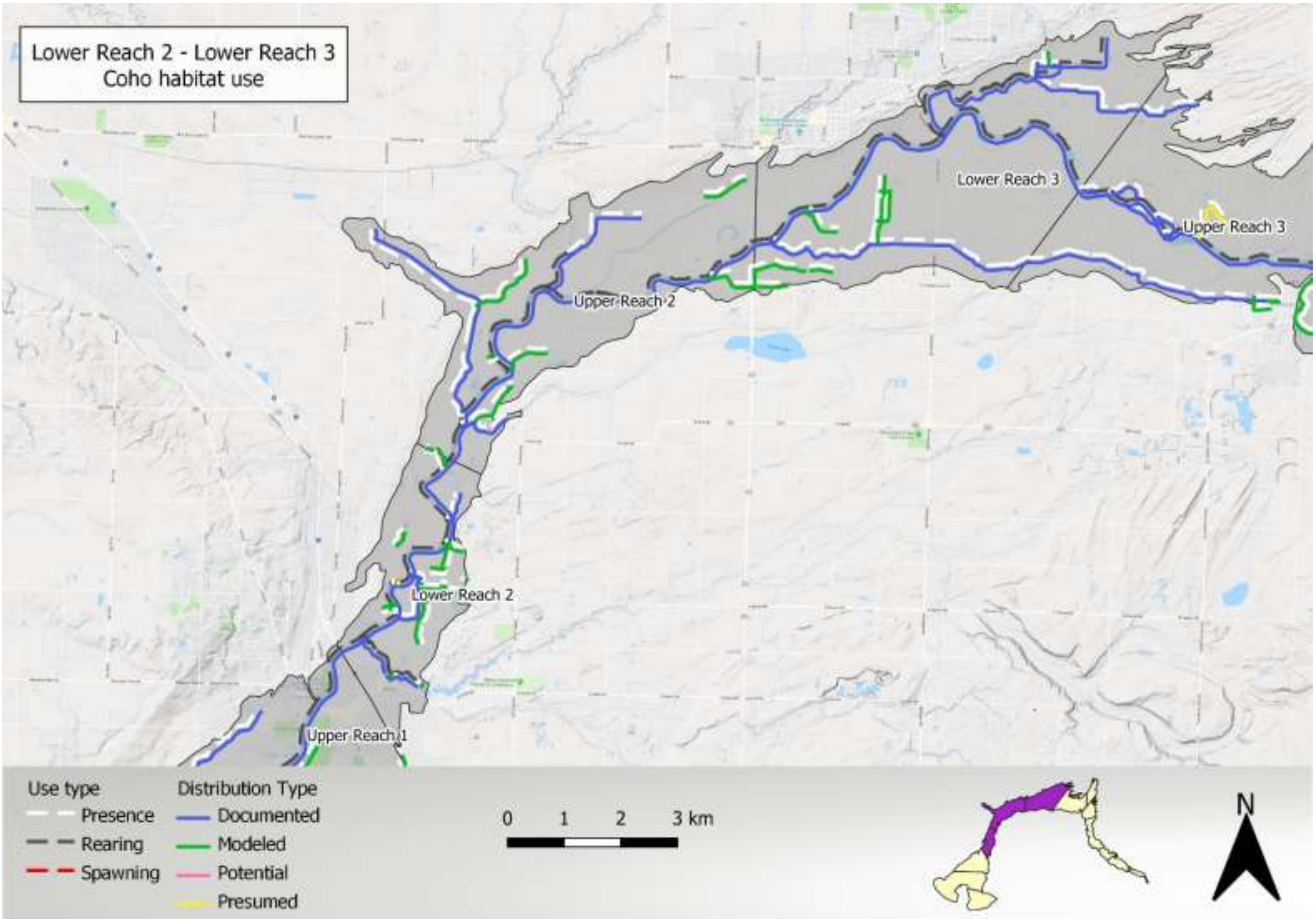

Figure 71: Statewide Integrated Fish Distribution for coho in Reach 2 and Lower Reach 3. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

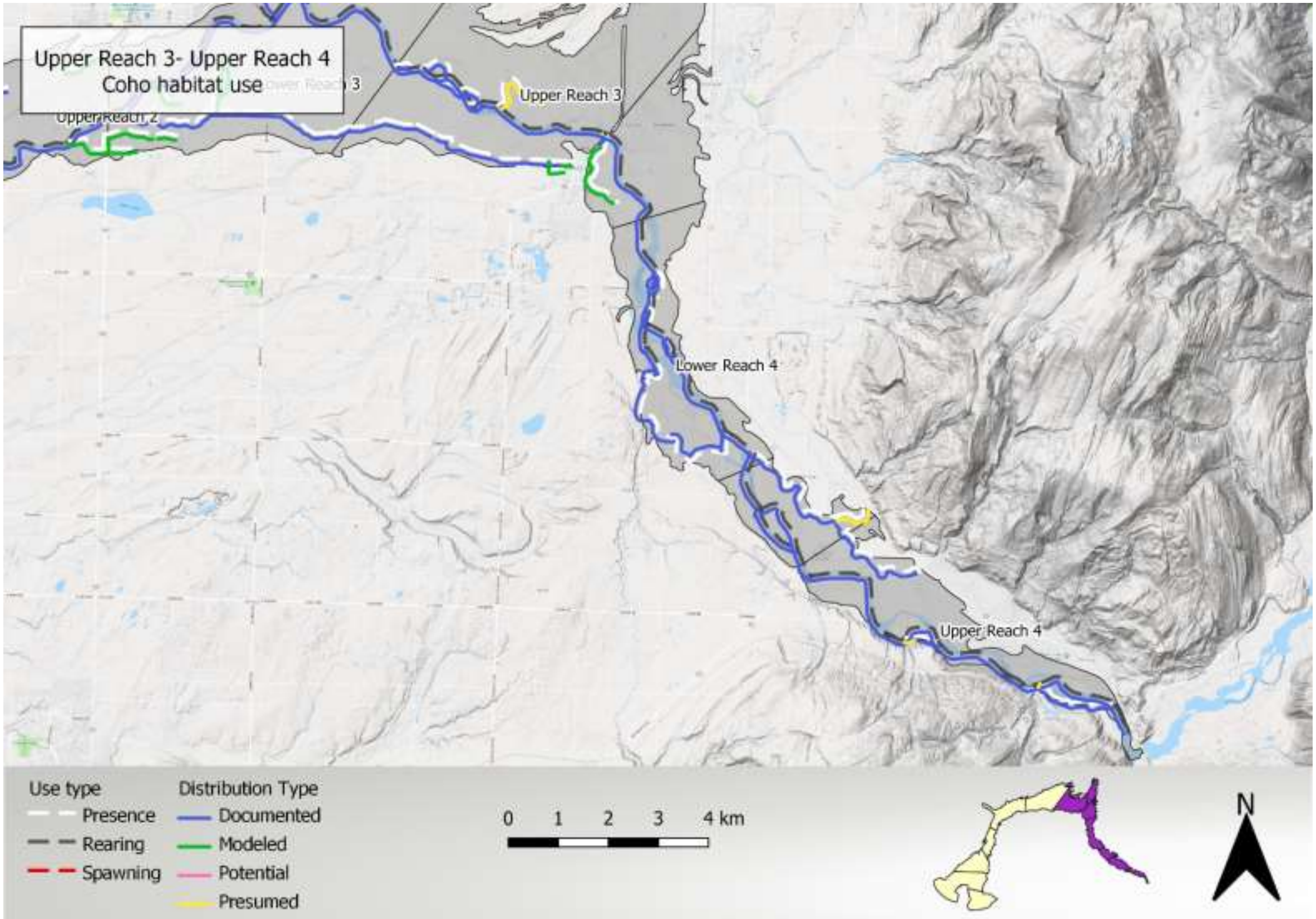

Figure 72: Statewide Integrated Fish Distribution for coho in Upper Reach 3 and Reach 4. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

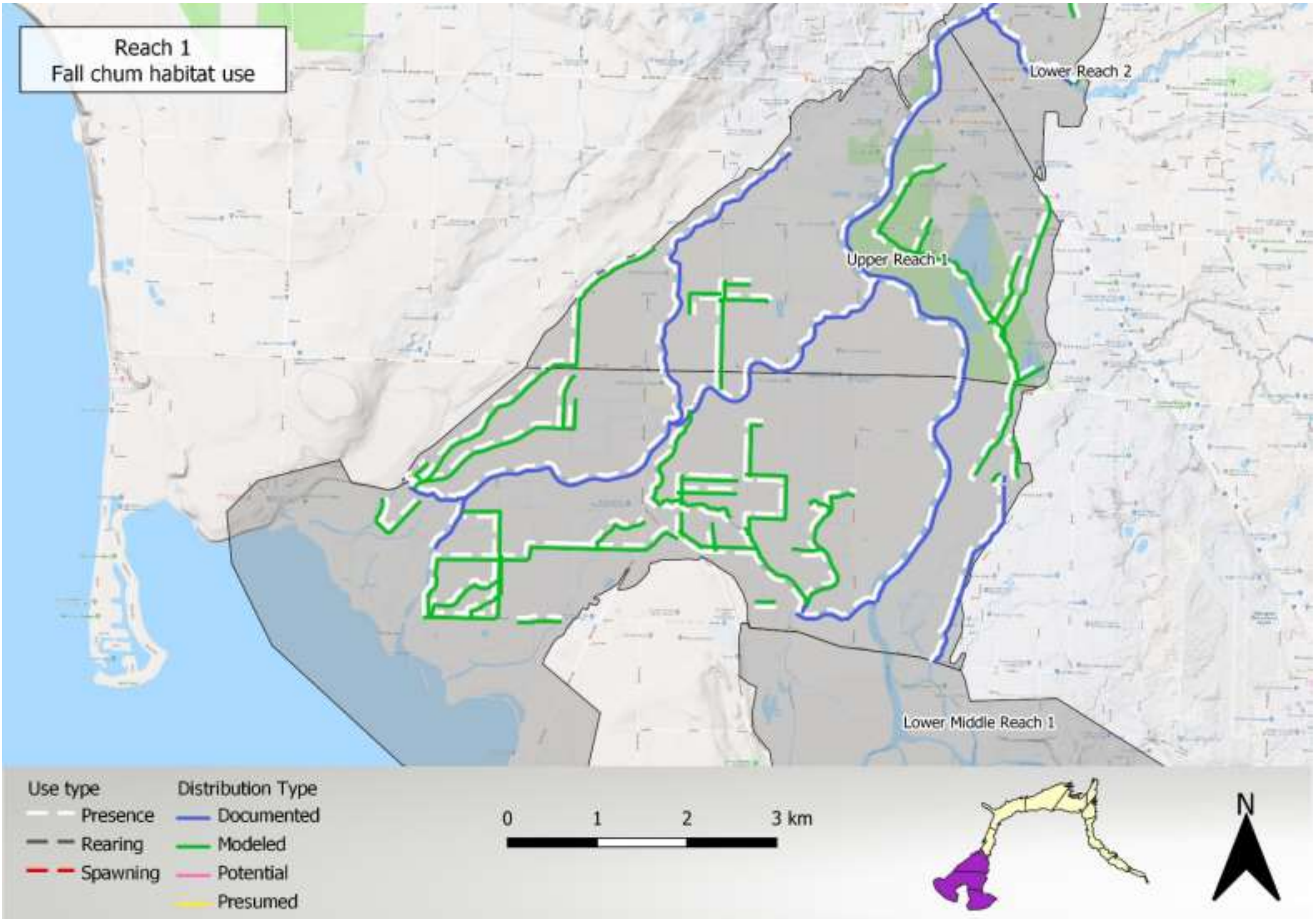

Figure 73: Statewide Integrated Fish Distribution for fall chum in Reach 1. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

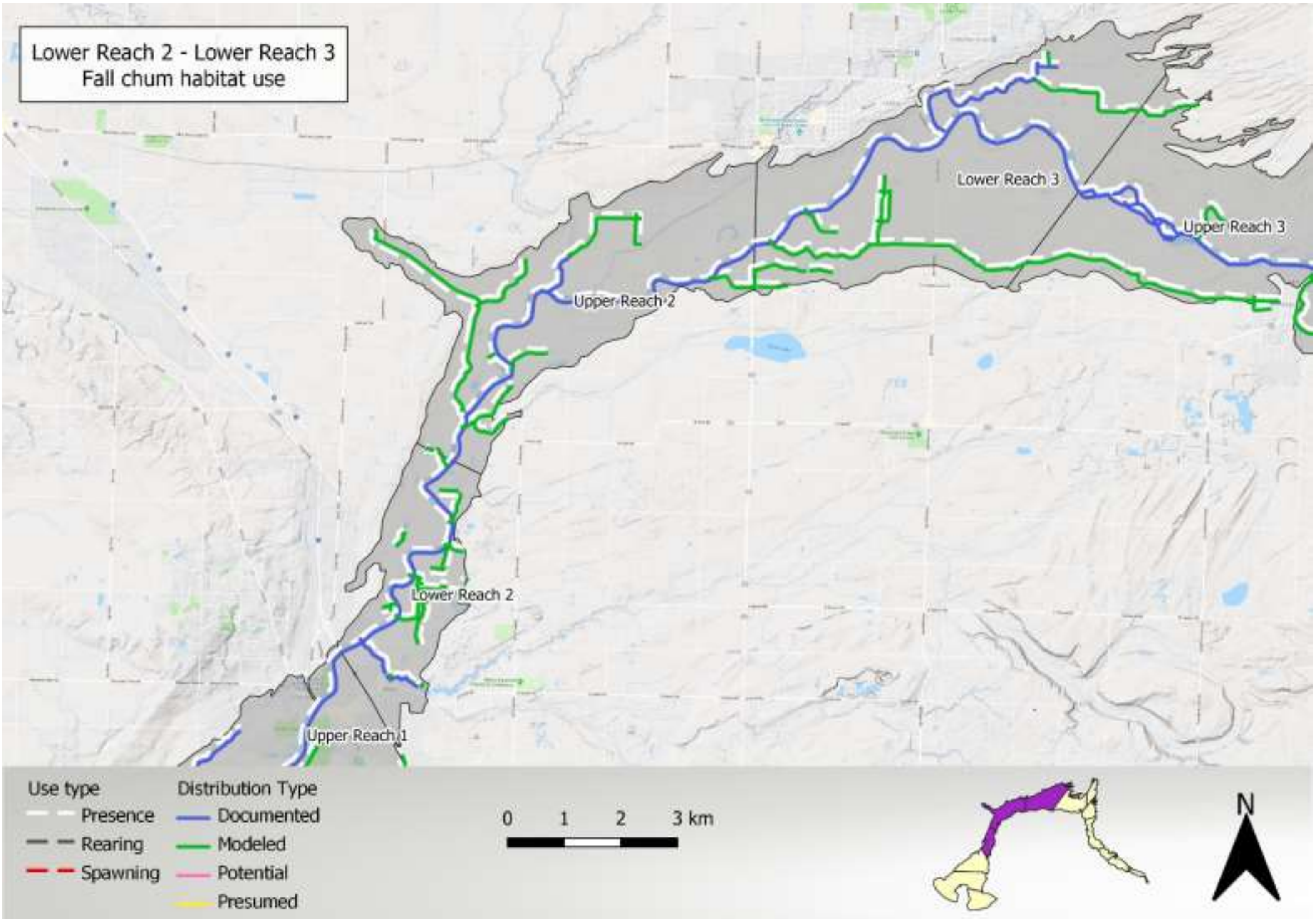

Figure 74: Statewide Integrated Fish Distribution for fall chum in Reach 2 and Lower Reach 3. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

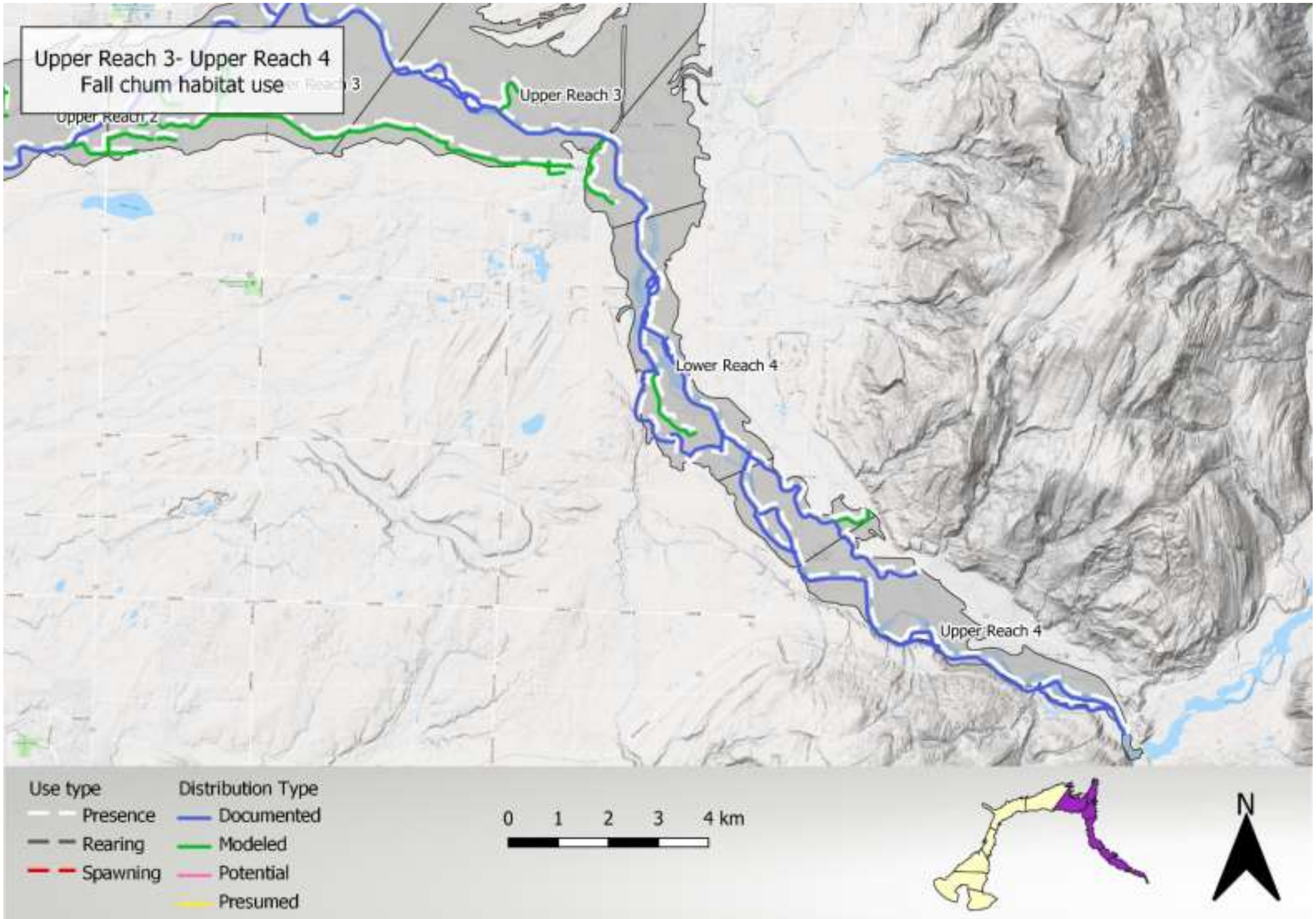

Figure 75: Statewide Integrated Fish Distribution for fall chum in Upper Reach 3 and Reach 4. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

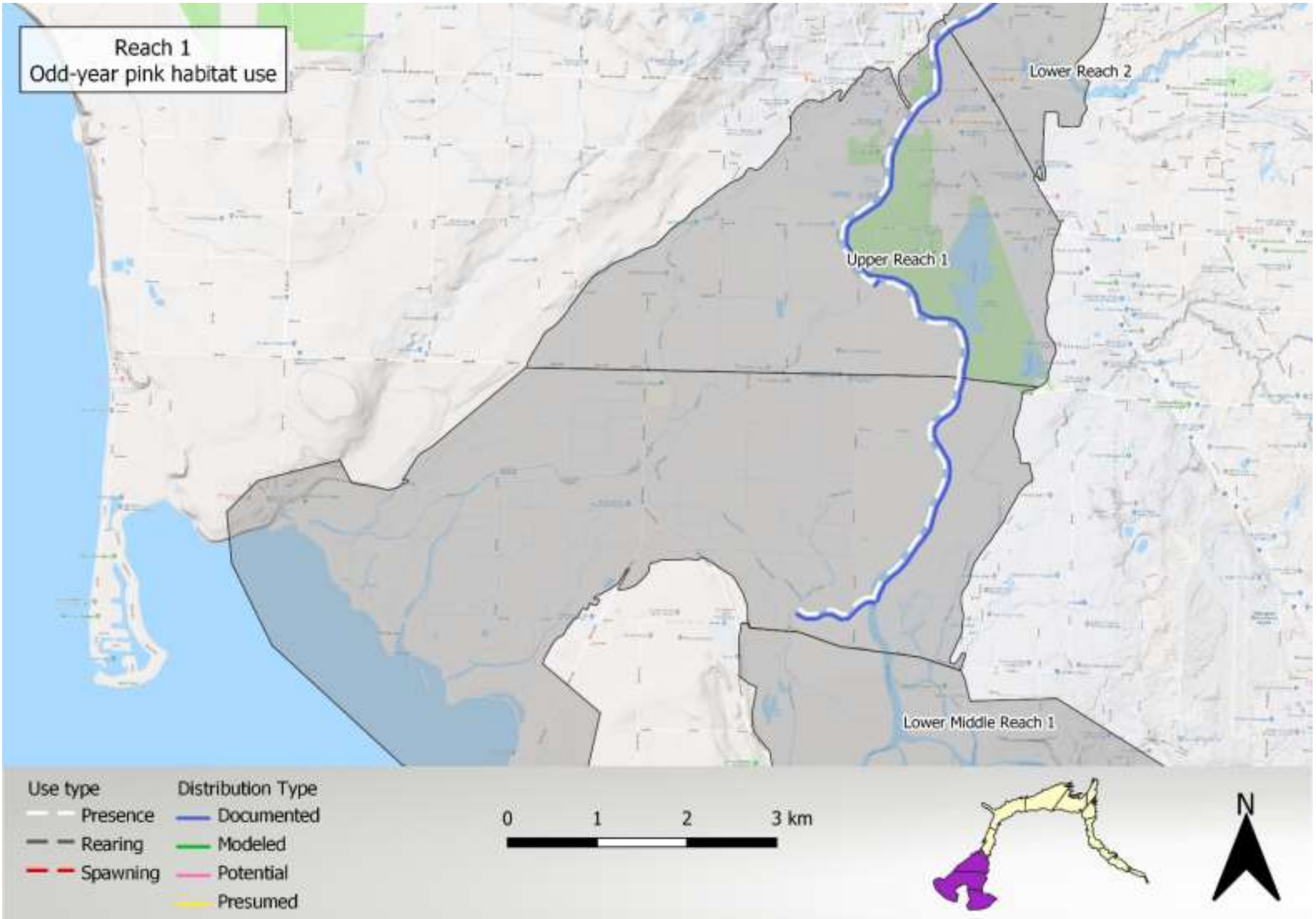

Figure 76: Statewide Integrated Fish Distribution for odd-year pink in Reach 1. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

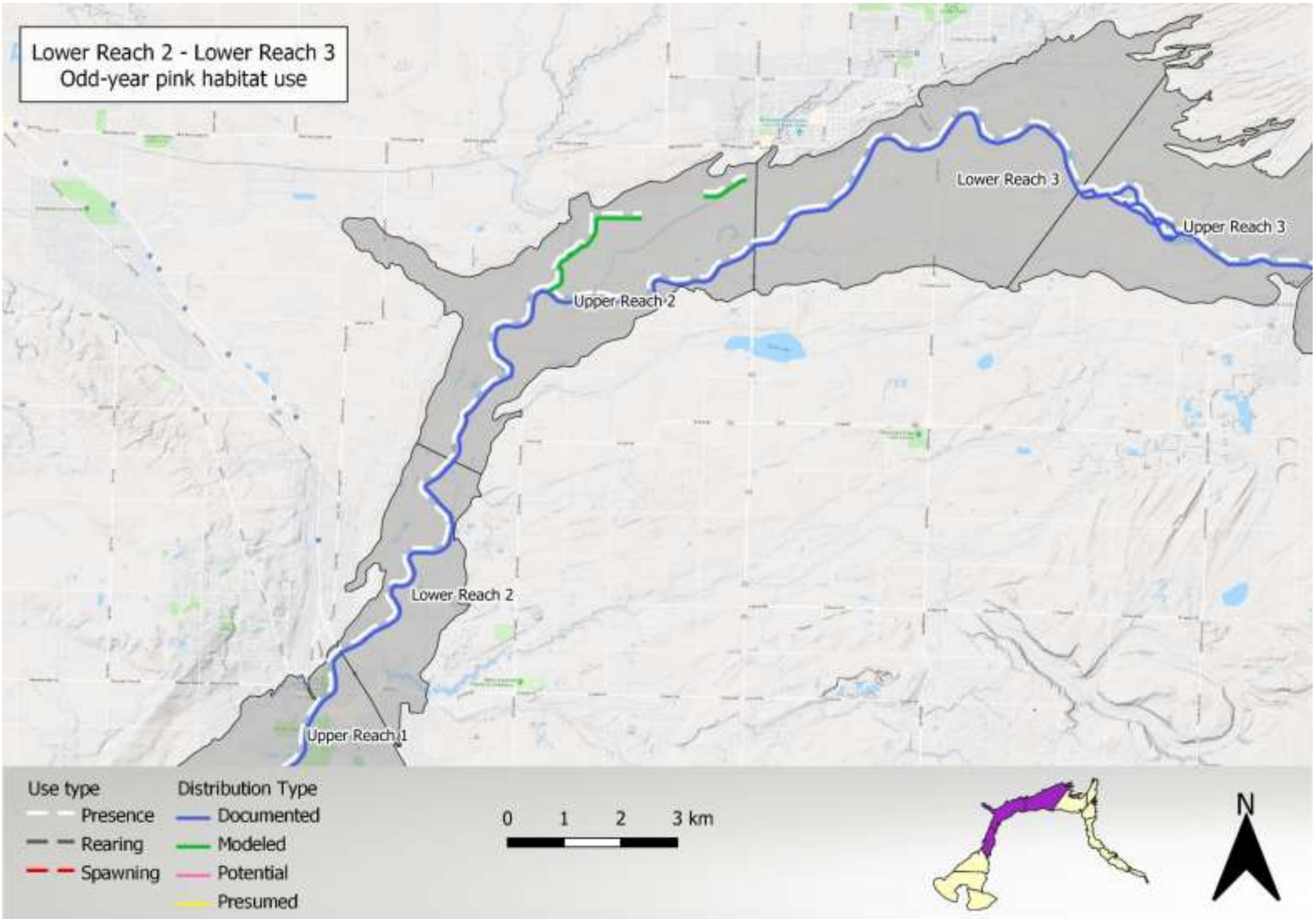

Figure 77: Statewide Integrated Fish Distribution for odd-year pink in Reach 2 and Lower Reach 3. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

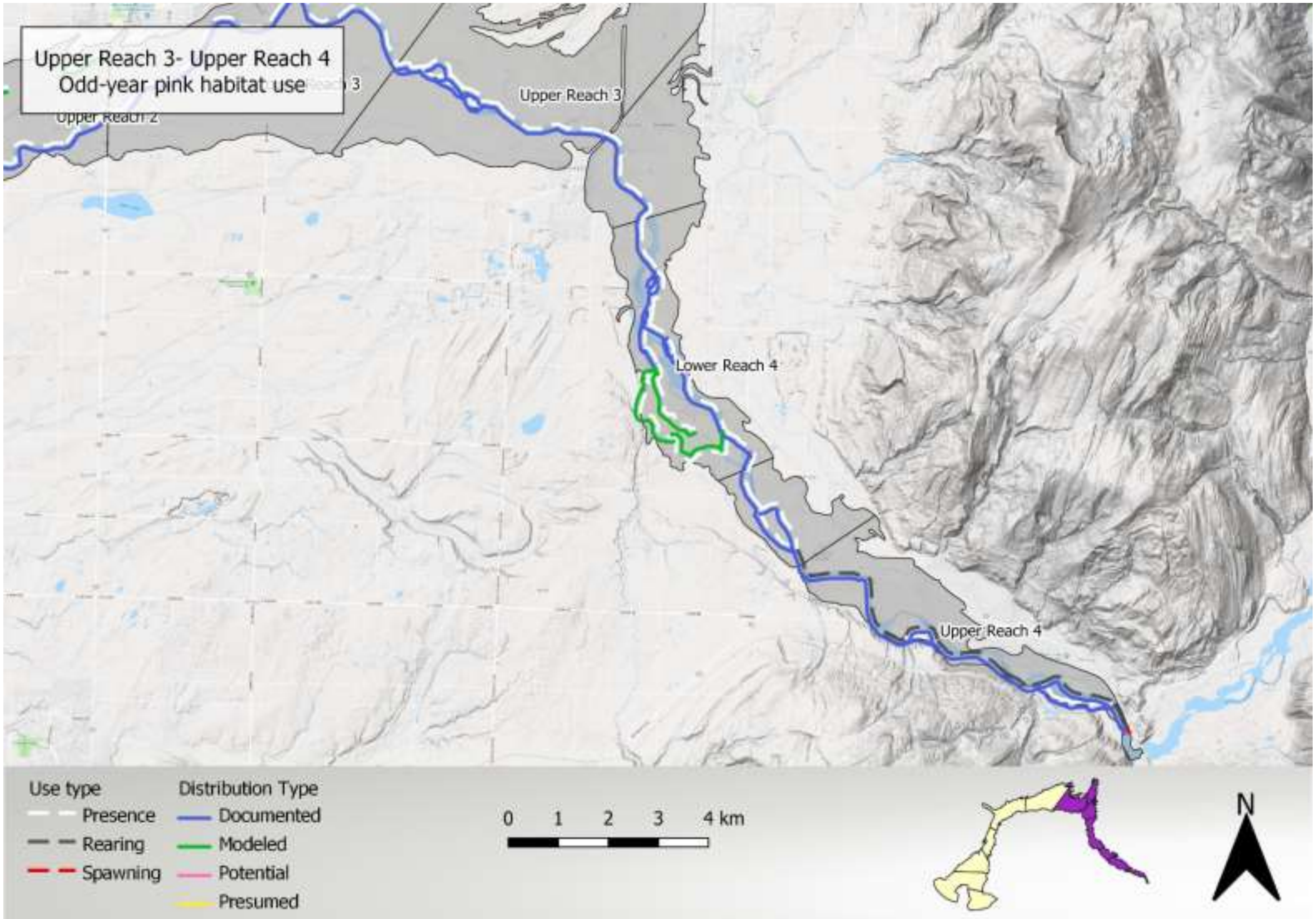

Figure 78: Statewide Integrated Fish Distribution for odd-year pink in Upper Reach 3 and Reach 4. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

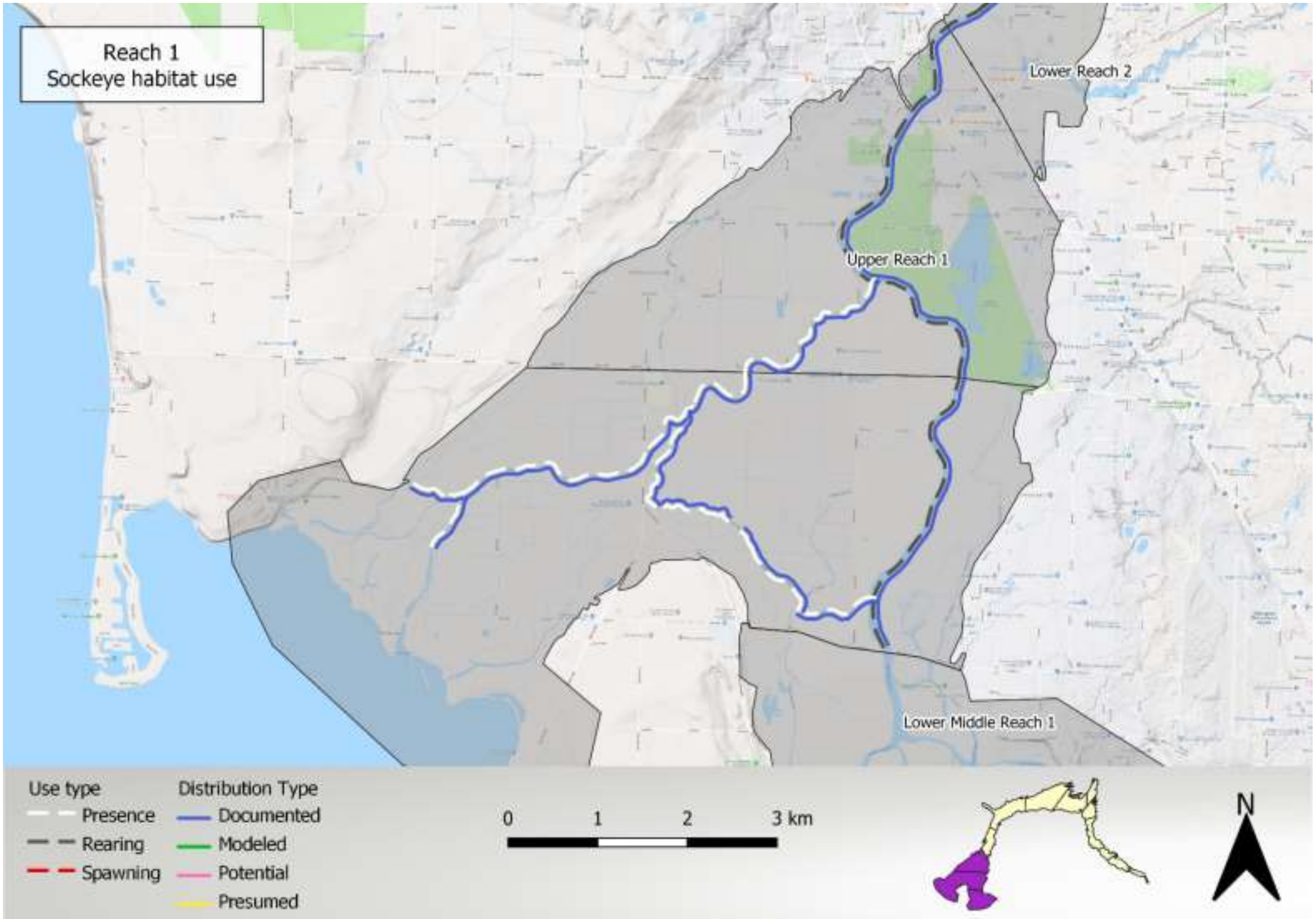

Figure 79: Statewide Integrated Fish Distribution for sockeye in Reach 1. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

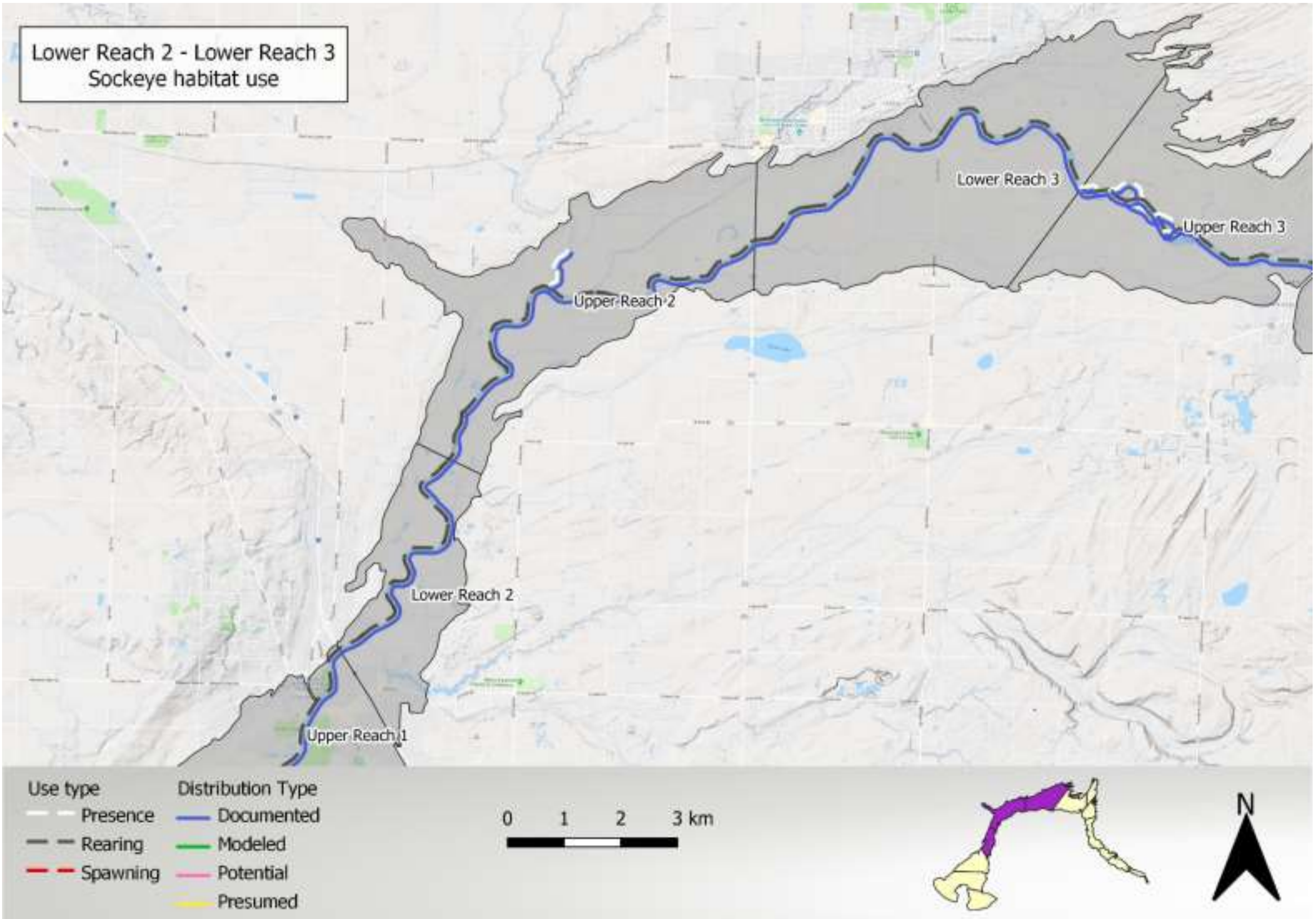

Figure 80: Statewide Integrated Fish Distribution for sockeye in Reach 2 and Lower Reach 3. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

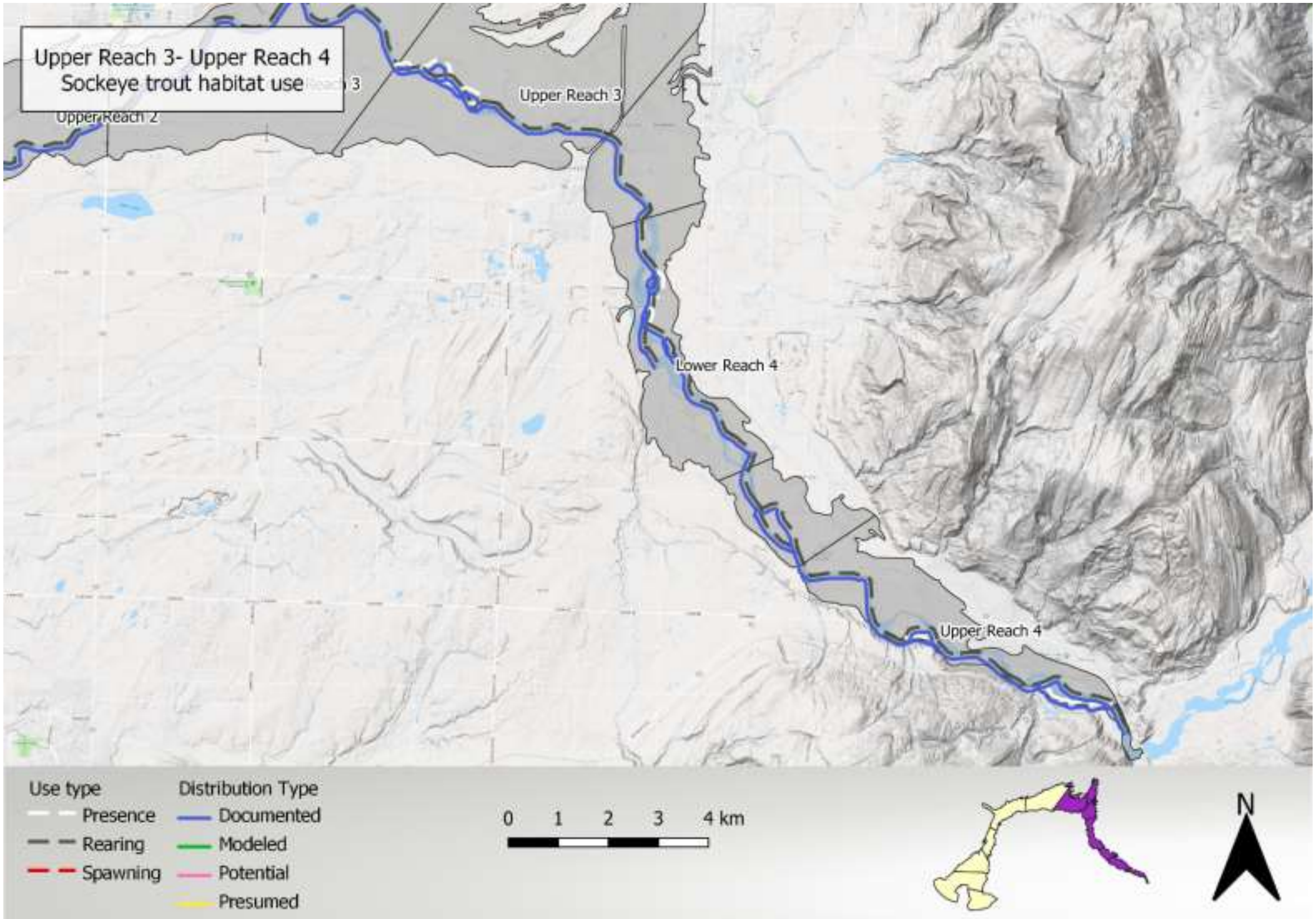

Figure 81: Statewide Integrated Fish Distribution for sockeye in Upper Reach 3 and Reach 4. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

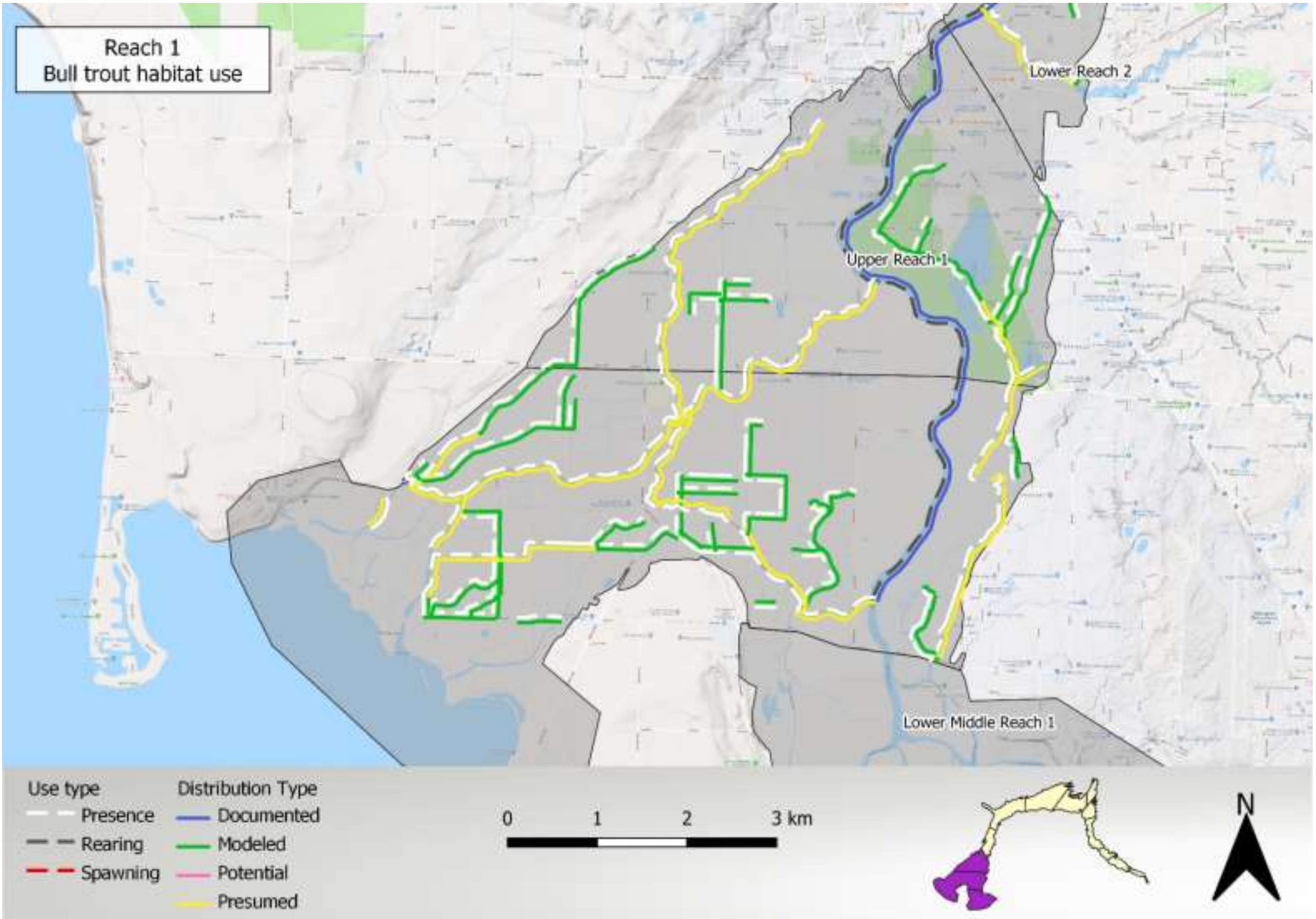

Figure 82: Statewide Integrated Fish Distribution for bull trout in Reach 1. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

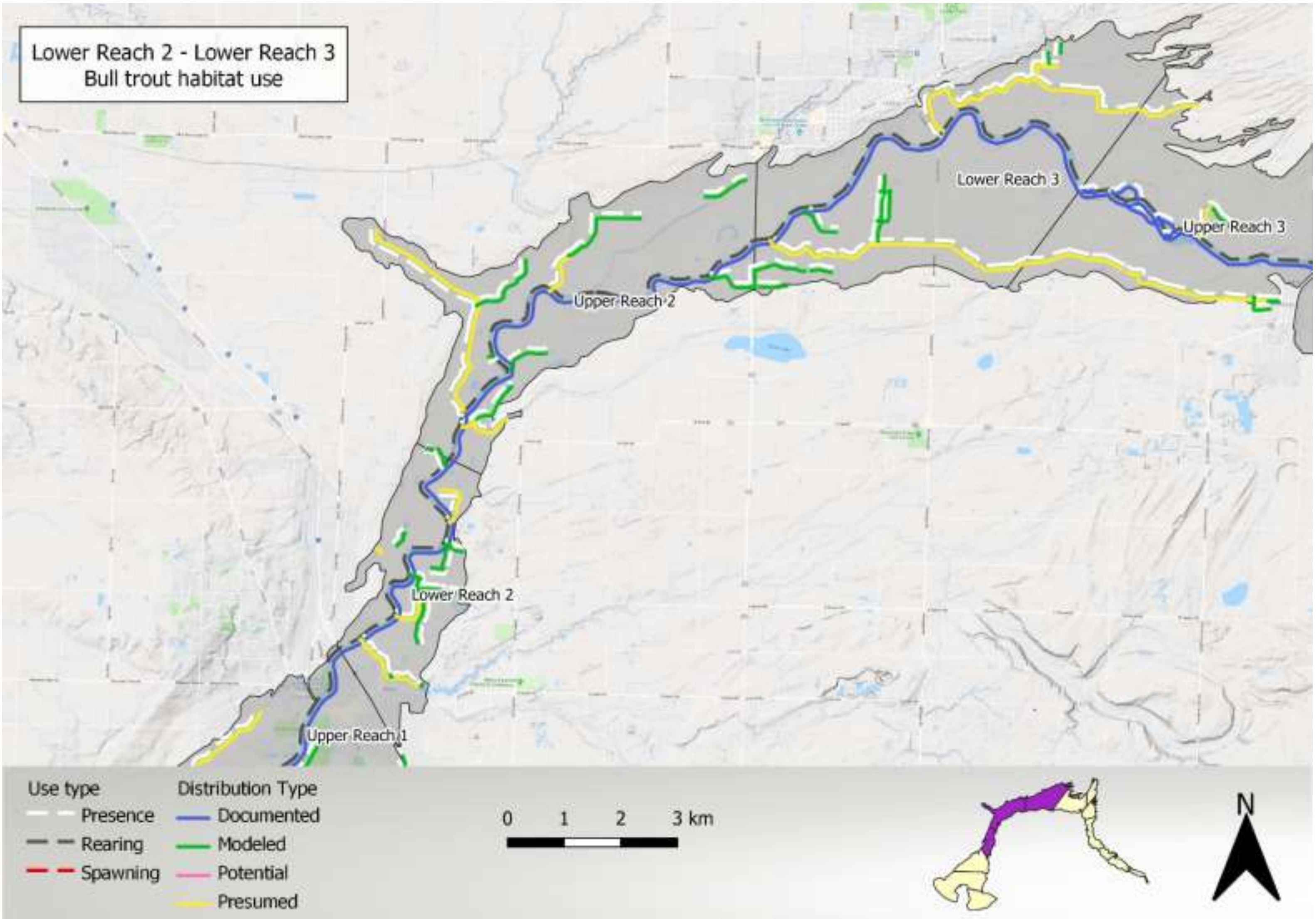

Figure 83: Statewide Integrated Fish Distribution for bull trout in Reach 2 and Lower Reach 3. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

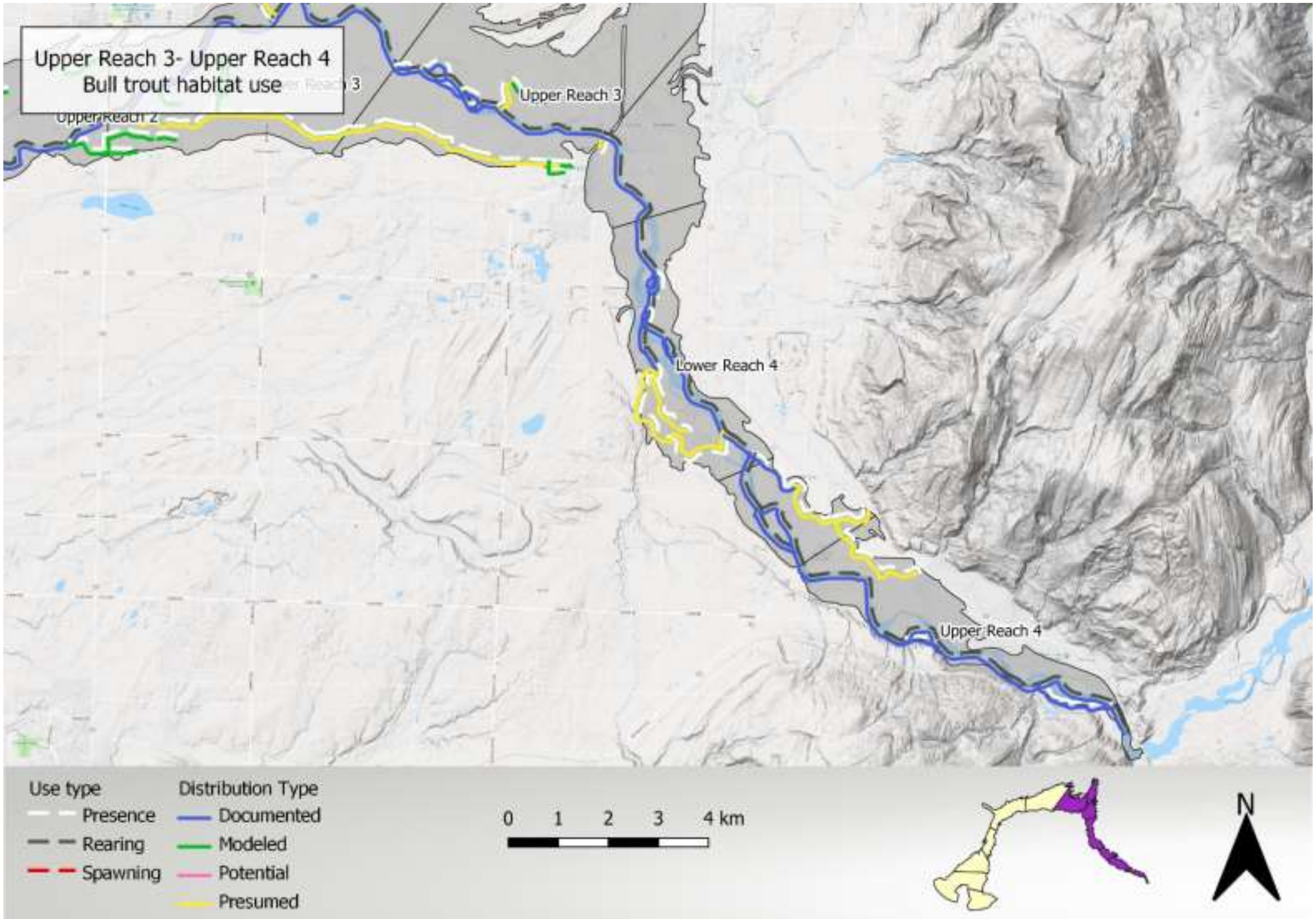

Figure 84: Statewide Integrated Fish Distribution for bull trout in Upper Reach 3 and Reach 4. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

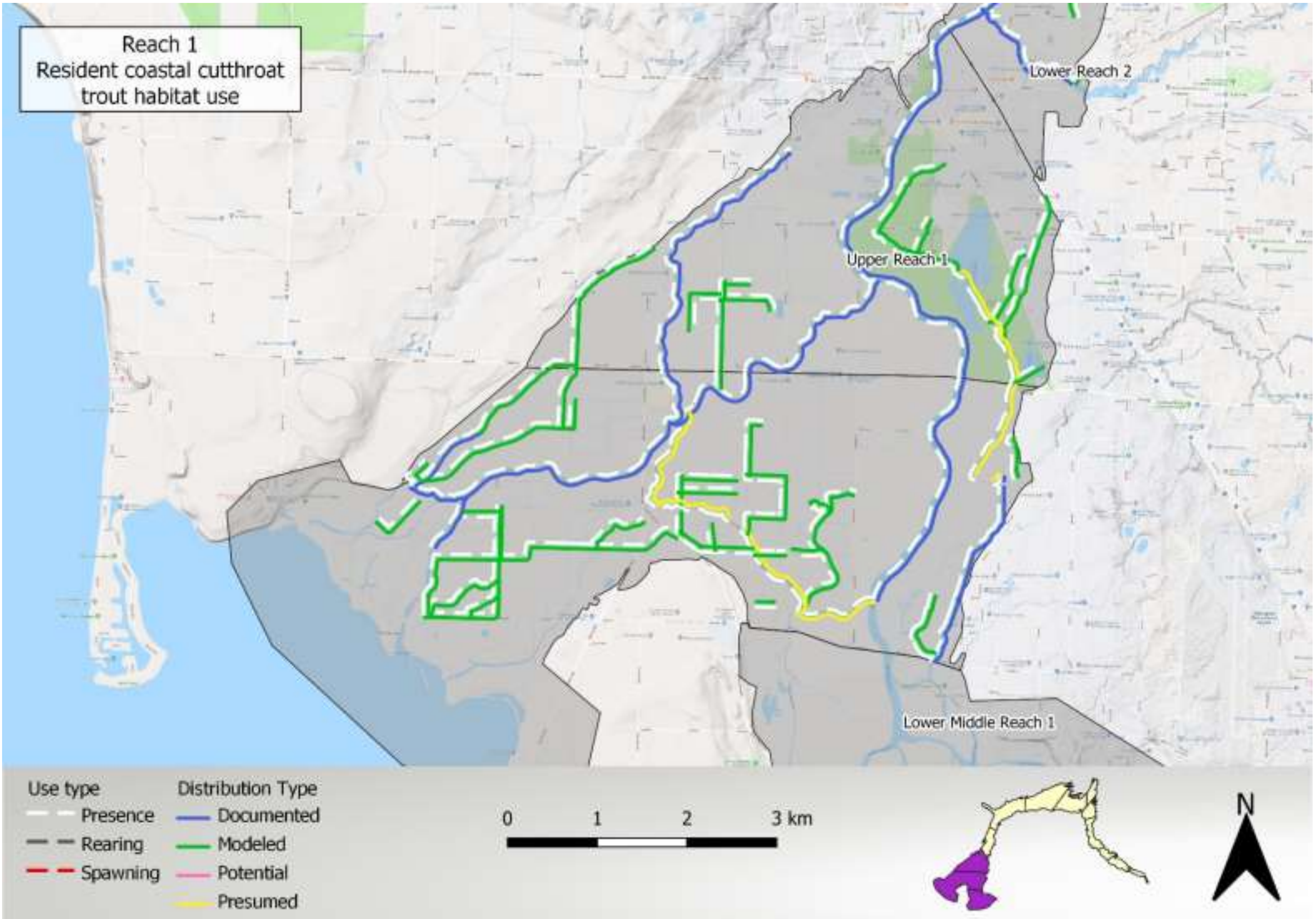

Figure 85: Statewide Integrated Fish Distribution for residential coastal cutthroat trout in Reach 1. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

