Beaver Creek

REACH ASSESSMENT

Yakama Nation Fisheries

TETRA TECH

December 2017

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Acronyms and Abbreviations

°F	degrees Fahrenheit
2008 Fish Accords	2008 Columbia Basin Fish Accords Memorandum of Agreement between the Three Treaty Tribes and Federal Columbia River Power System Action Agencies
BPA	Bonneville Power Administration
CTCR	Confederated Tribes of the Colville Reservation
DEM	digital elevation model
Ecological Concerns	Limiting factors and threats identified in salmon recovery plans (also known as limiting factors)
Ecology	Washington State Department of Ecology
ESA	Endangered Species Act
FCRPS	Federal Columbia River Power System
GIS	geographic information system
HEC-RAS	Hydrologic Engineering Centers River Analysis System
HUC	Hydrologic Unit Code
Limiting Factors	Environmental variables that limit the productivity of salmonids (also known as ecological concerns)
LiDAR	light detection and ranging
LWD	large woody debris
MSRF	Methow Salmon Recovery Foundation
MWAT	Methow Watershed Action Team
NMFS	National Oceanic and Atmospheric Administration National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
OCD	Okanogan Conservation District
RBT	River Bathymetry Toolkit
REI	Reach-based Ecosystem Indicators
RM	river mile
RUIP	Recovery Unit Implementation Plan
SR	State Route
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
USGS	U.S. Geological Survey
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WRIA	Watershed Resource Inventory Area
WSDOT	Washington State Department of Transportation

1. INTRODUCTION

The Beaver Creek Reach Assessment (this Project) evaluates existing conditions and impairments in the Beaver Creek drainage to support development of a fish habitat restoration strategy. The Beaver Creek drainage, also referred to as the Assessment Area, covers approximately 110 square miles on the eastern slopes of the Cascade Mountains in Okanogan County, joining the Methow River from the east about 5 miles downstream from the town of Twisp, Washington. The reach of Beaver Creek assessed for this Project is from the Methow River confluence (RM 0.0) to Lightning Creek (RM 11.1), herein referred to as the Survey Area (Figure 1-1).

A history of development and resource extraction in the Beaver Creek 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 non-listed species. Additionally, the 2006 Tripod Complex Fire and the 2014 Carlton Complex Fire together have significantly affected geomorphic conditions and processes in much of the drainage. The Yakama Nation, in coordination with the Methow Watershed Action Team, identified the Beaver Creek Survey Area as a high value area for intensive habitat restoration and enhancement actions that restore natural river processes. Numerous restoration measures have already been implemented in the Beaver Creek drainage, and future restoration, including those described in this assessment, are intended to build upon those efforts.

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. 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 that benefit ESA-listed fish species. This reach assessment is one in a series of assessments that have been completed by the UCHRP and others in coordination with the Upper Columbia Regional Technical Team (UCRTT). Reach assessments are integral technical documents for subbasin restoration that inform reach-level restoration strategies. The reach assessment includes a synthesis of existing scientific information, field data collection, data analyses, and interpretation to describe geomorphic conditions, hydrology, aquatic habitat, and riparian conditions.

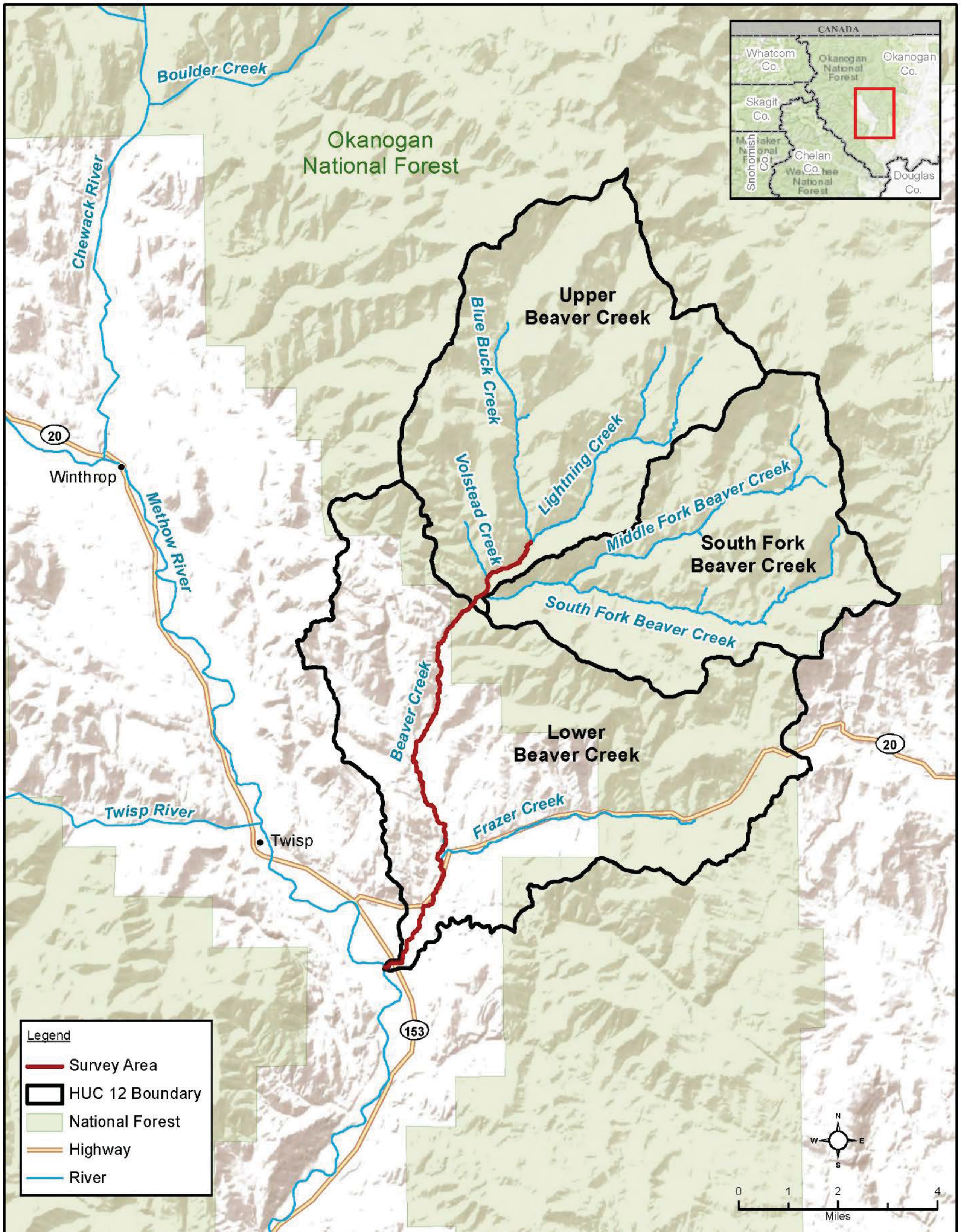


Figure 1-1. Project Location Map–Beaver Creek Drainage and Survey Area

1.1 Purpose

The purpose of this Project is to develop a science-based reach assessment and reach-based restoration strategy to address ecological concerns (also known as limiting factors) and improve habitat conditions for ESA-listed species in Beaver Creek. This assessment documents and evaluates hydrologic processes, geomorphic processes, and aquatic habitat conditions that establish the technical basis for the restoration strategy. Evaluating the biological and physical traits is fundamental to identifying effective habitat restoration actions and priority areas. This restoration strategy is intended to assist habitat restoration practitioners with identifying and prioritizing restoration efforts.

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 Beaver Creek drainage. Key recovery planning efforts that have addressed conditions in the Beaver Creek drainage, as part of the Methow Subbasin, include the Methow Subbasin Plan (NPCC 2005), Methow Subbasin Geomorphic Assessment (USBR 2008), the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSRB 2007), the Recovery Plan for the Coterminous United States Population of Bull Trout (USFWS 2015b), and the revised 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 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 resource for information regarding watershed-level ecological concerns in Beaver Creek (see Ecological Concerns discussion in Section 2.7) and restoration strategies most likely to help achieve broader Methow subbasin goals.

Methow Subbasin Geomorphic Assessment

The Methow Subbasin Geomorphic Assessment 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.

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 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) (USFWS 2015b), within which the Methow Subbasin is one of 24 bull trout core areas.

The Methow River Subbasin has 10 identified bull trout populations that are considered to be at risk, with the Beaver Creek population considered to be functionally extirpated (USFWS 2015b). The Mid-Columbia RUIP details recovery actions in the Methow River core area to address habitat, demographic, and non-native fish threats. Although functionally extirpated in Beaver Creek, the restoration strategy in this assessment took the general and specific guidance for the issues related to populations in the Methow Subbasin from the Mid-Columbia RUIP into account. Additionally, Beaver Creek is designated as Critical Habitat for bull trout within the entire Survey Area (76 *Federal Register* 63898).

Revised Biological Strategy

The UCRTT was created to provide technical support to the UCSRB. In 2014, the UCRTT published the revised Biological Strategy, which provides specific support and guidance on implementing the 2007 Recovery Plan described above (UCRTT 2014). In the revised Biological Strategy, Beaver Creek is designated as a Priority 2 area for restoration (on scale of 1 to 4, 1 being highest priority) within the Methow River Subbasin. Restoration priority action types include increasing instream flow and restoring natural geomorphic processes such as channel migration, floodplain interaction, and sediment transport (UCRTT 2014). Specific actions are recommended for improving these functions in the revised Biological Strategy. These include (in priority order) (UCRTT 2014):

1. Water quantity – Increase stream flow through irrigation practice improvements and water leases/purchases
2. Channel structure and form – Address roads and dikes
3. Habitat quantity – Remove or modify instream diversion structures to maintain effective fish passage at the Beatty diversion, replace Stokes Ranch culvert (approximately river mile [RM] 3.0)
4. Riparian Condition – Plant riparian vegetation to restore adequate riparian buffer, increase LWD recruitment and retention, livestock exclusion fencing in riparian areas, implement Respect the River Program (20 acres on USFS land, 40 acres on WDFW land)
5. Sediment – Road management, reduction, and maintenance to restore sediment and large wood recruitment rates within riparian and upland areas; in particular, around WDFW and USFS campgrounds
6. Injury and Mortality – Replace or properly modify diversion screens to meet fish passage standards
7. Species interactions – Reduce or eliminate brook trout

The strategy also identified specific priority ecological concerns for the Beaver Creek, which are discussed in greater detail in Section 2.7. As part of the revised Biological Strategy, a series of reference tables were also developed as a public resource (UCRTT 2013). The tables identify priority actions for Beaver Creek including increasing instream flow and restoring natural geo-fluvial processes such as channel migration, floodplain interaction, and sediment transport.

The revised Biological Strategy also identifies data gaps for Beaver Creek, which included the lack of reach assessment and habitat survey data on the lower, privately owned, areas. The data collected as part of this Project and the assessment completed by Hopkins (2013) provided significant coverage of this data gap.

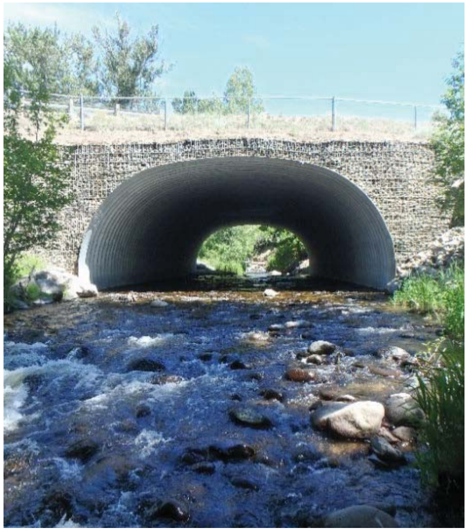
Conservation Agreement for Pacific Lamprey

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 2016). 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 Subbasin (Nelle et al. 2016). While it does not specifically discuss Beaver Creek, actions such as improving passage at mainstem dams and proposed adult translocation and larval/juvenile supplementation into the Methow Subbasin and tributaries could improve the potential migration into Beaver Creek 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 reach assessment, recovery planning context, and overview of document organization.
- Section 2: Assessment Area Conditions – Provides project context, relevant historical information, and existing background data used in the assessment.
- Section 3: Reach Assessment Methods – Describes assessment methods for topobathymetric light detection and ranging (LiDAR) data collection, geomorphic and habitat field surveys, identification of potential project areas and restoration opportunities, reach assessment data analyses and Reach-based Ecosystem Indicators (REI) assessment.
- Section 4: Reach Assessment Results – Includes topobathymetric LiDAR surface, hydrology, reach descriptions, geomorphology and habitat, REI, and potential climate impacts.
- Section 5: Restoration Strategy – Describes past restoration actions, reach-scale restoration strategies, project areas, and potential restoration actions including prioritization of project areas.
- Section 6: Conclusion and Next Steps – Provides recommended follow-up actions for implementing the restoration strategy.
- Section 7: References – Lists all references cited in the report.



2. ASSESSMENT AREA CONDITIONS

The Assessment Area for this Project includes the entire Beaver Creek drainage. Reach assessment results specific to the Survey Area are contained in Section 4.0

The evaluation of Assessment Area conditions 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. Specifically, numerous studies of restoration action effectiveness, fire impacts, and fish presence and abundance have been completed in Beaver Creek by the U.S. Bureau of Reclamation (USBR), USFS, and others. In particular, the USFS stream inventory surveys and summary reports completed for Beaver Creek and upper Beaver Creek tributaries provide a wealth of valuable stream habitat data and summary information (USFS 2004, 2007; Hopkins 2013).

As a critical first step in the development of this Project, relevant data, reports, and literature were compiled and reviewed. The background data and reports have been organized and indexed to allow for convenient searchable access for stakeholders utilizing this assessment in the future. The index of existing reach 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) Final Report (Andonaegui 2000)
- Methow Subbasin Plan (NPCC 2005)
- Methow Watershed Plan (WRIA 48) (MBPU 2005)
- Mid-Columbia Coho Restoration Master Plan (Yakama Nation 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)
- Mid-Columbia Coho Reintroduction Feasibility Study (Kamphaus et al. 2011)
- Lower Beaver Creek Stream Habitat Assessment (Hopkins 2013)
- Revised Biological Strategy (UCRTT 2014)
- Beaver Creek Watershed Summary Methow River Basin (TU 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)

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 Beaver Creek. The background information includes a description of the setting and climate, geology and glacial history, human disturbance history, wildfires, water quality and quantity, fish use and population status, ecological concerns, and the recovery planning context for the Project.

2.1 Setting and Climate

Beaver Creek has a length of 22.3 miles, and is fed by tributaries including Frazer, South Fork Beaver, Middle Fork Beaver, Lightning, and Blue Buck Creeks (Andonaegui 2000; USBR 2013a). The Beaver Creek drainage is within WRIA 48 and the Middle Methow River watershed (10-digit HUC 1702000806). The Beaver Creek drainage area includes the Lower Beaver Creek subwatershed (12-digit HUC 170200080608; 48 square miles), Upper Beaver Creek subwatershed (12-digit HUC 170200080607; 35 square miles), and South Fork Beaver Creek subwatershed (12-digit HUC 170200080606; 27 square miles). There is a combination of federal, state, county, and private land throughout the drainage, with most of the public land managed by the USFS and the State of Washington Department of Fish and Wildlife (WDFW) and Department of Natural Resources (WDNR). The lower drainage is predominately private ownership used for agriculture and ranching (TU 2015).

Elevations of the Beaver Creek drainage range from approximately 1,500 feet at the confluence with the Methow River (RM 36.9) to a maximum elevation of 7,366 feet (Granite Mountain). The area is within the Columbia Cascade Ecological Province as identified by the Northwest Habitat Institute (NWHI 2016) and the Northern Cascades physiographic province. Precipitation in the Beaver Creek drainage falls as rain during the spring, summer, and fall, and snow during the late fall and winter. Average annual precipitation ranges from 13.3 inches to 34.8 inches in the upper elevations of the drainage (PRISM 2016). Peak flow in Beaver Creek typically occurs during May and June driven by snowmelt runoff, and low flows extend from August to February. The Methow River Subbasin where the Beaver Creek drainage resides is one of the coldest of 24 western climate zones, located on the east side of the Cascades 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 Beaver Creek 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). This landscape was 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 2004). The primary tectonic feature of the Methow Subbasin is the Tertiary Methow-Pasayten Graben which is depressed (lowered) block of land that is bordered by parallel faults. The Methow-Pasayten Graben defined 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 and volcanic 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).

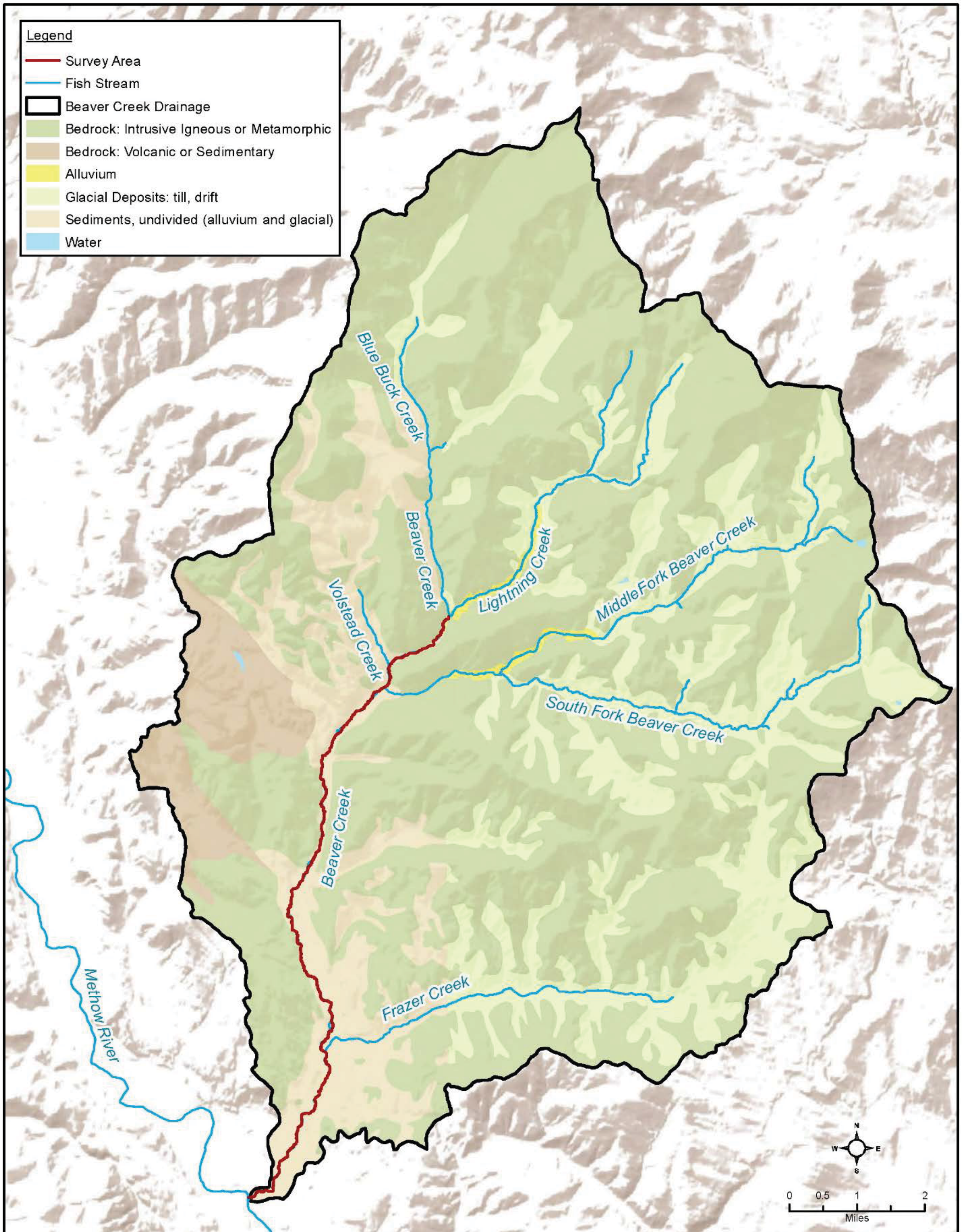


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Figure 2-1. Surficial Geology of the Beaver Creek Drainage (Source: WDGER 2016)

While Beaver Creek flows into the Methow River, most of the drainage lies east of the Pasayten Fault, on lands described as the Okanogan Block. Haugerud and Tabor (2009) note that while the Pasayten Fault clearly separates the upper Methow valley from the higher Okanogan Block to the east, it appears to end near the town of Twisp and Beaver Creek. Beaver Creek drainage's surface geology primarily consists of igneous or metamorphic bedrock formed in the Cretaceous to Jurassic periods with valley bottoms overlain by more recent Quaternary glacial and alluvial deposits (WDGER 2016). A small portion of the drainage along its western boundary is underlain by sedimentary and volcanic rocks near Pipestone Canyon (see Figure 2-1).

The landforms in the Beaver Creek 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 areas near Twisp were covered by over 1,600 feet of ice from the Okanogan Lobe of the Cordilleran ice sheet (WDNR 2017). As the glaciers retreated, the surface flows cut through the glacial deposits, creating terraces and stream channels consisting of poorly graded gravels mixed with silt, sands, cobbles, and boulders. This material is erosion resistant, resulting in the sandy soils that are the source of the fines found in Beaver Creek today (Anchor 2008).

2.3 Human Disturbance History

Human activity within the Methow River Subbasin goes back at least 7,500 years (NPCC 2005; USFS 2006a) and can be described in two phases: 1) the presettlement era of the Methow Indians, and 2) post-European settlement and the creation of the Moses Columbia Reservation. 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 Beaver Creek drainage. 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).

2.3.1 Presettlement

Presettlement-era residents of the Methow Valley were the ancestors of the Confederated Tribes and Bands of the Yakama Nation 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). The settlement of Lchupchupoos was located a short distance up Beaver Creek, near its confluence with Frazer Creek, and is thought to have been used seasonally, possibly for salmon fishing or trade (USFS 2006a).

Typical land use during this time period was primarily hunting, fishing, and gathering activities (NPCC 2005). People lived in small groups and moved seasonally across the landscape, settling along water bodies (USFS 2006a). 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, sockeye (*O. nerka*), coho (*O. kisutch*) and steelhead were captured throughout the Methow River Subbasin, and at the mouth along the Columbia River (NPCC 2005). Mullen et al. (1992) estimated the maximum annual catches for the Methow Subbasin at 238,391 pounds. Fishing techniques included constructing platforms for netting and harpooning salmon, and the construction of weirs in smaller tributaries (USFS 2006a).

2.3.2 Post-European Settlement

The first Europeans began showing up in the Methow Subbasin in 1811 to 1845, typically trappers and explorers (NPCC 2005), with beaver trapping noted as one of their primary activities (USBR 2008). Fort Okanogan, located at the mouth of the nearby Okanogan River was a base for trading goods for beaver pelts and other furs. By the mid-1880s, trapping had wiped out most of the beavers in Beaver Creek and other nearby areas and some early residents transitioned from the fur trade to mining (Portman, 2002 cited in USBR 2008).

In the Methow Valley, the first known settler was John “Chickamun” Stone, who is reported to have built the first cabin on Beaver Creek in 1885 and discovered gold at the Red Shirt Mine site in 1887 (USFS 2006a; Smith n.d.). Heavy settlement by Europeans began in 1886, when the reservation was opened to non-native settlers after gold strikes were made.

