

MIDDLE PILCHUCK RIVER ASSESSMENT

Habitat Report

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Executive Summary

The Pilchuck River, a tributary to the Snohomish River, has been identified as a high priority watershed for the recovery of salmonids in the Snohomish River basin. The Pilchuck provides documented spawning and rearing habitat for ESA-listed Chinook salmon, steelhead, and bull trout as well as other important salmonids. The Snohomish River Basin Salmon Conservation Plan (SBSRF, 2005) identified the Middle Pilchuck River sub-basin as part of the Mainstem Primary Restoration sub-basin strategy group, and highlights the sub-basin's importance in maintaining and restoring the diversity and spatial structure of the Skykomish Chinook population (SBSRTC, 2004). Within this strategy group, the Middle Pilchuck River is one of the only sub-basins in Snohomish County that does not have a completed watershed assessment to guide recovery efforts.

The overall goals of the Middle Pilchuck River Assessment (MPRA) are to identify opportunities to address salmonid habitat deficiencies through restoration activities and to develop preliminary designs for capital projects at three high priority sites. Salmon recovery priorities for this sub-basin strategy group include preservation (along focus reaches), reconnection of off-channel habitats, restoration of shoreline conditions, riparian enhancement, and enhancement of in-stream structure (SBSRF, 2005). Therefore, this habitat assessment focused on describing the conditions that help inform those preservation or restoration objectives, namely:

- Side channel conditions,
- Shoreline (Streambank/levee) conditions,
- Riparian conditions, and
- Instream conditions (pools, wood jams, gravel and temperature).

The assessment area encompasses an eighteen-mile section of the Pilchuck River divided into 8 river reaches, extending upstream from the confluence with Dubuque Creek at OK Mill Road (RM 8.6) to the City of Snohomish diversion dam (RM 26.4). Previously, the Tulalip Tribes (Savery and Hook 2003) conducted an assessment in 2002 that included the downstream portion of the Middle Pilchuck River. The County assessment differs from this previous effort because it collects data for bank conditions, side channels, log jams, fish habitat, and riparian conditions along the entire 18 miles of the entire Middle Pilchuck River and provides up-to-date information on habitat limiting factors for project planning and feasibility analysis.

Habitat data were analyzed to assess the condition of both spawning and rearing habitat in the Pilchuck River. The major factors limiting Chinook salmon production in the Middle Pilchuck River appear to be a lack of rearing habitat in the form of side channel habitat, deep pools with natural cover, high quality bank edge habitat, and temperature impairment during summer months. The root causes of these habitat limiting factors in the Middle Pilchuck River are floodplain and streambank modifications and clearing of natural vegetation in floodplain forests.

The following is a summary of the assessment of each of the key salmon life stages, including how the data supports the above conclusion that rearing habitat is limiting and spawning habitat is underutilized.

Assessment of Adult Spawning Habitat

Spawning needs

Chinook returning to the Pilchuck River to spawn need clean and appropriately sized gravel and deep pools with overhead cover.

Conclusions

- Available spawning gravels appear to be underutilized, so spawning habitat is not limiting.
- The lack of deep pools with cover and wood structures forming pools may become limiting in the future if more adult Chinook return to the river.
- High summer water temperature may affect adult migration timing or survival prior to spawning.

Supporting data

The following is a list of data used to support this conclusion and a brief summary of findings:

- Substrate size - Of the 957 habitat units inventoried during the survey, 645 were determined to have gravel size suitable for spawning in areas likely to be utilized by salmonids.
- Embeddedness - Sixty-five percent of spawnable areas were classified as having relatively low (0% -25%) embeddedness.
- Redd locations (data from the Tulalip Tribes and WDFW) – Only a fraction of areas suitable for spawning are being used by Chinook.
- Pool quality & quantity (location, depth, how formed, and amount of cover) - While spawning gravels are numerous and widely distributed, deep holding pools and the jams that create and provide cover for them were not abundant over much of the assessment area, particularly in reach 2. Of the 423 pools identified, only 20% met the criteria for adult holding pools.
- LWD jams – In reaches where most of the spawning occurred (reaches 1 - 3), jams were infrequent and restricted to a few location that remained geomorphically active.
- Water temperature – Temperatures in reaches 1 - 3 exceeded standards during summer months.

Assessment of Juvenile Rearing Habitat

Rearing needs

Juvenile salmonids need protected areas that provide a safe place for foraging and refuge from high temperatures and flooding. Natural channel edges, wood formed pools with abundant cover, and side channels in floodplain forests typically provide this type of habitat.

Conclusions

Analysis indicates that much of the Middle Pilchuck lacks high quality rearing habitat due to bank armoring, riparian degradation, lack of floodplain connectivity, and lack of wood-formed backwater pools. Areas of high quality rearing are small and isolated and are often located a considerable distance from spawning areas (especially in the lower reaches where most spawning currently occurs).

Supporting data

The following is a list of data used to support this conclusion and a brief summary of findings:

- Bank condition – Armored banks impact the quality (especially depth of pools and overhead cover) of edge habitat (see Beamer and Henderson 1998) over 5 1/2 miles of Middle Pilchuck.
- Riparian condition – Degraded riparian conditions limit the quality of edge habitat and future wood recruitment within the lower reaches (1 - 3).
- Side channel habitat – Many side channels were disconnected from the main channel, thereby reducing rearing capacity. Some side channels contained colder water during summer months that flowed back to the mainstem in some places.
- Pool quality & quantity (location, depth, how formed, and amount of cover) – Deficient in-stream structure and low quality pools were found throughout, but they have improved since 2002.
- LWD jams – Most wood jams formed as a result of channel migration into intact riparian vegetation and most occurred in reaches 5 and 7, upstream from most spawning areas in reaches 1 - 3. Otherwise few stable bar apex jams affecting channel complexity and habitat quality were found in reaches 1 - 3.

Comparison with Tulalip Report (Savery and Hook, 2003)

The Tulalip Tribes assessment (Savery and Hook, 2003) was updated by the County's current assessment for several reasons: (1) to assess changes in habitat conditions after the large 2009 flood event, (2) to cover a longer reach of the river, particularly with the potential removal of the City of Snohomish Diversion Dam at river mile 26.4, (3) to better document certain habitat and geomorphic conditions, and (4) to develop project recommendations based on current conditions and landowner coordination.

Similarities in Approach

Where appropriate, the same data collection protocols were used to allow for comparison of results with the Tulalip Tribes report (Savery and Hook, 2003).

Differences in Approach

The Snohomish County assessment extended further upriver to the City of Snohomish Diversion Dam (RM 26.4) whereas the Tulalip assessment ended at river mile 18.1 (downstream of Granite Falls). The County assessment evaluated certain habitat conditions more thoroughly, such as spawning substrate suitability and extent, bank armor locations and conditions, and side channel locations and connectivity. The County assessment was also more accurate in identifying locations of specific habitat conditions. All of the above were intended to help when evaluating habitat conditions in terms of geomorphic processes, selecting project locations, and evaluating restoration outcomes.

Comparative Conclusions

- Wood jam abundance has increased markedly in the past 8 years and pool frequency has also increased, but stable jams that influence river process and habitat formation are infrequent in reaches 1 - 3.
- Pools formed by wood comprise a greater proportion of all pools than previously, but pool frequency is low nevertheless.
- Approximately five and a half miles of river bank are modified and affect juvenile rearing habitat quantity and quality.
- 37% of side channels are isolated or disconnected, some by river modifications.

1 Introduction

1.1 Salmon Recovery Planning

The Pilchuck River, a tributary to the Snohomish River, has been identified as a high priority watershed for the recovery of salmonids in the Snohomish River watershed. The Pilchuck supports four Pacific salmon species [Chinook (*Oncorhynchus tshawytscha*), coho (*Oncorhynchus kisutch*), chum (*Oncorhynchus keta*), pink (*Oncorhynchus gorbuscha*)]; anadromous and resident trout [cutthroat (*Oncorhynchus clarki*), steelhead/rainbow (*Oncorhynchus mykiss*)]; and bull trout char (*Salvelinus confluentus*). Chinook salmon (1999), steelhead (2007), and bull trout (1999) are listed as “threatened” under the Endangered Species Act (NOAA 1999; 2007; USDI-Fish and Wildlife Service 1999). The Pilchuck provides documented spawning and rearing habitat for both Chinook and steelhead and rearing/foraging habitat for bull trout. The Puget Sound Steelhead NOAA Technical Recovery Team proposed (in draft) that Pilchuck River winter-run steelhead be considered a separate demographically independent population (NOAA 2011). In addition, the Washington state fishery co-managers have designated the Pilchuck winter steelhead stock as a distinct stock based on the geographical isolation of the spawning population and an older age structure than other steelhead in the Snohomish River watershed (WDF, WDW and WWTIT 1993). The stock status was rated as depressed in 2002 (WDFW and WWTIT 2002).

Historically a major Chinook salmon river, the Pilchuck now supports only about one hundred natural origin spawners per year (SBSRTC, 2004). Likewise, steelhead production in the Pilchuck Basin is at a small fraction of its historic abundance. Population performance modeling completed during development of the Snohomish River Basin Salmon Conservation Plan (SRBSCP) (SBSRF, 2005) highlighted the sub-basin’s importance in maintaining and restoring the diversity and spatial structure of the Skykomish Chinook population (SBSRTC, 2004), which overall is at 3.4% of its estimated historical abundance. As such, the SRBSCP identifies the Middle Pilchuck River sub-basin as part of the mainstem-primary restoration sub-basin strategy group. The 13 sub-basins in this strategy group contain crucial spawning and rearing areas for Chinook salmon, have moderately degraded or degraded watershed processes and have a great need and high potential for restoration.

Recovery priorities for the mainstem-primary Restoration sub-basin strategy group are listed in the SRBSCP as:

Tier 1 – preservation (along focus reaches), preservation to support hydrologic and sediment processes, removal of barriers, reconnection of off-channel habitats, restoration of shoreline conditions, restoration of hydrologic and sediment processes, riparian enhancement.

Tier 2 – enhance in-stream structure, and address water quality impacts

Along with nearshore restoration and estuary restoration strategy groups these sub-basins are identified as the priority areas for restoring watershed processes and salmon habitat. The SRBSCP does not prioritize restoration actions among sub-basins within the mainstem-primary restoration strategy group as substantial improvement was deemed necessary in each sub-basin. This assessment was initiated because the Middle Pilchuck River was one of few sub-basins in Snohomish County that did not have a completed watershed assessment to guide recovery efforts.

1.2 Assessment Goals

The goals of the Middle Pilchuck River Assessment (MPRA) are to identify opportunities to address salmonid habitat deficiencies through restoration activities and to develop preliminary designs for capital projects at three high priority sites. To meet these goals, a strategic approach was developed including the following steps:

- 1) Compile existing data and collect new data on salmonid habitat conditions.
- 2) Evaluate habitat data to identify habitat limiting factors.
- 3) Complete a geomorphic assessment of habitat forming processes.
- 4) Identify and prioritize opportunities for habitat restoration.
- 5) Complete public outreach to evaluate and build support for projects.
- 6) Select three high priority sites for near-term work.
- 7) Complete 30% designs for the three sites and generate cost estimates.
- 8) Prepare a final assessment report.

This Habitat Technical Report completes the first 2 steps. The habitat assessment provides information to determine which areas have limiting habitat and, in concert with the geomorphic assessment, help identify which sites are most appropriate for potential habitat restoration projects. The geomorphic assessment (step 3) provides information on habitat forming processes to support the development of projects that address limiting factors for listed salmonid populations, and is reported in a companion report. Data were collected for both stages of the assessment concurrently. The workflow for the overall assessment is shown below in Figure 1-1.

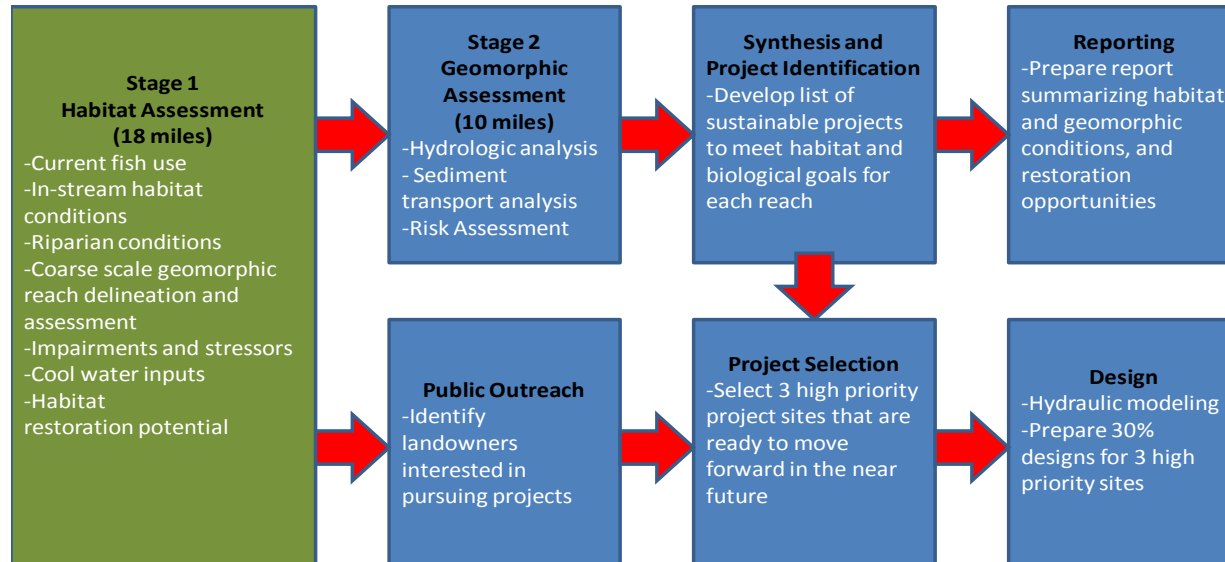


Figure 1-1: MPRA Workflow.

As summarized above, salmon recovery priorities for this sub-basin strategy group include preservation (along focus reaches), reconnection of off-channel habitats, restoration of shoreline conditions, riparian vegetation enhancement, and enhancement of in-stream structures. Therefore, the habitat assessment focuses on describing the conditions that help inform those preservation and restoration objectives, namely:

- Side-channel conditions,
- Shoreline (Streambank/levee) conditions,
- Riparian conditions, and
- Instream conditions (pools, wood jams, gravel and temperature).

Unaltered, unconfined, low gradient rivers migrate across their floodplain over time (Beechie et al. 2006). Chinook and other salmon have evolved with this process, and are dependent on the diversity within the river channel that results from this process (Beechie and Bolton 1999). As a river channel moves laterally, banks on the outside of bends erode, recruiting wood and depositing gravel on inside bends that eventually re-colonize with vegetation. Erodible streambanks protected by mature forest vegetation allow the river to move steadily, abandoning and reoccupying historic channels, creating the diversity of complex off channel, side channel, and main channel habitats on which Chinook and other salmon species depend.

Side-channel conditions

Side channels provide a range of habitat functions for salmon, primarily for juvenile rearing, that vary depending on flow. Side channels provide refuge from flooding in winter, and may contain higher quality habitat conditions (pools, cover, woody debris, foraging, temperature and refuge from predators) than mainstem channels (Swales and Levings 1989; Morley et al. 2005). Side channels are typically formed where a wider floodplain exists and where channel slope is low. These locations are also where floodplain forests naturally grow to eventually contribute large woody debris. Large wood forms log jams that, in turn, reduces local channel slope and act to distribute flood flows across the floodplain and side channels (Brummer et al. 2006). In short, where channel process favors this kind of multi-channel environment, fish habitat capacity and habitat quality are generally high.

Prior to this assessment, information about side-channel conditions or connections along the Middle Pilchuck River had not been recorded and analyzed. Savery and Hook (2003) investigated one side channel in the assessment area and concluded habitat quality was good. They proposed that Pilchuck River floodplain connectivity be improved by connecting side channel habitat, but specific side channel locations and existing or potential connectivity were not identified. For this assessment, side channel locations are identified and are summarized by estimating length by connection type among reaches. Side channel information from this assessment may be used to identify candidate side channels for restoration feasibility.

Shoreline (Streambank/levee) conditions

As human land-use and development have transformed the Pilchuck River valley, river migration has become a threat to farms, roads and houses. In attempts to protect these features and other private and public infrastructure, streambanks have been armored in many places. Tracking the extent of these modified banks is useful for characterizing the condition of edge habitat and therefore the suitability of habitat for Chinook rearing (Beamer and Henderson 1998; Beechie et al. 2005). While hard revetments cause localized scour pools that are utilized by adult salmon for holding purposes, streambanks armored with rock are not suitable for rearing (Beamer and Henderson, 1998) since they have higher velocity flows and often lack the structure and cover provided by pools formed by scour around large wood (Schmetterling et al. 2001, Snohomish Co. Public Works, Skagit Co., and Washington Dept. of Ecology, 2008). Furthermore, hard revetments within floodplain areas restrict natural river meandering and, thereby, the processes that form and renew natural habitats for fish (Beechie and Bolton 1999) over

time. Removal or softening of hardened banks is one type of restoration project that can improve habitat conditions for Chinook rearing, as recommended by Savery and Hook (2003) for the Pilchuck River. Mapping and characterizing modified banks is important for determining the location and feasibility of river restoration projects. The proximity of modifications to infrastructure or developed land uses as well as identification of remnant modifications that no longer provide protection value provides guidance for salmon recovery implementation programs.

Riparian conditions

Mature vegetation communities along river banks provide many direct and indirect benefits to salmon. Riparian vegetation intercepts surface water runoff and associated contaminants, shades the water surface to reduce solar heating, provides resistance to and attenuates high energy in-channel and overbank flows, and serves as a source of large wood and smaller organic matter that contribute to complex natural edge and instream habitat (Knutson and Naef 1997). Savery and Hook (2003) characterized riparian conditions along both banks, classified vegetation by type, age and density, and mapped these conditions as one-dimensional lines along the bank edge. Cottonwood galleries, identified as important sources of large wood in reaches 1 - 3, were also identified and mapped. Recent land cover data summarized as part of this assessment provides an updated view of vegetation in the Middle Pilchuck River floodplain. This new information can guide riparian restoration planning.

Instream conditions (gravel, wood jams, pools, and temperature)

Salmon benefit from habitat preservation or restoration actions that provide habitat for two critical life history stages: spawning and rearing. Chinook returning to spawn in the Pilchuck River need clean and appropriately sized gravel and hydrologic conditions that allow them to access those spawning areas while avoiding predation. Chinook salmon and steelhead typically spawn in large gravel (16-64 mm) (Kondolf 1993), although they may also spawn in larger or smaller gravel sizes. Smaller gravel (2-16mm) may be more suitable for spawning by steelhead (Kondolf 1993). Adult salmon, prior to and during spawning, also require deep pools (>1m residual pool depth; NMFS 1996) with overhead cover, and suitable temperatures (Groot and Margolis 1991; Bjornn and Reiser 1991). Savery and Hook (2003) report observing most Chinook redds in wood debris-forced pool-riffle reaches which tend to produce more frequently spaced pools (Montgomery et al. 1999). Wood-formed pools in these reaches with overhead cover are well-suited for adult holding during upstream migration and provide safe resting areas during spawning.

Large woody debris jams directly affect channel hydraulics and floodplain dynamics by splitting flows, storing sediment, reducing local water slope and influencing floodplain riparian forest development and diversity (Abbe and Montgomery 1996, 2003; Brummer et al. 2006; Montgomery and Abbe 2006). Woody debris jams also form deep scour pools with cover suitable for adult holding and juvenile rearing. Where stabilized by large key pieces, jams accumulate debris from streambanks and upstream sources. In addition to influencing channel hydraulics, jams provide different functions related to habitat and flow (e.g.; hydraulic complexity, cover, edge condition, refuge). Characteristic types of wood jams have been described by Abbe and Montgomery (2003). Bar Apex Jams and Meander Jams in larger meandering rivers have the greatest influence on habitat formation and quality. Bar Top Jams may contain an abundance of wood that is part of the overall wood budget in rivers, but generally do not force changes in channel responses or provide habitat for fish, so are assumed to have less importance (Abbe and Montgomery 2003). The amount and functions of woody debris in rivers may be limited by

the presence of armored streambanks that reduces migration of the river, direct land clearing and land use that precludes mature tree growth, as well as direct wood removal by people.

Juvenile Chinook salmon require complex pool habitat with woody debris for cover. Backwater pools with cover, away from the channel centerline are particularly important (Beamer and Henderson 1998). Side channel habitats are also important, especially during higher spring flooding, though they may be shallow or disconnected in summer. Suitable temperature in summer (and possibly temperature refuges) is important for summer rearing species such as steelhead and coho salmon (Welsh et al. 2001). Suitable river temperature in late summer while adult salmon are migrating upstream to spawn is also critical (Torgersen et al. 1999).

Finally, the existing habitat conditions and the potential effects of restoration actions on salmon populations may be dependent upon fish use within the assessment area. Areas with poor habitat conditions but little fish use may not deliver habitat restoration benefits for fish as might occur in other restoration locations with relatively higher fish use. Therefore, integrating fish use information can help inform and integrate protection and restoration strategies in the Pilchuck River.

1.3 Assessment Questions and Indicators

The MPRA habitat assessment was guided by the five questions listed in Table 1-1 below. Existing data were used to answer questions 1 and 3 and new data were collected to answer questions 2, 4, and 5. Columns two through four list available indicators, data collection activities used as part of this assessment, and outputs from the data analyses.

Table 1-1. Habitat assessment questions, indicators, data collection information, and outputs.

Habitat Assessment Question	Indicators	Data Collection Activities and Protocols	Outputs
How are ESA-listed fish populations currently using habitat within the Middle Pilchuck River sub-basin?	Salmon redds Areas of known and probable high rearing use based on edge habitat quality, woody debris and pools	No new data collection. Review of existing data from co-managers and interpretation of habitat characteristics for rearing consistent with Beamer and Henderson (1998).	Areas of relatively high current use for spawning and (assumed) rearing.
Where do salmonid habitat deficiencies and areas of high function exist?	Large woody debris (LWD) jams Side channels Pools Spawning gravels Percent embeddedness Bank conditions	Remote sensing and field survey of LWD jams and side channels. Field survey of pools, spawning gravels, embeddedness, and bank conditions.	Areas with habitat deficiencies and needs; limiting factors; areas of high habitat function.