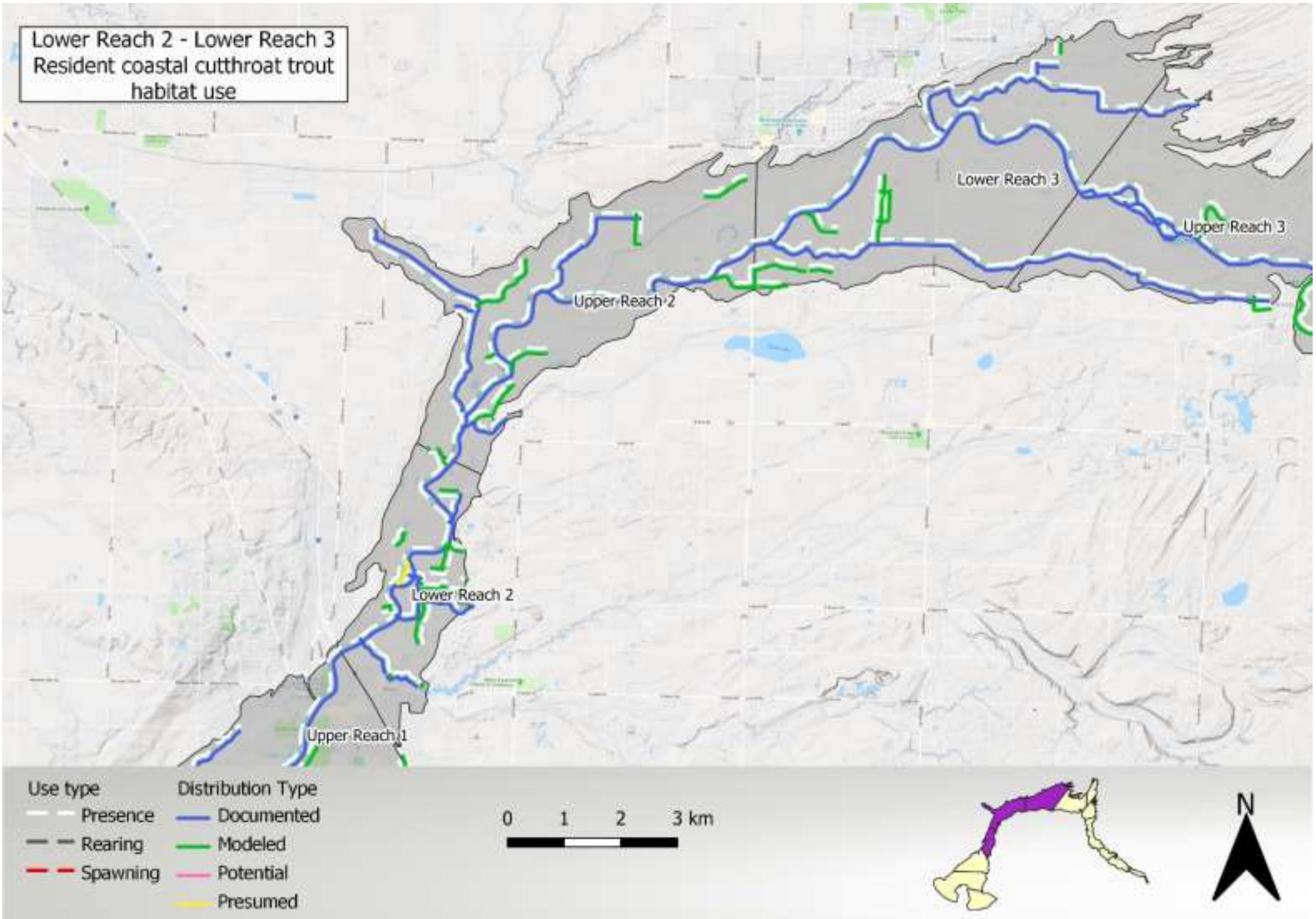

Figure 86: Statewide Integrated Fish Distribution for residential coastal cutthroat trout in Reach 2 and Lower Reach 3. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

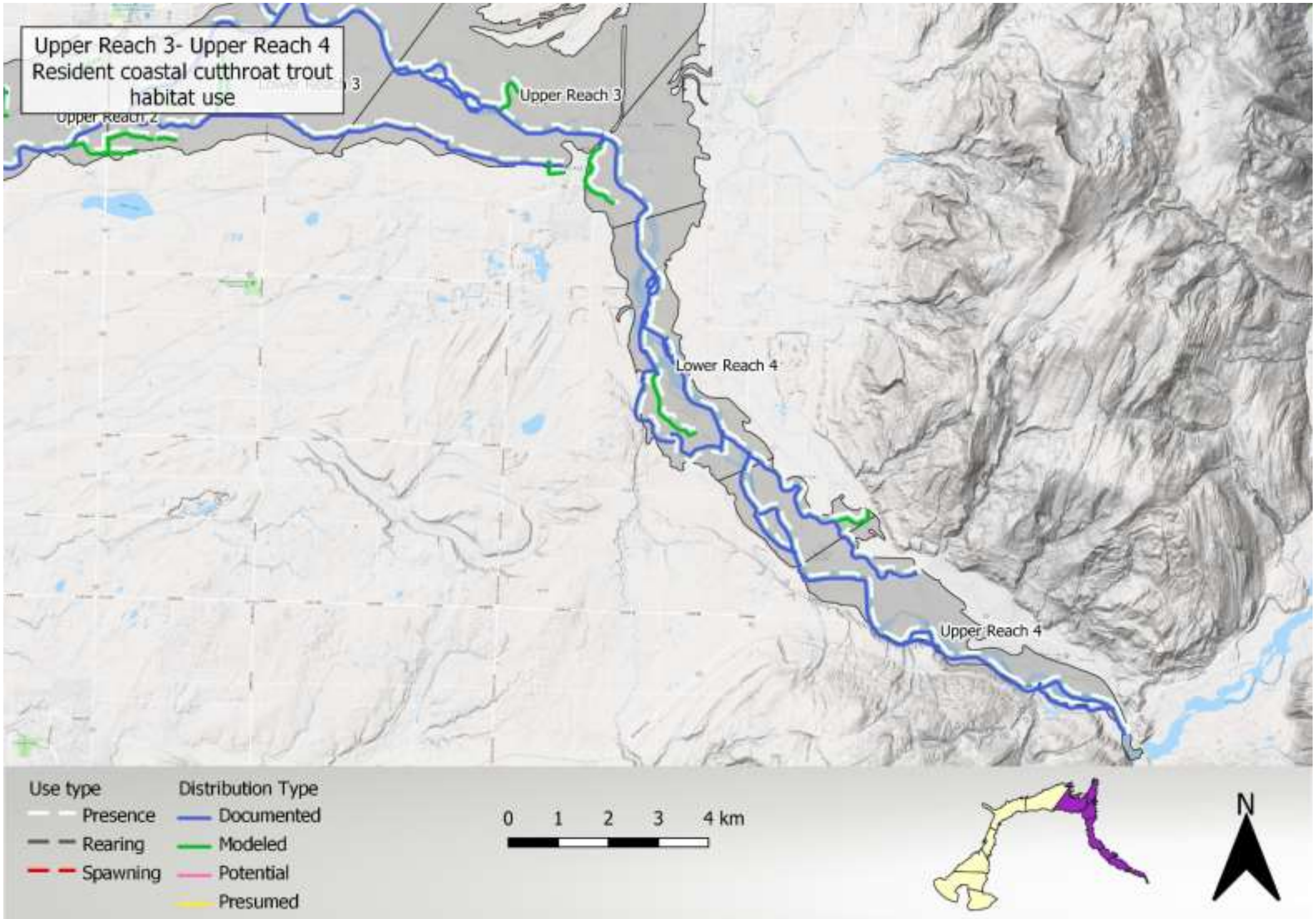

Figure 87: Statewide Integrated Fish Distribution for residential coastal cutthroat trout in Upper Reach 3 and Reach 4. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

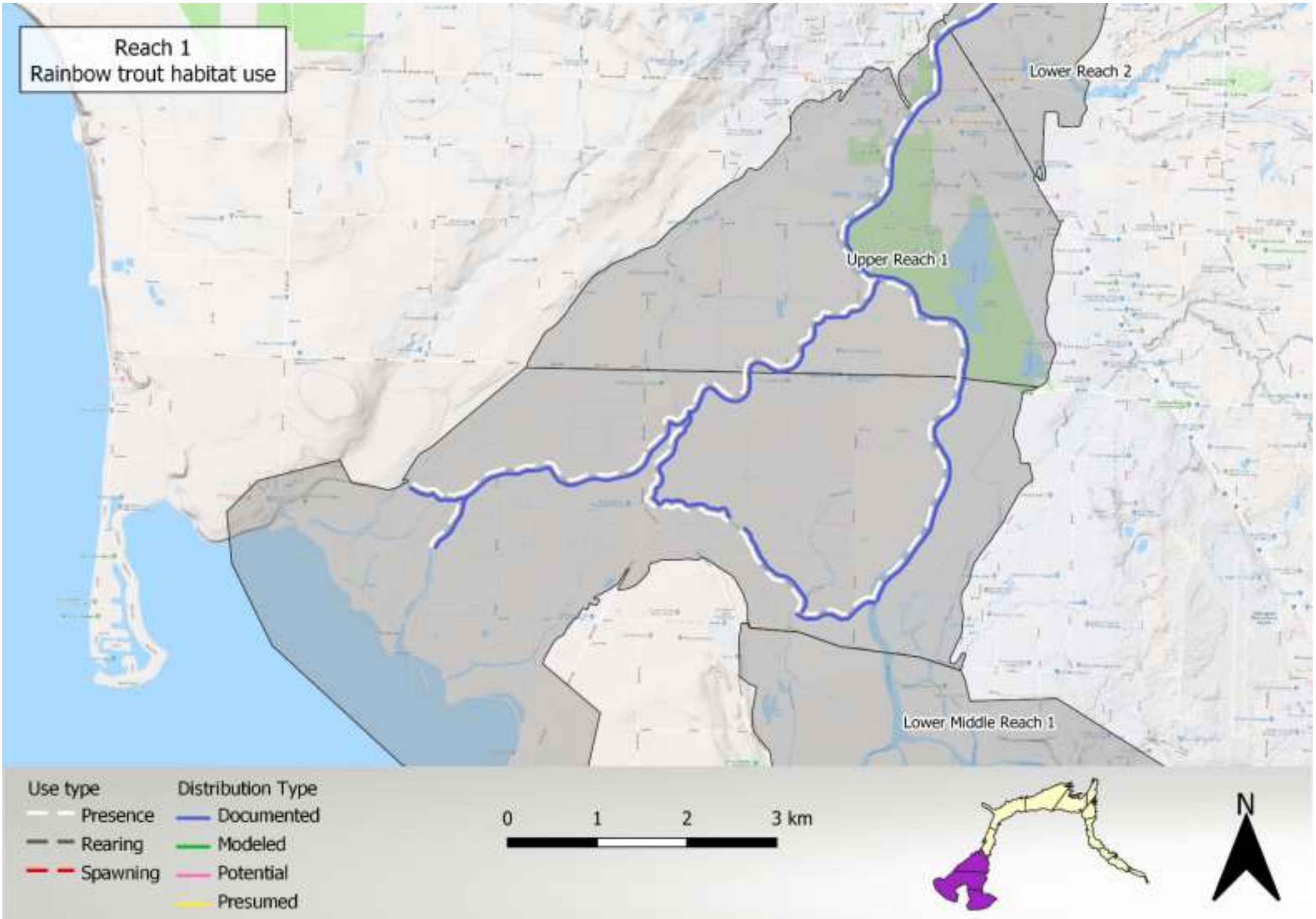

Figure 88: Statewide Integrated Fish Distribution for rainbow trout in Reach 1. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

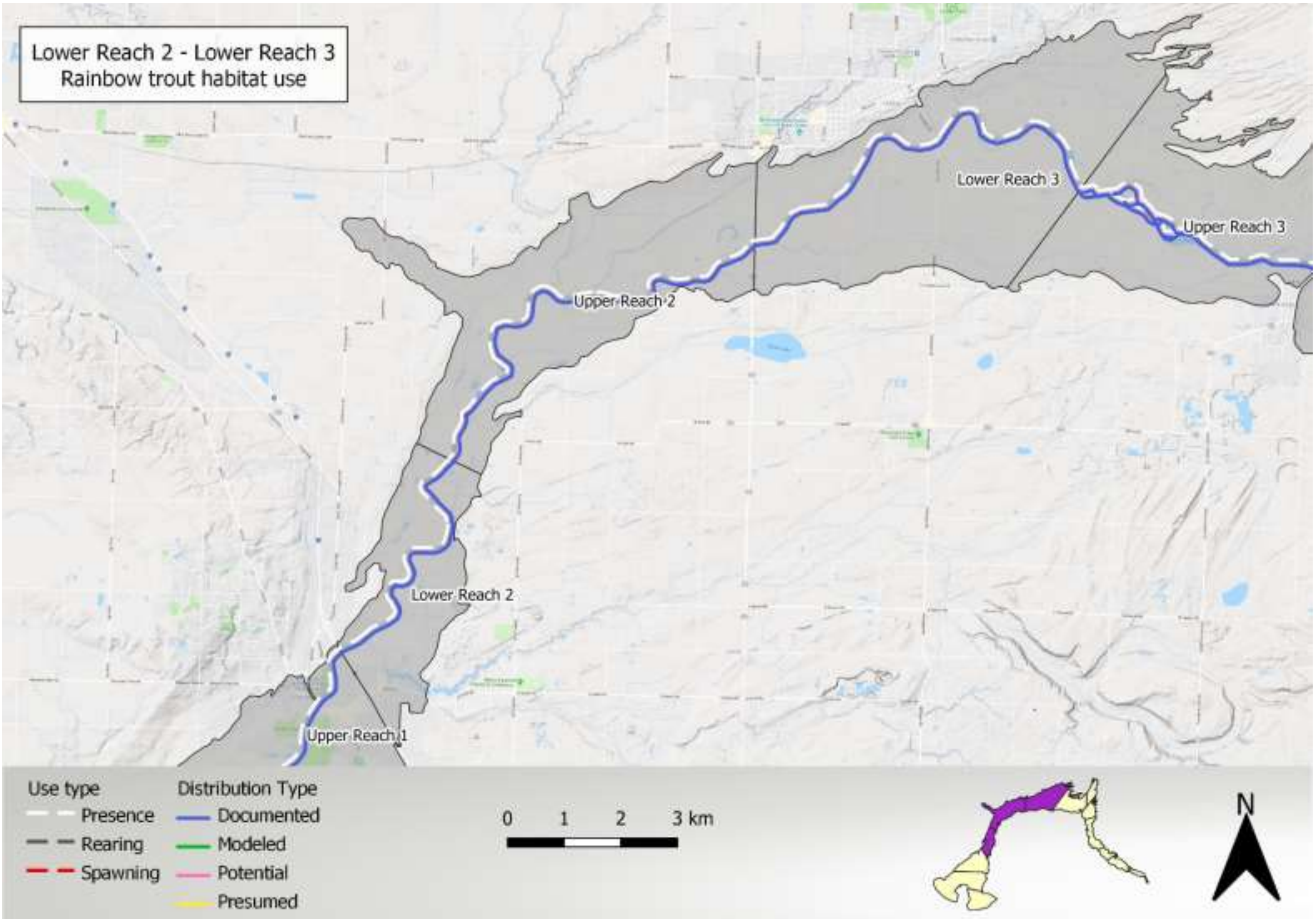

Figure 89: Statewide Integrated Fish Distribution for rainbow trout in Reach 2 and Lower Reach 3. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

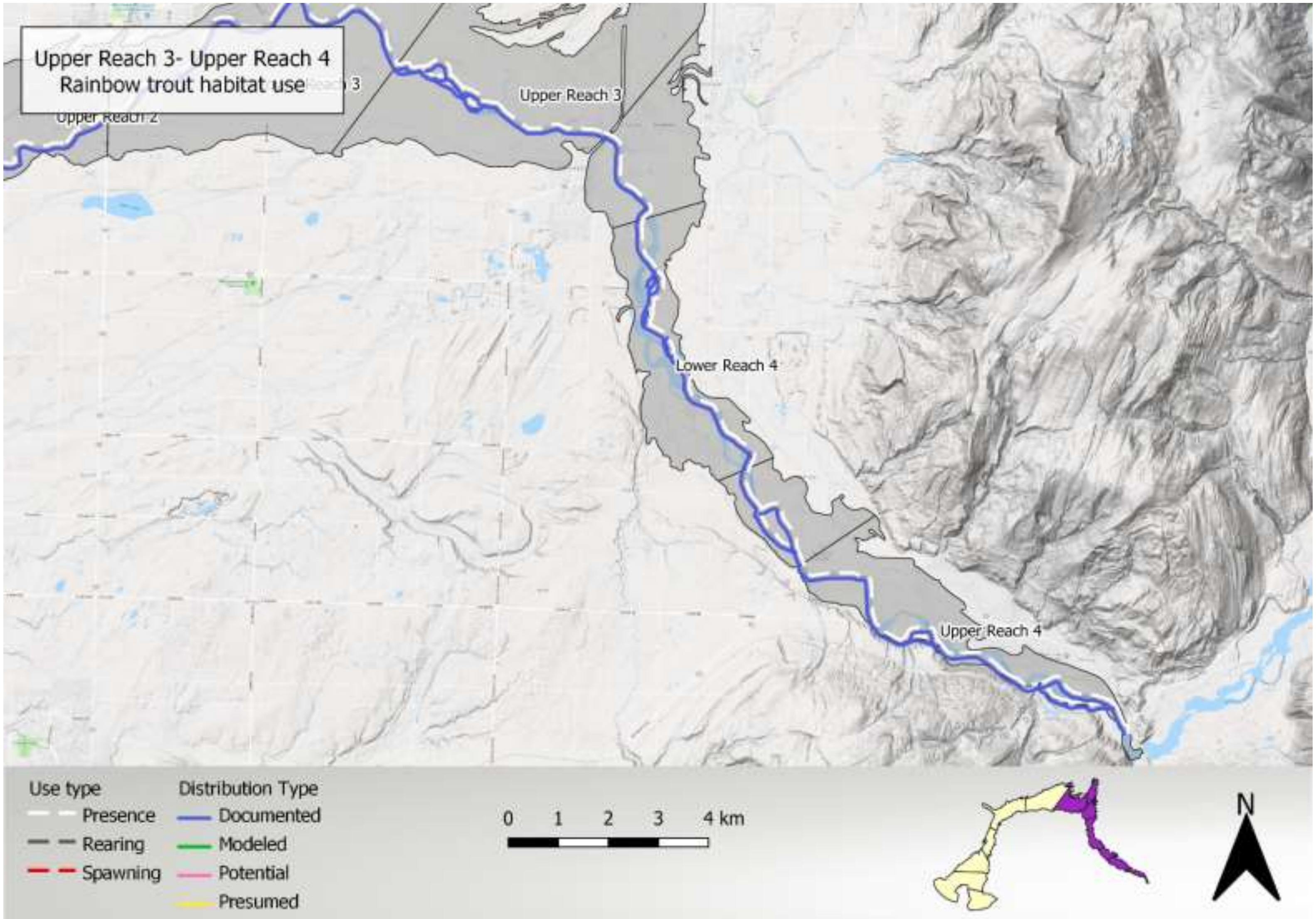

Figure 90: Statewide Integrated Fish Distribution for rainbow trout in Upper Reach 3 and Reach 4. Documented, modeled, potential, and presumed presence, rearing, and spawning distributions are shown. Source WDFW and Northwest Indian Fisheries Commission (NWIFC 2017). "Presence" may indicate presence of multiple life stages.

Appendix B:
Survey Methods and Results

Final Report

October 29, 2019

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Appendix B provides details on habitat survey results for survey reaches, summer habitat estimation for floodplain habitats from validation surveys, and data collection components from field surveys completed as part of this assessment.

Reach Habitat Summary Tables:

This section contains tables and figures referenced in the Reach Conditions: section and is organized by reach.

Reach: Lower – Middle Reach 1

Table 31: Tidally influenced habitat areas for Lower and Middle Reach 1 as reported in Beamer et al. (2016) that represent current conditions circa 2013. These summaries do not include any habitat surveyed within these reaches as part of this assessment. Tidal channels include tidal and blind tidal channels that are not part of the distributary network. Habitat type codes are EEM = Estuarine Emergent Marsh, ESS = Estuarine Scrub-Shrub, and FRT = Forested Riverine Tidal.

Habitat Type	Channel Type	Nooksack River Delta (meters^2)	Lummi/Red River (meters^2)	Silver Creek (meters^2)	Smugglers Slough (meters^2)	Total Area (meters^2)
EEM	Tidal Channel	42,600	91,040	0	66,220	199,860
	Distributary	185,540	118,790	0	0	304,330
	Wetland	1,175,440	270,640	0	43,060	1,489,140
ESS	Tidal Channel	16,510	0	0	0	16,510
	Distributary	112,610	15,680	0	0	128,290
	Wetland	741,920	13,890	0	0	755,810
FRT	Tidal Channel	78,150	0	139,300	120,660	338,110
	Distributary	632,470	6,080	0	0	638,550
	Wetland	3,793,760	0	1,099,210	221,120	5,114,090
Total	Tidal Channel	137,260	91,040	139,300	186,880	554,480
	Distributary	930,620	140,550	0	0	1,071,170
	Wetland	5,711,120	284,530	1,099,210	264,180	7,359,040

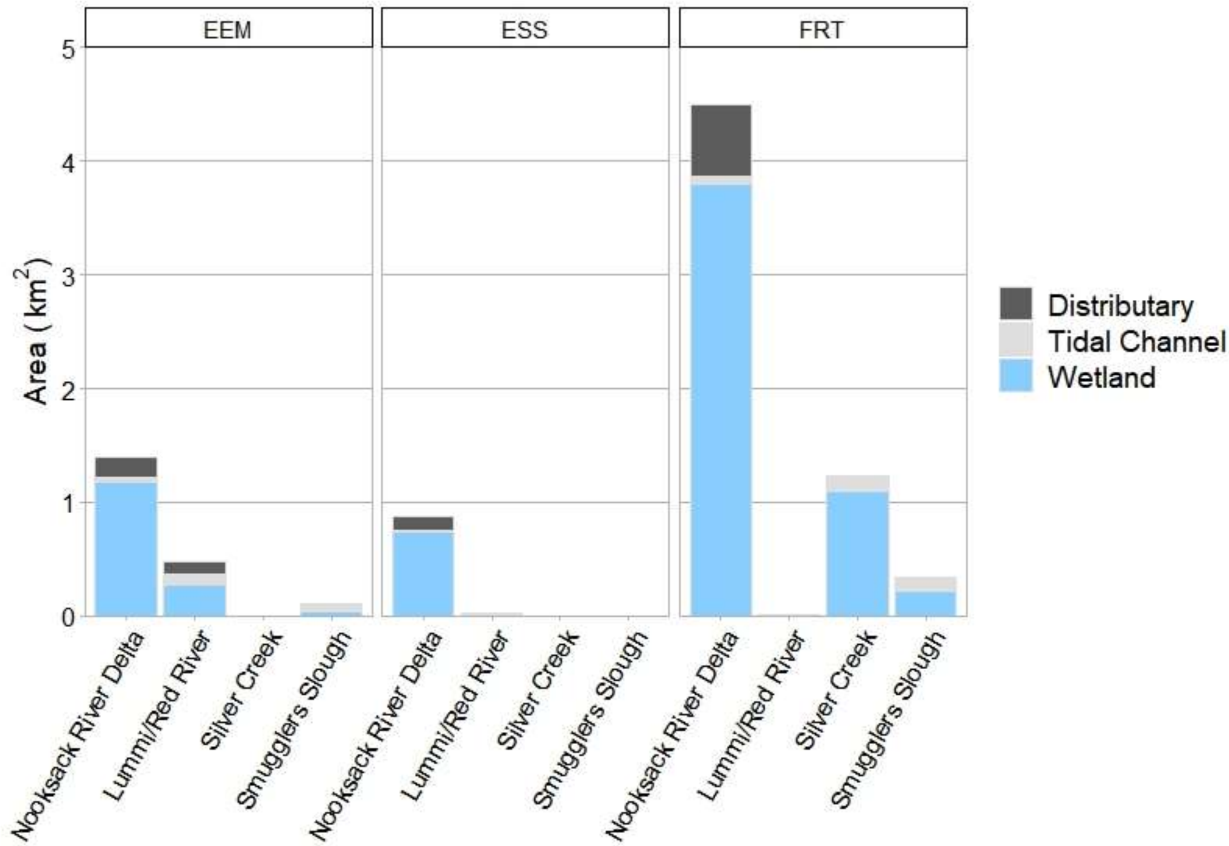

Figure 91: Tidally influenced habitat areas for Lower and Middle Reach 1 as reported in Beamer et al. (2016) that represent current conditions circa 2013. These summaries do not include any habitat surveyed within these reaches as part of this assessment. Tidal channels include tidal and blind tidal channels that are not part of the distributary network. Habitat type codes are EEM = Estuarine Emergent Marsh, ESS = Estuarine Scrub-Shrub, and FRT = Forested Riverine Tidal.

Table 32: Mainstem Nooksack habitat unit and edge type summaries for surveys of Middle Reach 1 completed by Cramer Fish Sciences (CFS) in 2018 and 2019. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey.

				Total		Bar Edge		Natural Bank Edge		Hydro-modified Bank Edge	
Flow Condition	**Channel Type**	**Dominant Unit Type**	**n**	**Area (meters^2)**	**Length (meters)**	**Length (meters)**	**Slow-water Edge Area (meters^2)**	**Length (meters)**	**Slow-water Edge Area (meters^2)**	**Length (meters)**	**Slow-water Edge Area (meters^2)**
Winter Flow (Jan-19)	Mainstem	Glide	3	269,776	3,484	-	-	949	949	6,019	7,531
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	3	269,776	3,484	-	-	949	949	6,019	7,531
	Braid	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-
	Side Channel	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-
Summer Low Flow (Mar-18)	Mainstem	Glide	3	253,865	3,087	1,318	1,318	357	357	4,499	4,760
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	3	253,865	3,087	1,318	1,318	357	357	4,499	4,760
	Braid	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-
	Side Channel	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-

Table 33: Mainstem Nooksack riparian, large woody debris, and substrate summaries for Middle Reach 1 from surveys completed in 2018 and 2019 by CFS. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent. No braid or side-channel habitat was observed in Upper Reach 1.

			Riparian	Large Wood Jams		Dominant Substrate			
Flow Condition	**Channel Type**	**Dominant Unit Type**	**% Canopy Closure**	**n**	**Cover Area (meters^2)**	**% Fines**	**% Sand**	**% Gravel**	**% Cobble**
Winter Flow (Jan-19)	Mainstem	Glide	1.3	3	305	ND	ND	ND	ND
		Pool	-	-	-	ND	ND	ND	ND
		Riffle	-	-	-	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	1.3	3	305	ND	ND	ND	ND
	Braid	Glide	-	-	-	ND	ND	ND	ND
		Pool	-	-	-	ND	ND	ND	ND
		Riffle	-	-	-	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	-	-	-	ND	ND	ND	ND
	Side Channel	Glide	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-
Summer Low Flow (Mar-18)	Mainstem	Glide	1.0	3	1,400	ND	ND	ND	ND
		Pool	-	-	-	ND	ND	ND	ND
		Riffle	-	-	-	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	1.0	3	1,400	ND	ND	ND	ND
	Braid	Glide	-	-	-	ND	ND	ND	ND
		Pool	-	-	-	ND	ND	ND	ND
		Riffle	-	-	-	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	-	-	-	ND	ND	ND	ND
	Side Channel	Glide	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-

Table 34: Floodplain habitat unit, riparian, large woody debris, and substrate summary for Lower Reach 1, Middle Reach 1, and the Lummi Reservation below Slater Road from surveys completed in 2018 and 2019 by CFS. Surveys completed were a small subset of total habitat area and were limited to channel habitat due to difficulty in accessing and assessing wetlands and tidal habitats. Total habitat for Lower and Middle Reach 1 areas used for capacity analysis and historic comparisons were estimated using Beamer et al. (2016) data and are reported separately in **Table 31**. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey.

			Habitat Units				Riparian	Large Wood Jams			Substrate			
Flow Condition	**Channel Type**	**Dominant Unit Type**	**n**	**Area (meters^2)**	**Length (meters)**	**Depth (meters)**	**% Canopy Closure**	**n**	**Total Wetted Cover Area (meters^2)**	**Total # of Wetted Pieces**	**% Fines**	**% Sand**	**% Gravel**	**% Cobble**
Winter (Mar-18)	Hydro-modified natural channel	Glide	15	28,686	3,419	1	16.5	17	531.2	89	89.9	11.1	0	0
		Pool	-	-	-	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	24	69,770	5,434	1	21.5	2	78.5	16	98.0	2.0	0	0
		Total	39	98,456	8,853	1	19	19	609.7	105	93	7	0	0
	Distributary	Glide	14	244,474	6,776	1.0	16.0	0	0	8	100	0	0	0
		Pool	-	-	-	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	-	-	-	-	-	-	-	-	-	-	-	-
		Total	14	244,474	6,776	1.0	16.0	0	0	8	100	0	0	0
	Hydro-modified channel	Glide	-	-	-	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	-	-	-	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-	-	-	-

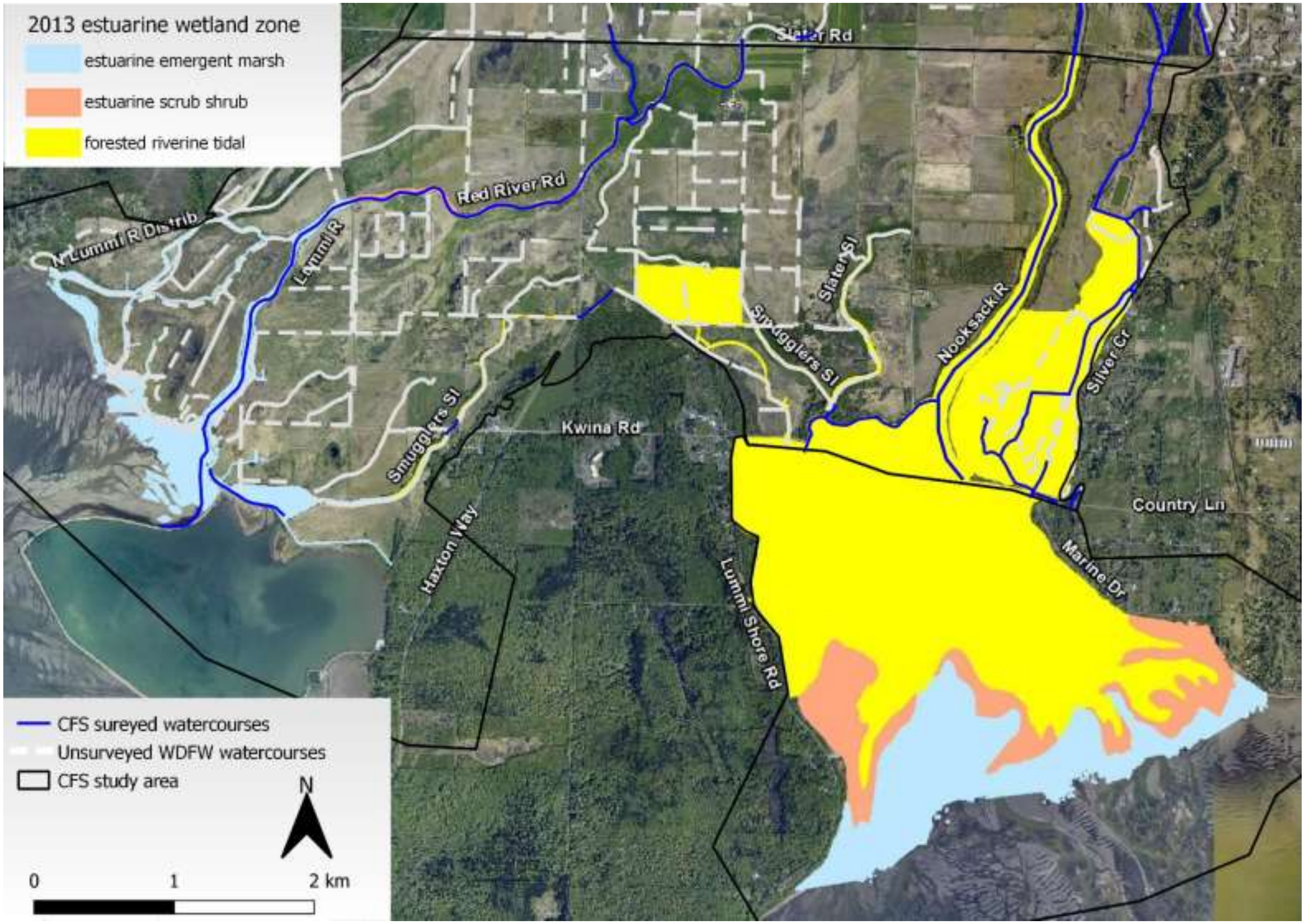

Figure 92: Map from Beamer et al. (2016) showing estuary habitat mapping extent and estuarine zones. Note: Map is taken directly from Beamer et al. 2016. and overlaid with channels surveyed during 2018-2019 CFS surveys and unsurveyed WDFW watercourses.

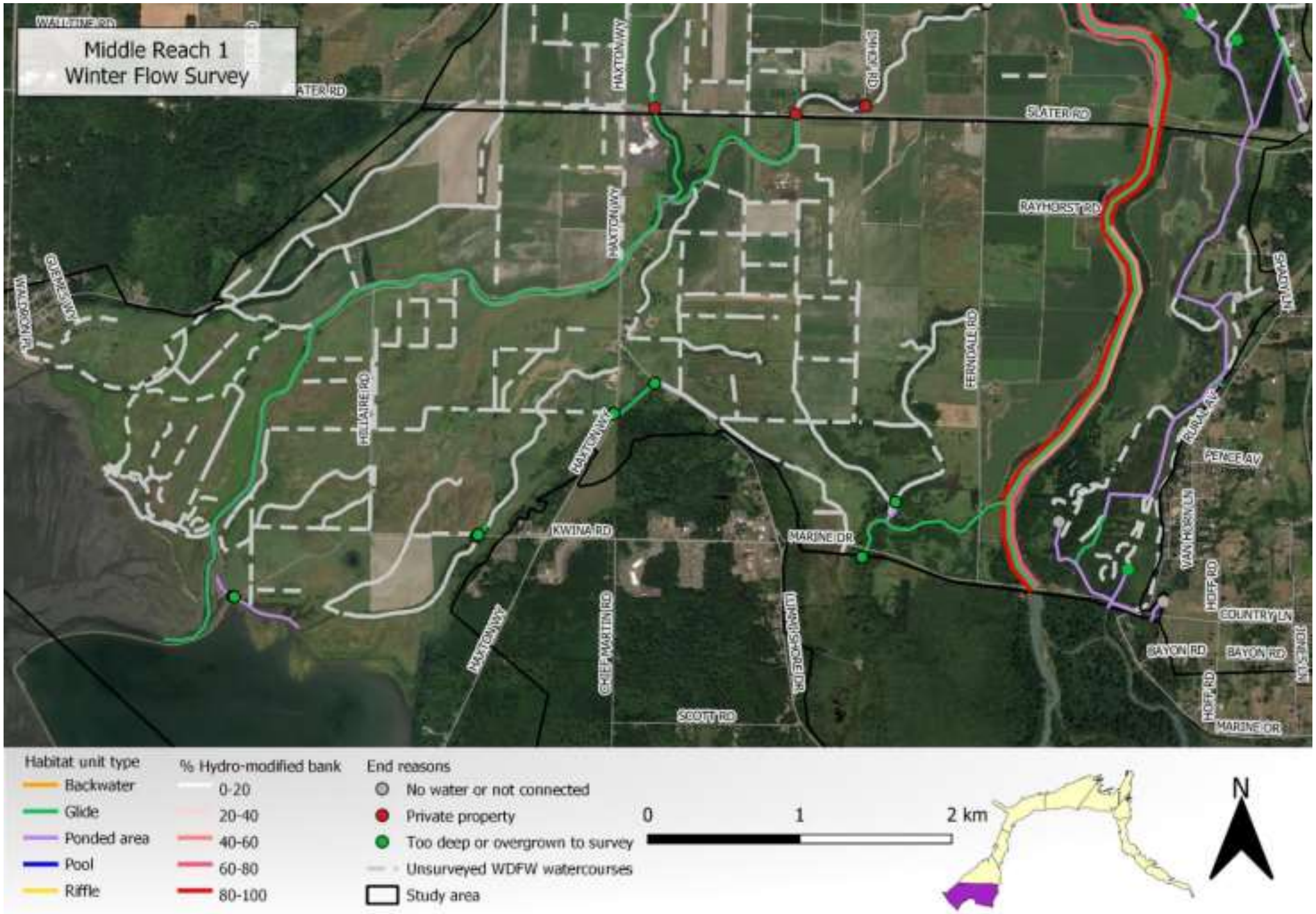

Figure 93: Map of hydro-modified banks of mainstem and distributary channels, and floodplain habitat in Middle and Lower Reach 1 during winter flow surveys. Percent hydro-modified banks are derived from field estimated proportions of edge type for each bank per habitat unit, and therefore specific edge types do not have start or stop points within each mapped unit. Average daily flows at the Cedarville gage ranged from 2,750 to 7,600 cfs for mainstem surveys and 1,400 to 4,200 cfs for floodplain surveys. Note that water courses have changed due to several restoration projects and these are note reflected in the current watercourse layer shown in this map.

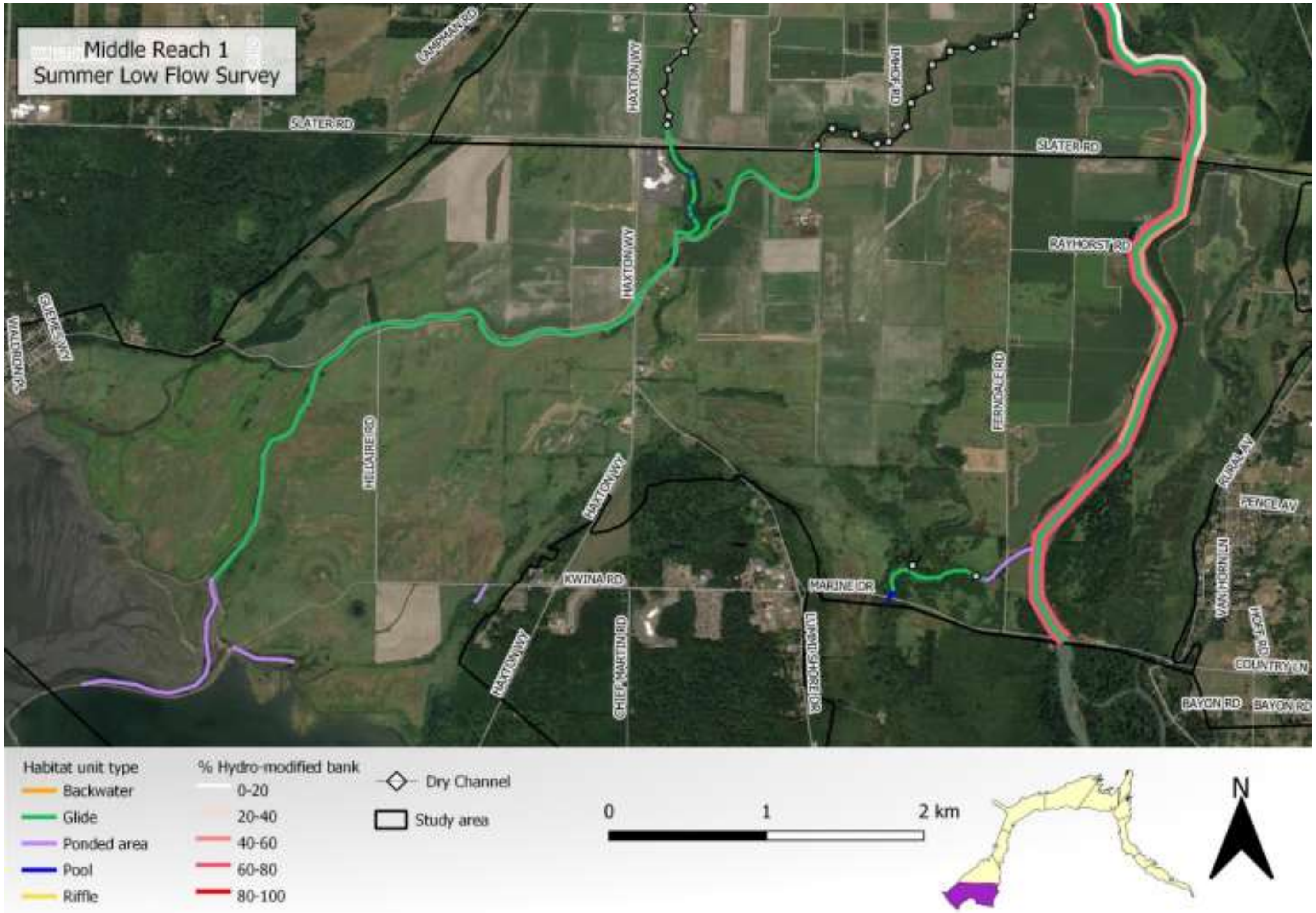

Figure 94: Map of hydro-modified banks and habitat units during summer low flow conditions for Middle Reach 1. Percent hydro-modified banks are derived from field estimated proportions of edge type for each bank per habitat unit, and therefore specific edge types do not have start or stop points within each mapped unit. Average daily flows at the Cedarville gage ranged from 1,400 to 1,500 cfs for mainstem surveys and 1,500 to 2,500 cfs for floodplain surveys. Summer low flow floodplain surveys were completed as a subset of winter flow surveys and only surveyed watercourses are shown. All WDFW watercourses are shown in **Figure 95**.

Figure 95: Map of overlapping summer and winter floodplain extent by channel type for Middle Reach 1. Summer low flow floodplain surveys were conducted as a subset of the winter floodplain survey extent when flows at the Cedarville gage ranged from 1,500 to 2,500 cfs. Channel types are adapted from Washington Department of Fish and Wildlife's classifications (WDFW Regulatory Layer).

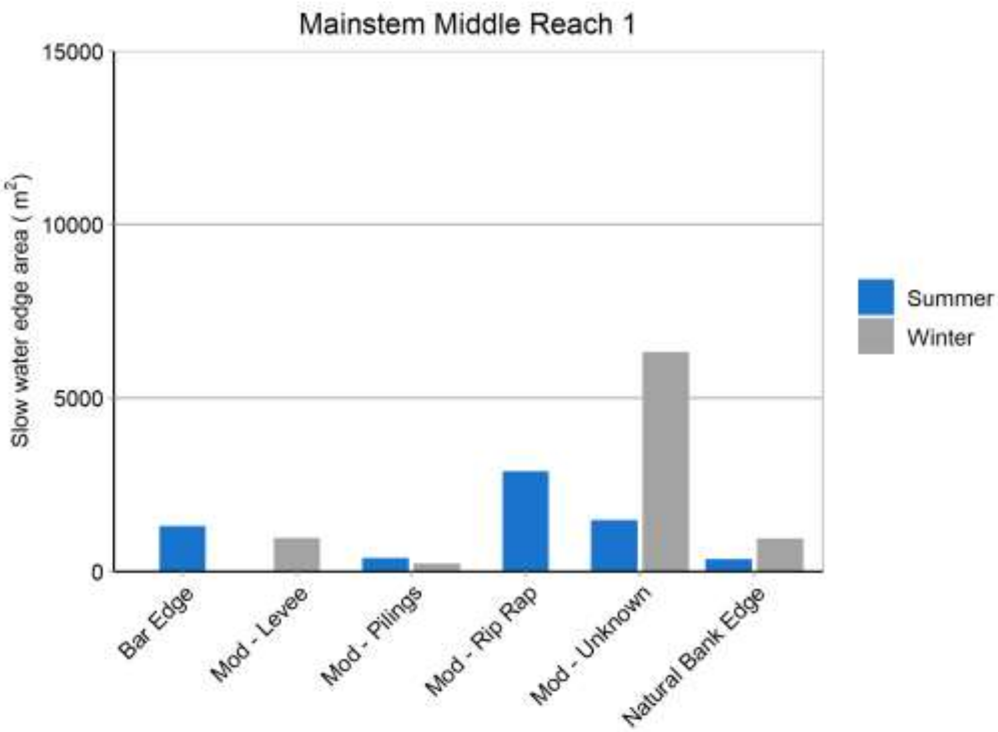

Figure 96: Slow water edge area (meters^2) of edges by edge type surveyed for present day Nooksack mainstem surveys for summer low flow and winter flow surveys for Middle Reach 1.

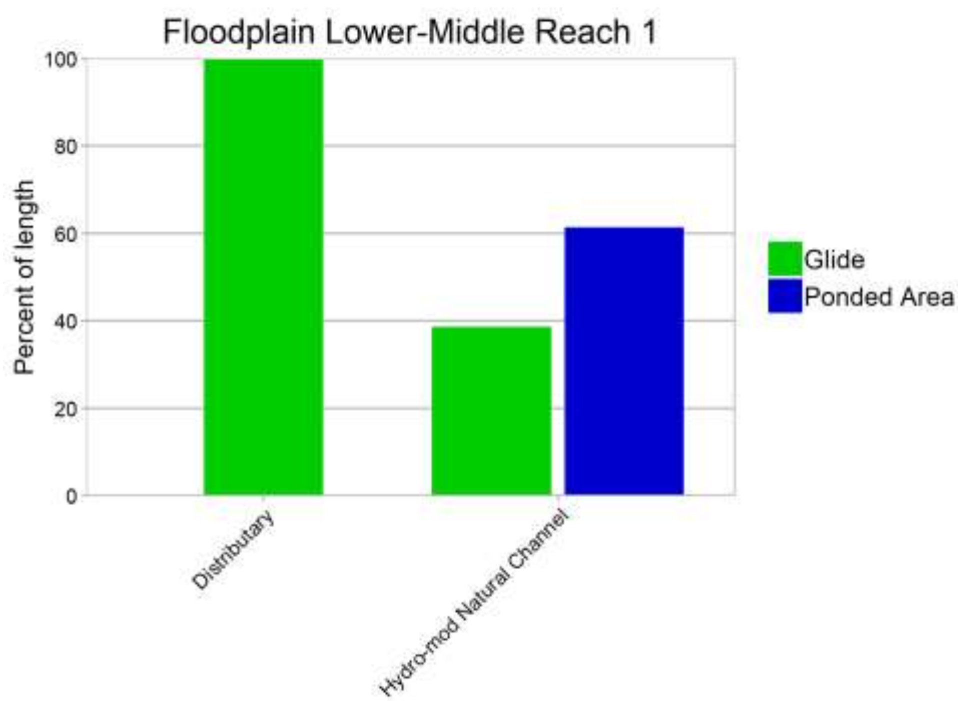

Figure 97: Percent of length surveyed in glide and ponded area habitats for distributary and hydro-modified natural channel types in winter flow floodplain surveys for Lower-Middle Reach 1. This reach is tidally influenced and thus the proportion of glides to pond would be influenced by tidal elevation.

Figure 98: Example of Lummi River estuary where channel becomes fully tidally influenced.

Table 35: Comparison of current estuary habitat (circa 2013) mapped by Beamer et al. (2016) and historical reconstructions (circa 1880) from Collins and Sheikh (2004). Historical tidal channel area estimates include blind tidal channels and tributary habitats within the tidally influenced extent and estimates of blind tidal channel area from tidal wetland area to tidal channel area relationships from Collins and Sheikh (2004). Habitat type codes are EEM = Estuarine Emergent Marsh, ESS = Estuarine Scrub-Shrub, and FRT = Forested Riverine Tidal.

		Circa 2013	Circa 1880
Habitat Type	Channel Type	Total Area (meters^2)	Total Area (meters^2)
EEM	Tidal Channel	199,860	433,542
	Distributary	304,330	151,700
	Wetland	1,489,140	3,447,541
ESS	Tidal Channel	16,510	137,553
	Distributary	128,290	85,665
	Wetland	755,810	2,241,303
FRT	Tidal Channel	338,110	231,697
	Distributary	638,550	427,932
	Wetland	5,114,090	9,147,865
Total	Tidal Channel	554,480	802,792
	Distributary	1,071,170	665,297
	Wetland	7,359,040	14,836,709
Total	Estuary	8,984,690	16,304,798

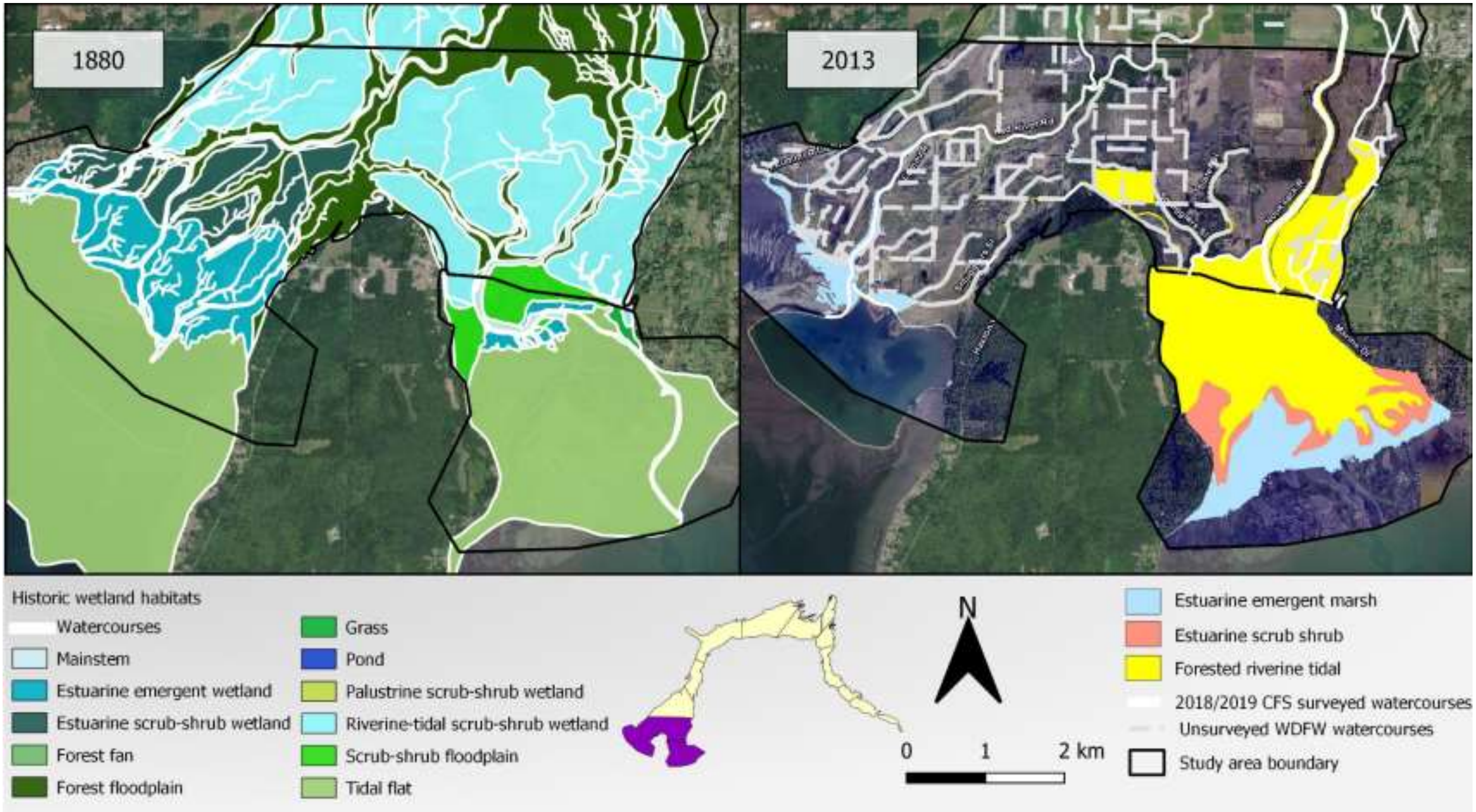

Figure 99: Map of current winter habitat and historical winter habitat extents (Collins and Sheikh) for Lower-Middle Reach 1. Current tidal wetland and estuarine habitats are from Beamer et al. (2016) reports from surveys completed in 2013. Watercourses surveyed by CFS in winter flows in 2018/2019 are also shown.

Reach: Upper Reach 1

Table 36: Mainstem habitat unit and edge summaries for surveys of Upper Reach 1. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

				Total		Bar Edge		Natural Bank Edge		Hydro-modified Bank Edge	
Flow Condition	Channel Type	Dominant Unit Type	n	Area (meters^2)	Length (meters)	Length (meters)	Slow-water Edge Area (meters^2)	Length (meters)	Slow-water Edge Area (meters^2)	Length (meters)	Slow-water Edge Area (meters^2)
Winter flow (Jan-19)	Mainstem	Glide	5	504,312	5,745	301	1,254	815	2,326	10,374	12,406
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	5	504,312	5,745	301	1,254	815	2,326	10,374	12,406
	Braid	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-
	Side Channel	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-
Summer Low Flow (Mar-18)	Mainstem	Glide	6	377,875	5,541	2,059	2,059	944	944	8,079	8,079
		Pool	2	65,290	1,020	1,020	1,020	0	0	1,020	1,600
		Riffle	1	10,773	155	0	0	155	155	155	155
		Backwater	-	-	-	-	-	-	-	-	-
		Total	9	453,938	6,716	3,079	3,079	1,099	1,099	9,254	9,834
	Braid	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-
	Side Channel	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-

Table 37: Mainstem riparian, large woody debris, and substrate summaries for Upper Reach 1. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent. No braid or side-channel habitat was observed in Upper Reach 1.

			Riparian	Large Wood Jams		Dominant Substrate			
Flow Condition	Channel Type	Dominant Unit Type	% Canopy Closure	n	Cover Area (meters^2)	% Fines	% Sand	% Gravel	% Cobble
Winter flow (Jan-19)	Mainstem	Glide	1.0	7	525	ND	ND	ND	ND
		Pool	-	-	-	ND	ND	ND	ND
		Riffle	-	-	-	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	1.0	7	525	ND	ND	ND	ND
	Braid	Glide	-	-	-	ND	ND	ND	ND
		Pool	-	-	-	ND	ND	ND	ND
		Riffle	-	-	-	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	-	-	-	ND	ND	ND	ND
	Side Channel	Glide	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-
Summer Low Flow (Mar-18)	Mainstem	Glide	1.2	0	0	ND	ND	ND	ND
		Pool	3.0	0	0	ND	ND	ND	ND
		Riffle	1.0	0	0	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	1.7	0	0	ND	ND	ND	ND
	Braid	Glide	-	-	-	ND	ND	ND	ND
		Pool	-	-	-	ND	ND	ND	ND
		Riffle	-	-	-	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	-	-	-	ND	ND	ND	ND
	Side Channel	Glide	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-

Table 38: Floodplain habitat unit, riparian, large woody debris, and substrate summary for Upper Reach 1. Estimated lengths were derived from WDFW hydrography for all channel types (WDFW regulatory layer) based on ratios derived in **Table 39**. Wetlands areas were estimated from the U.S. Fish and Wildlife Service National Wetlands Inventory (NWI) (USFWS 2017), no lengths were estimated for wetland units due to lack of adequate data. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey.

			Habitat Units				Riparian	Large Wood			Substrate			
Flow Condition	**Channel Type**	**Dominant Unit Type**	**n**	**Area (meters²)**	**Length (meters)**	**Depth (meters)**	**% Canopy Closure**	**n**	**Total Wetted Cover Area (meters²)**	**Total # of Wetted Pieces**	**% Fines**	**% Sand**	**% Gravel**	**% Cobble**
Winter (Mar-18)	Hydro-modified natural channel	Glide	9	3,033	969	0.3	21.7	3	17.2	6	87.5	0	0	12.5
		Pool	8	1,973	182	0.3	12.9	1	2.1	6	100	0	0	0
		Riffle	1	16	7	0.1	5	0	0.0	1	0	0	100	0
		Ponded	38	266,500	6,253	0.5	40.1	7	718.0	81	100	0	0	0
		Estimated	-	149,211	11,943	-	-	-	-	-	-	-	-	-
		Total	56	420,733	19,354	0.3	19.9	11	737.3	94	71.9	0.0	25.0	3.1
	Tributary	Glide	-	-	-	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	-	-	-	-	-	-	-	-	-	-	-	-
		Estimated	-	-	-	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-	-	-	-
	Hydro-modified channel	Glide	1	176	140	0.2	15	0	0.0	0	0	0	100	0
		Pool	-	-	-	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	-	-	-	-	-	-	-	-	-	-	-	-
		Estimated	-	-	-	-	-	-	-	-	-	-	-	-
		Total	1	176	140	0.2	15	0	0.0	0	0	0	100	0
	Wetland	Wetland	8	31,804	1,155	0.5	39.3	0	0.0	5	100	0	0	0
		Estimated	-	1,926,258	NA	-	-	-	-	-	-	-	-	-
		Total	8	1,958,062	1,155	0.5	39.3	0	0.0	5	100	0	0	0
	Constructed channel	Glide	-	-	-	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	-	-	-	-	-	-	-	-	-	-	-	-
		Estimated	-	21,072	16,790	-	-	-	-	-	-	-	-	-
		Total	-	21,072	16,790	-	-	-	-	-	-	-	-	-

Table 39: Current summer floodplain habitats estimated using winter floodplain habitat survey data and ratios of wetted to dry channel derived from summer and winter habitat validation surveys for Upper Reach 1. An explanation for how ratios were derived is available in **Appendix B**.