2.3.3 Agriculture

Agriculture and irrigation diversions on Beaver Creek began before the area was even opened for settlement, as noted above. Intensive settlement for agricultural purposes, as well as for mining, followed the opening of the Methow Valley for settlement in 1886. Across the Methow, farming produced dairy and fruit products, and ranching raised cattle and sheep, moving animals seasonally from lowlands to uplands. Within the Beaver Creek drainage, a significant agricultural use is cattle grazing, with impacts concentrated in wetlands and meadows and in low gradient areas along creeks (NPCC 2005). Hopkins (2013) reports that much of the land managed by the USFS in the Beaver Creek drainage is grazed by cattle, though some natural protection to the streambanks is provided by steep slopes and forests. As shown in Figure 2-2, the lower reaches of Beaver Creek are privately owned and have been particularly impacted by channel straightening and floodplain loss due to past agricultural activities (NPCC 2005; USBR 2013a), and Andonaegui (2000) and Hopkins (2013) note the role of current agricultural practices impacting streams. The lower 6 miles of Beaver Creek include irrigated private lands planted in alfalfa and mixed hay, as well as livestock production (Johnson and Molesworth 2015). The following section describes the long history and extensive impact of irrigation diversions in the Beaver Creek drainage.

2.3.4 Diversions

As noted above, water has been diverted from Beaver Creek beginning over 130 years ago for mining-related purposes. Water from Beaver Creek was diverted at RM 5.0 and conveyed in a ditch to the Red Shirt Mill (Smith n.d.). One of the first irrigation diversions from Beaver Creek was built by a settler named Joe White even before the land was opened to settlement (USFS 2006a). The height of irrigation for agriculture occurred between 1940 and 1968, when 20,240 acres of land were irrigated using unlined surface diversions (NPCC 2005). Estimates for the Methow Subbasin as of 2005 included roughly 17,000 acres of irrigated land, with much of the crops sold locally (NPCC 2005).

Water rights in the Beaver Creek drainage have been adjudicated. In most years, water use exceeds availability and the lower portions of Beaver Creek are dry during part of the irrigation season. The exception to this is the lowest 0.3 mile where surface flow is maintained by irrigation return flows (USBR 2013b). Water quantity in Beaver Creek is further described in Section 2.5.

Many diversions presented full or partial passage barriers to adult and juvenile salmonids for many years, although the Methow Subbasin Plan reported that all diversions in Beaver Creek had been screened (NPCC 2005) and many have been altered or replaced to provide passage. The Okanogan Conservation District and USBR partnered with local landowners to replace seven diversions within the Survey Area that were known fish passage barriers on Beaver Creek (USBR 2013a). Although the primary aim of the passage improvements was to reconnect habitat for salmonids, the projects also included related improvements including culvert removal, pump and headgate replacement, additional diversion replacement, piping, and water acquisition actions (USBR 2013a). Ongoing maintenance and monitoring of irrigation diversion structures is needed to ensure continued passage of fish at all life stages. Figure 2-3 shows a recent photograph of the log weir and fish ladder structure at the Batie Diversion near RM 6.3.

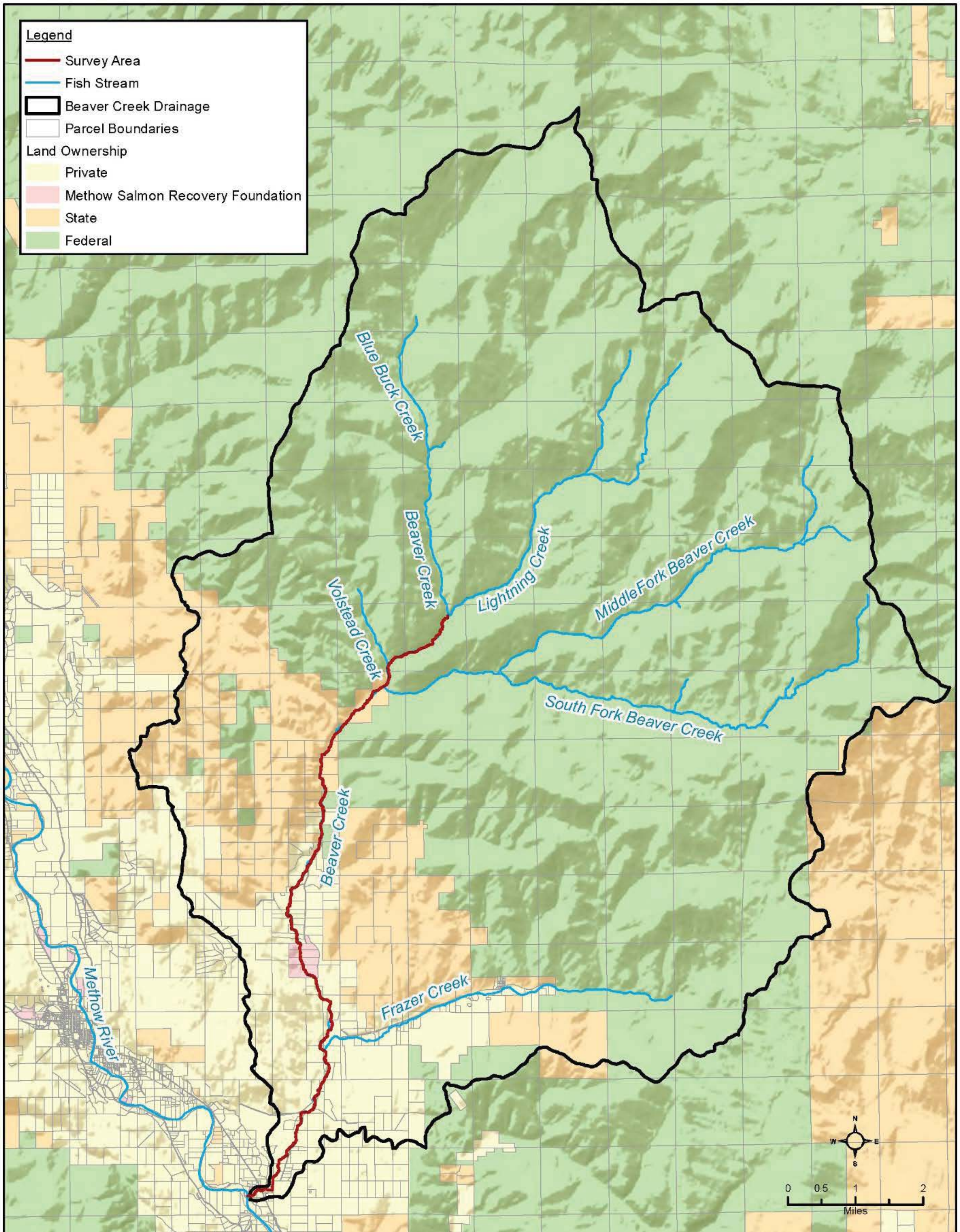

Figure 2-2. Land Ownership in the Beaver Creek Drainage

Figure 2-3. Photograph of Log Weir and Ladder Structure near RM 6.3 at Batie Diversion

Currently, there are nine active diversions on Beaver Creek within the Study Area, shown by river mile in Table 2-1. Figure 2-4 shows the diversion structures and stream gages (see Section 2.5) in the Survey Area. Passage studies have been conducted to evaluate the completed passage improvements (Connolly et al 2010; Hopkins 2013; USBR 2013a). However, the continued long-term fish passage effectiveness of the replaced diversion structures has been identified as a concern requiring potential ongoing maintenance (UCRTT 2014).

Table 2-1. Diversion Structures within the Beaver Creek Reach Assessment Survey Area

Name	River Mile
Fort-Thurlow Diversion	1.6
Tice Diversion	1.6
Lower Stokes Diversion	2.9
Thurlow Transfer Diversion	4.0
Lampson Diversion	4.8
Redshirt Diversion	5.0
Batie Diversion	6.3
Marracci Diversion	6.6

Source: TU 2015

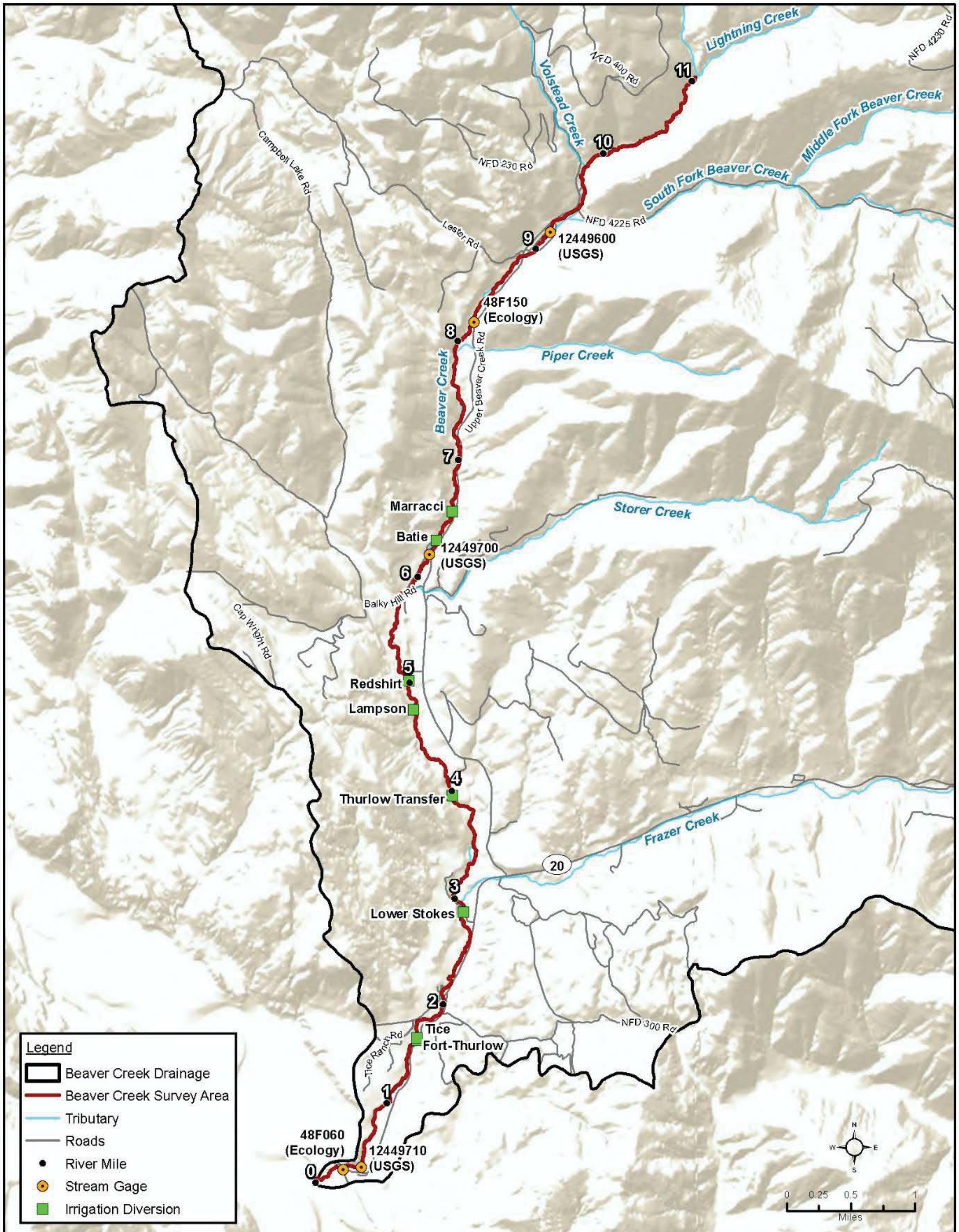

Figure 2-4. Diversions and Stream Gages within the Beaver Creek Reach Assessment Survey Area

2.3.5 Mining

There are no mines currently operating in the Beaver Creek drainage area (Hopkins 2013). Mining was a historically significant activity in the area, including the gold-, silver-, and copper-producing Red Shirt Mine, which was located between Beaver and Benson Creeks (USFS 2006a). The Red Shirt Mine was actively mined until 1900 (Smith n.d.). Water from Beaver Creek within the Survey Area was diverted to provide water for the Red Shirt Mill, located adjacent to the Methow River near the town of Twisp, Washington, in order to process the ore from the Red Shirt and Alder mines (Smith n.d.).

2.3.6 Roads

The Beaver Creek drainage has a high density of roads relative to the entire Methow River Subbasin with an average of 1.9 road miles per square mile. In comparison, the road density for the Methow River Subbasin was 1.1 road miles per square mile (USBR 2011). These roads are potential sources of sediment input into Beaver Creek, but the specific sediment inputs have not been quantified. Apparent accelerated fine sediment delivery to streams from roads caused the USFS to rate fine sediment as functioning at unacceptable risk in the Beaver Creek drainage, and specific roads in the drainage were identified for relocation, obliteration, or improved drainage (USFS 2004). South Beaver Creek Road was identified as an access point for cattle as well as a source of fine sediment delivery from the road itself (USFS 2004). A large amount of cattle exclusion fencing has been installed since the Carlton Complex Fire in 2014, and ongoing maintenance will be required to ensure effectiveness. A related impact identified in the Beaver Creek drainage is the approximately 152.6 miles of bulldozer line that were installed during the fire suppression activities for the Carlton Complex Fire in 2014, with more than 100 miles of that total on public land and the remainder on private land, and the anticipated construction of new logging roads due to salvage timber operations following recent fires (Johnson and Molesworth 2015). See the road density analysis completed for the REI in Section 4.5 for more road-related analyses, including floodplain road density.

A number of culvert replacements have occurred in the Beaver Creek drainage since 2000. The State Route (SR) 153 (also known as the Methow Valley Highway) culvert crossing near RM 0.3 was replaced in 2000, and the SR 20 culvert crossing near RM 2.1 was replaced in 2006. A partial fish passage barrier culvert on the mainstem Beaver Creek, near the mouth of the Middle Fork of Beaver Creek, was replaced in 2005, and a second culvert in Lightning Creek was replaced in 2007. Three fish passage barrier culvert crossings on roads crossing South Fork of Beaver Creek were replaced in 2004 (Hopkins 2013; TU 2015), and undersized culverts on SR 20 crossing Frazer Creek were replaced with bridges in 2015 (TU 2015).

There are also existing culverts that have been identified as known or potential sources of sediment within the Beaver Creek drainage. For example, there are 11 NF-200 Road crossings on Volstead Creek within the lower 1.25 miles that are prone to plugging and have resulted in excessive sediment inputs (Molesworth pers. comm. 2017). Road crossing impacts on Volstead Creek increased following the 2006 Tripod Fire, which burned most of the Volstead Creek drainage and altered runoff and peak flow hydrology. In 2011, the road failed at multiple locations transporting large volumes of sediment into Beaver Creek that severely impacted fish habitat. The road was repaired through the Emergency Relief for Federally Owned Roads (ERFO) process, but the repairs did not address the underlying issues. Volstead Creek road failures and sediment delivery to Beaver Creek are ongoing occurring in 2014 following the Carlton Complex Fire, in 2016, and most recently in 2017 following an intense rainfall event (Wagner 2017). The photograph in Figure 2-5 shows the location of a catastrophic road crossing failure on Volstead Creek that occurred on 2017.

Figure 2-5. Photograph of Road Crossing Failure Location on Volstead Creek (Source: J. Johnson)

The NF-4225 road culvert crossing of Beaver Creek near RM 9.5 also poses a considerable risk of catastrophic failure due to a high potential for plugging. The photograph in Figure 2-6 shows sediment deposition and wood racking at the inlet of the culvert.

Figure 2-6. Photograph of Wood Racking at Culvert Crossing Inlet on NF-4225 Road near RM 9.5

2.3.7 Timber Harvesting

Recent timber harvest has been minimal in riparian areas along most of Beaver Creek drainage area, with the majority of near-stream harvest occurring along the South Fork (Hopkins 2013). However, historical harvest in the drainage has been significant, extending to the upper reaches of the drainage, and total harvest activity from the 1960s to the end of the twentieth century is estimated at around 1.38 million board feet, excluding Frazer Creek (USFS 1997; Andonaegui 2000). For the Beaver Creek and surrounding drainages, historical timber harvest (1920s to 1955) primarily used the selective harvest or "high grading" method, but since then, partial cutting and clear-cutting have predominated through the 1990s (UCRTT 2014). Recent harvests have been based on ecological restoration goals on USFS land and harvest on state and private lands.

Both timber harvest and the construction of logging roads in the Beaver Creek drainage have caused heavy sediment loading, reducing the potential recruitment of large woody debris (LWD), and may be linked to channel damage from flashier spring runoffs (Andonaegui 2000). 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). Salvage logging has been conducted following the 2014 Carlton Complex Fire on WDNR and private land.

2.4 Wildfires

Wildfires are a natural part of the western landscape, interacting with streams by providing the benefits of large wood, supplies of fresh bedload and gravel, nutrients, and rejuvenated vegetation. Fires have been shown, in some instances, to increase baseflows post-fire (USBR 2008, Hallema et al. 2016). Reduction of riparian vegetation reduces evapotranspiration and interception, providing more water to the system (USBR 2008), while reduced subsurface flow may be responsible for the increased surface flow in other areas (Hallema et al. 2016). Within the Methow Subbasin, monitoring of Andrews Creek before and after the 2004 Farewell Fire showed a significant increase in baseflows, with the largest increase occurring in drier years (Konrad pers. comm. 2017).

The natural fire regime in the Methow Subbasin includes annual and frequent fires burning large areas (USBR 2008). Nearly a century of aggressive fire suppression, however, has altered regional fire regimes, resulting in less frequent, but larger and higher intensity fires than historical conditions (USBR 2008; Flintcroft et al. 2016). The greater intensity wildfires can have a deleterious effect on stream habitat conditions (USBR 2011; Johnson and Molesworth 2015). While shrubs tend to recover more quickly, negative effects associated with these modern day wildfires include loss of shading vegetation and mature trees, reduced water infiltration and increased runoff, increased water temperatures, hydrograph volatility and increased peak flows, increased fine sediment transport, and landslides. The extent of these negative effects depends on several factors: burn severity, fire intensity, burn area, topography, soil properties, climate, road drainage networks and channel proximity (Moody et al. 2013; Johnson and Molesworth 2015).

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). The 2006 Tripod Complex Fire burned more than half of the Upper Beaver Creek watershed, including Lightning and Blue Buck Creeks, with several locations of high and moderate burns levels. The USFS BAER report documented severely impacted soil erosion, infiltration rates, and surface runoff following the fire (USFS 2006b). Post-fire treatments included helicopter application of straw over severely burned areas, hydro-mulching along roads, and road drainage improvements (USBR 2013b).

In 2014, the Carlton Complex Fire started with lightning strikes on July 14 that created four separate fires that joined together on July 20 and ultimately burned roughly 256,000 acres (TU 2015). Figure 2-7 shows the soil burn severity in the Beaver Creek drainage as a result of Carlton Complex Fire (BAER 2014). For the most part, the 2014 Carlton Complex Fire did not overly impact the fish-bearing tributaries within the burn boundaries, with the exception of Beaver Creek, where the fire extended over 42 percent of the Beaver Creek drainage area, with 12 percent of the area having moderate to high severity, mostly along Frazer Creek (Johnson and Molesworth 2015; TU 2015). When the areas of the two fires are combined, the majority of the land in the Beaver Creek drainage has burned over the past decade (Watson and Crandall 2015). The photographs in Figure 2-8 show an example of a burned riparian area of Beaver Creek after the 2014 Carlton Complex Fire (left), and an area representative of post-fire riparian understory regrowth (right, photograph taken in 2017).

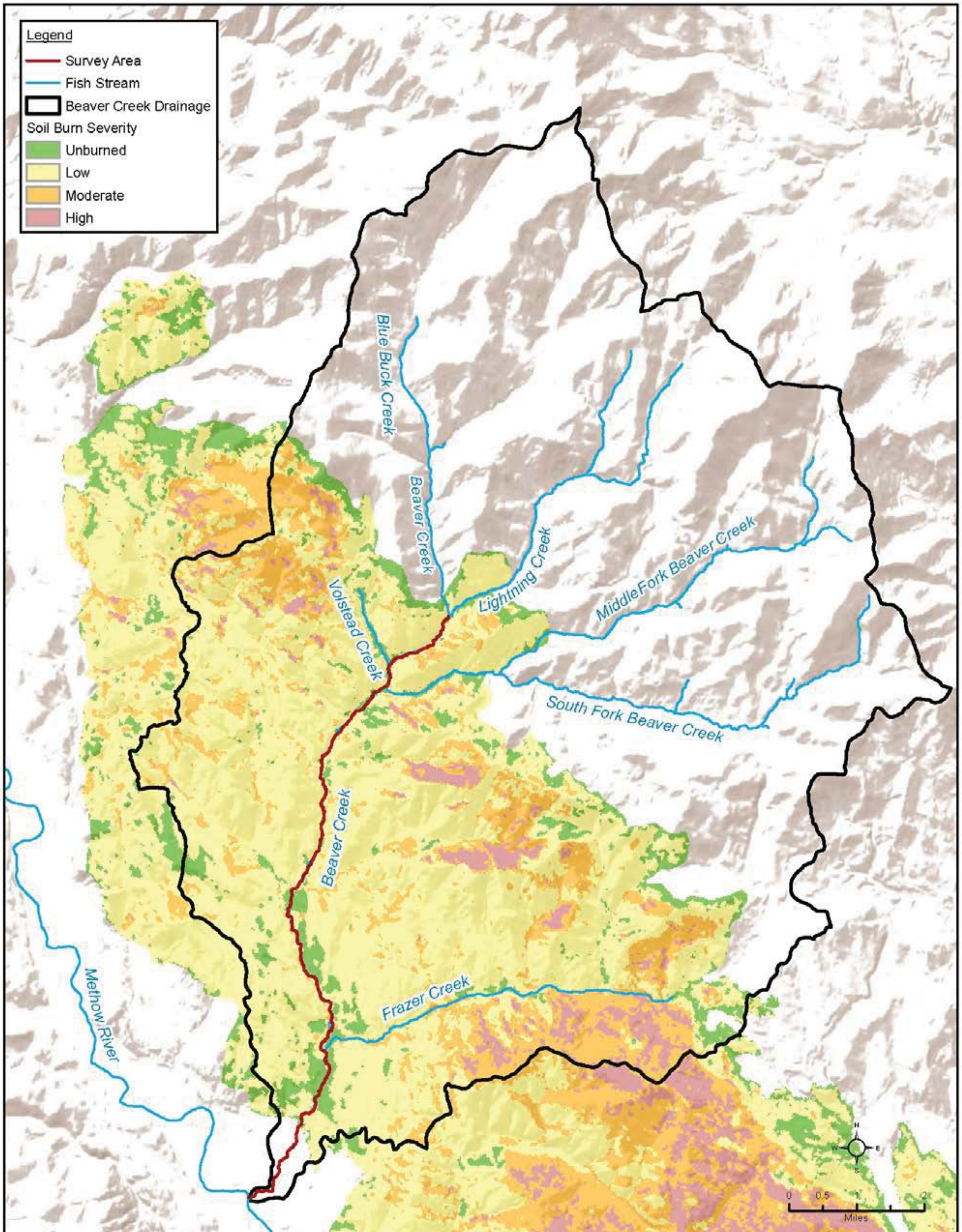

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Figure 2-7 Soil Burn Severity in Beaver Creek following the 2014 Carlton Complex Fire

Figure 2-8. Photograph of Burned Riparian Area in Reach 2 Following the 2014 Carlton Complex Fire (Source: BAER 2014) (left), and Regrowth of Riparian Understory in 2017 (right); (photos are representative and were not taken in the exact same location)

The Cougar Flats Fire, a component of the Carlton Complex Fire, burned through the lower 10 miles of the Beaver Creek drainage (Watson and Crandall 2015). Within the Beaver Creek drainage, 40 percent of the riparian areas were burned, 16 percent at a moderate to high severity. After the fires, a major rainstorm hit the region twice in one month (August 14 and 21-22), resulting in major surface erosion, transporting silt, sand, wood, gravel, cobble, and ash into Beaver Creek (TU 2015). The photograph in Figure 2-9 shows surface erosion from Storer Creek following the 2014 Carlton Complex Fire. Frazier Creek is heavily impacted and confined by Highway 20, resulting in loss of connectivity with the historic floodplain and sinuosity, and has numerous road crossings and high densities of logging roads in the upper watershed (Molesworth pers. comm. 2017). It was particularly hard hit by the Carlton Complex Fire, and the resulting debris flows and road crossing failures in particular have adversely affected the lowest 3 miles of Beaver Creek (Johnson and Molesworth 2015). There were reports that Beaver Creek turned into a black, frothy torrent following the fire and debris flows (Watson and Crandall 2015). Beaver Creek was already experiencing high water temperatures and fine sediment inputs; the immediate aftermath of the fire exacerbated these issues (TU 2015). In 2015, the Okanogan Complex (Lime Belt Fire) burned the upper extent of the South Fork Beaver Creek drainage (BAER 2015).