Habitat Assessment Question	Indicators	Data Collection Activities and Protocols	Outputs
What is the condition of riparian forests?	Mature forest Cleared or degraded forest conditions	No new data collection. Remote sensing of land cover.	Areas with/without potential to provide LWD recruitment, bank stability, temperature control. Areas for potential planting.
Where are cold water inputs from tributaries and groundwater?	7-day moving average high temperature In-situ temperature	Field survey using in-situ measurements and continuously recording temperature sensors.	Areas of cold water input or refugia; areas with high temperatures.
What are the modifications and constraints to natural river processes within each reach?	Bank armoring Dikes Roads and bridges Utilities	Remote sensing of locations of dikes/levees, roads, bridges, and land cover. Field survey of bank armoring, dikes/levees, and other modifications or river infrastructure.	Areas with modifications that disrupt habitat-forming processes (overlaps with geomorphic assessment outputs).

Because the habitat assessment was completed within a short time period, the indicators chosen were those for which data were either already available or could be easily collected (see descriptions of new data collection in Section 2.2). Data collection activities and protocols were chosen for their relevance to the habitat assessment questions, their relevance to conditions and functions important for salmonids, their common use within the region, and in consideration of time constraints.

2 Methods

2.1 Assessment Area

The assessment area encompasses an 18-mile section of the Pilchuck River in the Middle Pilchuck sub-basin (Figure 2-1). This portion of the river is contained between its confluence with Dubuque Creek at OK Mill Road (RM 8.60) to an area just below the City of Snohomish diversion dam (RM 26.44). The Stage 1 Habitat Assessment was completed for this entire reach, whereas the Stage 2 Geomorphic Assessment was implemented in the lower 10 miles only (Figure 2-1). The assessment area was divided into 8 reaches based on channel slope, floodplain width, and channel constraints. These reaches are shown in Figure 2-1 and listed in Table 2-1.

Table 2-1. Assessment reaches.

Reach	River Mile		Length (mi.)
	Start	End	
1	8.60	11.38	2.78
2	11.38	14.45	3.07
3	14.45	18.32	3.86
4	18.32	20.12	1.80
5	20.12	21.29	1.17
6	21.29	22.52	1.23
7	22.52	24.79	2.27
8	24.79	26.44	1.65

The City of Snohomish water diversion dam located at the upstream limit of the Middle Pilchuck sub-basin represents a high priority restoration opportunity. The dam and associated channel and habitat areas were not included in this assessment, though, since the City of Snohomish owns and operates the facility and is currently evaluating (based on their own data collection) the possibility of removing it. If dam removal occurs, information gathered in this assessment will provide a baseline to evaluate the downstream impacts of dam removal.

2.2 Data Collection

Habitat assessment data were collected between June and December 2010. The collection of new data was planned and implemented based on a review of existing data and the use of remotely sensed information already available to Snohomish County (e.g., high-resolution Light Detection and Ranging (LiDAR) topographic mapping, 2005). Major data elements of the habitat assessment include:

- Review of existing fish presence/use data,
- Review of remote sensing information, and
- Field surveys of habitat units and bank conditions.

2.2.1 Fish Presence/Use

The spatial locations of Chinook salmon redds were recorded in 1999, 2001, and 2002 by the Tulalip Tribes (Savery and Hook, 2003) and in 2009 and 2010 by the Washington Department of Fish and Wildlife (Peter Verhey, WDFW, unpublished data, personal communication). These surveys were conducted during fall spawning periods in the Pilchuck River, and redd abundance and locations were recorded with GPS. Steelhead redds were similarly recorded in 2009 and 2010 by WDFW. The Tulalip Tribe surveys were implemented in reaches 1 - 3 of the assessment area.

2.2.2 Remote Sensing

Remote sensing information was used in combination with field data collection to estimate channel, floodplain, and habitat conditions. LiDAR imagery (2005) and recent orthorectified aerial photographs (1998, 2001, 2003, 2007, 2009) were used to locate side channels, floodplain modifications (such as dikes obscured by vegetation), and LWD jams. Vegetative land cover data, derived from high-resolution satellite sensors, were used to classify riparian vegetation types (Snohomish County SWM, 2010).

Side Channels

Side channels, either dry or containing summer flows, were mapped using 2005 LiDAR imagery. Side channels were characterized by identifying the physical connection to the mainstem channel at either the upstream inlet or downstream outlet (or both). Mapped locations were field verified as to their presence and condition.

Floodplain Modifications

The locations of floodplain modifications that would be out of view during the field surveys were mapped using LiDAR, and generally included setback levees and abandoned roads that are higher than surrounding ground elevations. Existing roads or bridges within floodplain areas were already mapped.

LWD Jams

LWD jams were mapped (point locations) using recent aerial photography (2003, 2007, and 2009). The identification of these jams was based on the Snohomish County protocol for woody debris jams (Rustay et al. 2008), which requires at least 3 large pieces of woody debris (≥ 7.6 meters length and ≥ 30 cm diameter). Larger sized wood pieces are detectable and measurable in these air photos.

Riparian Analysis

Riparian vegetation conditions along each assessment reach were characterized using a previously completed land cover classification (Snohomish County SWM, 2010), which yielded an eight-class land cover product consisting of open water, vegetated, bare earth, and built cover types. For the Middle Pilchuck Assessment, five of the eight classes were further consolidated into three classes describing riparian function as follows: “intact” (mature evergreen and deciduous trees), “moderately degraded” (shrub/small tree) and “degraded” (impervious surface, grass/pasture/lawn, and bare earth). The three riparian functional classes were mapped and summarized by percent of total cover for each reach within 150 ft of the existing river bank (see Table 3.7). The objective of the riparian cover type analysis is to help inform selection and prioritization of potential riparian vegetation restoration projects in conjunction with in-channel and floodplain restoration efforts.

2.2.3 Field Surveys

Salmonid habitat data were collected within all eight assessment reaches (eighteen miles total) in order to characterize habitat conditions for salmonids, focusing on pools, LWD jams, side channels, and salmon spawning gravel size and embeddedness. Field sampling was accomplished mostly on foot and data were recorded using Trimble™ GeoXH GPS data loggers (per Snohomish County 2004).

Habitat Units

The downstream location of each habitat unit (pools, riffles, and glides) was mapped and all habitat unit-specific information (channel type, pool type, pool forming factor, maximum pool depth, pool tailout depth, pool cover category, dominant substrate size category, embeddedness, and riffle type) was recorded. Pools meeting habitat criteria were at least 0.4 meters residual depth and 5 m² in surface area (Snohomish County 2004), consistent with Savery and Hook (2003). Habitat units are summarized

by type, frequency, and other screening criteria described below to determine location, abundance and quality of pool habitats for adult and juvenile salmon. Screening criteria are included in Section 3.1.2.

LWD Jams

LWD data collection included counting LWD jams, classifying jam type, recording jam locations and channel position using GPS, measuring jam height, and determining key piece length, width, and rootwad presence. LWD jams were defined as 10 or more pieces of wood (minimum size of >2m length and >10cm diameter) contained in one aggregation (Schuett-Hames et al. 1999), the same criteria used by Savery and Hook (2003). This protocol is different from the one described above to count jams using air photos (smaller pieces are not discernable in air photos) and as a result yields a larger number of qualifying jams and a difference in report results in section 3.1.2. Large key wood pieces were considered to be any piece >7.6 m long and 30cm diameter (measured at 7.6 m) (Snohomish County 2004), with larger categories also being >15 m length, 30-60 cm diameter, 60-90 cm diameter, and >90 cm diameter. Jam types were identified (either Bar Apex, Meander, or Bar Top jam based on Abbe and Montgomery 2003) along with jam channel positions (e.g. in-channel, on gravel bar, on vegetated bar, on bank).

LWD jam information will help inform decision-making about suitable locations for the placement of engineered log jams (ELJs), appropriate ELJ jam sizes, and expected jam functions or outcomes from restoration (particularly pertaining to pool habitat). LWD jam information was summarized by total count by jam type among reaches, and by screening criteria to identify large stable jams, jams contributing to adult salmon habitat quality, and jams contributing to juvenile salmon habitat. LWD jams were compared in different years to highlight any changing trends in the number or general locations of the jams.

Side Channels

Existing side channels identified through the remote sensing analysis were field verified. Side channels containing flowing water were sampled for habitat units, LWD jams, and bank conditions. Side channels were categorized by their apparent connection type to the main channel (connected at upstream and downstream ends, connected at one end, or not connected). The number of side channels and their total length was summarized by assessment reach.

Spawning Gravel Size and Embeddedness

For each habitat unit (pools, riffles, and glides), the size of the dominant substrate was visually estimated and categorized as small gravel (2-16mm), large gravel (16-64mm), small cobble (64-128 mm), large cobble (128-256 mm), and boulders (>256mm). Next, each habitat unit was qualitatively estimated to be spawnable or not spawnable based on gravel size, local slope, local velocity, shallow depth, insufficient spawning area or gravel thickness (in the case of some bedrock outcrops) or other reason. In some cases, no gravel size description was made where spawning was judged to be unsuitable.

A visual estimate of gravel embeddedness – the degree to which gravels (> 2mm) are covered up by surface fine sediments (sand, silt, clay, < 2mm) – was made for spawnable locations (similar to Peck et al., 2003). Embeddedness estimates were approximated to the nearest of the following values: 0%, 25%, 50%, 75% or 100% embedded (recommended by Paul Devries, personal communication, 2010) by viewing several locations within the habitat unit at potential spawnable areas. The data were used to

determine if embeddedness of spawning gravels is a problem overall and to identify channel segments suitable for potential placement of instream LWD to create pool habitat in non-embedded segments. For the purposes of this assessment, embeddedness values $\leq 25\%$ are considered a low habitat risk, partly due to the fact that spawning salmon are able to expel some fine sediments from gravels as they construct their nests (Kondolf 2000).

Stream Temperature

Fifteen continuously recording temperature sensors were deployed in mainstem, floodplain, or tributary habitats to determine temperature standard exceedances and variability among reaches. Seven additional sensors were placed in shaded riparian areas to record ambient air temperature. Four of the temperature probes were not recovered, resulting in data for eleven sites. Temperature data were compared to Washington State water quality standards for temperature (WDOE 2006). The 7-day average of daily maximum temperature values (7-DADMax) and the amount of time exceeding the standard temperature criterion (16°C) are reported. Temperature information among reaches along with riparian vegetation conditions will help to identify locations that may benefit from reforestation projects or preservation efforts.

Additionally, stream temperature was measured during field surveys with a hand-held calibrated YSI-meter at side channel locations as well as at adjacent mainstem channel locations. Temperature differences between paired locations will help identify where the reconnection of side channels that have cold water might provide more temperature refugia or help reduce water temperatures in the main channel.

Bank Conditions

Bank conditions data were collected within all eight assessment reaches in order to characterize and map bank modifications and bank erosion. Data were collected for the most outer river banks only (right and left); in other words, bank conditions along vegetated islands (i.e., inner banks) where split flow occurred were not inventoried. Definitions of and criteria for bank modification and erosion follow Snohomish County's large river protocol (Snohomish County, 2004). Bank condition points were recorded at each location where a change in bank type, modification type, toe material class, and/or erosion occurred. If neither erosion nor a bank modification were observed, then the banks were categorized as stable and natural. Length of modified bank is summarized by reach for a general characterization of conditions among reaches. Individual modified bank segments are mapped to identify potential restoration sites.

3 Results and Discussion

3.1 Answering Habitat Assessment Questions with Key Indicators

Results are discussed below as they pertain to the questions and key indicators in Table 1-1 that formed the basis of the data collection and analysis.

3.1.1 How are ESA-listed fish populations currently using habitat within the Middle Pilchuck River sub-basin?

Two indicators were used to answer this question:

- Salmon and steelhead redds; and,
- Areas of known and probable high rearing use based on edge habitat quality, woody debris and pools.

Salmon Redds

In most years in which salmon redd locations were determined (1999, 2001, 2002, 2009, 2010), Chinook and steelhead redds were located throughout the Lower and Middle Pilchuck River (downstream from the City of Snohomish Diversion Dam). Chinook salmon redds appeared to be consistently more abundant, in reaches 1 - 3 of the Middle Pilchuck River (Table 3-1, Figure 3-1), where 66% of all redds were observed in this lower 38% of the habitat assessment area. Calculated mean annual redd density was 2.6 redds per mile, considerably less than the 4.0 - 26.4 redds per mile reported for Chinook salmon in the Stillaguamish River (Montgomery et al. 1999).

Steelhead redds in 2010 appeared to be most abundant and dense (number redds/mile) in reaches 1 and 2 (Table 3-1, Figure 3-1). Some steelhead redds, however, were observed in reaches 7 and 8. Reaches 4 and 6 do not appear to be used by either species for spawning, since they are generally steeper, more confined, have larger gravel size and contain infrequent potential spawning areas. All redds are mapped in Figure 3-1.

Table 3-1. Recent Chinook and steelhead spawning redd counts by co-manager staff in Middle Pilchuck River assessment area. Redd counts from the Lower Pilchuck River are also included for comparison. Redd density estimates are based on annual or averaged annual count information.

Sub-basin	Redd survey length (mi)	Assessment reach	Chinook redds					Steelhead redds	
			2010	2009	(2002, 2001, 1999)	Total count	Avg. yearly redd density/ mi	2010	Redd density/ mi
Lower Pilchuck River	7.2	N/A	0	27	13	40	1.1	2	0.3
	2.78	1	7	11	18	36	2.6	21	7.6
	3.07	2	10	11	19	40	2.6	16	5.2
Middle Pilchuck River	3.86	3	4	2	17	23	1.2	5	1.3
	1.8	4	0	0	2	2	0.2	1	0.6
	1.17	5	0	4	N/A	4	0.7	0	0.0
	1.23	6	0	0	N/A	0	0	0	0.0
	2.27	7	2	0	N/A	2	0.2	6	2.6
	1.65	8	1	1	N/A	2	0.25	8	4.8

The redd location information comes from a limited number of years and therefore makes it difficult to interpret whether the current spatial distribution in the Middle Pilchuck River has changed as the population has decreased. The SRBSCP indicates that current Skykomish River Chinook abundance of

adults is estimated to be 3.4% of an historic amount and Pilchuck River Chinook are a component of this larger population.

There was no definite conclusion as to why adult Chinook or steelhead would prefer spawning habitat in Reaches 1 - 3. One explanation could be that adult Chinook migrating upstream may spawn in the first available suitable habitat, especially if there is little competition for spawning sites. Also, fish may spawn where they locate a mate, which at very low population abundance would likely be at the first available suitable habitat, regardless of whether suitable (or better) habitat is located upstream.

Rearing Habitat

High quality pool habitat for juvenile rearing consists of backwater pools in mainstem or side channels, not formed by riprap, and with some type of in-water cover. For this assessment, high quality edge habitats are defined as locations of vegetated streambanks, connected side channels and locations with an absence of streambank armoring. High quality woody debris habitat is defined as stable wood jams that contain a rootwad. Where these conditions exist, the best site-specific rearing conditions are found. Where none of these conditions are present, rearing habitat is considered relatively poor.

Locations where all beneficial conditions for rearing were present in reaches 1 - 8 are shown in Figure 3-2. These locations vary in river length from 150 m to 1.3 km. Smaller, but more frequently spaced areas of high quality rearing habitat exist in the lower 10 miles (reaches 1 - 3), while larger, but less frequently spaced areas appear in the upper river (reaches 5-8). In the upper river, larger areas of high quality rearing habitat appear to coincide with wood jams. In reaches 1 - 3, high quality rearing habitat that appears to be smaller in extent may have been historically larger where and when jam abundance was greater or prior to streambank clearing and armoring. The size of quality rearing areas in reaches 1 - 3 would be expected to increase with instream enhancement, riparian restoration, and /or removal of streambank or floodplain modifications.

3.1.2 Where do salmonid habitat deficiencies and areas of high function exist?

Several indicators were used to determine habitat deficiencies, including:

- Spawning gravel size and percent embeddedness,
- Large woody debris (LWD) jams,
- Pool quantity and quality,
- Side-channel habitat, and
- Bank conditions.

Spawning gravels and embeddedness

A total of 957 habitat units were evaluated for dominant substrate gravel size and, of these, 645 were judged to be spawnable habitat. Large gravel (16-64 mm) was the dominant substrate size among all spawnable habitat units (Figure 3-3) and it was well distributed throughout the assessment area (Figure 3-4). Smaller gravel (2-16mm) may be more suitable for spawning by steelhead (Kondolf 1993) than Chinook salmon and it appeared to be more abundant in assessment reaches 1 and 2 (Figure 3-4).

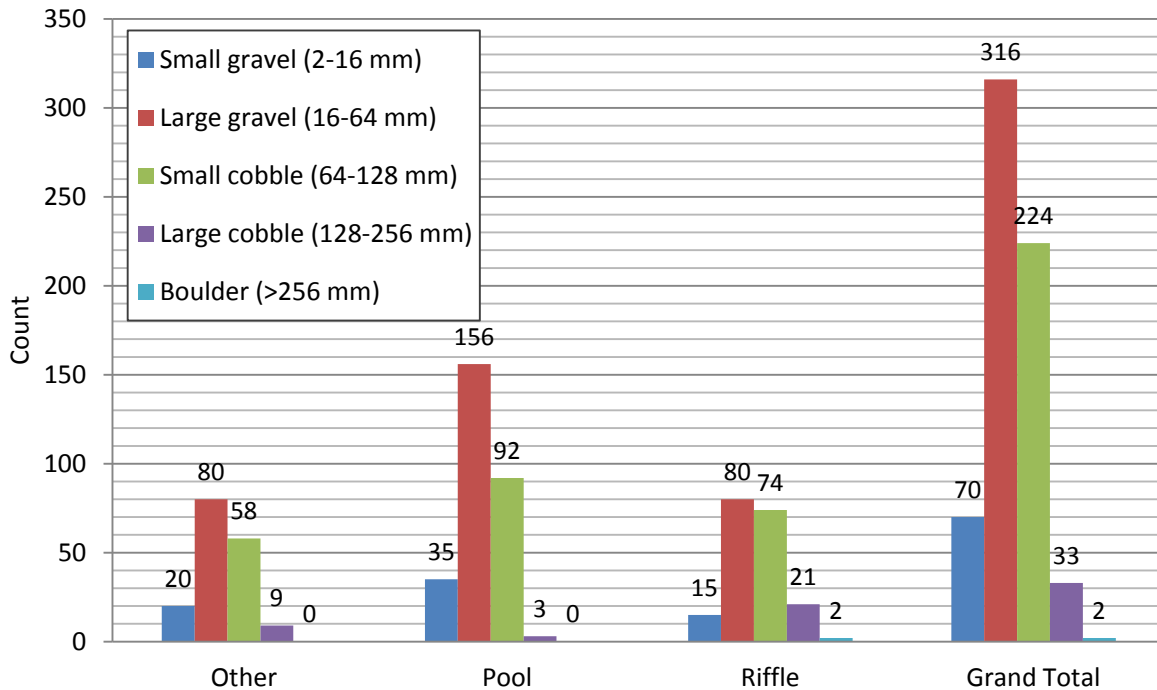


Figure 3-3. Dominant substrate size categories among major habitat types.

Of the habitat units (pools, riffles or glides) containing suitable substrate for spawning, 65% had low embeddedness values of 0% or 25% throughout the 8 assessment reaches (Figure 3-5). Reaches 1 and 2 appeared to have greater relative embeddedness, particularly the upper extent of reach 2, which had unique locations of very low channel gradient. Reaches 3, 5, 7, and 8 had the lowest values of embeddedness relative to the other assessment reaches, thus indicating better spawning substrate conditions compared to reaches 1 and 2. Reach 3, however, was surveyed during a heavy rain which obscured some view of the gravel surface, so embeddedness values may have been underestimated.

In summary, the distribution, abundance, and embeddedness of river gravel for spawning by Chinook and steelhead suggests spawning gravel is not a habitat limiting factor for current salmonid population levels. More spawning areas may be needed if populations increase. These results also suggest that apparent spawning preference by Chinook and steelhead in reaches 1 - 3, more so than reaches 5, 7, or 8, may be due to factors other than spawning gravel size and embeddedness, because spawning habitat quality appears to be better upstream in reaches 5 and 7. Furthermore, an apparent spawning preference for reaches 1 - 3 suggests that rearing habitat improvements in these same reaches may be most beneficial to the salmonid populations.

Large woody debris (LWD) jams

The number of mapped LWD jams increased over time throughout the assessment area as delineated from air photos taken in 2003, 2007, and 2009. The number of jams in each category (bar apex, bar top, or meander jam) also increased over time, except in 2010 (Table 3-2) when field inventory data suggest that the number of jams decreased. One reason for the increase in jam abundance between 2003 and 2009 were large floods in 2006 and 2009 (prior to the air photo). One possible reason for the small decline in 2010 could be that jams broke up or coalesced into larger jams between 2009 and 2010.

Nevertheless, the general trend shows that the number of wood jams has increased over time since 2003, likely due in part to larger flood events.

Table 3-2. Change in woody debris jam count by jam type over time.

Year & data source	Jam type			
	Bar apex	Bar top	Meander	Total
2003 – air photo	2	6	19	27
2007 – air photo	6	19	27	52
2009 – air photo	13	17	50	80
2010 – field inventory ¹	16	15	41	72

1. Protocols for field inventory in this table are different than protocols for data in Table 3-3

For the field inventory of wood jams in 2010, the inventory protocol from Washington State (Schuett-Hames et al. 1999) was used, which is the same protocol used in 2002 by Savery and Hook (2003). Because this inventory protocol includes smaller pieces of wood, more woody debris accumulations qualify as jams. The woody debris jam count from field surveys is listed by assessment reach in Table 3-3. A total of 106 jams were counted in 2010, which is more than the number shown in Table 3-2 due to the differences in inventory protocols.

Jams were more frequent in reaches 5 and 7, and infrequent or absent in reaches 4, 6, and 8 (Table 3-3 and Figure 3-6). Jams appeared to be more evenly spaced (see figure) throughout the lower 10 miles (reaches 1 - 3) and totaled 58 jams in those reaches. In 2002, Savery and Hook (2003) observed 35 jams in reaches 1 - 3; thus indicating again that jam number has increased recently. The higher number and density of jams in reaches 5 and 7 (Figure 3-6) is likely the result of the recruitment of large wood from adjacent mature riparian buffers due to channel migration and bank undercutting in these unconfined (and unmodified) channel locations. By comparison, reaches 1 - 3 and parts of reaches 7 and 8 appear to have deficiencies of large wood jams, though channel migration and bank undercutting are present.

