UPPER WENATCHEE RIVER

STREAM CORRIDOR ASSESSMENT AND HABITAT RESTORATION STRATEGY

YAKAMA NATION FISHERIES | PO BOX 15, FORT ROAD | TOPPENISH, WA 98948

Prepared by

INTER-FLUVE, INC.
1020 WASCO STREET, SUITE I | HOOD RIVER, OR 97031
541.386.9003 | www.interfluve.com

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Image credit:

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1 INTRODUCTION

1.1 Overview

This Reach Assessment evaluates aquatic habitat and watershed process conditions in the Upper Wenatchee River and identifies habitat restoration strategies. The assessment area is the mainstem Wenatchee River corridor from Lake Wenatchee to Tumwater Canyon (River Mile 35.5 to River Mile 54.5). This Reach Assessment provides the technical foundation for understanding existing conditions and for identifying restoration strategies and specific opportunities. This assessment evaluates conditions at the valley- and reach-scales and ensures that restoration actions address key factors limiting the productivity of aquatic species as well as fit within the appropriate geomorphic context of the system.

Restoration strategies were developed by comparing existing aquatic habitat conditions to target conditions obtained from reference areas and regional habitat thresholds. In areas where existing conditions were found to be deficient, restoration strategies and specific action types have been identified to restore degraded conditions.

Although restoration measures are expected to benefit numerous different aquatic and terrestrial species, there is a particular emphasis on restoration measures for recovery of Endangered Species Act (ESA) listed salmonids, including spring Chinook salmon (*Oncorhynchus tshawytscha*) and summer steelhead (*Oncorhynchus mykiss)*.

This report includes the following primary components:

- Study area characterization – Evaluation of valley- and basin-scale factors influencing aquatic habitat and stream geomorphic processes
- Reach-scale characterization – Inventory and analysis of habitat and geomorphic conditions at the reach and sub-reach scales
- Stream habitat assessment – Aquatic habitat inventory at the reach-scale
- Reach-Based Ecosystem Indicators (REI) analysis – Comparison of habitat conditions to established functional thresholds
- Restoration strategy – Includes a comparison of existing conditions to target conditions and identification of recommended reach-scale restoration measures
- Specific project opportunities – A list of specific potential project opportunities and areas that would help to accomplish the reach-scale restoration strategies.

2 BACKGROUND

This effort is being conducted as part of the Yakama Nation's Upper Columbia Habitat Restoration Program (UCHRP), which implements projects to recover habitat for ESA-listed salmon and steelhead in the Upper Columbia region. Restoration efforts by the

UCHRP work to achieve the objectives of the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (Recovery Plan, UCSRB 2007) and the associated Biological Strategy (UCRRT 2008). This effort has been conducted with input and coordination from multiple entities, including the Regional Recovery Team (RTT), US Forest Service, and the Wenatchee Habitat Subcommittee.

This assessment builds off of a large body of work produced in the basin beginning in the late 1990s and proceeding throughout the 2000s. Assessment and analysis work to date has included water use reports, instream flow reports, physical assessments, biological assessments, and restoration recommendations for portions of the Wenatchee River mainstem and the majority of its tributaries. In contrast to previous assessments, this effort provides a comprehensive reach-scale analysis of the Upper Wenatchee between Lake Wenatchee and Tumwater Canyon, and identifies specific restoration strategies and actions that address identified limiting factors.

2.1 Purpose

The purpose of this assessment is to document and evaluate geomorphic processes and aquatic habitat conditions in the upper Wenatchee River and to present a comprehensive reach-based restoration strategy to address habitat limiting factors. Evaluations used in this assessment include historical characterization, geomorphic assessment, hydraulic assessment, and an aquatic habitat inventory.

Specific goals and outcomes of this assessment include:

- Provide a comprehensive inventory and assessment of geomorphic and physical habitat conditions and trends
- Identify strategies and actions that address critical aquatic habitat impairments limiting the productivity of local salmonid populations
- Identify strategies and actions that protect and restore the dynamic landscape processes that support sustainable riparian and salmonid habitat
- Coordinate efforts with local landowners, resource managers, and other stakeholders in order to establish collaborative efforts that contribute to the success of restoration strategies

2.2 Study Area

The Wenatchee River Basin is located on the east slope of the Cascade Mountains in Northern Washington (Figure 1). The Wenatchee River is a tributary to the Columbia River with a confluence at the city of Wenatchee near Columbia RM 468.4 (MWG 1995).

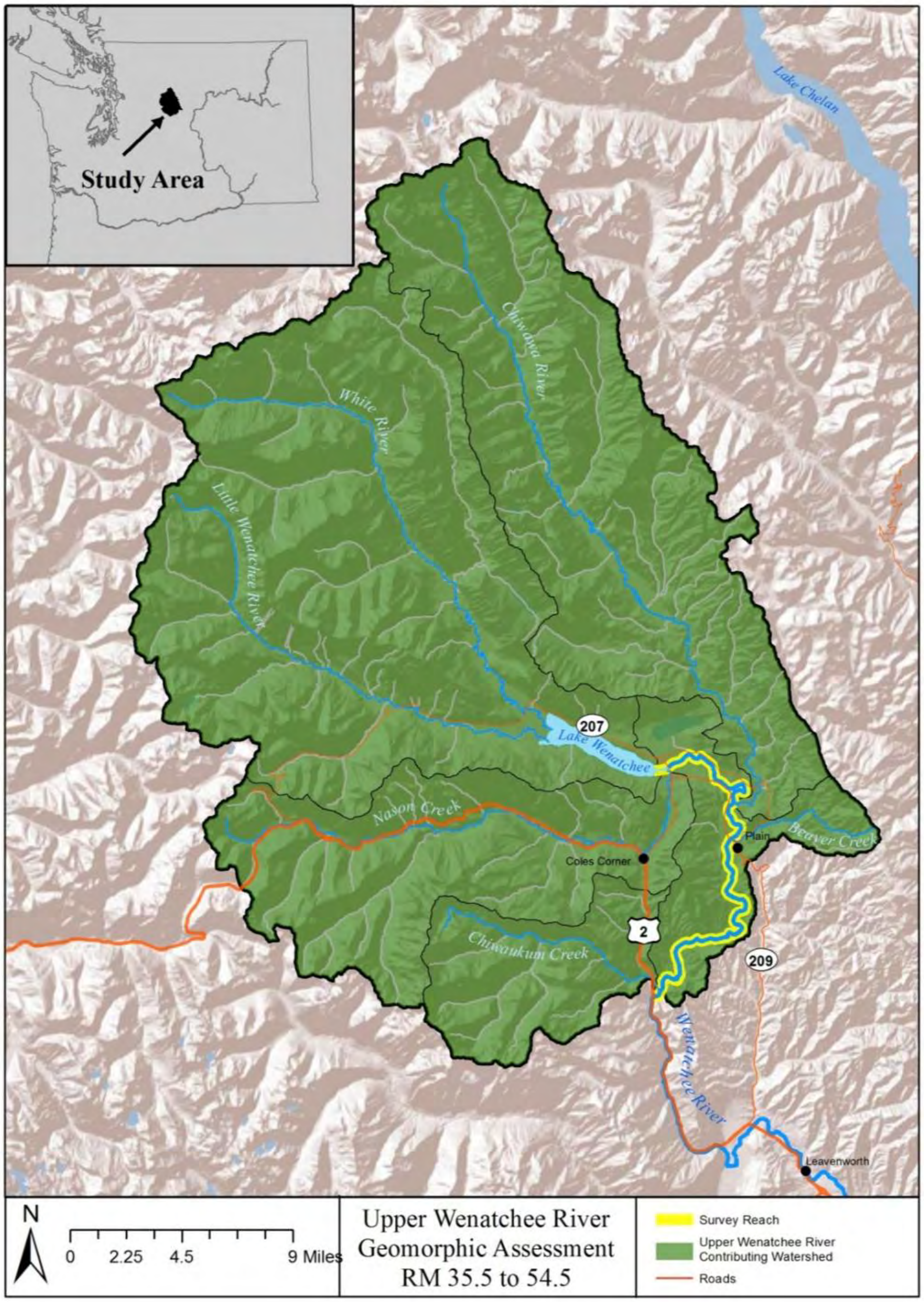

Figure 1. Upper Wenatchee River study area. The study area extends from Tumwater Canyon at RM 35.5 to Lake Wenatchee at 54.5.

2.3 Salmonid Use and Population Status

Salmonid use of the upper Wenatchee River includes spring and summer Chinook salmon, summer run steelhead, bull trout, Westslope cutthroat trout, and sockeye salmon. Spring Chinook salmon and summer steelhead are listed as Threatened under the Endangered Species Act (ESA). Human-induced changes to aquatic habitat have affected the key parameters used by federal agencies to evaluate the viability of salmonid populations; known collectively as the “viable salmonid population” (VSP) parameters: *abundance, productivity, diversity, and spatial structure* (UCSRB 2007). Failure to meet viability (i.e. VSP) criteria resulted in the listing of species under the ESA in the late 1990s. Upper Columbia River (UCR) steelhead trout and spring Chinook salmon were listed as Endangered in 1997 and 1999, respectively (UCSRB 2007). UCR steelhead were upgraded to Threatened in 2006, but were reinstated to Endangered in 2007 (UCSRB 2007). Bull trout were listed as Threatened under the ESA in 1999 (UCSRB 2007). Life-stage usage and ESA status for each species are summarized in Table 1.

Table 1. Species usage in the Upper Wenatchee River. Adapted from Pevin 2004, StreamNet 2012, and Andonaegui 2001.

Population	ESA Status	General Use	Timeframe	Distribution	Abundance	Productivity	Diversity
Spring Chinook	Endangered	Spawning & Rearing	Historic	High	Moderate-High	Moderate	High
		Rearing & Migration	Current	Moderate-High	Low-Moderate	Low-Moderate	
Steelhead	Endangered	Spawning & Rearing	Historic	High	Moderate-High	Moderate	High
		Rearing & Migration	Current	Moderate-High	Low-Moderate	Low-Moderate	
Summer Chinook	Not listed	Spawning & Rearing	Historic	High	Very High	Very High	High
		Rearing & Migration	Current	High	High	High	
Sockeye	Not listed	Migration	Historic	High	Very High	Moderate-High	High
		Spawning & Rearing	Current	High	High	Moderate-High	
Coho	Not listed – Reintroduced (domesticated Lower Columbia River stock)	Migration, Spawning & Rearing	Current				
	Extirpated	Migration, Spawning & Rearing	Historic				
Bull trout	Threatened	Migration	Historic	High	Moderate	Moderate	High
		Spawning & Rearing	Current	Moderate-High	Low-Moderate	Low-Moderate	
Westslope Cutthroat trout	Not listed	Unknown	Historic	Low-Moderate	Low	Moderate	High
			Current	Low-Moderate	Low	Low-Moderate	

2.4 Recovery Planning Context

Spring Chinook salmon, summer steelhead and bull trout are listed and protected under the Endangered Species Act (ESA) and recovery plans were completed in 2007 to prevent the extinction of Wenatchee River ESA listed fish. The Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSRB 2007) states that recovery of species viability will require reducing threats to the long-term persistence of fish populations, maintaining widely distributed and connected fish populations across diverse habitats of their native ranges, and preserving genetic diversity and life-history characteristics. The Recovery Plan calls for recovery actions within all of the “Hs” that affect salmon throughout their life history; namely Harvest, Hatchery, Hydropower, and Habitat. This upper Wenatchee River Reach Assessment addresses the Habitat component of the Recovery Plan, with a focus on the upstream 19.0 miles of the Wenatchee River corridor.

The following habitat restoration and preservation objectives were set forth in the Recovery Plan (UCSRB 2007). These objectives apply to spring Chinook, steelhead, and bull trout habitat and are consistent with the Subbasin Plan (NWPCC 2004), the Watershed Management Plan (WWPU 2006), and the Biological Strategy (UCRTT 2008). The objectives are intended to reduce threats to the habitat needs of the listed species. Objectives that apply to areas outside the study area or that are outside the scope of this plan are not included. A list of regional objectives (applicable to all streams in the Recovery Planning area) is followed by a list of specific objectives for the upper Wenatchee River basin. These objectives provided a framework and guidance for the Reach Assessment and ultimate selection of specific restoration and preservation activities conducted as part of this assessment and included in this report.

Short-Term Objectives

- Protect existing areas where high ecological integrity and natural ecosystem processes persist
- Restore connectivity (access) throughout the historic range where feasible and practical for each listed species
- Protect and restore water quality where feasible and practical within natural constraints
- Increase habitat diversity in the short term by adding instream structures (e.g. large wood, boulders) where appropriate
- Protect and restore riparian habitat along spawning and rearing streams and identify long-term opportunities for riparian habitat enhancement
- Protect and restore floodplain function and reconnection, off-channel habitat, and channel migration processes where appropriate and identify long-term opportunities for enhancing these conditions
- Restore natural sediment delivery processes by improving road network, restoring

natural floodplain connectivity, riparian health, natural bank erosion, and wood recruitment

Long-Term Objectives

- Protect areas with high ecological integrity and natural ecosystem processes
- Maintain connectivity through the range of the listed species where feasible and practical

Restoration Objectives Specific to the upper Wenatchee River Basin

- Increase habitat diversity and quantity in the upper Wenatchee River by restoring riparian habitat, reconnecting side channels and the floodplain (where feasible), and adding instream habitat structures within the river.
- Provide access to naturally-forming, high quality, watered off-channel habitat and protect those areas that already exist
- Maintain (White River, Little Wenatchee River, Chiwawa River) or restore (Nason Creek, Icicle Creek, Peshastin Creek) connectivity to Wenatchee subbasin watersheds

3 ASSESSMENT AREA CONDITIONS

3.1 Setting

The Wenatchee River Basin is located in Chelan County in North Central Washington State on the east side of the Cascade Mountains within the Columbia Cascade Ecological Province. Headwater drainages upstream of Lake Wenatchee, as well as in the Nason Creek and Chiwawa River drainages, originate in the Alpine Lakes and Glacier Peak Wilderness areas. The total basin area is 1,371 square miles. The catchment area contributing to the downstream extent of the study area (RM 35.5 at Tumwater Canyon) is approximately 664 square miles and includes the watersheds of Chiwaukum Creek (50 square miles at RM 36), the Chiwawa River (199 square miles at RM 48.4), Nason Creek (106 square miles at RM 53.6), the Little Wenatchee and White Rivers above Lake Wenatchee (279 square miles), and several smaller drainages.

Eleven distinct geomorphic reaches were delineated within the study area (Figure 1). Reach delineation was based on basin size (i.e. major tributary confluences), valley confinement, underlying geology, channel gradient, and channel type (e.g. dominant bed morphology). Reach delineation was initially conducted using remotely available data (e.g. aerial photos, LiDAR, and geology maps) and was field-verified during surveys.

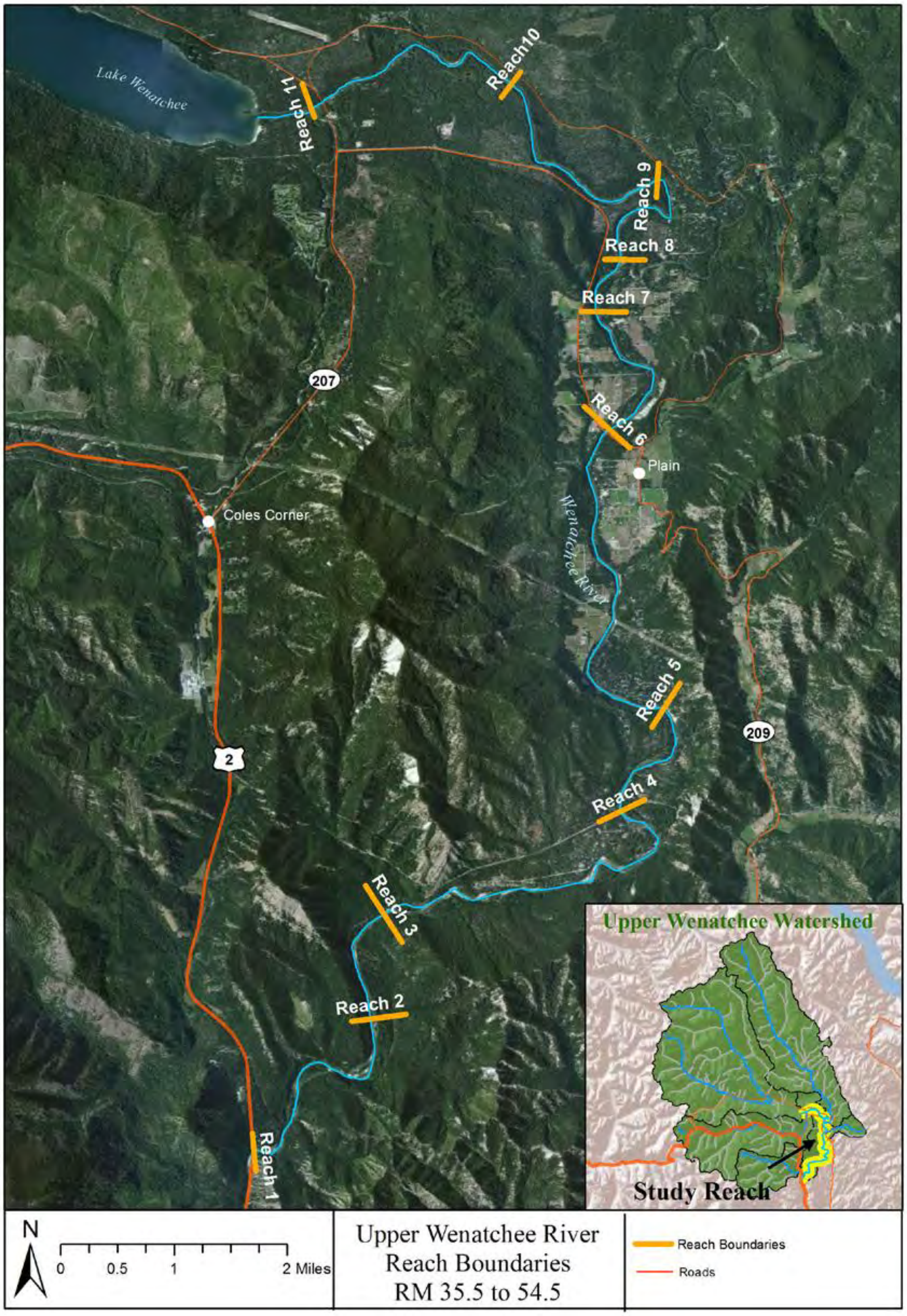

Figure 2. Geomorphic Reach boundaries for the Upper Wenatchee River Assessment.

3.2 Geology

The Wenatchee River basin is located within the Northern Cascades geologic province. This province is bounded by the Straight Creek fault system to the west, the Pasayten fault system to the east, and a less distinct structural break to the south. The Upper Wenatchee River is located within the eastern portion of the North Cascades province. Here, there are multiple northwest-southeast trending fault systems with underlying crustal fragments of differing geologic origin, known as terranes. The Upper Wenatchee River basin is primarily affected by the dynamic relationship between two of these fault systems, the Entiat and Leavenworth faults, and by the geology of their underlying terranes (Figure 3).

The Entiat fault to the east and the Leavenworth fault to the west both display normal and strike-slip movement. Movement by both these faults during the Eocene era (50 to 30 million years ago) formed a pull-apart basin known as the Chiwaukum Graben. This basin experienced high rates of deposition from the relative up-thrown structural blocks to the east and west, which formed two distinct formations within the Chiwaukum Graben. One of these formations, the Chumstick Formation, is a thick blend of deposited sandstone, conglomerate, shale, and tuff. Sandstone (of alluvial and lacustrine origin) comprises the majority this formation. This sandstone-dominated formation is a relatively easily erodible rock type and is the primary bedrock outcrop and vertical grade control encountered along the river in the study area (Gresens et al. 1978).

The Upper Wenatchee basin is also impacted by glacially (see Glacial History section below) and fluvially transported materials imported from surrounding areas. Some materials found in the bed and banks of the Upper Wenatchee originated in the highlands to the east (Mad River Terrane) and to the west (Nason-Ingalls Terrane). These rock types are primarily crystalline in nature such as gneiss, schist, and granitic rocks and form the more persistent sources of boulders in the channel (Figure 4).

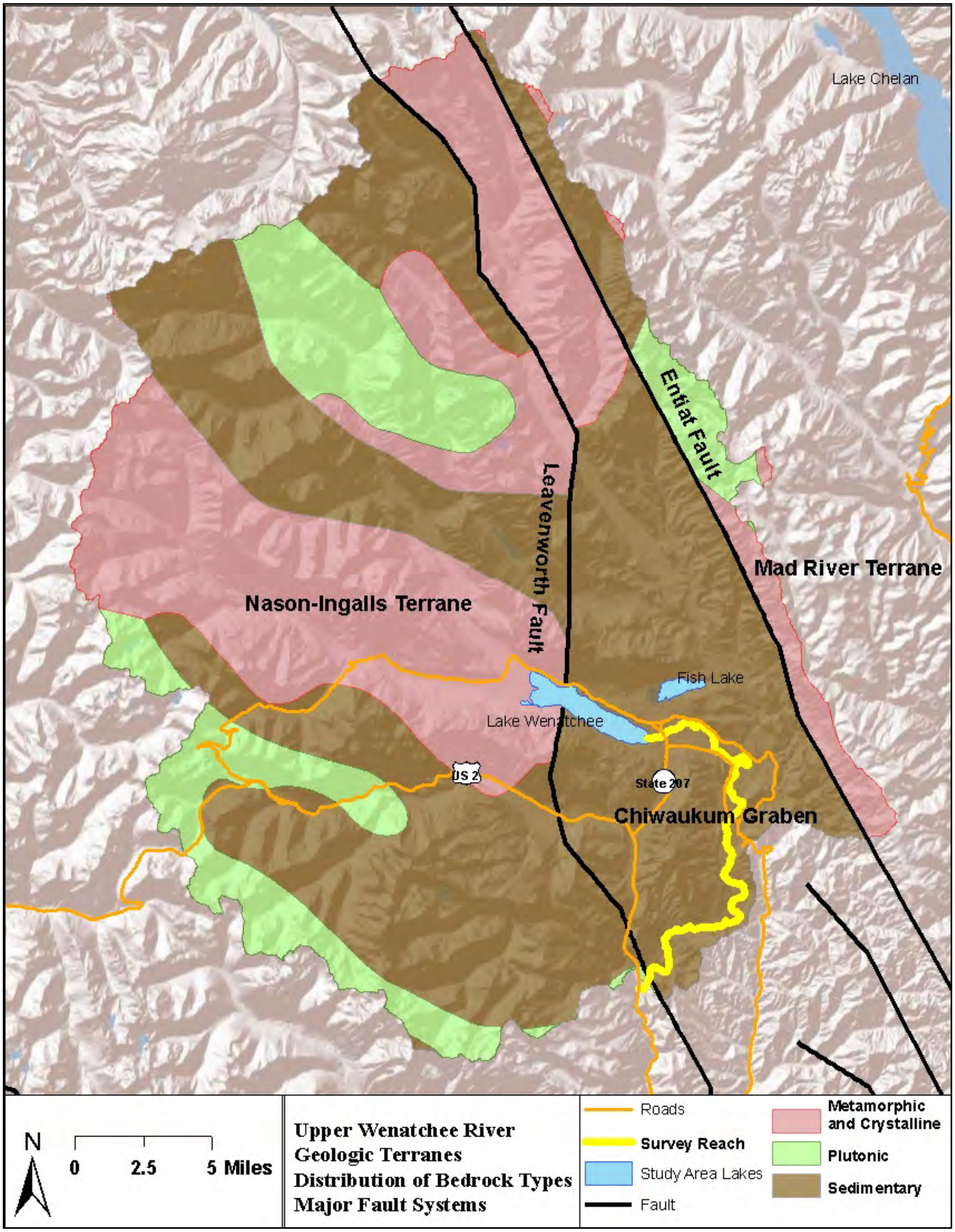

Figure 3. Geologic map of the study area showing generalizations of bedrock types, fault systems, and major geologic terranes within the contributing watershed of the study area. (Adapted from Tabor et al. 1987).

Figure 4. Boulders located in the channel and along the toe of the hillslope adjacent to the channel. This material is likely sourced from crystalline bedrock in tributary watersheds and brought into the study area as glacial deposits.

Glacial History

There are six major glacial cycles recognized in the region ranging in age from 12,500 to 165,000 thousand years before present (Porter and Swanson 2008, Table 2). During the last glaciation (late Pleistocene), masses of ice moved from higher elevations in the basin downslope, carving out rock masses and leaving behind remnant glacial erratics. Glaciation extended downstream from Lake Wenatchee through much of the study reach. Glacial deposits can be found fairly continuously along the river throughout the study area. A glacial moraine marks the upstream extent of the study area at the outflow of Lake Wenatchee. Till deposits, formed by active glacial erosion and often deposited as moraines, form the hillslopes to the north of the river from the upstream end of the study area to RM 49.3 where the Chiwawa River incises the till. Glaciation also provided substantial meltwater, which flowed downslope depositing silt, sands, and gravel. These glacial and fluvial terraces of Pleistocene age confine the channel on both sides for much of the study reach (Figure 5).

Table 2. Regional glacial cycles derived from study of deposits in the Icicle Creek drainage, and the relative ages of these respective glacial periods (adapted from Porter and Swanson 2008).

Glaciation periods that correlate with till deposits in the Icicle Creek Drainage	Approximate age of deposit
Rat Creek I and II	12,500±500 and 13,300±800
Leavenworth I and II	16,100±1100 and 19,100±3000
Mountain Home	70,900±1500
Pre-Mountain Home	93,100±2600
Peshastin	105,400±2200
Boundary Butte	At least 165,000

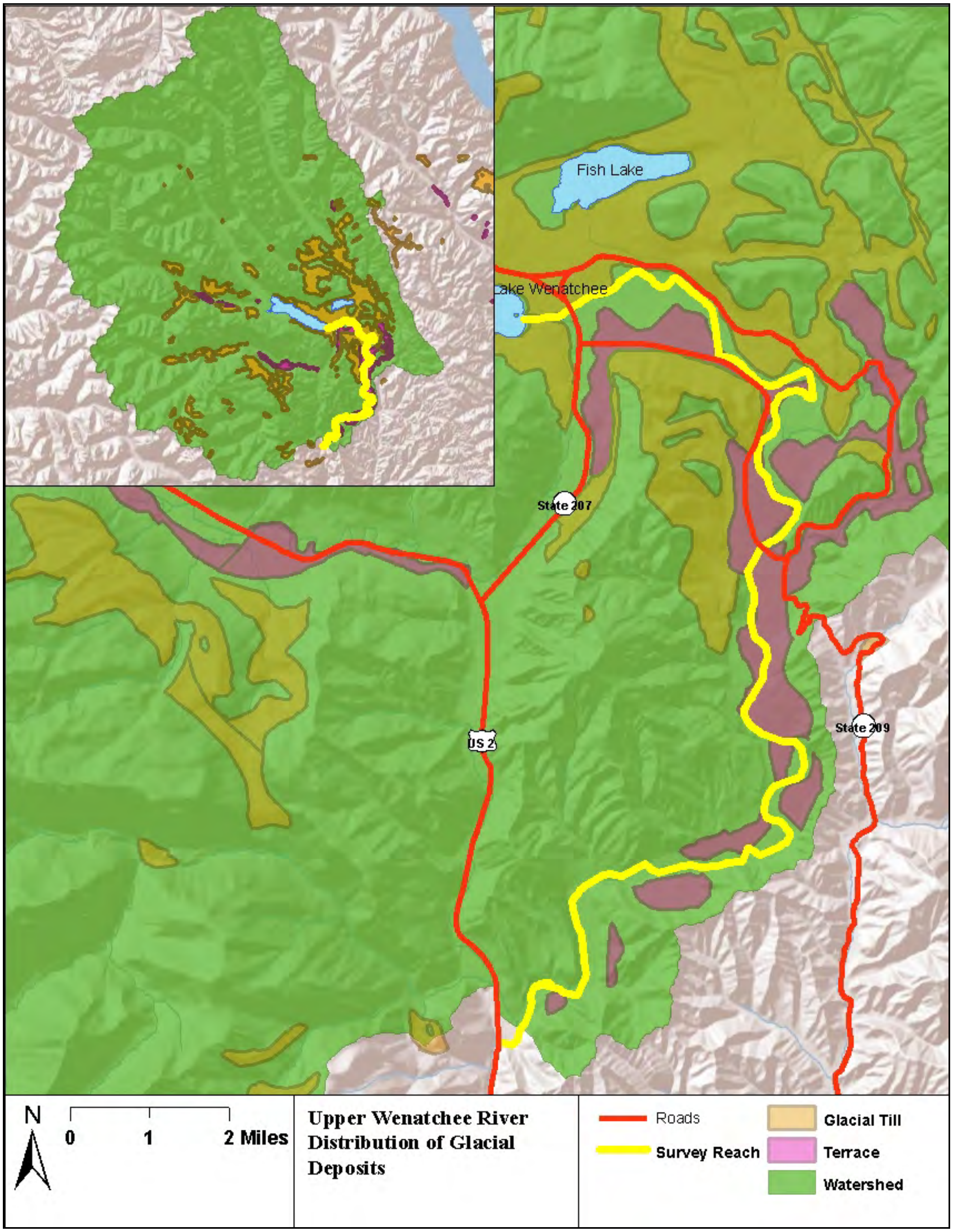

Figure 5. Topographic map depicting the distribution of mapped glacial deposits in the study area. The inset shows the wider distribution of glacial deposits in the contributing watershed (adapted from Tabor et al. 1987).

3.3 Historical Forms and Processes

3.3.1 Channel Form and Process

Although there is little direct evidence of conditions prior to Euro-American settlement (late-1800s), a couple of early surveys help to characterize historical conditions. These include the General Land Office cadastral surveys between 1899 and 1906 and a more detailed survey by the USGS in 1911. These surveys suggest that the historical channel planform geometry was similar to what is seen in modern times (Figure 6 and Figure 7), with only minor changes at naturally unconfined segments. Similar to contemporary geomorphic form and processes, alluvial reaches with relatively wide, well-connected floodplains alternated with naturally confined reaches where bedrock and glacial deposits set lateral limits on channel migration.

Within alluvial reaches (e.g. Reach 1), geomorphic processes of channel migration, channel avulsion, deposition of sediment, channel braiding, and deposition of large wood would have created complex habitat features. In contrast to the alluvial reaches, confined or partially confined reaches, such as the river through the Plain area, would not have provided the same degree of instream and off-channel habitat complexity. In many of these reaches, glacial terraces naturally confine the channel on both sides. Slow re-working at the toe of glacial terraces would have resulted in boulders, glacial lag, and boulder erratics in the channel and along the channel margin. These features would have created some hydraulic variability, scour pools, pocket water, and temporary locations for riparian vegetation establishment and accumulation of large woody material, but most of the habitat complexity would likely have been confined to the channel margins.

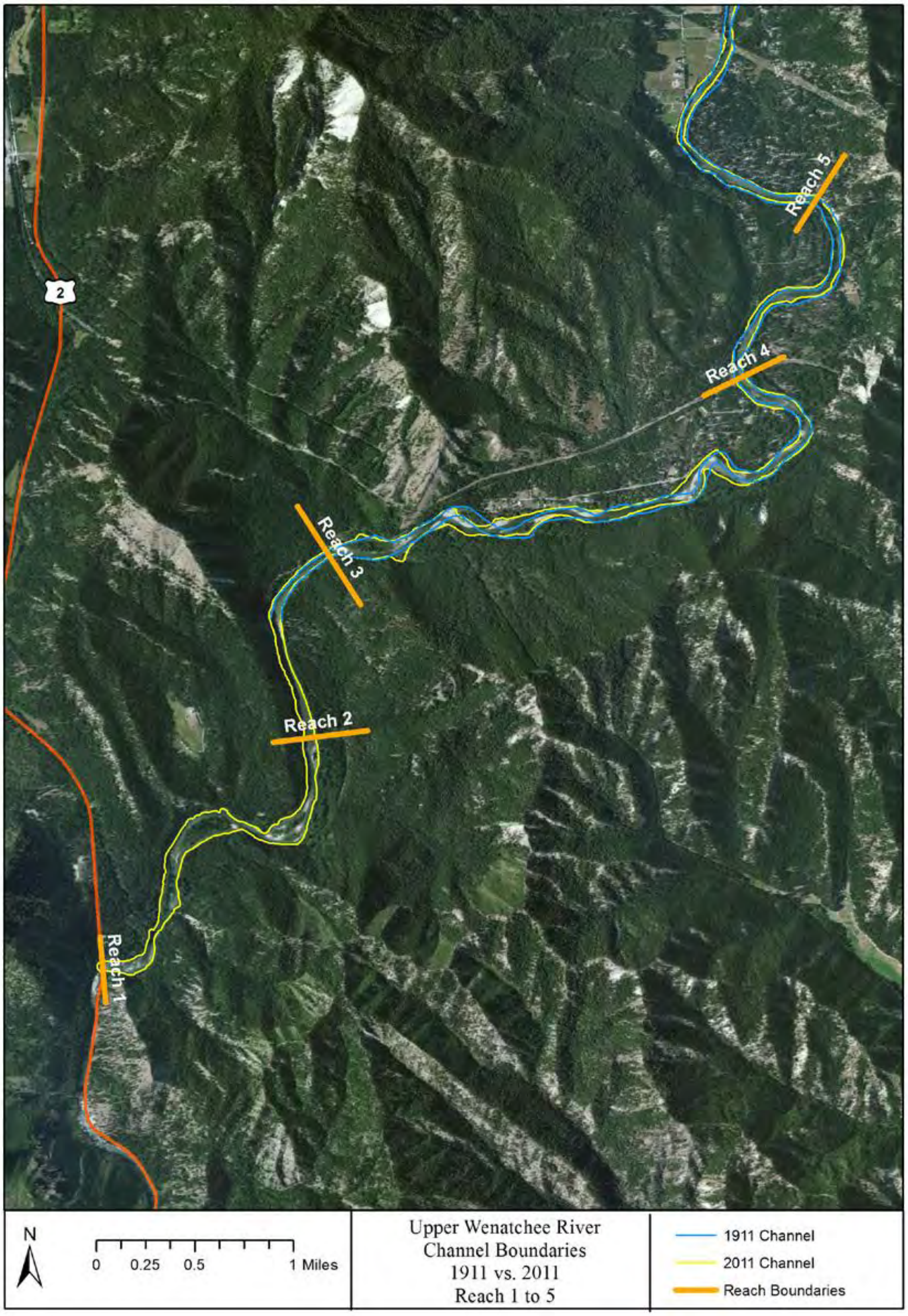

Figure 6. Channel boundary comparison between 1911 survey and 2011 aerial photo for Reaches 1-5 (1911 maps ended between reaches 2 and 3).

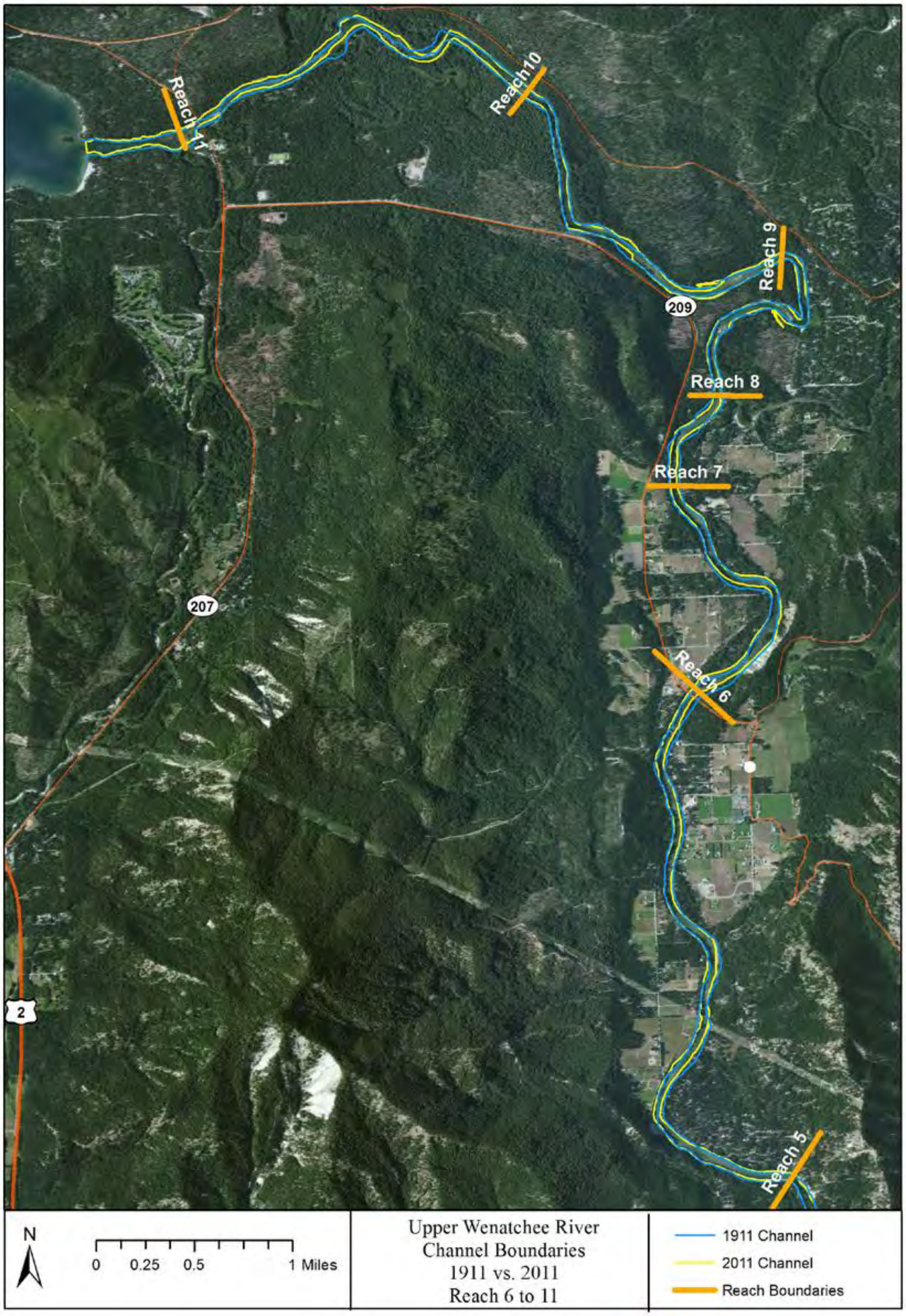

Figure 7. Channel boundary comparison between 1911 survey and 2011 aerial photo for Reaches 6-11 (1911 maps ended between reaches 2 and 3).

3.3.2 Hydrologic Regime

Similar to contemporary conditions, the natural hydrologic regime within the study area was dominated by the seasonal dynamics of a snowmelt runoff system. The flow pattern would have exhibited increasing flow through the spring with an annual peak in June and a rapid decline to baseflow conditions by late July or August. Brief high flow periods would have occurred from late October through February due to extended rain, and the largest flows would have occurred during winter months due to rain-on-snow events. As in modern times, Lake Wenatchee would have buffered hydrologic inputs from the Little Wenatchee and White Rivers. Tributary contributions downstream of the Lake are historically important as sources of non-buffered flood pulses carrying sediment and wood to the mainstem of the Wenatchee.

3.3.3 Large Wood Dynamics

Historically, large wood would have been an important driver of geomorphic form and process, and would have had a strong influence on instream habitat availability and complexity. The following section outlines large wood dynamics, including sources of instream large wood (sources), how wood is made available to the stream (recruitment), and how wood is retained within the stream where it provides habitat functions (retention).

Sources

Instream wood source areas for the Upper Wenatchee included: (1) wood additions from the river corridor (floodplain, terrace slopes, and riparian areas), and (2) wood contributed from the upper basin that has moved through Lake Wenatchee, Nason Creek, or the Chiwawa River. Wood from upstream sources has been shown to be an important component of wood loading in larger streams (McDade et al. 1990, Martin and Benda 2001), and therefore upstream areas were likely an important source of large wood for the study area. Nason Creek and the Chiwawa River would have been major contributors of upstream large wood inputs. The Little Wenatchee and the White River (Lake Wenatchee tributaries), and the margins of Lake Wenatchee itself, would also have provided wood to the study area. Given the orientation (northeast to southwest) and the four mile fetch along Lake Wenatchee, wind would likely have moved much of the large wood across the lake and down to the Wenatchee River. However, the presence of Lake Wenatchee may have reduced downstream wood loading to some degree due to the retention of wood in the lake from beaching and sinking.

Wood sourced from upstream areas and from the study reaches would have had a range of sizes depending on forest type and time since last disturbance (e.g. floods and fires). Compared to existing conditions, there would have been a greater source of large old-growth trees that would have been periodically recruited to the system. Plummer (1902) describes the forests of the “upper basin” like this:

> In the upper basin is a fine forest of old-growth red fir, red cedar, white pine, and hemlock, besides smaller growth of lovely fir. Some trees in this old growth have a diameter of 4 to 5 feet and make up a forest such as is seldom seen in eastern Washington.

In the alluvial reaches within the study area, source areas would have included much of the active floodplain, whereas in confined reaches, riparian source areas would have been closer to the channel margins. Riparian source areas historically included a valley floor heavily forested with conifers and with a dense shrub understory (Fenner 1897, Plummer 1902, US Bureau of Fisheries 1935).

Recruitment

Historically, large wood would have entered the Upper Wenatchee and upstream contributing stream channels from both chronic (i.e. single-tree mortality) and episodic disturbance-related events. Disturbance-related contributions would have included fire, floods, windstorms, avalanches, diseases, and landslides. These contributions likely provided a greater amount of wood loading than chronic contributions. Laterally-active alluvial reaches would have recruited wood via lateral and transverse scrolling of the channel, whereas recruitment in the more confined reaches would have occurred primarily through single-tree mortality. Reaches confined by high glacial terraces (see reach descriptions in Section 4) would also have recruited wood via toe erosion that initiates mass wasting events on the terrace bank. These "colluvial jams" would have been an important source of channel margin wood in confined reaches (Figure 8).

Figure 8. Example of contemporary 'colluvial jam' on Upper Wenatchee River. Historically, these types of jams would have been composed of much larger riparian trees (photo October 2011).

Retention

Retention of large wood is related to characteristics of the wood itself and also characteristics of the stream channel (Gurnell 2003). In general, the larger the wood piece (e.g. diameter and length) with respect to channel size (e.g. width and depth), the more likely it is that wood will be retained (Bilby and Ward 1989, Brauderick and Grant 2000, Bocchiola et al. 2008). In large rivers, wood is frequently retained in the channel in the form of log jams. Large, stable pieces that initiate log jam formation are often referred to as “key pieces” (WFPB 1997). Key pieces, which typically have attached rootwads, are retained in the channel first and serve as foundation pieces for capturing and racking additional wood from upstream. In the pre-disturbance Upper Wenatchee River, the greater availability of these larger key piece sized pieces, as discussed previously, would have supported a greater degree of log jam formation.

Another important factor affecting wood retention is the degree of channel complexity. A complex channel with numerous obstructions to flow such as bank protrusions, islands, gravel deposits, boulders, or other wood pieces will retain wood more readily than simplified uniform channels (Fetherston et al. 1995, Gurnell et al. 2000a, Gurnell et al. 2000b, Haga et al. 2002, Bocchiola et al. 2008). A historically more complex channel, prior to human alteration, would have provided a greater degree of in-channel wood retention compared to contemporary conditions. These wood accumulations would have promoted both geomorphic and habitat functions including creation of pools, sediment retention (trapping) and sorting, creation of multi-thread channels, and increased channel complexity and cover for fish. Jams would have formed throughout alluvial reaches in the study area, and based on jams surveyed as part of this assessment in the relatively intact Reach 1, jams may have been composed of over 200 pieces. Depending on the wood type forming the larger key pieces, these large jams could have been stable for decades.

3.3.4 River Ice

River ice on the Upper Wenatchee River (e.g. Figure 9) is a driver of geomorphic form and process. In years the Upper Wenatchee freezes over, ice impacts channel form by attaching to and then breaking off of stream banks and contributing to bed and bank scour. River ice can cause large overbank flood events due to ice-dams. As river ice begins to break-up during warming or thawing events, ice blocks move downstream and build up behind river ice or other obstructions further downstream. Areas prone to ice-damming include transitions from riffles to pools, meander bends, and mid-channel bars. Flooding has been linked to river ice on the lower Wenatchee River, Peshastin Creek, and the Entiat River. The frequency of occurrence of ice-related flooding events on the Upper Wenatchee is relatively low, but the specific extent and geomorphic impact is not well known.

Figure 9. Photo of Upper Wenatchee frozen over (1960s) (photo courtesy of Bryon Newell)

3.3.5 Habitat Conditions

The earliest descriptions of the Upper Wenatchee describe the river as “clear and pure- the lakes and larger streams in the township teem with trout of different varieties, and salmon come up the Wenatchee River in great numbers in their season” (Fenner 1897). The first known physical habitat assessment of the Upper Wenatchee describes the River as having plentiful spawning areas and adequate areas of refugia and resting. “Spawning rubble” accounted for over 40% of substrate throughout the study reach (Figure 10) (US Bureau of Fisheries 1935). The assessment notes that “good spawning areas are plentiful throughout this section.” P 19 repla

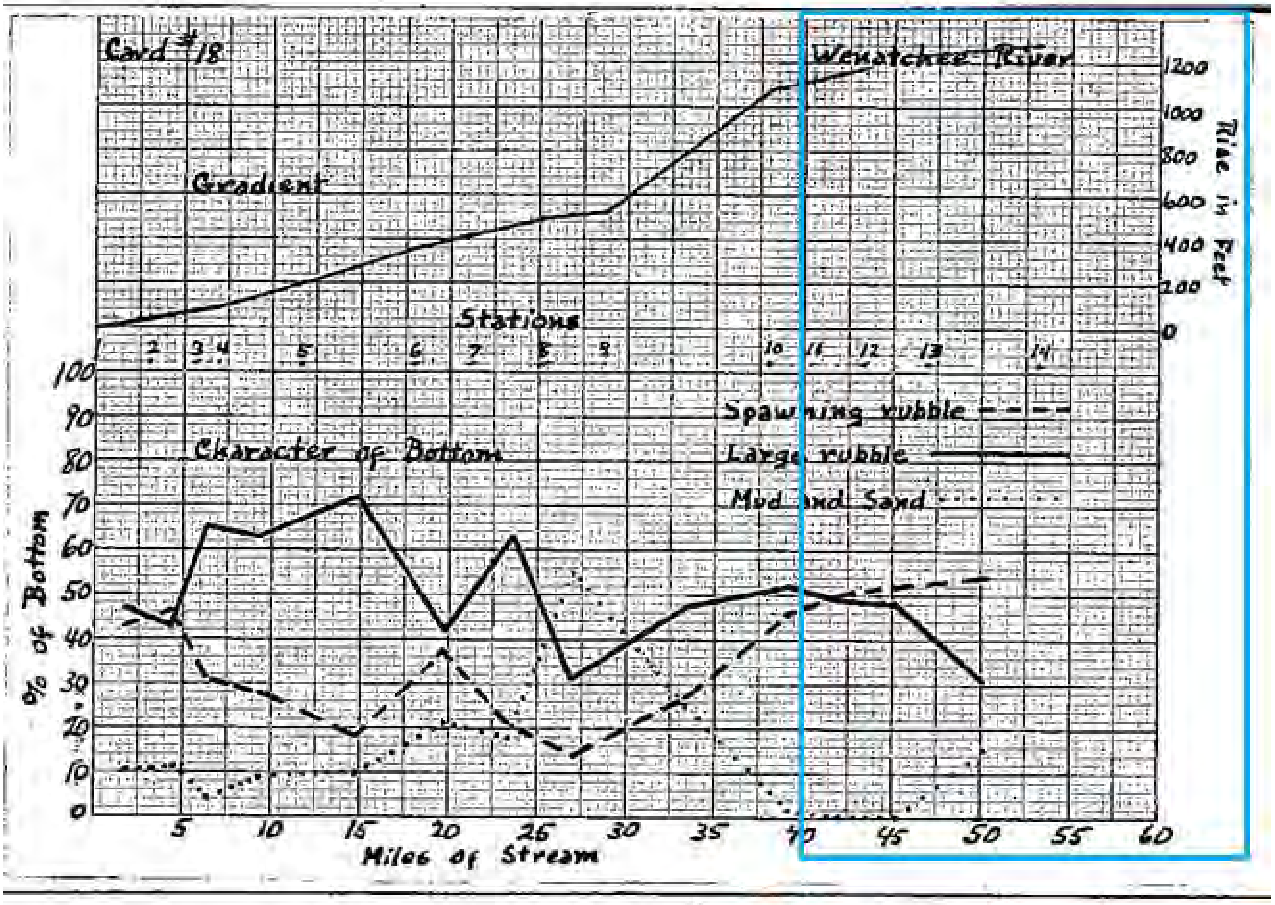

Figure 10. Physical habitat assessment results from 1935. Area enclosed in blue box is approximate study reach.

A 1950 survey documents quality habitat in the upper portion of the study reach: "the best riffles are in the upper 9 miles below the outlet of the lake" (RM 54- RM 45).

Large wood accumulations were also an important part of fish habitat. As discussed in Section 3.3.3, large wood was a major driver of geomorphic forms and processes, and their associated habitat elements throughout the Upper Wenatchee River. Historical habitat function provided by large wood included creation of pools, gravel recruitment, creation of multi-thread channels, hiding cover, and refugia during high and low flows.

3.4 Human Disturbance History

3.4.1 Early Disturbance

The first documented inhabitants of the region were members of the Wenatchi Tribe, who called the Wenatchee River the Pisquoise or the Wenatshapam River (Beckham 1995). There were three known villages in the area, Tciw'as, a fishing village (population approximately 100) at the confluence of the Wenatchee and Chiwawa Rivers, Tcitciw'aux, at Rock Creek and the Chiwawa River, and Tahkwut, at Lake Wenatchee (Roe 2002). Native American tribes hunted, gathered, and fished throughout the region. Native Americans also utilized fire to manage their berry production areas (Mullan et al. 1992).

The first Euro-American visitors to the Upper Wenatchee were fur trappers traveling through the region in the mid-1800s. With over 2,000 acres identified in the early 1900s as "beaver-dam" country (Plummer 1902), fur trapping resulted in the extirpation or large reduction in number of beavers in the basin (Andonaegui 2001). The removal of beaver from the area likely altered side-channel and floodplain dynamics by removing wetlands and bogs, altering sediment dynamics, and decreasing groundwater storage (as based on Naiman et al. 1988).

More permanent settlement began in the region by Euro-American homesteaders in 1860 (Beckham 1995). Early settlement included grazing, construction of boat ramps, small-scale logging, mining, and construction of a hotel on Lake Wenatchee in 1890.

3.4.2 Great Northern Railroad

In 1890, construction of the Great Northern Railroad promoted further settlement into the Wenatchee Basin (Beckham 1995). Completion of the railway construction in 1893 through the town of Leavenworth brought extensive economic development to the area, driven largely by timber harvest and export. The railway line was built up through Tumwater Canyon, where Highway 2 is today. As the town of Leavenworth expanded, settlement moved up the valley into the Upper Wenatchee Basin. This expansion of settlement brought increased disturbance to the region including clearing for homesteads, increased grazing, and mining. By 1908, the Great Northern Railroad built a hydroelectric plant and associated dam in Tumwater Canyon above Leavenworth to provide electricity to the railway's Cascade Tunnel (Beckham 1995). This dam was one of the first major fish passage barriers installed on the Upper Wenatchee River. Railroad construction included construction of bridges across the Wenatchee and accelerated timber harvesting.

3.4.3 Timber Harvest and Log Drives

Small-scale timber harvest began in the Upper Wenatchee in the late 1800s. Cabins, boat ramps, early roads, and fords are visible on survey maps from 1893, indicating that by this point small-scale timber harvest was ongoing in the area. In the early 1900s, the pace and scope of the region's timber harvest accelerated with the expansion of the railroad, improved technology, and the construction of sawmills in the area. Two known sawmills were located on the Wenatchee River, one on the current site of Lake Wenatchee State Park (Newell 2011) and a second in Leavenworth (Figure 11) (Roe 2002).

Figure 11. Power dam and mill pond in Leavenworth, WA. Early 1900s.

Riparian zones were cleared of large trees, which likely ranged up to four or five feet in diameter (Fenner 1897, Plummer 1905). Extensive timber was cleared throughout the region and selective harvest of the region's largest timber or "high-grading" was the predominant silvicultural method until 1955 (McIntosh et al. 1994). Riparian trees were often the first to be harvested due to ease of access and transport (Figure 12, Figure 13). In 1926 alone, 80 million board feet of timber was processed at the Leavenworth Mill (Beckham 1995). Although riparian clearing is no longer occurring in the study reach, the effects of this historical practice will continue to affect wood-loading for the foreseeable future (see Section 3.5.1).

Figure 12 Historical photo (late 1920s) taken from the Old Plain Bridge looking upstream towards a logged right bank alluvial terrace (left-hand side of photo).

Figure 13. Recent photo (2011) from the Plain Bridge looking upstream. Historical logged right bank alluvial terrace is revegetated (left-hand side of photo).

Early sawmill operations included damming of the creek for log ponds and log transport via splash damming (Farnell 1979, Taylor 1999). Logs were pooled behind or placed downstream of channel-spanning dams, and typically during high spring flows, water was released from the dam to allow logs to rush downstream. Logs were driven down Nason Creek, the Chiwawa, the Chiwaukum, and the Wenatchee to the Mill in Leavenworth until 1926 (Roberts 1996, Hull 1929, BOR 1999) (Figure 14, Figure 15, and Figure 16). Leavenworth Mill operation continued until 1927, although timber harvesting continued long after this. Logs were also driven from the White River and Little Wenatchee drainages through the lake to the mill built at the current site of Lake Wenatchee State Park (Newell 2011). Impacts from these splash dams and log drives include channel simplification through the dynamiting and removal of large in-channel boulders and natural logjams and the obstruction of side channels and backwater areas. These actions would have eliminated many habitats outright and would have reduced overall habitat complexity and cover.

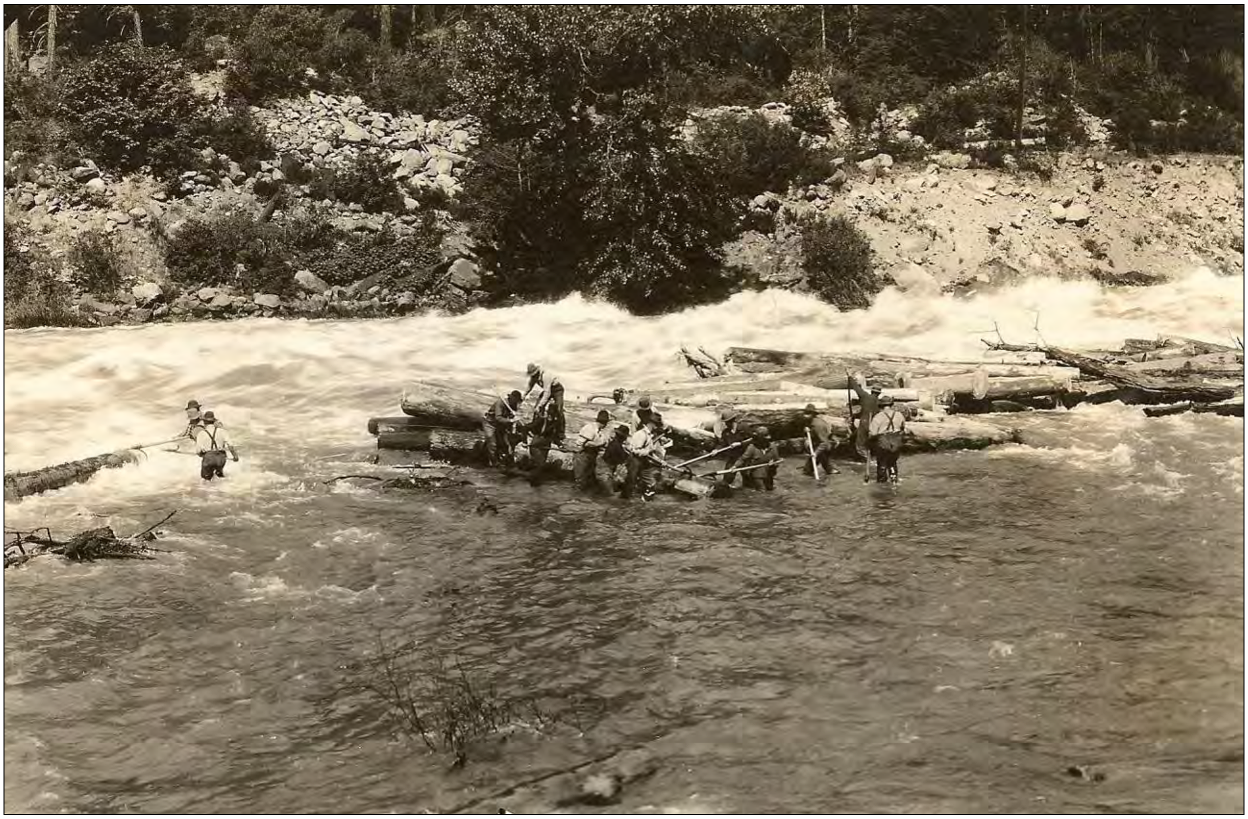

Figure 14. Early 1900s log drive on an unknown location of the Wenatchee River. In order to get the logs efficiently downstream, obstructions such as natural logjams and boulders would often be removed (Photo courtesy of the Wenatchee Historical Society).

Figure 15 Early 1900s log drive on an unknown location of the Wenatchee River (Photo courtesy of the Wenatchee Historical Society).

Figure 16. Early 1900s log drive on the Upper Wenatchee River (Photo courtesy of the Wenatchee Historical Society).

By the 1950s, timber harvest within the basin began to increase. The 1980s represented the heaviest timber harvest within the basin (McIntosh et al. 1994, Mullan 1992, USFS 1990). Clearcutting became the most common method of harvest. Timber harvest removed the Upper Wenatchee's native climax tree species, and combined with fire suppression, helped to shift species composition.

3.4.4 Fire Suppression

The fire regime within the Upper Wenatchee Basin is a major driver in forest ecology and influences riparian stand conditions and ultimately, instream large wood conditions. Prior to Euro-American settlement, the lower elevations of the Wenatchee Basin would have experienced frequent low intensity fires every five to ten years; and higher elevations would have experienced less frequent and higher intensity fires (often stand-replacing) every 50 to 100 years (USFS 1999, Andonaegui 2001). Decades of fire suppression beginning in the early 1900s have altered this pattern and have shifted the entire basin to a less frequent, higher intensity fire regime. Fire suppression within the basin has led to shifts in vegetative composition from more open stands of fire-tolerant species (e.g. ponderosa pine and Douglas fir) to higher density stands of less fire-tolerant species (e.g. grand fir). The historically more open stands had larger trees than the higher density stands seen today, which has served to decrease the size of riparian trees that are now available to be recruited to the river. Fire suppression has also led to a higher occurrence of noxious weeds within the area (USFS 2003).

3.4.5 Residential Development and Roadways

Human infrastructure in the form of residential development, roadways, and bridges has altered channels, riparian areas, and floodplains in portions of the study area. Residential development is most prevalent in Reaches 3-8 and Reach 10. In many areas, residential development consists of numerous small parcels that are part of organized community clubs. Most of these communities are in the Plain area and occupy significant portions of the middle reaches of the study area. Residential development is frequently associated with bank hardening, riparian clearing, and floodplain filling and grading (Figure 17). Increased road density has also accompanied increased human density in the area, and in some places has altered the drainage network and has limited the extent of floodplain inundation. Highway 207 (Lake Wenatchee Hwy), Highway 209 (Beaver Valley Road), and River Road are the primary roadways that affect the channel, riparian areas, and floodplains in the study area. Highway 209 limits floodplain function near the upstream end of the study area (right bank near RM 50.5), and has led to disconnection of areas that historically were prone to flooding (see Hydraulics discussion, Section 3.5.2). The bridge on highway 207 at the upstream end of the study area creates a hydraulic constriction at high flows, and reduces floodplain function at the confluence of Nason Creek and the Wenatchee River (see Section 3.5.2). Numerous sections of bank protection (riprap and rock spurs) are located along River Road in reaches 3-5. The Burlington Northern Railroad Bridge also creates a floodplain constriction at RM 41.9. The overall effect of these anthropogenic activities has been to reduce channel and floodplain complexity as well as the connectivity of channel and floodplain habitat.

Figure 17. Residential development and bank hardening near the upstream end of the study area.

3.4.6 Habitat Alterations

The various human alterations discussed previously began to affect fish populations by the early 1900s. A 1935 habitat assessment (US Bureau of Fisheries 1935) describes declining populations of historically abundant spring Chinook and steelhead runs. By this point, habitat conditions had already been altered by construction of six irrigation diversions, dams (including the mill pond at Leavenworth and the Tumwater Dam), log drives, and railroad construction. By the late 1920s, habitat alterations had led to the extirpation of the Upper Wenatchee Coho population. The US Bureau of Fisheries (1935) reported that:

> Silvers [coho] were present in large numbers 25 years ago. It was reported that the last of the silver run was in 1926-7. In early years the silvers congregated below the mill dam at Leavenworth in such numbers that it was not uncommon to hook out six to a dozen in a few hours.

A 1950 habitat survey again documents the impacts of human alteration on the reach, particularly on changes in channel substrate. Between Plain and Tumwater Canyon, spawning substrate that was documented as plentiful in 1935 was absent by 1950: “[the] stream bed is composed mainly of large rubble and bedrock with little spawning area found” (Bryant and Parkhurst 1950). Surveyors also note that Chinook are having “considerable difficulty passing the Dryden and Tumwater Dams,” despite the presence of a fish ladder documented at Tumwater in 1935. Bryant and Parkhurst (1950) go on to say “in some years the majority [of Chinook] are forced to spawn in the portion of the river below Tumwater Dam.”

The impacts of historical habitat alterations continue to affect salmonid populations throughout the study reach. Although overall runs were of similar size from the 1850s to the 1980s, species composition shifted dramatically, and overall run sizes have been drastically reduced between the 1980s and today (Table 3).

Table 3. Historical run sizes of naturally produced salmonids in the Wenatchee River Basin (Mullan et al. 1992; USFS 2003; WDFW & CCPUD 2011).

Species	1850s	1986-87	2011
Chinook Salmon	41,3000	204,800	9,327
Coho Salmon	3,900	0	1,439
Sockeye Salmon	228,100	93,700	18,634
Steelhead	7,300	8,200[1]	1,299
TOTAL	280,600	306,7000	30,699

[1]Count from 1987-1988.

3.5 Existing Forms and Processes

3.5.1 Hydrology

The Wenatchee River is a 4th Order tributary of the Columbia River and flows generally south and east through the basin. Its flow is augmented primarily by tributary flows from the Little Wenatchee River, White River, Chiwawa River, Nason Creek, Icicle Creek, Chumstick Creek, Peshastin Creek, Mission Creek, and other smaller drainages. The approximate percentage contributions of the aforementioned tributaries to the Wenatchee River's annual flow are identified in Table 4. Approximately 73% of the Wenatchee's total annual flow can be accounted for within the study area.

Table 4. Percent contribution to Wenatchee River flow by tributary basins (adapted from Washington Department of Ecology 1983; USFS 1999).

Tributary	Percentage Contribution to Annual Flow
Little Wenatchee River	15%
White River	25%
Chiwawa River	15%
Nason Creek	18%
Icicle Creek	20%
Chumstick & Peshastin Creeks	3%
Mission Creek	1%
Other Sources	3%
Total	100%

Hydrology in the basin is driven by a combination of precipitation and snowmelt. Precipitation, in the form of snow and rain, varies with elevation and distance from the Cascade Crest. The higher, headwaters elevations of the Wenatchee Basin receive 50 to 140 inches of precipitation annually, whereas lower elevation areas receive less than 8.5 inches (WDOE 1983, Andonaegui 2001, CCG et al. 2003). These low areas are also farther east and are more affected by the rain shadow of the Cascades.

Precipitation in the form of snow, and subsequent spring snowmelt, dominates the seasonal streamflow pattern in the basin (Figure 18). Snowmelt primarily occurs during the spring and early summer, and is driven by changes in ambient air temperature, snowpack mass, and the elevational distribution of the season's snowpack (WDOE 1983). Peak runoff usually occurs from April through July, with the highest rates typically in late June. The Wenatchee typically returns to baseflows in September.

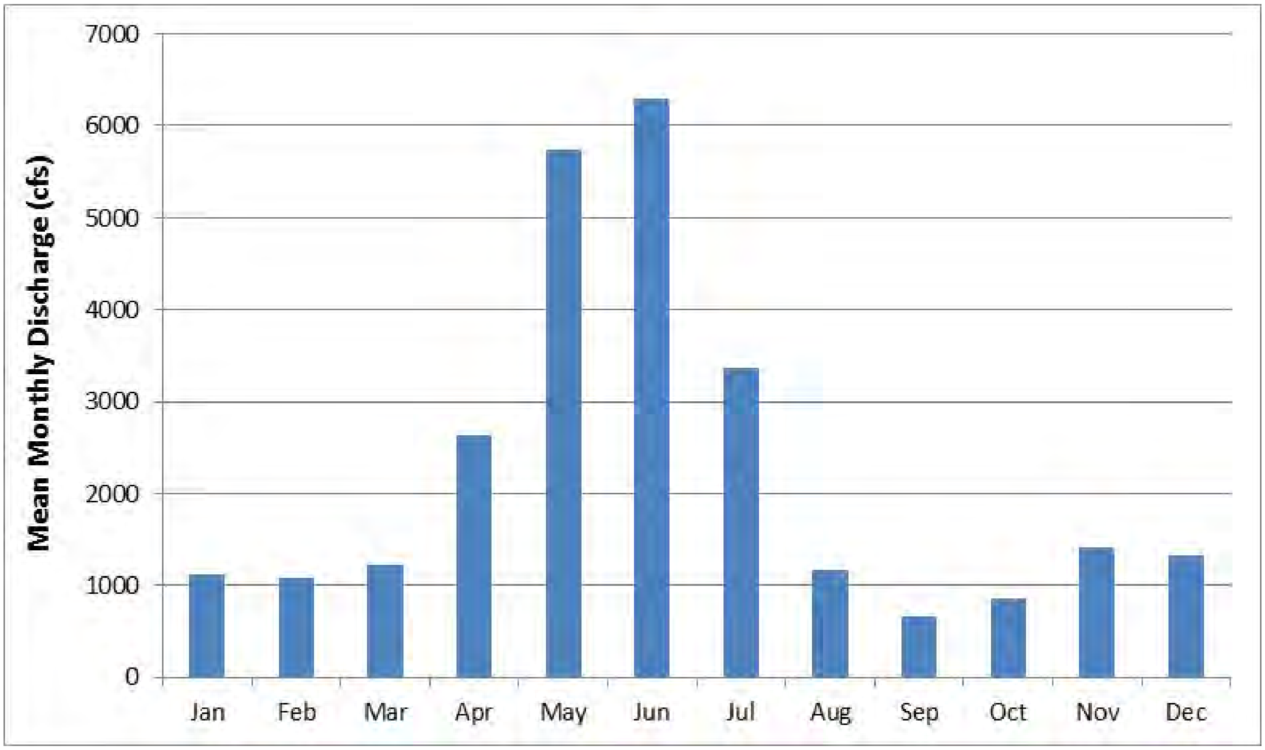

Figure 18. Mean monthly discharge for the period of record at the USGS gage at Plain, WA (Gage 12457000, 1911 to present).

The hydrology of the study area is significantly affected by Lake Wenatchee. Temporary storage in Lake Wenatchee buffers the snowmelt runoff signal from the Little Wenatchee and White River drainages, which contribute 40% of the total annual runoff to the Wenatchee River. Thus, runoff from some of the highest elevation, and highest precipitation regions of the basin are moderated by temporary storage in Lake Wenatchee. Snowmelt from the Nason Creek drainage is the first unattenuated snowmelt signal to reach the Wenatchee River.

The USGS gage at Plain, WA (Gage 12457000) has a period of record extending from 1911 to present. Flood recurrence analysis of this gage record is presented in Table 5. Annual peak flow typically occurs in late June, but the largest instantaneous peak flows on record have occurred mainly in November (Figure 19). The highest measured discharge was on November 20, 1995 and was recorded at 36,100 cubic feet per second (cfs). Large floods sometimes occur as rain-on-snow events (Figure 20).

Table 5. Flood Recurrence Analysis (Bulletin 17 B Analysis) for USGS Gage at Plain, WA (Gage 12457000). Data retrieved on 20 January 2012. Period of record extends from 1911 to 2012.

Exceedance Probability (% Chance)	0.2	1	2	5	10	20	50	80	99
Recurrence Interval (years)	**500**	**100**	**50**	**20**	**10**	**5**	**2**	**1.25**	**1.01**
Discharge (cfs)	37,285	29,045	25,799	21,728	18,764	15,827	11,683	8,870	5,824

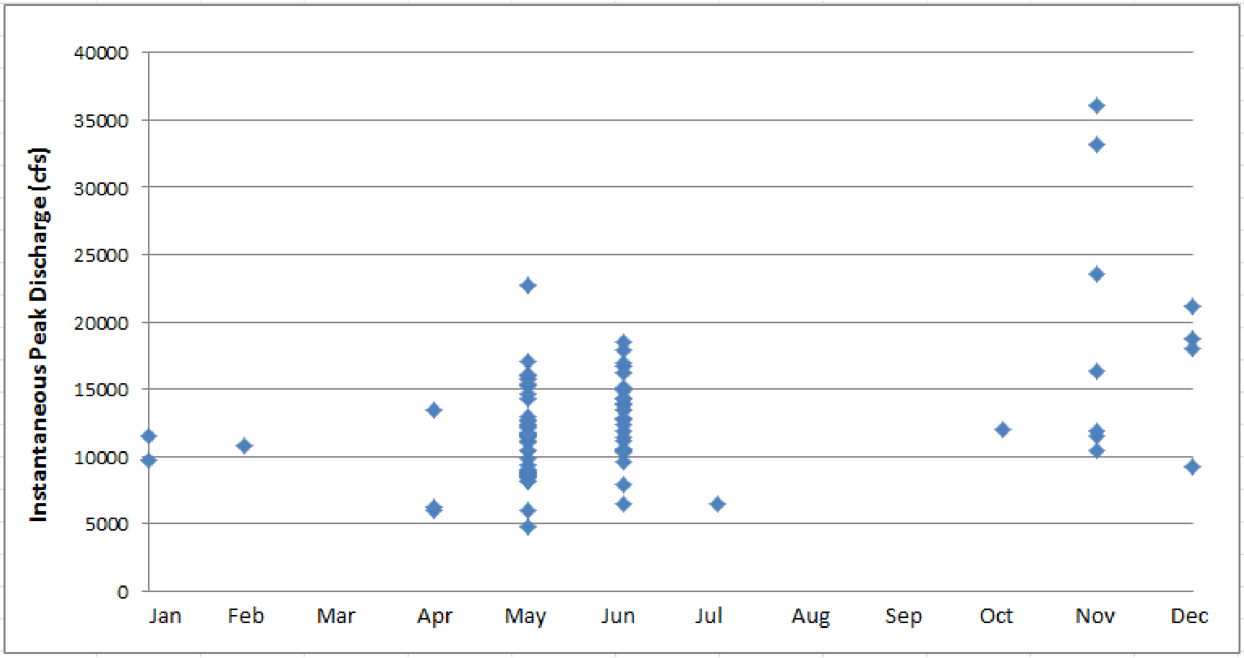

Figure 19. Instantaneous peak flow magnitudes and month of occurrence for the period of record at the USGS gage at Plain, WA on the Wenatchee River (Gage 12457000).

Figure 20. Flooding at the Headwaters Tavern near the upstream end of the study area. Photo date unknown (assumed Nov, 1990) (Photo courtesy of Bryon Newell).

Groundwater storage and release regulates base flow of the Wenatchee River during low flow periods. Alluvial aquifers are located within the channel migration zone of river valleys, and other areas where there are sizeable deposits of alluvium. The unconsolidated cobbles, sands, and gravels characteristic of alluvium provide pore space for significant groundwater storage.

Recharge of the alluvial aquifer is enhanced through channel/floodplain connectivity and off-channel features such as wetlands. Approximately 585 acres of wetlands are located within the study area from the mouth of Lake Wenatchee to Fish Lake Run. These wetlands slowly release groundwater, regulate base flows, and contribute to cooler stream temperatures (Andonaegui 2001). Other substantial sources of groundwater storage and recharge are glacial deposits that drape hillslopes and form terraces along significant portions of the valley in the study area. Direct precipitation or percolation through surface sediment recharges bedrock in the study area as well (WDOE 1983; Andonaegui 2001; Cascadia Consulting Group et al. 2003; USFS 1999). The Chumstick Formation has aquifer forming sandstone units.

3.5.2 Hydraulics

Background

A one-dimensional hydraulic model was developed to support the Upper Wenatchee Assessment. The model is used as one of several tools for analyzing flood inundation levels and for comparing stream energy patterns among reaches within the study area.

Methods

Hydraulic Model

The hydraulic model was created using the HEC GeoRAS framework to create the boundaries of the model system (stream centerline, bank stations, overbank flowpaths, and cross sections). These features were overlaid on a digital elevation model (in this case, LiDAR) from which elevations were extracted for all components of the geometric data set. Cross sections were spaced every 500 feet. This spacing was reduced to approximately every 200 feet through areas around meander bends, upstream and downstream of bridges, or where additional resolution was warranted. Once the geometric data was developed, the model was exported from ArcGIS and brought into HEC-RAS 4.1.0, a one-dimensional water surface profiling program. Steady-flow data was input based on flood frequency data at several river stations (Table 6). Flows ranging from the 2-year to 100-year floods were modeled. For the purposes of this effort, we used a Manning's n value of 0.035 for the channel and 0.08 for overbank areas based on the average channel geometry and roughness characteristics.

There are limitations for utilizing LiDAR to model floodplain inundations. The LiDAR data available for the Upper Wenatchee River is capable of producing accurate elevation data in terrestrial environments, but cannot produce ground elevations below water (i.e. bathymetry). Consequently, results of these analyses should not be used for detailed modeling, restoration, or infrastructure planning purposes. Despite this limitation, the inundation analysis is assumed to be relatively accurate for larger flood flows (i.e. 2-year return interval and above), where the topography errors would have less effect (proportionally) on the results. A sensitivity analysis was performed to see if subtracting the known discharge on the date the LiDAR was flown improved results. Flood stage elevation typically differed by less than 0.1 feet, so no discharge was subtracted for model development.

Table 6. Flood frequency data used in the hydraulic model developed for the inundation analyses based on hydrologic analyses by USBR (2008). Discharge units at each reach are cubic feet per second.

Flood Recurrence Interval	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11
2	10,657	10,657	10,657	10,657	10,657	10,657	10,657	8,336	8,336	8,336	6,817
5	14,197	14,197	14,197	14,197	14,197	14,197	14,197	11,105	11,105	11,105	9,082
10	16,858	16,858	16,858	16,858	16,858	16,858	16,858	13,187	13,187	13,187	10,784
25	20,605	20,605	20,605	20,605	20,605	20,605	20,605	16,117	16,117	16,117	13,180
50	23,693	23,693	23,693	23,693	23,693	23,693	23,693	18,533	18,533	18,533	15,156
100	27,051	27,051	27,051	27,051	27,051	27,051	27,051	21,160	21,160	21,160	17,304

Flood Inundation Analysis

Flood inundation was modeled using HEC GeoRAS. HEC-GeoRAS allows for visualization of floodplain inundation by overlaying HEC-RAS modeling outputs on digital terrain models. Georeferenced hydraulic modeling outputs are then displayed in ArcGIS. As described previously, there are limitations to utilizing LiDAR to model floodplain inundation and results of these analyses should not be used for detailed modeling, restoration, or infrastructure planning purposes.

Stream Power Analysis

Stream power was analyzed as one of several variables to compare stream energy among reaches. Stream power (Ω) is a measure of the potential energy exerted per unit length of channel (Bagnold 1966) and is based on the concept that the stream is a sediment transport vehicle with varying degrees of efficiency. Stream power (Ω) represents the potential amount of 'geomorphic work' (e.g. sediment transport, scour) the stream is capable of performing:

$$\Omega = \gamma Qs$$

Where:

γ = the specific weight of water

Q = discharge

S = channel bed slope

When slope and/or discharge increase, stream power will increase (Bagnold 1966). Stream power calculations were output from the HEC-RAS model.

Sediment Competence Analysis

Sediment competence was analyzed to provide an overview of streambed mobility. Streambed sediments will only move when the force of water acting on those sediments is greater than the force keeping those sediments in place. The force of flowing water acting on a sediment particle is the shear stress. The amount of force required to move that sediment particle is the critical shear stress. If the shear stress is greater than the critical shear stress, then the sediment will be transported. Conversely, if shear stress is less than the critical shear stress, the sediment will remain stable or be deposited. A value of “excess shear stress” can be calculated as the ratio of the applied shear stress to the critical shear stress, which yields a useful term in which values greater than one represent a mobile bed condition and values less than one represents a stable bed condition.

To evaluate general trends in the ability of the Upper Wenatchee River to mobilize and convey sediment, excess shear ratios were calculated for the study reach. The Shields (1936) equation was used for this analysis. The shear stress applied to the bed is:

$$\tau = \rho g R s$$

And the critical shear stress needed to mobilize the streambed sediments is (Komar 1987):

$$\tau_C = \tau^*_{C50}(\rho_s - \rho) D_{84}^{0.3} D_{50}^{0.7}$$

The ratio of shear stress to critical shear stress is known as excess shear stress (τ^*):

$$\tau^* = \frac{\tau}{\tau_c} = \frac{\rho R s}{\tau^*_{c50}\, D_{84}\ (\rho_s - \rho)}$$

Where:

τ = bed shear stress

ρ = density of water (lb. /ft^3)

g = gravity (ft/s)

R = hydraulic radius

ρ_s = density of sediment (lb. /ft^3)

τ_c = critical shear stress (lb. /ft^2)

D_{84} = 84th percentile of grain size (ft.)

D_{50} = median grain size (ft.)

s = slope

τ^*_{c50} = critical dimensionless shear stress (Shields Parameter)

Here, τ^*_{c50} was adapted from Julien (1995) and the D_{84} was utilized to determine the conditions required for most of the streambed to be mobilized and the potential for bed change to occur (Leopold 1992). For each reach, two Wolman (1954) pebble counts were taken at riffle crests where flows allowed. A total of 16 pebble counts were conducted. Due to high flows and non-wadeable conditions experienced during the survey there are significant limitations associated with the pebble count data. In some reaches, pebble counts were done in side channels or in glides, and for some reaches, none or only one pebble count was collected. Consequently, this data should only be utilized to understand sediment transport patterns at a conceptual level, and should not be utilized for design purposes.

Results

Floodplain Inundation

Inundation analysis results are presented in the five maps located at the end of this section. Throughout the confined reaches (Reaches 4-6, Reach 9, Reach 11), flows for both the 2-year and 100-year flood events remain largely in-channel. Throughout the unconfined reaches (e.g. Reach 1, Reach 3, Reach 10), water surface elevations extend beyond the main channel boundaries. In many places these flows activate side channels and inundate floodplain surfaces.

Hydraulics

Results of the 2-year and 100-year flood event hydraulic analyses are presented in Table 7 and Table 8. For both the 2- and 100-year events, reaches 2 through 6 displayed the highest stream power, highest excess shear stress, and highest velocities, with Reach 6 having the maximum values for all of these parameters. These results are consistent with the higher gradient and confinement of these reaches (see Section 3.5.3). Stream power, excess shear, and velocity displayed a decreasing trend moving upstream from Reach 7 to Reach 11, as well as low values in Reach 1.

Table 7. Hydraulic analysis results for the 2-year flood event.

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11
Avg Velocity (ft /sec)	5.79	7.38	7.08	6.82	7.24	7.77	6.66	4.88	4.17	4.28	3.36
Shear stress (avg)	0.67	1.07	1.04	0.91	0.98	1.22	0.82	0.44	0.3	0.35	0.23
Stream Power (lb/ft/s)	731	1044	1181	829	833	1273	681	258	144	198	135
Incipient Particle Size (in)	3.2	5.2	5	4.4	4.7	5.9	4	2.1	1.4	1.7	1.1
Excess Shear Ratio	0.68	0.58	0.75	*	0.68	*	*	0.40	0.58	0.55	0.14

* Pebble counts not taken within these reaches due to high flows.

Table 8. Hydraulic analysis results for the 100-year flood event.

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11
Avg Velocity (ft /sec)	7.67	10.74	9.5	9.71	10.36	10.84	9.19	7.1	5.75	5.36	4.44
Shear stress (avg)	1.05	1.94	1.62	1.58	1.67	1.98	1.32	0.78	0.49	0.53	0.33
Stream Power (lb/ft/s)	1683	2940	2792	2215	2064	2999	1591	697	366	480	265
Incipient Particle Size (in)	5.1	9.4	7.8	7.7	8.1	9.6	6.4	3.8	2.4	2.6	1.6
Excess Shear Ratio	1.06	1.05	1.17	*	1.17	*	*	0.72	0.95	0.83	0.20

* Pebble counts not taken within these reaches due to high flows

Discussion

Overall, the hydraulic analysis confirms higher stream energy and less floodplain inundation in the confined reaches (i.e. Reach 2, 4-6, Reach 11) and greater floodplain inundation and lower stream energy in the unconfined reaches. Combining the hydraulic analysis with the geomorphic and habitat assessments shows that current channel and floodplain complexity tended to increase in reaches with the greatest potential of regular floodplain inundation (2 year flood recurrence).

Hydraulic floodplain inundation modeling provided some insight into the geologic processes of incision. The Wenatchee River has incised down through the more easily erodible Pleistocene glacial outwash terraces that border the modern floodplain surfaces. These abandoned terraces are often 10+ feet above existing floodplain surfaces, and xeric (dry) vegetation communities indicate these areas have long been abandoned. In some locations such as meander bends, terrace edges are gradual and sloping. The hydraulic inundation models of the 100 year flood helped to verify the boundaries between the abandoned and modern floodplain surfaces.

Hydraulic analysis supports the assessment that human alterations have affected floodplain inundation patterns, stream energy, and incision processes at several locations within the study area. For example, in Reach 9 (RM 50.5) Highway 209 limits floodplain inundation within the river right overbank floodplain area. In Reach 10, the Highway 207 Bridge and road fill constrict channel dimensions and have interrupted floodplain overbank flow near the Nason Creek confluence. A similar effect is observed at the Burlington Northern Railroad Bridge at the downstream end of Reach 4. Channel confinement in these areas has increased flow energy within the active channel resulting in bed scour, channel incision, and related floodplain disconnection.

More subtle anthropogenically-influenced incision processes are also highlighted by the floodplain inundation analysis. Recently abandoned surfaces that are only one to two feet above currently active floodplain surfaces are delineated by the model. These surfaces contain visible topographic evidence of scour and deposition but no evidence of modern inundation. These results support the assessment that historical splash damming, and other alterations to the floodplain such as bank hardening, homesite construction, and vegetation alterations, have accelerated incision processes in those areas. Sections of the floodplain of Reach 8 and lower Reach 9 are examples of such surfaces that were likely very active until 20-50 years ago.

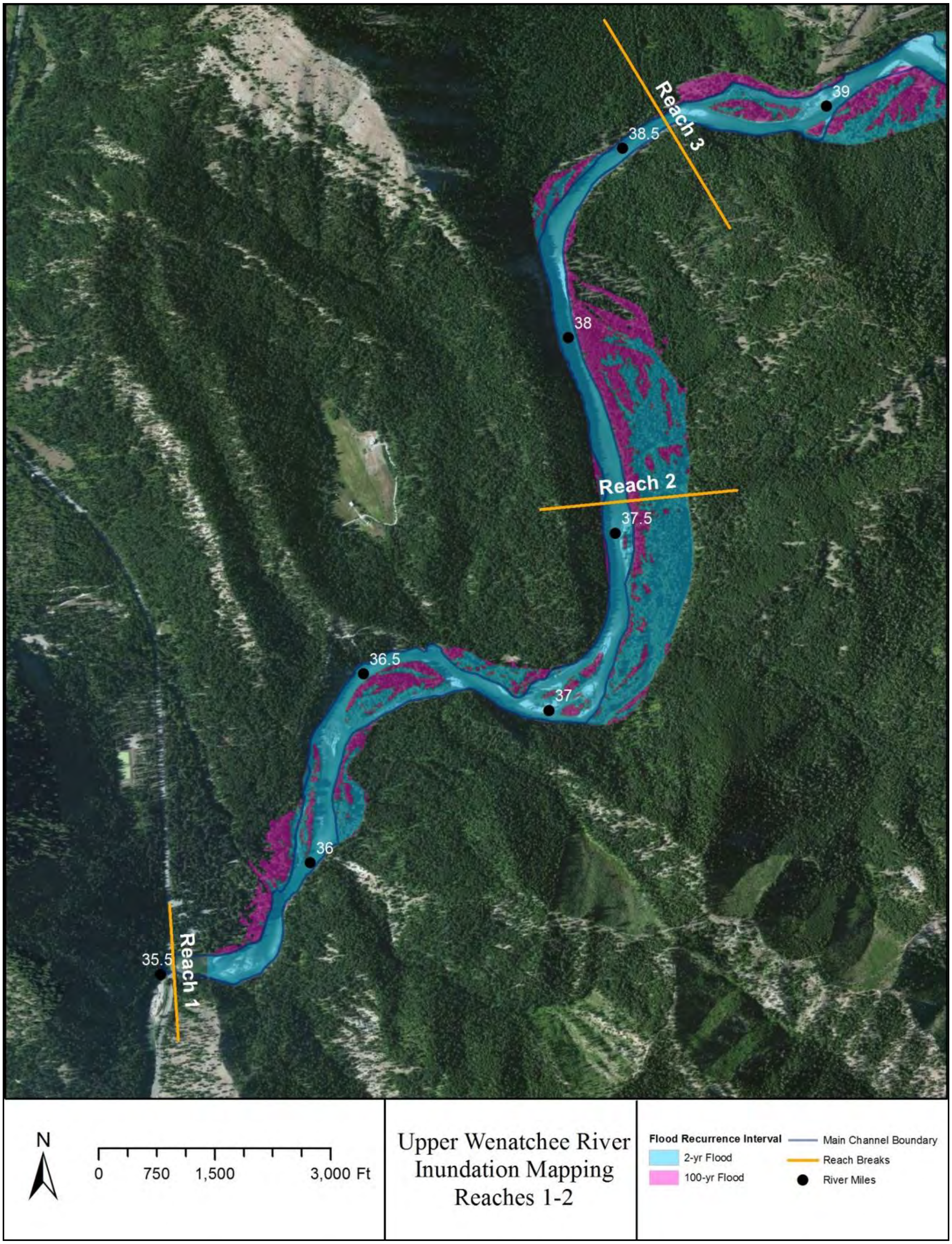

Figure 21. Reach 1 and 2 floodplain inundation potential for the 2- and 100-year flood events.

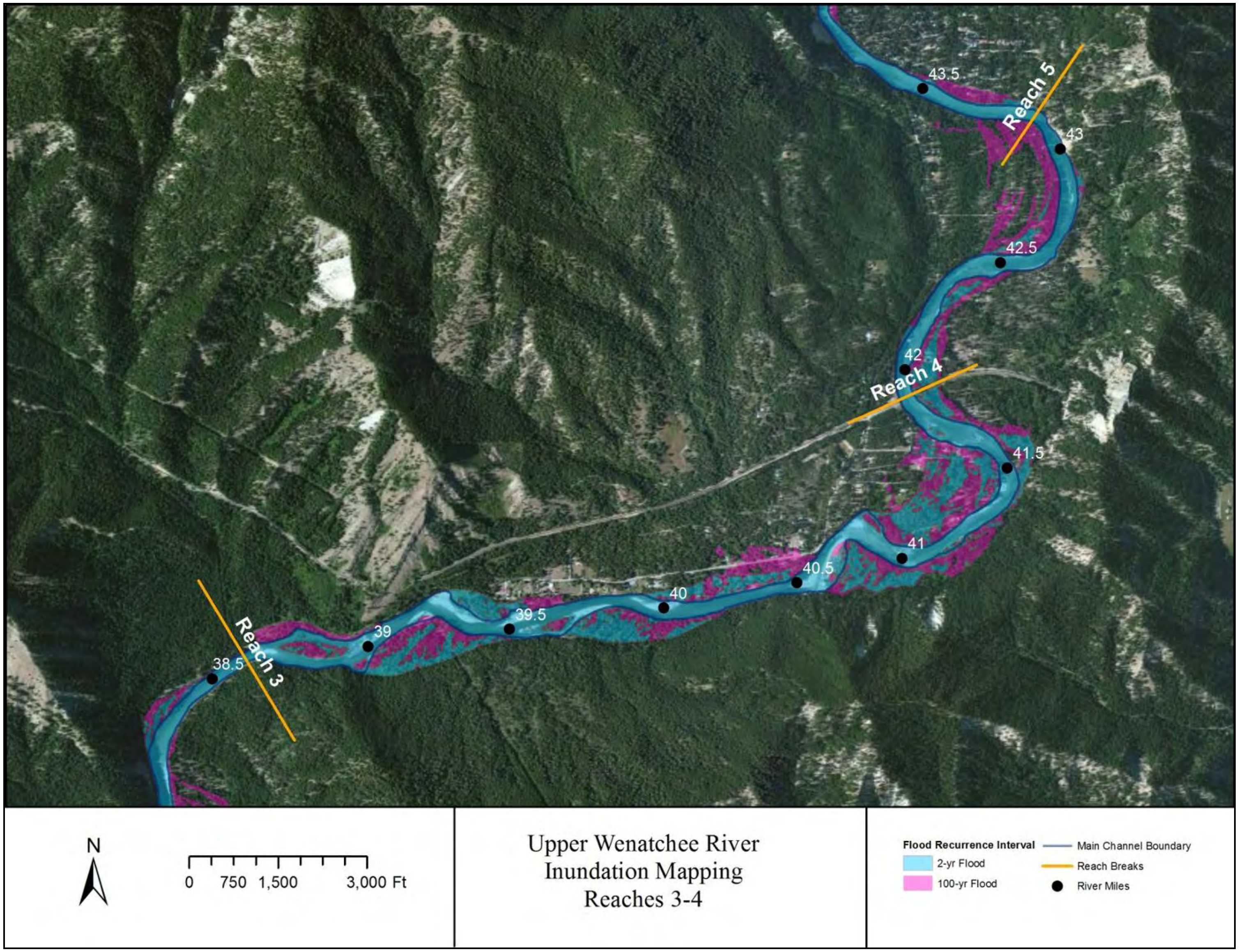

Figure 22. Reach 3 and 4 floodplain inundation potential for the 2- and 100-year flood events.

Figure 23. Reach 5 and 6 floodplain inundation potential for the 2- and 100-year flood events

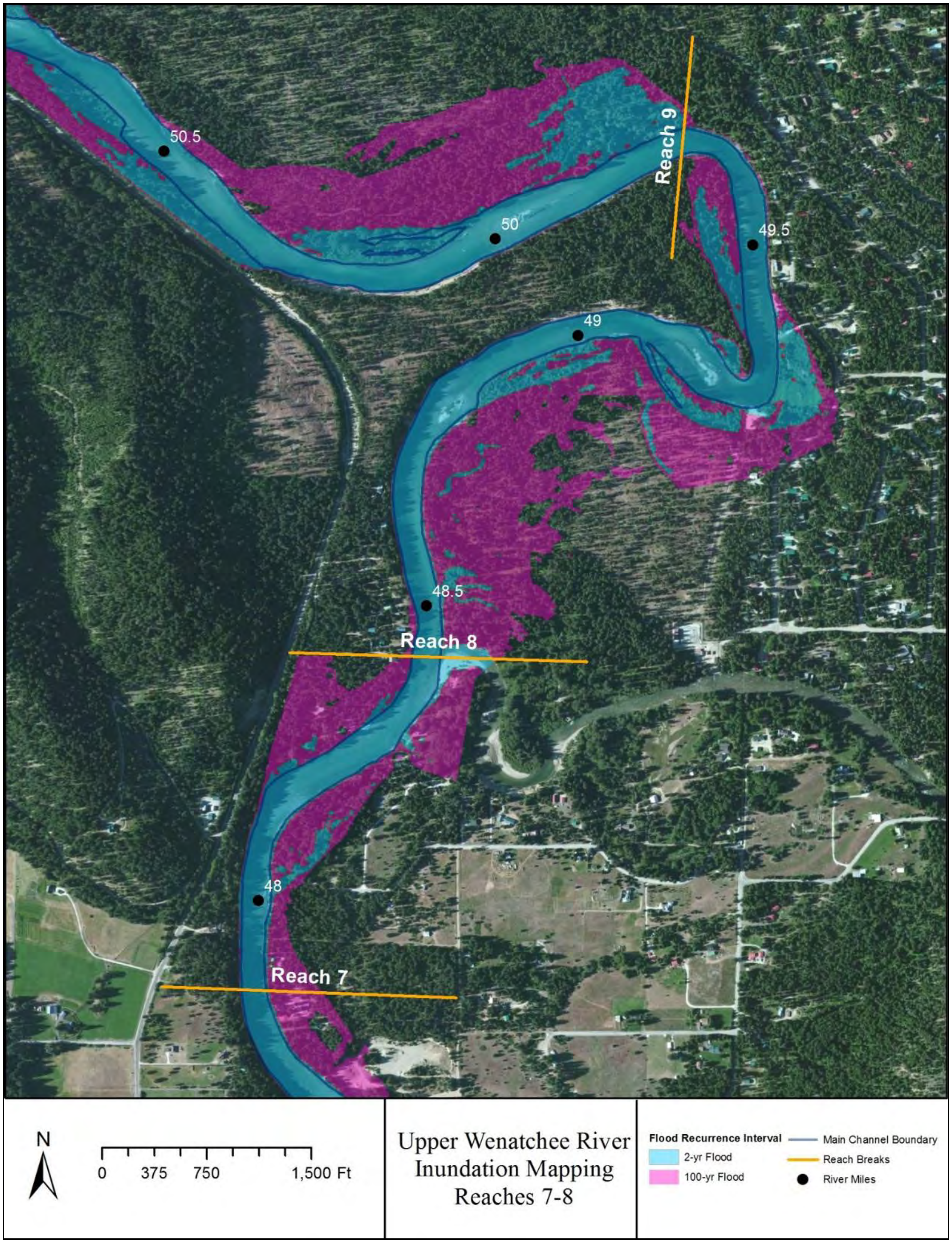

Figure 24. Reach 7 and 8 floodplain inundation mapping for the 2- and 100- year flood events

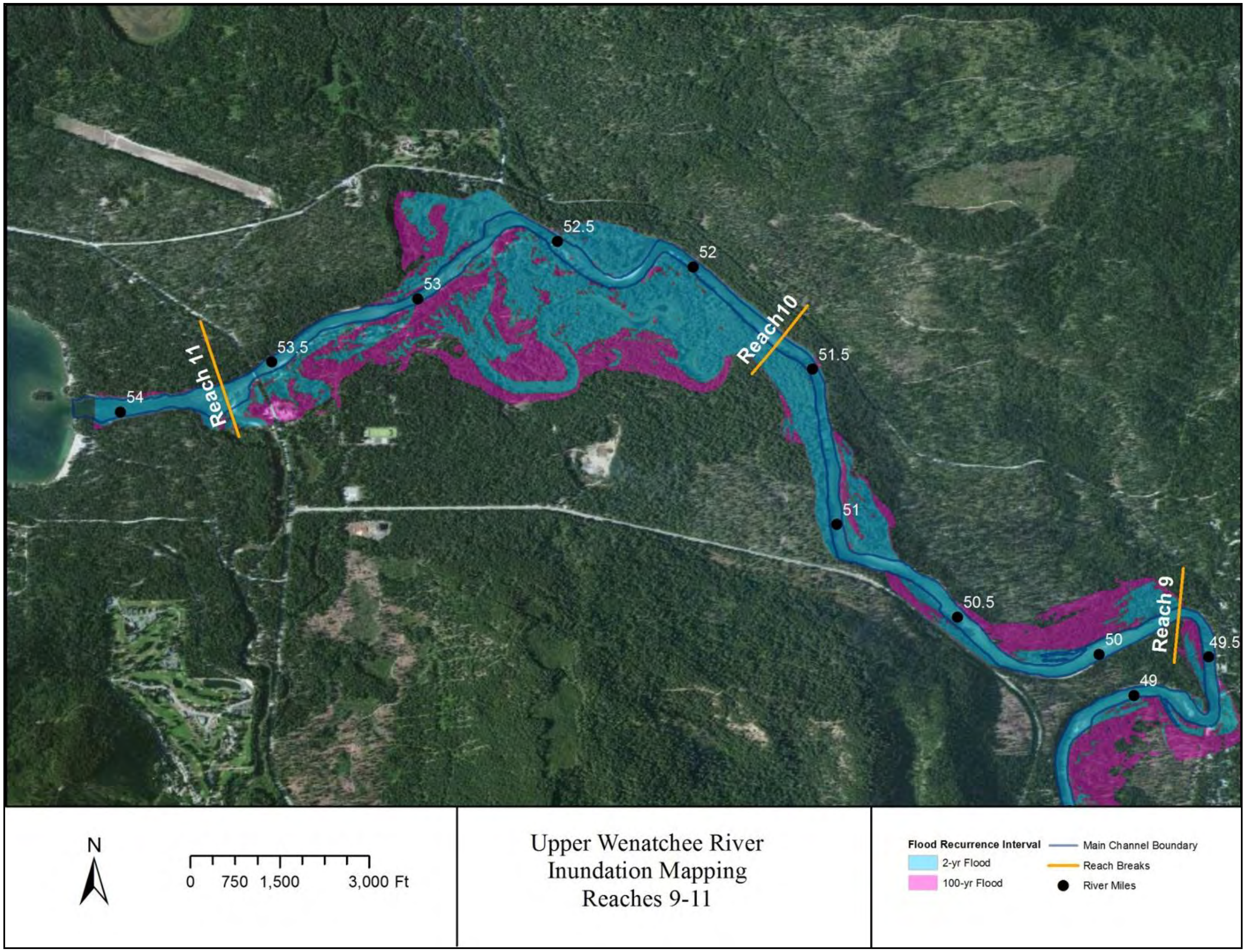

Figure 25. Reach 9, 10, and 11 floodplain inundation potential for the 2- and 100-year flood events.

3.5.3 Geomorphology

Valley Morphology

The Upper Wenatchee meanders south and eastward with channel sinuosity ranging from 1.0 to 1.62. Valley morphology within the study area is a direct result of the relationship between glacial erosion, bedrock lithology, and faulting. In terms of bedrock lithology, the Chumstick Formation that underlies the study reach and outcrops in adjacent hillslopes is relatively easily erodible in comparison to the metamorphic and plutonic rocks of adjacent terranes. Thus glaciers, and later the Wenatchee River, have been able to remove larger amounts of material and create wider valley bottoms than in tributary watersheds or directly downstream portions of the Wenatchee River that flow atop harder bedrock (i.e. Tumwater Canyon). The widest valley width in the study area is located at the upstream end between RM 53.9 and 51.0. Maximum valley width here is over 3,000 feet where Fish Lake Run flows in from the north near RM 52.9; however, the average width in this area is closer to 1,000 feet. Downstream of this point the valley narrows to under 1,000 feet at the widest with several lengths of channel with valley bottoms of only a few hundred feet. Glacial deposits, primarily terraces, create the narrow valley width that persists down to about RM 43.7 (Reach 5). Downstream of RM 43.7, the river has created a wider valley bottom through lateral channel migration at two large bends centered on RM 43 and 41.4. The valley width here increases to over 2,000 ft. Around RM 41 bedrock hillslopes constrict valley width down to under 1,500 feet at wide portions with constrictions of under 200 feet wide. The downstream end of the study reach is at the top of Tumwater Canyon where the river flows out of the sedimentary rocks of the Chiwaukum Graben and onto the crystalline rocks of the Nason-Ingalls Terrane, forming a steep, narrow canyon for several miles downstream.

Channel Morphology

Bed morphology is predominantly pool-riffle and plane-bed with channel slopes ranging from 0.1 to 0.35%. The channel frequently alternates between alluvial and confined reaches. Alluvial reaches are found in areas with wider floodprone widths, and have more channel complexity (point and mid-channel bars, large wood accumulations) and intact riparian vegetation. Confined reaches flow through areas with narrower floodprone widths, with abandoned alluvial terraces naturally limiting lateral migration. In some areas, sediment deposition at the toe of these alluvial terraces has created small, relatively mobile point bars atop which vegetation has established.

Sediment is contributed to the Upper Wenatchee from tributaries and near-channel banks and hillslopes. These banks and hillslopes provide localized sediment from the easily erodible unconsolidated glacial till, glacial terraces, and alluvial deposits along the channel margins (Figure 26). Glacial deposits provide some erosion resistance because in many locations large material has accumulated at the toe of these slopes. However, high flows are still able to easily erode above this toe support and entrain large amounts of fine grain material from banks. Bedrock outcrops found in the study reach hillslopes is chiefly from the Chumstick Formation, which exhibits downslope trending bed planes that make it more susceptible to mass wasting in weaker units (Figure 27). Sediment contributions from the Chumstick Formation would be expected to provide fine-grain material out of sandstone and shale units, and some gravels out of conglomerates. Channel morphologic characteristics are summarized in Figure 28 and Table 9. More detailed geomorphic descriptions for each reach can be found in Section 4.

Figure 26. View of unconsolidated fine grain sediment in terrace slopes along the channel in the study area.

Figure 27. Bedrock outcrop along the channel in the study area (Chumstick Formation). Note that tilting of stratigraphy has resulted in steep dip-slopes toward the channel that can result in planar failures along weak bedding planes.

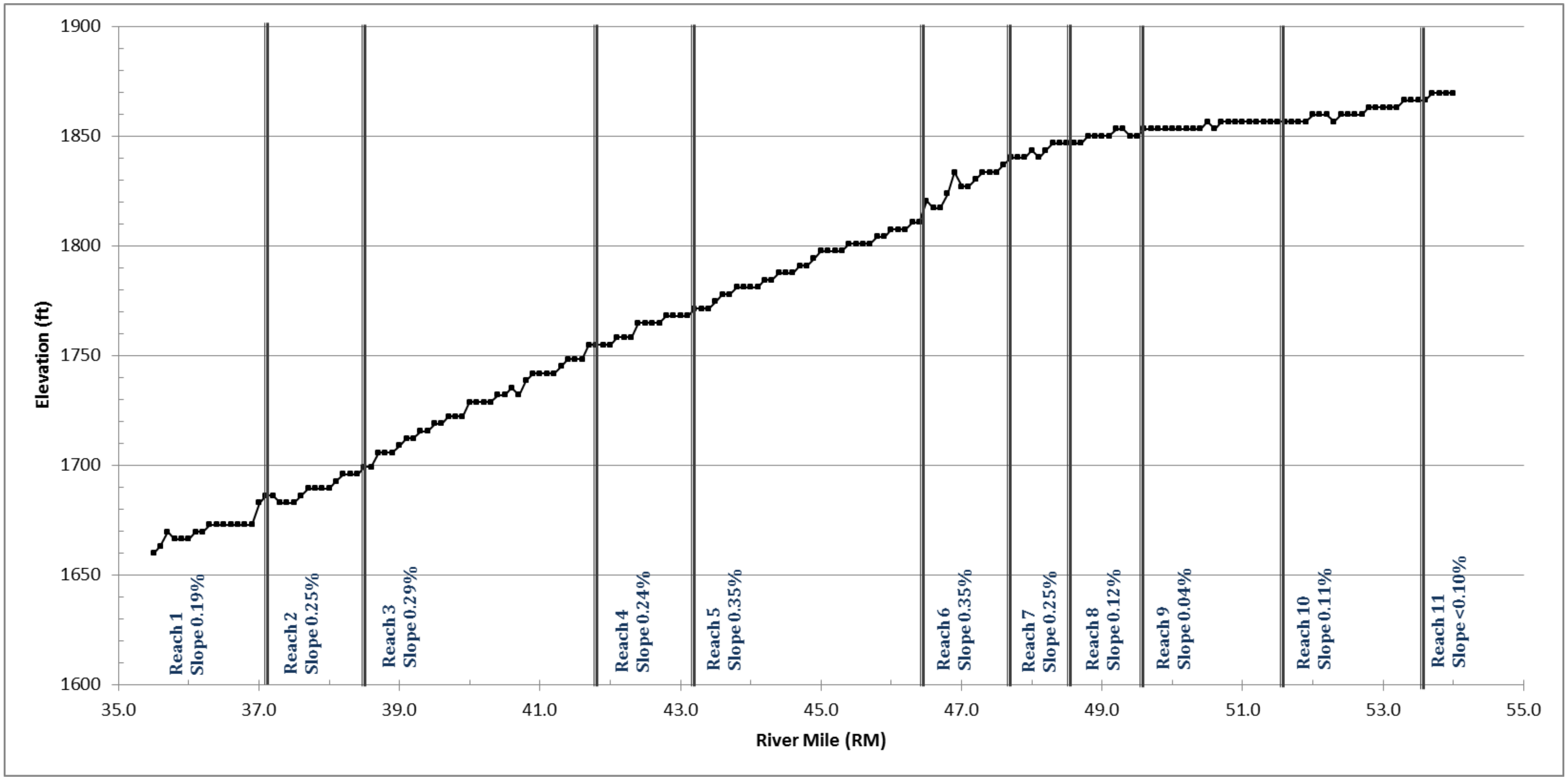

Figure 28 Longitudinal Profile of the Upper Wenatchee River study area from Lake Wenatchee to the top of Tumwater Canyon. Elevation data derived from LiDAR.

Table 9. Summary of geomorphic and habitat conditions at the valley and channel scale among geomorphic reaches in the Upper Wenatchee River.

	Metric	*Reach 1*	*Reach 2*	*Reach 3*	*Reach 4*	*Reach 5*	*Reach 6*	*Reach 7*	*Reach 8*	*Reach 9*	*Reach 10*	*Reach 11*
Channel	**River Miles**	35.5 – 37.6	37.6 – 38.6	38.6 – 41.9	41.9 – 43.1	43.1 – 46.5	46.5 – 47.9	47.9 – 48.4	48.4 – 49.7	49.7 – 51.7	51.7 – 53.7	53.7 – 54.2
	Gradient	0.19%	0.25%	0.29%	0.24%	0.25%	0.35%	0.25%	0.12%	0.04%	0.11%	<0.1 %
	Sinuosity	1.31	1.15	1.42	1.28	1.26	1.44	1.06	1.62	1.28	1.23	1.01
	Dominant Channel Morphology	Pool-riffle	Plane-bed	Pool-riffle	Pool-riffle	Riffle-glide	Riffle-glide	Riffle-glide	Pool-riffle	Plane-bed	Pool-riffle	Plane-bed
	Average Bankfull Width (ft)	325.5	312	270	276	278	NA	282	300	282	242.5	360
Floodplain	**Average Floodprone Width (ft)**	1025.5	671	1164	726	395	NA	882	605	575	786.7	590
	% Floodplain Disconnected[1]	0.0%	14.9%	56%	85.50%	81.10%	90.30%	80.70%	60.50%	0%	58.40%	0%
	% Floodplain Connected	100.0%	85.1%	44%	14.50%	23.30%	9.70%	19.30%	39.50%	100%	41.60%	100%
% Habitat Area	**Pool**	40%	13%	27%	41%	11%	0%	0%	41%	35%	57%	77%
	Riffle	10%	34%	31%	30%	56%	67%	54%	21%	14%	20%	0%
	Glide	26%	47%	23%	22%	33%	23%	46%	31%	47%	20%	18%
	Side Channel	24%	6%	19%	7%	0%	10%	0%	7%	4%	3%	5%

[1] *"Disconnected" indicates that the floodprone surface's historical pattern and processes (e.g. inundation extent or frequency) have been altered due to anthropogenic actions. See Appendix B for the analysis of connected and disconnected areas.*

3.5.1 Existing Large Wood Dynamics

Existing large wood dynamics in the Upper Wenatchee River are a function of a legacy of river and forest management dating back to the early years of Euro-American settlement. Historical and on-going human disturbances have impacted sources of instream large wood, the recruitment of large wood to the channel, and the ability of the channel to trap and retain wood. These processes (sources, recruitment, and retention) are discussed below with respect to contemporary large wood dynamics in the study area.

Sources

Contemporary large wood sources have been altered by timber harvest and residential development within the study area and within upstream contributing areas. Riparian clearing dating back to the late 1800s has and will continue to impact large wood loading for the foreseeable future. Reforested timberlands now dominate the riparian buffers but the trees are considerably smaller than what would be expected under non-harvested conditions (Figure 29). The 2011 habitat survey (Appendix A) classified nearly half (48%) of the riparian canopy as being dominated by trees less than 21 inches diameter (dbh). It will be decades or centuries before riparian areas mature to the degree that they are able to provide a LWD recruitment source that resembles historical conditions. Although there are relatively few areas with fully cleared riparian corridors, many riparian zones in developed areas have a cleared understory, which limits the future replacement of existing maturing trees, which is needed to provide for long-term large wood recruitment to the channel.

Figure 29. Existing riparian area in Reach 9 (taken October 2011). Large ponderosa pine at center represents an older tree that escaped the last harvest and gives some indication of what historical LWD sources may have looked like.

Recruitment

Recruitment processes have been altered within the study area as well as in upstream contributing areas. Although processes of bank erosion (e.g. meander scrolling) still recruit wood to the channel in some areas, this recruitment process has been limited in many areas due to bank armoring, channel constrictions (e.g. bridges), and human-induced incision that reduces lateral migration rates and therefore reduces the frequency of wood recruitment. Recruitment has also been reduced in upstream contributing areas, particularly in Nason Creek where much of the channel has been straightened, armored, and leveed throughout much of the lower 14 miles. Wood is currently recruited to the study area via transport from upstream sources, bank erosion (where it still occurs), single-tree mortality, and from mass wasting on the high glacial terrace banks. These mass wasting events sometimes form what we refer to as ‘colluvial jams’, which is a pile of wood debris from the landslide that remains in the channel and provides fish habitat. These were likely more common, and more stable once they reached the river, when riparian areas contained larger trees.

Retention

As discussed previously, retention of wood in the channel is a function of both wood size as well as instream complexity, both of which have been affected by the legacy of human alterations. The size of wood that is now contributed to the channel mostly represents second or third growth timber that is smaller than historical LWD and does not have the same ability to self-stabilize within the channel. Although the habitat assessment (Appendix A) found an average of 123 pieces of wood per mile, only 26% of these were greater than 20 inches in diameter, which means the number of “key pieces”, which are the very large diameter pieces that are able to initiate jam formation, would be even less. The shift in riparian seral stage and the corresponding reduction in available key pieces have reduced the ability of wood to accumulate and stay in place throughout the river. Shifts in species compositions from fire-tolerant to fire-intolerant species may have also impacted retention and jam formation. Retention has been further reduced by channel simplification and alterations to streambanks. In many channel margin areas, historical complexity would have been provided via bank irregularities, overhanging vegetation, embayments, and obstructions. These features would have provided locations for wood to become trapped and to initiate log jam formation. Bank complexity was reduced in the early 1900s as part of log drives (see Section 3.4.3) and later by riparian clearing and bank armoring.

3.5.2 Habitat Conditions

Stream habitat conditions were recorded using the USFS Level 2 stream habitat inventory methods. The survey recorded information on habitat unit composition, substrate sizes, large wood quantity, riparian conditions, and bankfull channel dimensions. The habitat assessment summary and reach reports are provided in Appendix A. A brief summary is included below.

Pool frequency ranged from 0.0 to 2.7 pools/mile at the reach-scale and totaled approximately 30% of the total habitat in the study area. Riffles and glides were nearly equally abundant at around 31%. The amount of glide habitat is higher than might be expected if large wood jams were more abundant and available to create and maintain scour pools. Side channels made up 9%

of the measured habitat units, with a total of 33 wetted side-channel units. Reach 1 had the greatest area of side-channel habitat and Reach 3 had the greatest number of side-channel units. The study area also had nine “marsh” habitat types, ranging from small backwaters to large open water ponds. Reach 10 had the greatest amount of “marsh” habitat. Some large side-channels, particularly the Natapoc side-channel complex in Reach 10, were not counted as side-channel habitat in the survey because they were not connected via surface flow. The connectivity of these side-channels has been reduced over time partially as a result of human-induced incision and confinement.

An average of 123 pieces of wood per mile was counted in the study area; 48% of these were “small” pieces with diameters between 6 and 12 inches and lengths greater than 20 feet. Wood frequency at the reach-scale ranged from 13 (Reach 7) to 294 (Reach 1) pieces/mile. As discussed previously, the size, availability, and quantity of wood is lower than what would have been expected historically, which has affected instream channel dynamics and habitat suitability for salmonids.

Bed substrate was dominated by cobbles, followed by gravels and then boulders. Sand typically made up less than 20% of the substrate and bedrock was uncommon. Suitable spawning areas were observed throughout the study area, primarily at the downstream (reaches 1-3) and upstream (reaches 8-11) ends of the study area.

Riparian areas were dominated by native riparian forest vegetation although past timber harvest has reduced overall stand ages. Residential development has impacted riparian conditions in numerous locations, particularly reaches 3-8 and 10. In many areas affected by residential development, large trees dominate the overstory but the understory has been cleared. Results for riparian forest stand ages at the study area scale were 52% large tree (≥ 21” dbh), 41% small tree (9 – 21” dbh), and 7% sapling/pole (5 – 9” dbh).

3.5.3 Reach-Based Ecosystem Indicators

This section presents an overview and summary of the REI results (Table 10), which are presented in more detail in the REI Report (Appendix C). The REI applies habitat survey data and other analysis results to a suite of REI indicators in order to develop reach-scale ratings of functionality with respect to each indicator. Functional ratings include **adequate**, **at risk**, or **unacceptable**. The REI analysis helps to summarize habitat impairments and to distill the impairments down to a consistent value that can be compared among reaches. This analysis is also used to help derive restoration targets as part of the restoration strategy presented in Section 5. The rating definitions, and explanations of how the ratings were made, can be found in Appendix C.

There were no fish passage barriers within the study area so each reach was therefore given a rating of **adequate** for this indicator. Substrate and fine sediment ratings were generally **adequate** or **at risk**, with no **unacceptable** ratings. For the remainder of the indicators, some general patterns are observed. Reaches 1 and 2, which are the least impacted reaches at the downstream end of the study area, tend to have **adequate** ratings for most, if not all, indicators. The two exceptions are LWD and pools in Reach 2. These lower reaches flow through US Forest

Service land and display some of the most complex habitat and geomorphic characteristics of the study reach.

Reach 3 transitions into more human alteration and is rated as **at risk** for most indicators. This reach is bordered by US Forest Service land on the east side but is highly developed with streamside residences on the west side. Reaches 4 through 7 are mostly **at risk** or **unacceptable** for all indicators. These reaches are heavily impacted by on-going human alterations including residential development, roadways, and floodplain alterations. Riparian and floodplain development limit off-channel habitat and channel complexity in these reaches. In reaches 8 through 11, human impacts are less except for in the upstream portion of Reach 10. These reaches are dominated by **at risk** conditions, but are also rated as **adequate** or **unacceptable** depending on the indicator.

For the study area as a whole, **at risk** was the most common rating (52), followed by **adequate** (41), and then **unacceptable** (28).

Table 10. Reach-Based Ecosystem Indicator (REI) results. See Appendix C for the REI report.

General Characteristics	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11
Habitat Assessment	Physical Barriers	Main Channel Barriers	adequate	adequate	adequate	adequate	adequate	adequate	adequate	adequate	adequate	adequate	adequate
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	adequate	adequate	adequate	at risk	adequate	adequate	adequate	at risk	at risk	adequate	adequate
	LWD	Pieces per mile at bankfull	adequate	unacceptable	at risk	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable
	Pools	Pool frequency and quality	adequate	at risk	at risk	at risk	at risk	unacceptable	unacceptable	at risk	at risk	at risk	at risk
	Off-Channel Habitat	Connectivity with main channel	adequate	adequate	at risk	unacceptable	unacceptable	at risk	unacceptable	at risk	at risk	at risk	at risk
Channel	Dynamics	Floodplain connectivity	adequate	adequate	at risk	unacceptable	unacceptable	unacceptable	unacceptable	at risk	at risk	at risk	adequate
		Bank stability/Channel migration	adequate	adequate	unacceptable	unacceptable	unacceptable	at risk	adequate	adequate	adequate	unacceptable	adequate
		Vertical channel stability	adequate	adequate	at risk	unacceptable	at risk	at risk	at risk	at risk	unacceptable	at risk	at risk
Riparian Vegetation	Condition	Structure	adequate	adequate	at risk	at risk	at risk	at risk	at risk	at risk	at risk	at risk	at risk
		Disturbance (human)	adequate	adequate	unacceptable	at risk	unacceptable	unacceptable	at risk	at risk	at risk	at risk	at risk
		Canopy Cover	adequate	adequate	at risk	at risk	unacceptable	at risk	at risk	at risk	adequate	at risk	at risk

4 REACH-SCALE CONDITIONS

This section describes forms and processes and the effects of human alterations at the reach-scale. Additional information on instream habitat conditions, riparian conditions, and channel geometry can be found in the Habitat Assessment (Appendix A).

4.1 Reach 1

4.1.1 Reach Overview

Reach 1 is 2.1 miles long and extends from the Highway 2 Bridge (RM 35.5) upstream to RM 37.6 (Figure 30). This reach has a braided form with multiple point and mid-channel bars, partially vegetated islands, and connected backwaters. Additional sediment and surface water is contributed by Chiwaukum Creek that enters the mainstem Wenatchee River 0.4 miles from the downstream boundary of the reach. Other minor seasonal surface water sources include ephemeral hillslope drainages (ten on river left and six on river right). With an average bankfull width of 325.5 feet, the channel is relatively wide compared to most upstream reaches. Modern geomorphic forms and processes and their associated habitat elements appear relatively unaffected by direct human influence over the past 50 years. However, some evidence of historical log drives, splash damming, and riparian timber harvest exist. This reach is bordered primarily by public lands managed by the US Forest Service. The topography of the surrounding hillslopes is relatively steep and difficult to access upstream of the Chiwaukum Creek confluence. Due to the limited effects of human alterations, this reach serves as a reference for habitat restoration targets for other reaches within the study area.

Figure 30. Overview map of Reach 1. Flow is from north to south.

4.1.2 Forms and Processes

Reach 1 is a braided reach with multiple bars and islands (Figure 31). Active depositional surfaces are present as mid-channel features and marginally along the channel's edge (e.g. RM 36.35 to RM 36.8). Both the mid- and margin-bar deposits are partially to well-vegetated and are often associated with complex secondary channels and/or backwater alcoves. Hyporheic flow through gravel and mid-channel bars occurs throughout the reach but is most prevalent in the widest segments of the valley. Channel units alternate between riffle-glide and pool-riffle. The pools throughout the reach are relatively deep (3 to >12 feet) and often channel-spanning. The riffles are complex and often transverse.

The channel and its modern floodplain are partially confined by terrace deposits and hillslopes composed of sedimentary conglomerates, ultramafic rocks, and outcrops of the Chumstick Formation. We applied the definition of partial confinement used by Brierley and Fryirs (2005), which is 10 to 90 percent of a channel's banks having contact with a valley wall. This confinement limits lateral migration and sinuosity. Although partially confined, the channel and modern floodplain of Reach 1 range in width from 0.1 to 0.25 miles – this is relatively wide compared to other reaches in the study area. The gradient of the channel in this reach is 0.19%, with a sinuosity of 1.31.

This reach is generally transport-limited, resulting in the predominance of the depositional features described above. Channel margin and mid-channel roughness features (e.g. riparian vegetation and large wood) promote gravel accumulation in these areas. The sediment supply of Reach 1 is further supplemented by the modern Chiwaukum Creek's alluvial fan. The sediment inputs from the Chiwaukum are prevalent from the downstream reach boundary to RM 36.0. The bedrock boundary of Tumwater Canyon, which is immediately downstream of this reach, serves as a hydraulic constriction and grade control for the reach as a whole.

Observed deposition and scour on floodplain surfaces indicates regular inundation by the channel. This is confirmed by the floodplain inundation hydraulics analysis presented in Section 3.5.2. Prominent floodplain scarring visible in LiDAR and aerial imagery suggests that creation and abandonment of braids and side-channels occurs somewhat regularly throughout portions of this reach. These processes have created channel and floodplain complexity.

Large wood accumulations are found on point bars and as apex jams at the upstream end of mid-channel bars and islands throughout the reach. It is well supported in the literature that bar complexes act as flow obstructions that promote the retention of wood more readily than simplified channels (Fetherston et al. 1995, Gurnell et al. 2000a, Gurnell et al. 2000b, Haga et al. 2002, Bocchiola et al. 2008). Such accumulations are predicted to promote both geomorphic and habitat function (Bisson et al. 1987) including the creation of pools, sediment retention (trapping) and sorting, creation of multi-thread channels, and increased channel complexity and cover for fish (Bjorn and Reiser 1991, Beechie and Sibley 1997, Montgomery et al. 2003, Beechie et al. 2005). Therefore, it is assumed that the presence of LWD is both a driver and a result of the complex channel-floodplain processes occurring in Reach 1.

Banks and beds are composed of gravels, sands, and cobbles with cobbles (41-44%) and gravels (32-52%) dominating. Bedrock was observed in two isolated units at RM 35.9 and RM 37.0. The riparian canopy is dense, of mid-seral stage in most locations, and provides excellent canopy cover. Dense thickets of dogwood provide significant floodplain roughness throughout the reach. Future sources of large wood material exist throughout the reach along the margins of the channel. However, larger key pieces for recruitment of other large wood are currently uncommon in the channel.

Figure 31. Representative geomorphology of Reach 1.