Figure 2-9. Photograph of Road Drainage Failures and Surface Erosion at Storer Creek (Reach 4) Following the Carlton Complex Fire (Source: BAER 2014)

Increased rates of erosion and highly dynamic conditions are continuing to persist in Beaver Creek. 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). Beaver Creek and many tributaries are experiencing increased runoff volatility and flooding caused by thunderstorm-generated rain and rain-on-snow events. Extreme flooding and channel instability in May 2017 caused two major road failures along Beaver Creek. As shown in Figure 2-10, a large asphalt section of Upper Beaver Creek Road washed out upstream of Balky Hill Road near RM 6.5 (Johnson 2017). During the same event, multiple road crossing failures on Volstead Creek resulted in large volumes of sediment input to upper Beaver Creek. The continued instability of Beaver Creek poses a substantial risk to public safety and infrastructure, and continues to considerably alter fish habitat.

Figure 2-10. Photograph of Road Erosion in May 2017 (Source: J. Johnson)

2.4.1 Effects of Fire on Fish

The heavy stream siltation and debris flows from the 2006 Tripod Complex Fire substantially reduced fish populations in surveyed streams and was thought to have wiped out the remnant bull trout population in Blue Buck Creek (USFS 2007). In 2014, the Carlton Complex Fire burned over 40 percent of the Beaver Creek drainage area and resulted in heavy ash/debris flows (Watson and Crandall 2015). Short-term impacts to fish populations following the fires were significant (Watson and Crandall 2015). Immediate impacts included the mortality from high water temperatures, loss of vegetation cover, and resulting debris flows likely fatal to any resident fish or eggs present in the system at the time (Johnson and Molesworth 2015; Watson and Crandall 2015). Post-fire and flood surveys indicated significant decreases in fish abundance 2 months after the events, with just 4 rainbow trout/steelhead captured in the same reach that had ranged from 167 to 809 rainbow trout/steelhead in surveys conducted during the previous 9 years (Watson and Crandall 2015). Snorkel observations in 2017 have suggested rapid recolonization of Chinook, coho, rainbow trout/steelhead, and other fish species in Beaver Creek (Molesworth pers. comm. 2017). Additional information on fish use and population status in Beaver Creek is provided in Section 2.6.

2.5 Water Quantity and Quality

Water quantity and quality are two important factors for sustainable anadromous populations. Low 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. The ecological concern of water quantity was given the highest priority rating by the UCRTT, and increased instream flow identified as a priority action type (UCRTT 2014). Since salmonids require clean, cool, highly oxygenated water (Andonaegui 2000), poor water quality inhibits fish health and further limits the amount of available habitat.

Beaver Creek is impacted by low flows, particularly during the summer and fall irrigation season. In low water years, lower Beaver Creek was known to go dry in the fall in some areas (USFS 2006b). Numerous actions have been taken to improve instream flows, such as irrigation efficiency upgrades and acquisition of irrigation withdrawal sites (TU 2015). This has improved flows; however, stream discharge monitoring in the lower creek shows that flows are continuing to drop to around 4 cfs during the summer (Ecology 2017a). Because of this, the lower reach of Beaver Creek is listed on the Washington 303(d) list for inadequate instream flows (NPCC 2005). The Washington 303(d) listing for Beaver Creek includes reports between 1991 and 1994 that indicate three accounts where the entire flow of Beaver Creek was being diverted into a diversion ditch at RM 3 (Ecology 2017b). Instream flow measurements during the irrigation season showed higher flow near the confluence with South Fork Beaver Creek (RM 9.2) compared to a downstream site near RM 1.6, and that flows near the mouth were routinely less than 5 cubic feet per second (TU 2015).

Currently, the factors affecting water quality standards for Beaver Creek are high water temperatures, fine sediments from roads, past timber harvest, grazing, recreational use, and high pH levels (USBR 2013b; TU 2015; Ecology 2017c). Water temperatures measured in Beaver Creek and Frazer Creek in 2012 exceeded Washington State Department of Ecology (Ecology) standards for salmonids at all monitoring sites (Hopkins 2013). Water temperature data collected that same year showed water temperature increases between RM 3.6 and RM 5.8, and demonstrated that temperatures from ditch returns were warmer than the temperature in Beaver Creek (Hopkins 2012). Extensive water temperature monitoring in Beaver Creek has been conducted by the USFS and the Methow Subbasin Water Quality Monitoring Program (TU 2015). Data from both monitoring programs show water temperatures in the lower areas of the Beaver Creek drainage exceeding standards for core salmonid habitat and spawning and rearing habitat from both Ecology and National Ocean and Atmospheric Administration National Marine Fisheries Service (NMFS) (TU 2015).

Beaver Creek is listed on the Washington 303(d) list as a Category 2-Waters of Concern for high pH excursions (Ecology 2017c). Water quality sampling in Beaver Creek has included ground and surface water sampling for temperature, major ions, dissolved oxygen, pH, nitrite plus nitrite, chloride, and, to a limited extent, concentrations of arsenic and lead (Konrad et al. 2005). Related to the 303(d) listing, the value of pH measured for Beaver Creek meets the criteria for a class C (fair) stream, with all other sites in neighboring drainages meeting the criteria for class AA streams (Konrad et al. 2005). There have been temporary increases in nutrient inputs to Beaver Creek after recent wildfires (i.e., Tripod Complex and Carlton Complex fires). Nitrogen, ammonium, and potassium were transported into tributaries from surface runoff along with fine sediment (Johnson and Molesworth 2015).

2.6 Fish Use and Population Status

Beaver Creek is known to support steelhead spawning and rearing, and is also host to cutthroat trout (*O. clarkia*) and a small population of bull trout in the upper reaches. In recent years, limited spring Chinook and coho spawning has been seen in the lower reach near the mouth of the creek. There are also a number of non-anadromous species that are typical of higher elevation streams of the east slope Cascades including shorthead sculpin (*Cottus confuses*), bridgelip sucker (*Catostomus columbianus*), and longnose dace (*Rhinichthys cataractae*) (USBR 2013a). Bridgelip sucker and longnose dace have generally only been observed using the lower reaches of Beaver Creek. Pacific lamprey (*Entosphenus tridentatu*) have not been found in Beaver Creek fish surveys, though they were historically found in large numbers in the Methow River and there were no known barriers to their use of Beaver Creek before European settlement (NPCC 2005; WDFW 2011; Crandall 2016; Nelle et al. 2016).

2.6.1 Salmonids

Salmonids are present in the Methow River Subbasin year-round (see Table 2-2), including ESA-listed species. Chinook salmon, steelhead/rainbow trout, coho salmon, cutthroat trout, bull trout, mountain whitefish (*Prosopium williamsoni*), and brook trout (*Salvelinus fontinalis*) are known to be present in various areas of the Beaver Creek drainage (Andonaegui 2000; USBR 2013a). While brook trout are not native to the area, they are present throughout Beaver Creek and are believed to have nearly replaced all the cutthroat and bull trout in the system (NPPC 2002), as well as interbreeding with bull trout (USFS 2006a). ESA-listed species present within the Beaver Creek drainage include Upper Columbia River spring-run Chinook salmon, Upper Columbia River summer steelhead, and Columbia River bull trout. Each of these species is described in greater detail below, and their distribution in the Beaver Creek drainage is shown on Figure 2-11.

Chinook Salmon

Observed use of Beaver Creek by Chinook salmon has generally been limited to the lower reaches (Martens et al. 2014a, Andonaegui 2000; Anchor 2008, Yakama Nation 2012), and mostly restricted to spring Chinook, rather than the summer runs (USBR 2013b). Spawning surveys in the Twisp River suggest that timing of spawning in the tributaries is similar that in the mainstem Methow River, with peak spawning occurring between August and September (Humling and Snow 2006). Beaver Creek is considered as rearing habitat only for Chinook salmon in the revised Biological Strategy (UCRTT 2014). In 2011, three juvenile and two adult Chinook were noted by the U.S. Geological Survey (USGS) at the PIT tag site at RM 3.1 (Hopkins 2013). During USGS surveys in 2013, one juvenile Chinook was observed in the lower portion of Beaver Creek.

Steelhead

Beaver Creek is considered an important spawning and rearing stream for Upper Columbia River summer steelhead (Peven 2003; Hopkins 2013). Steelhead utilize the Beaver Creek drainage from the mouth, upstream to between Frazer Creek and the South Fork of Beaver Creek (Andonaegui 2000), while resident rainbow trout are known to be within the Beaver Creek headwaters, Frazer Creek, South Fork Beaver Creek, and Blue Buck Creek (Andonaegui 2000). Steelhead spawning is known to occur in Beaver Creek up to RM 8.7, just below the USFS boundary (USFS 2007); however, resident rainbow trout and *O. mykiss* are found throughout the drainage, and interbreeding may occur between rainbow trout and steelhead (USFS 2006a). WDFW steelhead surveys between 2002 and 2012 show the highest redd counts in the lower 2.1 river miles, with the most being 70 redds in 2002 and the fewest being 9 redds in 2007. Between 2010 and 2012, the average number of redds in the lower 2.1 miles was 13.7 redds/mile; however, during that same timeframe, no redds were recorded between RM 2.1 and 9.0 (Hopkins 2013). Barriers to upstream migration have been removed in recent years, which should aid in more effective dispersal of spawning steelhead upstream (Martens et al. 2014a). Although steelhead juvenile outmigration timing for the Methow Subbasin is estimated between April and June (see Table 2-2), research in Beaver Creek indicates that juveniles migrate out of the Beaver Creek drainage in fall and spring (USBR 2013a), between June of their brood year (heaviest in fall) to July of the following year (Weigel 2013). However, steelhead may spend multiple years in tributary and mainstem habitat before migrating out to sea (NMFS 1998). Similarly, adults passed the weir near the mouth of Beaver Creek between March and May (Weigel 2013).

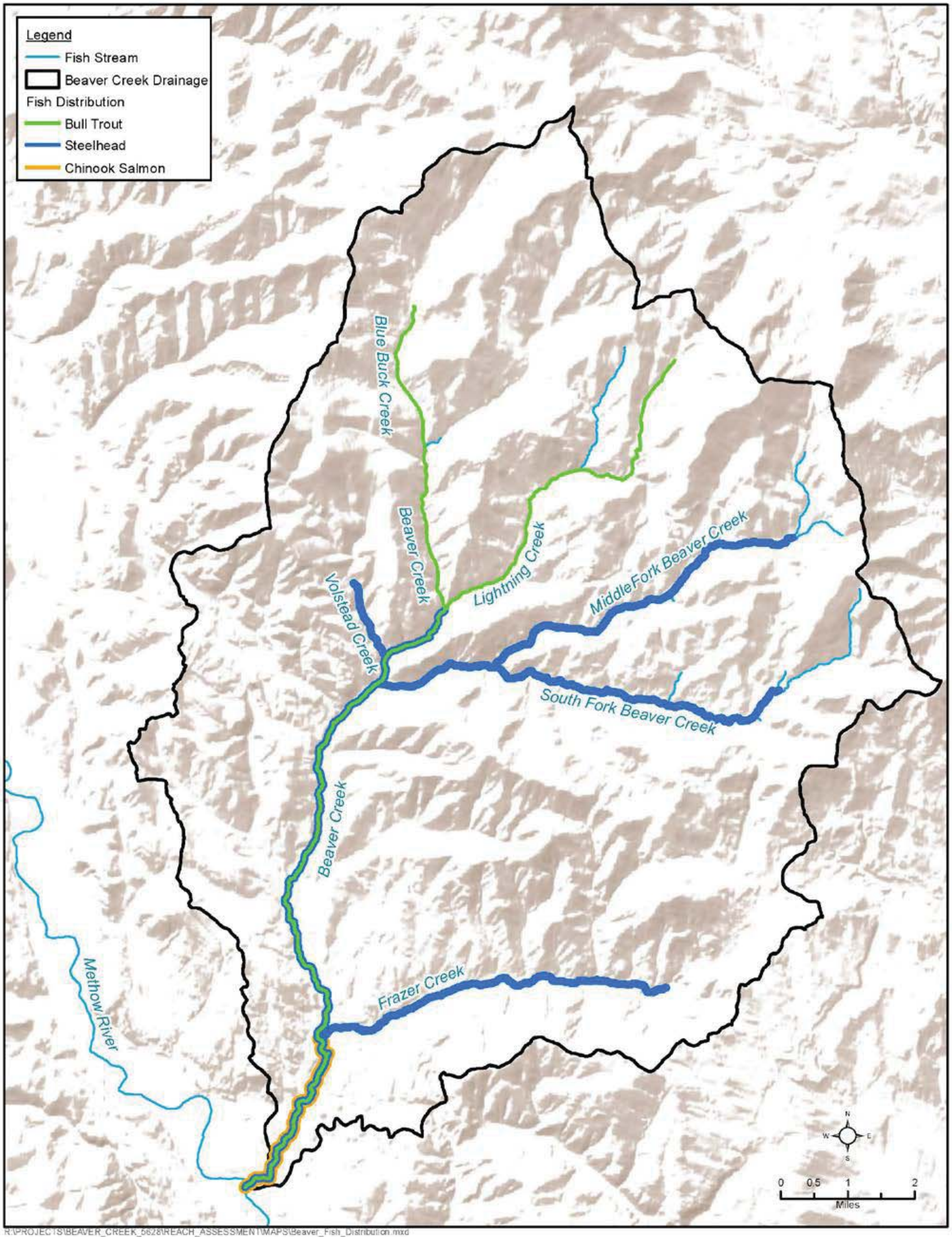


Figure 2-11. ESA-Listed Species Distribution in the Beaver Creek Drainage

Table 2-2. Beaver Creek Spring Chinook Salmon, Summer Steelhead, and Bull Trout Periodicity

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

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/ While adults have access to Beaver Creek, it is generally recognized as rearing habitat only (UCRTT 2014)

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

Bull Trout

The Methow River bull trout population was evaluated during the USFWS 5-year review and was determined to be declining (USFWS 2008), which was reiterated in the 2015 Mid-Columbia Recovery Unit Implementation Plan for Bull Trout (USFWS 2015b). The Columbia River Instream Atlas Project listed all bull trout stocks in the Methow River as “unknown” status except for the Lost River stock which is considered to be “healthy” (WDFW 2011). Historically, both fluvial and resident populations of bull trout were present within South Fork Beaver Creek and Blue Buck Creek (Andonaegui 2000; NPPC 2002). Currently, however, they are only present in remnant populations, with few being observed in recent surveys (WDFW and USFWS 2015), and are at risk due to habitat degradation, migration barriers and competition and hybridization with brook trout (Andonaegui 2000; USFWS 2015a). Surveys within the last 10 years have indicated the bull trout population in Beaver Creek is very low (USFS 2007; USBR 2013a,b; Martens et al. 2014b; Crandall 2017). Fires appear to have affected these small subpopulations, with surveys in 2007 indicating that the 2006 Tripod Complex Fire likely wiped out the population in Blue Buck Creek, where previous surveys in 2004 identified 24 bull trout (USFS 2007). One bull trout was also observed in Beaver Creek in 2007, but 180 brook trout and brook trout/bull trout hybrids were recorded (USFS 2007). Only 2 bull trout (near RM 14) were detected during USGS surveys of Beaver Creek and its tributaries between 2008 and 2012, while 148 brook trout were documented in the same survey areas and time frame as for bull trout (Martens et al. 2014b). No bull trout have been observed in Beaver Creek during the last three years of snorkel surveys conducted in coordination with the Methow Restoration Council (Crandall 2017).

Coho Salmon

While coho salmon are not currently ESA-listed in this region, they are a species of interest due to ongoing restoration and reintroduction efforts by the Yakama Nation since 1997. 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). Coho adults and redds have been found in the lower part of the Beaver Creek drainage, with 17 redds identified between 2003 and 2012 up to RM 2.1 at the SR 20 bridge (Yakama Nation 2009 and 2012; Kamphaus et al. 2011; Hopkins 2013; CRITFIC 2012). Juvenile coho salmon have also been observed in the lower mile of Beaver Creek (Yakama Nation 2012; Hopkins 2013).

2.6.2 Non-Salmonid Species of Interest

Pacific lamprey are increasingly a species of management interest and are present in the Methow River. Although the historical abundance of Pacific lamprey is believed to have been relatively high, the current population is severely diminished (Nelle et al. 2016). Fish surveys have not identified Pacific lamprey in the Beaver Creek drainage (Crandall 2016); however, they have been found in reaches of the Methow River both upstream and downstream of the Beaver Creek confluence as well as in the Chewuch River (Martens et al. 2014b; Crandall 2016). In recent years, the Yakama Nation has been working on recovery efforts for Pacific lamprey, called the Pacific Lamprey Project. 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” (Yakama Nation Fisheries 2016). Efforts include documenting historical occurrences and current presence; working on artificial propagation and outplanting; and developing a management action plan identifying threats and restoration work to improve conditions for lamprey populations and migration (Yakama Nation Fisheries 2016).

Within the Methow River Subbasin, lamprey restoration efforts include implementing restoration designs that take lamprey needs into consideration. For passage projects, this includes project designs that accommodate lamprey passage requirements, which are different than the passage requirements for salmonids. 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 River Subbasin (Nelle et al. 2016). Threats to Pacific lamprey in the Methow River Subbasin include small population size and mainstem obstructions (high threats); dewatering and flow management, stream and floodplain degradation, and climate change (moderate threats); and predation, juvenile passage, and adult passage (low threats) (Nelle et al. 2016).

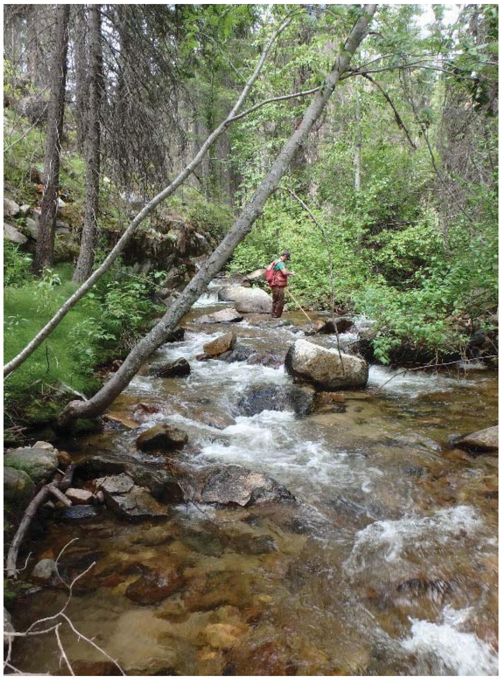
2.7 Ecological Concerns

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 Beaver Creek and the Methow Subbasin including:

- The salmon, steelhead, and bull trout habitat limiting factors report for WRIA 48 (Andonaegui 2000)
- The Methow Subbasin Plan (NPCC 2005)
- The 2008 Fish Accords (Three Treaty Tribes-Action Agencies 2008)
- The Methow Subbasin Geomorphic Assessment (USBR 2008)
- The Federal Columbia River Power System (FCRPS) Biological Opinion (FCRPS 2012)
- The Upper Columbia Revised Biological Strategy (UCRTT 2014)

The revised Biological Strategy (UCRTT 2014) contains the most up-to-date ecological concerns information. The revised Biological Strategy 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 State-wide Steelhead Management Plan (WDFW 2008). The revised Biological Strategy identifies seven ecological concerns for the Beaver Creek assessment unit, in priority order (UCRTT 2014):

1. Water quantity (decreased water quantity)
2. Channel structure and form (bed and channel form)
3. Habitat quantity (anthropogenic barriers – need to maintain passage)
4. Riparian restoration (condition)
5. Sediment (increased sedimentation)
6. Injury and mortality (mechanical injury)
7. Species interactions (introduced species that compete and or predate on native fish)



3. REACH ASSESSMENT METHODS

The methods employed in the development of the reach assessment included LiDAR data acquisition, field surveys, and analytical methods focused on identifying habitat impairments. The LiDAR data were acquired October 12 and 13, 2016, with data acquisition described below. Field surveys were conducted on foot from June 27 to July 1, 2016. Topobathymetric LiDAR data were also acquired on Fraser Creek concurrently as a component of a separate project. The field team, including a geomorphologist, fisheries biologist, and professional engineer, walked the length of the Survey Area.

The following subsections provide the methods used to develop the reach assessment and restoration strategy: topobathymetric LiDAR data collection (Section 3.1), geomorphic and habitat field surveys (Section 3.2), field identification of restoration opportunities (Section 3.3), reach assessment analyses (Section 3.4), and Reach-based Ecosystem Indicators (Section 3.5).

3.1 Topobathymetric LiDAR Data Collection

The topobathymetric LiDAR survey was accomplished using traditional LiDAR and topobathymetric (or "green") LiDAR collected simultaneously. While the traditional LiDAR laser pulses do not penetrate water surfaces, the topobathymetric sensor uses a narrow green beam laser that penetrates the water surface. The resulting surface was utilized for a detailed visualization of channel and floodplain features as well as for reach assessment analyses and calculations. The technical data report describing topobathymetric LiDAR acquisition, processing, and accuracy estimates is included as Appendix C.

3.2 Geomorphic and Habitat Field Surveys

Geomorphic and habitat field surveys were conducted to characterize current in-channel and riparian habitat and establish baseline conditions in Beaver Creek. Specific attention was given during field surveys to making observations related to sediment transport and fire/flood response conditions; channel incision and channel stability trends (erosion or aggradation); substrate characteristics (e.g., size, distribution, supply); the abundance and influence of instream wood; floodplain connectivity; the influence of human alterations; and the interaction of the stream with riparian ecological processes. These geomorphic conditions data were collected and observations recorded during field surveys.

The field habitat surveys were completed generally following the USFS Level II protocol (USFS 2016). Habitat units, also referred to as channel units, were mapped and data collected for each unit in the Survey Area. Habitat units included pools (scour pool, dam pool, plunge pool), fast turbulent water (riffles, rapids, and cascades), and fast non-turbulent water (glides). Habitat unit type, channel dimensions, and wood data were collected at every habitat unit throughout the Survey Area. More detailed data, including observations of substrate and riparian characteristics, fish cover, floodprone width, and Rosgen classification, were collected at 10 percent of the habitat units. Other important features such as side channels, tributary junctions, log jams, culverts, diversion structures, eroding or armored banks, or other points of interest were identified, documented, and their locations mapped during field surveys.