Table 3-3. Jam count by type among assessment reaches and per mile (frequency). Bolded numbers (reaches 1 - 3) denote the lower 10 miles of the assessment area where the Stage 2 Geomorphic Assessment was completed and where data compare to Savery and Hook (2003).

Reaches	Bar apex	Bar top	Meander	Total	Jam frequency (count/ mile)
1	3	4	17	24	8.6
2	4	2	10	16	5.2
3	0	6	12	18	4.7
4	0	0	0	0	0.0
5	6	3	9	18	15.4
6	1	0	0	1	0.8
7	6	7	12	25	11.0
8	1	3	0	4	2.4
Total count	20	25	61	106	
Jam height (m), avg.	1.8	1.4	1.7		

Larger, stable log jams with key pieces and rootwads, located within the wetted channel or on active gravel bars are likely to be most influential for habitat formation and habitat quality (Abbe and Montgomery 2003). Therefore, high quality jams were defined as follows:

- Bar apex and meander jam types only
- Large key piece is present (>7.6 m length or >60 cm diameter)
- Presence of a rootwad on the key piece
- In contact with low flow or gravel bar
- In the main channel (for adult salmon); and in main channel and side channels (for juveniles)

Fifty jams, or 47% of the total count, met the above criteria for high quality jams. Eleven of these were bar apex jams, 9 of which were clustered in reaches 5 and 7. Bar apex jams were tallest on average (1.8 m) presumably because jam formation by a large rootwad occurred low in elevation near the upstream part of the bar apex and was resistant to transport by recent flood flows. These characteristics of bar apex jams indicate that they may be more stable over time and more directly influence instream habitat formation and channel forming processes (such as formation of side channels and floodplain forest regeneration). However, the presence of only 2 bar apex jams (that met these criteria) in reaches 1 - 3 suggests these jams do not readily form in the lower river because large key pieces of wood are rare and/or because channel migration processes and bar formation have been reduced. Given the relative scarcity of large mature trees in reaches 1 - 3, there may be little potential for improved natural wood recruitment. Therefore, increasing the number of these critical wood jams may require instream placement of wood structures (of similar size and height as natural analogs) at feasible locations where local adult and juvenile rearing habitat conditions could be improved. Jam placement could also direct channel movement away from developed areas and, or restore connections to side channels.

Meander jams also contacted the low flow channel (95% of the time for bar apex jams and meander jams combined) and were the most numerous throughout the assessment area, including reaches 1 - 3. Forty five meander jams (74% of all meander jams) were associated with 55 pools containing more than 10% cover (surface area) of wood, brush, vegetation, or undercut streambanks. By comparison, only 8 out of 21 (35%) bar apex jams were associated with 8 pools containing more than 10% cover (surface area). This indicates that meander jams either directly form, or are associated with, higher quality pool habitat in meander bends. As the name implies, these jams form where wood accumulates in river bends and as lateral channel migration cuts into remaining floodplain forest. This contributes to forming sinuous meanders and local accumulations of wood that create greater habitat quality and hydraulic scour within each meander (Abbe and Montgomery 2003). Long term sustainability of abundant meander jams therefore, depends on active channel processes and riparian forests. Results from this assessment suggest that meander jams would provide high habitat functions at locations where presently there are no debris accumulations if safe and feasible to do so.

Although the recent increase in LWD jams is due, in part, to bar top jams that are less functional, the aerial photo count of bar apex and meander jams from 2003 (21 total) to 2009 (63 total) also increased, probably due to flooding that increased bank erosion and recruitment of woody debris. Given these observations of changing jam abundance and current mapping of spatial location (Figure 3-6), locations with deficits in jam frequency and without stable jams could be evaluated to determine if bar apex jam or meander jam placement is feasible to improve channel and habitat functions (wood formed pools with cover or splitting flow into side channels) for juvenile salmon rearing where these conditions are lacking (as in Figure 3-2).

Pool Quality and Quantity

Pools meeting habitat criteria were at least 0.4 meters residual depth and 5 m² in surface area, and are listed by reach in Table 3-4. 423 pools were observed in the assessment area and 240 of these were in reaches 1 - 3. Wood-formed pools comprised 49% of all pools in the assessment area and 52% of all pools in reaches 1 - 3. In 2002, Savery and Hook (2003) observed that wood-formed pools formed 39% of all pools in reaches 1 - 3. Therefore it appears wood-formed pools have increased overall.

Table 3-4. Pool habitat summary values.

Reach	Freq. (pools / km)	Location (count)		Type (count)		Forming factor (count)					
		Main channel	Side channel	Primary	Backwater	Beaver	Bed rock	Boulder	Free form	Rip rap	Wood
1	15.0	66	1	50	17	0	3	6	12	13	33
2	15.2	74	1	56	19	0	11	2	5	16	41
3	15.8	83	15	67	31	0	12	4	20	11	51
4	10.4	30	0	26	4	0	16	1	3	7	3
5	25.0	31	16	22	25	1	2	2	9	2	31
6	13.1	26	0	23	3	0	1	4	5	11	5
7	16.7	51	10	37	24	0	2	4	14	3	38
8	7.2	19	0	17	2	0	3	2	1	6	7
Total	14.7	380	43	298	125	1	50	25	69	69	209

Deep pools with cover near spawning areas provide refuge to adult salmon prior to and during spawning as salmon migrate upstream traveling from pool to pool. High quality pools for adult use are defined as follows:

- Pool location – within the mainstem channel;
- Pool type – primary;
- Pool depth – ≥1.0 m residual depth;
- Pool cover – ≥10%; and
- Cover type – wood debris, boulder, riprap, and brushy/overhanging vegetation.

Within the assessment area, 85 out of 423 pools (20%) met these criteria and, of these, 45% were formed by wood (either jams or single pieces) (Figure 3-7). In addition to wood formed pools, many pools that met the criteria for high quality adult use were formed by riprap (21%), bedrock outcrops (20%), natural bank scour (12%), and boulders (2%). Reach 1 contained the most frequently spaced adult holding pools, because 7 riprap formed pools (out of 18 total) are located in reach 1. However, the higher frequency of adult holding pools in reach 1 does not directly overlap with higher spawning use in reaches 2 and 3. These adult habitat pools are also illustrated in reach maps (Figures 3-16 to 3-23).

Although there is relatively greater spawning activity in reaches 2 - 3, adult holding pools are not more frequent or of higher quality than in upstream reaches. These data suggest that the locations of deep holding pools do not appear to structure spawning distribution, but, nevertheless, deep holding pools could be very beneficial where restored near Chinook spawning areas in reaches 2 - 3.

For juvenile rearing, many of the same adult holding pools with cover provide habitat. However, high quality pools for rearing were screened from all pools using the following indicator criteria:

- All pools in side channels,
- Main channel backwater pools,
- No riprap formed pools, and
- No minimum depth (other than 0.4 m residual depth)

Within the assessment area, 106 out of 423 pools (25%) met the criteria for juvenile rearing. Of these 106 pools, 76% of these were formed by woody debris (jams or single pieces) (Figure 3-7).

Reaches 5 and 7 contained the densest pool spacing among all reaches, which was strongly associated with wood jam abundance at these locations. Reaches 4, 6, and 8 contained few high quality rearing pools (Figure 3-7). Within reaches 1 - 3, high quality backwater rearing habitat occurs at channel meander locations, away from armored banks, and generally where the channel retains some migration tendency. These are mostly formed by woody debris that creates pool-forming scour and provides cover from predation. Backwater pools occur away from the channel centerline and therefore have less velocity and disturbance during flooding. A recent increase in woody debris abundance may have contributed to forming more backwater pools in locations that currently favor rearing. However, locations with bank armor, degraded riparian conditions, and less meandering are still impaired with respect to backwater pool habitat formation. Addressing these limiting factors will likely increase backwater pool habitat area and frequency to help expand existing rearing areas.

Side Channel Habitat

There were 108 side channel features delineated within the assessment area using remote sensing data. Eighty-six of these were field verified to evaluate whether the side channel was present and if it was connected to the mainstem (with a gravel streambed or surface flow). Tributary streams were not considered as part of this summary of flow connections to the mainstem. Although 22 of the mapped side channels were not field verified due to private property, accessibility, or daily time constraints, they are included in the total because they show characteristics similar to other side channels in the LiDAR imagery and contribute to the evaluation of habitat types and how those vary among reaches. Figure 3-8 displays these side channel locations.

Table 3-5. Side channels by reach are categorized by the type of connection with the mainstem river.

Reach	No connection	Upstream OR downstream connection	Upstream AND downstream connection	Total
1	3	7	6	16
2	8	9	2	19
3	14	6	7	27
4	0	2	0	2
5	3	11	6	20
6	1	2	0	3
7	6	10	1	17
8	0	4	0	4
Total	35	51	22	108

Reach 5 contained the greatest number of connected side channels (17 out of 20). Reach 3 contained the greatest number of un-connected or isolated side channels and the greatest number of side channels overall. Reaches 2 and 7, respectively had the next greatest number of isolated or un-connected side channels. Reaches 4, 6, and 8 had few side channels, suggesting that very little natural side-channel rearing habitat is located in these reaches. This is consistent with greater slope and floodplain confinement in these reaches.

The length and proportion of connected and un-connected side channels were estimated (Table 3-6). Reach 3 had the greatest total length of side channels, including the greatest length of un-connected side channels, partly due to revetments and levees. The total length of all side channels in reach 3 totaled 80% of the length of the mainstem within that reach. As a relative measure, reach 5 had side channels that totaled 120% of the length of the mainstem within that reach, exhibiting a high density of side channel length, and therefore greater side-channel rearing habitat. Reach 5 had the lowest proportion of un-connected side channels (10.5%, among channels with un-connected habitat) and contained the most diverse channel types and habitat conditions within the Middle Pilchuck River.

Table 3-6. Estimated side channel length among reaches and the ratio of side channel length to mainstem length. Increasing the length and total ratio of side channels may be more feasible in reaches 2, 3 or 7 based on length of un-connected channels.

Reach	Un-connected (feet)	Connected (feet)	Grand total (ft)	Side channel miles	Mainstem miles	Ratio; connected side channels/ mainstem	% Un-connected
1	1313	5609	6922	1.3	2.8	0.5	19.0
2	4866	7291	12157	2.3	3.1	0.7	40.0
3	8837	7040	15877	3.0	3.9	0.8	55.7
4	0	1087	1087	0.2	1.8	0.1	0.0
5	1440	12300	13740	2.6	1.2	2.2	10.5
6	1027	1054	2081	0.4	1.2	0.3	49.3
7	4339	5724	10063	1.9	2.3	0.8	43.1
8	0	2210	2210	0.4	1.7	0.3	0.0
Total	21,822	42,315	64,137	12.1	17.8		

Based on the coarse-scale side-channel indicators of mapped length, side-channel flow, and connection types, it is concluded that reaches 2, 3, 5, and 7 are locations where side channels naturally form in greater relative abundance and therefore represents an appropriate habitat type to restore in these reaches. Reaches 2 and 3, in particular, contain over 50% of all un-connected side channel length in the assessment area. Figure 3-9 shows the comparative length among un-connected and isolated channels, (blue is the longest category, etc.). Because salmon spawning currently is relatively more abundant in reaches 2 and 3, restoration of side-channel connections in these reaches makes sense from the standpoint of restoring floodplain connectivity and creating habitat benefits that overlap with fish use.

Bank Conditions and Floodplain Modifications

Both right and left banks along the 18 mile assessment area were characterized by the extent (length and %) to which they were modified by direct human activity (rock riprap, or other means of bank revetment, construction of levees, etc.) and their stability (Table 3-7, Figure 3-10). These data represent a baseline for bank conditions in the Middle Pilchuck River.

Over 16% of total bank length was identified as modified by human activity with approximately 5.6 miles of armoring distributed throughout the eight reaches surveyed. As expected, reaches with private and public infrastructure near the channel margin contained the highest proportion of modified streambanks, including reaches 1, 6 and 8 (the latter of which included a water supply pipeline). Floodplain modifications setback from the streambank edge were located in each reach except reaches 4 - 6.

Table 3-7. Streambank characteristics by condition (modified or natural) and stability (stable or unstable). Total length and percent of total by reach is reported.

Reaches	Modified	Natural	Stable*	Unstable*	Total (ft)	Modified (%)	Unstable (%)
1	7025	21115	19260	8881	28140	25.0	31.6
2	4086	27678	20747	11016	31764	12.9	34.7
3	4771	33928	25464	13234	38699	12.3	34.2
4	3430	14865	14208	4087	18294	18.7	22.3
5	519	10605	7043	4082	11125	4.7	36.7
6	3684	9324	9627	3381	13008	28.3	26.0
7	2065	21187	14078	9174	23252	8.9	39.5
8	3767	9497	10837	2426	13264	28.4	18.3
Total (ft)	29,348	148,198	121,263	56,282	177,546	25.0	31.7

* Includes lengths for both modified and natural streambanks.

Reaches 5 and 7 contain relatively low amounts of bank modifications and at the same time have the highest percent of bank instability. These reaches contain active river meandering that is reflected in bank instability, but these reaches also are bordered by well vegetated conifer forest that contributes woody debris to the channel. Intermediate levels of bank modification are found in reaches 2-4, but bank instability is higher in reaches 2 and 3. Higher bank instability in reaches 2 and 3 may be due to the degraded stream buffer (especially on the right bank). Even though flooding was severe in 2009, it's not known whether the magnitude of instability is greater now, though there are notable locations of new erosion. The geomorphic assessment in reaches 1 - 3 highlights locations of recent bank movement.

Bank modifications not only alter and degrade the quality of edge habitat for rearing salmon in terms of substrate type (riprap or rubble), cover, flow velocity, and riparian vegetation (Beamer and Henderson 1998), but also limit channel meandering within the floodplain, which, in turn limits natural geomorphic processes that form, change and renew complex habitats over time. For example, reach 1 contains bank modifications that highly constrain the river to an alignment that hasn't changed much since the 1970s. Numerous primary pools are formed by riprap armor but backwater pools are rare, except in unmodified locations with natural banks, wood debris accumulations, and some channel migration. In reach 1 and elsewhere much of the bank modification (but not all) directly protects homes, roads, and

other infrastructure or land uses in close proximity to the river banks. In other locations, such as reaches 2, 3, and 7, some armoring is located to prevent or limit channel migration, but no homes, roads, or other infrastructure are nearby. Reducing streambank armoring has the potential to improve edge habitat conditions, especially where such projects also include woody debris placement and riparian planting.

Floodplain modifications outside of the streambank edges may also limit natural channel processes, and thereby limit the quality, quantity and type of habitats available for rearing salmonids. Floodplain modifications identified include dikes and revetments that were setback from the edge of streambanks. These structures may currently (or historically) limit channel migration processes or act to isolate habitat area, and streambanks adjacent to these modifications may (or may not) be armored.

All reaches except 4 - 6 contain such modifications (and are shown in Figures 3-2 and 3-15). In particular, reaches 1, 2 and 3 each contained one older levee (totaling 2,800 feet) that appeared to not receive maintenance or protect infrastructure, but nevertheless affects river channel migration process and disconnects habitat area.

Although bank armoring and floodplain modifications were not individually classified by protective functions for this habitat assessment, reviewing individual locations of bank armor or dikes for protective function and restoration potential will be an important consideration in developing possible treatments. This may be particularly true for the 47 instances of active erosion or failure at existing bank modifications (totaling nearly one mile).

3.1.3 What is the condition of riparian forests?

Figure 3-11 shows a summary of the land-cover data within a 150 ft buffer from the edge of the streambanks. There was little to no vegetation in the assessment area that could be described as pristine or unaltered. Cover types were classified in terms of ecological function as intact (evergreen and deciduous trees 25 ft and taller), moderately degraded, (shrubs and small trees), or degraded (grass, bare earth and impervious surface).

Historic photos, as well as current land-cover classification, confirm that human land use on the banks of the Pilchuck River has altered natural riparian vegetation and consequently the functions it provides to river process. Approximately 64% of the analyzed riparian buffer can be described as intact with another 13% classified as moderately intact. Degraded riparian cover types made up the remaining 23% (Table 3-8). These alterations have not occurred uniformly across the assessment area.

There was a clear distinction in riparian forest quality between both banks of the river within some reaches. This was due primarily to land use zoning designations, road access to properties, and topography. The left banks (facing down-river) of reaches 3 and 4, and to a large extent reach 2, are almost continuously forested while right bank land cover is largely non forested, dominated by agriculture and residential use. This fact could influence a restoration strategy especially if it is found that river flow could be directed away from infrastructure on one bank and toward more natural riparian conditions on the opposite bank.

Table 3-8. Riparian land cover information as percentage of cover within 150 feet of the outer river banks. Cover types are organized into broad classes indicating riparian function; intact, moderately degraded, and degraded.

Reach	Intact	Moderately degraded	Degraded		
	Forest	Shrub/Small tree	Grass	Bare earth	Impervious
1	62%	12%	19%	4%	2%
2	57%	13%	23%	6%	1%
3	69%	10%	18%	1%	2%
4	78%	8%	11%	1%	2%
5	68%	21%	11%	1%	0%
6	44%	17%	32%	1%	6%
7	62%	21%	15%	1%	1%
8	73%	10%	15%	1%	2%
Total	64%	13%	19%	2%	2%

While this rapid land cover analysis provides useful information about riparian quality and function, there are other factors to consider when developing potential restoration projects. For example, observations from the field revealed that not all “intact” riparian conditions provide the same level of benefit, are as resistant to disturbance, or are as likely to persist over time as others. Tree species composition and diversity differed among riparian forest stands. These site specific observations along with aerial photo interpretation are will help guide the development of riparian forest restoration prescriptions at a sub-reach or site scale.

3.1.4 Where are cold water inputs from tributaries and groundwater?

Temperature was measured in 2010 at 11 locations with continuously recording temperature probes in the mainstem Pilchuck River, tributaries, and side channels (Figure 3-12). Figure 3-13 displays the running 7-day average daily maximum temperature during the sampling period among mainstem Pilchuck River locations. Table 3-9 shows the maximum seven day temperature and percent of time each site exceeded the 16° C state water quality standard.

Generally, temperature increased among sites in a downstream direction and mostly exceeded the temperature standard in July and August. Only the Upper Pilchuck River and Menzel Lake Road locations occasionally met the temperature standard during this time. From the Upper Pilchuck River (upstream from assessment area) to Skinner Road (reach 5), temperature increased significantly. Downstream from here in reaches 4 and 2, temperature decreased. The daily pattern of temperature in reach 2 at Schwarzmiller (purple line in Figure 3-13) suggests that upstream inflow from cooler groundwater, floodplain, and or hyporheic water sources is reducing temperature. Between Schwarzmiller and Russell Road in reach 1, temperature increased significantly, again. Notably, on the hottest summer day in 2010, the Schwarzmiller location was approximately 5 degrees cooler than downstream (Russell Road bridge) and 2 degrees cooler than upstream (reach 4).

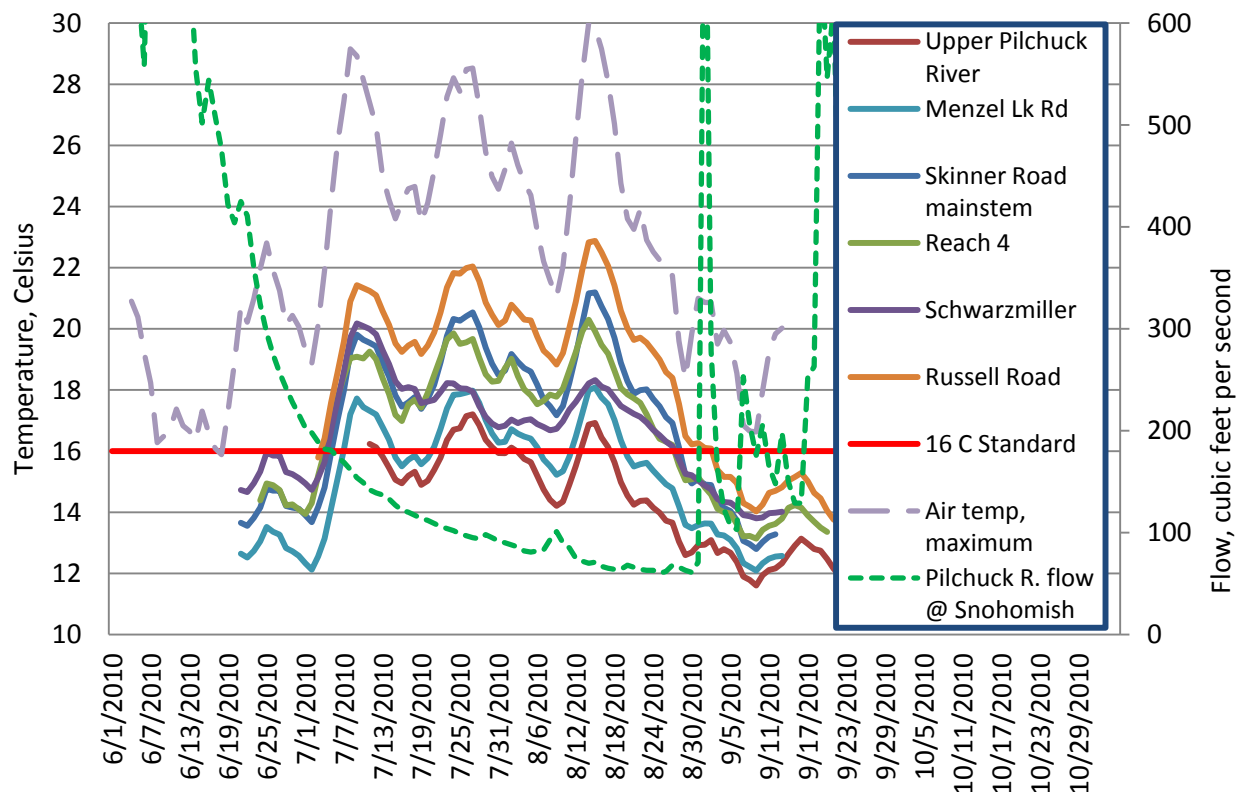


Figure 3-13. Seven-day average daily maximum temperature among Pilchuck River mainstem locations – the list reads from upstream to downstream. Also shown are the applicable Washington State temperature standard of 16° C, 7-day average daily maximum air temperature, and Pilchuck River flow, cubic feet per second (right axis).