4.1.3 Effects of Human Alterations

Modern human alterations to this reach are limited, but there is evidence of historical timber harvest and log transport, including a mid-seral stage riparian forest, remnant log pilings (Figure 32), and sunken cut logs (presumably log drive remnants). Potential impacts from these activities are discussed in Section 3.4, but without historical data it is difficult to estimate the specific extent of human alteration. Despite past impacts, it is believed that this reach has been on a trajectory of recovery over at least the past 50 years, which has resulted in the modern habitat complexity observed today.

Modern human impacts are relatively minor and include a US Forest Service Campground (Tumwater Campground), a limited-access gravel road, and the Highway 2 Bridge. The campground is located along the right bank at the downstream end of the Chiwaukum - Wenatchee River confluence, near the downstream end of the reach. The site of the campground is atop the historical floodplain and fan deposit terraces of Chiwaukum Creek. Segments of the campground road network traverse western portions of the Chiwaukum alluvial fan(s), but do not appear to impact Chiwaukum Creek's geomorphic function. A US Forest Service road runs along much of Reach 1's right bank, but it is elevated above the modern floodplain surfaces. Located at the downstream boundary of the reach is the Highway 2 Bridge. Large boulder riprap armors the two cement bridge abutments and banks.

Human alterations are displayed in Figure 33, Figure 34, and Figure 35.

Figure 32. Remnant pilings assumed to be from historical logging practices (splash damming).

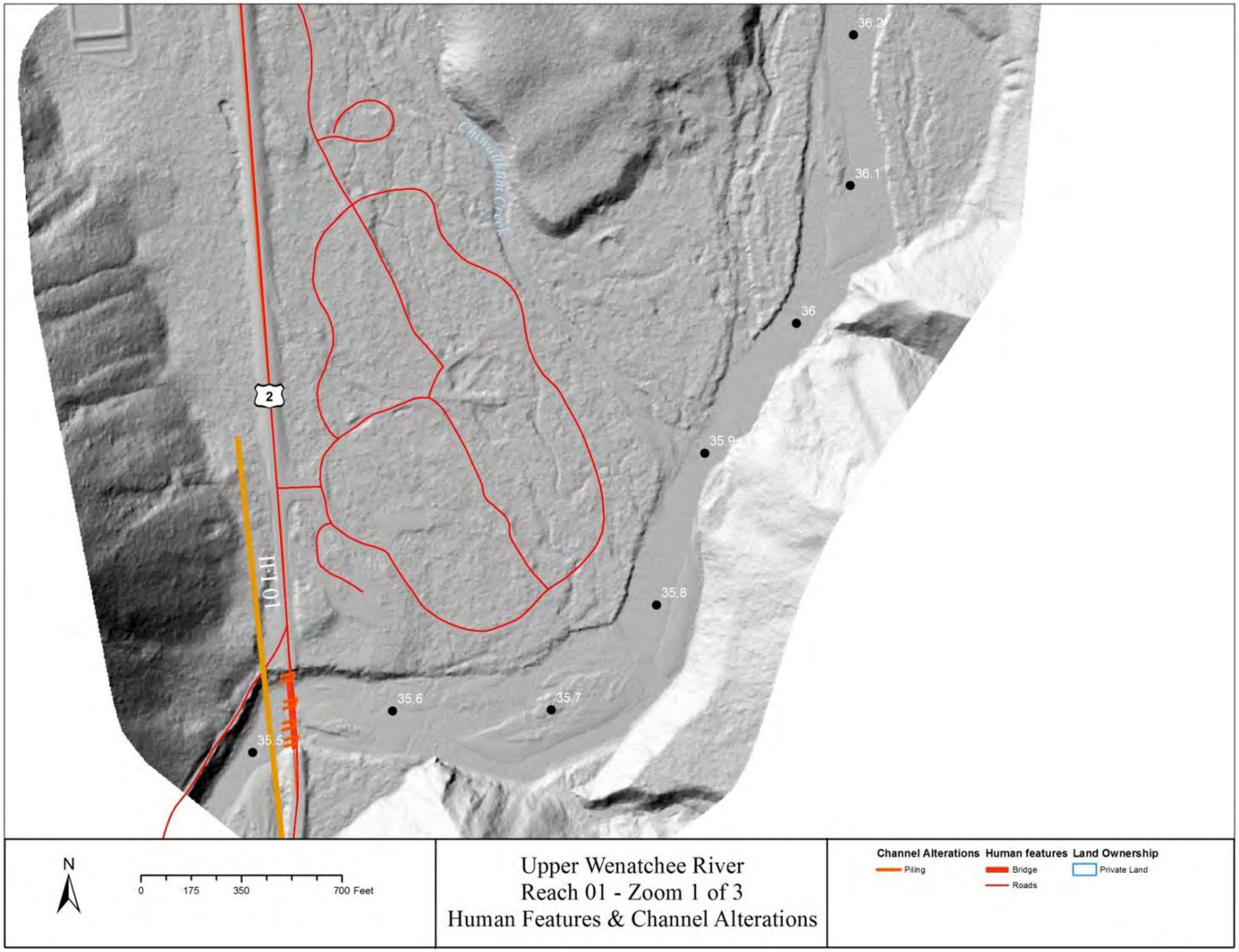

Figure 33. Human alterations in the downstream portion of Reach 1. Flow is from north to south.

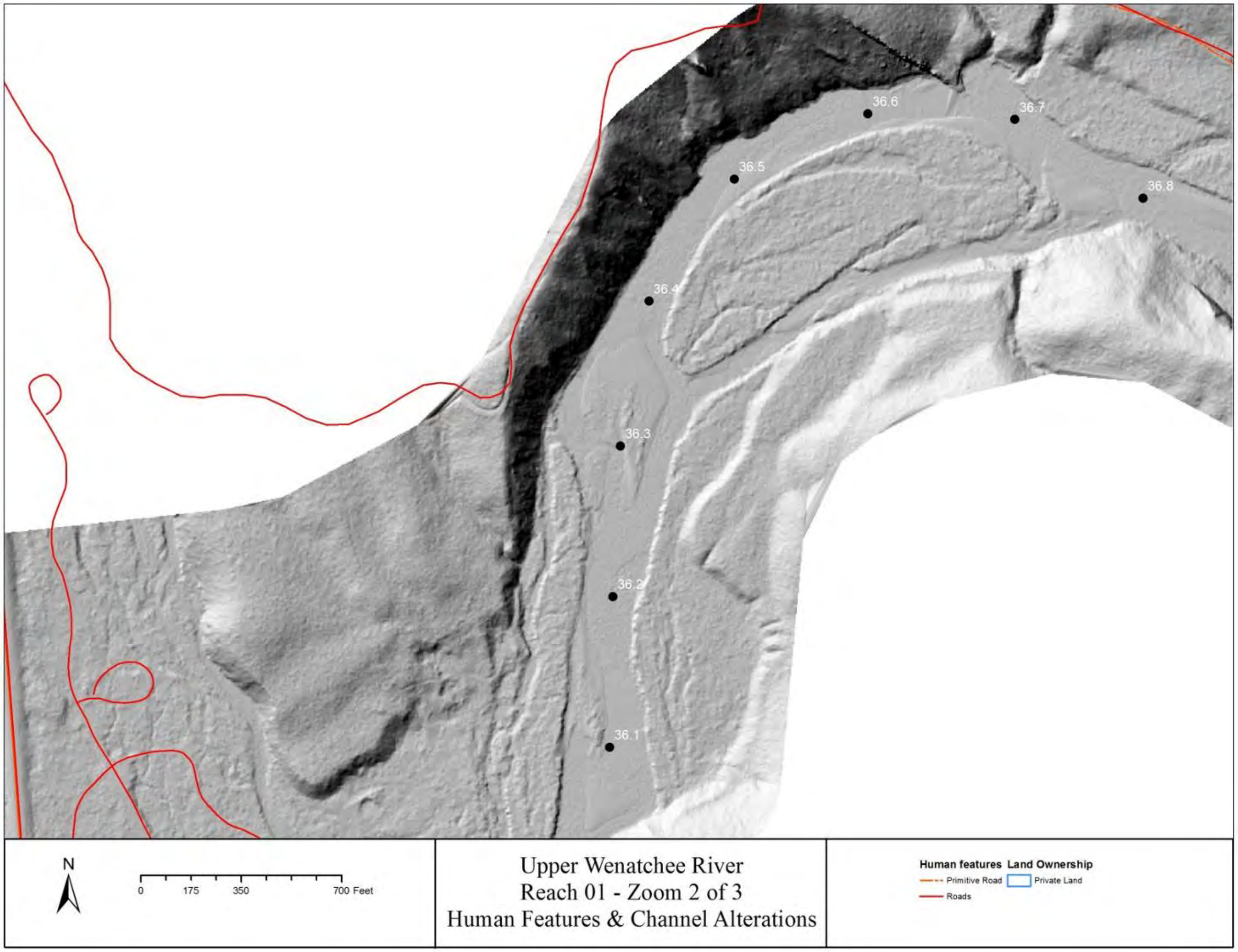

Figure 34. Human alterations in Reach 1. Flow is from north to south.

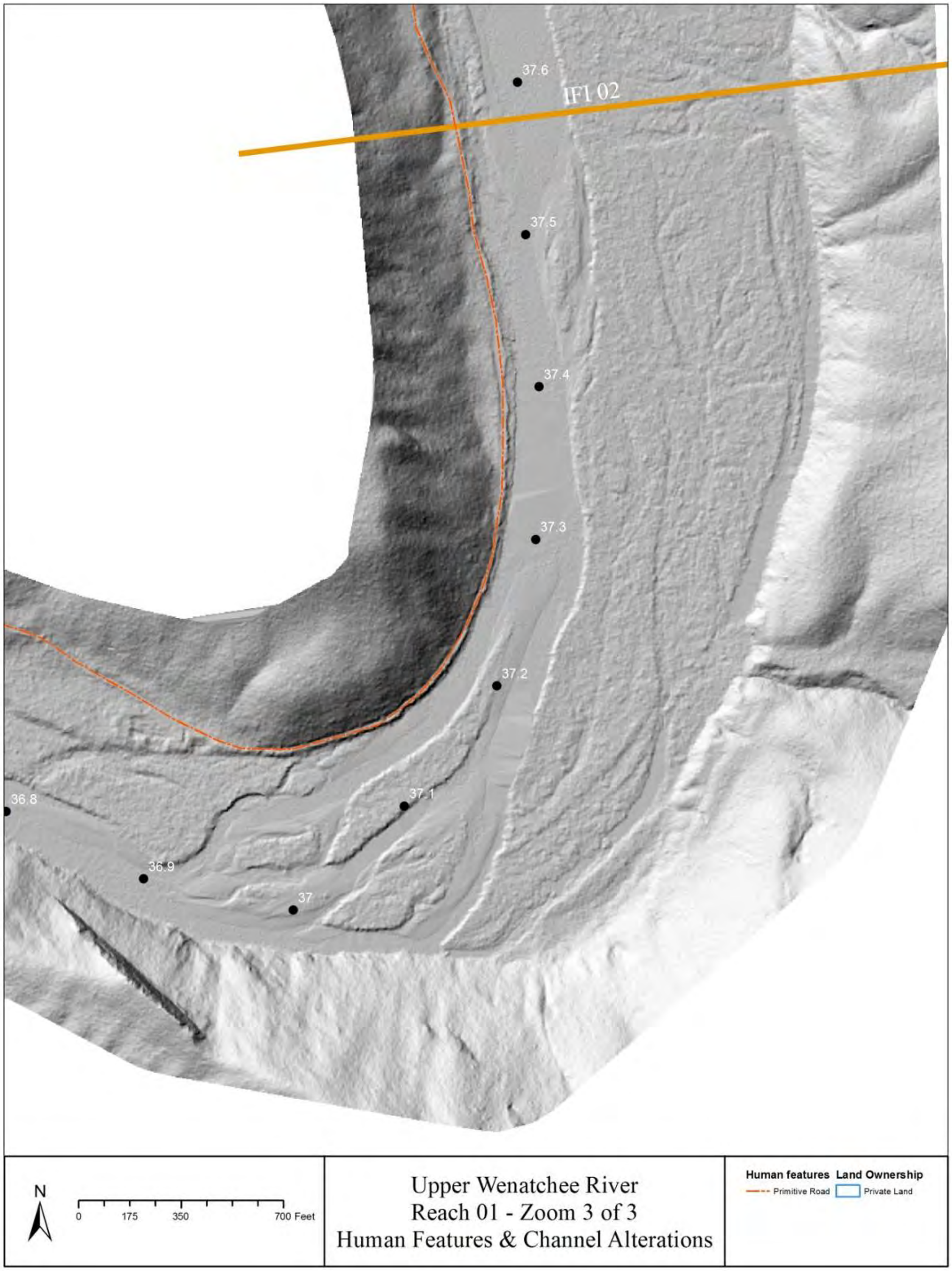

Figure 35. Human alterations in the upstream portion Reach 1. Flow is from north to south.

4.2 Reach 2

4.2.1 Reach Overview

Reach 2 is one mile long and extends from RM 37.6 to RM 38.6 (Figure 36). The reach has a confined slight meandering form with some longitudinal bar development at the channel margin and one mid-channel bar and a point bar that are located at the downstream end of the single meander bend. The channel is notably less wide than Reaches 1and 3. The channel and its floodplain surfaces are confined by hillslopes of the Chumstick Formation on river-right and river-left. Minor seasonal surface water sources include ephemeral hillslope drainages (four on river left and nine on river right). Similar to Reach 1, the geomorphic forms and processes, and their associated habitat elements, seem relatively unaffected by direct human influence for the past 50 years. However, evidence of historical riparian timber harvest exists. The reach is bordered primarily by forested public lands managed by the US Forest Service. Surrounding hillslopes are relatively steep with ground-access limited to an unmaintained USFS road on river-right.

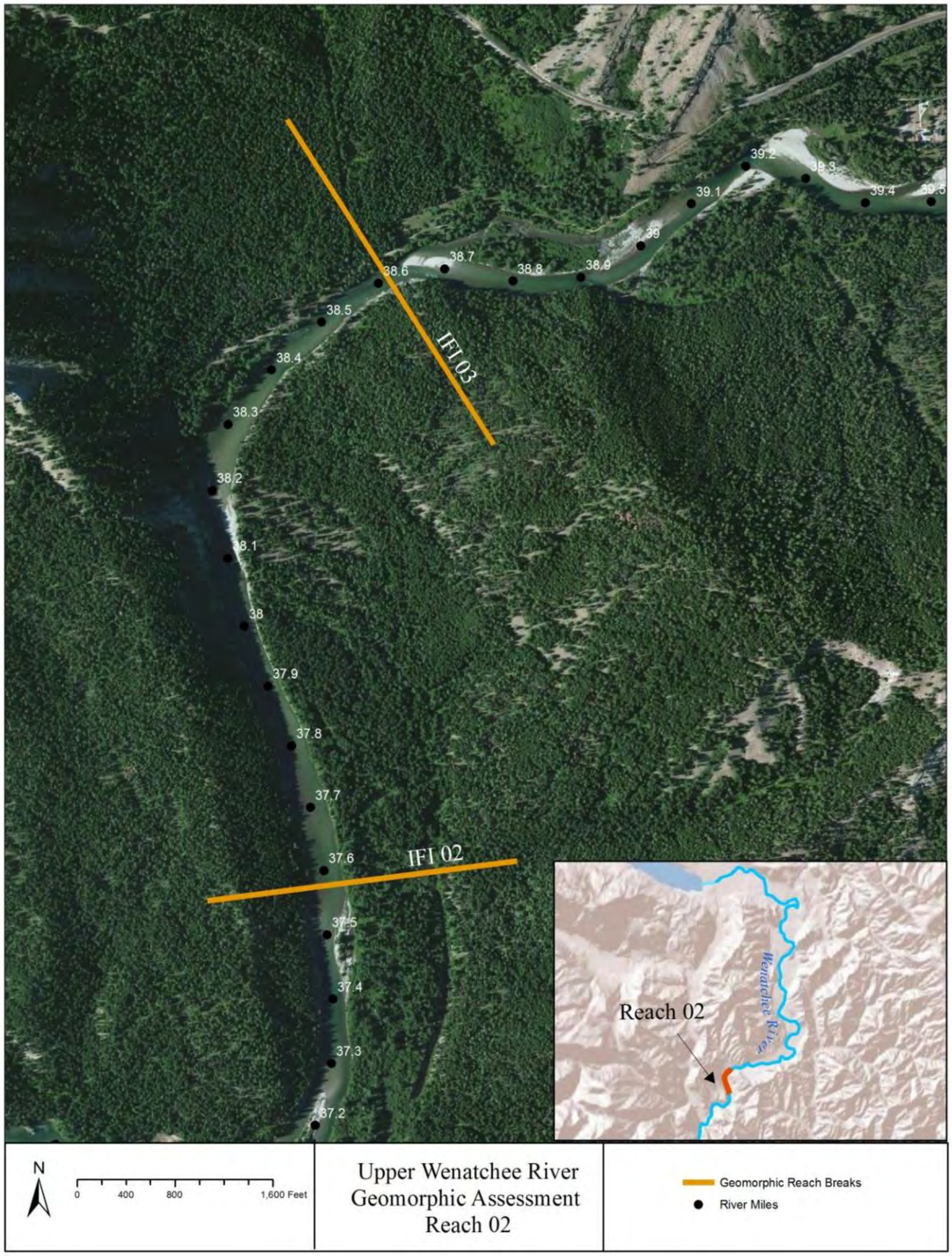

Figure 36. Overview map of Reach 2. Flow is from north to south.

4.2.2 Forms and Processes

Reach 2 slightly meanders with a channel sinuosity of only 1.15. The channel is relatively flat, homogenous, and plane-bed. The gradient of the channel in Reach 2 is 0.25%. Bed substrate ranges from sands to boulders but is dominated by cobbles (See Habitat Assessment – Appendix A). The channel and its modern floodplain surfaces are partially confined by hillslopes composed of the Chumstick Formation along river-right from RM 37.6 to RM 38.2 and river-left from RM 38.4 to RM 38.6. A small (9.24 acres) abandoned historical alluvial floodplain surface further confines the channel along river-left from RM 38.1 to 38.15.

Although more narrow and with a higher gradient than Reaches 1and 3, this reach maintains modern floodplain surfaces but only minor active bar surfaces (see Figures 4 and 5 in Appendix B). A single mid-channel bar and a point bar are present at the downstream end of the only meander bend (RM 38.2). The largest floodplain surface at RM 37.6 to RM 38.1 is on river-left and connects to a similar surface downstream in Reach 1. Average combined width of the channel and its modern floodplain surfaces here is 671 feet.

Figure 37. Representative plane-bed morphology of Reach 2.

Reach 2 is marginally transport dominant. This classification is based on increased bed-material grain sizes and slope compared to Reach 1 and 3, minimal active bar surfaces, simplified bed topography, reduced width, and in-channel sediment supplied downstream to Reach 1.

Along the landward side of the main floodplain unit (river-left, RM 37.6 to RM 38.1), there are wetted channel scars that connect to similar features downstream in Reach 1. These wetted areas are sourced by both hillslope runoff and hyporheic flow. In Reach 2, the wetted abandoned channels are silting in and discontinuous in the upstream portion. The floodplain scaring suggests that the lower portion of this reach was recently more complex than present. It is stipulated that large wood jam(s) likely influenced more dynamic channel-floodplain connectivity here.

This reach has experienced incision resulting in the abandoned historical floodplain surface on river-left. Parallel topographic steps extend from the abandoned floodplain surface in a downstream transverse pattern onto the modern floodplain. Age of established tree cover on the transverse scrolls decreases with relative elevation of the step surfaces. This suggests that channel straightening and simplification occurred in tandem with incision. Hydraulic modeling of floodplain inundation (Section 3.5.2) confirms the transverse incision pattern and it highlights the subtle natural levee developing along river-left as a result of high-flow deposition of the simplified channel. The hydraulic modeling also indicates that much of the wide, wetted and scarred floodplain behind the natural levee is inundated at flows equivalent to or less than the two year flood event. Further analysis of tree stand age would establish rate of incision through the reach and may provide more insight to historical conditions.

Exposed bedrock is located at RM 37.9 and RM 38.6. The presence of bedrock imposes a vertical control on channel processes. At these locations, the river has reached an elevation at which incision rates are limited. This has possibly allowed Reach 2 to maintain connectivity with much of its floodplain.

Large wood accumulations are minor but present. Some accumulations are found at the margin of the channel. Large wood is also present where bar development is occurring.

Riparian vegetation in Reach 2 is well-developed relative to other portions of the study area. Vegetation is primarily of mid-seral stage. This provides for well-functioning canopy cover along the banks, future sources of large wood material, and hydrologic and hydraulic regulation.

4.2.3 Effects of Human Alterations

Modern human alterations throughout this reach are limited in the past 50 years. However, evidence of historical timber harvest and log transport exists throughout the study area. Potential impacts of these practices are discussed in detail in Section 3.4.3. Notable in this reach is the past harvest of mature riparian trees, which has reduced the available large wood sources to the stream and floodplain. It is likely that the incision andchannel simplification of this reach was accelerated by past log drives and splash dams (primarily through channel scouring and/or removal of large wood jams). However, without historical data it is difficult to estimate the specific extent of human alterations to this reach.

Existing human alterations include a primitive road that abuts the channel on river-right from RM 38.5 to RM 38.6. There is some fill associated with the road but impacts to the channel are minimal as it does not appear to affect channel migration rates or impact floodplain inundation.

Human alternations and development are illustrated in Figure 38 and Figure 39.

Figure 38. Human alterations in the downstream portion of Reach 2. Flow is from north to south.

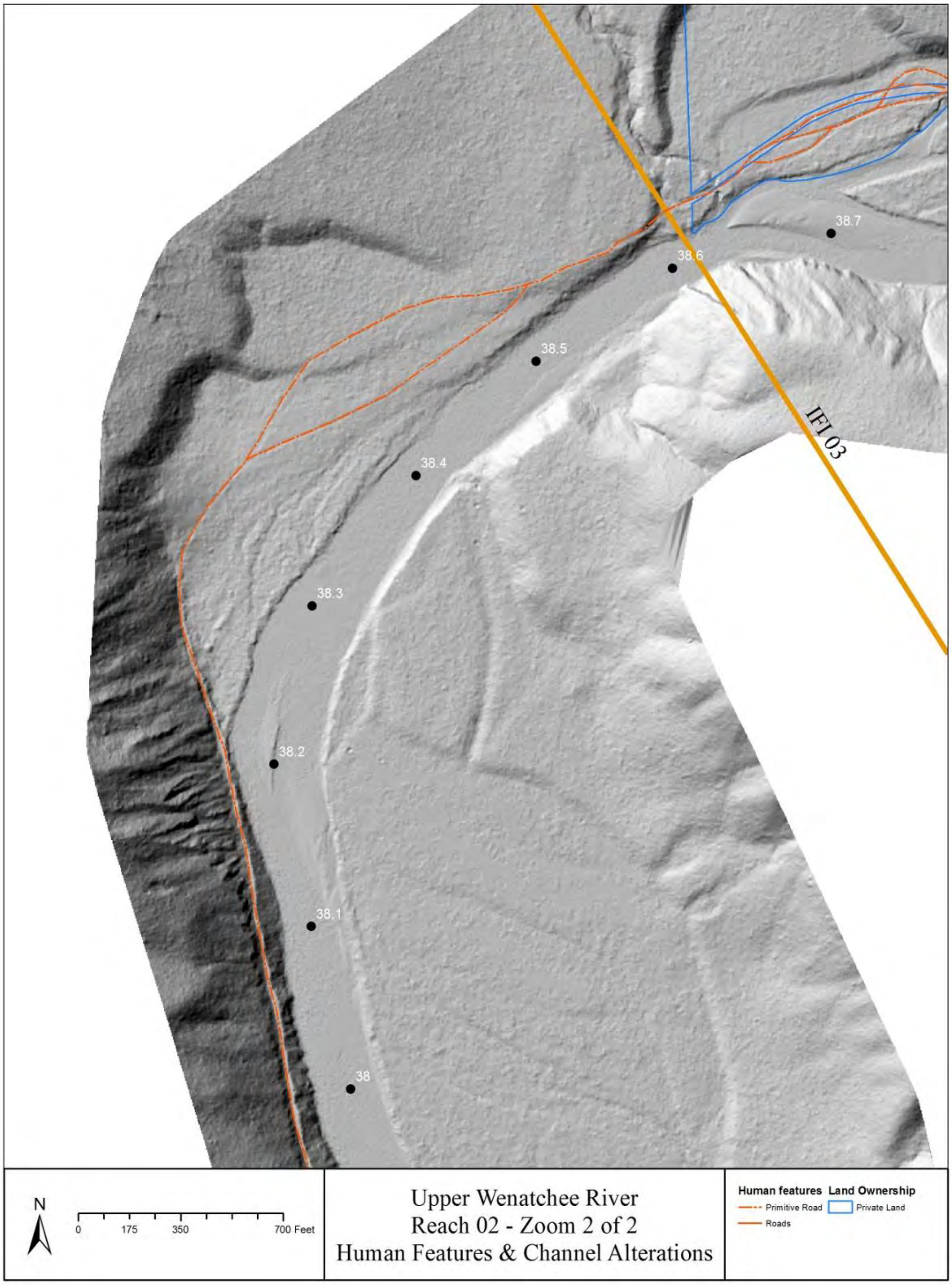

Figure 39. Human alterations in the upstream portion of Reach 2. Flow is from north to south.

4.3 Reach 3

4.3.1 Reach Overview

Reach 3 is 3.3 miles long and extends from RM 38.6 upstream to the Burlington Northern Railroad Bridge at RM 41.9 (Figure 40). This is a complex reach with prevalent point and mid-channel bars and a few small vegetated islands. Floodplain surfaces contain numerous connected high flow channels and backwater features. Fourteen ephemeral drainages on the left bank and twelve on the right bank contribute seasonal surface water inputs to the system. Deadhorse Creek enters on river-right at RM 38.62 and is substantial enough that it continues to contribute small quantities of surface flow during the dry summer months. Impacts on geomorphic forms and processes from anthropogenic development begin to increase in Reach 3 relative to Reaches 1 and 2. Private homesite and infrastructure development on the floodplain as well as bank hardening through the installation of riprap and retaining walls exists throughout much of the reach on the river-right floodplains and banks. Despite this development, limited incision or confinement is occurring in the channel. As a result, access to off channel habitat is available through much of the reach.

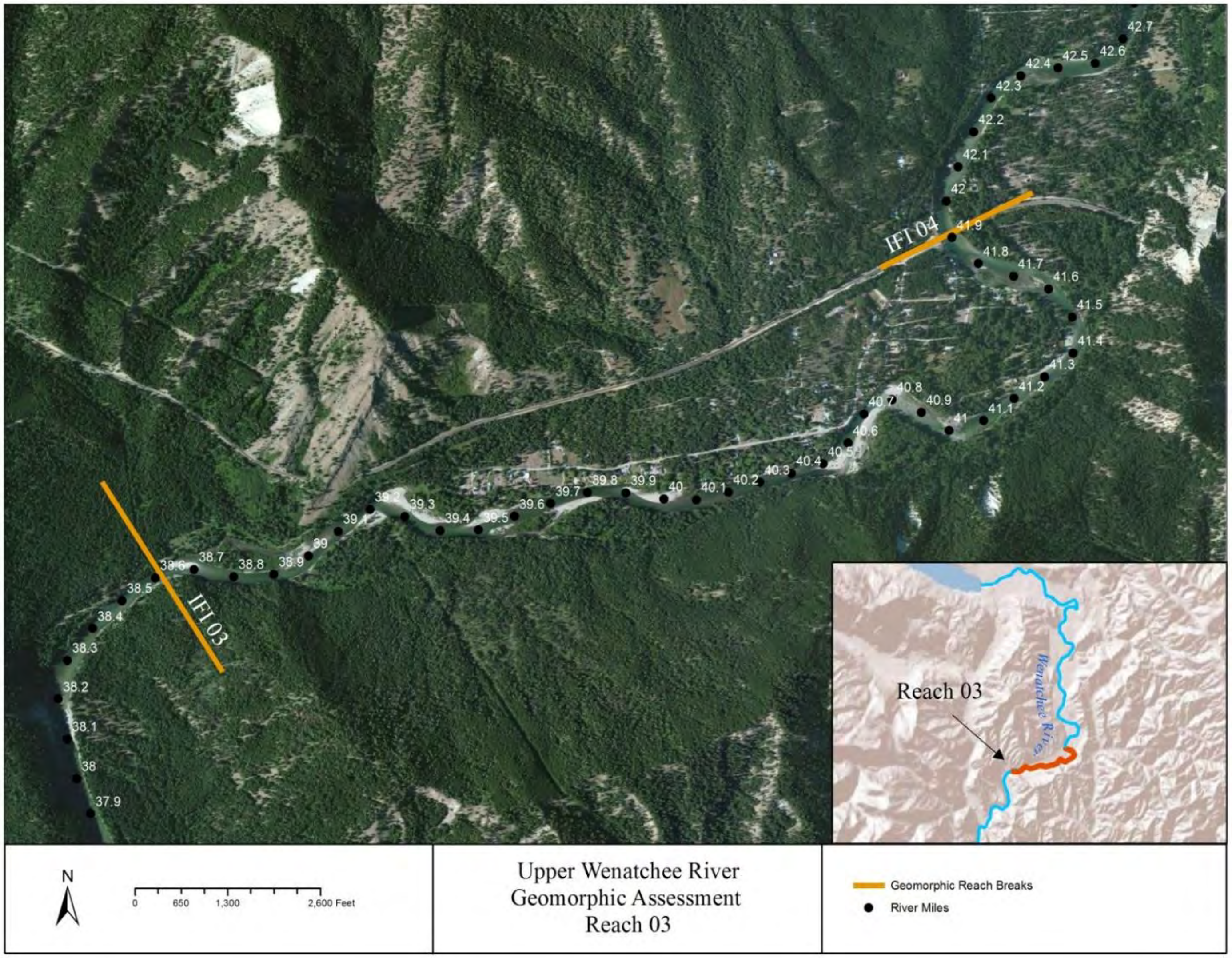

Figure 40. Overview map of Reach 3. Flow is from northeast to southwest.

4.3.2 Forms and Processes

Reach 3 is a meandering channel with plentiful active bar surfaces and relatively low floodplain surfaces that have gradually sloping banks. Large mid-channel bars are prominent in the upper half of the reach and the presence of vegetated islands shifts the lower half of the reach into a partially braided form. The bed morphology is primarily pool-riffle, with periodic occurrences of riffle-glide sequences (Figure 41 and Figure 42). There are extensive transverse riffles in the lower portion of the reach. Bedrock exposures of the Chumstick Formation are visible within the channel between RM 40.8 and RM 41, which control and steepen the channel gradient. Hyporheic flow through gravels and mid-channel bars occurs throughout the reach.

Figure 41. Representative of upstream portion of Reach 3 (July 25, 2011). Taken at RM 41.9 on right bank facing downstream.

Figure 42. Representative of downstream portion of Reach 3 (July 26, 2011). Photo taken at RM 38.61 from right bank facing upstream.

The channel and its modern floodplain are partially confined by the Chumstick Formation and glacial deposit terraces. The channel is further confined by development and periodic bank hardening of the floodplain on river-right. The channel and modern floodplain of Reach 3 range in width from 0.1 to 0.37 miles - widening in a downstream pattern. Topographic features on the anthropologically-impacted floodplains suggests that the active floodplain was wider historically (pre-development). Over-bank deposits and visible scarring/scour indicate that the modern floodplain surfaces along the left bank are active (i.e. regularly inundated) especially between RM 40.6 and RM 41. This is confirmed by the floodplain inundation hydraulics analysis presented in Section 3.5.2. The gradient of the channel in this moderately complex reach is 0.29%, with a sinuosity of 1.42.

Although Reach 3 exhibits the steepest gradient of the entire study area, it is generally transport-limited, resulting in the predominance of active depositional features. Most of the bars lack mature or well-developed vegetation indicating frequent inundation (scour and deposition), temporary sediment storage, and frequent remobilization of bedload. Throughout the reach, high flow events activate secondary channels and scour floodplain surfaces (especially along river-left). Where banks are not hardened by riprap, this appears to be a laterally active reach.

Substrate, bars, and islands are composed of sands to large cobbles and sparse boulders with cobbles (37%) and gravel (28%) dominating. The riparian canopy increases in density and maturity in a downstream pattern. The lower portion is of mid-seral stage in most locations along river-left and provides good canopy cover. The mature riparian and floodplain vegetation provides hydraulic roughness during overbank flows - important for floodplain development and stabilization. Vegetation is altered in the residentially developed areas. Where banks have been hardened with riprap, the riparian bank vegetation has been removed.

Large wood accumulations are found on bars and as apex jams at the upstream end of some mid-channel bars. Two notably large bar apex log jams are located at RM 39 and at RM 41.8 (Figure 43). These massive apex jams add localized complexity to the system. Historically, depositional areas throughout this reach likely accumulated large amounts of wood during flood events, creating geomorphic and habitat complexity.

Figure 43. Locations of large wood accumulation in Reach 3.

4.3.3 Effects of Human Alterations

Throughout the reach, the right bank has been highly modified by anthropogenic development. At the upstream end of Reach 3 (RM 41.9) the railroad bridge abutments and associated riprap create a localized artificial channel constriction. This constriction limits lateral channel migration and creates a localized increase in channel velocities, which has created scour pools.

Bank hardening (e.g. riprap, concrete walls) and boulder spurs associated with the development of homesites are present in Reach 3 along the right bank (RM 39.55 to RM 41.81). Extensive riprap (Figure 44) and cement wall construction are located at RM 40.9 to RM 41.8. This bank hardening has disconnected a significant portion of floodplain and restricts channel migration. Site assessment and LiDAR elevation data indicate that this area would be active if bank hardening and walls did not prevent (or limit) floodplain inundation. Despite extensive bank alteration, field observations indicate that flooding continues to be a challenge to homeowners.

Residential development along river-right further reduces floodplain connectivity. Floodplain dissection from road construction to homesites is common and often includes fill or grading of surfaces. A primitive gravel road extends along river-right from RM 38.6 to RM 39.45 that turns into a paved primary road (River Road) from RM.45 to RM 41.9. Vegetation removal and alteration is also common in association with homesite development in Reach 3.

Figure 44. Riprap on river-right (RM 42.8).

Historical timber harvest and log transport occurred throughout the study area (see Section 3.4.3). The historical harvest of mature riparian trees has reduced large wood sources available to the stream and floodplain.

At the downstream boundary of the reach (RM 38.62), a perched culvert disconnects the Deadhorse Creek tributary from the mainstem (Figure 45). The culvert (5ft x 3ft) is perched approximately 2 feet above a connector pool to the Wenatchee River. On the date of the survey, juvenile salmonids were observed in the scour pool that is created at the downstream end of the culvert. Although this perched culvert disconnects potential habitat in Deadhorse Creek, the estimated loss of in-channel habitat is only 190 feet due to a natural salmonid barrier created by a gradient increase at the valley wall.

Human alterations are mapped in Figure 46, Figure 47, Figure 48, and Figure 49.

Figure 45. Perched culvert in Deadhorse Creek (RM 38.6). Surface water connection was present on day of survey (July 26, 2011).

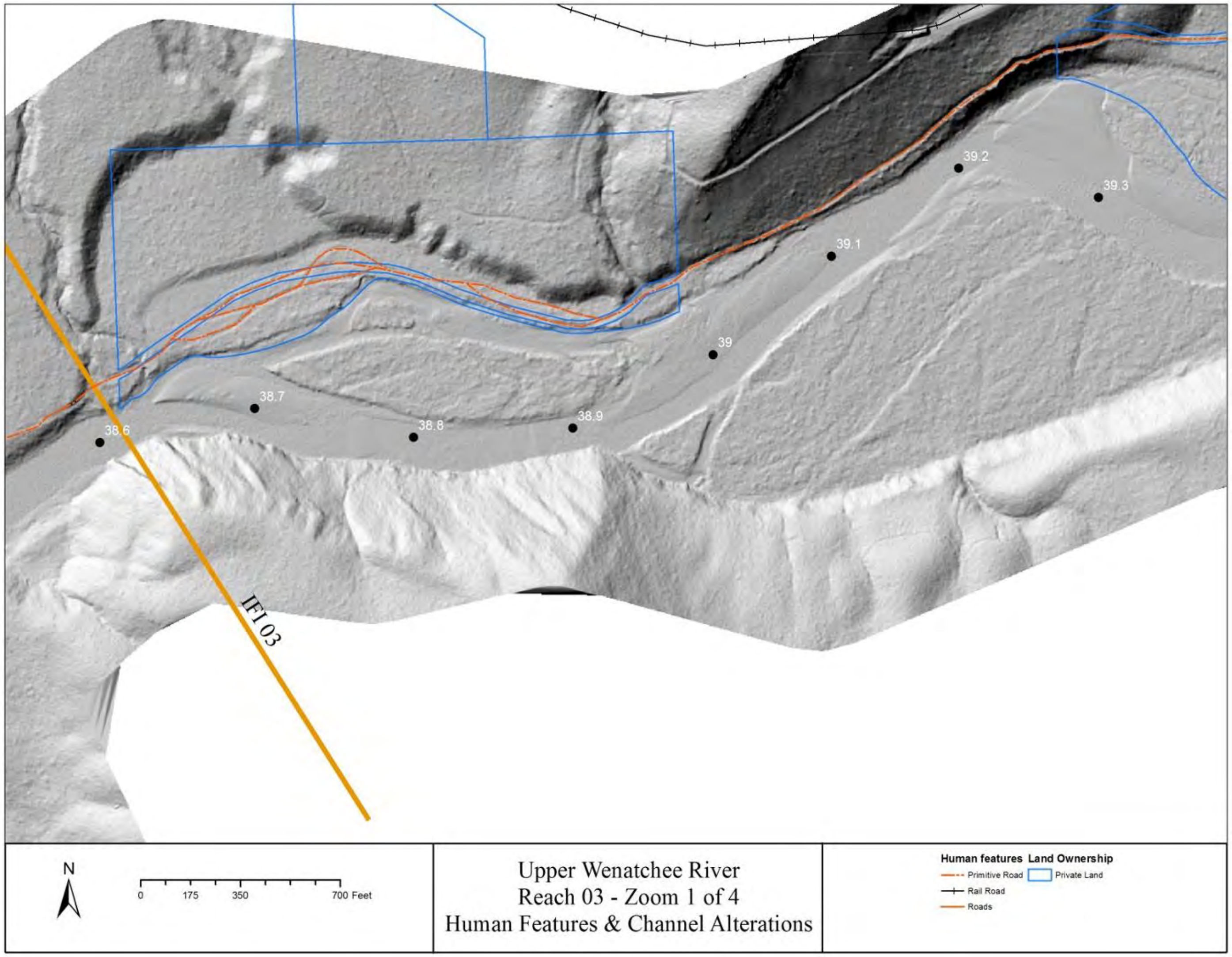

Figure 46. Human alterations in the downstream portion of Reach 3. Flow is from east to west.

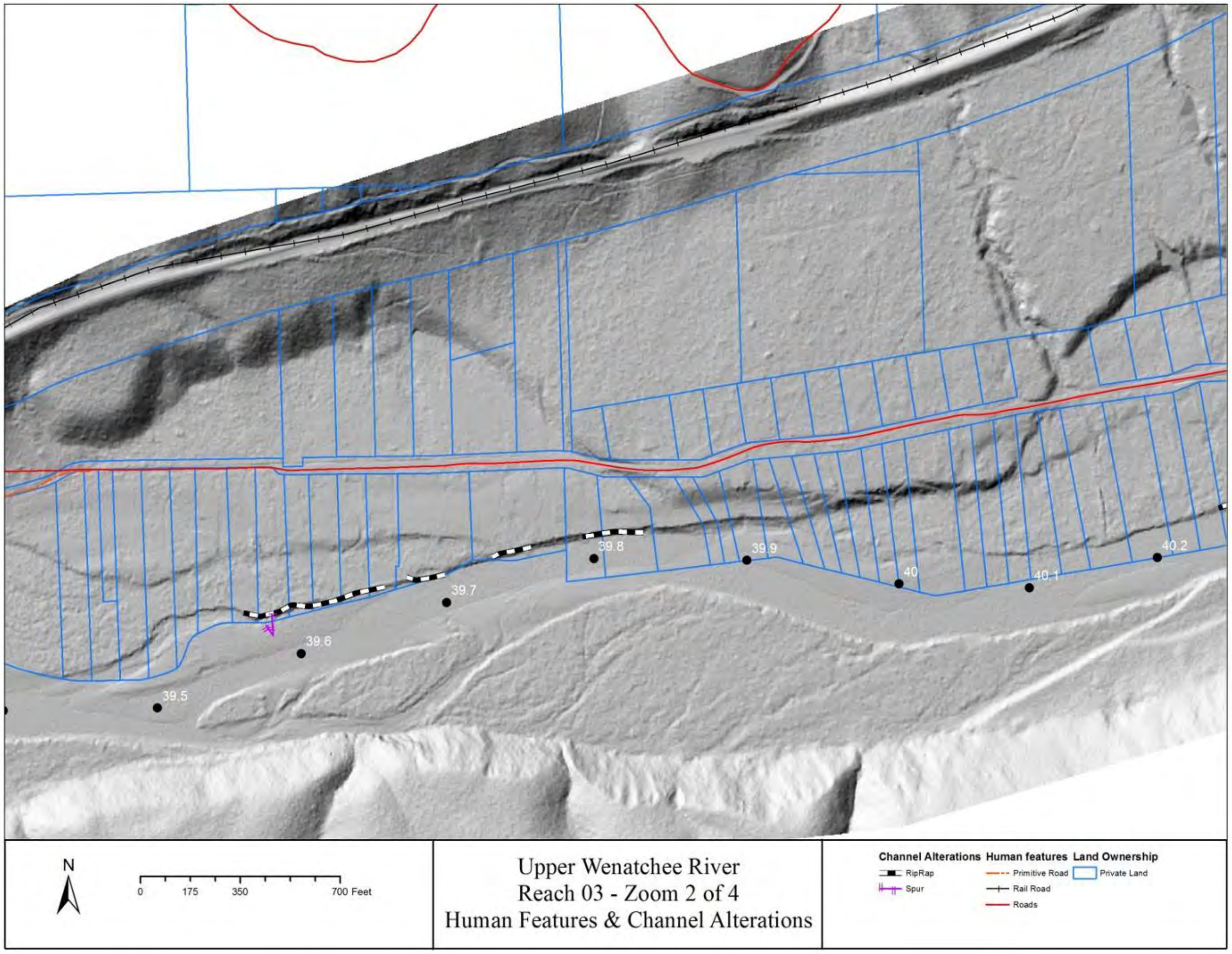

Figure 47. Human alterations in Reach 3. Flow is from east to west.

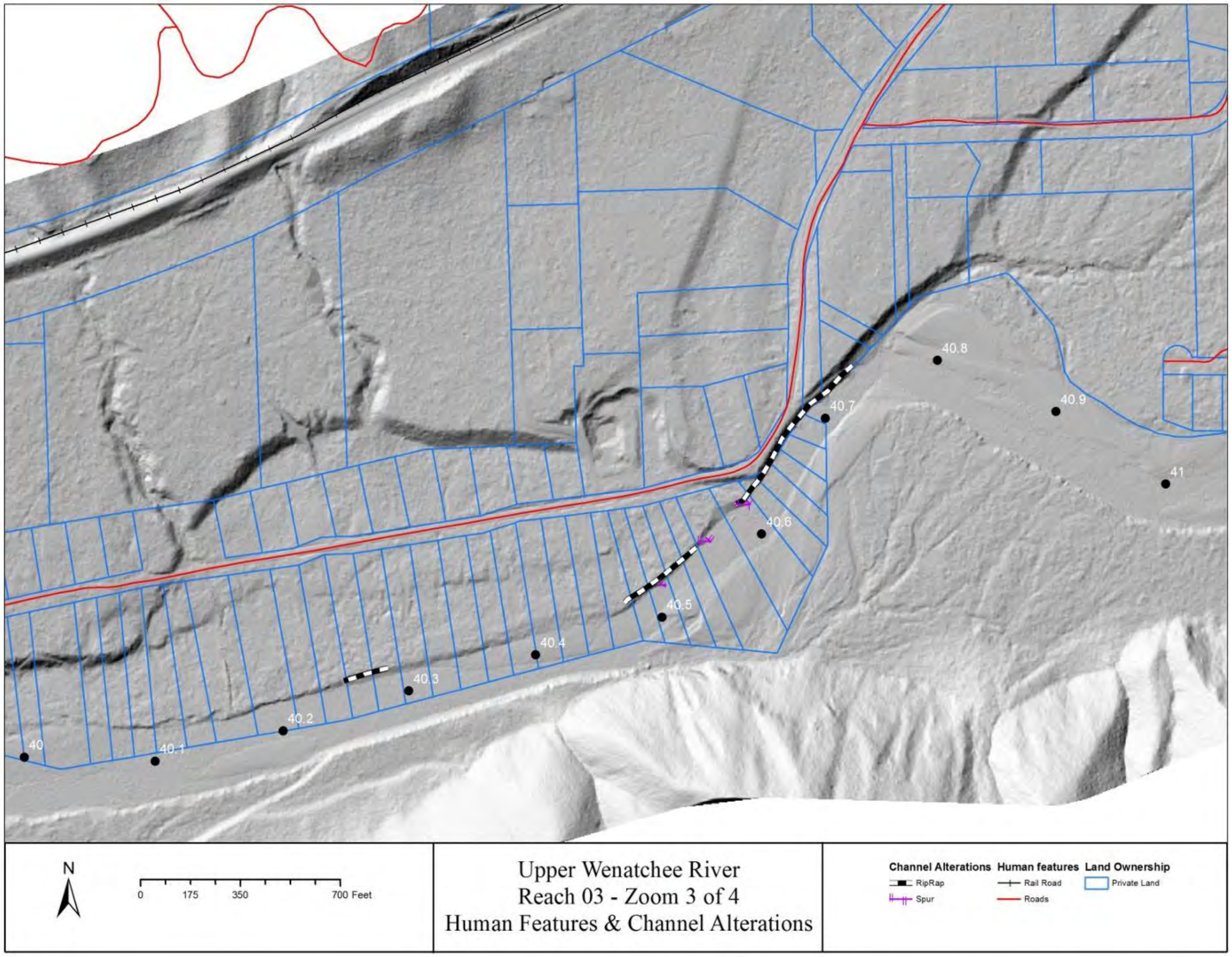

Figure 48. Human alterations Reach 3. Flow is from east to west.

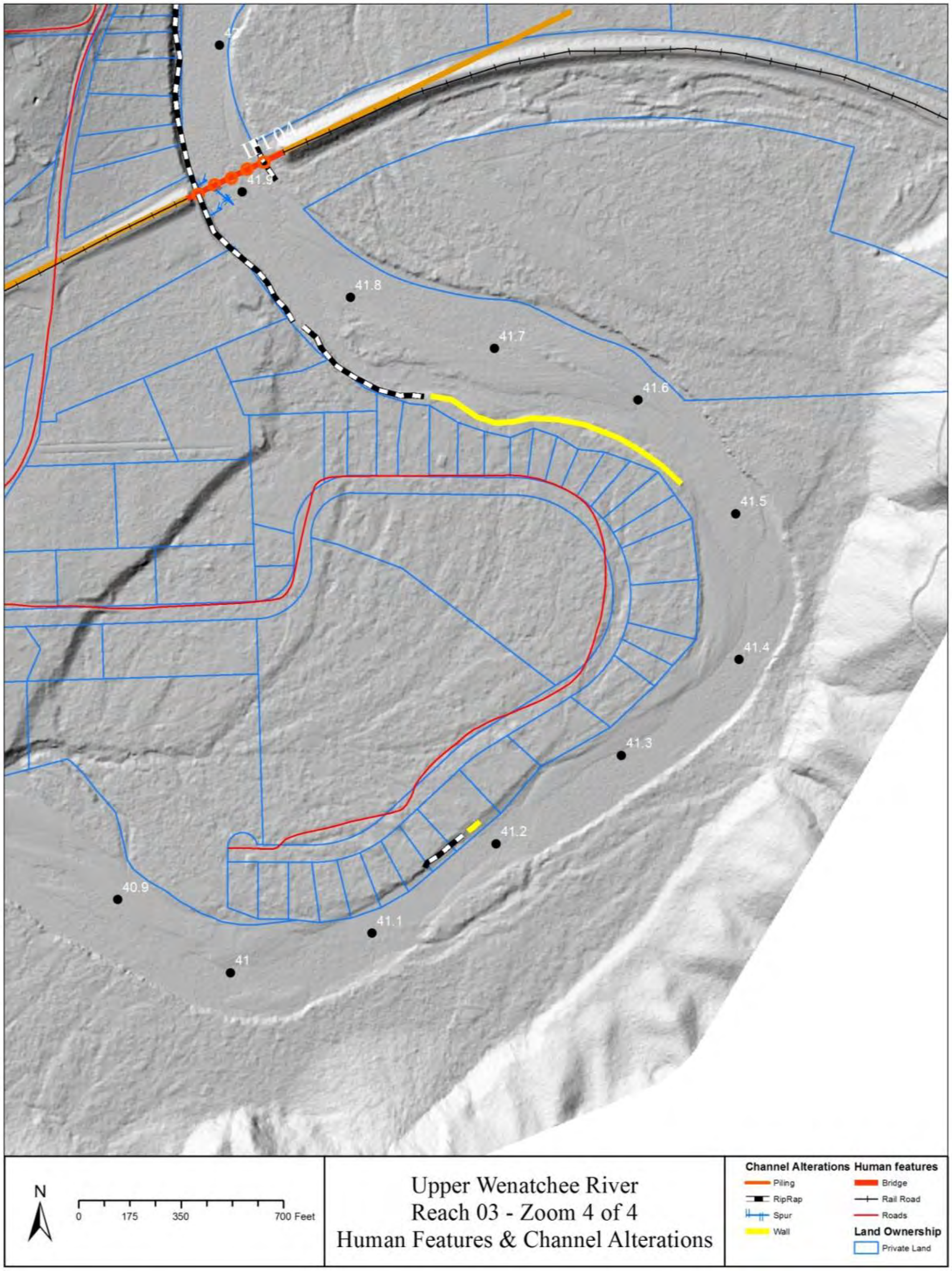

Figure 49. Human alterations in the upstream portion of Reach 3. Flow is from north to south.

4.4 Reach 4

4.4.1 Reach Overview

Reach 4 is 1.2 miles long and extends from the Burlington Northern Railroad (RM 41.9) upstream to RM 43.1 (Figure 50). This is a confined meandering reach with minimal mid-channel and point bar development. Mid-channel bars are present in conjunction with pockets of connected floodplain surfaces and side channel habitat. Minor seasonal surface water input sources include ephemeral hillslope drainages (three on river-left and four on river-right). Two additional ephemeral drainages are leveed by the railroad and redirected to enter the Wenatchee at RM 41.9 on river-right. Residential development influences floodplain inundation.

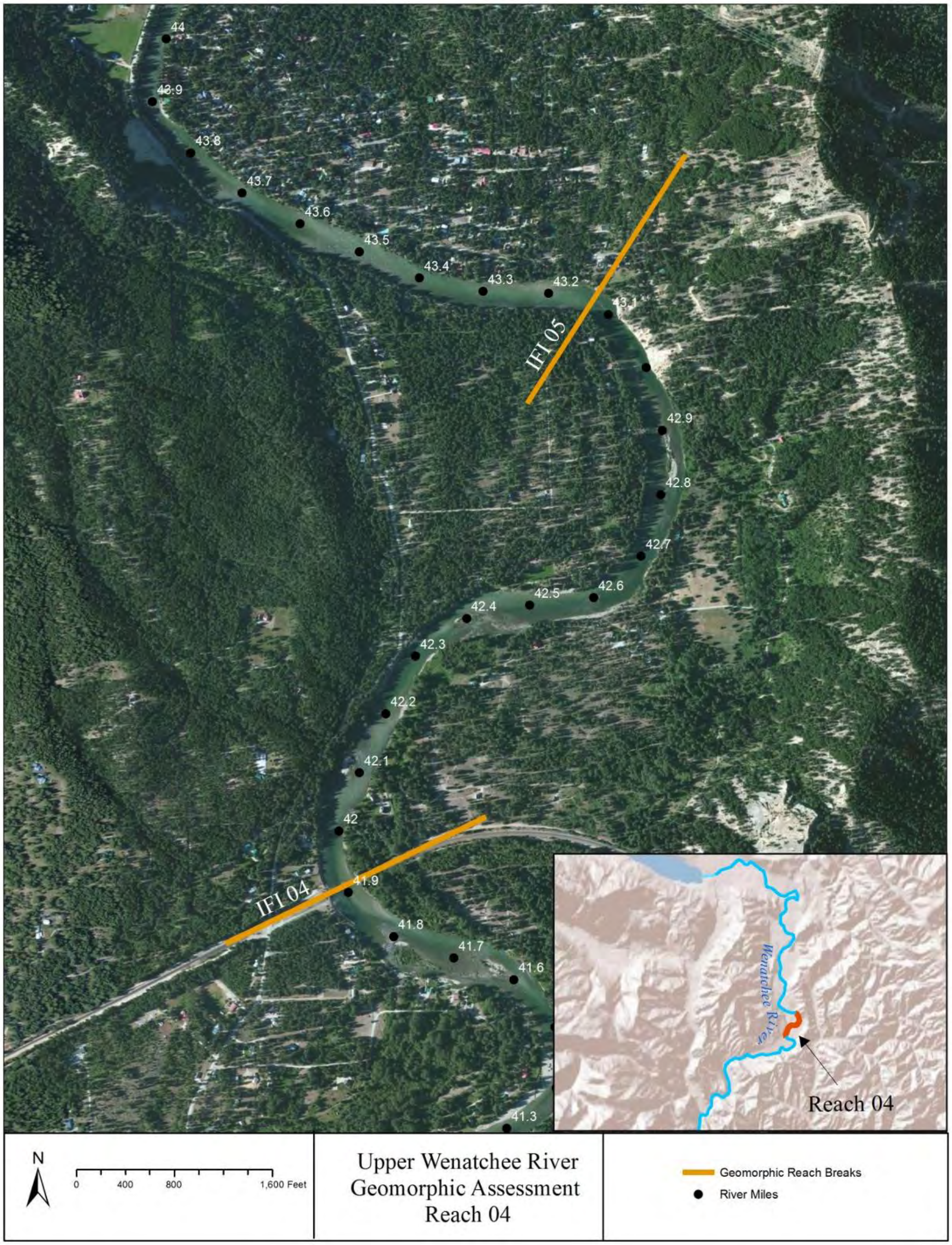

Figure 50. Overview map of Reach 4. Flow is from north to south.

4.4.2 Forms and Processes

Reach 4 is a meandering reach with minor mid-channel and point bar development (Figure 51). Sinuosity of the channel is 1.28. Mid-channel bars were located at RM 42.1, RM 42.4 and RM 42.9, which correspond with widening of the channel and a reduction in channel gradient. Bed morphology is pool-riffle throughout the reach. Areas of increased gradient occur where in-channel bedrock composed of the Chumstick formation is present. The presence of bedrock serves as a vertical grade control and limits localized potential incision. Hyporheic flow is evident at the downstream end of point bars, most notably at RM 42.4.

The channel and the modern floodplain are confined by terraced glacial deposits and exposures of the Chumstick formation. The channel is further confined by anthropogenic development and bank hardening on the low floodplain surfaces. The width of the channel and its modern floodplain ranges from 500 to 800 feet, widening in a downstream direction. The gradient of Reach 4 is 0.24%. The gradient locally increases in relation to the in-channel bedrock exposures.

The modern floodplain surfaces in this reach have gradually sloping banks that alternate with steep terrace or Chumstick confining bank walls. Where terrace banks are being undercut they appear to supply a significant sediment source to the reach. Substrate of the channel ranges from sands to cobbles, with cobble (43%) and large gravel (29%) as the dominant size classes. Some minor boulder inputs from the banks occur where the channel abuts the Chumstick formation. Floodplain and bar composition throughout the reach is primarily gravel and cobble. The bars are partially vegetated with willow indicating some degree of in-channel sediment storage.

Large wood accumulations occur in correlation with bar development in Reach 4. At the time of the survey (summer 2011), a significant apex jam was present on the point bar located at RM 43.05. Riparian vegetation is primarily large trees.

Figure 51. Representative geomorphology of Reach 4.

4.4.3 Effects of Human Alterations

Anthropogenic landscape alterations are prevalent throughout Reach 4. At the downstream-most boundary of the reach the Burlington Northern Railroad laterally confines the channel. Both the left and right bank bridge abutments currently act as hydraulic constrictions during over-bank flows (Figure 52). Riprap has also been installed up and downstream of the railroad bridge further immobilizing the channel and impairing the growth of riparian vegetation (Figure 53).

Figure 52. Burlington Northern Railroad Bridge Pilings

Figure 53. Right bank armoring

Homesite development has occurred along both banks and atop floodplain surfaces throughout Reach 4. A majority of the development is located on terrace surfaces and therefore does not directly impact channel geomorphology. Development on the low floodplain surfaces include removal or alteration of riparian vegetation, grading of floodplain surfaces for homesites, and some infrastructure (access roads and utilities). As a result, limited channel-floodplain interactions occur here and thermal shading has been reduced. Small riprap walls at RM 42.2, RM 42.35, and RM 42.9 likely have minimal impact on the stream. A portion of a side-channel appears to have been filled on the left bank near RM 42.3.

Historical timber harvest and log transport exists throughout the study area. Potential impacts of these practices are discussed in detail in Section 3.4.3. Removal of timber along floodplain surfaces has also occurred.

Inundation mapping conducted as part of the hydraulics analysis shows that considerable floodplain constriction is created by the Burlington Northern Railroad Bridge crossing at the downstream end of Reach 4, which has likely caused base lowering that has progressed upstream. This is supported by inundation extents within the meander bends in Reach 4 that show limited inundation only at the largest flood events (e.g. 50 to 100-yr events) despite scroll scars evident from LiDAR that indicate these surfaces were laid down in relatively recent history and would therefore be expected to have greater floodplain connectivity.

Locations of human alterations are displayed in Figure 54 and Figure 55.

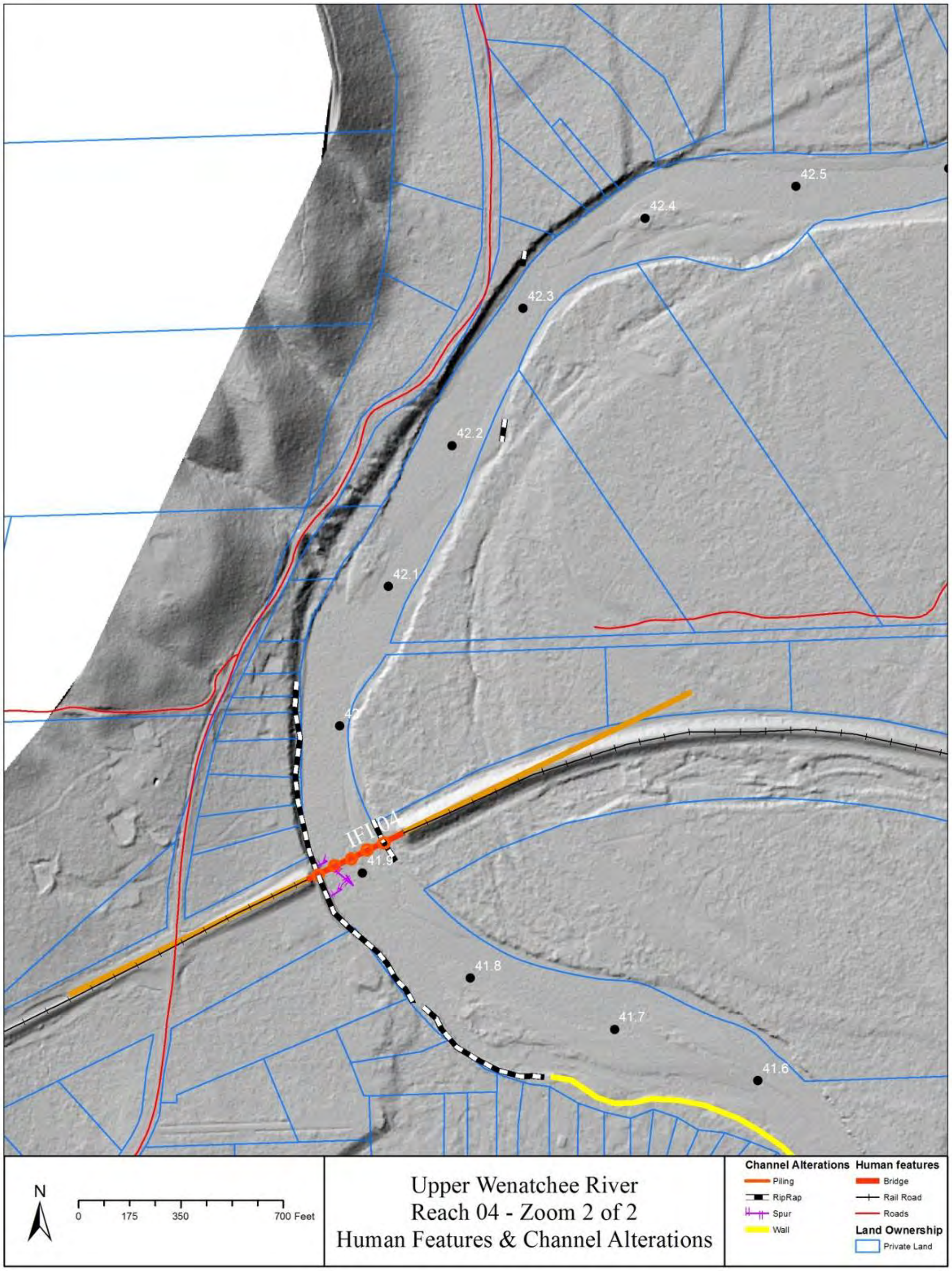

Figure 54. Human alterations in the downstream portion of Reach 4. Flow is from north to south.

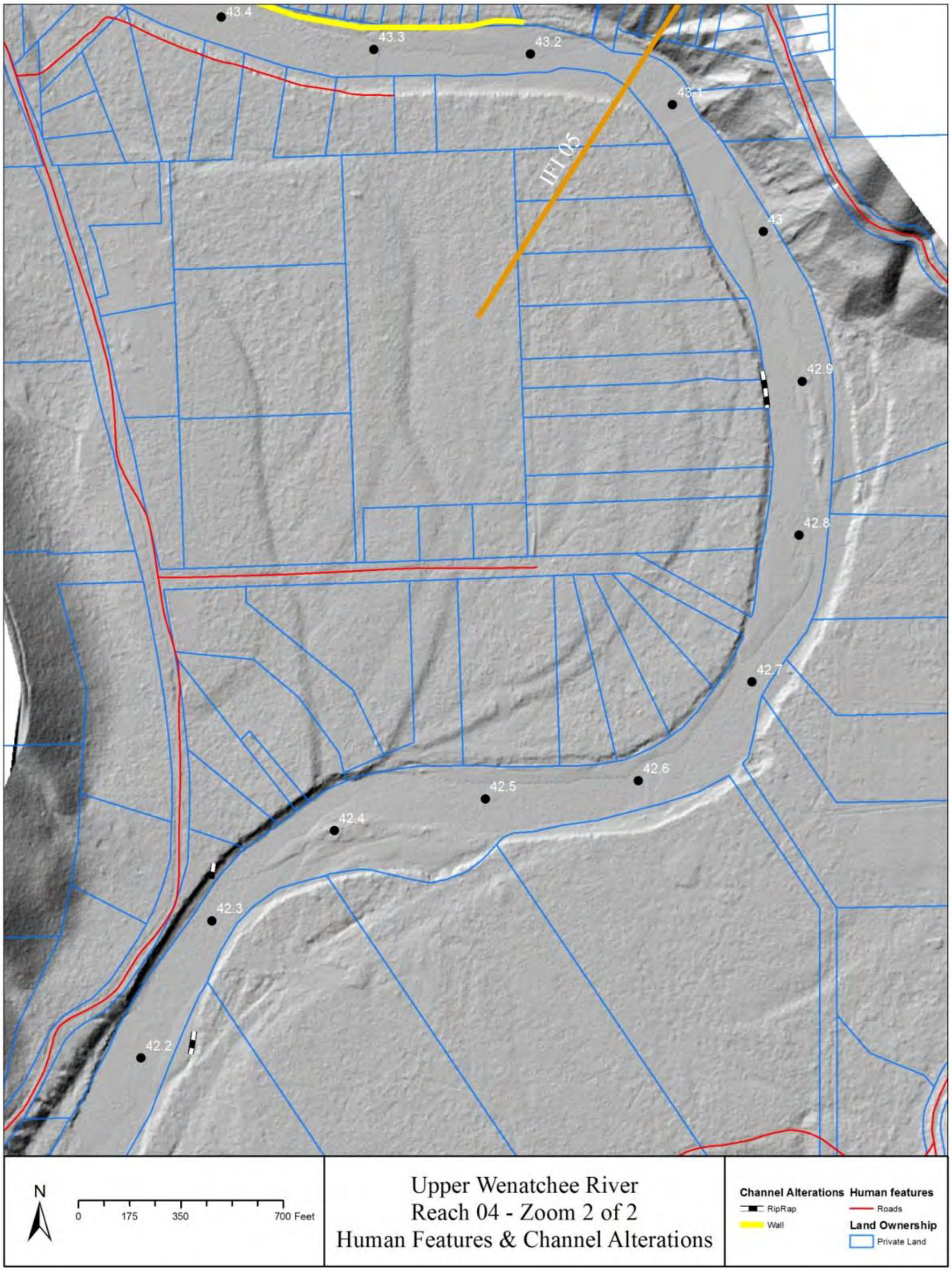

Figure 55. Human alterations in the upstream portion of Reach 4. Flow is from north to south.

4.5 Reach 5

4.5.1 Reach Overview

Reach 5 is 3.4 miles long and extends from RM 43.1 to the confluence of Beaver Creek at RM 46.5 (Figure 56). The reach is meandering and naturally confined within steep terrace banks and high walls of exposed Chumstick Formation. There are small narrow modern floodplain units and minimal bar development. Reach 5 receives surface water and sediment inputs from Beaver Creek (1-2 cfs throughout the year), which enters from river-left at RM 46.5. A second left bank tributary (waterfall) enters at RM 44.7 and provides additional but minimal surface water inputs. Residential development in Reach 5 increases substantially compared to the downstream reaches.

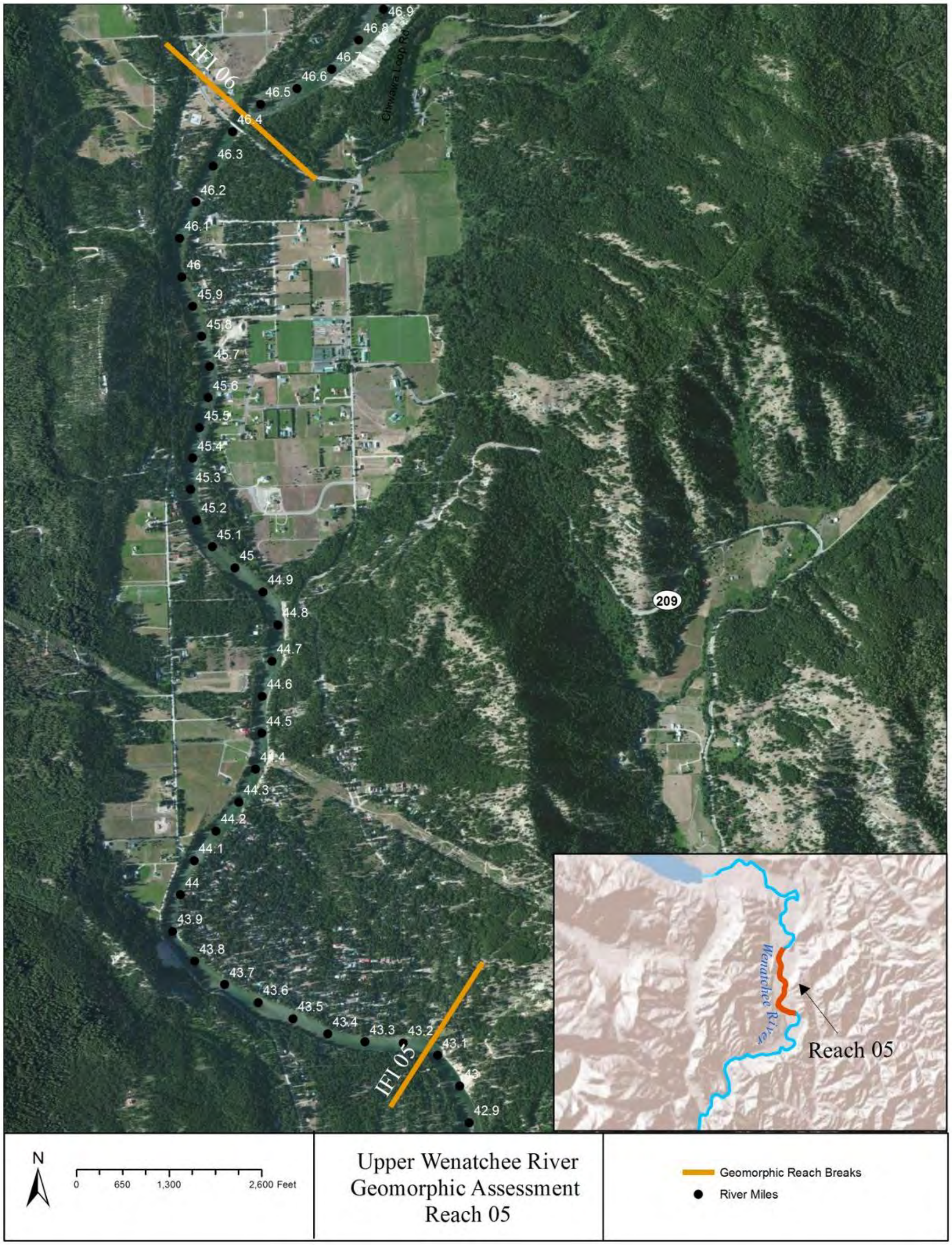

Figure 56. Overview map of Reach 5. Flow is from north to south.

4.5.2 Forms and Processes

Reach 5 is a slightly meandering reach with minimal bar and floodplain development (Figure 57). Overall sinuosity is 1.26 and it is more exaggerated in the downstream portion of the reach. The bed morphology is primarily riffle-glide with periodic shifts to pool-riffle sequences. The pools are channel-spanning and greater than eight feet deep. The riffles offer localized increases in velocity.

Figure 57. Representative geomorphology of Reach 5.

The channel and its modern floodplain are naturally confined within terraces of glacial outwash (Figure 58) and exposures of the Chumstick Formation. The glacial outwash terraces are a result of glacial meltwater mobilizing, transporting, and depositing materials in the Wenatchee valley during and after the last glacial period. Since deposition, the channel has incised into and reworked the glacial outwash deposits (NPCC 2004, Tabor et al. 1987). The channel is further confined by development and bank hardening of the marginal floodplain surfaces. Confinement limits lateral migration and exaggerates changes in flood stage relative to discharge. As a result the river is a transport dominant reach with minimal available off-channel habitat or large wood retention. The gradient of Reach 5 is 0.25%.

The banks of the low modern floodplain surfaces are sloping and composed of sands with cobbles at the base. They are vegetated with a well-established mix of riparian trees and shrubs. This provides canopy cover along the banks and future sources of large wood material. Bank slumping and mass wasting of the terraces in the upper portion of this reach has influenced the development of a few small narrow floodplain surfaces. The channel substrate ranges from sand to boulders, but cobbles are the dominant size class (41%) through the reach.

Figure 58. Terraced banks (alluvium terrace deposits). Terrace surface was approximately 8' above water surface elevation (August 2011).

4.5.3 Effects of Human Alterations

Anthropogenic landscape alterations are present throughout Reach 5. At the upstream-most end of the reach the Old Plain Bridge (RM 46.21) and the Beaver Valley Rd Bridge (RM 46.4) both have sets of cement pilings and associated large boulder riprap that influence flow patterns that create local scour pools. An additional set of pilings (RM 46.39) from a decommissioned bridge also remain in the channel. Because of natural confinement, it is unlikely that these pilings present a significant impediment to overbank flow.

Bank hardening (e.g. riprap, concrete walls) associated with homesite and road development and maintenance exists in Reach 5. Large granite boulder riprap lines a steep terrace bank at RM 43.6 to 44.1 where River Road runs parallel to the channel. Along the banks on river-left at RM 43.2 to 44.1 a series of riprap and cement walls periodically armor the bank.

Residential homesite development and its related infrastructure are located next to the channel on both the high terrace surface and many of the low floodplain surfaces. The development on the terraces does not have direct impact on the channel but secondary impacts such as vegetation alteration and bank stability are of concern. Development on the low floodplain surfaces include removal or alteration of riparian vegetation, grading of floodplain surfaces for homesites, and some infrastructure (access roads and utilities). As a result, minimal channel-floodplain interactions occur here and thermal shading has been reduced.

Historical timber harvest and log transport occurred throughout the study area. Potential impacts of these practices are discussed in detail in Section 3.4, which also includes a comparison of historical and current photos of this reach.

Locations of human alterations are displayed in Figure 59, Figure 60, Figure 61, and Figure 62.

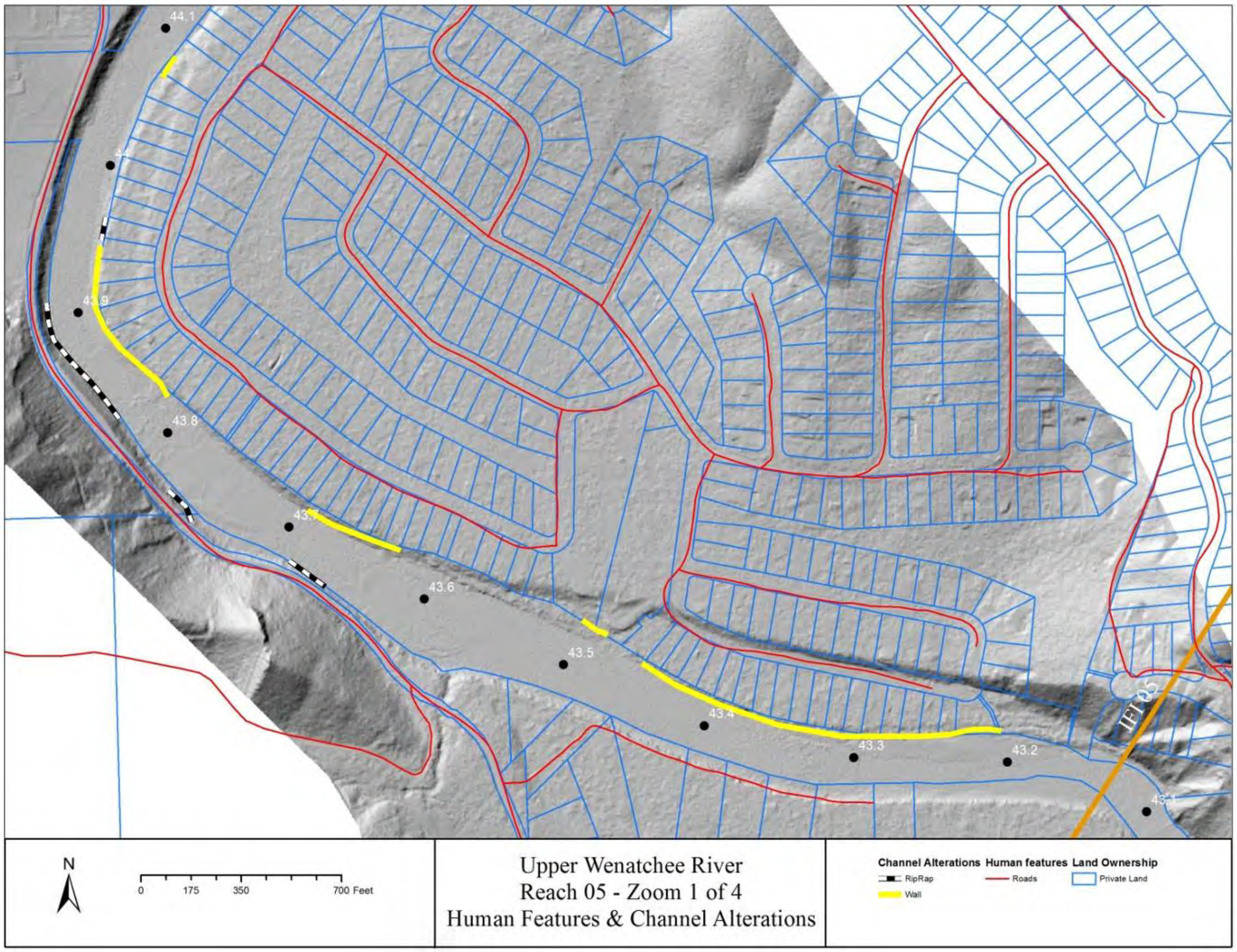

Figure 59. Human alterations in the downstream portion of Reach 5. Flow is from northwest to southeast.

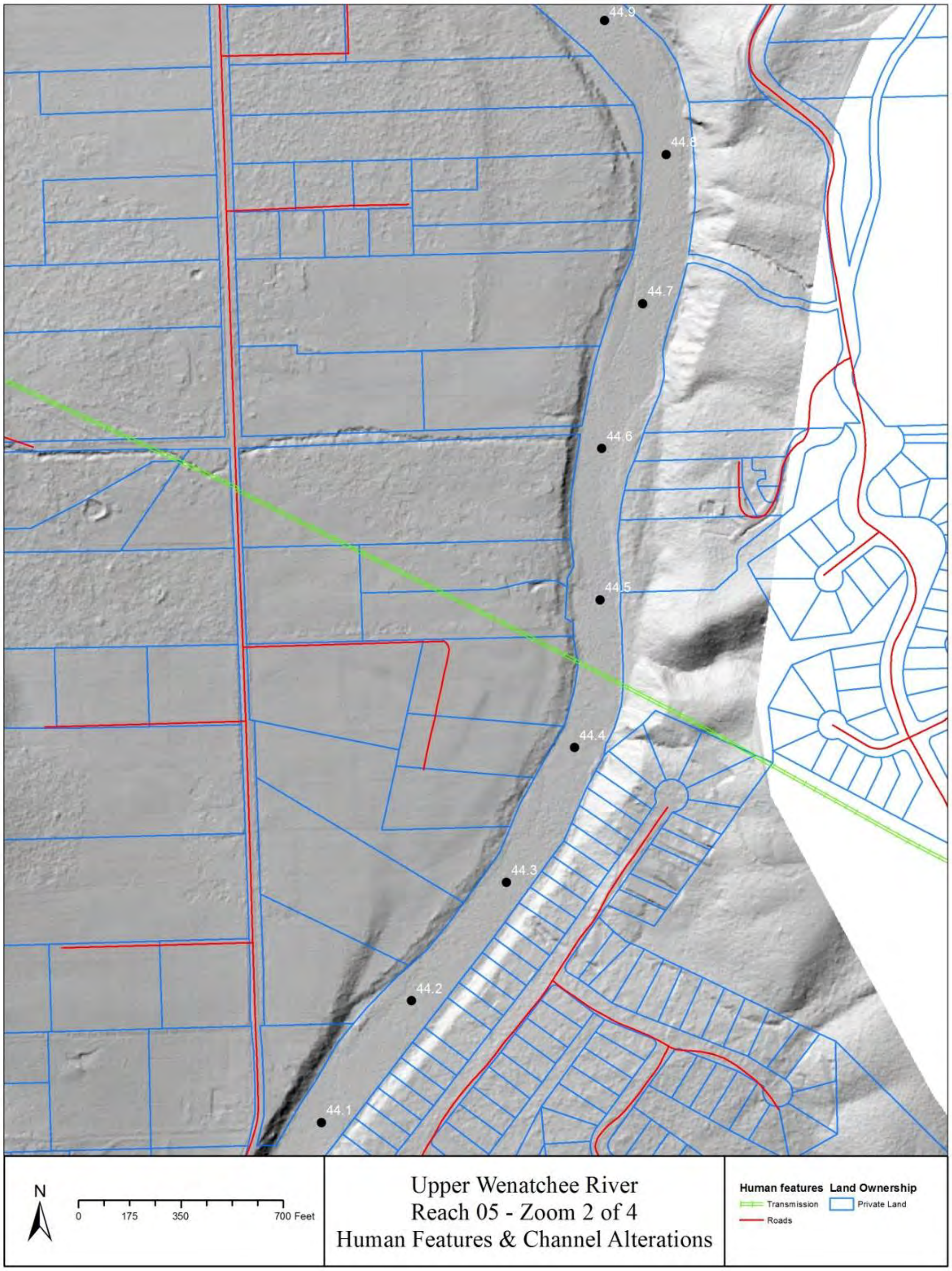

Figure 60. Human alterations in Reach 5. Flow is from north to south.

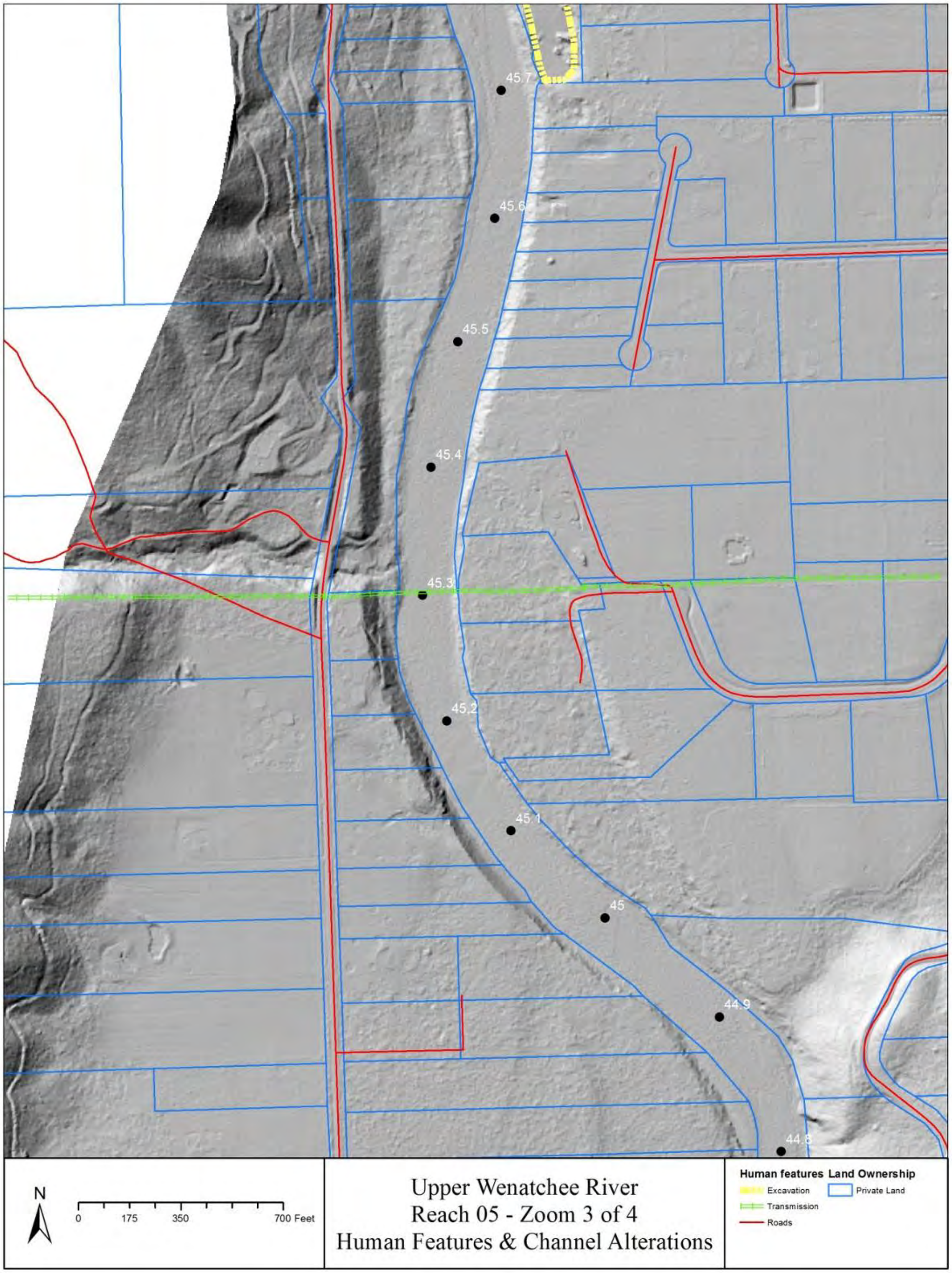

Figure 61. Human alterations in Reach 5. Flow is from north to south.

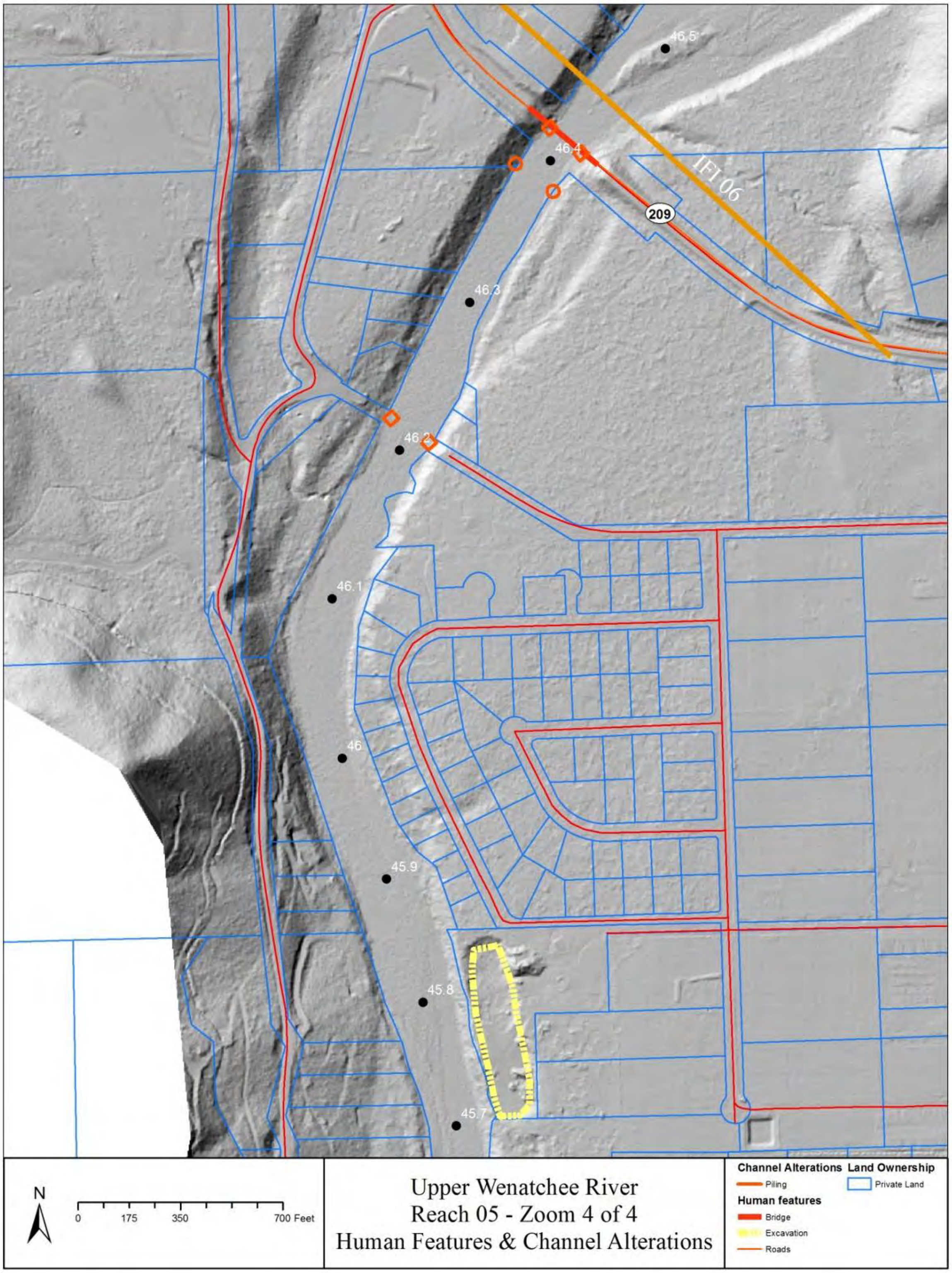

Figure 62. Human alterations in Reach 5. Flow is from north to south.

4.6 Reach 6

4.6.1 Reach Overview

Reach 6 is 1.4 miles long and extends from the confluence of Beaver Creek (RM 46.5) to RM 47.9 (Figure 63). This reach is partially confined and has only minor bar deposition. Large vegetated islands exist in the downstream portion of the reach where an exposure of the Chumstick Formation confines the channel on river-left. One unnamed tributary at RM 47.1 contributes negligible surface water inputs. Residential development has further confined this reach and likely accelerated its rate of channel incision by reducing the frequency and extent of floodplain inundation. Due to the prevalence of development on the floodplain, combined with natural channel confinement, there are limited restoration opportunities within the reach.

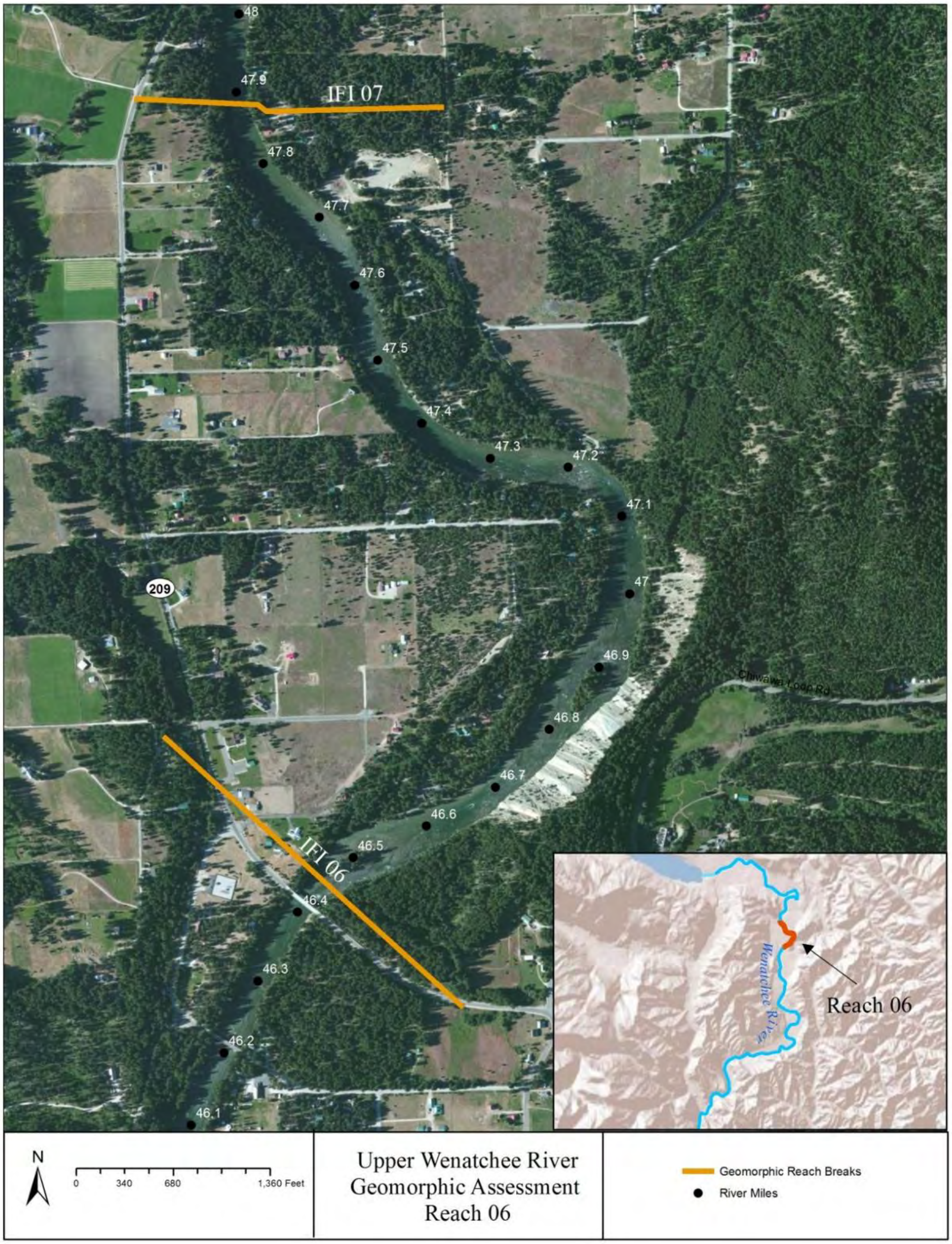

Figure 63. Overview of map of Reach 6. Flow is from north to south.

4.6.2 Forms and Processes

Reach 6 contains a meandering channel with a sinuosity of 1.44 and only minor bar development. Two large vegetated islands in the downstream section of the reach locally widen the channel and add complexity. The bed morphology is primarily riffle-glide with extended units of each. The glides are relatively short and narrower than the alternating riffle units in the straighter downstream portion. Substrate throughout the reach ranges from coarse sands to boulders with cobbles (45%) and boulders (30%) composing most of the bed material. Boulders are prominent in the riffles where gradient increases. In the downstream portion boulders are locally sourced from the adjacent Chumstick Formation.

The channel and its modern floodplain are partially confined by a steep wall of the Chumstick Formation on river-left (RM 47.1 to RM 49.7) and terraces of glacial outwash deposits on river-right (RM 47.4 to RM 47.9). See Figure 64 and Figure 65 for images of the confining terraces. Lateral left meander amplitude is controlled by the exposed Chumstick Formation. The vertical grade is likely controlled by bedrock of the Chumstick Formation at points throughout this reach, but high water velocities made this difficult to verify. The channel is further confined by development and bank hardening on modern floodplain surfaces. Reach 6 has the highest gradient within the study area with a gradient of 0.35%, creating higher flow velocities. Gradient is greatest in the downstream portion of the reach.

Despite the increase in slope and velocity in the downstream portion of the reach, there are two vegetated islands. These mid-channel areas of sediment storage briefly shift channel form to braided and offer access to lower-velocity side channels. According to the hydraulic analysis in Section 3.5.2, neither the floodplain nor the islands in Reach 6 are inundated during flow events equivalent to or less than the two year flood. Large bar apex logjams were located at the upstream end of each island at RM 46.54 and RM 46.92. The large wood, boulders, and islands offer refuge from high flow velocities and some minor margin complexity in the downstream portion of the reach.

The islands and floodplains are vegetated with mature trees and shrubs of mid-seral stage. Where development and bank hardening has occurred, the vegetation is altered. The island banks are sloping and composed of large cobbles topped with coarse sands. The banks of other floodplain surfaces are gradually sloping and composed of gravels to sands.

Figure 64. Chumstick Formation along river-left from RM 46.7 to RM 47.1

Figure 65. Terraced deposits forming right bank at upstream end of reach (August 2011).

4.6.3 Effects of Human Alterations

Throughout Reach 6 the floodplain has been modified by anthropogenic development. Eighty-one percent of the modern floodplain has been affected by bank armoring, levees, residential development, and riparian modifications in Reach 6 (see Appendix B). Residential homesite development and its related infrastructure are located next to the channel on both the high terrace surface and many of the low floodplain surfaces (Figure 66). Homesite development on the floodplain surfaces also includes floodplain dissection by roads and utilities installation, removal or alteration of riparian vegetation, fill or grading, and minor localized bank hardening (riprap constructed of tires).

On the river-left floodplain surface at RM 47.7 there is a 3.52 acre gravel excavation pit (Figure 67). Adjacent to the pit a push-up levee has been constructed along river-left to protect the excavation pit. The levee extends up and downstream of the pit in front of residential homes and alters the frequency and extent of floodplain inundation.

Figure 66. Homesites along the right bank across from the exposed Chumstick Formation (photo taken at RM 47.1, facing upstream).

Figure 67. Gravel excavation pit (highlighted in yellow) along left bank in upstream portion of Reach 6.

Historical timber harvest and log transport occurred throughout the study area. Potential impacts of these practices are discussed in detail in Section 3.4.3. The Habitat Assessment (Appendix A) includes a comparison of historical and current photos of this reach. Removal of timber along floodplain surfaces has also occurred.

Locations of human alterations are displayed in Figure 68 and Figure 69.

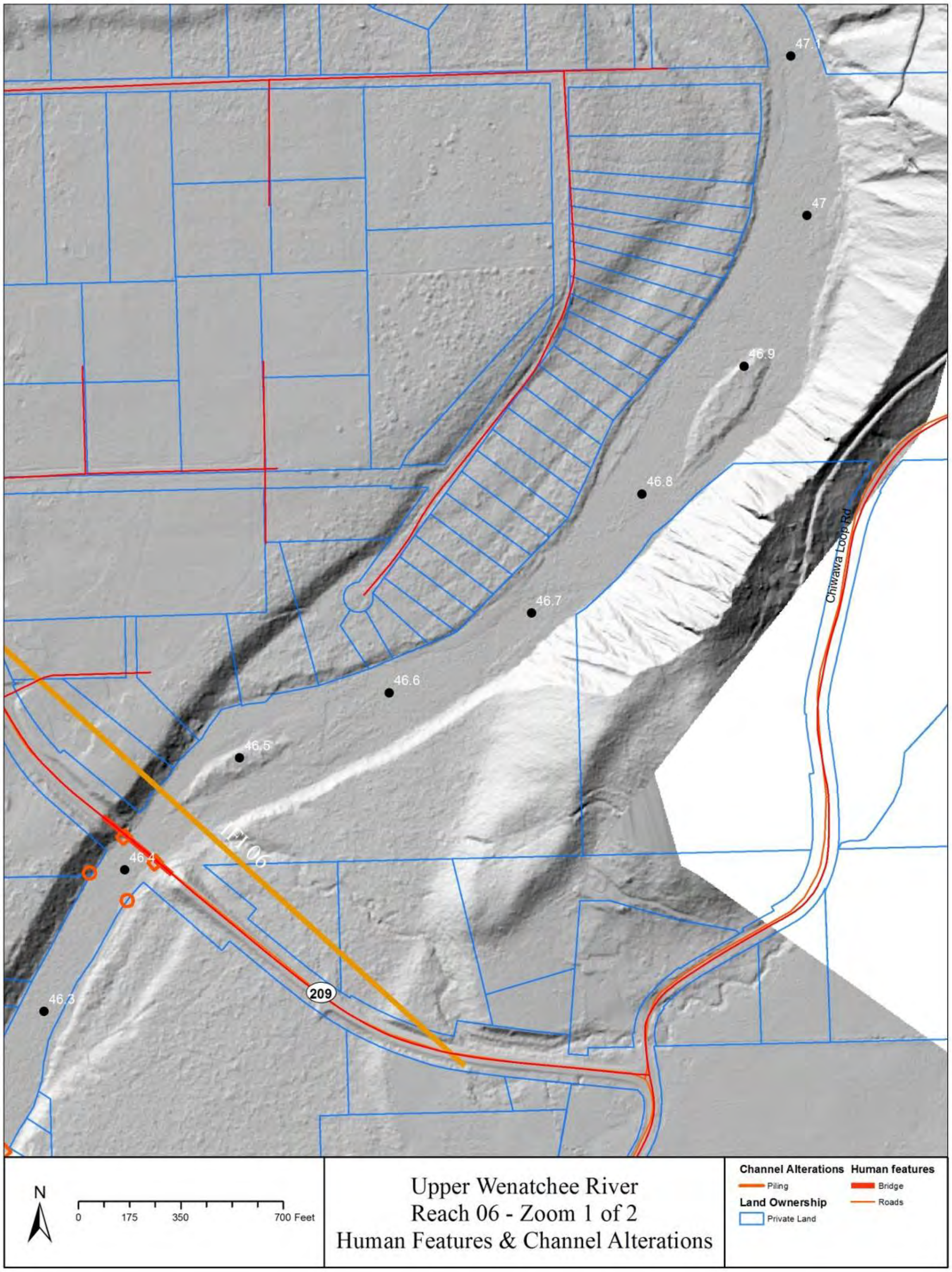

Figure 68. Human alterations in the downstream portion of Reach 6. Flow is from northeast to southwest.

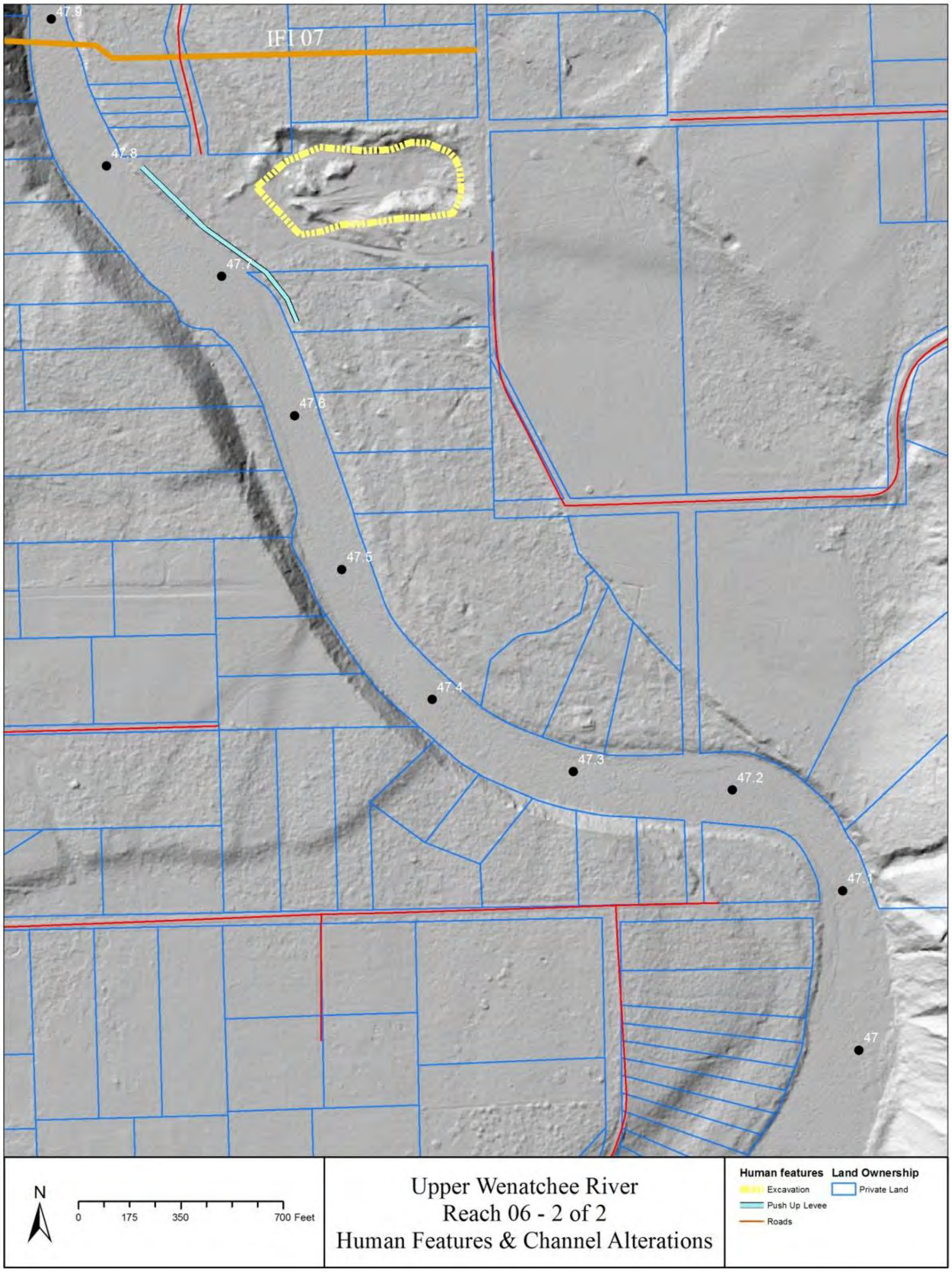

Figure 69. Human alterations in the upstream portion of Reach 6. Flow is from north to south.

4.7 Reach 7

4.7.1 Reach Overview

Reach 7 is 0.5 miles in length and extends from RM 47.9 upstream to the confluence of the Chiwawa River at RM 48.4 (Figure 70). The slightly meandering channel and its modern floodplain are confined by terraces of glacial outwash. Point bar development is present with minor large wood accumulations occurring along the margins of the channel. Surface water discharge and sediment inputs from the Chiwawa River influence channel form and processes in Reach 7. In places, residential development has impacted channel processes by altering or removing riparian canopy and influencing connectivity of floodplain surfaces. The natural and development-induced confinement presents few restoration opportunities.

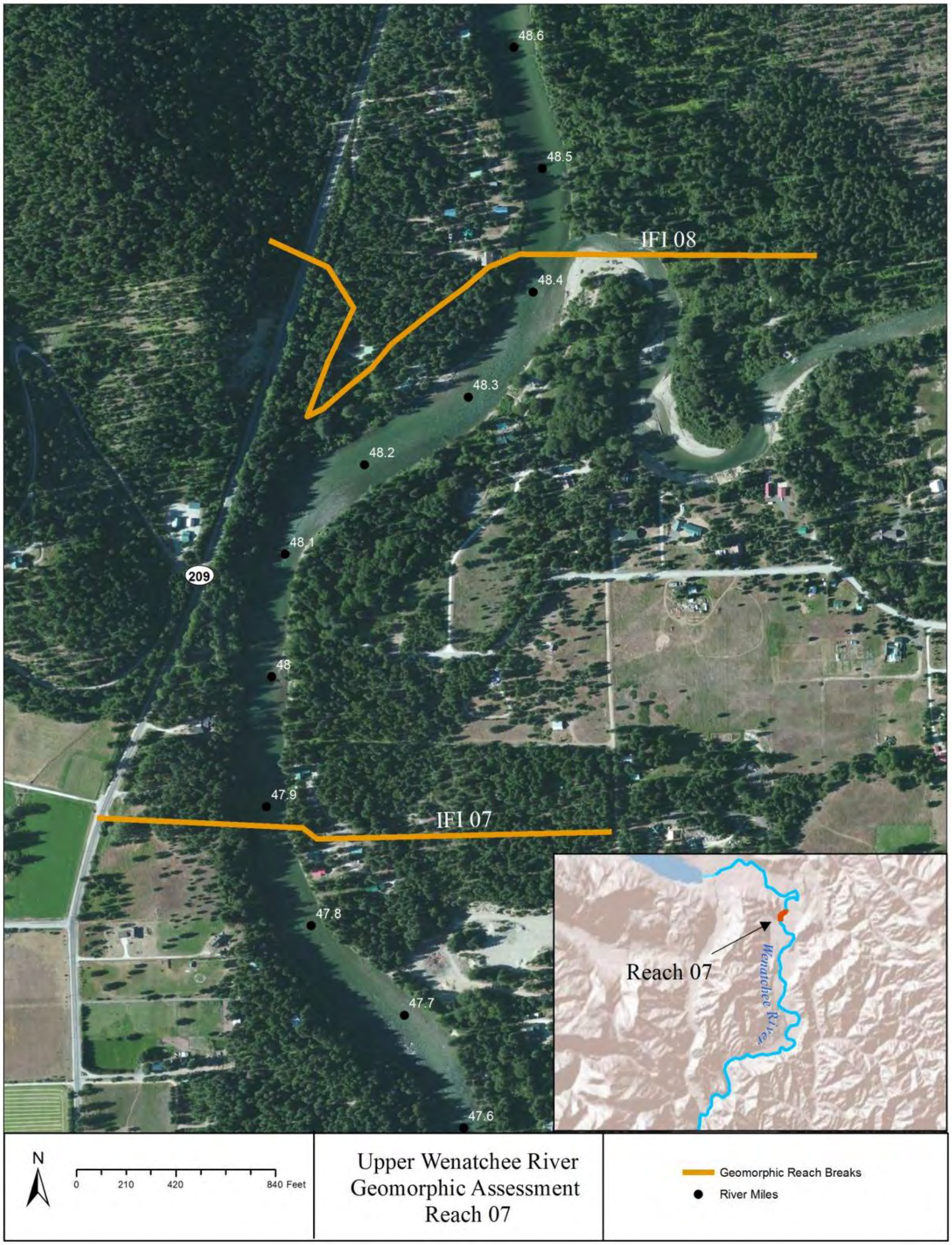

Figure 70. Overview map of Reach 7. Flow is from north to south.

4.7.2 Forms and Processes

Reach 7 contains a slightly meandering channel with minor point bar development but some lateral channel margin deposits. The point bars (RM 48 and RM 48.15) have slowly vegetating bar-tail deposits on the downstream ends. Bed morphology is riffle-glide (Figure 71) with the exception of a pool located downstream of the convergence of the Chiwawa River.

Figure 71. Riffle-glide facing downstream standing on Chiwawa River's alluvial fan.

Channel morphology and hydraulics are influenced in Reach 7 by an increase in discharge and sediment sourced from the Chiwawa River and its alluvial fan (Figure 72). Relative to upstream, the channel widens slightly and velocity increases. The increased flow allows the channel to effectively transport the increased bed-load inputs. Hyporheic flow exchange is evident within the alluvial fan deposits at the confluence of the Chiwawa and Wenatchee Rivers. Substrate ranges from sands to boulders with boulders (35%) and cobbles (33%) dominating. Sands to cobbles are prominent at the Chiwawa River confluence (Figure 73).

Figure 72. Alluvial fan deposits from Chiwawa River.

Figure 73. Sand to cobble on alluvial fan of Chiwawa River.

The channel and its modern floodplain are partially confined by terraces of glacial outwash deposits. The channel abuts the high terrace bank on river-right from RM 47.9 to RM 48.14. The modern floodplain surfaces are low with sloping banks and alternate between human-altered and functioning. Hydraulic modeling of floodplain inundation reveals that most of the modern floodplain surfaces in Reach 7 are not inundated with flow events equivalent to or less than the two year flood (Section 3.5.2). This suggests that incision is occurring in this reach even with the additional sediment inputs from the Chiwawa River and its alluvial fan. The relatively short length of the reach and terrace confinement result in a sinuosity of 1.06. The gradient of Reach 7 is 0.25%. Slope is greatest in the downstream portion of the reach where the channel is confined by the terrace. Here transport capacity of wood and sediment also increases, as evidenced by modern scour at the base of riparian vegetation throughout the reach (Figure 74).

Only minor large wood accumulations occur along the margins of the channel. Floodplain surfaces are vegetated with mature trees and shrubs except where vegetation has been altered or removed at homesites.

Figure 74. Scour at base of mature ponderosa pine in riparian area.

4.7.3 Effects of Human Alterations

Human alterations affecting the channel are primarily restricted to the left bank. These alterations include home development and riparian vegetation removal and/or alteration. Where homesite development has occurred much of the floodplain has been altered by fill or grading. The riparian canopy has been completely cleared at many homesites, and at other sites, understory shrubs and saplings have been cleared and only select large trees remain. Where canopies have been completely cleared, lateral channel scour is undercutting banks and they are slumping into the channel (Figure 75 and Figure 76).

Figure 75. Clearing of riparian vegetation resulting in bank slumping.

Figure 76. Left bank slumping due to lack of riparian vegetation.

The modern floodplain and its banks alternate between human altered and functioning (Figure 77 and Figure 78). In the lower portion of the reach fewer impacts to riparian vegetation have occurred in conjunction with homesite development. However, the relative seral stage of these canopies is young compared to intact riparian canopies. Only small-scale riprap was observed at two sites and presents minimal influence on the channel or floodplain inundation.

Figure 77. Homesite where small willows and dogwood has been allowed to establish.

Figure 78. Intact riparian canopy.

Historical timber harvest and log transport occurred throughout the study area. Potential impacts of these practices are discussed in detail in Section 3.4.3. Removal of timber along floodplain surfaces has also occurred.

Locations of human alterations within Reach 7 are located in Figure 79.

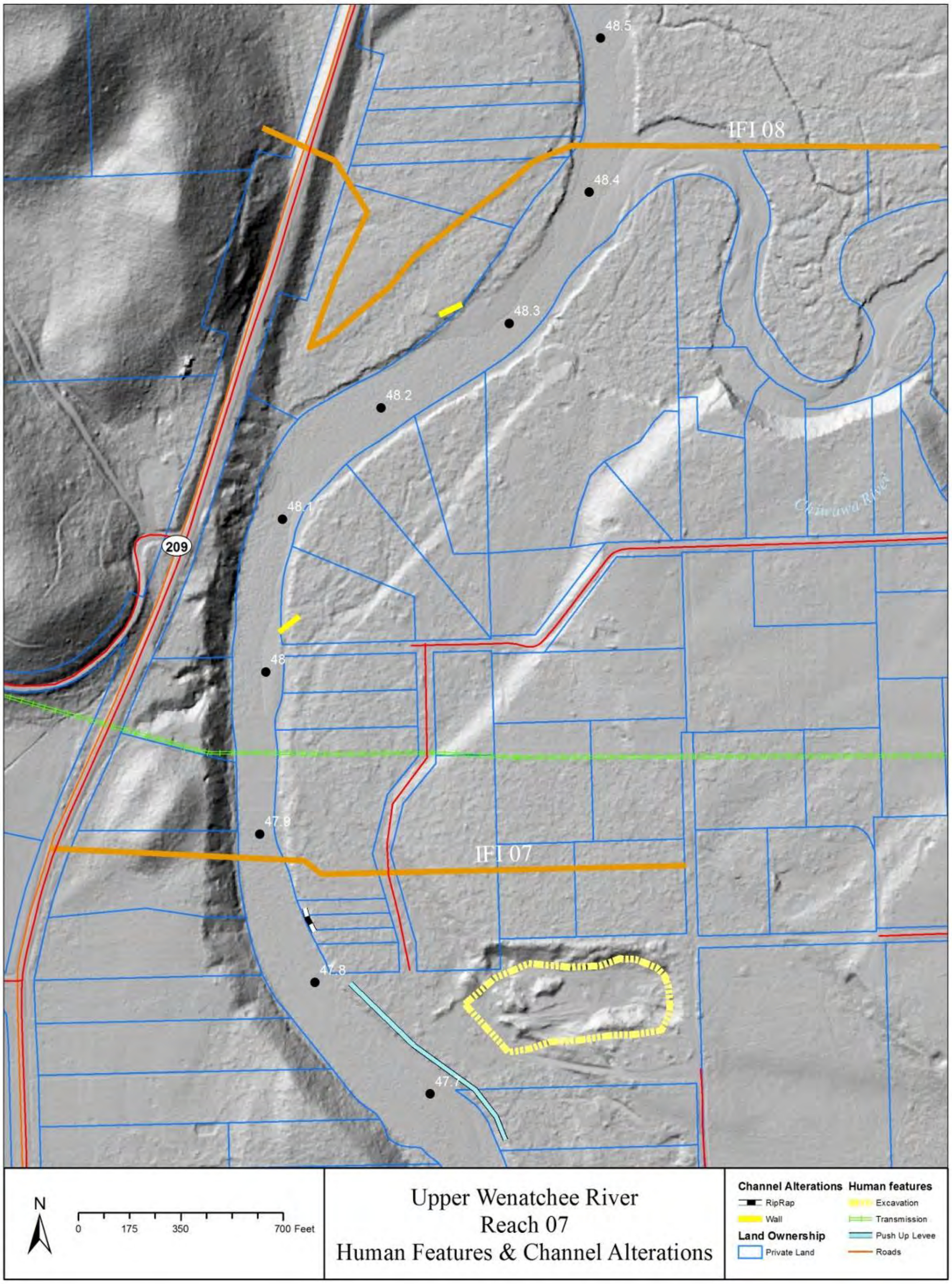

Figure 79. Human alterations in Reach 7. Flow is from north to south.

4.8 Reach 8

4.8.1 Reach Overview

Reach 8 is 1.3 miles long and extends from the confluence of the Chiwawa River (RM 48.4) to RM 49.7 (Figure 80). The channel is meandering with point bar development and two mid-channel bar features. Channel bank confinement from terraces of glacial drift and outwash deposits alternates with modern floodplain banks. A few small ephemeral streams sourced off the terraces and hillslopes contribute minor seasonal discharge inputs into the Wenatchee River. This reach offers both connected and disconnected backwater habitat within the modern floodplain surfaces. Geomorphic forms and processes are relatively unaffected by human disturbance on the floodplain and terrace surfaces that are managed by the US Forest Service. On private and state lands, anthropogenic development, including bank hardening, has disconnected portions of the modern floodplain.

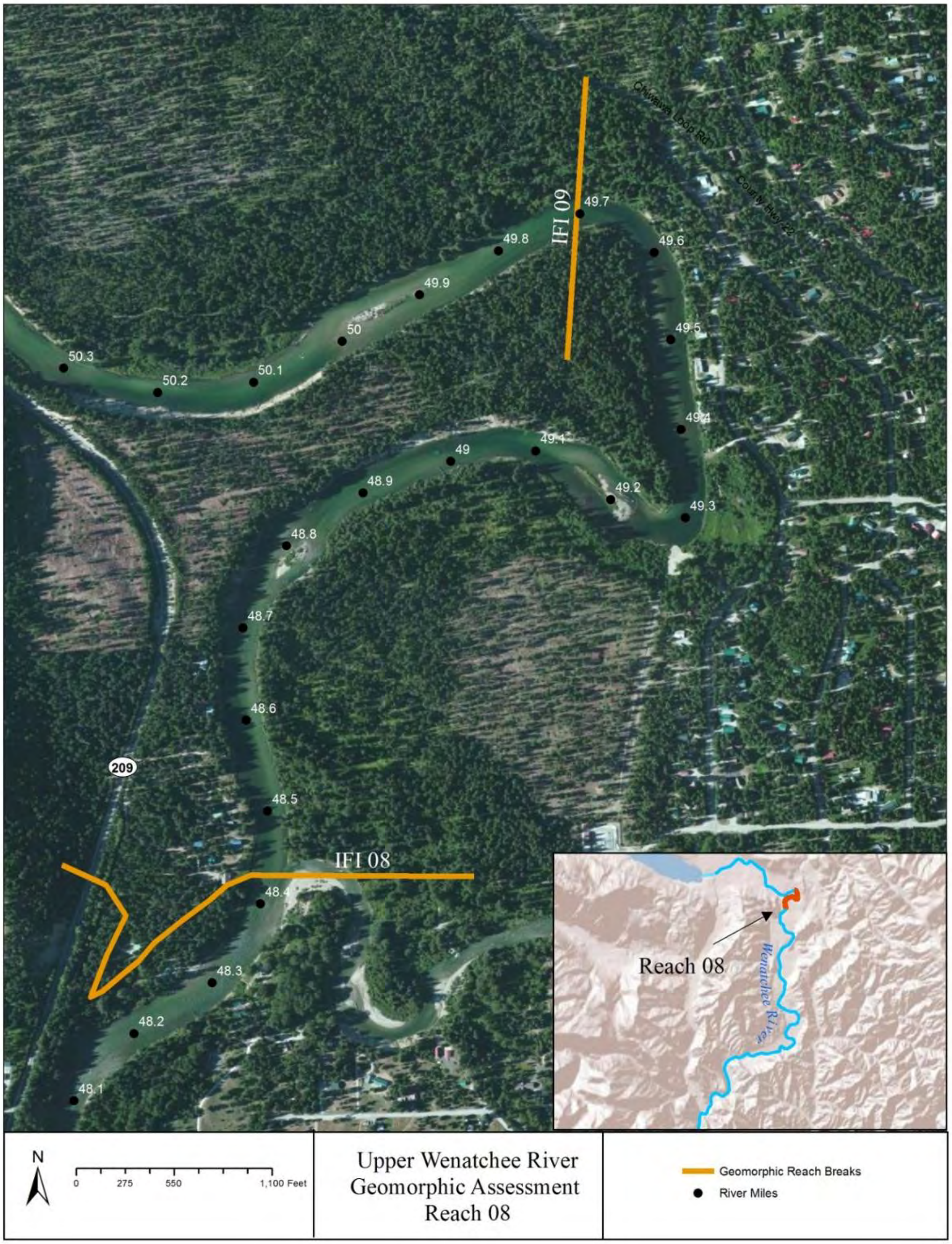

Figure 80. Overview map of Reach 8. Flow is from north to south.

4.8.2 Forms and Processes

Reach 8 is a meandering reach with a channel sinuosity of 1.62. Bar development is occurring as narrow elongate point bars associated with meanders and two established mid-channel bars located within riffles at RM 48.4 and RM 49.2. Bed morphology is mostly pool-riffle with interspersed glide units. A large channel-spanning pool is located at the meander at the upstream-most portion of the reach. The pools are relatively long and deepest at meander bends (RM 49.3 and RM 49.1). Substrate ranges from sands to boulders but is dominated by cobbles (39%) and gravel (30%).

This reach is partially-confined by terraces of glacial drift and outwash. Ninety percent of the right bank is confined by glacial terraces and river-left abuts terrace banks at RM 49.45 to RM 49.7. The channel is further confined in the downstream portion of river-right by the disconnection of the modern floodplain from anthropogenic development. The low modern floodplain surfaces alternate with terraces to form the channel banks. Overall gradient of the reach is 0.12%.

In the upstream portion of the reach incision (translating into Reach 9) is resulting in minor floodplain disconnection. Multiple elevations of abandoned floodplain surfaces exist along the left bank indicating a long-term process of incision. A disconnected floodplain wetland on river-left at RM 49.3 is evidence of more modern incision. The upstream-most modern floodplain surface on river-right has sandy soils but inundation is historical or only very infrequent Hydraulic modeling of floodplain inundation (Section 3.5.2) confirms these findings. Low elevation floodplain surfaces with sloping banks are present further downstream where modern incision processes are minimal. These lower surfaces house narrow backwater habitats that connect to the main channel at the downstream end. These backwaters exchange both surface and hyporheic flow with the mainstem Wenatchee (Figure 81).