	Winter Floodplain		Conversion			Summer Floodplain Estimates		
	Total Area (meters^2)	Total Length (meters)	Wet Channel Area Ratio	Wet Channel Length Ratio	Dry Channel Length Ratio	Total Wet Area (meters^2)	Total Wet Length (meters)	Total Dry Length (meters)
Hydro-modified natural channel	420,733	19,354	0.5	0.5	0.5	225,082	10,231	9,240
Tributary	0	0	0.4	0.7	0.4	0	0	0
Hydro-modified channel	176	140	0.2	0.1	0.9	28	20	122
Wetland	1,958,062	1,155	0.6	1.0	0	1,211,074	1,155	0
Constructed channel	21,072	16,790	0.2	0.1	0.9	3,375	2,391	14,575

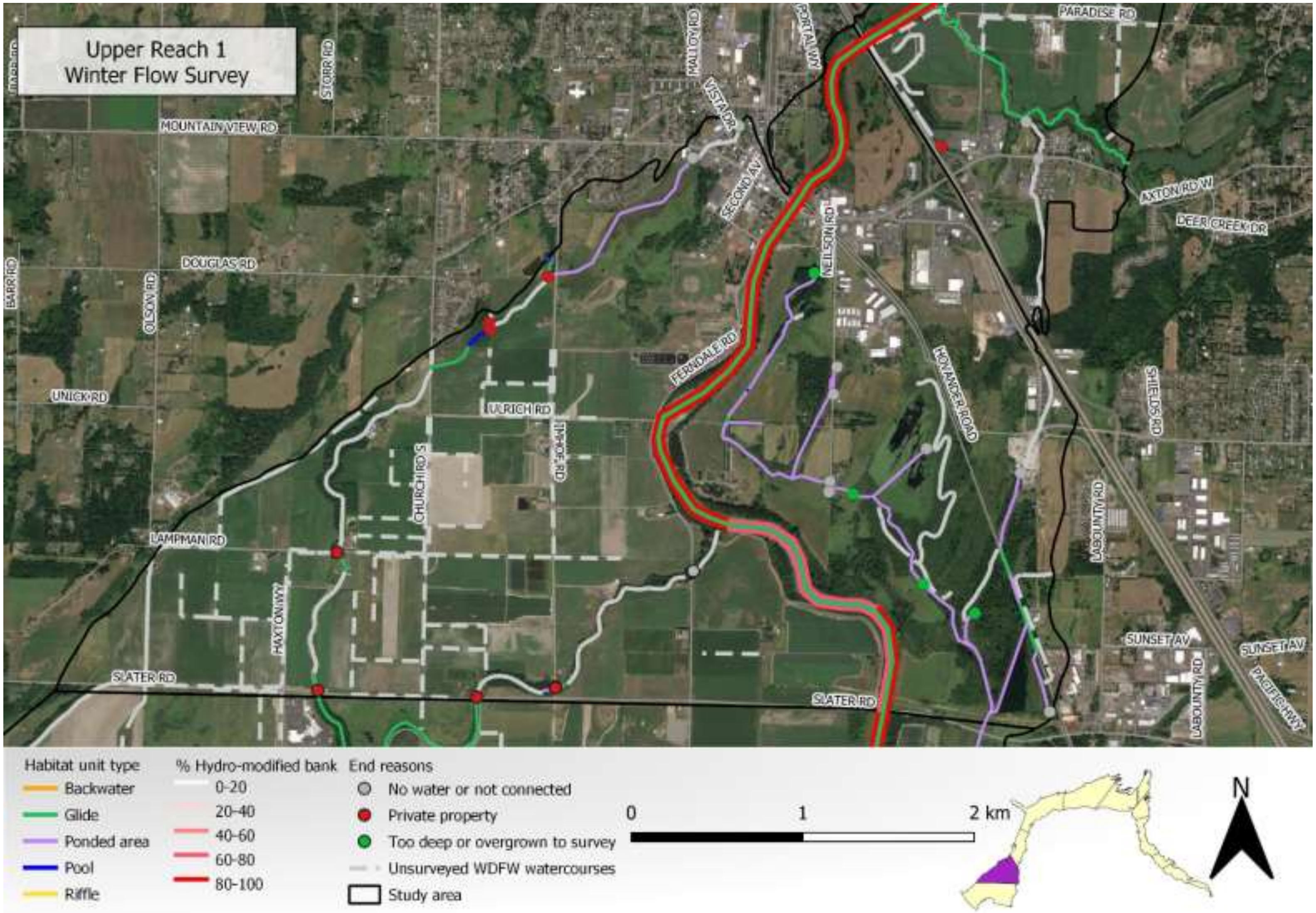

Figure 100: Map of hydro-modified banks and habitat units during winter flow conditions for Upper Reach 1. Average daily flows at the Cedarville gage ranged from 2,750 to 7,600 cfs for mainstem surveys and 1,400 to 4,200 cfs for floodplain surveys. Floodplain surveys were conducted in March 2018 between 1,900 and 3,400 cfs. WDFW watercourses that were not field surveyed in this effort are shown in gray.

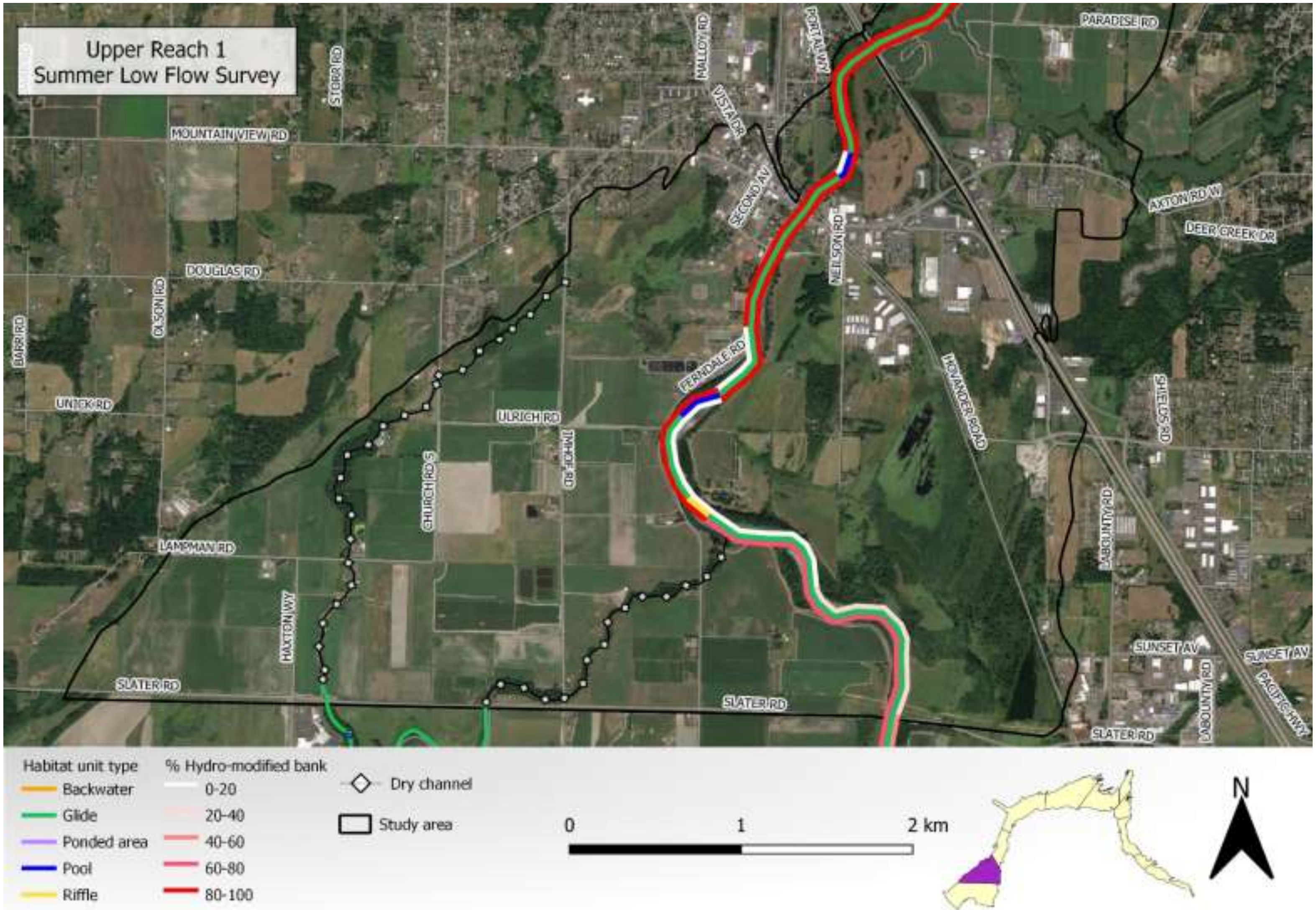

Figure 101: Map of hydro-modified banks and habitat units during summer low flow conditions for Upper Reach 1. Average daily flows at the Cedarville gage ranged from 1,400 to 1,500 cfs for mainstem surveys and 1,500 to 2,500 cfs for floodplain surveys. Summer low flow floodplain surveys were completed as a subset of winter flow surveys and only surveyed watercourses are shown. All WDFW watercourses are shown in **Figure 102**.

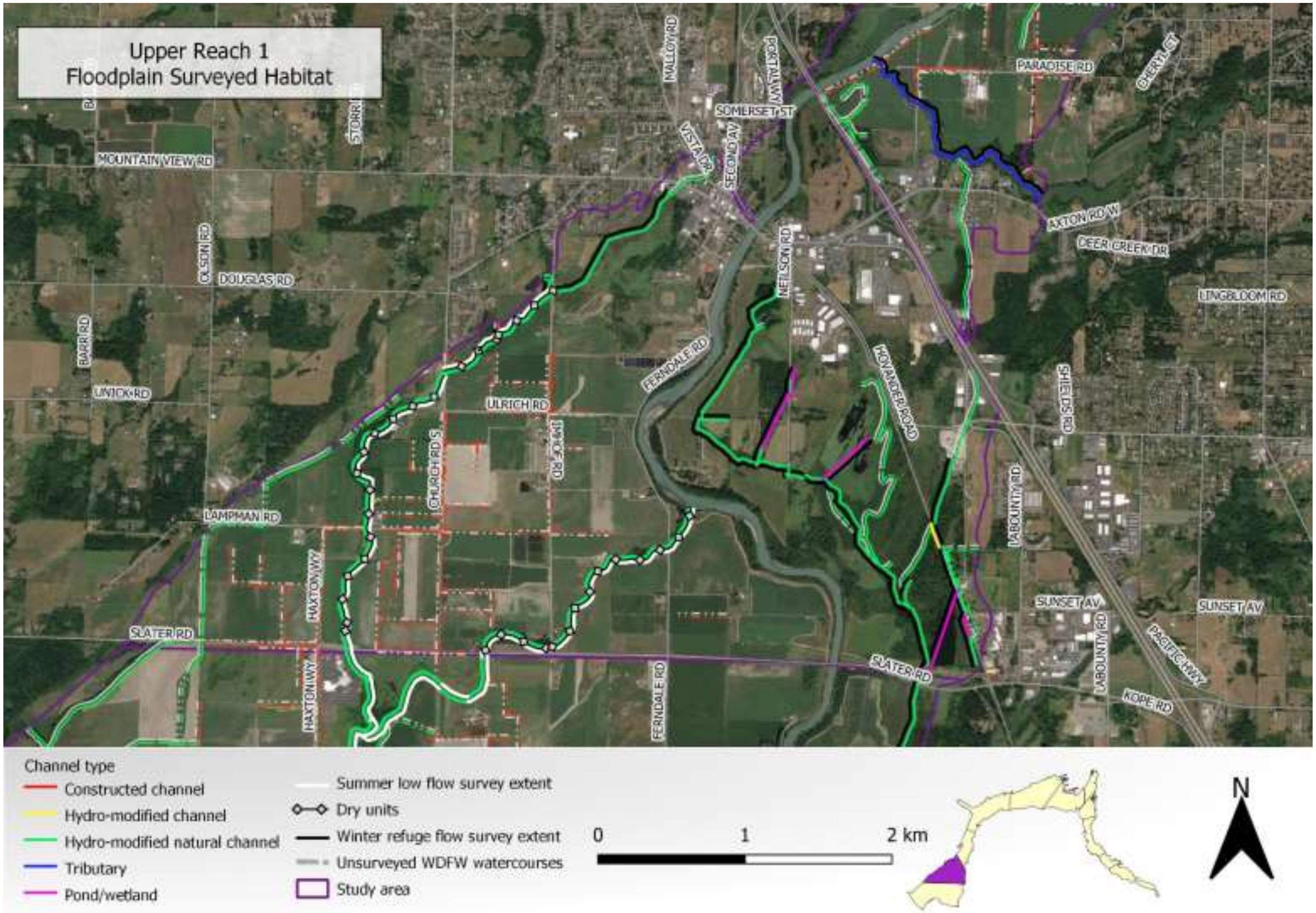

Figure 102: Map of overlapping summer and winter floodplain extent by channel type for Upper Reach 1. Summer low flow floodplain surveys were conducted as a subset of the winter floodplain survey extent when flows at the Cedarville gage ranged from 1,500 to 2,500 cfs. Channel types adapted from Washington Department of Fish and Wildlife's classifications (WDFW Regulatory Layer). Summer floodplain channel lengths areas were estimated using the ratio of wet to dry channels applied to winter floodplain channel lengths and areas. Detailed methods are provided in **Appendix B**.

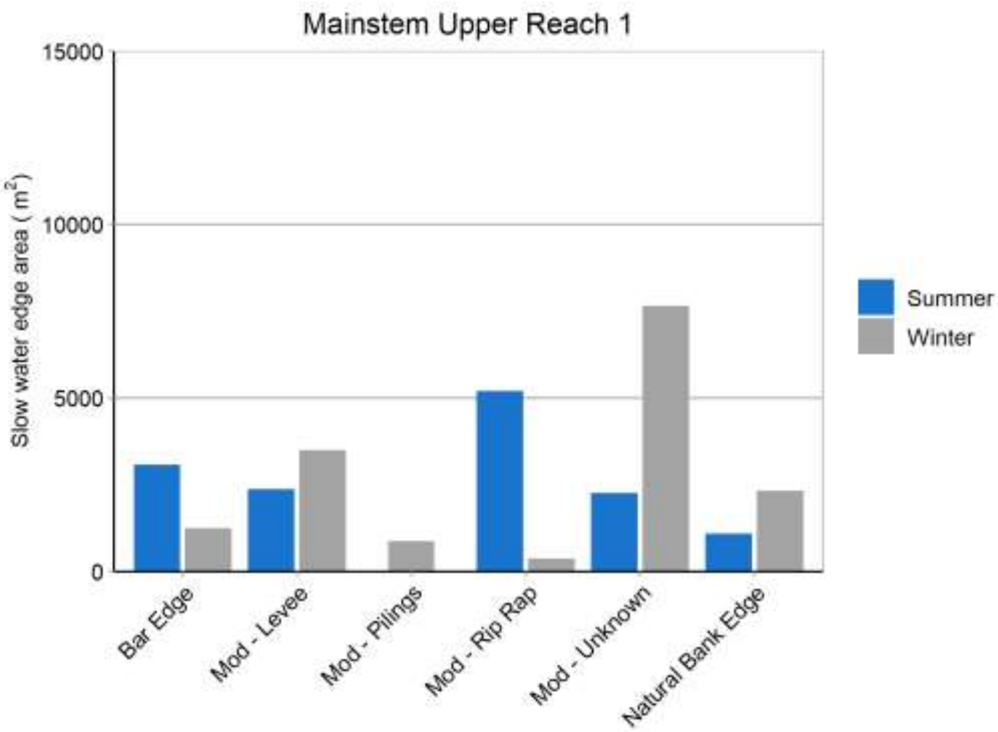

Figure 103: Slow water edge area (meters^2) of edges by edge type surveyed for present day mainstem surveys for summer low flow and winter flow surveys for Upper Reach 1.

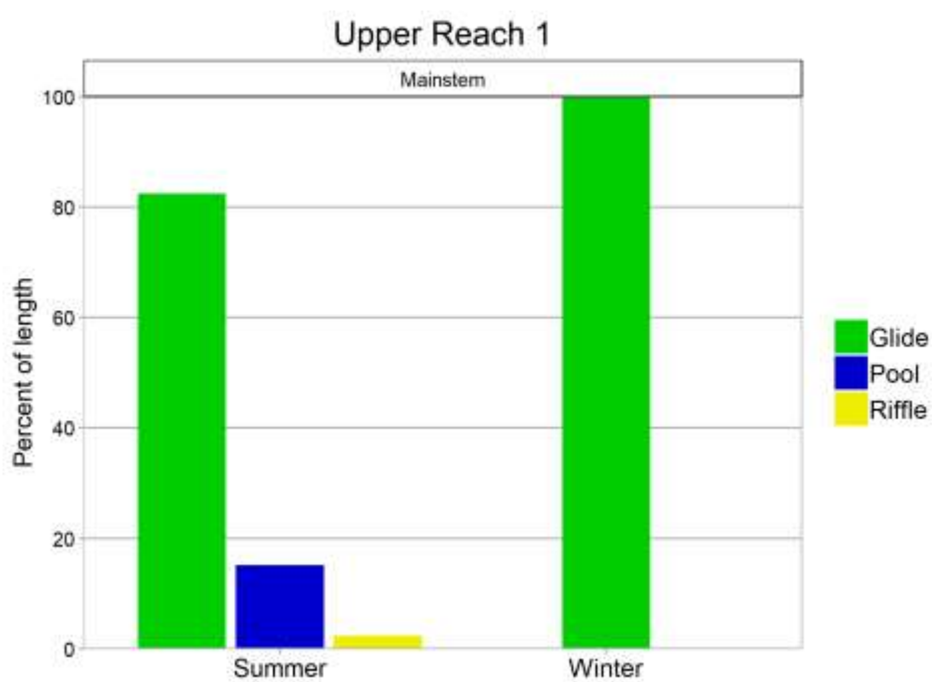

Figure 104: Percent of length surveyed in glide, pool, and riffle habitats for each channel type in mainstem surveys for summer low flow and winter flow surveys for Upper Reach 1. No braid or side-channel habitat was observed in this reach.

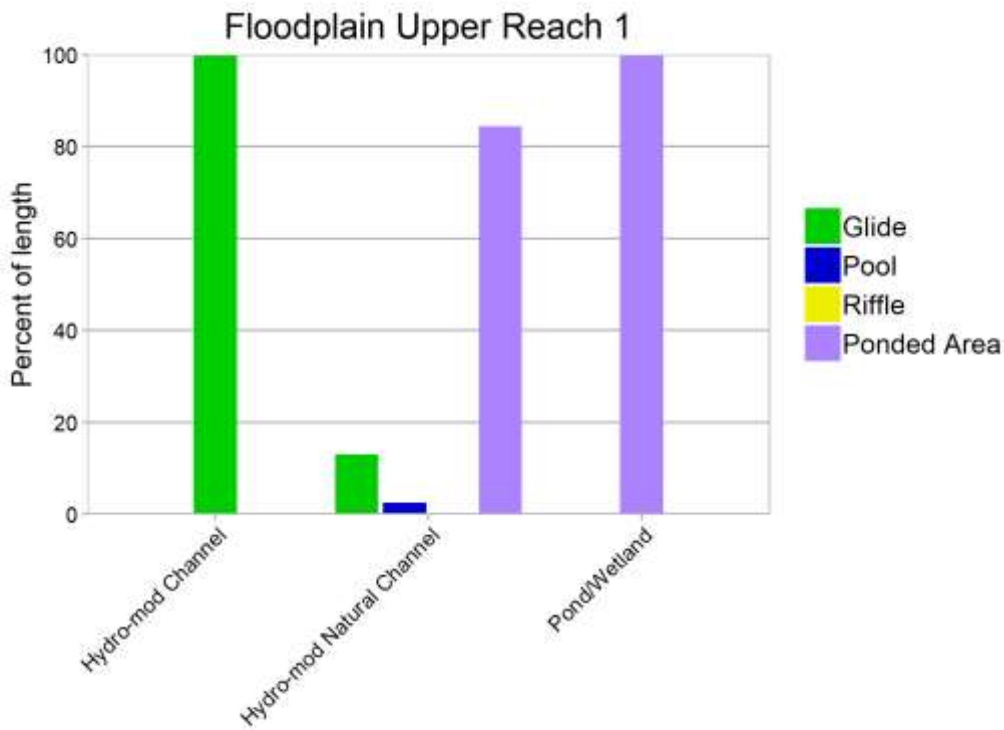

Figure 105: Percent of length surveyed in glide, pool, riffle, and ponded area habitats for channel types in winter flow floodplain surveys for Upper Reach 1. Riffle units accounted for 1% of the habitat units of hydro-modified natural channels and thus are not visible in this figure.

Table 40: Historical and current habitat summarized at same resolution as historical data for Upper Reach 1. For historical reconstructions; no differences in summer and winter condition were derived for floodplain and estuary habitats; total areas are derived from polygon feature areas and line feature lengths assuming a 1-meter width; total lengths are derived from line length for polyline features and polygon perimeters divided by two; total edges are derived from line feature lengths plus polygon perimeters; and slow-water edge areas are derived from two times the total edge lengths. Estuary habitats were not observed in this reach and are not included in this table.

				Historic Circa 1880s				Current Circa 2018/2019			
Flow	**Habitat Strata**	**Habitat Type**	**Channel Type**	**Area (meters^2)**	**Length (meters)**	**Edge Length (meters)**	**Slow-water Edge Area (meters^2)**	**Area (meters^2)**	**Length (meters)**	**Edge Length (meters)**	**Slow-water Edge Area (meters^2)**
Winter Flow	Floodplain	Secondary	Slough and Tributary	17,871	11,268	NA	NA	441,980	36,284	NA	NA
		Pond/Wetland	Pond/Wetland	3,922,661	NA	NA	NA	1,958,062	NA	NA	NA
	Mainstem	Secondary	Side-Channel/Braid	NA	266	531	1,062	0	0	0	0
		Mainstem	Natural Bank Edge	NA	NA	6,322	12,644	NA	NA	815	2,326
			Modified Bank Edge	NA	NA	0	0	NA	NA	10,374	12,406
			Bar Edge	NA	NA	177	354	NA	NA	301	1,254
Summer Low Flow	Floodplain	Secondary	Slough and Tributary	17,871	11,268	NA	NA	228,485	12,642	NA	NA
		Pond/Wetland	Pond/Wetland	2,426,191	NA	NA	NA	1,211,074	NA	NA	NA
	Mainstem	Secondary	Side-Channel/Braid	NA	396	793	1,585	0	0	0	0
		Mainstem	Natural Bank Edge	NA	NA	7,740	15,480	NA	NA	1,099	1,099
			Modified Bank Edge	NA	NA	0	0	NA	NA	9,254	9,834
			Bar Edge	NA	NA	1,960	3,921	NA	NA	3,079	3,079

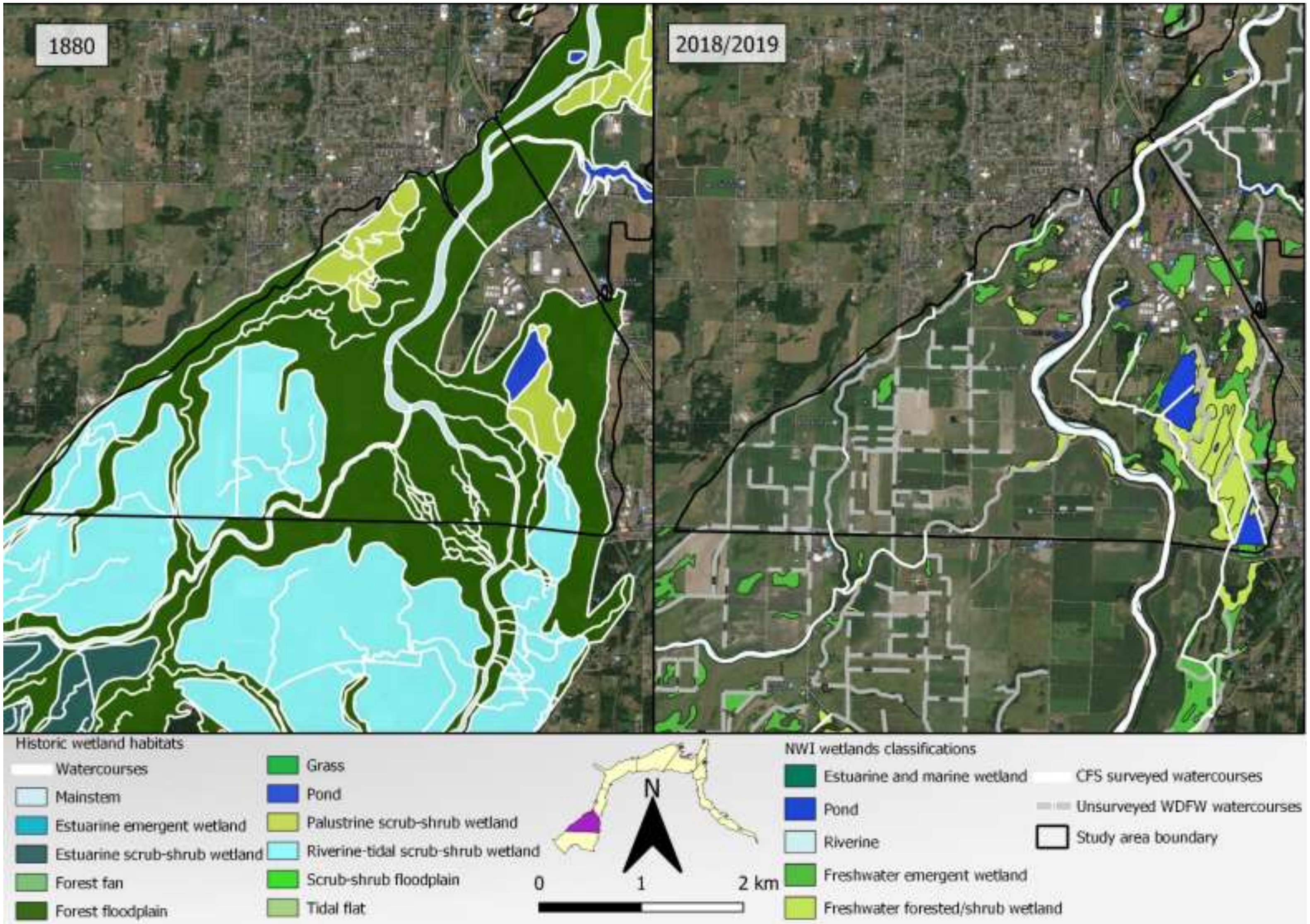

Figure 106: Map of current winter habitat and historical winter habitat extents (Collins and Sheikh) for Upper Reach 1. Surveyed watercourses and unsurveyed watercourses from current surveys are depicted, current wetland habitats are from the U.S. Fish and Wildlife Service National Wetlands Inventory (2017).

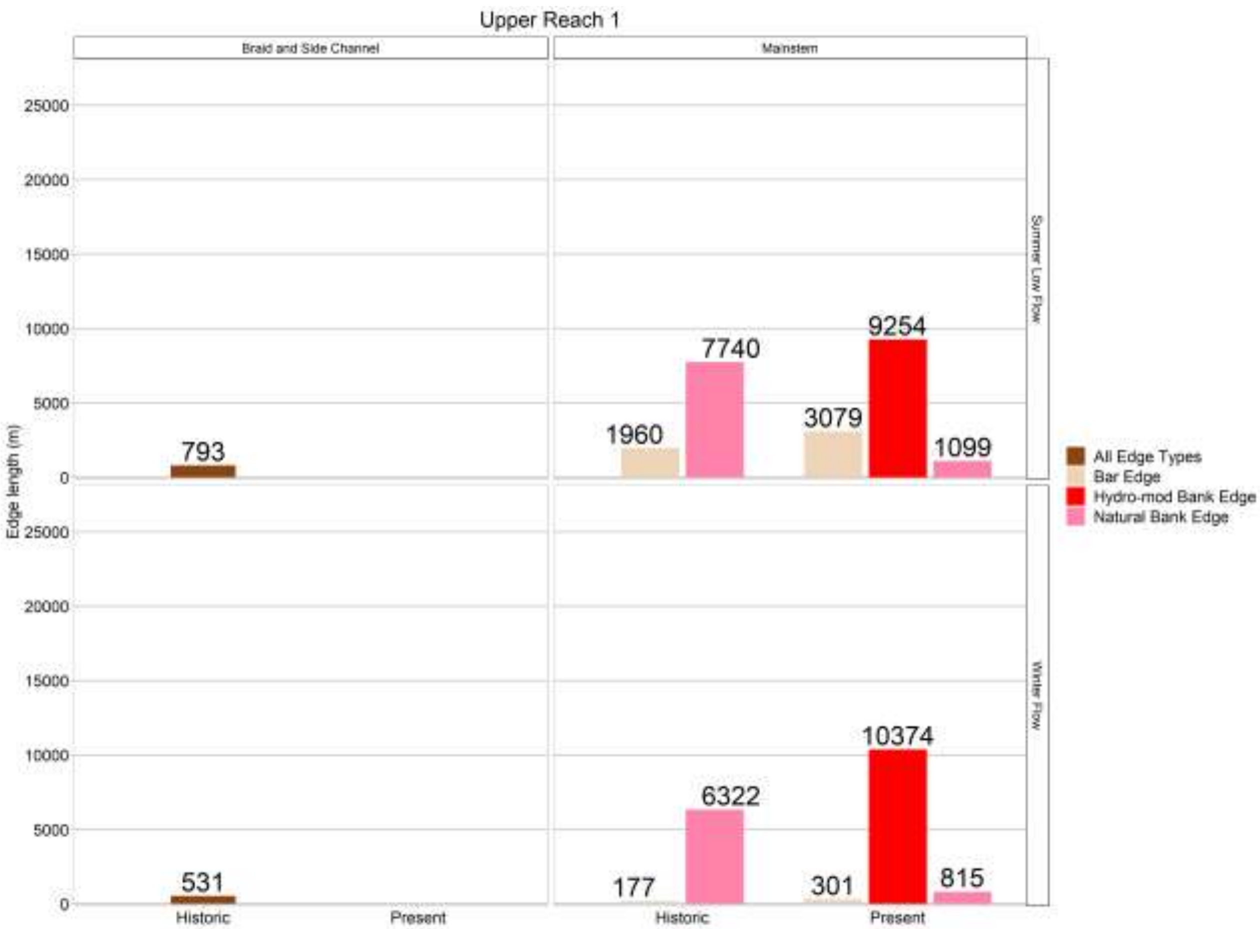

Figure 107: Edge lengths of bank types for summer low flow and winter flow conditions for historic versus present data. Edge type data for historic braid and side-channel habitats were not available. No braid or side-channel habitat was observed in Upper Reach 1.

Figure 108: Slow water edge areas (meters^2) of bank types for summer low flow and winter flow conditions for historic versus present data. Edge type data for historic braid and side-channel habitats were not available. No braid or side-channel habitat was observed in Upper Reach 1.

Reach: Lower Reach 2

Table 41: Mainstem habitat unit and edge summaries for surveys of Lower Reach 2. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

Flow Condition	Channel Type	Dominant Unit Type	n	Total		Bar Edge		Natural Bank Edge		Hydro-modified Bank Edge	
				Area (meters²)	Length (meters)	Length (meters)	Slow-water Edge Area (meters²)	Length (meters)	Slow-water Edge Area (meters²)	Length (meters)	Slow-water Edge Area (meters²)
Winter flow (Jan-19)	Mainstem	Glide	6	314,918	4,883	554	1,724	0	0	9,212	10,610
		Pool	1	8,510	148	0	0	0	0	296	296
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	7	323,428	5,031	554	1,724	0	0	9,508	10,906
	Braid	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-
	Side Channel	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-
Summer Low Flow (Mar-18)	Mainstem	Glide	5	204,408	4,000	850	850	0	0	7,151	7,700
		Pool	2	18,474	443	443	443	0	0	443	443
		Riffle	1	15,200	190	0	0	0	0	380	380
		Backwater	-	-	-	-	-	-	-	-	-
		Total	8	238,081	4,633	1,293	1,293	0	0	7,974	8,523
	Braid	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-
	Side Channel	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-

Table 42: Mainstem riparian, large woody debris, and substrate summaries for Lower Reach 2. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

			Riparian	Large Wood Jams		Dominant Substrate			
Flow Condition	**Channel Type**	**Dominant Unit Type**	**% Canopy Closure**	**n**	**Cover Area (meters^2)**	**% Fines**	**% Sand**	**% Gravel**	**% Cobble**
Winter flow (Jan-19)	Mainstem	Glide	1.8	0	0	ND	ND	ND	ND
		Pool	1.0	0	0	ND	ND	ND	ND
		Riffle	-	-	-	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	1.4	0	0	ND	ND	ND	ND
	Braid	Glide	-	-	-	ND	ND	ND	ND
		Pool	-	-	-	ND	ND	ND	ND
		Riffle	-	-	-	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	-	-	-	ND	ND	ND	ND
	Side Channel	Glide	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-
Summer Low Flow (Mar-18)	Mainstem	Glide	1.2	0	0	ND	ND	ND	ND
		Pool	4.0	0	0	ND	ND	ND	ND
		Riffle	1.0	0	0	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	2.1	0	0	ND	ND	ND	ND
	Braid	Glide	-	-	-	ND	ND	ND	ND
		Pool	-	-	-	ND	ND	ND	ND
		Riffle	-	-	-	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	-	-	-	ND	ND	ND	ND
	Side Channel	Glide	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-

Table 43: Floodplain habitat unit, riparian, large woody debris, and substrate summary for Lower Reach 2. Estimated lengths were derived from WDFW hydrography (WDFW regulatory layer) based on ratios derived in **Table 44**. Wetlands areas were estimated from the NWI (USFWS 2017), no lengths were estimated for wetland units due to lack of adequate data. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

			Habitat Units				Riparian	Large Wood Jams			Substrate			
Flow Condition	**Channel Type**	**Dominant Unit Type**	**n**	**Area (meters^2)**	**Length (meters)**	**Depth (meters)**	**% Canopy Closure**	**n**	**Total Wetted Cover Area (meters^2)**	**Total # of Wetted Pieces**	**% Fines**	**% Sand**	**% Gravel**	**% Cobble**
Winter (Mar-18)	Hydro-modified natural channel	Glide	4	85	577	0.5	11.3	1	9.2	5	100	0	0	0
		Pool	1	20	8	0.3	3.0	1	4.1	2	100	0	0	0
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	1	435	29	ND	0	0	0	0	100	0	0	0
		Estimated	-	52,463	10,575	-	-	-	-	-	-	-	-	-
		Total	6	53,004	11,188	0.4	4.8	2	13.2	7	100	0	0	0
	Tributary	Glide	7	10,041	1,621	1.3	5.0	1	27	8	71	29	0	0
		Pool	-	-	-	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	-	-	-	-	-	-	-	-	-	-	-	-
		Estimated	-	-	-	-	-	-	-	-	-	-	-	-
		Total	7	10,041	1,621	1.3	5.0	1	27	8	71	29	0	0
	Hydro-modified channel	Glide	5	1,993	795	0.4	17.8	0	0	3	100	0	0	0
		Pool	-	-	-	-	-	-	-	0	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	1	532	92	0.5	25.0	0	0	0	100	0	0	0
		Estimated	-	-	-	-	-	-	-	-	-	-	-	-
		Total	6	2,525	887	0.4	21.4	0	0	3	100	0	0	0
	Wetland	Wetland	-	-	-	-	-	-	-	-	-	-	-	-
		Estimated	-	666,403	NA	-	-	-	-	-	-	-	-	-
		Total	-	666,403	-	-	-	-	-	-	-	-	-	-
	Constructed channel	Glide	-	-	-	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	-	-	-	-	-	-	-	-	-	-	-	-
		Estimated	-	41,015	8071	-	-	-	-	-	-	-	-	-
		Total		41,015	8,071	-	-	-	-	-	-	-	-	-

Table 44: Current summer floodplain habitats estimated using winter floodplain habitat survey data and ratios of wetted to dry channel derived from summer and winter habitat validation surveys for Lower Reach 2. An explanation for how ratios were derived is available in **Appendix B**.

	Winter floodplain		Conversion			Summer Floodplain Estimates		
	Total Area (meters^2)	Total Length (meters)	Wet Channel Area Ratio	Wet Channel Length Ratio	Dry channel Length ratio	Total Wet Area (meters^2)	Total Wet Length (meters)	Total Dry Length (meters)
Hydro-modified natural channel	53,004	11,188	0.5	0.5	0.5	28,356	5,914	5,342
Tributary	10,041	1,621	0.4	0.7	0.4	4,083	1,099	608
Hydro-modified channel	2,525	887	0.2	0.1	0.9	404	126	770
Wetland	666,403	-	0.6	1.0	0	412,175	-	-
Constructed channel	41,015	8,071	0.2	0.1	0.9	6,570	1,149	7,006

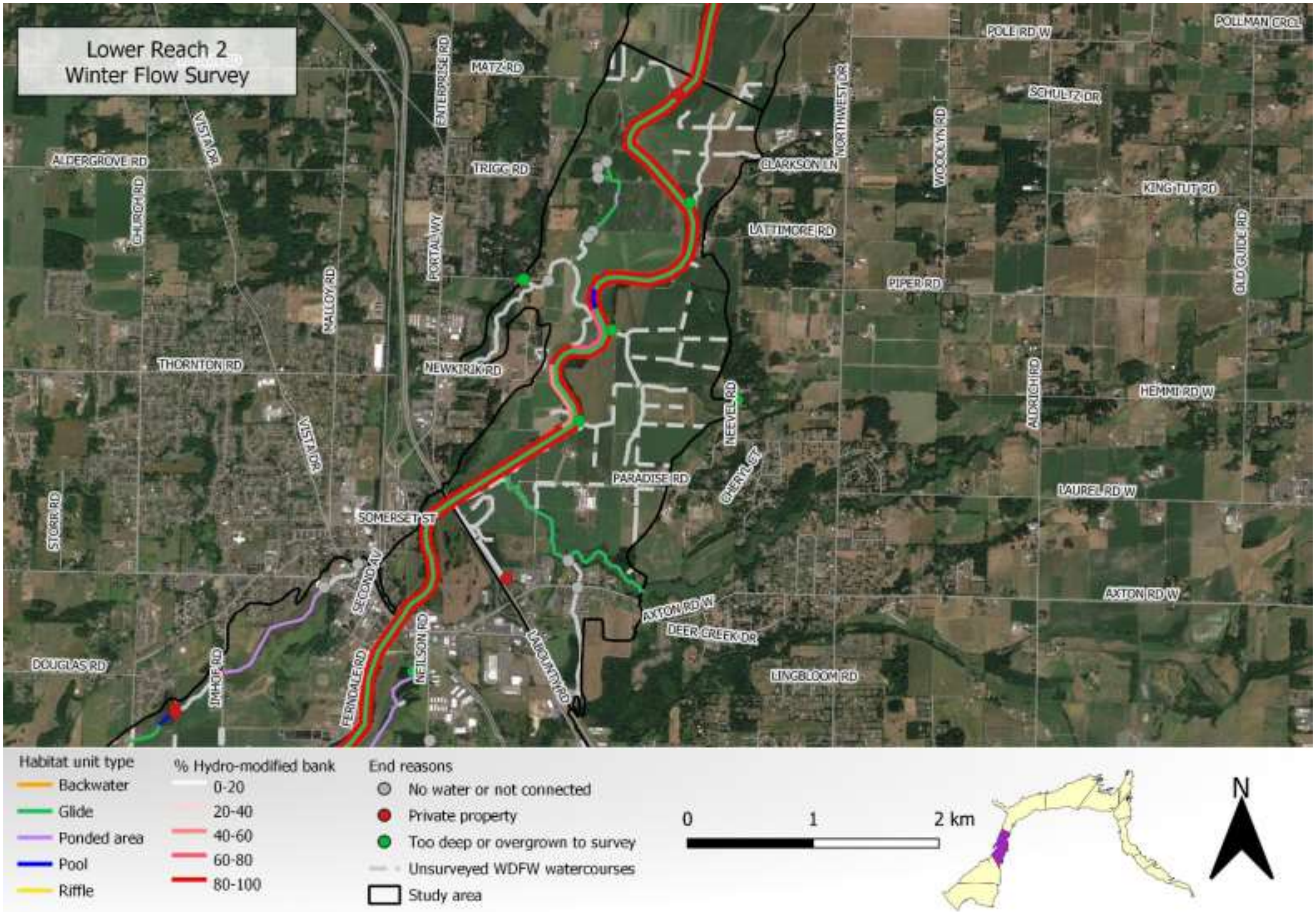

Figure 109: Map of hydro-modified banks and habitat units during winter flow conditions for Lower Reach 2. Average daily flows at the Cedarville gage ranged from 2,750 to 7,600 cfs for mainstem surveys and 1,400 to 4,200 cfs for floodplain surveys. WDFW watercourses that were not field surveyed in this effort are shown in gray.

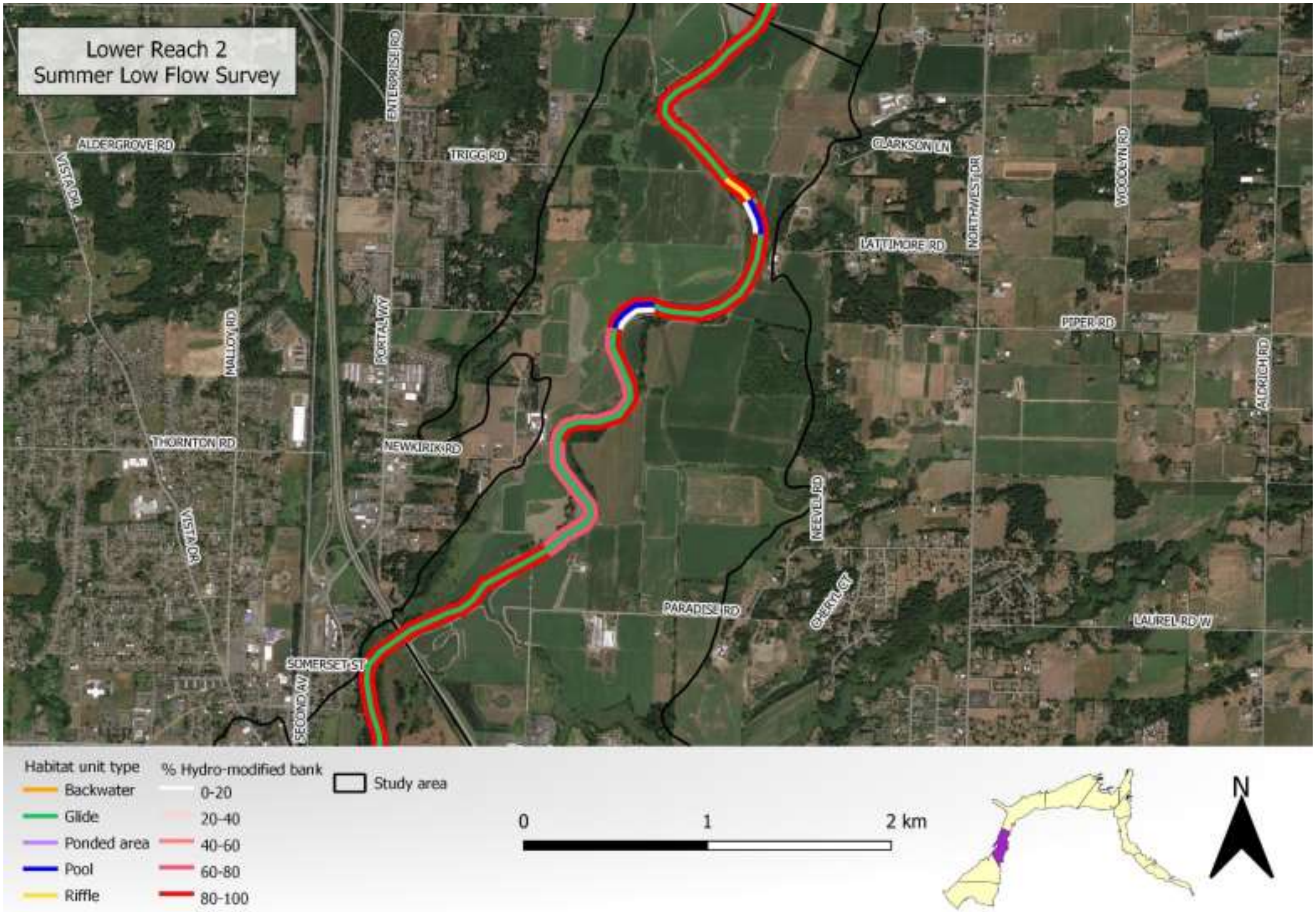

Figure 110: Map of hydro-modified banks and habitat units during summer low flow conditions for Lower Reach 2. Average daily flows at the Cedarville gage ranged from 1,400 to 1,500 cfs for mainstem surveys and 1,500 to 2,500 cfs for floodplain surveys. Summer low flow floodplain surveys were completed as a subset of winter flow surveys, but no summer low flow floodplain validation surveys were completed in this reach. All WDFW watercourses are shown in **Figure 111**.

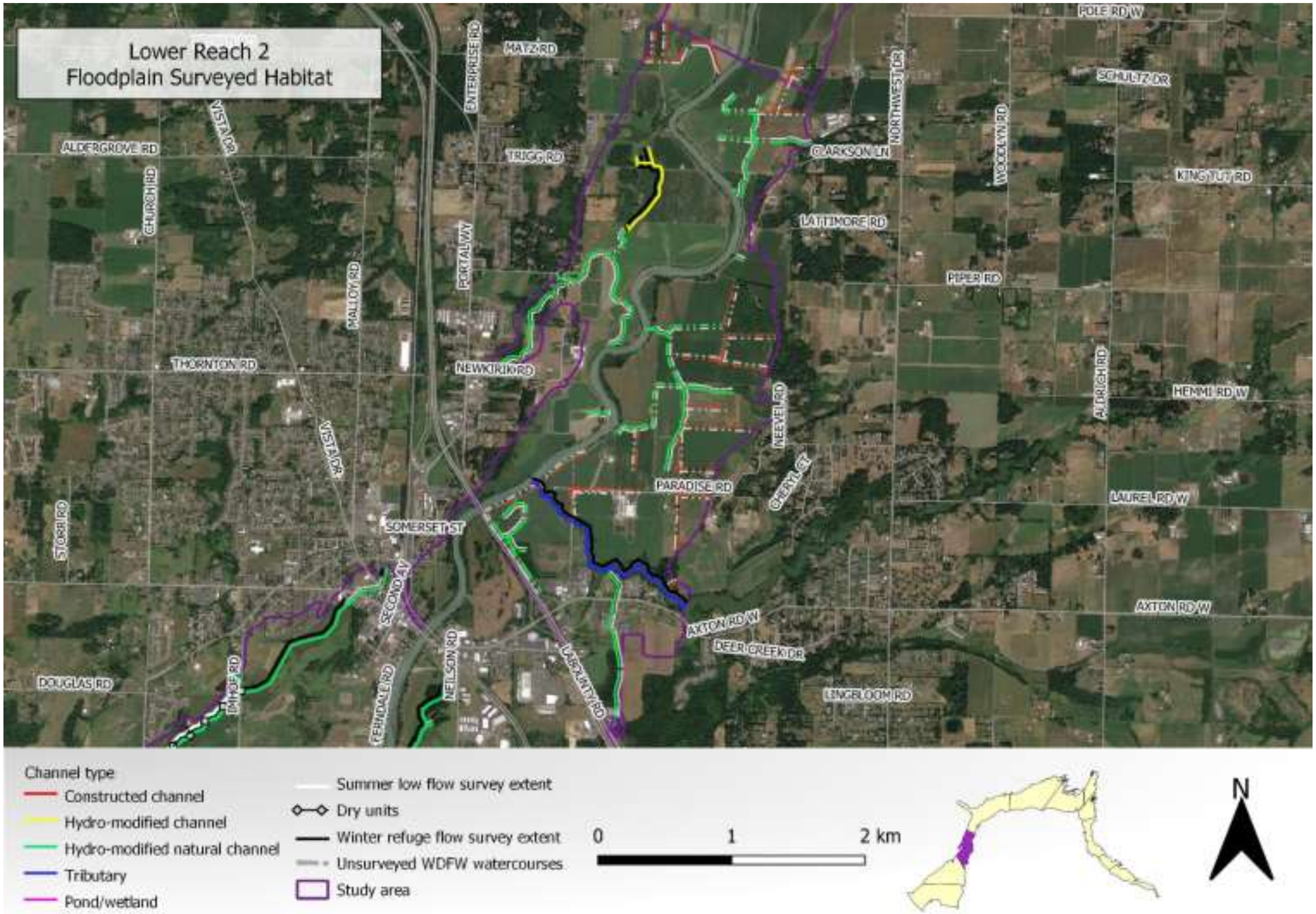

Figure 111: Map of summer and winter floodplain survey extents by channel type for Lower Reach 2. Summer low flow floodplain surveys were conducted as a subset of the winter floodplain survey extent when flows at the Cedarville gage ranged from 1,500 to 2,500 cfs. Channel types adapted from Washington Department of Fish and Wildlife's classifications (WDFW Regulatory Layer). Summer floodplain channel lengths areas were estimated using the ratio of wet to dry channels applied to winter floodplain channel lengths and areas. No summer low flow floodplain validation surveys were completed in this reach, so lengths were calculated using winter habitat surveys. Detailed methods are provided in **Appendix B**.

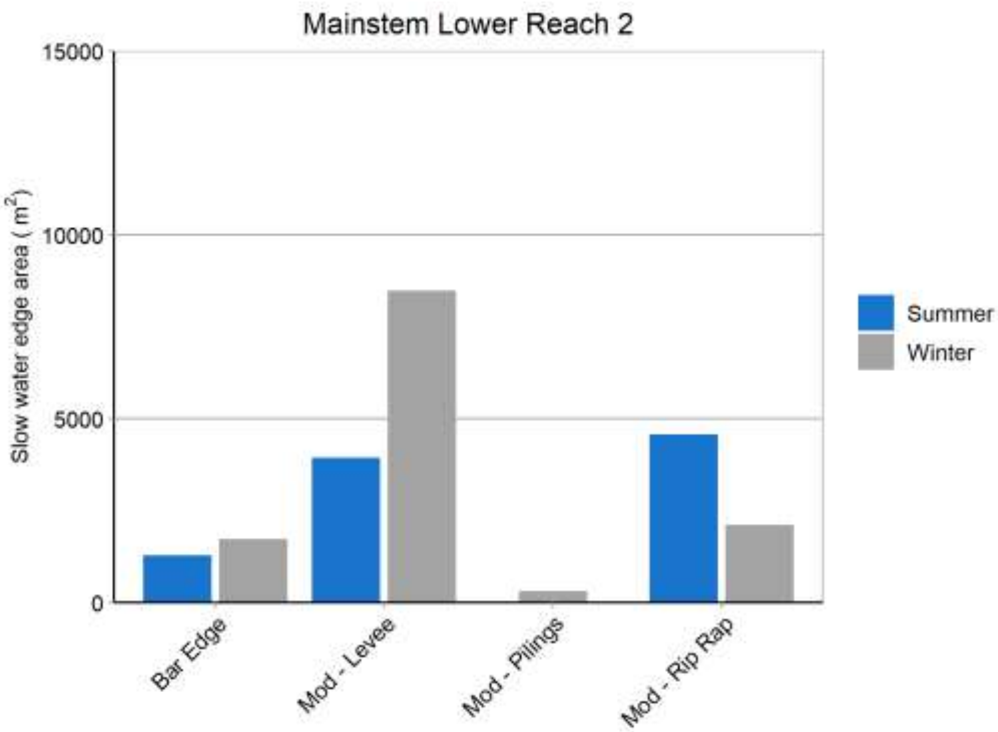

Figure 112: Slow water edge area (meters^2) of edges by edge type surveyed for present day mainstem surveys for summer low flow and winter flow surveys for Lower Reach 2.

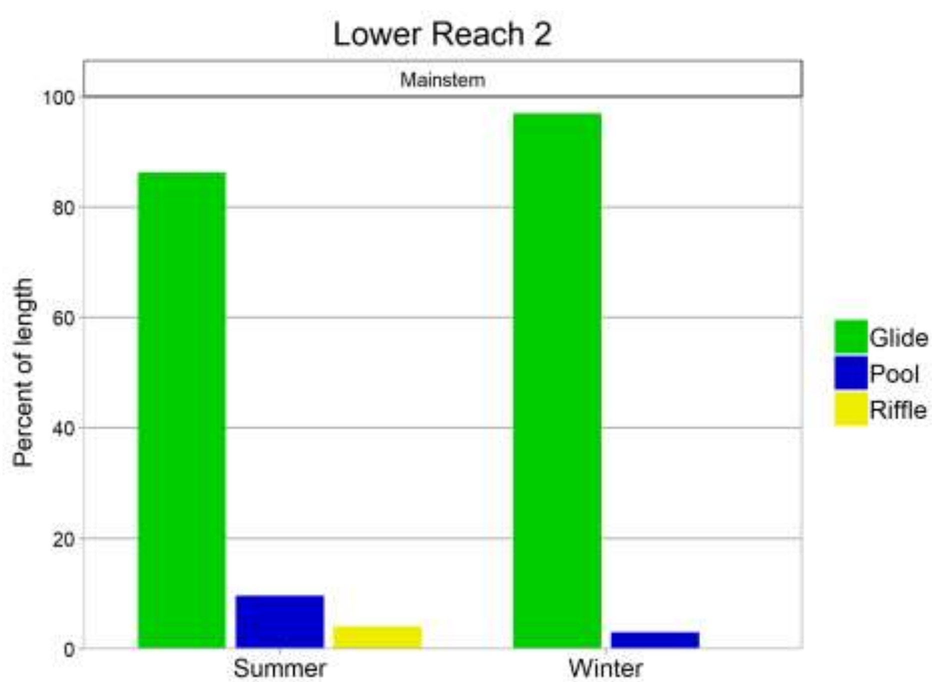

Figure 113: Percent of length surveyed in glide, pool, and riffle habitats for each channel type in mainstem surveys for summer low flow and winter flow surveys for Lower Reach 2. No braid or side-channel habitat was observed in this reach.

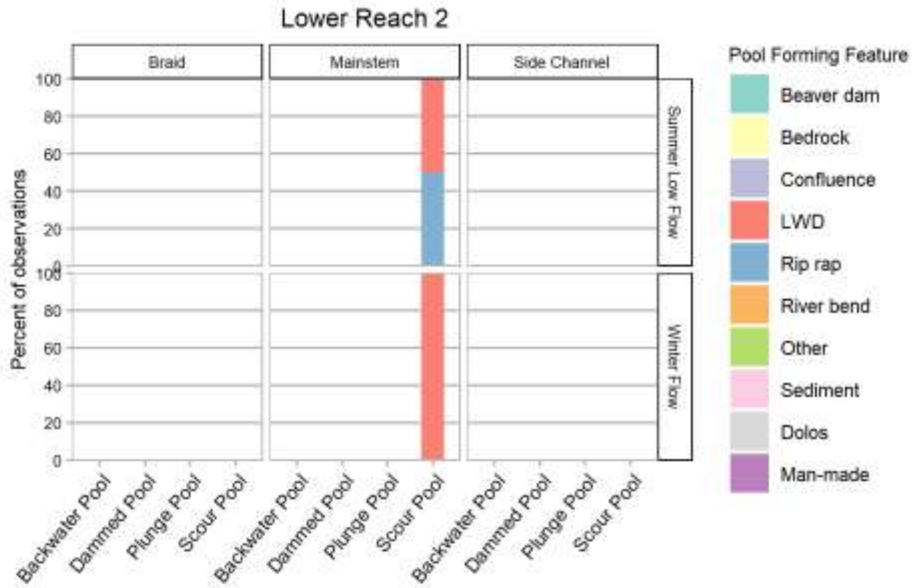

Figure 114: Percent of pool observations by pool type and pool forming feature for Lower Reach 2 for mainstem habitats.

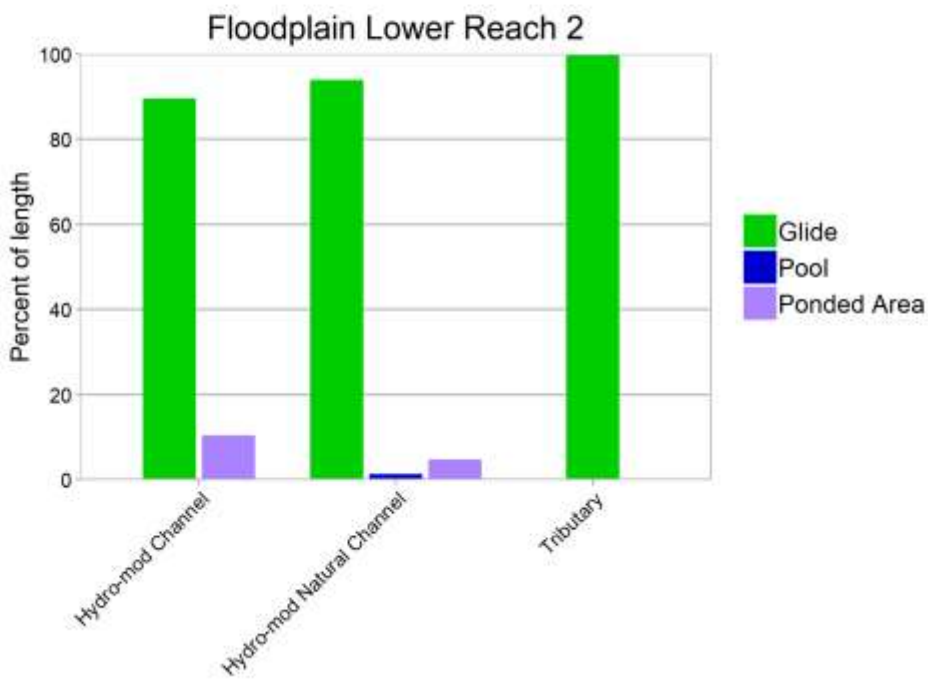

Figure 115: Percent of length surveyed in glide, pool, and riffle habitats for channel types in winter flow floodplain surveys for Lower Reach 2. No riffle habitat was observed in floodplain habitat in this reach.

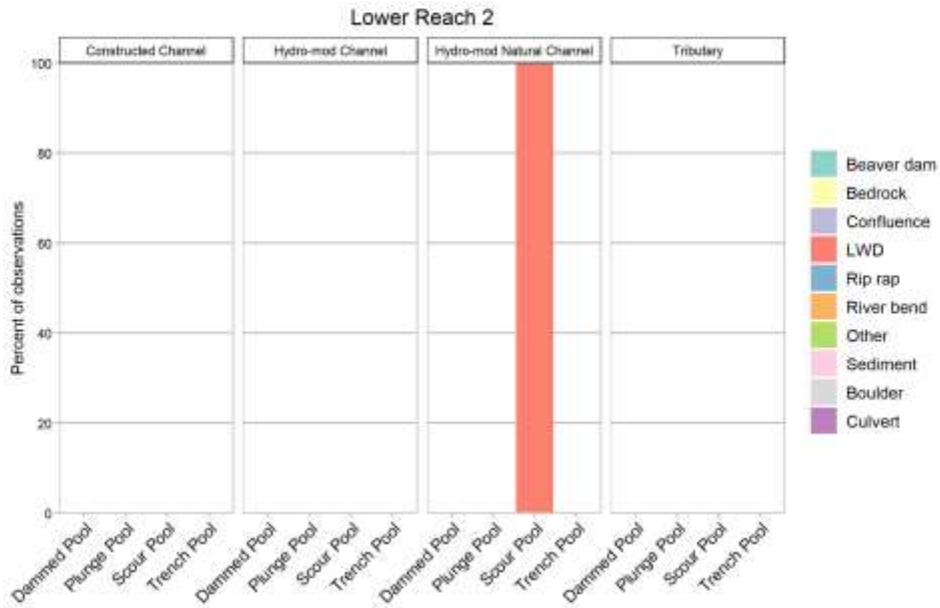

Figure 116: Percent of pool observations by pool type and pool forming feature for Lower Reach 2 for floodplain habitats.

Table 45: Historical and current habitat summarized at same resolution as historical data for Lower Reach 2. For historical reconstructions; no differences in summer and winter condition were derived for floodplain and estuary habitats; total areas are derived from polygon feature areas and line feature lengths assuming a 1-meter width; total lengths are derived from line length for polyline features and polygon perimeters divided by two; total edges are derived from line feature lengths plus polygon perimeters; and slow-water edge areas are derived from two times the total edge lengths. Estuary habitats were not observed in this reach and are not included in this table.