Additional data are needed to confirm this apparent cooling in reaches 2 and 3 as two temperature probes placed in reach 3 were not recovered. River floodplain geomorphology, as influenced strongly by glacial advance and retreat, suggests that groundwater discharge in reaches 2 and 3 may influence river temperature. Reach 3 is located in a broad alluvial and glacial outwash valley with permeable surficial geology, higher relative groundwater recharge, and observed groundwater discharge to the Pilchuck River.

Table 3-9. Temperature summary values for continuously recording temperature sites by ascending river mile location. The 7DADMax (°C) is the running 7-day average of daily maximum temperature. Exceedance time is percent of days in summer exceeding 16 °C, the Washington State temperature standard for core summer habitat in the Pilchuck River and its tributaries.

Site name	Channel	River mile	7DADMax Celsius	Exceedance time (%)
Dubuque Cr.	trib	8.8	19.5	61
Little Pilchuck Cr.	trib	8.9	21.1	82
Russell Rd. Dept. of Ecology	main	10.7	22.9	69
Conner Lake Cr.	trib	11.7	22.3	63
Pilchuck R., Schwarzmiller	main	13.4	20.2	64
Pilchuck R., Reach 4	main	18.5	20.3	61
Pilchuck R., Skinner Rd.	main	20.6	21.2	64

Site name	Channel	River mile	7DADMax Celsius	Exceedance time (%)
Pilchuck R., Skinner Rd. side channel	main	20.6	14.9	0
Pilchuck R., Menzel Lake Rd.	main	25.6	18.1	39
Pilchuck R., Upper	main	28.4	17.2	21
Worthy Cr.	trib	28.4	12.4	0

In addition to recording temperature continuously at the above fixed stations, ambient water temperature was sampled during habitat assessment surveys in reaches 1 - 3. Temperatures were compared at six locations (Figure 3-14), where surface water flow entered the mainstem from a side channel that had no inflow from the river at the upstream end. Return flow was therefore likely originating from hyporheic flow, groundwater inflow, or shallow floodplain aquifer areas. In each case, the temperature of the return flow was markedly lower than the mainstem and below the 16°C temperature standard in most cases (Figure 3-14). The same was true of a seventh side channel located at Skinner Road where a continuously recording temperature probe was deployed and where temperatures in the side channel (7DADMAX = 14.9° C) were much lower than the adjacent main stem (7DADMAX=21.2° C; as noted in Table 3-9). Fish (primarily coho parr) were present within each of these side channels.

Although this evaluation of spatial temperature variability represents a snapshot in time, the information supports the interpretation that more geomorphically diverse and active river segments bordered by strong water recharge and discharge processes promotes cold water refuge areas for rearing fish as a result of side channel formation. Reach scale cooling due to coldwater inflow could provide a substantial habitat benefit for summer rearing species. Improving structural habitat quality and quantity (such as side channels, edge habitat, pools, and LWD) at locations of suitable temperature may provide high benefit. Implementing structural habitat enhancements in these locations may provide greater habitat benefits during summer. The same habitat benefits would be valuable for species migrating out of Pilchuck River during spring when temperatures are not typically exceeded.

3.1.5 What are the modifications and constraints within each reach?

In addition to defining the location of highly functioning river segments, and conversely, those areas with habitat deficits, it is important to consider the many possible physical and logistical limitations to implementing restoration projects. As described above, data was collected to identify locations of instream and floodplain modifications that limit river movement. Some of these structures provide restoration opportunities while others clearly constrain the type and magnitude of projects that might be reasonably proposed as they provide protection to important infrastructure or land uses. Figure 3-15 displays some of the data that will be considered as project locations and types are evaluated during the synthesis and project identification phase of this project.

3.2 Comparison with Tulalip Tribes Report (Savery & Hook, 2003)

The Tulalip Tribes assessment (Savery and Hook, 2003) was updated by the County's current assessment for several reasons: (1) to assess changes in habitat conditions after the large 2009 flood event, (2) to cover a longer reach of the river, particularly with the potential removal of the City of Snohomish

Diversion Dam, (3) to better document certain habitat and geomorphic conditions, and (4) to develop project recommendations based on current conditions and landowner coordination.

Similarities in Approach

Where appropriate, the same data collection protocols were used to allow for comparison of results with the Tulalip Tribes report (Savery and Hook, 2003).

Differences in Approach

The Snohomish County assessment extended farther upriver to the City of Snohomish Diversion Dam whereas the Tulalip assessment ended at Granite Falls. The County assessment evaluated certain habitat conditions more thoroughly, such as spawning substrate type and extent, bank armor locations and conditions, and locations and connectivity of side channels. The County assessment was also more accurate in its locations of specific habitat conditions, primarily due to advancements in available technology (e.g., LiDAR and GPS). All of the above were intended to help when evaluating alongside of geomorphic process information, selecting project locations, and evaluating restoration outcomes or trends over time.

Conclusions

- This assessment concludes that river restoration should focus on limiting factors for juvenile salmon rather than spawning habitat, which was not distinguished in the Tulalip assessment.
- This assessment determined that there is low use of the upper Middle Pilchuck for spawning, which was not surveyed by the Tulalip assessment.
- This assessment indicated that wood jam abundance has increased markedly in 8 years and that pool frequency has also increased compared to the Tulalip assessment, but stable jams that influence river process and habitat formation are infrequent in reaches 1 - 3.
- This assessment determined that pools formed by wood comprise a greater proportion of all pools than previously reported, but pool frequency is low nevertheless.
- This assessment identified locations and connectivity of side channels within the floodplain (37% are disconnected) to characterize relative amounts of side channel formation and potential reconnections among reaches.
- This assessment determined approximately 5 1/2 miles of river bank are modified and maps locations of these existing conditions, necessary for investigating project feasibility.

3.3 Limitations and Uncertainties

This assessment of the Middle Pilchuck River provides summary information for high level indicators of salmon habitat quality and quantity. This report, with supporting mapping, identifies where high quality habitats for salmonid fishes are found and where habitat deficiencies exist.

This report summarizes the conditions that were observed, but does not describe watershed or floodplain processes that create salmonid habitat in the Pilchuck River. The relationship between habitat conditions and geomorphic conditions will be considered during the project synthesis phase so that site specific recommendations for important project types can be developed with a high level of confidence in outcomes both for habitat restoration and benefits to fish in the Middle Pilchuck River.

Also beyond the scope of this project was any deliberate consideration of future habitat targets for protection or restoration in the Middle Pilchuck subbasin in support of overall Snohomish Basin Salmon

Recovery goals. If such targets for future habitat protection and restoration are identified later, then locations for protection and restoration and level of effort needed to support targets can be better determined for project types or actions that address habitat deficiencies described in this report.

4 Conclusions

Previously, the Tulalip Tribes (Savery and Hook 2003) conducted an assessment in 2002 in part of the Middle Pilchuck River. This assessment differs from that effort because it accomplishes a spatial census of bank conditions, side channels, log jams, fish habitat, and riparian conditions along the entire 18 miles of the Middle Pilchuck River sub-basin and provides up-to-date information on habitat limiting factors for project planning and feasibility analysis. Habitat data were analyzed to assess the condition of both spawning and rearing habitat in the Pilchuck River. The major factors limiting Chinook salmon production in the Middle Pilchuck River appear to be a lack of rearing habitat in the form of side-channel habitat, deep pools with natural cover, high quality bank edge habitat (due to armoring) and temperature impairment during summer months. The root causes of these habitat limiting factors within the Middle Pilchuck River are floodplain and streambank modifications and clearing of natural vegetation in floodplain forests.

The following is a summary of the assessment conclusions for key life stages including how the data supports the above conclusion that rearing habitat is limiting and spawning habitat is underutilized.

Assessment of Adult Spawning Habitat

Spawning needs

Chinook returning to the Pilchuck River to spawn need clean and appropriately sized gravel and deep pools with overhead cover.

Conclusions

- Available spawning gravels appear to be underutilized at currently low adult salmon abundance, so spawning habitat is not limiting.
- The lack of deep pools with cover and wood structures forming pools favored by adults prior to spawning may become limiting in the future if more adult Chinook return to the river.
- Another concern is that high summer stream temperatures may affect adult migration timing or survival, as noted in Savery and Hook (2003), but was not specifically investigated as part of this assessment.

Supporting data

The following is a list of data used to support this conclusion and a brief summary of findings:

- Substrate size - Of the 957 habitat units inventoried during the survey, 645 were determined to have gravel size suitable for spawning in areas likely to be utilized by salmonids.
- Embeddedness - Sixty-five percent of spawnable areas were classified as having relatively low (0% -25%) embeddedness.
- Redd locations (data from the Tulalip Tribes and WDFW) – Only a fraction of areas suitable for spawning are being used by Chinook. Currently, it appears most adult Chinook and steelhead spawning occurs in reaches 1 - 3 although adequately sized spawning substrate

and adult holding areas are available throughout the assessment area. In the future, as salmon abundance increases, spawning may become limiting, and sooner, if most spawning remains restricted to reaches 1 - 3.

- Pool quality & quantity (location, depth, how formed, and amount of cover) - While spawning gravels are numerous and widely distributed, deep holding pools and the jams that create and provide cover for them were not abundant over much of the assessment area, particularly in reach 2. Of the 423 pools identified, only 20% met the criteria for adult holding pools.
- LWD jams – In reaches where most of the spawning occurred (reaches 1 - 3), jams were infrequent and restricted to a few locations that remained geomorphically active. These reaches have more bank modifications and degraded riparian vegetation (that limit jam formation), but nevertheless have higher spawning use. Given the relative scarcity of stable bar apex jams in parts of reaches 1 - 3 and a low source of large mature trees, there may be little potential for improved future recruitment and stable jam formation. Habitat complexity, however, would likely increase closer to spawning areas with the addition or augmentation of jams in a number of locations. Specific locations could be evaluated to determine if log jam placement is feasible in order to improve habitat functions for adult spawning salmon (with important juvenile rearing benefits as well) where these conditions are lacking near high fish use areas.
- Water temperature – Temperatures in reaches 1 - 3 exceeded standards during summer months.

Assessment of Juvenile Rearing Habitat

Rearing needs

Juvenile salmonids need protected areas that provide a safe place for foraging and refuge from high temperatures and flooding. Natural channel edges, wood formed pools with abundant cover, and side channels in floodplain forests typically provide this type of habitat.

Conclusions

Analysis indicates that much of the Middle Pilchuck River, particularly reaches 1 - 3, lacks high quality rearing habitat due to bank armoring, riparian degradation, lack of floodplain connectivity, lack of wood-formed backwater pools, and high water temperature in summer. Areas of high quality rearing are small and isolated and are often located a considerable distance from spawning areas (especially in the lower reaches where most spawning currently occurs). Rearing habitat quality and quantity for juvenile Chinook salmon are therefore concluded to be limiting. The lack of abundant high quality rearing habitat reduces survival rates for emergent juveniles that typically use complex edge and backwater habitat, wetted side channels, and wood-formed pools with cover for refuge.

Supporting data

The following is a list of data used to support this conclusion and a brief summary of findings:

- Bank condition – Armored banks impact the quality (especially depth of pools and overhead cover) of edge habitat (see Beamer and Henderson 1998) over 5 1/2 miles of Middle Pilchuck. These altered bank conditions not only affect remaining habitat quality, but have also affected rearing habitat capacity by cutting off river flow to several side channels throughout the assessment area.

- Riparian condition – Degraded riparian cover vegetation types made up 23% of the buffer area evaluated. Degraded riparian conditions limit the quality of edge habitat, future wood recruitment, and shade within the lower reaches (1 - 3), where, in particular, right bank erosion has further reduced narrow vegetated buffers. These (and completely un-vegetated) streambanks are highly susceptible to continued erosion, which might be reduced if the channel centerline were shifted toward the forested and, largely, unpopulated left bank. Reaches 2 and 3, in particular, have several areas that would benefit from riparian vegetation restoration that will, over time, stabilize the river banks, slow channel migration and provide valuable stream functions.
- Side-channel habitat – Many side channels were disconnected from the main channel, thereby reducing rearing capacity, particularly in reaches 2-3. Some side channels exhibited colder water during summer months, some of which flowed back to the mainstem. The potential reconnection of side channels could be evaluated by considering adjacent land uses and constraints, whether a natural or infrastructure barrier exists, the potential length and channel width to be re-connected, the potential channel avulsion risk, and whether a natural riparian buffer exists (to promote high quality habitat formation).
- Pool quality & quantity (location, depth, how formed, and amount of cover) – Deficient in-stream structure and low quality pools were found throughout, though they have improved since 2002. Pool frequency and quality (backwater with cover) was better where the main channel is more geomorphically active and large woody debris accumulates from adjacent forested areas. At these locations (with examples in reaches 3, 5, and 7), pools are frequently spaced, formed by woody debris in backwater locations and have greater amounts of cover for salmonids. Alternatively, pool rearing habitats in reaches 1, 2, and parts of 3 are most degraded primarily due to riprap armoring, degraded riparian vegetation and lower abundance of stable wood jams. The total area and locations of quality rearing areas in reaches 1 - 3 would be expected to increase with instream enhancement, riparian restoration and restoration of bank modifications.
- LWD jams – Although the overall abundance of wood jams appears to have increased since this area was surveyed in 2002, there are few stable jams with key pieces and rootwads throughout the assessment area. The jams that are present are trapping fine sediment, sorting spawning gravels, scouring pools, and providing cover for salmonids, thereby demonstrating important habitat functions. Where most abundant, jams formed as a result of channel migration into intact riparian vegetation and most occurred in reaches 5 and 7, however, upstream from key spawning areas. Few stable bar apex jams affecting channel complexity and habitat quality were found in reaches 1 - 3, where rearing habitat near spawning areas should be enhanced.
- Water temperature - Water temperatures in summer 2010 exceeded the Washington State standard at all nine continuous monitoring sites within the main channel. Seven of these sites exceeded the standard over 60% of the summer sampling period. These data are sufficient for 303(d) listing consideration by the Washington Department of Ecology. Monitoring indicated that several geomorphically active and diverse channel areas contain cooler hyporheic or groundwater flow connections. Lower water temperatures in discrete habitat areas, particularly with side channels reflect additional habitat benefits in locations where natural channel migration and habitat formation still occurs.

5 References

- Abbe, T.B., and D.R. Montgomery. 1996. Large woody debris jams, channel hydraulics and habitat formation in large rivers. *Regulated Rivers: Research & Management*, Vol. 12, 201-221.
- Abbe, T.B., D.R. Montgomery. 2003. Patterns and geomorphic effects of wood debris accumulations in the Queets River watershed. *Geomorphology* 51, 81–107.
- Beamer, E.M. and R.A. Henderson. 1998. Juvenile Salmonid use of Natural and Hydromodified Stream Bank Habitat in the Mainstem Skagit River, Northwest Washington. Prepared for: United States Army Corps of Engineers, Seattle District, Environmental Resources Section, 4735 East Marginal Way South, Seattle, Washington 98134-2385.
- Beechie, T.J. and S. Bolton. 1999. An approach to restoring salmonid habitat-forming processes in Pacific Northwest watersheds. *Fisheries* 24(4):6-15.
- Beechie T. J., M. Liermann, E. Beamer and R. Henderson. 2005. A Classification of Habitat Types in a Large River and Their Use by Juvenile Salmonids. *Transactions of the American Fisheries Society* 134: 717–729.
- Beechie, T. J., M. Liermann, M. M. Pollock, S. Baker, and J. Davies. 2006. Channel pattern and river-floodplain dynamics in forested mountain river systems. *Geomorphology* 78 (2006) 124–141.
- Bjornn, T. C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. *American Fisheries Society Special Publication* 19:83-138. Meehan, W.R., editor.
- Brummer, C. J., T.B. Abbe, J.R. Sampson, and D.R. Montgomery. 2006. Influence of vertical channel change associated with wood accumulations on delineating channel migration zones, Washington, USA. *Geomorphology* 80: 295–309.
- Groot, C. and L. Margolis (*Editors*). 1991. Pacific salmon life histories. UBC Press, Vancouver, B.C.
- Knutson, K.L. and V.L. Naef. 1997. Management recommendations for Washington's priority riparian habitats. Washington Department of Fish and Wildlife, Olympia, WA.
- Kondolf, G.M. 1993. The sizes of salmonid spawning gravels. *Water Resources Research*, 29 (7): 2275-2285.
- Kondolf, G.M. 2000. Assessing Salmonid Spawning Gravel Quality. *Trans. Am. Fish. Soc.* 129:262-281.
- Montgomery, D.R., E.M. Beamer, G.R. Pess, and T.P. Quinn. 1999. Channel type and salmonid spawning distribution and abundance. *Canadian Journal of Fisheries and Aquatic Science* 56: 377-387.
- Montgomery, D.R., and T. Abbe. 2006. Influence of log jam formed hard points on the formation of valley-bottom landforms in an old-growth forest valley, Queets River, Washington, USA. *Quaternary Research* 65:147–155.
- Morley, S., P.S. Garcia, T.R. Bennett, and P. Roni. 2005. Juvenile salmonid (*Oncorhynchus* spp.) use of constructed and natural side channels in Pacific Northwest rivers. *Can. J. Fish. Aquat. Sci.* 62: 2811–2821.
- National Marine Fisheries Service. 1996. Coastal salmon conservation: working guidance for comprehensive salmon restoration initiatives on the Pacific Coast. USDC-NOAA, NMFS, Portland, OR. Report dated September 15, 1996.

National Oceanic and Atmospheric Administration. 1999. Endangered and Threatened Species; Threatened Status for Three Chinook Salmon Evolutionarily Significant Units (ESUs) in Washington and Oregon, and Endangered Status for One Chinook Salmon ESU in Washington. 50 CFR Parts 223 and 224[Docket No. 990303060–9071–02; I.D. 022398C]. Volume 64, Number 56 Pages 14308-14328.

National Oceanic and Atmospheric Administration. 2007. Endangered and Threatened Species: Final Listing Determination for Puget Sound Steelhead. 50 CFR Part 223 [Docket No. 070123015–7086–02; I.D. 031006D]. Volume 72, Number 91, Pages 26722-26735.

National Oceanic and Atmospheric Administration. 2011. Identifying Historical Populations of Steelhead Within the Puget Sound Distinct Population Segment. October 31, 2011 Review Draft. NATIONAL MARINE FISHERIES SERVICE Northwest Fisheries Science Center 2725 Montlake Boulevard East SEATTLE, WASHINGTON 98112-2097

National Research Council. 1996. Upstream: Salmon and Society in the Pacific Northwest. National Academy of Sciences. Washington, D.C.

Peck, D.V., J.M. Lazorchak, and D.J. Klemm (editors). 2003. Environmental Monitoring and Assessment Program -Surface Waters: Western Pilot Study Field Operations Manual for Wadeable Streams. EPA/XXX/X-XX/XXXX. U.S. Environmental Protection Agency, Washington, D.C.

Rustay, M.D., Leonetti, F.E., Haas, A.D., Purser, M.D. and B. Gaddis. 2008. Snohomish County wadeable stream habitat survey protocol for status and trend monitoring. Snohomish County, Public Works, Surface Water Management, Everett, WA.

Savery, A. and A. Hook. 2003. Habitat Conditions and Chinook Use in the Pilchuck River. Tulalip Tribes Natural Resources Department.
<http://www.tulalip.nsn.us/pdf.docs/Pilchuck%20River%20Chinook%20Report.pdf>

Schmetterling, D. A., C.G. Clancy and T.M. Brandt. 2001. Effects of riprap bank reinforcement on stream salmonids in the Western United States. Fisheries 26(7): 6-13.

Schuett-Hames, D., A.E. Pleus, J. Ward, M. Fox, and J. Light. 1999. TFW Monitoring Program methods manual for the large woody debris survey. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-004. DNR #106.

Snohomish Basin Salmonid Recovery Technical Committee (SBSRTC). 2004. Snohomish River Basin Ecological Analysis for Salmonid Conservation. Snohomish County Department of Public Works, Surface Water Management Division, Everett, WA.

Snohomish Basin Salmon Recovery Forum (SBSRF). 2005. Snohomish River Basin Salmon Conservation Plan. Snohomish County Department of Public Works, Surface Water Management Division, Everett, WA.

Snohomish County Public Works, Skagit County, and Washington Department of Ecology. 2008. Sauk River Corridor Assessment Project Report, Habitat and Bank Conditions & Geomorphic Assessment. Snohomish County, Washington. March 2008 (Grant No. G0600122)

Snohomish County SWM. 2002. Physical habitat survey and monitoring protocol for wadeable streams. Snohomish County, Public Works, Surface Water Management, Version 6.2.
[http://www1.co.snohomish.wa.us/Departments/Public Works/Divisions/SWM/Library/Publications/Aquatic Habitat/Inventory Assessment Restoration/](http://www1.co.snohomish.wa.us/Departments/Public%20Works/Divisions/SWM/Library/Publications/Aquatic%20Habitat/Inventory%20Assessment%20Restoration/)

- Snohomish County SWM. 2004. Snohomish River Pollutant Diagnosis and Implementation Project: Physical Habitat Survey and Monitoring Protocol for Large Rivers Version 1.2, 2004 (http://www1.co.snohomish.wa.us/Departments/Public_Works/Divisions/SWM/Library/Publications/Aquatic_Habitat/Inventory_Assessment_Restoration/)
- Snohomish County SWM. 2010. Snohomish County Critical Area and Shoreline Monitoring 2010 Status Report. Snohomish County, Public Works, Surface Water Management. Everett, WA.
- Swales, S., and C.D. Levings. 1989. Role of off-channel ponds in the life cycle of coho salmon (*Oncorhynchus kisutch*) and other juvenile salmonids in the Coldwater River, British Columbia. Can. J. Fish. Aquat. Sci. 46: 232–242.
- Torgersen, C.E., D.M. Price, H.W. Li, and B.A. McIntosh. 1999. Multiscale thermal refugia and stream habitat associations of Chinook salmon in northeastern Oregon. Ecological Applications, 9(1), 1999, pp. 301–319.
- USDA-Forest Service. 1999. Stream inventory handbook: Level I & II. USDA, Region 6, Version 9.9.
- Wolman, M.G., 1954. A method of sampling coarse bed material. American Geophysical Union, Transactions, 35: 951-956.
- USDI-Fish and Wildlife Service. 1999. Determination of threatened status for Bull Trout in the coterminous United States. 50 CFR Part 17. Volume 64, Number 210, November 1, 1999. Pages 58910-58933.
- Verhey, Peter. Personal communication. Chinook salmon and steelhead redds (2009, 2010) from Washington Department of Fish and Wildlife, unpublished data.
- Washington Department of Ecology (WDOE). 2006. Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A WAC. Publication Number 06-10-091. Olympia WA.
- Washington Department of Fisheries, Washington Department of Wildlife, Western Washington Treaty Tribes. 1993. 1992 Washington State salmon and steelhead stock inventory. Olympia, Washington. 211pp.
- Washington Department of Fisheries, Washington Department of Wildlife, Western Washington Treaty Tribes. 2002. 2002 Washington State salmon and steelhead stock inventory. Olympia, Washington. (http://wdfw.wa.gov/conservation/fisheries/sasi/sasi_2002_introduction.html)
- Welsh, H.H., G.R. Hodgson, B.C. Harvey, and M.F. Roche. 2001. Distribution of juvenile coho salmon in relation to water temperatures in tributaries of the Mattole River, California. North American Journal of Fisheries Management 21: 464-470.

