Upper Methow River Reach Assessment

River Miles 61 - 80

SUBMITTED TO
Yakama Nation Fisheries

FINAL - DECEMBER 2015

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1 Introduction and Background

1.1 OVERVIEW

This assessment evaluates aquatic habitat and watershed process conditions in the Upper Methow River and identifies habitat restoration strategies. The Methow River Basin is located on the eastern slope of the Cascade Mountains in Northern Washington (Figure 1). The Methow River is a tributary to the Columbia River, entering the Columbia at river mile (RM) 524 near the town of Pateros, WA. The assessment area extends from Methow River RM 61 (Weeman Bridge) to RM 81 (confluence with Trout Creek).

This reach assessment provides the technical foundation for understanding existing conditions and for identifying restoration strategies for the Upper Methow River. Conditions are assessed at both the valley- and reach-scales. The aim is to identify restoration actions that address significant factors limiting the productivity of native salmonids, and to ensure that these actions fit within the appropriate geomorphic context of the river system. An emphasis is placed on understanding the underlying biological and physical processes at work and how human impacts have affected these processes and the habitat they support. Restoration measures focus on recovering, to the extent possible, these impaired processes. Although the proposed restoration measures are expected to benefit a large suite of native aquatic and terrestrial species, there is a particular emphasis on recovery of Endangered Species Act (ESA) listed salmonids, including spring Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*Oncorhynchus mykiss*), and bull trout (*Salvelinus confluentus*).

This study builds on considerable data collection and assessment work performed by others as part of past studies, including the Methow Subbasin Geomorphic Assessment (USBR 2008). This Reach Assessment updates and further refines previous data collection and assessment efforts and provides a new comprehensive habitat restoration strategy that identifies restoration targets and recommends specific actions to address habitat and stream process impairments.

This report includes the following 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 – 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 achieve the reach-scale restoration strategies.

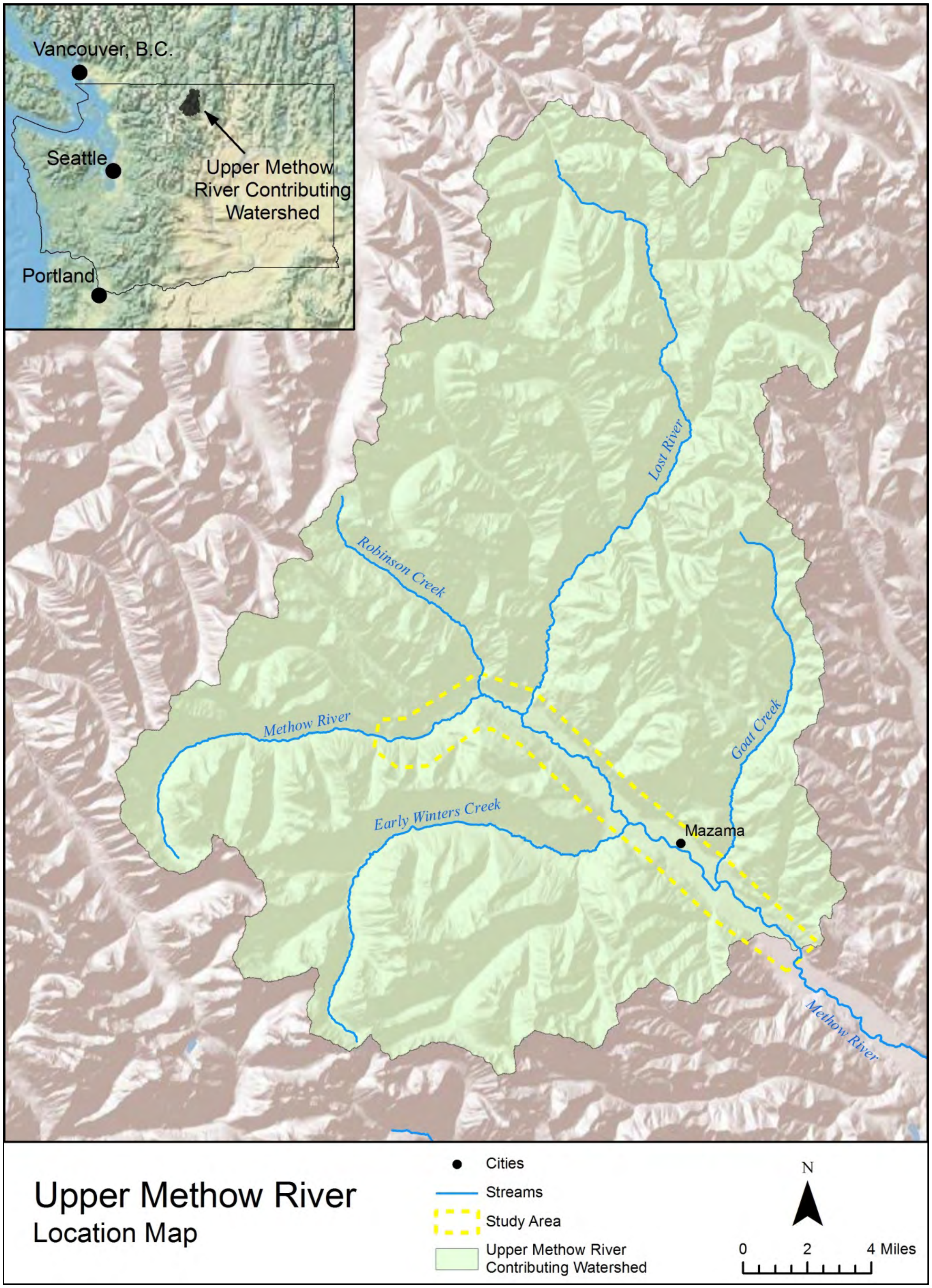

Figure 1. Upper Methow River study area. The study area extends from RM 61 (Weeman Bridge) to RM 81.

1.2 BACKGROUND

This effort is being conducted as part of the Yakama Nation's Upper Columbia Habitat Restoration Project (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 2014).

This assessment builds off of a large body of work produced in the basin primarily throughout the 1990s and 2000s. Assessment and analysis work to date has included physical assessments, biological assessments, and restoration recommendations for portions of the Methow River. The previous assessments include the US Bureau of Reclamation's 2008 Methow Subbasin Geomorphic Assessment, the Methow Watershed Plan (MBPU 2005), the Hydrogeology of the Unconsolidated Sediments, Water Quality, and Ground-Water/Surface-Water Exchanges in the Methow River Basin (USGS 2005), US Forest Service's Upper Methow River Stream Survey Report (USFS 1997) and their West Fork Methow River Stream Survey Report (USFS 2003), and the Methow Subbasin Plan (KWA et al. 2004).

1.3 PURPOSE

The purpose of this assessment is to document and evaluate hydrologic processes, geomorphic processes, and aquatic habitat conditions in the Upper Methow River (RM 61 to RM 81) and to present a comprehensive reach-based restoration strategy to address limiting factors to aquatic habitat. Evaluations used in this assessment include historical characterization, geomorphic assessment, hydraulic assessment, and an aquatic habitat inventory.

Specific goals and outcomes of this assessment include:

- Provide a comprehensive inventory and assessment of geomorphic and aquatic habitat 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

1.4 SALMONID USE AND POPULATION STATUS

1.4.1 Species Status and Distribution

Salmonid use of the Upper Methow River includes spring Chinook salmon, steelhead, bull trout, west-slope cutthroat trout, rainbow trout, and brook trout. Spring Chinook salmon are listed as Endangered under the Endangered Species Act (ESA), and steelhead and bull trout are listed as Threatened. Life-stage usage and ESA status for each species are summarized in Table 1.

Table 1. Species usage in the Upper Methow River. Adapted from NMFS 1998, Mullen 1992, and USBR 2008.

Population	ESA Status	General Use	Timeframe
Spring Chinook	Endangered	Spawning & Rearing	Historical
		Spawning & Rearing	Current
Steelhead	Threatened	Spawning & Rearing	Historical
		Spawning & Rearing	Current
Bull trout	Threatened	Foraging, Migration, Over-wintering	Historical
		Foraging, Migration, Over-wintering	Current

A distribution map for steelhead, Chinook, and bull trout is presented in Figure 2. Spring Chinook spawning within the study area occurs at the highest densities from RM 61 (start of study area; Weeman Bridge) to RM 68 (near Mazama). Survey data from 2003 to 2013 report an average of 333 spring Chinook redds and 395 steelhead redds annually in the Upper Methow River basin (above the town of Winthrop, upstream of RM 50). In the study area, specifically in 2013 (RM 61-80), the highest number of redds occurred downstream of the confluence with Lost River from RM 72-75 and upstream of the Weeman Bridge from RM 60 to 62.8. That year a total of 142 steelhead redds and 141 spring Chinook redds were counted in the study area, including Early Winters Creek, Lost River, and Suspension Creek.

The spawning activities of spring Chinook peak in late August and early September. Juvenile rearing occurs year-round throughout the study area, when and where flows allow. Steelhead trout use the Upper Methow River for spawning, in- and out-migration, and rearing. Steelhead spawning occurs March through May and juvenile rearing occurs year-round. Bull trout use the Upper Methow River for year-round foraging, migration, and over-wintering (Andoneagui 2000).

Historically, spring Chinook and steelhead utilized the mainstem of the Upper Methow River and the larger tributaries, such as Early Winters Creek and Lost River. Currently they inhabit the same distribution, although the highest densities are found in the mainstem Methow and Lost River. The numbers of spring Chinook and steelhead returning are much lower than historical estimates. In-basin and out-of-basin anthropogenic impacts have contributed to these declines. The Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSCRP) rated the Methow spring

Chinook salmon population as "at high risk of extinction within the next 100 years" if no action is taken. The UCSCRP gave steelhead trout a "Moderate to High" risk rating for extinction within the next 100 years if no action is taken.

Bull trout occupied the largest historical distribution in the basin, covering the mainstem Methow River as well as many tributaries such as Early Winters Creek, Goat Creek, Lost River, and Trout Creek. Bull trout, either fluvial, adfluvial, or resident, presently continue to have the largest range throughout the rivers and creeks of the watershed, although it is less than the historical range.

1.4.2 Proportion of Hatchery Fish

The numbers of returning spawners has been influenced by the addition of hatchery fish in the Methow and greater Columbia River basins. The effects of hatchery fish on wild fish runs is an important area of research (OCAFS 2015) but it is not addressed as part of this assessment. In the Upper Methow River (upstream of RM 50-77), the annual average number of returning spring Chinook spawners that are hatchery fish is 718 and the number of wild fish is 216, based on data from 1998-2007. In 2013, these numbers were below average with a total of 505 hatchery and 113 wild fish counted. In the study area specifically (RM 61-77) during 2013, including Lost River, Early Winters, and Suspension Creeks, a total of 195 hatchery and 63 wild spring Chinook spawners were counted (Snow etal 2014).

1.4.3 Effects of Subsurface Flow Conditions

The hydrology of the mainstem Upper Methow River between Goat Creek (RM 65) and Lost River (RM 75) can pose a risk to salmonid survival during the summer and winter (NMFS 1998, Konrad et.al 2005). In this section of the channel, seasonal low-flow conditions in late summer and autumn can result in dewatering of the channel, except for at deep pools (See section 2.6.3 for a description of the hydrology). The extent of the dewatering is dependent on the year's seasonal hydrograph which is determined by precipitation and quantity of snow pack. Very dry years have been reported to extend the zone of dewatered impacts from the Weeman Bridge (RM 61) to Robinson Creek (RM 76.5) (Andonaegui 2000). When dewatering occurs for over twelve days, eggs and embryos can become dehydrated and cause mortality. Dewatering can also result in stranding of fish in pools. The shallow and/or pooled water conditions result in increased water temperatures and reduced dissolved oxygen levels, both of which pose risks to fish survival. Studies utilizing observations made during snorkel surveys have concluded that smaller, less mature fish are less likely to migrate away from areas of the basin with declining flows. The risks associated with low or no-flow in winter months can be exacerbated by snow burial and freezing (USFS 1997, USFS 2003). During field observations in October 2014 by Inter-Fluve (IFI) staff, the mainstem channel was dry from RM 70.2 to 71.75, except in the deep pools. More information on dewatering is provided in Section 2.6.3.

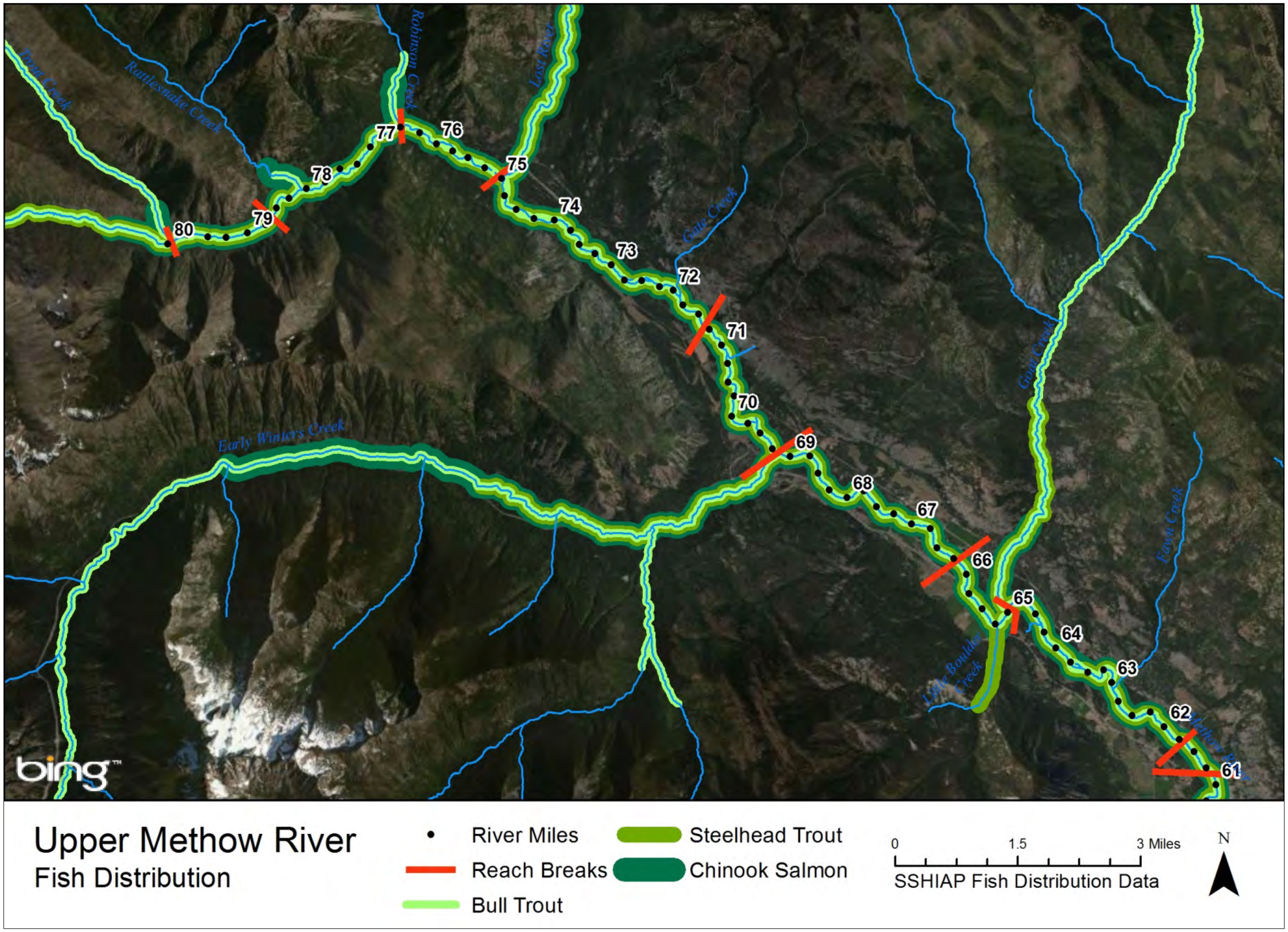

Figure 2. Chinook salmon, steelhead trout, and bull trout distribution in the Upper Methow River and major tributaries.

During survey work for this assessment in early September 2014, spring Chinook were seen spawning by IFI survey crews at the highest concentrations in the off-channel habitat commonly referred to as Suspension Creek. The confluence of Suspension Creek is located on river-right at RM 64.35. Local knowledge and WDFW employees encountered on the river confirmed this to be a common location for high densities of returning spawners. This is supported by the 2013 steelhead and spring Chinook redd counts reported by the Washington Department of Fish and Wildlife for Suspension Creek (Steelhead: 29; spring Chinook: 11). The Lost River (steelhead: 29; spring Chinook: 28) and Early Winters Creek also support high numbers of spawners. The potential risks associated with seasonal dewatering of sections of the Upper Methow mainstem emphasizes the value of wetted connected tributaries and backwater features as available summer and fall salmonid habitat.

1.5 RECOVERY PLANNING CONTEXT

Spring Chinook salmon and steelhead are listed and protected under the ESA. The Upper Columbia 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 Methow River Reach Assessment falls under the Habitat component of the Recovery Plan.

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 and are consistent with the Methow Subbasin Plan (KWA et al. 2004) and the Methow Watershed Plan (MBPU 2005). The objectives are intended to reduce threats to the habitat requirements 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 provided. 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.

1.5.1 Short-Term Objectives

- Protect existing areas where high ecological integrity and natural ecosystem processes persist
- Restore connectivity (access) throughout the historical 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

1.5.2 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

1.5.3 Restoration Objectives Specific to the Methow Basin

- Preserve, protect, and manage instream water uses to balance flows for local uses (e.g. agriculture) and instream habitat where appropriate
- Protect and restore riparian corridors where feasible
- Remove or recondition human infrastructure that currently limits habitat connectivity and complexity (e.g. culverts, riprap) where feasible
- Increase diversity and complexity of habitat types by adding instream structures (e.g. large wood, boulders) where appropriate

2 Assessment Area Conditions

2.1 SETTING

The Methow River Basin is located in Okanagan County in north central Washington on the east side of the Cascade Mountains within the Columbia Cascade Ecological Province. The study area includes RM 61 to RM 81 of the Upper Methow River and its floodplains. The catchment area contributing to the downstream extent of the study area includes several small drainages such as Fawn Creek, Goat Creek, Little Boulder Creek, Early Winters Creek, Gate Creek, McGee Creek, Lost River, Robinson Creek, Rattlesnake Creek, and Trout Creek. The total catchment area of the study area is 426 square miles.

Nine distinct geomorphic reaches were delineated within the study area (Figure 3). Reach delineation was based on 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 reach boundaries used in past surveys. The reach boundaries were then verified in the field during survey work.

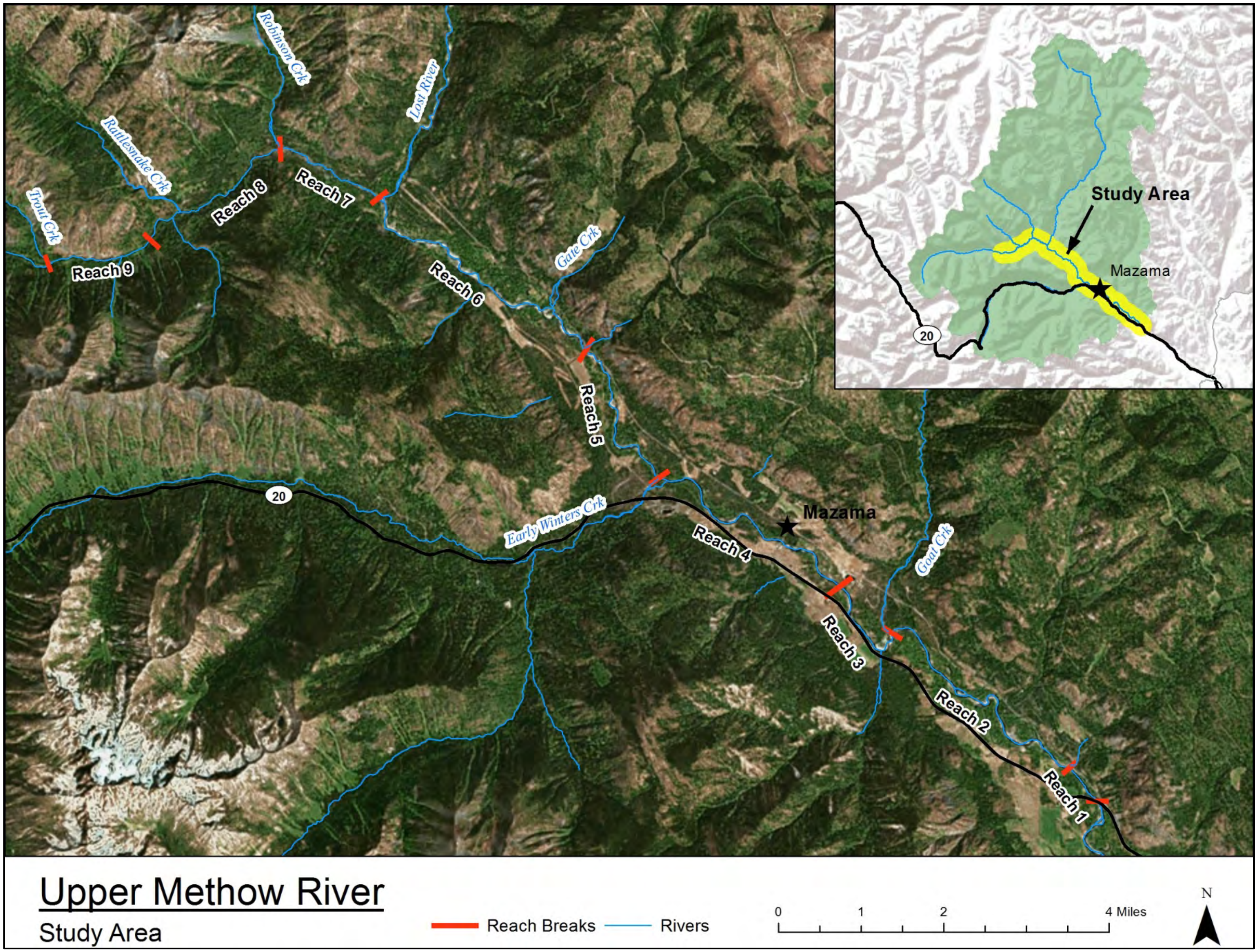

Figure 3. Geomorphic reach breaks in the Upper Methow study area.

2.2 GEOLOGY

The Upper Methow River Basin is located in the northeastern portion of the rugged North Cascades geologic province. The basin is geologically bound structurally by northwest-southeast running faults that define the eastern side of the geologic province (Schuster 2005). The faults act as hydrographic and topographic features that influence the pathway of the modern and historical Upper Methow River. The Pasayten fault zone bounds the Methow terranes on the east side and the Rose Lake and Hozameen Fault zones bound the west side (DeGraaff-Surpless et al 2003). This geologic province is a complicated mosaic of terranes that reflect about 400 million years of geologic history (Tabor and Haugerud 1999).

The surficial geologic terranes specific to the Upper Methow Basin include units of sedimentary rock of marine and riverine origin, intrusive and extrusive volcanics, metamorphic rock, and unconsolidated alluvium and colluvium (Figure 4). Sedimentary rocks form over long periods of time when the original deposits are exposed to relatively subtle geologic processes (heat, pressure, oxidation, etc.) that cement the deposits into a rock mass without drastically altering the mineralogy of the original material. The oldest surficial terranes associated with the study area are deep marine (132-110 million years) and shallow marine (110-105 million years) deposits that accumulated during the Cretaceous and Jurassic period when this area was a sea, now referred to as the Methow Ocean (Haugerud and Tabor 2009). These marine and riverine deposits have been transformed to siltstone, sandstone, argillite, and conglomerates in the Upper Methow Basin (Lasmanis 1991, USBR 2008).

Millennia of plate tectonics in this region have resulted in the construction of impressive mountain topography through processes of accretion, subduction zone volcanism, and crustal deformation. The volcanism within and near the Methow Basin included extrusive (above the surface) volcanic events of andesitic breccia and tuff (~90 million years ago), as well as intrusive (subsurface) volcanic magmatic plutons of tonalite and granodiorite (79-90 million years ago and 45-50 million years ago). Directly west of the study area, additional volcanism of the Cascade Magmatic Arc over the last 35 million years has contributed pyroclastic material (material ejected into the air from a volcano) such as ash to the Methow Basin. Most recently, these contributions have come from Glacier Peak (11,250 years ago), Mount Mazama (7,000 years ago), and Mount Saint Helens (3,400 and 35 years ago) (Beget 1984, USGS 1997).

The heat and pressure generated by mountain building (orogeny) has interestingly resulted in only minor metamorphism of the sedimentary and volcanic rocks of the Methow terranes (Haugerud and Tabor 2009). Metamorphic rocks are the result of relatively intense geologic processes (heat and/or pressure) that physically or chemically change the original mineralogy of a rock into a different material. In the Upper Methow study area portions of the volcanic materials have been metamorphosed into marble, schist, and gneiss and subsequent mineralization produced small deposits of copper and gold in a few locations of the Upper Methow Basin (Lasmanis 1991, USBR 2008).

The high-relief valleys and peaks of the Upper Methow Basin have been carved, carried away, and deposited downstream by ice and water for thousands of years – creating an impressive alpine landscape. These processes of erosion and deposition have exposed the area's complicated mosaic of bedrock and created an array of alluvial features such as terraces, fans, and floodplains composed of unconsolidated materials in the valleys. The U-shaped valley that the Upper Methow River flows through is the result of alpine and continental ice sheet glaciation most directly linked to the last glacial period (Ice Age) of the late Pleistocene and early Holocene (approximately 20,000 to 9,500 years ago). Alpine glaciers extended from the headwaters down valley as rivers of ice about 18,000 years ago, carving and deepening the upper valleys of the Methow River (Waitt 1975, Haugerud and Tabor 2009). Remnant deposits from this glacial period are found in the less disturbed upland areas. Distribution of these and other Pleistocene and Holocene deposits are included in Figure 4.

At approximately 15,000 to 14,000 years ago, lobes of the Cordilleran continental ice sheet extended into the Methow Valley (Wait and Thorson 1983, Booth et al 2003, Kovanen and Slaymaker 2004). The ice sheet overtopped mountain passes and extended down tributaries into the valley from the north at Lost River and from the west at Early Winters Creek. This coalescence of glaciers created a thick valley of ice that left only the high peaks exposed and carved a deep trough into the bedrock of the Methow terrane (Wait 1975, Riedel et al 2007). By approximately 11,000 years ago, the Cordilleran ice sheet had receded from the lower valley, leaving remnant pieces of continental ice in the upper-most valley and its tributaries. The material carved and carried by the ice becomes glacial outwash when it is transported and deposited by flowing water generated by the glacial ice melting. The outwash generated during the Cordilleran glacial recession filled the valley floor of the Methow Basin with a thick deposit of unconsolidated sediment (large boulders, cobbles, gravels, and sand). Between the Weeman Bridge and Lost River confluence, the glacial outwash deposits range from 200 to 1,000 feet deep (Konrad 2006). A re-advance of alpine glaciers at approximately 11,000 to 9,500 years ago likely combined with the remnant continental ice in the uplands to produce the necessary streamflow and sediment during their recession to create the large alluvial fans that extend out into the valley atop the glacial outwash fill (USBR 2008). Holocene alpine glacial advances described at Glacier Peak in the North Cascades (Beget 1984) at 8,400-8,300, 5,100, 3,400, and less than 1,000 years ago (Little Ice Age) suggest that additional periods of small-scale Holocene alpine glaciation was possible in the upper-most highlands of the Methow Basin.

The streamflow and sediment regime of the Methow River were greatly reduced after the glaciers retreated between nine and ten thousand years ago. In response to the modern regimes, the channel has incised into the glacial outwash deposits that had previously filled the valley floor. Today, the glacial outwash deposits form paired terraces throughout much of the study area. The Upper Methow River and its modern alluvial surfaces are inset four to forty feet below the glacial outwash terraces and alluvial fans. Talus, landslide, and debris fan deposits dress the toe of most of the steep bedrock walls that border the valley. In the confined upstream reaches above Robinson Creek, direct hillslope inputs contribute plentiful coarse-grained material to the channel and narrow floodplains.

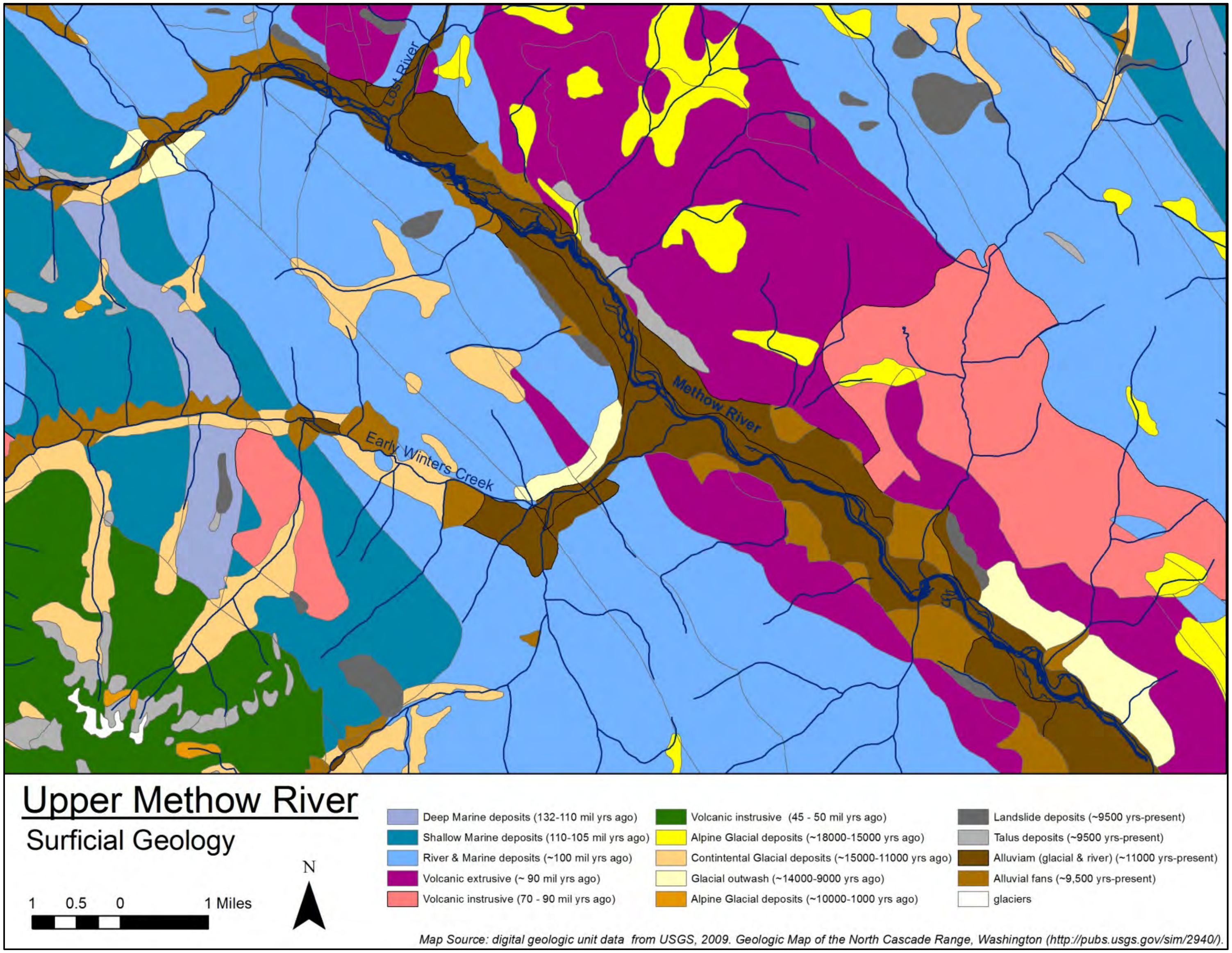

Figure 4. Surficial geology of the Upper Methow Basin study area with approximate age of origin (Waitt 1975, Burtchard 1998, Booth et al 2003, DeGraaff-Surpless et al 2003, Schuster 2005, USBR 2008, Haugerud and Tabor 2009).

2.3 HISTORICAL FORMS AND PROCESSES

Within this Reach Assessment historical conditions are considered as those that would have existed just previous to Euro-American settlement (i.e. prior to large-scale human alteration). Historical conditions represent the conditions to which native species such as salmonids were presumably best adapted, prior to the population crashes that ensued as human interventions increased on the landscape in the last two hundred years. In many cases, restoration to historical conditions will be impossible or inappropriate; however, historical conditions nevertheless provide a reference point for helping to determine how habitats and processes have changed and can help inform the identification of restoration objectives. This section provides a brief summary of historical conditions; more information is provided in Appendix D.

Although there is little direct evidence about conditions of the Upper Methow River before the early twentieth century, field observations, USGS records and related surveys, LiDAR, as well as underlying geology and glaciation cycles can provide some theories on historical channel forms of the Upper Methow River. The earliest published record of geological observation was from Russell (1900). Overall, the watershed and riparian forests were relatively undisturbed and the valley bottom was vegetated with mature forests composed of very large trees. The mature forests covered much more of the Upper Methow Valley and slopes than we see today. These forest conditions allowed the river channel to incorporate large wood into the system via floods, bank erosion, and channel avulsions. The established vegetation also metered the rate of bank erosion and created a higher degree of sinuosity in the unconfined reaches. The available aquatic habitat was likely very complex – with plentiful backwater and side-channel features, active channel migration, and avulsions.

2.4 HUMAN DISTURBANCE HISTORY

2.4.1 Land Use History

With the exception of some early explorers, fur trappers, and miners, Euro-American settlement began in the Methow Basin in the late 1890s (Appendix D). Since then, there have been several human disturbances that have impacted natural channel processes, including mining, agriculture, timber harvesting, and fire suppression.

Timber harvesting in the region has played a large part in the changes to the hydraulic and sediment regime within the Methow River. Upland timber harvest and its associated practices have likely increased the amounts of slides and debris flows that the Methow River has experienced (Appendix D). Log drives to transport harvested lumber downriver likely scoured out spawning gravels. Timber harvest along the valley floor led to the associated loss of the important channel functions this vegetation serves, including flood moderation, regulation of inundation processes, shade, moderation of stream temperature fluctuations, and providing future sources of large wood material to the channel. Past stream cleanouts have also had a significant impact on habitat. Following both the floods of 1948 and 1972, the Army Corps of Engineers removed natural large wood accumulations and channel substrate, as well as straightened portions of the channel, reducing available habitat and high flow refuge. Although large-scale snagging and riparian clearing is no longer occurring in the study area, the effects of this historical practice will continue to affect wood-loading for the foreseeable future (see Section 2.9).

2.4.2 Development Trends since 1950

The study area is currently 24% public property and 76% private property within the low geomorphic surface, with the Okanogan National Forest accounting for a majority of the public property. Much of the private property has undergone vegetation clearing, floodplain grading, and residential development. The low surface within the study area has a road density of 1.88 mi/mi^2.

Flood mitigation practices of the mid- to late-1970s led to removal of native substrate and other habitat elements such as log jams. Those practices also included the construction of levees to prevent flooding on private property, which reduces floodplain connectivity and lateral channel migration. Riprap is also used intermittently throughout the study area as a method of bank stabilization for residential properties as well as roadway embankments and bridge abutments. This armoring limits natural lateral channel migration and sediment sourcing from streambanks.

Table 2. Human alterations and modern development in the study area. The low geomorphic surface includes the contemporary floodplain and alluvial terraces.

Metric	Value in the Low Geomorphic Surface
Road Density	1.88 mi/mi^2
Public Land	24%
Private Land	76%
Portion of Channel with Levees & Bank Armoring	1%
Developed & Cleared Land	25.6%

2.5 POTENTIAL EFFECTS OF CLIMATE CHANGE

The Upper Methow River has expressed a geomorphic sensitivity to changes in discharge and sediment regimes at the close of the recent ice-age (9,500 years ago). As described previously in the Geology section, the channel has responded to the reduction in sediment and discharge regimes after the glaciers retreated by incising into the glacial outwash deposits. The channel then re-established a new floodplain and new sinuosity to equilibrate itself to the modern regimes. Since 9,000 years ago, there is evidence that subtle winter-time climate shifts have been shown to instigate periods of aggradation in the upper mainstem Columbia (between the Methow and Okanogan rivers) and lower portion of major tributaries. This research concluded that in periods of relatively warmer winters, where precipitation resulted in the buildup of snowpack and a high frequency of rain-on-snow events, increased flood frequency led to aggradation in the larger mainstem channels. Likewise, drier colder winters reduced the probability of large floods and allowed for accumulation of sediment in the upper portions of the watershed and tributaries that was then available for transport during periods of climate transitions (Chatter and Hoover 1992). It can be inferred by regional proximity that the Methow River likely experienced a higher probability of flooding and some degree of aggradation during the warmer time periods for this region during the Holocene (9,000 to 8,000; 7,000 to 6,500; 4,400 to 3,900; and 2,400 to 1,800 years before present). However, it is unclear whether this dynamic would apply to the Upper Methow study area, which is much higher in elevation than the mainstem stream segments that were evaluated.

The US Geological Survey (Voss and Mastin 2012) examined the potential impacts of predicted climate change scenarios in the Methow Basin – all of which predict increases in winter temperature. Warmer winters result in more precipitation falling as rain instead of snow. This is expected to decrease streamflow during spring and summer because of reduced snowpack, but to increase flow during fall and winter. Voss and Mastin (2012) provide a web-based tool to plot modeled flows based on climate change scenarios. Figure 5 shows the modeled data for USGS gage 12447383 (Methow River above Goat Creek near Mazama, WA), which is in the study area. These results suggest that overall snowmelt peaks will be less than existing conditions, and fall and winter peaks will be greater than existing conditions. Overall, annual peak flows would be expected to decrease in size. The effects of these potential changes on the Methow River and aquatic habitat depend on many factors such as timing of the events, sediment supply, and icing. Higher fall and winter flows could result in a greater degree of channel change, greater sediment recruitment and transport, and more frequent icing events. However, lower snowmelt peaks would result in less channel change and sediment mobilization during the spring, potentially resulting in greater channel stability. Such channel response mechanisms are important to consider with the inevitable influence that present and future climate change will have on the river.

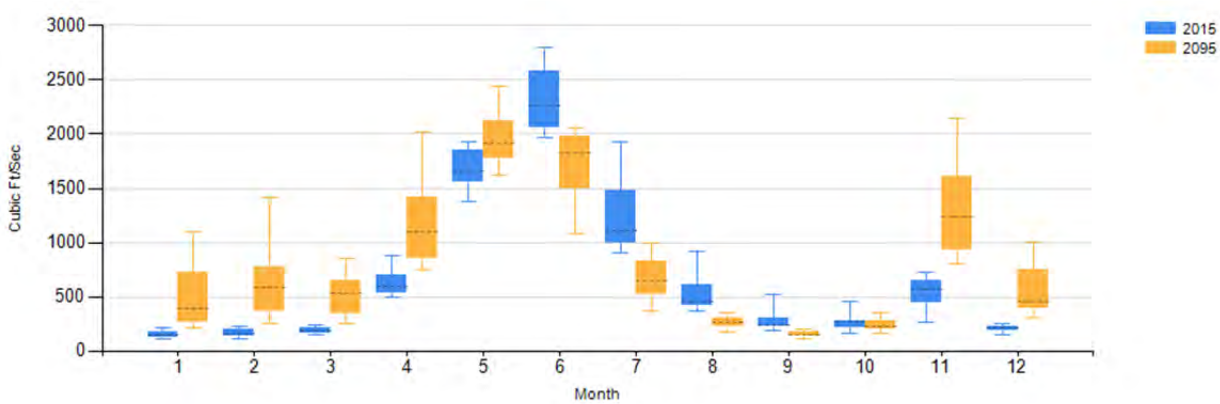

Figure 5. Boxplot of modeled average monthly flows at USGS gage 12447383 (Methow River above Goat Creek near Mazama, WA) for existing (2015) and future (2095) climate scenarios generated from Voss and Mastin (2012) web-based tool (http://wa.water.usgs.gov/projects/methow/cc.htm). Boxplots represent modeled values for all general circulation models and greenhouse gas emission scenarios. The boxes represent the semi-quartile range (25 to 75 percentile); dashed line is the median; and vertical lines extent to minimum and maximum values.

2.6 HYDROLOGY

2.6.1 Surface Water

The Methow River watershed is a sub-basin to the Columbia River in western Okanogan County, Washington. The Methow River flows from its headwaters off the eastern flanks of the Cascades (elevation 8,950 feet) for about 86 miles to its confluence with the Columbia River (elevation 775 feet), and drains approximately 1,814 square miles. The Upper Methow watershed is about 426 square miles, and has an elevation gain of approximately 1,000 feet (1,951 ft at the downstream extent of the study area to 2,950 ft at the upstream extent).

Precipitation amounts vary spatially throughout the Methow Valley. Average annual precipitation along the crest of the Cascades near the headwaters of the Methow exceeds 80 inches, but drops to only 10 inches at the confluence of the Methow and Columbia Rivers near Pateros, WA. Most of the precipitation is delivered in late autumn to early spring in the form of snow or rain (USBR 2008, Andonaegui 2000). Dominant hydrologic patterns are driven by precipitation in the form of snow and subsequent spring snowmelt. The flood regime of the Methow River is strongly influenced by spring snowmelt and precipitation regimes; river flows increase rapidly between April and June, which is typical for rivers in the region.

There is one USGS real-time stream gage on the Methow within the study area (USGS gage number 12447383) located above Goat Creek at RM 65.5 on the mainstem Methow River. This gage has a period of record for discharge from 1991 to 2015. The daily minimum, mean, and maximum for the period of record are presented in Figure 6. Peak runoff usually occurs from April to August, with the highest flows typically in June. Stream discharge is typically reduced to baseflow by September. Mean annual flow is 525 cubic feet per second, based on annual average flows from 1993-2013 (USGS 2014).

Tributaries in the study area include Fawn Creek (RM 62.85), Goat Creek (RM 65), Little Boulder Creek (RM 65.25), Early Winters Creek (RM 69.2), Goat Wall Creek (RM 71.3), Gate Creek (RM 72.9), Lost River (RM 75), Robinson Creek (RM 76.5), Rattlesnake Creek (RM78.05), Trout Creek (RM 79.9), and a number of smaller tributaries and unnamed ephemeral drainages.

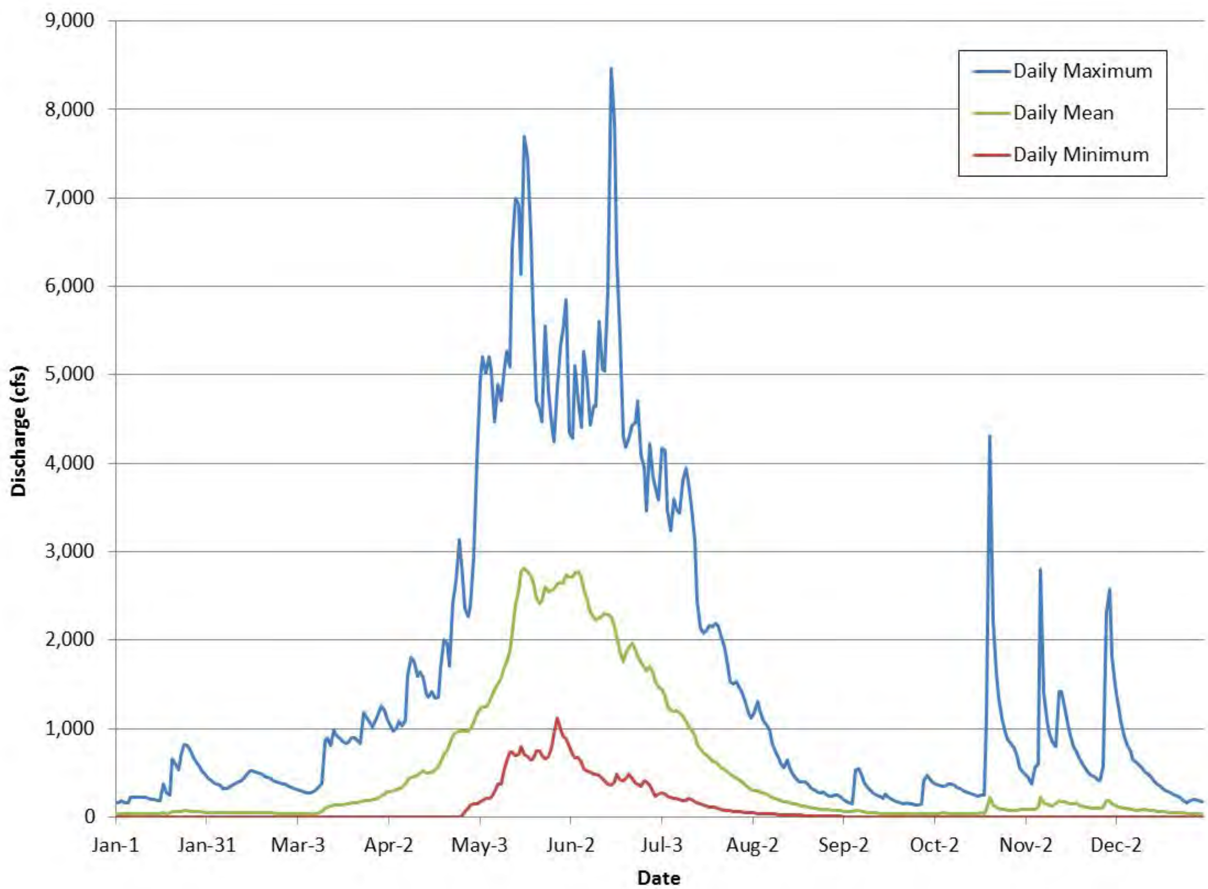

Figure 6. Mean, maximum, and minimum discharge of mean daily flows for the period 1991 to 2015 (as measured at USGS gage 12447383 - Methow River above Goat Creek near Mazama, WA).

2.6.2 Groundwater

An important component of the hydrology of the Upper Methow River is its groundwater, which is transmitted through the valley's unconfined aquifer. The aquifer is contained within the unconsolidated alluvium, glacial outwash deposits, alluvial fans, and colluvium that have filled the valley floor. These unconsolidated sediments are composed mostly of highly permeable coarse grained material (sand, gravel, cobble, boulder) that allow for active groundwater to surface water exchange and vice versa within the Methow River and its tributaries (Konrad et al 2005). Groundwater inputs contribute baseflow discharge to the mainstem channel and many of its side and off-channel features, including the groundwater-activated floodplain tributaries. The cold groundwater inputs to surface water enhance the quality of the available aquatic habitat (Andonaegui 2000). Groundwater inputs to the channel are sourced from up-valley or adjacent sections of the aquifer, as well as some lateral inflow from the terraces, alluvial fans, and tributaries (Konrad 2006a). Active hyporheic flow along the margins of the channel and through bars and bed substrate is another common groundwater/surface water exchange that occurs within the unconsolidated alluvium in the study area. Canals, used for irrigation and/or flow control, divert surface water across portions of the floodplain in the study area. On the west side of the channel, groundwater and surface flow from the alluvial fans of Early Winters Creek, Looney Creek, Little

Boulder Creek, and Lucky Jim Bluff are captured in unlined canals and re-routed. Although the flow is rerouted as surface water, it is expected that the water in the canals recharges groundwater through seepage at a rate of 1.8-3.2 thousands of acre-feet per year (Konrad et.al 2005).

The bedrock of the U-shaped Methow Valley acts as a flow boundary at the base of the basin's aquifer. The slope of the valley's bedrock controls the general down-valley flow (hydraulic gradient) of groundwater through the unconsolidated fill (Konrad 2006a). The size (width and depth) of the groundwater aquifer varies longitudinally downstream within the study area. In the narrow, higher-gradient upstream reaches above Robinson Creek (RM 76.5), direct valley wall contributions of talus and debris add a higher percentage of coarser-grained boulders and cobbles to a more shallow aquifer than the downstream reaches. Downstream from Robinson Creek, the glacial outwash deposits filled the valley with a relatively continuous surface, but the depth of the aquifer varies as the valley widens with a downstream trend. Between the confluence of Lost River (RM 75) and Goat Creek (RM 65), the slope and depth of the underlying bedrock increases. This is likely the result of a glacier from the Upper Methow, one from Lost River, and another from Early Winters Creek coalescing during the last ice-age (~15,000 years ago) and carving a deep trough in the valley floor (Kovanen and Slaymaker 2004). During the subsequent glacial retreat at approximately 10,000 years ago, the valley filled with the unconsolidated glacial outwash and alluvial fan deposits that are 500 to 1,000 feet deep in the section between Lost River and Goat Creek. Downstream from Goat Creek, the thickness of the deposits gradually decreases (Konrad et al 2005).

2.6.3 Seasonal Subsurface Flow Conditions

Seasonal variations in discharge and precipitation are reflected in the aquifer's groundwater elevation and availability. Groundwater levels reflect the seasonal hydrograph of the basin – usually decreasing from late summer or early autumn through spring and then increasing in spring and summer with snowmelt and precipitation. When groundwater levels are decreased below the elevation of the exposed channel bed, surface flow elevations are reduced or go subsurface. This seasonal variation can change the hydrologic relationship from groundwater inputs to the channel to groundwater recharge by the channel (Konrad 2006b), depending on the local characteristics of the aquifer. The impacts that seasonal dewatering of the sections of the channel has on fish survival in these river segments, such as increased water temperatures, drying of redds, and stranding, are discussed in Section 1.4.3 and Appendix A.

Subsurface flow conditions occur in the study area at low flow periods when groundwater storage is reduced and the infiltration capacity of the river bed exceeds the incoming surface water flow (Konrad 2003). This type of river reach is considered a "losing reach" because it contributes its incoming surface water to groundwater recharge. The aquifer configuration in the Upper Methow Basin that results in dewatering also produces a groundwater discharge zone from approximately Goat Creek to downstream of the Weeman Bridge (Figure 7). Here groundwater inputs usually contribute discharge to the surface water flow in the channel ("gaining reach"). However, reports indicate that in very low precipitation years, even portions of the channel between Goat Creek and the Weeman Bridge can be dry (WDW 1990).

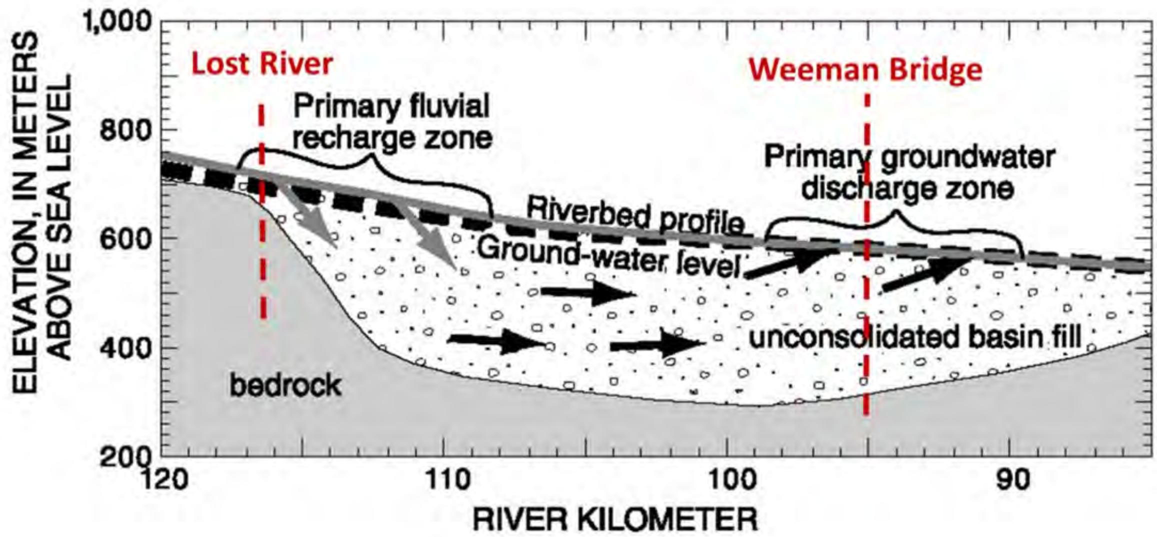

Figure 7. Section of the Upper Methow River valley showing how the configuration of the aquifer (vertical depth of the bedrock from the riverbed) influences the locations of fluvial recharge and ground-water discharge zones (derived from Figure 12, Konrad 2006a).

In the Upper Methow, river segments between the confluences of Lost River (RM 75) and Goat Creek (RM 65) often seasonally go dry with only small residual holding pools during late summer and autumn (Andonaegui 2000, Konrad 2003, WDW 1990). In this section of the river, the unconsolidated glacial outwash material is up to ~1,000 feet deep and the groundwater table usually drops below the elevation of the channel bed by late summer. The timing and extent of dewatering in the study area depends on the amount, type, and timing of precipitation that is received during the year for recharging the aquifer. A map that combines records of the extent of observed dewatering, and the location of spring Chinook redds impacted during surveys, is presented in Figure 8. Reports of dewatering or partial dewatering extend from Robinson Creek (RM 76.5) to the Weeman Bridge (RM 61) with persistent pools reported at the confluence with the Lost River, Early Winters Creek, and Goat Creek.

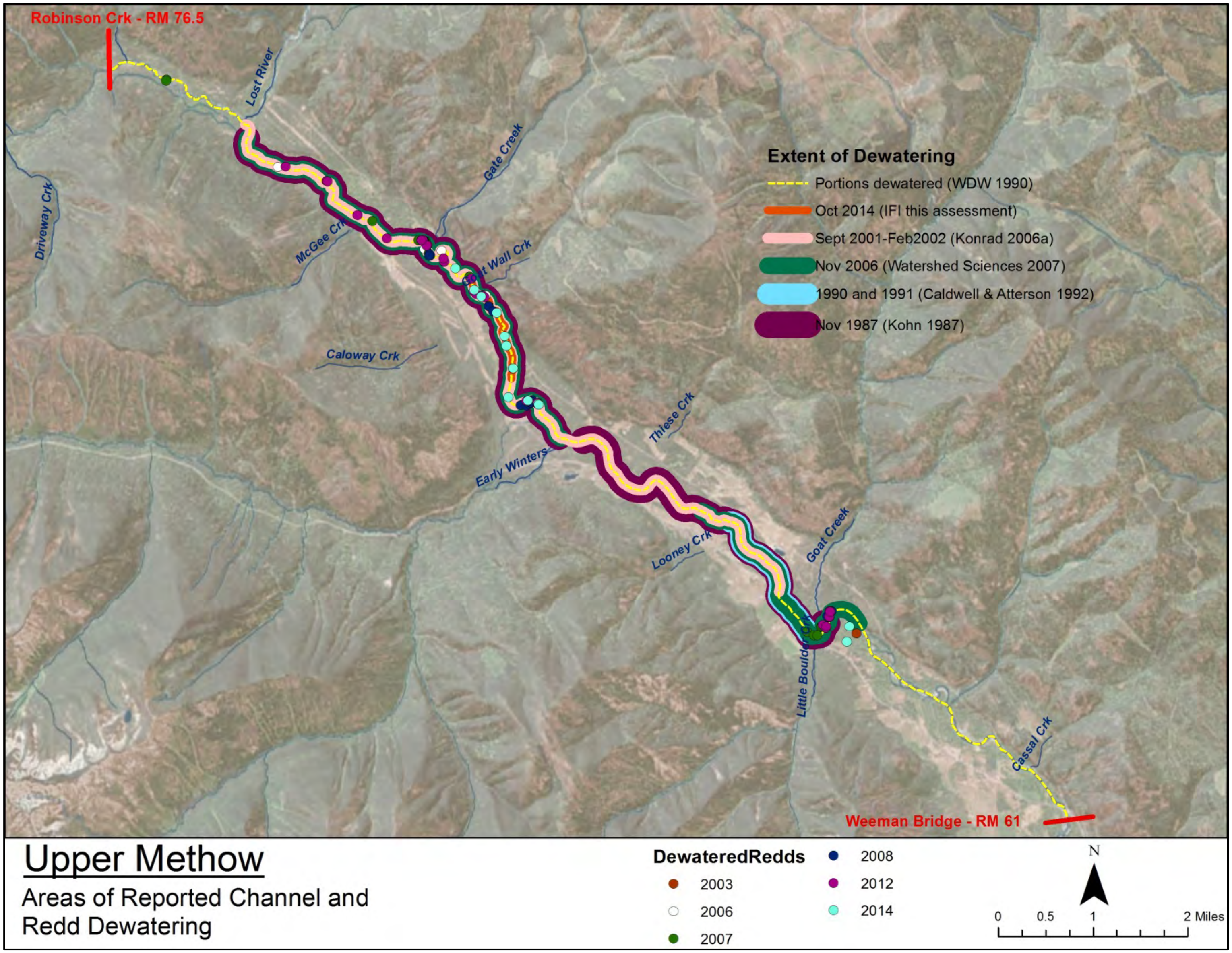

Figure 8. Extent of reported dry-season channel dewatering and observed dry redds. Dewatering includes dry channel beds and partial drying with stranding pools. Redd survey data completed by the Washington Department of Fish and Wildlife and supplied by the Yakama Nation Fisheries Department for this report.

2.7 HYDRAULICS

2.7.1 Background

The floodplain of the Upper Methow River includes many relict side-channels and surfaces with different elevations, which produce complex hydraulics and floodplain inundation patterns. While a one-dimensional model can produce relatively accurate hydraulic results, this process would require multiple iterations to break the floodplains into different channel reaches and would still lack the ability to simulate the lateral flow for proper side-channel activation and deactivation. Two-dimensional hydraulic models perform well in these situations and SRH-2D (version 2) (hereafter SRH) was therefore utilized. Using available LiDAR data, Reaches 1 to 7 and the downstream portion of Reach 8 were simulated for flood events with return periods of 2 and 100 years. 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.

2.7.2 Methods

Hydraulic Model development

The SRH hydraulic model was built in Aquaveo's Surface-water Modeling System (SMS) (version 11.2) using LiDAR data for boundary extents and elevation. The mesh was constructed with higher resolution in and near the active channels (8.5 feet triangle edge lengths), and coarser cell resolutions near the outer boundaries (25 feet triangle edge lengths) to produce a final cell count of 1,061,380. This variation in resolution ensured that river channels, bridge geometries, and grade breaks were well defined while the outer ineffective extents were limited, thus improving model efficiency.

Roughness values for the model were delineated in ArcGIS using the available aerial images and exported to SMS. One roughness value was specified throughout the main channel based on the pebble count data. The 84th percentile largest grain size was applied to Strickler's equation (Chow 1959) to obtain the estimate of 0.034. This value is consistent with the values predicted with the empirical approach described by Arcement and Schneider (1989). Other roughness values were estimated using the Arcement and Schneider (1989) method and look-up tables (Chow 1959) (Table 3).

Table 3. Manning's roughness values used in the 2D model.

Area	Manning's roughness value
Forest	0.130
Road	0.015
Floodplain vegetation	0.060
Channel	0.038
Unpaved roads	0.020

The downstream boundary condition for the model was the estimated water surface elevation calculated using Manning's equation and the total discharge. Since the model's downstream boundary was well past Reach 1, the water surface level had sufficient channel length to establish a stable and accurate level. The upstream boundary conditions and discharge estimates at river miles for the two and one-hundred year flows were calculated using the US Geological Survey National Flood-Frequency Program's contributing drainage area method for estimating flood magnitude and frequency in unregulated Washington streams (USGS 2001). This method allows for peak discharge at an ungaged location to be calculated from gaged data on the same river, if the drainage area at the ungaged location is 50-150% that of the gaged site. We used the available annual peak flow data (1991-2013) from USGS gage #12447383 located at RM 65.5 to determine the recurrence interval discharge values for the 2 and 100 year flood events and to estimate flood peak values at the ungaged locations (see Table 4). Tributary flow inputs for the 2 and 100 year flood events were extracted from the US Bureau of Reclamation estimated flow rates (USBR 2008). Upstream from the confluence with Lost River, the drainage area of the mainstem Methow River is less than 50% that at the gaged site. However, we selected to use the USGS contributing drainage area method to remain consistent with the values calculated downstream. Using these values also resulted in the 2-D model results matching observed conditions more realistically. All models were simulated with a time step of 0.5 seconds, which was consistent with the Courant condition (see Wu 2008). Each flood simulation was routed through the model for at least 6 hours to allow sufficient time for steady-state hydraulic conditions to occur.

Table 4. Peak discharge estimates at river miles within the study area for the 2 year and 100 year flood events

	RM 61	RM 62.90	RM 64.9	GAGE RM 65.5	RM 65.25	RM 67.35	RM 67.8	RM 69.25	RM 71.25	RM 72	RM 73.2	RM 75	RM 76.5	RM 78.2
2 yr flood														
Q peak (cfs)	5574	5434	4945	4902	4837	4760	4719	3666	3559	3469	3409	1168	881	822
100 yr flood														
Q peak (cfs)	14839	14468	13165	13051	12879	12674	12564	9762	9474	9236	9075	3108	2344	2187

There are limitations for utilizing LiDAR to model floodplain inundations. The 2006 LiDAR data available for the Upper Methow River is capable of producing elevation data in terrestrial environments, but cannot produce ground elevations below water (i.e. bathymetry) and the data includes frequent errors of at least up to 0.5 feet. 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.

Flood Inundation Analysis

Flood inundation was modeled by exporting the SRH-2D result from SMS into ArcGIS, which allowed for visualization of the floodplain inundation over aerial photographs. 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. Further, it is noted that the contributing flows of tributaries entering the Upper Methow River were simulated, but in most cases the inundation of the tributaries required slight modification to ensure reasonable inundated areas near the Upper Methow floodplain. Therefore, all contributing tributary inundation is specifically for maintaining accurate Upper Methow River flow rates, and not a full or accurate representation of tributary inundation. Please refer to Table 4 for river mile discharge values. The model was calibrated using the best available aerial imagery taken during a high-flow event with gaged discharge. The photos are from May 24, 2006, which captured the equivalent of a 1.8 year flow recurrence (daily average discharge of 4,000 cfs at the gaged site at RM 65.5).

Sediment Mobility Evaluation

An evaluation of sediment mobility during selected flood discharges (2 year and 100 year) was conducted at thirteen representative riffle crest sites in Reaches 1-8. Streambed sediments are transported only 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 a sediment particle of a specific size is the critical shear stress. If the shear stress is greater than the critical shear stress, then the sediment grain has the potential to 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.

During the summer of 2014, Inter-Fluve collected 13 pebble counts distributed between river miles 61 and 76 following the Wolman Pebble Count method (Woman 1954). This sparse data collection was only intended to support a reach-scale assessment, and is not considered a detailed analysis. However, combining the sediment size distributions with SRH model shear stress distribution results provides insight into the potential mobility of sediment and stream power of the modeled flood events. To evaluate general trends in the ability of the Upper Methow to mobilize and convey sediment, excess shear ratios were calculated using the Shields (1936) equation.

The shear stress applied to the bed is:

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

The critical shear stress needed to mobilize the streambed sediments is (Shields 1936):

$$\tau_{c1} = \tau_{c50*} \, (\rho s - \rho)_{50}$$

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

$$\tau^* = \frac{\tau}{\tau_c} = \frac{\rho R s}{\tau_{c50*} D_{50}\,(\rho_s - \rho)}$$

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_{50} = median grain size (ft)

s = slope

τ_{c50*} = critical dimensionless shear stress (Shields Parameter)

Here, τ_{c50*} was adapted from Julien (2010) and the movement of the D_{50} was assumed to represent bed mobility.

The 13 pebble counts were conducted at representative riffle crests to evaluate the stream substrate that is providing grade control. Pebble count data were used to evaluate the potential of sediment mobility during selected flood events. Since several years lapsed between the LiDAR (2006) utilized for the SRH model and the conducted pebble counts (2014), an analysis was performed to ensure that the location of each pebble count was representative to the location within the model, since in some areas channel position may have changed. This was accomplished by examining aerial photographs of 2006 and 2014; in a few cases, pebble count locations were moved a short distance (less than 100 feet) in the model to ensure the pebble counts were in appropriate locations. Further, since the SRH model produces spatial distribution of shear stress, a method was developed to provide a representative shear stress for the 13 pebble count locations. This was accomplished by averaging the shear stress values in a wide transect (cross-section) perpendicular to flow. This transect was centered at the pebble count location and bound between the river banks; and extended 25 feet upstream and 25 downstream. Finally, these averaged shear stress values for the 2-year and 100-year flood events were compared to the calculated critical shear stresses.

2.7.3 Results

Floodplain inundation

An overview of the inundation analysis results for the 2 and 100 year flood events are shown below in Figure 10 and Figure 11. These maps provide a broad overview of inundation patterns at study reaches. Higher resolution inundation maps at the reach-scale are included in the reach-specific sections later in this document. The inundation of the 2 year flood was kept in-channel only in Reach 8, whereas downstream reaches had significant side-channel activation and floodplain inundation. Similar results occurred for the 100 year flood results, with the exception of moderate side-channel activation of the confined downstream segment of Reach 8. In addition to floodplain inundation, the 2 and 100 year flood event results showed overtopping of Highway 20 in Reach 1, inundation of Highway 20 in Reach 3, and the 100 year event inundation connected to the gravel mining pit located in the river-left floodplain at river mile 66.25.

Flood inundation shown in the Lost River Community (Reach 6) is partly a function of additional flow added to the model in that region based on professional judgment to account for the flow additions in that reach according to the USBR (2008) hydrology. These inundations should therefore be interpreted with caution, particularly with respect to the modeled inundation of structures. Although there is uncertainty associated with the inundations in this area, it is clear that this community has experienced flooding issues based on field observations of numerous pushup levees and drainage canal systems throughout the floodplain in this area.

Sediment mobility

An overview of the modeled shear stress results for the 2 and 100 year flood events are shown below in Figure 12 and Figure 13. These maps provide insight into the potential sediment dynamics and stream power of these floods. As shown, shear stresses regularly range between 0.5 and 5 lb/ft^2. When the excess shear stress ratio for the selected grain size is < 1 then mobilization does not occur, but when the ratio is > 1 them mobilization is expected to occur (See Figure 9). The results of the sediment mobility evaluation suggest that bedload sediment at seven of the thirteen sampled sites becomes mobile during the modeled 2-year flood event. During the modeled 100-year flood event twelve of the thirteen sites are expected to have a mobilized bedload.

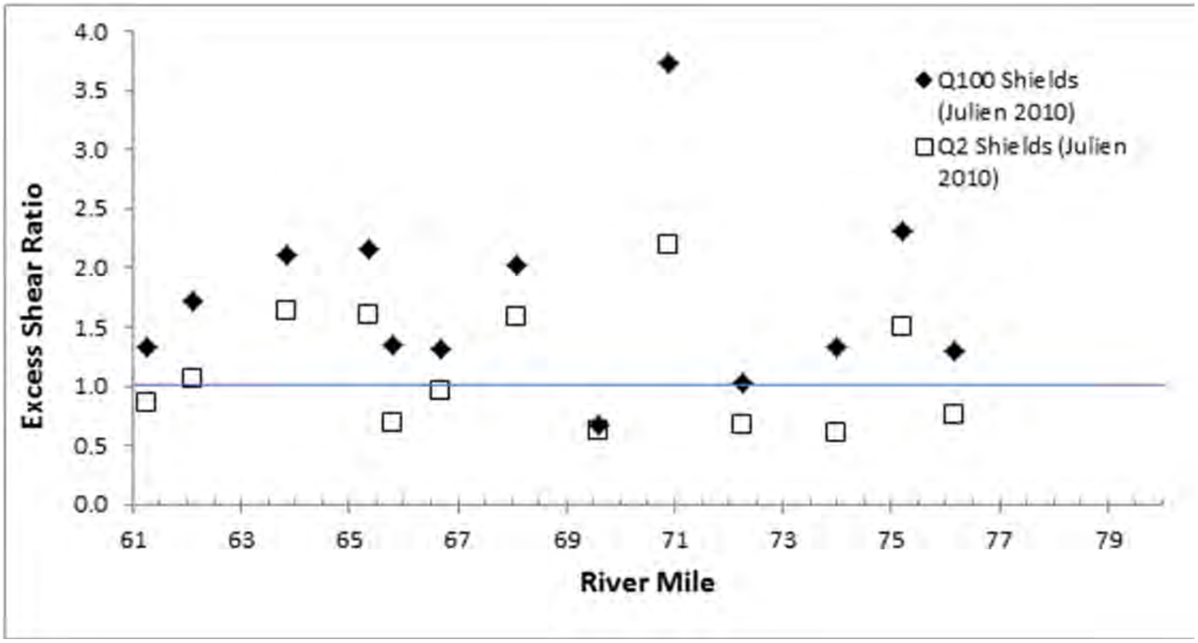

Figure 9. Sediment mobility potential at sampled sites between RM 61-76.

2.7.4 Discussion

The hydraulic analysis provides insight into flood inundation and stream energy at the time of LiDAR acquisition in 2006. The 100 year flood simulation has also helped to define the boundaries between abandoned terraces and modern floodplain surfaces. Flood simulations show that the floodplain is activated in numerous areas. Although many of the side-channels are shown as active during floods, human impacts such as levee construction, floodplain grading, and bridge crossings affect inundation patterns, floodplain connectivity, and habitat. Examples include push-up levee construction preventing floodplain inundation in Reach 2 (RMs 63.75-63.25) and Reach 8 (RM 76.75). Bridges in Reach 1 and the middle of Reach 4 (RM 67.2) have also impacted floodplain processes. These bridges and their associated approach fills interrupt floodplain flow by routing flow back into the channel at the crossing. They also limit any potential channel migration due to the bridge abutments and associated riprap. These impacts not only disrupt floodplain connectivity, but they also contribute to stream channel incision and habitat simplification in the areas near the crossings.

Although this evaluation offers only limited information with respect to sediment mobility, we can infer that the stream power generated by frequent high-flow events (2 year recurrence) is generally capable of mobilizing bedload sediment. This is consistent with the dynamic conditions observed in portions of the study area. Some of the more dynamic results (i.e. near RM 71 and 75.5) are from areas with high bedload and multi-thread channels (more transport-limited). Some of the more stable locations (i.e. RM 61.5, 69.5, and 72.3) are located in areas where the channel is influenced by confinement from either a bridge (RM 61.5) or tributary fans. These influences may be increasing stream power and therefore result in coarsening of the bed (more supply-limited). Tributary fans may also be contributing larger material to the channel at these locations. Further sediment data collection and analysis at the reach-scale is recommended as part of future restoration project design to better understand sediment transport dynamics.

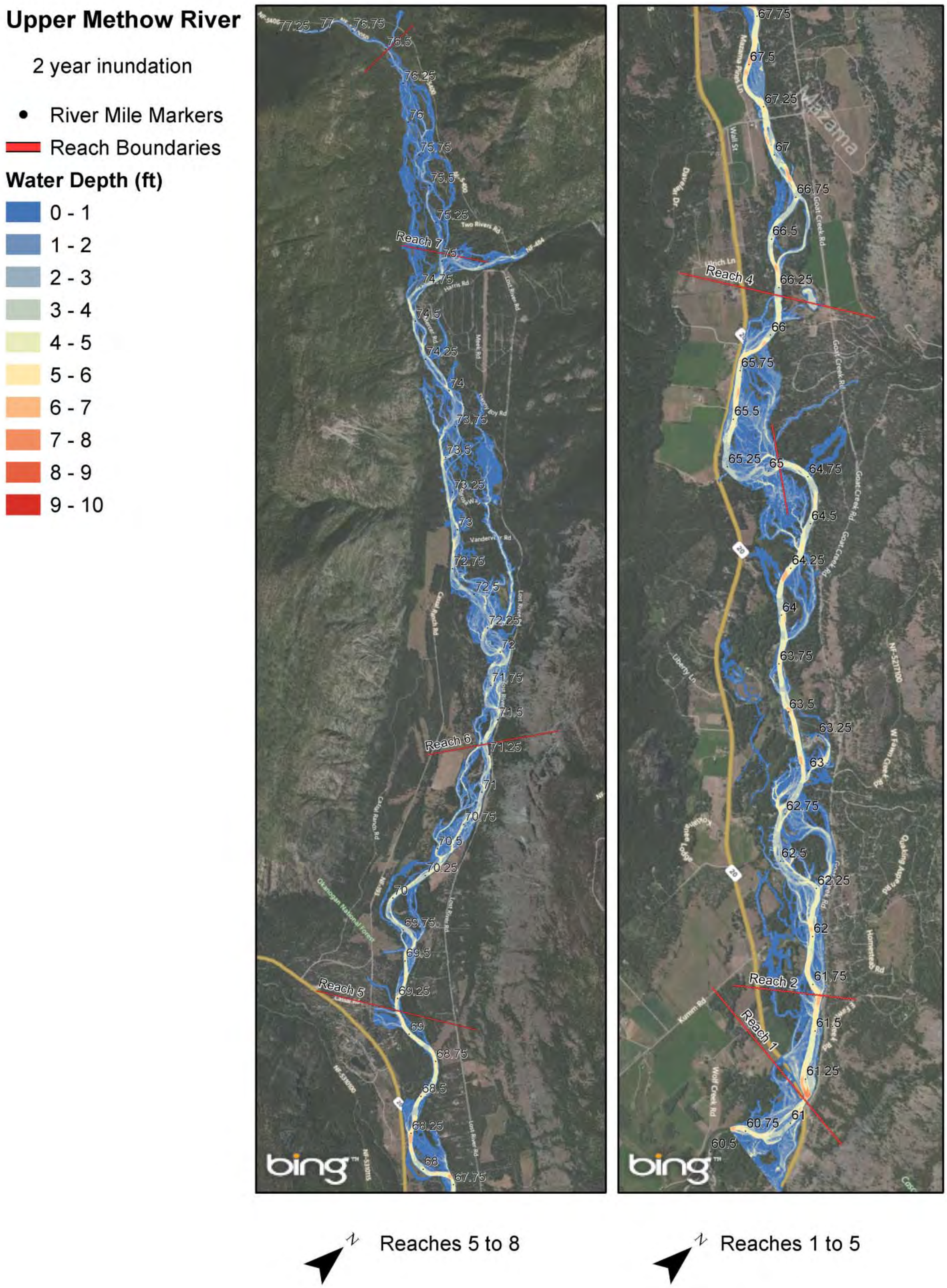

Figure 10. 2D model output for water depth for the 2YR flood. Reach scale detail is provided in the reach sections later in this report.

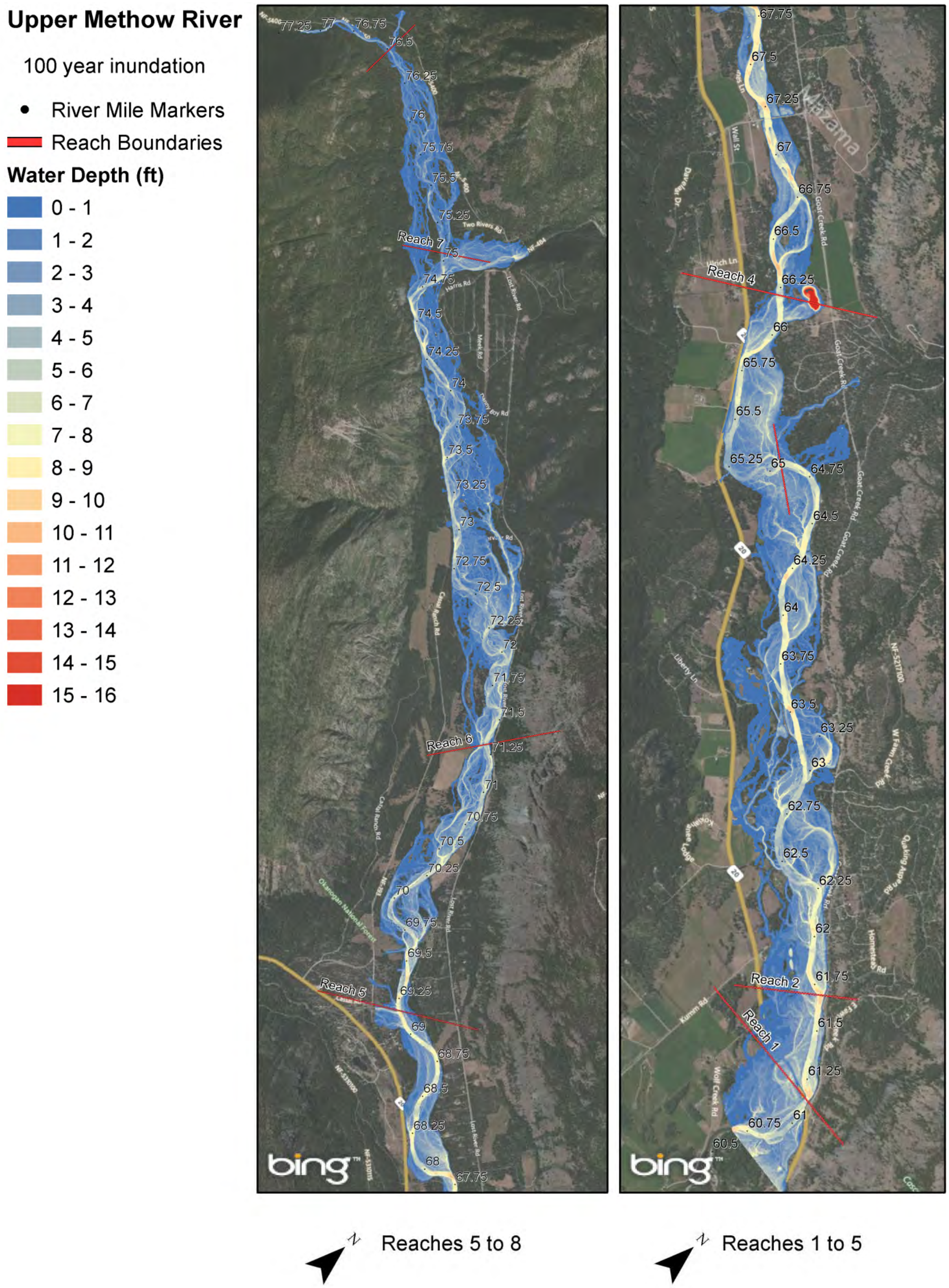

Figure 11. 2D model output for water depth for the 100YR flood. Reach scale detail is provided in the reach sections later in this report.

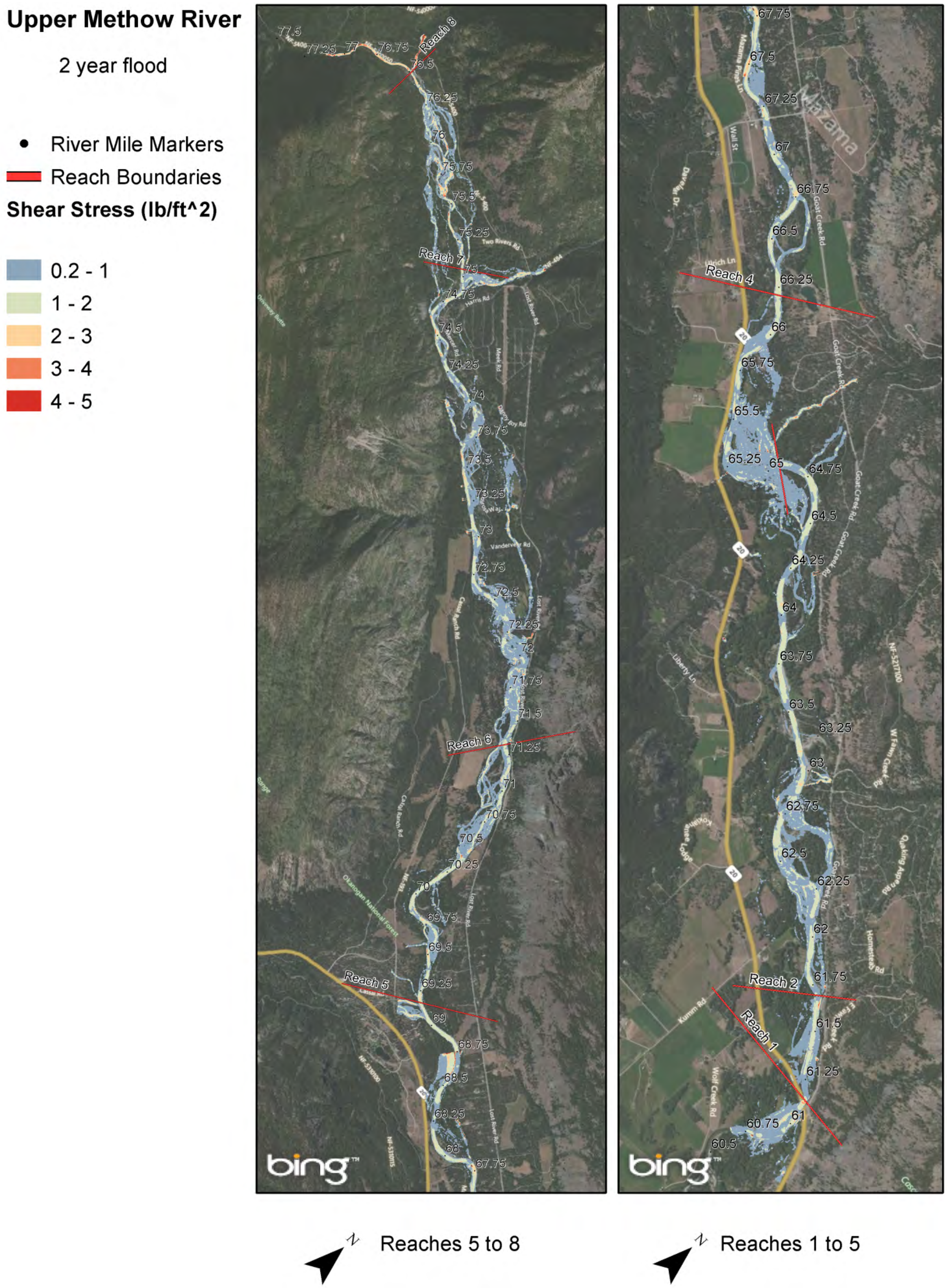

Figure 12. Output of shear stress in lb/ft² from the 2D model for the 2YR flood event.

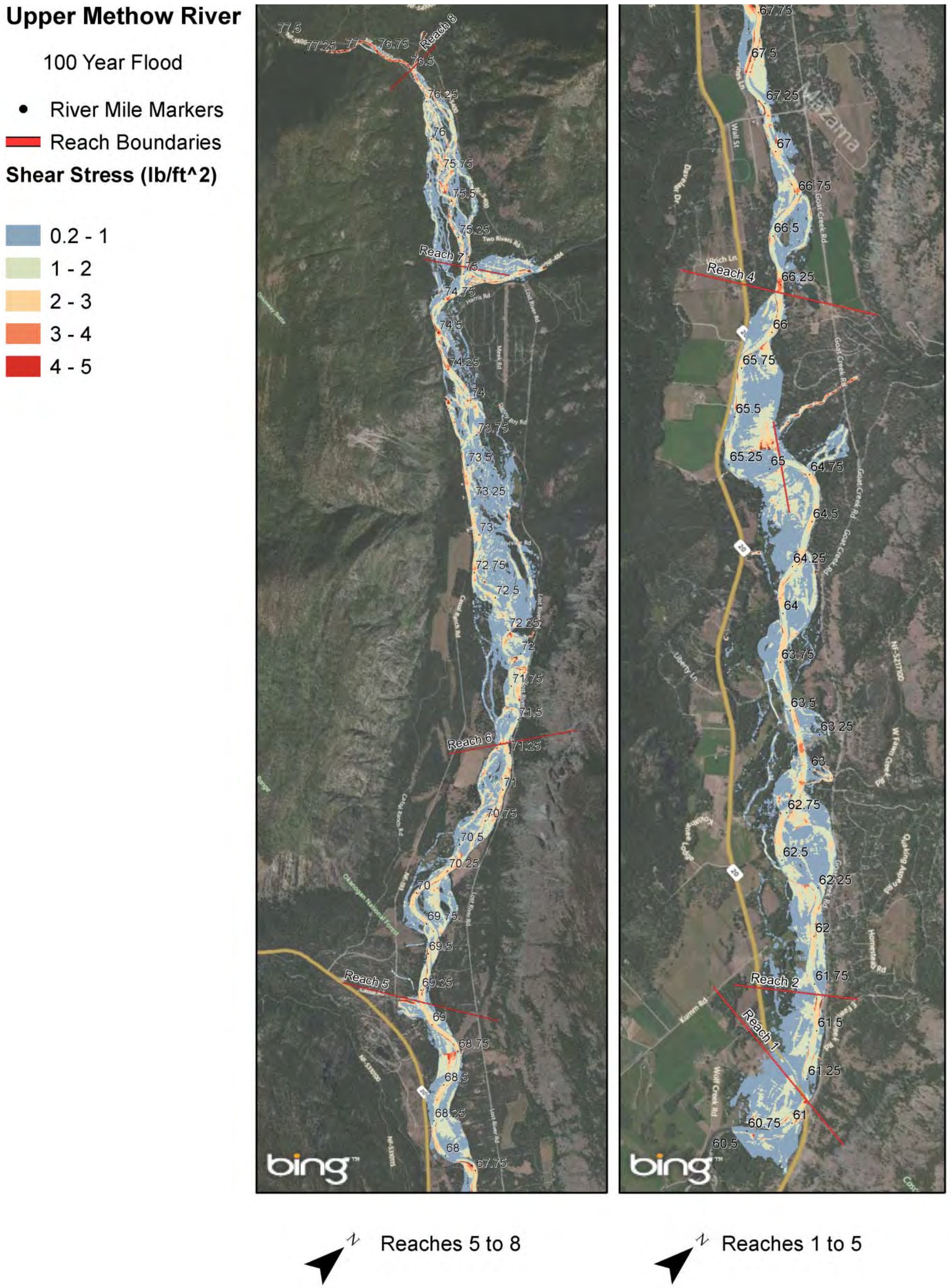

Figure 13. Output of shear stress in lb/ft^2 from the 2D model for the 100YR flood event.

2.8 GEOMORPHOLOGY

2.8.1 Valley Morphology

The Upper Methow River valley rests within a dramatic high-relief alpine landscape. The contemporary aspect of the valley is governed by regional fault zones that have imposed both hydrographic and topographic influences on the drainage basin for millennia. The main valley (downstream from the Lost River confluence) trends northwest to southeast, reflecting the direction of the dominant regional faults. The upper portion of the study area (from Lost River to Trout Creek) trends west to east, along what appears to be a transform fault that extends between the primary fault zones. The high, steep walls of the U-shaped valley were carved out of the area's bedrock during periods of glaciation. The most recent valley glaciation occurred between 20,000 and 9,500 year ago (late Pleistocene to early Holocene), at the end of the last ice age. Most of the headwaters and tributaries of the valley have also been formed or influenced by glacial processes, creating features such as cirques and hanging valleys in the uplands.

At the close of the last ice age, increased discharge and sediment that was generated by the melting of the glaciers filled the valley floor with a thick layer of glacial outwash deposits. Today, these deposits make an almost continuous surface that extends down-valley from Robinson Creek. On top of the glacial outwash surface are large alluvial fans, also composed of glacial-fluvial deposits. These features were created by the increased discharge and sediment generated during the retreat of the upland glaciers. The alluvial fans extend out from points where tributaries enter the valley. Glacial deposit terraces that are higher than the glacial outwash surface are present along the edges in the upper valley above Robinson Creek and as a narrow terrace on the east side of the valley below Goat Creek. These features are evidence of the sequences of glacial retreat and extension at the end of the ice age when the volume of ice in the valley was diminishing. Another result of increased discharge during glacial retreat is the v-shaped incision into the bedrock at the base of the valley in the upper-most portion of the study area above Driveway Creek and Rattlesnake Creek. Infilling of the v-notched valley floor has also occurred here via glacial-fluvial and hillslope deposits in this narrow portion of the study area. The width of the modern valley floor increases from about 0.02 miles in the upper section to 0.3 miles at Robinson Creek, to about one mile wide at the downstream end of the study area at the Weeman Bridge.

The geomorphology of the modern Upper Methow River valley is dictated by the glacial processes and features described above, superimposed on by the modern discharge and sediment regimes. Driven by reduced discharge and sediments loads, the modern channel has incised into the glacial deposits, abandoning and thus creating sets of glacial outwash terraces along the edges of the valley. The alluvial fans coming from the edges of the valley influence the channel pathways and modern floodplain dimensions. The terraces, alluvial fans, and glacially-influenced tributaries supply sediment to the modern system. Talus, landslides, and debris fan deposits are generated off of the weathered slopes and steep bedrock walls along the edge of the valley or into the channel and/or its tributaries. A map of the geomorphic surfaces of the valley including alluvial fans, terrace deposits, and the modern floodplain surfaces is presented in Figure 14. Detailed geomorphic-surface maps are provided in the reach-specific sections later in this report.

The modern channel and floodplain is referred to as the "low surface" within this report. The low surface is composed of alluvially developed geomorphic features, which are further differentiated into the following categories: Active Channel, Active Floodplain, Disconnected Floodplain, and High Floodplain. These surfaces are the product of modern sediment and climate regimes of the mid to late Holocene and as such are inset below the glacial outwash terraces and alluvial fans that border much of the valley. The low surface is likely to experience inundation during large flood events (e.g. 100 year recurrence). The area included within the low surface generally depicts the extent of modern lateral channel migration and floodplain development. However, future lateral migration is not restricted to the low surface where lateral migration may occur along glacial terraces or alluvial fan deposits. Definitions of the low surface features are provided below.

Active Channel: The bed, bars, and banks of the channel that are activated regularly by flow (1-2 years). The boundary of the active channel generally corresponds to the bankfull elevation and represents the area that is inundated by the discharge that mobilizes a majority of the available sediment and that plays the strongest role in creating the bedforms within the channel. This includes side or mid-channel bars that may be vegetated seasonally by riparian grasses, forbes, or shrubs, but that become activated frequently enough to limit permanent woody vegetation establishment.

Active Floodplain: The low-elevation floodplain surfaces adjacent to and connected to the active channel by overbank flow every 1-10 years. Regular inundation of these surfaces results in deposition of overbank deposits on the floodplain, surface scarring, and exchange of nutrients with the channel. The active floodplain surfaces are well vegetated, unless otherwise cleared, with a dense mix of forest and understory that often includes cottonwood or other riparian zone trees and shrubs.

Disconnected Floodplain: Active floodplain surfaces where magnitudes, frequencies, or patterns of floodplain inundation and/or channel migration have been altered by human modifications including roads, levees, dikes, armoring, floodplain grading, or other impacts.

High Floodplain: The modern alluvial surfaces that are higher in elevation than the active floodplains and express no evidence of current inundation (10-25 years). Modern topsoil and organic accumulations are lacking fresh overbank deposits, and floodplain scarring is less pronounced on these surfaces. In most areas, hydraulic modeling confirms that the high floodplain surfaces are likely inundated by the 100-year flood event, but inundation depths are shallow or only follow floodplain channel scar paths. Where clearing has not occurred, vegetation on these surfaces is a mixed forest and understory that often includes establishing pine seedlings (~10+ years old) and dying mature cottonwood trees – an indication of a surface that is experiencing drying, or is at risk of transitioning from a connected floodplain to a terrace. The trend towards floodplain abandonment appears to be relatively modern (within the last 100-150 years or less) and may indicate incision within the reach.

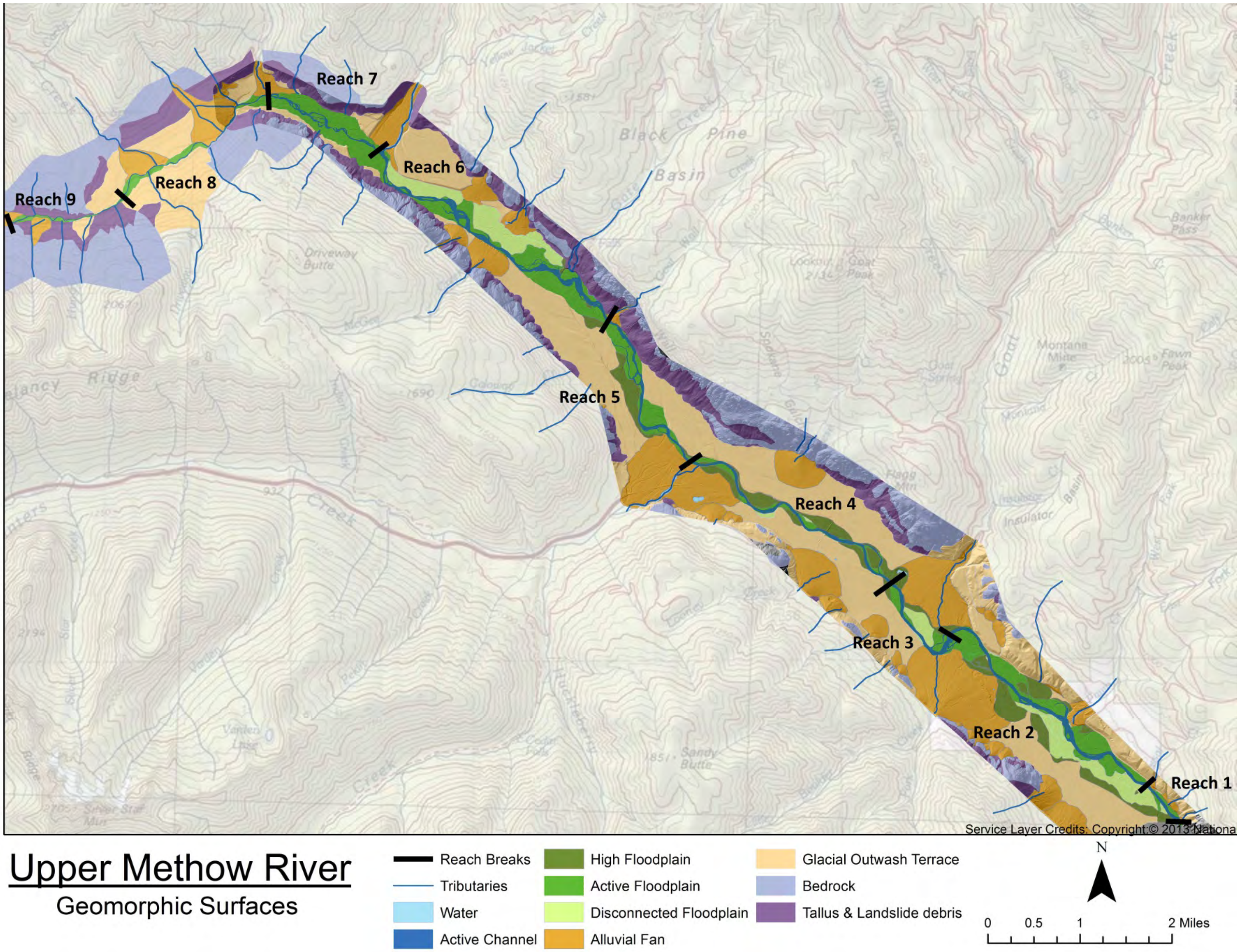

Figure 14. Geomorphic surfaces of the Upper Methow River (RM 61.15 to 80).

2.8.2 Channel Morphology

The contemporary channel form of the Upper Methow River is largely influenced by the geologic and glacial-fluvial history of the landscape described previously. Today the modern channel and its alluvial surfaces are inset below the glacial outwash terraces and alluvial fans that were deposited during the high discharge and sediment fluxes generated during glacial retreat (~10,000 years ago). As the climate became warmer and drier through the early Holocene, discharge and sediment flux was reduced. This led to the channel incising into the glacial outwash deposits, creating paired terraces from the abandoned surfaces. This is a classic channel evolution process described by Schumm et al. (1984), where incision occurs due to changes in discharge or sediment regimes, and then the channel develops a new active floodplain that is inset within the abandoned terraces. Anthropogenic modifications have imposed some additional influences on the system in the last 150 years. For example, channel incision processes in reaches one through seven have likely been influenced by modern human-imposed channel modification such as vegetation clearing and logging, log rafting, bank armoring, road and bridge building, home site development, etc. Further discussion of localized incision and the anthropogenic influences are provided in the reach-scale condition section of this report (Section 3).

A study on the potential channel migration zone of the Methow River downstream from the Lost River confluence (Golder Assoc. 2005) reveals that the estimated migration zone of the river is basically confined to the modern floodplain surfaces, with some exceptions where potential channel migration is identified along terraces or hillslope boundaries (Figure 15). Avulsion hazard areas were also identified, and were assumed to conform to the FEMA floodplain boundary.

Sediment is contributed to the channel from alluvial fans, tributaries, occasional mass-wasting processes, near-channel banks, and hillslopes. The banks of the terraces and fan toes provide localized sediment composed of glacial outwash material (sand, gravel, cobble, and sparse boulders). The modern floodplain surfaces provide and store sediment for the system that is activated through processes of overbank scour, lateral bank erosion, channel avulsion, or side-channel reactivation. Additional sediment is stored in and activated from the channel bed during high-flow events. Lateral channel migration is related to riparian condition, the density of large wood accumulations, bar development, and increased channel complexity. Lateral migration, avulsions, and side-channel activation appear to be most common in the unconfined lower-gradient reaches. More detailed geomorphic descriptions for each reach can be found in the reach-specific sections later in this document.

The study area reflects both conventional and unconventional downstream geomorphic trends. Sinuosity of the channel within the study area ranges from 1.05 in the narrow upstream section, to 1.22 in the gradually meandering unconfined mid-valley section, to almost straight (1.01) at the downstream section where anthropogenic modifications have confined the channel between bridge abutments and riprap. Stream gradient basically increases from downstream (0.30%) to upstream (2.7%). Between Reaches 6 and 7, demarcated by the confluence of Lost River, the channel gradient doubles from 0.7% to 1.5% (Figure 16).

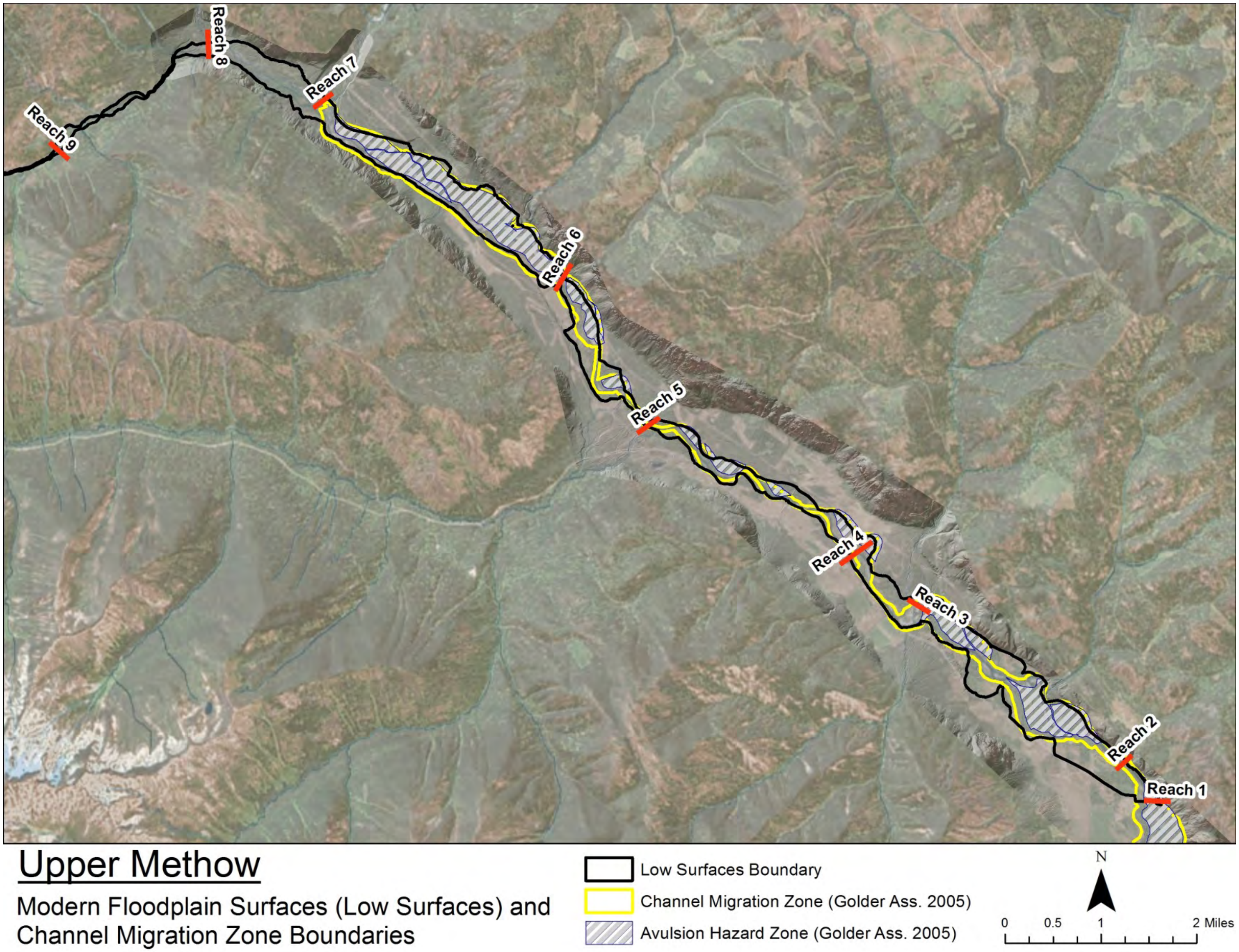

Figure 15. Lower Surfaces Boundary (mapped modern floodplain surfaces as defined in this report) within the study area and delineated channel migration and avulsion zones (Golder Ass. 2005).

The predominant bed types are extended plane-bed glides in the lower gradient reaches and riffles in the higher gradient reaches. The average floodplain widths in the study area do not increase in a downstream trend as expected. Instead, the width of the floodplain in the mid-valley reaches (3-5) decreases in comparison to the wide reaches of 2, 6, and 7. This is most notable for Reach 4 where floodplain width (365 feet) is about half of that for Reaches 5 (721 feet) and 3 (848 feet) and only a third of the width of Reaches 6 (1,394 feet) and 7 (1,345 feet). Floodplain width decreases in mid-valley because of inputs provided to the system from Early Winters Creek, located at the upstream end of Reach 4. Early Winters Creek has produced a large alluvial fan that extends across the glacial outwash terrace. The toe of the fan influences the location of the channel in the valley and the notable discharge inputs from the creek appear to locally change the hydro-geomorphic relationship to supply-limited. In supply-limited sections, a river has the capacity to transport more sediment than is delivered to it. As a result, the channel often incises vertically instead of laterally building floodplains.

Basic morphometric characteristics of each reach are listed below (Table 5) and further descriptions and explanations of the characteristics of each reach are provided in Section 3.

Table 5. Summary of geomorphic and habitat conditions at the valley and channel scale by geomorphic reach in the Upper Methow River.

	METRIC	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9
Channel and Floodplain	Length (miles)	0.55	3.1	1.3	3.1	2.1	3.7	1.5	2.2	1.3
	River Mile	61.15 - 61.70	61.70 - 64.80	64.80 - 66.10	66.10 - 69.20	69.20 - 71.30	71.30 - 75.00	75.00 - 76.50	76.50 - 78.70	78.70 - 80.00
	Stream Gradient (%)	0.30	0.5	0.4	0.5	0.6	0.7	1.5	2.2	2.7
	Channel Sinuosity	1.01	1.1	1.22	1.09	1.13	1.11	1.17	1.07	1.05
	Dominant Channel Type	Glide	Riffle	Glide	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle
	Dominant Substrate	cobble	cobble	gravel	cobble	gravel	cobble	cobble	lg cobble	boulders
	Average Bankful Width (ft)	172	141	159	129	95	100	76	56	52
	Average Floodplain Width (ft)	556	1193	848	365	721	1394	1345	290	161
	Confinement*	Moderate	Unconfined	Unconfined	Moderate	Unconfined	Unconfined	Unconfined	Unconfined	Moderate
Riverine Habitat Area (%)	Pool	0	5	21	11	21	27	16	2	10
	Riffle	43	52	34	56	44	47	57	92	84
	Glide	57	24	43	30	13	15	5	1	2
	Side Channel	0	19	2	3	22	11	22	5	4

*Confinement ratio: average floodplain width/average bankful width. If ≥ 4 = unconfined, ≥2 and < 4 = moderate, < 2 = confined (Pleus & Schuett-Hames 1998)

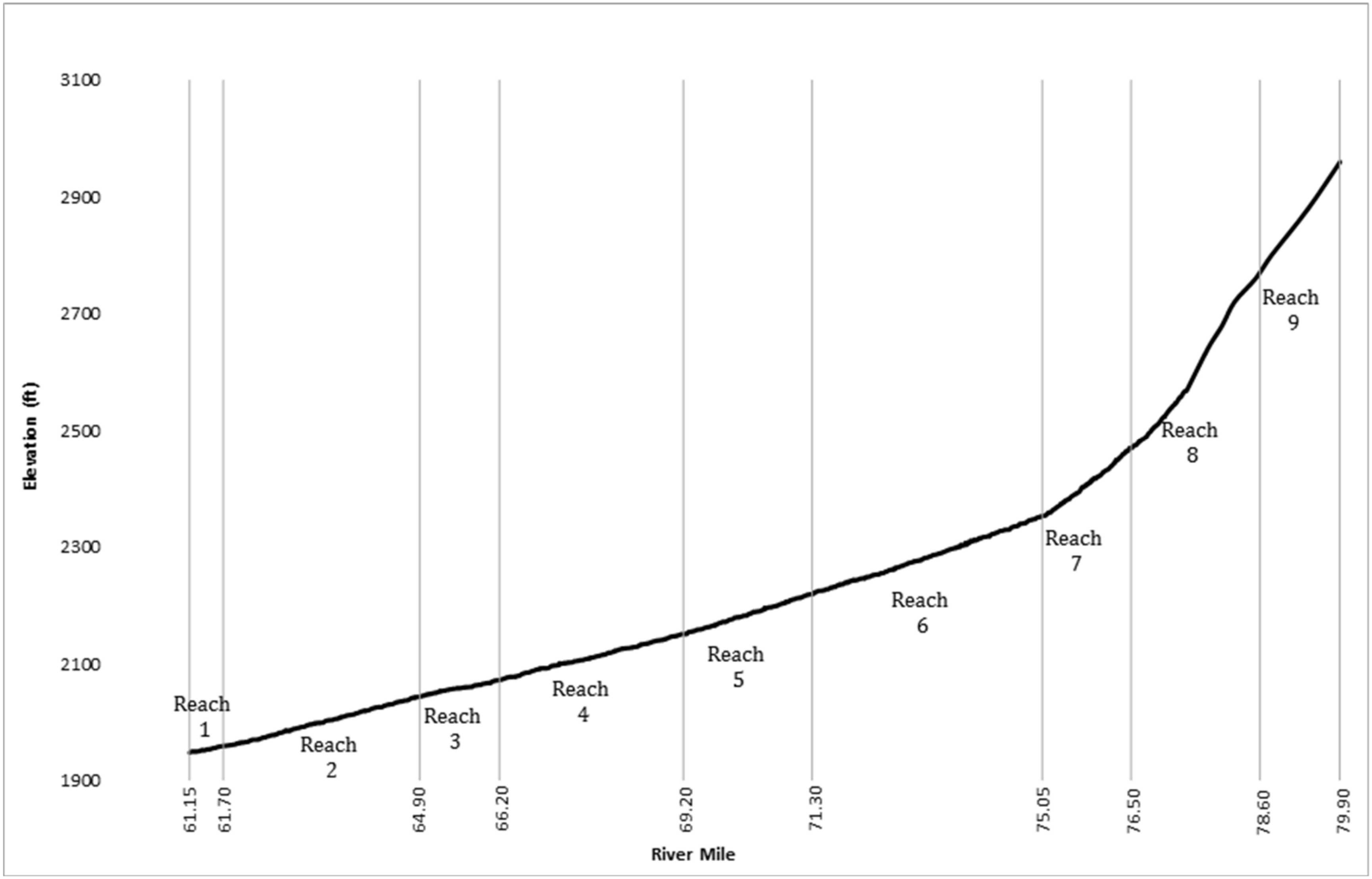

Figure 16. Longitudinal profile of the Upper Methow River study area. Elevation derived from 2006 LiDAR for Reaches 1 – 7 and USGS topographic maps for Reaches 8 and 9.

2.9 LARGE WOOD DYNAMICS

Existing large wood dynamics in the Upper Methow are a function of a legacy of river and forest management dating back to the late 1800s. 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.

2.9.1 Sources

Large old growth wood sources have been replaced largely by smaller second growth. This was reflected in the results of the 2014 Habitat Assessment (Appendix A) which identified 97% of the riparian area surveyed within 100 feet of the river as being small trees measuring 9.0 – 20.9 in. diam., or smaller. Only 3% of sampled areas were considered large (21.0 – 31.9 in. diam) as the dominant size class throughout the survey area.

One of the major sources of large wood in the Methow today is fire. The most recent large fire to impact the area, and correspondingly provide an increased source of large wood, was the Needles fire (Figure 17 and Figure 18), which burned 21,305 acres in 2003 (InciWeb 2014). While a majority of the fire was located upriver of the survey area, the final two miles of the 2014 Habitat Assessment (ending at Trout Creek) were located within the fire perimeter. The 2014 Habitat Assessment compares wood counts between the 2014 survey, a 2003 survey that occurred just before the fire, and a 1994 survey. While survey protocols have changed slightly between the three surveys, the data indicate that large wood in the Methow River has seen vast increases over the last 20 years. Small wood increased by 336%; medium wood by 550%; and large wood by 1850%.

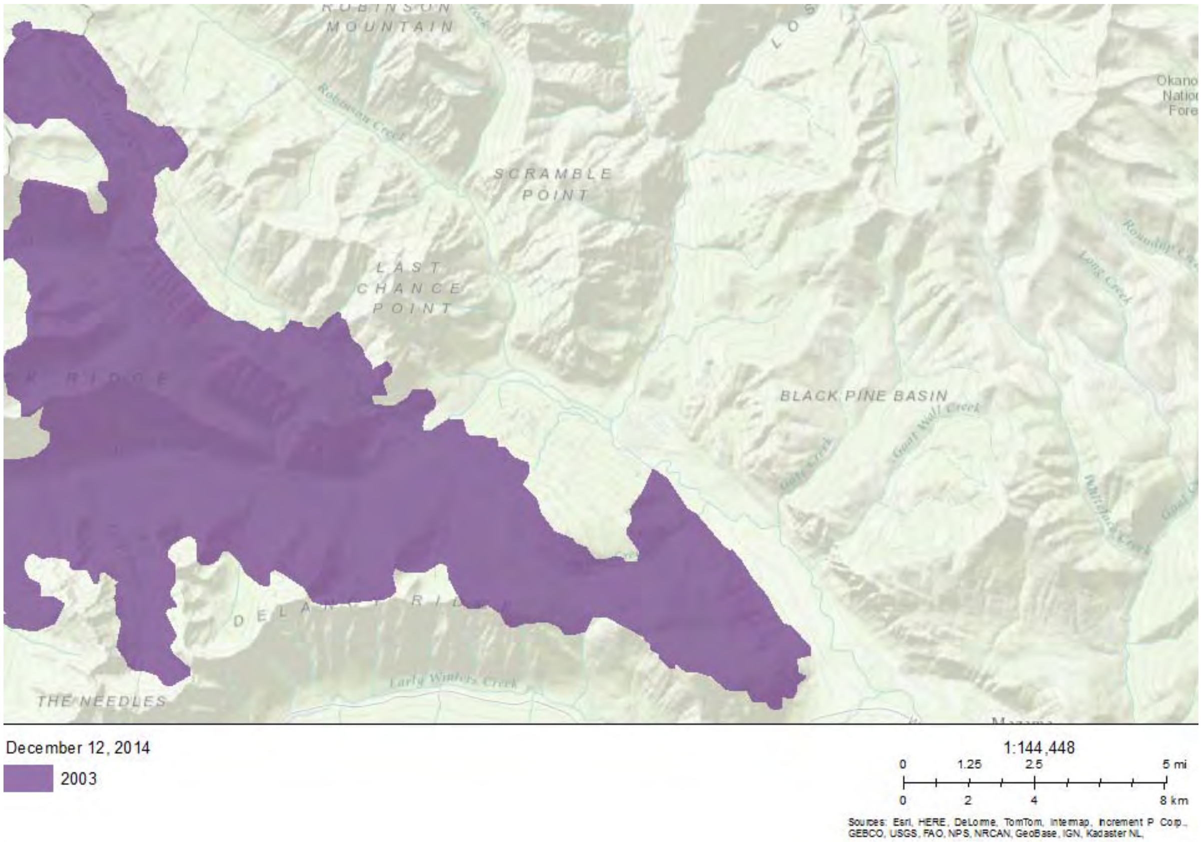

Figure 17. The Needles Fire (2003) burned 21,305 acres in 2003. Today, snags from the fire are source material for downstream logjams like the ones at RM 79.75.

Figure 18. Trees on either side of the Upper Methow River in Reach 9 were burned during the Needles Fire of 2003, leaving upright dead snags. This large log jam at RM 79.75 is believed to be the result of a snow avalanche.

2.9.2 Recruitment

In unconfined reaches, channel scrolling and floodplain avulsions lead to riparian and floodplain tree recruitment. This is particularly evident in the sinuous downstream portion of Reach 7 as well as other unconfined portions of the study area (primarily in Reaches 2, 5, and 6). This recruitment is principally driven by scour at the toe of channel banks that leads to bank failure and tree recruitment, but it also happens in avulsions (i.e. meander cutoffs). Confined areas with non-erodible banks (e.g. bedrock) only experience riparian tree recruitment through tree-fall, or from fluvial transport from upstream. Large wood is also recruited to the channel through episodic mass wasting events, particularly from debris flows, landslides during large flood events, or from snow avalanches (as occurred recently in Reach 9). Recruitment processes are mostly intact throughout the study area except for areas where lateral channel dynamics or bank stability has been modified through human alterations. The most common human alteration to LW recruitment in the study area is the presence of the roads on either side of the channel (Goat Creek Cut-off Road and Highway 20), which lie adjacent to the channel through much of the lower reaches (1- 4) and on the right bank through portions of Reaches 5-8. Bank armoring associated with the road limits not only the available riparian sources for large wood, but also the potential for wood to be recruited through natural bank erosion processes. Bridge constrictions also limit channel migration processes that reduce the potential for LW recruitment. There are other stretches of bank armoring associated with streamside residences that limit local recruitment, particularly in Reaches 1, 2, 3, 5, and 6.

2.9.3 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 in the study area. The same alterations to recruitment, described above, also affect retention. These include bank armoring that reduces margin complexity necessary for wood to become retained on margins, and confinement (e.g. bridges) that confine the channel and result in stream power that favors wood transport over deposition. These impacts only occur at specific locations and are not widespread throughout the study area.

The legacy of in-channel wood clearing and log drives, using the stream corridor as transportation for cut timber, may have some effect on contemporary retention processes, especially in the lower portion of the study area where clearing was known to occur. This clearing may have also led to the removal of large boulders, channel straightening, and simplification of channel margins, which would have reduced the potential for the channel to retain wood.

The currently available wood size also affects the ability of the channel to retain wood. The wood that is now contributed to the channel mostly represents second or third growth timber that is smaller than historical wood sizes and does not have the same ability to self-stabilize within the channel. Even though the habitat assessment (Appendix A) found an average of 125 pieces of wood per mile (>6 in. diameter; >20 ft. long), a majority (56%) of these pieces were less than 20 inches in diameter (were in the “small” size classification) and are not large enough to initiate log jam formation. The shift in riparian seral stage, and the corresponding reduction in available key pieces, has 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 tree size, retention, and the potential for jam formation.

Although today's second and third growth timber is generally smaller than historical wood sizes, Appendix A does indicate a trend towards an increased quantity of medium and large pieces since 1994 between Goat Creek and Trout Creek. The average medium/large wood (measuring more than 35 feet long and more than 12 in. diameter) has increased from 15 pieces per mile in 1994 to 58 pieces per mile in 2014.

2.10 HABITAT CONDITIONS

Stream habitat conditions were recorded using the USFS Level 2 stream habitat inventory methods. The survey recorded information on habitat unit composition and habitat characteristics including pool depth, substrate size, 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.

The Upper Methow River reaches were dominated by pool-riffle and plane-bed morphology, with some partially confined step-pool channels in Reach 8. Overall, channel bed substrate consisted primarily of cobbles (48%) and gravels (48%) with 2% boulder and 2% sand (See Habitat Assessment Appendix A). Although present in some locations, bedrock was not recorded in significant quantities to register at the reach-scale.

Riffles were the dominant habitat type, comprising 54% of the total habitat unit composition for the study area. Glides comprised 22% of the area, and pools and side-channels comprised 13% and 11% of project area, respectively. In general, glide habitat decreased and riffle habitat increased as the grade increased going upstream. Pool frequency ranged from 0 pools/mile (Reach 1) to 7.5 pools/mile (Reach 7), with an average pool frequency throughout the study area of 3.6 pools/mile. The majority of pools throughout the study area had residual depths of less than three feet (72%).

Channel widths were variable, generally becoming narrower going upstream as the river decreased in flow. Mean bankfull depths also decreased going upstream, ranging from an average bankfull depth of 3.9 feet in Reach 1 to an average of 1.6 feet in Reach 9. Floodprone widths varied substantially in the project area, ranging from 3,400 feet in Reach 1 to 70 feet in Reach 9 where the river was constrained by valley walls for parts of the reach.

Secondary channel habitat (side-channels and off-channels) accounted for approximately 11% of the habitat area throughout the study area. In total, 47 secondary channel units were observed. The average side-channel was 961 feet long (StDev 918). Reach 2 maintained not only the longest side-channel observed in the project area (4,800 feet), but also had the most overall secondary channel habitat area of all 9 reaches.

All reaches had significant human impacts, including residential development on the floodplain, channelization, roads, agriculture clearing adjacent to the river and riparian areas, levee construction, and impacts from logging. There were also fire and avalanche-related instability and disturbance. Anthropogenically caused bank erosion was minimal throughout the study area.

An average of 125 pieces of large wood per mile was counted in the project area; 56% were "small" pieces with diameters between 6 and 12 inches and lengths greater than 20 feet.

The dominant size class of riparian trees was small trees measuring 9.0 – 20.9 inches diameter (83%). Sapling/pole trees measuring 5.0 – 8.9 inches diameter were the second most dominant class (7%). The remaining 10% was distributed between large trees measuring 21 – 31.9 inches diameter (3%); shrub/seedling measuring 1 – 4.9 inches diameter (5%); and grassland/forbs (2%). The dominant riparian understory species were dogwood and cottonwood, accounting for 30% of the understory each. Additional dominant riparian understory species included snowberry/mountain maple (13%); grassland forbs (12%); willow (5%); small shrubs (5%); manzanita (3%); and cedar (2%). The overstory was dominated by cottonwood and ponderosa pine (42% and 25% respectively). Additional species observed as dominant in the overstory included dogwood (10%); cedar (10%); Douglas fir (10%); and aspen (3%).

2.11 WATER QUALITY

State water quality standards for the Upper Methow River are designated according to the Aquatic Life Use "core summer salmonid habitat", which determines the standards for various water quality parameters including temperature, dissolved oxygen, turbidity, and others (WDOE 2012). The main water quality issue in the Methow River is water temperature. The water temperature standard is 16°C from June 15 to September 15 for the 7-DADMax, which is the 7-day moving average of the daily maximum temperature. There is an additional standard for spawning and incubation protection, which is 13°C for the 7-DADMax from August 15 to July 1 (Payne 2011). Low discharge volumes and high summer air temperatures result in a warming trend as the water moves downstream. Water temperatures of 16°C or greater have been documented in the study area; however, springs and groundwater inputs along the study area contribute to some cool water pockets and locations with decreased water temperatures (USFS 2003, Watershed Sciences 2009).

Airborne thermal infrared (TIR) imagery was collected in August of 2009 for the Methow River (Watershed Sciences 2009). TIR imagery measures the thermal energy emitted from a surface and thus indicates the temperature of the surface of the water. TIR surface water temperature data were collected within the study area from the Weeman Bridge at RM 61 to RM 75 at the confluence with Lost River. It was noted that the Upper Methow River showed highly variable temperatures, with three large-scale warming and cooling cycles (Figure 19). It is assumed that the high variability in water temperature from RM 75-61 is influenced by groundwater to surface water exchanges. This is supported by the large number of seeps and springs shown in the TIR imagery near areas of surface water cooling (Figure 20). According to the TIR data, stream temperatures in August 2009 ranged from 12.4°C just below Little Boulder Creek (RM 65.17) to 19.4°C at the mouth of the Methow River. At the upstream end of the survey, Lost River (RM 75) contributed to the first cooling trend (Figure 20), but the mainstem Methow quickly warmed back up moving downstream. Near RM 70, temperatures decreased due to the input of a cool spring contributing groundwater to the channel. Again, the channel warmed up as it moved downstream until RM 64.5 near the confluence of Gate and Boulder Creek and a spring complex that adds cool water to the main channel. After each temperature decrease, the Methow quickly warmed moving downstream.

Low flow periods in the summer exaggerate water temperature variability and issues. Higher water temperatures throughout the summer months, and particularly in August and September during spring Chinook spawning, are likely detrimental to salmonid survival in the Upper Methow River (See Section 1.4 for additional fish use information). High water temperatures pose potential negative impacts to rearing salmonids, in addition to acting as a thermal barrier to migrating salmonids. Preferred temperature ranges for rearing Chinook and steelhead are 12-14°C and 10-13°C, respectively. When temperatures exceed 23-25°C, they are life threatening and will cause fish to move to other areas (Bjornn and Reiser 1991). This is of particular concern from Goat Creek (RM 65) to Lost River (RM 75) where late summer low-flows can result in large portions of the channel going dry (see Section 2.6.3). Gradual dewatering of the channel produces shallow water and pools that warm more easily. When surface water temperatures increase and flow is reduced, the potential for fish stranding, predation, and/or the desiccation of redds also increases. Low instream flows and sections that go subsurface leaving the riverbed dry during the late summer and early fall months are seasonally designated by the Washington State Department of Ecology as water quality limited (Category 4C). This underscores the importance of the availability of cool-water refugia during warm low-flow months for salmonid survival in sections of the Upper Methow River.

Other than the temperature data presented here, there is minimal water quality data for the Methow River. Adjacent land uses including residential lawns, roads, livestock grazing, dispersed camping, and gravel mining have the potential to affect water quality conditions, but the degree of impact of these actions on water quality is relatively unknown.

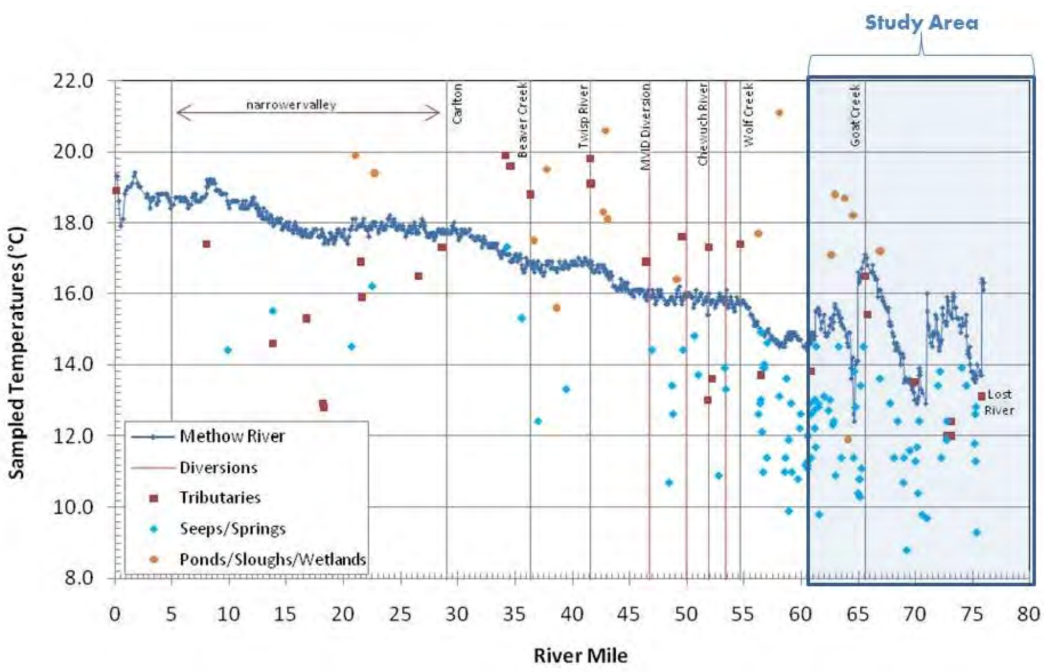

Figure 19. Surface water temperatures of the Methow River from slightly upstream of the Lost River confluence at RM 75 to its confluence with the Columbia River. Study area surface water temperatures highlighted in blue (RM61-80) indicate a high level of variability. (Derived from Figure 11 in Watershed Sciences 2009).

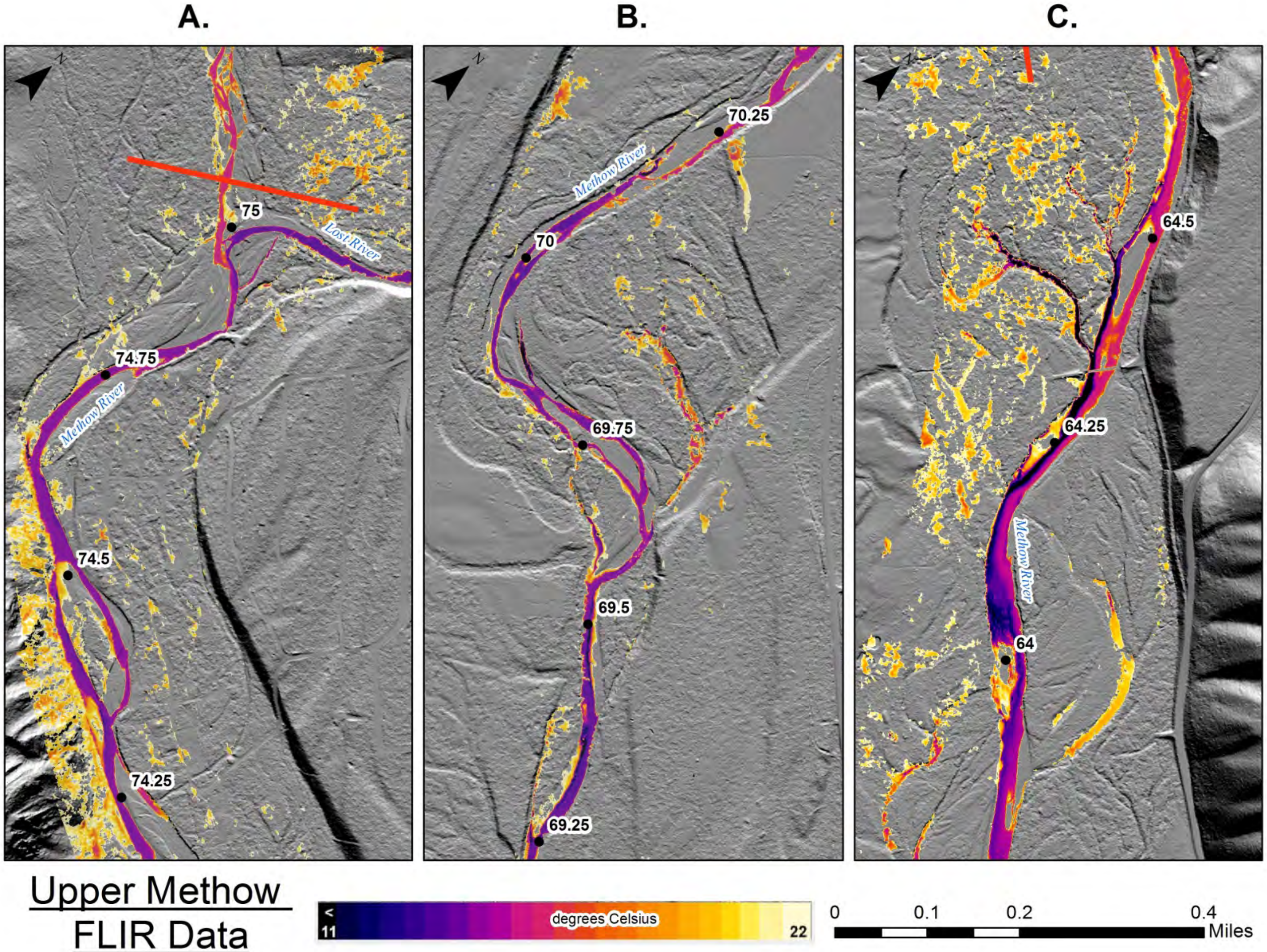

Figure 20. Surface water temperatures (FLIR) of select sections of the Upper Methow River study area. Groundwater and tributary inputs result in varied surface water temperatures.

2.12 REACH-BASED ECOSYSTEM INDICATORS

This section presents an overview and summary of the Reach-based Ecosystem Indicators (REI) analysis (Table 13), which is presented in more detail in the REI Report (Appendix B). 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 later in this document. The rating definitions, and explanations of how the ratings were made, can be found in Appendix B.

Within the study area, reaches below the confluence of Lost River (Reaches 1-6) were generally the most impacted reaches, having the highest number of **Unacceptable** ratings. Reaches 5 and 6, although having slightly fewer **Unacceptable** ratings, both had high numbers of **At Risk** ratings due to the amount of residential development along the banks of those reaches. Reach 7 had seven **At Risk** ratings, with only one **Unacceptable** rating. Reaches 8 and 9 were the least impacted, with Reach 9 receiving all **Adequate** ratings and Reach 8 having only one **At Risk** and **Unacceptable** rating each.

All reaches were given **Adequate** ratings for the Habitat Access Pathway- Main Channel Barriers indicator since there were no barriers within the main channel that completely excluded fish passage in any of the reaches. All reaches (except Reaches 8 and 9, which did not have substrate sampled) were also given an **Adequate** rating for the Dominant Substrate/Fine Sediment indicator due to gravel counts meeting appropriate percentages and minimal fine sediments in all reaches. LWM was rated **Adequate** only in Reach 9 and **At Risk** only in Reach 5; all other reaches were given **Unacceptable** ratings due to low numbers of pieces of large and medium woody debris per mile and limited (or no) jams present in the reach. The lowest three reaches were given **Unacceptable** rankings for the degree of off-channel connectivity with the main channel. Canopy cover over the main channel was **Unacceptable** in Reaches 1 – 5 due to riparian clearing from residential and agricultural development. Reaches 6 and 7, although less developed, still received **At Risk** rankings for canopy cover due to the legacy of timber harvests which has resulted in smaller, younger trees within the riparian zone. Bank Stability and Floodplain Connectivity indicators were similar, with Reaches 7, 8, and 9 receiving ratings of **Adequate** in both indicators. Reaches 3 and 5 were rated **At Risk**, and Reaches 1, 2, 4, and 6 were given **Unacceptable** ratings due to the number of human features and disturbances in those reaches.