Floodplain surfaces are well-vegetated with a mix of conifers and shrubs. Riparian and modern floodplain vegetation has been removed or altered in areas of development. Large wood is lacking in the system with only minor accumulations occurring along the margins. Tree mortality atop the high terrace banks offers key pieces of wood to the system that could promote large wood accumulations.

Figure 81. Off-channel habitat at RM 49.2 (river-left) looking downstream (left photo), and looking upstream (right photo).

4.8.3 Effects of Human Alterations

Floodplain connection is limited by geologic factors, incision, and anthropogenic development. The hydraulic analysis and modeling of floodplain inundation indicates that floodplain connectivity is reduced below its potential in Reach 8 (Section 3.5.2). Without historical data it is not possible to determine how much human alterations have affected natural rates of incision and channel evolution in Reach 8. However, it is clear that anthropogenic development has directly disconnected portions of the floodplain from the channel. Beginning at RM 48.7, fill and construction of Beaver Valley Road (Highway 209) has disconnected pockets of the floodplain behind it on river-right. Where homesite development has occurred the floodplain is dissected by roads, vegetation has been altered or removed, and many surfaces have been filled or graded.

Bank hardening at RM 49.3 further impairs floodplain inundation and lateral migration. A cement and steel retaining wall protrudes slightly into the channel protecting the bank from all channel processes (Figure 82). The wall is part of the Washington Department of Fish and Wildlife's Chiwawa Ponds fish hatchery facility. This facility also includes fill and small buildings. Just upstream from the fish hatchery facility the floodplain surface has been graded and much of the native vegetation has been removed (now dominated with mowed grass) to facilitate community recreational activities. This area contains a disconnected wetland complex. According to the hydraulic modeling, the fish pond facility and its structures directly limit inundation on this low surface. The nearby disconnected wetland complex does get inundation with flows equivalent or less than a two year flood event.

Figure 82. WDFW Chiwawa Ponds Fish Hatchery intake structure.

Without historical data it is difficult to determine if the lack of large wood in the system is a result of localized riparian clearing or historical logging practices that cleared and scoured the channel for log transport. Other potential impacts of historical logging practices are discussed in detail in Section 3.4.3.

Human alterations are mapped in Figure 83 and Figure 84.

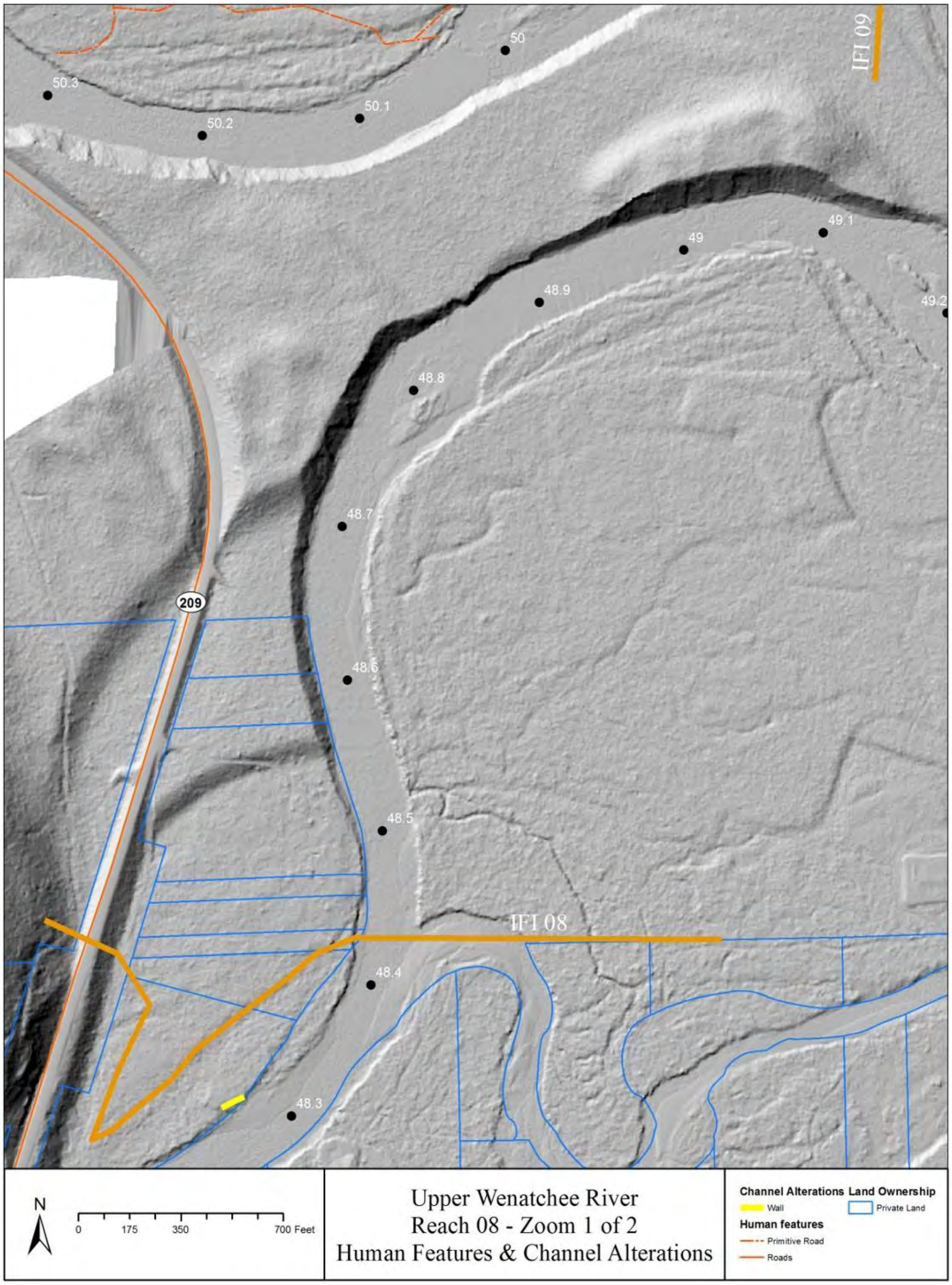

Figure 83. Human alterations in the downstream portion of Reach 8. Flow is from north to south.

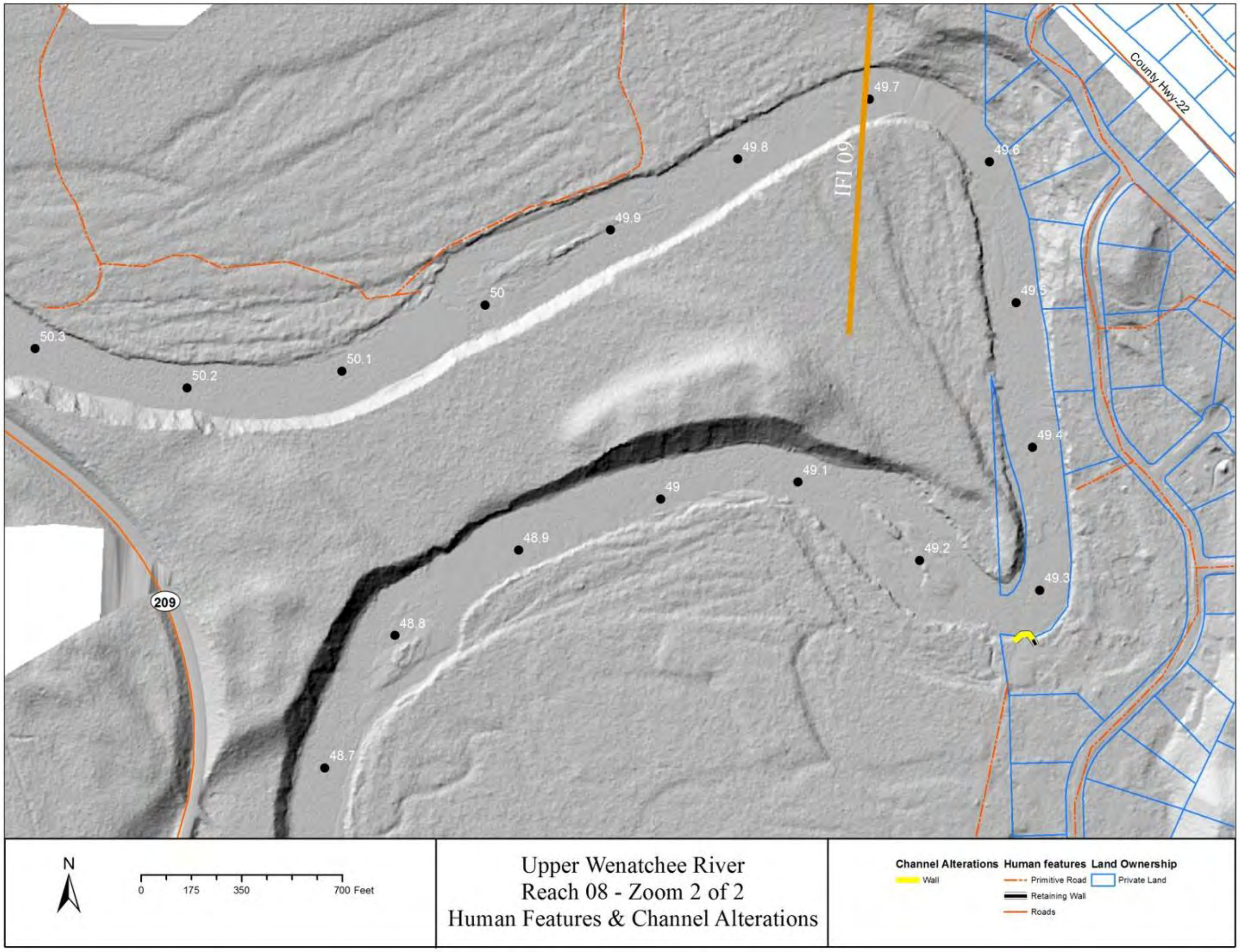

Figure 84. Human alterations in the upstream portion of Reach 8. Flow is from northwest to the south.

4.9 Reach 9

4.9.1 Reach Overview

Reach 9 extends 1.92 miles from RM 49.73 to RM 51.65 (Figure 85). This channel slightly meanders through a partially confined alluvial valley. High quality connected backwater habitats and disconnected wetlands are located within the low elevation floodplain surfaces. The banks alternate between modern floodplain surfaces and high steep terraced banks of glacial drift and outwash. Incision is notably reducing floodplain connectivity in the downstream portion of the reach. A few small ephemeral streams sourced off the terraces and hillslopes contribute minor seasonal discharge inputs into the Wenatchee River. There is evidence of past riparian timber harvest. This reach is bordered primarily by public lands managed by the US Forest Service. The high steep terrace walls make access challenging on river-right in the downstream portion of the reach.

Figure 85. Overview map of Reach 9. Flow is from northwest to southeast.

4.9.2 Forms and Processes

Reach 9 contains a slightly meandering channel with a sinuosity of 1.28. Channel morphology is largely homogeneous plane-bed with riffle-glide characteristics. The riffle-like characteristics include an increase in channel width and gradient, and a slight decrease in depth, and at RM 49.98, the development of mid-channel bar complexes that are associated with a bar apex logjam. At the downstream-most portion of the reach, the glide deepens as the channel approaches the meander bend to meet the deep channel-spanning pool of Reach 8. Substrate ranges from sands to sparse boulders, but gravels (47%) and sands (26%) dominate the composition of the channel bed as well as the modern floodplain surfaces.

The channel and its modern floodplain are partially confined by terraces of glacial drift and outwash. The steep terrace banks supply sediment to the system at cut-bank exposures. Minor periodic large-wood inputs are supplied by the forested terrace surfaces that create wood accumulations at the base of the terrace slope (Figure 86). Alternating terrace banks have naturally limited the channel's lateral migration throughout the reach.

Figure 86. Example of a channel margin large wood accumulation from steep terrace banks.

The modern floodplain surfaces contain backwater and wetted off-channel habitat. The backwater habitats are connected to the channel at the downstream outlets of partially abandoned secondary or overflow channel scars. Wetland habitats occupy similar features but surface water connectivity with the main channel has been eliminated by incision and/or outlet infilling in the downstream portion of the reach. This pattern of connectivity is visible in the inundation analysis presented in Section 3.5.2. The wetland habitats and backwater in the upper portion of the reach are regularly inundated and their surrounding floodplain surfaces are almost fully inundated with flows equivalent to a two-year flood event. The backwaters exchange both surface and hyporheic flow with the channel.

The gradient of Reach 9 is 0.04%, less than half that of Reach 8 and 10. However, the minimal complexity and relative straight form of the channel through Reach 9 gives the flow a stream power that is more than half of its neighboring reaches (Section 3.5.2). Incision is resulting in the disconnection of modern floodplain surfaces in the downstream portion of the reach. Evidence of relatively modern incision includes recently abandoned or very rarely inundated floodplain surfaces, a hanging tributary junction at RM 49.8 on river-left, and surface topography of elevated point bar scrolls at RM 50.2 that are now sequentially vegetated with maturing forest.

If incision continues in Reach 9, it has the potential to lead to reduced channel complexity, increased channel slope and flow energy, reduced flood peak attenuation, and increased peak magnitude for a given event. A lack of bedrock in Reach 9 means that incision processes have the potential to migrate upstream and start reducing inundation rates in Reach 10.

The floodplain and terraces bordering the channel are well vegetated with maturing mixed forests. This provides for well-functioning canopy cover throughout the reach. Despite the vegetated banks, Reach 9 is lacking in large wood. Some accumulations are found at the margin of the channel and at one apex jam on the mid-channel bar complex located at RM 49.98.

4.9.3 Effects of Human Alterations

Minor anthropogenic alterations currently exist within Reach 9. There are no private land-holdings but established transportation routes directly influence two of the floodplain units. Fill used in the construction of Beaver Valley Road (Hwy 209) isolates floodplain surfaces from channel processes on river-right between RM 50.3 and 50.75. A set of primitive dirt roads and trails cross the downstream river-left floodplain unit between RM 49.7 and 50.5, but these appear to impose little to no impact on river processes.

Evidence of historical timber harvest and log transport exists throughout the study area. Potential impacts of these practices are discussed in detail in Section 3.4.3. Notable in Reach 9 is the historical harvest of mature trees, lack of channel complexity and form, and creosote soaked logs buried in the banks and bed of the channel. These clues suggest bed scour and channel simplification as a result of harvest practices. Without historical data it is difficult to know how much incision processes have been accelerated by historical timber harvest practices compared to natural downcutting through the glacial drift and outwash deposits. Regardless, simplification and resultant incision of the channel’s bed has led to variability in floodplain connectivity within Reach 9. The pattern of incision and disconnection in the downstream portion of the reach is visible in the inundation analysis presented in Section 3.5.2. These processes are also influencing floodplain connectivity in the upstream-most portion of Reach 8.

Human alterations are mapped in Figure 87, Figure 88, and Figure 89.

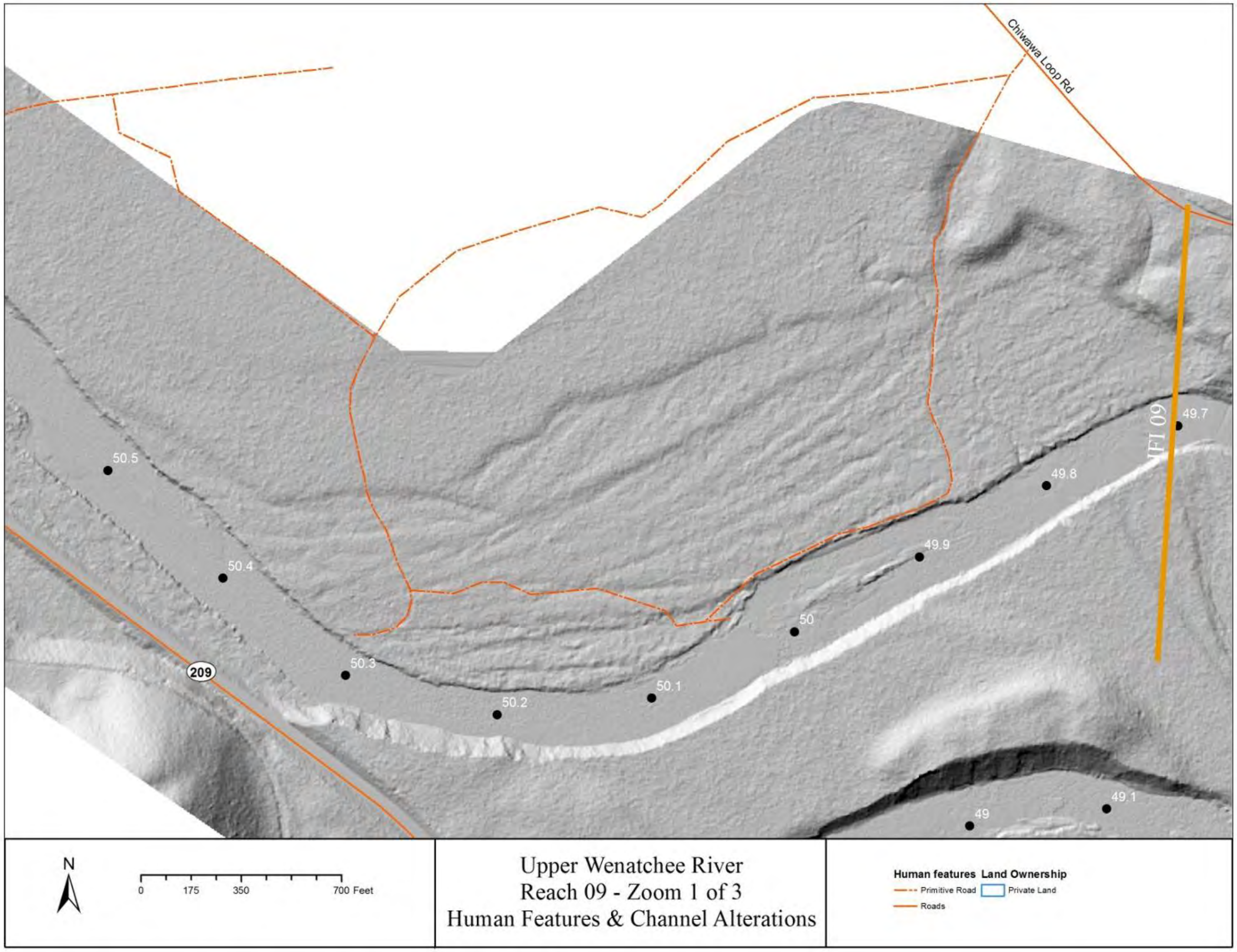

Figure 87. Human alterations in the downstream portion of Reach 9. Flow is from west to east.

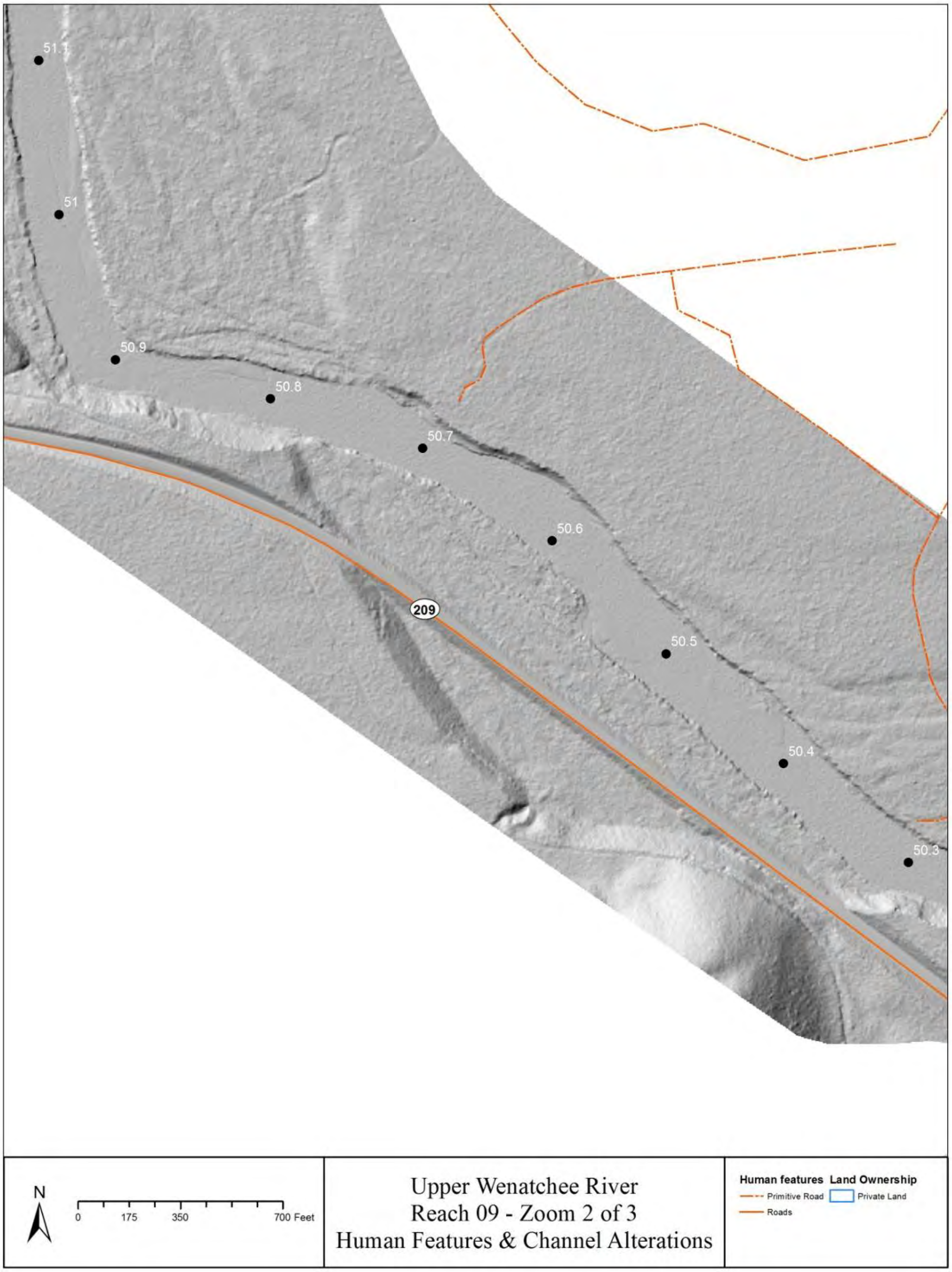

Figure 88. Human alterations in the Reach 9. Flow is from northwest to southeast.

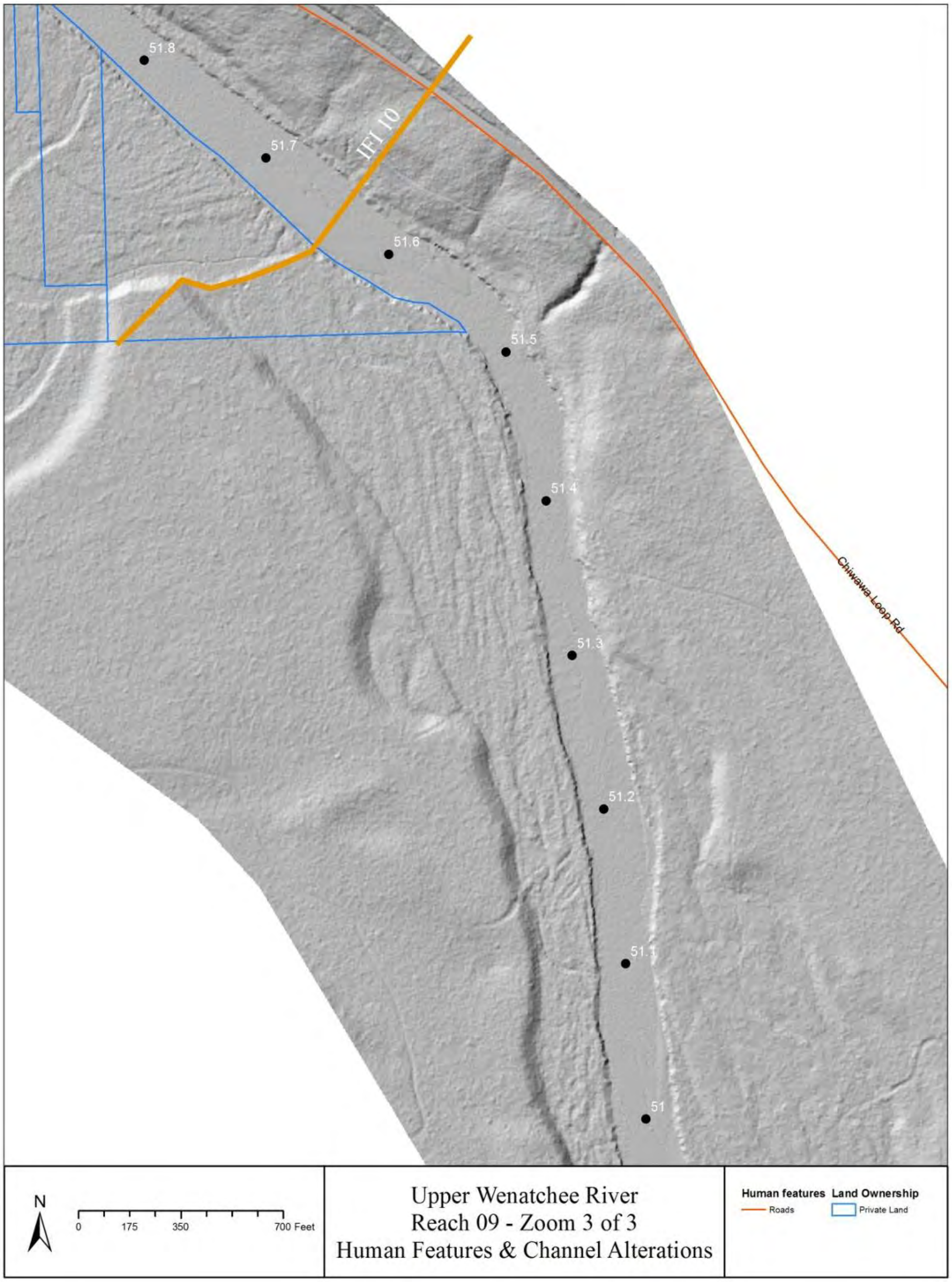

Figure 89. Human alterations in the upstream portion of Reach 9. Flow is from north to south.

4.10 Reach 10

4.10.1 Reach Overview

Reach 10 is 2.02 miles long and extends from RM 51.65 upstream to the confluence with Nason Creek at RM 53.67 (Figure 90). The channel meanders through a wide alluvial reach that is partially confined by terraces of glacial drift and outwash. Floodplains contain large complex backwaters and off-channel aquatic habitat located in abandoned channels and scroll scars. Surface water discharge and sediment inputs from Nason Creek influence channel form and processes in Reach 10. Fish Lake Run Creek is a small tributary that enters the mainstem via the backwater complex at RM 52.1. Other small ephemeral streams sourced from the hillslopes contribute additional seasonal surface water inputs. Anthropogenic impacts associated with homesite development dominate processes on the right bank. Additional impacts from bridge/road construction and historical logging practices are also evident. Most of the river-left floodplain is US Forest Service land.

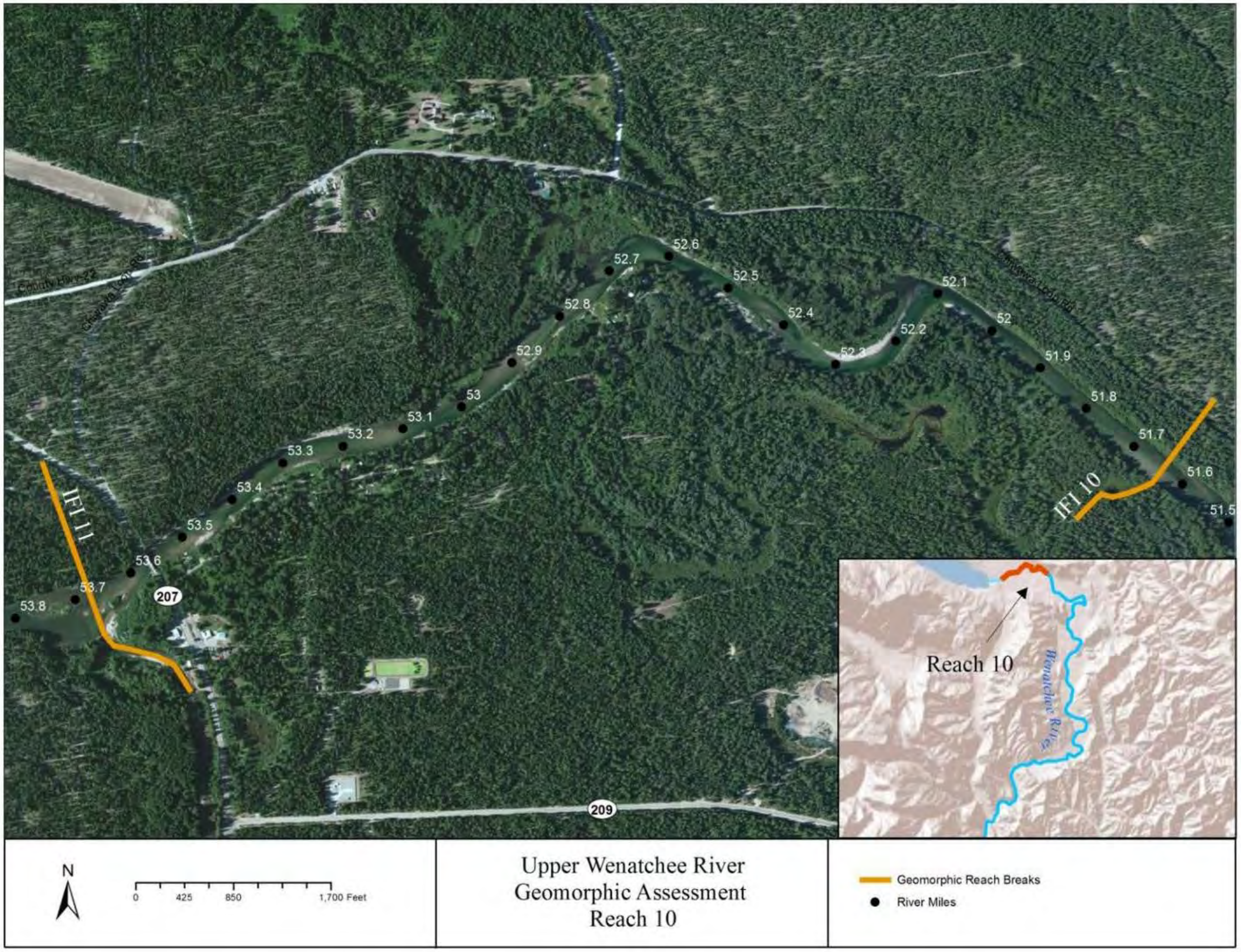

Figure 90. Overview map of Reach 10. Flow is from west to east.

4.10.2 Forms and Processes

Reach 10 contains a slightly meandering channel with long straight sections in the up and downstream portions. The channel's sinuosity is 1.23 with a gradient of 0.11%. Bed morphology is a mix of subtle pool-riffle and plane-bed glide units. Near the confluence with Nason Creek and where the channel is more sinuous, complexity of bed morphology is greater. Point and mid-channel bar development occurs in the upper half of the reach prior to channel simplification in the downstream portion. Substrate ranges from sands to sparse boulders with cobbles (49%) and gravel (36%) dominating the composition of the channel bed.

The channel and its modern floodplain occupy a partially-confined alluvial valley with an average width of 786 feet. Terraces of glacial drift and outwash confine the channel on river-left at RM 53.05 to RM 53.7 and at RM 52.6 (Figure 91). Homesite development and bank hardening on river-right at RM 52.6 to RM 53.57 further confine lateral channel migration in the upper portion of the reach (Brae Burn Rd area). Historical survey maps and channel migration scars visible in high resolution LiDAR imagery indicate that this reach was more sinuous and actively mobile in recent history.

Figure 91. Representative geomorphology of Reach 10 with river-left terrace confinement and low-elevation river-right floodplain surfaces.

Depositional patterns, photo imagery, and floodplain topography suggest that the majority of alluvial floodplain materials in Reach 10 originated as fan deposits from Nason Creek. Inputs from Nason Creek had a greater influence on the geomorphic processes of Reach 10 prior to road and bridge construction that now confines the location of the confluence. Based on bar and island development at the modern confluence, Nason Creek still provides substantial bedload that influences channel processes at its mouth (Figure 92).

Figure 92. Point bar development as part of the alluvial fan deposits at the mouth of Nason Creek.

The modern floodplains are composed of sands to cobbles with bank steepness increasing relative to increasing sand/loam content. Floodplain bank elevations range slightly in Reach 10 but all are capable of being inundated during flood flows. Hydraulic modeling presented in Section 3.5.2 confirms that a large portion of the modern floodplain surfaces are capable of being inundated during flow events equivalent to a two year flood.

The floodplains in Reach 10 contain extensive off-channel wetlands and large connected backwater complexes. Both features are located in abandoned channel scars or scrolls and offer highly functioning habitat. The extensive wetland features are located within the downstream half of the river-right floodplain (Figure 93). These features are disconnected from each other and the mainstem channel, except during flood events. The extensive backwaters located within the two small floodplain surfaces on river-left offer very good connected aquatic refugia. Emergent vegetation and large wood accumulations at these features offer highly functioning habitat.

The floodplain and terraces bordering the channel in Reach 10 are well vegetated with maturing mixed forests, except where residential development is occurring. This provides for well-functioning canopy cover throughout large portions of the reach. There are sufficient forested surfaces adjacent to the channel yet Reach 10 appears to be lacking in large wood material accumulations that could add habitat and geomorphic complexity to the reach. Sparse minor wood accumulations are found at the margins of the channel and at bar locations.

Figure 93. Wetland located within historical channel scar on right bank from RM 51.7 to RM 52.9 (photo taken facing upstream).

4.10.3 Effects of Human Alterations

A large portion of the right bank has been modified by anthropogenic development. At the upstream end of Reach 10 (RM 53.57) fill for the construction of Hwy 207 isolates downstream floodplain surfaces from historical geomorphic processes associated with both the Wenatchee River and Nason Creek. Additionally, the Hwy 207 bridge abutments and associated riprap create a localized artificial channel constriction. This constriction limits lateral channel migration and creates a localized increase in channel velocities which has created scour pools. Here the Wenatchee River is held in place against the confining terrace slopes on river-left.

In general, the construction of Hwy 207 impedes the natural migration rates and patterns of what was once a dynamic channel confluence of Nason Creek and the Wenatchee River. This historically active area is evidenced by 1887 survey maps (Figure 94), surface topography, and channel scars visible in LiDAR imagery. Modern flood history (1990) and the hydraulic floodplain inundation model (Section 3.5.2) confirm the potential for dynamic flood hydraulics to occur at the confluence of Nason Creek and the Wenatchee. It appears that the confinement of the channel at the Hwy 207 Bridge further backs up floodwaters at the confluence. As a result, serious flooding of the small community of Lake Wenatchee along Hwy 207 can occur as flood stages breach the road and its fill.

Residential homesite development further disconnects the upper 1.5 miles of the river-right floodplain. Homesite development here also includes floodplain dissection by roads and utilities installation, removal or alteration of riparian vegetation, fill or grading of surfaces, and installation of localized bank hardening or protection such as riprap and retaining walls, as well as small boat docks and rock spurs for diverting flow. The off-channel wetland features described above extend across the river-right floodplain behind the homesite development.

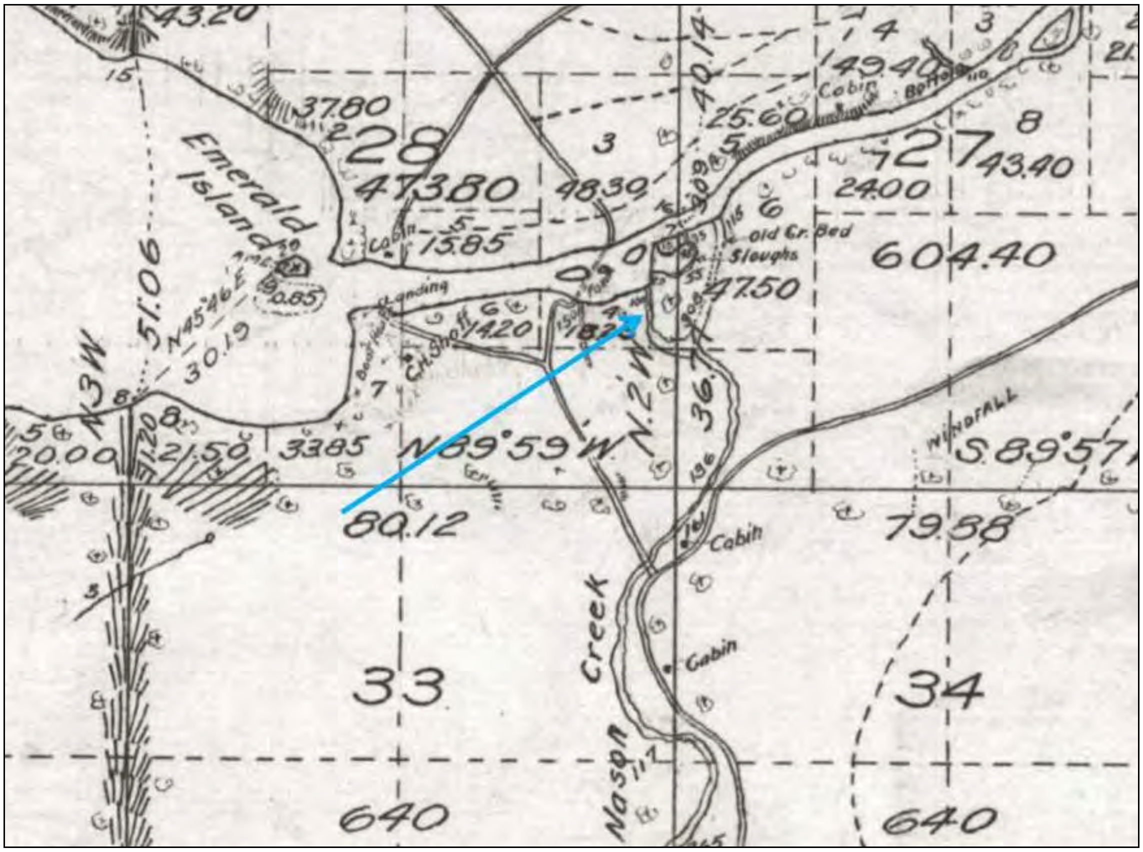

Figure 94. 1887 survey map of confluence of Wenatchee River and Nason Creek. Delineated "Old Cr. Bed" highlights Nason Creek's formerly highly active alluvial fan.

Evidence of historical timber harvest and log transport exists throughout the study area. Potential impacts of these practices are discussed in detail in Section 3.4.3. It is inferred that splash damming at the historical mill site located upstream in Reach 11, and related downstream scour, resulted in channel simplification in Reach 10. The hydraulic inundation model presented in Section 3.5.2 shows that river-right floodplain connectivity is limited in areas of homesite development and bridge construction. Incomplete inundation at the two year flood discharge stage of some low-elevation modern floodplain surfaces in Reach 10 raises the concern of some degree of human-accelerated incision processes in the upstream portion of the reach where anthropogenic influences are most prevalent. However, without historical data it is difficult to determine the extent that the effects of these practices have had on the channel. The oldest survey maps of record from the area (1883 and 1893) depict human development (cabins, boat ramps, etc.) on the floodplain (see Figure 94). In these maps the mainstem channel is already located against the river-left terrace banks indicating that form and location of the channel was already established by that time.

Human alterations are mapped in Figure 95, Figure 96, and Figure 97.

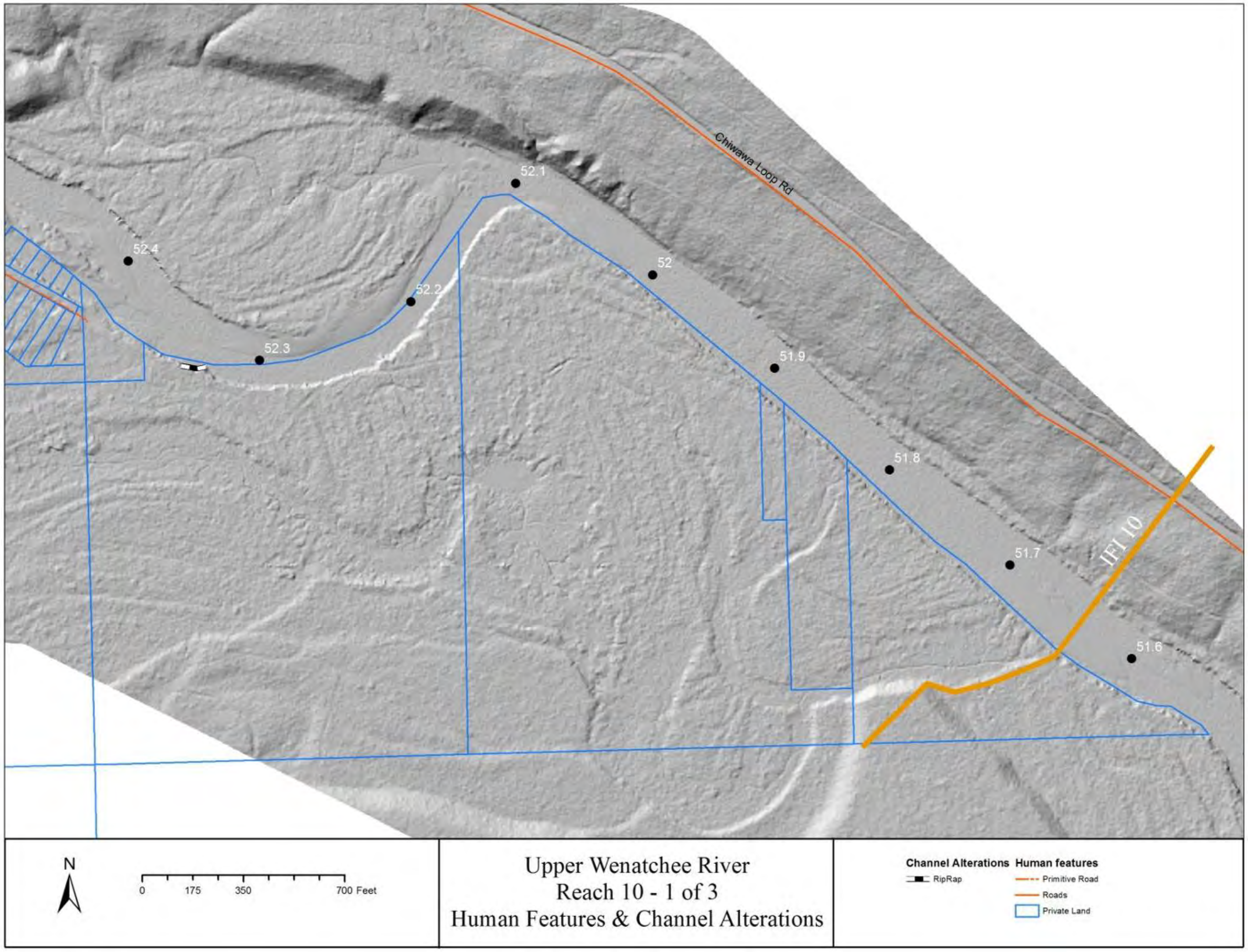

Figure 95. Human alterations in the downstream portion of Reach 10. Flow is from northwest to southeast.

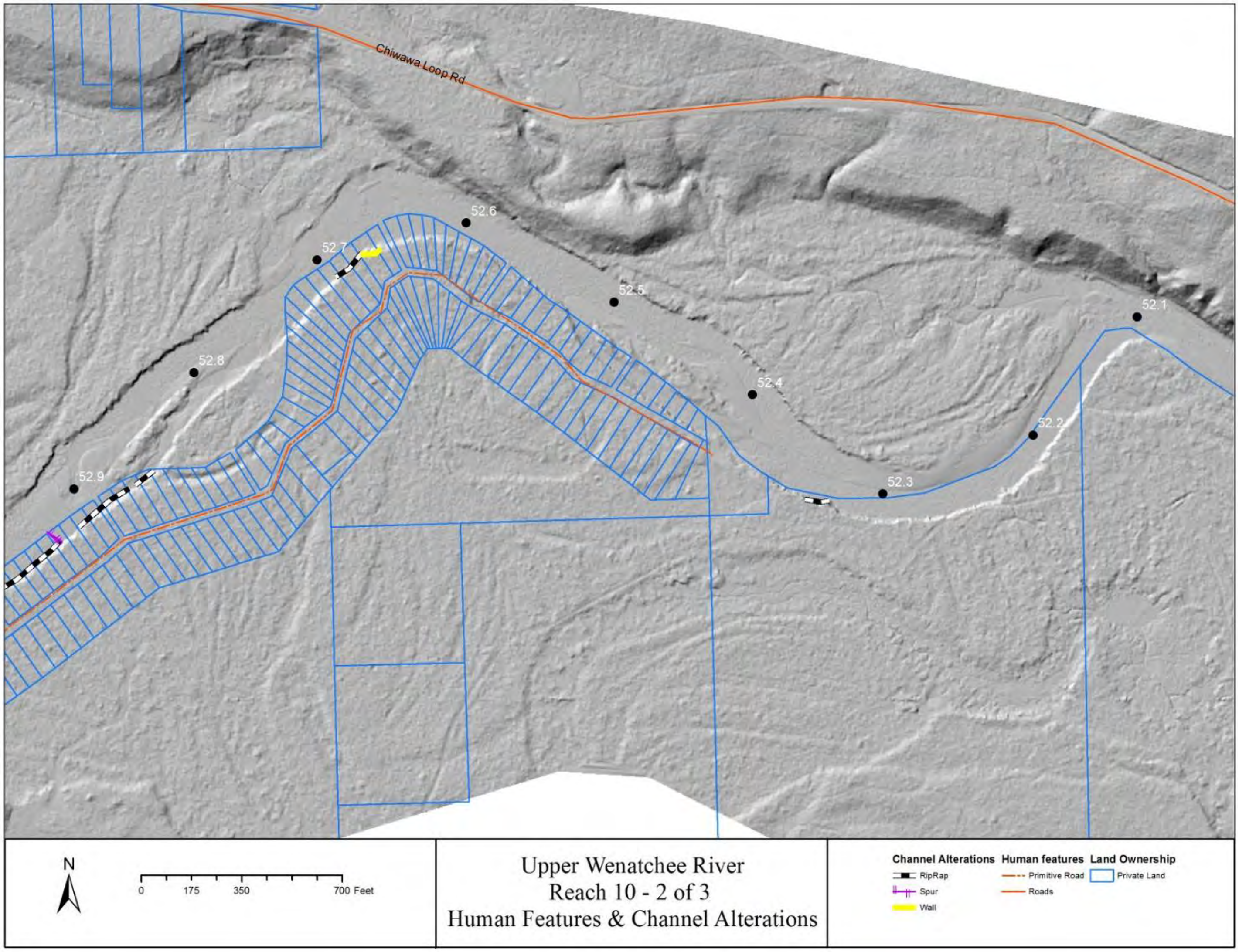

Figure 96. Human alterations in Reach 10. Flow is from west to east.

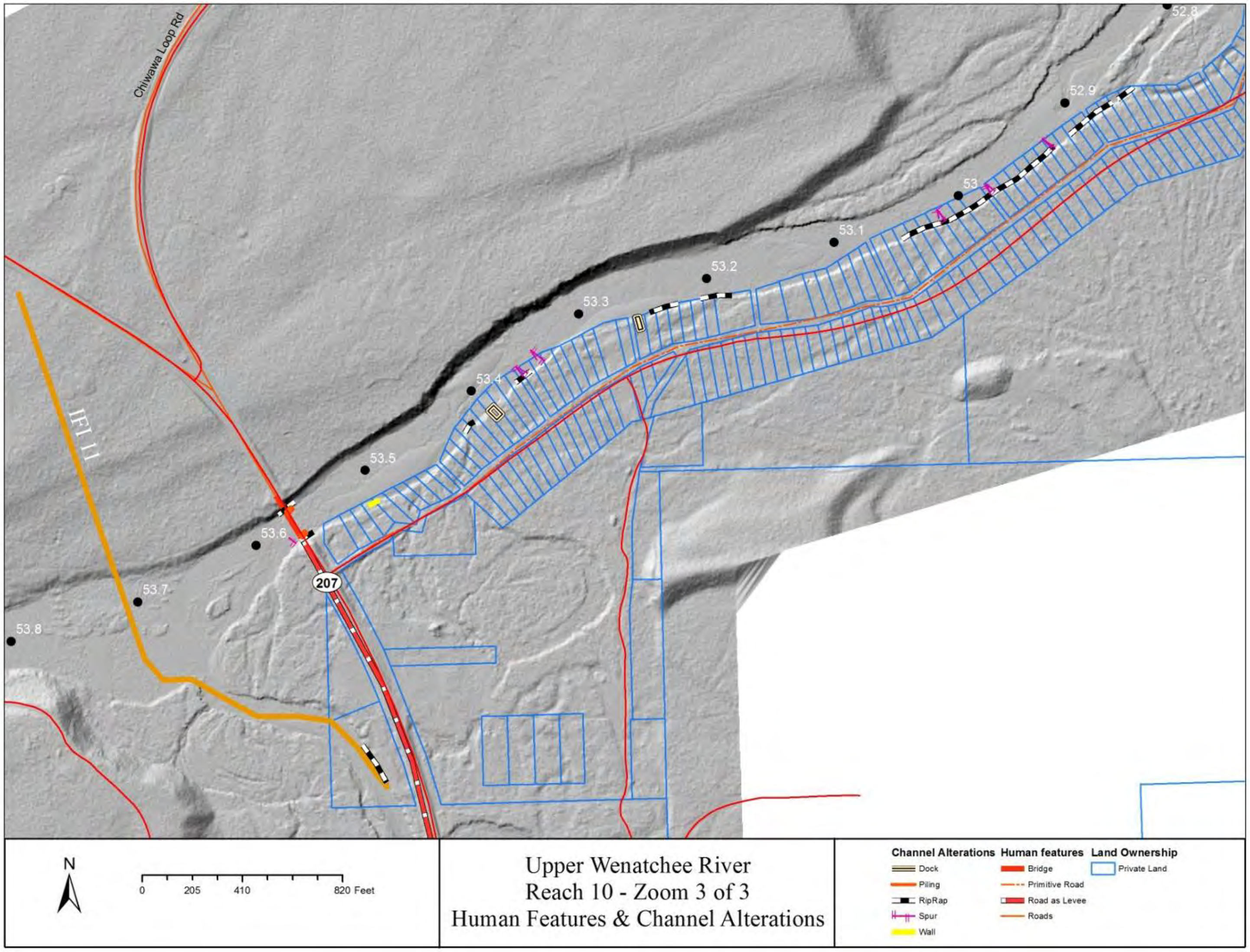

Figure 97. Human alterations in the upstream portion of Reach 10. Flow is from west to east.

4.11 Reach 11

4.11.1 Reach Overview

Reach 11 is 0.5 miles long and begins at the confluence of Nason Creek and extends upstream to the outlet of Lake Wenatchee at RM 54.15 (Figure 98). This is the upstream-most reach of the mainstem Wenatchee River and it is defined by a mix of lacustrine and riverine geomorphology between the Lake and the Upper Wenatchee River. Lake Wenatchee acts a hydrologic moderator that supplies base-flow discharge to Reach 11 during low flow late-summer months. It is assumed that groundwater inputs to the channel through the surrounding glacial deposits are also occurring. The channel is straight and confined until it widens at the confluence with Nason Creek. The geomorphic processes of the downstream portion of Reach 11 are influenced by discharge and sediment inputs from Nason Creek. The upper half of the reach is managed by Washington State Parks and Recreation and the lower half is managed by the US Forest Service. Historically, the upstream most 2,000 feet of the channel were used as a log holding pond for a mill located where Lake Wenatchee State Park is today (Hink 2008, HEC 2009).

Figure 98. Overview map of Reach 11. Flow is from West to East.

4.11.2 Forms and Processes

Reach 11contains an almost perfectly straight channel with a sinuosity of 1.01. The upper 0.5 miles of the reach is entirely confined by glacial terrace deposits that the Wenatchee River has incised through. The channel is planebed with a subtle pool-glide morphology and very limited complexity (Figure 99). At the lower 0.1 miles of the reach channel form and processes are influenced by sediment and discharge inputs from Nason Creek. Here the channel widens and mid-channel island and bar development is occurring behind large glacially deposited boulders and accumulating large wood. Channel substrate throughout the reach ranges from sands to large boulders, with cobbles as the dominant grain size (60%). The overall gradient of the channel in Reach 11 is <0.10%.

Figure 99. Representative geomorphology of Reach 11, facing downstream (July 20, 2011).

Where the channel has incised through the glacial deposits in the upper 0.5 miles of the reach, there are no existing floodplain surfaces. The lower portion of the reach widens near the confluence of Nason Creek but remains confined by a glacial deposit terrace on river-left. On river-right at the confluence with Nason Creek, there are low-elevation floodplain surfaces that experience regular inundation. Small backwaters that occupy channel scars on these floodplains connect to lower Nason Creek.

The floodplain and terraces bordering the channel are well vegetated with maturing mixed forests and riparian plants. This provides good canopy cover along the margins of the channel. Despite the vegetated banks, Reach 11 is lacking in large wood. The steep banks of the confining glacial terraces are currently supplying only minor large wood inputs. However, wood accumulations are part of the developing mid-channel bar/island complex in the lower portion of the reach and are found as driftwood deposits along the margins of the upper portion of the reach.

4.11.3 Effects of Human Alterations

Modern anthropogenic alterations have only minor direct impacts on Reach 11 but the effects of past transportation routes and timber harvest practices continue to influence channel processes. The upper section of Reach 11 is currently managed by Washington State Parks and Recreation. This land contains campgrounds with recreational beaches, boat docks and launches, and minor road and trail development. The lower 0.1 miles of channel and the Nason Creek confluence area are managed by the US Forest Service. A low-impact walking trail bisects the floodplain at the confluence of Nason Creek.

Abandoned cement bridge pilings are located at RM 53.85 along both channel banks. The pilings create minor localized scour pools at their base. The bridge no longer exists but the remnant pilings are associated with access roads on both the right and left banks atop the glacial deposit terraces.

Historical timber harvest and log transport practices have altered the channel in Reach 11. Impacts include excavation in the uppermost 2,000 feet of the reach to create a log-holding pond for a mill located where Lake Wenatchee State Park is today (Hink 2008, HEC 2009). It is presumed that large boulders and remnant glacial erratics in the channel were dynamited and cleared to create space for this log-holding pond. Dredging and scour associated with downstream log transport likely further reduced channel complexity throughout the reach. Due to minimal sediment inputs from the lake, the upper section of Reach 11 remains altered by these historical land-use practices.

The construction of Hwy 207 and its bridge-crossing only 0.1 miles downstream from the Reach 11 boundary influences channel location and mobility. These structures and their associated fill and bank riprap currently restrict natural channel migration patterns of both Nason Creek and the Wenatchee River.

Human alterations in Reach 11 are mapped in Figure 100.

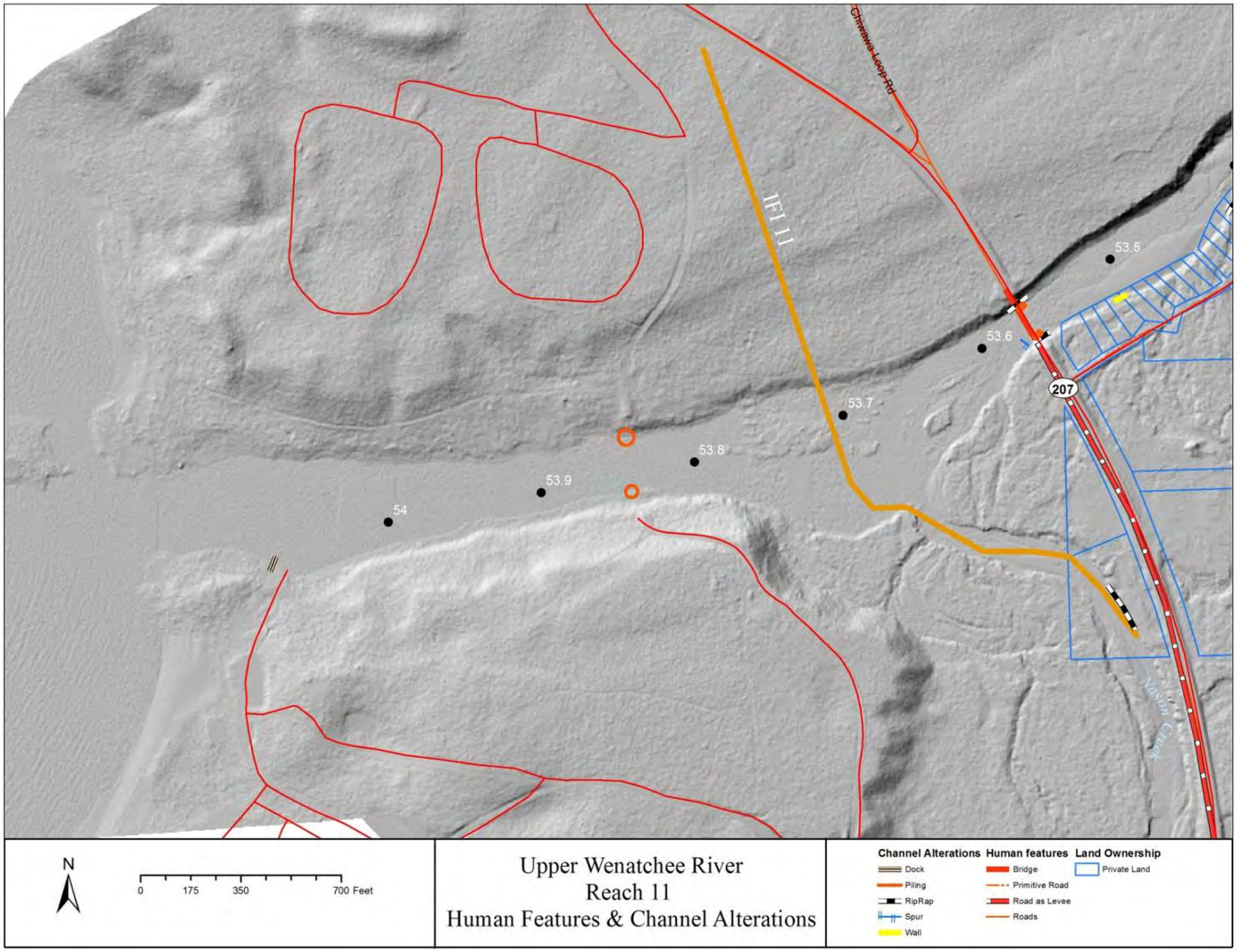

Figure 100 Human alterations in Reach 11. Flow is from west to east.

5 RESTORATION STRATEGY

5.1 Introduction

Development of the restoration strategy was guided by the habitat objectives set forth in the Upper Columbia Recovery Plan (UCSRB 2007) and by field and analytical work conducted as part of this Reach Assessment. Specifically, strategies were developed based on: 1) previous studies, 2) new analyses and field surveys conducted as part of this reach assessment, 3) a comparison of existing and target habitat conditions, and 4) current site conditions and human uses. The restoration strategy is presented in Section 5.4 and includes narrative descriptions and strategy tables that outline the restoration strategy for each reach.

The restoration strategy includes ‘action types’ as well as specific potential project opportunities. Five general action types were developed for use in this assessment and are applied as appropriate to individual reaches. Action types are developed at a broader scale than projects, and may be achieved through the use of numerous project types. For example, the action type “off-channel habitat enhancement” might be achieved via numerous project types ranging from re-connecting habitat blocked by a levee to excavating new off-channels in the floodplain.

For most reaches, at least 4 of the 5 action types are recommended, which indicates that much of the study area suffers from similar types of habitat impairments. The specific project opportunities, on the other hand, are more site specific and have unique characteristics depending on the particular habitat conditions, land uses, and geomorphic context of the site. Despite the additional specificity for projects, more analysis will still be necessary before projects are implemented; this may include topographic survey, hydraulic modeling, engineering analysis, and alternatives evaluation.

Specific potential project opportunities are linked to their respective action type(s) in the tables in Section 5.4 and are described in greater detail in Appendix D. The projects listed in Appendix D represent an initial step in identifying projects that fit the action types for each reach. Because of potential feasibility constraints (e.g. landowner cooperation), numerous potential projects have been identified, with the assumption that only a fraction of the potential opportunities will be taken to implementation. Additional information related to the approach to project identification is included in Appendix D.

5.2 Existing and Target Habitat Conditions

One of the primary tools for identifying action types and projects is a comparison of existing and target habitat conditions. This highlights habitat deficiencies and helps to develop restoration strategies. For each reach, existing and target habitat conditions are presented for a suite of habitat and geomorphic categories (Section 5.4 tables). Existing conditions were developed based directly on analyses and surveys performed as part of this Reach Assessment. Existing conditions information draws heavily from the habitat survey data (Appendix A) and also from the hydraulics and geomorphology assessments (Section 3.5.2 and 0).

Target conditions were developed using the REI targets as well as reference site conditions and inference from regional studies. See Section 3.5.3 and Appendix C for more information on the

REI analysis. The REI analysis is based on previous REI analyses conducted as part of previous Reach Assessments conducted by the USBR in other Upper Columbia tributaries. Due to unique conditions in the Upper Wenatchee River, a couple of notable variations were made to the REI and the corresponding restoration targets. These variations apply to the LWD metric and the pools metric, and are discussed below.

For the large wood and log jam category, the targets are: 1) greater than 80 wood pieces per mile (>12 inches diameter; >35 feet long, which constitutes the ‘medium’ and ‘large’ sizes from the habitat survey) and 2) greater than 4 log jams per mile (minimum 10 qualifying pieces). We chose to use the western cascades 80 pc/mi target from NMFS (1996) as opposed to the eastern cascades 20 pc/mi target for the following reasons. First, based on measurements of wood in unmanaged streams in eastern Washington, Fox and Bolton (2007) determined that the NMFS (1996) standard is low for larger eastern Washington streams (5m-50m bankfull width), which had greater than 40 pc/mi on average. Because the bankfull widths on the upper Wenatchee are even larger than the streams included in the Fox and Bolton study (i.e. average of 90m), historical wood numbers would be expected to be even greater, primarily due to large log jams that are assumed to have been present in this reach historically (see Section 3.3.3). Second, Reach 1, which serves as a reference reach due to its relatively undisturbed condition, has 142 pc/mi currently; and there is no reason to believe that wood numbers here would be higher now than under historical conditions. Lastly, the upper Wenatchee study area as a whole averaged 64 pc/mi under existing conditions; consequently, achieving >80/pieces per mile is believed to be an appropriate and attainable restoration goal.

The log jam target of 4 log jams/mi was obtained with reference to existing conditions in Reach 1 (3.8 jams/mi). It is believed that historically, wood pieces within the study area would have mainly been associated with log jams. Fox (2003) reported that in unmanaged streams in Washington, for channels >50-100m bankfull width, over 80% of the wood pieces occurred in groups of 10 or more.

The pool frequency and quality metric was also adapted for the Upper Wenatchee River. The largest bankfull channel width provided in the NMFS matrix is 65 to 100 feet, and 4 pools per mile is the standard for this width. Because Upper Wenatchee bankfull widths far exceed the criteria (ranging from 270 feet to 360 feet), reaches were primarily evaluated based on the pool quality metrics provided by NMFS (1996) (e.g. depth, substrate, cover, refugia), rather than number of pools.

5.3 Restoration Strategy Descriptions

The Restoration Strategy includes five general action types. These are described in the sections below. There is not a specific action type identified to address water quality and quantity. Although these are not believed to be significant limiting factors in the study area, they will nevertheless be partially addressed through improvements to riparian conditions and habitat connectivity (i.e. increased floodplain storage). The potential impact of water withdrawals is being addressed through other efforts (e.g. WRIA planning) and is beyond the scope of this study.

5.3.1 Protect and maintain

Protection projects involve preservation of high quality habitat. Preventing further degradation of other areas is generally not identified as a ‘protect and maintain’ action because it is considered inherent in all potential actions. In many cases, adequate protection may already be in place through existing laws and regulations. The adequacy and enforcement of these regulations needs to be considered when planning for protection activities.

Examples:

- Direct purchase (fee acquisition) of an area of functioning habitat and physical processes, or of an area at risk of further degradation through development
- Obtaining a conservation easement from a landowner in order to eliminate agricultural or residential development uses within a riparian buffer zone

5.3.2 Riparian restoration

Riparian restoration projects are located in areas where native riparian vegetation communities have been significantly impacted by anthropogenic activities such that riparian functions and connections with the stream are compromised. Restoration actions are focused on restoring native riparian vegetation communities in order to reestablish natural stream stability, stream shading, nutrient exchange, and large wood recruitment. Even though it is not always explicitly stated, riparian restoration is a recommended component of most restoration projects, particularly within the disturbance limits of the project.

Examples:

- Replanting a riparian buffer area with native forest vegetation
- Eliminating invasive plant species that are preventing the reestablishment of a native riparian forest community

5.3.3 Habitat reconnection via infrastructure modification

This strategy includes removal/modification of bank armoring, levees, roadways, or fill. Habitat reconnection projects are located in areas where floodplain and channel migration processes have been disconnected due to anthropogenic activities. These are areas that have the potential for an increase in habitat quality and a reestablishment of dynamic processes through their reconnection. Restoration actions are focused on reclaiming a component of the system that has been lost, therefore regaining habitat and process that was previously a functional part of the river system.

Habitat reconnection projects may also include the reestablishment of fish passage where it has been blocked. For the Upper Wenatchee, there are no passage barriers on the mainstem but there are off-channel habitats where fish access has been affected by fill or by legacy incision of the mainstem.

Examples:

- Removal or selective breaching of a levee or road embankment to enhance floodplain connectivity

- Removal of rip-rap and replacement with LW in order to eliminate bank hardening and channelization that restricts channel migration, simplifies the channel, and compromises instream aquatic habitat quality and quantity

5.3.4 Placement of structural habitat elements

This strategy includes placement of habitat structures such as large wood, log jams, or boulders in order to achieve numerous habitat and geomorphic objectives. These types of projects can span a broad range of structure versus function-based approaches. For instance, a single log placement might be used in an existing pool to simply provide salmonid hiding cover, which would be chiefly a form-based approach. In contrast, a large constructed log jam might be used as a more function-based element that is intended to create split-flow conditions, create a bar/island complex, and to create and maintain scour pools. Structural elements are placed in areas where they would naturally accumulate and would be maintained by the existing stream hydrology and geomorphology.

Examples:

- Installation of a bar apex log jam to create and maintain a multi-thread channel system with mid-channel bars/islands and split-flow conditions, thus maximizing margin habitat and complexity
- Installation of a meander-bend log jam to maintain pool scour and to increase velocity refuge and cover for juvenile salmonids
- Installation of individual pieces of large wood in an existing off-channel area to increase hiding cover from aquatic, terrestrial, and avian predators

5.3.5 Off-channel habitat enhancement

Off-channel habitat enhancement projects are located in areas (e.g. floodplains) where there is the potential to increase the quantity and quality of off-channel habitat. Off-channel projects may include the activation of existing floodplain habitat areas that have been disconnected via channel incision or floodplain alterations. In other cases, off-channel areas can be created via excavation and construction of floodplain features such as backwaters, groundwater-fed channels, and flow-through side channels.

Examples:

- Construction of off-channel features such as alcoves, backwaters, or flow-through side channels that are connected to the main channel
- Construction of a groundwater-fed channel to provide cool summer and warm winter temperatures for rearing salmonids

5.4 Reach-Scale Strategies

5.4.1 Reach 1

Reach 1 has been relatively unaffected by direct human alterations for at least the past 50 years. Previous impacts included log drives and riparian timber harvest but the reach has been on a trajectory of recovery since these historical impacts. Except for at the downstream end (Highway 2 crossing), the reach has limited access and is almost entirely within US Forest Service ownership. Because of the relatively intact and functional geomorphic processes and aquatic habitat, this reach is used as a reference reach to help develop target conditions for the remainder of the study area.

The primary restoration strategy for Reach 1 is to protect and maintain. This designation is given due to the particularly high quality habitat, not because there are any imminent threats to this reach. The one potential project opportunity in this reach is to add large key pieces of wood that would be available to initiate log jam formation and enhance lateral channel dynamics, pool scour, cover, and complexity. The very large key pieces needed to form log jams are much less abundant than historical conditions and it is believed that re-introducing key pieces would create a positive habitat response by collecting additional wood, sorting sediment, and providing direct habitat benefits. Access is difficult so key pieces would likely have to be flown in and placed by helicopter. In some areas, decommissioned access roads may be able to be utilized.

Reach 1 Restoration Strategy

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	55% large tree 45% small tree or smaller No human disturbance	At least a 100 ft riparian buffer with: > 80% mature trees. < 20% riparian disturbance (human) [REI]	**Protect and maintain** Allow existing forest to mature.	No specific actions identified. Land is completely within USFS ownership and is assumed to be protected from riparian clearing.
Floodplain Connectivity	Floodplain width / BFW = 3.2. No human disturbance in the floodplain	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain [adapted from REI]	**Protect and maintain**	No actions identified
Bank condition / Channel migration	Channel migration is operating at or near natural rates. No bank armoring	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	**Protect and maintain**	No actions identified
Vertical channel stability	No significant human-induced aggradation or incision.	No measurable trend of human-induced aggradation or incision [adapted from REI]	**Protect and maintain**	No actions identified
Pools	Pools per mile = 2.7 40% pool habitat 100% of pools >1 m deep	~3-4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Each reach has many large pools >1 m deep with good fish cover. [Reach 1 and REI]	**Protect and maintain**	No actions identified

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Large wood and log jams	142 pieces / mi 3.8 jams /mi	> 80 pieces/mi (>12 diam; > 35 ft long) [Reach 1 and inferred from Fox 2003] > 4 log jams/mi [based on conditions in Reach 1 and inferred from Fox 2003]	**Protect and maintain** **Placement of structural habitat elements including large wood, log jams, or boulders** Potential key piece supplementation: add large key pieces of wood that would be available to initiate log jam formation. The very large key pieces needed to form log jams are much less abundant than historical conditions.	Key piece supplementation at natural log jam formation locations (e.g. bar apexes, off-channel areas, meander bends).
Off-Channel Habitat	24% side-channel habitat. Multiple abandoned oxbows and floodplain wetlands are currently connected to the channel.	Reach has ponds, oxbows, backwaters, side-channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas. [adapted from REI]	**Protect and maintain**	No actions identified

5.4.2 Reach 2

Similar to Reach 1, this reach has been relatively unaffected by direct human alterations for at least the past 50 years. Previous impacts included log drives and riparian timber harvest but the reach has been on a trajectory of recovery since these historical impacts. Reach 1 is higher gradient, lower sinuosity, and has less habitat complexity than adjacent reaches. Previous log drives and decreased wood quantities likely contribute to simplification.

The primary restoration strategy for Reach 2 is to protect and maintain. This designation is given due to the existing degree of limited human impact, not because there are any imminent threats to this reach. As with Reach 1, the one potential project opportunity in this reach is to add large key pieces of wood that would be available to initiate log jam formation and enhance lateral channel dynamics, pool scour, cover, and complexity. The very large key pieces needed to form log jams are much less abundant than historical conditions and it is believed that re-introducing key pieces would create a positive habitat response by collecting additional wood, sorting sediment, and providing direct habitat benefits. Access is difficult but not as challenging as in Reach 1. There is a primitive road (now closed) along the river-right bank that could be utilized or key pieces could be flown in and placed by helicopter.

Reach 2 Restoration Strategy

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	56% large tree 44% small tree or smaller. No human disturbance	At least a 100 ft riparian buffer with: > 80% mature trees. < 20% riparian disturbance (human) [REI]	**Protect and maintain** Allow existing forest to mature.	No specific actions identified. Land is completely within USFS ownership and is assumed to be protected from riparian clearing.
Floodplain Connectivity	Floodplain width / BFW = 2.2. No human disturbance in the floodplain	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain [adapted from REI]	**Protect and maintain**	No actions identified
Bank condition / Channel migration	Channel migration is operating at or near natural rates. No bank armoring	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	**Protect and maintain**	No actions identified
Vertical channel stability	No significant human-induced aggradation or incision.	No measurable trend of human-induced aggradation or incision [adapted from REI]	**Protect and maintain**	No actions identified

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Pools	Pools per mile = 0.9 13% pool habitat 100% of the pools are between 1 and 2 m deep	~3-4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Each reach has many large pools >1 m deep with good fish cover. [Reach 1 and REI]	**Protect and maintain** Key piece supplementation described for large wood could help enhance pool habitat.	Key piece supplementation described for large wood could help enhance pool habitat.
Large wood and log jams	26 pieces / mi 1.0 jams /mi	> 80 pieces/mi (>12 diam; > 35 ft long) [Reach 1 and inferred from Fox 2003] > 4 log jams/mi [based on conditions in Reach 1 and inferred from Fox 2003]	**Protect and maintain** **Placement of structural habitat elements including large wood, log jams, or boulders** Potential key piece supplementation: add large key pieces of wood that would be available to initiate log jam formation. The very large key pieces needed to form log jams are much less abundant than historical conditions.	Key piece supplementation at natural log jam formation locations (e.g. bar apexes, off-channel areas, meander bends).
Off-Channel Habitat	6% side-channel habitat. Natural confinement limits off-channel development. Off-channels exist where they would have historically.	Reach has ponds, oxbows, backwaters, side-channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas. [adapted from REI]	**Protect and maintain**	No actions identified.

5.4.3 Reach 3

The restoration strategy for Reach 3 includes two primary approaches: 1) addressing human alterations to riparian areas and floodplains (primarily along river-right), and 2) enhancing existing habitat that has moderate-to-high function (primarily along river-left). Opportunities for addressing human alterations include riparian restoration, removing or modifying bank armoring, and removing or modifying floodplain encroachments. These efforts would help to accomplish the floodplain and bank condition targets. This work is primarily associated with addressing alterations at a few large riverside communities including the High Valley Community and the Meacham Road area. Due to the degree of existing human presence, this will be challenging in many locations.

Opportunities for enhancing existing habitat include creating off-channel habitats and adding wood pieces and log jams for pools, cover, and complexity. These efforts would help to achieve the log jam and pool frequency targets. Much of this work could occur along river-left except at the downstream end of the reach where there are good opportunities for projects along both banks. The river-right bank is primarily privately-owned and the river-left bank is primarily National Forest land. Accessing the river-left bank will be challenging except for at the upstream end where there may be the potential for access off of Camp 12 Road.

Reach 3 Restoration Strategy

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	40% large tree 60% small tree or smaller >20% human disturbance Human disturbance is located within much of the riparian zone, mostly along the right bank. Disturbance includes roadway, houses, and bank armoring.	At least a 100 ft riparian buffer with: > 80% mature trees. < 20% riparian disturbance (human) [REI]	**Riparian restoration** Work with landowners to plant cleared riparian and floodplain areas. Look for opportunities to set back roadways and other human infrastructure out of riparian areas.	Multiple locations, primarily along the river-right bank, have been identified for riparian planting. These include residential areas associated with the Meacham Road area, the Meacham Flats area, the High Valley community, and the Wenatchee Pines community. In addition, projects that address other attributes should all include riparian restoration as a component of restoration work. <u>Specific Project Opportunities:</u> Meacham Road Project (RM 41.7R), High Valley US Riparian & Margin Habitat Enhancement (RM 40.6R), High Valley DS Riparian & Margin Habitat Enhancement (RM 39.7R)

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Floodplain Connectivity	Floodplain width / BFW = 4.3 Nearly half of the floodplain has been disconnected due to residential development and roadways. Impacts include filling, grading, walls, and clearing.	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Where possible, set back roadways, remove retaining walls, remove fill, and remove/modify other human infrastructure affecting floodplain processes.	Work with landowners to address floodplain development at the Meacham Road area, the Meacham Flats area, the High Valley community, and the Wenatchee Pines community. Investigate the potential to set-back or modify River Road where it abuts the channel near RM 40.7. Removal of bank armoring and installation of log jams (described for other attributes) will allow more natural rates of overbank flows. Specific Project Opportunities: See projects under bank condition/channel migration below.
Bank condition / Channel migration	28% of the streambanks in this reach are affected by bank armoring	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Remove or modify bank armoring.	Multiple locations along river-right have been identified for removing or modifying bank armoring, which includes rip-rap, spur dikes, and concrete walls. These include areas along the Meacham Road area, Meacham Flats, the High Valley community, and along River Road. Specific Project Opportunities: Meacham Road Project (RM 41.7R), High Valley US Riparian & Margin Habitat Enhancement (RM 40.6R), High Valley DS Riparian & Margin Habitat Enhancement (RM 39.7R)

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Vertical channel stability	There was likely minor past incision related to historical log drives and bank armoring.	No measurable trend of human-induced aggradation or incision [adapted from REI]	**Placement of structural habitat elements including large wood, log jams, or boulders** Apex jams to trap sediment and build grade.	Projects incorporating bar apex log jams listed below under LWD would be expected to trap sediments, help control grade, and raise the channel bed over time.
Pools	Pools per mile = 1.9 27% pool habitat 100% of the pools are >1 m deep	~3-4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Each reach has many large pools >1 m deep with good fish cover. [Reach 1 and REI]	**Placement of structural habitat elements including large wood, log jams, or boulders** Placement of structure to form pools. **Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Removing bank armoring to enhance pool quality.	Several locations have been identified for enhancing margin habitat (e.g. removing bank armoring), and placing large wood and log jams. Margin enhancement will improve pool quality and cover. Placement of wood (described below) will develop and maintain local scour pools. Specific Project Opportunities: See large wood and bank condition enhancement projects.

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Large wood and log jams	133 pieces / mi 1.2 jam /mi	> 80 pieces/mi (>12 diam; > 35 ft long) [Reach 1 and inferred from Fox 2003] > 4 log jams/mi [based on conditions in Reach 1 and inferred from Fox 2003]	**Riparian restoration** Riparian projects to improve long-term LW recruitment. **Placement of structural habitat elements including large wood, log jams, or boulders** Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit.	Large wood additions include individual pieces or jams along margins to enhance margin habitat and pool scour, as well as mainstem bar apex jams to enhance lateral channel dynamics. Several other projects described for other metrics also include wood placements. Specific Project Opportunities: RM 41.3 Meander Bend Jams RM 41 Jams (bar apex) RM 40.4 Meander Bend Jams RM 40 Meander Bend Jams RM 39.4 Meander Bend Jams Zimmerman Off-Channel and Mainstem Enhancement (RM 39.3)

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Off-Channel Habitat	19% side-channel habitat. Existing side and off-channel habitat is relatively well-connected but lacks adequate cover and complexity. Human alterations affect off-channel function in a few locations.	Reach has ponds, oxbows, backwaters, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas. [adapted from REI]	**Off-channel habitat enhancement** Excavation to increase off-channel habitat area. **Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Removal of armoring that limits side-channel function or connectivity. **Placement of structural habitat elements including large wood, log jams, or boulders** Placement of wood for cover and to enhance connectivity of off-channel areas.	There are opportunities to enhance existing side-channels and to create new ones. Specific Project Opportunities: Meacham Road Project (RM 41.7) Wenatchee Pines Off-Channel Enhancement (RM 41.5) RM 41.1 Side Channel Enhancement Meacham Flats Off-Channel Enhancement RM 40.5 Alcove Enhancement RM 39.6 Off-Channel Enhancement Zimmerman Off-Channel and Mainstem Enhancement (RM 39.3) Tunnel Alcove Enhancement (RM 39) Deadhorse Island Side-Channel Enhancement (RM 38.9)

5.4.4 Reach 4

Lack of off-channel habitat, lack of large wood and log jams, and lack of pools are the primary deficiencies to be targeted for restoration in Reach 4. Residential development throughout this reach has affected floodplain processes via fill and structural encroachments on the floodplain; but opportunities for floodplain restoration are limited due to the heavy human presence and the numerous individual private parcels. The Primitive Park Side-Channel project, which would reconnect a side-channel via removal of floodplain fill, would be a great project if landowner collaboration could be achieved. There are a few opportunities to place bar apex log jams to directly enhance habitat as well as to increase lateral channel dynamics associated with wood.

Reach 4 Restoration Strategy

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	78% large tree 22% small tree >20% human disturbance Isolated but consistent riparian disturbance along the reach, mostly associated with homes and River Road.	At least a 100 ft riparian buffer with: > 80% mature trees. < 20% riparian disturbance (human) [REI]	**Riparian restoration** Work with landowners to plant cleared riparian and floodplain areas. Look for opportunities to set back roadways and other human infrastructure out of riparian areas.	The riparian disturbance is primarily associated with residential development. Specific riparian-only projects have not been identified as they are isolated and associated with individual residences off of Mule Tail Flats Road (west side) and Primitive Park Road (east side). Look for opportunities to work with willing landowners to conduct riparian restoration. <u>Specific Project Opportunities:</u> Railroad Bridge Channel Margin Enhancement (RM 41.9) Other projects for this reach include some degree of riparian restoration opportunity
Floodplain Connectivity	Floodplain width / BFW = 2.6 Over half of the floodplain is considered disconnected due to residential development and roadways. Impacts primarily include filling, grading, and clearing. There are no levees or other significant individual floodplain disconnections.	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Where possible, set back roadways, remove fill, and remove/modify other human infrastructure affecting floodplain processes.	Work with landowners to address floodplain development at residences off of Mule Tail Flats Road (west side) and Primitive Park Road (east side). Floodplain projects associated with residential development will require working with individual landowners to address residential development impacts (e.g. fill, grading, clearing). <u>Specific Project Opportunities:</u> Investigate the potential to set-back or modify River Road where it abuts the channel near RM 42.2.

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Bank condition / Channel migration	<8% of the streambanks in this reach are affected by bank armoring	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Remove or modify bank armoring.	There are isolated areas of bank armoring (rip-rap, stairways) associated with residences. The largest bank armoring is associated with the railroad bridge crossing at the downstream end of the reach (RM41.9). <u>Specific Project Opportunities:</u> Railroad Bridge Channel Margin Enhancement (RM 41.9)
Vertical channel stability	There is past incision related to bank armoring and confinement (railroad bridge). Floodplains within the broad meander bends are not inundated at the same frequency as historical conditions.	No measurable trend of human-induced aggradation or incision [adapted from REI]	**Placement of structural habitat elements including large wood, log jams, or boulders** Apex jams to trap sediment and build grade.	Projects incorporating bar apex log jams listed below under LWD would be expected to trap sediments, help control grade, and raise the channel bed over time.
Pools	Pools per mile = 2.2 41% pool habitat 67% of the pools are >1 m deep	~3-4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Each reach has many large pools >1 m deep with good fish cover. [Reach 1 and REI]	**Placement of structural habitat elements including large wood, log jams, or boulders** Placement of structure to form pools. **Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Removing bank armoring to enhance pool quality.	The railroad bridge project would enhance pool habitat along the channel margin. Placement of wood (described below) will develop and maintain local scour pools. <u>Specific Project Opportunities:</u> See large wood and bank condition enhancement projects.

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Large wood and log jams	35 pieces / mi 0.8 jam /mi	> 80 pieces/mi (>12 diam; > 35 ft long) [Reach 1 and inferred from Fox 2003] > 4 log jams/mi [based on conditions in Reach 1 and inferred from Fox 2003]	**Riparian restoration** Riparian projects to improve long-term recruitment. **Placement of structural habitat elements including large wood, log jams, or boulders** Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit.	Large wood additions include individual pieces or jams along margins to enhance margin habitat and pool scour, as well as mainstem bar apex jams to enhance lateral channel dynamics. Several other projects described for other metrics also include wood placements. Along the toe of the high glacial terraces, "colluvial" jams can be created that mimic natural jams formed by mass wasting events off the terrace slope. Specific Project Opportunities: Mule Tail Flats Log Jams (RM 42.9) Primitive Park Apex Jams (RM 42.4) Railroad Bridge Apex Jams (RM 42.1) Railroad Bridge Channel Margin Enhancement (RM 41.9)

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Off-Channel Habitat	7% side-channel habitat. At a couple of sites, side-channel habitat is disconnected due to human disturbance (residential-related). In general, natural confinement tends to limits off-channel development in this reach.	Reach has ponds, oxbows, backwaters, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas. [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Removal of fill to reconnect side-channel habitat. **Off-channel habitat enhancement** Potential for excavation, in addition to fill removal, to create a flow-through side-channel (Primitive Park Side-Channel Enhancement) **Placement of structural habitat elements including large wood, log jams, or boulders** Placement of wood in off-channel areas for cover and to enhance connectivity.	There are opportunities to reconnect and enhance existing side-channels and to create new habitat. <u>Specific Project Opportunities:</u> Primitive Park Alcove Enhancement (RM 42.7) Primitive Park Side-Channel Enhancement (RM 42.3)

5.4.5 Reach 5

Reach 5 has high natural confinement but has been further confined by human development in riparian and floodplain areas. These impacts have also degraded streambanks and riparian forests and have simplified channel margin habitat. There are numerous private parcels including small riverside parcels that are a part of the Ponderosa Community Club and the Alpine Community Club. Restoration efforts will need to address habitat deficiencies to achieve the targets for riparian tree size, floodplain connectivity, bank condition, pools, large wood / log jams, and off-channel habitat. Restoration opportunities primarily include addressing riparian and channel margin impairments associated with residential development. This includes riparian planting as well as removing or modifying bank armoring. There are also a few opportunities for meander-bend and bar apex log jam placements.

Reach 5 Restoration Strategy

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	61% large tree 39% small tree or smaller Significant clearing in some areas. Clearing is related to residential development, agriculture, and the powerline crossing near RM 44.4. Houses and other structures are located within 100-ft of streams in many areas.	At least a 100 ft riparian buffer with: > 80% mature trees. < 20% riparian disturbance (human) [REI]	**Riparian restoration** Work with landowners to plant cleared riparian areas. Look for opportunities to set back human infrastructure out of riparian areas.	Multiple locations have been identified for riparian planting. These include residential areas associated with the Ponderosa Estates development, the River Road area on river-right, and the powerline corridor and nearby rural residential areas. In addition, projects that address other attributes should all include riparian restoration as a component of restoration work. Opportunities to work collaboratively with landowners to revegetate riparian corridors should be pursued where feasible. <u>Specific Project Opportunities:</u> Ponderosa Estates Riparian and Channel Margin Enhancement (RM 43.5R) Powerline Riparian and Margin Habitat Enhancement (RM 44.3) River Road Channel Margin Enhancement (RM 43.7R) 45-Mile Margin Jams and Riparian Enhancement (RM 45.1R)

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Floodplain Connectivity	Floodplain width / BFW = 1.42 The channel corridor is largely confined by natural terraces. The majority of the historically available floodplain is developed and affected by human alteration. The Beaver Valley Road Bridge bisects a portion of the left-bank floodplain.	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain [adapted from REI]	**Protect and maintain** Allow no further alteration of floodplains or loss of floodplain connectivity.	Specific opportunities to promote floodplain connectivity were not observed due to a high degree of natural confinement. Preventing further degradation should be prioritized. Projects listed under Bank condition/Channel migration will partially address floodplain functions. Removing the floodplain fill on the eastern approach to the Beaver Valley Road Bridge should be considered when the bridge is replaced, but it is probably not a significant enough impairment to warrant removing in the near-term.
Bank condition / Channel migration	At the downstream portion of the reach, banks are impacted by armoring associated with residential development and River Road. This includes riprap, retaining walls, and concrete stairways. Less than 5% of the total bank length is armored. Channel migration is largely naturally limited by high terraces.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Remove or modify bank armoring.	Opportunities to address channel migration and bank condition are associated with residential bank armoring and River Road. <u>Specific Project Opportunities:</u> River Road Channel Margin Enhancement (RM 43.7R) Ponderosa Estates Riparian and Channel Margin Enhancement (RM 43.5R)

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Vertical channel stability	There is past incision likely related to historical log drives and possibly related to existing bank armoring.	No measurable trend of human-induced aggradation or incision [adapted from REI]	**Placement of structural habitat elements including large wood, log jams, or boulders** Apex jams to trap sediment and build grade	Projects incorporating bar apex log jams listed below under LWD would be expected to trap sediments, help control grade, and raise the channel bed over time.
Pools	Pools per mile = 1.0 11% pool habitat 100% of the pools are >1 m deep	~3-4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Each reach has many large pools >1 m deep with good fish cover. [Reach 1 and REI]	**Placement of structural habitat elements including large wood, log jams, or boulders** Placement of structure to create and enhance pools. **Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Removing or modifying bank armoring to enhance pool quality.	The margin habitat enhancement projects, bank condition enhancement projects, and large wood projects will create scour pools and enhance cover within pools. <u>Specific Project Opportunities:</u> See large wood and bank condition enhancement projects.

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Large wood and log jams	32 pieces / mi No log jams.	> 80 pieces/mi (>12 diam; > 35 ft long) [Reach 1 and inferred from Fox 2003] > 4 log jams/mi [based on conditions in Reach 1 and inferred from Fox 2003]	**Riparian restoration** Riparian projects to improve long-term recruitment. **Placement of structural habitat elements including large wood, log jams, or boulders** Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit.	Large wood additions include individual pieces or jams along margins to enhance margin habitat and pool scour, as well as mainstem bar apex jams to enhance lateral channel dynamics. <u>Specific Project Opportunities</u> Gravel Pit Colluvial Jams (RM 45.8L) 45-Mile Margin Jams and Riparian Enhancement (RM 45.1R) Camp 12 Apex Jam Powerline Riparian and Margin Habitat Enhancement (RM 44.3) River Road Channel Margin Enhancement (RM 43.7R) Riata Bend Enhancement (RM 43.2L)
Off-Channel Habitat	0% side-channel habitat. Existing and future potential off-channel habitat is limited by natural confinement and past incision related to log drives and bank armoring.	Reach has ponds, oxbows, backwaters, side-channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas. [adapted from REI]	**Off-channel habitat enhancement** Excavation of off-channel habitat where altered river processes reduce the likelihood of future off-channel habitat creation.	A few areas with low floodplain terraces may have opportunities for excavation of off-channel habitats. Most of these areas are dominated by residential development and so opportunities are limited. <u>Specific Project Opportunities</u> Riata Bend Enhancement (RM 43.2L)

5.4.6 Reach 6

This reach has high natural confinement and a steep plane-bed channel, which has limited the degree of habitat impairments and reduces the need and opportunities for restoration. Riparian degradation and a lack of log jams are the primary habitat deficiencies. There may be some opportunities to work with riverside landowners to re-plant riparian areas, but they primarily just need time to mature. The Schugart Flat Levee Removal and Riparian Enhancement project is the only specific project that was identified. This project would remove a low push-up levee and restore riparian conditions at a Chelan County gravel pit and adjacent private parcels.

Reach 6 Restoration Strategy

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	12% large tree 88% small tree or smaller The riparian corridor has been affected by past clearing associated with residential and municipal uses and is in early seral stages. There are not many large cleared areas compared to Reach 5 downstream.	At least a 100 ft riparian buffer with: > 80% mature trees. < 20% riparian disturbance (human) [REI]	**Protect and maintain** Allow the existing young forest to mature. **Riparian restoration** Work with landowners to revegetate riparian corridors where feasible.	Work with landowners to replant native riparian species and to prevent additional clearing. <u>Specific Project Opportunities</u> Schugart Flat Levee Removal and Riparian Enhancement (RM 47.6L)
Floodplain Connectivity	Development, grading, and a levee within the floodplain has disconnected floodplain surfaces. Natural confinement by high terraces limits floodplain availability throughout much of the reach.	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Remove levees, fill, and infrastructure affecting floodplain connectivity.	Address the levee and grading at the Chelan County gravel pit (Schugart Flat). Where feasible, work with owners of private streamside residences to remove floodplain infrastructure and fill. <u>Specific Project Opportunities</u> Schugart Flat Levee Removal and Riparian Enhancement (RM 47.6L)

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Bank condition / Channel migration	Roads, residential development, fill, bank armoring, and one levee affect channel migration. Banks are affected by residential uses (yards).	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Remove or modify bank armoring.	Where feasible, work with owners of private streamside residences to remove infrastructure that affects bank conditions and channel migration. <u>Specific Project Opportunities</u> Schugart Flat Levee Removal and Riparian Enhancement (RM 47.6L)
Vertical channel stability	There is likely minor past incision related to historical log drives.	No measurable trend of human-induced aggradation or incision. [adapted from REI]	No strategies identified	No actions identified
Pools	Pools per mile = 0.0 0% pool habitat	This is a steep reach that consists naturally of riffle and glide habitat types. Pocket pools currently exist within these habitat types. [Channel typing]	No strategies identified	No actions identified
Large wood and log jams	67 pieces / mi 0.7 jams/mi Most of the wood is located in 2 apex log jams.	> 80 pieces/mi (>12 diam; > 35 ft long) [Reach 1 and inferred from Fox 2003] > 4 log jams/mi [based on conditions in Reach 1 and inferred from Fox 2003]	**Riparian restoration** Allow for long-term maturation of existing forested riparian areas that are in early seral stages.	No actions identified

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Off-Channel Habitat	10% side-channel habitat. Natural confinement limits off-channel development.	Reach has ponds, oxbows, backwaters, side-channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas. [adapted from REI]	No strategies identified	No actions identified

5.4.7 Reach 7

Reach 7 has similar confinement as Reach 6 and also has limited restoration need or opportunity. The primary habitat deficiencies are pool habitat, large wood, and bank condition. The primary restoration opportunity is riparian and channel margin work associated with a degraded riparian buffer and eroding streambank along river-left near the upstream end of the reach.

Reach 7 Restoration Strategy

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	100% large tree 0% small tree or smaller >20% human disturbance Human disturbance is located within much of the riparian zone. Disturbance includes houses and bank armoring.	At least a 100 ft riparian buffer with: > 80% mature trees. < 20% riparian disturbance (human) [REI]	**Riparian restoration** Work with landowners to plant cleared riparian areas. Look for opportunities to set back infrastructure out of riparian areas.	The riparian disturbance is primarily associated with residential development. Look for opportunities to work with willing landowners to conduct riparian restoration. <u>Specific Project Opportunities:</u> Riparian and Streambank Restoration (RM 48.3L)
Floodplain Connectivity	Floodplain width / BFW = 3.12 There has been some impairment of floodplain function through residential development, fill, and bank armoring.	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Remove fill and infrastructure affecting floodplain connectivity.	Work with landowners to address floodplain development where feasible.
Bank condition / Channel migration	80% of the channel margins are affected by human development and alteration.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Remove or modify bank armoring. Address residential development impacts to streambanks.	There are retaining walls at RM 48.02R and RM 48.29L. These walls are currently protecting residential development, so removal may be unlikely. Work with landowners where feasible to remove bank armoring and prevent further bank armoring.

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Vertical channel stability	There is likely minor past incision related to historical log drives.	No measurable trend of human-induced aggradation or incision [adapted from REI]	No strategies identified	No actions identified
Pools	Pools per mile = 0.0 0% pool habitat	~3-4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Each reach has many large pools >1 m deep with good fish cover. [Reach 1 and REI]	**Placement of structural habitat elements including large wood, log jams, or boulders** Placement of structure to create and enhance pools.	Work with landowners to place pool-forming structures and to enhance pool cover along channel margins. <u>Specific Project Opportunities:</u> Riparian and Streambank Restoration (RM 48.3L)
Large wood and log jams	13 pieces / mi No log jams	> 80 pieces/mi (>12 diam; > 35 ft long) [Reach 1 and inferred from Fox 2003] > 4 log jams/mi [based on conditions in Reach 1 and inferred from Fox 2003]	**Riparian restoration** Riparian projects to improve long-term recruitment. **Placement of structural habitat elements including large wood, log jams, or boulders** Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit.	Work with landowners on wood placement along channel margins to enhance localized pool scour and habitat complexity. <u>Specific Project Opportunities:</u> Riparian and Streambank Restoration (RM 48.3L)

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Off-Channel Habitat	0% side-channel habitat. Creation of future side-channel habitat is limited by human development in floodplain areas.	Reach has ponds, oxbows, backwaters, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas. [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Removal of floodplain alterations to improve processes of off-channel habitat creation. **Off-channel habitat enhancement** Excavation of off-channel habitat where altered river processes reduce the likelihood of future off-channel habitat creation.	A few areas with low floodplain terraces may have opportunities for excavation of off-channel habitats. Most of these areas are dominated by residential development and so opportunities are limited. No specific action identified.

5.4.8 Reach 8

Reach 8 has relatively high natural confinement from glacial terraces. The floodplain areas that do exist have been impacted by residential development and the hatchery intake near RM 49.3. Most of the land is National Forest except for private residential lands at the upstream end on river-left (Chiwawa River Pines Community) and the downstream end on river-right. Habitat impairments include degraded riparian areas, lack of large wood and log jams, disconnected off-channel habitat, and floodplain/CMZ disconnections due to bank armoring. Addressing bank armoring associated with the hatchery intake could help long-term channel migration processes and off-channel development in this area. There are opportunities to place wood and log jams for both instream cover and to increase lateral channel dynamics (e.g. split flow conditions). The Cottonwood Lane Off-Channel Enhancement project area presents a good opportunity to create new off-channel habitat and is likely an area where fill was historically placed in potential off-channel habitat. This would be a great opportunity for riparian restoration even if off-channel creation work at this site is not feasible. There may be other opportunities to work with individual private landowners to conduct riparian restoration. There are also a few opportunities to enhance the connectivity of existing off-channel areas.

Reach 8 Restoration Strategy

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	37% large tree 63% small tree >20% human disturbance There is riparian disturbance throughout the reach, primarily along the left bank at the upstream end and right bank at the downstream end.	At least a 100 ft riparian buffer with: > 80% mature trees. < 20% riparian disturbance (human) [REI]	**Riparian restoration** Work with landowners to plant cleared riparian areas and to allow for the maturation of existing early seral stage forests. Look for opportunities to set back human infrastructure out of riparian areas.	The riparian disturbance is primarily associated with residential development. Specific riparian-only projects have not been identified as they are isolated and associated with individual residences. Riparian restoration should accompany all projects listed for this reach.
Floodplain Connectivity	Floodplain width / BFW = 2.02 Over 60% of the floodplain is considered disconnected due to residential development and roadways. Impacts primarily include filling, grading, and clearing. There are no levees or other significant individual floodplain disconnections.	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Where possible, Remove fill and infrastructure affecting floodplain connectivity. **Protect and maintain** Allow no further alteration of floodplains or loss of floodplain connectivity.	Work with landowners to address floodplain development where feasible. Work with WDFW on addressing the floodplain impacts of the hatchery diversion.
Bank condition / Channel migration	There are only two areas with bank armoring in the reach. One associated with a residence and one associated with the hatchery intake near RM 49.3.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Remove or modify bank armoring.	The most notable bank armoring is associated with the WDFW Chiwawa Ponds Hatchery. Work with WDFW to enhance this channel margin area. Work with landowners to prevent the use of riprap and other bank armoring techniques.

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Vertical channel stability	There is likely minor past incision related to human uses including historical log drives and bank armoring.	No measurable trend of human-induced aggradation or incision [adapted from REI]	**Placement of structural habitat elements including large wood, log jams, or boulders** Apex jams to trap sediment and build grade	Projects incorporating bar apex log jams listed below under LWD would be expected to trap sediments, help control grade, and raise the channel bed over time.
Pools	Pools per mile = 1.8 41% pool habitat 100% of the pools are >1 m deep	~3-4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Each reach has many large pools >1 m deep with good fish cover. [Reach 1 and REI]	**Placement of structural habitat elements including large wood, log jams, or boulders** Placement of structure to create and enhance pools. **Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Removing bank armoring to enhance pool quality.	Work with landowners to place pool-forming structures and to enhance pool cover along channel margins. <u>Specific Project Opportunities:</u> See large wood enhancement projects
Large wood and log jams	57 pieces / mi 0.8 jam /mi	> 80 pieces/mi (>12 diam; > 35 ft long) [Reach 1 and inferred from Fox 2003] > 4 log jams/mi [based on conditions in Reach 1 and inferred from Fox 2003]	**Riparian restoration** Riparian projects to improve long-term recruitment. **Placement of structural habitat elements including large wood, log jams, or boulders** Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit.	Large wood additions include individual pieces or jams along margins to enhance margin habitat and pool scour, as well as mainstem bar apex jams to enhance lateral channel dynamics. <u>Specific Project Opportunities</u> Cottonwood Lane Habitat Complexity (RM 49.5) Intake Island Log Jams (RM 49.2) Chiwawa Fan Island Jams (RM 48.8) Chiwawa Jct Jams (RM 48.6L)

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Off-Channel Habitat	7% side-channel habitat. In general, natural confinement tends to limit off-channel development in this reach.	Reach has ponds, oxbows, backwaters, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas. [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Removal of floodplain alterations to improve processes of off-channel habitat creation. **Off-channel habitat enhancement** Excavation of off-channel habitat where altered river processes reduce the likelihood of future off-channel habitat creation.	There are a couple of opportunities to enhance existing off-channels and to create new ones. <u>Specific Project Opportunities:</u> Cottonwood Lane Off-Channel Habitat (RM 49.3L) Intake Island Off-Channel Habitat (RM 49.1L) Chiwawa Fan Island Off-Channel Habitat (RM 48.85L)

5.4.9 Reach 9

Reach 9 has habitat impairments related to floodplain disconnection (Beaver Valley Road fill), riparian stand ages, log jam frequency, and pool frequency. Although this reach has experienced natural incision into Pleistocene glacial terraces, anthropogenic-related incision and upstream confinement (in Reach 10) has likely resulted in channel simplification and disconnection of off-channel habitats. The reach is entirely bordered by National Forest land and there are several opportunities for habitat restoration. Although Beaver Valley Road cuts off a portion of the river-right floodplain near RM 50.5, the small amount of disconnection and the cost of road relocation would likely not justify a project here. Pool frequency, jam frequency, and off-channel impairments can be addressed through various types of log jam placements. Jams can be used in this reach to create mid-channel islands and to induce split-flow conditions. Jams and selected excavation could also be used to increase off-channel complexity (e.g. Mosquito Alley Off-Channel and Complexity Enhancement Project). This reach is currently dominated by glide habitat; log jams could also be used to increase the quantity of pool and riffle habitat, which are lacking in this reach. Riparian areas are only moderately impaired and primarily need time for stand ages to increase.

Reach 9 Restoration Strategy

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	62% large tree 38% small tree Densely vegetated riparian canopy and intact understory. Riparian areas are affected by dispersed camping areas along the river-left bank in some areas.	At least a 100 ft riparian buffer with: > 80% mature trees. < 20% riparian disturbance (human) [REI]	**Protect and maintain** Allow the existing young forest to mature.	Riparian restoration should accompany all projects listed for this reach.
Floodplain Connectivity	Floodplain width / BFW = 2.04 A portion of the floodplain is disconnected by Beaver Valley Road along the right bank near RM 50.5. Portions of the floodplain show signs of past incision, potentially related to historical log drives.	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain [adapted from REI]	**Protect and maintain** Allow no further alteration of floodplains or loss of floodplain connectivity. **Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Address existing floodplain impairments through removal or relocation of human infrastructure.	Consider set-back of Beaver Valley Road where it cuts off a portion of the floodplain near RM 50.5.

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Bank condition / Channel migration	There is no bank armoring in Reach 9. This reach has the highest percentage of actively eroding banks within the study reach at 22%. Much of this erosion appears natural but may be partially related to past incision and the presence of early seral riparian vegetation.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	**Protect and maintain** Allow maturation of riparian vegetation to bring erosion/migration rates closer to natural rates. **Placement of structural habitat elements including large wood, log jams, or boulders** Provide channel margin structure that will reduce rapid erosion and help to bring erosion rates closer to natural rates.	There is the opportunity to enhance margin complexity via wood placements. These projects will also serve to reduce rapid erosion by deflecting stream energy from streambanks. Projects should be configured to not reduce natural bank migration rates. <u>Specific Project Opportunities:</u> Mosquito Alley Channel Complexity (RM 51.2) Mosquito Bend Off-Channel and Complexity Enhancement (RM 50.9R) Beaver Valley Rd Off-Channel and Complexity Enhancement (RM 50.5)
Vertical channel stability	There is past incision related to confinement by glacial terraces along both banks. This reach, more than others, appears to have undergone somewhat accelerated incision processes that may result from building of Beaver Valley Road, upland timber harvest, and/or log drives. Active incision appears to have stabilized in the existing condition.	No measurable trend of human-induced aggradation or incision [adapted from REI]	**Placement of structural habitat elements including large wood, log jams, or boulders** Apex jams to trap sediment and build grade.	Projects incorporating bar apex log jams listed below under LWD would be expected to trap sediments, help control grade, and raise the channel bed over time.

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Pools	Pools per mile = 1.4 35% pool habitat 100% of the pools are >1 m deep	~3-4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Each reach has many large pools >1 m deep with good fish cover. [Reach 1 and REI]	**Placement of structural habitat elements including large wood, log jams, or boulders** Placement of structure to create and enhance pools.	Placement of large wood could enhance pools by providing cover for habitat, and can create localized scour to develop and maintain pools. Specific Project Opportunities: See large wood and bank condition enhancement projects.
Large wood and log jams	75 pieces / mi 0.5 jam /mi	> 80 pieces/mi (>12 diam; > 35 ft long) [Reach 1 and inferred from Fox 2003] > 4 log jams/mi [based on conditions in Reach 1 and inferred from Fox 2003]	**Placement of structural habitat elements including large wood, log jams, or boulders** Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit.	Large wood additions include individual pieces or jams along margins to enhance margin habitat and pool scour, as well as mainstem bar apex jams to enhance lateral channel dynamics. Along the toe of the high glacial terraces, "colluvial" jams can be created that mimic natural jams formed by mass wasting events off the terrace slope. Specific Project Opportunities Mosquito Alley Channel Complexity (RM 51.2) Mosquito Bend Off-Channel and Complexity Enhancement (RM 50.9R) Beaver Valley Rd Off-Channel and Complexity Enhancement (RM 50.5) Fifty-Mile Log Jams (RM 50)

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Off-Channel Habitat	4% side-channel habitat. There are existing alcoves and off-channel wetlands, many of which are only inundated at high flows.	Reach has ponds, oxbows, backwaters, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas. [adapted from REI]	**Off-channel habitat enhancement** Excavation of off-channel habitat where altered river processes reduce the likelihood of future off-channel habitat creation. **Placement of structural habitat elements including large wood, log jams, or boulders** Placement of wood for cover and to enhance connectivity.	There are a couple of opportunities to enhance existing off-channels and to create new ones where they have been disconnected by incision processes. A few of the existing low surfaces that have off-channel wetland habitat that is inundated only during high flows provide the opportunity for near-margin bar apex jams that would build islands and divert flow into off-channel areas. Specific Project Opportunities: Mosquito Alley Channel Complexity (RM 51.2) Mosquito Bend Off-Channel and Complexity Enhancement (RM 50.9R) Beaver Valley Rd Off-Channel and Complexity Enhancement (RM 50.5) Fifty-Mile Side Channel (RM 50.2L)

5.4.10 Reach 10

Reach 10 is a complex section of the Wenatchee River with conditions ranging from nearly pristine backwater habitat to dense residential areas within riparian areas. This results in a range of restoration opportunities within the reach. Habitat impairments include moderate riparian impairment (mostly associated with streamside residences), impaired channel migration and floodplain inundation (i.e. fill and armoring associated with Braeburn Road developments and floodplain disconnection associated with the Lake Wenatchee Hwy Bridge), log jam frequency, and off-channel habitat. Impaired off-channel habitat includes lack of cover in existing backwater areas and impaired connectivity of the large Natapoc off-channel area in the river-right floodplain.

There are a variety of restoration opportunities depending on the type of impairments and land uses. Addressing riparian degradation and bank armoring along Braeburn Road residences will require cooperative partnerships with willing landowners to enhance riparian vegetation and channel margin complexity. Large-scale changes to channel migration or floodplain processes associated with these developments are not anticipated. In several locations, adding log jams could be used to enhance lateral channel dynamics as well as to increase channel margin complexity and pool habitat. The two large existing backwater habitat areas (Chiwawa Jct and Fish Lake Run backwaters) could be enhanced by adding cover and complexity via large wood placements. The Natapoc project is one of the best potential opportunities for enhancing floodplain and off-channel connectivity in the entire study area. This off-channel complex is connected to the mainstem via surface flows during high water periods but connectivity at lower flows is believed to be affected by anthropogenic-related channel incision and residential developments along Braeburn Road. These impacts also reduce the potential for long-term creation and maintenance of off-channel habitats in this area via floodplain flows, channel migration, and avulsion processes.

Reach 10 Restoration Strategy

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	75% large tree 19% small tree 6% sapling/pole Dominated by large trees, and wetland vegetation in connected off-channel areas. There is cleared vegetation and human infrastructure within the riparian zone at the upstream end of the reach on the right bank associated with residential development along Brae Burn Road.	At least a 100 ft riparian buffer with: > 80% mature trees. < 20% riparian disturbance (human) [REI]	**Riparian restoration** Work with landowners to re-plant cleared areas and to move infrastructure out of riparian areas.	Work with landowners along Brae Burn Road to enhance riparian conditions. Riparian restoration should accompany all projects listed for this reach. <u>Specific Project Opportunities:</u> Brae Burn Streambank Enhancement (RM 53.5R)

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Floodplain Connectivity	Floodplain width / BFW = 3.25 Much of the floodplain along this reach lies within the Nason Creek fan and is disconnected via Highway 207 and residential developments along Brae Burn Road.	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Where possible, set back roadways, remove fill, and remove/modify other human infrastructure affecting floodplain processes. **Off-channel habitat enhancement** Reconnect existing off-channel habitats where connectivity has been impacted by development or incision.	Work with landowners on a long-term approach to restore floodplain connectivity affected by the Brae Burn Road developments. Enhance connections to off-channel habitats where connectivity has been impacted by development or incision, such as the large Natapoc off-channel. See the Off-Channel section for specific projects.
Bank condition / Channel migration	Over 700 feet of the right bank at the upstream end of the reach is armored (Brae Burn Road area). 18% of the banks within the reach are actively eroding, some of which is related to residential development, some which is related to past incision, and some which may be natural.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Remove or modify bank armoring.	Remove bank armoring and set back development and roadways where feasible. <u>Specific Project Opportunities:</u> Brae Burn Streambank Enhancement (RM 53.5R)

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Vertical channel stability	There is past incision related to confinement by glacial terraces. Accelerated incision may be related to bank armoring, artificial confinement, roads, and historical log drives. Active incision appears to have stabilized in the existing condition.	No measurable trend of human-induced aggradation or incision [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Remove bank armoring where possible to promote more natural rates of channel aggradation and incision. **Placement of structural habitat elements including large wood, log jams, or boulders** Apex jams to trap sediment and build grade	Where possible, address artificial confinement at the upper end of the reach within the Nason Creek fan area. <u>Specific Project Opportunities:</u> Brae Burn Streambank Enhancement (RM 53.5R) Projects incorporating bar apex log jams listed below under LWD would be expected to trap sediments, help control grade, and raise the channel bed over time.
Pools	Pools per mile = 2.3 57% pool habitat	~3-4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Each reach has many large pools >1 m deep with good fish cover. [Reach 1 and REI]	**Placement of structural habitat elements including large wood, log jams, or boulders** Placement of structure to create and enhance pools.	Placement of large wood could enhance pools by providing cover for habitat, and can create localized scour to develop and maintain pools. <u>Specific Project Opportunities:</u> See large wood and bank condition enhancement projects.

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Large wood and log jams	101 pieces / mi 1.5 jams /mi	> 80 pieces/mi (>12 diam; > 35 ft long) [Reach 1 and inferred from Fox 2003] > 4 log jams/mi [based on conditions in Reach 1 and inferred from Fox 2003]	**Riparian restoration** Riparian projects to improve long-term recruitment. **Placement of structural habitat elements including large wood, log jams, or boulders** Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit.	Large wood additions include individual pieces or jams along margins to enhance margin habitat and pool scour, as well as mainstem bar apex jams to enhance lateral channel dynamics. Along the toe of the high glacial terraces, "colluvial" jams can be created that mimic natural jams formed by mass wasting events off the terrace slope. <u>Specific Project Opportunities</u> Lower Nason Jams (RM 53.65R) Midway Jams (RM 53.1L) Pirate Island and Pirate Island II (RM 52.8 and 52.45) Natapoc Margin Jams (RM 52.3R) Mile 52 Colluvial Jams (RM 52L) Natapoc Outlet Apex Jams (RM 51.7)

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Off-Channel Habitat	3% side-channel habitat. The reach has two large backwater complexes that provide excellent refuge, but flowing side channels were uncommon within the reach. There are existing off-channel wetland (i.e. Natapoc), but most of these are only inundated at high flows.	Reach has ponds, oxbows, backwaters, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas. [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Removal of floodplain alterations to improve processes of off-channel habitat creation. **Off-channel habitat enhancement** Excavation of off-channel habitat where altered river processes reduce the likelihood of future off-channel habitat creation. **Placement of structural habitat elements including large wood, log jams, or boulders** Placement of wood for cover and to enhance connectivity.	There are several opportunities to enhance existing off-channels and to create new ones where they have been disconnected by incision processes. The large Natapoc Project on river right near the downstream end of the reach offers a good opportunity to enhance connectivity of a large off-channel complex. <u>Specific Project Opportunities:</u> Nason Confluence Downstream (RM 53.6R) Alcove and Side-Channel Enhancement (RM 53.4L) Midway Backwater Enhancement (RM 53L) Chiwawa Jct Backwater (RM 52.7L) Natapoc Project (RM 52R) Fish Lake Run Backwater (RM 52.1L)

5.4.11 Reach 11

This short reach has limited habitat impairments and corresponding limited opportunities for restoration. The primary habitat impairments are a lack of log jams and impaired off-channel habitat. Off-channel impairments are associated with a lack of cover in an existing alcove and general loss of off-channel habitat in the Nason Creek delta area. The First Island Project presents a good opportunity for construction of a bar apex log jam; this jam would be expected to capture more wood from upstream and would enhance pool scour and split-flow conditions at this location. There is an existing off-channel area upstream of the confluence of Nason Creek that is only connected at high flows. This area could be excavated to enhance off-channel rearing at a greater range of flows. This project would help mitigate for the alteration that the Hwy 207 road fill and bridge have on long-term creation and maintenance of floodplain habitats within the Nason Creek fan area. Landownership is mostly State Park and National Forest and access conditions are good.

Reach 11 Restoration Strategy

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	100% large tree The overstory is dominated by large conifers but some clearing has occurred associated with the State Park at the upstream end.	At least a 100 ft riparian buffer with: > 80% mature trees. < 20% riparian disturbance (human) [REI]	**Protect and maintain**	Riparian restoration should accompany all projects listed for this reach.
Floodplain Connectivity	Floodplain width / BFW = 1.64 The floodplain is well-connected.	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain [adapted from REI]	**Protect and maintain**	No actions identified
Bank condition / Channel migration	The reach is migrating at or near natural rates. There are remnant concrete pilings near RM 53.85 but these are believed to have a minimal effect on channel processes and may be providing habitat in the form of localized scour pools and cover.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	**Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill** Remove or modify bank armoring.	Remove bridge pillars <u>Specific Project Opportunities</u> Bridge Pillar Removal (RM 53.85)

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Vertical channel stability	There has been local scour and incision related to the Hwy 207 Bridge at the downstream end of the reach but no significant measurable incision in the reach as a whole.	No measurable trend of human-induced aggradation or incision [adapted from REI]	No strategies identified	No actions identified
Pools	Pools per mile = 2.0 77% pool habitat	~3-4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Each reach has many large pools >1 m deep with good fish cover. [Reach 1 and REI]	**Placement of structural habitat elements including large wood, log jams, or boulders** Placement of structure to create and enhance pools.	Placement of large wood could enhance pools by providing cover for habitat, and can create localized scour to develop and maintain pools. Specific Project Opportunities: See large wood projects
Large wood and log jams	242 pieces / mi 0 jams /mi Most of the wood is scattered along channel margins at the upstream end of the reach (windblown lake wood) or is sunken wood believed to be from historical log drives.	> 80 pieces/mi (>12 diam; > 35 ft long) [Reach 1 and inferred from Fox 2003] > 4 log jams/mi [based on conditions in Reach 1 and inferred from Fox 2003]	**Placement of structural habitat elements including large wood, log jams, or boulders** Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit.	Large wood additions include individual pieces or jams along margins to enhance margin habitat and provide localized cover. Specific Project Opportunities First Island (RM 53.75) Nason Confluence Upstream (RM 53.7R)

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Off-Channel Habitat	5% side-channel habitat. There is one mainstem side-channel. There is one alcove along the right bank.	Reach has ponds, oxbows, backwaters, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas. [adapted from REI]	**Protect and maintain** Protect and maintain Nason Creek confluence area. **Off-channel habitat enhancement** Enlarge and enhance connectivity of off-channel area at mouth of Nason.	There is a good opportunity at the upstream end of the Nason Creek confluence to enhance and enlarge existing off-channel habitat. Specific Project Opportunities: Nason Confluence Upstream (RM 53.7R)

6 NEXT STEPS

This restoration strategy does not take the next step of prioritizing potential project opportunities, which is beyond the scope of this Assessment. However, prior to project implementation, projects should be prioritized in order to select and move forward with the projects that have the greatest potential benefits. As part of the YN's UCHRP, the YN uses an internal process for prioritization that considers numerous factors including: 1) biological and habitat benefits, 2) the degree to which projects address root causes of problems, 3) costs, and 4) feasibility and risk constraints. Other project sponsors are encouraged to apply similar criteria to project prioritization to ensure that the most beneficial projects are moved forward to implementation.

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Appendix A

Wenatchee River Stream Habitat Assessment

River Mile 35.5 to 54.2

Survey: August 2011

Table of Contents

Special Thanks:
to Bryon Newell, the Upper Valley Museum, and the Wenatchee Valley Museum and Cultural Center for providing historical information and photographs (including aerial photos).

1 Introduction

The Wenatchee River is located on the east slope of the Cascade Mountains in Chelan County, WA. It flows into the Columbia River upstream of Rock Island Dam, near the town of Wenatchee. A habitat survey was conducted along the upper 18.7 river miles of the Wenatchee River from the top of Tumwater Canyon (Hwy 2 Bridge) to Lake Wenatchee (Figure 1). This survey was conducted from August 9 to August 31, 2011 from approximately RM 35.51 to RM 54.15. Stream flow during the survey period ranged from 1,210 to 2,940 cubic feet per second (cfs) at the USGS Wenatchee River at Plain, WA gage (#12457000) located at RM 46.2.

The objective of the Habitat Assessment is to characterize the habitat quantity and quality for salmonid species native to the Wenatchee River by quantifying in-channel morphologic features, characterizing riparian conditions, and identifying anthropogenic features influencing aquatic habitat. This information is used to inform potential restoration/preservation actions and will provide a baseline for evaluating future habitat trends and for measuring the effectiveness of restoration efforts. To our knowledge, this is the first comprehensive stream habitat survey and assessment for this portion of the upper Wenatchee River.

Chinook salmon (spring and summer runs), coho, sockeye, steelhead (summer run), rainbow trout, bull trout, west slope cutthroat trout, and mountain whitefish are native salmonid species of the Wenatchee River. The upper Wenatchee River is utilized for spawning, rearing, and as a migration corridor for Chinook, coho, sockeye, and steelhead. The Washington Department of Fish and Wildlife (WDFW) has determined that the Wenatchee River watershed offers fair to excellent spawning and rearing habitat and is considered one of the best salmon producing systems in eastern Washington (WDFW 1990).

The results of this assessment highlight habitat deficiencies by reach that will be useful for establishing objectives and performance targets to guide enhancement, restoration, and preservation activities.

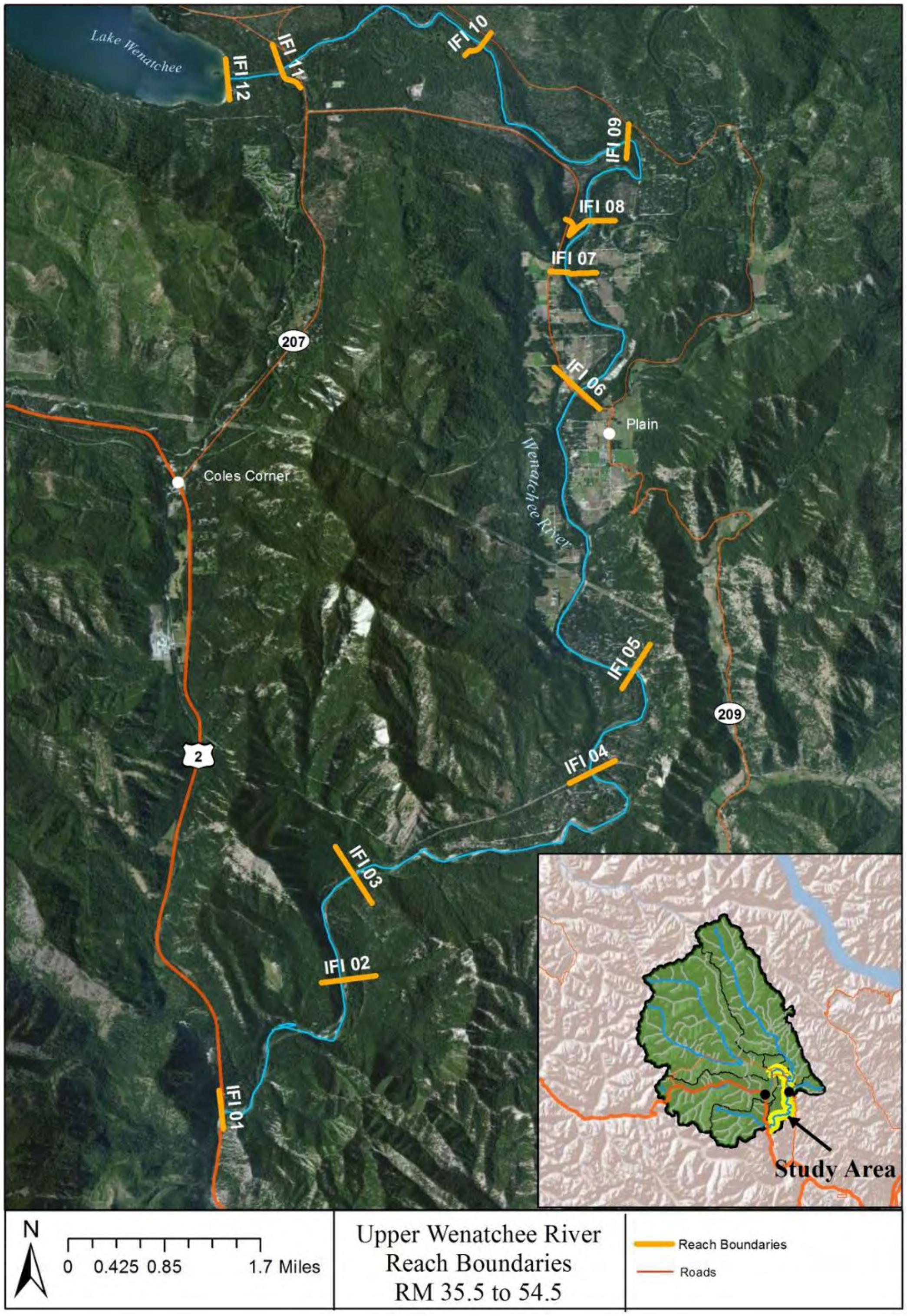

Figure 1. Locator map of the Habitat Assessment area showing the stream habitat survey reaches used in the assessment.