				Historic circa 1880s				Current circa 2018/2019			
Flow	**Habitat Strata**	**Habitat Type**	**Channel Type**	**Area (meters²)**	**Length (meters)**	**Edge Length (meters)**	**Slow-water Edge Area (meters²)**	**Area (meters²)**	**Length (meters)**	**Edge Length (meters)**	**Slow-water Edge Area (meters²)**
Winter Flow	Floodplain	Secondary	Slough and Tributary	30,919	10,230	NA	NA	106,584	21,768	NA	NA
		Pond/Wetland	Pond/Wetland	1,692,929	NA	NA	NA	666,403	NA	NA	NA
	Mainstem	Secondary	Side-Channel/Braid	NA	846	1,692	3,383	NA	0	0	0
		Mainstem	Natural Bank Edge	NA	NA	9,246	18,492	NA	NA	0	0
			Hydro-Modified Bank Edge	NA	NA	0	0	NA	NA	9,508	10,906
			Bar Edge	NA	NA	503	1,007	NA	NA	554	1,724
Summer Low Flow	Floodplain	Secondary	Slough and Tributary	30,919	10,230	NA	NA	39,413	8,290	NA	NA
		Pond/Wetland	Pond/Wetland	1,047,088	NA	NA	NA	412,175	NA	NA	NA
	Mainstem	Secondary	Side-Channel/Braid	NA	6,316	12,633	25,265	0	0	0	0
		Mainstem	Natural Bank Edge	NA	NA	11,318	22,636	NA	NA	0	0
			Hydro-Modified Bank Edge	NA	NA	0	0	NA	NA	7,974	8,523
			Bar Edge	NA	NA	3,233	6,466	NA	NA	1,293	1,293

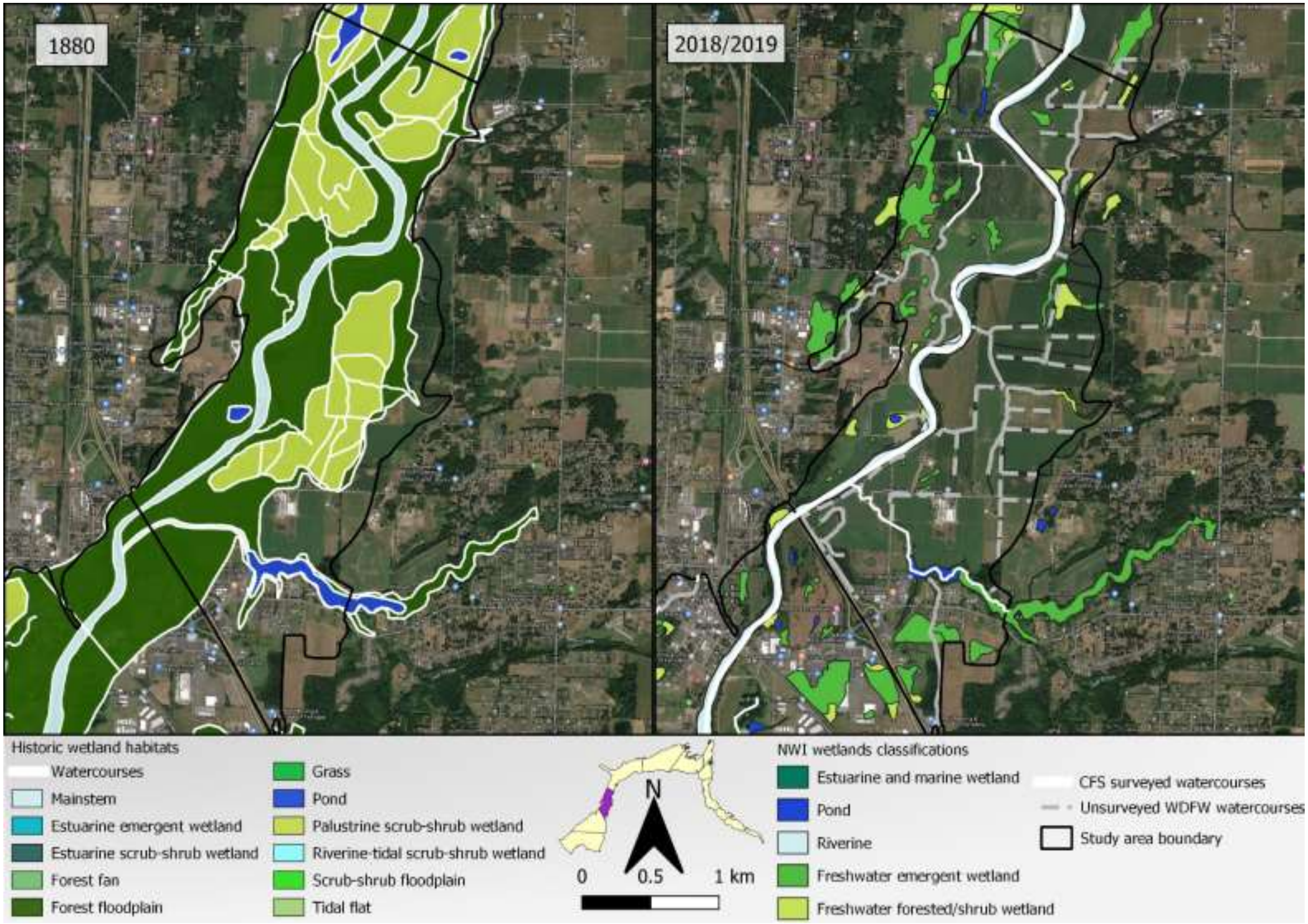

Figure 117: Map of current winter habitat and historical winter habitat extents (Collins and Sheikh) for Lower Reach 2. Surveyed watercourses and unsurveyed watercourses from current surveys are depicted, current wetland habitats are from the NWI (USFWS 2017).

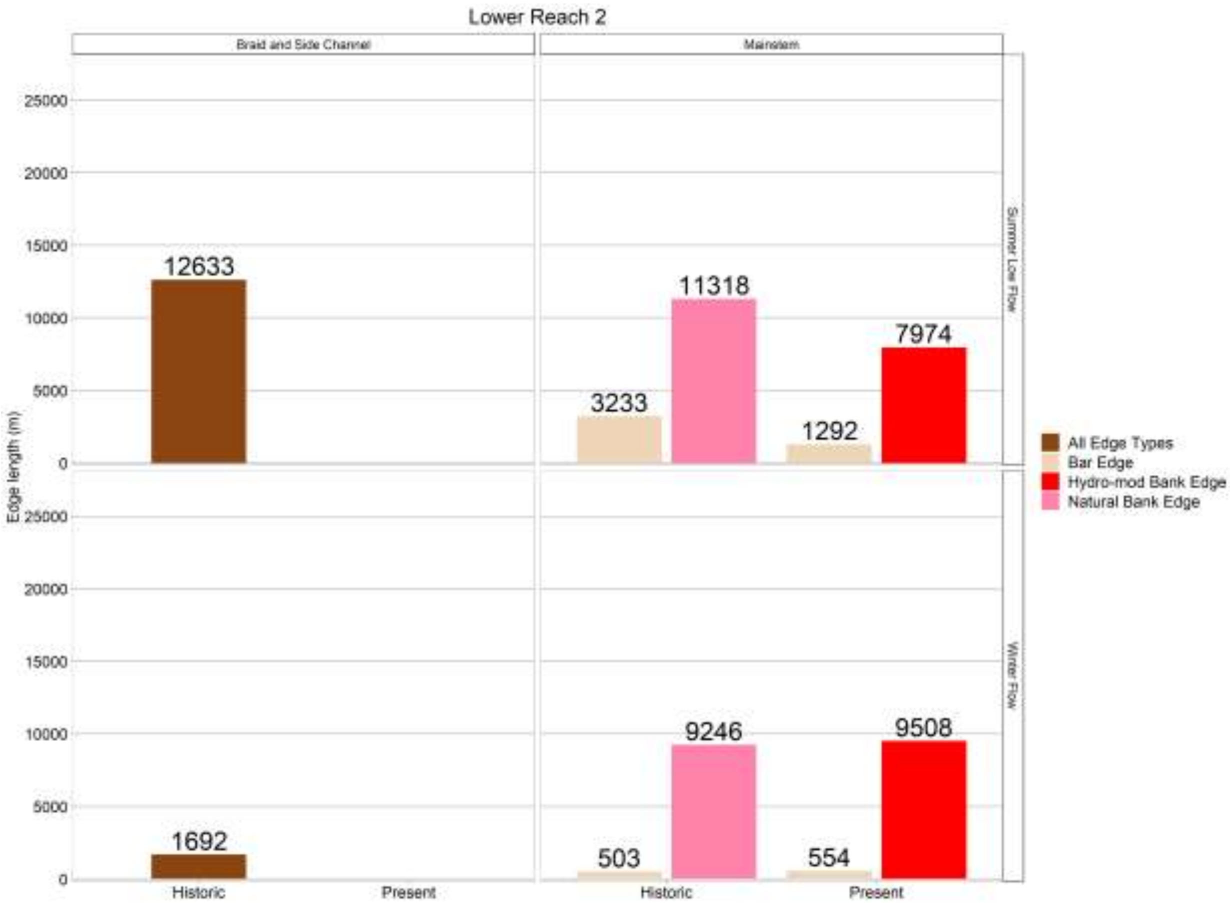

Figure 118: Edge lengths (meters) of bank types for summer low flow and winter flow conditions for historic versus present data. Edge type data for historic braid and side-channel habitats were not available. No braid or side-channel habitat was observed in Lower Reach 2.

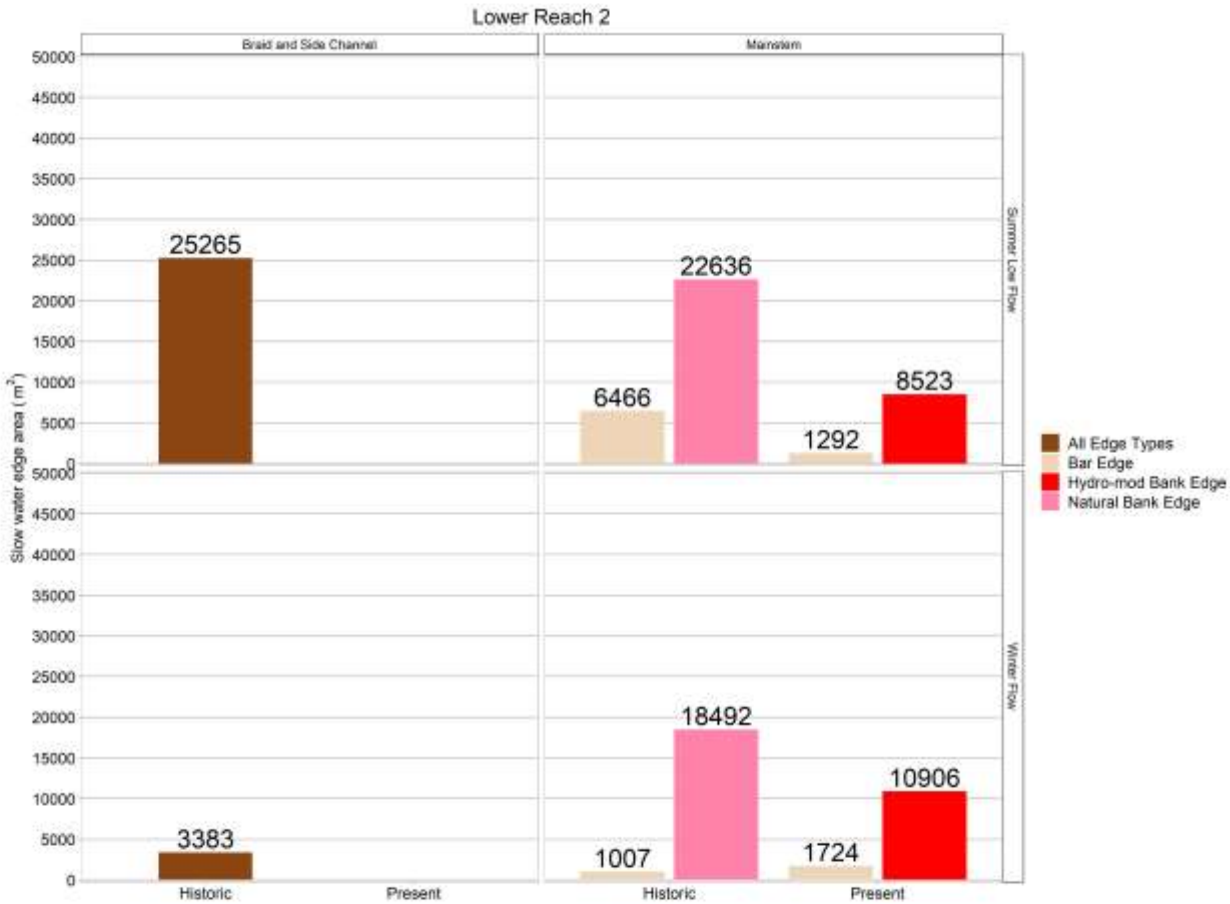

Figure 119: Slow water edge area (meters^2) for bank types for summer low flow and winter flow conditions for historic versus present data. Edge type data for historic braid and side-channel habitats were not available. No braid or side-channel habitat was observed in Lower Reach 2.

Reach: Upper Reach 2

Table 46: Mainstem habitat unit and edge summaries for surveys of Upper Reach 2. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

				Total		**Bar Edge**		**Natural Bank Edge**		**Hydro-modified Bank Edge**	
Flow Condition	**Channel Type**	**Dominant Unit Type**	**n**	**Area (meters²)**	**Length (meters)**	**Length (meters)**	**Slow-water Edge Area (meters²)**	**Length (meters)**	**Slow-water Edge Area (meters²)**	**Length (meters)**	**Slow-water Edge Area (meters²)**
Winter flow (Jan-19)	Mainstem	Glide	7	616,327	9,192	1,259	4,589	256	1,137	16,870	22,785
		Pool	2	22,743	418	51	84	0	0	785	1,066
		Riffle	3	38,027	567	270	2,089	0	0	864	1,423
		Backwater	-	-	-	-	-	-	-	-	-
		Total	12	677,097	10,177	1,580	6,762	256	1,137	18,518	25,274
	Braid	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-
	Side Channel	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-
Summer Low Flow (Mar-18)	Mainstem	Glide	9	400,340	6,580	2,066	2,066	288	288	10,806	11,300
		Pool	5	38,033	743	526	526	0	0	960	960
		Riffle	4	45,347	676	415	415	0	0	937	937
		Backwater	-	-	-	-	-	-	-	-	-
		Total	18	483,720	7,999	3,007	3,007	288	288	12,703	13,196
	Braid	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total									
	Side Channel	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-

Table 47: Mainstem riparian, large woody debris, and substrate summaries for Upper Reach 2. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

			Riparian	Large Wood Jams		Dominant Substrate			
Flow Condition	Channel Type	Dominant Unit Type	% Canopy Closure	n	Cover Area (meters^2)	% Fines	% Sand	% Gravel	% Cobble
Winter flow (Jan-19)	Mainstem	Glide	1.0	3	242	ND	ND	ND	ND
		Pool	1.0	1	15	ND	ND	ND	ND
		Riffle	1.5	2	182	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	1.2	6	439	ND	ND	ND	ND
	Braid	Glide	-	-	-	ND	ND	ND	ND
		Pool	-	-	-	ND	ND	ND	ND
		Riffle	-	-	-	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	-	-	-	ND	ND	ND	ND
	Side Channel	Glide	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-
Summer Low Flow (Mar-18)	Mainstem	Glide	1.6	1	175	ND	ND	ND	ND
		Pool	1	0	0	ND	ND	ND	ND
		Riffle	1.5	0	0	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	1.4	1	175	ND	ND	ND	ND
	Braid	Glide	-	-	-	ND	ND	ND	ND
		Pool	-	-	-	ND	ND	ND	ND
		Riffle	-	-	-	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	-	-	-	ND	ND	ND	ND
	Side Channel	Glide	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-

Table 48: Floodplain habitat unit, riparian, large woody debris, and substrate summary for Upper Reach 2. Estimated lengths were derived from WDFW hydrography (WDFW regulatory layer) based on ratios derived in Table 49. Wetlands areas were estimated from the NWI (USFWS 2017), no lengths were estimated for wetland units due to lack of adequate data. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

			Habitat Units				Riparian	Large Wood Jams			Substrate			
Flow Condition	Channel Type	Dominant Unit Type	n	Area (meters^2)	Length (meters)	Depth (meters)	% Canopy Closure	n	Total Wetted Cover Area (meters^2)	Total # of Wetted Pieces	% Fines	% Sand	% Gravel	% Cobble
Winter (Mar-18)	Hydro-modified natural channel	Glide	66	36,936	10,718	0.6	29.9	14	141.1	42	95	5	0	0
		Pool	11	926	188	0.6	13.7	0	0	6	64	36	0	0
		Riffle	4	70	45	0.2	48.8	2	4.7	4	50	25	25	0
		Ponded	17	10,536	1,871	0.7	38	0	0	0	100	0	0	0
		Estimated	-	27,650	5,839	-	-	-	-	-	-	-	-	-
		Total	98	76,118	18,661	0.5	32.6	16	146.7	52	77	17	6	0
	Tributary	Glide	17	50,394	6,136	1.1	12.9	8	549.0	29	20	53	27	0
		Pool	1	408	32	2.1	10	0	0	1	0	100	0	0
		Riffle	2	1,664	275	1.3	22.5	3	51	7	50	50	0	0
		Ponded	-	-	-	-	-	-	-	-	-	-	-	-
		Estimated	-	-	-	-	-	-	-	-	-	-	-	-
		Total	20	52,466	6,443	1.5	15	11	600.0	37	23	68	9	0
	Hydro-modified channel	Glide	9	2,690	1,404	0.4	14.9	0	0	0	89	11	0	0
		Pool	-	-	-	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	2	138	177	ND	20	0	0	0	100	0	0	0
		Estimated	-	-	-	-	-	-	-	-	-	-	-	-
		Total	11	2,828	1,581	0.4	34.9	0	0	0	95	6	0	0
	Wetland	Wetland	3	3,007	149	ND	31.7	0	0	0	100	0	0	0
		Estimated	-	1,894,915	NA	-	-	-	-	-	-	-	-	-
		Total	3	1,897,922	149	ND	31.7	0	0	0	100	0	0	0
	Constructed channel	Glide	-	-	-	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	-	-	-	-	-	-	-	-	-	-	-	-
		Estimated	-	29,958	5,895	-	-	-	-	-	-	-	-	-
		Total	-	29,958	5,895	-	-	-	-	-	-	-	-	-

Table 49: Current summer floodplain habitats estimated using winter floodplain habitat survey data and ratios of wetted to dry channel derived from summer and winter habitat validation surveys for Upper Reach 2. An explanation for how ratios were derived is available in **Appendix B**.

	Winter Floodplain		Conversion			Summer Floodplain Estimates		
	Total Area (meters^2)	**Total Length (meters)**	**Wet Channel Area Ratio**	**Wet Channel Length Ratio**	**Dry channel Length ratio**	**Total Wet Area (meters^2)**	**Total Wet Length (meters)**	**Total Dry Length (meters)**
Hydro-modified natural channel	76,118	18,661	0.5	0.5	0.5	40,721	9,865	8,909
Tributary	52,466	6,443	0.4	0.7	0.4	21,334	4,370	2,415
Hydro-modified channel	2,828	1,581	0.2	0.1	0.9	453	225	1,372
Wetland	1,897,922	149	0.6	1.0	0	1,173,877	149	0
Constructed channel	29,958	5,895	0.2	0.1	0.9	4,799	839	5,118

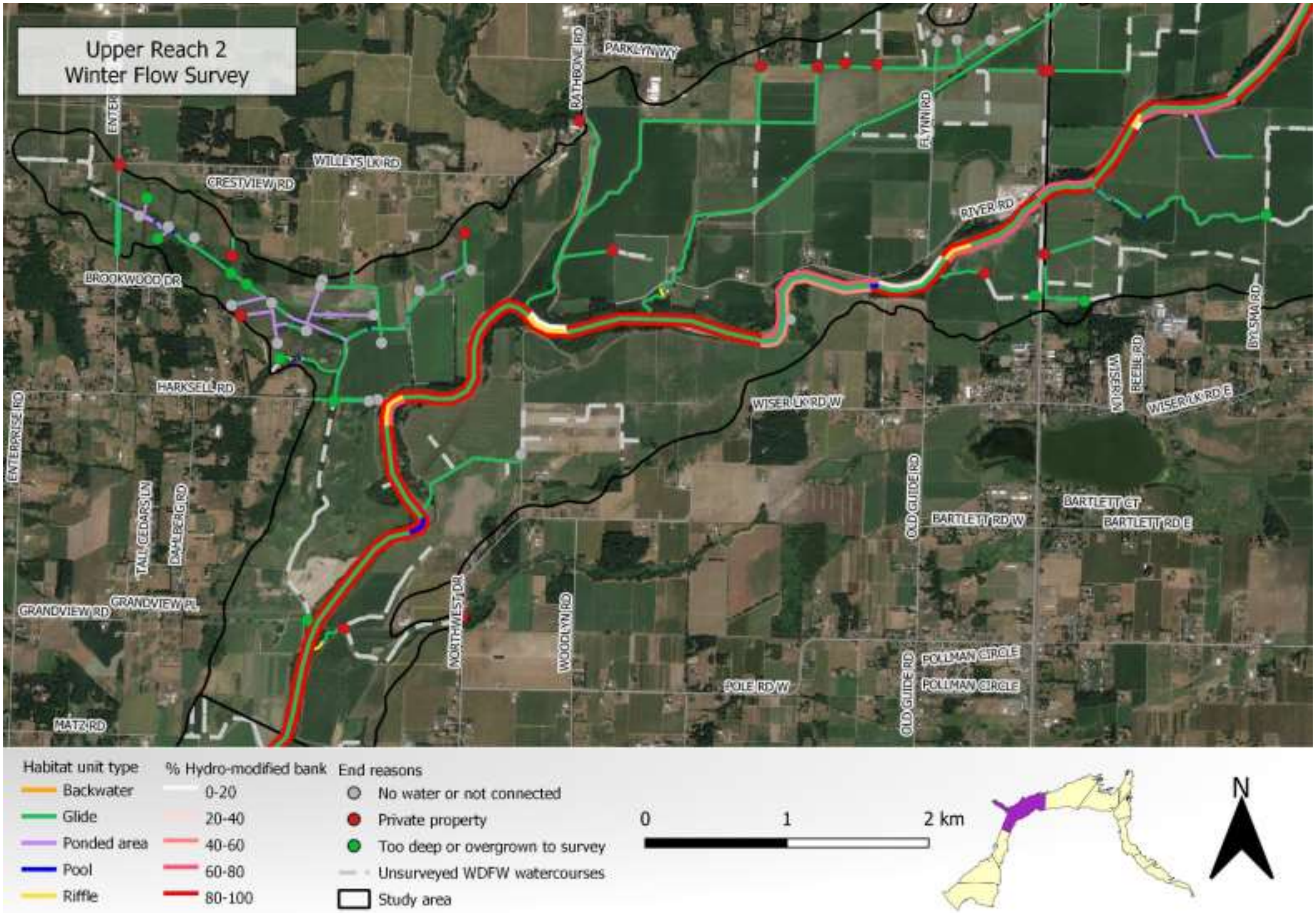

Figure 120: Map of hydro-modified banks and habitat units during winter flow conditions for Upper Reach 2. Average daily flows at the Cedarville gage ranged from 2,750 to 7,600 cfs for mainstem surveys and 1,400 to 4,200 cfs for floodplain surveys. WDFW watercourses that were not field surveyed in this effort are shown in gray.

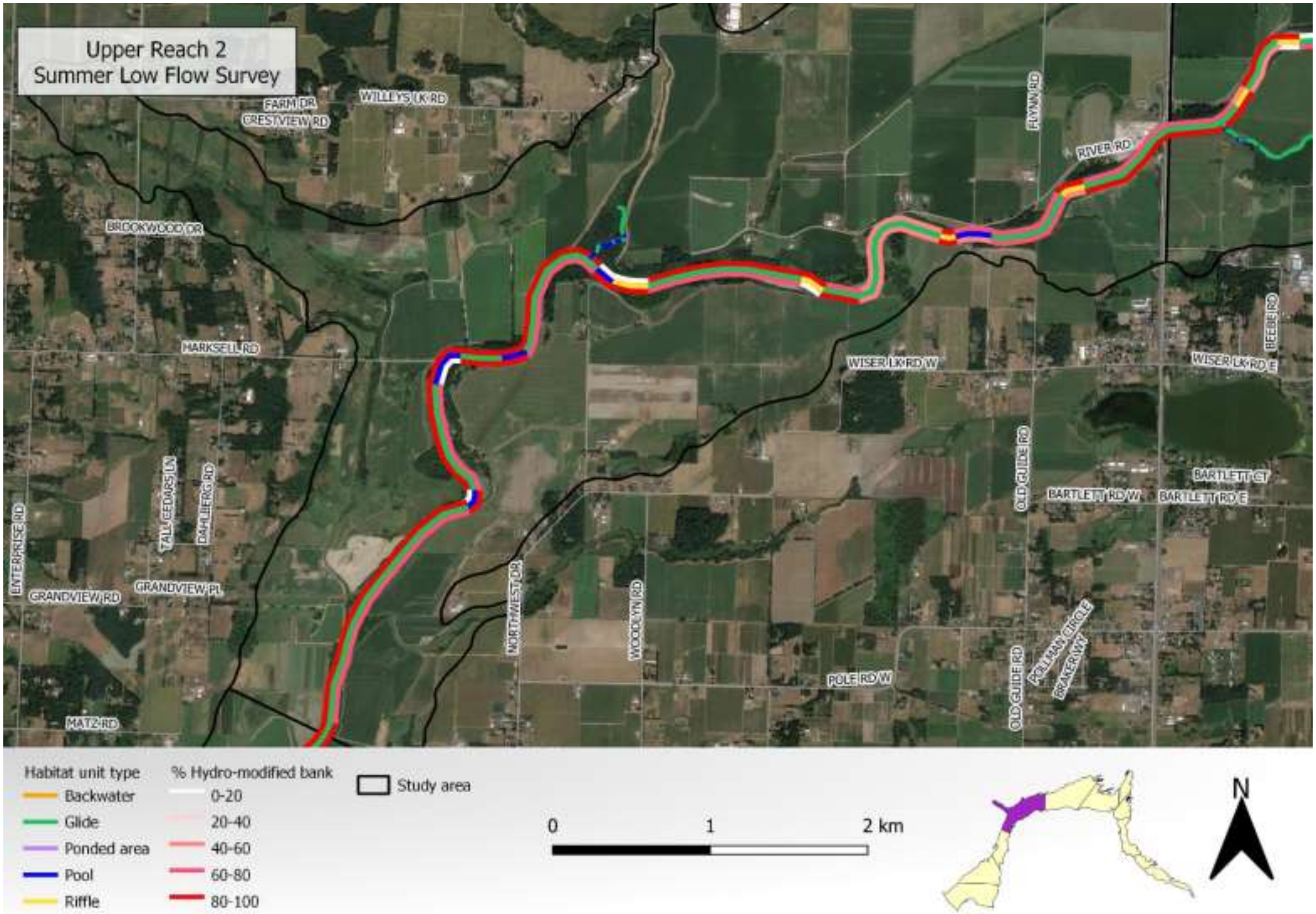

Figure 121: Map of hydro-modified banks and habitat units during summer low flow conditions for Upper Reach 2. Average daily flows at the Cedarville gage ranged from 1,400 to 1,500 cfs for mainstem surveys and 1,500 to 2,500 cfs for floodplain surveys. Summer low flow floodplain surveys were completed as a subset of winter flow surveys and only surveyed watercourses are shown. All WDFW watercourses are shown in **Figure 122**.

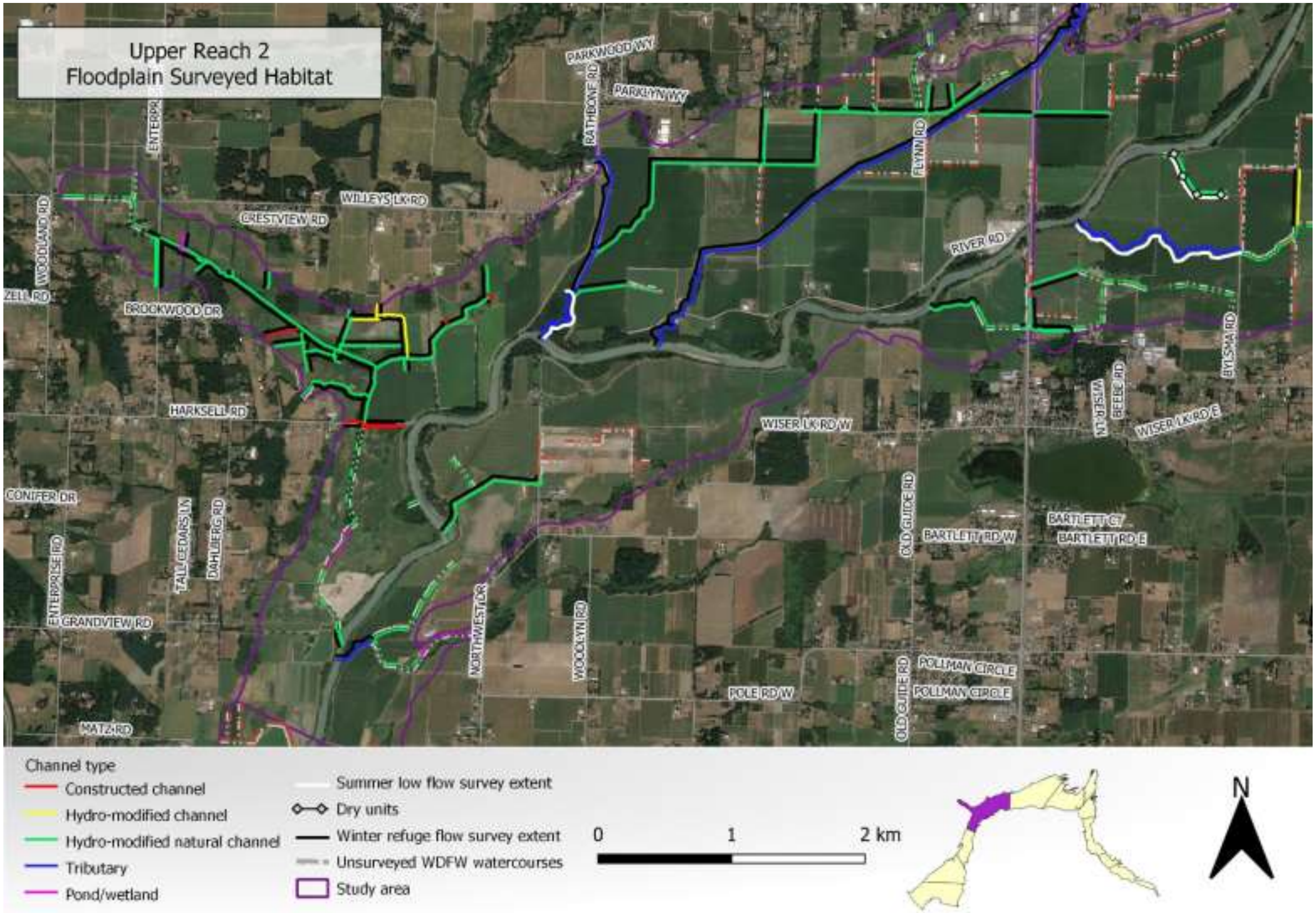

Figure 122: Map of summer and winter floodplain survey extents by channel type for Upper Reach 2. Summer low flow floodplain surveys were conducted as a subset of the winter floodplain survey extent when flows at the Cedarville gage ranged from 1,500 to 2,500 cfs. Channel types adapted from Washington Department of Fish and Wildlife's classifications (WDFW Regulatory Layer). Summer floodplain channel lengths areas were estimated using the ratio of wet to dry channels applied to winter floodplain channel lengths and areas. Detailed methods are provided in **Appendix B**.

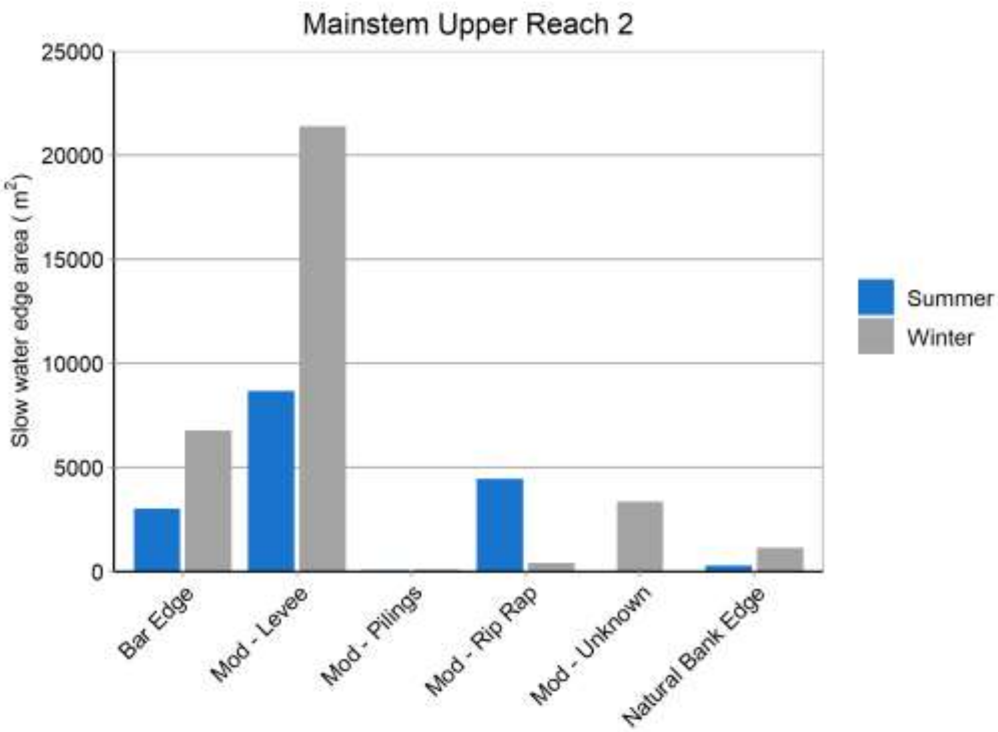

Figure 123: Slow water edge area (meters^2) of edges by edge type surveyed for present day mainstem surveys for summer low flow and winter flow surveys for Upper Reach 2.

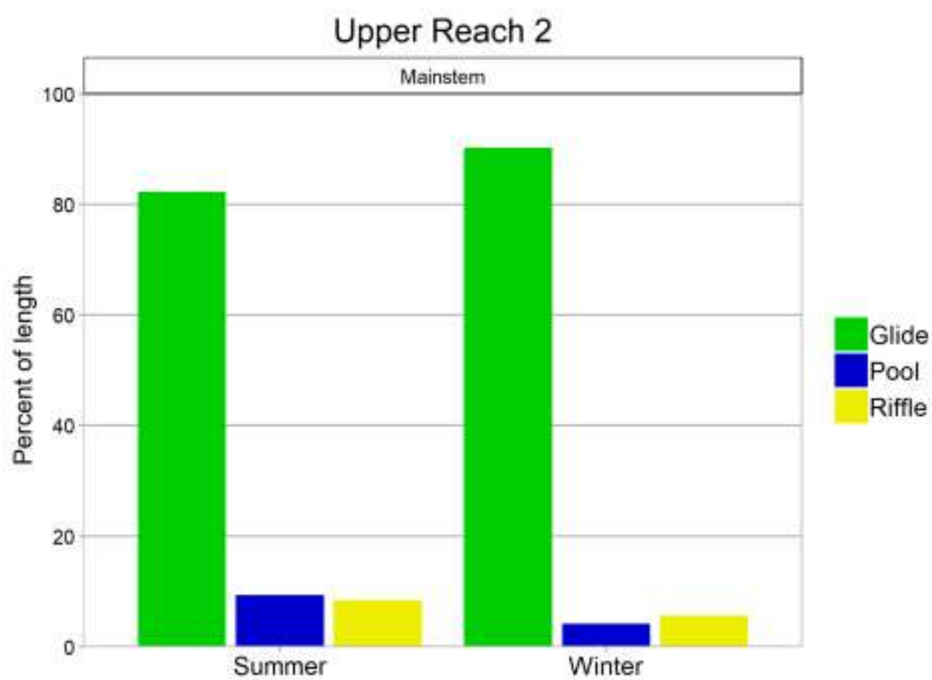

Figure 124: Percent of length surveyed in glide, pool, and riffle habitats for each channel type in mainstem surveys for summer low flow and winter flow surveys. No braid or side-channel habitat was observed in this reach.

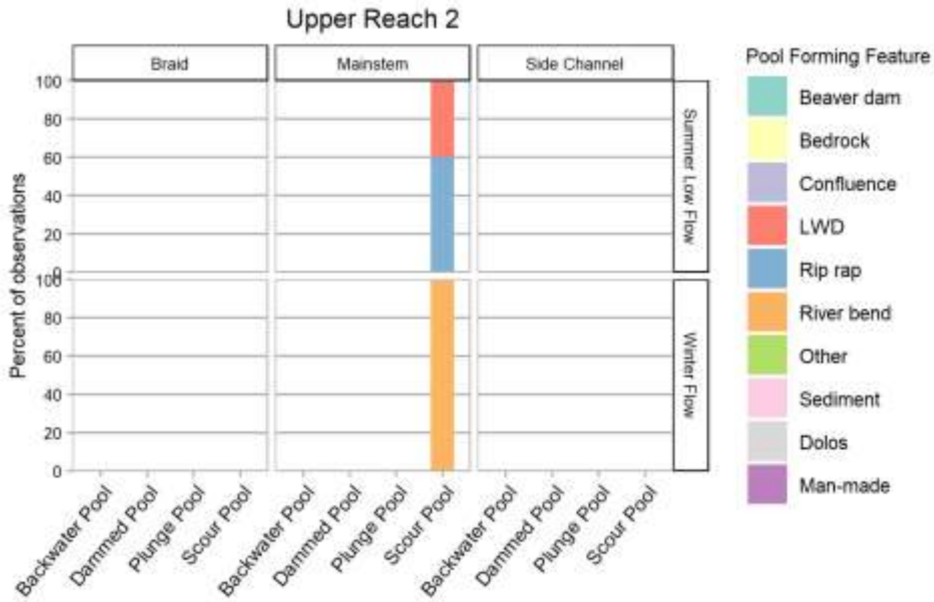

Figure 125: Percent of pool observations by pool type and pool forming feature for Upper Reach 2 for mainstem habitats.

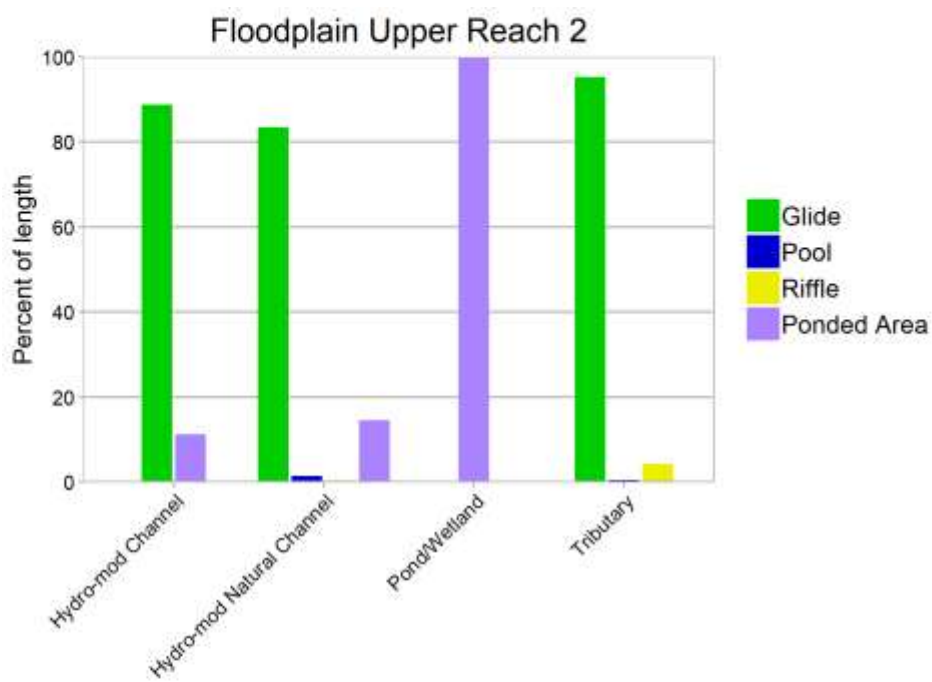

Figure 126: Percent of length surveyed in glide, pool, and riffle habitats for channel types in winter flow floodplain surveys for Upper Reach 2.

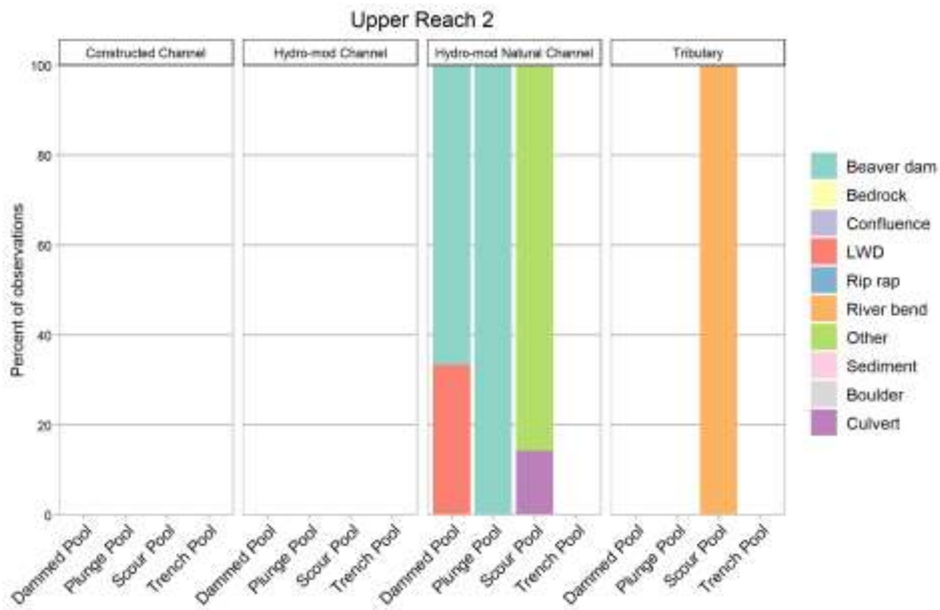

Figure 127: Percent of pool observations by pool type and pool forming feature for Upper Reach 2 for floodplain habitats. Other refers to pools where the forming feature was unable to be determined.

Table 50: Historical and current habitat summarized at same resolution as historical data. For historical reconstructions; no differences in summer and winter condition were derived for floodplain and estuary habitats; total areas are derived from polygon feature areas and line feature lengths assuming a 1-meter width; total lengths are derived from line length for polyline features and polygon perimeters divided by two; total edges are derived from line feature lengths plus polygon perimeters; and slow-water edge areas are derived from two times the total edge lengths. Estuary habitats were not observed in this reach and are not included in this table.

				Historic Circa 1880s				Current Circa 2018/2019			
Flow	**Habitat Strata**	**Habitat Type**	**Channel Type**	**Area (meters^2)**	**Length (meters)**	**Edge Length (meters)**	**Slow-water Edge Area (meters^2)**	**Area (meters^2)**	**Length (meters)**	**Edge Length (meters)**	**Slow-water Edge Area (meters^2)**
Winter Flow	Floodplain	Secondary	Slough and Tributary	30,404	16,900	NA	NA	161,369	32,580	NA	NA
		Pond/Wetland	Pond/Wetland	7,818,466	NA	NA	NA	1,897,922	NA	NA	NA
	Mainstem	Secondary	Side-Channel/Braid	NA	913	1,827	3,654	NA	0	0	0
		Mainstem	Natural Bank Edge	NA	NA	19,417	38,833	NA	NA	256	1,137
			Modified Bank Edge	NA	NA	0	0	NA	NA	18,518	25,274
			Bar Edge	NA	NA	1,570	3,141	NA	NA	1,580	6,762
Summer Low Flow	Floodplain	Secondary	Slough and Tributary	30,404	16,900	NA	NA	67,307	15,299	NA	NA
		Pond/Wetland	Pond/Wetland	4,835,772	NA	NA	NA	1,173,877	NA	NA	NA
	Mainstem	Secondary	Side-Channel/Braid	NA	1,364	2,727	5,453	0	0	0	0
		Mainstem	Natural Bank Edge	NA	NA	23,766	47,532	NA	NA	288	288
			Modified Bank Edge	NA	NA	0	0	NA	NA	12,703	13,196
			Bar Edge	NA	NA	7,558	15,115	NA	NA	3,007	3,007

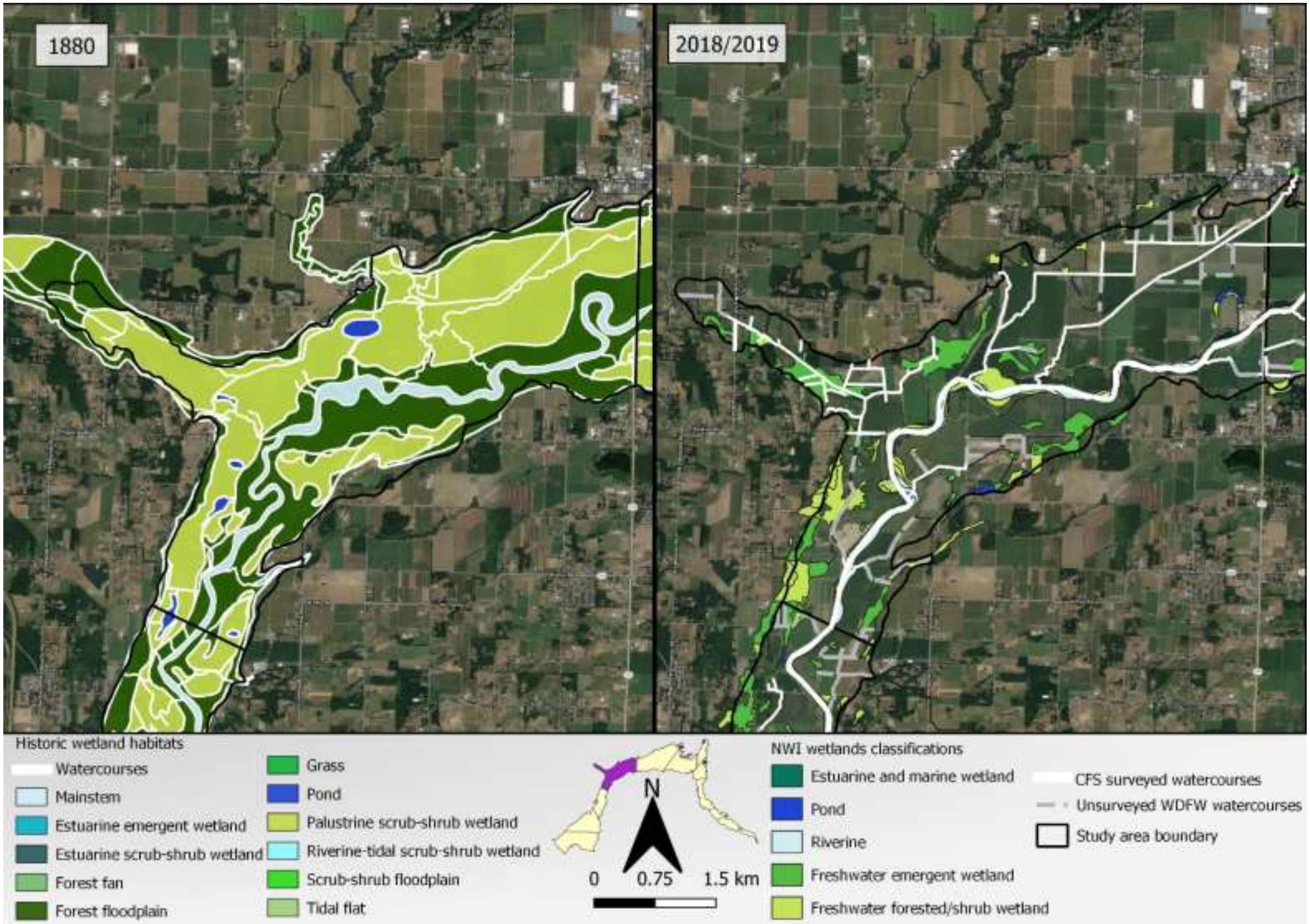

Figure 128: Map of current winter habitat and historical winter habitat extents (Collins and Sheikh) for Upper Reach 2. Surveyed watercourses and unsurveyed watercourses from current surveys are depicted, current wetland habitats are from the NWI (USFWS 2017).

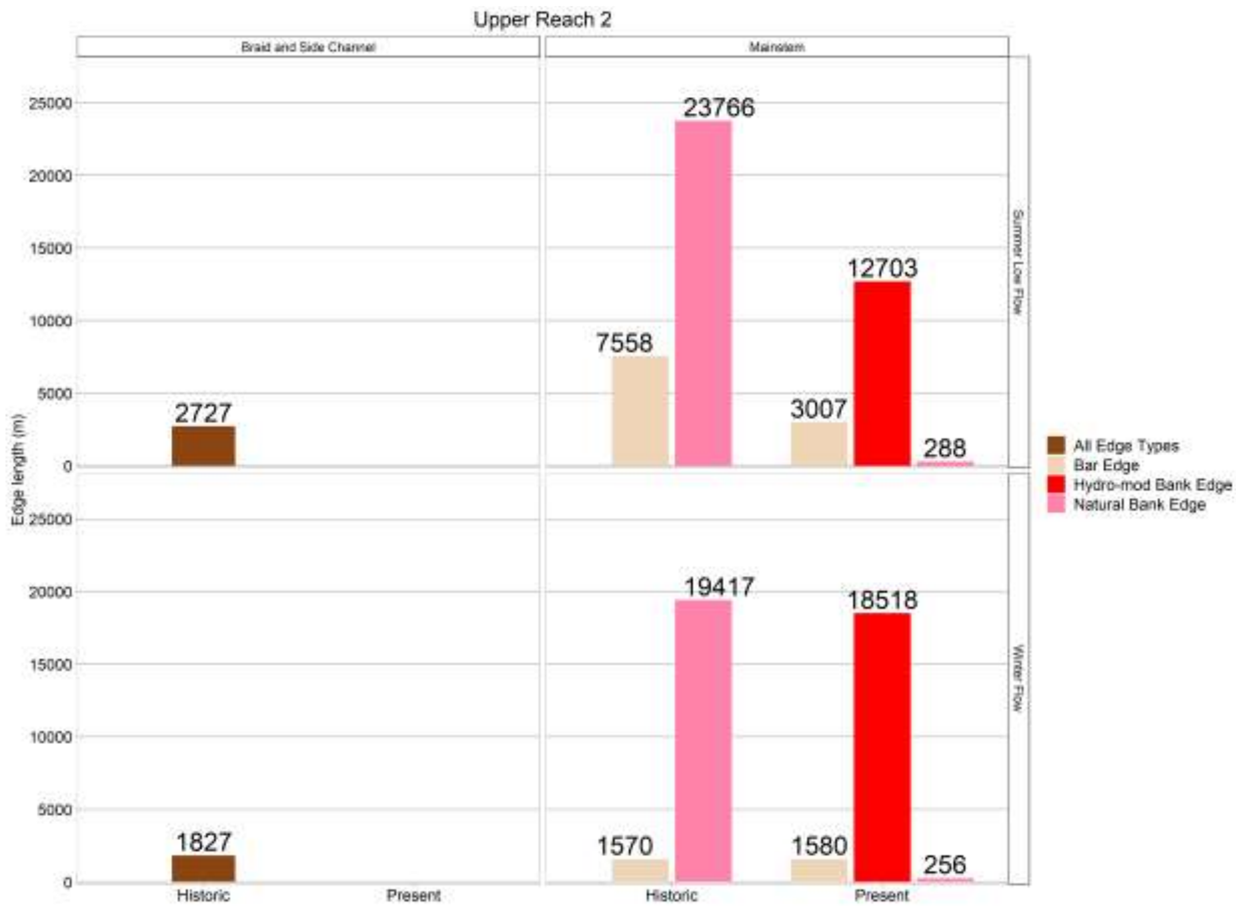

Figure 129: Edge lengths (meters) of bank types for summer low flow and winter flow conditions for historic versus present data. Edge type data for historic braid and side-channel habitats were not available. No braid or side-channel habitat was observed in Upper Reach 2.

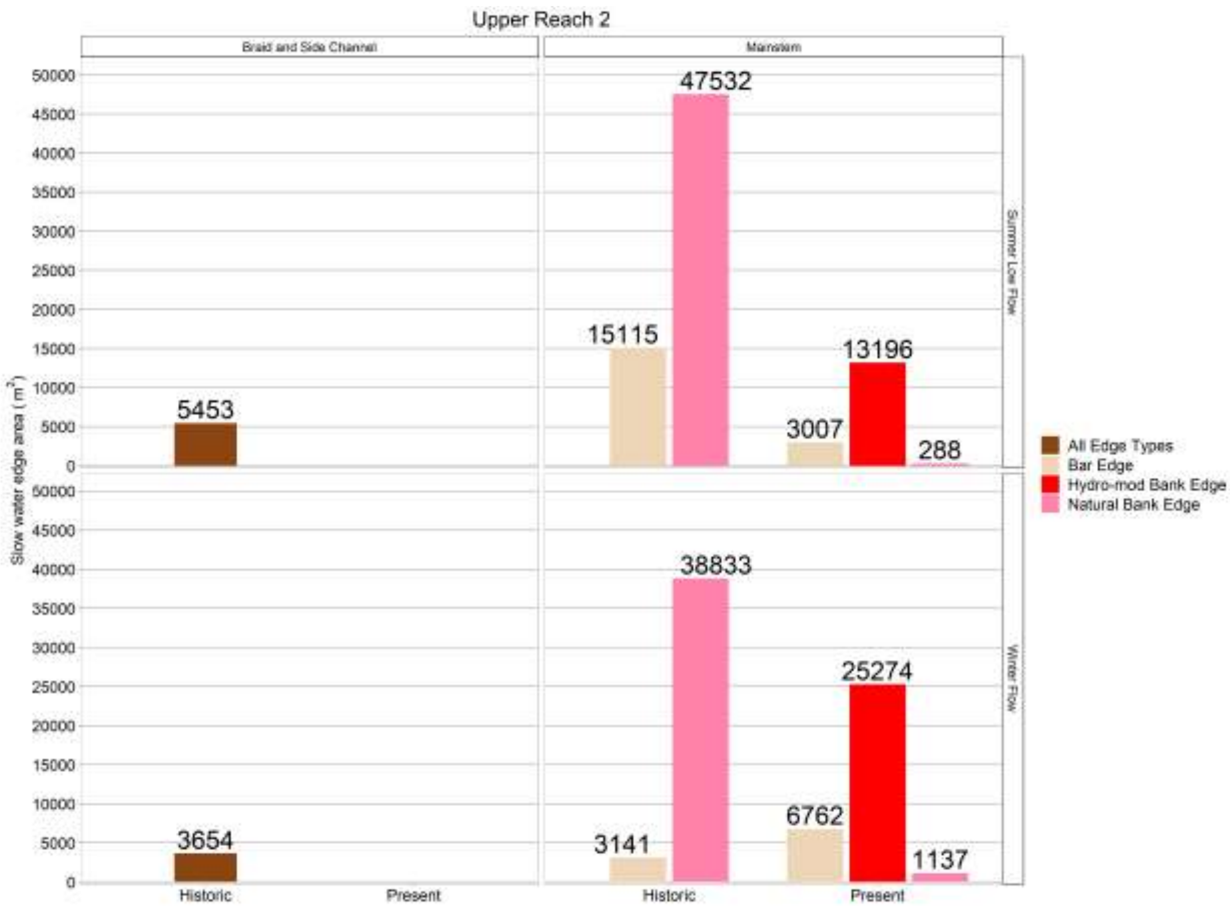

Figure 130: Slow water edge area (meters^2) for bank types for summer low flow and winter flow conditions for historic versus present data. Edge type data for historic braid and side-channel habitats were not available. No braid or side-channel habitat was observed in Upper Reach 2.