6 Maps

Figure 3-1. Recent salmon and steelhead redd locations. Tulalip surveys did not include reaches 4-8.

Figure 3-2. Key rearing areas (pink circles) for juvenile salmon based on bank conditions, pool habitat, riparian conditions (not shown), and connected side channel proximity.

Figure 3-4. Habitat unit (pools, riffles, other) small and large gravels as observed in the field.

Figure 3-5. Habitat unit (pools, riffles, other) estimated substrate embeddedness category values.

Figure 3-6. Middle Pilchuck River Wood Jam Locations. Bar apex and meander jams meet criteria described in report section 3.1.2.

Figure 3-7. Middle Pilchuck River key adult and juvenile salmon pool habitat by mainstem primary pools and backwater pools at least 0.4m residual depth and other criteria.

Figure 3-8. Pilchuck River side channel locations among reaches by connection type.

Figure 3-9. Pilchuck River un-connected/isolated side channel locations by length category.

Figure 3-10. Middle Pilchuck River Bank Conditions. Banks are displayed by condition at the highest level of classification as either modified or natural.

Figure 3-11. Middle Pilchuck River Riparian Land Cover. Land cover types are grouped into broad classes based on intactness of riparian function. The area extracted for this analysis is a 150ft buffer extending outward from active river banks.

Figure 3-12. Locations of continuous temperature data collection (triangles) and in situ day sampling (boxes). In situ temperature samples were collected on different days.

Figure 3-14. Water temperature variability between the cooler contributing side channel location and the adjacent mainstem. Temperature was sampled on different days, so comparisons are relevant within each photo. Scale is 1:5000 for each panel.

Figure 3-15. Potential physical and logistical constraints to restoration project implementation.

Figure 3-16. Habitat Conditions Map Reach 1.

Figure 3-17. Habitat Conditions Map Reach 2.

Figure 3-18. Habitat Conditions Map Reach 3.

Figure 3-19. Habitat Conditions Map Reach 4.

Figure 3-20. Habitat Conditions Map Reach 5.

Figure 3-21. Habitat Conditions Map Reach 6.

Figure 3-22. Habitat Conditions Map Reach 7.

Figure 3-23. Habitat Conditions Map Reach 8.

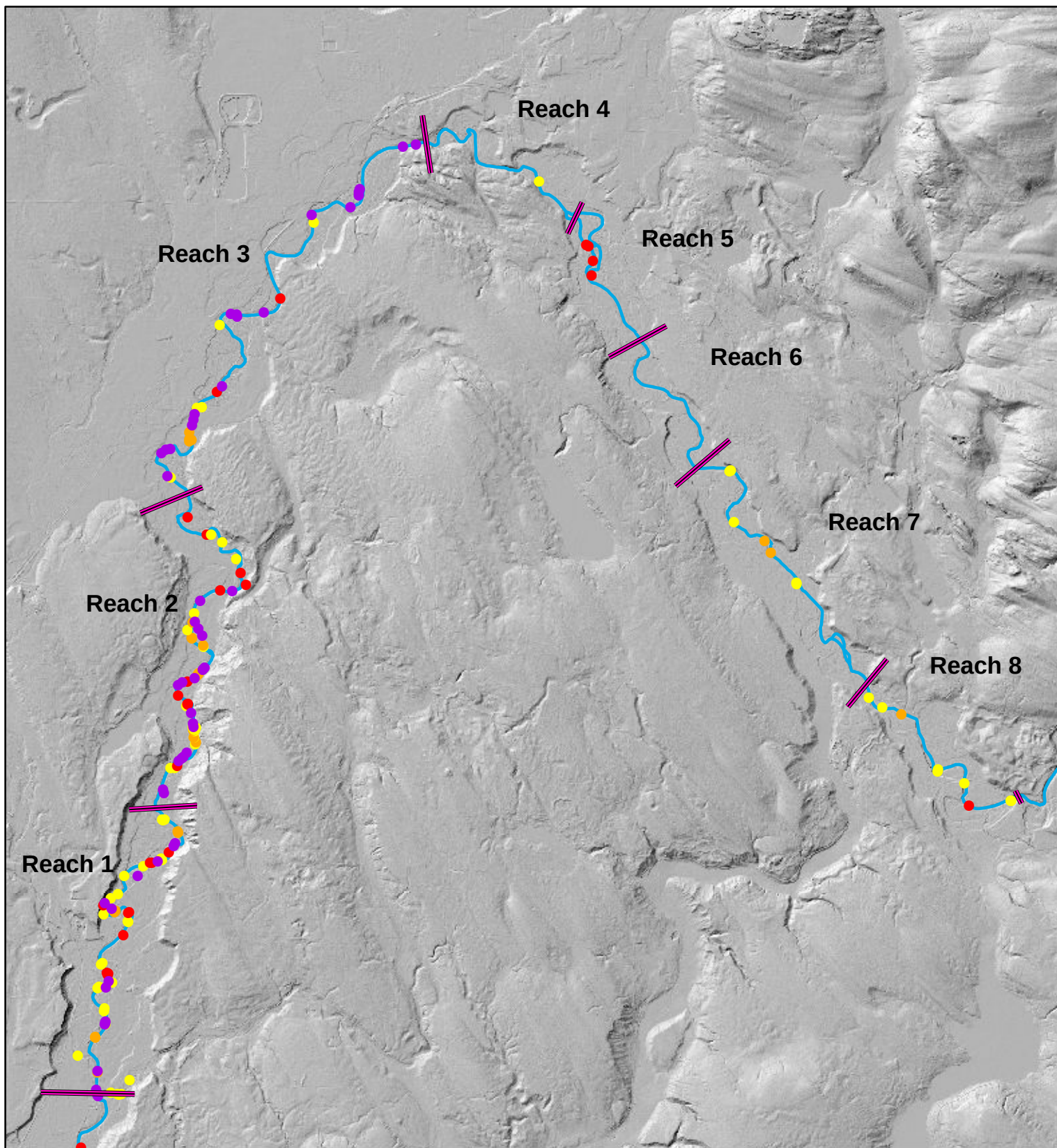
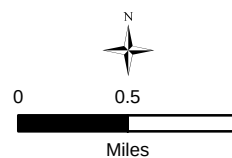


Figure 3-1. Recent salmon and steelhead redd locations. Tulalip surveys did not include reaches 4-8.

- Tulalip Redd Sites
- WDFW Redd Surveys, Year Species
- 2009 Chinook
 - 2010 Chinook
 - 2010 Steelhead

- Assessment Reach Boundaries
- Assessment Reach



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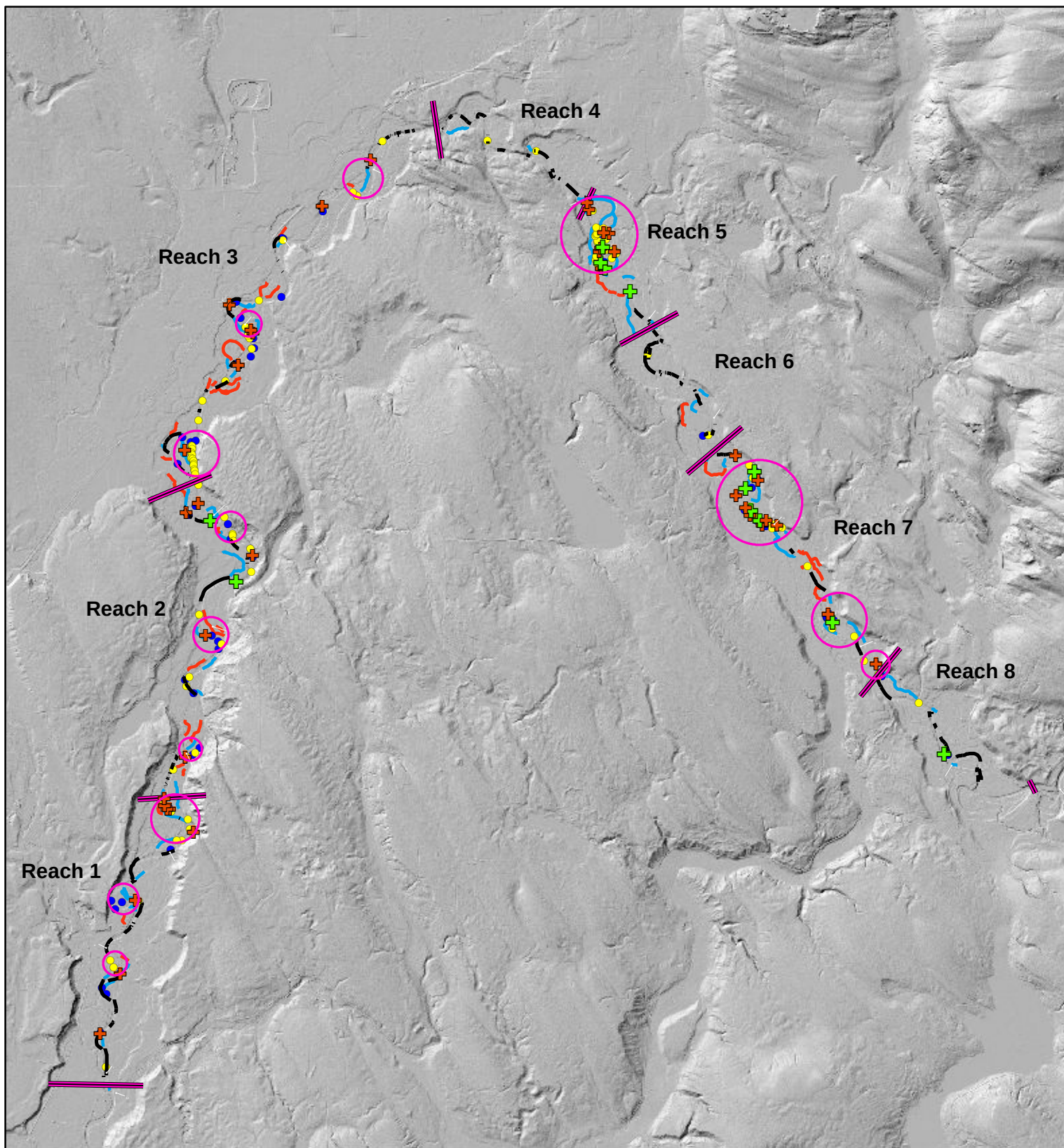
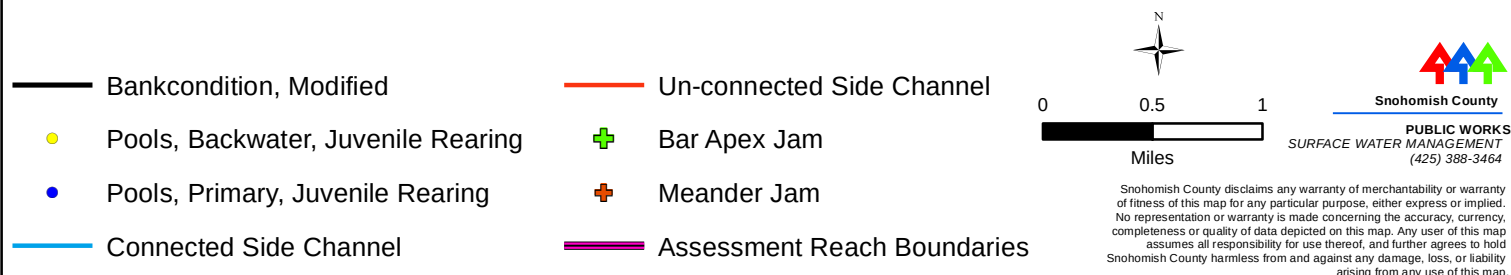


Figure 3-2. Key rearing areas (pink circles) for juvenile salmon based on bank conditions, pool habitat, riparian conditions (not shown), and connected side channel proximity.



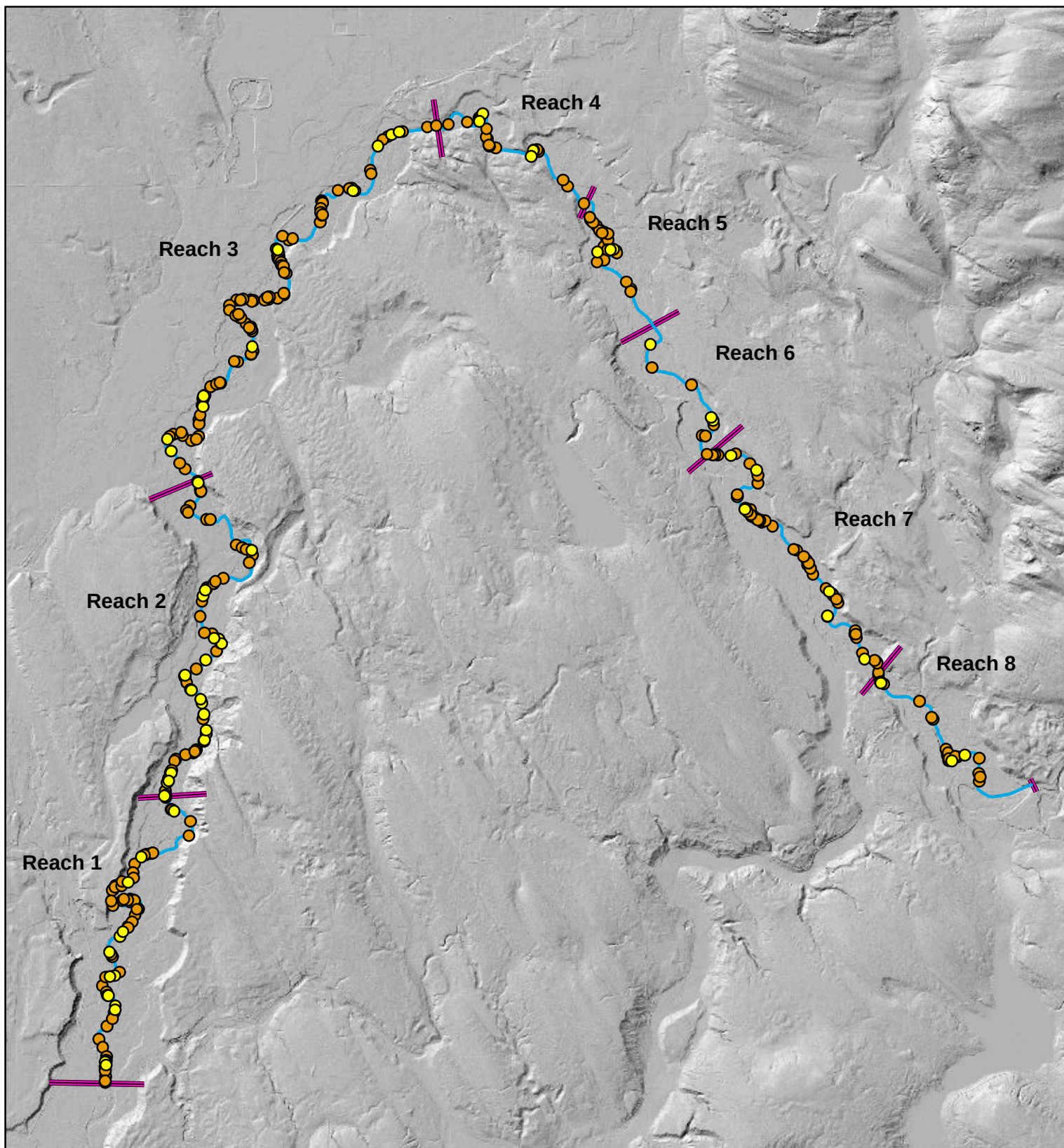


Figure 3-4. Habitat unit (pools, riffles, other) small and large gravels as observed in the field.



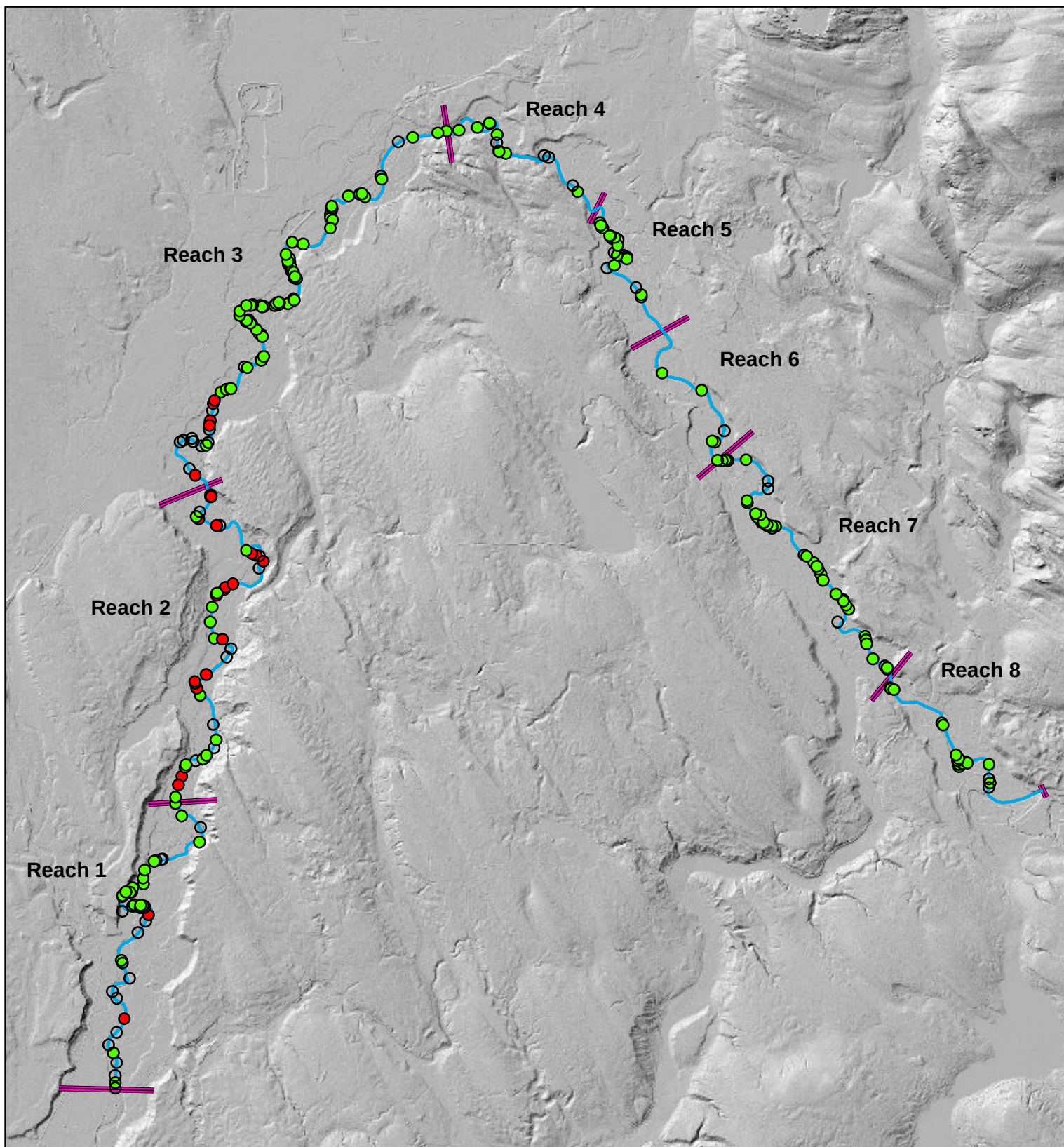


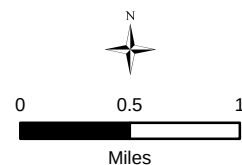
Figure 3-5. Habitat unit (pools, riffles, other) estimated substrate embeddedness category values.

Embeddedness (%)

- 0
- 25
- 50
- 75
- 100

— Assessment Reach Boundaries

— Assessment Reach



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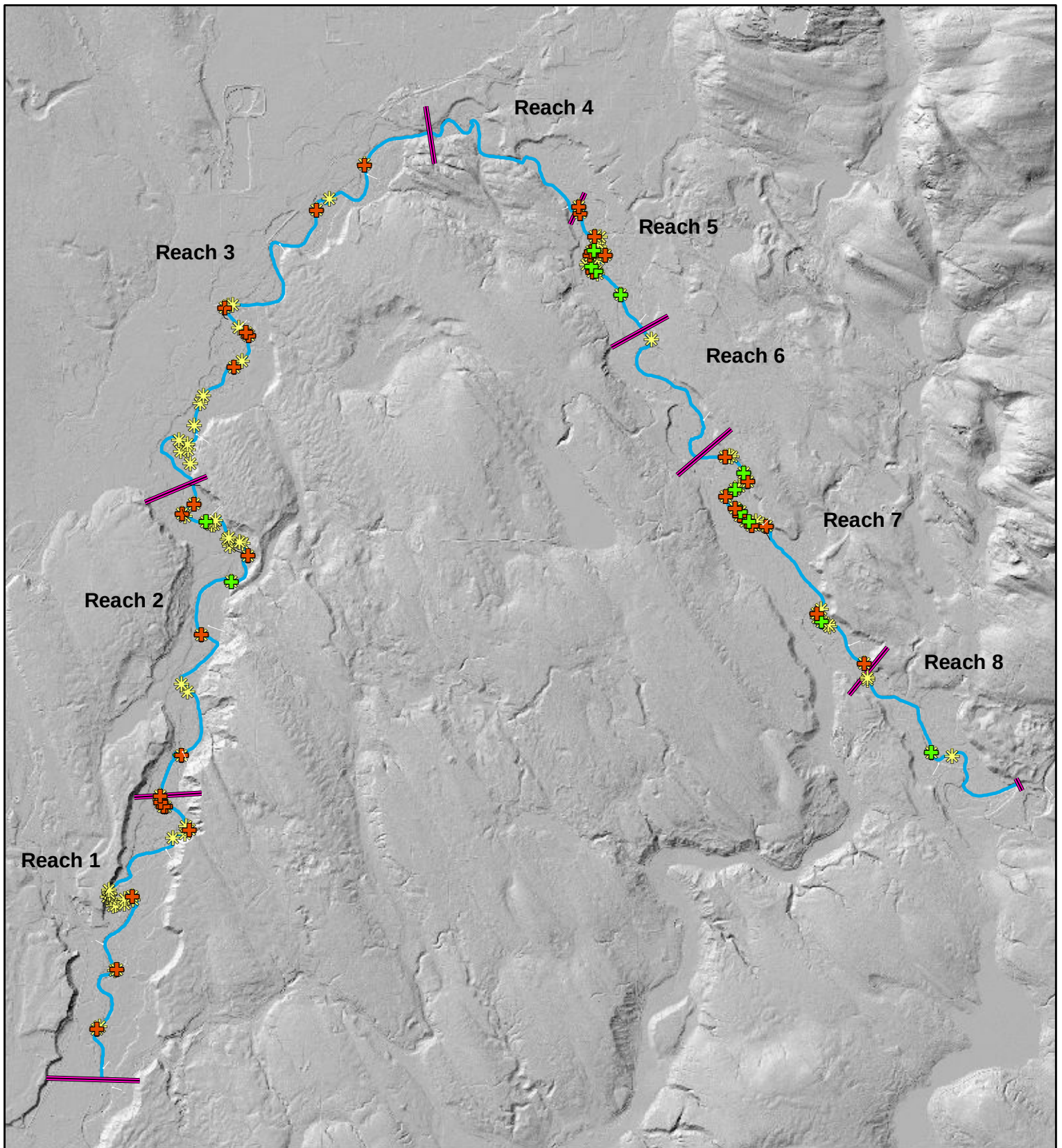


Figure 3-6. Middle Pilchuck River Wood Jam Locations. Bar apex and meander jams meet criteria described in report section 3.1.2.

