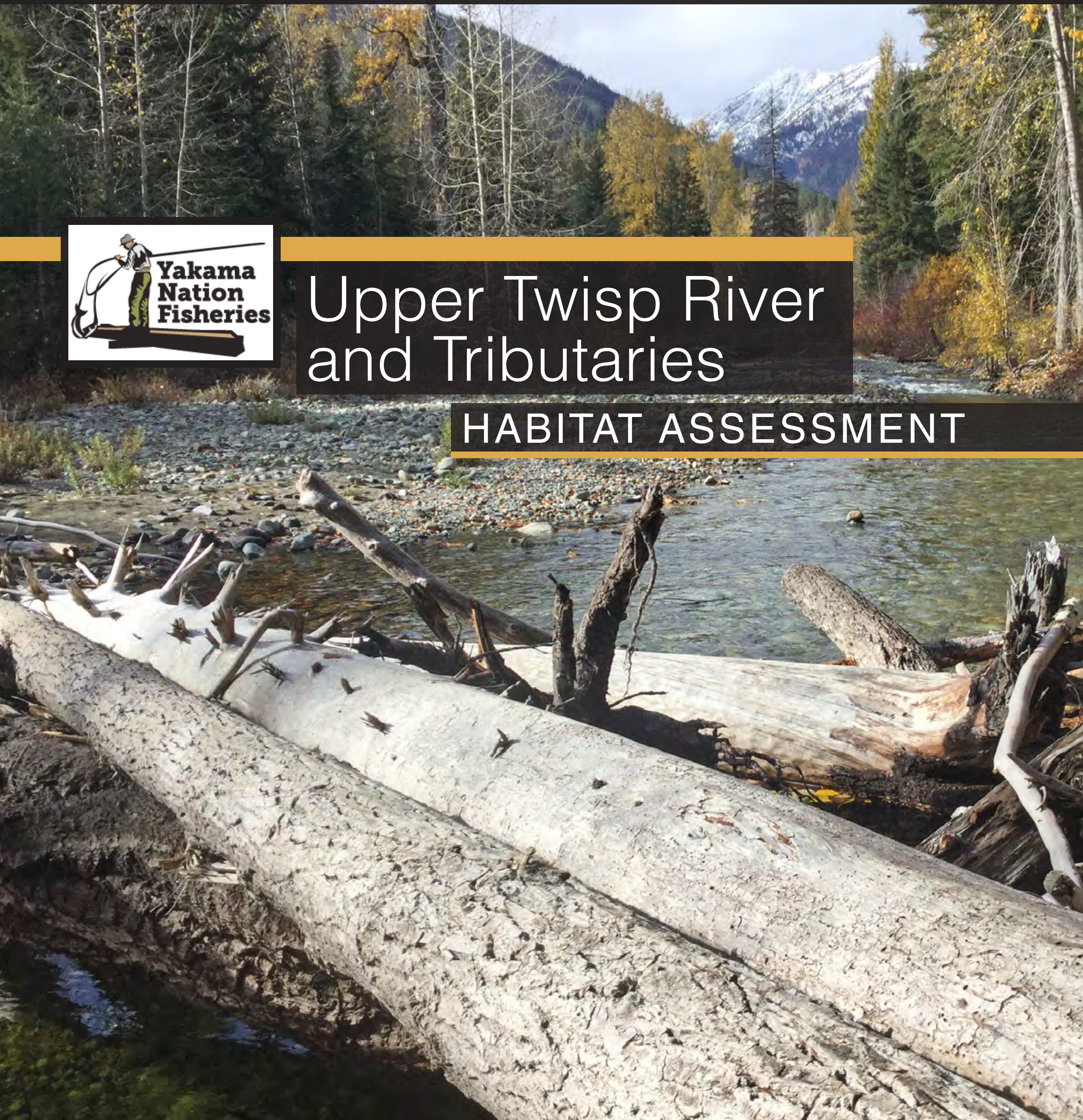
Yakama Nation Fisheries

Upper Twisp River and Tributaries

HABITAT ASSESSMENT



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Acronyms and Abbreviations

°F	degrees Fahrenheit
AU	Assessment Unit
cfs	cubic feet per second
CTCR	Confederated Tribes of the Colville Reservation
dbh	diameter at breast height
DEM	digital elevation model
ESA	Endangered Species Act
HUC	Hydrologic Unit Code
LBC	Little Bridge Creek
LiDAR	light detection and ranging
LTR	lower Twisp River
LWD	large woody debris
NED	National Elevation Dataset
NLCD	National Land Cover Database
NMFS	National Oceanic and Atmospheric Administration National Marine Fisheries Service
PRISM	Parameter-elevation Relationships on Independent Slopes Mode
REI	Reach-based Ecosystem Indicators
RM	river mile
RUIP	Recovery Unit Implementation Plan
UCHRP	Upper Columbia Habitat Restoration Program
UCRTT	Upper Columbia Regional Technical Team
UCSRB	Upper Columbia Salmon Recovery Board
USBR	U.S. Bureau of Reclamation
USFS	U.S. Department of Agriculture Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UTR	upper Twisp River
WA	Washington
WRIA	Watershed Resource Inventory Area

1. INTRODUCTION

The Upper Twisp River and Tributary Habitat Assessment (this Project) includes a geomorphic and aquatic habitat assessment that evaluates existing conditions and impairments in the Twisp River and tributaries to support the development of a restoration strategy. The Twisp River watershed drains approximately 246 square miles on the eastern slopes of the Cascade Mountains, in Okanogan County, entering the Methow River at the town of Twisp, Washington. The Project's primary focus area, referred to as the Assessment Area, includes the upper Twisp River (UTR) drainage upstream of U.S. Geological Survey (USGS) river mile (RM) 17.8 (USGS 2017) and several anadromous UTR tributary drainages including North Creek, South Creek, Reynolds Creek, War Creek, Eagle Creek, Canyon Creek, and Little Bridge Creek (LBC). The Assessment Area is mostly within the Okanogan-Wenatchee National Forest. The reaches field surveyed for this Project, herein referred to as the Survey Area, are shown in Figure 1-1 and described in Section 2.1.

A history of land use and resource extraction in the UTR drainage has resulted in degraded conditions for Endangered Species Act (ESA)-listed salmonids including Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*O. mykiss*), and bull trout (*Salvelinus confluentus*), and other species. This habitat assessment synthesizes existing scientific information, field data collection, data analyses, and interpretation to describe geomorphic conditions, hydrology, aquatic habitat, and riparian conditions.

The restoration strategy presented in this report includes a project ranking and evaluation process for potential project areas. This strategy evaluates potential habitat restoration actions based on current habitat conditions, geomorphic restoration potential, feasibility, infrastructure, and social constraints. Potential project areas are identified, described in detail, and their locations mapped, where possible. Future site-specific analyses will build upon this information to refine potential project areas, evaluate alternatives, and develop detailed designs for implementation.

This Project is being conducted by the Yakama Nation Department of Fisheries Resource Management Upper Columbia Habitat Restoration Program (UCHRP). The UCHRP is focused on identifying and implementing restoration projects in the Upper Columbia River Basin in accordance with the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (Recovery Plan) (UCSRB 2007).

1.1 Purpose

The purpose of this Project is to develop a science-based habitat assessment and restoration strategy to address ecological concerns (also known as limiting factors) and improve habitat conditions for ESA-listed species in the UTR and tributaries. The habitat assessment will provide the technical basis for the restoration strategy by describing complex biological and physical processes as they relate to degraded habitat conditions. The biological and physical understanding developed in the habitat assessment is critical for identifying effective restoration actions and high priority areas.

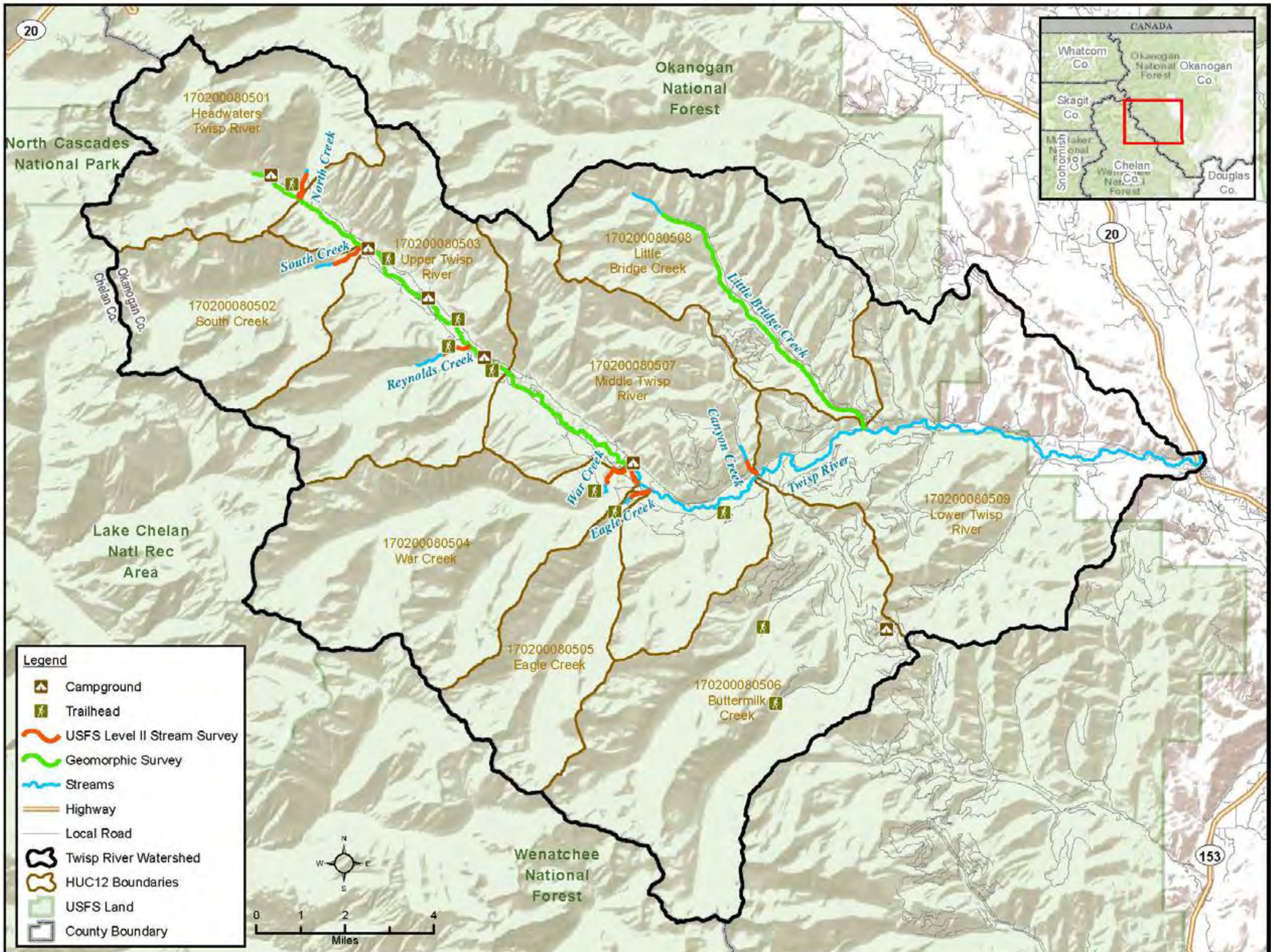

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Figure 1-1. Project Location Map–Upper Twisp River Assessment Area

1.2 Recovery Planning Context

Recovery planning for ESA threatened and endangered fish species in the upper Columbia River region has been robust. This assessment provides additional information aimed at continuing the ongoing effort to bring prior guidance and action items forward for evaluation and implementation in the UTR and its tributaries. Key recovery planning efforts that have addressed conditions in the Twisp River watershed, as part of the Methow River Subbasin, include the Methow Subbasin Plan (NPCC 2005), the Methow Subbasin Geomorphic Assessment (USBR 2008), the Recovery Plan (UCSRB 2007), the Recovery Plan for the Coterminous United States Population of Bull Trout (USFWS 2015a), and the revised Upper Columbia Biological Strategy (Biological Strategy) (UCRTT 2014). Additionally, in 2012, tribes and state and federal agencies signed the Conservation Agreement for Pacific Lamprey, which was developed “to promote implementation of conservation measures for Pacific Lamprey in Alaska, Washington, Oregon, Idaho, and California” (USFWS 2012). Each of these is described briefly below.

Methow Subbasin Plan

The Methow Subbasin Plan (NPCC 2005) included a technical assessment of subbasin conditions, an inventory of fish and wildlife activities and management plans within the subbasin, and a management plan laying out a vision for the subbasin with specific biological objectives and strategies to meet those objectives. For this assessment, the Subbasin Plan serves as a key resource for information about limiting factors in the UTR and its tributaries (see Ecological Concerns discussion in Section 2.7) and restoration strategies most likely to help achieve broader Methow River Subbasin goals.

Methow Subbasin Geomorphic Assessment

The Methow Subbasin Geomorphic Assessment (USBR 2008) included a tributary reach-based assessment approach to evaluate physical river processes and habitat conditions within the Methow Subbasin. The report includes a subbasin-scale geomorphic conditions assessment, identification of potential habitat restoration actions, and a prioritization strategy for restoring channel and floodplain connectivity and complexity in the mainstem Methow River and tributary reaches included in the assessment.

Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan

The Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (Recovery Plan) established regional objectives for habitat restoration along streams that currently support or may support ESA-listed salmonids. The following list of short-term objectives, long-term objectives, and general recovery actions identified in the Recovery Plan underpins the development of the restoration strategy in this assessment (UCSRB 2007).

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 woody debris, rocks, etc.) where appropriate.
- Protect and restore riparian habitat along spawning and rearing streams and identify long-term opportunities for riparian habitat enhancement.

- Protect and restore floodplain function and reconnection, off-channel habitat, and channel migration processes where appropriate and identify long-term opportunities for enhancing these conditions.
- Restore natural sediment delivery processes by improving road network, restoring natural floodplain connectivity, riparian health, natural bank erosion, and wood recruitment.

Long-Term Objectives

- Protect areas with high ecological integrity and natural ecosystem processes.
- Maintain connectivity through the range of the listed species where feasible and practical.
- Protect and restore water quality where feasible and practical within natural constraints.
- Protect and restore off-channel and riparian habitat.
- Increase habitat diversity by rebuilding, maintaining, and adding instream structures (e.g., large woody debris, rocks, etc.) where long-term channel form and function efforts are not feasible.
- Reduce sediment recruitment where feasible and practical within natural constraints.
- Reduce the abundance and distribution of non-native species that compete and interbreed with or prey on listed species in spawning, rearing, and migration areas.

General Recovery Actions Specific to the UTR Assessment Unit (AU)

- Use administrative and institutional rules and regulations to protect and restore stream and riparian habitats on public lands.
- Increase habitat diversity and quantity in the upper Twisp by restoring riparian habitat and floodplain connectivity.
- Reduce sediment load by improving road maintenance throughout the assessment unit.

Recovery Plan for the Coterminous United States Population of Bull Trout

While the Recovery Plan outlined above was also intended to address bull trout, in September 2015 the U.S. Fish and Wildlife Service (USFWS) published an updated Recovery Plan for the Coterminous United States Population of Bull Trout (USFWS 2015a). This includes a Mid-Columbia Recovery Unit Implementation Plan for Bull Trout (Mid-Columbia Recovery Unit Implementation Plan [RUIP]) (USFWS 2015b), within which the Methow Subbasin is one of 24 core bull trout areas.

The Mid-Columbia RUIP details recovery actions in the Methow River core area to address habitat, demographic, and non-native fish threats. The Twisp River bull trout population is one of the largest in the Methow River Subbasin (USFWS 2002; USFS 2014), and the restoration strategy in this assessment took the general and specific guidance for the issues related this population from the Mid-Columbia RUIP into account.

Revised Biological Strategy

The UCRTT was created to provide technical support to the Upper Columbia Salmon Recovery Board (UCSRB). The revised Biological Strategy provides specific support and guidance on implementing the 2007 Recovery Plan described above (UCRTT 2014). This Project includes two AUs from the revised Biological Strategy: the Upper Twisp River AU, which contains the UTR and all Project tributaries except LBC; and the lower Twisp River (LTR) AU, which includes LBC.

In the revised Biological Strategy, the UTR AU is designated as a Priority 1 area (on a scale of 1 to 4, 1 being highest priority), and a priority 2 for protection, with restoration priority action types including restoring natural geomorphic processes such as channel structure, form and migration, floodplain interaction, and sediment transport (UCRTT 2014). Specific actions are for the UTR AU are recommended for improving these functions in the revised Biological Strategy. These include (in priority order) (UCRTT 2014):

1. Peripheral and transitional habitats – Reconnect disconnected side channels or where low wood loading has changed the inundation frequency, improve hydraulic connection of side channels and wood complexity within the side channels;
2. Channel structure and form (instream structural complexity) – Install large wood and engineered log jams in strategic locations to provide short-term habitat benefits and intermediate-term channel form and function benefits;
3. Channel structure and form (bed and channel form) – Remove levees, undersized bridges, bank armoring, and other human features;
4. Riparian condition – Restore conditions in degraded areas, improve large woody debris (LWD) recruitment, fence riparian areas and wetlands, and implement the Respect the River Program for North Creek/Gilbert area; Reynolds Creek; and the Roads End, South Creek, Mystery, Poplar Flat, and War Creek campgrounds, as well as other dispersed areas;
5. Food – Estimate amount of nutrients needed in the assessment unit, and increase nutrients to the watershed using hatchery carcasses and/or carcass analogs;
6. Sediment – Road management, reduction, and maintenance to restore sediment and large wood recruitment rates within riparian and upland areas; and
7. Species interactions – Reduce or eliminate brook trout in high-density areas.

In the revised Biological Strategy, the LTR AU, including LBC, is designated as a Priority 2 area for restoration. Specific actions are for the LTR AU are recommended for improving these functions in the revised Biological Strategy. These include (in priority order) (UCRTT 2014):

1. Water Quantity – LBC diversion may impact bull trout migration, spawning, and rearing;
2. Channel structure and form (bed and channel form) – Remove levees, undersized bridges, bank armoring;
3. Peripheral and transitional habitats – Reconnect disconnected side channels or where low wood loading has changed the inundation frequency, improve hydraulic connection of side channels and wood complexity within the side channels;
4. Channel structure and form (instream structural complexity) – Install large wood and engineered log jams in strategic locations to provide short-term habitat benefits and intermediate-term channel form and function benefits;
5. Riparian condition – Restore condition in degraded areas associated with residential development or where there are legacy effects from past riparian logging practices;
6. Food – Estimate amount of nutrients needed in the AU, and increase nutrients to the watershed using hatchery carcasses and/or carcass analogs;

7. Sediment – Road management, reduction, and maintenance to restore sediment and large wood recruitment rates within riparian and upland areas; and

8. Species interactions – Reduce or eliminate brook trout in the LBC.

The revised Biological Strategy also identified specific priority ecological concerns for the UTR and its tributaries, as discussed below in Section 2.7. As part of the Biological Strategy, a series of reference tables were also developed as a public resource (UCRTT 2013). The tables identify priority actions for the UTR AU including restoring natural geo-fluvial processes, for example, channel structure and form and migration, floodplain interaction, and sediment transport.

Conservation Agreement for Pacific Lamprey

The Conservation Agreement for Pacific Lamprey aims to: “a) develop regional implementation plans derived from existing information and plans; b) implement conservation actions; c) promote scientific research and d) monitor and evaluate the effectiveness of those actions” (USFWS 2012). The Pacific Lamprey 2016 Regional Implementation Plan for the Upper Columbia Regional Management Unit discusses the current state of Pacific lamprey populations in the Methow River Subbasin (Nelle et al. 2016). While it does not specifically discuss the Twisp River, actions such as improving passage at mainstem dams and proposed adult translocation and larval/juvenile supplementation into the Methow River Subbasin and tributaries could improve the potential migration into the Twisp River and its tributaries and future recovery of Pacific lamprey.

1.3 Report Organization

This report includes the following key components:

- Section 1: Introduction – Describes the purpose of the habitat assessment, the recovery planning context, and overview of document organization.
- Section 2: Assessment Area Conditions – Provides relevant historical information and existing background data used to describe conditions in the Assessment Area.
- Section 3: Habitat Assessment Methods – Describes assessment methods for geomorphic and habitat field surveys, field identification of potential restoration opportunities, geomorphic and habitat assessment data analyses, and Reach-based Ecosystem Indicators (REI) assessment.
- Section 4: Habitat Assessment Results – Provides the assessment results including hydrology, geomorphology and habitat descriptions, reach descriptions, reach comparisons, REI, and potential climate impacts.
- Section 5: Restoration Strategy – Describes reach-scale restorations strategies, project areas and potential restoration actions, addressing ecological concerns, and project prioritization and scoring
- Section 6: Conclusion and Next Steps – Provides recommended follow-up actions for implementing the restoration strategy.
- Section 7: References – Lists all references cited in this habitat assessment report.

2. ASSESSMENT AREA CONDITIONS

As previously described, the Assessment Area for this Project includes the UTR drainage upstream of RM 17.8 and several anadromous UTR tributary drainages including North Creek, South Creek, Reynolds Creek, War Creek, Eagle Creek, Canyon Creek, and LBC. Habitat assessment results specific to the Survey Area are described in Section 4.

The evaluation of the Assessment Area builds on a large amount of previous data, analyses, effectiveness monitoring, and recovery planning efforts. The intent of this Project is not to replicate but rather to supplement existing studies, assessments, and planning documents. To support the development of this Project, relevant data, reports, and literature were compiled and reviewed. The background data and reports were organized and indexed to allow for convenient searchable access for stakeholders utilizing this assessment in the future. The index of existing habitat assessment data is included as Appendix A.

The following contains a partial list of previous assessments and planning documents reviewed for this Project:

- Middle Methow Watershed Analysis (USFS 1997)
- Salmon, Steelhead, and Bull Trout Habitat Ecological Concerns – Watershed Resource Inventory Area (WRIA) 48 (Andonaegui 2000)
- Methow Subbasin Plan (NPCC 2005)
- Methow Watershed Plan (WRIA 48) (MBPU 2005)
- Mid-Columbia Coho Restoration Master Plan (YNF 2005)
- Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSRB 2007)
- Methow Subbasin Geomorphic Assessment (USBR 2008)
- Statewide Steelhead Management Plan: Statewide Policies, Strategies, and Actions (WDFW 2008)
- Lower Twisp River Reach Assessment (Inter-Fluve 2010).
- Mid-Columbia Coho Reintroduction Feasibility Study (Kamphaus et al. 2011)
- Revised Biological Strategy (UCRTT 2014)
- Middle Twisp River Reach Assessment and Restoration Strategy (Inter-Fluve 2015)
- Recovery Plan for the Coterminous United States Population of Bull Trout (USFWS 2015a)
- Pacific Lamprey 2016 Regional Implementation Plan for the Upper Columbia Regional Management Unit (Nelle et al. 2016)

Additionally, numerous specific studies of fish presence and abundance have been completed for the Twisp River watershed by the Yakama Nation, USFS, and others. Stream habitat surveys were completed by the USFS on the UTR (USFS 1994a, 2001, and 2014), the LBC (USFS 1993, 1996, and 2006a), UTR tributaries (USFS 1995a), and Canyon Creek (USFS 1994a and 1994b), which provide a wealth of valuable stream habitat data and summary information.

Based on the literature and existing data identified above, the following subsections were developed to provide relevant background information, context, and an increased understanding of conditions in the UTR and its tributaries. The background information includes a description of the setting and climate, geology and glacial history, human disturbance history, wildfires, water quantity and quality, fish use and population status, and ecological concerns.

2.1 Setting and Climate

The Twisp River watershed (hydrologic unit code [HUC] 1702000805) is within the Methow River Subbasin (HUC 17020008) and WRIA 48. Almost half of the watershed is within the Lake Chelan-Sawtooth Wilderness, a 153,057-acre area managed by the USFS (NPCC 2005). Overall, federal management covers nearly 95 percent of the watershed, with private landownership and human activity concentrated in the lower 15 miles of the river (NPCC 2005).

The Twisp River watershed is within the Columbia Cascade Ecological Province (NPCC 2005). Elevations in the watershed range from 8,680 feet at the upper elevations in the Lake Chelan-Sawtooth Wilderness to 1,600 feet at the confluence with the Methow River. Average annual precipitation ranges 18.1 inches near the outlet of the LBC to 76 inches in the upper elevations of the watershed (PRISM 2016). Peak flows occur from April through August driven by snowmelt runoff and infrequent rain-on-snow events (Nelson 2004). Natural falls block fish passage in some tributary headwaters of the Twisp River, including a barrier falls reported at the confluence of the North and South Forks, and sections of the mainstem go dry in the late summer (USFWS 2004; NPCC 2005). The Methow River Subbasin, which includes the Twisp River watershed, is one of the coldest of 24 western climate zones, with a mean winter temperature of 8.6 degrees Fahrenheit (°F) (1970 to 1990) at Mazama, Washington. The lower portions of the Methow River Subbasin have August high temperatures of 80°F to 95°F, only occasionally hotter than 100°F (NPCC 2005).

2.2 Geology and Glacial History

The topography of the Methow River Subbasin is a result of a complex history of geologic and glacial processes including terrane accretion, deformation, uplift, and erosion. The following section contains an overview summary of the primary geologic characteristics and glacial history that define the Methow River Subbasin and the Twisp River drainage. Figure 2-1 shows the generalized surficial geology.

The geology of the Methow River Subbasin ranges from the crest of the Cascade Mountains (8,500 feet) down to a wide gently sloping valley that connects to the Columbia River (800 feet), mostly developed from alpine and continental ice-sheet style of glaciation. The upper reaches of the Methow Valley are deeply cut into the east side of the Cascades, showing avalanche chutes, steep and sharp ridges, and cirques. The upper valley is a U-shaped glaciated intermountain valley, bordered with bedrock uplands rising steeply from the floor of the valley (NPCC 2005).

Approximately 50 to 65 million years ago, the North Cascade subcontinent was pushing on the Okanogan subcontinent. As the two subcontinents pressed against each other, north to south faults formed in the region (NPCC 2005). The primary tectonic feature of the Methow Subbasin is the Tertiary Methow-Pasayten Graben which is a depressed (lowered) block of land that is bordered by parallel faults. The Methow-Pasayten Graben is bounded on the west side by the Hozameen-North Creek fault zone (Stoffel et al. 1991 as cited in USBR 2008) and on the east side by the Pasayten Fault (Barksdale 1975; Haugerud and Tabor 2009). The Methow River Subbasin is currently described with folded Mesozoic sediments and volcanic rocks, pressed between crystalline blocks. The sediment strata comprises various sandstones, shales, siltstones, conglomerates, andesitic flows, breccias, and tuffs. The crystalline rocks comprise granitic types, igneous intrusive rocks, and high-grade metamorphic types (gneiss, marble, and schist) (NPCC 2005).

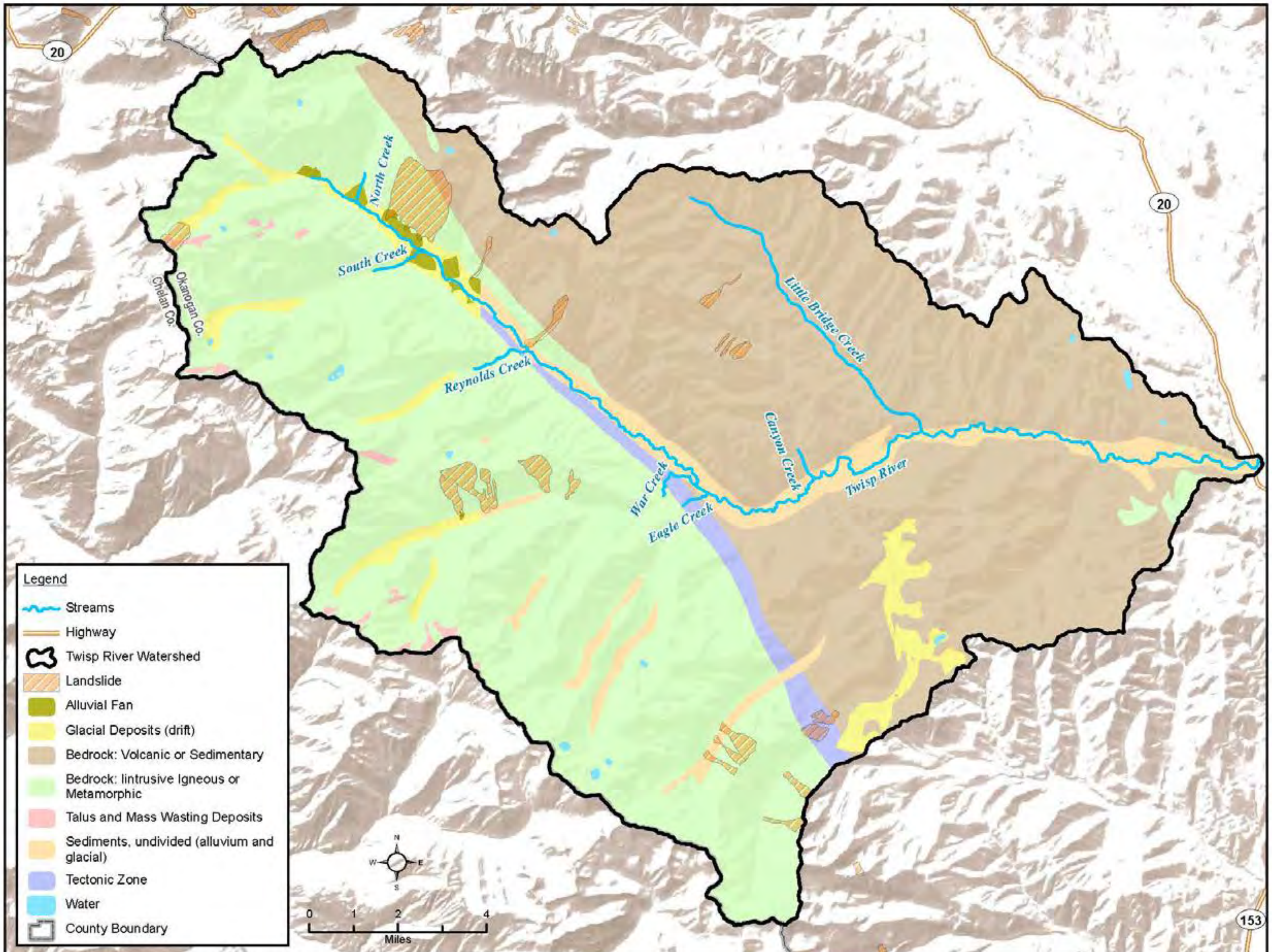

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Figure 2-1. Surficial Geology of the Twisp River Drainage

The UTR roughly marks the divide between the Cascade Crystalline Core and the Methow Basin domains in a faulted area of the Northern Cascades geologic province (WDNR 2017). The Twisp River flows into the Methow River Subbasin from the west where it follows a portion of a mapped tectonic zone southeasterly before it abruptly turns to the east and leaves the fault zone (Figure 2-1). This fault zone is described as the Twisp-River-Foggy Dew fault zone, a zone roughly separating the igneous and metamorphic bedrock to the west from the volcanic and sedimentary bedrock to the east (Bunning 1992; WDGER 2016). The Twisp River drainage's surface geology primarily consists of igneous or metamorphic bedrock formed in the Tertiary to Permian periods to the west and volcanic and sedimentary bedrock formed in the Cretaceous to Jurassic periods to the east (WDGER 2016). More recent Quaternary period glacial drift, alluvium, alluvial fan deposits, and unconsolidated sediments occur in valley bottoms along with several mapped landslides (WDGER 2016).

The landforms in the Twisp River drainage are a product of more recent glacial scour, deposits, and runoff that carved valleys and left behind glacial sediments. Thousands of years ago, the area near Twisp was covered by over 1,600 feet of ice from the Okanogan Lobe of the Cordilleran ice sheet (WDNR 2017), covering much of the northeastern North Cascade Range (USBR 2008). As the glaciers retreated, the flows cut through the glacial deposits, creating terraces. About 18,000 to 20,000 years ago, alpine glaciers extended down the Twisp River drainage as far as Little Bridge Creek in the lower Twisp River Valley (USBR 2008), carving the U-shaped valley form along the way and leaving glacial deposits. More recent alpine glaciation is suspected to have occurred about 9,500 years ago (USBR 2008). In the valley bottom, glacial and hillslope-derived sediments have been reworked by the Twisp River.

The periodic glacial meltwater flows created a large valley and channel capable of carrying large volumes of water and eroded sediments. Currently, the Twisp River has incised through many of these glacial deposits leaving a patchwork of floodplain and terrace surfaces throughout the upper Twisp River Valley. Intermittent bedrock outcrops, large landslide deposits, and alluvial fans also add complexity to the valley topography.

2.3 Human Disturbance History

Human activity within the Methow River Subbasin goes back at least 7,500 years (NPCC 2005; USFS 2006b) and can be described in three phases: the presettlement era of the Methow Indians, settlement of Europeans and the creation of the Moses Columbia Reservation, and recent history. Although humans have been living in and using the resources of the subbasin for thousands of years, only in the most recent 150 or so years have human activities significantly altered the form and function of the Methow River and its tributaries, including the Twisp River watershed. As part of their Treaty, the Yakama Nation have access to usual and accustomed sites in the Methow Subbasin and participate as co-managers for fish and wildlife resources (NPCC 2005). This section summarizes the human disturbance in the Twisp River watershed, with a focus on the Assessment Area. Appendix F of the Middle Twisp River Reach Assessment (Inter-Fluve 2015) contains a description of the human disturbance history in the Twisp River watershed.

2.3.1 Early Settlement

Presettlement-era residents of the Methow Valley were the ancestors of the Confederated Tribes and Bands of the Yakama Nation (YN) and Confederated Tribes of the Colville Reservation (CTCR) (NPCC 2005). Early documentation of the region in 1811 indicated at least 10 villages along the Methow River, from the mouth up to the confluence of the Chewuch River (NPCC 2005). There were also 8 villages on upper tributaries that were identified by anthropologist Jay Miller, with a summer village located on Buttermilk Creek, and a village at the confluence of the Twisp and the Methow Rivers (Hart 2010).

Typical land uses during this time period were primarily hunting, fishing, and gathering activities (NPCC 2005). People lived in small groups and moved seasonally across the landscape, settling along water bodies (USFS 2006b). Hunting focused on deer, elk, bear, sheep, mountain goat, and antelope while gathering consisted of roots, berries, and nuts. Pacific salmon was counted as the most important part of the traditional diet; Chinook salmon, sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*), and steelhead were captured throughout the Methow River Subbasin and at the mouth along the Columbia River (NPCC 2005). Fishing techniques included constructing platforms for netting and harpooning salmon and building weirs in smaller tributaries (USFS 2006b). Fish traps were reported just below Twisp on the Methow River and on the Twisp River near Buttermilk Creek (Hart 2010).

The first Europeans began showing up in the Methow Subbasin in 1811 to 1845, typically trappers and explorers (NPCC 2005). The fur trader Alexander Ross likely passed through the Twisp pass in 1814 as part of his search for beaver (NPS 2017). By the mid-1880s, trapping had wiped out most of the beavers in the area and some early residents transitioned from the fur trade to mining which is discussed below (Portman 2002 cited in USBR 2008).

In 1853, under the direction of Washington Territory's first governor Isaac Stevens, Captain George McClellan of the Corps of Engineers led an expedition to find a viable railroad route from the east to Puget Sound, reaching the Twisp area at the end of September (NPS 2017). McClellan followed the Twisp River upstream to War Creek, and then followed War Creek until the route became clearly impracticable (NPS 2017). The Pierce expedition, in 1882, and later expeditions in 1883 led by First Lieutenant George Backus, Jr., and Second Lieutenant Samuel Rodman, Jr., separately followed the Twisp River upstream based on reports from miners and Indians that it would lead to a pass over the Cascade Mountains (NPS 2017).

2.3.2 Mining

The Methow area mining rush began in 1886 when a large gold ledge was discovered on War Creek (Smith 2013 cited in Inter-Fluve 2015). The first known settler in the Methow was John "Chickamun" Stone, who discovered gold at the Red Shirt Mine site in 1887, about 5 miles south of the town of Twisp (USFS 2006b; West 2011; Smith n.d.). Heavy settlement by Europeans began in 1886, when the reservation was opened to non-native settlers after gold strikes were made. There were three mines in the Twisp Mining District by 1897, and a mining encampment was established at Gilbert, in the upper Twisp River adjacent to North Creek (West 2011). At one time, Gilbert had a dozen buildings but only one cabin from that era, shown in Figure 2-2, remains partially standing (Ghost Towns of Washington 2012). Placer and hydraulic mining occurred on the Twisp River in the vicinity of North Creek (USFS 1995b, PWI 2003). Mining and associated land uses have impacted the assessment area through clearing of riparian vegetation and abandoned mining infrastructure instream or on the floodplain.

Figure 2-2. Photograph of Gilbert Mining Camp Cabin

2.3.3 Grazing

Ranching of cattle and sheep followed shortly behind the beginning of mining, with the highest grazing pressure extending from the late 1800s into the 1930s (McLean 2011; UCRTT 2014). At the height of demand for wool during World War I, 75,000 sheep grazed the Sawtooth above the Twisp River (McLean 2011). Grazing pressure decreased through the 1940s and 1950s. Today, the LBC is included as the largest of five livestock grazing allotments which also include Canyon Creek (USFS 2004; McLean 2011). Cattle and sheep grazing in the Assessment Area has resulted in localized bank erosion, the loss of riparian understory vegetation, and soil compaction. In 2006, barbed wire fence was installed along LBC, with the goal of preventing cattle from accessing steelhead spawning habitat (USFS 2006).

2.3.4 Diversions

The first major irrigation diversion in the Twisp River watershed was started by Thomas Blythe, who began what are now known as the East Side and West Side Canals in 1905; the project was completed in 1919 by the Methow Valley Irrigation District and meets the criteria for inclusion on the National Register (USFS 2006b). The 1935 U.S. Bureau of Fisheries survey of the Twisp River identified 18 diversions on the Twisp River. At that time, the entire flow was diverted for irrigation during late summer and early fall by about one-half mile upstream of the Methow River confluence (Bryant and Parkhurst 1950)

There are currently no known diversions on the UTR mainstem, North Creek, South Creek, Reynolds Creek, War Creek, or Eagle Creek. The irrigation diversion on Eagle Creek was removed and replaced with a well in 2002 (RCO 2017). Canyon Creek and LBC both have existing irrigation diversions. The Aspen Meadows Irrigation Ditch diverts water from Little Bridge Creek for agricultural and domestic use. The ditch was piped in the early 2000s to increase efficiency and reduce water loss. The U.S. Bureau of Reclamation (USBR) replaced a channel-spanning wood weir with a rock weir, shown in Figure 2-3, designed to improve upstream fish passage (USFS 2006a).

Figure 2-3. Photographs of Intake (left panel) and Rock Weir (right panel) Diversion in Little Bridge Creek Reach 2 near RM 2.2

2.3.5 Timber Harvesting and Roads

Past timber harvest and associated road construction management actions have negatively impacted stream health and habitat in the Twisp River watershed (USBR 2008; Inter-Fluve 2015). Timber harvest was a significant industry in the Twisp River watershed from the early twentieth century through the 1980s (NPCC 2005), which is when harvest peaked (UCRTT 2014). As of 1994, the Twisp River watershed was reported to have had the most intensive timber harvest within the entire Methow River Subbasin (USFS 1994c). Approximately 25 percent of the watershed has been impacted by timber harvest, particularly Buttermilk Creek and drainages to the east (Andonaegui 2000). West (2011) describes a local history of intense timber harvest and associated road building, with one logger quoted as saying "… we opened up every major drainage in the Methow Valley … We built or rebuilt every road on the forest."

LWD has also been removed from the Twisp River over time, resulting in a loss of instream complexity and habitat. Following the flood of 1972, heavy equipment was used in the mainstem river channel to remove LWD from the War Creek confluence to North Creek confluence (USFS 1995b).

Current timber practices on land managed by the USFS have changed in that only partial cuts and thinning are used, and the existing road network is utilized for access (USBR 2011). Road building accelerated during the timber harvests of the 1950s and 1960s. The USFS (2004) estimated 220 miles of road and 530 stream crossings in the Twisp River watershed. Currently, about half of the Twisp River watershed is within the Chelan-Sawtooth Wilderness, with rules in place prohibiting timber harvest and road construction (USBR 2008). The current road density for the Twisp River watershed is 1.1 miles per square mile.

Impacts have included increased sediment flows, reduced channel functions (e.g., bank stability, hydraulic roughness, nutrient contributions, and temperature moderation), and reduced recruitment of LWD to the channel (Andonaegui 2000; USBR 2008; USBR 2011; Inter-Fluve 2015). Quantitative sediment rates are not available, but past timber harvest and road construction in the Twisp River watershed have apparently accelerated naturally high sediment delivery rates (USFS 2004). Addressing increased sediment from road management in the upper Twisp River was given the sixth highest priority rating in the revised Biological Strategy (UCRTT 2014). The photograph in Figure 2-4 shows an example of recent road erosion that has been repaired on the NF-4440 Road near RM 23.7.

Figure 2-4. Photograph of Repaired Road Erosion on the NF-4440 Road near RM 23.7

2.3.6 Recreation

The Okanogan-Wenatchee National Forest lands in the Twisp River watershed are used extensively for recreation. The land is used by the public for hunting, fishing, horsebacking, hiking, mountain biking, snowmobiling, and firewood gathering. There are five developed campgrounds (Roads End, South Creek, Poplar Flat, Mystery, and War Creek) adjacent to the UTR and many dispersed camping sites throughout the Assessment Area including tributary drainages. The Twisp River Horse Camp is also located adjacent to the upper Twisp River near the South Creek confluence. A series of hiking and horse riding trails are accessed from five established trailheads (Gilbert, Slate Creek, War Creek, and Eagle Creek/Oval) adjacent to the UTR. There are no managed campgrounds in the LBC drainage; however, there are several large dispersed campgrounds and numerous smaller sites (USFS 2006a).

Recreation use in riparian areas, particularly unsanctioned roads and trails, dispersed camping, firewood cutting, off-road use, and waste dumping has resulted in negative impacts. Figure 2-5 shows an example of an eroding bank encroaching on a camp site at the Poplar Flats Campground in UTR Reach 3 near RM 24.2. Beginning in

1993, the Methow Valley Ranger District has developed a program to manage recreation use impacts, called the Respect the River Program, which combines riparian vegetation treatments with a strong public outreach and education component (USFS 2012). The Twisp River is included in the Respect the River focus area.

Figure 2-5. Photograph of Eroding Bank at the Poplar Flats Campground in the Upper Twisp River Reach 3 near RM 24.2

2.4 Wildfires

Across the Methow River Subbasin, changes in land use and land management since the settlement of Europeans have altered the composition, structure, and function of riparian and upland forests (Andonaegui 2000; USBR 2011). Increased use of suppression as a primary fire management tool beginning in the early twentieth century resulted in accumulations of combustible fuels, shifting the fire regime from short-term and frequent lower intensity disturbances to less frequent and more severe disturbances (USBR 2011; Inter-Fluve 2015). Fire suppression since the 1920s has led to a dramatic shift from open stands of fire-tolerant species to high density stands with high fuel loads (USFS 1995a). More recently, the USFS has been conducting controlled burns in the Assessment Area to help mitigate past fire suppression (USFS 2006a)

Wildfires can have a serious detrimental effect on fish-bearing streams, but fire regimes are also a natural part of the western landscape and can provide long-term benefits to streams as well. The direct effect is the loss of shading vegetation, soil infiltration, and surface runoff, which translates into increased water temperatures, high peak flows, increased fine sediment transport, and landslides. The extent of this effect depends on several factors: burn severity, fire intensity, burn area, topography, soil properties, climate, and channel proximity (Moody et al. 2013). However, in the longer term, fires can lead to increases in inputs of LWD, improved supplies of fresh bedload and gravel, and rejuvenated vegetation, all of which provide benefits to streams and fish (Andonaegui 2000; USBR 2011; Johnson and Molesworth 2015). The post-fire recovery of watershed processes varies widely by fire and watershed characteristics but may persist for more than 10 years after the fire (Wondzell and King 2003).

In 2015, the Okanogan Complex Fires, aided by extremely dry conditions, burned over 520,000 acres, including the Twisp River Fire in the Twisp River watershed (BAER 2015; USFS 2016a). The Twisp River Fire started on August 19, 2015 in a subdivision about 5 miles west of Twisp (USFS 2016a), and burned 11,222 acres (BAER 2015). Tragically, three USFS firefighters were killed during the fire, and a fourth was critically injured (USFS 2016a). The majority of impacts in the Twisp River watershed were downstream of the Survey Area; however, the Twisp River Fire burned the upper portions of the LBC drainage (BAER 2015). Figure 2-6 shows burned riparian vegetation that has been felled for safety in LBC Reach 3 near RM 4.3.

Figure 2-6. Photograph of Burned and Felled Riparian Vegetation in Little Bridge Creek (LBC) Reach 3 near RM 4.3

2.5 Water Quantity and Quality

Water quantity and quality are two important factors for sustainable anadromous populations. Poor water quantity restricts the overall amount of available habitat, can concentrate the effect of bad water quality conditions (Andonaegui 2000), and can block passage at key life stages. Since salmonids require clean, cool, highly oxygenated water (Andonaegui 2000), poor water quality restricts proper fish health and development and limits the amount of available habitat.

For the Twisp River watershed, water quantity and quality are excellent in the upper reaches, but both are concerns in the lower reaches of the Twisp River (NPCC 2005; Inter-Fluve 2010 and 2015). The ecological concern of water quantity was given the highest priority rating, and water quality the second highest priority rating, for the LTR AU by the UCRTT (2014). Sections of the LTR are listed as Category 4C for insufficient flow, Category 2 for temperature and dissolved oxygen, and Category 1 for ammonia and bacteria (Ecology 2017).

2.5.1 Subsurface Flow and Dewatering

Seasonal dewatering occurs in isolated reaches of Twisp River due to subsurface flows. An approximately 1.8-mile section of the Twisp River near the Poplar Flats Campground flows subsurface, except in years where the precipitation is above normal. The dewatering near the Poplar Flats Campground has resulted in observed stranding mortality for bull trout (USFWS 2004).

Seasonal water losses to subsurface flow is a natural process in many parts of the Methow River Subbasin due to the hydrogeology of deep, unconsolidated sediment deposits that fill many of the basin drainages. Konrad et al. (2005) provide a detailed description of groundwater and surface water interaction throughout the subbasin.

The earliest known records of the seasonal dewatering in the Twisp River are from spawning surveys in 1987 (Ecology 1992). The extent to which past disturbance affects the degree of seasonal dewatering near the Poplar Flats Campground is uncertain. Previous studies indicate the Twisp River has aggraded in this reach, which may be increasing the amount of subsurface flow and exacerbating dewatering (PWI 2003). However, the recent aggradation may be in response to past disturbance and, based on recent field observations, the amount of aggradation does not appear to have raised the bed elevation above what would be expected under natural conditions.

2.6 Fish Use and Population Status

The Twisp River drainage is used by multiple salmonid species. These include spring Chinook salmon, summer/fall Chinook salmon, sockeye salmon, coho salmon, summer steelhead and resident trout (*Oncorhynchus mykiss* and *O. mykiss gairdneri*), resident and migratory bull trout, westslope cutthroat trout (*O. clarki lewisi*), mountain whitefish (*Prosopium williamsoni*) and the introduced eastern brook trout (*Salvelinus fontinalis*) (Andonaegui 2000; NPCC 2005; Snow and Frady 2015). The Twisp River and its tributaries are also used by non-salmonid species, including various species of sculpin, suckers, and dace. While the Twisp River is believed to be historical habitat for Pacific lamprey (*Entosphenus tridentatus*) (Peven 2003), targeted surveys have not identified them in the river in recent years (Andersen et al. 2011).

2.6.1 Salmonids

Salmonids are present in the Methow River Subbasin, including the Twisp River drainage, year-round. Table 2-1 illustrates periodicity for the UTR, with some general subbasin periodicity for bull trout. As shown in Figure 2-7, the upper Twisp River and tributaries provide spawning and rearing habitat for ESA-listed threatened Upper Columbia summer steelhead and endangered spring Chinook salmon throughout its length (USFS 2014; NPCC 2005); threatened Columbia River bull trout are present throughout the mainstem and some tributaries as well, with spawning predominantly occurring in the headwaters. Westslope cutthroat trout are also found predominantly in the headwater tributaries (NPCC 2005). Upper Columbia River coho salmon populations were decimated in the early 1900s as a result of excessive harvest downstream, passage barriers such as hydroelectric dams, and habitat modifications (Andonaugi 2000), but recent reintroduction efforts have resulted in coho spawning in the Twisp River, as far upstream as the bridge on War Creek (USFS 2014). Additional salmonid species present in the drainage include resident rainbow trout, eastern brook trout, and mountain whitefish.

Table 2-1. Upper Twisp River Salmonid Periodicity

Species	Lifestage	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec
Spring Chinook Salmon	Adult Immigration												
	Adult Spawning												
	Egg Incubation/ Fry Emergence												
	Juvenile Rearing												
	Juvenile Outmigration												
Summer Steelhead	Adult Immigration												
	Adult Spawning												
	Egg Incubation/ Fry Emergence												
	Juvenile Rearing												
	Juvenile Outmigration												
Bull Trout	Adult Immigration												
	Adult Spawning												
	Egg Incubation/ Fry Emergence												
	Juvenile Rearing												
	Juvenile Outmigration												

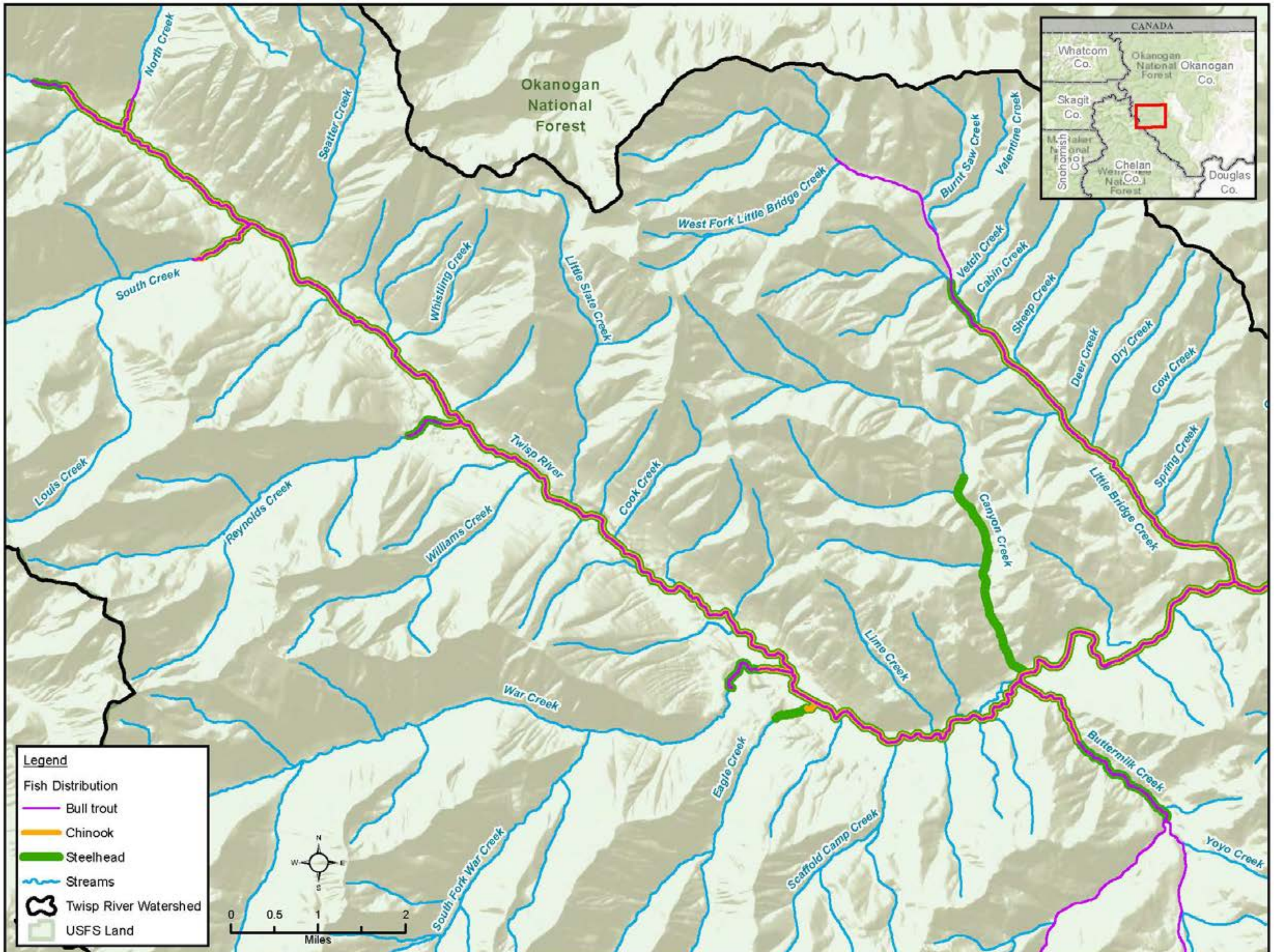
Indicates periods of most common or peak use and high certainty that the species and life stage are present

Indicates periods of less frequent use or less certainty that the species and life stage are present

Indicates periods of rare or no use

1/ Although most out-migration occurs in spring, some parr migrations from upper Methow Subbasin tributaries have been observed in the fall (NPCC 2005).

2/ Periodicity is for the Methow Subbasin, in general



Sources: StreamNet 2012: WDFW 2017a and 2017b

Figure 2-7. ESA-Listed Species Distribution in the Upper Twisp River Survey Area

As with all tributaries to the middle and upper Columbia River, the fish populations in the Twisp River were dramatically affected by mainstem dams. The Twisp River lost much of its anadromous salmonid populations, as did the entire Methow River Subbasin, following the construction of the Washington Water Power Company dam near the mouth of the Methow River in 1915 (USFWS 1950). By the time the dam was removed in 1929, coho salmon had been extirpated from the subbasin and Chinook salmon nearly so. The steelhead population, however, persisted through the isolation period as resident rainbow trout (USFWS 1950; NPCC 2005). The development of the Columbia River dams added additional and continuous pressure to remaining stocks. Various reintroduction efforts have met with variable success in an effort to reestablish and improve anadromous stocks within the Methow River and its tributaries, including the Twisp River. Anadromous species known to use the UTR include spring Chinook, steelhead, bull trout (Andonaegui 2000; USFS 2014), and coho salmon (WDFW 2014).

Chinook Salmon

The Twisp River is an important rearing and spawning stream for mid-Columbia River summer Chinook and ESA-listed (threatened) spring Chinook (USFS 2014). Historically, the Twisp River, especially the central mainstem, was considered to have good spawning gravel throughout, supporting healthy runs of spring Chinook salmon (Fulton 1968; Mullen et al. 1992), and has the second highest egg-to-emigrant survival rate in the upper Columbia River basin (UCSRB 2014). The Twisp River spring Chinook are one of the distinct stocks comprising the Methow River spring Chinook population (NPCC 2005). Surveys along the Twisp River in 2001 determined that juvenile Chinook rearing occurred in the mainstem Twisp River up to RM 22.8, within Buttermilk Creek up to RM 6.0, as well as in a few tributaries near the mouth of Eagle Creek (USFS 2001 and 2014). Chinook spawning in the Twisp River can be highly variable across years. The average annual redd count between 2003 and 2014 was 79 redds for the Twisp River (Snow et al. 2016), with a low of 18 redds in 2003 and a high of 145 redds in 2010. Surveys in 2001 identified 370 redds, comprising 8.1 percent of the Methow River Subbasin Chinook salmon redds observed that year (USFS 2014), while the 138 redds observed in 2014 comprised approximately 12-percent of redds observed in the Methow River Subbasin in 2014 (Snow et al. 2016). Most of the spawning in the mainstem occurs above RM 12 (USBR 2008), with the highest concentration of spawning activity occurring between Buttermilk and War Creeks (USFS 2014). Roughly half (56 percent) of the spring Chinook spawners in the Twisp River are estimated to be of wild stock, compared to 16-percent for the rest of the Methow River Subbasin. While the general juvenile outmigration timing estimates for the Methow River Subbasin are between March and June, captures on the Twisp River indicate subyearling migration between March and September, with parr migration occurring between September and December (Snow et al. 2011).

Steelhead

Steelhead/rainbow trout are plentiful and distributed throughout the length of the Twisp River. Snorkel surveys have documented juveniles extending from the mouth, upstream, almost into the headwaters (OWNF 2002) while redds have been observed in the mainstem up through Poplar Flats Camp Ground (Snow et al. 2016). The highest tributary abundances of juveniles were observed in the middle Twisp River tributaries of Little Bridge and Buttermilk Creeks (West Fork Buttermilk Creek also contains genetically distinct redband trout [USFS 2014], despite heavy stocking efforts in the region with coastal rainbow trout). Spawning occurs along the entire length of the Twisp River, with the highest densities occurring from the Twisp Weir (RM 7.5) to Buttermilk Creek. A significant number of redds are also found in the UTR, however, between Buttermilk Creek and War Creek (Snow et al. 2016). Spawning is also known to occur in five tributaries and the Methow Salmon Recovery Foundation pond outfall. Four of these tributaries are within the UTR assessment area: LBC, War Creek, Eagle Creek, and South Creek (USFS 2014). Annual Twisp River redd counts, conducted by WDFW between 2001 and 2014, range from a maximum of 696 redds in 2003 to a minimum of 78 redds in 2007 (USFS 2014; Snow et al. 2016). No redds were counted above Mystery Bridge between 2007 and 2012. In 2013, one redd was counted upstream, out of a total of 128 redds for the whole river (USFS 2014). While adult steelhead migration timing for the Methow River Subbasin peaks between August and October, steelhead were detected entering the Twisp River between March and May (Snow et al. 2011).

Coho Salmon

The Twisp River has been used extensively for coho reintroduction efforts, with rearing ponds located within the lower reaches (YNF 2006; USFS 2014). While initial coho reintroduction efforts in the mid-twentieth century were not successful, coho reintroduction efforts, started by the Yakama Nation in 1997, have resulted in reestablishment of natural spawners and returns to the Methow River Subbasin sufficient in some years for a limited fishery (CRITFC 2012). Coho spawn naturally in the Methow River Subbasin and are also spawned at the Winthrop hatchery as part of the ongoing efforts (Kamphaus et al. 2011). This effort has also resulted a limited number of coho returning to spawn in the Twisp River. Most of these spawners appear to build their redds within the first three miles of the mainstem Twisp River, with a few additional redds located between Buttermilk and War Creeks (USFS 2014).

Sockeye Salmon

While not considered to be historically present in the Methow River, over 1.8 million sockeye salmon were released into the river between 1945 and 1957 and small numbers have been recorded as continuing to return the Methow River (Gustafson et al. 1997; WDFW 2017b).

Bull Trout

The Methow River bull trout population is considered at high risk (USFWS 2008); however, the Twisp River bull trout population is the most productive population of the nine Methow River Subbasin bull trout populations (USFS 2014). Bull trout are present in the Twisp River up to near the headwaters, in Buttermilk Creek past both forks, and in the lowest portion of many of the smaller tributaries above and including Lower Buttermilk Creek (NPCC 2005; StreamNet 2012; USFS 2015a). West Fork Buttermilk Creek is considered to have one of the largest bull trout populations in the Twisp River drainage (USFS 1994a). North Creek and the East and West Forks of Buttermilk Creek contained the highest number of bull trout redds (USFS 2014). Surveys along the Twisp River in 2001 determined that bull trout rearing in the mainstem Twisp River occurred between RM 0.8 and RM 29.1 (with most fish observed above RM 25.8).

Westslope cutthroat trout and Eastern brook trout are also present in the Twisp River system. Westslope cutthroat trout are assumed to spawn in the Upper Methow, including the Twisp River (NPCC 2005), and have been confirmed above the fish passage barrier at RM 29.7, as well as observed in upper eagle Creek and the East Fork Buttermilk Creek (USFS 2014). Eastern brook trout, an introduced species from the eastern United States, have been detected rearing in the mainstem Twisp River between RM 2.7 and RM 27.2. They have also been found in Reynolds Creek and War Creek and spawning at Elbow Coulee (Andonaegui 2000). More recently, the majority of brook trout have been found near RM 13.7, with the addition of two observations at the culvert pool on Reynolds Creek as well (USFS 2014).

2.6.2 Non-Salmonid Species of Interest

Multiple non-salmonid fish species are also present within the Twisp River. Predatory fish, particularly introduced species such as largemouth, smallmouth bass, and walleye, can be of concern for native salmonid production. While distribution of these introduced fish is not well documented, they are most likely to be found in downstream reaches of streams (MRC 2014). Additional non-salmonid species, such as sculpin (*Cottus* spp.) and longnose dace (*Rhinichthys cataractae*), occur within the Twisp River watershed (Martens et al. 2014) are likely occur within the UTR and its tributaries. Bridgelip suckers can be found lower in the drainage and may also be present in upper reaches, but at reduced densities. While Pacific lamprey have not been documented in the Twisp River, their historical presence is assumed and could occupy stretches of the drainage.

