Chewuch River
Reach Assessment

Provided for:

Yakama Nation Fisheries Program
P.O. Box 15, Fort Road
Toppenish, WA 98948

JUNE 2010

Table of Contents

1 OVERVIEW AND OBJECTIVES

1.1 Overview

This assessment evaluates aquatic habitat conditions in the lower 20 miles of the Chewuch River and identifies strategies to restore and preserve salmonid habitat and natural river processes.

This assessment builds off the work conducted as part of the Methow Sub-basin Geomorphic Assessment (USBR 2008b), also known as the Tributary Assessment. Reach Assessments are conducted at a finer scale than Tributary Assessments. Whereas the Tributary Assessment provides a watershed and valley-scale context for primary controls on bio-physical processes, this Reach Assessment describes conditions operating at the scale of individual stream reaches and sub-reaches. This Reach Assessment characterizes geomorphic conditions on the Chewuch River from river mile (RM) 2.2 to RM 20.0 and uses this information to identify restoration and preservation strategies.

This report includes two primary components:

1. Reach Assessment – Reach and Sub-Unit scale evaluation and project opportunity identification
2. REI Metrics – An analysis of Reach-Based Ecosystem Indicators (REI) at the tributary and reach scales.

1.2 Study Area

The Chewuch River Basin is located on the east slope of the Cascade Mountains in Northern Washington. The Chewuch River is a tributary to the Methow River and flows into the Methow River near RM 51.5. The study area includes the Chewuch River channel and floodplain from RM 2.2 to RM 20.0. See Figure 1 for a locator map of the study area and the geomorphic subdivisions (reaches) used in this study.