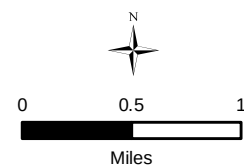
 Bar Apex Jam

 Meander Jam

 Other Jams

 Assessment Reach Boundaries

 Assessment Reach




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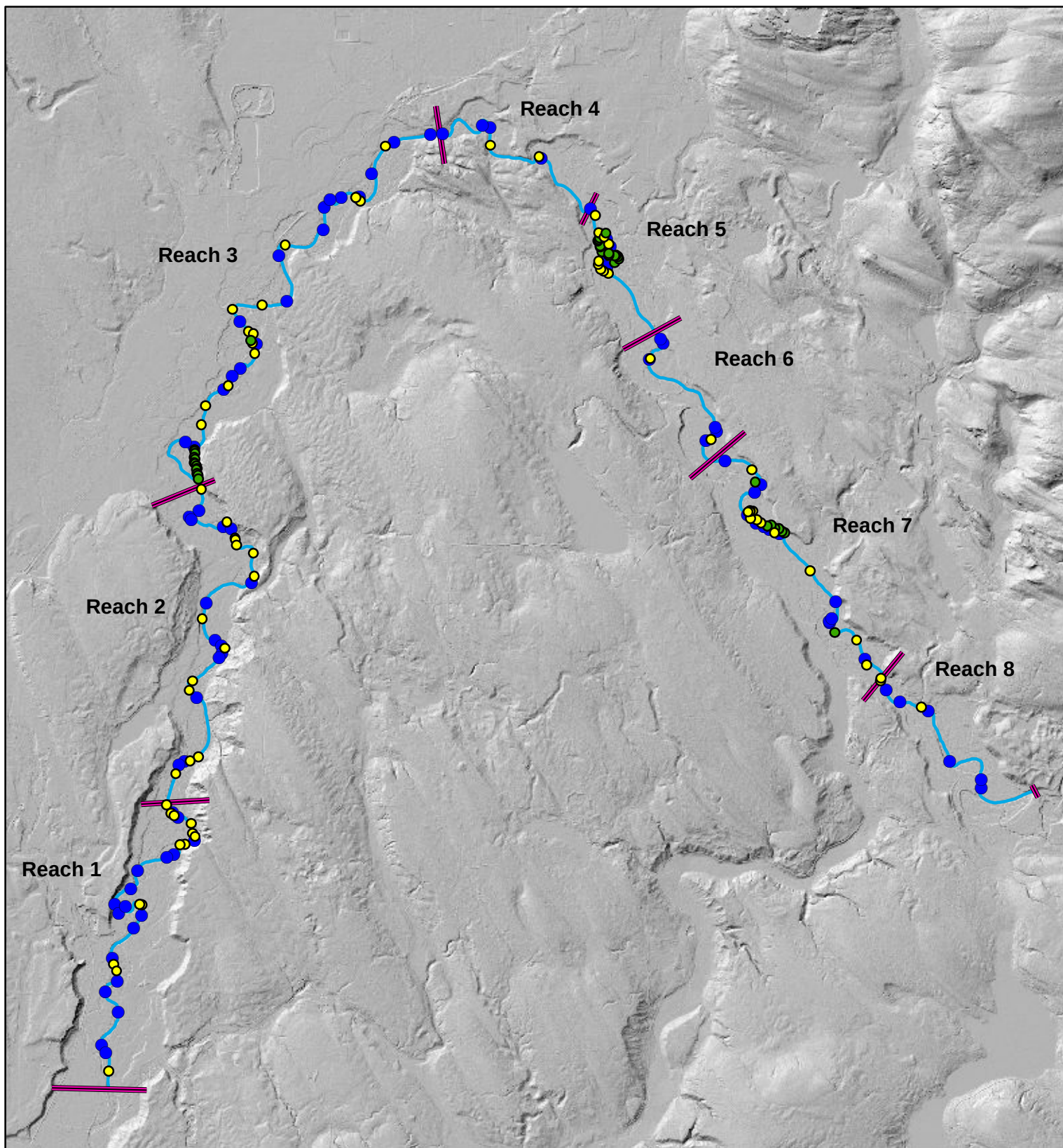


Figure 3-7. Middle Pilchuck River key adult and juvenile salmon pool habitat by mainstem primary pools and backwater pools at least 0.4m residual depth and other criteria.

Backwater Pools

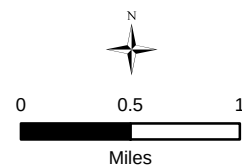
- Main Channel
- Side Channel

Primary Pools

- Mainstem Pools (85)

--- Assessment Reach Boundaries

— Assessment Reach



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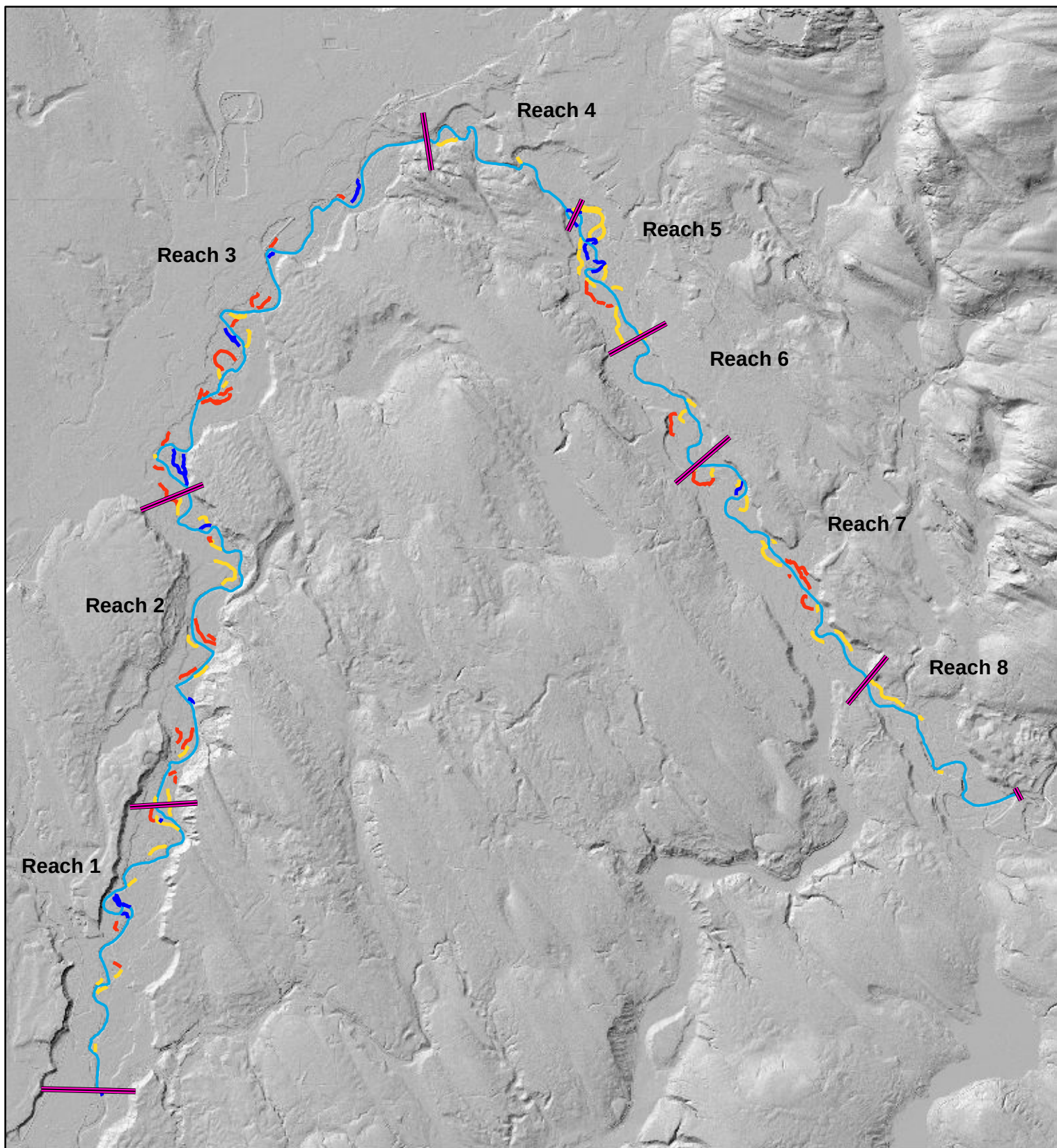


Figure 3-8. Pilchuck River side channel locations among reaches by connection type.

Side Channel Connection Type

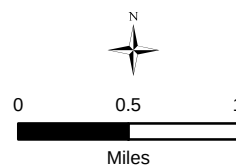
— Un-connected/ Isolated

— One Connection

— Two Connections

— Assessment Reach Boundaries

— Assessment Reach



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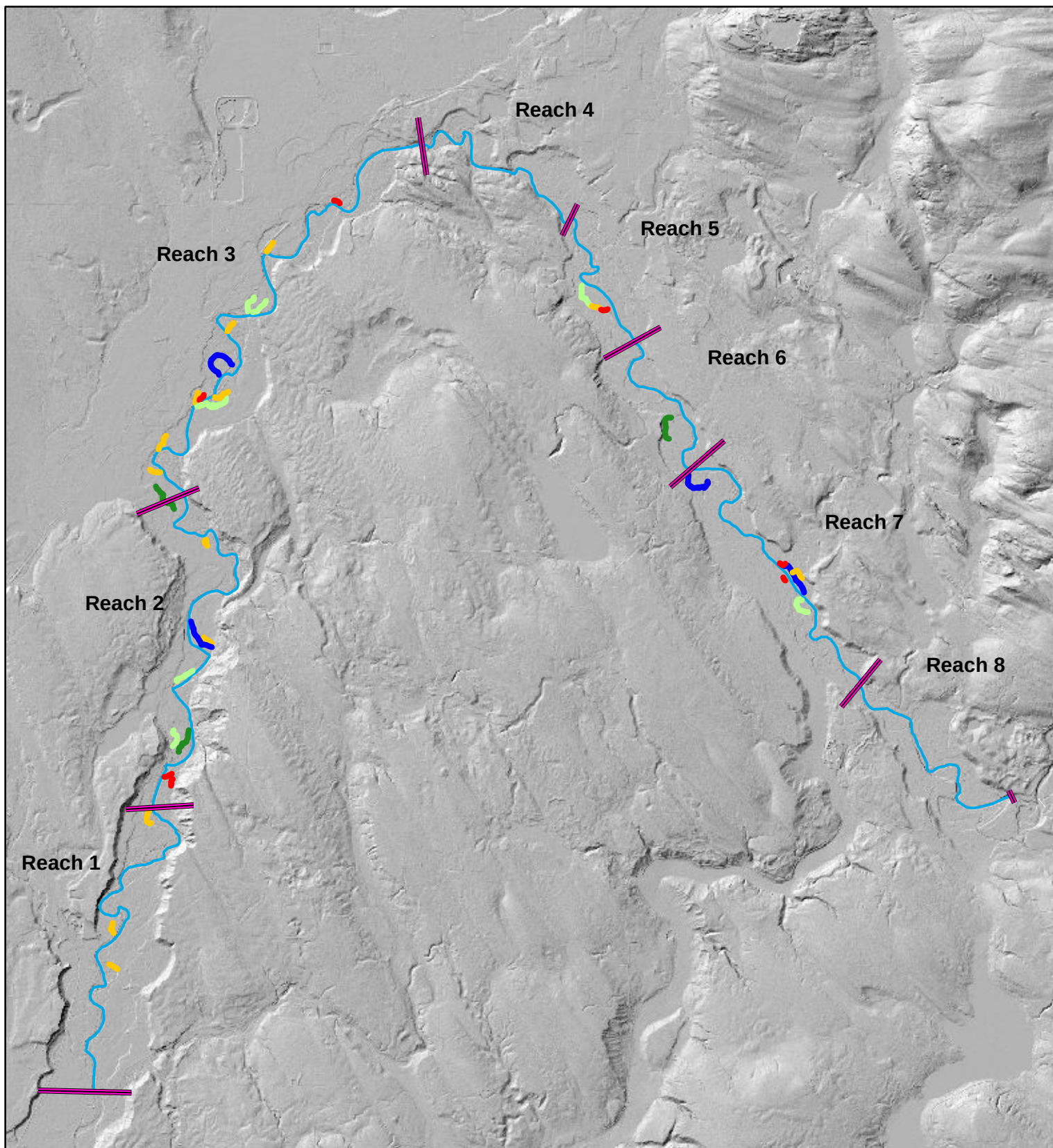


Figure 3-9. Pilchuck River unconnected/isolated side channel locations by length category.

Length, feet

Red <300

Yellow 301 - 600

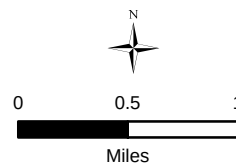
Light Green 601 - 900

Dark Green 901 - 1200

Blue >1201

Thick Purple Line Assessment Reach Boundaries

Blue Line Assessment Reach



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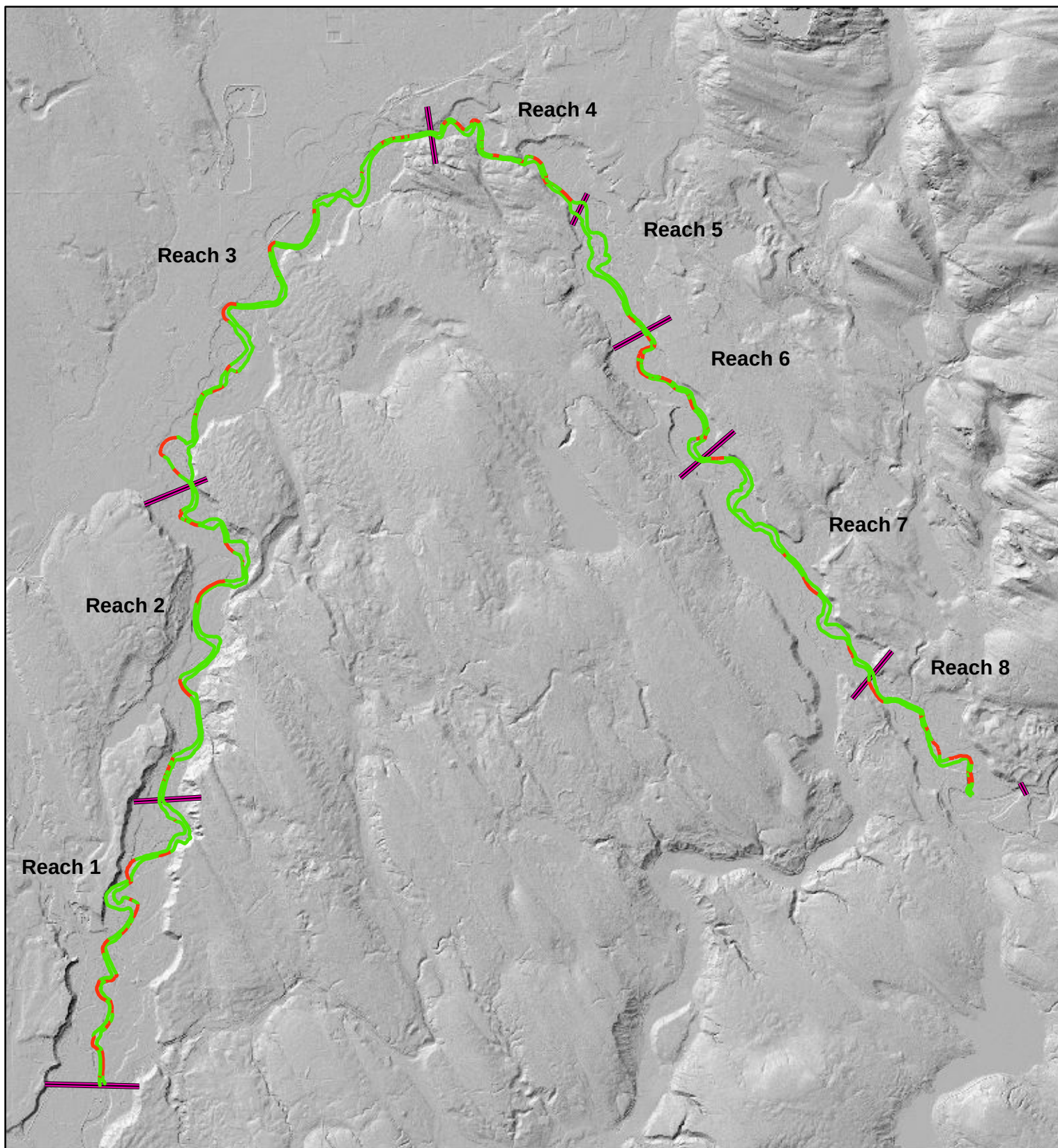


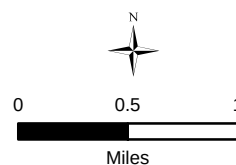
Figure 3-10. Middle Pilchuck River Bank Conditions. Banks are displayed by condition at the highest level of classification as either modified or natural.

Bank Condition

— Modified

— Natural

— Assessment Reach Boundaries



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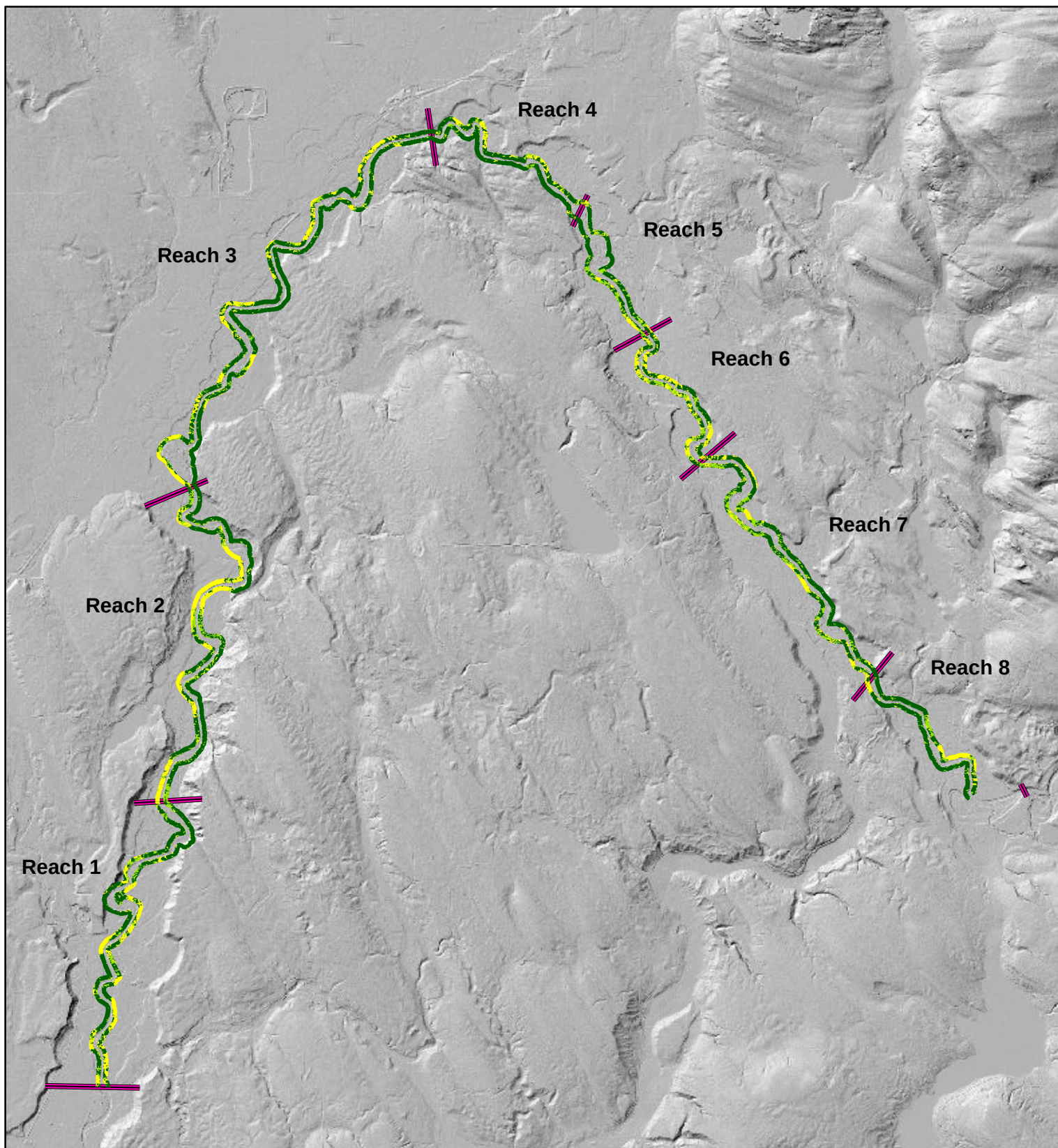
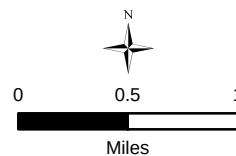


Figure 3-11. Middle Pilchuck River Riparian Land Cover. Land cover types are grouped into broad classes based on intactness of riparian function. The area extracted for this analysis is a 150 foot buffer extending outward from active river banks.