Pacific Lamprey

Pacific lamprey are increasingly a species of management interest present in the Methow River (DCPUD 2009; Nelle et al. 2016), and assumed to be historically present in the Twisp River (CCPUD 2000). They are of cultural and ecological importance due to their role in tribal customs and fisheries. Pacific lamprey have similar spawning habitat requirements as salmon, however larvae rear in sandy bottomed areas, such as the margins of larger mainstem habitats. Electrofishing surveys of the Twisp River since the late 2000s (Wild Fish Conservancy) did not show any evidence of ammocoetes (lamprey juveniles) presence (DCPUD 2009; USFS 2014). Because there are no obvious barriers that would preclude Pacific lamprey from utilizing the Twisp River, however, their presence cannot be discounted.

In recent years, the Yakama Nation has been working on recovery efforts for Pacific lamprey, called the Pacific Lamprey Project (YNF 2016). The objective of this project is to restore natural production of Pacific lamprey to a "level that will provide robust species abundance, significant ecological contributions and meaningful harvest within the Yakama Nations Ceded Lands and in the Usual and Accustomed areas" (YNF 2016). Efforts include documenting historic occurrences and current presence, and working on artificial propagation and outplanting (ongoing since 2012; Nelle et al. 2016; YNF 2016), and developing a management action plan to identify threats and work to improve conditions for lamprey populations and migration (YNF 2016).

The 2015 Pacific lamprey habitat restoration guide (MSRF 2015) provides guidance for such designs. Additionally, surveys are conducted throughout the subbasin (Crandall 2016) and limited releases of adults by the Yakama Nation have occurred (Stamper 2015; ASWG 2017). The Pacific lamprey 2016 Regional Implementation Plan for the Upper Columbia Regional Management Unit discusses approaches for research, monitoring, and restoration of Pacific lamprey within the Upper Columbia, including within the Methow Subbasin. Threats to Pacific lamprey in the Methow River Subbasin include small population size and mainstem obstructions (high threat); dewatering and flow management, stream and floodplain degradation, climate change (moderate threat); and predation, juvenile passage, and adult passage (low threat) (Nelle et al. 2016).

2.7 Ecological Concerns

Ecological concerns, also referred to as "limiting factors," serve to define and evaluate the habitat conditions inhibiting salmonid recovery. Multiple reports have identified ecological concerns affecting salmonid production in the upper Twisp River and the Methow Subbasin including the following:

- Salmon, Steelhead, and Bull Trout Habitat Limiting Factors Report – WRIA 48 (Andonaegui 2000)
- Methow Subbasin Plan (NPCC 2005)
- 2008 Fish Accords (Three Treaty Tribes-Action Agencies 2008)
- Methow Subbasin Geomorphic Assessment (USBR 2008)
- Federal Columbia River Power System Biological Opinion (FCRPS 2012)
- Revised Biological Strategy (UCRTT 2014)

The revised Biological Strategy (UCRTT 2014) contains the most up-to-date ecological concerns information. It identifies key biological considerations in protecting and restoring habitat, which are guided, in part, by the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSRB 2007), and are consistent with the

Washington Statewide Steelhead Management Plan (WDFW 2008). The Assessment Area includes both the UTR AU and the LTR AU which includes all of the LBC.

The revised Biological Strategy identified seven ecological concerns for the UTR AU, in priority order (UCRTT 2014):

1. Peripheral and transitional habitats (side channel and wetland habitat conditions);
2. Channel structure and form (instream structural complexity);
3. Channel structure and form (bed and channel form);
4. Riparian condition (riparian condition and large wood recruitment);
5. Food (altered primary productivity or prey species competition and diversity);
6. Sediment (increased sediment quantity); and
7. Species interactions (introduced competitors and predators).

The revised Biological Strategy also identified the need for a better understanding of the extent and effect of interactions between bull trout and other native species with brook trout in the UTR AU (UCRTT 2014).

For the LTR AU (including LBC), the revised Biological Strategy identified the following nine ecological concerns, in priority order (UCRTT 2014):

1. Water Quantity (Decreased Water Quantity),
2. Water Quality (Temperature),
3. Channel Structure and Form (Bed and Channel Form),
4. Peripheral and Transitional Habitats (Side channel and Wetland Habitat Conditions),
5. Channel Structure and Form (Instream Structural Complexity),
6. Riparian Condition (Riparian Condition),
7. Sediment (Increased Sediment Quantity),
8. Food (Altered Primary Productivity), and
9. Species Interactions (Introduced Competitors and Predators.

3. HABITAT ASSESSMENT METHODS

The methods employed in the development of the habitat assessment included field surveys and analytical methods focused on identifying opportunities for providing habitat improvements for target fish species. Field surveys were conducted on foot during the fall of 2016, between October 24 and November 8, by a field team consisting of a restoration design engineer, fisheries biologist, and fluvial geomorphologist. The team assessed the Project area on foot, including the upper mainstem Twisp River from the NF-4430 road bridge near RM 17.8 to the end of anadromous fish distribution at a bedrock falls near RM 29.6, and seven anadromous tributaries (North Creek, South Creek, Reynolds Creek, War Creek, Eagle Creek, Canyon Creek, and LBC).

The following subsections provide the methods used to develop the habitat assessment and restoration strategy: geomorphic surveys (Section 3.1), stream habitat surveys (Section 3.2), field-identification of restoration opportunities (Section 3.3), geomorphic and habitat assessment analyses (Section 3.4), and REI (Section 3.5).

3.1 Geomorphic Surveys

Geomorphic field survey data were collected and observations were made throughout the Project area. Information gathered during the geomorphic survey was used to evaluate channel morphology, channel migration processes, sediment transport patterns and processes, in-channel characteristics, and the influence of anthropogenic modifications on the current system function and form. The geomorphic survey field data and observations were also used to assist with evaluating REI metrics and inform the identification of potential restoration sites and the selection of appropriate habitat restoration actions for this Project.

3.2 Stream Habitat Surveys

Tributary stream habitat field surveys were completed following the USFS Level I and II Stream Survey Protocols described in the Stream Inventory Handbook (USFS 2016b). Prior to the field surveys, a Level I inventory was completed for each of the tributaries and included the necessary analysis to complete a Survey Form and a Preliminary Reach Form. Field data were collected in standard USFS field forms for integration with the USFS Stream Inventory database. Following the stream habitat survey a Final Reach Form was completed for each of the Project area tributaries.

The stream survey protocols divided habitat units into four categories: slow, fast, fast non-turbulent, and side channel. Slow habitat units are pools, further described by type as plunge, dam, or scour pools and forming mechanisms which are beaver, wood, bedrock, boulder, or stream bend. Fast habitat units are riffles, rapids, and cascades, the latter being steep reaches with a series of small, fast-water step pools. Fast non-turbulent habitat units are glides, and side channels are broken into fast or slow types, depending on the majority habitat within the side channel.

The stream survey protocols include three sizes of LWD: small, medium, and large. Small wood pieces are a minimum of 20 feet long and 6 inches in diameter. Medium LWD pieces are a minimum 35 feet long, and 12 to 20 inches in diameter. LWD pieces that are at least 35 feet long and ≥20 inches in diameter are considered large LWD. Medium and large size class LWD are considered “qualifying” and used to calculate the number of LWD pieces per mile to be used to compare the results with federal targets for properly functioning conditions (USFWS 1998), and other estimates of standard wood abundance (Fox and Bolton 2007).

3.3 Field Identification of Restoration Opportunities

Potential opportunities for restoration and habitat enhancement were initially identified during field surveys. This preliminary determination was further refined by utilizing the habitat assessment analyses and other existing data.

The identification of potential restoration project opportunities was guided by a combination of site observations of geomorphology and field identification of specific opportunities for addressing habitat, riparian, and land-use impairments. Potential restoration opportunities were selected that address the reach-scale restoration targets developed as part of the restoration strategy. The project opportunities and potential actions are discussed in Section 5.2.

3.4 Geomorphic and Habitat Analyses

A number of different technical tools and software were used for various aspects of the geomorphic and habitat analyses. The key geomorphic and habitat analyses are described below.

3.4.1 Hydrology

The hydrologic analysis included evaluating available discharge data from a number of sources including USGS gaging stations. The nearest long-term gaging station on the Twisp River is the USGS 12448998 gage (Twisp River near Twisp, WA) which has been in operation from 1975 to present (2017). Daily flow statistics including the minimum, mean, and maximum discharge were calculated for the Twisp River gage.

Peak discharges for the Survey Area were evaluated based on the USBR Methow Subbasin Geomorphic Assessment (USBR 2008) hydrologic analysis and also calculated using the USGS regional regression equations of Sumioka et al. (1998) and the recently updated USGS regional regression equations of Mastin et al. (2016).

3.4.2 Channel Morphology

The channel morphology of Survey Area was evaluated using the classification systems of Montgomery and Buffington (1997), Rosgen (1996), and other geomorphic characteristics. These systems use river form and process to describe channel morphology through a set of standard metrics such as channel dimensions (bankfull width and depth, gradient, etc.), sediment characteristics, channel planform (e.g., straight, sinuous, etc.) bed forms, channel meander process (stable, avulsion, etc.), and the presence of floodplain features (e.g., side channels, vegetated islands, floodplain ponds, etc.).

3.4.3 Light Detection and Ranging and Digital Elevation Model Processing

The topography of the Survey Area is represented by three elevation models including a 10-meter National Elevation Dataset (NED) digital elevation model (DEM) and two light detection and ranging (LiDAR) datasets. The 10-meter DEM is the only topographic surface the covers the entire Survey Area including the UTR, LBC, and tributary reaches.

The first LiDAR data were collected in 2006 to a 1-meter resolution mapping standard (Watershed Sciences 2007). The 2006 LiDAR coverage area includes the UTR corridor from the downstream of the Survey Area to approximately RM 29.0 and the lower portion (approximately 0.2 miles) of the LBC and the other tributary reaches. More recently, 1-meter resolution LIDAR data were collected in 2015 for the Oregon LiDAR Consortium Okanogan FEMA Study (QSI 2016). The 2015 LiDAR coverage area corridor is wider than the 2006 LiDAR and includes the entire survey area for the UTR and tributary reaches with the exception of the LBC. The 2015 LiDAR coverage area only includes the lower 1.1 miles of the LBC. Figure 3-1 shows the 2006 and 2015 LiDAR coverage of the Survey Area.

The River Bathymetry Toolkit for ArcGIS was used for processing stream channel topography and creating a relative elevation model, derived from the 2006 LiDAR. The relative elevation model removes the slope of the valley (i.e., detrending) to reveal subtle changes in floodplain topography which informs geomorphic analyses and the identification of potential projects (McKean et al. 2009).

3.4.4 Canopy Height and Percent Cover

Canopy height was calculated using the 2015 LiDAR dataset to determine the height of vegetation in the LiDAR survey area. The calculation used both the bare earth and highest hit DEM. The highest hit DEM comprises the LiDAR first returns that include the tree tops and are removed from the bare earth model by classification. To calculate canopy height, the bare earth DEM was subtracted from highest hit DEM resulting in a DEM of canopy height above the bare earth surface. To remove the low understory vegetation from this analysis, only canopy heights of greater than 15 feet were included in the canopy cover layer. Canopy cover was also calculated using canopy cover layer. The percentage canopy cover was based on the extent of canopy cover within the riparian area, which was represented by a 100-foot buffer from the stream channel approximating one site-potential tree height.

3.5 Reach-based Ecosystem Indicators

The REI metrics are used to characterize how the geomorphic and ecological processes are functioning within each waterbody where habitat data was collected within the Project area. The REI is based primarily on the “Matrix of Diagnostics/Pathways and Indicators” (USFWS 1998), the National Oceanic and Atmospheric Administration National Marine Fisheries Service (NMFS) Matrix of Pathways and Indicators (1996), and work conducted within the region by the USBR and Yakama Nation Fisheries and takes into account known habitat preferences for target species, such as various life stages of ESA-listed fish. Data collected during the habitat survey, and geomorphic assessment inform the REI to understand the current conditions and assign a condition rating for each metric. The REI process applies habitat survey data and other analysis results in order to assign reach-scale ratings of functionality (i.e. adequate, at risk, or unacceptable condition). This analysis is also used to help select restoration targets as part of the restoration strategy presented in Section 5.

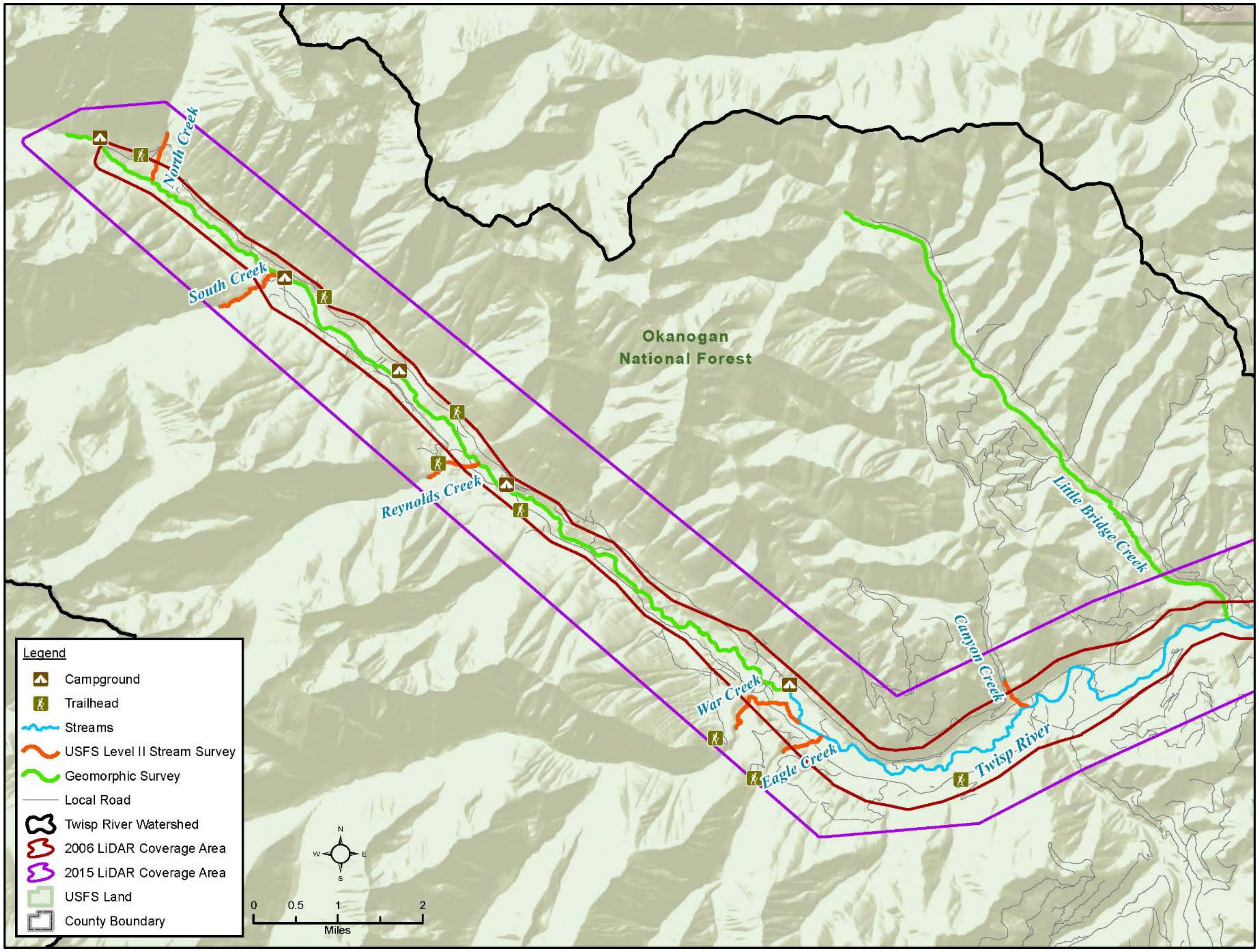


Figure 3-1. 2006 and 2015 LiDAR Coverage of the Survey Area

4. HABITAT ASSESSMENT RESULTS

This section provides a summary of the existing conditions in the UTR in the surveyed reaches based on field data and observations, as well as changes documented in previous survey data and summary reports. The completed Preliminary and Final Reach Forms are in Appendix B. The completed field forms, including the channel unit forms, forest options forms, special case forms, pebble count forms, and the discharge forms are also in Appendix B. The habitat assessment results provided in this section provide the scientific foundation and site-specific information needed to develop the project opportunities and potential restoration actions included in the restoration strategy (Section 5). The following subsections describe the Project hydrology (Section 4.1); the habitat assessment results for the UTR (Section 4.2), LBC (Section 4.3), and the tributaries (Section 4.4); REI (Section 4.5), and climate change impacts (Section 4.6). Section 4.7 contains a summary of the habitat assessment results.

4.1 Hydrology

The hydrologic patterns of the Twisp River drainage are driven by winter snow accumulation and spring snowmelt. Peak flows typically occur from April to August returning to base flow by September. During the low-flow period, there are intermittent, short-duration, flow increases in response to storms, particularly rain-on-snow events. Figure 4-1 shows the minimum, mean, and maximum daily Twisp River discharge as recorded at the Twisp River gage (USGS 12448998) over the period of record.

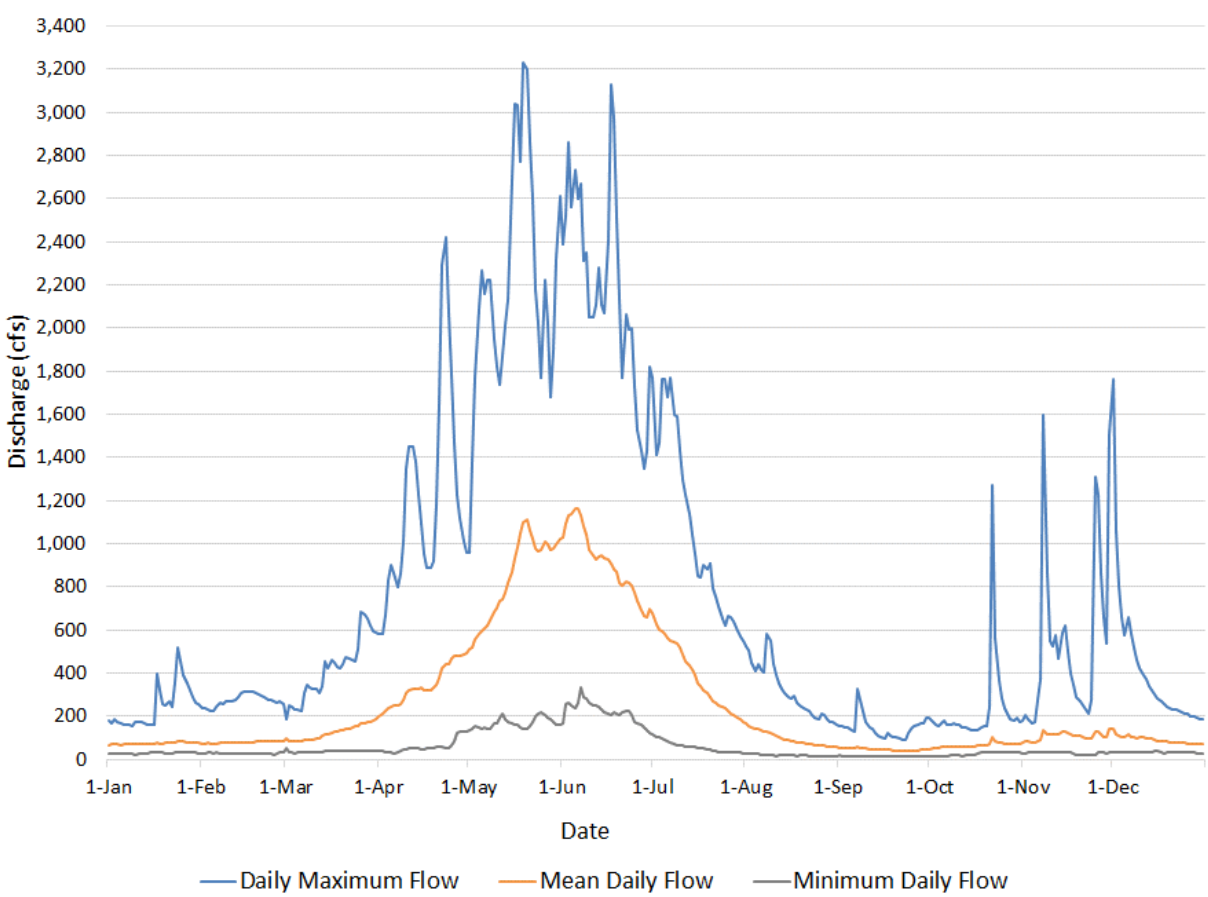


Figure 4-1. Twisp River Daily Minimum, Mean, and Maximum Discharge for the Period from 1975 to 2016 (as measured at USGS gage 12448998 Twisp River near Twisp, WA)

During winter months, the Twisp River is frequently impacted by river ice due to the area climate, topography, and hydrology. River ice can cause a damming effect, particularly during thawing periods, that results in flooding, erosion, and deposition on adjacent floodplains. The impact of river ice on the lower Twisp River near Twisp has been well-documented (Inter-Fluve 2016) but the extent of impacts on the UTR and tributaries is uncertain.

4.1.1 Peak Flows

Peak flows for the upper Twisp River and tributaries were evaluated based on existing gage data, previous flood recurrence analyses, and calculations using USGS regional regression equations. Previous flood recurrence analyses for the Twisp River gage have been completed for the Middle Twisp River Reach Assessment (Inter-fluve 2015) and the War Creek Restoration Design, Draft Concept Report (Richardson 2016) which includes a flood frequency analysis for the Twisp River upstream of War Creek based on the Twisp River gage data, adjusted for drainage area differences.

The maximum peak discharge recorded at the Twisp River gage was 3,880 cubic feet per second (cfs) occurring on May 18, 2006. For this Project, the UTR, LBC, and tributary peak discharges were evaluated based on the USBR Methow Subbasin Geomorphic Assessment (USBR 2008) hydrologic analysis, and also calculated using USGS regional regression equations. Table 4-1 contains peak discharges for the 2-year, 10-year, 25-year, 50-year, and 100-year flood events for the Twisp River at the NF-4430 crossing (War Creek Bridge) and the outlet of all Project tributaries.

For comparison, peak discharges were calculated using the previous regression equations (Sumioka et al. 1998) and the recently updated USGS regional regression equations (Mastin et al. 2016). The two main differences between the regression equations is that the updated equations use an area-weighted mean Parameter-elevation Relationships on Independent Slopes Model (PRISM) precipitation data (PRISM 2016) and the equations include the National Land Cover Database (NLCD) canopy cover data (Homer et al. 2007) as an additional variable. The percent canopy cover was added as a variable in the updated regression equations because the error statistics in the regression analysis suggested the equations would improve significantly by adding percent canopy cover (Mastin 2017).

Peak discharges calculated with the updated regional regression equations vary considerably when compared to the results of the previous regression equations (see Table 4-1). Calculated peak discharges are higher (up to 86 percent) in North Creek, South Creek, and Reynolds Creek, which all have relatively low percentages of canopy cover values (36 to 52 percent) and lower (up to 58 percent) when compared with the results of previous regression equations in the LBC and Canyon Creek, which have relatively low values for estimated annual precipitation (26.6 and 25.5 inches, respectively). Although peak discharge estimates vary considerably at some locations, all estimates are within the standard error of the prediction at the 90 percent confidence level.

Table 4-1. Peak Discharges for the 2-Year, 10-Year, 25-Year, 50-Year, and 100-Year Flood Events

Stream Reach	Upper Twisp River and Tributaries Peak Discharge			
	Recurrence Interval	USBR (2008)[1/]	USGS (1998)[2/]	USGS (2016)[3/]
Twisp River at War Creek Bridge	2-year (cfs)	597	936	850
	10-year (cfs)	1109	1640	1680
	25-year (cfs)	1392	1980	2160
	50-year (cfs)	1613	2260	2580
	100-year (cfs)	1842	2550	2990

Table 4-1. Peak Discharges for the 2-Year, 10-Year, 25-Year, 50-Year, and 100-Year Flood Events (continued)

Stream Reach	Upper Twisp River and Tributaries Peak Discharge			
	Recurrence Interval	USBR (2008)1/	USGS (1998)2/	USGS (2016)3/
Little Bridge Creek	2-year (cfs)	188	215	90
	10-year (cfs)	349	424	241
	25-year (cfs)	439	529	346
	50-year (cfs)	508	619	442
	100-year (cfs)	580	710	544
North Creek	2-year (cfs)	54	148	167
	10-year (cfs)	99	262	372
	25-year (cfs)	125	314	507
	50-year (cfs)	145	361	630
	100-year (cfs)	165	407	755
South Creek	2-year (cfs)	121	358	401
	10-year (cfs)	225	600	800
	25-year (cfs)	282	708	1050
	50-year (cfs)	327	803	1260
	100-year (cfs)	373	899	1480
Reynolds Creek	2-year (cfs)	62	87	135
	10-year (cfs)	116	175	257
	25-year (cfs)	145	219	329
	50-year (cfs)	168	257	393
	100-year (cfs)	192	296	454
War Creek	2-year (cfs)	206	258	341
	10-year (cfs)	382	498	624
	25-year (cfs)	479	617	784
	50-year (cfs)	556	719	925
	100-year (cfs)	634	822	1060
Eagle Creek	2-year (cfs)	104	148	150
	10-year (cfs)	193	288	292
	25-year (cfs)	242	357	377
	50-year (cfs)	280	417	452
	100-year (cfs)	320	477	524
Canyon Creek	2-year (cfs)	69	76	35
	10-year (cfs)	127	159	93
	25-year (cfs)	160	201	134
	50-year (cfs)	185	238	172
	100-year (cfs)	212	275	213

1/ Methow Subbasin Geomorphic Assessment, Appendix J – Hydrology Analysis and GIS Data (USBR 2008)
2/ Discharges calculated using regional regression equations (Sumioka et al. 1998)
3/ Discharges calculated using updated regional regression equations (Mastin et al. 2016)

Peak flows have been shown to increase following fire, often substantially, with the magnitude of increase related to the burn severity, watershed characteristics, and post-fire infiltration and water repellency among other factors (Moody et al. 2013). As described in Section 2.4, the 2015 Twisp River Fire burned a considerable portion of the Twisp River watershed including a portion of the LBC drainage. The majority of the burned area was assessed as low soil severity with an estimated 1 percent (95 acres) with a moderate to high soil burn severity indicating post-fire peak flow increases are likely to be relatively modest. The recovery time for increased peak flows can range from 3 to 10 years depending on the rate of recovery of soil conditions and the reestablishment of vegetation (Moody and Martin 2001).

4.1.2 Measured Low Flows

Tributary stream flows were measured during the stream habitat field surveys following the USFS Level II Protocols (USFS 2016b). The measured stream flows, shown in Table 4-2, illustrate the range of low flow conditions found in Project tributaries. Measured discharges ranged from 1.7 cfs in Canyon Creek to 24.6 cfs in South Creek. LBC and UTR flows were not measured during field surveys.

Table 4-2. Field Measured Tributary Stream Flows

Location	Date	Discharge (cfs)
North Creek	11/02/2016	10.2
South Creek	11/03/2016	24.6
Reynolds Creek	11/04/2016	8.2
War Creek	11/05/2016	16.1
Eagle Creek	11/04/2016	5.6
Canyon Creek	11/06/2016	1.7

4.2 Upper Twisp River

This section provides a summary of the existing conditions in the UTR in the surveyed reaches based on field data and observations, as well as changes documented in previous survey data and summary reports. The field surveys of the UTR included documenting geomorphic characteristics and field identification of project opportunities. Georeferenced field observations, notes, and photographs documenting existing conditions in the surveyed area of the UTR are included in the Project geodatabase (Appendix C). These data will be used to supplement the existing habitat data to assess current conditions using the REI and develop the restoration strategy.

4.2.1 Upper Twisp River Geomorphology and Habitat

Geomorphic conditions in the UTR were evaluated during field surveys and desktop analyses completed to characterize conditions with respect to channel migration, floodplain connectivity, sediment transport dynamics, the role of instream wood, and the impact of land use practices on reach-scale geomorphic processes.

The geomorphic and habitat conditions in the UTR are tightly coupled with the local geology and glacial history, as described in Section 2.2. The history of human disturbance and the role of land use practices has also had an impact on geomorphic conditions, particularly in reaches that are more sensitive to disturbance.

The glacial history of the upper Twisp River valley is the primary driver of the landscape-scale morphology. Glacial till and outwash deposits fill much of the valley. Today, the valley morphology is highly complex comprised of a variety of landforms including, alluvial floodplains, glacial terraces, bedrock outcrops, large landslide deposits, and alluvial fans. In many areas, these landforms limit lateral channel migration and are strong drivers of geomorphic processes and existing habitat conditions.

Figure 4-2 shows the longitudinal profile of the UTR channel bed elevation and valley bottom width, derived from the 2015 LiDAR data. The location of the six geomorphic reaches, their average gradient, and the location of tributary junctions and road crossings, are shown on the figure for reference. The channel gradient of the UTR remains relatively consistent in Reaches 1 through 3, ranging from 1.3 percent to 1.7 percent, increasing slightly in Reaches 4 and 5 to approximately 3 percent. The UTR gradient in Reach 6, downstream of the bedrock waterfall, is considerably steeper than downstream reaches at 7.1 percent.

There is an abundant supply of sediment to the UTR. Steep tributary channels throughout the UTR supply large quantities of sediment. The surrounding hillslopes are steep and prone to landslides. Eroded sediments are highly connected to tributary stream systems and the main channel, in most areas. Bank erosion from channel migration as well as erosion of alluvial fans and glacial terraces also contribute sediments. Past USFS management activities such as timber harvesting and road building have likely elevated the sediment levels in the river. Sediment storage varies throughout the UTR Survey Area. Large gravel and cobble bars are frequent in relatively unconfined areas, particularly in Reaches 1 and 3.

There is good floodplain connectivity and off-channel habitat in many of the unconfined areas of the UTR. Extensive floodplain wetlands and beaver dam complexes are found in some areas. Unconfined areas also tend to be highly dynamic and prone to migration through channel avulsions. An extensive network of active and relict floodplain channels and channel scars are visible across the floodplain. In contrast, isolated areas throughout the UTR are somewhat incised with limited floodplain connectivity. In these areas, bedforms are mostly featureless, the substrate is relatively coarse, and sediment storage in bars is limited. As previously mentioned in Section 2.3.5, a history of LWD removal from the Twisp River has resulted in reduced LWD quantity and diminished habitat quality.

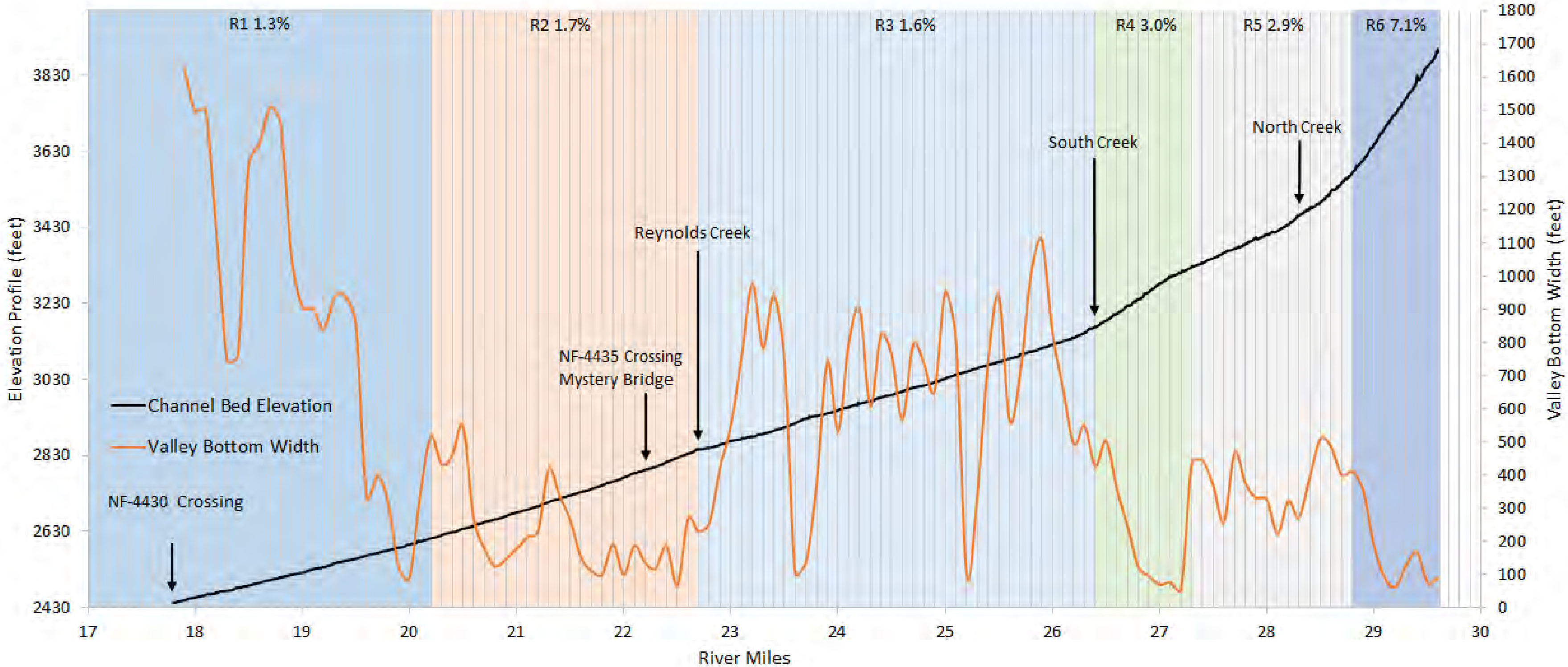


Figure 4-2. Upper Twisp River Longitudinal Profile of Channel Bed Elevation and Valley Width

4.2.2 Upper Twisp River Reach Descriptions

Stream surveys have previously been conducted by the USFS throughout the survey area, most recently in 2013, which will be used to describe the habitat in the UTR for this Project. Previous stream habitat surveys were completed by the USFS on the UTR in 1993 and 2001. The Twisp River stream survey reports contain detailed descriptions of geomorphic and habitat conditions for each survey (USFS 1994, 2001, and 2014). Making direct comparison of habitat survey data over time was not possible due to changes in survey protocols and reach break differences. The USFS stream survey protocols changed considerably in 1996, particularly as they relate to pools (Mariah Mayfield pers. comm. 2017). The location of Survey Area reach breaks in the UTR also changed over time.

The field surveys covered six geomorphic reaches of the UTR from the NF-4430 road bridge near the War Creek Campground (RM 17.8) to the anadromous fish passage barrier waterfall near RM 29.6. The reach breaks, identified during the 2013 USFS stream survey, were delineated based on differences in channel confinement, gradient, and/or flow. The location of the six reaches is shown in Figure 4-3. The following sections provide a summary of existing conditions in UTR Reaches 1 through 6. The map series in Appendix D shows the distribution of canopy cover throughout the UTR riparian corridor as calculated from the 2015 LiDAR data.

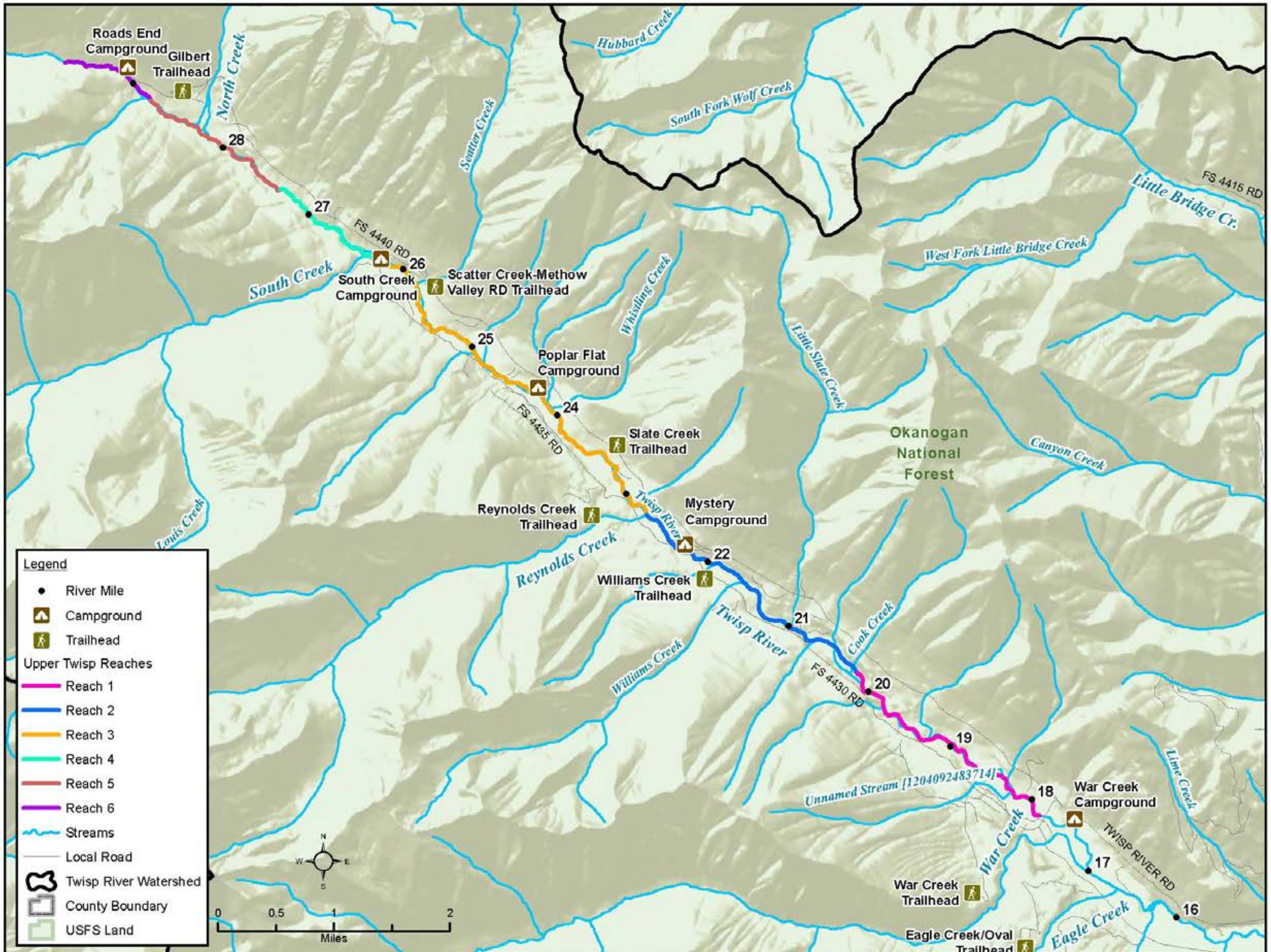


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Figure 4-3. Upper Twisp River (UTR) Reaches from 2013 USFS Stream Survey

UTR Reach 1: The UTR Reach 1 extent is from the NF-4430 road bridge near the War Creek Campground (RM 17.8) to the upstream extent of the reach near RM 20.2. The NF-4400 and NF-4430 roads both parallel the river throughout the reach on opposite sides of the valley. The NF-4400 road is on the northeast side of the river and the NF-4430 road is on the southwest. Both roads are located at the base of the hillslope and out of the valley bottom throughout the reach. There is one exception to this, which occurs at the downstream end of the survey where the NF-4430 road crosses the Twisp River and its floodplain (War Creek Bridge). The road at this location crosses the floodplain for a length of approximately 650 feet. This area has been evaluated in the War Creek Restoration Design Draft Concept Report (Richardson 2016).

UTR Reach 1 has a relatively gentle slope with an average gradient of 1.3 percent. The valley floor is wide and flat ranging from 300 to 1,500 feet. There is a confined segment near the upstream extent of the reach from RM 19.9 to RM 20.1 that flows through a narrow (45 feet) bedrock gorge. Throughout the rest of the reach, a complex system of channel scars across the floodplain show this reach of the Twisp River is highly dynamic, prone to migration through channel avulsions, and has an extensive network of active and relict floodplain channels. The substrate in this reach is cobble-dominated, with high proportions of gravel stored in frequent bars of all types, and effective sediment sorting. The flow is split into multiple low flow channels in many places typically forced by the presence of LWD or log jams. Bank erosion was observed throughout the reach on the opposite bank from point bars, in proximity to existing jams, and associated with channel avulsions.

Figure 4-4. Log Jams and Habitat Complexity in the Upper Twisp River Reach 1 near RM 18.0

The habitat of UTR Reach 1 exhibits a great deal of complexity and diversity, dominated by riffles and lateral scour pools, as shown in Figure 4-4. Spawning habitat is abundant throughout UTR Reach 1. Evidence of beaver activity is prevalent throughout this reach in the main channel and side channels. Beaver dams are frequent on side channels in this reach and are resulting in large open-water beaver ponds on the floodplain near RM 18.5. Observations of beaver activity in the mainstem Twisp River were limited to individual chewed trees and small, temporary, low-flow main channel dams. Beaver activity was not called out in the earlier surveys, but the 2013 survey did note beaver activity in this reach.

UTR Reach 2: This reach extent is from approximately RM 20.2 to the Reynolds Creek confluence near RM 22.7. The NF-4400 road continues to parallel the river to the northeast, connecting with the NF-4440 road near the Mystery Campground. The NF-4430 and the NF-4435 road parallel the river on the southwest side. Similar to UTR Reach 1, all but short segments of these roads are located out of the valley bottom. Also similar to UTR Reach 1, the NF-4435 road crosses the floodplain and Twisp River (Mystery Bridge) bisecting the floodplain for a length approximately 320 feet and interrupting hydrologic connectivity. The Mystery Bridge is located at the Mystery Creek Campground near RM 22.2.

UTR Reach 2 remains relatively low gradient with an average of 1.8 percent. The valley is more confined than in UTR Reach 1, ranging from 175 to 750 feet, and is U-shaped. Large landslide deposits, terraces, bedrock outcrops, and alluvial fans confine the channel to various degrees throughout UTR Reach 2. The substrate in this reach is cobble-dominated, with a higher proportion of boulders than in UTR Reach 1 and less spawning gravels. The channel is single-thread and incised throughout the majority of UTR Reach 2, limiting floodplain connectivity. Bars are less frequent than in UTR Reach 1, particularly upstream of RM 20.8. Frequent bank erosion was observed on the outside bends with point bars and where the channel was interacting with the valley edge, as shown in Figure 4-5. Bank erosion and channel erosion are restricted somewhat in deeply incised areas due to naturally boulder-armored bank materials.

The habitat of UTR Reach 2 is simplified, dominated by riffles, and has fewer pools than in the other upper Twisp River reaches. There is far less available spawning habitat in this reach than in UTR Reach 1. LWD and jams were also less frequent in UTR Reach 2 than in UTR Reach 1. In contrast to both upstream and downstream reaches, there was little evidence of beaver activity in UTR Reach 2.

Figure 4-5. High Eroding Bank on the Upper Twisp River Reach 2 near RM 21.4

UTR Reach 3: This reach extent is from the Reynolds Creek confluence near RM 22.7 to the South Creek confluence near RM 26.4. The NF-4440 road continues to parallel the river on the northeast side throughout this reach. There is a short segments of the NF-4440 road in the floodplain from RM 25.8 to 26.1, however, it is located out of the valley bottom throughout the remainder of the reach. The NF-4435 road parallels the river on the southwest side. It is also located out of the valley bottom and ends before the upstream extent of the reach near RM 26.2.

UTR Reach 3 remains relatively low gradient at an average of 1.6 percent. In general, this reach is less confined than UTR Reach 2; however, geomorphic conditions, including valley confinement, vary considerably throughout the reach. There are areas within UTR Reach 3 that have a broad, flat bottom valley floor over 1,000 feet across and other areas where landslide deposits, terraces, and alluvial fans confine the channel to various degrees. The channel is incised in some areas and not in others depending, in part, on the degree of confinement. The substrate in this reach is cobble-dominated with considerable variability in the proportion of boulders and gravel throughout the reach. Eroding banks were relatively infrequent in this reach, with the exception being a highly dynamic segment of the reach at the Poplar Flats Campground near RM 24.2. UTR Reach 3 experiences seasonal dewatering for an approximately 1.8-mile segment near the Poplar Flats Campground resulting in observed bull trout stranding mortality, as described in Section 2.5.1.

The habitat quality of UTR Reach 3 varies widely and ranges from simplified segments dominated by riffles with few pools to highly complex segments with split flows, gravel bars, and quality pools with good cover, connected floodplains, and off-channel habitat. Spawning gravels were observed in this reach particularly from the downstream end of the reach (22.7) to RM 23.6 and near RM 25.6. Evidence of beaver activity is prevalent throughout this reach in side channels and this activity is resulting in a series of large open-water beaver ponds on the floodplain near RM 23.1, as shown in Figure 4-6. The 2013 survey noted that inactive beaver dams were observed in some of the side channels in the reach while evidence of recent beaver activity was observed in this reach in 2016.

Figure 4-6. Beaver Dam Pond on the Upper Twisp River Reach 3 near RM 23.1

UTR Reach 4: This reach is a relatively short reach (0.9 mile) from the South Creek confluence near RM 26.4 to RM 27.3. The NF-4440 road continues to parallel the river on the northeast side throughout this reach and is located out of the valley bottom.

UTR Reach 4 is steeper than downstream reaches with an average gradient of 3.7 percent. This reach is highly confined throughout most of the length by landslide deposits, terraces, and bedrock outcrops. Deep-seated landslides were observed in this reach adjacent to the river. The channel is single thread, straight, and stable. The substrate in this reach is cobble-dominated with a high proportion of boulders. Eroding banks and bars are very infrequent in UTR Reach 4.

The habitat of UTR Reach 4 is dominated by riffles and short rapids, as shown in Figure 4-7, with relatively frequent scour and plunge pools. The presence of spawning gravels is limited in this reach. No beaver activity was observed in this reach. Beaver activity was not called out in the earlier surveys, but the 2013 survey did note there was no beaver activity in Reaches 6 through 8 in 2013.

Figure 4-7. Habitat Conditions in the Upper Twisp River Reach 4 near RM 27.1

UTR Reach 5: This reach extent is from RM 27.3 to upstream of the North Creek confluence near RM 28.8. The size of the Twisp River reduces considerably in this reach, particularly upstream of North Creek confluence near RM 28.3. The NF-4440 road continues to parallel the river on the northeast side throughout this reach. The road is located out of the valley bottom and climbs to cross North Creek at approximately RM 0.5.

UTR Reach 5 has a lower gradient than upstream and downstream reaches at 2.5 percent. This reach varies considerably in geomorphic and habitat conditions. Most the reach is incised, stable and has limited floodplain connectivity. In these areas, the substrate is cobble-dominated with a high proportion of boulders. Channel-spanning log steps were observed in these areas. In contrast, there are segments within UTR Reach 5 that are less confined and have relatively good floodplain connectivity, increased channel complexity, and multiple low-flow channels and side channels, as shown in Figure 4-8. Eroding banks and bars are frequent in these areas. They are also cobble dominated but have a much higher proportion of gravels than in the incised segments.

The habitat of UTR Reach 5 varies widely but, in general, is dominated by riffles and rapids, with relatively frequent scour pools and plunge pools associated with log steps and boulders. There are spawning gravels present, more commonly in the relatively unconfined segments. There was also a beaver-dammed side channel in this reach at the North Creek confluence near RM 28.3. No evidence of beaver activity was observed at this location in the 2013 survey.

Figure 4-8. Laterally Active Area of the Upper Twisp River Reach 5 near RM 27.4

UTR Reach 6: This reach is a relatively short (approximately 0.8 mile) reach from RM 28.8 to the anadromous fish passage barrier waterfall near RM 29.6, shown in Figure 4-9. The NF-4440 road continues to parallel the river on the northeast side to its end at RM 29.2 at the Road's End Campground.

UTR Reach 6 is the steepest of the reaches at 7.3 percent. The valley is increasingly narrow and confined in this reach in the upstream direction. The valley hillslopes become steep in this reach with long debris flow paths leading from alpine terrain to the river near RM 29.5. The channel is predominately single thread, straight, and stable. The substrate of this reach is dominated by cobbles and boulders with isolated pockets of gravel in areas of low velocity. Eroding banks and bars are infrequent in this reach but do occur in isolated areas typically forced by LWD and jams. One relatively large jam was observed near RM 29.3.

The habitat of UTR Reach 6 is dominated by rapids, cascades, and short riffles. Plunge pools are frequent and associated with cascades, log steps, and boulders. Bull trout spawning habitat is abundant in UTR Reach 6 with the highest densities of bull trout redds in the Methow River Subbasin (USFS 2014). No evidence of beaver activity was observed in this reach.

Figure 4-9. Fish Passage Barrier Waterfall (approximately 15 feet high) on the Upper Twisp River Reach 6 near RM 29.6

4.2.3 Upper Twisp River Reach Comparison

The metrics in Table 4-3 provide a quantitative comparison of the habitat conditions and other features of UTR reaches described in the sections above. The data in Table 4-3 have been adapted from the 2013 USFS stream habitat survey of the UTR (USFS 2014).

Table 4-3. Upper Twisp River 2013 USFS Stream Habitat Data Summary

Metric	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
River Mile	17.3 to 20.3	20.3 to 22.8	22.8 to 26.2	26.2 to 27.3	27.3 to 28.9	28.9 to 29.7
Measured Reach Length (miles)	3.0	2.4	4.0	1.1	1.6	0.9
Beginning Elevation (feet)	2,400	2,610	2,840	3,160	3,360	3,570
Ending Elevation (feet)	2,610	2,840	3,160	3,360	3,570	3,905
Pools						
Pool Frequency (pools/mile)	17.8	5.4	18.4	26.4	29.6	60.4
Pools Frequency > 3 feet Deep (pools/mile)	10.1	2.5	9.8	12.3	4.4	17.2
Average Maximum Pool Depth (feet)	3.5	2.9	3.1	3.0	2.5	2.7
Average Pool Residual Depth (feet)	2.4	1.7	2.1	1.8	1.6	1.8

Table 4-3. Upper Twisp River 2013 USFS Stream Habitat Data Summary (continued)

Metric	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
LWD						
Small (>20 feet length, >6 inches diameter)	130	71	192	44	81	63
Medium (>35 feet length, >12 inches diameter)	88	35	113	26	45	26
Large (>35 feet length, >20 inches diameter)	32	3	41	6	26	12
LWD Frequency (pieces/mile)1/	40.4	15.7	38.8	30.2	45.7	41.8
Habitat						
Percent Pool	26%	6%	20%	17%	17%	29%
Percent Fast (riffle, rapid, cascade)	59%	91%	64%	79%	71%	70%
Percent Fast Non-Turbulent (glide)	5%	4%	4%	0	4%	0
Percent Side Channel	11%	<1%	12%	4%	8%	2%
Bank Erosion						
Bank Erosion (feet per mile)	475	1,091	633	373	214	81
Percent Eroding Banks (total of both banks)	5.9%	5.3%	4.5%	10.3%	6.0%	3.5%
Channel Characteristics						
Average Wetted Width (feet)	34	38	29	23	22	19
Bankfull Width (feet)	64	57	58	36	42	26
Width/Depth Ratio	37	32	33	21	28	17
Entrenchment Ratio	5.06	1.85	5.5	2.4	2.58	1.41
Sinuosity	1.25	1.05	1.2	1.05	1.15	1.05
Average Gradient (percent)	1.3	1.8	1.6	3.7	2.5	7.3
Rosgen Channel Type2/ (primary, secondary)	C3	B3	C3, B3	B3,	C3, B3	B2a, B3a
Substrate						
D50 (mm)	92	146	101	145	107	206
D84 (mm)	200	333	244	422	238	565
Percent Sand (< 2 mm)	8%	6%	5%	4%	6%	4%
Percent Gravel	28%	15%	28%	17%	27%	14%
Percent Cobble	56%	51%	53%	51%	54%	40%
Percent Boulder	8%	28%	14%	28%	13%	40%
Percent Bedrock	0	0	0	0	0	2%

1/ Large woody debris (LWD) in the medium and large size classes is included in the pieces per mile calculation.
2/ See Rosgen (1996) for channel type descriptions.
Source: USFS (2014)

4.3 Little Bridge Creek

LBC is a tributary to the Twisp River entering near RM 9.6. It is the longest tributary within the Project with a survey length of 7.2 miles. This section provides a summary of the existing conditions and documented changes in the LBC based on field data and observations, as well as previous survey data and summary reports. The field surveys of the UTR included describing geomorphic characteristics, and field identification of project opportunities. An inventory of pools and LWD was also conducted during field surveys. Similar to the UTR field survey described above, georeferenced field observations, notes, and photographs documenting existing conditions in the surveyed area of the LBC are included in the Project geodatabase (Appendix C). These data will be used to supplement existing habitat data to assess current conditions using the REI and develop the restoration strategy.

4.3.1 Little Bridge Creek Geomorphology and Habitat

Geomorphic conditions in the LBC were evaluated during field surveys and desktop analyses completed to characterize conditions with respect to channel migration, floodplain connectivity, sediment transport dynamics, the role of instream wood, and the impact of land use practices on reach-scale geomorphic processes.

In contrast to the UTR, the LBC has a relatively simple valley morphology. LBC generally flows through a V-shaped valley with intermittent bedrock outcrops and small alluvial fans on the valley margins. The valley bottom width is narrow in most areas. Reach 3 has the widest valley bottom width at approximately 300 feet.

Figure 4-10 shows the longitudinal profile of the LBC channel bed elevation, derived from a 10-meter DEM. The location of the four geomorphic reaches, their average gradient, and the location of road crossings and other relevant features are shown on the figure for reference. The channel gradient of the LBC remains relatively consistent in Reaches 1 through 3, ranging from 2.9 percent to 3.6 percent. The gradient in LBC Reach 4 is considerably steeper than downstream reaches at 5.9 percent. LBC Reach 5 from the 2006 survey extends from RM 7.2 to RM 8.1, which is beyond the survey area for this Project and thus not included in this summary.

There is a moderate supply of sediment to LBC. The surrounding hillslopes are moderately steep with relatively small tributary channels with sediment transport capacities insufficient to transport large quantities of coarse sediment. Sediment supply from landslides and bank erosion also seems to be relatively limited. Observations of sediment accumulations at the confluence with the Twisp River does indicate that LBC contributes a considerable amount of sediment to the Twisp River (Inter-Fluve 2015). The LBC has a high proportion of fine sediments, in part due to the volcanic and sedimentary bedrock (see Section 2.2). Past USFS management activities such as timber harvesting and road building have likely elevated the sediment levels in the Creek. The recent 2015 Twisp River Fire likely also increased the fine sediment supply. Sediment storage varies throughout the LBC Survey Area. Gravel and cobble bars are relatively frequent in fairly unconfined areas, particularly in Reaches 2 and 3. Sediment storage in upstream reaches is primarily the result of accumulation upstream of channel-spanning log and/or boulder steps or log jams.

There is good floodplain connectivity and off-channel habitat in many of the unconfined areas of the LBC. Extensive beaver dam complexes are found in some areas. Unconfined areas also tend to be highly dynamic and prone to migration through channel avulsions. In contrast, isolated areas throughout the LBC are somewhat incised with limited floodplain connectivity. LWD and logs jams are the primary drivers for instream complexity in these areas.

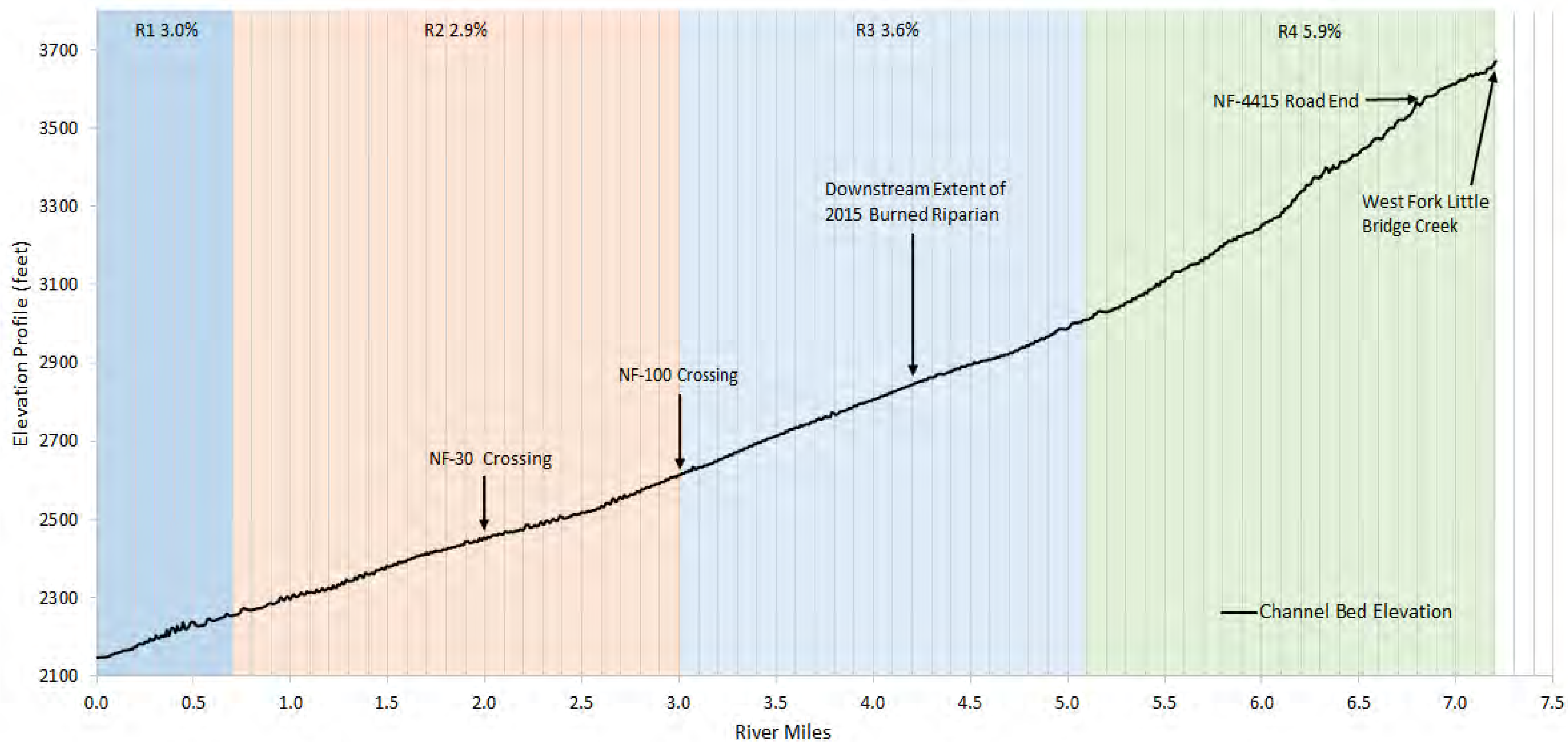

Figure 4-10. Little Bridge Creek Longitudinal Profile and Reach Gradients

4.3.2 Little Bridge Creek Reach Descriptions

Stream surveys have been conducted by the USFS on the LBC in 1992, 1996, and 2006. The LBC stream survey reports contain detailed descriptions of geomorphic and habitat conditions for each survey (USFS 1993, 1996, and 2006a). As previously described in Section 4.2.2, direct comparison of habitat survey data over time was not possible due to changes in survey protocols and reach break differences.

The field surveys covered four geomorphic reaches of the LBC from the Twisp River Confluence (RM 0) to the confluence with West Fork Little Bridge Creek (RM 7.2). The reach breaks, identified during the USFS (2006a) stream survey, were delineated based on differences in channel confinement, gradient, and/or flow. The location of the four reaches is shown in Figure 4-11. The following sections provide a summary of existing conditions in LBC Reaches 1 through 4.