Sediment samples (pebble counts) were taken to document significant changes in bed sediment texture following the methods described in Bunte and Abt (2001). LWD in the Survey Area were inventoried in every habitat unit. Instream wood that was shorter than the size criteria in the USFS Level II protocol was inventoried separately. This wood was included because relatively small wood has the ability to provide important functions in Beaver Creek. Standing trees within the bankfull channel were not inventoried as LWD.

3.3 Field Identification of Restoration Opportunities

Potential opportunities for restoration and habitat enhancement were initially identified during field surveys. This preliminary look at restoration opportunities was further refined through reach assessment analyses and existing data.

The identification of potential restoration 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. Previously completed restoration projects were identified through an evaluation of existing data and available information (see Section 2). Potential restoration opportunities were selected to address the reach-scale restoration targets developed as part of the restoration strategy. The project areas and potential actions are discussed in Section 5.3.

3.4 Reach Assessment Analyses

A number of different technical tools and software were used for various aspects of the geomorphic analyses. For example, the TerEx Toolbox for ArcGIS was used for semi-automated selection and calculating heights of terrace features from LiDAR (Stout and Belmont 2014). The River Bathymetry Toolkit (RBT) for ArcGIS was used for processing stream channel topography, calculating metrics, and creating a relative elevation model with the slope of the valley removed (i.e., detrending) to reveal subtle changes in floodplain topography (McKean et al. 2009). The following subsections describe the methods for delineating this reach assessment into individual reaches (Section 3.4.1) and geomorphic analyses (Section 3.4.2). REIs are discussed in Section 3.5.

3.4.1 Reach Delineation

Survey Area reaches were delineated based on desktop- and field-identified habitat and geomorphic characteristics. Changes in the following characteristics were used to identify the geomorphic reach breaks:

- Geologic controls on channel confinement and channel grade
- Channel pattern, form, and migration process
- Channel morphology and geometry
- Channel substrate
- Significant tributary junctions
- Habitat types (including the presence of side channels and off-channel areas)

The locations of previous reach breaks from the recent Lower Beaver Creek Stream Habitat Assessment (Hopkins 2013) were also evaluated during field surveys.

3.4.2 Geomorphic Analyses

Channel Morphology

The channel morphology of Beaver Creek 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).

Sediment Characteristics and Flow Competence

Sediment size distributions, characteristic sediment sizes, and percent composition by sediment type (e.g., sand, gravel, cobble, boulder) were calculated from surface sediment samples (i.e. pebble counts). Specific sediment transport characteristics including threshold grain size were evaluated using hydraulic characteristics (i.e. shear stress and unit stream power). Threshold of motion sediment size estimates were calculated with the Shields threshold of motion equation (Shields 1936). The equation is based on the Shields number, which is a non-dimensional number that relates the fluid force acting on sediment to the weight of the sediment. The inputs were calculated from the hydraulic model for channel hydraulics, channel gradient, and sediment size estimated from surface sediment samples.

Canopy Height and Percent Cover

Canopy height was calculated using the 2016 LiDAR dataset (see Section 3.1) to determine the height of vegetation in the LiDAR survey area. The calculation used both the bare earth and highest hit digital elevation models (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.

Hydrology and Floodplain Inundation

The hydrologic analysis included evaluating available discharge data from a number of sources including USGS and Ecology gaging stations. Ecology's River and Stream Flow Monitoring Program has been collecting data at two stream flow monitoring stations (ID 48F060 and ID 48F150) since June 2015. The upstream station (ID 48F150) is located downstream of the Lester Road crossing near Burns Canyon (Piper Creek confluence) at RM 8.2. The downstream station (ID 48F060) is located near the Methow Valley Highway (SR 153) crossing at RM 0.3. The data collected at both gages thus far are not considered reliable due to highly dynamic post-fire conditions at gaging sites (Anderson 2017).

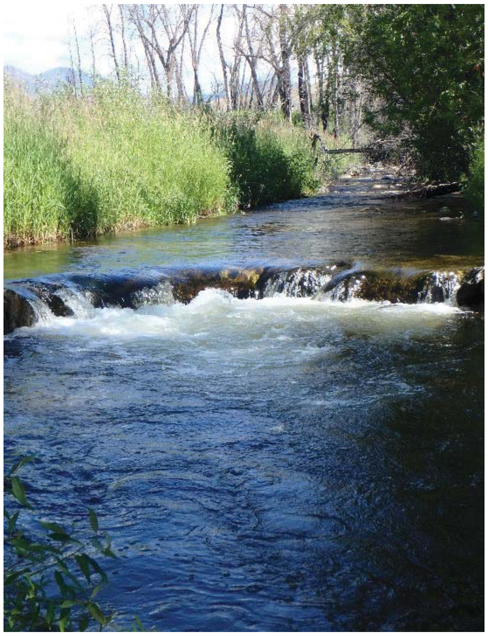
There have been three USGS gaging stations on Beaver Creek, none of which are currently functioning consistently. The three gages were the USGS 12449600 gage (Beaver Creek below South Fork near Twisp), the USGS 12449700 gage (Beaver Creek near Twisp), and the USGS 12449710 gage (Beaver Creek near Mouth near Twisp). Peak flows were calculated using a Log-Pearson Type III Analysis (USGS 1981) at the Beaver Creek gage below the South Fork of Beaver Creek (USGS 12449600), which has the longest duration of operation from 1960 to 1978.

The analysis also took into consideration peak discharge estimates that were developed for the Schoolhouse Fish Habitat Enhancement (Inter-fluve 2014) and Upper Beaver Creek Habitat Improvement (Anchor 2008) design reports. Peak flow estimates were also developed throughout the length of the Survey Area using the USGS regional regression equations (Sumioka et al. 1998) and the recently updated USGS regional regression equations (Mastin et al. 2016).

The peak discharges described above were used in a planning-level hydraulic model that was developed to determine flood inundation for a range of flows including the 2-year, 10-year, 50-year, and 100-year flood events. The hydraulic model was developed with the Hydrologic Engineering Centers River Analysis System (HEC-RAS), which is a cross section–based one-dimensional model developed by the U.S. Army Corps of Engineers (USACE 2010) for computing velocity, flow depth, shear stress, and other hydraulic characteristics in riverine systems. Hydraulic model outputs were exported to HEC-GeoRAS, which is a custom interface between HEC-RAS and geographic information system (GIS), for mapping HEC-RAS water surfaces, flow depths, and velocities. The flood inundation tool in HEC-GeoRAS interpolates the water surface elevations from HEC-RAS cross sections to two-dimensional geospatial data.

3.5 Reach-based Ecosystem Indicators

The REI were used to characterize how the geomorphic and ecological processes are functioning within each reach of Beaver Creek. The REI are based primarily on the “Matrix of Diagnostics/Pathways and Indicators” (USFWS 1998), the NMFS Matrix of Pathways and Indicators (NMFS 1996), and work conducted within the region by the USBR (USBR 2012). 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). This analysis is also used to help select restoration targets as part of the restoration strategy presented in Section 5.



4. REACH ASSESSMENT RESULTS

The reach assessment results provided in this section provide the scientific foundation and site-specific information used to develop the project areas and potential restoration actions included in the restoration strategy (Section 5). The following subsections describe the reach assessment results including topobathymetric LiDAR (Section 4.1), hydrology (Section 4.2), reach descriptions (Section 4.3), geomorphology and habitat (Section 4.4), REI (Section 4.5), and climate change impacts (Section 4.6). Section 4.7 provides a summary of all the information provided in this section. The Beaver Creek existing conditions and reach assessment results map series are shown in Appendix B.

4.1 Topobathymetric LiDAR

The topobathymetric LiDAR, acquired on October 12 and 13, 2016, fully integrated traditional near-infrared LiDAR with green wavelength (bathymetric) LiDAR in order to map the topography and bathymetry of the Survey Area. Figure 4-1 shows an example of the topobathymetric LiDAR surface extraction from raw data points. The topobathymetric LiDAR provided a highly detailed surface for visualization, technical analyses, and modeling, as described in the subsections below. Figures B-1a through B-1k in Appendix B and Tables 4-3 through 4-9 show the topographic surface and relative elevation model created from the LiDAR data.

The topobathymetric LiDAR data were evaluated for fundamental vertical accuracy by guidelines presented in the Federal Geographic Data Committee National Standard for Spatial Data Accuracy (FGDC 1998). The absolute accuracy of the data ranged from an absolute vertical accuracy of 1.26 inches for topography, 1.6 inches for wetted edge, and 3.9 inches for bathymetry. Bathymetric depths were successfully mapped with high confidence for 95 percent of the survey area identified as water. Appendix C describes the topobathymetric LiDAR data and provides technical details about data acquisition procedures, processing methods, and analysis of the final dataset including LiDAR accuracy, depth penetration, and data density.

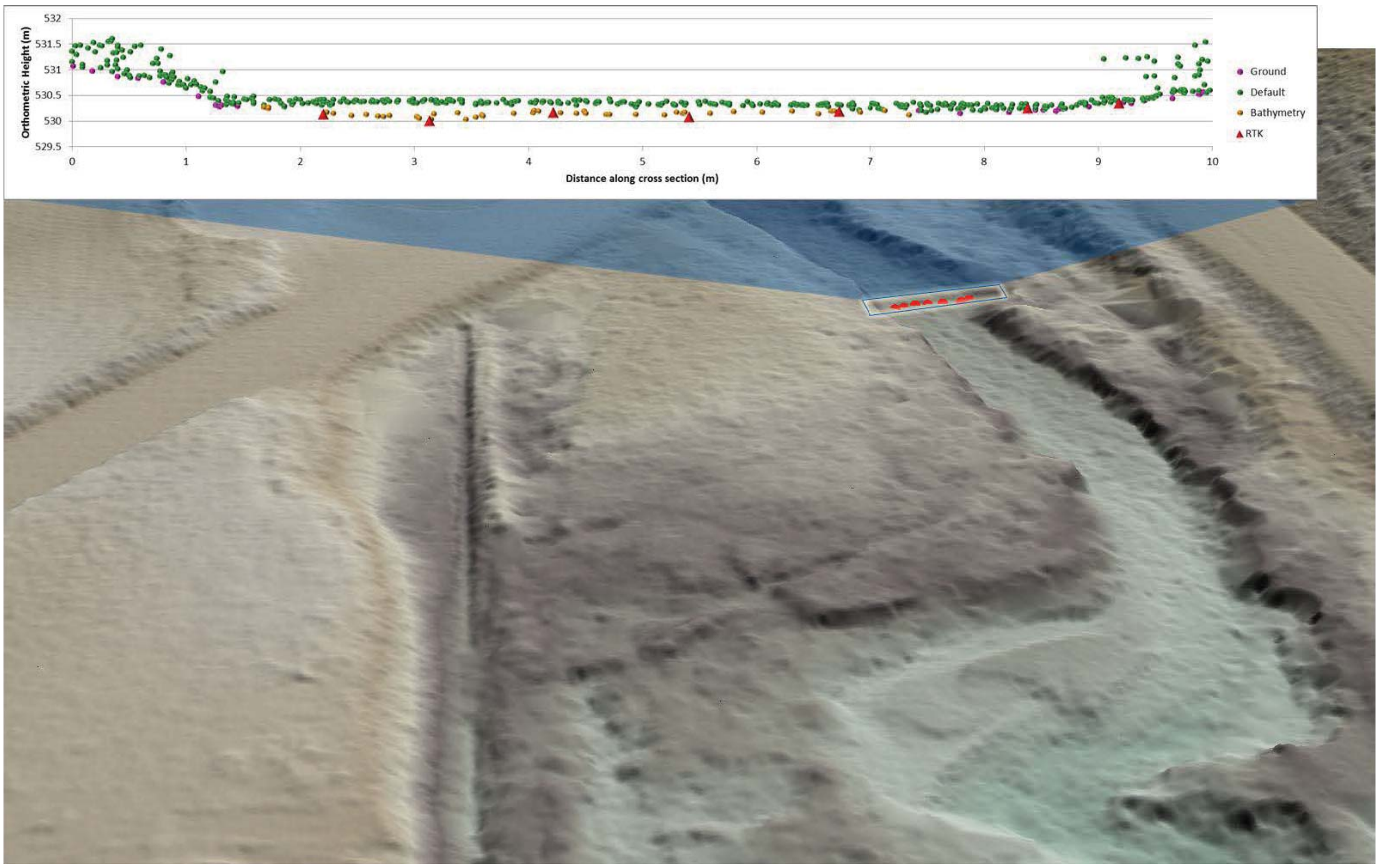


Figure 4-1. Bare-Earth Topobathymetric LiDAR (colored by elevation) Showing Bathymetric RTK Points in relation to Actual Mapped Bathymetric Ground Points

4.2 Hydrology

Peak flow discharges typically occur in Beaver Creek during May and June driven by snowmelt runoff. Peak flows typically recede relatively quickly, returning to low-flow conditions from August to February. During the low-flow period, there are intermittent, short-duration, flow increases in response to storm events. As described in Section 2.3.3, Beaver Creek is an adjudicated drainage where water uses are granted in excess of available water during some part of the irrigation season. As much as the lower 0.5 mile of the creek has been documented to run dry in some years (USFS 2006a); however, efforts to improve irrigation efficiency and other water conservation measures have been implemented in more recent years in an effort to improve flow conditions. Ecology installed two stream flow monitoring gauges on Beaver Creek in 2015. These gauges have functioned intermittently since installation, resulting in significant data gaps. However, one significant observation from the recent available data is that streamflow measured at RM 8.2 was significantly higher than the volume at RM 0.3 during the summer months (July-October), despite tributary inputs in that section of creek. This suggests that more water was available in the upper reaches of Beaver Creek than in the lower reaches, which likely resulted from irrigation withdrawal between the gauge stations (Ecology 2017b).

During winter months, Beaver Creek is susceptible to ice buildup and jam formation due to the area climate, topography, and hydrology. River ice can cause a damming effect, particularly during thawing events, that results in flooding, erosion, and deposition on adjacent floodplains. The extent of river ice impacts in Beaver Creek are uncertain; however, the impact of river ice on the nearby lower Twisp River has been well-documented (Inter-fluve 2016).

Named tributaries to Beaver Creek include Frazer Creek entering from the east near RM 3.0; Storer Creek entering from the east near RM 5.9; Piper Creek (also known as Burns Canyon) entering from the east near RM 7.9; South Fork Beaver Creek entering from the east near RM 9.2; Volstead Creek entering from the north near RM 9.8; Lightning Creek entering from the northeast near RM 11.1; and Blue Buck Creek entering from the north upstream of the Survey Area. Figure 4-3 shows the location of tributaries in the Survey Area.

As previously described in Section 3.4 and mapped in Figure 2-4, there are three inactive USGS gaging station locations on Beaver Creek including USGS 12449600 (1960-1978), USGS 12449700 (1956-1961), and USGS 12449710 (2000-2001). Figure 4-2 shows the minimum, mean, and maximum daily Beaver Creek discharge from 1960-1978 as recorded at the USGS 12449600 gage near RM 9.0. Table 4-1 shows a comparison of peak discharge estimates at this gage location using a Log-Pearson Type III analysis (USGS 1981), drainage area gage-transfer methods, regional regression equations (Sumioka et al. 1998), and runoff estimates representing 2006 burned conditions (USFS 2006b). The Survey Area topography and existing features map series Figures B-1a through B-1k of Appendix B show the location of past and present stream gages on Beaver Creek.

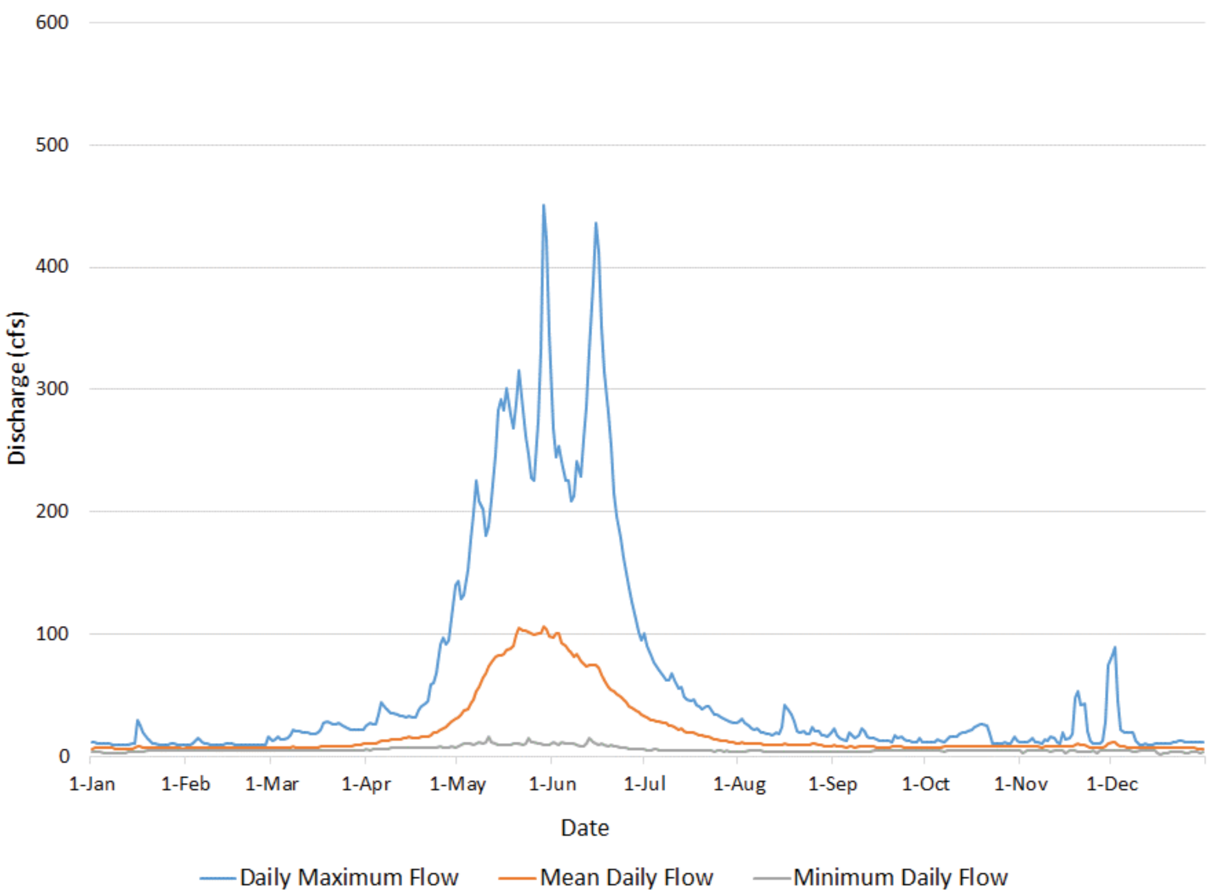


Figure 4-2. Beaver Creek Daily Minimum, Mean, and Maximum Discharge for the Period from 1960 to 1978 (as measured at USGS gage 12449600 below South Fork Beaver Creek near Twisp, WA)

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). The 2006 Tripod Complex Fire and the 2014 Carlton Complex Fire have had a major effect on Beaver Creek peak flows. The USFS Hydrology Specialist Report estimated peak flows following the Tripod Complex Fire would increase by 153 percent (USFS 2006b, as cited in Anchor 2008). The two fires combined burned the majority of the land in the Beaver Creek drainage (Watson and Crandall 2015), with the Tripod Complex Fire burning 51 percent (USBR 2013b) and the Carlton Complex Fire burning over 42 percent of the Beaver Creek drainage area (Johnson and Molesworth 2015). Assuming a direct correlation between percent area burned and peak flow increases, Beaver Creek peak flows should increase by approximately 126 percent with a 42 percent burned area. A 2015 report for the Okanogan County Fires estimated increases in modeled 25-year recurrence interval 24-hour rainfall runoff events ranging from 137 percent to 478 percent (BAER 2015). These results are based on rainfall-runoff modeling, rather than instream gaged data. 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).

Table 4-1. Comparison of Peak Discharges Estimates Downstream of the South Fork Beaver Creek Confluence

Estimation Method	USGS 12449600 Peak Discharge Estimates			
	2-year (cfs)	10-year (cfs)	50-year (cfs)	100-year (cfs)
Log-Pearson Type III[1/]	136	367	615	727
Revised Estimates including 1957 Flood Event[2/]	161	470	828	998
Regional Regression Equations[3/]	241	541	845	989
Assuming Burned Conditions (based on 2006 Tripod Complex Fire)[4/]	Unknown	Unknown	Unknown	1,776

1/ Discharge calculated using the Log Pearson Type III analysis (USGS 1981). Results reported by USBR (2008) and Anchor (2008).
2/ Discharge calculated by gage transfer methods from nearest gage (USGS 2001). Results reported by Inter-fluve (2014).
3/ Discharges calculated using regional regression equations (Sumioka et al. 1998)
4/ Discharge estimates based on 2006 burned conditions. Results of USFS (2006b) cited in Anchor (2008).

For this Project, peak discharges for Beaver Creek were evaluated based on the USBR Methow Subbasin Geomorphic Assessment (USBR 2008) hydrologic analysis, and also calculated using USGS regional regression equations. Peak discharges were calculated for the length of Beaver Creek Survey Area, accounting for tributary inflows and drainage area differences. Table 4-2 contains peak discharge estimates for the 2-year, 10-year, 50-year, and 100-year flood events.

For comparison, peak discharges were calculated using the equations of 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 discharge estimates are considerably higher (up to 52 percent) at some locations when calculated with the updated regional regression equations compared to the previous equations, particularly in the downstream reaches with lower percentage of canopy cover estimates. 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.

The regression equations of Sumioka et al. (1998) were used as inputs for the planning-level hydraulic model. Hydraulic model outputs were used to develop water surfaces, flow depths, and velocities for the floodplain connectivity and inundation analysis in Section 4.4.1.

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

Location	Beaver Creek Peak Discharge			
	Recurrence Interval	USBR (2008)1/	USGS (1998)2/	USGS (2016)3/
Beaver Creek at Methow River confluence (RM 0.0)	2-year (cfs)	242	326	299
	10-year (cfs)	654	741	874
	50-year (cfs)	1,096	1,170	1,670
	100-year (cfs)	1,295	1,370	2,080
Beaver Creek at SR 20 bridge (RM 2.1)	2-year (cfs)	233	318	291
	10-year (cfs)	866	722	826
	50-year (cfs)	1,053	1,130	1,550
	100-year (cfs)	1,245	1,330	1,920
Beaver Creek upstream of Frazer Creek confluence to (RM 2.9)	2-year (cfs)	186	272	249
	10-year (cfs)	501	616	685
	50-year (cfs)	839	967	1,260
	100-year (cfs)	992	1,130	1,560
Beaver Creek upstream of Storer Creek confluence (RM 5.9)	2-year (cfs)	149	241	212
	10-year (cfs)	403	541	506
	50-year (cfs)	676	845	861
	100-year (cfs)	799	989	1,030
Beaver Creek upstream of South Fork Beaver Creek confluence (RM 9.2)	2-year (cfs)	78	146	128
	10-year (cfs)	210	327	291
	50-year (cfs)	352	509	484
	100-year (cfs)	416	595	575

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)

The standard method for estimating baseflow requires using historical data. Unfortunately, data available on Beaver Creek span a historical date range from 1960 to 1978 from the USGS and a more recent, though incomplete, data record from 2015 to 2017 gathered by Ecology. Through our analyses, we determined that neither dataset was suitable for modeling the 95 percent exceedance interval, which typically represents baseflow. This analysis would not accurately represent the current hydrologic conditions by omitting impacts from recent fires, development, and efforts to improve hydrology that have occurred over the last few decades. Analysis of this type is important in understanding flow conditions within the watershed and how they relate to available habitat for ESA-listed fish; therefore, improvements to gaging stations and flow data quality should be pursued.