For the study area as a whole, **Adequate** was the most common rating (38), followed by **Unacceptable** (31), then **At Risk** (30).

Table 6. Reach-Based Ecosystem Indicator (REI) results. See Appendix B for the REI report.

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

3 Reach-Scale Conditions

The study area was divided into nine distinct geomorphic reaches to facilitate description and discussion of local channel characteristics and restoration needs (see Figure 3). Reach delineation was based on major tributary confluences, valley confinement, underlying geology, channel gradient, and channel type (e.g. dominant bed morphology). Reach boundaries utilized in previous studies of the area were also considered to help with data comparisons and change over time. Reach delineation was initially conducted using remotely available data (e.g. aerial photos, LiDAR, and geology maps). The reach boundaries were then verified in the field during survey work.

3.1 REACH 1

Refer to Section 2.2 and 2.8 for geologic and geomorphic context of the study area and explanation of terminology.

3.1.1 Reach Overview

Reach 1 is 0.55 miles long and extends from RM 61.15, at the Weeman Bridge, to 61.70. Land ownership throughout Reach 1 is private except for public easements at the bridge and the roads that border the reach (Figure 21). The channel is a single-thread stream limited to extended channel units of riffles and glides (Figure 22). The river in Reach 1 has a low sinuosity ratio of 1.01 and a relatively low gradient (0.4%). These and other reach metrics are provided in Table 7 and Figure 23.

The reach is semi-confined by a variety of features including riprapped channel banks, the Weeman Bridge, and a terrace hillslope with a reinforced road embankment. Hillslopes, glacial terraces, and the Goat Creek Road embankment confine the reach on river-left (east side of the channel). A narrow band of active floodplain is developing between the river and this road embankment. On river-right (west side of the channel) there is a wide, well-vegetated floodplain in the upper half of the reach, a disconnected floodplain surface in the middle of the reach, and a well vegetated high floodplain in the lower portion of the reach. The upstream end of the disconnected floodplain feature is delineated by a bank of boulder-sized riprap and a small push-up levee located in front of a private residence. A levee with riprapped banks on river-right in Reach 2 also disconnects section of the inland floodplain surface in Reach 1.

The habitat conditions in Reach 1 are discussed in Appendix A. Based on the REI analysis, 9 of 11 habitat indices are rated as either unacceptable or at risk (see Table 6). The salmon and steelhead redd distributions for the reach are mapped in Figure 21. Vegetation clearing and thinning has occurred on portions of the disconnected floodplain and away from the channel atop the alluvial terrace. Reach 1 has no log jams and only a few pieces of wood in the channel, resulting in the lowest large wood counts in the study area. A lack of large wood in the channel is likely due to past channel clearing and perhaps straightening which has resulted in minimal recent lateral channel migration. However, summer low-flows do expose alternating elongate gravel-cobble bars that indicate a gradually developing channel sinuosity. As a result, subtle westward lateral migration of the channel is occurring on river-right.

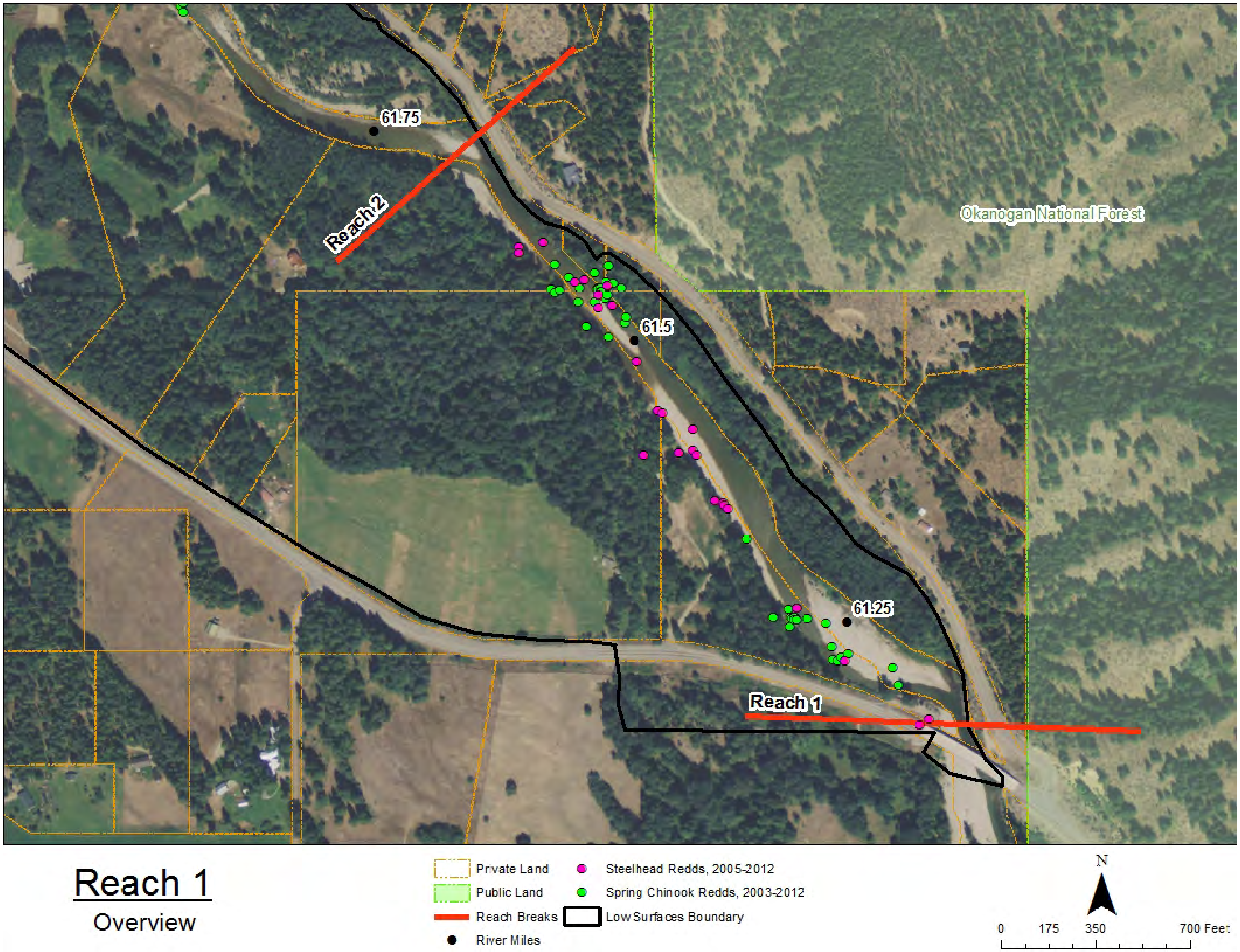

Figure 21. Reach 1 overview map with landownership and redd distribution.

Figure 22. Representative photo of Reach 1; looking upstream at RM 61.3 (9/5/2014).

Table 7. Reach 1 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	0.55
River Miles	61.15 – 61.70
Valley Gradient	0.6%
Stream Gradient	0.3%
Sinuosity	1.01
Dominant Channel Type	Extended glide-riffle
Average Bankfull Width (feet)	172
Average Floodplain Width (feet)	556
Dominant Substrate	cobble (52%); gravel (46%); sand (2%)
Bank Stability/Channel Migration	Unacceptable *(See Section2.12)*
Vertical Channel Stability	At Risk *(See Section2.12)*
Confinement Ratio	Moderate *(See Table 5)*

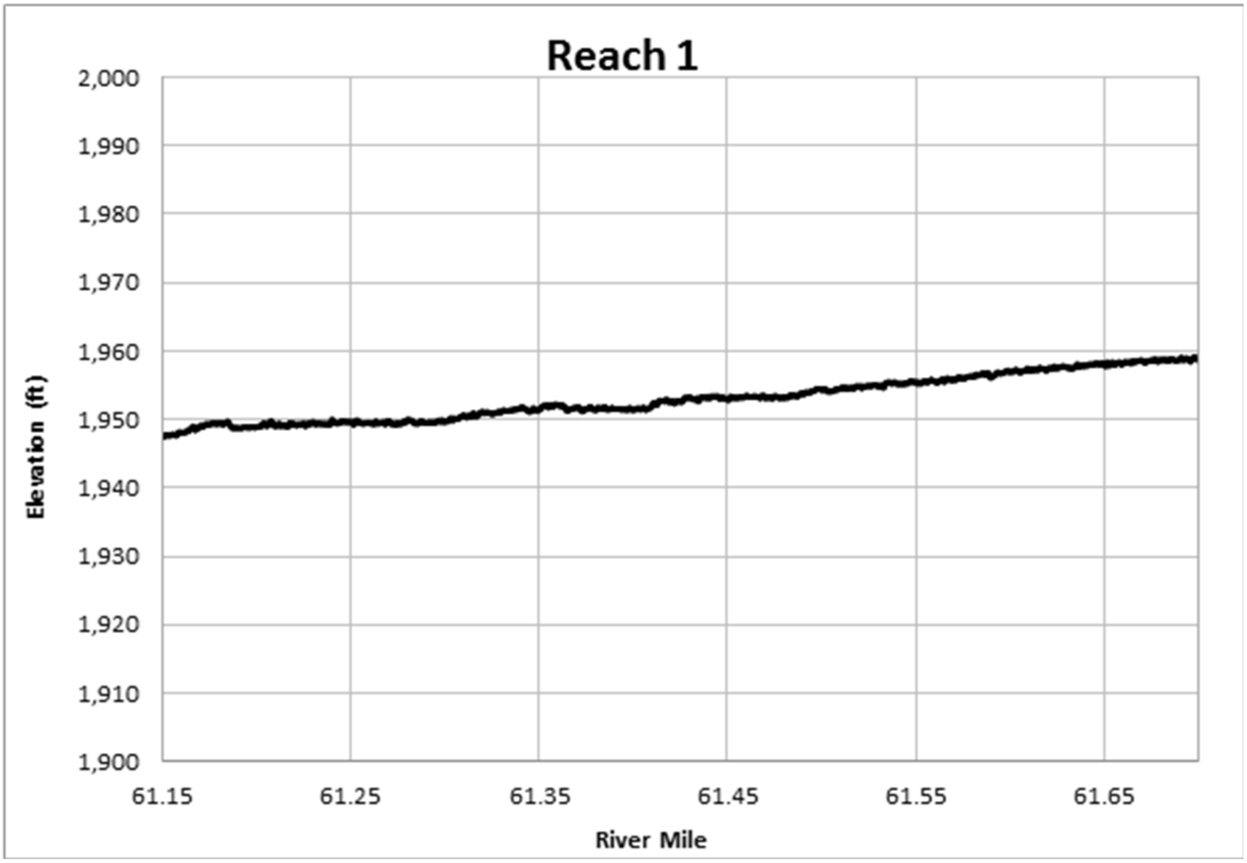

Figure 23. Longitudinal profile of the channel in Reach 1 (RM 61.15 to 61.70)

3.1.2 River Morphology and Geomorphic Processes

Geology and Landforms

Reach 1 is located on the eastern edge of a wide glacial U-shaped valley, most recently carved by Quaternary glaciation. Increased discharge and sediment regimes during early Holocene periods of glacial retreat resulted in a thick layer of glacial outwash deposits filling the valley floor. Today, glacial outwash terraces border both sides of the modern alluvial surfaces in this reach. On the east side of the valley, a narrow glacial debris terrace rests on the flanks of the valley wall. This outwash terrace has elevations that get as high as one hundred feet above the modern channel. Thus, it is older than the lower, wider glacial outwash terrace on the west side of the reach. Three small alluvial fans, composed of outwash and upslope talus debris, dress the slopes of the east-side glacial terrace. The Goat Creek Road and its reinforced embankment have been constructed along the east-side terrace approximately 15 feet above the modern channel. On the west side of the valley, a large alluvial fan from a hillslope tributary spreads out across the top of the glacial outwash terrace (visible in Figure 14). The alluvial fan toe is 0.5—0.8 miles from the modern channel and its active surfaces, thus it does not directly influence the geomorphology of the modern channel. However, hydrologic inputs from the fan's tributary influence ground and surface water inputs in the area.

The channel and modern alluvial surfaces in Reach 1 are inset below the glacial outwash terraces. The modern alluvial surfaces of Reach 1 consist of a narrow active floodplain on river-left and a broad active floodplain, disconnected floodplain surfaces, and a high floodplain surface on river-right (Figure 24). All of the floodplain surfaces on river-right are fluvially scarred and the banks are topped with fines from high-flow events. The high floodplain surface at the downstream end of the reach on river-right extends up-valley from the banks of the channel between the active floodplain and the glacial outwash terrace on the western side of the reach. The disconnected floodplains were created by levees and floodplain grading. At the downstream border of the reach are high, riprapped channel banks (approximately 15+ feet) constructed of large, angular boulders (Figure 24).

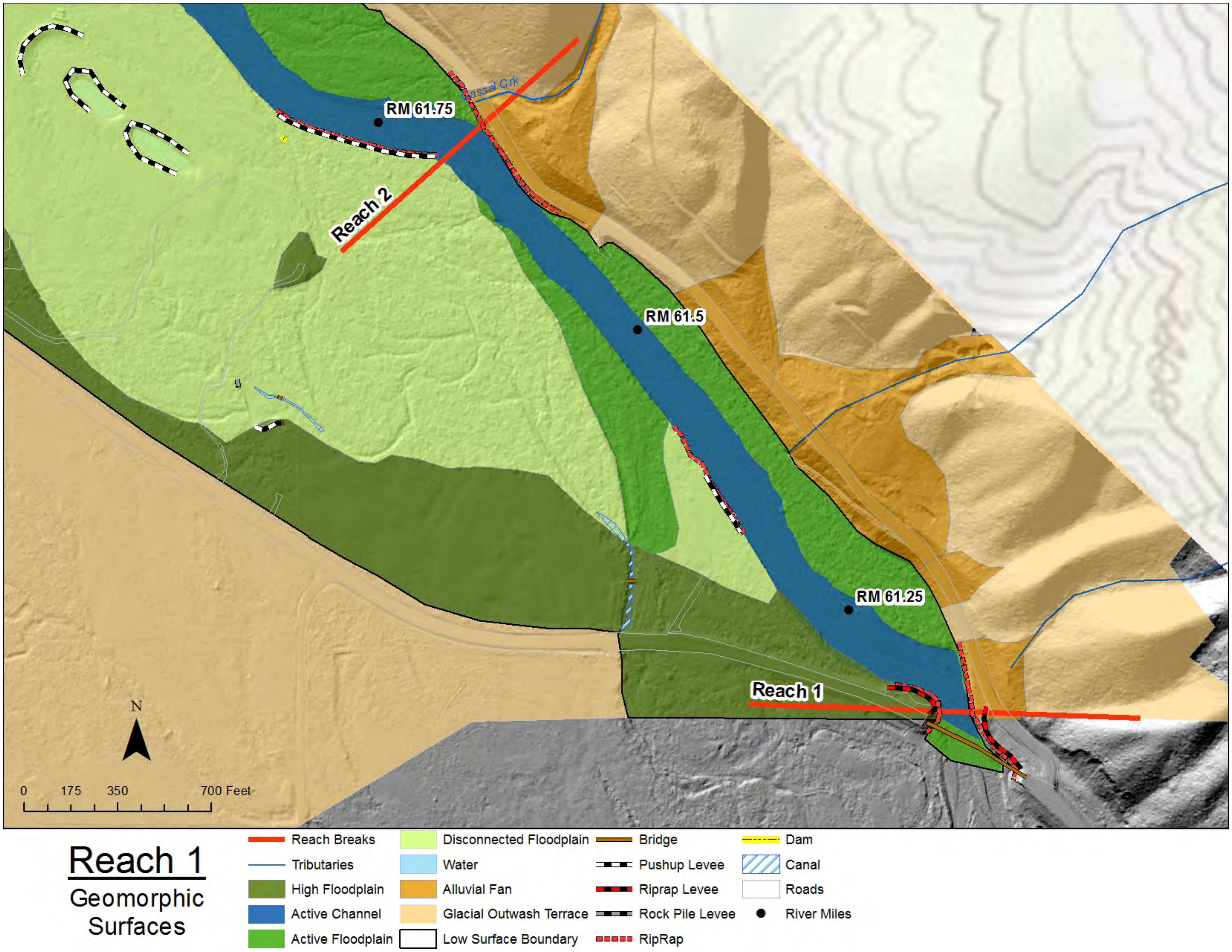

Figure 24. Geomorphic surfaces of Reach 1 overlain by selected human-built features (levees, riprap, check dams, canals, bridges, and roads).

Hydrology

Reach 1 has a seasonally fluctuating flow regime. Spring and early summer snowmelt high-flow events are expected to regularly inundate (2 year flood recurrence) the active floodplain surfaces (Figure 25). Autumn and winter low flows expose bars and banks throughout the channel with surface flows reduced to mere inches above the channel bed at riffle crests. Intense summer precipitation events and thunderstorms in the steep bedrock-dominated headwaters are capable of temporarily increasing channel discharge in Reach 1 if the precipitation event is able to recharge groundwater.

The valley floor is composed primarily of coarse-grained material that supports active hyporheic through-flow and groundwater inputs from upstream and the adjacent terraces, valley walls, and alluvial fans. Hydraulically, the channel in Reach 1 is considered a gaining reach (Konrad 2003, Konrad etal 2005). This means that incoming groundwater feeds the surface flow in the channel. However, reports of portions of the section of the channel seasonally going dry during low precipitation years exist (WDW 1990). It is expected that the channel and floodplain tributaries are actively exchanging surface flow with groundwater through hyporheic processes.

Reach 1 receives seasonal snowmelt or storm event discharge inputs from three tributaries on river-left. According to US Bureau of Reclamation surface flow estimates (2008 – Appendix J), the combined high-flow discharge inputs increase the mainstem flow by less than two percent. The tributaries are Cassal Creek at the upstream border of Reach 1 (RM 61.7) and two unnamed creeks coming off of Grizzly Mountain at RM 61.2 and RM 61.35. The large alluvial fans at the base of Lucky Jim Bluff at the west side of the valley do not directly contribute sediment or surface flow to Reach 1. Instead, irrigation canals along the edge of the fans divert surface flow for agricultural purposes. However, we suspect that the west-side fans and their tributaries do contribute groundwater inputs to the river's overall hydraulic system, but the percentage of flow that these features contribute to the channel throughout the year in Reach 1 is unknown.

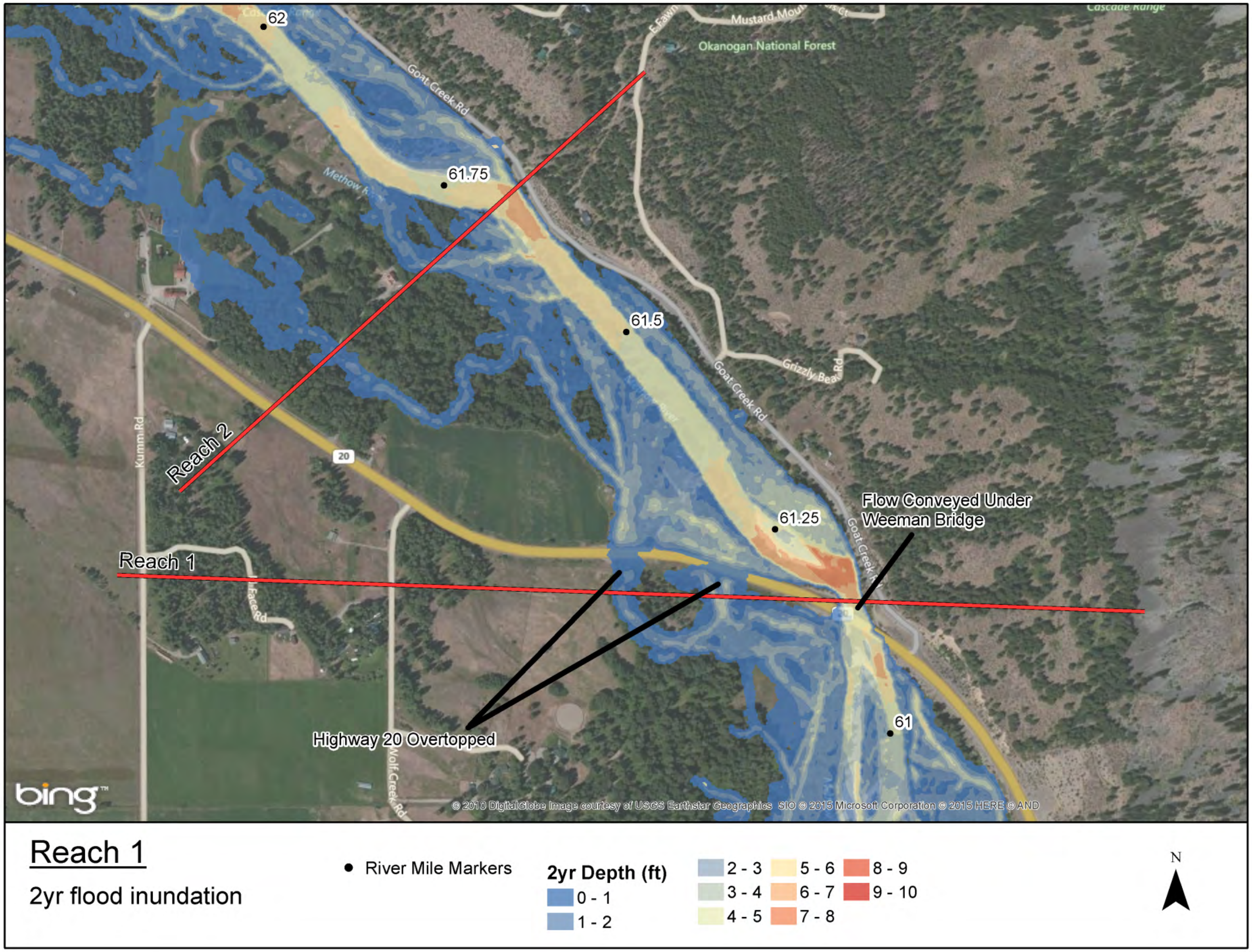

Figure 25. Floodplain inundation for 2YR flood in Reach 1 – developed using a 2D hydraulic model (SRH-2D) built with 2006 LiDAR elevation data.

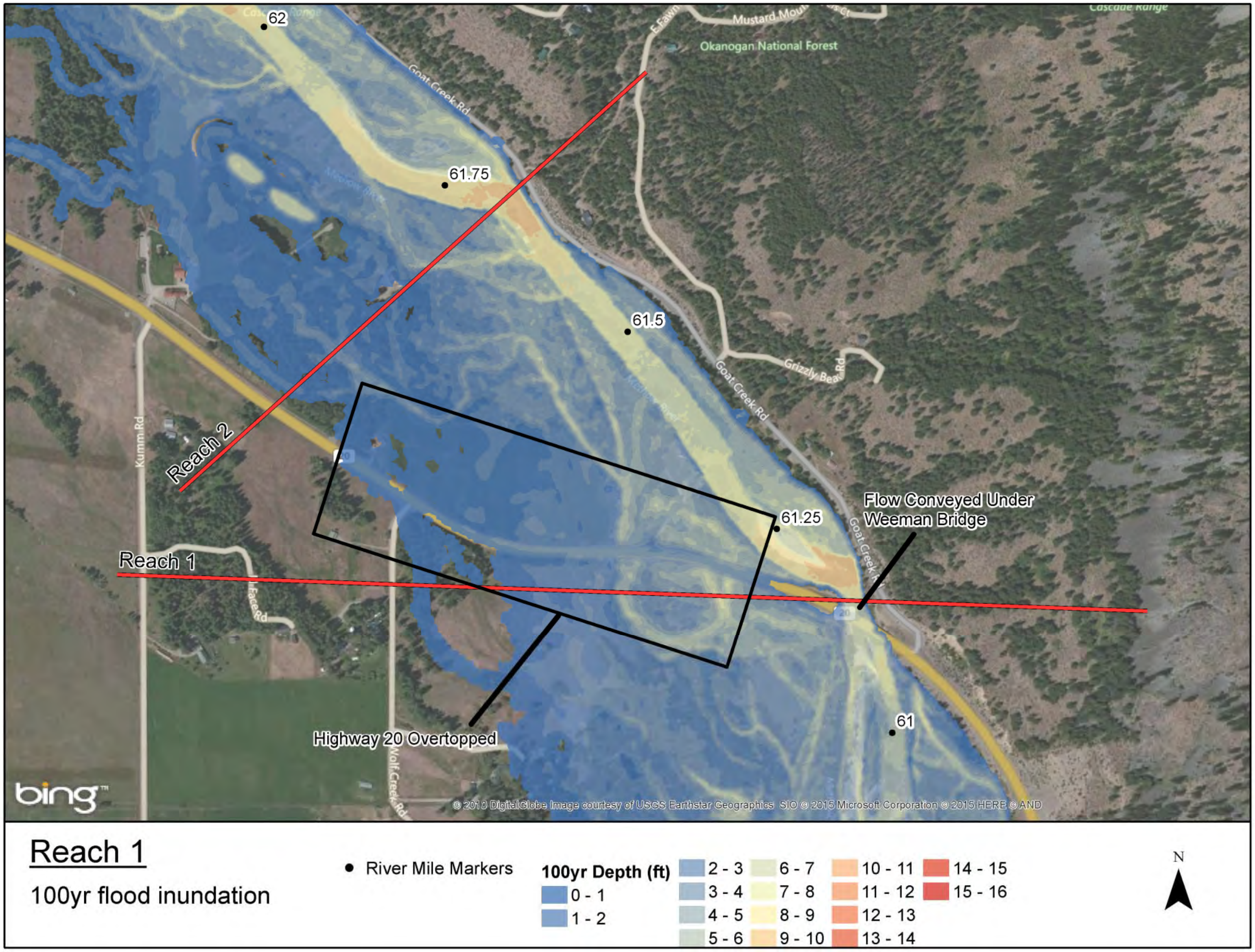

Figure 26. Floodplain inundation for 100YR flood in Reach 1 – developed using a 2D hydraulic model (SRH-2D) built with 2006 LiDAR elevation data.

Floodplain and Channel Migration Zone

Reach 1 is moderately stable vertically and laterally with a semi-confined channel that is relatively straight. Today the active floodplain available for migration is approximately 1,500 feet wide at the upstream end and diminishes to channel-width (115 feet) at the Weeman Bridge at the downstream end. Based on floodplain scarring, the historical migration zone at the downstream end of the reach was reduced by approximately 1,000 feet when Highway 20 and the Weeman Bridge were constructed. Today the channel remains laterally constricted and locked in place at its most downstream point between bridge abutments and high, riprapped banks. Because of its location – on the east side of the valley against glacial outwash terraces and alluvial debris toes that flank the valley walls – the channel is naturally partially confined on river-left. Bank hardening by the Goat Creek Road embankment increases the stability of the terrace banks which further confines Reach 1 on river-left. On river-right, the upper portion of Reach 1 contains an active floodplain with evidence of surface scarring and modern accumulations of over-bank deposits near the banks from RM 61.35 to 61.7. However, a leveed and riprapped bank in the downstream section of Reach 2 (RM 61.7 to 61.8) diverts much of the effective overbank flow during high waters away from the available floodplain on river-right. The other disconnected floodplain in Reach 1 is demarcated at its upstream end by boulder riprap and a low push-up levee at RM 61.35 to 61.4. However, the channel is creating a narrow, modern active floodplain surface on river-left between the channel and the road embankment from RM 61.2 to 61.65. This floodplain surface is developing as the channel gradually migrates westward into the non-riprapped banks of the floodplain on river-right. Historical imagery indicates that the only lateral migration since 1945 in this reach has occurred here and is minor (Figure 27).

Unnatural confinement and straightening of a river often reduces vertical stability by instigating incision processes. In Reach 1, bed scour during high-energy flow periods has likely decreased the frequency of inundation of the high floodplain surface in the downstream section on river-right. Bed lowering through incision likely migrates gradually upstream in this reach. However, pulses of incoming bedload inputs from upstream (Reach 2) partially off-set bed incision enough to support the development of the floodplain surfaces mentioned above on river-left and elongate channel bars visible during low-flow.

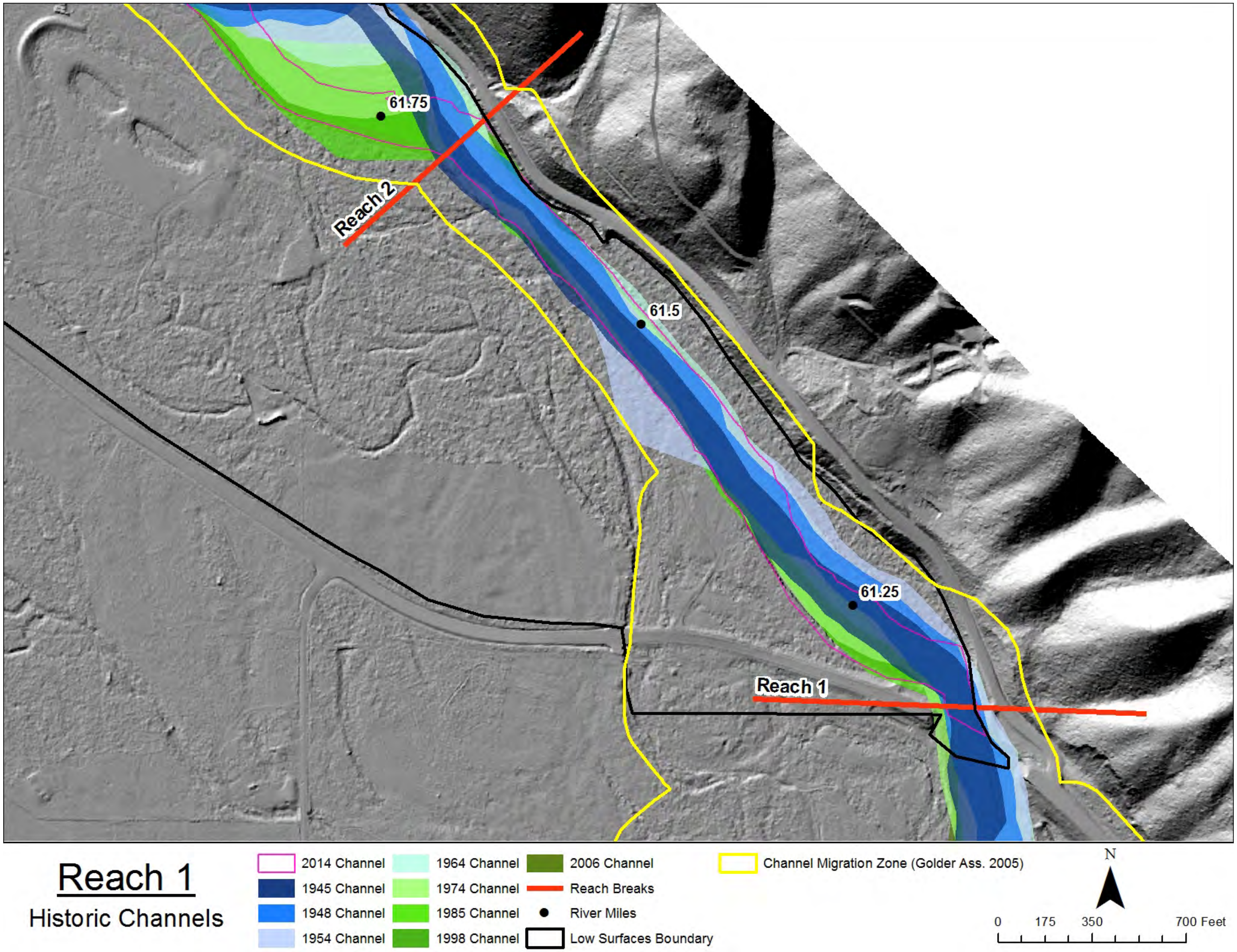

Figure 27. Historical channel locations in Reach 1.

Sediment

The substrate of Reach 1 is dominated by cobbles (52%) and gravels (46%) -- sand represents only 2%. Throughout Reach 1 the modern bedload is delivered from upstream inputs, the channel bed, and some minor bank erosion. Floodplains are composed of cobbles and gravels and topped with sand. Bedload sediment throughout the reach is well sorted (has a relatively similar diameter size range) and rounded, indicating that much of the substrate is transported fluvially during high flow events. Sands and fines accumulate on active floodplain surfaces as overbank deposits. They also are deposited at the downstream end of the channel in the backwater eddy which is located between the bar toe and road embankment on river-left at RM 61.2.

Large Wood

Reach 1 has no log jams and a low large wood count of only 4 pieces in the channel. In-channel wood distribution in the reach is presented in Figure 28 as a density, or the number of wood pieces per 100 feet within each delineated channel unit type. The marginally vegetated riprapped banks throughout the reach provide no potential for large wood recruitment. However, much of the floodplain surfaces are vegetated with maturing trees of up to 50 feet tall; the exception is at the cleared home site on river-right at RM 61.35. Recruitment from floodplain surfaces is limited by stand age and lack of lateral migration. The greatest potential for wood recruitment is along river-right where the channel is gradually migrating westward into the vegetated banks. Limited in-channel wood in Reach 1 may be the product of channel cleaning and/or historical log drives to mill sites located downstream from the Weeman Bridge. Long-term wood recruitment from upstream sources is expected to remain low due to upstream impairments to riparian zones and wood recruitment processes.

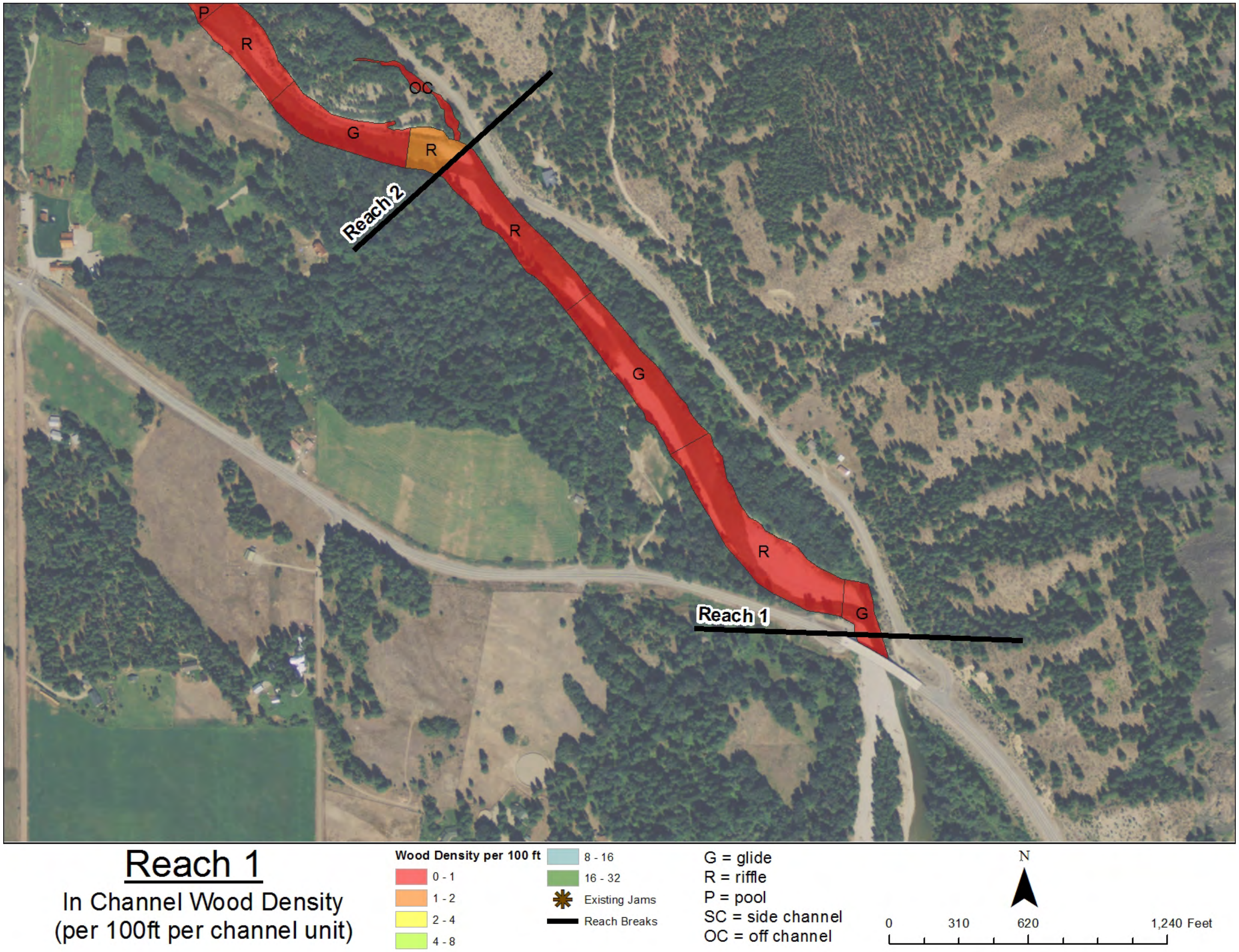

Figure 28. In-channel wood distribution (qualifying wood pieces per 100 ft channel length) within delineated channel units in Reach 1.

Vegetation

The banks of the channel in Reach 1 are vegetated except at riprapped banks and at the cleared residential site at RM 61.35. All floodplain surfaces host maturing forests (contains trees that are 50 years or older) composed primarily of a mix of cottonwood, aspen, fir, pine, and cedar (Figure 29). These surfaces have an understory dominated by grasses and forbs. Along the banks of the channel, mature trees offer shade and nutrients where they have established. However, the width of the channel limits the percent of water surface that receives shade. The presence of sparse tree stumps and the reduced complexity in the understory vegetation suggest that the west side floodplain was thinned or logged and cleared of underbrush within the last 100 years (Figure 30). A few pine trees have established within the other vegetation on the higher alluvial terrace surfaces adjacent to the channel. Sparse patches of willow and dogwood have taken root between the angular boulders near the channel along the riprapped embankments at the road and bridge.

Figure 29. Photo of channel and varied vegetation in Reach 1 – looking upstream from RM 61.2. (9/5/2014)

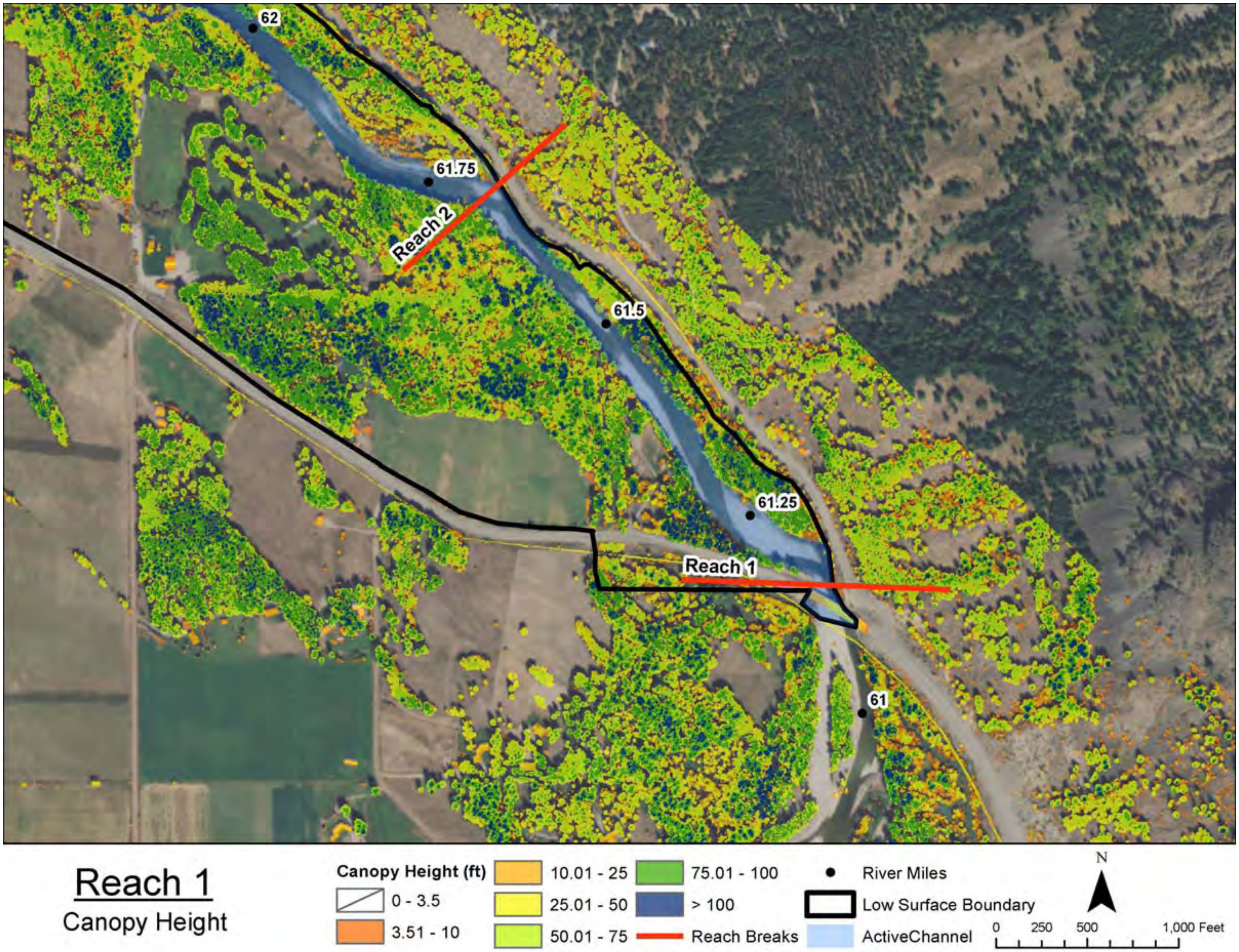

Figure 30. Vegetation canopy height for Reach 1 -- derived from LiDAR first return (highest hit) data (includes buildings and other human infrastructures).

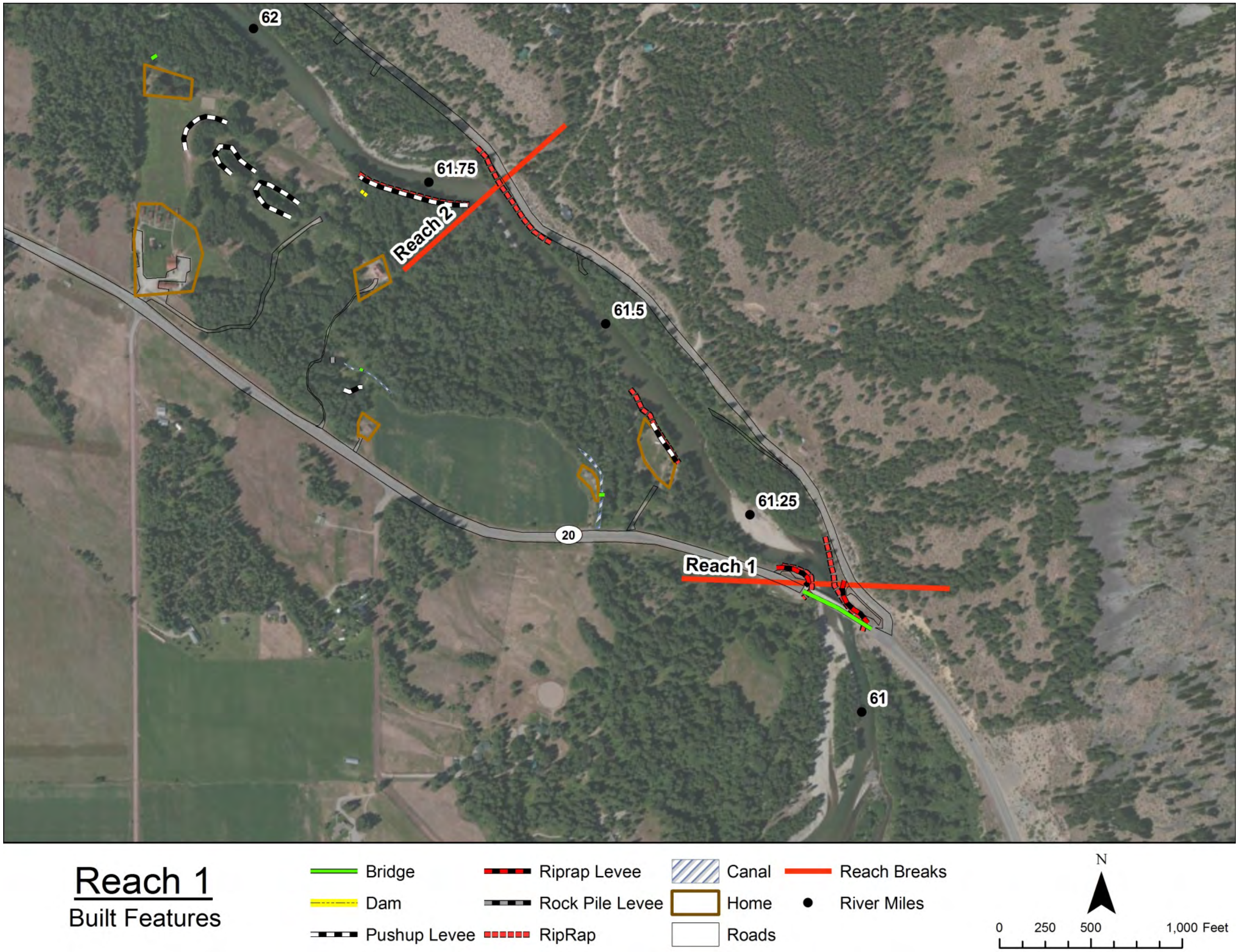

Figure 31. Primary human features in Reach 1.

3.1.3 Human Alterations

Human features are mapped in Figure 31. The primary human alterations in the reach include the following, and are described further in the subsections below.

- Changes to floodplain function and channel migration
- Loss of streambank complexity and riparian impacts
- Loss of instream habitat complexity

Changes to Floodplain Function and Channel Migration

Loss of floodplain function has occurred in the lower portion of Reach 1. The construction of Highway 20 and the Weeman Bridge crossing has resulted in unnatural constriction of the floodplain at the downstream border of the reach. Floodplain scarring and the raised road grade of Highway 20 indicate that approximately 1,000 feet of historical floodplain upstream of the bridge and approximately 2,000 feet of historical floodplain downstream of the bridge has been disconnected. This amounts to approximately 55 acres of disconnected floodplain habitat. These impacts reduce floodplain inundation, induce channel incision, and reduce the formation and long-term availability of off-channel rearing habitats that are created by channel migration processes (e.g. side-channels, alcoves, and oxbow wetlands). The right bank – immediately upstream and at the bridge crossing – has been raised. Large, angular boulder riprap that reinforces both banks was placed to restrict lateral channel migration and to protect the bridge and its abutments (Figure 32). The bridge crossing locks the channel in place along the naturally confining hillslopes on river-left. The bridge's two middle piers interact with channel flow that today results in scour on channel left and bar development on river-right.

From RM 61.35 to 61.4, the floodplain was cleared and graded for a private residence, and a subtle push-up levee and small boulder riprap were installed. Upstream from this private home site, a canal has been dug into a historical floodplain scar in order to divert surface flow off of the floodplain. All of these features combined disconnect the river from the floodplain by reducing the frequency and extent of inundation. In Reach 2 on river-right, from RM 61.7 to 61.8, large boulder riprap topped with a push-up levee holds the channel in place and diverts effective over-bank flow away from the active floodplain surface on river-right in Reach 1. This greatly reduces the capacity of the channel to laterally migrate into the floodplain, and it limits floodplain connectivity processes in the upstream portion of the reach.

Figure 32. Weeman Bridge and the associated riprapped banks at RM 61.15. (9/5/2014)

Loss of Streambank Complexity and Riparian Impacts

Stream bank complexity and riparian vegetation in Reach 1 have been reduced along riprapped banks. The high (approximately 15+ feet) riprapped banks at the Weeman Bridge and at channel-contact points along the Goat Creek Road embankment inhibit toe erosion and natural hillslope inputs, thus altering localized sediment contributions to the system. The riprap also reduces the complexity of the riparian vegetation community and notably decreases the potential for the establishment of mature stands of trees. Additionally, this reduces localized shade to the channel and removes the potential for large wood recruitment in these areas. At the private residence (RM 61.35 to 61.4), clearing and grading near the channel bank further reduces riparian vegetation communities and the benefits that they contribute to channel function.

Loss of Instream Habitat Complexity

The combination of human alterations described above has resulted in limited habitat complexity in Reach 1. Except for the forced meander in the channel at RM 62 immediately upstream from the bridge, the channel is basically straight with extended riffles and glides that have only minor bed variation. Records indicate that log drives utilized the mainstem channel here to transport cut timber to the Fender Mill located immediately downstream from the Weeman Bridge, as well as other mills downstream of the study area (Devin 1997, USBR 2008 – Appendix O). The Fender Mill was in operation until the 1930's. In-channel log transport requires clearing the channel of natural log jams and any other obstructions (large boulders, etc.). Additional clearing of large wood may have also occurred upstream of the Weeman Bridge following the large floods of 1948 and 1972, in an effort to protect bridges and other infrastructure. However, specific locations of these activities are not recorded. The expected impacts of log drives and/or "cleaning" a channel include bed scour, channel and bank simplification, and a reduction in habitat complexity (Nilsson etal. 2005, Wohl 2006, Miller 2010). Development of instream habitat complexity will be a slow process in this reach without the application of in-stream restoration, due to the riprap and levee features that minimize lateral migration and floodplain connectivity.

3.1.4 Recommended Actions

Recommended actions in Reach 1 are focused primarily on increasing mainstem channel complexity as well as mitigating for the impacts of bank armoring and the effects of the Weeman Bridge and Highway 20 road fill on floodplain connectivity and off-channel habitat. Main channel complexity can be addressed by adding log jams to mid-channel locations at the upstream end of the reach to encourage split flow conditions, and adding large wood to channel margins to enhance complexity along existing bank protection features (i.e. riprap that is currently protecting infrastructure). Channel margin jams are suggested along river-right upstream from the Weeman Bridge to reduce the need for additional bank hardening measures for bridge protection. Restoration objectives also include addressing, or at least mitigating for, the floodplain disconnection associated with the Weeman Bridge and the associated Highway 20 road fill. This may include measures to enhance flood flow through the road prism (e.g. adding culverts or bridges) and/or off-channel habitat enhancement in the river-right floodplain upstream and downstream of the crossing to create floodplain rearing habitat that does not exist due to floodplain disconnection.

Based on the available data, this reach rarely experiences subsurface flow conditions (see Section 2.6.3). There is also little opportunity within the reach for projects that would help to mitigate for the effects of subsurface conditions. For these reasons, recommended actions within the reach do not include mitigating for the effects of subsurface flow.

See Section 4 of this report for the restoration strategy and specific project recommendations for the reach.

3.2 REACH 2

Refer to Section 2.2 and 2.8 for geologic and geomorphic context of the study area and explanation of terminology.

3.2.1 Reach Overview

Reach 2 is 3.1 miles long and extends from RM 61.70, at its confluence with Cassal Creek, to RM 64.80, at its confluence with Goat Creek. Property in Reach 2 is owned by the Methow Salmon Recovery Foundation, the Edelweiss Maintenance Commission, the Washington Department of Fish and Wildlife, the Okanogan National Forest, and private landowners (Figure 33). The upper portion of the channel is a riffle-glide stream from RM 63 to 64.8. Channel complexity increases slightly in the downstream portion from RM 61.7 to 63, where there is increased bar development and stream type shifts to riffle-glide-pool (Figure 34 and Figure 35). The river in this reach is primarily a single-thread channel with relatively low sinuosity (1.1) and gradient (0.5%). The channel substrate is composed primarily of coarse gravels to cobbles. These and other reach metrics are provided in Table 8 and Figure 36.

The reach is semi-confined due to natural confining banks as well as human alterations along sections of the channel. The natural confining banks include glacial outwash terraces and alluvial fan toes. The modern floodplain occupies one half to one third of the valley floor, and has an average width of 1,193 feet. Floodplain scarring and deposition patterns indicate that high-flow events activate or contribute to side-channels and secondary channels in locations where human features have not altered floodplain inundation processes.

The habitat conditions in Reach 2 are discussed in Appendix A. Based on the REI analysis, 9 of 11 habitat indices are rated as either unacceptable or at risk (see Table 6). A salmon and steelhead redd distribution map for the reach is provided in Figure 33. Although sections of the floodplain and channel banks have been cleared or thinned of vegetation, over seventy-five percent of the channel banks are vegetated with maturing forests. Where they exist, these forests do provide some wood to the system and add roughness to the banks and floodplain surfaces. Natural hydrologic and geomorphic processes have been compromised due to human alterations. Riprap and levees disconnect the floodplain and off-channel features from the mainstem channel and confine lateral migration in sections of the reach. Vegetation clearing and thinning has reduced floodplain and riparian processes. Historical logging practices at the turn of the century utilized the river to transport cut logs to a mill site in the middle of the reach. This has likely influenced channel geomorphology over the last century.

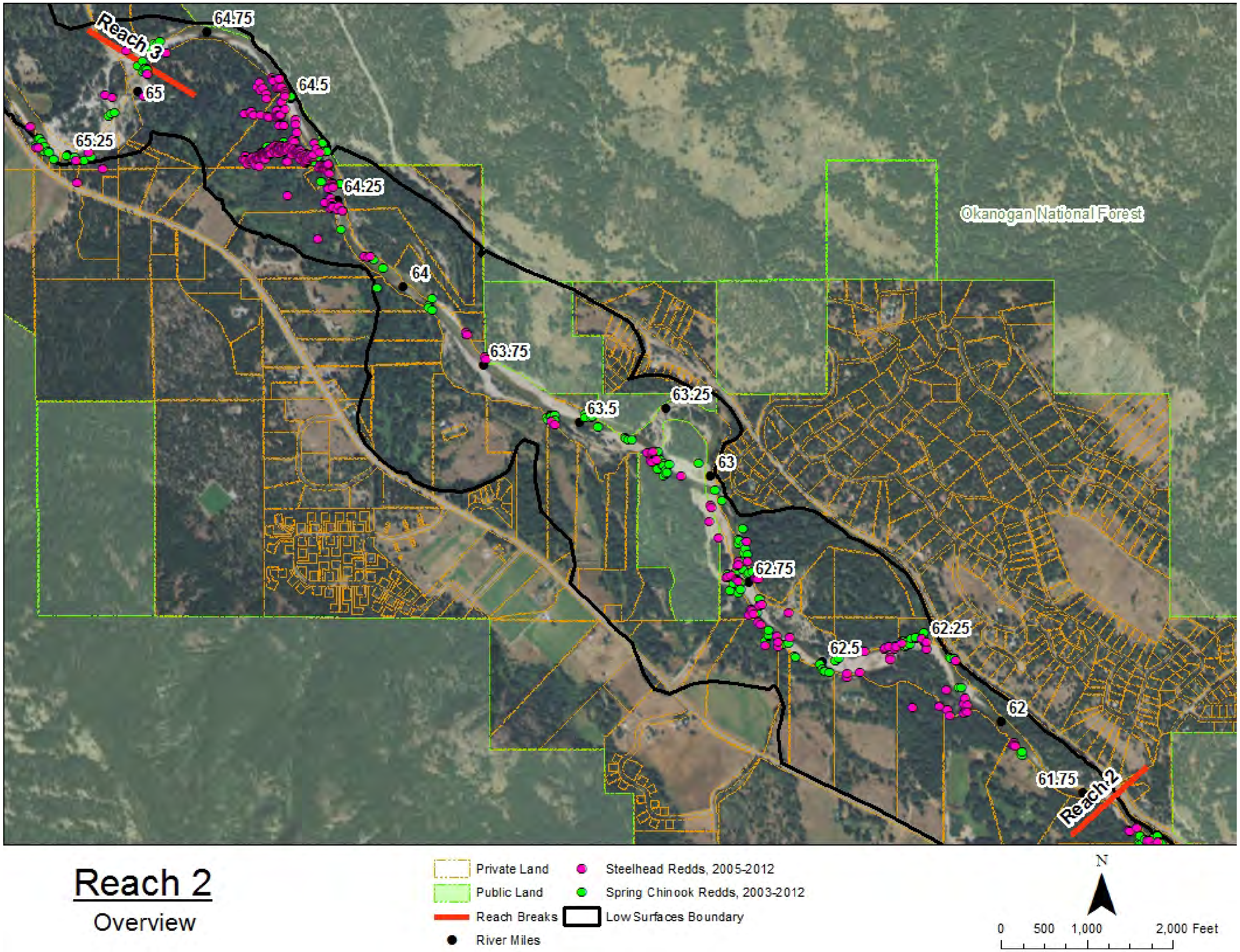

Figure 33. Reach 2 overview map with landownership and redd distribution.

Figure 34. Representative photo of upper section of Reach 2; looking downstream from RM 64.3. (8/31/2014)

Figure 35. Representative photo of lower section of Reach 2; looking downstream from RM 63.5. (9/4/2014)

Table 8. Reach 2 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	3.1
River Miles	61.70 – 64.80
Valley Gradient	0.5%
Stream Gradient	0.5%
Sinuosity	1.1
Dominant Channel Type	Riffle-glide
Average Bankfull Width (feet)	141
Average Floodplain Width (feet)	1193
Dominant Substrate	cobble (51%); gravel (49%)
Bank Stability/Channel Migration	Unacceptable *(See Section 2.12)*
Vertical Channel Stability	At Risk *(See Section 2.12)*
Confinement ratio	Unconfined *(See Table 5)*

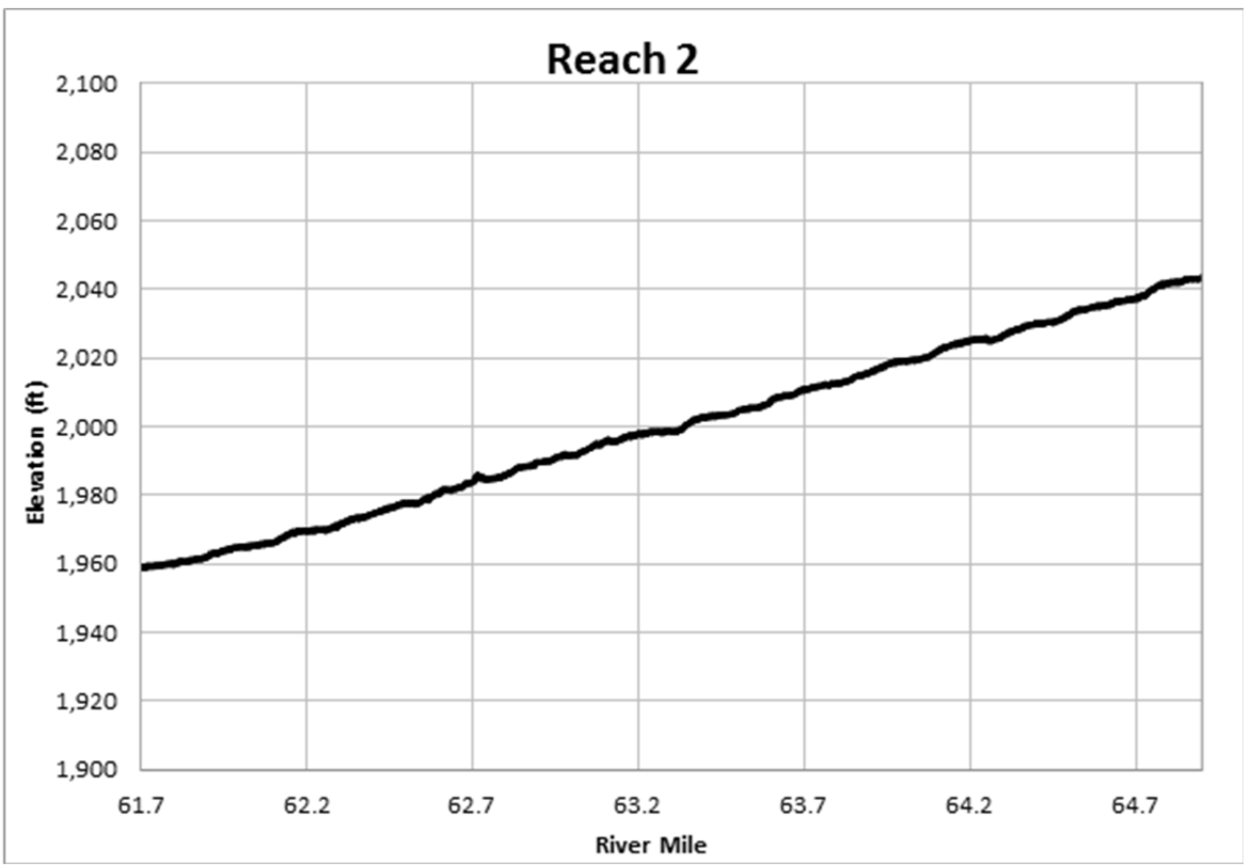

Figure 36. Longitudinal profile of the channel in Reach 2 (RM 61.15 to 61.70).

3.2.2 River Morphology and Geomorphic Processes

Geology and Landforms

Reach 2 is located on the eastern side of a wide U-shaped valley most recently carved by Quaternary glaciation. Increased discharge regimes during early Holocene glacial retreat resulted in the valley floor infilling with a thick layer of glacial outwash deposits. Today, a higher and older glacial deposit terrace is located on the flanks of the hillslopes on the east-side of the valley. A wide, lower, younger glacial outwash terrace borders the west side. The modern channel and floodplain of Reach 2 are inset between and below the glacial deposit terraces. The average width of the reach is 1,193 feet and the average width of the modern active channel through the reach is 141 feet (see Figure 37).

Large alluvial fans from Little Boulder Creek and Goat Creek (both glacially-carved) influence the location of the channel at the upstream end of the reach by restricting its pathway between the toes of the two fans. These fan deposits stretch across the valley from opposite sides. Goat Creek continues to contribute sediment and discharge to the reach. The Little Boulder Creek confluence is located in Reach 3, but its fan deposits and subsurface groundwater inputs influence the upper portion of Reach 2. The alluvial fan of Fawn Creek, which is in the middle of Reach 2 on river-left (the east side of the channel), also contributes sediment and discharge to the channel. The reinforced embankment of Goat Creek Road is constructed along and into the terrace and fan deposits on the east side of the valley above the modern channel. Steep, glacially-carved bedrock walls bordering the valley create talus and additional small debris fan deposits along the edges of the valley floor; however, these deposits currently do not contribute direct inputs to the channel in Reach 2.

The channel in Reach 2 has a relatively low overall sinuosity (1.1) that changes in relation to channel complexity. From RM 61.7 to 62, and RM 63 to 64.7, the channel is less sinuous and has elongate side-channel bars. Bar size and distribution – including mid-channel bars – increases in the middle section from RM 62 to 63.8, as does sinuosity at and downstream from the Fawn Creek alluvial fan. From RM 64.7 to 64.8, channel sinuosity and complexity also increase along the toe of the Goat Creek alluvial fan. Local contributions of sediment and large wood are generated from Goat Creek and by the channel migration cut-offs that occurred on river-left at RM 62.5, RM 63.25, and RM 64 in the last twenty years.

The floodplains in Reach 2 are composed of cobbles and gravels and then topped with sands where overbank deposition has occurred. The active floodplains contain scour and fill features composed of cobbles and gravels, as well as overflow channels activated during high-flow events. Groundwater-fed tributaries and abandoned channel scars add complexity and riparian features to the floodplain. Reach 2 contains the highest number of connected side-channel and backwater features in the study area. In addition, there are two small dug ponds on river-right (at RM 61.85) that are disconnected from overbank inundation by constructed levees.

High floodplain surfaces are composed of cobbles and gravels and then topped with two or more feet of sands and developing soil. The high floodplain surfaces bordering the active surfaces of the reach are disconnected from regular inundation processes by incision, floodplain grading, and the construction of levees.

A set of large levees is located in Reach 2 on river-right from RM 63.25 to 63.7. The levees vary in elevation from three to twelve feet high. They are composed of large, angular, boulder riprap and topped with gravels and sand to accommodate a single-track road that is currently designated as a community trail. These levees run parallel to the river for approximately 650 yards. They confine the channel on river-right and disconnect floodplain and side-channels located behind them.

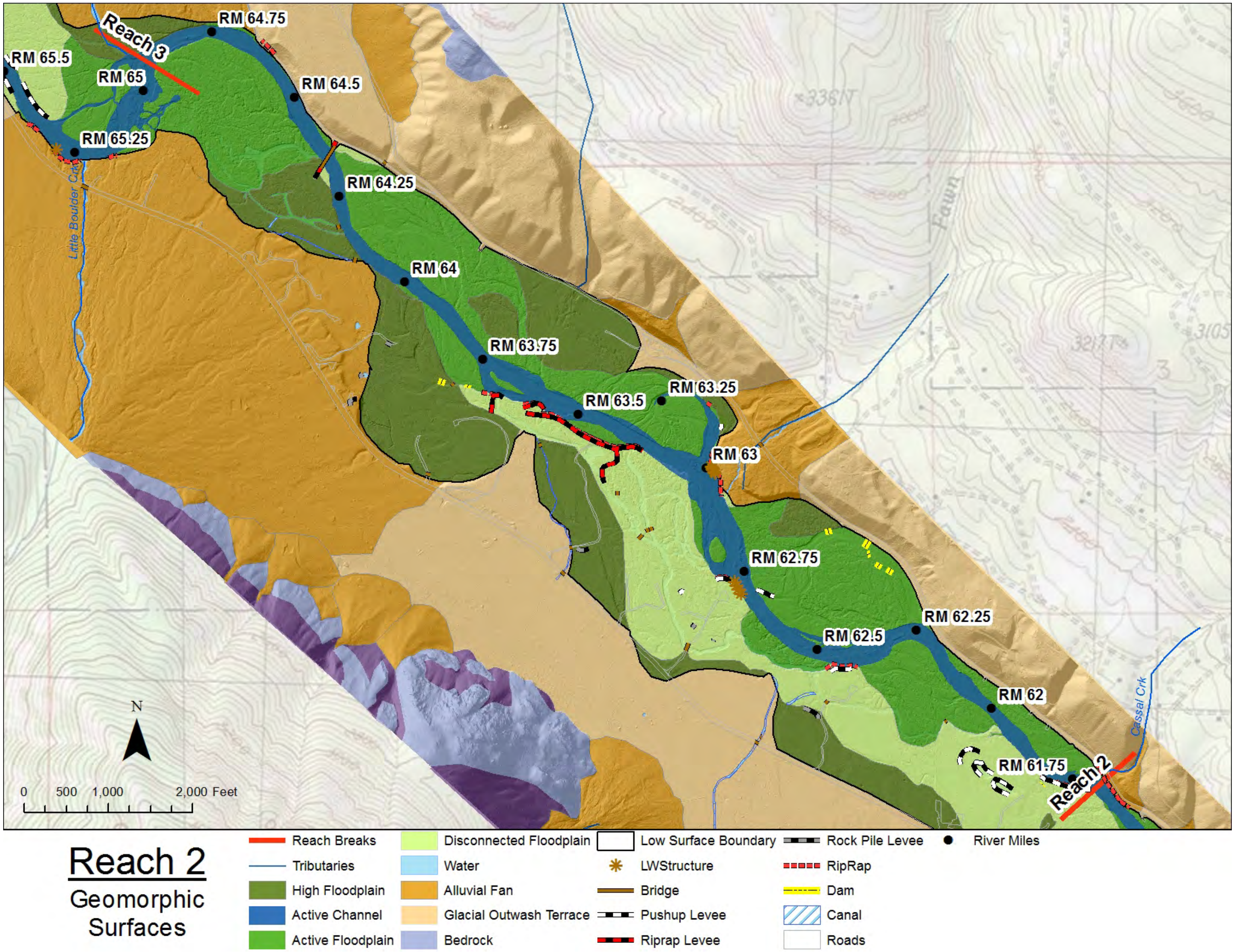

Figure 37. Geomorphic surfaces in Reach 2 with selected human-built features (levees, riprap, check dams, canals, bridges, and roads).

Hydrology

Reach 2 has a seasonally varied flow regime. Based on overbank deposits viewed in the field, spring and early summer high-flow events are expected to regularly inundate low floodplain surfaces and activate overflow channels every two to ten years (Figure 38). Late summer and autumn low flows expose bars, banks and sometimes portions of the bed throughout the reach – depending on the annual hydrograph. During the low-flow season, surface flow is often reduced to mere inches above the channel bed at riffles. Summer thunderstorms are capable of temporarily raising surface water elevations in Reach 2 if the precipitation event is significant enough to recharge the groundwater.

The valley floor is composed primarily of coarse-grained material that supports active hyporheic through-flow and groundwater inputs from upstream and the adjacent terraces, valley walls, and alluvial fans. Hydraulically, the channel in Reach 2 is considered a gaining reach (Konrad 2003, Konrad et.al 2005). This means that incoming groundwater feeds the surface flow in the channel. However, reports of portions of this section of the channel seasonally going dry in late summer and autumn during low precipitation years do exist (WDW 1990). See Section 2.6 of this report for a description of the groundwater to surface water interchange here. It is expected that the channel and floodplain tributaries are actively exchanging surface flow with groundwater through hyporheic processes.

Reach 2 receives discharge from Goat and Fawn Creeks. According to the US Bureau of Reclamation flow estimates (2008 – Appendix J), the upstream boundary of the reach receives an estimated 5% increase in surface water discharge from Goat Creek and an approximate 1% increase from Fawn Creek during high flow events. Additional subsurface contributions through the alluvial fan of Little Boulder Creek feed groundwater-activated tributaries on the floodplain in the upper portion of Reach 2. Five small, snowmelt- or precipitation-activated tributaries flow off the steep valley walls, and these contribute minor seasonal discharge. Three of these tributaries are located on river-right and have alluvial fans with irrigation canals along their fan toes. These canals divert flow for agricultural purposes and floodplain drainage. In Reach 2, the combined seasonal tributary inputs contribute an estimated 0.6% discharge to the channel during high flow events.

Groundwater-activated floodplain tributaries are important hydrologic features in Reach 2. These tributaries are fed by groundwater inputs generated upstream and from the adjacent terraces and alluvial fans. In Reach 2, these floodplain tributaries maintain off-channel riparian environments, transport sediment into the channel, and sometimes act as high-flow conduits or low points for flood-event avulsions. Many of these features are located in abandoned channel scars that have been maintained and altered by modern tributary discharge. Most of the groundwater-activated tributaries provide year-round surface water inputs and desirable off-channel aquatic habitat to the reach (Figure 40). Overflow from the mainstem causes periodic inundation and scouring, which can flush out fines and the occasional abandoned beaver dam. This appears to aid in the maintenance and complexity of these floodplain tributaries. In the groundwater fed tributaries of Reach 2 – where levees have not disconnected upstream surface-flow inputs – this sequence of fluvial processes creates salmon spawning and rearing habitat.

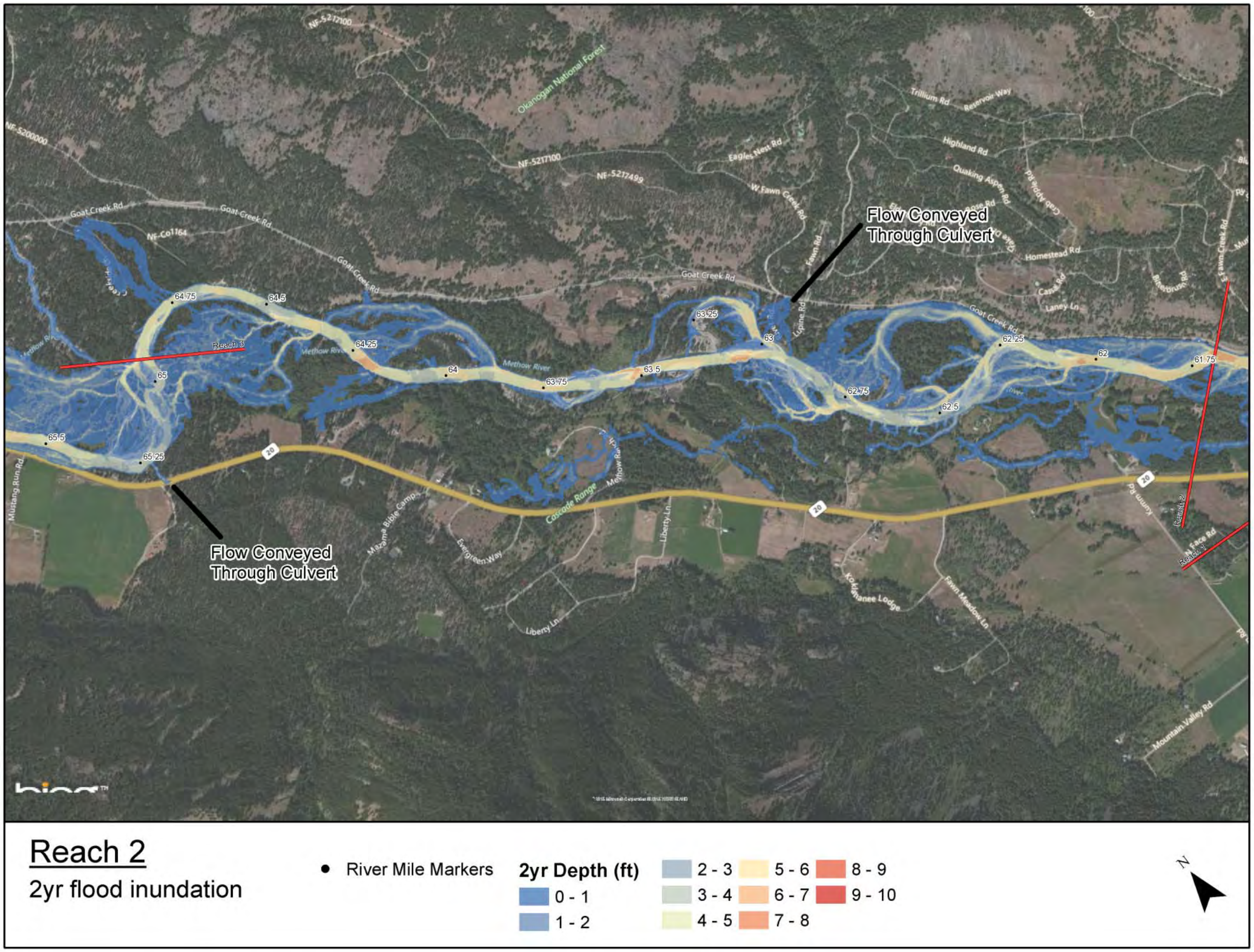

Figure 38. Floodplain inundation for 2YR flood in Reach 2 – developed using a 2D hydraulic model (SRH-2D) built with 2006 LiDAR elevation data.

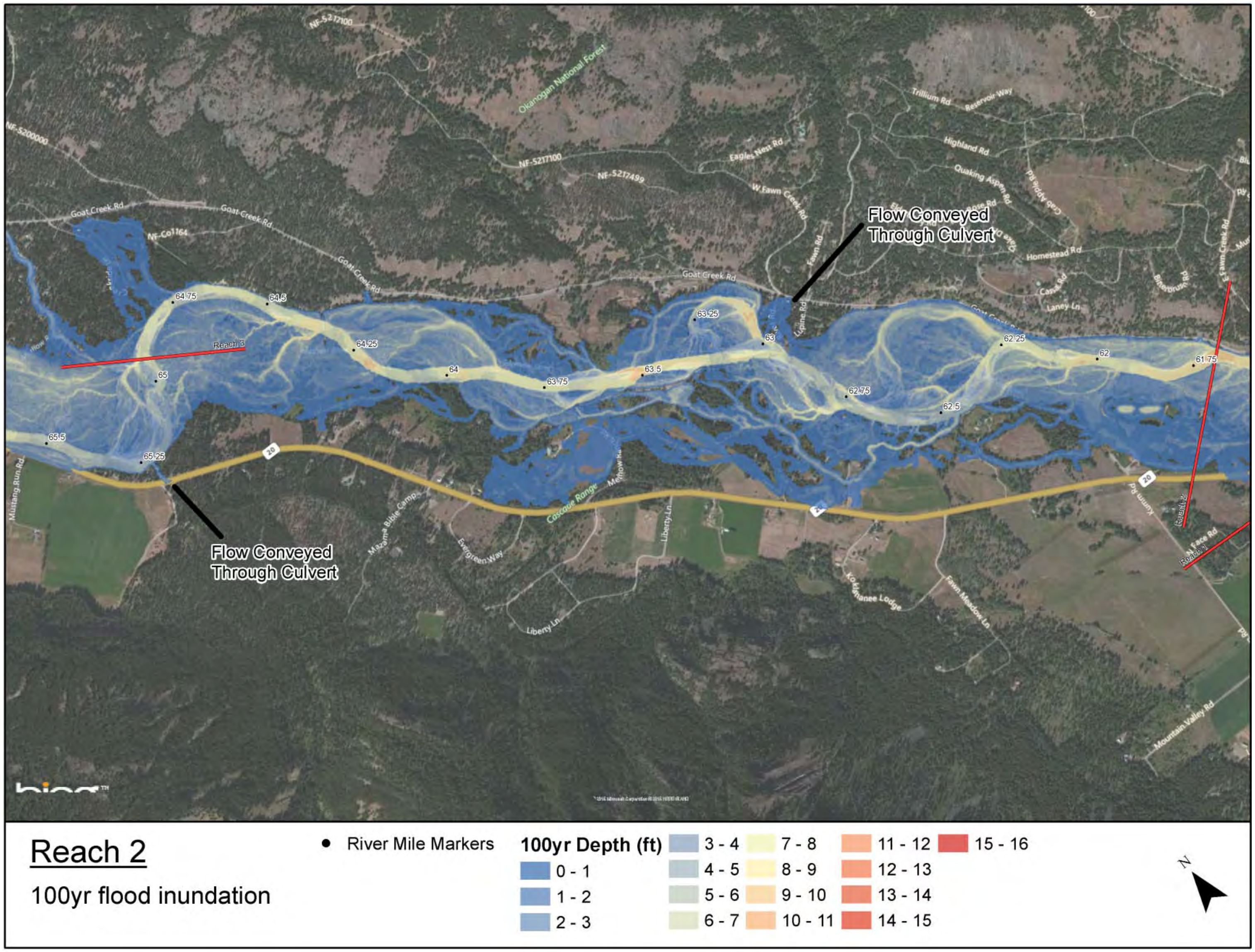

Figure 39. Floodplain inundation for 100YR flood in Reach 2 – developed using a 2D hydraulic model (SRH-2D) built with 2006 LiDAR elevation data.

Figure 40. Groundwater-fed tributary (Suspension Creek) on river-right floodplain at RM 64.35; inset photo of salmon spawning in this tributary. (9/3/2014)

Floodplain and Channel Migration Zone

Reach 2 is moderately stable both vertically and laterally. At the upstream end of the reach, the large alluvial fan features of Goat Creek and Little Boulder Creek influence the location and width of the reach on the eastern side of the valley floor. Riprap and levees at the downstream end maintain the location of the channel's pathway against the eastern edge of the valley and floodplain. The channel and its floodplain occupy approximately half of the valley floor with an average width of 1,193 feet. The surface of the active floodplain contains plentiful channel migration scars (scrolls and abandoned channel features) and overbank inundation features (scour and deposition). These indicate regular floodplain connectivity and channel migration patterns. However, in portions of the reach, recently constructed anthropogenic features (such as levees and riprapped banks) have disconnected sections of the floodplain and reduced the channel's capacity to migrate. Lateral migration is most restricted by riprapped banks and levees located on river-right from RM 63.25 to 63.7.

High glacial terraces and alluvial fan deposits also naturally confine lateral migration and thus influence the width of the migration zone. These features impose partial lateral confinement. The terrace banks are erodible, but the high slopes and presence of coarse boulder material are usually more difficult and slower to erode than the low-lying modern floodplain (Figure 41). Today, the mainstem channel has high cut-banks along glacial terraces on river-left from RM 62.2 to 62.25 and from RM 64.45 to 64.65. Cut-banks composed of alluvial fans contact the channel on river-right at Little Boulder Creek (RM 64.15) and on river-left at Fawn Creek (RM 62.9 to 63.1). The high bank at the Fawn Creek alluvial fan is riprapped with large, angular boulders and large constructed wood vanes; these features armor the bank and now unnaturally confine the channel here. The bank protection constructed along the Fawn Creek alluvial fan at RM 63 was constructed after a high-flow event in 2002 eroded the high bank and a private home was lost (State of Washington 2010).

Figure 41. Cut bank of glacial outwash terrace on river-left at RM 64.55. Old road grade cut into the bank with cement retaining wall for preserving community trail access. (9/3/2014)

Vertical stability of Reach 2 is considered moderate, but at risk of continued channel incision. The high floodplain surfaces in Reach 2 exist because of both natural- and human-influenced incision processes. Sections of the channel are experiencing bed incision that is likely due to the levees and riprap that constrict lateral migration. Floodplain scarring and historical channel pathways visible in aerial imagery collected between 1945 to 2012 show that three meander bends on river-left – at RM 62.5, RM 63.25, and RM 64 – have been cut off. This resulted in decreased channel length and sinuosity, which leads to an increase in channel gradient caused by bed incision (Figure 42). Additional disconnection of sections of the floodplain has occurred due to surface grading and levees. Combined, these elements will continue to simplify the channel and available habitat in Reach 2.

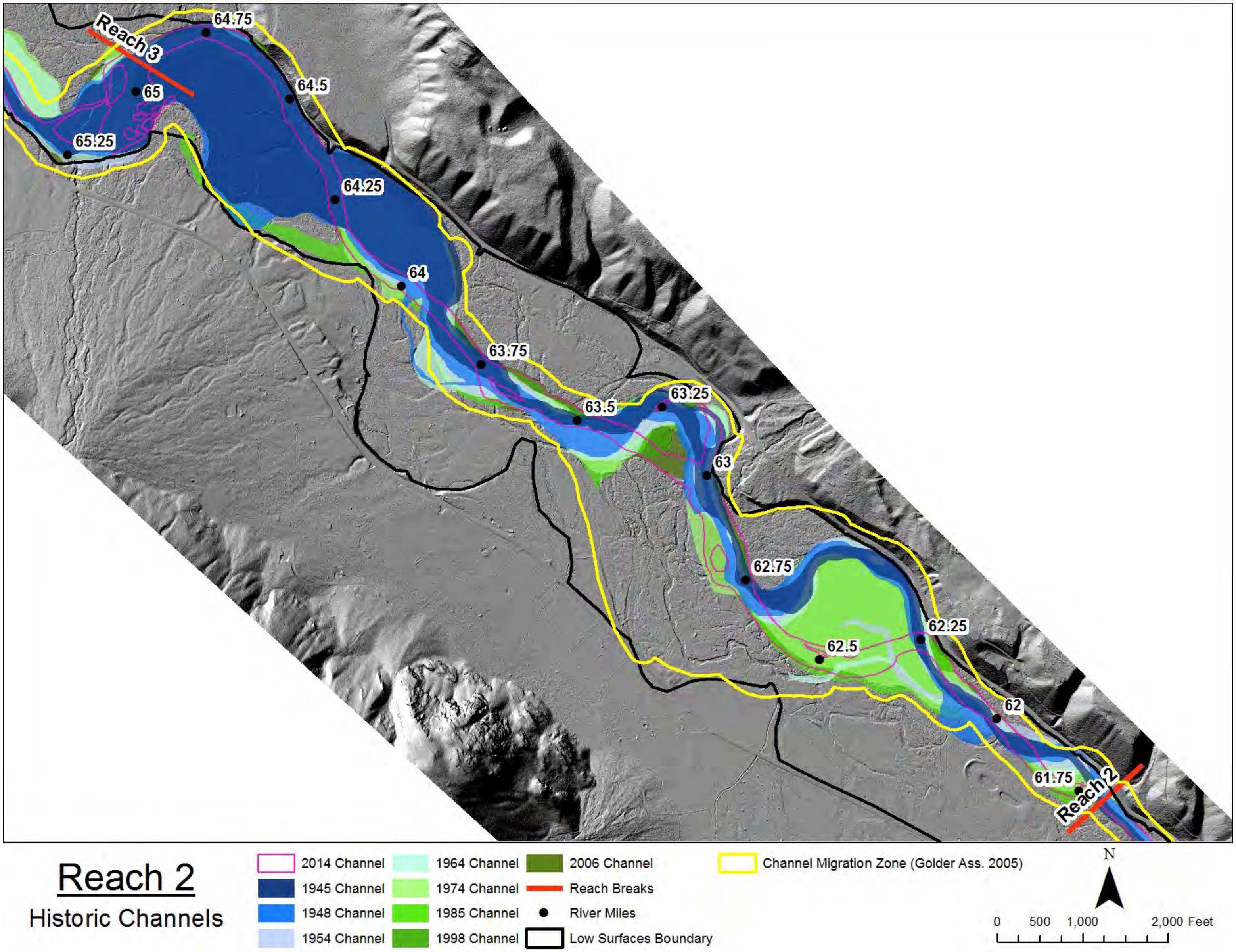

Figure 42. Historical channel locations in Reach 2.

Sediment

The substrate of Reach 2 is dominated by cobbles (48%) and gravels (48%), and has minor sand (2%) and boulders (2%). Sand is found in overbank deposits, backwater features, and eddies. Large boulders in the channel, from RM 64.5 to 64.6, are sourced directly from the steep slope of the glacial outwash terrace on river-left (see Figure 37). Groundwater tributaries that initiate on the floodplains also contribute sediment to the channel, but these inputs are usually gravels, sands and fines. The floodplains are composed of cobbles and gravels, and topped with sands. Goat Creek, Fawn Creek, and their alluvial fans all contribute additional sediment to the system. Inputs include fines and sands as well as bedload materials of small boulders, cobbles and gravels. Bedload sediment throughout the reach is fairly well sorted (has a relatively similar diameter size range) and rounded, indicating that much of the substrate is transported fluvially during high flow events.

Large Wood

Reach 2 has a relatively high in-channel large wood count. A total of 10 log jams and 398 logs (equivalent to 126 logs per mile) were counted. In-channel wood distribution in the reach is presented in Figure 43 as a density, or the number of wood pieces per 100 feet within each delineated channel unit type. The largest accumulations and jams occur where bar development is greatest – from RM 62 to 63.25 and from RM 64.8 to 64.8. The meander cut-offs that occurred in the last twenty years between RM 62.25 and RM 63.5 likely provided plentiful large wood to the reach. Today, large wood recruitment is minimal at riprapped and leveed banks or where vegetation clearing has occurred. Partial and full clearing of large trees has occurred next to the channel on private lands, near utility-pole crossings, and at foot-bridges. These occur at RM 61.85 (river-right), RM 62.65 (river-right), RM 62.75 (river-right), RM 63.6 (river-right and river-left), RM 64.35 (river-right), and RM 64.8 (river-left). The remainder of the floodplain surfaces are vegetated with both small and mature trees that provide some wood to the system (Figure 44). The width of the channel (average bankfull width is 141 feet) is too great for channel-spanning accumulations of large wood to develop in the mainstem in this reach. Instead, large jams accumulate within the active channel boundaries. The jams increase channel complexity by promoting bar development and scour pools. Where stands exist along the off-channel features, large wood contributes nutrients, shade, and complexity. The off-channel features are narrow enough that mature large wood can span the feature.

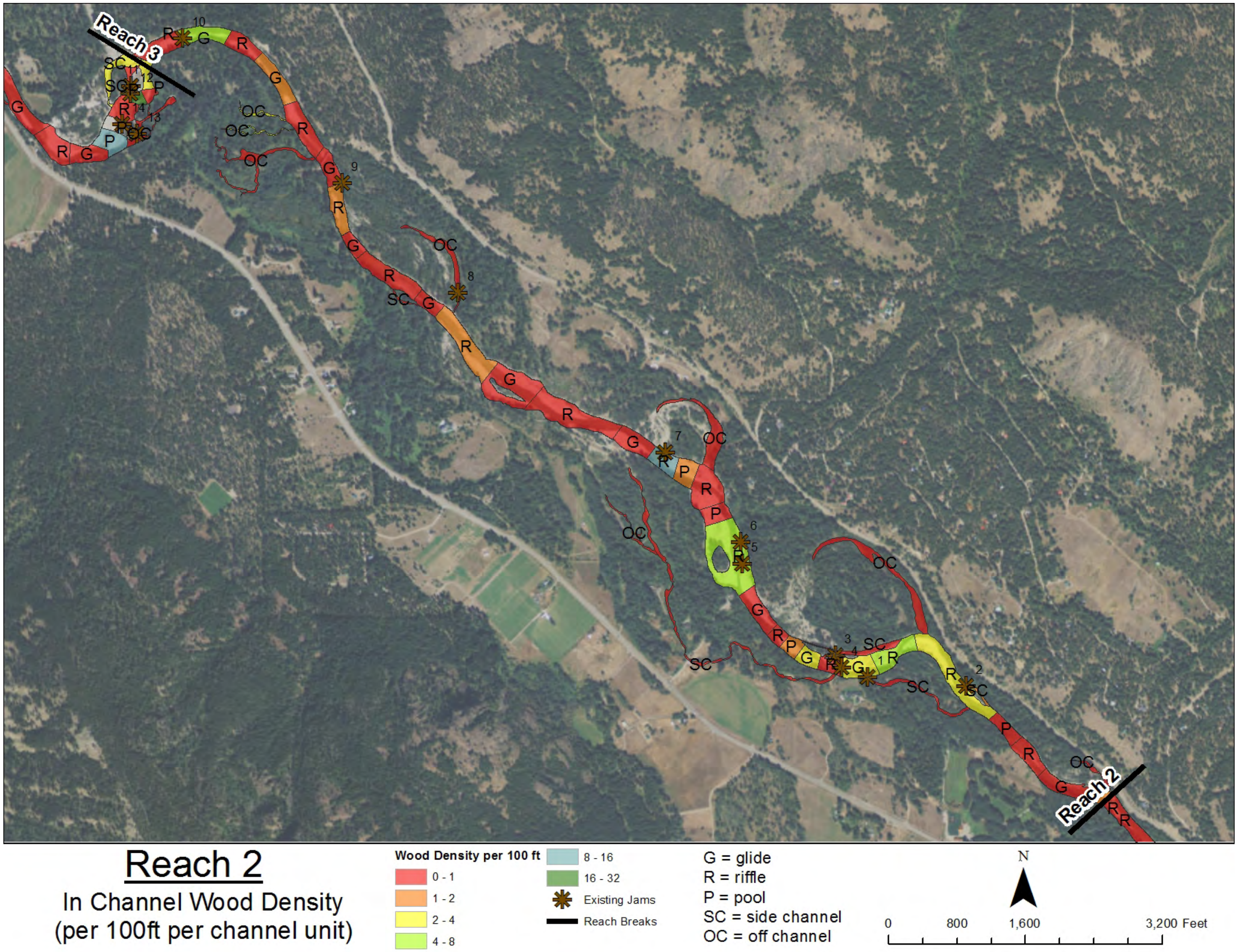

Figure 43. In-channel wood distribution (qualifying wood pieces per 100 ft channel length) within delineated channel units in Reach 2.

Vegetation

The banks of the channel in Reach 2 are relatively well vegetated except at the cleared locations listed above and where riprap and levees exist. Sparse vegetation occurs on the steep glacial terrace slope on river-left from RM 64.4 to 64.65. The vegetated banks throughout the reach contain forests composed primarily of a mix of cottonwood, aspen, fir, pine, and cedar. Recently abandoned surfaces – such as high bars or scour and fill features – have establishing communities of cottonwood, dogwood, fir, and aspen. The age of the establishing tree stands on these features aids in identifying the history of flooding and channel pathway changes in the reach. The understory on the undeveloped floodplain surfaces is dense and includes grasses, forbs, dogwood, maple, and snowberry. The cleared or partially-cleared banks have a less complex understory dominated by grasses and forbs. Along the riprapped banks, small patches of willow and dogwood have taken root in a few of the spaces between the angular boulders near the channel. See Figure 44 for a vegetation canopy height map.

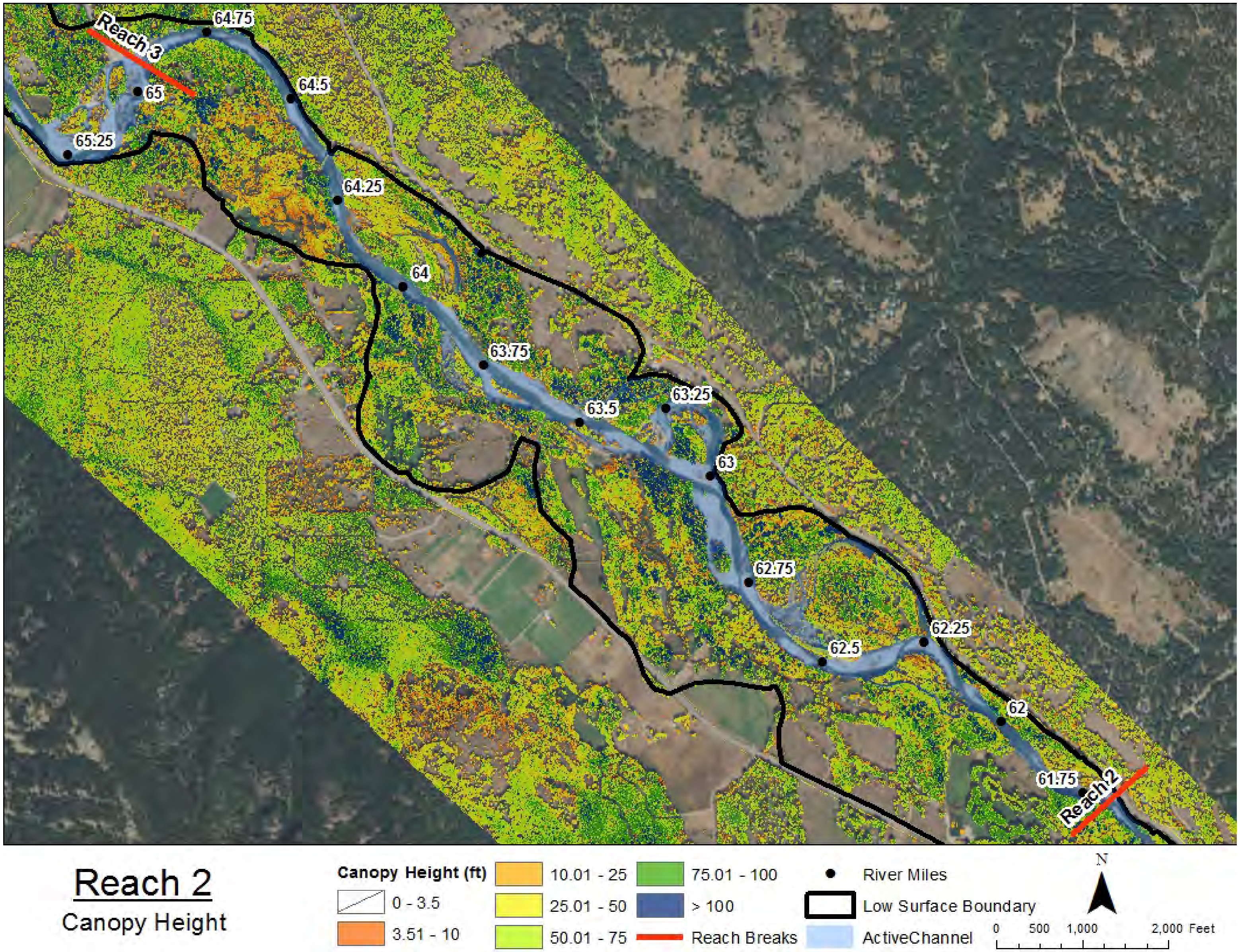

Figure 44. Vegetation canopy height for Reach 2 -- derived from LiDAR first return (highest hit) data; includes buildings and other human infrastructures.

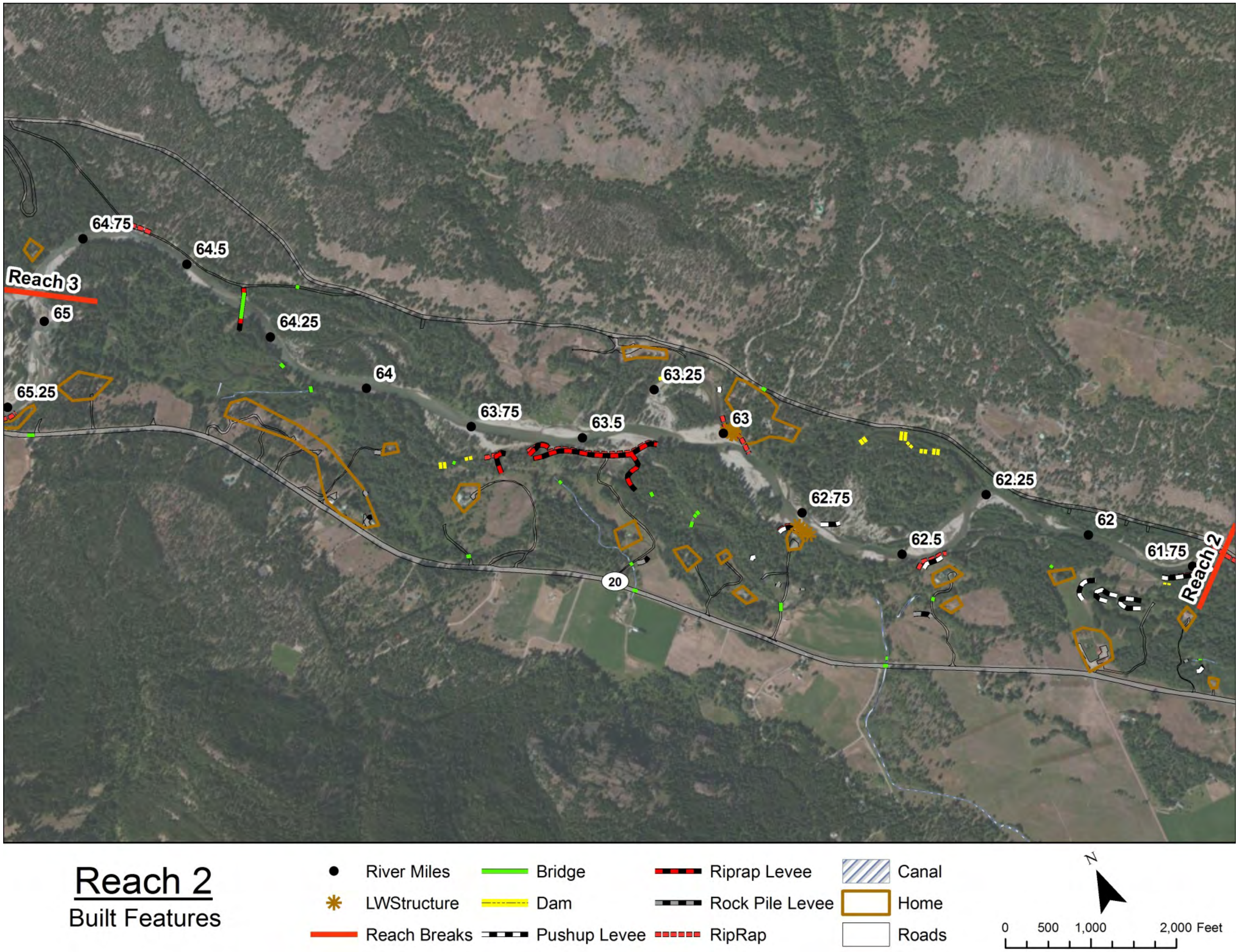

Figure 45. Primary human features in Reach 2.

3.2.3 Human Alterations

Human features are mapped in Figure 45. The primary human alterations in the reach include the following, and are described further in the subsections below.

- Changes to channel migration, floodplain function and off-channel habitat
- Changes to streambank complexity and riparian impacts
- Changes to instream habitat complexity

Changes to Channel Migration, Floodplain Function and Off-Channel Habitat

Levees and riprap have reduced the channel migration zone of Reach 2 (Figure 46). The channel width and location in the downstream portion of Reach 2 is largely locked in place. Lateral migration is limited by large-boulder riprapped banks topped with push-up levees on river-right from RM 61.7 to 61.85, RM 62.4 to 62.45, and RM 62.7 to 62.8. Riprap is used for bank protection on river-left from RM 61.7 to 61.75, RM 62.8 to 63.1, RM 63.15, and RM 64.6 to 64.65. Large wood has been attached to the riprapped banks at RM 62.7 (on river-right) and at RM 63 (on river-left).

The most severe alteration to floodplain and habitat function occurs behind the levees on river-right from RM 63.25 to 63.75. The levees are approximately eight to twelve feet high and eight to ten feet wide. The road on the top of the levee is a community trail. The levees completely block channel migration and floodplain inundation. They also block the upstream confluence points of several side-channels. This blockage keeps main channel flow from entering the side-channels, which has resulted in decreased habitat complexity and infilling with fines. The side-channels in this reach would be the longest in the study area had they not been disconnected by the levees. Today, these side-channels are currently wetted by groundwater inputs alone. Reactivation of the side-channel could be achieved by excavating notches into the levee, removing the levee entirely, or installing hydraulically-designed culverts that would allow partial through-flow from the mainstem.

Additional push-up levees composed of floodplain cobbles and soil reduce normal inundation processes on river-left from RM 62.65 to 62.7. Push-up levees built on the floodplain near dug ponds at RM 61.85 (river-right) disconnect a portion of the floodplain from normal through-flow and high-flow inundation processes. A series of check-dams in the abandoned meander scar on river-left from RM 62.25 to 65.65 reduces surface water inputs into the channel. The check-dams also limit the potential backwater habitat that this feature could provide.

Figure 46. Examples of confining features constructed of large angular riprap in Reach 2, (A) riprapped bank with cabled and anchored logs on river-right at RM 62.7; (B) section of the levee composed of riprap on river-right at RM 63.5. (9/4/2014)

Additional loss of floodplain function occurs at the suspension bridge abutments at RM 64.35 and at an armored bank at the downstream end of the reach on river-right. The suspension bridge abutments are composed of boulders, cobbles and soil (similar to push-up levees). The abutments constrict the channel between them and alter normal floodplain inundation downstream on river-right (Figure 47). At the downstream end of the reach on river-right from RM 61.7 to 61.8, a riprapped bank topped with a push-up levee also confines channel width and location. Floodplain connectivity is reduced behind and downstream from this bank and levee in Reach 2 and Reach 1. Additional floodplain levees in Reach 2 alter localized floodplain inundation processes.

Figure 47. Suspension footbridge abutment and public area on downstream side of bridge on disconnected floodplain at RM 64.35. (9/3/2014)

Changes to Streambank Complexity and Riparian Impacts

Armored banks and vegetation clearing have altered sediment and vegetation inputs to the channel in portions of Reach 2. Riprapped banks throughout the reach inhibit bank erosion and natural hillslope inputs, which in turn alter localized sediment inputs into the system. The riprap also reduces the complexity of the riparian vegetation community and notably decreases the potential for the establishment of mature tree stands. This also reduces both localized shade to the channel and large wood recruitment potential in these areas.

The loss of riparian vegetation communities and the accompanying loss of the benefits they provide have occurred on private lands, near utility poles, and at footbridge crossings. Along the main channel, these impacts are visible at RMs 61.85 (river-right), 62.65 (river-right), 62.75 (river-right), 63.6 (river-right and river-left), 64.35 (river-right), and 64.8 (river-left). Some vegetation thinning and clearing has also occurred along groundwater-fed tributaries and on floodplain surfaces near side-channels or backwater features. Loss of vegetation near these features can also increase water temperature, reduce natural bank stabilization, limit tree-fall nutrients, and reduce off-channel habitat complexity.

Changes to Instream Habitat Complexity

Instream habitat complexity has been impacted by the human alterations described previously. The armored banks and levees have contributed to reduced channel sinuosity over the past few decades. Reduced sinuosity shortens a channel, thus increasing its gradient. This promotes bed incision and reduces floodplain connectivity. According to aerial imagery, in the last ten years the channel has cut off three meanders on river-left at RM 62.5, RM 63.25, and RM 64. These avulsions recruited sediment and large wood from the floodplain into the channel. These inputs are currently maintaining local mainstem channel complexity even though sinuosity has been reduced. However, there is high potential for channel incision to continue here because of the confinement that has been imposed by the levees and armored banks. This is also true for the downstream end of Reach 2, where the channel is confined between riprapped banks. Upstream migrating bed incision from Reach 1 may also influence bed scour at the downstream end of Reach 2.

Historical gold mining in Goat Creek in the early 20th century, along with extensive logging and channel straightening, likely increased past sediment inputs and perhaps influences the character and quantity of modern sediment contributions (USBR 2008 – Appendix O). From the late 1800s to the early 1900s, records indicate that loggers utilized the mainstem channel to transport cut timber to mills downstream of Reach 2 (Devin 1997). This required clearing the channel of natural log jams and any other obstructions (large boulders, etc.). The expected impacts of log drives and/or "cleaning" a channel include bed scour, channel and bank simplification, and a reduction in habitat complexity (Nilsson etal. 2005, Wohl 2006, Miller 2010).

3.2.4 Recommended Actions

Recommended actions in Reach 2 are focused on increasing channel complexity and lateral channel dynamics as well as improving connectivity to side-channels and floodplains. Complexity and lateral dynamics can be addressed by adding large wood jams to the main channel to enhance and create bar and island development and enhance split flow dynamics. Channel margin jams are suggested to create local pool development and enhance existing features. Side channel and floodplain connectivity can be addressed by removing unnecessary riprap, push-up levees, check dams, and sediment accumulations in off-channel habitat areas. Removal or breaching of levees at RM 63.35-63.7 has the potential to reconnect the largest off-channel impairment in the study area – but further evaluation and planning is needed to address the human-based function that the levees currently serve. Reach 2 also offers good opportunity to take advantage of public-access and recreation that occurs here by adding educational signage at restoration sites. Native riparian vegetation restoration where clearing has occurred is also recommended. Restoration recommendations recognize the importance of maintaining connectivity of the mainstem channel to perennial or groundwater fed tributaries and side-channels. This has been identified as a critical component for fish survival in a system with the potential to seasonally dewater.

See Section 4 of this report for the restoration strategy and specific project recommendations for the reach.

3.3 REACH 3

Refer to Section 2.2 and 2.8 for geologic and geomorphic context of the study area and explanation of terminology.

3.3.1 Reach Overview

Reach 3 is 1.3 miles long and extends from RM 64.90, at the confluence with Goat Creek, to RM 66.20. Land in Reach 3, including the land owned by Foster Guest Ranch Homeowners Association, is all private (Figure 48). In the upper two-thirds of the reach, from RM 65.35 to 66.20, the channel is a straight riffle-pool-glide stream, with only two pools. Bar development is minimal here, and off-channel features are limited to a few overflow channels at the upstream end on river-right from RM 66.8 to 66.20 (Figure 49). Channel complexity improves downstream of RM 65.35, where the river becomes partially braided. In addition to increased channel sinuosity, this area has plentiful pools, bars, log jams, and connected side- and off-channel features (Figure 50). The channel substrate of Reach 3 is composed primarily of coarse gravels and cobbles. Floodplain composition is similar to the channel substrate but with sparse small boulders at the base and overbank deposits of sand. The river in this reach has a relatively low average sinuosity ratio (1.2) and gradient (0.4%). These and other reach metrics are provided in Table 9 and Figure 51.

The reach is semi-confined laterally due to a combination of natural features and human alterations. High glacial outwash terraces and the alluvial fans sourced from Goat Creek and Little Boulder Creek act as natural, partially confining features to Reach 3. The human features confining Reach 3 include levees and riprapped banks. Floodplain scarring and deposition patterns indicate that high-flow events activate or contribute to side-channel and off-channel features in locations where human features have not altered floodplain inundation processes. Atop adjacent terrace surfaces on river-right (west side of the channel), the construction of private homes and Highway 20 alter sediment and large wood inputs.

The habitat conditions in Reach 3 are discussed in Appendix A. Based on the REI analysis, 9 of 11 habitat indices are rated as either unacceptable or at risk (see Table 6). The salmon and steelhead redd distributions for the reach are mapped in Figure 48. Vegetation clearing and thinning on portions of the floodplain along river-left (east side of the channel) locally reduce bank roughness and nutrient inputs. Channel banks in the lower third of the reach are well vegetated with maturing forests. These forests provide wood to the system and add roughness to the banks and floodplain surfaces. Historical logging practices cleared large trees from the Reach. At the turn of the century, the channel was utilized to transport cut logs to mills downstream. This has likely influenced channel and floodplain processes over the last century. Natural hydrologic and geomorphic processes have been compromised where levees and riprap disconnect the channel from its floodplain and limit lateral channel migration. Off-channel human alterations such as irrigation canals, culverts, roads, a pond, home development, and tributary crossings alter sediment and discharge routing into the system.

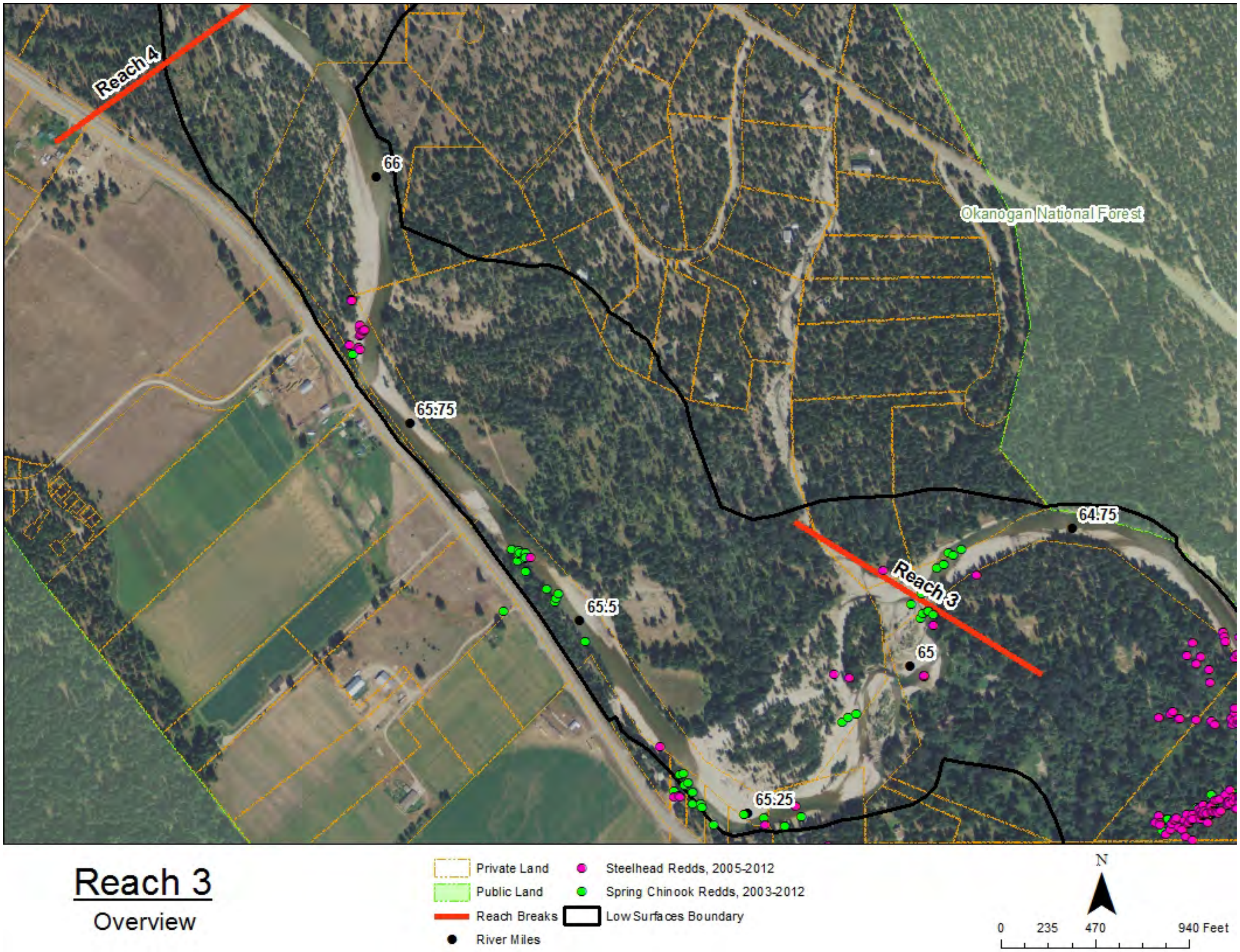

Figure 48. Reach 3 overview map with landownership and redd distribution.


Figure 49. Representative photo of upper section of Reach 3; looking downstream at RM 66.75. (9/3/2014)

Figure 50. Representative photo of lower section of Reach 3; looking downstream at RM 65.15. (9/3/2014)

Table 9. Reach 3 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	1.3
River Miles	64.80 – 66.10
Valley Gradient	0.6%
Stream Gradient	0.4%
Sinuosity	1.22
Dominant Channel Type	Pool-riffle-glide
Average Bankfull Width (feet)	159
Average Floodplain Width (feet)	848
Dominant Substrate	cobble (48%); gravel (51%); boulder (1%)
Bank Stability/Channel Migration	At Risk *(See Section 2.12)*
Vertical Channel Stability	At Risk *(See Section 2.12)*
Confinement ratio	Unconfined *(See Table 5)*

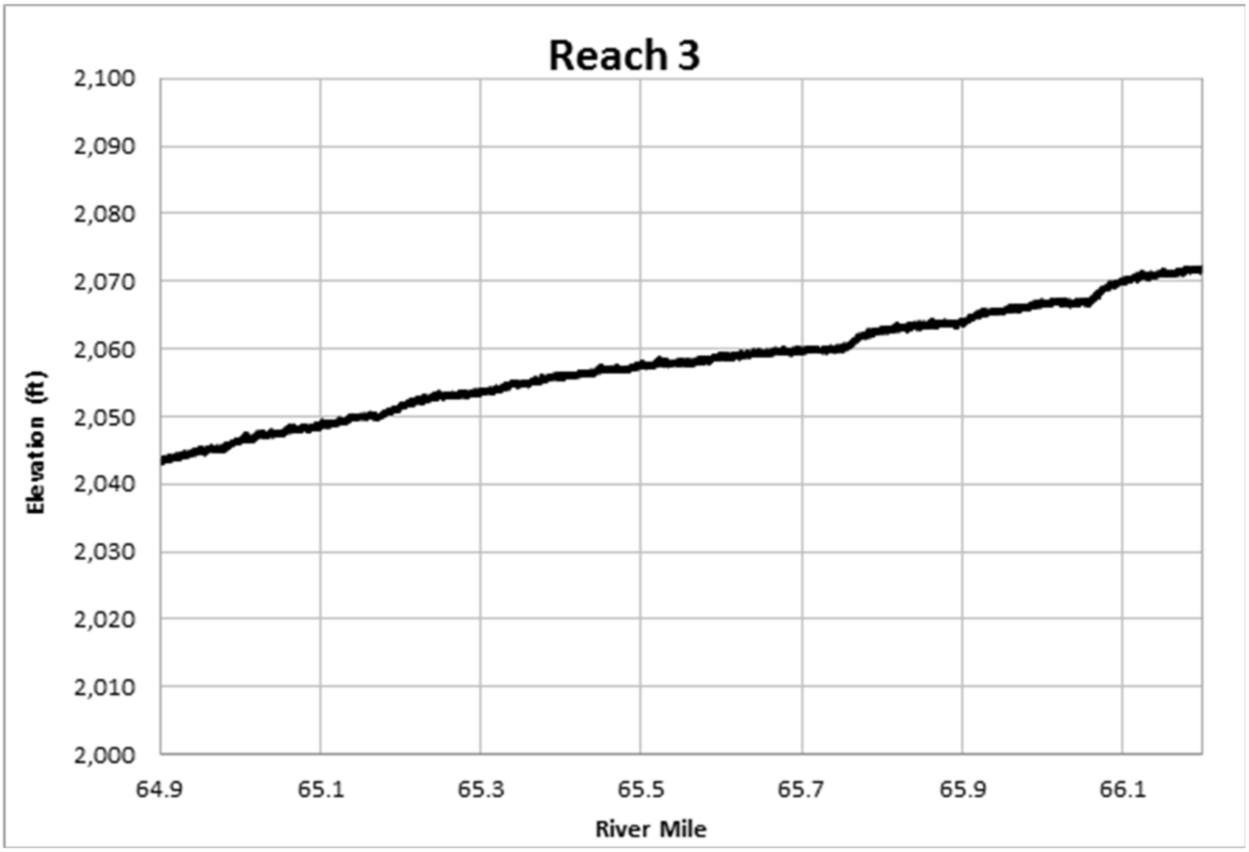

Figure 51. Longitudinal profile of the channel in Reach 3 (RM 64.80 to66.10).

3.3.2 River Morphology and Geomorphic Processes

Geology and Landforms

Reach 3 is located in the center of a wide, U-shaped valley most recently carved by Quaternary glaciation. Increased discharge regimes during early Holocene glacial retreat resulted in the valley floor infilling with a thick layer of glacial outwash deposits (sand, gravel, cobbles and boulders). During glacial retreat, the tributaries also carried an increased sediment load, and this resulted in the creation of large alluvial fan deposits at the mouths of the Goat Creek and Little Boulder Creek drainages. The modern channel and floodplain of Reach 3 are inset between and below the outwash terraces and alluvial fans (Figure 52).

The channel and its modern floodplain surfaces occupy only a quarter of the valley floor. The average width of Reach 3 is 848 feet and the average bankfull width of the channel is 159 feet. Modern floodplain surfaces border the channel on river-right from RM 64.9 to 65.2, RM 65.4 to 65.6, and RM 65.8 to 66.2. The floodplain from RM 65.4 to 65.6 is a narrow strip of land between the channel and a glacial outwash terrace. This strip of floodplain has been disconnected by a levee and riprap. On river-left, the channel is bordered by floodplain surfaces from RM 64.95 to 66.85. However, levees and riprap partially disconnect the floodplain on river-left from RM 65.35 to 65.6. Along river-right, from RM 66.4 to 66.2, a glacial outwash terrace borders the river and its modern alluvial surfaces; it is six feet higher than the modern channel. Downstream from the glacial terrace on river-right, the reach borders the Little Boulder Creek alluvial fan. From RM 65.9 to 66.4, the channel is eroding the toe of the Little Boulder Creek alluvial fan. The resulting cut-bank is 10 to 12 feet higher than the modern active-channel. The Goat Creek alluvial fan borders the entire river-left side of the reach. The channel directly contacts the Goat Creek alluvial fan from RM 65.9 to 66.1. High floodplain surfaces skirt the edge of the glacial terrace in the upstream portion of the reach as well as the toe of the Goat Creek alluvial fan. The high floodplain surfaces in Reach 3 were created by the incision and channel migration of the Methow River into the glacial outwash and alluvial fan deposits.

The channel is notably influenced by the Little Boulder Creek and Goat Creek alluvial fans. The location of the channel within the valley has been determined by the extension of the fan deposits across the valley. Since glacial retreat, both creeks continue to contribute sediment and discharge to the Upper Methow River. Goat Creek's modern contributions of sediment and discharge are greater than Little Boulder Creek's. Today, Goat Creek and its modern alluvial fan are inset below historical fan deposits. The elevation of Goat Creek at its mouth (RM 64.9) is similar to the Methow River. Unlike Goat Creek, Little Boulder Creek is a hanging tributary at its confluence point (RM 65.25). This indicates that the modern discharge and stream power of Little Boulder Creek is not capable of incising into its paleo-fan deposits as quickly as the Methow River is locally incising. At the upstream border of the reach, approximately 720 feet from the channel, a pond was constructed within the Goat Creek alluvial fan. According to historical aerial imagery, the pond was dug in a meander scar that was abandoned between 1954 and 1964. The pond captures surface flow and groundwater for private irrigation and recreational purposes.

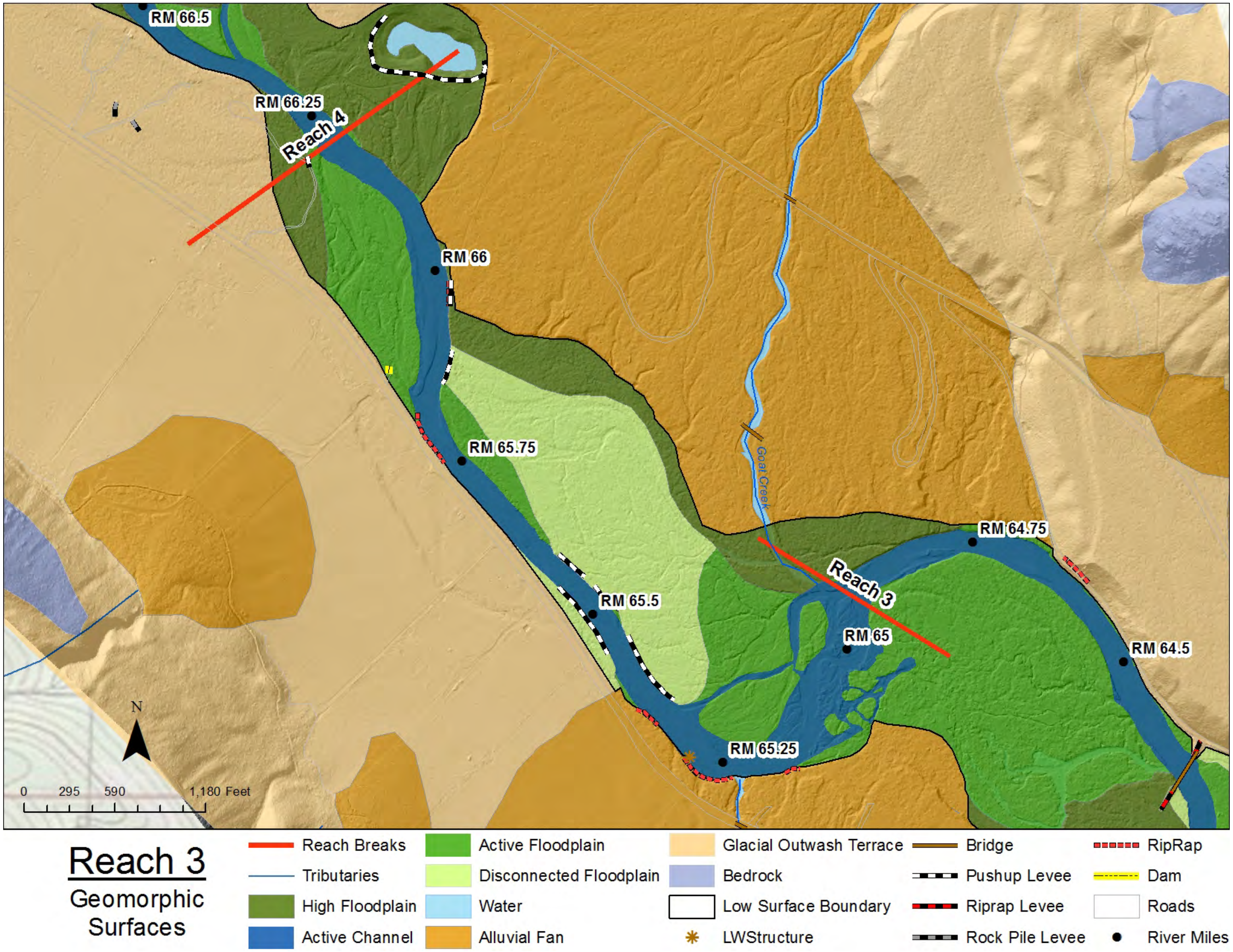

Figure 52. Geomorphic surfaces of Reach 3 with selected human-built features (levees, wood structures, riprap, check dams, bridges, and roads).

Hydrology

Reach 3 has a seasonally exaggerated flow regime with high spring and early summer snowmelt flows (Figure 54) and very low autumn and winter low flows. During low-flows, the channel can go completely subsurface or be reduced to just inches above the channel bed at riffles and glides. The extent of dewatering in this reach is dependent on the annual hydrograph. The scour pool at the meander bend (RM 65.3) is deep enough that it likely remains at least partially wetted annually during normal precipitation years. Summer thunderstorms are capable of temporarily raising surface water elevations in Reach 3 only if the storms generate enough discharge to recharge local groundwater elevations.

The valley floor and alluvial fans are composed primarily of coarse-grained material. This material supports active hyporheic through-flow and groundwater influx from upstream and from the adjacent terraces and alluvial fans. Reach 3 is the most downstream section in the study area considered to be a "losing" reach (Konrad 2003, Konrad et.al 2005). This means that the channel contributes its incoming surface flow to the subsurface groundwater reservoir. Thus, surface water in the channel of Reach 3 is only the exposed top inches-to-feet of the valley's groundwater reserve. This section of the channel can go dry in late summer and autumn (Caldwell and Atterson 1992, Andonaegui 2000, Konrad 2006a). See Section 2.6 of this report for a description of the groundwater to surface water interchange processes that occur here.

During field surveys, visible hyporheic flow was observed on the downstream end of active bar surfaces upstream of RM 65.25. Based on side-channel pool temperatures and clarity, the mainstem and multiple side-channels in the downstream section of Reach 3 are actively exchanging groundwater with surface water. The side-channels are important features in Reach 3 because they provide complex off-channel habitat that is particularly important during seasonal low- or no-flow periods.

Reach 3 receives surface flow discharge from Little Boulder Creek. According to the US Bureau of Reclamation's surface flow estimates (2008 – Appendix J), the reach receives an estimated 1.2% increase in discharge from Little Boulder Creek during high-flow events. Based on bank seepage and wetted off-channel features, the alluvial fans of Goat Creek and Little Boulder Creek contribute groundwater to the reach. However, the annual quantity and percent of that contribution are unknown.

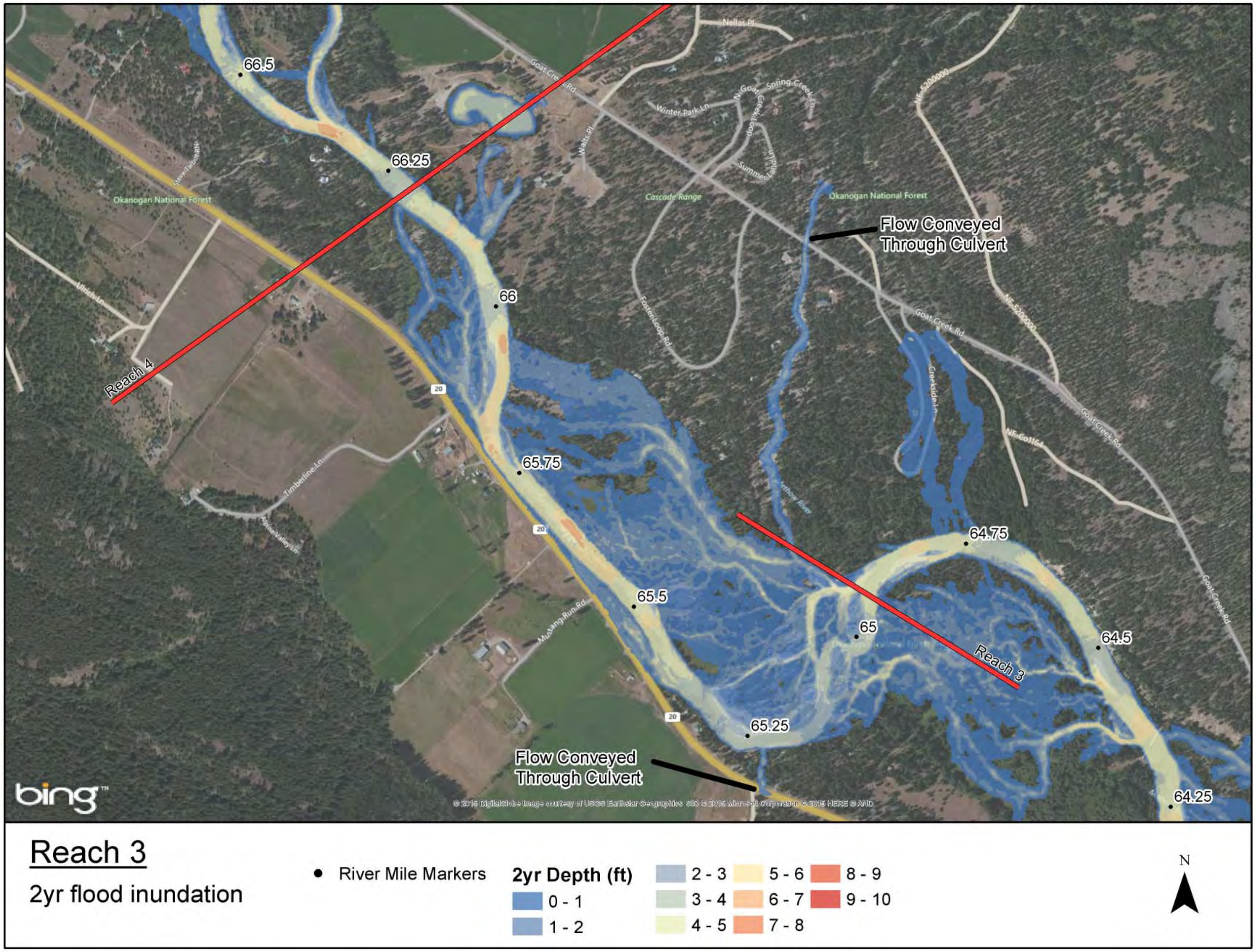

Figure 53. Floodplain inundation for 2YR flood in Reach 3 – developed using a 2D hydraulic model (SRH-2D) built with 2006 LiDAR elevation data.