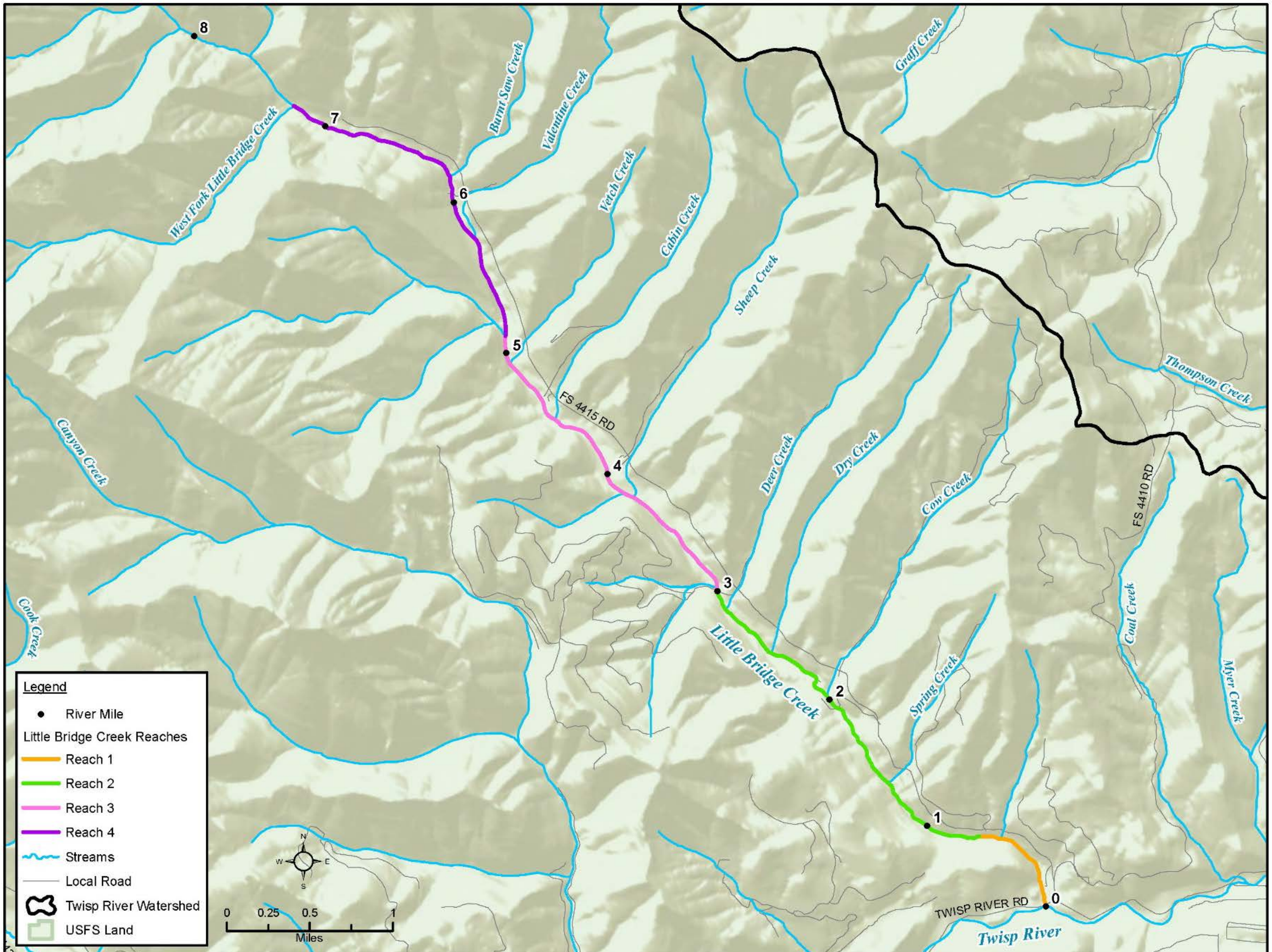

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Figure 4-11. Little Bridge Creek Reaches from 2006 USFS Stream Survey

LBC Reach 1: This reach extent is from the Twisp River Confluence (RM 0.0) to RM 0.7. The Twisp River Road crosses LBC in Reach 1 near the confluence. There is an open bottom arch culvert with a 35-foot span that is larger than the average bankfull width of 19 feet. The NF-4415 Road parallels the creek on the east side throughout this reach. A section of rip rap armoring measuring approximately 75 feet protects the road upstream of the Twisp River Road crossing.

LBC Reach 1 has an average gradient of 3.0 percent with a somewhat steeper drop near the Twisp River confluence. Most of LBC Reach 1 is incised with little or no floodplain connectivity. The valley narrows from the confluence to RM 0.3 where it becomes narrow and V-shaped. The substrate in this reach is cobble dominated, with higher proportions of gravel observed in infrequent bars. Point bars and active bank erosion were observed in several locations. There was one mid-channel bar in LBC Reach 1 observed upstream of a log jam. The step formed by this jam, shown in Figure 4-12, may be temporarily limiting fish passage due to a 36-inch jump height and a 22- inch plunge pool downstream. Accumulations of fine sediment were observed throughout this reach. Deposits of sand and very fine gravel as deep as 6 inches were observed in areas of lower velocity. The LBC has naturally high quantities of fine sediments that have been exacerbated by past management activities such as timber harvesting, roads, and cattle grazing. Sediment inputs have also increase in the LBC as a result of post-fire erosion following the 2015 Twisp River Fire. Several large boulders with associated scour pools were observed in this reach. The LBC Reach 1 is dominated by riffle habitat with frequent plunge and scour pools, and infrequent, short rapid drops. The pool frequency is 61 pools per mile and the LWD frequency is 56 pieces per mile. There was one short side channel observed in this reach, with inlet flows being controlled by a log jam.

Figure 4-12. Log Jam Step and Plunge Pool in Little Bridge Creek Reach 1 near RM 0.5

LBC Reach 2: This reach extent is from RM 0.7 to the NF-100 road crossing near RM 3.0. The NF-4415 Road continues to parallel the creek on the east side throughout this reach, although it is well above the creek on the valley hillslope and out of the floodplain. The NF-030 road and NF-100 road cross LBC near RM 2.0 and RM 3.0 to access the terrain west of the creek. Both crossing structures are open bottom arch culverts installed in 2005 (USFS 2006a). The NF-030 road crossing has a 40-foot span relative to a reach average bankfull width of 26.5 feet and appears to be functioning properly. Scour at the upstream end of the NF-100 road crossing has exposed the left bank concrete foundation making that structure vulnerable. There is an existing irrigation diversion structure near RM 2.2 that has been modified to improve fish passage (USFS 2006a); however, a channel-spanning boulder weir remains to backwater the diversion, which may be seasonally affecting juvenile fish passage.

The average channel gradient in LBC Reach 2 is 2.9 percent. Most of the reach has a well-connected floodplain, although there are areas of incision and disconnected floodplain downstream of RM 1.6. The valley is wider in LBC Reach 2 than LBC Reach 1 but remains relatively narrow (100 to 300 feet) bordered by moderately steep hillslopes. The substrate in this reach is cobble-dominated, but there is a higher proportion of gravel than in LBC Reach 1. Bars are frequent in this reach and many contain good quality spawning size material. Point bars and active bank erosion were observed in several locations and deposits of fine sediments were observed in areas of lower velocity throughout this reach.

The distinguishing habitat feature in LBC Reach 2 is the presence of channel-spanning beaver dams near RM 0.9 and from RM 1.7 to RM 1.8, as shown in Figure 4-13. In both areas, an extensive system of beaver dams has completely dammed the main channel and side channels, inundating nearly the entire floodplain. The habitat between beaver dams is dominated by riffles with frequent plunge and scour pools. Dam pools upstream of channel-spanning LWD were common in this reach. The pool frequency is 72 pools per mile and the LWD frequency is 33 pieces per mile. Off-channel areas and side channels are frequent in this reach, many of which were influenced by beaver activity. No beaver dams were observed in the 1996 or 2006 surveys of the LBC, which indicates a significant change in habitat conditions over that time.

Figure 4-13. Beaver Dam Complex in Little Bridge Creek Reach 2 near RM 1.7

LBC Reach 3: This reach extent is from the NF-100 road crossing (RM 3.0) to RM 5.1. The NF-4415 Road continues to parallel the creek on the east side throughout this reach. There are no road crossings or irrigation diversions in this reach. There has been more riparian disturbance in LBC Reach 3 than in other reaches. Past logging of the floodplain has provided increased access to the creek for cattle (USFS 2006a). There was a relatively recent (within the last 15 years) harvest unit that was logged to the channel banks in LBC Reach 3 near RM 3.8. The riparian area was also recently burned in some areas upstream of RM 4.2 in the 2015 Twisp River Fire. Several post-fire erosional areas were observed on the floodplain in this reach, some resulting in narrow, incised channels up to several feet deep.

The slope in LBC Reach 3 is greater than in LBC Reach 2 with an average channel gradient of 3.6 percent. Most of the reach has a well-connected floodplain although there are isolated areas of moderate incision and disconnected floodplain intermittently throughout. LBC Reach 3 is the most unconfined reach of the LBC, the most active reach in channel migration, and contains the most instream complexity. LBC Reach 3 has a broad valley floor (over 300 feet) bordered by moderately steep hillslopes. The substrate in this reach is cobble dominated, but there is a higher proportion of gravel than all other reaches. Bars are frequent in this reach, including mid-channel bars with many containing good quality, spawning-size material. There are bedrock grade controls in LBC Reach 3, beginning upstream of RM 3.6. Areas of active bank erosion and evidence of recent and historic channel avulsions were also observed in this reach. Deposits of fine sediments were observed in areas of lower velocity throughout this reach.

The distinguishing habitat features in LBC Reach 3 are the presence of vegetated islands and areas of high channel complexity and braided morphology associated with large channel-spanning log jams. Figure 4-14 shows split flow around a vegetated island near RM 3.0. The habitat in LBC Reach 3 is dominated by riffle with frequent pools. Lateral scour pools and LWD forced pools are more common in this reach than plunge pools or dam pools. The pool frequency is 61 pools per mile and the LWD frequency is 36 pieces per mile. There were multiple side channels in this reach, including both wetted side channels and dry, high-flow channels.

Figure 4-14. Split Flow around Vegetated Island in Little Bridge Creek Reach 3 near RM 3.0

LBC Reach 4: This reach extent is from RM 5.1 to the confluence with West Fork Little Bridge Creek (RM 7.2). The NF-4415 Road continues to parallel the creek on the east side up to the end of the road near RM 6.8. The road is more of a confining feature in LBC Reach 4 than in downstream reaches and requires areas of bank protection beginning near RM 5.6. The riparian area in LBC Reach 4 was burned during the 2015 Twisp River Fire in some areas, while others remain unburned. Some of the burned trees in the riparian area have been felled following the fire. Most of the felled burned trees have been left on the floodplain and channel banks with some ending up within the bankfull channel.

The slope in LBC Reach 4 is much steeper than downstream reaches with an average channel gradient of 5.9 percent. The valley in LBC Reach 4 is relatively narrow (100 to 300 feet) and confining with complex and varied topography. The channel has intermittent segments that are deeply incised followed by segments that are more connected with the floodplain as a result of large jams causing vegetated islands and high-flow side channels. The substrate in this reach is cobble-dominated but there is a higher proportion of boulders than in downstream reaches. Bars are infrequent in this reach and are found mostly in depositional areas upstream of channel-spanning LWD and jams. There are a number of wood and boulders steps in this reach with jump heights greater than 3 feet that may be temporary fish passage barriers. Areas of active bank erosion and evidence of channel avulsions were also observed in this reach, as well as deposits of fine sediments in areas of lower velocity and lower gradient segments throughout the reach.

The habitat of LBC Reach 4 is dominated by riffles and rapids with short cascades and frequent pools. Figure 4-15 shows a cascade downstream of the West Fork Little Bridge Creek confluence near RM 7.2. LWD and boulder forced plunge pools and dam pools are common in this reach. The pool frequency is 54 pools per mile and the LWD frequency is 34 pieces per mile. Side channels are infrequent in this reach and associated with channel-spanning log jams.

Figure 4-15. Cascade downstream of West Fork Little Bridge Creek Confluence Reach 4 near RM 7.2

4.3.3 Little Bridge Creek Reach Comparison

The metrics in Table 4-4 provide a quantitative comparison of the habitat conditions and other features of the LBC described in the sections above. The majority of the data in Table 4-4 have been adapted from the USFS (2006a) stream habitat survey of the LBC. The LWD and pool data in Table 4-4 were collected in 2016 during the geomorphic surveys for this Project.

Table 4-4. Little Bridge Creek Data Summary

Metric	Reach 1	Reach 2	Reach 3	Reach 4
River Mile	0.0 to 0.7	0.7 to 3.0	3.0 to 5.1	5.1 to 7.2
Reach Length (miles)	0.7	2.3	2.1	2.1
Beginning Elevation (feet)	2,150	2,250	2,610	3,000
Ending Elevation (feet)	2,250	2,610	3,010	3,670
Pool				
Pool Frequency (pools/mile)	47.5	46.4	50.2	51.8
Pools Frequency > 3 feet Deep (pools/mile)	2.8	0.8	0.8	1.4
Average Maximum Pool Depth (feet)1/	2.0	1.9	1.8	1.7
Average Pool Residual Depth (feet)1/	1.3	1.3	1.3	1.3
LWD				
Small (>20 feet length, >6 inches diameter)	61	130	84	67
Medium (>35 feet length, >12 inches diameter)	30	50	51	52
Large (>35 feet length, >20 inches diameter)	9	26	24	20
LWD Frequency (pieces/mile)2/	56	33	36	34
Habitat1/				
Percent Fast (riffle, rapid, cascade)	77%	74%	75%	81%
Percent Pool	23%	23%	23%	19%
Percent Fast Non-Turbulent (glide)	0	0	0	0
Percent Side Channel	0	3%	2%	<1%
Bank Erosion1/				
Bank Erosion (feet per mile)	112	195	350	88
Percent Eroding Banks (total of both banks)	1.1%	1.8%	3.3%	0.8%
Channel Characteristics				
Average Wetted Width (feet) 1/	13	13	12	10
Bankfull Width (feet)1/	19	27	22	19
Width/Depth Ratio1/	10	18	15	11
Entrenchment Ratio1/	1.92	2.88	2.30	2.14
Sinuosity	1.05	1.05	1.06	1.03
Average Gradient (percent)	3.0%	2.9%	3.6%	5.9%
Rosgen Channel Types3/ (primary, secondary)1/	B3	B3, C3	B3, C4	A3, B3a
Substrate1/				
D50 (mm)	92	67	48	96
D84 (mm)	405	185	148	224
Percent Sand (< 2 mm)	10%	14%	15%	12%
Percent Gravel	29%	33%	44%	28%
Percent Cobble	42%	46%	37%	49%
Percent Boulder	19%	7%	4%	11%
Percent Bedrock	0	0	0	0

1/ Source: Little Bridge Creek Stream Report 2006 (USFS 2006a)
2/ Large woody debris (LWD) in the medium and large size classes is included in the pieces per mile calculation.
3/ See Rosgen (1996) for channel type descriptions.

4.4 Upper Twisp River Tributaries

The following sections provide an overview of existing conditions in each of the remaining Project tributaries (other than the LBC) including North Creek, South Creek, Reynolds Creek, War Creek, Eagle Creek, and Canyon Creek. Georeferenced field observations, notes, and photographs documenting existing conditions in the tributaries are included in the Project geodatabase (Appendix C). The Preliminary Reach Form and Final Reach Form for all of the tributaries are in Appendix B. The completed field forms including the channel unit form, forest options form, special case form, pebble count form, and the discharge form for each tributary are also in Appendix B. These forms will be used by the USFS to enter the tributary survey data into the USFS stream inventory database. The map series in Appendix D shows the distribution of canopy cover in the riparian corridor of the tributary reaches, as calculated from the 2015 LiDAR data.

The following sections provide a summary of existing conditions and reach comparisons for each of the tributaries.

4.4.1 Tributary Geomorphology and Habitat

All of the tributaries in this section except Canyon Creek (i.e., North Creek, South Creek, Reynolds Creek, War Creek, and Eagle Creek) share some common geomorphic and habitat characteristics in large part because they are all on relatively large alluvial fans. Although the fans do differ somewhat in size and character, each tributary has a transitional reach that extends from the confluence with the Twisp River to a confined bedrock canyon and fish passage barrier just upstream from the head of the fan. All of these tributary reaches exhibit the following patterns in the upstream direction:

- Increasing gradient,
- Increasing confinement,
- Transition from cobble-dominated to boulder-dominated substrate, and
- Transition from rapid-dominated to cascade-dominated habitat.

In addition they share similar characteristics in channel migration processes and relative stability. Each of the reaches are relatively stable with naturally erosion resistant bed and banks and moderate to deep channel incision in many areas. As is typical with streams on alluvial fans, these reaches are most prone to lateral migration through channel avulsions likely in response to landslides, large floods, or other disturbance events. Previous channel scars across the fan surface indicate this pattern of migration across the fan over time.

Sediment supply in all tributary reaches is dominated by upstream erosion, which is typical of stream reaches on alluvial fans. Bank erosion rates were relatively low in all reaches with isolated areas of incision and aggradation, particularly adjacent to road crossings.

There is a trend of transition from riffle-dominated to rapid- and cascade-dominated in the upstream direction in the tributary reaches with the exception of Canyon Creek, which is riffle-dominated with isolated rapids throughout the survey reach. Section 4.4.3 describes tributary geomorphology and habitat comparisons for sediment characteristics, LWD, and habitat.

4.4.2 Tributary Reach Descriptions

Stream surveys have been conducted by the USFS on the UTR tributaries in 1994 and Canyon Creek in 1993. The Twisp River tributaries and Canyon Creek stream survey reports contain detailed descriptions of geomorphic and habitat conditions for each tributary (USFS 1994a, 1994b, and 1995).

North Creek: North Creek is the uppermost perennial tributary to the Twisp River, entering from the north near RM 28.3. The field survey of North Creek occurred from the confluence with the Twisp River (RM 0.0) to about RM 0.6 where there is a complete fish passage barrier waterfall (Figure 4-16). There is one existing road crossing structure on North Creek on the NF-4440 road near RM 0.5. The crossing is an open bottom arch culvert in good condition, but the culvert width of 17 feet does not span the bankfull width of North Creek, as shown in Figure 4-17. As a result, the North Creek crossing may be susceptible to plugging and possible catastrophic failure, particularly following a large disturbance event such as a flood or landslide. Upstream of the road crossing there is a levee on the right bank and an existing cabin structure. Previous surveys of North Creek noted the presence of a water diversion near RM 0.5 of North Creek for domestic use and an ore mill (USFS 1995a). This diversion structure was not observed in 2016.

The average gradient of the North Creek survey reach is 8.4 percent. The average wetted width is 15 feet and an average bankfull width of 30 feet. A total of 6.7 percent of banks were identified as eroding. There are several natural small wood and boulder drops that are potentially limiting fish access to the upper extent of the survey reach. Figure 4-18 shows the most downstream and shortest of those drops near RM 0.2.

The habitat of North Creek is dominated by fast water units (i.e., riffle, rapid, cascade) for 77 percent of the total length and pools comprise 20 percent of the total habitat area. The frequency of qualifying LWD in the survey reach was 67 pieces per mile. The overstory along North Creek primarily consists of large conifers, with small alders dominating the understory.

Figure 4-16. Fish Passage Barrier Falls at the Upstream Extent of the North Creek Survey Reach near RM 0.6

Figure 4-17. NF-4440 Road Crossing Culvert on North Creek near RM 0.5

Figure 4-18. Small Wood and Boulder Drop near RM 0.2 on North Creek

South Creek: South Creek enters the Twisp River from the southwest near RM 26.4, across from the South Creek Campground. The field survey of South Creek included a single reach that extends from the confluence with the Twisp River (RM 0.0) to about RM 0.6, where there is a complete fish passage barrier at a series of waterfalls (Figure 4-19). There are no road crossings of South Creek but there is one pedestrian bridge on the South Creek Trail near RM 0.3, shown in Figure 4-20.

South Creek is one of largest tributaries in this section of the Twisp River (War Creek is the other), with an average bankfull width of 32 feet and the highest discharge at the time of survey at 24.6 cfs. The average gradient of South Creek is 6.6 percent, with an average wetted width of 23 feet and a total of 5.2 percent of banks identified as eroding.

The habitat of South Creek is dominated by fast water habitat units for 84 percent of the total length and pools cover the remaining 16 percent of the total habitat area. South Creek differs from the other tributaries slightly in that there are more relatively low gradient riffles and rapid habitat in the lower part of the reach extending to about RM 0.3. Downstream of RM 0.3 there is a relatively large log jam, shown in Figure 4-21, that is locally increasing channel complexity and forming gravel bars, which are uncommon in all of the tributaries. The frequency of qualifying LWD in the survey reach was 45 pieces per mile. The overstory along South Creek consists primarily of conifers (ranging from 9 to 21 inches in diameter at breast height [dbh]), with a mixture of alders and red-osier dogwood as the dominant understory.

Figure 4-19. Fish Passage Barrier Falls at the Upstream Extent of the South Creek Survey Reach near RM 0.6

Figure 4-20. Pedestrian Bridge on the South Creek Trail near RM 0.3

Figure 4-21. Log Jam on South Creek Downstream of RM 0.3

Reynolds Creek: Reynolds Creek enters the Twisp River from the southwest RM 22.7. The field survey of Reynolds Creek occurred from the confluence with the Twisp River (RM 0.0) to about RM 0.6 where there is a complete fish passage barrier at a series of four waterfalls (Figure 4-22). There is one existing road crossing structure on Reynolds Creek on the NF-4435 road near RM 0.1. The crossing structure, shown in Figure 4-23, is an open bottom arch culvert in good condition with a width of 27 feet. Bank erosion, sediment deposition, and racking wood were all observed at the upstream end of the culvert. The 1993 survey noted a fish passage barrier at this location with a 3-foot jump from the pool to the culvert, so it is assumed that the existing structure was installed after that survey was conducted.

The average gradient of the Reynolds Creek survey reach is 9.9 percent. Reynolds Creek is relatively small compared to the other tributaries with an average wetted width of 15 feet and an average bankfull width of 25 feet. A total of 3.4 percent of banks in the survey reach were identified as eroding.

The habitat of Reynolds Creek is dominated by fast water units for 73 percent of the total length. Reynolds Creek has the highest percentage of pool habitat of all of the tributaries with pools, accounting for 27 percent of the total habitat area. Figure 4-24 shows an example of a cascade dropping into a boulder plunge pool which is common in Reynolds Creek and the other tributaries. The frequency of qualifying LWD in the survey reach was 23 pieces per mile. The overstory along Reynolds Creek is dominated by a mixture of conifers and deciduous trees (ranging from 9 to 21 inches dbh) throughout the drainage, and a mix of shrubby alder and red osier dogwood as the dominant understory.

Figure 4-22. Fish Passage Barrier Falls at the Upstream Extent of the Reynolds Creek Survey Reach near RM 0.6

Figure 4-23. NF-4435 Road Crossing Culvert on Reynolds Creek near RM 0.1

Figure 4-24. Cascade Drop to Boulder Plunge Pool on Reynolds Creek near RM 0.4

War Creek: War Creek enters the Twisp River from the west at approximately RM 17.3, across from the War Creek Campground. However, the confluence of War Creek and the Twisp River appears to be mapped incorrectly on the National Hydrography Dataset layer, most likely due to an avulsion of the Twisp River which is apparent on the aerial imagery. The mapping error results in river mile discrepancies when comparing data with previous surveys. War Creek was the longest tributary surveyed, beginning at the confluence (RM 0.3) and end ending at a narrow bedrock canyon near RM 1.3, as shown in Figure 4-25. The 1993 survey of war Creek documented a 45-foot waterfall barrier upstream of this point near RM 1.5 (USFS 1994). There is one bridge on the NF-4420 road crossing War Creek near RM 0.6. The bridge was constructed in 2005 and was observed to be functioning properly. The 1937 U.S. Bureau of Fisheries survey of War Creek noted that the gradient was steep and the stream bed was composed mostly of large rubble and boulders and a lack of suitable spawning area (Bryant and Parkhurst 1950).

The average gradient of the War Creek survey reach is the lowest of all surveyed tributaries at 4.6 percent. War Creek is also the largest tributary in the Project area, with average wetted width of 23 feet and an average bankfull width of 36 feet. A total of 2.2 percent of banks were identified as eroding. There are a number of relict and active high-flow side channels in the survey reach downstream of the FS-4420 road crossing, but no flowing side channels at the time of the survey. An example of a high-flow side channel observed in War Creek is shown in Figure 4-26. The upper half of the survey reach is intermittently confined by bedrock outcrops on both banks.

The habitat of War Creek is dominated by fast water units for 80 percent of the total length, with pools comprising 17 percent, and fast non-turbulent (i.e., glides) comprising 3 percent of the remaining length. The frequency of qualifying LWD in the survey reach was 79 pieces per mile. There is a large existing log jam near RM 0.5 that is creating localized channel complexity and an upstream dam pool, as shown in Figure 4-27. The overstory along War Creek primarily comprises conifers (ranging from 9 to 21 inches dbh) in the lower half of the reach with larger conifers (ranging from 21 to 32 inches dbh) in the upper half of the reach and a mixture of dense alders and dogwood as the dominant understory.

Figure 4-25. The Upper Extent of Surveys on War Creek near RM 1.2

Figure 4-26. High-Flow Side Channel Adjacent to War Creek near RM 0.6

Figure 4-27. Dam Pool on War Creek Formed by Large Log Jam near RM 0.5

Eagle Creek: Eagle Creek enters the Twisp River from the west near RM 16.7, less than a mile south of War Creek. The field survey of Eagle Creek was conducted from the confluence with the Twisp River (RM 0.0) to about RM 0.5 where there is a complete fish passage barrier waterfall (Figure 4-28). There is one existing road crossing structure on Eagle Creek on the NF-4420 road near RM 0.2. There is also a pedestrian foot bridge that crosses the creek upstream of the road crossing. The road crossing is an open bottom arch culvert in good condition, but the culvert width of 18.5 feet does not span the bankfull width of Eagle Creek, as shown in Figure 4-29. As a result, the Eagle Creek crossing may be susceptible to plugging and possible catastrophic failure, particularly following a large disturbance event such as a flood or landslide.

The average gradient of the Eagle Creek survey reach is 6.2 percent. The average wetted width in the survey reach is 14 feet, with an average bankfull width of 20 feet, and a total of 0.9 percent of banks identified as eroding. Similar to War Creek, there are a number of relict and active high-flow side channels in the survey reach downstream of the FS-4420 road crossing; however, in contrast to War Creek, there were also flowing side channels, as shown in Figure 4-30.

The habitat of Eagle Creek is dominated by fast water units for 69 percent of the total length. Eagle Creek has the highest proportion of side channel habitat at 18 percent, with pools comprising 13 percent of the total habitat area. The frequency of qualifying LWD in the survey reach was 80 pieces per mile. Instream LWD and channel-spanning blowdown were particularly prevalent in the upper extent of the survey reach. The overstory along

Eagle Creek is dominated by deciduous trees (ranging from 9 to 21 inches dbh) with a mix of bushy alders and red osier dogwood as understory.

Figure 4-28. Fish Passage Barrier Falls at the Upstream Extent of the Eagle Creek Survey Reach near RM 0.5

Figure 4-29. NF-4420 Road Crossing Culvert on Eagle Creek near RM 0.2

Figure 4-30. Existing Eagle Creek Right Bank Side Channel near RM 0.1

Canyon Creek: Canyon Creek enters the Twisp River from the north at RM 13.3. The survey reach extended from the Twisp River confluence (RM 0.0) to upstream of RM 0.4. No permanent, natural, fish passage barriers were observed at the upstream extent of the survey. Previous USFS surveys of Canyon Creek in 1993 extended to the confluence of the west and east forks of Canyon Creek at RM 2.6 and no permanent, natural, fish passage barriers were documented during that survey either (USFS 1994b). Canyon Creek differs from the other tributaries described above in that the majority of the reach is in a narrow, steep sided, V-shaped canyon with only a short incised segment downstream of the Twisp River Road, near the confluence.

Canyon Creek is more impacted by land use in the last several decades than the other tributaries in this section of the UTR. There were several fish passage barriers identified at the Twisp River Road crossing. The crossing structure is an elliptical culvert with a width of 11 feet. The culvert is a partial barrier with a jump height of 0.8 feet, no sediment in the culvert bed, and a 4.3 percent gradient. The riprap-forced drop immediately downstream of the culvert also appears to be blocking fish passage, as shown in Figure 4-31. There are two diversion structures on Canyon Creek, one near the Twisp River confluence, shown in Figure 4-32, and another near RM 0.2. There are a number of drops functioning as temporary barriers, some of them naturally formed by racking of woody debris and others from diversion piping debris, as shown in Figure 4-33. Roads also parallel the creek on both sides of the creek upstream of the Twisp River Road. Road surface erosion due to improper drainage was noted on the road to the east of Canyon Creek during field surveys. Past logging in the 1980s and 1990s removed riparian vegetation to the channel banks in parts of the survey reach and in upstream reaches (USFS 1994b).

Canyon Creek is the smallest of the tributaries in this section of the river with an average wetted width in the survey reach of 10 feet and an average bankfull width of 16 feet. The average gradient of the Canyon Creek survey reach is 7.3 percent. A total of 6.1 percent of banks were identified as eroding.

The habitat of Canyon Creek is dominated by fast water units for 67 percent of the total length. Canyon Creek has the highest proportion of pool habitat at 30 percent, with side channels comprising 4 percent of the total habitat area. The frequency of qualifying LWD in the survey reach was 36 pieces per mile. The overstory of the lower half of the Canyon Creek survey reach is dominated by large conifers (ranging from 21 to 32 inches dbh), while the upper half is dominated by sapling-sized deciduous trees (ranging from 5 to 9 inches dbh), with large, thick, patches of red osier dogwood shrubs as the dominant understory.

Figure 4-31. Riprap Drop Downstream of Twisp River Road Culvert near RM 0.2

Figure 4-32. Water Diversion Structure on Canyon Creek near the Twisp River Confluence

Figure 4-33. Temporary Passage Barrier on Canyon Creek from Diversion Piping Debris

4.4.3 Tributary Reach Comparison

The metrics in Table 4-5 and the data in Figures 4-34 through 4-37 provide a more detailed description of the existing habitat conditions and other features of the tributaries described in this section. The completed field forms including all the stream survey data collected for each tributary are in Appendix B.

Table 4-5. Upper Twisp Tributary Level II Survey Data Comparison

Metric	North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
River Miles Surveyed	0.6	0.6	0.6	0.9	0.5	0.5
Measured Distance (feet)	3,426	2,548	3,171	5,064	3,726	2,662
Beginning Elevation (feet)	3,465	3,182	2,831	2,401	2,381	2,283
Ending Elevation (feet)	3,753	3,349	3,146	2,632	2,611	2,478
Pools						
Total Number of Pools	36	11	39	26	23	31
Pool Frequency (pools/mile)	55.5	22.8	64.9	27.1	32.6	61.5
Pools Frequency > 3 feet Deep (pools/mile)	6.2	6.2	8.3	5.2	2.8	2.0
Average Maximum Pool Depth (feet)	2.4	3.2	2.3	2.7	2.1	1.5
Average Pool Residual Depth (feet)	0.7	1.2	0.8	0.9	0.6	0.4
LWD						
Small (>20 feet length, >6 inches diameter)	17	15	45	98	101	53
Medium (>35 feet length, >12 inches diameter)	30	16	9	55	28	15
Large (>35 feet length, >20 inches diameter)	10	11	5	16	12	1
LWD Frequency (pieces/mile)[1/]	61.6	55.9	23.3	74.0	56.7	31.7
Habitat						
Percent Pool	20%	16%	27%	17%	13%	30%
Percent Fast (riffle, rapid, cascade)	77%	84%	73%	80%	69%	67%
Percent Fast Non-Turbulent (glide)	0	0	0	3%	0	0
Percent Side Channel	3%	0	0	0	18%	4%
Bank Erosion						
Bank Erosion (feet per mile)	459	263	215	220	70	645
Percent Eroding Banks (total of both banks)	6.7	5.2	3.4	2.2	0.9	6.1
Channel Characteristics						
Average Wetted Width (feet)	15	23	15	23	14	10
Bankfull Width (feet)	30	32	25	36	20	16
Width/Depth Ratio	25	13	15	15	6	7
Entrenchment Ratio	1.36	2.31	4.68	5.06	8.66	2.68
Sinuosity	1.16	1.22	1.07	1.14	1.39	1.12
Reach Average Gradient (percent)	8.4	6.6	9.9	4.6	6.2	7.3
Rosgen Channel Types[2/] (primary, secondary)	A3, A2	A3, A2	A3, B3a	A3, B3a	A3, B3a	A3, A2
Substrate						
D_{50} (mm) (downstream, upstream)	80, 140	100, 210	93, 150	83, 150	73, 180	51, 75
D_{84} (mm) (downstream, upstream)	250, 470	290, 540	270, 480	240, 480	120, 490	190, 350
Percent Sand (< 2 mm)	0	1%	4%	1%	0	4%
Percent Gravel	34%	24%	30%	29%	31%	47%
Percent Cobble	40%	43%	39%	46%	44%	35%
Percent Boulder	25%	31%	25%	25%	25%	14%
Percent Bedrock	1%	2%	3%	0	0	0

1/ Large woody debris (LWD) in the medium and large size classes are included in the pieces per mile calculation.
2/ See Rosgen (1996) for channel type descriptions.

4.4.4 Sediment Supply and Substrate Characteristics

Pebble counts and ocular substrate estimates were used to characterize bed sediment size distributions in the tributary reaches. Reach-averaged estimates of percent sand, gravel, cobble, and boulder are shown in Figure 4-34. In addition, sediment supply and substrate characteristics were evaluated during field surveys, in part, by identifying eroding areas as well as areas of channel incision or aggradation.

In general, North Creek, South Creek, Reynolds Creek, War Creek, and Eagle Creek are cobble-dominated with relatively similar substrate characteristics. Canyon Creek is gravel-dominated with more sand and less boulders than the other tributaries due, in part, to being a relatively small stream (16-foot average bankfull width).

Sediment supply in all tributary reaches is dominated by upstream erosion, which is typical of stream reaches on alluvial fans. Bank erosion rates were relatively low in all reaches, ranging from 0.9 percent in Eagle Creek to 6.7 percent in North Creek. Isolated areas of incision and aggradation were observed in the tributary reaches, particularly adjacent to road crossings (e.g., Reynolds Creek).

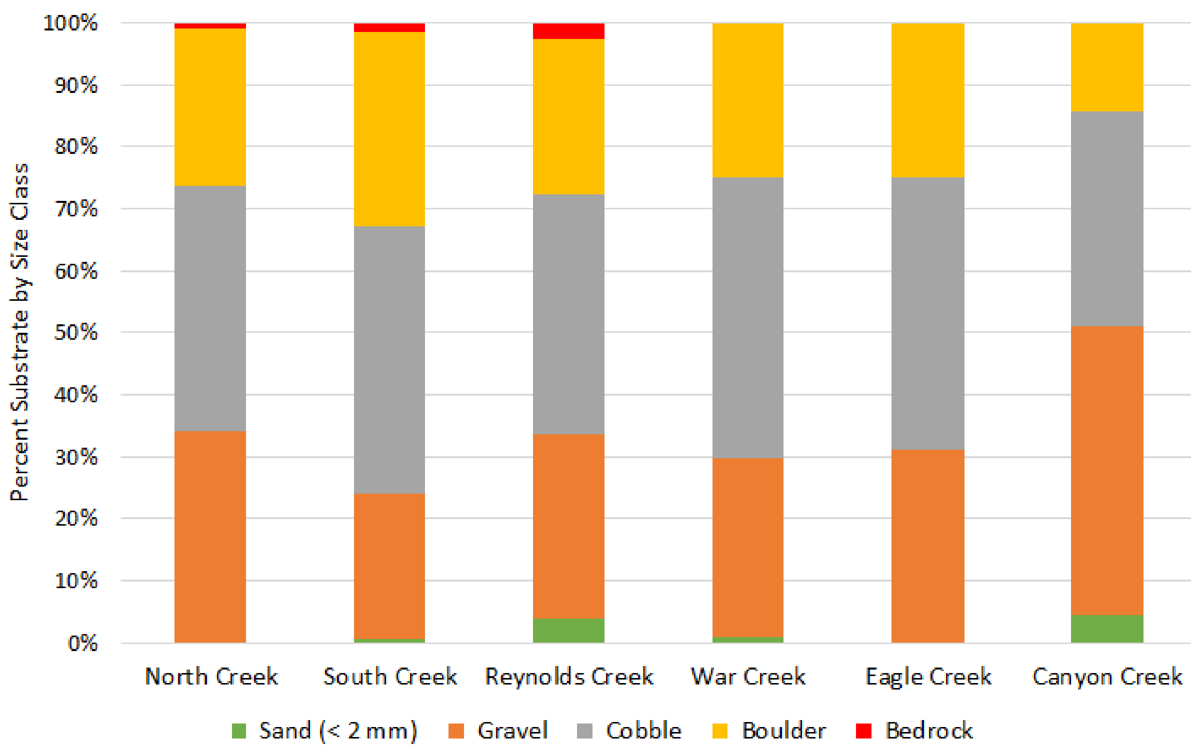


Figure 4-34. Distribution of Substrate Size Classes in Upper Twisp River Tributaries

4.4.5 Large Woody Debris

LWD was inventoried by size class in the tributary reaches as part of the habitat survey. The quantity of LWD in tributary reaches ranged from 23.3 pieces per mile in Reynolds Creek to 74.0 pieces per mile in War Creek, as shown in Figure 4-35. The quantity of qualifying LWD (medium and large size classes) in Reynolds Creek and Canyon Creek are both below the Fox and Bolton (2007) standard of 42.5 pieces per mile while the remaining tributary reaches exceed the standard. The quantity of small wood was relatively low in North and South creeks at 26.2 and 31.1 pieces per mile respectively. Eagle Creek had the most small wood (non-qualifying) at 143.1 pieces per mile. In all tributaries, the amount of instream LWD increased in the upstream direction.

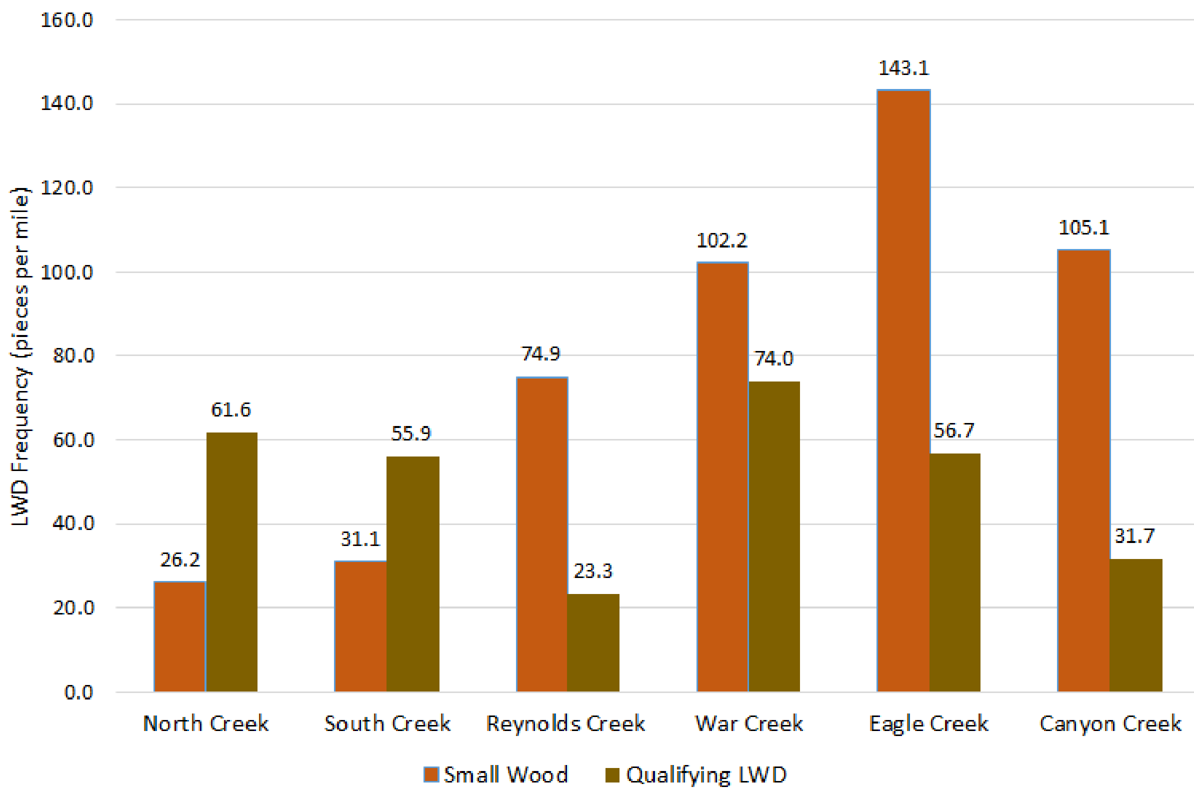


Figure 4-35. Size Distribution of LWD in Upper Twisp River Tributaries

4.4.6 Habitat Units

Habitat units were inventoried as part of the habitat survey. Figure 4-36 shows the proportion of fast (riffle, rapid, cascade), fast non-turbulent (glide), slow (pool), and side channels (fast or slow) in each tributary reach. Fast water habitats dominate in all tributary reaches.

Figure 4-37 shows the distribution of pool types (plunge, dam, scour) and the pools per mile frequency in each tributary reach. All tributary reaches are dominated by plunge pools typically formed by log and/or boulder drops or cascades. The pool frequency in tributary reaches ranges from 22.8 pools per mile in South Creek to 64.9 pools per mile in Reynolds Creek.

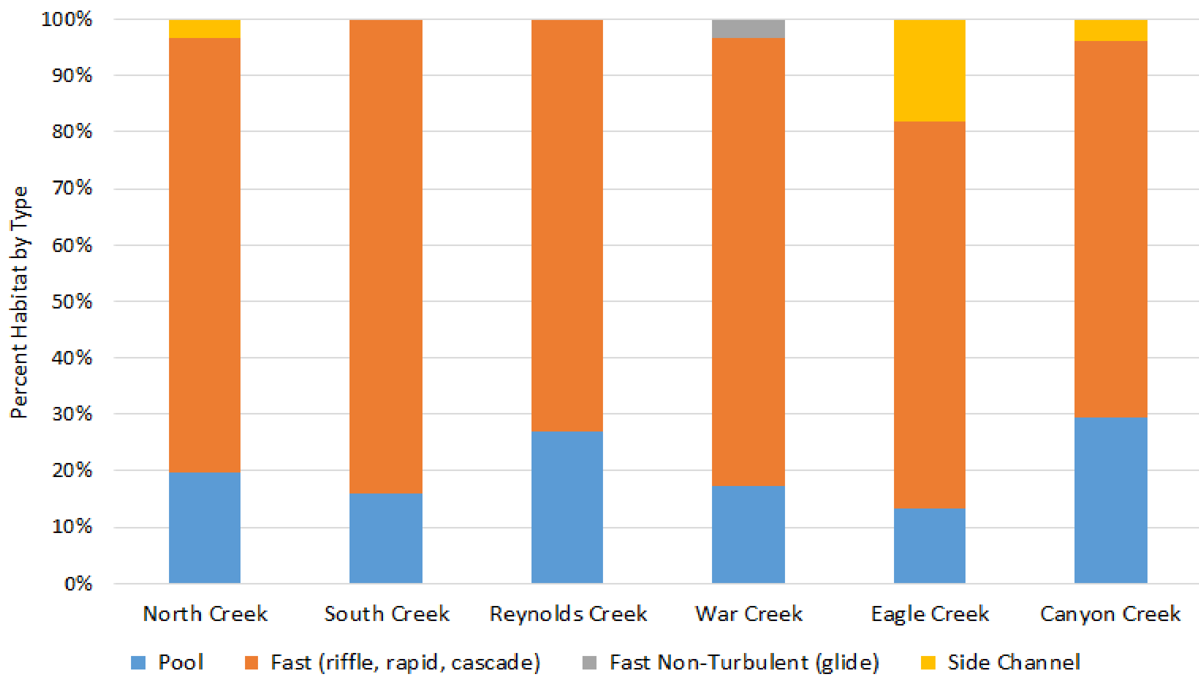


Figure 4-36. Distribution of Habitat Units in Upper Twisp River Tributaries

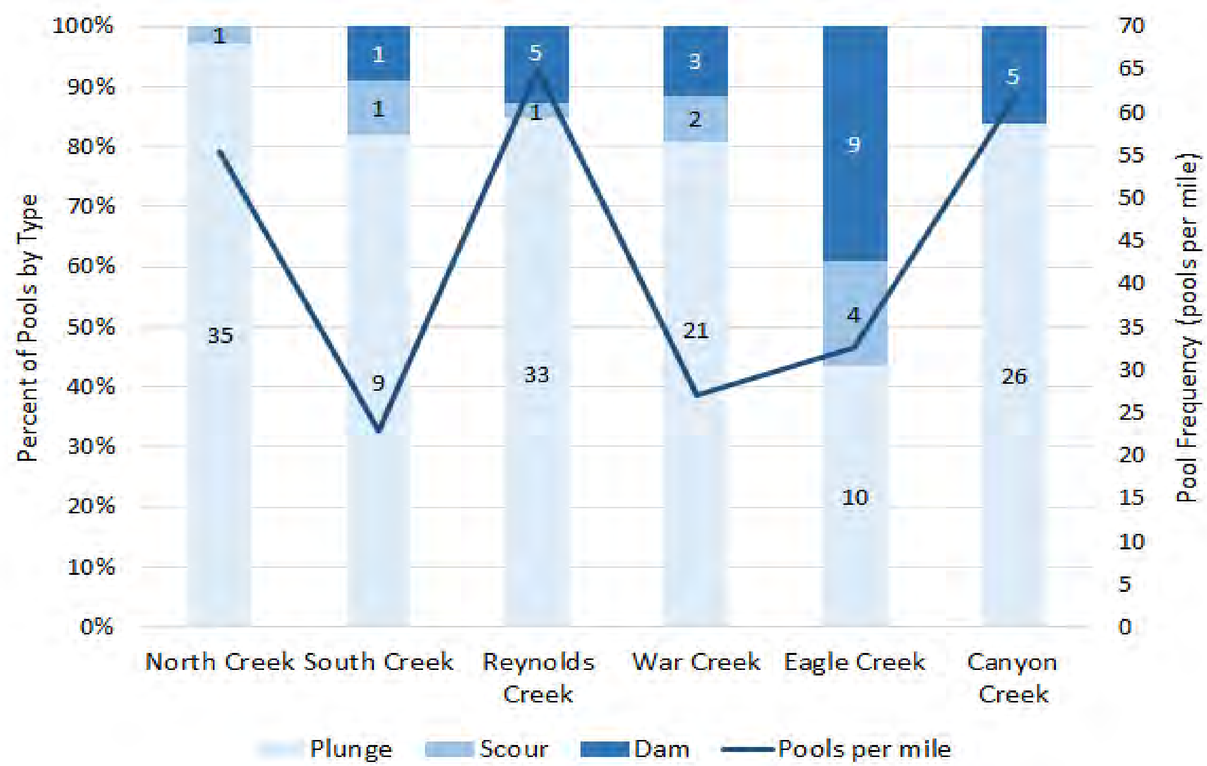


Figure 4-37. Distribution of Pool Types in Upper Twisp River Tributaries

4.5 Reach-based Ecosystem Indicators

This section presents an overview of the REI results, which are presented in detail in Appendix E. The REI analysis provides a standardized method to summarize habitat impairments and compare geomorphic and ecosystem functionality. Each metric is evaluated against REI criteria and rated as adequate, at risk, or unacceptable condition.

The REIs were evaluated at the scale of the Assessment Area and at the reach-scale for the surveyed areas. At the Assessment Area scale, the REI includes an assessment of road density, natural and human-caused disturbance regime, and alteration of the natural hydrologic regime (peak/base flow). For the road density indicator, the UTR watershed (upstream of the NF-4430 road bridge near RM 17.8) is rated adequate with an average of 0.4 mile of road per square mile. Canyon Creek and LBC drainages have higher road densities with 1.56 and 1.55 miles of road per square mile area, respectively, and are therefore functioning at risk for the road density indicator.

For the disturbance regime indicator, the Twisp River watershed is rated as at risk because of past and ongoing disturbances that limit the resiliency of habitat to recover. This is a result of historical and ongoing land use and land management activities in the area, as described in Section 2.3. The Twisp River watershed is also rated at risk for the hydrologic regime indicator.

Reach-scale results for the 11 specific indicators in the UTR and tributaries are summarized below. Overall, the UTR reaches are functioning adequate for most indicators, as shown in Table 4-6. The exception is UTR Reach 2, which has the most at risk (5) and unacceptable ratings (2). Conversely, UTR Reach 5 has the highest number of adequate ratings (10) with only one at risk rating.

The LWD indicator showed the highest degree of impairment in the UTR reaches. The LWD indicator is unacceptable in all UTR reaches, except Reach 5; however, UTR Reaches 1, 3, and 6 have LWD quantities approaching the 42.5 pieces per mile standard of Fox and Bolton (2007) and also have good short- and long-term recruitment potential. In contrast, the USFS (2014) stream survey report rated the LWD indicator as adequate in all reaches of based on the NMFS Matrix of Pathways and Indicators (1996) and USFWS (1998) target of 20 pieces per mile with a length greater than 35 feet and a diameter greater than 12 inches.

The canopy cover indicator also showed a relatively high degree of impairment, being rated as unacceptable in UTR Reaches 1 and 3 and at risk in UTR Reaches 2 and 4 through 6. As described in Section 3.4.4, the percentage canopy cover was calculated from LiDAR first return data.

The pool frequency and quality indicator was rated as adequate in UTR Reaches 1 and 4 through 6, at risk in Reach 3, and unacceptable in Reach 2. In contrast, the USFS (2014) stream survey report rated the pool frequency and quality indicator as adequate in all reaches although specific criteria were not used to make that determination. The USFWS (1998) pool frequency and quality criteria used for this Project are shown in Appendix E.

There are several additional indicators including off-channel habitat, floodplain connectivity, and bank erosion that are rated as at risk for UTR Reach 2 in Table 4-6 but were rated as adequate in the USFS (2014) stream survey report. The justification for the adequate bank erosion rating in UTR Reach 2 was that observed erosion was described to be mostly from natural causes (USFS 2014). The criteria and rationale for the off-channel habitat and floodplain connectivity at risk determinations is shown in Appendix E.

Table 4-6. Upper Twisp River Reach-Based Ecosystem Indicator Ratings

General Characteristics	General Indicators	Specific Indicators	Reach					
			1	2	3	4	5	6
Habitat Assessment	Physical Barriers	Main Channel Barriers	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
Habitat Quality	Substrate	Dominant substrate/Fine sediment	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
	LWD	Pieces/mile at bankfull	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Adequate	Unacceptable
	Pools	Pool frequency and quality	Adequate	Unacceptable	At risk	Adequate	Adequate	Adequate
	Off-Channel Habitat	Connectivity with main channel	Adequate	At risk	Adequate	At risk	Adequate	Adequate
Channel	Dynamics	Floodplain connectivity	Adequate	At risk	Adequate	Adequate	Adequate	Adequate
		Bank stability/Channel migration	Adequate	At risk	Adequate	Adequate	Adequate	Adequate
		Vertical channel stability	Adequate	At risk	Adequate	Adequate	Adequate	Adequate
Riparian Vegetation	Condition	Structure	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
		Disturbance (human)	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
		Canopy cover	Unacceptable	At risk	Unacceptable	At risk	At risk	At risk

Adequate At risk Unacceptable

Overall, the LBC reaches are more impaired than the UTR reaches for all indicators, as shown in Table 4-7. The amount of at risk and unacceptable ratings is similar in all LBC reaches, although the specific indicators at risk or unacceptable vary by reach. The LWD and riparian condition (structure and human disturbance) indicators have the highest degree of impairment in the LBC reaches. The LWD indicator is unacceptable in LBC Reaches 2 through 4 with limited short-term recruitment potential in Reaches 1 and 2 because the riparian areas are dominated by sapling-to-pole sized trees. Short-term recruitment potential is good in LBC Reaches 3 and 4 but long-term recruitment potential is limited in riparian areas recently burned by 2015 Twisp River Fire. Riparian structure and human disturbance are rated at unacceptable in LBC Reaches 1 through 3 and at risk in Reach 4.

In general, the LBC REI results in Table 4-7 are similar to the results in the USFS (2006a) stream survey report. There is a discrepancy in the LWD indicator ratings because of the criteria differences described above for the UTR. No ratings were provided in the USFS (2006a) stream survey report for pool frequency and bank stabilization but it was noted that the LBC was close to meeting or met the pool frequency standard in all reaches and that banks were greater than 90 percent stable in all reaches. The criteria and rationale for the determinations in Table 4-7 are shown in Appendix E.

Table 4-7. Little Bridge Creek Reach-Based Ecosystem Indicator Ratings

General Characteristics	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4
Habitat Assessment	Physical Barriers	Main Channel Barriers	Adequate	At risk	Adequate	Adequate
Habitat Quality	Substrate	Dominant substrate/Fine sediment	At risk	At risk	At risk	At risk
	LWD	Pieces/mile at bankfull	At risk	Unacceptable	Unacceptable	Unacceptable
	Pools	Pool frequency and quality	At risk	At risk	At risk	Unacceptable
	Off-Channel Habitat	Connectivity with main channel	At risk	Adequate	At risk	At risk
Channel	Dynamics	Floodplain connectivity	At risk	At risk	At risk	At risk
		Bank stability/Channel migration	At risk	At risk	Adequate	At risk
		Vertical channel stability	At risk	At risk	At risk	At risk
Riparian Vegetation	Condition	Structure	Unacceptable	Unacceptable	Unacceptable	At risk
		Disturbance (human)	Unacceptable	Unacceptable	Unacceptable	At risk
		Canopy cover	At risk	At risk	At risk	At risk

Adequate · At risk · Unacceptable

Overall, the tributary reaches are functioning in adequate condition for most indicators, as shown in Table 4-8. Canyon Creek has the highest degree of impairment of the tributaries based on the indicators with the most at risk condition ratings (6), two unacceptable ratings, and three adequate ratings. Conversely, Eagle Creek has eight adequate ratings, only two at risk ratings, and no unacceptable ratings. The off-channel connectivity, channel migration, and riparian condition (canopy cover) indicators have the highest degree of impairment in the tributaries. South Creek, Reynolds Creek, and War Creek have very limited off-channel habitat with no observed side channels (excluding high flow channels). These tributary reaches are located on alluvial fans that typically have less off-channel habitat than other stream types; however, the amount of side channel/off-channel habitat is likely less than what would be expected in the absence of human disturbance. The presence of road crossings and/or channel incision is limiting natural channel migration processes, resulting in at risk condition ratings for all tributary reaches. The canopy cover indicator is also rated as at risk for all tributary reaches. The criteria and rationale for the determinations in Table 4-8 are shown in Appendix E.

Table 4-8. Tributary Reach-Based Ecosystem Indicator Ratings

General Characteristics	General Indicators	Specific Indicators	Tributary					
			North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
Habitat Assessment	Physical Barriers	Main Channel Barriers	Adequate	Adequate	Adequate	Adequate	Adequate	Unacceptable
Habitat Quality	Substrate	Dominant substrate/Fine sediment	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
	LWD	Pieces/mile at bankfull	Adequate	Adequate	Unacceptable	Adequate	Adequate	Unacceptable
	Pools	Pool frequency and quality	Adequate	Adequate	Adequate	Adequate	At risk	Adequate
	Off-Channel Habitat	Connectivity with main channel	At risk	Unacceptable	Unacceptable	Unacceptable	Adequate	At risk
Channel	Dynamics	Floodplain connectivity	Adequate	Adequate	Adequate	Adequate	Adequate	At risk
		Bank stability/Channel migration	At risk	At risk	At risk	At risk	At risk	At risk
		Vertical channel stability	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
Riparian Vegetation	Condition	Structure	At risk	Adequate	Adequate	Adequate	Adequate	At risk
		Disturbance (human)	At risk	Adequate	Adequate	Adequate	Adequate	At risk
		Canopy cover	At risk	At risk	At risk	At risk	At risk	At risk

Adequate At risk Unacceptable

4.6 Climate Change Impacts

The impacts of climate change are already apparent in Washington State. These impacts include a long-term warming trend, a longer frost-free season, more frequent night-time heat waves, declining glacial area and spring snowpack, and earlier peak stream flows. By the 2050s, the average annual temperature in Washington is expected to increase by 2 to 8.5°F, and by the 2040s the average April 1 snowpack could decrease by 38 to 46 percent relative to historical (1916–2006) conditions (Snover et al. 2013). Climate change–related impacts to water availability and flow timing are expected to have broad ecological and socioeconomic consequences due to competing demands for public and private uses as well as instream flow management for salmonids (Crozier 2014).

Results from the Columbia Basin Climate Change Scenarios Project indicate dramatic changes in spring snowpack and a shift from snow and mixed-rain-and-snow to rain-dominant systems across most of the Pacific Northwest (Hamlet et al. 2013). Corresponding shifts in the timing of peak flows are likely for basins that currently experience large winter snow accumulation (Hamlet et al. 2013).

Decreases in summer low flows are anticipated throughout the region with the greatest declines west of the Cascades and smaller reductions in the more arid, water-limited basins on the east side of the Cascades (Tohver et al. 2014). Climate-driven changes are expected to also alter groundwater hydrology, which may impact baseflow discharges to streams. Climate change–related increases in water demand and usage are likely to cause the greatest risk to groundwater resources (Pitz 2016).

In most rivers in the Pacific Northwest, stream temperatures are expected to increase, and the threat to ESA-listed salmon recovery is high where temperatures are currently near tolerance thresholds. Changes in stream flow and temperature will affect species differently as they occupy different habitats and vary in timing of life history events, leading to varied exposure to altered conditions (Beechie et al. 2013).

Figure 4-38 shows recent modeling results for changes in mean August stream temperature and mean summer flows for the Survey Area. Both datasets use the global climate model A1B emissions scenario for the future periods, representing a medium warming scenario (USFS 2015b, 2015c; Cristea and Burges 2010). The trend toward warmer stream temperatures and lower summer flows is shown Figure 4-38. These results indicate that conditions will not likely return to historical baseline conditions. Therefore, the restoration strategy presented in Section 5 was developed with the intent to increase ecological features and processes that are resilient over the long term in an altered environment. Analysis of the combined effects of climate change and habitat restoration indicates that restoration projects may be effective at offsetting the negative effects of climate change, although it is expected that those impacts cannot be completely ameliorated (Battin et al. 2007). Restoration actions that increase habitat diversity so that salmon are able to follow alternative life history strategies could potentially increase the resilience of populations to climate change (Beechie et al. 2013).

4.7 Habitat Assessment Results Summary

This habitat assessment utilized historical information, field survey data (previous and current), geologic mapping, hydrology, geomorphic and habitat analyses, REI analyses, a climate change assessment, and other data sources to evaluate historical, current, and potential future conditions in the Survey Area. The data and analyses were used to characterize conditions in the Survey Area and describe reach-scale forms and processes. The results of the habitat assessment were used to identify and refine the project areas and the potential restoration actions described in the restoration strategy. Reach-scale restoration strategies are described in Section 5.1.

The results demonstrate that there are unique geomorphic and habitat characteristics in each of the Survey Area reaches that can be used to assist in evaluating potential restoration actions and to develop effective, long-lasting solutions to address watershed-level ecological concerns for ESA-listed salmonids and other species.

Based on the results of the habitat assessment, the LBC and Canyon Creek are the most impaired streams in the Survey Area. LBC Reaches 2 and 3 have the highest level of restoration potential due to relatively low gradient, less confinement, more potential for floodplain reconnection, and more impaired or disconnected side channel/off-channel habitat areas. Restoration potential is more limited in Reach 4 because of steeper gradient (5.9 percent), confinement, less available floodplain, and large substrate. Restoration actions in the LBC also have the potential for partially ameliorating the impacts of the recent 2015 Twisp River Fire. In the short term, the fire has caused a number of impacts including the loss of shade and cover in burned riparian areas and increased fine sediment inputs resulting high turbidity and sedimentation impacts. Peak flows increases and associated channel scouring events may also be possible in the LBC as a result of impacts of the recent 2015 Twisp River Fire.

In general, all reaches of the UTR, North Creek, South Creek, Reynolds Creek, War Creek, and Eagle Creek are less impaired than the LBC and Canyon Creek. Reach 2 of the UTR is more impaired than the other UTR reaches due channel incision and a lack of floodplain connectivity. Restoration potential is relatively high in the UTR due to low gradient and relatively unconfined conditions. Restoration potential is more limited in UTR Reach 6 due to steep gradient (7.1 percent), confinement, less available floodplain, and large substrate. Restoration potential in North Creek, South Creek, Reynolds Creek, War Creek, and Eagle Creek is relatively limited and generally highest in the lower extent (approximately 0.2 mile) near the Twisp River confluence and at road crossings.