4.3 Reach Descriptions

Seven distinct reaches were delineated in Beaver Creek from the mouth (RM 0.0) to the Lightning Creek confluence (RM 11.1). The reaches ranged from less than 0.4 mile in length to 2.8 miles in length. The differentiating characteristics of each of the reaches are qualitatively summarized below and the location of each reach is shown in Figure 4-3. Tables 4-3 through 4-9 include metrics describing reach characteristics, a reach map showing the relative elevation model, and representative photographs. The relative elevation model shown in Tables 4-3 through 4-9 is colored by the difference in elevation compared to the water surface elevation at the time of the LiDAR survey (October 12 and 13, 2016).

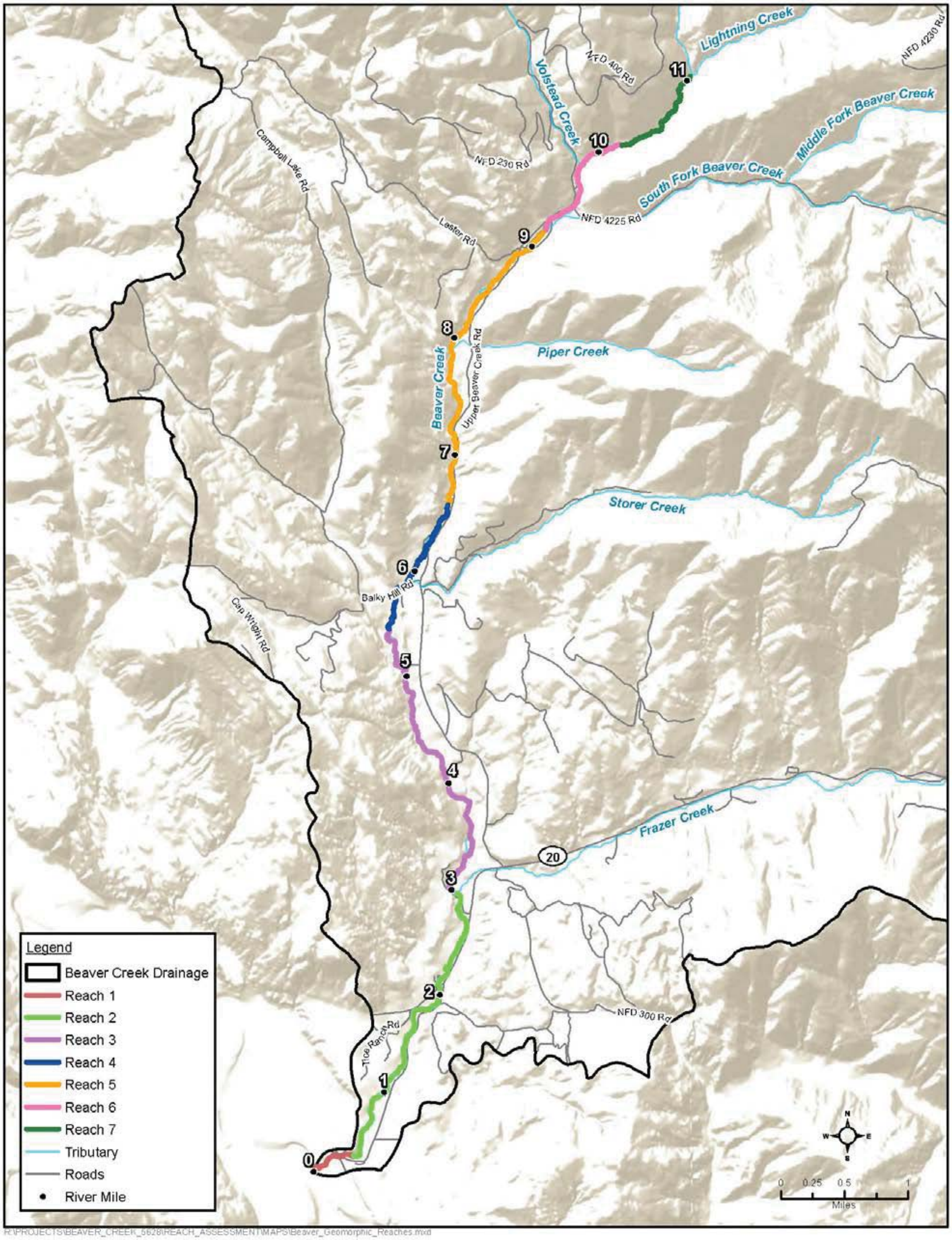


Figure 4-3. Beaver Creek Reach Assessment Geomorphic Reaches Overview

Reach 1: This is a relatively short reach from the confluence with the Methow River to RM 0.4; key features include the alluvial fan and the Methow Valley Highway (SR 153) crossing near RM 0.3. The Lower Beaver Creek Road parallels the creek to the east upstream of the Methow Valley Highway (SR 153). The channel in this reach is 2 percent gradient, deeply incised, and lacks instream habitat complexity and cover. Most of the channel banks downstream of the Methow Valley Highway (SR 153) crossing show signs of active erosion. There are multiple side channels across the fan in this reach but they are hydrologically disconnected at most flows due to channel incision. The planform of Reach 1 is relatively straight with limited sediment storage in sparse bars. This reach was not burned in the 2014 Carlton Complex Fire.

Reach 2: This reach extends from RM 0.4 to the Frazer Creek confluence near RM 3.0. The Lower Beaver Creek Road parallels the creek to the east to the junction with SR 20 near the crossing of Beaver Creek at RM 2.1. From there SR 20 parallels the creek for most of the remaining reach length. The valley in this reach is characterized by stepped glacial terraces. The planform in this reach is slightly more sinuous with channel migration occurring through irregular lateral channel avulsions. The channel in this reach has a similar gradient to Reach 1 but is less incised and has more instream wood and channel complexity. The upper half of Reach 2 was burned in the 2014 Carlton Complex Fire beginning near RM 1.4. Both Reaches 1 and 2 have been impacted by the 2014 Carlton Complex Fire by the subsequent debris flows from Frazer Creek that followed.

Reach 3: This is a relatively long reach of Beaver Creek from the Frazer Creek confluence near RM 3.0 to near RM 5.5. The Upper Beaver Creek Road parallels the creek throughout most of Reach 3 but is perched high above the creek and well out of the floodplain. Agricultural land uses, including irrigated hay production and winter livestock feeding, border the creek to the east throughout this reach. The reach is similar in gradient to downstream reaches at 1.9 percent, moderately confined, with limited floodplain connectivity. Short sections of Beaver Creek in the reach are braided as a result of several large log jam complexes, otherwise this reach lacks an abundance of existing side channel and off-channel habitat. The frequency of instream wood and pools within the reach are generally similar to Reach 2. Reach 3 and all upstream reaches (Reaches 4 through 7) were within the perimeter of the 2014 Carlton Complex Fire and have intermittent burned riparian areas.

Reach 4: This reach is the most modified in the Survey Area and extends to near RM 6.6. Segments of Beaver Creek in this reach have been straightened and roads and road crossings limit channel migration and floodplain connectivity. Balky Hill Road crosses Beaver Creek in this reach and the Upper Beaver Creek Road bisects the floodplain from near RM 6.2 to the upper end of the reach. There are multiple disconnected side channels throughout the reach, and the floodplain connectivity is limited. Similar to Reach 2 and 3, this reach lacks pools and is dominated by riffle habitat and has an only slightly steeper gradient at 2.5 percent. The channel in Reach 4 is incised, lacks sinuosity, and has the highest percentage of armored banks in the Survey Area.

Reach 5: This reach extends to the South Fork Beaver Creek confluence near RM 9.2. The reach is under public ownership (excluding the downstream 0.3 mile) with a combination of WDFW and USFS lands. There is a makeshift diversion in this reach near RM 7.2 that flows into a man-made pond on the private land. The NF-200 road parallels the creek to the east until the crossing of Beaver Creek near RM 8.9 and the Lester Road junction. This reach has the lowest frequency of pools and is dominated by rapid habitat units. The channel is steeper than downstream reaches at 3.0 percent and is incised with intermittent confined and unconfined areas. There are multiple relic channel scars and disconnected side channels across the floodplain in the unconfined areas. There is limited beaver activity in Reach 5.

Reach 6: The valley becomes increasingly confined throughout this reach extending to near RM 10.2. The NF-4225 Road crosses Beaver Creek near RM 9.5 and the NF-200 Road parallels the creek to the west to near the

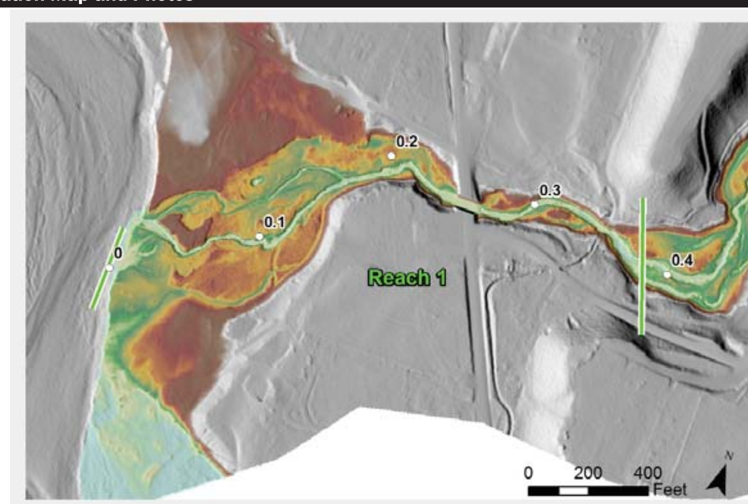
Volstead Creek confluence at RM 9.8. Upstream of this point, Beaver Creek flows through valley with no road access. This reach has a channel gradient of 4.4 percent, limited floodplain availability, and channel banks are increasingly naturally armored with boulder substrate. Recreational use is relatively heavy in this reach compared with other Survey Area reaches, due to the WDFW campground and unofficial campsites. There are no armored banks and limited bank erosion (1.4 percent) identified in Reach 6.

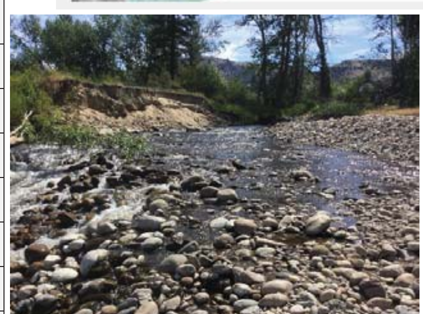
Reach 7: This reach extends to the upstream end of the Survey Area at the Lightning Creek confluence near RM 11.1. Beaver Creek is confined in a narrow, v-shaped valley in throughout this reach. The channel gradient of 5.1 percent is steeper than all downstream reaches and cascades and plunge pool habitat units become more frequent. As with downstream reaches, the riparian area in Reach 7 was burned in the 2014 Carlton Complex Fire but the reach is otherwise in relatively undisturbed condition. Similar to Reach 6, there are no armored banks and limited bank erosion (1.4 percent) identified in Reach 7.

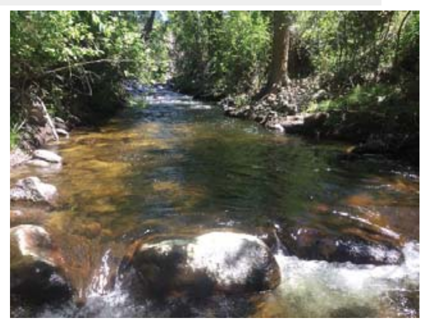
Table 4-3. Reach 1 Physical Characteristics, Location Map, and Photos

Reach Characteristics	
River Miles (mapped)	0.0 to 0.4
Valley Setting	Alluvial fan
Channel Morphology	Pool-riffle
Migration Type	Irregular lateral
Rosgen Type	G3
Gradient	2.0%
Sinuosity	1.16
Bankfull Width (feet)	17.4
Width-to-Depth Ratio	5
Floodprone Width (feet)	21
Entrenchment Ratio	1.21
Substrate (dominant (%), subdominant (%))	Cobble (52%), gravel (25%)[1/]
Bank Condition	Armored (0.0%), eroding (44.6%)
Floodplain Disconnected	51.7%
LWD (pieces/mile)	30.4
Jams (jams/mile)	0
Pools (pools/mile)	27.9
Unit Stream Power (watts/meter)	269
Habitat Units	Pool (25%), glide (0%), riffle (69%), rapid (6%), cascade (0%)
REI Score	12

Location Map and Photos





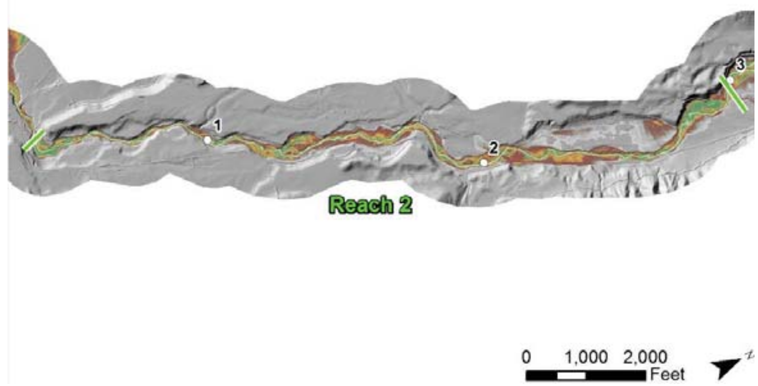


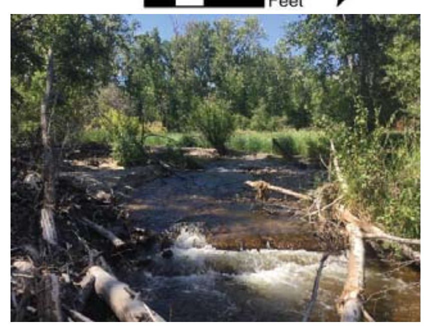
1/ Substrate from pebble count survey near RM 0.3

Table 4-4. Reach 2 Physical Characteristics, Location Map, and Photos

Reach Characteristics	
River Miles (mapped)	0.4 to 3.0
Reach Length (miles)	2.82
Valley Setting	Broad, terraced
Channel Morphology	Pool-riffle
Migration Process	Irregular lateral
Rosgen Type	C3
Gradient	2.0%
Sinuosity	1.22
Bankfull Width (feet)	24.4
Width-to-Depth Ratio	9
Floodprone Width (feet)	54
Entrenchment Ratio	2.25
Substrate (dominant (%), subdominant (%))	Cobble (45%), gravel (21%)1/
Bank Condition	Armored (0.9%), eroding (3.8%)
Floodplain Disconnected	39.8%
LWD (pieces/mile)	6.4
Jams (jams/mile)	3.5
Pools (pools/mile)	10.6
Unit Stream Power (watts/meter)	253
Habitat Units	Pool (11%), glide (7%), riffle (71%), rapid (10%), cascade (0%)
REI Score	15

Location Map and Photos



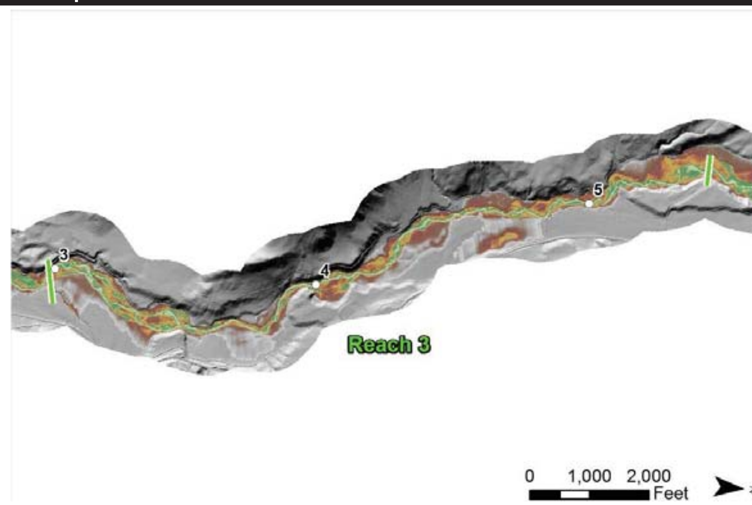


1/ Substrate from pebble count survey near RM 2.6

Table 4-5. Reach 3 Physical Characteristics, Location Map, and Photos

Reach Characteristics	
River Miles (mapped)	3.0 to 5.5
Valley Setting	U-shaped, terraced, moderately confined
Channel Morphology	Pool-riffle
Migration Type	Irregular lateral
Rosgen Type	C3
Gradient	1.9%
Sinuosity	1.26
Bankfull Width (feet)	28.9
Width-to-Depth Ratio	11
Floodprone Width (feet)	64
Entrenchment Ratio	2.21
Substrate (dominant (%), subdominant (%))	Cobble (58%), gravel (33%)1/
Bank Condition	Armored (0.2%), eroding (1.8%)
Floodplain Disconnected	53.3%
LWD (pieces/mile)	3.5
Jams (jams/mile)	6.0
Pools (pools/mile)	8.9
Unit Stream Power (watts/meter)	232
Habitat Units	Pool (15%), glide (3%), riffle (76%), rapid (6%), cascade (0%)
REI Score	16

Location Map and Photos

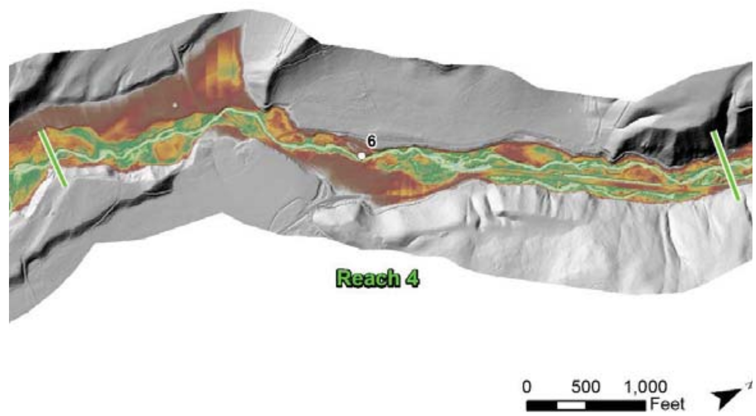


1/ Substrate from pebble count survey near RM 5.4

Table 4-6. Reach 4 Physical Characteristics, Location Map, and Photos

Reach Characteristics	
River Miles (mapped)	5.5 to 6.6
Valley Setting	U-shaped, terraced, moderately confined
Channel Morphology	Pool-riffle
Migration Type	Irregular lateral
Rosgen Type	C3
Gradient	2.5%
Sinuosity	1.16
Bankfull Width (feet)	25.0
Width-to-Depth Ratio	9
Floodprone Width (feet)	77
Entrenchment Ratio	3.08
Substrate (dominant (%), subdominant (%))	Cobble (53%), gravel (25%)[1/]
Bank Condition	Armored (5.7%), eroding (14.8%)
Floodplain Disconnected	53.3%
LWD (pieces/mile)	3.2
Jams (jams/mile)	2.4
Pools (pools/mile)	11.0
Unit Stream Power (watts/meter)	248
Habitat	Pool (12%), glide (2%), riffle (69%), rapid (18%), cascade (0%)
REI Score	14

Location Map and Photos

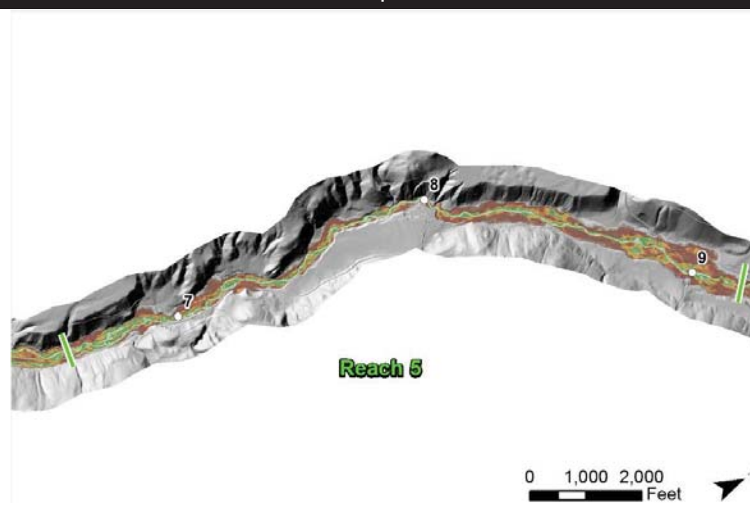


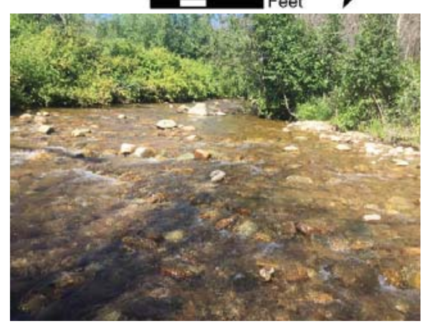
1/ Substrate from average ocular substrate estimates of each habitat unit

Table 4-7. Reach 5 Physical Characteristics, Location Map, and Photos

Reach Characteristics	
River Miles (mapped)	6.6 to 9.2
Valley Setting	U-shaped, terraced, moderately confined
Channel Morphology	Riffle-rapid
Migration Type	Irregular lateral
Rosgen Type	C3b
Gradient	3.0%
Sinuosity	1.15
Bankfull Width (feet)	25.5
Width-to-Depth Ratio	10
Floodprone Width (feet)	61
Entrenchment Ratio	2.39
Substrate (dominant (%), subdominant (%))	Cobble (54%), gravel (24%)[1/]
Bank Condition	Armored (1.3%), eroding (2.9%)
Floodplain Disconnected	60.9%
LWD (pieces/mile)	6.8
Jams (jams/mile)	5.0
Pools (pools/mile)	5.3
Unit Stream Power (watts/meter)	322
Habitat Units	Pool (5%), glide (2%), riffle (27%), rapid (65%), cascade (0%)
REI Score	22