Reach: Lower Reach 3

Table 51: Mainstem habitat unit and edge summaries for surveys of Lower Reach 3. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

Flow Condition	Channel Type	Dominant Unit Type	n	Total		Bar Edge		Natural Bank Edge		Hydro-modified Bank Edge	
				Area (meters²)	Length (meters)	Length (meters)	Slow-water Edge Area (meters²)	Length (meters)	Slow-water Edge Area (meters²)	Length (meters)	Slow-water Edge Area (meters²)
Winter flow (Jan-19)	Mainstem	Glide	11	483,583	8,230	2,413	6,298	1,481	4,921	12,567	28,445
		Pool	1	13,351	169	169	169	0	0	169	439
		Riffle	1	4,650	100	90	90	0	0	110	250
		Backwater	-	-	-	-	-	-	-	-	-
		Total	13	501,584	8,499	2,672	6,557	1,481	4,921	12,846	29,134
	Braid	Glide	4	1,016	158	197	197	85	85	34	34
		Pool	5	2,982	232	218	218	67	67	179	235
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	9	3,998	390	415	415	152	152	213	269
	Side Channel	Glide	2	351	91	39	39	52	52	91	91
		Pool	4	1,594	148	0	0	274	274	21	21
		Riffle	2	128	45	53	53	36	36	0	0
		Backwater	4	4,297	490	406	406	574	574	0	0
		Total	12	6,371	773	498	498	936	936	112	112
Summer Low Flow (Mar-18)	Mainstem	Glide	9	346,888	6,111	3,609	4,709	1,101	1,101	7,513	9,258
		Pool	2	19,083	473	331	347	0	0	615	615
		Riffle	9	72,028	1,288	1,065	2,012	418	418	1,093	1,865
		Backwater	-	-	-	-	-	-	-	-	-
		Total	20	437,998	7,872	5,005	7,067	1,518	1,518	9,221	11,738
	Braid	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-
	Side Channel	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-

Table 52: Mainstem riparian, large woody debris, and substrate summaries for Lower Reach 3. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

Flow Condition	Channel Type	Dominant Unit Type	Riparian	Large Wood Jams		Dominant Substrate			
			% Canopy Closure	n	Cover Area (meters^2)	% Fines	% Sand	% Gravel	% Cobble
Winter flow (Jan-19)	Mainstem	Glide	2.2	0	0	ND	ND	ND	ND
		Pool	1.0	0	0	ND	ND	ND	ND
		Riffle	1.0	0	0	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	1.4	0	0	ND	ND	ND	ND
	Braid	Glide	8.3	0	0	ND	ND	ND	ND
		Pool	26.0	2	240	ND	ND	ND	ND
		Riffle	-	-	-	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	17.2	2	240	ND	ND	ND	ND
	Side Channel	Glide	22.5	0	0	100	0	0	0
		Pool	9.3	1	40	100	0	0	0
		Riffle	11.0	0	0	100	0	0	0
		Backwater	8.8	1	72	100	0	0	0
		Total	12.9	2	112	100	0	0	0
Summer Low Flow (Mar-18)	Mainstem	Glide	2.0	3	156	ND	ND	ND	ND
		Pool	2.0	0	0	ND	ND	ND	ND
		Riffle	1.6	1	25	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	1.9	4	181	ND	ND	ND	ND
	Braid	Glide	-	-	-	ND	ND	ND	ND
		Pool	-	-	-	ND	ND	ND	ND
		Riffle	-	-	-	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	-	-	-	ND	ND	ND	ND
	Side Channel	Glide	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-

Table 53: Floodplain habitat unit, riparian, large woody debris, and substrate summary for Lower Reach 3. Estimated lengths were derived from WDFW hydrography (WDFW regulatory layer) based on ratios derived in **Table 54**. Wetlands areas were estimated from the NWI (USFWS 2017), no lengths were estimated for wetland units due to lack of adequate data. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

			Habitat Units				**Riparian**	**Large Wood Jams**			**Substrate**			
Flow Condition	**Channel Type**	**Dominant Unit Type**	**n**	**Area (meters²)**	**Length (meters)**	**Depth (meters)**	**% Canopy Closure**	**n**	**Total Wetted Cover Area (meters²)**	**Total # of Wetted Pieces**	**% Fines**	**% Sand**	**% Gravel**	**% Cobble**
Winter (Mar-18)	Hydro-modified natural channel	Glide	57	16,286	6,162	0.6	13.2	5	17.7	75	66	13	21	0
		Pool	9	744	197	0.6	15.7	0	0	1	56	11	33	0
		Riffle	15	1,478	566	0.3	9.3	1	0.7	0	60	20	20	0
		Ponded	9	11,459	717	0.7	11.7	0	0	8	100	0	0	0
		Estimated	-	71,457	15,984	-	-	-	-	-	-	-	-	-
		Total	90	101,424	23,627	0.5	12.5	6	18.4	84	70	11	19	0
	Tributary	Glide	46	25,722	4,311	0.9	14.5	6	202.4	79	91	9	0	0
		Pool	18	2,052	340	0.8	9.4	9	63.2	29	78	17	6	0
		Riffle	4	135	90	0.5	34.5	1	11.9	7	100	0	0	0
		Ponded	-	-	-	-	-	-	-	-	-	-	-	-
		Estimated	-	-	-	-	-	-	-	-	-	-	-	-
		Total	68	27,910	4,742	0.7	19.5	16	277.5	115	90	8	2	0
	Hydro-modified channel	Glide	18	2,763	1,419	0.3	9.4	2	5.3	13	87	13	0	0
		Pool	5	66	34	0.4	7.0	2	5.3	4	100	0	0	0
		Riffle	8	194	91	0.2	0.0	0	0	0	25	38	38	0
		Ponded	2	241	139	0.6	15.0	1	4.0	1	100	0	0	0
		Estimated	-	-	-	-	-	-	-	-	-	-	-	-
		Total	33	3,264	1,683	0.4	7.9	5	14.6	18	78	13	9	0
	Wetland	Wetland	2	23,200	520	ND	ND	0	0.0	0	0	0	0	0
		Estimated	-	612,862	NA	-	-	-	-	-	-	-	-	-
		Total	2	636,062	520	ND	ND	0	0.0	0	0	0	0	0
	Constructed channel	Glide	-	-	-	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	-	-	-	-	-	-	-	-	-	-	-	-
		Estimated	-	29,619	20,195	-	-	-	-	-	-	-	-	-
		Total	-	29,619	20,195	-	-	-	-	-	-	-	-	-

Table 54: Current summer floodplain habitats estimated using winter floodplain habitat survey data and ratios of wetted to dry channel derived from summer and winter habitat validation surveys for Lower Reach 3. An explanation for how ratios were derived is available in **Appendix B**.

	Winter floodplain		**Conversion**			**Summer floodplain estimates**		
	Total Area (meters²)	**Total Length (meters)**	**Wet Channel Area Ratio**	**Wet Channel Length Ratio**	**Dry channel Length ratio**	**Total Wet Area (meters²)**	**Total Wet Length (meters)**	**Total Dry Length (meters)**
Hydro-modified natural channel	101,424	23,627	0.5	0.5	0.5	54,259	12,490	11,280
Tributary	27,910	4,742	0.4	0.7	0.4	11,349	3,216	1,777
Hydro-modified channel	3,264	1,683	0.2	0.1	0.9	523	240	1,461
Wetland	636,062	520	0.6	1.0	0	393,408	520	0
Constructed channel	29,619	20,195	0.2	0.1	0.9	4,744	2,876	17,531

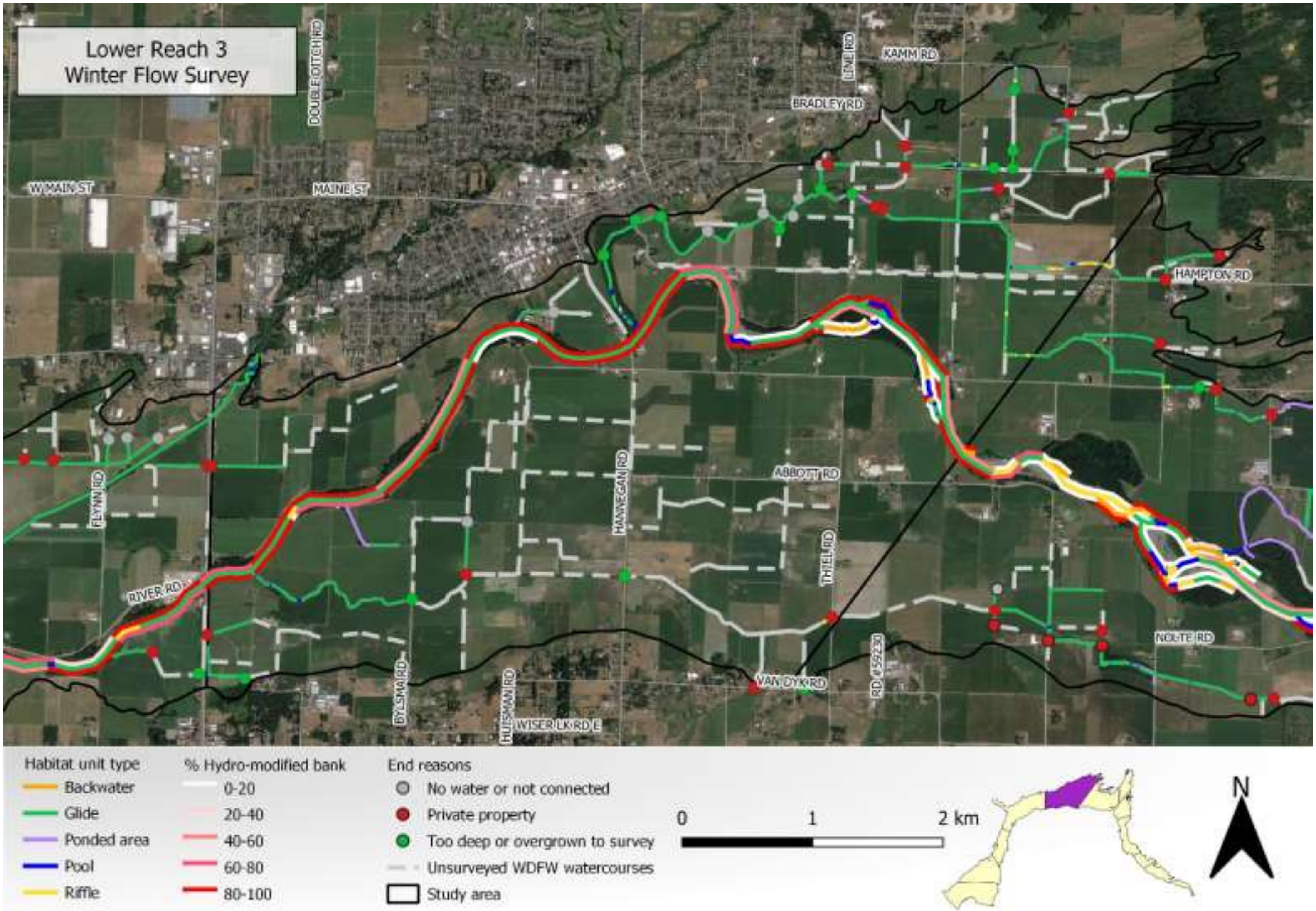

Figure 131: Map of hydro-modified banks and habitat units during winter flow conditions for Lower Reach 3. Average daily flows at the Cedarville gage ranged from 2,750 to 7,600 cfs for mainstem surveys and 1,400 to 4,200 cfs for floodplain surveys. WDFW watercourses that were not field surveyed in this effort are shown in gray.

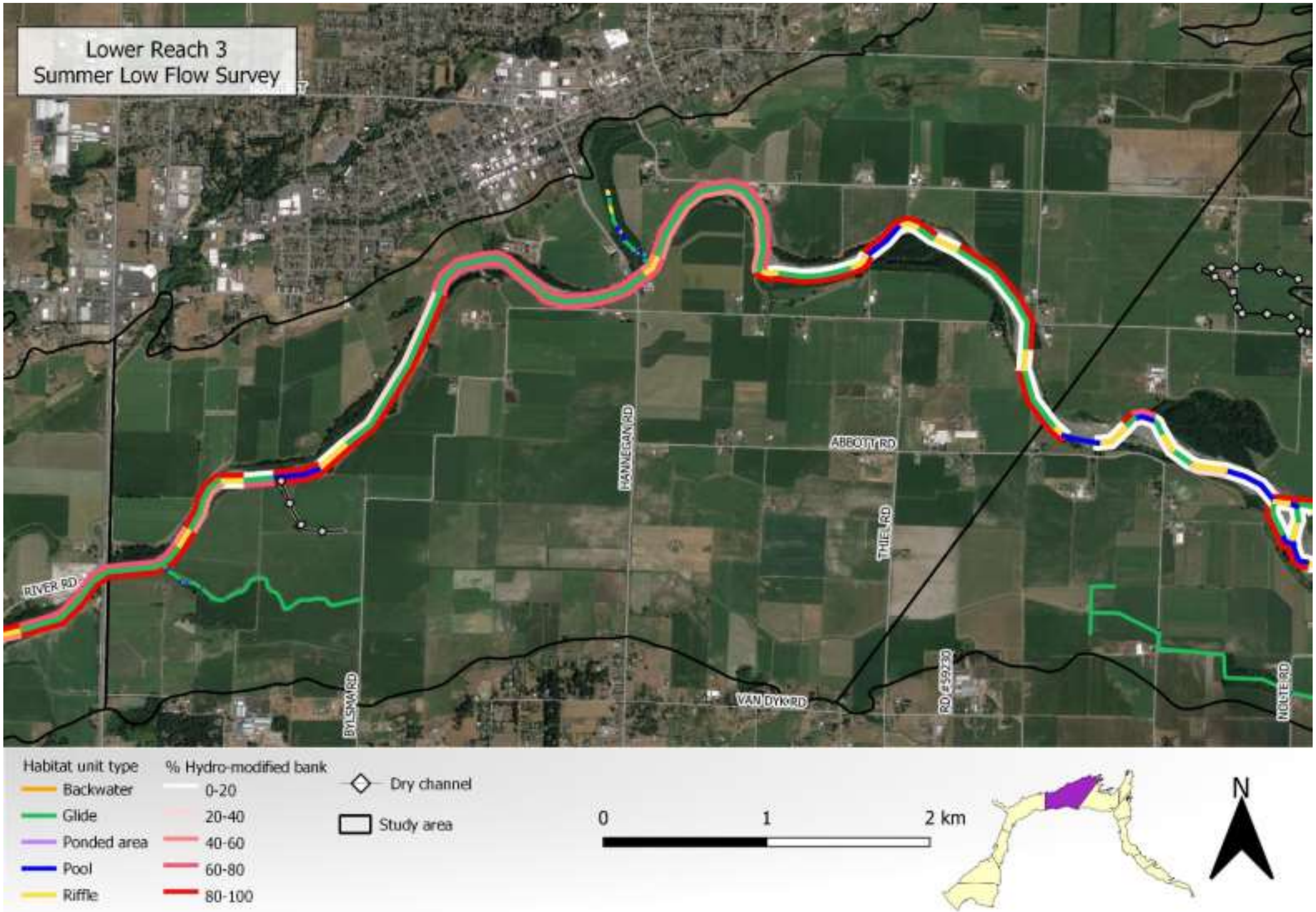

Figure 132: Map of hydro-modified banks and habitat units during summer low flow conditions for Lower Reach 3. Average daily flows at the Cedarville gage ranged from 1,400 to 1,500 cfs for mainstem surveys and 1,500 to 2,500 cfs for floodplain surveys. Summer low flow floodplain surveys were completed as a subset of winter flow surveys. All WDFW watercourses are shown in **Figure 133**.

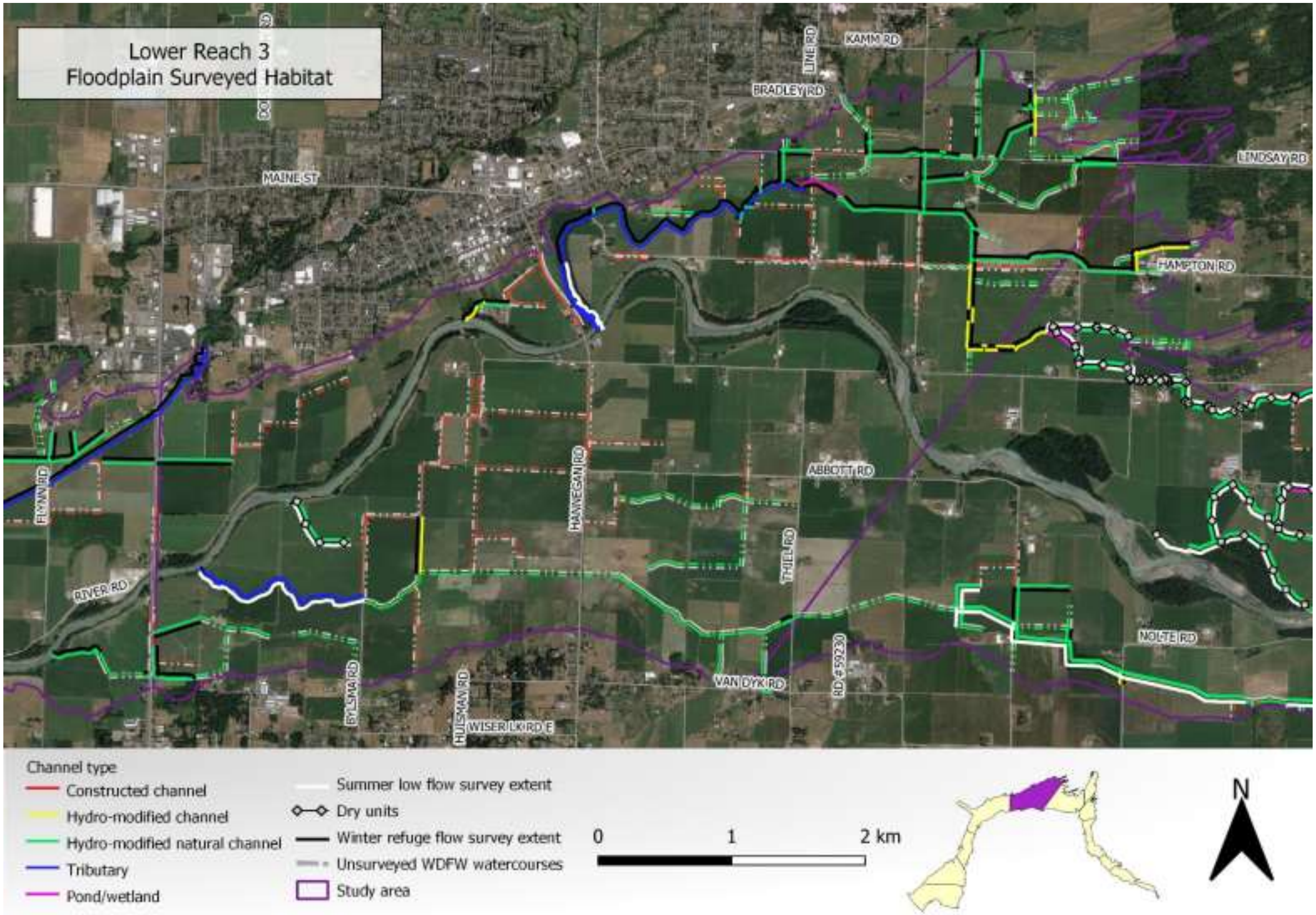

Figure 133: Map of summer and winter floodplain survey extents by channel type for Lower Reach 3. Summer low flow floodplain surveys were conducted as a subset of the winter floodplain survey extent when flows at the Cedarville gage ranged from 1,500 to 2,500 cfs. Channel types adapted from Washington Department of Fish and Wildlife's classifications (WDFW Regulatory Layer). Summer floodplain channel lengths areas were estimated using the ratio of wet to dry channels applied to winter floodplain channel lengths and areas. Detailed methods are provided in **Appendix B**.

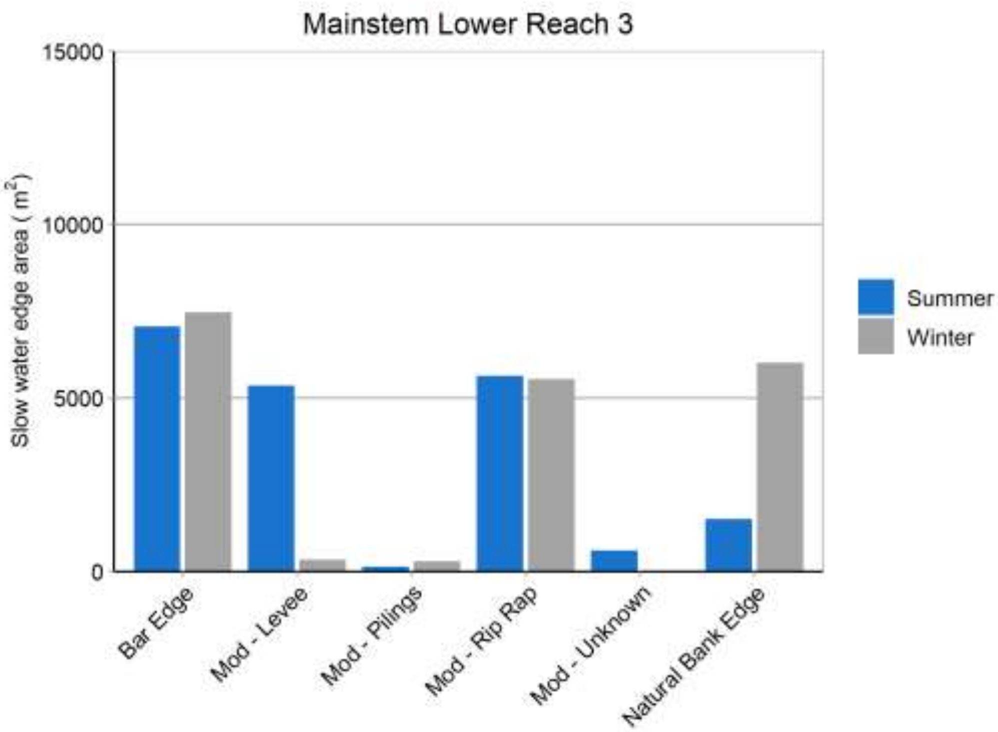

Figure 134: Slow water edge area (meters^2) of edges by edge type surveyed for present day mainstem surveys for summer low flow and winter flow surveys for Lower Reach 3.

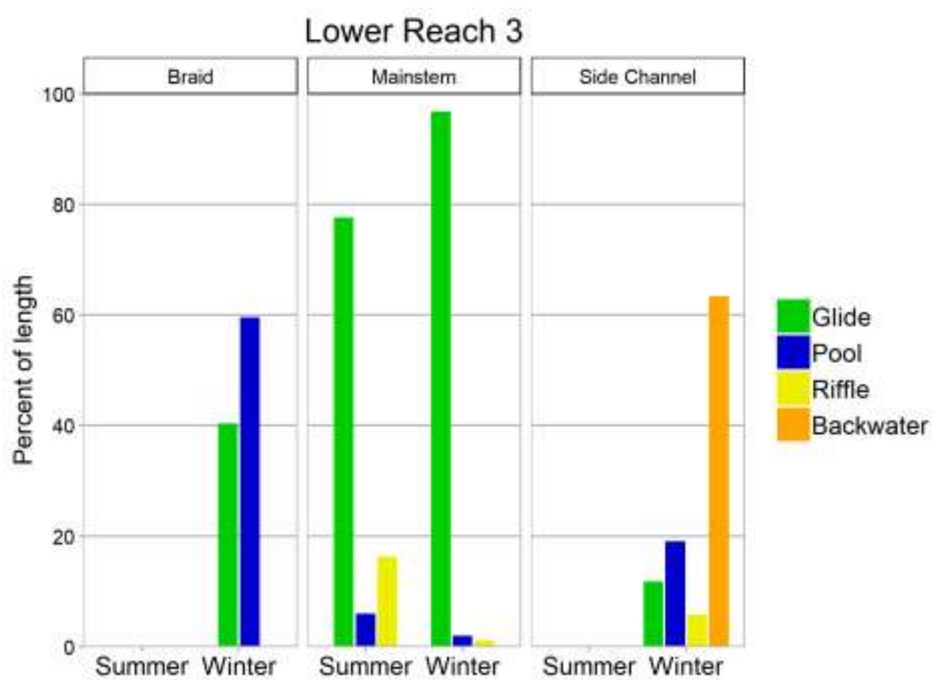

Figure 135: Percent of length surveyed in glide, pool, and riffle habitats for each channel type in mainstem surveys for summer low flow and winter flow surveys for Lower Reach 3.

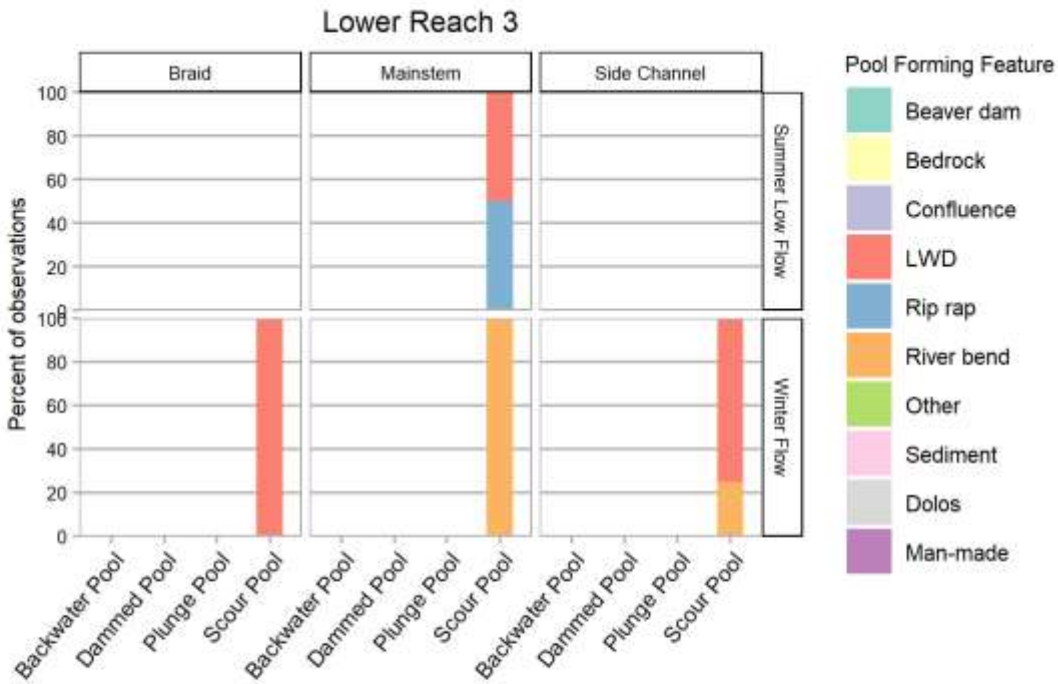

Figure 136: Percent of pool observations by pool type and pool forming feature for Lower Reach 3 for mainstem habitats.

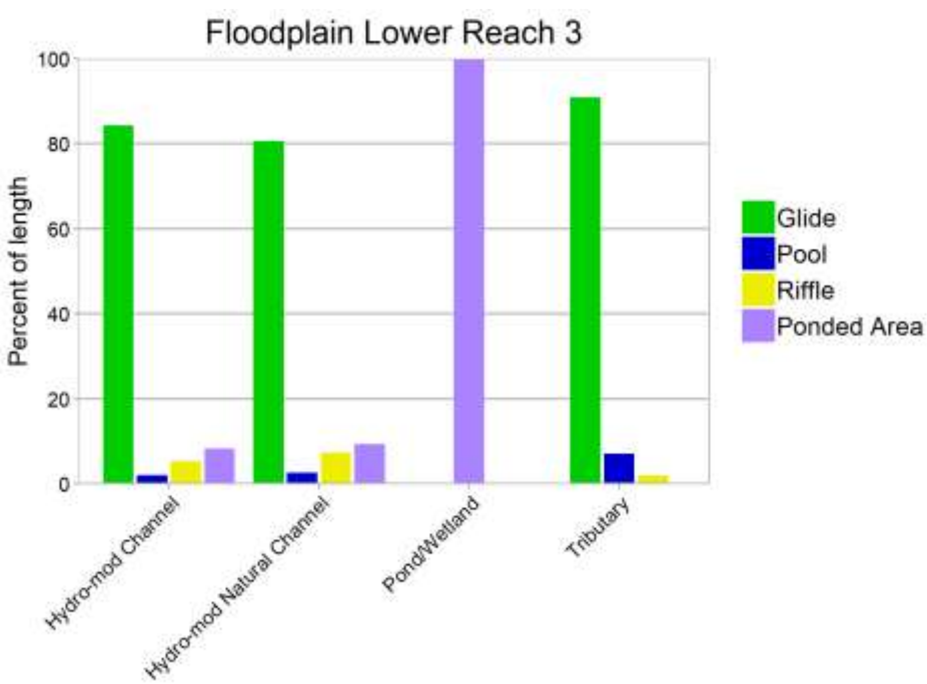

Figure 137: Percent of length surveyed in glide, pool, and riffle habitats for channel types in winter flow floodplain surveys for Lower Reach 3.

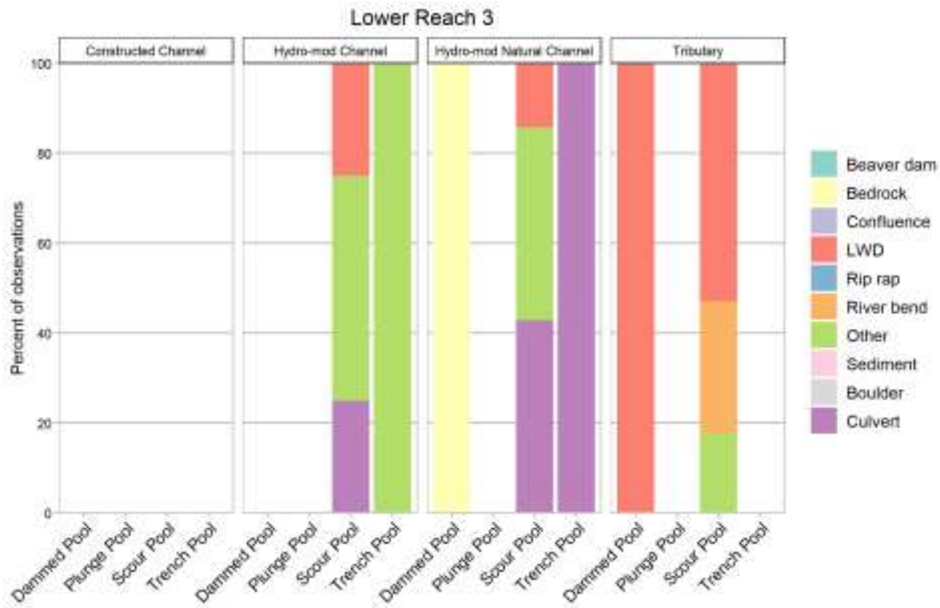

Figure 138: Percent of pool observations by pool type and pool forming feature for Lower Reach 3 for floodplain habitats. Other refers to pool s where the forming feature was unable to be determined.

Table 55: Historical and current habitat summarized at same resolution as historical data for Lower Reach 3. For historical reconstructions; no differences in summer and winter condition were derived for floodplain and estuary habitats; total areas are derived from polygon feature areas and line feature lengths assuming a 1-meter width; total lengths are derived from line length for polyline features and polygon perimeters divided by two; total edges are derived from line feature lengths plus polygon perimeters; and slow-water edge areas are derived from two times the total edge lengths. Estuary habitats were not observed in this reach and are not included in this table.

				Historic circa 1880s				Current circa 2018/2019			
Flow	**Habitat Strata**	**Habitat Type**	**Channel Type**	**Area (meters^2)**	**Length (meters)**	**Edge Length (meters)**	**Slow-water Edge Area (meters^2)**	**Area (meters^2)**	**Length (meters)**	**Edge Length (meters)**	**Slow-water Edge Area (meters^2)**
Winter Flow	Floodplain	Secondary	Slough and Tributary	61,405	20,217	NA	NA	162,217	50,247	NA	NA
		Pond/Wetland	Pond/Wetland	6,355,107	NA	NA	NA	636,062	NA	NA	NA
	Mainstem	Secondary	Side-Channel/Braid	NA	1,374	2,747	5,494	10,369	1,163	2,326	2,382
		Mainstem	Natural Bank Edge	NA	NA	19,659	39,317	NA	NA	1,481	4,921
			Modified Bank Edge	NA	NA	0	0	NA	NA	12,846	29,134
			Bar Edge	NA	NA	2,109	4,219	NA	NA	2,672	6,557
Summer Low Flow	Floodplain	Secondary	Slough and Tributary	61,405	20,217	NA	NA	70,875	18,821	NA	NA
		Pond/Wetland	Pond/Wetland	3,930,675	NA	NA	NA	393,408	NA	NA	NA
	Mainstem	Secondary	Side-Channel/Braid	NA	2,050	4,100	8,201	0	0	0	0
		Mainstem	Natural Bank Edge	NA	NA	24,060	48,120	NA	NA	1,518	1,518
			Modified Bank Edge	NA	NA	0	0	NA	NA	9,221	11,738
			Bar Edge	NA	NA	8,430	16,859	NA	NA	5,005	7,067

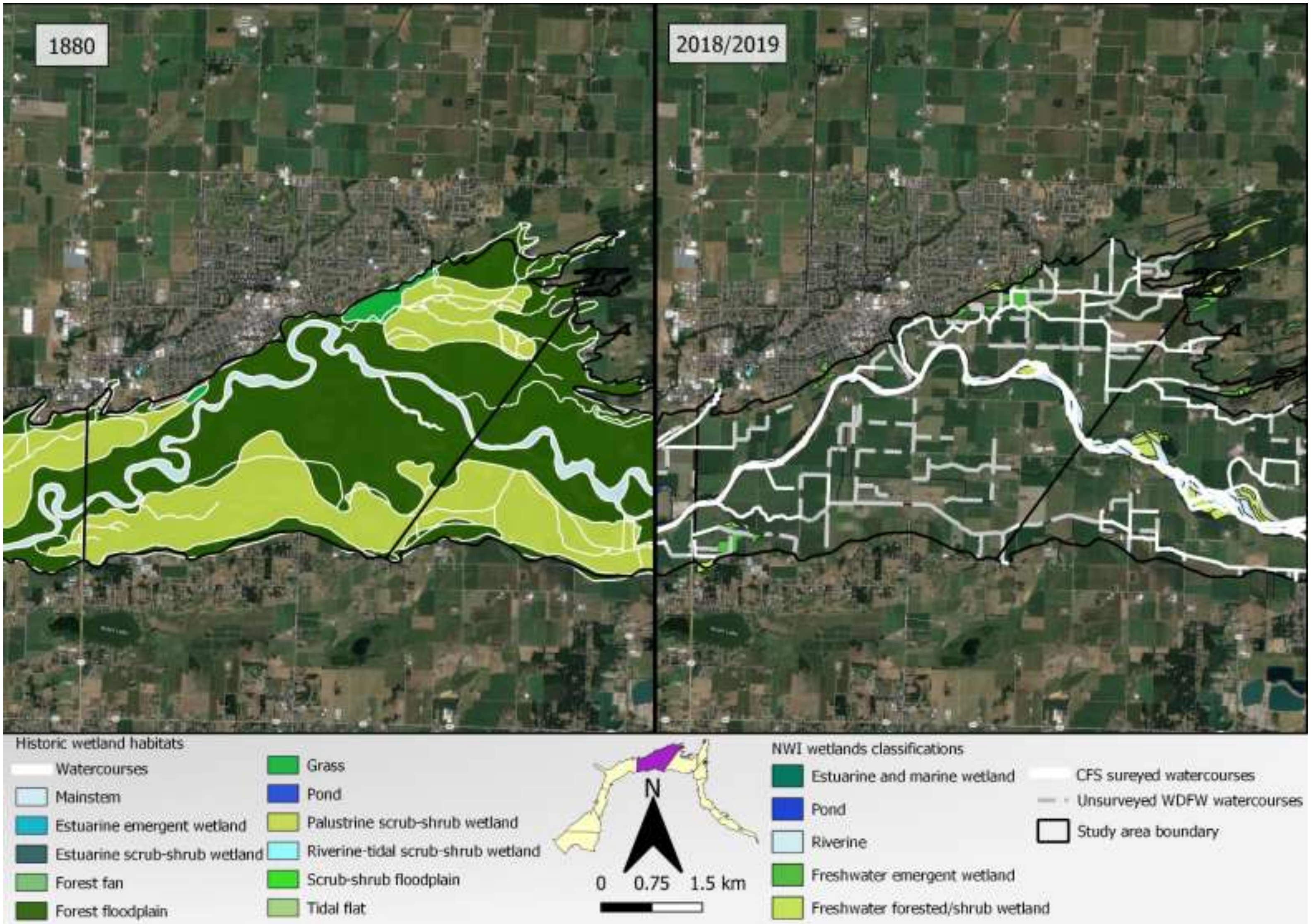

Figure 139: Map of current winter habitat and historical winter habitat extents (Collins and Sheikh) for Lower Reach 3. Surveyed watercourses and unsurveyed watercourses from current surveys are depicted, current wetland habitats are from the from the NWI (USFWS 2017).

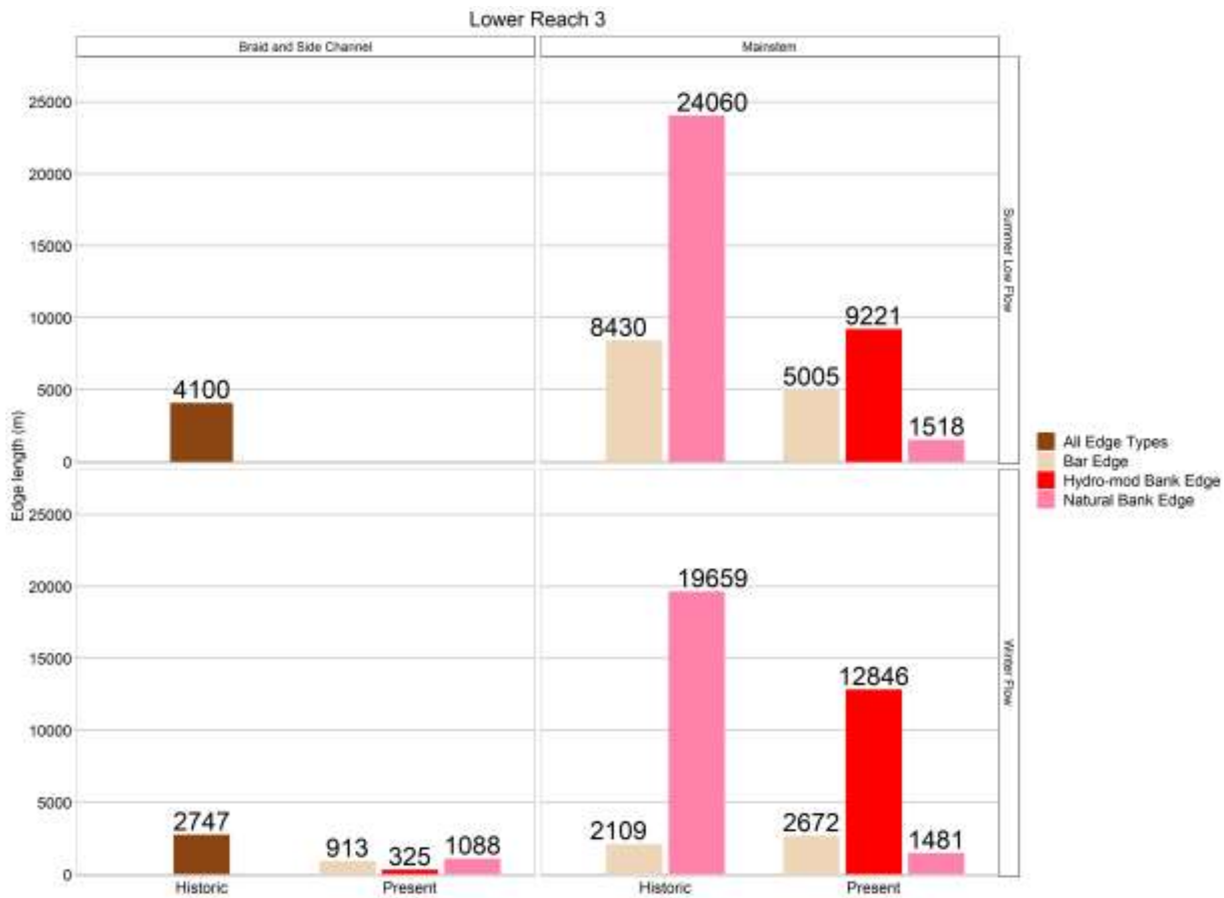

Figure 140: Edge lengths (meters) of bank types for summer low flow and winter flow conditions for historic versus present data For Lower Reach 3. Edge type data for historic braid and side-channel habitats were not available.

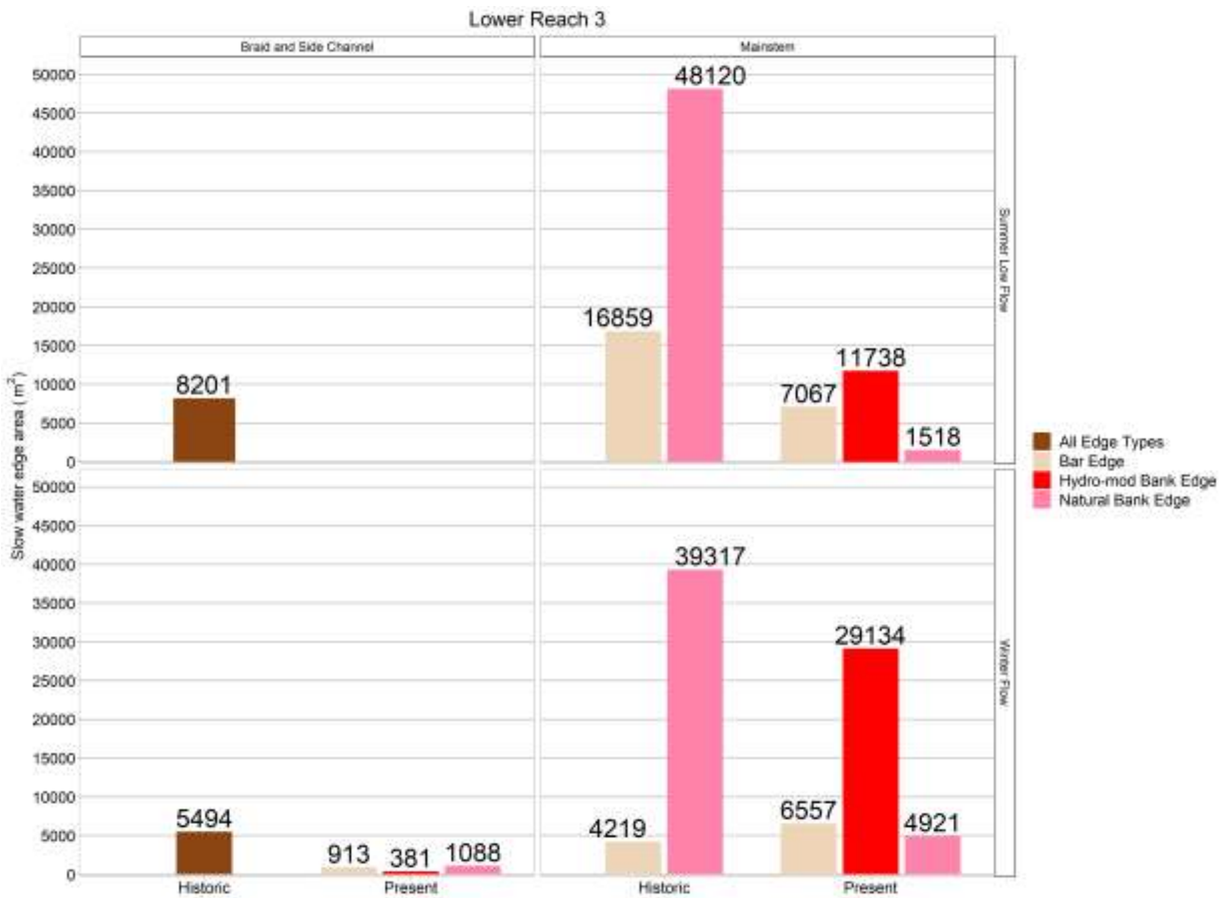

Figure 141: Slow water edge area (meters^2) for bank types for summer low flow and winter flow conditions for historic versus present data. Edge type data for historic braid and side-channel habitats were not available.

Reach: Upper Reach 3

Table 56: Mainstem habitat unit and edge summaries for surveys of Upper Reach 3. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

				Total		Bar Edge		Natural Bank Edge		Hydro-modified Bank Edge	
Flow Condition	**Channel Type**	**Dominant Unit Type**	**n**	**Area (meters²)**	**Length (meters)**	**Length (meters)**	**Slow-water Edge Area (meters²)**	**Length (meters)**	**Slow-water Edge Area (meters²)**	**Length (meters)**	**Slow-water Edge Area (meters²)**
Winter flow (Jan-19)	Mainstem	Glide	6	274,659	4,389	3,153	3,661	2,266	3,306	3,359	4,737
		Pool	2	13,251	447	428	428	211	211	255	255
		Riffle	5	70,846	1,144	1,604	3,419	447	800	238	692
		Backwater	3	6,495	411	251	251	160	160	411	411
		Total	16	365,251	6,391	5,436	7,759	3,084	4,477	4,262	6,095
	Braid	Glide	14	16,968	1,086	1,098	1,787	644	644	430	430
		Pool	9	10,636	452	376	376	112	112	416	577
		Riffle	14	8,698	657	718	752	361	361	236	236
		Backwater	9	8,777	527	519	519	324	324	210	210
		Total	46	45,078	2,721	2,710	3,434	1,440	1,440	1,292	1,453
	Side Channel	Glide	8	12,070	638	300	384	809	977	168	168
		Pool	7	4,296	322	51	51	426	426	167	167
		Riffle	7	8,498	229	116	116	314	314	28	28
		Backwater	7	15,260	897	249	249	872	872	673	673
		Total	29	40,124	2,086	716	800	2,421	2,589	1,036	1,036
Summer Low Flow (Mar-18)	Mainstem	Glide	9	140,482	2,508	2,780	4,264	1,137	1,947	1,100	1,762
		Pool	8	58,533	1,166	1,166	1,962	579	1,308	587	918
		Riffle	10	96,295	1,491	1,540	2,269	934	1,175	508	590
		Backwater	-	-	-	-	-	-	-	-	-
		Total	27	295,310	5,165	5,485	8,495	2,649	4,430	2,196	3,270
	Braid	Glide	9	20,216	982	1,315	1,348	527	527	121	121
		Pool	2	5,384	179	179	210	77	77	102	102
		Riffle	6	8,203	376	468	611	210	210	75	75
		Backwater	-	-	-	-	-	-	-	-	-
		Total	17	33,803	1,537	1,962	2,168	814	814	298	298
	Side Channel	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-

Table 57: Mainstem riparian, large woody debris, and substrate summaries for Upper Reach 3. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

Flow Condition	Channel Type	Dominant Unit Type	Riparian	Large Wood Jams		Dominant Substrate			
			% Canopy Closure	n	Cover Area (meters^2)	% Fines	% Sand	% Gravel	% Cobble
Winter flow (Jan-19)	Mainstem	Glide	1.5	5	787	ND	ND	ND	ND
		Pool	2.0	1	144	ND	ND	ND	ND
		Riffle	3.0	1	10	ND	ND	ND	ND
		Backwater	10.0	0	0	ND	ND	ND	ND
		Total	4.1	7	941	ND	ND	ND	ND
	Braid	Glide	12.0	1	100	ND	ND	ND	ND
		Pool	25.8	0	0	ND	ND	ND	ND
		Riffle	16.7	0	0	ND	ND	ND	ND
		Backwater	14.3	3	628	ND	ND	ND	ND
		Total	17.2	4	728	ND	ND	ND	ND
	Side Channel	Glide	9.7	2	18	83	17	0	0
		Pool	17.2	1	16	33	17	50	0
		Riffle	18.2	0	0	40	0	40	20
		Backwater	20.5	1	1,140	57	0	43	0
		Total	16.4	4	1,174	53	8	33	5
Summer Low Flow (Mar-18)	Mainstem	Glide	1.9	5	2,231	ND	ND	ND	ND
		Pool	1.1	4	1,124	ND	ND	ND	ND
		Riffle	1.8	2	307	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	1.6	11	3,661	ND	ND	ND	ND
	Braid	Glide	3.5	1	85	ND	ND	ND	ND
		Pool	1.0	0	0	ND	ND	ND	ND
		Riffle	4.0	0	0	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	2.8	1	85	ND	ND	ND	ND
	Side Channel	Glide	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-

Table 58: Floodplain habitat unit, riparian, large woody debris, and substrate summary for Upper Reach 3. Estimated lengths were derived from WDFW hydrography (WDFW regulatory layer) based on ratios derived in **Table 59**. Wetlands areas were estimated from the NWI (USFWS 2017), no lengths were estimated for wetland units due to lack of adequate data. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

			Habitat Units				Riparian	Large Wood Jams			Substrate			
Flow Condition	**Channel Type**	**Dominant Unit Type**	**n**	**Area (meters^2)**	**Length (meters)**	**Depth (meters)**	**% Canopy Closure**	**n**	**Total Wetted Cover Area (meters^2)**	**Total # of Wetted Pieces**	**% Fines**	**% Sand**	**% Gravel**	**% Cobble**
Winter (Mar-18)	Hydro-modified natural channel	Glide	52	16,233	5,714	0.5	19.2	0	0	24	90	0	8	0
		Pool	16	2,471	313	0.6	16.1	0	0	23	81	6	6	0
		Riffle	6	281	135	0.3	9.4	0	0	0	50	17	33	0
		Ponded	18	32,118	2,421	0.6	26.2	1	0.7	11	78	0	0	0
		Estimated	-	12,788	5,714	-	-	-	-	-	-	-	-	-
		Total	92	63,889	14,297	0.5	17.7	1.0	0.7	58	75	6	12	0
	Tributary	Glide	-	-	-	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	-	-	-	-	-	-	-	-	-	-	-	-
		Estimated	-	-	-	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-	-	-	-
	Hydro-modified channel	Glide	12	3,247	1,474	0.4	23.8	0	0	0	100	0	0	0
		Pool	3	158	89	0.4	12.5	0	0	0	100	0	0	0
		Riffle	1	13	13	0.1	0.0	0	0	0	0	100	0	0
		Ponded	2	85	134	0.2	5.0	0	0	0	100	0	0	0
		Estimated	-	-	-	-	-	-	-	-	-	-	-	-
		Total	18	3,503	1,710	0.3	10.3	0.0	0.0	0	75	25	0	0
	Wetland	Wetland	-	-	-	-	-	-	-	-	-	-	-	-
		Estimated	-	641,871	NA	-	-	-	-	-	-	-	-	-
		Total	-	641,871	-	-	-	-	-	-	-	-	-	-
	Constructed channel	Glide	2	268	87	0.6	12.5	5	71.6	6	100	0	0	0
		Pool	1	12	6	0.6	5.0	1	6	0	100	0	0	0
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	1	519	85	1.7	1.0	4	57.8	6	100	0	0	0
		Estimated	-	4,444	3,187	-	-	-	-	-	-	-	-	-
		Total	4	5,243	3,364	0.9	6.2	10.0	135.4	12	100	0	0	0

Table 59: Current summer floodplain habitats estimated using winter floodplain habitat survey data and ratios of wetted to dry channel derived from summer and winter habitat validation surveys for Upper Reach 3. An explanation for how ratios were derived is available in **Appendix B**.

	Winter floodplain		Conversion			Summer floodplain estimates		
	Total Area (meters^2)	**Total Length (meters)**	**Wet Channel Area Ratio**	**Wet Channel Length Ratio**	**Dry channel Length ratio**	**Total Wet Area (meters^2)**	**Total Wet Length (meters)**	**Total Dry Length (meters)**
Hydro-modified natural channel	63,889	14,297	0.5	0.5	0.5	34,179	7,558	6,826
Tributary	-	-	0.4	0.7	0.4	-	-	-
Hydro-modified channel	3,503	1,710	0.2	0.1	0.9	561	244	1,485
Wetland	641,871	-	0.6	1.0	0	397,001	-	-
Constructed channel	5,243	3,364	0.2	0.1	0.9	840	479	2,920

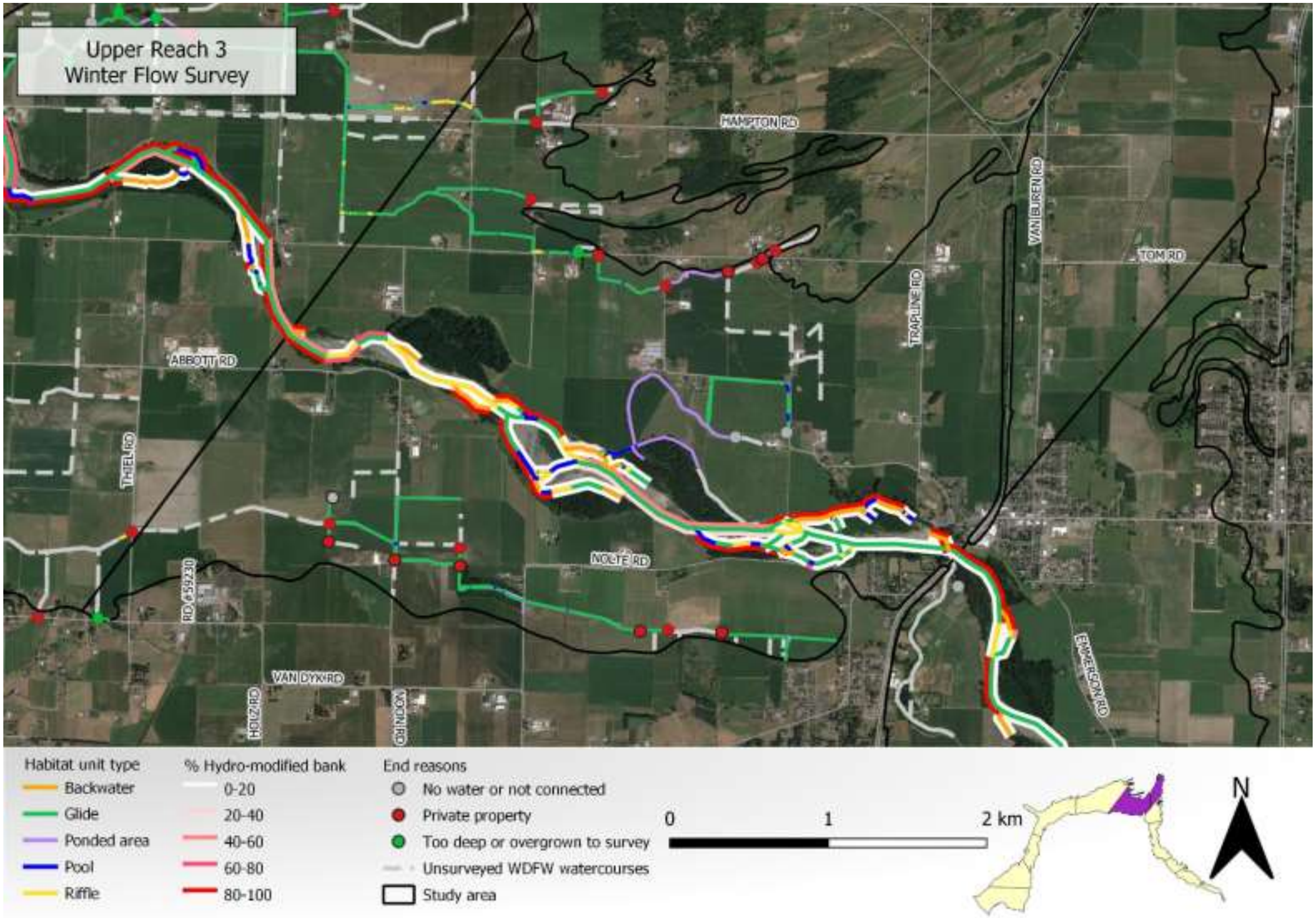

Figure 142: Map of hydro-modified banks and habitat units during winter flow conditions for Upper Reach 3. Average daily flows at the Cedarville gage ranged from 2,750 to 7,600 cfs for mainstem surveys and 1,400 to 4,200 cfs for floodplain surveys. WDFW watercourses that were not field surveyed in this effort are shown in gray.

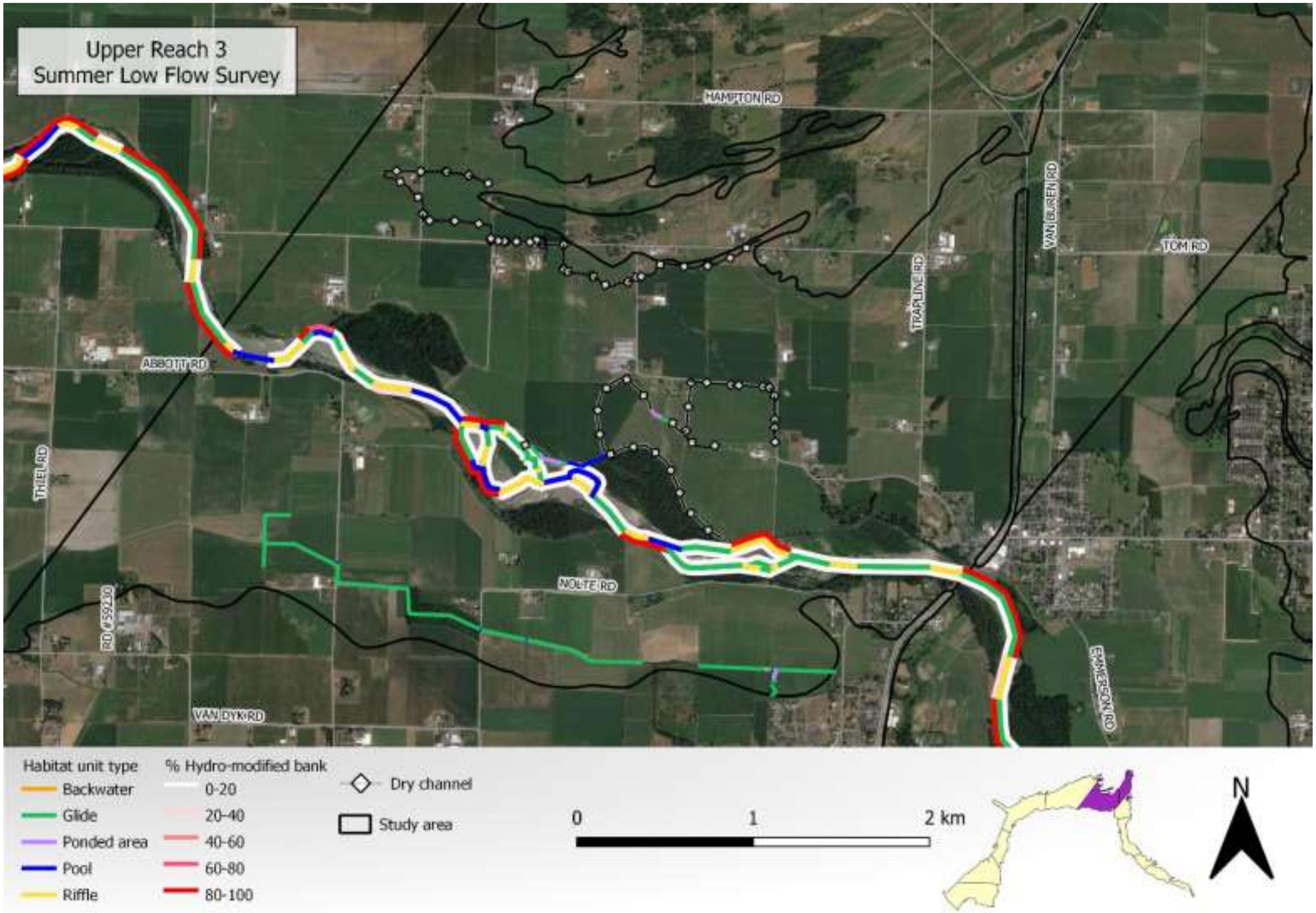

Figure 143: Map of hydro-modified banks and habitat units during summer low flow conditions for Upper Reach 3. Average daily flows at the Cedarville gage ranged from 1,400 to 1,500 cfs for mainstem surveys and 1,500 to 2,500 cfs for floodplain surveys. Summer low flow floodplain surveys were completed as a subset of winter flow surveys and only surveyed watercourses are shown. All WDFW watercourses are shown in **Figure 144**.