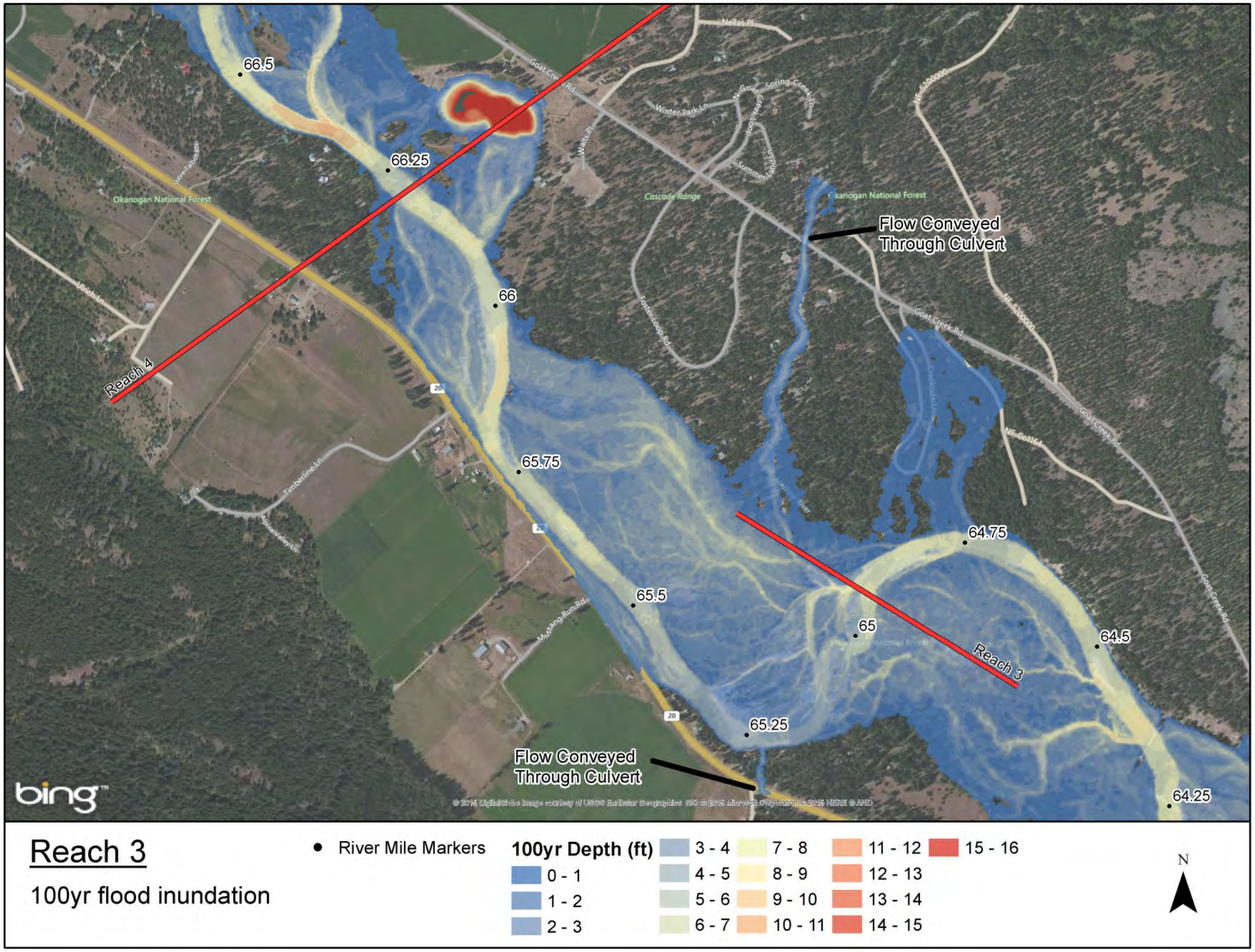

Figure 54. Floodplain inundation for 100YR flood in Reach 3 – developed using a 2D hydraulic model (SRH-2D) built with 2006 LiDAR elevation data.

Floodplain and Channel Migration Zone

Reach 3 is considered laterally semi-confined and vertically moderately unstable. Lateral confinement is due to a combination of natural features and human alterations. Natural, partial confinement is imposed by the high glacial outwash terrace on river-right and the alluvial fans of Goat Creek on river-left and Little Boulder Creek on river-right. From RM 65.3 to 66, levees and riprap have been constructed on sections of floodplain, terrace, and fan toes, further confining the channel. In this laterally-confined section (RM 65.3 to 66), the channel is mostly straight with only a slight meander from RM 65.85 to 66.2. The existing pools in this reach occur at the bend. The less confined section (RM 64.9 to 65.3) is between the confluences of Little Boulder Creek and Goat Creek. Here the channel is a sweeping meander with multiple side-channels and a braided channel form.

Upstream of RM 65.3, in the confined section of Reach 3, vertical stability is at risk. This is due in large part to the unnatural confinement of the channel between riprapped banks and levees. Confinement and straightening of a river often reduces vertical stability by instigating incision processes. According to historical aerial imagery, levees and riprap were constructed here after 1985. This exaggerated both pool scour and the lateral erosion of the cut-bank immediately downstream from the levees on river-right at RM 65.3. As a result, additional large-boulder riprap along the base of the high banks of the Little Boulder Creek alluvial fan was installed to reduce bank erosion and protect homes and the infrastructure of Hwy 20. Large cement slabs on the channel bed and a cement septic tank exposed in the bank at RM 65.3 are evidence of the risk of lateral bank erosion here due to upstream confinement. The lateral confinement of the channel has also led to channel-bed incision upstream of RM 65.3. Channel confinement with downstream pool scour establishes a positive feedback mechanism that is expected to result in continued incision. Downstream from RM 65.3, the channel's form changes from single-thread to partially braided with active side-channel and off-channel features. The large bars here are sourced from upstream bed scour as well as local sediment inputs from Goat Creek. Thus, the downstream section of the reach is transport limited with a locally reduced channel gradient and notably increased geomorphic complexity.

Fluvial scarring indicates that the modern floodplains in Reach 3 are inundated by high-flow events every two to ten years. However, historical aerial imagery and field observation of overbank deposition patterns indicate that the constructed levees and riprap in Reach 3 have reduced active-channel width and normal floodplain inundation. This is most evident from RM 65.35 to 66.75 along river-left, and on river-right from RM 65.4 to 65.6. As a result, the floodplains behind the levees and armored banks have been classified as disconnected. Channel migration has been limited since the construction of the levees and riprap (Figure 55).

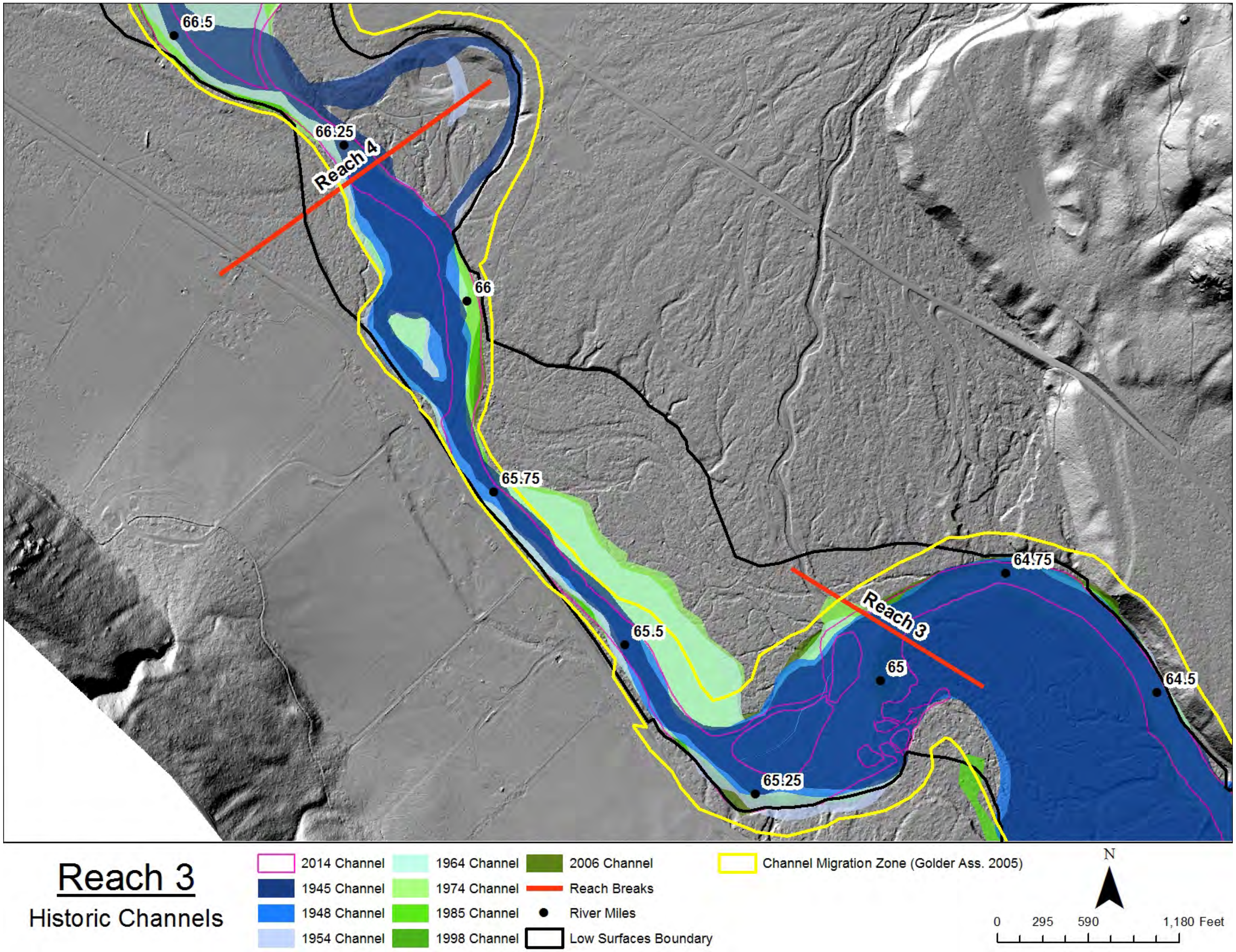

Figure 55. Historical channel locations in Reach 3.

Sediment

The substrate of Reach 3 is dominated by gravels (51%) and cobbles (48%); sparse boulders account for only 1%. The bedload is sourced from upstream inputs, the bed of the active channel, bank erosion, and contributions from Goat Creek and Little Boulder Creek. Available bank sediment is sourced from the unarmored sections of floodplains, glacial terrace, and alluvial fan toes. Floodplains are composed of cobbles and gravels and topped with sand. Some soil development is occurring on the modern alluvial surfaces. Bedload sediment throughout the reach is well sorted (has a relatively similar diameter size range) and rounded, indicating that much of the substrate is transported fluvially during high flow events. Sediment is stored in the active bars. Bar size and distribution is greatest downstream of RM 65.35. Gravels and sands accumulate on active floodplain surfaces as overbank deposits. Sand is also found in some of the side-channel pools – in the downstream section of the reach where the gradient is locally reduced.

Large Wood

Reach 3 has plentiful large wood in the channel but almost all of it is located in the unconfined section of the channel downstream of RM 65.3. In-channel wood distribution in the reach is presented in Figure 56 as a density, or the number of wood pieces per 100 feet within each delineated channel unit type. Four log jams and 190 logs were counted (the equivalent of 149 pieces per mile). Large wood accumulations in the downstream section are sourced both locally and from upstream. Potential wood recruitment from the banks of Reach 3 is limited at cleared home sites and along the large-boulder riprapped banks. From RM 65.4 to 65.8, the available forest is reduced to a vegetated-buffer that is only two to ten trees wide between the channel and the Highway 20 road prism on river-right. Recruitment from floodplain surfaces is also limited by the levees and riprap that restrict lateral migration and floodplain connectivity. Only temporary retention of large wood occurs on the narrow, longitudinal bars located in the leveed section of the reach (RM 65.3 to 66). The large wood accumulations in the downstream section of the reach maintain large pools and bars. The mainstem is too wide for channel-spanning logs to occur, but on river-right from RM 64.9 to 65.15, channel-spanning wood is plentiful in the narrow side-channels.

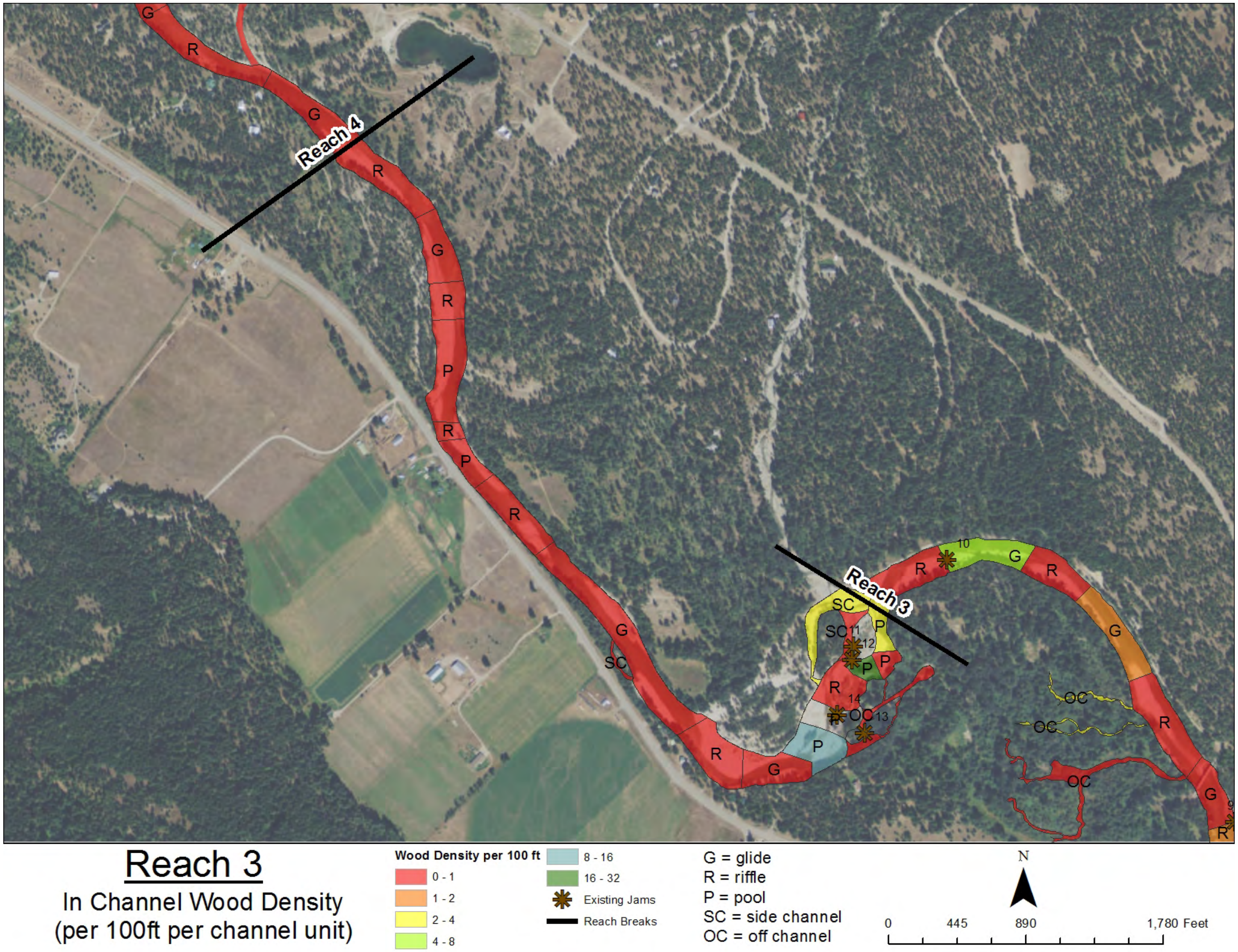

Figure 56. In-channel wood distribution (qualifying wood pieces per 100 ft channel length) within delineated channel units in Reach 3.

Vegetation

In Reach 3, vegetation density and type is variable (Figure 57). In the downstream-most portion of the reach (RM 64.9 to 65.15), the banks and floodplain are vegetated with a dense, maturing forest consisting of trees that range from 25 to 100 years old. There is a mix of conifer and deciduous trees, such as fir and cottonwood. This forest has a low, brushy understory composed mostly of snowberry and Oregon grape. The recently active floodplain surfaces and high bars in this lower portion of the reach are vegetated with young willow, cottonwood, alder, and some sparse conifers. These trees range from five to 25 years old, and their age aids in identifying the extent of inundation and sediment mobilization that have occurred during recent flood events. Moderately dense maturing forests also exist on river-right in the upper portion of the reach from RM 65.8 to 66.2.

The terrace and alluvial fans on river-right (from RM 65.15 to 65.8) host thinned forests dominated by pine and fir, and sparse undergrowth (forbs and grasses). Exceptions to this occur along water sources where the underbrush increases in complexity and density. Recent forest thinning and clearing on the floodplain on river-left (from RM 65.2 to 66.2) have reduced floodplain vegetation complexity and roughness. On river-right, from RM 65.15 to 65.8, vegetation was removed and thinned for home sites and the construction of the Hwy 20 road prism. However, a buffer of maturing trees (two to ten deep) lines most of the channel banks throughout the reach – except near the home sites and riprapped banks on river-right from RM 65.15 to 65.35. The maturing trees offer shade and nutrients along the sections of the channel where they occur. However, the width of the channel limits the percent of water surface that can receive shade. Along the riprapped banks, sparse patches of willow and dogwood have taken root between the angular boulders.

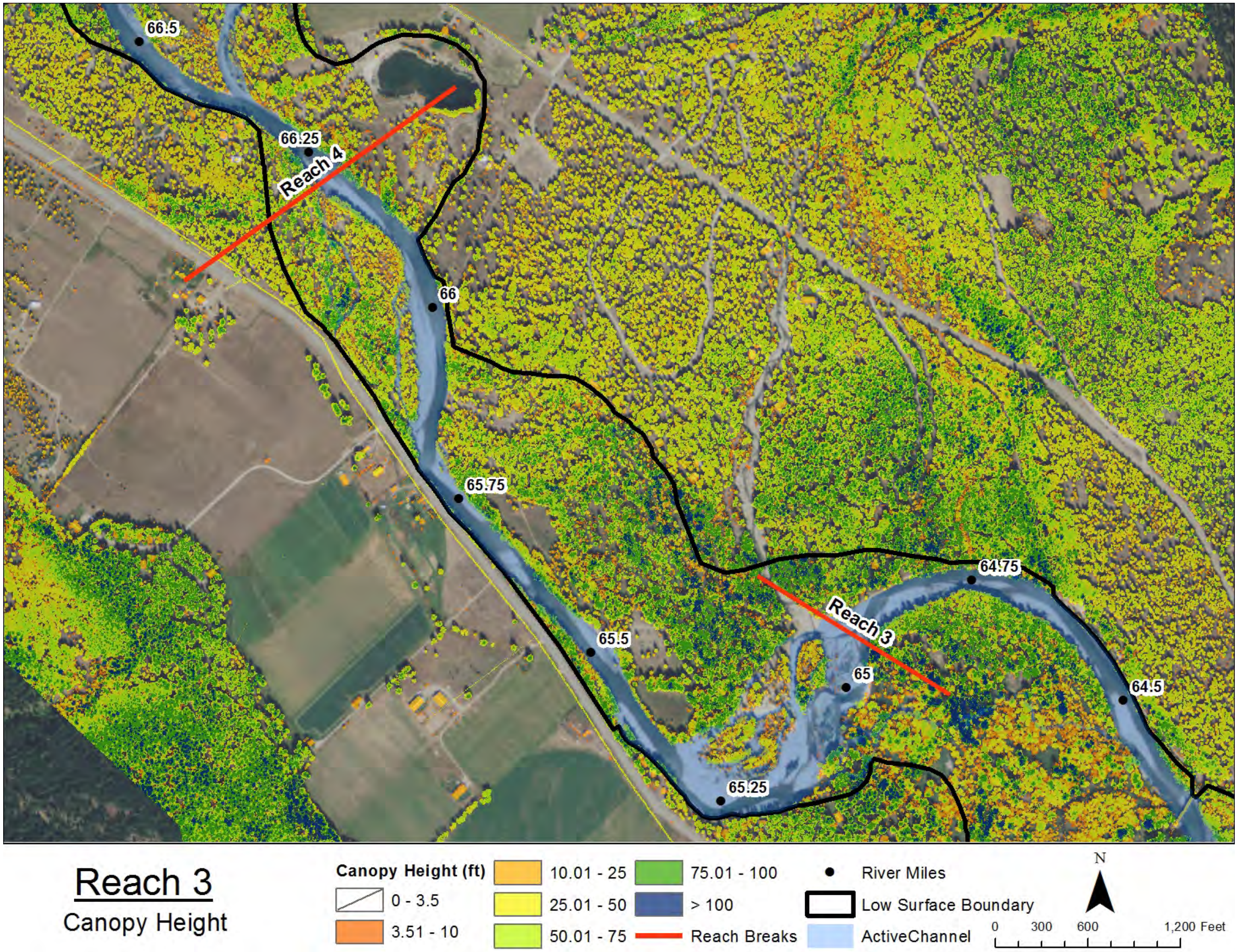

Figure 57. Vegetation canopy height for Reach 1 -- derived from LiDAR first return (highest hit) data (includes buildings and other human infrastructures).

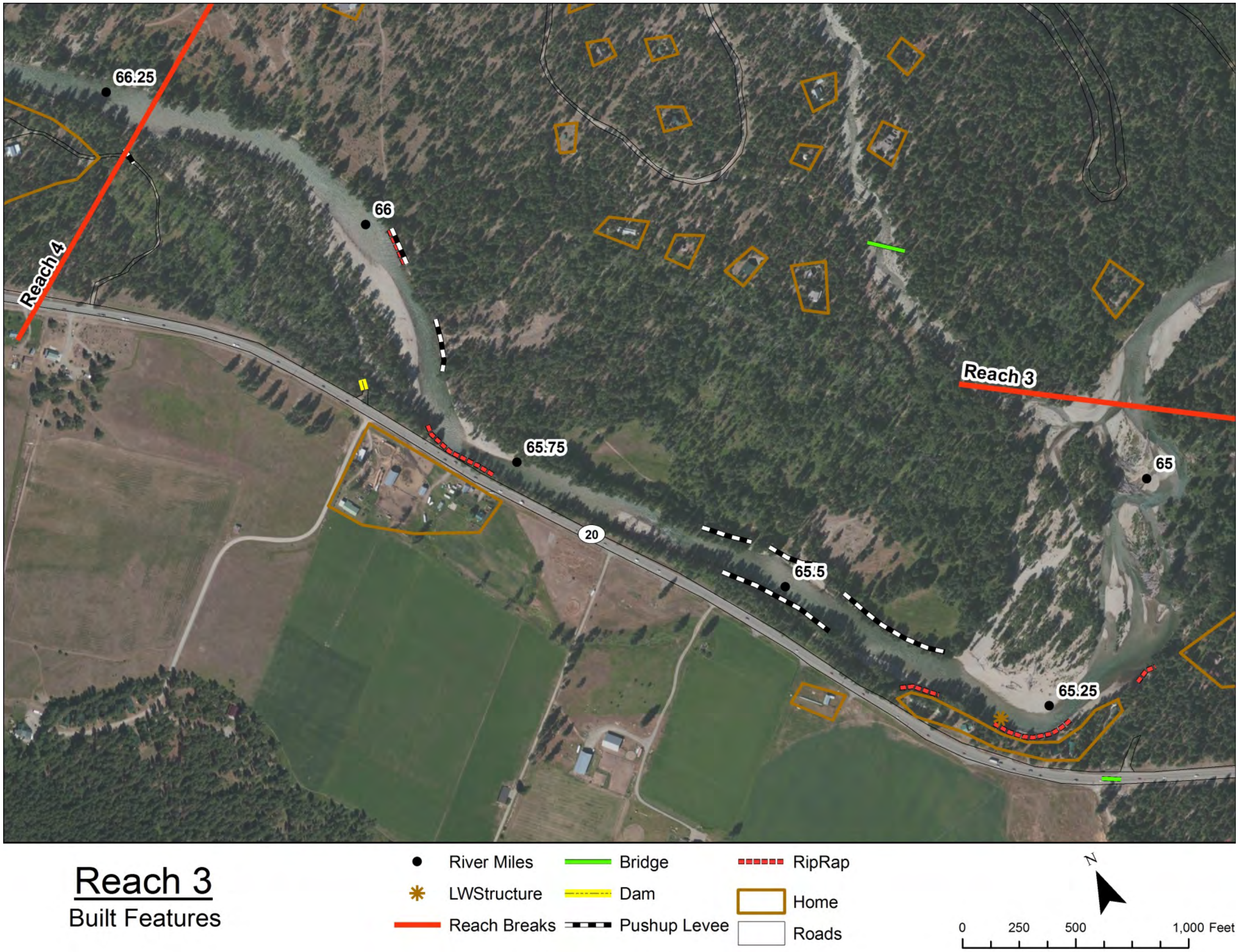

Figure 58. Primary human features in Reach 3.

3.3.3 Human Alterations

Human features are mapped in Figure 58. The primary human alterations in the reach include the following, and are described further in the subsections below.

- Changes to floodplain function and channel migration
- Changes to streambank complexity and riparian impacts
- Changes to flow inputs and sediment supply

Changes to Floodplain Function and Channel Migration

Floodplain function and channel migration have been reduced in Reach 3 as a result of constructed levees and boulder riprap. Approximately one-third of the available floodplain surfaces in Reach 3 have been disconnected from the channel by the construction of push-up levees. The levees have been built on river-right from RM 65.45 to 65.55, and on river-left from RM 65.35 to 65.55, at RM 65.85 (230 feet long), and at RM 65.9 (170 feet long). The most upstream bank protection is a boulder riprap reinforced levee at RM 65.9 on river-left. This levee aids in diverting the channel away from the alluvial fan toe and floodplain surfaces on this side of the reach. In general, the levees range from approximately two to four feet high and are composed of local boulders, cobbles, and soil (Figure 59). From RM 65.35 to 65.55, the channel is straight and basically locked in place due to the levees constructed on both sides of the channel. Here, the channel migration zone has been reduced from approximately 1,000 feet to the width of the channel (approximately 160 feet). Large boulder riprap armors the banks of the channel on river-right at RM 65.15 (100 feet long), at RM 65.35 (175 feet long), from RM 65.25 to 65.3, and from RM 65.75 to 65.8. The riprap between RM 65.15 and 65.35 is installed at the base of a high cut-bank where private homes are located. From RM 65.75 to 65.8, the riprap was installed to reduce bank erosion and protect the infrastructure of Hwy 20 (which lies approximately twenty feet behind the bank). The levees and riprap throughout Reach 3 restrict lateral channel migration and disconnect floodplain surfaces by stabilizing the banks and reducing the frequency and extent of inundation.

Figure 59. Push-up levee from land-ward side in Reach 3 on river-left at RM 65.35. (9/3/2014)

Changes to Streambank Complexity and Riparian Impacts

Streambank complexity and riparian vegetation in Reach 3 have been reduced along the riprapped banks. The riprap inhibits bank erosion, and thus alters localized sediment inputs into the system. This is particularly evident along the riprapped cut-bank on river-right from RM 65.25 to 65.3 and from RM 65.75 to 65.8 (Figure 60). The riprap also reduces the complexity of the riparian vegetation community and notably decreases the potential for the establishment of mature stands of trees along these banks. Additionally, this reduces localized shade to the channel and removes the potential for large wood recruitment in these areas. At the private residence on river-right (RM 65.15 to 65.35) and between the channel and Hwy 20 (RM 65.35 to 65.8), vegetation clearing and thinning near the channel bank further reduces the complexity of riparian vegetation and its corresponding benefits to channel function. Historical logging practices at the turn of the century cleared vegetation and utilized the river to transport cut logs to mill sites downstream (Devin 1997). This has likely reduced riparian function and channel complexity over the last century.

Most of the channel banks in Reach 3 are treed, however this vegetation buffer is only 10 to 20 feet wide in some places. Partial or complete vegetation removal on adjacent floodplain surfaces reduces bank and surface roughness and stability. On river-left, between RM 65.35 and RM 66.2 (the upstream boundary), floodplain forests have been thinned and cleared. On river-right, between RM 65.15 and 65.85, adjacent banks and surfaces have also been cleared for agricultural purposes, road construction, and home-site development. Reduced vegetation and the existence of the road and home sites alter normal surface flow routing and sediment delivery across the floodplain.

Figure 60. Riprap protected cut bank toe in Reach 3 on river-right at RM 65.30. (9/3/2014)

Changes to Flow Inputs and Sediment Supply

Roads and tributary crossings outside of the active channel and floodplain alter the natural routing of surface water inputs across the glacial outwash terraces and alluvial fans that border Reach 3. The raised road berm of Hwy 20 traverses the glacial outwash and alluvial fan terraces on the west side of the reach. Due to this road berm, natural surface water run-off from the terrace and hillslopes west of Hwy 20 are diverted through ditches, irrigation canals, and culverts. For example, Little Boulder Creek passes under Hwy 20 through a culvert. On the east side of the reach, Goat Creek passes under the Goat Creek Road at a small bridge, and then it passes under a foot bridge – both of which have abutments on the banks of the tributary. The footbridge is part of the Methow Community Trail network; these trails cross the alluvial fan and disconnected floodplain surfaces on river-left. The bridge crossings and culverts alter tributary sediment inputs by restricting the tributary's pathway across its alluvial fan. Additionally, driveways and access roads related to private residences on both sides of the reach likely alter surface water infiltration and run-off patterns.

Another constructed feature that interrupts natural surface and groundwater inputs to Reach 3 is the pond located at the upstream boundary of the reach on river-left (Figure 61). The pond was dug in a meander scar that, according to aerial imagery, was abandoned between 1954 and 1964. A levee (composed of the material removed to create the pond) is located at the edge of the feature, between the pond and the channel. It appears that one purpose of this levee is to protect the pond from potential flood inundation or channel reactivation by the mainstem Methow River. The pond is dug below the elevation of the channel bed, thus allowing it to capture area groundwater. Surface water from a spring sourced off the Goat Creek alluvial fan is also captured by the pond via a small rock-lined canal. The pond is used for private recreation and irrigation. The portion of the floodplain where the pond is located is designated as a high floodplain surface. This high floodplain surface and similar features in Reach 3 appear to be the result of local channel incision.

Historical gold mining in the early 20th century at Goat Creek, along with extensive logging in the lower portion of the tributary, likely increased past and perhaps modern sediment inputs to the reach (USBR 2008 – Appendix O).

Figure 61. Dug pond and levee (foreground) located in abandoned channel scar on river-left floodplain; upstream border of Reach 3 at RM 66.25. (8/28/2014)

3.3.4 Recommended Actions

Recommended actions in Reach 3 are focused primarily at the upstream section of the reach and include increasing channel complexity and lateral dynamics as well as improving floodplain connectivity. Complexity and lateral dynamics can be addressed by adding large wood jams to the main channel to enhance and create bar and island development. Channel margin jams are suggested for pool development and to enhance existing pool features. Floodplain connectivity can be addressed by removing unnecessary levees and bank armoring. The proximity of Highway 20 will need to be considered with these actions. Native riparian vegetation restoration where clearing has occurred is also recommended. Restoration recommendations recognize the importance of maintaining connectivity of the mainstem channel to perennial or groundwater fed tributaries and side-channels. This has been identified as a critical component for fish survival in a system with the potential to seasonally dewater. The lower portion of Reach 3 is highly complex, full of wood, and very dynamic (Figure 62). No significant work in this lower section is recommended, as it is mainly an area that should be targeted for protection, including a highly-functioning side-channel in the river-right floodplain (RM 64.4 – 65).

See Section 4 of this report for the restoration strategy and specific project recommendations for the reach.

Figure 62. Dynamic, well-functioning downstream portion of Reach 3. (8/29/2014)

3.4 REACH 4

Refer to Section 2.2 and 2.8 for geologic and geomorphic context of the study area and explanation of terminology.

3.4.1 Reach Overview

Reach 4 is 3.1 miles long and extends from RM 66.1 to the confluence of Early Winters Creek at RM 69.2. Property within and along Reach 4 is a combination of Okanogan National Forest, private landowners, and a section of public land designated as a "common area"(Figure 63). The channel is a single-thread stream with extended riffles and glides (Figure 64). Bar development is minimal in the upper two-thirds of the reach, but large mid-channel bars with extensive wood jams exist immediately downstream of the Mazama Bridge. At these bars and log jams, channel complexity increases, including the presence of pools. The reach is considered semi-confined by glacial outwash terraces and the Early Winters Creek alluvial fan. The active floodplain has an average width of 365 feet and the channel's average bankfull width is 129 feet. The channel meanders gradually, with a sinuosity ratio of 1.09. In this Reach, the gradient of both the river and its floodplain is 0.5 percent. These and other reach metrics are provided in Table 10 and Figure 65.

The outside meander bends are predominately tall terrace cut-banks composed of glacial outwash that moderately confine the channel. The modern floodplain surfaces occupy the inside portions of the meanders. Scarring and deposition patterns indicate that overbank flood events inundate the majority of the active floodplain surface every two to ten years. This is confirmed by hydraulic modeling. The relative elevation of the floodplain surfaces to the bed of the channel and high water marks observed in the field indicate that this semi-confined reach experiences a greater fluctuation in river stage than the reaches upstream and downstream from it. The substrate of the channel is dominated by cobbles and gravels. The active floodplain, although also composed of cobbles and gravels, is topped with sand and loam. The high floodplain surfaces are similar in composition, but they are topped with developing soils.

The habitat conditions in Reach 4 are discussed in Appendix A. Based on the REI analysis, 9 of 11 habitat indices are rated as either unacceptable or at risk (see Table 6). The salmon and steelhead redd distributions for the reach are mapped in Figure 63. Along sections of the floodplain and terrace banks, home-sites have been developed and vegetation has been cleared or thinned. Most of the modern floodplain banks are vegetated with maturing forests, and this enhances the roughness of the bank and floodplain surfaces. Floodplain grading has reduced the connectivity of two small sections of the floodplain at mid-reach. Riprap-enforced abutments and a levee at the Mazama Bridge locally constrict the channel. Along a high-flow activated side-channel in the downstream portion of the reach, rock piles and cement bridge abutments restrict lateral channel migration potential. Channel-bed incision is the dominating geomorphic process in this reach – both historically and recently. The lack of large wood in the channel in the upper third of the reach is likely due to past channel clearing and minimal lateral channel migration.

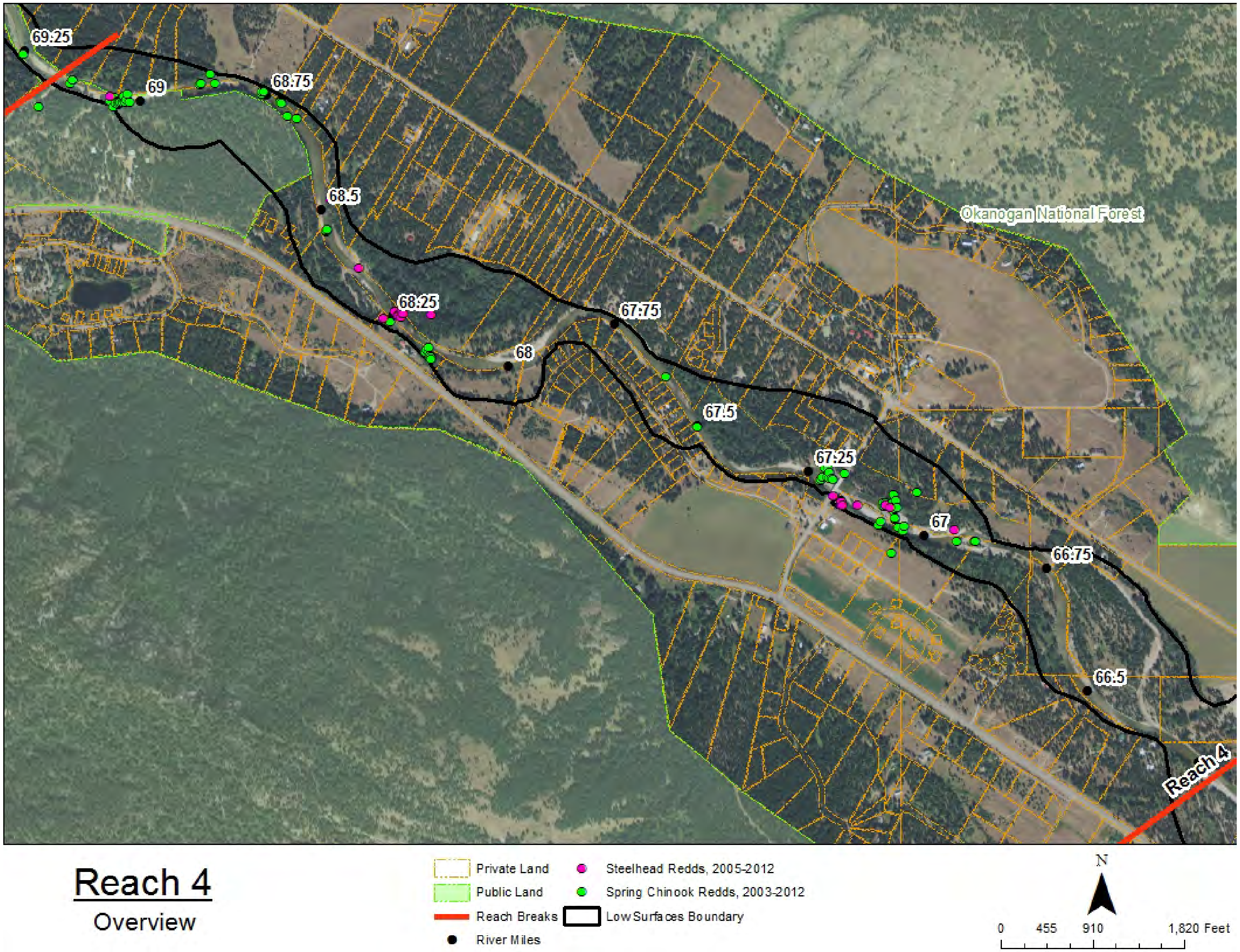

Figure 63. Reach 4 overview map with land ownership and redd distribution.

Figure 64. Representative photo of Reach 4; looking downstream at RM 68. (8/27/2014)

Table 10. Reach 4 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	3.1
River Miles	66.10 – 69.2
Valley Gradient	0.5%
Stream Gradient	0.5%
Sinuosity	1.09
Dominant Channel Type	Riffle-glide
Average Bankfull Width (feet)	129
Average Floodplain Width (feet)	365
Dominant Substrate	cobble (66%); gravel (29%); boulder (5%)
Bank Stability/Channel Migration	Unacceptable *(See Section 2.12)*
Vertical Channel Stability	At risk *(See Section 2.12)*
Confinement ratio	Moderate *(See Table 5)*

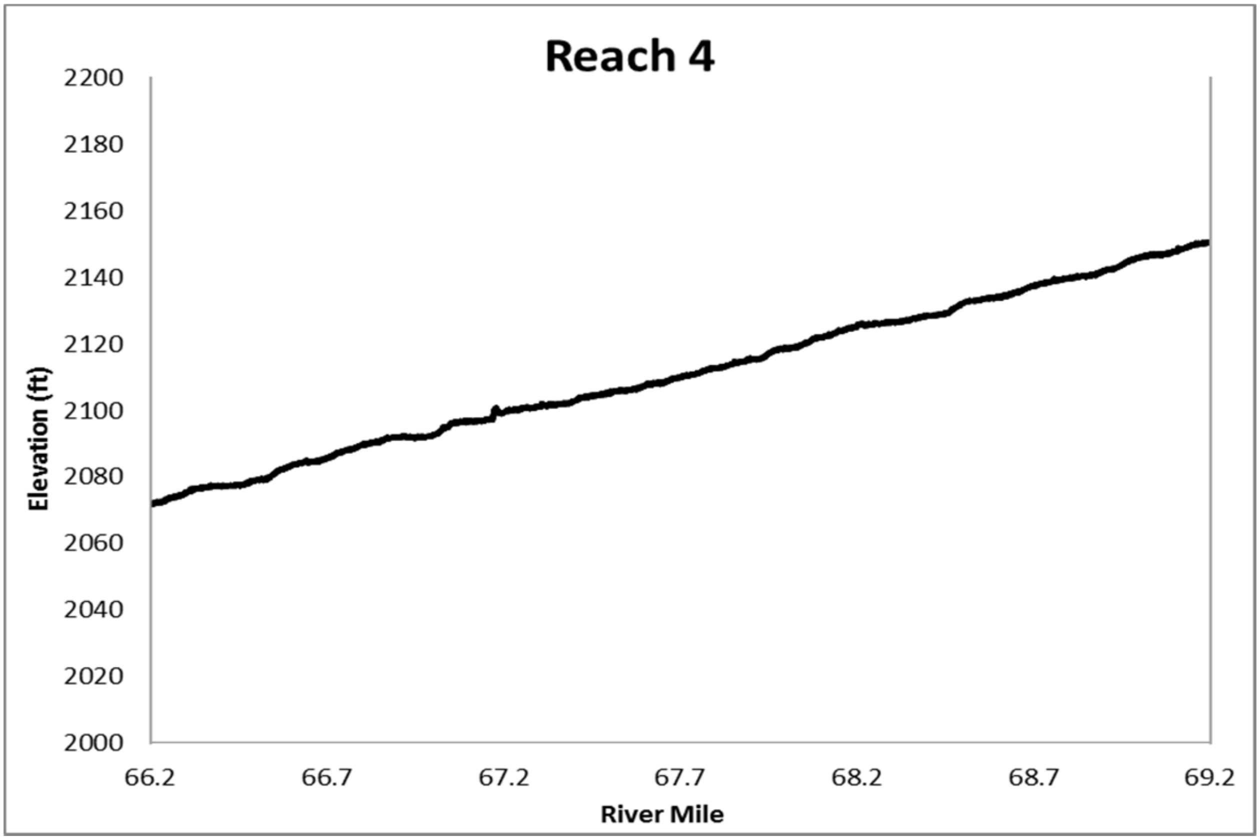

Figure 65. Longitudinal profile of the channel in Reach 4 (RM 66.10 to 69.2).

3.4.2 River Morphology and Geomorphic Processes

Geology and Landforms

Reach 4 is located in a wide, glacially-carved, U-shaped valley most recently carved by Quaternary glaciation. Increased discharge and sediment regimes during early Holocene periods of glacial retreat resulted in a thick layer of glacial outwash deposits filling the valley floor. At the mouths of the tributaries that enter the valley, large alluvial fans of outwash material were also created during this time. The channel runs through the middle of the valley without contacting the steep bedrock walls. The modern channel and its relatively narrow floodplain are inset into the glacial outwash terrace and the Early Winters Creek alluvial fan. Other alluvial fans spread across the outwash terrace at Theise Creek (on the east side of the valley), at Looney Creek, and at two unnamed creeks on the west side of the valley. Although these tributaries contribute discharge to the system, none of their fan deposits extend far enough into the valley to interact with the modern channel or the floodplains of Reach 4 (Figure 66).

The active and high floodplain surfaces of Reach 4 are relatively narrow compared to those upstream and downstream. The valley floor is approximately 4,000 feet wide, yet the average active floodplain width of Reach 4 is just 365 feet. At RM 67.2, the channel is constricted between the bridge abutments of the Mazama Bridge and its associated riprapped and leveed banks. Otherwise, the channel meanders gradually between the high banks of the glacial outwash terrace and its inset floodplains. The outside meander bends often contact high terrace cut-banks composed of sands, cobbles and boulders (Figure 67). Floodplain surfaces are primarily located on the inside bends of the meanders. Where surface grading and human development has not altered surface topography of the glacial outwash terrace, subtle scarring and insets indicate that channel incision into the outwash terrace was initially gradual. Incision into the terrace was then exaggerated, most likely due to the increased discharge inputs from Early Winters Creek during glacial retreat. The increased discharge created a local hydro-geomorphic relationship where the capacity of the flow to transport sediment is greater than the available local sediment. In response to this condition, channels incise vertically instead of laterally migrating and creating floodplains with the excess sediment (Simon and Rinaldi 2006). As a result, today a relatively narrow inset floodplain exists throughout much of the reach. The active floodplain surfaces are flanked in most instances with a high floodplain surface. This indicates that incision remains a primary geomorphic process in the modern channel evolution of Reach 4.

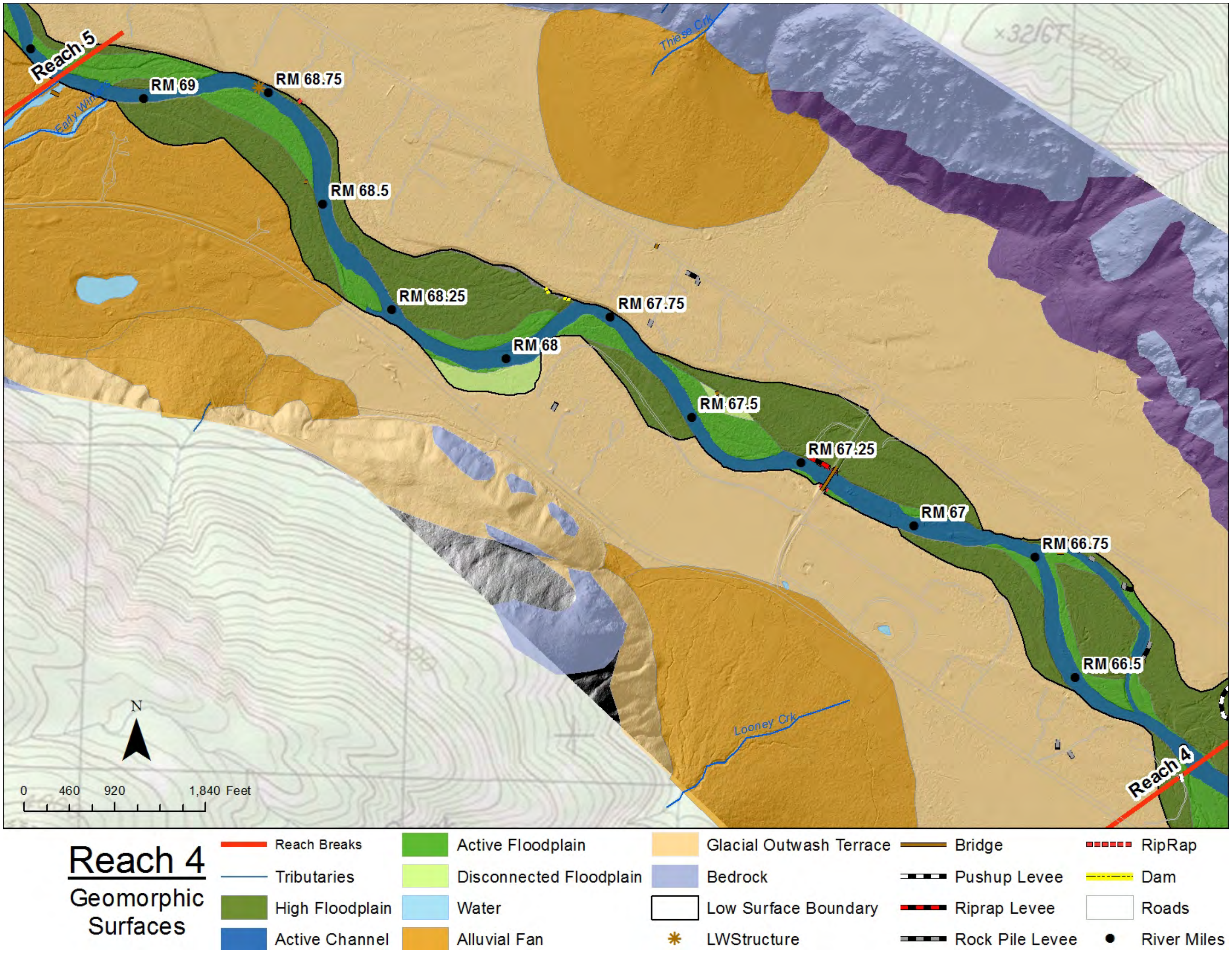

Figure 66. Geomorphic surfaces of Reach 4 with human-built features (levees, riprap, check dams, bridgess, and roads).

Figure 67. Glacial outwash terrace cut bank on river-left; looking downstream at RM 67.75. (8/27/2014)

The channel in Reach 4 is single-thread with only two overflow side-channel features and one off-channel, groundwater-fed tributary. The groundwater-fed tributary enters the channel on river-left (east side of the channel) at RM 67.8. This tributary originates from groundwater seepage at the base of the glacial terrace. It is located in an abandoned channel scar that is inset between the outwash terrace and a high floodplain surface. The tributary is a complex off-channel feature with an abandoned beaver dam, racked wood which creates small pools, and substrate of sands to gravel (Figure 68). Tree and shrub vegetation along the banks of the tributary provide shade to this off-channel feature. Decreased water temperatures were observed in the deeper pools of this tributary due to groundwater influx. In August, 2014, fingerlings were seen in the pools of this tributary during field observation. Maintaining the connectivity of this tributary to the mainstem channel is important because it provides approximately 600 yards of cool, shaded, off-channel habitat. Another groundwater-fed feature is offset from the channel by approximately 180 feet on river-left between RM 67.45 and RM 67.65. This feature also occupies an abandoned channel scar, but its surface water has been captured by a dug pond with a levee. The levee ensures that the feature remains disconnected from channel processes.

Figure 68. Ground-water fed tributary with abandoned beaver dam; looking upstream near RM 67.8. (8/27/2014)

Two side-channels that are activated during high flow locally reduce incision potential by providing additional channel area for flow transmission. A side-channel that runs from RM 66.35 to 66.75 on river-left is over 700 yards long (2,100 feet) (Figure 69). The other side-channel runs from RM 68.25 to 68.35 on river-right (west side of the channel). It is only 225 yards long (675 feet) but it offers a backwater feature during low flows that, if maintained, could provide perennial off-channel habitat. Both sode channel features have been scoured and then filled with large cobbles and gravel during high flow events.

Figure 69. High flow side-channel (dry) on river-left near RM 67.75; looking upstream. (8/27/2014).

Throughout Reach 4, the river's path gradually meanders with a sinuosity of 1.09. Fairly stable banks and minimal channel complexity confirm that this reach is relatively stable laterally. The primary channel units are extended riffles and glides with a low frequency of pools. There is a scour pool downstream from the confluence with Early Winters Creek. The series of large pools downstream from the Mazama Bridge correlate with the localized increase in channel complexity. The localized complexity is induced by accumulations of sediment and wood that create large, mid-channel bars with extensive log jams from RM 66.85 to 67.15 (Figure 70). The average bankfull width of the channel in Reach 4 is 129 feet with its widest point (approximately 230 feet) occurring in the section with the large wood jams and bars. Channel complexity increases in proximity to the large jams and bars, while lateral channel processes only slightly increase.

Figure 70. Large wood accumulations on cobble bars; looking downstream from the Mazama Bridge (RM 67.2). (8/28/2014)

The Early Winters Creek drainage, also carved by glaciers and then filled with outwash during retreat, is now inset below its historical floodplain and alluvial fan deposits. Scarring across the fan surface indicates multiple historical channel pathways upstream from the modern confluence point. Today, discharge contributions from Early Winters Creek still noticeably increase the flow in the Methow River. However, gravel-to-cobble sediment contributions from the creek do not appear to increase bar density or the presence of smaller grained sediment downstream from the confluence. Bar development at the mouth of the confluence consists of a single side-channel bar composed of large cobbles. All other sediment contributions appear to be transported downstream. Large-grained sediment contributions from high flow events in Early Winters Creek have created a subtle grade control feature in the mainstem channel that influences upstream channel elevation and localized channel gradient. The current channel bed of Early Winters Creek is composed of large cobbles and small boulders. At the confluence point, Early Winters Creek drops a few feet along the sloping toe of its alluvial fan into the Methow River. Even though this creek is incising into its fan, it is not able to incise at the rate of the mainstem channel. This continues to instigate bed incision in the lower portion of Early Winters Creek during flows with a transport capacity large enough to mobilize the available bedload. Less capable flows move laterally to dissipate stream energy across the fan toe. A secondary channel off of Early Winters Creek enters the Methow River approximately 450 feet downstream from the main confluence.

Hydrology

Reach 4 has a seasonally fluctuating flow regime. Spring snowmelt high flow events activate overflow channels. Flood events inundate available low floodplain surfaces on a regular basis (two to ten year flood recurrence) (Figure 71). Late summer, autumn, and winter low flows often leave portions of the reach dry, with isolated pools susceptible to temperature extremes (Caldwell and Atterson 1992, Andonaegui 2000, Konrad 2006a). Summer and autumn thunderstorms are capable of temporarily raising surface water elevations if discharge inputs are substantial enough to recharge groundwater elevations. The active floodplain surfaces in Reach 4 can be as much as six feet higher than the channel bed. This represents a greater fluctuation in flow stage than the wider, less confined reaches upstream and downstream.

The valley floor and alluvial fans within Reach 4 are composed primarily of coarse-grained material. This material supports active hyporheic through-flow and groundwater influx from upstream and from the adjacent terraces and alluvial fans. Despite notable discharge inputs from Early Winters Creek, Reach 4 is considered a "losing" reach (Konrad 2003, Konrad et.al 2005). This means that the channel contributes its incoming surface flow to the valley's large subsurface groundwater reservoir. Thus, surface water in the channel of Reach 4 is only the exposed top inches-to-feet of the valley's groundwater reserve. Sections of the channel in this reach can go dry in late summer and autumn, except for the pool at the confluence with Early Winters Creek (Caldwell and Atterson 1992, Andonaegui 2000, Konrad 2006a). See Section 2.6 of this report for a description of the groundwater to surface water interchange processes that occur here.

It is expected that the channel and floodplain tributaries are actively exchanging surface flow with groundwater through hyporheic processes. During field surveys in August and September 2014, hyporheic through-flow at the downstream ends of active bars was observed.

Reach 4 receives discharge inputs from Early Winters Creek, Theise Creek, Looney Creek, a few small unnamed ephemeral tributaries, and a groundwater-fed floodplain tributary. According to the US Bureau of Reclamation's surface flow estimates (2008 – Appendix J), discharge of the upper Methow River increases by 22 percent at the Early Winters Creek confluence during high flows. Early Winters Creek increases the contributing upstream drainage area of the Methow River from 276 to 358 square miles. During high flows, the other tributaries combined are estimated to increase the discharge of the river by another three percent. Neither Theise Creek nor Looney Creek have visible modern surface water input points to the Methow River. Instead, after passing under the Lost River Road through a culvert, Theise Creek's flow goes subterranean while still on its alluvial fan surface. However, the groundwater from the Theise Creek alluvial fan is a suspected groundwater source for the floodplain tributary that enters the channel on river-left at RM 67.8. Surface flow from Looney Creek and the two unnamed ephemeral tributaries on the west side of the valley are captured for agricultural purposes in canals dug at the base of their alluvial fans before reaching the Methow River.

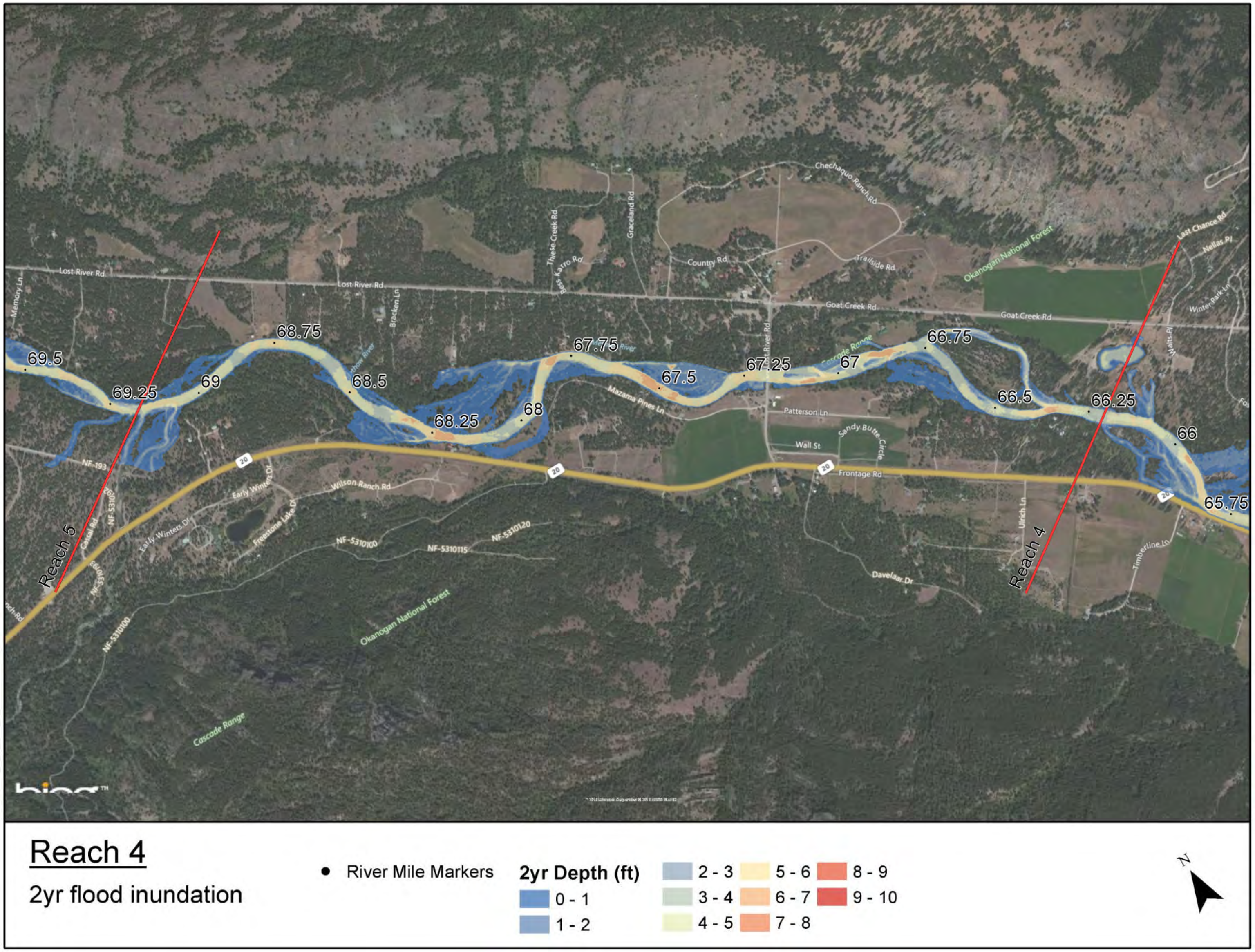

Figure 71. Floodplain inundation for 2YR flood in Reach 4 – developed using a 2D hydraulic model (SRH-2D) built with 2006 LiDAR elevation data.

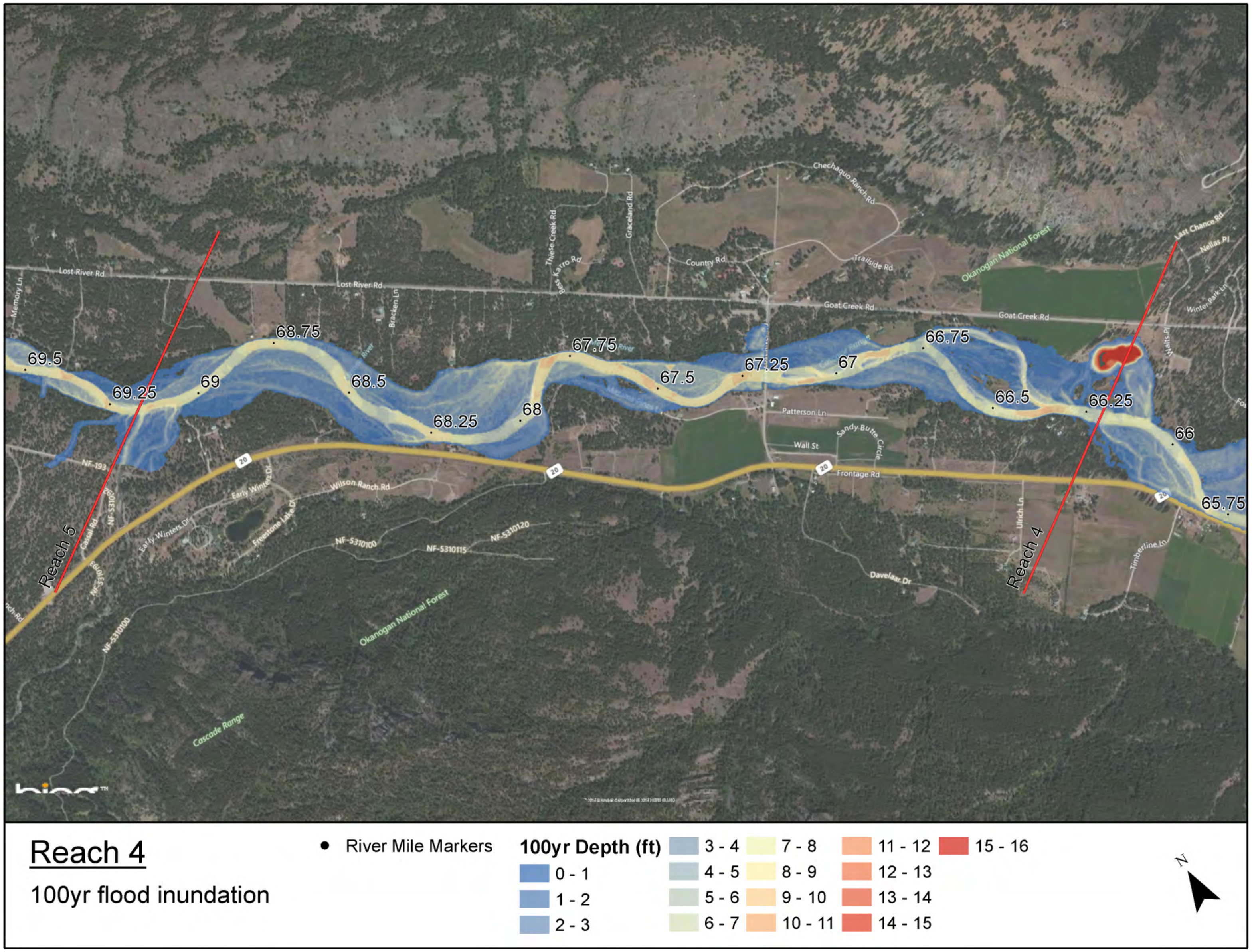

Figure 72. Floodplain inundation for 100YR flood in Reach 4 – developed using a 2D hydraulic model (SRH-2D) built with 2006 LiDAR elevation data.

Floodplain and Channel Migration Zone

Reach 4 is considered laterally stable and vertically active. Aerial imagery from 1945 and current times show that, except at its downstream boundary with Reach 3, the path of the channel has not changed horizontally (laterally) in the last 70 years (Figure 73). Channel banks consist of mostly boulders and large cobbles. Stable boulder and cobble banks with established moss and/or cemented sands were observed between meander bends on river-left at RM 68.2 and on river-right at RM 68.6. Evidence of minor recent lateral migration was observed on relatively short, fresh, cut banks located at RM 66.6, RM 68.45, and RM 67.1. Here, minor wood recruitment from the banks was occurring due to minor channel migration. Subtle scarring on floodplain surfaces indicates that lateral migration and avulsions did occur in Reach 4 in the past.

The historical trend of incision in Reach 4 is marked by sequences of subtle meander scars on the glacial outwash terrace and the Early Winters Creek alluvial fan. These meander scars gradually stair-step into the outwash terrace that filled the valley floor during glacial retreat. The gradual stair-step style of the scars indicates an initial and relatively gradual trend of incision into the outwash deposits. The modern inset channel and floodplain are the result of a subsequent exaggerated period of incision that perhaps was induced by increased discharge from Early Winters Creek during glacial retreat. Modern incision trends are creating the high floodplain surfaces in Reach 4. On the high floodplain surfaces, the vegetation is transitioning towards a drier pine-dominated forest with a less dense understory of grasses and forbs than what is found on the lower, more active floodplain surfaces. This further reveals that modern vertical incision processes are occurring in Reach 4. The trend of incision was likely exaggerated in the last century by logging and the transport of timbers downstream. Without additional research, the rate of modern incision throughout the reach will remain unknown. However, the relative elevation of the high floodplain surfaces suggests that the incision rate is more exaggerated in the downstream portion of the reach.

The channel and its floodplain traverse the middle of the valley between and below the glacial outwash terraces. At no point does the channel contact the valley wall or bedrock in Reach 4. The outwash terrace banks are approximately eight to twelve feet above the modern channel. Though erodible, the terrace banks partially confine the current pathway of the channel throughout the reach. The relative elevation of the active floodplain surfaces over the channel bed is greater in Reach 4 than in other reaches in the study area. Here, active floodplain surfaces range from three to six feet above the channel. The relative elevation of floodplain surfaces increase in the downstream portion of the reach where the width of the channel narrows. This confirms that flow stage varies more dramatically in Reach 4 than in the less confined reaches upstream and downstream.

Evidence of relatively modern lateral channel processes exists at the downstream-most section of Reach 4. At the downstream reach boundary on river-left there is an abandoned channel scar. The feature now resides on a high floodplain surface and has since been dug out to create a pond with a levee. According to aerial imagery, this old channel pathway was abandoned between 1954 and 1964 – only 55 years ago. As a result, the local sinuosity of the channel was reduced, increasing local incision processes and the development of a high floodplain surface on river-left.

Small units of disconnected floodplain surfaces have been created by floodplain grading and clearing along river-right (from RM 67.9 to 68.15) and behind an active floodplain surface on river-left (from RM 67.4 to 67.55).

Sediment

Based on field observations and two representative gravel counts, the substrate of Reach 4 is dominated by cobbles (53%). The percent of gravel-sized material is lower (39%) and boulder-sized material is higher (4%) than in the reaches upstream and downstream from it. Sand is a minor component (5%) in the channel and is found in developing soils on floodplains, as topping on high bars, and as still water deposits in backwater features. Gravel is found as topping on high bars or in off-channel features. The floodplains have large cobbles and boulders at their bases and a top layer of gravel and sands. Where channel contact points occur, glacial outwash terrace banks offer local sources for sand-to-boulder-sized material. Early Winters Creek and its alluvial fan have contributed a notable amount of sediment to the upper portion of Reach 4. Early Winters Creek has deposited large cobbles and boulders across the Methow River at its modern confluence point. The deposit imposes a subtle grade control on the Methow River that influences upstream channel elevation.

The groundwater-fed floodplain tributary on river-left at RM 68 is sand-to-gravel bedded. Bedload throughout the reach is moderately sorted (within similar diameter size range) and rounded, indicating that much of the substrate is transported fluvially during high flow events.

Although high flow inputs from Early Winters Creek notably increase downstream discharge of the river, sediment inputs from the creek do not result in a higher density of bars, nor does it appear to alter grain-size distribution downstream from its confluence point. The increased discharge provided by Early Winters Creek appears to increase the transport capacity of the channel such that the upper portion of the reach is sediment-limited. This higher discharge, and thus higher sediment transport capacity, could also help to explain the shift in channel form from the upper reaches, which are more aggradational, to this reach, which is less aggradational. At the downstream end of the reach, once the converging fans of Goat Creek and Little Boulder Creek come in, the regime shifts back to aggradational.

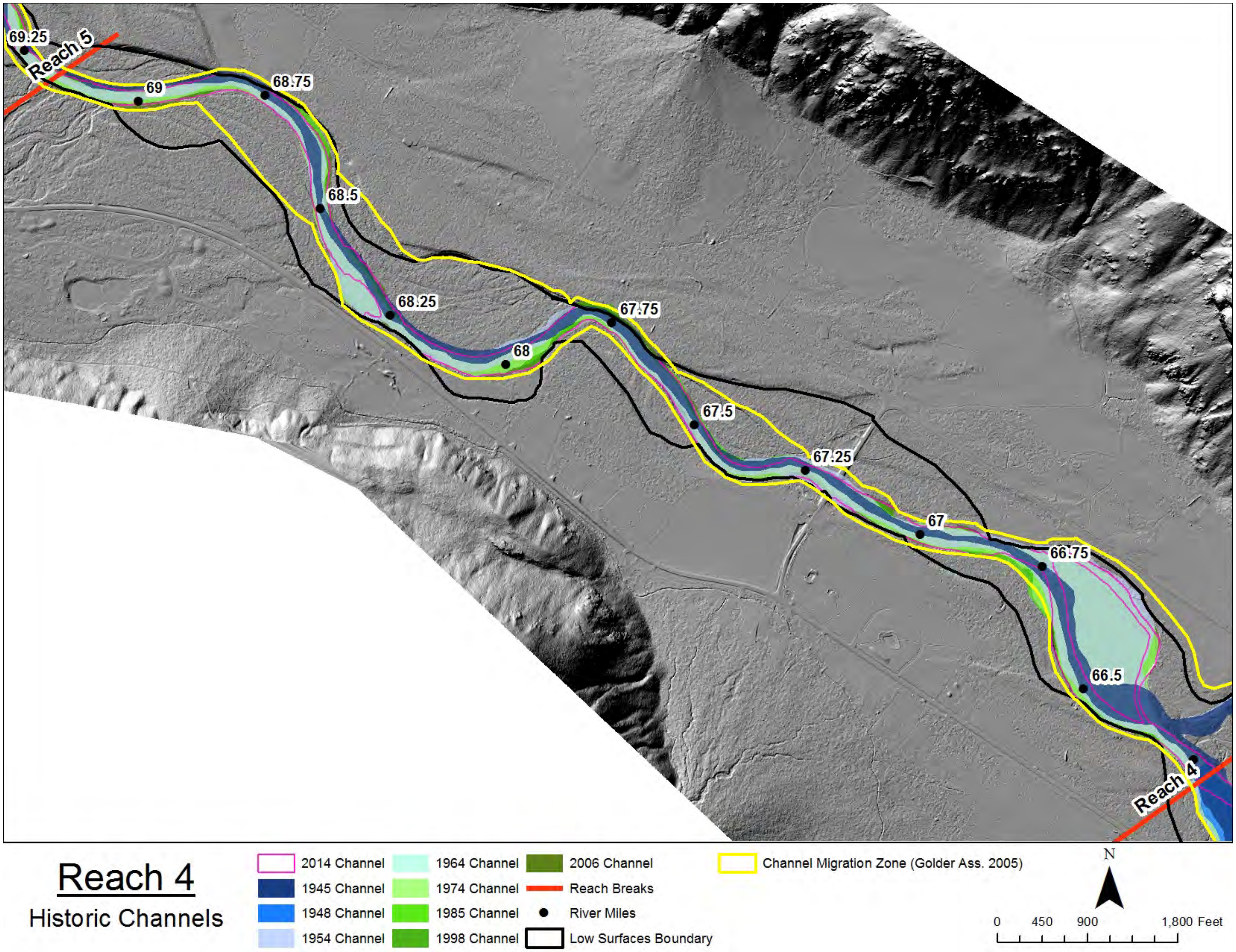

Figure 73. Historical channel locations in Reach 4.

Large Wood

Reach 4 has a moderate in-channel large wood count of 362 logs (56.7 logs per mile) but only three log jams. In-channel wood distribution in the reach is presented in Figure 74 as a density, or the number of wood pieces per 100 feet within each delineated channel unit type. Almost all the large wood pieces are part of the three large log jams located between RM 66.85 and RM 67.15, just downstream of the Mazama Bridge (Figure 75). These jams are geomorphically effective at creating local channel complexity and habitat complexity in an otherwise simplified reach. At these three log jams, large active bars are maintained and there are deep scour pools. It is assumed that at least part of this wood was sourced from Reach 5 and transported to this location since lateral erosion processes (and thus tree recruitment) in the upper third of Reach 4 are minimal. Besides these large log jams, the other in-channel wood counted in the reach is a handful of single pieces on river-left at RM 68.45. Here, a bar is now developing and very slight lateral migration towards river-right has recently occurred. A horizontal ballast log acting as a weir has been placed and secured to large boulders in the channel bed at RM 68.75. This log is serving as a subtle grade control for sediment accumulations on the upstream side (which includes some gravels) and a shallow plunge pool (approximately 2.5 feet deep) on the downstream side. Due to the slight increased bed elevation on the upstream side, the channel has widened locally such that effective flow now passes around the ends of the placed log.

Large wood recruitment potential exists in Reach 4 due to vegetated floodplain surfaces adjacent to the channel. However, wood retention is limited to the section of the channel immediately downstream from the Mazama Bridge. Approximately 70 percent of the floodplain banks in the reach are vegetated with maturing trees – stands with trees 50 years old and older. However, recruitment of the large wood is limited by the lack of lateral mobility, as well as reduced beaver populations and vegetation clearing. Minimal large wood retention occurs between the Mazama Bridge at RM 67.2 and the upstream boundary of the reach at RM 69.2. All notable large wood retention occurs between RM 66.3 and 67.15 in conjunction with the accumulations of gravels and cobbles that create large bars. Simplification of the channel above the bridge and the accumulation of material below the bridge may be the result of historical log drives to a mill site near Mazama at approximately RM 67.2.

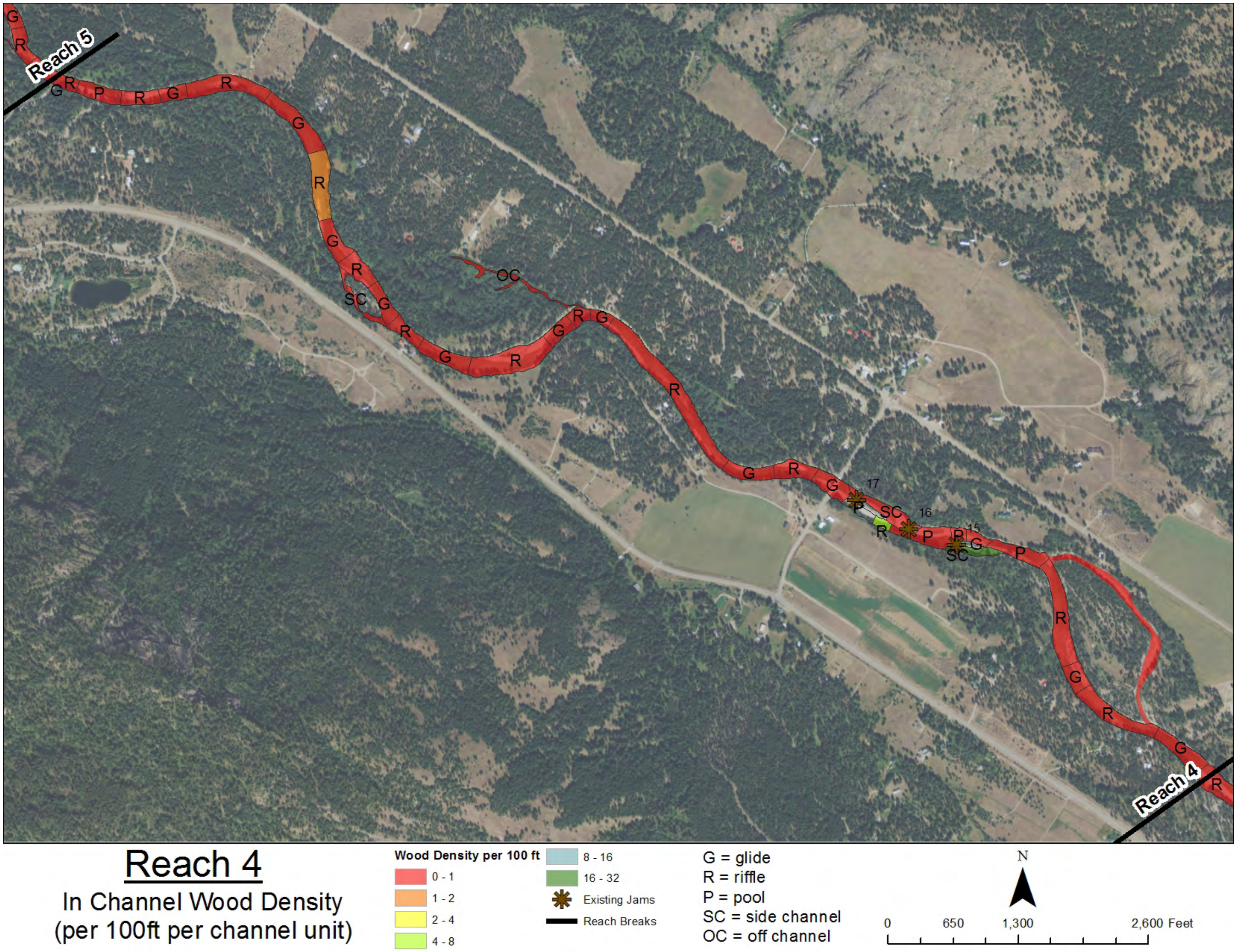

Figure 74. In-channel wood distribution (qualifying wood pieces per 100 ft channel length) within delineated channel units in Reach 4.

Figure 75. Large wood jam at apex of a cobble bar (RM 67.15). (8/28/2014)

Vegetation

Anthropogenic influences and the relative elevation of floodplain surfaces compared to the channel bed create varied vegetation densities and types in Reach 4 (Figure 76). For example, the high glacial outwash terraces next to the channel have been extensively cleared and graded for agriculture and/or home-site development. As a result, the vegetation composition on almost all of the terrace banks has been greatly reduced to pastures, grasses and lawns with only small areas of sparse pine trees. The Early Winters alluvial fan has also been thinned and cleared for road, campground, and home development. However, the edge of the fan along river-right between RM 69.1 and 69.2 has a vegetated buffer that is composed of a maturing forest of mixed conifers (trees 50 years old and older).

Where modern vegetation removal has not occurred, the floodplain surfaces are vegetated with a maturing forest. About 70 percent of the floodplain surfaces are at least partially vegetated with forests older than fifty years old. Modern vegetation clearing has occurred on the active floodplain surfaces primarily at trails and access points. On uncleared floodplains, forests are composed of a mix of conifers and deciduous trees that include cedar, fir, cottonwood, and aspen. These forests have a dense understory that includes grasses, forbs, dogwood, maple, devil’s club, equisetum, snowberry, willow, and box-elder. Less dense vegetation is found on low floodplain surfaces on river-left between RM 67.85 and 68.2 and on river-right between RM 68.25 and 68.35 and RM 66.7 and 66.8. In these less-densely vegetated areas, floodwaters appear to have partially scoured soil and vegetation in the last ten to twenty years. Here, the vegetation is either larger trees that survived the flood-scour or young establishing vegetation. The medium-to-high floodplain surfaces (three to six feet above the channel bed) have maturing forests of 50-plus years old where clearing has not occurred. The higher floodplain surfaces have maturing mixed forests that also include young (5- to 25-year-old) pine trees and a slightly less dense understory. The presence of young pine trees on the high floodplain surfaces indicates a relatively modern decrease in floodplain connectivity on these surfaces – likely the result of incision. The uncleared high floodplain surfaces that flank the active floodplains are vegetated with a mix of maturing conifers that include pine trees. The understory on the high floodplain surfaces has more grasses and forbs and is less variable and less dense than the understory on the active floodplain surfaces.

Where clearing or thinning has occurred, the complexity of the understory and the density of the maturing trees have been reduced. Two floodplain surfaces have been classified as disconnected from the channel due to vegetation clearing and surface grading. The disconnected floodplain surfaces are located on river-right between RM 67.9 and 68.15 and on river-left between RM 67.45 and 67.55. The small disconnected floodplain unit on river-left is set off of the channel approximately 180 feet behind a vegetated floodplain. This area is partially cleared with a dug pond and levee for private recreational use. Modern partial vegetation clearing has occurred on the active and high floodplains in Reach 4 on river-right from RM 66.35 to 66.7, RM 67.45 to 67.7, RM 68.3 to 68.75, and RM 68.9 to 69.1, and on river-left from RM 66.2 to 66.35, RM 66.85 to 67.3, and RM 67.4 to 67.65. Along the riprapped banks at the Mazama Bridge, sparse communities of willow and dogwood cling to the spaces between the angular boulders. The main channel in Reach 4 is wider than the average tree height, thus shading is partial and limited to only 20 to 70 percent of the channel depending on the time of day.

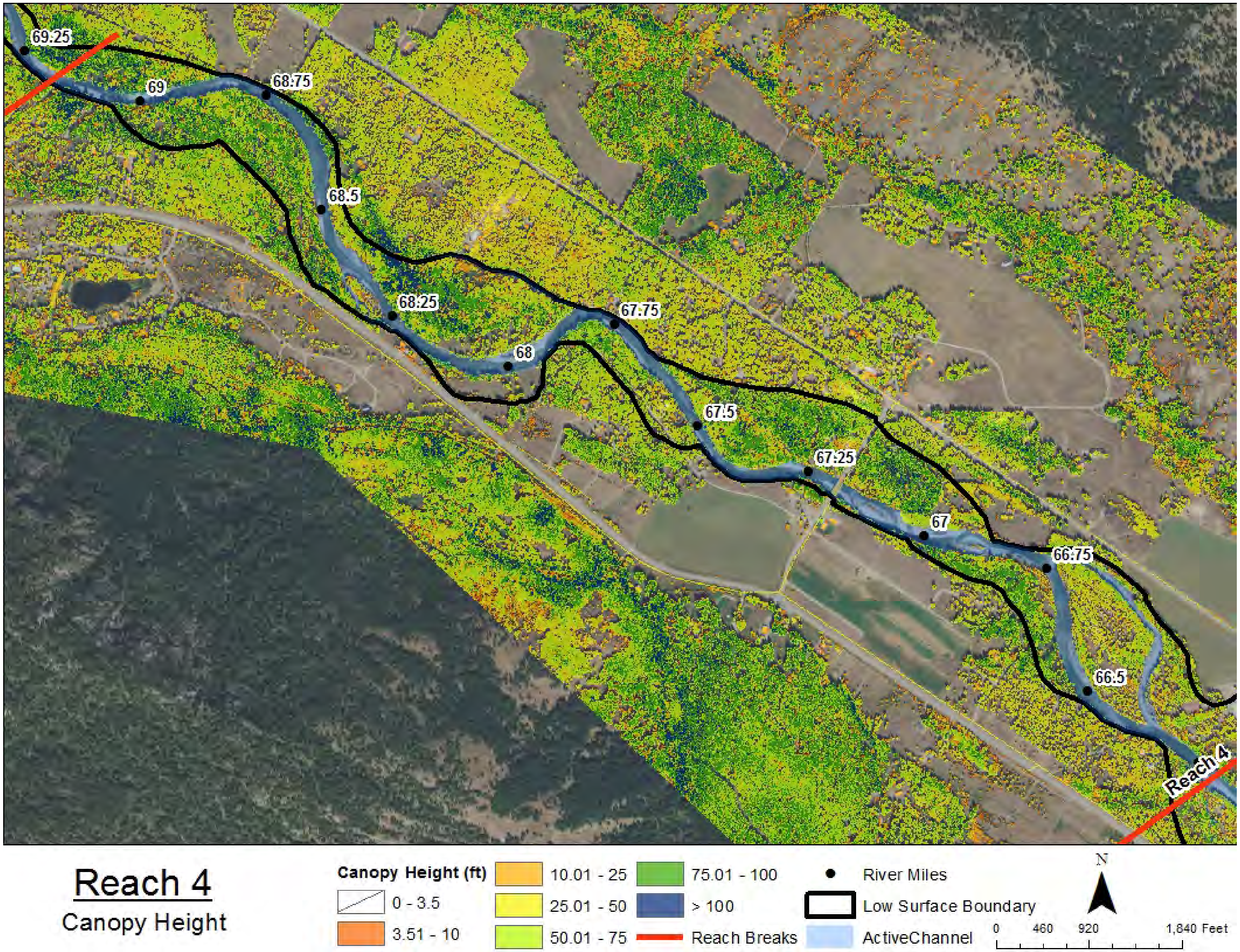

Figure 76. Vegetation canopy height for Reach 4 -- derived from LiDAR first return (highest hit) data (includes buildings and other human infrastructures).

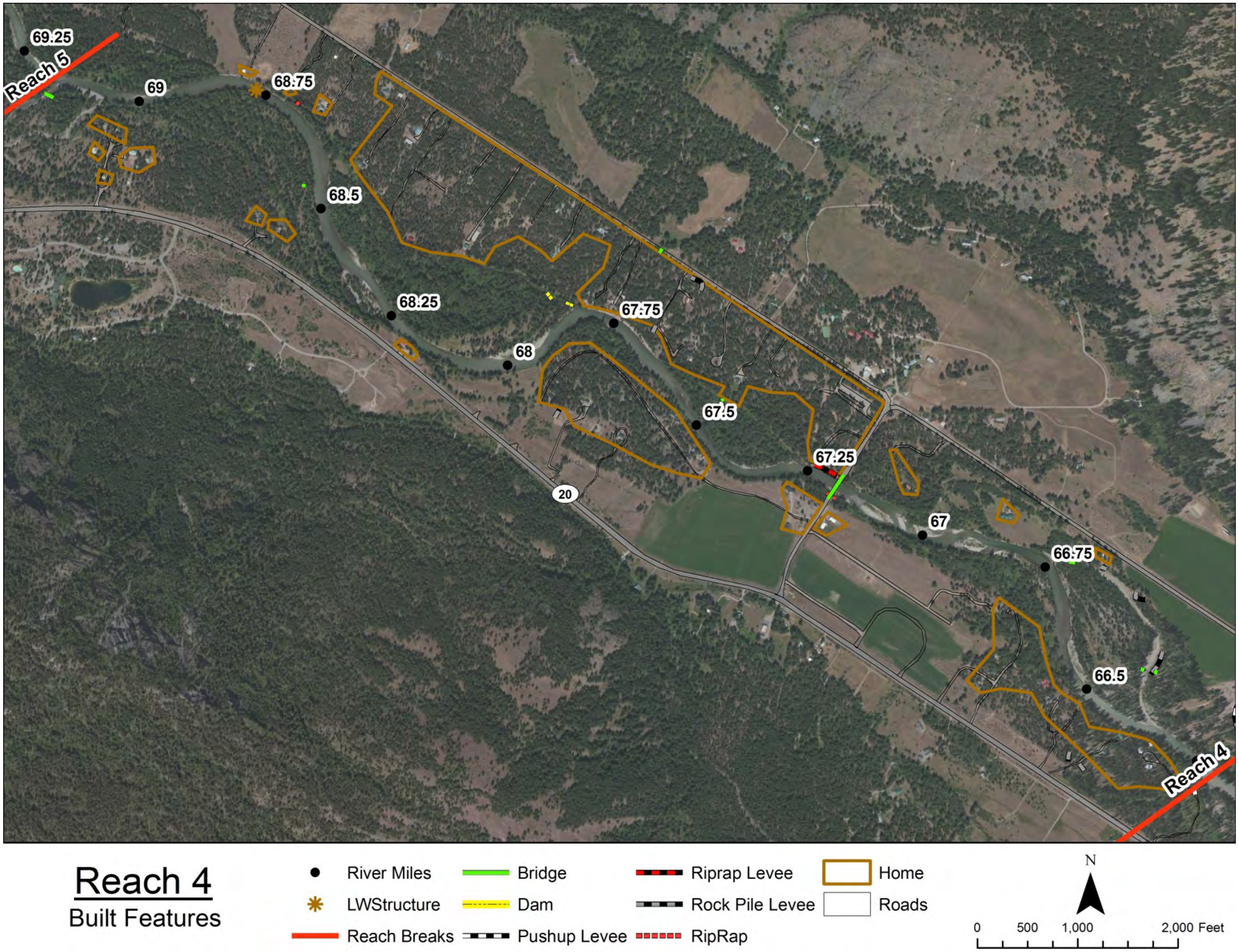

Figure 77. Primary human features in Reach 4.

3.4.3 Human Alterations

Human features are mapped in Figure 77. The primary human alterations in the reach include the following, and are described further in the subsections below.

- Changes to floodplain function and off-channel habitat
- Changes to streambank complexity and riparian impacts
- Changes to channel migration and sediment supply
- Changes to instream habitat and channel complexity

Changes to Floodplain Function and Off-Channel Habitat

Floodplain function and off-channel habitat have been altered in sections of Reach 4 due to floodplain grading and vegetation removal. Surface grading and vegetation clearing have disconnected sections of the modern floodplain on river-right between RM 67.9 and 68.15 and on river-left between RM 67.45 and 67.55. Reduced vegetation and grading alters normal surface flow routing and sediment delivery across the floodplain surfaces. The grading on river-left at RM 67.45 includes a dug pond with a levee. This relatively small pond captures surface flow from a groundwater-fed floodplain tributary before it connects to the mainstem channel. This eliminates the potential cold-water, off-channel habitat that this tributary could provide to the reach. Similarly, a dug pond and levee constructed on the river-left floodplain at the downstream boundary of the reach captures groundwater as well as surface water from an incoming tributary for private irrigation and recreational use. Both of the ponds were dug into abandoned channel scars that, if reconnected to the mainstem channel, could potentially provide perennially available off-channel habitat.

Changes to Streambank Complexity and Riparian Impacts

Streambank complexity and riparian vegetation in Reach 4 have been reduced where channel banks have been cleared of vegetation and/or armored with riprap. Vegetation clearing and thinning reduces bank and surface roughness and stability. It also decreases the hydro-ecological benefits that established riparian vegetation provides: shade, large wood, nutrients, and the regulation of sediment inputs. Almost all of the glacial outwash terrace banks and surfaces have been cleared for agricultural and home site development in Reach 4 – decreasing vegetation input potential. Although approximately 70 percent of the floodplain banks are at least partially vegetated, vegetation clearing and thinning has reduced modern riparian function on river-right from RM 66.35 to 66.7, RM 67.45 to 67.7, RM 68.3 to 68.75, and RM 68.9 to 69.1 and on river-left from RM 66.2 to 66.35, RM 66.85 to 67.3, and RM 67.4 to 67.65.

The large boulder riprap at the Mazama Bridge (RM 67.2) inhibits bank-toe erosion and natural bank and hillslope processes, thus altering localized sediment inputs to the system. The riprap also reduces the complexity of the riparian vegetation and notably decreases the potential for the establishment of mature tree stands. Additionally, this reduces localized shade to the channel and removes the potential for large wood recruitment in this area. The riprap armors both channel banks at the bridge and extends approximately 250 feet upstream from the bridge on river-left.

Changes to Channel Migration and Sediment Supply

Bridge crossings impact natural geomorphic processes of the Methow River in Reach 4 and its primary tributary, Early Winters Creek. The Mazama Bridge and its associated abutments and riprapped banks constrict the channel's width and limit lateral channel processes by locking the pathway of the channel in place at RM 67.2 (Figure 78). Early Winters Creek has two bridge crossings that influence its lateral processes across the top of its alluvial fan. The Highway 20 Bridge and a Methow Valley Community Trail footbridge cross the creek near each other approximately 550 yards upstream from the confluence. The bridges and their associated abutments and riprapped banks locally lock the pathway of the creek in place. This can promote incision and influence downstream sediment delivery to the Methow River. However, below these bridges, the creek is laterally active, creating a secondary channel that traverses the fan to the mainstem channel. An old river crossing located 280 yards upstream from the confluence was removed over twenty years ago – likely by flood waters. When in use, this crossing likely restricted the pathway of the creek as well as sediment delivery to the mainstem.

Figure 78. Mazama Bridge and riprapped bank on river-left (RM 67.2). (8/28/2014)

New but small cement bridge abutments and rock pile levees constructed on the banks of the side-channel on river-left between RM 66.35 and 66.75 impose potential restrictions on lateral migration. uring high flows, activation of the side-channel creates an island feature that is otherwise connected to the Methow Valley Community Trail network. Bridge abutments appear to be part of two new footbridges that will allow island access when the side-channel is wetted. A set of cement bridge abutments is located 200 feet from the upstream confluence and another set is located 550 feet from the downstream confluence. The abutments are built on the existing banks and thus restrict lateral channel processes (migration or widening). The rock piles are the result of surface grading on the adjacent alluvial surfaces.

Changes to Instream Habitat and Channel Complexity

Channel geomorphology throughout much of Reach 4 is simplified, except in the short section between RM 67.85 and 68.15 where large wood and sediment accumulations locally increase channel complexity. Otherwise, the channel is laterally stable, comprised of extended riffles and glides, lacking in large wood accumulations, and is experiencing a modern trend of bed incision. From the late 1800s to the early 1900s, records indicate that loggers utilized the mainstem channel to transport cut timber to mills located near the town of Mazama (RM 67.25) and to other mills downstream (Devin 1997). This required clearing the channel of natural log jams and any other obstructions (large boulders, etc.). Following the large floods of 1948 and 1972, in an effort to protect bridges and other infrastructures, it is likely that the US Bureau of Reclamation did additional clearing of large wood above RM 67.25 -- specific locations of these activities are not all recorded (USBR 2008 – Appendix O). The expected impacts of log drives and/or "cleaning" a channel include bed scour, channel and bank simplification, and a reduction in habitat complexity (Nilsson etal. 2005, Wohl 2006, Miller 2010). These practices likely amplified modern incision throughout much of the reach and removed the gravels and fines from the channel bed.

3.4.4 Recommended Actions

Recommended actions in Reach 4 are focused on increasing channel complexity and lateral dynamics as well as improving side-channel and floodplain connectivity. Complexity and lateral dynamics can be addressed by adding large wood jams to the main channel to create bars and islands, and adding large wood jams to channel margins to enhance cover to existing features and promote localized wood recruitment. Channel margin jams are suggested to initiate pool development and to enhance complexity in existing pools. A meander bend jam on river-left at RM 68.75 could shift flow energy from the cut bank (with a dwelling) towards the floodplain on the opposite side. Log jams could also be used to capture fluvially-transported wood from upstream reaches. The large jams downstream of the Mazama Bridge indicate that fluvial wood is available if stable jams can be constructed to capture and retain it.

Side channel connectivity can be addressed by removing unnecessary push-up levees and installing apex jams at the upstream end to encourage split flow. The pond/gravel pit on river-left at the boundary between Reaches 4 and 3 has the potential for reconnection to the mainstem (Figure 61). Native riparian vegetation restoration where clearing has occurred is also recommended.

Restoration recommendations recognize the importance of maintaining connectivity of the mainstem channel to perennial or groundwater-fed tributaries and side-channels. This has been identified as a critical component for fish survival in a system with the potential to seasonally dewater. Improving fish access to groundwater-fed areas, including the ponds in the river-left floodplain near RMs 67.5 and 66.25 could provide important low water refuge. Lower Early Winters Creek and the mainstem area just downstream of the confluence remain wetted even during very dry periods. Improving access to lower Early Winters Creek, and improving habitat conditions around the confluence area, could also help to provide low water refuge.

See Section 4 of this report for the restoration strategy and specific project recommendations for the reach.

3.5 REACH 5

Refer to Section 2.2 and* 2.8 *for geologic and geomorphic context of the study area and explanation of terminology.

3.5.1 Reach Overview

Reach 5 is 2.1 miles long and extends from RM 69.20, at its confluence with Early Winters Creek, to RM 71.30, at its confluence with Goat Wall Creek. Except for the upstream-most 900 yards on river-left at the Goat Wall Creek alluvial fan (which is within the Okanogan National Forest), property in Reach 5 is privately owned (Figure 79).

The channel is laterally active with a moderate sinuosity of 1.13 and an average stream gradient of 0.6%. The channel is primarily a single-thread stream with braided sections occurring where sediment accumulations create relatively large mid-channel and transverse bars at low flow. The dominant channel type in the upper half of the reach is riffle-pool and the dominant channel type in the lower half is riffle-glide. The substrate of the channel is dominated by cobbles and gravels. The modern floodplain is also composed of cobbles but topped with gravels and sands. Reach metrics are provided in Table 11 and Figure 81.

The reach is semi-confined at its downstream end from RM 69.1 to 69.55 between the Early Winters Creek alluvial fan terrace on river-right (west side of the channel) and a glacial outwash terrace on river-left (the east side of the channel). The remaining upstream portion of the reach is unconfined. The modern floodplain has an average width of 721 feet and the channel's average bankfull width is 95 feet. However, active floodplain width varies from as narrow as 85 feet at RM 70.3 to approximately 1,800 feet at RM 69.85. Active side-channel and off-channel features increase system complexity from RM 69.25 to 69.8 and from RM 70.4 to RM 70.9. Floodplain scarring and deposition patterns indicate that high-flow events activate additional side- and off-channel features.

The habitat conditions in Reach 5 are discussed in Appendix A. Based on the REI analysis, 7 of 11 habitat indices are rated as either unacceptable or at risk (see Table 6). The salmon and steelhead redd distributions for the reach are mapped in Figure 79. Surface grading and vegetation clearing and thinning have occurred on most of the glacial outwash terrace surfaces adjacent to the reach, as well as on sections of the inset high floodplain surfaces. The floodplain surfaces are well vegetated with maturing forest (trees of 50 years or older). These forests provide wood to the system and enhance the roughness of bank and floodplain surfaces. Floodplain levees and riprap-armored banks impose local restriction on lateral migration and natural sediment input processes.

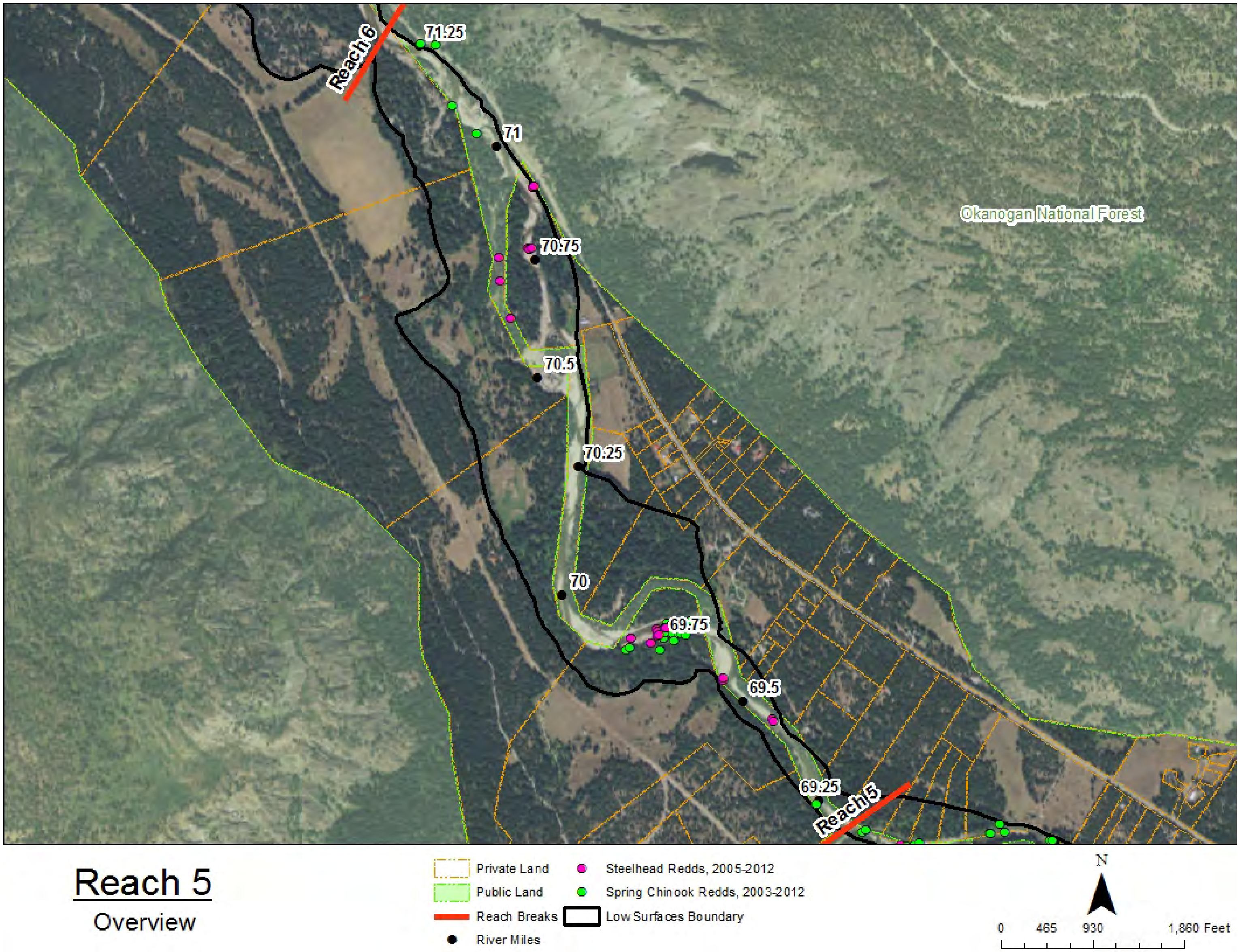

Figure 79. Reach 5 overview map with landownership and redd distribution.

Figure 80. Representative photo of Reach 5; looking upstream at RM 71. (8/26/2014)

Table 11. Reach 5 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	2.1
River Miles	69.20 – 71.30
Valley Gradient	0.7%
Stream Gradient	0.6%
Sinuosity	1.13
Dominant Channel Type	Pool-riffle-glide
Average Bankfull Width (feet)	95
Average Floodplain Width (feet)	721
Dominant Substrate	Gravel 61%; cobble 33%; sand 5%; boulder 1%
Bank Stability/Channel Migration	At Risk *(See Section 2.12)*
Vertical Channel Stability	At Risk *(See Section 2.12)*
Confinement ratio	Unconfined *(See Table 5)*

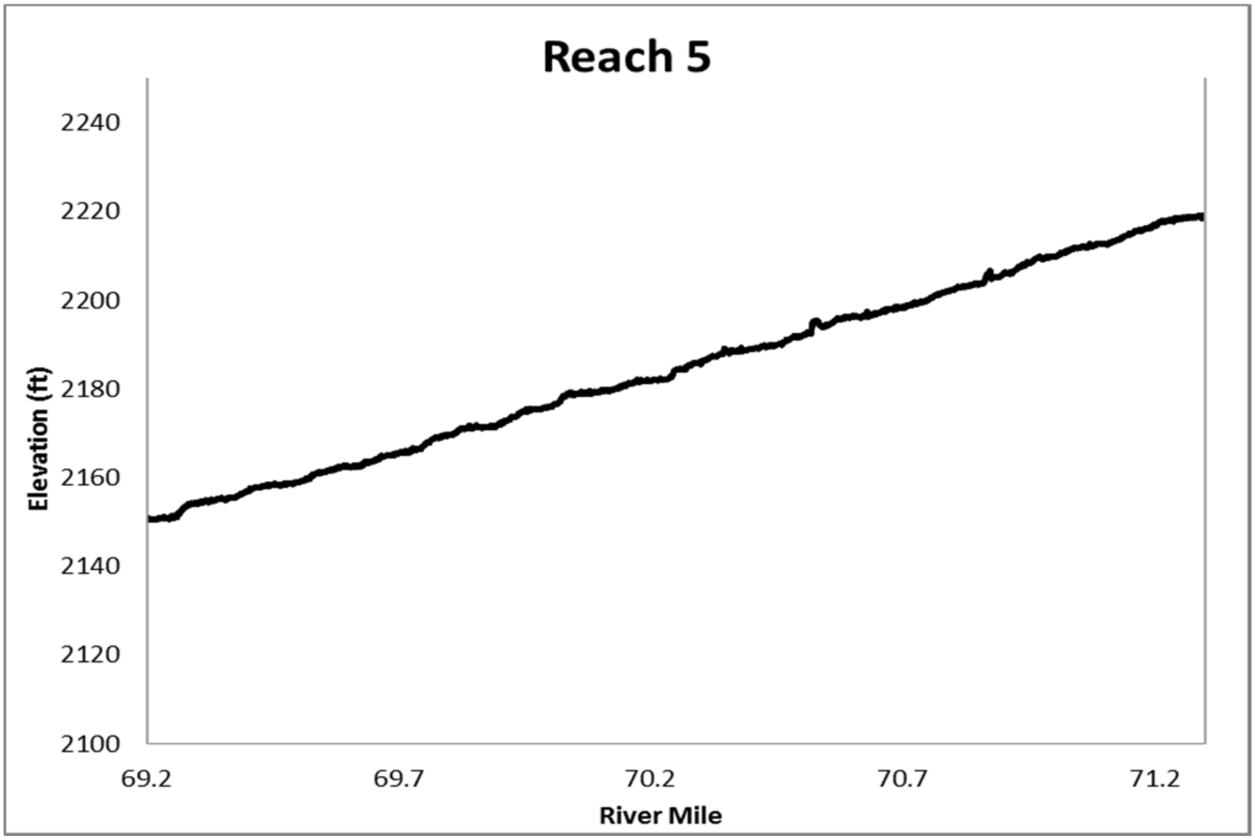

Figure 81. Longitudinal profile of the channel in Reach 5 (RM 69.20 to 71.30).

3.5.2 River Morphology and Geomorphic Processes

Geology and Landforms

Reach 5 is located in a wide, U-shaped valley most recently carved by Quaternary glaciation. Increased discharge and sediment regimes during early Holocene periods of glacial retreat resulted in a thick layer of glacial outwash deposits (coarse sand to boulder-sized alluvium) filling the valley floor. A large alluvial fan also composed of outwash material was created during this time at the mouth of Early Winters Creek. The channel, its active floodplain, and the high floodplain surface are inset below the glacial outwash terraces and the Early Winters Creek alluvial fan. The glacial outwash deposits form terraces on the west side of the valley in the upper half of Reach 5 (RM 69.75 to 71.3) and on the east side in the lower half of the reach (RM 69.2 to 70.85). Goat Wall Creek has a steep alluvial fan that also borders the channel in the upstream portion of the reach, but its toe is also inset below the outwash terrace (Figure 82).

Compared to the rest of the reach, the channel is less sinuous from RM 69.2 to 69.6 where it is confined within the high banks of an outwash terrace on river-left and the Early Winters Creek alluvial fan on river-right. Sinuosity is also reduced in the upstream section between RM 70.85 and 71.2 where the channel currently skirts the toe of the valley wall on river-left. Large side- and mid-channel bars composed of cobble and gravel are abundant upstream of RM 69.6 in the less confined portion of the reach. From RM 69.3 to 71.3, the large mid-channel cobble bars exposed at low-flow give the channel a braided form. Large boulders in the channel at RM 69.65 create a subtle knickpoint, with a change in bed elevation of approximately two feet.

Alluvial surfaces of Reach 5 consist of two high floodplain surfaces and a relatively wide active floodplain. The active floodplain surfaces range in height over the channel bed from three to five feet. The surfaces of the floodplains are fluvially scarred and the banks are topped with fines and debris deposited by recent high-flow events. The high floodplain surfaces are six or more feet higher than the channel. Where surface grading has not occurred, some subtle fluvial scarring is visible on the high floodplain surfaces. A narrow high floodplain surface flanks the floodplain on river-left between RM 69.2 and 69.4. The other high floodplain surface is relatively large and borders the active floodplain and the channel. Cut-banks on this surface contact the river or side-channels for approximately 175 feet near RM 69.65 and between RM 69.9 and 70.15, and between RM 70.45 and 70.55. From RM 71.2 to the upstream boundary at RM 71.3, the river-left side of the channel contacts the steep alluvial fan of Goat Wall Creek. Downstream from RM 69.75, the reach is bordered on river-right by the high cut-bank of the Early Winters Creek alluvial fan.

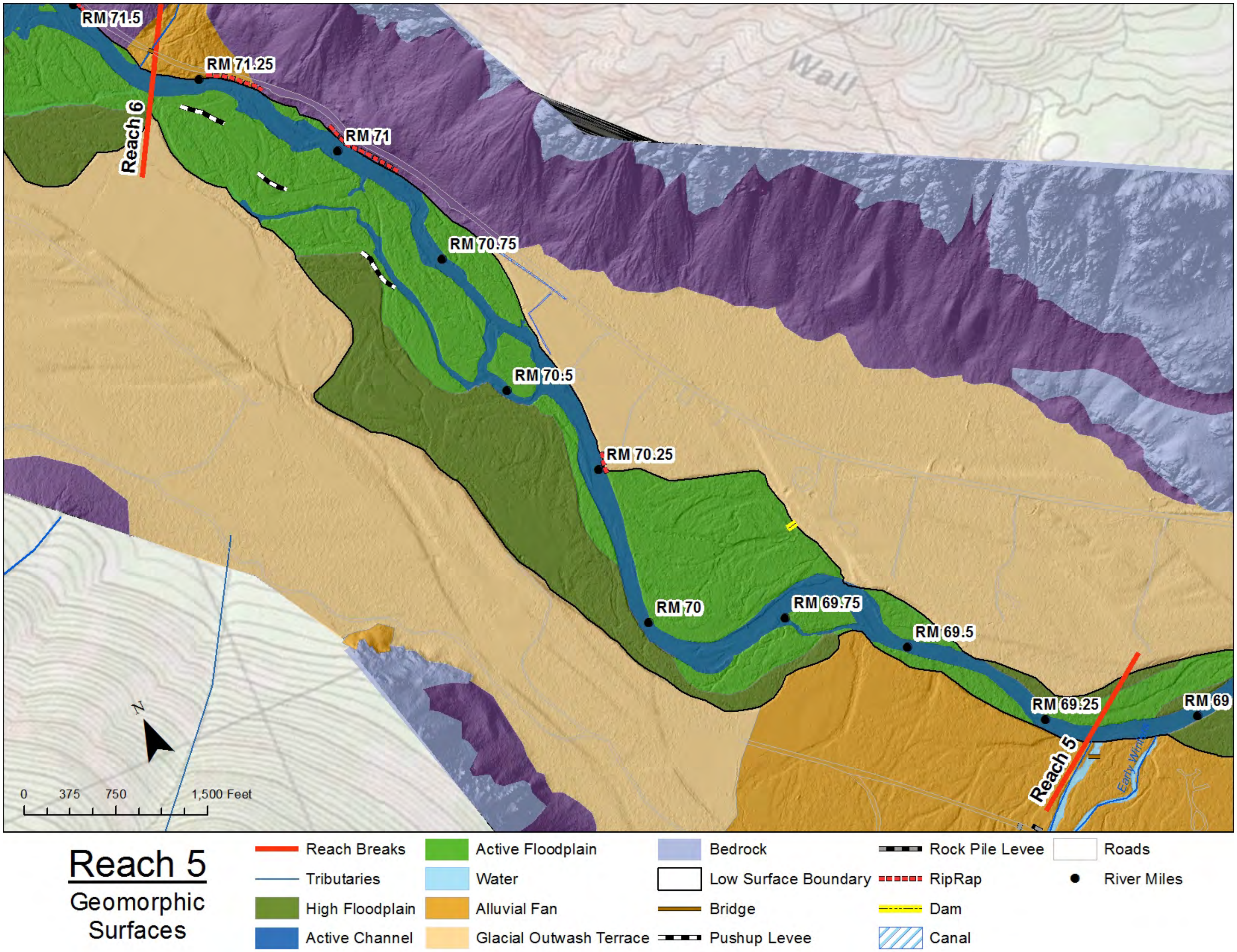

Figure 82. Geomorphic surfaces of Reach 5 with select human built features (bridges, levees, riprap, check dams, canals, and roads)

Figure 83. Pool with large boulders at RM 71.2. (8/26/2014)

The wide valley of Reach 5 is bordered by steep bedrock walls. These valley walls contribute talus and alluvial debris fan deposits to the valley floor and the channel. In the upper portion of the reach, direct talus and rock-fall inputs to the channel have occurred on river-left between RM 71.85 and 71.2. At this location, massive rock-fall boulders in the channel contribute to pool development and maintenance (Figure 83). However, modern rock-fall inputs are reduced here by the steep, fifteen-to-thirty-foot-high riprapped embankment of the Lost River Road. At RM 71, on river-left, the channel contacts a bedrock wall for a length of approximately 60 feet.

Extended side- and off-channel features add complexity to the geomorphology and hydrology of Reach 5. These features occupy abandoned channel scars located on active floodplain surfaces; and where connectivity with the channel is maintained, they provide important off-channel aquatic habitat. Groundwater inputs contribute cold surface water to these features. The most extensive off-channel feature is a groundwater-fed tributary located in a meander scar that is approximately 1,200 feet long (Figure 84). This feature enters the channel on river-right via a side-channel connector that runs between RM 70.6 and 70.4. The other two side-channel and two off-channel features are located between RM 69.25 and 69.8. This includes a groundwater activated tributary that enters the channel on river-right at RM 69.25. This tributary (off-channel feature) captures groundwater seepage from the cut bank of the Early Winters Creek alluvial fan.

Figure 84. Groundwater-fed tributary near RM 70.4; at downstream end looking upstream. (8/26/2014)

A variety of features in Reach 5 indicate that during high flow events, there is notable sediment transport as well as floodplain connectivity with the channel. Aerial photos from 1945, 1974, 1998, 2006, and the present, confirm that historically the channel migrated laterally within its modern floodplain via side-channel occupation, meander extension, and avulsion. Near both of the side-channels described above, there are scour and fill features composed of cobbles and gravels. These features occur where a flood event has filled in a side-channel or overflow channel with bedload material. Based on observed overbank deposits, floodplain scour, and hydraulic modeling, numerous floodplain channels are activated during flood events every two-to-ten years.

Hydrology

Reach 5 has a seasonally fluctuating flow regime. Spring snowmelt events regularly activate overflow channels and flood events inundate low floodplain surfaces on a regular basis (2 year flood recurrence) (Figure 86). Late summer, autumn, and winter low flows often leave most of the channel dry, with isolated pools susceptible to temperature extremes. During field observations in October 2014, the channel was dry from RM 70.2 to 71.75, except in isolated deep pools. Summer and autumn thunderstorms are capable of temporarily raising surface water elevations if discharge inputs are substantial enough to recharge groundwater elevations.

The valley floor and alluvial fans within Reach 5 are composed primarily of coarse-grained material. This material supports active hyporheic through-flow and groundwater influx from upstream and from the adjacent floodplains, terraces, and alluvial fans. Hyporheic flow at the downstream ends of active bars was observed in August and September 2014 during field surveys. However, Reach 5 is considered a "losing" reach hydrologically (Konrad et al 2005). This means that the channel contributes its incoming surface flow to the valley's large subsurface groundwater reservoir. Sections of the channel become dry when the incoming surface water flow is less than the quantity of water the channel is contributing to the groundwater reservoir. Sections of the channel in this reach often go dry in late summer and autumn, except for deep pools (Caldwell and Atterson 1992, Andonaegui 2000, Konrad 2006a). See Section 2.6 of this report for a description of the groundwater to surface water interchange processes that occur here.

Reach 5 receives surface water inputs from Goat Wall Creek, Caloway Creek, and a few ephemeral tributaries generated from the hillslopes. According to US Bureau of Reclamation surface flow estimates (2008 – Appendix J), discharge of the upper Methow River increases by one percent at the Goat Wall Creek confluence (river-left at RM 71.3) during high flows. Combined, Caloway Creek and the few other ephemeral tributaries that enter the valley on the west side of the reach are estimated to increase flows by an additional one percent during high flow periods.

It is important to note that most of the off-channel features in Reach 5 likely become active side-channels during flood or high-flow events. When disconnected from the channel during low flow periods, these features are wetted by groundwater. The groundwater appears to be generated from both hyporheic inputs from upstream and from the adjacent floodplains, terraces, and alluvial fans. Groundwater seepage was observed (August 2014) from the toe of the Early Winters Creek alluvial fan into the off-channel feature and the mainstem channel. This off-channel feature traverses the edge of the floodplain along the toe of the fan and eventually delivers the collected groundwater to the mainstem as surface flow at RM 69.25.

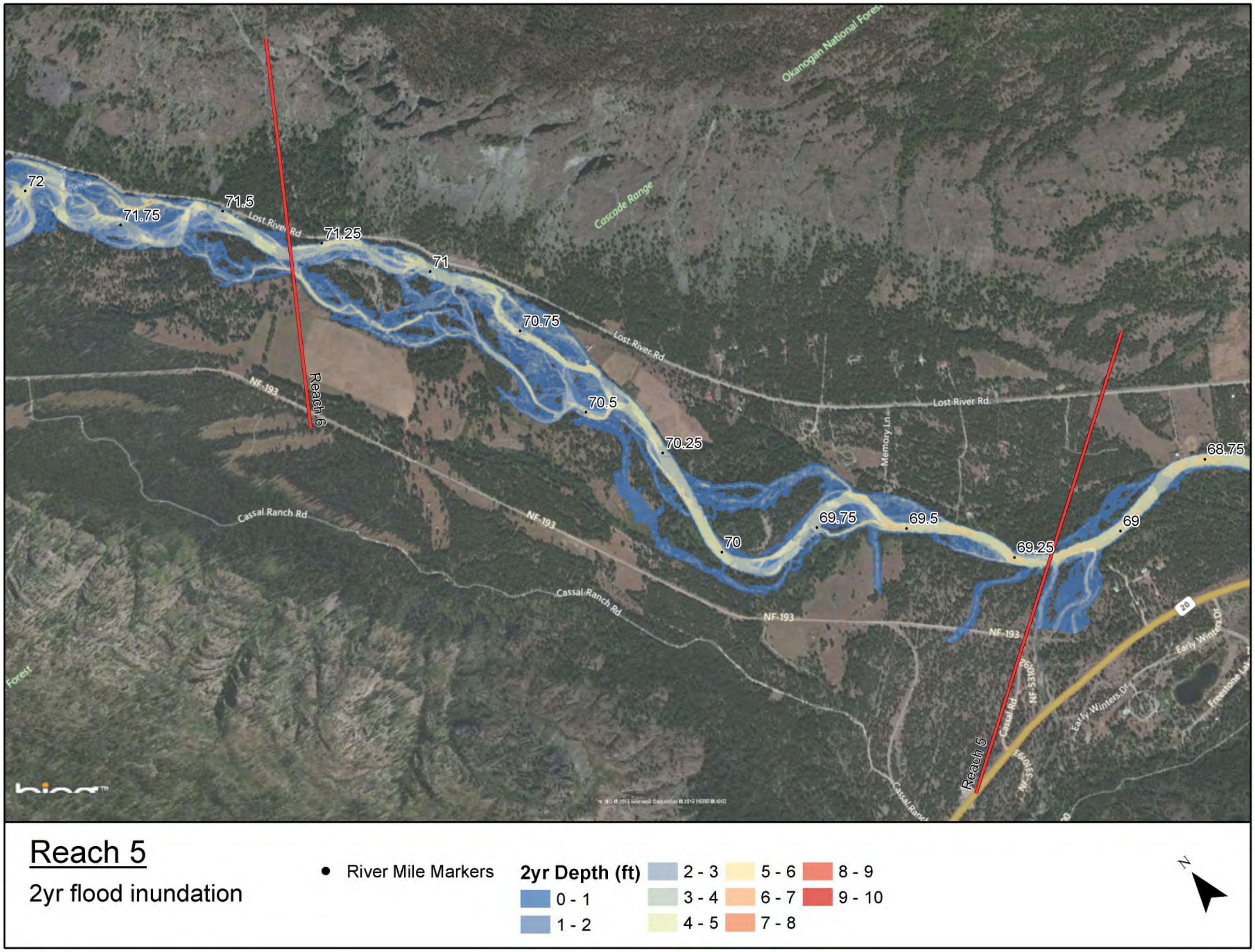

Figure 85. Floodplain inundation for 2YR flood in Reach 5 – developed using a 2D hydraulic model (SRH-2D) built with 2006 LiDAR elevation data.

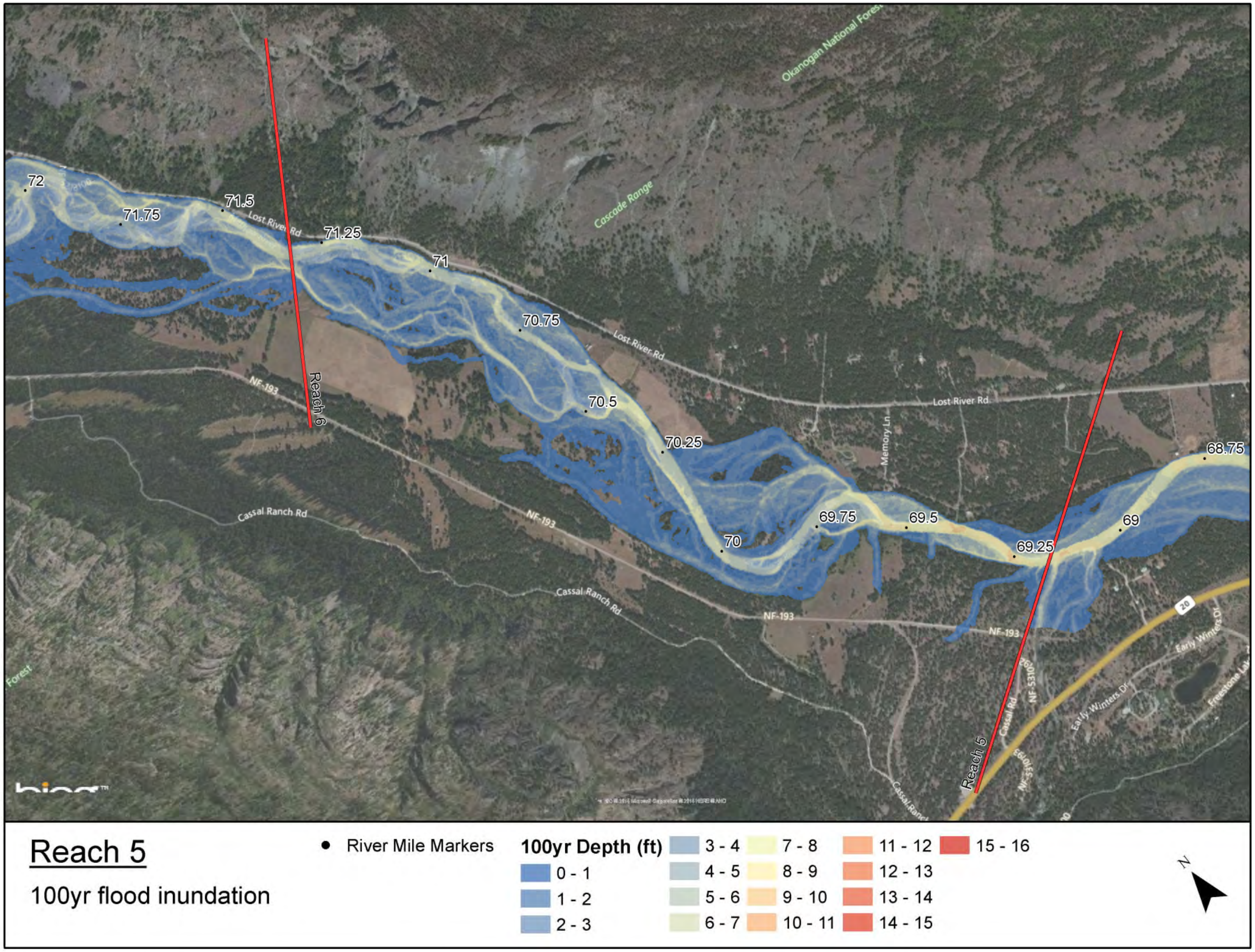

Figure 86. Floodplain inundation for 100YR flood in Reach 5 – developed using a 2D hydraulic model (SRH-2D) built with 2006 LiDAR elevation data.

Floodplain and Channel Migration Zone

Reach 5 is relatively active laterally (Figure 87). It is vertically stable in the upper third of the reach but potentially vertically unstable in the lower third of the reach. In the lower part of the reach, downstream from RM 69.6, the channel is naturally partially confined between a high glacial outwash terrace on river-left (approximately 7-12 feet above the channel) and the high cut toe of the Early Winters Creek alluvial fan (approximately 6-8 feet above the channel). In this section of the reach, the inset modern surfaces and channel are only 250 to 400 feet wide. Aerial photos from 1945 and 1974 show some lateral channel processes that were likely instigated by the large 1948 flood of record (Figure 87). More current aerial imagery indicates that since that time, lateral channel processes have been minimal in this confined section of the reach. A subtle knickpoint (approximately 2-3 feet high) at RM 69.65 is created by boulders that appear to be placed in the channel. The boulders are acting as a local grade and head-cut control on what could be minor upstream migrating bed incision. Reduced-but-not-eliminated floodplain connectivity occurs in the lower confined portion of the reach. Bar size and distribution is notably reduced to narrow, elongate lateral cobble bars in this section. The side- and off-channel features fed by groundwater are currently maintaining the hydrologic and geomorphic complexity in this section.

Upstream from RM 69.6 to the reach border at RM 71.3, the channel is considered mostly unconfined. Minor partial confinement occurs where the channel contacts bedrock, slope talus debris, and the Goat Wall Creek alluvial fan toe along the valley's edge between RM 70.75 and 71.3 on river-left. Confinement here is considered minimal due to the width of the active available floodplain at this location on river-right (up to 900 feet). However, remnant sections of push-up levees located on river-right at RM 70.75 (400 feet), RM 71 (250 feet), and RM 71.25 (350 feet) provide evidence of an attempt at channel confinement in the past. The levees are located on what is now active floodplain, but according to aerial imagery was the channel bank in 1945. The levee has been breached and historical aerial imagery confirms channel migration behind all of the levees except the one located at the edge of the high floodplain surface at RM 70.75. This levee appears to have successfully diverted active channel flows from the bank of the high floodplain surface behind it. Partial confinement also occurs from RM 70.25 to 70.4 where the channel and its floodplain are constricted between a graded and cleared glacial terrace on river-left and a graded and thinned high floodplain surface on river-right. At the base of this outwash terrace bank (river-left at RM 70.3) is a naturally cemented cobble-sand shelf that is hardened and stable – further hardening this bank (Figure 88). This section of the reach has a constricted width of approximately 250 feet. The remainder of the reach is unconfined and laterally active.

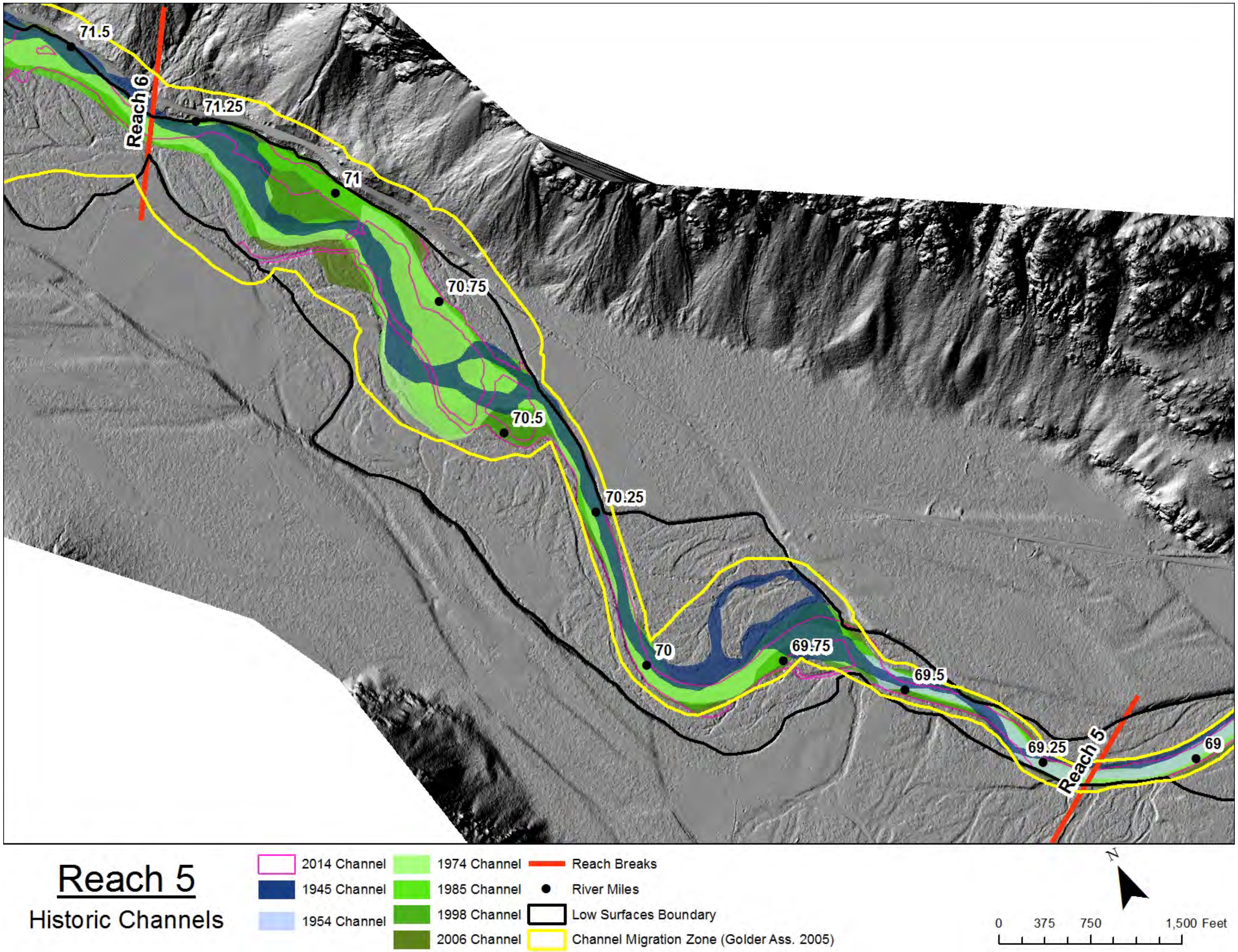

Figure 87. Historical channel locations for Reach 5.

Figure 88. Cobble-sand shelf -- hardened through plucking and armoring (RM 70.3). (8/26/2014)

Aerial photos from 1945, 1974, 1998, 2006, and 2011 confirm that modern lateral migration through side-channel occupation, meander extension, and avulsion has occurred in the past seventy years in Reach 5 upstream from RM 69.6. Active lateral processes generate large wood inputs to the channel through bank erosion and channel migration. Fluvial scaring and observed overbank deposits indicate that floodplain surfaces throughout reach 5 were recently inundated during high flow events – likely the 2006 and 2008 high flows. A variety of features in Reach 5 indicate that during high flow events, there is notable sediment transport as well as floodplain connectivity with the channel. In addition to active side- and off-channel features located in abandoned channel scars, there are scour and fill features on the floodplain from RM 69.6 – 70 and RM 70.4 – 71.3. During high flow events, these features experience bed scouring at peak flow and bed infilling during receding flow. Plentiful large active cobble bars indicate abundant sediment availability and transport throughout the reach. From RM 69.3 to 71.3, cobble bars exposed at low flow give the channel an active braided form.

Sediment

Based on field observations and two representative gravel count surveys, the substrate of Reach 5 is dominated by gravels (67%) and cobbles (29%) with minor sand (3%) and negligible boulders. Sand is found as overbank deposits on floodplains, as topping on high bars, and as still-water deposits in backwater features or at eddy points. Massive boulders (5 feet diameter or more) in the channel from RM 70.8 to 71.2 were locally sourced as rock-fall talus from the bordering valley wall on river-left. Floodplain surfaces are composed of cobbles and gravel with a thick topping of coarse sands and fines. The base of these surfaces contain large cobbles and small boulders. A developing soil horizon rich in loam and organic material tops the high floodplain surfaces. The high cut-banks of the glacial outwash terraces supply coarse sands, gravels, cobbles, and boulders. Goat Wall Creek and its alluvial fan contribute a mix of coarse sands to cobble-sized material at the upstream border of the reach. Sediment inputs from Goat Wall Creek may have been altered during periods of gold placer mining in the early 1900s (USBR 2008). Incoming sediment from upstream provides additional sand-to-cobble sized substrate during high flow. The side-channels and groundwater-fed tributaries (off-channel features) that traverse the floodplains contribute gravels, sands, and fines to the channel. Bedload throughout the reach is well sorted (has a similar diameter size range) and rounded, except for minor contributions to the channel from the bedrock and talus slopes on river-left between RM 70.85 and 71.25. These sediment contributions are generally larger in size and more angular.