Location Map and Photos



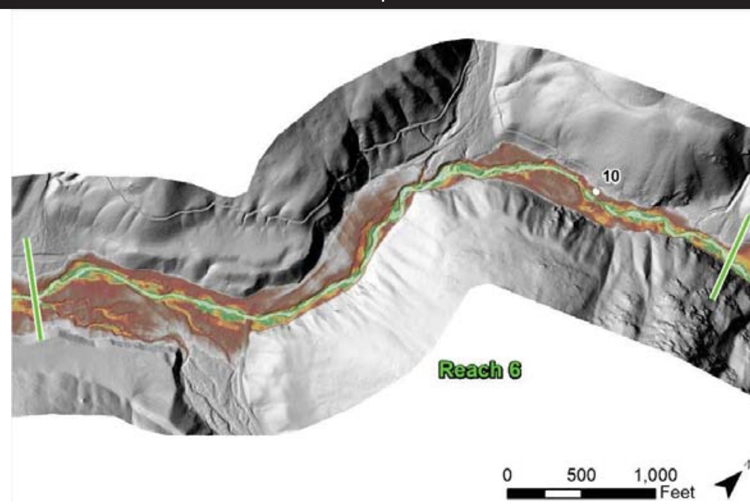


1/ Substrate from pebble count survey near RM 7.6

Table 4-8. Reach 6 Physical Characteristics, Location Map, and Photos

Reach Characteristics	
River Miles (mapped)	9.2 to 10.2
Valley Setting	Varied, moderately confined
Channel Morphology	Riffle-rapid
Migration Type	Confined, limited migration
Rosgen Type	A3
Gradient	4.4%
Sinuosity	1.10
Bankfull Width (feet)	21.7
Width-to-Depth Ratio	11
Floodprone Width (feet)	41
Entrenchment Ratio	1.89
Substrate (dominant (%), subdominant (%))	Cobble (51%), boulder (25%)[1/]
Bank Condition	Armored (0.0%), eroding (1.4%)
Floodplain Disconnected	50.2%
LWD (pieces/mile)	12.7
Jams (jams/mile)	1.8
Pools (pools/mile)	20.8
Unit Stream Power (watts/meter)	389
Habitat Units	Pool (11%), glide (1%), riffle (11%), rapid (75%), cascade (2%)
REI Score	27

Location Map and Photos

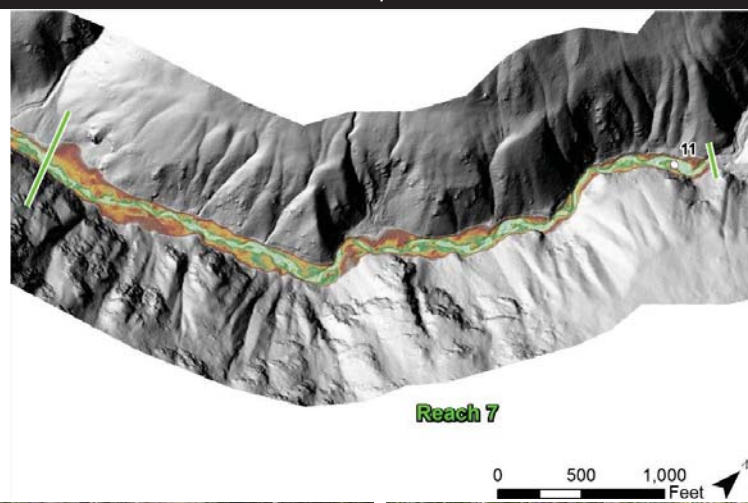


1/ Substrate from average ocular substrate estimates of each habitat unit

Table 4-9. Reach 7 Physical Characteristics, Location Map, and Photos

Reach Characteristics	
River Miles (mapped)	10.2 to 11.1
Valley Setting	V-shaped, confined
Channel Morphology	Rapid-cascade
Migration Type	Confined, limited migration
Rosgen Type	A3
Gradient	5.1%
Sinuosity	1.13
Bankfull Width (feet)	23.7
Width-to-Depth Ratio	10
Floodprone Width (feet)	42
Entrenchment Ratio	1.75
Substrate (dominant (%), subdominant (%))	Cobble (56%), boulder (27%)1/
Bank Condition	Armored (0.0%), eroding (1.3%)
Floodplain Disconnected	46.8%
LWD (pieces/mile)	26.4
Jams (jams/mile)	5.3
Pools (pools/mile)	30.6
Unit Stream Power (watts/meter)	366
Habitat Units	Pool (15%), glide (0%), riffle (3%), rapid (74%), cascade (8%)
REI Score	30

Location Map and Photos



1/ Substrate from pebble count survey near RM 10.5

4.4 Geomorphology and Habitat

Geomorphic conditions in Beaver Creek 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 subsections below describe the results of the geomorphic field survey data and analyses in terms of floodplain connectivity and inundation (Section 4.4.1), sediment supply and transport characteristics (Section 4.4.2), hydraulic characteristics and flow competence (Section 4.4.3), LWD (Section 4.4.4), habitat units (Section 4.4.5), and riparian vegetation (Section 4.4.6). The REI analysis in Appendix D also contains additional geomorphic data and analysis.

The geomorphic and habitat conditions in Beaver Creek 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 landscape of the Beaver Creek valley today is a patchwork of deep glacial deposits and alluvium with isolated bedrock outcrops at the valley margins, as well as tributary alluvial fans and hillslopes. As described in Section 2.2, since the last glaciation, Beaver Creek has eroded down through many layers of glacial sediments resulting in a complex pattern of terraces bordering the creek throughout most of the Survey Area. There has been channelization that has occurred in many parts of Beaver Creek which has reduced channel complexity and increased velocity, adversely impacting juvenile rearing areas.

The inundation and terraces map series Figures B-2a through B-2k in Appendix B show the mapped terraces labeled with their average elevation above the stream channel. As shown in the figures, the terrace landforms are most prevalent downstream of RM 8.0 in Reaches 1 through 5. Upstream from that point, the landscape gradually transitions to a confined, V-shaped valley, particularly in Reach 7. The relative confinement from terraces and valley hillslopes has a strong influence on the reach-specific geomorphic characteristics of Beaver Creek. The level of valley confinement affects the potential for the channel to adjust laterally or vertically, impacting sinuosity and bed material transport and storage patterns. For example, more confined reaches generally have increased sediment transport capacity (i.e., the ability to transport the incoming sediment supply), and limited availability for sediment storage in bars and islands, while less confined reaches have greater sinuosity, increased sediment storage availability and decreased transport capacity. Less confined reaches are commonly referred to as storage, or response reaches, whereas more confined reaches are referred to as transport reaches. In Beaver Creek, the unconfined segments of Reaches 1 through 3 are examples of response reaches, while Reaches 6 and 7 are good examples of transport reaches.

Figure 4-4 shows the longitudinal profile of the Beaver Creek channel bed elevation, derived from the topobathymetric LiDAR data, along with valley and floodplain characteristics including the 100-year inundation width (described in Section 4.4.1) and the low surface boundary width. The location of the seven geomorphic reaches, their average channel gradient, and the location of tributary junctions and road crossings are shown on the figure for reference. The channel gradient of Beaver Creek remains relatively consistent throughout reaches 1 through 4 ranging from 2.0 to 2.5 percent. The gradient increases throughout Reaches 5 through 7 from 3.0 to 5.1 percent. These reaches also have a relatively narrow 100-year inundation width and low surface boundary width, except for a segment from RM 8.2 to 9.4 that has a relatively wide valley bottom.

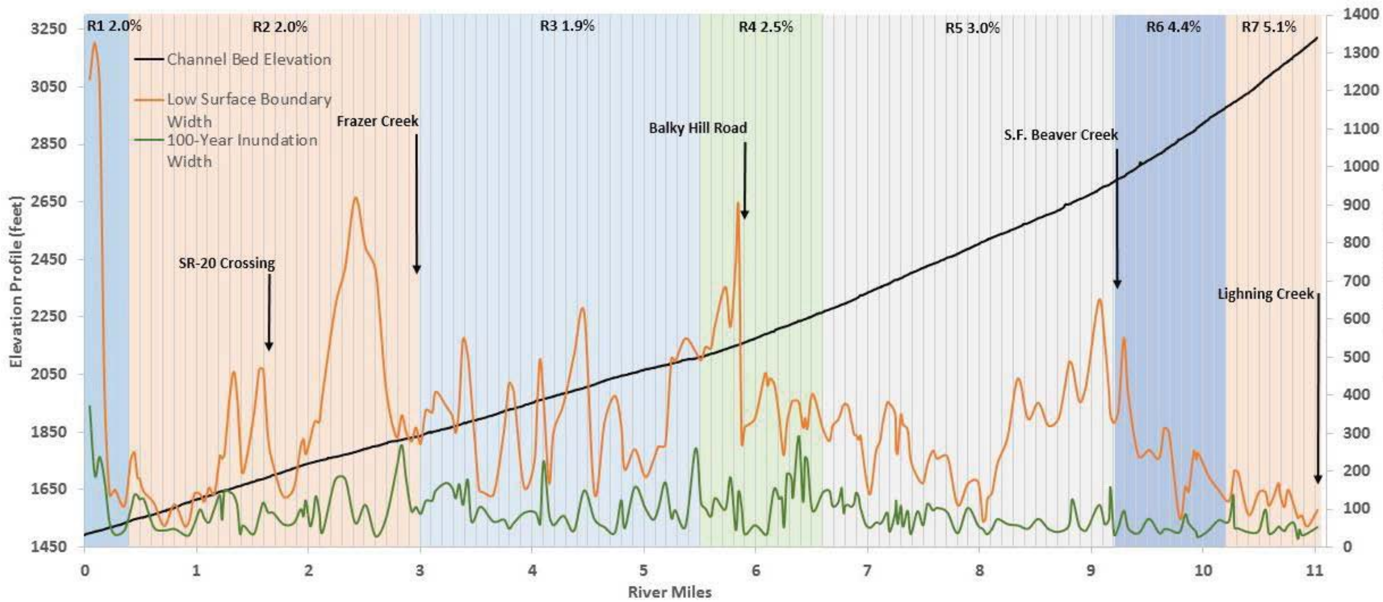


Figure 4-4. Longitudinal Profile of Channel Bed Elevation, 100-year Inundation Width and Low Surface Boundary Width

4.4.1 Floodplain Connectivity and Inundation

Floodplain connectivity and floodplain inundation were evaluated based on the results from the hydraulic modeling and floodplain inundation mapping. Hydraulic model outputs of water surface elevation, flow depth, and velocity were used to map floodplain inundation and evaluate floodplain connectivity for the 2-year, 10-year, and 100-year flood events. Additional hydraulic characteristics from the modeling are described in Section 4.4.3. The inundation and terraces map series Figures B-2a through B-2k in Appendix B show the water surface extent at the time of survey (October 12 and 13, 2016), the flood inundation extent for the 100-year flood, and the depth for the 2-year event for Beaver Creek. The figures illustrate that floodplain inundation extents are limited in most areas, even during the 100-year flood event.

Floodplain connectivity is lacking in many parts of the Survey Area. Channel incision into the floodplain, artificial channel confinement, road crossings, and roads that bisect the floodplain are resulting in hydrologically disconnected floodplain areas limiting floodplain connectivity and inundation. Reaches 4 and 5, in particular have roads, bank armoring, and development that limit floodplain connectivity, as shown in the Survey Area topography and existing features map series Figures B-1a through B-1k in Appendix B. As previously described, the presence of glacial terraces, fans, bedrock, and valley hillslopes also confine the creek and limit the amount of available floodplain. Based on field observations and limited floodplain connectivity, estimated through hydraulic modeling, Reach 1 is the most deeply incised reach resulting in severely limited floodplain connectivity and floodplain inundation relative to the natural condition.

The percent of floodplain disconnected was calculated for each reach to evaluate connectivity by comparing the 100-year inundation area with the potential floodplain area delineated using the relative elevation model. The percent of floodplain disconnected is high in all reaches ranging from 40 percent in Reach 2 to 61 percent in Reach 5. However, there is a relatively high degree of uncertainty around the percent of floodplain disconnected estimates due to the difficulty determining the maximum extent of potentially accessible floodplain within the complex topography of the Survey Area and the sensitivity of the metric because of the relatively small 100-year inundation area.

4.4.2 Sediment Supply and Substrate Characteristics

Pebble counts and ocular substrate estimates were completed during Project field surveys following the USFS Level II protocols (USFS 2016). 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.

Sediment inputs from several different sources including bank and glacial terrace erosion, post-fire surface rilling, and landslides were all observed throughout the Survey Area during field surveys. Figure 4-5 shows three examples of eroding areas in the Survey Area including an eroding bank, an eroding glacial terrace, and a small stream adjacent landslide.

Figure 4-5. Photographs of Typical Eroding Areas Including Bank Erosion near RM 0.6 in Reach 2 (left), Glacial Terrace Erosion near RM 7.9 in Reach 5 (center), and a Stream-adjacent Landslide near RM 10.1 in Reach 6 (right)

Beaver Creek has naturally high quantities of fine sediments which have been exacerbated by past management activities such as timber harvesting, roads, and cattle grazing. As described in Section 2.4, post-fire rates of erosion and sediment input to Beaver Creek were extremely high following the 2014 Carlton Complex Fire and the debris flows which occurred in response to a large convective thunderstorm shortly after the fire. Post-fire sand deposition in Beaver Creek is important to floodplain development processes. Increased rates of erosion and sediment supply are continuing to persist in Beaver Creek with major road crossing failures and channel instability occurring in 2017. The photograph taken during field surveys in Figure 4-6 shows an example of deep sand deposits in Reach 2. Similar sand deposits on the floodplain were observed intermittently throughout the Survey Area.

Figure 4-6. Photograph of Deep Sand Deposit near RM 1.9 in Reach 2

Pebble counts and ocular substrate estimates were used to characterize bed sediment size distributions. Reach-averaged estimates of percent sand, gravel, cobble, and boulder are shown in Figure 4-7. In general, Beaver Creek is cobble-dominated throughout the Survey Area with relatively consistent substrate. The two upstream reaches (Reaches 6 and 7) have a higher proportion of boulders and fewer gravels.

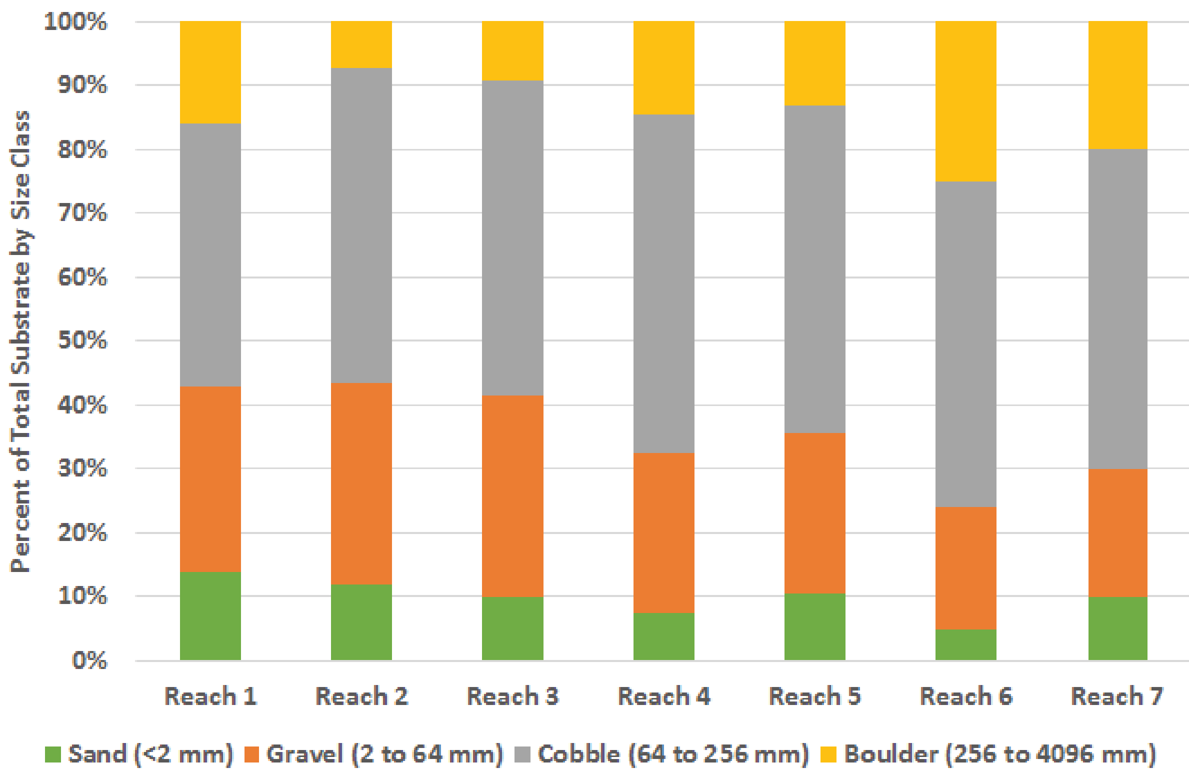


Figure 4-7. Distribution of Substrate Size Classes by Reach for Beaver Creek

4.4.3 Hydraulic Characteristics and Flow Competence

Hydraulic characteristics and flow competence were evaluated using HEC-RAS model outputs including unit stream power, shear stress, excess shear stress, and threshold of motion grain size, also referred to as incipient motion. Figure 4-8 shows the longitudinal variation in hydraulic conditions throughout the Survey Area with reach breaks, road crossings and tributary junctions shown for reference. In general, the hydraulic characteristics are in agreement with the observed sediment size distributions in that there are relatively consistent hydraulic characteristics throughout the Survey Area with an increase in shear stress and threshold grain size in the two upstream reaches (Reaches 6 and 7). Reach 2 has the lowest shear stress and threshold grain size values.

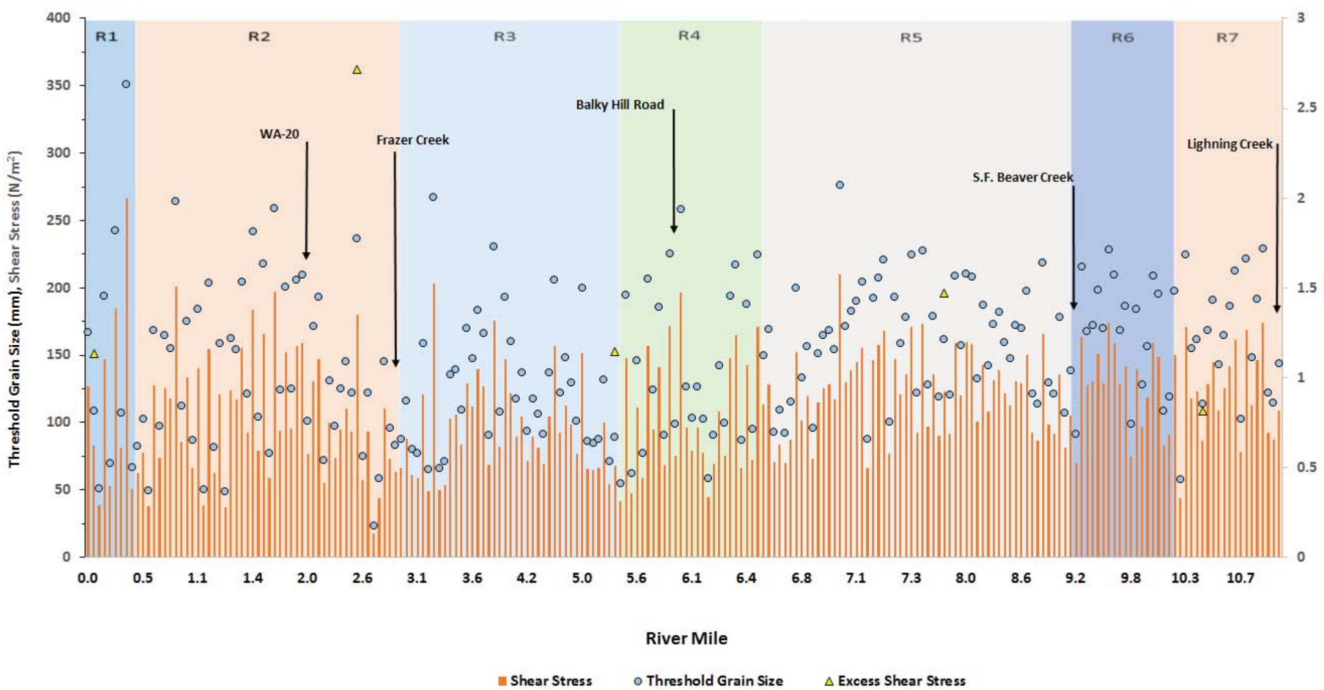


Figure 4-8. Shear Stress, Threshold Grain Size, and Excess Shear Stress by River Mile in Beaver Creek

4.4.4 Large Woody Debris

LWD within the bankfull channel was inventoried during Project field surveys following the USFS Level II protocols (USFS 2016). All medium (greater than 12 inch diameter and 35 feet length) and large (greater than 20 inch diameter and 35 feet length) LWD was tallied within each habitat unit. These sizes of LWD are referred to as qualifying and were used to determine the LWD frequency in pieces per mile. The quantity of LWD ranged from 3.2 pieces per mile in Reach 4 to 26.4 pieces per mile in Reach 7, as shown in Figure 4-9. The quantity of log jams ranged from no jams in Reach 1 to 6 jams per mile in Reach 3 (Figure 4-9). The quantity of LWD in Reaches 1 through 6 is below the federal target of 20 pieces per mile (USFWS 1998). In addition, Fox and Bolton (2007) determined that standard was low for larger eastern Washington streams (16 to 164 feet bankfull width) in unmanaged forested basins which had an average of 42.5 pieces per mile. The quantity of LWD in all reaches is well below the Fox and Bolton (2007) standard pieces per mile. The REI analysis in Appendix D contains additional LWD information.

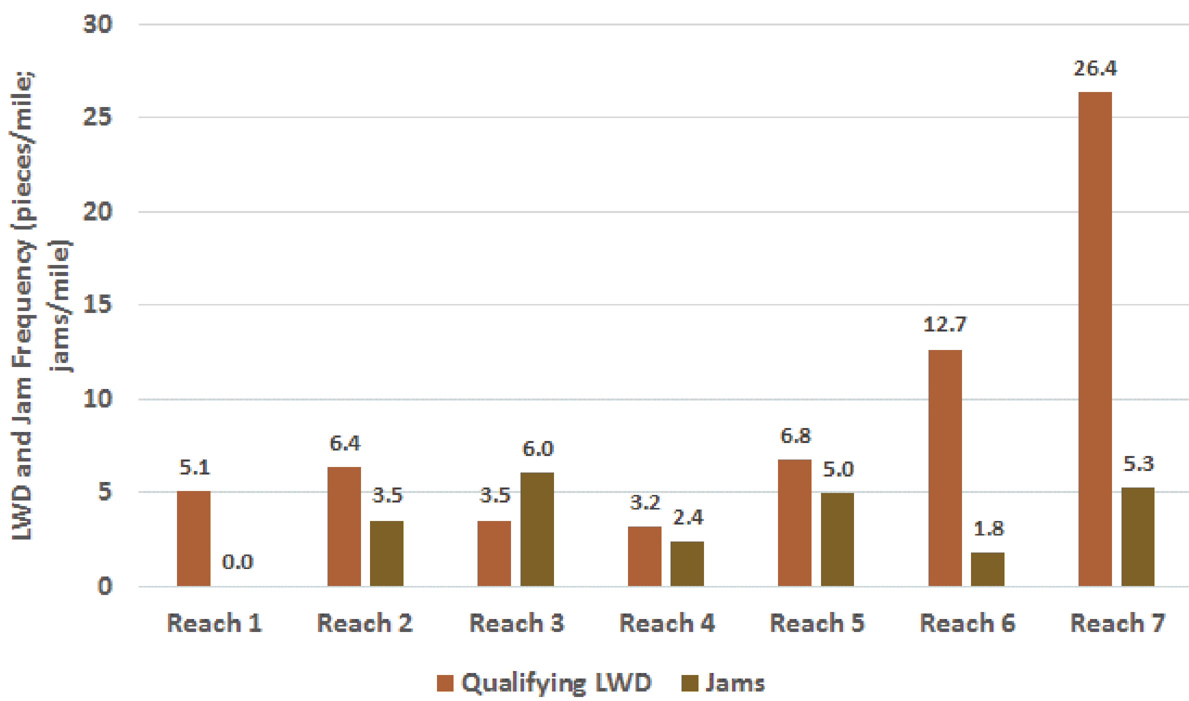


Figure 4-9. Frequency of Qualifying LWD and Log Jams by Reach in Beaver Creek

Previous USFS stream inventories in 2006 and 2012 identified similar LWD quantities in the Survey Area at 11 pieces per mile in the area from RM 5.8 to 9.3 (Reaches 4 and 5). USFS stream inventory surveys have also been completed for upper Beaver Creek tributaries. The survey of South Fork Beaver Creek (RM 0 to RM 6.1) found 30 pieces per mile (USFS 2004), while Blue Buck Creek (RM 0 to RM 2.9) had 56 pieces LWD per mile (USFS 2007), and Lightning Creek (RM 0 to RM 2.7) had 48 pieces per mile (USFS 2007). The higher quantity of LWD in the upper Beaver Creek tributaries is due to less development and more intact riparian areas in the upper drainage. The 2006 Tripod Fire burned large portions of the upper tributary basins, likely impacting current LWD quantities.