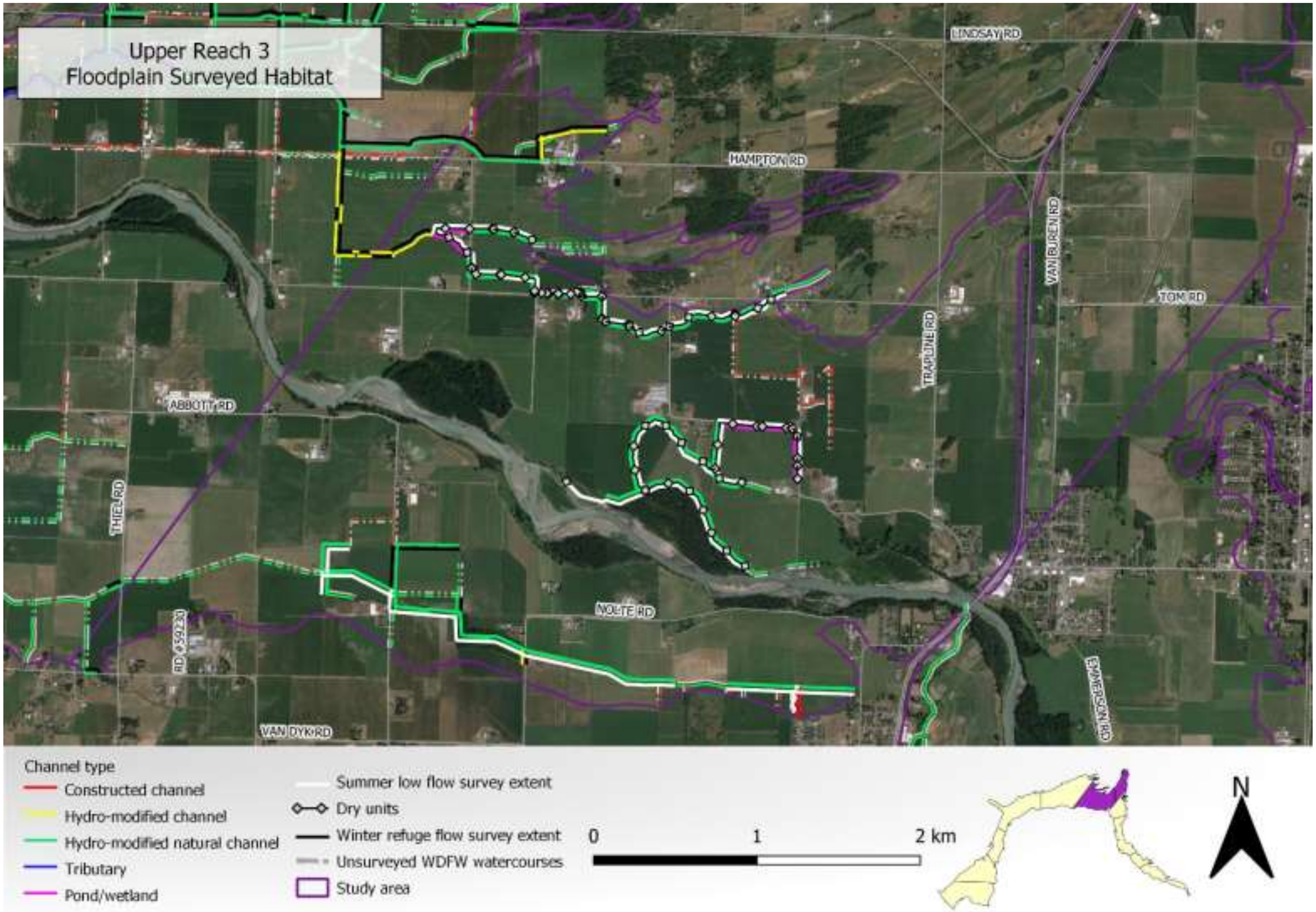

Figure 144: Map of overlapping summer and winter floodplain extent by channel type for Upper Reach 3. Summer low flow floodplain surveys were conducted as a subset of the winter floodplain survey extent when flows at the Cedarville gage ranged from 1,500 to 2,500 cfs. Channel types adapted from Washington Department of Fish and Wildlife's classifications (WDFW Regulatory Layer). Summer floodplain channel lengths areas were estimated using the ratio of wet to dry channels applied to winter floodplain channel lengths and areas. Detailed methods are provided in **Appendix B**.

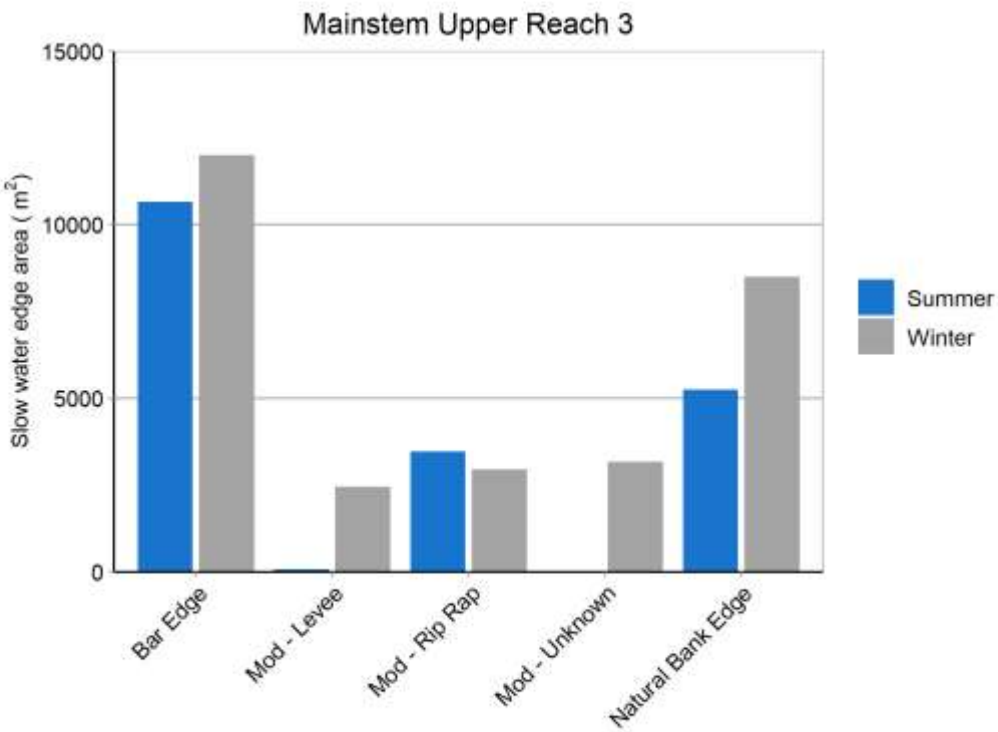

Figure 145: Slow water edge area (meters^2) of edges by edge type surveyed for present day mainstem surveys for summer low flow and winter flow surveys for Upper Reach 3.

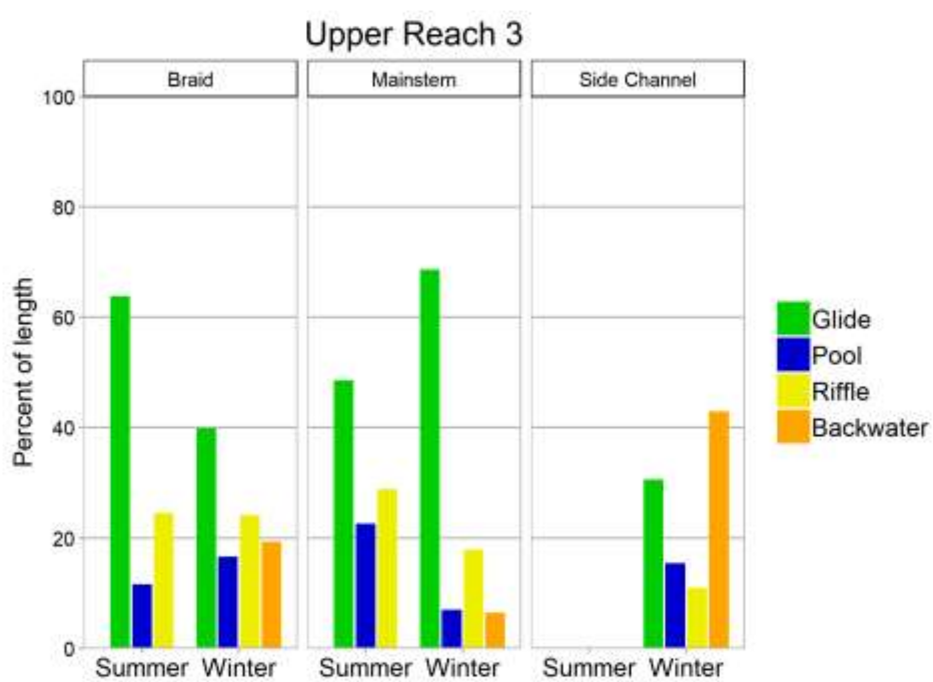

Figure 146: Percent of length surveyed in glide, pool, and riffle habitats for each channel type in mainstem surveys for summer low flow and winter flow surveys for Upper Reach 3.

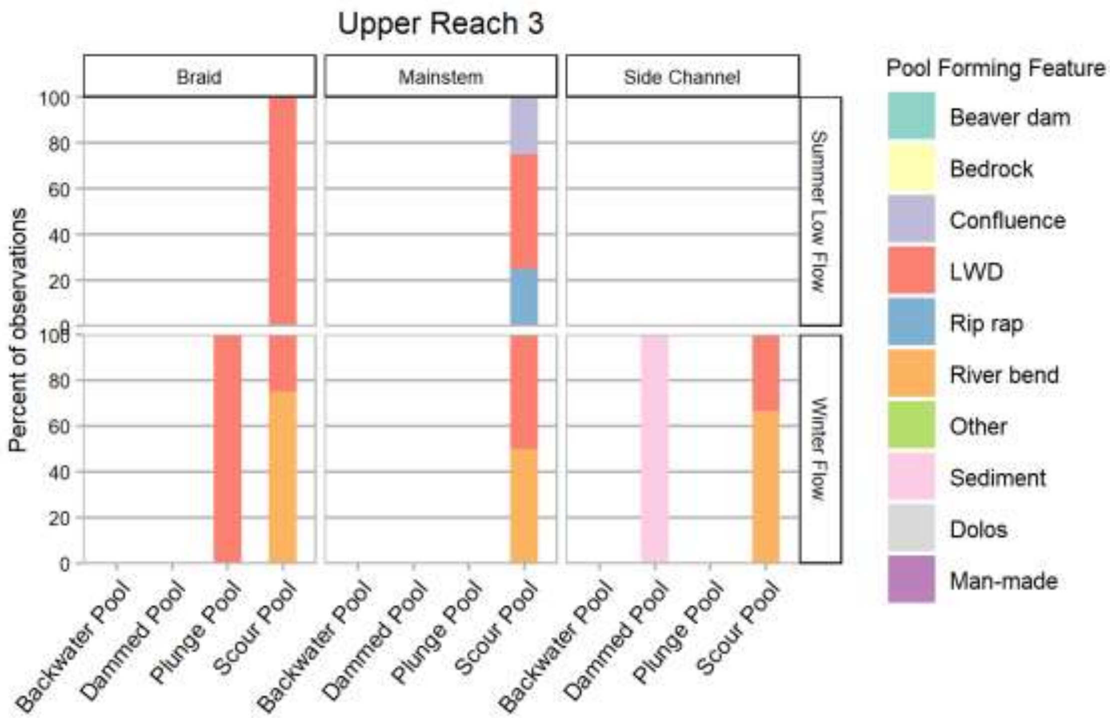

Figure 147: Percent of pool observations by pool type and pool forming feature for Upper Reach 3 for mainstem habitats.

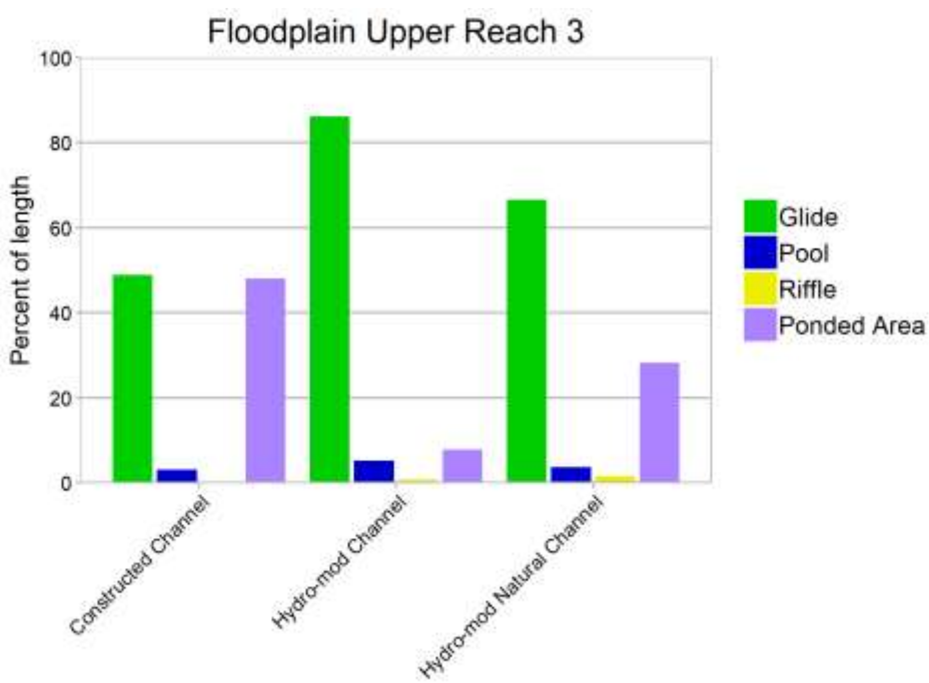

Figure 148: Percent of length surveyed in glide, pool, and riffle habitats for channel types in winter flow floodplain surveys for Upper Reach 3.

Figure 149: Percent of pool observations by pool type and pool forming feature for Upper Reach 3 for floodplain habitats. Other refers pools where the forming feature was unable to be determined.

Table 60: Historical and current habitat summarized at same resolution as historical data for Upper Reach 3. For historical reconstructions; no differences in summer and winter condition were derived for floodplain and estuary habitats; total areas are derived from polygon feature areas and line feature lengths assuming a 1-meter width; total lengths are derived from line length for polyline features and polygon perimeters divided by two; total edges are derived from line feature lengths plus polygon perimeters; and slow-water edge areas are derived from two times the total edge lengths. Estuary habitats were not observed in this reach and are not included in this table.

				Historic Circa 1880s				Current Circa 2018/2019			
Flow	Habitat Strata	Habitat Type	Channel Type	Area (meters^2)	Length (meters)	Edge Length (meters)	Slow-water Edge Area (meters^2)	Area (meters^2)	Length (meters)	Edge Length (meters)	Slow-water Edge Area (meters^2)
Winter Flow	Floodplain	Secondary	Slough and Tributary	5,689	5,689	NA	NA	72,636	19,371	NA	NA
		Pond/Wetland	Pond/Wetland	2,883,063	NA	NA	NA	641,871	NA	NA	NA
	Mainstem	Secondary	Side-Channel/Braid	NA	2,258	4,515	9,031	85,202	4,807	9,615	10,751
		Mainstem	Natural Bank Edge	NA	NA	6,577	13,153	NA	NA	3,084	4,477
			Modified Bank Edge	NA	NA	0	0	NA	NA	4,262	6,095
			Bar Edge	NA	NA	5,679	11,358	NA	NA	5,436	7,759
Summer Low Flow	Floodplain	Secondary	Slough and Tributary	5,689	5,689	NA	NA	35,580	8,280	NA	NA
		Pond/Wetland	Pond/Wetland	1,783,193	NA	NA	NA	397,001	NA	NA	NA
	Mainstem	Secondary	Side-Channel/Braid	NA	3,370	6,739	13,478	33,803	1,537	3,074	3,280
		Mainstem	Natural Bank Edge	NA	NA	8,287	16,575	NA	NA	2,649	4,430
			Modified Bank Edge	NA	NA	0	0	NA	NA	2,196	3,270
			Bar Edge	NA	NA	10,005	20,009	NA	NA	5,485	8,495

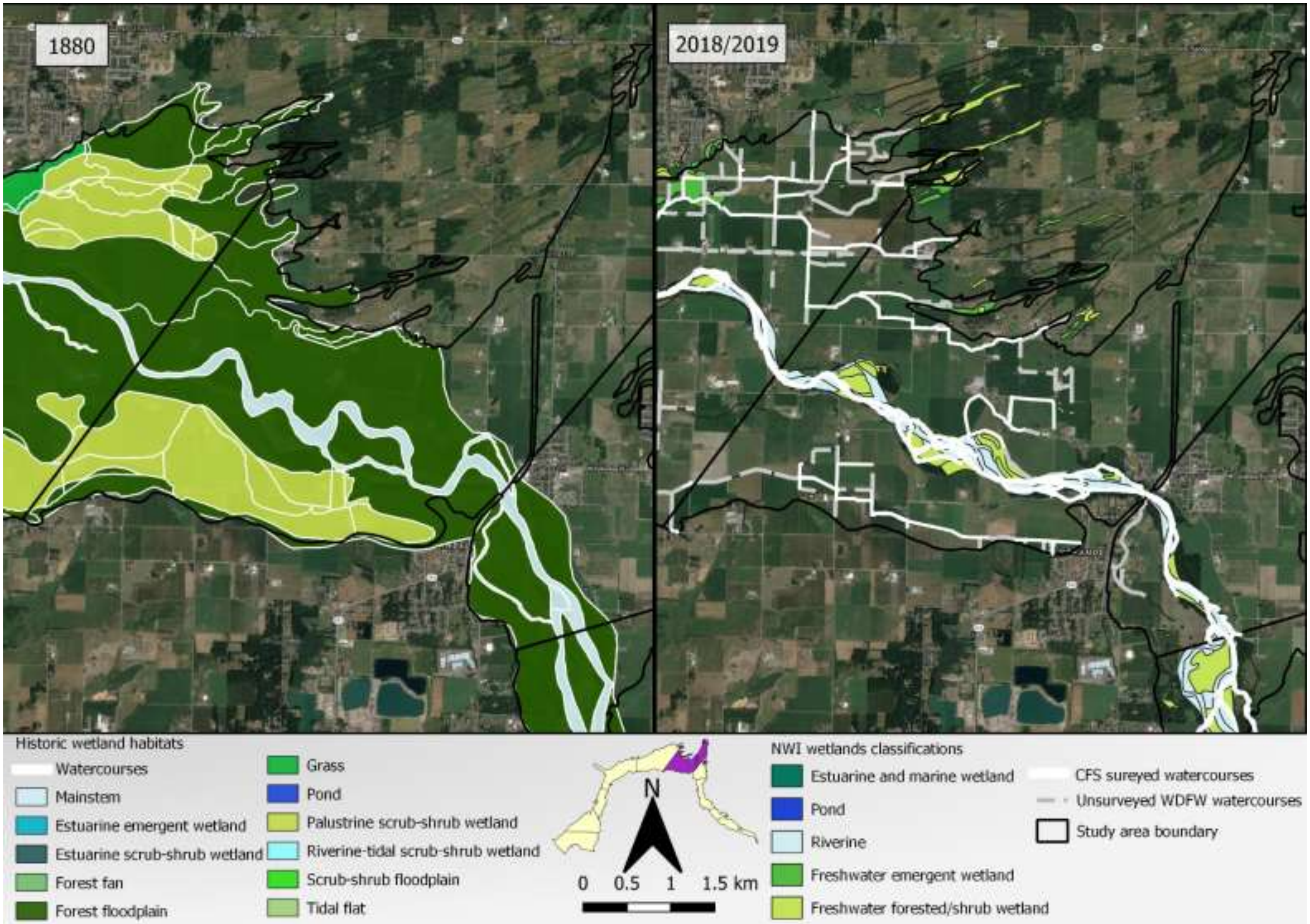

Figure 150: Map of current winter habitat and historical winter habitat extents (Collins and Sheikh) for Upper Reach 3. Surveyed watercourses and unsurveyed watercourses from current surveys are depicted, current wetland habitats are from the NWI (USFWS 2017).

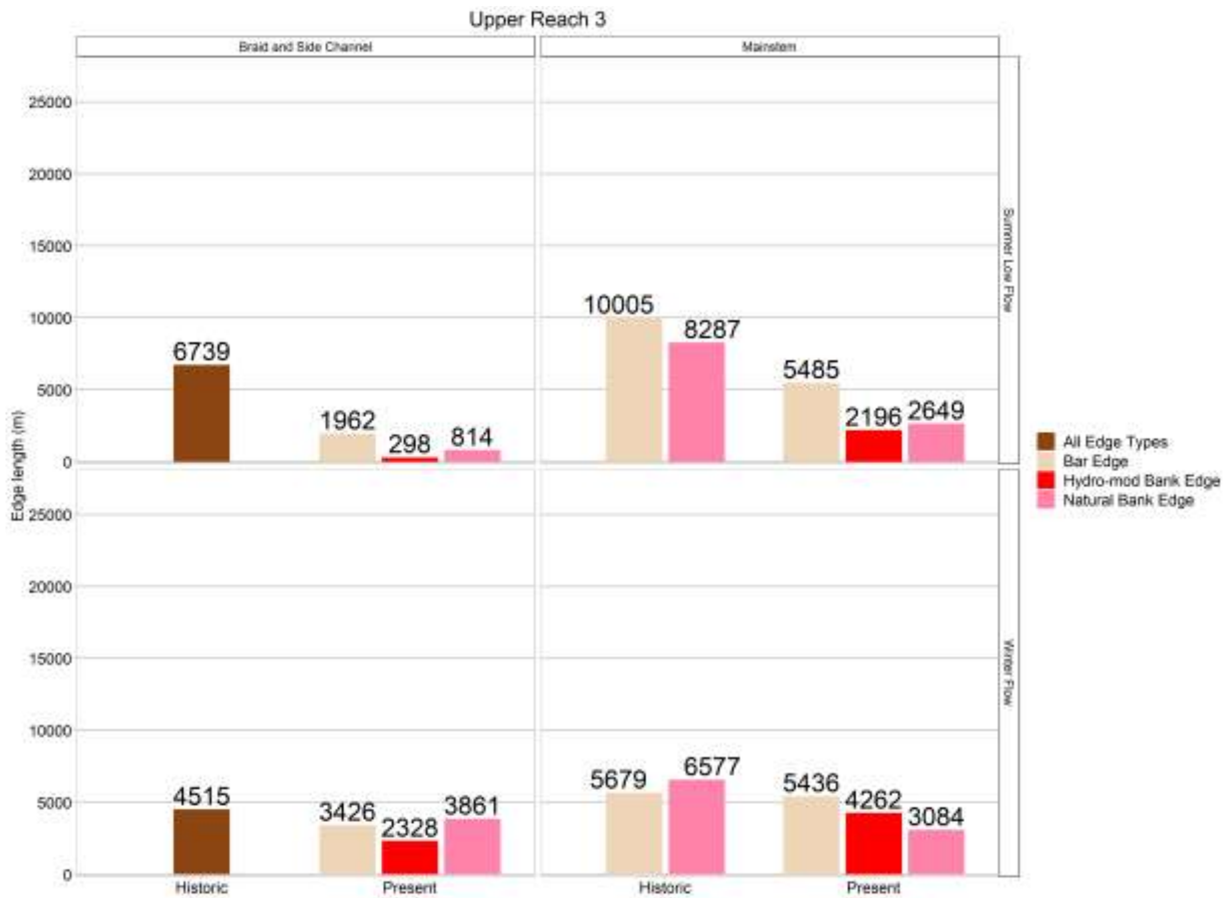

Figure 151: Edge lengths (meters) of bank types for summer low flow and winter flow conditions for historic versus present data for Upper Reach 3. Edge type data for historic braid and side-channel habitats were not available.

Figure 152: Slow water edge area (meters^2) for bank types for summer low flow and winter flow conditions for historic versus present data. Edge type data for historic braid and side-channel habitats were not available.

Reach: Lower Reach 4

Table 61: Mainstem habitat unit and edge summaries for surveys of Lower Reach 4. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

Flow Condition	Channel Type	Dominant Unit Type	n	Total		Bar Edge		Natural Bank Edge		Hydro-modified Bank Edge	
				Area (meters²)	Length (meters)	Length (meters)	Slow-water Edge Area (meters²)	Length (meters)	Slow-water Edge Area (meters²)	Length (meters)	Slow-water Edge Area (meters²)
Winter flow (Jan-19)	Mainstem	Glide	17	449,362	6,970	6,259	9,838	5,126	7,441	2,555	4,065
		Pool	7	84,398	1,609	2,203	2,798	381	963	634	1,131
		Riffle	15	216,041	3,325	3,746	5,061	2,038	2,281	866	992
		Backwater	-	-	-	-	-	-	-	-	-
		Total	39	749,801	11,904	12,208	17,697	7,545	10,685	4,056	6,189
	Braid	Glide	100	105,608	6,324	8,579	9,194	3,792	4,253	277	277
		Pool	40	23,925	1,606	1,979	2,364	1,151	1,224	83	83
		Riffle	92	66,898	3,979	5,530	6,577	2,377	2,587	51	51
		Backwater	15	15,812	1,077	1,224	1,224	750	750	180	180
		Total	247	212,244	12,987	17,311	19,359	8,071	8,815	591	591
	Side Channel	Glide	51	148,217	5,693	3,339	4,936	7,729	9,594	319	319
		Pool	32	34,924	1,629	1,121	1,121	1,892	2,502	244	244
		Riffle	40	166,022	3,980	2,847	3,640	5,073	7,219	40	40
		Backwater	8	9,924	644	326	626	733	1,033	228	228
		Total	131	359,086	11,946	7,633	10,323	15,427	20,348	831	831
Summer Low Flow (Mar-18)	Mainstem	Glide	23	394,757	6,268	6,501	17,494	4,074	4,837	1,960	2,391
		Pool	7	40,931	754	881	1,653	445	634	182	402
		Riffle	22	208,837	3,671	5,155	6,856	1,683	2,243	504	504
		Backwater	-	-	-	-	-	-	-	-	-
		Total	52	644,524	10,693	12,537	26,003	6,202	7,714	2,647	3,298
	Braid	Glide	5	33,701	820	1,083	1,083	558	558	0	0
		Pool	7	6,070	283	402	402	108	108	56	56
		Riffle	6	14,047	399	535	535	263	263	0	0
		Backwater	1	113	25	0	0	50	50	0	0
		Total	19	53,929	1,527	2,019	2,019	979	979	56	56
	Side Channel	Glide	23	93,506	3,908	3,666	4,543	3,994	4,132	156	156
		Pool	22	17,619	1,120	1,146	1,146	1,030	1,030	64	64
		Riffle	23	38,794	1,654	2,194	2,263	1,115	1,237	0	0
		Backwater	4	4,867	510	350	350	595	595	75	75
		Total	72	154,786	7,192	7,356	8,303	6,734	6,994	295	295

Table 62: Mainstem riparian, large woody debris, and substrate summaries for Lower Reach 4. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

			Riparian	Large Wood Jams		Dominant Substrate				
Flow Condition	Channel Type	Dominant Unit Type	% Canopy Closure	n	Cover Area (meters^2)	% Fines	% Sand	% Gravel	% Cobble	% Boulder
Winter flow (Jan-19)	Mainstem	Glide	1.8	18	1,443	ND	ND	ND	ND	ND
		Pool	2.0	8	431	ND	ND	ND	ND	ND
		Riffle	2.3	13	455	ND	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND	ND
		Total	2.0	39	2,329	ND	ND	ND	ND	ND
	Braid	Glide	9.3	29	6,922	ND	ND	ND	ND	ND
		Pool	12.9	27	2,713	ND	ND	ND	ND	ND
		Riffle	5.2	19	4,219	ND	ND	ND	ND	ND
		Backwater	8.2	7	569	ND	ND	ND	ND	ND
		Total	8.9	82	14,423	ND	ND	ND	ND	ND
	Side Channel	Glide	12.6	20	1,934	31	21	34	14	0
		Pool	11.2	16	2,220	57	33	5	0	5
		Riffle	10.2	23	2,104	13	0	63	25	0
		Backwater	22.3	1	5	0	67	0	33	0
		Total	14.1	60	6,263	25	30	25	18	1
Summer Low Flow (Mar-18)	Mainstem	Glide	1.6	21	5,809	ND	ND	ND	ND	ND
		Pool	1.3	3	1,396	ND	ND	ND	ND	ND
		Riffle	1.0	18	3,834	ND	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND	ND
		Total	1.3	42	11,039	ND	ND	ND	ND	ND
	Braid	Glide	1.7	4	1,480	ND	ND	ND	ND	ND
		Pool	2.4	2	176	ND	ND	ND	ND	ND
		Riffle	3.0	1	83	ND	ND	ND	ND	ND
		Backwater	1.0	1	11	ND	ND	ND	ND	ND
		Total	2.0	8	1,749	ND	ND	ND	ND	ND
	Side Channel	Glide	2.9	20	2,484	20	20	60	0	0
		Pool	2.9	14	1,069	10	30	50	0	0
		Riffle	3.5	7	608	0	10	60	40	0
		Backwater	3.0	-	-	30	0	70	0	0
		Total	3.1	41	4,161	20	10	60	10	0

Table 63: Floodplain habitat unit, riparian, large woody debris, and substrate summary for Lower Reach 4. Estimated lengths were derived from WDFW hydrography (WDFW regulatory layer) based on ratios derived in **Table 64**. Wetlands areas were estimated from the NWI (USFWS 2017), no lengths were estimated for wetland units due to lack of adequate data. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

			Habitat Units				Riparian	Large Wood Jams			Substrate			
Flow Condition	**Channel Type**	**Dominant Unit Type**	**n**	**Area (meters²)**	**Length (meters)**	**Depth (meters)**	**% Canopy Closure**	**n**	**Total Wetted Cover Area (meters²)**	**Total # of Wetted Pieces**	**% Fines**	**% Sand**	**% Gravel**	**% Cobble**
Winter (Mar-18)	Hydro-modified natural channel	Glide	23	20,454	2,681	0.7	28.0	10	188.4	50	52	48	0	0
		Pool	3	674	61	0.8	70.0	0	0.0	5	67	33	0	0
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	2	1,789	166	0.4	15.0	0	0.0	0	100	0	0	0
		Estimated	-	16,384	2,678	-	-	-	-	-	-	-	-	-
		Total	28	39,301	5,586	0.6	37.7	10	188.4	55	73	27	0	0
	Tributary	Glide	36	15,079	2,553	0.5	8.5	7	212.8	69	28	39	31	2
		Pool	35	18,870	1,692	0.4	5.3	13	539.8	51	31	35	32	2
		Riffle	22	2,489	445	0.2	11.7	6	0.0	11	0	5	95	0
		Ponded	1	1,454	188	ND	5.0	0	122.8	16	100	0	0	0
		Estimated	-	12,671	1,585	-	-	-	-	-	-	-	-	-
		Total	94	50,564	6,463	0.4	7.6	26	875.4	147	40	20	40	1
	Hydro-modified channel	Glide	-	-	-	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	-	-	-	-	-	-	-	-	-	-	-	-
		Estimated	-	-	-	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-	-	-	-
	Wetland	Wetland	1	3,078	114	ND	3.0	0	0.0	0.0	100	0	0	0
		Estimated	-	1,796,977	NA	-	-	-	-	-	-	-	-	-
		Total	1	1,800,055	114	ND	3	0	0.0	0.0	100	0	0	0
	Constructed channel	Glide	-	-	-	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	-	-	-	-	-	-	-	-	-	-	-	-
		Estimated	-	-	-	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-	-	-	-

Table 64: Current summer floodplain habitats estimated using winter floodplain habitat survey data and ratios of wetted to dry channel derived from summer and winter habitat validation surveys for Lower Reach 4. An explanation for how ratios were derived is available in **Appendix B**.

	Winter floodplain		**Conversion**			**Summer Floodplain Estimates**		
	Total Area (meters²)	**Total Length (meters)**	**Wet Channel Area Ratio**	**Wet Channel Length Ratio**	**Dry channel Length Ratio**	**Total Wet Area (meters²)**	**Total Wet Length (meters)**	**Total Dry Length (meters)**
Hydro-modified natural channel	39,301	5,586	0.5	0.5	0.5	21,025	2,953	2,667
Tributary	50,564	6,463	0.4	0.7	0.4	20,561	4,383	2,422
Hydro-modified channel	-	-	0.2	0.1	0.9	-	-	-
Wetland	1,800,055	114	0.6	1.0	0	1,113,346	114	0
Constructed channel	-	-	0.2	0.1	0.9	-	-	-

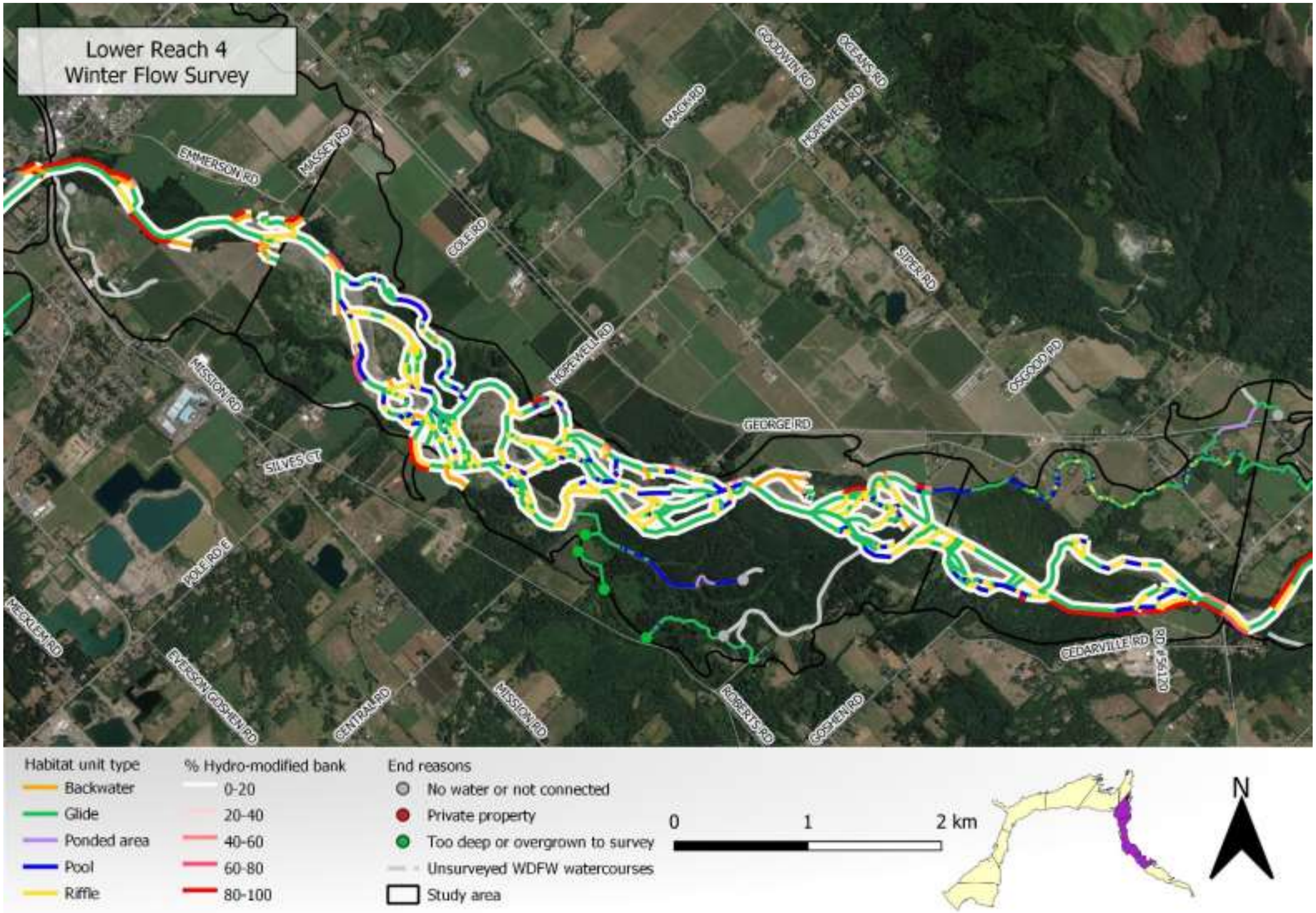

Figure 153: Map of hydro-modified banks and habitat units during winter flow conditions for Lower Reach 4. Average daily flows at the Cedarville gage ranged from 2,750 to 7,600 cfs for mainstem surveys and 1,400 to 4,200 cfs for floodplain surveys. Floodplain surveys were conducted in March 2018 between 1,900 and 3,400 cfs. WDFW watercourses that were not field surveyed in this effort are shown in gray.

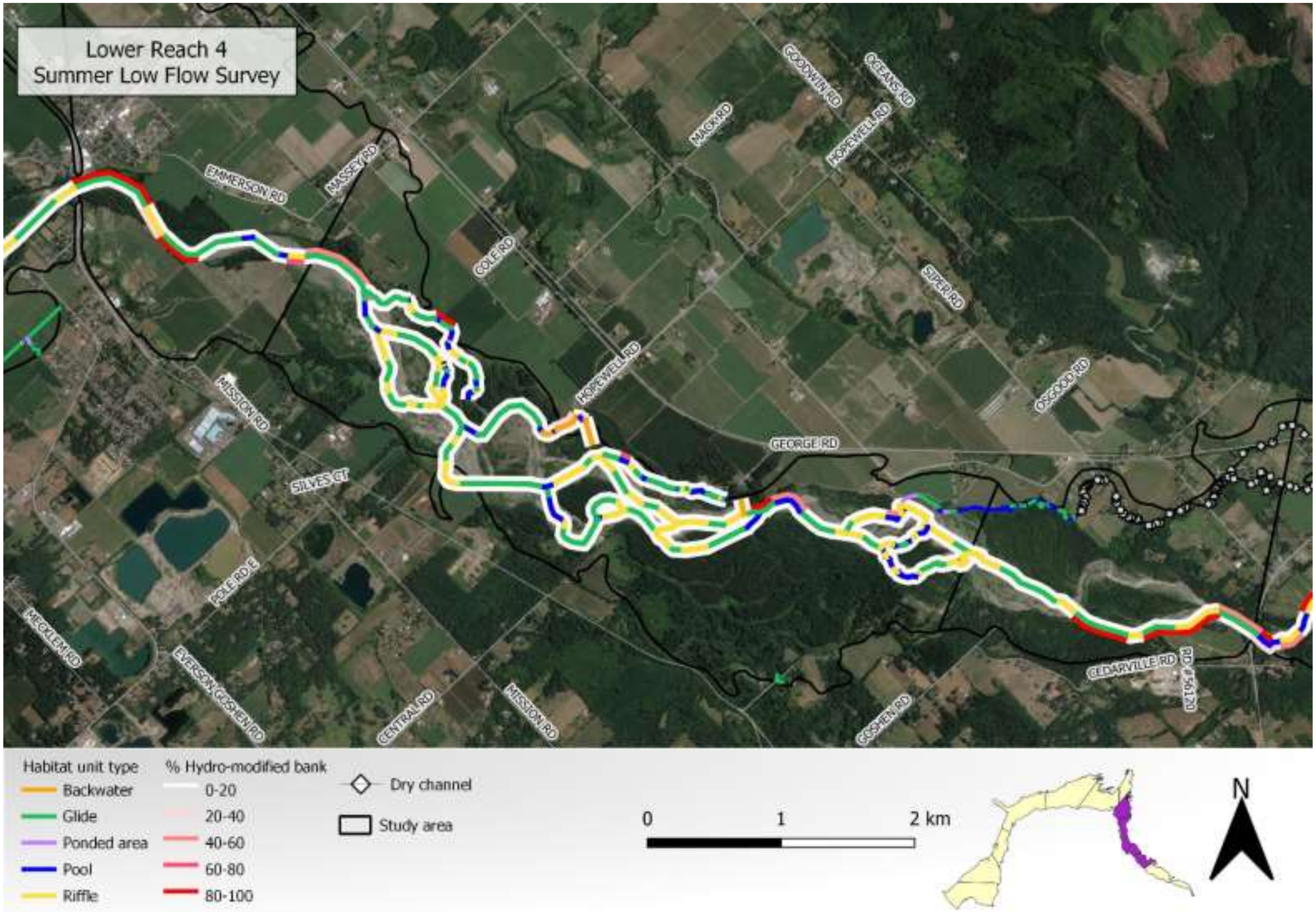

Figure 154: Map of hydro-modified banks and habitat units during summer low flow conditions for Lower Reach 4. Average daily flows at the Cedarville gage ranged from 1,400 to 1,500 cfs for mainstem surveys and 1,500 to 2,500 cfs for floodplain surveys. Summer low flow floodplain surveys were completed as a subset of winter flow surveys. All WDFW watercourses are shown in **Figure 155**.

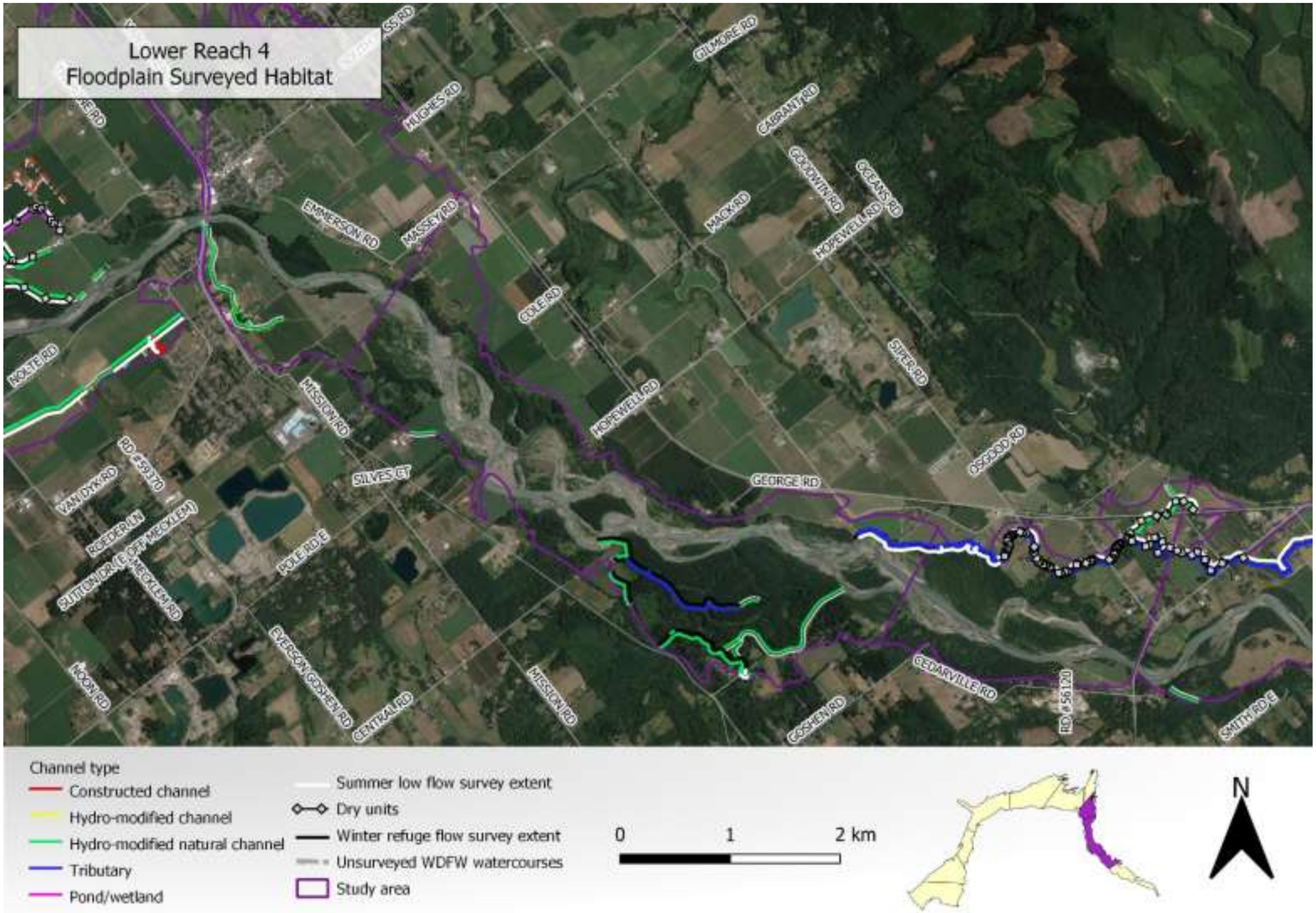

Figure 155: Map of summer and winter floodplain survey extents by channel type for Lower Reach 4. Summer low flow floodplain surveys were conducted as a subset of the winter floodplain survey extent when flows at the Cedarville gage ranged from 1,500 to 2,500 cfs. Channel types adapted from Washington Department of Fish and Wildlife's classifications (WDFW Regulatory Layer). Summer floodplain channel lengths areas were estimated using the ratio of wet to dry channels applied to winter floodplain channel lengths and areas. Detailed methods are provided in **Appendix B**.

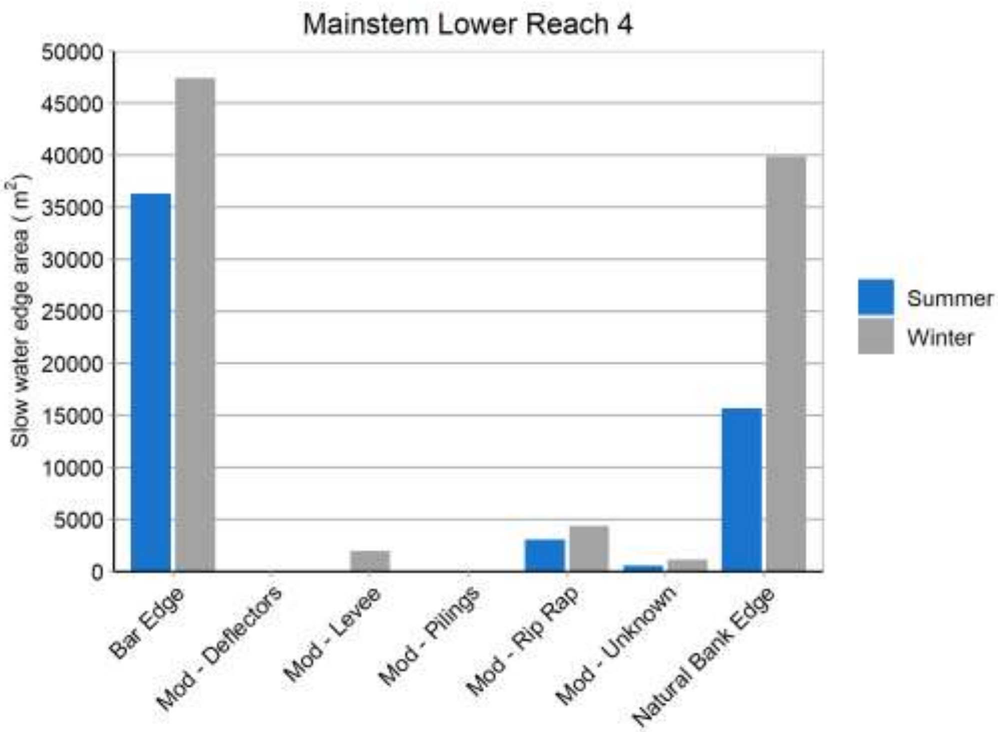

Figure 156: Slow water edge area (meters^2) of edges by edge type surveyed for present day mainstem surveys for summer low flow and winter flow surveys for Lower Reach 4.

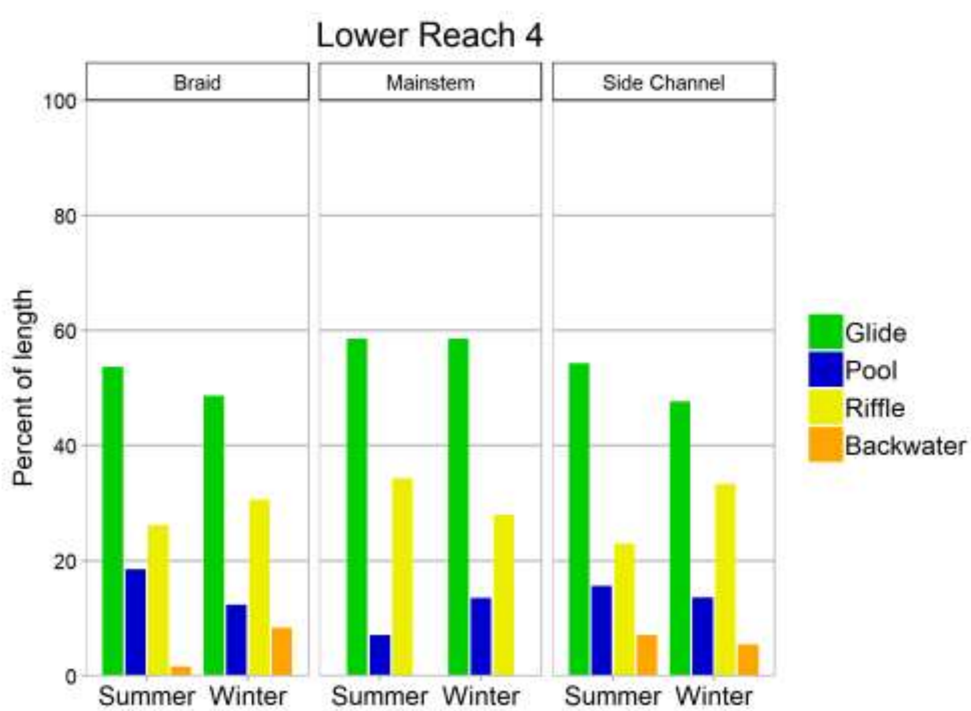

Figure 157: Percent of length surveyed in glide, pool, and riffle habitats for each channel type in mainstem surveys for summer low flow and winter flow surveys for Lower Reach 4.

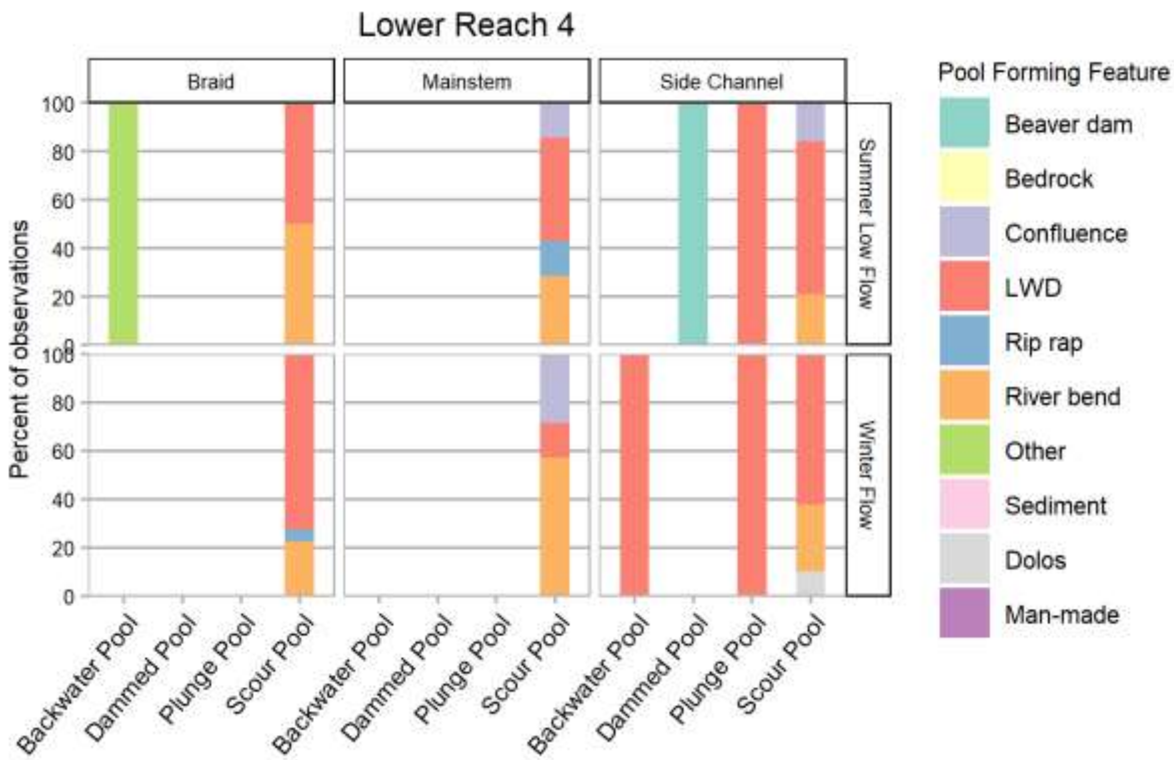

Figure 158: Percent of pool observations by pool type and pool forming feature for Lower Reach 4 for mainstem habitats.

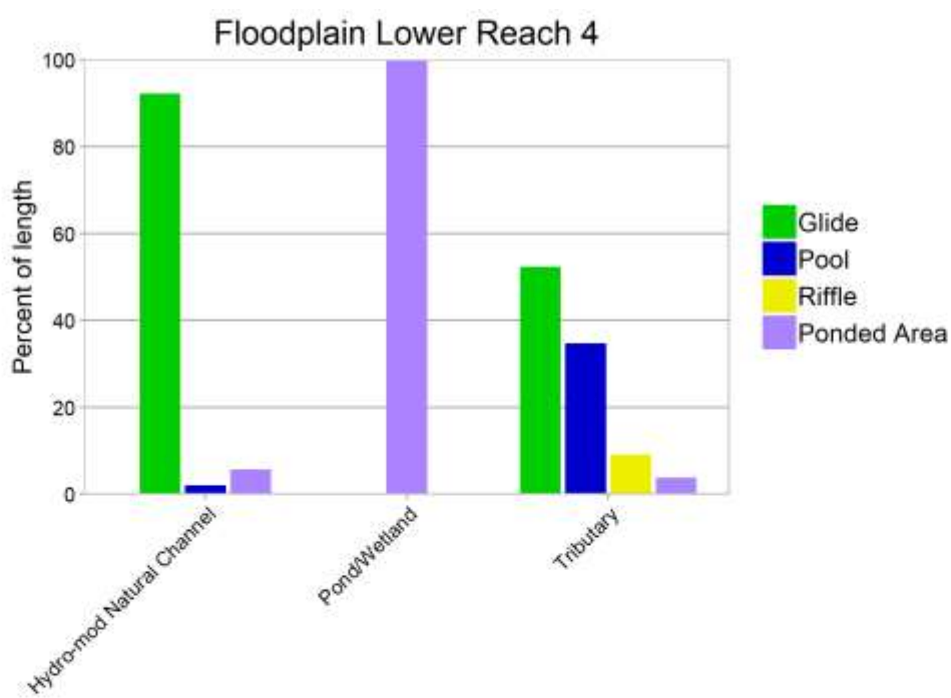

Figure 159: Percent of length surveyed in glide, pool, and riffle habitats for channel types in winter flow floodplain surveys for Lower Reach 4.

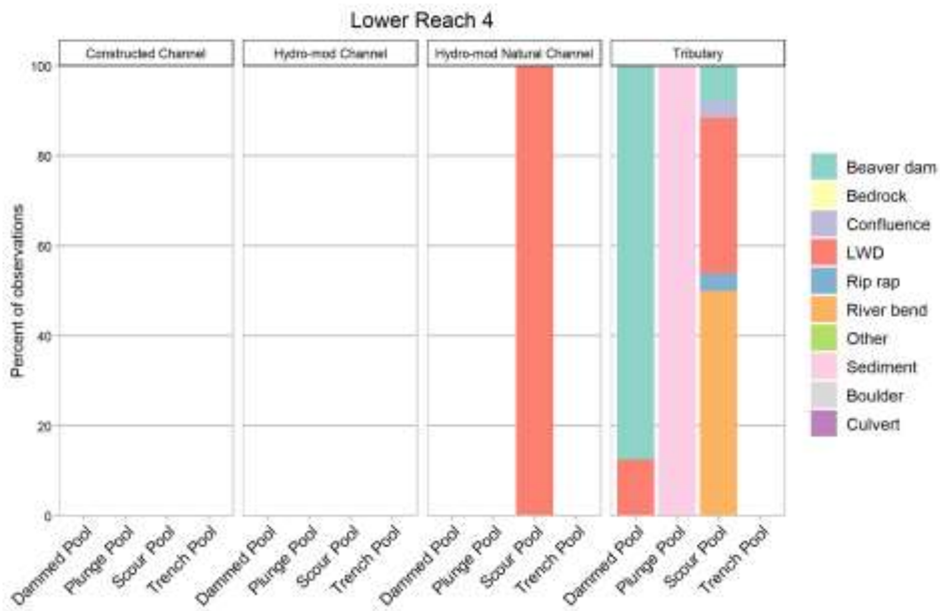

Figure 160: Percent of pool observations by pool type and pool forming feature for Lower Reach 4 for floodplain habitats.

Table 65: Historical and current habitat summarized at same resolution as historical data for Lower Reach 4. For historical reconstructions; no differences in summer and winter condition were derived for floodplain and estuary habitats; total areas are derived from polygon feature areas and line feature lengths assuming a 1-meter width; total lengths are derived from line length for polyline features and polygon perimeters divided by two; total edges are derived from line feature lengths plus polygon perimeters; and slow-water edge areas are derived from two times the total edge lengths. Estuary habitats were not observed in this reach and are not included in this table.