2 Methods

Eleven geomorphic reaches have been delineated as part of the reach assessment. These same reaches were used for both the stream habitat and geomorphology assessments to maintain consistency for this and future inventories. Data collected in this survey is intended to compliment preexisting data for the Wenatchee Basin.

Field methods for the habitat survey used the USFS Region 6 Level II Stream Survey Protocol Version 2.6 (USFS 2006). The protocol was modified because the Wenatchee River is not a wadeable stream. Therefore, this stream habitat survey was conducted by navigating the river from Lake Wenatchee to Tumwater Canyon using inflatable kayaks. Record snow pack throughout the Cascade Mountain range during the winter of 2010/2011 provided the Wenatchee River with extremely high spring and summer stream flows. Due to scheduling constraints and spring Chinook spawning timing, the survey was unable to be conducted during minimum stream flows. Stream flows were recorded at 2,940 cfs on August 9, and continued to decrease throughout the stream habitat survey period to 1,210 cfs on August 31, 2011.

An additional modification was made to the protocol with respect to the n^{th} unit measurement frequency. Due to varying reach lengths and the scale of habitat units along the upper Wenatchee River, every habitat unit was measured to obtain consistent quantitative data throughout the entire study area. Habitat unit length was measured using GPS points taken in the field and analyzed for approximate length within 20 feet of accuracy. Habitat unit width was measured with a hand-held range finder at several locations along the unit and averaged for best accuracy. Habitat unit depths were collected with measuring rods (i.e. wading rods and graduated paddles) to a depth of 7 feet and conservatively estimated when unit depth exceeded the measuring rod.

Data collection in fast water units (i.e. riffles and glides) was challenging and in some reaches impossible due to deep and swift water. Bankfull measurements and Wolman pebble counts (Wolman 1954) were collected when stream conditions allowed (i.e. wadeable). Bankfull measurements were collected at 29% of the fast water units, including one glide and 20 riffles. Visual (ocular) estimates of bed sediment composition (considered a “forest option” in the USFS protocol) were recorded for every fast water unit. The lengths of unstable banks were visually estimated for every unit.

Side-channel units were identified when the main channel split to form a stable island with soil or fine sediment deposits and vegetation older than 2 to 3 years old, or in places where large cobble deposits have persisted for over 40 years (verified with 1966 DOT aerial photos). Each side-channel was designated as either a pool, riffle, or glide based on the dominant habitat type. Off-channel marshlands were identified and inventoried during this survey following specifications of the USFS Region 6 Level II Stream Survey Protocol.

For the riparian assessment, the Level II survey manual indicates that it is a "forest option" to designate either a single 100-ft wide zone or two adjacent riparian zones (inner and outer zones) totaling 100 feet in width (USFS 2006). For reasons best suited to this assessment, one single 100-ft wide riparian zone was designated for the Wenatchee River study area. Survey methods dictate defining a dominant class of vegetation type for the riparian zone (e.g. large trees, small trees, shrubs), then defining the dominate species observed in the over and understory.

3 Summary of Results

This section summarizes the results across all eleven reaches. Detailed reach summaries with reach-specific results are included in Appendix A.

3.1 Channel Morphology

Upper Wenatchee River reaches were dominated by pool-riffle and plane-bed morphology. Channel bed substrate consisted primarily of cobbles and gravels, with a moderate frequency of boulders and sand in some reaches. Bedrock occurred relatively infrequently.

Channel widths did not vary substantially between stream reaches but did increase slightly in Reach 1 and Reach 2 (Figure 2). Limited channel widening in the downstream direction may be attributed to channel simplification and artificial channel confinement that affects stream width throughout much of the study area. Mean bankfull widths were 276.3 ft (stdev 39.1). Bankfull depths, however, are more variable, both among and within individual reaches (Figure 3). Mean bankfull depth was 5.9 ft (stdev 1.0). Bankfull depth ranged from 3.4 to 9.5 feet, with the largest bankfull depths occurring in Reach 10. Floodprone widths vary considerably throughout the upper Wenatchee study area (Figure 4), with a mean floodprone width of 749.5 ft (stdev 315.4). Reaches 1 and 3 had the widest active floodplains (>1,000 ft) and Reach 5 was the most disconnected (<400 ft).

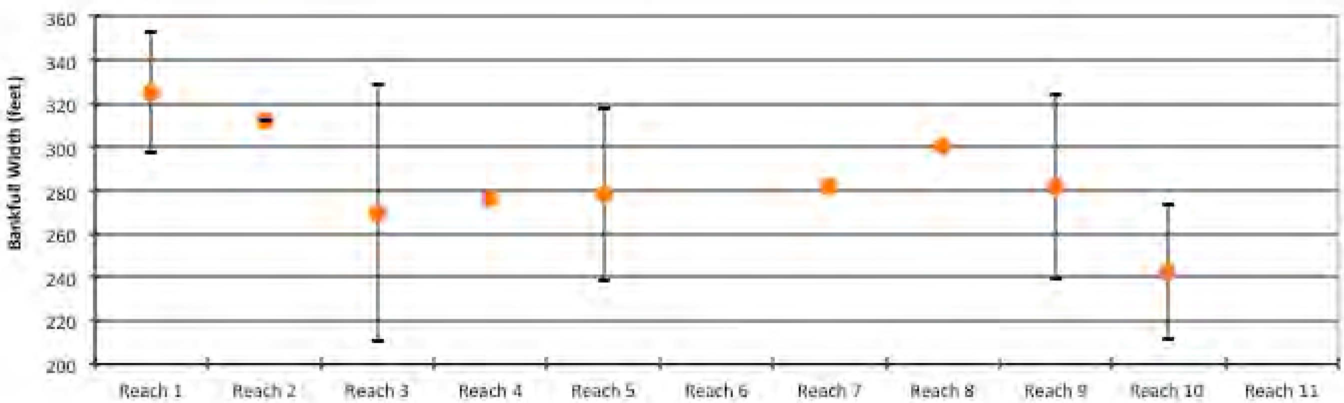

Figure 2. Plot of mean bankfull widths for each reach with error bars representing the standard deviation.

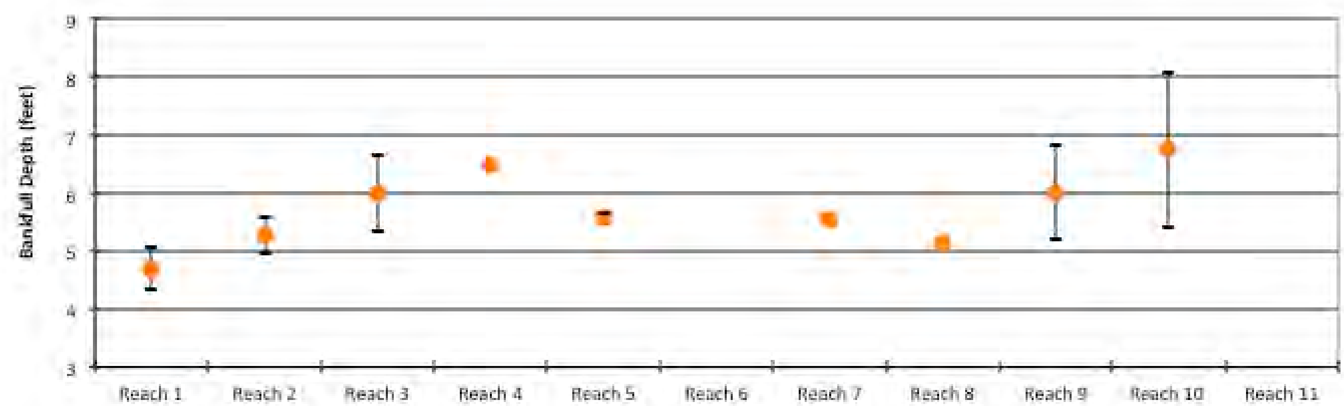

Figure 3. Plot of mean bankfull depths for each reach with error bars representing the standard deviation. Each value is an average of three individual measurements taken at wadeable riffle units (n= 0 to 6) in each reach.

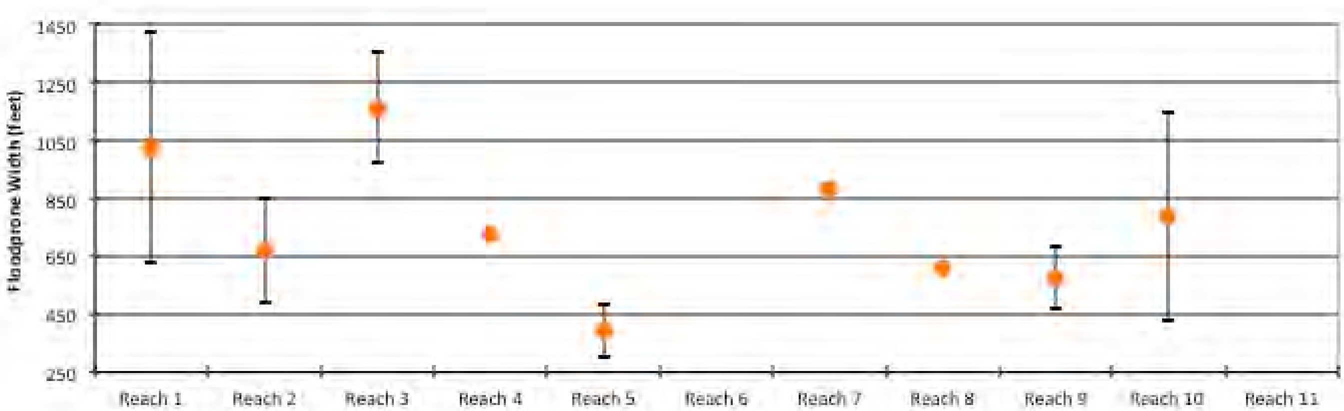

Figure 4. Plot of mean floodprone widths for each reach with error bars representing the standard deviation.

3.2 Habitat Unit Composition

Riffles, pools, and glides made up equal portions of the total habitat unit composition for the study area (31%, 30%, and 30%, respectively). The remaining 9% was side channel habitat (Figure 5).

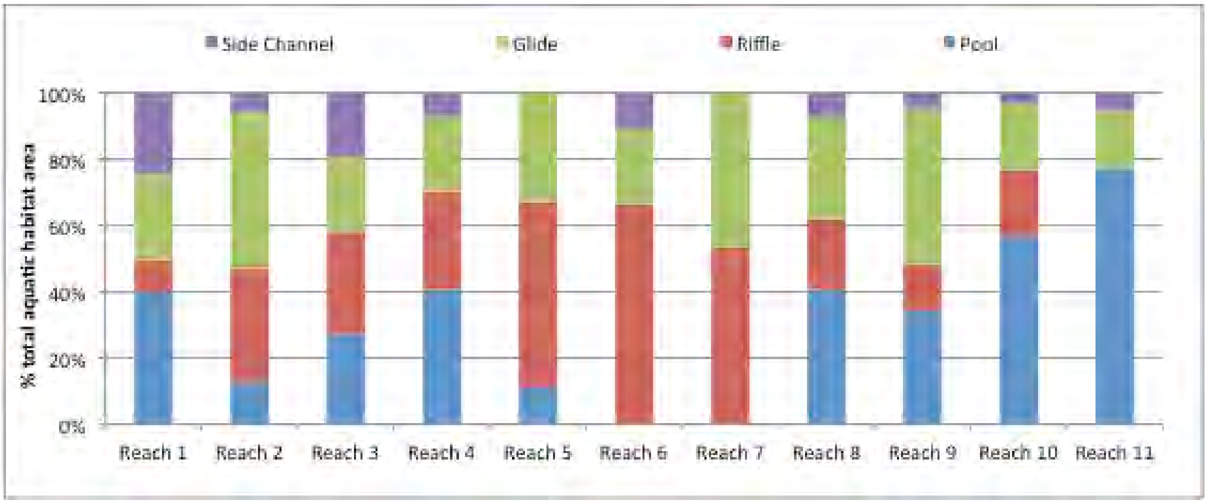

Figure 5. Habitat unit composition by reach.

Pool frequency ranged from 0.0 to 2.7 pools/mile, with a mean pool spacing of 8.0 to 28.3 channel widths per pool. Reach 6 and 7 had no pool habitat. Reaches 10 and 11 had the greatest proportion of pool habitat (57% and 77%, respectively), although Reach 1 had the greatest number of pools/mile (2.7). Reaches 1 and 11 had the shortest pool spacing (9.4 and 8.0 channel widths per pool, respectively). Reaches 1 and 3 had the greatest number of deep pools with residual depths exceeding 3 ft (6 pools in each reach). The majority of the pools throughout the study area were relatively deep, with shallow residual depths (<3 ft) comprising less than 7% of total pools.

Mean wetted widths were 206.4 feet (stdev 10.9). Mean riffle depths were 2.7 feet (stdev 0.8) with mean maximum depths of 4.6 feet (stdev 1.5). Riffle depths should not present a problem for migrating fish, as minimum depths reported necessary to maintain Chinook and large trout passage (0.8 feet and 0.6 feet, respectively: Thompson 1972) were well exceeded throughout the upper Wenatchee study area. However, riffle depths at the lowest summer flow period would be lower than those reported here.

Average unit lengths for the three habitat types (pools, riffles, and glides) are presented in Figure 6. Reaches 8, 9, 10, and 11 had the longest pools. Reaches 5, 6, and 7 had the longest riffles and Reach 9 had the longest glides. In general, reaches 6, 7, and 9 had longer habitat units, which were comprised mostly of long riffles and glides.

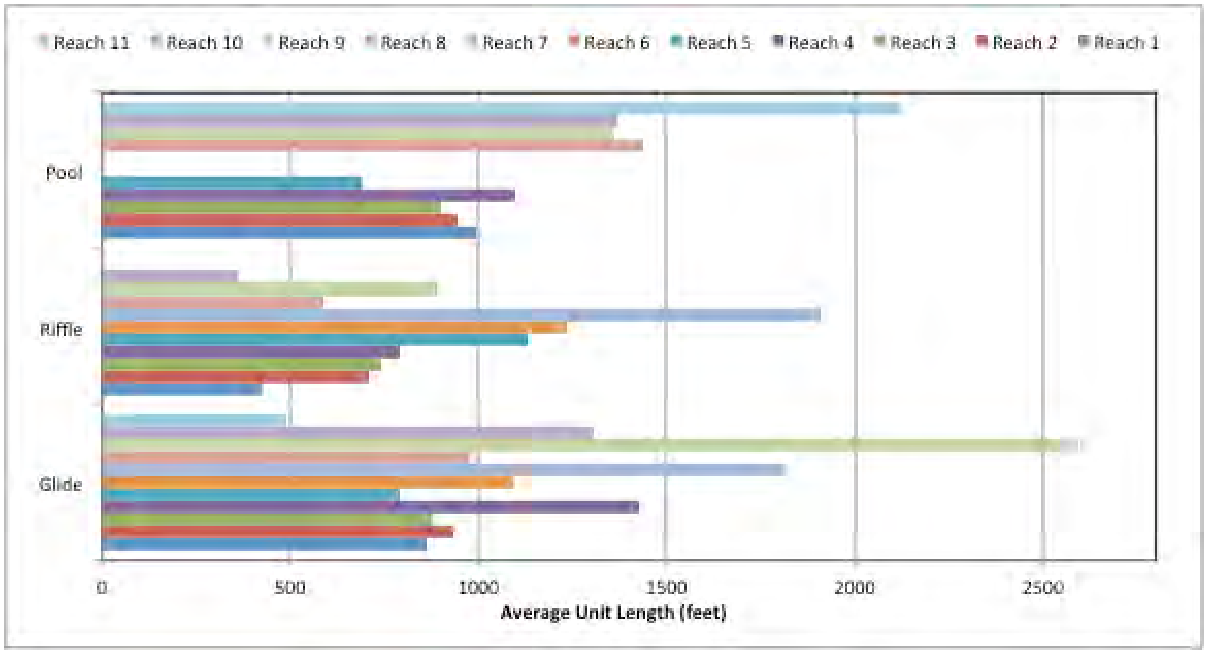

Figure 6. Comparison of average habitat unit lengths for Reaches 1-11 in the upper Wenatchee River.

3.3 *Off-Channel Habitat*

Side-channel habitat accounts for approximately 19% of the surveyed length along the upper 18.7 miles of the Wenatchee River. A total of 33 wetted side-channel habitat units were measured during the survey. Reach 1 had the greatest area of side-channel habitat and Reach 3 had the greatest number of side-channel units. Reaches 5 and 7 had no side-channel habitat. Side-channel riffles (n=21) accounted for 64% of all side-channel units. Side-channel pools (n=8) accounted for 24%, all occurring in Reaches 1 and 3. Side-channel glides (n=4) were the least common off-channel habitat observed throughout the study area. Average and maximum side-channel depths were 1.7 feet (stdev 0.9) and 3.7 feet (stdev 1.8), respectively, with the deepest side-channels observed in Reach 8.

In addition to side-channels, the upper Wenatchee study area had nine marshes ranging from small backwaters to large open water ponds. These off-channel marshlands often provided food sources (invertebrates), LWD, refuge, and rearing habitat for fish and wildlife species. Off-channel marshes were identified in Reach 1, 8, 9, and 10. Reach 9 had the greatest number of marsh units (n=3) and Reach 10 had the largest marsh habitat within the study area.

Natural and artificial confinement limits off-channel habitat throughout some portions of the study area. In some areas, human development of riparian areas and floodplains also impairs floodplain and channel migration processes that are necessary to create and maintain off-channel habitats. The primary impairments to off-channel habitat occur along the reaches that flow through the community of Plain, from Reach 4 through Reach 7. Roads, bank armoring, berms, and channel/floodplain filling have reduced the abundance and connectivity of off-channel habitat and have impaired the floodplain and channel migration dynamics necessary to create and maintain off-channel habitats over time.

3.4 Large Wood

An average of 123 pieces of wood per mile were counted in the upper Wenatchee River; 48% of these were “small” pieces with diameters between 6 and 12 inches and lengths greater than 20 feet (Figure 7). Reaches 1 and 3 had the highest number of “large” LWD pieces per mile (133 and 211, respectively), and overall these two reaches also contained the highest frequencies of LWD at 294 and 252 pieces per mile, respectively. The numbers of pieces per mile in each reach ranged from 13 to 294.

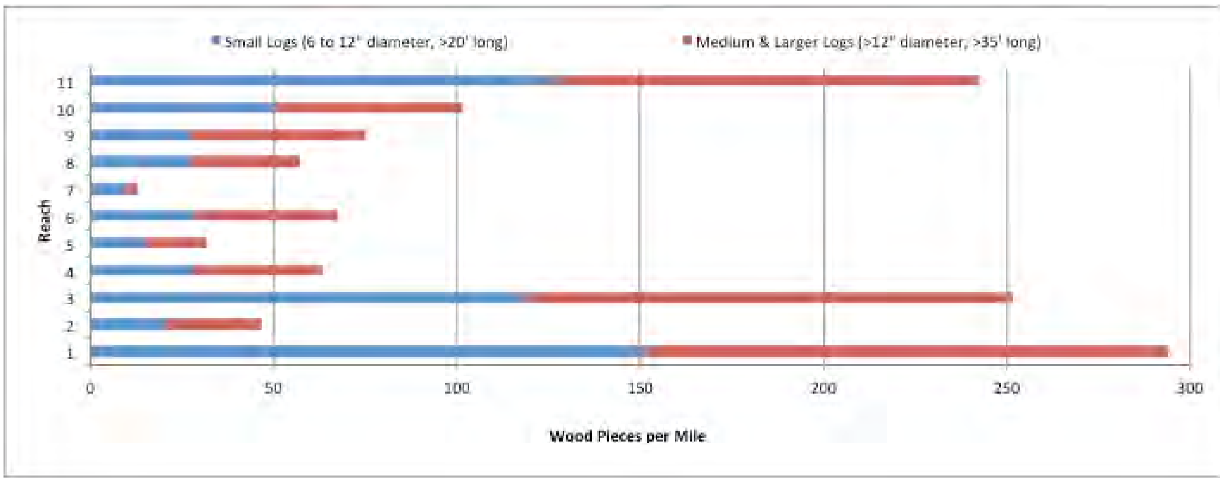

Figure 7. Small and medium/large wood pieces/mile for each reach.

3.5 Substrate and Fine Sediment

Bed substrate was based on ocular estimates at each habitat unit and pebble counts at one or two representative locations within each of the eleven reaches (when wading conditions allowed). Riffle pebble counts were not achievable for reaches 4, 6, and 7 due to high flow velocity and depth. One pebble count was collected for reaches 1, 2, 5, 8, and 11. Two pebble counts were collected for reaches 2, 9, and 10. The ocular estimates and pebble counts correlate well with respect to cobble dominance. Percent coverage of sand, gravel, and boulder varies. In general, bed substrate in the upper Wenatchee River was gravel and cobble, with smaller amounts of boulder, bedrock and sand (Figure 8 and Figure 9). Bedrock was rare and was mostly observed in the lower four reaches and in Reach 6. Results of the ocular estimates demonstrate that reaches 8 and 9 have the highest proportion of sand whereas reaches 6 and 7 had the highest proportion of boulders.

Sediment measurements indicated that the presence of fine sediment (<2mm) was at low to moderate levels throughout much of the upper Wenatchee study area. An excess of fine sediment does appear to be a concern in reaches 4, 8, and 9.

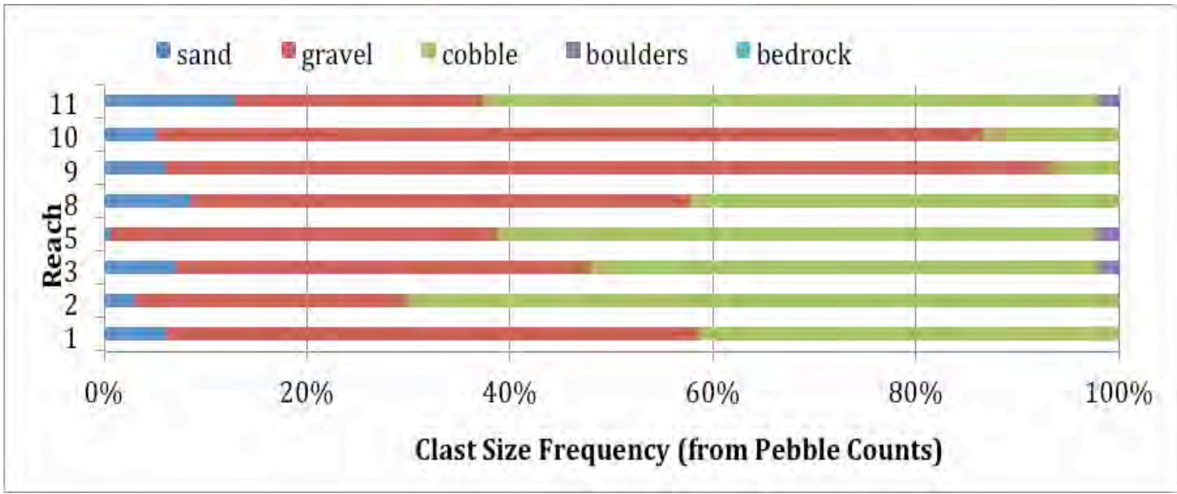

Figure 8. Pebble count classification of substrate by reach for the upper Wenatchee River. Riffle pebble counts were not achievable for Reaches 4, 6, and 7 due to high flow velocity and depth.

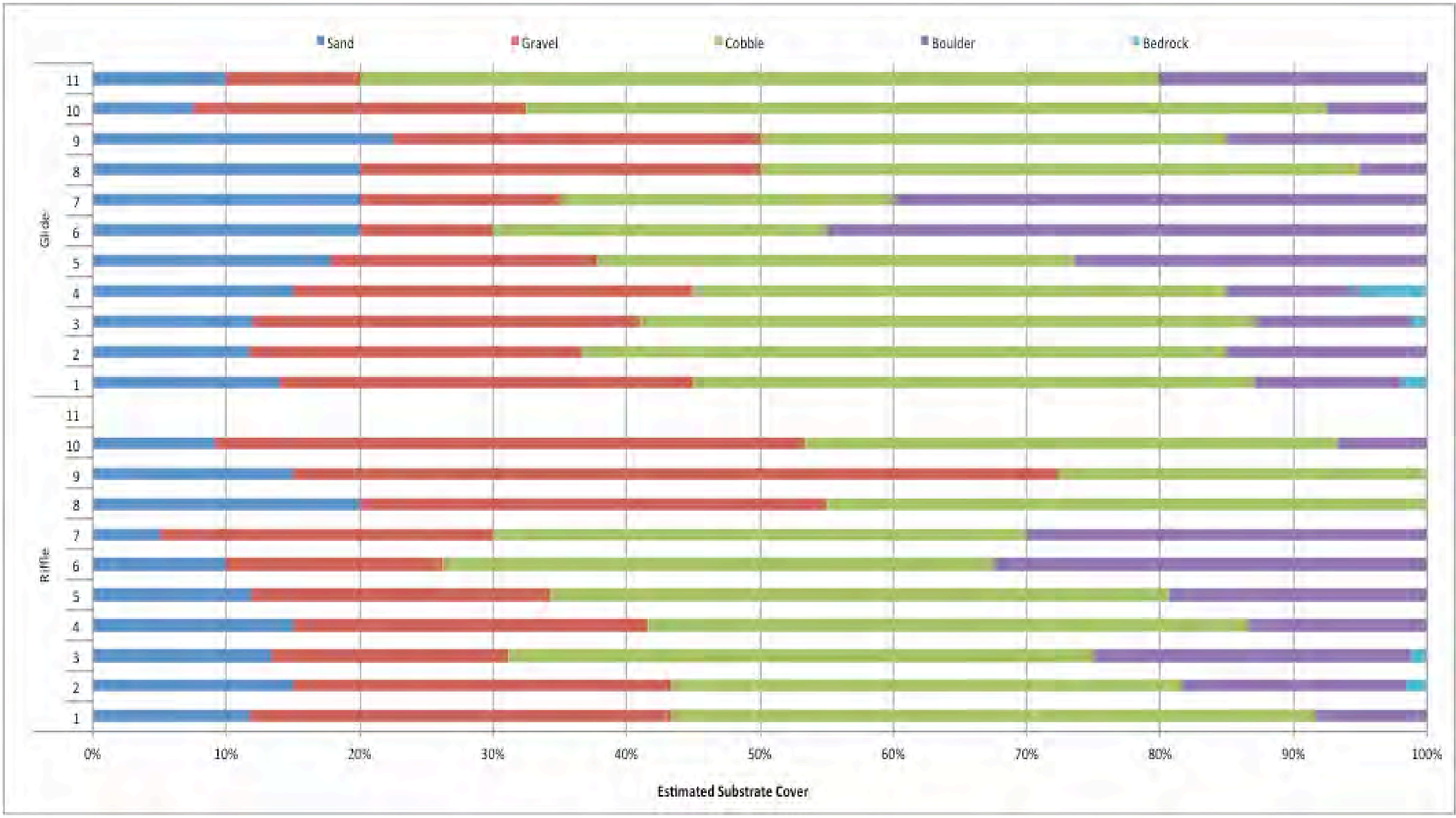

Figure 9. Ocular estimates of substrate by habitat unit type and reach for the upper Wenatchee River.

3.6 Instability and Disturbance

There has been significant human alteration along portions of the channel, riparian zone, and floodplain throughout the study area. These alterations are related to past and ongoing land-uses in the upper Wenatchee River Valley, including timber harvest, agriculture, road building, and residential development. Artificial channel confinement in the form of bridges, floodplain fill, berms, and bank armoring affects channel and floodplain dynamics in many areas. Reaches 4 through Reach 7 flow through the community of Plain and experience the greatest modifications that alter channel and floodplain processes. The other seven reaches have low-to-moderate amounts of human disturbance. Active erosion and disturbance was often related to natural valley confinement throughout the study area.

In total, 12% of the streambanks along the upper 18.7 miles of the Wenatchee River were actively eroding. The greatest amount of bank erosion was observed in reaches 9 and 10, where an average of 23% and 18% (respectively) of the streambanks displayed active erosion. The other nine reaches contained between 0% to 16% bank erosion overall. Bank erosion was observed in all habitat unit types (Figure 10), but was most common along pool habitat. Twenty-eight percent (28%) of all pool habitat in the study area exhibited bank erosion. Much of the erosion is natural process and is related to the natural incision of the channel into terrace deposits of glacial origin. In some cases, the incision and related bank erosion has been exacerbated by human alterations including past riparian clearing, past splash damming/log drives, and bank armoring. Streambank erosion has been halted at some locations by riprap, spur dikes, concrete retaining walls, and other bank hardening features.

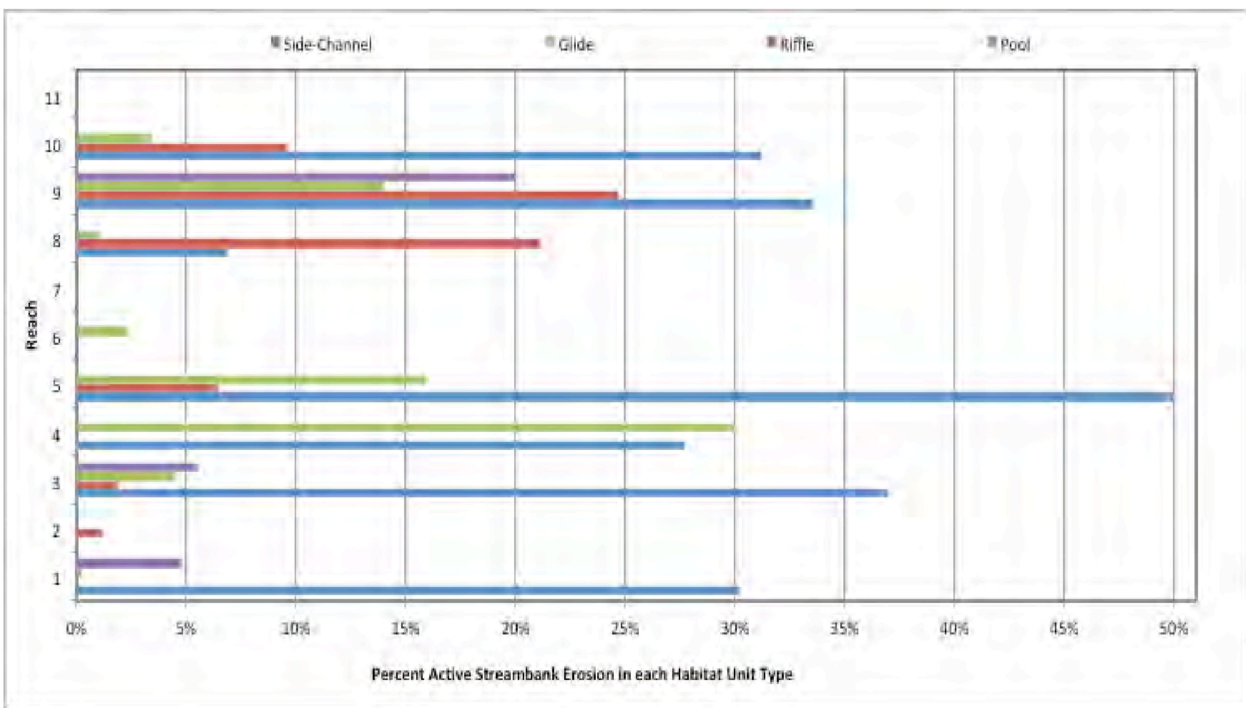

Figure 10. Percent active streambank erosion in each habitat unit type.

3.7 Fish Passage Barriers

There were no fish passage barriers in the study area. Access to some off-channel areas may be limited during low flow periods. Low flow, especially during low water years, may impact adult fish passage in localized shallow riffles and side-channel units.

3.8 Riparian Corridor

Much of the upper Wenatchee Basin was heavily logged in the early 1900s. Reforested timberlands now dominate the riparian buffers but the trees are considerably smaller than what would be expected under non-harvested conditions. Only a handful of areas have cleared riparian conditions. However, in many reaches, particularly those with heavy residential development (Reaches 3-8 and 10), the understory has been cleared of shrubs and small trees to facilitate human uses and views of the river.

The upper Wenatchee riparian zone was typically dominated by large trees (52%). Small trees were dominant in 41% of units and the sapling/pole size class was dominant in just 7% of units (Figure 11). The riparian overstory was primarily conifer (70%) (Figure 12) and ponderosa pine was the dominant overstory species. Overstory species also included cottonwood and Douglas fir. The understory was composed mostly of shrubs (58%) and hardwoods (39%), and exhibited greater species diversity than the overstory. Understory species included (in order of frequency) willow, alder, dogwood, and cottonwood.

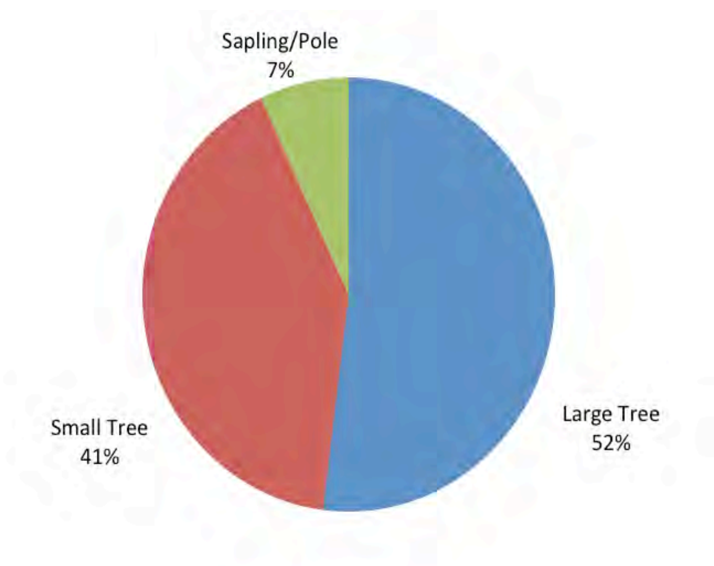

Figure 11. Distribution of the dominant size class category for the riparian inner zones, all reaches combined.

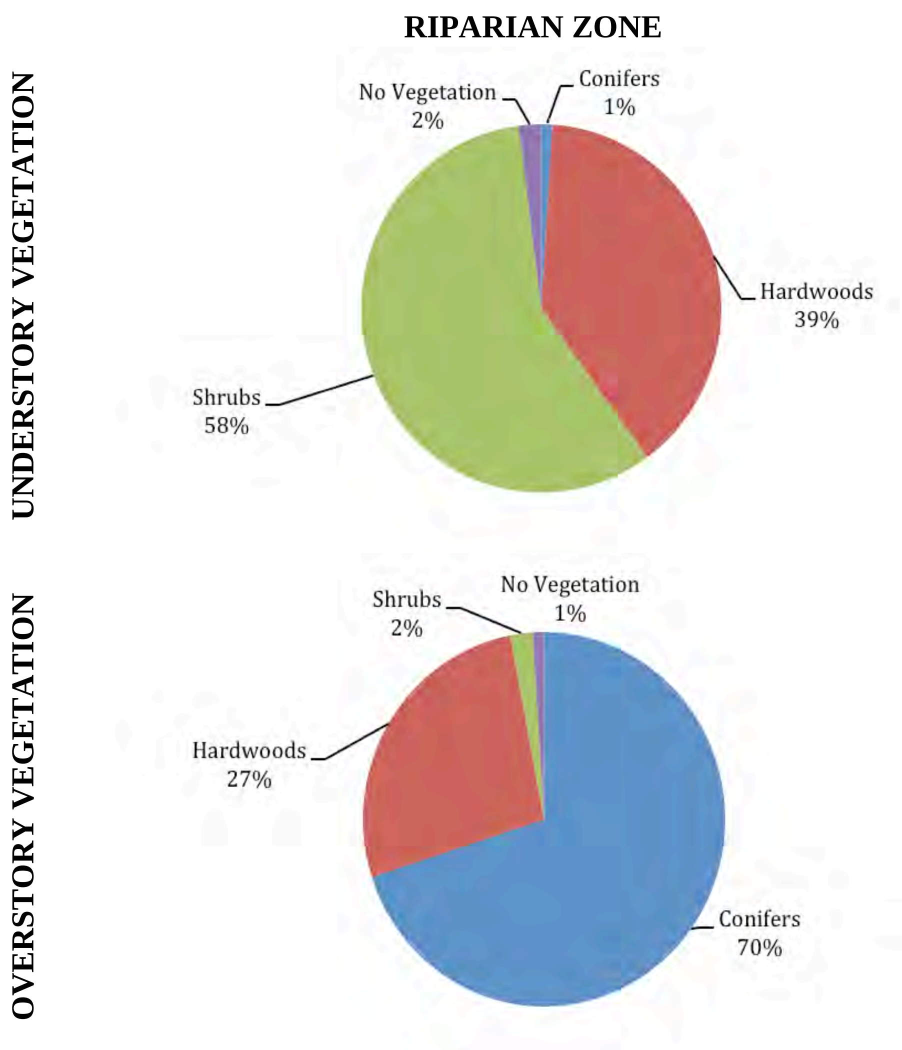

Figure 12. Proportions of vegetation cover types in the riparian zone along the upper 18.7 miles of the Wenatchee River.

Table 1. Upper Wenatchee River Data Summary: RM 35.5 to RM 54.2.

		Total	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11
Reach Mileage Boundaries		35.5 – 54.2	35.5 – 37.6	37.6 – 38.6	38.6 – 41.9	41.9 – 43.1	43.1 – 46.5	46.5 – 47.9	47.9 – 48.4	48.4 – 49.7	49.7 – 51.7	51.7 – 53.7	53.7 – 54.2
Channel Morphology			Pool-riffle	Plane-bed	Pool-riffle	Pool-riffle	Plane-bed	Plane-bed	Plane-bed	Pool-riffle	Plane-bed	Pool-riffle	Plane-bed
Slope													
Average		0.07%	0.07%	0.07%	0.10%	0.07%	0.08%	0.10%	0.07%	0.03%	0.01%	0.04%	0.04%
Wetted Width (ft)													
Pool													
	Mean	201.9	207.3	178.0	186.5	212.3	186.0	n=0	n=0	194.0	214.7	191.8	330.0
	Median	197.0	196.5	178.0	196.0	225.0	190.0	n=0	n=0	194.0	200.0	177.0	330.0
	StDev	42.1	43.5	n=1	46.6	35.7	14.4	n=0	n=0	2.8	27.2	38.3	n=1
Riffle													
	Mean	209.3	222.7	215.7	172.2	235.0	220.0	258.8	228.0	232.5	193.5	189.2	n=0
	Median	210.0	235.0	206.0	156.0	255.0	210.0	265.0	228.0	232.5	193.5	206.0	n=0
	StDev	57.8	52.6	32.6	68.8	65.3	33.6	39.7	n=1	74.2	87.0	68.8	n=0
Glide													
	Mean	207.9	182.0	230.0	193.6	270.0	211.6	192.5	205.0	216.0	220.0	170.0	324.0
	Median	200.0	182.0	236.0	195.0	270.0	200.0	192.5	205.0	216.0	220.0	170.0	324.0
	StDev	36.8	28.0	35.4	35.4	n=1	20.1	10.6	n=1	0.0	14.1	14.1	n=1
Water Depth (ft)													
Pool Maximum Depth													
	Mean	11.1	12.5	6.5	9.6	10.0	11.3	n=0	n=0	11.0	15.0	10.2	12.0
	Median	10.0	12.5	6.5	9.0	9.0	12.0	n=0	n=0	11.0	15.0	10.0	12.0
	StDev	3.4	5.0	n=1	2.9	4.6	1.2	n=0	n=0	1.4	0.0	1.8	n=1

Pool Residual Depth												
Mean	7.4	9.1	3.5	6.2	6.7	7.8	n=0	n=0	7.5	10.0	6.1	8.0
Median	7.3	9.4	3.5	5.5	6.7	8.5	n=0	n=0	7.5	10.2	7.0	8.0
StDev	3.2	4.8	n=1	3.0	4.3	1.6	n=0	n=0	1.4	0.4	2.4	n=1
Maximum Riffle Depth												
Mean	4.6	3.7	3.2	4.7	3.8	4.5	5.0	6.5	3.5	2.8	6.3	n=0
Median	4.0	3.5	2.1	4.3	4.0	4.0	4.8	6.5	3.5	2.8	6.3	n=0
StDev	1.5	0.8	1.8	1.1	0.3	1.0	1.5	n=1	0.0	1.8	2.0	n=0
Average Riffle Depth												
Mean	2.7	2.5	2.2	3.1	2.0	2.9	3.2	3.5	2.1	1.5	2.8	n=0
Median	2.5	2.5	1.5	3.0	2.0	2.5	3.3	3.5	2.1	1.5	3.0	n=0
StDev	0.8	0.6	1.6	0.5	0.5	0.9	0.6	n=1	0.1	0.8	0.3	n=0
Maximum Glide Depth												
Mean	6.6	5.8	5.1	6.4	10.0	6.4	6.8	8.0	7.0	8.3	7.8	5.5
Median	6.5	6.0	5.1	6.2	10.0	6.0	6.8	8.0	7.0	8.3	7.8	5.5
StDev	1.4	0.8	0.7	1.0	n=1	1.3	1.8	n=1	0.7	1.1	1.1	n=1
Average Glide Depth												
Mean	4.0	3.6	3.5	3.9	5.0	4.4	3.9	4.8	3.6	4.2	4.0	3.0
Median	3.9	3.8	3.5	4.0	5.0	4.3	3.9	4.8	3.6	4.2	4.0	3.0
StDev	0.7	0.5	0.5	0.5	n=1	0.9	0.6	n=1	0.8	0.2	0.3	0.7
Bankfull Characteristics												
Width (ft)												
Mean	280.3	325.5	312.0	270.0	276.0	278.0	NA	282.0	300.0	282.0	242.5	360.0
StDev	42.3	27.6	0.0	59.4	NA	39.9	NA	NA	NA	42.4	30.9	NA
Depth (ft) Averaged over 3 depth measurements												
Mean	5.9	4.7	5.3	6.0	6.5	5.6	NA	5.6	5.1	6.0	6.8	4.7
StDev	1.0	0.4	0.3	0.7	NA	0.1	NA	NA	NA	0.8	1.3	NA
Maximum Depth (ft)												
Mean	7.6	6.4	6.3	8.3	7.3	7.2	NA	6.4	6.1	7.2	9.1	7.2

StDev	1.7	0.8	0.8	2.8	NA	1.1	NA	NA	NA	0.6	2.0	NA
Width:Depth Ratio												
Mean	49.8	69.7	59.2	44.7	42.5	49.9	NA	50.7	58.4	46.8	37.9	76.1
StDev	13.9	11.5	3.4	5.0	NA	7.8	NA	NA	NA	0.6	13.4	NA
Floodprone Width (ft)												
Mean	741.9	1025.5	671.0	1164.0	726.0	395.0	NA	882.0	605.0	575.0	786.7	590.0
StDev	309.4	396.7	182.4	192.3	NA	91.4	NA	NA	NA	106.1	358.1	NA
Habitat Area %												
Pool	30%	40%	13%	27%	41%	11%	0%	0%	41%	35%	57%	77%
Riffle	31%	10%	34%	31%	30%	56%	67%	54%	21%	14%	20%	0%
Glide	30%	26%	47%	23%	22%	33%	23%	46%	31%	47%	20%	18%
Side Channel	9%	24%	6%	19%	7%	0%	10%	0%	7%	4%	3%	5%
Pools												
Pools per mile	1.6	2.7	0.9	1.9	2.2	1.0	0.0	0.0	1.8	1.4	2.3	2.0
Residual Depth (% of pools)												
Pools < 3 ft	7%	0%	0%	0%	33%	0%	0%	0%	0%	0%	20%	0%
Pools 3-6 ft	20%	33%	100%	50%	0%	0%	0%	0%	0%	0%	0%	0%
Pools 6-9 ft	43%	17%	0%	33%	34%	67%	0%	0%	100%	0%	80%	100%
Pools 9-12 ft	27%	33%	0%	17%	33%	33%	0%	0%	0%	100%	0%	0%
Pools > 12 ft	3%	17%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Riffle:Pool Ratio	1.4	0.5	3.0	1.5	1.0	2.7	NA	NA	1.0	0.7	1.2	0.0
Mean Pool Spacing (channel widths per pool)	16.1	9.4	28.3	14.9	9.9	27.0	n=0	n=0	14.0	17.6	12.7	8.0
Large Wood												
Total Number Pieces												
Total	*2329*	642	52	785	85	100	91	9	65	157	223	120
Small (6 in x 20 ft)	1120	331	23	372	38	48	39	7	31	56	112	63
Medium (12 in x 35 ft)	611	178	9	202	15	24	23	1	13	44	64	38
Large (20 in by 35 ft)	598	133	20	211	32	28	29	1	21	57	47	19

Number of Pieces/Mile												
Total	123	294	47	252	63	32	67	13	57	75	101	242
Small (6 in x 20 ft)	59	151	21	119	28	15	29	10	27	27	51	127
Medium (12 in x 35 ft)	32	81	8	65	11	8	17	1	11	21	29	77
Large (20 in by 35 ft)	32	61	18	68	24	9	21	1	18	27	21	38
Bank Erosion (% eroding banks)												
Mainstem Total	12%	11%	0%	11%	16%	15%	1%	0%	6%	22%	18%	0%
Pool	28%	30%	0%	37%	28%	50%	n=0	n=0	7%	34%	31%	0%
Riffle	5%	0%	1%	2%	0%	6%	0%	0%	21%	25%	10%	n=0
Glide	7%	0%	0%	4%	30%	16%	2%	0%	1%	14%	3%	0%
Side-Channel	4%	5%	0%	5%	0%	n=0	0%	n=0	0%	20%	0%	0%
Substrate (Ocular Estimate)												
Total												
% Sand	16%	17%	13%	19%	19%	15%	8%	12%	28%	26%	10%	10%
% Gravel	27%	32%	26%	28%	29%	21%	17%	20%	30%	47%	36%	10%
% Cobble	41%	43%	44%	37%	42%	41%	45%	33%	39%	22%	49%	60%
% Boulder	15%	7%	15%	12%	8%	23%	30%	35%	3%	5%	5%	20%
% Bedrock	1%	1%	2%	4%	2%	0%	0%	0%	0%	0%	0%	0%
Riffle												
% Sand	13%	12%	15%	13%	15%	12%	10%	5%	20%	15%	9%	n=0
% Gravel	30%	32%	28%	18%	27%	23%	16%	25%	35%	58%	44%	n=0
% Cobble	42%	48%	38%	44%	45%	46%	41%	40%	45%	27%	40%	n=0
% Boulder	15%	8%	17%	24%	13%	19%	33%	30%	0%	0%	7%	n=0
% Bedrock	0%	0%	2%	1%	0%	0%	0%	0%	0%	0%	0%	n=0
Glide												
% Sand	15%	14%	12%	12%	15%	18%	20%	20%	20%	22%	8%	10%
% Gravel	23%	31%	25%	29%	30%	20%	10%	15%	30%	28%	25%	10%
% Cobble	42%	42%	48%	46%	40%	36%	25%	25%	45%	35%	60%	60%

% Boulder	19%	11%	15%	12%	10%	26%	45%	40%	5%	15%	7%	20%
% Bedrock	1%	2%	0%	1%	5%	0%	0%	0%	0%	0%	0%	0%
Side-Channels												
% Sand	19%	20%	12%	23%	25%	n=0	8%	n=0	22%	40%	12%	10%
% Gravel	32%	33%	25%	30%	30%	n=0	17%	n=0	43%	55%	40%	10%
% Cobble	39%	42%	45%	32%	43%	n=0	45%	n=0	32%	5%	46%	60%
% Boulder	9%	5%	13%	9%	2%	n=0	30%	n=0	3%	0%	2%	20%
% Bedrock	1%	0%	5%	6%	0%	n=0	0%	n=0	0%	0%	0%	0%
Riffle Pebble Count *(1-2 samples per reach when stream conditions allowed)*												
% Sand	6%	6%	3%	7%	NA	1%	NA	NA	9%	6%	5%	13%
% Gravel	50%	53%	27%	40%	NA	38%	NA	NA	49%	87%	82%	24%
% Cobble	43%	41%	70%	51%	NA	58%	NA	NA	42%	7%	7%	61%
% Boulder	1%	0%	0%	2%	NA	3%	NA	NA	0%	0%	0%	2%
% Bedrock	0%	0%	0%	0%	NA	0%	NA	NA	0%	0%	0%	0%
Vegetation (% of sampled units)												
Riparian Zone (100-ft wide zone averaged between both banks)												
Sapling/Pole	7%	9%	11%	16%	0%	0%	0%	0%	0%	0%	6%	0%
Small Trees	41%	36%	33%	44%	22%	39%	87%	0%	63%	38%	19%	100%
Large Trees	52%	55%	56%	40%	78%	61%	13%	100%	37%	62%	75%	0%

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5 Stream Habitat Reach Reports

A-1 Reach 1

Location: River mile 35.5 to 37.6

Survey Date: August 17, 2011

Survey Crew: Christa Strickwerda Heller and Adrianne Zuckerman (Inter-Fluve)

A-1.1 Reach Overview

Reach 1 is located upstream of Tumwater Canyon from the Hwy 2 Bridge at RM 35.5 to a small (right bank) backwater marsh at RM 37.6. This complex reach is low gradient (0.19%) and the channel flows through a partially confined valley. Channel form is braided with alternating riffle-glide and pool-riffle morphology. Steep hillslopes, the historical floodplain terrace of Chiwaukum Creek, and expansive low-elevation floodplains border the channel. Chiwaukum Creek enters the channel from river-right at RM 35.9 supplying additional sediment and discharge to the system. The modern floodplain surfaces offer complex off-channel habitat in most meander scars. Surrounding land is US Forest Service. Reach 1 was historically used for timber harvest and logging operations. Evidence of splash dams and other logging practices remain today. A Forest Service campground (RM 35.6) and primitive road provides recreational opportunities along river-right. There is very little development or human infrastructure found in Reach 1. Disturbance is limited to the area surrounding the Hwy 2 Bridge (RM 35.5). Large boulder riprap and current bridge re-construction at this location confines the channel, disturbs the streambank, and fragments the riparian corridor.

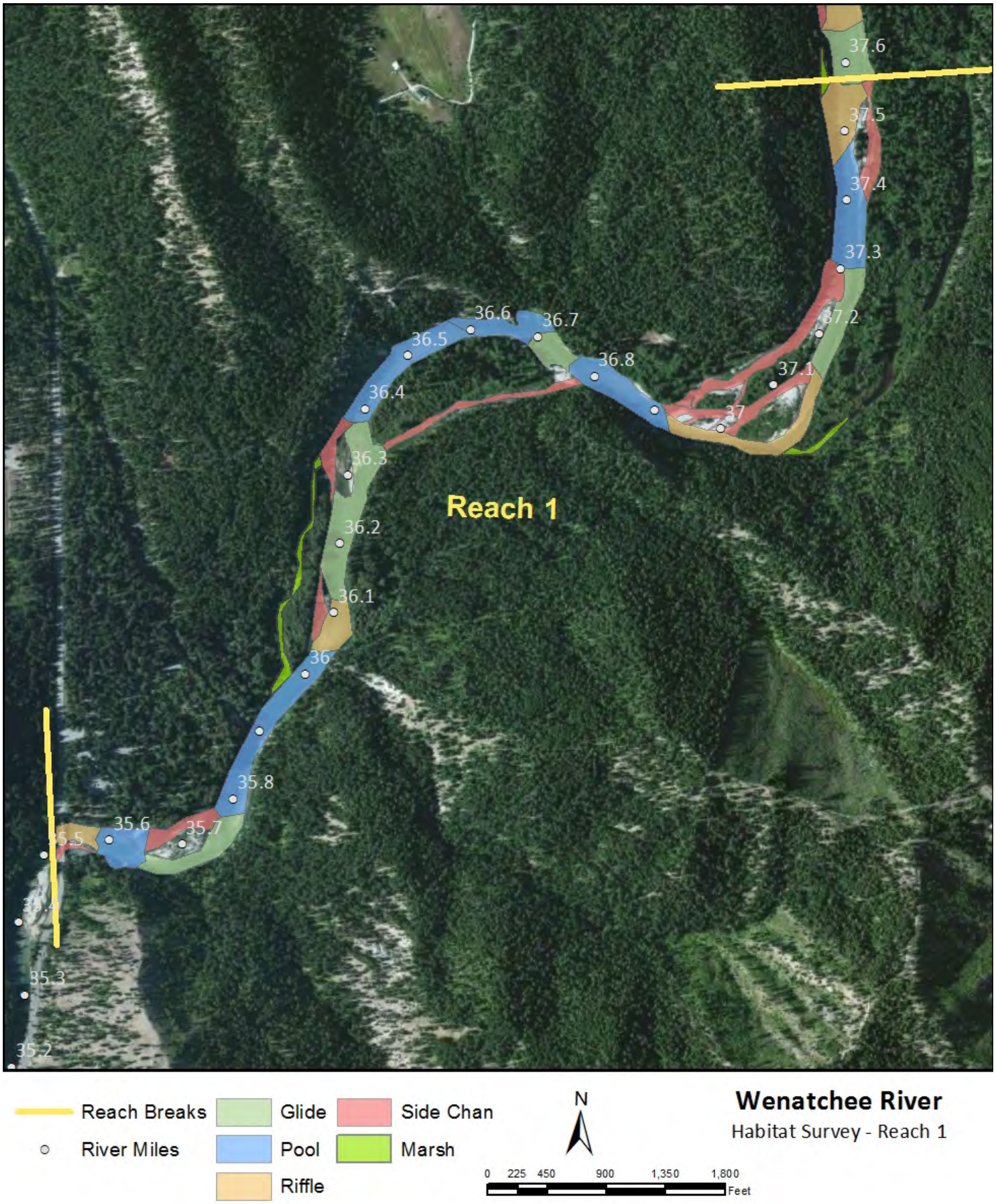


Figure 13. Reach 1 locator and habitat unit composition map.

Figure 14. View looking upstream towards the left bank sedimentary conglomerate hillslope at RM 36.8 (August 2011).

A-1.2 Habitat Unit Composition

Reach 1 consisted of 40% pool, 26% glide, 24% side-channel, and 10% riffle habitat (Figure 3 and Figure 4). Pool frequency was 2.7 pools/mile, with mean pool spacing of 9.4 channel widths per pool. Average residual pool depth was 7.4 feet. Average maximum pool depth was 11.1 feet.

Reach 1 had the highest pool count (6) and the two deepest pools when compared to other reaches in the Upper Wenatchee study area. The maximum pool depths were estimated to be at least 15 and 20 feet. Additionally, Reach 1 had the highest side-channel habitat by area (24%) and second highest count of side-channel units (8).

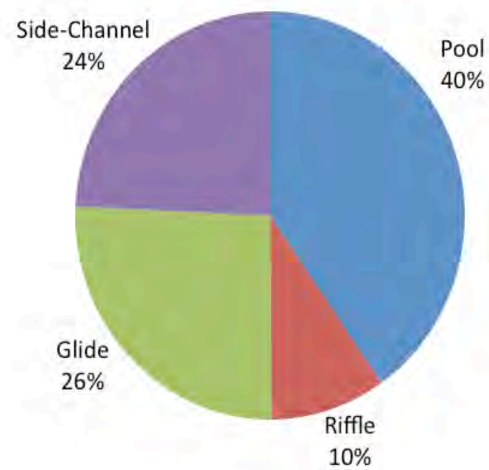


Figure 15. Habitat unit composition for Reach 1.

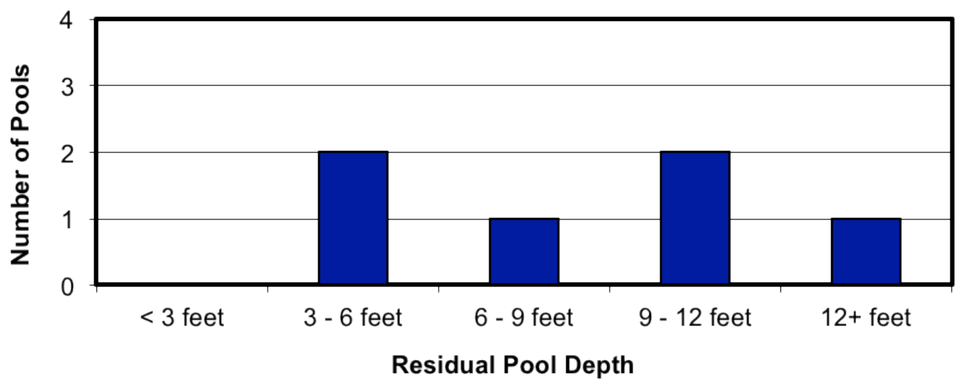


Figure 16. Reach 1 residual pool depths.

A-1.3 Off-Channel Habitat

Reach 1 had the greatest diversity of off-channel habitats found throughout the Upper Wenatchee study area. Eight side channels and two backwater marshes were observed in Reach 1. All backwater marshes and side-channels had evidence of being activated during high flow and flood events. Beaver and bear activity was observed throughout the reach, especially in off-channel and floodplain habitats. Reach 1 had two distinct braided side-channel complexes with high habitat diversity.

The first side-channel complex (RM 35.95 to 36.35) was located in a wide well-connected floodplain valley. A backwater marsh that appeared to be historically used for splash damming (based on remnant creosote pilings in the channel) paralleled the main channel (RM 35.95 to RM 36.30) (Figure 5). Thick shrubs and wetland vegetation (spirea, dogwood, alder, willow, and cottonwood) lined the channel. Large Woody Debris (LWD) and beaver activity were found throughout the marsh. Additionally, there was a large LWD jam at the upstream end (RM 36.3) blocking regular streamflow from entering the channel. Two small side-channels flowed along the right bank (RM 36.15 and RM 36.35) and were separated from main channel flow by cobble bars vegetated with young willows. Both side-channels had spawning gravels and canopy cover and would provide juvenile salmonid refuge during high mainstem flows (Figure 6). Creosote pilings were found embedded in both side-channels.

Further upstream (RM 36.90 to 37.25) was a second side-channel complex located where the floodplain narrowed and became confined by steep sedimentary hillslopes (along both banks). A straight side-channel (Figure 7) paralleled the mainstem along the right bank, separated by a well-vegetated island with small ponderosa pine, willow, alder, and dogwood. Streamflow was deep and swift, providing little spawning or rearing habitat, with the exception of the pool tail-out at the downstream end. Abundant LWD was found throughout the side-channel, including both remnant harvested (cut ends) and naturally recruited logs. The main channel flowed along a left bank connected floodplain and split into an additional side-channel (RM 37.1) with small braids towards the downstream end. A backwater marsh located along the left bank (RM 37.05) abutted the steep sedimentary hillslope at a meander bend. Ponded along the downstream end (Figure 8), the channel narrowed to two small beaver damned pools. Salmonid fry were observed in these pools. This backwater marsh may function as a high flow channel during flood events, yet year-round inputs persist with hyporheic flow.

Between these two complexes was a meander bend side-channel (RM 36.35 to RM 36.80). It flowed along a left bank terrace separated from the main channel by a densely vegetated island. The side-channel may have been simplified by historical logging operations. This side-channel appeared to provide spawning, rearing, and flood refuge habitat (Figure 9).

Additional off-channel habitat was observed along the upstream portion of Reach 1, including a left bank disconnected side-channel (RM 37.40 to RM 37.55) and a right bank backwater marsh (RM 37.55). The side-channel was well defined and appeared to function as a high flow channel during flood events. This disconnected side-channel had an elongated pond along the floodplain surface and upstream hyporheic flow inputs. Waterfowl and bear foraging was observed. The backwater marsh was located along a river-right floodplain surface and was maintained by small seeps or hyporheic flow. It was densely vegetated with mature alder and willow.

Figure 17. A backwater marsh (RM 35.95to RM 36.30) has filed in a historical splash dam channel along the right bank floodplain surface in Reach 1 (August 2011).

Figure 18. View looking downstream at a side-channel near RM 36.15 that provides spawning, rearing, and refuge habitat in Reach 1 (August 2011).

Figure 19. View looking downstream towards a river-right side-channel at RM 37.25.

Figure 20. View looking upstream along a ponded backwater marsh at RM 37.05 (river-left). A left bank steep forested hillslope confines and shades the marsh while providing large and small woody debris (August 2011).

Figure 21. View looking upstream at a meander bend side-channel (RM 36.35 to RM 36.80) with sparsely vegetated cobble bars and LWD.

A-1.4 Large Woody Debris

Reach 1 had the second highest LWD count in the study area, totaling 642 pieces (Table 1). Reach 1 had the highest LWD frequency for the study area, at 294 pieces/mile. “Small” pieces comprised 51% of all LWD counted in the reach, “medium” comprised 21%, and “large” pieces comprised 28%. LWD recruitment potential is very high both in the short and long-term. Local topography and off-channel habitats recruit large quantities of woody material (Figure 10).

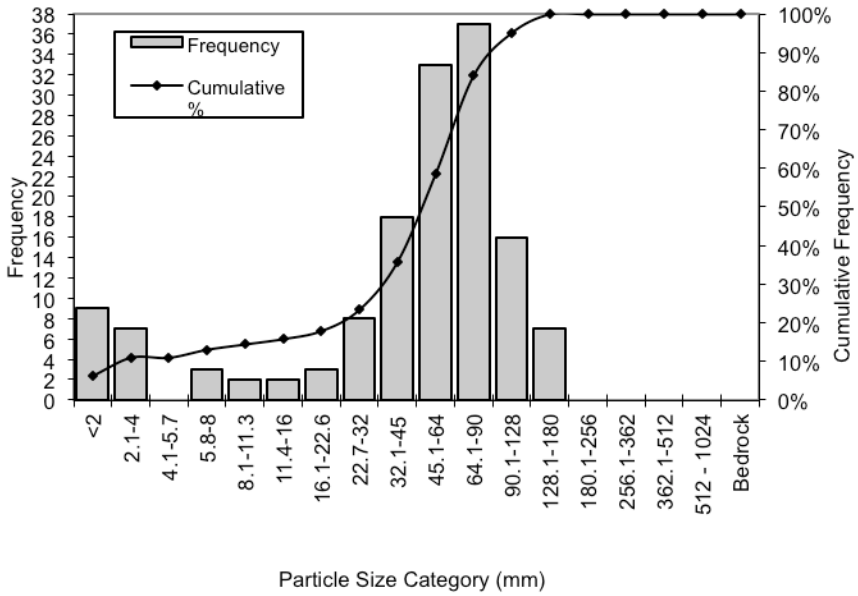
Table 2. Large woody debris quantities in Reach 1.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Pieces	331	178	133	642
Number of Pieces/Mile	151	81	61	294

Figure 22. LWD jams contribute to island formation and bank stabilization, Reach 1 (August 2011).

A-1.5 Substrate and Fine Sediment

Bed substrate was dominated by gravels and cobbles. Boulders made up 7% of the distribution. Bedrock was observed in two isolated units in Reach 1 and made up less than 0.5% of the distribution. Bedrock was encountered where the steep sedimentary hillslope abutted the channel at RM 35.9 and RM 37.0. Percent fines (<2mm) were low to moderate (6-17%) based on the ocular estimates and pebble counts. Only one pebble count was attainable in Reach 1 due to high water conditions. A side-channel riffle was sampled; mainstem riffles were too deep and swift. The pebble count and size class data are depicted in Figure 11 and Figure 12.



Material	Percent Composition
Sand	6%
Gravel	52%
Cobble	41%
Boulder	0%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	<2
D16	16
D50	57
D84	90
D95	126

Figure 23. Grain size distribution and particle size classes from pebble count taken at RM 35.75.

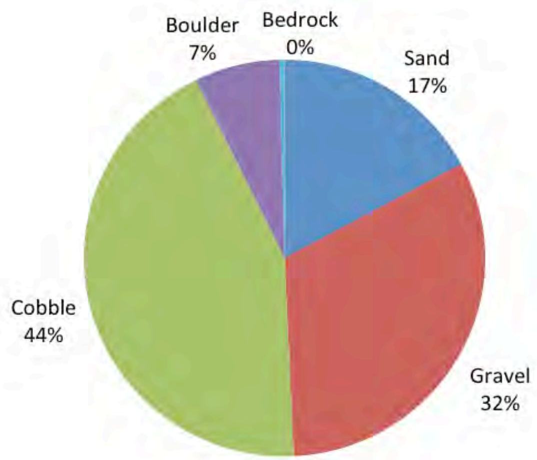


Figure 24. Percent composition of bed substrate based on ocular estimates, Reach 1.

A-1.6 Instability and Disturbance

Human activities have impacted the channel, floodplain, and associated riparian corridor within the reach. The primary elements of disturbance were remnants from historical timber harvest and logging operations throughout Reach 1 (Figure 13). Embedded creosote logs and straightened splash dam channels remain at several locations throughout the reach. There is a campground (RM 35.6) and hiking trail along the right bank but their level of disturbance is low. The Hwy 2 Bridge had localized riprap armoring and construction disturbance. It is unlikely that there will be future floodplain development or vegetation clearing within Reach 1 under current US Forest Service management.

Erosion was moderate when compared to other reaches within the Upper Wenatchee study area. Reach 1 had a total of 4,266 feet of actively eroding streambank (measured above bankfull), consisting of 11% of the reach length along both banks. Bank disturbance was associated with steep banks and exposed sedimentary hillslopes primarily along left bank pool habitats. Active erosion was observed along the left bank floodplain surface of the meander bend side-channel (RM 36.35 to RM 36.80).

Figure 25. Wood pilings that are presumed to be remnants from historical log drives are found throughout Reach 1.

A-1.7 Available Spawning and Rearing Habitat

There was abundant spawning and rearing habitat in Reach 1. Bed substrate was dominated by gravels (32-52%) and cobbles (41-44%). Many of the side-channels and pool tail-outs provided substrate for both Chinook (13-102 mm) and steelhead (6-102 mm). Coho may use the smaller, more protected, braided side-channels (Figure 14). Several large Chinook were observed (August 17, 2011) holding in the reach's deep pools.

Reach 1 had abundant pool habitat. This reach provided refugia and canopy cover in off-channel habitats and along lateral margins. LWD was plentiful and will continue to provide habitat and complexity in Reach 1.

Figure 26. Spawning gravel and rearing habitat near RM 36.9 where the channel becomes confined at the downstream end of a side-channel complex (August 2011).

A-1.8 Riparian Corridor

Reach 1 had a healthy and undisturbed forested riparian corridor. Very little development or human infrastructure was found in Reach 1. Disturbance of the riparian corridor was limited to the area surrounding the Hwy 2 Bridge (RM 35.5) and campground.

The riparian zone along Reach 1 was dominated by large trees (55%) (Figure 15), primarily consisting of conifers (59% conifers, 36% hardwoods, 5% shrubs). Small trees were subdominant (36%). Douglas fir, ponderosa pine, cottonwood, willow, dogwood, alder, and oceanspray were the most prevalent riparian species. Side-channels and backwater marshes found in Reach 1 also had wetland vegetation that included, cottonwood, willow, dogwood, alder, spirea, carex, rushes, sedges, and assorted floating aquatics.

The level of stream shade provided by the riparian canopy and local topography was high throughout Reach 1. A dense understory also provided canopy cover and refuge along lateral margins. Large snags were observed along the steep hillslopes bordering Reach 1.

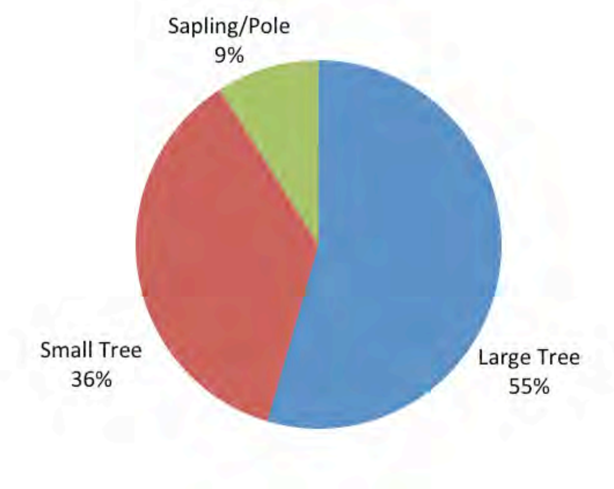


Figure 27. Distribution of the dominant size class category for the riparian zone, Reach 1.

A-2 Reach 2

Location: River mile 37.6 to 38.6

Survey Date: August 16, 2011

Survey Crew: Christa Strickwerda Heller and Adrianne Zuckerman (Inter-Fluve)

A-2.1 Reach Overview

Reach 2 is a marginally transport dominant reach that runs from RM 37.6 to RM 38.6. The reach is low gradient (0.25%) and flows through a partially-confined valley of alternating alluvial surfaces and steep hillslopes. Channel form is slightly meandering and morphology is plane-bed. The reach lies within a slightly more confined valley than adjacent reaches. Fast water habitat dominates much of Reach 2 (Figure 16). Land is managed by the US Forest Service. There is no bank armor or human built features directly impacting this reach. Reach 2 is connected to narrow elongate floodplains along most channel margins. See reach locator and habitat unit map in Figure 17.

Figure 28. View looking upstream at the reach boundary near RM 38.5 (August 2011).

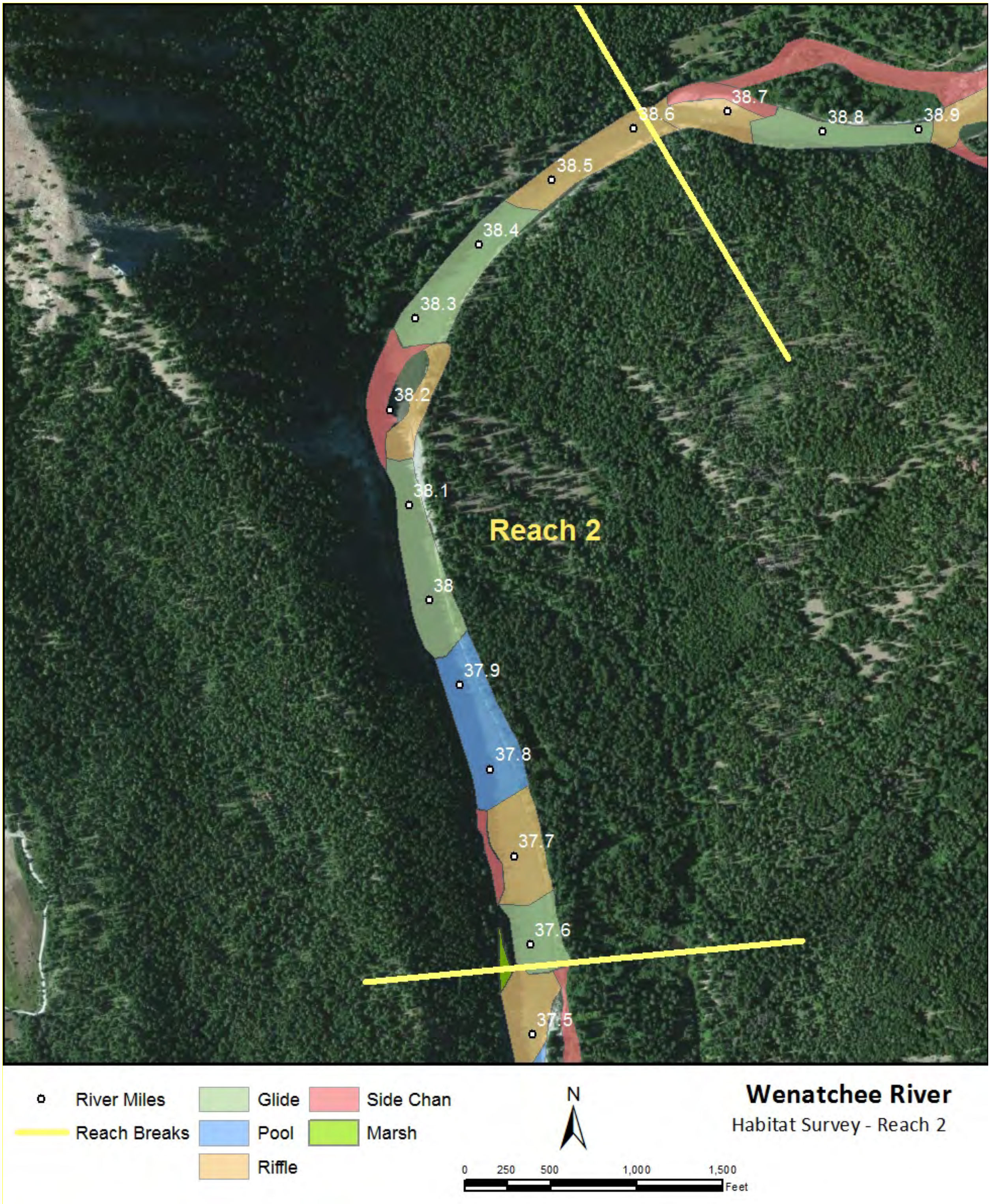


Figure 29. Reach 2 locator and habitat unit composition map.

A-2.2 Habitat Unit Composition

Reach 2 consisted of 47% glide, 34% riffle, 13% pool, and 6% side-channel habitat (Figure 18 and Figure 19). Pool frequency was 0.9 pools/mile, with mean pool spacing of 28.3 channel widths per pool. Reach 2 had one of the lowest pool quantities (1 pool) when compared to other reaches within the study area. Residual pool depth was 3.5 feet. Maximum pool depth was 6.5 feet.

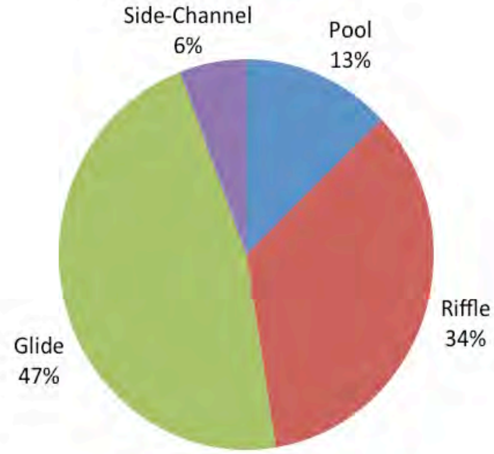


Figure 30. Habitat unit composition for Reach 2.

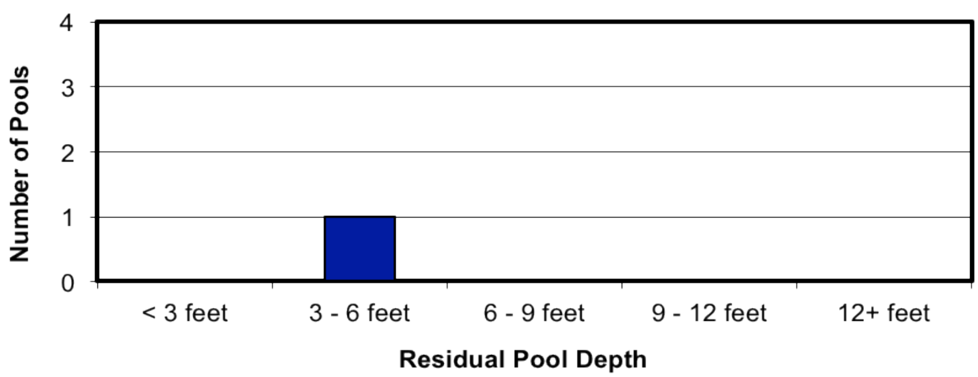


Figure 31. Reach 2 residual pool depths.

A-2.3 Off-Channel Habitat

There were two side-channels in Reach 2. A small side-channel, located at RM 37.7, provided some of the only slow water refuge, canopy cover, and LWD observed throughout Reach 2 (Figure 21). It was located near a narrow elongate floodplain surface that abuts the steep hillslope on river-right. A small sparsely vegetated (rushes, grasses, and small willows) sandbar separated this off-channel unit from the mainstem. A second side-channel (RM 38.2) was wide, shallow, and dominated by small cobbles (Figure 21). It lacked habitat features common throughout many of the off-channel units of the Upper Wenatchee study area.

Figure 32. View looking downstream at a river-right side-channel near RM 37.7 that has a frequently inundated sandbar with willow and grasses (August 2011).

Figure 33. View looking downstream at a shallow, fast water side-channel near RM 38.2 (August 2011).

A-2.4 Large Woody Debris

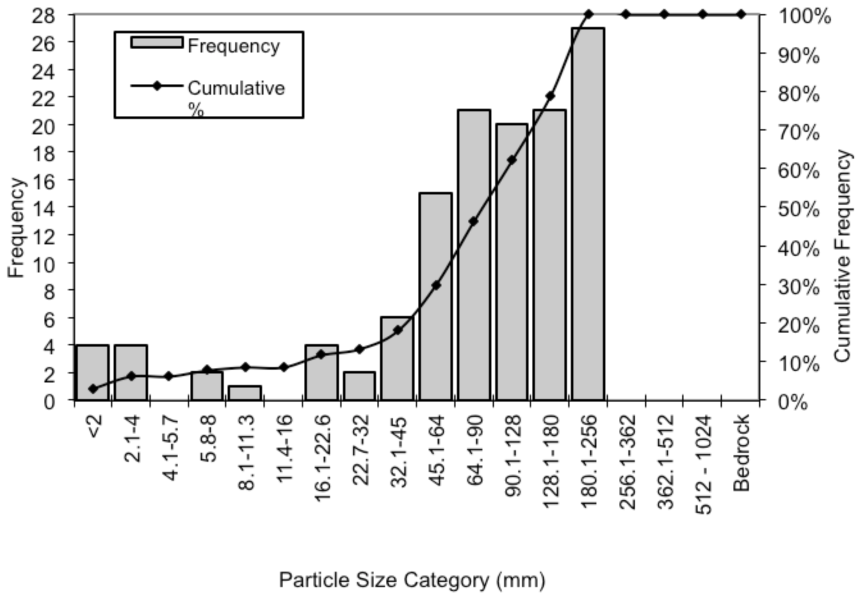
LWD quantities were relatively low in Reach 2 compared to other reaches in the study area. LWD frequency was 47 pieces/mile, with “small” pieces comprising 44% of all LWD counted in the reach (Table 2). “Medium” and “Large” wood pieces comprised 56% of the LWD in the reach; 17% and 38% respectively. LWD recruitment potential was limited in the short-term because Reach 2 lacks channel complexity and off-channel habitats that aid in recruitment. Long-term LWD sources were available along the steep hillslopes bordering Reach 2 and from upstream sources.

Table 3. Large woody debris quantities in Reach 2.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Pieces	23	9	20	52
Number of Pieces/Mile	21	8	18	47

A-2.5 Substrate and Fine Sediment

Bed substrate was dominated by cobbles. Gravels were subdominant. Boulders made up 15% of the distribution. Bedrock was observed in two isolated units in Reach 2 and made up less than 2% of the total distribution. Bedrock was encountered where the steep sedimentary hillslope abutted the channel at RM 37.9 and RM 38.6. Percent fines (<2mm) were low (3-13%) based on the ocular estimates and pebble counts. Only one pebble count was attainable in Reach 2 due to high water conditions. The pebble count and size class data are depicted in Figure 22 and Figure 23.



Material	Percent Composition
Sand	3%
Gravel	27%
Cobble	70%
Boulder	0%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	3
D16	39
D50	99
D84	199
D95	238

Figure 34. Grain size distribution and particle size classes from pebble count taken at RM 38.3.

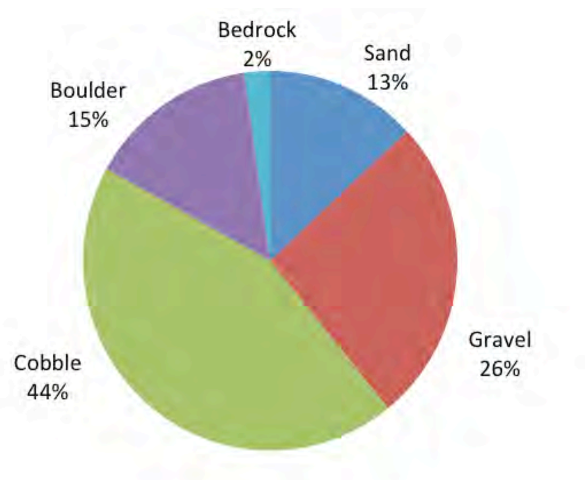


Figure 35. Percent composition of bed substrate based on ocular estimates, Reach 2.

A-2.6 Instability and Disturbance

Human activities have had minimal recent impact to the channel, floodplain, and associated riparian corridor within the reach. Any disturbance within Reach 2 was either related to natural process or remnants from historical logging operations. It is unlikely that there will be future floodplain development or vegetation clearing within Reach 2 under current US Forest Service management.

Erosion was very low when compared to other reaches within the Upper Wenatchee study area. Reach 2 had a total of 49 feet of actively eroding streambank (measured above bankfull), consisting of 0.4% of the reach length along both banks. Similar to what was observed in Reach 1, bank disturbance was associated with unstable banks along floodplain surfaces and exposed sedimentary hillslopes along the left bank. The only active erosion observed in Reach 2 was along a left bank steep hillslope at the gradual meander bend near RM 38.55. Additional disturbance was observed along a left bank terrace near RM 38.2 that was noticeably void of understory vegetation.

A-2.7 Available Spawning and Rearing Habitat

There was a moderate amount of spawning and rearing habitat available in Reach 2. The dominant substrate in the riffles was cobble (70%) and subdominant was gravel (27%). Although steelhead and spring Chinook spawning occurs in this reach, many of the pool tail-outs and side-channel areas consisted of large cobbles (> 128 mm) that are larger than the ideal size for Chinook (i.e. 13 – 102 mm) and steelhead (6 – 102 mm) spawning. However, coarse bed material provided areas of localized velocity refuge that may be utilized during migration and by rearing juvenile steelhead.

Pool quantity within Reach 2 was low. The one pool (13% of reach total) provided adequate residual depth greater than 3 feet. This reach primarily functions as a spawning and migration reach, as it lacks both LWD and off-channel rearing areas.

A-2.8 Riparian Corridor

Reach 2 had a healthy and undisturbed forested riparian corridor, with the exception of a lack of understory vegetation along the left bank floodplain surface near RM 38.2. No development or human infrastructure has recently affected the riparian corridor in Reach 2.

The riparian zone along Reach 2 was dominated by large trees (56%) (Figure 24), primarily consisting of conifers (78% conifers, 22% hardwoods). Small trees were subdominant (33%). Douglas fir, ponderosa pine, cottonwood, maple, willow, alder, and rose were the most prevalent riparian species.

The level of stream shade provided by the riparian canopy and local topography was moderate throughout Reach 2. Small shrubs and saplings have recruited along low-elevation floodplains (Figure 25), providing canopy cover and localized refuge along lateral margins.

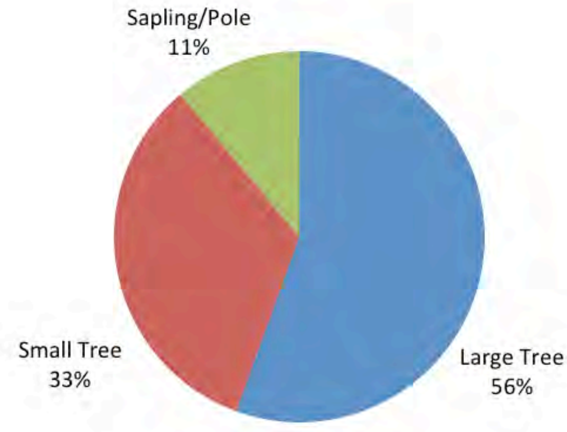


Figure 36. Distribution of the dominant size class category for the riparian zone, Reach 2.

Figure 37. Small shrubs and saplings have recruited on a low-elevation floodplain along Reach 2 (August 2011).

A-3 Reach 3

Location: River mile 38.6 to 41.9

Survey Date: August 15, 2011

Survey Crew: Christa Strickwerda Heller and Adrianne Zuckerman (Inter-Fluve)

A-3.1 Reach Overview

Reach 3 extends from a side-channel complex at RM 38.6 to the Burlington Northern Railroad Bridge at RM 41.9. It flows through an artificially and naturally partially-confined valley, bordered by low-elevation floodplains, moderately sloping banks, steep terrace banks (of the Chumstick formation), and bank hardening materials. Channel form is meandering with braiding in the lower portion of the reach. The reach has a gradient of 0.29%. Bed morphology is primarily pool-riffle with some riffle-glide units. Land use in Reach 3 is predominantly private residential property along river-right and US Forest Service managed land along river-left. There are homes, roads, and a railroad along the river-right floodplain from RM 39.0 to 41.9. River Road parallels the channel from RM3 9.4 to RM 41.9 on river-right. Road dissection, vegetation removal/alteration, homesite construction, and bank hardening material are common throughout this portion of Reach 3. Despite human disturbance along much of the reach, Reach 3 had relatively abundant off-channel habitat and LWD (Figure 26). See Figure 27 for a reach overview and habitat unit map.

Figure 38. View looking downstream towards a high-flow side-channel along the left bank at RM 39.0 (August 2011).

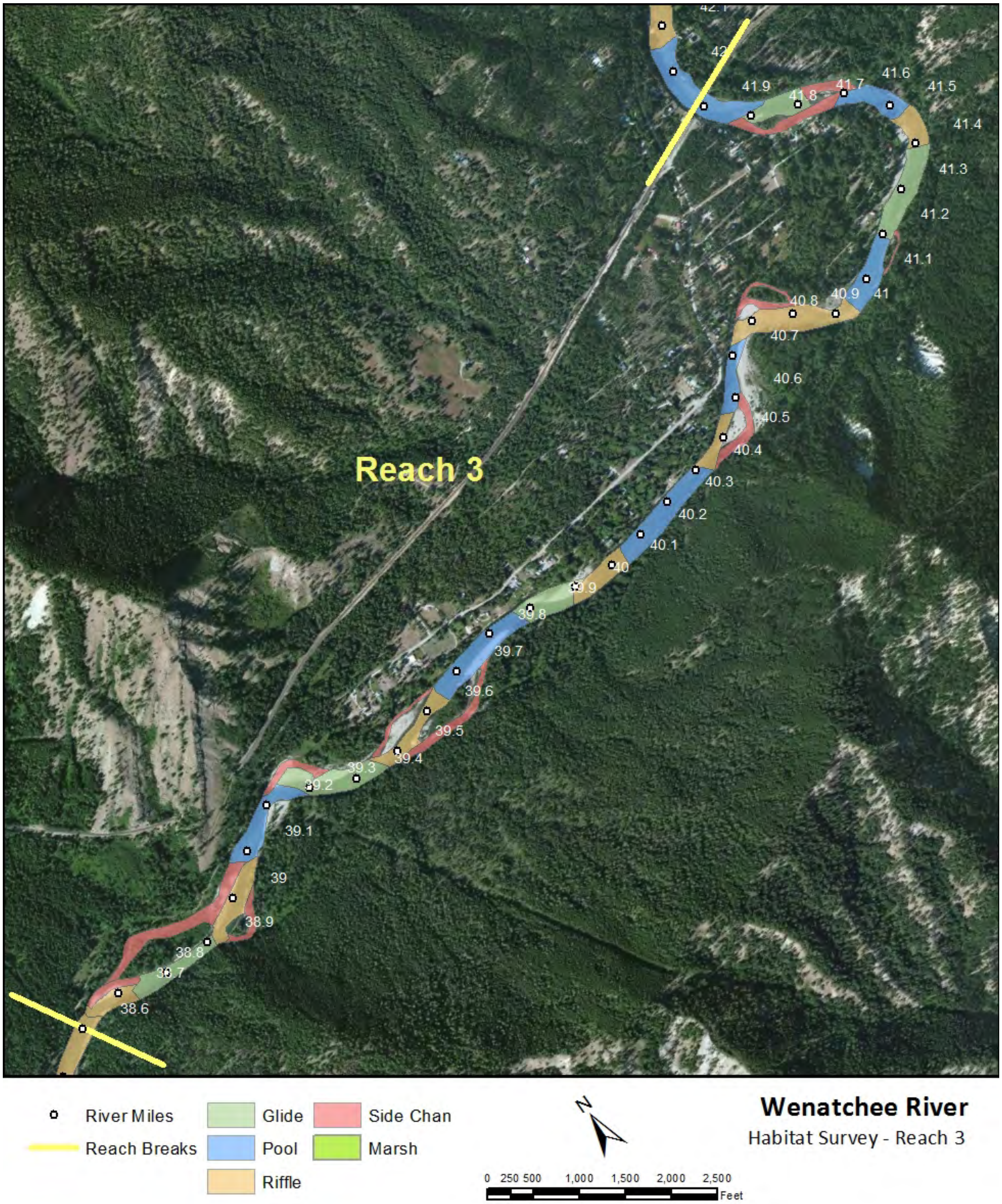


Figure 39. Reach 3 locator and habitat unit composition map.

A-3.2 Habitat Unit Composition

Reach 3 consisted of 31% riffle, 27% pool, 23% glide, and 19% side-channel habitat (Figure 28 and Figure 29). Pool frequency was 1.9 pools/mile, with a mean pool spacing of 14.9 channel widths per pool. Average residual pool depth was 6.2 feet. Average maximum pool depth was 9.6 feet. Reach 3 had the second highest proportion of side-channel habitat by area and the highest number of side-channel units (12).

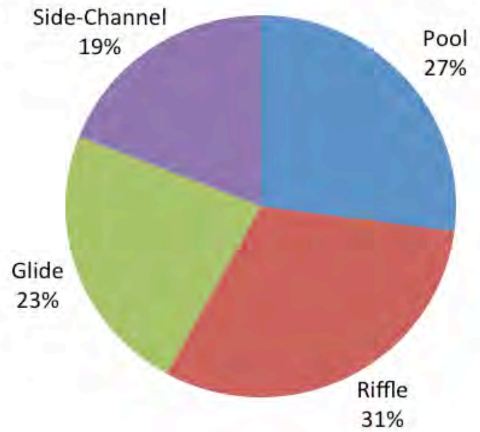


Figure 40. Habitat unit composition, Reach 3.

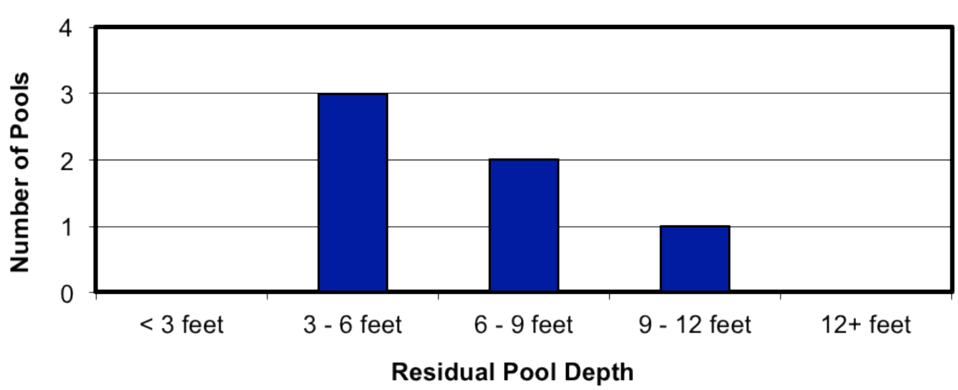


Figure 41. Reach 3 residual pool depths.

A-3.3 Off-Channel Habitat

There were 12 side-channels in Reach 3, comprising 19% of the total reach area. This was the second highest proportion of side-channel habitat by area and the highest number of side-channel units compared to other reaches in the Upper Wenatchee study area. Side-channels generally had vegetated island and bar development, and were often associated with LWD jams and beaver activity.

A side-channel complex just upstream of the reach boundary (RM 38.6 to RM 39.1) included a large forested island and expansive cobble bar. The cobble bar accumulated three LWD jams and extended nearly 0.2 RMs upstream from the stable mid-channel island (RM 38.70-38.95). Large conifers, mature cottonwoods, and a dense understory provided island refuge for deer and other riparian mammals. A right bank side-channel braided through additional LWD jams, gravel bars, and small-vegetated islands (Figure 30). Several spring Chinook were observed actively spawning throughout the lower braided side-channel (August 16, 2011). A small high-flow side-channel was found along the left bank floodplain at RM 38.9 to RM 39.0. Ponded water was observed along the downstream end where the channel abuts a steep sedimentary hillslope, which continues downstream and confines the side-channel along the left bank (Figure 31).

Several narrow disconnected high-flow side-channels were found along the developed floodplain surfaces further upstream in Reach 3. Many of these side-channels flowed around sparsely vegetated, yet highly stable cobble bars that have endured for over 40 years (verified with 1966 WSDOT aerial photos). High water or hyporheic flow maintains these wetted disconnected side-channels (Figure 32). Fry, waterfowl, and wetland vegetation was found in many of the off-channel units in Reach 3. The narrow floodplain surfaces and off-channel habitats throughout Reach 3 are impacted by residential development (Figure 33).

No off-channel marshes were identified within this reach. Reach 3 likely had higher historical off-channel complexity that has been reduced as a result of development and river management, especially along the right bank.

Figure 42. A right bank braided side-channel provides excellent spawning and rearing habitat near RM 38.75 in the lower portion of Reach 3 (August 2011).

Figure 43. Left bank floodplain and off-channel habitat at RM 38.9 to RM 39.0 abuts a steep sedimentary hillslope that continues downstream confining the side-channel complex along river-left (August 2011).

Figure 44. Representative disconnected (at average flows) side-channel found throughout the upper portion of Reach 3. Many of these side-channels flow around sparsely vegetated, yet highly stable cobble bars. High water or hyporheic flow maintains surface water in these side-channels (August 2011).

Figure 45. A low elevation floodplain surface along river-right affected by clearing and residential impacts (RM 40.1).

A-3.4 Large Woody Debris

LWD quantities were high in Reach 3. Reach 3 had the highest LWD count in the upper Wenatchee study area, totaling 785 pieces (Figure 34). LWD frequency was 252 pieces/mile, with "small" pieces comprising 47% of all LWD counted in the reach (Table 3). "Medium" and "Large" wood pieces comprised 53% of the LWD in the reach, with 26% and 27% respectively. Reach 3 had the second highest LWD frequency compared to other reaches in the study area. LWD recruitment potential was very high both in the short and long-term. Local topography and off-channel habitats recruit large quantities of woody material (Figure 35).

Table 4. Large woody debris quantities in Reach 3.

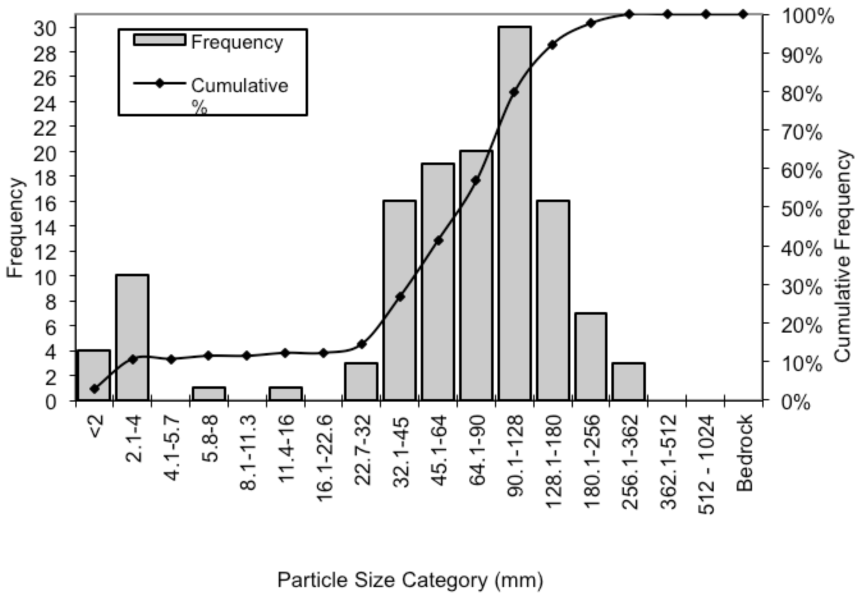
	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Pieces	372	202	211	785
Number of Pieces/Mile	119	65	68	252

Figure 46. The largest LWD jam observed throughout the Upper Wenatchee study area was located in Reach 3, just downstream of the Burlington Northern Railroad Bridge at RM 41.8 (August 2011).

Figure 47. LWD with attached root wad provides habitat complexity and refuge in Reach 3 (August 2011).

A-3.5 Substrate and Fine Sediment

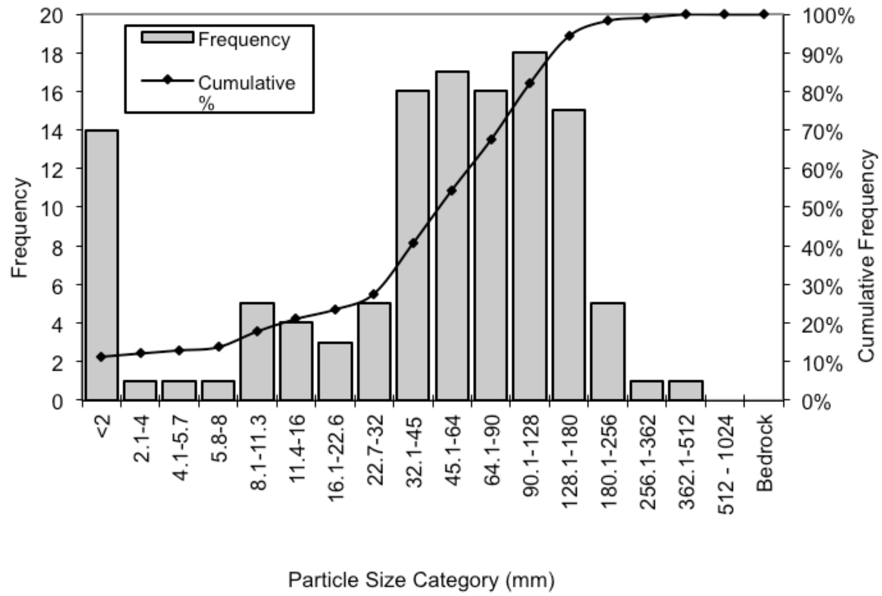
Bed substrate was dominated by cobbles. Gravels were subdominant, and boulders made up 12% of the distribution. Bedrock was observed in Reach 2 but made up less than 4% of the total distribution. Larger quantities of bedrock were encountered along two left bank side-channels at RM 39.0 and RM 40.55. Percent fines (<2mm) were low to moderate ranging from 3-19% based on the ocular estimates and pebble counts. The pebble count and size class data are depicted in Figure 36, Figure 37, and Figure 38.



Material	Percent Composition
Sand	3%
Gravel	38%
Cobble	56%
Boulder	2%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	3
D16	33
D50	78
D84	145
D95	218

Figure 48. Grain size distribution and particle size classes from pebble count taken at RM 38.7.



Material	Percent Composition
Sand	11%
Gravel	43%
Cobble	44%
Boulder	2%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	<2
D16	10
D50	76
D84	136
D95	193

Figure 49. Grain size distribution and particle size classes from pebble count taken at RM 41.0.

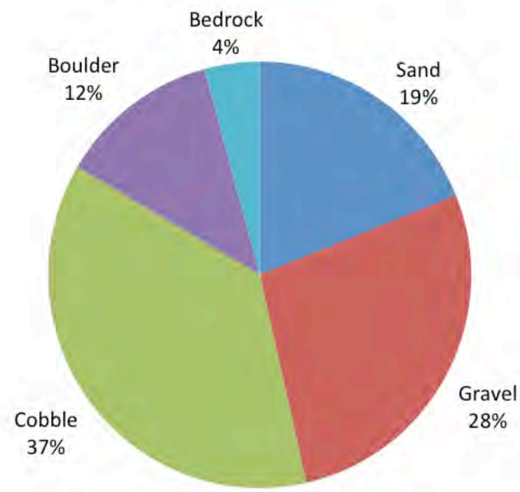


Figure 50. Percent composition of bed substrate based on ocular estimates, Reach 3.

A-3.6 Instability and Disturbance

Human activities have modified the channel, floodplain, and associated riparian corridor within the reach. Primary elements of disturbance include channel simplification, channel confinement, bank armoring, floodplain development, loss of an intact riparian buffer, the railroad, and roadways.

Bank erosion was moderate when compared to other reaches within the study area. Reach 3 had a total of 5,721 feet of actively eroding streambank (measured above bankfull), consisting of 11% of the reach length along both banks. Bank disturbance was often associated with land clearing, roadways, residential uses, river access, and steep banks along terrace surfaces. Erosion was greatest between RM 39.7 to RM 39.9 and from RM 40.3 to RM 40.7 (1,100 and 1,284 feet, respectively). This portion of Reach 3 has been straightened and highly armored with large boulder riprap and spur dikes. Additional bank hardening material was observed near RM 39.55-39.7, RM 41.1-41.2, and RM 41.53-41.81 (Figure 39).

Other areas of impact include: the Burlington Northern Railroad Bridge (RM 41.9) crossing; River Rd abuts and parallels the channel (RM 39.4 to RM 40.7); and a power line corridor (RM 39.22) crosses the channel. These sites are associated with fill and grading, bank armor, land clearing, clearing of riparian buffers, and fragmentation of the riparian corridor and floodplain. Localized artificial channel constriction is present at the upstream end of the reach from bridge abutments and associated riprap related to the railroad. Natural bank disturbance occurred at few isolated locations in Reach 3 (Figure 40).

Figure 51. Concrete bank armor and riprap prevent natural channel process along much of Reach 3's right bank as seen near RM 41.7 (August 2011).

Figure 52. Erosion along the right bank continues upstream at this meander bend near RM 39.25.

A-3.7 Available Spawning and Rearing Habitat

Off-channel units provided abundant spawning and rearing habitat in Reach 1. Mean riffle substrate was dominated by cobbles (51%), with gravels subdominant (40%, from ocular estimates). Many of the side-channels and pool tail-outs provided substrate for both Chinook (13-102 mm) and steelhead (6-102 mm) spawning, yet mainstem riffle substrates were often larger than these ranges (Figure 41). Spring Chinook were observed actively spawning (August 16, 2011) throughout the side-channel complex in lower Reach 3 and along the right bank channel from RM 38.6 to RM 39.1. This portion of Reach 3 provided some of the best spawning and rearing habitat observed throughout the Upper Wenatchee study area.

Reach 3 had moderate pool habitat (27% total reach area). This reach provided refugia and canopy cover in off-channel habitats and along lateral margins. LWD was relatively abundant but log jam frequency was relatively low.

Figure 53. Large substrate was encountered throughout many mainstem Reach 3 riffles and bars (August 2011).

A-3.8 Riparian Corridor

The presence and width of the forested riparian buffer varied within Reach 3. The riparian corridor was disconnected and fragmented by private residential properties, roads, and the railroad along most of the right bank from RM 39.0 to RM 41.9. The presence of a riparian buffer was scarce and fragmented along right bank residential properties, some with lawns extending to the top of bank (Figure 42). Conifer forest dominated the US Forest Service Lands along river-left, while cottonwood and shrubs were dominant along floodplain surfaces along river-right.

The riparian zone along Reach 3 was dominated by small trees (44%) (Figure 43), primarily consisting of conifers (50% conifers; 47% hardwoods, 3% shrubs). Large trees were subdominant (40%). Cottonwood, Douglas fir, ponderosa pine, willow, and alder were the most prevalent riparian species.

The level of stream shade provided by the riparian canopy was moderate throughout Reach 3. Local topography and large conifers provided ample morning and afternoon shade.

Figure 54. Riparian buffers were scarce and highly fragmented along much of Reach 3's right bank (August 2011).

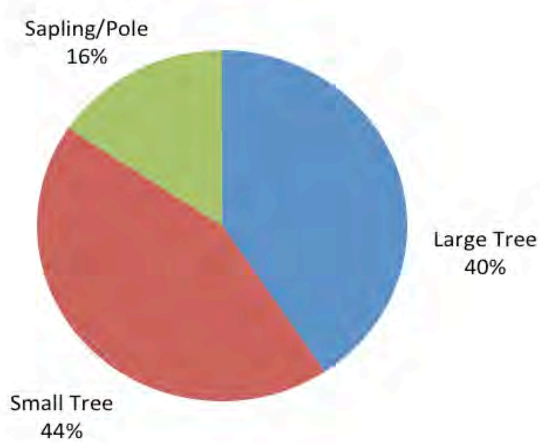


Figure 55. Distribution of the dominant size class category for the riparian zone, Reach 3.

A-4 Reach 4

Location: River mile 41.9 to 43.1

Survey Date: August 12, 2011

Survey Crew: Christa Strickwerda Heller and Adrianne Zuckerman (Inter-Fluve)

A-4.1 Reach Overview

Reach 4 is located in a naturally confined valley from the Burlington Northern Railroad Bridge at RM 41.9 to RM 43.1. Steep terrace banks and gradually sloping floodplains alternate throughout this reach (Figure 44). Overall slope of the reach is 0.24%. Channel form is meandering and bed morphology is pool-riffle. Reach 4 has good habitat complexity and potential for additional enhancement opportunities. Land use throughout Reach 4 includes large private land parcels, residential property, and roadways. Localized artificial channel constriction is present at the downstream end of the reach from bridge abutments and associated riprap related to the railroad. Riprap is located upstream of the railroad bridge and along the channel at a few scattered private properties.

Several low elevation floodplain surfaces and narrow elongate floodplains are scattered between steep terrace banks. Loss of floodplain functions results from road building, fill and grading, vegetation removal/alteration, and development of homesites. See Figure 45 for a reach overview and habitat unit map.

Figure 56. View looking upstream at the boundary of Reach 4 (RM 43.1). High bank exposure from the Chumstick formation confines the channel along river-left (August 2011).

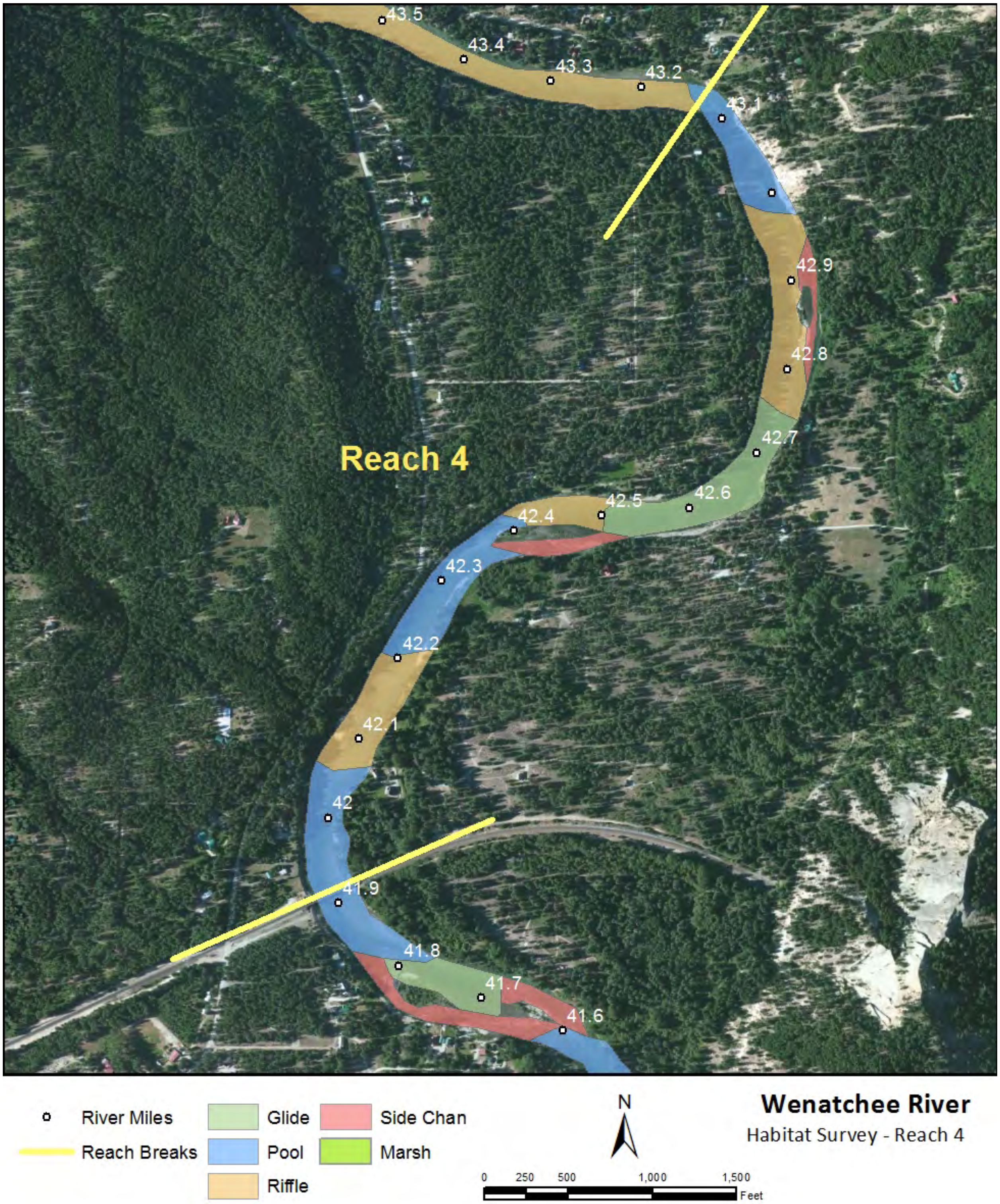


Figure 57. Reach 4 locator and habitat unit composition map.

A-4.2 Habitat Unit Composition

Reach 4 consisted of 41% pool, 30% riffle, 22% glide, and 7% side-channel habitat (Figure 46 and Figure 47). Pool frequency was 2.2 pools/mile, with mean pool spacing of 9.9 channel widths per pool. Average residual pool depth was 6.7 feet. Average maximum pool depth was 10.0 feet. Reach 4 had the second highest pool frequency when compared to other reaches within the study area.

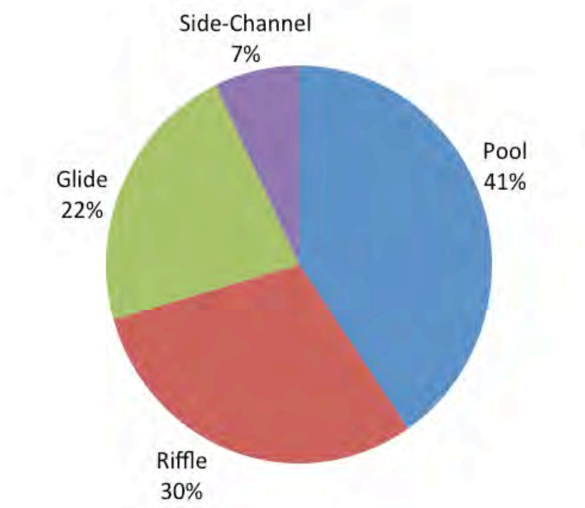


Figure 58. Habitat unit composition, Reach 4.

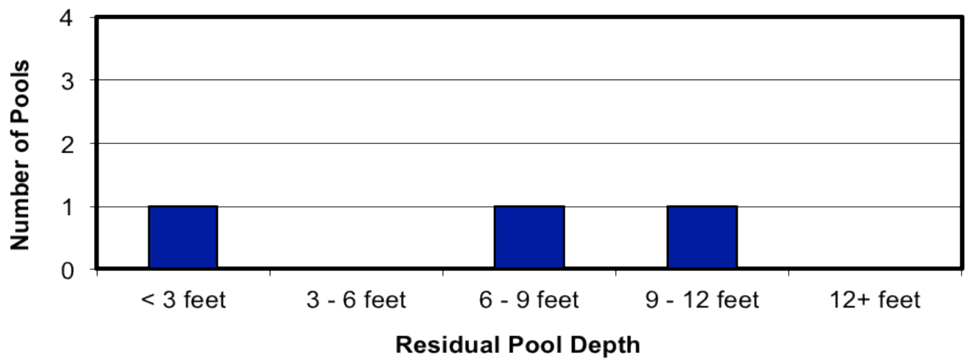


Figure 59. Reach 4 residual pool depths.

Figure 60. View looking downstream towards riffle habitat and the right bank terrace towards the downstream end of Reach 4, near RM 42.1 (August 2011).

A-4.3 Off-Channel Habitat

There were two side-channels in Reach 4. A fast-water side-channel (Figure 49), located from RM 42.8 to RM 42.9, bends away from a steep exposed cliff as the floodplain widens. A braided side-channel, located from RM 42.4 to RM 42.5, collects considerable LWD and provides refuge from mainstem flows. Both side-channels flowed along left bank floodplain surfaces with wetland vegetation that included rushes, spirea, and willow. A deep left bank alcove, located at RM 42.66, provided refugia from mainsteam flow and collected woody debris and fine sediment.

Figure 61. Representative fast water side-channel, Reach 4 (August 2011).

A-4.4 Large Woody Debris

LWD quantities were low-to-moderate in Reach 4 when compared to other reaches in the study area. LWD frequency was 63 pieces/mile, with “small” pieces comprising 45% of all LWD counted in the reach (Table 4). “Medium” and “Large” wood pieces comprised 18% and 37%, respectively. LWD recruitment potential was low within this reach. Reach 4 receives minimal wood input from upstream sources and lacks mature trees within the riparian corridor (Figure 50).

Table 5. Large woody debris quantities in Reach 4.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Pieces	38	15	32	85
Number of Pieces/Mile	28	11	24	63

Figure 62. Downstream view looking at side-channel habitat and small LWD accumulation along the left bank near RM 42.5 (August 2011).

A-4.5 Substrate and Fine Sediment

Bed substrate was dominated by large gravels and cobbles. Cobble was dominant, comprising 43% of the total bed composition. Boulders were found in all habitat types throughout this reach. Bedrock was prevalent along the channel margins and in portions of the channel due to exposure of the Chumstick formation. Bedrock consisted of just 2% of the bed composition for measured units. Fine sediment (<2mm) made up approximately 15-30% of the substrate distribution. No pebble count data were attainable for riffle habitat within Reach 4 due to high water conditions. Results of the ocular substrate measures are depicted in Figure 51.

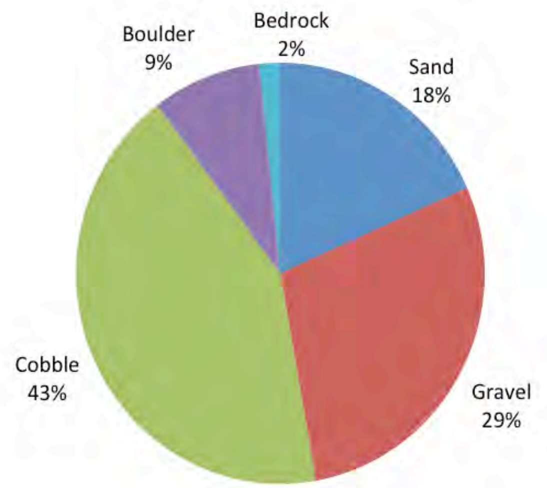


Figure 63. Percent composition of bed substrate based on ocular estimates, Reach 4.

A-4.6 Instability and Disturbance

Human development has modified the channel, floodplain, and riparian corridor within Reach 4. Bank erosion was moderately high when compared to other reaches within the Upper Wenatchee study area. Reach 4 had a total of 2,679 feet of actively eroding streambank (measured above bankfull), consisting of 16% of the reach length along both banks.

Bank disturbance was amplified in Reach 4 by the presence of steep terrace banks and human influence (Figure 52). Erosion was observed primarily along the undercut floodplain terrace from RM 42.5 to RM 42.7, and along the Burlington Northern Railroad Bridge (RM 41.9).

Riprap was scattered along steep streambanks at some private properties throughout the reach. Instream pilings and associated riprap surround the Burlington Northern Railroad Bridge, constraining the natural both upstream and downstream of the reach boundary.

Figure 64. View looking upstream towards the right bank terrace, riprap armoring, and Burlington Northern Railroad Bridge at RM 41.9 (August 2011).

A-4.7 Available Spawning and Rearing Habitat

Substrate within Reach 4 was dominated by large gravels and cobbles (based on ocular estimates only). Riffles had between 0 to 30% boulders. It is unlikely that salmon species other than Chinook would be able to spawn within the coarse substrate. Adult salmon and steelhead would be expected to primarily use this reach as a migration corridor. Long pool tail-outs and side-channels may provide potential spawning habitat.

Reach 4 had two deep pools with residual depths greater than 3 feet. Pool habitat (41% total area) would be expected to provide adult holding and juvenile rearing opportunity for multiple salmonid species. Juvenile steelhead may use the fast water side-channels for rearing.

A-4.8 Riparian Corridor

The width of the forested riparian buffer varied within Reach 4. The riparian corridor is disconnected and fragmented by scattered residential properties. Ponderosa pine dominates the terraces and floodplain surfaces throughout much of the reach. Small trees and shrubs (including willow, alder, cottonwood, and hawthorn) were only found along channel margins and floodplain surfaces.

The riparian zone along Reach 4 was dominated by large trees (78%) (Figure 53), primarily consisting of conifers (89% conifer; 11% hardwood). Ponderosa pine, Douglas fir, cottonwood, willow, alder, and hawthorn were the most prevalent species within the riparian corridor. Reach 4 generally lacked a riparian understory.

The level of stream shade provided by the riparian canopy was low-to-moderate throughout Reach 4. Local topography and large conifers may provide morning and afternoon shade.

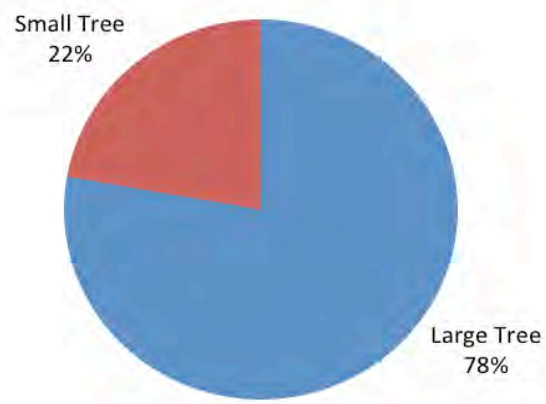


Figure 65. Distribution of the dominant size class category for the riparian zone, Reach 4.

A-5 Reach 5

Location: River mile 43.1 to 46.5

Survey Date: August 11, 2011

Survey Crew: Christa Strickwerda Heller and Adrianne Zuckerman (Inter-Fluve)

A-5.1 Reach Overview

Reach 5 flows through a confined alluvial valley that extends from RM 43.1 to the confluence of Beaver Creek at RM 46.5 (Figure 54). The channel and floodplain are further confined as the stream passes through the unincorporated community of Plain. Overall reach slope is 0.25%. Channel form is meandering and bed morphology is primarily riffle-glide with periodic sequences of pool-riffle. Dominated by fast water units, Reach 5 lacks off-channel and side-channel habitat. Reach 5 streambanks vary from narrow low-elevation floodplains to steep exposed terraces of the Chumstick formation. Present land use is primarily rural residential, agricultural, and transportation corridors.

Modern floodplains and terrace surfaces surrounding Reach 5 have been extensively logged and cleared for pasture and homesites. In the early 1900s, the river was blasted and straightened to transport logs to the Leavenworth Mill (Bryon Newell, personal communication, Sept. 24, 2011). Streambanks were cleared of vegetation and logjams were removed. Riparian conditions have improved since the late-1920s. Historical and recent photos of this reach are included in Figure 55 and Figure 56. Anthropogenic alterations to the floodplain include land clearing, irrigation diversions, road building, and filling and grading. Riprap, concrete retaining walls, and large river rock armor most of the streambank. Exposed steep outcroppings of the Chumstick formation confine the channel along isolated portions of the reach (especially at RM 44.85 and RM 43.85).

The Old Plain Bridge (RM 46.2), Beaver Valley Rd Bridge (RM 46.4), and a transmission line (RM 44.45) bisect the channel and floodplain in the upper portion of Reach 5. River Rd parallels the channel along the river-right floodplain for much of the reach. The road directly abuts the channel from RM 43.6 to RM 44.1.