As described in Section 3.2, instream wood that did not meet the size criteria in the USFS Level II protocol was inventoried separately. The length and diameter ranges for the wood size classes inventoried are shown in Table 4-10. This instream wood was surveyed since many of these pieces are large enough to perform geomorphic functions in Beaver Creek. Most of the wood in in Beaver Creek is in the small size class ranging from 6 to 12 inches in diameter and greater than 10 feet in length. As shown in Figure 4-10, the vast majority of wood in Beaver Creek does not meet the size criteria for LWD of greater than 12 inches in diameter and 35 feet in length identified for federal targets of properly functioning (USFWS 1998).

Table 4-10. Diameter and Length Ranges for Wood Size Classes

Wood Size Class	Diameter (inches)	Length (feet)
Small	6 to 12	>10
Medium	12 to 20	10 to 35
Large	>20	10 to 35
Qualifying	> 12	> 35

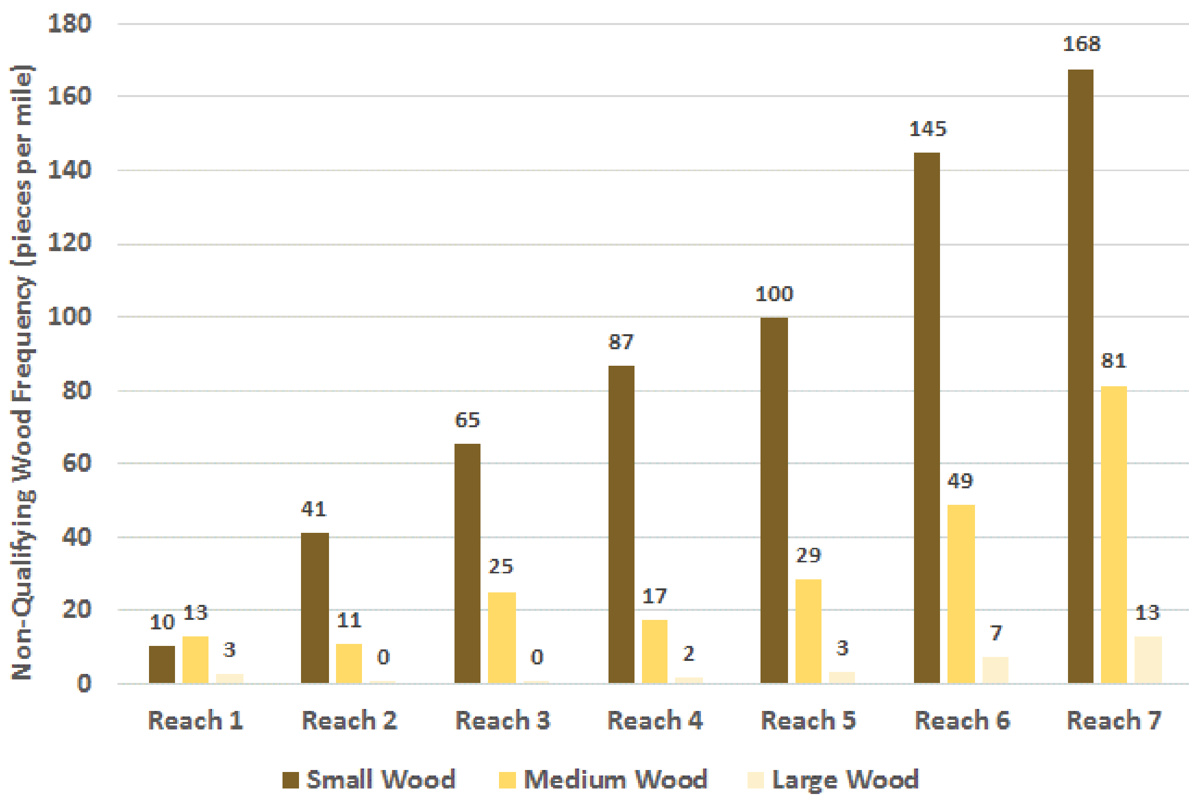


Figure 4-10. Distribution of Size Classes of Non-Qualifying Wood by Reach in Beaver Creek

There has been an increase in mainstem and tributary wood loading in Beaver Creek following the Carlton Complex fire due to tree mortality, flooding, and debris flow events, as described in Section 2.4. The addition of wood can increase channel and habitat complexity, sediment sorting, and provide nutrient inputs and fish cover. Several large, natural jams were observed in the Survey Area that were resulting in considerable sediment storage, localized aggradation, scour pools, and split flow channels. The photograph in Figure 4-11 shows an example of a natural log jam near RM 6.5 in Reach 4. The longevity of these jams is likely reduced due to a lack of large wood acting as key pieces. Large key wood pieces provide increased jam stability and trap LWD that would otherwise be transported out of the system (Collins and Montgomery 2002).

Figure 4-11. Photograph of Large Natural Log Jam near RM 6.5 in Reach 4

4.4.5 Habitat Units

Habitat units were inventoried during Project field surveys following the USFS (2016) Level II protocols. The slow water mainstem habitat units identified during surveys included scour pools, plunge pools, and dam pools. The fast water habitat units included glides (fast non-turbulent), riffles, rapids, and cascades. Side channels were also mapped and identified as slow water or fast water.

Figure 4-12 shows the distribution of habitat units by reach in Beaver Creek. Fast water riffle habitat units dominate the lower reaches of Beaver Creek (Reaches 1 through 4) ranging from 69 to 76 percent of the total, while rapid habitat units dominate the upper reaches (Reaches 5 through 7) ranging from 65 to 75 percent of the total. Reach 7 had the highest proportion of cascade habitat units at 8 percent of the total. The photographs in Figure 4-13 show typical riffle, rapid, and cascade habitat units in the Survey Area.

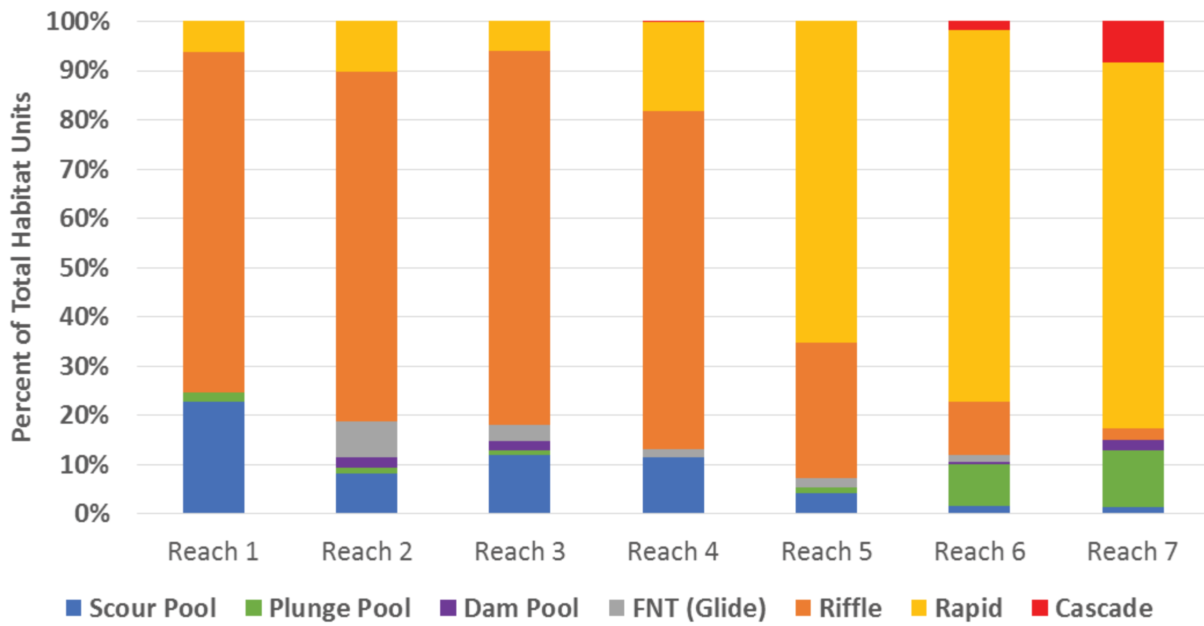


Figure 4-12. Distribution of Habitat Units by Reach in Beaver Creek

Figure 4-13. Photographs of Typical Fast Water Habitat Units Including a Riffle near RM 4.4 in Reach 3 (left), a Rapid near RM 7.8 in Reach 5 (center), and a Cascade in RM 10.6 in Reach 7 (right).

Pool frequency in Beaver Creek ranged from 5.3 pools per mile in Reach 5 to 30.6 pools per mile in Reach 7, as shown in Figure 4-14. Pools as a proportion of the total habitat ranged from 5 percent in Reach 5 to 25 percent in Reach 1. Scour pools were the most frequent type of pool in the lower reaches (Reaches 1 through 5) while plunge pools were the most frequent in the upstream reaches (Reaches 6 and 7). Dam pools were typically associated with log jams and were found in Reaches 2, 3, 6, and 7.

For this Project, deep pools were defined as those with a residual pool depth of greater than 2 feet. Reach 1 had the greatest frequency of deep pools at 7.6 per mile (a total of 3). Typically, deep pools are defined as those over 3 feet deep; however, pool depth is scaled by stream size, and since the Beaver Creek bankfull width is relatively small, ranging from 13.4 to 20.4 feet, a depth of over 2 feet was selected for determining deep pools. The photographs in Figure 4-15 show typical scour pool, plunge pool, and dam pool habitat units in the Survey Area.

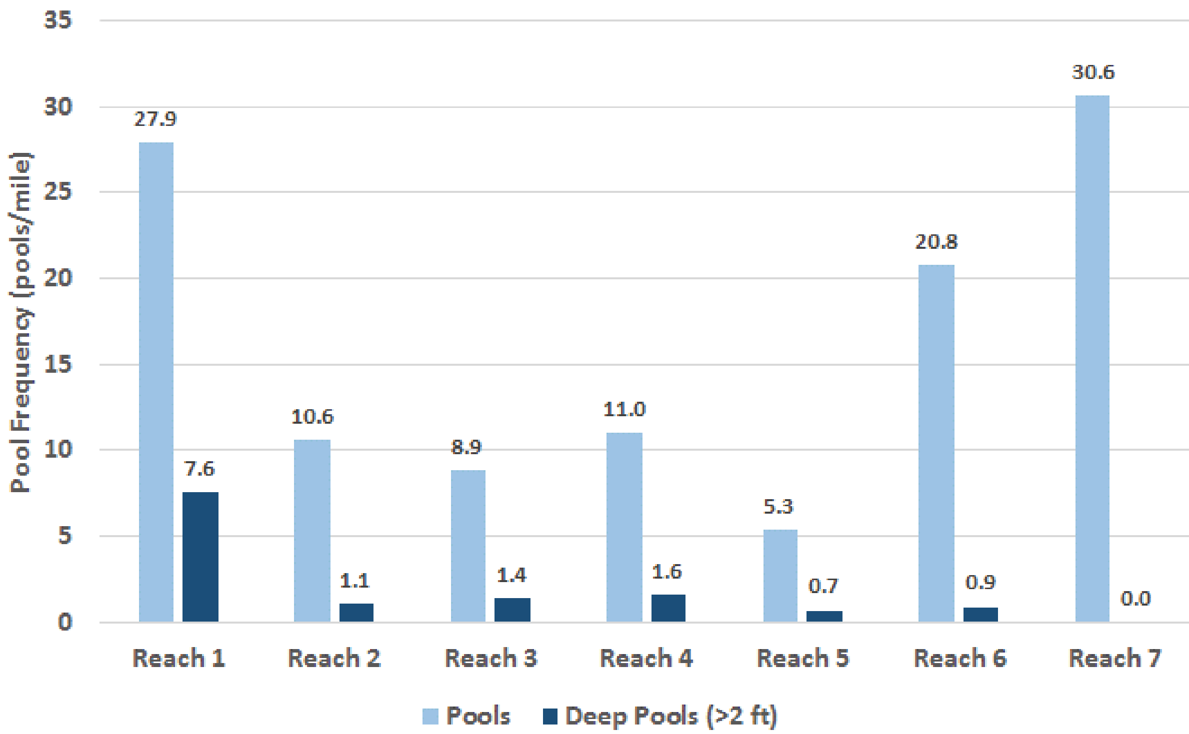


Figure 4-14. Frequency of Pools by Reach in Beaver Creek

Figure 4-15. Photographs of Typical Pools Including a Scour Pool near RM 2.6 in Reach 2 (left), and Dam Pool near RM 3.2 in Reach 3 (center), and a Boulder Plunge Pool near RM 11.0 in Reach 7 (right)

Off-channel habitat availability is limited throughout Beaver Creek. The distribution of channel braids and side channels (fast and slow) varies considerably throughout the Survey Area. The lower reaches (Reaches 1 through 4) have the highest amount of side channels and split flow channels; however, many of them are high-flow floodplain channels that are disconnected at most flows due to incision or disconnected by the presence of roads or channel straightening. The remaining reaches (Reaches 5 through 7) have fewer side channels, which are typically shorter in length, and dominated by high-flow channels. Many of the side channels in Beaver Creek are abandoned main channels that are the result of channel migration in the form of avulsions.

4.4.6 Riparian Vegetation

Riparian vegetation data were collected at 10 percent of the habitat units during field surveys following the USFS Level II protocols (USFS 2016). The riparian vegetation data collection included identifying dominant and subdominant vegetation types, and estimating size classes (i.e., shrub/seedling, sapling/pole, small trees, or large trees) based on diameter at breast height. In addition to field data, the 2016 LiDAR dataset was used to describe riparian characteristics including canopy height and canopy cover. The map series Figures B-3a through B-3k in Appendix B show the canopy height as calculated from the LiDAR data for the entire Survey Area. The REI analysis in Appendix D contains additional vegetation information.

In general, mature riparian vegetation is limited in Beaver Creek throughout much of the Survey Area. Vegetation management practices including grazing, road construction, timber harvesting, and fire suppression have led to significant changes to vegetation communities. Riparian vegetation throughout the lower reaches of Beaver Creek (Reaches 1 through 4) consists of a mixture of second-growth deciduous trees including black cottonwood (*Populus trichocarpa*), red alder *(Alnus rubra)*, water birch (*Betula occidentalis*), red-osier dogwood (*Cornus sericea*), interspersed with a mature conifers including Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*). Riparian vegetation in the upstream reaches (Reaches 5 through 7) is conifer dominated.

Overall canopy cover is relatively low in Beaver Creek, particularly in the lower reaches (Reaches 1 through 3), ranging from 20 to 30 percent. The canopy cover in Reach 4 is also relatively low at 44 percent while it ranges from 53 to 62 percent in the upstream reaches (Reaches 5 through 7).

Riparian vegetation in the Survey Area has been severely impacted by the 2014 Carlton Complex Fire. There has been extensive riparian mortality within the extent of the Carlton Complex Fire. An estimated 40 percent of riparian areas in Beaver Creek burned in the fire. Of that burned riparian area, 16 percent was rated as moderate to high severity (Johnson and Molesworth 2015). Since the fire, burned riparian areas are experiencing rapid growth of understory vegetation and are expected to recover relatively quickly. Management of noxious weeds should be considered post-fire and as part of any restoration efforts that are implemented in the riparian zone. The photograph in Figure 4-16 shows a burned riparian stand with dense understory growth near RM 3.5 in Reach 3.

Figure 4-16. Photograph of Burned Riparian Vegetation and Dense Understory Growth near RM 3.5 in Reach 3

4.5 Reach-based Ecosystem Indicators

This section presents an overview of the REI results, which are presented in detail in Appendix D. 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 REI were evaluated at the scale of the Beaver Creek drainage and at the reach-scale for the Survey Area. At the drainage 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 Beaver Creek drainage is rated at risk with an average of 1.9 miles of road per square mile. For the disturbance regime, the Beaver Creek drainage is rated as unacceptable because of frequent flooding, catastrophic fires, and channel instability. This is a result of historical and ongoing human activities, development, and land management in the area, as described in Section 2.3. The Beaver Creek drainage is rated unacceptable for the hydrologic regime indicator.

Reach-scale results on Beaver Creek for 11 specific indicators are summarized in Table 4-11. The indicators highlight the high degree of impairment related to LWD, pools, and riparian condition (structure, disturbance and canopy cover), particularly in Reaches 1 through 5. Overall, Reaches 1 and 4 have the most unacceptable ratings (10 out of 11 and 9 out of 11, respectively), followed closely by Reaches 2 and 3. Conversely, Reach 7 has the most adequate ratings (7), three at risk ratings, and one unacceptable rating. Reach 6 is similar with a majority of adequate (6) ratings, three at risk ratings, and two unacceptable ratings.

Table 4-11. Reach-Based Ecosystem Indicator (REI) Ratings for Beaver Creek

General Characteristics	General Indicators	Specific Indicators	Reach						
			1	2	3	4	5	6	7
Habitat Assessment	Physical Barriers	Main Channel Barriers	Adequate	At risk	At risk	At risk	Adequate	Adequate	Adequate
Habitat Quality	Substrate	Dominant substrate/Fine sediment	Unacceptable	Unacceptable	At risk	Adequate	At risk	Adequate	Adequate
	LWD	Pieces/mile at bankfull	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable
	Pools	Pool frequency and quality	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	At risk
	Off-Channel Habitat	Connectivity with main channel	Unacceptable	At risk	At risk	Unacceptable	At risk	Adequate	Adequate
Channel	Dynamics	Floodplain connectivity	Unacceptable	At risk	At risk	Unacceptable	At risk	Adequate	Adequate
		Bank stability/Channel migration	Unacceptable	At risk	At risk	Unacceptable	At risk	Adequate	Adequate
		Vertical channel stability	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Adequate	Adequate
Riparian Vegetation	Condition	Structure	Unacceptable	Unacceptable	Unacceptable	Unacceptable	At risk	At risk	At risk
		Disturbance (human)	Unacceptable	Unacceptable	Unacceptable	Unacceptable	At risk	At risk	Adequate
		Canopy cover	Unacceptable	Unacceptable	Unacceptable	Unacceptable	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 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 is 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 effect 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. 2012).

Figure 4-17 presents recent modeling results for changes in mean August stream temperature and mean summer flows for Beaver Creek. Both datasets use the global climate model A1B emissions scenario for the future periods, representing a medium warming scenario (USFS 2015a, 2015b; Cristea and Burges 2010). The trend toward warmer stream temperatures and lower summer flows is shown Figure 4-17. 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).

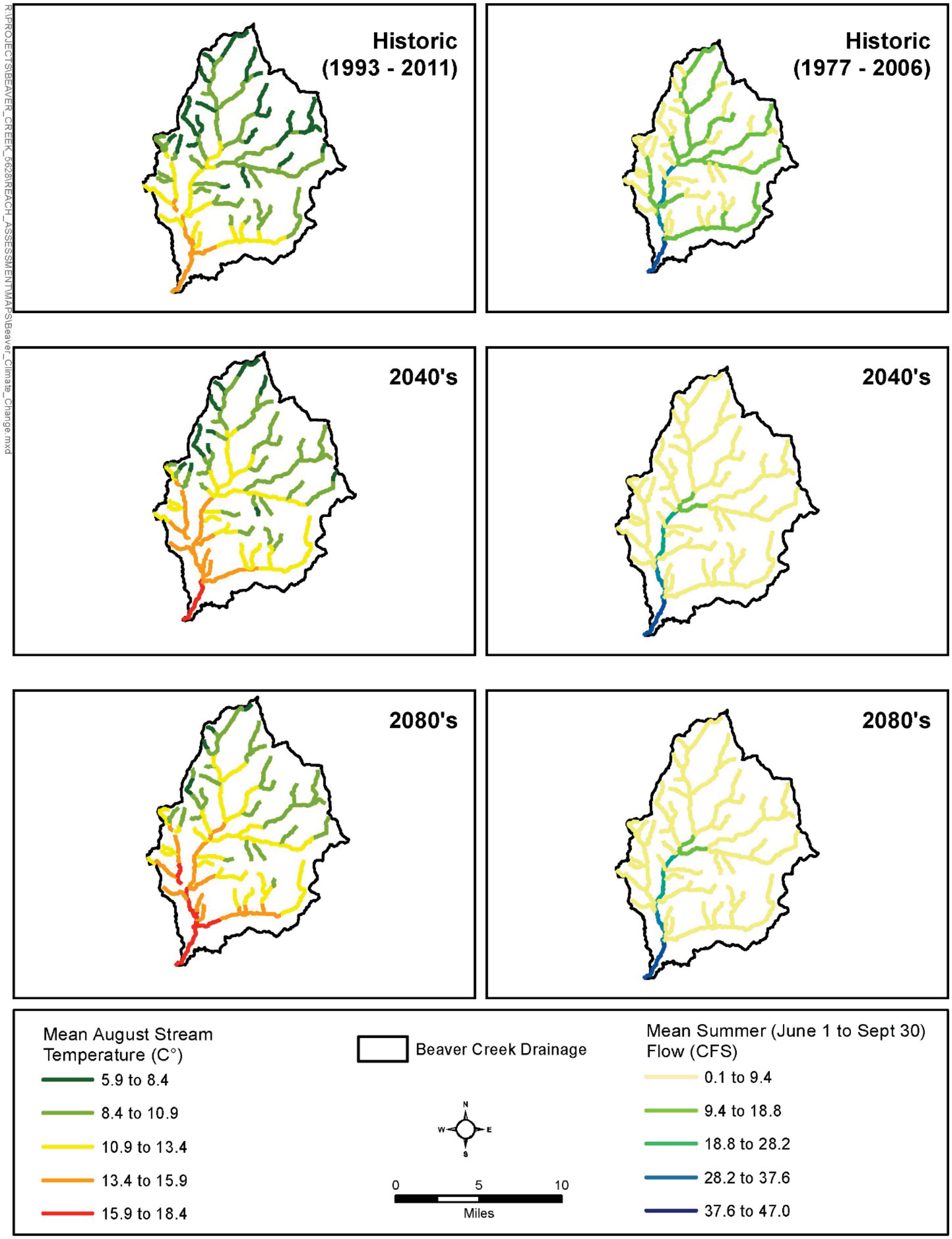


Figure 4-17. Modeled Historical and Future Climate Change Scenario Mean August Stream Temperatures and Mean Summer Flows along Beaver Creek (Data Source: USFS 2015a, 2015b)

4.7 Reach Assessment Results Summary

This reach assessment utilized topobathymetric LiDAR data, historical information, field survey data (previous and current), geologic mapping, hydrology and hydraulic modeling, geomorphic analyses, REI analyses, a climate change assessment, and other data sources to evaluate historic, current, and potential future conditions in Beaver Creek. The data and analyses were used to characterize conditions with respect to floodplain connectivity, sediment transport dynamics, the role of instream wood, and the impact of land use practices (historical and current) on reach-scale processes. The results demonstrate that there are unique geomorphic and habitat characteristics in each of the seven reaches of Beaver Creek that can be used to evaluate potential restoration actions and to develop effective, long-lasting solutions to address watershed-level ecological concerns for ESA-listed salmonids and other species.