				Historic Circa 1880s				Current Circa 2018/2019			
Flow	Habitat Strata	Habitat Type	Channel Type	Area (meters^2)	Length (meters)	Edge Length (meters)	Slow-water Edge Area (meters^2)	Area (meters^2)	Length (meters)	Edge Length (meters)	Slow-water Edge Area (meters^2)
Winter Flow	Floodplain	Secondary	Slough and Tributary	85,454	15,108	NA	NA	89,865	12,049	NA	NA
		Pond/Wetland	Pond/Wetland	100,000	NA	NA	NA	1,800,055	NA	NA	NA
	Mainstem	Secondary	Side-Channel/Braid	NA	7,133	14,267	28,533	571,330	24,933	49,865	60,268
		Mainstem	Natural Bank Edge	NA	NA	12,298	24,596	NA	NA	7,545	10,685
			Modified Bank Edge	NA	NA	0	0	NA	NA	4,056	6,189
			Bar Edge	NA	NA	10,620	21,240	NA	NA	12,208	17,697
Summer Low Flow	Floodplain	Secondary	Slough and Tributary	85,454	15,108	NA	NA	41,586	7,336	NA	NA
		Pond/Wetland	Pond/Wetland	61,851	NA	NA	NA	1,113,346	NA	NA	NA
	Mainstem	Secondary	Side-Channel/Braid	NA	10,647	21,293	42,587	208,715	8,720	17,439	18,646
		Mainstem	Natural Bank Edge	NA	NA	15,497	30,995	NA	NA	6,202	7,714
			Modified Bank Edge	NA	NA	0	0	NA	NA	2,647	3,298
			Bar Edge	NA	NA	18,708	37,417	NA	NA	12,537	26,003

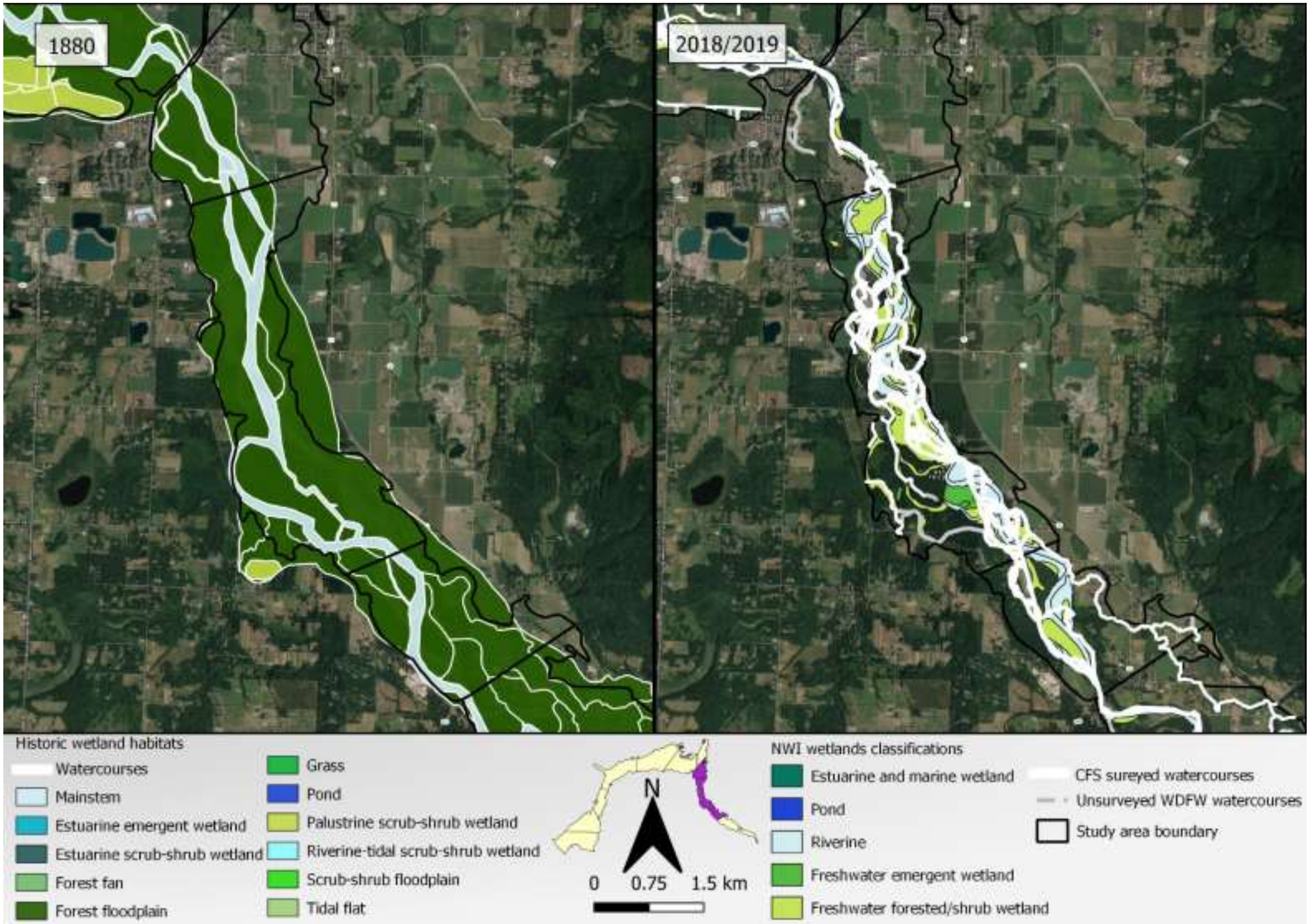

Figure 161: Map of current winter habitat and historical winter habitat extents (Collins and Sheikh) for Lower Reach 4. Surveyed watercourses and unsurveyed watercourses from current surveys are depicted, current wetland habitats are from the NWI (USFWS 2017).

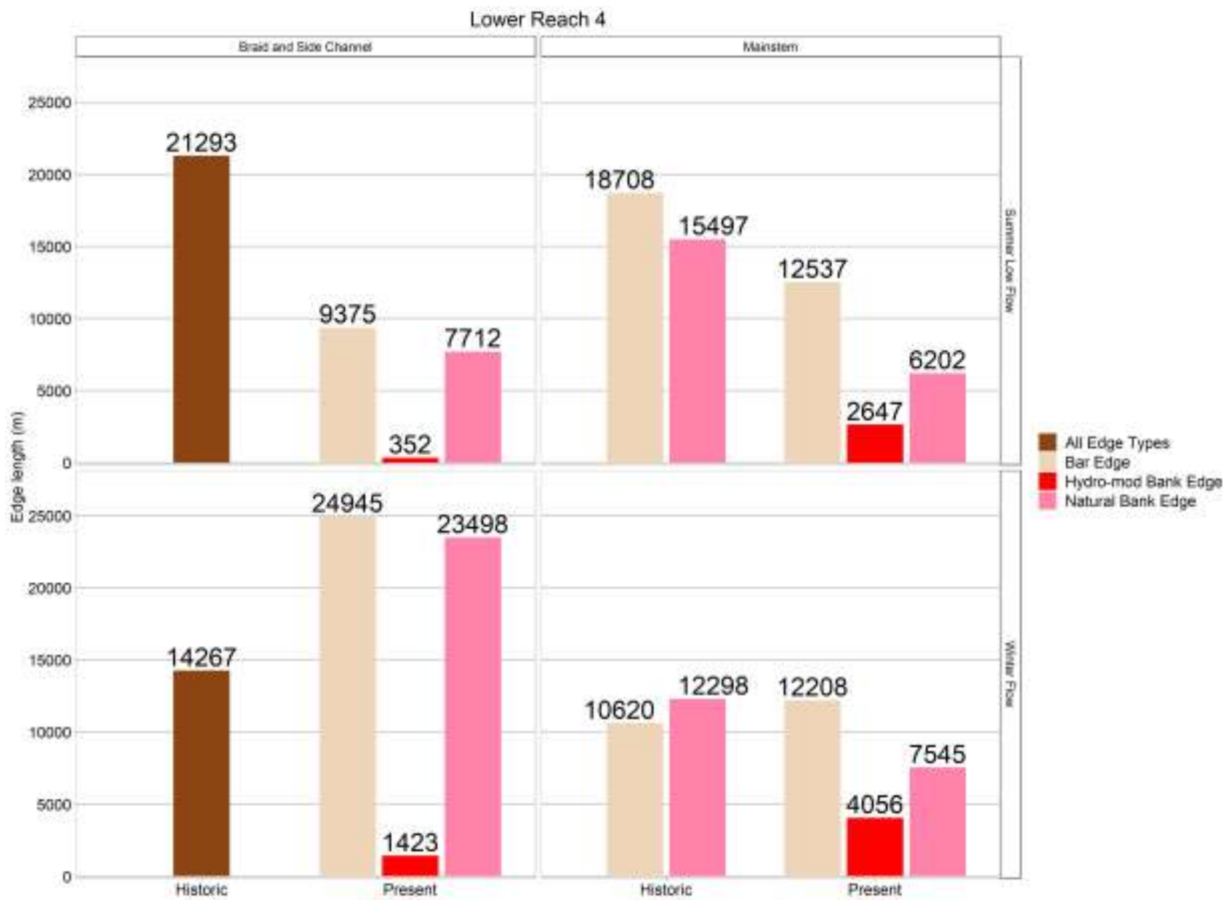

Figure 162: Edge lengths (meters) of bank types for summer low flow and winter flow conditions for historic versus present data for Upper Reach 4. Edge type data for historic braid and side-channel habitats were not available.

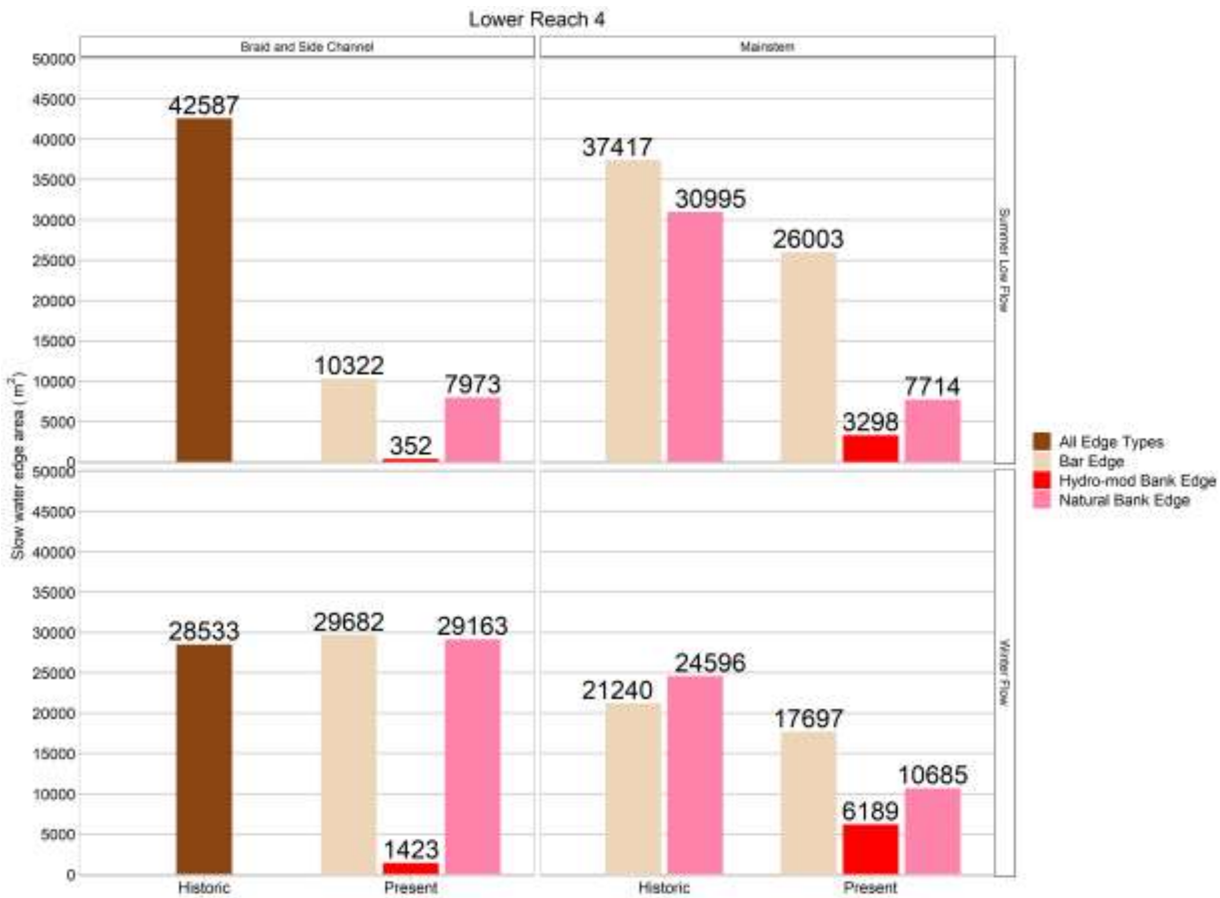

Figure 163: Slow water edge area (meters^2) for bank types for summer low flow and winter flow conditions for historic versus present data for Upper Reach 3. Edge type data for historic braid and side-channel habitats were not available.

Reach: Upper Reach 4

Table 66: Mainstem habitat unit and edge summaries for surveys of Upper Reach 4. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

				Total		Bar Edge		Natural Bank Edge		Hydro-modified Bank Edge	
Flow Condition	**Channel Type**	**Dominant Unit Type**	**n**	**Area (meters²)**	**Length (meters)**	**Length (meters)**	**Slow-water Edge Area (meters²)**	**Length (meters)**	**Slow-water Edge Area (meters²)**	**Length (meters)**	**Slow-water Edge Area (meters²)**
Winter flow (Jan-19)	Mainstem	Glide	14	531,375	6,086	6,640	17,430	3,443	10,154	2,089	3,373
		Pool	5	60,226	833	886	1,897	435	443	346	531
		Riffle	10	206,094	2,463	1,894	3,137	1,926	2,345	1,106	1,908
		Backwater	4	8,934	419	330	330	300	300	208	208
		Total	33	806,628	9,801	9,750	22,794	6,104	13,241	3,748	6,020
	Braid	Glide	8	13,247	955	1,350	1,506	195	195	365	365
		Pool	4	6,482	259	311	328	154	154	53	68
		Riffle	11	9,878	533	988	1,053	38	38	40	44
		Backwater	-	-	-	-	-	-	-	-	-
		Total	23	29,606	1,747	2,649	2,887	387	387	458	477
	Side Channel	Glide	32	41,312	3,107	3,113	3,182	3,100	3,277	0	0
		Pool	26	10,252	852	822	822	882	882	0	0
		Riffle	20	6,340	685	717	764	652	652	0	0
		Backwater	5	2,760	275	532	532	19	19	0	0
		Total	83	60,664	4,918	5,184	5,300	4,653	4,830	0	0
Summer Low Flow (Mar-18)	Mainstem	Glide	15	275,552	4,451	3,880	19,443	3,579	6,211	1,443	2,195
		Pool	10	94,319	1,731	1,754	4,095	881	2,574	827	2,891
		Riffle	15	237,720	3,648	4,555	6,681	1,640	1,701	1,101	1,312
		Backwater	-	-	-	-	-	-	-	-	-
		Total	40	607,591	9,830	10,189	30,219	6,100	10,487	3,371	6,398
	Braid	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-
	Side Channel	Glide	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-

Table 67: Mainstem riparian, large woody debris, and substrate summaries for Upper Reach 4. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

Flow Condition	Channel Type	Dominant Unit Type	Riparian: % Canopy Closure	Large Wood Jams: n	Large Wood Jams: Cover Area (meters^2)	Dominant Substrate: % Fines	% Sand	% Gravel	% Cobble
Winter flow (Jan-19)	Mainstem	Glide	1.2	6	732	ND	ND	ND	ND
		Pool	2.0	0	0	ND	ND	ND	ND
		Riffle	2.0	5	1,160	ND	ND	ND	ND
		Backwater	1.0	1	430	ND	ND	ND	ND
		Total	1.6	12	2,321	ND	ND	ND	ND
	Braid	Glide	5.0	2	370	ND	ND	ND	ND
		Pool	0	0	0	ND	ND	ND	ND
		Riffle	5.0	2	535	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	5.0	4	905	ND	ND	ND	ND
	Side Channel	Glide	3.5	26	662	64	21	7	7
		Pool	2.3	12	733	47	26	11	16
		Riffle	4.2	5	49	11	21	47	21
		Backwater	2.3	6	1,663	100	0	0	0
		Total	3.1	49	3,107	59	14	19	9
Summer Low Flow (Mar-18)	Mainstem	Glide	1.3	3	364	ND	ND	ND	ND
		Pool	1.8	4	930	ND	ND	ND	ND
		Riffle	1.3	2	152	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	1.5	9	1,445	ND	ND	ND	ND
	Braid	Glide	-	-	-	ND	ND	ND	ND
		Pool	-	-	-	ND	ND	ND	ND
		Riffle	-	-	-	ND	ND	ND	ND
		Backwater	-	-	-	ND	ND	ND	ND
		Total	-	-	-	ND	ND	ND	ND
	Side Channel	Glide	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-
		Backwater	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-

Table 68: Floodplain habitat unit, riparian, large woody debris, and substrate summary for Upper Reach 4. Estimated lengths were derived from WDFW hydrography (WDFW regulatory layer) based on ratios derived in **Table 69**. Wetlands areas were estimated from the NWI (USFWS 2017), no lengths were estimated for wetland units due to lack of adequate data. Entries with a (-) indicate that the habitat unit or edge type combination was not observed during the respective survey. ND values indicate that the survey did not include that component or extent.

			Habitat Units				Riparian	Large Wood Jams			Substrate			
Flow Condition	**Channel Type**	**Dominant Unit Type**	**n**	**Area (meters^2)**	**Length (meters)**	**Depth (meters)**	**% Canopy Closure**	**n**	**Total Wetted Cover Area (meters^2)**	**Total # of Wetted Pieces**	**% Fines**	**% Sand**	**% Gravel**	**% Cobble**
Winter (Mar-18)	Hydro-modified natural channel	Glide	-	-	-	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	2	502	161	0.2	85.0	0	0	3	100	0	0	0
		Estimated	-	1,672	291	-	-	-	-	-	-	-	-	-
		Total	2	2,174	452	0.2	85.0	0	0	3	100	0	0	0
	Tributary	Glide	23	15,999	2,777	0.5	32	14	211	35	17	22	61	0
		Pool	5	743	127	0.6	54	1	7.5	4	20	60	20	0
		Riffle	7	1,151	201	0.3	45			2	14	0	71	14
		Ponded	-	-	-	-	-	-	-	-	-	-	-	-
		Estimated	-	-	-	-	-	-	-	-	-	-	-	-
		Total	35	17,893	3,105	0.5	43.5	15	218.5	41	17	27	51	5
	Hydro-modified channel	Glide	2	243	155	0.2	60.0	0	0	0	100	0	0	0
		Pool	-	-	-	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	3	6,318	972	0.6	46.7	1	12	12	100	0	0	0
		Estimated	-	-	-	-	-	-	-	-	-	-	-	-
		Total	5	6,561	1,127	0.4	53.3	1	12	12	100	0	0	0
	Wetland	Wetland	-	-	-	-	-	-	-	-	-	-	-	-
		Estimated	-	927,518	NA	-	-	-	-	-	-	-	-	-
		Total	-	927,518	-	-	-	-	-	-	-	-	-	-
	Constructed channel	Glide	-	-	-	-	-	-	-	-	-	-	-	-
		Pool	-	-	-	-	-	-	-	-	-	-	-	-
		Riffle	-	-	-	-	-	-	-	-	-	-	-	-
		Ponded	-	-	-	-	-	-	-	-	-	-	-	-
		Estimated	-	-	-	-	-	-	-	-	-	-	-	-
		Total	-	-	-	-	-	-	-	-	-	-	-	-

Table 69: Current summer floodplain habitats estimated using winter floodplain habitat survey data and ratios of wetted to dry channel derived from summer and winter habitat validation surveys for Upper Reach 4. An explanation for how ratios were derived is available in **Appendix B**.

	Winter floodplain		**Conversion**			**Summer floodplain estimates**		
	Total Area (meters^2)	**Total Length (meters)**	**Wet Channel Area Ratio**	**Wet Channel Length Ratio**	**Dry channel Length Ratio**	**Total Wet Area (meters^2)**	**Total Wet Length (meters)**	**Total Dry Length (meters)**
Hydro-modified natural channel	2,174	452	0.5	0.5	0.5	1,163	239	216
Tributary	17,893	3,105	0.4	0.7	0.4	7,276	2,106	1,164
Hydro-modified channel	6,561	1,127	0.2	0.1	0.9	1,051	160	978
Wetland	927,518	-	0.6	1.0	0	573,676	-	-
Constructed channel	-	-	0.2	0.1	0.9	-	-	-

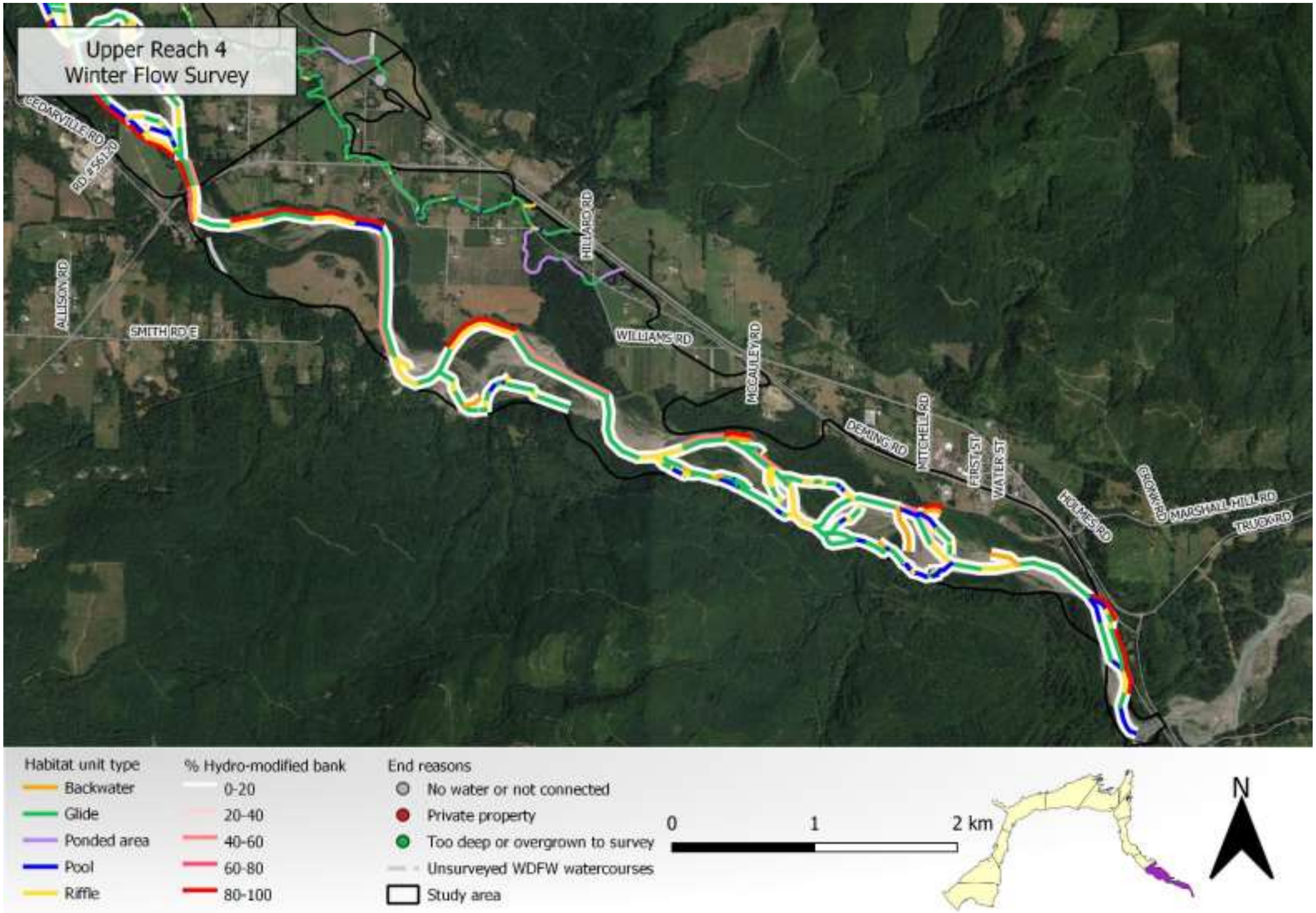

Figure 164: Map of hydro-modified banks and habitat units during winter flow conditions for Upper Reach 4. Average daily flows at the Cedarville gage ranged from 2,750 to 7,600 cfs for mainstem surveys and 1,400 to 4,200 cfs for floodplain surveys. WDFW watercourses that were not field surveyed in this effort are shown in gray.

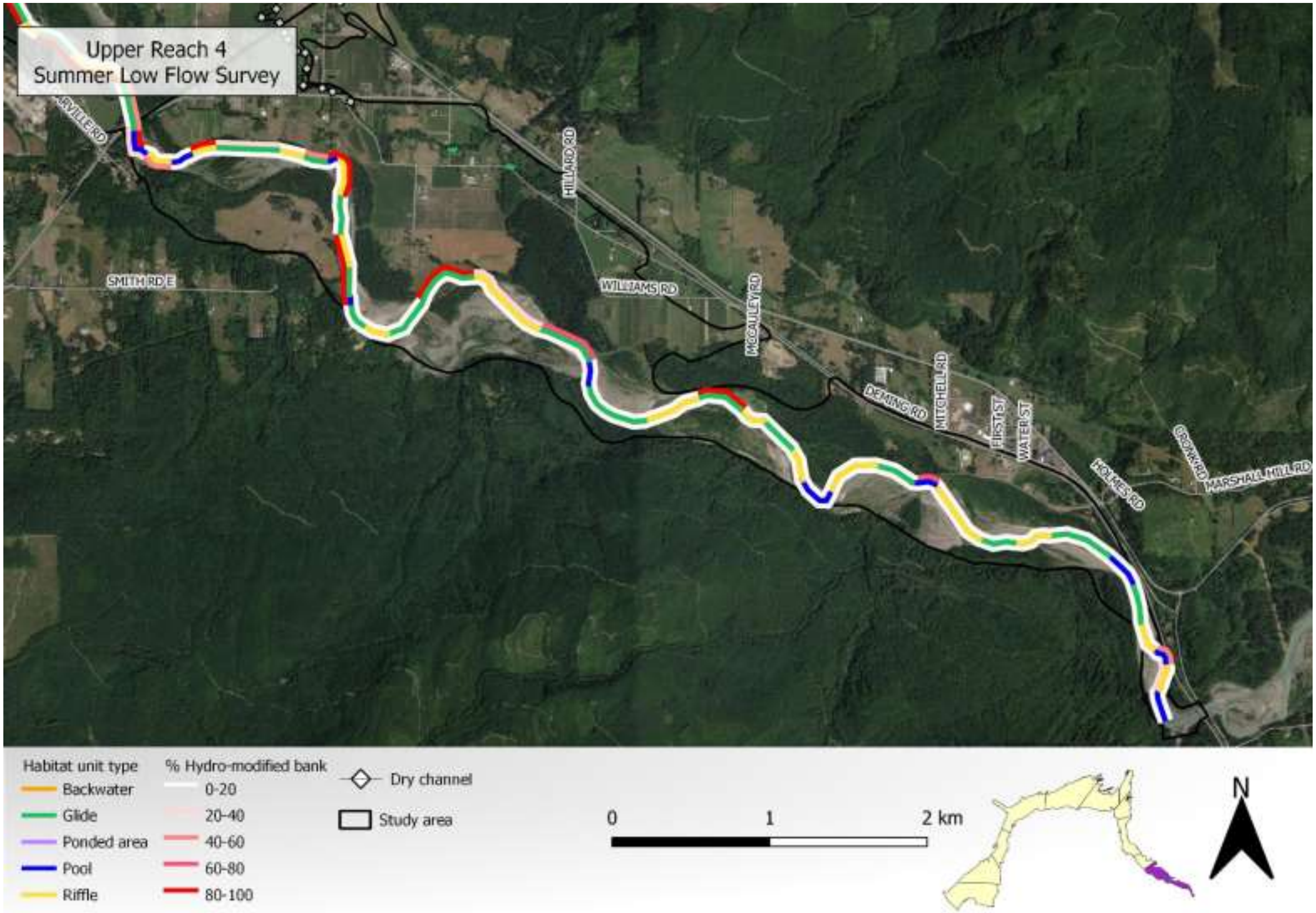

Figure 165: Map of hydro-modified banks and habitat units during summer low flow conditions for Upper Reach 4. Average daily flows at the Cedarville gage ranged from 1,400 to 1,500 cfs for mainstem surveys and 1,500 to 2,500 cfs for floodplain surveys. Summer low flow floodplain surveys were completed as a subset of winter flow surveys and only surveyed watercourses are shown. All WDFW watercourses are shown in **Figure 166**.

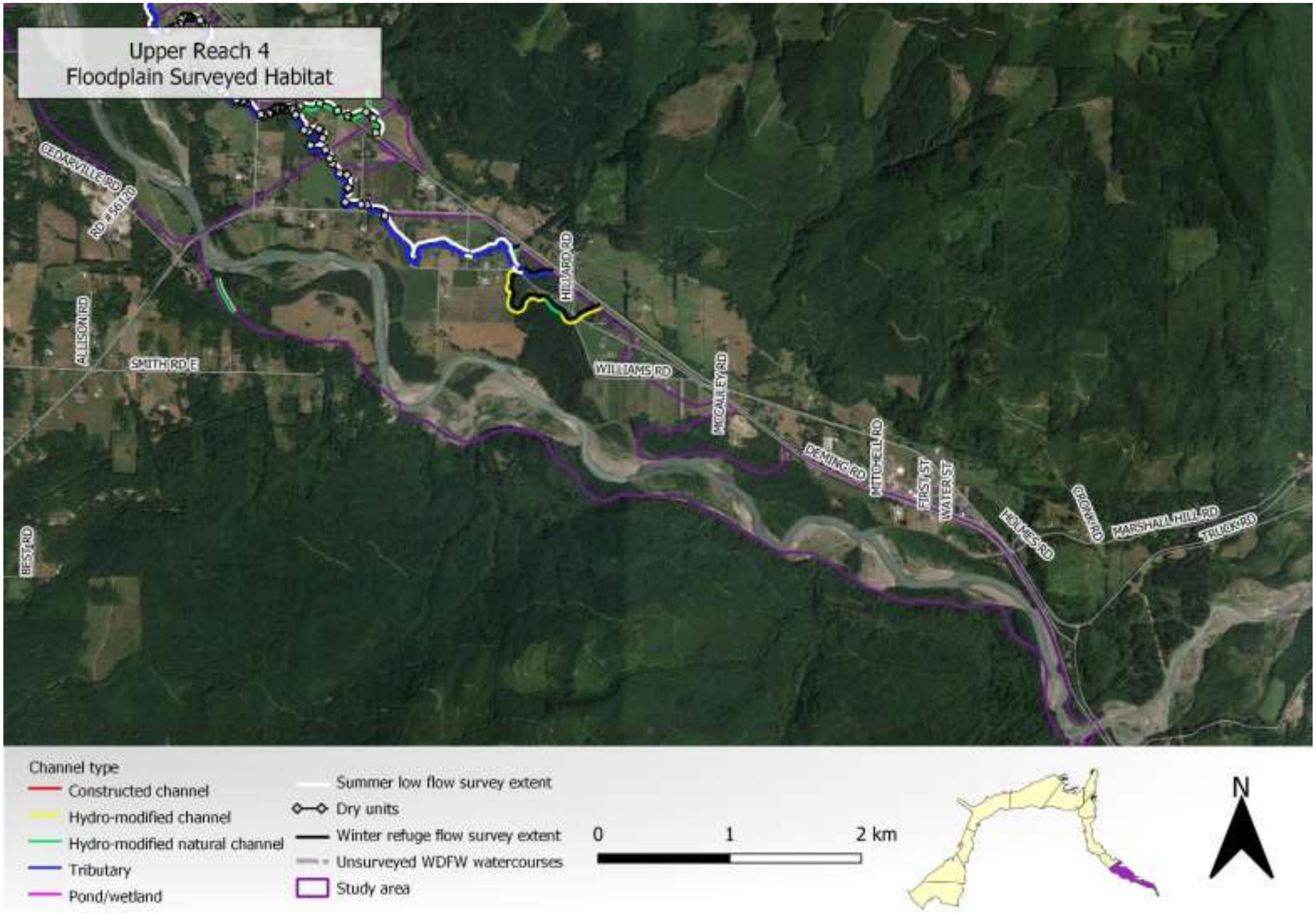

Figure 166: Map of overlapping summer and winter floodplain extent by channel type for Upper Reach 4. Summer low flow floodplain surveys were conducted as a subset of the winter floodplain survey extent when flows at the Cedarville gage ranged from 1,500 to 2,500 cfs. Channel types adapted from Washington Department of Fish and Wildlife's classifications (WDFW Regulatory Layer). Summer floodplain channel lengths areas were estimated using the ratio of wet to dry channels applied to winter floodplain channel lengths and areas. Detailed methods are provided in **Appendix B**.

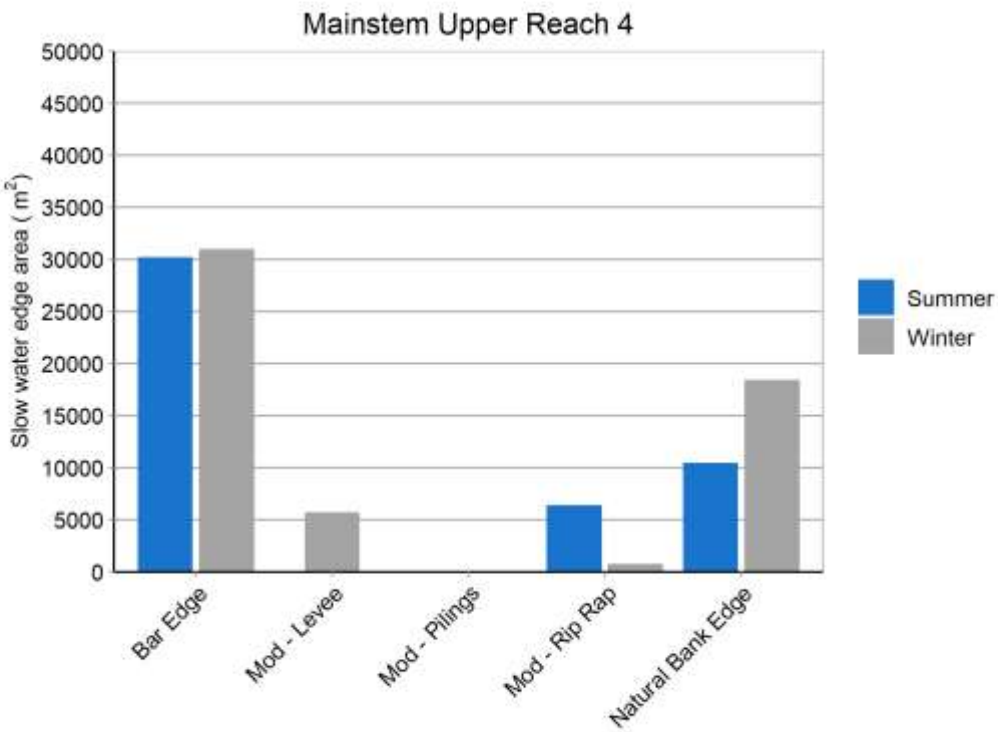

Figure 167: Slow water edge area (meters^2) of edges by edge type surveyed for present day mainstem surveys for summer low flow and winter flow surveys for Lower Reach 4.

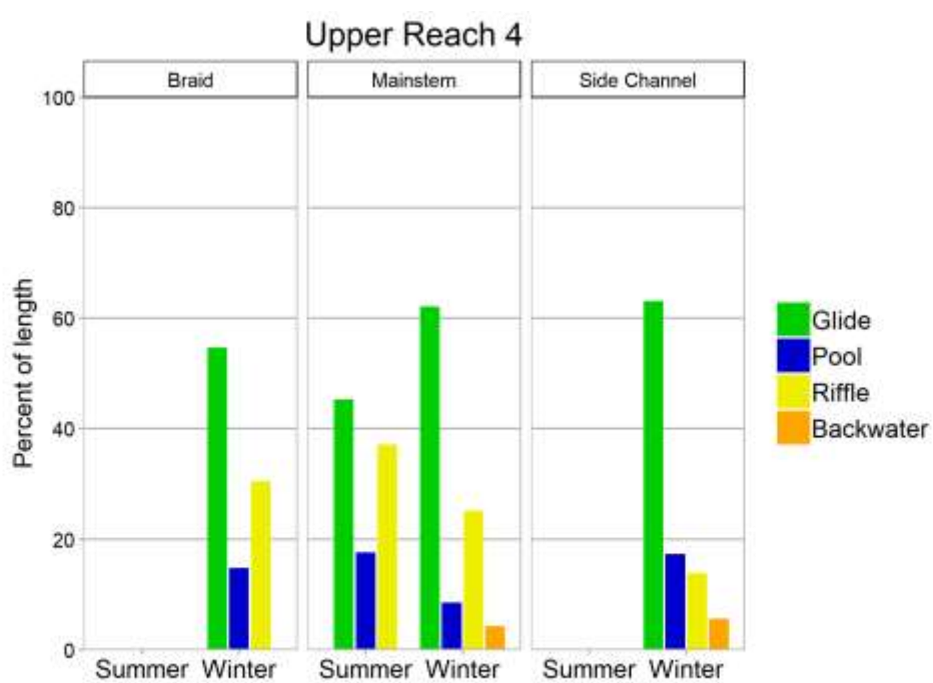

Figure 168: Percent of length surveyed in glide, pool, and riffle habitats for each channel type in mainstem surveys for summer low flow and winter flow surveys for Upper Reach 4.

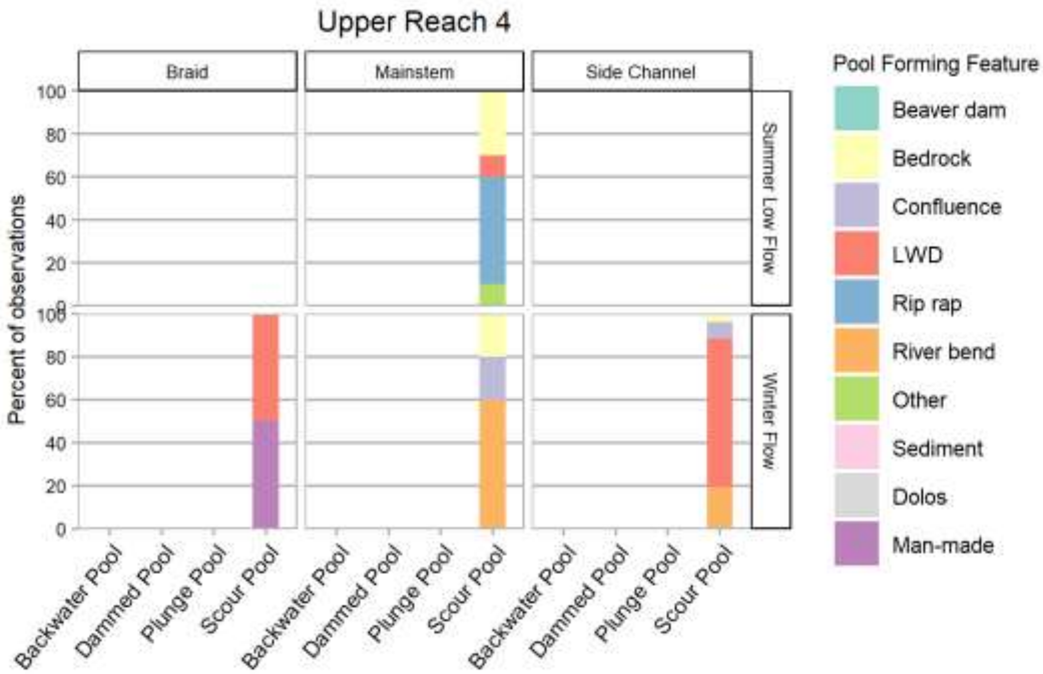

Figure 169: Percent of pool observations by pool type and pool forming feature for Upper Reach 4 for mainstem habitats.

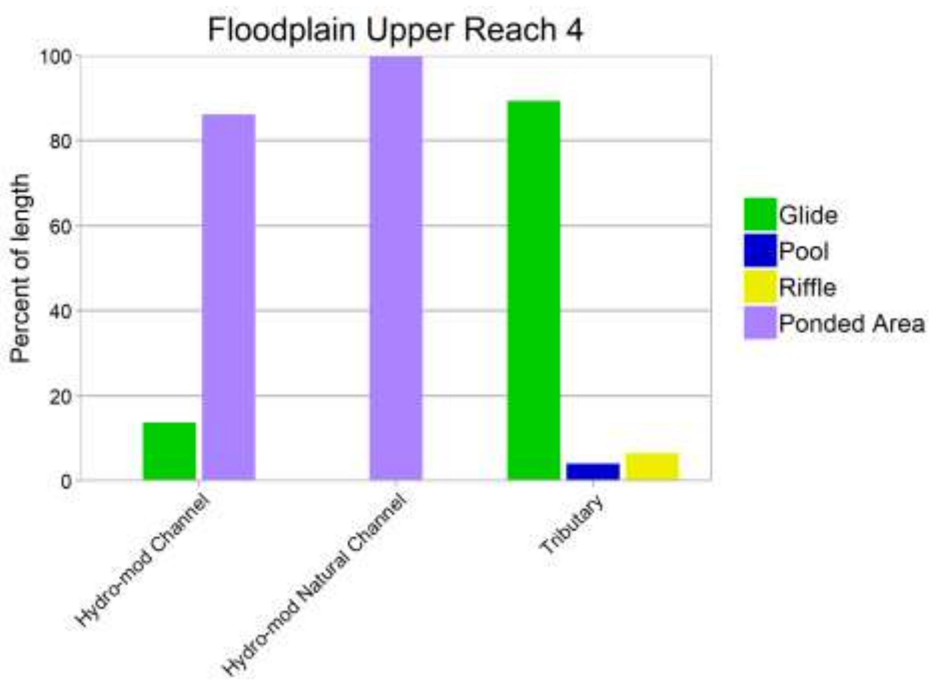

Figure 170: Percent of length surveyed in glide, pool, and riffle habitats for channel types in winter flow floodplain surveys for Upper Reach 4.

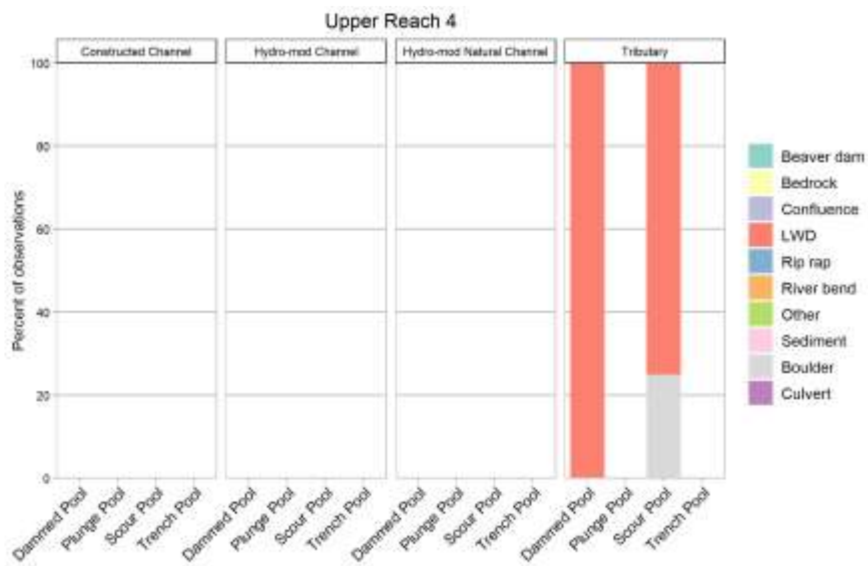

Figure 171: Percent of pool observations by pool type and pool forming feature for Upper Reach 4 for floodplain habitats.

Table 70: Historical and current habitat summarized at same resolution as historical data for Upper Reach 4. For historical reconstructions; no differences in summer and winter condition were derived for floodplain and estuary habitats; total areas are derived from polygon feature areas and line feature lengths assuming a 1-meter width; total lengths are derived from line length for polyline features and polygon perimeters divided by two; total edges are derived from line feature lengths plus polygon perimeters; and slow-water edge areas are derived from two times the total edge lengths. Estuary habitats were not observed in this reach and are not included in this table.

				Historic Circa 1880s				Current Circa 2018/2019			
Flow	**Habitat Strata**	**Habitat Type**	**Channel Type**	**Area (meters^2)**	**Length (meters)**	**Edge Length (meters)**	**Slow-water Edge Area (meters^2)**	**Area (meters^2)**	**Length (meters)**	**Edge Length (meters)**	**Slow-water Edge Area (meters^2)**
Winter Flow	Floodplain	Secondary	Slough and Tributary	49,182	13,371	NA	NA	26,629	4,684	NA	NA
		Pond/Wetland	Pond/Wetland	100,000	NA	NA	NA	927,518	NA	NA	NA
	Mainstem	Secondary	Side-Channel/Braid	0	4,232	8,464	16,928	90,270	6,665	13,331	13,881
		Mainstem	Natural Bank Edge	NA	NA	11,494	22,989	NA	NA	6,104	13,241
			Modified Bank Edge	NA	NA	0	0	NA	NA	3,748	6,020
			Bar Edge	NA	NA	9,926	19,851	NA	NA	9,750	22,794
Summer Low Flow	Floodplain	Secondary	Slough and Tributary	49,182	13,371	NA	NA	9,490	2,505	NA	NA
		Pond/Wetland	Pond/Wetland	61,851	NA	NA	NA	573,676	NA	NA	NA
	Mainstem	Secondary	Side-Channel/Braid	NA	6,316	12,633	25,265	0	0	0	0
		Mainstem	Natural Bank Edge	NA	NA	14,484	28,969	NA	NA	6,100	10,487
			Modified Bank Edge	NA	NA	0	0	NA	NA	3,371	6,398
			Bar Edge	NA	NA	17,486	34,971	NA	NA	10,189	30,219

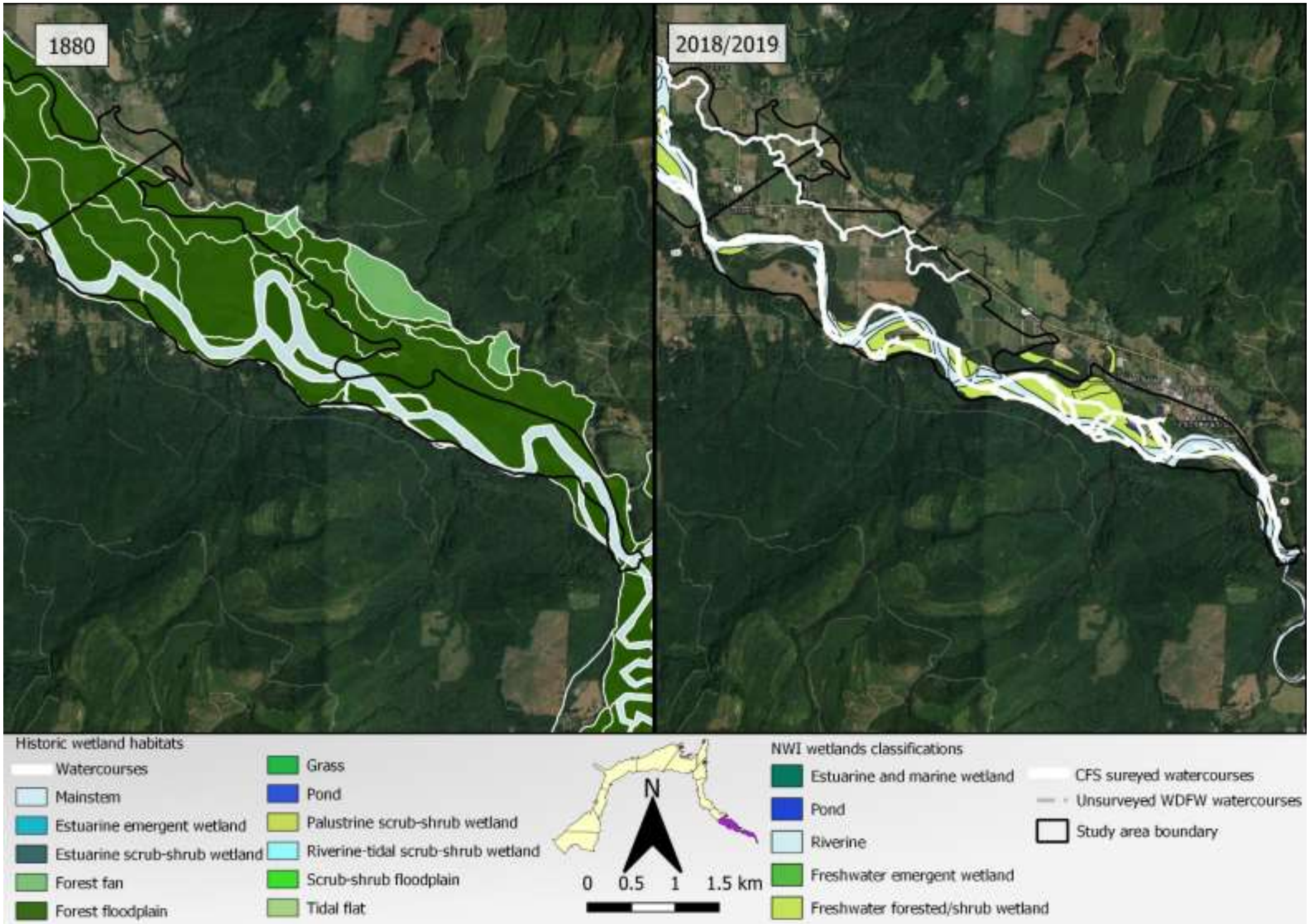

Figure 172: Map of current winter habitat and historical winter habitat extents (Collins and Sheikh) for Upper Reach 4. Surveyed watercourses and unsurveyed watercourses from current surveys are depicted, current wetland habitats are from the NWI (USFWS 2017).

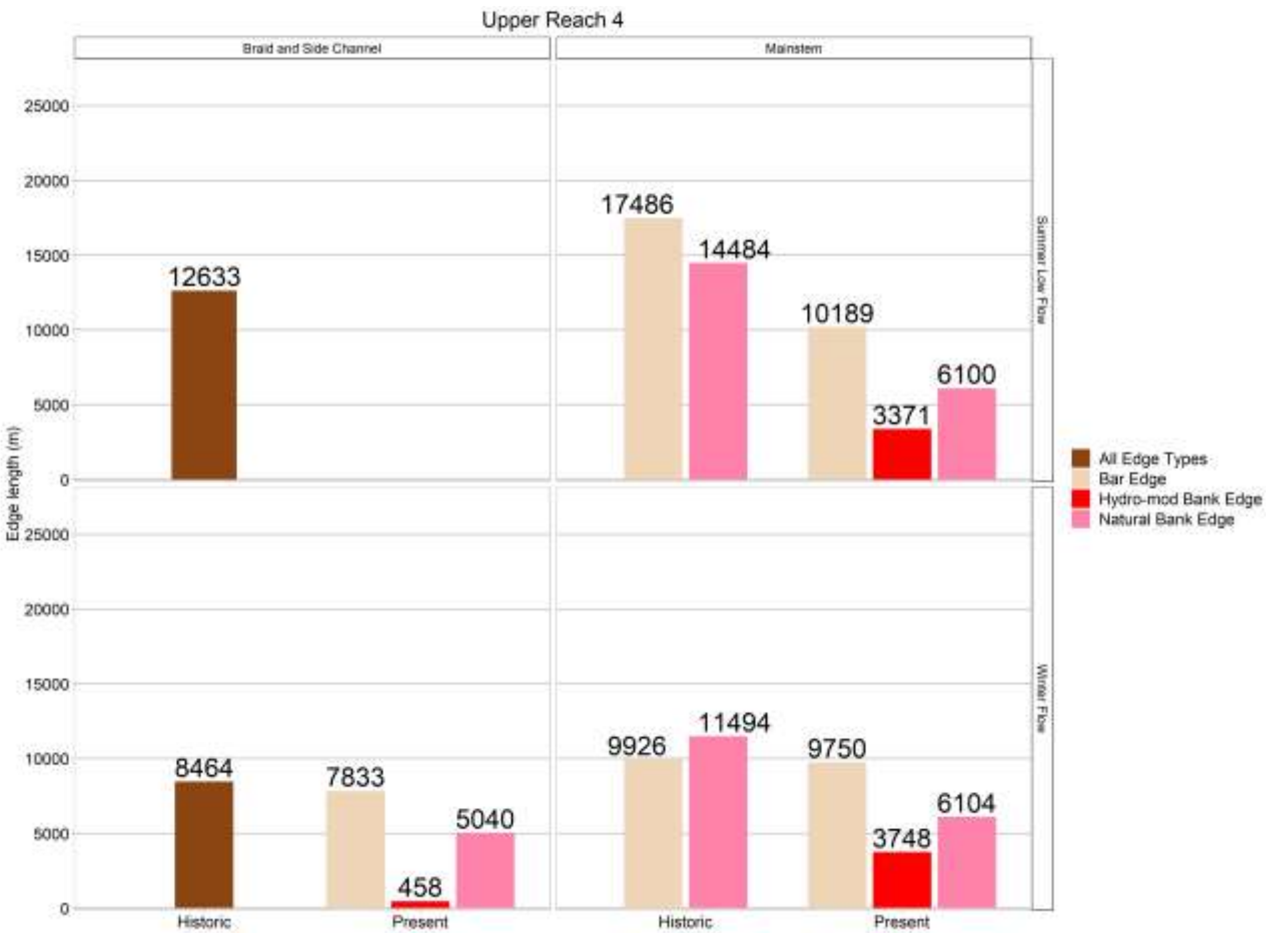

Figure 173: Edge lengths (meters) of bank types for summer low flow and winter flow conditions for historic versus present data for Upper Reach 4. Edge type data for historic braid and side-channel habitats were not available.

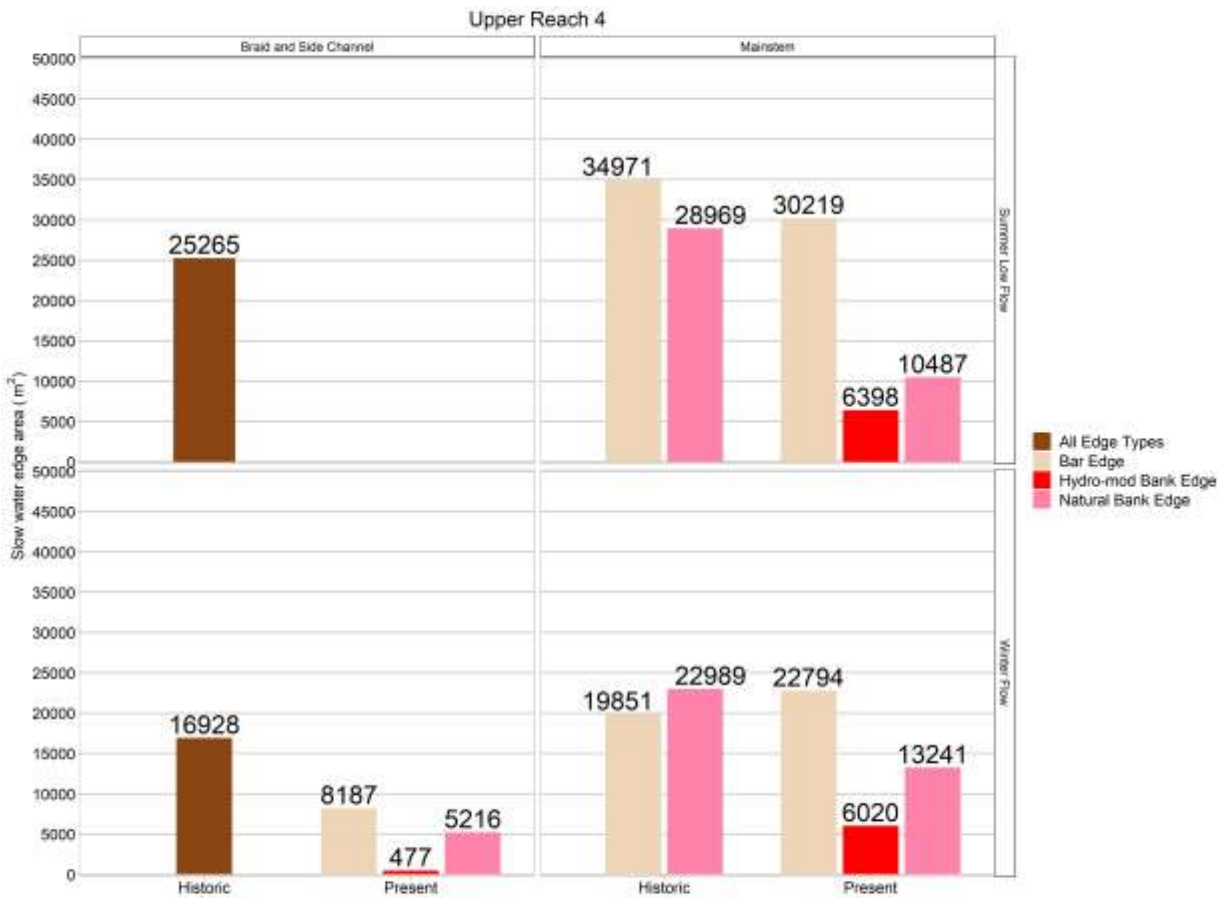

Figure 174: Slow water edge area (meters^2) for bank types for summer low flow and winter flow conditions for historic versus present data. Edge type data for historic braid and side-channel habitats were not available.

Summer Floodplain Habitat Estimation Detail:

Floodplain habitat surveys in the summer were conducted as a subset of surveyed winter floodplain habitats due to limited access and budget constraints. The overlapping winter and summer habitats were used to estimate the remaining summer habitat (**Figure 175**). A substantial portion of the floodplain habitat area with flow in the winter is dry in the summer (**Figure 176**). To account for this in our habitat estimates, we used a ratio of wet to dry summer to winter habitat to calculate total wet and total dry channel lengths. Within the validation survey area where both summer and winter habitats were surveyed, we took the ratio of the wetted summer channel length to the wetted winter channel length as well as the ratio of the dry summer channel length to wetted winter channel length (**Table 71**). The wet and dry ratios were multiplied by the total potential channel length, as calculated by the full winter survey extent plus the estimated channel lengths taken from the WDFW hydrography (WDFW regulatory layer), to calculate the estimated summer wetted and dry channel lengths.

Winter wetland areas were calculated using the NWI layer (USFWS 2017). Summer validation surveys did not include enough wetland area to derive estimates of wet-to-dry habitat areas, and thus Collins and Sheikh (2004) data were used to calculate summer wetland habitat. Collins and Sheikh estimated roughly 38% of habitat area wet in the winter was dry in the summer, which is comparable to our observed estimates which ranged from 40-60% (**Appendix B**).