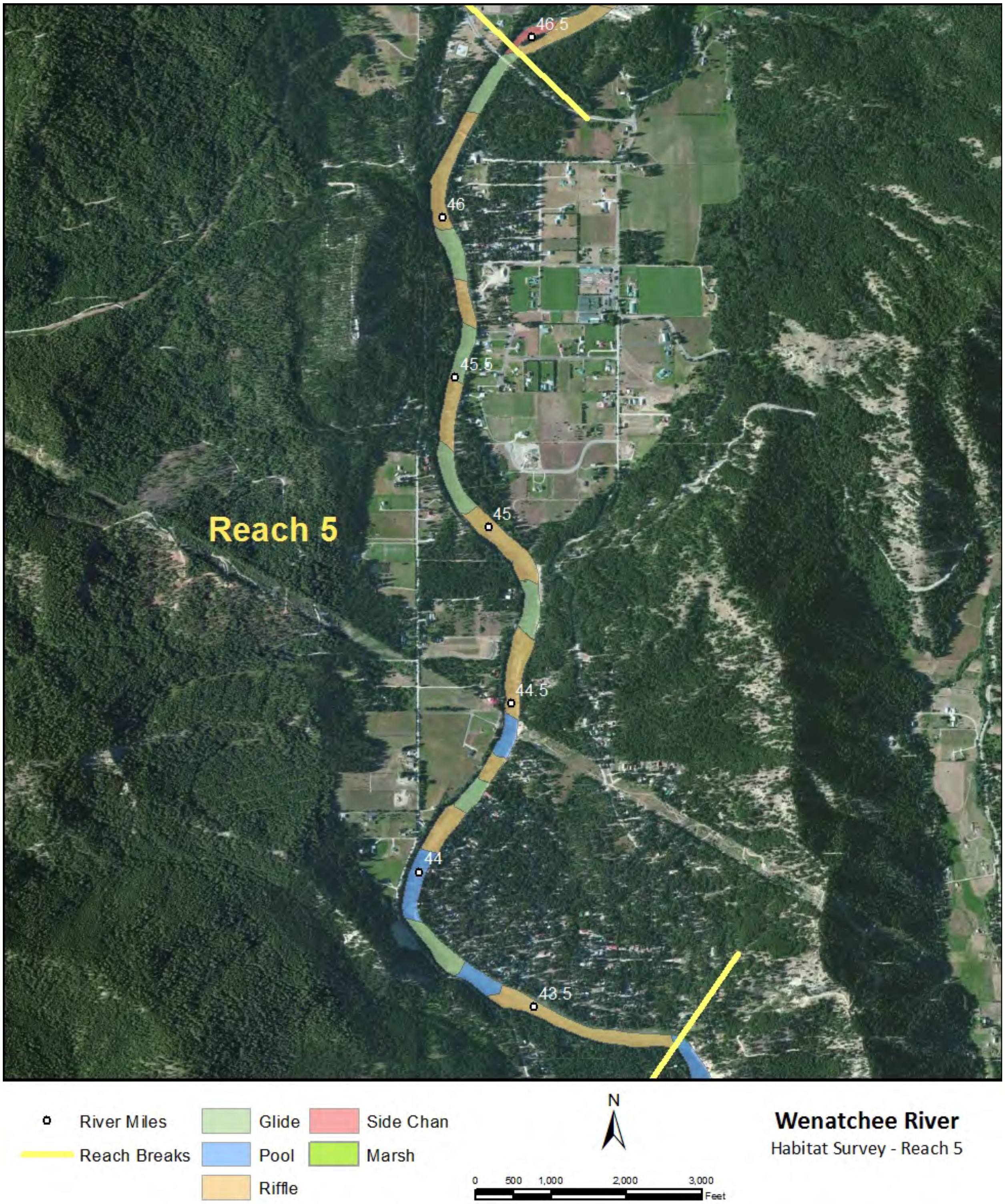


Figure 66. Reach 5 locator and habitat unit composition map.

Figure 67. Historical photo (late 1920s) taken from the Old Plain Bridge looking upstream towards a logged right bank alluvial terrace (left-hand side of photo).

Figure 68. Recent photo (2011) from the Plain Bridge looking upstream. Historical logged right bank alluvial terrace is revegetated (left-hand side of photo).

A-5.2 Habitat Unit Composition

Reach 5 consisted of 56% riffle, 33% glide, and 11% pool habitat (Figure 57 and Figure 58). No side-channel habitat was present within this reach. Pool frequency was 1.0 pool/mile, with mean pool spacing of 27.0 channel widths per pool. Average residual pool depth was 7.8 feet. Average maximum pool depth was 11.3 feet.

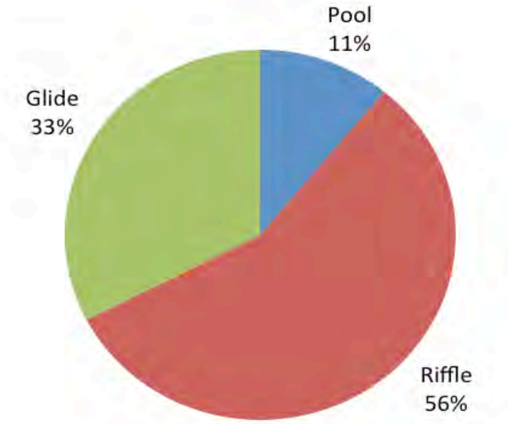


Figure 69. Habitat unit composition, Reach 5.

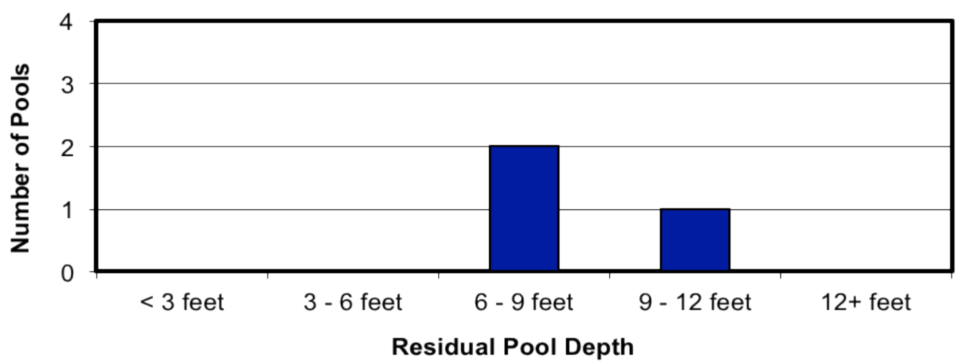


Figure 70. Reach 5 residual pool depths.

A-5.3 Off-Channel Habitat

Reach 5 has no side-channel habitat or off-channel marshlands. This area likely had a greater amount of historical off-channel habitat that has been reduced as a result of human development of riparian areas and floodplains.

A-5.4 Large Woody Debris

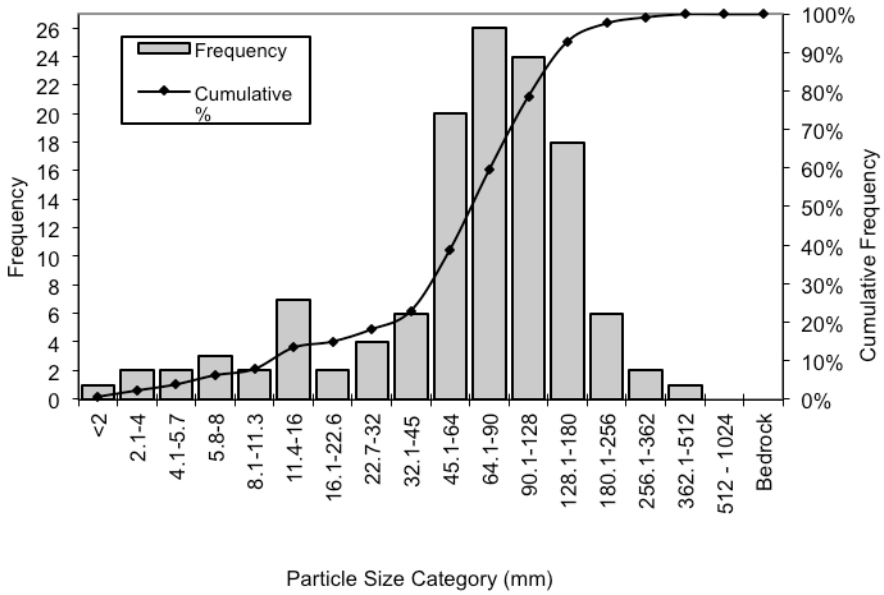
LWD quantity was moderate but LWD frequency was low in Reach 5 compared to other reaches in the study area. LWD frequency was 32 pieces/mile, with “small” pieces comprising 48% of all LWD counted in the reach (Table 5). “Medium” and “large” wood pieces comprised 52% of the LWD in the reach (24% and 28%, respectively). Reach 5 LWD recruitment potential was limited both in the short and long-term. This reach had low riparian species diversity and lacked mature trees.

Table 6. Large woody debris quantities in Reach 5.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Pieces	48	24	28	100
Number of Pieces/Mile	15	8	9	32

A-5.5 Substrate and Fine Sediment

Bed substrate was dominated by cobbles, with gravels and boulders subdominant. Bedrock was not observed. Sand composed 15% of the total ocular estimate, ranging from between 5-25% for all measured units. The percentage of fine sediment (<2mm) varied greatly between ocular estimates (15%) and the riffle pebble count (1%). Only one pebble count was attainable within the fast moving riffles representative of Reach 5. The pebble count and size class data are depicted in Figure 59 and Figure 60.



Material	Percent Composition
Sand	1%
Gravel	38%
Cobble	59%
Boulder	2%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	7
D16	25
D50	78
D84	148
D95	214

Figure 71. Grain size distribution and particle size classes from riffle pebble count taken at RM 43.6.

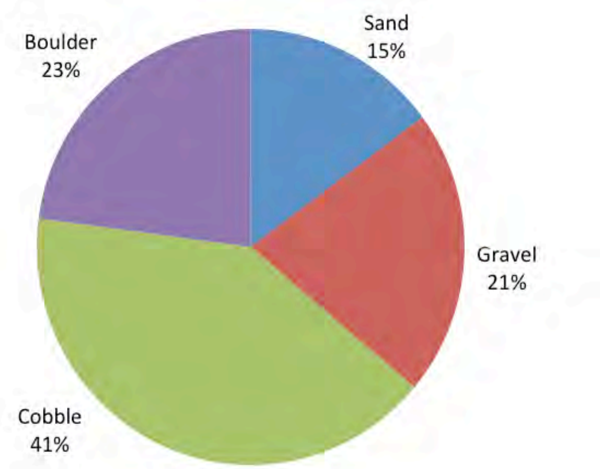


Figure 72. Percent composition of bed substrate based on ocular estimates, Reach 5.

A-5.6 Instability and Disturbance

Human activities have modified the channel, floodplain, and associated riparian corridor within the reach. The primary elements of disturbance include channel simplification, channel confinement, bank armoring, floodplain residential development, clearing of riparian vegetation, bridge crossings, and roadways. Few isolated pools and slow-water eddies were found throughout Reach 5.

Bank erosion was moderately high when compared to other reaches within the study area. Reach 5 had a total of 5,000 feet of actively eroding streambank (measured above bankfull), consisting of 15% of the reach length along both banks. Bank disturbance was often associated with land clearing, roadways, residential uses, river access, and steep terrace banks.

Areas of greatest impact include: the Old Plain Bridge (RM 46.2) crossing; Beaver Valley Rd Bridge (RM 46.4); River Rd where it abuts the channel (RM 43.6 to RM 44.1); and a transmission line (RM 44.45) crossing. These sites were associated with bank armor, land clearing, removal of riparian vegetation, and/or fragmenting the riparian corridor and floodplain. Examples of these impacts are included in Figure 61 and Figure 62.

Figure 73. Beaver Valley Rd Bridge bisects the upper portion of Reach 5, where the channel is artificially confined by riprap armoring (August 2011).

Figure 74. Transmission line clearing affects the riparian buffer and erosion near RM 44.45 (August 2011).

A-5.7 Available Spawning and Rearing Habitat

Substrate within Reach 5 riffles was coarse, consisting primarily of cobbles (58%). Although Chinook spawning occurs in this reach, many of the riffles provide minimal substrate within the range suitable for spawning (13-102 mm). It is unlikely that salmon species other than Chinook would be able to spawn within Reach 5.

Reach 5 provides low-to-moderate rearing habitat. Pool frequency is 1.0 pools/mile, yet three deep pools (residuals depths >3ft) would be expected to provide juvenile rearing, adult holding, and overwintering opportunity. Additionally, large boulders throughout the reach create small eddy pockets with localized velocity refuge.

LWD was below adequate levels and the potential LWD recruitment was poor in both the short and long-term.

A-5.8 Riparian Corridor

The presence and width of the forested riparian buffer varied within the reach. Past land clearing for timber, agriculture, roads, and housing results in a narrow forested or highly fragmented riparian buffer along most of Reach 5. This also includes areas of localized vegetation clearing.

Most of the riparian zone was dominated by large trees (61%) (Figure 63), primarily conifers (100% of units dominated by conifers). Ponderosa pine, alder, and cottonwood were the most prevalent species.

The level of stream shade provided by the riparian canopy varied throughout the reach. Large ponderosa pines provided morning and afternoon shade. Topographic shading was provided by steep terrace walls at localized sites throughout the reach.

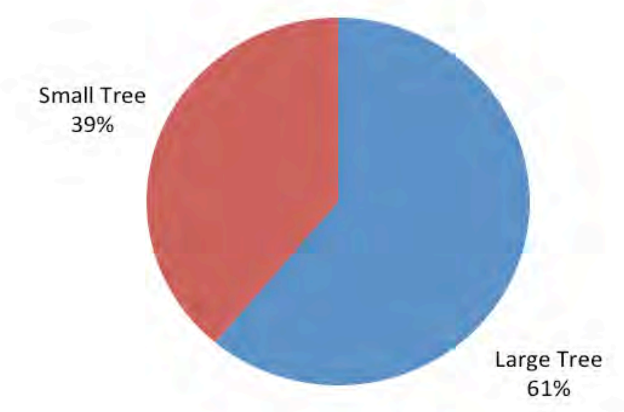


Figure 75. Distribution of the dominant size class category for the riparian zone, Reach 5.

A-6 Reach 6

Location: River mile 46.5 to 47.9

Survey Date: August 11, 2011

Survey Crew: Christa Strickwerda Heller and Adrianne Zuckerman (Inter-Fluve)

A-6.1 Reach Overview

Reach 6 is located in a partially confined valley from the confluence of Beaver Creek (RM 46.5) to Shuggart Flats (RM 47.9). This reach is a low gradient (0.35%) reach primarily bordered by historically abandoned terrace deposits (river-right) and steep sedimentary rock formations (Chumstick formation, river-left) (Figure 64). Channel form is meandering and bed morphology is primarily riffle-glide. Two stable and well-vegetated islands (RM 46.5 and RM 46.9) are located in the lower portion of Reach 6. See Figure 65 for a reach overview and habitat unit map.

As described for Reach 5, this reach was also used for log transport in the early 1900s (Bryon Newell, personal communication, Sept. 24, 2011). Streambanks were cleared of vegetation and logjams were removed. Riparian conditions have improved since the late-1920s. Historical and recent photos of this reach are included in Figure 66 and Figure 67.

Floodplain functions have been impacted by homesite construction, fill, and grading. A narrow low-elevation floodplain (RM 47.2 to RM 47.9) borders the upper portion of this reach near Shuggart Flats. Localized bank armoring and riparian clearing were observed along residential properties in the upper portion of the reach.

Figure 76. The Chumstick formation confines much of Reach 6 along river-left. This steep exposed sedimentary rock formation extends from RM 46.7 to RM 46.9 (August 2011).

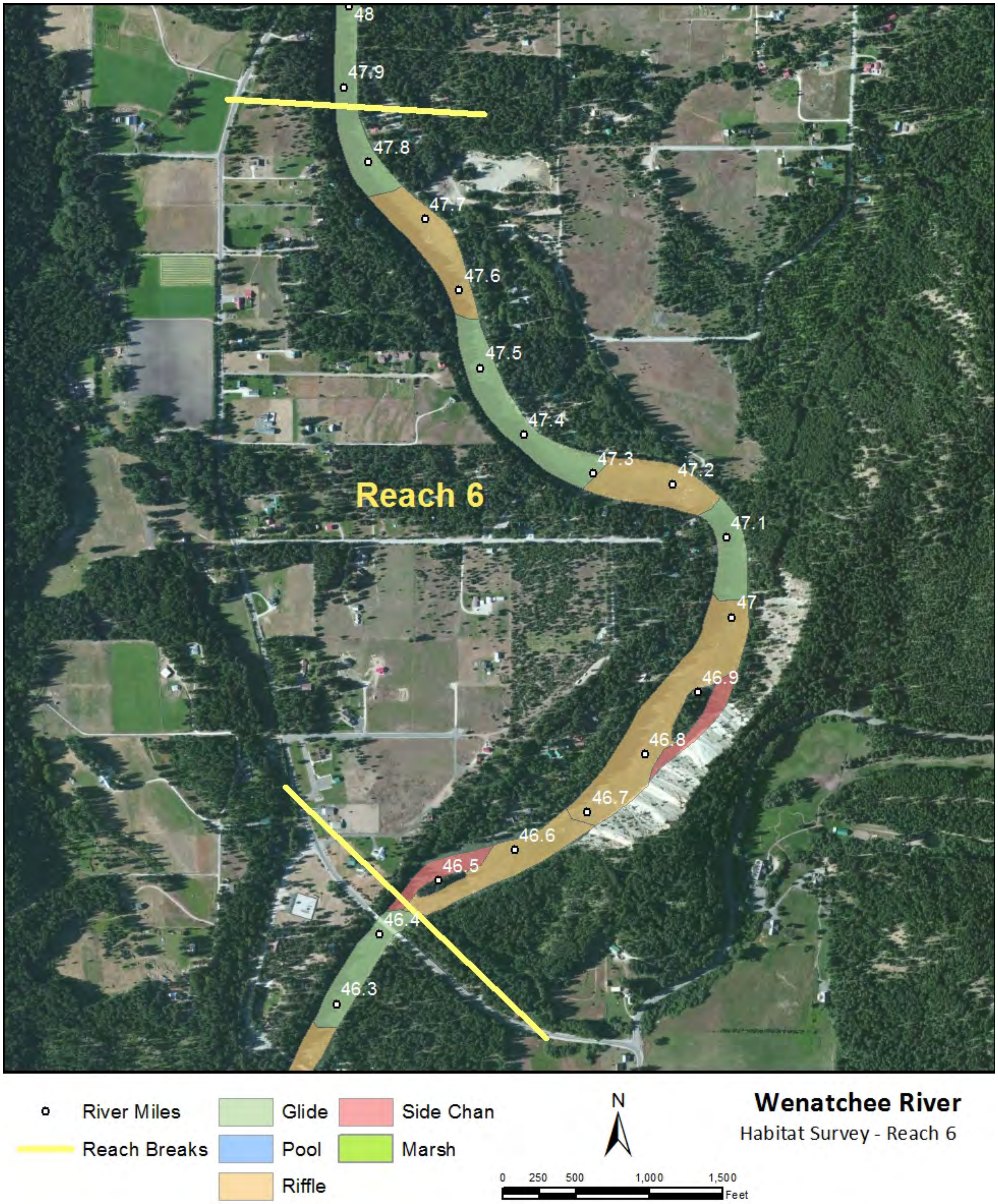


Figure 77. Reach 6 locator and habitat unit composition map.

Figure 78. Historic photo (circa 1920-1930) looking upstream towards the present day location of Beaver Valley Rd Bridge. Photo courtesy of Bryon Newell.

Figure 79. View looking upstream from the Beaver Valley Road Bridge (RM 46.5) (September 2011).

A-6.2 Habitat Unit Composition

Reach 6 was dominated by fast water units, consisting of 67% riffle, 23% glide, and 10% side-channel habitat (Figure 68). No pool habitat was present within this reach.

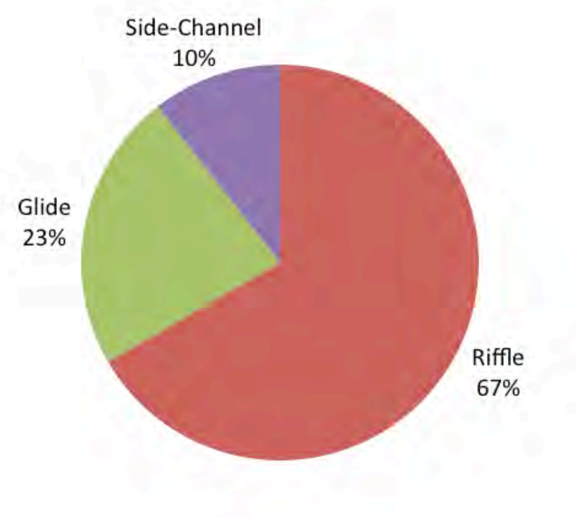


Figure 80. Habitat unit composition, Reach 6.

A-6.3 Off-Channel Habitat

Two fast water side-channels were found in Reach 6 (Figure 69). Both had large islands that split the channel. Each island had well-established vegetation composed of mixed trees (conifers and deciduous) and shrubs. LWD jams along the upstream margins of the islands created small back water eddies providing localized velocity refuge and juvenile rearing habitat. These jams appear to continue to recruit and trap woody material and fine sediments.

The side-channel at RM 46.9 flowed along river-right (opposite the sedimentary rock formation). It was composed primarily of cobbles (30%) and boulders (50%), providing little spawning habitat and limited velocity refuge. Riparian vegetation along the right bank did provide stream shade despite understory clearing and home building.

The second side-channel (RM 46.5) flowed along the left bank over gravels (20%) and cobbles (60%). Beaver Creek flows into the downstream end of this unit, delivering sediment inputs. Local topography and tall conifers shade portions of the side-channel. No off-channel marshlands were observed in Reach 6.

Figure 81. A side-channel (RM 46.9) flows along river-right opposite the steep sedimentary rock formation of Reach 6 (August 2011).

A-6.4 Large Woody Debris

LWD quantities were moderate in Reach 6 compared to other reaches in the study area. LWD frequency was 67 pieces/mile, with "small" pieces comprising 43% of all LWD counted in the reach (Table 6). "Medium" and "Large" wood pieces comprised 57% of the LWD in the reach (25% and 32%, respectively). LWD recruitment appeared high throughout Reach 6 although there is a lack of large and mature trees in the riparian area. The presence of mid-channel islands (Figure 70) would be expected to continue to trap and retain fluvial wood transported from upstream sources (including the Chiwawa River).

Table 7. Large woody debris quantities in Reach 6.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Pieces	39	23	29	91
Number of Pieces/Mile	29	17	21	67

Figure 82. LWD jams have formed along the upstream margins of both mid-channel islands in Reach 6 (August 2011).

A-6.5 Substrate and Fine Sediment

Bed substrate was dominated by cobbles. Boulders were subdominant. Sand and gravels were less common, making up 7% and 18% of the bed substrate, respectively. No bedrock was observed within the stream channel despite its close proximity to the Chumstick formation. No pebble count data were collected due to high water conditions at the time of the survey. Results of the ocular substrate measures are depicted in Figure 71.

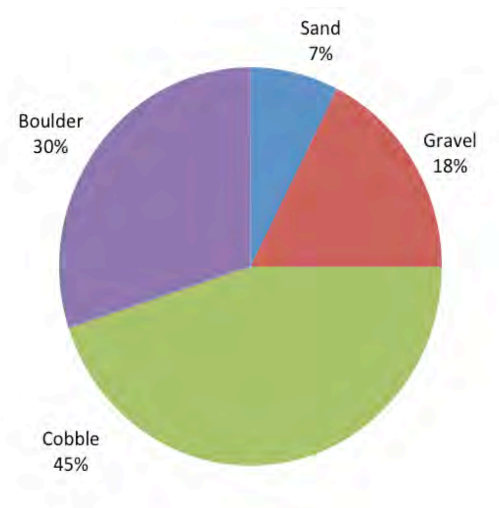


Figure 83. Percent composition of bed substrate based on ocular estimates, Reach 6.

A-6.6 Instability and Disturbance

Human activities have impacted the channel, floodplain, and associated riparian corridor within the reach. The primary elements of disturbance include bank armoring, floodplain development, and vegetation clearing. River access and associated disturbance was observed along the narrow low-elevation floodplains throughout Reach 6 (Figure 72). Bank armoring (RM 47.85) made of tires and rock, and an earthen levee (RM 47.55 to RM 47.67), have been constructed along the left bank.

As a result of bank armoring and natural confinement, actively eroding streambanks were uncommon in Reach 6 when compared to other reaches in the study area. Reach 6 had a total of 100 feet of actively eroding streambank (measured above bankfull), consisting of 1% of the reach length along both banks. Bank disturbance was associated with failed riprap armoring along the right bank.

Figure 84. Vegetation clearing and river access impacts riparian buffers at residential properties in Reach 6 (August 2011).

A-6.7 Available Spawning and Rearing Habitat

There was very minimal available spawning and rearing habitat in Reach 6. Large substrates dominated this reach, consisting primarily of cobbles (45%) and boulders (30%). Riffle substrate (ocular estimates) ranged from 10-20% gravels, 30-60% cobbles and 10-50% boulders. Fine sediment was at adequate levels, averaging just 5% of the total bed composition (ocular estimate). It is unlikely that salmon would make much spawning use of Reach 6 due to its coarse substrate composition and water velocity. Adult salmon and steelhead would be expected to primarily use this reach as a migration corridor.

Reach 6 had no pool habitat. The reach lacked flood refugia and provided minimal canopy cover along lateral margins. Reach 6 only had a few areas of localized velocity refuge near LWD jams. Large boulders throughout the upper portion of Reach 6 may also provide velocity refuge for rearing and during upstream migration.

A-6.8 Riparian Corridor

The width of the forested riparian buffer varied within the reach. Past land clearing for timber harvest and residential development has resulted in a fragmented riparian buffer along Shuggart Flats (river-left from RM 47.2 to 47.9) and along the right bank throughout the reach. The riparian buffer is sparsely vegetated along the sedimentary rock formation (river-left from RM 46.7 to RM 46.9) due to the steep grade and exposed growing conditions. Cottonwood, willow, and spirea grow along the alluvial deposits near Beaver Creek, providing localized species diversity and canopy cover.

The riparian zone throughout Reach 6 was dominated by small trees (88%) (Figure 73), primarily consisting of conifers (75% conifer; 25% hardwood). Ponderosa pine, cottonwood, and alder were the most prevalent species.

The level of stream shade provided by the riparian canopy was low throughout the upper portion of Reach 6. Moderate shading was provided by two well-vegetated mid-channel islands and the steep exposed sedimentary rock formation along the downstream portion of the reach (RM 46.5–47.1).

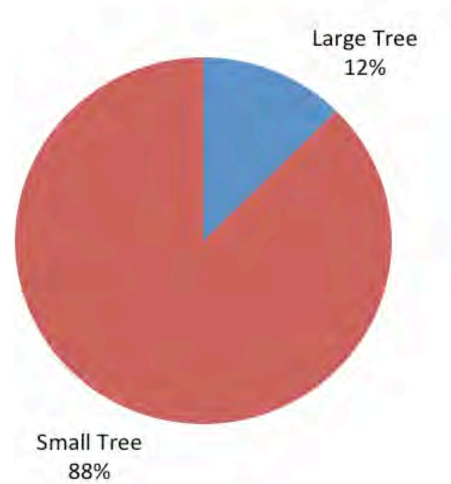


Figure 85. Distribution of the dominant size class category for the riparian zone, Reach 6.

A-7 Reach 7

Location: River mile 47.9 to 48.4

Survey Date: August 11, 2011

Survey Crew: Christa Strickwerda Heller and Adrianne Zuckerman (Inter-Fluve)

A-7.1 Reach Overview

Reach 7 flows through a partially-confined alluvial valley from Shuggart Flats (RM 47.9) to the confluence of the Chiwawa River (RM 48.4). It is a low gradient reach (0.25%). Channel form is slightly meandering and bed morphology is mostly riffle-glide. Reach 7 is influenced by sediment and water inputs from the Chiwawa River (Figure 75). Entering from river-left, the Chiwawa River originates in the Glacier Peak Wilderness and drains 183 square miles of national forest and wilderness. Land use throughout Reach 7 is primarily rural residential. Reach 7 has been altered as a result of road building, fill, grading, vegetation removal/clearing, and homesite construction.

Beaver Valley Rd bisects the floodplain and riparian corridor, paralleling this reach along river-right. Chiwawa River alluvial deposits (sand and gravel) create a vegetated low-elevation floodplain throughout the upstream portion of this reach along the left bank. This portion of Reach 7 experiences minor inundation during seasonal high-flow/flood events. Slightly higher alluvial terraces border this reach along river-right. See Figure 74 for a reach overview and habitat unit map.

Figure 86. Sand and gravel alluvial deposits form a bar along the upper portion of Reach 7 on river-left just downstream of the Chiwawa River confluence (August 2011).

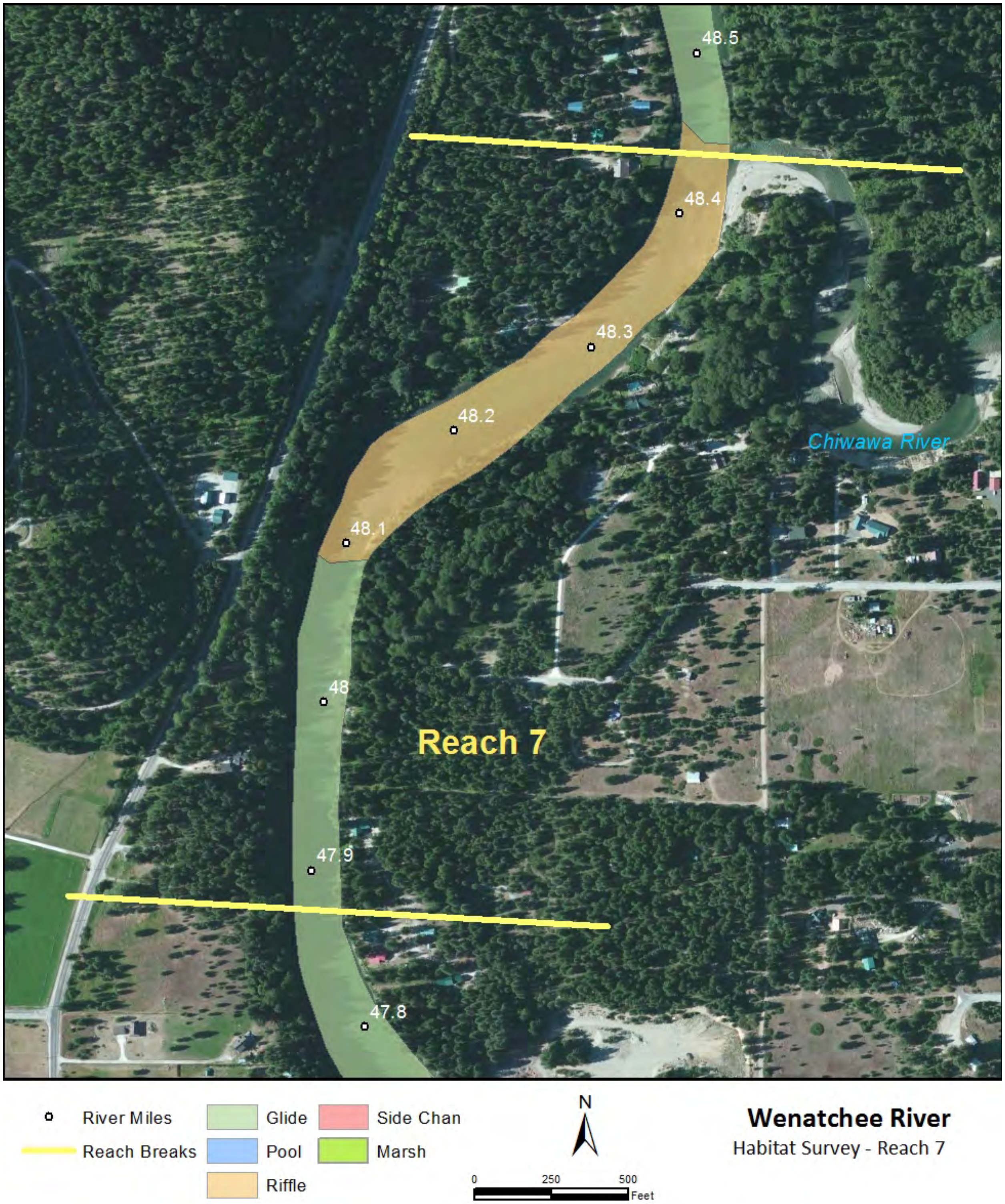


Figure 87. Reach 7 locator and habitat unit composition map.

A-7.2 Habitat Unit Composition

Reach 7 was the second shortest reach in the Upper Wenatchee study area, measuring 0.54 miles in length. This reach was composed of 54% riffle and 46% glide habitat (Figure 76).

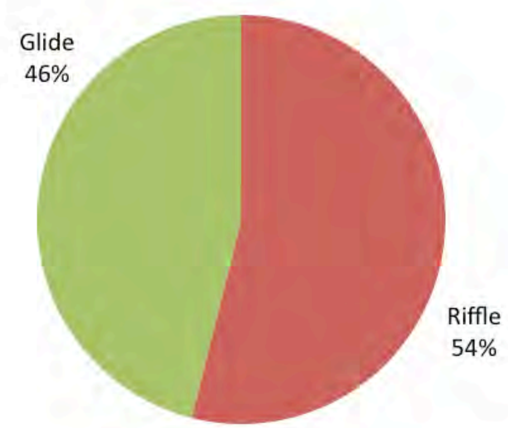


Figure 88. Habitat unit composition, Reach 7.

A-7.3 Off-Channel Habitat

Reach 7 has no side-channel habitat or off-channel marshlands. Off-channel habitat is limited due to natural confinement throughout much of the reach but has also been limited to some degree by human development in riparian areas and floodplains.

A-7.4 Large Woody Debris

LWD quantity and frequency were the lowest observed throughout the study area. LWD frequency was 13 pieces/mile, with "small" pieces comprising 78% of all LWD counted in the reach (Table 7). "Medium" and "Large" wood pieces comprised 22% of the total LWD count, with only one piece of each observed in Reach 7. LWD recruitment potential was low within this reach. Reach 7 receives wood inputs from upstream sources (both the Chiwawa and Wenatchee River), yet low channel sinuosity and fast water channel units limit the ability of the reach to retain wood. Additionally, LWD recruitment potential is limited by the lack of natural channel migration.

Table 8. Large woody debris quantities in Reach 7.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Pieces	7	1	1	9
Number of Pieces/Mile	10	1	1	13

A-7.5 Substrate and Fine Sediment

Bed substrate was dominated by cobbles and boulders. Boulders were dominant, comprising 35% of the total bed composition; cobbles were subdominant (33%). No bedrock was observed in Reach 7. Sand comprised 12% of the total bed composition. Pebble count data were not collected within Reach 7 due to high water conditions. Results of the ocular substrate measures are depicted in Figure 77.

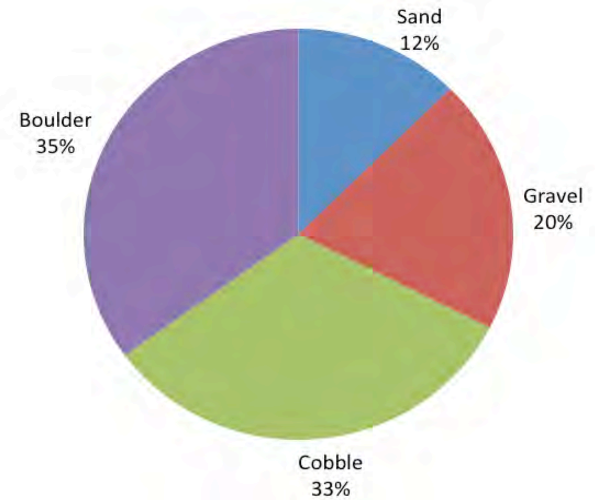


Figure 89. Percent composition of bed substrate based on ocular estimates, Reach 7.

A-7.6 Instability and Disturbance

No instability or recent disturbance was observed in Reach 7.

A-7.7 Available Spawning and Rearing Habitat

Spawning and rearing habitat was limited in Reach 7. Large substrates consisting of cobbles and boulders dominated this reach. Riffle substrate (ocular estimate) observed in Reach 7 was 5% sand, 25% gravels, 40% cobbles, and 30% boulders. Alluvial deposits from the Chiwawa River (Figure 78) and a small right bank tributary create areas of localized spawning gravel. Chinook and steelhead would likely use these small spawning areas. However, salmon and steelhead would most likely use this reach primarily as a migration corridor. Large boulders throughout Reach 7 may provide areas of localized velocity refuge.

Reach 7 had no substantial pool habitat. This reach lacked LWD and off-channel habitat. Riparian vegetation provided canopy cover along lateral margins for most of Reach 7.

Figure 90. Alluvial gravel deposits from the Chiwawa River create areas of localized spawning habitat in Reach 7 (August 2011).

A-7.8 Riparian Corridor

The width of the forested riparian buffer varied within the reach. Past land clearing and development throughout Shuggart Flats has resulted in a fragmented forest riparian buffer along river-left.

The riparian zone throughout Reach 7 was dominated by large trees (100% of units), consisting of both conifers (50%) and hardwoods (50%). Douglas fir, cottonwood, willow, and alder were the most prevalent species.

The level of stream shade provided by the riparian canopy was moderate throughout the reach. Low-elevation floodplains and alluvial terraces were vegetated with hardwoods and small shrubs providing stream shading along much of Reach 7.

A-8 Reach 8

Location: River mile 48.4 to 49.7

Survey Date: August 11, 2011

Survey Crew: Christa Strickwerda Heller and Adrianne Zuckerman (Inter-Fluve)

A-8.1 Reach Overview

Reach 8 is located in a partially confined valley from the confluence of the Chiwawa River at RM 48.4 to a meander bend at RM 49.7 (Figure 79). This reach is low gradient (0.12%). Channel form is meandering and bed morphology is pool-riffle with interspersed glide units.

Land use throughout Reach 8 includes private residential (Figure 80), private community access (Chiwawa Community Association), US Forest Service land, and a Washington Department of Fish and Wildlife (WDFW) fish hatchery (Chiwawa Ponds facility). The WDFW facility is protected by a short section of concrete retaining wall along river-left (Figure 81). Bank armoring at this location may be responsible for channel simplification and disconnection of a side-channel just downstream of the retaining wall.

Floodplain functions have been impacted as a result of road building, fill and grading, vegetation removal/alteration, and homesite construction. Reach 8 is bordered by historically abandoned terrace deposits and road fill from the construction of Beaver Valley Road along the river-right bank. The left bank has been altered by both current and historical land uses including residential development and logging activities.

Figure 91. Reach 8 locator and habitat unit composition map.

Figure 92. Glide habitat (RM 49.5) bordered by homesites in the upstream portion of Reach 8 (August 2011).

Figure 93. Small concrete retaining wall at meander bend just upstream from the WDFW hatchery facility (August 2011).

A-8.2 Habitat Unit Composition

Reach 8 consisted of 41% pool, 31% glide, 21% riffle, and 7% side-channel habitat (Figure 82 and Figure 83). Pool frequency was 1.8 pools/mile, with a mean pool spacing of 14.0 channel widths per pool. Average residual pool depth was 7.5 feet. Average maximum pool depth was 11.0 feet.

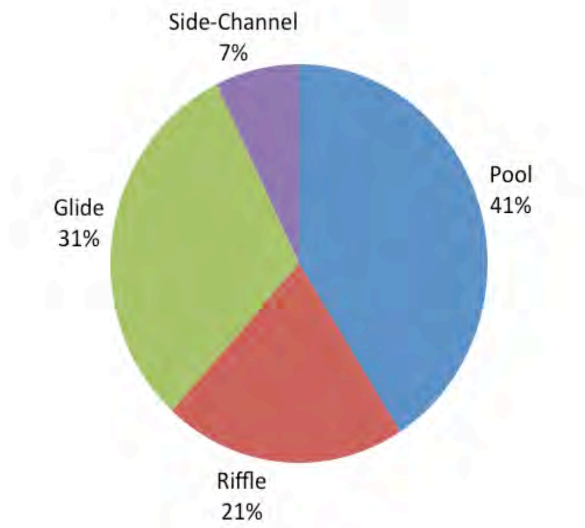


Figure 94. Habitat unit composition, Reach 8.

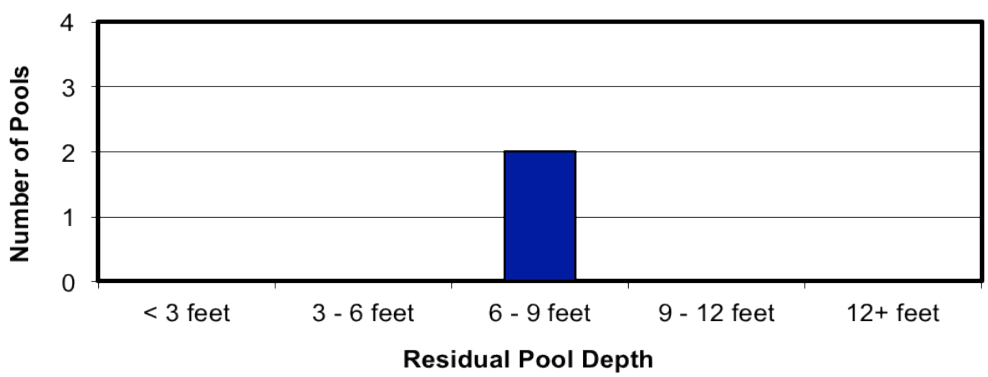


Figure 95. Reach 8 residual pool depths.

A-8.3 Off-Channel Habitat

Reach 8 had two side-channels. The first side-channel was located downstream of the WDFW facility at RM 49.2. It was a fast water (riffle) unit flowing along the right bank terrace. LWD had accumulated throughout the side-channel creating deep pockets and refugia. A mid-channel cobble bar collected soil and sand along the downstream margins and was sparsely vegetated with young willows.

The second side-channel flowed along the river-left bank at RM 48.8. It was a fast water (riffle) unit separated from the main channel by a sparsely vegetated cobble bar (Figure 84). This side-channel appeared to provide both spawning and rearing habitat (gravels and cover).

An off-channel marsh (Figure 85) was observed in an abandoned side-channel (meander scar) downstream of the WDFW facility along the river-left bank. Evidence of large wood and scour deposits indicated that this is a high flow channel during floods.

Figure 96. View downstream at a sparsely vegetated cobble bar and right bank terrace in the lower portion of Reach 8 near RM 48.8 (August 20011).

Figure 97. Off-channel marsh along the river-left bank at RM 49.1 (August 2011).

A-8.4 Large Woody Debris

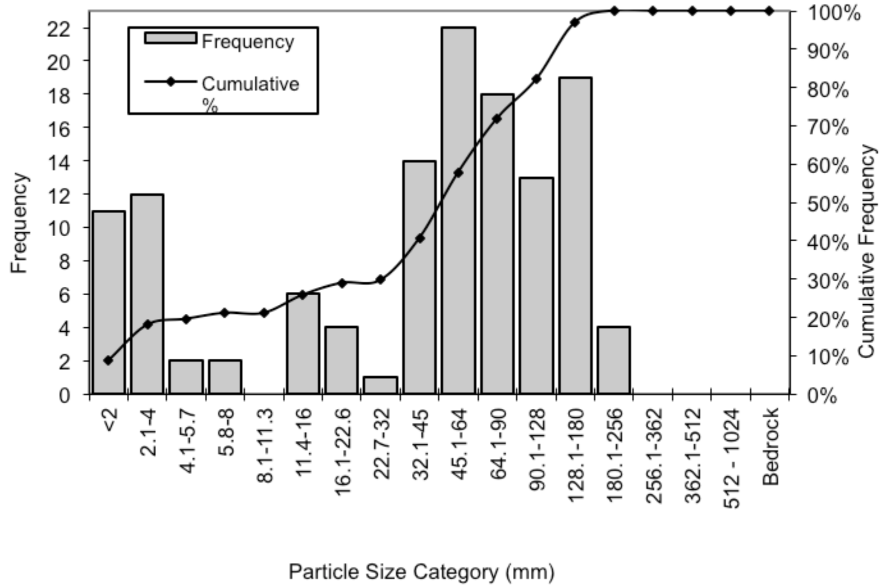
LWD quantities were moderately low in Reach 8 compared to other reaches in the study area. LWD frequency was 57 pieces/mile, with “small” pieces comprising 48% of all LWD counted in the reach (Table 8). “Medium” and “Large” wood pieces comprised 52% of the LWD in the reach (20% and 32%, respectively). Throughout Reach 8, LWD recruitment potential was limited both in the short and long-term. This reach had low riparian species diversity that lacked large and mature trees. The high-flow channel and marsh at RM 49.1 had collected LWD (8 pieces) that may become active in future flood events.

Table 9. Large woody debris quantities in Reach 8.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Pieces	31	13	21	65
Number of Pieces/Mile	27	11	18	57

A-8.5 Substrate and Fine Sediment

Bed substrate was dominated by cobbles, with gravels subdominant. Bedrock was not observed. Sand comprised 28% of the total ocular estimates and averaged 20% for all measured riffles. The percentage of fine sediment (<2mm) varied greatly between ocular estimates (20%) and the riffle pebble count (9%). Only one riffle pebble count was recorded within Reach 8 due to high water conditions. The pebble count and size class data are depicted in Figure 86 and Figure 87.



Material	Percent Composition
Sand	9%
Gravel	49%
Cobble	42%
Boulder	0%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	<2
D16	1
D50	55
D84	135
D95	173

Figure 98. Grain size distribution and particle size classes from pebble count taken at RM 48.8.

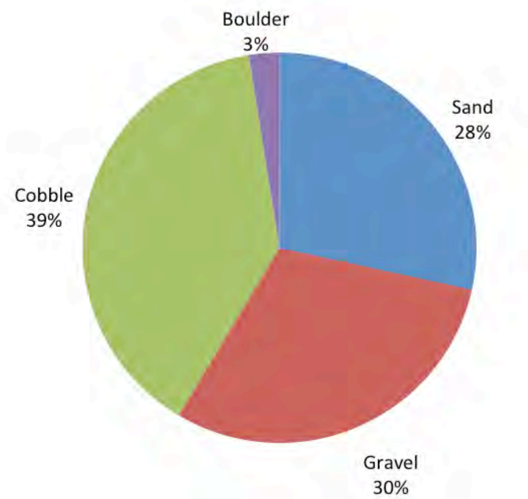


Figure 99. Percent composition of bed substrate based on ocular estimates, Reach 8.

A-8.6 Instability and Disturbance

Human development has modified the channel, floodplain, and riparian corridor within Reach 8. Bank erosion was moderate when compared to other reaches in the study area. Reach 8 had a total of 931 feet of actively eroding streambank (measured above bankfull), consisting of 6% of the reach length along both banks.

Bank disturbance primarily occurred along the steep right bank terrace. Erosion was observed along both banks throughout the pool bordering the WDFW facility (RM 49.3) and along the steep terraces from RM 48.8 to RM 49.0. The WDFW hatchery facility was bordered by a concrete retaining wall (Figure 88).

Figure 100. Concrete intake structure at the WDFW hatchery facility (August 2011).

A-8.7 Available Spawning and Rearing Habitat

There was a moderate amount of spawning and rearing habitat available in Reach 8. The dominant substrate in riffles was gravels (49%) and subdominant was cobbles (42%). Riffle pebble count data suggested that Reach 8 had ideal substrate for both Chinook (13-102 mm) and steelhead (6-102 mm) spawning. Spawning would likely occur near side-channels and throughout the downstream portion of Reach 8. Pool frequency and quality were high within Reach 8 (41% pool habitat), which would support high juvenile salmonid rearing use.

A-8.8 Riparian Corridor

The width of the forested riparian buffer varied within the reach, especially along the upper half mile of the reach. Past land clearing and residential development has resulted in a fragmented riparian buffer along river-left from RM 49.2 to 49.7. The remaining riparian buffer has been sparsely reforested by ponderosa pine.

The riparian zone throughout Reach 8 was dominated by small trees (63%) (Figure 89), primarily consisting of conifers (88% conifer; 13% shrub). Ponderosa pine, willow, and alder were the most prevalent species. Generally, Reach 8 lacked both species and age-class diversity.

The level of stream shade provided by the riparian canopy was low throughout the reach. Topographic shading was provided by the steep right bank terrace along the downstream portion of the reach (RM 48.4 – 49.2).

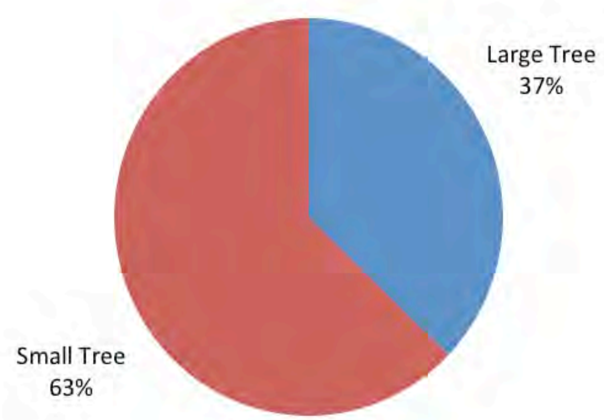


Figure 101. Distribution of the dominant size class category for the riparian zone, Reach 8.

A-9 Reach 9

Location: River mile 49.73 to 51.65

Survey Date: August 10, 2011

Survey Crew: Christa Strickwerda Heller and Adrianne Zuckerman (Inter-Fluve)

A-9.1 Reach Overview

Reach 9 is located in a partially confined alluvial valley from RM 49.73 to 51.65 (Figure 91). This reach is very low gradient (0.04%) (Figure 90). Channel form is slightly meandering with bed morphology that is primarily plane-bed. Accessible floodplain areas and steep terraces alternate along the streambanks. Reach 9 lacks both channel complexity and habitat differentiation. Presently, lands along Reach 9 are managed by the US Forest Service and have minimal human development. Beaver Valley Road parallels the main channel along river-right from RM 50.2 to 50.9. This section of road limits floodplain connectivity and access to off-channel habitat. See Figure 91 for a reach overview and habitat unit map.

Figure 102. Typical slow deep-water habitat and alternating narrow floodplains and steep terraces in Reach 9 (August 2011).

Figure 103. Reach 9 locator and habitat unit composition map.

A-9.2 Habitat Unit Composition

Reach 9 consisted of 47% glide, 35% pool, 14% riffle, and 4% side-channel habitat (Figure 92 and Figure 93). Pool frequency was 1.4 pools/mile, with mean pool spacing of 17.6 channel widths per pool. Average residual pool depth was 10.0 feet. Average maximum pool depth was 15.0 feet.

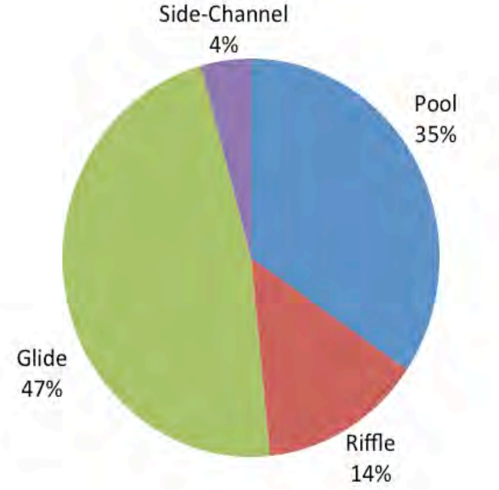


Figure 104. Habitat unit composition, Reach 9.

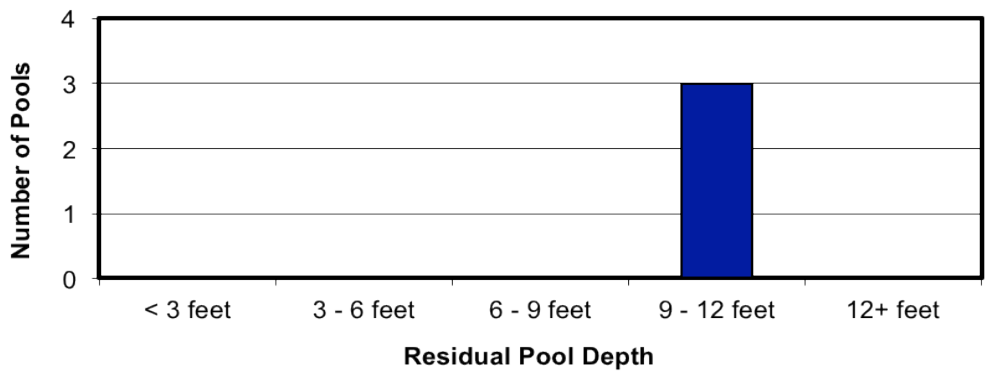


Figure 105. Reach 9 residual pool depths.

A-9.3 Off-Channel Habitat

Reach 9 had one side-channel near RM 50. Side-channel habitat was short and limited within this reach, yet would be expected to provide both spawning and rearing habitat. At the time of the survey, spring Chinook were observed spawning in the river-right channel that provided shallower riffle habitat with adequately sized gravel and small cobble (Figure 94).

Three small backwater marshes were identified in Reach 3. These were located at RM 50 and RM 50.75 on river-left and at RM 50.9 on river-right. Each provided minimal-to-no LWD. Beaver activity was observed within each of the backwater marshlands in Reach 9 (Figure 95).

Figure 106. Reach 9 side-channel habitat provides adequately sized spawning gravels (August 2011).

Figure 107. Beaver activity was observed along a river-right backwater near RM 50.9 (August 2011).

A-9.4 Large Woody Debris

LWD quantities were moderate in Reach 9 compared to other reaches in the study area. LWD frequency was 75 pieces/mile, with "small" pieces comprising 36% of all LWD counted in the reach (Table 9). "Medium" and "Large" wood pieces comprised 64% of the LWD in the reach (28% and 36%, respectively). Beaver activity was observed at scattered locations along the reach and may contribute to LWD recruitment. Large wood recruited and retained along channel margins provides rearing cover and contributes to low water off-channel development in some locations (Figure 96). Surrounding US Forest Service timberlands also have the potential to contribute LWD in the long-term.

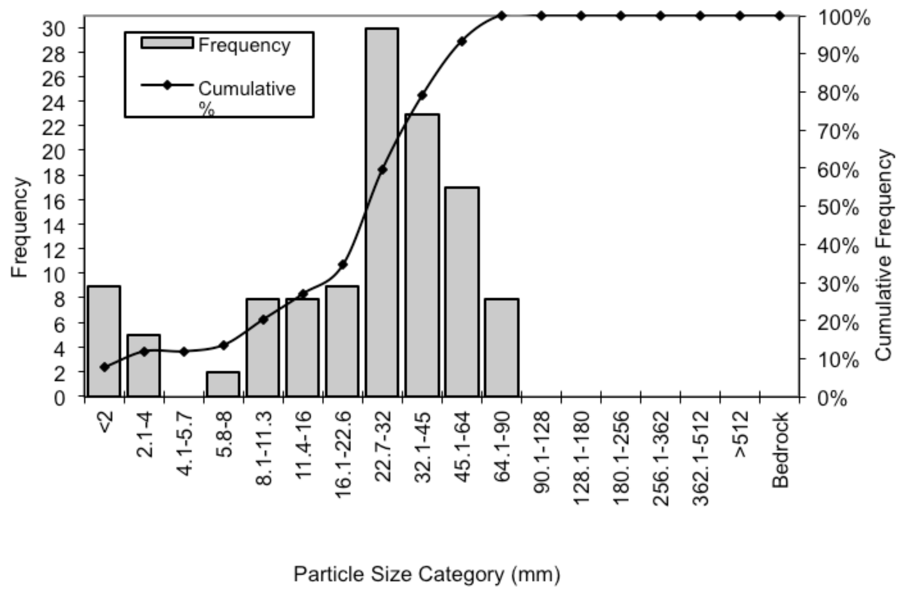
Table 10. Large woody debris quantities in Reach 9.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Pieces	56	44	57	157
Number of Pieces/Mile	27	21	27	75

Figure 108. Woody debris accumulations upstream of the off-channel marsh (RM 50.0) along river-left (August 2011).

A-9.5 Substrate and Fine Sediment

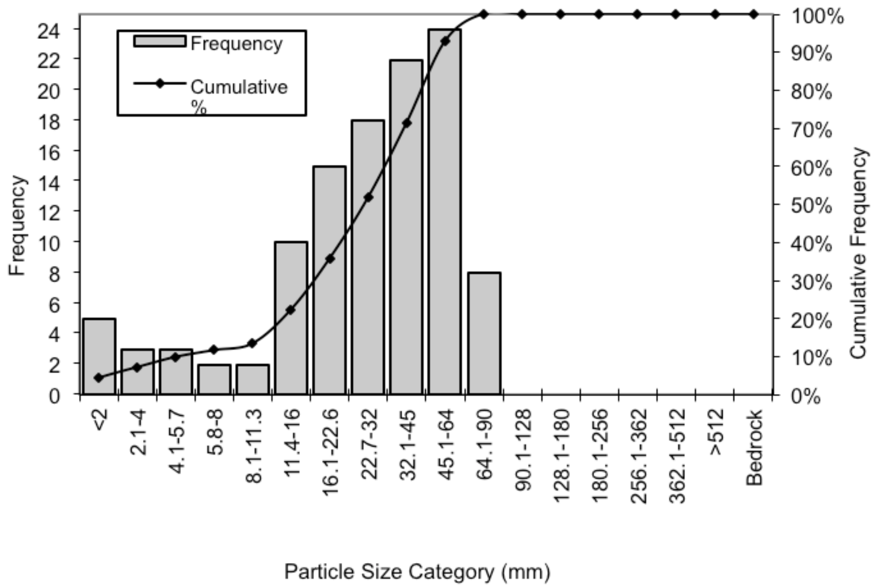
Bed substrate was dominated by gravels, with cobbles subdominant. No bedrock was observed in Reach 1 and boulders made up no greater than 5% of the distribution. The percentage of fine sediment (<2mm) was variable, making up approximately 4-26% of the substrate distribution. The pebble count and size class data are depicted in Figure 97, Figure 98, and Figure 99.



Material	Percent Composition
Sand	8%
Gravel	86%
Cobble	7%
Boulder	0%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	<2
D16	9
D50	28
D84	52
D95	71

Figure 109. Grain size distribution and particle size classes from pebble count taken at RM 50.0.



Material	Percent Composition
Sand	4%
Gravel	88%
Cobble	7%
Boulder	0%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	2
D16	13
D50	31
D84	56
D95	72

Figure 110. Grain size distribution and particle size classes from pebble count taken at RM 50.4.

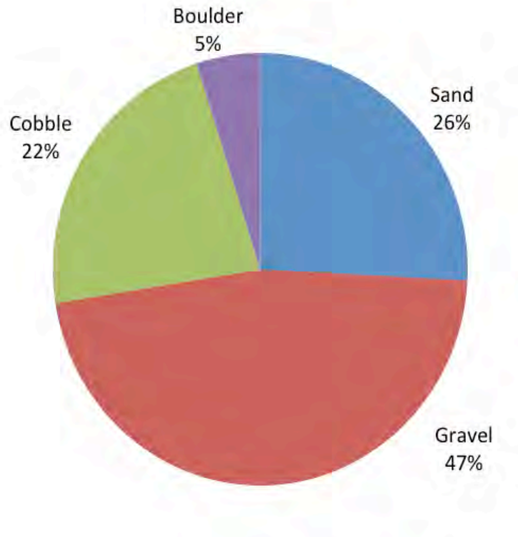


Figure 111. Percent composition of bed substrate based on ocular estimates, Reach 9.

A-9.6 Instability and Disturbance

Bank erosion was high, with the greatest amount of actively eroding streambanks observed in the study area. Reach 9 had a total of 5,455 feet of actively eroding streambank (measured above bankfull), consisting of 22% of the reach length along both banks. Bank erosion was primarily associated with steep terrace banks bordering much of Reach 9 (Figure 100), and is largely a natural erosion process that may be exacerbated by loss of mature riparian trees and loss of LWD jams along the channel margin.

Beaver Valley Rd parallels Reach 9 along river-right from RM 50.2 to 50.9 and bisects a portion of the floodplain.

Figure 112. Bank instability was observed along many of the steep terrace banks throughout Reach 9 (August 2011).

A-9.7 Available Spawning and Rearing Habitat

There was a moderate amount of spawning and rearing habitat available in Reach 9. The dominant substrate in riffles was gravels (86-88%). Riffle pebble count data suggested that Reach 8 offers substrate for both Chinook (13-102 mm) and steelhead (6-102 mm) spawning. Chinook were observed (August 10, 2011) spawning and holding (Figure 101) along channel margins where cobble was present. Coho may also utilize the slower water spawning riffles (Figure 102) and off-channel habitats found in Reach 9. Pool frequency and quality were moderate within Reach 9 (35% of total area).

Figure 113. Submerged woody material provides refugia for Chinook in Reach 9 (August 2011).

Figure 114. Low velocity riffles and small gravels provide moderate spawning habitat in Reach 9 (August 2011).

A-9.8 Riparian Corridor

The width of the forested riparian buffer varied within Reach 9, especially along the middle portion of the reach that parallels Beaver Valley Road from RM 50.3 to 50.9. Generally, the forested riparian buffer was greater than 100 feet wide along the entire reach. Reach 9 had minimal streamside development and lacked the riparian fragmentation seen in Reaches 3 through 8. Second-growth timber surrounds Reach 9.

The riparian zone along Reach 9 was dominated by large trees (62%) (Figure 103), primarily consisting of conifers (88% conifer; 12% hardwood). Ponderosa pine, cottonwood, willow, and alder were the most prevalent species within the riparian zone. Due to the topography and lack of recent human disturbance, Reach 9 has developed a densely vegetated riparian buffer and intact understory compared to downstream reaches. The three off-channel marshlands and the presence of beavers add species and age-class diversity to the riparian buffer.

The level of stream shade provided by the riparian canopy was moderate throughout Reach 9. Large ponderosa pines provided morning and afternoon shade along much of the stream channel.

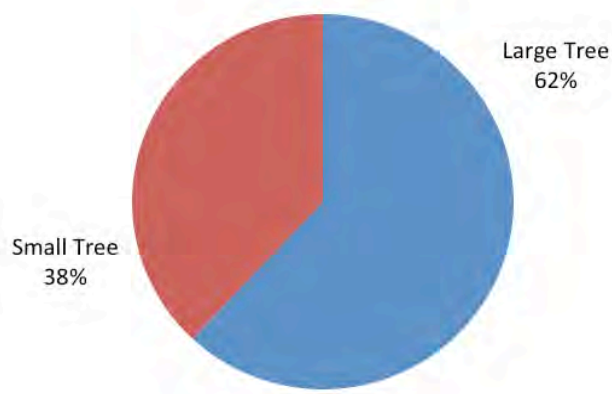


Figure 115. Distribution of the dominant size class category for the riparian zone, Reach 9.

A-10 Reach 10

Location: River mile 51.65 to 53.67

Survey Date: August 9 - 10, 2011

Survey Crew: Christa Strickwerda Heller and Adrianne Zuckerman (Inter-Fluve)

A-10.1 Reach Overview

Reach 10 extends from RM 51.65 upstream to the confluence with Nason Creek at RM 53.67 (Figure 106). This portion of the Wenatchee River flows through a wide partially-confined alluvial valley. Channel gradient is 0.11%. Channel form is slightly meandering and bed morphology is a mix of pool-riffle and plane-bed glide units.

On river-right there is scattered development and human infrastructure, including houses, businesses, roadways, and bank armoring (Figure 104). WDFW maintains and seasonally operates a rotary smolt trap for juvenile sockeye monitoring. The trap is secured to cables just upstream of the Hwy 207 Bridge.

Hwy 207 crosses the Wenatchee River at RM 53.6 and disconnects the Nason Creek alluvial fan by reducing the potential range of lateral migration of lower Nason Creek. Riprap and the Hwy 207 bridge abutments constrain the Wenatchee River channel in the vicinity of the bridge. Private infrastructure near the upper portion of this reach experiences periodic flooding (Figure 105).

Residential development (primarily vacation homes) is located along river-right (Braeburn Road) for most of Reach 10. River-left is dominated by low elevation floodplain areas and moderately steep-banked terraces topped with ponderosa pine forests. There are two large open-water marshlands within river-left floodplains that offer connected aquatic refugia and marsh habitat.

Figure 116. Bank armoring and channel confinement near the Hwy 207 Bridge, Reach 10 (August 2011).

Figure 117. The Headwaters Tavern experienced flooding after a winter rain-on-snow event in the 1990s. The Tavern is located on river-right downstream of the confluence with Nason Creek. Photo courtesy of Bryon Newell.

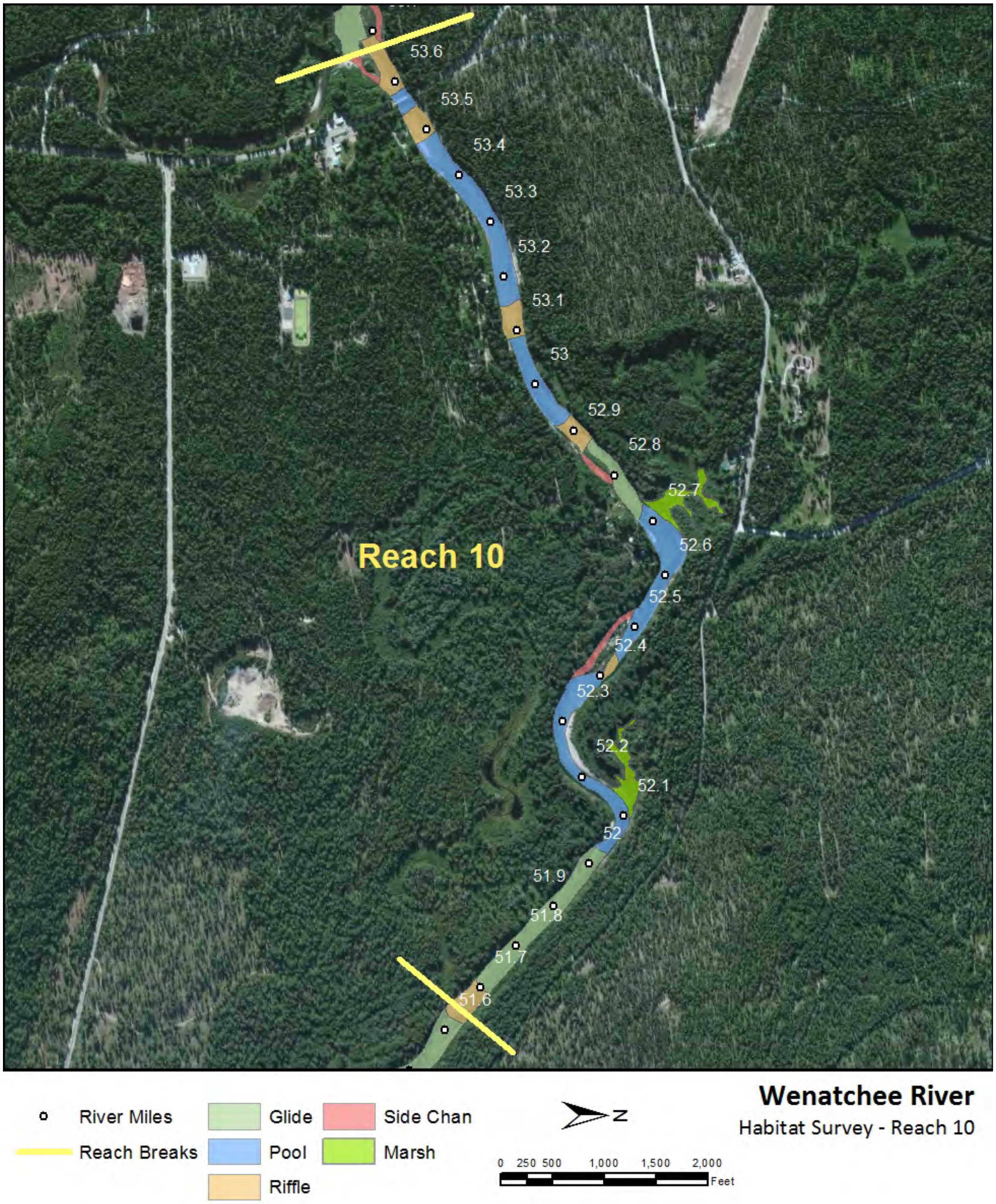


Figure 118. Reach 10 locator and habitat unit composition map.

A-10.2 Habitat Unit Composition

Reach 10 consisted of 57% pool, 20% riffle, 20% glide, and 3% side-channel habitat (Figure 107 and Figure 108). Pool frequency was 2.3 pools/mile, with mean pool spacing of 12.7 channel widths per pool. Average residual pool depth was 6.1 feet. Average maximum pool depth was 10.2 feet. Figure 109 shows a representative glide unit in this reach.

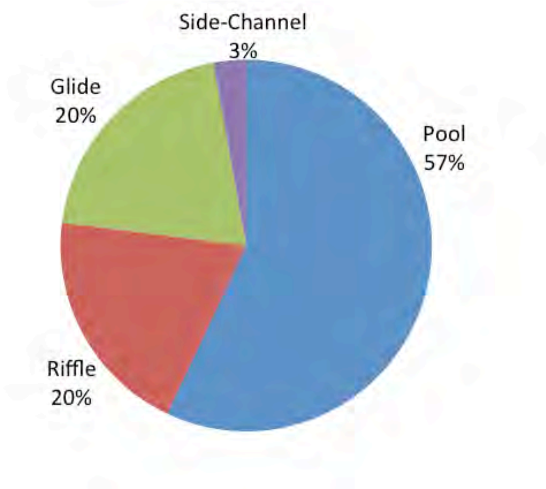


Figure 119. Habitat unit composition, Reach 10.

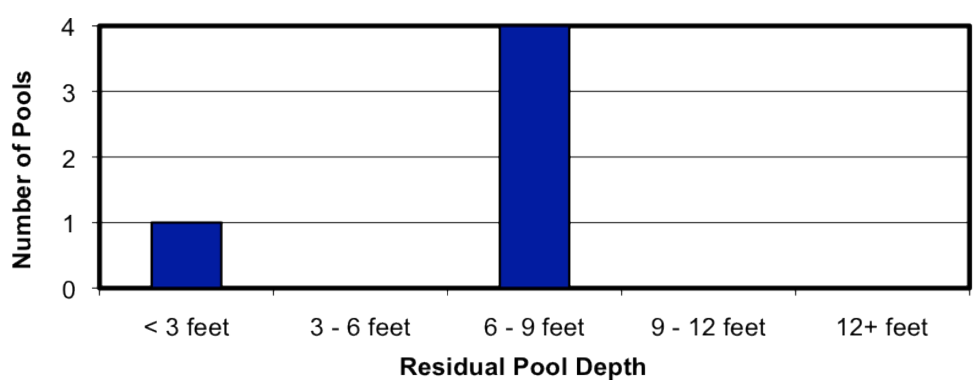


Figure 120. Reach 10 residual pool depths.

Figure 121. View looking upstream at a representative glide in Reach 10, near RM 51.8 (August 2011).

A-10.3 Off-Channel Habitat

There were three side-channels in Reach 10. Each side-channel provides spawning and rearing habitat not found in many of the faster mainstem riffles. These side-channels were composed of smaller substrate preferred by steelhead and coho.

Reach 10 contained two large open-water marshlands along river-left at RMs 52.1 and 52.7 (Figure 110). High densities of salmonid juveniles and cyprinid fry were observed (August 10, 2011) throughout both marshes (Figure 111). Wetland vegetation (cottonwood, willow, dog wood, spirea, carex, reed canary grass, and yellow pond lily) provided shading and refuge for both fish and wildlife species. Waterfowl and great blue herons were observed utilizing these protected off-channel areas to feed. Reach 10 likely had higher historical off-channel complexity that has been reduced as a result of residential development and associated floodplain filling and grading, especially along the right bank.

The large right bank off-channel complex (Natapoc) along Reach 10 was not counted as off-channel habitat in this reach because it was not connected via surface flow at the time of the survey.

Figure 122. One of two extensive open water marshlands on river-left, Reach 10 (August 2011).

Figure 123. Fry were observed throughout the open-water marshes in Reach 10 (August 2011).

A-10.4 Large Woody Debris

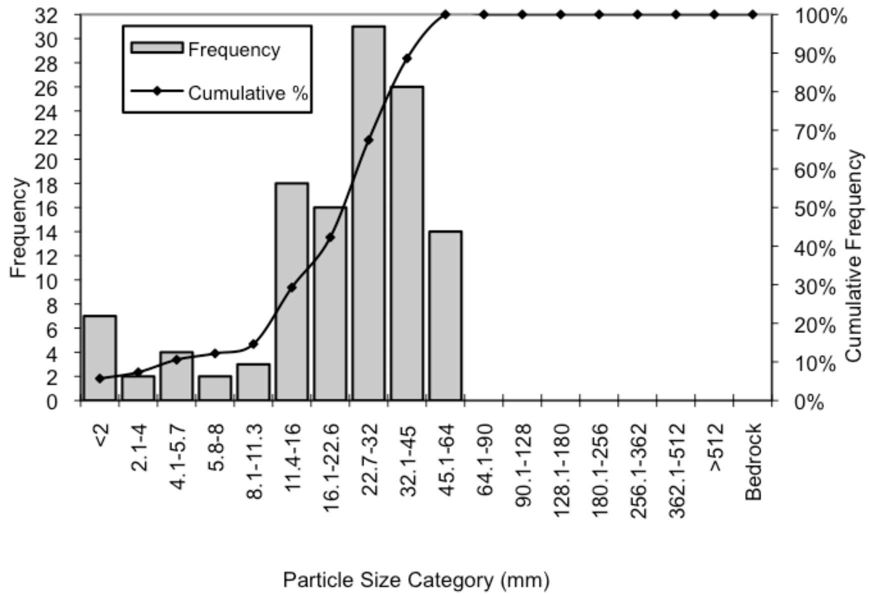
LWD quantities were moderate in Reach 10 compared to other reaches in the study area. LWD frequency was 101 pieces/mile, with "small" pieces comprising 50% of all LWD counted in the reach (Table 10). "Medium" and "large" wood pieces also comprised 50% of the LWD in the reach (29% and 21%, respectively). Reach 10 has a good short and long-term wood supply from the forested left-bank terrace and upstream sources (from both Nason Creek and Lake Wenatchee). Anthropogenic constraints (e.g. bridge, riprap, fill) along the right-bank from RM 52.4 to 53.6 limit lateral channel dynamics that would otherwise recruit wood. Beaver activity provides a limited amount of wood to the reach, particularly in off-channel areas.

Table 11. Large woody debris quantities in Reach 10.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Pieces	112	64	47	223
Number of Pieces/Mile	51	29	21	101

A-10.5 Substrate and Fine Sediment

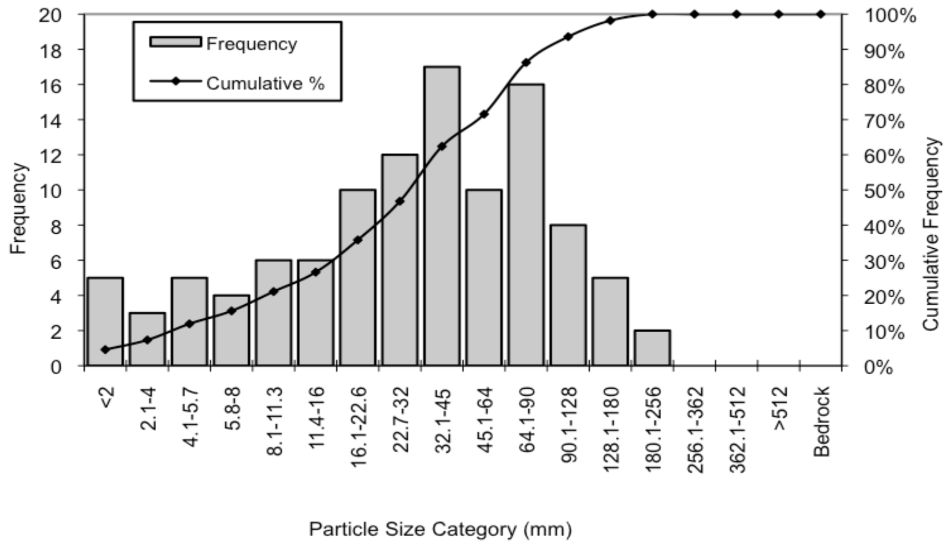
Bed substrate was dominated by cobbles. Gravels were subdominant. No bedrock was observed in Reach 10 and boulders made up no greater than 5% of the distribution. The percentage of fine sediment (<2mm) was relatively low, making up approximately 5-10% of the substrate distribution. The pebble count and size class data are depicted in Figure 112, Figure 113, and Figure 114.



Material	Percent Composition
Sand	6%
Gravel	94%
Cobble	0%
Boulder	0%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	<2
D16	12
D50	25
D84	42
D95	56

Figure 124. Grain size distribution and particle size classes from pebble count taken at RM 51.7.



Material	Percent Composition
Sand	5%
Gravel	67%
Cobble	28%
Boulder	0%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	2
D16	8
D50	35
D84	86
D95	144

Figure 125. Grain size distribution and particle size classes from pebble count taken at RM 53.1.

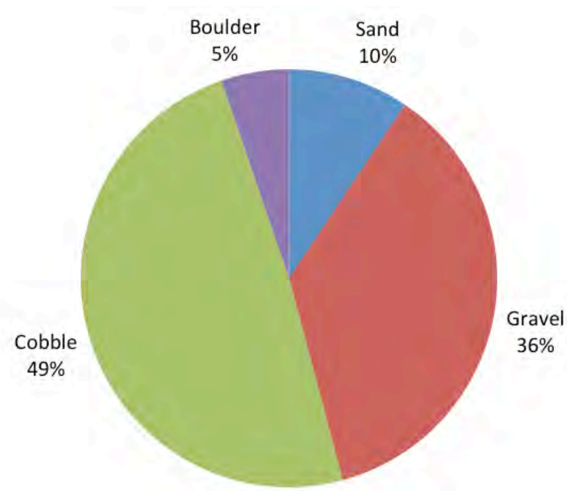


Figure 126. Percent composition of bed substrate based on ocular estimates, Reach 10.

A-10.6 Instability and Disturbance

Human activities have modified the channel, floodplain, and riparian corridor in Reach 10. Bank erosion was relatively high compared to other reaches in the study area. Reach 10 had a total of 4,866 feet of actively eroding streambank (measured above bankfull), consisting of 18% of the reach length along both banks.

Scattered development and human infrastructure has altered natural channel processes throughout the upper portion of Reach 10, especially from RM 52.6 to RM 53.7. This includes recreational access, houses, businesses, roadways (HWY 207), and bank armoring. Channel confinement and bank armoring is responsible for most of the disturbance in the upstream portion of Reach 10 (Figure 115).

Bank erosion was primarily associated with the moderately steep banked terraces bordering much of Reach 10 along river-left (Figure 116).

Figure 127. View looking upstream at a concrete retaining wall that borders a residential property along river-right near RM 53.1 (August 2011).

Figure 128. Bank erosion was primarily associated with moderately steep bank terraces along Reach 10 on river-left (August 2011).

A-10.7 Available Spawning and Rearing Habitat

There is spawning and rearing habitat available in Reach 10. The dominant substrate in riffles (derived from one representative pebble count) was gravel (81%) and subdominant was cobble (14%). Substrate within this reach was ideal size for steelhead (6-102 mm) and Chinook (13-102 mm). Pool quantity and residual pool depths are suitable for juvenile salmonid rearing. Reach 10 had a total of five pools, making up 57% of the total channel area, plus two additional off-channel units. Four pools (80% of reach total) had residual depths greater than 3 feet. LWD was limited, although there is potential for short and long term recruitment.

The side-channel directly downstream from the Nason Creek confluence provides suitable habitat for steelhead and coho spawning. Lower in Reach 10, spring Chinook were observed (August 10, 2011) holding in deeper riffle pockets, presumably waiting for stream flows to drop. Figure 117 shows riffle habitat representative of Reach 10.

Figure 129. Gravel was the dominant substrate found in spawning riffles throughout Reach 10 (August 2011).

A-10.8 Riparian Corridor

The width of the forested riparian buffer varied within Reach 10, especially along the right bank from RM 52.4 to RM 53.6. Residential development and road building throughout this portion has resulted in a fragmented riparian buffer with little understory vegetation.

The riparian zone along Reach 10 was dominated by large trees (75%) (Figure 118), primarily consisting of conifers (56% conifer; 38% hardwood, 6% no vegetation). Small trees were subdominant (19%). Ponderosa pine, cottonwood, willow, dogwood, and alder were the most prevalent species in the riparian zone. Side-channels and open water marshlands found in Reach 10 also had wetland vegetation that included cottonwood, willow, dogwood, spirea, carex, reed canary grass, and yellow pond lily.

The level of stream shade provided by the riparian canopy was low-to-moderate throughout Reach 10. Small trees and shrubs provided ample shading and refugia within the open water marshes and side-channels. Large ponderosa pines only provided morning and afternoon shade along portions of the main channel.

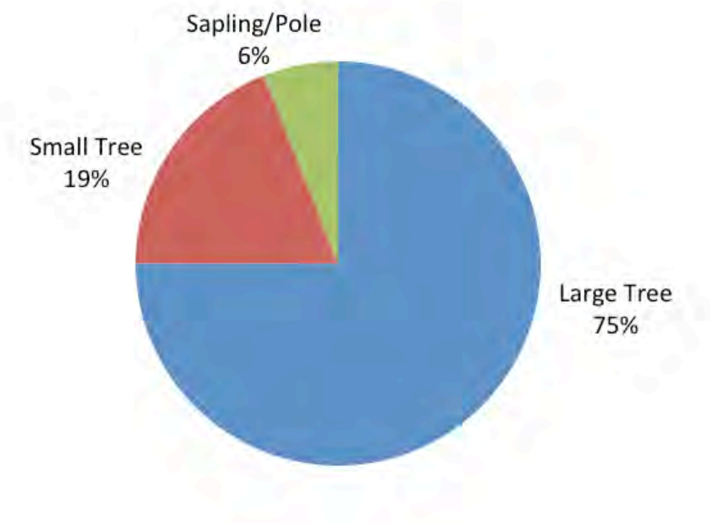


Figure 130. Distribution of the dominant size class category for the riparian zone, Reach 10.

A-11 Reach 11

Location: River mile 53.67 to 54.15

Survey Date: August 9, 2011

Survey Crew: Christa Strickwerda Heller and Adrianne Zuckerman (Inter-Fluve)

A-11.1 Reach Overview

Reach 11 is the upstream-most reach of the mainstem Wenatchee River. This short reach is located between the confluence of Nason Creek (RM 53.7) and the outlet of Lake Wenatchee (RM 54.15). Reach 11 has a mix of lacustrine and riverine geomorphology (Figure 119). The slope of the channel is < 0.10%. Channel form is almost straight and bed morphology is plane-bed glide with limited complexity. The upper 0.5 miles is confined within steep banked terraces and the lower 0.1 miles is influenced by sediment and discharge from Nason Creek.

The Lake Wenatchee State Park sits at the headwaters of the Wenatchee River along river-right. The Park uses include both summer and winter recreation activities, including cross-country skiing, camping, fishing, boating, and swimming. In the early 1900s, the State Park had been the site of the Lake Wenatchee Mill. Evidence of past logging practices remains today. See Figure 120 for a reach overview and habitat unit map.

Figure 131. View looking upstream towards Lake Wenatchee and the plane-bed channel of Reach 11 (August 2011).

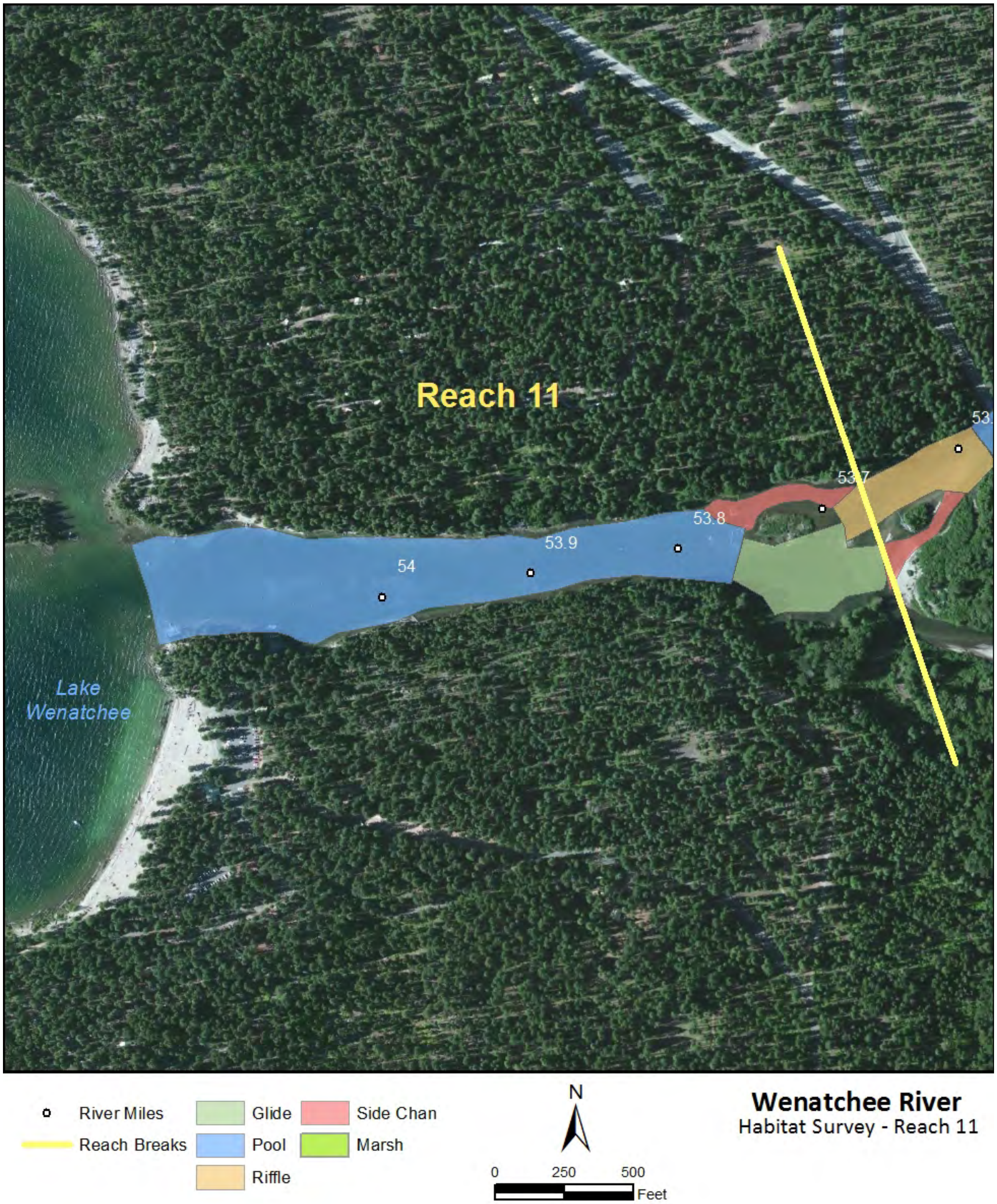


Figure 132. Reach 11 locator and habitat unit composition map.

A-11.2 Habitat Unit Composition

Reach 11 was the shortest reach in the Upper Wenatchee study area, measuring just 0.48 miles in length. This reach consisted of only 3 habitat units and was composed of 77% pool, 18% glide, and 5% side-channel habitat (Figure 121 and Figure 122). Pool frequency was 2.0 pools/mile, with mean pool spacing of 8.0 channel widths per pool. Average pool depth was 8.0 feet and maximum pool depth was 12.0 feet.

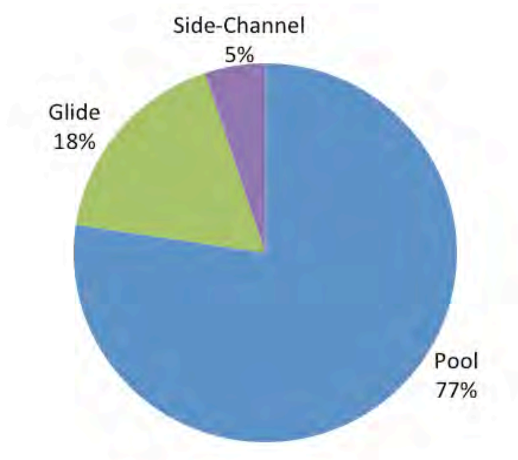


Figure 133. Habitat unit composition, Reach 11.

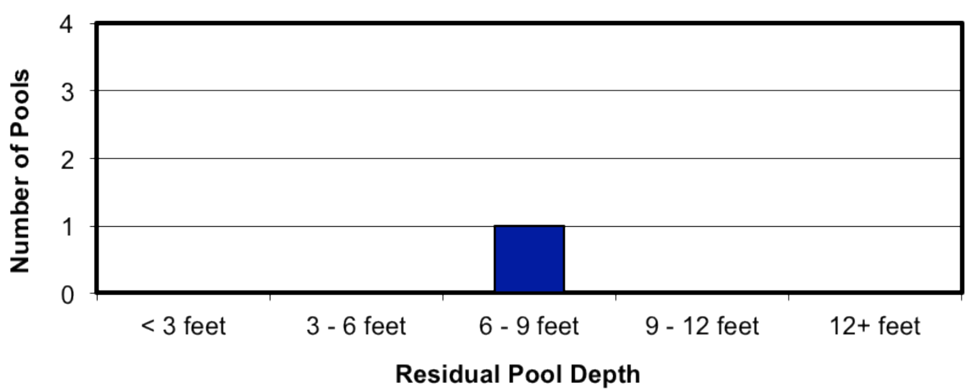


Figure 134. Reach 11 residual pool depth.

A-11.3 Off-Channel Habitat

There was one side-channel in Reach 11. It was relatively short, shallow, and faster than the main channel glide (Figure 123). Old pilings, which are potentially remnants of past log-driving activities, remained embedded in the channel along the left bank. Lateral margins of the channel offer shallow water refuge along the frequently inundated and vegetated sloping streambank. A small backwater area, located approximately 130 feet upstream of the Nason Creek confluence, receives surface water from Nason Creek in addition to hyporheic flow from both the Wenatchee River and Nason Creek.

Figure 135. Side-channel habitat during moderate summer stream flow, Reach 11 (August 2011).

A-11.4 Large Woody Debris

LWD frequency was high in Reach 11, having the third highest wood count per mile within the upper Wenatchee study area. There were many submerged cut logs throughout the upper 0.4 miles of the reach, possibly remnants from historical logging operations. LWD frequency was 242 pieces/mile, with "small" pieces comprising 52% of all LWD counted in the reach (Table 11). "Medium" and "Large" wood pieces comprised 48% of LWD in the reach (32% and 16%, respectively). Reach 11 has high LWD recruitment potential from upstream sources, which includes drift from Lake Wenatchee and streams higher in the basin (Figure 124). High winds funnel into the upper reach that may aid in LWD recruitment. In contrast, near-term LWD recruitment potential is low due to a lack of large, mature trees in the riparian area. Only a few snags were observed along the left bank.

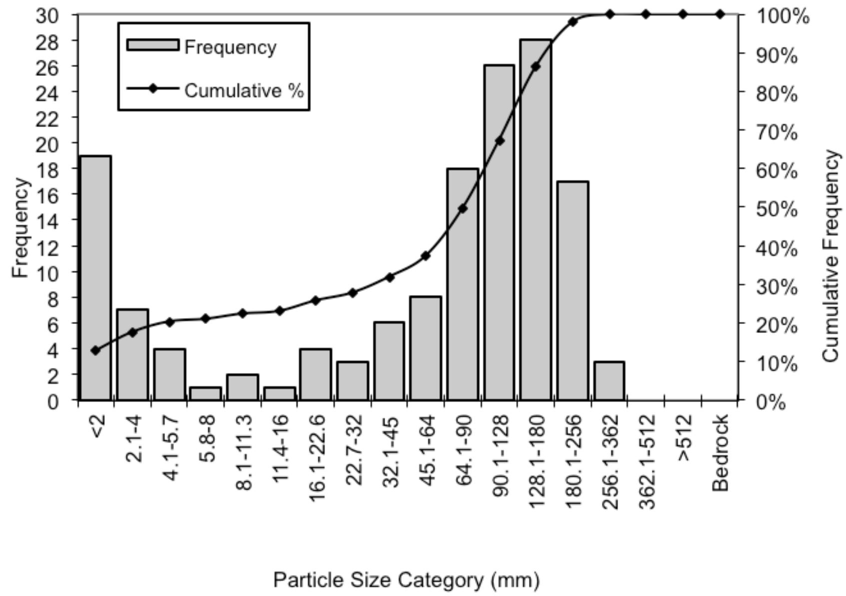
Table 12. Large woody debris quantities in Reach 11.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of Pieces	63	38	19	120
Number of Pieces/Mile	127	77	38	242

Figure 136. Pool habitat in Reach 11 has accumulated moderate quantities of large wood along river-right (August 2011).

A-11.5 Substrate and Fine Sediment

Bed substrate was dominated by cobbles; boulders were subdominant (20%). Sand and gravel both made up 10% of the distribution. No bedrock was observed in Reach 11. The pebble count was unable to be collected in a riffle unit, as Reach 11 is void of this habitat type; therefore the pebble count was collected at the upstream end of a glide. Pebble count data were consistent with the ocular estimates for substrate composition with the exception of boulders. The pebble count and size class data are depicted in Figure 125 and Figure 126.



Material	Percent Composition
Sand	13%
Gravel	24%
Cobble	61%
Boulder	2%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	<2
D16	3
D50	91
D84	173
D95	237

Figure 137. Grain size distribution and particle size classes from pebble count taken at RM 53.8.

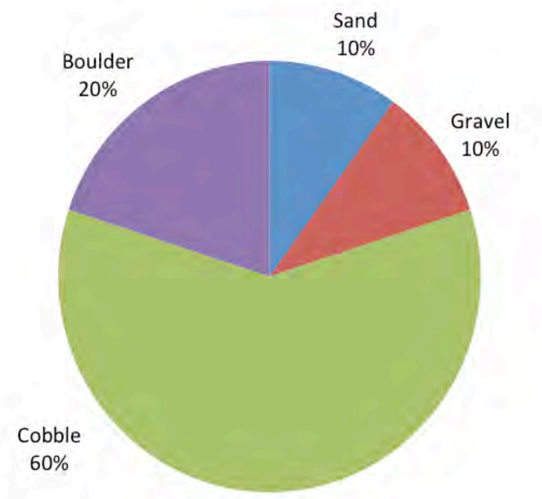


Figure 138. Percent composition of bed substrate based on ocular estimates, Reach 11.

A-11.6 Instability and Disturbance

Remnant concrete pilings are located in the upper portion of this reach along both banks (Figure 127). At the upstream end on river-right, small trails and river access associated with the State Park limit understory growth.

Figure 139. Remnant concrete pilings on river-left, Reach 11 (August 2011).

A-11.7 Available Spawning and Rearing Habitat

The slow, lacustrine nature of this reach provides minimal spawning habitat. Spawning is unlikely to occur in the cobble dominant (60%) side-channel. Many large cobbles and boulders (> 128 mm) were also present, which is not ideal substrate for Chinook (13-102 mm) or steelhead spawning (6-102 mm). Reach 11 had one pool (77% of reach total area) with a residual depth greater than 3 feet, which provides adequate rearing habitat for juvenile salmonids.

Adult sockeye use this reach as a migration corridor and holding area prior to accessing the spawning beaches and tributaries of Lake Wenatchee.

A-11.8 Riparian Corridor

The width of the forested riparian buffer was fairly consistent throughout Reach 11. The riparian buffer was dominated by small trees (dominant within 100% of units), with the overstory comprised nearly entirely of conifers (100% of units). Douglas fir, ponderosa pine, willow, and alder were the most prevalent species in the riparian zone. Rushes and other frequently inundated grasses were growing throughout the lateral margins of the upper reach.

The level of stream shade provided by the riparian canopy was low throughout Reach 11. Douglas fir and ponderosa pine provide limited morning and afternoon shade along the main channel.

APPENDIX B: SUB-UNIT MAPPING AND GEOMORPHOLOGY

1 INTRODUCTION

This appendix provides sub-unit mapping and geomorphic characterization at the sub-unit scale. Sub-units are finer-scale units than reaches and are comprised of individual geomorphic features such as a distinct floodplain surface or a specific segment of active channel. Mapping and describing conditions at this scale helps to further characterize the underlying geomorphic processes and the effects of human alterations on physical processes and habitat. Each sub-unit was mapped in the field and geomorphic conditions were characterized using field observations and remote sensing data sources (e.g. LiDAR and aerial photos). Each sub-unit was given a designation of "connected" or "disconnected" depending on the degree to which human alterations have disrupted the natural physical processes (e.g. channel migration or floodplain inundation) operating on the sub-unit. This information is used to help ensure that appropriate restoration projects are developed that fit within the proper geomorphic context of the reach.

2 METHODS

These methods generally follow the procedures established by the US Bureau of Reclamation in mapping sub-units as part of USBR Reach Assessments in the Upper Columbia Basin (e.g. USBR 2009).

There are two general types of sub-units – "inner zone" (IZ) sub-units and "outer zone" (OZ) sub-units. The IZ is defined as the active channel, which is the wetted low-flow channel and all related areas that annually experience ground-disturbing flow (i.e. including secondary channels and active bars). Boundaries between IZ sub-units were delineated using breaks in geomorphic control such as bedrock constrictions, changes in geomorphic patters (e.g. step-pool to riffle-run), or anthropogenic alterations that resulted in variations in channel pattern and channel type.

Outer zone units are within the floodplain, which is defined as the area that may become inundated at higher flows and is at a surface elevation equivalent to what would be the active channel migration zone in the absence of human alteration. The OZ frequently includes scoured flood overflow channels and floodplain wetlands. The OZ was identified via observation of flood deposits, the presence of relic channel scars and features, surface elevations in relation to the channel, and riparian vegetation. Boundaries between OZ sub-units were delineated based on natural breaks, confining geologic features (e.g. bedrock, valley wall), variation in the dominant ecology, or anthropogenic barriers.

Inner and outer zones were further designated as "connected" or "disconnected". A disconnected zone is denoted with a "D" before the IZ or OZ identifier. A designation of "disconnected" indicates that a zone's historical pattern and processes have been significantly altered due to anthropogenic alterations. Inner and outer zones may become disconnected through channel or floodplain manipulations including straightening, ditching, filling, and riprap; and through construction of levees, road embankments, or bridges. In addition, OZs may be disconnected via indirect alterations that affect channel migration and flood inundation processes. These may include upstream or downstream bridge crossings that limit channel migration or land-use induced channel incision that reduces the extent of floodplain inundation. Note that to receive a designation of "disconnected" does not necessarily mean that the entire floodplain unit is cut-off from floodplain inundation or channel migration, but it does indicate significant deviation from the natural function that would be expected in the absence of human alteration.

3 RESULTS

The sub-unit maps and descriptions are provided below by reach. Sub-units are numbered in the downstream direction. Thus, the furthest upstream sub-units are presented first and subsequent summaries proceed in the downstream direction within a given reach. Each sub-unit summary includes a description of geomorphic conditions and effects of human alteration. Notes on potential restoration constraints are also included.

3.1 REACH ONE

Sub-Unit	Description	Potential Constraints
1-IZ-02	RM 35.9-37.57: This braided riffle-pool unit contains well vegetated island OZ units associated with complex secondary channels. The pools are deep and the riffles (point and mid-channel) are complex and often transverse. LWD (large woody debris) accumulations are found on both bar and island features. The channel has a substrate of sands to cobbles. This is an aggrading section. The channel and its floodplain are semi-confined within steep sedimentary conglomerate hillslopes on both river-left (RL) and river-right (RR). Except for the straight upper RM 0.2 the channel form is moderately sinuous. An eddy cove at RM 36.65 on RR is ~3m deep with sands and gravel substrate and buried LWD. The eddy cove has steep high banks of hard sedimentary conglomerate rock and is at the mouth of a tributary outlet. Very good backwater habitat is provided during lower flows in a high-flow secondary channel behind a developing bar at RM 37.4-37.57. There is potential for the backwater feature to be lost due to natural aggradational processes. There is no bank hardening materials or human built features directly influencing this subunit. The majority of the channel banks are relatively low, composed of sands to cobbles and well vegetated.	US Forest Service managed property; FS primitive road access near RR, no road access on RL.
1-IZ-02	RM 37.05: This is an extended backwater on RL with its inlet located at the downstream end of 1-OZ-01. This unit is wide and deep enough to navigate by paddle boat but LWD inputs from beaver activity create navigation obstacles. This backwater IZ unit is connected to an upstream sequence of wetted abandoned channel scars. It is well vegetated with spirea, dogwood, alder, sedges and rush. The mouth of the blackwater is ~ 15m wide and currently maintained by a well-established secondary channel pool at the meander bend.	none
1-IZ-03	RM 35.51-35.9: This braided riffle-pool unit contains complex riffles (point and mid-channel) that are often transverse. At the upstream boundary of the unit is the confluence with Chiwaukum Creek on RR. An accumulation of cobbles and boulders on both RR and RL deposited by a historic flood wash from the creek act as an influence on channel morphology and sediment source. The channel has a substrate of sands to cobbles and some small boulders. This is an aggrading section with moderate sinuosity and no floodplain units. The channel is confined within a high alluvial terrace on RR and a sedimentary conglomerate hillslopes on RL. The downstream boundary of the unit is delineated by the Hwy 2 bridge crossing located at the up-stream most portion of Tumwater Canyon. The highway bridge, large boulder riprap and current construction of a massive culvert near the bridge and Tumwater Campground could have immediate or unknown impact to the geomorphology of the channel in Reach 1.	none
1-OZ-01	RM 37.05-37.57: This is the downstream portion of a wide connected floodplain unit on RL (02-OZ-03). It is composed of cobbles at the base and topped with sands. The surface is low with thick practically impenetrable vegetation (spirea, dogwood, alder, willow and cottonwood). A series of overbank flow channels and abandoned channels scar the surface creating wetted off-channel habitat. A navigable backwater (1-IZ-02) borders the inland side of this unit and connects to the surface waters of the upstream portion of	US Forest Service managed property; no road access on RL.

	this unit located in Reach 2. The backwater appears to receive seasonal surface water inputs from the adjacent hillslope as well as some hyporheic flow through the floodplain.	
1-OZ-02	RM 37.03-37.2: This is a mid-channel island OZ unit. It is a low well vegetated surface composed of large cobbles to sands. A mix of mature well-established trees and shrubs populate its surface. LWD jams accumulate at it apex. A complex set of developing bars with some riparian shrub vegetation (primarily willow) and LWD are present both up and downstream from the island.	none
1-OZ-03	RM 36.7-37: This low elevation floodplain surface on RR is well vegetated. It is composed of cobbles at the base and topped with sands. Wood accumulations are present along the banks and on the attached bars associated with this unit. Wetted off-channel habitat exists at mid-unit in an abandoned secondary channel scar. An outlet at RM 36.8 that connects the wetted area to the main channel is mostly dry, sandy, and vegetated.	US Forest Service managed; good access on primitive FS road with a cleared landing directly above site.
1-OZ-04	RM 36.48-36.75: This is a large mid-channel island OZ unit. It is a low well vegetated surface composed of large cobbles to sands and banks are low but vertical. A mix of mature well-established trees and shrubs populate its surface. Log jams accumulate at it apex. The island is developing in a downstream direction with a lower scoured bar surface extending at its toe. The bar extension is vegetated with riparian vegetation but show evidence of regular scour and deposition.	none
1-OZ-05	RM 36.06-36.4: This RL floodplain surface is low with practically impenetrable vegetation on its banks and surface (difficult to access from the channel). There was no visible recent scour or deposits on the surface but localized accumulations of LWD are present on the banks. There are no attached bar associated with this unit.	none
1-OZ-06	RM 36-36.3: This is an island OZ unit near RR. It is a low floodplain with practically impenetrable vegetation on its banks and surfaces. It is composed of large cobbles to sands and banks are low but vertical. A mix of mature well-established trees and shrubs populate its surface. A massive log jam is accumulating at it apex. The log jam has blocked off flow in the secondary channel on RR of the island. This is creating an elongate backwater that extends the length of the island. The backwater/secondary channel is experiencing depositional infilling, wood inputs (some beaver inspired) and other vegetation encroachment. Bar development at the upstream and downstream end of the island add to the features complexity	none
1-OZ-07	RM 35.9-36.25: This is a thin elongate surface on RR behind the island 1-OZ-06 floodplain. It is a very low well-vegetated surface. It is separated from the island and dissected by narrow secondary channel flow. Large wood from the channel and beaver activity creates complex habitat in this unit that is connected to the main channel at the downstream end.	none

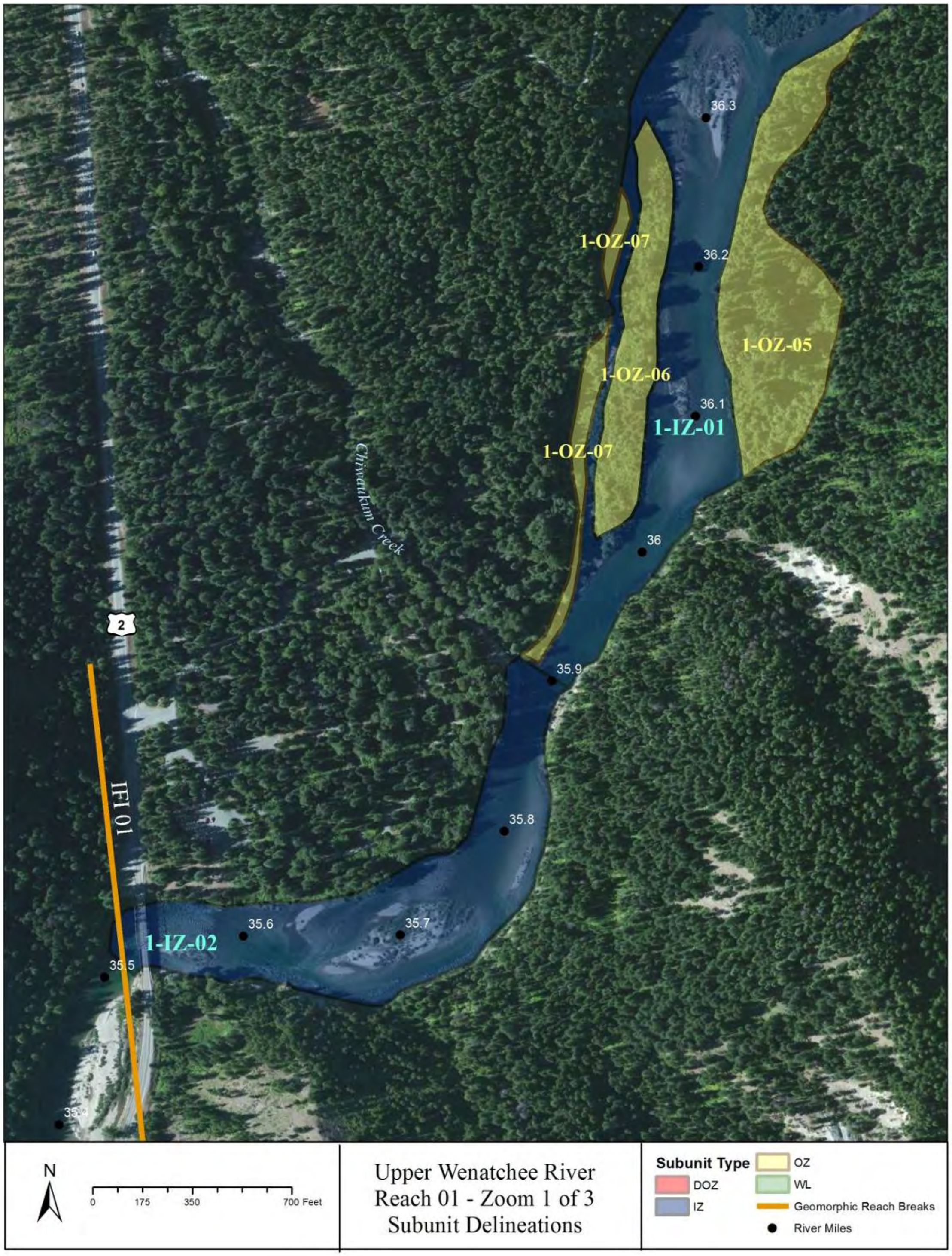


Figure 1. Subunit delineations for the downstream most portion of Reach 1. Flow is from north to south.

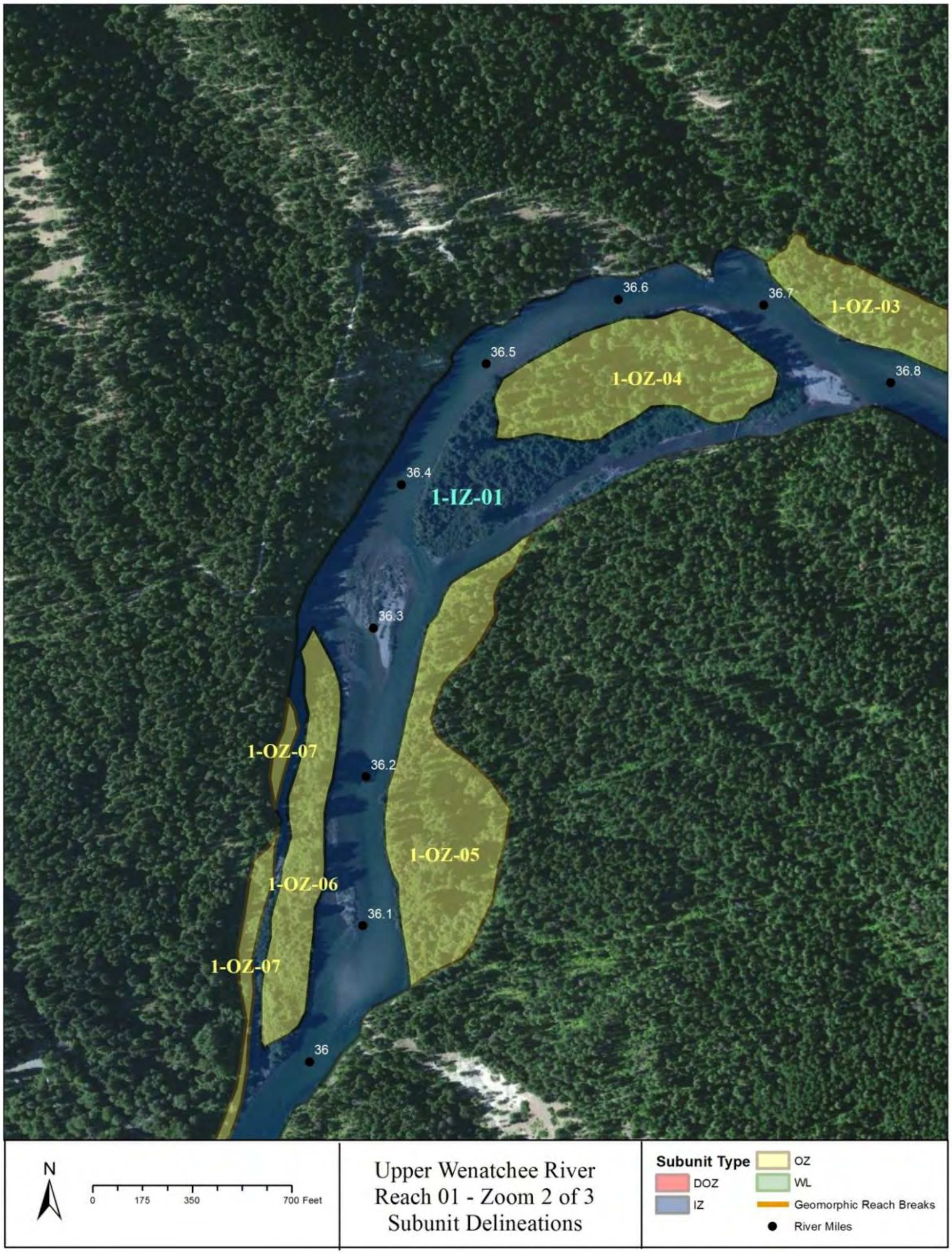


Figure 2. Subunit delineations for Reach 1. Flow is from north to south.

Figure 3. Subunit delineations for the upstream most portion of Reach 1. Flow is from north to south.

3.2 REACH TWO

Sub-Unit	Description	Potential Constraints
2-IZ-01	RM 37.57-38.61: This riffle-glide sequence extends the entirety of Reach 2. The glides are not shallow (pool-like), less deep than the pools of Reach 3 but extended with minimal bed topography. The channel has a substrate of sands to cobbles. Some large boulders from the RL hillslope are found in the channel in the upper 0.2 miles. Large side-attached bars are present, but the braiding of Reach 3 is gone. The active channel width (IZ zone) is reduced compared to Reach 3. In the upper 0.2 miles of Reach 2 the channel is slightly confined between a historic alluvial terrace (RR) and a sedimentary conglomerate hillslope (RL). Downstream the floodplain widens but the channel remains confined to the right side of the valley where it borders a hillslope of sedimentary conglomerate rock on RR. Here the active IZ zone is straight and appears to be incising slightly. There is no bank hardening materials or human built features directly impacting this Reach. A sequence of alternating aggradational and degradational is occurring between Reaches 1-3 with minor degradation currently occurring in Reach 2. The majority of the channel banks are relatively low, composed of sands to cobbles and well vegetated.	US Forest Service managed property; FS primitive road access near RR, no road access on RL.
2-OZ-01	RM 38.22-38.47: This is a low elevation well-vegetated floodplain unit on RR. It is composed of sands to cobbles with very gradually sloping banks on the upstream end. The inland side of the unit is bordered by stair-step of historic alluvial terraces on the upstream end and a hillslope of sedimentary conglomerate on the downstream end. The surface is well vegetated with a mix of trees and shrubs (alder, hawthorne, spirea, snowberry, aspen, and cottonwood). A channel margin backwater heavily vegetated with dogwood exists along the back of the unit on the downstream end. Some wood is naturally accumulating near the backwater inlet where it connects to the main channel (RM 38.21).	US Forest Service managed property; easy FS primitive road access.
2-OZ-02	RM 38.2-38.32: This is a small OZ floodplain unit on RL that is inset within abandoned alluvial terraces. It is a margin OZ unit with a slightly higher surface containing mixed transitional vegetation of conifers (5-50 years old), Oregon grape, spirea, grasses, and lupin. Evidence of rare but recent floodwater inundation is noted as thin sand deposits on the surface.	none
2-OZ-03	RM 37.57-38.12: This is an extensive floodplain unit on RL of cobbles at the base and topped with sands. The surface is low and well vegetated throughout. On the downstream end vegetation along the banks is practically impenetrable. A series of overbank flow scars and abandoned channels scar the surface. The most prominent channel scars are wetted off-channel habitat that runs the inland perimeter of the unit at the upstream end between RM 37.7-38. At RM 37.57-37.7 it meanders into the middle of the unit. The wetted areas range in width from ~ 2-10m wide with a 30m diameter wetland pool at 37.57. This series of wetted abandoned channels are silting in and discontinuous in the upstream portion. They appear to receive seasonal surface water inputs from the adjacent hillslope as well as some hyporheic flow. The surface water in the wetted areas is connected to the floodplain unit directly downstream in Reach 1 (1-OZ-01) which eventually	US Forest Service managed; no road access on the left side of the channel (primitive road on RR but channel crossing could be challenging and damaging).

	connects to the mainstem channel. See survey map for excavation options	
2-OZ-04	RM 37.57-37.7: This is a very small elongate floodplain unit on RR. It is a low elevation surface that is well vegetated with mixed trees and riparian shrubs. A developing cobble-gravel bar is attached to the length of the unit. Vegetation (willow) is beginning to establish on the bar upstream of the unit and some wood is accumulating on the downstream banks.	none
2-DOZ-01	RM 38-38.15: This vegetated surface is located on RL directly upstream of 2-OZ-04. The boundary between these two units is gradual. Vegetation on the DOZ is less dense and dominated by conifers and ferns. Downstream transverse migrating scroll bars are visible on the surface of the DOZ. The maturity of the vegetation on the scrolls increases in an upstream pattern (historic channel migration and modern incision). DOZ designation has been given to this unit because there is no evidence of modern (50+ years) inundation. A gravel-cobble point bar is developing in front of this unit with some accumulated large wood and a high-water scour channel along the bank of the DOZ. This unit is composed of cobbles-sands. The inland side is bordered by a slightly higher and older alluvial terrace.	none

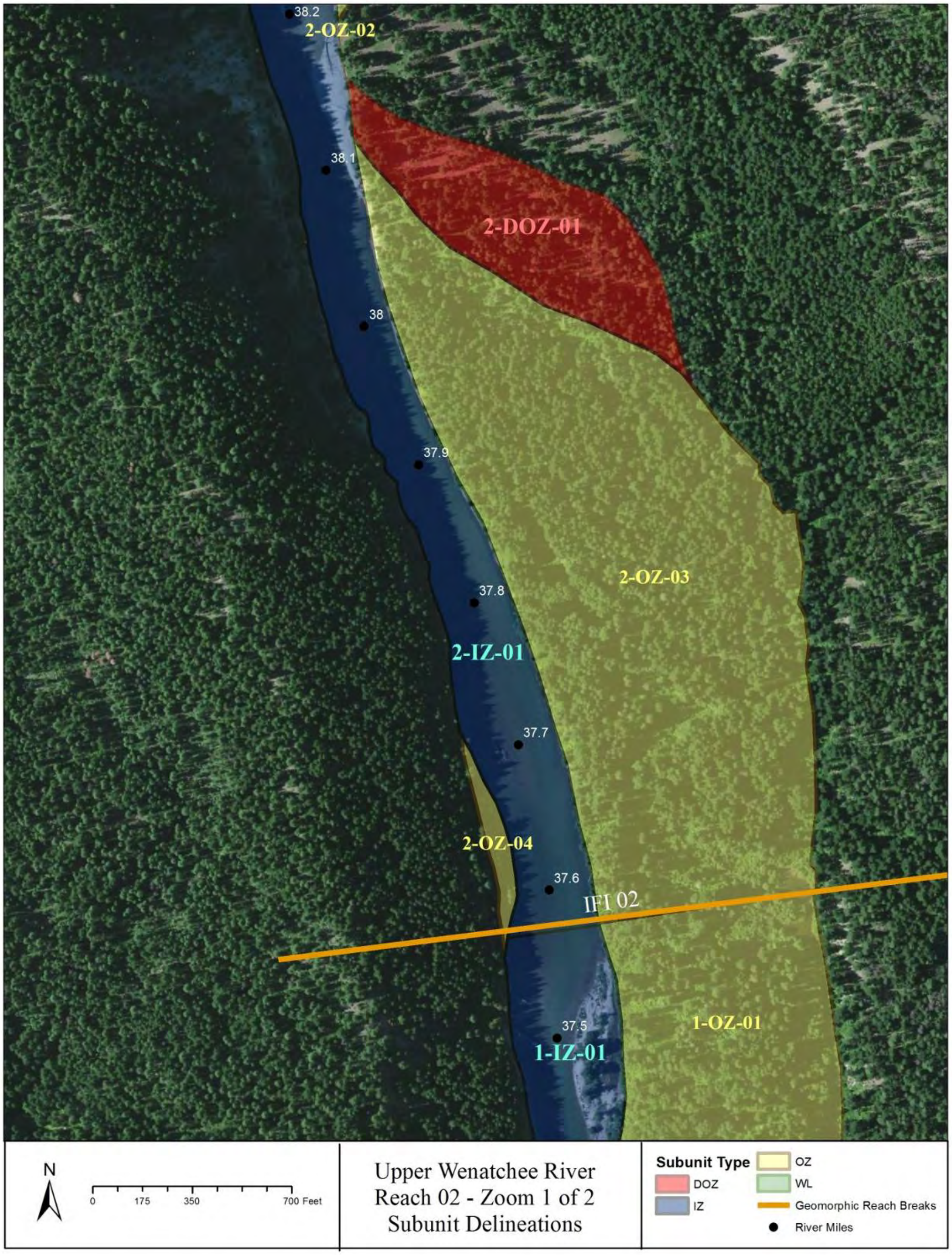


Figure 4. Subunit delineations for the downstream portion of Reach 2. Flow is from north to south.