Riparian Function

- Degraded
- Moderately Degraded
- Intact

Assessment Reach Boundaries




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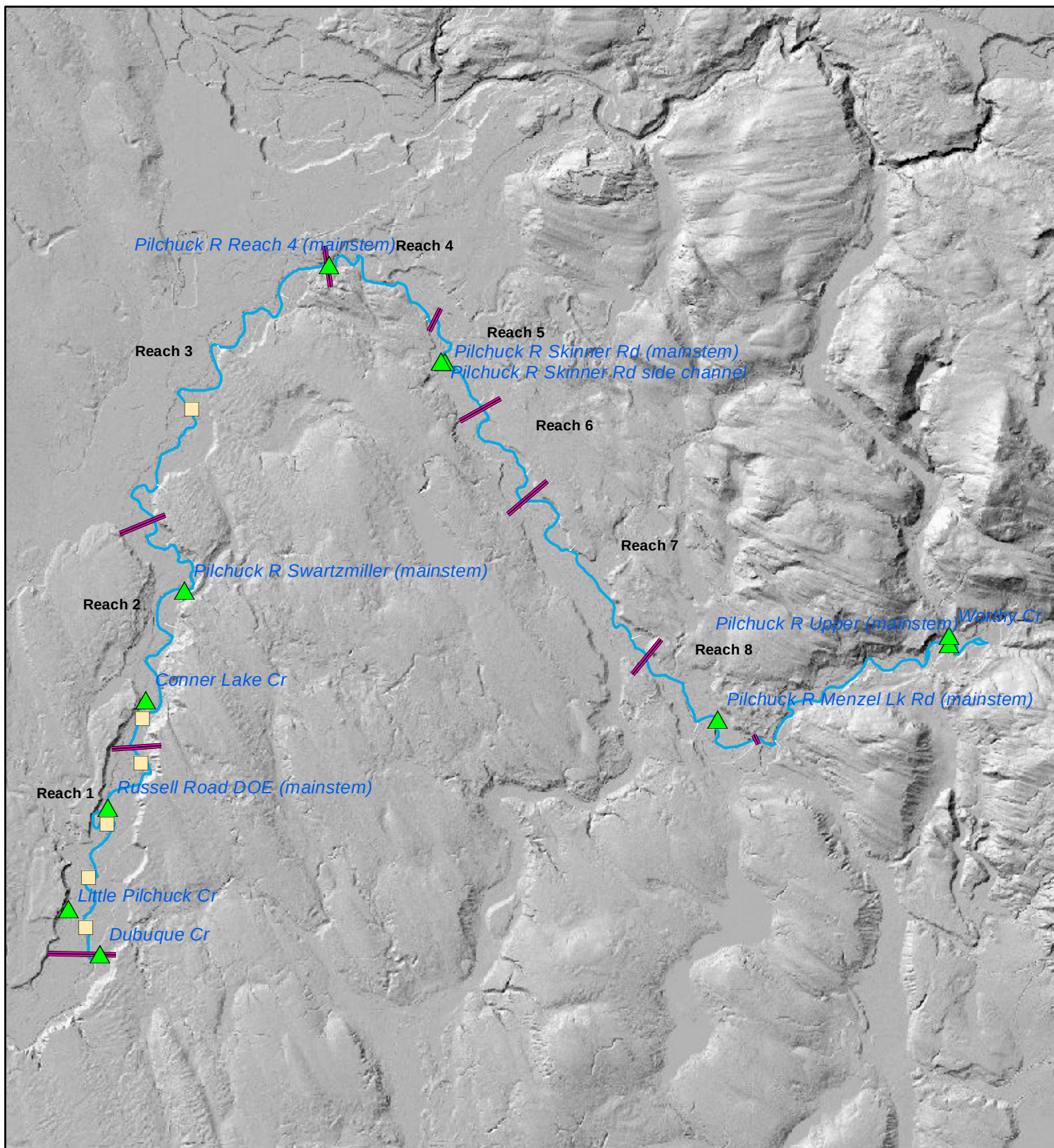


Figure 3-12. Locations of temperature data collection. In situ temperature samples were collected on different days.

-  Continuous Temperature Collection
-  In Situ Day Sampling
-  Assessment Reach Boundaries
-  Assessment Reach




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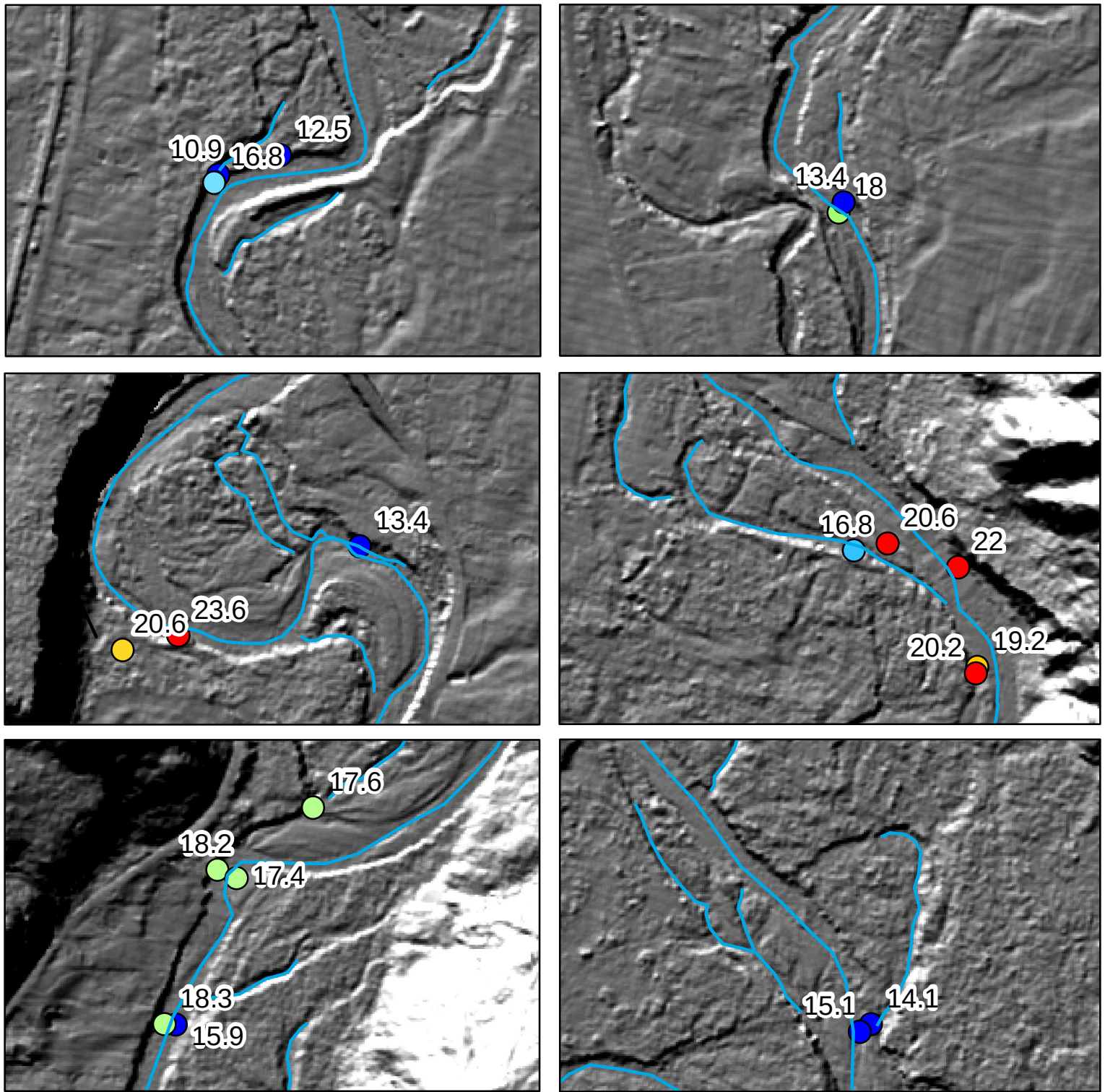


Figure 3-14. Water temperature variability between the cooler contributing side channel location and the adjacent mainstem. Temperature was sampled on different days, so comparisons are relevant within each photo.

Temperature (Degrees Celsius)

- 10.9 - 15.1
- 15.2 - 17.0
- 17.1 - 18.5
- 18.6 - 20.0
- 20.1 - 22.5

— Assessment Reach



Scale: 1:5000 for each panel



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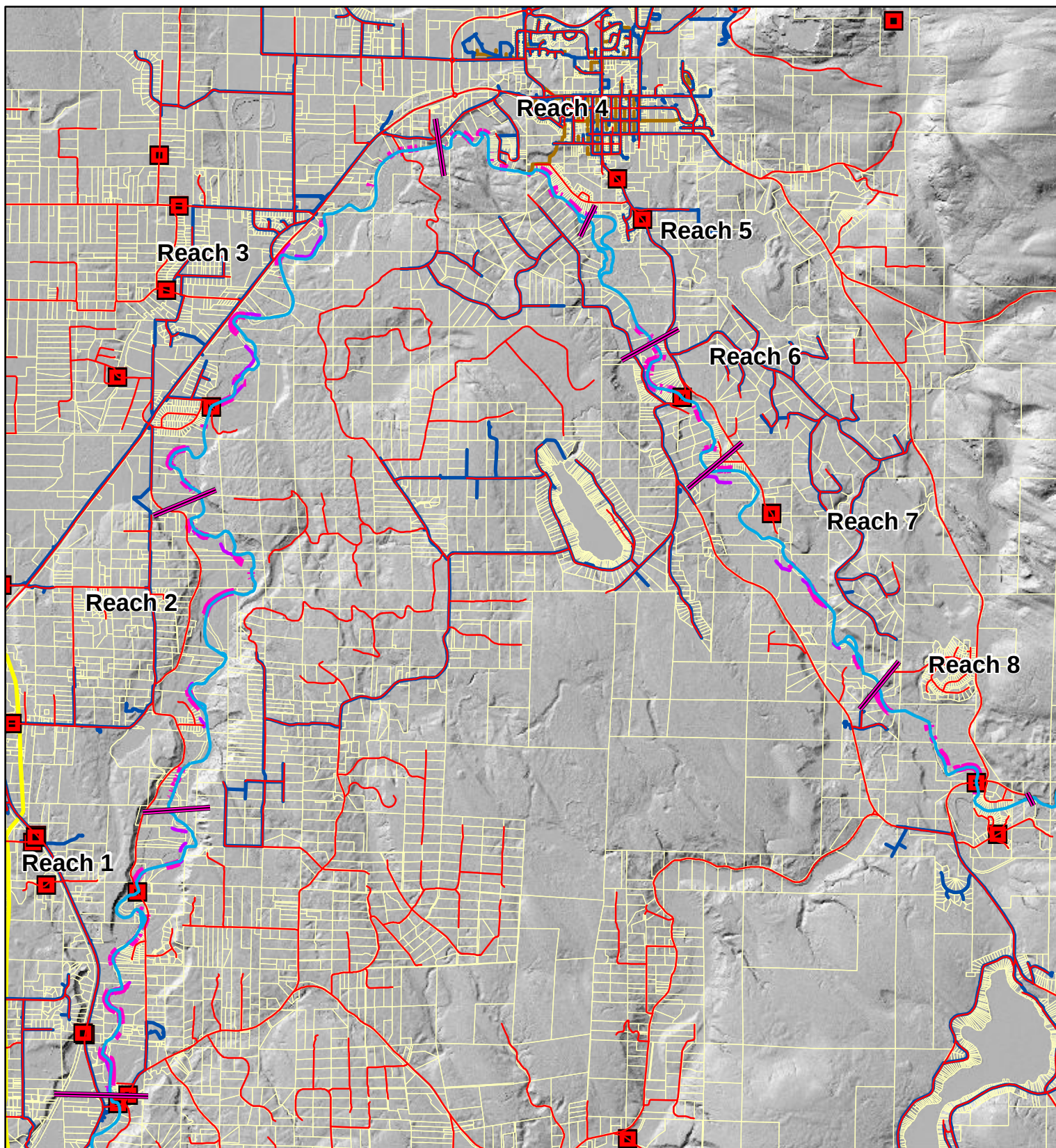
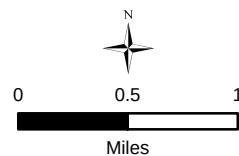
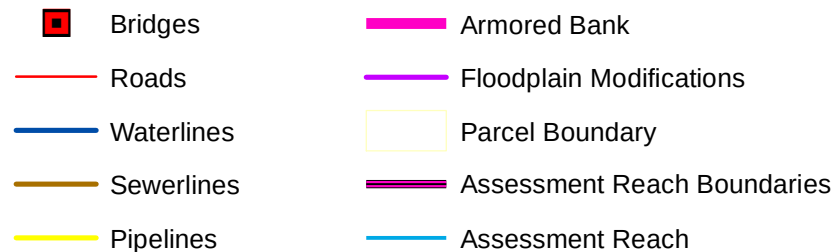


Figure 3-15. Potential physical and logistical constraints to restoration project implementation.



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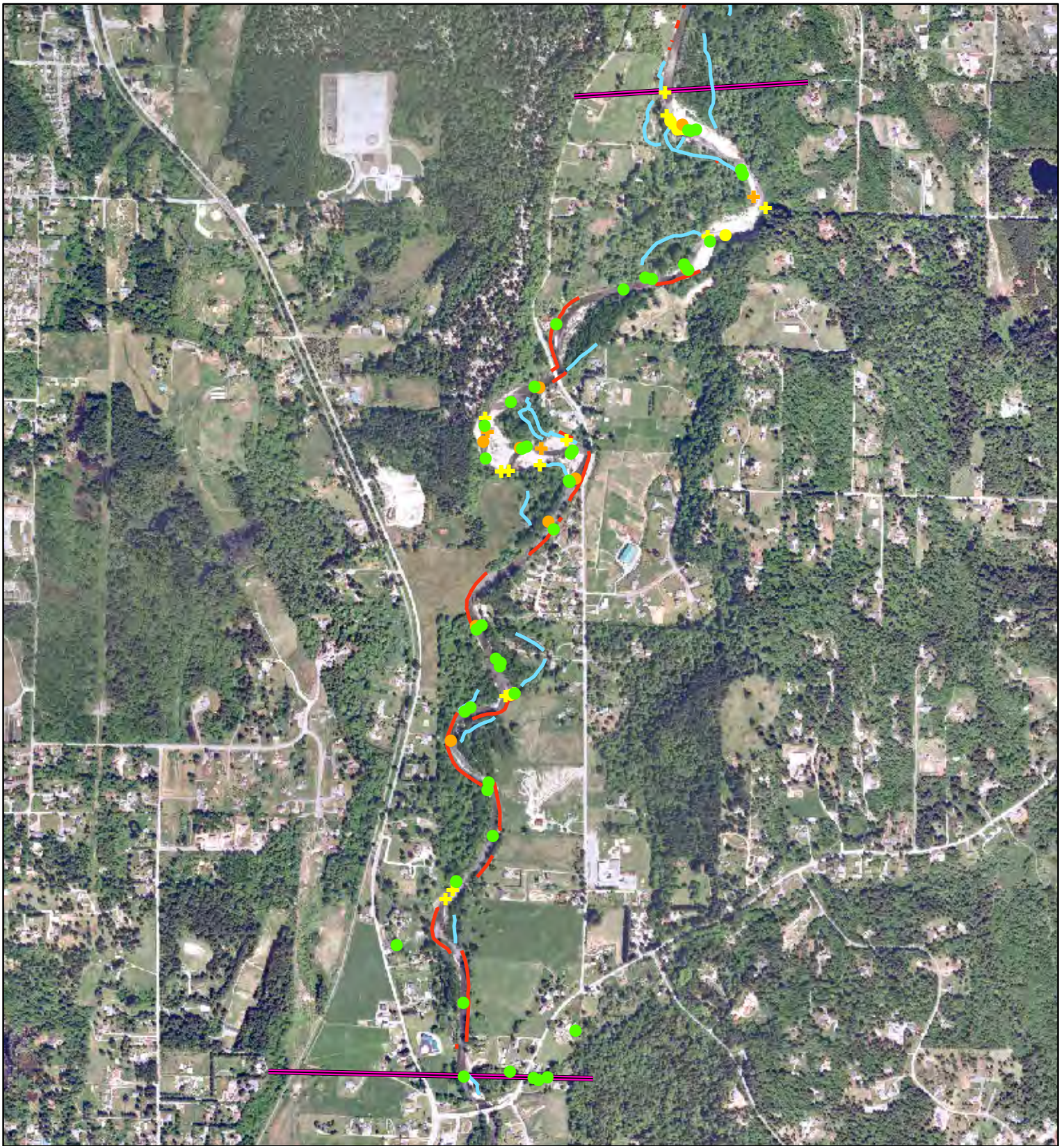


Figure 3-16. Habitat Conditions Map - Reach 1

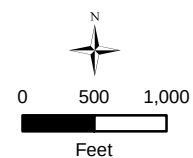
- Salmon Spawning Locations
- Side Channels
- Armored Bank
- Assessment Reach Boundaries

Adult Habitat

- + Jam
- Pool

Juvenile Habitat

- + Jam
- Pool



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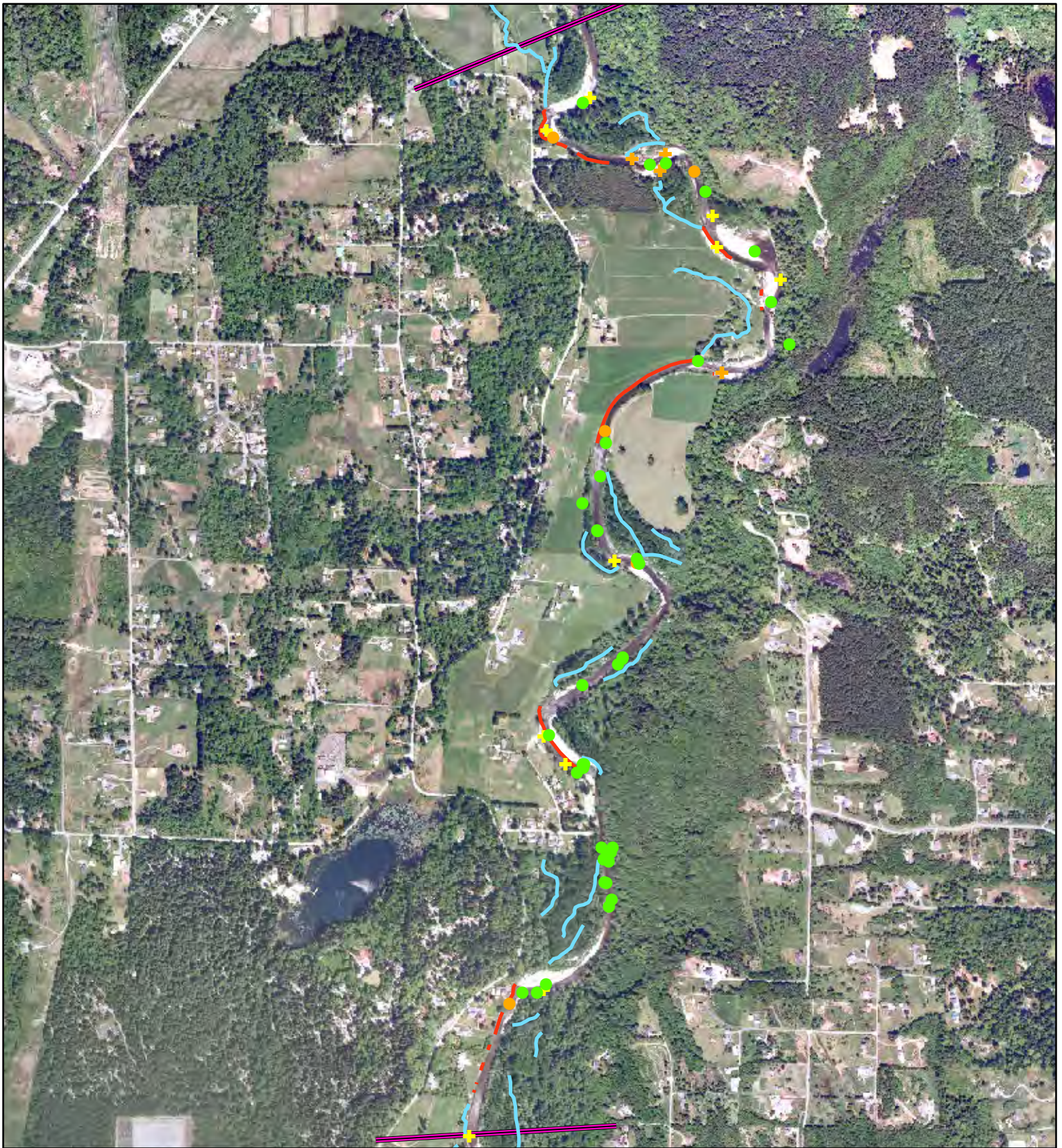
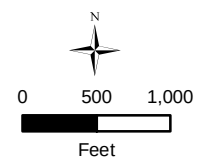


Figure 3-17. Habitat Conditions Map - Reach 2

- Salmon Spawning Locations
- Side Channels
- Armored Bank
- Assessment Reach Boundaries