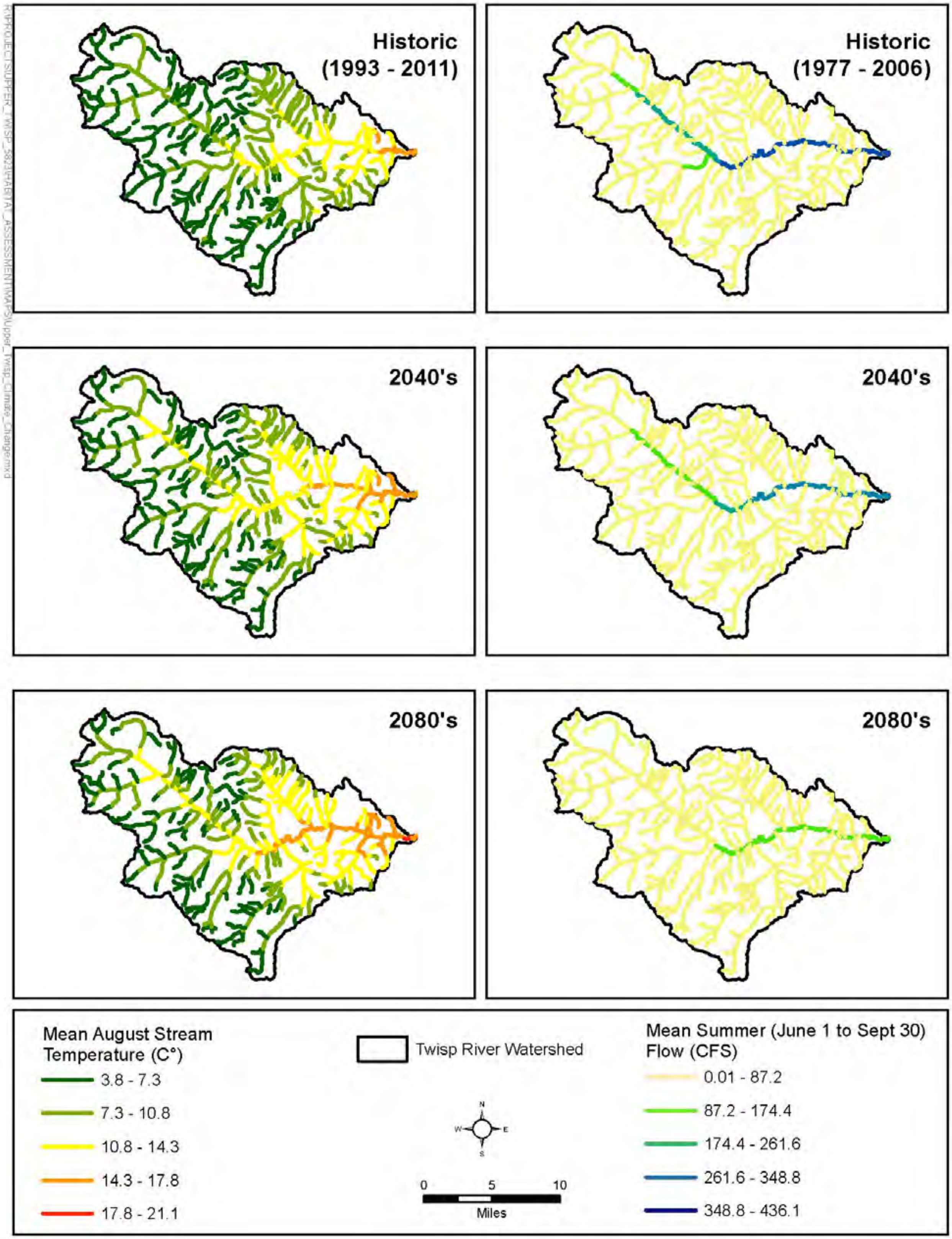


Figure 4-38. Modeled Historic and Future Climate Change Scenario Mean August Stream Temperatures and Mean Summer Flows in the Upper Twisp River and Tributaries (Data Source: USFS 2015b, 2015c)

5. RESTORATION STRATEGY

The restoration strategy described below provides the framework for targeted and effective habitat restoration in the UTR and tributaries. The strategy utilizes the technical information gathered from the stream habitat, geomorphic, hydraulic, and REI analyses to identify and prioritize specific project opportunities and effective restoration actions at those sites. The restoration strategy describes existing and target conditions based on historical information, habitat needs of the fish species of concern, and properly functioning conditions identified by the REI analysis. Project opportunities and restoration actions identified are those that could achieve target habitat conditions.

The following subsections describe specific elements of the restoration strategy including reach-scale restorations strategies (Section 5.1), identifying project opportunities and potential restoration actions (Section 5.2), addressing ecological concerns (Section 5.3), and prioritization of project opportunities (Section 5.4). Section 5.5 provides a summary of the restoration strategy information provided in this section. The next steps for implementing the restoration strategy are discussed in Section 6.

Existing geomorphic and habitat conditions for the UTR and tributaries were described in Section 4 of this document. Target habitat conditions have been developed based on the REI assessment in Appendix E, the Matrix of Diagnostics/Pathways and Indicators (USFWS 1998), the NMFS Matrix of Pathways and Indicators (NMFS 1996), as well as more recent work conducted within the region by the USBR and their adaptation of these indicators (USBR 2012). This section describes the recommended restoration strategy and action types that would address the ecological concerns and lead to target conditions.

5.1 Reach-Scale Restoration Strategies

Reach-scale restoration strategies were developed based on the results of the habitat assessment. The intent of the reach-scale restoration strategies is to describe, in general, the types of restoration actions that are best suited to address the specific impairments and geomorphic conditions of each reach of the Survey Area. This section provides a narrative overview of the reach-scale restoration strategies within the UTR, LBC, and the tributary reaches. Potential restoration projects and proposed actions are described in Section 5.2.

Upper Twisp River

In general, the UTR has moderate-to-high existing ecosystem function and habitat quality. There are several areas of the UTR where no potential instream projects were identified because of adequate existing conditions. A total of 13 potential project areas were identified for the UTR. Out of those, 11 projects are instream and floodplain restoration projects, while 2 are resource management projects.

The primary restoration strategy for the UTR should be to reconnect existing side channels and disconnected floodplains in incised areas by placing LWD structures in the channel to promote lateral migration, aggrade the streambed, and create instream complexity. Opportunities exist in isolated areas to enhance existing side channels, wetlands, and off-channel habitat and evaluate flow for a groundwater-fed side channel to create refugia and improve thermal diversity.

There are also potential opportunities for resource management on the UTR including road drainage improvements, road decommissioning, recreation management, beaver management, and introduced species management.

Little Bridge Creek

In general, the LBC has been more impacted by land-use practices and has a lower level of existing ecosystem function and habitat quality than the UTR. A total of 12 potential projects were identified for the LBC. Out of those, 8 projects are instream and floodplain restoration projects, while 4 are resource preservation and management projects.

The primary restoration strategy for the LBC should be to reconnect existing side channels and disconnected floodplains in incised areas by placing LWD structures in the channel to promote lateral migration, aggrade the streambed, and create instream complexity. Riparian restoration, including the removal of invasive species and riparian planting, should also be a high priority. Additional opportunities to install riparian fencing to exclude cattle grazing should be evaluated for each potential project area that has not already had fencing installed. Opportunities also exist in isolated areas to remove bank armoring and enhance streambanks with bioengineering. In burned riparian areas upstream of RM 4.2, opportunities exist for floodplain erosion control to reduce sedimentation impacts in isolation areas. In the relatively unconfined areas (Reaches 2 and 3), opportunities exist in isolated areas to enhance existing side channels, wetlands, and off-channel habitat and evaluate flow for a groundwater-fed side channel to create refugia and improve thermal diversity.

There are also potential opportunities for resource management on the LBC including road drainage improvements, road decommissioning, recreation management, beaver management, instream flow management, and introduced species management.

Tributary Reaches

There are relatively limited opportunities for instream and floodplain restoration on the remaining Project tributaries. These opportunities are typically found in the lower reaches (lower 0.3 mile) of each tributary. Upstream of this point, the tributaries (with the exception of Canyon Creek) are relatively stable with naturally erosion-resistant bed and banks. South Creek has the greatest potential for instream and floodplain restoration with opportunities to reconnect existing side channels and off-channel habitat. Canyon Creek has been more impacted by land-use practices than the other tributaries and has a lower level of existing ecosystem function. A primary restoration action identified for Canyon Creek is to replace the fish passage barrier on the Twisp River Road. There are also opportunities on Canyon Creek for improving diversions, and instream flow management, and riparian restoration.

In all tributary reaches, there are also potential opportunities for resource management including road drainage improvements, road decommissioning, and recreation management.

5.2 Project Areas and Potential Restoration Actions

Potential restoration projects and project actions are grouped into resource preservation and land management, described in Section 5.2.1, and instream and floodplain restoration, described in Section 5.2.2. Resource preservation and land management actions identified for the Survey Area include land and water preservation, land management, instream flow management, beaver management, and introduced species management. Instream and floodplain actions identified for the Survey Area include riparian restoration, sediment reduction, installing instream LWD structures, floodplain restoration and reconnection, side channel and off-channel habitat restoration, and fish passage restoration.

5.2.1 Resources Preservation and Management

Resource preservation and management actions were identified that have the potential to address ecological concerns from the revised Biological Strategy (UCRTT 2014), as described in Section 2.7. The following sections contain a description of the types of proposed preservation and management actions identified for the UTR, LBC, and tributary reaches.

Land and Water Preservation

Restoration actions related to preservation are passive in nature and include acquisitions, easements, and cooperative agreements. Acquisitions and easements are mostly applicable on the private land at the downstream end of the LBC and Canyon Creek. Long-term land and water preservation can be used to protect or improve existing higher quality habitat, as well as improve existing degraded habitat (Beechie et al. 2010).

Land Management

Land management actions are an important component of an overall restoration strategy and have the potential for significant improvements because of the high percentage of the drainage area impacted. Implementation of large-scale land management plans for timber harvest, fire management, and grazing in particular have the potential for improving conditions, particularly sediment reduction. Land management actions are important for reducing sedimentation and potentially important for enhancing water quantity and quality.

Restoration actions related to water quality improvements include reducing and mitigating point or non-point source impacts, nutrient additions (i.e., carcasses), and upland vegetation treatment and management. Point source impacts are not known to be a major issue in the UTR, LBC, or tributary reaches but non-point source impacts may be addressed through a variety of land management actions.

Instream Flow Management

Instream management restoration actions to address decreased water quantity include irrigation efficiency improvements, water storage, and water right negotiations. Decreased water quantity was not identified as one of the ecological concerns for the UTR AU in the revised Biological Strategy; however, it was listed as the highest priority for the LTR AU which includes LBC. As described in Section 2.3.4, there is one existing diversion on the LBC that may be evaluated for instream flow management actions.

Beaver Management

Historically, beaver were very abundant in the Survey Area and contributed considerably to habitat diversity and ecosystem function. Recent research has demonstrated that beaver restoration can assist in improving ecosystem functions and considerably decrease recovery time for deeply incised channels (Beechie et al. 2008; Pollock et al. 2007). Field surveys completed for this Project documented current beaver activity in several UTR and LBC reaches.

The reintroduction of beavers and/or beaver management may assist in addressing several of the ecological concerns identified in the revised Biological Strategy (UCRTT 2014), including side-channel and wetland habitat conditions, reduced water quantity, instream structural complexity, and riparian restoration. Beaver reintroduction and/or management may require the development of a beaver restoration management plan.

Introduced Species Management

Introduced species that compete and/or predate on native fish are identified as an ecological concern for both the UTR AU and the LTR AU including LBC (UCRTT 2014). As described in Section 2.6, brook trout are not native to the Twisp River and compete with native species. Brook trout management may be accomplished by a combination of sport fishing regulations that allow higher harvest limits, and active suppression of brook trout through mechanical, electrical, biological, or chemical means (WDFW 2000). A brook trout management plan should be developed to help guide efforts to address this ecological concern.

5.2.2 Instream and Floodplain Restoration

Instream and floodplain restoration project actions were identified during field surveys and further refined throughout the habitat assessment development process. In the UTR, there were a total of 11 distinct instream and floodplain restoration and enhancement project areas identified, while in the LBC, there were a total of 8. Each of the tributary reaches were included as a distinct project area.

Appendix F contains project area descriptions and maps showing proposed project actions for each of the project areas. Project area extents and potential restoration actions for all Survey Areas are also included in the Project geodatabase (Appendix C). The following sections contain a description of the types of proposed instream and floodplain restoration actions identified for the project areas.

Riparian Restoration

Riparian plant communities are intricately tied to stream functions. Riparian condition was identified as an ecological concern for both the UTR and LTR AUs in the revised Biological Strategy (UCRTT 2014). Riparian restoration actions include the removal of non-native plants, off-site water developments, planting of riparian buffer strips, selective thinning, beaver reintroduction, and riparian fencing. Riparian plant communities provide bank stability, shading, cover, nutrient input, and future supply of LWD. Removal of invasive plant species (weed control) should also be part of any riparian management plan and may be the responsibility of individual landowners or cooperating parties.

New riparian conservation zones and livestock exclusion, where applicable in the LBC, will ensure that riparian plantings survive and provide long-term protection for restoration projects. Springs and wetlands, which are especially sensitive to overgrazing, will benefit from livestock exclusion and management.

Sediment Reduction

Increased sediment quantity was identified as an ecological concern for both the UTR and LTR AUs in the revised Biological Strategy (UCRTT 2014). Road grading and drainage improvements, road decommissioning, and road abandonment are proposed project actions that have been identified to reduce sediment inputs. Roads that are deemed necessary for recreation, timber harvest, and other land uses may be improved to reduce sediment inputs through grading and improved drainage. Roads that are no longer needed, or roads that can be rerouted to less sensitive areas, may be decommissioned or abandoned.

When roads have been constructed adjacent to channels or within floodplains, road decommissioning or abandonment may offer additional benefits to channel and floodplain function by removing the constricting effect of the road prism, allowing unobstructed access for floodplain inundation, channel migration, and riparian vegetation recovery. Road decommissioning in sensitive areas typically involves decompacting the road surface, removing culverts and other infrastructure, blending the slopes to provide improved infiltration and drainage, and replanting the abandoned roadway with site-appropriate native vegetation.

Streambank bioengineering and/or bank stabilization structures may be appropriate at some sites where very steep banks are contributing to excess sediment, and recovery on their own would not be expected within a reasonable time frame. Bank stabilization in selected areas may also be necessary to protect land or infrastructure (e.g., NF-4415 Road in LBC Reach 4), but can be constructed to maintain most of the restoration and habitat enhancement objectives. These techniques may be used at sites where a softer bioengineering approach is considered more appropriate than traditional “hard” engineering techniques. Bank stabilization structures typically incorporate bank sloping combined with live cuttings that sprout and grow to further strengthen the stabilization structure over time (e.g., Polster 2003; NRCS 2007), and may be combined with LWD structures.

Instream LWD Structures

Degraded channel bed and form and instream complexity was identified as an ecological concern for both the UTR and LTR AUs in the revised Biological Strategy (UCRTT 2014). Instream LWD structures aid in restoring channel bed and form by creating complex pools, maintaining side channels and islands, retaining sediment, and providing channel complexity. Individual LWD and LWD structures may be used in conjunction with other restoration actions in any areas where large wood is limited.

Placing root wads and LWD into the wetted area provides hiding cover from predators, increases hydraulic diversity, and aids in sediment sorting. Individual pieces of LWD should be sized appropriately, and portions may be buried to reduce potential risks and increase stability where applicable. The size of LWD to be used should be determined during development of project designs, and LWD should consist of durable species (generally conifers). Scour and stability calculations may be necessary during the design development process to create stable features.

LWD may be placed on point or lateral bars, which develop on the inside of meander bends in areas of active channel migration. In areas where the supply of coarse gravel is not limited, these bars can promote increased lateral movement and the development of an inset floodplain. Bars increase hydraulic diversity, retain mobile sediments, and provide habitats for focal fish species. Point bar structures can promote natural sediment deposition processes on bars. LWD structures may be placed specifically at the head of existing mid-channel bars to divert flows into split-flow channels immediately downstream of the main channel. The formation of such split-flow channels encourages aggradation, increases habitat diversity, and creates pools. Most of the LWD structures mentioned above should also include live willow stakes and riparian plantings for cover, shading, bank stability, and habitat complexity.

Floodplain Restoration and Reconnection

As previously noted, decreased water quantity was identified as an ecological concern for the LTR AU in the revised Biological Strategy (UCRTT 2014). Wetland habitat conditions were identified as an ecological concern for both the UTR and LTR AUs in the revised Biological Strategy. A properly functioning floodplain acts as an extension of the alluvial aquifer, attenuating stream flows as floodwaters disperse onto the floodplain and discharging stored water during drier months. Connected floodplains will aid in regulating stream flows, water temperature, and water quality. Floodplain groundwater discharge to streams provides cool water areas for rearing fish and floodplain groundwater storage has also been shown to attenuate peak flows (Acreman et al. 2003).

Where possible, floodplain infrastructure should be relocated or removed to eliminate physical features disconnecting the floodplain. The addition of instream LWD structures may be required in many areas to restore geomorphic processes to create well-connected floodplains. Properly designed instream LWD structures provide a backwater effect that can increase sediment retention and raise the channel bed and water-table, which increases overbank flows and floodplain connectivity. Beaver reintroduction may also assist with restoring and reconnecting the floodplain.

Restoring or enhancing wetlands and springs is also am important aspect of floodplain restoration. Since wetlands store water during periods of heavy precipitation and then release it slowly, they provide important buffering of both water quantity and quality (Hammersmark et al. 2008). This slow release of cooled water during summer periods of low flow and warm temperatures provides thermal refugia for target fish species.

Side-Channel or Off-Channel Habitat Restoration

Side-channel and wetland habitat conditions were identified as an ecological concern for both the UTR and LTR AUs in the revised Biological Strategy (UCRTT 2014). Side channels and off-channel areas provide important rearing habitat for target fish species. Martens and Connolly (2014) found higher densities of salmonids in seasonally disconnected, partially connected, and fully connected side channels than in mainstem channels. Restoration actions to restore or enhance side channel and off-channel habitat include reconnecting or constructing perennial side channels, secondary channels, floodplain ponds, wetlands, alcoves, and groundwater-fed off-channel habitat.

The removal of constraining features on the floodplain may allow for natural inundation of existing perennial and ephemeral side channels and wetlands. Roni et al. (2002) found that projects involving reconnection of existing off-channel habitats had a higher probability of success than projects creating entirely new off-channel habitat. These types of restoration actions might be classified as full restoration because they restore natural processes (Beechie et al. 2010). The addition of instream LWD is often needed to reconnect existing side channel and off-channel habitat. Side-channel and off-channel habitat is typically enhanced with LWD and riparian planting and may also be associated with wetland restoration and other project actions.

Alcoves, which are off-channel habitat areas connected to the main channel only at the outlet, provide high-quality off-channel habitat for juvenile salmonids, refugia during flood flows, and year-round thermal refuge. They also have the propensity for fine material deposition which may also support lamprey habitat. Tributary junctions and groundwater seeps and springs are ideal locations for alcoves because of the consistent source of cooled groundwater.

Fish Passage Restoration

Fish passage was not identified as an ecological concern for either the UTR or LTR AU in the revised Biological Strategy (UCRTT 2014). However, resolving partial or full passage barriers is important for restoring longitudinal connectivity in stream systems, which is critical for the success of focal fish species. Additionally, barrier removal can open access to high quality headwater streams, where water quantity and quality, habitat, and sediment are all optimal for key lifestages of target fish species. Fish passage restoration may be implemented as a discrete action (e.g., removal of a culvert), or as the result of numerous other indirect actions (e.g., elimination of a low-flow barrier through improvements in water quantity, riparian vegetation that shades the stream and reduces summer temperatures, and upland land management changes).

Fish passage restoration actions include structural passage (i.e., diversions, screening), and barrier or culvert replacement or removal. The primary fish passage issues identified during field surveys were the passage barrier at the Twisp River Road crossing of Canyon Creek and the diversion structure on the LBC. Additionally, fish passage restoration may be accomplished by implementing other actions that involve the removal or alleviation of thermal and low-flow barriers created by degraded channel and watershed conditions.

5.3 Addressing Ecological Concerns

A primary objective of this Project is to identify potential restoration actions that will make quantifiable progress toward addressing ecological concerns, as identified in the revised Biological Strategy (UCRTT 2014). The impact of proposed restoration actions on ecological concerns guides the project prioritization and ultimately determines project effectiveness. Tables 5-1 and 5-2 summarize the relative potential of proposed project action types to address ecological concerns identified for the UTR and LTR AUs, respectively.

Table 5-1. Relative Potential of Restoration Action Types to Address Ecological Concerns in the Upper Twisp River Assessment Unit

Restoration Action Type	Ecological Concerns1/						
	Side Channels and Wetlands 1	Instream Structural Complexity 2	Bed and Channel Form 3	Riparian Restoration (condition and LWD recruitment) 4	Food (altered primary productivity and competition) 5	Sediment (increased quantity) 6	Species Interactions (introduced species) 7
Protect and Maintain			M	H			
Land Management						M	
Introduced Species Management					H		H
Beaver Management	M			M	M	M	
Riparian Restoration	L		M	H			
Sediment Reduction			L			H	
Bank Restoration and Stabilization		M				L	
Instream LWD Structures		H	H			H	
Floodplain Restoration and Reconnection	H		H	M	M	H	
Side Channels or Off-channel Habitat	H		H	M			

1/ Ecological concerns for the Upper Twisp River (UTR) Assessment Unit (AU), in priority order (UCRTT 2014)

H = High – Actions that are critical to be addressed to improve target fish species population performance (abundance, productivity, and sustainability) in the immediate term.

M = Medium – Actions that are important (not critical) to be addressed to improve target fish species population performance in the long term.

L = Low – Beneficial to address, but not critical to improve target fish species population performance.

Table 5-2. Relative Potential of Restoration Action Types to Address Ecological Concerns in the Lower Twisp River Assessment Unit including Little Bridge Creek

	Ecological Concerns1/								
	Water Quantity (decreased)	Water Quality (temperature)	Bed and Channel Form	Side channels and Wetlands	Instream Structural Complexity	Riparian Restoration (condition)	Sediment (increased quantity)	Food (altered primary productivity and competition)	Species Interactions (introduced species)
Restoration Action Type	1	2	3	4	5	6	7	8	9
Protect and Maintain		M	M			H			
Land Management							M		
Introduced Species Management								H	H
Instream Flow Management	H	H							
Beaver Management	M	M		M		M	M	M	
Riparian Restoration	L	H	M	L		H			
Sediment Reduction			L				H		
Bank Restoration and Stabilization					M		L		
Instream LWD Structures			H		H		H		
Floodplain Restoration and Reconnection	L	M	H	H		M	H	M	
Side Channels or Off-channel Habitat	L	M	H	H		M			
Fish Passage			L						

1/ Ecological concerns for the Lower Twisp River (LTR) Assessment Unit (AU) in priority order (UCRTT 2014)

H = High – Actions that are critical to be addressed to improve target fish species population performance (abundance, productivity, and sustainability) in the immediate term.

M = Medium – Actions that are important (not critical) to be addressed to improve target fish species population performance in the long term.

L = Low – Beneficial to address, but not critical to improve target fish species population performance.

5.4 Project Prioritization and Scoring

The importance of project prioritization is increasingly being recognized by river restoration practitioners as a necessary step to focus restoration efforts. The projects proposed for the UTR, LBC, and tributary reaches were prioritized primarily based on a total benefit score calculated for each project type or project area. For the UTR, proposed projects include introduced species management and the 12 instream and floodplain restoration project areas identified throughout the Survey Area. For LBC, proposed projects include resource protection and management projects and the 8 instream and floodplain restoration project areas identified throughout the Survey Area. For the tributary reaches, proposed projects include instream flow management and land acquisition in Canyon Creek, and instream and floodplain restoration projects in each tributary reaches. Tables 5-3 through 5-5 show a summary of the project prioritization scoring and ranking for the UTR, LBC, and the tributary reaches. The complete prioritization matrix, including supplemental information used for prioritization and scoring rationale, is included in Appendix G.

Table 5-3. Upper Twisp River Project Prioritization, Scoring, and Rank

Project Name	Project Prioritization Scoring and Rank1/				
	Total Benefit Score	Benefit-to-Cost Score	Feasibility Designation	Climate Change Impact	Project Rank
UTR Project Area 2 – RM 20.1 to 20.9	11	5.5	High	Moderate	1
UTR Project Area 5 – RM 22.4 to 22.7	11	5.5	High	Moderate	2
UTR Project Area 8 – RM 24.8 to 25.5	10	5.0	High	Moderate	3
UTR Project Area 11 – RM 27.5 to 28.0	10	5.0	High	Moderate	4
UTR Project Area 3 – RM 20.9 to 21.6	9	4.5	High	Moderate	5
UTR Project Area 4 – RM 21.8 to 22.2	9	4.5	Moderate	Low	6
UTR Project Area 9 – RM 26.0 to 26.4	9	4.5	Moderate	Moderate	7
UTR Project Area 1 – RM 17.8 to 18.2	8	4.0	Moderate	Low	8
UTR Project Area 6 – RM 23.5 to 23.7	8	4.0	High	Moderate	9
UTR Introduced Species Management	7	3.5	Moderate	Low	10
UTR Project Area 10 – RM 26.5 to 27.2	6	3.0	High	Low	11
UTR Project Area 7 – RM 24.2 to 24.5	5	5.0	Moderate	Low	12
UTR Project Area 12 – RM 28.5 to 29.6	5	2.5	High	Low	13

1/ Project prioritization scoring methods and rationale are included in Appendix G.

Table 5-4. Little Bridge Creek Project Prioritization, Scoring, and Rank

Project Name	Project Prioritization Scoring and Rank[1/]				
	Total Benefit Score	Benefit-to-Cost Score	Feasibility Designation	Climate Change Impact	Project Rank
LBC Project Area 6 – RM 3.0 to 5.1	12	6.0	High	High	1
LBC Beaver Management	11	11.0	High	High	2
LBC Project Area 1 – RM 0.0 to 0.7	10	5.0	Moderate	Low	3
LBC Project Area 5 – RM 2.1 to 3.0	9	4.5	High	Moderate	4
LBC Project Area 3 – RM 1.0 to 1.7	8	4.0	High	Low	5
LBC Land Acquisition	8	4.0	Moderate	Low	6
LBC Project Area 7 – RM 5.1 to 5.6	7	3.5	High	Low	7
LBC Introduced Species Management	7	3.5	Moderate	Low	8
LBC Project Area 2 – RM 0.7 to 1.0	6	6.0	High	Low	9
LBC Project Area 4 – RM 1.7 to 2.1	6	6.0	High	Low	10
LBC Instream Flow and Water Management	6	6.0	Moderate	Moderate	11
LBC Project Area 8 – RM 5.6 to 6.8	6	3.0	Moderate	Low	12

1/ Project prioritization scoring methods and rationale are included in Appendix G.

Table 5-5. Tributary Reaches Project Prioritization, Scoring, and Rank

Project Name	Project Prioritization Scoring and Rank[1/]				
	Total Benefit Score	Benefit-to-Cost Score	Feasibility Designation	Climate Change Impact	Project Rank
Canyon Creek	8	4.0	Moderate	Low	1
War Creek	8	4.0	Moderate	Low	2
Canyon Creek Land Acquisition	8	4.0	Moderate	Low	3
Reynolds Creek	7	7.0	Moderate	Low	4
Eagle Creek	7	7.0	Moderate	Low	5
South Creek	7	3.5	High	Low	6
Canyon Creek Instream Flow and Water Management	6	6.0	Moderate	Moderate	7
North Creek	4	4.0	High	Low	8

1/ Project prioritization scoring methods and rationale are included in Appendix G.

The scoring of project benefit included an evaluation of the potential recovery gap, fish use potential, and the ability to address root causes and ecological concerns. The potential recovery gap represents the difference in ecological functions between existing and target conditions that can be gained through restoration measures. Projects were also evaluated based on a benefit-to-cost score, which is a relative value used to compare potential project benefits. The cost score is a categorical ranking of relative cost based on construction techniques, access, and project requirements. Projects were ranked first by project benefit and secondarily by the benefit-to-cost score.

In addition to the benefit and benefit-to-cost scores, feasibility was also evaluated for all projects. The feasibility was assessed based on the likelihood of being able to implement the project within a 10-year timeframe. This assessment was based on landownership and other known constraints that could potentially impact feasibility, including economic, regulatory, political, social, and permitting considerations. Feasibility was not used as part of the project prioritization and scoring because feasibility may change drastically over time based on landownership and other factors.

The ability of projects to ameliorate climate change effects and increase salmon resilience was also evaluated based on the analysis of Beechie et al. (2013). The assessment identified the relative potential for proposed project actions to ameliorate climate change related temperature increases, flow changes, and the ability of proposed actions to increase salmon resilience.

5.5 Restoration Strategy Summary

The restoration strategy described above, along with details included in Appendices F and G, identified restoration project opportunities, their locations, and associated restoration actions and action types. The project geodatabase will facilitate in tracking of future projects, providing restoration planners with a tool to evaluate which areas are being under-represented, and aid in identifying how various restoration projects interact with each other and important features. In addition, available implementation data on completed restoration projects has been incorporated into the project opportunity geodatabase to document past efforts. The restoration strategy includes a prioritization of project opportunities (Appendix G) that incorporates field data, analyses of physical and biological data, restoration objectives based on the needs of fish species of concern, feasibility, and logistical factors. The restoration strategy helps document and predict project impacts, and aids in planning of allocation of financial resources within the UTR.

6. CONCLUSION AND NEXT STEPS

The UTR and tributaries habitat assessment establishes a framework and restoration strategy for improving natural origin recruitment leading towards recovery of ESA fish in the subbabsin. It also identifies potential project actions that are appropriate for specific sites based on landscape history, geomorphic and biological conditions, predicted climate impacts, and other relevant data presented. It also provides a project scoring system that can be used to communicate priorities with stakeholders who may choose to participate in habitat restoration actions.

Included in this report are several resources that will be useful in the planning process for habitat restoration practitioners, including the project area descriptions and map series (Appendix F), the Project geodatabase (Appendix C), and the project area prioritization matrix spreadsheet (Appendix G). The intent of these resources is to provide the necessary information for making informed and effective habitat restoration decisions in a format that is clear, concise, and user-friendly.

For each project area identified, a number of proposed restoration actions have been mapped that will assist with project planning and design development; however, the actions will need to be further developed to produce conceptual designs and should not be considered an exhaustive list of possible actions. The potential restoration project areas and actions can also be modified and adapted to refine the extent of project areas and the details of specific restoration actions during design development. Site-specific analyses, including hydraulic modeling, would be required to refine these potential projects, evaluate design alternatives, and develop detailed designs for construction.

Next steps were identified throughout the development of this Project. These include ongoing data collection and research efforts, developing site-specific project designs, implementing projects, and monitoring completed projects. The preliminary list of next steps identified is provided below:

- Continue to perform stakeholder outreach and communicate the results of this habitat assessment and restoration strategy.
- Continue to implement the prioritized projects identified in the restoration strategy.
- Identify opportunities to fill data gaps, including:
  - Conduct groundwater monitoring and analysis in targeted areas;
  - Continue to conduct surveys of target fish species distribution, particularly bull trout and lamprey;
  - Evaluate the effects of interactions between bull trout and other native species with brook trout (UCRTT 2014);
  - Conduct consistent bull trout redd surveys in all tributaries (UCRTT 2014);
  - Consider developing a monitoring plan and intervention policy in response to isolated and stranded bull trout, including examining the effects and risks/benefits of rescuing isolated bull trout (USFWS 2004);
  - Investigate causes and possible solutions to dewatering, and the feasibility of improving pool habitat upstream of the dewatered reach (USFWS 2004); and
  - Monitor distribution of brook trout and their interaction and hybridization with bull trout in the Twisp River (USFWS 2004).

- Incorporate recommendations and continue to evaluate potential opportunities for future habitat improvement and habitat preservation based on predicted climate changes.
- Continue to integrate the results of ongoing research, monitoring, and data collection and evaluation into the restoration strategy.

The resources provided in this report are flexible and may be adapted to fit changing circumstances. This approach was taken with the understanding that conditions can change over time and new data are being collected. This strategy allows for effective planning and prioritization of resources for habitat restoration programs for years to come.

7. REFERENCES

Acreman, M.C., R. Riddington, and D.J. Booker. 2003. Hydrological impacts of floodplain restoration: a case study of the River Cherwell, UK. *Hydrology and Earth System Sciences Discussions, European Geosciences Union* 7(1): 75-85. Available online at: hal.archives-ouvertes.fr/file/index/docid/304758/filename/hess-7-75-2003.pdf.

Andersen, E., B. Le, B. Nass, C. Peery, and M. Clement. 2011. 2010 Pacific Lamprey Management Plan Comprehensive annual Report. Priest Rapids Hydroelectric Project (FERC No. 2114). Prepared for Public Utility District No. 2 of Grant County. Ephrata, WA. March 2011.

Andonaegui, C. 2000. Salmon, Steelhead, and Bull Trout Habitat Limiting Factors – Water Resource Inventory Area 48. Final Report. Washington State Conservation Commission. July 18, 2000.

ASWG (Aquatic Settlement Work Group). 2017. Final Minutes of the January 11, 2017 Aquatic SWG Meeting. Available online at: http://www.douglaspud.org/ASWG%20Documents/2017_01_11%20Final%20Aquatic%20SWG%20mtg%20minutes-updated.pdf.

BAER (Interagency Burn Area Emergency Response Team). 2015. Okanogan County Fires, Interagency BAER Final Summary Report, State, Private, and Other Non-Federal Lands. September 2015.

Barksdale, J.D. 1975. Geology of the Methow Valley Okanogan County, Washington. State of Washington Department of Natural Resources, Division of Geology and Earth Resources Bulletin No 68.

Battin, J., M.W. Wiley, M.H. Ruckelshaus, R.N. Palmer, E. Korb, K.K. Bartz, and H. Imaki. 2007. Projected impacts of climate change on salmon habitat restoration. *Proceedings of the National Academy of Sciences* 104(16): 6720–6725.

Beechie, T.J., G. Pess, P. Roni, and G. Giannico. 2008. Setting River Restoration Priorities: a Review of Approaches and a General Protocol for Identifying and Prioritizing Actions. *North American Journal of Fisheries Management* 28:891–905.

Beechie, T.J., D.A. Sear, J.D. Olden, G.R. Pess, J.M. Buffington, H. Moir, P. Roni, M.M. Pollock. 2010. Process-based principals for restoring river ecosystems. *BioScience* 60:209–222.

Beechie, T.J., H. Imaki, J. Greene, A. Wade, H. Wu, G. Pess, P. Roni, J. Kimball, J. Stanford, P. Kiffney & N. Mantua. 2013. Restoring Salmon Habitat for a Changing Climate. River Research and Applications 29[8]: 939–960. First published July 3, 2012. doi: 10.1002/rra.2590: 22.

Bryant, F.G., and Z.E. Parkhurst. 1950. Survey of the Columbia River and its Tributaries – Part IV. Special Scientific Report – Fisheries No. 37. U.S. Department of the Interior, Fish and Wildlife Service.

Bunning, B. (compiler). 1992. Geologic Map of the East Half of the Twisp 1:100,000 Quadrangle, Washington.

CCPUD (Chelan County Public Utility District). 2000. A status of Pacific lamprey in the Mid-Columbia region (Final). Rocky Reach Hydroelectric Project. Prepared by BioAnalysts, Inc for Public Utility District No. 1 of

Chelan County, Wenatchee, WA. FERC Project No. 2145. December 15, 2000. Accessed at: http://www.nwd-wc.usace.army.mil/tmt/documents/FPOM/2010/Task%20Groups/Task%20Group%20Lamprey/2000%20Final%20PUD%20Mid-Col%20lamprey%20status%20report.pdf.

Crandall, J. 2016. October 18, 2016 meeting notes for the Methow Restoration Council. Accessed at: http://www.methowrestorationcouncil.org/meetings/MRC_Meeting_NotesOctober2016.pdf.

Cristea, N., and S. Burges. 2010. An assessment of the current and future thermal regimes of three streams located in the Wenatchee River basin, Washington State: some implications for regional river basin systems. *Climate Change* 102:493-520. doi 10.1007/s10584-009-9700-5.

CRITFC (Columbia River Inter-Tribal Fish Commission). 2012. Coho Restoration in the Methow and Wenatchee Rivers A tribal success story. Methow/Wenatchee Success Brochure. Yakama Nation.

Crozier, L. 2015. Impacts of Climate Change on Salmon of the Pacific Northwest: A review of the scientific literature published in 2014. NOAA National Marine Fisheries Service, Northwest Fisheries Science Center. Seattle, WA.

DCPUD (Douglas County Public Utility District). 2009. Pacific Lamprey Management Plan – Wells Hydroelectric Project. FERC Project No. 2149. Prepared by: Public Utility District No. 1 of Douglas County. East Wenatchee, WA. Accessed at: http://www.douglaspud.org/ASA%20Documents/Wells_Project_Pacific_Lamprey_MP.pdf.

Ecology (Washington State Department of Ecology). 1992. Methow River Basin Fish Habitat analysis Using the Instream Flow Incremental Methodology. Water Resources Program, Department of Ecology. Olympia, Washington.

Ecology. 2017. Twisp River Listing IDs 6219, 8435, 39350, 71466, 7433, 77665. Available online at: https://fortress.wa.gov/ecy/approvedwqa/ApprovedSearch.aspx (Accessed April 15, 2017).

FCRPS (Federal Columbia River Power System). 2012. Tributary Habitat Program — 2012 Expert Panel Map Tools. Available online at: http://www.usbr.gov/pn/fcrps/habitat/panels/2012panels/piemaps/index.html#uppercolumbia.

Fox, M.J., and S.M. Bolton. 2007. A regional and geomorphic reference for quantities and volumes of instream wood in unmanaged forested basins of Washington State. *North American Journal of Fisheries Management* 27(1):342–359.

Fulton, L.A. 1968. Spawning Areas and Abundance of Chinook Salmon in the Columbia River Basin – Past and Present. U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries. Washington, D.C.

Ghost Towns of Washington. 2012. Gilbert Site Visited in 2012. Available online at: http://www.ghosttownsofwashington.com/gilbert.html (Accessed July 2017).

Gustafson, R.G., T.C. Wainwright, G.A. Winans, F.S. Waknitz, L.T. Parker, and R.S. Waples. 1997. Status review of sockeye salmon from Washington and Oregon. U.S. Dept. Comm., NOAA Tech. Memo. NMFS-NWFSC-33, 282 p. Accessed online at: http://leg.wa.gov/CodeReviser/documents/sessionlaw/1899c133.pdf.

Hammersmark, C.T., M.C. Rains, and J.F. Mount. 2008. Quantifying the Hydrological Effects of Stream Restoration in a Montane Meadow, Northern California, USA. *River Research and Applications* 24:735–753.

Hamlet, Alan, Marketa McGuire Elsner, Guillaume S. Mauger, Se-Yeun Lee, Ingrid Tohver, and Robert A. Norheim. 2013. An Overview of the Columbia Basin Climate Change Scenarios Project: Approach, Methods, and Summary of Key Results. *Atmosphere-Ocean* 51(4):392–415, doi: 10.1080/07055900.2013.819555.

Hart, E. Richard. 2010. The Methow Indian's Footprint on the Valley. Article for the Methow Grist. Available online at: http://www.methownet.com/grist/history/methow_indians_footprint.html (Originally published as "Methow Indian Allotments" in Heritage, the journal of the Okanogan County Historical Society, Spring, 2005. A fully footnoted copy of this article is on file at the Wilson Research Center, Okanogan County Historical Society.)

Haugerud, .A., and R.W. Tabor. 2009. Geologic map of the North Cascade Range, Washington: U.S. Geological Survey Scientific Investigations Map 2940, 2 sheets, scale 1:200,000; 2 pamphlets, 29 p. and 23 p.

Homer, C., J. Dewitz, J. Fry, M. Coan, N. Hossain, C.,Larson, N. Herold, A. McKerrow, J.N. VanDriel, and J. Wickham. 2007. Completion of the 2001 National Land Cover Database for the Conterminous United States. Photogrammetric Engineering and Remote Sensing, Vol. 73, No. 4, pp 337-341.

Inter-Fluve. 2010. Lower Twisp River Reach Assessment. Prepared for Yakama Nation Fisheries. Toppenish, WA.

Inter-Fluve. 2015. Middle Twisp River Reach Assessment and Restoration Strategy. Prepared for Yakama Nation Fisheries. February 2015.

Inter-Fluve. 2016. Technical Memorandum: Lower Twisp River Ice Jams – RM 0.2 to RM 0.7. Provided for the Confederated Tribes and Bands of the Yakama Nation. Toppenish, WA. May, 2016.

Johnson, J., and J. Molesworth. 2015. Carlton Complex Fire, State and Private Lands, Burned Area Emergency Response Aquatic Resources Report.

Kamphaus, C.M., K.G. Murdoch, G.C. Robinson, M.B. Collins, R.F. Alford, and K.E. Mott. 2011. Mid-Columbia Coho Reintroduction Feasibility Study: 2010 Annual Report. October 1, 2009 through September 30, 2010. Yakama Nation. Fisheries Resource Management. Prepared for Bonneville Power Administration. Division of Fish and Wildlife. Project # 1996-040-00. Contract #00022180.

Konrad, C.P., B.W. Drost, and R.J. Wagner. 2003. Hydrogeology of the unconsolidated sediments, water quality, and ground-water/surface-water exchanges in the Methow River Basin, Okanogan County, Washington: U.S. Geological Survey Water-Resources Investigations Report 03-4244, 137 p.

Martens, K.D., and P.J. Connolly. 2014. Effectiveness of Redesigned Water Diversions Using Rock Vortex Weirs to Enhance Longitudinal Connectivity for Small Salmonids. *North American Journal of Fisheries Management* 30:1544–1552.

Martens, K.D., T.M. Fish, G.A. Watson, and P.J. Connolly. 2014. Methow River Studies, Washington—Abundance estimates from Beaver Creek and the Chewuch River screw trap, methodology testing in the Whitefish Island side channel, and survival and detection estimates from hatchery fish releases, 2013: U.S. Geological Survey Open-File Report 2014-1154, 38 p., http://dx.doi.org/10.3133/ofr20141154.

Mastin, M.C., C.P. Konrad, A.G. Veilleux, and A.E. Tecca. 2016. Magnitude, frequency, and trends of floods at gaged and ungaged sites in Washington, based on data through water year 2014 (ver 1.1, October 2016): U.S. Geological Survey Scientific Investigations Report 2016–5118, 70 p., http://dx.doi.org/10.3133/sir20165118.

Mastin, M.C. 2017. Email exchange between Mark Mastin, U.S. Geological Survey and Jeff Phillips, Tetra Tech. June.

Mayfield, M. 2017. Email from Mariah Mayfield, USFS Fish Biologist (Okanogan-Wenatchee National Forest) to Tetra Tech and Yakama Nation Fisheries regarding comments on Twisp River survey report. January 27.

MBPU (Methow Basin Planning Unit). 2005. Methow Watershed Plan (WRIA 48). June 20, 2005.

McKean, J., D. Nagel, D. Tonina, P. Bailey., C.W. Wright, C. Bohn, and A. Nayegandhi. 2009. Remote sensing of channels and riparian zones with a narrow-beam aquatic-terrestrial LIDAR. *Remote Sensing* 1:1065–1096; doi:10.3390/rs1041065.

McLean, S.. 2011. Coming Off the Range. Accessed April 15, 2017 from: http://www.methownet.com/grist/features/grazing.html.

Montgomery, D.R., and J.M. Buffington. 1997. Channel-Reach Morphology in Mountain Drainage Basins. *Geological Society of America Bulletin* 109:596–611.

Moody, J.A., and D.A. Martin. 2001. Initial hydrologic and geomorphic response following a wildfire in the Colorado Front Range. *Earth Surf. Process. Landforms* 26:1049–1070. doi:10.1002/esp.253.

Moody, J.A., R.A. Shakesby, P.R. Robichaud, S.H. Cannon, and D.A. Martin. 2013. Current research issues related to post-wildfire runoff and erosion processes. *Earth-Science Reviews* 122:10–37.

MRC (Methow Restoration Council). 2014. Methow Monitoring Plan. Appendix C of the Monitoring Strategy for the Upper Columbia Basin.

MSRF (Methow Salmon Recovery Foundation). 2015. Pacific Lamprey Habitat Restoration Guide. Accessed at: http://www.methowsalmon.org/Documents/PacificLampreyRestorationGuide_web.pdf.

Mullen, J.W., K.R. Williams, G. Rhodus, T.W. Hillman, J.D McIntyre. 1992. Production and habitat of salmonids in Mid-Columbia River tributary streams. Appendix J – Time of Appearance of the Runs of Salmon and

Steelhead Trout Native to the Wenatchee, Entiat, Methow, and Okanogan Rivers. United States Department of the Interior, Fish and Wildlife Service. May 1941.

Nelle, R.D., P. Verhey, R. Lampman, J. Easterbrook, S. Camp, A. Grote, B. Kelly-Ringel, and A. Conley. 2016. Pacific Lamprey 2016 Regional Implementation Plan for the Upper Columbia Regional Management Unit. Submitted to the Conservation Team May 27, 2016. Available online at: https://www.fws.gov/pacificlamprey/Documents/RIPs/Draft%20RIP%20-%20Upper%20Columbia%2005_27_16.pdf.

Nelson, M.C. 2004. Movements, Habitat Use, and Mortality of Adult Fluvial Bull Trout Isolated by Seasonal Subsurface Flow in the Twisp River, WA. U.S. Fish and Wildlife Service, Leavenworth, WA.

NMFS (National Oceanic and Atmospheric Administration National Marine Fisheries Service). 1996. Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Watershed Scale. The National Marine Fisheries Service, Environmental and Technical Services Division, Habitat Conservation Branch. Available online at: http://www.westcoast.fisheries.noaa.gov/publications/reference_documents/esa_refs/matrix1996.pdf (Accessed on March 17, 2015).

NPCC (Northwest Power and Conservation Council). 2005. Methow Subbasin Plan. In Columbia River Basin Fish and Wildlife Program. Portland, Oregon.

NPS (National Park Service). 2017. Early Impressions: Euro-American Explorations and Surveys. Historic Resource Study. Accessed on January 31, 2017 from: https://www.nps.gov/parkhistory/online_books/noca/hrs/sec1.htm.

NRCS (Natural Resources Conservation Service). 2007. Streambank Soil Bioengineering. Technical Supplement 14I, Part 654, National Engineering Handbook.

Peven, C. 2003. Population Structure, Status and Life Histories of Upper Columbia Steelhead, Spring and Summer/fall Chinook, Sockeye, Coho Salmon, Bull Trout, Westslope Cutthroat Trout, Non-migratory Rainbow Trout, Pacific Lamprey, and Sturgeon. Peven Consulting, Inc. February 2003.

Pitz, C.F. 2016. Predicted Impacts of Climate Change on Groundwater Resources of Washington State. Washington Department of Ecology, Olympia, WA. Publication No. 16-03-006.

Pollock, M.M., T.J. Beechie, and C.E. Jordan. 2007. Geomorphic Changes Upstream of Beaver Dams in Bridge Creek, an Incised Stream Channel in the Interior Columbia River Basin, Eastern Oregon. *Earth Surface Processes and Landforms* 32:1174–1185.

Polster, D.F. 2003. Soil Bioengineering for Slope Stabilization and Site Restoration. Paper presented at Sudbury 2003: Mining and the Environment III, May 25 – 28, 2003, Laurentian University, Sudbury, Ontario, Canada.

PRISM (Parameter-elevation Relationships on Independent Slopes Model Climate Group). 2016. Descriptions of PRISM Spatial Climate Datasets for the Conterminous United States. 30-year normal precipitation gridded data for the years 1981–2010. Oregon State University.

PWI (Pacific Watershed Institute). 2003. Twisp watershed assessment: restoration activities and action plan. Report to the Salmon Recovery Funding Board, U.S. Forest Service and U.S. Fish and Wildlife Service. Prepared by The Pacific Watershed Institute, Olympia WA. April 2003.

QSI (Quantum Spatial Inc.). 2016. Oregon LiDAR Consortium (OLC) Okanogan Federal Emergency Management Agency (FEMA). Portland, OR.

RCO (Washington State Recreation and Conservation Office). 2017. Project Information System (PRISM), Project View Okanogan County Eagle Creek Ditch Fish Screen (02-UTW-1999-1). Accessed July 2017 from: http://waconnect.ekosystem.us/project.aspx?sid=290&id=13235.

Richardson, R. 2016. War Creek Restoration Design: Draft Concept Report. Provided for the Yakama Nation Fisheries. Toppenish, Washington.

Roni, P., T.J. Beechie, R.E., Bilby, F.E. Leonetti, M.M. Pollock, and G.P. Pess. 2002. A Review of Stream Restoration Techniques and a Hierarchical Strategy for Prioritizing Restoration in Pacific Northwest Watersheds. *North American Journal of Fisheries Management* 22:1–20.

Rosgen, D. 1996. *Applied River Morphology.* Wildland Hydrology Books, Pagosa Springs, Colorado. 350 pp.

Smith, J. no date. More on the Red Shirt Mine. Boom Town Tales & Historic People. Available online at: http://www.ghosttownsusa.com/bttales42.htm (Accessed on March 20, 2017).

Snover, A.K., G.S. Mauger, L.C. Whitely Binder, M. Krosby, and I. Tohver. 2013. Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision Makers. State of Knowledge Report prepared for the Washington State Department of Ecology. Climate Impacts Group, University of Washington, Seattle.

Snow, C., C. Frady, A. Repp, A. Murdoch, M.P. Small, S. Small, and C. Dean. 2011. Monitoring and evaluation of Wells and Methow Hatchery programs in 2010. Prepared for Douglas County Public Utility District and Wells Habitat Conservation Plan Hatchery Committee. April 2011.

Snow, C., and C. Frady. 2015. May hatchery and natural production report. Washington department of Fish and Wildlife. Fish Program/Science Division/Methow Field office. Twisp, WA.

Snow, C., C. Frady, D. Grundy, B. Goodman, and A. Murdoch. 2016. Monitoring and evaluation of the Wells Hatchery and Methow Hatchery programs: 2015 annual report. Report to Douglas PUD, Grant PUD, Chelan PUD and the Wells and Rocky Reach HCP Hatchery Committees and the Priest Rapids Hatchery Subcommittees, East Wenatchee, WA.

Stamper, M. 2015. Lamprey release seeks to re-establish the ancient fish in the Methow River. Methow Valley News. October 1, 2015. Available online at: http://methowvalleynews.com/2015/10/01/lamprey-release-seeks-to-re-establish-the-ancient-fish-in-the-methow-river/.

StreamNet. 2012. StreamNet Generalized Fish Distribution, All Species Combined (January 2012). Derived from tabular data - Pacific States Marine Fisheries Commission. GenFishDist_January2012.zip. Access at: http://www.streamnet.org/data/interactive-maps-and-gis-data/.

Sumioka, S.S., D.L. Kresch, and K.D. Kasnick. 1998. Magnitude and Frequency of Floods in Washington, Water Resources Investigations Report 97-4277, United States Geological Survey.

Three Treaty Tribes-Action Agencies (Umatilla, Warm Springs, and Yakama Tribes – Bonneville Power Administration, U.S. Army Corps of Engineers, and U.S. Bureau of Reclamation). 2008. 2008 Columbia Basin Fish Accords Memorandum of Agreement Between the Three Treaty Tribes and FCRPS Action Agencies.

Tohver, I., A. Hamlet, S.Y. Lee. 2014. Impacts of 21st-Century Climate Change on Hydrologic Extremes in the Pacific Northwest Region of North America. *Journal of the American Water Resources Association* 1-16. doi: 10.1111/jawr.12199.

UCRTT (Upper Columbia Regional Technical Team). 2013. Reference tables for a biological strategy to protect and restore salmonid habitat in the Upper Columbia Region. The Upper Columbia Regional Technical Team. Prepared for the Upper Columbia Salmon Recovery Board. Available online at: http://www.ucsrb.org/library/documents-and-resources/.

UCRTT. 2014. A biological strategy to protect and restore salmonid habitat in the Upper Columbia Region. Prepared for the Upper Columbia Salmon Recovery Board. 44 pp. and appendices.

UCSRB (Upper Columbia Salmon Recovery Board). 2007. Upper Columbia Spring Chinook Salmon, Steelhead, and Bull Trout Recovery Plan. Upper Columbia Salmon Recovery Board, Wenatchee, WA.

UCSRB. 2014. Integrated Recovery Program Habitat Report. Upper Columbia Salmon Recovery Board Wenatchee, WA.

USBR (U.S. Bureau of Reclamation). 2008. Methow Subbasin Geomorphic Assessment Okanogan County, Washington. Reclamation: managing water in the west. Technical Service Center, Denver, CO; Pacific Northwest Regional Office, Boise, ID; Methow Field Station, Winthrop, WA.

USBR. 2011. Winthrop Area (W2). Assessment of Geomorphic and Ecological Indicators. Methow River, Methow Subbasin, Okanogan County, Washington. U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Region, Boise, Idaho. December 2011.

USBR. 2012. Lower Entiat Reach Assessment. U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Region, Boise, ID.

USFS (U.S. Department of Agriculture Forest Service). 1993. Little Bridge Creek Stream Survey Report July-August 1992. Okanogan National Forest, Twisp Ranger District. Twisp, WA.

USFS. 1994a. Twisp River: 1993 Stream Survey Report, including Canyon Creek. Okanogan National Forest, Twisp Ranger District. Twisp, WA.

USFS. 1994b. Canyon Creek: 1993 Stream Survey. Performed as part of the Twisp River Watershed monitoring process. Okanogan National Forest, Twisp Ranger District. Twisp, WA.

USFS. 1994c. Management History of Eastside Ecosystems: Changes in Fish Habitat Over 50 Years, 1935 to 1992. Pacific Northwest Research Station.

USFS. 1995a. Twisp River Tributaries: 1994 Stream Survey Report. Okanogan National Forest, Twisp Ranger District. Twisp, WA.

USFS. 1995b. Twisp River Watershed Analysis. U.S. Forest Service, Okanogan National Forest, Methow Valley Ranger District. June 1995.

USFS. 1996. Little Bridge Creek Stream Survey. Okanogan National Forest, Twisp Ranger District. Twisp, WA.

USFS. 1997. Middle Methow Watershed Analysis. Methow Valley Ranger District. Okanogan National Forest. March 1997.

USFS. 2001. Twisp River Stream Survey Report 2001. Okanogan National Forest, Twisp Ranger District. Twisp, WA.

USFS. 2004. Okanogan and Wenatchee National Forests Roads Analysis: Methow Sub-Basin. March 2004.

USFS. 2006a. Little Bridge Creek Stream Report 2006. Okanogan National Forest, Twisp Ranger District. Twisp, WA.

USFS. 2006b. Methow Transmission Project. Final Environmental Impact Statement. Volume 1. Final EIS and Appendices A-F. US Forest Service. Okanogan and Wenatchee National Forests, Okanogan Valley Office. March 2006.

USFS. 2012. Respect the River/Rio webpage. Available online at: https://www.fs.fed.us/rtr/ (Accessed July 2017).

USFS. 2014. Draft Twisp River Stream Survey Report – 2013. Okanogan-Wenatchee National Forest. Methow Valley Ranger District. February 2014. Twisp, WA.

USFS. 2015a. Twisp River Watershed BT redd info. Unpublished summary information about 2015 bull trout surveys.

USFS. 2015b. Western U.S. Stream Flow Metrics. Rocky Mountain Research Station Air, Water, & Aquatic Environments Program. Available online at: http://www.fs.fed.us/rm/boise/AWAE/projects/modeled_stream_flow_metrics.shtml.

USFS. 2015c. NorWest Stream Temp Regional Database and Modeled Stream Temperatures. Rocky Mountain Research Station Air, Water, & Aquatic Environments Program. Available online at: http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html.

USFS. 2016a. Twisp River Fire Fatalities and Entrapments. Learning Review Narrative. Fall 2016.

USFS. 2016b. Stream Inventory Handbook, Level I & II. Pacific Northwest Region 6, Version 2.16.

USFWS (U.S. Fish and Wildlife Service). 1950. Survey of the Columbia River and Its Tributaries – Part IV. Special Scientific Report: Fisheries No. 37. Available online at: http://docs.streamnetlibrary.org/USFWS/ssrf-037.pdf.

USFWS. 1998. A Framework to Assist in Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Bull Trout Subpopulation (substitute core area) Watershed Scale. Region 1, Portland, Oregon.

USFWS. 2002. Chapter 22, Upper Columbia Recovery Unit, Washington. 113 p. In: U.S. Fish and Wildlife Service. Bull Trout (Salvelinus confluentus) Draft Recovery Plan. Portland, Oregon.

USFWS. 2004. Movements, Habitat Use, and Mortality of Adult Fluvial Bull Trout Isolated by Seasonal Subsurface Flow in the Twisp River, WA. Leavenworth, WA.

USFWS. 2008. Bull Trout (*Salvelinus confluentus*) 5-Year Review: Summary and Evaluation. Portland, OR.

USFWS. 2012. Conservation Agreement for Pacific Lamprey (*Entosphenus tridentatus*) in the states of Alaska, Washington, Oregon, Idaho, and California. Portland, Oregon. Available online at: www.fws.gov/pacific/Fisheries/sphabcon/Lamprey/lampreyCI.html.

USFWS. 2015a. Recovery Plan for the Coterminous United States Population of Bull Trout (*Salvelinus confluentus*). Portland, Oregon. xii + 179 pp. Available online at: http://www.fws.gov/pacific/ecoservices/endangered/recovery/plans.html.

USFWS. 2015b. Mid-Columbia Recovery Unit Implementation Plan for Bull Trout (*Salvelinus confluentus*). Portland, Oregon. i + 345pp. Available online at: http://www.fws.gov/pacific/ecoservices/FinalBullTroutRP.htm.

USGS (U.S. Geological Survey). 2017. USGS River Miles. GIS data available online at: http://www.ecy.wa.gov/services/gis/data/data.htm.

Watershed Sciences. 2007. Lidar Remote Sensing Data Collection: Upper and Lower Okanogan River, Methow River, Lake Roosevelt, Wenatchee River and John Dar River Study Areas. Portland, OR.

WDFW (Washington Department of Fish and Wildlife). 2000. Bull trout and Dolly Varden Management Plan. Washington Department of Fish and Wildlife Fish Program, Olympia, WA.

WDFW. 2008. Statewide Steelhead Management Plan: Statewide Policies, Strategies, and Actions. Olympia, WA.

WDFW. 2017a. PHS on the Web. The web-based maps for all species and habitats on the Priority Habitats and Species List. Available online at: http://apps.wdfw.wa.gov/phsontheweb/.

WDFW. 2017. SalmonScape. Available online at: http://apps.wdfw.wa.gov/salmonscape/map.html.

WDNR (Washington Department of Natural Resources). 2017. Geologic history of the North Cascades website. http://www.dnr.wa.gov/programs-and-services/geology/explore-popular-geology/geologic-provinces-washington/north-cascades#glaciation-and-erosion (Accessed 3/31/2017).

WDGER (Washington Division of Geology and Earth Resources). 2016. Landslides and landforms--GIS data, July, 2016: Washington Division of Geology and Earth Resources Digital Data Series 12, version 4.2, previously released February, 2016.

West, K. 2011. Twisp – Thumbnail History. Available online at: http://www.historylink.org/File/9943 (Accessed March 20, 2017).

Wondzell, S.M., and J.G. King. 2003. Postfire erosional processes in the Pacific Northwest and Rocky Mountain regions. *Forest Ecology and Management* 178(1):75.

YNF (Yakama Nation Fisheries). 2005. Mid-Colombia Coho Restoration Master Plan. Yakama Nation Fisheries.

YNF. 2006. Appendix C.2. Methow rearing facilities. Proposed plan site descriptions and capital costs. Yakama Nation Fisheries Resource Management. In: Mid-Columbia Coho Restoration Master Plan document. Prepared for the NPCC. Available online at: http://yakamafish-nsn.gov/sites/default/files/projects/Appendix%20C.2%20-%20Methow%20Rearing%20Facilities.pdf.

YNF. 2016. Pacific Lamprey Project. Webpage. Available online at: http://yakamafish-nsn.gov/restore/projects/lamprey (Accessed January 2013).

APPENDIX A

Index of Existing Habitat Assessment Data

(provided on DVD)

This appendix is provided separately.

APPENDIX B

Completed Reach Forms and Field Forms

FINAL REACH FORM Page: 1 of 1
R6-2500/2600-21

A. State WA B. County Okanogan C. Forest O-W NF D. District Methow

E. Stream Name North Creek

F. 8-digit HUC Code 17, 02, 00, 08 10-digit 05 12-digit 01

G. USGS Quad Gilbert, WA 48120D5

* Indicates a Forest Option

1 Reach Number	2 SO From	3 SO To	4 Start Date	5 End Date	6 Protocol	7 Observer	8 Recorder	9 Elevation Min (ft)	10 Elevation Max (ft)
1	1	68	11/01/16	11/02/16	R6E	Jef Parr	Jeff Phillips	3465	3753
11 *Stream Order	**12 *Valley Type**	**13 *Flow Regime**	**14 Rosgen Class**	**15 Reach Length (ft)**	**16 Mapped Valley Width (ft)**	**17 *Discharge Type**	**18 Discharge (cfs)**	**19 Start Distance (RM From)**	**20 End Distance (RM To)**
			A3	3426	Varied		10.2	0.0	0.6

21 Mapped Valley Length (ft)	22 Mapped Channel Gradient (%)	23 Mapped Sinuosity Value	24. Reason for Reach Break: / 25. *Inner Riparian Zone Width: / 26. Comments:
2945	8.4	1.16	24. Reason for Reach Break: Single reach from Twisp River confluence to end of anadromous and end of survey. 25. *Inner Riparian Zone Width: 26. Comments: Waterfall downstream of RM 0.6 is a complete passage barrier.

1 Reach Number	2 SO From	3 SO To	4 Start Date	5 End Date	6 Protocol	7 Observer	8 Recorder	9 Elevation Min (ft)	10 Elevation Max (ft)
11 *Stream Order	**12 *Valley Type**	**13 *Flow Regime**	**14 Rosgen Class**	**15 Reach Length (ft)**	**16 Mapped Valley Width (ft)**	**17 *Discharge Type**	**18 Discharge (cfs)**	**19 Start Distance (RM From)**	**20 End Distance (RM To)**

21 Mapped Valley Length (ft)	22 Mapped Channel Gradient (%)	23 Mapped Sinuosity Value	24. Reason for Reach Break: / 25. *Inner Riparian Zone Width: / 26. Comments:

FINAL REACH FORM Page: 1 of 1
R6-2500/2600-21

A. State WA B. County Okanogan C. Forest O-W NF D. District Methow

E. Stream Name South Creek

F. 8-digit HUC Code 17 , 02 , 00 , 08 10-digit 05 12-digit 02

G. USGS Quad Gilbert, WA 48120D5

* Indicates a Forest Option

1 Reach Number	2 SO From	3 SO To	4 Start Date	5 End Date	6 Protocol	7 Observer	8 Recorder	9 Elevation Min (ft)	10 Elevation Max (ft)
1	1	23	11/01/16	11/03/16	R6E	Jef Parr	Jeff Phillips	3182	3349
11 *Stream Order	**12 *Valley Type**	**13 *Flow Regime**	**14 Rosgen Class**	**15 Reach Length (ft)**	**16 Mapped Valley Width (ft)**	**17 *Discharge Type**	**18 Discharge (cfs)**	**19 Start Distance (RM From)**	**20 End Distance (RM To)**
			A3	2548	Varied (fan)		24.6	0.0	0.6
21 Mapped Valley Length (ft)	**22 Mapped Channel Gradient (%)**	**23 Mapped Sinuosity Value**	**24. Reason for Reach Break:** Single reach from Twisp River confluence to end of anadromous and end of survey. **25.*Inner Riparian Zone Width:**						
2096	6.6	1.22	**26. Comments:** Series of waterfalls downstream of RM 0.6 are a complete passage barrier.						