Large Wood

Reach 5 has a high in-channel wood count of 321 pieces (155.6 logs per mile) and nine log jams. In-channel wood distribution in the reach is presented in Figure 89 as a density, or the number of wood pieces per 100 feet within each delineated channel unit type. The greatest abundance of in-channel wood occurs between RM 70.5 and 71.25 where large cobble bars are plentiful and a few of the massive rock-fall boulders act as racking agents for wood. Throughout the remainder of the reach, in-channel wood accumulations occur in conjunction with mid- and side-channel bars. Off-channel wood accumulations also occur on low floodplain surfaces. Single-piece and channel-spanning log jams occur in the side- and off-channel features. The width of the main channel is too great for channel-spanning accumulations to develop. Instead, wood accumulates on, across, and between the large cobble-gravel bars.

Large wood retention and recruitment is fairly good in Reach 5 with the exception of the riprapped and/or cleared banks. Even in the downstream section of the reach where the channel is confined and less complex, wood retention on the active bar surfaces appears only slightly reduced compared to the more complex middle section of the reach. Retention of wood is high in the upper section of the reach where channel complexity is greatest. Most of the wood in Reach 5 appears to be recruited from local banks or from immediately upstream of the reach boundary. The well-vegetated floodplain and alluvial surfaces adjacent to the channel offer high recruitment potential. Past and current lateral channel migrations resulted in local wood inputs to the channel. In August 2014, fresh wood inputs were observed from eroding banks (Figure 90).

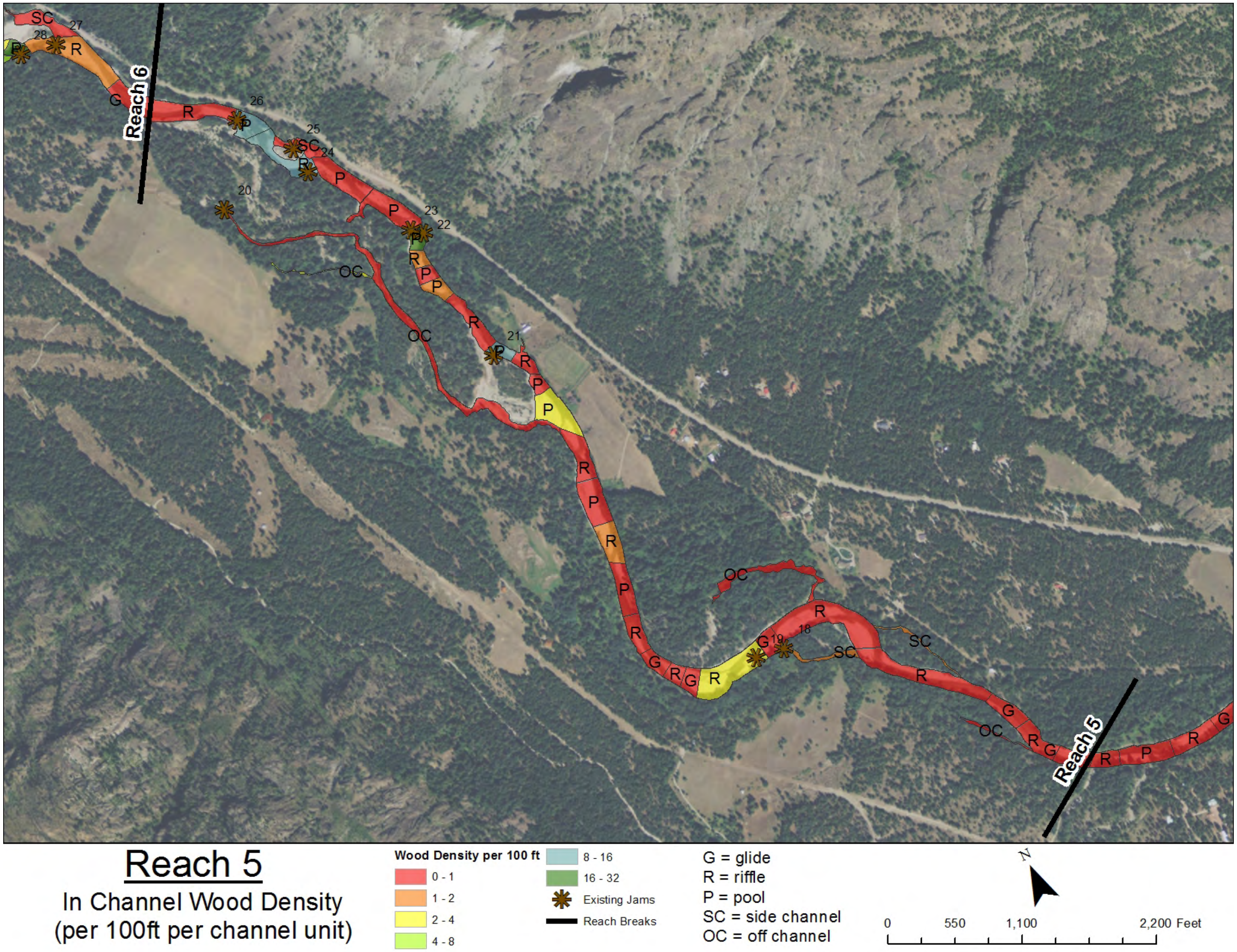

Figure 89. In-channel large wood distribution (qualifying wood pieces per 100 ft channel length) within delineated channel units in Reach 5.

Figure 90. A) Active large wood recruitment through bank erosion (RM 70.7); B) Large wood accumulations on bars. (8/27/2014)

Where vegetation has been removed or the banks have been armored, recruitment potential of large wood is reduced or eliminated. Vegetation has been cleared or thinned for home-site development and/or agricultural purposes along every section where the channel contacts outwash terrace banks (river-left RM 70.25 – 70.55, RM 69.6 – 69.65, and RM 69.4 for 200 feet). Vegetation thinning and clearing has also occurred on river-right adjacent to the channel on the high floodplain surface from RM 69.9 to 70.1 and adjacent to a side-channel from RM 70.45 to 70.85. Large boulder riprap placed on the banks reduces or eliminates wood recruitment on river-left at RM 70.25 (for 180 feet) and from RM 70.9 – 71.1 and RM 71.15 – 71.25. The cobble/soil push-up levee located on the banks of the high floodplain surface on river-right (RM 70.75 to 70.85) reduces recruitment behind and downstream from it.

Vegetation

Anthropogenic influences result in varied vegetation densities in Reach 5 (Figure 91). For example, most of the high glacial outwash terraces have been cleared or thinned, and frequently graded, for agriculture and/or home-site development. As a result, the vegetation composition on the altered terrace banks has been reduced to pastures and lawns, sometimes with sections of sparse pine trees. The most extreme example of vegetation clearing and surface grading is on the outwash terrace on river-left between RM 70.25 and 70.55. The Early Winters alluvial fan has also been thinned and cleared for road, campground, and home development. However, the edge of the fan along river-right between RM 69.2 and 69.55 has a wide vegetated buffer that is composed of maturing forest (trees 50 years old and over) with mixed conifers. The Goat Wall Creek alluvial fan hosts a maturing forest of mixed conifers along the channel on river-left between RM 71.25 and 71.3 that is 50 to 125 feet wide. The remainder of the fan toe edge is dissected from RM 71.15 to 71.25 by the Lost River Road. The road cut is riprapped and tree density is greatly reduced there.

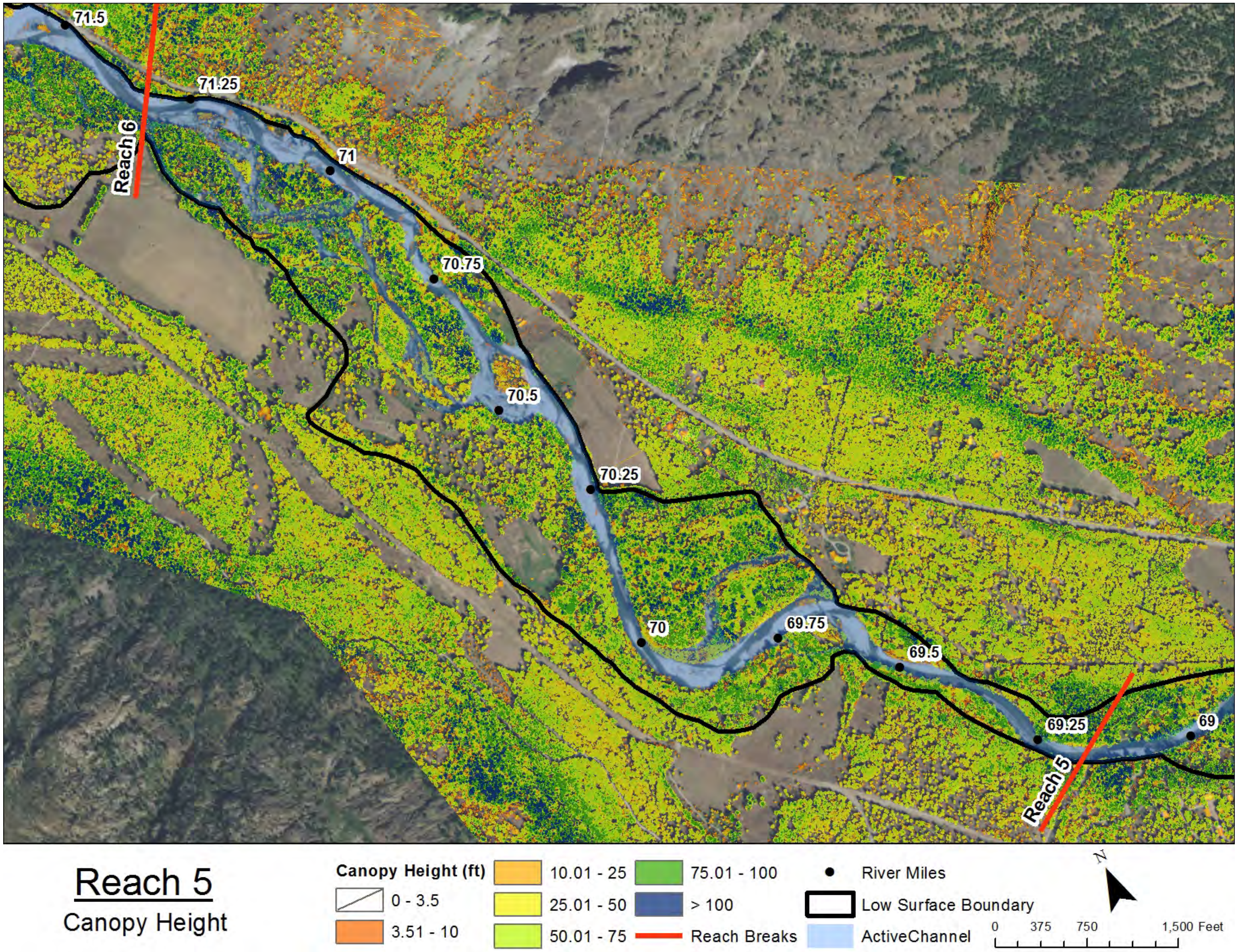

Figure 91. Vegetation canopy height for Reach 5 -- derived from LiDAR first return (highest hit) data (includes buildings and other human infrastructures)

The floodplains of Reach 5 are vegetated with maturing forests (50-plus years old) composed of mixed deciduous and conifer trees with a thick, well-developed understory. Historic logging reduced stand density to some degree on most of the inset surfaces. Noticeable vegetation clearing, thinning, and surface grading have occurred on sections of the high floodplain surface on river-right between RM 70.15 and 70.8 and RM 69.75 and 69.85. Where these actions have occurred, the tree density is reduced and the understory has been simplified such that it is dominated by grasses and forbs. All of the floodplain surfaces in Reach 5 are well vegetated with maturing forests and a healthy understory – although stand density may be slightly reduced due to past historical logging. The low active floodplain surfaces (such as high bar tops) contain establishing vegetation that includes willow, cottonwood, and alder (0-15 year age range). The age of the establishing tree stands on these features aids in identifying the history of flooding (scour and fill) and channel migration in the reach. The higher floodplain surfaces are vegetated with a maturing mosaic forest that includes both conifers and deciduous trees such as cedar, fir, cottonwood, and alder; trees in these areas range from 25 to 100 years old. The understory on the floodplain surfaces is dense and includes grasses, forbs, dogwood, maple, devil’s club, equisetum, and snowberry.

The vegetation on surfaces adjacent to the channel increases bank and floodplain roughness and stability throughout the reach. Along the sections of riprapped banks and road fill on river-left at RM 70.25 (for 170 feet), between RM 70.9 and 71.1, and RM 71.15 and 71.25, either no vegetation exists or very sparse communities of willow and dogwood cling to the spaces between the angular boulders near the channel. Here, only a few trees are located atop the 15 to 30 foot high embankments. The side-channels receive shade and organic material where established floodplain vegetation exists. The main channel in Reach 5 is wider than the average tree height, thus shading occurs primarily along the banks.

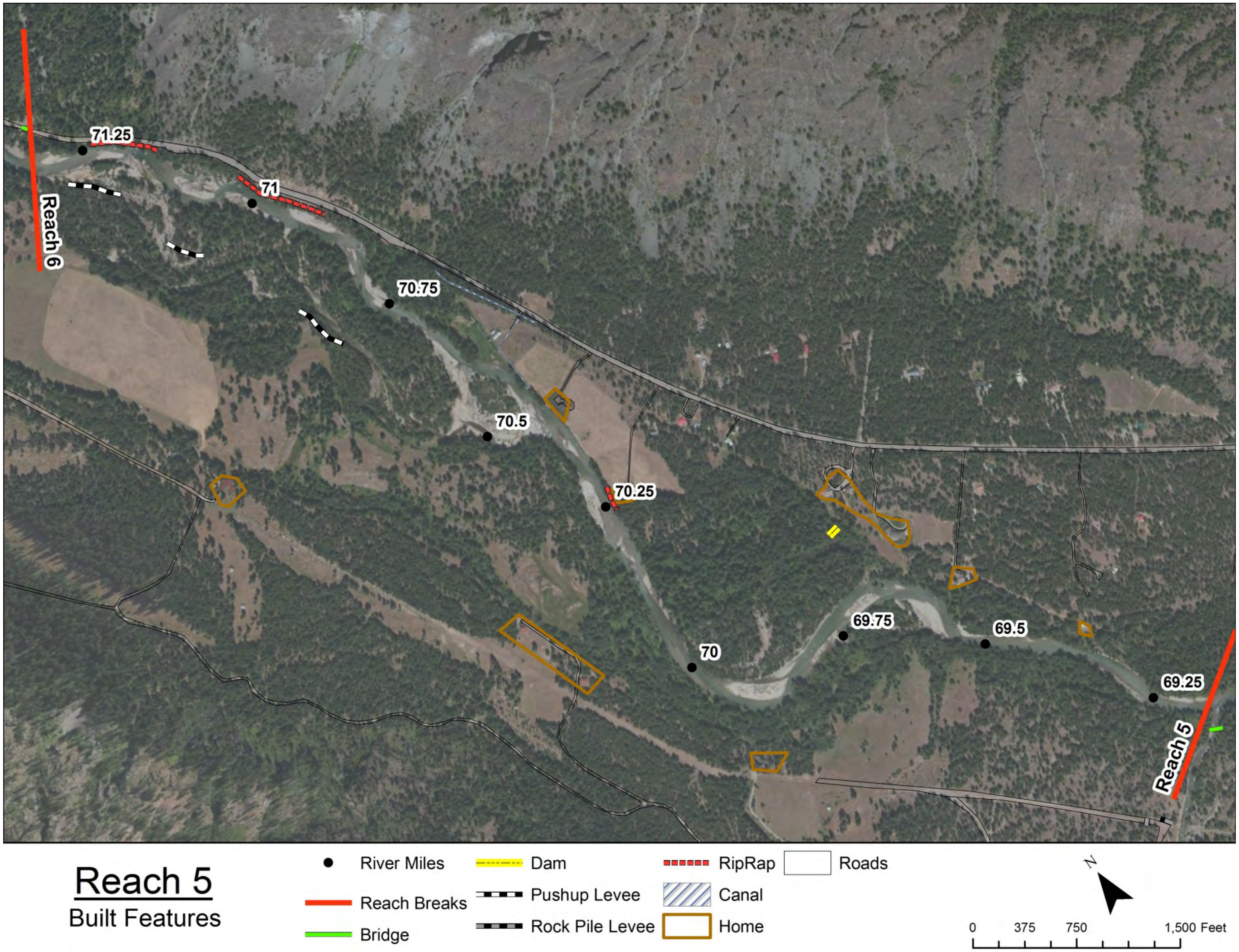

Figure 92. Primary human features in Reach 5.

3.5.3 Human Alterations

Human features are mapped in Figure 92. The primary human alterations in the reach include the following, and are described further in the subsections below.

- Changes to floodplain function
- Changes to streambank complexity and riparian impacts

Changes to Floodplain Function

Historical vegetation removal, grading, and levee construction have had some impact on modern floodplain function. The floodplains are currently vegetated with maturing forests that include trees 50 to 100 years in age. However, historical logging from the early 1900s (evidenced by stumps and cut wood) has resulted in a minor reduction in stand density and tree height across the modern floodplain surfaces. The initial impacts of logging on floodplain function would have been greater than the residual impacts that we see today. Initial impacts would have included a reduction of bank and surface roughness, increased avulsion rates and instability, and limited large wood recruitment potential.

The push-up levee at the edge of the high floodplain surface on river-right at RM 70.75 disconnects floodplain processes. This levee is approximately 400 feet long and diverts channel flow away from the banks of this surface. It is likely that this levee is partially responsible for the disconnection of this surface from the channel. Remnant sections of another push-up levee are located on the floodplain on river-right between RM 71 and 71.25. This levee has been breached by flood waters leaving only an upstream section that is approximately 350 feet long and three feet tall and a downstream section approximately 250 feet long, four feet tall, and 15 feet wide. The downstream section of this levee has a flat road prism on top (Figure 93). It appears this levee was originally built along the 1945 channel boundary, which would have affected floodplain connectivity until the levees were finally breached and eroded. Although the levees have been breached, their presence continues to influence flood inundation patterns and possibly the location of the main channel and side-channels.

Figure 93. Section of the breached push-up levee on the floodplain near RM 71.1. (8/26/2014)

Changes to Streambank Complexity and Riparian Impacts

Stream bank complexity and riparian vegetation in Reach 5 have been reduced along a levee and at riprapped banks. Construction of the Lost River Road (on river-left between RM 70.75 and 71.3) resulted in banks that are reinforced with large angular boulders. This inhibits toe erosion and natural bank and hillslope inputs from the slope talus and alluvial fan deposits, thus altering localized sediment inputs to the reach. The riprap also reduces the complexity of the potential riparian vegetation and limits the establishment of mature tree stands. These impacts reduce shade and large wood recruitment potential. Similarly, a boulder-riprapped bank at the toe of the high outwash terraces on river-left at RM 70.25 (175 feet long) reduces streambank complexity by altering natural sediment inputs and vegetation establishment. At this site, the riprap-reinforced bank also limits local lateral channel migration where it protects a private residence near the edge of the terrace surface.

Additional loss of riparian vegetation and the benefits it provides has occurred to some degree on most of the surfaces adjacent to the channel in Reach 5. Partial or complete vegetation removal along outwash terrace banks near the channel and/or its side- and off-channel features are visible on river-left between RM 69.35 and 69.75, and RM 70.25 and 70.55, and on river-right between RM 70.9 and 71.3. Sections of the high floodplain surface on river-left between RM 70 and 70.8 have also been cleared or thinned. Loss of vegetation near these features can increase local water temperatures, reduce natural bank stabilization, limit tree-fall nutrients, and reduce off-channel habitat complexity. The banks of the floodplain are well-vegetated with maturing forests, but evidence of historical logging here (a few stumps and cut wood) has resulted in a minor reduction of stand density and potential tree height. There is no modern clearing or homesite development occurring on the floodplains and thus these surfaces are naturally recovering. As a result, the active and high floodplain surfaces do provide both small and large wood to the channel through lateral channel processes. However, the loss of beaver populations in this reach has likely reduced riparian wood inputs to the mainstem as well as to the side-channels and tributaries.

3.5.4 Recommended Actions

Recommended actions in Reach 5 are focused on improving the habitat and connectivity of the existing side-channel network, enhancing floodplain function, increasing channel complexity, and restoring riparian function. Side-channel network enhancement can be addressed by removing push-up levees, placing apex jams to encourage split flows, adding large wood, and creating pools. Improving floodplain function can occur through removal of push-up levees and passive recovery of mature floodplain forests. Restoring riparian function can occur through native riparian vegetation planting where clearing has occurred. Channel complexity can be addressed with log jams and debris capture jams designed to collect and retain wood that is fluvially-transported into the reach.

Restoration recommendations recognize the importance of maintaining connectivity of the mainstem channel to perennial or groundwater-fed tributaries and side-channels. This has been identified as a critical component for fish survival in a system with the potential to seasonally dewater.

See Section 4 of this report for the restoration strategy and specific project recommendations for the reach.

3.6 REACH 6

Refer to Section 2.2 and** 2.8 **for geologic and geomorphic context of the study area and explanation of terminology.

3.6.1 Reach Overview

Reach 6 is 3.75 miles long and extends from RM 71.3, at its confluence with Goat Wall Creek, to RM 75, at its confluence with Lost River. Property ownership in Reach 6 is Washington Department of Fish & Wildlife, Okanogan National Forest, and private landowners (Figure 94). This is the longest reach in the study area. The reach has both semi-confined and unconfined sections. Confining features include glacial outwash terraces, alluvial fans, talus-draped hillslopes, levees, and riprap-armored banks. The channel is single-thread with a riffle-pool-glide form and a moderate sinuosity of 1.11 (Figure 95). The substrate of the channel is dominated by cobbles and gravels. The modern floodplain is also composed of cobbles and gravels, but topped with plentiful sands. The natural floodplain has an average width of 1,394 feet. In the middle portion of the reach, the maximum width of the floodplain was approximately 2,400 feet prior to human confinement of the channel. Floodplain width diminishes to approximately 275 feet at the downstream border, where it is naturally confined between alluvial debris fan deposits and a terrace. These and other reach metrics are provided in Table 12 and Figure 96.

Floodplain scarring and deposition patterns indicate that high-flow events activate side- and off-channel features where human alterations have not modified floodplain inundation processes. Historically, the channel was laterally active and had multiple side-channels. Modern migration rates and the number of off-channel features have been reduced over the last few decades by the installation of riprap and levees. However, combined sediment inputs from upstream, Lost River, and local cut-banks supply sufficient bedload to maintain active bars. Even in the artificially confined sections of the reach, the channel contains large bars composed of cobble and gravel; these add complexity and sinuosity at low flows. Side channels and groundwater-fed tributaries on the floodplain contribute habitat complexity to the reach where connectivity has not been blocked by levees or canals. On the floodplain adjacent to the channel, flood events create scour and fill features that are composed of bedload material. These features indicate active bedload transport during high-flow events.

The habitat conditions in Reach 6 are discussed in Appendix A. Based on the REI analysis, 8 of 11 habitat indices are rated as either unacceptable or at risk (see Table 6). The salmon and steelhead redd distributions for the reach are mapped in Figure 94. Although some of the floodplain and channel banks have been cleared or thinned of vegetation, most of the channel banks are vegetated with maturing forests. These forests provide large wood to the system and enhance the roughness of bank and floodplain surfaces. Where armored banks and home-site development obstruct channel and floodplain connectivity, natural geomorphic processes are compromised. The community of Lost River is located in the upper portion of the reach on the terrace and floodplain surfaces on the northeast side of the channel (river-left).

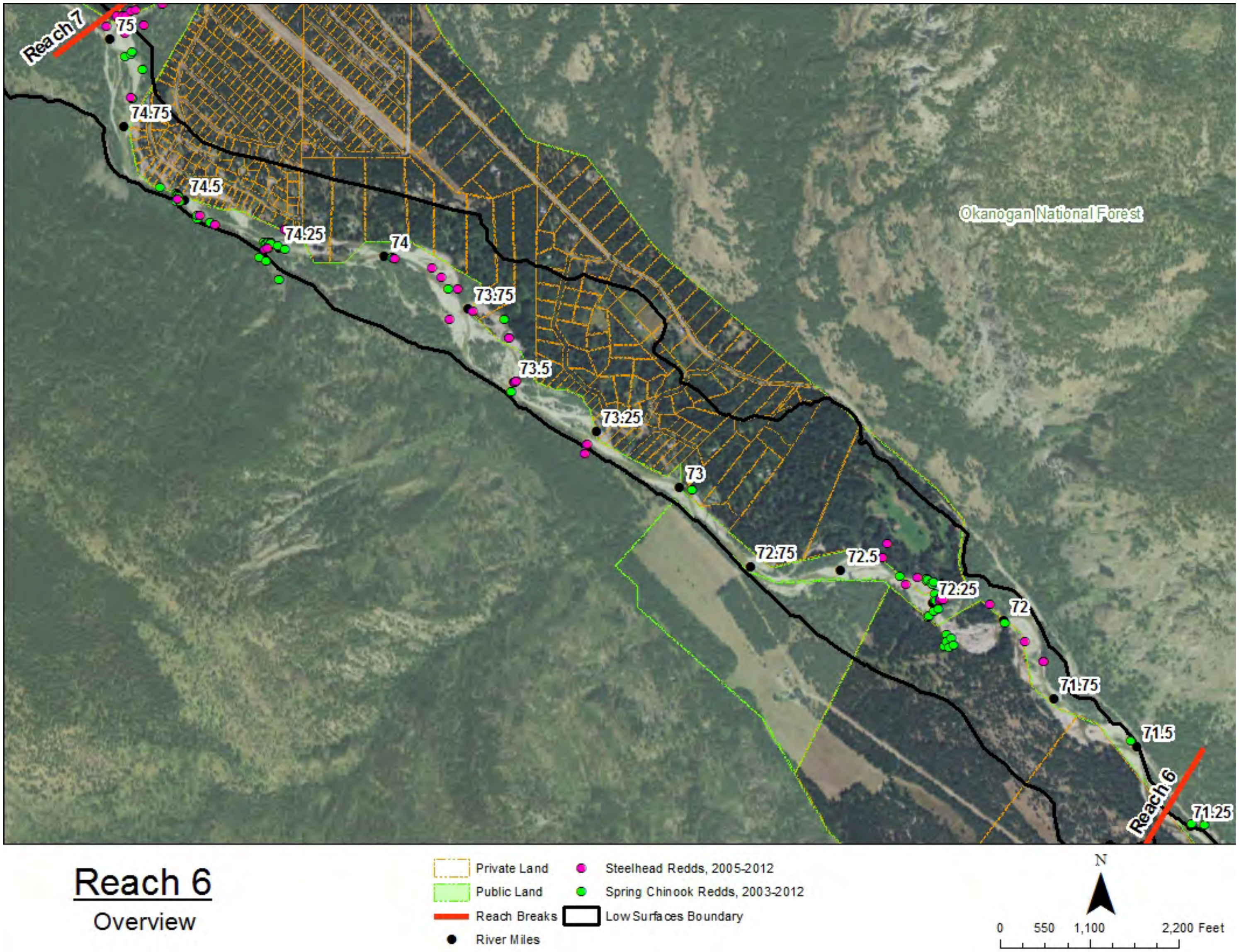

Figure 94. Reach 6 overview map with landownship and redd distribution.

Figure 95. Representative photo of Reach 6; looking downstream at RM 74.25. (8/14/2014)

Table 12. Reach 6 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	3.7
River Miles	71.30 – 75
Valley Gradient	0.8%
Stream Gradient	0.7%
Sinuosity	1.11
Dominant Channel Type	Pool-riffle-glide
Average Bankfull Width (feet)	100
Average Floodplain Width (feet)	1394
Dominant Substrate	cobble 51%; gravel 45%; boulder 2%; gravel 2%
Bank Stability/Channel Migration	Unacceptable *(See Section 2.12)*
Vertical Channel Stability	At Risk *(See Section 2.12)*
Confinement ratio	Unconfined *(See Table 5)*

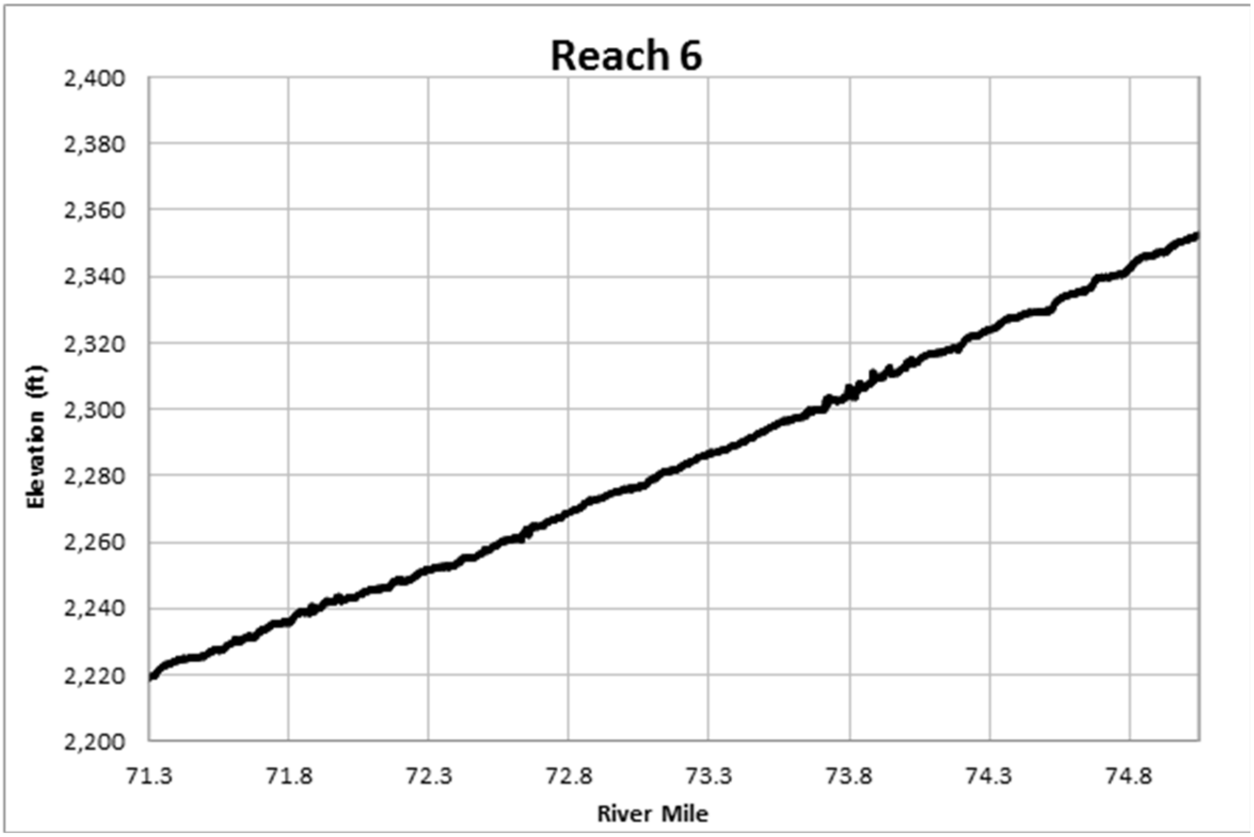

Figure 96. Longitudinal profile of the channel in Reach 6 (RM 71.30 to 75).

3.6.2 River Morphology and Geomorphic Processes

Geology and Landforms

Reach 6 is located in a wide, glacially-carved, U-shaped valley. Increased discharge and sediment regimes during early Holocene periods of glacial retreat resulted in a thick layer of glacial outwash deposits filling the valley floor (Figure 97). The modern channel and floodplain in Reach 6 are inset into the outwash deposits that today form terraces along the edges of the valley. In the upper portion of the reach, glacial outwash terraces are located along river-left (the northeast side of the valley). In the lower portion, they are located along river-right (the southwest side of the valley). The Lost River drainage, also carved by glaciers, is now inset below its historical floodplain and alluvial fan deposits. Lost River's notable contribution of sediment and discharge to the Methow River influences geomorphic features and processes downstream. Discharge contributions from Lost River more than double the flow in the Methow River and the abundant sediment contributions influence bar development in the upper portion of the reach.

Reach 6 is located in a valley bordered by steep bedrock walls. These valley walls contribute talus and alluvial debris fan deposits to the valley floor and the channel. In the upper portion of the reach, direct talus and rock-fall inputs to the channel occur from RM 74.15 to 74.7 on river-right. In the lower portion of the reach, they occur on river-left from RM 71.4 to 72.1. However, modern rock-fall inputs in this lower section are reduced by the riprapped embankment of the Lost River Road. At mid-reach between RM 72.85 and 73.85, alluvial debris fan deposits stretch from both sides of the valley walls across the glacial terraces. The steep, high, cut-bank of McGee Creek's historical alluvial fan currently borders the channel on river-right (from RM 72.85 to 73.4). McGee Creek continues to contribute sediment and discharge to the modern channel.

The channel in Reach 6 varies from relatively straight to meandering with a moderate average sinuosity of 1.11. The channel is less sinuous from RM 72.85 to 73.5 and from RM 74 to 74.7 where it is confined by hillslopes and terraces on river-right, and then riprap, levees, and cleared banks on river-left. Primary classification of the channel is riffle-pool, but glide units are present in the more confined and less complex areas of the channel. Reach 6 does contain a relatively high number of pools (6.3 per mile) compared to the average of the study area (3.6 per mile). Large side- and mid-channel bars composed of cobble and gravel are abundant throughout the reach. Bar size and distribution increases in unconfined channel sections. Island features and mid-channel bars split the channel into active side-channels that redistribute flow, thus increasing the overall complexity of both channel and floodplain features. Based on observed overbank deposits and scour, multiple side- and off-channel features as well as many high-flow and abandoned channel scars are activated during flood events approximately every two years.

A variety of features in Reach 6 indicate that during high flow events, there is notable sediment transport as well as floodplain connectivity with the channel. Aerial photos from 1945, 1974, and 1985 confirm that historically, the channel migrated laterally within its modern floodplain via side-channel occupation, meander extension, and avulsion. Near the channel, there are scour and fill features composed of cobbles and gravels (Figure 98). These features occur where a flood event has filled in a side-channel or overflow channel with bedload material – sometimes to an elevation approximately equal to that of the floodplain surface. Groundwater-fed side-channels and abandoned channel scars add complexity to the geomorphology and hydrology of the reach. The side-channels and groundwater-fed tributaries also provide important off-channel aquatic habitat.

Small high floodplain surfaces in the most downstream portion of the reach on river-right have remnant scroll bar features and developing soil. These alluvial surfaces are the result of channel bed incision, which is likely being amplified by the modern artificial confinement of the channel at RM 71.3 (the downstream border of Reach 6). There is a unique cut-bank feature located at RM 72.2 on river-left where the active channel is eroding into alluvial deposits comprised primarily of fines (silts, sands, and clays). The stratigraphy in the cut-bank reveals a complex layering that includes former locations of a tributary channel, evidenced by gravel lenses and surface depressions (Figure 99).

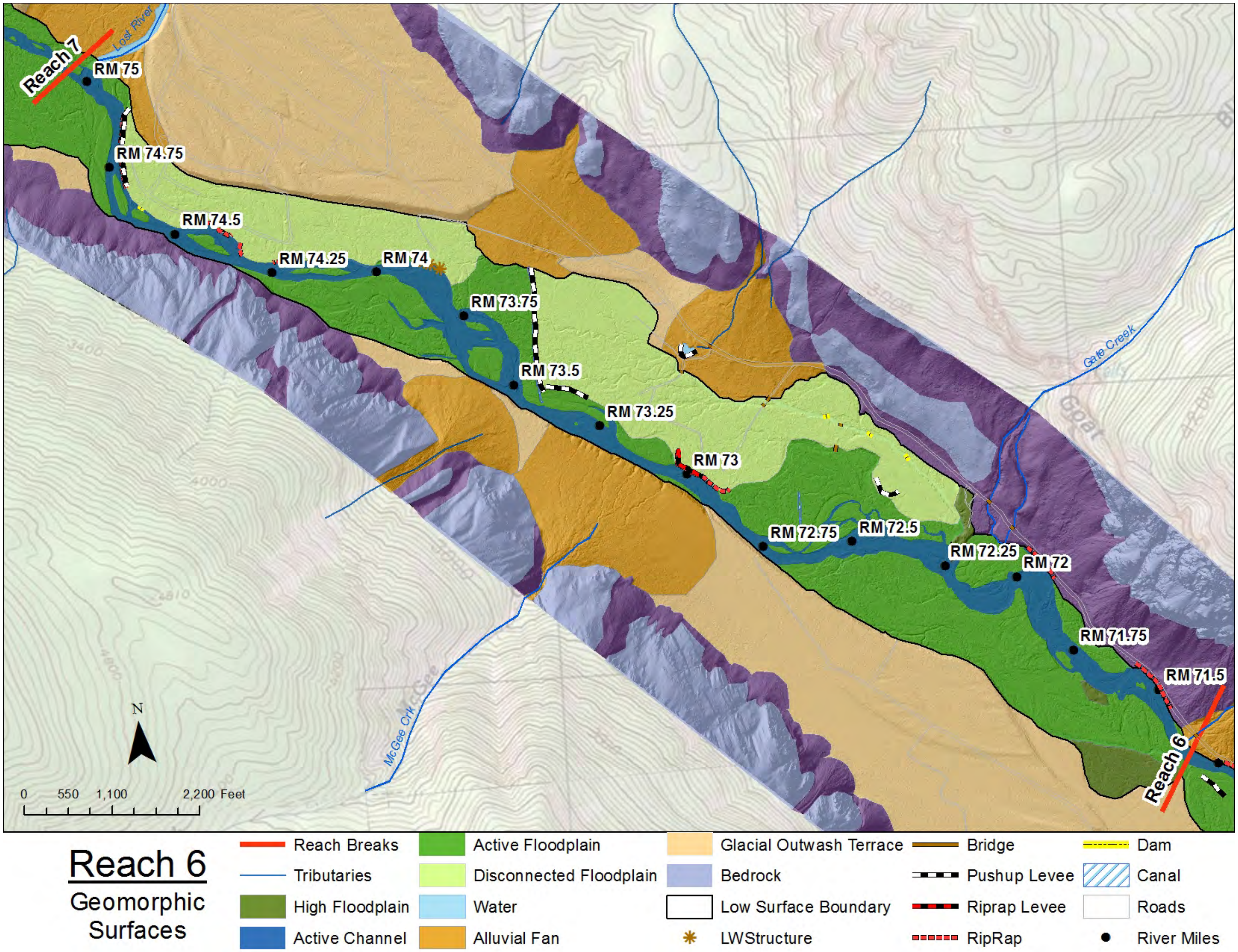

Figure 97. Geomorphic surfaces of Reach 6 with selected human-built features (log structures, levees, riprap, check dams, canals, bridges, and roads).

Figure 98. Cobble-gravel filled side-channel near RM 72.5.

Figure 99. Cut-bank located at RM 72.2 on river-left -- composed of alluvium (silts, sands, and clays with gravel lenses), with a paleo-channel notch. (8/15/2014)

Hydrology

Reach 6 has a seasonally fluctuating flow regime. Spring snowmelt events activate overflow channels. Flood events inundate available low floodplain surfaces on a regular basis (2 year flood recurrence) (Figure 100). Late summer, autumn, and winter low flows often leave most of the reach dry, with isolated pools susceptible to temperature extremes (see discussion in Section 2.6.3). Summer and autumn thunderstorms are capable of temporarily raising surface water elevations if discharge inputs are substantial enough to recharge groundwater elevations.

The valley floor is composed primarily of coarse-grained material that supports hyporheic flow and groundwater influx from upstream and the adjacent terraces, valley walls, and alluvial fans. Hyporheic through-flow at the downstream ends of active bars was observed during field surveys in August and September 2014. Despite notable discharge from Lost River, Reach 6 is considered a "losing" reach (Konrad etal 2005). This means that the channel contributes its incoming surface flow to the valley's large subsurface groundwater reservoir that is up to 1,000 feet deep in this area (Konrad 2006b). During low flow periods, sections of the channel become dry when the incoming surface water flow is less than the quantity of water the channel is contributing to the reservoir to recharge groundwater. See Section 2.6 of this report for a description of the groundwater to surface water interchange processes that occur here.

Reach 6 receives surface water inputs from Lost River, McGee Creek, Gate Creek, and a handful of seasonal or ephemeral hillslope tributaries. According to US Bureau of Reclamation surface flow estimates (2008 – Appendix J), discharge of the Methow River increases by 66% at the Lost River confluence during high flows. The Lost River increases the contributing upstream drainage area from 85 square miles to 256 square miles. Thus, the Lost River watershed is an important hydrologic and geomorphic agent in the upper Methow Basin. During high flows, McGee Creek, on river-right at RM 73, increases discharge by less than 1%, and Gate Creek, on river-left at RM 72.3, increases discharge by approximately 1.3%.

An important hydrologic feature in Reach 6 is the side-channel that traverses the floodplain on river-left from RM 73.8 to 72.3. The feature is now disconnected from the mainstem at the upstream end by a constructed canal that crosses its path. The canal blocks surface flow from entering the side-channel, and instead diverts it off the floodplain. Today, downstream from the canal, this side-channel still has surface flow but it is fed by groundwater inputs alone. The groundwater is generated upstream and from the adjacent terraces and alluvial fans. Where the side-channel borders the toe of a large alluvial fan, notable upslope groundwater inputs lower the temperature of its surface water. This side-channel traverses the edge of the floodplain along the north side of the valley and eventually delivers the collected groundwater to the mainstem as surface flow at RM 72.3. Three large beaver dams and a few log jams create pools that impose natural grade control on the stream and facilitate the local accumulation of fines and nutrients (Figure 102).

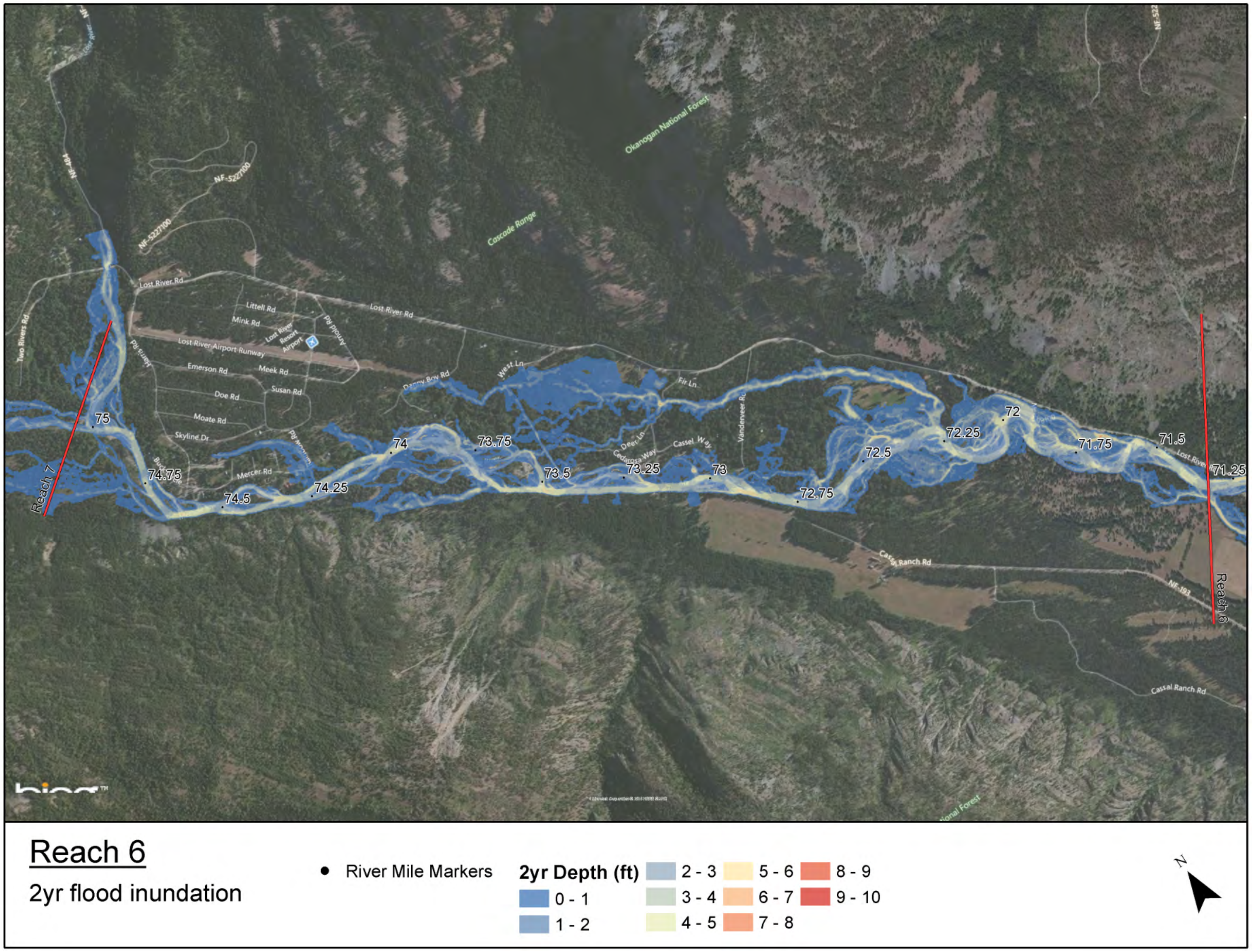

Figure 100. Floodplain inundation for 2YR flood in Reach 6 – developed using a 2D hydraulic model (SRH-2D) built with 2006 LiDAR elevation data.

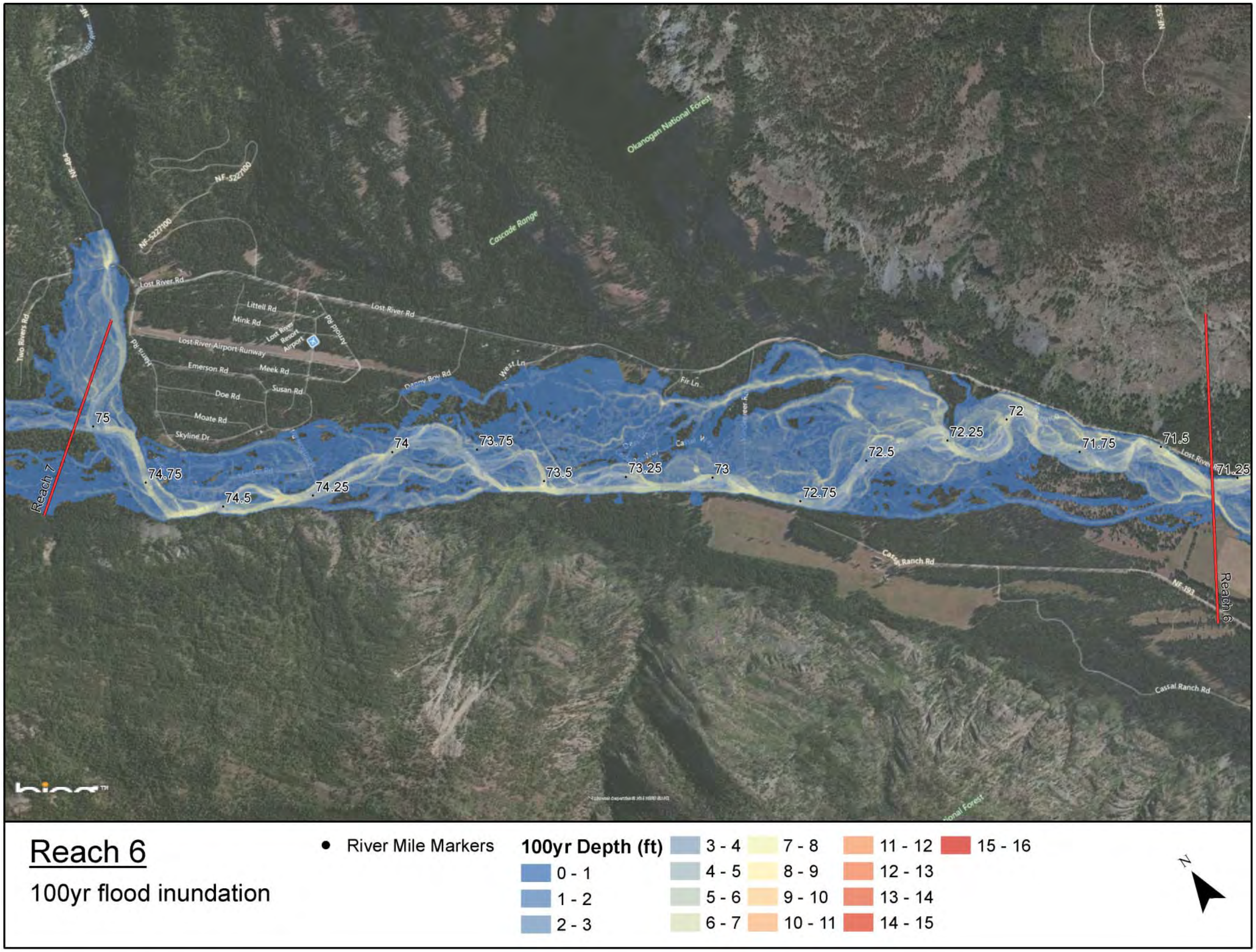

Figure 101. Floodplain inundation for 100YR flood in Reach 6 – developed using a 2D hydraulic model (SRH-2D) built with 2006 LiDAR elevation data.

Figure 102. Ground-water wetted side-channel, disconnected from mainstem at upstream end by canal. Located on river-left between RM 73.8 and 72.3. (8/24/2014).

Floodplain and Channel Migration Zone

Reach 6 is naturally active laterally and vertically. Natural partial confinement of the reach occurs where it contacts valley walls and terrace banks. Aerial photos from 1945 to 1985 confirm modern lateral migration through meander extension and avulsion (Figure 103). However, in sections of the reach, modern lateral processes have been restricted by riprap and levees constructed along the channel banks. For example, the historical migration zone on river-left from RM 72.85 to 73.5 was reduced by 700 to 1,000 feet, and from RM 74 to 74.85 by 650 to 900 feet. At these sites, the channel is also confined on river-right by valley walls or banks cut into alluvial fan and glacial terrace slopes that are 10 to 15 feet higher than the active channel. Artificial confinement of a river often reduces vertical stability by instigating incision processes. However, bed incision is partially offset here by plentiful sediment inputs sourced from the Lost River and the terrace slopes. These sediments support bar and island development in the upper half of the reach.

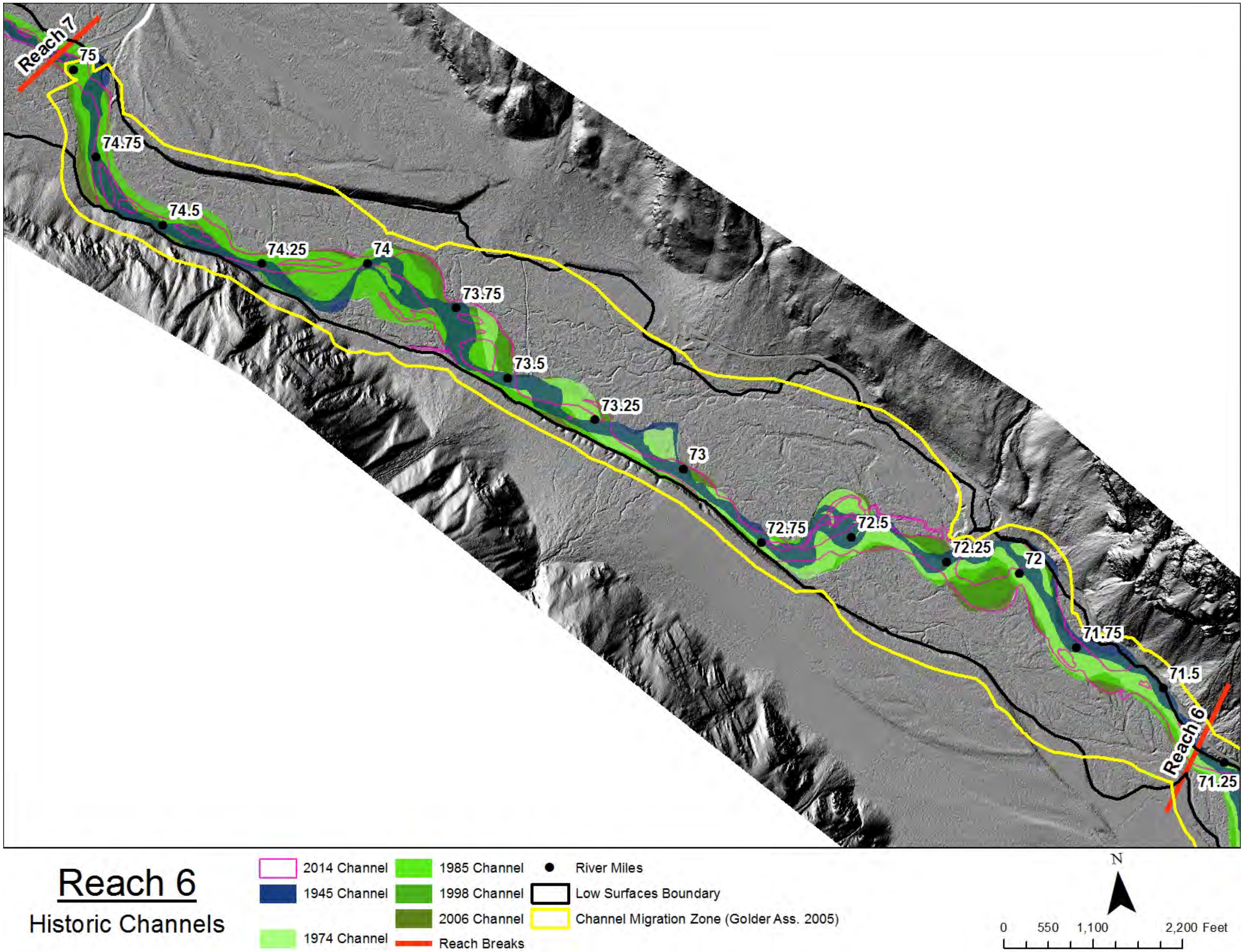

Figure 103. Historical channel locations for Reach 6.

The location of the channel and its active floodplain shifts from one side of the valley to the other. As a result, it is naturally confined on river-right in the upstream section and on river-left in the downstream sections by valley walls and high (10 to 15 foot) cut-banks along glacial outwash terraces and alluvial fans. At the downstream border, the channel migration zone is naturally reduced to only 275 feet between the Goat Wall Creek alluvial fan on river-left and glacial and alluvial terraces on river-right. As expected, where migration zones are reduced, incision has occurred. At the downstream end of Reach 6, an alluvial terrace and ascending scroll bars on the high floodplain surface on river-right (west side of the reach) confirm a history of gradual incision. The elevation of active floodplain surfaces varies; going from approximately two feet (low), four feet (medium), and six feet (high) above the channel bed. Overbank deposits observed in the field indicate that all elevations of floodplains were recently inundated during high-flow events – likely the 2006 and 2008 flood events. This is confirmed by hydraulic modeling (Figure 100 and Figure 101). The variance and mixed distribution of floodplain elevations indicate historically active vertical and lateral migration patterns in the reach. Where human features have not altered floodplain inundation processes, high-flow events activate side and off-channel features on river-left from RM 72 to 72.7, and on river-right from RM 71.35 to 72.7 and RM 73.65 to 74.25.

Sediment

The substrate of Reach 6 is dominated by cobbles (51%) and gravels (45%) with minor sand (2%) and boulders (2%). Sand is found as overbank deposits on floodplains, as topping on high bars, and as still-water deposits in backwater features or at eddy points. Large boulders in the channel on river-right from RM 74.35 to 74.65 were locally sourced from talus on the bordering valley wall. Boulders, cobbles, and coarse sand are supplied from the high cut-banks of glacial terrace and alluvial fan deposits on river-right from RM 72.7 to 73.6. A unique cut-bank on river-left at RM 72.25 is currently being eroded by the channel. This bank is composed of clay and sand with lenses of gravel and a submerged base of cobbles and small boulders. The deepest meander bend scour pool in the reach is at the base of this cut-bank. The side-channels that traverse the floodplains also contribute sediment to the channel and these inputs are usually gravels, sands, and fines. The floodplains are composed of cobbles and gravels and are topped with sands. Lost River and its alluvial fan contribute a large amount of cobbles and gravels to the bedload of Reach 6. Bedload sediment throughout the reach is well sorted (has a relatively similar diameter size range) and rounded, indicating that much of the substrate is transported fluvially during high flow events

Large Wood

Reach 6 has a moderate in-channel large wood count of 388 logs (48 logs per mile) and 10 log jams. In-channel wood distribution in the reach is presented in Figure 104 as a density, or the number of wood pieces per 100 feet within each delineated channel unit type. The most geomorphically effective wood accumulations occur where channel and floodplain complexity is greatest – from RM 71.5 to 72 and from RM 73.5 to 73.75. Large wood recruitment is minimal at riprapped and leveed banks or where vegetation clearing has occurred. Partial and full clearing of large trees has occurred on private lands along channel banks on river-left from RM 72.85 to 73.25 and from RM 73.8 to 74.85.

On river-right, from RM 72.25 to 73.1, clearing of vegetation for agriculture has occurred on the top of the terrace and alluvial fan, but the high cut-bank remains treed. Clearing along the banks has occurred on river-right from RM 71.65 to 71.85, and also on active floodplain surfaces that are set back from both sides of the channel from RM 72.25 to 72.5. The remainder of the floodplain, terrace, and hillslope surfaces are well vegetated with both small and mature trees. These trees provide wood to the main channel and side-channels. Channel-spanning log jams occur in the smaller side-channels, but the width of the main channel is generally too great for channel-spanning accumulations to develop given the size of currently available large wood pieces. Instead, wood accumulates on the cobble-gravel bars. Where large jams occur, they create channel complexity by promoting bar development and scour pools. In Reach 6, large and small wood recruitment, especially of cottonwood, is enhanced by the active presence of beavers (Figure 103). Wood contributions by beavers play an important role in side-channel pool development and grade control.

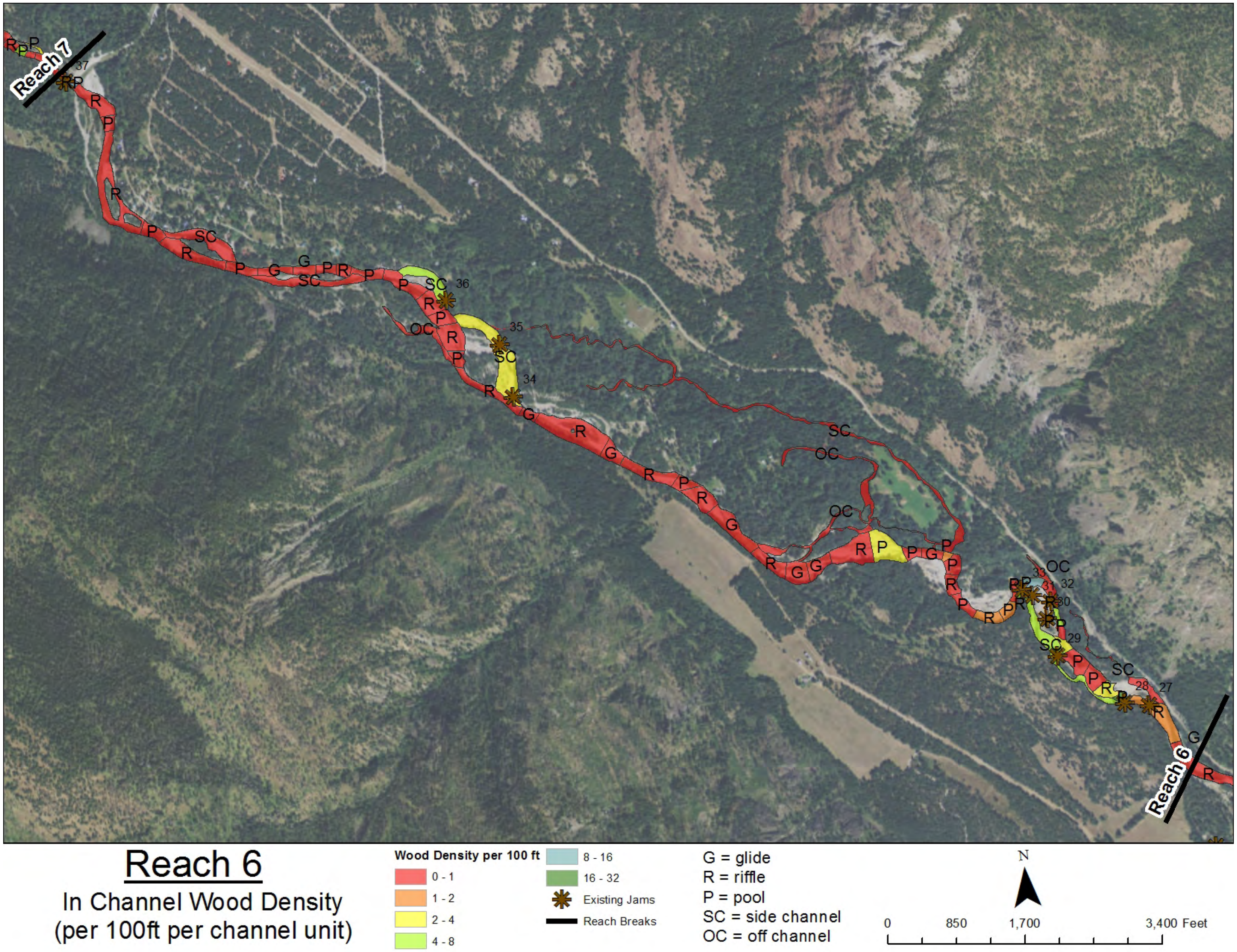

Figure 104. In-channel wood distribution (qualifying wood pieces per 100 ft channel length) within delineated channel units in Reach 6.

Figure 105. Beaver chew on a large cotton adjacent to the mainstem in Reach 6. (8/15/2014)

Vegetation

The banks of the channel in Reach 6 are well vegetated except at the cleared locations listed above and where riprap and levees have been constructed (Figure 106). A sparse distribution of trees and shrubs exist on the high cut-banks of the glacial terrace and alluvial fan deposits on river-right from RM 72.7 to 73.6, but density and age is reduced due to the instability of the slopes. The other vegetated floodplain banks throughout the reach contain forests composed of a mix of cottonwood, aspen, fir, pine, and cedar. Stands of massive cedar and aspen occur in well-vegetated sections of the floodplain on river-left between RM 73.2 and 73.5. Recently abandoned low surfaces, such as high bars or scour and fill features, have establishing communities of cottonwood, dogwood, fir, and aspen. The understory on the undeveloped floodplain surfaces is dense and includes grasses, forbs, dogwood, maple, devil’s club, equisetum, and snowberry. Vegetation increases surface roughness and stability in these areas. The cleared or partially-cleared banks have a less complex understory dominated by grasses and forbs. Along the riprapped banks, either no vegetation exists, or very sparse communities of willow and dogwood cling to the spaces between the angular boulders near the channel. The side-channels receive shade and organic material from floodplain vegetation. The main channel in Reach 6 is wider than the average tree height, thus shading occurs primarily along the banks on river-right (southwest side).

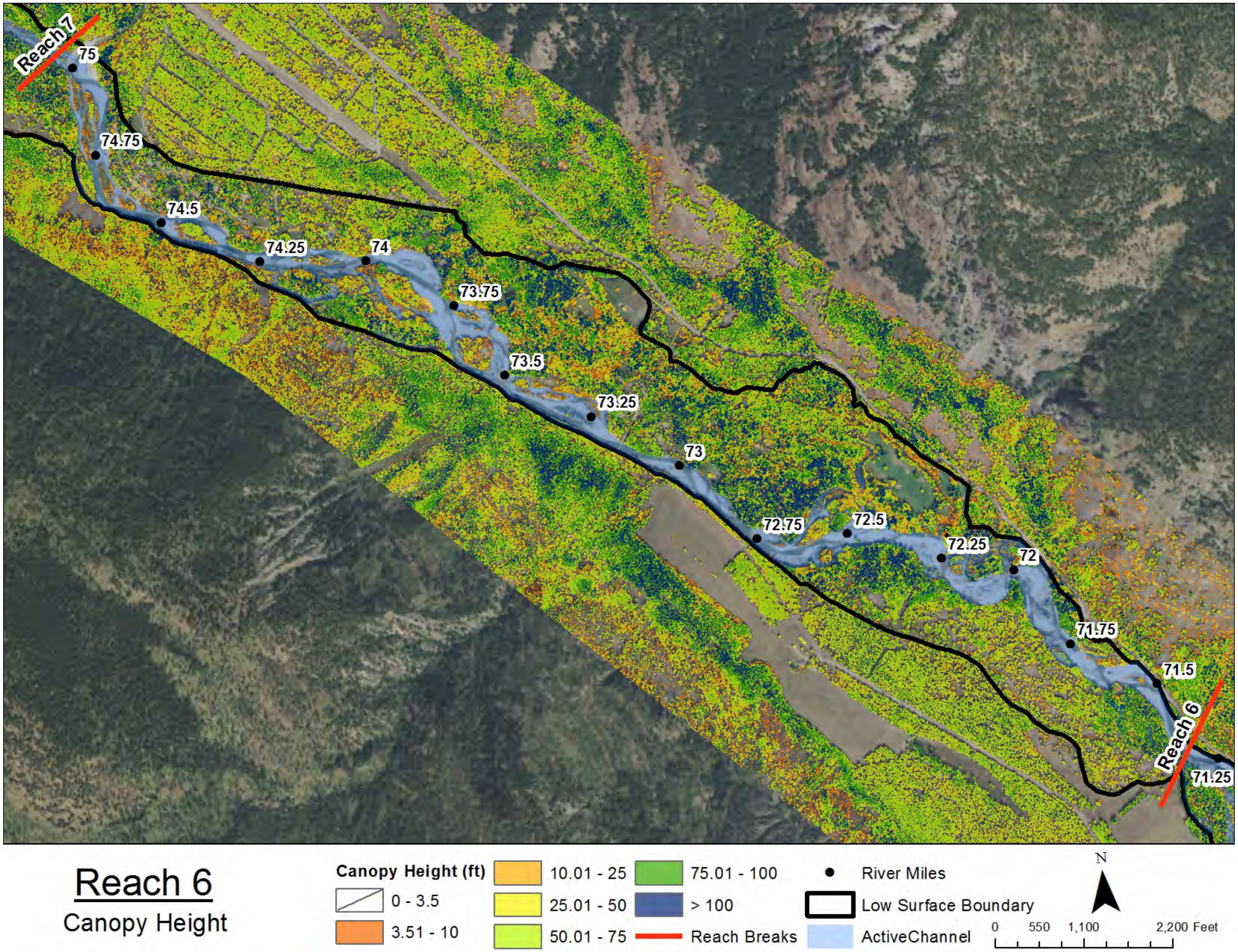

Figure 106. Vegetation canopy height for Reach 6 -- derived from LiDAR first return (highest hit) data (includes buildings and other human infrastructures).

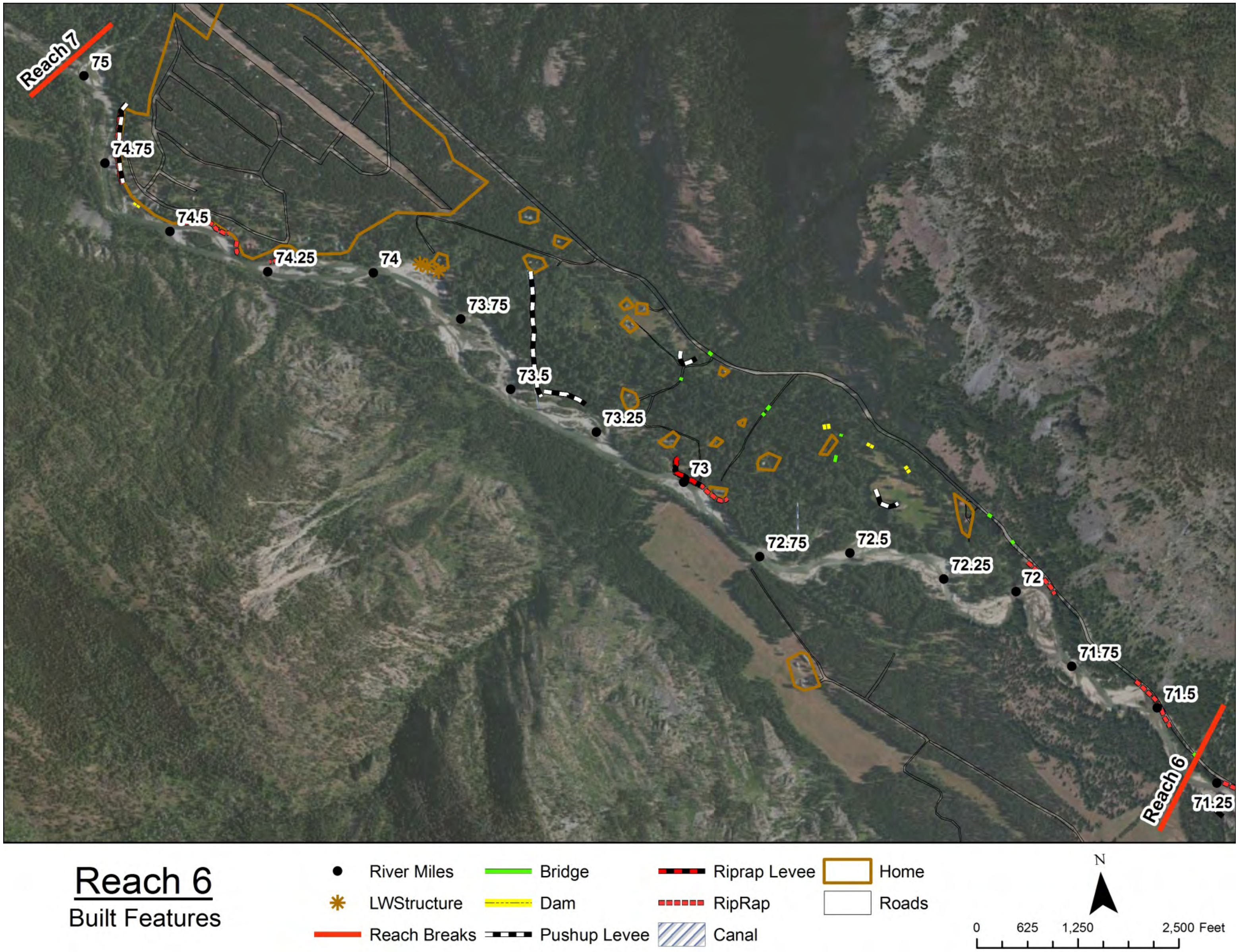

Figure 107. Primary human features in Reach 6.

3.6.3 Human Alterations

Human features are mapped in Figure 107. The primary human alterations in the reach include the following, and are described further in the subsections below.

- Changes to floodplain function and channel migration
- Loss of streambank complexity and riparian impacts
- Loss of instream habitat complexity

Changes to Floodplain Function and Channel Migration

Loss of floodplain function has occurred in Reach 6 on river-left from RM 72.25 to 74.85. These losses represent over half of the floodplain surfaces in the reach. The losses differ in severity, but all have occurred as a result of a variety of human-induced activities. The most severe floodplain losses are associated with the development of the Lost River Community. Road construction, vegetation clearing, and the surface grading and filling that comes with home construction have altered riparian and floodplain processes severely from RM 73.8 to 74.85 and moderately from RM 72.25 to 73.8. Installation of riprap and levees (push up and riprap) along sections of the bank restrict lateral channel migration and floodplain connectivity by stabilizing the banks and reducing the frequency and extent of inundation. This occurs on river-left at the following: from RM 72.9 to 73.1, from RM 73.3 to 73.45, at RM 73.85 and 74.25, from RM 74.35 to 74.45, and from RM 74.65 to 74.85. A push-up levee on river-left at RM 72.45 is constructed of material graded from the pasture. This levee reduces local inundation rates from mainstem and side-channel overbank flows.

The feature that disconnects the largest amount of floodplain from the channel is a 1,600-foot-long canal constructed across the floodplain on river-left at RM 73.45 (Figure 108). The canal captures surface flow and diverts it off of the floodplain and back to the mainstem channel. It was built to reduce flooding of the private property downstream. This feature also disconnects a prominent side-channel from upstream surface water inputs. The canal was made of material dug from the floodplain; this same material was used to construct a levee along the canal’s east side in an effort to further reinforce the canal’s purpose.

The channel migration zone of Reach 6 has been notably reduced. The riprapped banks and levees mentioned above stabilize the banks and constrict natural lateral migration. The historical migration zone on river-left from RM 72.85 to 73.5 was reduced by 700 to 1,000 feet. Now the active width of the channel here is approximately 250 feet. Here, the channel is basically locked in place between the riprap on river-left and the naturally confining high cut-bank of the McGee Creek alluvial fan on river-right. From RM 74 to 74.85, the historical channel migration zone was reduced by 650 to 900 feet. At RM 74.4, the channel is confined to a width of only 400 feet between riprap and the valley wall.

Figure 108. Constructed canal that drains surface water from the floodplain and disconnects a side-channel. Photo taken at the downstream end looking up-canal near RM 73.45. (8/14/2014)

Loss of Streambank Complexity and Riparian Impacts

Streambank complexity and riparian vegetation in Reach 6 have been reduced along riprapped banks. The large boulder riprap in front of the Lost River Community and at channel-contact points along the Lost River Road embankment (RM 71.45 to 71.55 and RM 71.9 to 72.1) inhibit toe erosion and natural bank and hillslope inputs, thus altering localized sediment inputs to the system. The riprap also reduces the complexity of the riparian vegetation and notably decreases the potential for the establishment of mature tree stands. These impacts reduce localized shade to the channel and remove the potential for large wood recruitment in these areas.

Additional loss of riparian vegetation and the benefits it provides has occurred on private lands. Partial or complete vegetation removal along the banks of the main channel is visible on river-left from RM 72.85 to 73.25, RM 73.8 to 74.8, and RM 71.6 to 72.15. The surface of the glacial terrace has been cleared and graded for agricultural use near the channel on river-right from RM 72.75 to 73.1, but the slope of the terrace is fully treed. Some vegetation thinning and clearing has also occurred in patches on floodplain surfaces near side-and off-channel features. Loss of vegetation near these features can also increase water temperature, reduce natural bank stabilization, limit tree-fall nutrients, and reduce off-channel habitat complexity.

Loss of Instream Habitat Complexity

Records indicate that log drives utilized the mainstem channel in Reach 6 to transport cut timber to historical log mills that operated in the early 1900s. The known mills were located near RM 73

(Green Mill), RM 72 at Gate Creek, and RM 71 at Goat Wall Creek (Goat Wall Mill) (Devin 1997, USBR 2008 – Appendix O). In-channel log transport requires clearing the channel of natural log jams and any other obstructions (large boulders, etc.). Additional clearing of large wood likely occurred following the large floods of 1948 and 1972, in conjunction with floodplain and bank protection features (riprap, levees, canals). However, specific locations of these activities are not recorded. The expected impacts of log drives and/or "cleaning" a channel include bed scour, channel and bank simplification, and a reduction in habitat complexity (Nilsson etal. 2005, Wohl 2006, Miller 2010).

3.6.4 Recommended Actions

Recommended actions in Reach 6 are focused on improving floodplain and side-channel function and connectivity as well as increasing channel complexity. Floodplain function and connectivity can be improved by removing/modifying unnecessary riprap and levees, placing meander jams along the bank to improve margin habitat, and removing or selectively breaching the floodplain drainage canal (RM 73.5). Enhanced alcove and side-channel connectivity can be addressed by removing unnecessary riprap and push-up levees, and placing apex jams with select excavation to enhance through-flow. The design and extent of these actions will need to consider the impacts to infrastructure and private property in the Lost River Community. Channel complexity can be increased by placing large wood jams that capture wood, build islands, enhance lateral migration, and deflect flow away from the Lost River Road and Community. Planting native riparian vegetation where clearing has occurred is also recommended.

Restoration recommendations recognize the importance of maintaining connectivity of the mainstem channel to perennial or groundwater fed tributaries and side-channels. This has been identified as a critical component for fish survival in a system with the potential to seasonally dewater.

See Section 4 of this report for the restoration strategy and specific project recommendations for the reach.

3.7 REACH 7

Refer to Section 2.2 and 2.8 for geologic and geomorphic context of the study area and explanation of terminology.

3.7.1 Reach Overview

Reach 7 is 1.5 miles long and extends from the Lost River Confluence at RM 75.05 to the Robinson Creek confluence at RM 76.5. Except for one private residence on the Lost River alluvial fan terrace at RM 75.2, Reach 7 lies entirely within the Okanogan National Forest (Figure 109). The river is a complex riffle-pool-glide stream with channel bed material dominated by gravels and cobbles and some small boulders (Figure 110). The reach is geomorphically active. It receives pulses of sediment sourced from upstream and local channel beds and banks. The channel in Reach 7 contains complex multi-threaded sections and vegetated islands. At low-flow stages, large side- and mid-channel bars of cobble and gravel are exposed. The floodplains are composed of the same material as the channel substrate but with more boulders at the base and accumulations of sands and fines on top. The modern floodplain surfaces have an average width of 1,345 feet. The channel is moderately sinuous (1.17) and is unconfined. The channel has an average bankfull width of 76 feet and a gradient of 1.5%. These and other reach metrics are provided in Table 13 and Figure 111.

The valley is bordered by narrow bands of glacial outwash terraces and bedrock hillslopes overlain with talus debris. Lost River and Robinson Creek both have active alluvial fans that contribute discharge and sediment to the reach. The floodplain and banks are vegetated with maturing or mature forests and a mixed understory. The vegetated floodplains supply plentiful large wood to the system and add roughness to most of the banks. Burn scars on the older trees indicate historical forest fires.

The habitat conditions in Reach 7 are discussed in Appendix A. Based on the REI analysis, 6 of 11 habitat indices are rated as either unacceptable or at risk (see Table 6). The salmon and steelhead redd distributions for the reach are mapped in Figure 109. Partial clearing and a sparse web of single-track dirt roads – used for river access and camping – exist along the majority of river-left (north side of the channel). A recreational trail runs along the edge of the valley on river-right (south side of the channel); it was created from a decommissioned road. Healthy, natural, hydrologic and geomorphic processes are occurring in this reach.

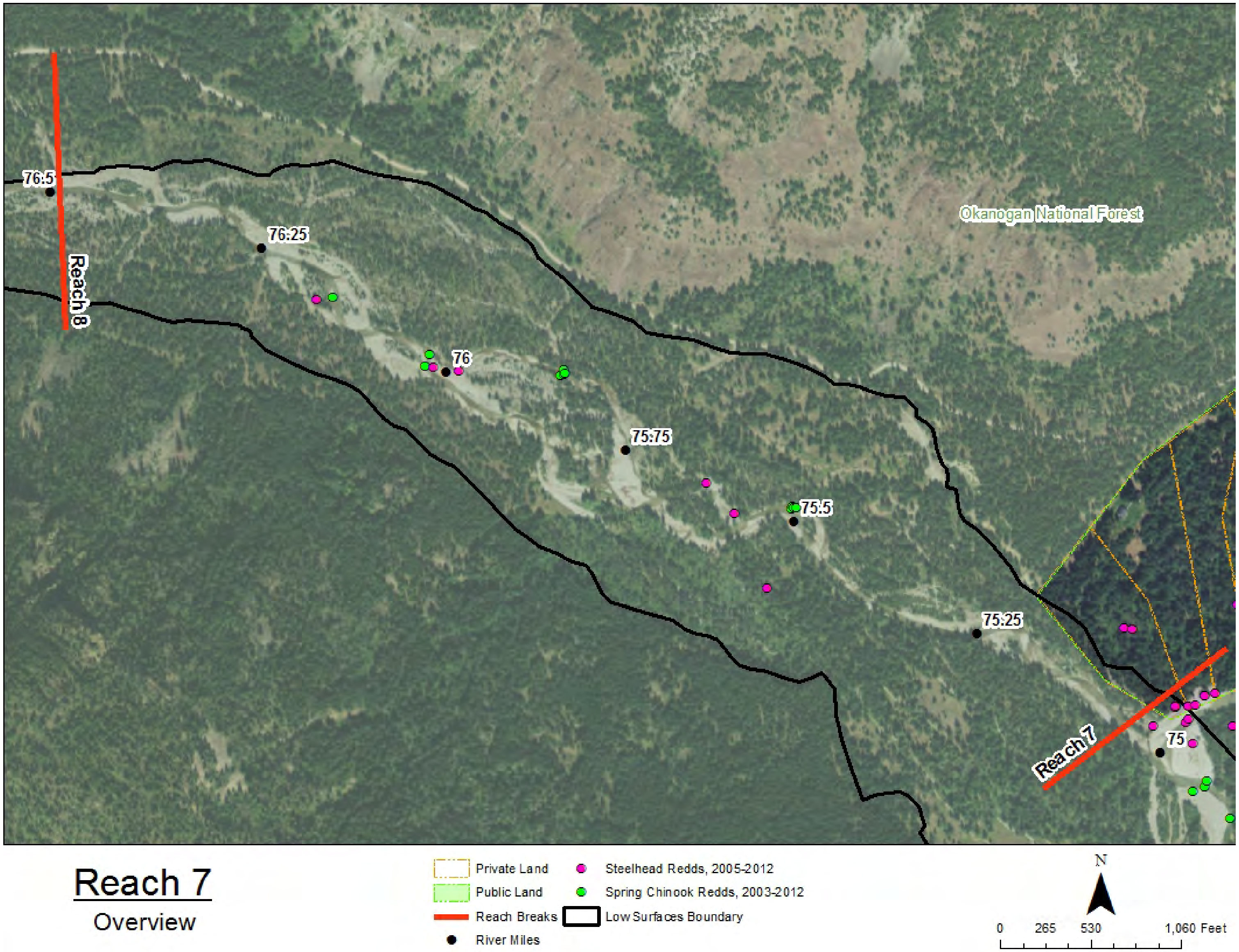

Figure 109. Reach 7 overview map with landownership and redd distribution.

Figure 110. Representative photo of Reach 17 looking upstream at RM 76.15. (8/15/2014)

Table 13. Reach 7 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	1.5
River Miles	75 – 76.5
Valley Gradient	1.8%
Stream Gradient	1.5%
Sinuosity	1.17
Dominant Channel Type	Riffle-pool
Average Bankfull Width (feet)	76
Average Floodplain Width (feet)	1345
Dominant Substrate	cobble 51%; gravel 42%; boulder 5%; sand 2%
Bank Stability/Channel Migration	Adequate *(See Section 2.12)*
Vertical Channel Stability	Adequate *(See Section 2.12)*
Confinement ratio	Unconfined *(See Table 5)*

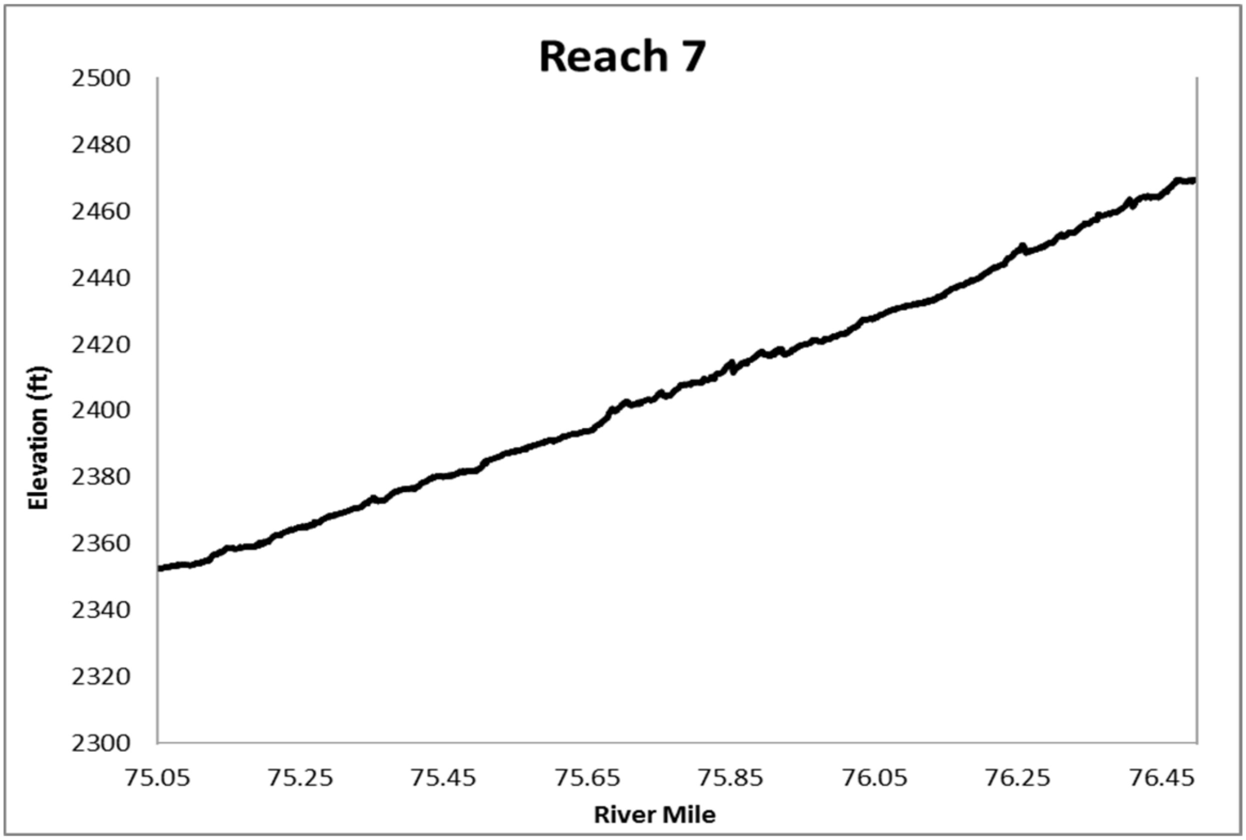

Figure 111. Longitudinal profile of the channel in Reach 8 (RM 75 to 76.5).

3.7.2 River Morphology and Geomorphic Processes

Geology and Landforms

Reach 7 is located within a wide U-shaped valley most recently carved by Quaternary glaciation. Increased discharge regimes during early Holocene glacial retreat resulted in the valley floor infilling with a thick layer of glacial outwash deposits. The modern channel and floodplain in Reach 7 are inset into the surface of the glacial outwash deposits that today form terraces along the edges of the valley. Like the Methow Valley, both the Robinson Creek and Lost River drainages were carved by glaciers. Both contribute outwash material to Reach 7, and today, their modern alluvial fans are inset below their historical fan deposits. The valley in Reach 7 is wider and less confined than the upstream reaches of the study area. Sediment is transported into Reach 7 from the upstream, higher gradient Reach 8. Pulses of mobilized sediment periodically render Reach 7 transport limited. The valley is bordered by steep bedrock hillslopes that contribute talus and small debris fan deposits to the edges of the valley floor. However, these deposits do not contribute direct inputs to the channel. A map of the geomorphic surfaces is provided as Figure 112.

The modern active floodplain surfaces in Reach 7 range in elevations and inundation rates. The outside edge of the floodplain is relatively higher than the floodplain surfaces near the channel. Modern fluvial scarring patterns indicate infrequent inundation at the outside edges of the floodplain. However, regular groundwater and/or seasonal snowmelt-activated tributaries divert surface flow across the outer floodplain surfaces to the main channel. Near the channel, the active floodplain surfaces vary in elevation [1-2 feet (low); 2-4 feet (medium); 4-5 (high)] relative to the channel bed in a manner that is sometimes incongruent with the age and type of established vegetation. For example, near RM 75.7 on river-left, there are surfaces with tall mature trees at the water's edge with fresh sand-to-cobble deposits around the base of the trees. Infilling of a recently abandoned channel at RM 75.5 on river-right resulted in a bare cobble surface that is flush with the adjacent floodplain surface. This surface is approximately five feet above the bed of the channel. The forested, mid-channel islands in Reach 7 also have varied elevations and stages of established vegetation. These features indicate that the channel experiences fluxes of mobilized sediment during high flow events. The sediment is delivered from upstream as well as scoured from the channel bed and banks of Reach 7. The activated sediment is then transported through the channel in pulses. This results in sequences of aggradation and degradation that can change the relative elevation of the channel bed to the existing floodplain surfaces.

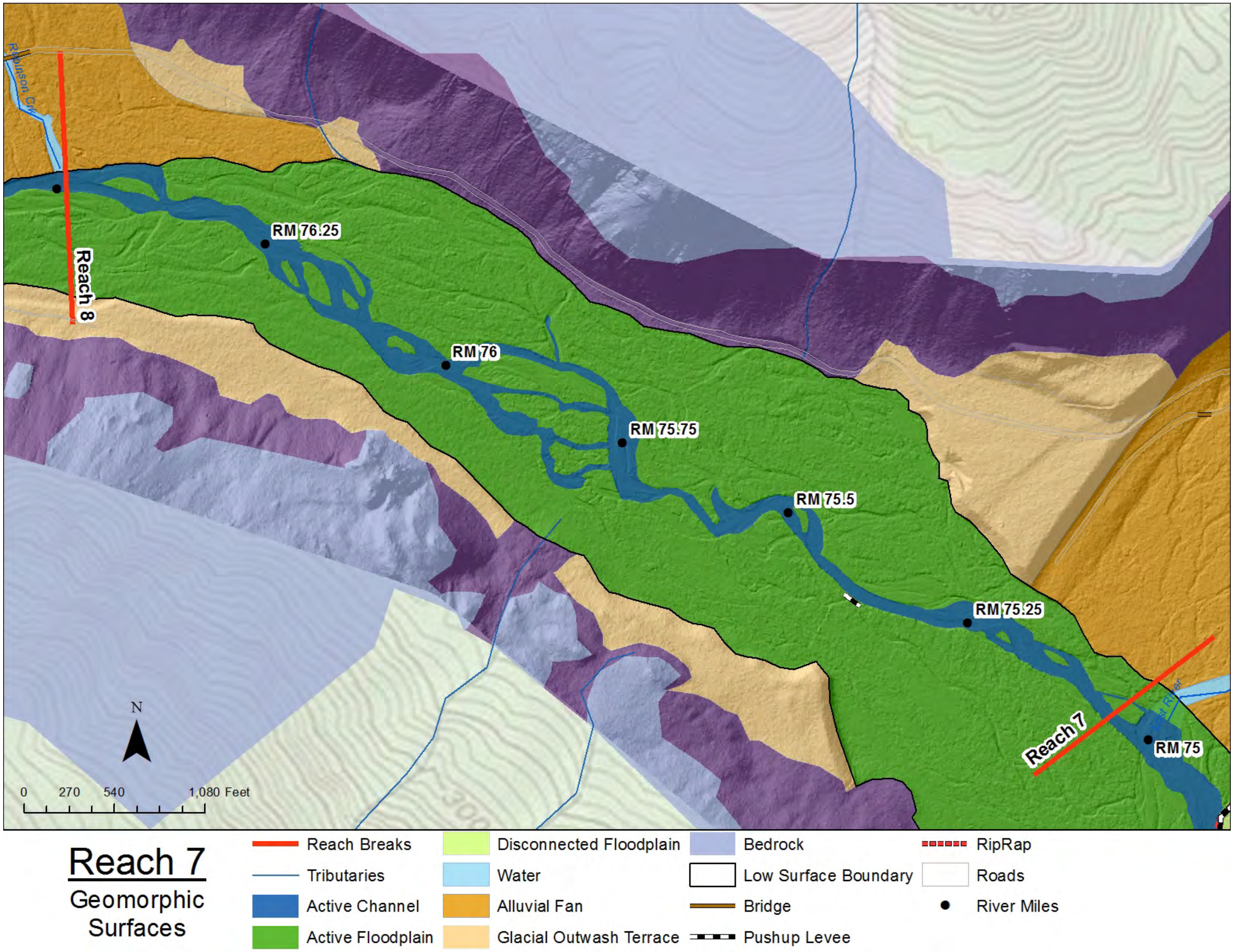

Figure 112. Geomorphic surfaces of Reach 7 with selected human built features (levees, riprap, bridges, and roads).

Hydrology

Reach 7 has a seasonally fluctuating flow regime. Based on field observations, late spring and early summer snowmelt events activate side-channels and inundate the low and medium elevation floodplain surfaces every two to ten years (Figure 113). Autumn low flows expose bars and banks throughout the reach. There are reports of portions of the channel going dry seasonally during low precipitation years (WDW 1990), but this does not appear to be the norm. When this occurs, the channel is contributing its surface flow to the large subsurface groundwater reservoir located downstream from Reach 7 (Konrad 2006b). Otherwise, this reach is considered a "gaining" reach -- incoming groundwater and surface water feeds the surface flow in the channel. See Section 2.6 of this report for a description of the groundwater to surface water interchange processes that occur at the downstream end of Reach 7.

The upstream watershed is dominated by bedrock peaks and valley walls; these features have low surface-water retention. For this reason, large summer thunderstorms are capable of temporarily raising surface water elevations in reach 7. The valley floor is composed primarily of coarse-grained material that supports active hyporheic flow. As a result, within the active floodplain of Reach 7, the channel and its side-channels are actively exchanging surface flow with groundwater through hyporheic processes. There are also groundwater inputs from upstream and from adjacent terraces, valley walls, and alluvial fans. The bedrock floor of the glacially-carved valley confines groundwater; and that groundwater flows below and through the glacial outwash deposits that infilled the valley thousands of years ago.

Reach 7 receives discharge from Robinson Creek and ephemeral tributaries. According to the US Bureau of Reclamation's surface flow estimates (2008 – Appendix J), the upstream boundary of the reach receives an estimated 24% increase in discharge from Robinson Creek during high flow events. It is assumed that Robinson Creek and Lost River contribute subsurface groundwater but the quantity or percent of that contribution annually is currently unknown. Four small ephemeral tributaries contribute the equivalent of approximately 2% of the discharge in the reach. Activated by seasonal snowmelt or precipitation, their minor seasonal discharge runs off of the steep walls to the valley floor. Two of these ephemeral tributaries are located on river-right and two are on river-left. It is assumed that most of the ephemeral tributary inputs contribute to the groundwater system near the edge of the valley. Several tributaries that initiate on the modern floodplains are activated and fed by groundwater generated from upstream, as well as groundwater from the adjacent terraces and hillslope. In Reach 7, these floodplain tributaries maintain off-channel riparian environments, transport sediment into the channel, and sometimes provide low points on the floodplain for high flow or flood event avulsions.

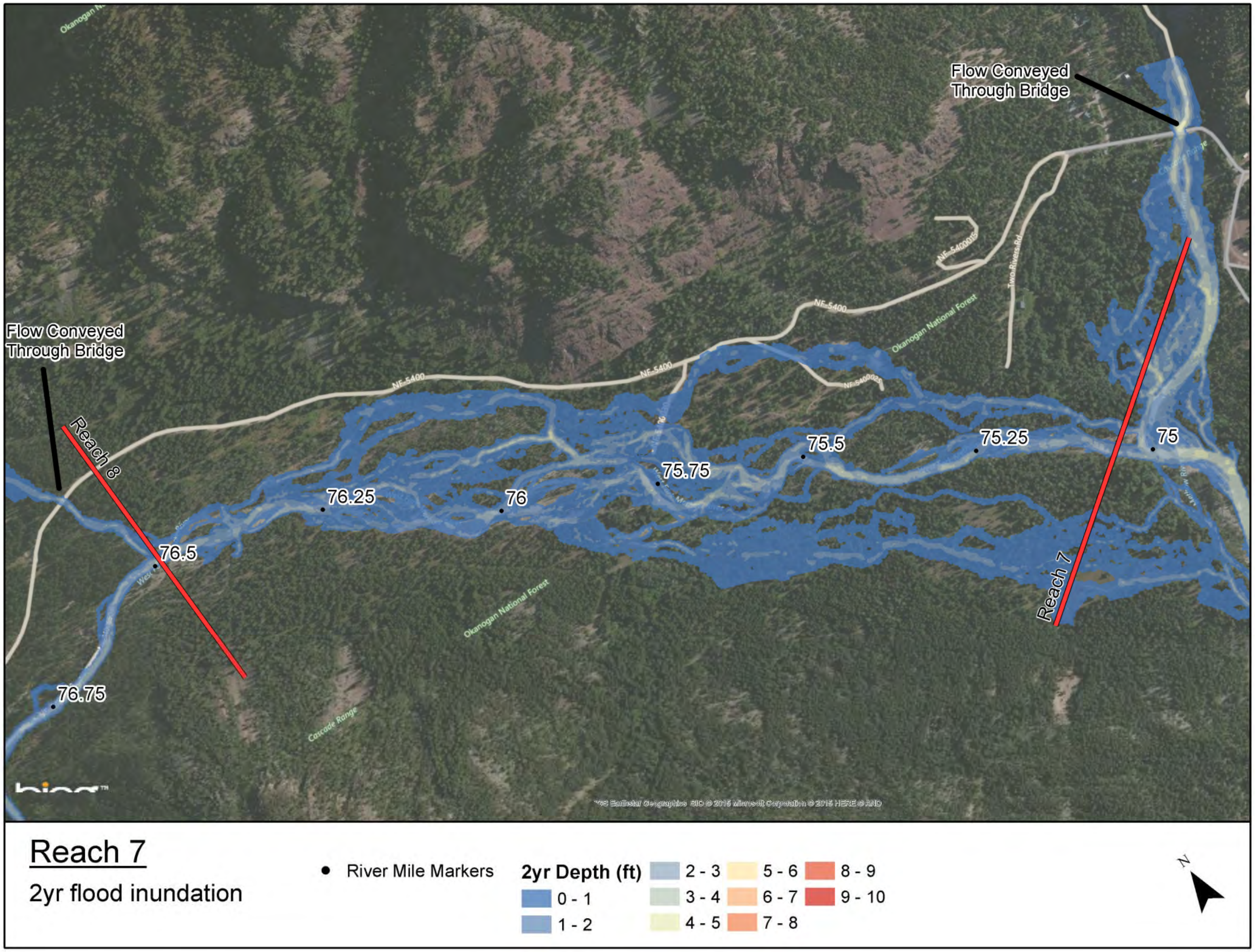

Figure 113. Floodplain inundation for 2YR flood in Reach 7 – developed using a 2D hydraulic model (SRH-2D) built with 2006 LiDAR elevation data.

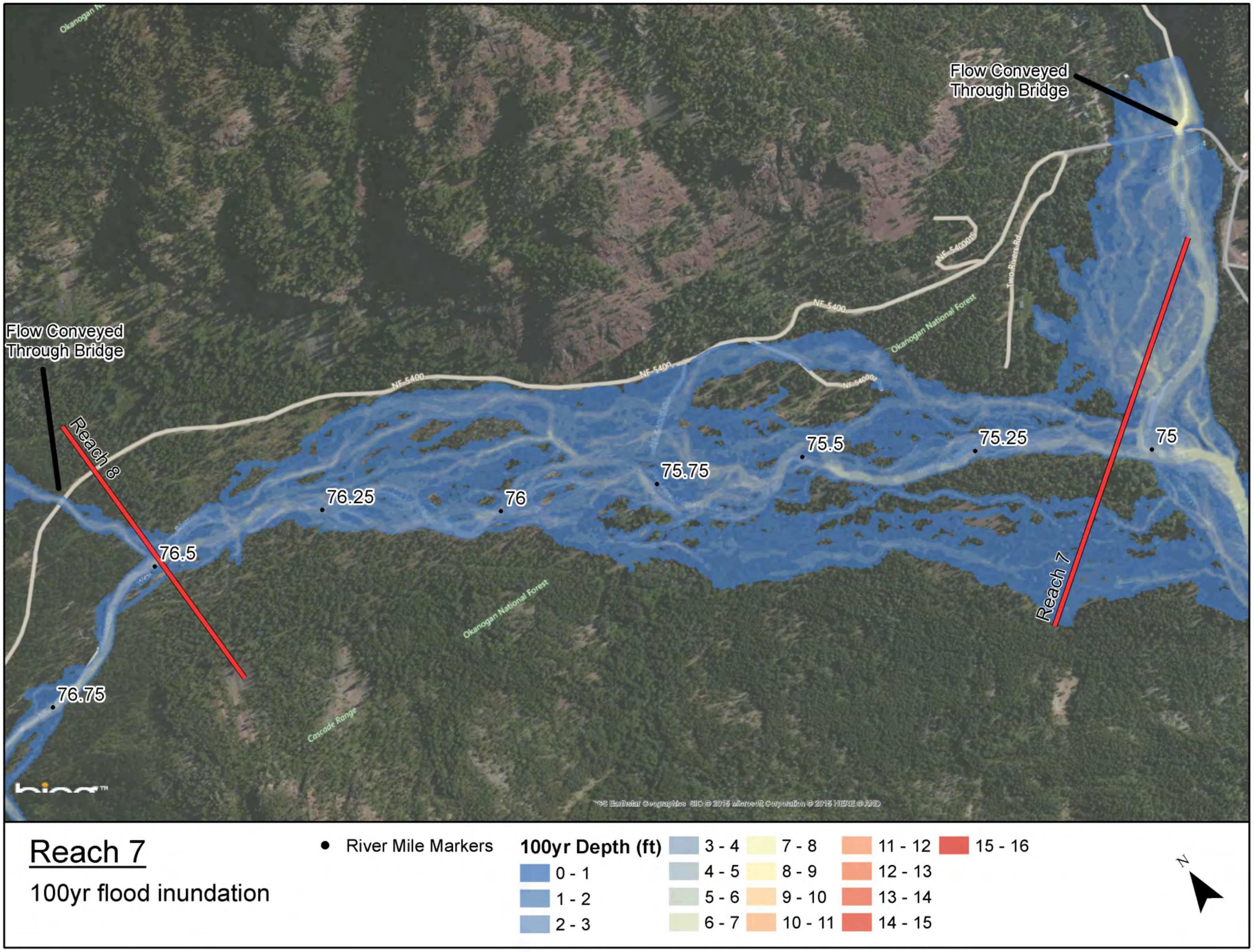

Figure 114. Floodplain inundation for 100YR flood in Reach 7 – developed using a 2D hydraulic model (SRH-2D) built with 2006 LiDAR elevation data.

Floodplain and Channel Migration Zone

The channel in Reach 7 is well-connected to its modern floodplain. Overbank deposits (sand, gravel, wood, and organic debris) indicate regular inundation of the floodplain surfaces along the channel. The potential channel migration zone throughout the reach is laterally unconfined within a floodplain that occupies most of the valley floor. The width of the floodplain increases from 740 feet at the upstream end to 1,500 feet at the downstream end. The channel currently flows through the central portion of the floodplain without contacting the terraces and hillslopes that border the valley. The banks throughout the reach are composed of small boulders and cobbles. In most locations, the banks are reinforced with established vegetation. Thus, during normal or low flows, the banks are relatively resistant to bank failure and erosion. A single push-up levee, at RM 75.4 on river-right, is the only confining human-built feature on the floodplain. Composed of local floodplain material, and approximately 130-feet long and three-feet high, this levee is located on a cut-bank that is currently being eroded by the channel. The levee currently limits surface flow connectivity to a 2,400 foot long side-channel through the river-right floodplain.

The river is vertically and laterally active during high flow events. Channel migration processes in Reach 7 include multichannel and side-channel avulsions, as well as high flow activated channels (Figure 115). The channel is periodically vertically mobile due to abundant bedload inputs, large wood accumulations, and a sufficient amount of stream power during high flow events. Sediment inputs in this reach are sourced from upstream (Reach 8), Robinson Creek and its fan, and from the local channel bed and floodplain. The abundance of sediment in Reach 7 maintains large side- and mid-channel bars throughout much of the reach. Bedload sediment fluxes likely occur in pulses that result in sequences of bed aggradation and degradation. These sequences migrate upstream and downstream as a result of normal channel bed evolution in this sediment-rich reach.

In Reach 7, the floodplain features are inundated at different rates due to the range in surface elevations relative to the channel bed [low (1-2 feet), medium (2-4 feet) and high (4-5 feet)]. Through processes of bed erosion or deposition, the rate of inundation for a particular floodplain surface can change if the channel bed elevation changes. Accumulations of sediment and/or large log jams that force changes in the river’s hydraulics at a site can instigate lateral migration, channel avulsions, or the creation of multiple channels. High flow events can result in scour and/or fill of channel beds. A good example of this can be seen at the recently filled and abandoned channel on the south side of the channel at RM 75.75 (Figure 116).

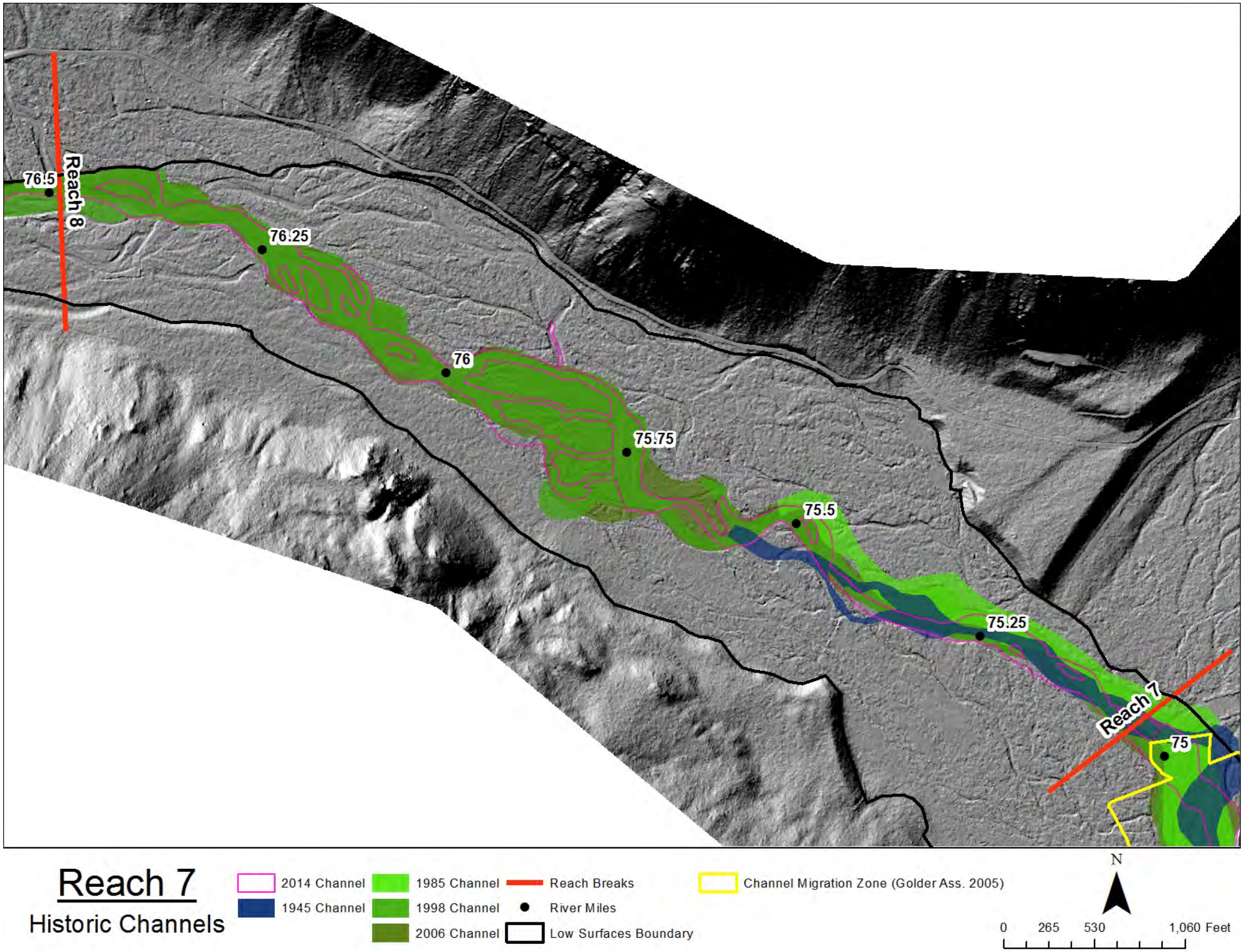

Figure 115. Historical channel locations for Reach 7.

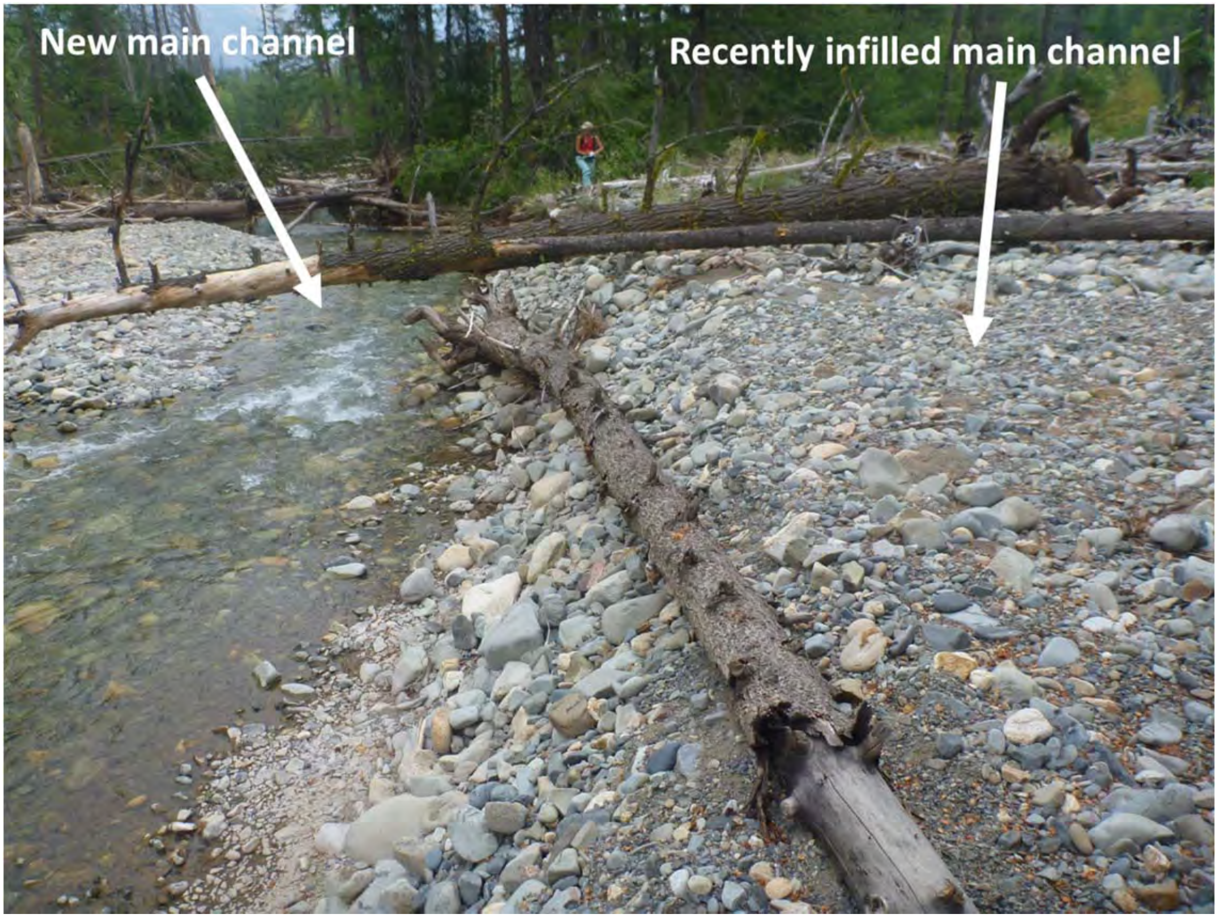

Figure 116. Change in channel location through infilling (instigated by wood accumulations during high flow) and avulsion at RM 75.75.

Sediment

The substrate of Reach 7 is dominated by cobbles (51%) and large gravels (42%) with some small boulders (5%). Sand (2%) is rare within the active channel, except at backwater locations or eddy points (such as near large wood accumulations). The floodplain is composed of materials similar to those seen in the channel bed, but the floodplain has more boulders at its base, as well as accumulations of small gravels, coarse sands, and fines on its surface from overbank deposition. Although this reach regularly mobilizes sediment, it is considered slightly transport limited relative to the quantity of sediment it has available. The excess sediment is stored in the large channel bars and floodplains. Reach 7 receives a notable amount of sediment from the confined transport reach upstream (Reach 8). Robinson Creek and its alluvial fan (modern and historical) also contribute additional gravels, cobbles, and boulders to the upstream section of Reach 7. The channel from RM 76.4 to 76.5 is cutting into the higher, coarser, historical alluvial fan of Robinson Creek. These sediment sources give the channel here a higher percentage of boulder-sized substrate than found downstream.

Large Wood

Reach 7 has abundant large wood in the channel. Six log jams and 221 pieces of wood were counted (the equivalent of 139 pieces per mile). In-channel wood distribution in the reach is presented in Figure 117 as a density, or the number of wood pieces per 100 feet within each delineated channel unit type. Much of the wood (88%) is small or medium sized (<12 inches diameter) and is therefore very transient. There is a lack of the large pieces necessary to self-stabilize in the channel and to serve as the key pieces for log jam formation. The log jam frequency of 3.8 jams per mile is much less than would be expected under natural conditions. Many of the banks and floodplain surfaces are vegetated with mature conifers and deciduous trees with high recruitment potential. Other surfaces have younger stands of typically less than 50 years, which may represent vegetation colonization of bar features created during the 1948 flood. Bank erosion, surface inundation, and channel avulsions all recruit large wood. Once recruited, it is then retained in the channel on the large bars and adjacent, low floodplain features. Channel-spanning logs do occur in Reach 7, especially in the multi-threaded sections where channel widths are reduced. A fresh avulsion path cutting through a vegetated island at RM 75.8 has created a large log jam that includes channel-spanning and racked large wood. Large wood and debris accumulations are common on floodplain surfaces near the active channel. They are also common in ephemeral tributaries and high flow or groundwater-activated channels on the floodplain. Large wood jams and accumulations further increase the geomorphic complexity of the reach by enhancing bar development and maintaining scour pools and off- and side-channel features.

Vegetation

The channel banks and floodplains of Reach 7 are well vegetated (Figure 118). There are maturing forests with trees 50 years or older along the banks and islands that provide shade to the channels and increase bank stability. Mature trees and the dense understory increase floodplain roughness and surface stability. This supports overbank deposition and promotes soil development on floodplain surfaces. The overstory is composed of a mixed forest that includes fir, pine, cedar, aspen, maple, and cottonwood. The understory is a mosaic of shrubs and forbs that includes snowberry, Oregon grape, dogwood, rosehip, elderberry, and thimbleberry (Figure 119). From RM 75.3 to 76.4 along river-left, and at RM 75.7 on river-right, vegetation density is reduced on the floodplains where clearing has occurred to accommodate river access and camping.

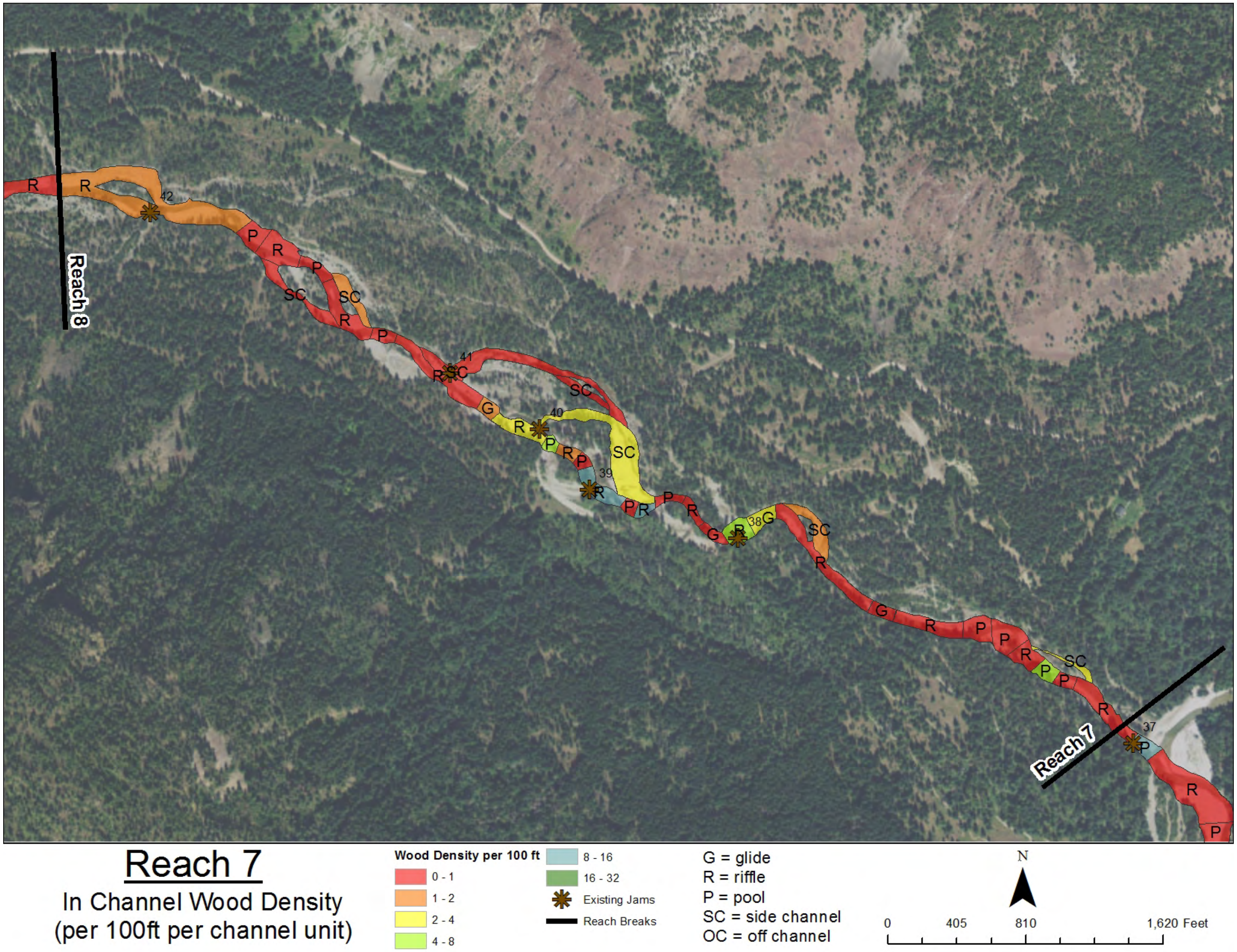

Figure 117. In-channel wood distribution (qualifying wood pieces per 100 ft channel length) within delineated channel units in Reach 7.

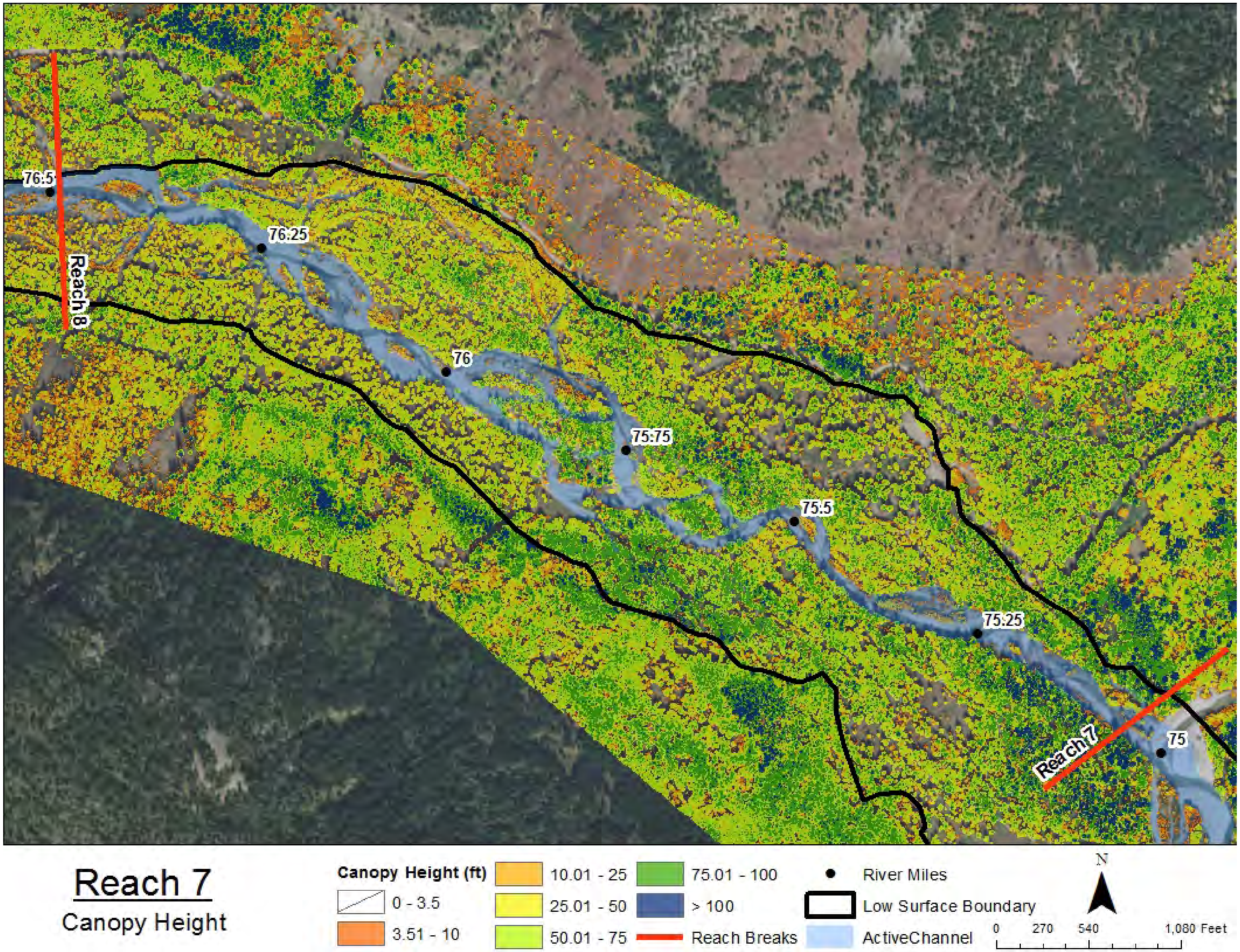

Figure 118. Vegetation canopy height for Reach 7 -- derived from LiDAR first return (highest hit) data (includes buildings and other human infrastructures).

Figure 119. Example of mixed vegetation along a side-channel at RM 75.8. (10/15/2015)

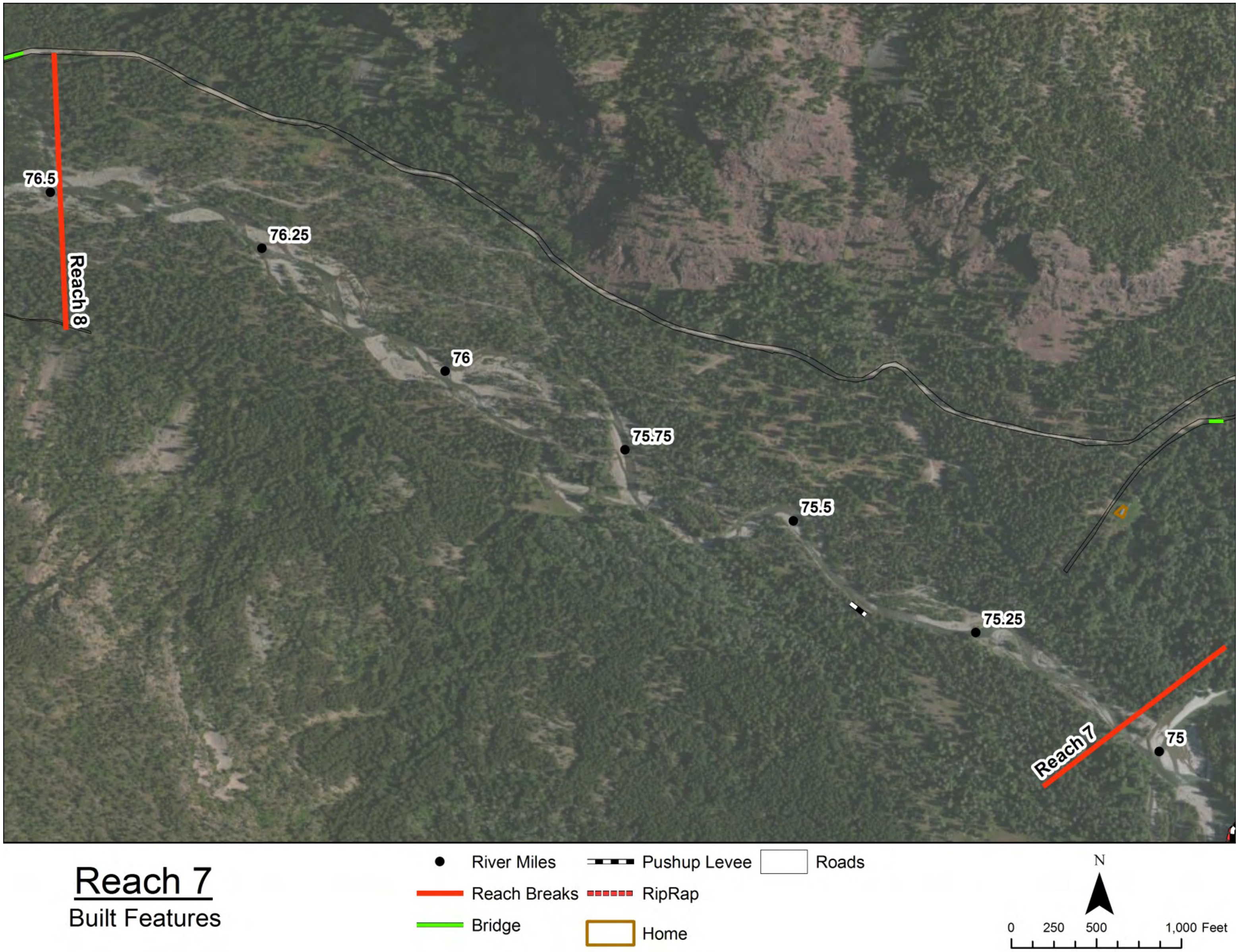

Figure 120. Primary human features in Reach 7.

3.7.3 Human Alterations

Human features are mapped in Figure 120. The primary human alteration in the reach includes the following, which is described further in the subsection below.

- Changes to channel and floodplain function

Changes to Channel and Floodplain Function

One push-up levee, approximately 130 feet long by three feet tall, and constructed from local cobbles and soil, is located on river-right at RM 75.4. The intention of this feature appears to be to reduce the connectivity between the mainstem channel and a small but prominent floodplain side-channel. It is assumed that this effort was made to keep the mainstem from avulsing into and through the floodplain during a high flow event.

A double track, dirt, Forest Service Road (FS 5400) borders the floodplain on the north side of the reach. On river-left, from RM 75.3 to 76.4, a sparse web of single track dirt roads provides access to the river and floodplain. Forest Service Road 5400 crosses Robinson Creek and Lost River over bridges at the edge of the valley above the active floodplain. The bridge crossings have the potential to alter tributary sediment inputs and to restrict shifts in tributary pathways across their alluvial fans. Along the south side of the valley, a decommissioned road has been converted to a recreational trail. This trail travels through a few open meadows on the floodplain, including one that borders the channel at RM 75.7. Historical human alterations to the river-right floodplain in Reach 7 are indicated by the trail and meadows described above, as well as by the presence of a small dilapidated structure. However, the ungraded condition of the meadows and the lack of stumps suggest that no recent vegetation removal has occurred there.

Partial vegetation clearing, single-track dirt road construction, and historical gravel extraction has slightly impaired natural floodplain function. Within Okanogan National Forest lands, vegetation thinning and dirt roads accommodate river access, camping, and hunting on river-left from RM 75.3 to 76.4. The roads and reduced vegetation cover alter normal surface flow routing and sediment delivery across the floodplain. However, the vegetation clearing on river-left in Reach 7 only slightly impacts forest density and composition along the banks of the channel. Historical gravel pit extraction is demarcated on old topographic maps near the channel along river-left at RM 75.3. Channel migration and bar development has removed evidence of the pit, but a dirt road still accesses the channel in this area.

3.7.4 Recommended Actions

Recommended actions in Reach 7 are focused on restoring channel complexity and increasing side-channel and floodplain connectivity. Channel complexity is best addressed by placing apex and debris capture log jams to establish more islands and enhance lateral and split flow conditions. Debris capture jams are likely to be effective at capturing much of the smaller wood anticipated to enter the reach from upstream due to recent wildfire, debris flow, and snow avalanche contributions. Side-channel and floodplain connectivity can be addressed by removing the push-up levee, constructing apex jams, and targeted excavation. Channel margin improvements can be made with large wood complexes along unvegetated banks. Native riparian vegetation planting in the few areas where clearing has occurred is also recommended.

Restoration recommendations recognize the importance of maintaining connectivity of the mainstem channel to perennial or groundwater-fed tributaries and side-channels. This has been identified as a critical component for fish survival in a system with the potential to seasonally dewater.

See Section 4 of this report for the restoration strategy and specific project recommendations for the reach.

3.8 REACH 8

Refer to Section 2.2 and 2.8 for geologic and geomorphic context of the study area and explanation of terminology.

3.8.1 Reach Overview

Reach 8 is 2.2 miles long and extends from the Robinson Creek confluence (at RM 76.50) to RM 78.60. All of Reach 8 is within the Okanogan National Forest (Figure 121). The channel and its narrow floodplain are confined between hillslopes, glacial outwash terraces, and alluvial fans. The channel in Reach 8 has a relatively high gradient (2.2%) and a moderate sinuosity of 1.07. The active floodplain has an average width of 290 feet; however, it narrows to channel width in the confined section from RM 78.85 to77.35 and then widens to 760 feet at the confluence with Robinson Creek. The average active channel width in Reach 8 is 56 feet. These and other reach metrics are provided in Table 14 and Figure 123.