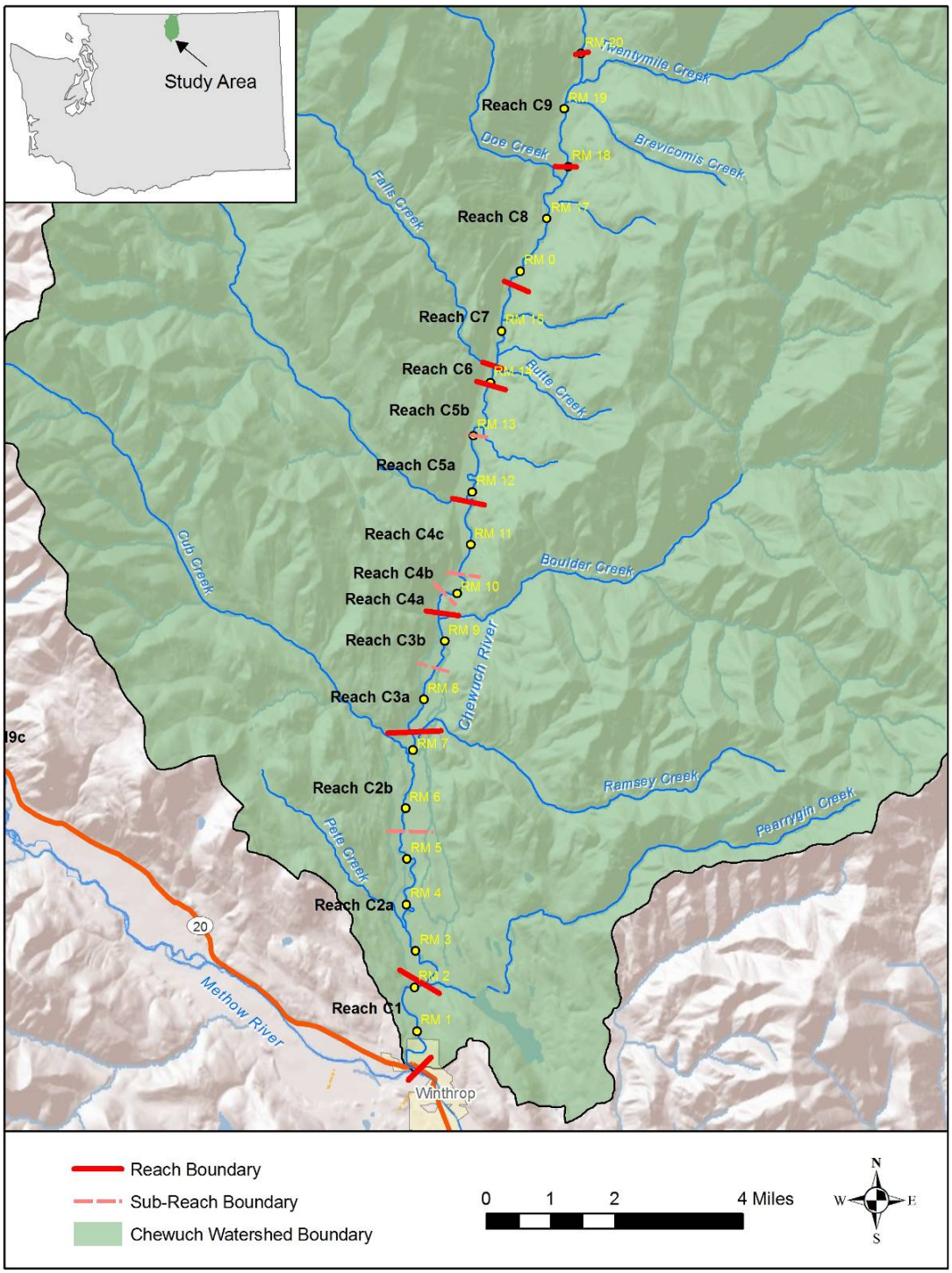

Figure 1. Lower Chewuch River Study Area and geomorphic reaches. The Reach Assessment study area extends from RM 2.2 (Reach C2a) to RM 20.0 (Reach C9).

1.3 Goals and Objectives

The Chewuch River supports populations of salmonids that are currently listed under the Endangered Species Act (ESA), including spring Chinook salmon, summer steelhead, and bull trout. Habitat for these species has been impacted by anthropogenic activities throughout the basin. Specific goals of this assessment include:

- Identify actions that address critical aquatic habitat impairments limiting the productivity of local salmonid populations.
- Identify actions that protect and restore the dynamic landscape processes that support sustainable riparian and salmonid habitat.
- Identify actions that improve and protect water quality to promote salmonid recovery.
- Coordinate efforts with local landowners, resource managers, and other stakeholders in order to establish collaborative efforts that contribute to the success of restoration strategies.

The Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (Recovery Plan, UCSRB 2007) states that recovery of species viability will require reducing threats to the long-term persistence of fish populations, maintaining widely distributed and connected fish populations across diverse habitats of their native ranges, and preserving genetic diversity and life-history characteristics. The Recovery Plan calls for recovery actions within all of the "Hs" that affect salmon throughout their life history; namely Harvest, Hatchery, Hydropower, and Habitat. This Chewuch River Reach Assessment addresses the Habitat component of the Recovery Plan, with a focus on the lower 20 miles of the Chewuch River corridor.

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

Short-Term Objectives

- Protect existing areas where high ecological integrity and natural ecosystem processes persist.
- Restore connectivity (access) throughout the historic range where feasible and practical for each listed species.
- Protect and restore water quality where feasible and practical within natural constraints.

- Increase habitat diversity in the short term by adding instream structures (e.g., LWD, 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.

Restoration Objectives Specific to the Chewuch River Basin

- Increase habitat diversity and quantity in the lower Chewuch River between river miles 0 and 8 by restoring riparian habitat, reconnecting side channels and the floodplain, and adding instream structures.
- Decrease water temperatures in the lower Chewuch River by increasing riparian vegetation, increasing stream flows, and reconnecting side channels and the floodplain with the river.

2 STUDY AREA CHARACTERIZATION

2.1 Setting

The Chewuch River Basin is located in Okanogan County in Northern Washington State on the east side of the Cascade Mountains. The total catchment area is 531 square miles. The mainstem Chewuch River flows through a glacially-carved valley down to its confluence with the Methow River. With the entire Basin glaciated, rock type plays the dominant role in determining valley shape and width and channel gradient. Between RM 9 and 10 the Pasayten Fault zone juxtaposes resistant crystalline bedrock upstream with more erodible sedimentary rocks downstream. The study area (RM 2.2 to 20) straddles this fault zone. The result is a steep "step" in the bed profile between RM 9 and 10, laterally expansive valleys downstream with glacial deposits composing the low surface boundary, and narrower valleys upstream of the step with bedrock composing the low surface boundary. The major tributaries to the Chewuch River within or near the study area include Boulder Creek (RM 9.4), Eight-Mile Creek (RM 11.8), Falls Creek (RM 14.3), and 20-Mile Creek (RM 19.7).