1 Reach Number	2 SO From	3 SO To	4 Start Date	5 End Date	6 Protocol	7 Observer	8 Recorder	9 Elevation Min (ft)	10 Elevation Max (ft)
11 *Stream Order	**12 *Valley Type**	**13 *Flow Regime**	**14 Rosgen Class**	**15 Reach Length (ft)**	**16 Mapped Valley Width (ft)**	**17 *Discharge Type**	**18 Discharge (cfs)**	**19 Start Distance (RM From)**	**20 End Distance (RM To)**
21 Mapped Valley Length (ft)	**22 Mapped Channel Gradient (%)**	**23 Mapped Sinuosity Value**	**24. Reason for Reach Break:** **25.*Inner Riparian Zone Width:**						
			26. Comments:						

FINAL REACH FORM Page: 1 of 1
R6-2500/2600-21

A. State WA B. County Okanogan C. Forest O-W NF D. District Methow

E. Stream Name Reynolds Creek

F. 8-digit HUC Code 17 , 02 , 00 , 08 10-digit 05 12-digit 03

G. USGS Quad Midnight Mountain, WA 48120D4

* Indicates a Forest Option

1 Reach Number	2 SO From	3 SO To	4 Start Date	5 End Date	6 Protocol	7 Observer	8 Recorder	9 Elevation Min (ft)	10 Elevation Max (ft)
1	1	61	11/03/16	11/04/16	R6E	Jef Parr	Jeff Phillips	2831	3146
11 *Stream Order	**12 *Valley Type**	**13 *Flow Regime**	**14 Rosgen Class**	**15 Reach Length (ft)**	**16 Mapped Valley Width (ft)**	**17 *Discharge Type**	**18 Discharge (cfs)**	**19 Start Distance (RM From)**	**20 End Distance (RM To)**
			A3	3170	Varied (fan)		8.2	0.0	0.6

21 Mapped Valley Length (ft)	22 Mapped Channel Gradient (%)	23 Mapped Sinuosity Value	
2966	9.9	1.07	

24. Reason for Reach Break: Single reach from Twisp River confluence to end of anadromous and end of survey.

25.*Inner Riparian Zone Width:

26. Comments: Series of 4 waterfalls downstream of RM 0.6 are a complete passage barrier.

1 Reach Number	2 SO From	3 SO To	4 Start Date	5 End Date	6 Protocol	7 Observer	8 Recorder	9 Elevation Min (ft)	10 Elevation Max (ft)
11 *Stream Order	**12 *Valley Type**	**13 *Flow Regime**	**14 Rosgen Class**	**15 Reach Length (ft)**	**16 Mapped Valley Width (ft)**	**17 *Discharge Type**	**18 Discharge (cfs)**	**19 Start Distance (RM From)**	**20 End Distance (RM To)**

21 Mapped Valley Length (ft)	22 Mapped Channel Gradient (%)	23 Mapped Sinuosity Value

24. Reason for Reach Break:

25.*Inner Riparian Zone Width:

26. Comments:

FINAL REACH FORM Page: 1 of 1
R6-2500/2600-21

A. State WA B. County Okanogan C. Forest O-W NF D. District Methow

E. Stream Name War Creek

F. 8-digit HUC Code 17 , 02 , 00 , 08 10-digit 05 12-digit 04

G. USGS Quad Midnight Mountain, WA 48120D4

* Indicates a Forest Option

1 Reach Number	2 SO From	3 SO To	4 Start Date	5 End Date	6 Protocol	7 Observer	8 Recorder	9 Elevation Min (ft)	10 Elevation Max (ft)
1	1	52	11/05/16	11/05/16	R6E	Jef Parr	Jeff Phillips	2401	2632
11 *Stream Order	**12 *Valley Type**	**13 *Flow Regime**	**14 Rosgen Class**	**15 Reach Length (ft)**	**16 Mapped Valley Width (ft)**	**17 *Discharge Type**	**18 Discharge (cfs)**	**19 Start Distance (RM From)**	**20 End Distance (RM To)**
			A3	5064	Varied (fan)		16.1	0.3	1.2

21 Mapped Valley Length (ft)	22 Mapped Channel Gradient (%)	23 Mapped Sinuosity Value	24. Reason for Reach Break: / 25. *Inner Riparian Zone Width:
			Single reach from Twisp River confluence to end of survey. Preliminary assessment of 2 reaches based on mis-mapped channel
4456	4.6	1.14	**26. Comments:** The confluence with the Twisp River is just downstream of the mapped RM 0.3. The upstream end of the survey is a steep, narrow, inaccessible, bedrock canyon downstream of RM 1.2

1 Reach Number	2 SO From	3 SO To	4 Start Date	5 End Date	6 Protocol	7 Observer	8 Recorder	9 Elevation Min (ft)	10 Elevation Max (ft)
11 *Stream Order	**12 *Valley Type**	**13 *Flow Regime**	**14 Rosgen Class**	**15 Reach Length (ft)**	**16 Mapped Valley Width (ft)**	**17 *Discharge Type**	**18 Discharge (cfs)**	**19 Start Distance (RM From)**	**20 End Distance (RM To)**

21 Mapped Valley Length (ft)	22 Mapped Channel Gradient (%)	23 Mapped Sinuosity Value	24. Reason for Reach Break: / 25. *Inner Riparian Zone Width:
			26. Comments:

FINAL REACH FORM Page: 1 of 1
R6-2500/2600-21

A. State WA B. County Okanogan C. Forest O-W NF D. District Methow

E. Stream Name Eagle Creek

F. 8-digit HUC Code 17, 02, 00, 08 10-digit 05 12-digit 05

G. USGS Quad Oval Peak, WA 48120C

* Indicates a Forest Option

1 Reach Number	2 SO From	3 SO To	4 Start Date	5 End Date	6 Protocol	7 Observer	8 Recorder	9 Elevation Min (ft)	10 Elevation Max (ft)
1	1	49	11/04/16	11/04/16	R6E	Jef Parr	Jeff Phillips	2381	2611
11 *Stream Order	**12 *Valley Type**	**13 *Flow Regime**	**14 Rosgen Class**	**15 Reach Length (ft)**	**16 Mapped Valley Width (ft)**	**17 *Discharge Type**	**18 Discharge (cfs)**	**19 Start Distance (RM From)**	**20 End Distance (RM To)**
			A3	3726	Varied (fan)		5.6	0.0	0.5
21 Mapped Valley Length (ft)	**22 Mapped Channel Gradient (%)**	**23 Mapped Sinuosity Value**	**24. Reason for Reach Break:** Single reach from Twisp River confluence to end of anadromous and end of survey. **25.*Inner Riparian Zone Width:**						
2689	6.2	1.39	**26. Comments:** Waterfall just upstream of RM 0.5 is a complete passage barrier.						

1 Reach Number	2 SO From	3 SO To	4 Start Date	5 End Date	6 Protocol	7 Observer	8 Recorder	9 Elevation Min (ft)	10 Elevation Max (ft)
11 *Stream Order	**12 *Valley Type**	**13 *Flow Regime**	**14 Rosgen Class**	**15 Reach Length (ft)**	**16 Mapped Valley Width (ft)**	**17 *Discharge Type**	**18 Discharge (cfs)**	**19 Start Distance (RM From)**	**20 End Distance (RM To)**
21 Mapped Valley Length (ft)	**22 Mapped Channel Gradient (%)**	**23 Mapped Sinuosity Value**	**24. Reason for Reach Break:** **25.*Inner Riparian Zone Width:**						
			26. Comments:						

FINAL REACH FORM Page: 1 of 1
R6-2500/2600-21

A. State WA B. County Okanogan C. Forest O-W NF D. District Methow

E. Stream Name Canyon Creek

F. 8-digit HUC Code 17 , 02 , 00 , 08 10-digit 05 12-digit 07

G. USGS Quad Hoodoo Peak, WA 48120C3 and Thompson Ridge, WA 48120D3

* Indicates a Forest Option

1 Reach Number	2 SO From	3 SO To	4 Start Date	5 End Date	6 Protocol	7 Observer	8 Recorder	9 Elevation Min (ft)	10 Elevation Max (ft)
1	1	51	11/06/16	11/06/16	R6E	Jef Parr	Jeff Phillips	2283	2478
11 *Stream Order	**12 *Valley Type**	**13 *Flow Regime**	**14 Rosgen Class**	**15 Reach Length (ft)**	**16 Mapped Valley Width (ft)**	**17 *Discharge Type**	**18 Discharge (cfs)**	**19 Start Distance (RM From)**	**20 End Distance (RM To)**
			A3	2662	60		1.7	0.0	0.45
21 Mapped Valley Length (ft)	**22 Mapped Channel Gradient (%)**	**23 Mapped Sinuosity Value**	**24. Reason for Reach Break:** This is a single reach in a narrow valley and accross a small fan to the confluence with the Twisp River. **25.*Inner Riparian Zone Width:**						
2370	7.3	1.12	**26. Comments:** In contrast to other tributaries surveyed, the end of the surveyed was not at a waterfall but instead small, steep, cascades in a narrow but ongoing canyon.						

1 Reach Number	2 SO From	3 SO To	4 Start Date	5 End Date	6 Protocol	7 Observer	8 Recorder	9 Elevation Min (ft)	10 Elevation Max (ft)
11 *Stream Order	**12 *Valley Type**	**13 *Flow Regime**	**14 Rosgen Class**	**15 Reach Length (ft)**	**16 Mapped Valley Width (ft)**	**17 *Discharge Type**	**18 Discharge (cfs)**	**19 Start Distance (RM From)**	**20 End Distance (RM To)**
21 Mapped Valley Length (ft)	**22 Mapped Channel Gradient (%)**	**23 Mapped Sinuosity Value**	**24. Reason for Reach Break:** **25.*Inner Riparian Zone Width:**						
			26. Comments:						

APPENDIX C

Project Geodatabase

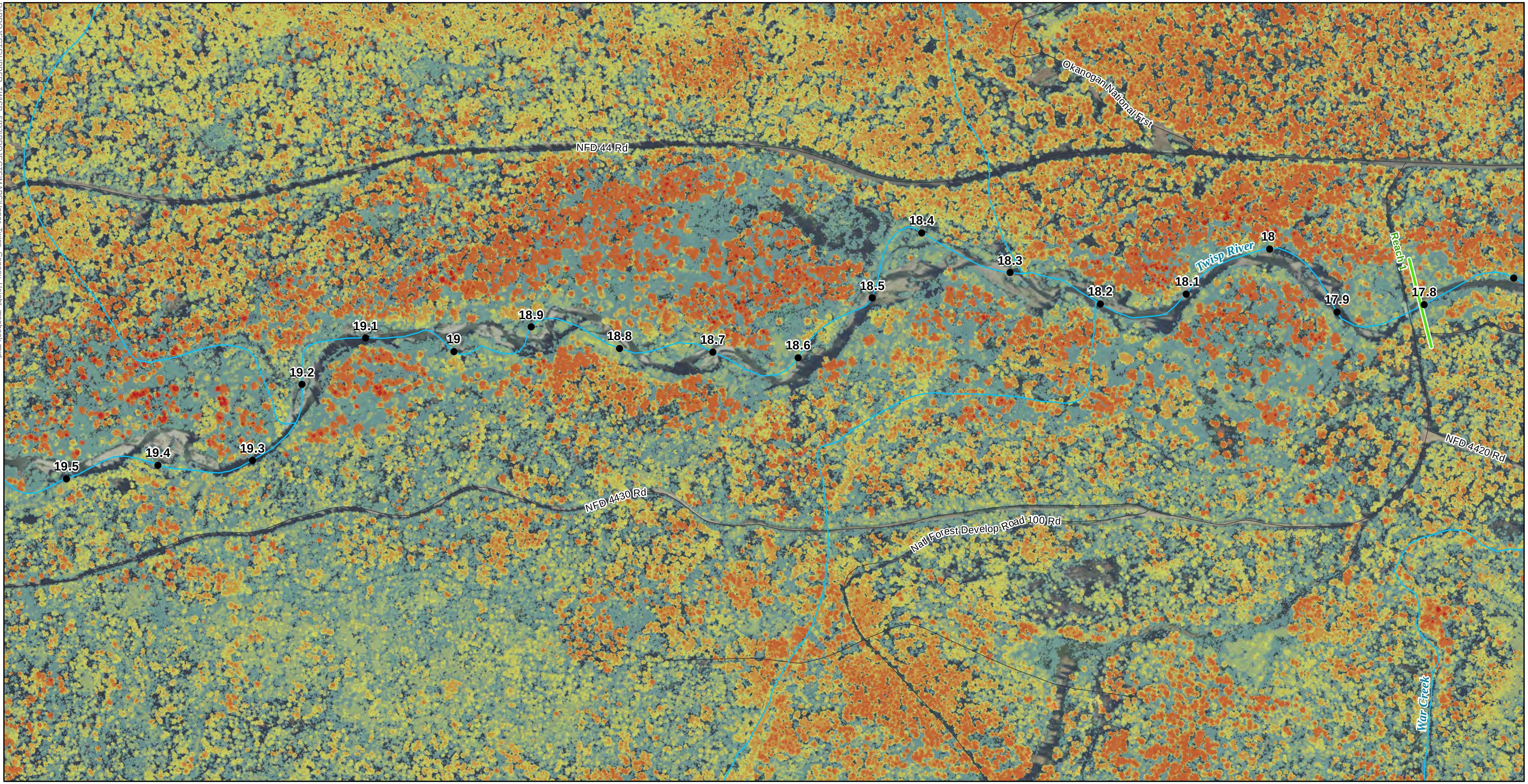
(provided on DVD)

This appendix is provided separately.

APPENDIX D

Canopy Cover Map Series

List of Figures



Legend

- River Mile
- Reach Breaks
- Streams

Tree Height (ft)

- 0 - 3
- 3.1 - 25
- 25.1 - 50
- 50.1 - 75
- 75.1 - 100
- 100.1 - 150
- 150.1 - 204

Figure D-1a. Canopy Height Map Series - Upper Twisp River RM 17.8 to 19.5

Sheet 1 of 13

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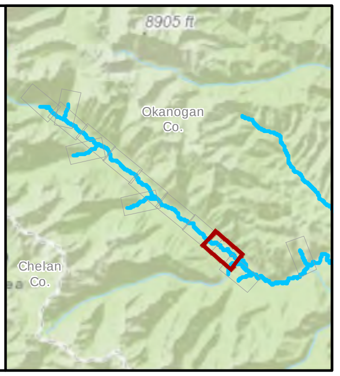

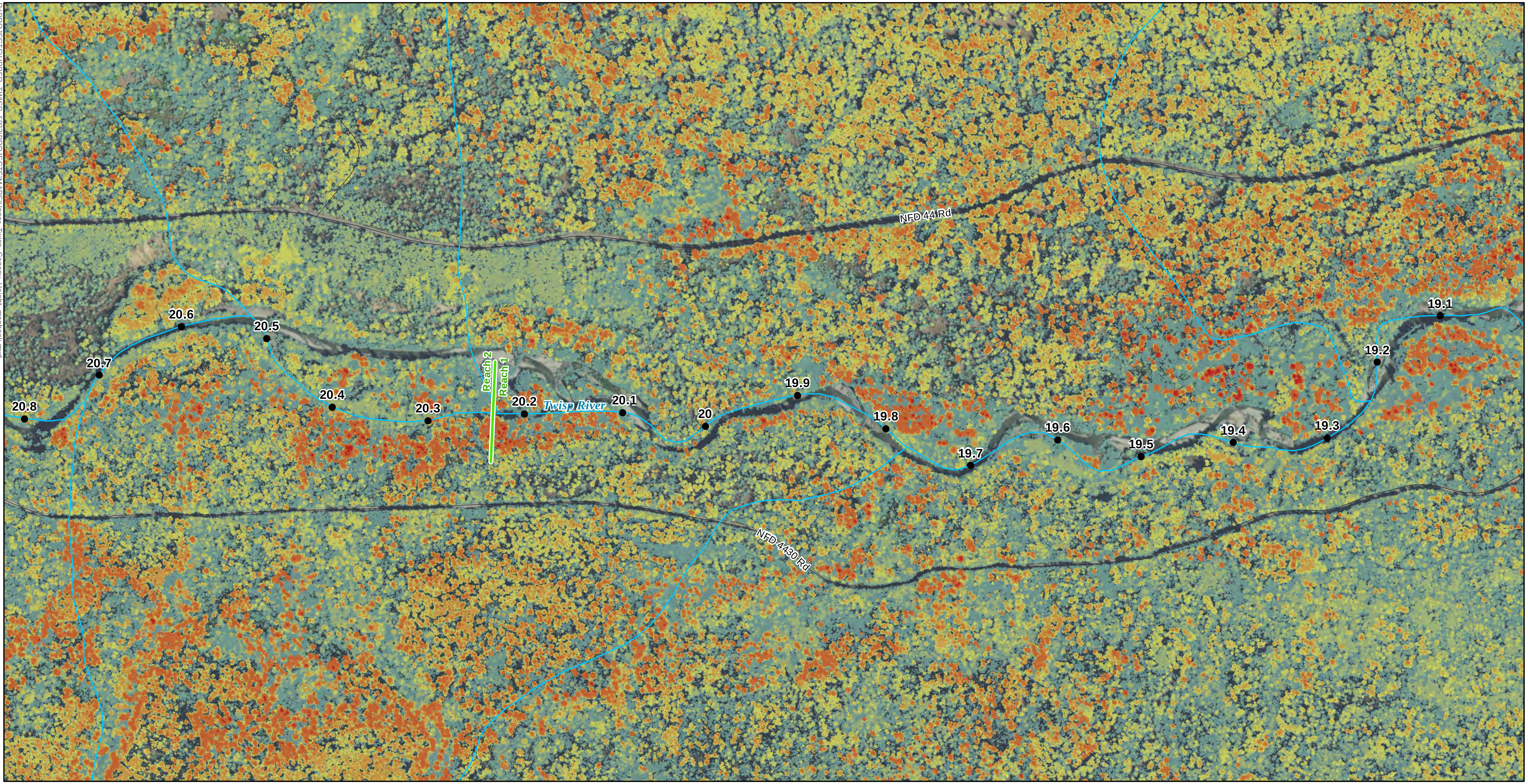

Legend

- ● River Mile
- Reach Breaks
- Streams

Tree Height (ft)

- 0 - 3
- 3.1 - 25
- 25.1 - 50
- 50.1 - 75
- 75.1 - 100
- 100.1 - 150
- 150.1 - 204

Figure D-1b. Canopy Height Map Series - Upper Twisp River RM 19.1 to 20.8

Sheet 2 of 13

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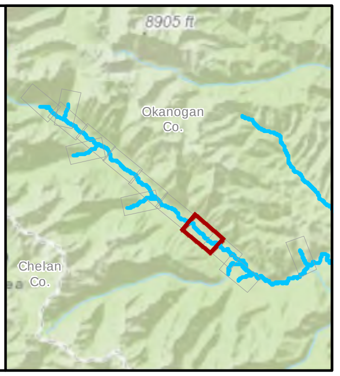

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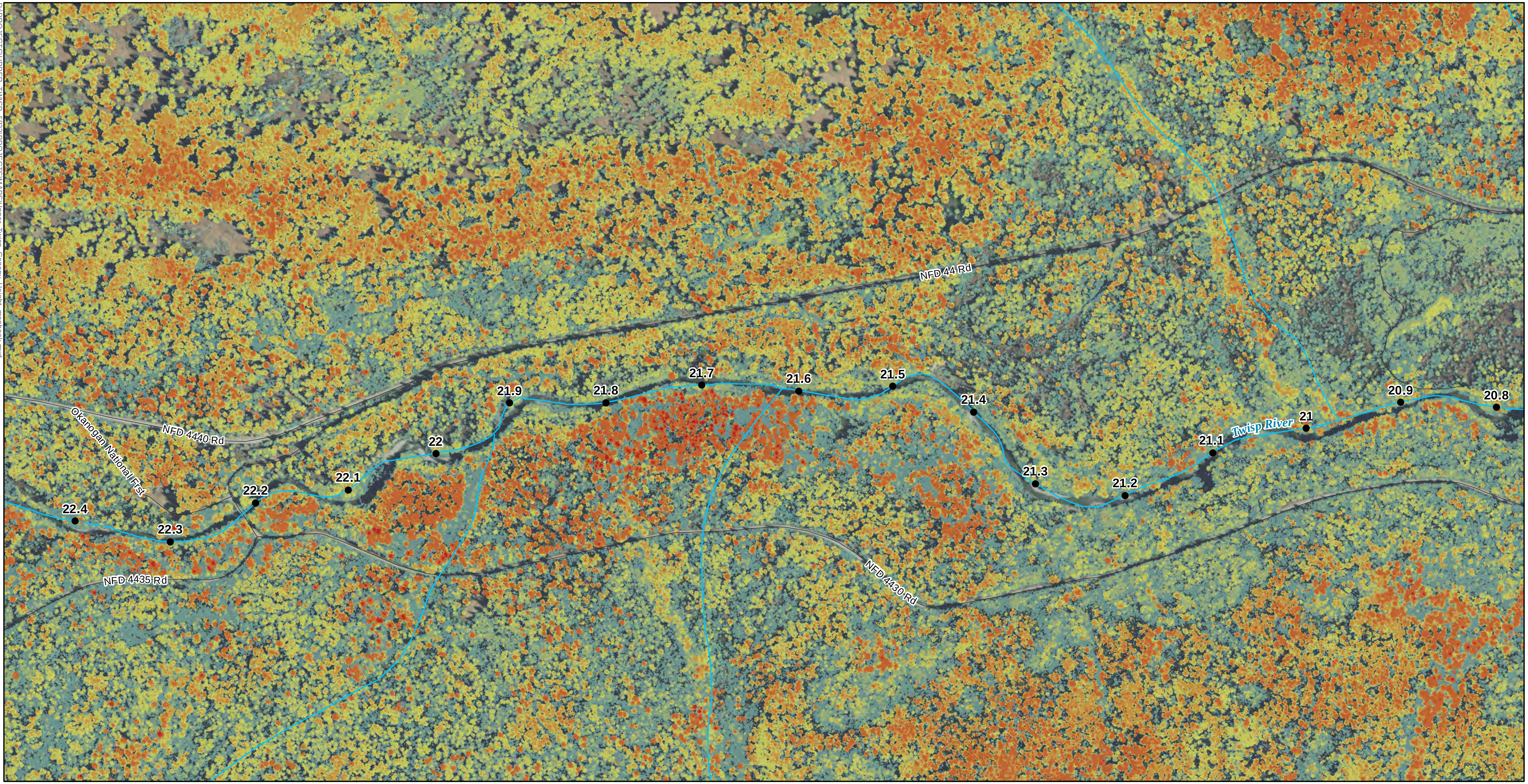

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Legend
- River Mile
- Reach Breaks
- Streams

Tree Height (ft)
- 0 - 3
- 3.1 - 25
- 25.1 - 50
- 50.1 - 75
- 75.1 - 100
- 100.1 - 150
- 150.1 - 204

Figure D-1c. Canopy Height Map Series - Upper Twisp River RM 20.8 to 22.4

Sheet 3 of 13

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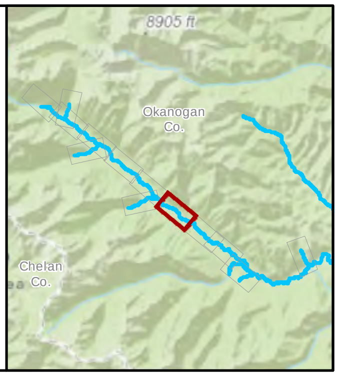

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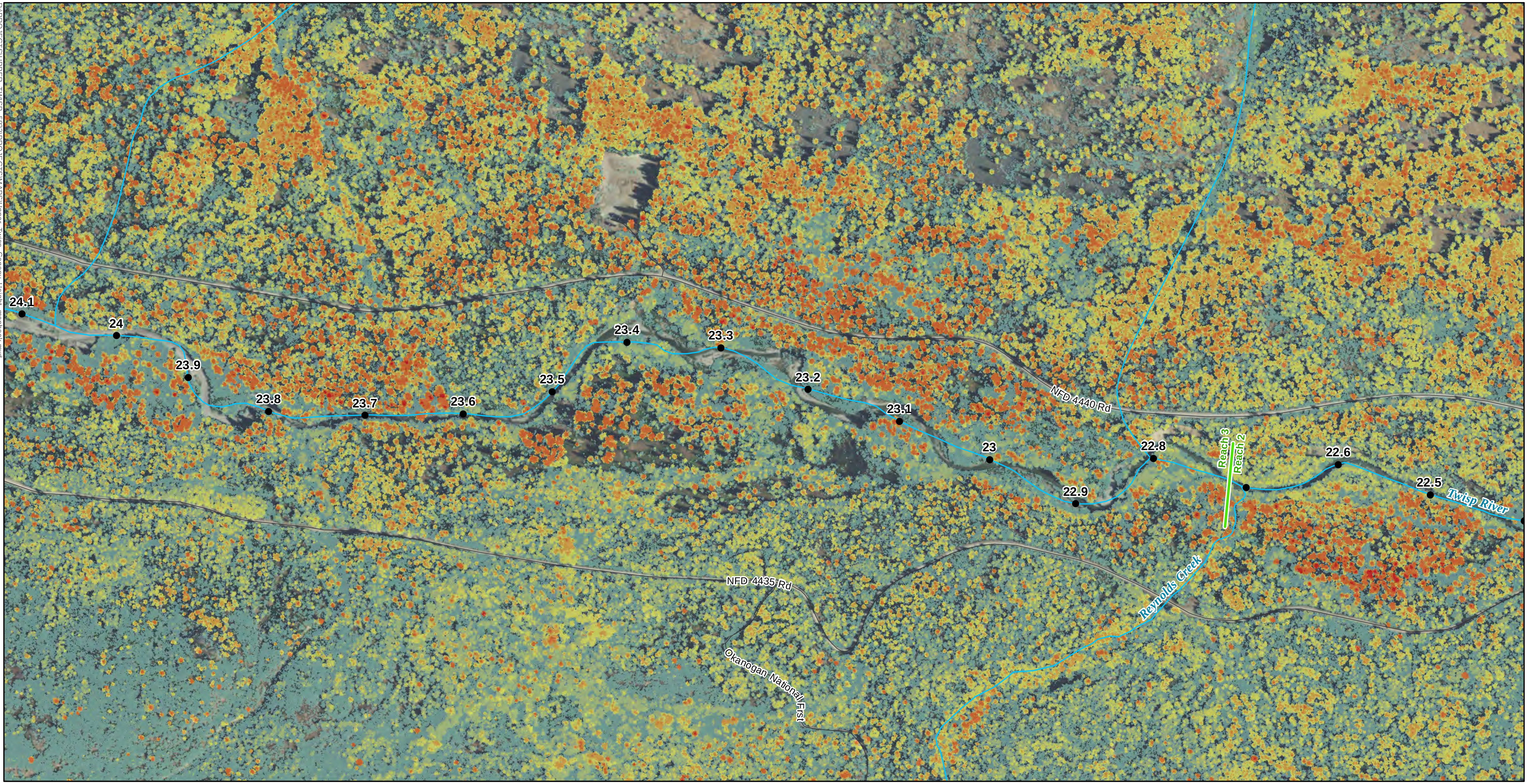

Legend

- ● River Mile
- Reach Breaks
- Streams

Tree Height (ft)

- 0 - 3
- 3.1 - 25
- 25.1 - 50
- 50.1 - 75
- 75.1 - 100
- 100.1 - 150
- 150.1 - 204

Figure D-1d. Canopy Height Map Series - Upper Twisp River RM 22.4 to 24.1

Sheet 4 of 13

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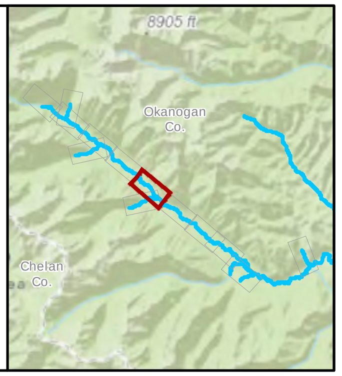

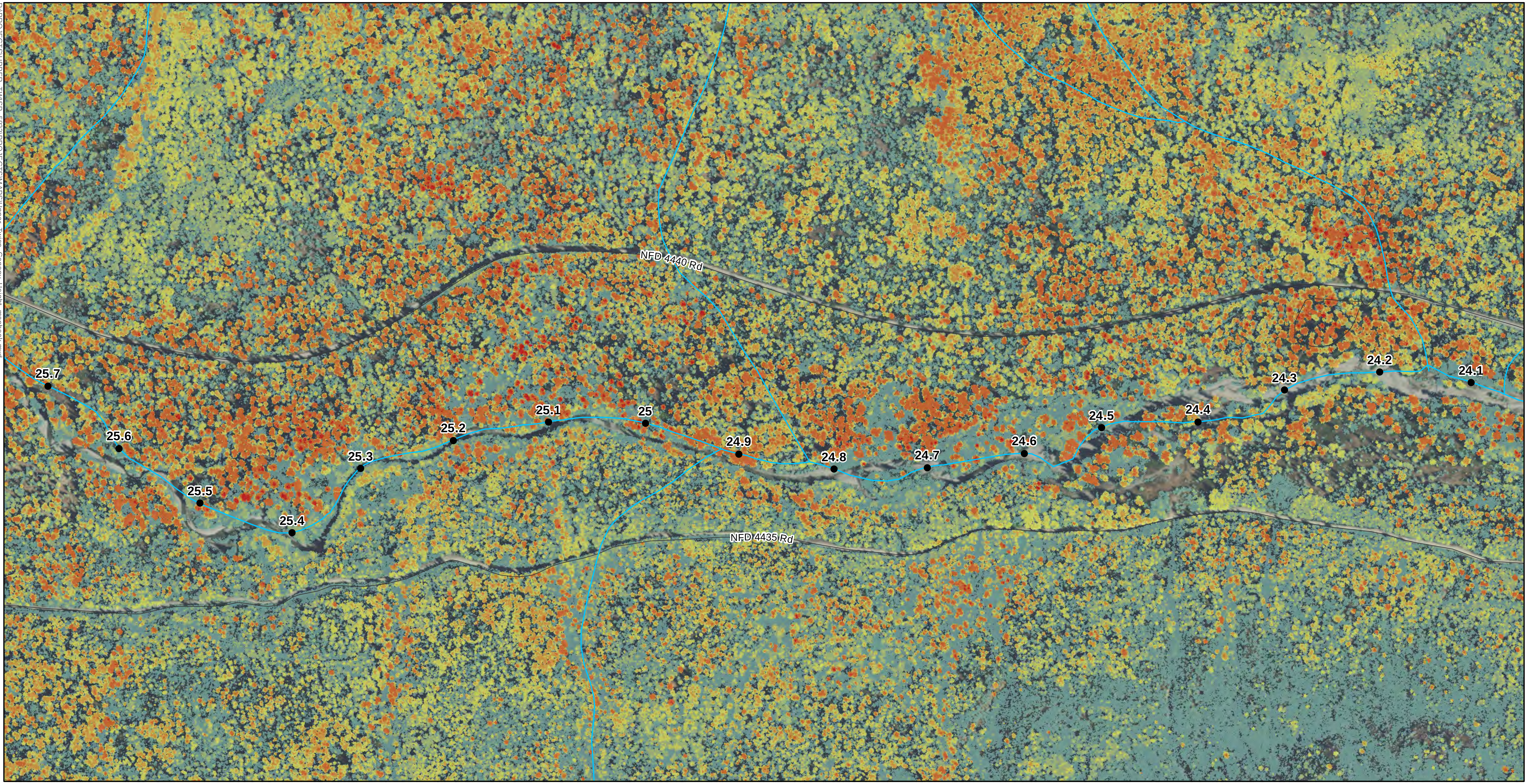

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Legend

- River Mile
- Reach Breaks
- Streams

Tree Height (ft)

- 0 - 3
- 3.1 - 25
- 25.1 - 50
- 50.1 - 75
- 75.1 - 100
- 100.1 - 150
- 150.1 - 204

Figure D-1e. Canopy Height Map Series - Upper Twisp River RM 24.1 to 25.7

Sheet 5 of 13

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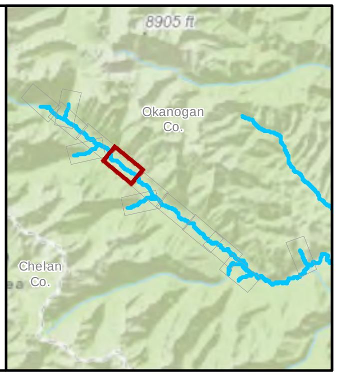

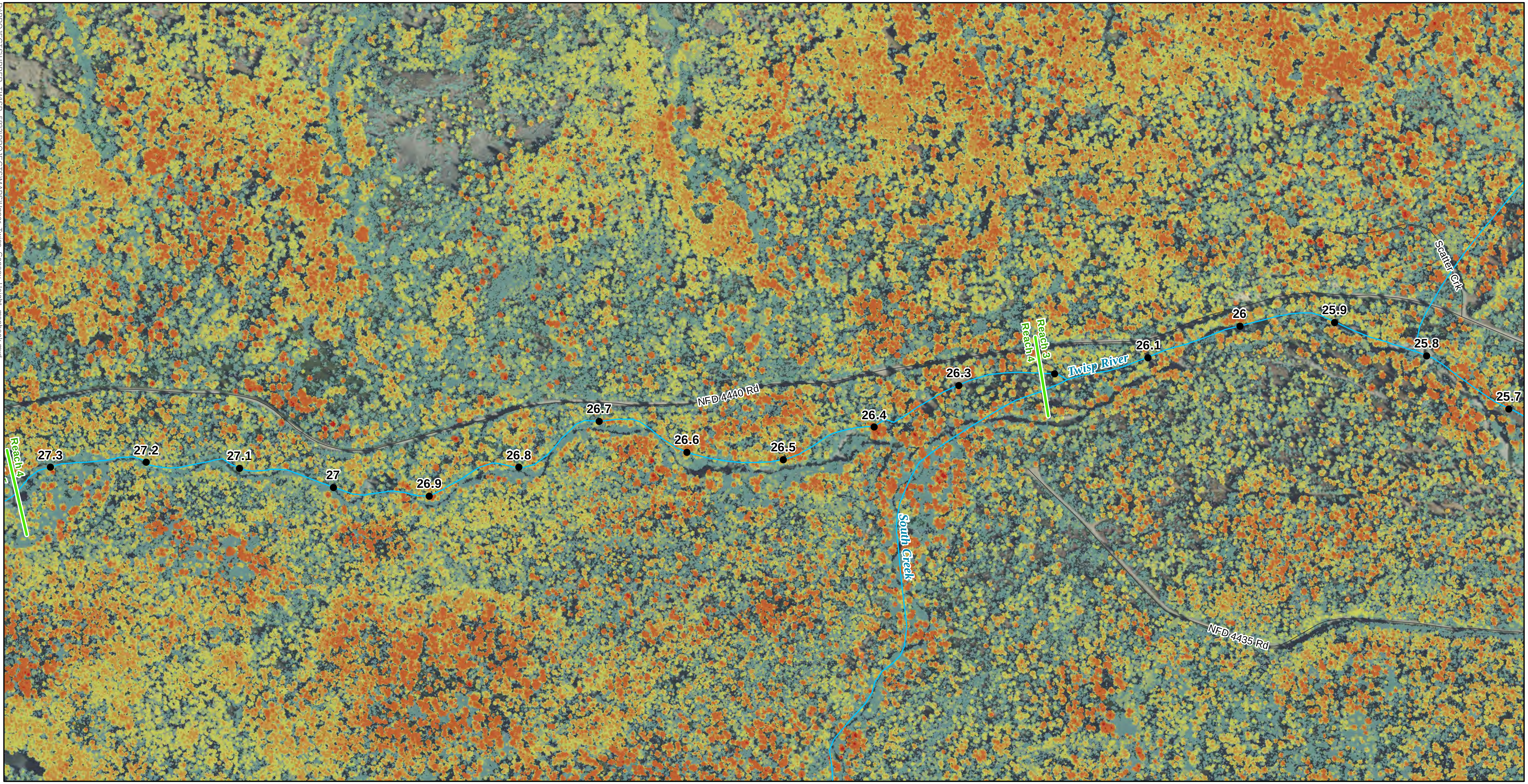

Legend

- River Mile
- Reach Breaks
- Streams

Tree Height (ft)

- 0 - 3
- 3.1 - 25
- 25.1 - 50
- 50.1 - 75
- 75.1 - 100
- 100.1 - 150
- 150.1 - 204

Figure D-1f. Canopy Height Map Series - Upper Twisp River RM 25.7 to 27.3

Sheet 6 of 13

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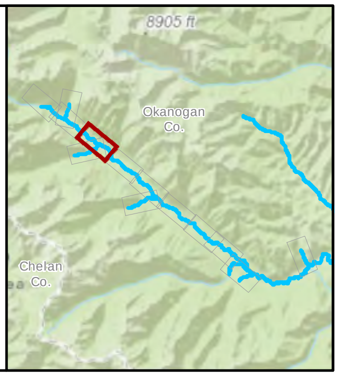

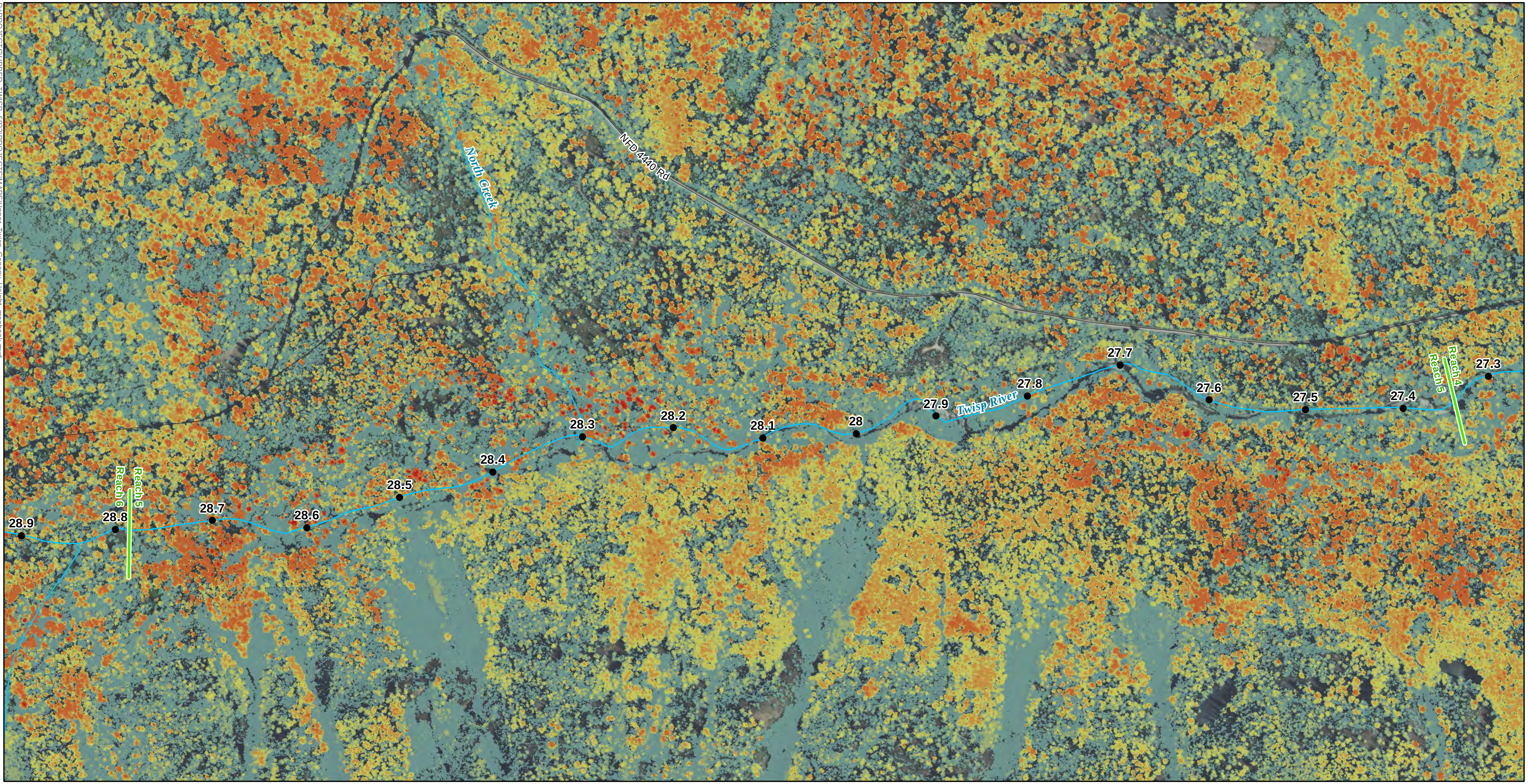

Legend

- ● River Mile
- Reach Breaks
- Streams

Tree Height (ft)

- 0 - 3
- 3.1 - 25
- 25.1 - 50
- 50.1 - 75
- 75.1 - 100
- 100.1 - 150
- 150.1 - 204

Figure D-1g. Canopy Height Map Series - Upper Twisp River RM 27.3 to 28.9

Sheet 7 of 13

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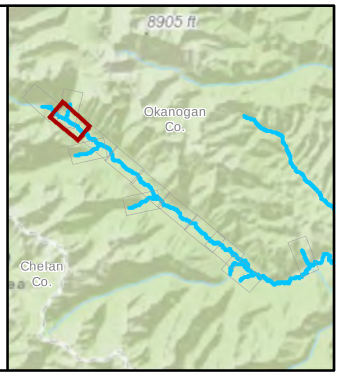

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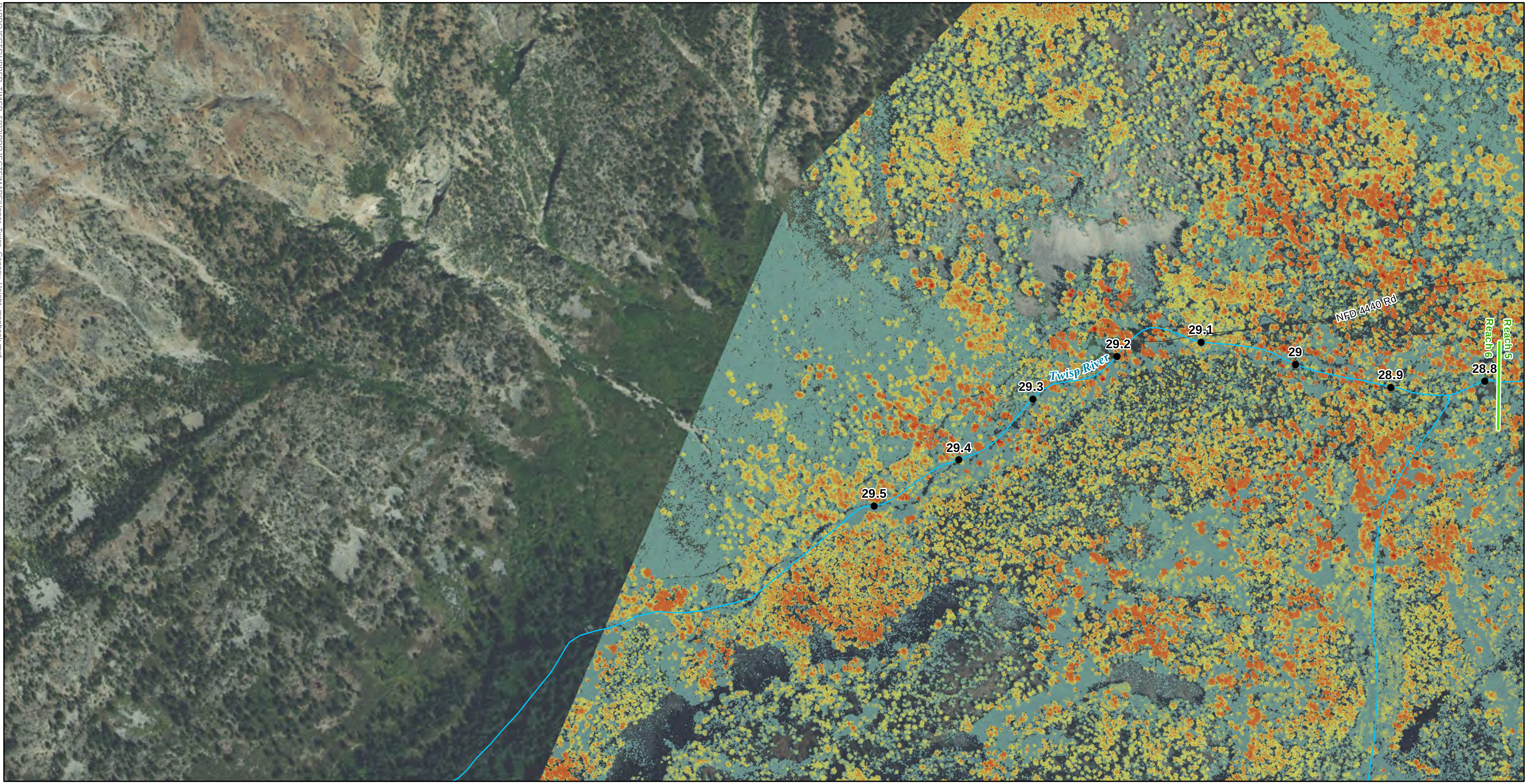


Legend

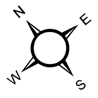
- ● River Mile
- Reach Breaks
- Streams

Tree Height (ft)

- 0 - 3
- 3.1 - 25
- 25.1 - 50
- 50.1 - 75
- 75.1 - 100
- 100.1 - 150
- 150.1 - 204

Figure D-1h. Canopy Height Map Series - Upper Twisp River RM 28.8 to 29.7

Sheet 8 of 13



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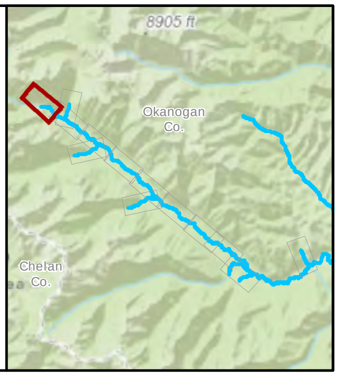

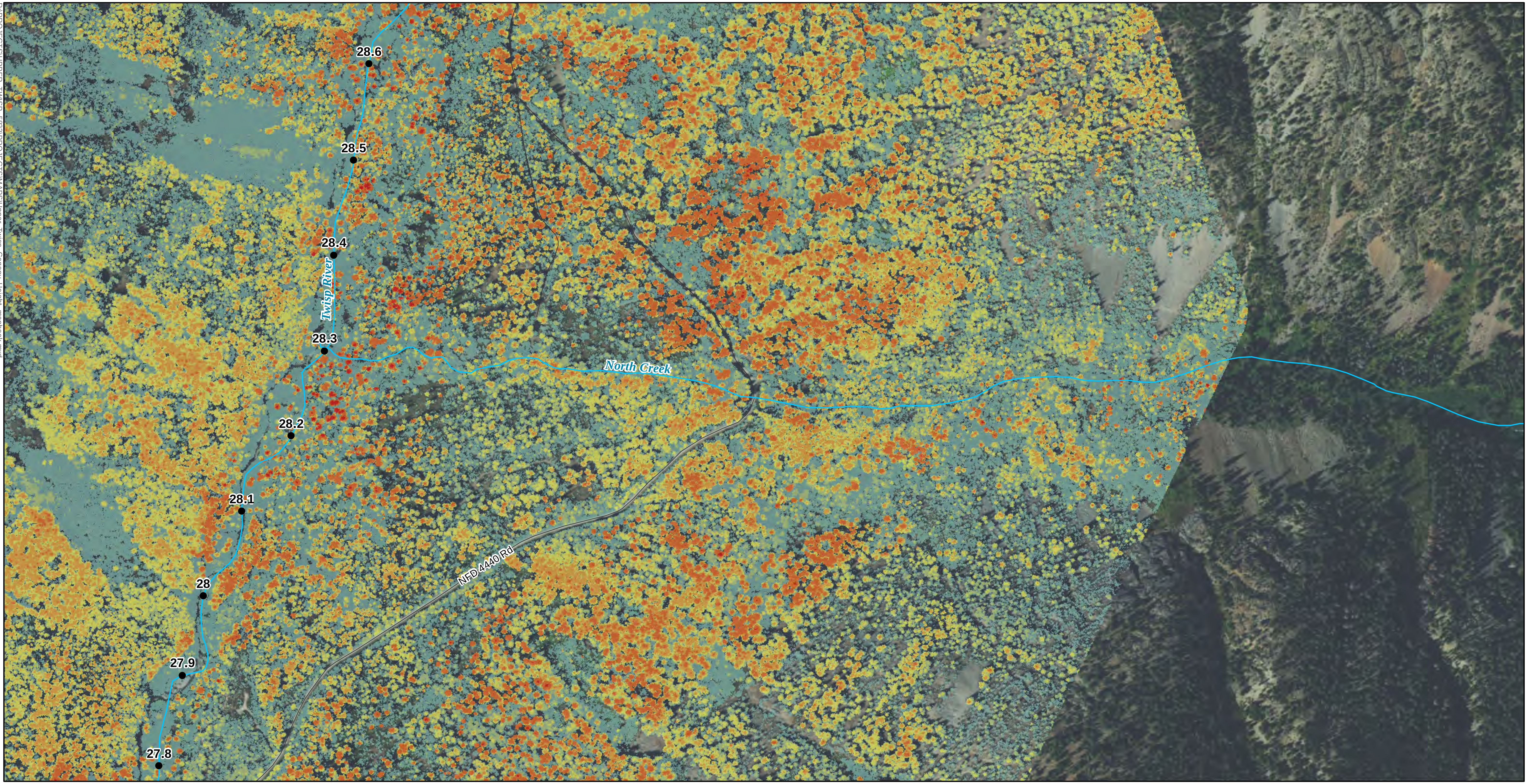

Legend

- ● River Mile
- Reach Breaks
- Streams

Tree Height (ft)

- 0 - 3
- 3.1 - 25
- 25.1 - 50
- 50.1 - 75
- 75.1 - 100
- 100.1 - 150
- 150.1 - 204

Figure D-1i. Canopy Height Map Series - North Creek

Sheet 9 of 13

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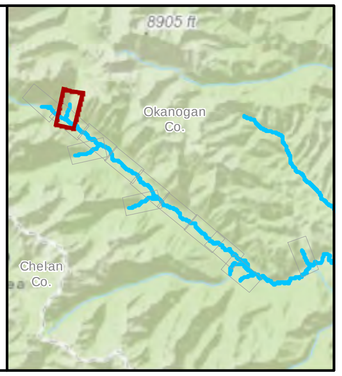

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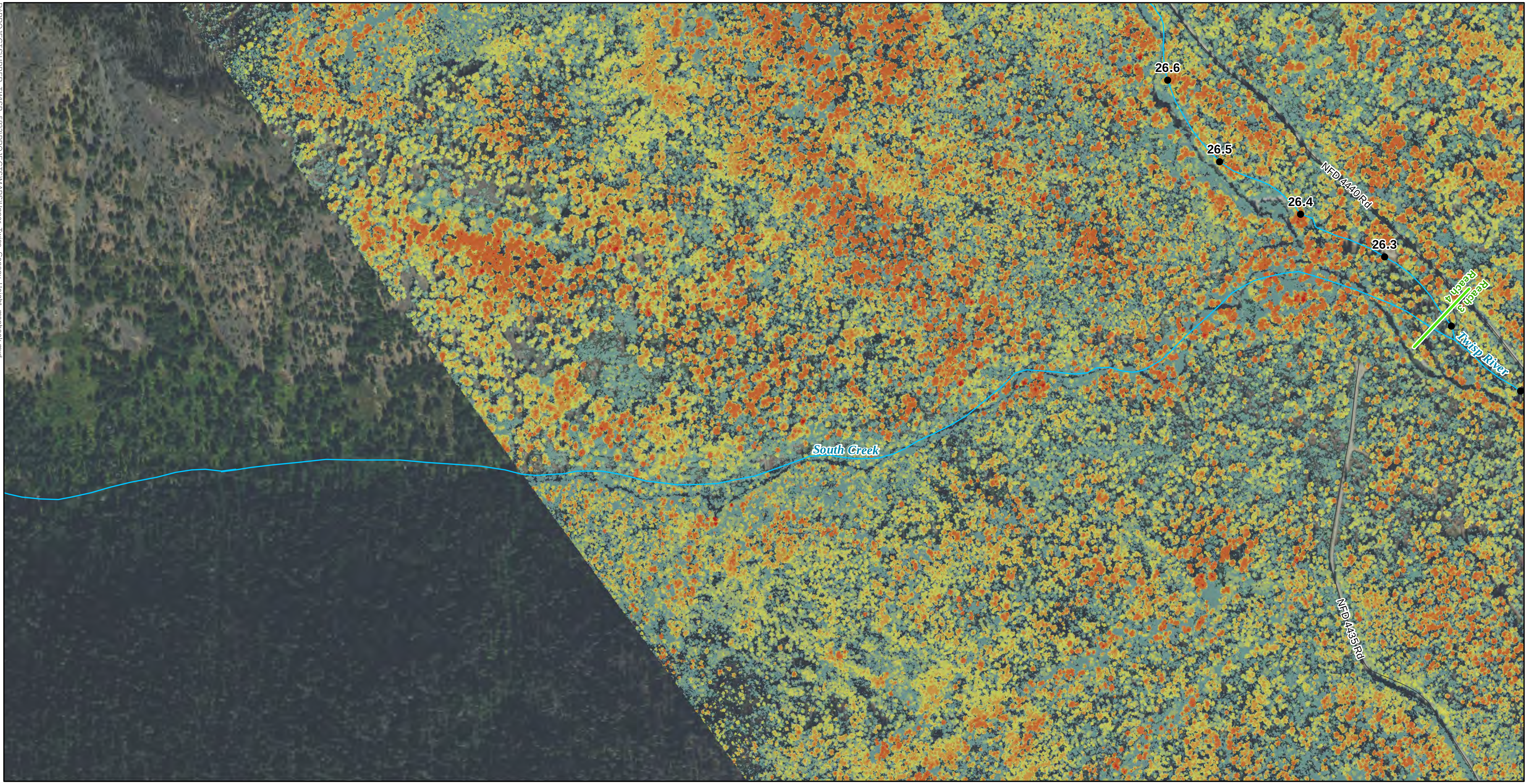

Legend

- ● River Mile
- Reach Breaks
- Streams

Tree Height (ft)

- 0 - 3
- 3.1 - 25
- 25.1 - 50
- 50.1 - 75
- 75.1 - 100
- 100.1 - 150
- 150.1 - 204

Figure D-1j. Canopy Height Map Series - South Creek

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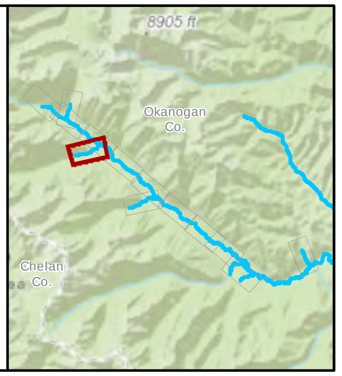

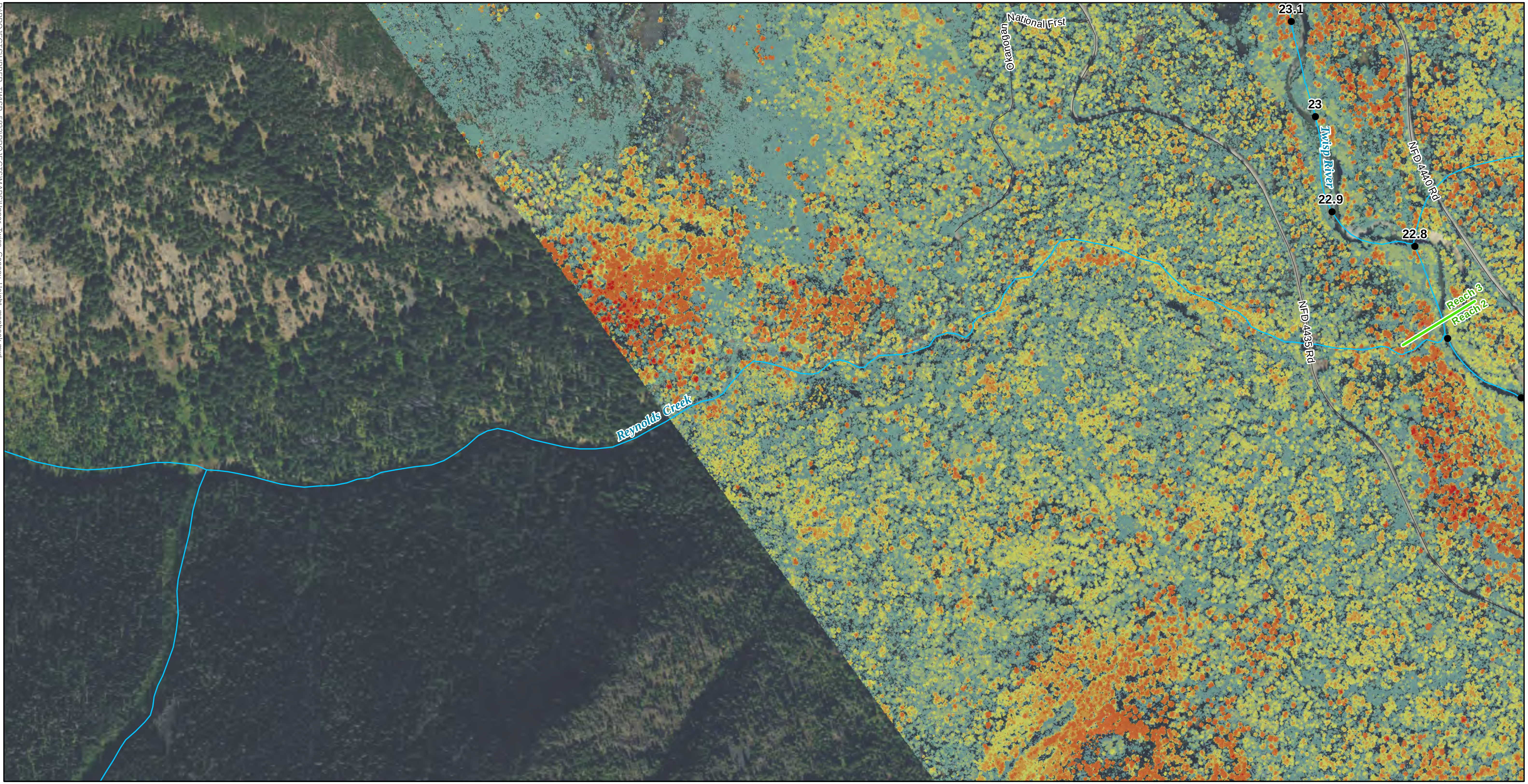

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Legend

- ● River Mile
- Reach Breaks
- Streams

Tree Height (ft)

- 0 - 3
- 3.1 - 25
- 25.1 - 50
- 50.1 - 75
- 75.1 - 100
- 100.1 - 150
- 150.1 - 204

Figure D-1k. Canopy Height Map Series - Reynolds Creek

Sheet 11 of 13

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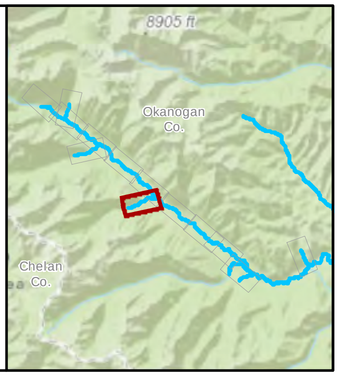

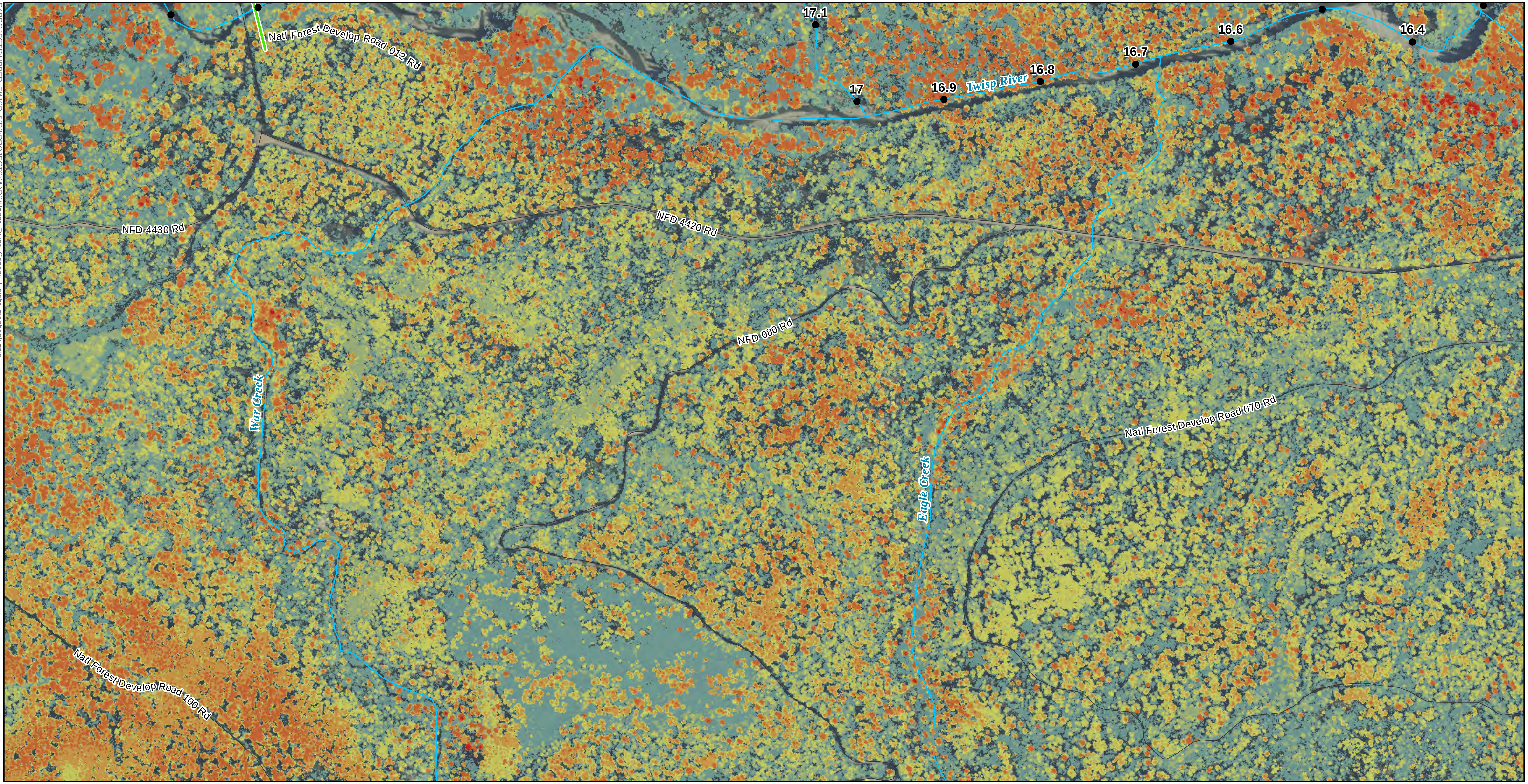

Legend

- River Mile
- Reach Breaks
- Streams

Tree Height (ft)

- 0 - 3
- 3.1 - 25
- 25.1 - 50
- 50.1 - 75
- 75.1 - 100
- 100.1 - 150
- 150.1 - 204

Figure D-1l. Canopy Height Map Series - War and Eagle Creeks

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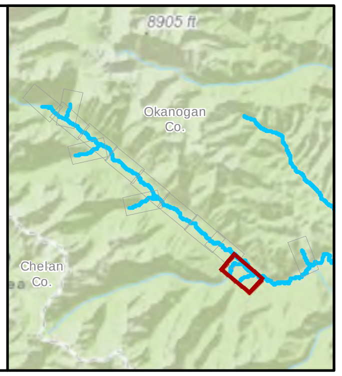

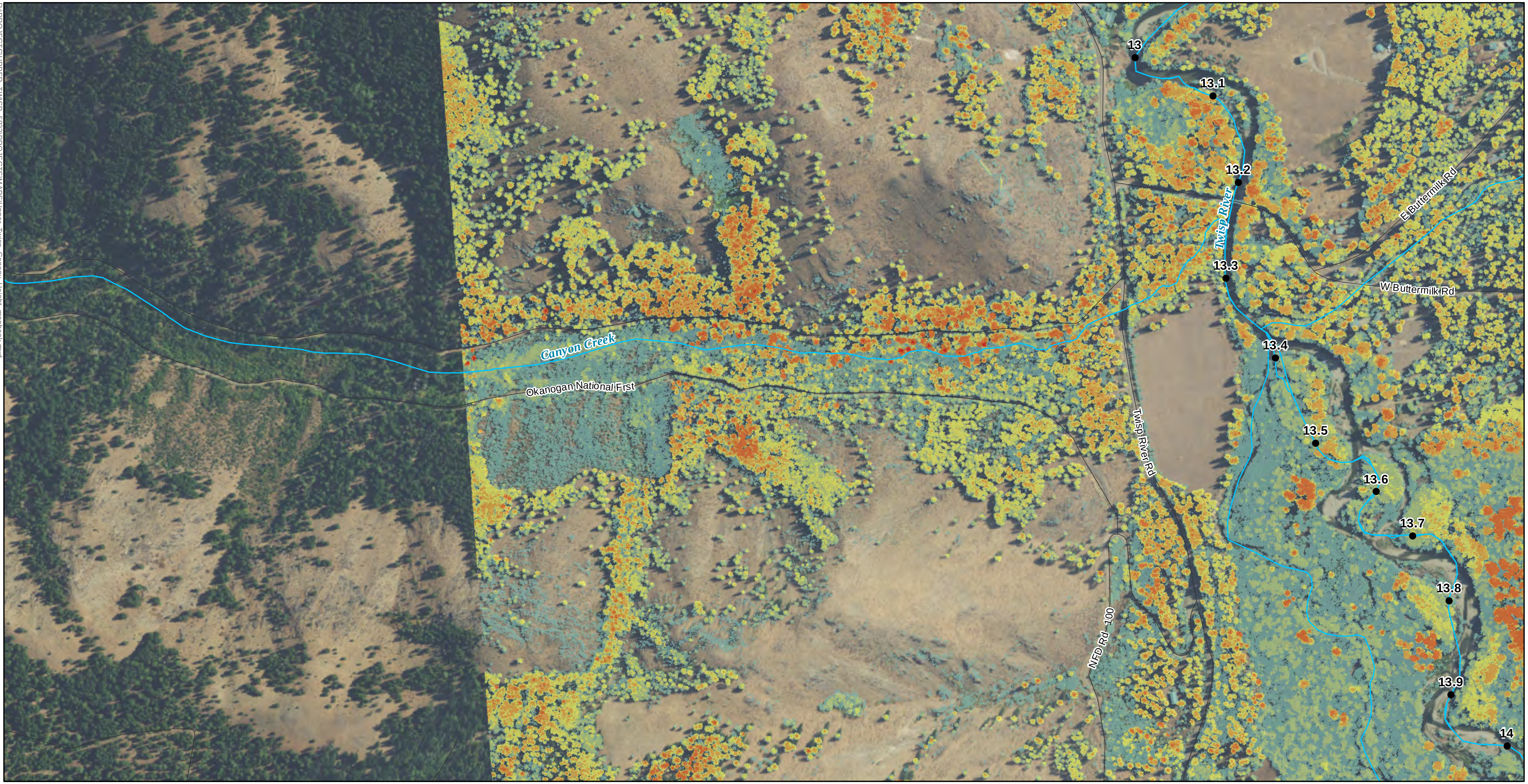

Legend

- River Mile
- Reach Breaks
- Streams

Tree Height (ft)

- 0 - 3
- 3.1 - 25
- 25.1 - 50
- 50.1 - 75
- 75.1 - 100
- 100.1 - 150
- 150.1 - 204

Figure D-1m. Canopy Height Map Series - Canyon Creek

Sheet 13 of 13

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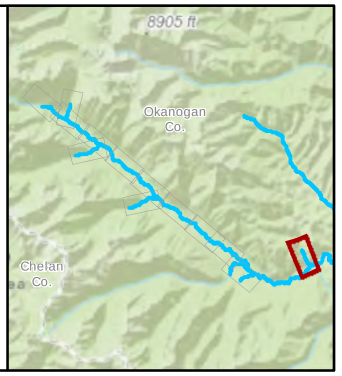

APPENDIX E

Reach-Based Ecosystem Indicators

1. INTRODUCTION

This assessment of Reach-based Ecosystem Indicators (REI) provides a well-established and consistent means of evaluating biological and physical conditions in relation to criteria that represent known habitat requirements for aquatic biota. The REI assessment characterizes the state of geomorphic and ecological processes within the upper Twisp River and Project tributaries. The REI criteria used in this assessment are based on the Matrix of Diagnostics/Pathways and Indicators (USFWS 1998), the National Oceanic and Atmospheric Administration National Marine Fisheries Service (NMFS) Matrix of Pathways and Indicators (1996), as well as more recent work conducted within the region by the Bureau of Reclamation and their adaptation of these indicators (USBR 2012).