The channel in Reach 8 is a single-thread, riffle-pool stream with extended riffles and short pools (Figure 122). Many of the pools are maintained with boulder steps. There are three side-channels from RM 76.6 to 76.9, where aggradation is occurring due to local sediment inputs and large wood accumulation. The channel bed and active floodplains are composed of materials ranging in size from gravels to boulders, but large cobbles dominate the substrate. Hillslope inputs include weathered bedrock debris, glacial lag, and glacial terraces (rounded sand to boulders). Alluvial fan inputs from river-left (north side of the channel) also contribute sand- to boulder-sized material to the channel. Coarse sand and gravels are efficiently transported through the channel except where they are temporarily stored on floodplains or in localized deposition zones such as bar tops or eddies. The reach is vegetated with maturing forests except where forest fires recently burned most of the vegetation. The forest fire in 2003 left standing snags from RM 77.9 to 78.6; this section now has an establishing understory of shrubs and saplings. The remaining snags are now a plentiful source of large wood to the channel. This wood is influencing and will continue to influence geomorphic processes in Reach 8, and downstream reaches, for a decade or more.

The habitat conditions in Reach 8 are discussed in Appendix A. Based on the REI analysis, only 4 of 11 habitat indices are rated as either unacceptable or at risk (see Table 6). Human alterations to Reach 8 are minimal and limited to a dirt road, trails, and three campgrounds that are mostly located above the active floodplain. Construction of push-up levees and the partial clearing of vegetation at Ballard Campground (RM 76.75) have the potential to locally impede natural channel processes. Otherwise, healthy, natural, hydrologic and geomorphic processes are occurring in this reach.

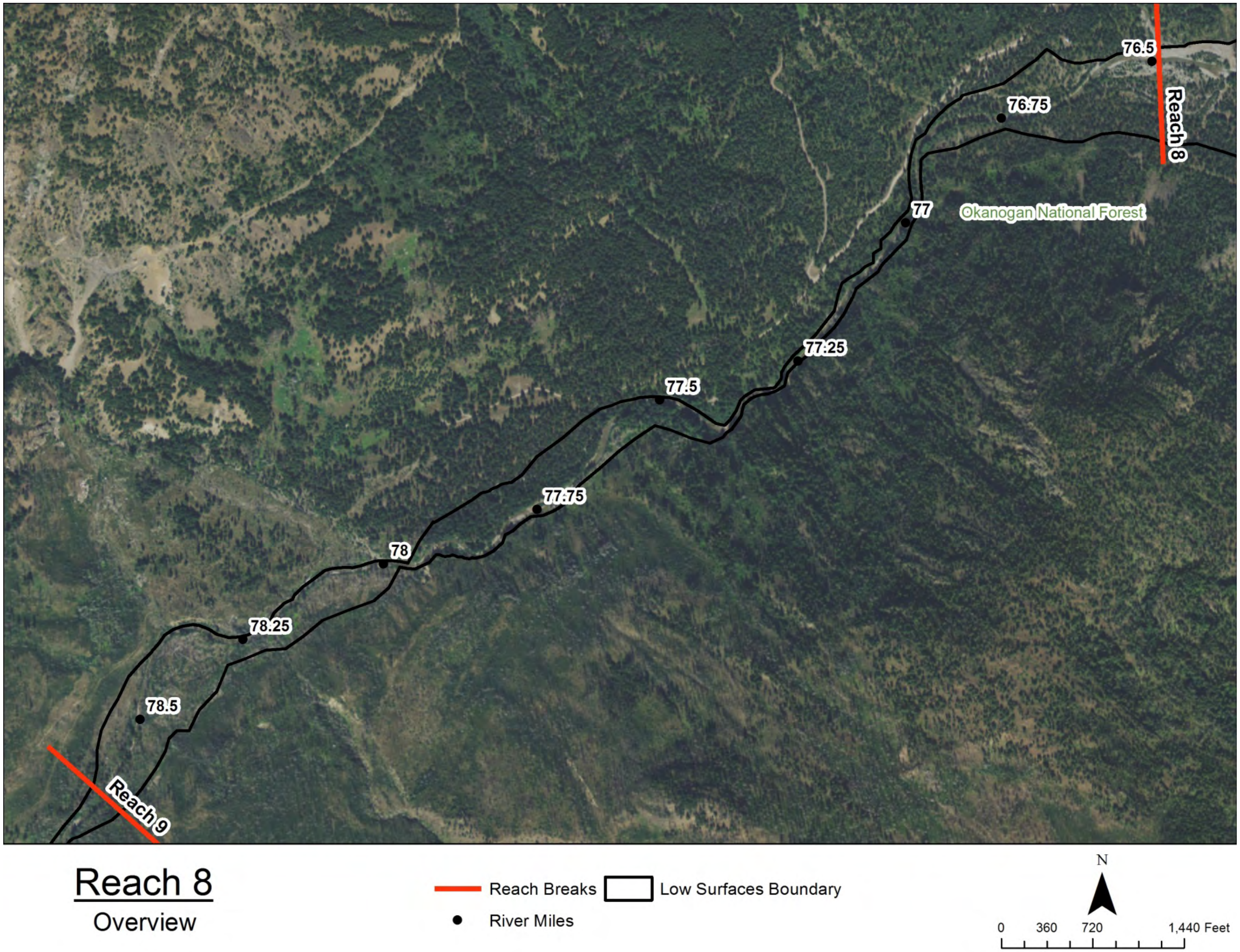

Figure 121. Reach 8 overview map.

Figure 122. Representative photo of Reach 8; looking downstream at RM 78.25. (10/15/2014

Table 14. Reach 8 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	2.2
River Miles	76.5 – 78.7
Valley Gradient	2.6%
Stream Gradient	2.2%
Sinuosity	1.07
Dominant Channel Type	Cascading riffle-pool
Average Bankfull Width (feet)	56
Average Floodplain Width (feet)	290
Dominant Substrate	large cobble & boulder; sparse sand and gravel
Bank Stability/Channel Migration	Adequate *(See Section 2.12)*
Vertical Channel Stability	Adequate *(See Section 2.12)*
Confinement ratio	Unconfined *(See Table 5)*

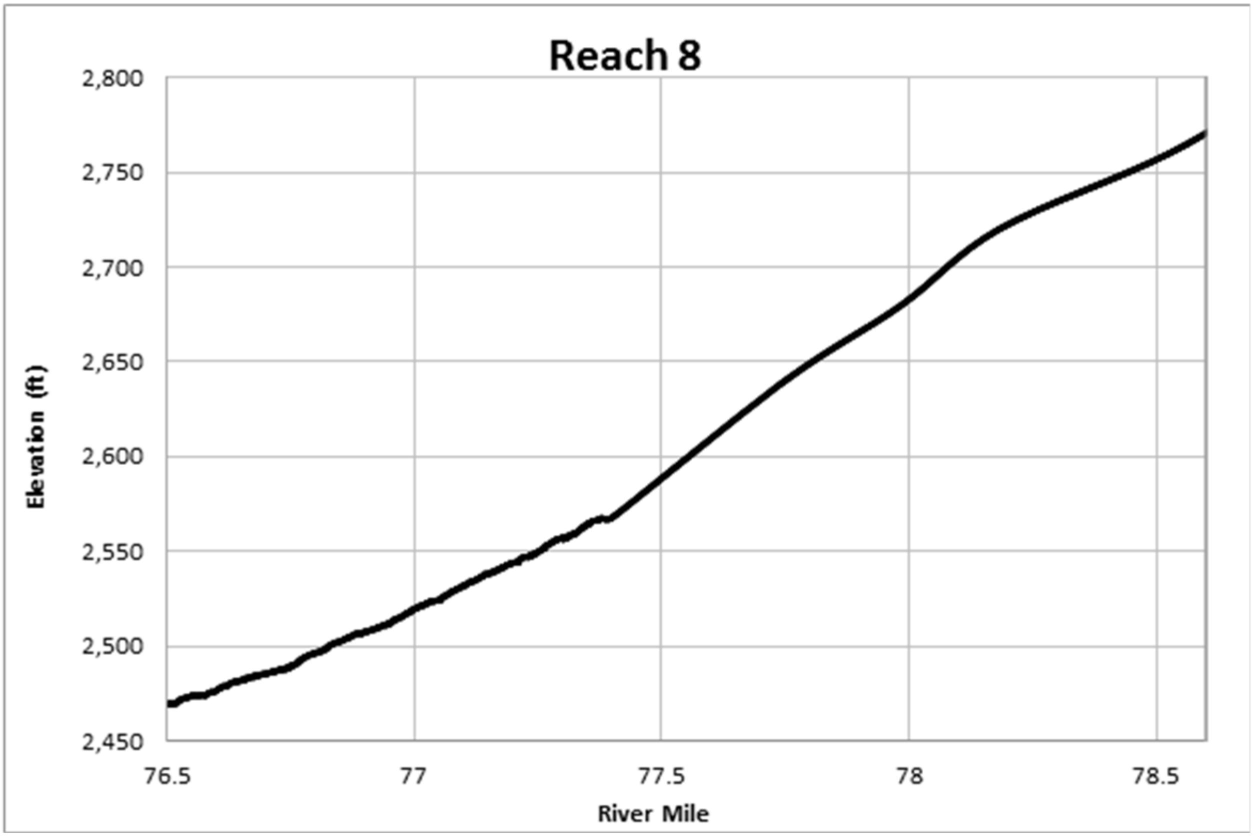

Figure 123. Longitudinal profile of the channel in Reach 8 (RM 76.5 to 78.7).

3.8.2 River Morphology and Geomorphic Processes

Geology and Landforms

Reach 8 is located within a U-shaped valley that was most recently carved by Quaternary glaciation. Increased discharge regimes during early Holocene glacial retreat deposited thick layers of glacial outwash across the valley floor. The valley walls are less confining in Reach 8 than upstream in Reach 9. In Reach 8, there are remnants of a paired set of glacial outwash terraces that form tall hillslopes on the edges of the valley. A lower set of outwash terraces is located from RM 77 to 78, indicating at least one sequence of incision and/or glacial extension, followed by more valley infilling during glacial retreat. Subsequent high discharge and sediment loads from glacially-carved tributaries on river-left have created wide boulder-to-cobble alluvial fans across the glacial outwash terraces. These same tributaries continue to deposit material across their alluvial fans and to the channel, but with a reduced hydrologic regime. A map of the geomorphic surfaces is provided as Figure 124.

In response to the modern sediment and discharge regimes, the channel in Reach 8 has incised into the terrace and fan deposits, creating a narrow, inset, active floodplain. Modern vertical incision rates are limited in this reach by the size of the underlying substrate and incoming sediment supplies. Where the channel contacts the terrace hillslope, inputs are a mix of sand- to boulder-sized rounded sediment. An example of such inputs is visible on river-right at RM 77.9, where a recent landslide occurred from a terrace slope that overlies bedrock. The landslide contributed glacial outwash material and large wood directly into the channel. These inputs have temporarily increased local and downstream channel complexity. Weathered bedrock and talus slopes also contribute direct hillslope inputs where they contact the channel on river-right, from RM 77.15 to 77.4.

Hydrology

Reach 8 has a seasonally fluctuating flow regime. Late spring and early summer snowmelt events activate side-channels and often inundate the narrow, low floodplain surfaces. Fresh accumulations of coarse sand and gravels on the lower floodplain surfaces suggest regular inundation rates of every two to 10 years. Hydraulic modeling performed on the lower third of the reach, where surface elevation LiDAR was available, confirms side-channel activation by high flow events in the more confined downstream section of the reach (Figure 125 and Figure 126). It is only during high flow events that the channel is capable of mobilizing its over-sized bedload of cobbles and boulders. Autumn low flows expose banks and large instream boulders. Summer thunderstorms are capable of temporarily raising surface-water elevations in Reach 8 because the bedrock-dominated valley walls and upstream drainage areas have low surface-water retention capacity.

The valley floor is composed primarily of coarse-grained material that supports active hyporheic flow and groundwater influx from upstream and the adjacent terrace slopes and alluvial fans. The mainstem channel and side-channels within the active floodplain of Reach 8 are actively exchanging surface flow with groundwater through hyporheic processes. At pools, temperatures collected during the survey were markedly lower, suggesting groundwater influx.

Surface water contributions in Reach 8 include four ephemeral tributaries and two perennial tributaries. These deliver discharge from steep hillslopes and adjacent glacially-carved hanging valleys. One of the unnamed ephemeral creeks enters the reach on river-left. This tributary flows over a well-developed fan that splits the flow of the tributary such that it has two input points (RM 77.2 and RM 76.85) to the reach. Hydrologic inputs from the ephemeral tributaries are dependent on local snowpack and summer thunderstorms. The main ephemeral contributions occur at river miles 76.55, 76.8, 76.85, 77.2, and 77.35. According to the US Bureau of Reclamation's surface-flow estimates (2008 – Appendix J), the combined ephemeral tributaries contribute an estimated 4% of the discharge within the reach during high flows. The perennial Driveway Creek enters the valley on river-right at RM 78.25 with no-to-little modern alluvial fan, and contributes approximately 3% of the surface flow. The other perennial tributary, Rattlesnake Creek (RM 78.1), contributes approximately 10% of the discharge in the reach and enters the valley on river-left over a well-developed alluvial fan. The fans are composed of coarse material that acts as a conduit for subsurface groundwater contributions. However, the quantity of groundwater that the tributaries contribute to Reach 8 is unknown.

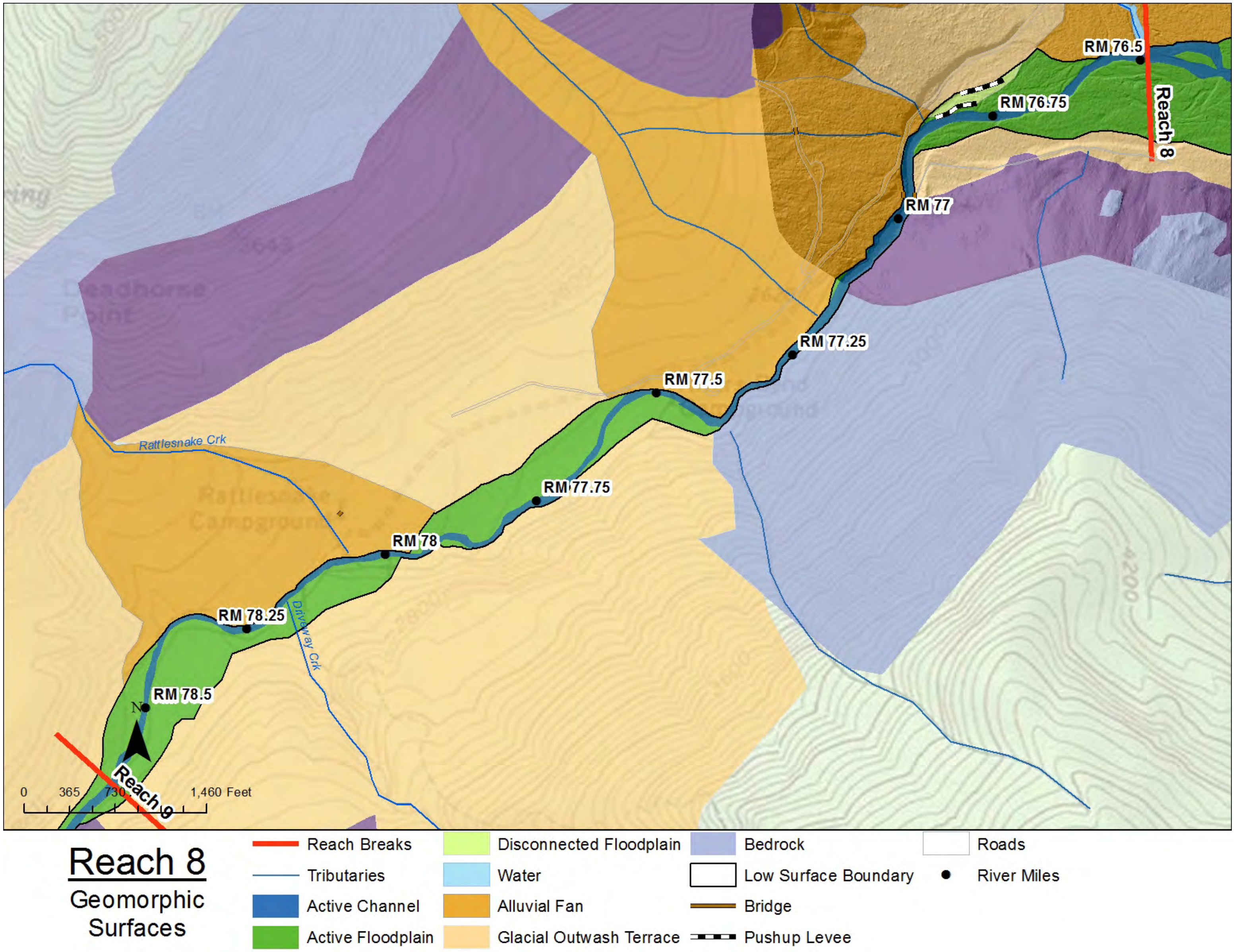

Figure 124. Geomorphic surfaces of Reach 8 with human-built features (bridges, levees, and roads).

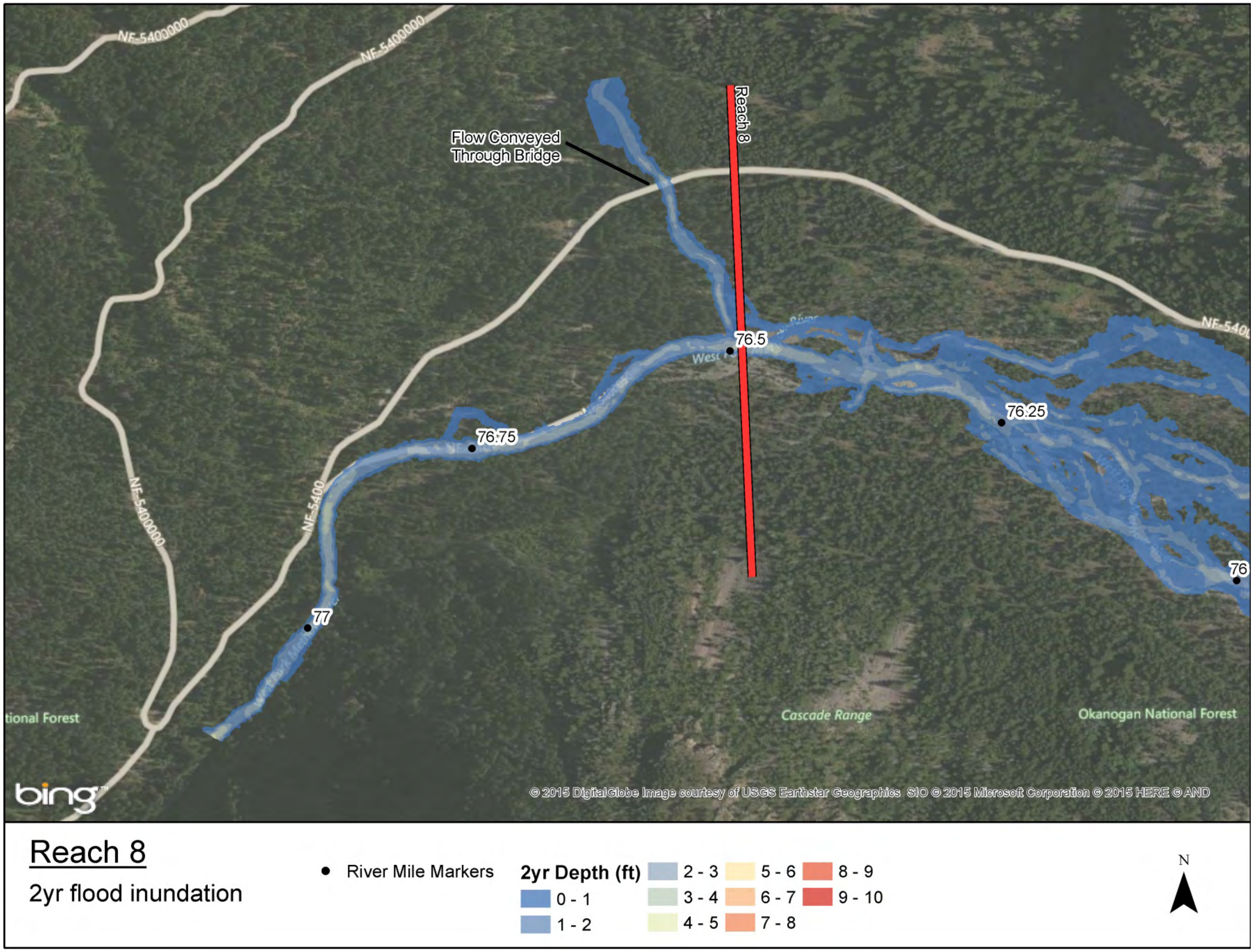

Figure 125. Floodplain inundation for 2YR flood in Reach 8 – developed using a 2D hydraulic model (SRH-2D) built with 2006 LiDAR elevation data.

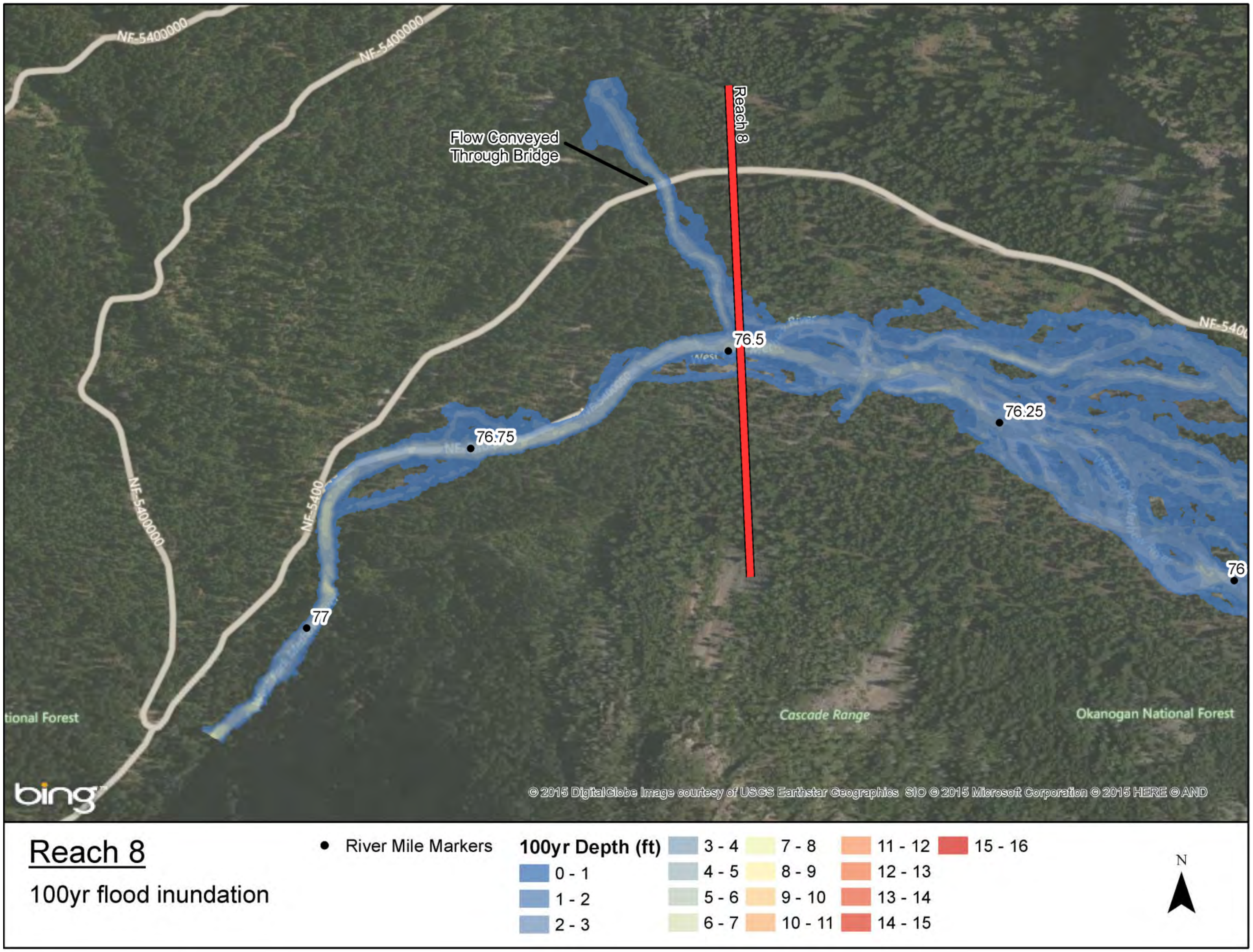

Figure 126. Floodplain inundation for 100YR flood in Reach 8 – developed using a 2D hydraulic model (SRH-2D) built with 2006 LiDAR elevation data.

Floodplain and Channel Migration Zone

The floodplain and channel migration zone of Reach 8 alternates between confined and moderately confined. Lateral movement is restricted by glacial outwash terraces, alluvial fan toes, and adjacent bedrock walls. The inset, active, floodplain width ranges from 36 feet to 760 feet with an average overall width of 290 feet. The migration zone and active floodplain surfaces are the most narrow and straight from RM 76.85 to 77, where the channel is confined by bedrock and talus on river-right and the steep toe of a fan on river-left. Minimal change of mainstem channel location has occurred in the last fifteen years according to aerial imagery (Figure 127). Vertical stability is maintained in Reach 8 by plentiful incoming sediment from upstream and the adjacent slopes. Vertical incision here is also limited by the relative size of the substrate to the modern discharge regime. Currently, the modern channel is mostly connected to the inset floodplain surfaces of the narrow valley. Fresh accumulations of coarse sand and gravels on the lower floodplain surfaces suggest regular inundation rates of every two to 10 years. The presence of small side-channels from RM 76.6 to 76.9 indicates that this section of Reach 8 has aggraded in response to sediment inputs. Most recent sediment and large wood inputs to this section are from a landslide off of a glacial terrace slope at RM 76.9, on river-right.

Sediment

The substrate of this reach is dominated by large cobbles. However, bedload size in Reach 8 ranges from gravels to large boulders, with very sparse accumulations of sand. The extended riffle beds are composed of cobbles and boulders. Direct hillslope inputs to this reach include material from weathered bedrock, glacial outwash terraces, and alluvial fans. The sediment load is primarily locally sourced, but clasts are rounded to sub-angular due to the variety of hillslope sources. Where large boulders are present, they add hydraulic roughness to the bed and banks. The step-pool channel units are defined by relatively stable boulder steps. Gravel-sized bedload is present in pockets and as bars in depositional zones in the channel near large wood accumulations, at eddies, or as bar features in seasonally-occupied, high flow secondary channels. Coarse sands are present as overbank deposits on low-lying vegetated floodplain surfaces and as a top layer on some of the bar features, especially immediately downstream from landslides or colluvium. All other fine-grained sediment is fluvially transported through this reach. Gravel counts were not conducted in Reach 8 because of large bedload size relative to channel geometry, and the lack of LiDAR for hydraulic modeling.

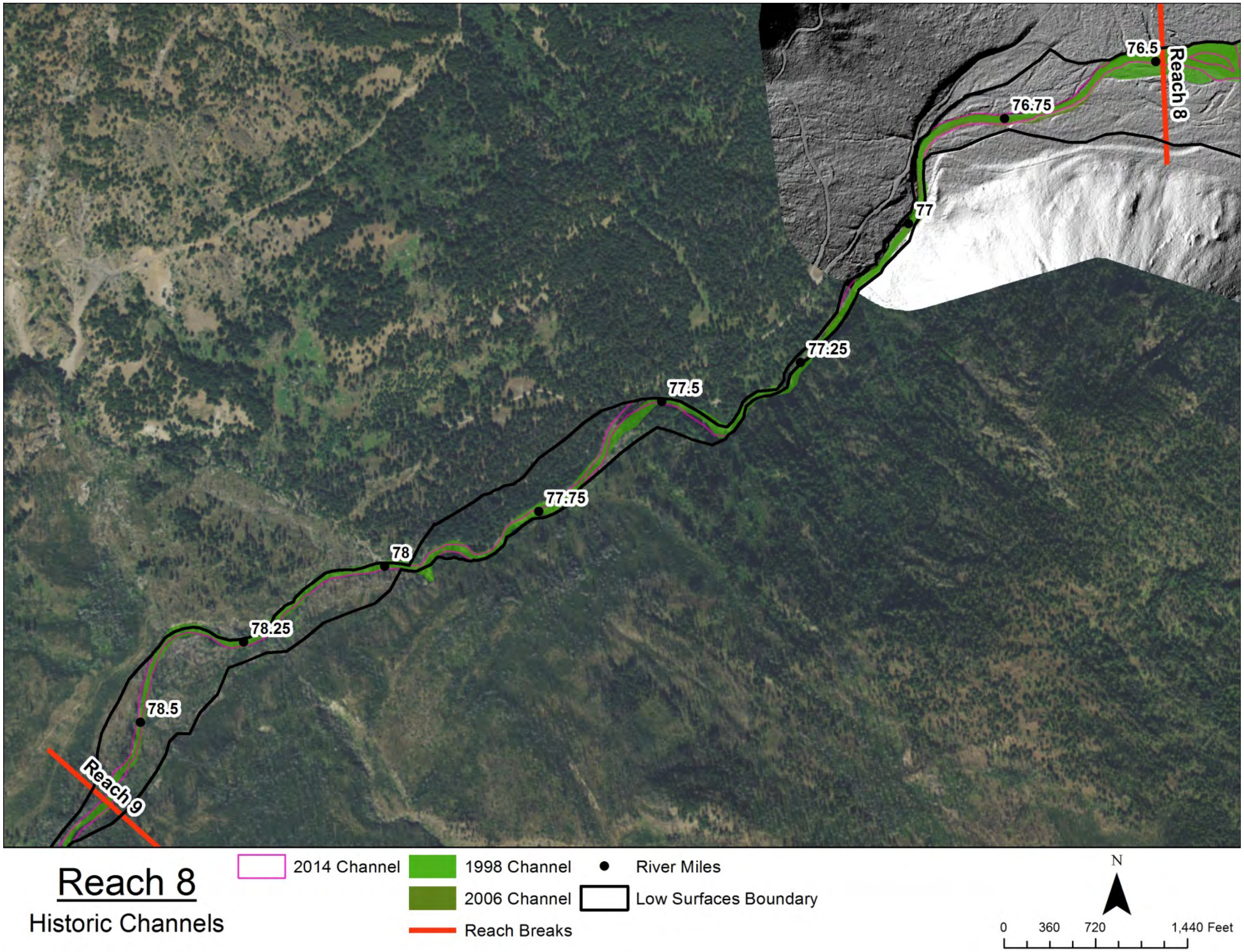

Figure 127. Historical channel locations for Reach 8.

Large Wood

Reach 8 has a moderate amount of large wood in the channel. Four log jams and 275 logs were counted; the equivalent of 123 logs per mile. In-channel wood distribution in the reach is presented in Figure 129 as a density, or the number of wood pieces per 100 feet within each delineated channel unit type. The valley floor and adjacent terraces and fan slopes throughout this reach are well vegetated with mature conifers. These mature trees offer high recruitment potential for wood. The upper 0.7 miles of Reach 8 recently burned in the Needles forest fire (2003), leaving burnt standing snags near the channel. These snags currently increase the likelihood of local wood inputs to the upper section of the reach. Channel width allows for channel-spanning logs to occur in Reach 8 even though the extended riffle sections have a steep enough gradient to transport large wood downstream. Channel complexity and floodplain connectivity is increased where in-channel large wood retention has occurred in the form of log jams.

Vegetation

The channel banks and floodplains of Reach 8 are well vegetated. Low vegetation density on the confining slopes is due to slope steepness and rocky composition, patchy historical thinning, and forest fires (Figure 130). Vegetation density is also reduced at bedrock contact points. The overstory of vegetation on the valley floor is composed of a mature forest of fir and cedar. These trees reach heights of more than 50 feet, except in the upstream section which was recently impacted by the Needles forest fire in 2003. The mature conifer forest supplies ample shade to the channel and floodplain. The understory along the banks is a mixed composition of vegetation that includes dogwood, maple, ninebark, and sparse cottonwood (Figure 128). The density of the understory increases where conifers are young, and where the overstory has been removed by forest fires and/or landslides. The lack of stumps on floodplain surfaces indicates that no major logging activities occurred in the upper two-thirds of the reach in the last 100 years.

Figure 128. Varied bank vegetation in Reach 8 - burned snags, dense understory, mature conifers; looking upstream at RM 77.5. (9/5/2104)

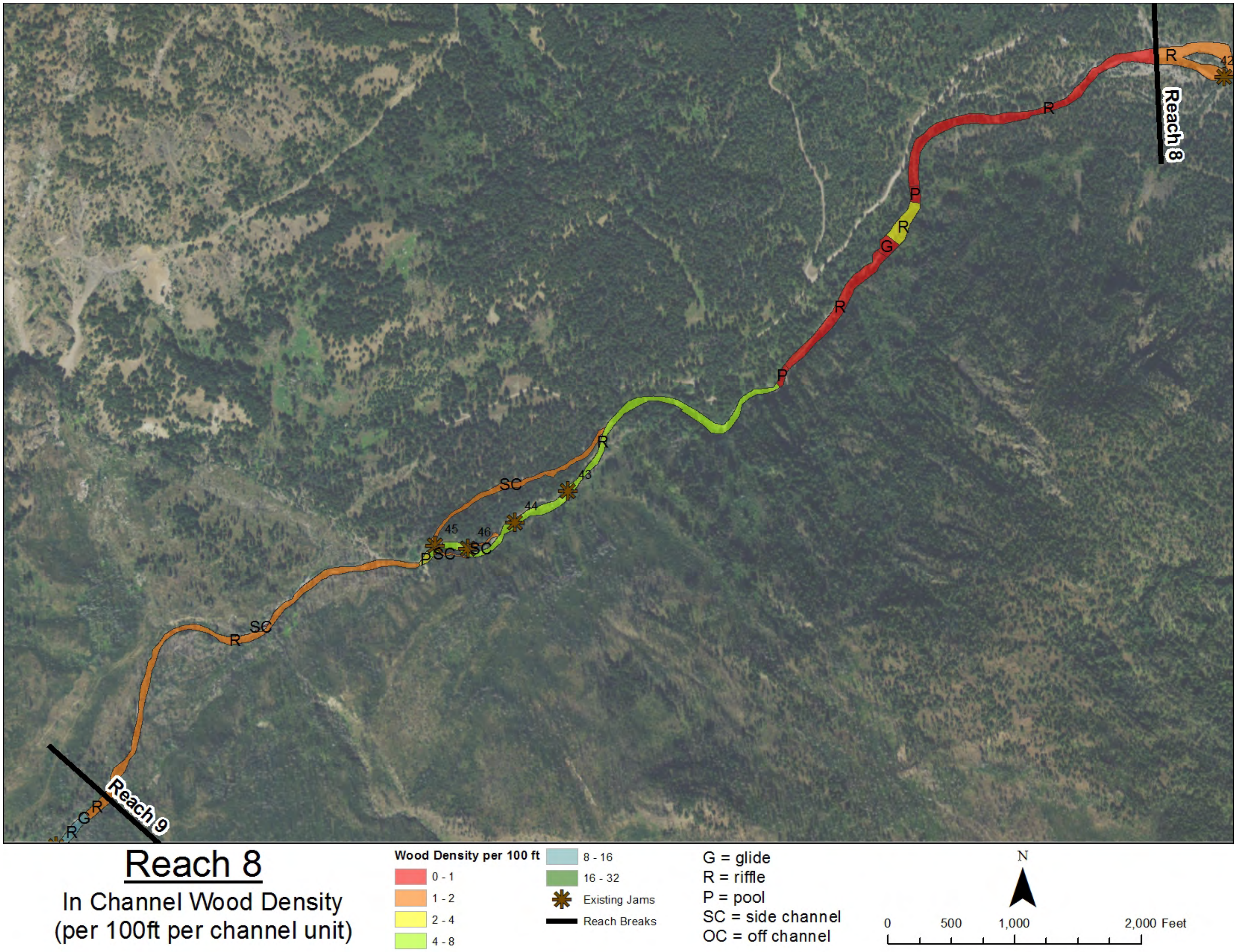

Figure 129. In-channel wood distribution (qualifying wood pieces per 100 ft channel length) within delineated channel unitsin Reach 8.

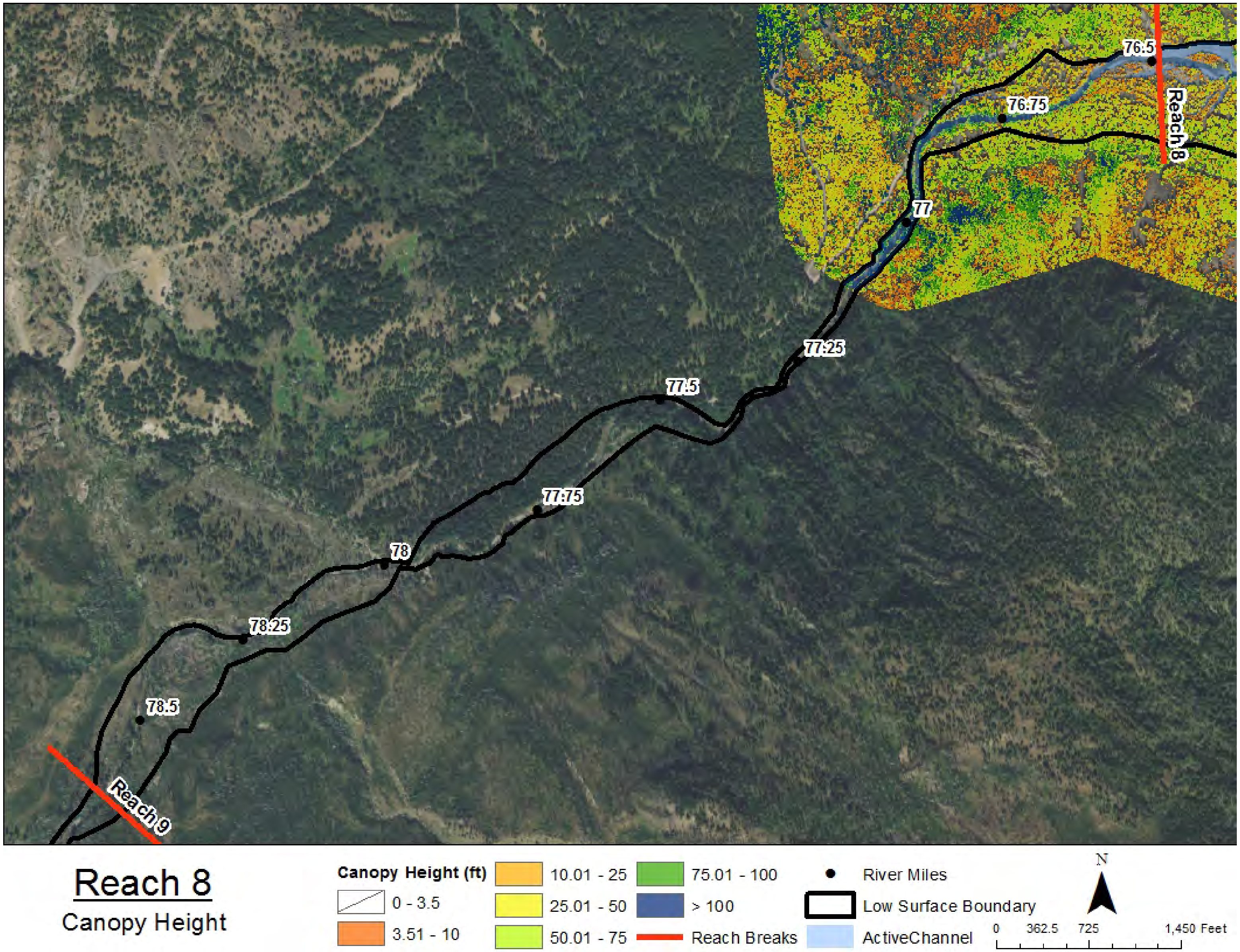

Figure 130. Vegetation canopy height for Reach 8 -- derived from LiDAR first return (highest hit) data. Available only for the lower portion of the reach from RM 76.5 to 77.15.

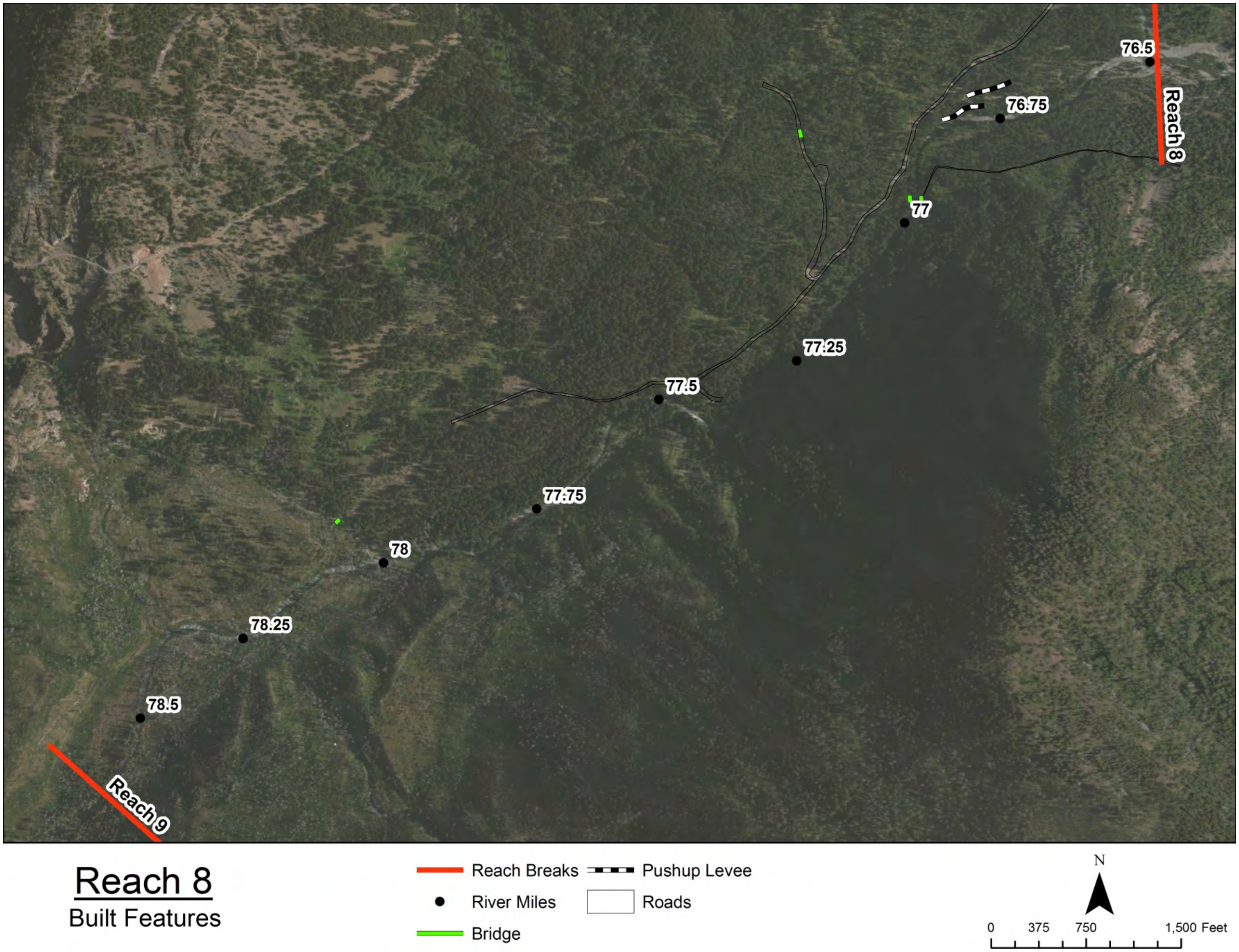

Figure 131. Primary human features in Reach 8.

3.8.3 Human Alterations

Reach 8 has experienced only minor anthropogenic alterations to modern channel processes. Human features are mapped in Figure 131. The primary human alteration in the reach includes the following, which is described further in the subsection below.

- Changes to channel and floodplain function

Changes to Channel and Floodplain Function

A set of push-up levees was constructed at the upstream end of Ballard Campground on river-left from RM 76.75 to 76.8. They were made from local cobbles, boulders, and soil. The intention of these features appears to be to restrict the channel from flooding or laterally migrating into the campground and trails. The campground and trails are located on the active floodplain adjacent to the channel and slightly downstream from the levees. The levees slightly constrict natural lateral channel processes here and reduce the active floodplain and channel migration zone by approximately 100 feet.

A few other human-built features interact relatively inconsequentially with natural channel processes in Reach 8. A double track, dirt Forest Service road (FS 5400) runs along the terrace and fan surfaces on river-left above the active floodplain and channel. A few single track dirt roads branch off of this road allowing access to Ballard, River Bend, and Rattlesnake Campgrounds. Forest Service road 5400 has four tributary crossings (fords, small bridges, or culverts). These features have the potential to alter tributary sediment inputs and to restrict shifts in tributary pathways across their alluvial fans. Rattlesnake Campground is also the trailhead (Trail No. 480) for a one- to three-foot-wide path that runs across the terrace and alluvial fan slopes on river-left. The trail is higher in elevation than the channel and its active floodplain features. A decommissioned road has been converted to a recreational trail on the other side of the river. Located on top of the glacial terrace on river-right, and in the downstream portion of the reach, this road/trail intersects the channel where the channel is completely confined between hillslopes at RM 76.95. Cement bridge abutments remain at this historical crossing, but the alterations they currently pose to channel processes is inconsequential. The river-right abutment was constructed on an existing bedrock wall, only slightly altering natural bank roughness. The river-left abutment is approximately 15 feet above and 20 feet inland from the channel bank on a terrace surface.

3.8.4 Recommended Actions

Recommended actions in Reach 8 are focused on reactivating side-channels and floodplain surfaces. However, existing mostly undisturbed conditions and access challenges limit restoration opportunities in Reach 8. Side-channel and floodplain reactivation can be addressed by removing the push-up levee and bank armoring near Ballard Campground.

See Section 4 of this report for the restoration strategy and specific project recommendations for the reach.

3.9 REACH 9

Refer to Section 2.2 and 2.8 for geologic and geomorphic context of the study area and explanation of terminology.

3.9.1 Reach Overview

Reach 9 is 1.3 miles long and extends from RM 78.7 to the confluence with Trout Creek at RM 80. The Trout Creek confluence is the upstream boundary of the study area. The channel in Reach 9 is a relatively straight, single-thread, cascading stream with extended riffles and boulder steps (Figure 133). The channel and its narrow floodplain are confined between adjacent hillslopes with an average floodplain width of 161 feet and an average bankfull width of 52 feet. Valley width is greatest at approximately 350 feet at the upstream end at the Trout Creek alluvial fan and narrowest at approximately 55 feet near RM 79. The reach has a relatively high gradient compared to the rest of the study area (2.7%). These and other reach metrics are provided in Table 15 and Figure 23.

The channel geomorphology is driven by seasonal spring snowmelt discharge, hillslope contributions, and large wood inputs. The valley floor of the reach is well vegetated with mature forests, but a forest fire in 2003 left only snags standing from RM 79.6 to the upstream boundary of the reach. Locally-sourced boulders and large cobbles dominate both channel bed and bank material. During normal flow conditions, gravel- to sand-sized material is transported downstream, while the boulder substrate remains relatively stable.

The habitat conditions in Reach 9 are discussed in Appendix A. Based on the REI analysis, none of the 11 habitat indices are rated as either unacceptable or at risk (see Table 6). Natural, healthy, hydrologic and geomorphic processes are occurring in this reach. There are minimal-to-no modern human alterations influencing channel processes. All of Reach 9 is contained within the Okanogan National Forest.

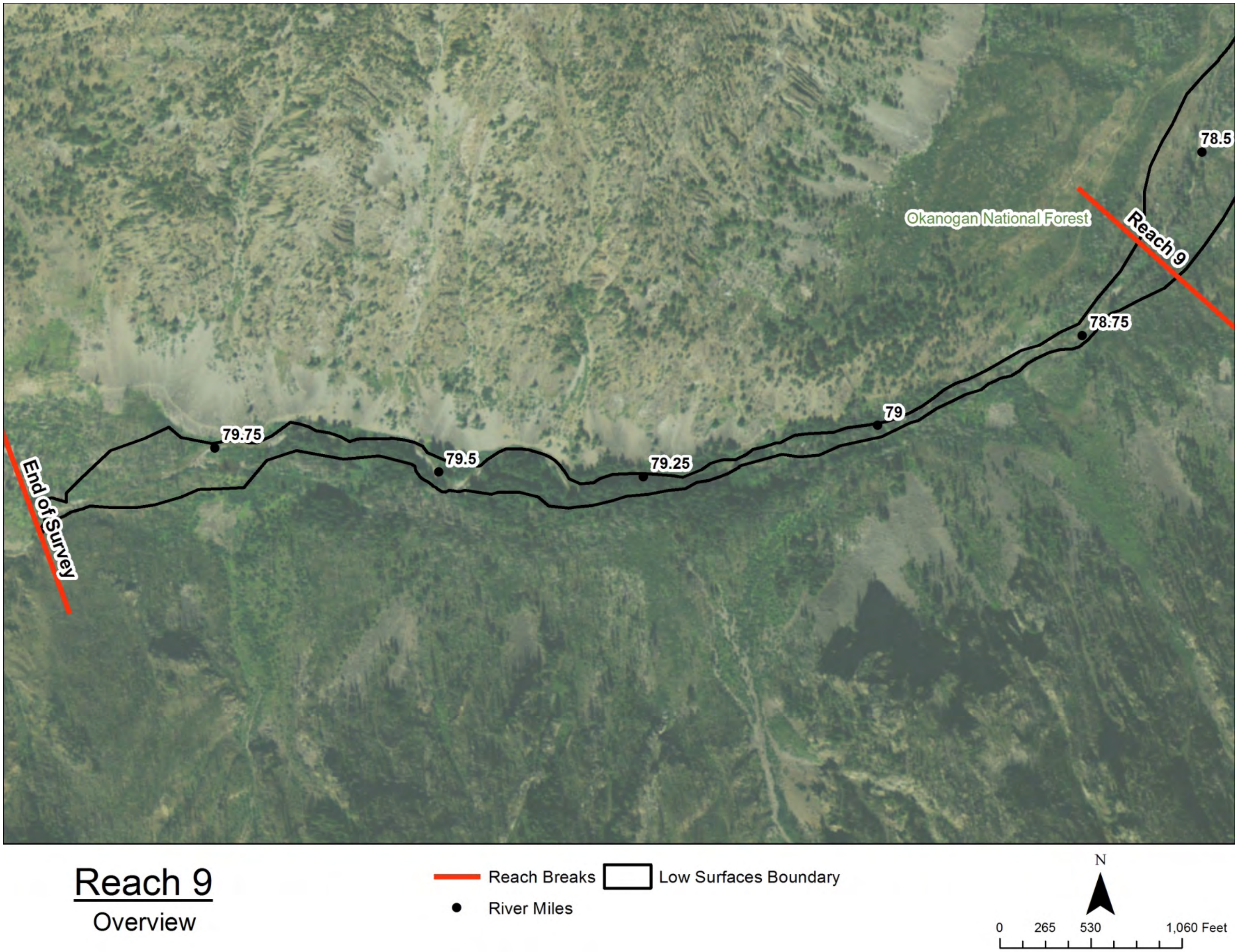

Figure 132. Reach 9 overview map.

Figure 133. Representative photo of Reach 9; looking downstream at RM 79.30. (9/2/2014)

Table 15. Reach 9 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	1.3
River Miles	78.7 – 80
Valley Gradient	2.5%
Stream Gradient	2.7%
Sinuosity	1.05
Dominant Channel Type	Cascading riffle
Average Bankfull Width (feet)	52
Average Floodplain Width (feet)	161
Dominant Substrate	boulder & large cobble; sparse sand and gravel
Bank Stability/Channel Migration	Adequate *(See Section 2.12)*
Vertical Channel Stability	Adequate *(See Section 2.12)*
Confinement ratio	Moderate *(See Table 5)*

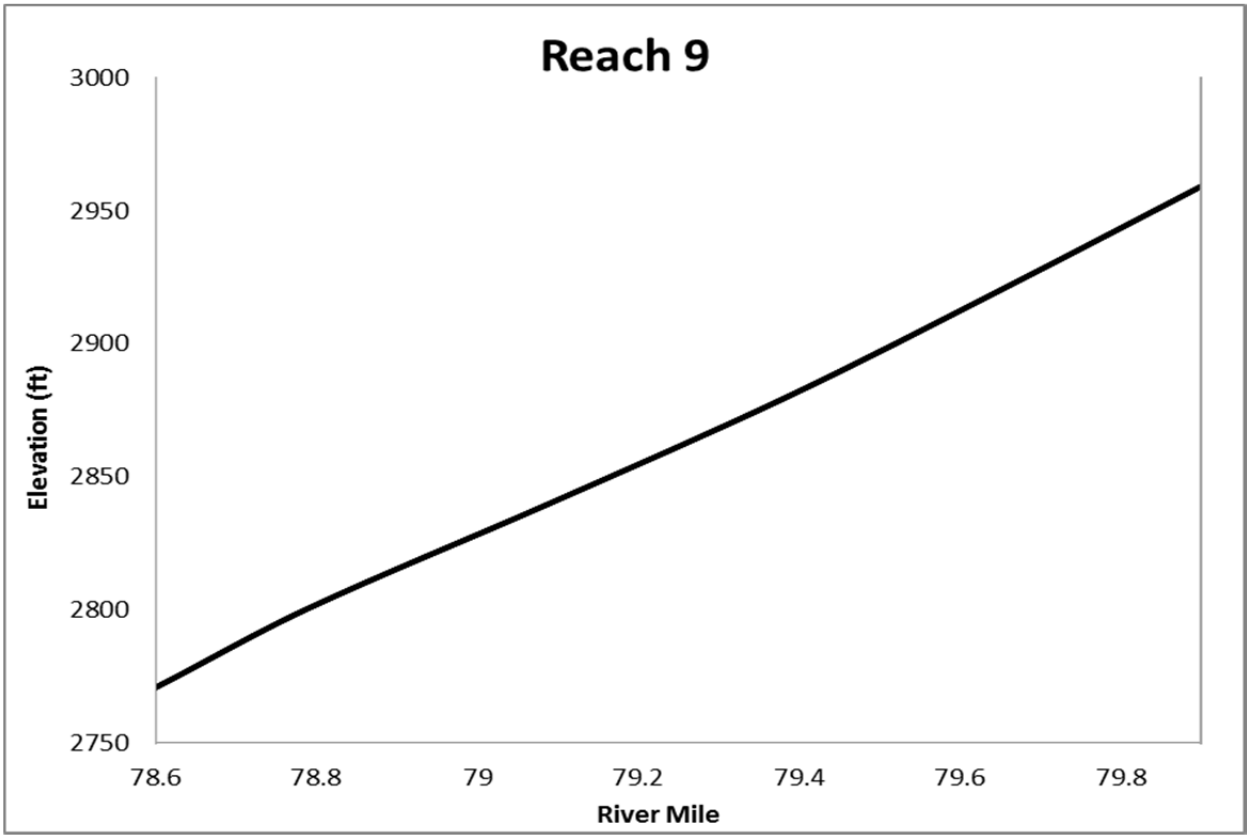

Figure 134. Longitudinal profile of the channel in Reach 19 (RM 78.7 to 80).

3.9.2 River Morphology and Geomorphic Processes

Geology and Landforms

Reach 9 is confined within a narrow U-shaped valley carved by Quaternary glaciation. Increased discharge regimes during early Holocene glacial retreat further incised the floor of the valley in Reach 9. This has resulted in a subtle V-shape at the valley's base, which is most notable from RM 79 to 79.75. Once the glaciers retreated and the discharge regime was reduced, the floor of the valley has been infilling with coarse-grained sediment. These sediment inputs are sourced from local hillslopes, debris fans, and outwash coming from upstream. Today, the floodplain and the substrate in the channel are dominated by large cobbles and boulders. The steep walls and peaks of the adjacent hillslopes contain other glacial features, such as the cirque-carved headlands of Hungry Creek and an unnamed creek slightly upstream. Outwash generated from these hanging valleys creates the fan deposits located from RM 79.1 to 79.2 and from RM 79.5 to 79.6; both of these sections are on river-right (Figure 135).

The valley walls that confine Reach 9 are composed of weathered ancient bedrock of varied geologic compositions – metamorphic, sedimentary, and plutonic. Through seasonal freeze/thaw cycles and snowmelt-driven fluvial processes (including avalanches), the steep bedrock walls produce rock fall and landslides that accumulate as talus along the foot of the slopes and onto the narrow floodplains. The loose composition and active nature of the talus fans on river-left (north) slopes render these areas mostly unvegetated – except at fan toe accumulations near the channel and floodplain. The outwash fans coming off the river-right (south) slopes are more vegetated because they are less steep, more matrix-supported, and have a more seasonally-consistent water supply.

The valley in Reach 9 is narrow enough for outwash fans and landslides to create toe run-out deposits of rock and debris that often extend across the valley. In response to such inputs, and depending on their quantity and character, the channel may be forced to shift location from one side of its narrow floodplain to the other. Some very large boulder rock-fall inputs from the valley walls (four to ten feet in diameter) also influence channel position, bank stability, and roughness. A good example of this occurs at RM 79.4.

The floodplain surfaces of Reach 9 are irregular and vary in elevation due to the formative processes described previously. Floodplain surfaces are narrow and discontinuous throughout the reach because the position of the channel oscillates between the confining walls. Coarse sand and gravels deposited from overbank flows have accumulated on top of most of the floodplain surfaces. These deposits host developing soils that support mature forests.

In May 2014, an avalanche deposited hillslope debris and a massive quantity of downed large wood onto the floodplain from RM 79.6 to 79.7. Generated by unstable mountaintop snow accumulation, the avalanche entered the valley, toppling trees and distributing debris onto the valley floor. This event contained enough mass and force to distribute snapped trees on the opposite side of the valley where the avalanche ran up the foot of the slope. Today, large wood debris from this event buries the valley floor and toe slopes for approximately 500 feet (Figure 136). Avalanche-generated fines that had been deposited directly into the channel were subsequently flushed out by late spring high flows of 2014. However, Reach 9 and downstream areas will likely be influenced by this source of large wood and debris for decades.

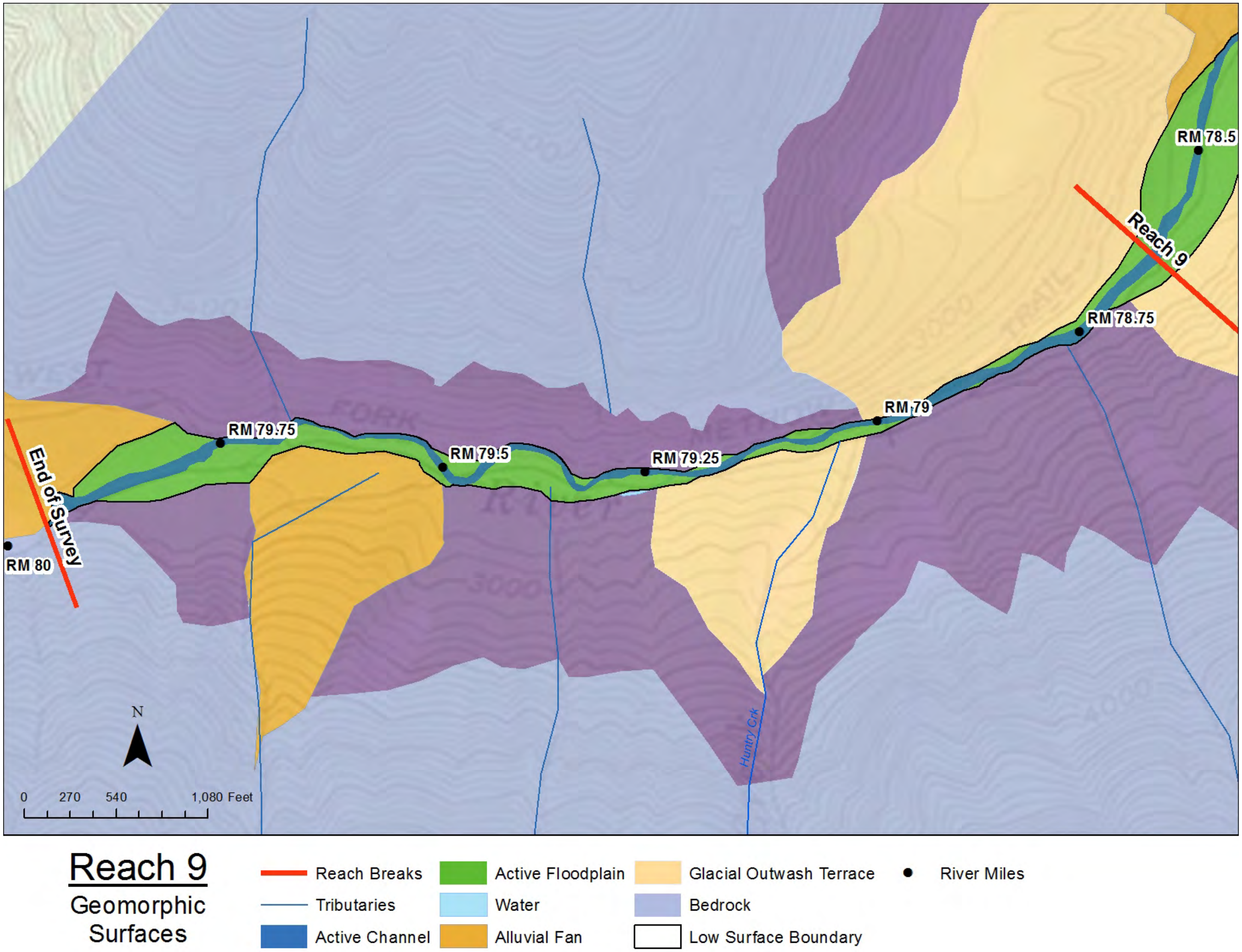

Figure 135. Geomorphic surfaces of Reach 9.

Figure 136. Downed trees and debris from May 2014 avalanche; looking upstream at RM 79.6. (10/15/2014)

Hydrology

Reach 9 has a seasonally dynamic flow regime. Late spring and early summer snowmelt flood events activate side-channels and potentially inundate narrow, low floodplain surfaces. Even though the reach has a relatively high gradient, it is only during high flow events that the channel is likely capable of mobilizing its over-sized bedload. The reach remains wetted throughout the year, but low flows in summer and autumn expose bank tops and large instream boulders. Summer thunderstorms are capable of temporarily raising surface-water elevations in Reach 9 because the bedrock-dominated walls and upstream drainage areas have low surface-water retention capacity. Based on the pattern of vegetation establishment observed in this reach, it is rare that a single thunderstorm is capable of generating enough flow to inundate floodplain surfaces.

The valley floor is composed primarily of coarse-grained material, and this material supports active hyporheic flow and groundwater influx from upstream and the adjacent hillslopes. The mainstem channel and side-channels within the active floodplain of Reach 9 are actively exchanging surface flow with groundwater through hyporheic processes. Groundwater seepage from the toe of a debris fan was also observed in the bank of a side-channel on river-right near RM 79.35.

Surface water contributions to the Methow River in Reach 9 include Trout Creek and a handful of ephemeral snowmelt- or precipitation-activated tributaries. The tributaries deliver discharge from the steep hillslopes and adjacent glacially-carved hanging valleys. According to the US Bureau of Reclamation’s surface-flow estimates (2008 – Appendix J), discharge increases by 30% at the confluence of Trout Creek. The ephemeral snowmelt- or precipitation-activated tributaries contribute a total of approximately 6% of the surface water discharge during high flows. Hydrologic inputs from the tributaries are dependent on local snowpack and summer thunderstorms. Two tributaries feed outwash (alluvial/debris) fans at Hungry Creek (RM 79.1 to 79.2), and an unnamed creek (RM 79.5 to 79.6) on river-right. Surface flow from these tributaries is minimal during the summer months; even so, dense communities of dogwood, vine maple, and aspen on the fans indicate that subsurface flow occurs through the porous matrix of debris that the fans are composed of. The scale of influence or percentage of groundwater flow contributed by the tributaries is unknown.

Floodplain and Channel Migration Zone

The floodplains and channel migration zone of Reach 9 are narrow and confined laterally between the bedrock valley walls and their hillslope debris fans. Vertical stability is maintained by both the relatively large size of the channel's substrate and regular hillslope inputs. Episodic events of aggradation caused by hillslope inputs (landslides, outwash, avalanches, etc.) can force localized channel responses that include changes in channel location and elevation. Minimal change of mainstem channel location has occurred in the last fifteen years according to the aerial imagery (Figure 137). The hillslope inputs that extend across the valley floor force processes of incision when the channel is required to re-establish a pathway. However, substrate size here has a limiting effect on incision rates and depths. Currently, the modern channel remains actively connected to the low-to-medium elevation (a half foot to three feet) floodplain surfaces of the narrow valley. Fresh accumulations of coarse sand and gravels on the majority of the floodplain surfaces suggest regular (two- to ten-year) inundation. The presence of small side-channels along the edge of the valley walls and low active floodplain surfaces from RM 79.3 to 79.55 indicate that this section of Reach 9 is responding to a period of bed aggradation caused by a localized abundance of sediment.

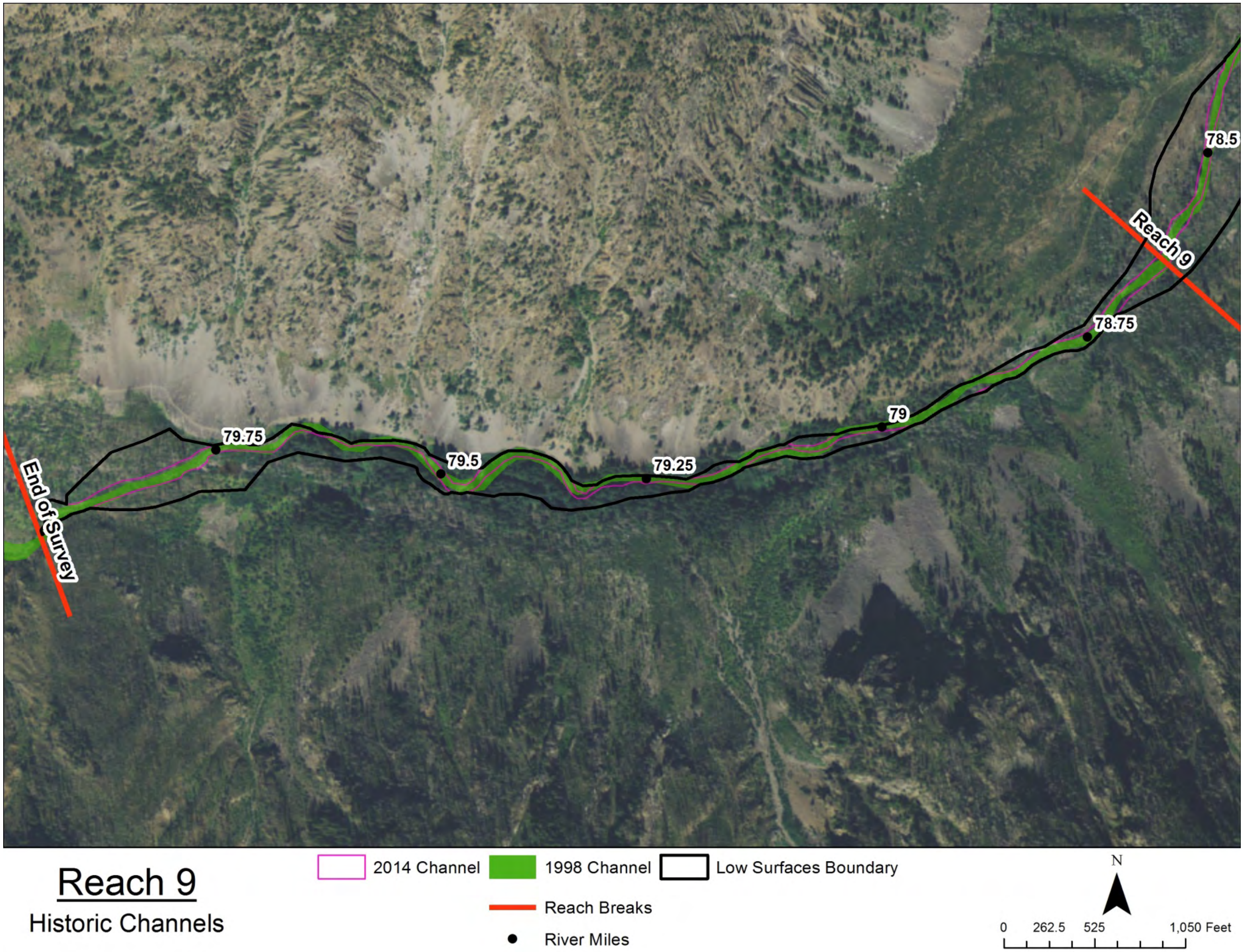

Figure 137. Historical channel locations for Reach 9.

Sediment

The substrate of Reach 9 is dominated by boulders and large cobbles. The sediment is primarily sourced directly from the steep, adjacent, confining hillslopes. These adjacent slopes are composed of weathered bedrock and talus fans. The Trout Creek confluence and its alluvial fan contribute additional sediment to the upstream portion of the reach, and these inputs include cobbles and boulders. Downstream from the confluence, most of the bedload is locally sourced and thus is angular to sub-angular. The rock-fall boulders add hydraulic roughness and stability to the channel bed and banks. Some small, gravel-sized bedload is present at a few transient, depositional zones in the channel near large wood accumulations or at eddies. Sands are present as overbank deposits on the few, very narrow floodplain surfaces. Otherwise, all fine-grained material is fluvially transported through this dynamic, cascading reach. Gravel counts were not conducted in Reach 9 because of the large bedload size relative to channel geometry, and the lack of LiDAR for hydraulic modeling.

Large Wood

Reach 9 has the highest wood count in the study area. Seven log jams and 467 logs were counted; an equivalent of 116 logs per mile. In-channel wood distribution in the reach is presented in Figure 138 as a density, or the number of wood pieces per 100 feet within each delineated channel unit type. The valley floor and channel banks of this reach are well vegetated and mature conifers offer high recruitment potential for large wood throughout the reach. The upper 0.3 miles of the reach was burned in the Needles forest fire in 2003, and standing snags left by that fire currently increase the likelihood of large wood inputs to the upper section of the reach. From RM 79.6 to 79.7, the 2014 avalanche described earlier supplied a massive quantity of downed trees directly to the valley floor and across the channel. There are channel spanning logs throughout this reach because channel width is smaller than mature tree height (at least 50 feet) (Figure 139). In Reach 9, channel complexity and floodplain connectivity is increased where log jams occur.

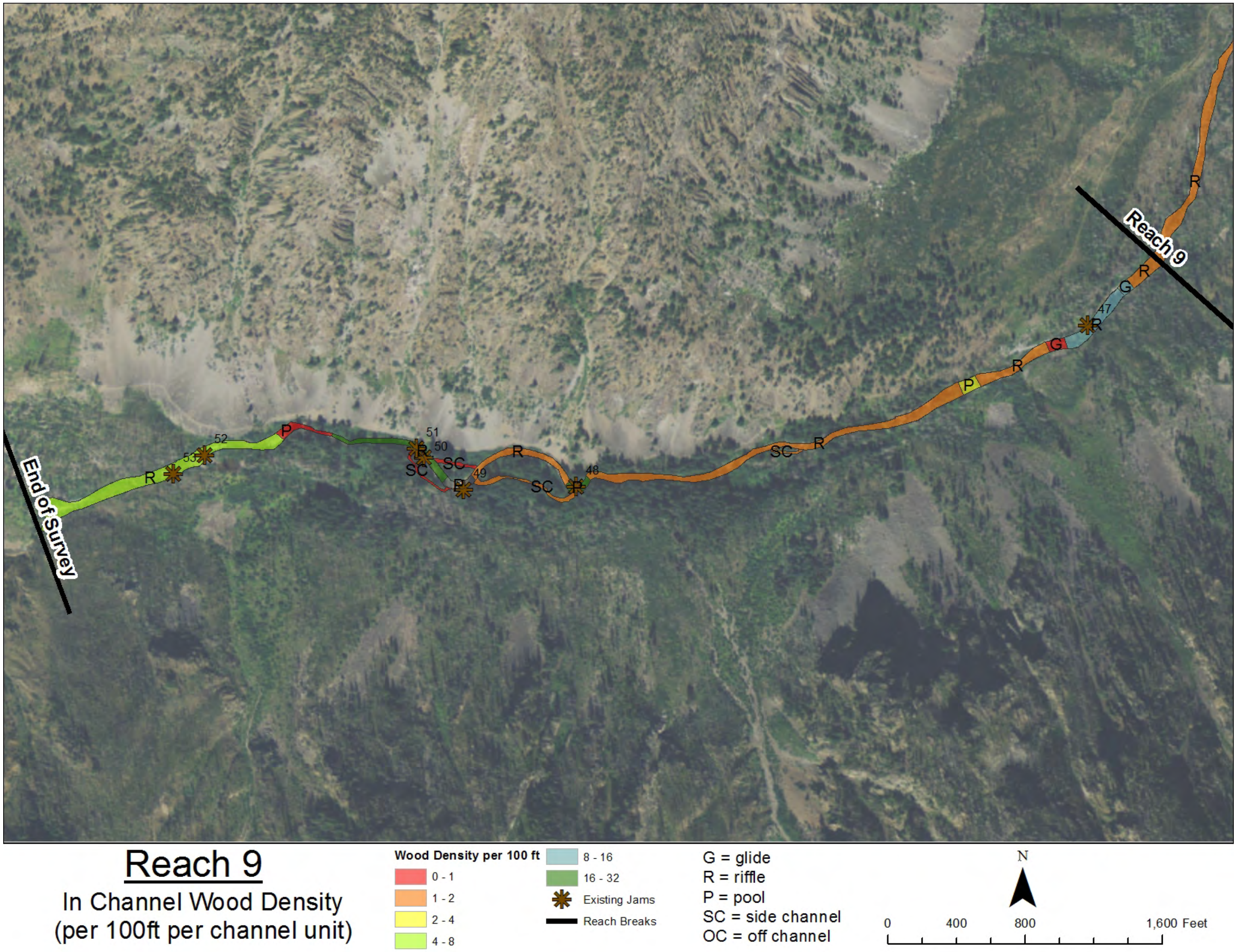

Figure 138. In-channel wood distribution (qualifying wood pieces per 100 ft channel length) within delineated channel units in Reach 9.

Figure 139. A) Channel-spanning logs and dense floodplain vegetation in Reach 9; looking downstream at RM 79.2, B) Large wood accumulation and cobble accumulations at RM 79.1. (09/02/2014)

Vegetation

The channel banks and floodplain of Reach 9 are mostly well vegetated. The overstory of vegetation is composed of a mature forest of fir and cedar. This forest reaches heights of more than 50 feet except in the upstream section, which was impacted by the forest fire. The mature conifer forest supplies ample shade to the channel, side-channels, and floodplain. The understory is mixed in composition, and includes dogwood, maple, ninebark, and sparse cottonwood. The density of the understory increases along some of the banks, at talus fan toes, and at other locations where conifers are young or have been removed by modern landscape process (i.e. forest fires, avalanches, relatively-modern hillslope deposits). Thus, in Reach 9, the composition and maturity of the vegetation indicates the modern stability of floodplain surfaces.

3.9.3 Human Alterations

Reach 9 has no-to-minimal modern anthropogenic alterations. The lack of stumps on floodplain surfaces indicates that no major logging activities have occurred here in the last 100 years. An established foot trail (Trail No. 480) runs along the base of the hillslope on river-left; it varies from one- to three-feet wide. Higher in elevation than the channel and its active floodplain features, it imposes no-to-minimal impact on channel processes. At the avalanche debris slide described above, the trail has been destroyed.

3.9.4 Recommended Actions

No specific restoration or preservation actions are recommended for this reach. The reach lies entirely within the Okanogan National Forest so is assumed to already receive sufficient protection from future human alteration.

See Section 4 of this report for the restoration strategy and specific recommendations for the reach.

4 Restoration Strategy

4.1 INTRODUCTION

The restoration strategy provides the linkage between the technical analyses performed in the Reach Assessment and the identification and prioritization of specific restoration actions. The key goals and guiding principles of the restoration strategy include the following:

1) Provide an explicit and direct linkage between assessment findings and project identification/prioritization.
2) Acknowledge and incorporate the interactions between fish use, aquatic habitat, geomorphology, hydrology, hydraulics, and riparian ecological processes.
3) Identify the recovery "gap", which is the difference between existing conditions and target conditions. Use this gap to identify and prioritize projects.
4) Consider the trajectory of the system if no actions are taken and the recovery potential given land use, social, and economic constraints.
5) Emphasize the recovery of root causes (i.e. habitat-forming processes) of impairments. Rely on projects that enhance or create habitats as secondary measures where full recovery is not possible or where the timeline for full recovery may be too long for species recovery.

Included in the strategy is a snapshot summary of the Reach Assessment findings, followed by reach-scale restoration objectives, recommended action types, specific restoration project opportunities, and project prioritization/ranking. Appendix C is an integral piece of the restoration strategy and includes detailed project information, project maps, and results of the project prioritization.

4.2 RESTORATION STRATEGY FRAMEWORK

An overview of the restoration strategy for the entire study area is presented in Section 4.3. Following this, in Section 0, are the individual reach-scale restoration strategies. The information included in the reach-scale strategies is described in the subsections below.

4.2.1 Summaries of Reach Assessment Findings

For each reach, the summary of reach assessment findings distills the large amount of information contained in the Reach Assessment into a snapshot summary for each reach. It includes a designation of good, moderate, or high for overall ecological function. The rationale for the designation is provided in the table. The summary also includes a description of the trajectory of the system if no action is taken. This is based primarily on the geomorphic analysis including current trends and the effects of land use. A rating of high, medium, or low is also provided for the recovery potential of the reach. This designation is based on the likelihood of being able to effectively address degraded processes and habitat based on the realities of current and anticipated land use, infrastructure, and ownership.

4.2.2 Restoration Objectives

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

Target conditions were developed using the REI targets as well as reference to site conditions and inference from regional studies. The REI analysis is based on previous REI analyses conducted as part of previous Reach Assessments conducted by the USBR and YN in other Upper Columbia tributaries, with some modifications. See Section 2.12 and Appendix B for more information on the REI analysis.

4.2.3 Restoration Action Types

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 elements. For example, the action type "off-channel habitat enhancement" might be achieved via numerous project elements ranging from re-connecting habitat blocked by a levee to excavating new off-channels in the floodplain. 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.

The various action types and project elements may be considered either as Restoration, Enhancement, or Creation. We consider true restoration actions to be those that address root causes of impairments and that aim to return the system close to its naturally functioning state. This is often not achievable due to past changes to the underlying processes or due to process impairments that are unlikely to change due to infrastructure. An example true restoration project would be a project that fully removes a levee to restore natural floodplain inundation patterns. Enhancement measures are those that improve or rehabilitate habitat to the extent possible given existing impaired processes. Placement of large wood to provide cover and complexity is an example of enhancement. Creation projects are those that create new habitat that is currently lacking or that will not be created on its own in a reasonable timeframe given existing process impairments. Excavating a backwater alcove into the floodplain is an example of a creation project.

The five general action types are described in the sections below.

Protection

Protection projects involve preservation of existing habitat that may be at risk of degradation. Protection of other areas is generally not identified as a 'protect and maintain' action because it is considered inherent in all potential actions. Protection projects are identified in areas where existing or potential land ownership or land use suggests that further degradation could occur. Areas identified for protection may have existing high quality and functioning habitat or may contain impaired habitat in need of restoration. In many cases, adequate protection may already be in place through existing laws, policy, or management plans. The adequacy and enforcement of these regulations needs to be considered when planning for protection activities.

Examples:

- Direct purchase (fee acquisition) 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

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

Habitat Reconnection via Infrastructure Modification

This strategy includes removal/modification of bank armoring, levees, roadways, bridges, or fill. Habitat reconnection projects are located in areas where floodplain and channel migration processes have been disconnected due to anthropogenic activities. These types of projects are frequently applied to address issues associated with floodplain connectivity (i.e., alterations to flood inundation rates or patterns), bank stability/channel migration, vertical channel stability, and off-channel habitat availability. These project types are applied to areas that have the potential for an increase in habitat quality and a reestablishment of dynamic processes through their reconnection. In some cases, these actions are focused on restoring a component of the system that has been lost, therefore regaining habitat and process that was previously a functional part of the river system. In cases where full restoration is not possible, such as when a levee can only be partially removed or breached, these actions may only provide enhancement of conditions.

Habitat reconnection projects may also include the reestablishment of fish passage where it has been blocked by human infrastructure or management. For the upper Methow River, there are no passage barriers on the mainstem but there are side- and off-channel habitats where fish access has been affected by levees, fill, and roadways.

Examples:

- Removal or selective breaching of a levee or road embankment to enhance floodplain connectivity and/or to restore fish access to off-channel habitats
- Removal of riprap 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

Placement of Structural Habitat Elements

This strategy includes placement of habitat structures such as large wood, logjams, 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 logjam 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. These projects are generally considered enhancement measures, as they do not fully restore the root cause of the problem (e.g. growth and recruitment of key pieces).

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

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. These actions generally include the enhancement or creation of habitat, rather than the full restoration of root causes of the lack of off-channel habitat.

Examples:

- Construction or enhancement 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

4.2.4 Projects and Prioritization

Projects were identified through field surveys and analysis performed in the Reach Assessment. Project elements were identified that are believed to best achieve target conditions and to address key factors limiting salmonid populations. These projects represent an initial first step in this process; it is expected that projects will be modified as appropriate once project-specific surveys, analysis, and stakeholder coordination are performed as part of design. Project opportunities are linked to their respective action type(s) in the reach tables in Section 0 and are described in greater detail in Appendix C.

Project prioritization was performed to rank the projects into three priority tiers. Prioritization occurred by subjecting the projects to a set of scoring criteria. These criteria are based on several factors, including how well projects address the "gap" between existing and target conditions, fish use/potential use of the area, and whether or not projects address root causes of impairments. Projects are also given a cost score and feasibility designations in order to provide other relevant information used in project selection and planning.

4.3 RESTORATION STRATEGY OVERVIEW

An overview of the restoration strategy at the study area scale is presented in Table 16 and in map form in Figure 140 and Figure 141. The detailed reach-scale strategies are included in Section 4.4.

Table 16. Overview of restoration strategy.

Reach	Ecological Function	Trajectory	Recovery Potential	Projects & Priority
Reach 1	Poor	Same or decline	Low-to-Moderate	Weeman (Tier 1)
Reach 2	Poor	Same or decline	High	Weeman (Tier 1) Fawn Creek (Tier 1) Trail Bridge (Tier 1)
Reach 3	Poor	Same or decline	High	Goat Creek (Tier 1)
Reach 4	Poor	Same or decline	Moderate-to-High	Lower Mazama (Tier 2) Upper Mazama (Tier 2)
Reach 5	Poor-to-Moderate	Same or improve	High	A-Wall (Tier 2) Goat Wall (Tier 2)
Reach 6	Poor-to-Moderate	Same	Moderate-to-High	Gate Creek (Tier 3) Cedarosa (Tier 1) Lost River (Tier 2)
Reach 7	Moderate-to-High	Same or improve	High	Two Rivers (Tier 3) Robinson (Tier 3)
Reach 8	Moderate-to-High	Improve	High	Ballard (Tier 3)
Reach 9	High	Improve	High	No projects identified

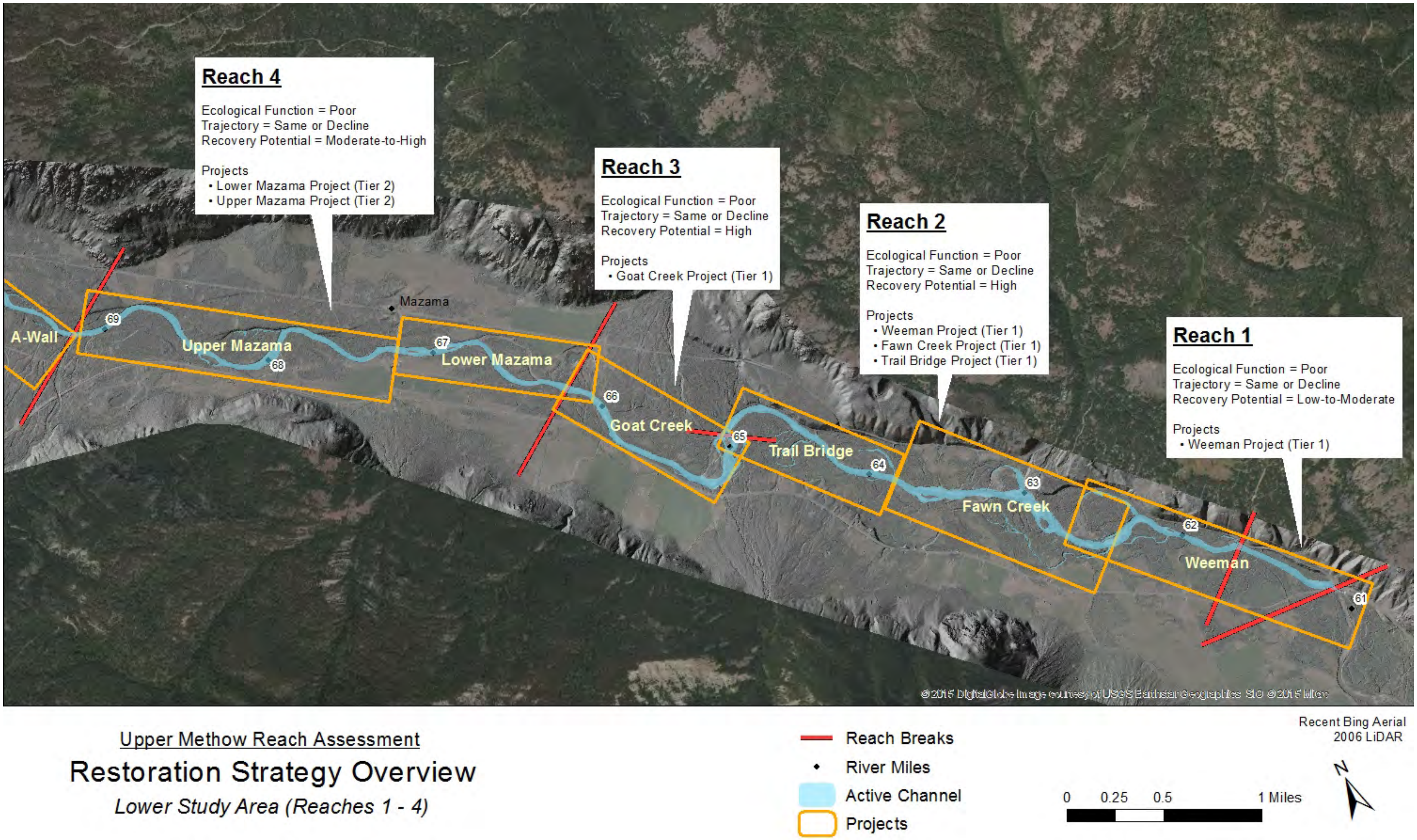

Figure 140. Overview of the Restoration Strategy for the downstream portion of the study area.

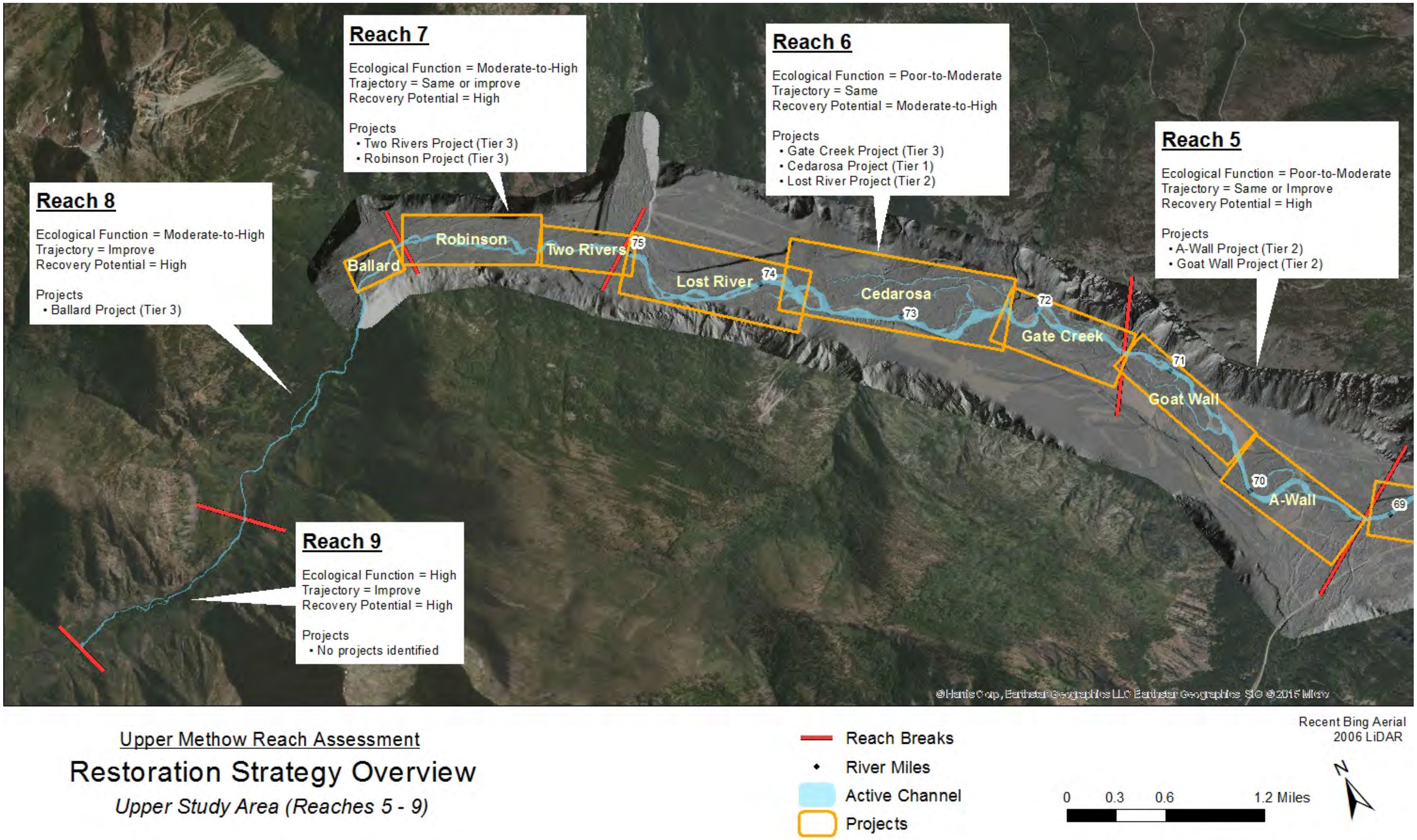

Figure 141. Overview of the Restoration Strategy for the upstream portion of the study area.

4.4 REACH-SCALE STRATEGIES

4.4.1 Reach 1 Restoration Strategy

Overall ecological function	**Poor**
	Rating is based on the Reach Assessment evaluations of habitat, geomorphology, hydrology, hydraulics, and vegetation. 9 of 11 REI metrics are at risk or unacceptable. Significant impairments of channel and floodplain function due to Weeman Bridge, Highway 20 fill, bank armoring, and riparian clearing.
Trajectory if no action taken	**Same or decline**
	Continued degradation due to persistent anthropogenic impacts to floodplain, channel migration, riparian, and large wood processes. Some passive recovery of riparian function due to maturing vegetation.
Recovery potential	**Low-to-moderate**
	Highway 20 fill, Weeman Bridge, and other areas of bank armoring that protects infrastructure are unlikely to be modified; or modification will be challenging and require long time horizon for planning and significant expense.
Restoration objectives	**Target conditions in Table 17**
	Bring existing conditions to target conditions for the habitat and geomorphic metrics identified in Table 17 below. These targets apply to multiple habitat and geomorphic attributes. To the extent possible at this stage of planning, the targets are presented as measurable quantities.
Action Types	**Habitat reconnection via infrastructure modification** **Placement of structural habitat elements** **Off-channel habitat enhancement** **Riparian restoration**
	Actions fall primarily in the Enhancement and Creation categories since full restoration will be challenged by existing infrastructure and ownership.
Projects & Prioritization	**Weeman Project (Tier 1)**
	The downstream portion of the Weeman Project encompasses Reach 1. The project area also extends downstream of the study area as it relates to enhancing conditions associated with the Highway 20 crossing. Receives Tier 1 rank due to high fish use, high impairment, and moderate recovery potential. This reach is typically perennially wetted and is expected to have high year-round fish use.

Table 17. Reach 1 Restoration Objectives, Action Types, and Projects.

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Project
Riparian condition	<50% species composition, seral stage, and structural complexity are consistent with potential native community. 100% small tree 15% canopy cover Human disturbance is located within approximately 3% of the floodplain and 6% of the 100-foot riparian buffer zone. Disturbance includes a home site with riprap and pushup levee at RM 61.35, and a riprap wall along river-left at the upstream portion of the reach associated with Goat Creek Cutoff Road.	At least a 100 ft riparian buffer with: > 80% mature trees, or consistent with potential native community < 20% riparian disturbance (human) > 80% canopy closure in the riparian zone. [REI]	Riparian Restoration	Weeman Project
Floodplain Connectivity	This reach is naturally laterally constricted by terrace and alluvial fan deposits on river-left. Some riprap and levees are present in this reach, minimally impacting floodplain connectivity. The Weeman Bridge significantly affects floodplain connectivity at the downstream end of the reach. 1.07 mi/mi^2 of road 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. <2mi/mi^2 road density in the floodplain [adapted from REI]	Habitat Reconnection via Infrastructure Modification Placement of Structural Habitat Elements	Weeman Project

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Project
Bank condition / Channel migration	Minimal lengths of the streambanks in the reach are affected by bank armoring, mostly riprap along the road embankment or used to protect residential property. The Weeman Bridge restricts channel migration at the downstream end of the reach.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	Habitat Reconnection via Infrastructure Modification Placement of Structural Habitat Elements	Weeman Project
Vertical channel stability	Subtle channel bed incision and reduced floodplain connectivity is present in this reach due to channel confinement by riprap, bridge abutments, and levees. High floodplain surface development at the downstream section of the reach due to incision.	No measurable trend of human-induced aggradation or incision [adapted from REI]	Habitat Reconnection via Infrastructure Modification Placement of Structural Habitat Elements	Weeman Project
Pools	There are no pools in the reach. Pools per mile = 0 0% pool habitat 0 pools > 3 ft deep	~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >3 ft deep with good fish cover. [REI]	Placement of Structural Habitat Element	Weeman Project
Large wood and logjams	2.5 M-L pieces / mi 0 jams /mi	> 42.5 pieces/mi (>12 diam; > 35 ft long) [from Fox and Bolton 2007] ≥ 4 logjams/mi [based on conditions in Reaches 5 and 9]	Placement of Structural Habitat Elements	Weeman Project

Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Project
Off-Channel Habitat	0% side-channel habitat. There were no side-channels observed in this reach. Though channel confinement naturally limits the extent of side-channel habitat, the potential for off-channel habitat is somewhat more constrained by the effects of the roadway, residential development, and the Weeman Bridge on lateral channel migration and floodplain connectivity. A lack of logjams also limits potential 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]	Off-Channel Habitat Enhancement	Weeman Project

4.4.2 Reach 2 Restoration Strategy

Overall ecological function	**Poor**
	Rating is based on the Reach Assessment evaluations of habitat, geomorphology, hydrology, hydraulics, and vegetation. 9 of 11 REI metrics are at risk or unacceptable. Significant impairments of channel and floodplain function due to the levee system, trail bridge, bank armoring, riparian clearing, and development.
Trajectory if no action taken	**Same or decline**
	Continued degradation due to persistent anthropogenic impacts to floodplain, channel migration, riparian, and large wood processes. Some passive recovery of riparian function due to maturing vegetation. Channel incision expected to continue due to artificial confinement.
Recovery potential	**High**
	The primary impact is the levee/trail system, which is assumed to be challenging but not impossible to address given social and property constraints. The potential habitat and geomorphic function is high.
Restoration objectives	**Target conditions in Table 18**
	Bring existing conditions to target conditions for the habitat and geomorphic metrics identified in Table 18 below. These targets apply to multiple habitat and geomorphic attributes. To the extent possible at this stage of planning, the targets are presented as measurable quantities.
Action Types	**Habitat reconnection via infrastructure modification** **Placement of structural habitat elements** **Off-channel habitat enhancement** **Riparian restoration**
	Actions fall primarily in the Restoration and Enhancement categories assuming large-scale levee removal/modification can occur. Some actions will fall into the Enhancement category given existing infrastructure and ownership.
Projects & Prioritization	**Weeman Project (Tier 1)** **Fawn Creek Project (Tier 1)** **Trail Bridge Project (Tier 1)**
	Reach 2 has high restoration potential. Some of the greatest potential is associated with the levee complex on river-right midway through the reach (Fawn Creek Project). There are also other side-channel reconnection projects and opportunities to enhance in-channel complexity and lateral channel dynamics. Only the upstream portion of the Weeman Project is within Reach 2. Projects rank high due to high fish use, projects that address root causes, and a high potential for recovery. This reach is typically perennially wetted and is expected to have high year-round fish use.

Table 18. Reach 2 Restoration Objectives, Action Types, and Projects.

Reach 2 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	<50% species composition, seral stage, and structural complexity are consistent with potential native community. 100% small tree 20% canopy cover Human disturbance is located within approximately 26% of the floodplain. 9.6% of the 100-ft riparian buffer has been cleared. Disturbance includes roads and home sites with some riprap and cleared lawns. A large levee with riprap is present along the channel boundary and into the riparian zone between RM 63.25 and 63.75.	At least a 100 ft riparian buffer with: > 80% mature trees, or consistent with potential native community < 20% riparian disturbance (human) > 80% canopy closure in the riparian zone. [REI]	Riparian Restoration	Trail Bridge Project Fawn Creek Project Weeman Project
Floodplain Connectivity	Natural connectivity is reduced by high road density in the floodplain, residential and agricultural features, and the long river-right levee system. 2.75 mi/mi^2 of road 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] <2mi/mi^2 road density in the floodplain	Habitat Reconnection via Infrastructure Modification Placement of Structural Habitat Elements Off-Channel Habitat Enhancement	Trail Bridge Project Fawn Creek Project Weeman Project

Reach 2 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Bank condition / Channel migration	Between RM 62.5 and RM 63.25 the channel is naturally active and has recently avulsed resulting in the main channel straightening and a side-channel/oxbow remaining in the historic main channel. Additionally, RM 63.8 upstream to the end of the reach is naturally active and migrates frequently. The residential and agricultural features along the banks of the channel have restricted substantial natural migration activity, particularly on the river-right floodplain where high-value habitat is cut off from the main channel by a levee.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	Habitat Reconnection via Infrastructure Modification Placement of Structural Habitat Elements	Fawn Creek Project Weeman Project
Vertical channel stability	This reach has reduced channel sinuosity with a high potential for incision and reduced floodplain connectivity due to channel confinement by riprap and levees.	No measurable trend of human-induced aggradation or incision [adapted from REI]	Habitat Reconnection via Infrastructure Modification Placement of Structural Habitat Elements	Trail Bridge Project Fawn Creek Project Weeman Project
Pools	Pools have minimal cover and there are only 3 large pools (> 3 ft deep) in the reach. Pools per mile = 1.25 5% pool habitat 3 pools > 3 ft deep	~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >3 ft deep with good fish cover. [REI]	Placement of Structural Habitat Elements	Trail Bridge Project Fawn Creek Project Weeman Project

Reach 2 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Large wood and logjams	64.3 M-L pieces / mi 2.9 jams /mi	> 42.5 pieces/mi (>12 diam; > 35 ft long) [from Fox and Bolton 2007] ≥ 4 logjams/mi [based on conditions in Reaches 5 and 9]	Placement of Structural Habitat Elements	Trail Bridge Project Fawn Creek Project Weeman Project
Off-Channel Habitat	19% side-channel habitat. Man-made barriers such as levees are blocking portions of floodplain and reducing off-channel habitat connectivity.	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]	Habitat Reconnection via Infrastructure Modification Off-Channel Habitat Enhancement	Trail Bridge Project Fawn Creek Project Weeman Project

4.4.3 Reach 3 Restoration Strategy

Overall ecological function	**Poor**
	Rating is based on the Reach Assessment evaluations of habitat, geomorphology, hydrology, hydraulics, and vegetation. 9 of 11 REI metrics are at risk or unacceptable. Significant impairments of channel function due to push-up levees, the proximity of Hwy 20, bank armoring, and riparian clearing.
Trajectory if no action taken	**Same or decline**
	Continued degradation due to persistent anthropogenic impacts to floodplain, channel migration, riparian, and large wood processes. Continued incision from levees and riprap in the upper 2/3 of the reach. Continued lack of LW recruitment due to bank armoring. Some passive recovery of riparian function due to maturing vegetation.
Recovery potential	**High**
	Many of the push-up levees and some of the bank armoring do not appear to be protecting infrastructure and could potentially be removed or modified. Riparian work will have high long-term benefits. Roadway impacts are likely to remain.
Restoration objectives	**Target conditions in Table 19**
	Bring existing conditions to target conditions for the habitat and geomorphic metrics identified in Table 19 below. These targets apply to multiple habitat and geomorphic attributes. To the extent possible at this stage of planning, the targets are presented as measurable quantities.
Action Types	**Habitat reconnection via infrastructure modification** **Placement of structural habitat elements** **Off-channel habitat enhancement** **Riparian restoration** **Protection**
	Actions fall primarily in the Restoration and Enhancement categories assuming levee and bank armoring removal can occur. Protection is recommended for the downstream portion of the reach, the river-left floodplain, and the downstream river-right floodplain.
Projects & Prioritization	**Goat Creek Project (Tier 1)**
	There is moderate-to-high restoration opportunity in this reach, including some opportunities to remove levees and bank armoring and to increase in-channel structure and complexity. The Goat Creek Project is a high ranking project due to high fish use, relatively high impairment (upstream 2/3 or reach), and high potential for recovery.

Table 19. Reach 3 Restoration Objectives, Action Types, and Projects.

Reach 3 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	<50% species composition, seral stage, and structural complexity are consistent with potential native community. 75% small tree 25% grass/forb 20% canopy cover Human disturbance is located within approximately 45% of the floodplain. 4.5% of the 100 ft riparian buffer has been cleared. Disturbance includes Highway 20 road embankment at RM 65.75, homes with riprap throughout the reach, and push-up levees along the channel corridor, primarily at RM 65.5.	At least a 100 ft riparian buffer with: > 80% mature trees, or consistent with potential native community < 20% riparian disturbance (human) > 80% canopy closure in the riparian zone. [REI]	Riparian Restoration	Goat Creek Project
Floodplain Connectivity	The road adjacent to the channel on river-right for a majority of the reach restricts any potential floodplain activity. Levees and riprap have been used throughout the reach to prevent floodplain activation into agricultural and residential areas, particularly on river-left. 2.56 mi/mi^2 of road 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] <2mi/mi^2 road density in the floodplain	Habitat Reconnection via Infrastructure Modification Off-Channel Habitat Enhancement Placement of Structural Habitat Elements	Goat Creek Project

Reach 3 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Bank condition / Channel migration	The road adjacent to the channel on river-right for a majority of the reach restricts any potential migration activity. Levees and riprap have been used throughout the reach to prevent channel migration into agricultural and residential areas, particularly on river-left where historical channel migration activity occurred.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	Habitat Reconnection via Infrastructure Modification Placement of Structural Habitat Elements Protection (downstream end of reach)	Goat Creek Project
Vertical channel stability	There is channel bed incision and reduced floodplain connectivity in this reach due to channel confinement by levees and riprap. There is a high potential for continued incision processes in this reach.	No measurable trend of human-induced aggradation or incision [adapted from REI]	Habitat Reconnection via Infrastructure Modification Placement of Structural Habitat Elements	Goat Creek Project
Pools	All pools in this reach have a residual depth greater than 3 feet, and most have good cover. Pools per mile = 5.5 21% pool habitat 7 pools > 3 ft deep	~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >3 ft deep with good fish cover. [REI]	Placement of Structural Habitat Elements	Goat Creek Project
Large wood and logjams	76.3 M-L pieces / mi 3.1 jams /mi	> 42.5 pieces/mi (>12 diam; > 35 ft long) [from Fox and Bolton 2007] ≥ 4 logjams/mi [based on conditions in Reaches 5 and 9]	Placement of Structural Habitat Elements Protection (downstream end of reach)	Goat Creek Project

Reach 3 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Off-Channel Habitat	2% side-channel habitat. Four side-channels were present in this reach, though only one had slow-moving water. Man-made levees are blocking portions of floodplain and reducing connectivity of potential off-channel habitat.	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 Protection (downstream end of reach)	Goat Creek Project

4.4.4 Reach 4 Restoration Strategy

Overall ecological function	**Poor**
	Rating is based on the Reach Assessment evaluations of habitat, geomorphology, hydrology, hydraulics, and vegetation. 9 of 11 REI metrics are at risk or unacceptable. Significant impairments of channel function due to Mazama Bridge, levees, bank armoring, and riparian clearing.
Trajectory if no action taken	**Same or decline**
	Continued degradation due to persistent anthropogenic impacts to floodplain, channel migration, and large wood processes. Continued incision is expected, partly due to human actions (e.g. past log drives that removed wood) and bank armoring/bridge. Some passive recovery of riparian function due to maturing vegetation.
Recovery potential	**Moderate-to-High**
	The Mazama Bridge, riparian impacts from local residences, and floodplain grading are likely to persist. Some push-up levees and cleared riparian areas could be addressed.
Restoration objectives	**Target conditions in Table 20**
	Bring existing conditions to target conditions for the habitat and geomorphic metrics identified in Table 20 below. These targets apply to multiple habitat and geomorphic attributes. To the extent possible at this stage of planning, the targets are presented as measurable quantities.
Action Types	**Habitat reconnection via infrastructure modification** **Placement of structural habitat elements** **Off-channel habitat enhancement** **Riparian restoration**
	Actions fall primarily in the Enhancement category since full restoration will be challenged by existing infrastructure and ownership.
Projects & Prioritization	**Lower Mazama Project (Tier 2)** **Upper Mazama Project (Tier 2)**
	The restoration potential is high but is somewhat constrained by private infrastructure and roads (and bridge) around the town of Mazama. Two projects are identified. The boundary between the two projects is the Mazama Bridge. They rank as Tier 2 due to moderate fish use, moderate-to-high existing impairment, and moderate potential for full recovery. This reach typically runs dry in late summer and may have limited year-round fish use.

Table 20. Reach 4 Restoration Objectives, Action Types, and Projects.

Reach 4 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	<50% species composition, seral stage, and structural complexity are consistent with potential native community. 100% small tree 10% canopy cover Human disturbance is located within approximately 24% of the floodplain. 14.5% of the 100 ft riparian buffer has been cleared. Disturbance within the low geomorphic surfaces is relatively minimal due to the naturally moderately confined channel in this reach. However, there are substantial roads and home sites with associated cleared areas and lawns throughout the reach on both river-right and river-left, often very close or adjacent to the channel and which may influence condition of the riparian zone and channel.	At least a 100 ft riparian buffer with: > 80% mature trees, or consistent with potential native community < 20% riparian disturbance (human) > 80% canopy closure in the riparian zone. [REI]	Riparian restoration	Upper Mazama Project Lower Mazama Project

Reach 4 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Floodplain Connectivity	The bridge and associated bank armoring at RM 67.2 near Mazama somewhat reduces local connectivity with the floodplain, but otherwise few human features are present that affect the floodplain connectivity to the channel. The channel is naturally moderately confined in this reach. 0.33 mi/mi^2 of road 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] <2mi/mi^2 road density in the floodplain	Habitat Reconnection via Infrastructure Modification Placement of Structural Habitat Elements Off-Channel Habitat Enhancement	Upper Mazama Project Lower Mazama Project
Bank condition / Channel migration	There is bank armoring associated with the bridge at RM 67.2 near Mazama, but otherwise little human features are present. Though agricultural and residential uses are present along the banks in this reach, the channel is naturally moderately confined in this reach, therefore little bank migration has occurred	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	Habitat Reconnection via Infrastructure Modification Placement of Structural Habitat Elements	Upper Mazama Project Lower Mazama Project
Vertical channel stability	Subtle channel bed incision resulting in reduced active floodplain connectivity, and alluvial terrace development.	No measurable trend of human-induced aggradation or incision [adapted from REI]	Habitat Reconnection via Infrastructure Modification Placement of Structural Habitat Elements	Upper Mazama Project Lower Mazama Project
Pools	Pools have inadequate cover and there are few large pools (> 3 ft deep) in the reach. Pools per mile = 1.7 11% pool habitat 5 pools > 3 ft deep	~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >3 ft deep with good fish cover. [REI]	Placement of Structural Habitat Elements	Upper Mazama Project Lower Mazama Project

Reach 4 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Large wood and logjams	23.2 M-L pieces / mi 0.7 jams /mi	> 42.5 pieces/mi (>12 diam; > 35 ft long) [from Fox and Bolton 2007] ≥ 4 logjams/mi [based on conditions in Reaches 5 and 9]	Placement of Structural Habitat Elements	Upper Mazama Project Lower Mazama Project
Off-Channel Habitat	3% side-channel habitat. Four side-channels with little woody debris were identified. Minimal LWD within the side-channels limits off-channel habitat complexity.	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]	Habitat Reconnection via Infrastructure Modification Off-Channel Habitat Enhancement	Upper Mazama Project Lower Mazama Project

4.4.5 Reach 5 Restoration Strategy

Overall ecological function	**Poor-to-Moderate**
	Rating is based on the Reach Assessment evaluations of habitat, geomorphology, hydrology, hydraulics, and vegetation. 7 of 11 REI metrics are at risk or unacceptable. Impairments of channel and riparian function due to Lost River Road, residential development, riparian clearing, and push-up levees in the floodplain.
Trajectory if no action taken	**Same or slight improvement**
	Impacts to floodplain and off-channel connectivity are relatively minor. Complexity and structure expected to improve as riparian and floodplain vegetation matures.
Recovery potential	**High**
	Push-up levees affecting floodplain and off-channel connectivity are relatively minor and it is assumed they can be removed. Riparian impacts can possibly be addressed through establishment of buffers and replanting. Channel margin impacts along Lost River Road are expected to persist but their location along the valley wall limits their overall impact.
Restoration objectives	**Target conditions in Table 21**
	Bring existing conditions to target conditions for the habitat and geomorphic metrics identified in Table 21 below. These targets apply to multiple habitat and geomorphic attributes. To the extent possible at this stage of planning, the targets are presented as measurable quantities.
Action Types	**Habitat reconnection via infrastructure modification** **Placement of structural habitat elements** **Off-channel habitat enhancement** **Riparian restoration**
	Actions fall primarily in the Restoration and Enhancement categories assuming push-up levee removal and riparian enhancement can occur. Enhancement along existing riprap banks will improve margin complexity
Projects & Prioritization	**A-Wall Project (Tier 2)** **Goat Wall Project (Tier 2)**
	Reach 5 has moderate-to-high restoration opportunity. The projects include a combination of side-channel reconnection, side-channel enhancement, channel margin complexity, and in-channel wood structures designed primarily to capture in-coming wood expected from upstream reaches. These projects rank as Tier 2 due to moderate fish use and relatively high functioning habitat under existing conditions. This reach typically runs dry in late summer and may have limited year-round fish use.

Table 21. Reach 5 Restoration Objectives, Action Types, and Projects.

Reach 5 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	<50% species composition, seral stage, and structural complexity are consistent with potential native community. 67% small tree 33% sapling/pole 20% canopy cover Human disturbance is located within approximately 33% of the floodplain. 3.5% of the 100 ft riparian buffer has been cleared. Disturbance includes roads and cleared home sites with associated riprap and levees.	At least a 100 ft riparian buffer with: > 80% mature trees, or consistent with potential native community < 20% riparian disturbance (human) > 80% canopy closure in the riparian zone. [REI]	Riparian restoration	Goat Wall Project A-Wall Project
Floodplain Connectivity	There are several riprap or levee features in this reach, though they do not disconnect the floodplain very substantially. They occur near the upstream end of the reach primarily. Road embankments along the river channel and secondary channels also disconnect the floodplain from the channel on river-left. Due to these features, the channel is disconnected along portions of this reach. 3.86 mi/mi^2 of road 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 <2mi/mi^2 road density in the floodplain [adapted from REI]	Habitat Reconnection via Infrastructure Modification Placement of Structural Habitat Elements Off-Channel Habitat Enhancement	Goat Wall Project A-Wall Project

Reach 5 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Bank condition / Channel migration	There are a few instances of riprap or levees protecting houses and private property in this reach. These occur near the upstream end of the reach, between RM 70.75-71.25 primarily. Road embankments along the river channel and secondary channels also limit migration near RM 70 on river-right and near RMs 71 and 71.25 on river-left. Due to these human features, the channel is migrating below natural rates for this reach.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	Habitat Reconnection via Infrastructure Modification Placement of Structural Habitat Elements	Goat Wall Project A-Wall Project
Vertical channel stability	Subtle channel bed incision resulting in reduced active floodplain connectivity, and alluvial terrace development.	No measurable trend of human-induced aggradation or incision [adapted from REI]	Habitat Reconnection via Infrastructure Modification Placement of Structural Habitat Elements	Goat Wall Project A-Wall Project
Pools	Pools have relatively good cover and there are many large pools (> 3 ft deep) in the reach. Pools per mile = 5.3 21% pool habitat 9 pools > 3 ft deep	~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >3 ft deep with good fish cover. [REI]	Placement of Structural Habitat Elements	Goat Wall Project A-Wall Project
Large wood and logjams	54 M-L pieces / mi 3.86 jams /mi	> 42.5 pieces/mi (>12 diam; > 35 ft long) [from Fox and Bolton 2007] ≥ 4 logjams/mi [based on conditions in Reaches 5 and 9]	Placement of Structural Habitat Elements	Goat Wall Project A-Wall Project

Reach 5 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Off-Channel Habitat	20% side-channel habitat. A majority of the secondary channel habitat is hyporheic flow off-channel habitat located between RM 70.4 – 71.2, and had an average temperature approximately 2°C cooler than the main channel with decent canopy cover. Artificial levees are blocking portions of the floodplain at the upstream end of this reach. The channel in this reach is a naturally unconfined channel, therefore would expect to have greater amounts off-channel habitat.	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]	Habitat Reconnection via Infrastructure Modification Off-Channel Habitat Enhancement	Goat Wall Project A-Wall Project

4.4.6 Reach 6 Restoration Strategy

Overall ecological function	**Poor-to-Moderate**
	Rating is based on the Reach Assessment evaluations of habitat, geomorphology, hydrology, hydraulics, and vegetation. 8 of 11 REI metrics are at risk or unacceptable. Impairments of channel and floodplain function are related to bank armoring, levees, diversion of floodplain flow (i.e. canals), and residential clearing/development.
Trajectory if no action taken	**Same**
	Continued degradation due to persistent anthropogenic impacts to floodplain, channel migration, and large wood processes. Some passive recovery of riparian function due to maturing vegetation.
Recovery potential	**Moderate-to-High**
	Recovery potential varies throughout the reach. In the upstream half of the reach, full recovery will be challenging given the infrastructure protecting the Lost River Community and the Cedarosa Community. Recovery potential is high in the downstream portion of the reach.
Restoration objectives	**Target conditions in Table 22**
	Bring existing conditions to target conditions for the habitat and geomorphic metrics identified in Table 22 below. These targets apply to multiple habitat and geomorphic attributes. To the extent possible at this stage of planning, the targets are presented as measurable quantities.
Action Types	**Habitat reconnection via infrastructure modification** **Placement of structural habitat elements** **Off-channel habitat enhancement** **Riparian restoration**
	Actions fall primarily in the Enhancement category since full restoration will be challenged by existing infrastructure and ownership. There are some Restoration and Creation elements also included.
Projects & Prioritization	**Gate Creek Project (Tier 3)** **Cedarosa Project (Tier 1)** **Lost River Project (Tier 2)**
	Reach 6 has moderate-to-high restoration potential. Gate Creek is Tier 3 due to moderate fish use and relatively well-functioning habitat. Cedarosa is Tier 1 due to high relative impairment but high recovery potential. Lost River is Tier 2 due to moderate fish use, high impairment, but moderate recovery potential. This reach is typically dry in late summer/fall and may have limited year-round fish use.

Table 22. Reach 6 Restoration Objectives, Action Types, and Projects.

Reach 6 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	50-80% species composition, seral stage, and structural complexity are consistent with potential native community. 11% large tree 78% small tree 11% sapling/pole 30% canopy cover Human disturbance is located within approximately 27% of the floodplain. 8.2% of the 100 ft riparian buffer has been cleared. Disturbance is particularly located in the upstream portion of this reach between RM 72.5 – RM 75 in the Lost River community, and includes roads and cleared home sites, often with associated riprap and levees.	At least a 100 ft riparian buffer with: > 80% mature trees, or consistent with potential native community < 20% riparian disturbance (human) > 80% canopy closure in the riparian zone. [REI]	Riparian Restoration	Lost River Project Cedarosa Project
Floodplain Connectivity	There is significant riprap and levees along the channel in this reach. Additionally, a large number of roads are present in the floodplain that restrict floodplain activation throughout the reach, primarily on river-left. Due to the high density of human features, the channel is substantially cut off from the floodplain 4.02 mi/mi^2 of road 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 $<2mi/mi^2$ road density in the floodplain [adapted from REI]	Habitat Reconnection via Infrastructure Modification Placement of Structural Habitat Elements Off-Channel Habitat Enhancement	Lost River Project Cedarosa Project Gate Creek Project

Reach 6 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Bank condition / Channel migration	There are a number of instances of riprap or levees protecting houses and private property in this reach. Additionally, roads built in the floodplain contribute to restricted migration of the channel throughout the reach, primarily on river-left. Due to these human features, the channel is migrating significantly below natural rates for this reach.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	Habitat Reconnection via Infrastructure Modification Placement of Structural Habitat Elements	Lost River Project Cedarosa Project Gate Creek Project
Vertical channel stability	Reduced channel sinuosity with some potential for incision and reduced floodplain connectivity due to channel confinement by riprap, and levees.	No measurable trend of human-induced aggradation or incision [adapted from REI]	Habitat Reconnection via Infrastructure Modification Placement of Structural Habitat Elements	Lost River Project Cedarosa Project Gate Creek Project
Pools	Pools have relatively little cover, but there are many large pools (> 3 ft deep) in the reach. Pools per mile = 6.3 26% pool habitat (highest of all 9 reaches) 14 pools > 3 ft deep	~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >3 ft deep with good fish cover. [REI]	Placement of Structural Habitat Elements	Lost River Project Cedarosa Project Gate Creek Project
Large wood and logjams	48.3 M-L pieces / mi 2.8 jams /mi	> 42.5 pieces/mi (>12 diam; > 35 ft long) [from Fox and Bolton 2007] ≥ 4 logjams/mi [based on conditions in Reaches 5 and 9]	Placement of Structural Habitat Elements	Lost River Project Cedarosa Project Gate Creek Project

Reach 6 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Off-Channel Habitat	11% side-channel habitat. Eight side-channels, several over 1,000 ft with cool-water inputs from groundwater or tributaries, are present in this reach.	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]	Habitat Reconnection via Infrastructure Modification Off-Channel Habitat Enhancement	Lost River Project Cedarosa Project Gate Creek Project

4.4.7 Reach 7 Restoration Strategy

Overall ecological function	**Moderate-to-High**
	Rating is based on the Reach Assessment evaluations of habitat, geomorphology, hydrology, hydraulics, and vegetation. 6 of 11 REI metrics are at risk or unacceptable. Mostly at risk conditions except for Large Wood, which is unacceptable.
Trajectory if no action taken	**Same or improve**
	Some floodplain clearing for recreation expected to continue. Some continuing impacts from roadways in valley, primarily on tributary connectivity. Passive recovery of riparian function expected due to maturing vegetation.
Recovery potential	**High**
	Few significant human features impairing fundamental processes. Public land expected to offer continued protection.
Restoration objectives	**Target conditions in Table 23**
	Bring existing conditions to target conditions for the habitat and geomorphic metrics identified in Table 23 below. These targets apply to multiple habitat and geomorphic attributes. To the extent possible at this stage of planning, the targets are presented as measurable quantities.
Action Types	**Habitat reconnection via infrastructure modification** **Placement of structural habitat elements** **Off-channel habitat enhancement** **Riparian restoration**
	Actions fall primarily in the Restoration and Enhancement categories.
Projects & Prioritization	**Two Rivers Project (Tier 3)** **Robinson Project (Tier 3)**
	Reach 7 has moderate restoration potential, mostly related to restoring the large in-channel structure that is lacking in the reach, and also increasing side-channel and floodplain connectivity in a few locations, including one side-channel obstructed by a push-up levee. The projects are Tier 3 due to existing relatively high functioning habitat and moderate fish use.

Table 23. Reach 7 Restoration Objectives, Action Types, and Projects.

Reach 7 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	50-80% species composition, seral stage, and structural complexity are consistent with potential native community. 40% small tree 20% sapling/pole 40% shrub/seedling 25% canopy cover Human disturbance is located within approximately 18.4% of the floodplain. 8.8% of the 100 ft riparian buffer has been cleared. Disturbance is located on river-left of this reach, and includes roads and cleared areas.	At least a 100 ft riparian buffer with: > 80% mature trees, or consistent with potential native community < 20% riparian disturbance (human) > 80% canopy closure in the riparian zone. [REI]	Riparian Restoration	Robinson Project Two Rivers Project
Floodplain Connectivity	This reach is has few instances of human features in the floodplain that could restrict connectivity with the channel. 0.95 mi/mi² of road 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 <2mi/mi² road density in the floodplain [adapted from REI]	Habitat Reconnection via Infrastructure Modification Placement of Structural Habitat Elements Off-Channel Habitat Enhancement	Robinson Project Two Rivers Project
Bank condition / Channel migration	This reach is moderately unconfined, and there are few instances of human features in the floodplain that could restrict channel migration activity.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	Placement of Structural Habitat Elements	Robinson Project Two Rivers Project

Reach 7 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Vertical channel stability	No measurable trend of aggradation or incision and no visible change in channel planform.	No measurable trend of human-induced aggradation or incision [adapted from REI]	Placement of Structural Habitat Elements	
Pools	Pools have relatively little cover, but there are several deep pools (> 3 ft deep) in the reach. Pools per mile = 7.5 16% pool habitat 7 pools > 3 ft deep	~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >3 ft deep with good fish cover. [REI]	Placement of Structural Habitat Elements	Robinson Project Two Rivers Project
Large wood and logjams	48.3 M-L pieces / mi 2.8 jams /mi	> 42.5 pieces/mi (>12 diam; > 35 ft long) [from Fox and Bolton 2007] ≥ 4 logjams/mi [based on conditions in Reaches 5 and 9]	Placement of Structural Habitat Elements	Robinson Project Two Rivers Project
Off-Channel Habitat	11% side-channel habitat. Seven predominantly fast-moving side-channels are present in this reach.	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]	Habitat Reconnection via Infrastructure Modification Off-Channel Habitat Enhancement	Robinson Project Two Rivers Project

4.4.8 Reach 8 Restoration Strategy

Overall ecological function	**Moderate-to-High**
	Rating is based on the Reach Assessment evaluations of habitat, geomorphology, hydrology, hydraulics, and vegetation. 4 of 11 REI metrics are at risk or unacceptable. Mostly at risk conditions except for Large Wood, which is unacceptable.
Trajectory if no action taken	**Improve**
	Some floodplain clearing and road impacts at downstream end. Passive recovery of riparian function expected due to maturing vegetation.
Recovery potential	**High**
	Few significant human features impairing fundamental processes. Public land expected to offer continued protection.
Restoration objectives	**Target conditions in Table 24**
	Bring existing conditions to target conditions for the habitat and geomorphic metrics identified in Table 24 below. These targets apply to multiple habitat and geomorphic attributes. To the extent possible at this stage of planning, the targets are presented as measurable quantities.
Action Types	**Habitat reconnection via infrastructure modification** **Placement of structural habitat elements** **Off-channel habitat enhancement** **Riparian restoration**
	Actions fall in the Restoration and Enhancement categories.
Projects & Prioritization	**Ballard Project (Tier 3)**
	Reach 8 has relatively little restoration potential due to the existing mostly undisturbed condition and challenging access to the upper portion of the reach. There is one project identified, the Ballard Campground Project. It is Tier 3 due to existing relatively high functioning habitat and moderate fish use.

Table 24. Reach 8 Restoration Objectives, Action Types, and Projects.

Reach 8 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	50-80% species composition, seral stage, and structural complexity are consistent with potential native community. 100% small tree 90% canopy cover Human disturbance is located within approximately 4.1% of the floodplain. 1.9% of the 100 ft riparian buffer has been cleared. Disturbance is located in the downstream portion of this reach and includes roads and cleared areas associated with the campgrounds.	At least a 100 ft riparian buffer with: > 80% mature trees, or consistent with potential native community < 20% riparian disturbance (human) > 80% canopy closure in the riparian zone. [REI]	Riparian Restoration	Ballard Project
Floodplain Connectivity	This reach is naturally laterally constricted by terraces and hillslopes on both sides of the channel and has little natural floodplain throughout the entire reach. 1.32 mi/mi^2 of road 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 <2mi/mi^2 road density in the floodplain [adapted from REI]	Habitat Reconnection via Infrastructure Modification	Ballard Project

Reach 8 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Bank condition / Channel migration	This reach is naturally laterally constricted by terraces and hillslopes on both sides of the channel throughout the entire reach. Historic channel location has not moved considerably, therefore the rate of channel migration has not changed substantially.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	Habitat Reconnection via Infrastructure Modification	Ballard Project
Vertical channel stability	No measurable trend of aggradation or incision and no visible change in channel planform.	No measurable trend of human-induced aggradation or incision [adapted from REI]	None Identified	None Identified
Pools	Pool frequency is low and pools have minimal cover. Only two large pools (>3 ft deep) are present in this reach. Pools per mile = 1.4 2% pool habitat 2 pools > 3 ft deep	~9 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >3 ft deep with good fish cover. [REI]	Placement of Structural Habitat Elements	Ballard Project
Large wood and logjams	57.5 M-L pieces / mi 1.8 jams /mi	> 42.5 pieces/mi (>12 diam; > 35 ft long) [from Fox and Bolton 2007] ≥ 4 logjams/mi [based on conditions in Reaches 5 and 9]	Placement of Structural Habitat Elements	Ballard Project

Reach 8 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Off-Channel Habitat	5% side-channel habitat. Four side-channels were present in this reach. Though only one was classified as fast-moving, it was the longest side-channel at 1,740 feet, with all other slow-moving side-channels totaling only 550 feet.	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]	Habitat Reconnection via Infrastructure Modification Off-Channel Habitat Enhancement	Ballard Project

4.4.9 Reach 9 Restoration Strategy

Overall ecological function	**High**
	Rating is based on the Reach Assessment evaluations of habitat, geomorphology, hydrology, hydraulics, and vegetation. All REI metrics rated as adequate. Habitat quality is generally high.
Trajectory if no action taken	**Improve**
	Passive recovery of riparian and floodplain function expected due to maturing vegetation.
Recovery potential	**High**
	No significant human features impairing fundamental processes. Public land expected to offer continued protection.
Restoration objectives	**Target conditions in Table 25**
	Reach 9 has very little restoration potential due to the existing mostly undisturbed condition and challenging access. No projects were identified. Existing and target conditions are provided in Table 25 below. These targets apply to multiple habitat and geomorphic attributes. To the extent possible at this stage of planning, the targets are presented as measurable quantities.
Action Types	**No projects identified**
	Public land expected to offer continued protection.
Projects & Prioritization	**No projects identified**
	Public land expected to offer continued protection.

Table 25. Reach 9 Restoration Objectives, Action Types, and Projects.

Reach 9 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Riparian condition	50-80% species composition, seral stage, and structural complexity are consistent with potential native community. 100% small tree (due to recent fire and landslides) 60% canopy cover There is no human disturbance within the floodplain or 100-ft riparian buffer in Reach 9.	At least a 100 ft riparian buffer with: > 80% mature trees, or consistent with potential native community < 20% riparian disturbance (human) > 80% canopy closure in the riparian zone. [REI]	None Identified	None Identified
Floodplain Connectivity	This reach is naturally laterally constricted by terraces and hillslopes on both sides of the channel and has little natural floodplain throughout the entire reach. There are no human features that further restrict connectivity besides an old bridge abutment. 0 mi/mi^2 of road 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 <2mi/mi^2 road density in the floodplain [adapted from REI]	None Identified	None Identified

Reach 9 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Bank condition / Channel migration	This reach is naturally laterally constricted by terraces and hillslopes on both sides of the channel throughout the entire reach. Historic channel location has not moved significantly.	Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion. [adapted from REI]	None Identified	None Identified
Vertical channel stability	No measurable trend of aggradation or incision and no visible change in channel planform.	No measurable trend of human-induced aggradation or incision [adapted from REI]	None Identified	None Identified
Pools	Pool frequency is low and pools have minimal cover. Reaches have no large pools (>3 ft deep) with good fish cover. Pools per mile = 3 10% pool habitat 3 pools > 3 ft deep	~9 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >3 ft deep with good fish cover. [REI]	None Identified	None Identified
Large wood and logjams	110.2 M-L pieces / mi 4.5 jams /mi	> 42.5 pieces/mi (>12 diam; > 35 ft long) [from Fox and Bolton 2007] ≥ 4 logjams/mi [based on conditions in Reaches 5 and 9]	None Identified	None Identified

Reach 9 Attribute	Existing Condition (from assessment)	Target Condition [source]	Action Type	Potential Projects
Off-Channel Habitat	4% side-channel habitat. Only four side-channels, half of which are fast-moving, are present in this reach.	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]	None Identified	None Identified

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Appendix A

Stream Habitat Assessment

Upper Methow River Reach Assessment

December 2015

Habitat Inventory: Weeman Bridge (RM 61) to Trout Creek (RM 80)

Survey: July 16 – August 14, 2014

Table of Contents

1 Introduction & Background

The Methow River originates from the Cascade Crest in Okanogan County, Washington at 6,700 feet. It enters the Columbia River near the town of Pateros, WA on the east slopes of the Cascade Mountains. As part of the Reach Assessment work performed for the Yakama Nation, Inter-Fluve, Inc. conducted a 19-mile habitat survey of the upper Methow River on July 16 – August 14, 2014 from RM 61 (Weeman Bridge) to RM 80 (confluence with Trout Creek). The flow rate on July 16 was 711 cfs at USGS gage #12447383 on the Methow River above Goat Creek near Mazama, Washington. The August 14 flow rate was 314 cfs. Flows at the gage dropped as low as 110 cfs during the survey period (Figure 1). Stream flow was not measured as part of this survey.