An important factor for interpreting the results of the reach assessment described above is that Beaver Creek has experienced several large disturbance events in recent decades including the 2006 Tripod Fire and the 2014 Carlton Complex Fire. In the short term these events have caused substantial mortality of aquatic species and a reduction in the quality of aquatic habitat. Additional short-term impacts to aquatic habitats occurred through the loss of shade and cover in burned riparian areas and massive inputs of fine sediments resulting high turbidity and sedimentation impacts; however, increased base flows have been noted. Peak flows have increased following the 2014 Carlton Complex Fire as evidenced by debris flows and road crossing failures, particularly in Frazer Creek. Large accumulations of sediment and jams have formed in several locations in response to pulses of sediment and an increase in LWD recruitment.

The disturbance caused by the recent fires also provides opportunities for increasing the rate and effectiveness of restoration of natural processes in Beaver Creek. As demonstrated in the reach assessment analyses and REI evaluation above, the current condition of Beaver Creek is impaired, particularly in Reaches 1 through 5. The channel is incised in many areas (particularly in Reach 1), has limited floodplain connectivity, and lacks channel complexity, habitat diversity, and cover. In order to restore natural process and address ecological concerns, structural elements are needed in Beaver Creek that 1) retain sediment and mobile wood, and 2) create the hydraulic conditions necessary to aggrade the channel bed so that natural geomorphic processes of bank erosion, channel migration, floodplain inundation, and flood attenuation can occur. Beavers can play a significant role in developing these structural elements and supporting the restoration of natural processes. The proposed restoration actions to create these effects are described in Section 5.

Based on the results of the reach assessment, Reaches 1 through 5 have the highest level of restoration potential due to lower 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 confined reaches with less available floodplain and large substrate (e.g., Reaches 6 and 7). The results of the reach assessment were used to identify and refine the project areas and the potential restoration and management actions described in the restoration strategy. Reach-scale restoration strategies are described in Section 5.2.

5. RESTORATION STRATEGY

The restoration strategy presented in this section provides the framework for targeted and effective habitat restoration for Beaver Creek. Existing geomorphic and habitat conditions for Beaver Creek were described in Section 4 of this document, and target habitat conditions have been developed based on the REI assessment in Appendix D, the Matrix of Diagnostics/Pathways and Indicators (USFWS 1998), and 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). The restoration strategy describes specific project areas and effective restoration actions to achieve target habitat conditions based on existing information, habitat needs of the fish species present, and properly functioning conditions identified by the REI analysis

The following subsections describe specific elements of the restoration strategy including past restoration actions (Section 5.1), reach-scale restorations strategies (Section 5.2), potential restoration projects and proposed actions (Section 5.3), how proposed actions address limiting factors (Section 5.4), and project prioritization and scoring (Section 5.5). Section 5.6 provides a summary of the information provided in this section. The next steps for implementing the restoration strategy are discussed in Section 6.0.

5.1 Past Restoration Projects

Several restoration projects have been implemented in the Survey Area starting in the late 1990s and continuing until the most recent project in 2014. These projects include a variety of restoration actions completed in an effort to improve habitat conditions for ESA-listed fish. This section provides a brief description of these past habitat restoration projects. For a more detailed discussion of these past projects, refer to the Beaver Creek Watershed Summary, completed by Trout Unlimited (TU 2015).

Improving habitat conditions in Beaver Creek started in the late 1990s through a collaborative effort between WDFW, National Resources Conservation Service (NRCS), Bureau of Reclamation (USBR), the Bonneville Power Administration (BPA), the Okanogan Conservation District (OCD), and local landowners. This work consisted of installation of fish screens, numerous fish passage projects at road crossings, irrigation diversions, ditch piping, conversion to center pivot irrigation systems, and conservation easements to protect riparian areas.

In 2001, Washington State Department of Transportation (WSDOT) initiated a project to replace the existing culvert at the Methow Valley Highway (SR 153) crossing, near RM 0.3 with a larger structure to improve fish passage. In 2003 and 2004, the OCD and the USBR completed four projects to improve fish passage at existing irrigation diversion locations. At each location—Lower Stokes Diversion, Fort Thurlow Diversion, Thurlow Transfer Diversion, and Maracci Diversion—projects were implemented to remove the existing push-up dam and concrete dam diversion structures and replace them with a series of rock vortex weirs. The rock vortex weirs were constructed with the intent to maintain existing irrigation rights while providing improved fish passage. In 2014, the Fort Thurlow and Maracci rock vortex weirs were rebuilt as roughened channels through a joint effort between the USBR and the Methow Salmon Recovery Foundation (MSRF) (Molesworth pers. comm. 2017).

In 2006, WSDOT completed two fish passage improvement projects. These projects were located on SR 20 at the Beaver Creek and Frazer Creek crossing locations. Each project replaced the existing culvert with larger structures to improve fish passage. In 2007, OCD implemented a project to improve passage at the Redshirt Diversion. The existing diversion structure was replaced with a rock vortex weir to maintain existing irrigation rights while improving fish passage. In 2009, MSRF completed the Operskalski Complexity Restoration project. This project consisted of construction of instream large wood habitat structures, floodplain excavation, riparian vegetation planting, and riparian livestock exclusion fencing along a 700-foot segment of Beaver Creek. This project addressed instream and riparian degradation caused by livestock grazing and large woody debris removal that resulted in bank erosion, stream channel widening, and riparian vegetation loss.

In 2011, two projects, the Tice Diversion and the Fine Riparian projects, were completed to improve instream and riparian habitat conditions. The Tice Diversion project removed the existing diversion structure, relocated the point of diversion, and installed a pump irrigation system to increase irrigation efficiency and increase instream flows. The Fine Riparian project increased instream flows through channel reconstruction and re-established a riparian buffer with riparian vegetation planting.

The Upper Beaver Creek project was implemented in 2013 by MSRF to increase complexity for both instream and riparian habitat. A half-mile segment of Beaver Creek was realigned to a newly-constructed channel in the floodplain in increase channel complexity and floodplain connectivity. The existing armored channel was plugged and abandoned and the existing Batie Diversion was relocated to the new channel (Anchor 2008).

The Old Schoolhouse Fish Habitat Enhancement project was completed in 2013 by the Yakama Nation UCHRP. The project consisted of channel realignment, development of a spring-fed channel, and construction of 12 large wood habitat structures to increase instream channel complexity and habitat diversity. All work completed for this project survived the Carlton Complex fire in 2014 and the subsequent debris flows. The large wood habitat structures in the project area racked mobile wood, increased floodplain inundation, and efficiently dissipated energy (Johnson and Molesworth 2015).

In 2015, MSRF, the Governor’s Salmon Recovery Office (GSRO), and the Colville Confederated Tribes replaced undersized culverts crossing Frazer Creek with 6 free-spanning bridges ranging from 40 to 70 feet in length. The work was associated with WSDOT work on SR 20, and replaced culverts that were not adequate for the increased flow and debris following the recent fires (TU 2015).

5.2 Reach-Scale Restoration Strategies

Reach-scale restoration strategies were developed based on the results of the reach 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. This section provides a narrative overview of the reach-scale restoration strategies within each of the geomorphic reaches. Potential restoration projects and proposed actions are described in Section 5.3.

Reach 1: There is only one identified project area in Reach 1, encompassing the entire reach. The main channel in this reach is deeply incised with a severely disconnected floodplain and lacks complex instream habitat and cover. There are multiple side channels in the reach that are disconnected from the main channel at bankfull flows. The restoration strategy for Reach 1 should be reconnecting the existing side channels and disconnected floodplain by placing LWD structures in the channel to aggrade the streambed and reduce incision. This would increase floodplain and side-channel inundation at more frequent flows. Removing bank armoring within this reach would also increase the potential for channel migration through natural processes. There is potential to realign the main channel in Reach 1 into an existing side channel downstream of the Methow Valley Highway (SR 153) crossing.

Reach 2: Reach 2 has high geomorphic and habitat enhancement potential with three identified project areas. The existing conditions are considerably impacted based on the reach assessment and REI results. Although this reach has the least amount of disconnected floodplain, it has a low pool frequency and is dominated by riffle habitat. The restoration strategy for Reach 2 should be focused on actions that increase pool frequency and create off-channel and side-channel habitat complexity. There are two existing diversions (Fort Thurlow and Lower Stokes diversions) and one pump system (Tice Diversion) in this reach. Increased instream flow could be possible through an evaluation of the function and efficiency of these diversions. There could be an opportunity to evaluate flow for a groundwater-fed side channel to create refugia and improve thermal diversity in Beaver Creek near the Thurlow irrigation return. The restoration strategy in Reach 2 should also include placing LWD structures in incised areas designed to retain mobile sediment and wood to aggrade the streambed and reduce channel incision.

Reach 3: Reach 3 contains five project areas. There are three diversions (Thurlow Transfer, Lampson, and Redshirt diversions) located within the reach. Previous habitat restoration efforts (Old Schoolhouse project) have been completed in this reach to improve existing habitat conditions. The restoration strategy for Reach 3 should focus on supporting and building upon the efforts of the previous restoration actions by creating additional side channel and off-channel habitat, and installing LWD structures that create and maintain scour pools and retain mobile sediment and wood to aggrade the streambed in incised areas to increase floodplain connectivity and create habitat complexity. Additional actions may include the installation of livestock exclusion fencing to protect the riparian and stream corridor and management of noxious weeds. Irrigation diversion structures should be monitored and maintained to ensure continued fish passage, and the livestock exclusion fencing should be maintained to ensure functionality. Beaver management in this reach could also increase complexity and provide additional cover. Increased instream flow could be possible through an evaluation of the function and efficiency of the diversions in Reach 3.

Reach 4: There are two project areas in Reach 4. Segments of Beaver Creek in this reach have been confined by anthropogenic actions and straightened in many areas. This reach has the highest percentage of armored banks and the channel is incised and lacks sinuosity. There are two diversions located within the reach (Batie and Marracci diversions). The Upper Beaver Creek project was completed in this reach to increase instream habitat complexity and floodplain connectivity; however there are large portions of the floodplain that remain disconnected by the Upper Beaver Creek Road. The restoration strategy for Reach 4 should focus on removing the armoring along the banks of Beaver Creek, increasing pool frequency, reconnecting relic side channels, and creating off-channel habitat. Restoration actions to install LWD habitat structures in Reach 4 should be designed to restore natural channel migration processes, to the extent possible, and retain mobile sediment and wood to aggrade the streambed and reduce channel incision.

Increased instream flow could be possible through an evaluation of the function and efficiency of the diversions in this reach. There is an opportunity for increased sinuosity, habitat complexity, and floodplain connectivity by evaluating alternatives for the relocation of Upper Beaver Creek Road. There are also opportunities to improve multiple bridge crossings throughout Reach 4 to increase habitat complexity and floodplain connectivity.

Reach 5: Reach 5 contains three project areas. There are multiple relic channel scars and disconnected side channels in this reach as well as a mixture of public and private ownership. The restoration strategy for Reach 5 should be focused on installing large wood habitat structures to increase pool frequency and quality, and retain mobile sediment and wood to aggrade the streambed and reduce channel incision. The reintroduction of beavers in this reach could also increase complexity and provide additional cover. Increased instream flow could be possible through an evaluation of the function and efficiency of the diversion in this reach. There is also an opportunity to increase floodplain connectivity and increase side channel habitat by evaluating alternatives to improve the Upper Beaver Creek Road crossing and the abandoned crossing downstream.

Reach 6: The majority of the restoration efforts should be focused in the lower segment of this reach, as there is limited restoration potential upstream of the Volstead Creek confluence. The restoration strategy for Reach 6 should be focused on installing large wood habitat structures to create hydraulic diversity, with off-channel habitat creation being focused upstream of the confluence of Volstead Creek. There is an undersized culvert at the NF-4225 Road crossing that interrupts wood migration and is in need of ongoing maintenance to continue properly transporting sediment. Evaluating alternatives for recreation management to reduce impacts would improve riparian habitat conditions and large wood recruitment.

Reach 7: Reach 7 has only one project area that encompasses the entire reach. There is limited restoration potential in this reach and geomorphic potential is low. The channel is single thread and valley confined throughout the reach. There is no road in Reach 7 so access to the creek is limited. The focus of the restoration strategy for Reach 7 should be to evaluate alternatives for recreation management to reduce impacts and improve riparian habitat conditions.

5.3 Potential Restoration Projects and Proposed Actions

Potential restoration projects and project actions are grouped into resource preservation and land management, described in Section 5.3.1, and instream and floodplain restoration, described in Section 5.3.2. Resource preservation and land management actions identified for Beaver Creek include land and water preservation, land management, instream flow management, beaver management, and introduced species management. Instream and floodplain actions identified for Beaver Creek include riparian restoration, sediment reduction, installing instream LWD structures, floodplain restoration and reconnection, side channel and off-channel habitat restoration, and fish passage restoration.

5.3.1 Resource Preservation and Management

Resource preservation and management actions were identified that have the potential to address ecological concerns for Beaver Creek from the revised Biological Assessment (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 Beaver Creek.

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 private land in the lower Survey Area from the Methow River Confluence (RM 0.0) to RM 7.0. 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. Management of recreational areas such as campgrounds and unofficial campsites may also be considered land management, or recreation management, actions. 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 Beaver Creek drainage, but non-point source impacts may be addressed through a variety of land management actions.

Instream Flow Management

Decreased water quantity was identified as the highest priority ecological concern for Beaver Creek in the revised Biological Strategy (UCRTT 2014). Instream management restoration actions to address decreased water quantity include irrigation efficiency improvements, water storage, and water right negotiations. As described in Section 2.3.3, Beaver Creek is an adjudicated drainage and water is over-allocated. Adjudication and the over-allocation of water resources complicate instream flow management in Beaver Creek. Given these complications, restoration of instream flows should be viewed as a long-term strategy to be addressed incrementally through increased irrigation efficiency, acquisition of water rights, and all other actions that can potentially increase flows, particularly during summer low-flow periods.

Instream flow management can also address the injury and mortality (mechanical injury) ecological concern identified in the revised Biological Strategy (UCRTT 2014) by eliminating or reducing mechanical injury to target fish species at diversion structures and fish screens.

Beaver Management

Historically, beaver were very abundant in Beaver Creek 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). The reintroduction of beavers may assist in addressing several of the ecological concerns identified in the revised Biological Strategy (UCRTT 2014) including reduced water quantity, riparian restoration, and sedimentation.

The reintroduction of beavers is complicated, particularly in areas with significant infrastructure and development. Beaver reintroduction may be addressed through the development of a beaver restoration management plan. Such a plan should include analysis of potential flooding concerns when infrastructure is present, along with possible impacts to newly planted riparian areas.

Introduced Species Management

Introduced species that compete and or predate on native fish are identified as an ecological concern for Beaver Creek (UCRTT 2014). As described in Section 2.6, brook trout are not native to Beaver Creek but have nearly replaced all cutthroat and bull trout, and are interbreeding which has resulted in hybridization. Brook trout management will likely 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 for Beaver Creek should be developed to help guide efforts to address this ecological concern.

5.3.2 Instream and Floodplain Restoration

Instream and floodplain restoration project actions were identified during field surveys and further refined throughout the reach assessment development process. Within the Survey Area, a total of 17 distinct instream and floodplain restoration and enhancement project areas were identified. Appendix E contains a description and rationale for each of the 17 project areas including potential restoration actions, project area rankings, and project area maps, which are described in Section 5.2. Project area extents and potential restoration actions are included in the Project geodatabase (Appendix F). The following sections contain a description of the types of proposed 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 Beaver Creek 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, 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, 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

Sedimentation was identified as an ecological concern for Beaver Creek 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, 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 in Beaver Creek was identified as an ecological concern 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 in Beaver Creek was identified as the highest priority ecological concern in the revised Biological Strategy (UCRTT 2014). 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 regulate 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 and Off-Channel Habitat Restoration

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

Maintaining fish passage in Beaver Creek addresses an ecological concern identified in the revised Biological Strategy (UCRTT 2014). Fish passage restoration actions include structural passage (i.e., diversions, screening), and barrier or culvert replacement or removal. In Beaver Creek, barrier or culvert replacements would be the primary tool needed. 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. 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). Monitoring and maintenance of fish passage and diversion structures are important in preserving longitudinal connectivity for all fish life stages, which is key to population recovery.

5.4 Addressing Ecological Concerns

A primary objective of this Project is to identify potential restoration actions that will make quantifiable progress toward addressing ecological concerns in Beaver Creek, 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. Table 5-1 shows a summary of the relative potential of proposed project action types to address ecological concerns identified for Beaver Creek.

Table 5-1. Relative Potential of Restoration Action Types to Address Ecological Concerns

Restoration Action Type	Ecological Concerns[1/]						
	Water Quantity (decreased) 1	Channel Structure and Form 2	Habitat Quantity (maintain passage) 3	Riparian Restoration 4	Sediment 5	Injury and Mortality (mechanical injury) 6	Species Interactions (introduced species) 7
Protect and Maintain		M		H			
Land Management					M		
Introduced Species Management							H
Instream Flow Management	H					H	
Beaver Management	M			M	M		
Riparian Restoration	L	M		H			
Sediment Reduction		L			H		
Bank Restoration and Stabilization					L		
Instream LWD Structures		H			H		
Floodplain Restoration and Reconnection	L	H		M	H		
Side Channels or Off-channel Habitat	L	H		M			
Fish Passage		L	H				

1/ Ecological concerns for the Beaver Creek assessment unit, 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.

5.5 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 Beaver Creek were prioritized primarily based on a total benefit score calculated for each project type or project area. Proposed projects included both resource protection and management projects and the 17 instream and floodplain restoration project areas identified throughout the Survey Area. Table 5-2 shows a summary of the project prioritization scoring and ranking. The complete prioritization matrix, including supplemental information used for prioritization and scoring rationale, is included in Appendix G.

Table 5-2. 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
Project Area 1 – RM 0.0 to 0.4	12	6.0	Moderate	High	1
Project Area 2 – RM 0.4 to 1.1	12	6.0	Moderate	High	2
Project Area 3 – RM 1.1 to 1.8	12	6.0	Moderate	High	3
Project Area 4 – RM 1.8 to 3.0	12	6.0	Moderate	High	4
Project Area 10 – RM 5.3 to 6.0	11	5.5	Moderate	High	5
Project Area 11 – RM 6.0 to 6.6	11	5.5	Moderate	High	6
Beaver Management	10	10	Moderate	High	7
Project Area 5 – RM 3.0 to 3.5	10	5.0	Moderate	High	8
Project Area 6 – RM 3.5 to 4.2	10	5.0	Moderate	High	9
Project Area 7 – RM 4.2 to 4.8	10	5.0	Moderate	High	10
Project Area 8 – RM 4.8 to 5.0	10	5.0	Moderate	High	11
Project Area 12 – RM 6.6 to 7.4	10	5.0	Moderate	High	12
Project Area 13 – RM 7.4 to 8.1	10	5.0	High	High	13
Project Area 14 – RM 8.1 to 9.2	10	5.0	High	High	14
Instream Flow and Water Management	8	4.0	Low	High	15
Land Acquisition	7	3.5	Moderate	High	16
Project Area 9 – RM 5.0 to 5.3	7	3.5	Moderate	High	17
Project Area 15 – RM 9.2 to 9.8	7	3.5	High	Low	18
Project Area 16 – RM 9.8 to 10.2	7	3.5	High	Low	19
Introduced Species Management	6	3.0	Moderate	Low	20
Project Area 17 – RM 10.2 to 11.0	4	4.0	High	Low	21

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.

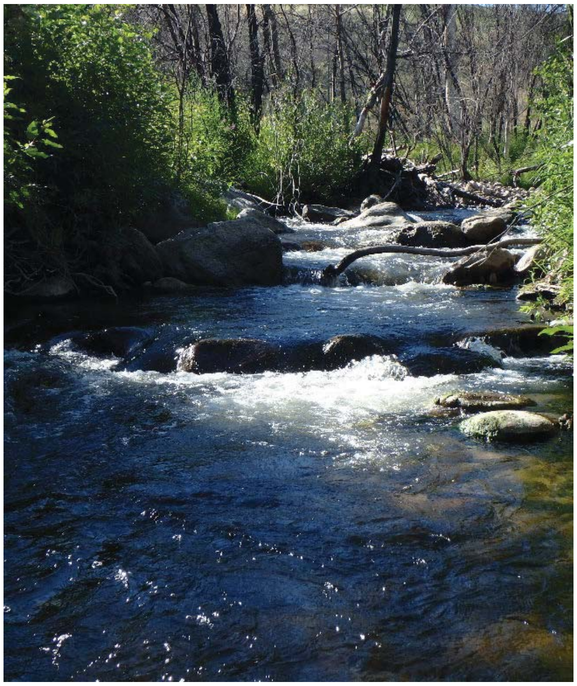
The ability of projects to ameliorate climate change effects and increase salmon resilience was also evaluated based on the analysis of Beechie et al. (2013). The assessment identified the relative potential for proposed project actions to ameliorate climate change related temperature increases, flow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

5.6 Restoration Strategy Summary

The restoration strategy described above presents a framework for restoring natural processes in Beaver Creek and also aids in planning of allocation of financial resources. The restoration strategy uses the scientific information, analyses, data synthesis, and interpretation from the reach assessment (see Section 4) to identify targeted restoration actions that provide habitat improvements for ESA-listed salmonids and other fish species.

A key component of the Beaver Creek restoration strategy is identifying project areas and actions that address the impacts from recent fires including increased water temperatures, high peak flows, debris flows, and increased fine sediment. In addition, the restoration strategy identifies potential opportunities for accelerated restoration that the recent fires have provided. The post-fire increase in sediment and wood loading caused by fire provides opportunities to jump start the progress toward restoring natural processes in Beaver Creek, as described in Section 4. The restoration strategy described above, along with project area details included in Appendix E, identified and described restoration project areas and associated restoration actions that will retain sediment and mobile wood, and create the hydraulic conditions necessary to aggrade the channel bed so that natural geomorphic processes of bank erosion, channel migration, floodplain inundation, and flood attenuation can occur. Potential project areas on Beaver Creek will benefit the most by restoration actions implemented in the short term, prior to full recovery from disturbance.

The resources provided in the restoration strategy will assist in tracking and prioritization 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 have been incorporated into the Project geodatabase to document past efforts.



6. CONCLUSION AND NEXT STEPS

The Beaver Creek reach assessment and restoration strategy provides a scientific foundation and identifies potential project alternatives to assist habitat restoration practitioners in identifying the most appropriate project areas and restoration actions within those areas proposed for further evaluation and implementation. This report establishes a framework and strategy for the restoration of Beaver Creek, which will support and contribute to regional salmon and steelhead recovery efforts and implementation of the Biological Strategy for supporting the recovery of ESA-listed species. The reach assessment identified 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 landowners and land managers 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 reach assessment map series (Appendix B), the project area descriptions and map series (Appendix E), the Project geodatabase (Appendix F), 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 on Beaver Creek, this report has identified and mapped out locations for a number of proposed restoration actions 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 for Beaver Creek is provided below:

- Continue to perform stakeholder outreach and communicate the results of this geomorphic 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).

- 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 year to come.

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