2.2 Salmonid Use and Population Status

Salmonid use of the Chewuch River includes spring Chinook salmon (about 30% of production in the Methow basin), summer run steelhead, bull trout, cutthroat trout, and resident rainbow trout. Human-induced changes to aquatic habitat have affected the key parameters used by federal agencies to evaluate the viability of salmonid populations; known collectively as the "viable salmonid population" (VSP) parameters: abundance, productivity, diversity, and spatial structure (UCSRB 2007). Failure to meet viability (i.e. VSP) criteria resulted in the listing of species under the ESA in the late 1990s. Upper Columbia River (UCR) steelhead trout and spring Chinook salmon were listed as Endangered in 1997 and 1999, respectively (UCSRB 2007). UCR steelhead has since been upgraded to Threatened. Bull trout were listed as Threatened under the ESA in 1999 (UCSRB 2007). Life-stage usage and ESA status for each species are summarized in Table 1.

Table 1. Species usage in the Chewuch River. Adapted from the US Bureau of Reclamation (2008).

Species	ESA Status	Life Stages	
		High density or abundant use	General use
Spring Chinook	Endangered	Migration	Spawning Rearing
Steelhead	Threatened	Migration	Spawning Rearing
Bull Trout	Threatened		Foraging Migration Over-wintering
Westslope cutthroat trout	Not listed		Present

Species	ESA Status	Life Stages	
		High density or abundant use	General use
Redband rainbow trout	Not listed		Present
Brook Trout	Not listed (non-native)		Present

2.3 Habitat Conditions

Aquatic habitat in the Chewuch River has been impacted by a number of historical and on-going land-use activities within the river corridor and in the contributing watershed. These changes have affected stream channels, riparian areas, floodplains, and the physical processes that create and maintain the habitat conditions to which aquatic species have adapted to over time. Road building has altered the river corridor through bank armoring, vegetation clearing, and sediment delivery. Agricultural and residential development has disconnected riparian areas and floodplains due to vegetation clearing, filling and grading, and bank armoring. Water withdrawals for agriculture reduce summertime flow levels. Impacts in the contributing watershed, including past grazing, mining, timber harvest, and road building and have also likely had an impact on aquatic habitat within the study area through changes to hydrologic, large woody debris (LWD), and sediment delivery processes.

Specific conditions with respect to hydrology, geomorphology, and human alterations are discussed in the individual reach profile summaries in Section 5. The quantity and quality of reach-scale habitat conditions have recently been reported by the USBR (2008b) and USFS (2008). A summary of geomorphic and habitat metrics among reaches within the study area are included in

Table 2. Summary of geomorphic and habitat conditions among reaches in the lower Chewuch River.