The objective of the Habitat Assessment is to characterize the habitat quantity and quality for salmonid species native to the upper Methow 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 measuring the effectiveness of restoration efforts.

To our knowledge, the earliest habitat assessment performed on the upper Methow River was completed in 1994 by Okanogan National Forest Methow Valley Ranger District (USFS 1997). It was a Hankin and Reeves Level 2 survey from Goat Creek to the impassable bedrock falls 20.0 miles upriver. This is the first comprehensive stream habitat survey and assessment for this portion of the upper Methow River. Additional surveys in the basin by the Okanogan National Forest Methow Valley Ranger District included Early Winters Creek in 2009 (USFS 2009), and the West Fork Methow River from the confluence with Lost River to the waterfall barrier above Brush Creek in 2003 (USFS 2003).

2 Methods

Nine geomorphic reaches were delineated in this stream assessment. The same reach delineations were used for both the stream assessment and the geomorphology assessment to maintain consistency.

Field methods for the habitat survey followed the US Forest Service Region 6 Level I & II Stream Inventory Handbook, Version 2.13 (USFS 2013). All protocols were followed when safe, and most of the suggested forest inventory options were applied in the survey. Due to high water levels at the beginning of the survey and also the last two days of the survey, surveyors estimated some instream measurements from the bank.

Flow rates at the USGS River Gage #12447383 above Goat Creek and near Mazama (at RM 65.5) were slightly above average throughout much of the survey, beginning at 711 cfs (median for July 16 is 570 cfs), and ending at 359 cfs (median for August 14 is 129 cfs). A spike in river levels on the last two days of the survey occurred due to heavy, unseasonal rainfall. River levels on August 13 reached 411 cfs (Figure 1).

All reach-scale metrics were calculated using GIS measurements as opposed to reach lengths measured in the field by tape. We chose GIS measurements because GIS provides a more accurate measurement at a reach scale.

All measurements were done at an n^{th} unit measurement frequency of 20%, or 1 unit measured in every 5. This choice was made to ensure that the n^{th} unit measurements were representative of the field area. In total, 40 n^{th} units were measured in Reaches 1-9. At n^{th} units the surveyors recorded the wetted channel width with a 100-foot or 200-foot tape. Flood prone widths (FPW) – width of the floodplain at twice the maximum bankfull depth -- were measured in the field when accurate measurements were possible, or done in the office via GIS where the floodplain was excessively wide. At every channel unit measured, modern unstable banks were tallied for both the left and right channel banks. This is one metric where the Stream Inventory Handbook protocol was not followed. Instead of measuring all actively eroding stream banks, only modern or active bank erosion that appeared to be "human-caused" was measured. As a result, total unstable bank measurements were much lower than past surveys.

Depth of pools, riffles, and glides was measured using an 8-foot graduated survey rod carried by the observer. Where water velocity or depth was unsafe for surveying (especially at the beginning and end of the survey), the observer either estimated depth or measured as close to the thalweg as possible.

Pebble counts were completed by the geomorphology team across the channel and exposed active bar surfaces at riffle crests. Two pebble counts were performed within Reaches 2-7 and one was performed in Reach 1. No pebble counts were completed in Reach 8 or 9 because of the large bedload size relative to channel geometry and the lack of LiDAR for conducting hydraulic modeling.

Open water wetlands on floodplains were measured and recorded when connected to the main river. When differentiating between wetlands and other secondary channels was challenging, vegetation was used as the primary indicator. Open water wetlands were not included in the overall secondary channel calculations because the width of some of these features is significantly wider, and thus not representative, of other secondary channels throughout the project reach.

The term “secondary channel” is being used to include both side channel and off-channel habitat. For this assessment, we consider “side-channels” as secondary channels that are, or would be, naturally connected to the mainstem flow at their upstream and downstream ends at average annual flow; this definition also includes artificially disconnected side channels. We consider “off-channels” to be all other types of secondary channels including backwater channels/alcoves, groundwater-fed channels, wall-base channels, abandoned oxbows, and other types of floodplain channels and open-water floodplain wetlands.

Secondary channel units were identified when the main channel split to form a stable island with soil or fine sediment deposits and with establishing vegetation older than 2 to 3 years. Each secondary channel was determined to be fast or slow, and its average width and length measured. Both total and wetted lengths were recorded. Wetted lengths are used in the report that follows, unless otherwise noted. Where secondary channels were either too long (some were several thousand feet long), or impassible due to downed wood, GIS was used to measure total channel length. Large wood (LWD) was counted in each secondary channel. Two side channels, one in Reach 2 and one in Reach 6, were further categorized as *disconnected* side channels. In both instances, human-built features block or alter the natural historical connection to the mainstem.

Water temperature in secondary channels and tributaries were recorded. In most instances, the main channel temperature was recorded within an hour of each secondary channel or tributary temperature recording. Due to the variety of thermometers used (three), daily fluctuations in air temperature, and variability in the water temperature depending on the depth of the measurement, the water temperature data is best interpreted in relation to other measurements taken within the hour or day for determining the relative water temperatures between main channel and secondary channel/tributaries.

No units were designated as “braided,” which is defined as a series of three or more roughly parallel channels structured during bankfull flow and separated from each other by unstable islands. LWD was counted using guidelines from the USFS Stream Inventory Guidebook for Eastside Forests. In the case of log jams, all individual logs that met guidelines and were attached to a log jam were counted, even if they were above the bankfull flow.

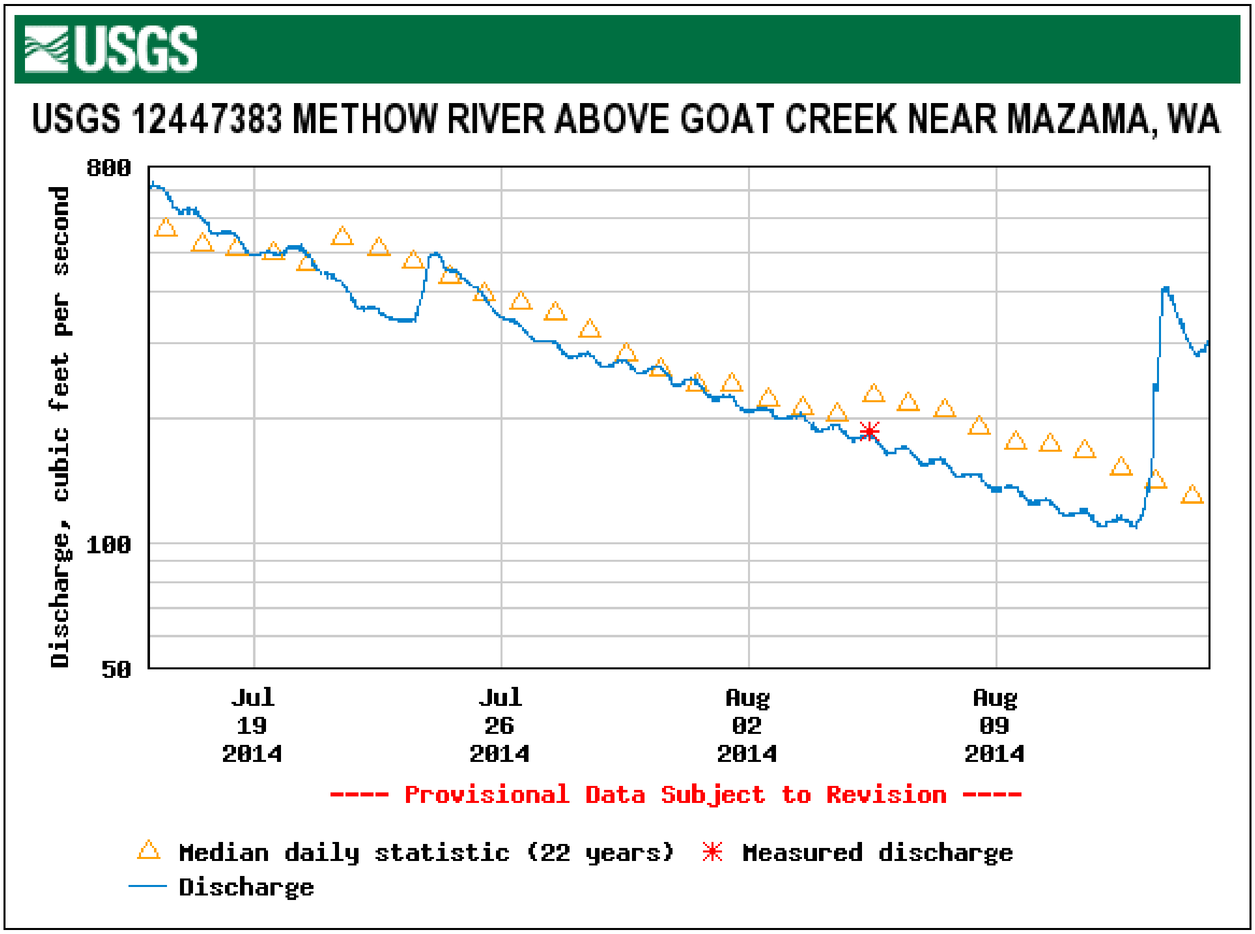


Figure 1. Flow measurements on the Methow River at USGS gauge 12447383 during the study (July 16 – August 14, 2014).

3 Summary of Results

This section summarizes the results for all nine reaches surveyed in between RM 61 to 80. Detailed reach summaries with reach-specific results are included in Section 5 of this report.

3.1 CHANNEL MORPHOLOGY

According to this survey, the upper Methow River reaches are dominated by pool-riffle and plane-bed morphology, with some partially confined step-pool channels in Reach 8. Overall, channel bed substrate consisted primarily of cobbles (48%) and gravels (48%) with 2% boulder and 2% sand (Figure 8). Bedrock was not recorded in significant amounts, although it is present at various places throughout the study area.

Channel geometry varied within the study area. In general, the channel becomes narrower going upstream as quantity of relative discharge decreases due to reduced upland drainage area and tributary inputs. Reach 1 has a mean width of 172 feet, based on one measurement; the average width decreases to 52 feet by Reach 9 (also based on one measurement). Reach 8 and 9 are more confined channels with less variation in width (Table 1). Mean bankfull depths also decrease going upstream, ranging from an average bankfull depth of 3.9 feet in Reach 1, to an average of 1.6 feet in Reach 9. The maximum mean bankfull depth is 4.0 feet in Reach 2 (Table 2). Flood prone widths vary substantially in the project area, ranging from 3,400 feet in Reach 1, to 70 feet in Reach 9 where the river is constrained by glacially carved walls for parts of the reach.

Table 1. Minimum (min), maximum (max), and mean bankfull widths (in feet) recorded in reaches 1-9.

Bankfull widths (feet)									
	Reach 1	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**	**Reach 7**	**Reach 8**	**Reach 9**
Min	172.0	105.0	145.0	92.0	72.0	69.0	52.0	52.0	52.0
Max	172.0	170.0	173.0	162.0	108.0	130.0	102.0	60.0	52.0
Mean	172.0	140.5	159.0	129.0	95.0	100.3	75.7	56.0	52.0
St Dev	n=1	23.9	19.8	27.8	20.0	22.5	25.1	5.7	n=1

Table 2. Minimum (min), maximum (max), and mean bankfull depths recorded in reaches 1-9. Bankfull depths were measured at all glides and riffles (fast water) by taking 10 measurements evenly distributed across the unit. The mean values identified below were calculated by first averaging the 10 depths recorded at each of the nth units, and then averaging the results for the Reach.

Bankfull depths (feet)									
	Reach 1	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**	**Reach 7**	**Reach 8**	**Reach 9**
Min	3.9	3.4	3.1	2.8	2.4	1.7	1.8	2.3	1.6
Max	3.9	4.4	3.2	3.7	3.3	3.1	2.5	2.8	1.6
Mean	3.9	4.0	3.2	3.2	2.7	2.6	2.2	2.6	1.6
St Dev	n=1	0.5	0.1	0.4	0.5	0.5	0.4	0.3	n=1

Table 3. Minimum (min), maximum (max), and mean flood prone widths for reaches 1-9 (in feet). Mean values are an average of all flood prone widths calculated in each reach. Where flood prone width could not be measured in the field, they were estimated using LiDAR.

Flood prone widths (feet)									
	Reach 1	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**	**Reach 7**	**Reach 8**	**Reach 9**
Min	3400	1150	1100	350	800	600	1300	60	70
Max	3400	3200	2100	1200	1750	2500	1750	1125	70
Mean	3400	2075	1600	817	1200	1375	1467	593	70
St Dev	n=1	762.1	707.1	312.5	492.4	681.7	246.6	753.1	n=1

3.2 HABITAT UNIT COMPOSITION

Riffles are the dominant habitat type, comprising 54% of the total habitat unit composition for the study area. Glides comprise 22% of the area, and pools and secondary channels each comprise 12% of the project area (Figure 3). In general, glide area habitat decreases and riffle area habitat increases as the grade increases going upstream. Reaches 5, 6, and 7 maintain some of the most complex habitat with higher ratios of secondary channels and pools than other reaches (Figure 2).

Pool frequency ranged from 0 pools per mile (Reach 1), to 7.5 pools per mile (Reach 7), with an average pool frequency throughout the project of 3.6 pools per mile. Reaches 3 and 6 have the most pool area habitat (21% and 27% respectively). Reaches 3 and 6 have the shortest pool spacing (19.7 and 19.6 channel widths per pool, respectively), while Reach 8 has the longest pool spacing (79.6 channel widths per pool). Reaches 5 and 6 have the most pools exceeding 3 feet (9 and 14 pools respectively). The majority of pools throughout the project area had residual depths of less than three feet (72%). Of the 28% of pools with residual depths of less than three feet, 47% (9 pools) are located in Reach 6.

The mean wetted width of the main channel is 51.9 feet. Mean riffle depths were 1.6 feet with mean maximum riffle depths of 3.0 feet. Due to slightly higher than normal flows, it is likely that depths at the end of the summer during normal water years would be lower than those recorded here.

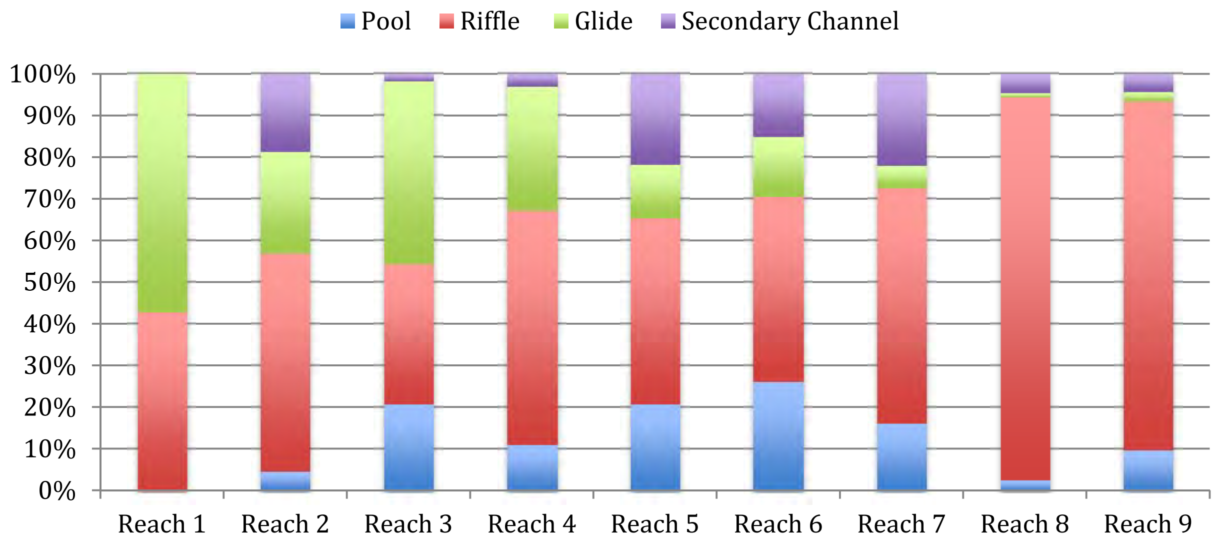


Figure 2. Habitat unit composition by reach.

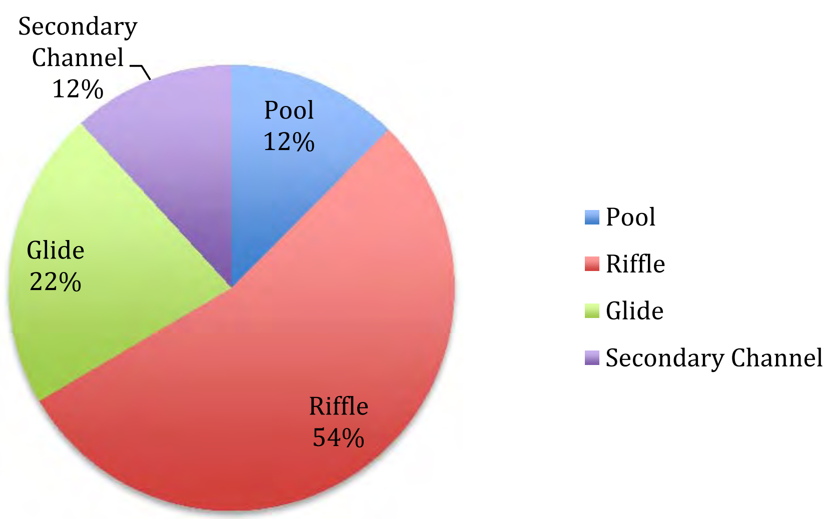


Figure 3. Habitat unit composition of reaches 1-9. Three open water floodplain wetlands that were recorded in Reach 2 are not included in the secondary channel habitat calculations for Figure 2 and Figure 3.

3.3 SECONDARY CHANNEL HABITAT

For this assessment, we consider "side-channel" features as secondary channels that are, or would be, naturally connected to the mainstem flow at their upstream and downstream ends at average annual flow; this definition also includes artificially disconnected side channels. We consider "off-channel" features to be all other types of secondary channels including backwater channels/alcoves, groundwater-fed channels, wall-base channels, abandoned oxbows, and other types of floodplain channels and open-water floodplain wetlands. For secondary channel habitat that has a dry component, e.g., a side channel with 1,000 feet of wetted length and 500 feet of additional dry length, only the wetted length is used to calculate secondary channel habitat.

Secondary channel habitat accounted for approximately 12% of the habitat area throughout the project area (Figure 3). In total, 48 secondary channel units were observed. Unless otherwise noted, all channel lengths identified in the report are wetted length. The average secondary channel was 1,042 feet (StDev 1,068 feet). While Reach 2 has the most overall secondary channel habitat area within the project area, the longest secondary channel observed was in Reach 6 (4,850 feet). No secondary habitat was observed in Reach 1 (Figure 2). Reaches 5 and 7 have the highest ratio of secondary channel habitat by reach (30% and 22%, respectively). Mean secondary channel width was 14 feet (StDev 12) throughout the project area. Two side channels, one in Reach 2 and one in Reach 6, were further categorized as being disconnected side channels. Both of these side channels have an inlet and outlet connected to the main channel but they are disconnected to one of those connection points due to a human constructed impediment.

Three open water floodplain wetland units (open water wetlands located on the floodplain) that were identified in Reach 2 of the assessment are not included in secondary channel calculations above. Together, they totaled 5.8 acres. While this type of habitat is important because it contains food sources (invertebrates), LWD, refuge, and rearing habitat for fish and wildlife species when connected to the mainstem channel, and is included in the definition of secondary channel habitat, these three units were not included because of their width, which is not representative of the majority of secondary channel habitat. The three units are outlined in Table 10.

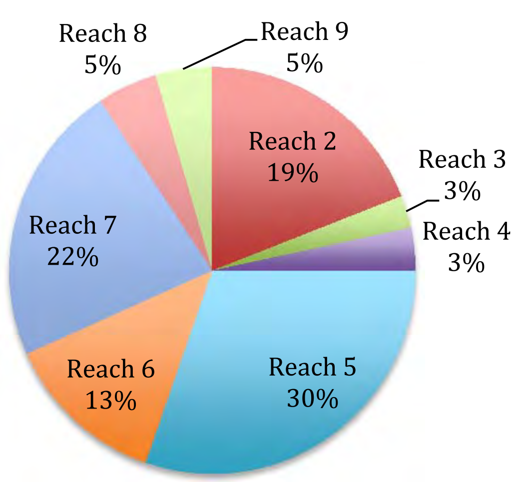


Figure 4. Percentage of secondary channel habitat in each reach. Three open water floodplain wetlands that were recorded in Reach 2 are not included in the secondary channel habitat calculations above.

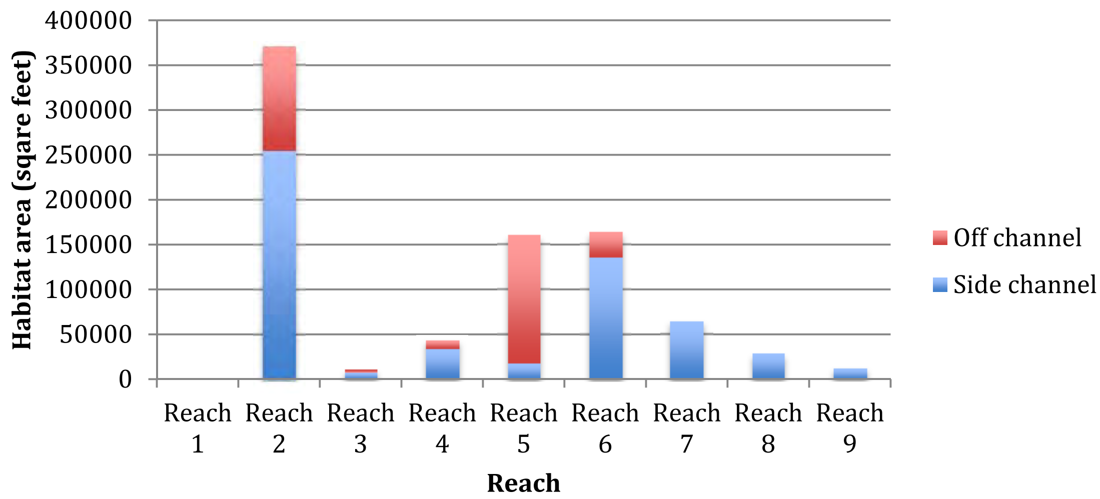


Figure 5. Secondary channel habitat by reach. Off-channel and side channel habitat identified. Three open water floodplain wetlands that were recorded in Reach 2 are not included in the secondary channel habitat calculations above.

3.4 LARGE WOOD

An average of 125 pieces of large wood per mile was counted in the project area; 56% were "small" pieces with diameters between 6 and 12 inches and lengths greater than 20 feet. Even though Reach 9 is a short reach at 1.3 miles, it maintains the highest wood count with a total of 467 pieces. This is more than double the wood per mile counts of the other reaches (Figure 6). The high wood count was largely due to several log jams at River Mile (RM) 79.75 that were caused by an avalanche in May 2014 that pushed hundreds of trees off the mountainside and into the Methow River. Reaches 2 – 8 maintain relatively similar large wood (LWD) densities, ranging from 107 – 152 pieces per mile.

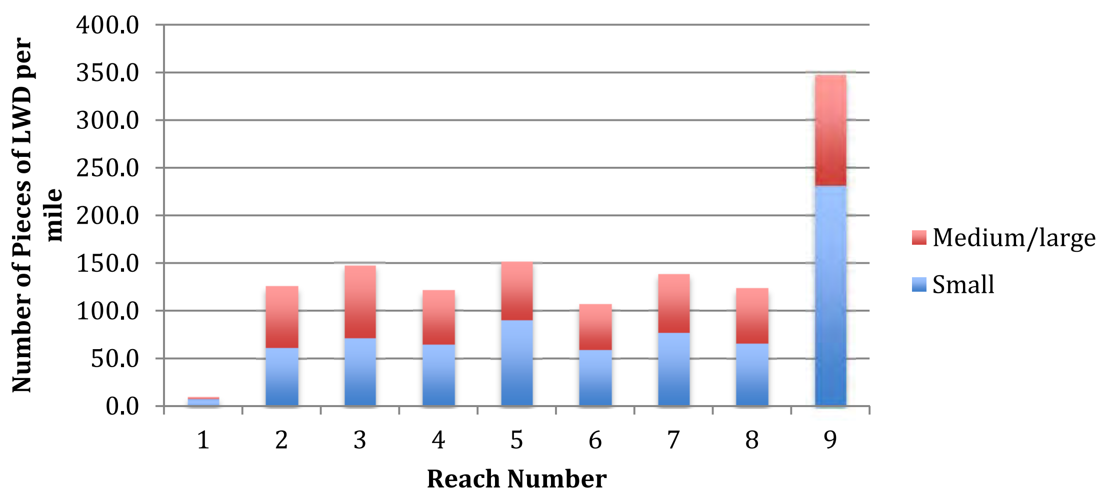


Figure 6. Small and medium/large wood pieces per river mile for reaches 1-9.

3.5 SUBSTRATE & FINE SEDIMENT

Bed substrate classification is based on thirteen pebble counts done between Reaches 1 through 7. Two pebbles counts were done per reach in Reaches 2-7 and one in Reach 1. All gravel counts were completed at representative glide to riffle transition points. Overall, substrate composition at the pebbles counts is generally similar with the exception of Reach 5, which has considerably more gravel (67%) and less cobble (29%). Reaches 1, 2, 3, 4, 6 and 7 have fairly similar distributions with approximately equal representation of gravel and cobble (Figure 8) and 5% or less sand and boulders. No bedrock was recorded in any of the pebble counts. Throughout all project reaches, an average of 2% of both boulder and sand were recorded (Figure 7). This indicates that fine sediment (<2mm), which can be harmful to salmonid survival in high concentrations, is general not an issue in the study area. Fine sediments appear to be washed through the system as suspended load. Fines accumulate in this system primarily as overbank deposits on floodplains as the result of flood events.

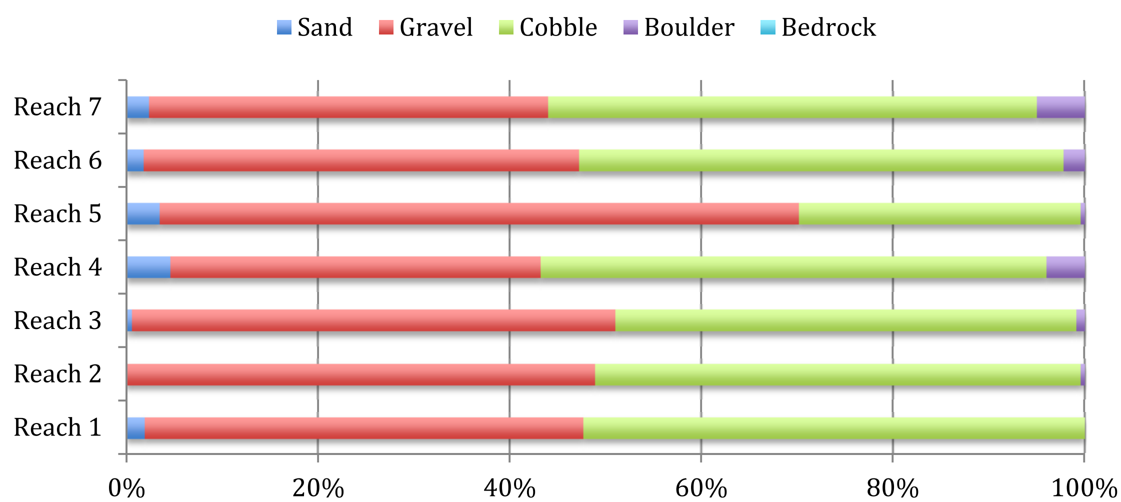


Figure 7. Pebble count classification of substrate by reach for Reaches 1-7 of the Upper Methow River. For each reach, two pebble counts were performed and then averaged. Pebble counts were not performed in Reaches 8 and 9.

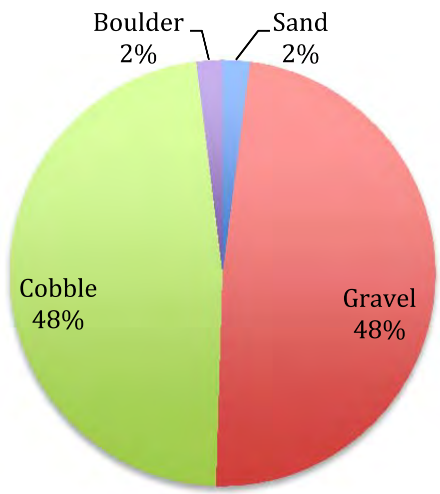


Figure 8. Pebble count classification averaged for Reach 1-7.

3.6 INSTABILITY & DISTURBANCE

Reaches 1-7 had significant human impacts, including residential development on the floodplain, channelization, roads, vegetation clearing adjacent to the river and riparian areas, levee construction, and impacts from logging. However, modern anthropogenically caused bank erosion was minimal throughout the study area. In total, 2,000 linear feet (or 1%) of modern bank erosion was identified as caused by human activity within the nine n^{th} unit measurements in the lower four reaches. No anthropogenically-caused bank erosion was identified in Reaches 5,6, 8, and 9.

Fire and avalanche-related instability and disturbance were observed in Reaches 8 and 9 during this survey. Both fire and avalanches have been elements of natural disturbance in this basin for centuries. However, the impacts and geographic scale of fire disturbance have increased since Euro-settlement and are expected to continue to increase with climate change forecasts. For example during the summer of 2014 the Carlton Complex Fire (Washington's largest recorded wildfire to date) burned approximately 256,108 acres in the nearby area. This fire did not impact the Upper Methow River but it is representative of the increased risk of large-scale fire disturbance in the watershed.

3.7 FISH PASSAGE BARRIERS

No fish passage barriers were observed in the mainstem channel. During dry years, portions of the Upper Methow River seasonally flow subsurface. However, during the 2014 habitat survey completed in August, the Upper Methow was not observed flowing subsurface. A discussion of some of the historical observations of portions of the Upper Methow River flowing subsurface (dewatering) is provided in section 4.2 of this report. The hydrologic and geologic processes responsible for seasonal dewatering are provided in section 2.6 of the Reach Assessment.

3.8 RIPARIAN CORRIDOR

A suggested stream inventory survey option is to designate a riparian corridor as either a single 100ft wide zone or two adjacent riparian zones (inner and outer zones) totaling 100 feet in width (USDA 2010). For this assessment, one single 100ft wide riparian zone was designated for the Upper Methow River study area. Survey methods dictate defining a dominant size class of vegetation type within the riparian corridor (i.e. large trees, small trees, shrubs), then defining the dominate species observed in the over and understory respectively.

In total, 40 n^{th} units were measured in Reaches 1-9. In these units the dominant riparian vegetation size class measured was small trees with a 9.0 – 20.9 inch diameter (83%). Sapling/pole trees measuring 5.0 – 8.9 inches diameter were the second most dominant class (7%). The remaining 10% was distributed between large trees measuring 21 – 31.9 inches diameter (3%); shrub/seedling measuring 1 – 4.9 inches diameter (5%); and grassland/forbs (2%) (Figure 9).

Within the units measured the dominant riparian understory observed was dogwood and cottonwood, accounting for 30% of the understory each. Additional dominant riparian understory species observed included snowberry (co-dominant with either mountain maple or huckleberry, 13%); grassland forbes (12%); willow (5%); other unidentified small shrubs (5%); ceanothus (3%);

and cedar (2%). Within the units measured the overstory was dominated by cottonwood and ponderosa pine (42% and 25% respectively). Additional species observed as dominant in the understory included dogwood (10%); cedar (10%); Douglas fir (10%); and aspen (3%) (Figure 12).

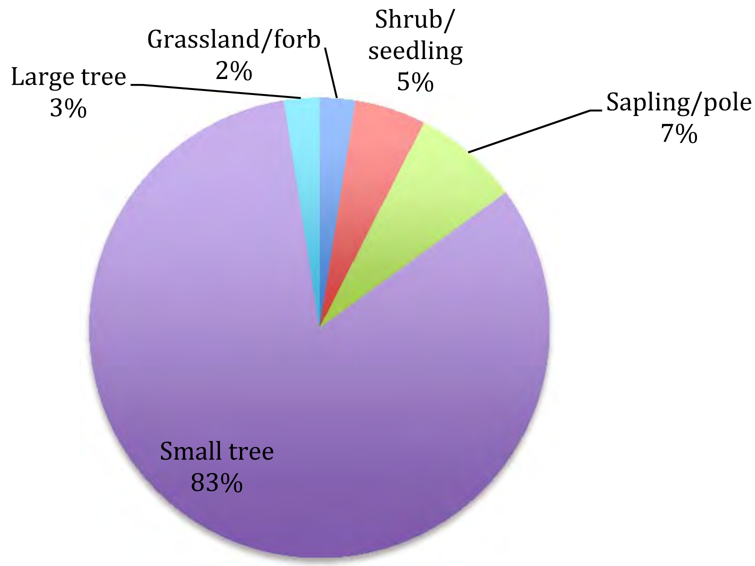


Figure 9. Distribution of dominant size class category for the riparian inner zone, all reaches combined.

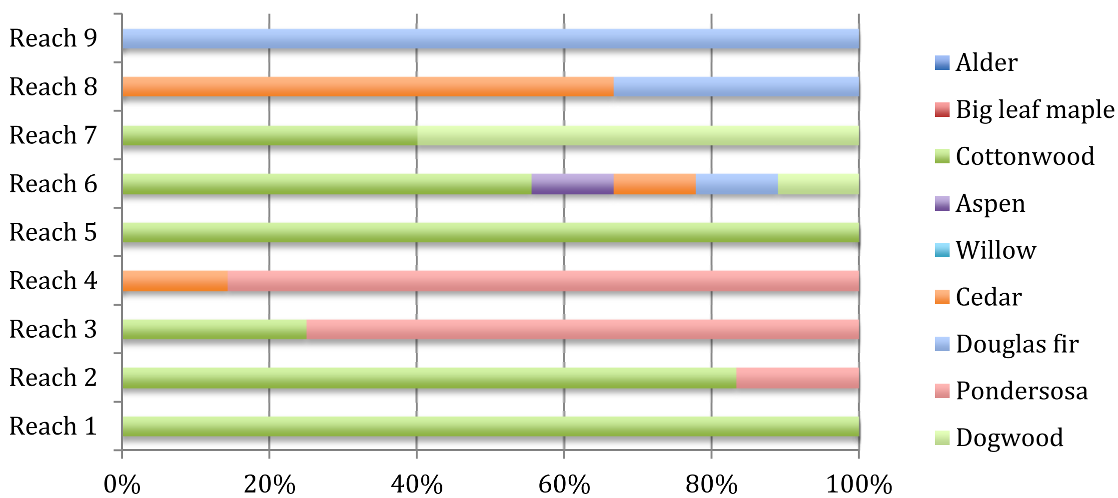


Figure 10. Distribution of overstory species by reach based on n^th unit measurements.

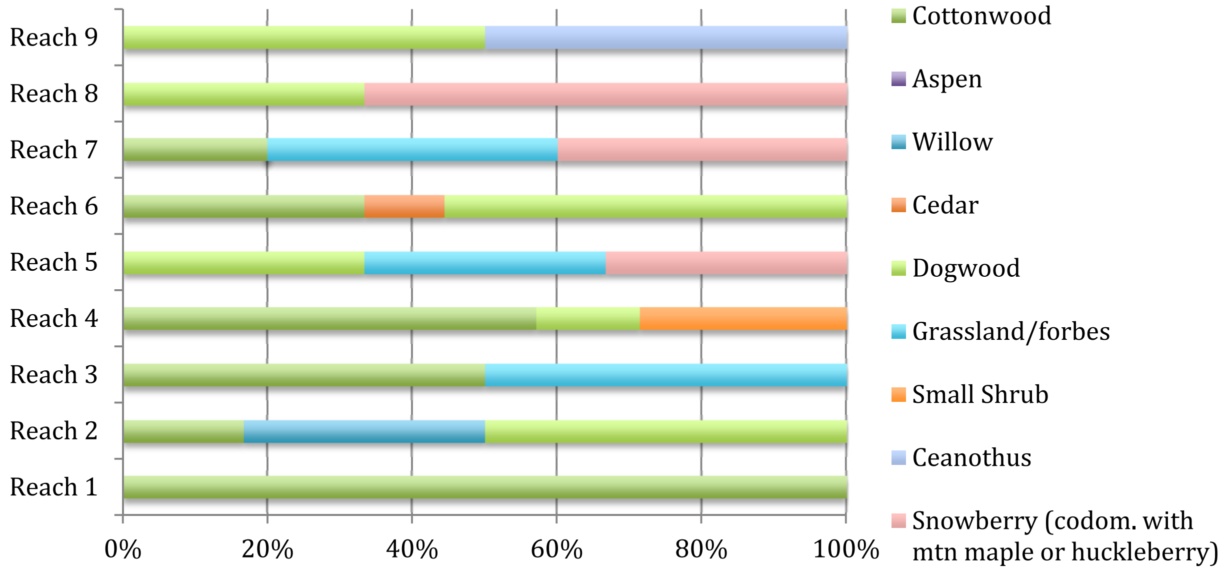
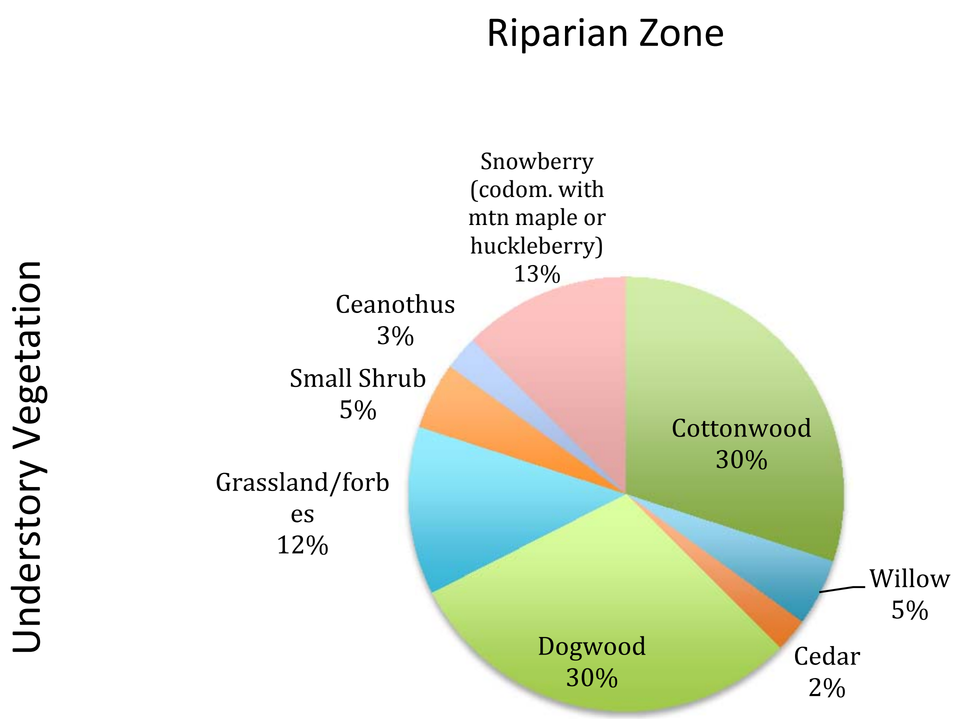


Figure 11. Distribution of understory species by reach based on n^{th} unit measurements.



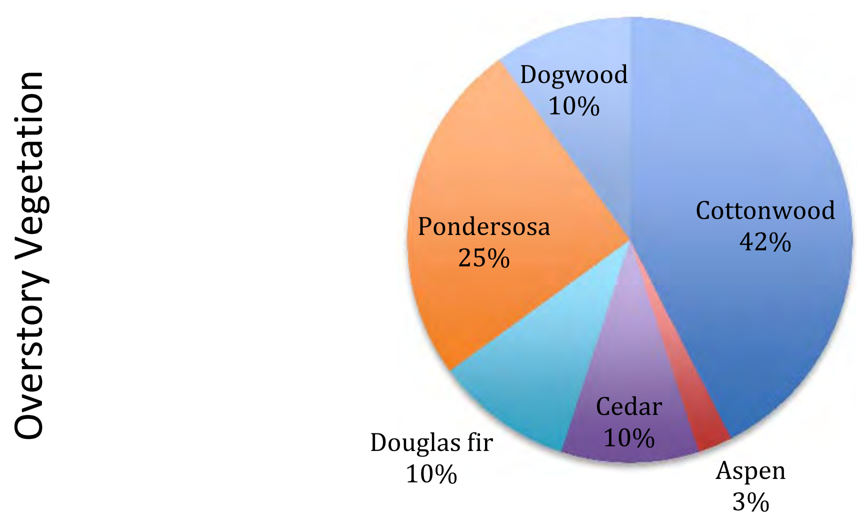


Figure 12. Dominant understory and overstory riparian vegetation observed at nth units throughout the project area.

4 Comparisons to Past Surveys

Two previous surveys were performed on the Upper Methow River that can be used for comparison purposes. Table 4 outlines approximate equivalent reaches and associated river miles. The Okanogan National Forest Methow Valley Ranger District performed the first habitat survey in 1994 from RM 64.9 at Goat Creek (the beginning of Reach 3 in this survey) to approximately RM 84.9 (site of a waterfall located about five miles upstream from the end of this survey). The write up for the 1994 survey was not completed until 1997. The second survey was performed in 2003 by the Okanongan-Wenatchee National Forest Methow Valley Ranger District from RM 75.0 at Lost River (the beginning of Reach 7 in this survey) to RM 80.0 at Trout Creek (the end of this survey).

Comparisons to previous surveys allow us to see trends in habitat characteristics over time. However, comparing between surveys is challenging because reach breaks change between surveys; survey protocols change from year to year; each survey team makes field judgments that may vary from other survey teams; and water levels vary considerably from year to year.

Table 4. Approximate equivalent reaches and associated river miles for 1994, 2003, and 2014 surveys.

<table>
<tr><th colspan="4">Equivalent Reaches – 1994, 2003 and 2014</th></tr>
<tr><th>2014 River Mile</th><th>2014 Survey</th><th>2003 Survey</th><th>1994 Survey</th></tr>
<tr><td>61.0 (Weeman Bridge) – 61.7</td><td>Reach 1 (0.7 mi.)</td><td rowspan="6"></td><td rowspan="2"></td></tr>
<tr><td>61.7 – 64.9 (Goat Creek)</td><td>Reach 2 (3.2 mi.)</td></tr>
<tr><td>64.9 (Goat Creek) – 66.2</td><td>Reach 3 (1.3 mi.)</td><td rowspan="2">Reach 1</td></tr>
<tr><td>66.2 – 69.2 (Early Winter's Creek)</td><td>Reach 4 (3.0 mi.)</td></tr>
<tr><td>69.2 (Early Winter's Creek) – 71.3</td><td>Reach 5 (2.1 mi.)</td><td rowspan="2">Reach 2</td></tr>
<tr><td>71.3 – 75.1 (Lost River)</td><td>Reach 6 (3.8 mi.)</td></tr>
<tr><td>75.1 (Lost River) – 76.5 (Robinson Creek)</td><td>Reach 7 (1.4 mi.)</td><td>Reach 1</td><td>Reach 3</td></tr>
<tr><td>76.5 (Robinson Creek) – 78.7</td><td>Reach 8 (2.2 mi.)</td><td rowspan="2">Reach 2</td><td rowspan="2">Reach 4</td></tr>
<tr><td>78.7 – 80.0 (Trout Creek)</td><td>Reach 9 (1.3 mi.)</td></tr>
</table>

4.1 HABITAT AREA

In general, pool and secondary channel area habitat have increased over time from Goat Creek to Trout Creek, while fast-water (riffle and glide) habitat has decreased. This characterization correlates with the LWD comparison in Table 6 that indicates a general increase in LWD from 1994 to 2014. More wood from Early Winters Creek to RM 75.1 indicate changes in habitat that show a 100% increase in pool area habitat and a 200% increase in secondary channel habitat area between 1994 and 2014.

Table 5. Habitat area comparisons between 1994, 2003, and 2014 surveys.

Habitat Area Comparisons – 1994, 2003 and 2014				
	% Pool	**% Riffle**	**% Glide**	**% Secondary channel**
RM 64.9 (Goat Creek) to RM 69.2 (Early Winters Creek)				
2014 Survey	14%	50%	34%	3%
1994 Survey	5%	86%	7%	3%
RM 69.2 (Early Winters Creek) to RM 75.1				
2014 Survey	25%	46%	14%	16%
1994 Survey	12%	83%	1%	5%
RM 75.1 (Lost River) to RM 76.5 (Robinson Creek)				
2014 Survey	16%	56%	5%	22%
2003 Survey	29%	62%[1]		10%
1994 Survey	12%	80%	0%	8%
RM 76.5 (Robinson Creek) to RM 80.0 (Trout Creek)				
2014 Survey	5%	89%	1%	5%
2003 Survey	11%	84%[1]		5%
1994 Survey	4%	94%	0%	3%

4.2 STREAMFLOW

Streamflow in the upper Methow River varied considerably between the 1997, 2003, and 2014 surveys. Figure 13 illustrates the variability in stream flows, with 2003 being the lowest water year and 1994 being the highest water year, on average. Heavy rains for the last two days of this 2014 survey raised river levels to par with 1997 flows.

Portions of the upper Methow River from approximately Lost River to Goat Creek flow subsurface during the summer and autumn months of dry precipitation years (USFS 2003). Sometimes dewatering can extend upstream of Lost River towards Robinson Creek on very dry years. This was not observed during IFI's August 2014 habitat survey, which passed Lost River on July 11. However, IFI staff did observe dewatered sections of the channel between RM 70.2 to 71.75 in October 2014.

A 1987 fish survey by the Yakama Indian Nation states that the river went subsurface for 7.6 miles. "No water was seen from the Mazama bridge to a point approximately 200 yards below the confluence with the Lost River. Only a 100 yard stretch below the confluence of Early Winters Creek had a pool of water throughout the 7.6 mile area" (Yakama Indian Nation 1987). The 1994 survey does not indicate the Methow River flowing subsurface.

See the main Reach Assessment report for more discussion of subsurface flow conditions.

[1] Riffles and glides were grouped together in the 2003 survey.

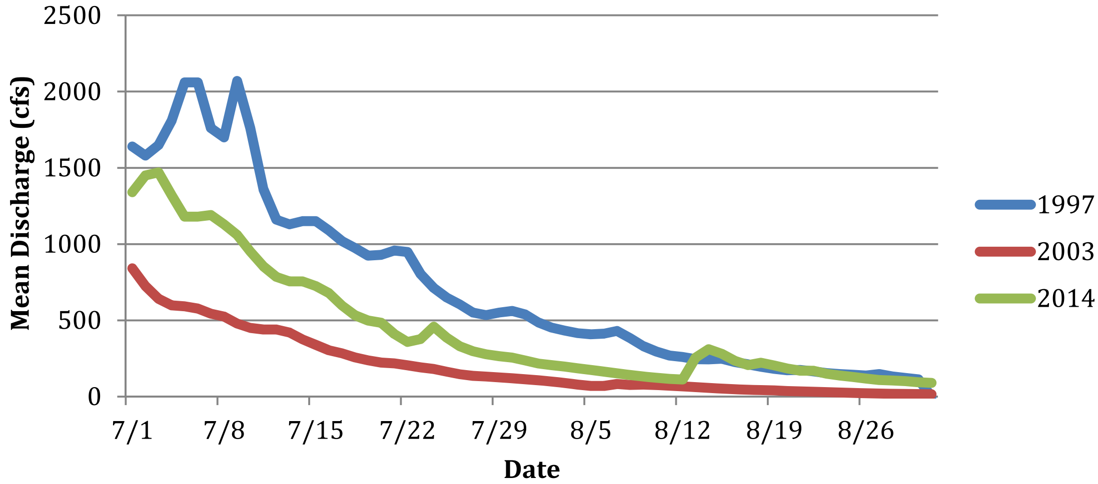


Figure 13. Streamflow data from July 1 - August 30 for 1997, 2003, and 2014 at USGS gauge 12447383 Methow River above Goat Creek Near Mazama.

4.3 SEDIMENT

Comparisons of sediment between the 1994, 2003 and 2014 surveys are very limited. Wolman pebble counts were not performed in the 1994 survey. Lost River to Robinson Creek (Reach 7 in 2014 and Reach 1 in 2003) is the only reach that had pebble counts completed in both the 2003 and 2014 surveys.

A comparison (Figure 14) of results from Wolman pebble counts of this reach between the two surveys indicates relatively equal numbers, and low amounts of fines in both surveys; there is more gravel and slightly less cobble in 2014. For the purposes of this assessment, the key finding from this comparison is that fines (<2mm) have remained relatively low (2% in both 2003 and 2014) – well below the "adequate guidelines" of ≤12% sand/fines (USBR 2012).

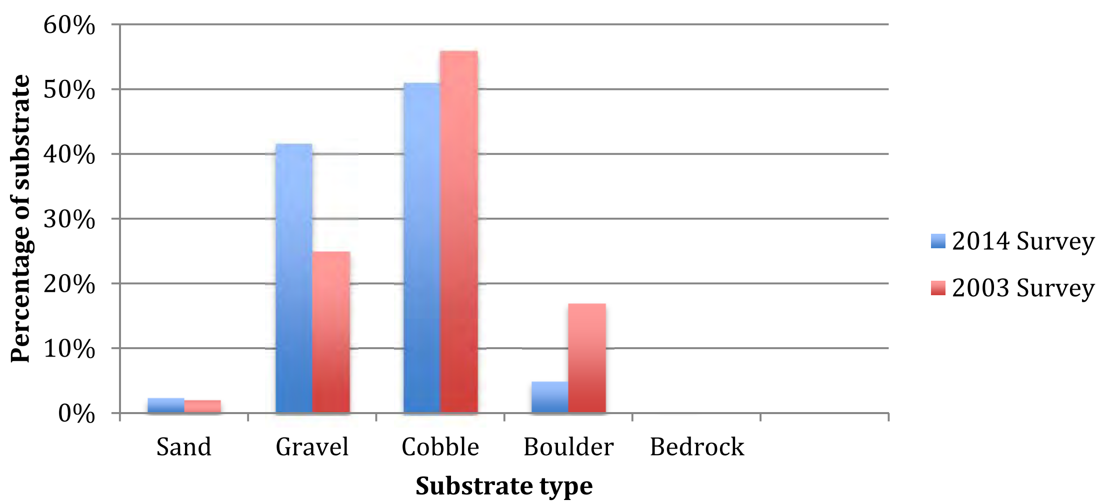


Figure 14. Gravel count comparison for Reach 7, 2003 and 2014 surveys.

4.4 LARGE WOOD

Large wood (LWD) was not counted in side channels in the 1994 survey. Also, neither of the past surveys extends the entire length of the 2014 survey. As a result, only Reaches 7 – 9 from the 2014 survey can be compared with both the 1994 and 2003 surveys. Data is also available for comparing 2014 Reach 3 and 4; and 5 and 6 with 1994 data.

Overall, LWD per mile increased significantly from 1994 – 2014. Table 6 compares LWD per mile in the main channel between the 1994, 2003 and 2014 surveys. Reach 8 and 9 (2014 survey) indicate the greatest recruitment of LWD over time (Figure 16) with small LWD (>20 ft. long and 6-12 in. diam.) increasing from 28.2 pieces per mile (1994), to 36.7 pieces per mile (2003), to 123 pieces per mile in 2014. Large LWD (>35 ft. long and >20 in. diam.) also increased notably in all reaches. LWD counts ranged from 0.5 – 2.7 pieces per mile in Reach 1-4 in 1994. By 2014, this increased to 11.5 – 23.4 pieces per mile.

Increases in LWD can be attributed to several variables. For example, a large majority of the 2014 in-channel wood in Reach 9 is from an avalanche that occurred in May 2014. It is possible that higher wood counts are also a result of the Needle Creek Fire that occurred after the completion of the 2003 survey, burning 21,305 acres, including forest on both sides of the Methow within the final two miles of the survey area. Finally, changes in survey protocol over the years could also be responsible for portions of the massive discrepancies in wood count between 1994 and 2014. The 1994 survey report does not identify techniques used to count wood aside from the size of wood counted and that the wood was in the main channel (not secondary channels).

Table 6. LWD per mile by class size compared between reaches in 1994, 2003 and 2014 surveys. All LWD is in-channel (does not include secondary channels).

LWD per mile – 1994, 2003 and 2014				
	Small (>20 ft. long) (6 - 12 in. diam.)	**Medium** (>35 ft. long) (12 - 20 in. diam.)	**Large** (>35 ft. long) (>20 in. diam.)	**Medium & Large**
RM 64.9 (Goat Creek) to RM 69.2 (Early Winters Creek)				
2014 Survey	64.4	38.6	21.4	60
1994 Survey	38.5	16	0.5	16.5
RM 69.2 (Early Winters Creek) to RM 75.1				
2014 Survey	57.6	33.6	11.5	45.1
1994 Survey	27.2	11	2.7	13.7
RM 75.1 (Lost River) to RM 76.5 (Robinson Creek)				
2014 Survey	51.9	34.4	15.6	50
2003 Survey	62.1	9.9	1.2	11.1
1994 Survey	33.2	17	2.7	19.7
RM 76.5 (Robinson Creek) to RM 80.0 (Trout Creek)				
2014 Survey	123	52.3	23.4	75.7
2003 Survey	36.7	19.4	4.3	23.7
1994 Survey	28.2	8	1.2	9.2

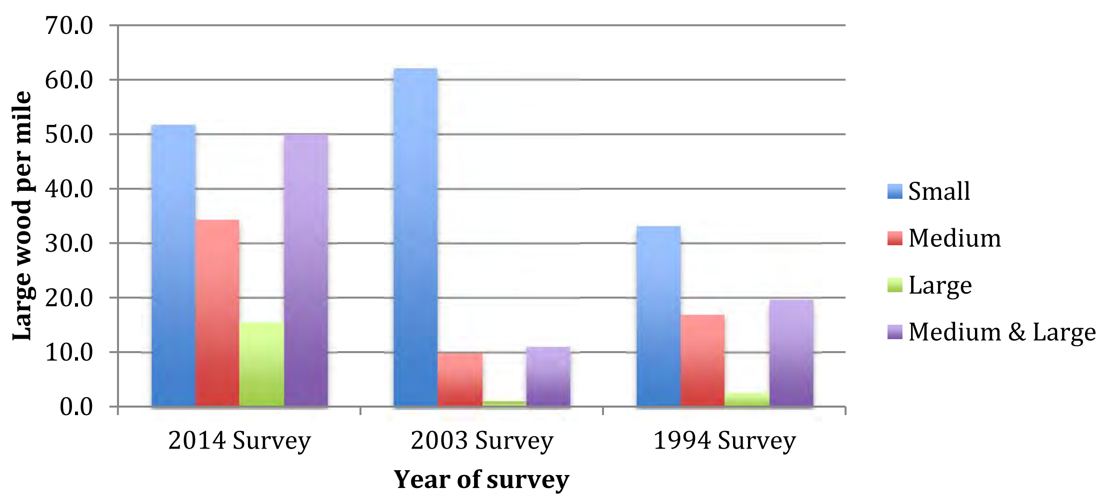


Figure 15. Comparison of LWD per mile from Lost River to Robinson Creek between 1994, 2003 and 2014 surveys.

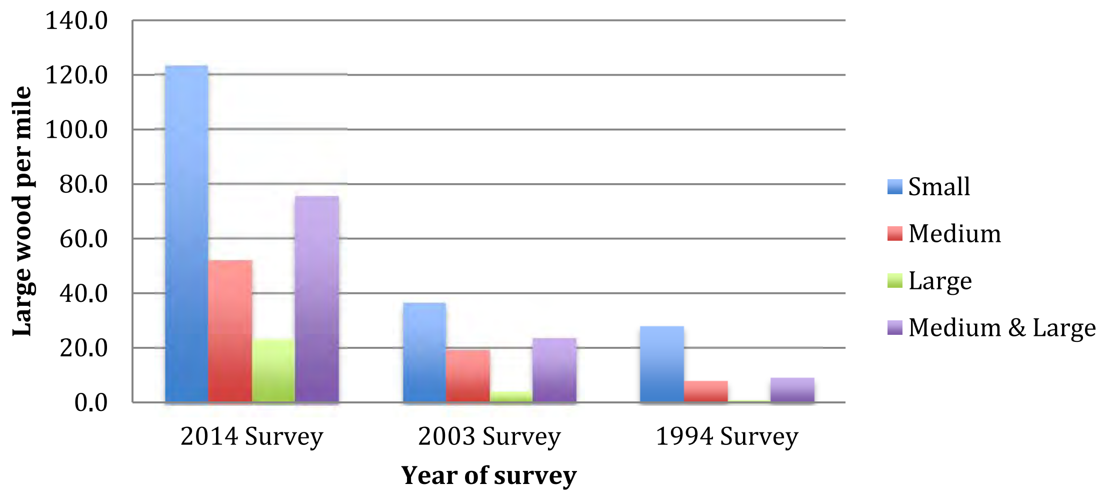


Figure 16. Comparison of LWD per mile in Reaches 8 and 9 (Robinson Creek to Trout Creek) between 1994, 2003 and 2014 surveys.

4.5 POOLS

Differences in protocols between the 1994, 2003, and 2014 surveys make comparing pools challenging and likely inaccurate. A 1996 protocol change allowed for counting plunge pools where the width of the pool was greater than the length. In 1994, all habitat units had to have a length greater than its width. In addition, the 1994 pool residual depth standard was not stated. The 2003 survey protocols were also significantly different from both 1994 and 2014. Most notable is the counting of pools in side channels in 2003. Also, protocol for 2003 followed the Okanogan Forest Plan definition of a "quality" pool, which included counted pools that spanned at least half the channel with a low flow maximum depth of 3 feet, or depth of 1.5 feet, with 40% or greater hiding cover.

While changes in survey protocols make comparisons challenging, a few general trends can be deduced from the data. Figure 7 compares pool habitat between surveys. Across the board, 2003 pools per mile, and pool habitat area are highest in 2003. However, in general, pool % habitat increases from 1994 to 2014. Pools per mile also increase in 3 of 4 reaches, even though there should be *more* pools in 1994 due to counting pools in side channels.

Table 7. Comparison of pools between 1994, 2003, and 2014 surveys. Note that protocols changed significantly between surveys.

Pool Habitat Comparisons – 1994, 2003 and 2014			
	Pools per mile	**Pool % habitat**	**Avg. Residual depth (ft)**
RM 64.9 (Goat Creek) to RM 69.2 (Early Winters Creek)			
2014 Survey	2.8	14%	5.4
1994 Survey	1.1	5%	3.3
RM 69.2 (Early Winters Creek) to RM 75.1			
2014 Survey	8.1	25%	4.3
1994 Survey	3.4	12%	3.5
RM 75.1 (Lost River) to RM 76.5 (Robinson Creek)			
2014 Survey	8.6	16%	3.4
2003 Survey	16.1	29%	2.1
1994 Survey	8.1	12%	2.6
RM 76.5 (Robinson Creek) to RM 80.0 (Trout Creek)			
2014 Survey	2	5%	4.4
2003 Survey	11.4	11.3%	2.1
1994 Survey	5.2	4%	2.7

4.6 WATER TEMPERATURES

Watershed Sciences, Inc. conducted airborne thermal infrared (TIR) imagery remote sensing in 2009 in the Upper Methow basin for the Yakama Tribe Fisheries department. The TIR acquisition was designed to support ongoing habitat assessments in the Basin. Data was collected during ideal weather conditions: warm temperatures, low humidity and clear skies on August 24, 2009. The air temperature in Twisp, WA had a high of 85°F, while flow rates in the Methow River on the day of the survey were below the historic average at all four USGS monitoring gages.

Thermal infrared sensors measure TIR energy emitted at the water's surface. Since TIR wavelengths cannot infiltrate water, the sensor only measured water surface temperature. Thermal infrared data accurately represents bulk water temperatures where the water column is thoroughly mixing, such as riffles. Other types of channel units are only showing the surface layer temperatures.

Watershed Sciences surveyed the Methow River from the mouth to the confluence with Lost River (RM 76.5). The aircraft was flown longitudinally along the stream corridor in order to collect thermal infrared images, which were referenced with time, position and heading information provided by a global positioning system (GPS). After desktop analysis, they found stream temperatures ranged from 12.4°C just below Little Boulder Creek (Rm 65.17) to 19.4°C at the mouth of the Methow River. It was noted that the upper Methow River showed highly variable temperatures, with three large-scale warming and cooling cycles noted. At the top of their survey, Lost River contributed to the first cooling trend, but the mainstem Methow quickly warmed back up moving downstream. Near RM

71.0, the temperatures decreased due to the input of a cool spring contributing groundwater to the channel. Again, the channel warms back up as it moves downstream until RM 65.0 where there is a large secondary channel and spring complex adding cool water to the main channel. After each temperature decrease, the Methow returns to or above the temperature at which it was prior to the cooling inputs. At low flow this section of the Methow is braided and fairly shallow, with a large amount of subsurface influence- either surface water infiltration or hyporheic input and springs.

In this type of alluvial and glacial sediment, streams often lose surface water to subsurface flow and groundwater. When flows are the lowest, which is usually between August-October for the Methow River, the relatively shallow surface water warms quickly in the warm air temperatures and direct sunlight. Further downstream, water will reappear as groundwater discharge. This pattern is evident on the upper Methow River as indicated by the large number of seeps and springs shown in the TIR imagery.

This habitat survey found similar results in July-August, 2014 as Watershed Sciences found in 2009. Eighty-three total units were measured: 11 pools, 22 riffles, 10 glides, 28 side channels/off-channel, and 12 tributaries. Overall, there was a general warming trend moving downstream from the confluence of Trout Creek to Weeman Bridge, with several large-scale cycles of cooling and warming demonstrated. Also similarly to Watershed Sciences results, we found that there were general trends of cooling occurring around RM 70 and 73, both of which quickly rewarmed downstream. Above the confluence with Lost River, the Methow maintains a cooling trend until the upstream extent of our survey reach. Though it is established that stream water temperatures decrease moving upstream, heavy rains and cooler average air temperatures occurring August 12, 2014 through August 14, 2014 may have slightly affected the water temperatures of Reaches 8 and 9. The tributaries measured as part of this survey were generally within a couple degrees of the temperatures measured by Watershed Sciences in 2009, with the exception of Goat Creek.

The temperatures in the mainstem and the off-channel units were highly variable and depended on a number of factors such as time of day, level of flow, and ambient environmental effects. Due to the nature of our survey as compared to Watershed Sciences, we observed water temperature variations influenced by the time of day and ambient environmental conditions. For example, throughout the day, observed water temperatures increased. Early morning temperature measurements were the lowest; the highest temperatures in the study reach were found in a glide, riffle, and secondary channel in the afternoon. In the mainstem channel the temperature of pools observed during the survey increased the most over the course of the day while riffles changed temperature (warmed) the least. Of all channel types measured, tributaries exhibited the least amount of temperature variation during a day, even less than riffles. Though Goat Creek was measured to be fairly warm by Watershed Sciences in 2009, Inter-Fluve staff measured an unusually high temperature for the creek, at 21°C. Human error, as well as localized heating or cooling patches may have caused this outlier. In general however, glides were the mainstem unit that was the warmest overall, while tributaries input the coldest water into the system.

Within the unit types themselves there was a large amount of temperature variability. Side channels were the most variable in temperature. Some of this may be attributed to the groundwater inputs and the different water characteristics between fast-moving secondary channels and slow-moving secondary channels creating different temperature environments. Generally, fast secondary channels (those that had substantial water movement) were cooler than slow secondary channels (those that flowed very slowly or not at all).

5 Stream Habitat Reach Reports

5.1 REACH 1

Location: River mile 61.15 (Weeman Bridge) – 61.7
Total length: 0.55 miles
Survey date: July 17, 2014

Figure 17. Representative view of Reach 1. Only three channel units were recorded in Reach 1; all were fast water. Observations at the one n^{th} unit in Reach 1 identified both the overstory and understory as dominated by cottonwood, also visible in this photo.

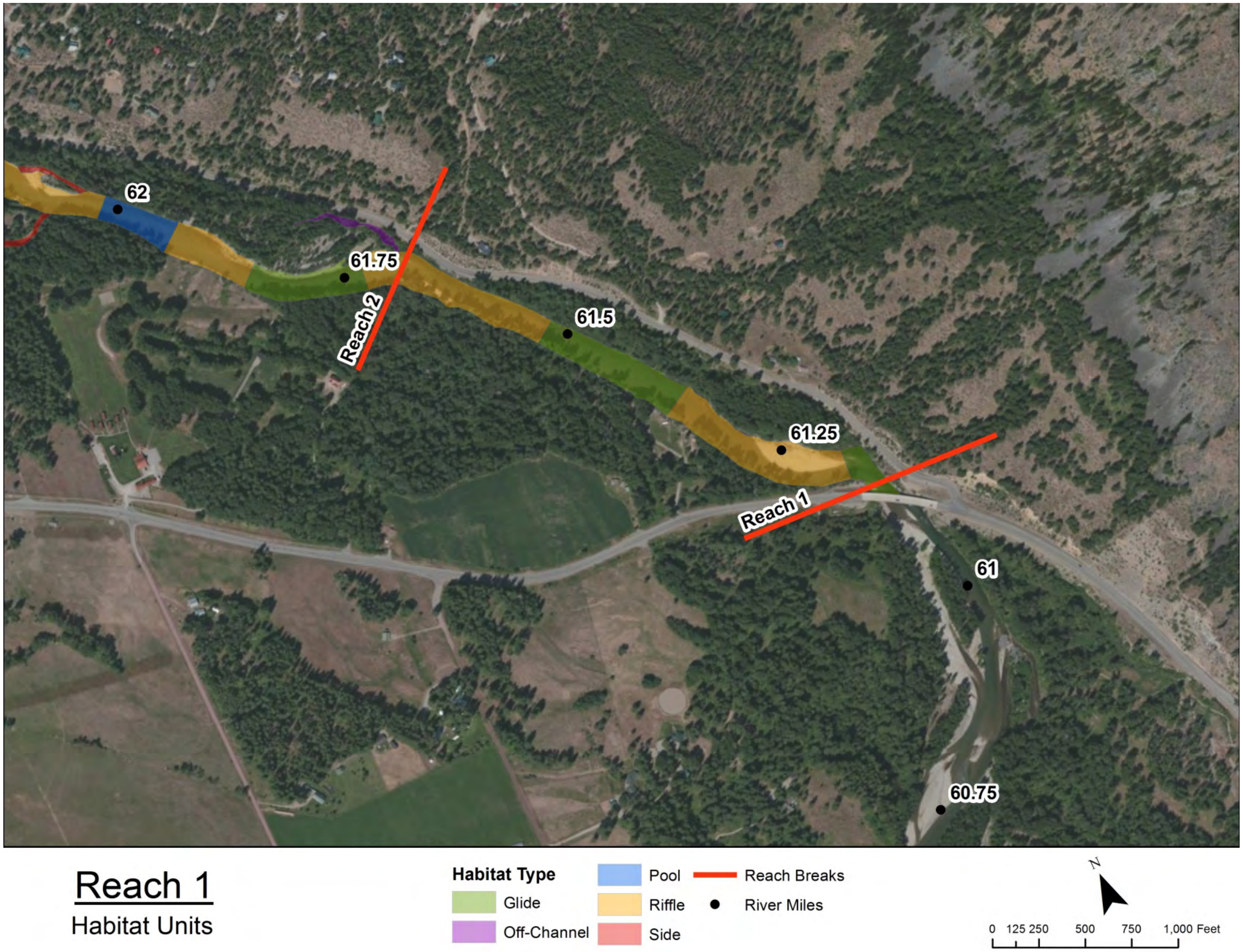


Figure 18. Overview of Upper Methow Reach 1 from RM 61 (Weeman Bridge) – RM 61.7.

5.1.1 Habitat Unit Composition

Reach 1 is the shortest reach with the fewest channel units of all reaches in the study area. Of the three channel units recorded, all were fast water. Over half of the reach was designated as glide (57%), with one riffle accounting for the remaining 43% of the habitat area (Figure 19). No pools or secondary channel habitat were observed. Overall, the reach was fairly deep and fast-moving with an average depth of 3.9 feet and average max depth of 8 feet.

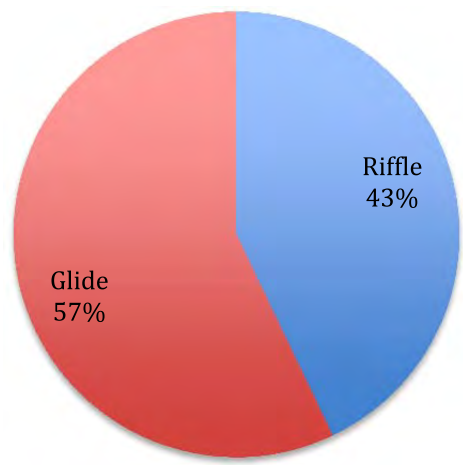


Figure 19. Habitat area composition of Reach 1.

5.1.2 Pools

No pools were observed in Reach 1.

5.1.3 Secondary Channel Habitat

No secondary channels were observed in Reach 1.

5.1.4 Large Woody Material

Large wood quantities in Reach 1 were the lowest of all nine reaches with 9.9 pieces per mile and 2.5 medium/large pieces per mile, compared to the project area average of 125 pieces per mile and 55 medium and large pieces per mile. In total, 4 pieces of large wood were counted. No log jams were observed.

Table 8. Large woody material 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	3	1	0	4
Number of pieces per mile	7.5	2.5	0	9.9
Number of med/lg pieces per mile				2.5
Number of jams per mile				0
Number of jams				0

5.1.5 Substrate & Fine Sediment

Bed substrate was primarily cobble (52%) with 46% gravel and 2% sand. This substrate composition was fairly close to the project average distribution of 48% cobble, 48% gravel, 2% sand, and 2% boulder. Only one pebble count was conducted in Reach 1 because it is much shorter in length than the other reaches.

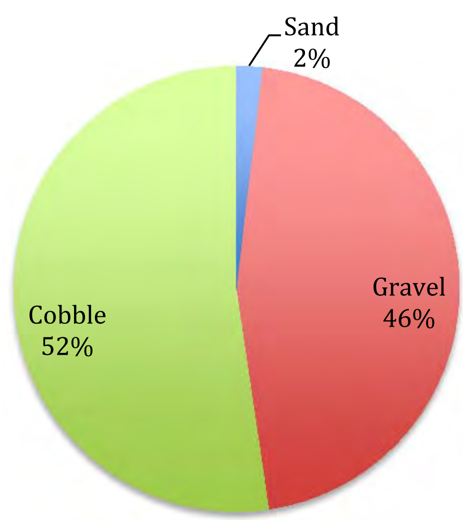
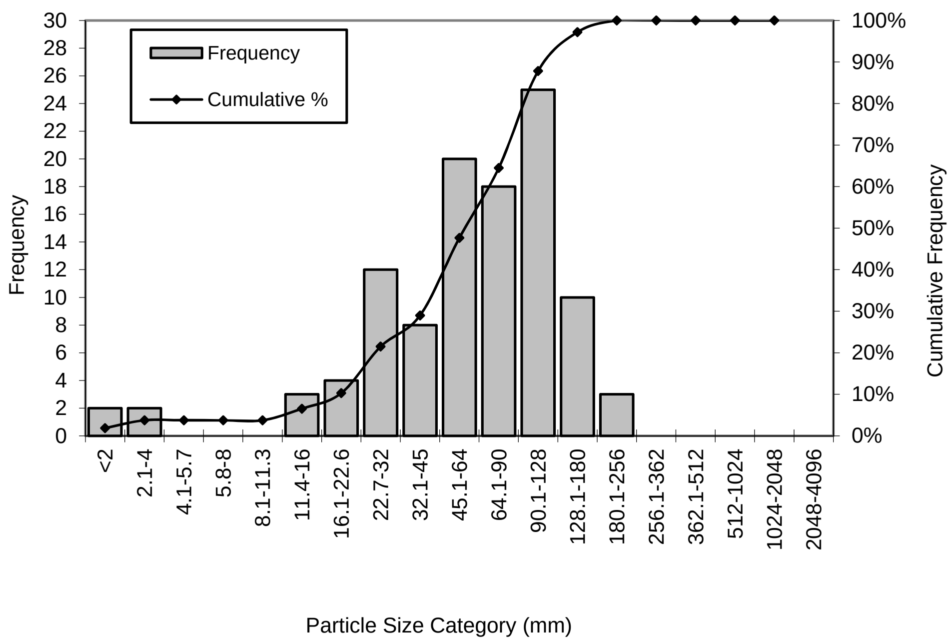


Figure 20. Percent composition of bed substrate based on one pebble count in Reach 1.

Figure 21. Substrate in Reach 1 is largely composed of gravel and cobble (left). Overall, Reach 1 is relatively deep and fast moving (right).



Material	Percent Composition	Size Class	Size percent finer than (mm)
Sand	2%	D5	13
Gravel	46%	D16	22
Cobble	52%	D50	68
Boulder	0%	D84	122
Bedrock	0%	D95	168

Figure 22. Grain size distribution and particle size classes from one pebble count in Reach 1.

5.1.6 Riparian Corridor

With only one n^{th} unit measurement in Reach 1, the riparian corridor observed was with small trees measuring 9 inches – 20.9 inches as the dominant class. Both the overstory and understory was dominated by cottonwoods (100%). Cottonwood was the dominant species observed throughout the study area, accounting for 30% of riparian understory and 42% of the observed riparian overstory (Figure 12).

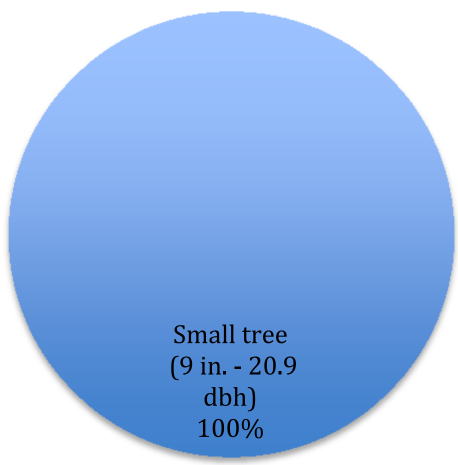


Figure 23. Dominant riparian vegetation identified within 100 feet of the Methow River by ocular estimate.

5.2 REACH 2

Location: River mile 61.7 – 64.8 (Goat Creek)
Total length: 3.1 miles
Survey Date: July 16 - 18, 2014

Figure 24. Representative view of Reach 2. In the background smokes rises from the Carlton Complex Fire – creating a pyrocumulus cloud.

5.2.1 Habitat Unit Composition

Overall, Reach 2 has excellent salmonid habitat. Reach 2 has 46% of the secondary channel habitat identified throughout the entire study area (Figure 5). In total, there is over 2.4 miles of secondary channel (19% of the habitat composition) in Reach 2, including the second longest side channel in the project area (4,800 feet). It is also the longest reach at 3.2 miles. Fast water is the dominant habitat, comprising 76% of the habitat area within the reach (Figure 26). Four pools are present in Reach 2, comprising 5% of the habitat area. Reach 2 also has the second highest wood count of the nine reaches with 398 pieces.

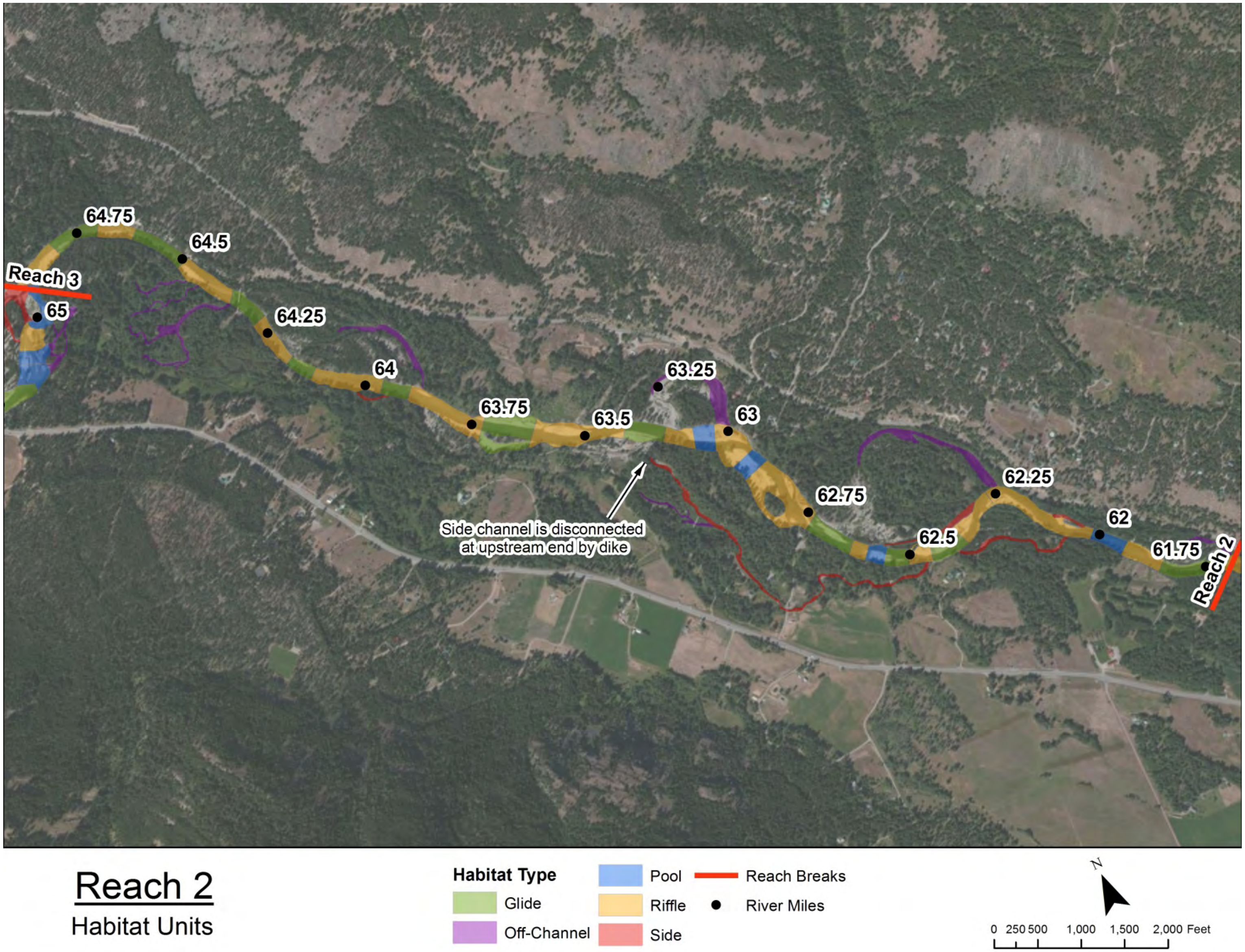


Figure 25. Overview of Upper Methow Reach 2 from RM 61.7 – RM 64.8 (Goat Creek).

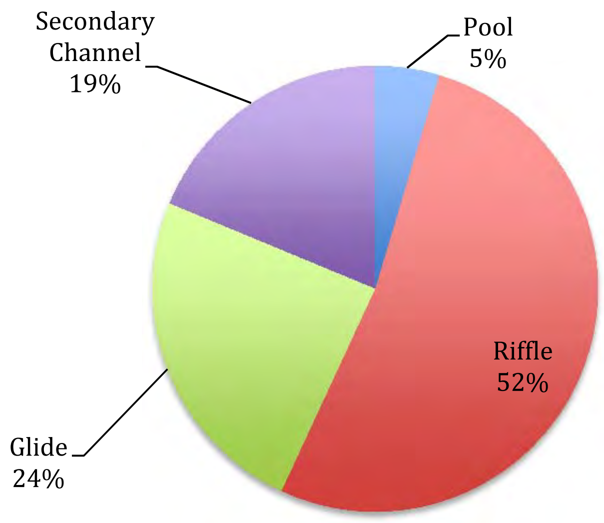


Figure 26. Habitat unit composition for Reach 2.

5.2.2 Pools

Four pools were identified in Reach 2, equating to a pool frequency of 1.3 pools per mile (compared to a study average of 3.6 pools per mile). Residual depths of the four pools were equally distributed in depths, ranging from <3 feet to between 9 and 12 feet (Figure 27). Reach 2 has a pool frequency of 49 channel widths per pool (verses an average of 31.8 for all reaches combined). Nine pieces of LWD were counted in the four pools.

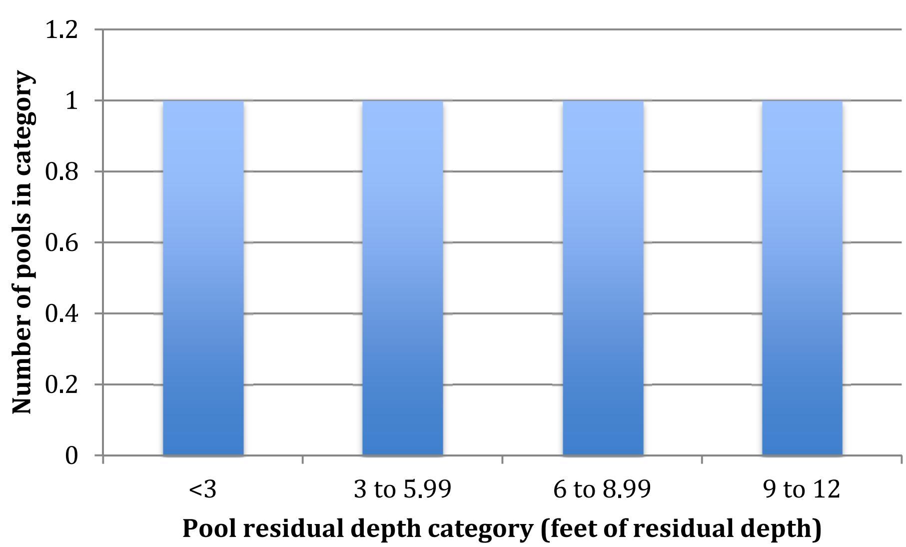


Figure 27. Pool residual depth and total pool count in Reach 2.

5.2.3 Secondary Channel Habitat

Reach 2 has the highest ratio of secondary channel habitat in the project area (41%), including the second longest side channel identified (SIDE4 – 4,800 feet) (Figure 5). The feature is disconnected from the main channel at the upstream end by a 10-foot-tall levee that crosses its path. Because it was historically connected at both its upstream and downstream ends, we considered it a “disconnected side channel.” Reach 6 also has disconnected side channel habitat.

Of the 9 secondary channels in Reach 2, 31% are off-channel habitat and 69% are side channel habitat. Three off-channels between RM 64.3 – 64.5 (SIDE7, SIDE8, and SIDE9) maintained hyporheic flows and high quality salmon habitat, including multiple redds that have been identified.

Three open water floodplain wetland units were identified in Reach 2 (Table 10) that are, by definition, secondary channel habitat. Together, they totaled 5.8 acres. Although this type of habitat is important because it contains food sources (invertebrates), LWD, refuge, and rearing habitat for fish and wildlife species, they were not included in the secondary channel metrics for the reach and entire study area because they were better classified as marshes according to the survey protocol. No other open water floodplain wetland was identified in the project area.

Table 9. Three off-channels entered the Methow River between River Mile 64.3 - 64.5. Photo below is Side 9F.

Table 10. Secondary channels identified in Reach 2.

Location	Length (ft)	Dominant unit type	Wood count	Off-channel (OC) or Side Channel (SC)
SIDE1S	1,450	Slow water	20	SC
SIDE2S	375	Slow water	17	SC
SIDE3F	1,170	Fast water	30	SC
SIDE4S[2]	4,800	Slow water	25	SC
SIDE5S	1,500	Slow water	16	OC
SIDE6S	350	Slow water	3	SC
SIDE7F	2,000	Fast water	13	OC
SIDE8F	350	Fast water	8	OC
SIDE9F	700	Fast water	16	OC
M1[3]	400	Slow water	0	OC
M2[3]	500	Slow water	0	OC
M3[3]	350	Slow water	0	OC
Total	12,695		148	

5.2.4 Large Woody Material

Reach 2 had 126.1 pieces of large wood per mile (compared to the project area average of 124.7 pieces per mile). The medium/large wood count was also higher than the project area average with 64.7 pieces per mile (compared to the project area average of 55 pieces per mile) (Table 11). Ten log jams were identified in Reach 2. Together they comprised 213 pieces of LWD, or 54% of the large woody debris within the reach.

[2] Side 4S is a "disconnected" side channel because the downstream end of the channel is blocked by a 10-foot-tall levee.

[3] *M1, M2, and M3 are all open channel floodplain wetland habitat. They were not included in the overall secondary channel calculations.*

Table 11. Large woody material 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	194	128	76	398
Number of pieces per mile	61.5	40.6	24.1	126.1
Number of med/lg pieces per mile				64.7
Number of jams per mile				3.2
Number of jams				10

5.2.5 Substrate & Fine Sediment

The results from two pebble counts in Reach 2 indicate a substrate composed of 51% cobble and 49% gravel. Reach 2 pebble counts are indicative of the project area average of 48% cobble, 48% gravel, 2% boulder, and 2% sand (Figure 29 and Figure 31).

Figure 28. Reach 2 pebble counts indicate a bed substrate of almost equal amount cobble and gravel, as well as a slightly higher than average count of LWD. The image above taken around RM 62.0 reflects these measurements.

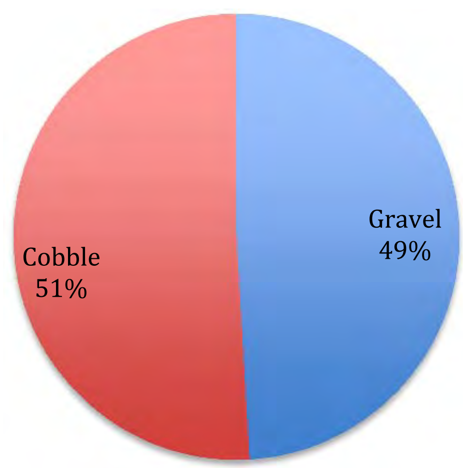
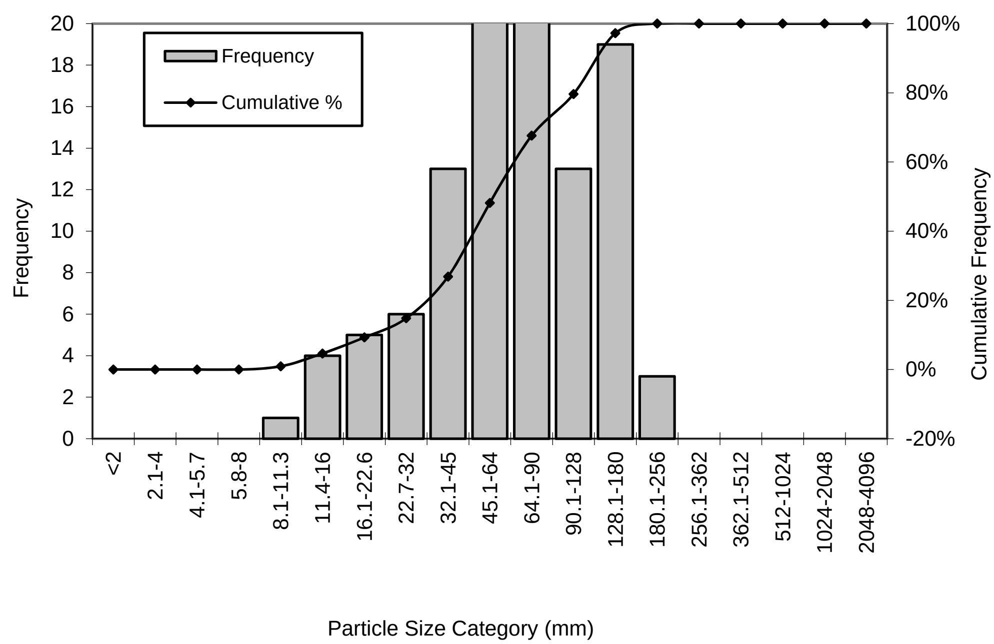
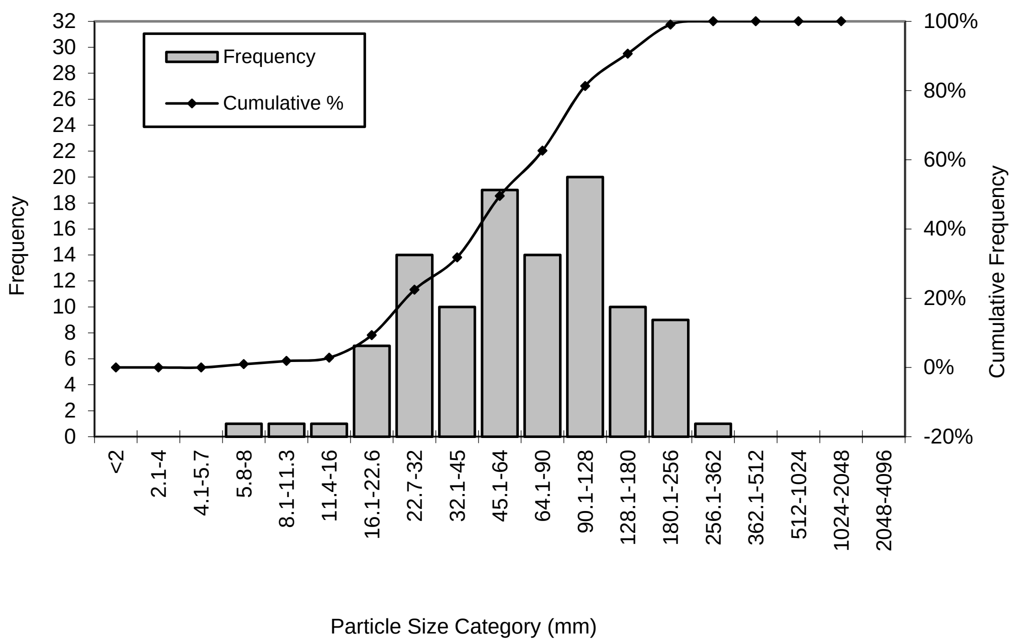


Figure 29. Percent composition of bed substrate based on two pebble counts in Reach 2.



Material	Percent Composition	Size Class	Size percent finer than (mm)
Sand	0%	D5	17
Gravel	48%	D16	33
Cobble	52%	D50	66
Boulder	0%	D84	141
Bedrock	0%	D95	173
		* Assumed linear interpolation	

Figure 30. Grain size distribution and particle size classes from pebble count 1 in Reach 2.



Material	Percent Composition	Size Class	Size percent finer than (mm)
Sand	0%	D5	18
Gravel	50%	D16	27
Cobble	50%	D50	65
Boulder	1%	D84	143
Bedrock	0%	D95	219
		* Assumed linear interpolation	

Figure 31. Grain size distribution and particle size classes from pebble count 2 in Reach 2.

5.2.6 Riparian Corridor

Six n^{th} unit measurements were performed in Reach 2. All identified small trees (9.0 – 21.9 in. diam.) as being the dominant riparian vegetation within 100 feet of the river (Figure 32). The overstory was dominated by cottonwood with some ponderosa (Figure 11). The understory was composed of dogwood, willow, and cottonwood (Figure 12).

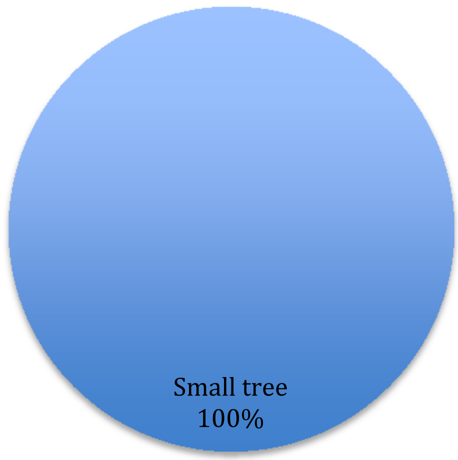


Figure 32. Small trees were the dominant riparian vegetation (100%) identified within 100 feet of the Methow River based on six ocular estimates.

5.3 REACH 3

Location: River mile 64.8 (Goat Creek) – 66.1
Total length: 1.3 miles
Survey date: July 19, 2014

Figure 33. Representative image of Reach 3, which had some of the highest wood counts and a higher than average pools per mile ratio.

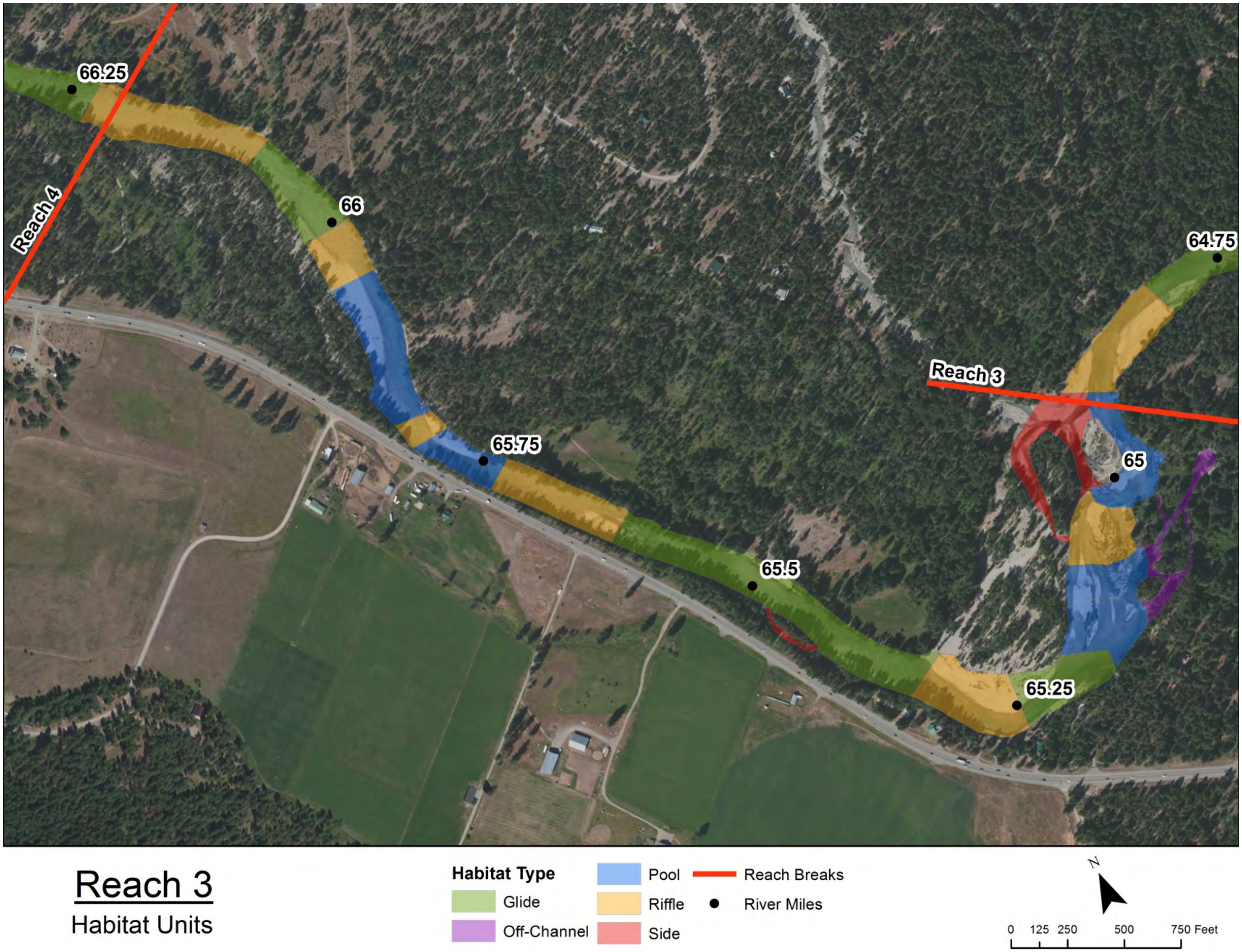


Figure 34. Overview of Upper Methow Reach 3 from RM 64.8 (Goat Creek) – RM 66.1.

5.3.1 Habitat Unit Composition

Reach 3 habitat composition was well distributed between glides, pools, and riffles with a majority identified as glide habitat (43%). Only 2% was secondary channel habitat (Figure 35).

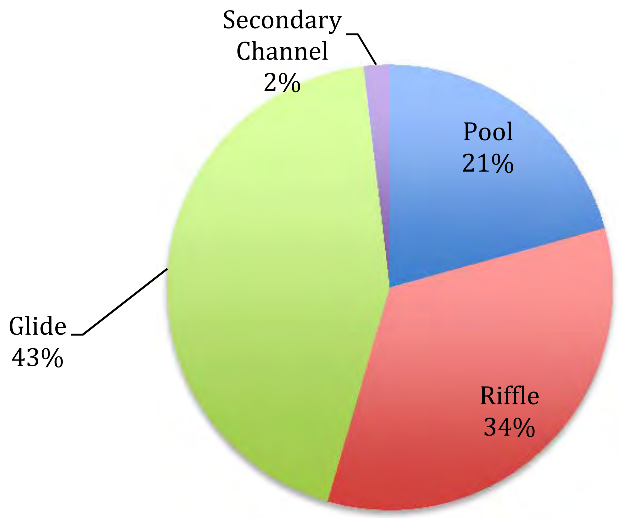


Figure 35. Habitat composition for Reach 3.

5.3.2 Pools

Reach three has a pool frequency of 5.5 pools per mile compared to average of 3.6 pools per mile throughout the project area. Mean pool spacing for the reach is 19.7 channel widths per pool, the second lowest in the project area, which averages 31.8 channel widths per pool. A total of seven pools were recorded. Figure 36 illustrates the residual depth of the pools, which are the deepest in the project area, averaging 5.8 feet of residual depth.

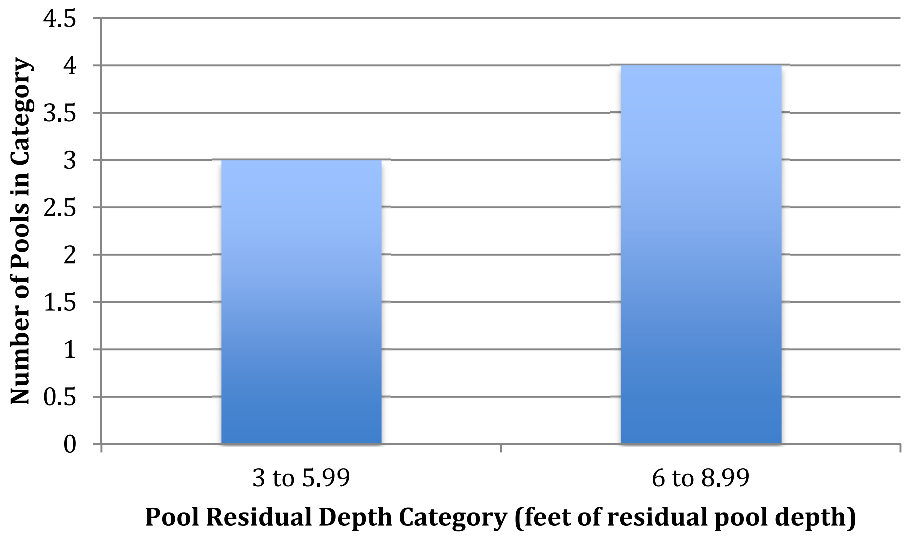


Figure 36. Reach 3 residual pool depth and count of total pools in the reach.

Figure 37. Reach 3 pools are deep, averaging a residual depth of 5.8 feet. Photo above of a pool a RM 65.1 and log jam on river left (right side of photo).

5.3.3 Secondary Channel Habitat

Secondary channel habitat in Reach 3 accounted for 1% of the total project area's secondary channel habitat. A total of four secondary channels were recorded, totaling 2,400 feet in length (Table 12). Three were identified as side channels, meaning they have an inlet and outlet, verses off-channels, which maintain only an inlet or an outlet.

Table 12. Secondary channel habitat in Reach 3.

Location	Length (ft)	Dominant unit type	Wood count	Off-channel (OC) or side channel (SC)
SIDE10F	300	Fast water	0	SC
SIDE11F	450	Fast water	2	SC
SIDE12F	1500	Fast water	0	OC
SIDE13S	150	Slow water	1	SC
Total	2,400		3	

5.3.4 Large Woody Material

Reach 3 had had a total of 190 pieces of LWD, averaging 149 pieces per mile (compared to an average of 124.7 pieces per mile in the project area). Large and medium wood averaged 76.3 pieces per mile, almost 50% higher than the project area average of 55 pieces per mile. Four log jams were counted, averaging 3.1 jams per mile (Table 13).

Table 13. Large woody debris 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	92	63	35	190
Number of pieces per mile	71.6	49.1	27.3	148.0
Number of med/lg pieces per mile				76.3
Number of jams per mile				3.1
Number of jams				4.0

5.3.5 Substrate & Fine Sediment

Reach 3 pebble counts identified cobble and gravel as being nearly equal with 48% cobble, and 51% gravel. Additionally, boulders accounted for 1% of the pebble count (Figure 38). This distribution is similar to the project area average of 48% gravel, 48% cobble, and 2% of both secondary channel and boulder.

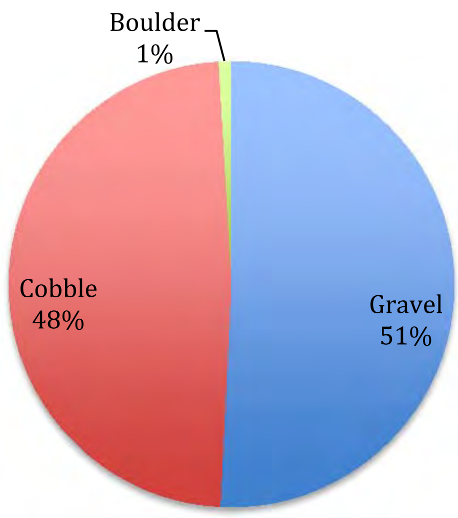
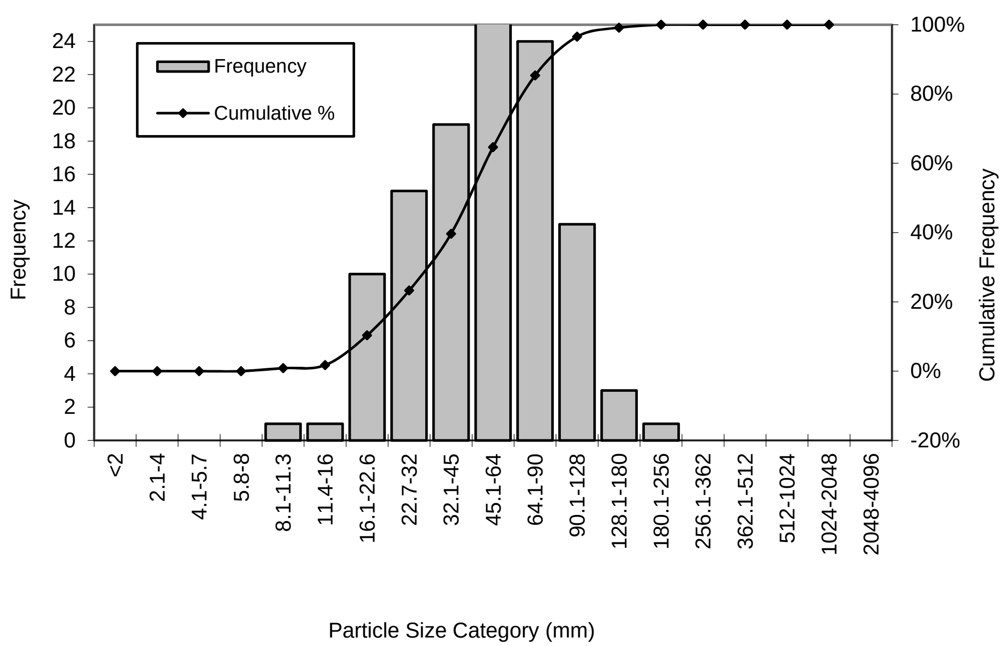
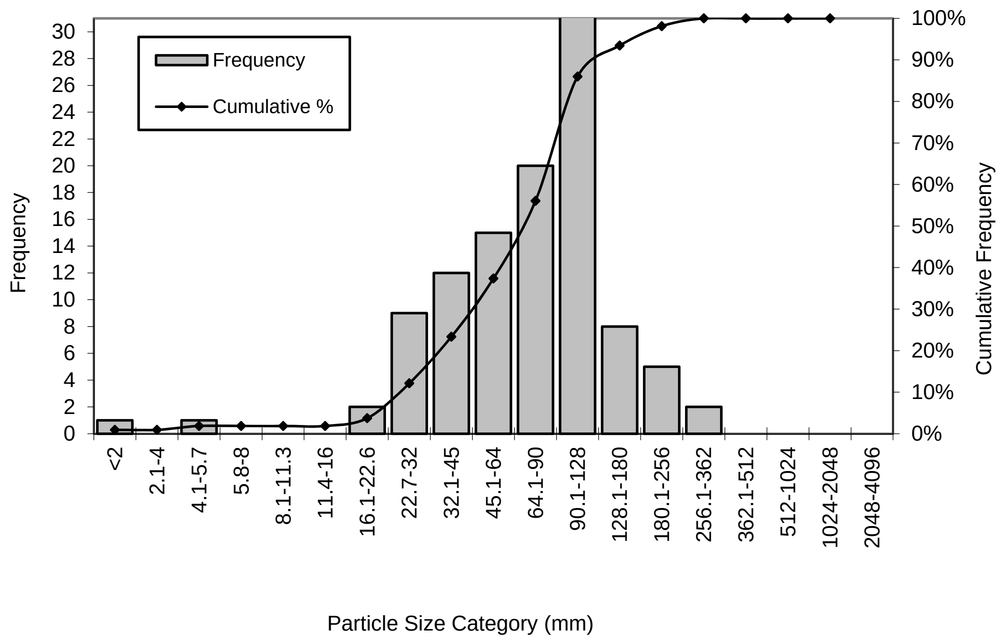


Figure 38. Percent composition of bed substrate based on two pebble counts in Reach 3.



Material	Percent Composition	Size Class	Size percent finer than (mm)
Sand	0%	D5	19
Gravel	65%	D16	27
Cobble	35%	D50	53
Boulder	0%	D84	88
Bedrock	0%	D95	123
		* Assumed linear interpolation	

Figure 39. Grain size distribution and particle size classes from pebble count 1 in Reach 3.



Material	Percent Composition	Size Class	Size percent finer than (mm)
Sand	1%	D5	24
Gravel	36%	D16	36
Cobble	61%	D50	82
Boulder	2%	D84	125
Bedrock	0%	D95	205
		* Assumed linear interpolation	

Figure 40. Grain size distribution and particle size classes from pebble count 2 in Reach 3.

5.3.6 Riparian Corridor

Reach 3 is overall a young riparian corridor composed mainly of small trees, with some grassland/forb (25%). A total of 4 nth unit measurements were measured. Ponderosa was the primary overstory species (75%), with 25% cottonwood. The understory was split between cottonwood (50%) and grassland/forbs (50%) (Figure 41).

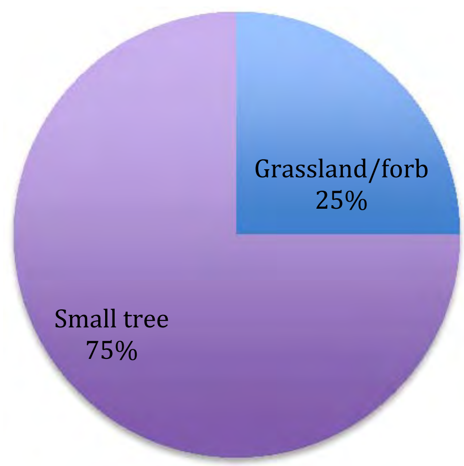


Figure 41. Dominant riparian vegetation identified within 100 feet of river by ocular estimate.

5.4 REACH 4

Location: River mile 66.1 – 69.2 (Early Winters Creek
Total length: 3.1 miles
Survey date: July 20, 2014

Figure 42. Representative view of Reach 4.

Figure 43. Overview of Upper Methow Reach 4 from RM 66.1 – RM 69.2 (Early Winters Creek).

5.4.1 Habitat Unit Composition

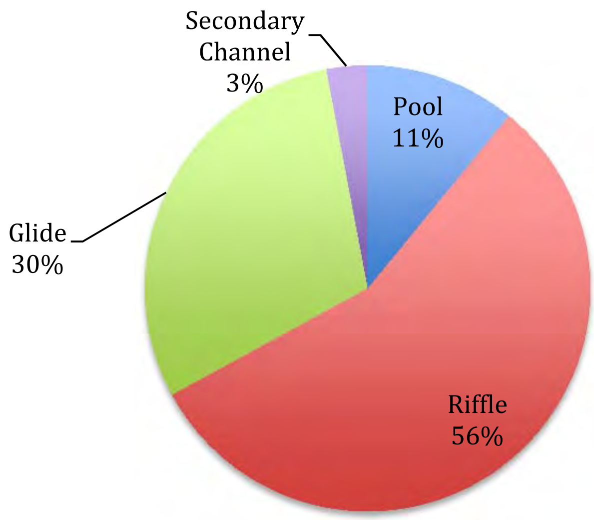


Figure 44. Habitat unit composition for Reach 4.

Reach 4 is developed with roads, houses, and levees constraining the Methow on both sides, resulting in fast-water habitat composed of 56% riffles, 30% glides, and 11% pools. Only 3% of the habitat area is secondary channels. Reach 4 also has relatively little large wood with 54 pieces per mile aside from a large jam (JAM15) at RM 66.9. This long-standing log jam maintains high-quality salmon habitat. Signs on a trail next to the log jam identify it as the "log jam point fish refuge."

5.4.2 Pools

Five pools were identified in Reach 4 with a rate of 1.7 pools per mile compared to the project area average of 3.6 pools per mile (Figure 45). This is the second lowest rate among the nine reaches. The average residual pool depth was 4.9 feet and mean pool spacing was 44.9 channel widths per pool. Only 5 pieces of LWD were counted in the five pools; neither of the two log jams present in Reach 4 were located in pools.

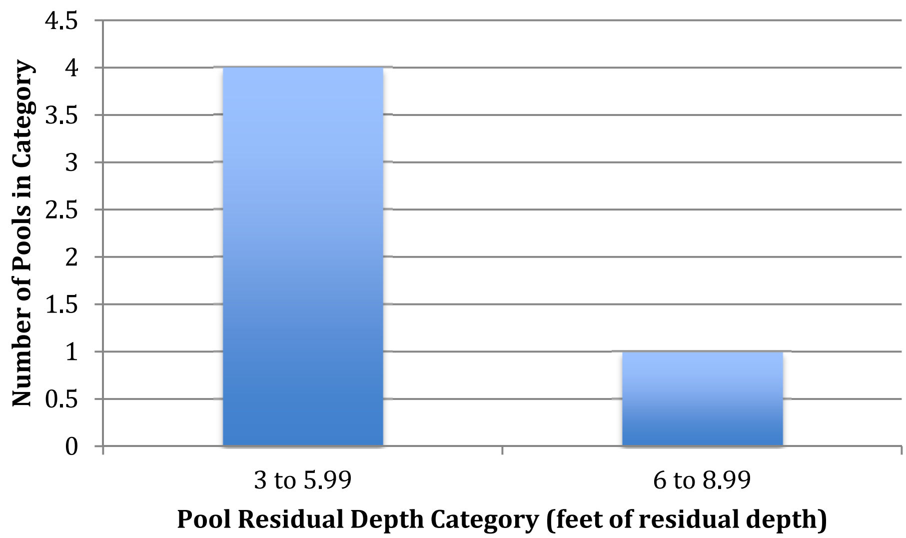


Figure 45. Reach 4 residual pool depth and count of total pools in the reach.

5.4.3 Secondary Channel Habitat

Four secondary channels were identified in Reach 4 including three side channels and one off-channel (Table 14). Together, they represent 4% of the secondary channel habitat area within the project area. Half of the secondary channels were slow water; half fast water. A total of 14 pieces of LWD were in the four secondary channels.

For this assessment, we consider "side-channels" as secondary channels that are, or would be, naturally connected to the mainstem flow at their upstream and downstream ends at average annual flow; this definition also includes artificially disconnected side channels. We consider "off-channels" to be all other types of secondary channels including backwater channels/alcoves, groundwater-fed channels, wall-base channels, abandoned oxbows, and other types of floodplain channels and open-water floodplain wetlands.

Table 14. Secondary channel habitat in Reach 4.

Location	Length (ft)	Dominant unit type	Wood count	Off-channel (OC) or Side Channel (SC)
SIDE14F	375	Fast water	2	SC
SIDE15F	550	Fast water	2	SC
SIDE16	1260	Slow water	10	OC
SIDE17S	300	Slow water	0	SC
Total	2,485		14	

5.4.4 Large Woody Material

Reach four had a total of 362 pieces of LWD, averaging 121.5 pieces per mile, compared to the project area average of 124.7 pieces per mile. Large/medium wood totaled 169 pieces and 56.7 pieces per mile – nearly average for the project area average of 55 pieces per mile (Table 15). A total of 3 jams were identified that together held 303 pieces of LWD or 83% of the LWD within the reach.

Table 15. Large woody debris 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	193	110	59	362
Number of pieces per mile	64.8	36.9	19.8	121.5
Number of med/lg pieces per mile				56.7
Number of jams per mile				1
Number of jams				3

Figure 46. Jam 17 in Reach 4 from the bridge on Lost River Road near the town of Mazama. The jam was estimated to have 100 small, 70 medium, and 30 large pieces of LWD.

5.4.5 Substrate & Fine Sediment

Two pebble counts were performed within Reach 4 at glide-riffle transition points. The dominant substrate type observed was cobble (53%) with additional 39% gravel, 5% sand, and 4% boulder. No bedrock was observed. This was the lowest gravel count observed within the project area. The pebble count and size class data are depicted in Figure 47 and Figure 48.

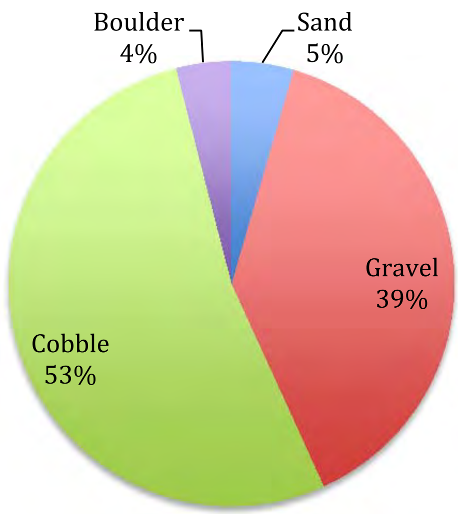
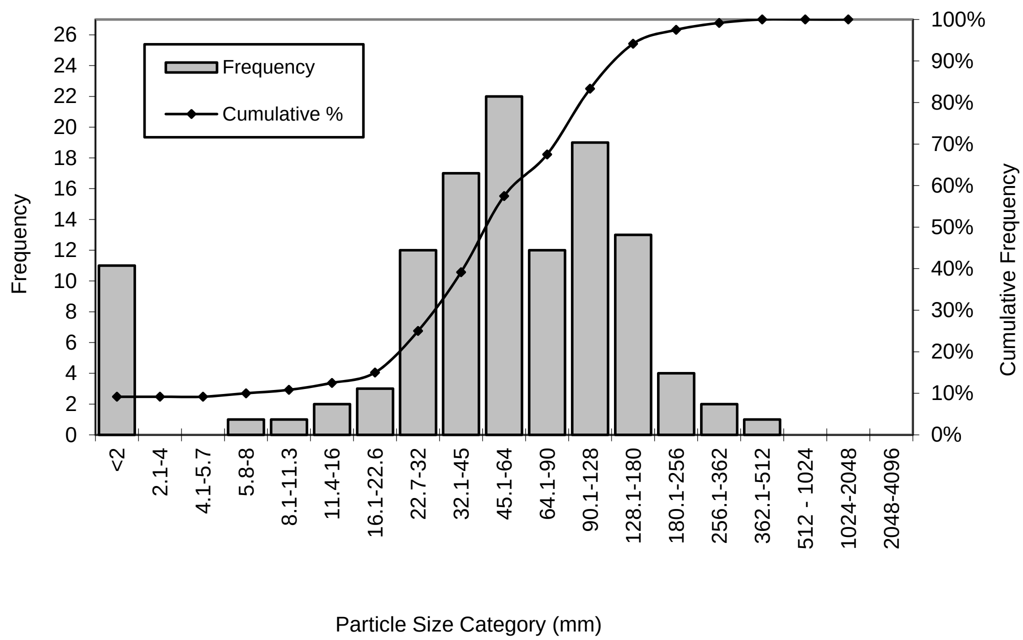
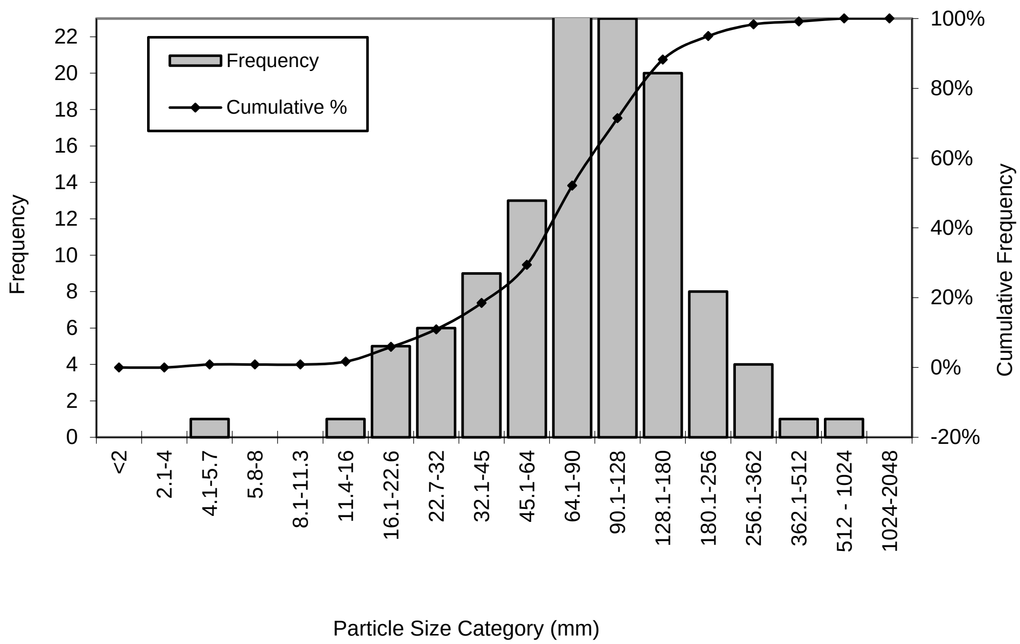


Figure 47. Percent composition of bed substrate based on two pebble counts in Reach 4.



Material	Percent Composition	Size Class	Size percent finer than (mm)
Sand	9%	D5	1
Gravel	48%	D16	24
Cobble	40%	D50	56
Boulder	3%	D84	131
Bedrock	0%	D95	199
		* Assumed linear interpolation	



Material	Percent Composition	Size Class	Size percent finer than (mm)
Sand	0%	D5	15
Gravel	29%	D16	28
Cobble	66%	D50	88
Boulder	5%	D84	167
Bedrock	0%	D95	257
		* Assumed linear interpolation	

Figure 48. Grain size distribution and particle size classes from two pebble counts performed at glide-riffle transition points in Reach 4.

5.4.6 Riparian Corridor

Small trees were the dominant riparian vegetation observed at seven n^{th} units within Reach 4 (Figure 49). Unlike most other reaches in the project area that were dominated by cottonwood, the Reach 4 overstory was primarily ponderosa pine with some cedar. The understory was composed of cottonwood with additional units of small shrubs and dogwood (Figure 11).

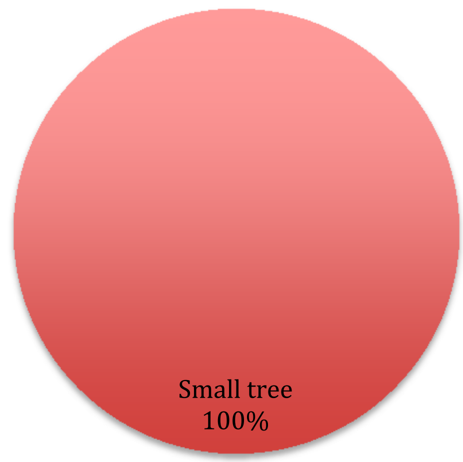


Figure 49. Dominant riparian vegetation identified within 100 feet of river by ocular estimate in Reach 4.

5.5 REACH 5

Location: River mile 69.2 (Early Winters Creek) – 71.3
Total length: 2.1 miles
Survey date: July 15, 2014

Figure 50. The first half of Reach 5 is mostly fast water with few pools, secondary channels or log jams (above photo left). The second half of Reach 5 contains seven log jams, high quality secondary channel habitat, and a high density of pools, (above photo right).

5.5.1 Habitat Unit Composition

Reach 5 is a 2.1-mile reach. The first mile of the reach contains mostly fast water with few pools, log jams, and secondary habitat. Habitat in the second mile is excellent with seven log jams, high-quality off-channel habitat, and a high density of pools, many of which are back-to-back. The composition of Reach 5 habitat is distributed relatively equally among the four habitat types with the lowest amount of fast water within the project area (57%), and ties with Reach 7 for the most secondary channel habitat (22%)(Figure 51).

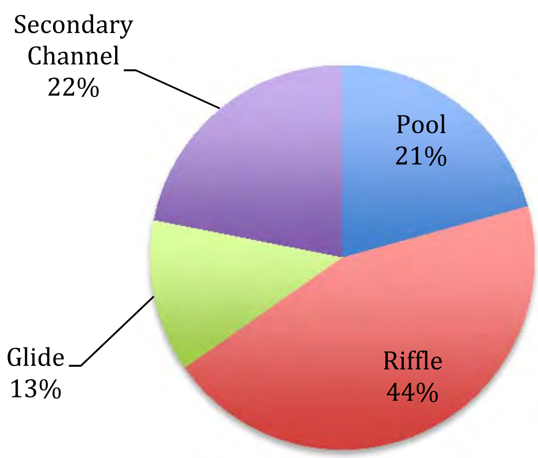


Figure 51. Habitat unit composition for Reach 5.

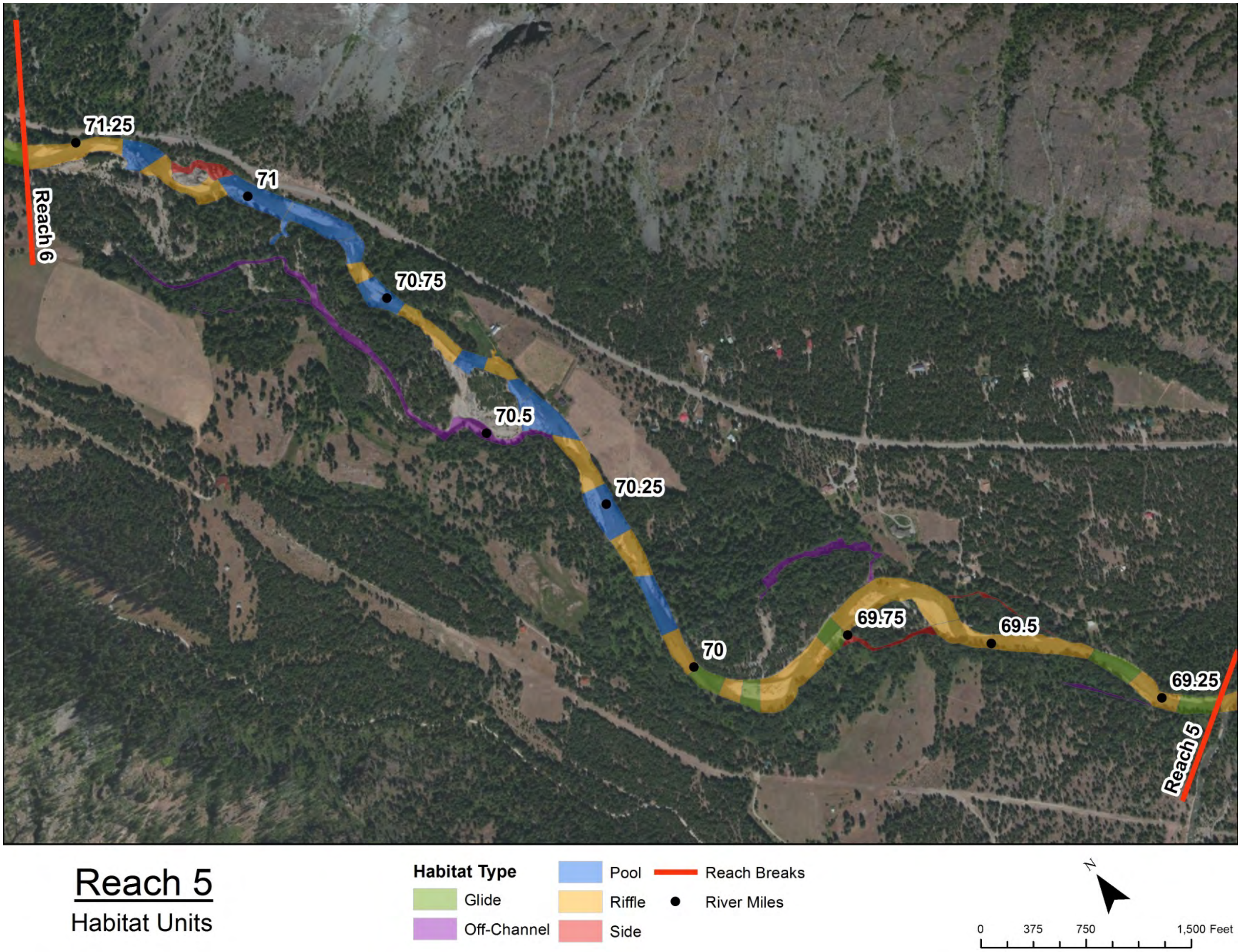


Figure 52. Overview of Upper Methow Reach 5 from RM 69.2 (Early Winters Creek) – RM 71.3.

5.5.2 Pools

Reach 5 contains 11 pools, averaging 5.3 pools per mile (compared to a project area average of 3.6 pools per mile (Figure 53). The average residual depth is 4.5 feet. Mean pool spacing within the reach is 23.3 channel widths per pool. Six of the 11 pools are back-to-back, meaning there was two consecutive and distinct pool units

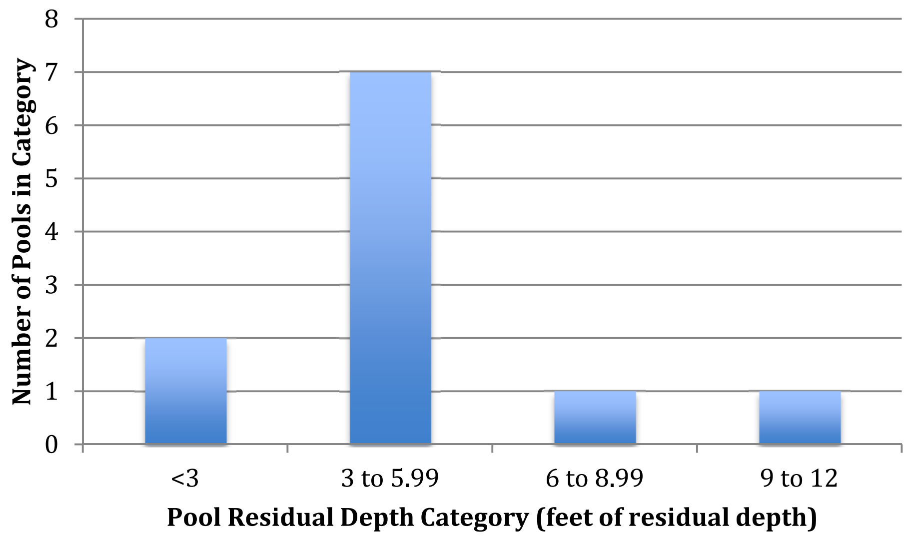


Figure 53. Reach 5 residual pool depth and count of total pools in the reach.

Figure 54.. A 9-foot deep pool and log jams at RM 70.8.

5.5.3 Secondary Channel Habitat

A total of seven secondary channels were identified in Reach 5, including 3 side channels and 4 off-channels. Together, they comprised 20% of the total secondary channel habitat within the project area. A majority of the secondary channel habitat (89%) is hyporheic flow off-channel habitat located between RM 70.4 – 71.2. Water temperatures in this set of secondary channels ranges from 10 º – 12 º Celsius, versus 14º – 15 º Celsius for the main channel.

For this assessment, we consider "side-channels" as secondary channels that are, or would be, naturally connected to the mainstem flow at their upstream and downstream ends at average annual flow; this definition also includes artificially disconnected side channels. We consider "off-channels" to be all other types of secondary channels including backwater channels/alcoves, groundwater-fed channels, wall-base channels, abandoned oxbows, and other types of floodplain channels and open-water floodplain wetlands.

Table 16. Secondary channel habitat in Reach 5.

Location	Length (ft)	Dominant unit type	Wood count	Off-channel (OC) or side channel (SC)
SIDE18S	610	Slow water	0	OC
SIDE19	870	Slow water	10	SC
SIDE20S	720	Slow water	23	SC
SIDE21S	1500	Slow water	11	OC
SIDE22S	3800	Slow water	26	OC
SIDE23S	1050	Slow water	33	OC
SIDE24S	425	Slow water	19	SC
Total	8,975		122	

5.5.4 Large Woody Material

Large woody debris averaged 155.6 pieces per mile compared to a project area average of 124.7 pieces per mile. Medium/large wood averaged 62.5 pieces per mile, also just above the project area average of 55 pieces per mile. In total, 321 pieces were counted, which includes 9 jams (Table 17). Seven of the nine jams were located in the second half of the reach.

Table 17. Large woody debris 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	192	99	30	321
Number of pieces per mile	93.0	48.0	14.5	155.6
Number of med/lg pieces per mile				62.5
Number of jams per mile				4.4
Number of jams				9

5.5.5 Substrate & Fine Sediment

Reach 5 substrate was primarily gravel (61%) with 33% cobble, 5% sand, and 1% boulder. A total of three pebble counts were performed throughout the project reach.