This assessment of REI was informed by previous studies in the Twisp River and Project tributaries, data collected for this assessment following the USFS Level II Stream Survey Protocols (USFS 2016), observations, and reach assessment analyses. Specific analysis results are presented and discussed for each indicator, and are used to assign a risk condition rating of “Adequate,” “At Risk,” or “Unacceptable.” The criteria for rating categories are explained in detail for each indicator below. The results for watershed-scale indicators are presented in Section 2. The reach-scale REI results in Sections 3 through 6 are organized into subsections for upper Twisp River (UTR) reaches, Little Bridge Creek (LBC) reaches, and the remaining Project tributaries. LBC is presented separately from other tributaries because it is the longest tributary and has multiple geomorphic reaches within the Survey Area. The remaining Project tributaries (North Creek, South Creek, Reynolds Creek, War Creek, Eagle Creek, and Canyon Creek) are relatively short (less than 1 mile) and include a single geomorphic reach.

2. PATHWAY: WATERSHED CONDITION

GENERAL INDICATOR: WATERSHED ROAD DENSITY AND EFFECTIVE DRAINAGE NETWORK

Metric Overview

Road density can be a good indicator of watershed condition, as it has been shown that high road density can result in altered drainage networks (Montgomery 1994; Wemple et al. 1996), which in turn often increase fine sediment load to streams and rivers (Reid and Dunne 1984; Goode et al. 2011). In addition, high road densities can result in more mass wasting events and erosion than in a less disturbed watershed (Montgomery 1994; Wemple et al. 1996). Greater sediment delivery to streams can have significant effects on aquatic systems, such as reducing suitable spawning habitat, smothering salmon eggs (Lisle 1989), clogging hyporheic flow paths (Boulton et al. 1998), reducing substrates for aquatic plants, biofilms, and aquatic invertebrates (Henley et al. 2000), as well as impacting channel morphology and water clarity (Waters 1995; Wood and Armitage 1997). For this assessment, road density was calculated using an ArcGIS layer developed by compiling all open roads from U.S. Department of Agriculture Forest Service (USFS), Esri Streetmap roads, and Okanogan County roads shapefiles.

Criteria: From USFWS (1998), modified by USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Watershed Condition	Effective Drainage network and Watershed Road Density	Increase in Drainage Network/Road Density	Zero or minimum increase in active channel length correlated with human-caused disturbance **And** Road density <1 miles/mile^2	Low to moderate increase in active channel length correlated with human-caused disturbance **And** Road density 1 to 2.4 miles/mile^2	Greater than moderate increase in active channel length correlated with human-caused disturbance **And** Road density >2.4 miles/mile^2

Watershed Assessment Results

Road density was assessed for the Twisp River watershed (Hydrologic Unit Code [HUC]-10 1702000805), the UTR drainage upstream of the NF-4430 road bridge near the War Creek Campground (river mile [RM] 17.8), and all Project tributaries. The road density for the entire Twisp River HUC-10 watershed is 1.1 miles per square mile. The road density for the UTR drainage upstream of the NF-4430 road bridge is 0.39 mile of road per square mile area with tributary road densities ranging from 0.01 to 0.40 mile of road per square mile area.

Based on the above rating criteria, the UTR drainage is functioning at an **adequate** condition for this indicator. The Canyon Creek and LBC drainages have higher road densities with 1.56 and 1.55 miles of road per square mile area, respectively, and are therefore functioning **at risk** for this indicator.

Twisp River Watershed and Tributary Drainage Road Density

Road Density (mi/mi²)								
Twisp River Watershed	Upper Twisp River Drainage1/	North Creek Drainage	South Creek Drainage	Reynolds Creek Drainage	War Creek Drainage	Eagle Creek Drainage	Canyon Creek Drainage	Little Bridge Creek Drainage
1.1	0.39	0.16	0.01	0.04	0.40	0.13	1.56	1.55

1/ Upper Twisp River drainage upstream of the NF-4430 road bridge near the War Creek Campground (RM 17.8).

REI Rating

Watershed Rating: **At Risk**

INDICATOR: DISTURBANCE REGIME (NATURAL & HUMAN-CAUSED)

Metric Overview

Disturbance is an integral part of natural systems (Ward 1998). Natural disturbance regimes create habitat and biological diversity (Nakamura et al. 2000; Ward 1998) that maintain the larger ecosystem processes. These regimes include events such as landslides, fire, flood, drought, and windstorms. Human activities such as flow regulation, channelization, bank stabilization, road construction, and land-use modifications (conversion to agriculture, development, etc.) can change how systems respond to natural events, the frequency of events, and the ability of a system to recover (Waples et al. 2009).

Criteria: From USFWS (1998)

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Condition
Watershed Condition	Disturbance Regime	Natural/Human Caused	Environmental disturbance is short lived; predictable hydrograph; high quality habitat and watershed complexity providing refuge and rearing space for all lifestages 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 disturbance is moderate.	Frequent flood or drought producing highly variable and unpredictable flows, scour events, debris torrents, or high probability of catastrophic fire exists throughout a major part of the watershed. The channel is simplified, providing little hydraulic complexity in the form of pools or side channels. Natural processes are unstable.

Watershed Assessment Results

Past and ongoing human alterations in the Twisp River watershed limit the resiliency of habitat to recover from disturbance events. For example, land use impacts have constrained channel migration, disconnected habitat, and decreased large woody debris abundance. Land use activities including riparian and hillslope timber harvest, mining, grazing, and road construction, as well as land management actions including fire suppression, have changed the composition, structure, and function of riparian and upland forests in the Twisp River watershed. These changes have modified the behavior of disturbances events and increased the risk of potential catastrophic disturbance including wildfires.

Based on the rating criteria, the watershed is functioning at an **at risk** condition for this indicator.

REI Rating

Watershed Rating: **At Risk**

INDICATOR: STREAMFLOW (CHANGE IN PEAK/BASE FLOW)

Metric Overview

The magnitude, timing, duration, and frequency of stream flows within a watershed are important drivers within the ecological system. Stream discharge and channel morphology are directly linked to these processes and largely controlled by climate, vegetation, geology, and human alterations and impacts. Alterations to the natural hydrology of a watershed can affect the timing and magnitude of peak-flow and low-flow events. The frequency of high-flow events can also be dramatically affected by human actions, potentially decreasing due to flow regulation (e.g., dams) and water withdrawals (e.g., for irrigation), or increasing from widespread timber harvest, increased impervious surfaces, or extensive road networks.

Criteria: From USFWS (1998), modified by USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Condition
Watershed Condition	Streamflow	Change in Peak/Base Flows	Magnitude, timing, duration, and frequency of peak flows within a watershed are not altered relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.	Some evidence of altered magnitude, timing, duration, and frequency of peak flows relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.	Pronounced evidence of altered magnitude, timing, duration, and frequency of peak flows relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.

Watershed Assessment Results

The hydrology of the Twisp River watershed is driven by precipitation and snowmelt. Snowmelt in spring and early summer is the primary source of peak-flow events typically occurring from April through July. Climate change projections indicate that rainfall may increase considerably by 2080 (e.g., Mote and Salanthe 2009). Past management actions including timber harvest have the potential to impact watershed hydrology. Climate change models also predict an increase in winter stream flows, earlier and lower peak runoff, and lower summer baseflows (CIG 2009). These analyses suggest that human-induced climate change is likely to alter the magnitude, timing, duration, and frequency of streamflows.

Based on the potential effects of climate change on criteria for watershed hydrology, this indicator is rated **at risk**.

REI Rating

Watershed Rating: **At Risk**

3. PATHWAY: REACH-SCALE HABITAT ACCESS

INDICATOR: PHYSICAL BARRIERS – MAIN CHANNEL BARRIERS

Metric Overview

Physical barriers restrict movement of aquatic species, such as salmonids, throughout a watershed. This can result in reduced genetic diversity within populations and reduced distribution of marine-derived nutrients throughout the system, and may also impact transport of woody debris material downstream from source areas. This metric evaluates mainstem fish passage barriers in the UTR and Project tributaries.

Criteria: From USFWS (1998), modified by USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Condition
Habitat Access	Physical Barriers	Main Channel Barriers	No human-made barriers present in the mainstem that limit upstream or downstream fish passage at any flows	Human-made barriers present in the mainstem that prevent upstream or downstream migration at some flows that are biologically significant	Human-made barriers present in the mainstem that prevent upstream or downstream migration at multiple or all flows

Upper Twisp River Assessment Results

All reaches of the UTR are rated as **adequate** condition for this indicator because no human-made fish passage barriers are present that limit upstream or downstream fish passage at any flows.

Main Channel Barriers REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Adequate	Adequate	Adequate	Adequate	Adequate	Adequate

Little Bridge Creek Assessment Results

No human-made complete fish passage barriers are present on the mainstem LBC. There is an existing irrigation diversion structure in Reach 2, near RM 2.2, that has been modified to improve fish passage (USFS 2006); however, a channel-spanning boulder weir remains to backwater the diversion, which may be seasonally affecting juvenile fish passage.

Based on the above rating criteria, Reach 2 is rated as **at risk** condition for this indicator because a diversion structure has the potential to be limiting juvenile migration at some flows. Reaches 1, 3, and 4 are rated as **adequate** condition because no barriers are present that limit upstream or downstream fish passage at any flows.

Main Channel Barriers REI Rating

Reach 1	Reach 2	Reach 3	Reach 4
Adequate	At Risk	Adequate	Adequate

Tributary Assessment Results

No human-made fish passage barriers are present on North Creek, South Creek, Reynolds Creek, War Creek, or Eagle Creek. Canyon Creek has a human-made fish passage barrier and two diversion structures. The Twisp River Road crossing culvert is a partial barrier with a jump height of 0.8 feet, no sediment in the culvert bed, and a 4.3 percent gradient. The riprap-forced drop immediately downstream of the culvert also appears to be blocking fish passage.

Based on the above rating criteria, North Creek, South Creek, Reynolds Creek, War Creek, or Eagle Creek are rated as **adequate** condition for this indicator because there are no human-made fish passage barriers present. Canyon Creek is rated as **unacceptable** condition because the Twisp River Road crossing culvert and the riprap-forced drop immediately downstream are preventing migration at multiple or all flows.

Main Channel Barriers REI Rating

North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
Adequate	Adequate	Adequate	Adequate	Adequate	Unacceptable

4. PATHWAY: REACH-SCALE HABITAT QUALITY

INDICATOR: SUBSTRATE – DOMINANT SUBSTRATE FINE SEDIMENT

Metric Overview

Stream substrate is important for salmon spawning, egg incubation, and rearing. High-quality spawning areas generally include gravel/cobble-dominated substrates with relatively low amounts of interstitial fine sediments. These factors provide conditions suitable for egg incubation (proper aeration and not smothered by fines) and young-of-the-year rearing (available interstitial spaces for cover and refuge). Streambed substrate was evaluated based on pebble counts collected during the 2013 stream habitat survey of the UTR (USFS 2014), the 2006 stream habitat survey of Little Bridge Creek (USFS 2006), and tributary habitat surveys completed for this Project in 2016.

Criteria: Modified from USFWS (1998) and USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Condition
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	Dominant substrate is gravel or cobble (interstitial spaces clear), or embeddedness <20%, <12% fines (<0.85 mm) in spawning gravel or <12% surface fines of <6 mm	Gravel and Cobble is subdominant, or if dominant, embeddedness is 20-30%; 12-17% fines (<0.85 mm) in spawning gravel or 12-20% surface fines of <6 mm	Bedrock, sand, silt, or small gravel dominant, or if gravel and cobble dominant, embeddedness >30%; >17% fines (<0.85 mm) in spawning gravel or >20% surface fines of <6 mm

Upper Twisp River Assessment Results

All reaches of the UTR are cobble dominated and have less than 12 percent of the surface represented by fine sediments (less than 6 millimeters [mm]) based on the 2013 stream habitat survey of the UTR (USFS 2014). Reach 6 has the highest proportion of boulders at 40 percent; however, given the relatively steep gradient and channel confinement there, this result if likely similar to historical conditions.

Based on the above rating criteria, all reaches of the UTR are rated as **adequate** condition for this indicator.

UTR Percent Substrate Size Class and Surface Fine Sediments by Reach (source: USFS 2014)

Substrate Size Class	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Percent Sand (<2 mm)	8%	6%	5%	4%	6%	4%
Percent Gravel (2 to 64 mm)	28%	15%	28%	17%	27%	14%
Percent Cobble (64 to 256 mm)	56%	51%	53%	52%	54%	40%
Percent Boulder (256 to 4096 mm)	8%	29%	14%	27%	13%	40%
Percent Bedrock	0	0	0	0	0	2%
Percent fines (<6mm)	11%	7%	8%	6%	8%	6%

UTR Dominant Substrate/Fine Sediment REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Adequate	Adequate	Adequate	Adequate	Adequate	Adequate

Little Bridge Creek Assessment Results

All reaches of the LBC are cobble dominated and have fine sediments (less than 6 mm) representing from 12 to 20 percent of the surface substrate based on the 2006 stream habitat survey of LBC (USFS 2006). A high proportion of fine sediments was also noted during the 2016 geomorphic field surveys for this Project.

Based on the above rating criteria, all reaches of LBC are rated as **at risk** condition for this indicator.

LBC Percent Substrate Size Class and Surface Fine Sediments by Reach (source: USFS 2006)

Substrate Size Class	Reach 1	Reach 2	Reach 3	Reach 4
Sand (<2 mm)	10%	14%	15%	12%
Gravel (2 to 64 mm)	29%	33%	44%	28%
Cobble (64 to 256 mm)	42%	46%	37%	49%
Boulder (256 to 4096 mm)	19%	7%	4%	11%
Bedrock	0	0	0	0
Percent fines (<6 mm)	13%	16%	17%	18%

LBC Dominant Substrate/Fine Sediment REI Rating

Reach 1	Reach 2	Reach 3	Reach 4
At Risk	At Risk	At Risk	At Risk

Tributary Assessment Results

All Project tributaries are cobble or gravel dominated and have fine sediments (less than 6 mm) representing less than 12 percent of the substrate. Reynolds Creek and Canyon Creek have the greatest proportion of fine sediments at 7 and 8 percent, respectively.

Based on the above rating criteria, all Project tributaries are rated as **adequate** condition for this indicator.

Tributary Substrate Size Class Distribution and Percent Embedded by Reach

Substrate Size Class	North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
Sand (<2 mm)	0	1%	4%	1%	0	4%
Gravel (2 to 64 mm)	34%	24%	30%	29%	31%	47%
Cobble (64 to 256 mm)	40%	43%	39%	46%	44%	35%
Boulder (256 to 4096 mm)	25%	31%	25%	25%	25%	14%
Bedrock	1%	2%	3%	0	0	0
Percent fines (<6 mm)	<1%	1%	7%	2%	<1	8%

Tributary Dominant Substrate/Fine Sediment REI Rating

North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
Adequate	Adequate	Adequate	Adequate	Adequate	Adequate

INDICATOR: LARGE WOODY DEBRIS

Metric Overview

Large woody debris (LWD) provides critical habitat structure and helps create and sustain channel complexity over time. Large pieces and log jams can generate quality pools, offer refuge, and provide potential food sources for salmonids. This metric evaluates the quantity of LWD in pieces per mile. Although the federal targets for properly functioning are 20 pieces per mile (USFWS 1998), Fox and Bolton (2007) determined that standard was low since larger eastern Washington streams (16 to 164 feet bankfull width) surveyed in unmanaged forested basins had an average of 42.5 pieces per mile. In addition, other inventories on eastern Washington streams have found LWD quantities much higher at over 140 pieces per mile (Inter-Fluve 2012). The criterion of 42.5 pieces per mile was chosen for the purposes of this analysis. LWD pieces and jams were inventoried during the 2013 stream habitat survey of the UTR (USFS 2014), the geomorphic survey of LBC, and tributary habitat surveys completed for this Project in 2016.

Criteria: USFWS (1998), modified from Fox and Bolton (2007)

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Condition
Habitat Quality	Large Woody Debris (LWD)	Pieces per mile at bankfull	>42.5 pieces/mile >12 inches dbh >35 feet length; and adequate sources of woody debris available for both long- and short-term recruitment.	Current levels meet piece frequency standard for **Adequate**, but lacks potential sources from riparian areas for wood debris recruitment to maintain that standard.	Does not meet standards for **Adequate** and lacks potential large woody material recruitment.

Upper Twisp River Assessment Results

Reaches 1 through 4 and 6 of the UTR do not meet the 42.5 pieces per mile standard; however, they do have moderate future recruitment potential for large wood. Reach 5 exceeds the standards for LWD at 46 pieces per mile and also has good short- and long-term recruitment potential.

Based on the above rating criteria, Reaches 1 through 4 and 6 are rated as **unacceptable** condition for this indicator, while Reach 5 is rated as **adequate**.

UTR Large Woody Debris Pieces per Mile by Reach (source: USFS 2014)

Large Woody Debris (LWD)	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Pieces/mile	40	16	39	30	46	42
Jams/mile	8.3	2.5	7.3	4.7	6.9	4.4

UTR Large Woody Debris REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Unacceptable	Unacceptable	Unacceptable	Unacceptable	Adequate	Unacceptable

Little Bridge Creek Assessment Results

Reaches 2 through 4 of LBC do not meet the 42.5 pieces per mile standard. Recruitment potential is fair in Reach 2. Short-term recruitment potential is good in Reaches 3 and 4 but long-term recruitment potential is limited in some areas due to the recently burned riparian vegetation from the 2015 Twisp River Fire. Reach 1 of LBC does meet the 42.5 pieces per mile standard but future recruitment potential is limited from the riparian area because it consists mainly of sapling to pole-sized trees.

Based on the above rating criteria, LBC Reaches 2 through 4 are rated as **unacceptable** condition for this indicator, while Reach 1 is rated as **at risk** condition.

LBC Large Woody Debris Pieces per Mile by Reach

Large Woody Debris (LWD)	Reach 1	Reach 2	Reach 3	Reach 4
Pieces/mile	56	33	36	34

LBC Large Woody Debris REI Rating

Reach 1	Reach 2	Reach 3	Reach 4
At Risk	Unacceptable	Unacceptable	Unacceptable

Tributary Assessment Results

Reynolds Creek and Canyon Creek do not meet the 42.5 pieces per mile standard. Reynolds Creek has good future recruitment potential throughout the reach but throughout much of Canyon Creek the recruitment potential is limited because the riparian area is dominated by sapling-sized alders (ranging from 5 to 9 inches diameter at breast height [dbh]), with large, thick, patches of red osier dogwood as the understory. North Creek, South Creek, War Creek, and Eagle Creek all exceed the 42.5 pieces per mile standard, with LWD frequency ranging from 56 to 74 pieces per mile. These reaches all have good future recruitment potential as well.

Based on the above rating criteria, Reynolds Creek and Canyon Creek are rated as **unacceptable** condition for this indicator, while North Creek, South Creek, War Creek, and Eagle Creek are rated as **adequate**.

Tributary Large Woody Debris Pieces per Mile

Large Woody Debris (LWD)	North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
Pieces/mile	61.6	55.9	23.3	74.0	56.7	31.7

Tributary Large Woody Debris REI Rating

North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
Adequate	Adequate	Unacceptable	Adequate	Adequate	Unacceptable

INDICATOR: POOLS – POOL FREQUENCY AND QUALITY

Metric Overview

Pools are well recognized as providing key habitat for salmonids. Pool frequency tends to increase in lower gradient channels and with increasing abundance of wood (Montgomery et al. 1995; Beechie and Sibley 1997). In channels with high wood abundance, pool spacing is typically around one channel-width between pools. However, in steeper channels, pool spacing tends to be controlled by the formation of steps at a spacing of about two channel-widths per pool (Montgomery et al. 1995). Pools were inventoried during the 2013 stream habitat survey of the UTR (USFS 2014), the geomorphic survey of Little Bridge Creek, and tributary habitat surveys completed for this Project in 2016.

Criteria: Adapted from USFWS (1998).

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Condition
Habitat Quality	Pools	Pool Frequency and Quality	Pool frequency in a reach closely approximates: **Wetted width (ft) — #pools/mile** 0-5 — 39 5-10 — 60 10-15 — 48 15-20 — 39 20-30 — 23 30-35 — 18 35-40 — 10 40-65 — 9 65-100 — 4 Also, pools have good cover and cool water, and only minor reduction of pool volume by fine sediment.	Pool frequency is similar to values in “adequate,” but pools have inadequate cover/ temperature, and/or there has been a moderate reduction of pool volume by fine sediment.	Pool frequency is considerably lower than values desired for “functioning appropriately”; also cover/ temperature is inadequate, and there has been a major reduction of pool volume by fine sediment.

Upper Twisp River Assessment Results

Reaches 2 and 3 of the UTR do not meet the pools per mile frequency standard. The pool frequency in Reach 2 is considerably lower than the standard of 10 pools per mile at 5 pools per mile. The pool frequency in Reach 3 is similar to the standards and would meet the standard if the wetted width was slightly greater. Reaches 1 and 4 through 6 all exceed the pools per mile frequency standard. Pools in these reaches generally have good cover and cool water, with limited fine sediments in pools.

Based on the above rating criteria, Reach 2 of the UTR is rated as **unacceptable** condition for this indicator, Reach 3 is rated as **at risk,** and Reaches 1 and 4 through 6 are rated as **adequate.**

UTR Pool Characteristics by Reach (source: USFS 2014)

Pool Characteristics	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Pools/mile	18	5	18	26	30	60
Wetted Width (feet)	34	38	29	23	22	19

UTR Pool Frequency and Quality REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Adequate	Unacceptable	At Risk	Adequate	Adequate	Adequate

Little Bridge Creek Assessment Results

Reach 4 of LBC does not meet the pools per mile frequency standard. The pool frequency in Reach 4 is considerably lower than the standard of 48 pools per mile at 39 pools per mile. Reaches 1 through 3 all meet or exceed the pools per mile frequency standard. Pools in all reaches generally have fair to good cover; however, water temperatures have been previously identified as functioning at risk for the lower 3 miles of LBC (USFS 2006) and fine sediments accumulating in pools are a concern throughout all reaches.

Based on the above rating criteria, Reach 4 of LBC is rated as **unacceptable** condition for this indicator, while Reaches 1 through 3 are rated as **at risk** due to high water temperatures and fines in pools.

LBC Pool Characteristics by Reach

Pool Characteristics	Reach 1	Reach 2	Reach 3	Reach 4
Pools/mile	49	61	48	39
Wetted Width (feet)[1/]	13	13	12	10

1/ Source: USFS (2006)

LBC Pool Frequency and Quality REI Rating

Reach 1	Reach 2	Reach 3	Reach 4
At Risk	At Risk	At Risk	Unacceptable

Tributary Assessment Results

Eagle Creek pool frequencies do not meet the pools per mile frequency standard while North Creek, South Creek, Reynolds Creek, War Creek, and Canyon Creek exceed the pools per mile frequency standard. Pools in all tributary reaches generally have good cover, cool water, and limited fine sediments in pools.

Based on the above rating criteria, Eagle Creek is rated as **at risk** condition for this indicator, while North Creek, South Creek, Reynolds Creek, War Creek, and Canyon Creek are rated as **adequate**.

Tributary Pool Characteristics

Pool Characteristics	North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
Pools/mile	55.5	22.8	64.9	27.1	32.6	61.5
Wetted Width (feet)	15	23	15	23	14	10

Tributary Pool Frequency and Quality REI Rating

North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
Adequate	Adequate	Adequate	Adequate	At Risk	Adequate

INDICATOR: OFF-CHANNEL HABITAT

Metric Overview

Off-channel habitats, sloughs, wetlands, oxbow lakes, backwaters, floodplain channels, and blind and flow-through side-channels can provide important rearing habitat for juvenile salmonids (Roni et al. 2002). These areas can provide high-flow refugia, temperature refuge, and protection from predators, as well as productive feeding areas. Side channels were inventoried during the 2013 stream habitat survey of the UTR (USFS 2014), the geomorphic survey of Little Bridge Creek, and tributary habitat surveys completed for this Project in 2016 and desktop assessment using light detection and ranging (LiDAR) data.

Criteria: Modified from USFWS (1998) and USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Condition
Habitat Quality	Off-Channel Habitat	Connectivity with main channel	Reach has ponds, oxbows, backwaters, and other low-energy off-channel areas with cover, similar to conditions that would be expected in the absence of human disturbance.	Reach has some ponds, oxbows, backwaters, and other low-energy off-channel areas with cover, but availability or access is less than what would be expected in the absence of human disturbance.	Reach has few or no ponds, oxbows, backwaters, or other off-channel areas relative to what would be expected in the absence of human disturbance.

Upper Twisp River Assessment Results

Reaches 2 and 4 of the UTR have somewhat limited side channel/off-channel habitat. Side-channel and off-channel rearing habitat is limited due to the moderately confined channel and channel incision in some areas. The amount of side-channel and off-channel habitat is likely less than what would be expected in the absence of human disturbance. Reaches 1, 3, and 5 of the UTR have abundant side-channel/off-channel habitat ranging from 7.9 to 11.9 percent of the total habitat. The off-channel habitat in these reaches includes large beaver dam complexes with ponds, oxbows, and other low-energy backwater areas. Reach 6 has limited side channels and off-channel habitat but that condition is believed to be similar to conditions that would be expected in the absence of human disturbance.

Based on the above rating criteria, Reaches 2 and 4 of the UTR are rated as **at risk** condition for this indicator, while Reaches 1, 3, 5, and 6 are rated as **adequate**.

UTR Percent Side Channel Habitat by Reach (source: **USFS 2014**)

Off-Channel Habitat	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Percent Side Channels	10.6%	0.2%	11.9%	4.1%	7.9%	1.7%

UTR Connectivity with Main Channel Habitat REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Adequate	At Risk	Adequate	At Risk	Adequate	Adequate

Little Bridge Creek Assessment Results

Reaches 1, 3, and 4 of LBC have somewhat limited side-channel/off-channel habitat. Side-channel and off-channel rearing habitat is limited by channel confinement, particularly in Reach 1, and channel incision in many areas. The amount of side-channel and off-channel habitat is likely less than what would be expected in the absence of human disturbance. Reach 2 of LBC has relatively abundant side-channel/off-channel habitat including large beaver dam complexes with small ponds and abundant low-energy backwater areas.

Based on the above rating criteria, Reaches 1, 3, and 4 of LBC are rated as **at risk** condition for this indicator, while Reach 2 is rated as **adequate.**

LBC Connectivity with Main Channel Habitat REI Rating

Reach 1	Reach 2	Reach 3	Reach 4
At Risk	Adequate	At Risk	At Risk

Tributary Assessment Results

South Creek, Reynolds Creek, and War Creek have very limited off-channel habitat with no observed side channels (excluding high-flow channels). These tributary reaches are located on alluvial fans that typically have less off-channel habitat than other stream types. Alluvial fans develop where stream gradients transition from steep mountain valleys to relatively flat alluvial valley floodplains. This change causes deposition of the coarsest fraction of sediment, which builds up in the active channel and forces lateral channel movement, thus forming the fan shape. These coarse materials do not provide optimal conditions for shallow groundwater very far outside the flowing channel, thus reducing hyporheic zones and groundwater exchange. As a result, alluvial fan features generally provide sub-optimal conditions for the development and maintenance of off-channel habitat. However, the amount of side-channel/off-channel habitat found in South Creek, Reynolds Creek, and War Creek is likely less than what would be expected in the absence of human disturbance from roads, stream crossings, timber harvest, mining activities and camping located on the existing fans. North Creek and Canyon Creek have limited off-channel habitat with 3 to 4 percent of the total habitat identified as side channels, respectively. Eagle Creek has relatively abundant side channel/off-channel habitat including several low-energy side channels and backwater areas.

Based on the above rating criteria, South Creek, Reynolds Creek, and War Creek are rated as **unacceptable** condition for this indicator, North Creek and Canyon Creek are rated as **at risk,** and Eagle Creek is rated as **adequate** condition. Due to the location of these tributary reaches on alluvial fans, additional analyses may be needed during project development to ensure appropriate restoration designs are implemented to address the specific conditions at each site.

Tributary Percent Side Channel Habitat

Off-Channel Habitat	North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
Percent Side Channels	3%	0	0	0	18%	4%

Tributary Connectivity with Main Channel Habitat REI Rating

North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
At Risk	Unacceptable	Unacceptable	Unacceptable	Adequate	At Risk

5. PATHWAY: CHANNEL FORMS AND PROCESSES

INDICATOR: CHANNEL DYNAMICS – FLOODPLAIN CONNECTIVITY

Metric Overview

Floodplains serve a number of significant geomorphic and ecological functions including conveyance of flood waters, sediment source and storage, supply of large wood, and development of diverse habitat for aquatic and terrestrial species (e.g., Allen 1970; Zwolinski 1992; Nanson and Croke 1992). Floodplain connectivity was evaluated based on field observations of channel incision, wetland and riparian function, and evidence of overbank flows.

Criteria: Modified from USFWS (1998).

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Condition
Channel	Dynamics	Floodplain Connectivity	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession.	Reduced linkage of wetlands, floodplains, and riparian areas to main channel; overbank flows are reduced relative to historical frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession.	Severe reduction in hydrologic connectivity between off-channel wetland, floodplain, and riparian areas; wetland extent drastically reduced and riparian vegetation/succession altered significantly.

Upper Twisp River Assessment Results

Reach 2 of the UTR has somewhat limited floodplain connectivity. Overbank flows are reduced relative to historical frequency in some areas due to channel incision. Reaches 1 and 3 through 6 of the UTR contain areas that are naturally confined and have limited floodplains or have floodplains that are hydrologically linked to the main channel, with evidence of frequent overbank flows, and high functioning riparian areas. The floodplains in Reaches 1 and 3 in particular include large beaver dam complexes and high functioning riparian areas.

Based on the above rating criteria, Reach 2 of the UTR is rated as **at risk** condition for this indicator, while Reaches 1, and 3 through 6 are rated as **adequate**.

UTR Floodplain Connectivity REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Adequate	At Risk	Adequate	Adequate	Adequate	Adequate

Little Bridge Creek Assessment Results

Reaches 1 and 4 of LBC have limited floodplain connectivity and riparian functions due to channel incision in many areas. In these areas, the overbank flows are limited relative to historical frequency and riparian functions are reduced. Most of Reach 2 has a well-connected floodplain, partly due to multiple beaver dam complexes, but there are areas of incision and disconnected floodplain downstream end of the reach. Reach 3 of LBC is slightly incised in isolated areas but has good floodplain connectivity and riparian function in most areas.

Based on the above rating criteria, all reaches of LBC are rated as **at risk** condition for this indicator.

LBC Floodplain Connectivity REI Rating

Reach 1	Reach 2	Reach 3	Reach 4
At Risk	At Risk	At Risk	At Risk

Tributary Assessment Results

The tributaries assessed for this Project (except Canyon Creek) are flowing from narrow valleys across alluvial fans to the confluence with the Twisp River. Because of this landscape position, the typical channel-floodplain morphology is not expected in the natural condition. The presence of road crossings on North Creek, Reynolds Creek, War Creek, and Eagle Creek limit the natural migration of these tributaries across the alluvial fan, likely resulting in channel incision in isolated areas; however, field evidence indicates relatively frequent overbank flows throughout most of the tributary reaches.

Based on the above rating criteria, all tributary reaches are rated as **adequate** condition.

Tributary Floodplain Connectivity REI Rating

North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
Adequate	Adequate	Adequate	Adequate	Adequate	At Risk

INDICATOR: BANK STABILITY/CHANNEL MIGRATION

Metric Overview

Channel migration and bank erosion are natural processes that maintain river habitats by recruiting substrate and LWD, and introducing new channel dynamics. Natural channel migration rates are a result of numerous physical and biological processes including the hydrologic regime, underlying geology, sediment supply, streambank vegetation, and floodplain hydraulic roughness. Human actions can affect these processes, which subsequently can alter channel migration rates and erosion locations. Bank armoring, levee construction, and channelization both restrict flow to generally more straightened paths and limit where erosion can occur; water withdrawals and dams can alter the hydrologic regime, affecting when and how much water interacts with the channel margins; and changes in riparian vegetation such as removal of streambank vegetation and development within the floodplain can affect channel migration rates. Eroding banks were identified during the 2013 stream habitat survey of the UTR (USFS 2014), the 2006 stream habitat survey of LBC (USFS 2006), and tributary habitat surveys completed for this Project in 2016.

Criteria: From USBR (2012)

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Condition
Channel	Dynamics	Bank Stability/ Channel Migration	Channel is migrating at or near natural rates.	Limited amount of channel migration is occurring at a faster/slower rate relative to natural rates, but significant change in channel width or planform is not detectable; large woody debris is still being recruited.	Little or no channel migration is occurring because of human actions preventing reworking of the floodplain and large woody debris recruitment; or channel migration is occurring at an accelerated rate such that channel width has a least doubled, possibly resulting in a channel planform change, and sediment supply has noticeably increased from bank erosion.

Upper Twisp River Assessment Results

Historical and current channel migration rates have not been determined for the UTR; therefore, this indicator was evaluated based on field observations of channel incision and the presence of armored or eroding banks. There are no artificially armored streambanks limiting channel migration in any of the UTR reaches. Reach 2 is incised and has the highest proportion of eroding banks at 10.3 percent. Channel incision and associated bed and bank armoring are likely impacting the natural rate of channel migration in this reach. Reaches 1 and 3 through 6 have relatively low bank erosion rates from 0.8 percent in Reach 6 to 6.0 percent in Reach 3. The low bank erosion rates are likely due to the naturally boulder-armored streambanks in this relatively confined, high-gradient reach.

Based on the above rating criteria, Reach 2 of the UTR is rated as **at risk** condition for this indicator, while Reaches 1 and 3 through 6 are rated as **adequate**.

UTR Bank Characteristics by Reach (source: USFS 2014)

Bank Characteristics	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Percent Eroding Banks	4.5%	10.3%	6.0%	3.5%	2.0%	0.8%

UTR Bank Stability/ Channel Migration REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Adequate	At Risk	Adequate	Adequate	Adequate	Adequate

Little Bridge Creek Assessment Results

Historical and current channel migration rates have not been determined for LBC; therefore, this indicator was evaluated based on field observations of channel incision and the presence of armored or eroding banks. The percentage of eroding banks is very low (less than 1.8 percent) in LBC Reaches 1, 2, and 4. Roads and road crossings limit channel migration in isolated areas. Particularly in Reach 4, the NF-4415 Road confines the creek and limits channel migration potential. Channel incision and channel bed and bank armoring also limit the channel migration potential in Reaches 1, 2, and 4. Reach 3 of LBC has no roads or road crossings confining the creek but is slightly incised in isolated areas. The percent of eroding banks was higher in Reach 3 than other reaches at 3.3 percent.

Based on the above rating criteria, Reaches 1, 2, and 4 of LBC are rated as **at risk** condition for this indicator, while Reach 3 is rated as **adequate.**

UTR Bank Characteristics by Reach (source: USFS 2006)

Bank Characteristics	Reach 1	Reach 2	Reach 3	Reach 4
Percent Eroding Banks	1.1%	1.8%	3.3%	0.8%

LBC Bank Stability/Channel Migration REI Rating

Reach 1	Reach 2	Reach 3	Reach 4
At Risk	At Risk	Adequate	At Risk

Tributary Assessment Results

Channel migration typically occurs through channel avulsions resulting in dramatic changes in course across the alluvial fan in the tributary reaches (except Canyon Creek). The presence of road crossings on North Creek, Reynolds Creek, War Creek, and Eagle Creek limits the natural migration of these tributaries across the alluvial fan but no change in channel width or planform is detectable. Channel incision is limiting channel migration in South Creek although a log jam forming near the head of the fan has the potential to aggrade the channel bed and cause an avulsion in the near future. Channel incision, roads, road crossings, and diversion structures are limiting channel migration in Canyon Creek, although the channel is moderately confined throughout the reach limiting the extent of natural lateral migration. Bank erosion rates in the tributaries were relatively low, ranging from 0.9 percent in Eagle Creek to 6.7 percent in North Creek.

Based on the above rating criteria, all tributary reaches are rated as **at risk** condition for this indicator.

Tributary Bank Characteristics by Reach

Bank Characteristics	North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
Percent Eroding Banks	6.7%	5.2%	3.4%	2.2%	0.9%	6.1%

Tributary Bank Stability/ Channel Migration REI Rating

North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
At Risk	At Risk	At Risk	At Risk	At Risk	At Risk

INDICATOR: VERTICAL CHANNEL STABILITY

Metric Overview

Under natural conditions, alluvial river systems tend toward a balanced state in which some erosion and deposition occurs during sediment transporting events but no net change in dimension, pattern, and profile over the course of years. These systems are frequently referred to as regime channels and are in a state of dynamic equilibrium in which there is a continuous inflow and output of water and sediment. Changes in the conditions including sediment supply, channel form modification, flow, or bank strength can upset the balance leading to higher rates and a trend of aggradation or incision. This can result in disconnection from the floodplain due to incision. Channel form modification can be the result of human actions including bank armoring, removal of riparian vegetation, levee building, channel straightening, and channelization, which can reduce vertical channel stability. Vertical channel instability was evaluated, in part, by the calculated entrenchment ratio from the 2013 stream habitat survey of the UTR (USFS 2014), the 2006 stream habitat survey of LBC (USFS 2006), and tributary habitat surveys completed for this Project in 2016.

Criteria: From USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Condition
Channel	Dynamics	Vertical Channel Stability	No measurable trend of aggradation or incision and no visible change in channel planform.	Measurable trend of aggradation or incision that has the potential to but not yet caused disconnection of the floodplain or a visible change in channel planform (e.g., single thread to braided).	Enough incision that the floodplain and off-channel habitat areas have been disconnected; or, enough aggradation that a visible change in channel planform has occurred (e.g., single thread to braided).

Upper Twisp River Assessment Results

The channel is incised in Reach 2 of the UTR and has an average entrenchment ratio of 1.85. The incision has not resulted in a complete disconnection of the floodplain or identifiable change in channel planform. Reaches 1 and 3 through 6 do not appear to exhibit a measurable trend of aggradation or incision and no visible change in channel planform and have reach average entrenchment ratios ranging from 1.41 (naturally confined reach) in Reach 6 to 5.50 in Reach 3.

Based on the above rating criteria, Reach 2 of the UTR is rated as **at risk** condition for this indicator, while Reaches 1 and 3 through 6 are rated as **adequate.**

UTR Entrenchment Ratio by Reach (source: USFS 2014)

Incision Characteristics	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Entrenchment Ratio[1/]	5.06	1.85	5.50	2.40	2.58	1.41

1/ Floodprone width divided by the bankfull width

UTR Vertical Channel Stability REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Adequate	At Risk	Adequate	Adequate	Adequate	Adequate

Little Bridge Creek Assessment Results

Reaches 1 and 4 of LBC have reduced vertical channel stability due to channel incision in many areas but no visible change in channel planform. Most of Reach 2 is not incised and has a well-connected floodplain, partly due to multiple beaver dam complexes, but there are areas of incision in the downstream end of the reach. Reach 3 of LBC is slightly incised in isolated areas but has good floodplain connectivity in most areas. Reach average entrenchment ratios are relatively low in all reaches of LBC ranging from 1.92 in Reach 1 to 2.88 in Reach 2.

Based on the above rating criteria, all reaches of LBC are rated as **at risk** condition for this indicator.

LBC Entrenchment Ratio by Reach (source: USFS 2006)

Incision Characteristics	Reach 1	Reach 2	Reach 3	Reach 4
Entrenchment Ratio1/	1.92	2.88	2.30	2.14

1/ Floodprone width divided by the bankfull width.

LBC Vertical Channel Stability REI Rating

Reach 1	Reach 2	Reach 3	Reach 4
At Risk	At Risk	At Risk	At Risk

Tributary Assessment Results

The tributaries assessed for this Project (except Canyon Creek) are flowing from narrow valleys across alluvial fans to the confluence with the Twisp River. This landscape position makes these reaches particularly prone to periods of vertical channel instability in the natural condition. There are no known measurable trend of aggradation or incision or visible change in channel planform as a result of vertical channel stability in the tributary reaches. Reach average entrenchment ratios in the tributaries were relatively high, ranging from 1.36 in North Creek to 8.66 in North Creek.

Based on the above rating criteria, all tributary reaches are rated as **adequate** condition for this indicator.

Tributary Entrenchment Ratio by Reach

Incision Characteristics	North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
Entrenchment Ratio	1.36	2.31	4.68	5.06	8.66	2.68

1/ Floodprone width divided by the bankfull width.

Tributary Vertical Channel Stability REI Rating

North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
Adequate	Adequate	Adequate	Adequate	Adequate	Adequate

6. PATHWAY: RIPARIAN CONDITION

INDICATOR: STRUCTURE

Metric Overview

Riparian areas have many important geomorphic and ecological roles within the river system. Intact riparian corridors help maintain streambank stability, provide large wood material, water filtration processes, organic input, streamside habitat and cover, hydraulic regulation, and temperature fluctuation modification (Gregory et al. 1991). The structure of riparian areas indicates how intact the riparian system is currently. This metric is evaluated based on how well the seral stage, species composition, and complexity approximate natural conditions that would be expected in the absence of human alterations. The analysis of riparian structure used a combination of data collected during the reach assessment survey and data from the 2013 stream habitat survey of the UTR (USFS 2014), the 2006 stream habitat survey of LBC (USFS 2006), and professional judgement evaluating LiDAR mapping of canopy height and potential fire impacts.

Criteria: From USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Riparian Vegetation	Condition	Structure	>80% species composition, seral stage, and structural complexity are consistent with potential native community.	50-80% species composition, seral stage, and structural complexity are consistent with potential native community.	<50% species composition, seral stage, and structural complexity are consistent with potential native community.

Upper Twisp River Assessment Results

The riparian areas of the UTR are owned by the USFS and managed according to the Aquatic Conservation Strategy guidelines included in the Northwest Forest Plan (USFS 1994a and 2006) for protecting and restoring riparian and aquatic habitat. The non-wilderness portion of the Twisp River watershed above the confluence with Buttermilk Creek has been designated as Late-Successional Reserve under the Northwest Forest Plan, managed to enhance habitat for late-successional and old growth–related species (USFS 2014). In general, all reaches of the UTR have species composition, seral stage, and structural complexity consistent with a potential native community, although more patches of mature cottonwoods and conifers would be expected under unaltered conditions.

Based on the above rating criteria, all reaches of the UTR are rated as **adequate** condition for this indicator.

UTR Riparian Structure REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Adequate	Adequate	Adequate	Adequate	Adequate	Adequate

Little Bridge Creek Assessment Results

The structure of the riparian areas of LBC has been impacted by past timber harvesting, cattle grazing, and fires including the recent 2015 Twisp River Fire. Timber harvest has occurred throughout the LBC reaches including a relatively recent clearcut harvest. Much of the riparian vegetation in Reaches 1 through 3 is dominated by sapling-sized alders and red osier dogwood. The riparian area in Reaches 3 and 4, upstream of RM 4.2, was also recently burned in some areas during the 2015 Twisp River Fire. The unburned riparian area of Reach 4 contains a riparian structure and complexity that is more consistent with a potential native community.

Based on the above rating criteria, Reaches 1 through 3 of LBC are rated as **unacceptable** condition for this indicator, while Reach 4 is rated as **at risk.**

LBC Riparian Structure REI Rating

Reach 1	Reach 2	Reach 3	Reach 4
Unacceptable	Unacceptable	Unacceptable	At Risk

Tributary Assessment Results

The non-wilderness portion of the Twisp River watershed above the confluence with Buttermilk Creek (including North Creek, South Creek, Reynolds Creek, War Creek, and Eagle Creek) has been designated as Late-Successional Reserve under the Plan, managed to enhance habitat for late-successional and old growth–related species (USFS 2014). In general, these tributaries have species composition, seral stage, and structural complexity consistent with a potential native community, although more patches of mature cottonwoods and conifers would be expected under unaltered conditions. North Creek has been impacted by previous mining including several cleared areas for an abandoned an ore mill (USFS 1995). Canyon Creek has a mixture of good riparian structure and composition near the Twisp River confluence with less structure and composition upstream dominated by sapling-sized alders and red osier dogwood. Past timber harvest in the 1980s and 1990s removed riparian vegetation to the channel banks in parts of the survey reach and in upstream reaches (USFS 1994b).

Based on the above rating criteria, South Creek, Reynolds Creek, War Creek, and Eagle Creek are rated as **adequate** condition for this indicator, while North Creek and Canyon Creek are rated as **at risk**.

Tributary Riparian Structure REI Rating

North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
At Risk	Adequate	Adequate	Adequate	Adequate	At Risk

INDICATOR: DISTURBANCE (HUMAN)

Metric Overview

Human disturbance changes how a river interacts with its floodplain and riparian areas. Often, human disturbance in the floodplain results in reduced occurrence of mature seral stages of vegetation and riparian structure, and limits channel migration and erosion processes. This can affect riparian processes including bank stability, wood recruitment, shade, and water quality. Riparian disturbance was assessed using observations made during the reach assessment survey and data from the 2013 stream habitat survey of the UTR (USFS 2014), the 2006 stream habitat survey of LBC (USFS 2006), and an analysis of road densities within the 100-year floodplain for the UTR. Road density was calculated using an ArcGIS layer developed by compiling all open roads from USFS, Esri Streetmap, and Okanogan County roads shapefiles.

Criteria: From USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Condition
Riparian Vegetation	Condition	Disturbance (human)	>80% mature trees (medium-large) in the riparian buffer zone (defined as a 30-meter [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 mile (mi)/mi^2 road density in the floodplain.	50-80% mature trees (medium-large) in the riparian buffer zone (defined as a 30-m belt along each bank) that are available for recruitment by the river via channel migration; 20-50% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); 2-3 mi/mi^2 road density in the floodplain.	<50% mature trees (medium-large) in the riparian buffer zone (defined as a 30-m belt along each bank) that are available for recruitment by the river via channel migration; >50% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); >3 mi/mi^2 road density in the floodplain.

Upper Twisp River Assessment Results

Human disturbance in the UTR reaches is limited. The area is owned by the USFS and does not contain agriculture or residential development. The road density in the UTR floodplain is relatively low at 1.4 miles per square mile. Roads that parallel the UTR are generally outside of the riparian zone not impacting riparian habitat. Disturbance on the floodplain is also limited and the area is designated as Late-Successional Reserve and managed to enhance habitat for late-successional and old growth–related species (USFS 2014). There are a number of USFS campgrounds and dispersed campsites along the UTR.

Based on the above rating criteria, all reaches of the UTR are rated as **adequate** condition for this indicator.

UTR Disturbance (Human) REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Adequate	Adequate	Adequate	Adequate	Adequate	Adequate

Little Bridge Creek Assessment Results

Timber harvest has occurred throughout the LBC reaches including a relatively recent clearcut harvest. Cattle have grazed in the riparian areas of LBC in the past. Several large dispersed campgrounds and numerous smaller sites are found in the LBC drainage (USFS 2006). Reaches 1 through 3 of LBC are estimated to have riparian areas with less than 50 percent mature trees. Reach 4 of LBC is estimated to have between 50 and 80 percent mature trees in the riparian area.

Based on the above rating criteria, Reaches 1 through 3 of LBC are rated as **unacceptable** condition for this indicator, while Reach 4 is rated as **at risk**.

LBC Disturbance (Human) REI Rating

Reach 1	Reach 2	Reach 3	Reach 4
Unacceptable	Unacceptable	Unacceptable	At Risk

Tributary Assessment Results

Human disturbance on South Creek, Reynolds Creek, War Creek, and Eagle Creek is limited. The area is owned by the USFS and does not contain agriculture or residential development. On North Creek, there is an abandoned mining facility and associated roads and cleared areas that have resulted in higher levels of human disturbance (USFS 1995). Canyon Creek has been more impacted by human disturbance than the other tributaries. Past timber harvest in the 1980s and 1990s removed riparian vegetation to the channel banks in parts of the survey reach and in upstream reaches (USFS 1994b). Cattle have also grazed in the riparian area of Canyon Creek of the stream in the past. There are also dispersed campsites on many of the tributary reaches. Road density in the floodplain is low in all tributary reaches.

Based on the above rating criteria, South Creek, Reynolds Creek, War Creek, and Eagle Creek are rated as **adequate** condition for this indicator, while North Creek and Canyon Creek are rated as **at risk**.

Tributary Disturbance (Human) REI Rating

North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
At Risk	Adequate	Adequate	Adequate	Adequate	At Risk

INDICATOR: CANOPY COVER

Metric Overview

Riparian canopies provide shade and moderate light availability and quality to the stream and riverbed. This affects water temperature and algae growth. Water temperature is a main driver of the health, productivity, and life cycles of many aquatic organisms, including salmonids. High water temperatures during the summer and fall can often be a factor limiting habitat quality for rearing and spawning salmonids. Canopy cover for the UTR and tributaries was estimated by identifying the area of canopy coverage using the first return data from the 2016 LiDAR dataset. A canopy height of greater than 15 feet was selected to calculate the canopy coverage area. The percentage canopy cover is based on the extent of canopy closure within riparian areas (100-foot buffer approximating one site potential tree height), not the percentage of the stream that is covered.

Criteria: Modified from USFWS (1998) and USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Condition
Riparian	Condition	Canopy Cover	Trees and shrubs within one site potential tree height distance have >80% canopy cover that provides thermal shading to the river.	Trees and shrubs within one site potential tree height distance have 50-80% canopy cover that provides thermal shading to the river.	Trees and shrubs within one site potential tree height distance have <50% canopy cover that provides thermal shading to the river.

Upper Twisp River Assessment Results

The calculated canopy cover in Reaches 1 and 3 of the UTR are less than 50 percent at 45 and 48 percent, respectively. Reaches 2 and 4 through 6 have canopy cover estimates ranging from 50 percent in Reach 5 to 58 percent in Reach 4.

Based on the above rating criteria, Reaches 1 and 3 of the UTR are rated as **unacceptable** condition for this indicator, while Reaches 2 and 4 through 6 are rated as **at risk**.

UTR Canopy Cover Percentage within 100 Feet of Stream Bank

Canopy Cover	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Percent coverage	45	57	48	58	50	57

UTR Canopy Cover REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Unacceptable	At Risk	Unacceptable	At Risk	At Risk	At Risk

Little Bridge Creek Assessment Results

The 2016 LiDAR data do not cover the LBC and therefore canopy cover was not calculated. Based on field observations made in the LBC and the calculated canopy cover in the UTR and the other tributaries, it is estimated that all of reaches of the LBC have canopy cover ranging from 50 to 80 percent.

Based on the above rating criteria, all reaches of the LBC are rated as **at risk** condition.

LBC Canopy Cover REI Rating

Reach 1	Reach 2	Reach 3	Reach 4
At Risk	At Risk	At Risk	At Risk

Tributary Assessment Results

The calculated canopy in the tributaries ranges from 54 percent in South Creek to 68 percent in Canyon Creek.

Based on the above rating criteria, all tributaries are rated as **at risk** condition.

Tributary Canopy Cover Percentage within 100 Feet of Stream Bank

Canopy Cover	North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
Percent coverage	57	54	62	62	67	68

Tributary Canopy Cover REI Rating

North Creek	South Creek	Reynolds Creek	War Creek	Eagle Creek	Canyon Creek
At Risk	At Risk	At Risk	At Risk	At Risk	At Risk

7. REFERENCES

Allen, J.R.L. 1970. *Physical Processes of Sedimentation: An Introduction.* American Elsevier Company. New York, NY.

Beechie, T.J., and T.H. Sibley. 1997. Relationships between channel characteristics, woody debris, and fish habitat in northwestern Washington streams. *Transactions of the American Fisheries Society* 126(2):217-229, doi:10.1577/1548-8659(1997)126<0217:rbccwd>2.3.co;2.

Boulton, A.J., S. Findlay, P. Marmonier, E.H. Stanley, and M. Valett. 1998. The functional significance of the hyporheic zone in streams and rivers. *Annual Review of Ecological Systems* 29: 59–81.

CIG (Climate Impacts Group). 2009. The Washington climate change impacts assessment: Evaluating Washington's future in a changing climate. Edited by J.S. Littell, M.M. Elsner, L.C. Whitely, Binder, and A.K. Snover. Climate Impacts Group, University of Washington, Seattle, Washington.

Fox, M.J., and S.M. Bolton. 2007. A regional and geomorphic reference for quantities and volumes of instream wood in unmanaged forested basins of Washington State. *North American Journal of Fisheries Management* 27(1):342–359.

Goode, J.R., C.H. Luce, and J.M Buffington. 2011. Enhanced sediment delivery in a changing climate in semi-arid mountain basins: Implications for water resource management and aquatic habitat in the northern Rocky Mountains. *Geomorphology* doi:10.1016/j.geomorph.2011.06.021.

Gregory, S.V., F.J. Swanson, A.K. Mckee, and K.W. Cummins. 1991. An ecosystem perspective of riparian zones. *Bioscience* 41(8):540–551.

Henley, W.F., M.A. Patterson, R.J. Neves, and D.A. Lemly. 2000. Effects of sedimentation and turbidity on lotic food webs: A concise review for natural resource managers. *Reviews in Fisheries Science* 2:125–139.