	Channel Metric	Reach												
		C2a	C2b	C3a	C3b	C4a	C4b	C4c	C5a	C5b	C6	C7	C8	C9
	Sinuosity	1.25	1.06	1.1	1.08	1.12	1.75	1..1	1.19	1.21	1.06	1.05	1.2	1.2
	Gradient	0.005	0.007	0.009	0.015	0.0012	0.0029	0.0046	0.0025	0.0035	0.0144	0.006	0.003	0.01
	Floodplain Width (ft)	700	444	225	152	331[1]	331[1]	331[1]	114[2]	114[2]	114[2]	362	242	154
	BF Width (ft)	140	134	120	98	117[1]	117[1]	117[1]	121[2]	121[2]	121[2]	96	106	84
% of Habitat Area	Pools	55.6%	42.7%	27.4%	18.8%	45.3%[1]	45.3%[1]	45.3%[1]	45.8%[2]	45.8%[2]	45.8%[2]	35.3%	35.1%	25.2%
	Riffles	33.8%	40.7%	59.6%	53.0%	36.2%[1]	36.2%[1]	36.2%[1]	29.9%[2]	29.9%[2]	29.9%[2]	45.3%	38.2%	59.4%
	Glides	7.7%	14.8%	5.6%	4.6%	17.4%[1]	17.4%[1]	17.4%[1]	13.6%[2]	13.6%[2]	13.6%[2]	19.5%	22.8%	3.9%
	Side-Channel	2.9%	1.8%	7.5%	23.6%	1.1%[1]	1.1%[1]	1.1%[1]	10.7%[2]	10.7%[2]	10.7%[2]	0.0%	3.9%	11.5%
Human Alterations	% Floodplain Disconnected[3]	20.1%	12.6%	68.5%	0.0%	0.0%	63.7%	63.5%	0.0%	18.0%	59.2%	0.0%	0.0%	0.0%
	% Bank w/ Riprap[4]	0.3%	1.8%	1.7%	1.3%	8.6%	1.9%	12.1%	3.2%	0.0%	0.0%	0%	0%	0%
	% Native Riparian Vegetation	79.0%[5]	97.0%[5]	66.0%[5]	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data	No Data
	% Riparian Veg Cleared	3 - 25%[6]	3 - 25%[6]	10 - 35%[6]	10 - 35%[6]	13 - 17%[6]	13 - 17%[6]	13 - 17%[6]	Minimal[6]	Minimal[6]	<20%[7]	Minimal[7]	Minimal[7]	Minimal[7]

[1] Data available for reaches C4a, C4b, C4c were reported as a larger combined reach (BOR 2008a).
[2] Data available for reaches C5a, C5b, C6 were reported as a larger combined reach (USFS 2008).
[3] Floodplain disconnection is based on an analysis of Inner Zone and Outer Zone polygons (see Section 4.1).
[4] Percentage of the bank protected with riprap was calculated using human features data obtained through remote sensing and field surveys and compiled in a GIS database by the BOR (2008b) and Inter-Fluve (2009).
[5] Riparian vegetation species composition was analyzed using a 30 meter buffer on either side of the Chewuch River in combination with the BOR vegetation GIS data (BOR 2008b).
[6] USBR 2008b.
[7] Percent riparian vegetation (within 30 meter buffer) cleared based on aerial photo analysis.

3 HABITAT RESTORATION AND PRESERVATION FRAMEWORK

3.1 Process-based Restoration Strategy

Selection of habitat restoration and preservation strategies was guided by the habitat objectives set forth in the Upper Columbia Recovery Plan (UCSRB 2007), which were described previously in Section 1.3.

Restoration and preservation activities are prioritized according to a process-based hierarchical framework, similar to those presented by Roni et al. (2002), Roni et al. (2005), and utilized by the USBR for other reach assessments in the region (e.g. Lyon and Maguire 2008). The framework used in this assessment emphasizes preservation and process-based restoration as the highest priority, followed by habitat enhancement and stabilization. Protecting functional habitats and stopping further degradation is given the highest priority and is considered an underlying principle. Figure 2 presents the hierarchical framework and terminology used for this assessment.