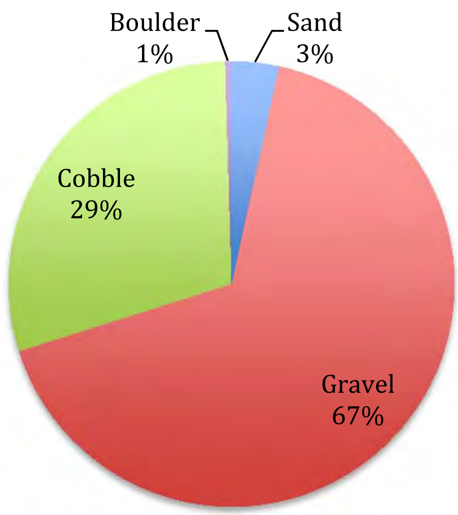
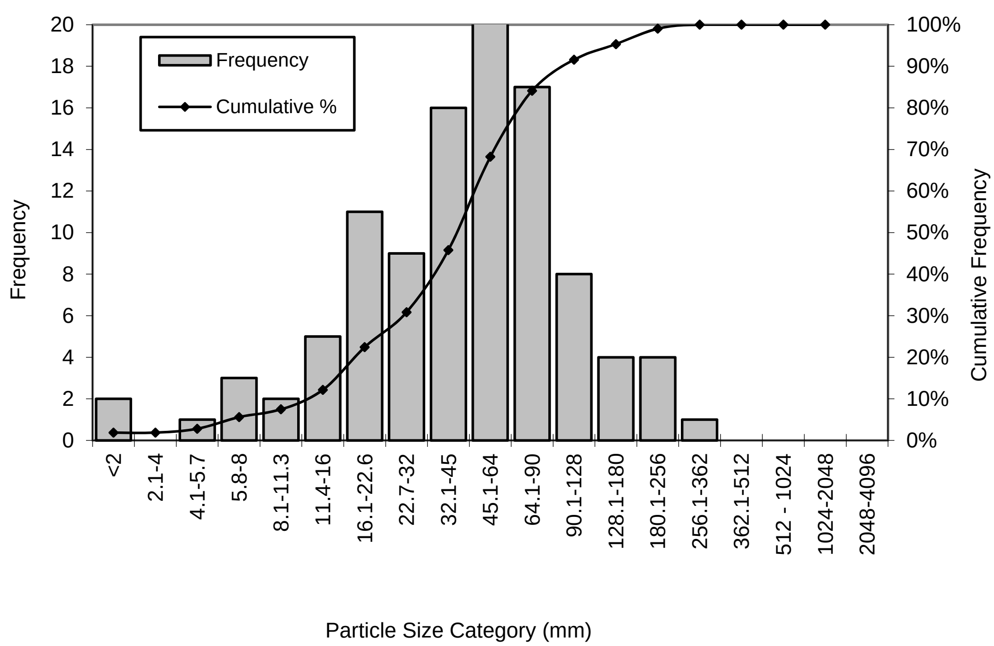
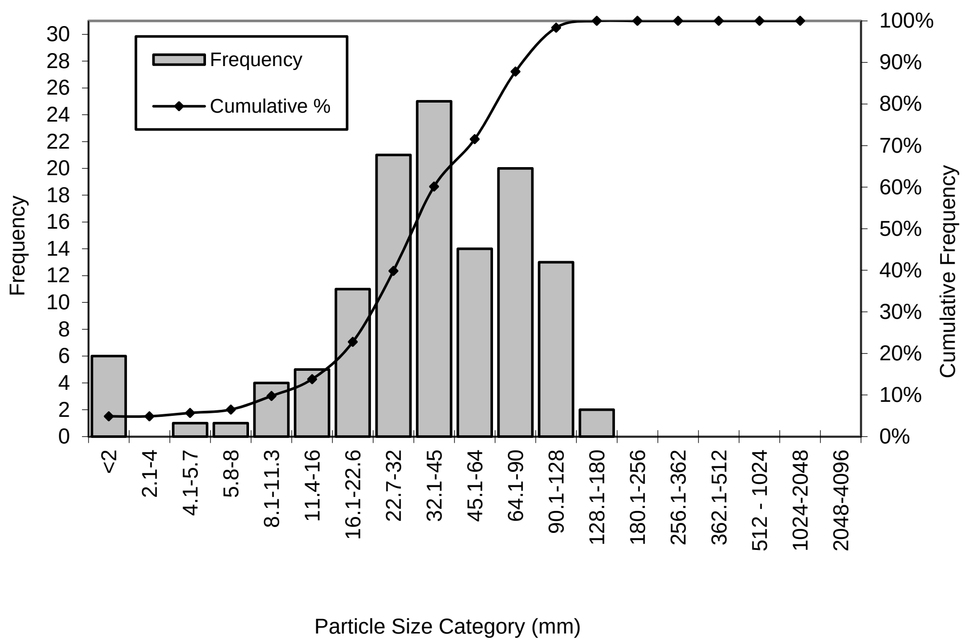


Figure 55. Percent composition of bed substrate based on two pebble counts in Reach 5.



Material	Percent Composition	Size Class	Size percent finer than (mm)
Sand	2%	D5	1
Gravel	66%	D16	18
Cobble	31%	D50	89
Boulder	1%	D84	90
Bedrock	0%	D95	175
		* Assumed linear interpolation	

Figure 56. Grain size distribution and particle size classes from pebble count 1 of 2 in Reach 5.



Material	Percent Composition	Size Class	Size percent finer than (mm)
Sand	5%	D5	1
Gravel	67%	D16	18
Cobble	28%	D50	39
Boulder	0%	D84	84
Bedrock	0%	D95	116
		* Assumed linear interpolation	

Figure 57. Grain size distribution and particle size classes from pebble count 2 of 2 in Reach 5.

5.5.6 Riparian Corridor

Based on observations at three n^{th} units, small trees were the dominant riparian vegetation in Reach 5 (67%); sapling/pole were the secondary habitat type at 33%. Overstory was 100% cottonwood.

Understory was evenly distributed between snowberry, mountain maple, grassland/forbs, and dogwood.

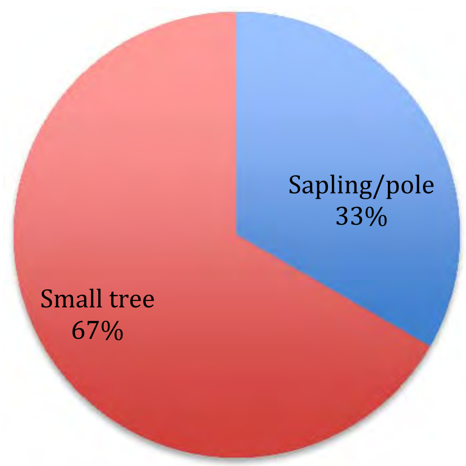


Figure 58. Dominant riparian vegetation identified within 100 feet of river by ocular estimate in Reach 5.

5.6 REACH 6

Location: River mile 71.3 – 75.0 (Lost River)
Total length: 3.7 miles
Survey date: July 30, 31, and August 11

Figure 59. Representative view of Reach 6.

Figure 60. Overview of Upper Methow Reach 6 from RM 71.3 – RM 75.0 (Lost River).

5.6.1 Habitat Unit Composition

Reach 6 is a 3.8-mile long reach that contains 59% fast water habitat, 15% secondary channel habitat, and 26% pool habitat. A total of 23 pools were counted, averaging 6.3 pools per mile (Figure 61). Twelve of the pools were back-to-back pools, meaning they were consecutive, but independent units with no other channel unit between them. Reach 6 also contained the longest side channel in the project area at 4,850 feet.

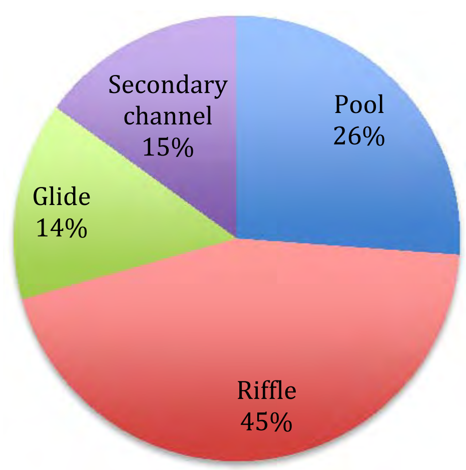


Figure 61. Habitat unit composition for Reach 6.

5.6.2 Pools

Reach 6 has 23 pools averaging 6.3 pools per mile, compared to the project area average of 3.6 pools per mile. Average residual pool depth is 4.2 feet and the mean pool spacing is 19.6 channel widths per pool – the lowest in the project area. Reach 6 also has the highest percentage of pool area habitat (26%) in the project area (Figure 61).

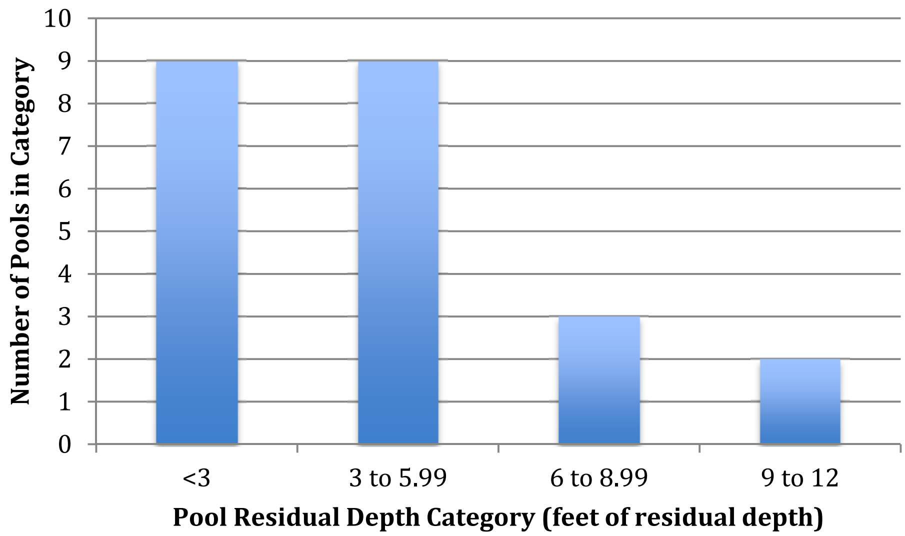


Figure 62. Reach 6 residual pool depth and count of total pools in the reach.

Figure 63. Reach 6 had 23 pools which together composed 27% of the habitat area within the reach. Photo above is a pool at RM 73.9.

5.6.3 Secondary Channel Habitat

Reach 6 contains 9 secondary channels representing 15% of the habitat area in the reach. Total wood count in the secondary channels was 213 pieces (55%) of the total wood count in the reach. Of note is the 4,850-foot-long side channel that traverses the floodplain on river-left from RM 73.8 – 72.3 that is disconnected from the mainstem at the upstream end by a constructed canal that crosses its path. The canal blocks surface flow from entering the side channel, and instead diverts it off the floodplain. Because of this diversion, it is being considered a disconnected side channel. No wood was recorded in this side channel because during the habitat assessment, this side channel was initially identified as a tributary. One other disconnected side channel was identified in Reach 2.

For this assessment, we consider “side-channels” as secondary channels that are, or would be, naturally connected to the mainstem flow at their upstream and downstream ends at average annual flow; this definition also includes artificially disconnected side channels. We consider “off-channels” to be all other types of secondary channels including backwater channels/alcoves, groundwater-fed channels, wall-base channels, abandoned oxbows, and other types of floodplain channels and open-water floodplain wetlands.

Table 18. Secondary channel habitat in Reach 6.

Location	Length (ft)	Dominant unit type	Wood count	Off-channel (OC) or side channel (SC)
SIDE25S	1850	Slow water	9	SC
SIDE26S	1450	Slow water	113	SC
SIDE26.5[4]	4,850	Slow water	0	SC
SIDE27S	2400	Slow water	9	OC
SIDE28S	600	Slow water	40	SC
SIDE29S	1350	Slow water	2	OC
SIDE30	200	Slow water	40	SC
SIDE31F	1350	Fast water	0	SC
SIDE32	1080	Slow water	0	SC
Total	15,130		213	

Figure 64. Remnants of an old bridge along SIDE25S.

[4] The side channel between RM 73.8 – 72.3 is disconnected from the mainstem at the upstream end by a constructed canal that crosses its path. The canal blocks surface flow from entering the side channel, and instead diverts it back to the mainstem channel. Because flow does not enter the side channel, it is being considered a *disconnected* side channel.

5.6.4 Large Woody Material

Reach 6 is slightly below average for large wood. Of the 388 pieces counted, 76% were from 10 log jams identified throughout Reach 6. The reach averaged 107.1 pieces per mile and 116.2 pieces per mile of medium and large wood, compared to the project area average of 24.7 and 55 pieces per mile, respectively) (Table 19).

Table 19. Large woody debris 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	214	131	43	388
Number of pieces per mile	59.1	36.2	11.9	107.1
Number of med/lg pieces per mile				48.0
Number of jams per mile				2.8
Number of jams				10.0

5.6.5 Substrate & Fine Sediment

Two pebble counts were performed in Reach 6. Substrate was very similar to the project area average with a slight majority cobble (51%), 45% gravel, and trace amounts of boulder and gravel (2% each).

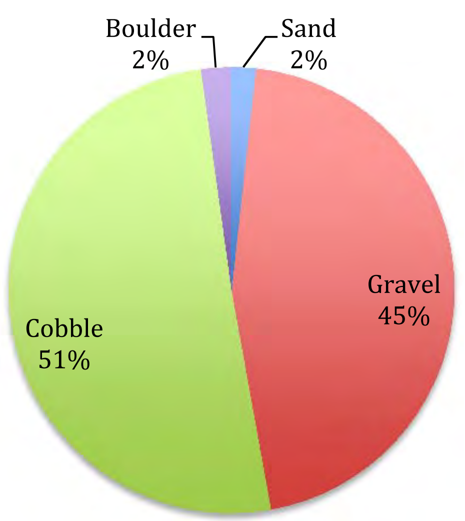
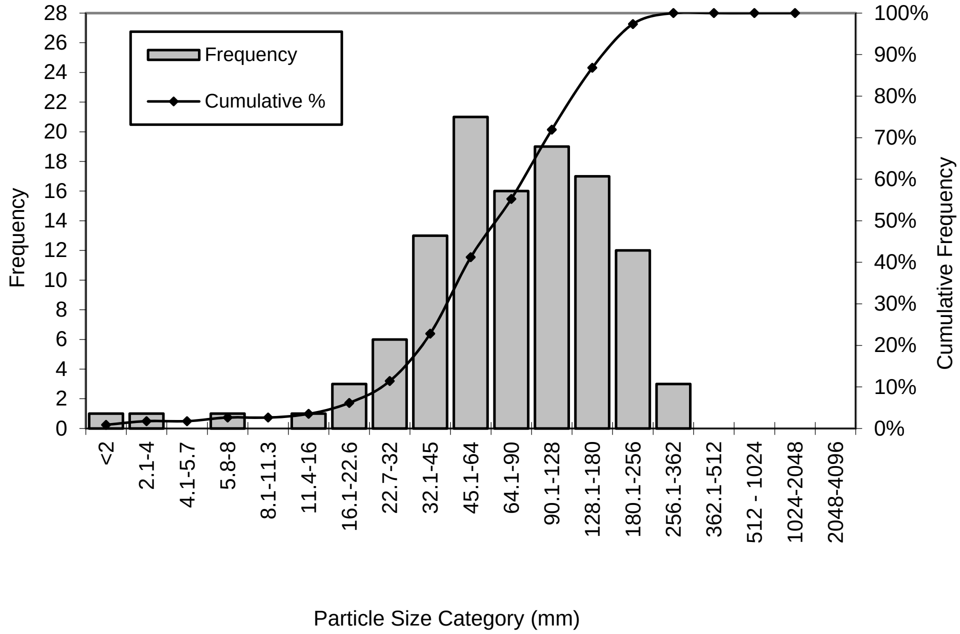
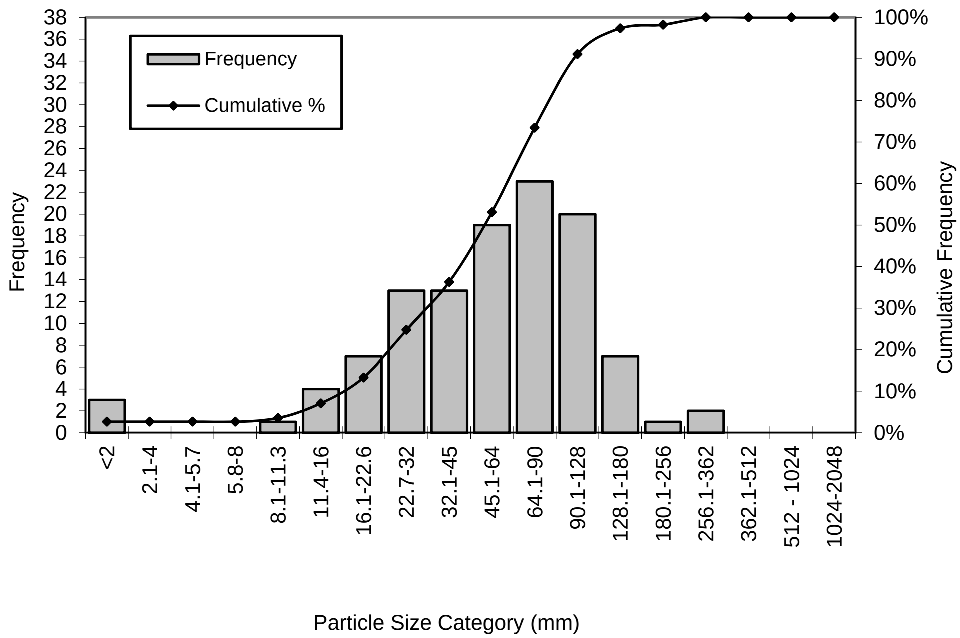


Figure 65. Percent composition of bed substrate based on two pebble counts in Reach 6.



Material	Percent Composition	Size Class	Size percent finer than (mm)
Sand	1%	D5	20
Gravel	40%	D16	37
Cobble	56%	D50	80
Boulder	3%	D84	170
Bedrock	0%	D95	239
		* Assumed linear interpolation	

Figure 66. Grain size distribution and particle size classes from pebble count 1 of 2 in Reach 6.



Material	Percent Composition	Size Class	Size percent finer than (mm)
Sand	3%	D5	28
Gravel	50%	D16	25
Cobble	45%	D50	61
Boulder	2%	D84	113
Bedrock	0%	D95	160
		* Assumed linear interpolation	

Figure 67. Grain size distribution and particle size classes from pebble count 2 of 2 in Reach 6.

5.6.6 Riparian Corridor

Small trees measuring 9.0 – 20.9 in. diameter were again the primary riparian vegetation (78%) observed in Reach 6 over nine n^{th} units (Figure 68). Large trees measuring 21 – 31.9 in. diameter and sapling/pole measuring 5 – 8.9 in. diameter were observed as well (11% each). Cottonwoods were the dominant overstory species with several other species composing the observed riparian overstory including aspen, cedar, Douglas fir, and ponderosa pine. Dogwood was the primary understory species with additional units of young cottonwood and cedar.

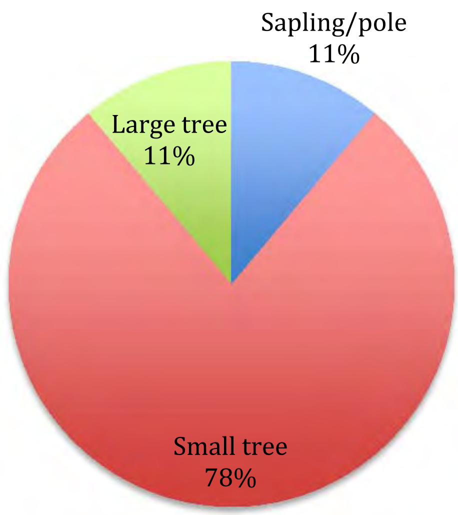


Figure 68. Dominant riparian vegetation identified within 100 feet of river by ocular estimate in Reach 6.

Figure 69. Small trees measuring 9.0 – 20.9 in. diameter were the primary riparian vegetation (78%).

5.7 REACH 7

Location: River mile 75.0 (Lost River) – 76.5 (Robinson Creek)
Total length: 1.5 miles
Survey date: August 12, 2014

Figure 70. Representative view of Reach 7.

Figure 71. Overview of Upper Methow Reach 7 from RM 75.0 (Lost River) – RM 76.5 (Robinson Creek).

5.7.1 Habitat Unit Composition

Reach 7 is a highly dynamic reach with considerably less water than downstream reaches due to being upstream from the confluence of Lost River at RM 75.1 (boundary between Reach 6 and 7). Habitat consists of 62% fast water, 22% secondary channel, 16% pools and 5% glides. Very short channel units were observed between RM 75.5 – 76.0 where the main channel was recently abandoned (Figure 72). This half-mile section contained four log jams, very short habitat units (the four pools identified were all under 130 feet long), and four secondary channels.

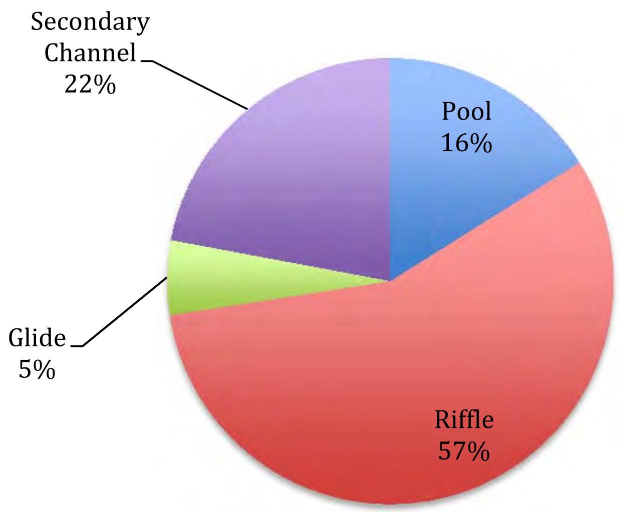


Figure 72. Habitat unit composition for Reach 7.

5.7.2 Pools

Reach 7 has 12 pools averaging 7.5 pools per mile – the highest rate of pools per mile within the project area, which averages 3.6 pools per mile. Over half the pools maintained between 3 – 5.99 feet of residual depth (Figure 73). Mean pool spacing calculated to 25.9 channel widths per pool, slightly lower than the project area average of 31.8.

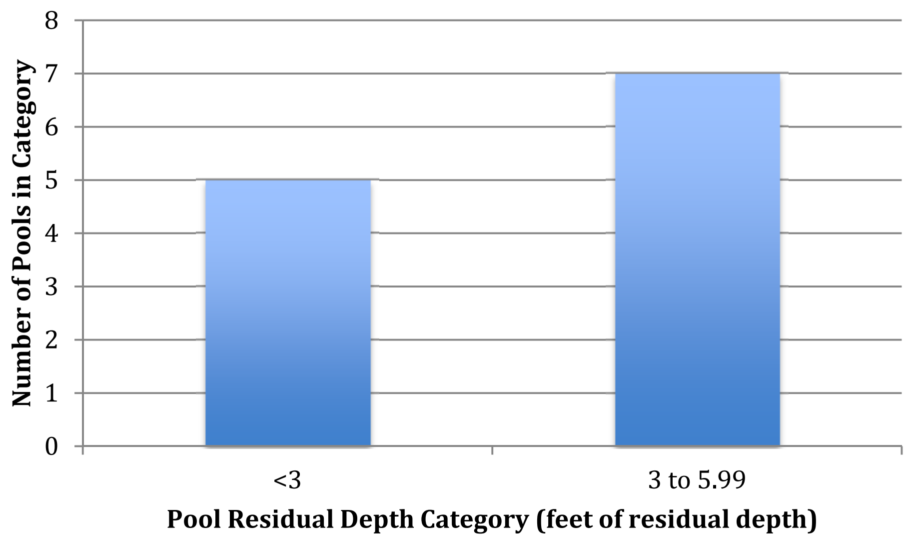


Figure 73. Reach 7 residual pool depth and count of total pools in the reach.

5.7.3 Secondary Channel Habitat

A total of seven secondary channels totaling 4,715 linear feet were identified in Reach 7. All are side channels that together total 22% of the habitat area in Reach 7. Both SIDE35F and SIDE36F were relatively equal in flow to the main channel.

For this assessment, we consider "side-channels" as secondary channels that are, or would be, naturally connected to the mainstem flow at their upstream and downstream ends at average annual flow; this definition also includes artificially disconnected side channels. We consider "off-channels" to be all other types of secondary channels including backwater channels/alcoves, groundwater-fed channels, wall-base channels, abandoned oxbows, and other types of floodplain channels and open-water floodplain wetlands.

Table 20. Secondary channel habitat in Reach 7.

Location	Length (ft)	Dominant unit type	Wood count	Off-channel (OC) or side channel (SC)
SIDE33F	440	Fast water	0	SC
SIDE34F	550	Fast water	0	SC
SIDE35F	1000	Fast water	0	SC
SIDE36F	1350	Fast water	12	SC
SIDE37S	400	Slow water	0	SC
SIDE38S	375	Slow water	40	SC
SIDE39	600	Slow water	0	SC
Total	4,715		52	

5.7.4 Large Woody Material

Reach 6 has a slightly above average wood count compared to the study area with 138.7 pieces per mile and 61.5 pieces of medium/large pieces of LWD per mile. The project area average is 124.7 and 55 pieces per mile, respectively. A total of 221 pieces were counted. This included six jams, equating to an average of 3.8 jams per mile (Table 19).

Figure 74. Lateral channel migration resulted in increased LWD at RM 76.0.

Table 21. Large woody debris 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	123	71	27	221
Number of pieces per mile	77.2	44.6	16.9	138.7
Number of med/lg pieces per mile				61.5
Number of jams per mile				3.8
Number of jams				6.0

5.7.5 Substrate & Fine Sediment

Two pebble counts within Reach 7 identified substrate that was on par with the project area average and included 51% cobble, 42% gravel, 5% boulder and 2% sand (Figure 75). Robinson Creek is a significant contributor of bedload and suspended sediment to the reach (see Figure 76).

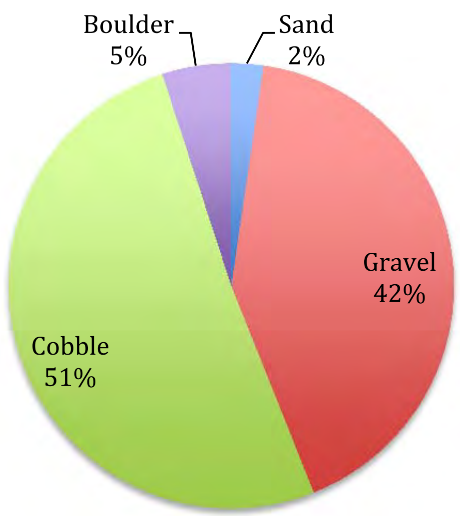


Figure 75. Percent composition of bed substrate based on two pebble counts in Reach 7.

Figure 76. Robinson Creek (left) meets the Methow at RM 76.5 following heavy rains

5.7.6 Riparian Corridor

Reach 7 riparian vegetation was relatively young. Small trees measuring 9 – 20.9 inches diameter and shrub/seedlings were the dominant riparian vegetation observed at 5 n^{th} units in Reach 7, each representing 40%. Sapling/pole sized vegetation accounted for the remaining 20% (Figure 77). Overstory vegetation was dominated by dogwood and cottonwood. The understory vegetation reflected the increased elevation of Reach 7 and included snowberry, mountain maple, huckleberry, grassland/forbs, and dogwood.

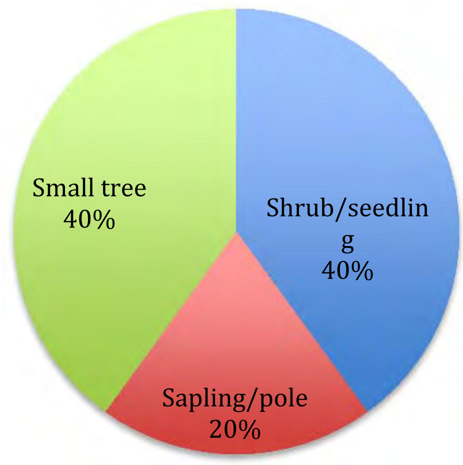


Figure 77. Dominant riparian vegetation identified within 100 feet of river by ocular estimate in Reach 7.

5.8 REACH 8

Location: River mile 76.5 (Robinson Creek) – 78.7
Total length: 2.2 miles
Survey date: August 13, 2014

Figure 78. Reach 8 was dominated by relatively high gradient riffles (92%).

Figure 79. Overview of Upper Methow Reach 8 from RM 76.5 (Robinson Creek) – RM 78.7.

5.8.1 Habitat Unit Composition

Reach 8 is a confined, steep reach composed of 92% riffles, 5% secondary channels, 2% pools, and 1% glides (Figure 80). Water levels were unseasonably high during the survey due to an intense two-day rain event (Figure 78). The higher water levels may have washed out smaller pools that would have been present at normal later summer levels. Reach 8 is a markedly smaller river due to the inflow of Robinson Creek at River Mile 76.5 that was estimated to add 15% of Methow River's flow. While the reach is dominated by riffles, there is high quality salmon habitat in side channels, especially SIDE40F between RM 77.5 – 77.9 which maintained considerable wood and a diversity of pools and riffles.

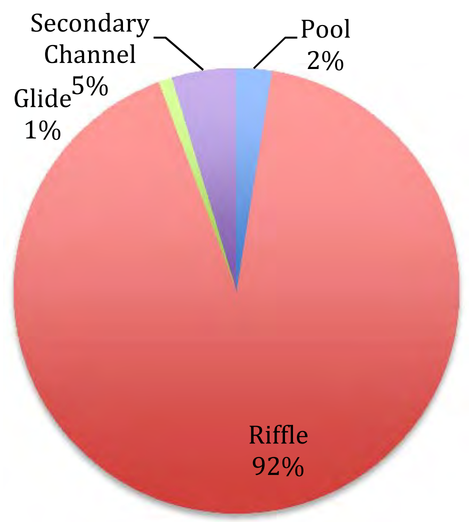


Figure 80. Habitat unit composition for Reach 8.

5.8.2 Pools

Reach 8 maintained an average of 1.3 pools per mile, lower than the average of 3.6 pools per mile. Three pools were identified with one under three feet of residual depth and two pools between 6 – 8.9 feet. The survey of Reach 8 was performed during a rain event on August 13, 2014 that increased river levels at the USGS gauge 12447383 (Methow River above Goat Creek Near Mazama) (Figure 1) to a max of 413 cfs. Average levels at this gauge for August 13 are approximately 140 cfs. These higher water levels may be responsible for a lower than average pool count.

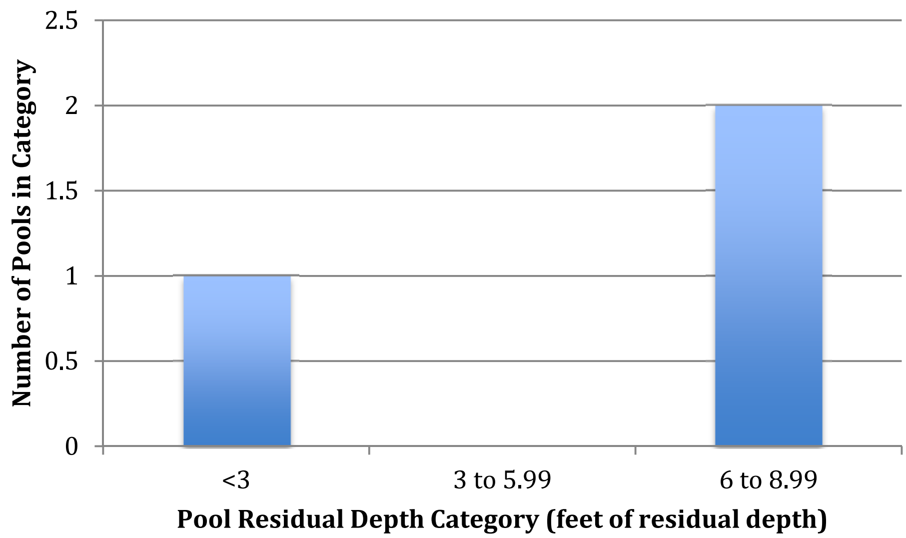


Figure 81. Reach 8 residual pool depth and count of total pools in the reach.

5.8.3 Secondary Channel Habitat

Reach 8 has four side channels comprising approximately 1% of the secondary channel habitat within the project area. The longest side channel is SIDE40F (Figure 82), which maintained a variety of riffles and pools, as well as a large apex log jam at the head of the side channel.

For this assessment, we consider "side-channels" as secondary channels that are, or would be, naturally connected to the mainstem flow at their upstream and downstream ends at average annual flow; this definition also includes artificially disconnected side channels. We consider "off-channels" to be all other types of secondary channels including backwater channels/alcoves, groundwater-fed channels, wall-base channels, abandoned oxbows, and other types of floodplain channels and open-water floodplain wetlands.

Figure 82. SIDE40F with the mainstem Methow River in the background.

Table 22. Secondary channel habitat in Reach 8.

Location	Length (ft)	Dominant unit type	Wood count	Off-channel (OC) or side channel (SC)
SIDE40F	1740	Fast water	0	SC
SIDE41S	100	Slow water	30	SC
SIDE42F	250	Fast water	0	SC
SIDE43S	200	Slow water	0	SC
Total	2290		30	

5.8.4 Large Woody Material

A total of 275 pieces of large wood was observed in Reach 8, averaging 123.6 pieces per mile, or 57.5 pieces of medium/large wood per mile. Wood counts were on par with the project area which averaged 124.7 pieces per mile and 55 medium/large pieces per mile. Four log jams were observed, averaging 1.8 jams per mile (Table 23).

Table 23. Large woody debris 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	147	79	49	275
Number of pieces per mile	66.1	35.5	22.0	123.6
Number of med/lg pieces per mile				57.5
Number of jams per mile				1.8
Number of jams				4.0

5.8.5 Substrate & Fine Sediment

Gravel counts were not conducted in Reach 8 and 9 because of the large bedload size relative to channel geometry and the lack of LiDAR for conducting hydraulic modeling.

The substrate of this reach is dominated by large cobbles; however, bedload size here ranges from gravels to boulders with very sparse accumulations of sand. Direct hillslope inputs in this reach include weathered bedrock and talus fans, glacial lag, and glacial outwash terraces. The sediment load is primarily locally sourced but clasts are rounded to subangular due to the mix of hillslope sources including glacial deposits. Where colluvial boulders are present they add hydraulic roughness to the bed and banks. Step-pool channel sequences are defined by relatively stable boulder steps. Gravel-sized bedload is present in pockets and as bars in depositional zones in the channel near large wood accumulations, at eddies, or as bar features in seasonally occupied high-flow secondary channels. Coarse sands are present as overbank deposits on low-lying vegetated floodplain surfaces and as a top layer on some of the bar features, especially immediately downstream from landslide or colluvial inputs. All other fine-grained sediment is fluvially transported through this dynamic cascading reach with long sequences of large cobble to boulder riffles and step-pool sections.

5.8.6 Riparian Corridor

Riparian habitat observed within 100 feet of the river was dominated by small trees (Figure 83). Cedar and Douglas fir were the primary overstory vegetation while snowberry, mountain maple, and dogwood were the primary understory vegetation.

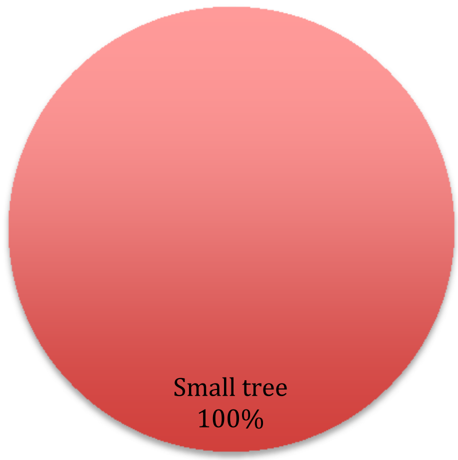


Figure 83. Dominant riparian vegetation identified within 100 feet of river by ocular estimate in Reach 8.

5.9 REACH 9

Location: River mile 78.7 – 80.0 (Trout Creek)
Total length: 1.3 miles
Survey date: August 14, 2014

Figure 84. Representative view of Reach 9. Image is taking looking downstream from Trout Creek.

Figure 85. Overview of Upper Methow Reach 9 from RM 78.7 – RM 80.0 (Trout Creek).

5.9.1 Habitat Unit Composition

Habitat in Reach 9 is a moderate- to highly-confined reach that maintains a higher gradient relative to lower reaches. The reach is composed 84% riffles, 10% pools, 4% secondary channels, and 2% glides. Large wood counts were the highest in the project area, mainly due to a large wood jam at RM 79.75 that was caused by an avalanche that pushed hundreds of trees into the river in the winter of 2013/2014. Three tributaries were identified in Reach 9. While Reach 9 is relatively steep and confined, four side channels were identified.

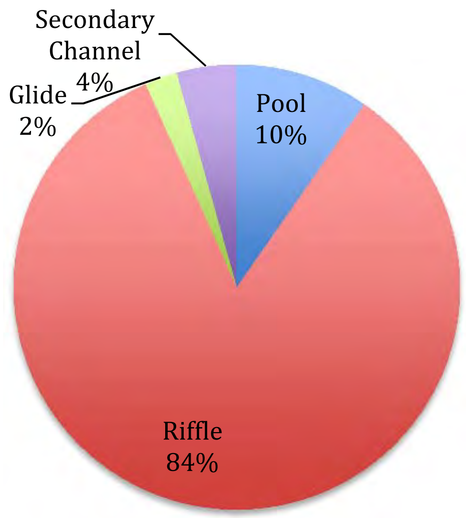


Figure 86. Habitat unit composition for Reach 9.

5.9.2 Pools

Reach 9 had four pools that averaged 4.1 feet of residual depth (Figure 87), which is slightly lower than the average residual depth of 4.4 feet. Pool spacing was 46.2 channel widths per pool, and there was 3 pools per mile – slightly lower than the reach area average of 3.6 pools per mile.

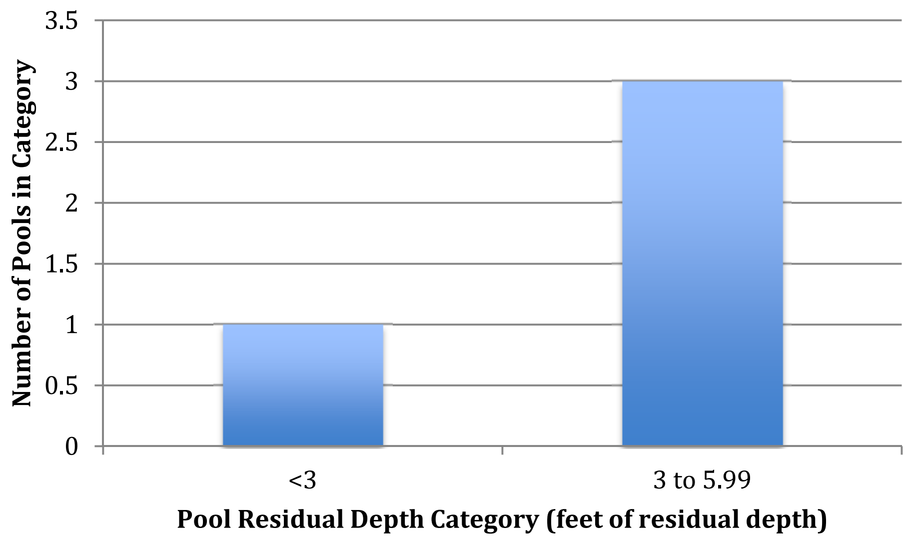


Figure 87. Reach 9 residual pool depth and count of total pools in the reach.

5.9.3 Secondary Channel Habitat

Four side channels were identified in Reach 9, totaling 5% of the habitat area. This is one of the lowest secondary channel habitat rates within the project area. It is likely due to the steep, confined nature of the reach. Only nine pieces of large wood were counted in the side channels (Table 24).

Table 24. Secondary cannel habitat in Reach 9.

Location	Length (ft)	Dominant unit type	Wood count	Off-channel (OC) or side channel (SC)
SIDE44S	20	Slow water	2	SC
SIDE45F	650	Fast water	7	SC
SIDE46F	300	Fast water	0	SC
SIDE47S	350	Slow water	0	SC
Total	1320		9	SC

5.9.4 Large Woody Material

Reach 9 had almost one-third of the wood count within the total project area. This translated into the highest wood count among the nine reaches (467), as well as the highest density of wood (347.8 pieces per mile). The project area average was 124.7 pieces per mile.

A majority of the large wood (75%) was confined to seven log jams in Reach 9. Four of the seven log jams located near RM 79.75 were the result of an avalanche that pushed hundreds of trees into the river during the winter of 2013/2014. While the four log jams resulting from the avalanche densely packed the river with wood, they did not appear to be hindering fish passage.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in x 35 ft)	Total
Number of pieces	311	119	37	467
Number of pieces per mile	231.6	88.6	27.6	347.8
Number of med/lg pieces per mile				116.2
Number of jams per mile				5.2
Number of jams				7.0

Figure 88. Log jam at RM 79.75 caused by an avalanche in May 2014. Much of the wood was likely dead snags that had burned during the 2003 Needles Fire.

5.9.5 Substrate & Fine Sediment

Gravel counts were not conducted in Reach 8 and 9 because of the large bedload size relative to channel geometry and the lack of LiDAR for conducting hydraulic modeling.

The substrate of Reach 9 is dominated by boulders and large cobbles. The sediment is primarily sourced directly from the steep adjacent confining hillslopes composed of weathered bedrock and talus fans. The Trout Creek confluence and its alluvial fan contribute additional cobbles and boulders to the upstream portion of this reach. Downstream from the confluence most of the bedload is locally sourced and thus is angular to sub-angular. The colluvial boulders add hydraulic roughness and stability to the channel bed and banks. Some small gravel-sized bedload is present at a few transient depositional zones in the channel near large wood accumulations or at eddies. Sands are present as overbank deposits on the few very narrow vegetated floodplain surfaces that are established by channel incision/erosion in to the colluvial debris deposits. Otherwise, all fine-grained material is fluvially transported through this dynamic cascading reach.

5.9.6 Riparian Corridor

Small trees measuring 9.0 – 20.9 in. diameter were the dominant riparian vegetation measured at two n^{th} unit in Reach 9 (Figure 89). Overstory vegetation observed was Douglas fir, while understory was a mix of ceanothus and dogwood.

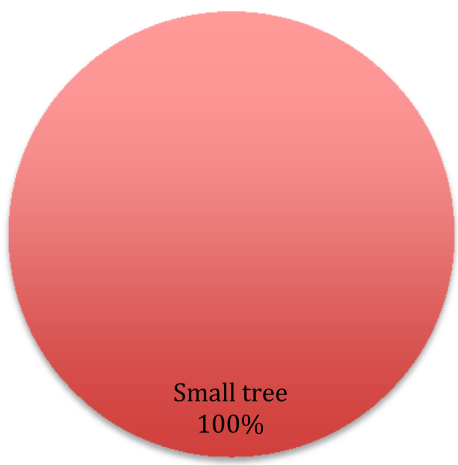


Figure 89. Dominant riparian vegetation identified within 100 feet of river by ocular estimate in Reach 9.

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Total
Reach Mileage Boundaries	61.15 - 61.7	61.7 - 64.8	64.8 - 66.1	66.1 - 69.2	69.2 - 71.3	71.3 - 75.0	75.0 - 76.5	76.5 - 78.7	78.7 – 80.0	19
Wetted Width (ft)										
All habitat types (Main Channel)										
Mean	n=0	85.0	49.3	70.0	43.2	43.3	27.1	43.3	37.5	51.9
Median	n=0	90.0	45.0	75.0	40.0	45.0	25.0	45.0	37.5	24.9
Pool										
Mean	n=0	85.0	49.3	70.0	43.2	43.3	27.1	43.3	37.5	45.1
Median	n=0	90.0	45.0	75.0	40.0	45.0	25.0	45.0	37.5	40.0
StDev	n=0	19.1	23.9	17.7	9.0	13.1	4.0	7.6	8.7	19.1
Glide										
Mean	102.5	91.4	98.3	82.0	74.0	48.9	26.5	55.0	42.5	72.3
Median	102.5	90.0	100.0	85.0	80.0	50.0	27.0	55.0	42.5	80.0
StDev	17.7	19.1	27.5	26.8	23.8	12.2	3.7	n=1	3.5	29.3
Riffle										
Mean	n=1	103.5	75.8	91.5	52.3	46.1	29.1	51.6	37.7	62.8
Median	n=1	100.0	70.0	90.0	45.0	45.0	30.0	55.0	42.0	55.0
StDev	n=1	24.2	18.6	24.4	17.3	13.4	10.9	4.8	13.7	31.9
Secondary Channel[5]										
Mean	n=0	23.4	7.5	19.5	13.1	10.7	12.3	7.0	9.0	13.8
Median	n=0	30.0	9.0	14.0	12.0	9.0	15.0	6.0	4.5	30.0
StDev	n=0	15.0	3.8	18.2	8.6	10.2	10.1	6.1	10.8	11.9

[5] Secondary Channel measurements do not account for three open water floodplain wetlands identified in Reach 2.

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Total
Water Depth (ft)										
Pool Maximum Depth										
Mean	*n=0*	*7.9*	*7.3*	*6.4*	*5.4*	*5.2*	*4.2*	*6*	*5.1*	*5.6*
Median	*n=0*	*8.0*	*7.0*	*6*	*4.5*	*5.0*	*4.0*	*7*	*5.5*	*5.0*
StDev	*n=0*	*3.8*	*2.1*	*1.8*	*2.3*	*2.3*	*1.1*	*1.7*	*1.2*	*2.3*
Pool Residual Depth										
Mean	*n=0*	*5.4*	*5.8*	*4.9*	*4.5*	*4.2*	*3.4*	*4.7*	*4.1*	*4.4*
Median	*n=0*	*7.1*	*6.5*	*5.0*	*3.5*	*4.0*	*3.4*	*6.0*	*4.4*	*4.0*
StDev	*n=0*	*2.7*	*2.3*	*1.6*	*2.4*	*2.2*	*1.1*	*2.4*	*1.1*	*2.1*
Glide Maximum Depth										
Mean	*8*	*3.8*	*4.5*	*3.3*	*2.3*	*2.4*	*2.7*	*n=1*	*3*	*3.3*
Median	*8*	*4*	*4*	*3.3*	*2.5*	*2.5*	*2.8*	*n=1*	*3*	*3.0*
StDev	*2.8*	*0.8*	*1.3*	*0.7*	*0.9*	*0.4*	*0.6*	*n=1*	*0*	*1.4*
Glide Average Depth										
Mean	*3.9*	*2.4*	*2.3*	*2*	*2.1*	*1.3*	*1.6*	*n=1*	*1.5*	*2.0*
Median	*3.9*	*2.5*	*2.5*	*2*	*2*	*1.0*	*1.5*	*n=1*	*1.5*	*2.0*
StDev	*1.6*	*0.6*	*0.3*	*0.4*	*0.2*	*0.7*	*0.3*	*n=1*	*0*	*0.7*
Riffle Maximum Depth										
Mean	*n=1*	*4.6*	*2.8*	*3.1*	*2.5*	*2.3*	*2.0*	*2.8*	*2.6*	*3.0*
Median	*n=1*	*4.0*	*3.0*	*3.5*	*2.5*	*2.0*	*2.0*	*2.8*	*2.8*	*2.5*
StDev	*n=1*	*2.8*	*0.8*	*0.9*	*0.7*	*0.6*	*0.5*	*0.4*	*0.7*	*1.6*
Secondary Channel Maximum Depth										
Mean	*n=0*	*3.0*	*2.3*	*3.4*	*2.6*	*1.8*	*1.9*	*2*	*1.1*	*2.3*
Median	*n=0*	*3.5*	*2.0*	*3.8*	*2.5*	*2*	*2.0*	*2.3*	*0.8*	*2.0*
StDev	*n=0*	*1.4*	*0.5*	*1.7*	*0.9*	*1.1*	*1.4*	*1.1*	*0.9*	*1.3*

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Total
Bankfull Characteristics										
Width (ft)										
Mean	*172.0*	*140.5*	*159.0*	*129.0*	*95.0*	*100.3*	*75.7*	*56.0*	*52.0*	*112.8*
StDev	*n=1*	*23.9*	*19.8*	*27.8*	*20.0*	*22.5*	*25.1*	*5.7*	*n=1*	*38.0*
Average Depth (ft)										
Mean	*3.9*	*4.0*	*3.2*	*3.2*	*2.7*	*2.6*	*2.2*	*2.6*	*1.6*	*3.0*
StDev	*n=1*	*0.5*	*0.1*	*0.4*	*0.5*	*0.5*	*0.4*	*0.3*	*n=1*	*1.3*
Maximum Depth (ft)										
Mean	*3.9*	*4.38*	*3.24*	*3.71*	*3.28*	*3.13*	*2.52*	*2.8*	*1.6*	*4.4*
StDev	*n=1*	*0.5*	*0.1*	*0.4*	*0.5*	*0.5*	*0.4*	*0.3*	*n=1*	*0.9*
Width:Depth Ratio										
Mean	*44.1*	*35.2*	*50.5*	*40.0*	*35.5*	*38.4*	*34.4*	*21.9*	*32.5*	*37.4*
StDev	*n=1*	*5.8*	*6.3*	*8.6*	*7.5*	*8.6*	*11.4*	*2.2*	*n=1*	*12.6*
Flood prone Width (ft)										
Mean	*3400*	*2075*	*1600*	*817*	*1200*	*1375*	*1467*	*593*	*70*	*1382*
StDev	*n=1*	*762.1*	*707.1*	*312.5*	*492.4*	*681.7*	*246.6*	*753.1*	*n=1*	*818.9*
Habitat area %										
Pool	*0%*	*5%*	*21%*	*11%*	*21%*	*26%*	*16%*	*3%*	*10%*	*12%*
Glide	*57%*	*24%*	*44%*	*30%*	*13%*	*14%*	*5%*	*1%*	*2%*	*22%*
Riffle	*43%*	*52%*	*34%*	*56%*	*45%*	*45%*	*56%*	*92%*	*84%*	*54%*
Secondary Channel	*0%*	*19%*	*2%*	*3%*	*22%*	*15%*	*22%*	*5%*	*4%*	*12%*

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Total
Pools										
Pools per mile	0	1.3	5.5	1.7	5.3	6.3	7.5	1.3	3.0	3.6
Residual Depth (% of pools)										
Pools < 3 ft	0	1	0	0	2	9	5	1	1	19
Pools 3-6 ft	0	1	3	4	7	9	7	0	3	34
Pools 6-9 ft	0	1	4	1	1	3	0	2	0	12
Pools 9-12 ft	0	1	0	0	1	2	0	0	0	4
Riffle:Pool ratio	N/A	11.2	1.6	5.1	2.2	1.7	3.5	36.0	8.6	4.3
Mean Pool Spacing (bankfull channel widths per pool)	n=0	49.0	19.7	44.9	23.3	19.6	25.9	79.6	46.2	31.8
Large Wood										
Total Number Pieces										
Total	4	398	190	362	314	388	221	275	467	2619
Large (20 in by 35 ft)	0	76	35	59	30	43	27	49	37	356
Medium (12 in by 35 ft)	1	128	63	110	97	131	71	79	119	799
Large and Medium	1	204	98	169	127	174	98	128	156	1155
Small (6 in x 20 ft)	3	194	92	193	187	214	123	147	311	1464
Number of Pieces per mile										
Total	9.9	126.1	148.0	121.5	152.2	107.1	138.7	123.6	347.8	124.7
Large (20 in by 35 ft)	0.0	24.1	27.3	19.8	14.5	11.9	16.9	22.0	27.6	18.7
Medium (12 in by 35 ft)	2.5	40.6	49.1	36.9	47.0	36.2	44.6	35.5	88.6	42.1
Large and Medium	2.5	64.7	76.3	56.7	61.5	48.0	61.5	57.5	116.2	60.8
Small (6 in x 20 ft)	7.5	61.5	71.6	64.8	90.6	59.1	77.2	66.1	231.6	77.1

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Total
Bank Erosion										
Total % Bank Erosion	0	450	300	1250	0	0	0	0	0	2000
Substrate (all pebble counts performed at the riffle/glide transition)										
Total										
% Sand	2%	0%	0%	5%	3%	2%	2%	0%	0%	2%
% Gravel	46%	49%	51%	39%	67%	45%	42%	0%	0%	48%
% Cobble	52%	51%	48%	53%	29%	51%	51%	0%	0%	48%
% Boulder	0%	0%	1%	4%	4%	2%	5%	0%	0%	2%
% Bedrock	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Vegetation (% of sampled units in 100-foot-wide zone averaged between both banks)										
Dominant Overstory Size Class										
Mature Tree	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Large Tree	0%	0%	25%	0%	0%	0%	0%	0%	0%	3%
Small Tree	0%	0%	0%	0%	0%	0%	40%	0%	0%	5%
Sapling/Pole	0%	0%	0%	0%	33%	11%	20%	0%	0%	8%
Shrub/Seedling	100%	100%	75%	100%	67%	78%	40%	100%	100%	83%
Grassland/Forb	0%	0%	0%	0%	0%	11%	0%	0%	0%	3%
No Vegetation	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Overstory Species Composition										
Cottonwood	100%	83%	25%	0%	100%	56%	40%	0%	0%	43%
Aspen	0%	0%	0%	0%	0%	11%	0%	0%	0%	3%
Cedar	0%	0%	0%	14%	0%	11%	0%	67%	0%	10%
Douglas fir	0%	0%	0%	0%	0%	11%	0%	33%	100%	10%
Pondersosa	0%	17%	75%	86%	0%	0%	0%	0%	0%	25%
Dogwood	0%	0%	0%	0%	0%	11%	60%	0%	0%	10%

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Total
Understory Species Composition										
Cottonwood	100%	17%	50%	57%	0%	33%	20%	0%	0%	30%
Willow	0%	33%	0%	0%	0%	0%	0%	0%	0%	5%
Cedar	0%	0%	0%	0%	0%	11%	0%	0%	0%	3%
Dogwood	0%	50%	0%	14%	33%	56%	0%	33%	50%	30%
Grassland/forbes	0%	0%	50%	0%	33%	0%	40%	0%	0%	13%
Small Shrub	0%	0%	0%	29%	0%	0%	0%	0%	0%	5%
Ceanothus	0%	0%	0%	0%	0%	0%	0%	0%	50%	3%
Snowberry (co-dom. with mtn maple or huckleberry)	0%	0%	0%	0%	33%	0%	40%	67%	0%	13%

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Appendix B

Reach-based Ecosystem Indicators (REI)

Upper Methow River Reach Assessment

December 2015

Contents

1 Introduction

1.1 BACKGROUND

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, the REI are based on the USBR's latest adaptations and use of these indicators (USBR 2012).

The REI evaluation for the Upper Methow 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 using USFS (2010) protocols, 2) assessment of geomorphic patterns and processes and how they have deviated, if at all, from historical conditions, and 3) analysis of existing watershed assessments and data (e.g. available ArcMap layers and shapefiles). 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.

1.2 SUMMARY OF RESULTS

Reaches below the confluence of Lost River with the upper Methow River (Reaches 1-6) were generally the most impacted reaches, having the highest number of **Unacceptable** ratings. Reaches 5 and 6, though having slightly fewer **Unacceptable** ratings, both had high numbers of **At Risk** ratings due to the amount of residential development along the banks of those reaches. Reach 7 had seven **At Risk** ratings, with only one **Unacceptable** rating. Reaches 8 and 9 were the least impacted, with Reach 9 receiving all **Adequate** ratings and Reach 8 having only one **At Risk** and **Unacceptable** rating each.

All reaches were given **Adequate** ratings for the Habitat Access Pathway- Main Channel Barriers indicator since there were no barriers within the main channel that completely excluded fish passage in any of the reaches. All reaches (except Reaches 8 and 9, which did not have substrate sampled) were also given an **Adequate** rating for the Dominant Substrate/Fine Sediment indicator due to gravel counts meeting appropriate percentages and minimal fine sediments in all reaches. LWM was rated **Adequate** only in Reach 9 and **At Risk** only in Reach 5, while all other reaches were given **Unacceptable** ratings due to low numbers of pieces of large and medium woody debris per mile and limited (or no) jams present in the reach. Canopy cover over the main channel was Unacceptable in Reaches 1 – 5 due to riparian clearing from residential and agricultural development. Reaches 6 and 7, though less developed, still only received **At Risk** rankings for canopy cover due to the legacy of timber harvests which has resulted in smaller, younger trees within the riparian zone. Bank Stability and Floodplain Connectivity indicators were similar, with Reaches 7, 8 and 9 receiving ratings of **Adequate** in both indicators. Reaches 3 and 5 were rated **At Risk**, and Reaches 1, 2, 4, and 6 were given **Unacceptable** ratings due to the number of human features and disturbances in those reaches.

For the study area as a whole, **Adequate** was the most common rating (38), followed by **Unacceptable** (31), then **At Risk** (30).

2 Metrics and Indicators

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Watershed Scale					
Watershed Condition	Effective Drainage Network and Watershed Road Density	Increase in Drainage Network/Road Density	Zero or minimum increases in active channel length correlated with human caused disturbance. Road density <1 miles/miles^2.	Low to moderate increase in active channel length correlated with human caused disturbances. Road density 1-2.4 miles/miles^2.	Greater than moderate increase in active channel length correlated with human caused disturbances. Road density >2.4 miles/miles^2.
	Disturbance Regime	Natural/Human Caused	Environmental disturbance is short-lived; predictable hydrograph, high quality habitat and watershed complexity providing refuge and rearing space for all life stages or multiple life-history forms. Natural processes are stable.	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 portion of the watershed. The channel is simplified, providing little hydraulic complexity in the form of pools or side channels. Natural processes are unstable.
Flow/Hydrology	Streamflow	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/or frequency of peak flows relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.	Pronounced changes in magnitude, timing, duration and/or frequency of peak flows relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.
Water Quality	Temperature	Daily maximum and 7-day mean maximum temperatures	Bull Trout: Incubation 2-5°C, rearing 4-10°C, spawning 1-9°C. Salmon and Steelhead: June-Sep t 15°C, Sept-May 12°C, rearing 15°C, migration 15°C, adult holding 15°C. OR 7-day daily maximum temperature performance standards: Salmon spawning 13°C, core summer salmonid habitat 16°C. Salmonid spawning, rearing and migration 17.5°C. Salmonid rearing and migration only 17.5°C.	MWMT in reach during the following life history stages: Incubation <2°C or <6°C; rearing <4°C or >13-15°C; spawning <4°C or >10°C. Temperatures in areas used by adults during the local spawning migration sometimes exceed 15°C. OR 7-day average daily maximum temperature standards are exceeded by ≤15%.	MWMT in reach during the following life history stages: Incubation <1°C or <6°C; rearing >15°C; spawning <4°C or >10°C. Temperatures in areas used by adults during the local spawning migration sometimes exceed 15°C. OR 7-day average daily maximum temperature standards are exceeded by ≤15%.
	Turbidity	Turbidity NTU's	Performance Standard: Acute <70 NTU, Chronic <50 NTU. For streams that naturally exceed these standards: Turbidity should not exceed natural baseline levels at the 95% CL <15% exceedance. OR Turbidity shall not exceed: 5 NTU over background when the background is 50 NTU or less; or a 10% increase in turbidity when the background turbidity is more than 50 NTU (WDOE 173-201A-200)	15-50% exceedance.	>50% exceedance.
	Chemical Contamination/ Nutrients	Metals/Pollutants, pH, DO, Nitrogen, Phosphorus	Low levels of chemical contamination from landuse sources, no excessive nutrients, no CWA 303d designated reaches. OR Washington State Department of Ecology standards 173-201A-200.	Moderate levels of chemical contamination from landuse sources, some excess nutrients, one CWA 303d designated reach.	High levels of chemical contamination from landuse sources, high levels of excess nutrients, more than one DWA 303d designated reach.

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Reach Scale					
Habitat Access	Physical Barriers	Main Channel Barriers	No man-made barriers present in the mainstem that limit upstream or downstream migration at any flow.	Man-made barriers present in the mainstem that prevent upstream or downstream migration at some flows that are biologically significant.	Man-made barriers present in the mainstem that prevent upstream or downstream migration at multiple or all flows.
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	Gravels or small cobbles make up >50% of the bed materials in spawning areas. ≤12%fines/sand (<2 mm) in spawning gravel.	Gravels or small cobbles make up 30-50% of the bed materials in spawning areas. 12-17% fines (<2 mm) in spawning gravel.	Gravels or small cobbles make up <30% of the bed materials in spawning areas. >17% fines (<2 mm) in spawning gravel.
	LWM	Pieces per Mile at Bankfull	>42.5 pieces/mile >12" diameter and >35 ft long (based on data from Fox and Bolton 2007); adequate sources of woody debris available for both long- and short-term recruitment. And, at least 4 jams/mile based on Reaches 5 and 9 as reference reaches for jam quantities.	Current levels are able to maintain the minimum requirements for an "adequate" rating, but potential sources for long-term woody debris recruitment, as determined by the Riparian Structure reach metrics, are lacking in order to maintain these current levels.	Current levels are not meeting the minimum requirements for an "adequate" rating, and potential sources of woody debris for short- and/or long-term recruitment are lacking as well.
	Pools	Pool Frequency and Quality; presence of large pools.	Pool frequency: Number of pools/mile for a given channel width. Channel widths were highly variable throughout the Upper Methow River, therefore channel width metrics of 65-100 ft = 4 pools/mile or 40-65ft = 9 pools/mile will be used to determine adequate conditions based on average bankfull widths in each reach. Reaches with average bankfull widths greater than 100 ft will be assessed using the 4 pools/mile metric. Pools must also have good cover and cool water with only a minor reduction in pool volume from fine sediment. Each adequate reach has many large pools >1 m (3 ft) deep with good fish cover.	Pool frequency is similar to the values for the "adequate" rating, but pools have inadequate cover/temperature and/or there has been a moderate reduction of pool volume by fine sediment. Reaches have few large pools (>1 m deep) present with good fish cover.	Pool frequency is considerably lower than the values for the "adequate" rating. Pools also have inadequate cover/temperature and there has been a major reduction of pool volume by fine sediment. Reaches have no large pools (>1 m deep) with good fish cover.
	Off-Channel Habitat	Connectivity with Main Channel	Reach has many ponds, oxbows, backwaters, and other off-channel areas with cover. Side channels are low energy areas. No man-made barriers present along the mainstem that prevent access to off-channel areas.	Reach has some ponds, oxbows, backwaters, and other off-channel areas with cover. Side channels are high energy areas. Man-made barriers are present that prevent access of off-channel habitat at some flows that are biologically significant.	Reach has few or no ponds, oxbows, backwaters, and other off-channel areas. Man-made barriers are present that prevent access to off-channel habitat at multiple or all flows.
Channel	Dynamics	Floodplain Connectivity	Floodplain areas are hydrologically linked to main channel within the context of the local process domain; overbank flows occur and maintain wetland functions, and riparian vegetation and succession. Naturally confined channels are considered adequate.	Reduced linkage of wetland, floodplains and riparian areas to main channel in reaches with historically strong connectivity; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function and riparian vegetation/succession.	Severe reduction in hydrologic connectivity between off-channel, wetland, floodplain, and riparian areas relative to historical connectivity; wetland extent drastically reduced and riparian vegetation/succession is altered significantly.

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
		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.
		Vertical Channel Stability	No measurable trend of aggradation or incision and no visible change in channel planform.	Measurable trend of aggradation of incision that has the potential to, but has not yet caused, disconnection of the floodplain or a visible change in channel planform (e.g. single thread to braided.)	Enough incision has occurred that the floodplain and off-channel habitat areas have been disconnected; or enough aggradation has occurred to create a visible change in channel planform (e.g. single thread to braided.)
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.
		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 miles/miles^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 miles/miles^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 miles/miles^2 road density in the floodplain.
		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.

3 REI Ratings

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

3.1 WATERSHED-SCALE RATINGS

General Characteristics	General Indicators	Specific Indicators	Rating	Discussion
Watershed Scale				
Watershed Condition	Effective Drainage Network and Watershed Road Density	Increase in Drainage Network/Road Density	Adequate Condition	Road density was calculated using USFS roads and Okanogan County roads shapefiles. Road density was calculated for the watershed area contributing to the study area as determined in the Streamstats online mapper application (USGS 2014). Areas of overlap in the data sets were removed to eliminate over overestimation of road density. A large portion of the watershed has little to no roads, and should therefore be given an Adequate rating, while other portions of the watershed, such as within the more populated area along the river and within the town of Mazama, have many roads and would likely have At Risk or Unacceptable ratings. Average road density for the entire contributing watershed was 0.57 miles/mile^2, which puts the study area within the Adequate category.
	Disturbance Regime	Natural/Human Caused	At Risk Condition	This disturbance history rating reflects historical accounts of riparian and hillslope timber harvest, mining, grazing, agriculture and roads and residential development. These activities have been shown to create channel instability and decrease the ability of the system to respond to natural disturbance regimes such as fire or flood. The watershed has a naturally frequent fire regime, annual snowmelt flooding and infrequent rain-on-snow floods, and active tributary alluvial fans. The channel has reduced complexity and floodplain connection, and is shown to be incising in some areas and aggrading in others. Furthermore, fire suppression within the basin has elevated the risk of potential catastrophic disturbance (e.g. stand-replacing fire) to the study area. Currently nearly all the watershed is within federal ownership and large portions of it are protected areas. Therefore, the likelihood of continuing disturbance other than from natural causes is low. However, the alterations from past human disturbance are still affecting the River (such as the lag between riparian timber harvest and in-stream LWD removal that takes many years for new trees to mature and fall into the river). The system is still recovering from these “press” disturbances that have a persistent and long-lasting impact. Based on this information, the Upper Methow receives a rating of At Risk.
Flow/Hydrology	Streamflow	Change in Peak/Base Flows	At Risk Condition	The hydrology of the watershed contributing to the Upper Methow study area on the Methow River is driven by a combination of precipitation and snowmelt. Annual snowmelt flooding in the spring and early summer, with infrequent rain-on-snow floods dominates the season streamflow pattern in the basin. Snowmelt runoff is primarily driven by changes in ambient air temperature, snowpack mass, and the elevation distribution of the season's snowpack. Peak runoff usually occurs from April through July, with the highest rates typically in late June. The Methow River typically returns to baseflow by late August. Low instream flows (sections that go subsurface leaving the riverbed dry during the late summer and early fall months) have been designated as water quality limited and placed on the 303(d) list by the state. Many of the land-use activities and channel alterations affecting the Methow River have been shown to change one or all of the above-mentioned attributes of peak flows in other basins. Climate change models indicate that rainfall is expected to increase one to two percent by 2040, and four percent by 2080 (e.g. Mote and Salanthe 2009) and likely result in an increase in winter stream flows, earlier and lower peak runoff, and lower summer baseflows. 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 effects of past watershed management, and the potential effects of climate change, this indicator is rated At Risk for the Upper Methow River.

Water Quality	Temperature	Daily maximum and 7-day mean daily maximum temperatures	Adequate Condition	Water quality in the upper Methow River is generally very good. It is classified as AA (extraordinary) by Washington Department of Ecology. Water temperatures in the lower portion of the study area can exceed the state water quality standards during the summer, while ice development in the winter has been recognized as a potential problem for juvenile salmonids in the mainstem Methow River.
	Turbidity	Turbidity NTU's	N/A	Data was unavailable.
	Chemical Contamination/ Nutrients	Metals/Pollutants, pH, DO, Nitrogen, Phosphorus	N/A	Data was unavailable.

3.2 REACH-SCALE RATINGS

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9
Habitat Access	Physical Barriers	Main Channel Barriers	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
			There are no anthropogenic barriers in the main channel in Reach 1.	There are no anthropogenic barriers in the main channel in Reach 2.	There are no anthropogenic barriers in the main channel in Reach 3.	There are no anthropogenic barriers in the main channel in Reach 4.	There are no anthropogenic barriers in the main channel in Reach 5.	There are no anthropogenic barriers in the main channel in Reach 6.	There are no anthropogenic barriers in the main channel in Reach 7.	There are no anthropogenic barriers in the main channel in Reach 8.	There are no anthropogenic barriers in the main channel in Reach 9.
Habitat Quality	Substrate	Dominant Substrate / Fine Sediment	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
			One pebble count: Gravel: 46% Cobble: 52% Sand: 2%	Two pebble counts: Gravel: 48% & 50% Cobble: 52% & 50% Sand: 0% & 1%	Two pebble counts: Gravel: 65% & 36% Cobble: 35% & 61% Sand: 0% & 1% Boulder: 2%	One pebble count: Gravel: 29% Cobble: 66% Sand: 0% Boulder: 5%	Three pebble counts: Gravel: 48% & 66% & 67% Cobble: 40% & 31% & 28% Sand = 9% & 2% & 5% Boulder: 3% & 1% & 0%	Two pebble counts: Gravel: 40% & 50% Cobble: 56% & 45% Sand: 1% & 3% Boulder: 3% & 2%	Two pebble counts: Gravel: 32% & 51% Cobble: 56% & 46% Sand: 5% & 0% Boulder: 6% & 4%	N/A	N/A
	LWM	Pieces per Mile at Bankfull	Unacceptable	Unacceptable	Unacceptable	Unacceptable	At Risk	Unacceptable	Unacceptable	Unacceptable	Adequate
			M+L pieces/mi = 2.5 Jams/mi = 0 Minimal availability of large wood for future recruitment.	M+L pieces/mi = 64.3 Jams/mi = 2.9 Moderate availability of large wood for future recruitment.	M+L pieces/mi = 76.3 Jams/mi = 3.1 Moderate availability of large wood for future recruitment.	M+L pieces/mi = 23.2 Jams/mi = 0.7 Limited availability of large wood for future recruitment.	M+L pieces/mi = 62.5 Jams/mi = 4.4 Moderate availability of large wood for future recruitment.	M+L pieces/mi = 48.3 Jams/mi 2.8 Moderate availability of large wood for future recruitment.	M+L pieces/mi = 68.4 Jams/mi = 3.8 Moderate-to-high availability of large wood for future recruitment.	M+L pieces/mi = 57.5 Jams/mi = 1.8 Moderate-to-high availability of large wood for future recruitment.	M+L pieces/mi = 110.2 Jams/mi = 4.5 Moderate availability of large wood for future recruitment.
	Pools	Pool Frequen-cy and Quality; presence of large pools.	Unacceptable	At Risk	At Risk	Unacceptable	Adequate	Adequate	At Risk	At Risk	Adequate
			Total Pools = 0 Pools/mi = 0 Pools > 3 ft = 0	Total Pools = 4 Pools/mi = 1.25 Pools > 3 ft = 3 Average residual pool depth: 5.4 ft Moderate pool shading and cover	Total Pools = 7 Pools/mi = 5.5 Pools > 3 ft = 7 Average residual pool depth: 5.8 ft Moderate pool shading and cover	Total Pools = 5 Pools/mi = 1.7 Pools > 3 ft = 5 Average residual pool depth: 4.9 ft Minimal pool shading and cover	Total Pools = 11 Pools/mi = 5.3 Pools > 3 ft = 9 Average residual pool depth: 4.5 ft Moderate pool shading and cover	Total Pools = 23 Pools/mi = 6.3 Pools > 3 ft = 14 Average residual pool depth: 4.2 ft Moderate pool shading and cover	Total Pools = 13 Pools/mi = 7.5 Pools > 3 ft = 7 Average residual pool depth: 3.4 ft Moderate pool shading and cover	Total Pools = 3 Pools/mi = 1.4 Pools > 3 ft = 2 Average residual pool depth: 4.7 ft Moderate pool shading and cover	Total Pools = 4 Pools/mi = 3 Pools > 3 ft = 3 Average residual pool depth: 4.1 ft Moderate pool shading and cover. This reach would not historically be expected to have many pools, therefore is Adequate.

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9
	Off-Channel Habitat	Connect-ivity with Main Channel	Unacceptable	Unacceptable	Unacceptable	At Risk	Adequate	At Risk	At Risk	Adequate	Adequate
			Total SC = 0 Fast water = 0 Slow water = 0 Cover = limited Is a naturally moderately confined channel, therefore would expect to have some, but not substantially greater amounts off-channel habitat.	Total SC = 9 Fast water = 4 Slow water = 5 Cover = limited Would expect to see more off-channel habitats in this reach. Artificial levees are blocking portions of floodplain and reducing connectivity.	Total SC = 4 Fast water = 3 Slow water = 1 Cover = limited Would expect to see more off-channel habitats in this reach. Artificial levees are blocking portions of floodplain and reducing connectivity.	Total SC = 4 Fast water = 2 Slow water =2 Cover = limited Would expect to have some, but not substantially greater amounts off-channel habitat due to natural moderate confinement.	Total SC = 7 Fast water = 0 Slow water = 7 Cover = moderate-adequate Would expect to have greater amounts off-channel habitat. Artificial levees are blocking portions of the floodplain at the upstream end of this reach.	Total SC = 8 Fast water = 1 Slow water = 7 Cover = moderate Naturally unconfined channel. Historically more side channels would be expected in this reach. Residential building has disconnected floodplain and secondary channel features.	Total SC = 7 Fast water = 5 Slow water = 2 Cover = moderate Historically more side channels, especially slow-moving channels, would be expected in this reach. Residential building has disconnected the floodplain and secondary channel features.	Total SC = 4 Fast water = 2 Slow water = 2 Cover = moderate-adequate Naturally confined channel in some locations. Few human alterations in this reach. Channel is adequately meeting its off-channel habitat potential.	Total SC = 4 Fast water = 2 Slow water = 2 Cover = moderate-adequate Naturally confined channel. Few human alterations in this reach. Channel is adequately meeting its off-channel habitat potential.
Riparian Vegetat-ion	Condition	Structure	Unacceptable	Unacceptable	At Risk	Unacceptable	At Risk	At Risk	At Risk	At Risk	Adequate
			100% small tree Seral stage - should see more patches of mature trees Species composition is lacking- only Cottonwood was observed Structural complexity is unacceptable, historically more mature trees would have been present.	100% small tree Seral stage - should see more patches of mature trees Species composition is adequate- Dogwood, Cottonwood, and willow were observed. Structural complexity is unacceptable, historically more mature trees would have been present.	75% small tree 25% grass/forb Seral stage - should see more patches of mature trees. Species composition is at risk. Ponderosa pine was observed as the primary overstory within the riparian area, indicating hydrological changes. Cottonwood was observed in both the overstory and understory, as well as grassland/forbs in the understory.	100% small tree Seral stage - should see more patches of mature trees. Species composition is at risk, due to the riparian zone being primarily Ponderosa Pine with some Western Red Cedar. Understory species such as dogwood were observed.	67% small tree 33% sapling/pole Seral stage - should see more patches of mature trees. Species composition is adequate- the overstory was entirely cottonwood which the understory consisted of snowberry, mountain maple, dogwood, and various grasses/forbs.	78% small tree 11% sapling/pole 11% large tree Seral stage – Though there are patches of larger trees in the riparian area, historically there would have been greater amounts of mature Cottonwoods, Douglas Fir, and Ponderosa Pine, which would contribute to a healthier structural complexity. Species composition is at risk.	40% small tree 20% sapling/pole 40% shrub/seedling Seral stage – The riparian zone is relatively young. Historically there would have been patches of larger, mature trees in this reach. Species composition is at risk, with overstory vegetation being primarily cottonwood and some large dogwood, while understory was snowberry,	100% small tree Seral stage – should include more patches of mature trees. The legacy of timber harvest has affected age classes in the riparian zone. Species composition is adequate, with Douglas fir and Western Red Cedar being primary overstory vegetation, while snowberry, mountain maple, and dogwood were the main understory species.	100% small tree Seral stage and species composition – though there should be more mature trees in this reach, the recent fire and avalanche (natural disturbances) have affected the seral stages present in this reach. The species composition of a Douglas fir overstory and manzanita/dogwood understory was also affected by the fire. This reach is still given an adequate ranking despite not

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9
					Structural complexity is unacceptable.				mountain maple, dogwood and grasses/forbs.		meeting the criteria, largely because the fire and avalanche are natural regimes that occur on the landscape.
		Disturb-ance (Human)	At Risk	At Risk	Unacceptable	Unacceptable	At Risk	Unacceptable	At Risk	At Risk	Adequate
			Disturbed low surfaces = 3.04% Road Density = 1.07 miles/miles2 Minimal-moderate amounts of medium-large trees within the riparian buffer available for recruitment of the river via channel migration. Much smaller and fewer patches than historically would be expected.	Disturbed low surfaces = 26.13% Road Density = 2.75 miles/miles2 Minimal medium-large trees in the riparian buffer available, except in a couple locations between RMs 63-64, for recruitment of the river via channel migration. Much smaller and fewer patches than historically would be expected.	Disturbed low surfaces = 44.65% Road Density = 2.56 miles/miles2 Almost no medium-large trees in the riparian buffer are available for recruitment of the river via channel migration. Historically much larger trees would have been present.	Disturbed low surfaces = 23.89% Road Density = 0.33 miles/miles2 Minimal amounts of medium-large trees in the riparian buffer available for recruitment of the river via channel migration. Historically much larger trees would have been present.	Disturbed low surfaces = 33.32% Road Density = 3.86 miles/miles2 Minimal-moderate amounts of medium trees in the riparian buffer available for recruitment of the river via channel migration. Historically much larger trees would have been present.	Disturbed low surfaces = 27.10% Road Density = 4.02 miles/miles2 Moderate amounts of medium-large trees in the riparian buffer are available for recruitment in the middle of this reach, although residential uses along the river have minimized much of the larger and more mature trees that would have been present historically.	Disturbed low surfaces = 18.38% Road Density = 0.95 miles/miles2 Minimal amounts of medium-large trees in the riparian buffer available for recruitment of the river via channel migration. Historically much larger trees would have been present.	Disturbed low surfaces = 4.18% Road Density = 1.32 miles/miles2 Minimal amounts of medium-large trees in the riparian buffer are available for recruitment. Historically much larger trees would have been present. The natural fire disturbance can be attributed to some of this, therefore this reach is only given an At Risk rating.	Disturbed low surfaces = 0% Road Density = 0 miles/miles2 Moderate amounts of medium-large trees in the riparian buffer are available for recruitment. Historically much larger trees would have been present. The natural fire and avalanche disturbances can be attributed to some of this, therefore this reach is given an Adequate rating.
		Canopy Cover	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	At Risk	At Risk	Adequate	Adequate
			Canopy Cover = 15% Portions of the main channel and a majority of the off-channel habitat have more thermal shading	Canopy Cover = 20% Large trees on river right between RMs 62.75and 63.25 provide moderate canopy cover and	Canopy Cover = 20% The trees atop a steep bank along river right contribute to increased thermal shading. However,	Canopy Cover = 10% A large portion of the river banks are cleared and graded, providing no thermal shading. Very few	Canopy Cover = 20% Portions of the river banks are cleared and graded, providing minimal to no thermal shading	Canopy Cover = 30% Portions of the main channel have no canopy cover or shading, while other sections (where there are	Canopy Cover = 25% Channel width decreases in this reach that is above the confluence with Lost River. There	Canopy Cover = 90% The channel is much smaller and more naturally confined with steep river bank walls in this reach	Canopy Cover = 60% There are fewer cleared areas along the banks due to residential or agricultural purposes, though

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9
			from canopy cover. Stream and banks highly visible at several portions of the reach. Other residential or agricultural clearing and the relatively young seral stage of riparian vegetation results in minimal thermal shading of the reach. Goat Creek Cut-off adjacent to the channel on river left near RM 61.7 provides no shading to that portion of the stream.	thermal shading. However, the stream channel and banks are highly visible at several portions of the reach. Other residential or agricultural clearing and the relatively young seral stage of riparian vegetation results in minimal thermal shading of the reach.	the road adjacent to the river along most of this reach limits canopy cover potential. River left has been thinned and cleared limiting shading of the channel. Stream and banks are highly visible along a majority of the reach.	large trees line the river where there is forest still left. Other residential or agricultural clearing and the relatively young seral stage of riparian vegetation results in minimal thermal shading of the reach.	on the river channel. Very few large trees line the river banks where they have not been cleared. This relatively young seral stage of riparian trees provides little thermal shading from canopy cover over the main channel of the reach. Secondary channels have somewhat more shading and cover.	taller trees in the riparian areas) such as near RM 72.8 or RM 73.5, have up to 50% canopy cover. Secondary channels have somewhat more shading and cover throughout the reach also. Some residential or agricultural clearing along the banks contributes to the low canopy cover and shading of the main channel.	are fewer cleared areas along the banks due to residential or agricultural purposes, though the legacy of timber harvests along the riparian area has resulted in smaller, younger trees providing less shade and cover along the main channel than would have been found historically. Secondary channels are more shaded and have higher canopy cover percentages than the main channel.	than downstream, resulting in more natural shading and cover. There are no cleared areas along the banks due to residential or agricultural purposes, though the legacy of timber harvests along the riparian area has resulted in somewhat smaller, younger trees providing less shade and cover along the main channel than would have been found historically. Secondary channels are more shaded and have higher canopy cover percentages than the main channel.	the legacy of timber harvests along the riparian area has resulted in smaller, younger trees providing less shade and cover along the main channel than would have been found historically. Additinally, the natural disturbances of fire and avalanche has resulted in temporarily lower canopy cover and thermal shading. This reach still receives a rating of Adequate, due to the natural causes of the reduced cover and shading. Secondary channels also are more shaded and have higher canopy cover percentages than the main channel.
Channel	Dynamics	Flood-plain Connect-ivity	Unacceptable	Unacceptable	At Risk	Unacceptable	At Risk	Unacceptable	Adequate	Adequate	Adequate
			The Weeman Bridge and its associated approach fill at the downstream end of the reach interrupts floodplain flow paths and concentrates flow into the channel. Other areas of bank armoring and levees also affect	This reach is naturally unconfined and has a large floodplain. In addition to the high road density in the floodplain, the residential and agricultural features along the banks of the channel have restricted substantial natural	The road adjacent to the channel on river right for a majority of the reach restricts any potential floodplain activity. Levees and riprap have been used throughout the reach to prevent floodplain activation into agricultural and residential areas,	The bridge and associated bank armoring at RM 67.2 near Mazama reduces connectivity with the floodplain by interrupting floodplain flow paths and concentrating flow in the channel. Occasional other push up levees,	There are several riprap or levee features in this reach, though they do not disconnect the floodplain very substantially. They occur near the upstream end of the reach primarily. Road embankments along the river channel and	There is significant riprap and levees along the channel in this reach. Additionally, a large number of roads are present in the floodplain that restrict floodplain activation throughout the reach, primarily on river left. Due to	This reach is has few instances of human features in the floodplain that could restrict connectivity with the channel. Therefore, this reach is given an Adequate rating.	This reach is naturally laterally constricted by terraces and hillslopes on both sides of the channel and has little natural floodplain throughout the entire reach.	This reach is naturally laterally constricted by terraces and hillslopes on both sides of the channel and has little natural floodplain throughout the entire reach.

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9
			floodplain connectivity.	floodplain activity, particularly on the river right floodplain where high-value habitat is present, resulting in an Unacceptable rating.	particularly on river left. Due to a relatively high road density in the floodplain, this reach is given an At Risk rating.	armored banks, and the floodplain gravel pit in the river-left floodplain at the downstream end of the reach all affect floodplain inundation rates and patterns.	secondary channels also disconnect the floodplain from the channel on river left. Due to these features, the channel is disconnected along portions of this reach, giving it an At Risk rating.	the high density of human features, the channel is substantially cut off from the floodplain and is therefore given an Unacceptable rating.			
		Bank Stability/ Channel Migration	Unacceptable	Unacceptable	At Risk	Unacceptable	At Risk	Unacceptable	Adequate	Adequate	Adequate
			This reach has some natural lateral constriction but occasional riprap and the Weeman Bridge constriction affect bank condition and channel migration processes significantly in these areas.	Between RM 62.5 and RM 63.25 the channel is naturally active and has recently avulsed resulting in the main channel straightening and a side channel/oxbow located in the historic main channel. RM 63.8 upstream to the end of the reach is naturally active and migrates frequently. The residential and agricultural features along the banks of the channel have restricted substantial natural migration activity, particularly on the river right floodplain where high-value habitat is present, resulting in an Unacceptable rating.	The road adjacent to the channel on river right for a majority of the reach restricts any potential migration activity. Levees and riprap have been used throughout the reach to prevent channel migration into agricultural and residential areas, particularly on river left where historical channel migration activity occurred.	The bridge at RM 67.2 near Mazama constrains lateral channel migration. Houses, roads, and other development along the banks also serve to impact bank conditions and channel migration rates. This reach is therefore given an Unaccptable rating.	There are a few instances of riprap or levees protecting houses and private property in this reach. These occur near the upstream end of the reach, between RM 70.75-71.25 primarily. Road embankments along the river channel and secondary channels also limit migration near RM 70 on river right and near RMs 71 and 71.25 on river left. Due to these human features, the channel is migrating below natural rates for this reach and is therefore given an At Risk rating.	There are a number of instances of riprap or levees protecting houses and private property in this reach. Additionally, roads built in the floodplain contribute to restricted migration of the channel throughout the reach, primarily on river left. Due to these human features, the channel is migrating significantly below natural rates for this reach and is therefore given an Unacceptable rating.	This reach is moderately unconfined, and there are few instances of human features in the floodplain that could restrict channel migration activity. Therefore, this reach is given an Adequate rating.	This reach is naturally laterally constricted by terraces and hillslopes on both sides of the channel throughout the entire reach. Historic channel location has not moved considerably, therefore the rate of channel migration has not changed substantially.	This reach is naturally laterally constricted by terraces and hillslopes on both sides of the channel throughout the entire reach. Historic channel location has not moved significantly.

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9
		Vertical Channel Stability	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	Adequate	Adequate	Adequate
			Subtle channel bed incision and reduced floodplain connectivity due to channel confinement by riprap, bridge abutments, and levees. Modern alluvial terrace development at the downstream section of the reach.	Reduced channel sinuosity with a high potential for incision and reduced floodplain connectivity due to channel confinement by dikes, riprap, and levees.	Channel bed incision and reduced floodplain connectivity due to channel confinement by levees and riprap. High potential for continued incision processes in this reach.	Subtle channel bed incision resulting in reduced active floodplain connectivity, and alluvial terrace development.	Subtle channel bed incision resulting in reduced active floodplain connectivity, and alluvial terrace development.	Reduced channel sinuosity with some potential for incision and reduced floodplain connectivity due to channel confinement by riprap, and levees.	No measurable trend of aggradation or incision and no visible change in channel planform.	No measurable trend of aggradation or incision and no visible change in channel planform.	No measurable trend of aggradation or incision and no visible change in channel planform.

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Appendix C

Project Opportunities and Prioritization

Upper Methow River Reach Assessment

December 2015

This table describes project opportunities by project area. Locator maps of the project opportunities are included below the table.

Reach	Project RM	Project Name	Project Description	Considerations
9	No Projects Identified			Well-functioning reach with high instream and off-channel complexity. Recent disturbance contributing abundant large wood.
8		Ballard Project	**Narrative** This project would remove push up levees and bank armoring (much of it naturally sourced) and activate river-left side-channels and floodplain adjacent to the US Forest Service campground. This is a fairly small project, and there are potential impacts to the campground (e.g. erosion potential) that would need to be further evaluated. **Project Elements** • RM 76.7 – 76.85 river-left: Remove push-up levees and bank armoring at campground • RM 76.6 – 76.85 river-left: Enhance side-channel connectivity and habitat at Ballard Campground. Add log jam in mainstem to enhance flow in side-channel. Add wood to side-channel complex. Riparian revegetation in campground area.	Erosion risk at campground would need to be evaluated and addressed (if necessary) as part of this project. Wood placements need to account for potential river recreational uses.
7		Robinson Project	**Narrative** The Robinson Project includes primarily the use of apex jams and debris capture structures designed to build stable log jams, encourage the establishment of vegetated islands, and enhance lateral channel complexity and split flow conditions. Apex jams could be constructed in select areas and combined with targeted excavation to activate specific side-channels and floodplain areas. Debris capture jams, which consist of partially buried logs angled upstream, would have high effectiveness here given the large amount of woody material that is expected to be transported into this reach from upstream over the next decade. They could be located in areas where mid-channel bars are currently forming but where the lack of structure results in these features being very transient and not able to support vegetation establishment. This project would address the lack of large channel structure in this reach. Although total instream large wood frequency is high, much of the wood is small and incapable of providing the key pieces necessary to form large stable jams. In addition, much of the riparian forest is relatively young and will not be able to provide effective key pieces for many decades. On the south side of the channel at the downstream end of the reach, there is a need for riparian planting in a cleared floodplain area and the opportunity to enhance channel margin complexity using large wood complexes along the unvegetated eroding bank at this location. **Project Elements** • RM 76.3: Large key pieces to capture upstream wood • RM 76.3: Mainstem log jams to help activate river-left floodplain surface • RM 76 – 76.5: Jams or large key pieces to initiate jams and capture upstream large wood that will be coming down. Use jams to help initiate broad river-left surface and side-channels in several locations. • RM 76.1: Apex jam to initiate river-right side channel • RM 75.9 – 76.0 river-right: Jams to capture wood and increase lateral channel dynamic, particularly to increase erosion toward the south. • RM 75.7 – 75.8 river-left: Apex jam and river-right LW catchers to activate river-left side-channel complex. • RM 75.75 river-right: Riparian revegetation and addition of margin complexity along eroding unvegetated bank. • RM 75.7 river-left: Add jams in mainstem to activate river-left side-channel at lower flows	Very little infrastructure at risk. Wood placements need to account for potential river recreational uses.

Reach	Project RM	Project Name	Project Description	Considerations
7		Two Rivers Project	**Narrative** The Two Rivers Project includes the reconnection of side-channels in the river-right floodplain via removal of a push-up levee, construction of apex log jams, and potentially select excavation within the side-channel alignment. The push-up levee is approximately 130 feet long and three feet tall and could be graded back into the floodplain. The primary side-channel to be reconnected is 2,400 feet long and joins back to the Methow River just downstream of the Lost River confluence in Reach 6. There is another side-channel upstream that could potentially connect into the main side-channel. This upstream side-channel is approximately 1,000 feet long. The connectivity of this side-channel would also be enhanced by removal of the levee, which is at the downstream end. Construction of an apex log jam and select excavation at the entrance would further enhance connectivity. **Project Elements** • RM 75.6 river-right: add apex jam and mainstem LW capture jam to initiate river-right side-channel • RM 75.4 river-right: remove push-up levee to reconnect 2,400-ft long river-right side-channel • Entire project area: Main channel jams including LW capture jams to capture LW and form stable, vegetated, mid-channel islands and split flow. Place jams strategically to encourage erosion into banks with mature forests and to discourage erosion into banks with young forest.	Very little infrastructure at risk. Wood placements need to account for potential river recreational uses.
6		Lost River Project	**Narrative** The Lost River Project includes several interrelated components. At the upstream end of the reach, there is the opportunity to re-activate a side-channel that begins on the river-left side of lower Lost River and that empties into the mainstem Methow below the confluence. This would be accomplished by construction of an apex jam and select excavation within the side-channel. The project also includes addressing the effects of riprap and levees at the Lost River community. Assuming these features will need to remain in place, enhancement could include the placement of meander jams along the bank to improve margin habitat and encourage flow away from these feature and toward valley-right. This could be paired with apex jams and select excavation to increase the activation of the river-right side-channel complexes across from the Lost River community. The main area for this work is at the upstream end of the reach from RM 74.7 to 74.95, with an additional area at RM 74.4. At RM 74.25, there is left-bank riprap that could possibly be removed, and margin jams placed to provide habitat and stability until newly planted riparian vegetation can become established. A floodplain canal that empties back into the river at this location could be improved as a connected alcove or groundwater-fed channel. Downstream of this (RM 73.65 to 74.2), treatments include mainstem jams to capture large wood, build stable vegetated islands, and enhance overall lateral complexity; similar to what was identified and discussed as part of the Robinson Project in Reach 7. There is also a river-right side-channel complex that could be enhanced using apex jams and select excavation to increase flow connectivity. **Project Elements** • RM 74.9: Side-channel reconnection and enhancement on river-left of Lost River. Use apex jam at upstream end and select excavation. • RM 74.7 – 74.9: Margin jams along riprap to enhance margin habitat and encourage flow to valley-right away from riprap. • RM 74.7 – 74.9: Address levee through here if possible • RM 74.9 – 75.0: Apex jams on river-right to activate right bank side channels • RM 74.65 – 75.0: Apex jams listed above, and select excavation can be used to increate the connectivity of the river-right side-channel complexes. At the downstream end, near RM 74.65, this could also be enhanced as a connected backwater/wall-based channel. • RM 74.35: Margin jams on river-left along existing riprap and existing large pool for cover and to enhance margin habitat. Apex jam on river-right to enhance split-flow condition and protect young forest stand on island • RM 74.25: Replace riprap on river-left with margin jams. Convert existing floodplain canal into a connected alcove or groundwater-fed channel feature. • RM 74.0 – 74.2 river-left: Margin complexity jams on river-left to enhance pools and margin habitat • RM 73.75 – 74.15: Apex jams and select excavation on river-right to activate river-right side-channel complex. • RM 73.65 river-right: Create alcove or groundwater-fed (wall-based) channel. • RM 73.7 – 74.0: Main channel LW capture jams to capture wood and form apex log jams to encourage split flow and development of stable vegetated island features. • Riparian restoration is identified over a broad area encompassing much of the Lost River Community where there has been clearing of riparian and floodplain vegetation. Look for opportunities to work with landowners to improve vegetation and floodplain hydraulic roughness conditions through this area.	Lost River Community including houses and other private infrastructure needs to be evaluated for erosion and flooding risk associated with restoration measures. Working near the Lost River alluvial fan could be challenging given high degree of dynamic delta conditions (i.e. high sediment loads, shifting channel positions). Portions of this project area go dry at low flows. This potentially makes construction easy but may impact the benefits accrued by certain project elements. Wood placements need to account for potential river recreational uses.

Reach	Project RM	Project Name	Project Description	Considerations
6		Cedarosa Project	**Narrative** The primary element of the Cedarosa Project is addressing the floodplain disconnection created by the floodplain drainage canal in the river-left floodplain near RM 73.5. Removing or selectively breaching this feature could help re-establish surface flow into several floodplain side-channels; however, flood risk to houses in this area would need to be addressed. There is also the potential for placement of log jams and LW capture structures in the main channel to increase the frequency of large stable jam features. There are a few opportunities for reconnection or enhancement of side-channels and off-channels through jam placement and select excavation, and one area where riprap removal could enhance connectivity to alcove habitat. **Project Elements** • RM 73.5 valley-left: Address floodplain and side-channel disconnection created by floodplain canal that diverts flow from floodplain back to river. Evaluate the potential for removing or altering this feature to improve surface flow connection to the side-channels. Potentially remove canal and levee feature, enhance flow through the side-channel network, and provide structure protection more local to individual residences. • RM 73.4 river-left: Potentially create a connected alcove or groundwater-fed off-channel feature in canal close to where it connects with the mainstem. Remove levees at downstream end of canal and other push-up levee parallel to channel in this area. • RM 73.0 – 73.4: Main channel jams including LW capture jams to capture LW and form stable, vegetated, mid-channel islands and split flow; margin complexity jams to increase cover and complexity in existing pools; and a meander jam to divert flow off of riprap bank and improve channel margin, pool scour, and complexity. • RM 73.0 – 73.2 river-left: Remove upstream extent of riprap bank and open up backwater channel or even flow-through side-channel. • RM 73.0 river-left: Look for opportunities to address channel migration and floodplain disconnection created by riprap bank and levee. • RM 72.3 – 72.9: Main channel jams including LW capture jams to capture LW and form stable, vegetated, mid-channel islands and split flow; targeted apex jams and select excavation to increase the degree of activation of side-channel complex on river-right. • RM 72.4 river-left: There is good groundwater return flow here. Perhaps develop into a groundwater-fed channel. Or at the least, enhance the surface water connectivity to the existing off-channel pond. • RM 72.3 river-left: Enhance off-channel areas at downstream end of where long valley-left side-channels re-enter. Excavate to enhance surface water connectivity, access, and extent of available habitat. • Riparian restoration is identified at a few locations along river-left where there has been clearing of riparian and floodplain areas.	Houses and private lands in the Cedarosa area. Houses on river-left near RM 73.0. Portions of this project area go dry at low flows. This potentially makes construction easy but may impact the benefits accrued by certain project elements. Wood placements need to account for potential river recreational uses.
6		Gate Creek Project	**Narrative** The Gate Creek Project includes in-channel jam structures as described above for the other projects. Jams could be strategically placed to encourage erosion into banks with mature forests and to discourage erosion into banks with young forest. This project also includes structures to deflect flow away from the Lost River Road embankment at two locations where the river runs along the road. There are also some opportunities to enhance existing backwater alcove habitat and tributary confluence habitat around the confluence of Gate Creek. **Project Elements** • RM 72.2 river-right: Side-channel enhancement; backwater alcove or groundwater-fed channel reconnection. • RM 71.9 to 71.2 river-left: Meander jams along road embankment to enhance margin and allow for the creation of a riparian buffer. Add wood to existing backwater habitat and to lower Gate Creek. Add margin complexity on bank upstream of backwater complex to enhance margin complexity and cover in existing pool. • RM 71.45 – 71.55 river-left: Meander jams along road embankment to enhance margin and allow for the creation of a riparian buffer. • Entire project area: Main channel jams including LW capture jams to capture LW and form stable, vegetated, mid-channel islands and split flow; margin complexity jams to increase cover and complexity in existing pools. Place jams strategically to encourage erosion into banks with mature forests and to discourage erosion into banks with young forest.	Lost River Road abuts the channel on river-left. Erosion and flooding risk to the road will need to be considered. Portions of this project area go dry at low flows. This potentially makes construction easy but may impact the benefits accrued by certain project elements. Wood placements need to account for potential river recreational uses.

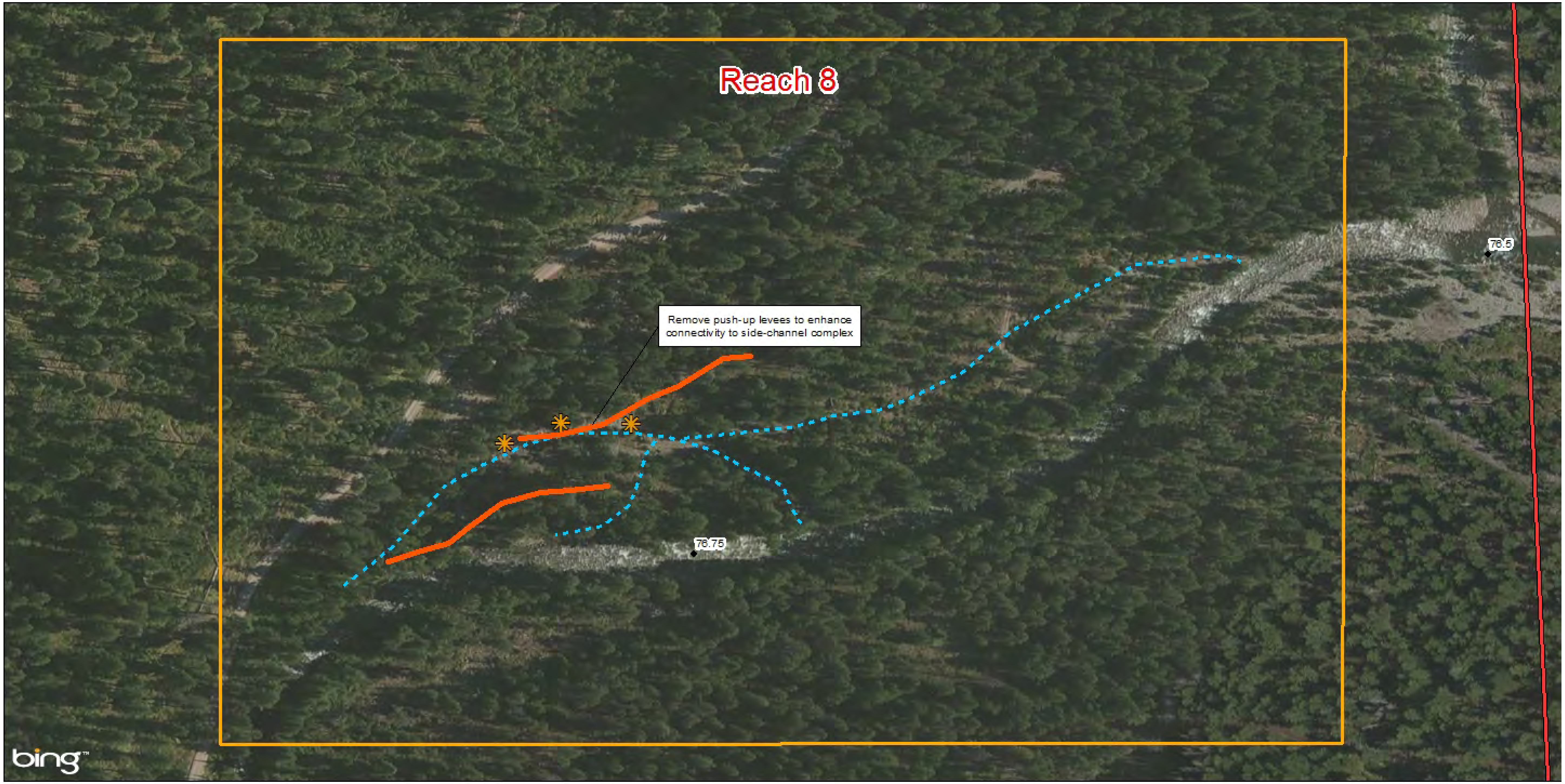
Reach	Project RM	Project Name	Project Description	Considerations
5		Goat Wall Project	**Narrative** There are two primary components of the Goat Wall Project. One is to improve the connectivity and habitat of the existing side-channel network in the river-right floodplain. There are a few push-up levees that could be removed to improve connectivity, as well as placement of apex log jams and select excavation at numerous potential inlet locations. Large wood for habitat complexity could be added throughout the length of the side-channel and could potentially be combined with pool creation. The other component of this project is addressing impairment to floodplain and riparian function on river-left at the downstream end of the reach. This area has cleared agricultural land and poor, rapidly eroding channel margin habitat. Work here would include channel margin jams to curtail the rapid erosion until planted riparian vegetation can mature and provide long-term natural stability. There is also some potential off-channel work in this area and an abundant amount of riparian revegetation potential. **Project Elements** • RM 70.5 – 71.3 river-right: Increase the activation and connectivity of the river-right side-channel complex. Use apex jams and select excavation to increase flow into side-channel complex. Remove existing push-up levees, some of which obstruct flow into side-channels. Enhance existing side-channel using large wood placements and exacavation of pools. • RM 70.25 – 70.75 river-left: Address impairments associated with ag and residential development on river-left. Use combinations of apex jams and bank margin jams to shift flow toward valley-right. Use smaller complexity jams to enhance channel margin complexity in numerous areas where there are currently bare eroding banks. Perform riparian vegetation enhancement along river-left. • RM 70.55 – 70.85 river-left: There are 2 opportunities for off-channel enhancement, including potential alcove and/or groundwater-fed channels. • RM 70.5 river-right: LW capture jams in primary side-channel in order to encourage more erosion into river-right bank that is composed of mature forest where beneficial recruitment would occur. • Riparian restoration is identified throughout the reach where there has been clearing of riparian or floodplain areas. For high bank areas on glacial terraces, the recommended riparian buffer width is narrower than on lower bank riparian areas in well-connected floodplains.	Houses and other infrastructure along banks and in floodplain/CMZ Lost River Road abuts the channel on river-left. Erosion risk to the road will need to be considered. Portions of this project area go dry at low flows. This potentially makes construction easy but may impact the benefits accrued by certain project elements. Wood placements need to account for potential river recreational uses.
5		A-Wall Project	**Narrative** The A-Wall Project includes in-channel wood work throughout, mostly debris capture jams that would be designed to capture the fluvial-transported wood that is expected to enter this reach from upstream over the next couple of decades. There is also some select side-channel work, including enhancing existing oxbow wetland habitat and enhancing connectivity to side-channels and wall-based channels. **Project Elements** • RM 69.85 river-right: Enhance existing floodplain depression as a wall-based groundwater-fed channel. • RM 69.65 river-left: Enhance existing abandoned oxbow and connector channel by adding large wood and potentially using select excavation to enhance fish passage. Possibly could extend backwater complex into other floodplain channel scars that connect to existing oxbow. Perform riparian restoration where land has been cleared near the outlet of the oxbow channel. • RM 69.55 – 69.75 river-right: Enhance connecivitity of river-right side-channel through select excavation and possibly through enhancing the existing apex jam at the upstream end. • Entire project area: Main channel jams including LW capture jams to capture LW and form stable, vegetated, mid-channel islands and split flow; margin complexity jams to increase cover and complexity in existing pools. Place jams strategically to encourage erosion into banks with mature forests and to discourage erosion into banks with young forest.	Houses and other infrastructure along banks and in floodplain/CMZ Wood placements need to account for potential river recreational uses.

Reach	Project RM	Project Name	Project Description	Considerations
4		Upper Mazama Project	**Narrative** The Upper Mazama Project includes primarily in-channel large wood work, both apex jams to increase lateral channel dynamics/floodplain connectivity as well as complexity jams along the channel margin to increase local pool scour and cover. There is one location near the upstream end on the left bank where larger channel margin jams could be used to address poor margin habitat and rapid erosion into a high unvegeted bank with a house on top. There are also a few locations where there may be potential for enhancing side-channel connectivity through placement of apex jams and select excavation. There are numerous opportunities for riparian revegetation. **Project Elements** • RM 68.75 river-left: Large meander bend jams to shift flow energy away from glacial terrace with house on top and toward the more well-connected floodplain surface on river-right. • RM 68.25 (river-right), 68.8 (river-left), and 67.5 (river-left): These are potential side-channel, wall-based channel, or alcove enhancement areas that warrant further evaluation for enhancement. They may require select excavation and/or placement of apex jams to re-connect them at lower flow levels. • Entire project area: Main channel jams including bar apex jams to form stable, vegetated, mid-channel islands and to capture LW; and margin complexity jams to increase cover and complexity in existing pools. Place jams strategically to encourage erosion into banks with mature forests and to discourage erosion into banks with young forest. Complexity jams should be designed to enhance local cover and complexity, not to limit bank erosion. Larger meander jams will limit erosion for the near-term and will shift flow energy away from the bank. These are used where infrastructure is at risk or where it is desired to shift flow away from the bank to improve habitat or channel processes. • Riparian restoration is identified throughout the reach where there has been clearing of riparian or floodplain areas. For high bank areas on glacial terraces, the recommended riparian buffer width is narrower than on lower bank riparian areas in well-connected floodplains.	Downstream bridge (Mazama Bridge) Houses and other infrastructure along banks and in floodplain/CMZ Wood placements need to account for potential river recreational uses.
4		Lower Mazama Project	**Narrative** The Lower Mazama Project includes in-channel wood work throughout, except at the upstream end where there are already two large bar apex jams. There is also work proposed within the existing high flow channel on river-left midway through the project area. This side-channel is affected by riparian clearing and push-up levees. Where possible, these levees could be removed, riparian areas replanted, and complexity jams placed along channel margins. At the downstream end in the river-left floodplain, there is a gravel pit and cleared floodplain. This site should be evaluated for potential reconnection and enhancement. There are numerous opportunities for riparian revegetation throughout the project area. **Project Elements** • RM 66.35 – 66.75 river-left: Enhance existing high-flow side-channel. Apex jam at upstream end to encourage split flow into side-channel. Remove push-up levees where possible within side-channel. Add channel margin complexity jams to areas where levees removed and other areas to enhance local pool scour, cover, and complexity in an otherwise uniform non-complex channel. • RM 66.25 river-left: Look for opportunities to reconnect and restore the area of the floodplain gravel pit. This may be challening given the mining history here and current uses, but would nevertheless be worth investigating further as it represents a considerable amount of former floodplain and potential off-channel habitat that is currently disconnected from the river. • Entire project area: Main channel jams including bar apex jams to form stable, vegetated, mid-channel islands and to capture LW; and margin complexity jams to increase cover and complexity in existing pools. Place jams strategically to encourage erosion into banks with mature forests and to discourage erosion into banks with young forest. Complexity jams should be designed to enhance local cover and complexity, not to limit bank erosion. • Riparian restoration is identified throughout the reach where there has been clearing of riparian or floodplain areas. For high bank areas on glacial terraces, the recommended riparian buffer width is narrower than on lower bank riparian areas in well-connected floodplains.	Upstream bridge (Mazama Bridge) Houses and other infrastructure along banks and in floodplain/CMZ Wood placements need to account for potential river recreational uses.

Reach	Project RM	Project Name	Project Description	Considerations
3		Goat Creek Project	**Narrative** The Goat Creek Project spans an area of stark contrasts with respect to channel complexity and structure. The upper portion is highly uniform and impacted by human infrastructure, whereas the lower portion, where the channel is working through bedload material contributed by the Goat Creek and Little Boulder Creek fans, is highly complex, full of wood, and very dynamic. No significant work in this lower section is recommended, as it is mainly an area that should be targeted for protection, including a highly-functioning side-channel in the river-right floodplain (RM 64.4 – 65). The river-left floodplain could also be targeted for protection through acquisitions or easements in order to prevent any future development or clearing. At the upstream portion of the project area, there is the opportunity to remove push-up levees, install mid-channel apex jams, install bank complexity jams, and conduct riparian restoration in cleared areas. The proximity of the road in this location will need to be considered. **Project Elements** • RM 65.85 – 66.2 river-right: Reconnect right-bank side-channel either as flow-through (with apex jam at top end) or as wall-based groundwater-fed channel at downstream end. Use select excavation and wood placements in channel. • RM 65.85 – 66.1 river-left: Great opportunity to remove two locations of levees and bank armoring. Replace with channel margin jams. • RM 65.35 – 65.6: Remove left-bank push-up levees (although there are mature trees on usptream levee that may not be worth disturbing), add margin complexity jams along bank where levees removed, add apex jams for mid-channel complexity and to develop split-flow, and riparian restoration. • Entire project area: Use of bar apex jams are described above as part of those elements. There are also many locations for potential channel margin complexity jams to create local pool scour and to increase cover and complexity in existing pools. Complexity jams should be designed to enhance local cover and complexity, not to limit bank erosion. • Riparian restoration is identified throughout the reach where there has been clearing of riparian or floodplain areas. • Protection is identified for the lower 1/3 of the reach where there are active lateral channel dynamics and abundant large wood. The river-left floodplain should be protected from development and clearing. The downstream river-right floodplain has high quality side-channel habitat that should be protected.	Hwy 20 is close to the river in a few locations and needs to be taken into consideration with respect to potential impacts from restoration treatments. Houses and other infrastructure along banks and in floodplain/CMZ Wood placements need to account for potential river recreational uses.
2		Trail Bridge Project	**Narrative** The Trail Bridge Project encompasses the area above and below the community trail bridge. This is a long segment of uniform planebed channel (slightly incised) that would benefit from apex jams and bank complexity jams to capture wood, create mid-channel vegetated islands, and promote lateral channel dynamics. For the most part, there is great opportunity to increase channel conditions and floodplain connectivity using log jams without much infrastructure or property at risk. There is also some off-channel reconnection and enhancement potential on river-left at the downstream end of the project area. **Project Elements** • RM 63.85 – 64.6: Apex jams to build off of existing processes of mid-channel bar formation to protect vegetation growth on bars and promote the development of vegetated islands and split flow. Also to trap fluvial-transported wood from upstream. This is an otherwise highly uniform, moderately incised segment with very scarce large wood. Also add bank margin jams to increase margin habitat and roughness. • RM 63.85 river-left: Enhance connectivity to existing oxbow wetland and beaver pond habitat. Sediment deposits are currently filling in channel and likely obstruct passage at low flows. Excavate to improve access to beaver pond habitat. Add wood for cover and complexity in oxbow wetlands. • Entire project area: Use of bar apex jams are described above as part of those elements. There are also many locations for potential channel margin complexity jams to create local pool scour and to increase cover and complexity in existing pools. Complexity jams are designed to enhance local cover and complexity, not to limit bank erosion.	The ski trail and trail bridge need to be taken into consideration with respect to potential impacts from restoration treatments. Wood placements need to account for potential river recreational uses.

Reach	Project RM	Project Name	Project Description	Considerations
2		Fawn Creek Project	**Narrative** The Fawn Creek Project likely represents the greatest restoration opportunity in the study area. There is an extensive disconnected side-channel complex in the river-right floodplain. The primary human feature obstructing connectivity is the complex of levees and bank armoring from RM 63.35 – 63.7, including the 1,600 foot long engineered levee that makes up a portion of the community trail. There are also numerous other earthern berms cutting off side-channels at various locations. The main levee obstructs the entrance to a 4,700-ft long disconnected side-channel, which easily constitutes the greatest off-channel habitat impairment in the entire Reach Assessment study area. This area has been the target of past restoration planning, but nothing has yet been implemented. The entire area warrants further site evaluation to determine how to reconnect and enhance critical side-channel habitat while continuing to support other human uses and infrastructure including the trail network. In addition to the main disconnected side-channel area, there are a few other side-channel reconnection and enhancement opportunities as well as the potential to enhance main channel lateral channel dynamics and complexity using apex log jams and bank complexity jams. There are also numerous opportunities for riparian revegetation throughout the project area. **Project Elements** • RM 62.45 – 64.0 river-right: There is an extensive disconnected side-channel complex in the river-right floodplain. The primary human feature obstructing connectivity is the complex of levees and bank armoring from RM 63.35 – 63.7, including the 1,600 foot long engineered levee that makes up a portion of the cross-country ski trail. There are also numerous other earthern berms cutting off side-channels at various locations. The main levee obstructs the entrance to a 4,700-ft long disconnected side-channel, which easily constitutes the greatest off-channel habitat impairment in the entire Reach Assessment study area. This area has been the target of past restoration planning, but nothing has yet been implemented. The entire area warrants further site evaluation to determine how to reconnect and enhance critical side-channel habitat while continuing to support other human uses and infrastructure including the trail network. • RM 63.0 river-left: Excavate accumulated sediment and remove check dams to reconnect oxbow wetland habitat. Remove downstream portion of riprap bank (does not appear necessary). Remove existing bank barbs and replace with a series (~3) channel margin log jams to enhance channel margin complexity and to create pool scour for habitat and to maintain connectivity to oxbow. • RM 62.5 river-right: If connection to this channel is not possible from the upstream end (best) then enhance existing backwater habitat here at the outlet using large wood and pool excavation. It may also be possible to reconnect and bring flow in from just upstream using existing floodplain channel scars. • Entire project area: Main channel jams including bar apex jams to form stable, vegetated, mid-channel islands and to capture LW; and margin complexity jams to increase cover and complexity in existing pools. Place jams strategically to encourage erosion into banks with mature forests and to discourage erosion into banks with young forest. Complexity jams should be designed to enhance local cover and complexity, not to limit bank erosion. • Riparian restoration is identified throughout the reach where there has been clearing of riparian or floodplain areas.	Cross-country ski trail lies atop levee system near RM 63.5. Levee may also provide protection to land to the south. There are several houses near the river that are protected with riprap. Potential effects of restoration treatments near these locations need to be considered. Wood placements need to account for potential river recreational uses.

Reach	Project RM	Project Name	Project Description	Considerations
1-2		Weeman Project	**Narrative** The Weeman Project spans Reach 1 and a portion of Reach 2. The portion in Reach 2 includes some good opportunities to enhance habitat within, and connectivity to, existing side-channel and oxbow wetland habitat. A couple of instances of cleared and rapidly eroding banks could be revegetated and enhanced with wood placed along the channel margin. At the downstream end of the reach, there is the opportunity to remove some failing riprap and push-up levees that appear to no longer be serving any protective purpose. In-channel log jam work is identified throughout to enhance lateral channel dynamics and the establishment of vegetated mid-channel island features. **Project Elements** • RM 62.25 river-left: Enhance connectivity to and habitat within existing oxbow wetland. Remove check dams, use select excavation, and add wood. • RM 62.1 river-right: Reconnect side-channel and education. This is a well-functioning side-channel that contains groundwater inputs and hyporheic flow but has small human-built check-dams that disconnect the channel during low flow (chin spawning). Remove check-dams and install educational sign for the campground (Rolling huts campground). • RM 61.75 river-right: Remove intermittent riprap and push-up levee that has partially failed. Add bank margin jams for complexity. • RM 61.7 river-left: Reconnect groundwater-fed wall-based alcove channel by modifying riprap at outlet, select excavation, and adding wood for habitat and to maintain scour at the outlet. • RM 61.25 river-right: Place channel margin jams on right bank upstream of bridge and river access to halt erosion toward highway and enhance channel margin habitat prior to this bank becoming armored by Dept of Transportation. • Entire project area: Main channel jams including bar apex jams to form stable, vegetated, mid-channel islands and to capture LW; and margin complexity jams to increase cover and complexity in existing pools. Place jams strategically to encourage erosion into banks with mature forests and to discourage erosion into banks with young forest. Complexity jams should be designed to enhance local cover and complexity, not to limit bank erosion. • Riparian restoration is identified throughout the reach where there has been clearing of riparian or floodplain areas.	Goat Creek Road, which is close to the river in two locations, and Weeman Bridge/Hwy 20 (downstream end) need to be taken into consideration with respect to potential impacts from restoration treatments. Houses and other infrastructure along banks and in floodplain/CMZ Wood placements need to account for potential river recreational uses.