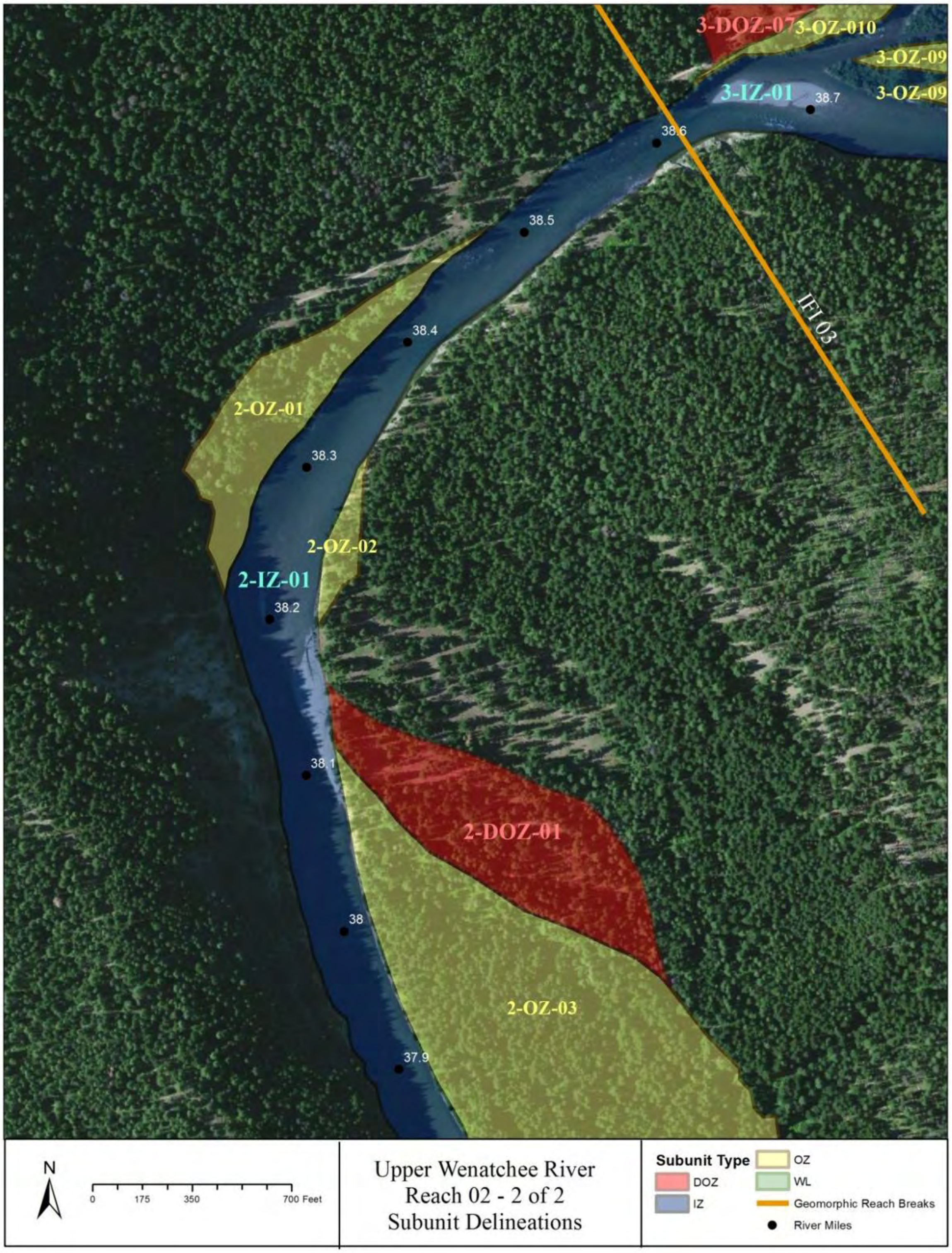


Figure 5. Subunit delineations for the upstream portion of Reach 2. Flow is from north to south

3.3 REACH THREE

Sub-Unit	Description	Potential Constraints
3-IZ-01	RM 38.61-41.9: This riffle-pool sequence extends the entirety of Reach 3. It has a substrate of sands to large cobbles with sparse boulders. Good island and bar development associated with wood accumulations enhance the IZ's geomorphic complexity. Large transverse mid-channel bar features are prominent in the upper half of the reach and the addition of vegetated islands shift the lower half of the reach into a partially braided riffle-pool sequence. The islands and mid-channel bars are composed primarily of cobble to sands. Flow velocity is increased relative to Reach 4. The highest flow velocity section of the Upper Wenatchee River is between RM 40.4-41.7. Localized velocity increases are associated with increased gradients. Except for the upstream-most one river mile (RM 40.9-41.9) this is an aggrading reach. The upper one mile is transitional with evidence of minor incision noted by a small neck cut-off (3-OZ-01) and abandoned alluvial terraces (3-DOZ-03; 3-DOZ-04) with steeply sloping banks. The channel banks in the rest of the reach are composed of sands to cobbles, are relatively low, connected and gradually sloping. Where banks are not hardened by riprap this is a laterally active reach.	Large boulder riprap and spurs are protecting or deflecting flow at privately owned residential areas; access downstream of RM 39.3 is by primitive road on RR only; RR upstream of RM 39.3 is privately owned; no current RL road access at RM 38.61-41.6.
3-OZ-01	RM 41.2-41.6: This floodplain unit on RL has moderately sloping banks (cobbles to sands). The surface is well vegetated with a mix of trees and shrubs (alder, hawthorne, spirea, snowberry, aspen, and cottonwood). The upper portion of the unit (RM 41.45-41.6) is a cut-off meander that curves behind a DOZ. Here the FP unit contains a wetted abandoned channel depression. Due to modern main-channel deposition the upstream inlet is not visible while the downstream outlet is wetted. The main channel here has enough gradient to support side/secondary channel reactivation in the abandoned channel scar. The secondary channel could be designed specifically for spawning habitat.	Land is private; nearest access at upstream end of unit appears to be privately owned secondary road.
3-OZ-02	RM 40.55-41.14: This unit widens in a downstream direction. The downstream OZ-IZ boundary is a set of whale-back transverse bars vegetated with successional vegetation and evidence of modern scour and deposition (including rafted wood). The transverse bars indicate a natural lateral/downstream channel migration pattern here. The unit is a low well vegetated surface composed of large cobbles to sands. A narrow wetted backwater extends from the downstream end inland between historic scroll bars. Highwater or hyporheic flow feeds these poorly developed moist low areas that are gradually filling. There is no evidence of modern human alterations. The inland boundary borders a hillslope of historic sedimentary deposits (Chumsitck Formation)	none
3-OZ-03	RM 40.8-40.93: Located on RR this unit is at the downstream end of a larger floodplain unit designated as a DOZ due to human alterations. This portion of the low-elevation floodplain is well-vegetated with mixed riparian trees and shrubs (ie. cottonwood, alder, aspen, vine maple, spirea, rose). Fresh scour and deposition,	Privately owned but road access is relatively close.

	including rafted wood, indicates inundation. Overbank and hyproeic flow converge into a narrow wetted channel at the downstream most side. Its outlet feeds a small secondary channel that borders 3-OZ-03. The secondary channel is separated from the main channel by a large cobble bar that is vegetated with willow and other riparian vegetation.	
3-OZ-04	RM 39.64-40.23: This unit widens in a downstream direction and has LW accumulating on the banks in the upper portion. The surface is a set of well vegetated transverse scrolls (mixed conifers and deciduous trees). Between the scrolls are areas of scour and deposition vegetated with riparian species. The transverse bars indicate a natural downstream channel migration pattern. The unit is a low well vegetated surface composed of large cobbles to sands. A wide backwater (~ 50cm deep) that extends into the unit is fed with cool hyporheic flow. It maintains connectivity at the downstream end of the unit where its outlet connects to a secondary channel that extends behind an island (3-OZ-05). There is no evidence of modern human alterations. The inland boundary borders a hillslope of historic sedimentary deposits (Chumstick Formation)	none
3-OZ-05	RM 39.6-39.7: This is an island OZ near RL. It is a low well vegetated surface composed of large cobbles to sands. A mix of established trees and shrubs populate its surface. Log jams accumulate at it apex. Transverse riffles are present both up and downstream from the island and a secondary channel flows on RL of it. The secondary channel offers geomorphic complexity.	none
3-OZ-06	39.24-39.57: Located on RR this unit is at the downstream end of a larger floodplain unit designated as a DOZ due to human alterations. This portion of the low-elevation floodplain is well-vegetated with mixed riparian vegetation. A wetland prairie habitat exists in the downstream portion. Fresh scour and deposition, including rafted wood and silts, indicates inundation. Overbank and hyporheic flow converge into a set of wetted channels that flow into/through the wetland. Its outlet feeds a low-flow secondary channel behind a large cobble-gravel bar in the main channel.	Properties are privately owned and occupied – wetland owner is pro-project
3-OZ-07	38.92-39.54: This unit widens in a downstream direction and has LW accumulating on the banks in the upper portion. The unit is a low well vegetated surface composed of large cobbles to sands. It is a downstream migrating transverse bar similar to 3-OZ-04 and 02. A secondary channel separates this unit at the downstream end from an established island unit (3-OZ-08). A powerline corridor crosses over this unit at RM 39.22 but no other evidence of modern human alterations is visible. The inland boundary borders a hillslope of historic sedimentary deposits (Chumsitck Formation)	none
3-OZ-08	RM 38.94-38.99: This is an island OZ near RL. It is a low well vegetated surface composed of large cobbles to sands. A mix of established trees and shrubs populate its surface. Log jams accumulate at it apex creating a small transverse riffle that feeds a secondary channel on RL of it. The secondary channel offers geomorphic complexity and habitat but is currently infilling.	US Forest Service approval for excavation; no current road access, closest road is a primitive dirt track across the river.
3-OZ-09	RM 38.7-38.96: This is a large mid-channel island OZ. It is a low well vegetated surface composed of large cobbles to sands. A mix of established trees and shrubs populate its surface. Log jams accumulate at it apex	none

	and at/near its banks on RR. The large wood creates bars and transverse riffle that feeds the secondary channel on RR of the island.	
3-OZ-10	RM 38.64-39.09: This elongate low-elevation floodplain surface is well vegetated with mixed trees and shrubs. Its inland side (3-DOZ- 07) has been disconnected from river processes by a US Forest Service road with a raised dirt berm that runs parallel to the river. The road crosses a tributary inlet at the downstream-most end of the unit. Pool scouring below the culvert and incision above it reduce tributary function for the system. The inland boundary is an historic alluvial terrace.	Berm protects US Forest Service maintenance road; access to road is through private property.
3-DOZ-01	RM 42.57-43.12: This low-elevation well-vegetated floodplain surface located on RL has been significantly altered by development. DOZ designation has been given to this unit as a result of railroad construction (fill and trusses) that border the upstream end, minor vegetation removal/alteration and home-site construction. This unit experiences some inundation during seasonal high-flow/flood events. The inland side is bordered by a slightly higher alluvial terrace that is more extensively developed. Topography suggests that this unit was historically connected to 4-DOZ-03 and, that combined, they were the point bar to the higher inland terrace.	Properties are privately owned and occupied; Railroad is in use.
3-DOZ-02	RM 40-92-41.81: This relatively low-elevation floodplain surface located on RR has been significantly altered by development. DOZ designation is based on road dissection, vegetation removal/alteration, home-site construction and extensive bank hardening. Large boulder riprap, cement retaining walls and levees form a continuously hardened bank along the upper-most portion from RM 41.53-41.81. Smaller sections of similar material are found on the banks between RM 41.1-41.2. Where bank hardening materials do not exist this unit experiences minor inundation during seasonal high-flow/flood events. The inland side is bordered by a slightly higher alluvial terrace that is also developed. Topography suggests that this unit was historically the point bar to the higher terrace.	Properties are privately owned and occupied; bank hardening materials is currently protecting occupied properties.
3-DOZ-03	RM 41.48-41.57: This floodplain surface on RL is rarely inundated (perhaps due to incision related to neck cut-off). Currently vegetated with pines and scrub brush. Composed of cobbles at base and topped with sands. Pine trees on and near the bank are a good source of LWD for the system	Properties are privately owned and no current road access is developed directly to this unit.
3-DOZ-04	RM 41.14-41.3: This is a partially abandoned alluvial terrace on RL that is rarely inundated. It is well-vegetated with a mix of conifers and deciduous trees & shrubs. Banks are composed of cobbles at base and topped with sands. A developing bar connected to this unit provides backwater habitat during low-flow periods in a scour channel at the base of this units banks. The bar is vegetated with willow, alder, cottonwood, and reed canary grass. Beaver activity is visible and a log jam is located at the upstream side. At low-flow there is no visible surface water but remainder of scour channel is wetted	Properties are privately owned and no current road access is developed directly to this unit.
3-DOZ-05	RM 39.91-40.62: This relatively low-elevation floodplain surface located on RR has been significantly altered by development. DOZ designation is based on road dissection, vegetation removal/alteration, home-site	Properties are privately owned and

	construction and the extent of bank hardening materials. Large boulder riprap and spurs exist along the banks at RM 40.25-40.3 and 40.49-40.62. The downstream portion of this unit experiences minor inundation during seasonal high-flow/flood events.	occupied.
3-DOZ-06	RM 39.4-39.87: This relatively low-elevation floodplain surface located on RR has been significantly altered by development. DOZ designation is based on road dissection, vegetation removal/alteration, home-site construction and the extent of bank hardening materials. Large boulder riprap and spurs exist along the banks at RM 39.55-39.7, 39.75 and 39.8-39.82.	Properties are privately owned and occupied.
3-DOZ-07	RM 41.9-42.27: This unit has been disconnected from the active floodplain (3-OZ-10) behind a graded road and berm. It is a thin elongate strip of relatively low-elevation floodplain surface. It appears to have been logged or thinned but does have a mix of deciduous and conifer trees and shrubs. The road is a primitive USFS access road	Road is a USFS access road .

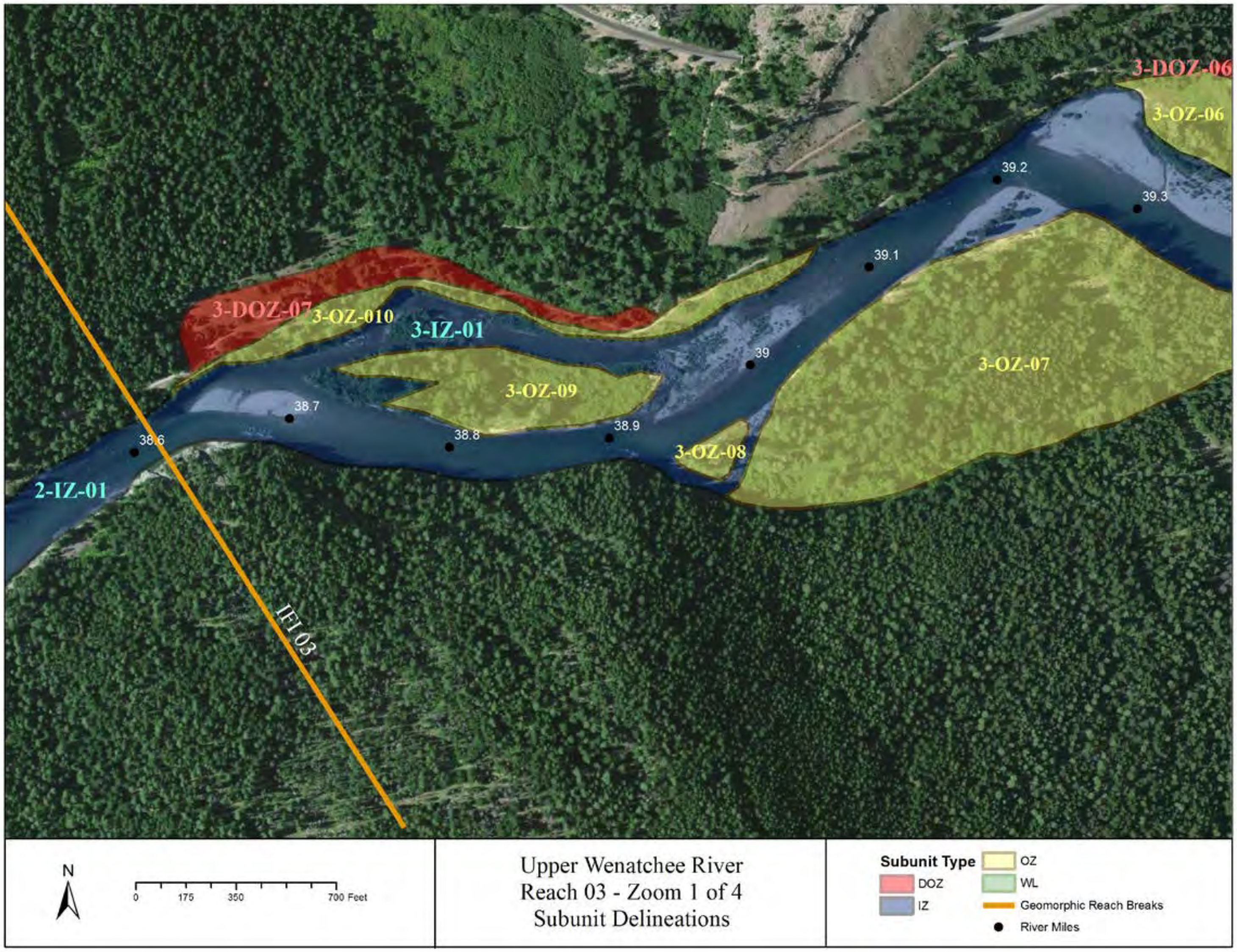


Figure 6. Subunit delineations in downstream portion of Reach 3. Flow is from west to east.

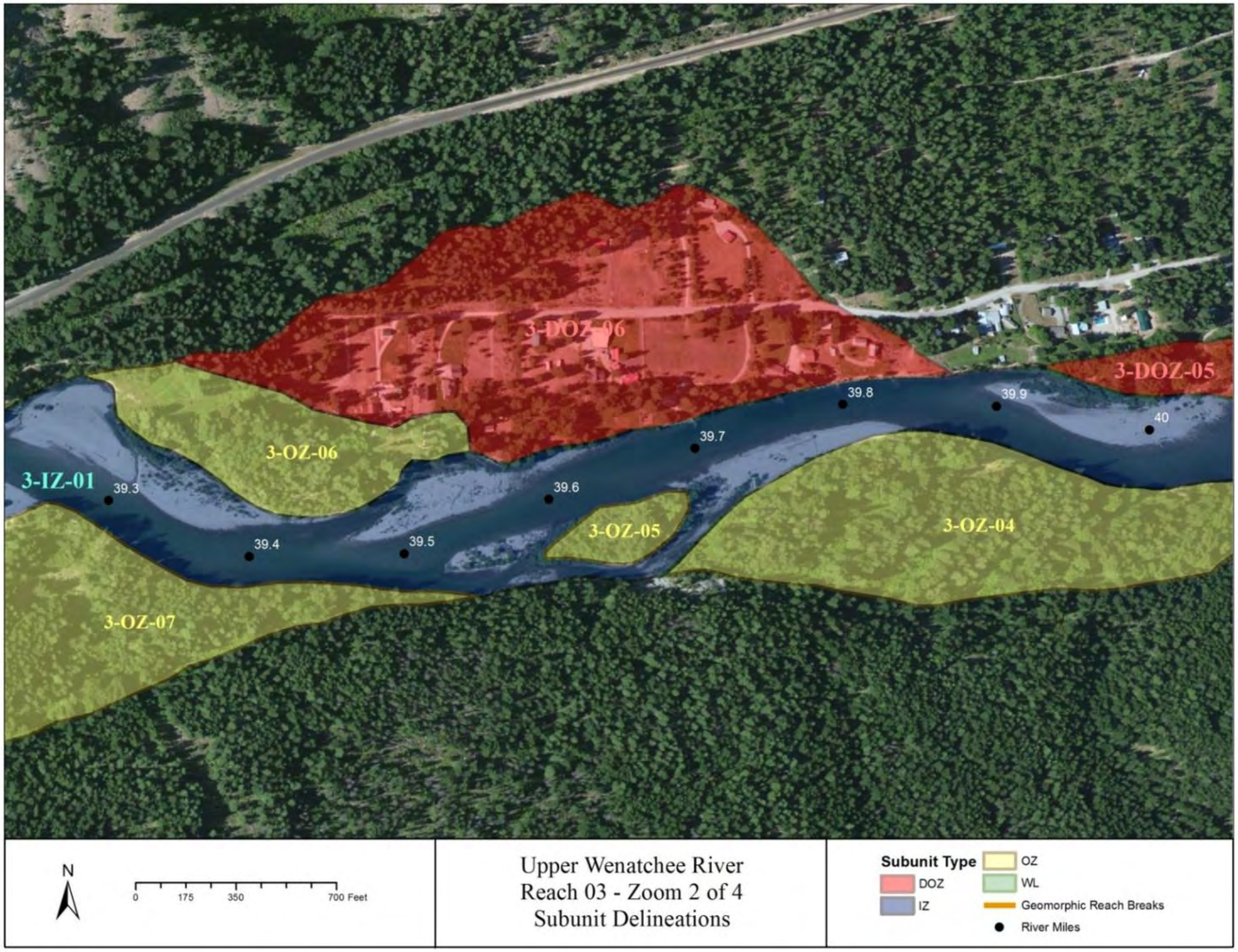


Figure 7. Subunit delineations in Reach 3. Flow is from west to east.

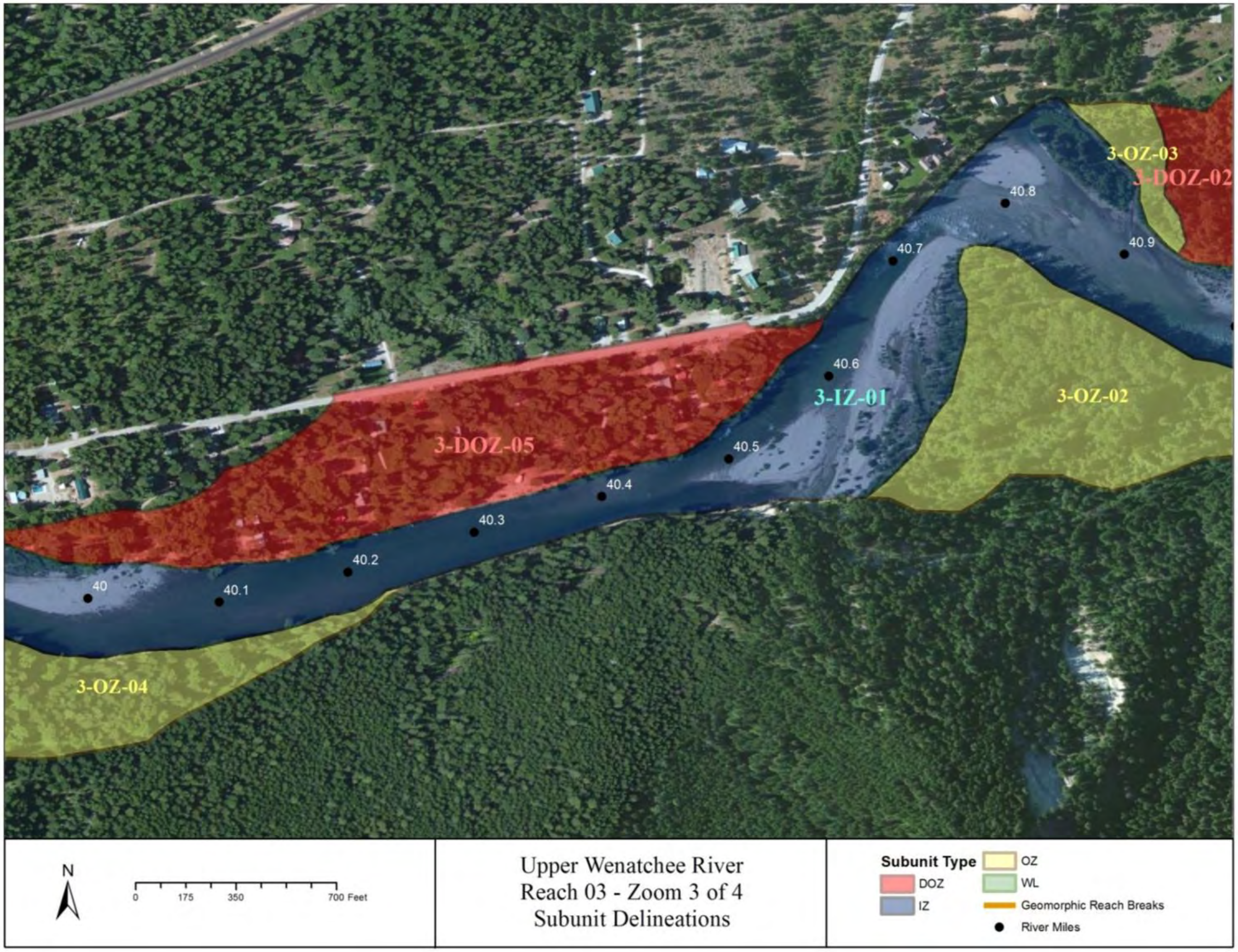


Figure 8. Subunit delineations in Reach 3. Flow is from west to east.

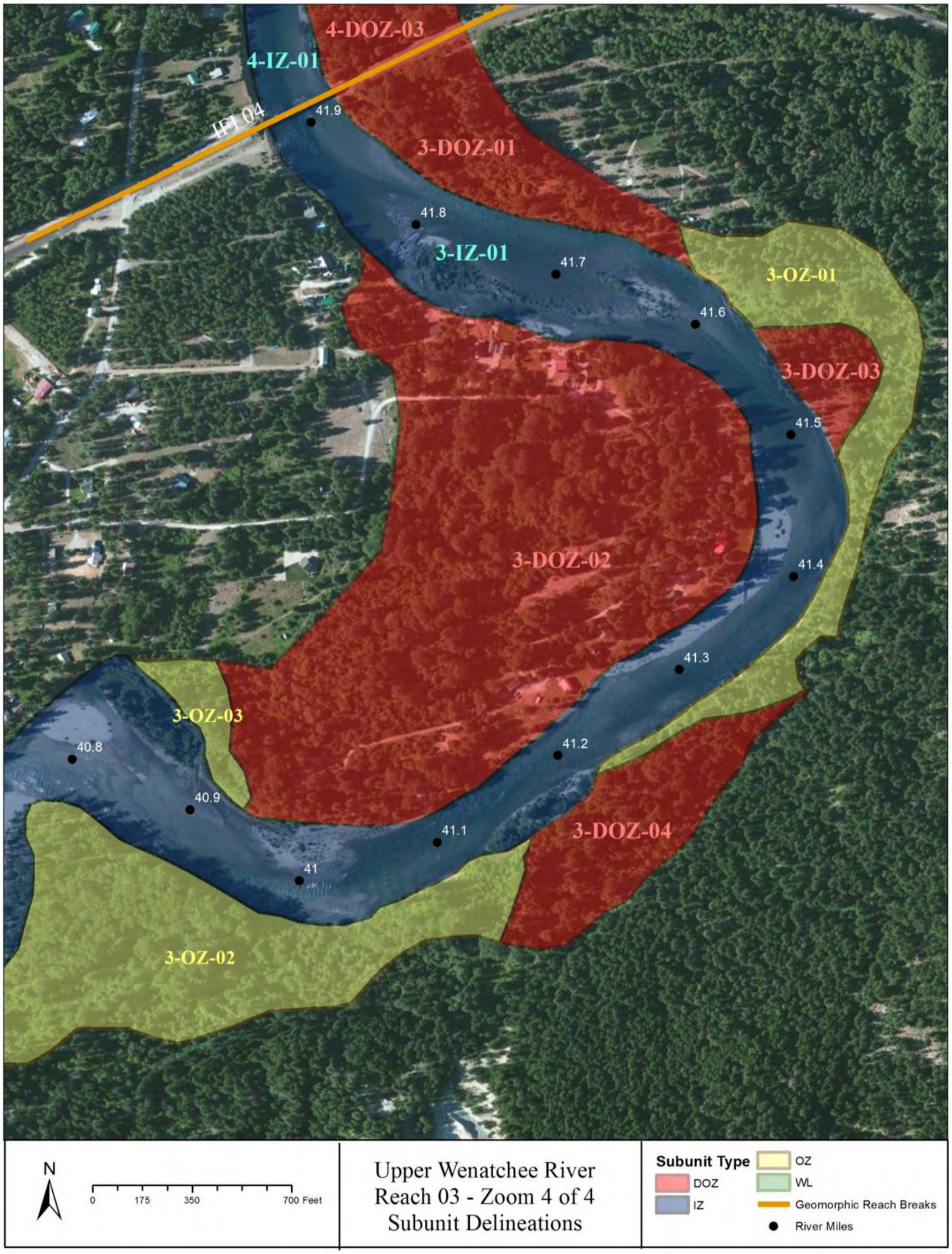


Figure 9. Subunit delineations in upstream most portion of Reach 3. Flow is from north to south.

3.4 REACH FOUR

Sub-Unit	Description	Potential Constraints
4-IZ-01	RM 41.9-43.12: This is an extended riffle-pool sequence with a substrate of sands to cobbles. There are some minor boulder inputs from the banks where the channel abuts the sedimentary conglomerate rock exposure of the Chumstick Formation (RM 42.3-42.21 & 42.93-43.12). Gradually sloping floodplains of sand and cobbles and steep terrace banks alternate throughout this unit. A unique feature to this section of the river is an eddy cove on RL (RM 42.66) with some large wood accumulations. In general this unit is lacking large wood that would be expected to accumulate here. At the downstream boundary of 4-IZ-01 is the railroad bridge. Bridge abutments and associated riprap along the banks and at the base of the abutments locally constrict the channel. Riprap composed of large granite boulders and river rock exists at and above the bridge as well as on some private properties.	Permitting large wood placements upstream from railroad bridge; boulder riprap upstream and at the bridge are protecting a transportation route that is in use; obtaining a permit to remove or alter bridges and/or pilings may prove difficult.
4-OZ-01	RM 42.8-42.93: This is a functioning low-elevation floodplain pocket on RL. The surface is well vegetated with a mix of trees and shrubs. The banks of this unit are both sloping and vertical and composed of cobbles as base and topped with sands. A wetted alcove at the downstream end of the unit is potential backwater habitat. Adjacent to this floodplain pocket the channel splits around a mid-channel bar making a good location for large wood inputs.	No established channel or floodplain access.
4-OZ-02	RM 42.43-42.57: This unit is located on the downstream end of a larger floodplain unit designated as a DOZ due to human alterations. This portion of the low-elevation floodplain is well-vegetated with mixed riparian trees and shrubs. Fresh deposition on the surface indicates inundation.	
4-OZ-03	RM 42.05-42.21: This is a narrow elongate floodplain surface located on RR in front of a high bank exposure of the Chumstick Formation. The surface is covered with a well-established mix of riparian trees and shrubs.	
4-DOZ-01	RM 42.57-43.12: This elongate floodplain surface located on RR has been significantly altered by development. DOZ designation has been given to this unit as a result of road building, fill and grading, vegetation removal/alteration, and home sites. The inland side is bordered by a slightly higher alluvial terrace that is also developed. Connectivity between the channel and floodplain does occur along the river-edge of the unit. Topography suggests that this unit was historically the point bar to the higher terrace.	Properties are privately owned and occupied.
4-DOZ-02	RM 42.27-42.52: This low-elevation floodplain surface located on RL has been moderately altered by development. DOZ designation has been given to this unit as a result of vegetation removal/alteration and home-site construction. This unit experiences minor inundation during seasonal high-flow/flood events and has good riparian vegetation. The inland side is bordered by a slightly higher alluvial terrace that is more extensively developed. Topography suggests that this unit was historically the point bar to the higher terrace.	Properties are privately owned and occupied.

4-DOZ-03	RM 41.9-42.27: This low-elevation floodplain surface located on RL has been significantly altered by development. DOZ designation has been given to this unit as a result of railroad construction (fill and trusses) that border the downstream end and vegetation removal/alteration and home-site construction at the upstream end. The downstream section is well vegetated. This unit experiences minor inundation during seasonal high-flow/flood events. The inland side is bordered by a slightly higher alluvial terrace that is more extensively developed. Topography suggests that this unit was historically the point bar to the higher terrace.	Properties are privately owned and occupied; Railroad is in use.

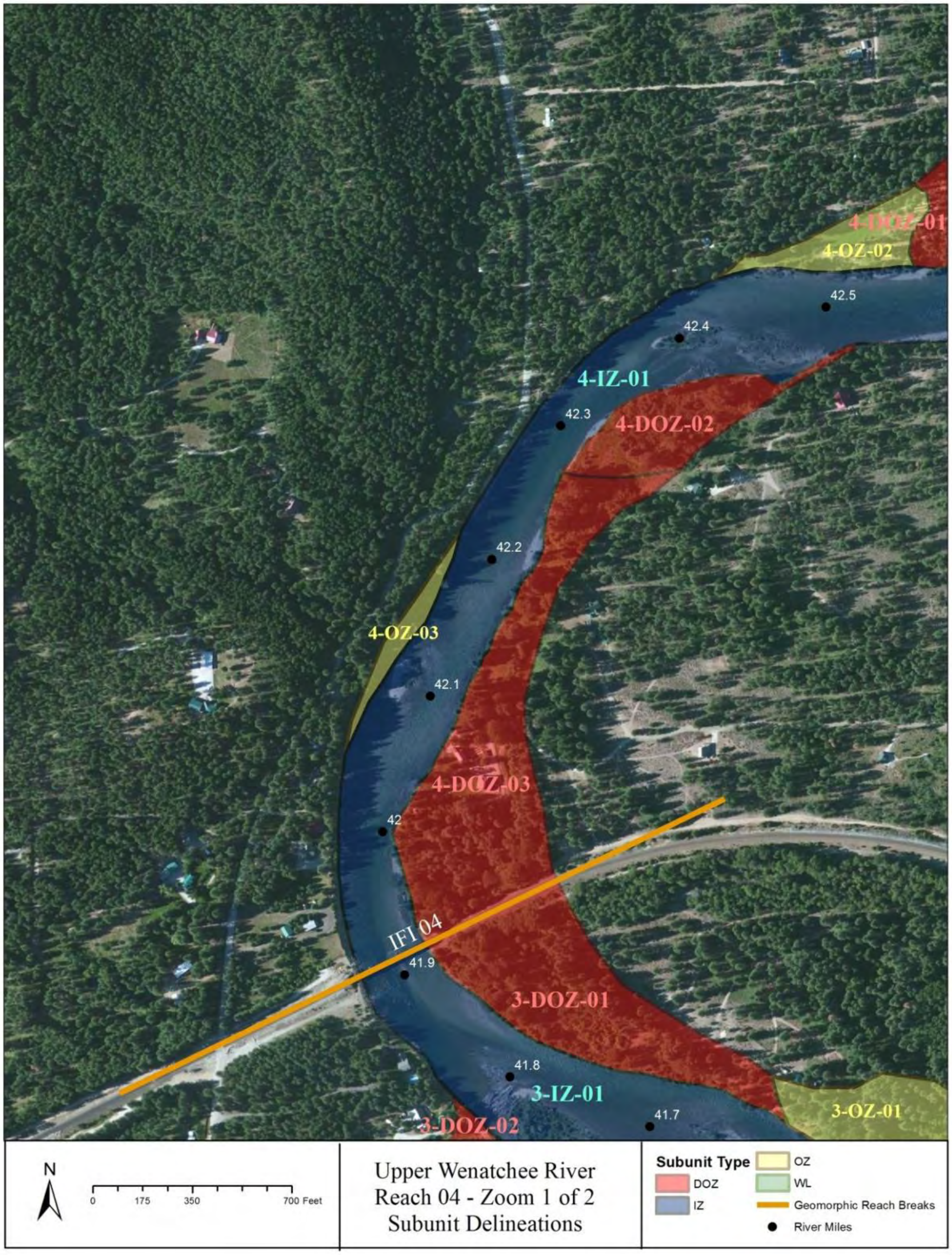


Figure 10. Subnit delineation map for downstream end of Reach 4. Flow is from north to south.

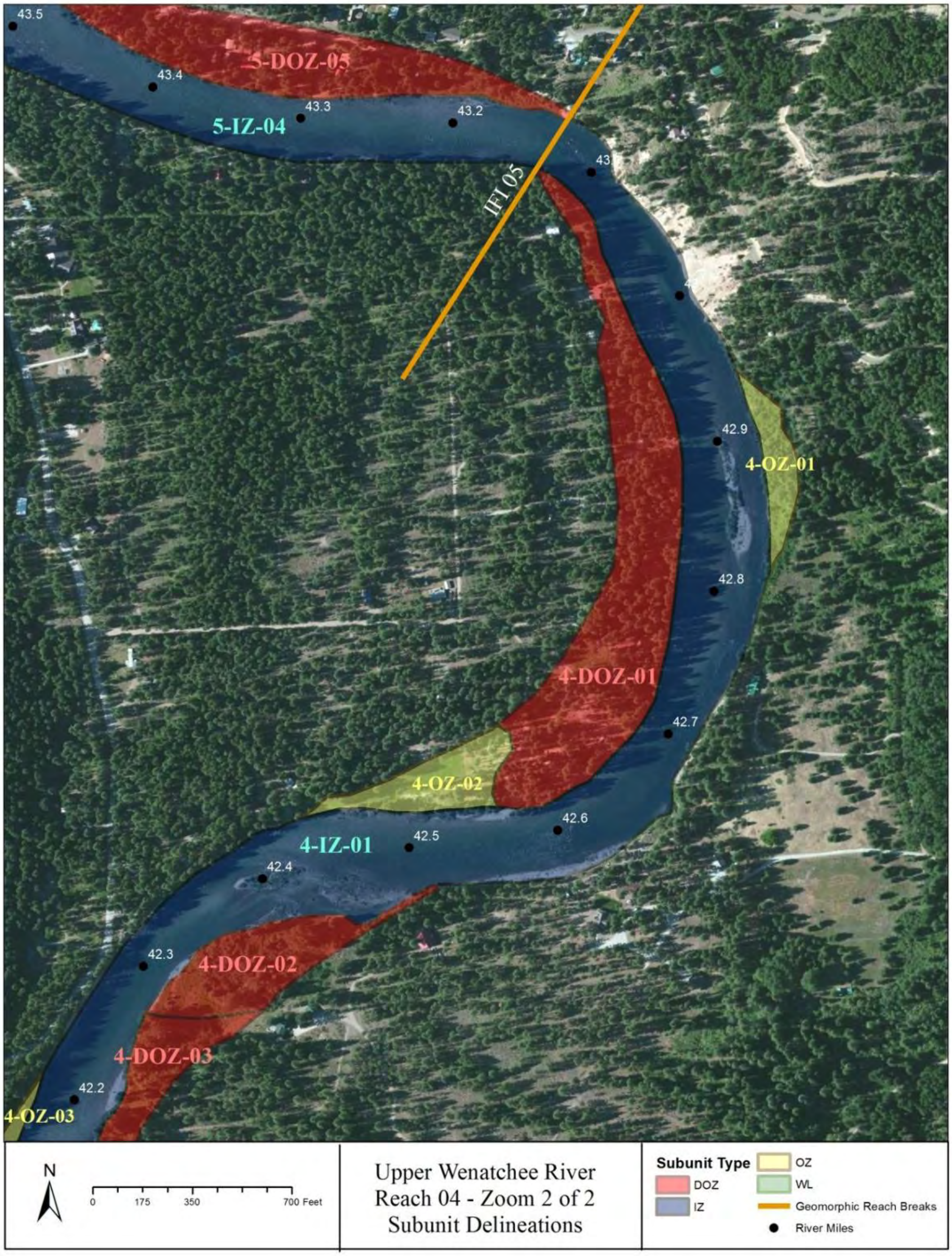


Figure 11. Subunit delineation map for upstream end of Reach 4. Flow is from north to south.

3.5 REACH FIVE

Sub-Unit	Description	Potential Constraints
5-IZ-01	RM 46.16-46.45: This is a straight, fast-moving section of the channel that is mostly confined by bridges and high steep terraces. The Beaver Valley Rd bridge (RM 46.41) and the Plain Bridge (RM 46.21) both have sets of cement pilings and associated large boulder riprap that influence flow patterns. An additional set of pilings (RM 46.39) from a decommissioned bridge also remain in-channel. This relatively deep unit has plentiful large boulders. The high terrace banks are steep but vegetated with conifers. The narrow two small low-elevation floodplains along this unit offer gradually sloping banks that are also well-vegetated. At the downstream end on RR is a set of very large boulders with an eddy pool that is used as a swimming hole and access point.	Beaver Valley Bridge is an established transportation route in use; Plain Bridge is an historic structure; obtaining a permit to remove or alter bridges and/or pilings may prove difficult.
5-IZ-02	RM 44.9-46.16: Width of channel increases relative to the upstream unit and gradient is reduced slightly. This is a fast-moving riffle-pool/glide section with substrate of sands to cobbles and some large boulders. The boulders are sourced from terrace banks that alternate with narrow sections of floodplain. The channel expresses a very low sinuosity meander pattern. Gravel and cobble mid-channel bar development could be enhanced to encourage deposition in this transport dominated reach.	Property is primarily privately owned.
5-IZ-03	RM 43.58-44.9: Sinuosity within the confined channel pathway increases and velocity increases compared to the upstream IZ. This extended riffle sequence contains substrate of gravels to cobbles with some hill-slope boulder inputs. Some in-channel deposits of gravels and cobbles are establishing vegetation (willow). These deposits could be enhanced to encourage mid-channel bar or island development. Banks are primarily high steep alluvial terraces. In the downstream portion of this unit a lower-elevation floodplain exist but is disconnect (5-DOZ-04). Riprap and retaining walls are found on the banks of both RL and RR in the downstream half of this unit.	Retaining walls are built on and protecting private property and home sites; riprap is hardening bank to maintain River Road.
5-IZ-04	RM 43.12-43.58: This is a riffle-glide unit with substrate of cobbles to boulders. The unit is straight and laterally confined by an abandoned alluvial terrace on RR and rock and cement retaining walls along the floodplain on RL. Banks are partially vegetated.	Property is privately owned. Retaining walls are protecting private property and home sites.
5-OZ-01	RM 51.46-51.65: This is a narrow elongate low-elevation floodplain surface located on RL. The upstream end of 5-OZ-01 beings at the Beaver Valley Rd bridge. This floodplain unit rests between the channel and a high alluvial terrace. Banks are sloping and composed of sands with cobbles at base. The surface is covered with a well-established mix of riparian trees and shrubs	
5-OZ-02	RM 46.07-46.23: This is a narrow elongate low-elevation floodplain surface located on RR. This floodplain unit rests between the channel and road fill added to a high alluvial terrace. Banks are sloping and composed of sands with cobbles at base. The surface is covered with a well-established mix of trees (conifers and	

	deciduous) and riparian and wetland vegetation. Large wood accumulation at downstream end creates a small eddy behind it.	
5-OZ-03	RM 44.5-44.69: This unit is located on RL at the base of a high steep terrace. It is topped with alluvium but its base is composed of talus material that originated from a landslide off the terrace slope behind it. It is now well vegetated with mixed trees (conifer & deciduous) and riparian vegetation. Landslide boulders extend into the channel. Some wood is accumulating on these boulders.	
5-DOZ-01	RM 45.9-46.09: This narrow elongate low-elevation floodplain surface located on RL has been significantly altered by development. DOZ designation has been given to this unit as a result of fill and grading, vegetation removal/alteration and home-site construction. There is no riprap or retaining walls on this floodplain unit. The inland side is bordered by a high alluvial terrace where the community of Plain is located.	Properties are privately owned and occupied.
5-DOZ-02	RM 45.32-45.79: This elongate low-elevation floodplain surface located on RR has been significantly altered by development. DOZ designation has been given to this unit as a result of road building, fill and grading, vegetation removal/alteration and home-site construction. There is no riprap or retaining walls on this floodplain unit. The inland side is bordered by a high terrace where River Road traverses.	Properties are privately owned and occupied.
5-DOZ-03	RM 50.75-51.3: This elongate low-elevation floodplain surface located on RL has been moderately altered by development. DOZ designation has been given to this unit as a result of vegetation removal/alteration and home-site construction. This unit experiences minor inundation during seasonal high-flow/flood events. The inland side is bordered by a slightly higher alluvial terrace that is more extensively developed. Topography suggests that this unit was historically the point bar to the higher terrace.	Properties are privately owned and occupied.
5-DOZ-04	RM 43.81-44.12: This elongate floodplain surface located on RL has been significantly altered by development. DOZ designation has been given to this unit as a result of road building, fill and grading, vegetation removal/alteration, riprap placement, and home site and retaining wall construction. The inland side is bordered by a slightly higher alluvial terrace that is more extensively developed. Topography suggests that this unit was historically the point bar to the higher terrace.	Properties are privately owned and occupied.
5-DOZ-05	RM 43.12-43.58: This elongate low-elevation floodplain surface located on RL has been moderately altered by development. DOZ designation has been given to this unit as a result of road building, fill and grading, vegetation removal/alteration, riprap placement, and home site and retaining wall construction. The downstream portion (RM 43.12-43.2 has minor development and is inundated by high flow events. The inland side is bordered by a higher alluvial terrace.	Properties are privately owned and occupied.

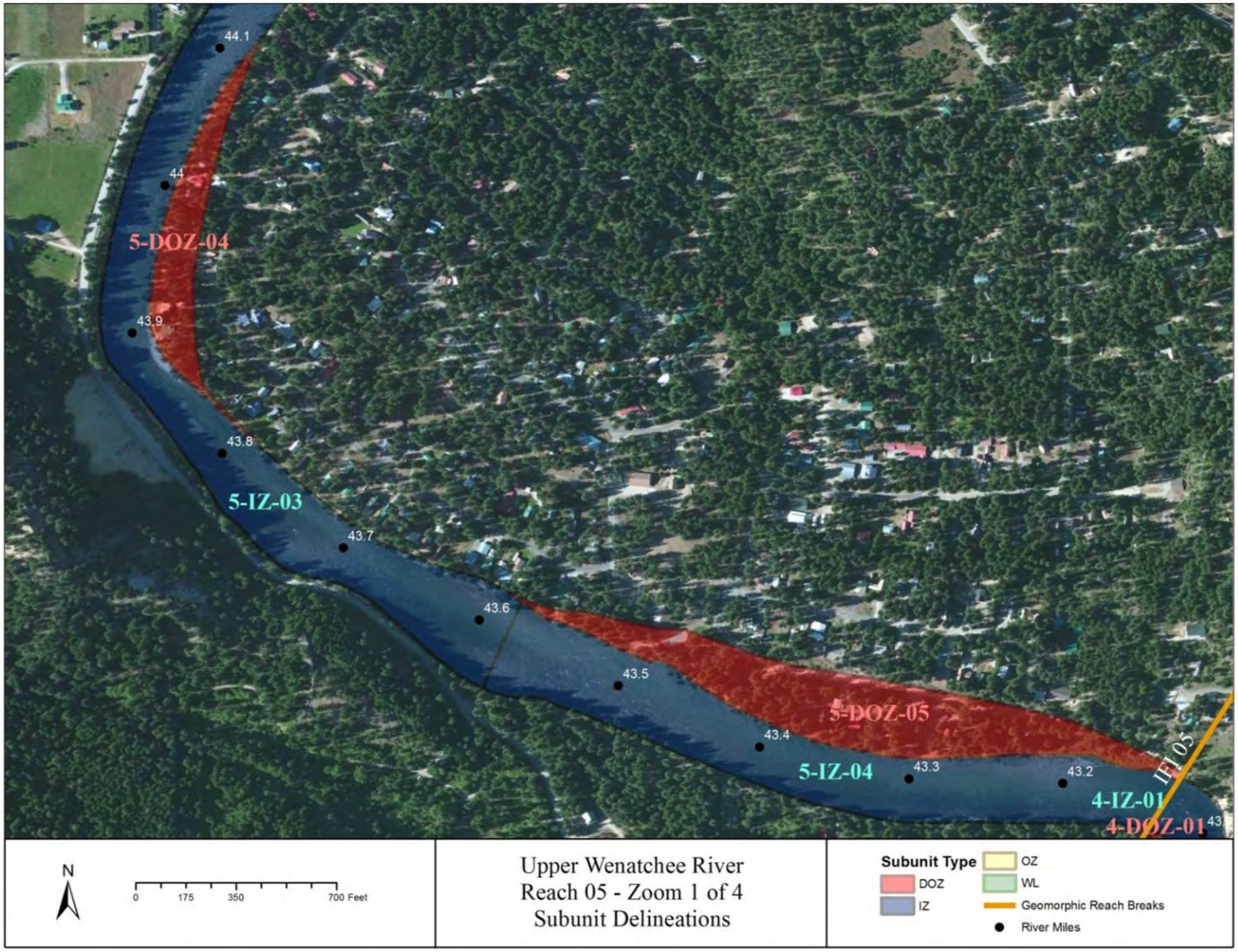


Figure 12. Subunit delineation map for downstream end of Reach 5. Flow is from northwest to to southeast.

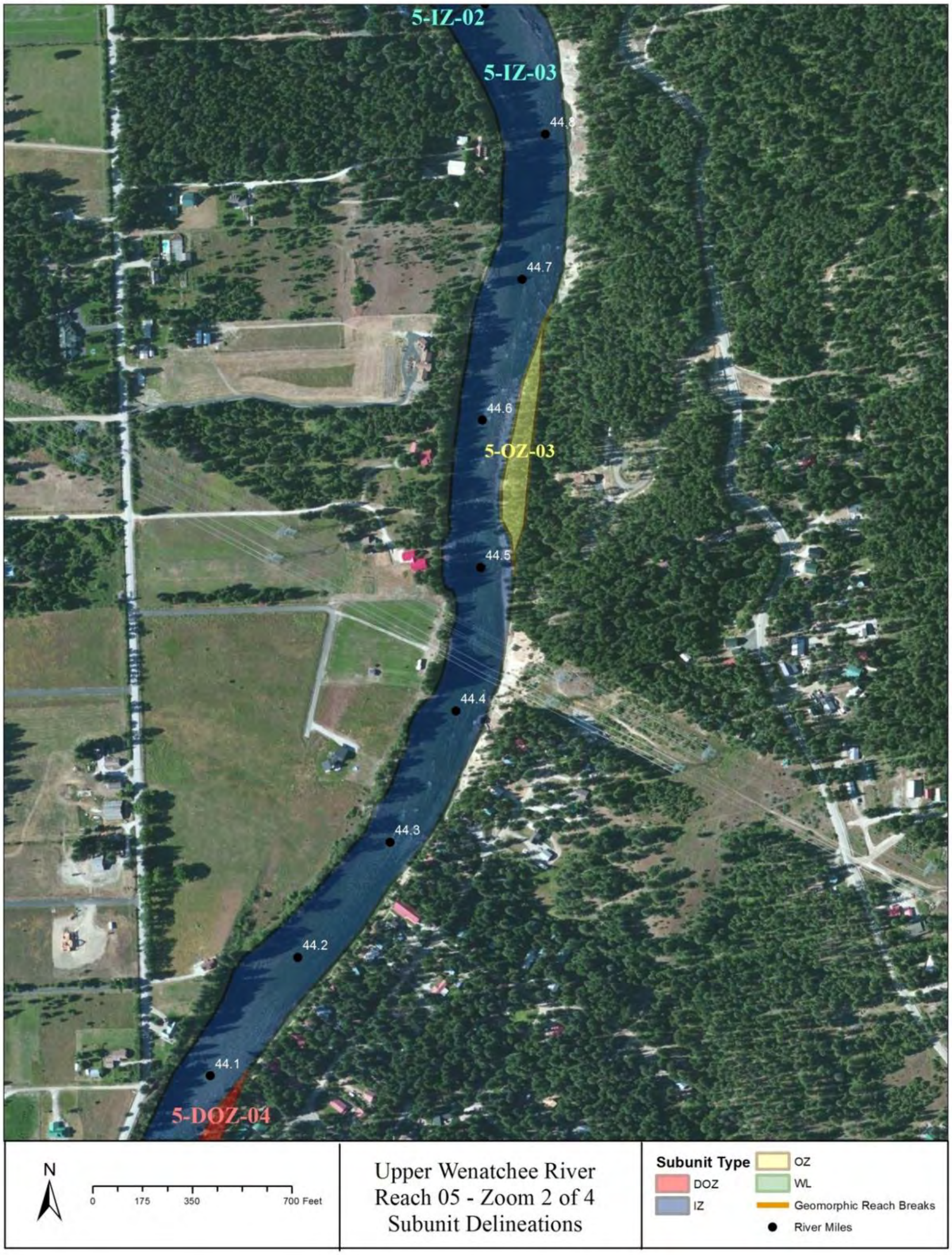


Figure 13. Subunit delineation map for upstream end of Reach 5. Flow is from North to South.

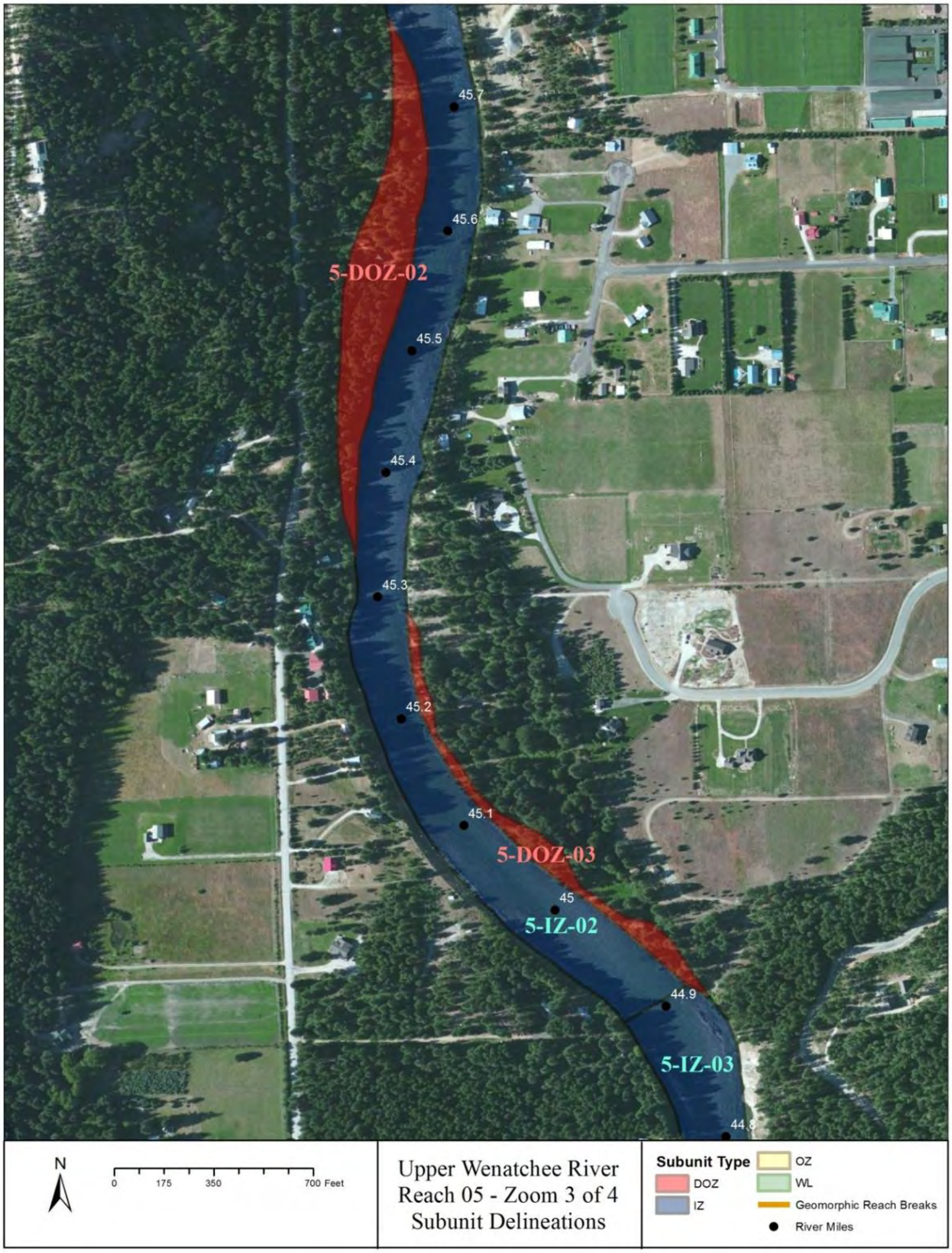


Figure 14. Subunit delineation map for upstream end of Reach 5. Flow is from north to south.

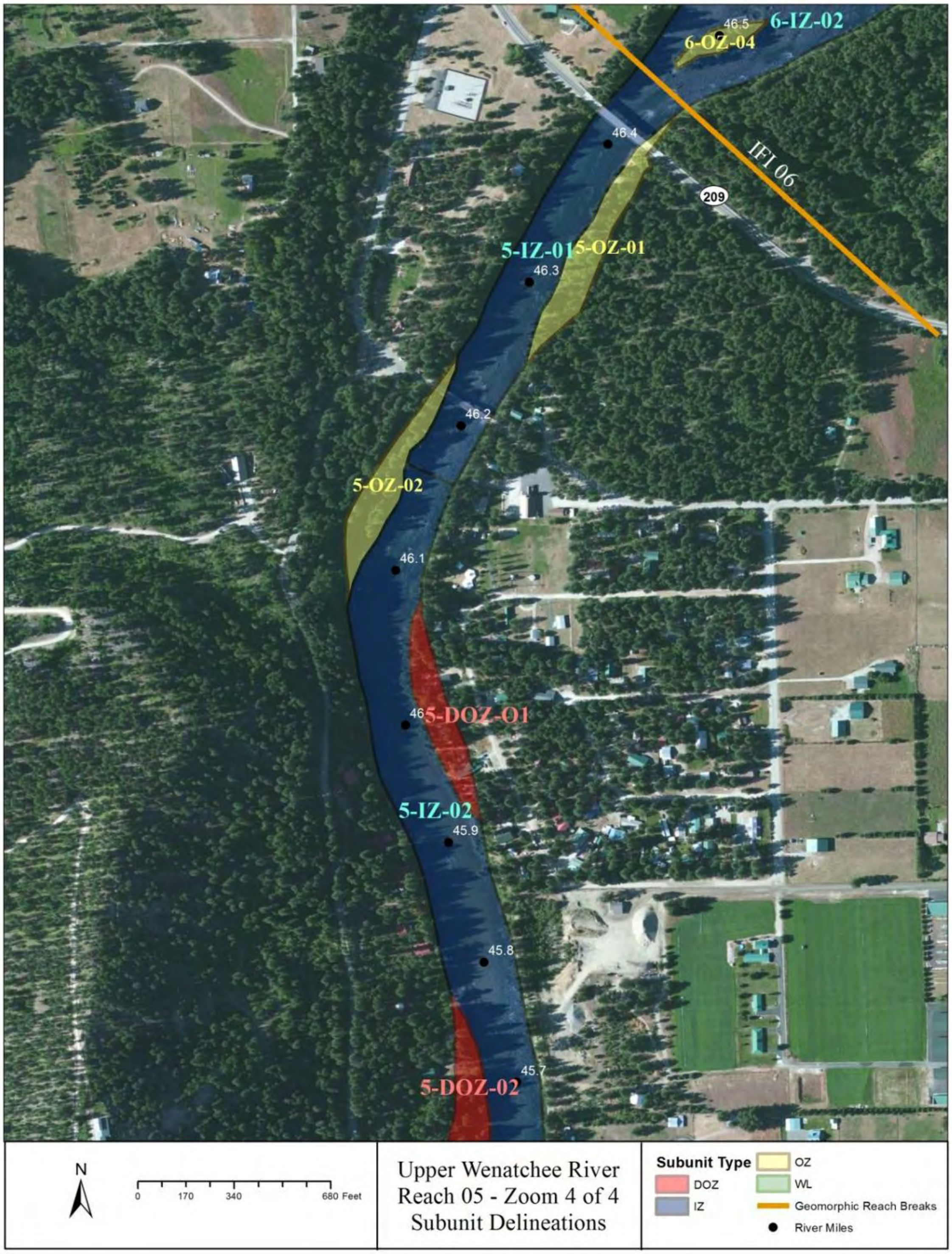


Figure 15. Subunit delineation map for upstream end of Reach 5. Flow is from north to south.

3.6 REACH SIX

Sub-Unit	Description	Potential Constraints
6-IZ-01	RM 47.12-47.89: This is a well-functioning low sinuosity pool-riffle unit of the channel. Substrate is dominated with large cobbles but ranges from very coarse sands to small boulders. Channel gradient and thus velocity are slightly increased from the upstream unit. Two small sections of the RR bank are low and sloping. Otherwise RR is bordered by a vegetated but steep bank of historic alluvial terrace deposits. On RL channel banks are gradually sloping and low but altered by human activities. Riprap (RM 47.85) made of tires and rock and an earthen levee (RM 47.55-47.67) have been constructed along the RL banks.	Riprap and levee are protecting private property and associated structures.
6-IZ-02	RM 46.45-47.12: Gradient of the channel increases notable from the upstream unit through 6-IZ-02. This an island-braided section of the channel with substrates ranging from gravels to boulders. Extended cobble riffles are followed by short pool section that express small standing waves (rapids). Channel width expands where the channel splits around the established islands and is narrowest at the pool sections. The islands have large accumulations of LWD at their apexes. Left bank of channel is a very high steep exposure of the Chumstick Formation composed of sedimentary deposits (sedimentary conglomerate). In-channel boulders are primarily located at the base of this formation. The right bank of the channel is low and gradually sloping with a composition of sands to small boulders. Banks of the island units (6-OZ-03 & 6-OZ-04) are well-vegetated with large cobbles at the base and topped with very coarse sand.	
6-OZ-01	RM 47.5-47.7: This is a narrow (~80 ft) low-elevation floodplain surface. It is bar-shaped and located at the inner bend of a meander. Lateral development of this point bar is likely restricted due to the constructed levee on the opposite bank. The surface is covered with a well-established mix of riparian trees and shrubs. The inland border is a historic alluvial terrace deposit	
6-OZ-02	RM 47.3-47.55: This is a narrow elongate low-elevation floodplain surface located on RL in front of a slightly higher floodplain surface that has been developed with home sites. Banks are sloping and composed of sands with gravels at base. The surface is covered with a well-established mix of riparian trees and shrubs	Incision processes occurring immediately downstream may migrate upstream and negatively impact this functioning OZ and backwater; access is from dirt road down steep terrace bank.
6-OZ-03	RM 46.84-46.91: This island OZ unit is a functioning floodplain ~1 acre in size. Mature well-established vegetation composed of mixed trees (conifers and deciduous) and shrubs populate the bar-shaped mid-channel surface. The unit is composed of large cobbles at the base that are topped with very coarse sands. Banks are semi-sloped and well vegetated. Large wood is accumulating at the apex supporting island	

	development.	
6-OZ-04	RM 46.44-46.53: This island OZ unit is a functioning floodplain ~0.5 acre is size. Mature well-established vegetation composed of mixed trees (conifers and deciduous) and shrubs populate the bar-shaped mid-channel surface. The unit is composed of large cobbles at the base that are topped with very coarse sands. Banks are semi-sloped and well vegetated. Large wood is accumulating at the apex, supporting island development.	
6-DOZ-01	RM 47.19-47.89: This floodplain surface on RL has been significantly altered by development. It is an extension of the upstream unit 7-DOZ-03. DOZ designation has been given to this unit as a result of road building, fill and grading, vegetation removal/alteration, levee and berm construction, excavation, and home-site construction. Even with these alterations the upstream portion (RM 47.7-47.89) experiences minor inundation during flood events. The remainder does not experience inundation due to the earthen levee and a county gravel excavation site (RM 47.7) with a constructed berm on the upstream side of the pit. The inland side is bordered by a slightly higher alluvial terrace that has been more extensively developed and altered.	County utilizes access point and extracted gravels; other properties are privately owned and occupied; levee and berm protecting properties.
6-DOZ-02	RM 46.5-47.25: This low-elevation floodplain surface located on RR has been significantly altered by development. DOZ designation has been given to this unit as a result of road building, fill and grading, vegetation removal/alteration and home-site construction. The inland side is bordered by a slightly higher alluvial terrace that has been more extensively developed and altered.	Properties are privately owned and occupied.

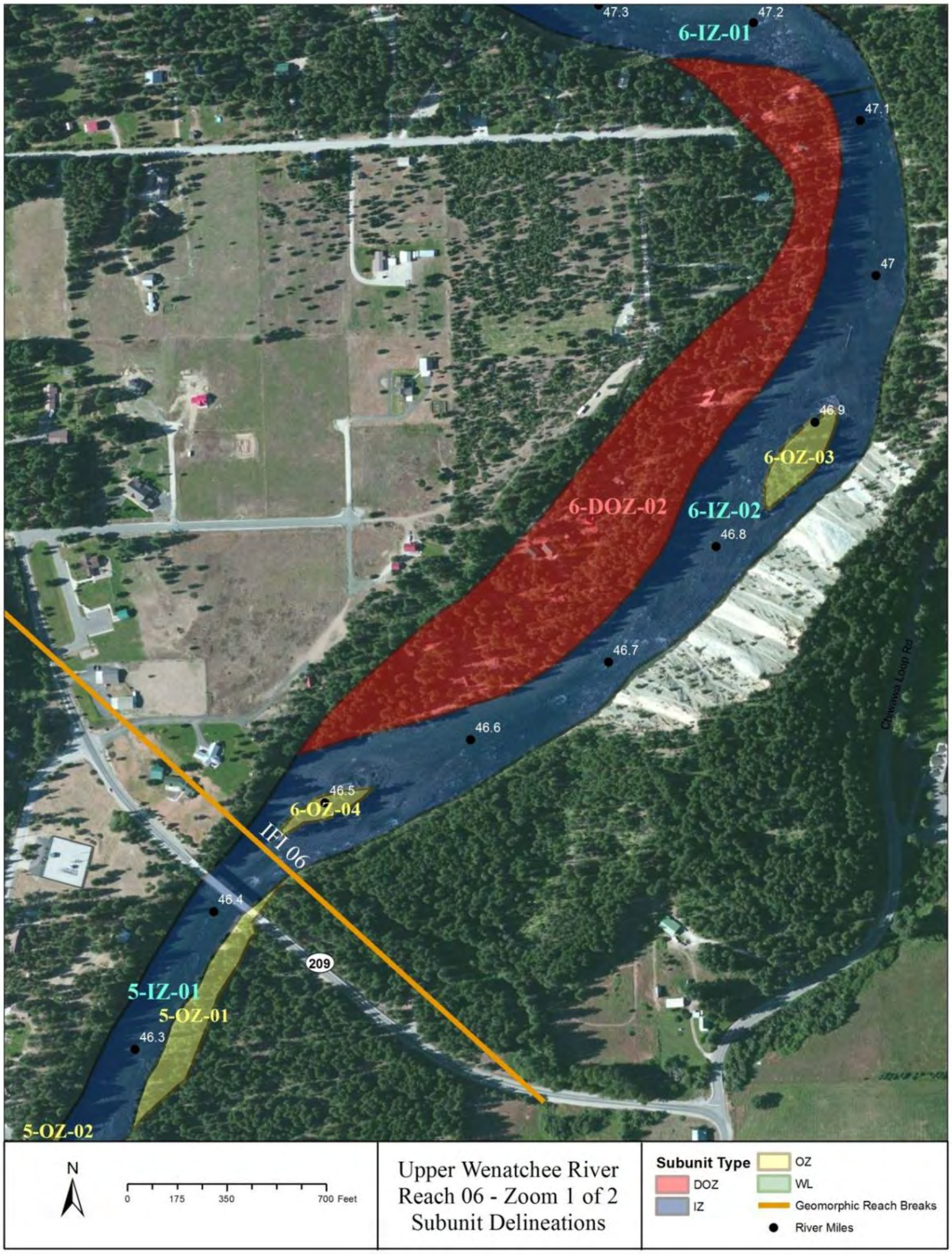


Figure 16. Overview map of Reach 6. Flow is from northwest to southwest.

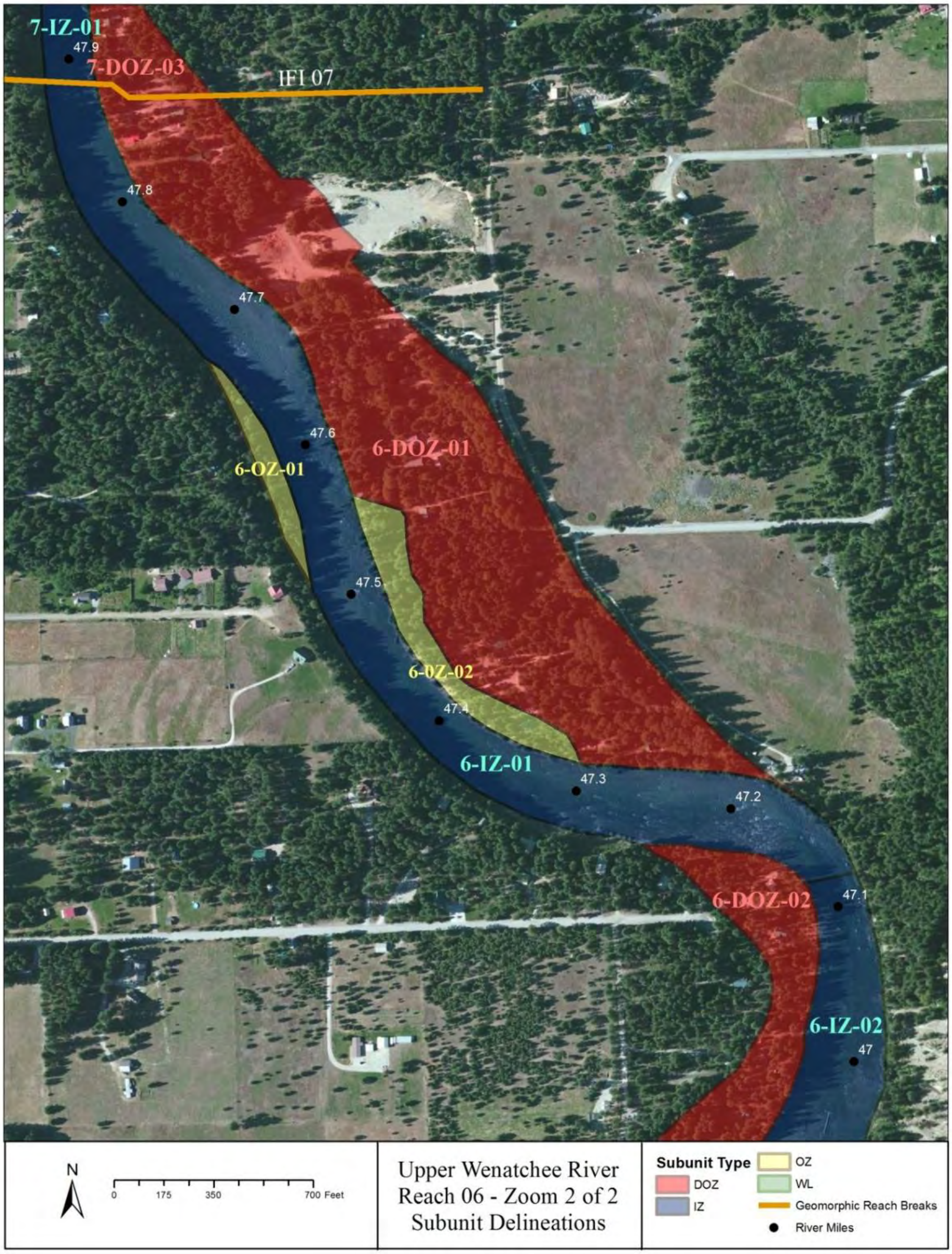


Figure 17. Overview map of Reach 6. Flow is from north to south.

3.7 REACH SEVEN

Sub-Unit	Description	Potential Constraints
7-IZ-01	RM 47.89-48.43: The Chiwawa Creek confluence defines the upper border of this IZ unit that occupies the full length of the reach. Increased discharge and sediment sourced from Chiwawa Creek and its alluvial fan influence channel morphology. The channel widens slightly compared to upstream but velocity increases. This is a riffle-glide unit with substrate ranging from sands to cobbles, but cobbles dominate. Channel form is moderately sinuous with confinement in the lower half by a steep vertical terrace bank. Low-elevation floodplain banks along RL alternate between human altered and functioning. The floodplain banks along the upper half of RR are relatively well vegetated and low.	Except for the upper-most RL floodplain unit (7-OZ-01), which is owned by Chelan County PUD, the remainder of bank access to the channel in this IZ is privately owned.
7-OZ-01	RM 48.3-48.43: This is a narrow (~65 ft) elongate floodplain surface located on RL along the downstream edge of the Chiwawa Creek alluvial fan. Banks are sloping and composed of sands to cobbles. The surface is covered with a mix of riparian trees and shrubs.	
7-OZ-02	RM 48.14-48.25: This unit is located on the downstream end of a larger floodplain unit designated as a DOZ due to human alterations. This portion of the low-elevation floodplain is well-vegetated with mixed riparian trees and shrubs. Fresh deposition on the surface indicates inundation.	
7-OZ-03	RM 47.94-48.02: This is a narrow and short segment of functioning floodplain on RL located between two disconnected units. The surface is well vegetated with mixed riparian trees and shrubs. Banks are low and gradually sloping.	
7-DOZ-01	RM 48.14-48.43: This is an extension of floodplain sub-unit 08-DOZ-03 on RR but is it slightly lower. This relatively low-elevation floodplain surface has been moderately altered by development. DOZ designation has been given to this unit as a result of localized and upstream road building, fill and grading, vegetation removal/alteration and home-site construction. This unit experiences minor inundation during seasonal high-flow/flood events. The inland side of the unit is bordered by road fill from the construction of Beaver Valley Rd built along a historic terrace.	Private properties are currently occupied and transportation routes are in use.
7-DOZ-02	RM 48.02-48.3: This floodplain surface on RL has been moderately altered by development. DOZ designation has been given to this unit as a result of road building, fill and grading, vegetation removal/alteration and home-site construction. Alterations to vegetation are minor and homes are constructed on stilts. This unit experiences minor inundation during seasonal high-flow/flood events. The inland side of the unit is bordered by a slightly higher alluvial terrace with more development.	Private properties are currently occupied and transportation routes are in use.
7-DOZ-03	RM 47.89-47.94: This floodplain surface on RL has been significantly altered by development. DOZ designation has been given to this unit as a result of road building, fill and grading, vegetation removal/alteration and home-site construction. This unit experiences minor inundation during seasonal high-flow/flood events. The inland side of is bordered by a slightly higher alluvial terrace that is also developed.	Private properties are currently occupied and transportation routes are in use.

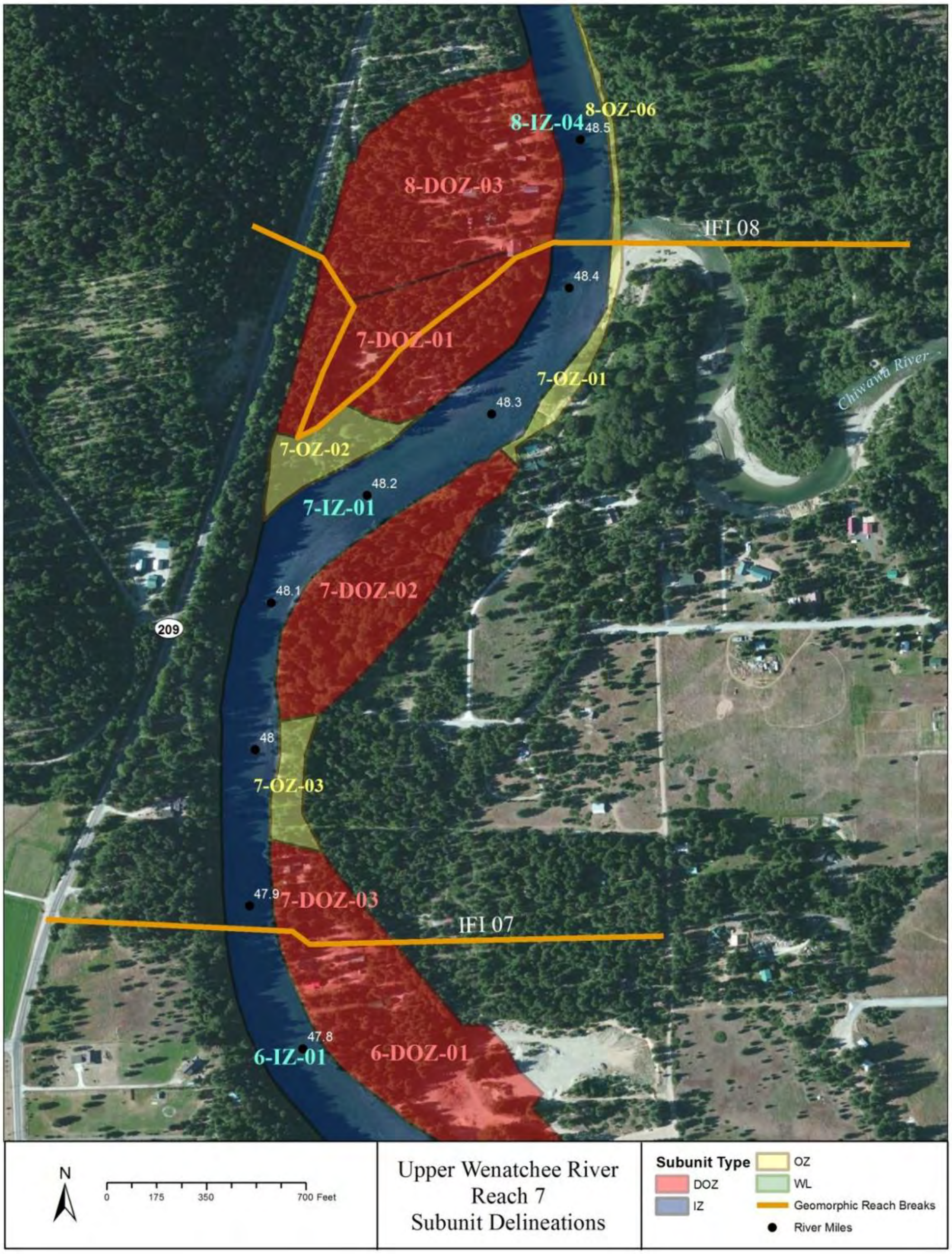


Figure 18. Subunit delineation map for Reach 7. Flow is from north to south.

3.8 REACH EIGHT

Sub-Unit	Description	Potential Constraints
8-IZ-01	RM 49.65-49.71: This is a narrow deep pool located at the apex of the meander bend. Substrate is sand to gravel with sparse large boulders sourced off the confining steep terrace bank on RL. Minor sand deposits on the inner bank are forming behind accumulating LWD at RM 49.7 on RR. The sand deposits are starting to form an elongate point bar along 8-DOZ-01 on RR. Upstream of the bar the RR banks are undercut and slumping from channel processes. This unit is influenced by the incision processes underway upstream in Reach 9.	Property managed by US Forest Service but no established access; nearest road on RR is 0.5 miles away; snowmobile roads/trails on RL may be enlarged for access.
8-IZ-02	RM 49.25-49.65: Width and velocity increase compared to the upstream unit. This deep glide contains sparse boulders sourced from the confining steep terrace bank on RL of the upper 2/3 of the unit. Substrate within the unit is primarily sand to cobbles. Hydraulic flow patterns/currents downstream from the upper meander and mid-unit boulders are creating marginal but visible elongate depositional features on the channel bed. This is a transitional unit between the incising processes upstream and the aggrading processes downstream. The lower 1/3 of RL are mostly vegetated floodplain banks. At RM 49.29 a cement retaining wall with fill forms a convex bank at the fish hatchery access area. Directly downstream from the retaining wall is an accumulation of LWD. The banks on RR are well-vegetated.	No established floodplain access on RR; there is access on RL but permission must be granted through the Chiwawa Community Assoc and private landowners; the retaining wall is part of the fish hatchery facility currently in use.
8-IZ-03	RM 48.72-49.25: This is a riffle-pool sequence with developing mid-channel bars and point-bar accumulations on the upstream portion of the extended meander. Mid-channel bars have establishing populations of willow. Channel width is increased from the upstream unit. A well-functioning backwater that is connected at its downstream outlet on RL extends almost 500 feet into the floodplain. Except for a pocket floodplain unit (9-OZ-03) in the upstream-most portion, banks on RR are composed of steep confining terrace banks that are sparsely vegetated. The banks are RL are well vegetated and generally sloping.	US Forest Service owns the adjoining land but there is no established access to either bank.
8-IZ-04	RM 48.43-48.72: Width of channel decreases slightly from the upstream unit. This glide unit contains large boulders sourced from the confining steep terrace bank on RR. Substrate within the unit is dominated with sand to cobbles. Except for a narrow strip of developing floodplain, the Chiwawa Creek alluvial fan deposits define floodplain material of RL.	There is no established access on RL through US Forest Service lands; except for the upper-most 200 feet, RR is privately owned lands.
8-OZ-01	RM 49.4-49.48: This is a thin (~50 ft) OZ unit located within the downstream portion of a recently disconnected floodplain unit (8-DOZ-01). The surface is well-vegetated with a mix of riparian trees and shrubs.	
8-OZ-02	RM 49.38-49.44: This is a small wedge-shaped low-elevation floodplain surface located on RL. It is bordered on the inland side by an abandoned historic terrace of alluvium. Banks are well-vegetated	Privately owned property but easy access.

	with mixed trees and shrubs. Some vegetation clearing associated with home-site development above this unit has occurred but the alterations are not impeding inundation or channel-side vegetation.	
8-OZ-03	RM 49.15-49.3: This floodplain surface includes the apex at the inside of a RR meander bend as well as a lobe of floodplain surface directly downstream from the apex. Both high-flow scour and some deposition on higher surfaces delineate the meander apex portion of this unit as an OZ. A margin point bar is developing here but the depth of the apex pool and the hardening of the opposite banks on RL (cement retaining wall and fill at RM 49.29) have minimized lateral migration processes. The surface near the meander bend is dominated by ferns while the rest of the unit is covered with a well-established mix of trees and shrubs. A mostly disconnected backwater habitat fed by groundwater exists within the lower portion of this unit.	Property is managed by US Fish and Wildlife Service; there is no established access to this unit; closest road (Beaver Valley Rd) is ~0.5 miles away.
8-OZ-04	RM 49.12-49.26: Located on RL this unit is well-vegetated with a mix of riparian trees and shrubs. An important backwater habitat connected at the downstream outlet extends ~500 ft along the inland boundary of this unit. The backwater defines the boundary between 8-OZ-04 and the slightly higher 8-OZ-05.	
8-OZ-05	RM 48.83-49.1: This floodplain surface is slightly higher than the OZ directly upstream from it (08-OZ-04). Natural levees near the bank mirror migrating scrolls across the surface that are visible in LiDAR . This unit is inundated during flood flows. The surface is covered with a well-established mix of riparian undergrowth and conifers. Wetted off-channel habitat with good vegetation cover is located within an inland scroll. No surface water connection to the channel was found.	Property is managed by US Fish and Wildlife Service but there is no established access to this unit.
8-OZ-06	RM 48.43-48.83: This is a very narrow (~25 ft) elongate floodplain surface located on RL at the edge of the Chiwawa Creek alluvial fan. Banks are sloping and composed of sands to cobbles. It appears to be a natural levee created by the interaction between the alluvial fan deposits and the Wenatchee River. The surface is covered with a mix of riparian trees and shrubs.	
8-DOZ-01	RM 50.75-51.3: Local channel incision has resulted in this disconnected floodplain surface on RR. There is evidence of historic or very infrequent inundation on the surface and soils are sandy. This unit is bordered on the inland side by a set of historically abandoned alluvial deposits. Large wood accumulations are occurring at the upstream end of the unit (RM 49.7) which could be enhanced to increase channel-floodplain interactions. Banks are sandy and sloping at the base but mostly vertical on top. The floodplain surface is vegetated with established conifers, vine maple and rose. A small section of the downstream end of this unit has been delineated an OZ (08-OZ-01). The geomorphology of the channel and floodplain along 8-DOZ-01 indicates that this zone is the transition area between upstream incision and downstream aggradation.	
8-DOZ-02	RM 49.26-49.38: This RL unit has been disconnected from channel and floodplain processes by alterations to its surface and banks. The cement retaining wall (RM 49.29) also includes fill, road and river access and small buildings. Upstream from the wall the surface has been graded and much of the native vegetation has been removed (now dominated with mowed grass) to facility recreational	Property owned, managed and utilized by the Chiwawa Community Association for recreational purposes;

	activities. The banks are marginally vegetated and steep. The inland side of this unit is bordered by notably higher terraces of alluvium and glacial deposits where residential home-sites and road development dominate the landscape.	retaining walls and related structures are currently in use.
8-DOZ-03	RM 48.43-48.56: This is a relatively low-elevation floodplain surface on RR that has been significantly altered by development. Disconnection has occurred as a result of road building, fill and grading, vegetation removal/alteration and home-site construction. The inland side of the unit is bordered by historically abandoned terrace deposits and road fill from the construction of Beaver Valley Rd.	Private properties are currently occupied and transportation routes are in use.

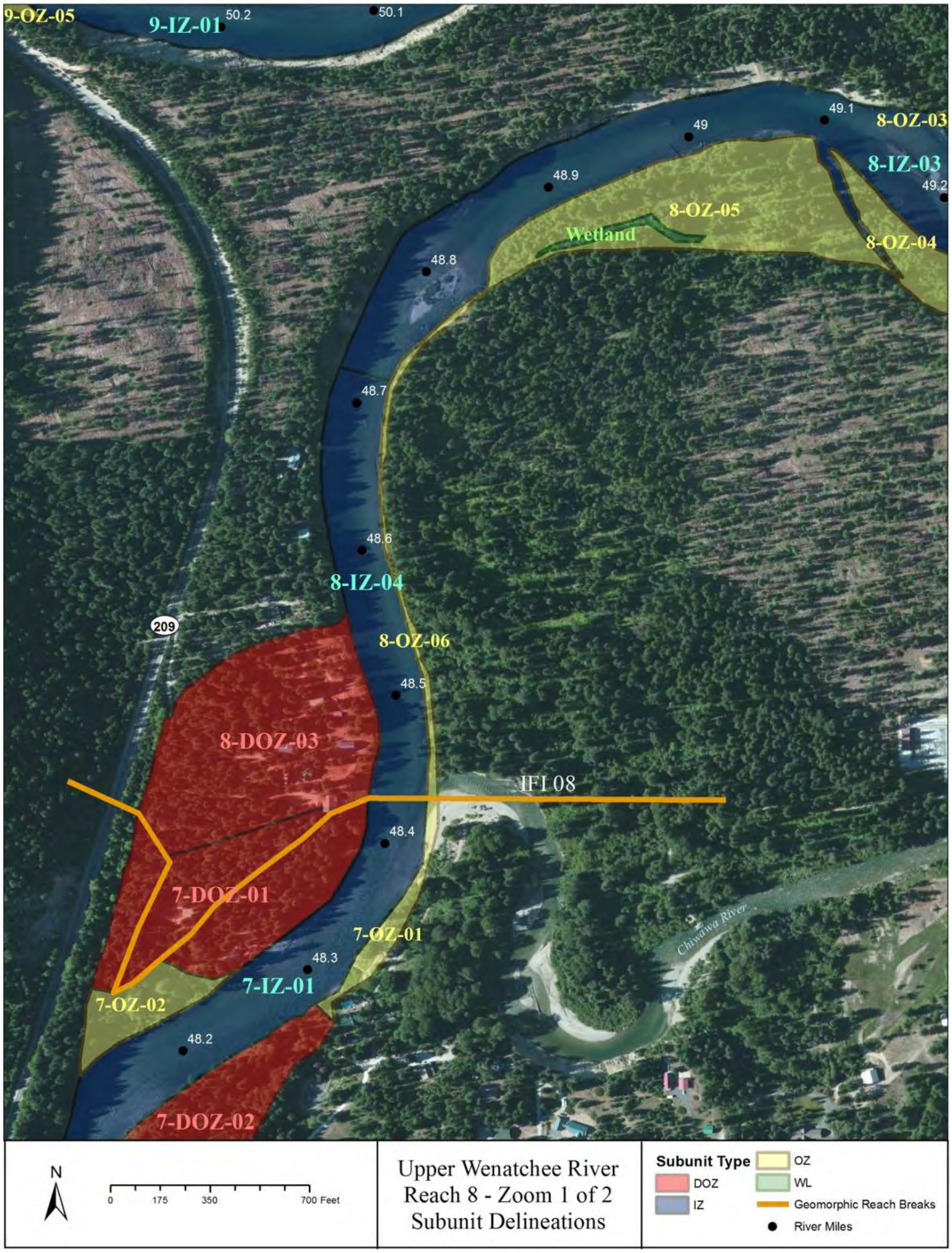


Figure 19. Subunit delineation map for downstream end of Reach 8. Flow is from north to south.

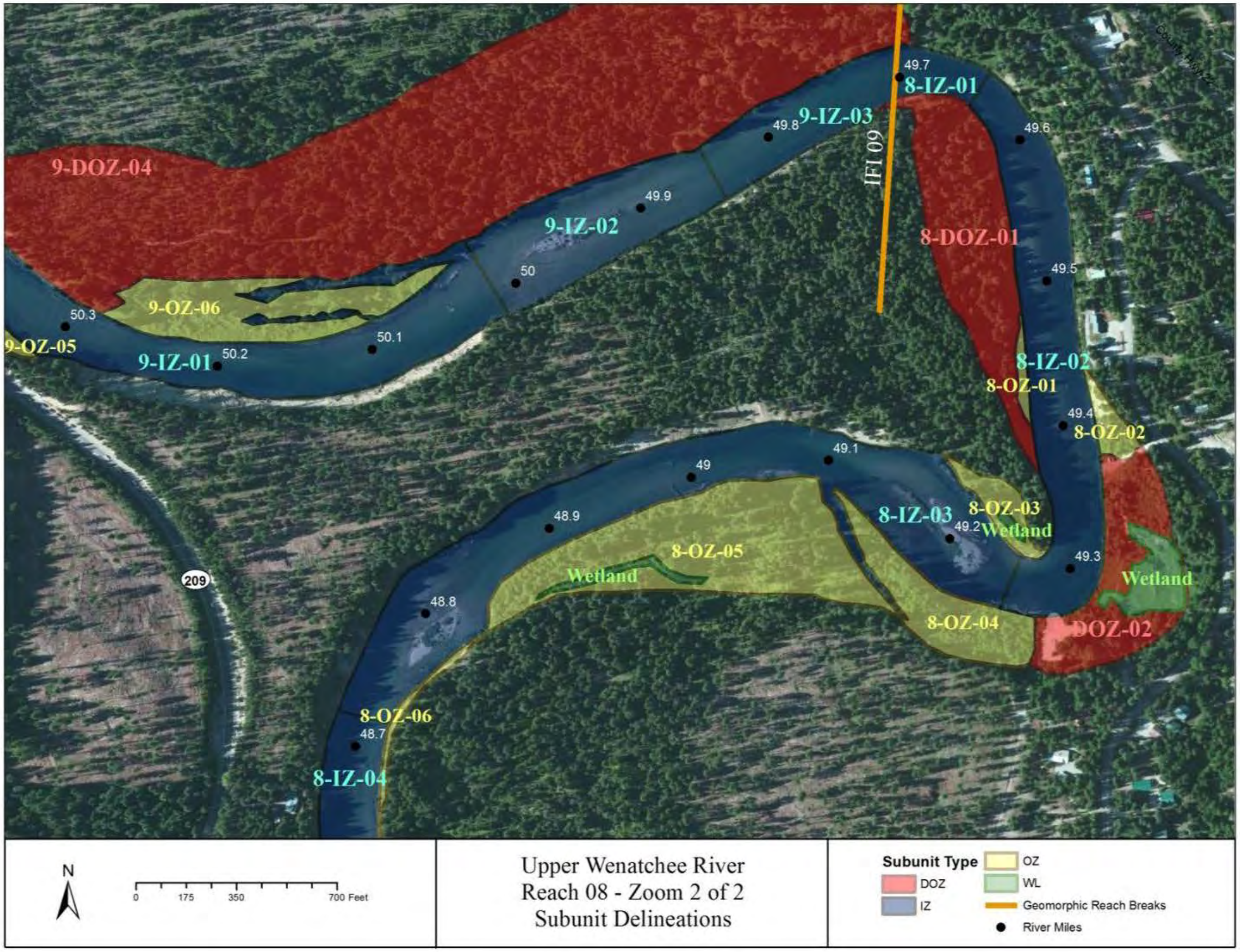


Figure 20. Subunit delineation map for upstream end of Reach 8.

3.9 REACH NINE

Sub-Unit	Description	Potential Constraints
9-IZ-01	RM 50.02-51.65: A slight increase in the gradient and sinuosity from upstream; however, channel form is primarily straight. This unit is a long glide with a cobble and gravel substrate and some boulders. Floodplain banks are well vegetated on both sides of the channel. Where the floodplain units have been disconnected via processes of incision banks are steeper but vegetation is thick. The five connected backwater habitats in Reach 9 are located in 9-IZ-01. This unit is lacking in-channel geomorphic complexity.	Floodplain and channel access from 50.87-51.65 and 50.02-50.3 is difficult for both RR and RL. There is a dirt road above RM 50.92; however access to channel is down steep terrace bank.
9-IZ-02	RM 49.85-50.02: Width of channel increases and depth decreases compared to upstream. Gravel deposit developing behind functioning mid-channel log jam. This feature depicts potential incision-reducing results of mid-channel large wood and boulder enhancement projects. Geomorphically, this unit is still a glide with riffle-like features form near the mid-channel bar at low flow. RB along vertical terrace bank is lacking complexity.	No established channel or floodplain access.
9-IZ-03	RM 49.71-49.85: The channel narrows slightly and deepens relative to the upstream IZ unit. Channel form remains straight but it is leading into a sharp meander bend that delineates the downstream reach boundary. This pool or deep glide unit has terrace banks on RR and a disconnected floodplain unit on RL. This IZ is in the process of incising. There are some very minor wood accumulations along the banks.	
9-OZ-01	RM 50.9-51.65: This is an elongate low-elevation floodplain surface located on RR that gradually narrows in the downstream direction. This unit is connected to 10-OZ-04, both of which are inundated regularly during seasonal high flows. The surface is covered with a thick well-established mix of riparian trees and shrubs including willow, dogwood, cottonwood, spirea, and vine maple. An important backwater habitat is located in abandoned channel scars near the center of 9-OZ-01. Wetted off-channel habitat at the downstream most section of the unit is an area for potential backwater habitat development.	Incision processes occurring immediately downstream may migrate upstream and negatively impact this functioning OZ and backwater; access is from dirt road down steep terrace bank.
9-OZ-02	RM 51.46-51.65: This is a very narrow (50 ft) elongate low-elevation floodplain surface located on RL at the base of confining terraces. The floodplain is composed of deposits from the channel and the hillslope. Banks are sloping and composed of sands with gravels at base. This unit is connected upstream to 10-OZ-05, both of which are inundated regularly during seasonal high flows. The surface is covered with a well-established mix of riparian trees and shrubs.	
9-OZ-03	RM 50.76-51.51.07: This unit is located on RL at the inside of a meander bend. Surface topography indicates that it was a scrolling point bar prior to channel bed incision. 9-OZ-03 is a low-elevation floodplain surface which is inundated during seasonal high flows. The surface is covered with a well-established mix of riparian trees and shrubs including willow, dogwood,	

	cottonwood, spirea, and vine maple. An important backwater habitat is located at the downstream end in an historic point bar scrolls.	
9-OZ-04	RM 50.57-50.74: This unit is located on RR at the inside of a minor meander bend. The surface is inundated during high flow events. A thick well-established mix of riparian trees and shrubs including willow, dogwood, cottonwood, spirea, and vine maple populate the surface. An important backwater habitat is located in what appears to be an abandoned secondary channel scar that extends along the inland side of the lower 2/3 of the unit.	
9-OZ-05	RM 50.3-50.5: This low-elevation floodplain surface is located on RR. It is bordered on the inland side by a steep bank of road fill associated with the construction of Beaver Valley Road. The surface is covered with a thick well-established mix of riparian vegetation dominated by dogwood and spirea. Wetted off-channel habitat (~1.5 acres) with good vegetation cover and sedges is located inland at RM 50.35. No surface water connection to the channel was found. Channel incision combined with infilling (aided by the roughness from the thick vegetation cover) has disconnected these backwaters. Good road access to this area.	There is no clear inlet or outlet for reactivation; would need to design something that is not naturally defined on the landscape. Area may be influenced by road fill.
9-OZ-06	RM 50.02 – 50.28: This unit is located on RL at the inside of a meander bend. Surface topography indicates that it was a scrolling point bar prior to channel bed incision. 9-OZ-06 is a low-elevation floodplain surface which is inundated during seasonal high flows. The surface is covered with a well-established mix of riparian trees and shrubs including willow, dogwood, cottonwood, spirea, and vine maple. Two connected backwater habitats are located at the downstream end in historic point bar scrolls.	Access to the floodplain unit is easy but access across it to the backwater outlet would need to be constructed which could harm riparian vegetation communities.
9-DOZ-01	RM 50.75-51.3: Minimal channel incision here makes this a relatively new disconnected floodplain surface. It is considered a transitional unit between an OZ and a DOZ. There is minor evidence of historical or very infrequent inundation on the surface and soils are sandy and moist. An ephemeral stream from the hillslope is contributing to wetted areas on this unit. The floodplain surface is vegetated with a mix of conifers and thick riparian forest that include vine maple and equisetum. Continued incision processes will result in full abandonment of this RL unit. Restoring connectivity of 9-DOZ-01 is dependent on in-channel actions that reverse incision processes.	The dirt roads into this unit have long sections of standing water and mud difficult to cross with a high clearance 4x4 truck. Plans to traverse this unit to access restoration projects on it or other units will need to consider this.
9-DOZ-02	RM 50.45-50.79: Channel incision has made this a relatively new disconnected floodplain surface on RR. There is evidence of historic or very infrequent inundation (buried trunks of old trees and topography scarring) on the surface and soils are sandy. This unit is bordered on the inland side by a high terrace slope at the upstream most section and then by a steep bank of road fill associated with the construction of Beaver Valley Road. Standing water exists on landward side but it is not clear if the water is from hyporheic flow or hillslope/roadfill influenced. LWD accumulations are occurring at the upstream most end of the unit (RM 50.75) along the banks that could be enhanced to increase channel-floodplain interactions. Banks are vertical but loose and sandy with	Road access is near but steep; no current established access across floodplain.

	healthy stands of hawthorne, snowberry, and dogwood. The floodplain surface is vegetated with established conifers (fir, cedar, pine) and vine maple. Continued incision processes will result in full abandonment of this unit. Restoring connectivity of 9-DOZ-02 is dependent on in-channel actions that reverse incision processes.	
9-DOZ-03	RM 50.33-50.7: This unit has been disconnected from channel and floodplain processes by the construction of Beaver Valley Rd. It is bordered on the inland side by high and steep Quaternary terrace deposits. An ephemeral stream from the hillslope contributes to soil moisture here. This unit is vegetated with mixed conifers, deciduous trees and shrubs.	This transportation route is currently in use.
9-DOZ-04	RM 49.69-50.53: Channel incision has made this a disconnected floodplain surface on RL. Topography scarring and sandy soils indicate that historic inundation did occur here. An ephemeral tributary that exits at RM 49.8 has a hanging outlet. This unit is bordered on the inland side by a high terrace of Pleistocene glacial deposits. US Forest Services dirt roads cross the surface at the up and downstream ends and traverse the length of the unit parallel to the channel. A maintained trail connects at the downstream end into the road system. Banks are marginally vegetated, sandy and steep. The floodplain surface is vegetated with mixed conifers including pine and fir with sparser understory of deciduous vine maple and other transitional shrubs. Restoring connectivity of 9-DOZ-04 is dependent on in-channel actions that reverse incision processes.	US Forest Service access roads. Projects in channel and on adjoining floodplain units will likely utilize these roads.

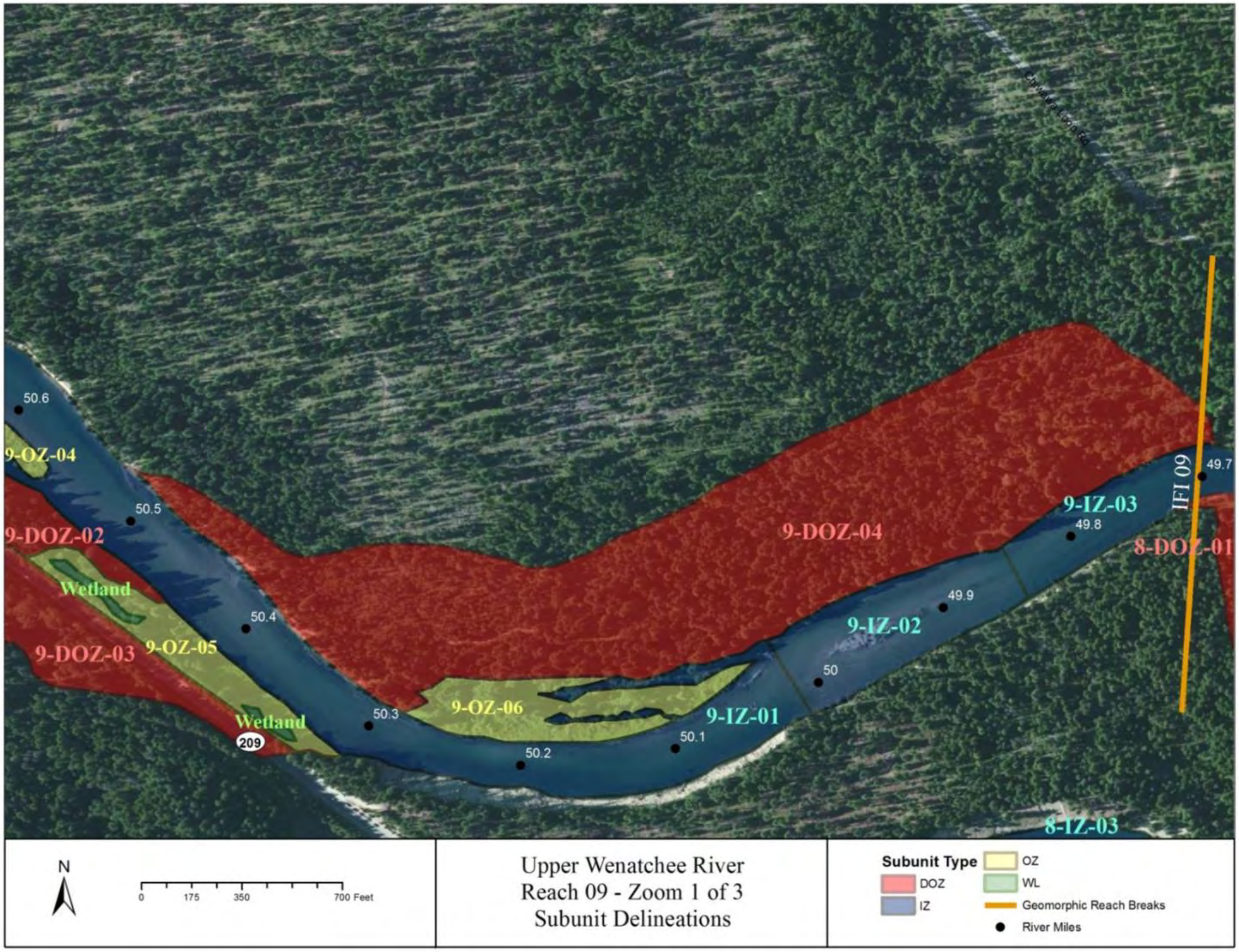


Figure 21. Subunit delineation map for downstream end of Reach 9. Flow is from west to east.

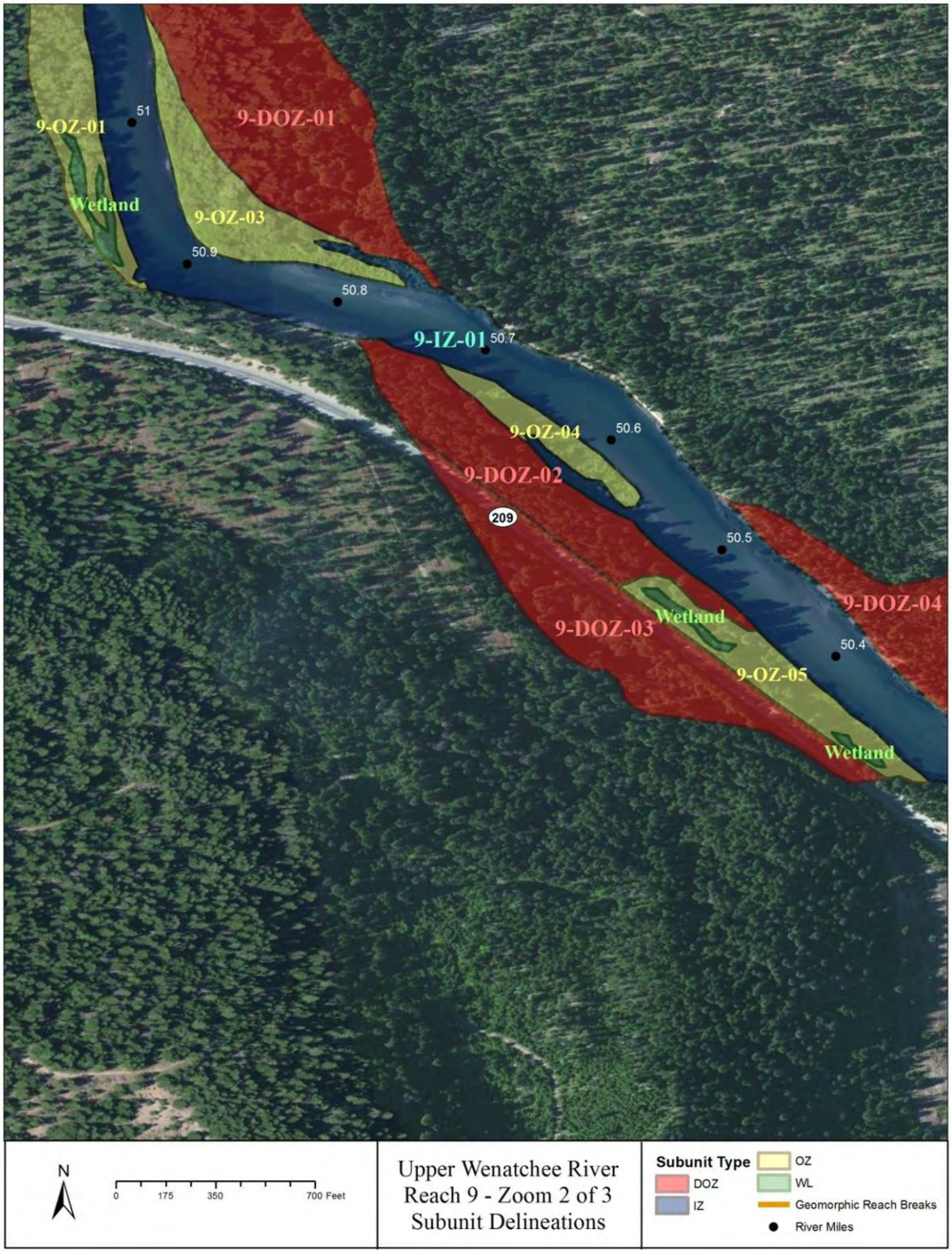


Figure 22. Subunit delineation map for upstream end of Reach 9. Flow is from northwest to southeast.

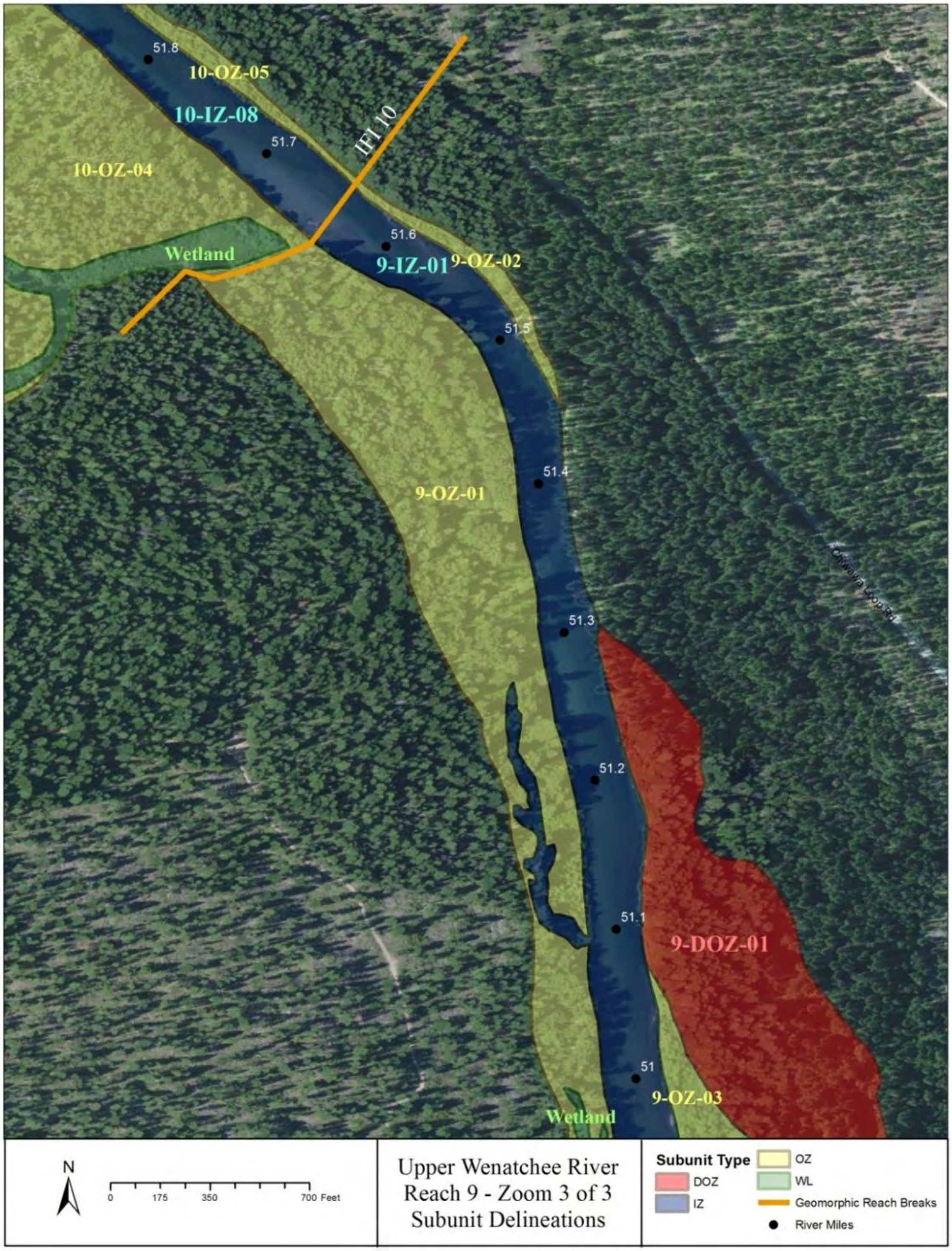


Figure 23. Subunit delineation map for upstream end of Reach 9. Flow is from north to south.

3.10 REACH TEN

Sub-Unit	Description	Potential Constraints
Nason-IZ-01	RM 53.67: The lower-most 0.18 river miles of Nason Creek. Nason-IZ-01 has a substrate of cobbles to sands. At the confluence on river-right is a large gravel to sand point bar with well-established scroll bars. Active high-water scour occurs behind the willow-vegetated scrolls defining the inland boundary of this unit. Nason Creek deepens on its left side as it approaches the confluence. There is a well-established backwater with sandy banks off of Nason Creek on river-left (0.03 RM Nason). The backwater inlet connection is at the downstream end of an abandoned channel scar and its wetted area extends the length of the river-left floodplain surface to the terrace boundary. It is possible that some hyporheic inputs to this backwater are from the Wenatchee River but it is most likely that it is primarily fed from Nason Creek.	Access from Hwy 207 on river-right is across privately owned property that is located on fill being protected by the river-right riprap. No access roads currently constructed to sites on river-left.
10-IZ-01	RM 53.39-53.67: This is a low-gradient unit with subtle riffle-pool characteristics. The pools are shallow. The substrate ranges from cobbles to sands. Island bar development near the confluence is influenced by sediment inputs from Nason Creek. Cement abutments and large granite boulder riprap and spurs constrict the channel at the Hwy 207 bridge (RM 53.57). The left bank is a steep glacial deposit terrace. Right bank is low elevation, moderately sloping sands to cobbles with heavily altered vegetation due to dense residential development.	Transportation features (Hwy 207 and bridge) are currently in use. The retaining wall, riprap, and dock on river-right are on privately owned lands.
10-IZ-02	RM 53.24-53.39: Channel morphology is classified as a low gradient, plane-bed deep glide unit. There are no depositional features within the zone. Channel banks on river-left are steep terraces with minor wood inputs. River-right are low but vertical banks of sands and cobbles with heavily altered vegetation and bank hardening features due to dense residential development	No access road to river-left. River-right is privately owned and occupied.
10-IZ-03	RM 52.66-53.39: This low gradient unit expresses a subtle riffle-glide sequence and a slightly greater channel width relative to 10-IZ-02. Substrate ranges from cobbles to sands with plentiful gravels. Few sparse boulders are present. An elongate mid-channel gravel bar with wood accumulating at the apex and establishing vegetation is located in the widest section of the unit at RM 52.8-52.9. A small functioning backwater on river-left is connected to 10-IZ-03 at a downstream outlet at RM 52.95. Except for the upstream most 0.05 miles of a steep terrace bank, the channel banks on river-left are low, sloping and composed of sands and cobbles. River-right are low but vertical banks composed of sands and cobbles with heavily altered vegetation and bank hardening features due to dense residential development. At RM 52.86-53.05 on river-right is an extended section of riprapped bank constructed of large granite boulders, kitchen appliances, cement, and gravel filled gabions as well as three large granite boulder spurs.	No good access road to river-left. River-right is privately owned and occupied. Existing riprap and retaining walls are currently protecting residential homes.
10-IZ-04	RM 52.7: This backwater complex is connected to the mainstem Wenatchee River via surface water and potential hyporheic flow from upstream. It is massive enough in scale (~ 1.8 acres) and unique enough in character that it has been designated a separate IZ unit. This unit occupies interconnected abandoned scrolls on the low elevation floodplain pocket (10-OZ-02) on river-left. This extensive backwater has	

	several interconnected coves. Bordering and within the unit is a mature mix of riparian and wetland vegetation that includes willow, dogwood, hawthorne, sedges, rushes and aquatic macrophytes. The mouth of this backwater unit where it joins the Wenatchee River is ~ 365 feet across.	
10-IZ-05	RM 52.52-52.66: This unit is a short deep narrow pool. Substrate ranges from large boulders to coarse sands. River-right is a well-vegetated sloping bank. River-left is a steep high terrace composed of glacial deposits. The steep terrace bank is a sediment source for the channel. The large boulders within this channel unit are from localized glacial deposits.	
10-IZ-06	RM 52.05-52.52: Channel morphology is classified as a riffle-pool sequence that is geomorphically more complex and slightly wider than the up and downstream IZ units. Substrate of 10-IZ-06 ranges from small cobbles to sands with plentiful gravels. An elongate mid-channel gravel bar with transverse bar characteristics and establishing vegetation is located in the widest section of the unit at RM 52.4-52.5. A large left bank point bar of gravels and sands and laterally migrating scrolls is located at RM 52.18-52.3. River-left channel bank is a steep glacial deposit terrace at RM 52.05-52.11. From RM 52.11-52.52 the channel bank on river-left is sloping and well vegetated with mixed riparian trees and shrubs. River-right is a low semi-vertical bank with minimal vegetation alterations at RM 52.28-52.52 and well established vegetation at RM 52.05-52.28.	Road access on river-right is through privately owned properties. RM 52.35 is owned by people interested in restoration work.
10-IZ-07	RM 52.12: This backwater complex is connected to the mainstem Wenatchee River via surface water and potential hyporheic flow from upstream. A small tributary stream also feeds this unit from the adjacent hillslope. 10-IZ-07 is massive enough in scale (~ 3.7 acres) and unique enough in character that it has been designated a separate IZ unit. This unit occupies interconnected abandoned scrolls on the low elevation floodplain pocket (10-OZ-03) on river-left. This extensive backwater has several interconnected coves. Bordering and within the unit is a mature mix of riparian and wetland vegetation that includes willow, dogwood, hawthorne, sedges, rushes and aquatic macrophytes. The mouth of this backwater unit where it joins the Wenatchee River is ~ 280 feet across.	
10-IZ-08	RM 51.65-52.52: Channel morphology is low gradient, straight, plane-bed glide. Substrate ranges from small cobbles to sands. This unit is lacking habitat and geomorphic complexity. River-right is a low semi-vertical bank with well-established vegetation. River-left has a narrow strip of low elevation floodplain banks that are well vegetated with mixed riparian species at RM 51.65-51.9. Otherwise, river-left is a high steep terrace of glacial deposits that acts as a source of sediment and LWD to the system. There are no depositional features within the active channel unit.	No established road access to channel.
10-OZ-01	RM 53.57-53.67: This is a low elevation floodplain surface located at the downstream side of the confluence of Nason Creek and the Wenatchee River. Extending from 10-OZ-01 is a developing gravel point bar. This surface is frequently seasonally inundated. Visible splay channels across the middle of this unit indicate that occasional high flow events have scoured this surface. Vegetation is successional with elongate bands of willow established along the tops of the scrolls. The older more mature vegetation occurs on the inland side of the unit.	

10-OZ-02	RM 52.63-53.15: This is a low elevation floodplain surface located on river-left. The surface is well-vegetated with established riparian trees and shrubs including willow, dogwood, cottonwood, spirea, and vine maple. Significant backwater complexes exist within the 10-OZ-02 floodplain unit.	No established road access to the floodplain unit.
10-OZ-03	RM 52.63-53.15: This is a low elevation floodplain surface located on river-left. The surface is well-vegetated with established riparian trees and shrubs including willow, dogwood, cottonwood, spirea, and vine maple. A significant backwater complex exists within the 10-OZ-03 floodplain unit.	No established road access to the floodplain unit.
10-OZ-04	RM 51.65-52.28: This is a wide, low elevation floodplain surface that is inundated frequently. The surface is covered with a thick well-established mix of riparian trees and shrubs. Significant off-channel habitat located in abandoned channel scars exist across this floodplain unit and the inland side of 10-DOZ-03. Most of the off-channel habitat is currently functioning as well developed wetlands that receive ground water influx from adjacent upland surfaces and hyporheic flow from the Wenatchee River. An inlet at RM 51.65 connects a downstream section of this habitat at high flows creating a seasonal backwater.	No established road access to downstream section; there is road access to upstream section; properties are private but people are interested in restoration work.
10-OZ-05	RM 51.65-51.9: This is a very narrow (50 ft) elongate low-elevation floodplain surface located on RL at the base of confining terraces. The floodplain is composed of deposits from the channel and the hillslope. This unit is connected downstream to 9-OZ-02, both of which are inundated regularly during seasonal high flows. The surface is covered with a well-established mix of riparian trees and shrubs.	
10-DOZ-01	RM 53.57-53.6: The surface of this unit has experienced significant alterations. Large quantities of fill have been added and buildings with parking lots have been constructed on top of most of this unit. The land side of unit 10-DOZ-01 is bordered by Hwy 207. Besides a few trees and shrubs near the bank all natural riparian vegetation has been altered. Riprap boulders have been placed along the length of the unit's bank.	Properties are occupied, riprap is hardening bank to reduce channel migration into occupied surface; Hwy 207 is in use.
10-DOZ-02	RM 52.6-53.57: The surface of this unit has been significantly altered. Hwy 207 borders its upstream end, successfully reducing the inputs of hyporheic and discharge events from Nason Creek and the upper Wenatchee to this surface. At the upstream land side, additional fill has been added to the surface and buildings with parking lots have been constructed. A large berm of graded fill material (~0.2 acres) acts as an additional barrier. The remainder of the floodplain surface is low elevation with sand dominated soils. Disconnection has occurred as a result of relatively dense residential development that includes roads, fill and grading, vegetation removal/alteration, riprap and retaining walls, and home-sites.	Properties are occupied, riprap is hardening bank to reduce channel migration into occupied surface, Hwy 207 is in use.
10-DOZ-03	RM 52.28-52.6: This is a wide low elevation floodplain surface with silty-loam dominated soils. This surface is moderately altered. Inundation occurs regularly but the surface is not functioning as connected floodplain habitat. Disconnection has occurred as a result of some residential development that includes roads, fill and grading, minor vegetation removal/alteration and home-site construction. The inland side of this unit contains extensive functioning wetland complexes that receive ground water influx from adjacent upland surfaces and hyporheic flow from the river. At RM 52.35 R large boulder riprap and road grade material currently block a potential high-water backwater inlet.	Properties are privately owned but people are interested in restoration work.

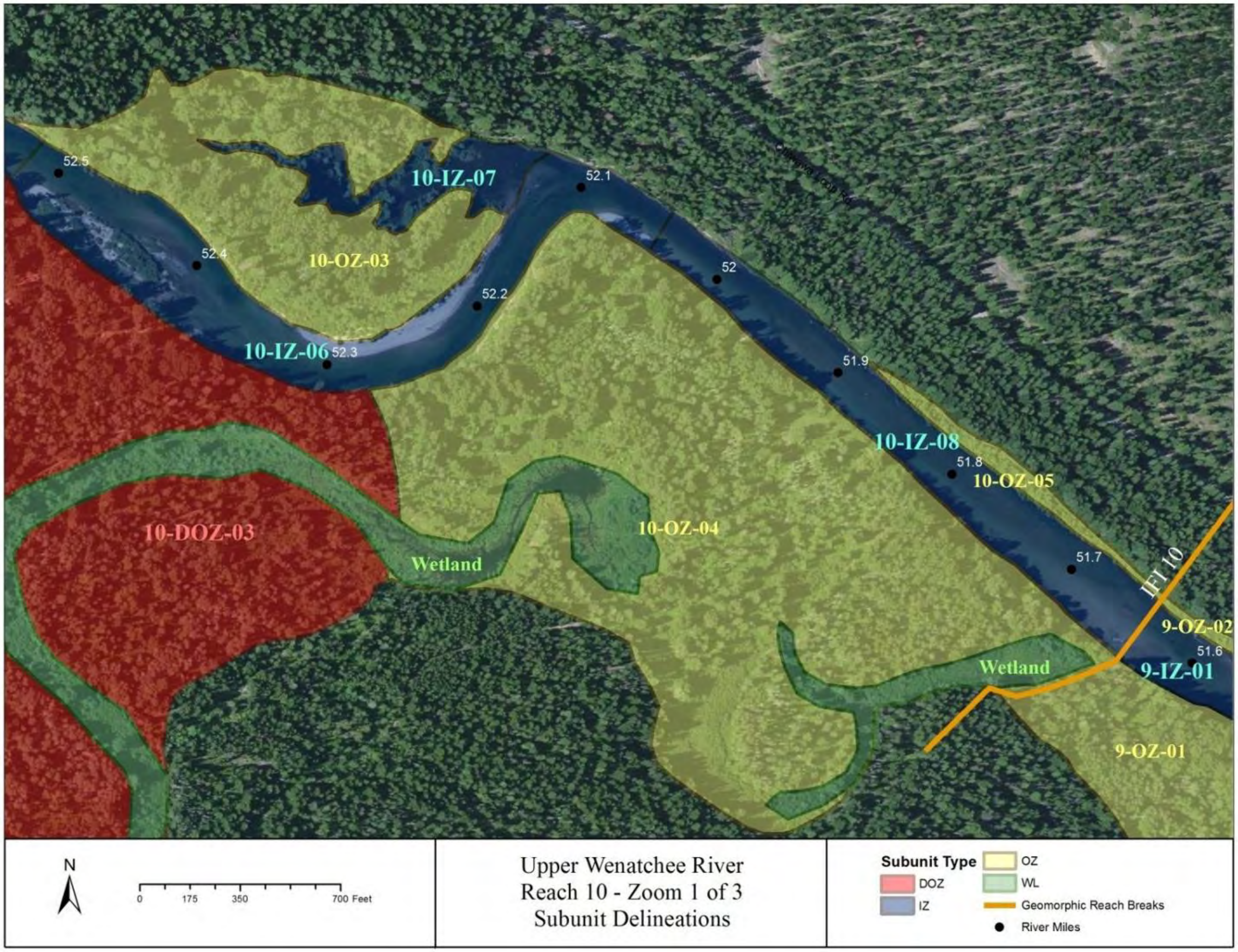


Figure 24. Subunit delineation map for downstream end of Reach 10. Flow is from northwest to southeast.