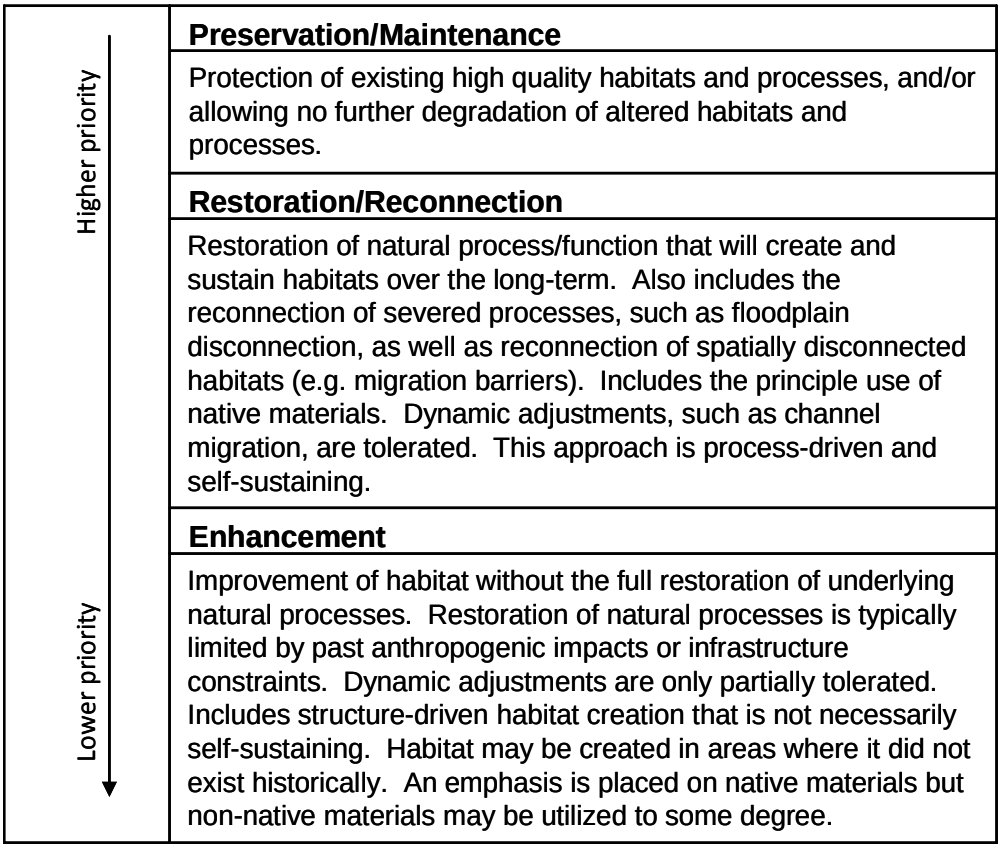

Figure 2. Hierarchical framework, prioritization, and terminology used to categorize and prioritize projects. Adapted from Gilliland et al. (2005) and Skidmore et al. (2009).

3.2 Project Types

All of the projects are categorized by project type. The project types are included below with a brief description and examples for each type. The project types are listed in priority order based on the hierarchical strategy presented in Figure 2. Specific priorities will vary depending on site-specific conditions and feasibility considerations.

Protect and Maintain

Protection projects are located in areas that are presently in a connected and functional state, as well as in impacted areas that should be preserved against further degradation. These actions should be considered obligatory when the opportunity arises, and are inherent in all potential actions. In many cases, adequate protection may already be in place through existing laws and regulations. The adequacy and enforcement of these regulations needs to be considered when planning for protection activities

Examples:

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

Reconnect Stream Channel Processes

Stream channel reconnection projects are located in areas where stream bio-physical processes have been disconnected due to anthropogenic activities. These are areas that have the potential for an increase in habitat quality and a reestablishment of dynamic processes through their reconnection. Restoration actions are focused on reclaiming a component of the system that has been lost, thus regaining habitat and process that was previously a functional part of the river system.

Examples:

- Removal of rip-rap in order to eliminate bank hardening and channelization that restricts channel migration, simplifies the channel, and compromises instream aquatic habitat quality and quantity.
- Removal of a road embankment or levee that has cut-off an older channel alignment in order to reconnect a side-channel or mainstem channel.
- Placement of a LWD jam where wood recruitment rates have been reduced to promote active lateral channel dynamics, such as development of a multi-thread channel system.

Reconnect Floodplain Processes

Floodplain reconnection projects are located in areas where floodplain and channel migration processes have been disconnected due to anthropogenic activities. These are areas that have the

potential for an increase in habitat quality and a reestablishment of dynamic processes through their reconnection. Restoration actions are focused on reclaiming a component of the system that has been lost, thus regaining habitat and process that was previously a functional part of the river system.

Examples:

- Removal of a levee that limits floodplain connectivity.
- Selective bridging or breaching of road embankments or levees or enhance floodplain connectivity.
- Removal of floodplain infrastructure or fill that limits floodplain connectivity.