Upper Methow Reach Assessment
Project Opportunities
Ballard Project

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

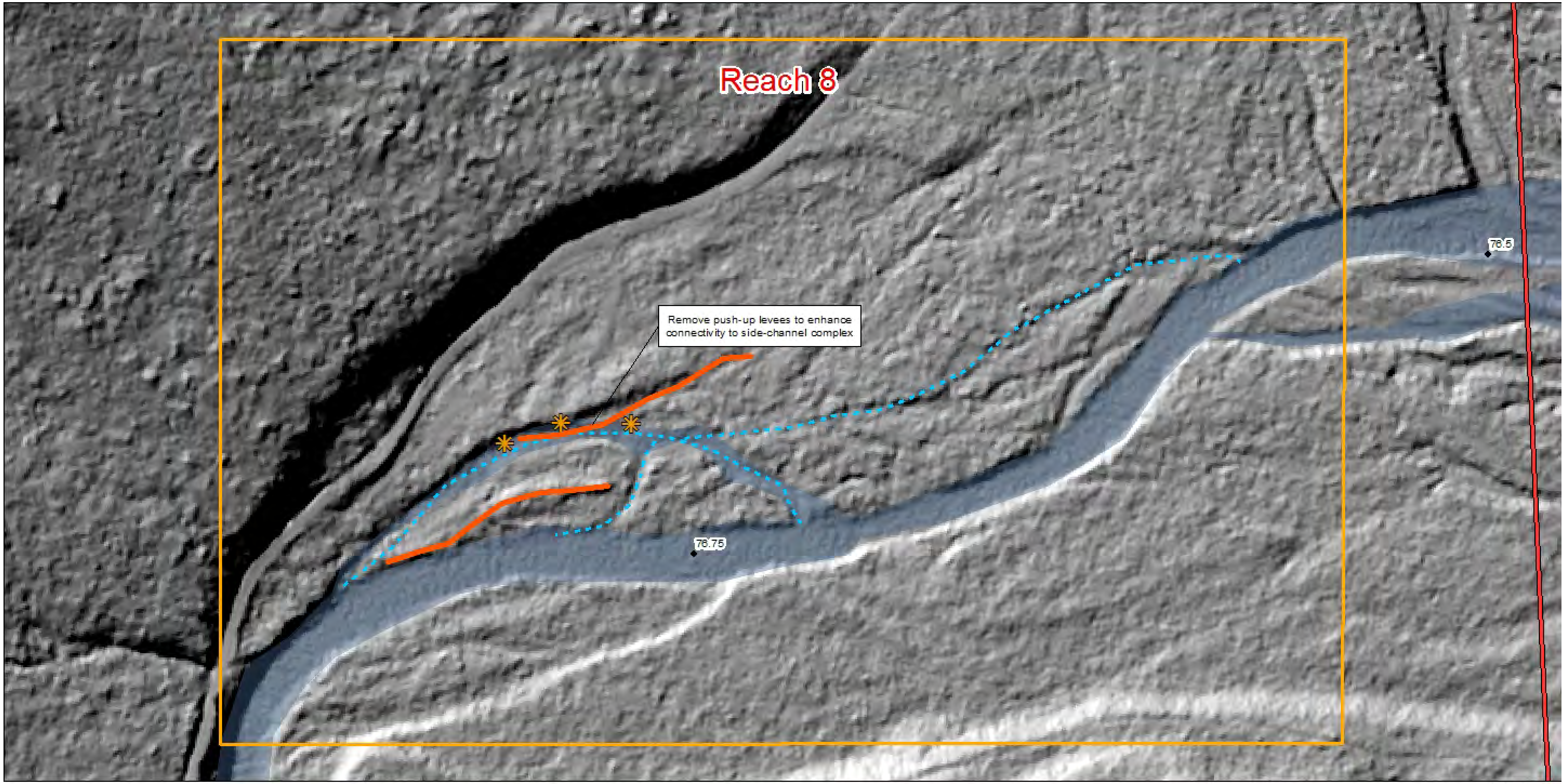
Project elements
- Large wood margin complexity
- Enhance side-channel connectivity
- Riparian revegetation

Bridge
Riprap
Levee
Dam
Canal

Recent Bing Aerial Image

0 100 200 400 Feet

N

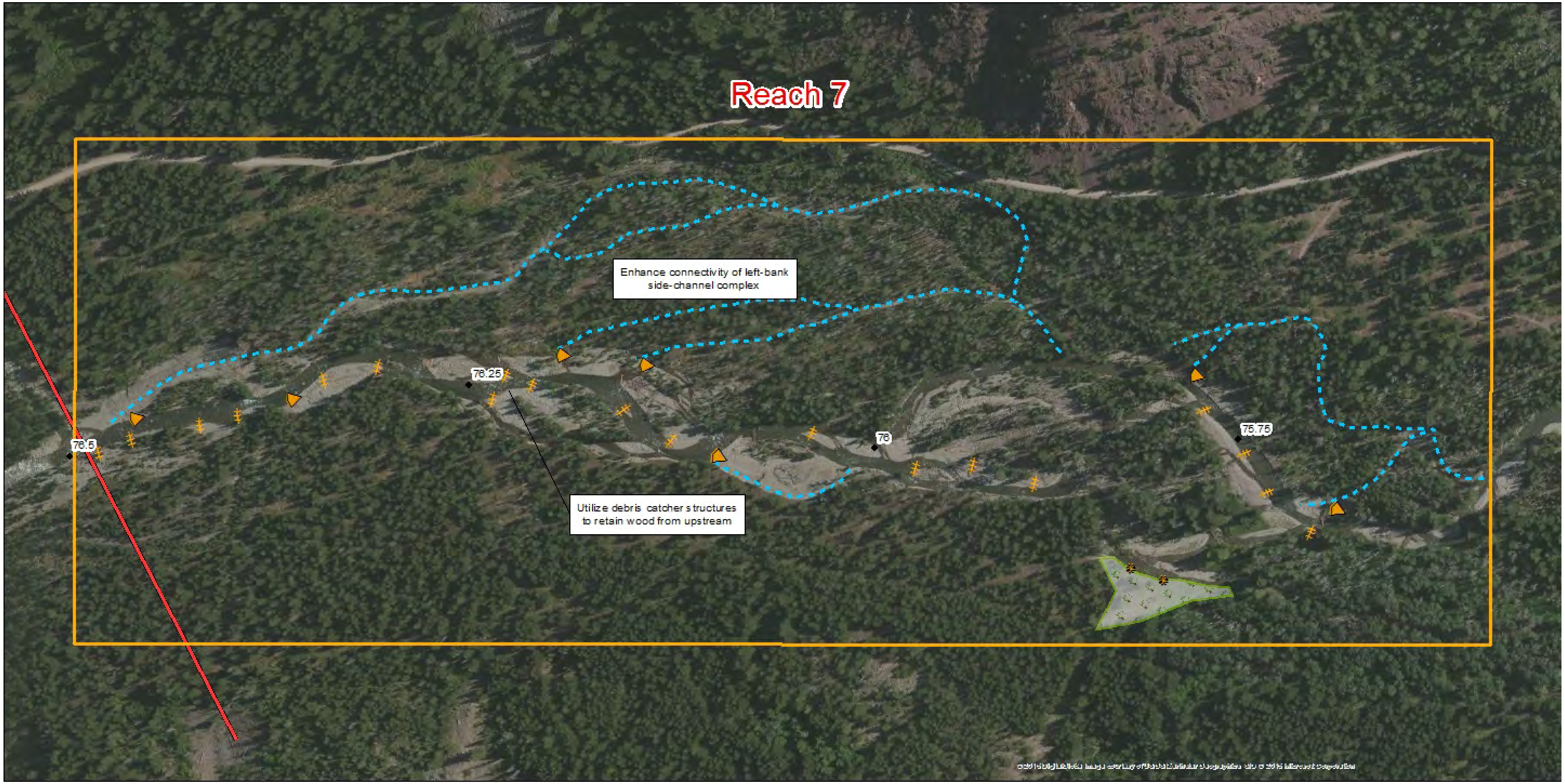


Upper Methow Reach Assessment

Project Opportunities

Ballard Project

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



Upper Methow Reach Assessment

Project Opportunities

Robinson Project

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

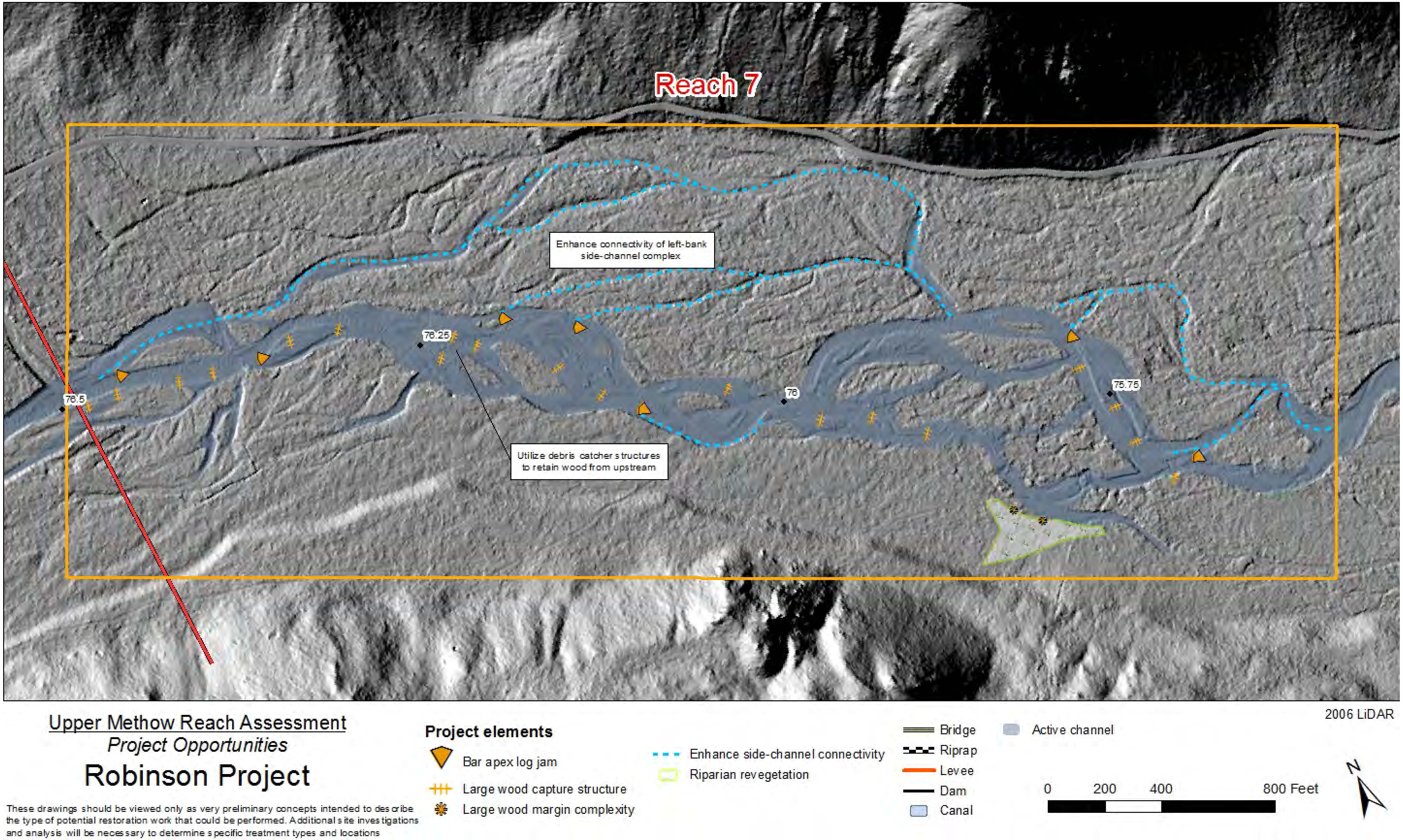
Project elements

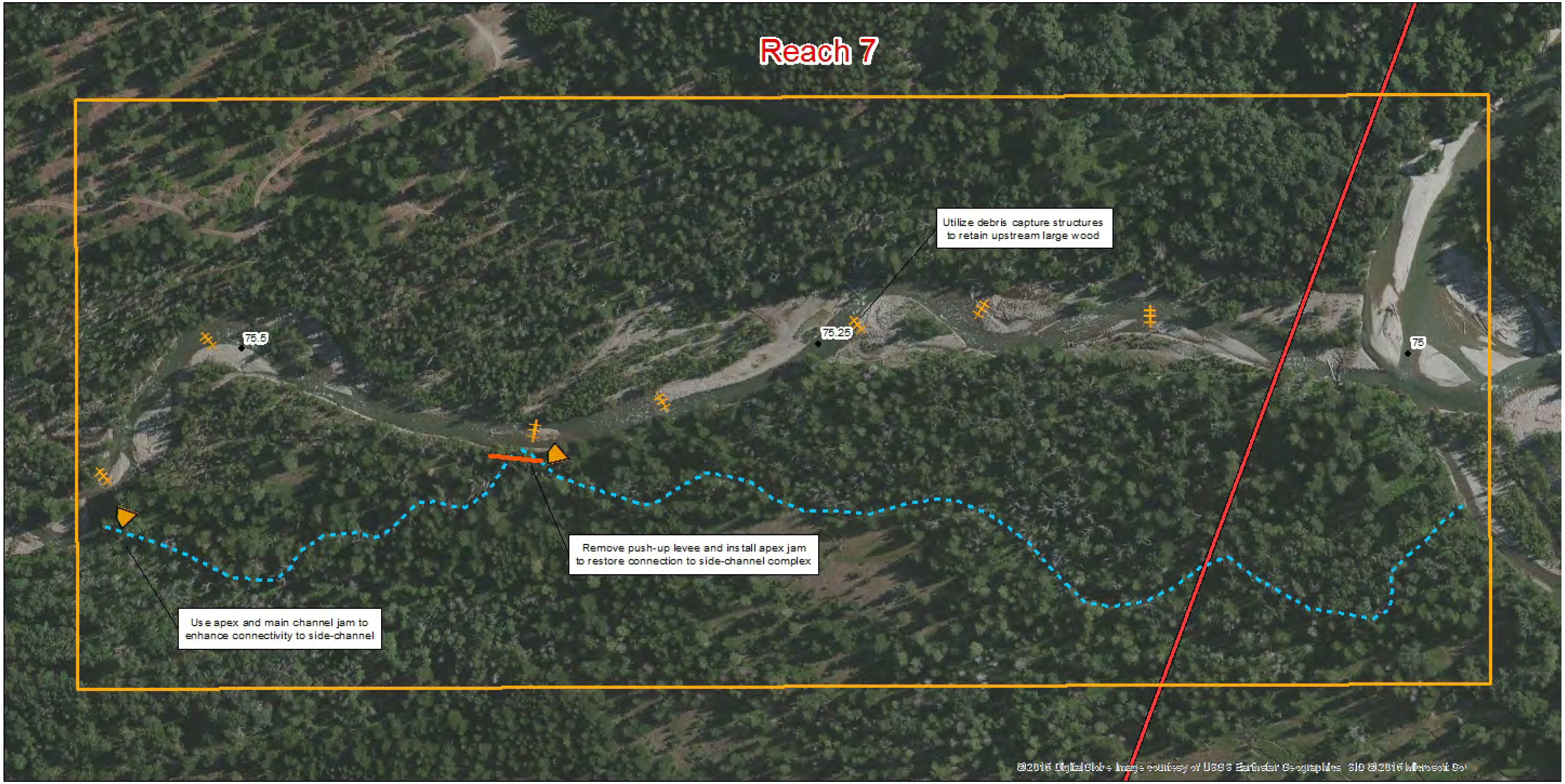
- Bar apex log jam
- Large wood capture structure
- Large wood margin complexity
- Enhance side-channel connectivity
- Riparian revegetation
- Bridge
- Riprap
- Levee
- Dam
- Canal

Recent Bing Aerial Image

0 200 400 800 Feet

N


Reach 7
Enhance connectivity of left-bank side-channel complex
Utilize debris catcher structures to retain wood from upstream
76.5
76.25
76
75.75
2006 LiDAR
Upper Methow Reach Assessment
Project Opportunities
Robinson Project
These drawings should be viewed only as very preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations
Project elements
Bar apex log jam
Large wood capture structure
Large wood margin complexity
Enhance side-channel connectivity
Riparian revegetation
Bridge
Riprap
Levee
Dam
Canal
Active channel
0
200
400
800 Feet
N



Upper Methow Reach Assessment

Project Opportunities

Two Rivers Project

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

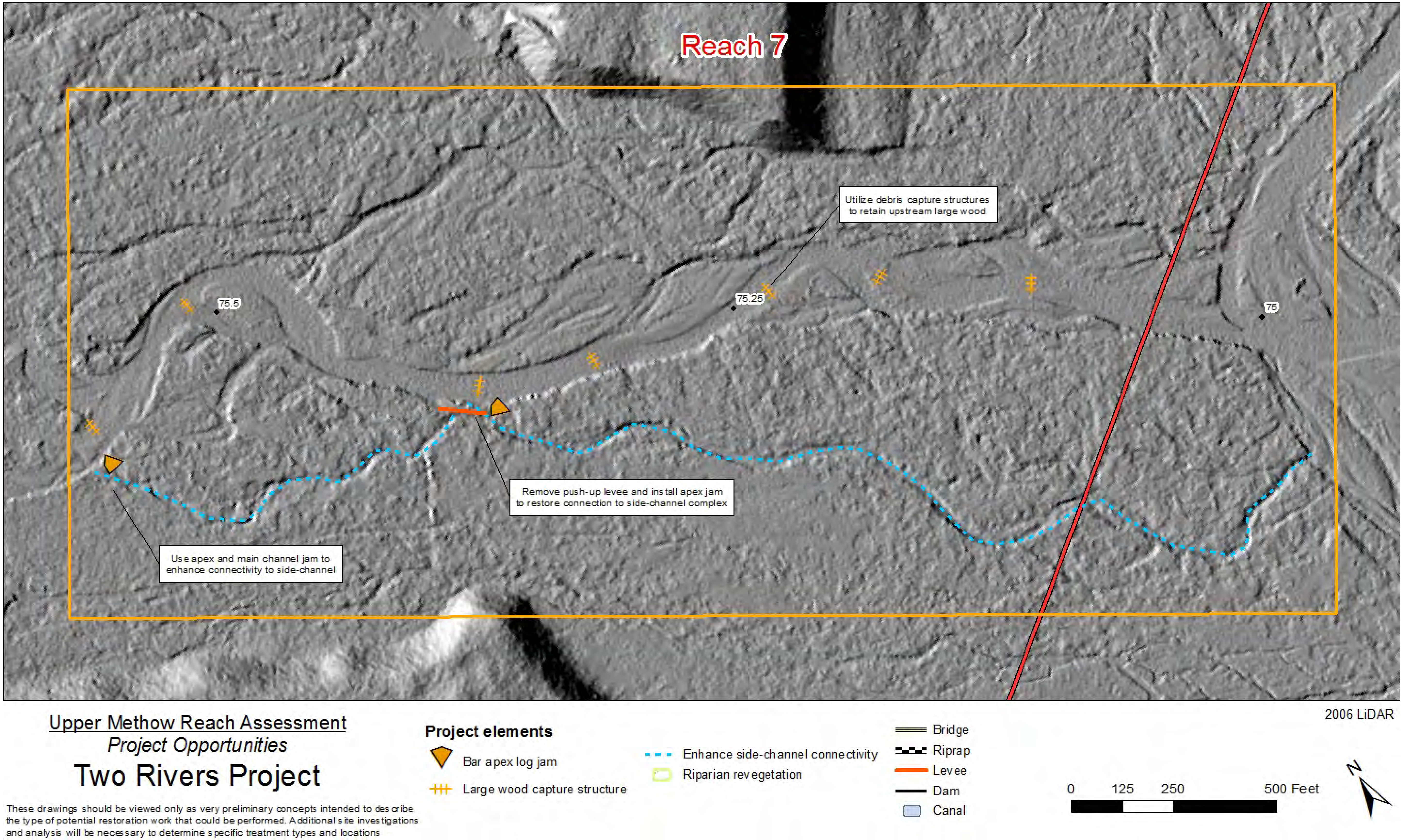
Project elements

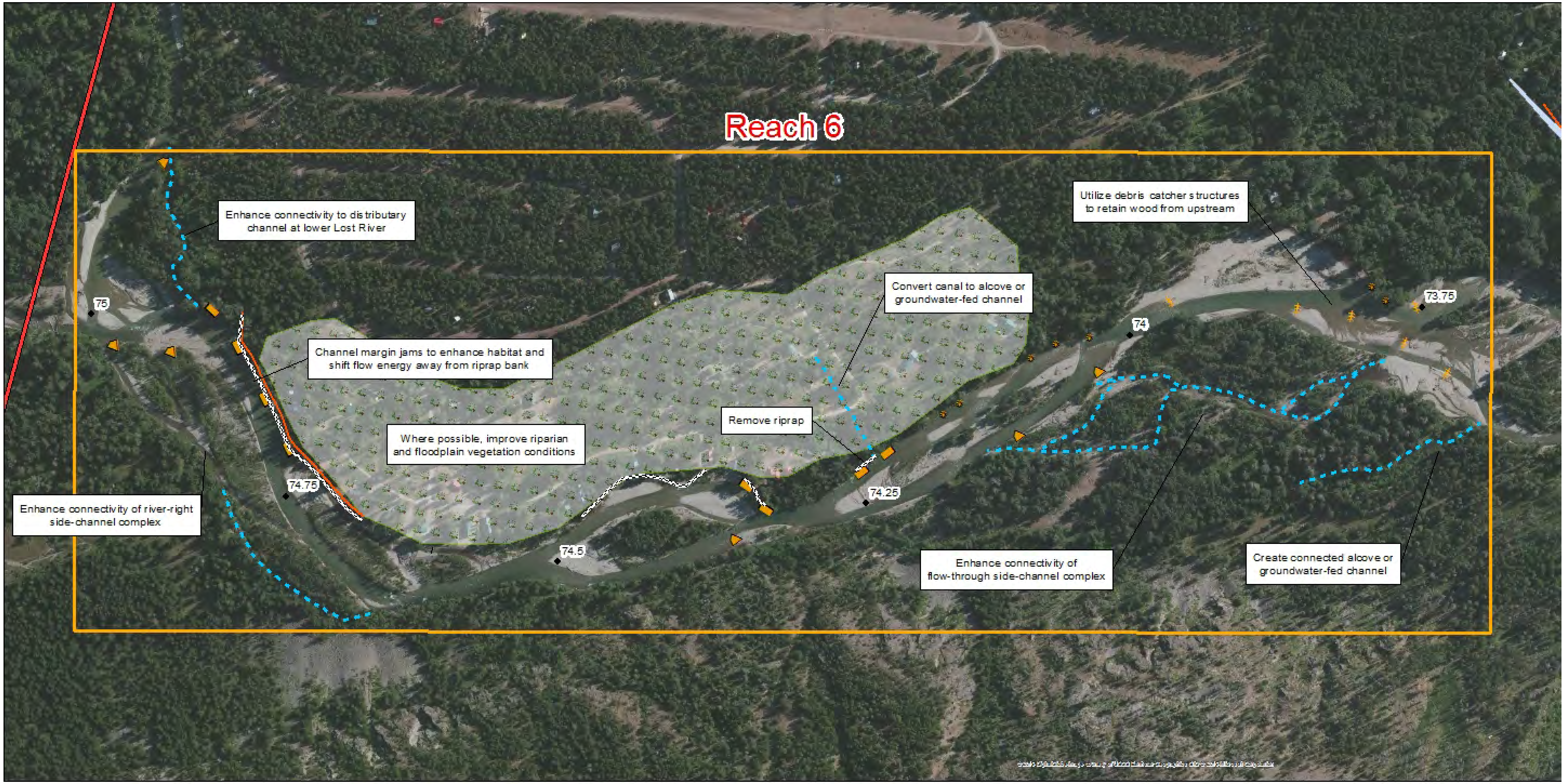
- Bar apex log jam
- Large wood capture structure
- Enhance side-channel connectivity
- Riparian revegetation
- Bridge
- Riprap
- Levee
- Dam
- Canal

Recent Bing Aerial Image

0 125 250 500 Feet

N


Reach 7
Utilize debris capture structures to retain upstream large wood
75.5
75.25
75
Remove push-up levee and install apex jam to restore connection to side-channel complex
Use apex and main channel jam to enhance connectivity to side-channel
2006 LiDAR
Upper Methow Reach Assessment
Project Opportunities
Two Rivers Project
These drawings should be viewed only as very preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations
Project elements
Bar apex log jam
Large wood capture structure
Enhance side-channel connectivity
Riparian revegetation
Bridge
Riprap
Levee
Dam
Canal
0 125 250 500 Feet
N



Upper Methow Reach Assessment

Project Opportunities

Lost River Project

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

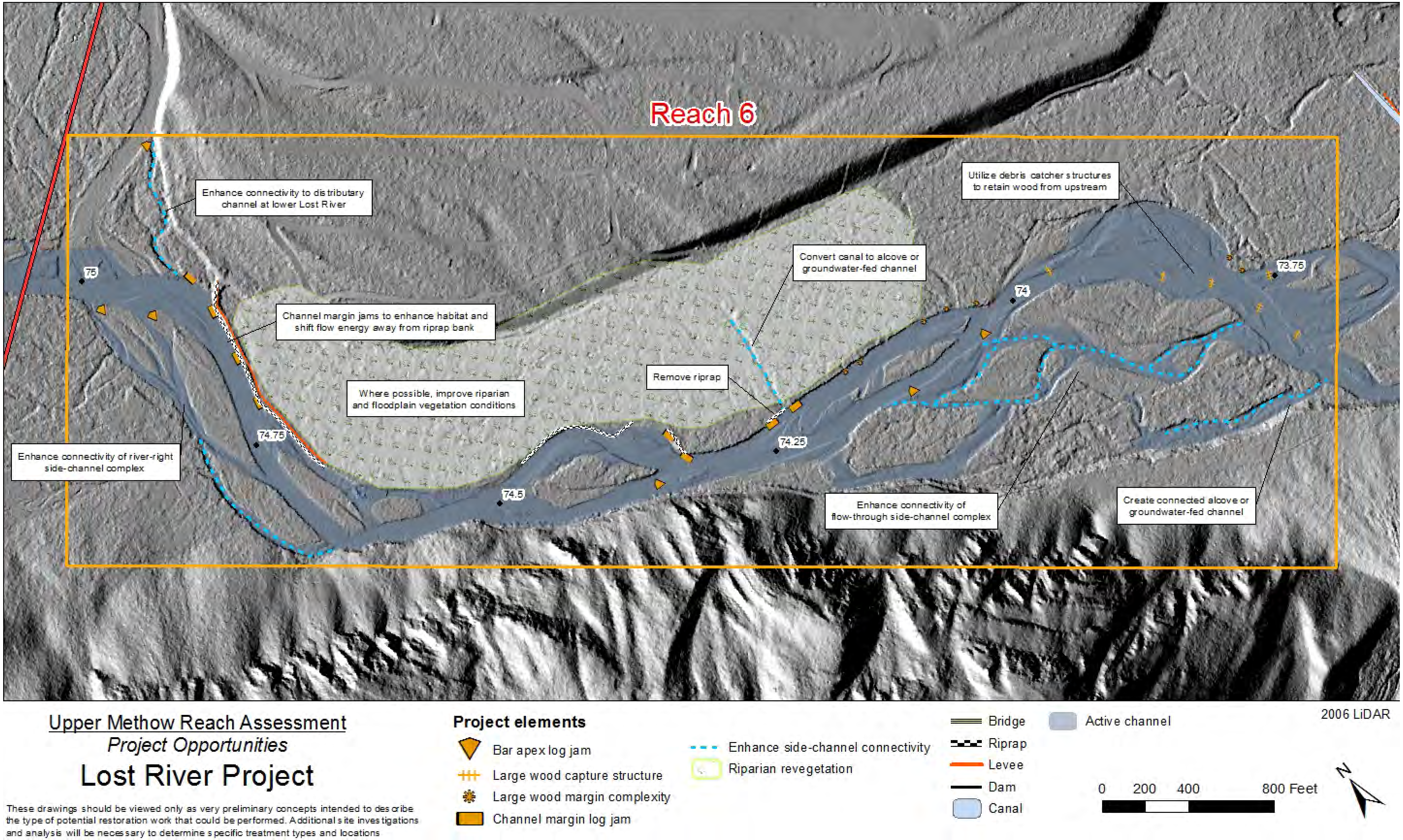
Project elements

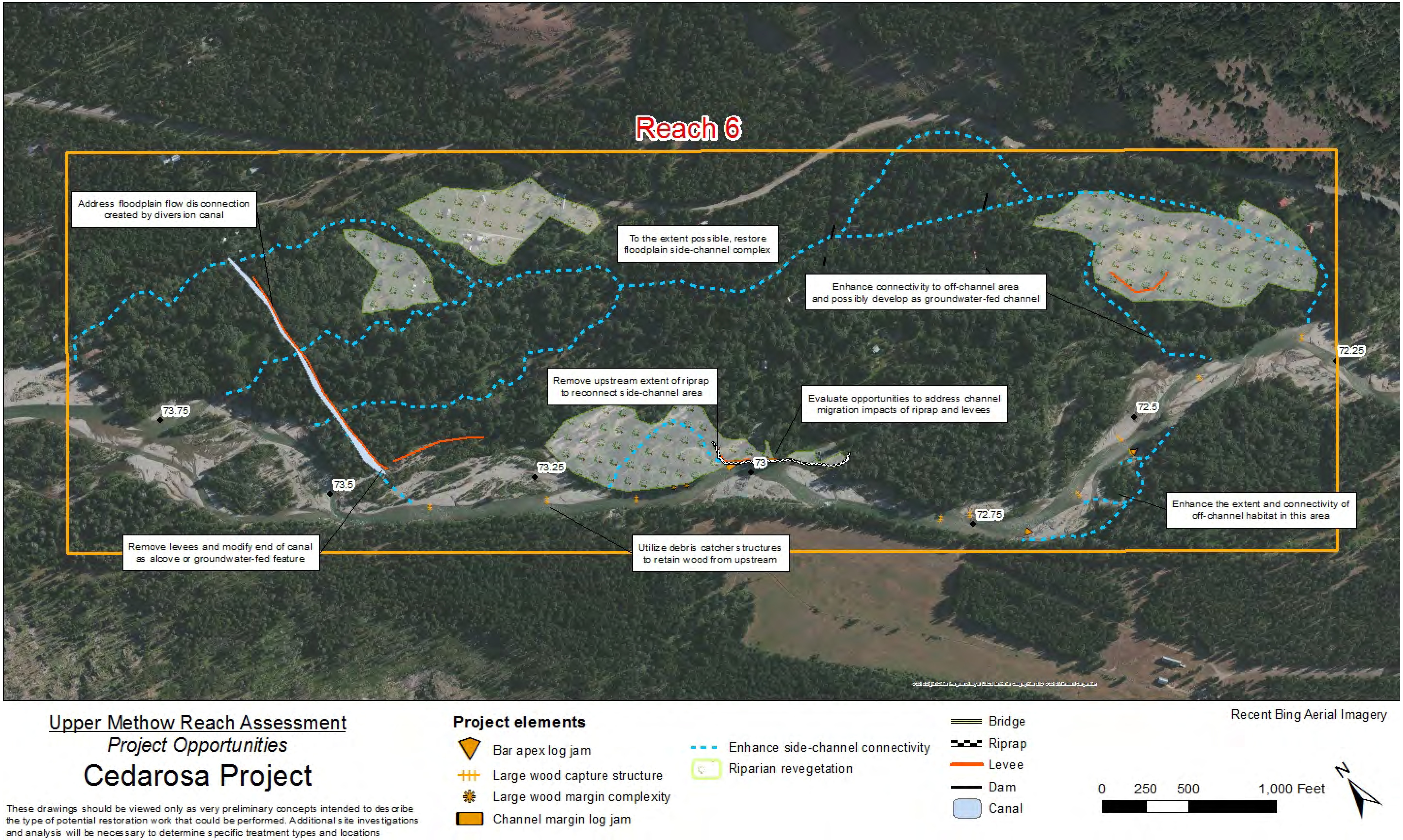
- Bar apex log jam
- Large wood capture structure
- Large wood margin complexity
- Channel margin log jam
- Enhance side-channel connectivity
- Riparian revegetation
- Bridge
- Riprap
- Levee
- Dam
- Canal

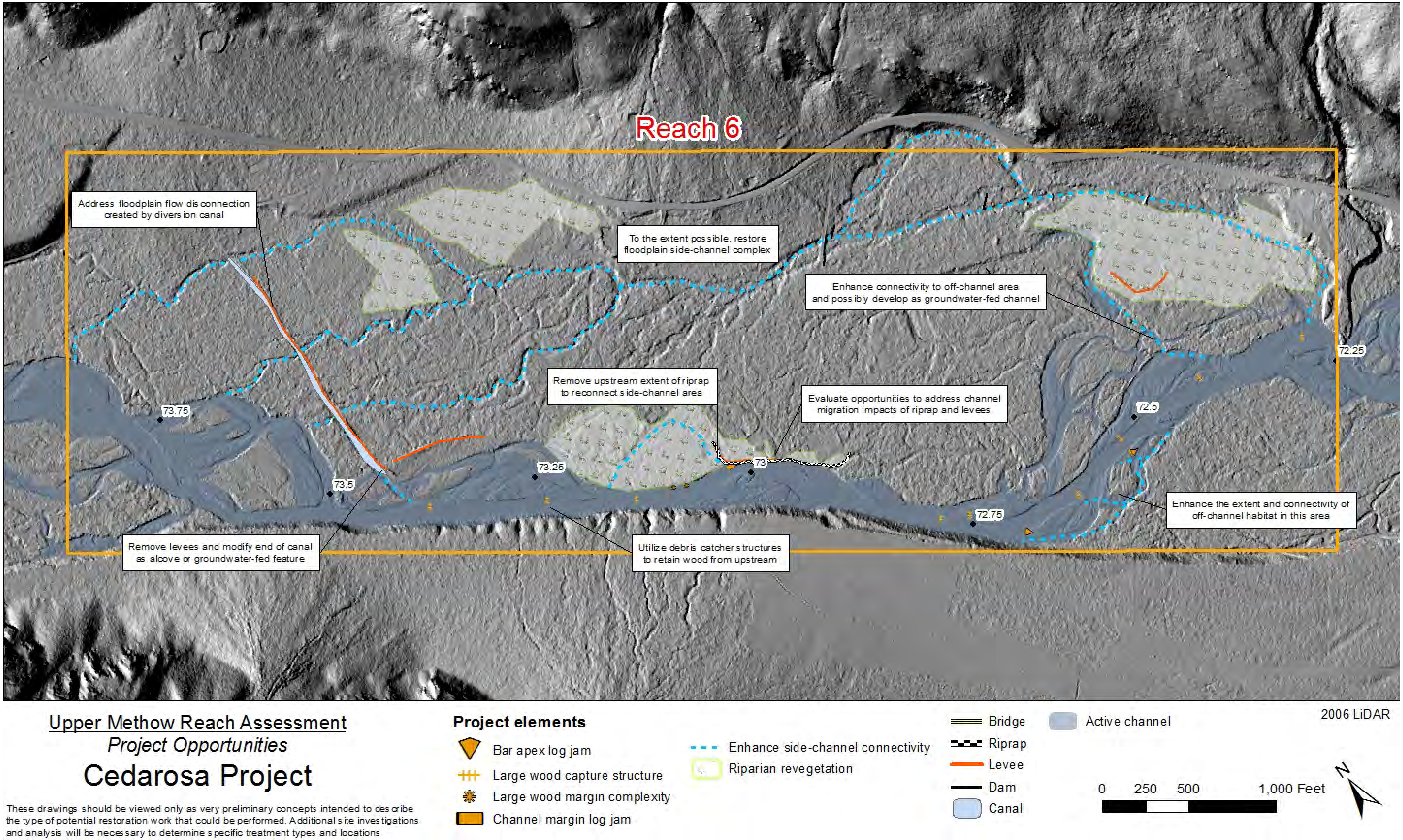
Recent Bing Aerial Imagery

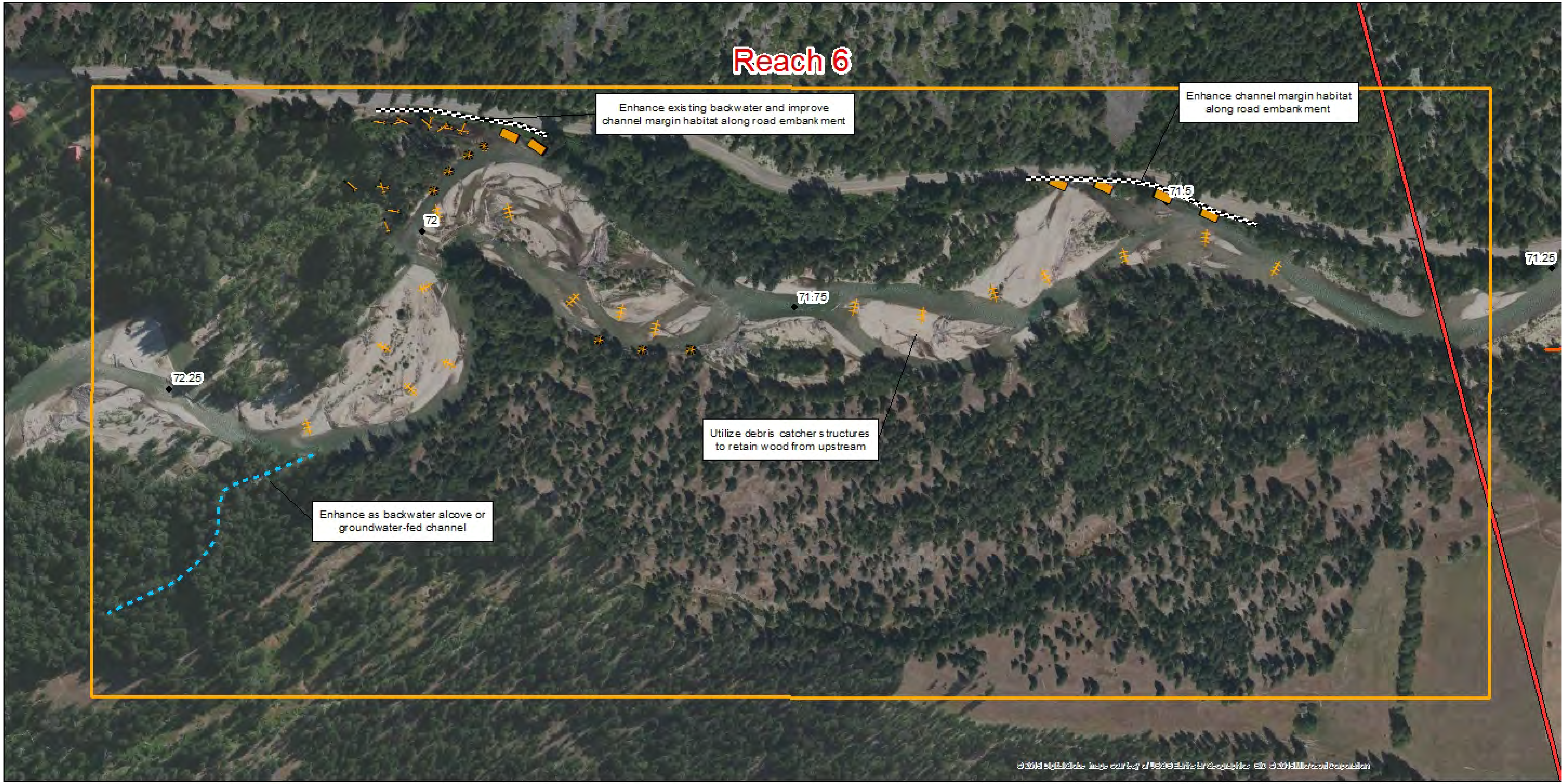
0 200 400 800 Feet

N


Reach 6
Enhance connectivity to distributary channel at lower Lost River
Channel margin jams to enhance habitat and shift flow energy away from riprap bank
Where possible, improve riparian and floodplain vegetation conditions
Enhance connectivity of river-right side-channel complex
Remove riprap
Convert canal to alcove or groundwater-fed channel
Utilize debris catcher structures to retain wood from upstream
Enhance connectivity of flow-through side-channel complex
Create connected alcove or groundwater-fed channel
75
74.75
74.5
74.25
74
73.75
Upper Methow Reach Assessment
Project Opportunities
Lost River Project
These drawings should be viewed only as very preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations
Project elements
Bar apex log jam
Large wood capture structure
Large wood margin complexity
Channel margin log jam
Enhance side-channel connectivity
Riparian revegetation
Bridge
Riprap
Levee
Dam
Canal
Active channel
2006 LiDAR
0 200 400 800 Feet
N


Reach 6
Address floodplain flow disconnection created by diversion canal
To the extent possible, restore floodplain side-channel complex
Enhance connectivity to off-channel area and possibly develop as groundwater-fed channel
Remove upstream extent of riprap to reconnect side-channel area
Evaluate opportunities to address channel migration impacts of riprap and levees
Enhance the extent and connectivity of off-channel habitat in this area
Remove levees and modify end of canal as alcove or groundwater-fed feature
Utilize debris catcher structures to retain wood from upstream
73.75
73.5
73.25
73
72.75
72.5
72.25
Upper Methow Reach Assessment
Project Opportunities
Cedarosa Project
These drawings should be viewed only as very preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations
Project elements
Bar apex log jam
Large wood capture structure
Large wood margin complexity
Channel margin log jam
Enhance side-channel connectivity
Riparian revegetation
Bridge
Riprap
Levee
Dam
Canal
Recent Bing Aerial Imagery
0 250 500 1,000 Feet
N


Reach 6
Address floodplain flow disconnection created by diversion canal
To the extent possible, restore floodplain side-channel complex
Enhance connectivity to off-channel area and possibly develop as groundwater-fed channel
Remove upstream extent of riprap to reconnect side-channel area
Evaluate opportunities to address channel migration impacts of riprap and levees
Enhance the extent and connectivity of off-channel habitat in this area
Remove levees and modify end of canal as alcove or groundwater-fed feature
Utilize debris catcher structures to retain wood from upstream
73.75
73.5
73.25
73
72.75
72.5
72.25
Upper Methow Reach Assessment
Project Opportunities
Cedarosa Project
These drawings should be viewed only as very preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations
Project elements
Bar apex log jam
Large wood capture structure
Large wood margin complexity
Channel margin log jam
Enhance side-channel connectivity
Riparian revegetation
Bridge
Riprap
Levee
Dam
Canal
Active channel
2006 LiDAR
0 250 500 1,000 Feet
N



Upper Methow Reach Assessment

Project Opportunities

Gate Creek Project

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

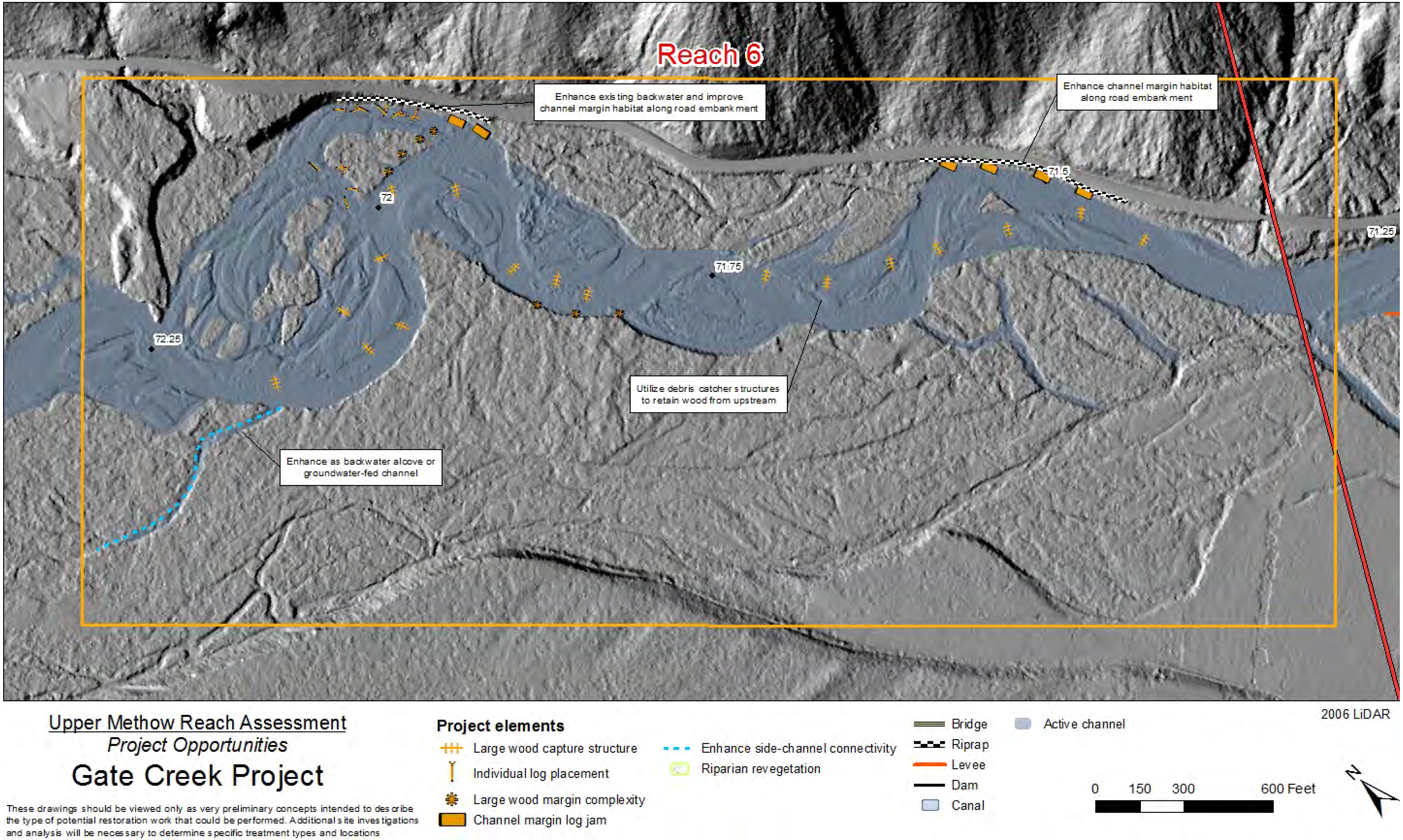
Project elements

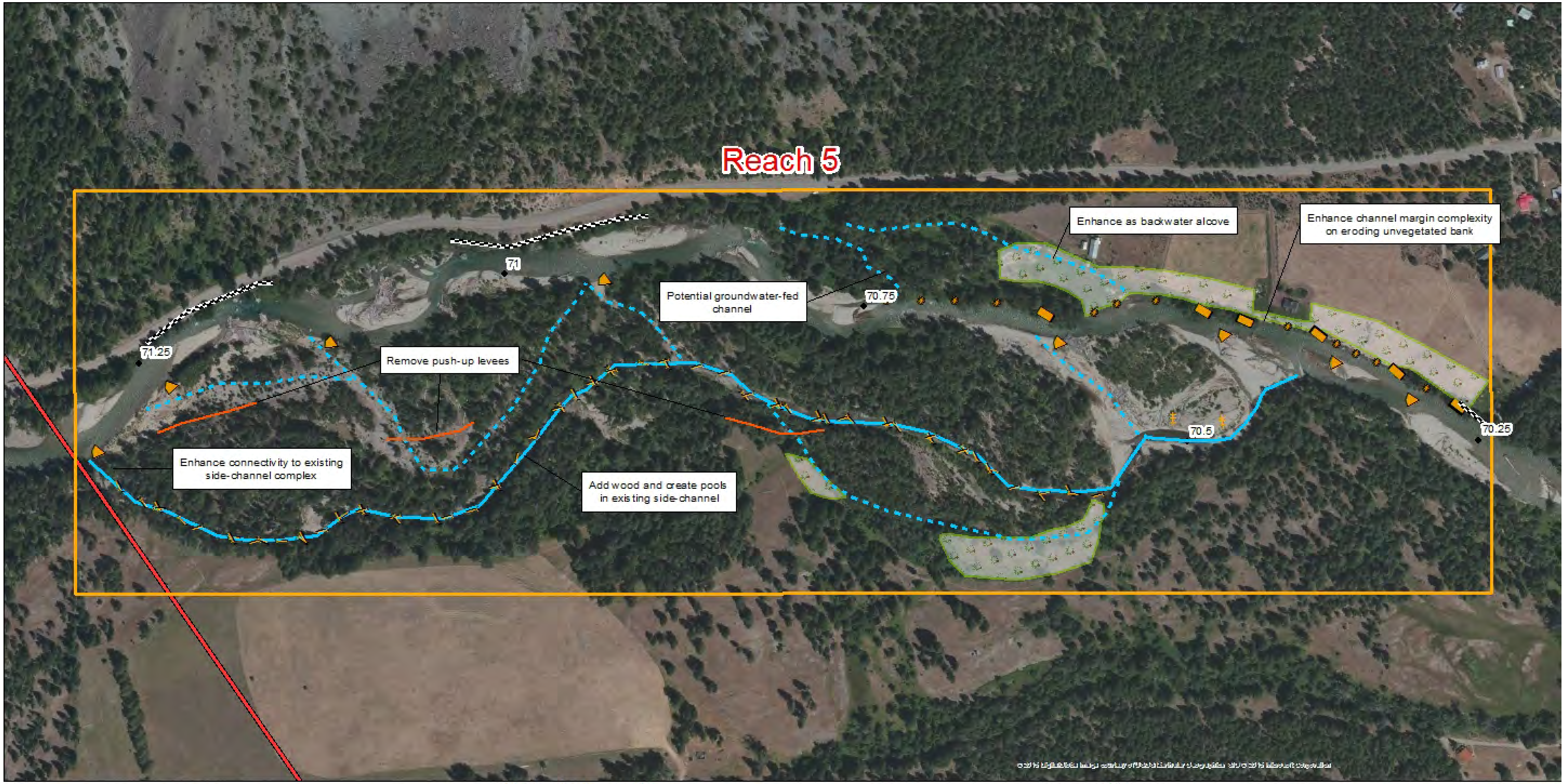
- Large wood capture structure
- Individual log placement
- Large wood margin complexity
- Channel margin log jam
- Enhance side-channel connectivity
- Riparian revegetation
- Bridge
- Riprap
- Levee
- Dam
- Canal

Recent Bing Aerial Imagery

0 150 300 600 Feet

N


Reach 6
Enhance existing backwater and improve channel margin habitat along road embankment
Enhance channel margin habitat along road embankment
72
71.5
71.25
71.75
72.25
Utilize debris catcher structures to retain wood from upstream
Enhance as backwater alcove or groundwater-fed channel
2006 LiDAR
Upper Methow Reach Assessment
Project Opportunities
Gate Creek Project
These drawings should be viewed only as very preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations
Project elements
Large wood capture structure
Individual log placement
Large wood margin complexity
Channel margin log jam
Enhance side-channel connectivity
Riparian revegetation
Bridge
Riprap
Levee
Dam
Canal
Active channel
0 150 300 600 Feet
N



<u>Upper Methow Reach Assessment</u>

Project Opportunities

Goat Wall Project

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

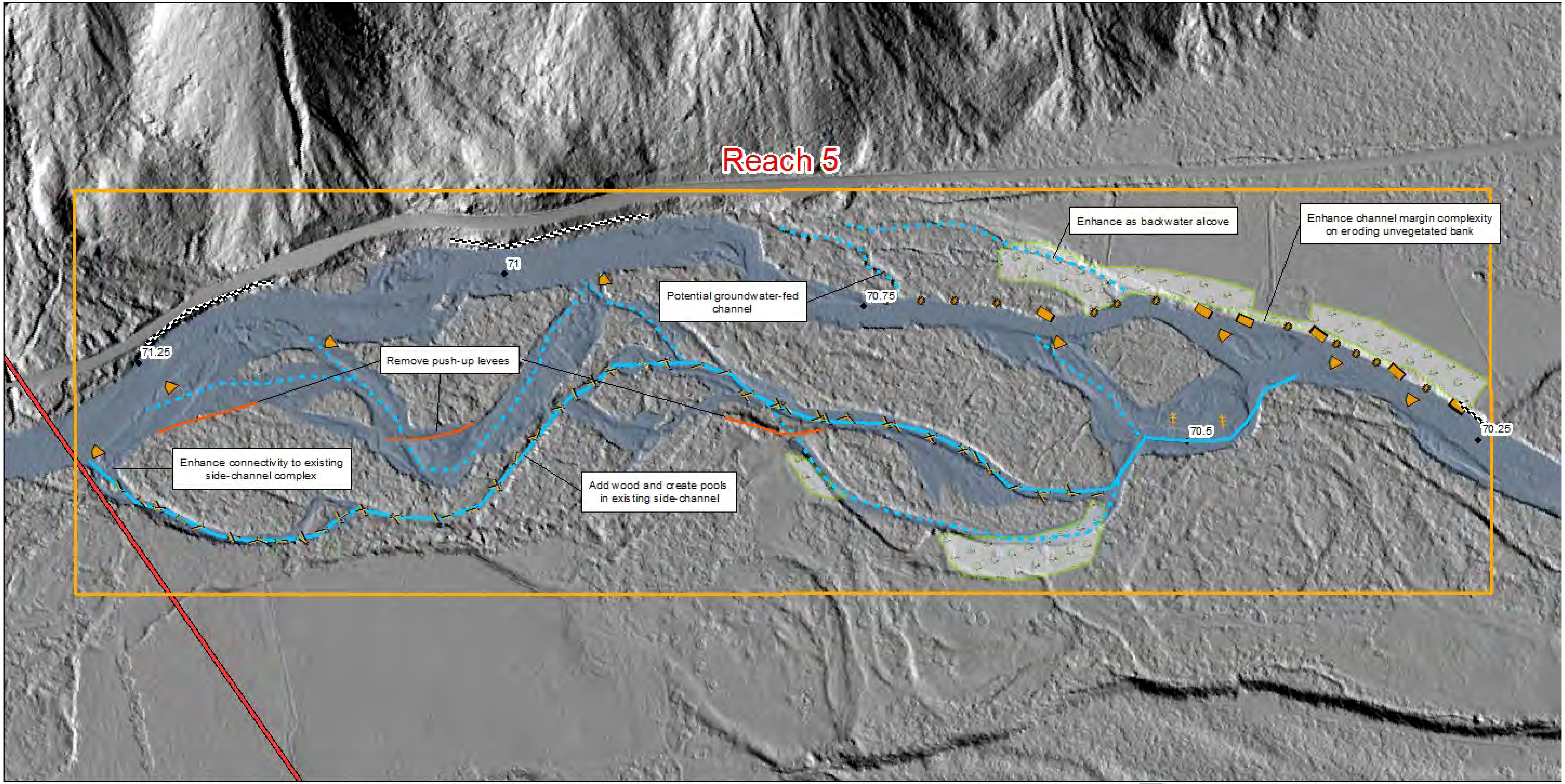
Project elements

- Bar apex log jam
- Large wood capture structure
- Individual log placement
- Large wood margin complexity
- Channel margin log jam
- Enhance side-channel connectivity
- Riparian revegetation
- Bridge
- Riprap
- Levee
- Dam
- Canal

Recent Bing Aerial Imagery

0 150 300 600 Feet

N



Upper Methow Reach Assessment

Project Opportunities

Goat Wall Project

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

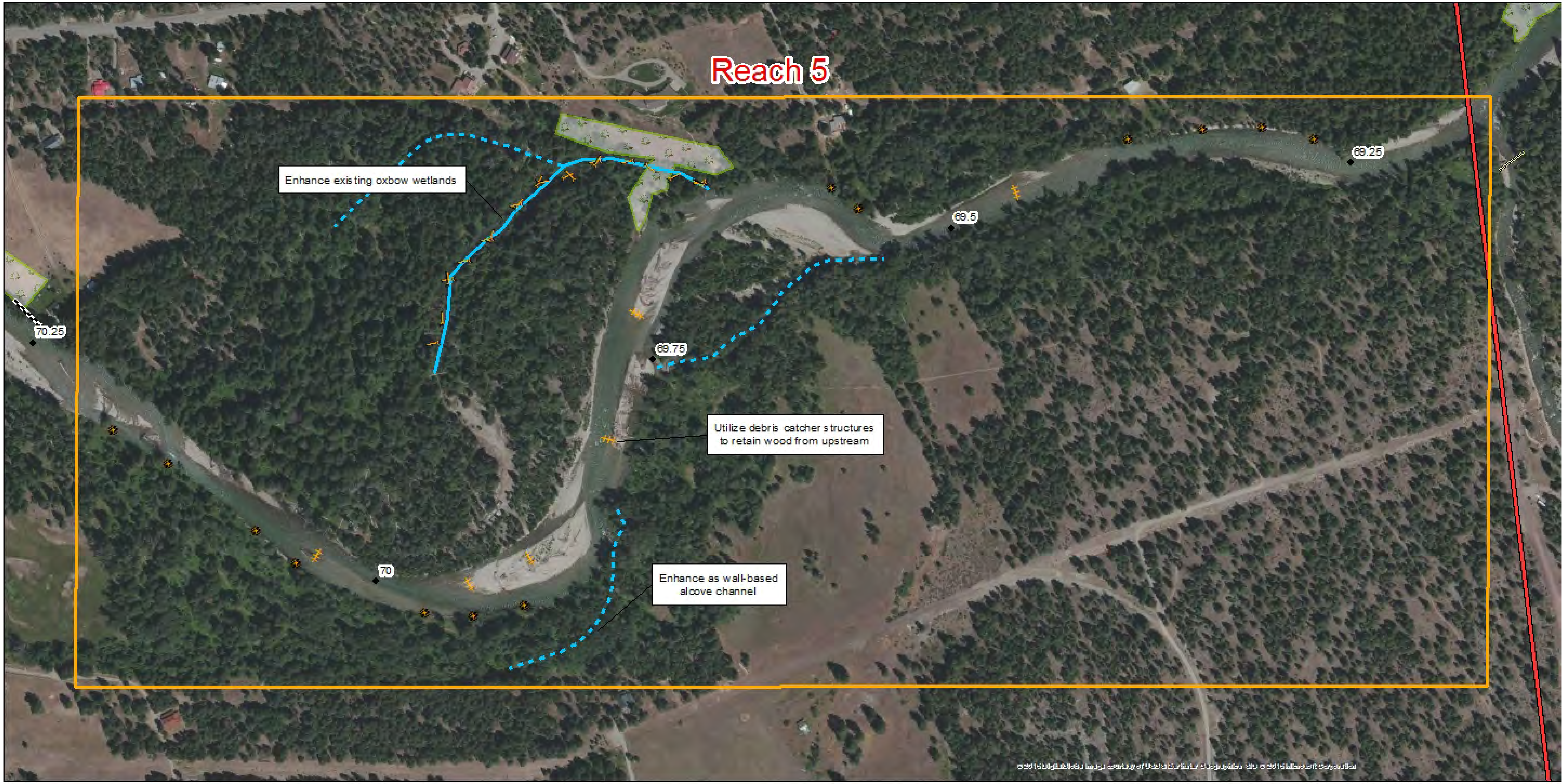
Project elements

- Bar apex log jam
- Large wood capture structure
- Individual log placement
- Large wood margin complexity
- Channel margin log jam
- Enhance side-channel connectivity
- Riparian revegetation
- Bridge
- Riprap
- Levee
- Dam
- Canal
- Active channel

2006 LiDAR

0 150 300 600 Feet

N



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Upper Methow Reach Assessment

Project Opportunities

A-Wall Project

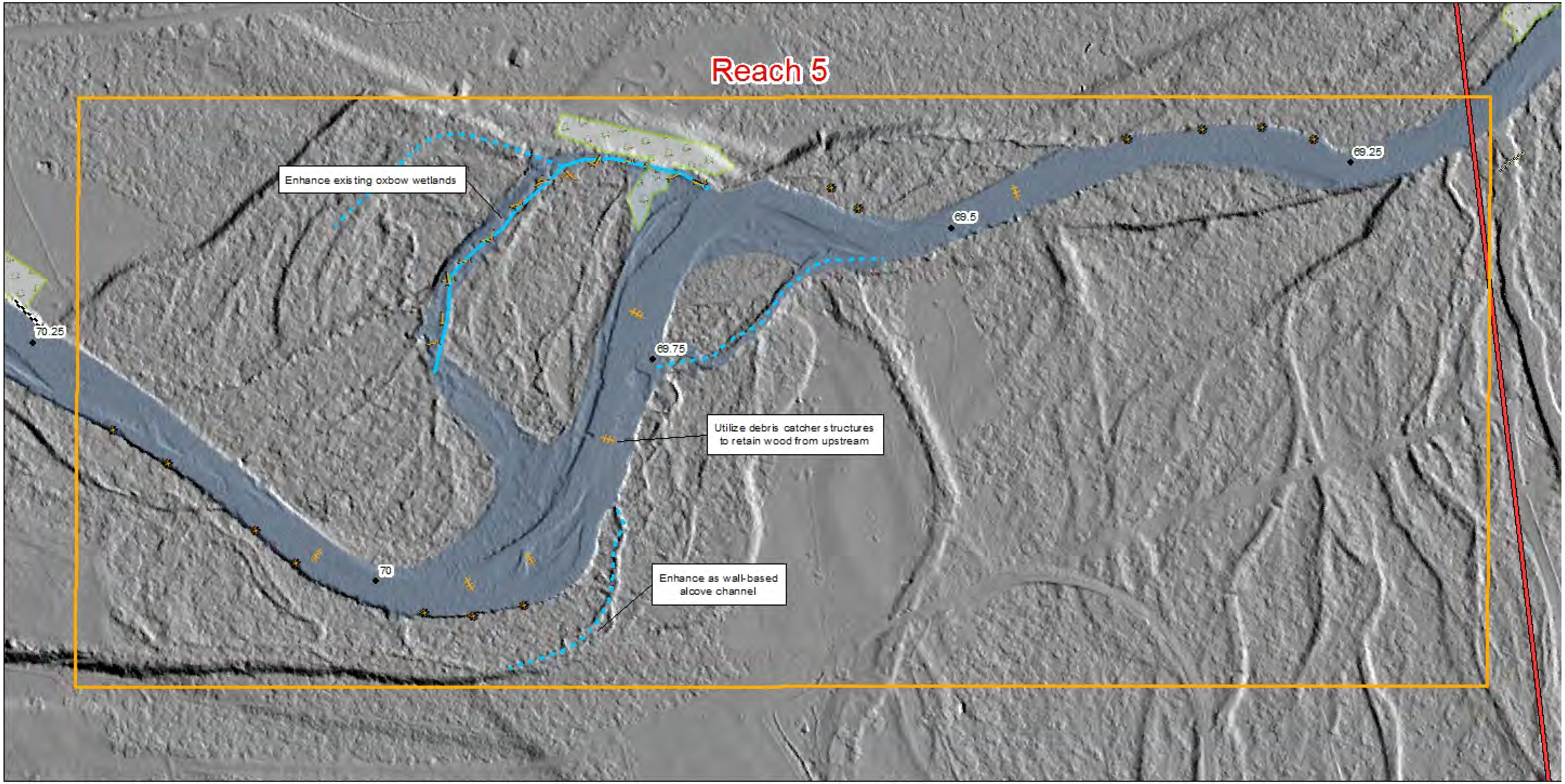
These drawings should be viewed only as very preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations

Project elements

- Large wood capture structure
- Individual log placement
- Large wood margin complexity
- Enhance side-channel connectivity
- Riparian revegetation
- Bridge
- Riprap
- Levee
- Dam
- Canal

0 150 300 600 Feet

N



2006 LiDAR

Upper Methow Reach Assessment

Project Opportunities

A-Wall Project

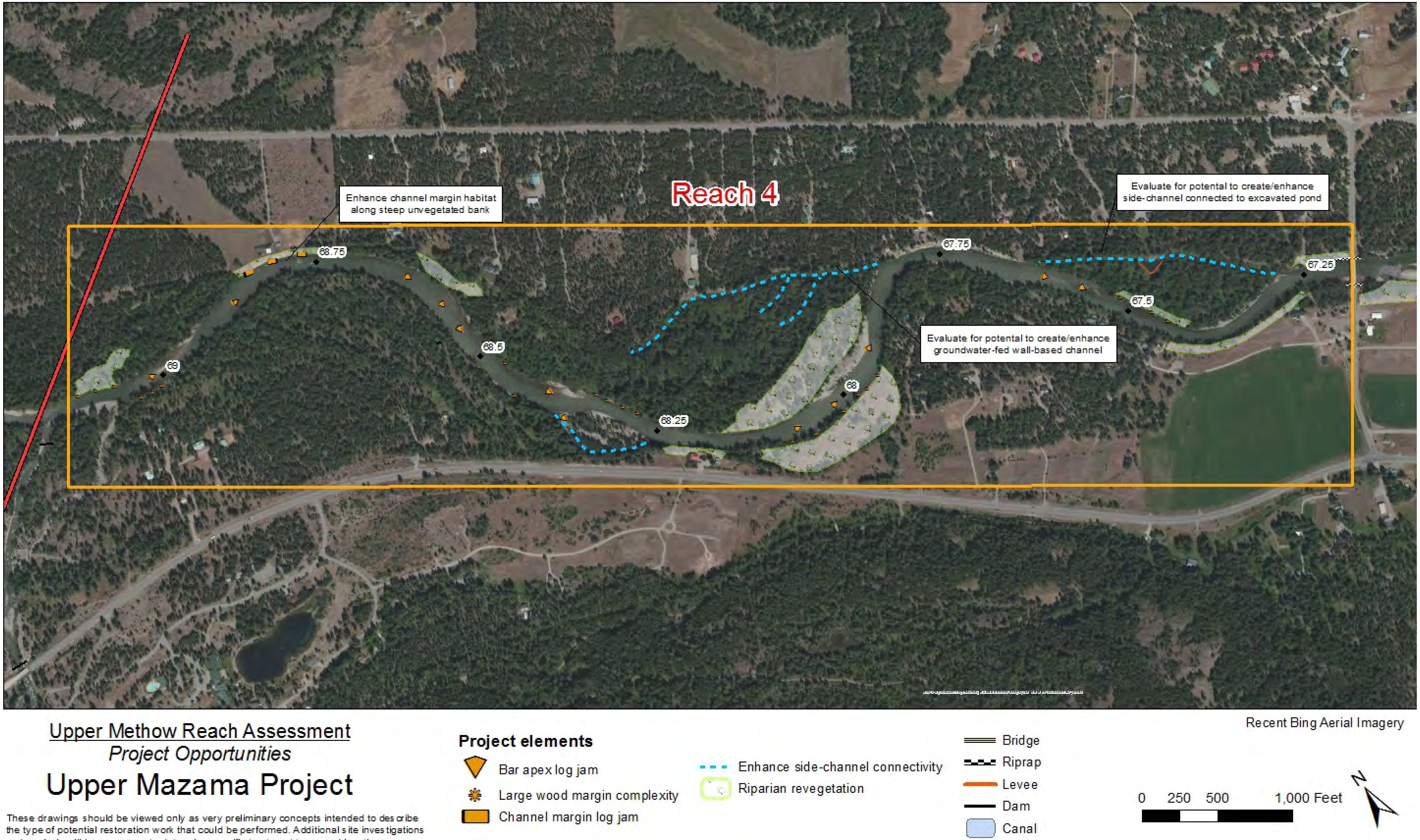
These drawings should be viewed only as very preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations

Project elements

- Large wood capture structure
- Individual log placement
- Large wood margin complexity
- Enhance side-channel connectivity
- Riparian revegetation
- Bridge
- Riprap
- Levee
- Dam
- Canal
- Active channel

0 150 300 600 Feet

N

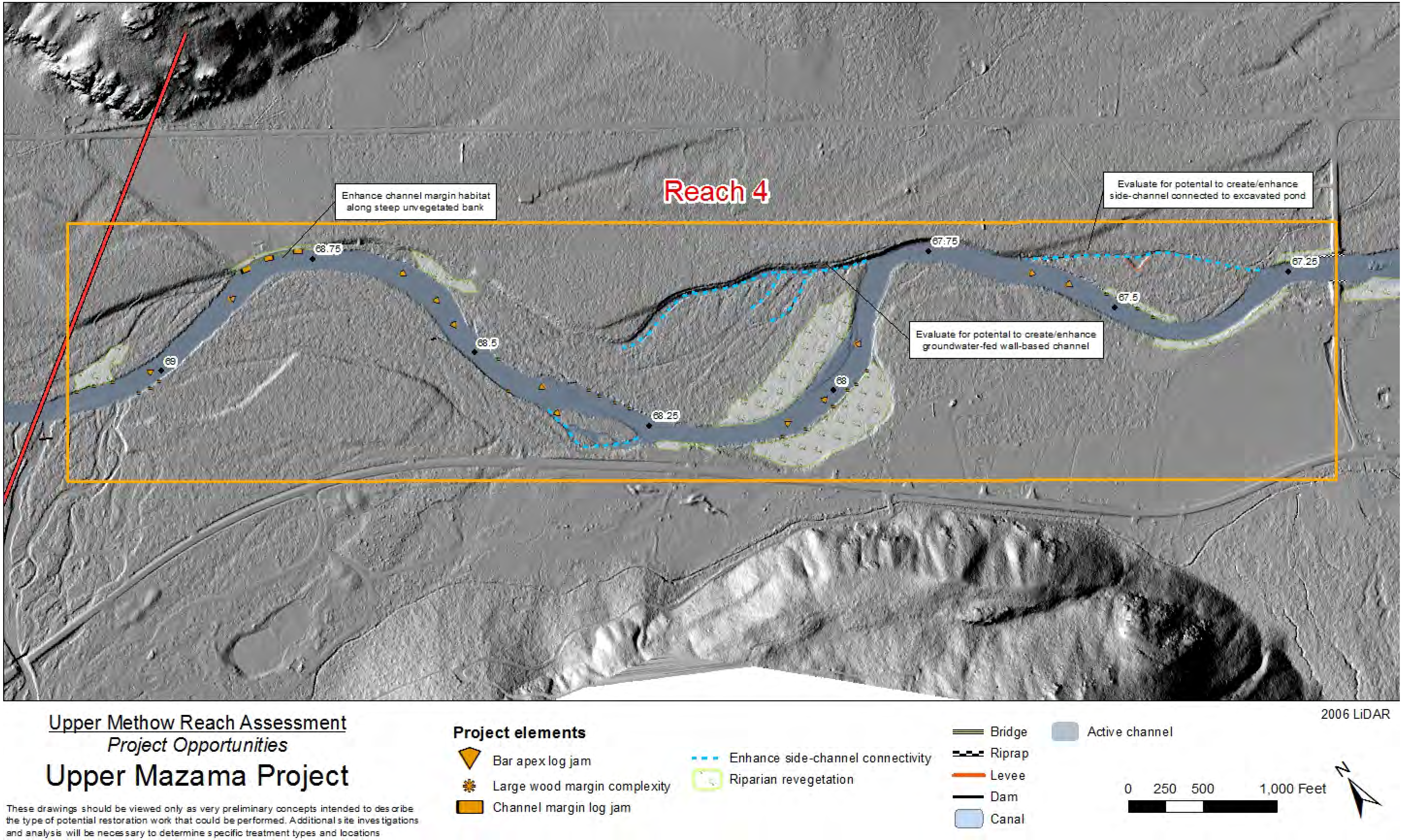


Upper Methow Reach Assessment

Project Opportunities

Upper Mazama Project

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


Reach 4
Enhance channel margin habitat along steep unvegetated bank
Evaluate for potental to create/enhance side-channel connected to excavated pond
Evaluate for potental to create/enhance groundwater-fed wall-based channel
69
68.75
68.5
68.25
68
67.75
67.5
67.25
2006 LiDAR
Upper Methow Reach Assessment
Project Opportunities
Upper Mazama Project
These drawings should be viewed only as very preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations
Project elements
Bar apex log jam
Large wood margin complexity
Channel margin log jam
Enhance side-channel connectivity
Riparian revegetation
Bridge
Riprap
Levee
Dam
Canal
Active channel
0 250 500 1,000 Feet
N

Recent Bing Aerial Imagery

Upper Methow Reach Assessment

Project Opportunities

Lower Mazama Project

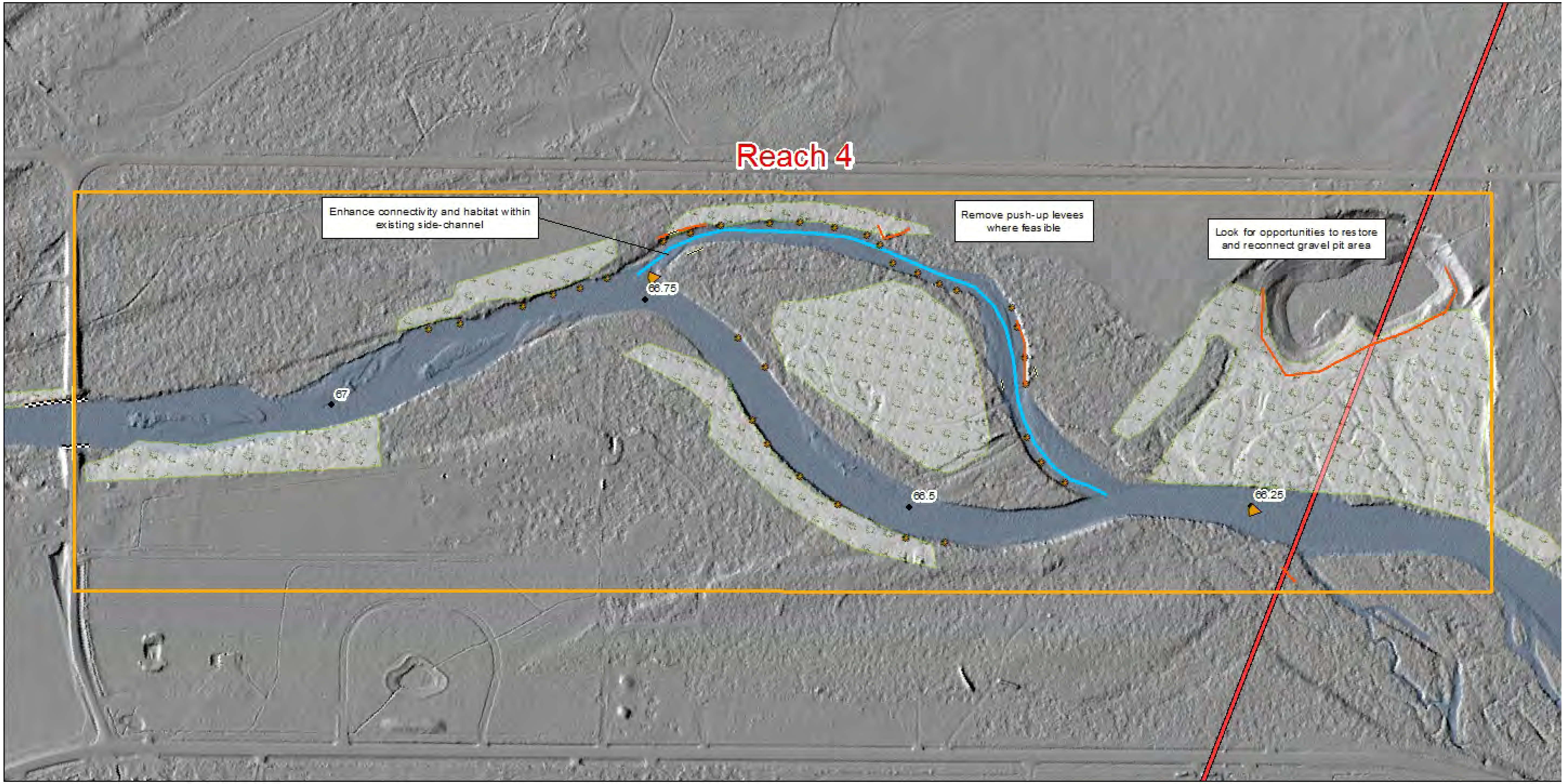
These drawings should be viewed only as very preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations

Project elements

- Bar apex log jam
- Large wood margin complexity
- Enhance side-channel connectivity
- Riparian revegetation
- Bridge
- Riprap
- Levee
- Dam
- Canal

0 200 400 800 Feet

N



2006 LiDAR

Upper Methow Reach Assessment

Project Opportunities

Lower Mazama Project

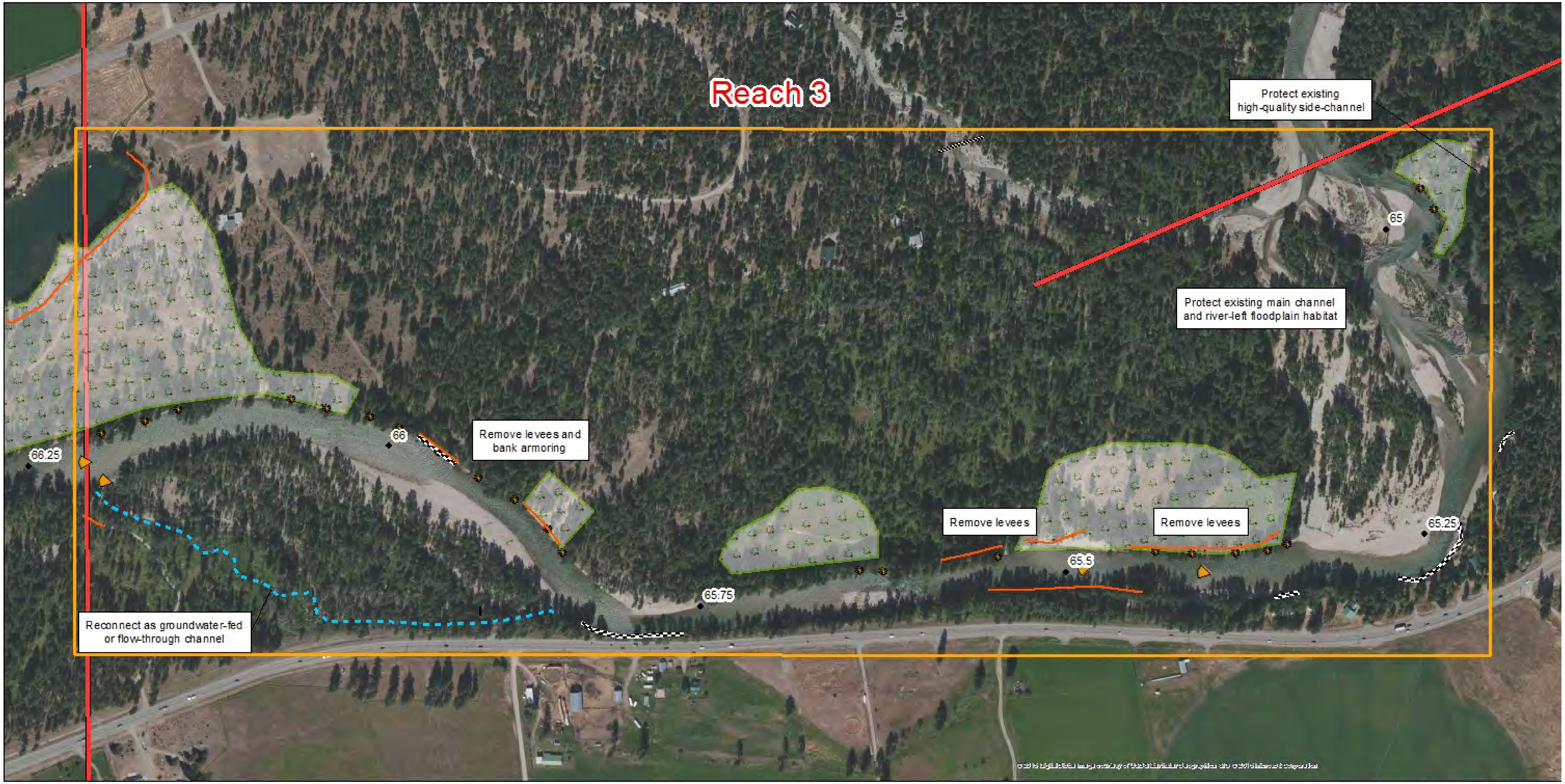
These drawings should be viewed only as very preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations

Project elements

- Bar apex log jam
- Large wood margin complexity
- Enhance side-channel connectivity
- Riparian revegetation
- Bridge
- Riprap
- Levee
- Dam
- Canal
- Active channel

0 200 400 800 Feet

N



Recent Bing Aerial Imagery

Upper Methow Reach Assessment

Project Opportunities

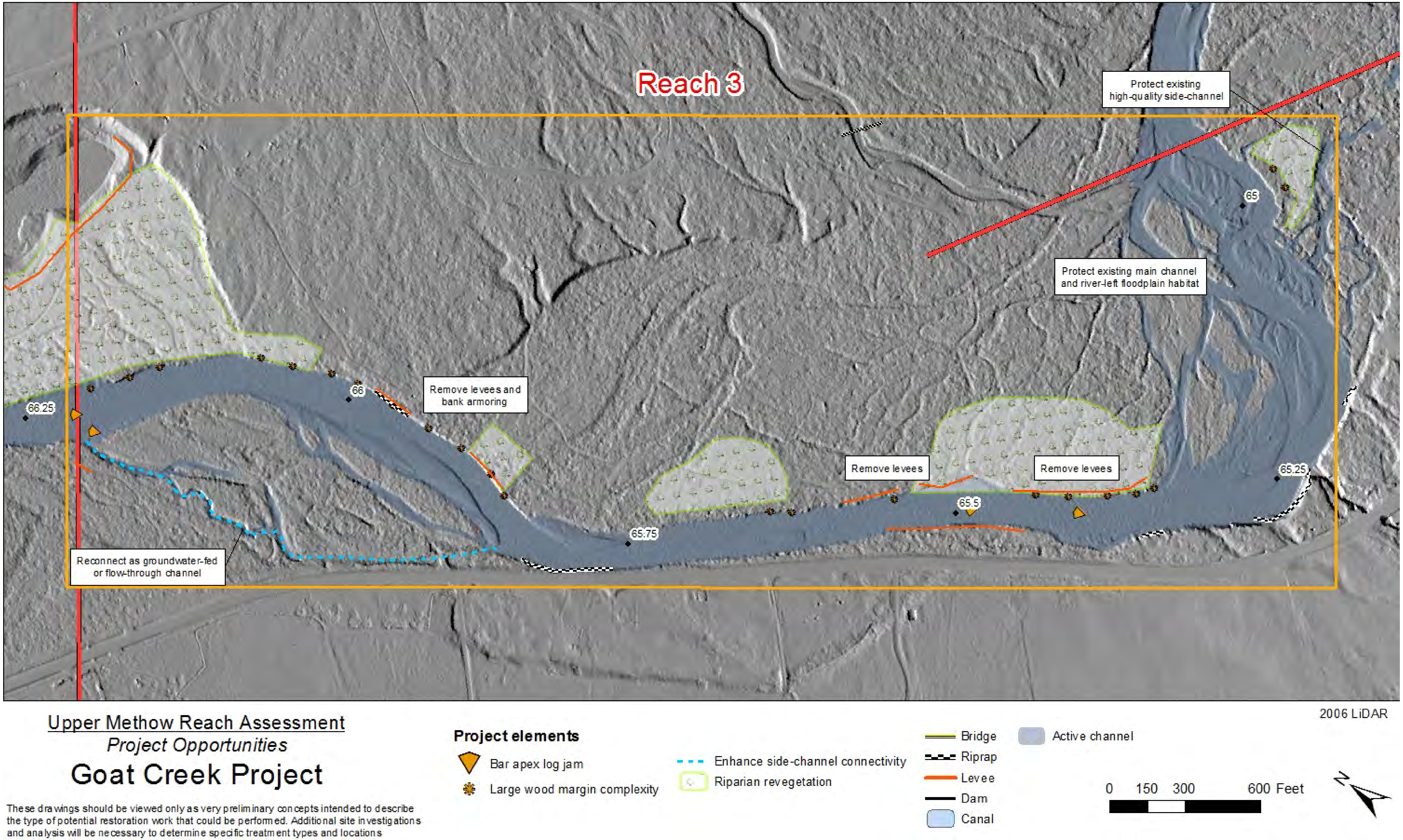
Goat Creek Project

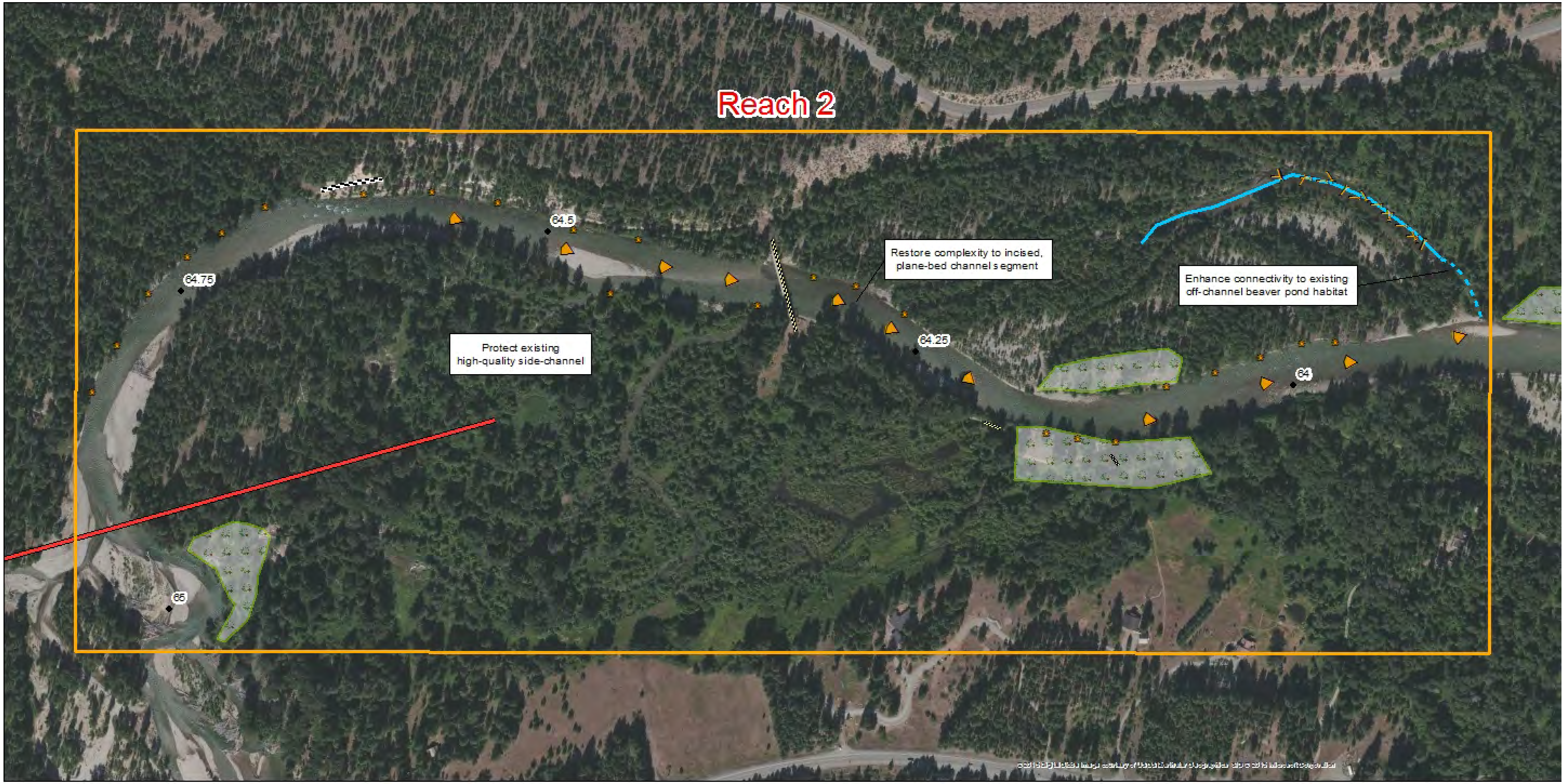
These drawings should be viewed only as very preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations

Project elements

- Bar apex log jam
- Large wood margin complexity
- Enhance side-channel connectivity
- Riparian revegetation
- Bridge
- Riprap
- Levee
- Dam
- Canal

0 150 300 600 Feet


Reach 3
Protect existing high-quality side-channel
Protect existing main channel and river-left floodplain habitat
Remove levees and bank armoring
Remove levees
Remove levees
Reconnect as groundwater-fed or flow-through channel
66.25
66
65.75
65.5
65.25
65
2006 LiDAR
Upper Methow Reach Assessment
Project Opportunities
Goat Creek Project
These drawings should be viewed only as very preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations
Project elements
Bar apex log jam
Large wood margin complexity
Enhance side-channel connectivity
Riparian revegetation
Bridge
Riprap
Levee
Dam
Canal
Active channel
0 150 300 600 Feet
N



Upper Methow Reach Assessment

Project Opportunities

Trail Bridge Project

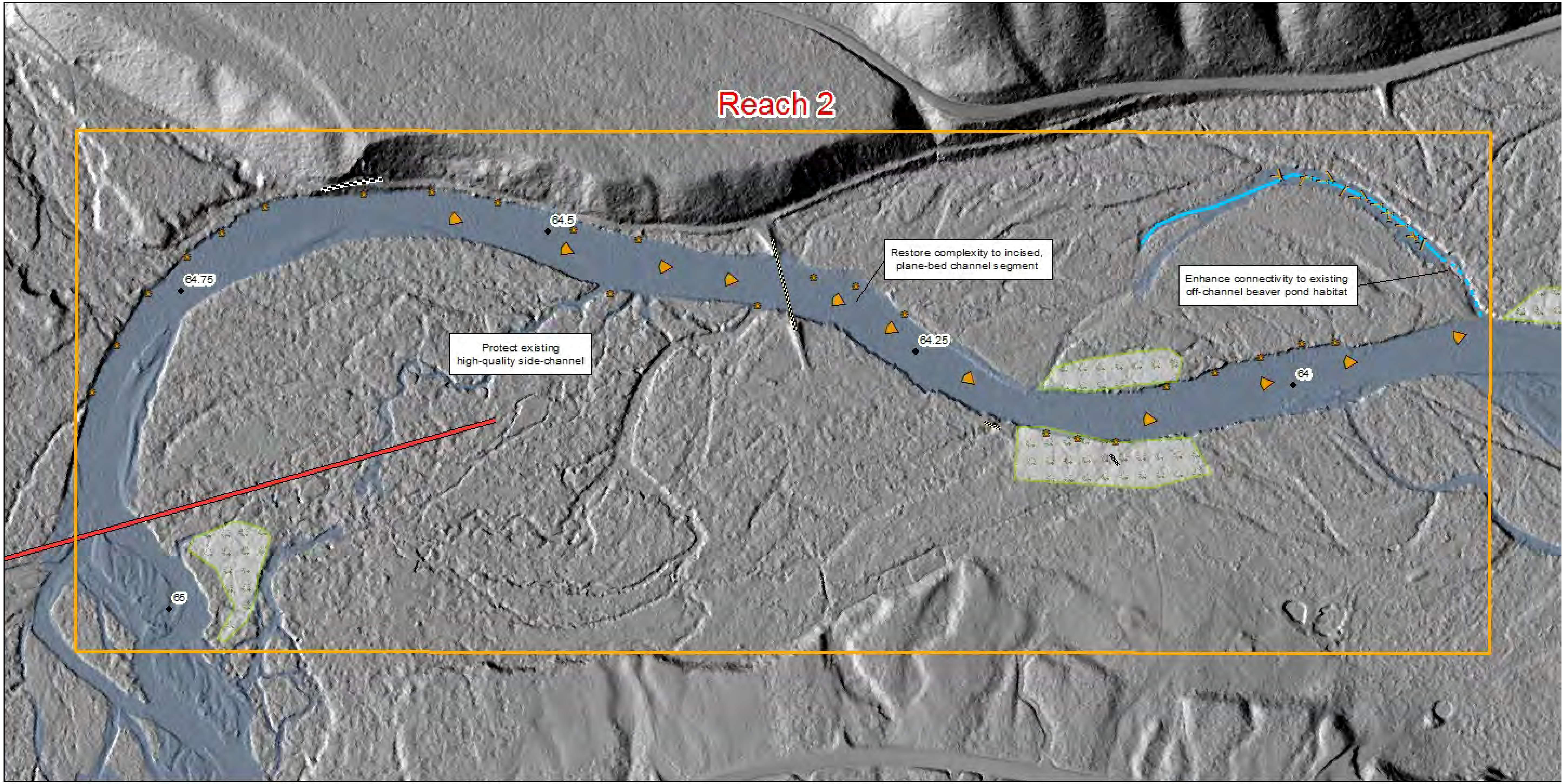
These drawings should be viewed only as very preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations

Project elements

- Bar apex log jam
- Individual log placement
- Large wood margin complexity
- Enhance side-channel connectivity
- Riparian revegetation
- Bridge
- Riprap
- Levee
- Dam
- Canal

Recent Bing Aerial Imagery

0 200 400 800 Feet



Upper Methow Reach Assessment

Project Opportunities

Trail Bridge Project

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

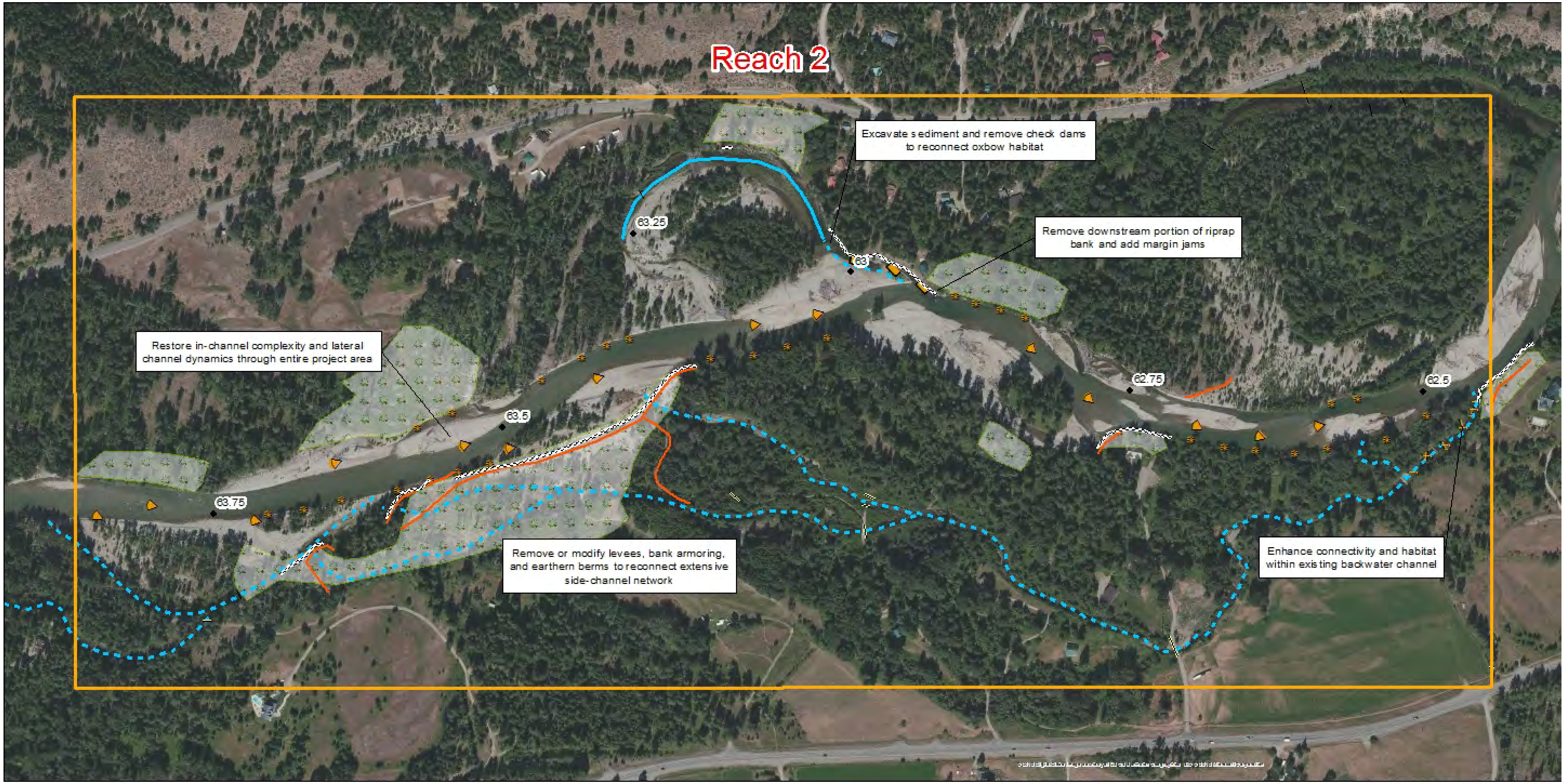
Project elements

- Bar apex log jam
- Individual log placement
- Large wood margin complexity
- Enhance side-channel connectivity
- Riparian revegetation
- Bridge
- Riprap
- Levee
- Dam
- Canal
- Active channel

2006 LiDAR

0 200 400 800 Feet

N



Upper Methow Reach Assessment

Project Opportunities

Fawn Creek Project

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

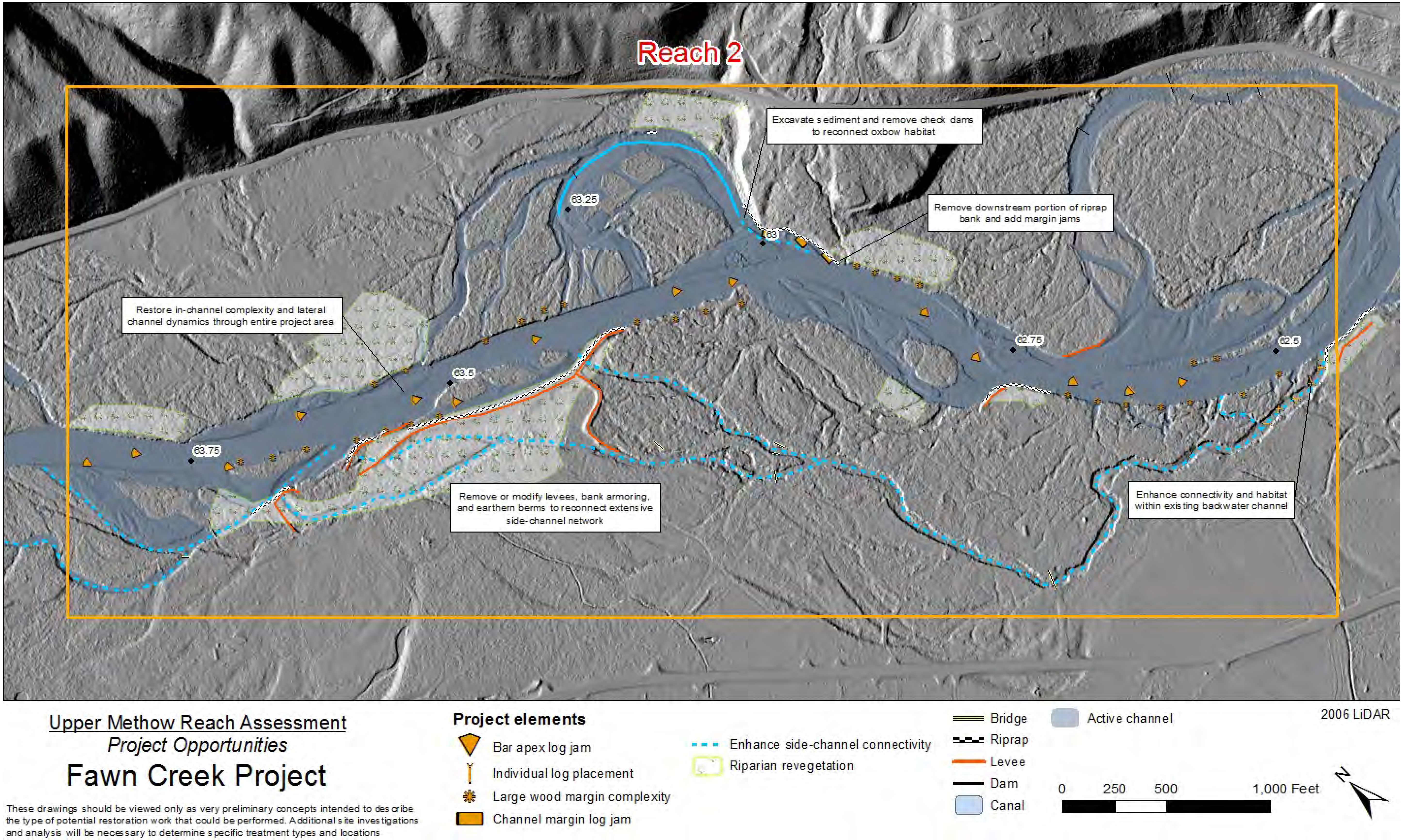
Project elements

- Bar apex log jam
- Individual log placement
- Large wood margin complexity
- Channel margin log jam
- Enhance side-channel connectivity
- Riparian revegetation
- Bridge
- Riprap
- Levee
- Dam
- Canal

Recent Bing Aerial Imagery

0 250 500 1,000 Feet

N

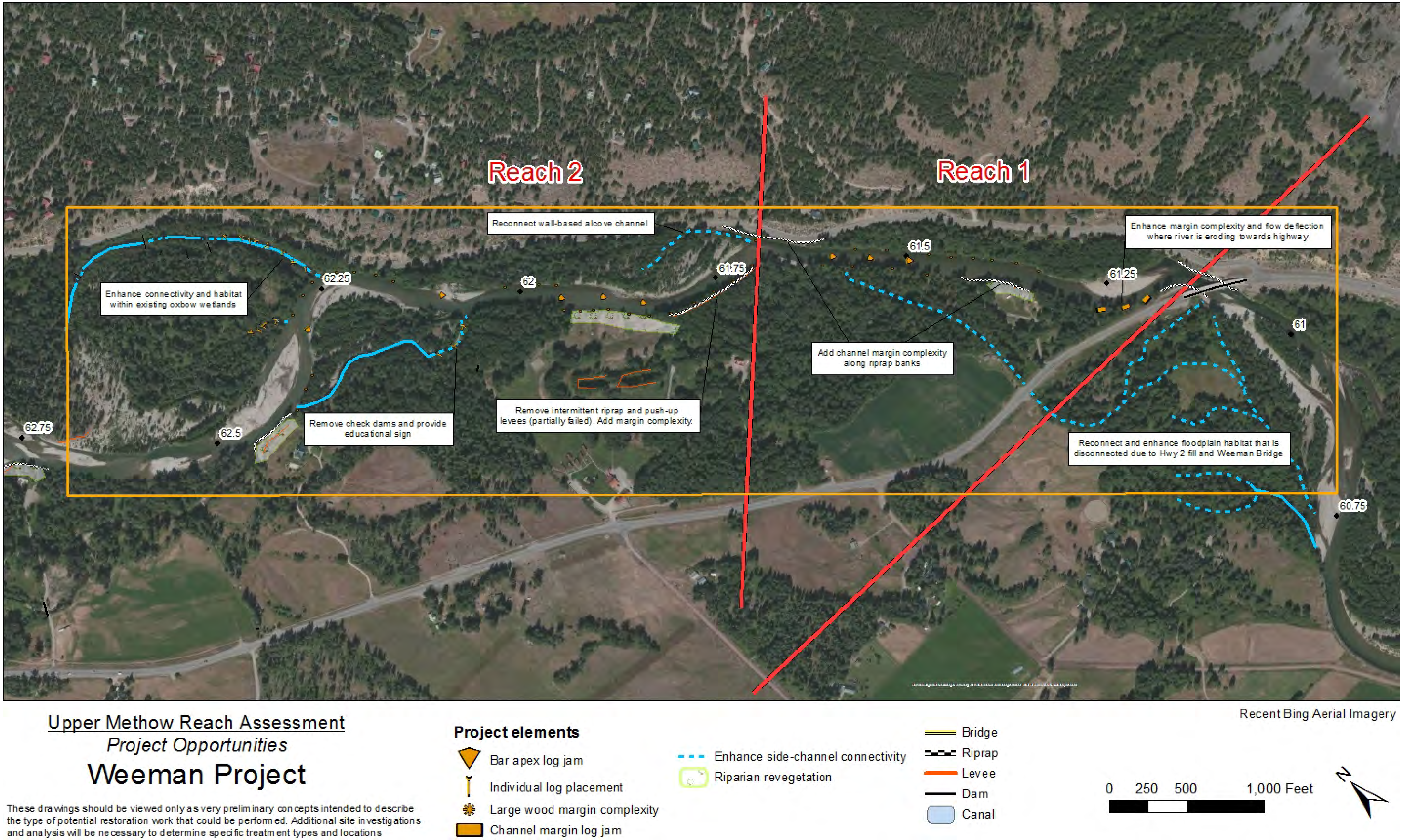


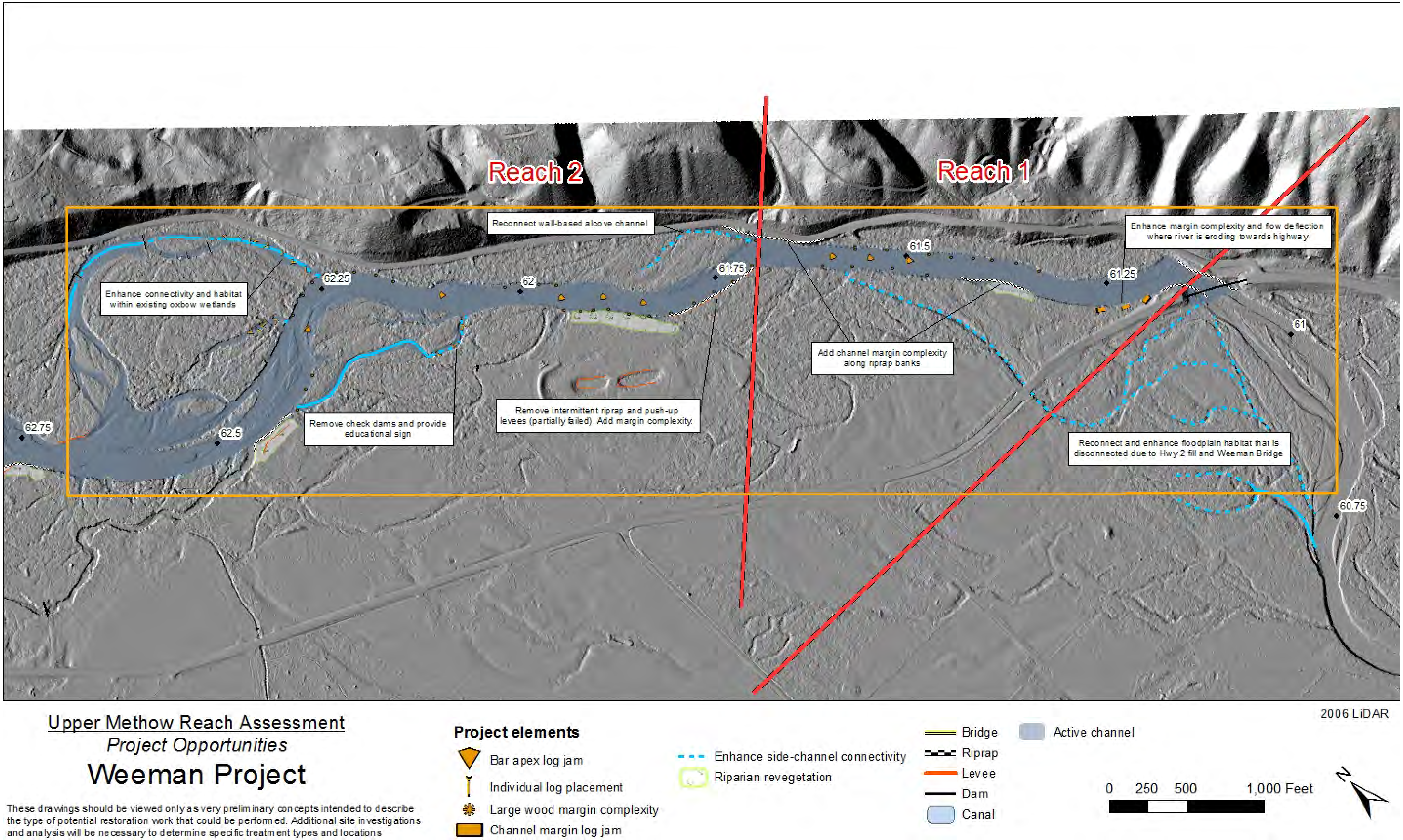
Upper Methow Reach Assessment

Project Opportunities

Fawn Creek Project

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


Reach 2
Reach 1
Reconnect wall-based alcove channel
Enhance margin complexity and flow deflection where river is eroding towards highway
Enhance connectivity and habitat within existing oxbow wetlands
Add channel margin complexity along riprap banks
Remove check dams and provide educational sign
Remove intermittent riprap and push-up levees (partially failed). Add margin complexity.
Reconnect and enhance floodplain habitat that is disconnected due to Hwy 2 fill and Weeman Bridge
62.75
62.5
62.25
62
61.75
61.5
61.25
61
60.75
Upper Methow Reach Assessment
Project Opportunities
Weeman Project
These drawings should be viewed only as very preliminary concepts intended to describe the type of potential restoration work that could be performed. Additional site investigations and analysis will be necessary to determine specific treatment types and locations
Project elements
Bar apex log jam
Individual log placement
Large wood margin complexity
Channel margin log jam
Enhance side-channel connectivity
Riparian revegetation
Bridge
Riprap
Levee
Dam
Canal
Recent Bing Aerial Imagery
0 250 500 1,000 Feet
N



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Riparian revegetation
Bridge
Riprap
Levee
Dam
Canal
Active channel
0 250 500 1,000 Feet
N

Project Ranking Methods (Version: Sept 2015)

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

Step 2: **Cost Score** Projects are given a *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** Projects are given a ***Feasibility Designation*** based on the overall likely feasibility of being able to implement the project within a 10-year timeframe.

Benefit Score

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

Recovery Gap

Existing Condition Rating (1-7)

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

Achievable Condition Rating (1-7)

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

Final Gap Score (0-6)

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

Fish Use

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

Root Causes

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

Cost Score

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

3 – High relative cost

- Uses high cost techniques (e.g. constructed banks, highly engineered log jams, extensive channel shaping, extensive infiltration galleries)
- Deep excavation or long distance hauling of spoils
- Entails construction of additional new flood control or bank erosion features (e.g. set-back levees or buried rip-rap)
- Extensive planting or invasive weed control
- Limited, difficult, or remote access
- Intensive de-watering requirements

2 – Moderate relative cost

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

1 – Low relative cost

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

Benefit-to-Cost Score

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

Feasibility Designation

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

High feasibility

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

Moderate feasibility

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

Unlikely feasibility

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

Upper Methow Reach Assessment and Restoration Strategy - Project Prioritization

Reaches ranked using the Total Benefit Score
Version: Sept 9, 2015

Project Information						Benefit Score									Cost Score		Cost Benefit	Feasibility Designation	
						Restoration Gap Analysis				Existing and Potential Fish Use		Root Causes							
Tiers	Project Name	Reach	Down-stream RM	Up-stream RM	Total Length (mi)	Existing Condition (1-7)	Achievable Target (1-7)	Final Gap Score (Target - Existing) (0-6)	Rationale/ assumption	Score (1-3)	Rationale/ assumption	Score (1-3)	Rationale/ assumption	Total Benefit Score	Cost Score	Rationale/ assumption	Benefit-to-Cost Score	Feasibility Designation	Rationale/ assumption
1	Fawn Creek	2	62.40	63.85	1.45	2	6	4	Low existing function. High potential assuming levees addressed	3	High spawning use. Assumed rearing. Typically remains wetted.	3	Mostly recovery (levee/riprap removals, riparian) with some enhancement [assumes levees can be removed]	10	2.5	Removal/set-back of engineered levee/trail. Mod dense main channel jams	4.0	Moderate	Challenging but possible to address levee/trail issues
	Goat Creek	3	65.00	66.25	1.25	3	6	3	Low to moderate existing. High potential assuming levees addressed	2.5	High spawning use. Assumed rearing but seasonally dry conditions may affect usability	2.5	Combination of Recovery (levee removal/modification, riparian work) and Enhancement (log jams)	8	1.5	Mostly push-up levees that can be spoiled on site. Mostly margin log jams	5.3	Moderate	Private lands. Some houses and infrastructure.
	Trail Bridge	2	63.85	64.90	1.05	3	6	3	Low to moderate existing. High potential due to low risk to infrastructure	3	High spawning use. Assumed rearing. Typically remains wetted.	2	Mostly enhancement	8	2	Moderately dense mainstem log jams	4.0	Moderate - High	Mostly in-channel work with relatively little risk to infrastructure, accessible
	Weeman	1-2	60.75	62.75	2.00	2	5	3	Low existing function. Moderate potential given existing infrastructure	3	High spawning use. Assumed rearing. Typically remains wetted.	2	Mostly enhancement due to existing infrastructure in place	8	2.5	Sparse mainstem log jams. Instrastructure mods at DS end potentially expensive.	3.2	Low	Full recovery challenging due to infrastructure limitations (Weeman Bridge and Hwy 20)
	Cedarosa	6	72.25	73.85	1.60	3	6	3	Low to moderate existing. High potential assuming addressing floodplain drainage	2	Moderate spawning use. Assumed rearing but seasonally dry conditions may affect usability	2.5	Combination of Recovery (levee removal/modification, riparian work) and Enhancement (log jams)	7.5	2	Moderately dense mainstem log jams. Levees can be spoiled on-site	3.8	Moderate	Streamside and floodplain residences. Good accessibility.
2	Lower Mazama	4	66.15	67.20	1.05	3	5	2	Low to moderate existing. Moderate potential given existing infrastructure	2.5	High spawning use. Assumed rearing but seasonally dry conditions may affect usability	2	Mostly enhancement	6.5	2	Mostly push-up levees that can be spoiled on site. Mostly margin log jams. Off-chan work DS LB could be expensive	3.3	Low - Moderate	Challenging due to streamside residences and private property
	Lost River	6	73.70	75.00	1.30	3	5	2	Low to moderate existing. Moderate potential given Lost River Community impacts	2.5	High spawning use. But seasonally dry conditions may affect usability	2	Mostly enhancement given existing infrastructure affecting underlying processes	6.5	2.5	Mod dense main channel jams. High engineering requirements due to infrastructure. Relatively easy access	2.6	Low - Moderate	Challenging due to streamside residences and private property
	Goat Wall	5	70.25	71.30	1.05	4	6	2	Moderate existing. High potential given lack of significant infrastructure	2	Moderate spawning use. Assumed rearing but seasonally dry conditions may affect usability	2.5	Combination of Recovery (levee removal/modification, riparian work) and Enhancement (log jams)	6.5	2	Moderately dense mainstem log jams. Levees can be spoiled on-site	3.3	Moderate - High	Private lands on river-right but little infrastructure. USFS and road on river-left.
	A-Wall	5	69.15	70.25	1.10	4	6	2	Moderate existing. High potential given lack of significant infrastructure	2.5	High spawning use. Assumed rearing but seasonally dry conditions may affect usability	2	Mostly enhancement	6.5	2	Moderately dense mainstem log jams	3.3	Moderate	Decent access. Private lands
	Upper Mazama	4	67.20	69.15	1.95	3	5	2	Low to moderate existing. Moderate potential given existing infrastructure	2.5	High spawning use. Assumed rearing but seasonally dry conditions may affect usability	2	Mostly enhancement	6.5	2.5	Moderately dense mainstem log jams. Engineered jams on margins. Some access challenges	2.6	Low - Moderate	Challenging due to streamside residences and private property
3	Gate Creek	6	71.30	72.30	1.00	5	6	1	Moderate to high existing. Moderate to high potential given lack of significant infrastructure	2	Moderate spawning use. Assumed rearing but seasonally dry conditions may affect usability	2	Mostly enhancement	5	2	Moderately dense mainstem log jams. Engineered jams on margins. Some access challenges	2.5	Moderate - High	Private lands on river-right but little infrastructure. USFS and road on river-left.
	Ballard	8	76.50	76.90	0.40	6	6.5	0.5	Moderate to high existing. High potential given lack of significant infrastructure	1.5	Mainly riffle habitat. Only one redd on record	3	Levee removals	5	1	No main channel work.Levee spoils likely spoiled on site	5.0	Moderate	Campground protection needs to be considered
	Two Rivers	7	74.90	75.60	0.70	6	6.5	0.5	Moderate to high existing. High potential given lack of significant infrastructure	1.5	Limited spawning use. Unknown rearing use. Rarely dewaters	2.5	Combination of Recovery (levee removal) and Enhancement (log jams)	4.5	2	Mod dense main channel jams. Small levee can be spoiled on site. Mod access requirements	2.3	High	USFS land. No infrastructure at risk
	Robinson	7	75.60	76.50	0.90	6	6.5	0.5	Moderate to high existing. High potential given lack of significant infrastructure	2	Moderate spawning based on redd surveys. Habitat would support rearing	2	Mostly enhancement using log jams	4.5	2.5	Dense main channel jams. Mod-hard access. Dewatering likely required	1.8	High	USFS land. No infrastructure at risk

Appendix D

Historical Conditions and Human Disturbance History

Upper Methow River Reach Assessment

December 2015

Contents

1 Native Americans

Native Americans first arrived in the region 8,000 – 10,000 years ago, and originally stayed in the Methow Valley year-round. Early documents reveal inhabitants were members of three major bands of the Sinkaietk people (or Northern Okanagans). The territory of the Methow encompassed most of the drainage of the Methow River, though they moved throughout the valley during the seasons as they hunted, fished, and gathered (USBR 2008). During the extreme winters, they sheltered in large pit houses dug down several feet into the ground.

Figure 1. Dwellings made of poles, rush mats and canvas were used by members of the Methow tribe. A photograph taken near Lake Wenatchee shows an example of similar styles of houses. Photo courtesy of Richard Hart and the Confederated Colville Tribes History Office and the Methow Grist Archive.

Most of the historical home sites are located down towards the mouth of the Methow River in the lower valley. When the Hudson's Bay Company started trading guns, ammunition and metal kettles for plush furs, the hunters and trappers became more interested in obtaining the plusher winter furs. That meant that winter hunting and trapping became more frequent and the trappers seasonally ventured further from the main villages, leading to more pit houses being built in the upper valley. An important village was located near today's Winthrop, where the Chewuch River flows into the Methow. Two summer settlements were located on the upper Methow River, one near the present-day town of Mazama and one near Goat Wall (Hart 2005). When horses arrived in Okanogan County in the 1700s, the seasonal migration patterns of the Methow tribes were fundamentally altered. Since horses couldn't eat when snow was on the ground in the valley, the tribes migrated to warmer climates to the south and east during the winter to allow for grazing, and to escape the harsh, cold winters of the Methow Valley (Portman 2002).

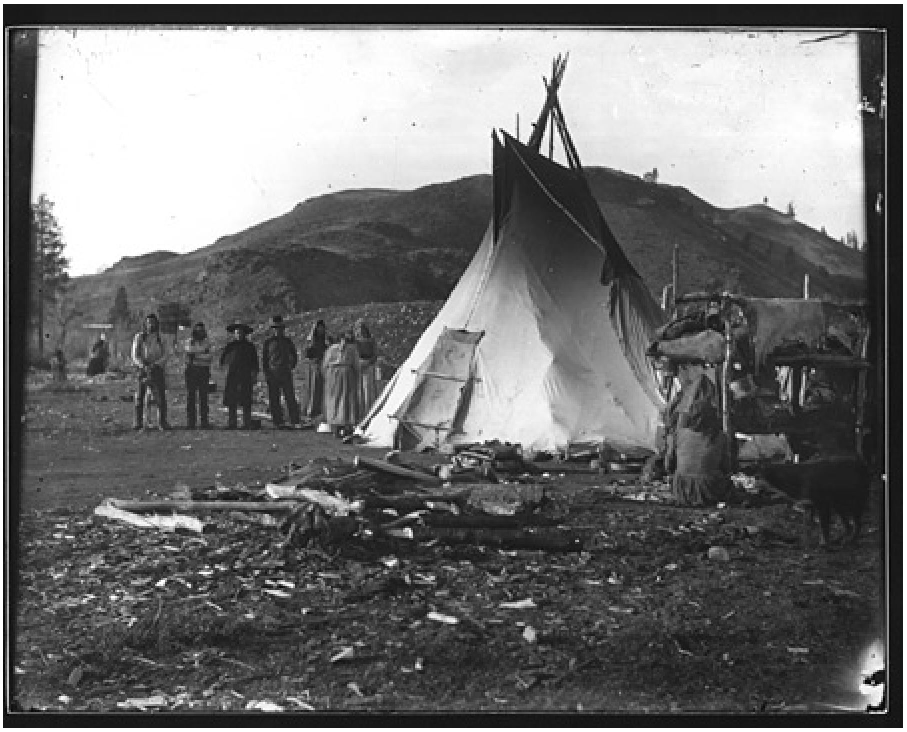

Figure 2. Members of the Methow tribe stand near a canvas and rush mat covered house. The woman in the foreground is tending to curing hides. Photo Courtesy of the Shafer Museum and the Methow Grist Archive.

Throughout this period, disturbance was relatively small-scale, and related only to using the floodplain and rivers as a basis for subsistence. However, there is some evidence of Native Americans logging huge old-growth – particularly cedars – to carve canoes. Massive stumps of trees believed to be around 500 years of age that were cut prior to Euro-American settlement in the valley have been found near Lost River. Even then, the size of those trees was rare and would have been a valuable commodity (USBR 2008). Additionally, some small fishing operations, using weirs, seine nets, spears, and basket traps, occurred throughout this time all along the Methow River and its tributaries.

Similar to other Native American tribes across the United States, the population of the Methow tribe was estimated to have been halved during the early- to mid-19th century, and then depleted by half again by 1900. By 1883, just over 300 Methow were in the valley, indicating that the population prior to European settlement may have been as high as 1,200 (Hart 2005). Under Executive Orders in 1878 and 1880, the Methow Valley was designated “Indian Land.” However, just a few years later in 1883 and 1886, the federal government opened the valley to European settlement and mining (USBR 2008).

2 Explorers, Fur Trappers, Traders and Miners

The first known occurrence of Anglo-Europeans visiting the basin was fur trappers in 1811. Western exploration for beaver pelts was heightened when hats utilizing beaver fur became desirable and fashionable. Large fur trading companies built up trading outposts on already established Native

American and trapper routes throughout the west, and the beginnings of white settlement in the Methow Valley occurred. Beaver was not the only fur that kept trappers in business throughout the Pacific Northwest and the Methow Valley; marten, lynx, weasel, mink, bobcat and cougar pelts were also a part of the fur trade. Native Americans, many of whom were trained by the original trappers and traders, supplied a large percentage of the pelts to the trading posts. By the mid-1800s, the fur trade had wiped out most of the species desired for their pelts, and some early residents transitioned from fur trapping to mining (Portman 2002).

Figure 3. Downtown Winthrop during the early days when the streets were made of dirt. The buildings to the right, including the blacksmith shop, stood where Winthrop Motors and Glassworks now stand. Photo courtesy of the Shafer Museum and the Methow Grist Archive.

Figure 4. A stage coach boards passengers in Winthrop, date unknown. Courtesy of the Shafer Museum and the Methow Grist Archive.

Many factors have contributed to habitat degradation in the Methow Basin. Although beaver trapping in the early 1800s may have had a small effect on riparian conditions, mining was probably the first major activity to affect riparian and stream conditions (Mullan et al. 1992). Placer mining at the mouth of the Methow River near Pateros began around 1860 by Chinese immigrants. Small mining activities continued in the Methow Basin throughout the 1870s. Hard rock mining, or the process of digging deep holes into sides of mountains, began in earnest in the late 1880s, when the first mineral discoveries in the middle Methow Valley came near Twisp. Local history suggests that a Methow Indian directed a white settler to a large ore deposit up War Creek on the Twisp River in 1886, which quickly created a rush to the Methow Valley (Portman 2002). By 1897 there were three mines listed in the Twisp Mining District – the Alder, Crescent, and Red Shirt mines.

Figure 5. The first source of power for Winthrop came from diverted Methow River water that ran a generator, operated by the Upper Methow Valley Power and Light Company and located on the Methow River near the present-day East 20 Pizza. Photo courtesy Shafer Museum and the Methow Grist Archive.

The mining surge in the Methow Valley peaked in the 1890s. Mining operations were carried on in the hills around Twisp, Methow, and above Winthrop for many years and some with considerable development. Goat Creek, near Mazama, had numerous productive mines, many of which were situated in very remote, rugged, and almost inaccessible areas. In 1893, a small pack trail between Robinson Creek and Slate Creek was enlarged, following the north side of the Methow Valley over a treacherous route (Lester 2013). Though somewhat more useable, this new road was still much narrower than the average wagon and had highly dangerous sections, such as Dead Horse Point, named after a pack train that slipped and fell down the thousand-foot-high cliffs.

Figure 6. The Flying Cloud puddlejumper truck hauls lumber, probably towards the Azurite Mine, date unknown. In the early 1930s, three Model T trucks nicknamed puddlejumpers were altered in Twisp. A vehicle was needed that could be driven from Robinson Creek, around Dead Horse Point and on to the Azurite Mine up and over the extremely narrow Hart's Pass. The front axle was narrowed by 12 inches and the rear axle replaced with one that allowed the trucks to gear down. An extra water tank, and an oil pump to lubricate the front bearing were also added. Ernie Cotton Collection, courtesy of the Shafer Museum and the Methow Grist Archive.

Figure 7. A crew delivering one of the three altered trucks to the Azurite mine, posing at Dead Horse Point for this photograph, circa 1930. Photo Courtesy of Lawrence Therriault and the Methow Grist Archive.

Named Hart's Pass after the Colonel who ran the operation, this road is still in use today. Terminating roughly at timberline in the North Cascades near 6100 feet in elevation, it is the highest point in the State of Washington that one can drive to. Much of the mining development work in the Upper Methow Valley was limited by lack of transportation or inadequate transportation that resulted in high costs to remove and transport the minerals down to the markets. Nonetheless, near the turn of the century, mining interests near the headwaters of the Methow River and north into Slate Creek, Bonita Creek, Goat Creek, and Mill Creek increased dramatically.

As early at 1895, the Hart's Pass and Slate Creek area near the headwaters of the Methow River and high up in the Cascades was a booming gold mining district. In 1893, a prospector named Alex Barron discovered deposits up near the headwaters of the Methow River. A town, named after Barron, was built 30 miles northwest (as the crow flies) of Winthrop (Lester 2013). As more mines, such as the Eureka Mine and Mammoth Mine, were developed in the area, numerous other small settlements sprung up; the town of Robinson, near the confluence of Robinson Creek and the Methow River, and the settlement near Lost River along the Methow River are two such examples (Wolff et al. 2003, Smith et al. 2005). During its peak, there were 3,500 people working and living at the mines. A power plant was even constructed to provide electricity, in addition to the three hotels, general store, post office, blacksmith shop, sawmill, and saloon. Supplying these productive camps proved a boon for both the towns of Winthrop, Twisp, and Mazama, and for many local entrepreneurs (Portman 2002). Thirty-two miles northwest of Winthrop, in the valley of Mill Creek and further west than the Hart's Pass mining district, are the remains of the remote, barely-reachable Azurite Mine. This legendary mine began production in 1915, gradually building to a peak of activity between 1936 and 1939, and quickly fading away by the early 1940s. It produced copper, silver and gold primarily, but due to the difficult terrain and long distance to ship freight, even after road improvements between Lost River and the mine, there were minimal profits to be made (Whiting 2013).

Figure 8. Snow cat and sled on a trip to the Azurite mine. Date unknown. Photo courtesy of the Larry Therriault Collection and the Methow Grist Archive.

Figure 9. A tractor clearing deep snow along Hart's Pass. Date unknown, but probably during the war period of 1941-1945. Photo from the Frankie Waller Collection, courtesy of the Shafer Museum and the Methow Grist Archive.

The American Smelting and Refining Company (ASARCO) leased the Azurite Mine in 1934 and dug deeper, developed the area, and assembled a crew. The winter of 1935 was an especially harsh one, and landslides destroyed many of the buildings at the Azurite Mine site (Portman 2002). Despite this, work continued throughout the bitterly cold winters. Driving or walking out from the mine site between the months of December to May was essentially impossible due to walls of snow, threatening avalanches, and difficult weather. A dog team was therefore the lifeline to the miners, bringing supplies, tools, and food in about four times a month, and in some cases a doctor up to the mine or a patient down into civilization (Portman 2002). By 1939, ASARCO terminated operations at the mine, after having failed to recoup their investments (Whiting 2013).

Figure 10. Ed Kikendall and his dogs on a supply run to the Azurite Mine. Date unknown. From the Dick Webb Collection, courtesy of the Shafer Museum and the Methow Grist Archive.

The historical methods of extracting minerals out of ore, soil or sediments were often detrimental to rivers at the time as well as after the mines had been closed due to contaminated runoff, waste and tailings. Due to the relatively low production of most mines in the valley, it can be surmised that effects to the Upper Methow and its tributaries were moderate and the ecosystem has since recovered (Mullan et al. 1992). However, mining likely did impact the Methow River and its tributaries by altering the hydrologic and sediment regime via the removal of instream gravels, diversion of water, and deposition of mining waste in the channel and floodplain.

Figure 11. These men are using horses and a V-plow to clear the road near Mazama. Date unknown. Photo from the Dick Webb Collection, Courtesy of the Shafer Museum and the Methow Grist Archive.

Extracting gold from the Methow's rocky hillslopes was not an easy task. The rugged terrain of the region made access difficult and hauling freight dangerous. Although there were few profitable mines in the region, the dream of striking gold led many early prospectors up the Methow River and its tributaries (Portman 2002). With these early miners and settlers, however, came the infrastructure that serviced homesteaders who followed. Cabins were built, bridges were erected, and towns popped up. Some miners and prospectors left the hills and took up raising livestock, planting crops, or harvesting timber. In addition, the increased accessibility to northern Washington in the early 1900s due to railroads and steamboats on the Columbia River transported people into the Methow Valley. This, in addition to the construction of a much safer road from Pateros to Winthrop up the lowlands of the valley compared to the narrow, rough mountain pass road that was utilized by travelers previously, made settlement in the Methow Valley a much easier prospect and brought even more homesteaders into the region (Portman 2002). Most of the land in the Methow Valley was settled by using the United States Congress Homestead Act of 1862 and the Homestead Entry Survey (HES) Act of 1906 (USBR 2008). The first homestead was noted in 1888 and by 1891, small villages began to crop up throughout the middle and upper Methow Valley, including near the present location of Winthrop (USBR 2008).

Human impacts to the valley increased during this period to accommodate the mining needs for transportation, the increased population needing goods and services, and the agricultural need for cleared, open land.

3 Timber Harvest, Livestock Grazing, and Other Land Use

Following the era of mining was a period of intense livestock grazing and agriculture. Agriculture and grazing were first documented in the region in 1889. Dairy cattle provided cream to local butter makers, who shipped their butter off to towns across the region in the early 1900s and which contributed considerably to the local economy (Portman 2002).

Figure 12. The Winthrop creamery sat on the bank of the Methow River where the Methow Conservancy is now located. The August 7, 1913 edition of the Met-how Valley Journal writes, "In this comparatively small building is transacted a business that means much to the Upper Valley. The yearly output of butter is over one hundred thousand pounds, thereby distributing about twenty-five thousand dollars among the ranchers. The Met-how Valley butter is known throughout the state for its excellence. The main officers of the creamery, to whom much credit is due, are A. J. Haase, General Manager, and Newton Nickell, Buttermaster." From the estates of Raymond M. and Gladys Badger and Warren F. and Lois Badger. Photo courtesy of the Shafer Museum and the Methow Grist Archive.

Grazing pressure was highest from the late 1800s to the 1930s, lessening as allotment systems replaced the open range. Cattle and sheep grazing resulted in localized soil compaction, bank erosion, and loss of riparian understory seedlings and shrubs. Another notable human disturbance was the installation of water diversions for mining and small- scale agriculture operations throughout the region. Many of the early diversions were unscreened and resulted in direct fish mortalities, while the combination of multiple diversions withdrawing instream flows during low flow periods reduced already critical salmonid habitat.

Figure 13. Loggers, likely men from Mazama, use four horses to pull a load of pine to the mill. Date unknown. Photo courtesy of the Northcott family and the Methow Grist Archive.

Figure 14. A team of horses hauls large logs from the forest, likely near Mazama. From the Della Northcott Collection, courtesy of the Shafer Museum and the Methow Grist Archive.

Timber harvest to open land for farming and grazing began in the 1880s, but the logging industry did not begin true harvesting practices until the 1920s. Selective harvest, or "high grading," was the primary harvest method up until the mid-1950s (Portman 2002, USBR 2008). Since then, partial cutting and clear-cutting have been the predominant practices.

Figure 15. An important local entrepreneur, Guy Waring had a sawmill at the north end of Winthrop. In the spring of 1898 it was capable of turning out 1,000 board feet of lumber per hour. Photo courtesy of the Methow Grist Archive and the Shafer Museum.

Figure 16. In June, 1919 George Fender purchased a big, new three-and-a-half ton truck so he could haul finished lumber from the Methow down to Pateros. In July 1919, his Bear Creek mill had cut its last logs, and in August 1919 local news reported that he had moved his operation near Weeman Bridge. It may have been easier to move the mill to a new log pile than move the logs to the mill. This photograph may have captured the process of moving the boiler used to create steam to run the sawmill's blades and log carriage from the old mill site to the new site near Weeman Bridge, though it cannot be determined for sure. Photo courtesy of the Shafer Museum and the Methow Grist Archive.

Timber harvesting in the region has played a considerable part in the changes to the hydraulic and sediment regime within the Methow River. Upland timber harvest and its associated practices have likely increased the amounts of slides and debris flows that the Methow River has experienced. Log drives that used the river to transport harvested lumber to mills likely scoured out spawning gravels (Mullan et al. 1992). Timber harvest along the valley floor led to the associated loss of the important riparian function that established vegetation serves, including flood moderation, regulation of inundation processes, shade, moderation of stream temperature fluctuations, and providing future sources of large wood material to the channel.

Past cleanouts of the channel have also had a significant impact on habitat. Following both the floods of 1948 and 1972, the Army Corps of Engineers removed natural large wood accumulations and channel substrate, as well as straightened portions of the channel, reducing available habitat and high flow refuge (USBR, 2008). Although large-scale snagging and riparian clearing is no longer occurring in the study area, the effects of this historical practice will continue to affect wood-loading for the foreseeable future.

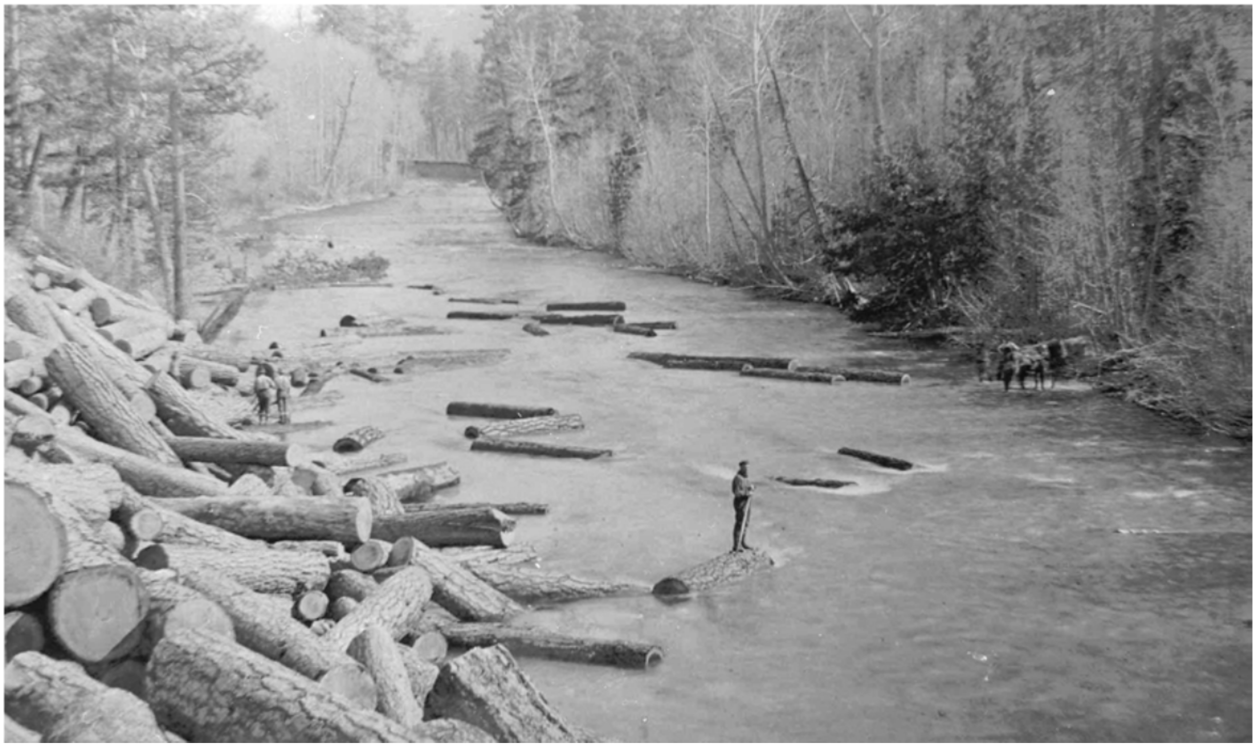

Figure 17. Ground photograph of log drive likely in the 1920s or 1930s on upper Methow River. Location is believed to be above Winthrop because the most commonly referenced log mills during this period were between 4 to 6 miles upstream of Winthrop. Photo courtesy of Shafer Museum.

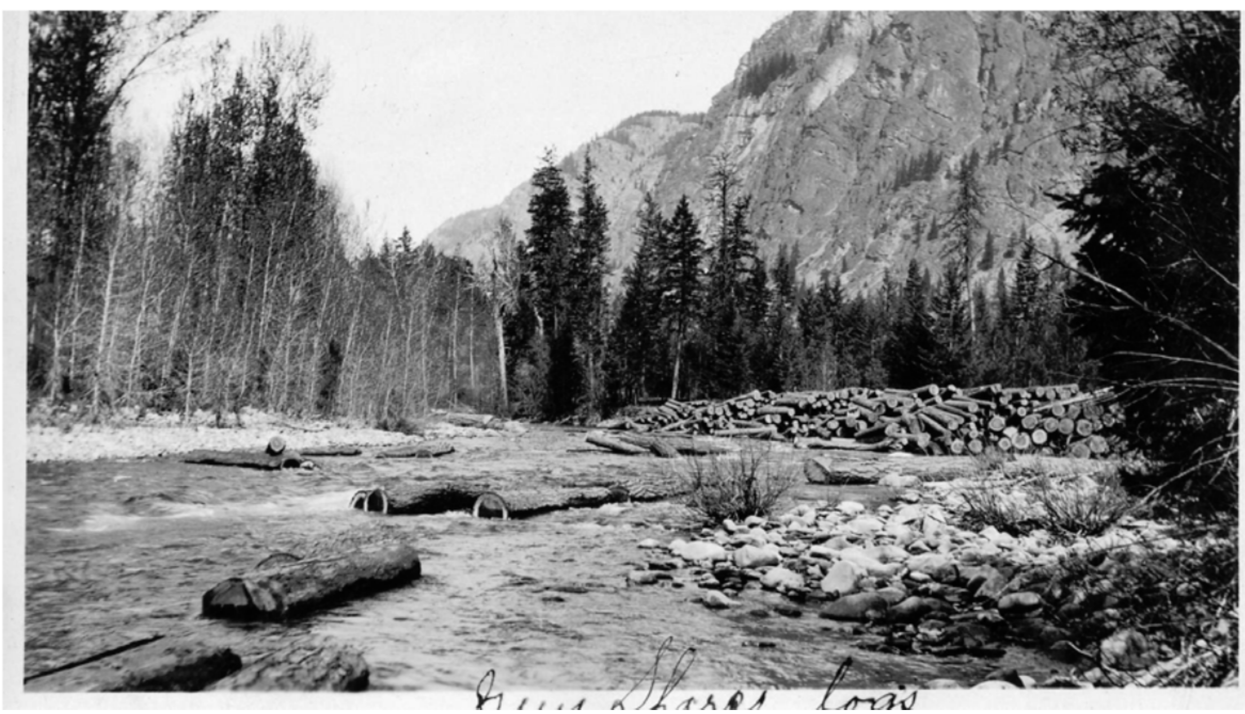

Figure 18. Another log drive scene in the Upper Methow believed to be looking at Goat Wall near Mazama. Photo courtesy of Shafer Museum.

Figure 19. Debris pile and destroyed bridge along the Twisp River by the old creamery after the flood of 1948. Photo from the Wink Byrum Collection, courtesy of the Shafer Museum and the Methow Grist Archive.

Flood mitigation practices of the mid- to late-1970s also included the construction of levees to prevent flooding on private property, which reduces floodplain connectivity and lateral channel migration. Riprap was also used intermittently throughout the study area as a method of bank stabilization for residential properties as well as roadway embankments and bridge abutments (USBR 2008). This armoring limits natural lateral channel migration and sediment sourcing from streambanks.

Fire suppression beginning in the early 1900s in the valley has resulted in altered fire disturbance regimes that continue today. The altered fire regime results in increased build-up of fuel loads between fires. Fires now occur further apart and the increased fuel loads have increased the risk of moderate to high intensity burns. This shifts the vegetative composition from more open stands of fire-tolerant species (primarily ponderosa pine) to higher density stands of less fire-tolerant species (primarily Douglas fir). The result is fewer large trees in the riparian zone that can be recruited into the river.

In 1972, the North Cascades Highway was completed and allowed travel through the previously quiet, largely uninhabited valley. A ski resort planned in the upper Methow Valley incited controversy and years of land development right issues (Portman 2002). Although the ski resort was never built, summer and winter recreational tourism is a large component of the business in the Methow Valley. Many vacation homes and rentals have been built in the valley, a lot of them during the speculative ski resort period. Agriculture and cattle farming is another significant part of the economy in the valley. Today, extensive trails for hiking, cross-country skiing, and mountain biking wind through the upper Methow Valley, including within the riparian zones and floodplain areas.

The Methow River has a high proportion of pristine habitat in the upper portions of major tributaries. The primary habitat conditions in the Methow Basin that currently limit abundance, productivity, spatial structure, and diversity of salmon and steelhead (and bull trout and Pacific lamprey) are mostly found in the middle and lower mainstem and lower portions of major tributaries that have been affected by state highways, county roads, and housing and agricultural development – practices that have diminished the overall function of the stream channel and floodplain. This has impaired stream complexity, wood and gravel recruitment, floodwater retention, and water quality. Additionally, late summer subsurface flow and winter instream ice conditions often reduce migration, spawning, and rearing habitat for native salmonids. These flow conditions are largely natural in the Upper Methow (a result of watershed-specific weather and geomorphic conditions) but may be exacerbated by human disturbances and irrigation withdrawals.

Today, the study area is currently 24% public property and 76% private property within the low geomorphic surface (valley bottom), with the Okanogan National Forest accounting for a majority of the public property. Much of the private property has undergone vegetation clearing, floodplain grading, and residential development (Table 1). The low geomorphic surface within the study area has a road density of 1.88 mi/mi^2.

Table 1. Human alterations and development in the study area. The low geomorphic surface includes the contemporary floodplain and alluvial terraces.

Metric	Value in the Low Geomorphic Surface
Road Density	1.88 mi/mi^2
Public Land	24%
Private Land	76%
Portion of Channel with Levees & Bank Armoring	1%
Developed & Cleared Land	25.6%

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