Inter-Fluve. 2012. Upper Wenatchee River Stream Corridor Assessment and Habitat Restoration Strategy. Prepared for Yakama Nation Fisheries. August. Toppenish, WA.

Lisle, T.E. 1989. Sediment transport and resulting deposition in spawning gravels, north coastal California. *Water Resources Research* 25(6):1303–1319.

Montgomery, D.R. 1994. Road surface drainage, channel initiation, and slope instability. 1994. *Water Resources Research* 30(6).

Montgomery, D.R., J.M. Buffington, R.D. Smith, K.M. Schmidt, and G. Pess. 1995. Pool spacing in forest channels. *Water Resources Research* 31(4):1097–1105, doi:10.1029/94wr03285.

Mote, P.W., and E.P. Salanthe, Jr. 2009. Future climate in the Pacific Northwest. In the Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate, Climate Impacts Group, University of Washington. Seattle, WA.

Nakamura, F., F.J. Swanson, and S.M. Wondzell. 2000. Disturbance regimes of stream and riparian systems – a disturbance-cascade perspective. *Hydrological Processes* 14:2849-2860.

Nanson, G.C., and J.C. Croke. 1992. A genetic classification of floodplains. *Geomorphology* 4:459-486.

NMFS (National Marine Fisheries Service). 1996. Making Endangered Species Act determinations of effect for individual or grouped actions at the watershed scale. Lacey, Washington, National Marine Fisheries Service, Environmental and Technical Services Division, Habitat Conservation Branch.

Reid, L.M., and T. Dunne. 1984. Sediment production from forest road surfaces. *Water Resources Research* 20(11):1753–1761, doi:10.1029/WR020i011p01753.

Roni, P., T.J. Beechie, R.E. Bilby, F.E. Leoneti, M.M. Pollock, and G.R. Pess. 2002. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. *North American Journal of Fisheries Management* 22:1-20.

USBR (U.S. Bureau of Reclamation). 2012. Lower Entiat Reach Assessment. U.S. Bureau of Reclamation Pacific Northwest Region, Boise, ID, U.S. Department of the Interior.

USFS (U.S. Department of Agriculture Forest Service and Bureau of land Management). 1994a. Record of Decision (ROD) for the Amendments to Forest Service and Bureau of Land Management Planning Documents within the Range of the Northern Spotted Owl. USDA Forest Service and BLM, Washington, D.C.

USFS. 1994b. Canyon Creek: 1993 Stream Survey. Performed as part of the Twisp River Watershed monitoring process. Okanogan National Forest, Twisp Ranger District. Twisp, WA.

USFS. 1995. Twisp River Tributaries: 1994 Stream Survey Report. Okanogan National Forest, Twisp Ranger District. Twisp, WA.

USFS. 2004. Record of Decision. Amending Resource Management Plans for Seven Bureau of Land Management Districts and Land and Resource Management Plans for Nineteen National Forests within the Range of the Northern Spotted Owl: Decision to clarify provisions relating to the Aquatic Conservation Strategy. USDA Forest Service, Portland, Oregon, and BLM, Moscow, Idaho.

USFS. 2006. Little Bridge Creek Stream Report 2006. Okanogan National Forest, Twisp Ranger District. Twisp, WA.

USFS. 2014. Twisp River Stream Survey Report 2013. Okanogan National Forest, Twisp Ranger District. Twisp, WA.

USFS. 2016. Stream Inventory Handbook, Level I & II. Pacific Northwest Region 6, Version 2.16.

USFWS (U.S. Fish and Wildlife Service). 1998. A Framework to assist in making Endangered Species Act determinations of effect for individual or grouped actions at the Bull Trout subpopulation watershed scale. USFWS, Department of the Interior.

Waples, R., T. Beechie, and G.R. Pess. 2009. Evolutionary history, habitat disturbance regimes, and anthropogenic changes: what do these mean for resilience of Pacific Salmon populations? *Ecology and Society* 14(1):3.

Ward, J.V. 1998. Riverine landscapes: biodiversity patterns, disturbance regimes, and aquatic conservation. *Biological Conservation* 83(3): 269–278.

Waters, T.F. 1995. Sediment in Streams: sources, biological effects, and control. American Fisheries Society, Monograph 7. Bethesda, MD.

Wemple, B.C., J.A. Jones, and G.E. Grant. 1996. Channel network extension by logging roads in two basins, western Cascades, Oregon. *Water Resources Bulletin* 32(6).

Wood, P.J., and P.D. Armitage. 1997. Biological effects of fine sediment in the lotic environment. *Environmental Management* 21(2):203–217.

Zwolinski, Z. 1992. Sedimentology and geomorphology of overbank flows on meandering river floodplains. *Geomorphology* 4(6):367–379.

APPENDIX F

Potential Project Opportunities

List of Figures

List of Tables

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- River Mile
- LWD Types
  - Bank Jam
  - Mid-Channel Jam
  - Supplement Existing LWD
- Side Channel
- Tributary
- Road Crossing
- Road Fill

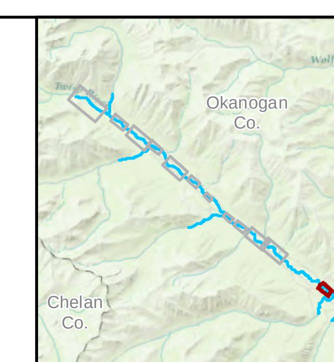
2006 LiDAR Relative Elevation Model
High : 110
Low : 95.9

Figure F-1a. Upper Twisp River
Project Area 1: RM 17.8 - RM 18.2

Sheet 1 of 24

1:1,500

0 200 400
Feet



- River Mile
- LWD Types
  - Bank Jam
  - Mid-Channel Jam
  - Supplement Existing LWD
- Side Channel
- Tributary
- Road Crossing
- Road Fill

Figure F-1b. Upper Twisp River
Project Area 1: RM 17.8 - RM 18.2

Sheet 2 of 24

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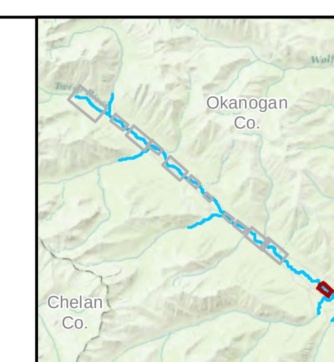

- River Mile

LWD Types

- Bank Jam
- Mid-Channel Jam
- Supplement Existing LWD
- Side Channel
- Tributary

- Road Crossing
- Road Fill

2006 LiDAR Relative Elevation Model

High : 110

Low : 95.9

Figure F-1c. Upper Twisp River
Project Area 2: RM 20.1 - RM 20.9

Sheet 3 of 24

N E W S

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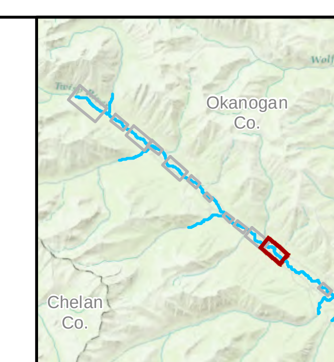
Feet



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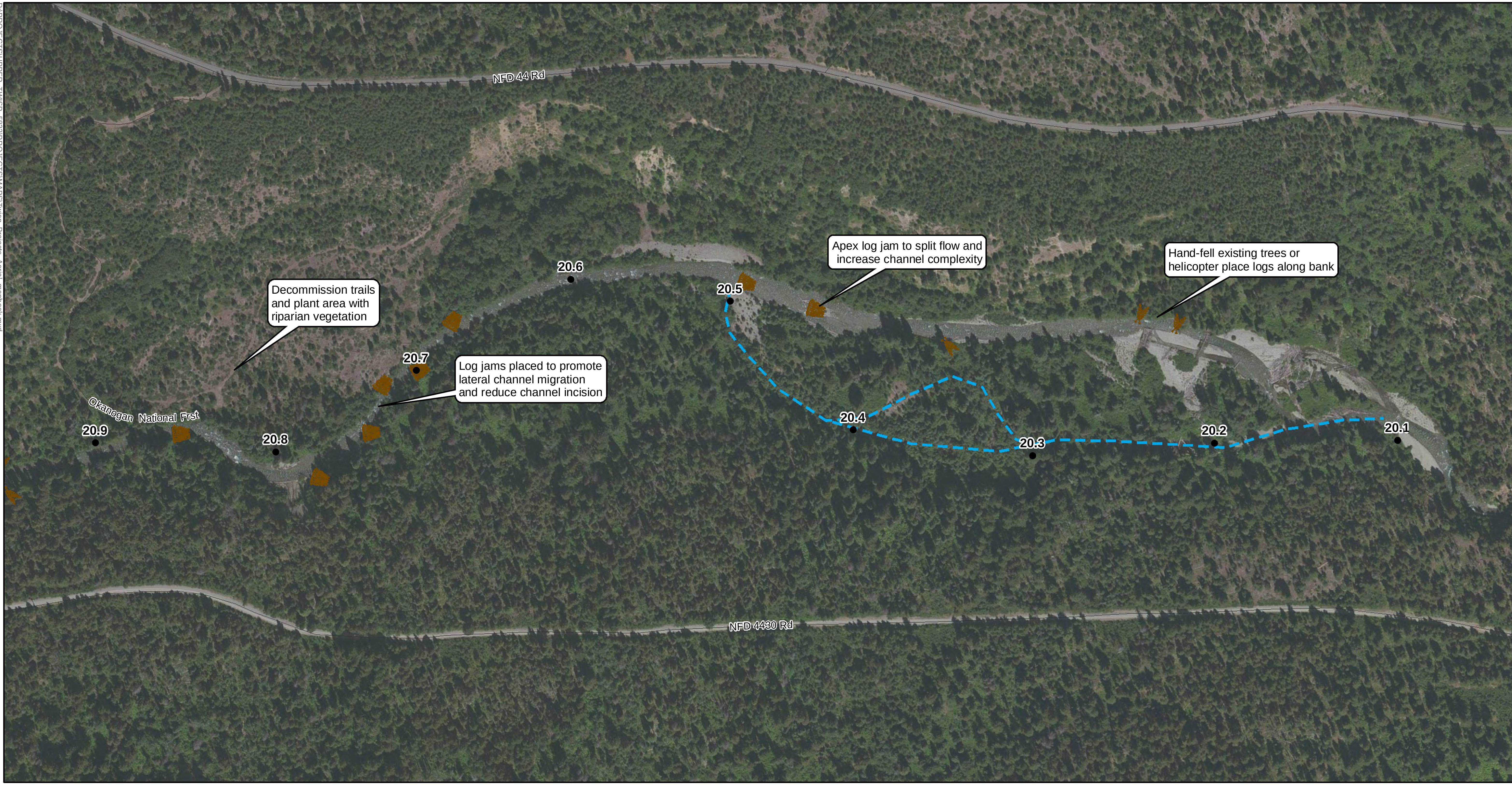

- River Mile
- LWD Types
  - Bank Jam
  - Mid-Channel Jam
  - Supplement Existing LWD
- Side Channel
- Tributary
- Road Crossing
- Road Fill

Figure F-1d. Upper Twisp River
Project Area 2: RM 20.1 - RM 20.9

Sheet 4 of 24

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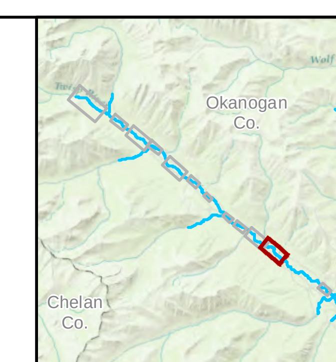
Feet



River Mile

LWD Types

Bank Jam

Mid-Channel Jam

Supplement Existing LWD

Side Channel

Tributary

Road Crossing

Road Fill

2006 LiDAR Relative Elevation Model

High : 110

Low : 95.9

Figure F-1e. Upper Twisp River
Project Area 3: RM 20.9 - RM 21.6

Sheet 5 of 24

N E W S

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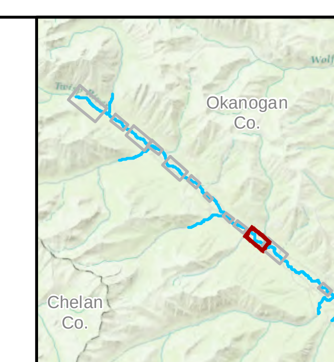
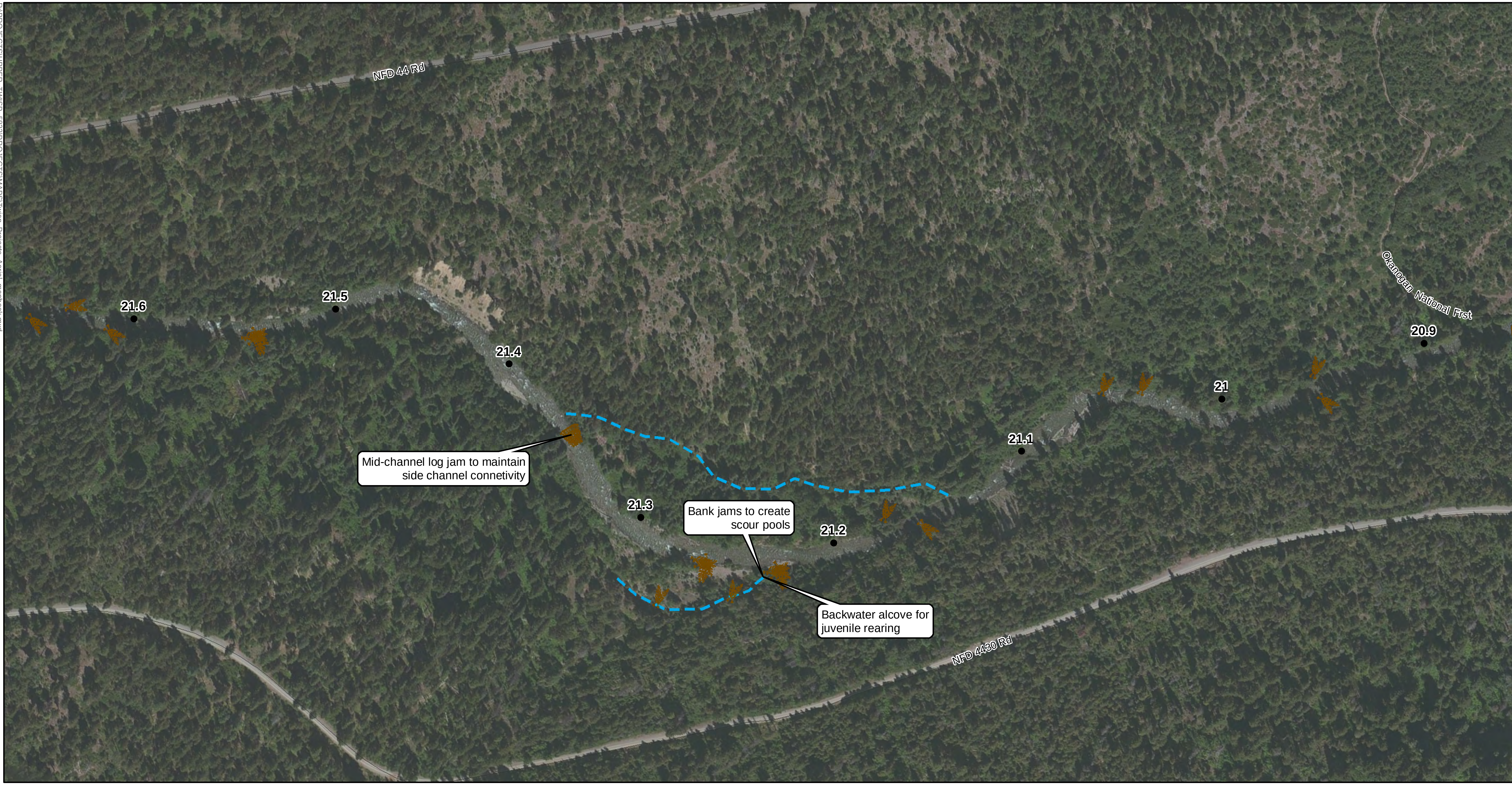
Feet





River Mile

LWD Types

Bank Jam

Mid-Channel Jam

Supplement Existing LWD

Side Channel

Tributary

Road Crossing

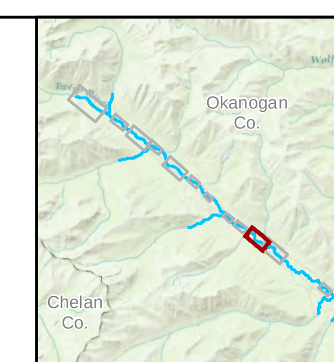
Road Fill

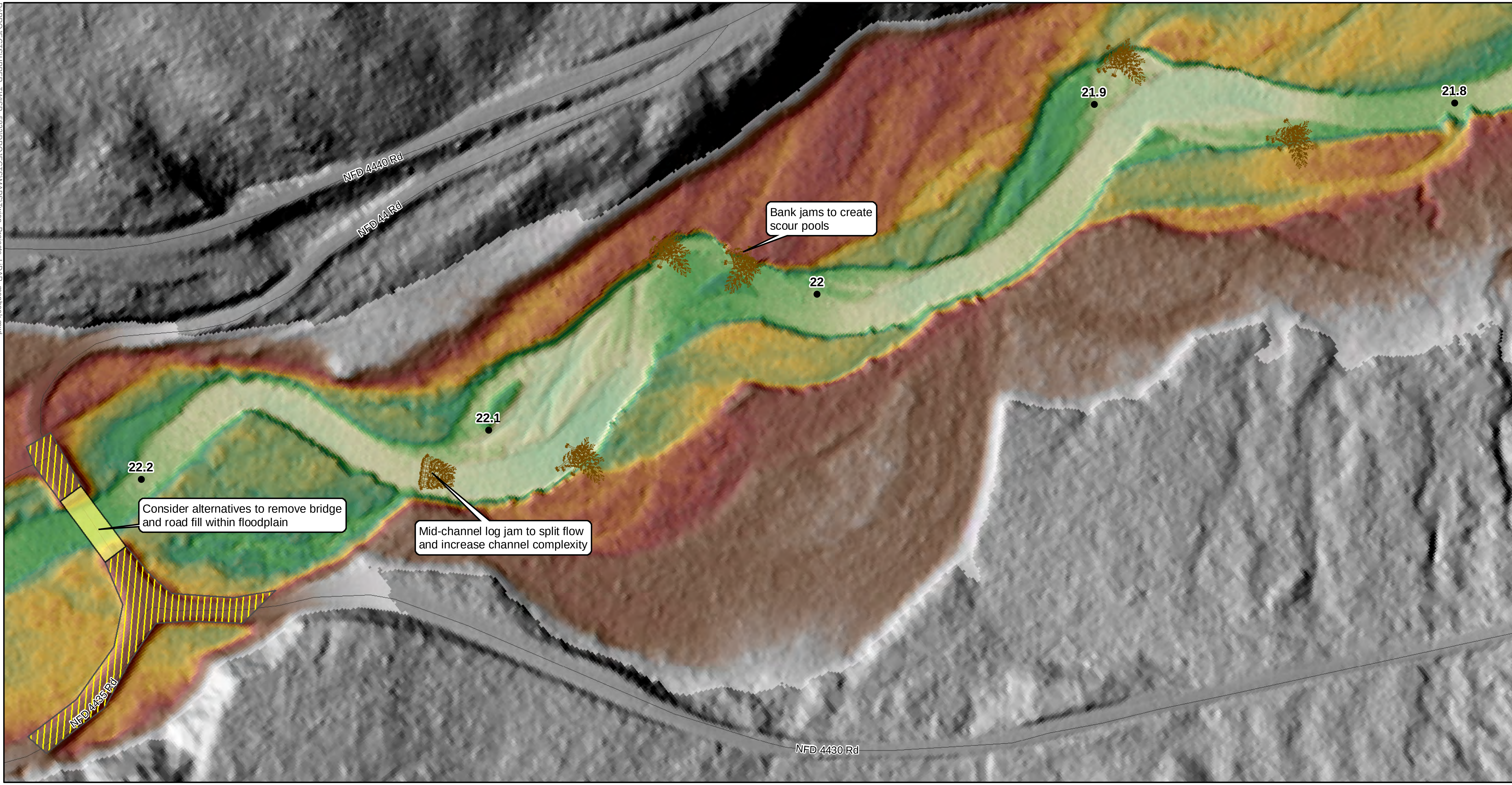
Figure F-1f. Upper Twisp River
Project Area 3: RM 20.9 - RM 21.6

Sheet 6 of 24

1:2,800

0 200 400
Feet





River Mile
LWD Types
Bank Jam
Mid-Channel Jam
Supplement Existing LWD
Side Channel
Tributary

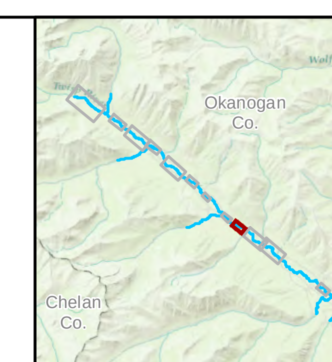
Road Crossing
Road Fill
2006 LiDAR Relative Elevation Model
High : 110
Low : 95.9

Figure F-1g. Upper Twisp River
Project Area 4: RM 21.8 - RM 22.2

Sheet 7 of 24

1:1,600

0 200 400
Feet



River Mile
LWD Types
Bank Jam
Mid-Channel Jam
Supplement Existing LWD
Side Channel
Tributary

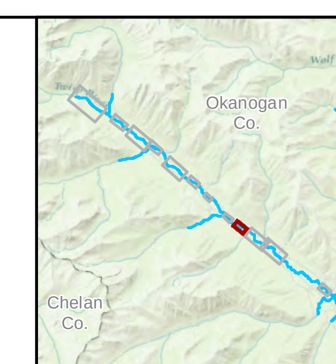
Road Crossing
Road Fill

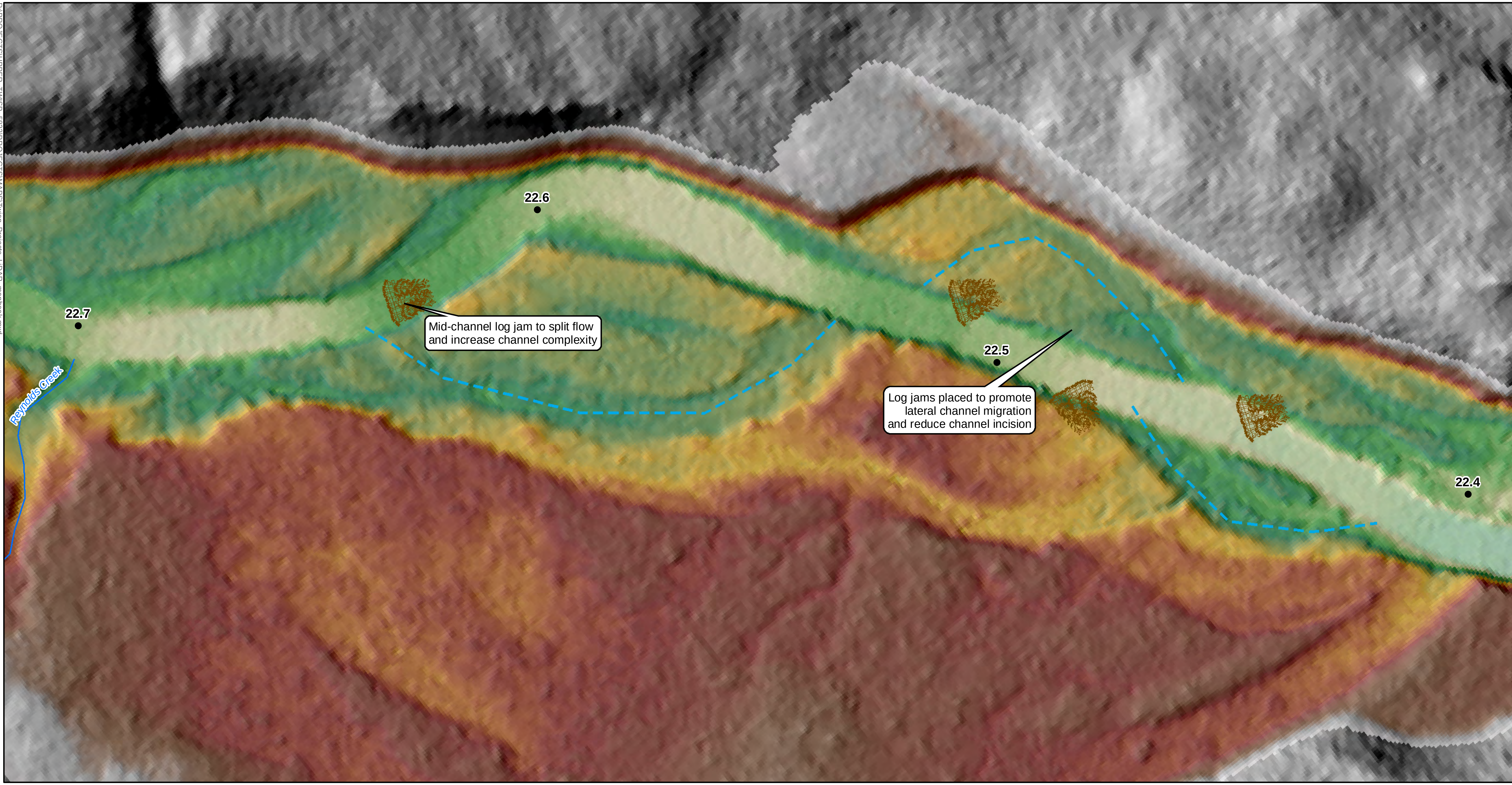
Figure F-1h. Upper Twisp River
Project Area 4: RM 21.8 - RM 22.2

Sheet 8 of 24

1:1,600

0 200 400
Feet





- River Mile
- LWD Types
  - Bank Jam
  - Mid-Channel Jam
  - Supplement Existing LWD
- Side Channel
- Tributary
- Road Crossing
- Road Fill

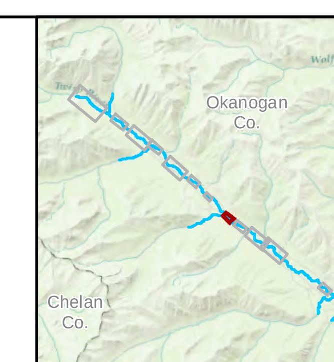
2006 LiDAR Relative Elevation Model
High : 110
Low : 95.9

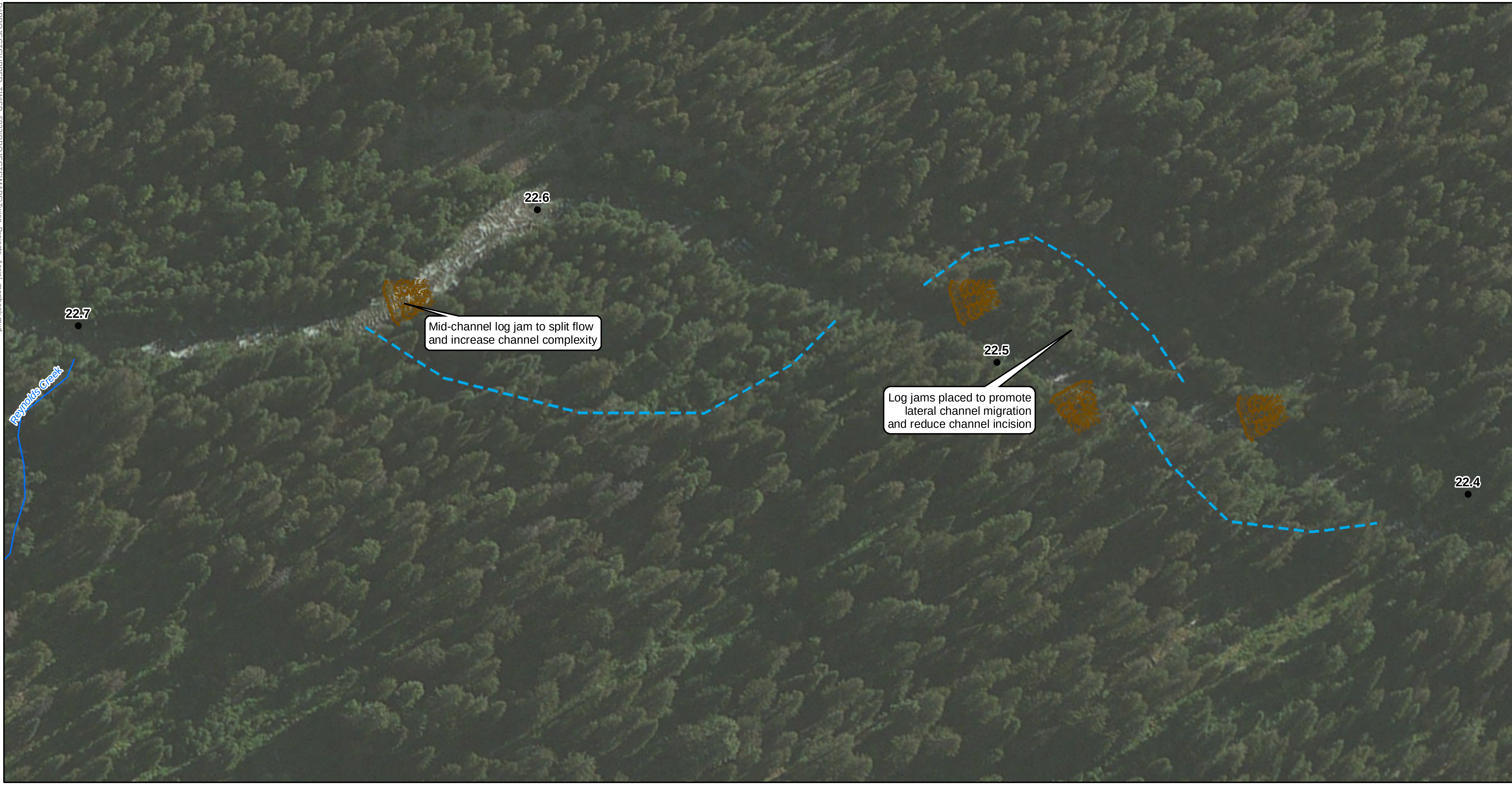
Figure F-1i. Upper Twisp River
Project Area 5: RM 22.4 - RM 22.7

Sheet 9 of 24

1:1,200

0 200 400
Feet





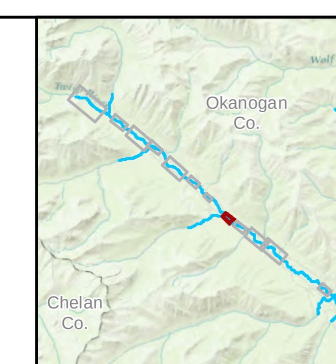
- River Mile
- LWD Types
  - Bank Jam
  - Mid-Channel Jam
  - Supplement Existing LWD
- Side Channel
- Tributary
- Road Crossing
- Road Fill

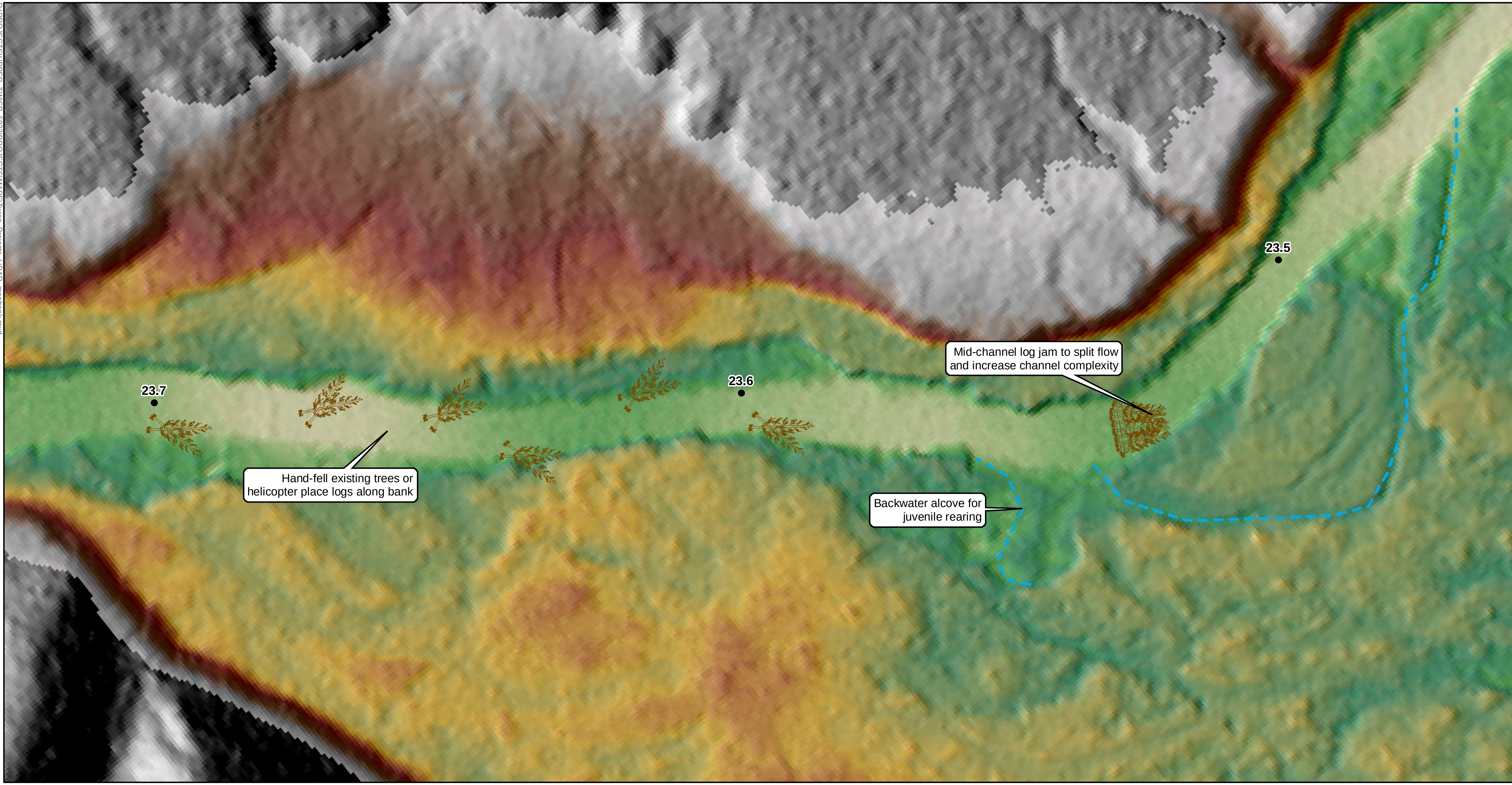
Figure F-1j. Upper Twisp River
Project Area 5: RM 22.4 - RM 22.7

Sheet 10 of 24

1:1,200

0 200 400
Feet





River Mile
LWD Types
Bank Jam
Mid-Channel Jam
Supplement Existing LWD
Side Channel
Tributary

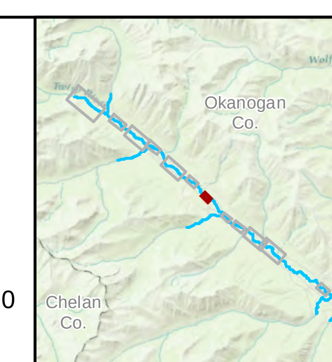
Road Crossing
Road Fill
2006 LiDAR Relative Elevation Model
High : 110
Low : 95.9

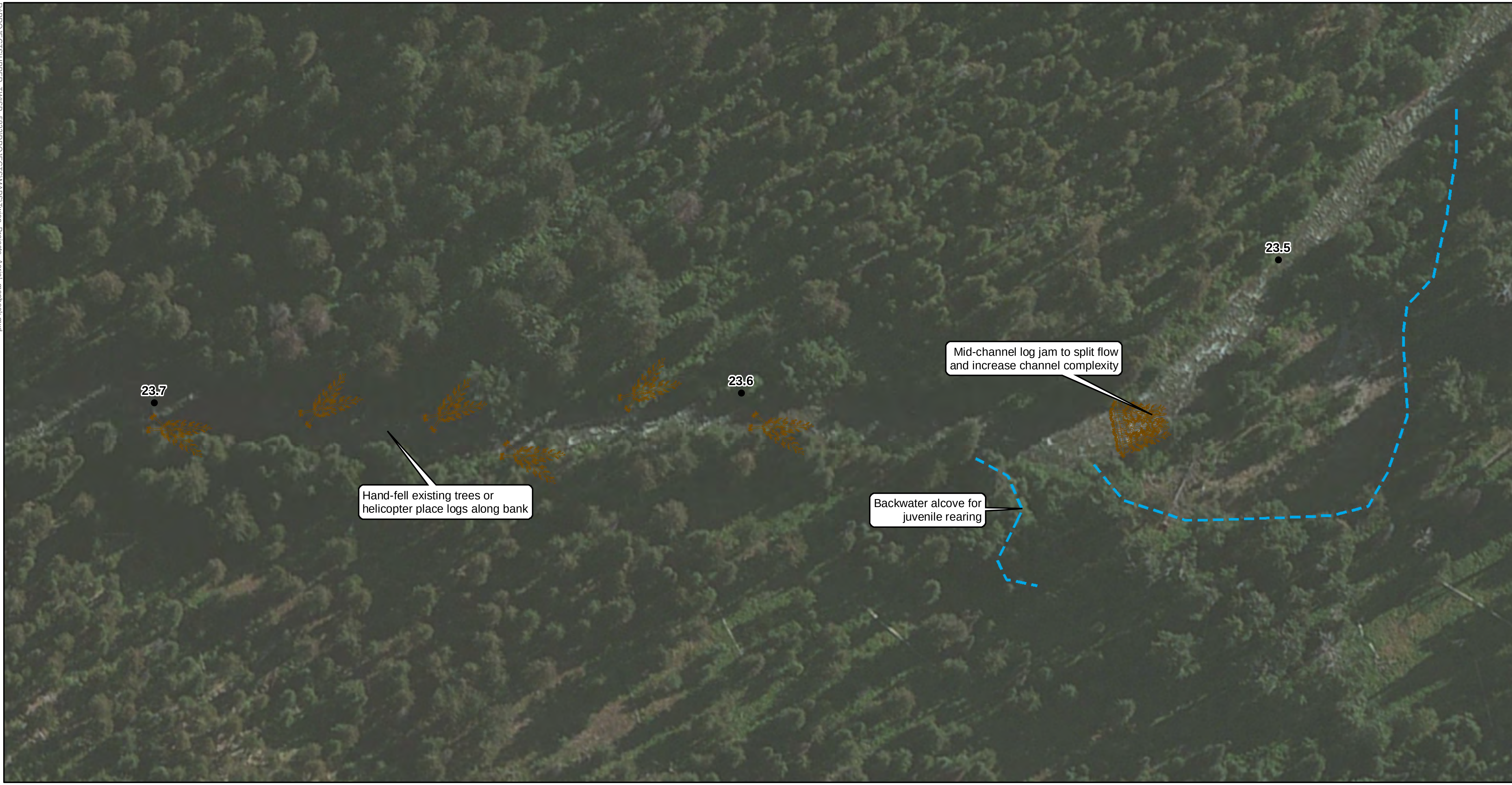
Figure F-1k. Upper Twisp River
Project Area 6: RM 23.5 - RM 23.7

Sheet 11 of 24

1:1,000

0 200 400
Feet





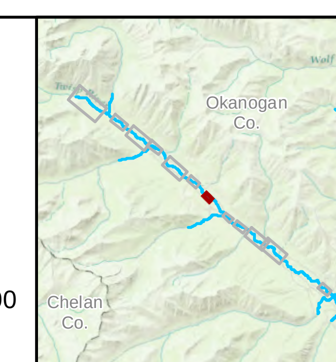
River Mile
LWD Types
Bank Jam
Mid-Channel Jam
Supplement Existing LWD
Side Channel
Tributary
Road Crossing
Road Fill

Figure F-1l. Upper Twisp River
Project Area 6: RM 23.5 - RM 23.7

Sheet 12 of 24

1:1,000

0 200 400
Feet



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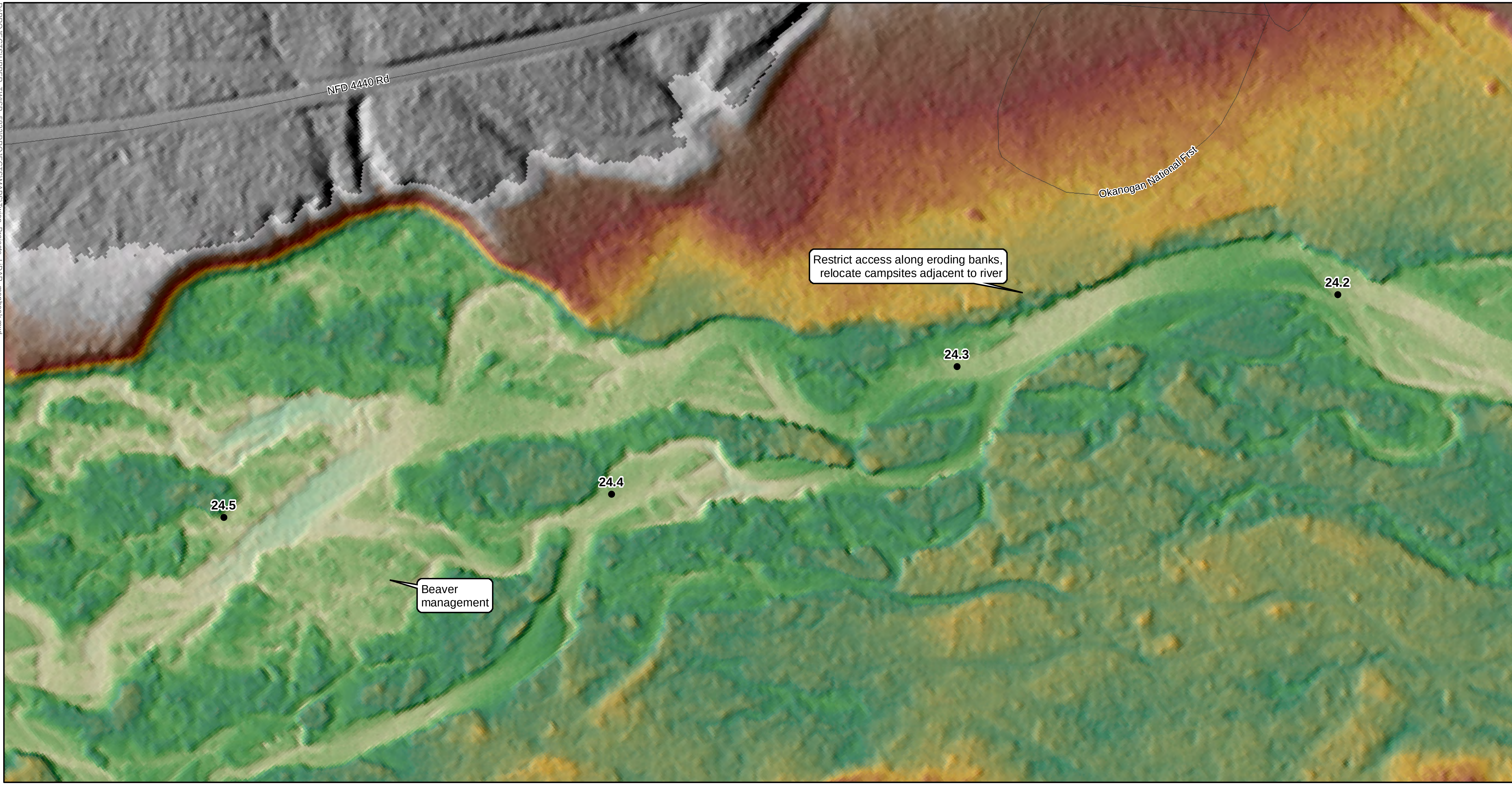


River Mile
LWD Types
Bank Jam
Mid-Channel Jam
Supplement Existing LWD
Side Channel
Tributary

Road Crossing
Road Fill
2006 LiDAR Relative Elevation Model
High : 110
Low : 95.9

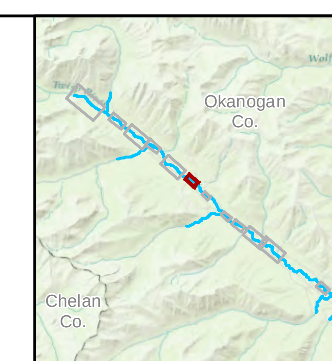
Figure F-1m. Upper Twisp River
Project Area 7: RM 24.2 - RM 24.5

Sheet 13 of 24

N E W S

1:1,500

0 200 400
Feet



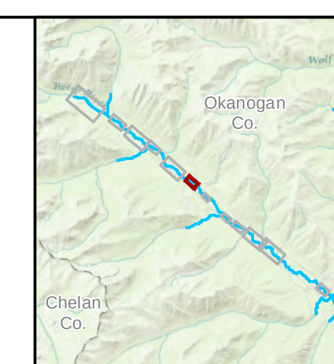
- River Mile
- LWD Types
  - Bank Jam
  - Mid-Channel Jam
  - Supplement Existing LWD
- Side Channel
- Tributary
- Road Crossing
- Road Fill

Figure F-1n. Upper Twisp River
Project Area 7: RM 24.2 - RM 24.5

1:1,500

0 200 400
Feet

Sheet 14 of 24



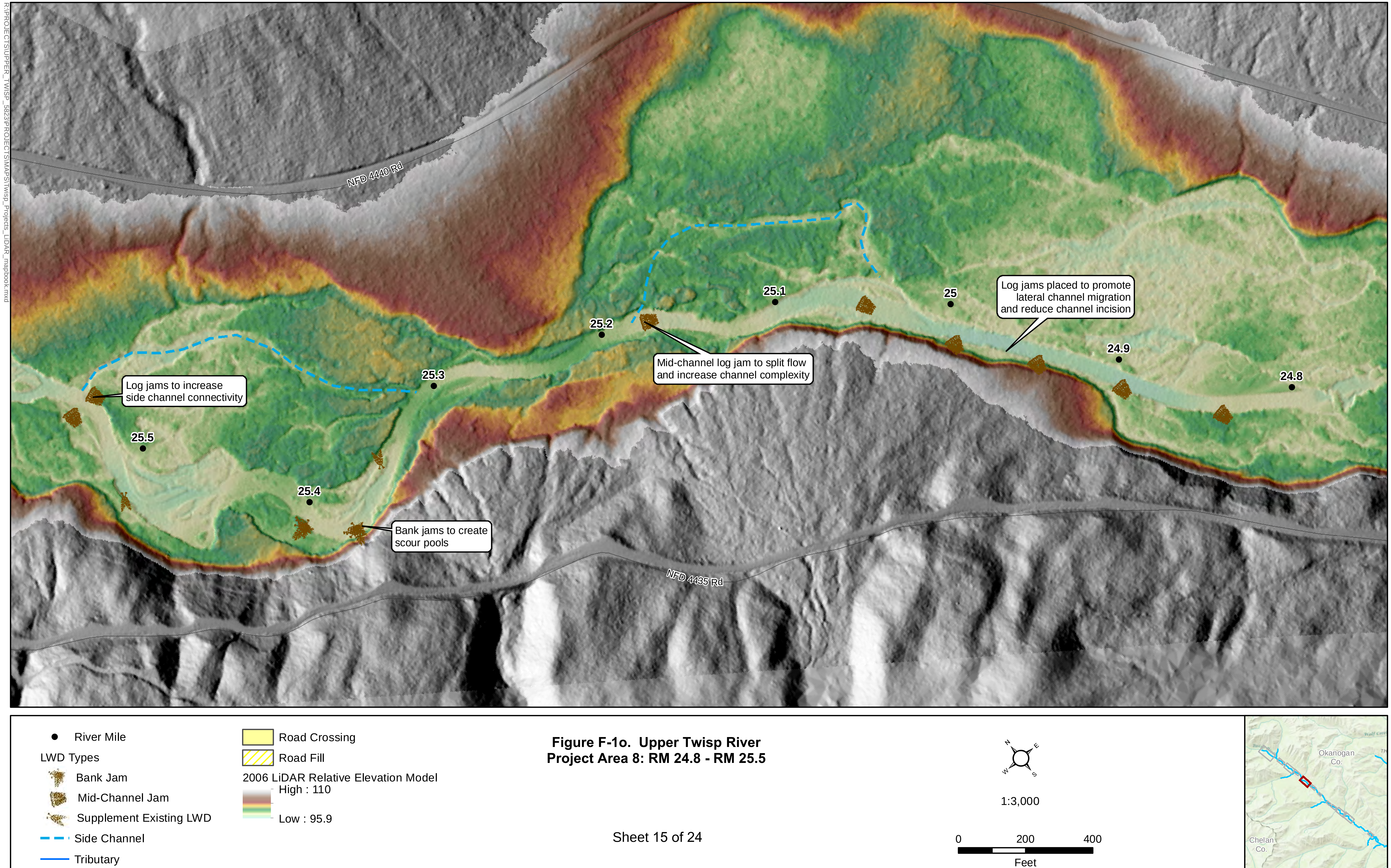
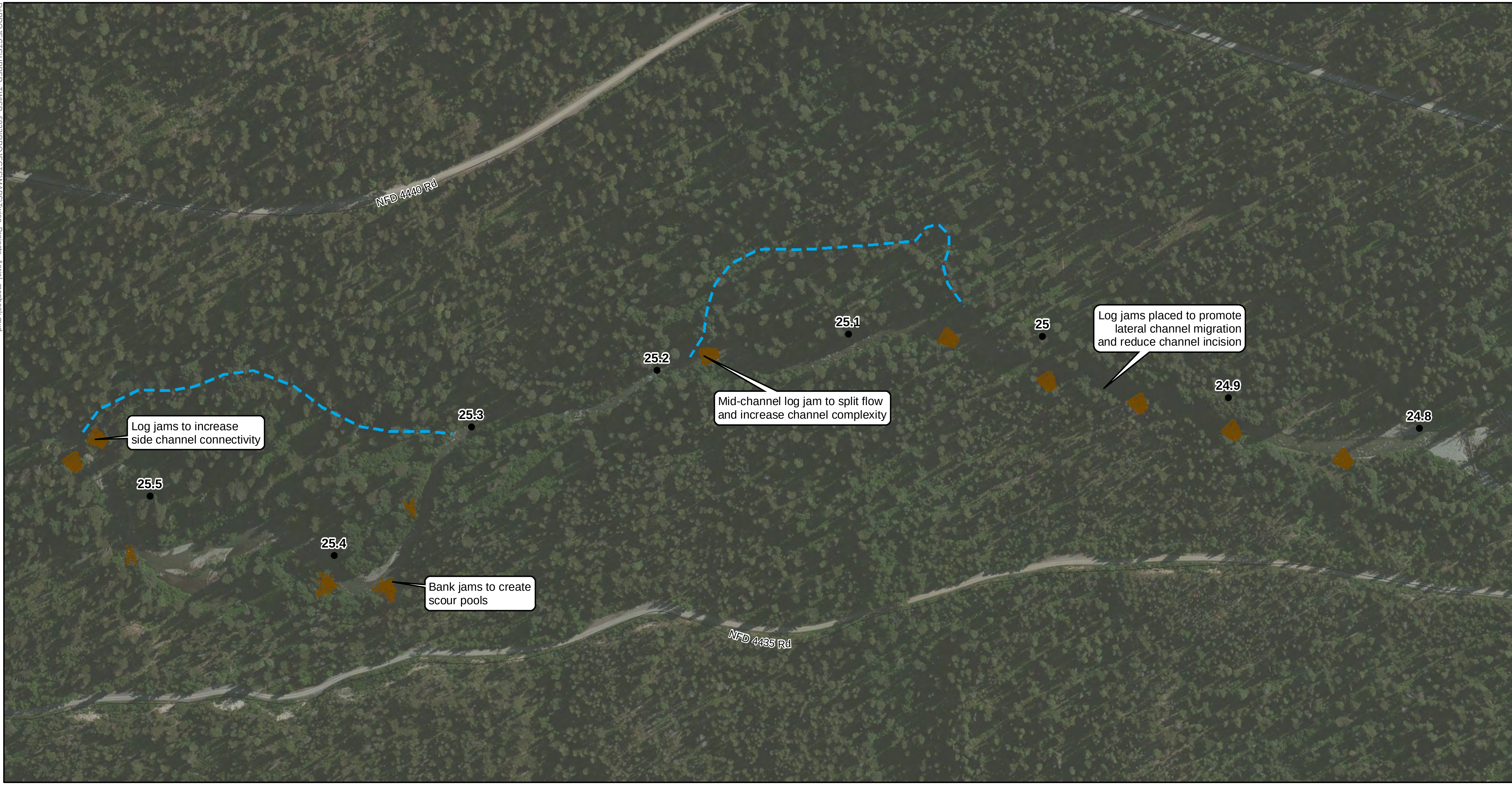


Figure F-1o. Upper Twisp River
Project Area 8: RM 24.8 - RM 25.5

Sheet 15 of 24



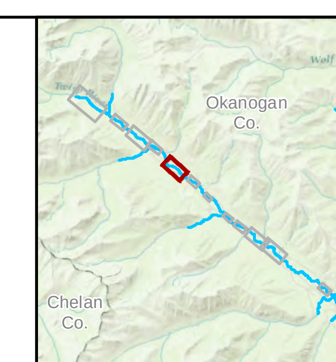
- River Mile
- LWD Types
  - Bank Jam
  - Mid-Channel Jam
  - Supplement Existing LWD
- Side Channel
- Tributary
- Road Crossing
- Road Fill

Figure F-1p. Upper Twisp River
Project Area 8: RM 24.8 - RM 25.5

Sheet 16 of 24

1:3,000

0 200 400
Feet



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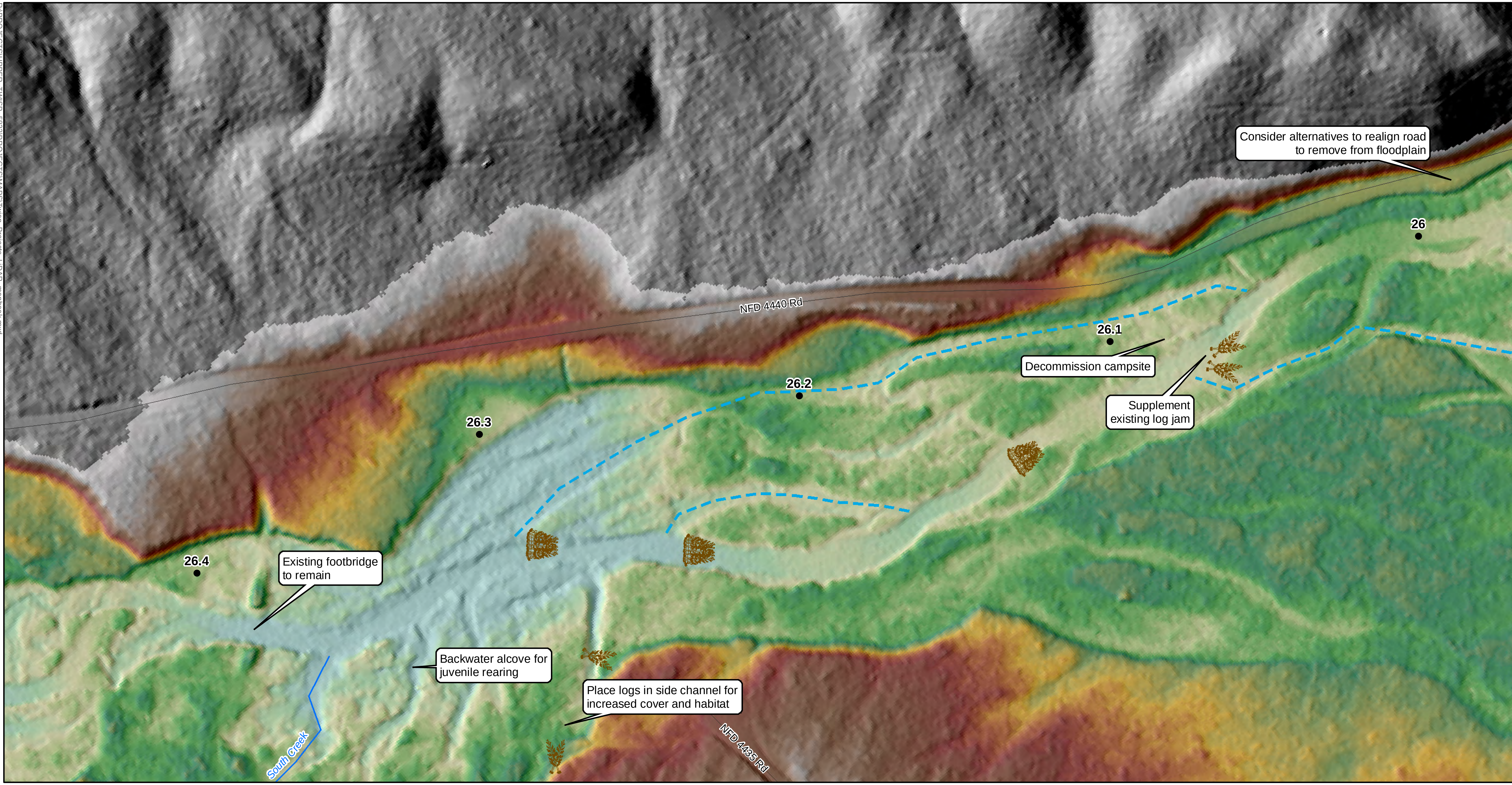


River Mile
LWD Types
Bank Jam
Mid-Channel Jam
Supplement Existing LWD
Side Channel
Tributary

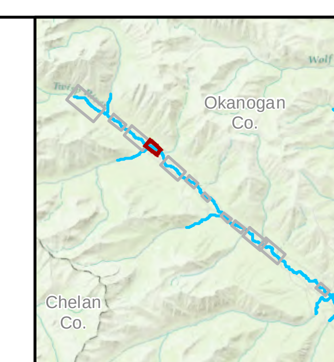
Road Crossing
Road Fill
2006 LiDAR Relative Elevation Model
High : 110
Low : 95.9

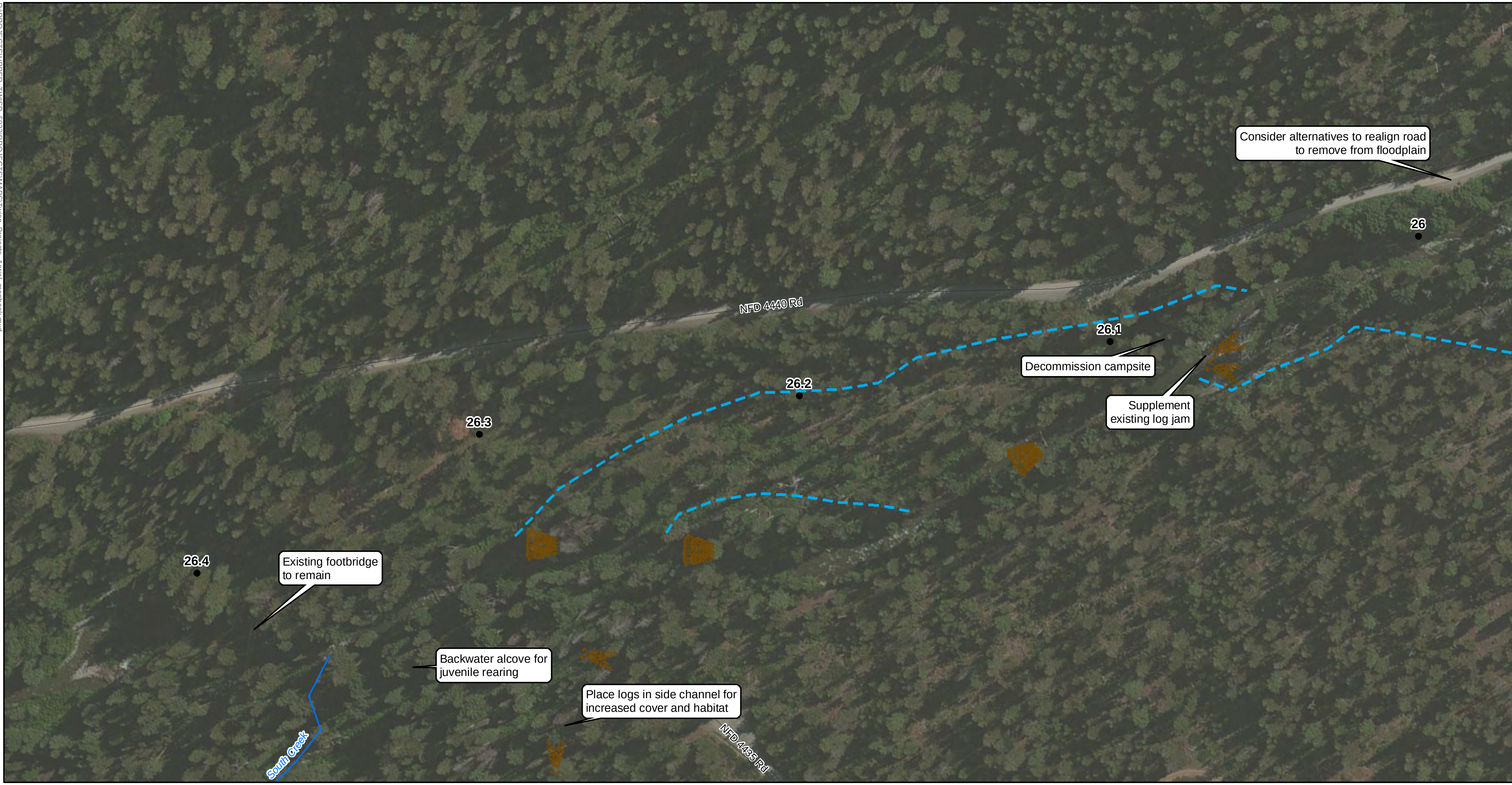
Figure F-1q. Upper Twisp River
Project Area 9: RM 26 - RM 26.4