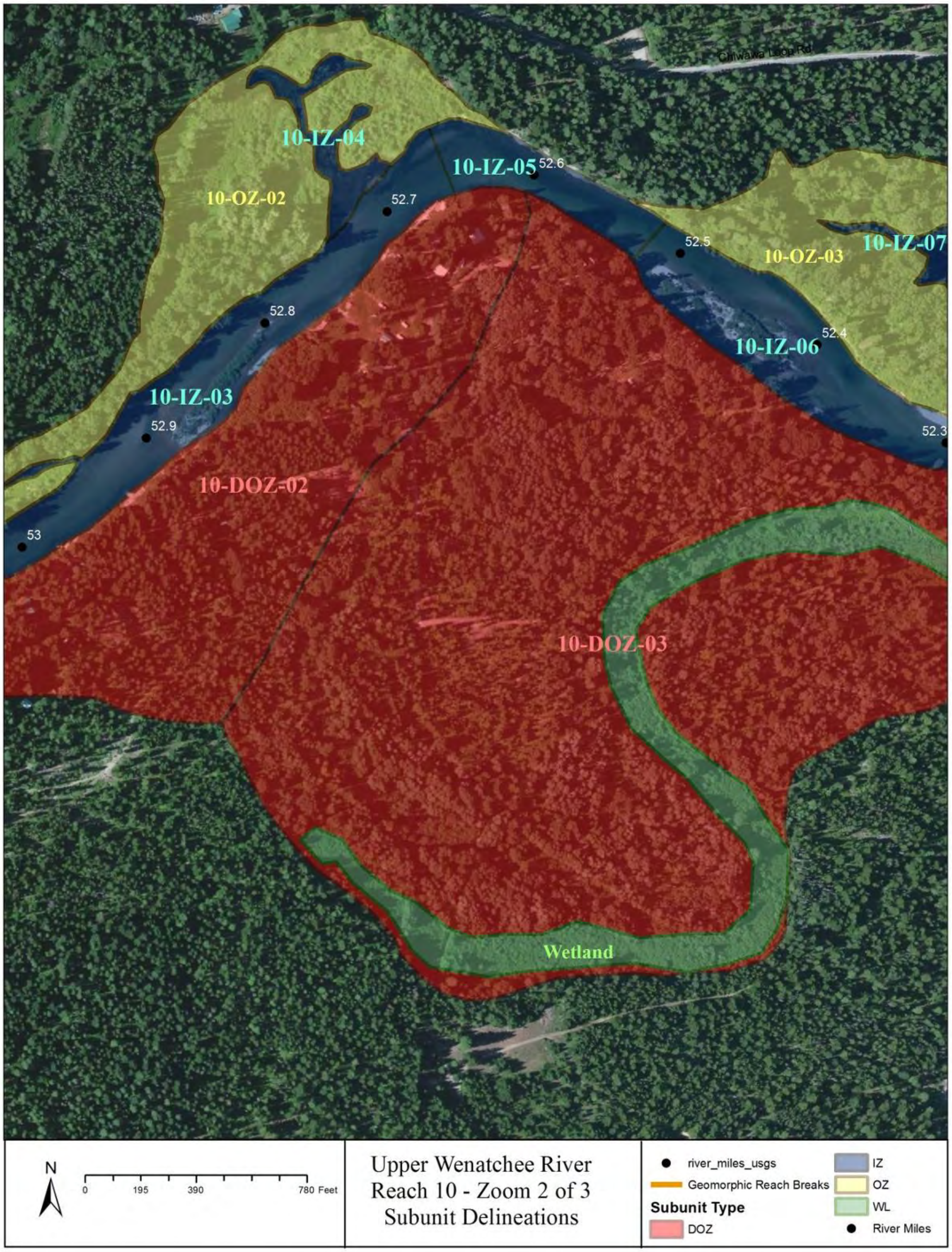


Figure 25. Subunit delineation map for Reach 10. Flow is from west to east.

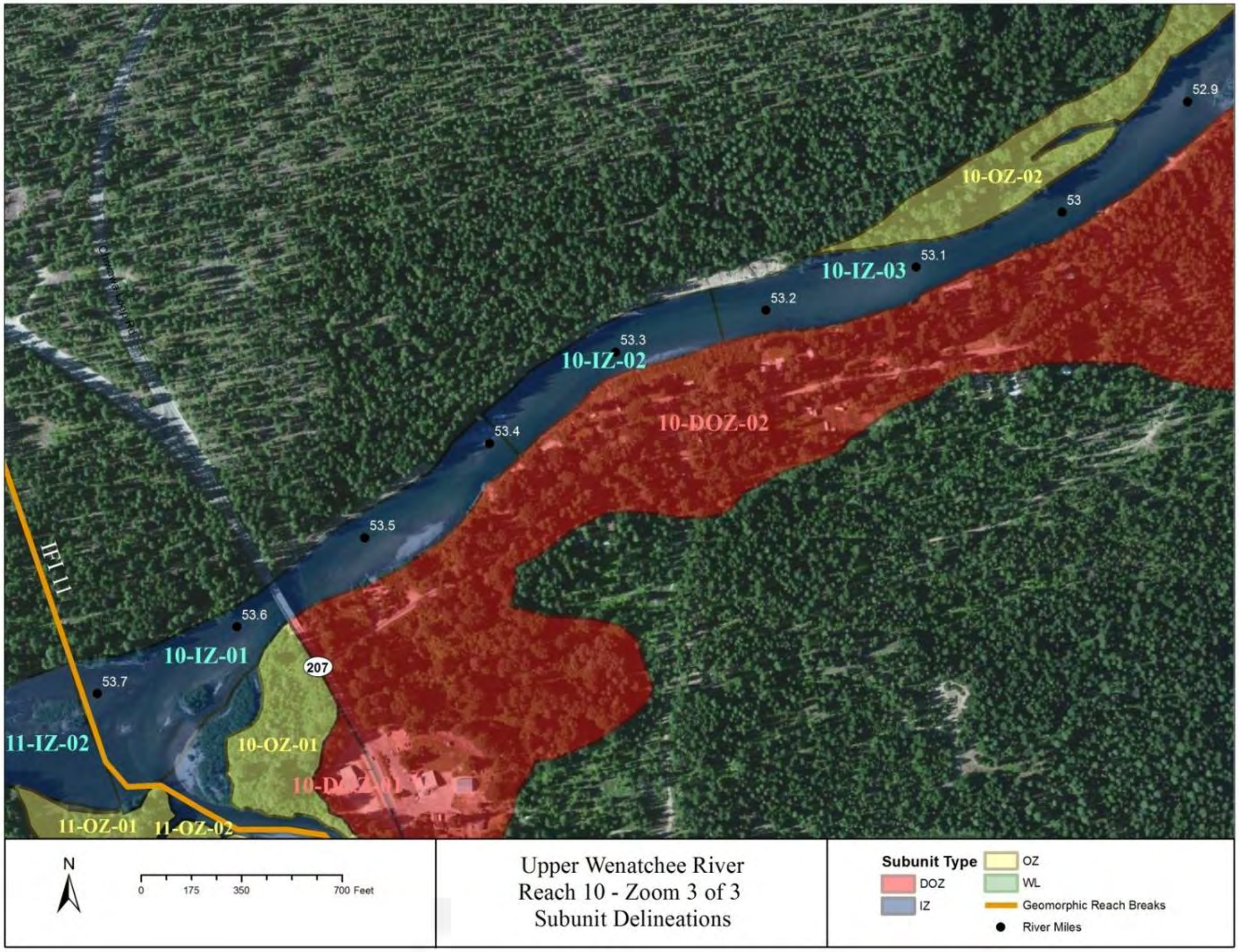


Figure 26. Subunit delineation map for the upstream end of Reach 10. Flow is from west to northeast.

3.11 REACH ELEVEN

Sub-Unit	Description	Potential Constraints
11-IZ-01	RM 53.8–54.15: The channel in this area is incised into glacial deposits creating a naturally confined channel with steep terraced banks. Human land-use practices have resulted in further incision and reduced channel complexity. Channel morphology is classified as a low gradient, plane-bed, glide unit. Substrate is comprised of cobbles to sands with few glacially deposited large boulders. Considering the potential supply from Lake Wenatchee upstream and the forested slopes of the adjacent terrace, this unit is lacking in LWD recruitment.	Property owned by WA State Parks and Recreation. Site is well utilized for recreation (boating, camping, and hiking); Hwy 207 and bridge downstream 0.25 miles.
11-IZ-02	RM 53.67–53.8: Velocity of flow is increased in IZ-02 compared to IZ-01. Large wood is accumulating behind a large glacially deposited boulder at mid-channel. A set of bars and islands are developing downstream of the boulder where minor large wood is accumulating. The left bank of the channel is confined by a terrace of glacial deposits. The channel and its valley widen on the right bank in this unit as it enters the upper-most portion of the Nason Creek alluvial fan. The flow dynamics between Nason and the Wenatchee are currently creating an eddy bay on river-right that is relatively shallow but maintains good connectivity to the adjacent floodplain. At the upstream most area of the eddy bay is a backwater of approximately 3,000 ft^2 with some minor LWD at its margins. Substrate in this unit is cobbles to sands.	The nearest road and trail access is through WA State Parks and Rec lands. Acquiring approval for constructing log jams upstream of HWY 207 and bridge.
11-OZ-01	RM 53.67-53.77: This is a low well-vegetated floodplain surface that is frequently inundated. Unit 11-OZ-01 is located at the upstream end of the Wenatchee River and Nason Creek confluence. Established vegetation includes mature cedar, dogwood, vine maple, and spirea. There is a WA State Parks and Rec trail that bisects this unit although it is owned by the US Forest Service.	
11-OZ-02	RM 53.6-53.7: Well-vegetated functioning floodplain surface on RL of lower Nason Creek. The floodplain has low, gradually sloping banks. Floodplain scarring visible in LiDAR indicates that flow and depositional processes associated with this unit have included both Nason Creek and the mainstem Wenatchee River. It is assumed that hyporheic input from the Wenatchee is currently influencing this unit's processes. Primary vegetation is willow, dogwood, and hawthorn near the channel's edge and mixed conifers at the inland side.	

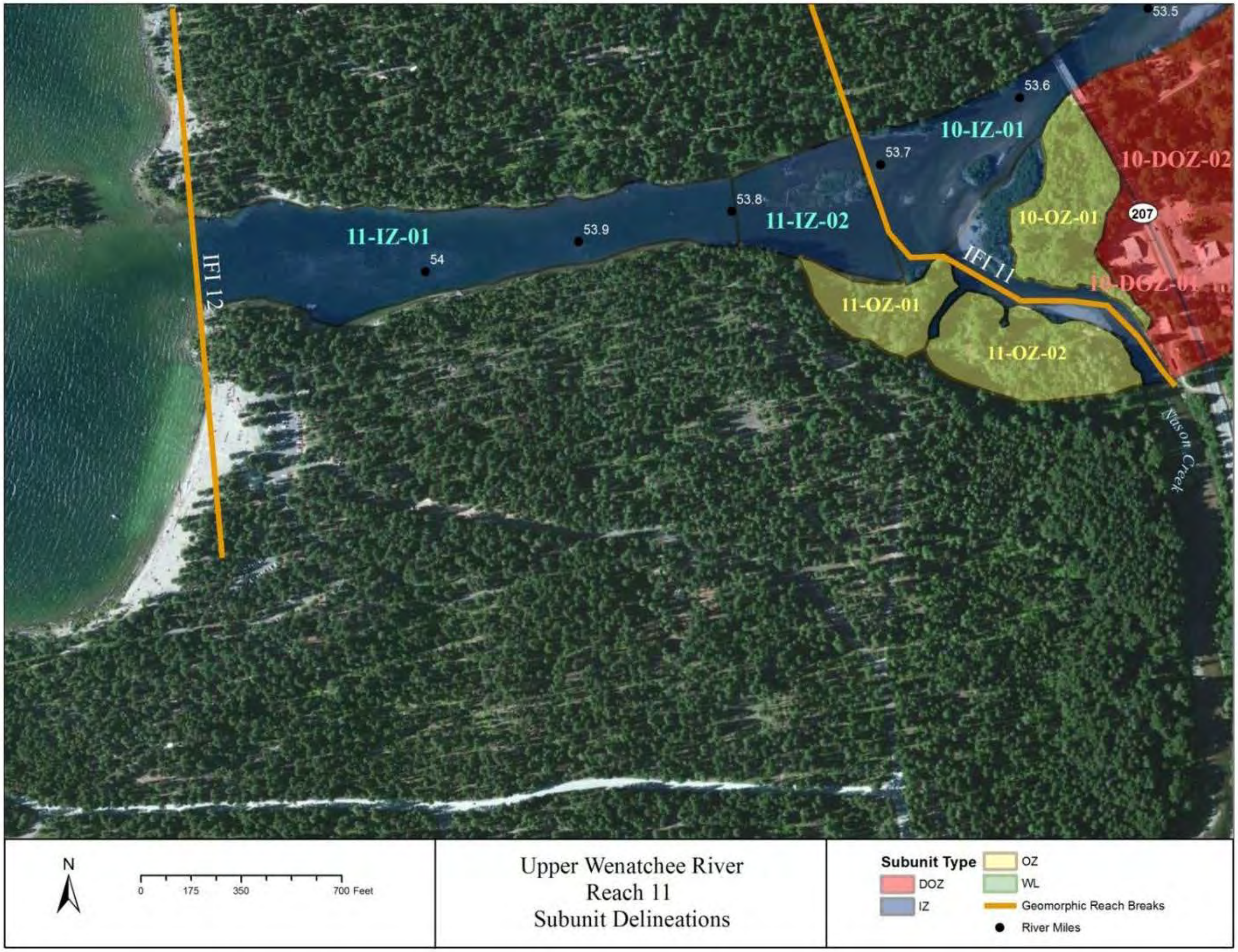


Figure 27. Subunit delineation map for Reach 11. Flow is from west to east.

4 REFERENCES

US Bureau of Reclamation (USBR). 2009. Stormy Reach Assessment – Entiat River. US Department of the Interior, Bureau of Reclamation, Pacific Northwest Region, Boise, ID.

Appendix C

Reach-Based Ecosystem Indicators (REI)

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1 INTRODUCTION

The REI provides a consistent means of evaluating biological and physical conditions of a watershed in relation to regional standards and known habitat requirements for aquatic biota. These indicators, along with other scientific evaluations, describe the current quality of stream biophysical conditions and can help inform restoration targets and actions. The REI indicators used in this assessment are adaptations from previous efforts including the NMFS matrix of pathways and indicators (NMFS 1996) and the USFWS (1998). With a few exceptions that are noted, the REI are based on the USBR's latest adaptations and use of these indicators (USBR 2011).

The REI evaluation for the Upper Wenatchee River was conducted using field data, observations, previous studies, and available data for the study area. In particular, the rankings were developed based on: 1) quantitative inventory information from the Habitat Assessment performed as part of the Reach Assessment, 2) assessment of geomorphic patterns and processes and how they have deviated, if at all, from historical conditions, and 3) analysis of existing watershed assessments and data (e.g. available ArcMap layers).

2 PATHWAY: WATERSHED CONDITION

2.1 GENERAL INDICATOR: WATERSHED ROAD DENSITY AND EFFECTIVE DRAINAGE NETWORK

2.1.1 Metric Overview

Watersheds with high road density can alter drainage networks and increase fine sediment loads to the river (USFS 2006). Soil erosion and mass wasting have been demonstrated to be higher in areas where there are high road networks than in undisturbed areas (Amaranthus et al 1985). Road networks can increase the frequency and quantity of sediment pulses to streams. Increased fine sediment can adversely affect aquatic habitat in numerous ways (Waters 1995, Wilber and Clarke 2001), including suffocation of salmonid eggs or larvae, reduced forage success due to impaired water clarity, limiting the growth of aquatic plants, channel instability from altered sediment budgets, and adverse physiological effects on invertebrates.

Criteria: From USFWS (1998), modified by USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Watershed Condition	Effective Drainage network and Watershed Road Density	Increase in Drainage Network/Road Density	Zero or minimum increase in active channel length correlated with human-caused disturbance **And** Road density <1 *miles/mile²*	Low to moderate increase in active channel length correlated with human-caused disturbance **And** Road density 1 to 2.4 *miles/mile²*	Greater than moderate increase in active channel length correlated with human-caused disturbance **And** Road density >2.4 *miles/mile²*

2.1.2 Assessment Results

Road density was calculated using Chelan County's roads ArcMap layer. Road density was calculated for the watershed area contributing to the study area (combining the HUC-12 layer (170200110701) and HUC-10 layers (1702001101, 1702001102, 1702001103). Road density for the entire contributing watershed area was 0.83 miles per square mile.

Historical channel planform and length were evaluated by georeferencing historical survey maps of the Upper Wenatchee. Evaluation of historical channel planform from 1887 and 1911 survey maps indicated that little to no increase in active channel length has occurred that is associated with human disturbance.

2.1.3 REI Rating

Watershed Rating: **Adequate**

2.2 INDICATOR: DISTURBANCE REGIME (NATURAL & HUMAN-CAUSED)

2.2.1 Metric Overview

Environmental disturbance is a natural ecosystem process that is important for creating and maintaining habitats over time. Natural disturbance events include wildland fire, flooding, landslides, and windstorms. In some cases, human alterations to the landscape can impair natural disturbance processes and create large catastrophic disturbance events or long-term ‘press’ disturbances that impair natural processes for extended periods. Artificial, human-caused disturbances include timber harvest and road-induced landslides. Human-caused ‘press’ disturbances include construction of roads, creation of impervious surfaces, and infrastructure that disconnects floodplains.

Criteria: From USFWS (1998).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Watershed Condition	Disturbance Regime	Natural/Human Caused	Environmental disturbance is short lived; predictable hydrograph; high quality habitat and watershed complexity providing refuge and rearing space for all life stages or multiple life-history forms. Natural processes are stable.	Scour events, debris torrents, or catastrophic fires are localized events that occur in several minor parts of the watershed. Resiliency of habitat to recover from environmental disturbances is moderate.	Frequent flood or drought producing highly variable and unpredictable flows, scour events, debris torrents, or high probability of catastrophic fire exists throughout a major part of the watershed. The channel is simplified, providing little hydraulic complexity in the form of pools or side channels. Natural processes are unstable.

2.2.2 Assessment Results

The disturbance history in the upper Wenatchee subbasin is deemed functioning at an **At Risk** condition. The rating reflects historical accounts of riparian timber harvest, splash damming, log drives, and development in and around the floodplain. Furthermore, fire suppression within the basin has elevated the risk of catastrophic wildland fires (USFS 1999). These alterations include past human disturbance to which the system is still recovering from or on-going ‘press’ disturbances that have a persistent and long-lasting impact. There is also risk for potential future catastrophic disturbance (e.g. stand-replacing fire) to the basin.

2.2.3 REI Rating

Watershed Rating: **At Risk**

2.3 INDICATOR: STREAMFLOW (CHANGE IN PEAK/BASE FLOW)

2.3.1 Metric Overview

Stream discharge and channel morphology are directly linked to the magnitude, timing, duration, and frequency of hydrologic inputs to the system. Hydrology is predominantly controlled by climate, vegetation, geology, and human alterations and impacts. Potential human impacts to hydrologic systems include flow regulation (e.g. dams), water withdrawals (e.g. for irrigation), widespread timber harvest, increased impervious surfaces, or intensive road building.

Criteria: From USFWS (1998), modified by USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Watershed Condition	Streamflow	Change in Peak/Base flows	Magnitude, timing, duration and frequency of peak flows within a watershed are not altered relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.	Some evidence of altered magnitude, timing, duration and frequency of peak flows relative to natural conditions of an undisturbed watershed of similar size, geology, and geography	Pronounced evidence of altered magnitude, timing, duration and frequency of peak flows relative to natural conditions of an undisturbed watershed of similar size, geology, and geography

2.3.2 Assessment Results

The hydrology of the Wenatchee Basin is driven by a combination of precipitation and snowmelt. Precipitation, in the form of snow and rain, varies with elevation and distance from the Cascade crest. The higher elevations of the Wenatchee Basin receive 50 to 140 inches of precipitation a year, whereas lower areas receive less than 8.5 inches (WDOE 1983, Andonegui 2001, CCG et al. 2003). These low areas are also further east, and more affected by the rain shadow of the Cascades.

Spring snowmelt dominates the seasonal streamflow pattern in the basin (Figure 2). Snowmelt primarily occurs during the spring and early summer, and is driven by changes in ambient air temperature, snowpack mass, and the elevation distribution of the season’s snowpack (WDOE 1983). Peak runoff usually occurs from April through July, with the highest rates typically in late June (USFS 1999). The Wenatchee typically returns to baseflows in September (MWG 2003).

The 1-, 2-, 5-, 20-, 50-, 100-, 200-, and 500-year recurrence intervals were calculated for the Wenatchee River using the USGS gage at Plain for the period 1911- present. Hydrologic data was then compared by time period. This comparison shows that floods have remained relatively constant, with the exception of 1991 to 2011 (Figure 1). These higher flows coincide with the three top water events on record (Table 4). These likely correlate with events that had coincidental occurrences of high precipitation and snowmelt, such as in the flood of 1948 (WDOE 1983). Precipitation records indicate that rainfall rates increased during the late 1940s and early 1950s, decreased in the 1960s, and have risen steadily since then. This analysis suggests that there could be potential changes in the watershed hydrologic regime (i.e. increased peak flows); however, the data and analysis are not sufficient enough to document changes or causation with certainty.

Climate change modeling indicates that rainfall is expected to increase one to two percent by 2040, and four percent by 2080 (e.g. Mote and Salanthe 2009). Climate change models (synthesized by CIG 2009) also indicate that changes will likely result in an increase in winter stream flows, earlier and lower peak runoff, and lower summer baseflows (Figure 3). These analyses suggest that human-induced climate change is likely to have an effect on the magnitude, timing, duration, and frequency of streamflows.

Based on the potential effects of climate change on watershed hydrology, this metric is rated **At Risk**.

2.3.3 REI Rating

Watershed Rating: **At Risk**

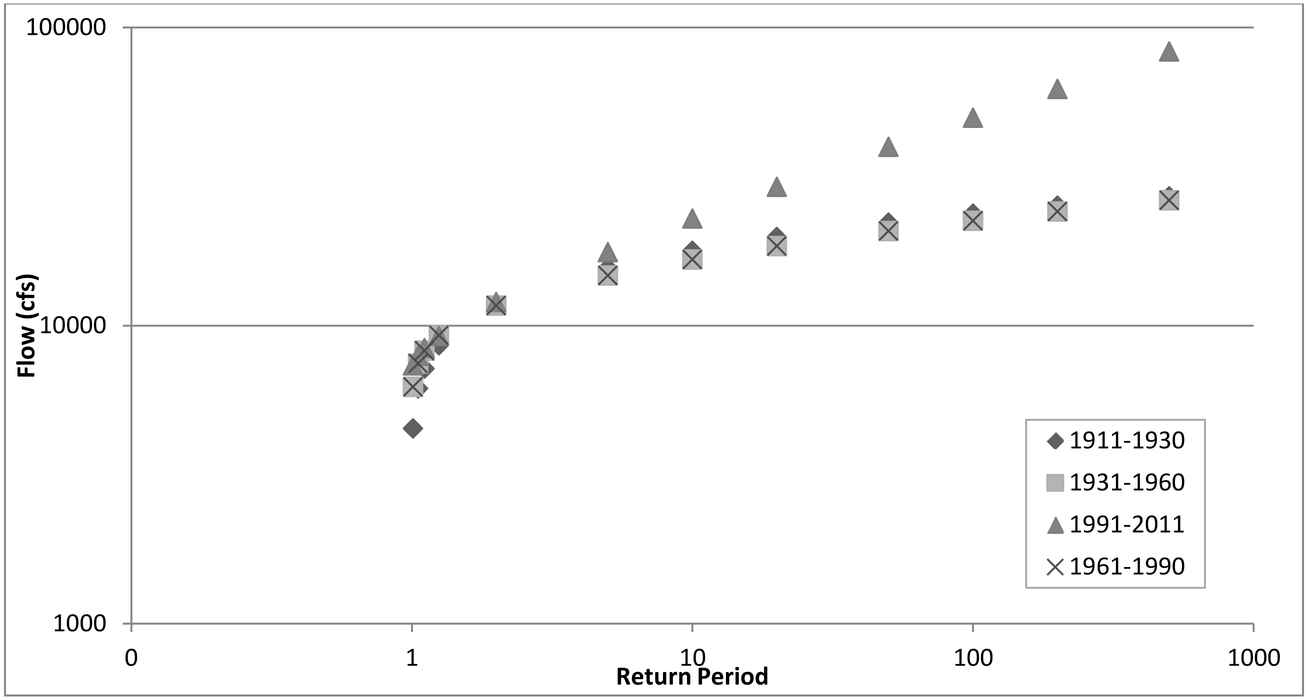

Figure 1. Changes in Hydrologic Regime Over time, beginning in 1911. Discharge was measured at the USGS gage at Plain, WA (Gage 12457000, 1911 to present).

Table 1. Top 20 water events (floods) since 1911.

Event Rank	Water Year	CFS
1	1996	36,100.0
2	1991	33,200.0
3	2007	23,600.00
4	1948	22,700.00
5	1922	21,100.00
6	1918	18,700.00
7	1974	18,500.00
8	1976	18,000.00
9	1972	17,900.00
10	1956	17,100.00
11	1955	17,000.00
12	1916	16,700.00
13	1950	16,300.00
14	1999	16,200.00
15	2006	16,100.00
16	1949	16,000.00
17	1997	15,800.00
18	2008	15,400.00
19	1951	15,300.00
20	1961	15,100.00

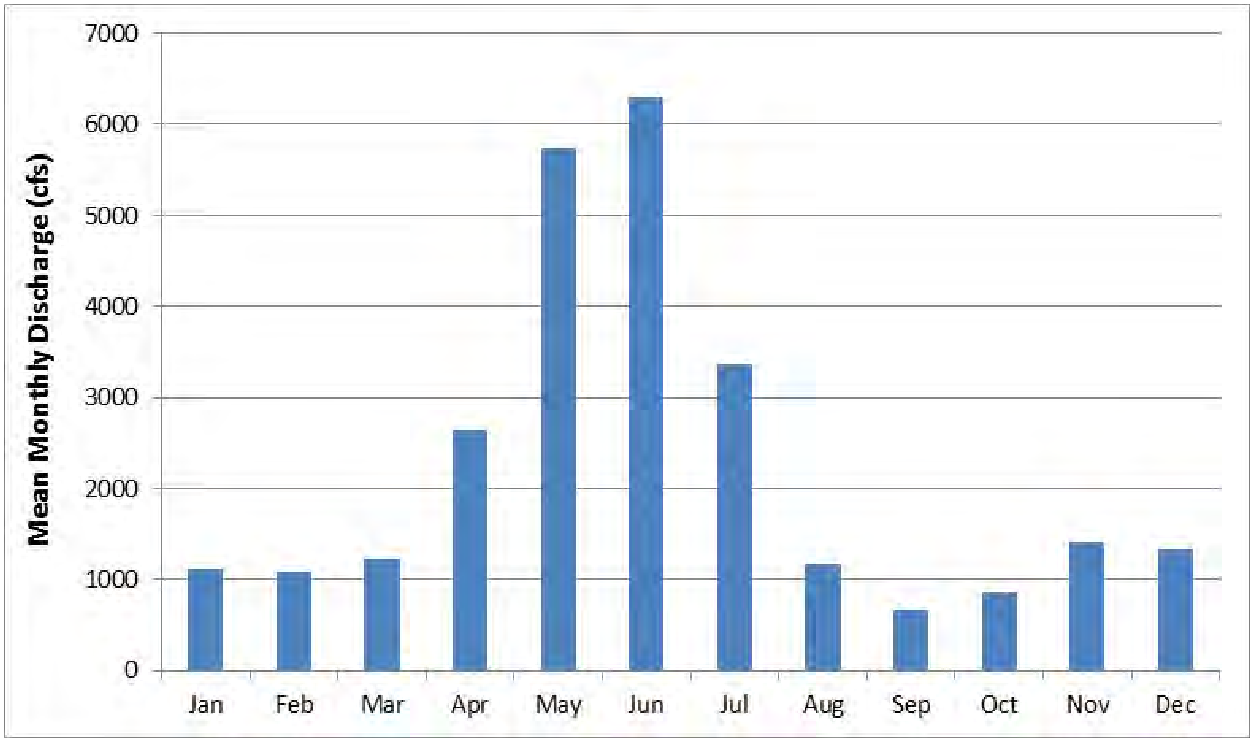

Figure 2. Mean monthly discharge for the period of record at the USGS gage at Plain, WA (Gage 12457000, 1911 to present).

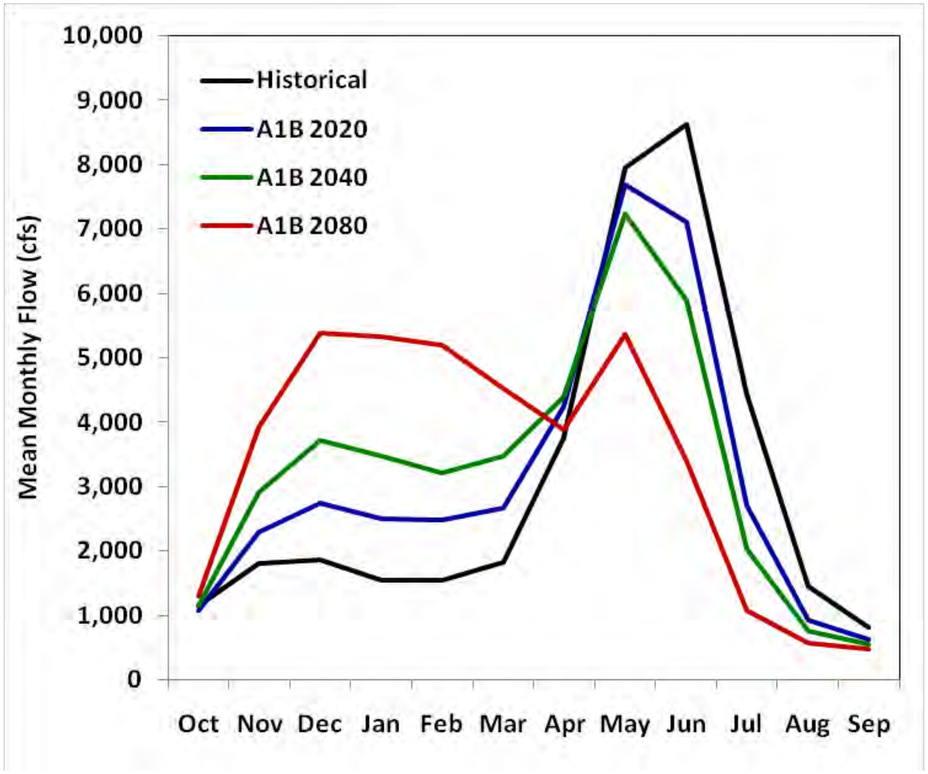

Figure 3. Projected impacts of climate change on the magnitude, timing, and frequency of the Wenatchee River at Peshastin (CIG 2009, Elsner 2011).

3 PATHWAY: REACH-SCALE HABITAT ACCESS

3.1 Physical Barriers – Main Channel Barriers

3.1.1 Metric Overview

This metric evaluates the presence or absence of fish passage barriers that affect upstream or downstream passage of fish in the Wenatchee River.

Criteria: From USFWS (1998), modified by USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Habitat Access	Physical Barriers	Main Channel Barriers	No manmade barriers present in the mainstem that limit upstream or downstream fish passage at any flows	Manmade barriers present in the mainstem that prevent upstream or downstream migration at some flows that are biologically significant	Manmade barriers present in the mainstem that prevent upstream or downstream migration at multiple or all flows

3.1.2 Assessment Results

No fish passage barriers were present on the mainstem Wenatchee River in the study area. Furthermore, the majority of tributaries were accessible to fish. The only barrier to fish passage observed was a perched culvert on Deadhorse Creek at RM 38.62 This tributary becomes naturally impassible within 200 feet, so this passage barrier is not limiting access to a significant amount of habitat.

3.1.3 REI Rating

General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11
Physical Barriers	Main Channel Barriers	adequate	adequate	adequate	adequate	adequate	adequate	adequate	adequate	adequate	adequate	adequate

4 PATHWAY: REACH-SCALE HABITAT QUALITY

4.1 Substrate – Dominant Substrate Fine Sediment

4.1.1 Metric Overview

Substrate conditions affect salmonid uses including spawning, egg incubation, and early rearing. Salmonids require adequately sized substrate that is free of excessive fines.

Criteria: Modified from USFWS (1998) and USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Habitat Quality	Substrate	Main Channel Barriers	Dominant Substrate is gravel or cobble (interstitial spaces clear), or embeddedness < 20%, <12% fines (<0.85mm) in spawning gravel or <12% surface fines of <6mm	Gravel and Cobble is subdominant, or if dominant, embeddedness is 20-30%; 12-17% fines (<0.85mm) in spawning gravel or 12-20% surface fines of <6mm	Bedrock, sand, silt, or small gravel dominant, or if gravel and cobble dominant, embededeness > 30%; >17% fines (<0.85mm) in spawning gravel or >20% surface fines of <6mm

4.1.2 Assessment Results

Bed substrate was based on pebble counts and the ocular estimates that were collected at each habitat unit. For most reaches, 1-2 pebble counts were collected per reach, except for reaches 4, 6, and 7 where high flows prevented pebble counts. The ocular estimate for each reach is the average of all the individual ocular estimates in the reach. The pebble count data are believed to be more reliable than ocular estimates; however, there were a greater number of ocular estimates and the ocular estimates have greater spatial coverage. For these reasons, the pebble count and ocular data were combined (and weighted evenly) for use in this analysis. They were first averaged within each reach to derive a pebble count and ocular count for each reach. These two values were then averaged together for each reach to obtain the substrate value used for the REI analysis (Table 8). In general, bed substrate in the Upper Wenatchee River was gravel and cobble, with smaller amounts of boulder, bedrock, and sand. Most reaches are considered **Adequate** with respect to substrate, except for reaches 4, 8, and 9, which are considered **At Risk** due to a higher incidence of fines.

Table 2. The values for this analysis used the average of the averaged pebble counts and the averaged ocular estimates. Reaches 4, 6, and 7 did not have pebble count data and so the values are the averaged ocular estimates only.

Total	**Reach 1**	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**	**Reach 7**	**Reach 8**	**Reach 9**	**Reach 10**	**Reach 11**
% Sand	12%	8%	13%	19%	8%	8%	12%	19%	16%	8%	12%
% Gravel	43%	27%	34%	29%	30%	17%	20%	40%	67%	59%	17%
% Cobble	42%	57%	44%	42%	50%	45%	33%	41%	15%	28%	61%
% Boulder	4%	8%	7%	8%	13%	30%	35%	2%	3%	3%	11%
% Bedrock	1%	1%	2%	2%	0%	0%	0%	0%	0%	0%	0%

4.1.3 REI Ratings

General Indicators	**Specific Indicators**	**Reach 1**	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**	**Reach 7**	**Reach 8**	**Reach 9**	**Reach 10**	**Reach 11**
Substrate	Dominant Substrate/Fine Sediment	adequate	adequate	adequate	at risk	adequate	adequate	adequate	at risk	at risk	adequate	adequate

4.1.4 INDICATOR: Large Woody Debris (LWD)

4.1.5 Metric Overview

For the purposes of this analysis, a variation was made to the LWD metric. We chose to use the western cascades 80 pc/mi target from NMFS (1996) as opposed to the eastern cascades 20 pc/mi target for the following reasons. First, based on measurements of wood in unmanaged streams in eastern Washington, Fox and Bolton (2007) determined that the NMFS (1996) standard is low for larger eastern Washington streams (5m-50m bankfull width), which had greater than 40 pc/mi on average. Because the bankfull widths on the upper Wenatchee are even larger than the streams included in the Fox and Bolton study (i.e. average of 90m), historical wood numbers would be expected to be even greater, primarily due to large log jams that are assumed to have been present in this reach historically (see discussion in the Reach Assessment in the Geomorphology section). Second, Reach 1, which serves as a reference reach due to its relatively undisturbed condition, has 142 pc/mi currently; and there is no reason to believe that wood numbers here would be higher now than under historical conditions. Lastly, the upper Wenatchee study area as a whole averages 64 pc/mi under existing conditions; consequently, achieving >80/pieces per mile is believed to be an appropriate and attainable restoration goal.

A second evaluation metric, log jam frequency, was added to the large wood indicator in order to better reflect the wood distribution types that would be expected under natural conditions (i.e. free of human influence). The **Adequate** condition was set at 4 jams per mile based on conditions found in Reach 1.

Criteria: See above description of criteria development.

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Habitat Quality	Substrate	Pieces per mile at bankfull	>80 pieces/mile >12'' dbh > 35' length; and adequate sources of woody material available for long and short term recruitment. And, At least 4 jams/mi (10 qualifying pieces per jam)	Currently meets piece frequency standards for **Adequate**, but lacks potential sources from riparian areas of wood debris recruitment to maintain that standard. And, 1-4 jams/mi	Does not meet standards for **Adequate** and lacks potential large woody material recruitment.

4.1.6 Assessment Results

Wood counts from the habitat surveys were queried to obtain counts of wood of the size classes used for this indicator (>12" diam; >35' long). Log jam counts were also derived from the habitat survey data. Only reaches 1, 3, and 11 met the piece frequency standard for **Adequate**, and only Reach 1 met the log jam standard (used rounded value) for **Adequate**.

Table 3. Large wood piece and jam frequency from the habitat survey (August 2011).

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11
Pieces/mi (>12" diam; >35' long)	142	26	133	35	17	38	2	29	48	50	115
Log jams/mi	3.8	1	1.2	0.8	0	0.7	0	0.8	0.5	1.5	0

4.1.7 REI Ratings

General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11
LWD	Pieces per mile at bankfull	adequate	unacceptable	at risk	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable

4.2 INDICATOR: Pools – Pool Frequency & Quality

4.2.1 Metric Overview

The pool frequency and quality metric was adapted for the Upper Wenatchee River. The largest bankfull channel width provided in the NMFS matrix is 65 to 100 feet, and 4 pools per mile is the standard for this width. Because Upper Wenatchee bankfull widths far exceed the criteria (ranging from 270 feet to 360 feet), reaches were primarily evaluated based on the pool quality metrics provided by NMFS (1996) (e.g. depth, substrate, cover, refugia), rather than number of pools.

Criteria: Adapted from NMFS (1996).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Habitat Quality	Pools	Pool frequency and quality	Pools have good cover and cool water and only minor reduction of pool volume by fine sediment; each reach has many large pools > 1m deep with good cover	Meets pool quality standards, but does not meet LW standards, so unable to maintain pools over time; reaches have few large pools (>1m) present with good fish cover	Lacking pools, pool quality is inadequate and there has been a major reduction of pool volume by fine sediment; reaches have no deep pools (> 1m) with good fish cover

4.2.2 Assessment Results

Pool frequency ranged from 0.0 to 2.7 pools/mile, with a mean pool spacing of 8.0 to 28.3 channel widths per pool. Reach 6 and 7 had no pool habitat. Reaches 10 and 11 had the greatest proportion of pool habitat (57% and 77%, respectively), although Reach 1 had the greatest number of pools/mile (2.7). Reaches 1 and 11 had the shortest pool spacing (9.4 and 8.0 channel widths per pool, respectively). Reaches 1 and 3 had the greatest number of deep pools with residual depths exceeding 3 ft (n=6 in both reaches). The majority of the pools throughout the study area were relatively deep, with shallow residual depths (<3 ft) comprising less than 7% of total pools. Most reaches were rated **At Risk** due to not meeting LW standards.

Table 4. Pools per mile based on the habitat assessment (August 2011).

Pools	**Total**	**Reach 1**	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**	**Reach 7**	**Reach 8**	**Reach 9**	**Reach 10**	**Reach 11**
Pools per mile	1.6	2.7	0.9	1.9	2.2	1	0	0	1.8	1.4	2.3	2
Residual Depth (% of pools)												
Pools < 3 ft	7%	0%	0%	0%	33%	0%	0%	0%	0%	0%	20%	0%
Pools 3-6 ft	20%	33%	100%	50%	0%	0%	0%	0%	0%	0%	0%	0%
Pools 6-9 ft	43%	17%	0%	33%	34%	67%	0%	0%	100%	0%	80%	100%
Pools 9-12 ft	27%	33%	0%	17%	33%	33%	0%	0%	0%	100%	0%	0%
Pools > 12 ft	3%	17%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

4.2.3 REI Ratings

General Indicators	**Specific Indicators**	**Reach 1**	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**	**Reach 7**	**Reach 8**	**Reach 9**	**Reach 10**	**Reach 11**
Pools	Pool frequency and quality	adequate	at risk	at risk	at risk	at risk	unacceptable	unacceptable	at risk	at risk	at risk	at risk

4.3 INDICATOR: Off-Channel Habitat

4.3.1 Metric Overview

Off-channel habitats include backwaters, abandoned oxbows, floodplain channels, and flow-through side-channels. Off-channel habitats that are accessible by fish from the mainstem provide important rearing habitats. Off-channel areas can provide various benefits to rearing fish including flood refuge, temperature refuge, and productive feeding areas.

Criteria: Modified from USFWS (1998).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Habitat Quality	Off-Channel Habitat	Connectivity with main channel	Reach has ponds, oxbows, backwaters, and other low-energy off-channel areas with cover; similar to conditions that would be expected in the absence of human disturbance	Reach has some ponds, oxbows, backwaters, and other low-energy off-channel areas with cover; but availability or access is less than what would be expected in the absence of human disturbance	Reach has few or no ponds, oxbows, backwaters, or other off-channel areas relative to what would be expected in the absence of human disturbance.

4.3.2 Assessment Results

A total of 33 wetted side-channel habitat units were measured in the study area during the habitat survey. Reach 1 had the greatest area of side-channel habitat and Reach 3 had the greatest number of side-channel units. Reaches 5 and 7 had no side-channel habitat. Side-channel riffles (n=21) accounted for 64% of all side-channel units. Side-channel pools (n=8) accounted for 24%, all occurring in Reaches 1 and 3. Average and maximum side-channel depths were 1.7 feet (stdev 0.9) and 3.7 feet (stdev 1.8) respectively, with the deepest side-channels observed in Reach 8.

In addition to side-channels, the Upper Wenatchee study area had nine marshes ranging from small backwaters to large open water ponds. Off-channel marshes were identified in Reaches 1, 8, 9, and 10. Reach 9 had the greatest number of marsh units (n=3) and Reach 10 had the largest marsh habitat within the study area.

Natural and artificial confinement limits off-channel habitat throughout some portions of the study area. In some areas, human development of riparian areas and floodplains also impairs floodplain and channel migration processes that are necessary to create and maintain off-channel habitats. The primary impairments to off-channel habitat occur along the reaches that flow through the community of Plain, from Reach 4 through Reach 7. Roads, bank armoring, berms, and channel/floodplain filling have reduced the abundance and connectivity of off-channel habitat and have impaired the floodplain and channel migration dynamics necessary to create and maintain off-channel habitats over time.

4.3.3 REI Ratings

General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11
Off-Channel Habitat	Connectivity with main channel	adequate	adequate	at risk	unacceptable	unacceptable	at risk	unacceptable	at risk	at risk	at risk	at risk

5 PATHWAY: CHANNEL FORMS & PROCESSES

5.1 Channel Dynamics - Floodplain Connectivity

5.1.1 Metric Overview

Floodplains serve a number of significant geomorphic and ecological functions including conveyance of flood waters, sediment source and storage, supply of large wood, and development of diverse habitat for aquatic and terrestrial species (e.g. Allen 1970, Zwolinski 1992, Nanson and Croke 1992). Floodplain connectivity was evaluated through geomorphic and hydraulic analysis. As part of the geomorphic assessment, floodplain areas were mapped and were given a designation of ***connected*** or ***disconnected*** based on the degree to which human influence has altered floodplain processes including floodplain inundation frequency, inundation extent, flood energy and scour, and channel migration. The hydraulic analysis was used to confirm the floodplain mapping and to further evaluate the effects of human development on floodplain inundation patterns.

Provided here is a brief summary of the floodplain mapping; more information can be found in Appendix B. Floodplains were initially delineated using LiDAR imagery, and then verified using hydraulics analysis and field surveys. A floodplain was determined to be ***disconnected*** if processes such as flood inundation and channel migration had been significantly altered due to anthropogenic modifications. A designation of ***disconnected*** does not mean the floodplain has been completely isolated from the main river, but it does indicate that significant human alterations have impaired floodplain and channel migration processes compared to historical conditions. These alterations can be direct contemporary (or remaining) alterations including straightening, ditching, filling, riprap, levees, road embankments, or bridges; or they can be historical alterations, such as splash damming and log drives, that have caused channel incision that persists today.

Criteria: Modified from USFWS (1998).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Channel	Dynamics	Floodplain connectivity	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession	Reduced linkage of wetlands, floodplains, and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession	Severe reduction in hydrologic connectivity between off-channel wetland, floodplain, and riparian areas; wetland extent drastically reduced and riparian vegetation/succession altered significantly

5.1.2 Assessment Results

Table 13 includes the percentage of mapped floodplain areas that were identified as "disconnected" as part of the geomorphic analysis. See Appendix B [##] for additional information. REI ratings were determined based on the degree of disconnection of floodplains. A ***disconnection*** amount of <20% is considered **Adequate**; 20-80% is **At Risk**; and greater than 80% is **Unacceptable**.

Table 5. Percent of "disconnected" floodplain (see Appendix B for more information).

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11
Proportion of floodplains that are "disconnected"	0%	14%	55%	85%	81%	90%	80%	61%	64%	62.8%	0%

5.1.3 REI Ratings

General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11
Channel Dynamics	Floodplain connectivity	adequate	adequate	at risk	unacceptable	unacceptable	unacceptable	unacceptable	at risk	at risk	at risk	adequate

5.2 INDICATOR: Bank stability/Channel migration

5.2.1 Metric Overview

Low gradient alluvial channels adjust laterally via bank erosion and channel avulsions (rapid shifting of channel location). These processes play important roles in maintenance of long-term aquatic habitat via large wood recruitment, gravel recruitment, and creation of new instream habitats. The rate and frequency of channel migration are a function of numerous physical and biological processes including hydrologic regime, underlying geology, sediment supply, streambank vegetation, and floodplain hydraulic roughness. Human alterations that affect these processes will affect the rate and frequency of channel migration. Common human alterations that affect rates of channel migration include bank armoring, removal of streambank vegetation, channelization, levee building, and development within the floodplain.

Criteria: From USBR (2011).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Channel	Dynamics	Bank Stability/Channel Migration	Channel is migrating at or near natural rates.	Limited amount of channel migration is occurring at a faster/slower rate relative to natural rates, but significant change in channel width or planform is not detectable; large woody debris is still being recruited.	Little or no channel migration is occurring because of human actions preventing reworking of the floodplain and large woody debris recruitment; or channel migration is occurring at an accelerated rate such that channel width has at least doubled, possibly resulting in a channel planform change, and sediment supply has noticeably increased from bank erosion.

5.2.2 Assessment Results

There has been significant human alteration and artificial armoring of streambanks that has reduced the ability of the stream to migrate laterally. Incidences of bank armoring are more prevalent than human-induced erosion, suggesting that impairments to channel migration are primarily related to a reduction in migration rates as opposed to acceleration of migration rates. Legacy incision (e.g. from log drives) and floodplain alterations (e.g. bridges and floodplain fill) have also likely reduced channel migration rates compared to historical conditions. An analysis of historical planform changes was performed and indicated relatively little change since 1911, which is the date of the earliest reliable map. However, log drives took place prior to this and likely resulted in channel bed degradation (incision) that served to limit channel migration, which was subsequently further limited by residential development in the mid-1900s.

Bank armoring in the form of riprap, concrete walls, concrete stairways, bridge abutments, and levees were mapped as part of the geomorphic assessment. The total length of bank armoring was calculated as a percentage of reach length (Table 6). This does not include areas of channel upstream and downstream of bridges where channel migration might be affected by the bridge. Reaches with greater degrees of bank armoring were considered more impaired than those with less armoring. For this analysis, reaches with <5% armoring were assumed **adequate**, 5-10% **at risk**, and >10% **unacceptable**.

Table 6. Percent bank armoring by reach.

Reach	Percent bank armoring by length[1]
1	2%
2	0%
3	17%
4	10%
5	13%
6	5%
7	3%
8	2%
9	0%
10	14%
11	2%

[1]*Total length of armoring divided by length of both banks*

5.2.3 REI Ratings

General Indicator	Specific Indicator	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11
Channel Dynamics	Bank stability/ Channel migration	adequate	adequate	un-acceptable	un-acceptable	un-acceptable	at risk	adequate	adequate	adequate	un-acceptable	adequate

5.3 INDICATOR: Vertical Channel Stability

5.3.1 Metric Overview

Alterations to stream energy, sediment transport, and bed stability can lead to aggradation or degradation (incision) of the streambed. Aggradation is the raising of the streambed elevation and incision is the lowering of the streambed elevation. Alterations that could affect vertical channel stability include bank armoring, log drives / splash damming, levee building, channel straightening, and channelization.

Criteria: From USBR (2011).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Channel	Dynamics	Vertical channel stability	No measurable trend of aggradation or incision and no visible change in channel planform.	Measureable trend of aggradation or incision that has the potential to but not yet caused disconnection of the floodplain or a visible change in channel planform (e.g., single thread to braided).	Enough incision that the floodplain and off-channel habitat areas have been disconnected; or, enough aggradation that a visible change in channel planform has occurred (e.g., single thread to braided).

5.3.2 Assessment Results

Since the period of last glaciation, the Wenatchee River has been naturally downcutting through glacial till and outwash, leaving behind abandoned alluvial terraces and establishing new floodplains. This metric evaluates vertical channel stability on a much more recent geologic timescale, evaluating shorter-term sediment storage and examining if aggradation or incision has become accelerated due to human alterations. The degree of alteration to vertical channel stability was assessed using results of the hydraulic and geomorphic analyses. The extent of floodplain inundation, width-to-depth ratios, and the presence of human alterations known to affect vertical stability were used to help determine the REI ratings. In general, most of the observed incision is believed to be related to natural incision into glacial terraces. In some reaches, additional incision is believed to have occurred due to past log-drives and more recent floodplain constrictions (i.e. bridges), bank armoring, and floodplain fill.

Reaches determined to be **unacceptable** include reaches 4 and 9. Inundation mapping conducted as part of the hydraulics analysis shows that considerable floodplain constriction is created by the Burlington Northern Railroad Bridge crossing at the downstream end of Reach 4, which has likely caused base lowering that has progressed upstream. This is supported by inundation extents within the meander bends in Reach 4 that show limited inundation only at the largest flood events (e.g. 50 to 100-yr events) despite scroll scars evident from LiDAR that indicate these surfaces were laid down in relatively recent history and would therefore be expected to have greater floodplain connectivity. Reach 9 has similar inundation patterns in overbank areas and also has a steep “hanging” tributary on the downstream left-bank alluvial surface, which suggests recent incision of the mainstem (i.e. tributary channel has not yet adjusted to mainstem incision). **At risk** ratings were given to reaches 3, 5-8, and 10-11 due to anthropogenic floodplain constrictions (e.g. bridges) and bank armoring, which are factors known to induce streambed lowering.

5.3.3 REI Ratings

General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11
Channel Dynamics	Vertical channel stability	adequate	adequate	at risk	unacceptable	at risk	at risk	at risk	at risk	unacceptable	at risk	at risk

6 PATHWAY: RIPARIAN CONDITION

6.1 INDICATOR: STRUCTURE

6.1.1 Metric Overview

Riparian areas serve a number of important geomorphic and ecological functions including streambank stability, current and future sources of large wood material, water filtration, habitat, hydraulic regulation, and temperature fluctuation modification (Gregory et al. 1991). Here, the structure of riparian areas is evaluated based on how well the seral stage, species composition, and complexity approximate natural conditions that would be expected in the absence of human alterations.

Criteria: From USBR (2011).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Riparian Vegetation	Condition	Structure	>80% species composition, seral stage, and structural complexity are consistent with potential native community.	50-80% species composition, seral stage, and structural complexity are consistent with potential native community.	<50% species composition, seral stage, and structural complexity are consistent with potential native community.

6.1.2 Assessment Results

Results of the habitat assessment were used to help determine the riparian structure REI ratings. General seral stage information was recorded as part of the habitat assessment and is presented in Table 17. Dominant overstory and understory species were also recorded as part of the habitat survey, and general notes and observations of riparian conditions were also taken. In general, riparian areas in the absence of human disturbance would be expected to be dominated by mature trees but to also have a diversity of other size classes. Riparian areas along the Upper Wenatchee River have been harvested in the past and many of the riparian areas lack the large sized trees that would be expected under natural conditions. Furthermore, many of the riparian areas affected by residential development lack the smaller size classes due to clearing of the understory for houses and yards. These developed areas also tend to have less species diversity than unaltered areas where flooding and erosion processes are still intact. Reaches 1 and 2 were given an **adequate** rating due to the lack of recent (last 50 years) riparian clearing, dominance by large trees, and representation by other size classes. Reach 3-11 were given **at risk** ratings due to either lack of dominance by large trees, lack of representation by other size classes, or by observed riparian clearing related to residential development (Reaches 3-8, & 10).

Table 7. Results of riparian size classes recorded during the stream habitat survey (August 2011).

Vegetation (% of sampled units)	Total	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11
Riparian Zone (100-ft wide zone averaged between both banks)												
Sapling/Pole	7%	9%	11%	16%	0%	0%	0%	0%	0%	0%	6%	0%
Small Trees	41%	36%	33%	44%	22%	39%	87%	0%	63%	38%	19%	100%
Large Trees	52%	55%	56%	40%	78%	61%	13%	100%	37%	62%	75%	0%

6.1.3 REI Ratings

General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11
Riparian	Structure	adequate	adequate	at risk	at risk	at risk	at risk	at risk	at risk	at risk	at risk	at risk

6.2 INDICATOR: Disturbance (human)

6.2.1 Metric Overview

Human disturbance to the floodplain affects riparian processes including bank stability, wood recruitment, shade, and water quality. Riparian disturbance was assessed using information from the habitat assessment (Appendix A) and an analysis of road densities within riparian areas.

Criteria: From USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Riparian Vegetation	Condition	Disturbance (human)	>80% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; <20% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); <2 mi/mi^2 road density in the floodplain.	50-80% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; 20-50% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); 2-3 mi/mi^2 road density in the floodplain.	<50% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; >50% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); >3 mi/mi^2 road density in the floodplain.

6.2.2 Assessment Results

Riparian size class information was obtained from the habitat assessment (Table 7). Road density in the floodplain was calculated using the Chelan County roads layer and floodplain areas delineated as part of the geomorphic assessment subunit mapping (see Appendix B). Road densities by reach are displayed in Table 8. For the purposes of this assessment, historical riparian timber harvest (> 50 yrs ago) was not considered a disturbance, as long as new riparian forests have become established.

Table 8. Results of floodplain road density per square mile.

Reach	**Reach 1**	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**	**Reach 7**	**Reach 8**	**Reach 9**	**Reach 10**	**Reach 11**
Road Density (miles/mi^2)	0	0	4.5	0	4.5	1.8	0.5	0	2.6	3.2	0

6.2.3 REI Ratings

General Indicators	**Specific Indicators**	**Reach 1**	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**	**Reach 7**	**Reach 8**	**Reach 9**	**Reach 10**	**Reach 11**
Riparian	Disturbance (human)	adequate	adequate	unacceptable	at risk	unacceptable	unacceptable	at risk	at risk	at risk	at risk	at risk

6.3 INDICATOR: Canopy Cover

6.3.1 Metric Overview

Riparian canopies serve a number of important instream functions including moderating water temperature fluctuations and governing light quantity and quality. Water temperature is a main driver of the health, productivity, and life cycles of many aquatic organisms, including salmonids.

Criteria: From USBR (2011).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Riparian	Condition	Canopy Cover	Trees and shrubs within one site potential tree height distance have >80% canopy cover that provides thermal shading to the river.	Trees and shrubs within one site potential tree height distance have 50-80% canopy cover that provides thermal shading to the river.	Trees and shrubs within one site potential tree height distance have >50% canopy cover that provides thermal shading to the river.

6.3.2 Assessment Results

REI canopy cover ratings were determined using recent aerial photography. The percentage canopy cover is based on the extent of canopy closure within riparian areas (100 ft buffer), not the percentage of stream that is covered.

6.3.3 REI Ratings

General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11
Riparian	Canopy Cover	adequate	adequate	at risk	at risk	unacceptable	at risk	at risk	at risk	adequate	at risk	at risk

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APPENDIX D: POTENTIAL PROJECT OPPORTUNITIES

1 BACKGROUND

Potential habitat restoration project opportunities were identified throughout the study reach. The objective of the project identification exercise was to identify projects that address habitat limiting factors, with a focus on ESA-listed salmonids. Projects are designed to achieve the restoration targets identified in the Restoration Strategy (Section 4) and are developed in consideration of the geomorphic and hydraulic context of the site, which is based on the results of analyses conducted as part of this assessment.

Potential project opportunities were identified through a combination of methods, including: 1) field surveys of project opportunities, 2) discussions with agency personnel, 3) previous studies, and 4) remote sensing using aerial photography and LiDAR. Location information, general site conditions, and photographs were acquired for each project opportunity area.

Projects are named using their river mile location, with the approximate midpoint used for long projects. An “R” (right bank) or “L” (left bank) designation is included in the name if the project is predominantly oriented along one side of the river. Reference to river-left or river-right is always oriented facing the downstream direction. Potential feasibility constraints are included in the descriptions where the information was available and is applicable.

2 SUMMARY OF PROJECT OPPORTUNITIES

This effort identified sixty-one project opportunities within the study reach (19 miles). The spatial distribution and types of projects are a function of the condition of biophysical processes, the level of human disturbance, and observed site-specific opportunities to achieve restoration targets.

Numerous projects were identified in order to provide a viable suite of projects available for potential implementation. This ensures there is an adequate source of projects in case some projects are not able to be implemented due to landownership, access, or other constraints. This is an important consideration in the Upper Wenatchee study area because many projects are located along private lands and/or have challenging and remote access conditions.

This project list should be viewed only as an initial effort to identify potential projects. Selecting specific projects and moving them forward to the design stage will require additional survey, analysis, and alternatives evaluation at the site-scale. The Yakama Nation Upper Columbia Habitat Restoration Program utilizes a project prioritization approach in order to identify project areas that warrant further analysis. The prioritization approach takes into consideration many factors, including the degree to which potential projects will address habitat limiting factors, how well the project addresses root causes of observed problems, geomorphic considerations, and cost and feasibility issues.

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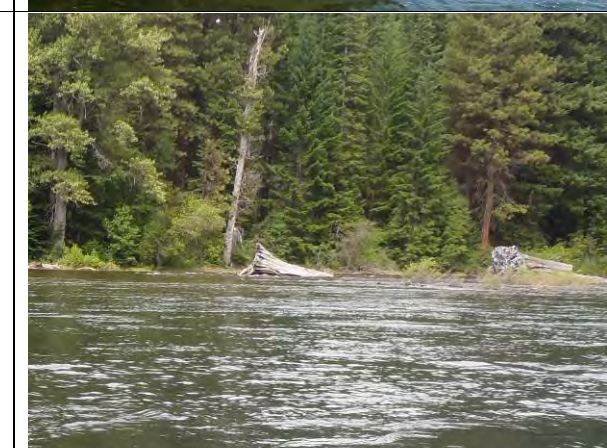
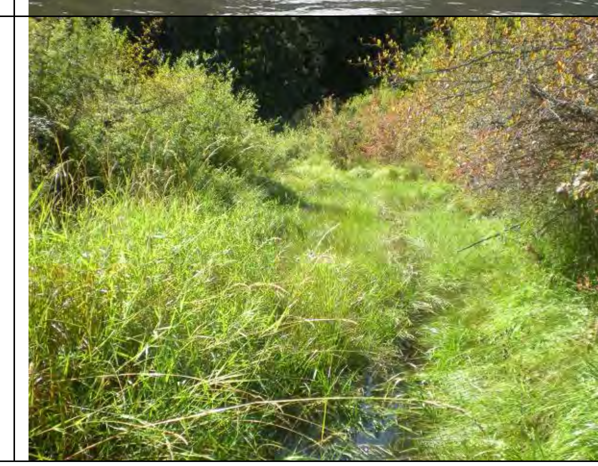
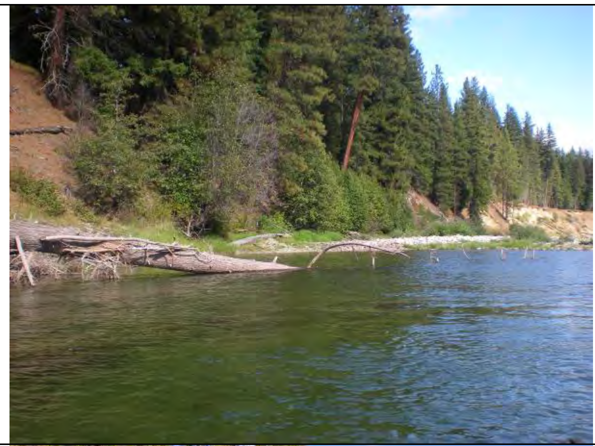
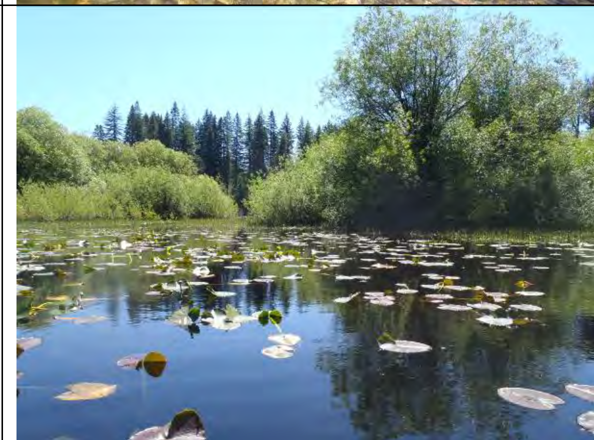
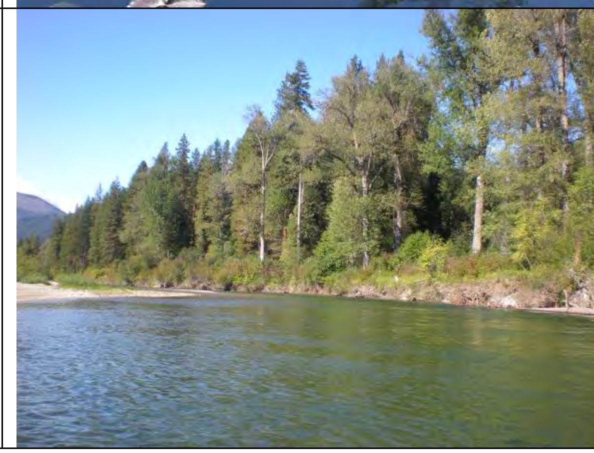
3 PROJECT OPPORTUNITY DESCRIPTIONS

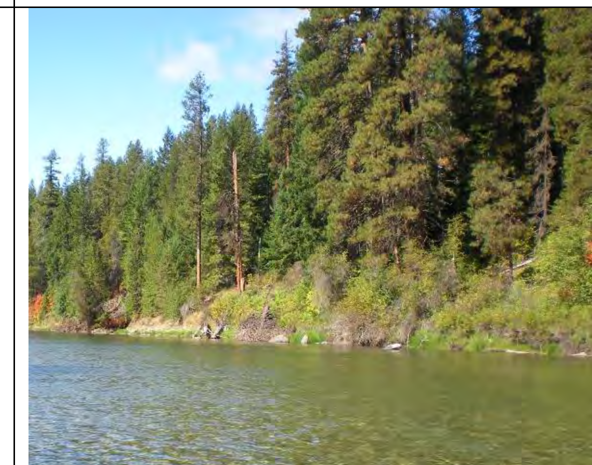
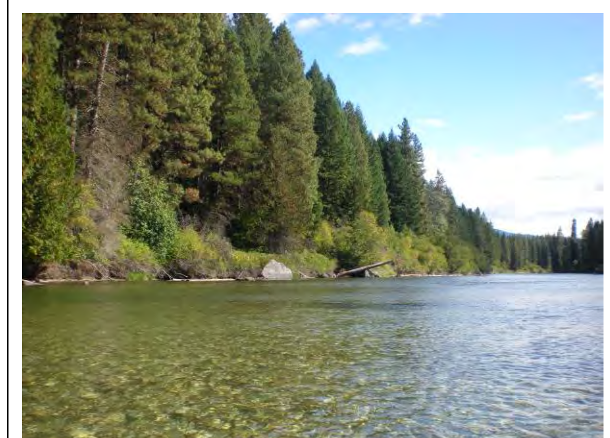
Reach	Project Number	Project Name	Action Type	Description	Photo	
11	Project RM 53.85	Bridge pillar removal	Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill Riparian restoration	Abandoned bridge piers from decommissioned bridge still remain on both banks. Remove piers and revegetate disturbed area.		Abandoned bridge pilings on river-left.
11	Project RM 53.75	First Island	Placement of structural habitat elements including large wood, log jams, or boulders	A small vegetated island complex splits the flow at the first riffle, which serves as the hydraulic control for lake Wenatchee during low flow periods. There are a couple of large rootwads here currently. One or two apex log jams at the head of the island complex could enhance split flow conditions, complexity, and cover habitat. Existing piling structures may be able to be utilized for anchoring or removed as part of the project.		View from right-bank of existing 2 rootwads on small island complex.
11	Project RM 53.7R	Nason Confluence Upstream	Off-channel habitat enhancement	A series of flood overflow/distributary channel scars are located along the left bank of Nason Creek and extend down to the confluence area. There is an existing small backwater area that is connected to lower Nason at low flows. This could be expanded via excavation and enhanced with LWD. There is a longer flood channel that is only connected at high flows. This channel extends further upstream on Nason and could be excavated to enhance connectivity and potentially be configured to connect directly to the Wenatchee at the right bank alcove at RM 53.7.		Existing small backwater connecting to lower Nason Creek just above the confluence.

Reach	Project Number	Project Name	Action Type	Description	Photo	
10	Project RM 53.6R	Nason Confluence Downstream	Off-channel habitat enhancement	A series of flood overflow/distributary channel scars are located at the downstream end of the confluence area between Nason Creek and the highway. This formerly complex and dynamic delta area has been simplified due to the highway. This area may provide a good opportunity to create side-channel habitat that will no longer be created via natural channel dynamics. Existing channel depressions could be excavated to enhance seasonal availability of side-channel habitat. The dynamic deltaic environment would need to be considered for any projects conducted here. There may be a high chance of filling with sediment at the downstream end due to Nason Creek sediments.		
10	Project RM 53.65R	Lower Nason Jams	Placement of structural habitat elements including large wood, log jams, or boulders	Large wood meander jams could be placed along the left channel margin on lower Nason Creek just before the confluence. Jams could extend up to the sand bar on the river-left. Jams would enhance pool scour, create complex margin habitat, and provide rearing cover.		Lower Nason left-bank just upstream of the confluence. The small backwater described in Project RM 53.7R is just to the left of this photo.
10	Project RM 53.5R	Brae Burn Streambank Enhancement	Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill Placement of structural habitat elements including large wood, log jams, or boulders Riparian restoration	Numerous sections of riprap, masonry walls, and spur dikes serve to armor banks and reduce margin habitat complexity along the Brae Burn Road development area. Look for opportunities to work with landowners to enhance habitat by removal of hard armoring, replacement with LWD jams or other bio-engineering techniques, or enhancement through incorporation of wood material.		Example of riprap bank along this section.

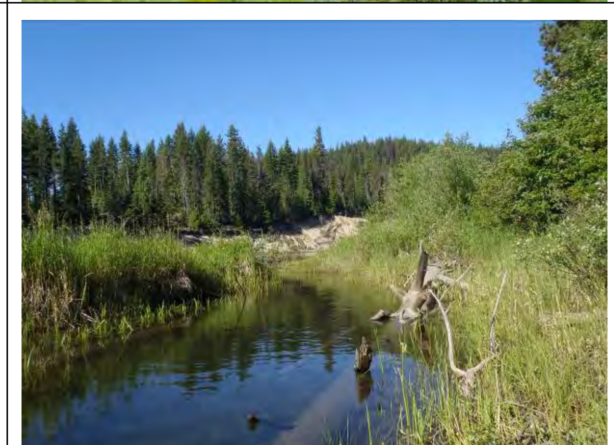
Reach	Project Number	Project Name	Action Type	Description	Photo	
10	Project RM 53.4L	Alcove and Side-Channel Enhancement	Placement of structural habitat elements including large wood, log jams, or boulders	A small low flow alcove and high flow channel are located along the left bank at a riffle. An apex jam(s) could enhance split-flow conditions and enhance habitat complexity in the alcove.		View from upstream of left bank low flow alcove and high flow channel.
10	Project RM 53.1L	Midway Jams	Placement of structural habitat elements including large wood, log jams, or boulders	Place LWD meander jams on river-left. Jams would enhance pool scour, create complex margin habitat, and provide rearing cover.		View of project site from upstream.
10	Project RM 53L	Midway Backwater Enhancement	Off-channel habitat enhancement Placement of structural habitat elements including large wood, log jams, or boulders	A backwater area within the river-left floodplain is connected at high flows. Excavation could be used at the entrance to enhance connectivity and within the site to increase off-channel rearing capacity. Enhance with LWD.		View of existing shallow backwater area from near outlet.

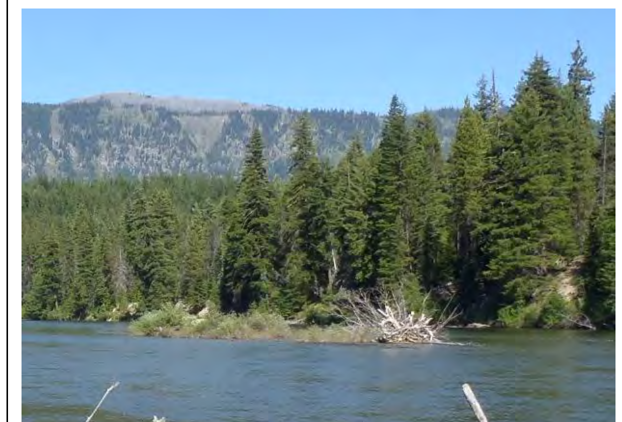
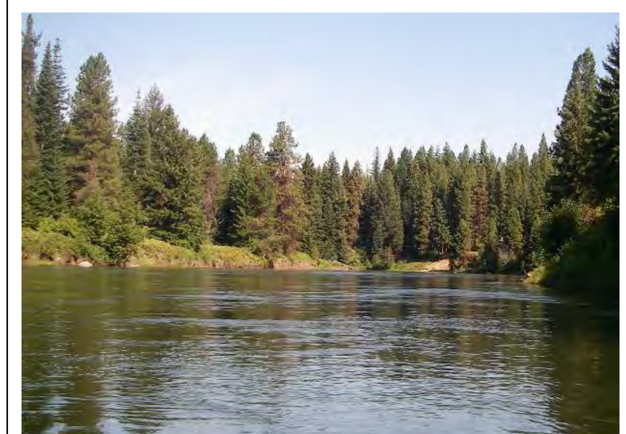
Reach	Project Number	Project Name	Action Type	Description	Photo	
10	Project RM 52.8	Pirate Island	Placement of structural habitat elements including large wood, log jams, or boulders	An island splits flow with a small side-channel on river right. Potential treatments include an apex jam on the island and margin jams along the banks of the left channel. Jams along the right bank of the left channel could be used to force erosion/migration into the left bank, resulting in recruitment of mature cottonwoods. Houses are located along the river-right bank.		View of left bank of project area from upstream.
10	Project RM 52.7L	Chiwawa Jct Backwater	Off-channel habitat enhancement Placement of structural habitat elements including large wood, log jams, or boulders	A large backwater area is connected to the mainstem at all flow levels. Add LWD to the backwater area to enhance rearing cover and complexity.		Backwater area.
10	Project RM 52.45	Pirate Island II	Placement of structural habitat elements including large wood, log jams, or boulders	An island splits flow with a small side-channel on river right. Potential treatments include an apex jam on the island and margin jams along the banks of the left channel. Jams along the right bank of the left channel could be used to force erosion/migration into the left bank, resulting in recruitment of mature cottonwoods. Houses are located along the river-right bank.		Upstream view of river-left channel around island and mature forest in river-left floodplain.

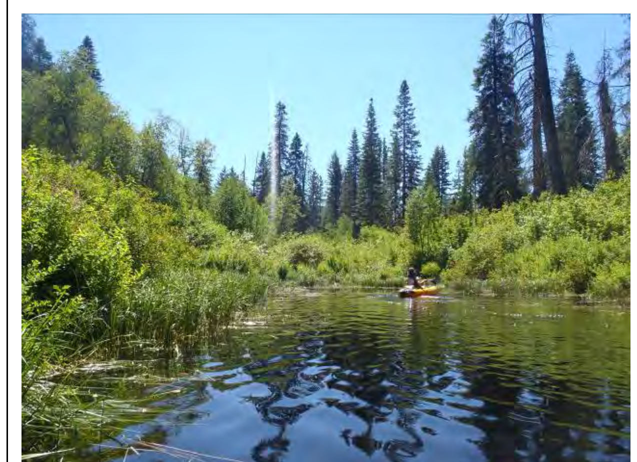
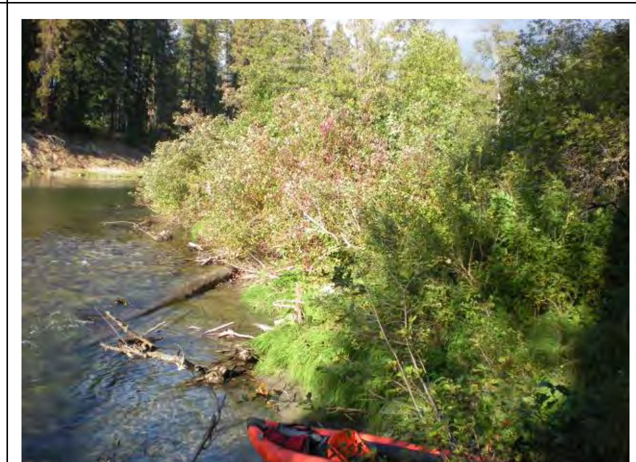
Reach	Project Number	Project Name	Action Type	Description	Photo	
10	Project RM 52.3R	Natapoc Margin Jams	Placement of structural habitat elements including large wood, log jams, or boulders	Potential for meander bend log jams along the outside of the bend but also some good erosion and tree recruitment happening. Place log jams, or just single or bundled “key pieces” to mimic recruited trees, but also allow for or encourage bank erosion and future tree recruitment in areas. Consider placement of jams on inside of bend if additional erosion and recruitment is desired. This project closely relates to what happens at the Natapoc Project (Project RM 52R)		View looking downstream of river-right bank.
10	Project RM 52R	Natapoc Project	Off-channel habitat enhancement Placement of structural habitat elements including large wood, log jams, or boulders Riparian restoration	A large off-channel complex made up of historical meander scars in the river-right floodplain is only connected at high flows. There are multiple potential restoration and enhancement scenarios at this site, ranging from select excavation to enhance existing connectivity to larger-scale excavation and enhancement to create a connected flow-through side-channel. Potential connection points include near RM 52.33 and RM 51.65. A meander bend migration analysis at the bend at RM 52.3 would help to determine the appropriate approach.		View of Natapoc off-channel area.
10	Project RM 52.1L	Fish Lake Run Backwater	Off-channel habitat enhancement Placement of structural habitat elements including large wood, log jams, or boulders	A large backwater area is connected to the mainstem at all flow levels. Fish Lake Run Creek empties into the backwater area. Add LWD to the backwater area to enhance rearing cover and complexity.		View of backwater area.

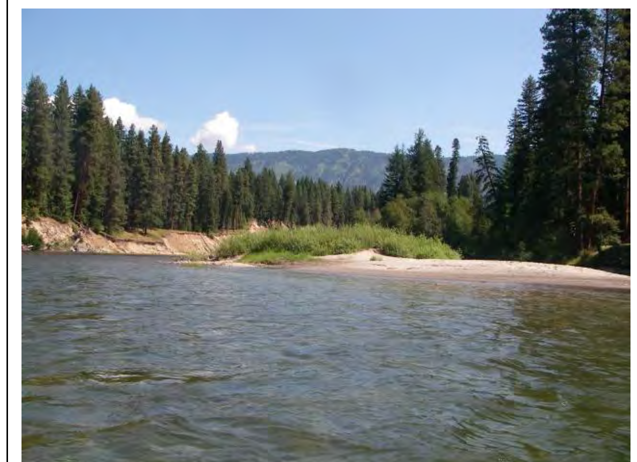
Reach	Project Number	Project Name	Action Type	Description	Photo	
10	Project RM 52L	Mile 52 Colluvial Jams	Placement of structural habitat elements including large wood, log jams, or boulders	A steep, mostly vegetated bank extends along river-left but channel margin habitat is low. Construct jams that mimic existing “colluvial jams”, which consist of jams formed by collapse of large trees at top of bank. These jams form key members that collect fluvially-transported wood to form large complex jams.		View looking upstream of river-left bank.
10	Project RM 51.7	Natapoc Outlet Apex Jams	Placement of structural habitat elements including large wood, log jams, or boulders	There is a shallow gravel deposition area within the channel (right half) near the outlet of the Natapoc backwater channel. One or two bar apex jams here would create pocket pool scour and would be expected to create additional gravel deposition and island formation behind the jam(s), resulting in a split flow channel, increased margin habitat, and increased channel and habitat complexity.		View looking downstream at shallow submerged gravel deposit

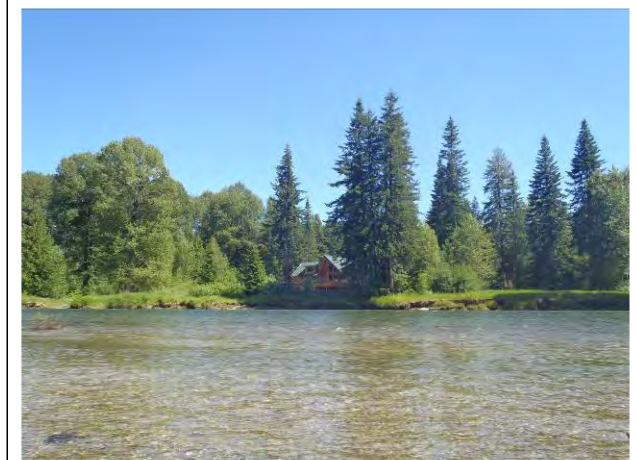
Reach	Project Number	Project Name	Action Type	Description	Photo	
9	Project RM 51.2	Mosquito Alley Channel Complexity	Placement of structural habitat elements including large wood, log jams, or boulders Off-channel habitat enhancement	This project opportunity area is located along the straight section of channel between RM 50.9 and 51.5. The river-left side is a steep bank along a high terrace. The river-right side consists of a low, narrow, partially connected off-channel complex. There is the potential for a series (3-4) of "colluvial jams" along the left bank. Along the right bank, a series of bar apex jams and select excavation could be used to divert flow into the low surface and create connected side channel and off-channel habitats. Access can be obtained through USFS property and unsurfaced access roads.		View looking upstream from downstream of this project area. The low surface on the river-right bank is on the left side of this photo.
9	Project RM 50.9R	Mosquito bend Off-Channel and Complexity Enhancement	Off-channel habitat enhancement	On river right, at the outside of the left hand bend there is the potential for excavating a connected backwater area. This treatment could potentially be tied into work described for the right bank as part of the Mosquito Alley project. Large wood for cover could be placed at the inside of the bend in existing alcove habitat. There may be potential for installing "colluvial jams" on the steep bank on river-right just downstream of the bend. Access can be obtained from Beaver Valley Road and unsurfaced access roads.	 	View looking upstream from downstream of project area. The backwater area is located to the left of the photo at the inside of the bend. View of river right bank from downstream

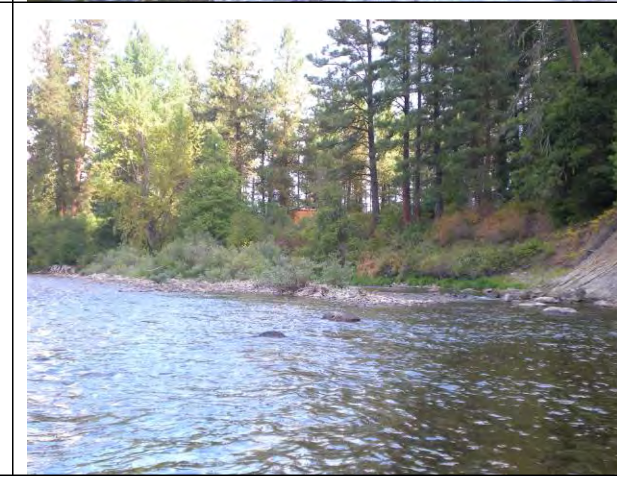
Reach	Project Number	Project Name	Action Type	Description	Photo	
9	Project RM 50.5	Beaver Valley Rd Off-Channel and Complexity Enhancement	Placement of structural habitat elements including large wood, log jams, or boulders Off-channel habitat enhancement	This project opportunity area is located between RM 50.3 and 50.77. The river-left side is a steep bank along a high terrace. There are dispersed camping areas along the top of the terrace. There is the potential for a series (2-5) of "colluvial jams" along the left bank. On river-right there is a variable width low surface with occasional alcoves and wetland habitats. This site could be enhanced with additions of wood and jams for complexity along channel margins and with possible select excavation and apex jam construction that would encourage side-channel and off-channel development. The downstream end may have filling risk (with fine sediment) if backwaters are created. Access to the river-left side can be obtained through USFS property and unsurfaced access roads. Access to the river-right side can be gained off of Beaver Valley Road.	 	View looking upstream at river-left bank near RM 50.7. View of existing alcove habitat on river-right near RM 50.56.
9	Project RM 50.2L	Fifty-mile Side Channel	Off-channel habitat enhancement	This is a low terrace on river-left where relic channel scars could be connected as an active side-channel via excavation. Access can be obtained through USFS property and unsurfaced access roads.		Alcove near downstream end of project area (left bank)

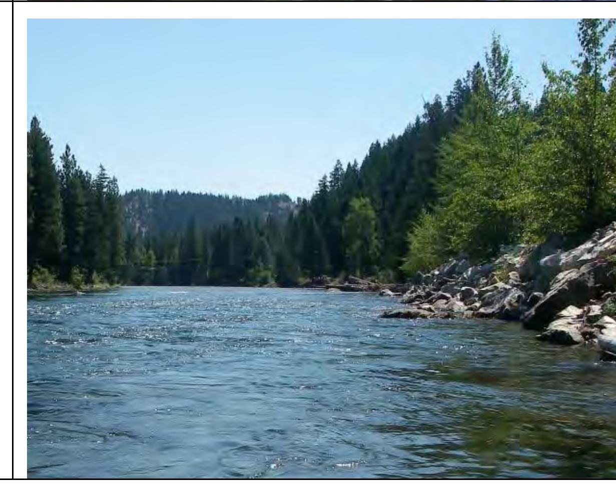
Reach	Project Number	Project Name	Action Type	Description	Photo	
9	Project RM 50	Fifty-mile Log Jams	Placement of structural habitat elements including large wood, log jams, or boulders	Log jams could add complexity and contribute to lateral channel dynamics between RM 49.7 and 50.1. Locations include a meander bend jam on the right-bank at RM 50.03, just downstream of the high steep bank; meander bend jams on river-left downstream of the outlet of the potential fifty-mile side channel project; apex jams at the head of the mid-channel bar between RM 49.9 and 50; and meander bend jams along the river-left bank between RM 49.7 and 49.9. Access to the river-left side can be obtained through USFS property and unsurfaced access roads. Access to the river-right side is undetermined.		Mid-channel bar between RM 49.9 and 50 where an apex jam(s) could help maintain split flow and habitat complexity.
8	Project RM 49.5	Cottonwood Lane Habitat Complexity	Placement of structural habitat elements including large wood, log jams, or boulders	There is a long sequence of uniform pools and glides at the outside extent of the large bend at RM 49.5. Large wood pieces and complexes could be placed almost anywhere throughout this segment to enhance habitat cover and complexity. Houses along the river-left bank will affect access and feasibility.		
8	Project RM 49.3L	Cottonwood Lane Off-Channel Habitat	Off-channel habitat enhancement Riparian restoration	There is a cleared low surface on river-left at RM 49.3 just upstream of the hatchery intake. There is an actively eroding low bank at the river with immature shrub vegetation. A backwater area could be excavated at this site to provide connected off-channel rearing habitat. Large wood could be added for cover and complexity within the backwater area and along the mainstem channel margin. There is good access off of Cottonwood Lane. Landownership is the Chiwawa Community Association.		Photo of cleared low surface area along river-left bank near RM 49.3.

Reach	Project Number	Project Name	Action Type	Description	Photo	
8	Project RM 49.2	Intake Island Log Jams	Placement of structural habitat elements including large wood, log jams, or boulders	Just downstream of the hatchery intake there is a mid-channel island. On the river-right bank there is existing alcove habitat. Large wood and log jams could be placed in the alcove to enhance cover and complexity. Wood could also be placed on the left bank of the river-left channel around the island. Apex jam(s) could be considered on the island but potential impacts to the nearby hatchery intake structure would need to be evaluated. Access would be from Cottonwood Lane for left bank work and access is unknown along the right bank.		View looking upstraem at island complex near RM 49.2.
8	Project RM 49.1L	Intake Island Off-Channel Habitat	Off-channel habitat enhancement Placement of structural habitat elements including large wood, log jams, or boulders	There is an existing channel scar and connected wetland/alcove area on the river-left bank that outlets near RM 49.1. This off-channel area could be enlarged and enhanced by adding large wood complexes for cover and complexity. Access would be obtained from Cottonwood Lane. Federal property.		Left bank off-channel area near RM 49.1.
8	Project RM 48.85L	Chiwawa Fan Island Off-Channel Habitat	Off-channel habitat enhancement	There is an existing small alcove and channel scar outlet on the river-left bank near RM 48.8. This could be enlarged as a connected backwater channel, and could potentially be connected up with Project RM 49.1. Access is via federal land off of Cottonwood Lane.		View of outlet area of potential off-channel project area on river-left near RM 48.8.

Reach	Project Number	Project Name	Action Type	Description	Photo	
8	Project RM 48.8	Chiwawa Fan Island Jams	Placement of structural habitat elements including large wood, log jams, or boulders	There is a mid-channel bar at RM 48.8. An apex log jam(s) here would help to maintain and enhance split flow conditions and habitat complexity. The river-right bank is a high sand terrace that would be a potential site for channel margin "colluvial jams" to enhance pool scour and habitat cover. Access to the left bank is via federal land off of Cottonwood Lane. Access to the right bank is via federal land off of Beaver Valley Road.		View looking upstream at mid-channel bar near RM 48.8.
8	Project RM 48.6L	Chiwawa Jct Jams	Placement of structural habitat elements including large wood, log jams, or boulders	There is opportunity for increasing channel margin habitat on river-left in this long uniform glide. Individual wood pieces and/or log jams could be placed along the channel margin to encourage local pool scour and to increase habitat cover and complexity.		View looking upstream at river-left bank from near RM 48.5.

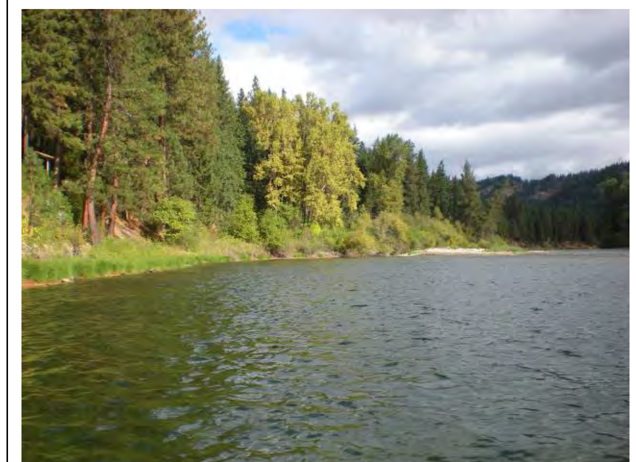
Reach	Project Number	Project Name	Action Type	Description	Photo	
7	Project RM 48.3L	Riparian and Streambank Restoration	Riparian restoration	There is a cleared riparian and streambank area along the river-left bank associated with a streamside residence. Re-plant with native riparian forest vegetation and streambank shrubs and trees. Wood could be added for interim stability along the eroding streambank.		View of river-left bank (cleared riparian and eroding streambank) near RM 48.3.
6	Project RM 47.6L	Schugart Flat Levee Removal and Riparian Enhancement	Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill Riparian restoration	There is a push-up levee along the river-left bank that extends from near RM 47.5 upstream to the Chelan County gravel pit at RM 47.75. The levee is small (<4 ft average height) and discontinuous but it likely impairs floodplain inundation rates and patterns. Look for opportunities to remove or selectively breach the levee. Riparian buffer width could be expanded in the area of the county gravel pit. County and private property protections are potential constraints with this project.		Aerial photo of county gravel pit near Schugart Flat.
5	Project RM 45.8L	Gravel Pit Colluvial Jams	Placement of structural habitat elements including large wood, log jams, or boulders	There is a high bank on river-left adjacent to a Chelan County gravel pit. Riparian conditions on the slope and at the top of the bank are degraded and are in a cleared or early seral stage condition. There are opportunities here to create "colluvial" jams to mimic jams that would have formed historically through riparian tree recruitment from slope failures.		Example of a natural "colluvial" jam from a site further upstream near RM 48.8.

Reach	Project Number	Project Name	Action Type	Description	Photo	
5	Project RM 45.1R	45-Mile Margin Jams and Riparian Enhancement	Riparian restoration Placement of structural habitat elements including large wood, log jams, or boulders	On river-right there is a high unvegetated eroding bank that extends from RM 45.3 to RM 45.15. Riparian restoration work on the bank and at the top of bank would enhance long term riparian processes. Channel margin "colluvial" jams could be placed to enhance margin habitat complexity. There is a good location for a meander bend jam further upstream on the right bank near RM 45.28. There is opportunity for riparian enhancement at this location as well. This area is private land and there are nearby houses.	 	View of cleared river-right bank at RM 45.1 Location of potential meander-bend jam on river-right near RM 45.28
5	Project RM 44.9L	Camp 12 Apex Jam	Off-channel habitat enhancement Placement of structural habitat elements including large wood, log jams, or boulders	There is an opportunity to enhance activation of a left-bank side channel at the bend near RM 44.9. An apex log jam on the existing bar would create a split flow condition and would enhance lateral channel dynamics as well as instream cover and complexity. There is bedrock (conglomerate) just downstream of the project site. Private land.		Upstream view of left bank project area and existing shallow gravel bar.

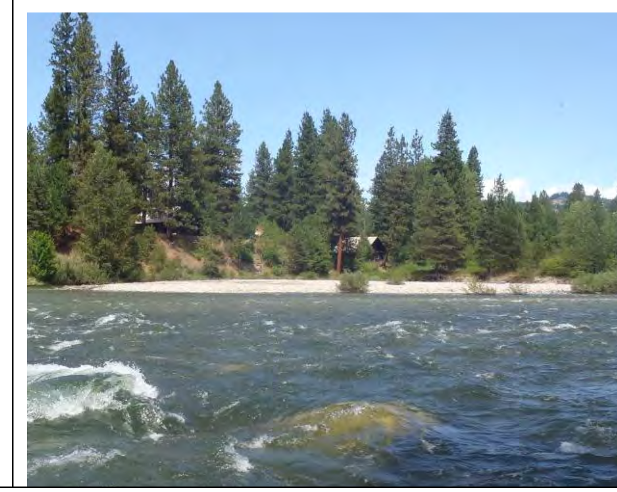
Reach	Project Number	Project Name	Action Type	Description	Photo	
5	Project RM 44.3	Powerline Riparian and Margin Habitat Enhancement	Placement of structural habitat elements including large wood, log jams, or boulders Riparian restoration	Just downstream of the powerline crossing (RM 44.4) and extending downstream to RM 44.13, there are potential sites for channel margin and riparian enhancement. Potential log jam sites to enhance local pool scour, habitat complexity, and cover include: 1) on river-left where an existing house-sized boulder could be utilized to help ballast a large jam, 2) on river-right near RM 44.35 (1-2 jams), 3) “colluvial” jams along the tall bank on river-left from RM 44.1 to RM 44.3, and 4) a bar apex jam on river-right near RM 44.2 to enhance side-channel activation. There are also opportunities for riparian work on both sides of the stream. There is a narrow riparian buffer on river-right (ag fields) and riparian clearing along river-left associated with residential development in the Ponderosa Estates community.	 	Upstream view of river-left bank and house-sized boulder near RM 44.4. Residential impacts to riparian conditions in the Ponderosa Estates development.
5	Project RM 43.7R	River Road Channel Margin Enhancement	Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill Riparian restoration	There is discontinuous riprap and rock spurs along River Road along the river-right bank. Look for opportunities to modify bank armoring to include bioengineering approaches and log jams. There are good meander bend log jam opportunities through here (4-6 jams total, between riprap sections) that would enhance local pool scour, cover, and complexity.		View of riprap bank along river-right near RM 43.8.

Reach	Project Number	Project Name	Action Type	Description	Photo	
5	Project RM 43.5L	Ponderosa Estates Riparian and Channel Margin Enhancement	Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill Riparian restoration	There is streamside residential development (Ponderosa Estates community) extending along the left bank from upstream of RM 44.1 down to RM 43.2. Many of the homes have clearing of riparian vegetation and rock or concrete walls to protect banks from erosion. Look for opportunities to enhance riparian conditions and to restore bank margin complexity through removal/modification of bank armoring or replacement with bioengineering approaches.		View looking downstrem at left bank residential development near RM 43.6.
5	Project RM 43.2L	Riata Bend Enhancement	Placement of structural habitat elements including large wood, log jams, or boulders Off-channel habitat enhancement	At the outside of the bend at RM 43.15, there is good opportunity for using log jams to increase lateral channel dynamics and to enhance pool scour, cover, and complexity. Meander bend jams could be placed along the left bank and could potentially be anchored to existing boulders in the channel. There may also be opportunities for excavation of alcove habitat at this bend. Right bank log jams could be placed for cover and complexity.		Upstream view of river left bend near RM 43.1.
4	Project RM 42.9	Mule Tail Flats Log Jams	Placement of structural habitat elements including large wood, log jams, or boulders	This area extends from RM 42.8 to RM 43.05. There is a series of gravel bars that offer a good opportunity for construction of bar apex log jams that would enhance lateral channel dynamics, split flow conditions, and improve local pool scour, cover, and habitat complexity. There are also opportunities for meander bend jams along the left bank from RM 42.8 to 42.9. Access would be through private lands from Mule Tail Flats Road.		View looking downstream ad gravel bar complex near RM 42.9.

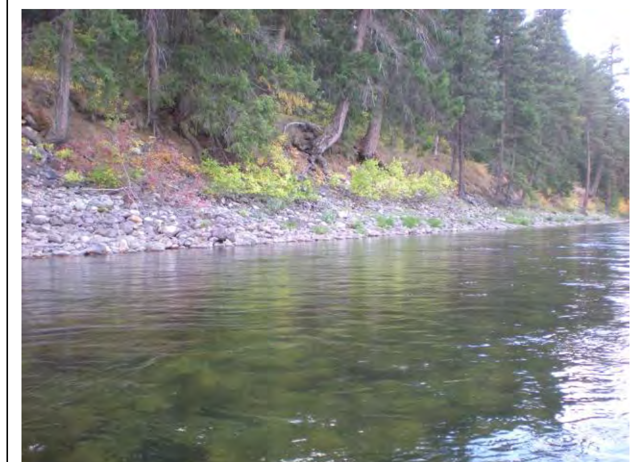
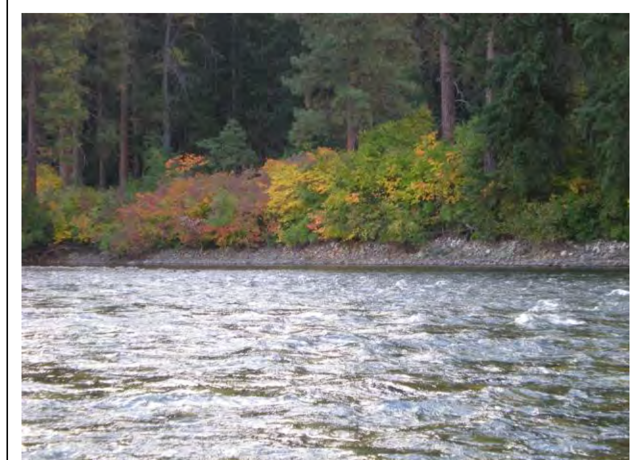
Reach	Project Number	Project Name	Action Type	Description	Photo	
4	Project RM 42.7L	Primitive Park Alcove Enhancement	Placement of structural habitat elements including large wood, log jams, or boulders Off-channel habitat enhancement Riparian restoration	There is existing small alcove habitat on river left between RM 42.65 and RM 42.73. Adding individual pieces and small log jams would enhance cover and complexity. There is also opportunity for riparian restoration in this area.		View of river-left bank near RM 42.7.
4	Project RM 42.4L	Primitive Park Apex Jams	Placement of structural habitat elements including large wood, log jams, or boulders	There is an island complex along the left bank between RM 42.4 and 42.5. These offer good opportunities for bar apex log jams that would enhance lateral channel dynamics, split flow conditions, and habitat complexity and cover. Meander bend jams along the left bank could also be beneficial here.		View looking downstream at island complex between RM 42.4 and 42.5.
4	Project RM 42.3L	Primitive Park Side Channel Enhancement	Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill Off-channel habitat enhancement Riparian restoration	There is potential side-channel reconnection potential along the left bank through the low surface extending from RM 42.2 to 42.45. Private lands prevented full field inspection of this surface but LiDAR suggests there has been fill placed in a channel scar and that this feature could be restored as a side-channel; either a flood flow channel or possibly an active low flow channel.		View looking downstream at left bank at potential upstream entry point for side-channel (near RM 42.5).

Reach	Project Number	Project Name	Action Type	Description	Photo	
4	Project RM 42.1R	Railroad Bridge Apex Jams	Placement of structural habitat elements including large wood, log jams, or boulders	There is a shallow gravel bar along river-right upstream of the railroad bridge. Bar apex jams could enhance lateral channel dynamics, split flow conditions, and habitat complexity and cover. Meander bend jams could be placed along the right bank downstream of the gravel bar to enhance local pool scour, complexity, and cover.		View looking upstream at gravel bar on river-right bank and location for potential apex and meander bend jams near RM 42.1.
4	Project RM 41.9R	Railroad Bridge Channel Margin Enhancement	Placement of structural habitat elements including large wood, log jams, or boulders Riparian restoration	There is a long, discontinuous riprap bank and cleared riparian area that extends upstream and downstream of the railroad bridge (RM 41.8 to RM 42). There are opportunities to construct meander bend “colluvial” jams at the base of the bank to enhance pool scour and habitat cover and complexity. Restore riparian vegetation on the bank and on top of bank. Remove or modify riprap where possible to utilize natural materials (e.g. wood) and bioengineering approaches to maintain stability.		View looking downstream at river-right bank at railroad crossing near RM 41.9.
3	Project RM 41.7R	Meacham Road Side Channel Enhancement	Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill Off-channel habitat enhancement Riparian restoration	There is a side-channel on river-right downstream of the railroad bridge. There is a large bar apex jam on the island apex forming the side channel. The river-right bank within and downstream of the side-channel is armored with concrete and rip-rap, which extends from RM 41.8 to 41.5. Look for opportunities to remove or modify bank armoring and to enhance margin complexity. Log jams could be placed throughout this side-channel and along the channel margin downstream. There are private residences close by. Many of these parcels could also benefit from riparian restoration, where possible.		View looking downstream within side-channel near RM 41.8.

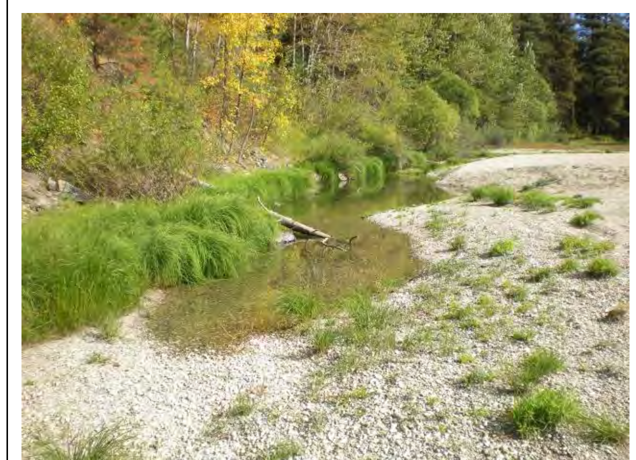
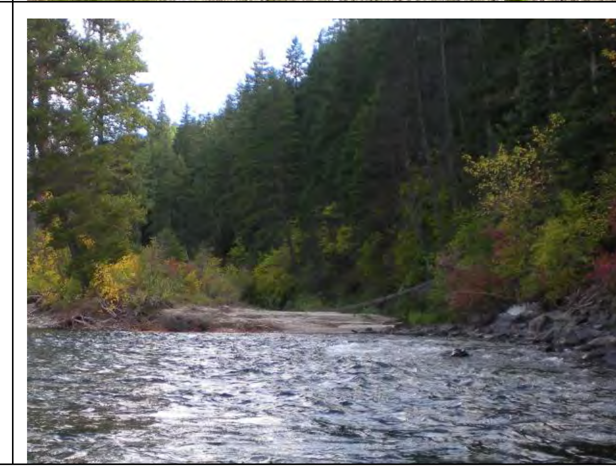
Reach	Project Number	Project Name	Action Type	Description	Photo	
3	Project RM 41.5L	Wenatchee Pines Off-Channel Habitat Enhancement	Off-channel habitat enhancement Placement of structural habitat elements including large wood, log jams, or boulders	There is a low floodplain surface on river left prior to the sharp bend at RM 41.5. There is the potential here for development of off-channel habitat. The surface is likely too high for reasonable excavation of a connected flow-through side-channel, but there may be the possibility of a connected backwater extending upstream from the downstream end. There are also opportunities for meander bend jams along the left bank at the upstream and downstream ends of this project area.		View looking downstream at river-left bank at low surface where there is the potential for backwater channel development (RM 41.5).
3	Project RM 41.3L	RM 41.3 Meander Bend Jams	Placement of structural habitat elements including large wood, log jams, or boulders	There is a good location to construct one or two meander bend jams on river-left near RM 41.3 to enhance pool scour, cover, and complexity. There is an existing rootwad to build off of.		View looking upstream at river-left bank at existing rootwad near RM 41.3.
3	Project RM 41.1	RM 41.1 Side Channel Enhancement	Off-channel habitat enhancement Placement of structural habitat elements including large wood, log jams, or boulders	There is an existing high flow side-channel along river left between RM 41.1 and 41.2. Select excavation, particularly at the upstream end, combined with a bar apex jam, could activate this side channel at lower flows. There is also the potential for a meander bend jam on the left bank downstream of the side-channel outlet.		View of side-channel near RM 41.2.

Reach	Project Number	Project Name	Action Type	Description	Photo	
3	Project RM 41L	RM 41 Jams	Placement of structural habitat elements including large wood, log jams, or boulders	There is a good location for a bar apex jam on an existing shallow gravel bar near RM 41 that would enhance lateral channel dynamics, split flow conditions, and improve local pool scour, cover, and habitat complexity. There are also good locations for 1 or 2 meander bend jams downstream along the left bank at the outside of the bend.		View looking downstream at left bank at potential bar apex and meander log jam locations near RM 41.
3	Project RM 40.8R	Meacham Flats Off-Channel Enhancement	Off-channel habitat enhancement	There is an existing alcove and side-channel on river-right at the outside of the bend at RM 40.8. This may be a good location to create a groundwater-fed channel that extends up-valley across the large Meacham Flats bar. Channel scrolling features visible on the LiDAR suggest the presence of hyporheic flow across the bar that could supply a groundwater channel. Additional investigation (groundwater monitoring) would be needed. An investigation of the location of bedrock would also assist with determining whether the necessary channel elevations could be achieved. This site offers a good opportunity for creating off-channel habitat because residential development and associated bank armoring along the upstream meander bend will prevent natural river processes from creating off-channel habitat on its own.		View of river-right bank at bend at RM 40.8.

Reach	Project Number	Project Name	Action Type	Description	Photo	
3	Project RM 40.6R	High Valley US Riparian & Margin Habitat Enhancement	Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill Riparian restoration	The river-right bank from RM 40.25 to RM 40.75 is dominated by riprap, rock spurs, and degraded riparian vegetation conditions associated with River Road and residential development. Look for opportunities to remove or modify riprap using log jams and bioengineering approaches to streambank stabilization. Replant riparian areas where possible.	 	Oblique aerial view of river-right bank with riprap and rock spurs near RM 40.7. View looking downstream at ripraped river-right bank near RM 40.7.
3	Project RM 40.5L	RM 40.5 Alcove Enhancement	Off-channel habitat enhancement Placement of structural habitat elements including large wood, log jams, or boulders	There is an existing alcove on river-left at the outside of the bend at RM 40.5. Wood could be added to the existing alcove to enhance habitat cover and complexity. There may be additional potential off-channel work on this low surface but the surface is relatively high and there is a lot of bedrock; further investigation would be necessary to evaluate additional off-channel potential.		View looking upstream at river-left alcove/backwater at RM 40.5.

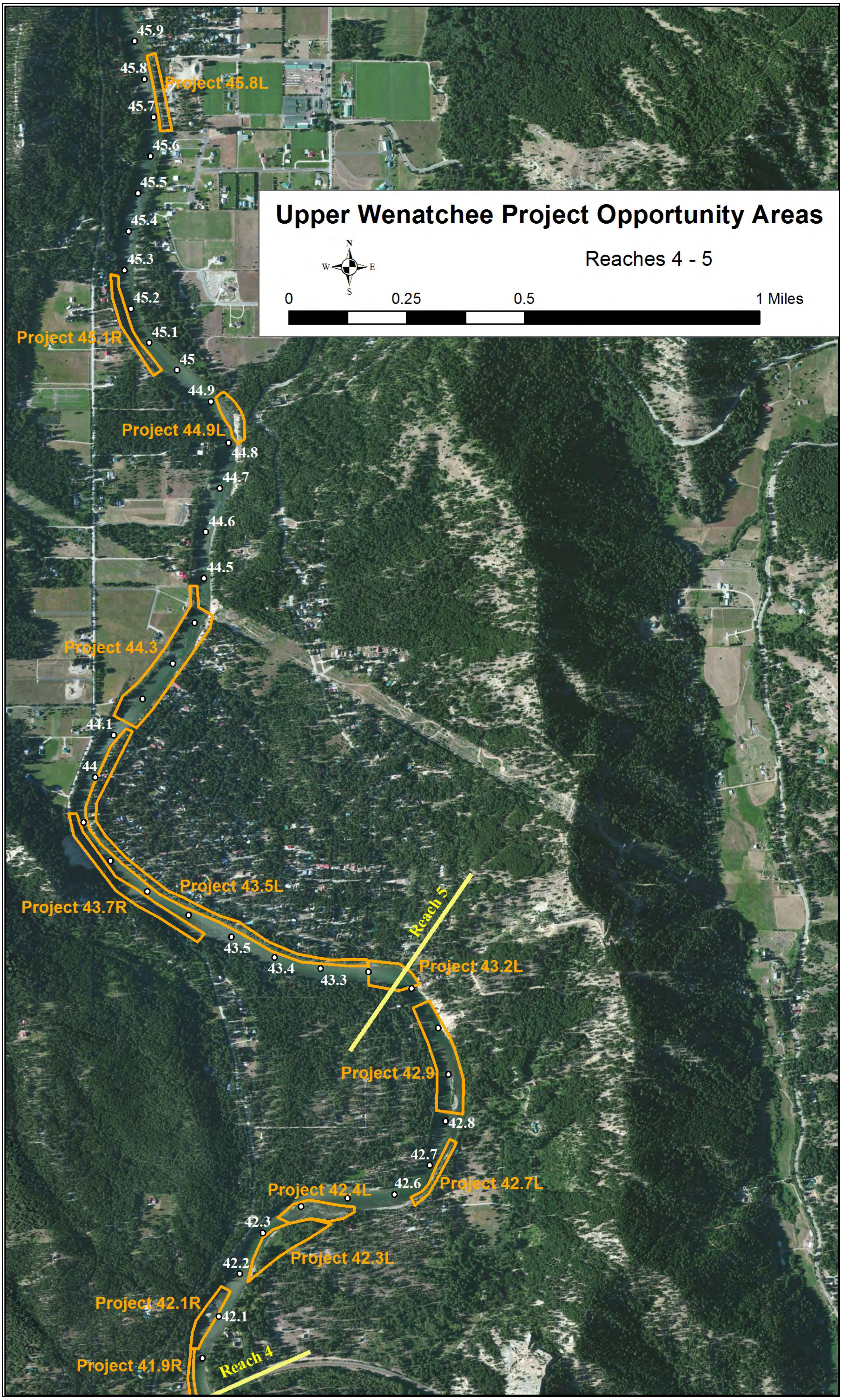
Reach	Project Number	Project Name	Action Type	Description	Photo	
3	Project RM 40.4L	RM 40.4 Meander Bend Jams	Placement of structural habitat elements including large wood, log jams, or boulders	There is a good opportunity for 1-2 meander bend log jams along the river-left bank near RM 40.4. The existing habitat lacks channel margin complexity. Jams would increase pool scour, cover, and complexity. Access may be difficult and may have to be obtained from across the river.		View of river-left bank near RM 40.4 that lacks channel margin complexity.
3	Project RM 40L	RM 40 Meander Bend Jams	Placement of structural habitat elements including large wood, log jams, or boulders	There is a good opportunity for several meander bend log jams along the river-left bank between RM 39.9 and 40.2. The existing habitat lacks channel margin complexity. Jams would increase pool scour, cover, and complexity. Access may be difficult and may have to be obtained from across the river.		View of river-left bank near RM 40 that lacks channel margin complexity.
3	Project RM 39.7R	High Valley DS Riparian & Margin Habitat Enhance	Habitat reconnection via removal/modification of bank armoring, levees, roadways, or fill Riparian restoration	The river-right bank from RM 39.5 to RM 39.9 is dominated by riprap, rock spurs, and degraded riparian vegetation conditions associated with streamside residential development. Look for opportunities to remove or modify riprap using log jams and bioengineering approaches to streambank stabilization. Replant riparian areas where possible.		Oblique aerial view at river-right bank and residential development near RM 39.7.

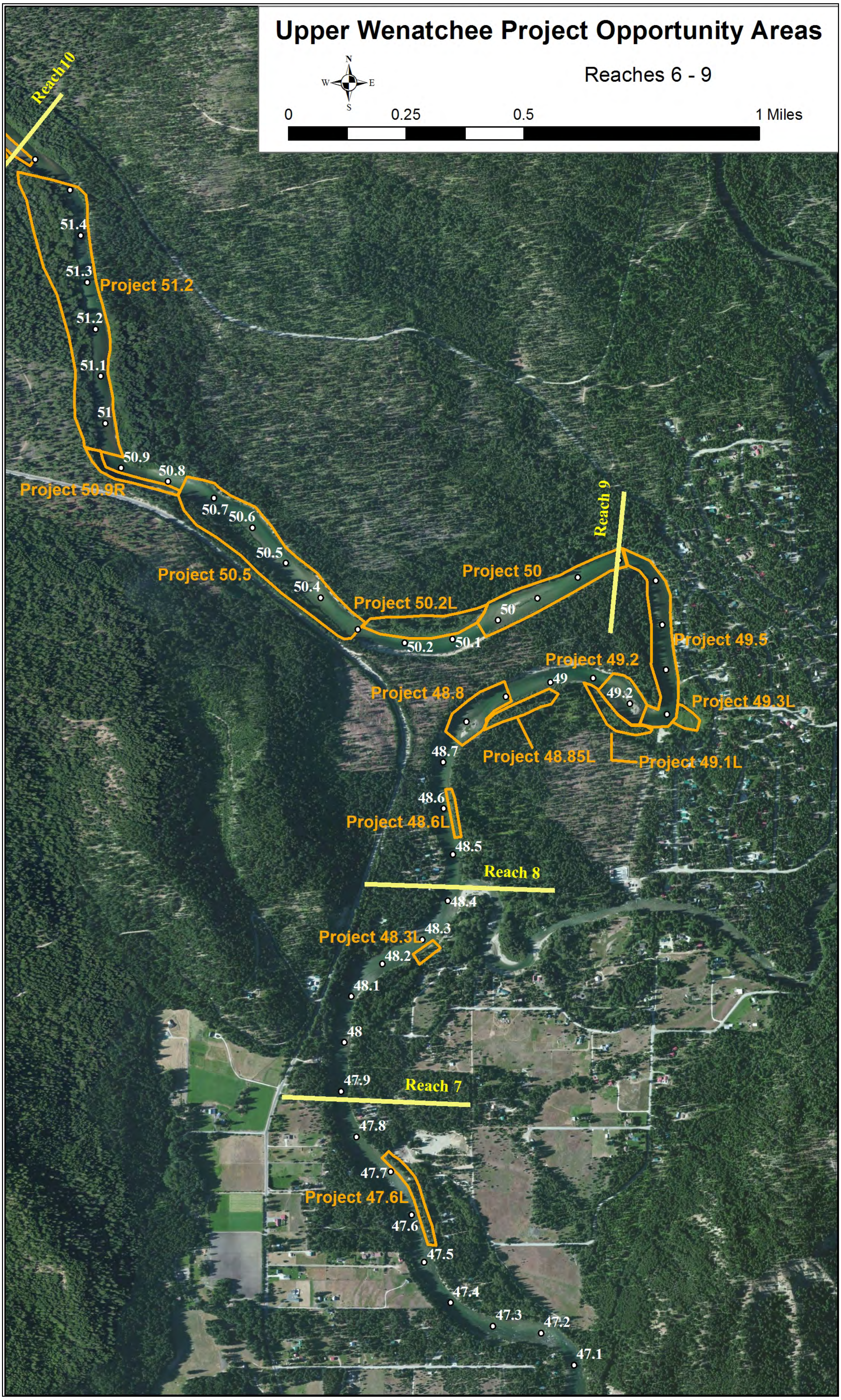
Reach	Project Number	Project Name	Action Type	Description	Photo	
3	Project RM 39.6L	RM 39.6 Off-Channel Enhancement	Off-channel habitat enhancement Placement of structural habitat elements including large wood, log jams, or boulders	There is an existing side-channel and alcove habitat on the left bank between RM 39.5 and RM 39.7. Wood jams could be added to these existing off-channel areas to enhance local pool scour, cover, and complexity. Mainstem wood placements in this area would be challenging given the high stream energy at this location.		Existing alcove habitat on river-right near RM 39.7.
3	Project RM 39.4L	RM 39.4 Meander Bend Jams	Placement of structural habitat elements including large wood, log jams, or boulders	There is a good opportunity for 1-3 meander bend log jams along the river-left bank between RM 39.3 and 39.5. The existing habitat lacks channel margin complexity. Jams would increase pool scour, cover, and complexity. Access may be difficult and may have to be obtained from across the river.		Oblique aerial view looking downstream near RM 39.4. The project opportunity area is along the left bank upstream of the left-hand bend in the river.

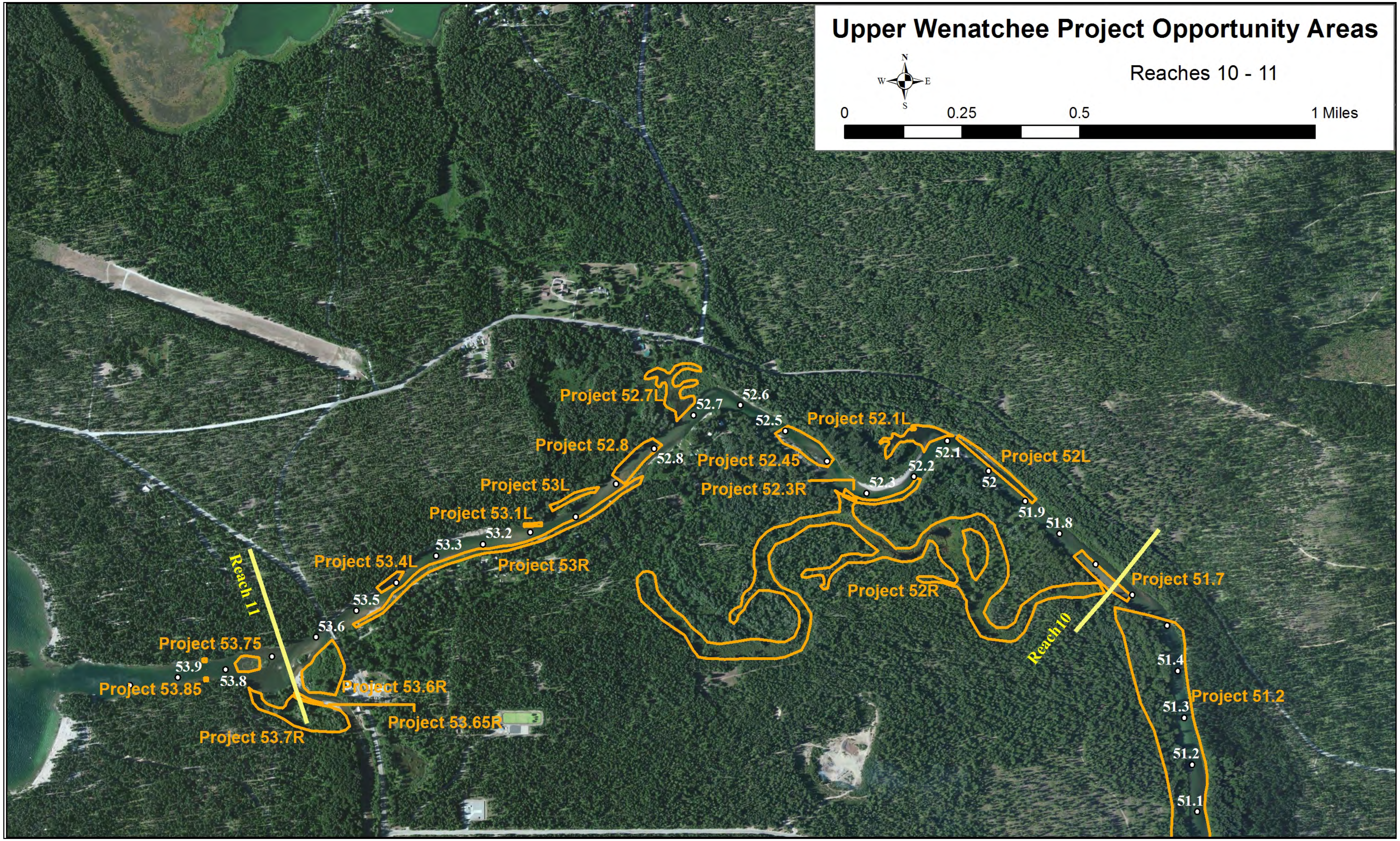
Reach	Project Number	Project Name	Action Type	Description	Photo	
3	Project RM 39.3R	Zimmerman Off-Channel and Mainstem Enhancement	Off-channel habitat enhancement Placement of structural habitat elements including large wood, log jams, or boulders	There is a large gravel bar and existing backwater/alcove near RM 39.2 at the crux of the bend. One option here includes excavating additional backwater habitat along the hillslope/terrace toe at the inside of the bend; however, due to the high rate of observed sediment deposition in this area, there may be a risk of filling with sediment over time. There is also the potential for creating a groundwater-fed channel within this floodplain surface that extends up to near the main channel at RM 39.5. More investigation is needed to evaluate groundwater flow potential. On the large existing gravel bar, there is the potential to create active split flow conditions through construction of a bar apex jam on the bar and other wood placements for bar roughness.	 	Oblique aerial view looking downstream at project area near RM 39.3. Existing low water backwater at crux of bend near RM 39.2.
3	Project RM 39L	Tunnel Alcove Enhancement	Off-channel habitat enhancement Placement of structural habitat elements including large wood, log jams, or boulders	This is a high flow side-channel between RM 38.9 and 39 that has a small low water alcove at the downstream end. Wood could be placed for cover habitat within the alcove. Excavation and a bar apex jam at the top end could also be considered to establish a low-flow active side-channel here; although there may be filling risk because of the relative difference in gradient compared to the mainstem. Access may have to be gained from across the river.		Upstream view of alcove at downstream end of river-left high flow side-channel near RM 38.9.