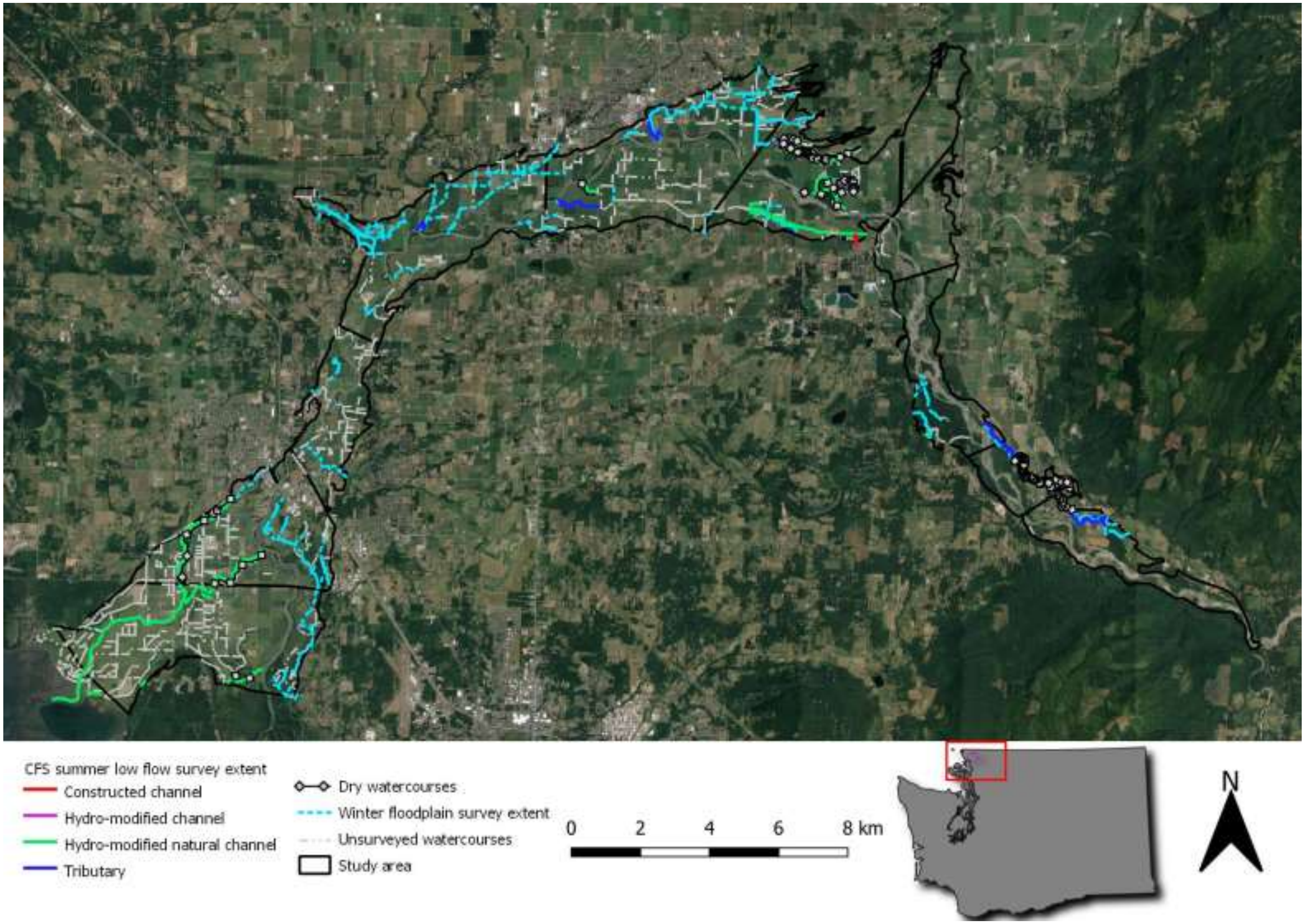

Figure 175: Full extent of summer floodplain surveys and winter validation surveys. Total lengths of summer floodplain habitat were calculated using the winter floodplain habitat extent and length of unsurveyed reaches.

Table 71: Lengths and areas of winter flow and summer low flow validation surveys. Overlapping survey extents were used to calculate the ratios of wet and dry channels. Total potential channel lengths from winter habitat surveys were multiplied by the ratios to calculate estimated summer low flow wet channel habitat and dry channels.

Channel Type	Winter flow Validation Surveys			Summer Low Flow Validation Surveys							Total Potential Winter Habitat		Estimated Summer Low Flow Habitat		
	Wetted Channel			Wetted Channel			Dry Channel				Wetted Channel		Wetted Channel		Dry Channel
	Area ($meters^2$)	Length (meters)	Depth (meters)	Area ($meters^2$)	Length (meters)	Depth (meters)	Length (meters)	Wet Area Ratio	Wet Length Ratio	Dry Length Ratio	Area ($meters^2$)	Length (meters)	Area ($meters^2$)	Length (meters)	Length (meters)
Hydro-Modified Natural Channel	335,638	25,448	0.6	179,559	13,453	0.4	12,150	0.53	0.53	0.48	1,108,046	141,738	592,778	74,928	67,671
Hydro-Modified/ Constructed	3,245	1,343	0.5	520	191	0.5	1,165	0.16	0.14	0.87	177,087	86,403	28,365	12,304	75,005
Tributary	50,587	8,606	0.5	20,570	5,837	0.6	3,225	0.41	0.68	0.37	129,786	19,584	52,775	13,282	7340
Wetland	0	0	0	0	0	0	0	0	1.00	1.00	198,611	7,987	0	7,987	0

Figure 176: Examples of floodplain habitat during winter flow (left) and summer low flows (right).

Table 72: Results from validation surveys across two season and years. March 2018 surveys were winter refuge floodplain surveys. October 2018 were summer low flow surveys. April 2019 were validation winter flow floodplain surveys.

		Oct-18	Mar-18	Apr-19
Kamm Creek	Length (meters)	559	478	519
	# of units	28	22	19
	Average wetted width (meters)	4.5	4.7	5.5
	Average depth (meters)	0.6	0.7	0.9
Smith Creek	Length (meters)	1,790	1,697	1,616
	# of units	28	33	46
	Average wetted width (meters)	5.0	5.4	5.8
	Average depth (meters)	0.5	0.4	0.6

Current Habitat Survey Data Collection Detail:

Table 73: Data collected at the survey level for habitat surveys for Mainstem and Floodplain habitat types.

Survey	Description	Dropdowns
pk_Survey	Unique Survey Number	-
DateCreated	Date surveyed	-
DateModified	Date exported	-
StreamName	Name (if known) of stream surveyed)	-
Hitch	Stream grouping by region (as determined by CFS)	-
Protocol	Protocol used to survey	Mainstem, floodplain
DirectionOfTravel	Direction moving when completing survey	Upstream, downstream
EndReason	Reason why a survey was stopped	Barrier, landowner access, no water, dangerous, 100 CMZ boundary, unable to rapid survey
USGS_Flow	Flow at Cedarville gage	-
Weather	Weather observations	-

Table 74: Data collected at the habitat unit level for habitat surveys for Mainstem and Floodplain habitats. Protocol refers to the what habitat units the data were recorded at, Mainstem=MS, Floodplain=FP, Side-channel=SC.

Units	Description	Dropdowns	Units	Protocol
fk_Survey	Unique Survey Number	-	-	MS, FP
pk_Units	Unique Unit Number	-	-	MS, FP
DateCreated	Date Surveyed	-	DD/MM/YYYY	MS, FP
DateModified	Date Modified	-	DD/MM/YYYY	MS, FP
GPS_Top_Lat	GPS coordinate taken from bad elf	-	DD	MS, FP
GPS_Top_Long	GPS coordinate taken from bad elf	-	DD	MS, FP
GPS_Top_EPE	GPS accuracy taken from bad elf	-	-	MS, FP
GPS_Bottom_Lat	GPS coordinate taken from bad elf	-	DD	MS, FP
GPS_Bottom_Long	GPS coordinate taken from bad elf	-	DD	MS, FP
GPS_Bottom_EPE	GPS accuracy taken from bad elf	-	-	MS, FP
ChannelType	Channel type as identified from WDFW hydro layer	Modified tributary, braid, side channel, constructed channel, natural channel, hydro-modified natural channel, pond, wetland, road shoulder ditch	-	MS, FP
UnitNumber	Non-unique sequential unit number for survey	-	-	MS, FP
UnitType_Dominant	Unit type as defined by Bouwes et al. 2011, Units must be at least one wetted width in length and occupy 50% of the wetted width.	Pool, riffle, glide, ponded area, end point, backwater	-	MS, FP
PoolType	Pool type as defined by hydrology (Bisson et al. 1982)	Plunge pool, scour pool, trench pool, dammed pool, backwater pool	-	MS, FP
PoolFormingFeature	Feature causing scour and pool formation	LWD Piece, LWD jam, boulder, bedrock, beaver dam, trib	-	MS, FP

Units	Description	Dropdowns	Units	Protocol
		junction, culvert, other		
UnitType_SubDominant	A subdominant unit must be at least one wetted width in length	Pool, riffle, glide, ponded area, end point, backwater	-	MS, FP
SubDomUnitPercent	Percentage of channel occupied by the subdominant unit	-	%	MS, FP
UnitLength	Total wetted length of unit	-	m	MS, FP
UnitWidth25	Wetted width at 25% of unit length	-	m	MS, FP
UnitWidth50	Wetted width at 50% of unit length (taken for pond units)	-	m	MS, FP
UnitWidth75	Wetted width at 75% of unit length	-	m	MS, FP
UnitDepth25	Depth at 25% of unit length measured for riffles, glides, and ponded areas	-	m	MS-SC only, FP
UnitDepth50	Depth at 50% of unit length measured for ponded areas and for maximum depth of pool	-	m	MS-SC only, FP
UnitDepth75	Depth at 75% of unit length measured for riffles, glides, and ponded areas	-	m	MS-SC only, FP
PoolTailDepth	Depth at tail out of pools	-	m	MS-SC only, FP
CanopyClosurePercent	Percent of stream shading (canopy cover)	-	%	MS, FP
DominantRiparianVegetation	Dominant vegetation comprising the canopy	Deciduous, coniferous, evergreen, grasses	-	MS, FP
Substrate_Dominant	Dominant substrate as defined by CHaMP protocols (Bouwes et al. 2011)	Fines, sand, gravel, cobble, boulder, bedrock, unknown	-	MS-SC only, FP

Units	Description	Dropdowns	Units	Protocol
Substrate_SubDominant	Subdominant substrate type	Fines, sand, gravel, cobble, boulder, bedrock, unknown	-	MS-SC only, FP
LeftBankVegetation_Dominant	Dominant vegetation from wetted edge to 10m inland as visible from channel	Deciduous, coniferous, evergreen, willow, blackberry, reed canary grass, sedges, rushes, shrubs, herbaceous, rock, bare, other	-	MS, FP
LeftBankVegetation_Height	Height of dominant vegetation	<3, 3-5m, >5m	m	MS, FP
LeftBank_Height	Height of the bank above the wetted edge	<3, 3-5m, >5m	m	FP
RightBankVegetation_Dominant	Dominant vegetation from wetted edge to 10m inland as visible from channel	Deciduous, coniferous, evergreen, willow, blackberry, reed canary grass, sedges, rushes, shrubs, herbaceous, rock, bare, other	-	MS, FP
RightBankVegetation_Height	Height of dominant vegetation	<3, 3-5m, >5m	m	MS, FP
RightBank_Height	Height of the bank above the wetted edge	<3, 3-5m, >5m	m	FP
Comments	-	-	-	MS, FP
NoJamsPresent	-	Y/N	-	MS, FP
NoLWDPiecesPresent	-	Y/N	-	MS, FP

Table 75: Data collected for edges unit level for habitat surveys for Mainstem and Floodplain habitat types. Protocol refers to the what habitat units the data were recorded at, Mainstem=MS, Floodplain=FP, Side-channel=SC

Edges	Description	Dropdowns	Units	Protocol
fk_Units	Unique Unit Number	-	-	MS, FP
pk_Banks	Unique bank identifier	-	-	MS, FP
DateCreated	Date Surveyed	-	DD/MM/YYYY	MS, FP
DateModified	Date Modified	-	DD/MM/YYYY	MS, FP
Bank	Left or right bank	Left, right	-	MS, FP
EdgeType	Edge habitat as defined by Hayman et al. (1996)	Bar edge, natural bank edge, other, hydro-modified bank edge, riprap bank edge, levee bank edge, placed LWD, deflectors, pilings	-	MS, FP
EdgeLength	Percent of channel unit length occupied by each edge type for left and right bank.	1-100 (increments of 10)	%	MS, FP
SlowWater	Presence of slow water next to bank.	Y/N	-	MS, FP
SlowWater_EdgeWidth	Width of slow water next to edge.	-	m	MS, FP

Table 76: Data collected for large wood for each unit for habitat surveys for Mainstem and Floodplain habitat types. For mainstem habitat types, only jam data were recorded. Individual pieces were recorded for floodplain habitats. Protocol refers to the what habitat units the data were recorded at, Mainstem=MS, Floodplain=FP, Side-channel=SC

LWD	Description	Dropdowns	Units	Protocol
fk_Units	Unique Unit number	-	-	MS, FP
pk_LWD	Unique LWD piece identifier	-	-	MS, FP
DateCreated	Date Surveyed	-	DD/MM/YYYY	MS, FP
DateModified	Date Modified	-	DD/MM/YYYY	MS, FP
LWDJamNum	Count of LWD jam located within the wetted channel or within 10m of distance and 1m of vertical elevation from the wetted edge	-	-	MS, FP
JamLength	Visually estimated length of the jam.	-	m	MS, FP
JamWidth	Visually estimated width of the jam.	-	m	MS, FP
JamUnitCoverPercent	Percent of the jam that is wetted.	-	-	MS, FP
LWDPieceNum	Count of LWD piece.	N/A	-	FP
LWDPieceLength	Length of LWD observed in the floodplain measured using Montgomery (2008).	B (1-2), C (2-4), D (4-8), E (8-16), F (16-32), G (>32)	m	FP
LWDPieceDiameter	Diameter of LWD observed in the floodplain measured using Montgomery (2008).	2 (0.1-0.2), 3 (0.2-2.4), 4 (0.4-0.8), 5 (0.8-1.6), 6 (1.6-3.2), 7 (>3.2)	m	FP
LWDPieceMontgomery	Combined Montgomery size code using length and diameter.	B2-G7	m	FP
WetDry	Whether the pieces are wet or dry.	Wet or Dry	-	FP

Appendix C:
Capacity Analysis

Final Report

October 29, 2019

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Appendix C provides summaries of the juvenile fish density data that were compiled from published and unpublished data sources. Juvenile density data were extracted from several previous literature reviews (Roni et al. 2014; Timm and Roni 2017; Roni et al. 2018). Floodplain and mainstem habitat data were synthesized from a literature review that included reviews of over 600 sources that identified 156 sources with juvenile salmon density data (Timm and Roni 2017), and an update to a previous NOAA literature survey (Roni et al. 2014) by Roni et al. (2018) that considered 163 sources. These literature searches were updated as part of this review to identify new potential sources published or produced since the previous reviews were completed (e.g., 2016–2018). In addition, unpublished survey data from the Lower Nooksack River, Skagit River, and Snohomish River were also integrated into these datasets.

For this synthesis, we considered only discrete density data for juvenile salmon that were in units of fish/m^2, or that were reported in such a way that values could be converted to fish/m^2 (e.g., reported catch per unit effort (CPUE) but net sizes were reported so that CPUE can be converted to an estimate of areal density). Tabular data were extracted as reported while graphical data were extracted using digitizing tools to ensure data extraction was consistent and calibrated to axis (e.g., rather than visually estimating values from graphs). We did not consider long duration (e.g., months) time integrated data sources (e.g., smolt traps), or data that were reported as peak values. In addition, we did not include data that expressed densities in terms of increases in response to restoration or relative to some other habitat type or site unless the actual discrete point measurements could be extracted. Rather, we focused on means of discrete measurements of fish densities derived from point sampling methods (e.g., beach seine, snorkel survey, fyke trap, and electrofishing). We did not consider differences in capture efficiency and report all data regardless of gear type so long as the derived density estimates met our criteria. However, gear types are reported with each record in the final database. Therefore, the data synthesized for the capacity analysis were selected to represent actual measurements of areal mean fish densities within key habitat types.

All qualifying data were classified by key habitat strata and sub-strata that were identified based on the availability of data and the habitats that could be quantified for both the historical reconstructions and current habitat assessments. Additional details on habitat are included in the final database, although use of this information needs to be evaluated with respect to sample sizes. The aggregated habitat classification matrix considered in this analysis includes habitats for estuary, mainstem, and floodplain habitats for which enough juvenile fish density data were available to estimate capacities for historical and current conditions (**Table 77**).

Table 77: Habitat matrix used to summarize juvenile fish density data from data sources. These classifications represent a subset and aggregation of the classifications used in the database. See **Appendix B** for more details on available habitat types.

Strata	Sub Strata	Unit Type
Mainstem	Mainstem Channel	Hydro-modified Bank Edge
		Natural Bank Edge
		Side Channel and Braid
		Large Wood Jam
Floodplain	Secondary channel	Slough or tributary
	Pond and Wetland	Pond and Wetland
Estuary	Distributary	Estuarine Emergent Marsh (EEM)
		Estuarine Scrub Shrub (ESS)
		Forested Riverine Tidal (FRT)
	Tidal Channel	Estuarine Emergent Marsh (EEM)
		Estuarine Scrub Shrub (ESS)
		Forested Riverine Tidal (FRT)

Regional classifications were also documented for each record and included: Puget Sound (all Puget Sound watersheds), Pacific Northwest (coastal Washington and Oregon), British Columbia, Alaska, and California. System (e.g., Columbia River or Skagit River) and sub-location (e.g., site or tributary) information were also included with each record where possible to allow further filtering or evaluation of the data to specific areas. See **Appendix B; Figure 178** for details on the geographic distribution of data considered in the capacity analysis.

Qualifying juvenile salmon density data were extracted and aggregated by season, site, and years when possible to maximize sample sizes. Season was based on metrological season adjusted based on a typical juvenile salmon migration and river flow patterns as follows; winter occurring from December through March and representing winter flow conditions and the beginning of emergence and downstream migration pulse for juvenile salmonids, spring occurring from April through June and representing spring melt pulse flow conditions and the typical peak downstream migration pulse of juvenile salmonids, summer occurring from July through September and representing a low flow condition with little juvenile salmon migration, and fall occurring from October through November representing an increasing flow condition with little juvenile salmon migration (see **Figure 3** for flow patterns). Where multiple dates within a season are reported, we summarized data as mean densities by season. Species and life stages have variable rearing and migration patterns within and among major habitat strata by season, and seasons can provide a useful level of detail for aggregating and comparing juvenile salmon densities among different habitats, species, and life stages.

We considered data for the following species: Chinook, coho, chum, pink, cutthroat, steelhead, and bull trout. No run type classifications were extracted or considered in this review, and only data for unmarked fish were considered. Where mixed catches were reported, we only considered catches where at least 90% of the catch were unmarked fish if densities were not reported by mark types. If mark types were not reported, we assumed all fish were natural origin or unmarked. Due to variations in reported species, all *O. mykiss* were lumped and will represent steelhead and resident rainbow trout life history types. In addition, all reported data for bull trout, char, and Dolly Varden were similarly lumped as bull trout. We only considered data for which densities by species were reported, and all mixed catch data were not considered unless a dominant species that exceeded 90% was reported.

Data were extracted by life stage and were aggregated to subyearling and yearling life stages. Data were not considered if a subyearling or yearling life stage could not be determined from the source. Due to variations in reporting, we considered data reported for smolts, yearlings, age 1+, river types, and fork lengths exceeding 100 mm as yearlings. Data were classified as subyearling when life stages or life histories were reported as fry, parr, fingerling, age 0+, or ocean type, or when fork lengths were less than 100 mm. All pink and chum juvenile data were assumed to be subyearling life stages. Bull trout were aggregated as juvenile, sub-adult, and adult stages due to the overlapping use of rearing habitats and lack of detail in reported data. Where life stages were mixed, we only considered data when a dominant life stage was reported that exceeded 90% of the mixed catch.

Statistical summaries of all qualifying juvenile salmon density data were developed by habitat type, species, life stage, and season for subyearling and yearling Chinook salmon. These summaries are presented in **Table 78**. For the capacity analysis completed as part of this assessment, we used the upper third quartile of the distribution of subyearling and yearling Chinook density data where sufficient data were available to estimate capacity by habitat type and season. The upper third quartile represents the upper range of densities that have been observed and therefore represent an approximate capacity for that habitat, species, life stage, and season combination. We assume that the theoretical capacity derived from the upper 75th percentile of observed juvenile salmon densities are applicable to both current and historical conditions and use the same data to estimate capacity for both conditions. However, it is possible that the distribution of densities observed in modern times are biased low due to a number of potential impacts and this may bias comparisons of current and historical capacities. Given that the density data represent mean seasonal densities, the capacity estimates based on the distribution of these means do not represent total juvenile production as they are not adjusted for rearing duration or timing.

Although our habitat surveys focused on a winter flow and summer low flow condition, we use these habitat estimates in combination with seasonal subyearling and yearling Chinook densities to estimate seasonal capacities. We assume winter conditions apply to winter and spring seasons, and that summer is described by the summer low flow condition. Capacities for floodplain habitats were highly influenced by wetland habitat estimates. In addition, data for juvenile salmon densities in pond and wetland habitats were relatively limited and considerably higher that other habitats. The higher relative density values for pond and wetland habitats may be the result of sampling biases in channel or ponded areas with high fish densities (e.g., fish cannot be easily sampled across marsh surfaces and marsh surfaces may not contain standing water that would support fish use). Furthermore, we rely on historical reconstructions for historical wetland extent and supplemental data for current wetland extents and do not have estimates of what portions of these habitats are accessible or usable to subyearling Chinook salmon. To address this issue, we use the lower 25th percentile (Q1 density) for winter pond and wetland habitats (0.02 fish/m2) in floodplains to estimate capacities for subyearling Chinook. This provides a conservative estimate based on the seasonal estimate with the most data (**Appendix C; Table 79**) that assumes not all wetland and pond habitats are accessible or usable to juvenile Chinook salmon.

Insufficient data were available to estimate yearling Chinook densities in floodplain habitats, including pond and wetland habitats.

Sample Size:

The compiled dataset of qualifying juvenile salmon density data includes 2,745 records covering the range of habitat types and focal species from 40 sources (**Figure 177**). These data included 526 records for subyearling Chinook salmon, which were used to develop the rearing capacity estimates for this assessment (**Table 79**). Data were included from all regions considered, although most data came from north Puget Sound systems (**Figure 178**). Including data from other regions was important for the capacity analysis given that measured densities of subyearling Chinook salmon are lower than the range of densities observed in other systems (**Figure 179**). Therefore, densities measured in other systems provide a reference that can be used to determine the rearing capacity of a particular habitat type rather than the current densities observed within the Nooksack River.

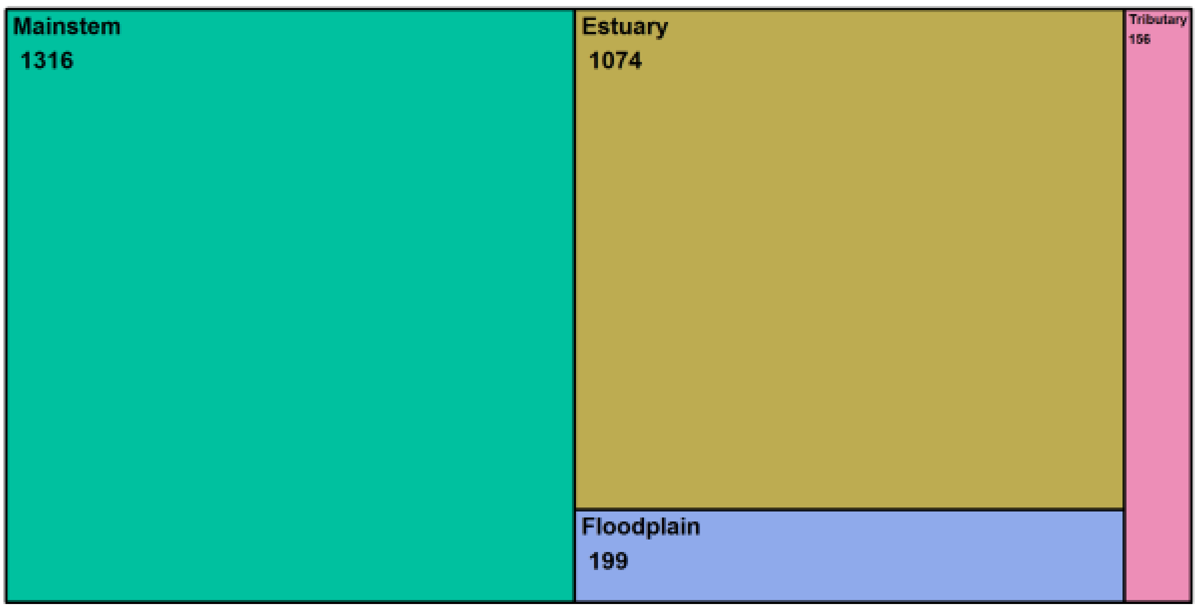

Figure 177: Tree map showing the number of records included in the juvenile fish density dataset by major habitat strata for all species. The size of the box is relative to the number of data points, with a label showing the exact number of data points available for each stratum.

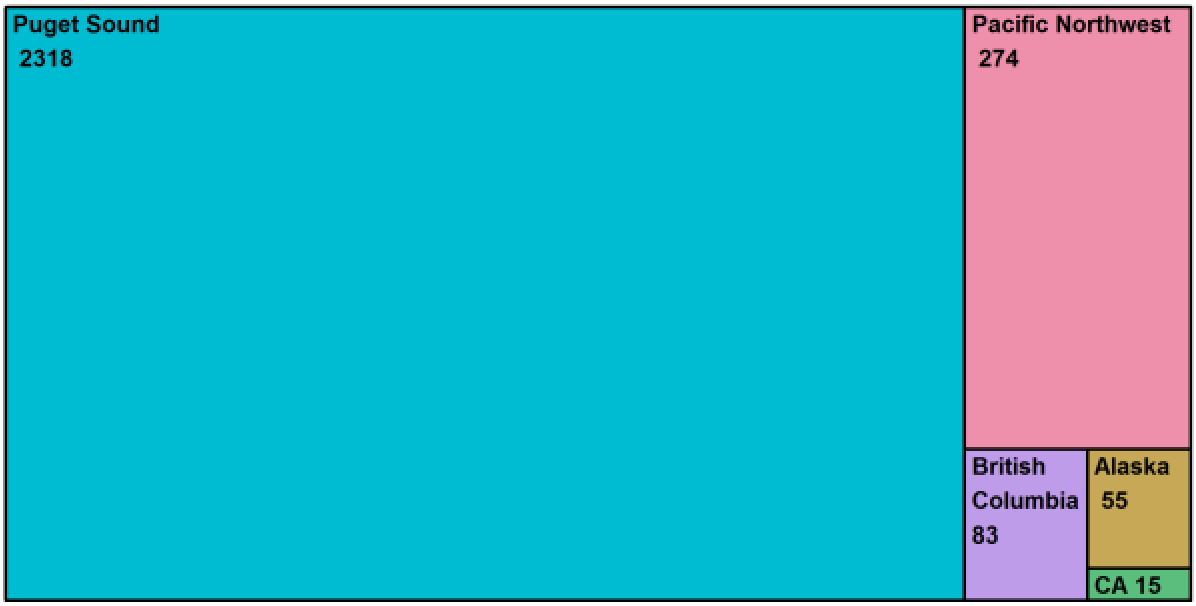

Figure 178: Tree map showing the number of records included in the juvenile fish density dataset by geographic region for all species. The size of the box is relative to the number of data points, with a label showing the exact number of data points available for each region.

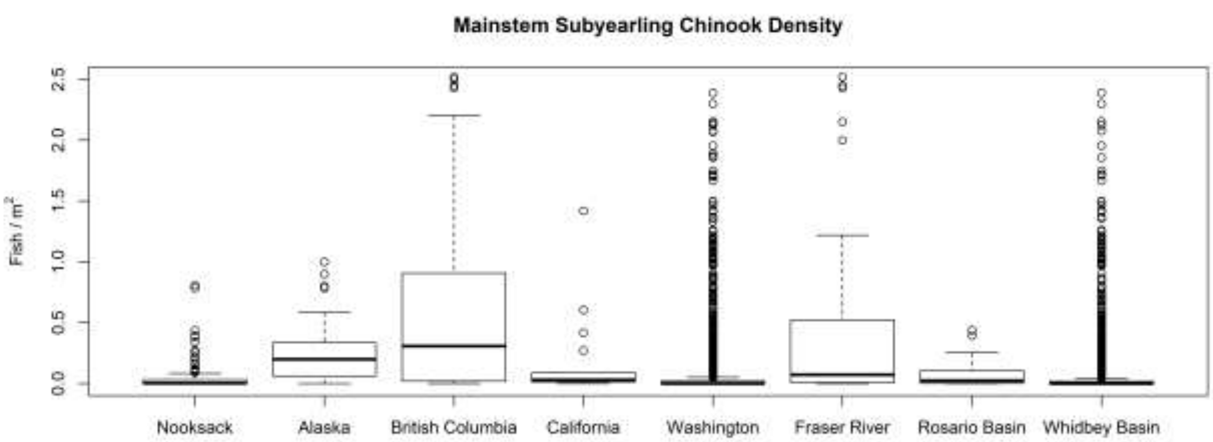

Figure 179: Boxplot showing subyearling Chinook densities (fish/m^2) measured in Nooksack River mainstem habitats compared to other regions and systems from which juvenile Chinook density data were compiled.

Statistical Summaries for Juvenile Chinook Density Data:

These tables provide statistical summaries of subyearling Chinook fish density data (subyearling life stage only) compiled for this study, which are used to estimate capacities based on the upper third quartile of the data for each habitat and season for subyearling Chinook (**Table 78**). Juvenile density summary statistics for other species and life stages are provided in a supplemental spreadsheet.

Table 78: Statistical summary of subyearling Chinook density (fish/m^2) used for the capacity analysis. Bold values indicate the statistic used for estimated capacity; ND indicates no data for that habitat type/season; Q1 indicates 25th percentile and Q3 indicates 75th percentile of density values; EEM indicates estuarine emergent marsh, ESS indicates estuarine scrub shrub, and FRT indicates forested riverine tidal.

Season	Strata	Sub-Strata	Unit	min	Q1	Median	Q3	Max
Winter	Estuary	Distributary	EEM	0.000	0.000	0.000	**0.013**	0.784
Winter	Estuary	Distributary	ESS	0.000	0.001	0.006	**0.034**	0.385
Winter	Estuary	Distributary	FRT	0.000	0.002	0.008	**0.015**	0.077
Winter	Estuary	Tidal Channel	EEM	0.000	0.000	0.006	**0.012**	0.020
Winter	Estuary	Tidal Channel	ESS	0.000	0.000	0.004	**0.007**	0.020
Winter	Estuary	Tidal Channel	FRT	0.000	0.000	0.000	**0.001**	0.007
Winter	Mainstem	Mainstem Channel	Natural Bank	0.000	0.229	0.450	**1.133**	3.404
Winter	Mainstem	Mainstem Channel	Hydro-mod Bank	0.024	0.122	0.160	**0.426**	0.542
Winter	Mainstem	Mainstem Channel	Bar	0.000	0.014	0.042	**0.174**	1.359
Winter	Mainstem	Mainstem Channel	Large Wood Jam	0.000	0.000	0.000	**0.000**	0.000
Winter	Mainstem	Braid and Side Channel	Large Wood Jam	0.000	0.000	0.000	**0.000**	0.000
Winter	Mainstem	Braid and Side Channel	NA	0.000	0.000	0.000	**0.000**	0.000
Winter	Floodplain	Pond and Wetland	NA	ND	**0.019**	ND	ND	ND
Winter	Floodplain	Secondary Channel	Slough and Trib	0.000	0.000	0.000	**0.008**	0.119
spring	Estuary	Distributary	EEM	0.000	0.002	0.012	**0.061**	0.903
spring	Estuary	Distributary	ESS	0.000	0.013	0.032	**0.053**	0.125
spring	Estuary	Distributary	FRT	0.000	0.008	0.038	**0.067**	0.344
spring	Estuary	Tidal Channel	EEM	0.000	0.006	0.018	**0.058**	0.197
spring	Estuary	Tidal Channel	ESS	0.000	0.004	0.015	**0.056**	0.556
spring	Estuary	Tidal Channel	FRT	0.000	0.000	0.002	**0.013**	0.556
spring	Mainstem	Mainstem Channel	Natural Bank	0.000	0.075	0.202	**0.589**	1.122
spring	Mainstem	Mainstem Channel	Hydro-mod Bank	0.008	0.053	0.150	**0.348**	1.146
spring	Mainstem	Mainstem Channel	Bar	0.000	0.000	0.018	**0.141**	0.278
spring	Mainstem	Mainstem Channel	Large Wood Jam	0.091	0.122	0.195	**4.415**	7.200
spring	Mainstem	Braid and Side Channel	Large Wood Jam	0.091	0.122	0.195	**4.415**	7.200
spring	Mainstem	Braid and Side Channel	NA	0.039	0.132	0.690	**5.912**	20.000
spring	Floodplain	Pond and Wetland	NA	ND	**0.019**	ND	ND	ND
spring	Floodplain	Secondary Channel	Slough and Trib	0.000	0.004	0.013	**0.041**	0.132
Summer	Estuary	Distributary	EEM	0.000	0.000	0.004	**0.040**	0.210
Summer	Estuary	Distributary	ESS	0.000	0.001	0.004	**0.012**	0.076
Summer	Estuary	Distributary	FRT	0.000	0.000	0.002	**0.009**	0.270
Summer	Estuary	Tidal Channel	EEM	0.000	0.000	0.002	**0.004**	0.012
Summer	Estuary	Tidal Channel	ESS	0.000	0.000	0.000	**0.004**	0.024

Season	Strata	Sub-Strata	Unit	min	Q1	Median	Q3	Max
Summer	Estuary	Tidal Channel	FRT	0.000	0.000	0.000	**0.000**	0.024
Summer	Mainstem	Mainstem Channel	Natural Bank	0.000	0.004	0.014	**0.024**	0.084
Summer	Mainstem	Mainstem Channel	Hydro-mod Bank	0.000	0.000	0.000	**0.004**	0.018
Summer	Mainstem	Mainstem Channel	Bar	0.000	0.000	0.002	**0.019**	0.088
Summer	Mainstem	Mainstem Channel	Large Wood Jam	0.000	0.005	0.035	**0.249**	0.810
Summer	Mainstem	Braid and Side Channel	Large Wood Jam	0.000	0.005	0.035	**0.249**	0.810
Summer	Mainstem	Braid and Side Channel	NA	0.000	0.034	0.056	**0.059**	0.065
Summer	Floodplain	Pond and Wetland	NA	ND	**0.019**	ND	ND	ND
Summer	Floodplain	Secondary Channel	Slough and Trib	0.000	0.000	0.005	**0.040**	5.520

Fish Capacity Estimates:

This section provides detailed tables of capacity estimates derived for current and historical conditions based on the third (75th percentile) quartiles of subyearling Chinook salmon densities by season and habitat type. Winter and spring capacities are based on seasonal fish densities and winter flow conditions, and summer capacities are based on seasonal densities with summer low flow conditions. Habitat estimates were aggregated based on the resolution of subyearling Chinook salmon density data so that estimates of capacity could be derived from a distribution of densities.

Table 79: Subyearling Chinook capacity estimates based on estimated current and historical habitat extent (**Table 80**) and the 75th percentile (Q3) densities for each habitat and season (**Table 78**), except for pond and wetland habitat where 25th percentile (Q1) of winter densities were used to estimate capacities for all pond and wetland habitat area estimates for each season. Winter and spring habitat estimates are based on winter flow surveys/reconstructions and summer habitat was based on summer low flow surveys/reconstructions. ND indicates no data.

				Subyearling Chinook Capacity (fish)					
				Winter		**Spring**		**Summer**	
Reach	**Sub-Reach**	**Strata**	**Sub-Strata**	**Current**	**Historic**	**Current**	**Historic**	**Current**	**Historic**
1	**Lower-Middle**	**Estuary**	**All**	**20,980**	**17,772**	**85,236**	**78,403**	**20,378**	**13,344**
1	Upper	Floodplain	Pond and Wetland	37,399	74,923	37,399	74,923	23,132	46,340
1	Upper	Floodplain	Secondary Channel	3,691	149	18,210	736	9,151	716
1	Upper	Mainstem	All	8,138	14,393	8,182	115,398	119	4,751
Reach 1 Upper Total				**49,227**	**89,465**	**63,791**	**191,057**	**32,401**	**51,807**
2	Lower	Floodplain	Pond and Wetland	12,728	32,335	12,728	32,335	7,873	19,999
2	Lower	Floodplain	Secondary Channel	890	258	4,391	1,274	1,578	1,238
2	Lower	Mainstem	All	4,944	21,139	4,038	132,659	54	6,367
Reach 2 Lower Total				**18,562**	**53,732**	**21,157**	**166,267**	**9,505**	**27,605**
2	Upper	Floodplain	Pond and Wetland	36,250	149,333	36,250	149,333	22,421	92,363
2	Upper	Floodplain	Secondary Channel	1,347	254	6,648	1,253	2,696	1,218
2	Upper	Mainstem	All	13,227	44,563	12,355	146,541	153	5,957
Reach 2 Upper Total				**50,825**	**194,150**	**55,254**	**297,127**	**25,270**	**99,538**
3	Lower	Floodplain	Pond and Wetland	12,149	121,383	12,149	121,383	7,514	75,076
3	Lower	Floodplain	Secondary Channel	1,355	513	6,683	2,530	2,839	2,459
3	Lower	Mainstem	All	19,125	45,299	29,599	157,857	256	6,166
Reach 3 Lower Total				**32,628**	**167,195**	**48,431**	**281,769**	**10,608**	**83,701**
3	Upper	Floodplain	Pond and Wetland	12,260	55,067	12,260	55,067	7,583	34,059
3	Upper	Floodplain	Secondary Channel	607	48	2,993	234	1,425	228
3	Upper	Mainstem	All	9,020	16,884	81,966	164,361	1,404	5,782
Reach 3 Upper Total				**21,886**	**71,998**	**97,219**	**219,662**	**10,412**	**40,068**
4	Lower	Floodplain	Pond and Wetland	34,381	1,910	34,381	1,910	21,265	1,181
4	Lower	Floodplain	Secondary Channel	750	714	3,702	3,521	1,666	3,422
4	Lower	Mainstem	All	17,825	31,574	468,877	287,792	6,009	8,172
Reach 4 Lower Total				**52,956**	**34,197**	**506,960**	**293,223**	**28,939**	**12,775**
4	Upper	Floodplain	Pond and Wetland	17,716	1,910	17,716	1,910	10,957	1,181
4	Upper	Floodplain	Secondary Channel	222	411	391	2,026	380	1,970
4	Upper	Mainstem	All	21,537	29,511	123,135	218,039	1,202	7,055
Reach 4 Upper Total				**39,475**	**31,831**	**141,241**	**221,975**	**12,539**	**10,206**
All Reaches Total				**286,540**	**660,341**	**1,019,289**	**1,749,483**	**150,053**	**339,044**

Table 80: Historical (circa 1880s) and current habitat area estimates used for each reach, habitat, and season. These habitat areas represent estimated slow-water edge area for all mainstem channel habitats (Mainstem and Braid and Side Channels) and total channel areas for estuary and floodplain channels.

					Current Conditions Habitat Area (m^2)		Historic Conditions Habitat or Slow Water Edge Area (m^2)	
Reach	Sub-Reach	Strata	Sub-Strata	Unit	Winter Flow	Summer Low Flow	Winter Flow	Summer Low Flow
1	Lower-Middle	Estuary	Distributary	EEM	304,330	304,330	151,700	151,700
1	Lower-Middle	Estuary	Distributary	ESS	128,290	128,290	85,665	85,665
1	Lower-Middle	Estuary	Distributary	FRT	638,550	638,550	427,932	427,932
1	Lower-Middle	Estuary	Tidal Channel	EEM	199,860	199,860	433,542	433,542
1	Lower-Middle	Estuary	Tidal Channel	ESS	16,510	16,510	137,553	137,553
1	Lower-Middle	Estuary	Tidal Channel	FRT	338,110	338,110	231,697	231,697
1	Upper	Mainstem	Mainstem Channel	Natural Bank	2,326	1,099	12,644	15,480
1	Upper	Mainstem	Mainstem Channel	Hydro-mod Bank	12,406	9,834	0	0
1	Upper	Mainstem	Mainstem Channel	Bar	1,254	3,079	354	3,921
1	Upper	Mainstem	Mainstem Channel	Large Wood Jam	525	0	2,329	11,039
1	Upper	Mainstem	Braid and Side Channel	Large Wood Jam	0	0	20,686	5,870
1	Upper	Mainstem	Braid and Side Channel	NA	0	0	1,062	1,585
1	Upper	Floodplain	Pond and Wetland	NA	1,958,062	1,211,074	3,922,661	2,426,191
1	Upper	Floodplain	Secondary Channel	Slough and Trib	441,980	228,485	17,871	17,871
2	Lower	Mainstem	Mainstem Channel	Natural Bank	0	0	18,495	22,636
2	Lower	Mainstem	Mainstem Channel	Hydro-mod Bank	10,906	8,523	0	0
2	Lower	Mainstem	Mainstem Channel	Bar	1,724	1,293	1,007	6,466
2	Lower	Mainstem	Mainstem Channel	Large Wood Jam	0	0	2,329	11,039
2	Lower	Mainstem	Braid and Side Channel	Large Wood Jam	0	0	20,686	5,870
2	Lower	Mainstem	Braid and Side Channel	NA	0	0	3,383	25,265
2	Lower	Floodplain	Pond and Wetland	NA	666,403	412,175	1,692,929	1,047,088

Reach	Sub-Reach	Strata	Sub-Strata	Unit	Current Conditions Habitat Area (m^2)		Historic Conditions Habitat or Slow Water Edge Area (m^2)	
					Winter Flow	Summer Low Flow	Winter Flow	Summer Low Flow
2	Lower	Floodplain	Secondary Channel	Slough and Trib	106,584	39,413	30,919	30,919
2	Upper	Mainstem	Mainstem Channel	Natural Bank	1,137	288	38,833	47,532
2	Upper	Mainstem	Mainstem Channel	Hydro-mod Bank	25,274	13,196	0	0
2	Upper	Mainstem	Mainstem Channel	Bar	6,762	3,007	3,141	15,115
2	Upper	Mainstem	Mainstem Channel	Large Wood Jam	439	175	2,329	11,039
2	Upper	Mainstem	Braid and Side Channel	Large Wood Jam	0	0	20,686	5,870
2	Upper	Mainstem	Braid and Side Channel	NA	0	0	3,654	5,453
2	Upper	Floodplain	Pond and Wetland	NA	1,897,922	1,173,877	7,818,466	4,835,772
2	Upper	Floodplain	Secondary Channel	Slough and Trib	161,369	67,307	30,404	30,404
3	Lower	Mainstem	Mainstem Channel	Natural Bank	4,921	1,518	39,317	48,120
3	Lower	Mainstem	Mainstem Channel	Hydro-mod Bank	29,134	11,738	0	0
3	Lower	Mainstem	Mainstem Channel	Bar	6,557	7,067	4,219	16,859
3	Lower	Mainstem	Mainstem Channel	Large Wood Jam	0	181	2,329	11,039
3	Lower	Mainstem	Braid and Side Channel	Large Wood Jam	352	0	20,686	5,870
3	Lower	Mainstem	Braid and Side Channel	NA	2,382	0	5,494	8,201
3	Lower	Floodplain	Pond and Wetland	NA	636,062	393,408	6,355,107	3,930,675
3	Lower	Floodplain	Secondary Channel	Slough and Trib	162,217	70,875	61,405	61,405
3	Upper	Mainstem	Mainstem Channel	Natural Bank	4,477	4,430	13,153	16,575
3	Upper	Mainstem	Mainstem Channel	Hydro-mod Bank	6,095	3,270	0	0
3	Upper	Mainstem	Mainstem Channel	Bar	7,759	8,495	11,358	20,009
3	Upper	Mainstem	Mainstem Channel	Large Wood Jam	941	3,661	2,329	11,039
3	Upper	Mainstem	Braid and Side Channel	Large Wood Jam	1,902	85	20,686	5,870
3	Upper	Mainstem	Braid and Side Channel	NA	10,751	3,280	9,031	13,478

Reach	Sub-Reach	Strata	Sub-Strata	Unit	Current Conditions Habitat Area (m^2) Winter Flow	Current Conditions Habitat Area (m^2) Summer Low Flow	Historic Conditions Habitat or Slow Water Edge Area (m^2) Winter Flow	Historic Conditions Habitat or Slow Water Edge Area (m^2) Summer Low Flow
3	Upper	Floodplain	Pond and Wetland	NA	641,871	397,001	2,883,063	1,783,193
3	Upper	Floodplain	Secondary Channel	Slough and Trib	72,636	35,580	5,689	5,689
4	Lower	Mainstem	Mainstem Channel	Natural Bank	10,685	7,714	24,596	30,995
4	Lower	Mainstem	Mainstem Channel	Hydro-mod Bank	6,189	3,298	0	0
4	Lower	Mainstem	Mainstem Channel	Bar	17,697	26,003	21,240	37,417
4	Lower	Mainstem	Mainstem Channel	Large Wood Jam	2,329	11,039	2,329	11,039
4	Lower	Mainstem	Braid and Side Channel	Large Wood Jam	20,686	5,910	20,686	5,870
4	Lower	Mainstem	Braid and Side Channel	NA	60,268	18,646	28,533	42,587
4	Lower	Floodplain	Pond and Wetland	NA	1,800,055	1,113,346	100,000	61,851
4	Lower	Floodplain	Secondary Channel	Slough and Trib	89,865	41,586	85,454	85,454
4	Upper	Mainstem	Mainstem Channel	Natural Bank	13,241	10,487	22,989	28,969
4	Upper	Mainstem	Mainstem Channel	Hydro-mod Bank	6,020	6,398	0	0
4	Upper	Mainstem	Mainstem Channel	Bar	22,794	30,219	19,851	34,971
4	Upper	Mainstem	Mainstem Channel	Large Wood Jam	2,321	1,445	2,329	11,039
4	Upper	Mainstem	Braid and Side Channel	Large Wood Jam	4,012	0	20,686	5,870
4	Upper	Mainstem	Braid and Side Channel	NA	13,881	0	16,928	25,265
4	Upper	Floodplain	Pond and Wetland	NA	927,518	573,676	100,000	61,851
4	Upper	Floodplain	Secondary Channel	Slough and Trib	26,629	9,490	49,182	49,182

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Appendix D:
Reach Strategies and Synthesis Information

Final Report

October 29, 2019

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Appendix D was in development by members of the WRIA 1 Salmon Recovery Staff Team (SRST) with support from Cramer Fish Science (CFS) at the time the Lower Mainstem Salmon Habitat Assessment report was finalized. The purpose of the synthesis exercise is to distill down the results of the Lower Mainstem Nooksack River Geomorphic Assessment (AGI 2019) and the CFS habitat assessment to create a “synthesis” of the biological and physical data that clearly links the physical drivers that have altered habitat, such as extensive bank armor, to habitat consequences and to then describe what this means in terms of direct impacts to salmon and salmon populations and what actions can be taken to address the impacts.

The synthesis will be used to help the Floodplain Integrated Planning Reach Teams understand, by reach, salmon habitat restoration needs and strategies that can be applied to produce the greatest benefit for recovering one or more salmonid populations in the study area. The Reach Teams are part of an update to the local flood hazard management plan and are tasked with developing reach scale plans, including specific projects, that will comprehensively integrate flood risk reduction, salmon recovery, and flood plain agriculture objectives and produce projects that can be implemented and be effective in meeting these multiple objectives. Reach Team meetings will begin in earnest in early 2020. Note that Synthesis products will also be incorporated into the WRIA 1 Lead Entity planning process once finalized.

Cramer Fish Sciences (CFS) met multiple times with the SRST to present study methods, results, and engage in discussion on possible habitat strategies and actions. This support has fulfilled Task 2.4 deliverable requirements as described in their contract scope of work. CFS continues to provide on-going support to SRST members, under separate funding, as the synthesis products are finalized.

Appendix D is composed of 4 parts; these are briefly described below. The Final version of each part will be attached in PRISM and will also be available to stakeholders and the public at: http://www.whatcomcounty.us/2971/FLIP-Reports

TABLE 1: HABITAT-SALMON

This table provides a summary of physical “drivers” that have affected the Nooksack River, its floodplain, and floodplain portion of tributaries as described in the Lower Mainstem Nooksack River Salmon Habitat Assessment (Cramer Fish Sciences 2019) and Lower Nooksack River Geomorphic Assessment (Applied Geomorphology Inc. 2019). Descriptions are provided for the habitat consequences that result from a driver and how these habitat consequences then impact both salmon individually and at the population level. The Physical, Salmon, and Population impacts are numbered within the table to link the salmon and population impacts associated with each physical impact. Please see the Synthesis Decision Framework narrative for additional information. A draft version of the table is found below.

TABLE 2: Salmon Habitat Use by Lifestage, Species, and Life History.

This table provides a concise overview of the salmonid species and life stages using the study area. A draft version of the table is found below.

SYNTHESIS DECISION FRAMEWORK

This narrative provides the context and describes the decision-making criteria used to develop Table 3. Table 3 connects the physical drivers affecting habitat to the strategies recommended to address each driver. A description will be provided as to how each strategy was evaluated and rated on its ability to address historic impacts to salmon habitat and the relative importance of each strategy in the reaches within the study area.

As noted above, final synthesis products will be attached to RCO Project No. 16-2048P in PRISM and will be available on the Whatcom County website at: http://www.whatcomcounty.us/2971/FLIP-Reports

TABLE 1: HABITAT-SALMON: This table provides a summary of physical "drivers" that have affected the Nooksack River, its floodplain, and floodplain portion of tributaries as described in the Lower Mainstem Nooksack River Salmon Habitat Assessment (Cramer Fish Sciences 2019) and Lower Nooksack River Geomorphic Assessment (Applied Geomorphology Inc. 2019). Descriptions are provided for the habitat consequences that result from a driver and how these habitat consequences then impact both salmon individually and at the population level. The Physical, Salmon, and Population impacts are numbered within the table to link the salmon and population impacts associated with each physical impact. Please see the Synthesis Decision Framework narrative for additional information.

Driver	**Primary Habitat Consequences**	**Physical Impacts**	**Salmon Impacts**	**Population impacts**
Channelization- straightening, meander cut-off, reduction in belt width	Loss of side-channel habitat and secondary channel length.	1. Increased mainstem velocities from concentration of flows. 2. Increased bed scour from increased flows. 3. Reduced habitat extent.	1. Flushing of juveniles during high flow events. 2. Increased redd scour during high flow events. 3. Reduced juvenile rearing and refuge habitat; reduced adult spawning habitat.	1. Reduced productivity through reduced survival of rearing and migrating juveniles. 2. Reduced productivity through reduced egg to fry survival; reduced spawning capacity. 3. Reduced productivity through reduced freshwater survival for rearing and migrating juveniles, and adult survival to spawning; reduced juvenile rearing and adult spawning capacity.
	Lack of mainstem habitat complexity and low habitat unit diversity.	1. Glides predominate, pools infrequent. 2. Reduced secondary channel habitats.	1. Reduced juvenile rearing and refuge habitat; reduced adult holding habitat. 2. Reduced juvenile rearing and refuge habitat; adult spawning habitat.	1. Reduced productivity through reduced adult survival to spawning; reduced juvenile rearing capacity and adult holding capacity. 2. Reduced productivity through reduced rearing survival; and reduced juvenile rearing and adult spawning capacity.
Extensive bank armor	Reduced quality of edge habitat.	1. Reduced slow-water edge habitat and increased edge velocities. 2. Reduced edge cover.	1. Reduced juvenile rearing habitat extent and quality. 2. Reduced predator refuge.	1. Reduced juvenile rearing capacity. 2. Reduced productivity through reduced juvenile survival.
	Channel migration impaired	See channelization consequences	See channelization consequences	See channelization consequences
	Wood delivery impaired	1. Mainstem habitat dominated by glides, pools infrequent	1. Reduced juvenile rearing and refuge habitat; reduced adult holding habitat	1. Reduced productivity through reduced adult survival to spawning; reduced juvenile rearing capacity and adult holding capacity.
Ditching of natural channels and ditching, draining, and filling of floodplain wetlands	Ditch and drainage networks may impair habitat connectivity as floods recede	1. Reduced connectivity of floodplain refuge habitats.	1. Stranding of juveniles in floodplain habitats; reduced juvenile rearing habitat	1. Reduced productivity through reduced juvenile survival; reduced juvenile rearing capacity.
	Reduced habitat complexity and quality of floodplain channels (largely glides and ponded areas)	1. Glides and ponded areas predominate; impaired water quality due to reduced connectivity and water exchange.	1. Reduced juvenile rearing habitat quality; reduced predator refuge.	1. Reduced productivity through reduced juvenile rearing habitat quality and reduced survival; reduced juvenile rearing capacity.
	Reduced areal extent of floodplain wetlands	1. Reduced floodplain storage of water; reduced recharge and base-flow reduces low flow wetted extent of floodplain tributaries and secondary channels. 2. Increased mainstem water velocities during high flows.	1. Reduced high flow refuge habitat; reduced summer low flow habitat extent. 2. Increased flushing of juveniles; increased redd scour.	1. Reduced productivity through reduced survival of rearing juveniles; reduced juvenile rearing capacity through reduced floodplain rearing habitat and summer low flow rearing habitat. 2. Reduced productivity through reduced survival of rearing and migrating juveniles; reduced productivity through reduced egg to fry survival.
	Reduced base flow	1. Reduced summer low flow habitat extent. 2. Increased summer low flow temperatures.	1. Reduced low flow rearing habitat. 2. Increased metabolic rate; increased disease susceptibility; increased thermal stress.	1. Reduced juvenile rearing capacity. 2. Reduced productivity through reduced juvenile survival.

Driver	Primary Habitat Consequences	Physical Impacts	Salmon Impacts	Population impacts
Levees	Channels confined by levees	1. Increased mainstem velocities from concentration of flows. 2. Increased bed scour. 3. Reduced channel migration and secondary habitat formation.	1. Flushing of juveniles during high flow events. 2. Increased redd scour and reduced spawning habitat. 3. Reduced juvenile rearing habitat; reduced spawning habitat; reduced cover habitat (recruitment of LWD). Reduced adult spawning habitat.	1. Reduced productivity through reduced survival of rearing and migrating juveniles. 2. Reduced productivity through reduced egg to fry survival; reduced spawning capacity. 3. Reduced juvenile rearing capacity and productivity from reduced habitat extent, complexity, and cover; reduced adult spawning capacity.
	Reduced connectivity of floodplain channels	1. Reduced access to floodplain habitat	1. Reduced juvenile rearing habitat extent; reduced high flow refuge access.	1. Reduced juvenile rearing capacity; reduced productivity through reduced survival of juveniles during high flows.
	Mainstem channel incision	1. Reduced connectivity to secondary mainstem channel habitats. 2. Reduced connectivity to floodplain habitats.	1. Reduced juvenile rearing, adult spawning, and adult holding habitat extent. 2. Reduced juvenile rearing habitat extent	1. Reduced juvenile rearing capacity and adult spawning and holding habitat capacity. 2. Reduced juvenile rearing capacity.
Tide gates/floodgates; disconnection of Lummi River	Connectivity to tidal channels limited	1. Reduced access to tidal channel habitat. 2. Reduced freshwater to saltwater transition habitat	1. Reduced estuary rearing habitat. 2. Reduced transition habitat; increased osmoregulatory stress.	1. Reduced juvenile rearing capacity. 2. Reduced productivity through reduced juvenile survival transitioning to marine habitats.
	Extent of tidal wetlands limited	1. Reduced access to tidal marsh habitat. 2. Reduced tidal channel habitat. 3. Reduced exchange/inputs from tidal wetlands (sediment, prey, organic matter)	1. Reduced predator refuge; reduced prey availability. 2. Reduced juvenile rearing habitat; reduced transition habitat. 3. Reduced juvenile food sources.	1. Reduced productivity through reduced juvenile survival and growth. 2. Reduced juvenile rearing capacity; reduced productivity through reduced juvenile survival transitioning to marine habitats. 3. Reduced juvenile growth during rearing/saltwater transition
Clearing of riparian/floodplain forest; degraded riparian conditions	Low wood loading and recruitment of large trees to form stable jams; increased rate of turnover	1. Reduced pool frequency. 2. Reduced sediment sorting. 3. Reduced secondary channel formation. 4. Reduced LWD/log jam cover	1. Reduced adult rearing habitat; reduced adult holding habitat. 2. Reduced spawning habitat; reduced spawning habitat quality. 3. Reduced juvenile rearing and adult spawning habitat. 4. Reduced juvenile cover habitat.	1. Reduced juvenile rearing and adult spawning capacity; reduced productivity through reduced juvenile rearing habitat quality and increased adult pre-spawning mortality. 2. Reduced adult spawning capacity; reduced productivity through reduced egg to fry survival. 3. Reduced juvenile rearing and adult spawning capacity. 4. Reduced productivity through reduced juvenile survival; reduced juvenile rearing capacity.
	Reduced riparian cover and nutrient exchange	1. Reduced terrestrial inputs (invertebrates, organic matter) from riparian	1. Reduced prey availability (terrestrial invertebrates); reduced juvenile growth.	1. Reduced productivity through reduced juvenile survival and growth.
	Reduced shading of water surface/increased water temperature (riparian buffers, climate change and reduced base flows)	1. Increased in-stream temperatures	1. Increased metabolic rate; increased disease susceptibility; increased thermal stress	1. Reduced productivity through reduced juvenile and adult survival; reduced juvenile rearing capacity.

Table 2: Salmon habitat use by life stage, species, and life history for Lower Nooksack River habitats (estuary, mainstem, and floodplain habitats collectively). YES indicates that Lower Nooksack River habitats are used by the particular life stage, while NO indicates that the habitats are not used by that life stage. YES(+) indicates that adult migrations can occur in both directions (upriver and downriver) for species that are capable of repeat spawning such as steelhead and bull trout. UNK indicates that the use of Lower Nooksack river habitats for that life stage is not currently known.

Species	Life Stage					
	Eggs - Incubation	Rearing	Over-winter Rearing	Juvenile Outmigration	Adult Upstream Migration & Holding	Adult Spawning
Chinook - Fall	YES	YES	YES	YES	YES	YES
Chinook – Spring/Summer	NO	YES	YES	YES	YES	NO
Coho	YES	YES	YES	YES	YES	YES
Chum	YES	YES	NO	YES	YES	YES
Pink – Odd year	YES	NO	NO	YES	YES	YES
Sockeye – Stream type	UNK	YES	YES	YES	YES	UNK
Steelhead - Summer	YES	YES	YES	YES	YES (+)	YES
Steelhead - Winter	YES	YES	YES	YES	YES (+)	YES
Coastal Cutthroat – Anad.	UNK	YES	YES	YES	YES (+)	UNK
Bull trout – Anad.	NO	YES	YES	YES	YES (+)	NO