Sheet 17 of 24

1:1,800

0 200 400
Feet





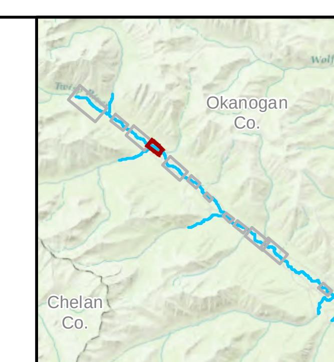
- River Mile
- LWD Types
  - Bank Jam
  - Mid-Channel Jam
  - Supplement Existing LWD
- Side Channel
- Tributary
- Road Crossing
- Road Fill

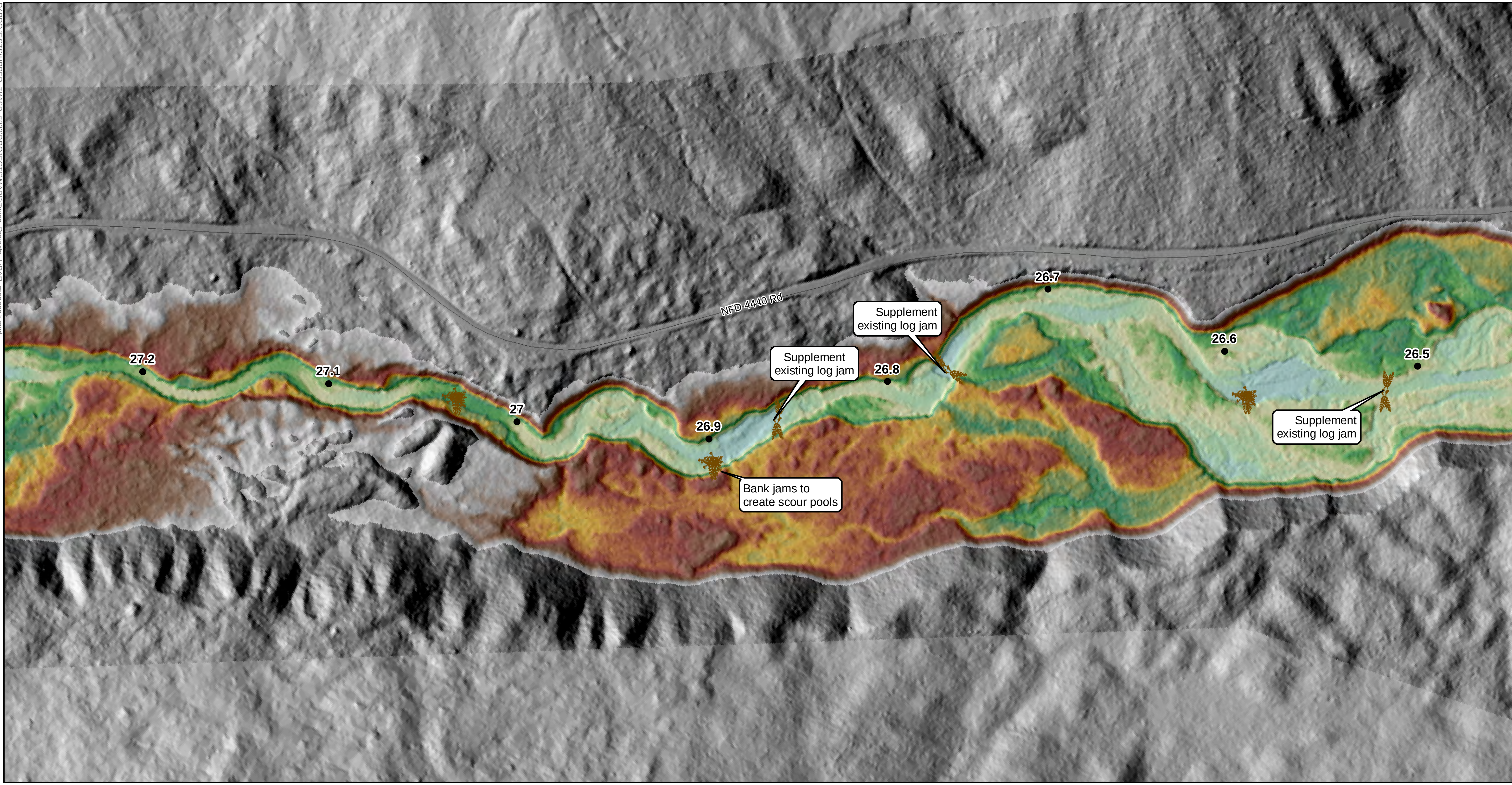
Figure F-1r. Upper Twisp River
Project Area 9: RM 26 - RM 26.4

Sheet 18 of 24

1:1,800

0 200 400
Feet





River Mile

LWD Types

Bank Jam

Mid-Channel Jam

Supplement Existing LWD

Side Channel

Tributary

Road Crossing

Road Fill

2006 LiDAR Relative Elevation Model

High : 110

Low : 95.9

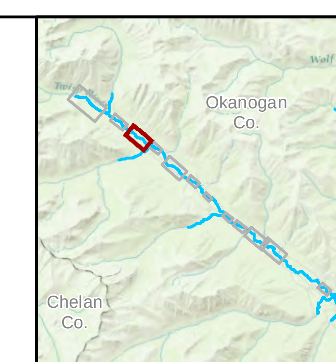
Figure F-1s. Upper Twisp River
Project Area 10: RM 26.5 - RM 27.2

Sheet 19 of 24

1:3,000

0 200 400

Feet



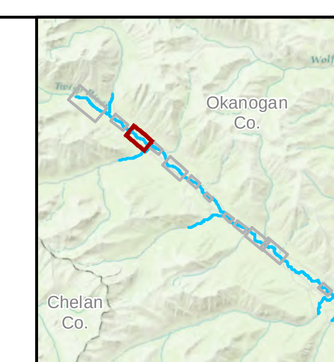
River Mile
LWD Types
Bank Jam
Mid-Channel Jam
Supplement Existing LWD
Side Channel
Tributary
Road Crossing
Road Fill

Figure F-1t. Upper Twisp River
Project Area 10: RM 26.5 - RM 27.2

Sheet 20 of 24

1:3,000

0 200 400
Feet



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River Mile

LWD Types

Bank Jam

Mid-Channel Jam

Supplement Existing LWD

Side Channel

Tributary

Road Crossing

Road Fill

2006 LiDAR Relative Elevation Model

High : 110

Low : 95.9

Figure F-1u. Upper Twisp River
Project Area 11: RM 27.5 - RM 28

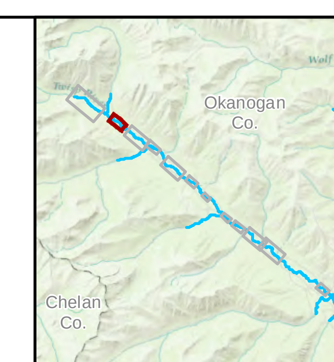
Sheet 21 of 24

N E W S

1:2,000

0 200 400

Feet



River Mile

LWD Types

Bank Jam

Mid-Channel Jam

Supplement Existing LWD

Side Channel

Tributary

Road Crossing

Road Fill

Figure F-1v. Upper Twisp River
Project Area 11: RM 27.5 - RM 28

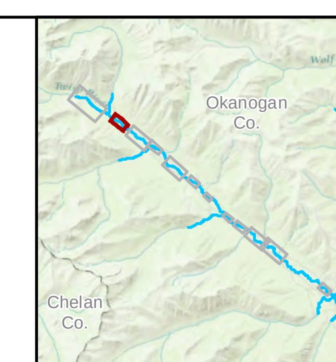
Sheet 22 of 24

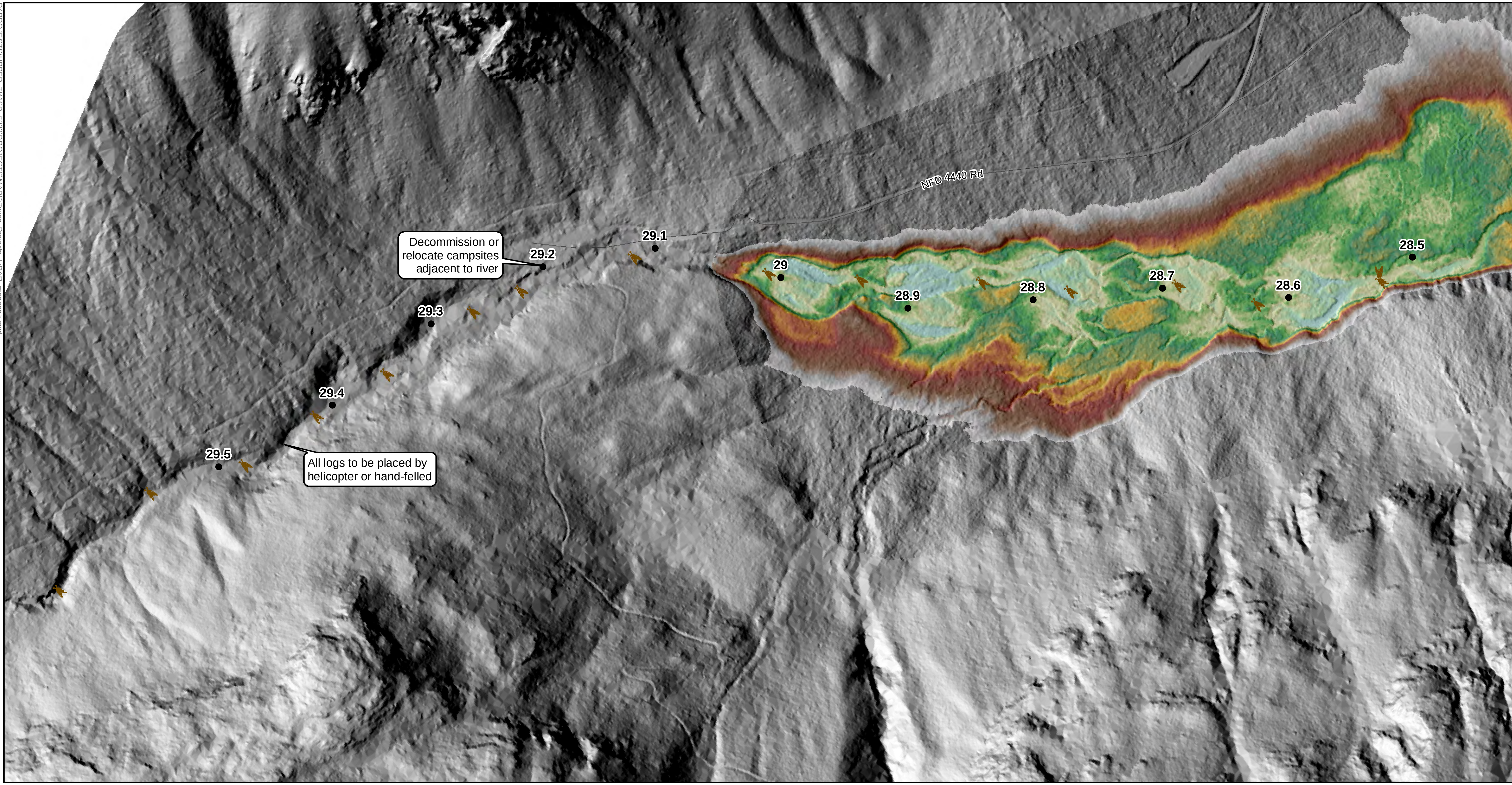
N E S W

1:2,000

0 200 400

Feet





River Mile
LWD Types
Bank Jam
Mid-Channel Jam
Supplement Existing LWD
Side Channel
Tributary

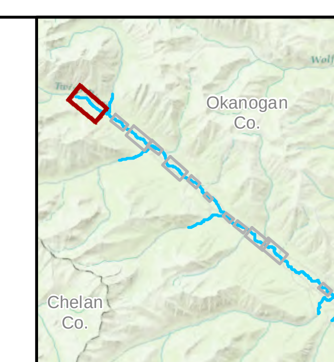
Road Crossing
Road Fill
2006 LiDAR Relative Elevation Model
High : 110
Low : 95.9

Figure F-1w. Upper Twisp River
Project Area 12: RM 28.5 - RM 29.6

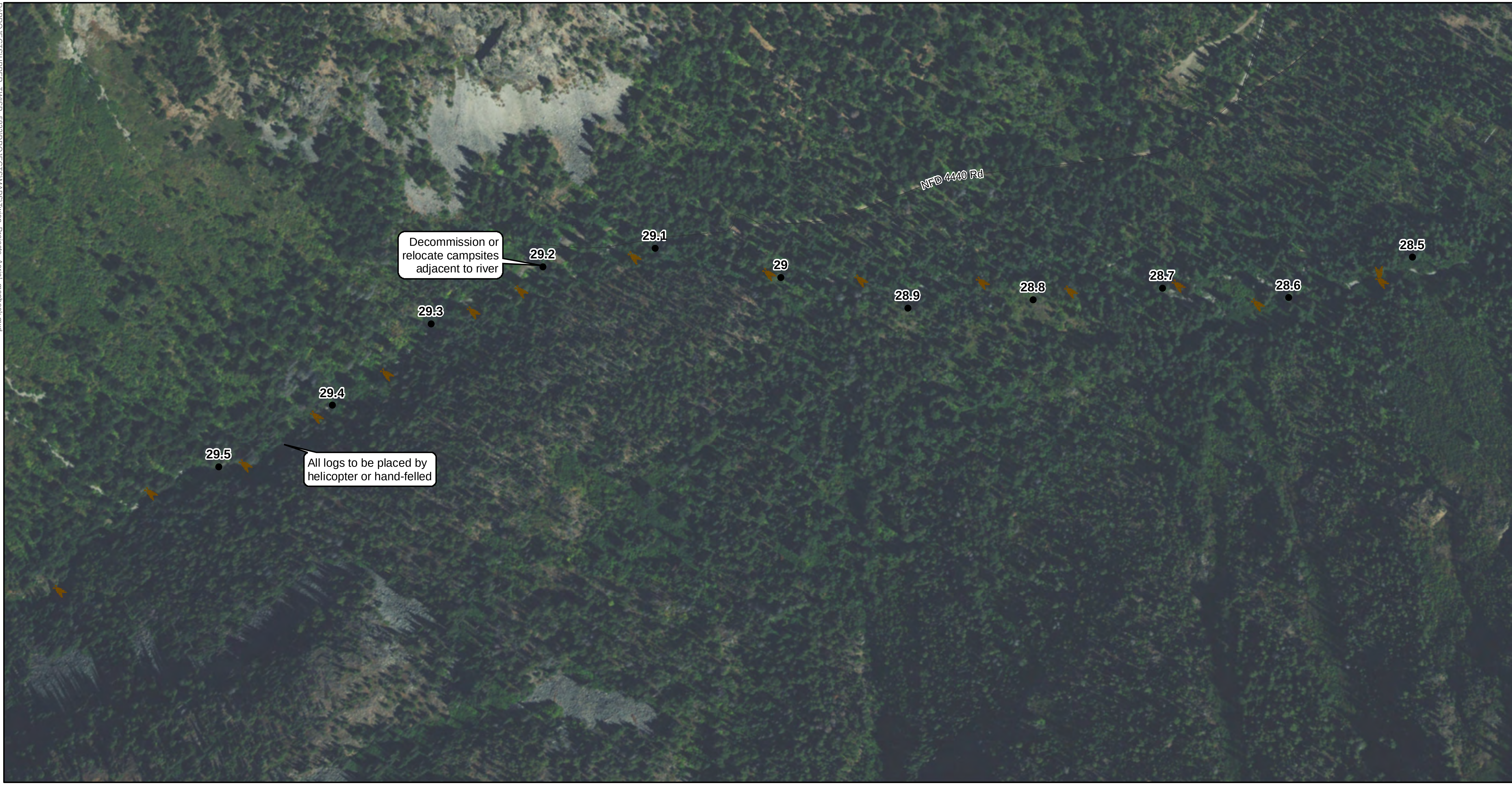
Sheet 23 of 24

1:4,500

0 200 400
Feet



R:\PROJECTS\UPPER_TWISP_5823\PROJECTS\MAPS\Twisp_Projects_LiDAR_mapbook.mxd



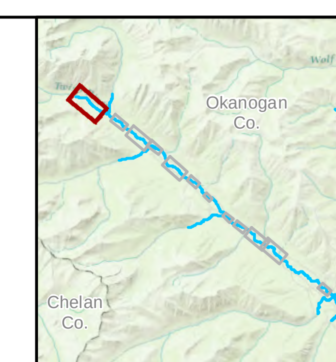
River Mile
LWD Types
Bank Jam
Mid-Channel Jam
Supplement Existing LWD
Side Channel
Tributary
Road Crossing
Road Fill

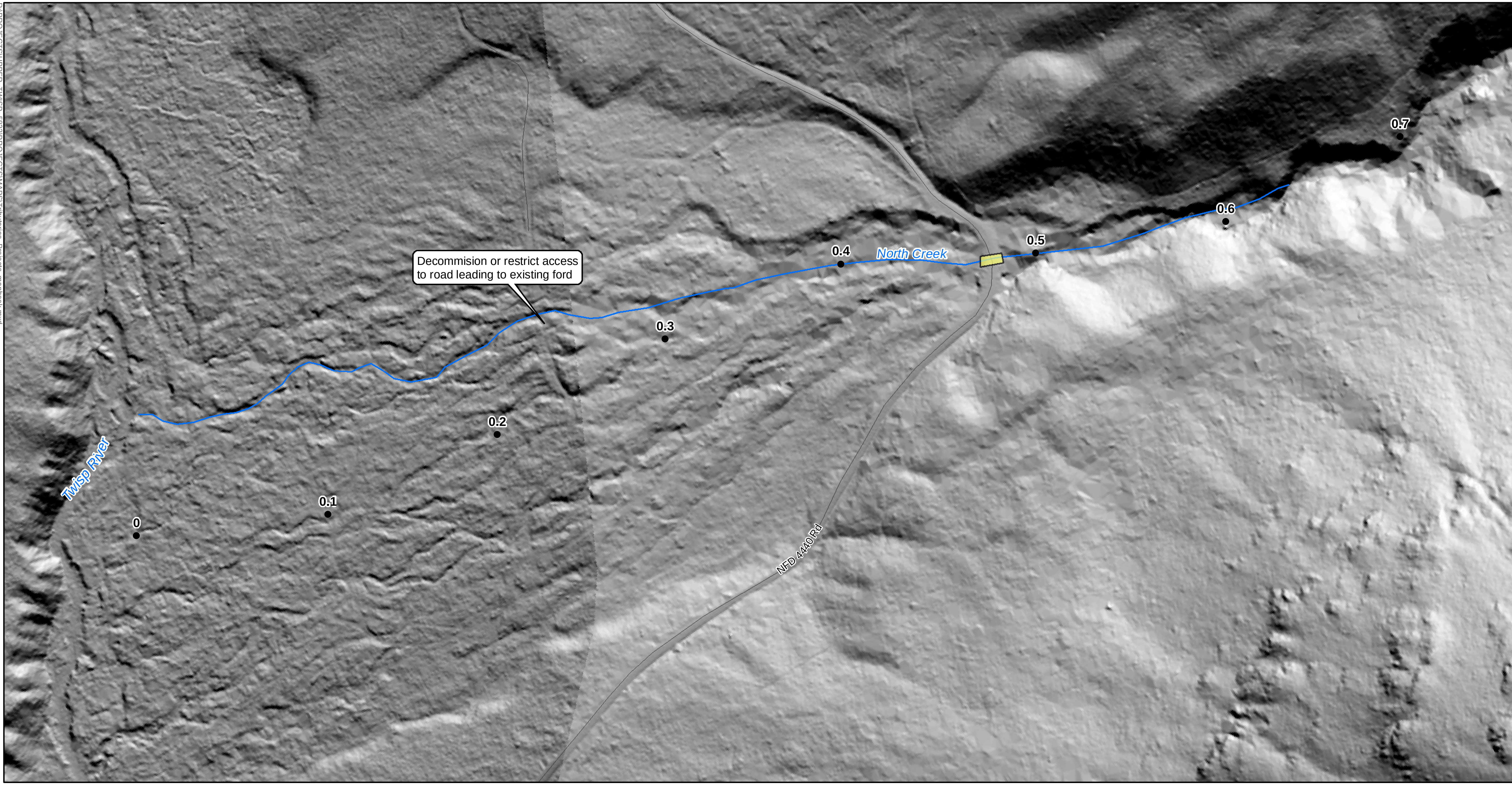
Figure F-1x. Upper Twisp River
Project Area 12: RM 28.5 - RM 29.6

Sheet 24 of 24

1:4,500

0 200 400
Feet





- River Mile

LWD Types

- Bank Jam
- Mid-Channel Jam
- Supplement Existing LWD
- Side Channel
- Tributary
- Road Crossing

Note: LiDAR 2006 and 2015 shown.

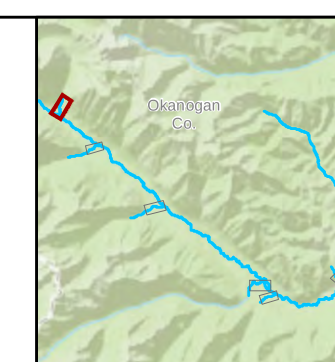
Figure F-2a. North Creek Project Area

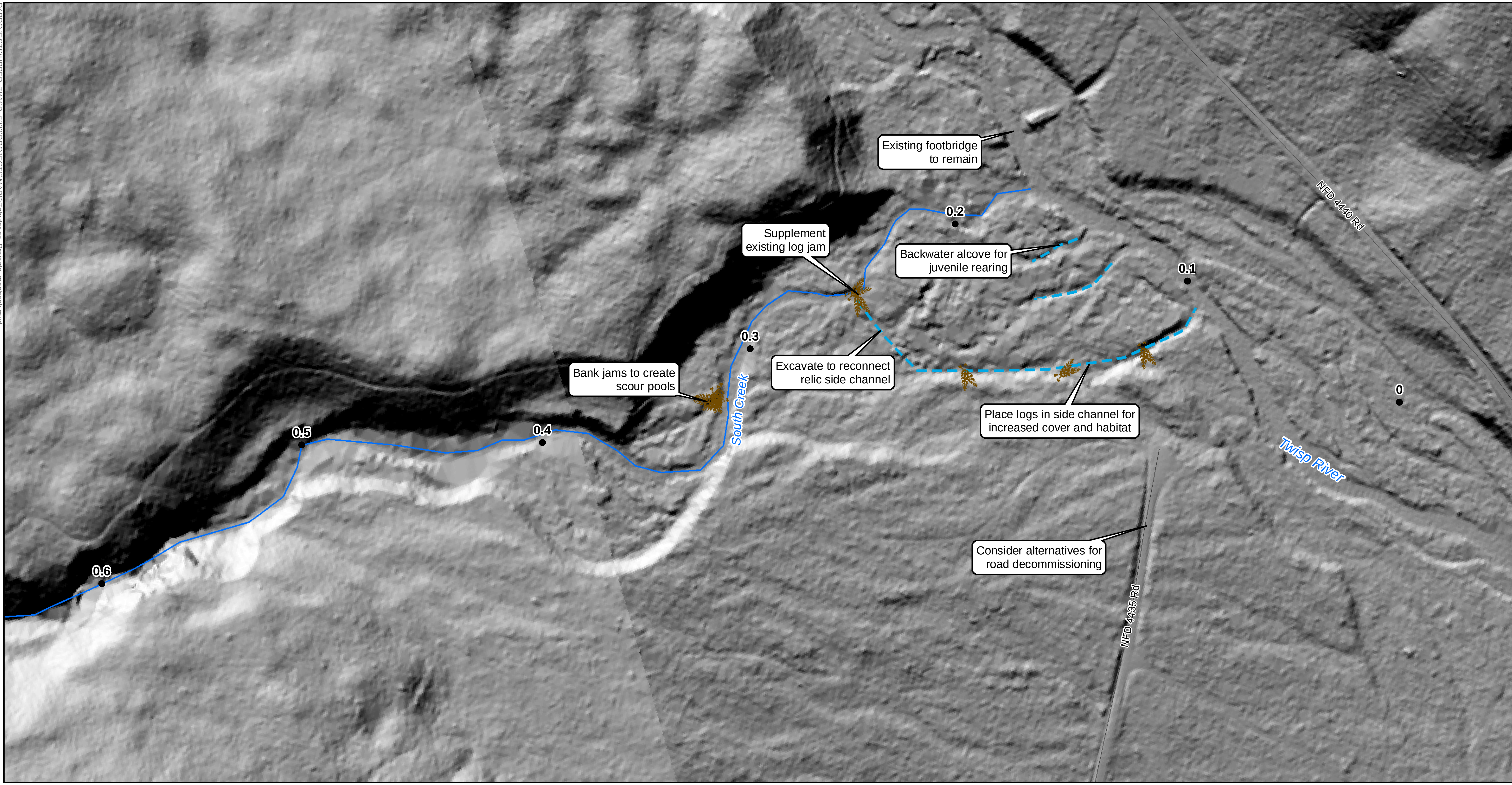
Sheet 1 of 6

1:3,000

0 200 400

Feet





- River Mile
- LWD Types
  - Bank Jam
  - Mid-Channel Jam
  - Supplement Existing LWD
- Side Channel
- Tributary
- Road Crossing

Note: LiDAR 2006 and 2015 shown.

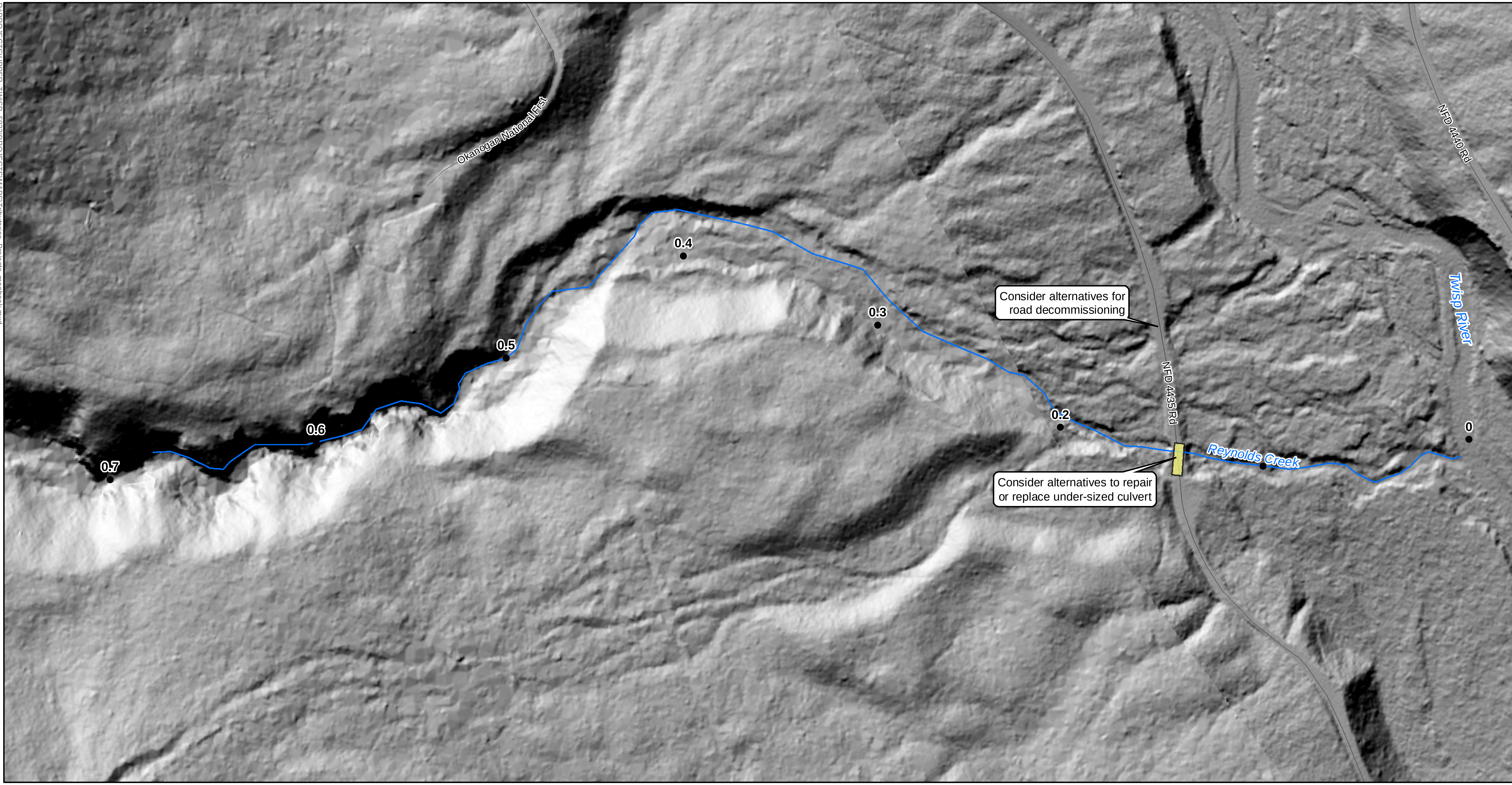
Figure F-2b. South Creek Project Area

Sheet 2 of 6

1:2,400

0 200 400
Feet

R:\PROJECTS\UPPER_TWISP_5823\PROJECTS\MAPS\Tributaries_Projects_mapbook.mxd



River Mile
LWD Types
Bank Jam
Mid-Channel Jam
Supplement Existing LWD
Side Channel
Tributary
Road Crossing

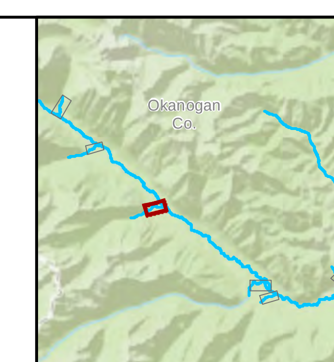
Note: LiDAR 2006 and 2015 shown.

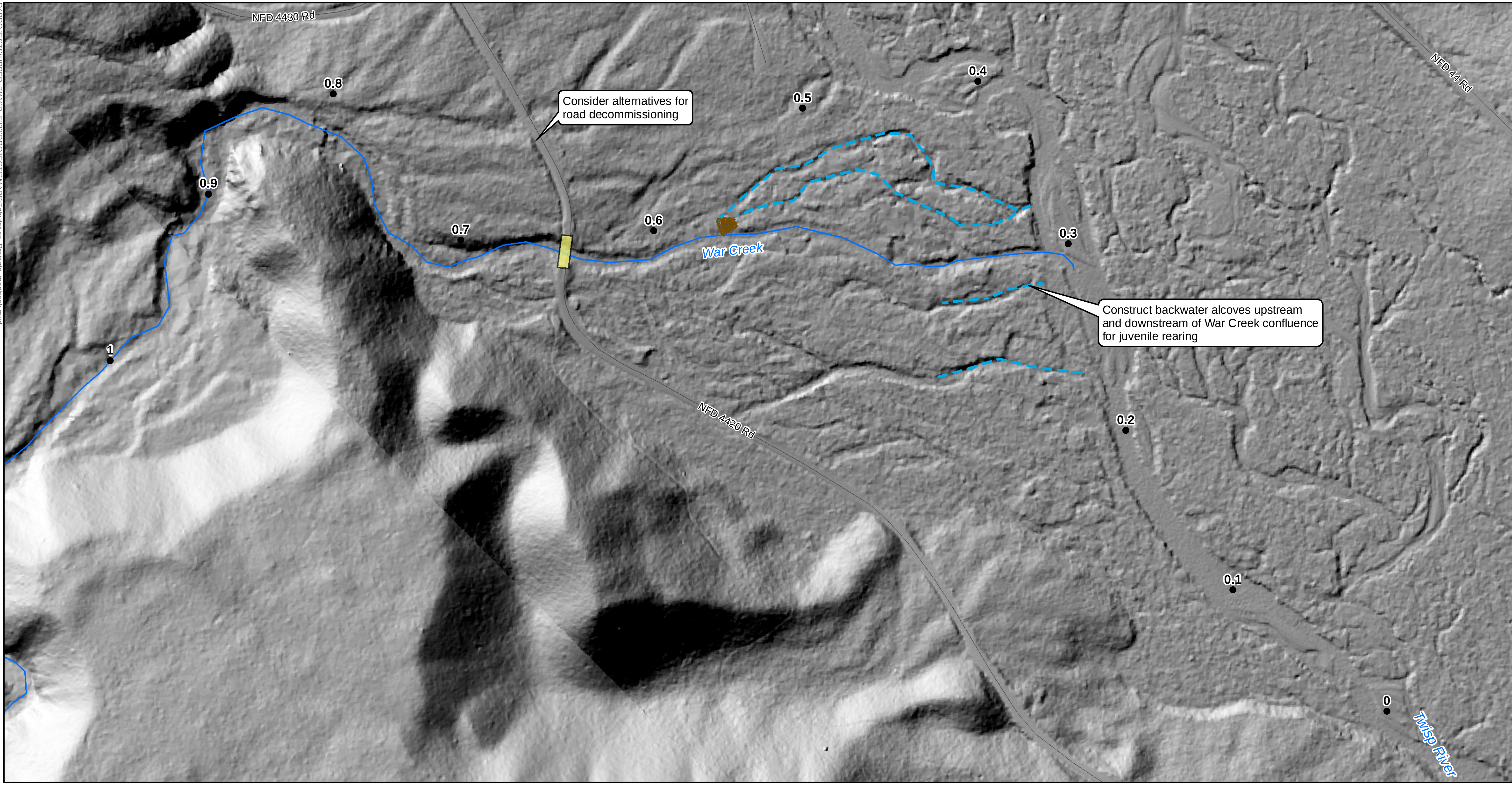
Figure F-2c. Reynolds Creek Project Area

Sheet 3 of 6

1:2,800

0 200 400
Feet





River Mile

LWD Types

Bank Jam

Mid-Channel Jam

Supplement Existing LWD

Side Channel

Tributary

Road Crossing

Note: LiDAR 2006 and 2015 shown.

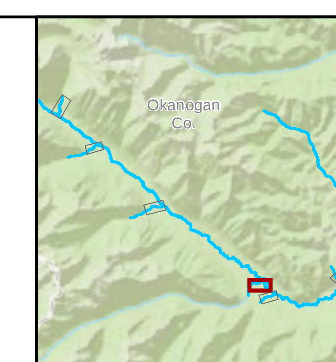
Figure F-2d. War Creek Project Area

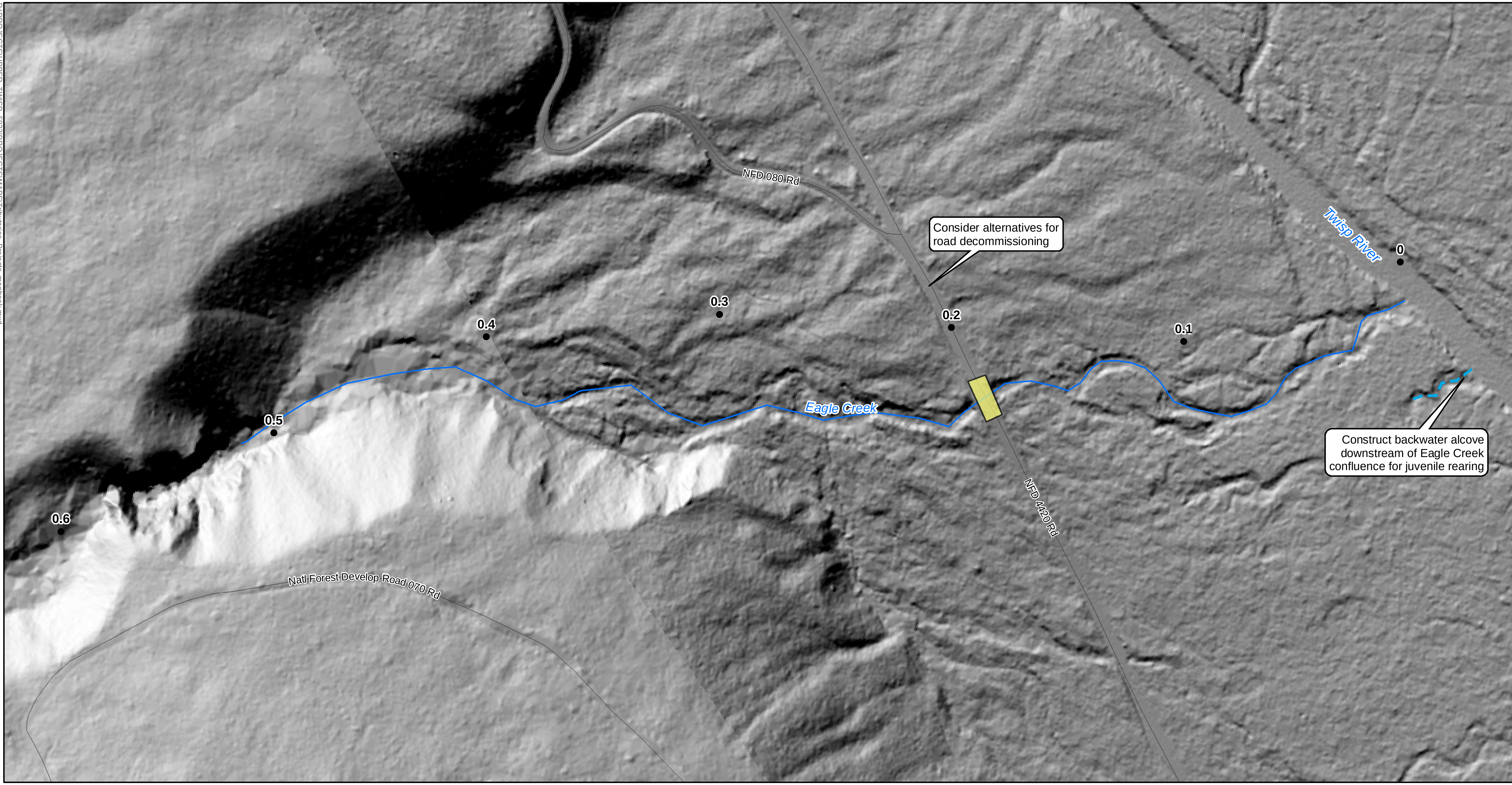
N W E S

1:3,000

0 200 400

Feet





River Mile
LWD Types
Bank Jam
Mid-Channel Jam
Supplement Existing LWD
Side Channel
Tributary
Road Crossing

Figure F-2e. Eagle Creek Project Area

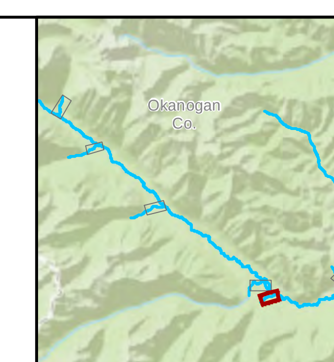
Note: LiDAR 2006 and 2015 shown.

Sheet 5 of 6

N W E S

1:2,500

0 200 400
Feet



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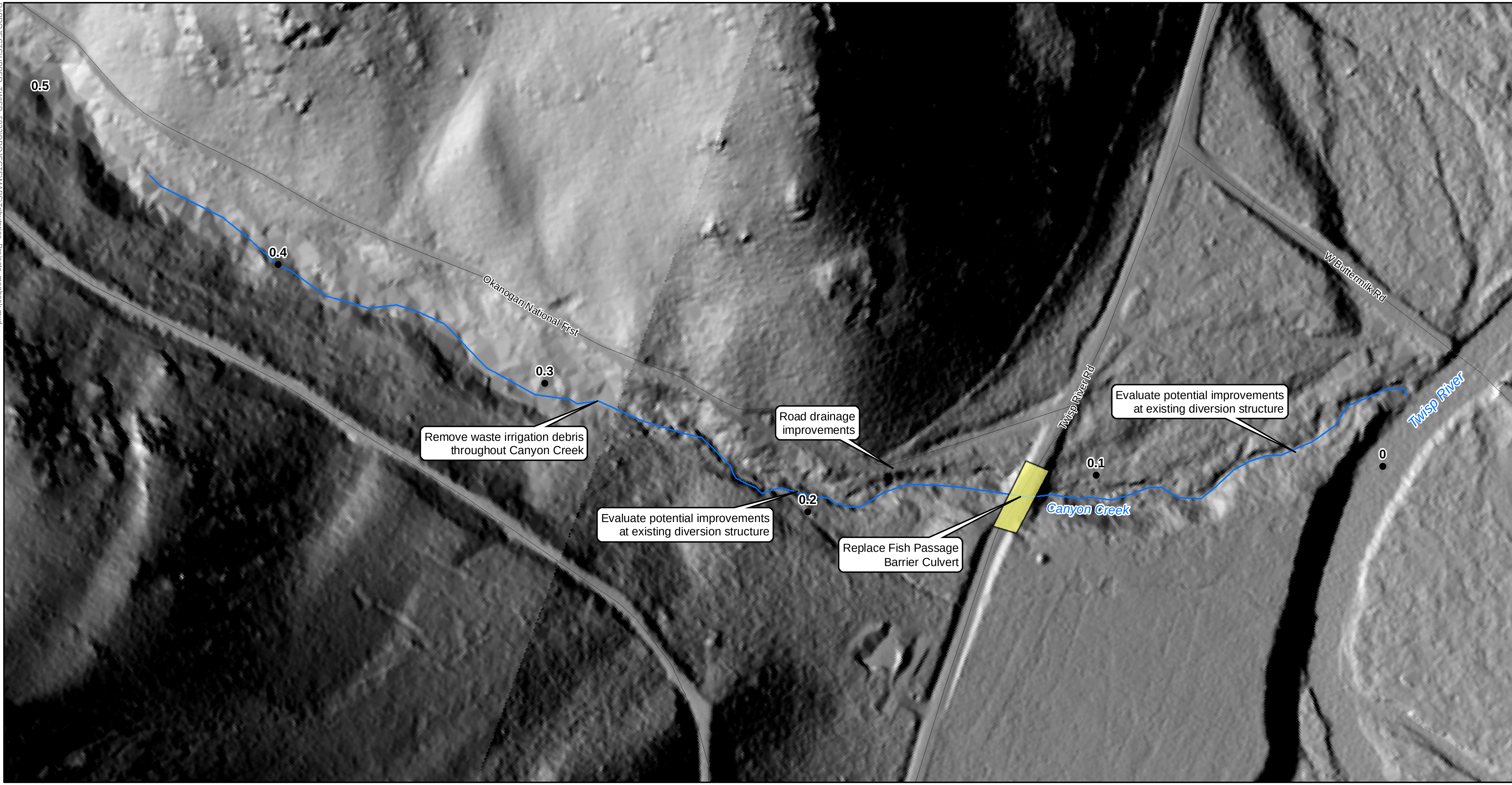


● River Mile
LWD Types
Bank Jam
Mid-Channel Jam
Supplement Existing LWD
Side Channel
Tributary
Road Crossing

Note: LiDAR 2006 and 2015 shown.

Figure F-2f. Canyon Creek Project Area

Sheet 6 of 6

1:2,000

0 200 400
Feet

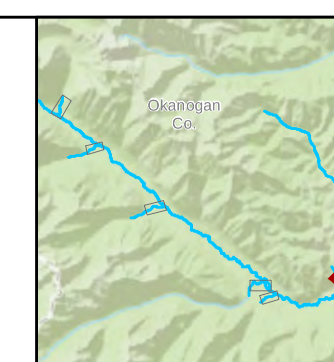


Table F-1. Little Bridge Creek Restoration Project Opportunities

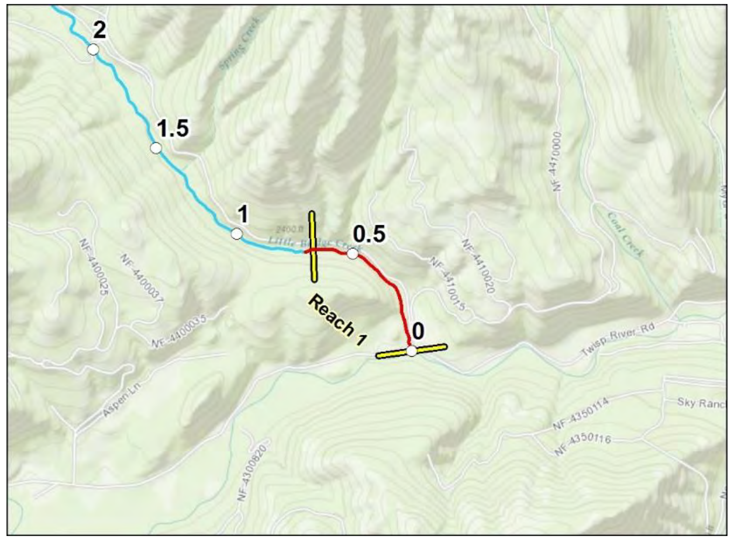
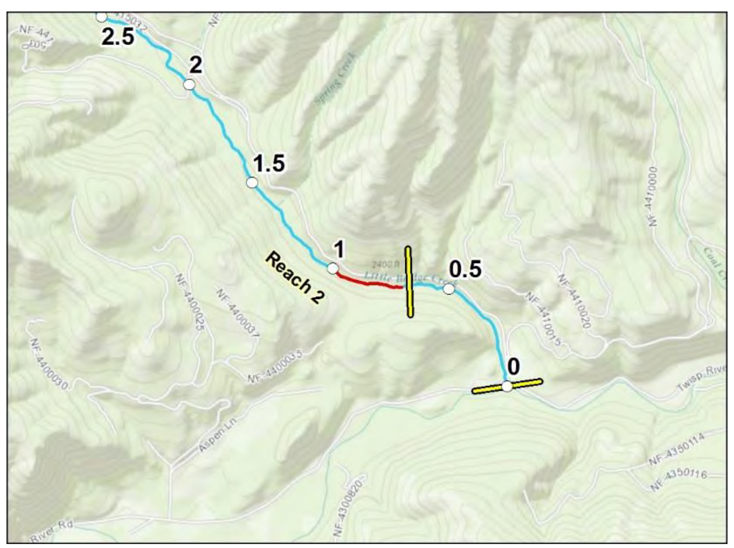
Geomorphic Reach	Project Opportunity Location	Name	Potential Restoration Actions	Description and Rationale	Rank	Photograph
Reach 1		LBC Project Area 1 RM 0.0 to 0.7	– Road grading – drainage improvements – Road decommissioning or abandonment – Remove bank armoring – Remove non-native plants – Riparian planting – Install LWD structures (whole trees, jams, etc.) – Remove and/or relocate floodplain infrastructure	Little Bridge Creek is incised in Reach 1 with little or no floodplain connectivity. The substrate is cobble-dominated, with higher proportions of gravel observed in infrequent bars. Accumulations of fine sediment were observed throughout the reach. It is riffle dominated with frequent plunge and scour pools. Reach 1 flows through narrow, V-shaped valley. Potential restoration actions include: decommission existing ford in lower section of project area; placing large woody debris structures to promote local scour and increase flow diversity and habitat complexity; supplementing existing log jams for increased pool scour and habitat complexity; and removing bank armoring in lower section of project area.	3	
Reach 2		LBC Project Area 2 RM 0.7 to 1.0	– Road grading – drainage improvements – Beaver re-introduction or management	Little Bridge Creek has a well-connected floodplain in this project area. Reach is cobble dominated, with frequent bars containing good quality spawning size material. Active beaver activity at RM 0.9 with channel-spanning beaver dams within the project area. Beaver dam complex has completely blocked main and side channels, inundating a major portion of the floodplain. Potential restoration actions in the project area include installing 'Beaver Deceivers' to increase passage through existing beaver dams and road grading and drainage improvements to reduce sediment inputs.	9	

Table F-1. Little Bridge Creek Restoration Project Opportunities

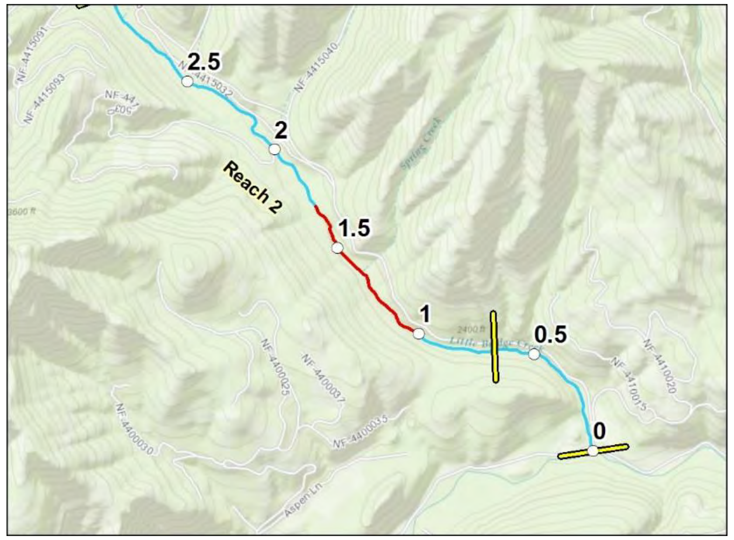
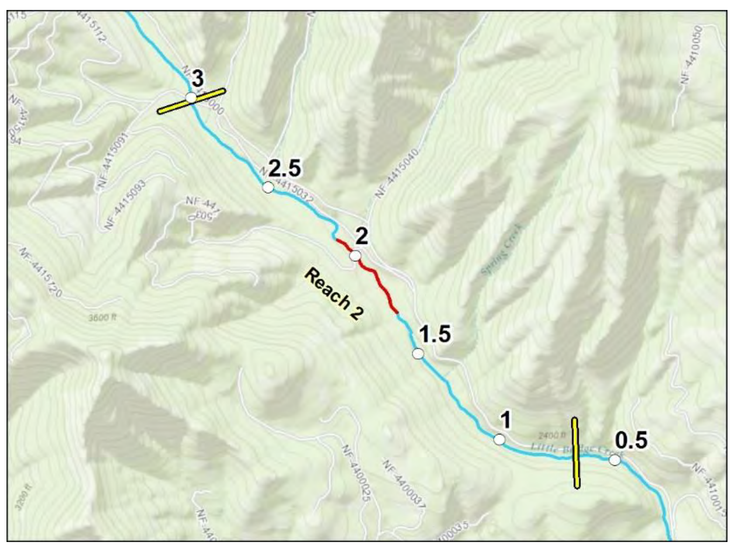
Geomorphic Reach	Project Opportunity Location	Name	Potential Restoration Actions	Description and Rationale	Rank	Photograph
Reach 2		LBC Project Area 3 RM 1.0 to 1.7	– Road grading – drainage improvements – Remove non-native plants – Riparian planting – Install LWD structures (whole trees, jams, etc.) – Pool creation/enhancement	Little Bridge Creek has a well-connected floodplain in this project area, with localized areas of incision and disconnected floodplain at RM 1.6. The valley is wider in Reach 2, but remains relatively narrow (100 – 300 feet). Beaver activity was not present in this project area. Point bars and active bank erosion was observed in several locations. Potential restoration actions in this project area include: improving road drainage to decrease sediment load into creek; installing large wood habitat structures to enhance scour pools and encourage floodplain inundation; and excavating pools in association with large wood habitat structures for increased habitat complexity.	5	
		LBC Project Area 4 RM 1.7 to 2.1	– Road grading – drainage improvements – Beaver re-introduction or management	Little Bridge Creek has a well-connected floodplain in this project area. Reach is riffle dominated with frequent plunge and scour pools. Dams pools upstream of channel-spanning LWD common in the reach. Active beaver activity from RM 1.7 to 1.8 with channel-spanning beaver dams within the project area. Beaver dam complex has completely blocked main and side channels, inundating a major portion of the floodplain. Potential restoration actions in the project area include installing 'Beaver Deceivers' to increase passage through existing beaver dams and road grading and drainage improvements to reduce sediment inputs.	10	

Table F-1. Little Bridge Creek Restoration Project Opportunities

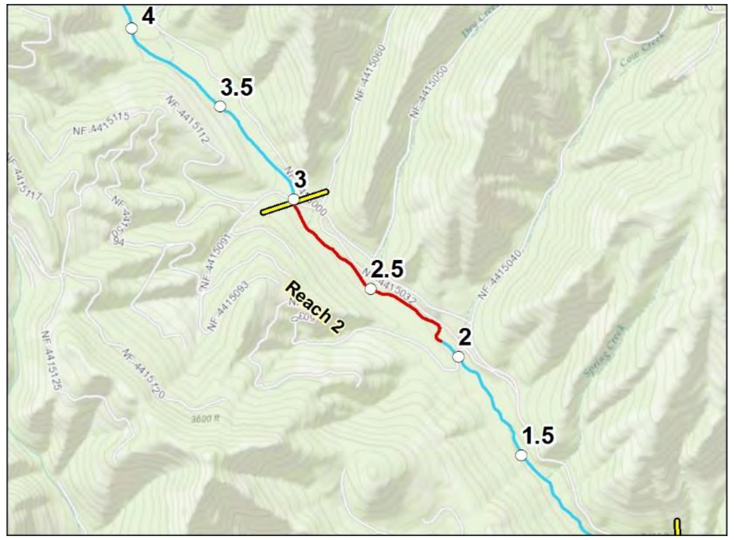
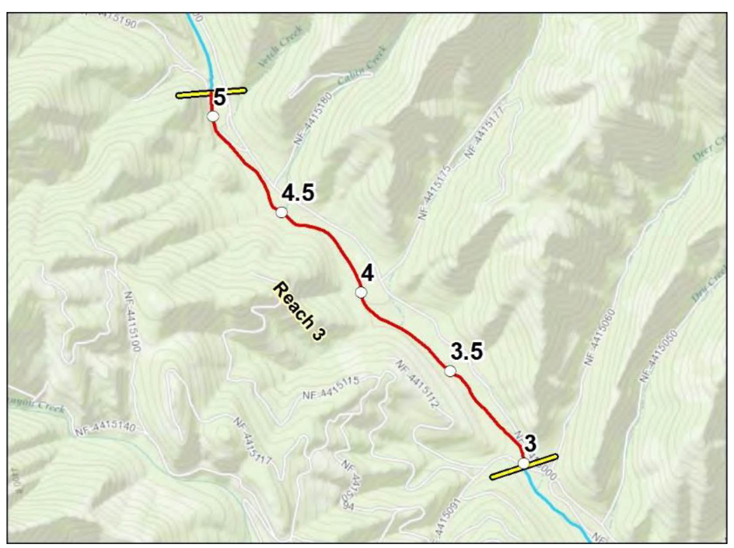
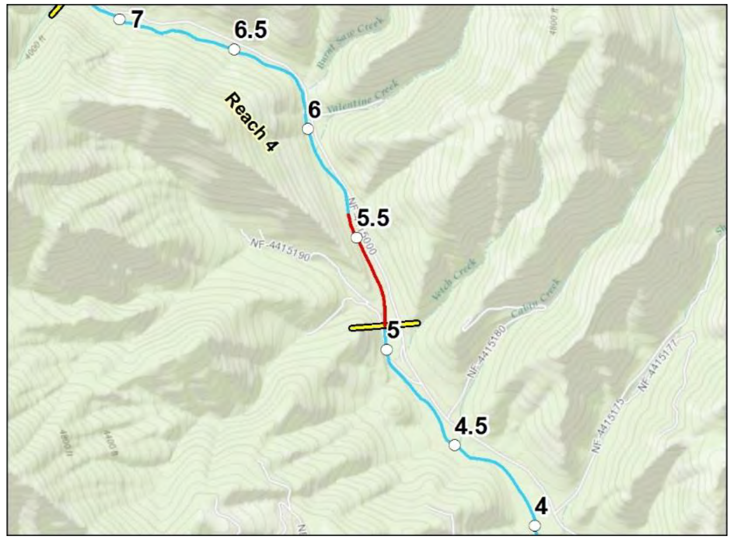
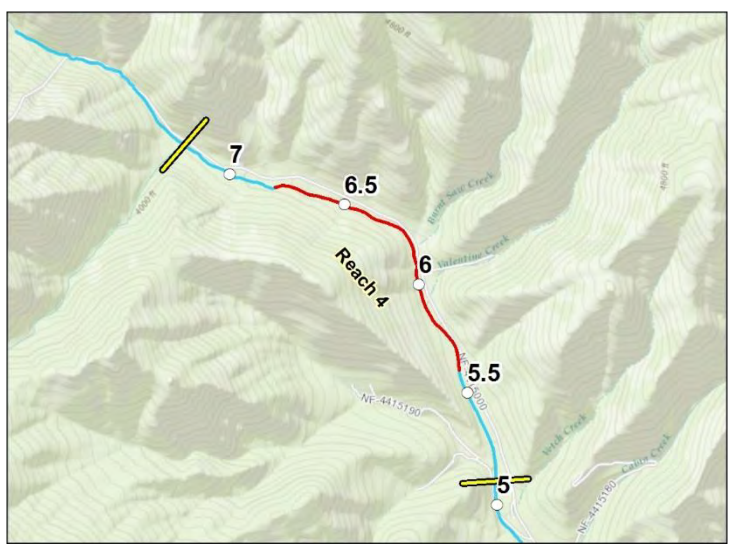
Geomorphic Reach	Project Opportunity Location	Name	Potential Restoration Actions	Description and Rationale	Rank	Photograph
Reach 2		LBC Project Area 5 RM 2.1 to 3.0	– Road grading – drainage improvements – Beaver re-introduction or management – Remove non-native plants – Riparian planting – Install LWD structures (whole trees, jams, etc.) – Perennial side channel creation/enhancement – Secondary channel (non-perennial) creation/enhancement – Improve fish passage at existing diversion	Little Bridge Creek has a well-connected floodplain in this project area. This section is riffle dominated, with multiple side channels, both wetted and dry. The existing irrigation diversion at RM 2.2 may be seasonally affecting juvenile passage. The road crossing at RM 3.0 has scour issues at the upstream end of the culvert. Potential restoration actions in this project area include: install large wood habitat structures to enhance scour pools and encourage floodplain inundation; reconnect relic side channels for increased flow diversity and habitat complexity; and constructing engineered riffle to alleviate passage issues at diversion.	4	
Reach 3		LBC Project Area 6 RM 3.0 to 5.1	– Road grading – drainage improvements – Road decommissioning or abandonment – Riparian fencing – Remove non-native plants – Riparian planting – Post-fire floodplain erosion control – Restore streambanks with LWD - bioengineering – Install LWD structures (whole trees, jams, etc.) – Remove and/or relocate floodplain infrastructure – Perennial side channel creation/enhancement – Secondary channel (non-perennial) creation/enhancement – Wetland creation/enhancement – Alcove creation/enhancement – Groundwater fed off-channel habitat enhancement – Pool creation/enhancement	Little Bridge Creek has increased riparian disturbance from livestock grazing. Riparian was also recently burned, creating areas of erosion. Most of Reach 3 has a well-connected floodplain, with isolated areas of incision. Reach has vegetated islands, braided morphology, and high channel complexity. Reach is riffle dominated with frequent pools. Potential restoration actions in this project area include: installing riparian fencing to restrict livestock access; improve road drainage on main road to decrease sediment inputs; constructing grade control structures upstream and downstream of culvert at RM 3.0 to resolve scour issues; alleviate scour on road fill at RM 3.1 with brush mattress, willow spur, or similar bioengineering techniques; decompact existing access road at RM 3.8 and riparian areas and plant with riparian vegetation; install post-fire erosion control measures to rehabilitate floodplain areas; place logs and install large wood habitat structures with pools to create scour pools and increase channel complexity; reconnect existing relic secondary channels, to increase floodplain connectivity and habitat complexity; and evaluate the potential for groundwater-fed off channel habitat enhancement.	1	

Table F-1. Little Bridge Creek Restoration Project Opportunities

Geomorphic Reach	Project Opportunity Location	Name	Potential Restoration Actions	Description and Rationale	Rank	Photograph
Reach 4		LBC Project Area 7 RM 5.1 to 5.6	– Road grading – drainage improvements – Install LWD structures (whole trees, jams, etc.) – Post-fire floodplain erosion control	Little Bridge Creek flows through relatively narrow valley in this project area. The creek has intermittent segments that are deeply incised followed by segments that are more connected to floodplain. Connected areas are due to large jams, vegetated islands, and high flow side channels. Riffle and rapid dominated, with short cascade sections and frequent pools. Potential restoration actions in this project area include: hand-felling existing trees or helicopter place logs to create scour pools and increase channel complexity; improving road drainage to decrease sediment inputs; and installing post-fire erosion control measures to rehabilitate floodplain areas.	7	
		LBC Project Area 8 RM 5.6 to 6.8	– Road decommissioning or abandonment – Post-fire floodplain erosion control	Little Bridge Creek is cobble-dominated in the project area, with increasing proportion boulders. There are a number of wood and boulder steps with jump heights greater than 3 feet that may be temporary fish passage barriers. Wood and boulder forced plunge pools and dam pools are common in the reach. The road starting at RM 5.6 is in close proximity to the creek in inhibits floodplain access. Potential restoration actions in this project area include (No project actions proposed past RM 6.8): considering alternatives for decommissioning road in close proximity to creek and installing post-fire erosion control measures to rehabilitate floodplain areas.	12	

APPENDIX G

Project Opportunities Prioritization Matrix

(provided on DVD)

This appendix is provided separately.

TETRA TECH