- Adult Habitat**
- + Jam
 - Pool

- Juvenile Habitat**
- + Jam
 - Pool




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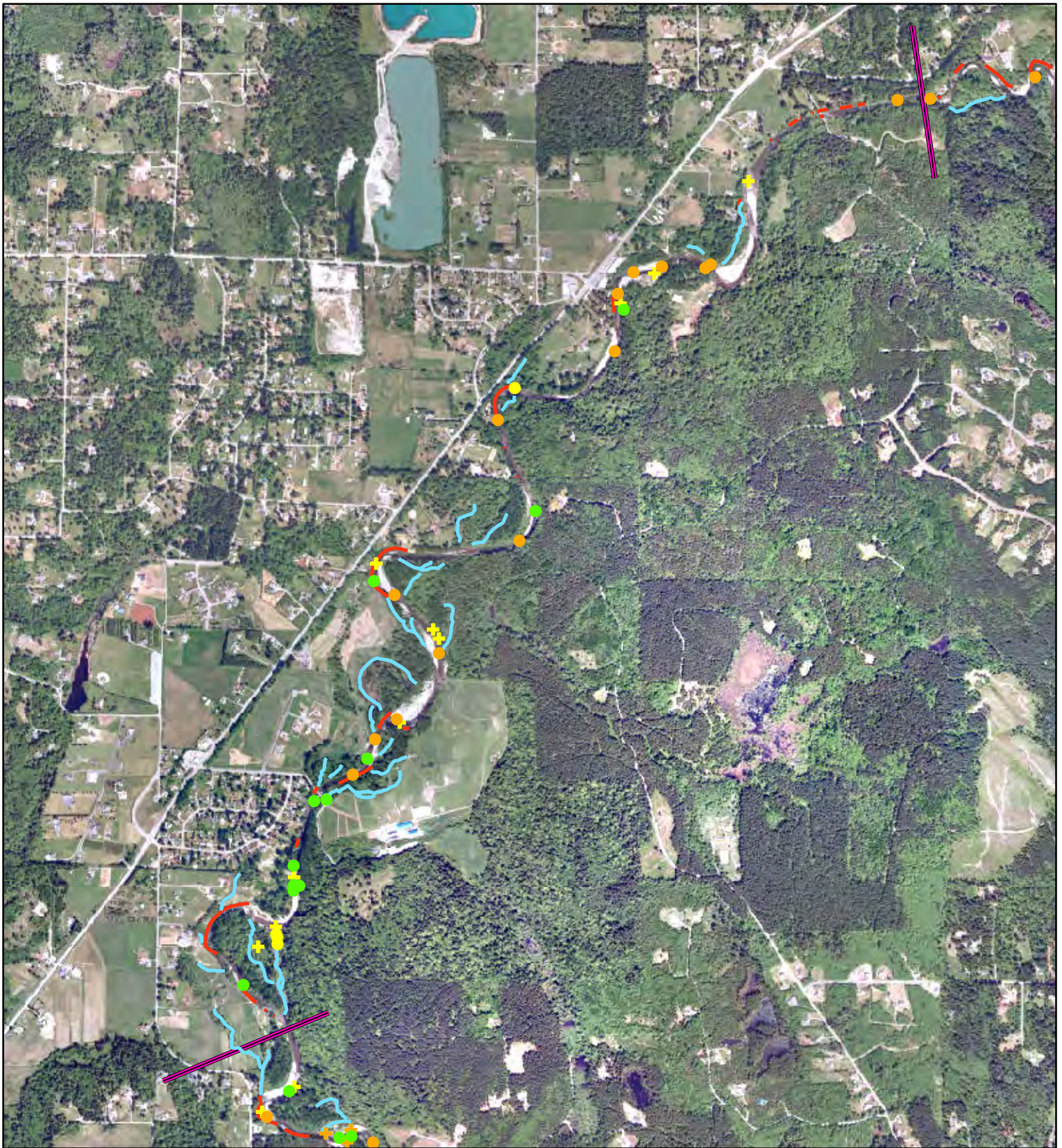
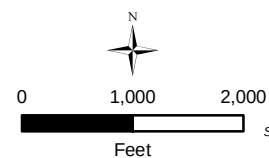


Figure 3-18. Habitat Conditions Map - Reach 3

- Salmon Spawning Locations
- Side Channels
- Armored Bank
- Assessment Reach Boundaries

- Adult Habitat**
- + Jam
 - Pool

- Juvenile Habitat**
- + Jam
 - Pool



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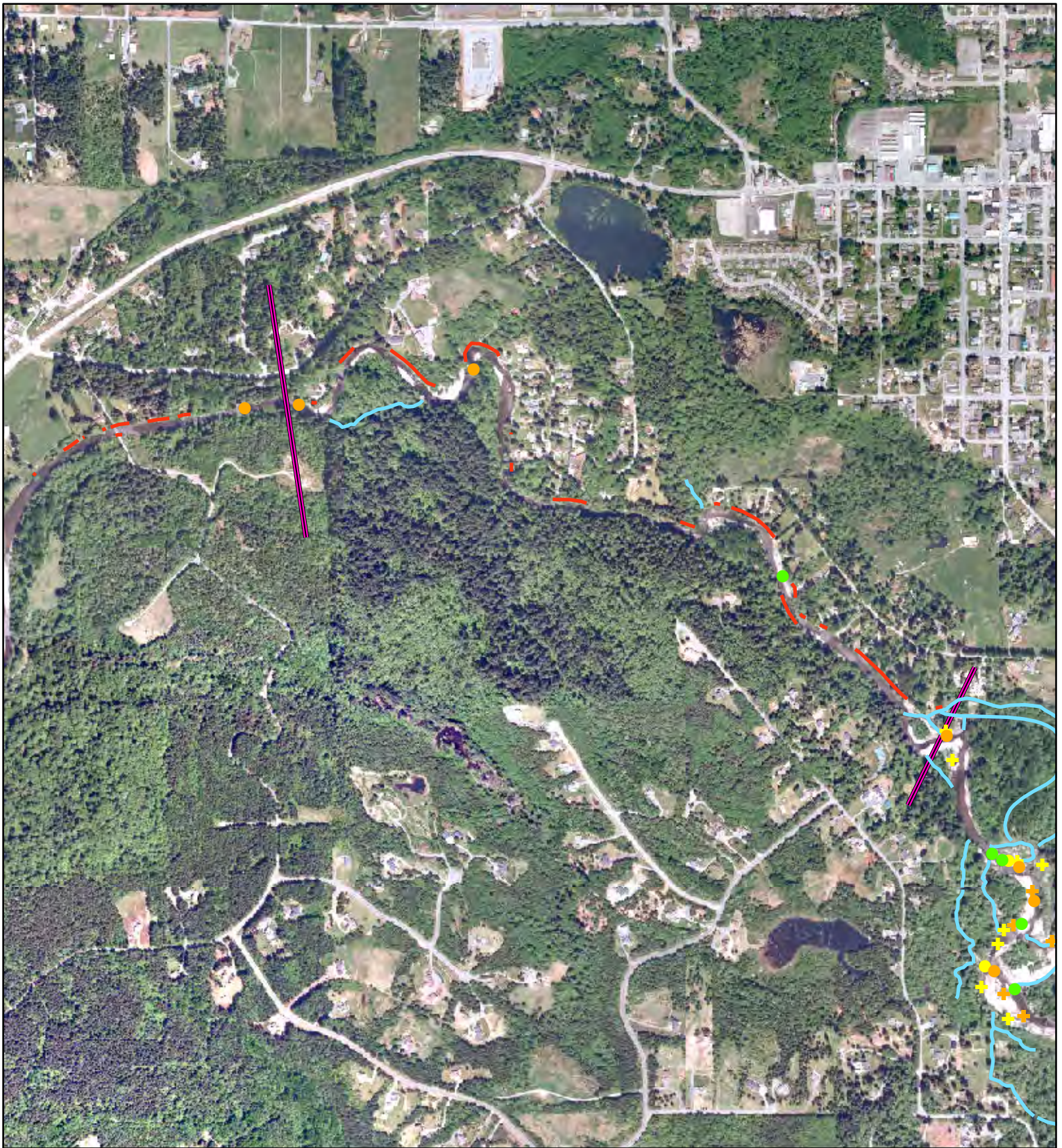
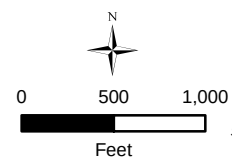


Figure 3-19. Habitat Conditions Map - Reach 4

- Salmon Spawning Locations
- Side Channels
- - - Armored Bank
- = Assessment Reach Boundaries

- Adult Habitat**
- + Jam
 - Pool

- Juvenile Habitat**
- + Jam
 - Pool



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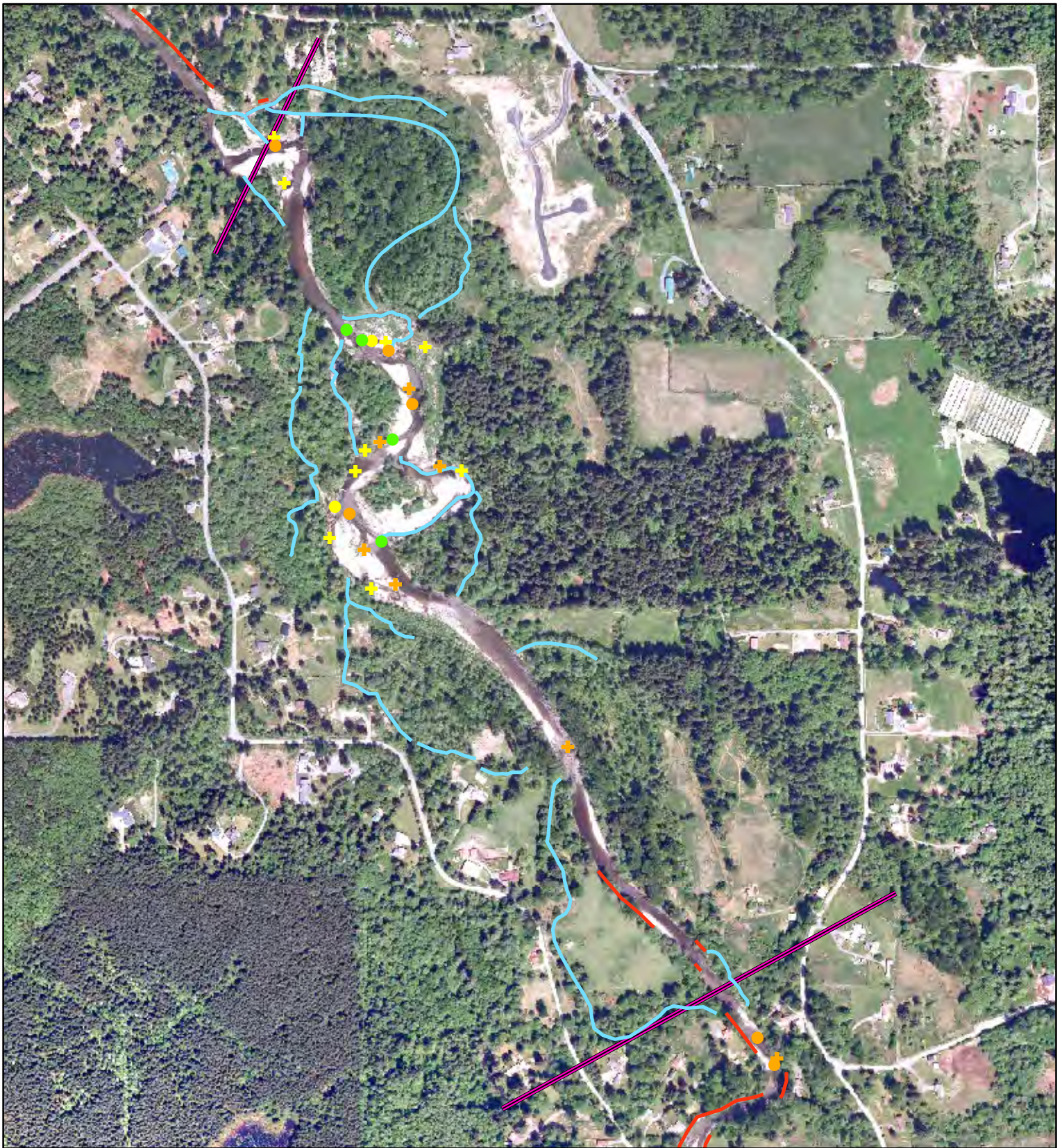


Figure 3-20. Habitat Conditions Map - Reach 5

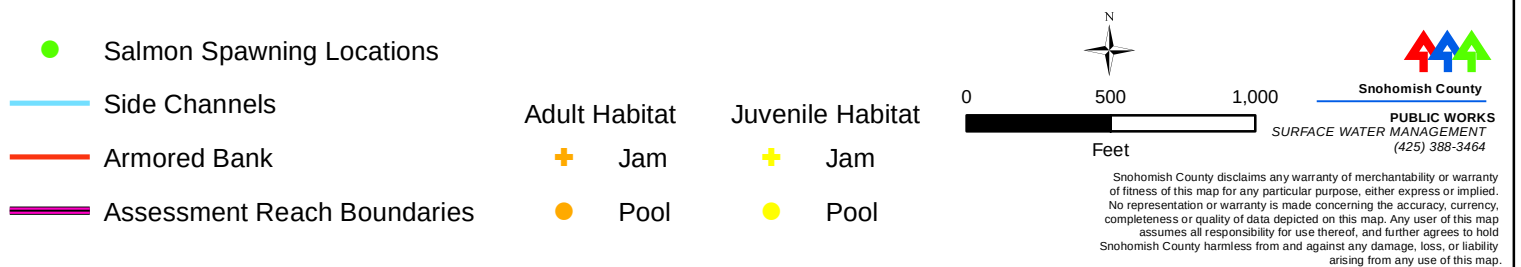




Figure 3-21. Habitat Conditions Map - Reach 6

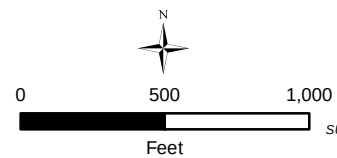
- Salmon Spawning Locations
- Side Channels
- Armored Bank
- Assessment Reach Boundaries

Adult Habitat

- + Jam
- Pool

Juvenile Habitat

- + Jam
- Pool



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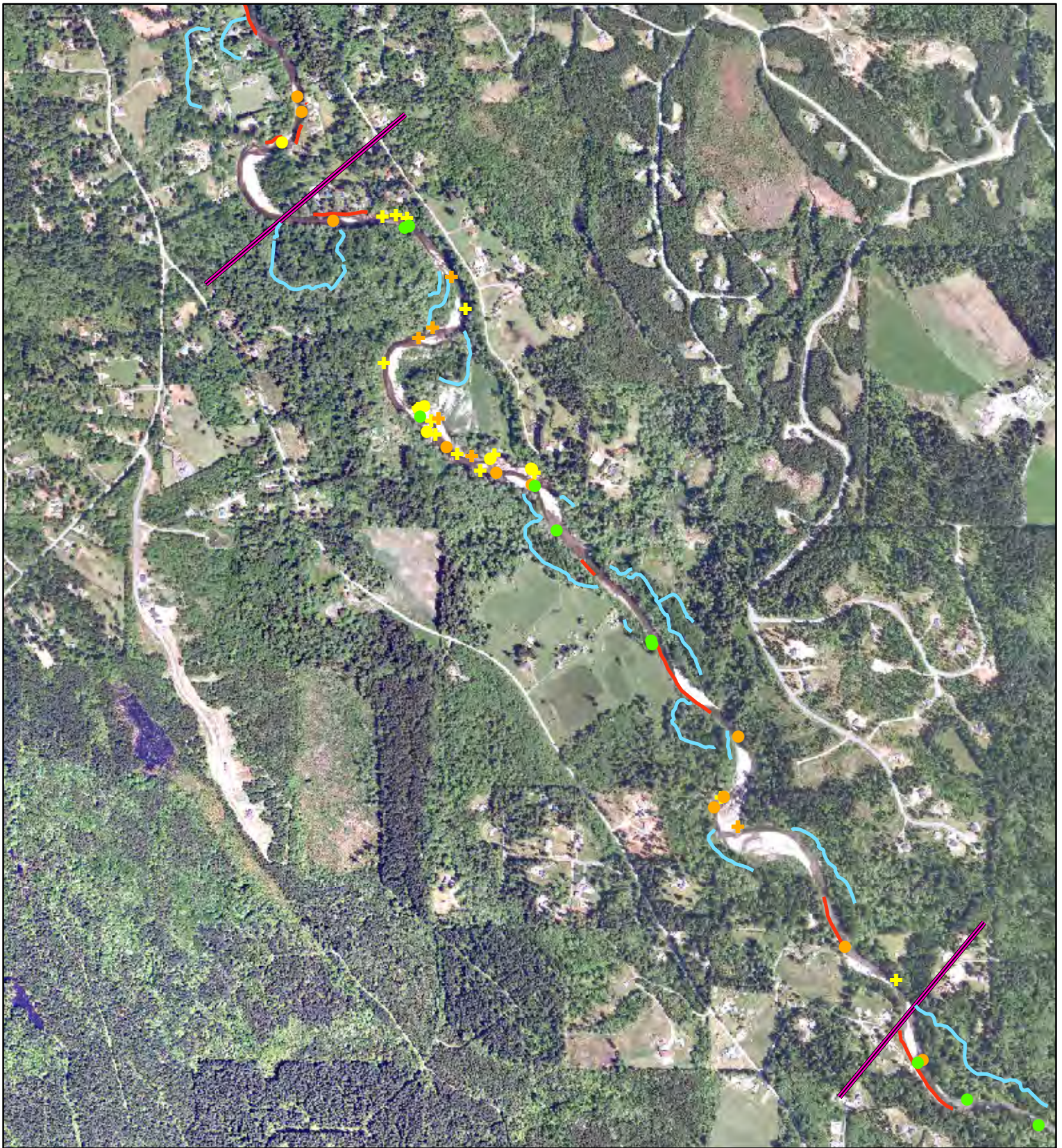
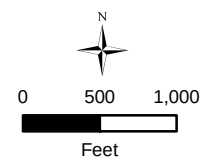
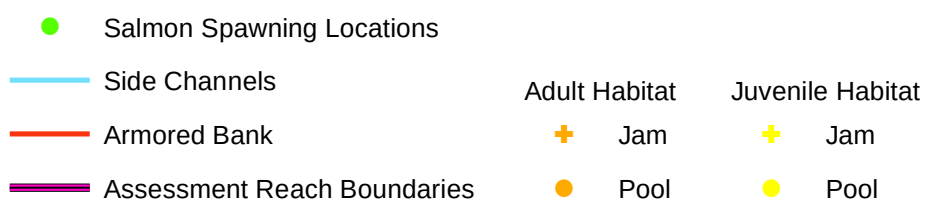


Figure 3-22. Habitat Conditions Map - Reach 7



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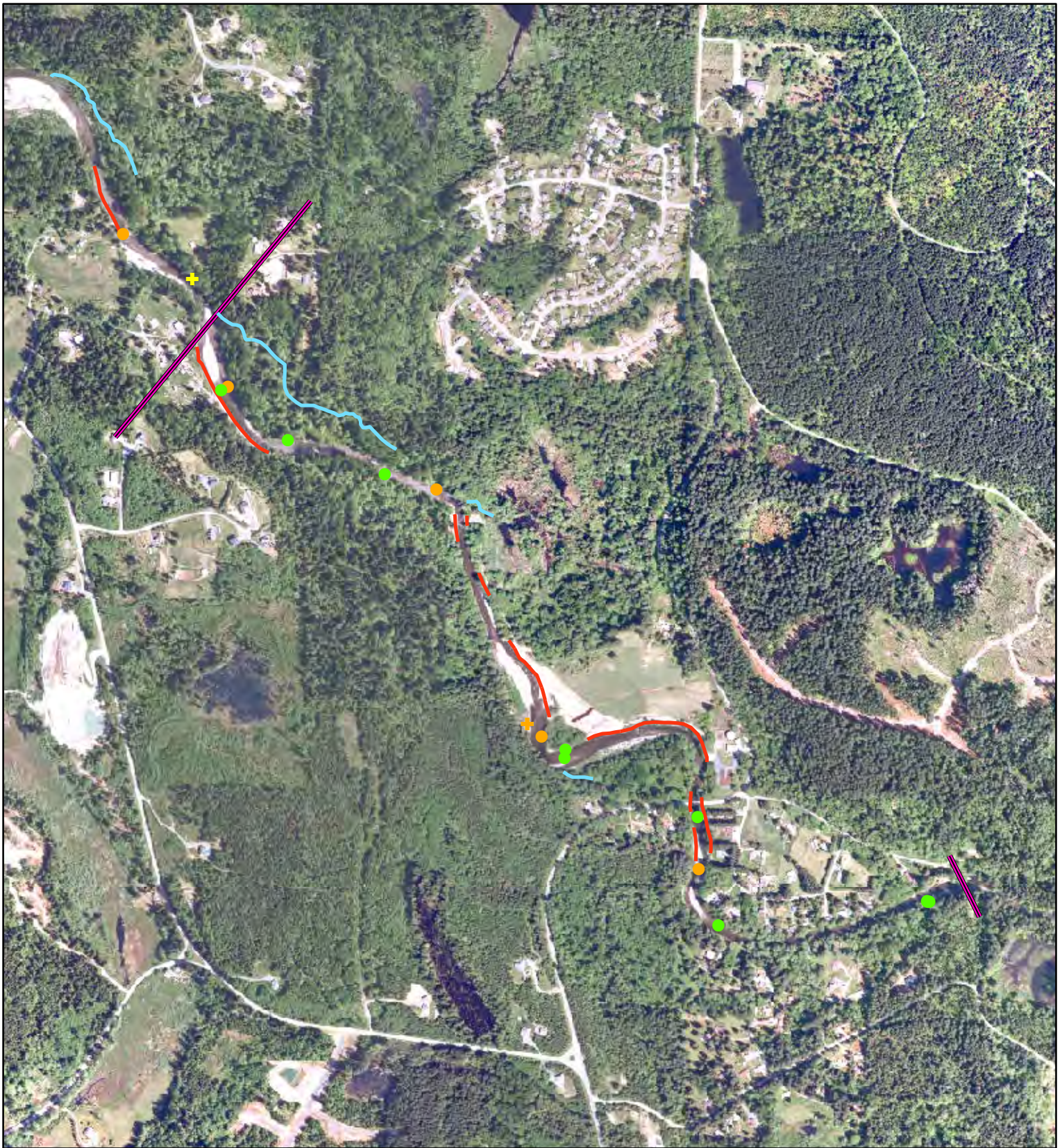


Figure 3-23. Habitat Conditions Map - Reach 8

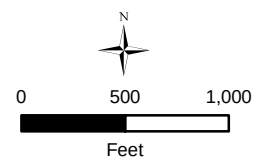
- Salmon Spawning Locations
- Side Channels
- Armored Bank
- Assessment Reach Boundaries

Adult Habitat

- + Jam
- Pool

Juvenile Habitat

- + Jam
- Pool



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