Reach	Project Number	Project Name	Action Type	Description	Photo	
3	Project RM 38.9R	Deadhorse Island Side-Channel Enhancement	Off-channel habitat enhancement Placement of structural habitat elements including large wood, log jams, or boulders	This large mainstem side-channel presents a good opportunity for placement of log jams within the active channel that are out of the way of river recreationists. Wood placements could be conducted throughout the side-channel. Upstream of the island along the river-right bank are good locations for wood jams to enhance cover habitat and complexity. Bar apex jams could be placed on the bar at the apex of the island although there are existing jams in this area. Bar apex jams could also be considered for the mainstem gravel bar at the downstream end near RM 38.7. Jams here would enhance split flow conditions, pool scour, cover, and complexity. Potential access from closed forest road along river-right.		Outlet of river-right mainstem side-channel near RM 38.7.
1-2		Protect and Maintain	Protect and maintain	Protect and Maintain is the highest priority action for the lower two reaches. These reaches are in relatively healthy condition and are within US Forest Service lands. There are multiple split flow conditions and abundant side-channel and off-channel habitats. Channel margin habitat is high quality, with overhanging riparian vegetation and high complexity. There are log jams and other wood pieces. Riparian areas are in more mature seral stages compared to upstream areas and are on a trajectory towards late seral conditions where they will eventually be able to provide adequate shade and LWD recruitment. There is abundant and high quality spawning habitat within pool tail-outs, riffles, and glides.		Oblique downstream aerial view of Reach 2 near RM 36-37.
1-2		Key Piece Supplementation	Placement of structural habitat elements including large wood, log jams, or boulders	A potential project opportunity identified for these lower reaches is to add large key pieces of wood that would be available to initiate log jam formation and enhance lateral channel dynamics, pool scour, cover, and complexity. The very large key pieces needed to form log jams are much less abundant than historical conditions and it is believed that re-introducing key pieces would create a positive habitat response by collecting additional wood, sorting sediment, and providing direct habitat benefits. Access is difficult so key pieces would likely have to be flown in and placed by helicopter. In some areas, existing access roads may be able to be utilized.		Example of bar in Reach 1 where large key pieces would help to encourage jam formation, island development, and split flow conditions.

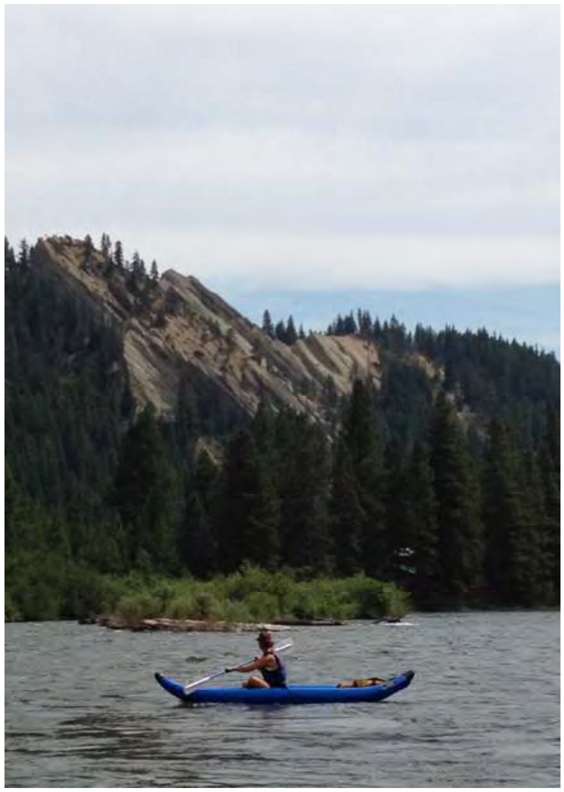

Upper Wenatchee Project Opportunity Areas
Reaches 3 - 4
N
S
W
E
0
0.25
0.5
1 Miles
Reach 3
Reach 4
Project 38.9R
Project 39L
Project 39.3R
Project 39.4L
Project 39.6L
Project 39.7R
Project 40L
Project 40.4L
Project 40.5L
Project 40.6R
Project 40.8R
Project 41L
Project 41.1L
Project 41.2R
Project 41.3L
Project 41.5L
Project 41.7R
Project 41.9R
Project 42.1R
Project 42.3L
Project 42.4L
Project 42.7L
Project 42.9
38.8
38.9
39
39.2
39.3
39.8
39.9
40
40.1
40.2
40.3
40.6
40.7
40.8
40.9
41
41.4
41.5
41.6
42.1
42.2
42.3
42.5
42.6
42.8


Upper Wenatchee Project Opportunity Areas
Reaches 4 - 5
N
W
E
S
0
0.25
0.5
1 Miles
45.9
45.8
Project 45.8L
45.7
45.6
45.5
45.4
45.3
45.2
Project 45.1R
45.1
45
44.9
Project 44.9L
44.8
44.7
44.6
44.5
Project 44.3
44.1
44
Project 43.5L
Project 43.7R
43.5
43.4
43.3
Reach 5
Project 43.2L
Project 42.9
42.8
42.7
42.6
Project 42.7L
Project 42.4L
42.3
Project 42.3L
42.2
Project 42.1R
42.1
Project 41.9R
Reach 4


Upper Wenatchee Project Opportunity Areas
Reaches 6 - 9
N
W
E
S
0
0.25
0.5
1 Miles
Reach10
Reach 9
Reach 8
Reach 7
Project 51.2
Project 50.9R
Project 50.5
Project 50.2L
Project 50
Project 49.5
Project 49.2
Project 49.3L
Project 49.1L
Project 48.8
Project 48.85L
Project 48.6L
Project 48.3L
Project 47.6L
51.4
51.3
51.2
51.1
51
50.9
50.8
50.7
50.6
50.5
50.4
50.2
50.1
50
49
49.2
48.7
48.6
48.5
48.4
48.3
48.2
48.1
48
47.9
47.8
47.7
47.6
47.5
47.4
47.3
47.2
47.1


Upper Wenatchee Project Opportunity Areas
Reaches 10 - 11
N
S
E
W
0
0.25
0.5
1 Miles
Project 52.7L
52.7
52.6
52.5
Project 52.1L
Project 52.8
52.8
Project 52.45
52.1
52.2
Project 52L
52
52.3
Project 52.3R
Project 53L
Project 53.1L
53.2
53.3
51.9
51.8
Project 53.4L
Project 53R
Reach 11
Project 51.7
Project 52R
53.5
53.6
Reach10
Project 53.75
53.9
53.8
51.4
Project 53.85
Project 53.6R
51.3
Project 51.2
Project 53.65R
Project 53.7R
51.2
51.1

Yakama Nation Upper Columbia River Habitat Restoration
River Safety Assessment Project Report
Upper Wenatchee River Study Reach



Submitted to

Jason Breidert
Yakama Nation Fisheries
1885 S. Wenatchee Ave.
Wenatchee, WA 98801

From
MIG
815 SW 2nd Avenue, Suite 200
Portland, OR 97204

December 17, 2012

Notice

On-river assessments conducted for this project are designed to characterize recreation use and existing large wood or other features of the river. This study does not endorse specific boating/tubing, scouting, or portaging options for future river users. The assessments will not specifically endorse particular craft or skill levels for specific reaches or flows, nor are they intended to identify specific locations of potential natural or human-built obstacles or hazards for recreation or navigation purposes. All river users need to make their own decisions about whether or how to scout, run, and/or portage these reaches during any on-river boating or tubing activities. These decisions should be based on several sources of information, knowledge of their own skill and equipment, and direct observation of a river's conditions.

Rivers are inherently hazardous settings and may be physically, mentally, and emotionally stressful, or may aggravate existing physical, mental or emotional conditions. Boating or tubing on rivers may result in damage to or destruction of personal property; serious physical injury or even death arising from a variety of hazards including, but not limited to (and by way of example only), rocks, hazardous terrain, trees, debris, powerful waves, waterfalls, hydraulics, and various man-made or natural hazards; and difficulty or improbability of rescue.

Table of Contents

I. Introduction

In 2012, the Yakama Nation Fisheries hired MIG, Inc. to conduct a detailed study of boating recreation and boater safety along a series of rivers in north central Washington, in support of the Upper Columbia Habitat Restoration Project. This report focuses on the Upper Wenatchee River (Figure 1), from the headwaters at Lake Wenatchee to Tumwater Campground approximately 20 miles downstream (RM 54 – 35.5). The goal of this report is to provide a resource in support of the Yakama Nation and partners as they continue to seek ways to balance the safety of recreation users with the many habitat benefits their restoration projects provide for salmonid species.

MIG employed a mix of qualitative and quantitative methods to complete the following tasks:

- Characterize existing boating recreation and County search and rescue response capability;
- Establish a baseline characterization of existing large woody material (LW) with respect to river navigability during the high-use season;
- Present a series of perspectives on potential boating hazards, including large wood, and related river management approaches; and
- Provide a programmatic assessment of potential structural enhancements and large wood projects.

This report includes the following sections:

- Introduction
- Study methods
- Characterization of recreation use
- River safety perspectives
- Evaluation of existing large wood
- Key findings and next steps

Figure 1: Upper Wenatchee River Regional Context

II. Study Methods

A Dynamic, Mixed-Methods Approach

Data collection for the Upper Wenatchee River began in June 2012 and ended the first week in September 2012. The study timeline and approach (outlined more specifically in Appendix A) were necessarily dynamic in nature to account for a rapid project start-up, quickly changing seasonal flows, and varied and limited availability of candidate interviewees, survey participants and on-water panelists.

The study team gathered information about the Upper Wenatchee River via a number of activities, including:

- A series of informal discussions and in-depth interviews;
- In-person surveys of boaters and tubers;
- User counts and first-hand observations of river use;
- On-water assessments and characterization of existing large wood and potential large wood hazards; and
- Review of existing reports and studies, including review of potential structural enhancement restoration projects.

A brief discussion of methods for each activity is provided below.

Boater and Expert Interviews

As part of this study, MIG conducted in-depth interviews with river users and others with first-hand knowledge of and experience on the Upper Wenatchee River. Interview questions were designed with the following objectives in mind:

- Obtain information about potential survey locations and recreation (i.e., boating/tubing) use levels;
- Obtain general impressions of current safety hazards within the Upper Wenatchee River study reach;
- Obtain general impressions of safety hazards associated with habitat restoration actions; and
- Recruit participants for on-water LW assessments.

Six formal telephone interviews were completed for the Upper Wenatchee River. Interviewees included County swiftwater rescue personnel, local commercial outfitters who serve or have served boaters of this reach, USDA Forest Service (USFS) personnel, residents of adjacent riparian properties, and boaters of varying skill and experience.

The information collected during interviews was used to help craft the survey instrument, approach and timeline, and directly informs findings presented in this report. The list of project interviewees is included as Appendix B.

Boater Surveys

In Summer 2012, MIG conducted in-person surveys of Upper Wenatchee River boaters and tubers. Surveys took place on three weekends during the 2012 peak use season and during peak afternoon and evening hours for a total of seven days.

The goal of surveying boaters and tubers was to collect information related to the participants' most recent river trip. Specific questions focus on the following:

- Use and experience levels;
- Easily observable or identifiable behaviors that may play a role in determining relative on-water risk, such as type of watercraft and use of personal flotation devices;
- User perceptions of river hazards; and
- Management preferences related to safety-related information and on-river conditions.

Data collection staff largely targeted boaters and tubers just completing their float and coming directly off the river, and so the majority (though not all) of responses related to the respondent's "most recent trip" are assumed to be based on that day's experience. The team began the study with five potential survey locations in mind (Table 1), based on the community's identification of five popular take-out locations (via interviews and informal discussions). To maximize the number of surveys completed, the most popular take-outs were visited most often.

To collect data from a representative sample of boaters, MIG staff contacted every party they encountered and asked if they wanted to participate in a brief survey. Requiring MIG staff to do this eliminated the potential bias associated with only approaching a particular type of person (e.g., male versus female, young versus old). Data were collected for as much of the summer season as was feasible, given the project scope and start date. The dates during which data were collected represented both holiday and non-holiday weekends; weekday sampling was explicitly avoided due to very low boating or tubing use that occurs during that time period. Finally, sampling occurred on days associated with a range of in-stream flows representing a variety of boating or tubing conditions.

A total of 133 people completed the survey. Surveys were self-completed on paper. Not every participant provided an answer to every question. Table 1 provides an overview of survey locations, surveys completed and flow conditions corresponding to the user experience.

Table 1: Upper Wenatchee River Survey Locations, Numbers and Conditions

	Number of surveys completed	**Primary Survey Locations**	**River Flow (Range)[1]**
Weekend 1: *Fri, Aug. 10 – Sun, Aug 12*	25	Mosquito Alley[2] Beaver Valley Bridge[3] River Road "Beach" Ponderosa Community Club Tumwater Campground	1,390 – 1,710 cfs
Weekend 2: *Sat, Aug 18 – Sun, Aug 19*	52	Ponderosa Community Club Beaver Valley Bridge	1,160 – 1,230 cfs
Weekend 3: *Sat, Sept 1 – Sun, Sept 2*	56	Mosquito Alley Ponderosa Community Club Beaver Valley Bridge	606 – 661 cfs

[1] USGS Stream Gauge at Plain, Washington.
[2] Beaver Valley Road cerca Mile Post 16.
[3] Commonly referred to as "Plain Bridge" by survey respondents.

Observation Data: Recreation Use Levels

Observational data were collected for this study to help make preliminary estimates of boating and tubing use levels, and to count and describe large woody material and other notable features in each study reach. Observational data to help estimate boating and tubing use levels were collected during the three weekends corresponding with in-person boater surveys. Recreation use estimates were cross-referenced with other estimates of use provided by surveyed boaters, interviewees and agency reports (to the extent they are available and relevant).

On-Water Assessment of Existing Large Wood

Well established protocols exist for using boater panels to conduct on-water evaluations of boatability (Whittaker et al., 1993), and numerous studies reflect those protocols. For this project, however, the on-water evaluation focused specifically on one attribute with potential to affect boatability: the presence of large wood in the water. The assessment protocols used in this study are accurately described below, but no research has evaluated whether other panels applying the same protocols would produce reliably similar results.

Observational data for large woody material (LW) were collected during the on-water boating assessments. Staff and expert volunteers recorded the location and defining characteristics of LW and classified it based on relative potential risk to tubers and boaters. Each location was assigned GPS coordinates and, for illustrative purposes, photographs were taken of LW characteristic of a given reach or risk level.

Boater panels comprised of experienced boaters, local search and rescue staff, and agency/stakeholder staff participated in the on-water evaluations. On-water LW assessments occurred at the following three flows, as measured at the stream gage located near Plain, Washington:

- High flow *(pilot assessment):* 4,900 cfs on July 20, 2012
- Medium flow: 1,900 cfs on August 8, 2012
- Low flow: 570 cfs on September 5, 2012

Each assessment occurred on a single day, with the group beginning at Lake Wenatchee, and ending at Tumwater Campground. Figures 2 and 3 (later in this report) depict locations of LW data collected during the assessment (discussed in Section V). Table 2 provides a summary of on-water panelist skills and experience.

All trips were completed without incident. Panelists identified and evaluated LW pieces and clusters as a group, with the intent of characterizing each identified large wood piece or cluster based on consensus opinion.

Table 2. Summary of Boater Panel Characteristics

Name	Affiliation	Skill Level	Craft used	Flow level evaluated
Panelist 1	Chelan County Swiftwater Rescue, outfitter-guide	Class III	Inflatable kayak	Medium
Panelist 2	Outfitter-guide	Class III	Tube	Medium
Panelist 3	Chelan County Sheriff's Office	Class III	Stand-up paddleboard	Medium
Panelist 4	River guide and kayaker	Class III	Kayak	Medium
Panelist 5	River guide and kayaker	Class IV	Inflatable kayak, raft	Low, Medium, and High
Panelist 6	River guide and kayaker	Class IV	Inflatable kayak	Low
Panelist 7	Paramedic at Cascade Medical	Class IV	Inflatable kayak	Low
Panelist 8	Yakama Nation	Class II	Cataraft	Low and High

Protocols were developed prior to the July 2012 high flow pilot run in July, then revised for more detailed and systematic data collection at target medium and low flows in August and September. LW categories and panelist instructions for classifying LW are summarized in Table 3. The variables used to classify LW included:

1. Location of LW in the channel (right side, center, left side)
2. Channel (identified as main or side channels)

3. LW projection into the channel (as a rough percentage of the boatable channel)
4. LW angle relative to bank/channel
5. Current power
6. Roughness: amount of branches
7. Complexity: ranges from a single log to a group of logs
8. Sight distance: line of sight from a boater's perspective approaching LW from upstream

The LW classification system was developed by MIG to rate the degree to which large woody material in the river could create navigability challenges. Large woody material was classified using a scale of “A” thru “F.” This on-water assessment focused on collecting information (location and key characteristics) for LW classified as “Type C” or greater. LW pieces or clusters classified as a Type C have one or two characteristics that increase the potential for a boater to interact with it, relative to Type B LW. At the highest end of the rating system, LW classified as a “Type F” would be LW that spans the entire channel and requires boater portage.

LW pieces or clusters classified as a Type C have one or two characteristics that increase the potential for interaction with a boater. In general, routine navigation allows a boater or tuber to avoid contact with a Type C, but contact could occur if he/she is inattentive or unskilled. Type D LW requires boaters to engage in active navigation (defined here as involving at least one substantial positive maneuver) to avoid contact with a Type D. In other words, routine navigation may not be sufficient to avoid contact with LW characterized as Type D. If contact occurs with Types C or D, consequences are uncertain and could be serious.

Table 3. Large Wood Types and Evaluation Protocol

LW Type and Assessment Action	Type Description
A *(do not count)*	• Located below ordinary high water but dry or projecting into boatable current less than 5 feet at this flow.
B *(do not count)*	• In general, it would take active navigation toward LW to make contact with a Type B, and the consequences of contact are generally low. • Located in water at this flow but generally has a small projection into boatable channel. • Located in side channels or on the inside of a bend, or is aligned parallel to current (so there is little current pressure against the obstacle). • Typically in a reach with lower current power and velocity. • Generally fewer logs in the cluster, little "roughness" or "complexity," and easy to see from a distance upstream.
C: *Count, characterize, GPS and take select photos*	• In general, "routine navigation" allows a floater to avoid contacting a Type C, but contact could occur if a floater is inattentive or unskilled. • If contact occurs, consequences are uncertain and could be serious. • Compared with "B", one or two characteristics increase potential for boater interaction. • At least one characteristic is one level higher than "low" but none is at "high levels."
D: *Count, characterize, GPS and photograph all*	• In general, these require floaters to engage in "active navigation" (at least one substantial positive maneuver) to avoid contact with a Type D ("routine navigation" may not be sufficient to avoid). • If contact occurs, consequences are uncertain and could be serious. • Three or more characteristics increase potential for interaction (at least one level higher from "low,") or there is at least one characteristic that is at a "high" level. • Center piling bridges and similar man-made features also fall into this category.
E: *Count, characterize, GPS and photograph all. When relevant, estimate width of boatable channel (in feet) and describe other navigation issues (eddy locations, class of rapid if relevant, etc.).*	• A boatable channel may exist, but substantial "active and accurate navigation" is likely needed to avoid contact. • If contact occurs, consequences are uncertain and likely to be serious. • Multiple characteristics at "high" levels that substantially increase potential for contact.
F: *Count, characterize, GPS and photograph all. Describe eddy and portage characteristics.*	• Channel spanning LW or characteristics that prevent navigation (portage required).

III. Characterization of Recreation Use

Overview of Boating and Tubing on the Upper Wenatchee

American Whitewater describes the Upper Wenatchee as mostly a Class II river. Starting at Lake Wenatchee, most of the river is Class I, but there are a few Class II rapids upstream of the bridge in Plain, a commonly used boat access point. According to local outfitter-guides, this reach is essentially Class I at low flows. Even at high flows, this reach is never more challenging than Class I-II+ whitewater. The only Class II+ rapid is a wave train through a left-hand turn that has a larger hydraulic on the inside of the bend at about RM 40.8.

The boating season for the Upper Wenatchee generally runs from April to October. During the peak summer season, when the weather is warm and water levels are relatively low, interviewees estimate that anywhere from 40 to over 100 people float the river on a given weekend day. Saturday is generally the most popular day on the river. Actual observed use during surveys and counts exceeded these estimates. An average of 130 boaters/tubers per day was observed, with an average of 23 groups per day.

During the week, use is far less frequent. Observations suggest that only a small number of groups or individuals float this reach on a typical weekday during boating season. On-water panelists encountered six adult boaters or tubers total during the August 8th assessment, and two adults from the Washington Department of Fish and Wildlife on September 5th (both Wednesdays). According to one County Swiftwater Rescue deputy interviewed, it is rare to see someone floating the Upper Wenatchee on a weekday.

American Whitewater (2012) reports a boatable range of 15,000 cubic feet per second (cfs) to 400 cfs, below which flows become unboatable. On-water assessment participants rated all flows as acceptable for boating in several craft, although the lowest flow had two shallow riffles areas that required participants to walk their boats briefly. On-water panelists also rated the amount of large wood as acceptable at all flows for the craft and skill level of those who commonly use the river.

River access is limited, particularly for boaters and users who do not have access to private property along the river. Some existing access points have steep slopes, lack of eddies, and nearby LW or other constructed hazards (e.g., exposed rebar, bridge pilings, etc.). One interviewee shared that his personal trips down the river have decreased significantly due to limited river access. Lack of river access is viewed by another interviewee as an important boating safety issue in that it can force a longer trip than boaters are prepared for.

The most commonly used access points include the following locations:

- Lake Wenatchee State Park
- Mosquito Alley
- “Plain Bridge” (i.e., Beaver Valley Bridge)
- River Road “Beach”

- Ponderosa Community Club
- Tumwater Campground

Roughly ten percent of survey participants reported that they ended their trip at a private residence along the river. All known public or semi-private river access points identified during this study are shown on Figures 2 and 3.

River User Profile

This section presents a profile of boaters and tubers of the Upper Wenatchee River based primarily on results of the in-person surveys conducted for this project (Summer 2012). Descriptions are also informed by direct observations and interviews.

Nature of Trip and Group Characteristics

By and large, trips down the Upper Wenatchee River are made by private boaters or tubers. Commercial outfitters who once rented tubes or ran groups down this portion of the river no longer do so, with required permitting and lack of physical river access the primary reasons for discontinuing services. Only one of 133 Summer 2012 survey respondents described his most recent trip as a commercial trip. All others characterized their most recent river trip as private.

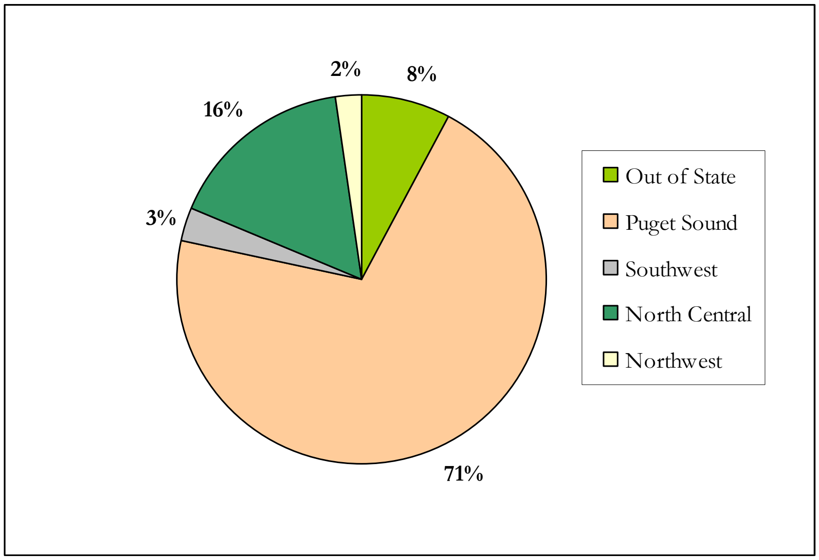
Group sizes ranged from one to over ten people. Ninety-eight percent of participants stated that their group included at least one adult. Over 35 percent and 2.6 percent of respondents had at least one young adult and at least one child under the age of 13 in their group, respectively. About two-thirds of users counted were adults (68.5%), and only about one-third (30.6%) of all respondents were observed wearing a PFD.

Location of Residence

The majority of survey respondents (71%) claimed Seattle/Puget Sound as their region of residence. Local residents (North Central Washington, primarily from Leavenworth and Wenatchee) comprised 16 percent of survey respondents. Out-of-state boaters made up 8 percent of all survey participants. Figure 4 illustrates the areas of residence of the survey sample.[1]

[1] Residency was reported by zip code and aggregated according to region, with regions defined by "Access Washington" (http://access.wa.gov/visiting/resources/washingtonmaps_images.aspx, accessed September 20, 2012). Northwest Washington includes all of Skagit County; Southwest Washington includes Clark and Cowlitz counties.

Figure 4: Survey Respondent Areas of Residence (Washington State and Out of State)



On-Water Experience

Survey respondents represent a range of boating skill levels. Reported boating and tubing experience levels on the Upper Wenatchee ranged from 0 to 42 years. Respondents reported an average 13.3 years of overall experience floating and tubing rivers; the median level of experience reported was 10 years. Approximately 17 percent reported two or fewer years of on-water boating or tubing experience.

Over 90 percent (91.1%) of participants claimed at least one year of former boating experience on the Upper Wenatchee River, and 62.5 percent of participants have prior experience floating the Upper Wenatchee on an inner-tube.

Craft and Skill Level

Over one-third (37.4%) of those who reported which type of craft they used personally floated the river using a raft, compared to almost 28 percent who reported floating in inner-tubes. Slightly over one-quarter (25.3%) used kayaks (Table 4), and over eight percent of survey participants used "other" craft types, primarily canoes. Use of one "pool toy" was reported.

Observational data collected on boaters and tubers indicated that most users floated the Upper Wenatchee in a tube (49.3%). This proportion of craft type is higher than what survey respondents reported, possibly due to field staff combining "cheap" vinyl rafts with inner tubes during user counts.

Table 5 presents self-reported skill levels in the craft used during the day's float. Nearly 60 percent of those surveyed are self-identified Class II boaters, and nearly 17 percent feel most comfortable boating a Class I river. However, this response may be overstated by the 27.7

percent of people who used inner-tubes, which by their very nature limit control, maneuverability and line of sight.

Table 4: Type of Craft Personally Used on Trip

Type of Craft	Response Percent[1]	Response Count
Raft (Total)	**37.4%**	**31**
Raft (multi-chamber)	22.9%	19
Raft (vinyl/cheap)	14.5%	12
Kayak (Total)	**25.3%**	**21**
Kayak (inflatable)	18.1%	15
Kayak (hardshell)	7.2%	6
Inner-Tube (Total)	**27.7%**	**23**
Inner-tube (covered, high quality manufactured)	16.9%	14
Inner-tube (black tire)	3.6%	3
Inner-tube (cheap/vinyl)	7.2%	6
Cataraft	**1.2%**	**1**
Other (please specify)	**8.4%**	**7**
Totals	**100%**	**83**

[1] Numbers reflect only those who reported the one craft used personally (i.e., those who provided only one answer to the question, "What type of boat/craft did you use today or on your most recent trip?)

Table 5: Skill Level in Craft Used Day of Float/Survey

Answer Options	Response Percent	Response Count
Class I: Moving water with a few riffles and small waves. Few or no obstructions.	16.8%	22
Class II: Easy rapids with smaller waves, clear channels that are obvious without scouting. Some maneuvering might be required.	59.5%	78
Class III: Rapids with high, irregular waves. Narrow passages that often require precise maneuvering.	16.0%	21
Class IV: Long, difficult rapids with constricted passages that often require complex maneuvering in turbulent water. The course may be hard to determine and scouting is often necessary.	4.6%	6
Class V: Extremely difficult, long, and very violent rapids with highly congested routes, which should be scouted from shore. Rescue conditions are difficult, and there is a significant hazard to life in the event of a mishap. The upper limit of what is possible in a commercial raft.	3.1%	4
Totals	100%	131

Nearly 60 percent (59.8%) of boaters/tubers surveyed stated that the day's flow was below their skill level. This is reflective of the slow current speeds and lack of whitewater challenge generally characteristic of this reach during the high use season. Almost 40 percent (39.4%) stated that the flow was at their skill level. Only one of the 127 people who answered stated that the day's flow was above his/her skill level.

Safety-Related Behavior

When reporting on their most recent trip, 46 percent of survey participants reported that no one in their group wore a personal flotation device (PFD). In comparison, 31 percent claimed that all group members wore a PFD, which is consistent with observational findings; 23 percent answered that "some" group members wore PFDs. One interviewee who lives in the Ponderosa community reported that only a small fraction of people he has witnessed pass by or come off the river at the Ponderosa Community Club wear PFDs.

Anecdotal evidence indicates that some boaters and tubers consume alcohol on their trip. However, observational data collected during the three weekends when surveys were administered indicated four out of 141 groups were intoxicated. MIG staff observed about 20 percent of all those observed had coolers with them, but direct observation of groups consuming alcohol was low, with one other group (in addition to the four referenced above) transporting alcohol.

Nearly two-thirds (62.3%) of all survey respondents did not obtain information about boating conditions prior to their trip. Of those who did, almost 90 percent (87.5%) received information via word of mouth, while almost one in ten respondents (8.9%) sought information online (Table 6).

Table 6: Where respondents obtained information for their trip[1]

Answer Options	Response Percent	Response Count
Word of mouth	83.5%	56
Website	8.9%	6
Spoke with representative of Forest Service or Washington State Parks	1.6%	1
Heard or saw a public service announcement	0.0%	0
Other	6.0%	4
Totals	100%	67

[1] Responses to this question represent those respondents (n=67) that indicated they had obtained information prior to their trip.

IV. River Safety: Perspectives, Management and Response

This section describes Chelan County organizational response capabilities to boating-related emergencies, including search and rescue resources and general dispatch procedures for the Upper Wenatchee River. It also describes survey respondents' perceptions of on-water conditions that may impact boater safety.

County Search and Rescue Capabilities

The Sheriff's Office Department of Emergency Management provides the primary resources for all river-related safety incidents in Chelan County. This Department includes the Search and Rescue Unit, the Marine Patrol Unit and the Swiftwater Rescue Unit. These three units work in collaboration with a variety of on-call responders and volunteers throughout the county.

The following section outlines the search and rescue resources and general dispatch procedures for the Upper Wenatchee River.

Initial Dispatch

Almost every safety incident report is called into the emergency 911 line, where dispatchers send the necessary resources to the area. For river-related safety incidents on the Upper Wenatchee reach, the following resources are automatically dispatched:

- Emergency responders, through the Sheriff's Department;
- A basic life support vehicle stationed at Lake Wenatchee and staffed with emergency medical technicians with advanced training;
- A Cascade Ambulance paramedic unit based out of Leavenworth; and
- Volunteer firefighters from District 9 Fire Department.

Department of Emergency Management Units

The Search and Rescue, Marine Patrol and Swiftwater Rescue Units are all Special Operations Units within the Department of Emergency Management. These resources are called upon by the Chelan County Sheriff's Department if the situation requires their expertise.

The Search and Rescue (SAR) Unit is composed of full-time employees trained in SAR management, the use of specialized equipment and outdoor survival. The SAR Unit also coordinates efforts with the Chelan County Volunteer Services and other volunteer SAR groups.

The Marine Patrol Unit, a component of the Chelan County Sheriff's Office, is responsible for performing rescue operations for any person or vessels in distress on Chelan County waters. The unit operates primarily on Lake Chelan, Columbia River and Lake Wenatchee.

The Unit is comprised of 16 marine deputies with a fleet consisting of three patrol vessels and one available rescue boat. The Unit also assists other divisions and agencies as needed and provides support to the search and rescue missions of the Sheriff's Office. In addition, the Marine Patrol Unit provides boating safety and education classes to the public.

The Swiftwater Rescue Unit is supervised by Marine Patrol Sergeant Randy Foltz. Swiftwater Rescue deputies respond on call to swiftwater incidents, and use a variety of water craft and tools, depending on the circumstance.

If the incident does not escalate into a search and rescue situation, then the Sheriff's Department does not keep special reports on the event. Safety incidents are often called in more as information than as a response, and they are often resolved before responders can get to the scene. Between January 1, 2001 and October 10, 2012 all Wenatchee River incidents occurred outside of the project area.[2] There were six reported incidents in the project vicinity including two at Nason Creek and four on the White River.

Safety and Rescue Volunteers

Although Chelan County Sheriff's Department has overarching authority in emergency response, the volunteer Fire Department acts as support for staff and equipment resources. For safety incidents on the Upper Wenatchee River, the primary Volunteer Fire District is No. 9, which is based out of Lake Wenatchee. District 9 covers the Wenatchee River from Lake Wenatchee to Tumwater Bridge, with any incidents beyond this covered by District 3 out of Leavenworth. District 9 also covers the entirety of Nason Creek.

The District 9 Volunteer Fire Department is comprised of three fire stations located near Lake Wenatchee, in Plain and at Chiwawa Pines. There are 25 volunteers spread throughout the three stations, and the majority of volunteers are formally trained in swiftwater rescue. Another close resource is the District 4 Volunteer Fire Department, based out of the Ponderosa community just south of Plain. These volunteers can be called to aid if additional river rescue resources are needed on the Upper Wenatchee River. District 4 has one head chief and approximately 12 volunteers. District volunteers have "Level 2" swiftwater rescue training. This level of training allows volunteer to perform rescue operation from the shore only (Wilson, 2012, personal communication).

User Risk and Safety Concerns

When asked, "when boating or floating this river, what are your primary safety concerns?" interviewees provided the following responses:

- Ill-prepared and unskilled users;
- Use of inner tubes and cheap rafts by inexperienced users;
- Parents not taking sufficient safety precautions with younger children (cold water, PFDs, etc.);
- Lack of user education about river safety;

[2] Information gathered from e-mail correspondence with Eileen Ervin of the Chelan County Sheriff's Office Emergency Management Unit. (10/10/12).

- Infrequent use of PFDs;
- Inattentive or intoxicated users;
- Lack of safe river access points (steep slopes, woody debris, no eddy);
- Lack of river access (forcing a longer trip than people come prepared to run);
- High, fast-moving spring flows; and
- Obstacles in the river such as logs and rocks.

To help gauge river user perceptions of existing on-water risk, survey participants were asked the question, "In your opinion, what were the greatest risks while you were boating today/during your most recent trip?" Respondents were asked to rate seven items, but were not asked to rank order their responses. In other words, all items could have been rated at a "high level of risk." "Rocks and rapids" were most frequently reported as features of the river that presented "some level of risk," a "high level of risk," or an "extreme level of risk".

These results indicate respondents' perceptions of only the seven items referenced above. The question about reported levels of risk did not include an "other" category, which would have allowed respondents to identify other risk related features not covered by the seven items.

Of the seven possible items, "channel spanning logs" and "large wood blocking parts of the channel" were most frequently noted to pose no risk at all (Table 7). Roughly 40 percent of respondents expressed that large wood on the side of the channel posed a slight level of risk. This is a higher proportion of respondents than the proportion who stated large wood blocking the channel (30.2%), and channel spanning logs (19.7%) posed a "slight level of risk."

Table 7: Reported Levels of Risk During Day's Float[1]

	No risk at all	Slight level of risk	Some level of risk	High level of risk	Extreme level of risk	Don't know	***Response Count***
a) Fast water	40.2%	40.2%	16.5%	2.4%	0.8%	0.0%	*127*
b) Cold water	42.5%	31.5%	19.7%	5.5%	0.8%	0.0%	*127*
c) Large wood on sides of channel	36.2%	40.2%	19.7%	3.9%	0.0%	0.0%	*127*
d) Large wood blocking part of the channel	55.6%	30.2%	8.7%	4.8%	0.0%	0.8%	*126*
e) Channel spanning logs	68.5%	19.7%	4.7%	5.5%	0.8%	0.8%	*127*
f) Rocks and rapids	21.4%	33.3%	34.9%	9.5%	0.8%	0.0%	*126*
g) Mix of the above	21.6%	45.0%	25.2%	3.6%	2.7%	1.8%	111

[1] Percentages are rounded to the nearest tenth of a percent.

In answer to a separate question, 70 percent of participants stated that potential hazards from large wood on the banks or in the river was either "acceptable" or "totally acceptable"; 26.1 percent either said that they were neutral on the subject, or that they didn't notice. Only

3.8 percent characterized the amount of potential hazards from large wood on the banks or in the river as “totally unacceptable.”

One interviewee, a professional river guide who has taught swiftwater rescue courses around the state, shared the following perspective: “Rivers are natural, and we do not consider natural features a river hazard. The user’s lack of skill, knowledge and awareness of such river features [lead them to] create their own hazards.”

Management Actions to Improve Boating Safety and Experiences

All study survey participants were asked to express their level of support for, or opposition to, a series of potential management actions related to behavioral risk and river safety (Table 8). The following key findings emerged:

- Of all management actions listed in the survey, participants most frequently expressed strong support for: a) using websites to post photos and information about hazards; and b) passing a PFD requirement for boaters/tubers.
- Over 26 percent of respondents strongly support passing a requirement for boaters/tubers to wear PFDs; 19 percent strongly oppose. A couple of participants expressed that their support of such a policy depends on the age of the boater/tuber to whom it would apply.
- Over half (55.4%) of respondents expressed some level of opposition to requiring boaters to self-register before floating the river.
- Fifty percent of survey participants who made note of their opinion on the issue felt “neutral” about providing more large wood information at put-ins and take-outs; placing warning signs about large wood that include directional suggestions received a slightly higher level of support than signs simply identifying large wood hazards.

Survey participants who noted that they believe existing large wood (irrespective of character, interaction with river or location) poses at least “some” level of risk to river users were asked to state whether they supported any of three possible management actions. Sixty-three participants responded. Results are reported in Table 9.

Survey participants most frequently expressed support for posting signs that inform boaters of large wood on the river, with a 38 percent rate of support among this group. Of the nine people who suggested that management agencies take "other" actions, five identified “no action” as their preferred management approach (i.e., "do nothing," "none," "at your own risk").

Table 8: Level of Support or Opposition to Potential Management Actions

Answer Options	Strongly oppose	Slightly oppose	Neutral	Slightly support	Strongly support	Don't know	Response Count
a) Require boaters/tubers to wear PFDs.	19.1%	15.3%	22.1%	15.3%	26.7%	1.5%	131
b) Require boaters to self-register before they float the river (to help agencies monitor use, skill levels, types of craft) and provide an opportunity to warn floaters of large wood hazards.	32.3%	23.2%	19.2%	19.2%	4.6%	1.5%	130
c) More large wood information at put-ins/take-outs.	6.3%	5.6%	50.0%	24.6%	11.9%	1.6%	126
d) Warning signs on site to identify large wood hazards.	8.7%	6.3%	39.4%	27.6%	15.0%	3.0%	127
e) Warning signs with directional suggestions ("go left") at large wood hazards.	10.8%	14.6%	26.1%	29.2%	17.7	1.5%	130
f) Websites with maps and photos of hazards.	7.7%	3.8%	34.6%	24.6%	27.7%	1.5%	130

Table 9: Support for Select Large Wood Management Actions by Participants who View Large Wood as Presenting a Potential Safety Risk

Answer Options	Response Percent	Response Count
Post signs informing boaters of large wood in the river	38.1%	24
Construct portage trails around areas with large wood in the river	12.7%	8
Remove large wood from the river to the extent practical	34.9%	22
Other (please specify)	14.3%	9
	100%	**63**

V. Evaluation of Existing Large Wood

On-Water Assessment Findings

As described in the methods section of this report, large woody material was evaluated and typed based on eight defining characteristics. Only LW with sufficient character to warrant a "Type C" rating or higher was counted and reported. On-water panelists did not identify any Types E or F present. Therefore, findings and related discussion focus largely on LW Types C and D.

As explained in section II above (Study Methods), LW pieces or clusters classified as a Type C have one or two characteristics that increase the potential for interaction with a boater but in general can be avoided with routine navigation by an attentive, skilled boater or tuber. Routine navigation may not be sufficient to avoid contact with LW characterized as Type D; Type D LW requires boaters to engage in active navigation to avoid contact. In general, the consequences of contact with Types C or D are uncertain but could be serious.

There are few consistent "rules" that determine whether a LW piece or cluster becomes a Type D hazard. Some LW rates higher because of a longer projection into the boatable channel or because of greater approaching current power. Other reasons for rating LW as a potential Type D hazard include a more perpendicular angle relative to the current or because of greater roughness and complexity (as defined in Section II). Few exhibit all of these characteristics at more hazardous levels; the specific geometry of the existing large wood and channel are highly individual and cluster-specific.

Interfluve (2012) conducted a habitat assessment in 2011 noting LW in the same river reach as this study. Most naturally occurring LW identified in this habitat assessment (Interfluve, 2012) are not substantial recreation hazards. Habitat studies identified an average of 123 pieces per mile over the 18.7 miles of river. Assessments conducted for this study estimate only 1.1 to 3.4 LW pieces or clusters (depending on the flow) that rose to a Type C or D.

Table 10 summarizes the number of LW pieces/clusters at different flows and compares it to LW counts from the habitat study (Interfluve, 2012). Counts are presented for individual reaches delineated in the Interfluve study, as well as for the entire study area.

Table 11 summarizes the percent of pieces/clusters with different characteristics for medium and low flows. Figures 2 and 3 illustrate the general locations of large wood clusters characterized as Types C and D relative to known river access points and other features. Data points presented in Figures 2 and 3 reflect represent unique clusters or pieces of LW. Following the on-water assessment, GPS points taken during the low and medium flow assessments were compared, and these were combined where points clearly represented the same LW.

Most of the LW pieces or clusters identified as potentially substantial recreation hazards were characterized as Type C rather than Type D. There are an average of 0.9 to 2.4 Type Cs per mile along the river (depending on flow), but only 0.1 to 0.8 Type Ds per

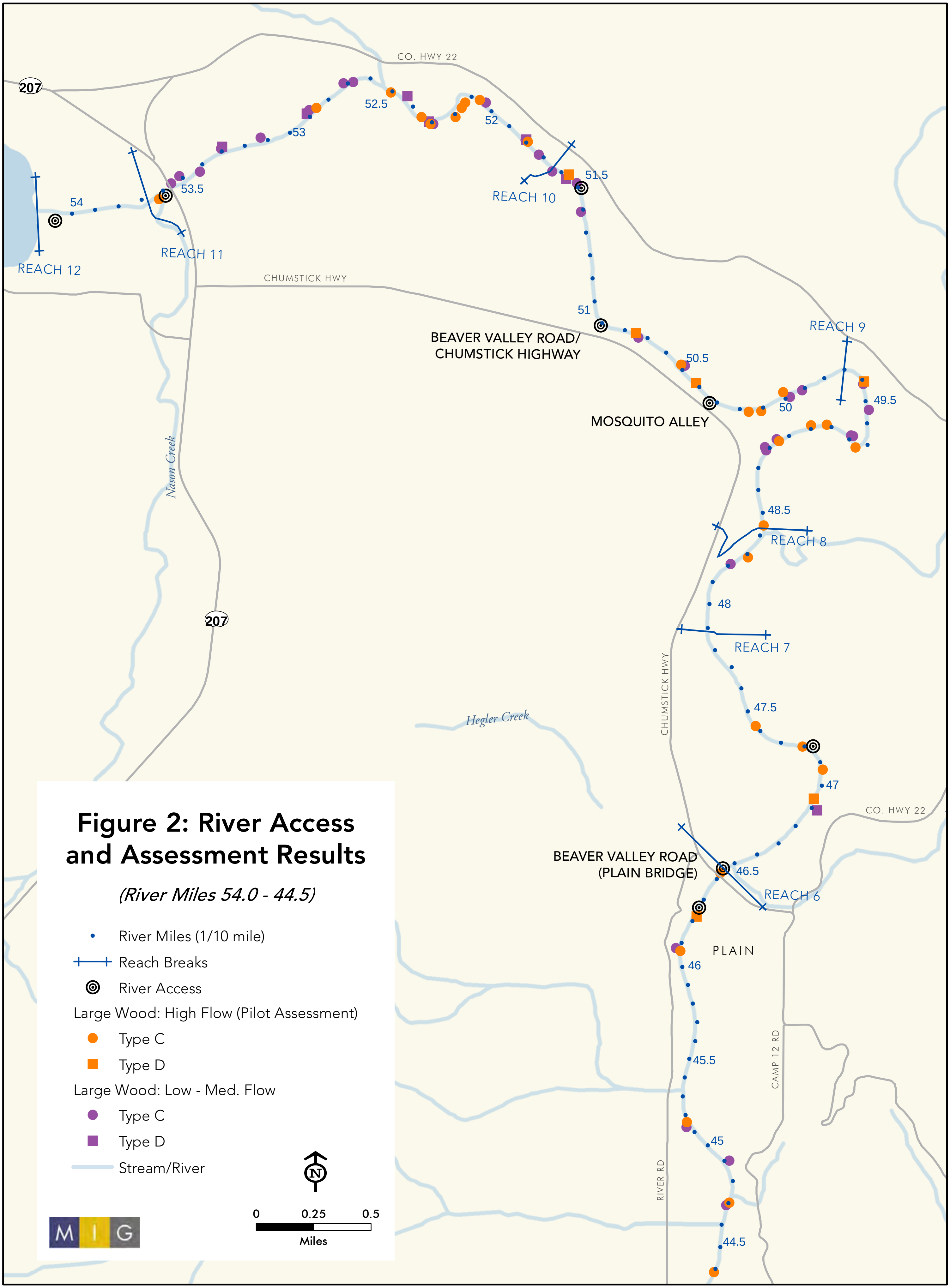


Figure 2: River Access and Assessment Results

(River Miles 54.0 - 44.5)

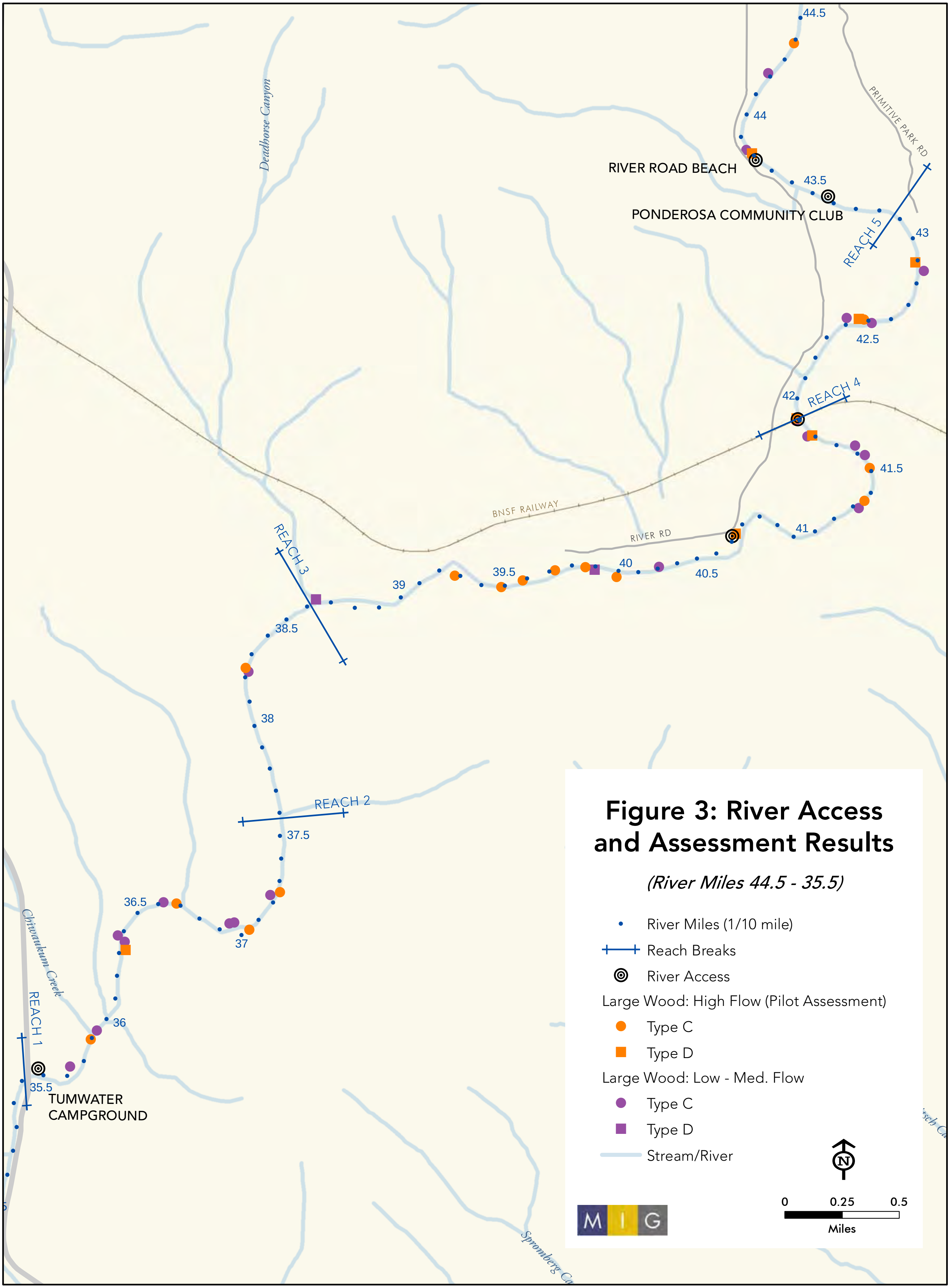


Figure 3: River Access and Assessment Results
(River Miles 44.5 - 35.5)
River Miles (1/10 mile)
Reach Breaks
River Access
Large Wood: High Flow (Pilot Assessment)
Type C
Type D
Large Wood: Low - Med. Flow
Type C
Type D
Stream/River
0
0.25
0.5
Miles
N
MIG
RIVER ROAD BEACH
PONDEROSA COMMUNITY CLUB
TUMWATER CAMPGROUND
PRIMITIVE PARK RD
BNSF RAILWAY
RIVER RD
Deadhorse Canyon
Chiwaukum Creek
Spromberg Ca
REACH 1
REACH 2
REACH 3
REACH 4
REACH 5
44.5
44
43.5
43
42.5
42
41.5
41
40.5
40
39.5
39
38.5
38
37.5
37
36.5
36
35.5

Table 10. Physical and LW Characteristics of Upper Wenatchee River Segments.

Segment	RM start	RM end	Length	Slope fpm	% riffle	Bankfull width	LW per mile	High flow			Medium flow			Low flow		
								C per mile	D per mile	total per mile	C per mile	D per mile	total per mile	C per mile	D per mile	total per mile
11	53.7	54.2	0.5	2	0	360	242	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	51.7	53.7	2.0	2	20	243	101	6.5	0.0	6.5	4.0	1.5	5.5	2.5	1.0	3.5
9	49.7	51.7	2.0	1	14	282	75	2.5	1.5	4.0	2.5	0.5	3.0	1.0	0.0	1.0
8	48.4	49.7	1.3	2	21	300	57	3.1	1.5	4.6	3.1	0.0	3.1	2.3	0.0	2.3
7	47.9	48.4	0.5	4	54	282	13	2.0	0.0	2.0	2.0	0.0	2.0	0.0	0.0	0.0
6	46.5	47.9	1.4	5	67	240	67	2.9	1.4	4.3	0.0	0.7	0.7	0.0	0.0	0.0
5	43.1	46.5	3.4	4	56	278	32	1.2	0.3	1.5	1.8	0.0	1.8	0.0	0.0	0.0
4	41.9	43.1	1.2	4	30	276	63	0.8	2.5	3.3	2.5	0.0	2.5	0.8	0.0	0.8
3	38.6	41.9	3.3	5	31	270	252	2.7	0.6	3.3	1.2	0.3	1.5	0.6	0.3	0.9
2	37.6	38.6	1.0	4	34	312	47	1.0	0.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0
1	35.5	37.6	2.1	4	10	326	294	3.3	0.5	3.8	1.9	0.0	1.9	2.4	0.0	2.4
Total	**35.5**	**54.2**	**18.7**	**4**	**31**	**280**	**123**	**2.4**	**0.76**	**3.4**	**1.8**	**0.27**	**2.2**	**0.9**	**0.12**	**1.1**

Table 11. Summary of key characteristics of LW recreation hazards (Types C and D) on the Upper Wenatchee River.

	High flow	Medium flow	Low flow
Number of Type C LW (total)	49	36	18
Number of Type D LW (total)	14	6	3
Number of Type C & D LW (total)	63	42	21
Percent projecting 10 to 20 feet	Individual variable data not collected during pilot assessment	10%	29%
Percent projecting 20+ feet		10%	14%
Percent in side channels		14%	33%
Percent angled steeply downstream (30 degrees or less from bank)		71%	48%
Percent perpendicular or angled upstream		12%	19%
Percent with low power / current velocity on facing edge		19%	14%
Percent with high power / current velocity on facing edge		5%	14%
Percent with single log		33%	43%
Percent of clusters with 5+ logs		7%	9%
Percent with "low" roughness (few branches or entrapment spaces)		31%	24%
Percent with "high" roughness (many branches or entrapment spaces)		14%	5%
Percent with "low" complexity		38%	52%
Percent with "high" complexity		14%	5%
Percent with "short" sight distance		7%	10%

mile. Overall, at low and medium flow levels, 82 percent of the more potentially hazardous large wood clusters were Type C, rather Type D. At the high flow, about 71 percent were Type C.

The number of large wood clusters rated C or D increased as flows increase. Medium flows resulted in twice the number of LW Types C and D than low flows (2.2 vs. 1.1 per mile), while the high flow assessment found substantially more Types C and D than those recorded at the medium flow level (3.4 vs. 2.2 per mile). This discrepancy may reflect the more conservative approach to characterization taken during this first high flow assessment, as well as a difference in actual on-river conditions.

Lower gradient river segments 8, 9 and 10 (RM 54 to 48) were found to have more Type C and D large wood clusters. The middle, more developed reaches of the river, corresponding with assessment reaches 5, 6, and 7 (from approximately RM 43 to 48), have relatively lower levels of potentially hazardous LW, especially at low and medium flows. More specific information about the 11 individual segments is shown in Table 6.

Several side channels were not visited by the entire panel during the low flow assessment, resulting in the potential "over-rating" of some LW clusters. In contrast, panelists reached near consensus on assessments of existing LW found in the main channel at all flows. Seven LW clusters during the low flow assessment were located in side channels, and about half of these may be on the border between a Type B and C but were counted as Type C. Rating these as Type B would only further support the general conclusion that lower flows provide many fewer LW hazards, even in side channels (many of which have less than boatable flows for larger craft).

VI. Key Findings

In summary, the final key findings are offered:

- The boating season for the Upper Wenatchee River (RM 54 – 35.5) generally runs from April to October. American Whitewater (2012) reports a boatable range of 15,000 cubic feet per second (cfs) to 400 cfs, below which flows become unboatable. Starting at Lake Wenatchee, most of the Upper Wenatchee River is Class I. There are a few Class II rapids upstream of the bridge in Plain, a commonly used boat access point.

- By and large, trips down the Upper Wenatchee River are made by private boaters or tubers. No commercial outfitters were identified as currently running trips, save for very limited, specially scheduled small group runs down the river.

- River access is limited, particularly for boaters and users who do not have access to private property along the river. Lack of river access, according to some, can force a longer trip than boaters are prepared for. Some existing access points, such as those with steep slopes, are less suitable for use by boaters than tubers.

- Over 90 percent of participants claimed at least one year of former boating experience on the Upper Wenatchee River. Over 62 percent of participants have prior experience floating the Upper Wenatchee on an inner-tube. Nearly 60 percent of boaters/tubers surveyed stated that the day's flow was below their skill level.

- Most naturally occurring large woody material identified in habitat assessments (Interfluve, 2012) does not constitute a substantial recreation hazard. Most of the LW pieces or clusters identified in this study were characterized as "Type C" (78%) rather than "Type D" (see Section II for definitions). Compared with Type D hazards, Type C large wood often blocks less of the boatable channel, interacts with less powerful currents, is angled in more of a downstream position relative to the bank, or has fewer branches and complexity.

- On-water assessment results suggest that the number of "Type C" and "Type D" large woody material increases as flows increase. Overall, lower gradient, upper reach river segments 8, 9 and 10 (RM 54 to 48) were found to have more "Type C" and "Type D" large wood clusters. The middle, more developed reaches of the river, corresponding with assessment reaches 5, 6, and 7 (from approximately RM 43 to 48), have relatively lower levels of "Type C" and "Type D" LW, especially at low and medium flows.

- Of the river features identified as potential hazards for boaters and tubers, study survey participants most frequently noted "channel spanning logs" and "large wood blocking parts of the channel" to pose no risk at all. Thirty-eight percent of survey participants who believe that existing large wood poses at least "some" level of risk to river users expressed support for posting signs that inform boaters of large wood on the river (the most frequent positive response to the potential management actions offered).

- Over 26 percent of survey respondents strongly support passing a requirement for boaters/tubers to wear PFDs; 19 percent strongly oppose. Over half (55.4%) of respondents expressed some level of opposition to requiring boaters to self-register before floating the river. Fifty percent of survey participants who made note of their opinion felt "neutral" about providing more large wood information at put-ins and take-outs.

Next Steps

This recreation assessment provides a snapshot of river use in late summer 2012. The information in this report will be used to work with nearby communities to develop a river access plan and to conduct outreach on boater safety issues. The data in the recreation assessment will also be used to guide the development of habitat restoration projects in the Upper Wenatchee corridor.

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APPENDICES

Yakama Nation Upper Columbia Habitat Restoration
River Safety Assessment Project

Study Work Plan | August 2012

Introduction

This work plan is intended to guide data collection efforts for the Upper Columbia Habitat Restoration Project River Safety Assessment. This plan specifically outlines methodological approach, task objectives, specific tools and methods, and a timeline for data collection and on-water river safety assessments. Health and safety protocols for field data collection also are noted.

The Yakama Nation has identified four river reaches in the Upper Columbia Basin where restoration of salmon habitat could occur, and where river safety assessments are needed for 2012 and 2013. These reaches include:

- Nason Creek (RM 0 – 19)
- Upper Wenatchee River (RM 35.5 - 54)
- Chewuch Reach (RM 0 – 20)
- Twisp River (RM 0 – 8)

Restoration actions could include installing engineered logjams, increasing surface flows, removing dikes and levees, and placing large woody debris (LWD) in the channel. To date, engineered logjams are the central element of proposed restoration concepts for the Upper Columbia project area. Recreational uses that could be affected include rafting, kayaking, canoeing, tubing, swimming and paddle-boarding.

The overall purpose of this project is to maximize river safety for the variety of known and anticipated river users as habitat restoration projects are implemented. To accomplish this, the Yakama Nation must evaluate current large wood occurrences and other safety-related conditions in each river reach under a range of surface flows during spring and summer seasons. If the Yakama Nation is considering habitat restoration actions in a reach that already has been evaluated as “high risk,” it will be necessary to consider carefully whether to install additional structures and, if so, to identify the designs and locations that would minimize risk.

Overview of Methodology

A Mixed-Methods Approach

Information about the four study reaches will be obtained via a number of methods, including:

- In-depth interviews and/or focus groups;
- Informal discussions with area residents, outfitters, and agency partners;
- In-person and online surveys completed by casual tubers and boaters, as well as more experienced boaters (as in the case of the Nason, Twisp and Chewuch reaches);
- On-water observations made by expert boaters; and
- Review of existing reports and studies.

The approach applies these different methods for data collection to achieve the following study goals:

Achieve a representative sample. The overall goal of this mixed methods approach is to ensure that the study participants represent the actual populations of river users. For example, if the majority of river users are beginning and experienced boaters and tubers that originate primarily in the Wenatchee/Leavenworth areas, these characteristics should be reflected in data collected. MIG will be able to measure how reliable or representative data are by comparing them to information provided by boating experts and in boating reports for the State of Washington and specific regions. For assessment of on-water conditions, MIG will work to ensure that recorded data are representative of consistent target flow and peak use levels, and that resulting analysis reflects the consensus of a range of expert perspectives.

Collect high quality data. A secondary goal of this study is to collect as much data as possible while maintaining high data quality and applying methodological rigor from start to finish. Our approach in this regard is to collect and document data consistently and accurately, and "cast a wide net" initially in terms of the tools used and participants targeted. Doing so will avoid the need to repeat work to address shortcomings in collected data.

Plan for seasonal flexibility. A third goal of this methodology is to maximize team flexibility to be able to respond to project and seasonal time constraints, rapidly changing river flows, the varied availability of outreach and survey participants and, in some places, infrequent river use. Most immediately, this mixed methods approach will allow the project team to meet data collection goals in the relatively short time in which boatable flows are available in 2012.

A Dynamic Work Plan

This work plan is necessarily dynamic in nature. While this document outlines a clear and carefully defined framework for data collection over the life of the project, MIG anticipates adaptations along the way. Data collection, in-stream studies and related analysis will occur over the course of two primary seasons and target four different reaches, all of which are part of a unique and changing river system. A rapid project start-up window beginning in June 2012 and a shortened 2012 data collection season further necessitate the need for an adaptive approach.

To account for variations in river use, as well as a different profile of river users in the Upper Wenatchee River, the project team will most likely need to modify data collection methods for the 2013 season. The following differences between the Upper Wenatchee River and the other three study reaches are anticipated to influence chosen tools and methods:

- Differences in the frequency of creek and river use;
- Differences in the most commonly used types of watercraft and the level of skill required; and
- River user "accessibility" as influenced by differences in riparian land ownership and the proportion of local and visiting users.

The MIG team also will consider additional factors when modifying the 2012 data collection approach, such as any notable differences in restoration strategy and concept, as well as and the changing profile of local and regional outfitters, advocates and boating clubs organized and interested in these specific reaches.

With that said, the MIG team will conduct a "lessons learned" de-brief with Yakama Nations staff at the end of the 2012 season and recommend any changes in data collection and assessment strategies and tools needed to achieve project data collection and assessment goals and objectives.

Timeline and Target Flows

In 2012, the MIG team will focus on completing data collection, assessments, analysis and reporting for the Upper Wenatchee reach (see Attachment A for proposed timeline). Data collection for Nason and the Twisp and Chewuch rivers will occur primarily in 2013 (timeline to come). Where possible, the team will take advantage of opportunities to learn about Nason Creek and the other study reaches. An important goal for the 2012 data collection season is to obtain experience with data collection efforts to inform the more robust data collection season in 2013.

Data will be collected during the spring and summer seasons. When data are collected, MIG staff also will collect information on daily flow rates. For each river, the MIG team is tasked with completing field research that corresponds with "medium" and "low" flow levels. The on-river data collection period (i.e., the window to complete in-person surveying and on-water assessments) for all reaches will be limited by seasonal flows and use levels. To help guide data collection and in an effort to apply an approach consistent across all study reaches, the MIG team has identified the following target ranges for "medium" and "low" flow levels (Table A). These ranges and associated dates have been identified based on July 15 and August 15 median flows and dates associated with target limits for the period of record.

Table A: Target Ranges for On-River Data Collection

Study Reach	July 15 Median Flow	Medium Flow Target Range	Medium Flow Target Dates	Aug. 15 Median Flow	Low Flow Target Range	Low Flow Target Dates	"Unboatable"
Upper Wenatchee River[1]	3,040 cfs	2,000 – 4,000 cfs	*asap*	798 cfs	700 – 1,300 cfs	*asap*	400 cfs
Nason Creek							
Chewuch River							
Twisp River							

Note: Information is forthcoming for the other three reaches that will be studied later in the project.

The July 2012 initiation of this project has limited the on-river data collection period for the Upper Wenatchee, since water levels decrease rapidly this time of year. For example, in-stream flow rates on the Upper Wenatchee decreased from approximately 6,000 cfs[2] on July 17, 2012 to 3,330 cfs[3] on July 24, just one week later. American Whitewater reports that flows become unboatable at approximately 400 cfs. MIG will make every possible effort to conduct the on-water assessment at medium flow levels this year (2,000 – 4,000 cfs). However, the completion of this task is contingent upon both water levels and the schedules and availability of volunteer boaters, which may pose a challenge and necessitate completion of this assessment in 2013.

[1] Source: USGS hydrography dataset for Plain, WA.
[2] 6,000 cfs is representative of a flow level higher than what most casual users are comfortable with.
[3] Approximately 3,000 cfs has been identified as the median July 15 flow for the Upper Wenatchee and, for the purposes of this study, is within the medium flow

River User Outreach and Data Collection

Interviews and Focus Groups

As part of this study, MIG plans to conduct in-depth interviews and focus groups with river users who have first-hand knowledge of and experience on at least one of the four study reaches. Interview and focus group questions (Attachment B) have been developed with the following objectives in mind:

- Obtain information about potential survey locations and recreation (i.e., boating/tubing) use levels;
- Obtain general impressions of current safety hazards along each reach;
- Obtain general impressions of safety hazards associated with habitat restoration actions; and
- Recruit participants for on-water safety assessments.

To overcome this field season's time constraints and meet the project team's data collection goals for the Upper Wenatchee in 2012, emphasis will be placed on completing in-depth interviews. Focus groups are not planned for data collection for the Upper Wenatchee. To the degree possible, the project team will collect information on both the Upper Wenatchee River and Nason Creek while interviewing individuals. Targeted interviewees include County swiftwater rescue personnel, local outfitters who serve or have served users of this reach, a USFS ranger district recreation officer, Lake Wenatchee State Park recreation staff, at least one highly skilled boater with direct on-water experience, and at least one casual boater of lesser skill.

At the completion of each interview, data collection staff will ask the interview participants for recommendations of others knowledgeable about boating and tubing on the Upper Wenatchee Reach. This process will be completed until 5 to 10 interviews have been completed. This approach was used by Dr. Baas for a recreation study for in-stream flow management and salmon habitat restoration on the lower Russian River in northern California, and for estimating current and future demand for whitewater boating use on several rivers on privately-owned timberlands in northern California and Washington. It is also recommended by Dr. Glenn Haas for estimating use levels and visitor capacities for rivers and other water based forms of recreation.

To date, the information collected via interviews has been used to help craft the survey instrument, approach and timeline. The MIG team will continue to schedule interviews focused on the Upper Wenatchee River as a way of strengthening understanding of river use, perceptions of safety, and local capacity to respond to safety incidents for the final report and to identify additional study participants, as needed.

In preparation for the 2013 spring and summer data collection season, interviews and/or focus groups for Nason Creek and the Chewuch and Twisp rivers will occur as early as Fall

2012, to be completed by February 2013. Interviews and focus group discussions will be documented and included in an appendix to the 2012 and 2013 reports.

"On-Water" Observations and Counts

The purpose of observational data collection is: 1) to make preliminary estimates of boating and tubing use; and 2) to count and describe large woody debris and other notable features in each study reach. This information is needed to understand the relative risks of anticipated habitat restoration actions associated with existing use levels and hazards.

Boating and Tubing Counts

Observational data for boating and tubing use levels will be collected during the on-water boating assessments for medium and low flow conditions, as well as on four additional weekend days for the Upper Wenatchee Reach corresponding with in-person boater surveys. The tool that will be used to record these counts is included as Attachment C.

Recreational use estimates will be cross-referenced with other estimates of use provided by surveyed boaters, interviewees, focus group participants, and agency reports (to they extent they are available and relevant).

For information obtained by interview or focus group, MIG data collection staff will qualify estimates by asking questions such as:

- What is the typical boating season for this river reach?
- What is the typical daily level of boating and tubing use?
- What is the highest boating and tubing use you have observed?

The objective of using multiple count methods is to "triangulate" a reasonably accurate level of use. When discrepancies in estimated use levels are found, reasonable attempts will be made to resolve and explain those discrepancies. During reporting, use levels will be characterized as ranges and will be carefully qualified and interpreted. Subject to modification at the end of the 2012 field season, this method will be used in some form for the other three river reaches.

Large Woody Debris Counts

Observational data for large woody debris (LWD) will be collected only during the on-water boating assessments for medium and low flow conditions. Completing the form requires data collection staff to record location and defining characteristics of large woody debris and to classify LWD based on relative potential risk to tubers and boaters. Each location will be assigned GPS coordinates and, for illustrative purposes, photographs will be taken of LWD characteristic of a given reach or risk level. MIG will take photos of all locations where LWD is defined as a class "D" or "E" (on-water assessment methodology and form to follow submission of this first work plan draft). As with collection of recreation use counts, field staff and boaters will be instructed in the use of the forms. Subject to modification at the end of the 2012 field season, this method will be used in some form for the other three river reaches.

Immediately following completion of the recreation and large woody debris counts, information from them will be entered into a database, backed up, and stored in a centralized and secure location.

Boater Surveys

Boater/tuber surveys are one component of field-based data collection for this study. The goal of surveying is to collect a range of information related to the participants' most recent river trip. Specific questions focus on use and experience levels; easily observable or identifiable behaviors that may play a role in determining relative on-water risk, such as type of watercraft, use of personal flotation devices; user perceptions of river hazards; and management preferences related to safety-related information and on-river conditions.

The survey instrument to be used for the Upper Wenatchee River is presented as Attachment D.... This survey may be modified in 2013 to reflect different river and use characteristics for the northern "three rivers."

To survey users of the Upper Wenatchee River, the project team will apply two approaches: 1) in-person surveys at key river access locations; and 2) development of a networking sample and administration of the survey on-line.[4] In-person surveys will be primarily self-administered. In-person surveys will take place on four separate days, on the second and third weekend in August, and during peak use times (between the hours of 1pm and 7pm).

MIG field staff will target the following commonly used river take-outs:

- Beaver Valley Road (cerca Mile Post 16; i.e., "Mosquito Alley")
- Beaver Valley Bridge (outside of Plain)
- River Road "Beach"
- Ponderosa Community Club beach (pending HOA approval)
- Tumwater Campground (time/resource-dependent)

Online administration of the boater survey will rely on collaborative MIG and Yakama Nation outreach to establish a networking sample of individuals who frequently or regularly boat the river study reach. To develop this sample, the project team will first target residential areas along the study reach, including Hi-Valley Community Club and Ponderosa Pines. The project team will also contact local river outfitters, and American Whitewater in an effort to involve regular visitors from the Seattle area (i.e., "Westsiders").

Selection of this sample relies on individuals identifying themselves and others as qualified to participate. MIG will control this sample to the degree possible, primarily by: 1) working through multiple channels to identify qualified participants; 2) keeping track of all contacts who fit the criteria and all emails sent inviting individuals to participate; and 3) enacting online controls to ensure that only one user per computer may complete the survey.

[4] If in-person surveying yields the target level of response/participation (150 surveys), development of an online networking sample will not be necessary.

MIG will use Survey Monkey to administer the online version of the survey and to record and synthesize all survey responses (i.e., those administered both in person and online).

To ensure that survey responses are accurate within industry standards for visitor survey research, MIG's goal is to obtain at least 150 completed surveys for the Upper Wenatchee River.

Research to date suggests that use levels on Nason Creek and the Chewuch and Twisp Rivers are much lower than along the Upper Wenatchee. To best utilize project resources, the MIG team plans to focus almost exclusively on developing a networking sample for these reaches and administering boater surveys online. The preliminary goal for participation is to obtain at least completed 50 surveys for Nason Creek and Chewuch and Twisp Rivers. Where use is even less common, this target may be modified. The MIG team will begin building the networking sample for Nason, Chewuch and Twisp in Fall/Winter 2012 and will complete surveys no later than March 2013. As with the Upper Wenatchee River, information gathered via the survey for these reaches will be supplemented with information gathered via a variety of other methods.

Health and Safety Protocols

To help ensure the safety of all field staff and volunteers, MIG will do the following:

- Require that MIG field staff check in with Nicole Lewis or John Baas at the start and end of each day in the field;
- Directly oversee each on-water assessment trip for the Upper Wenatchee (i.e., MIG staff on-site);
- Conduct safety briefings prior to each on-water session;
- Provide all staff and volunteers with emergency contact information for relevant organizations such as the Chelan County Sheriff's office, and Wenatchee Okanogan National Forest patrol staff; and
- Provide a first aid kit and snake bike kit to every group out in the field.

Conclusion

The methodology and protocols noted in this work plan have been reviewed by Kim Levesque, and were revised as needed before beginning in-field data collection. At this time, data collection and on-water assessments for the Upper Wenatchee River are anticipated to start as soon as possible, to take advantage of current water flows and levels of use that will continue decreasing throughout the summer. On-water assessments and surveys for Nason Creek and the Chewuch and Twisp Rivers will occur in Spring/Summer 2013, with specific tools and methods subject to review and revision based on further research of on-site conditions and 2012 "lessons learned".

Upper Wenatchee River • Data Collection, Assessment and Reporting Timeline (2012)

	July		August		September		October		November	
Kick-off and pilot on-water assessment *(Task 1)*		●								
Interviews *(Task 2)*		●	●	●						
Interview findings memo *(Task 2)*				●						
Counts and observations *(Tasks 4/5)*		●	●	●						
Networking sample development *(Task 4)*		●	●	●	●	●				
Boater surveys (in-person) *(Task 4)*			●	●						
Boater surveys (online) *(Task 4)*			●	●	●	●				
Boater survey results memo *(Task 4)*						●				
On-water assessment *(Task 5)*		●	●							
On-water assessment findings memo *(Task 5)*				●						
Review of restoration design and locations *(Task 6)*										
Draft Upper Wenatchee report *(Task 7)*							●			
Revised Upper Wenatchee report *(Task 7)*									●	

Summer 2012 Interviews for the Upper Wenatchee River

Interview Objectives

This summer, MIG plans to conduct telephone interviews with river users who have specific experience on the Upper Wenatchee River and Nason Creek. In an effort to prioritize work plan development for this summer's user surveys and on-water assessments, the first set of interviews (to occur largely during the month of July) will focus on the Upper Wenatchee River. To the degree possible, we will collect information on both reaches while interviewing individuals.

Telephone interviews questions (found on the following pages) are designed with the following objectives in mind:

- Obtain information about potential survey locations and boating use levels;
- Obtain general impressions of current safety hazards along each reach;
- Obtain general impressions of safety hazards associated with habitat restoration actions; and
- Recruit participants for the on-water safety assessment.

Project Introduction

MIG plans to introduce this project to interviewees using the following "preamble":

> MIG, Inc. is assisting the Yakama Nation with their Upper Columbia Habitat Restoration Program. The Yakama Nation is currently implementing habitat restoration projects to restore endangered spring Chinook and steelhead in priority streams and river reaches within the Methow, Entiat and Wenatchee river basins. MIG's role in this project is to assist the Yakama Nation in assessing existing boat conditions on select rivers in these basins, identify potential boating hazards, and suggest the safest locations possible for installing habitat features with the least potential impact on boaters.
>
> To accomplish this, we are interested in learning about boaters' use of the subject river reaches, their skill levels, and typical items (rapids, large wood) that can result in potentially hazardous conditions. MIG obtained your name from ____________________and I would like to interview you about boating issues. This will take about 20-30 minutes.

Draft Interview Questions

All interviewees will be asked the following questions. MIG will take detailed notes that capture all direct answers and relevant details, as well as any additional information of potential project interest.

Personal River Use

1. What is the general nature of your visits to the river? (i.e., independent float, raft guide, swiftwater rescue or marine patrol)
2. What type of water craft do you use when you are on this river?
3. What class river do you think this is?
4. What is your skill level?
5. How often to you visit/boat/float? During what season/time of day/time of week, typically?
6. Where do you launch/take out?

Observations: River Use

7. In your experience, who typically uses the river? (Prompts: skill level; ages; individuals v. guided groups; water craft)
8. What are common put-in and take-out spots? Where do people commonly congregate?
9. Please provide an estimate of the number of people you generally encounter by craft type.
   a) What is the typical total use season for this river reach?
   b) What is the typical daily boating and tubing use? (weekday and weekend)
   c) What is the highest boating and tubing use you have observed?

10. In addition to boating for recreation, what other activities do you see people engaging in both on the river and along the river's edge?

River Safety: Observations, Perceptions and Experiences

11. When boating/floating this river, what are your primary safety concerns?
12. What, if any, river hazards have you noticed or experienced?
13. Have you noticed large wood in-stream? Do you see existing large wood as a potential danger?
14. Have you heard of any safety incidents on-river? If so, please describe.
15. Do you know what an engineered logjam is? (Describe generally, if they don't)
16. Have you ever boated/floated a river with engineered log jams?

17. If so, please describe their size and location, if you can. How did they impact your experience?

For further research/participation

18. Do you know other people with specific experience along this reach? Can you please provide their contact info if you think they'd be interested in talking?
19. *For highly skilled boaters only:* Would you be interested in helping conduct an on-water assessment of river safety and current hazards to help with this project?
20. Do you know other people who might be qualified and able to participate in an on water-assessment? (see qualifications/desired characteristics below)

Questions for On-Water Assessment Recruitment

Interviewees who identify themselves as highly skilled boaters interested in further participating in the project will be asked the following questions:

- Do you have formal swiftwater rescue training? Can you provide documentation of your certification?
- What boats are you most skilled/comfortable using?
- What is your white-water skill level?
- Do you have experience on project area rivers?
- Where do you live?
- Do you have transportation?
- Do you have your own boat/kayak? (For the on water assessment we will be providing mileage and a field per diem, but no money for vehicle or watercraft rental)
- Schedule flexibility?
- Do you own a camera you can take on the water?

Upper Wenatchee River • Recreation Use Counts

Group #	Time	Appx. RM	Write number….								Comments
			Tubes	Rafts	Canoes	Kayaks	IKs	Adults	Kids	Wearing PFDs	

PFD codes: 0=None 88= available but not wearing them # = write number of people wearing them Use comments if mix

ID number__________

Upper Wenatchee River • Summer 2012 Boater-Tuber Survey

The Yakama Nation (YN) is engaged in a long-term program to restore fish habitat for salmon species on multiple rivers throughout the Upper Columbia River basin. YN is asking boaters and tubers about their experiences using rivers where habitat restoration could possibly occur. Please take a few minutes to answer the questions below.

Note: if you are completing this survey online or via mail please answer the questions below in reference to your most recent trip on the Upper Wenatchee River. ***All answers will be kept confidential***.

1. **About how many years have you been floating/tubing rivers?** _____ years

2. **Please estimate about how often you have engaged in the following types of river recreation on the Upper Wenatchee River.**

	Activities you have done on Upper Wenatchee	Years on the Upper Wenatchee	Times during the last 12 months	Times ever
Floating/boating	_____	_____	_____	_____
Tubing	_____	_____	_____	_____
Swimming	_____	_____	_____	_____
Other river recreation	_____	_____	_____	_____

3. **What type of boat/craft did you use today or on your most recent trip?**

- ❑ Raft (multi-chamber)
- ❑ Raft (vinyl/cheap)
- ❑ Kayak (inflatable)
- ❑ Kayak (hardshell)
- ❑ Cataraft
- ❑ Inner-tube (covered, high quality manufactured)
- ❑ Inner-tube (black tire)
- ❑ Inner-tube (cheap/vinyl)
- ❑ Other (please specify) ___________________

4. **What is your skill level in this boat? (i.e., the highest class you feel comfortable boating)**

- ❑ Class I: Moving water with a few riffles and small waves. Few or no obstructions.
- ❑ Class II: Easy rapids with smaller waves, clear channels that are obvious without scouting. Some maneuvering might be required.
- ❑ Class III: Rapids with high, irregular waves. Narrow passages that often require precise maneuvering.
- ❑ Class IV: Long, difficult rapids with constricted passages that often require complex maneuvering in turbulent water. The course may be hard to determine and scouting is often necessary.
- ❑ Class V: Extremely difficult, long, and very violent rapids with highly congested routes, which should be scouted from shore. Rescue conditions are difficult, and there is a significant hazard to life in the event of a mishap. The upper limit of what is possible in a commercial raft.

5. **Please rate the whitewater difficulty or challenge of the segment you ran at today's flow/during your most recent trip compared to your skill level.**

- ❑ The flow was below my skill level.
- ❑ The flow was at my skill level.
- ❑ The flow was above my skill level.

6. **In your opinion, what were the greatest risks while you were boating today/during your most recent trip?** ***(Please circle one response for each item below)***

	No risk at all	Slight level of risk	Some level of risk	High level of risk	Extremely level of risk	Don't know
a. Fast water	1	2	3	4	5	6
b. Cold water	1	2	3	4	5	6
c. Large wood on sides of channel	1	2	3	4	5	6
d. Large wood blocking part of the channel	1	2	3	4	5	6
e. Channel spanning logs	1	2	3	4	5	6
f. Rocks and rapids	1	2	3	4	5	6
g. Mix of the above	1	2	3	4	5	6

7. **If you rated any of items 6c, 6d, or 6e a "3" or higher, please answer the following question. The agencies responsible for managing the upper Wenatchee River should (*please check all that apply*):**

   - ❑ Post signs informing boaters of large wood in the river
   - ❑ Construct portage trails around areas with large wood in the river
   - ❑ Remove large wood from the review to the extent practical
   - ❑ Other (please specify) ______________________________

8. **Was your trip today/most recent trip guided, with rented boats/tubes, or independent with your own boat(s)/tube(s)?**

   - ❑ Commercial (rental)
   - ❑ Commercial (guided)
   - ❑ Private

9. **How many people were in your boat?** _____

10. **How many people were in your group? (please provide numbers for each category)**

    - ❑ Adults (over 18) _____
    - ❑ Young adults (13-17) _____
    - ❑ Children (under 13) _____

11. **How many boats/tubes in your group?** _____

12. **How many people in your group wore a life jacket (PFD) today/during your most recent trip? (please provide numbers)**

    - ❑ None
    - ❑ Some _____
    - ❑ All those in my group _____

13a. About what time did you put-in and where? Time: _______

Location:____

13b. About what time did you take out and where? Time: _______

Location:____

14. **Where do you live (please write your zip code)?** ☐☐☐☐☐ or country ______________________

As stated above, YN is engaged in a long-term program to improve conditions for salmon and to reduce bank erosion on rivers in the Upper Columbia Basin. YN wants to know about recreation use levels and existing recreation conditions on the Upper Wenatchee Reach.

15. In addition to your group, how many other people did you see on the water today? _______

16. Please rate the acceptability of conditions in reference to the segment you just floated today/on your most recent trip. "Totally unacceptable" means you would not float this reach again. "Totally acceptable" means you have no concerns about the level of difficulty or boating skill required on this reach.
(Circle one response for each item below)

		Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	Did not notice
a.	Information about hazards.	1	2	3	4	5	6
b.	Amount of large wood on the river.	1	2	3	4	5	6
c.	Amount of potential hazards from large wood on banks or in river.	1	2	3	4	5	6
d.	Number of challenging rapids in the river.	1	2	3	4	5	6

17. Please indicate if you support or oppose management actions that might be used to improve boating experiences. *(Circle one response for each item below)*

		Strongly oppose	Slightly oppose	Neutral	Slightly support	Strongly support	Don't know
a.	Require boaters/tubers to wear life jackets (PFDs)	1	2	3	4	5	6
b.	Require boaters to self-register before they float the river (to help agencies monitor use, skill levels, types of craft) and provide an opportunity to warn floaters of large wood hazards.	1	2	3	4	5	6
c.	More large wood information at put-ins/take-outs.	1	2	3	4	5	6
d.	Warning signs on site to identify large wood hazards.	1	2	3	4	5	6
e.	Warning signs with directional suggestions ("go left") at large wood hazards.	1	2	3	4	5	6
f.	Websites with maps and photos of hazards.	1	2	3	4	5	6

18a. Prior to this trip did you obtain information on boating conditions (e.g., difficulty level, put-in and takeout locations, potentially hazardous areas, flows)?

- ❑ Yes
- ❑ No

18b If yes, where did you obtain information about boating conditions?

- ❑ Word of mouth
- ❑ Website
- ❑ Spoke with Forest Service or Washington State Parks staff
- ❑ River guidebook
- ❑ Heard or saw a public service announcement

THANK YOU FOR YOUR TIME AND PARTICIPATION IN THIS SURVEY!

Do you have any additional comments about managing large wood on the Upper Wenatchee River and management actions to improve boating and safety experiences?

____

____

____

____

____

____

____

<u>Observational variables -- for surveyor use only:</u>

Day	❑Mon ❑Tue ❑Wed ❑Thu ❑Fri ❑Sat ❑Sun
Date	_____ / _____
Surveyor Name	__________________________
Time of interview	_____ _____ (Use military time – to closest half hour).
Location	❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑
Type of trip	❑ Commercial (guided) ❑ Commercial (rental) ❑ Private
Number of boats	__ Multi-chamber raft __ Inflatable kayak (K2) __ Covered tube (manufactured) __ Vinyl/cheap raft __ Inflatable kayak (K1) __ Black tire inner-tube __ Cataraft __ Other (please specify: __________________)
Length of rafts	__ Under 12 feet __ 12-14 feet __ 15 feet or longer
Weather	❑Sunny ❑Partly sunny ❑Partly cloudy ❑Cloudy ❑Off/on rain ❑ Rain ❑ Mixed
Flow	_____ cfs at Plains
Evidence of alcohol	❑ visible intoxicated ❑ visible and open ❑ potential/subtle use ❑ no evidence
People and PFDs	___ Adults (18 and over) with ___ wearing PFDs ___ Young adults (13-17) with ___ wearing PFDs ___ Children (under 13) with ___ wearing PFDs

Yakama Nation Upper Columbia Habitat Restoration
River Safety Assessment Project

On-Water Recreation Assessment Plan | July 2012 Draft

Notice: *This assessment plan guides fieldwork related to recreation and potential habitat restoration projects on several Washington streams in 2012-13. On-river assessments conducted for this project are designed to characterize recreation use and existing large wood or other features of the rivers. It does not endorse specific boating/tubing, scouting, or portaging options for future river users. The assessments will not specifically endorse particular craft or skill levels for specific reaches or flows, nor are they intended to identify specific locations of potential natural or human-built obstacles or hazards for recreation or navigation purposes. All river users need to make their own decisions about whether or how to scout, run, and/or portage these reaches during any on-river boating or tubing activities. These decisions should be based on several information sources, knowledge of their own skill and equipment, and direct observation of a river's conditions.*

Rivers are inherently hazardous settings and may be physically, mentally, and emotionally stressful, or may aggravate existing physical, mental or emotional conditions. Boating or tubing on rivers may result in damage to or destruction of personal property; serious physical injury or even death arising from a variety of hazards including, but not limited to, (and by way of example only) rocks, hazardous terrain, trees, debris, powerful waves, waterfalls, hydraulics, and various man-made or natural hazards; and difficulty or improbability of rescue.

Introduction

The Yakama Nation Fisheries (YN) Upper Columbia Habitat Restoration Project (UCHRP) is cooperating with state, federal, and non-governmental partners to develop habitat restoration projects for endangered spring Chinook and steelhead in priority reaches on the Upper Wenatchee River, Nason Creek, Chewuch River, and Twisp River. Restoration actions may include installing engineered logjams, increasing surface flows, removing dikes and levees, or adding large woody material into the rivers. The YN and its cooperating partners are interested in assessing recreation uses and potential impacts of potential habitat restoration projects on these reaches ("the recreation study"), one of several kinds of information that may help inform restoration project designs and siting.

A component of the recreation study involves on-water assessments of existing and potential recreation floating access, use, and navigation challenges. The goal is to describe existing physical characteristics that may affect the type and challenge of rafting, kayaking, canoeing, or tubing similar river recreation on the reaches. The assessment will evaluate boatability/tube-ability, whitewater challenge/difficulty, and the level of existing rapids and potential large wood-related hazards at representative boating flows.

Assessment Objectives

- Identify potential boating/tubing opportunities on each reach to compare with guidebook information and study survey and interview/focus group findings. Opportunities may vary by craft, skill level or preferences for different types of whitewater or scenic floating conditions.

- Identify and classify the difficulty of assessment reaches (using the I-VI International Scale) or notable (named) rapids at the assessment flows to compare with guidebook, survey, or interview/focus group information from other parts of the study.

- Describe the general amount, type, and location of large wood pieces or clusters (hereafter referred to as LW) that may present navigation obstacles or challenges to floaters with different craft or skill levels.

- Describe observable recreation use (activity, craft type, group size, PFD use, etc.) by location.

Assessment Reach and Flows

This assessment will occur on four reaches:

- Upper Wenatchee River from Lake Wenatchee (RM 54.0) to Tumwater Campground (RM 35.5).
- Middle and Lower Nason Creek (RM 0-19)
- Lower Chewuch River (RM 0-20)
- Lower Twisp River (RM 0-8)

Methods

The assessment will be conducted on each reach during at least two commonly boated flows. Logistical considerations for the study are outlined below by topic area.

Flow Choices

The assessment will target flows at the low and middle of the "commonly boated range" to be identified by information from other components of the study. This generally increases assessment boater safety because lower flows are less powerful, allowing boaters to learn the lines through any rapids or other navigational challenges, and offering more flexible rescue options in case of a mishap. Preliminary target flows for each river are identified below:

Table A: Target Assessment Flows

River	Commonly boated flow range	Low flow target	Medium flow target	Notes
Upper Wenatchee River	400 to 10,000	1,000	3,000	USGS gage at Plain, WA
Nason Creek				
Chewuch River				
Twisp River				

Note: Information is forthcoming for the other three reaches that will be studied later in the project.

Assessment Timing

Each assessment will be conducted on a single day during the season when target flows are available. This is expected to be in mid-to-late summer on the Upper Wenatchee and late spring or early summer for the other three rivers.

Participants

To increase safety, minimize logistical complexity, and ensure a sufficient panel for the assessment, three to five total boaters are expected to participate. They will ideally include hard shell kayakers, inflatable kayakers, and rafters/catarafters.

Participants for the Upper Wenatchee assessment will be selected in coordination with Chelan County Swiftwater Rescue and local commercial guides/outfitters. Participants for the other three rivers will be selected in coordination with American Whitewater (AW) and other local boating groups. Participants will be advanced or expert whitewater boaters (experience running Class IV or V) with swiftwater rescue training to ensure a safe on-water assessment. If possible, panelists will have:

- Previous experience on the assessment reaches in different craft at different flows (including tubes and paddle boards on the Upper Wenatchee);
- Experience on rivers with similar navigation challenges to the assessment reaches;
- Commercial raft guiding experience; and
- Experience with local swiftwater search and rescue training or response to incidents.

Panel Information

Participating panelists will complete a "participant information form" prior to conducting the assessment. This form (see below) will document panelists' swiftwater rescue training and general boating experience in different craft on different types of rivers.

Assessment Logs

Information from the on-water assessments will be based on primary observations made by the panelists as a group. This information will be recorded by two individuals.

The primary log will be kept by MIG Associate Ariahna Jones (Upper Wenatchee, Summer 2012) using a GPS device, and will track the type of individual LW pieces or clusters that present potential navigation obstacles or hazards (assessment log provided as a separate document). The general location of Type C, D, E, or F clusters will also be identified by GPS. The goal of this effort is to identify the amount and type of clusters for different reaches that might be used by boaters or tubers, not to identify specific hazard locations on a map for navigational purposes.[1]

A second log will track observed recreation use (see recreation use count form included as an attachment to work plan). The second recorder will note group size (adults and children), type and number of craft, and PFD use by reach.

A short focus group meeting will be conducted at the end of the assessment. Panelists will complete a "close-out form" as a group by consensus (with minority opinions documented if there is no

[1] LW pieces or clusters are part of a dynamic system that can change at any time and no information from the study is intended to suggest specific boating routes or hazards for on-river navigation. Boaters and tubers are expected to make their own decisions when recreating on these rivers (see notice on the cover of this assessment plan).

consensus). The close-out form includes questions about suitable craft and skill levels for the reach at the assessed flow. The primary trip recorder will also capture qualitative information about flows, hazards, uses, or other related topics discussed.

Still Camera Documentation

Still photos of representative LW clusters of different types will occur during the assessment. In general, photos should represent views from upstream locations in the main boating channel; these illustrate the appearance of LW clusters to floaters as they approach. Other photos will document access points or representative recreation use observed during the assessment.

Participant Craft and Related Equipment

Participants are expected to bring their own boats and boating equipment (e.g., helmets, paddles, oars, a Class III or V PFD in excellent condition, and clothing suitable to the river and weather). This may include dry or wet suits for the more challenging rivers (Class III and above), appropriate river-specific footwear, or other protective gear.

Shuttles, Food, and other Logistics

MIG will coordinate shuttles for all participating boaters. Panelists are expected to bring their own lunches or other food for the assessment. Meeting times will be arranged for specific assessments.

Safety and Liability

The Yakama Nation, MIG, and American Whitewater will work cooperatively to provide a safe and informative assessment. All participants will sign liability waivers and take appropriate safety measures before getting on the river. Boaters are expected to be strong Class IV-V boaters with commensurate self-rescue skills.

The study work plan (August 2012) outlines safety protocols that will be followed for all study field work, including on-water assessments. A short safety plan will be developed prior to the on-water assessment conducted on the three more challenging river reaches. The safety plan generally covers responsibilities of the boaters (e.g., use boats and equipment in good repair, have boaters with appropriate self-rescue skills for the expected challenge/difficulty of the reach, and require boaters to exercise responsible and conservative decision-making) and the study sponsor (e.g., provide communications in case of an accident). During similar whitewater flow studies, liability waivers have been jointly developed between AW and utilities. Examples from these other studies are available, but they should be reviewed by The Yakama Nation and MIG and modified as necessary.

Local law enforcement and rescue personnel may be notified of the assessments, but they are not expected to be needed on-site during the assessments unless a problem develops. The goal is to have highly skilled boaters on the river, with abundant self-rescue skills, to take care of the most likely problems. Assessments will occur on commonly boated rivers at commonly boated flows during the commonly boated season, and none are expected to provide difficulty greater than Class II (on the Upper Wenatchee) and Class III+/IV- on the other three rivers.

Assessment Participant Information Form

Date: _____ / _____ / _____

Your name: ____

Affiliation: ____

1. Please indicate your experience and skill level in different craft or on the assessment reaches:

	Years of experience in this craft (estimate)	**Highest class you regularly boat in this craft (Class I-VI scale)**	**Notes**
Hard shell kayak			
Inflatable kayak or duckie			
Canoe			
Raft			
Cataraft			
Tube			
Other (specify)			
Other (specify)			

2. Please estimate the amount of experience you have boating on assessment (or similar) reaches:

	Years of experience	**Typical craft used on river**	**Other notes**
Upper Wenatchee			
Nason Creek			
Chewuch			
Twisp			
Lower Wenatchee			
Class I-II scenic rivers			
Class III-IV whitewater rivers			
Class III-IV creeks/small rivers			
Class IV-V creeks/small rivers			

3. In general, how many days per year do you spend boating? _____ days per year

4. What is your age? _____ years

5. Please indicate your swiftwater rescue education or training:

Assessment Close-out Form

Date: _____ / _____ / _____ River: ______________________________________

Participants	Craft	Comments /Role
		Recorder
		GPS operator

Trip Schedule	Time	Location (appx RM)	Comments
Put-in			
Take-out			

Other Trip Information							
Day of week	❑ Sun	❑ Mon	❑ Tue	❑ Wed	❑ Thu	❑ Fri	❑ Sat
Weather	❑ Rain	❑ Part rain	❑ Part cloudy	❑ Mostly sunny	❑ Sunny		
Air temperature	Range (low to high):						
Water temperature							
Flow							

Close-Out: Overall Assessments and Discussion Topics

1. What was the overall class of reach at this flow (International I-VI scale). Note any sub-reaches that were different.

2. Please summarize the craft seen and make an evaluation of whether different craft are "appropriate" for the reach and flow (complete table on next page). These are group evaluations about whether a flow/reach combination is boatable in the craft specified. Notes can identify if certain skill or craft size/configurations may be needed to make the reach more boatable or less hazardous, of if such craft are only appropriate for specific sub-reaches.

	Observed on trip?	Appropriate craft?	Notes on "appropriateness" evaluation
Hard shell kayak	No Some Many	Yes Depends No	
Inflatable kayak or duckie	No Some Many	Yes Depends No	
Open canoe	No Some Many	Yes Depends No	
Raft	No Some Many	Yes Depends No	
Cataraft	No Some Many	Yes Depends No	
Tube	No Some Many	Yes Depends No	
Paddleboard	No Some Many	Yes Depends No	
Other (specify)	No Some Many	Yes Depends No	

3. Please rate the overall acceptability of the reach at the flow assessed for the following attributes. Note if there are differences for different craft or skill levels.

	Totally unacceptable		Marginal			Totally acceptable	
Boatability	1	2	3	4	5	6	7
Availability of challenging technical boating	1	2	3	4	5	6	7
Availability of powerful hydraulics	1	2	3	4	5	6	7
Availability of whitewater "play areas"	1	2	3	4	5	6	7
Overall whitewater challenge	1	2	3	4	5	6	7
Amount of large wood	1	2	3	4	5	6	7
Number of portages	1	2	3	4	5	6	7
Overall safety	1	2	3	4	5	6	7
Aesthetics	1	2	3	4	5	6	7
Rate of travel	1	2	3	4	5	6	7

4. Based on your experience, what other rivers in the area offer similar attributes?

5. Describe features of the assessment reach that are unique, special or important compared to other similar river recreation opportunities in the region (Puget Sound and central Washington).

Yakama Nation Upper Columbia Habitat Restoration
River Safety Assessment Project

Upper Wenatchee River Interviews

Duane Bolser
River guide & owner of Leavenworth Outfitters
8/1/12 Interview

Neal Hedges
Stewardship Director; Chelan-Douglas Land Trust
10/5/12 Interview

Mike Mcleod
Sherriff Deputy, Chelan County Swiftwater Rescue Unit
7/24/12 Interview

Doug Pendleton
Chair of the Watershed Committee at Ponderosa Community Club and resident
10/8/12 Interview

Bob Stoehr
Wenatchee Ranger District Recreation Resource Assistant, U.S. Forest Service
7/19/12 Interview

Bill Whitlow
Vice chair for the Watershed Committee at Ponderosa Community Club and local resident with property on the river
8/2/12 Interview

Upper Wenatchee River Summer 2012 Boater-Tuber Survey

1. About how many years have you been floating/tubing rivers?

	Response Count
	129
answered question	**129**
skipped question	**4**

2. Please estimate about how often you have engaged in the following types of river recreation on the Upper Wenatchee River.

	Never	Once	2-5 times	6-10 times	11-20 times	More than 20 times	Response Count
Floating/boating	1.0% (1)	**92.4% (97)**	4.8% (5)	0.0% (0)	0.0% (0)	1.9% (2)	105
Tubing	0.0% (0)	**96.4% (80)**	3.6% (3)	0.0% (0)	0.0% (0)	0.0% (0)	83
Swimming	1.9% (1)	**96.2% (50)**	0.0% (0)	0.0% (0)	0.0% (0)	1.9% (1)	52
Other river recreation	0.0% (0)	**95.5% (21)**	0.0% (0)	0.0% (0)	0.0% (0)	4.5% (1)	22
						answered question	**118**
						skipped question	**15**

3. Please indicate your years of experience with the following types of river recreation on the Upper Wenatchee River.

	Response Average	Response Total	Response Count
Floating/boating	9.82	1,002	102
Tubing	10.23	716	70
Swimming	12.87	605	47
Other river recreation	**16.65**	**383**	23
		answered question	**112**
		skipped question	**21**

4. What type of boat/craft did you use today or on your most recent trip?

	Response Percent	Response Count
Raft (multi-chamber)	**40.5%**	**51**
Raft (vinyl/cheap)	27.8%	35
Kayak (inflatable)	28.6%	36
Kayak (hardshell)	8.7%	11
Cataraft	2.4%	3
Inner-tube (covered, high quality manufactured)	31.0%	39
Inner-tube (black tire)	11.1%	14
Inner-tube (cheap/vinyl)	15.9%	20
	Other (please specify)	8
	answered question	**126**
	skipped question	**7**

5. What is your skill level in this boat? (i.e., the highest class you feel comfortable boating)

	Response Percent	Response Count
Class I: Moving water with a few riffles and small waves. Few or no obstructions.	16.8%	22
Class II: Easy rapids with smaller waves, clear channels that are obvious without scouting. Some maneuvering might be required.	**59.5%**	**78**
Class III: Rapids with high, irregular waves. Narrow passages that often require precise maneuvering.	16.0%	21
Class IV: Long, difficult rapids with constricted passages that often require complex maneuvering in turbulent water. The course may be hard to determine and scouting is often necessary.	4.6%	6
Class V: Extremely difficult, long, and very violent rapids with highly congested routes, which should be scouted from shore. Rescue conditions are difficult, and there is a significant hazard to life in the event of a mishap. The upper limit of what is possible in a commercial raft.	3.1%	4
	answered question	**131**
	skipped question	**2**

6. Please rate the whitewater difficulty or challenge of the segment you ran at today's flow/during your most recent trip compared to your skill level.

	Response Percent	Response Count
The flow was below my skill level.	**59.8%**	**76**
The flow was at my skill level.	39.4%	50
The flow was above my skill level.	0.8%	1
answered question		**127**
skipped question		**6**

7. In your opinion, what were the greatest risks while you were boating today/during your most recent trip? (Please indicate one response for each item below)

	No risk at all	Slight level of risk	Some level of risk	High level of risk	Extreme level of risk	Don't know	Response Count
a) Fast water	**40.2% (51)**	**40.2% (51)**	16.5% (21)	2.4% (3)	0.8% (1)	0.0% (0)	127
b) Cold water	**42.5% (54)**	31.5% (40)	19.7% (25)	5.5% (7)	0.8% (1)	0.0% (0)	127
c) Large wood on sides of channel	36.2% (46)	**40.2% (51)**	19.7% (25)	3.9% (5)	0.0% (0)	0.0% (0)	127
d) Large wood blocking part of the channel	**55.6% (70)**	30.2% (38)	8.7% (11)	4.8% (6)	0.0% (0)	0.8% (1)	126
e) Channel spanning logs	**68.5% (87)**	19.7% (25)	4.7% (6)	5.5% (7)	0.8% (1)	0.8% (1)	127
f) Rocks and rapids	21.4% (27)	33.3% (42)	**34.9% (44)**	9.5% (12)	0.8% (1)	0.0% (0)	126
g) Mix of the above	21.6% (24)	**45.0% (50)**	25.2% (28)	3.6% (4)	2.7% (3)	1.8% (2)	111
						answered question	**131**
						skipped question	**2**

8. In the previous question, if you rated items c, d, or e a “3” or higher, please answer the following question. The agencies responsible for managing the upper Wenatchee River should (please check all that apply):

	Response Percent	Response Count
Post signs informing boaters of large wood in the river	**47.1%**	**24**
Construct portage trails around areas with large wood in the river	15.7%	8
Remove large wood from the review to the extent practical	43.1%	22
Other (please specify)	17.6%	9
	answered question	**51**
	skipped question	**82**

9. Was your trip today/most recent trip guided, with rented boats/tubes, or independent with your own boat(s)/tube(s)?

	Response Percent	Response Count
Commercial (rental)	0.0%	0
Commercial (guided)	0.8%	1
Private	**99.2%**	**129**
	answered question	**130**
	skipped question	**3**

10. How many people were in your boat?

	Response Percent	Response Count
1	35.0%	42
2	**37.5%**	**45**
3	8.3%	10
4	13.3%	16
5	1.7%	2
6	1.7%	2
7	0.8%	1
8+	1.7%	2
	answered question	**120**
	skipped question	**13**

11. How many people were in your group? (please provide numbers for each category)

	Response Average	Response Total	Response Count
Adults (over 18)	**4.56**	**575**	126
Young adults (13-17)	2.57	118	46
Children (under 13)	2.27	75	33
		answered question	**129**
		skipped question	**4**

12. How many boats/tubes in your group?

	Response Percent	Response Count
1	8.8%	11
2	**36.8%**	**46**
3	14.4%	18
4	8.8%	11
5	12.0%	15
6	2.4%	3
7	4.0%	5
8	3.2%	4
9	1.6%	2
10+	8.0%	10
	answered question	**125**
	skipped question	**8**

13. How many people in your group wore a life jacket (PFD) today/during your most recent trip?

	Response Percent	Response Count
None	**46.0%**	**58**
Some	23.0%	29
All	31.0%	39
	If "some" or "all" please provide number	37
	answered question	**126**
	skipped question	**7**

14. About what time did you put-in and where?

	Response Percent	Response Count
Before 7am	0.0%	0
7am-9am	0.0%	0
9am-11am	3.1%	4
11am-1pm	33.1%	42
1pm-3pm	**59.1%**	**75**
After 3pm	4.7%	6
	Where?	120
	answered question	**127**
	skipped question	**6**

15. About what time did you take out and where?

	Response Percent	Response Count
Before 9am	0.0%	0
9am-11am	0.0%	0
11am-1pm	0.8%	1
1pm-3pm	23.8%	30
3pm-5pm	**55.6%**	**70**
5pm-7pm	19.8%	25
After 7pm	0.0%	0
	Where?	119
	answered question	**126**
	skipped question	**7**

16. Where do you live? (please enter your zip code)

	Response Count
	127
answered question	**127**
skipped question	**6**

17. In addition to your group, how many other people did you see on the water today?

	Response Count
	104
answered question	104
skipped question	29

18. Please rate the acceptability of conditions in reference to the segment you just floated today/on your most recent trip. “Totally unacceptable” means you would not float this reach again. “Totally acceptable” means you have no concerns about the level of difficulty or boating skill required on this reach. (Circle one response per row)

	Totally unacceptable	Unacceptable	Neutral	Acceptable	Totally acceptable	Did not notice	Resp Co
a) Information about hazards	2.4% (3)	1.6% (2)	27.6% (35)	26.0% (33)	**28.3% (36)**	14.2% (18)	
b) Amount of large wood on the river	3.1% (4)	0.8% (1)	19.8% (26)	**38.2% (50)**	31.3% (41)	6.9% (9)	
c) Amount of potential hazards from large wood on banks or in river	3.8% (5)	0.0% (0)	21.5% (28)	**39.2% (51)**	30.8% (40)	4.6% (6)	
d) Number of challenging rapids in the river	5.5% (7)	3.9% (5)	14.8% (19)	32.0% (41)	**37.5% (48)**	6.3% (8)	
						answered question	
						skipped question	

19. Please indicate if you support or oppose management actions that might be used to improve boating experiences. (Circle one response per row)

	Strongly oppose	Slightly oppose	Neutral	Slightly support	Strongly support	Don't know	Response Count
a) Require boaters/tubers to wear life jackets (PFDs).	19.1% (25)	15.3% (20)	22.1% (29)	15.3% (20)	**26.7% (35)**	1.5% (2)	131
b) Require boaters to self-register before they float the river (to help agencies monitor use, skill levels, types of craft) and provide an opportunity to warn floaters of large wood hazards.	**32.3% (42)**	23.1% (30)	19.2% (25)	19.2% (25)	4.6% (6)	1.5% (2)	130
c) More large wood information at put-ins/take-outs.	6.3% (8)	5.6% (7)	**50.0% (63)**	24.6% (31)	11.9% (15)	1.6% (2)	126
d) Warning signs on site to identify large wood hazards.	8.7% (11)	6.3% (8)	**39.4% (50)**	27.6% (35)	15.0% (19)	3.1% (4)	127
e) Warning signs with directional suggestions ("go left") at large wood hazards.	10.8% (14)	14.6% (19)	26.2% (34)	**29.2% (38)**	17.7% (23)	1.5% (2)	130
f) Websites with maps and photos of hazards.	7.7% (10)	3.8% (5)	**34.6% (45)**	24.6% (32)	27.7% (36)	1.5% (2)	130
						answered question	**131**
						skipped question	**2**

20. Prior to this trip did you obtain information on boating conditions (e.g., difficulty level, put-in and takeout locations, potentially hazardous areas, flows)?

	Response Percent	Response Count
Yes	37.7%	49
No	**62.3%**	**81**
answered question		**130**
skipped question		**3**

21. If yes, where did you obtain information about boating conditions?

	Response Percent	Response Count
Word of mouth	**91.8%**	**56**
Website	9.8%	6
Spoke with Forest Service or Washington State Parks staff	1.6%	1
River guidebook	0.0%	0
Heard or saw a public service announcement	0.0%	0
Other (please specify)		3
answered question		**61**
skipped question		**72**

22. Additional comments about managing large wood on the Upper Wenatchee River and management actions to improve boating and safety experiences?

	Response Count
	22
answered question	**22**
skipped question	**111**

			Counts									
Date	Time period (PM)	Approx. RM	Groups	Tubes	Rafts	Canoes	Kayaks	Inflatable kayaks	**Total craft**	Adults	Children	Wearing PFDs	**Total boaters**
8/10/2012	3:00-5:00	12	1	2	0	0	0	0	2	2	0	0	2
8/11/2012	12:00-2:00	8	18	22	17	0	2	24	65	68	31	45	99
8/12/2012	12:30 -3:30	11	21	34	12	3	0	14	63	59	15	24	74
8/12/2012	3:30-4:30	10	7	7	8	0	3	0	18	22	14	16	36
8/18/2012	1:15-2:45	8	24	24	29	0	2	10	65	92	35	53	127
8/18/2012	3:00-4:00	8	12	55	6		2	2	65	50	26	23	76
8/19/2012	12:30-4:00	11	18	32	25	5	0	11	73	70	31	27	101
9/1/2012	12:00-2:00	8	5	9	13	0	0	10	32	46	6	9	52
9/1/2012	2:30-4:30	11	12	22	22	0	0	2	46	38	32	18	70
9/1/2012	4:30-5:30	8	2	7	2	0	0	0	9	6	6	0	12
9/2/2012	11:45-1:45	8	10	25	9	0	0	5	39	34	24	16	58
9/2/2012	2:00-3:00	11	11	21	16	0	5	8	50	47	26	8	73
9/2/2012	3:00-5:30	12	17	22	24	2	1	8	57	68	27	34	95
Totals			**158**	**282**	**183**	**10**	**15**	**94**	**584**	**602**	**273**	**273**	**875**

Yakama Nation Upper Columbia Habitat Restoration
River Safety Assessment Project

Assessment Close-out Form

Date: 8 / 8 / 12 River: Upper Wenatchee

Participants	Craft	Comments /Role
Ariahna	Raft	Recorder GPS operator
Colin S.	Tube	
Eli C.	Kayak	
Lester	I.K.	
Paul	S.U.P.	

Trip Schedule	Time	Location (appx RM)	Comments
Put-in LK. Wenatchee ~ 9:45 am			
Take-out Tumwater Bridge Campground ~ 5:15 pm			

Other Trip Information

Day of week	☐ Sun	☐ Mon	☐ Tue	☒ Wed	☐ Thu	☐ Fri	☐ Sat
Weather	☐ Rain	☐ Part rain	☐ Part cloudy	☐ Mostly sunny	☒ Sunny		
Air temperature	Range (low to high):						
Water temperature							
Flow	1940 CFS						

Close-Out: Overall Assessments and Discussion Topics

1. What was the overall class of reach at this flow (International I-VI scale). Note any sub-reaches that were different.

   Class I with a few class II sections

2. Please summarize the craft seen and make an evaluation of whether different craft are "appropriate" for the reach and flow (complete table on next page). These are group evaluations about whether a flow/reach combination is boatable in the craft specified. Notes can identify if certain skill or craft size/configurations may be needed to make the reach more boatable or less hazardous, of if such craft are only appropriate for specific sub-reaches.

	Observed on trip?	Appropriate craft?	Notes on "appropriateness" evaluation
Hard shell kayak	No Some Many 1	Yes Depends No	
Inflatable kayak or duckie	No Some Many	Yes Depends No	
Open canoe	No Some Many	Yes Depends No	
Raft	No Some Many	Yes Depends No	
Cataraft	No Some Many 1	Yes Depends No	
Tube	No Some Many	Yes Depends No	
Paddleboard	No Some Many 1	Yes Depends No	
Other (specify)	No Some Many	Yes Depends No	

3. Please rate the overall acceptability of the reach at the flow assessed for the following attributes. Note if there are differences for different craft or skill levels.

	Totally unacceptable		Marginal			Totally acceptable	
Boatability	1	2	3	4	5	6	7
Availability of challenging technical boating	1	2	3	4	5	6	7
Availability of powerful hydraulics	1	2	3	4	5	6	7
Availability of whitewater "play areas"	1	2	3	4	5	6	7
Overall whitewater challenge	1	2	3	4	5	6	7
Amount of large wood	1	2	3	4	5	6	7
Number of portages	1	2	3	4	5	6	7
Overall safety	1	2	3	4	5	6	7
Aesthetics	1	2	3	4	5	6	7
Rate of travel	1	2	3	4	5	6	7

4. Based on your experience, what other rivers in the area offer similar attributes?

For the Skill level needed to have an enjoyable Float: Lower Icicle
Wenatchee (Fish Hatchery to Black Bird Island)
" " (cashmere to monitor + beyond)

For Scenery: White River + Chiwawa

5. Describe features of the assessment reach that are unique, special or important compared to other similar river recreation opportunities in the region (Puget Sound and central Washington).

Below Ponderosa Pine to Tumwater the Scenery + Solitude are amazing. The landscape + lush Forests around the river create excellent habitat for Fish and other wildlife. We saw one bear, eagles, osprey, Blue Herons, salmon +more.

Assessment Close-out Form

Date: 09 / 05 / 12 River: Wenatchee River

Participants	Craft	Comments /Role	
Arianna Jones		Recorder	IK
Matthew Simmons		GPS operator	IK
Shaun Kelley			IK
Jason Breidert			Cataraft

Trip Schedule	Time	Location (appx RM)	Comments
Put-in	9:30 am	Lk. Wenatchee	Boat Ramp
			~ 19 miles total
Take-out	5 pm	Tumwater	Bridge / campground

Other Trip Information

Day of week	☐ Sun	☐ Mon	☐ Tue	☒ Wed	☐ Thu	☐ Fri	☐ Sat
Weather	☐ Rain	☐ Part rain	☐ Part cloudy	☐ Mostly sunny	☒ Sunny		
Air temperature	Range (low to high):						
Water temperature							
Flow	~560 cfs						

Close-Out: Overall Assessments and Discussion Topics

1. What was the overall class of reach at this flow (International I-VI scale). Note any sub-reaches that were different.

   Class I with a short class II section

2. Please summarize the craft seen and make an evaluation of whether different craft are "appropriate" for the reach and flow (complete table on next page). These are group evaluations about whether a flow/reach combination is boatable in the craft specified. Notes can identify if certain skill or craft size/configurations may be needed to make the reach more boatable or less hazardous, of if such craft are only appropriate for specific sub-reaches.

	Observed on trip?	Appropriate craft?	Notes on "appropriateness" evaluation
Hard shell kayak	No Some Many	Yes Depends No	
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Open canoe	No Some Many	Yes Depends No	
Raft	No Some Many	Yes Depends No	
Cataraft	No Some Many	Yes Depends No	
Tube	No Some Many	Yes Depends No	
Paddleboard	No Some Many	Yes Depends No	
Other (specify)	No Some Many	Yes Depends No	

3. Please rate the overall acceptability of the reach at the flow assessed for the following attributes. Note if there are differences for different craft or skill levels.

	Totally unacceptable		Marginal			Totally acceptable	
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Overall whitewater challenge	1	2	3	4	5	6	7
Amount of large wood	1	2	3	4	5	6	7
Number of portages	1	2	3	4	5	6	7
Overall safety	1	2	3	4	5	6	7
Aesthetics	1	2	3	4	5	6	7
Rate of travel	1	2	3	4	5	6	7

4. Based on your experience, what other rivers in the area offer similar attributes?

White River & Chiwawa

5. Describe features of the assessment reach that are unique, special or important compared to other similar river recreation opportunities in the region (Puget Sound and central Washington).

Boatability for such a wide array of users in the area - allows people that have never been on the river to have a pleasant floating experience.

DRAFT MEMORANDUM

To: UC RTT
UC Project Sponsors

From: Joint RTT/YN workgroup

Re.: Guidance on the implementation of the Upper Wenatchee Reach Assessment

Date: **May 4, 2012**

Introduction

Members of the RTT and YN (the workgroup) met first on April 9 and then again on May 2 to discuss guidance on project development related to the Upper Wenatchee Reach of the Wenatchee River. In the first meeting (April 9), not enough RTT members were present to discuss more than general comments. Rob Richardson (USBR, assisting the RTT) gave the YN team many constructive general and specific comments. For the May 2 meeting, RTT members present included: Dale Bambrick, Tom Kahler, Joe Lange, and Chuck Peven. Members from the YN team included Brandon Rogers, Jason Breidert, and Gardner Johnston (Interfluve). Derek Van Marter and Rob Richardson were on the phone.

The purpose of the meeting was to develop a memorandum considering the draft Upper Wenatchee Reach Assessment and the biological strategy of the RTT. The intent of this memorandum is to provide detailed guidance to the Lead Entities and potential project sponsors in developing projects that are geomorphically and biologically appropriate for the Upper Wenatchee Assessment Area (UWAA).

Goals and Objectives

The goal (desired future condition) of restoration activities in the Upper Wenatchee is to *rehabilitate habitat in the UWAA to improve spring Chinook salmon, steelhead, and bull trout*[1] *populations in the Wenatchee River*.

The biological objectives associated with this reach are:

1. Increase summer and winter rearing habitat for juvenile steelhead and spring Chinook salmon;

2. Increase spawning, resting and holding areas for various life stages of spring Chinook salmon, steelhead, and bull trout; and

3. Ensure that geomorphically appropriate methods are used to rehabilitate habitat within the UWAA.

[1] Bull trout are not a target species for the FCRPS Action Agencies, but they are a focus species for the UCSRB and RTT. All of the actions proposed should benefit this species too.

Guidance on Project Development

Process

The workgroup reviewed the draft Upper Wenatchee Reach Assessment and draft tables that are currently being revised for the RTT's Biological Strategy pertaining to the UWAA. In addition, information being developed for the Expert Panel Process by a subgroup of the Expert Panel/RTT was also reviewed.

The process for reviewing the Upper Wenatchee Reach Assessment was fundamentally different than what was done with the Lower Entiat Reach Assessment conducted earlier this year. The reasons for this were:

1. The Upper Wenatchee Reach Assessment is more complex with more assessment units;

2. The Upper Wenatchee Reach Assessment was developed to a much finer scale (at the specific project level compared to project "type") than the Lower Entiat, and consequently;

3. The project list was too large for a similar review.

Therefore, the workgroup focused on reviewing each of the 11 sub-reaches that were identified within the Reach Assessment, and focused on the proposed strategies to address potential habitat restoration projects. Specific projects were not discussed.

In addition, the group reviewed and discussed the prioritization strategy that the YN team has used in the past to prioritize specific projects.

Results

General Comments

One of the general comments was that it appeared to some of the members of the workgroup that many of the actions described in the Reach Assessment appeared to rely on the placement of large woody material (LWM). Gardner described why LWM processes are impaired, including historic legacy issues (such as log drives and wood harvest, etc.). He also pointed out that while many of the proposed project types relied on LWM placement, the YN team was fully aware of the social issues surrounding LWM placement, and that the current assessment was just listing all potential actions, and should not be considered a prioritized list that it hopes to accomplish.

Another general issue that was discussed was whether some of the geomorphic problems in the area were caused by legacy actions or were natural features. In some cases, it is just not possible to determine, while in others, it was clear that actions such as log drives are still affecting the reach.

Discussion on sub-reaches
Gardner described the current condition within each sub-reach and restoration strategies, while showing the areas with various graphics (e.g., Lidar images) and photos. ***In each case, the members of the RTT that were present believed that the YN team's suggested approach was consistent with the goals and objectives of the RTT biological strategy.***

Prioritization Strategy

Because the workgroup did not believe it was feasible to walk through each sub-reach and discuss specific projects (as was done for the Lower Entiat), the group agreed that it would be more beneficial to discuss the prioritization strategy that will assist the YN (and potentially other project sponsors) in determining the project types that should be developed and implemented. Below is an outline of methodology and the criteria for the benefit scoring that the YN team has used in past assessments (e.g. Lower Chewuch and Lower Twisp) to assist in prioritization:

Project Ranking Methods (DRAFT)

Step 1: **Benefit Score** Projects are scored according to 4 benefit categories, which include 2 *biological* categories and 2 *physical process* categories. Scores for each category are summed to obtain the total ***Benefit Score***.

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

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

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

Benefit Score
Each of the 5 benefit categories (A through D below) are given a score of 1 to 3, with 3 representing the greatest benefit. The scores for each category are summed to obtain the total benefit score. Application of scores is based on consideration of several factors that are listed under the categories below. These will be further developed in subsequent drafts of the methodology:

Biological Categories

A Fish use score:
- 3 – High existing or potential productivity area for spawning or rearing for multiple species
- 2 – Moderate existing or potential productivity area for one or more species
- 1 – Low existing or potential productivity area for one or two species

B Fish life-stage limiting factors score:
- 3 – Addresses key habitat factors at key life-stages for multiple species
- 2 – Addresses either secondary habitat factors, non-key life-stages, or only one or more species

1 – Addresses low priority habitat factors at non-key life-stages for a single species

Physical Process Categories

C Root-causes score

3 – Restoration of root causes and key physical processes that create and maintain habitat over time

2 – Partial restoration of root causes

1 – Primarily a structurally-focused restoration strategy that doesn't significantly address underlying causes

D Existing physical process condition score

3 – Physical processes are significantly impaired or non-functioning. Habitat quantity and quality are impaired.

2 – Physical processes are moderately impaired with limited availability of quality habitat

1 – Physical processes are functioning well and are supporting high quality habitat conditions

Discussion

The group recommended that additional criteria for "complexity" and "risk" be added to the strategy. These criteria would add additional information and assist in understanding some of the technical and social issues that may limit some of the proposed actions.

The group also suggested it would be beneficial to have more definition in the biological benefit criteria concerning how much improvement the possible action is estimated to have. By doing this, it would be easier to understand the prioritization between a project with an estimated "large effect" in a lower priority area compared to a project within a high priority with an estimated "small or moderate effect".

Another helpful criterion would be an estimate of the "cost" of implementing the project on existing conditions (or fish) would have, so that the biological "cost" of implementing the action is worth the potential long-term benefit. For example, in sub-reach number 1, if it was determined that LWM placement would increase rearing habitat, temporary roads would need to be built, which would degrade the existing riparian habitat. In this example, it would probably not be worth the "cost" to the existing intact riparian habitat for the increase in rearing area.

There was some discussion on whether a hydraulic analysis and further geomorphic information would be of use at this stage of the project prioritization. The YN said they would look into obtaining additional information prior to finalizing the draft RA.

Conclusion

The project types identified within the draft Upper Wenatchee Reach Assessment appear to be consistent with the RTT's biological strategy, and that the projects will likely have biological benefit. However, there remained some concern regarding the need for additional geomorphic information before the RTT would be able to conclude that the actions are geomorphically appropriate. Further refinement and critique will occur during the normal project development and evaluation process once specific projects are identified and proposals developed.