Riparian Restoration

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

Examples:

- Replanting a riparian buffer area with native forest vegetation.
- Eliminating invasive plant species that are preventing the reestablishment of a native riparian forest community.
- Fencing livestock out of a riparian zone in order to recover natural vegetation and streambank stability conditions.

Instream Habitat Enhancement

Instream habitat enhancement projects are located in active channel areas where there is the potential to increase stream habitat quantity and quality. Instream enhancement projects typically involve active restoration measures that either directly increase key habitat components or indirectly improve habitat through structural enhancements that restore habitat-forming processes (e.g. pool scour from a LWD jam).

Examples:

- Construction of a log-jam to increase in-channel habitat complexity.
- Use of LWD and boulder structures to restore natural rates of channel migration.

Off-Channel Habitat Enhancement

Off-channel habitat enhancement projects are located in off-channel areas (e.g. floodplains) where there is the potential to increase the quantity and quality of off-channel habitat. In some

cases, the location may not have historically provided this habitat, but has the potential to support the habitat under current hydrologic and geomorphic conditions. Given limited opportunities and constraints in other parts of a reach, this may sometimes be the best option to achieve restoration objectives.

Examples:

- Improving fish connectivity to an existing off-channel habitat area.
- Construction of off-channel features such as alcoves, backwaters, or beaver ponds that are connected to the main channel.
- Addition of LWD cover and complexity in an existing off-channel area.

4 METHODS

4.1 Reach and Sub-Unit Delineations

Reaches were identified previously as part of the Tributary Assessment (USBR 2008b). These same reach delineations were utilized for this Reach Assessment to maintain consistency with tributary-scale assessments. However, the study area of the USBR Tributary Assessment ends at RM 14.3. Upstream of that point, reach breaks were taken from the USFS Habitat Survey (2008a). Thus all reach breaks are consistent with the most recent studies in the Chewuch Basin.

In some cases, reaches were further divided into smaller "sub-units". A sub-unit is a distinct segment of active channel (inner zone) or floodplain (outer zone) that comprises unique functional characteristics. A description of conditions and processes operating at the sub-unit scale provides a basis for identifying and describing site specific conditions that informs the project identification and prioritization process.

An inner zone sub-unit is defined as the wetted low-flow channel and all related areas that experience ground-disturbing flow such as secondary channels and active bars. An outer zone sub-unit is defined as the low-lying area adjacent to the channel that may become inundated at higher flow but does not normally experience ground disturbing flow (USBR 2009a). Inner zone sub-units were delineated using breaks in geomorphic control such as bedrock constrictions or roadways that result in variations in channel pattern and channel type. Outer zone sub-units were delineated as discrete floodplain areas separated by natural breaks or anthropogenic barriers.

Inner and outer zones may be identified as "disconnected", denoted with a "D" before the IZ (Inner Zone) or OZ (Outer Zone) identifier. A disconnected zone is a zone whose direct connectivity or physical processes have been disconnected from the existing channel or floodplain due to anthropogenic alterations. Inner and outer zones may become disconnected through channel or floodplain manipulations including straightening, ditching, filling, and rip-rap, and through construction of levees, road embankments, or bridges. In addition, outer zones may be disconnected via indirect alterations that affect channel migration and flood inundation processes. These may include upstream or downstream bridge crossings that limit channel migration or land-use induced channel incision that reduces the extent of floodplain inundation.

4.2 Project Identification and Prioritization

Project Identification

Projects were identified through a combination of methods, including the following: 1) field surveys of project opportunities, 2) discussions with agency personnel, 3) previous studies, and 4) remote sensing using aerial photography and LiDAR. Location information, general site conditions, and photographs were acquired for each project opportunity area. This information is provided in the maps for each reach summary and in the list of project opportunities (Appendix B).

Potential project opportunities were identified as part of the Methow Subbasin Geomorphic Assessment (aka Tributary Assessment, USBR 2008b). These project opportunities provided a baseline for identification of projects presented in this Reach Assessment. Table 3 summarizes general restoration strategies and concepts for the study area that were identified in the Tributary Assessment. Initial project scoping ideas identified in the Tributary Assessment, Appendix A, Attachment 2 (List of Potential Floodplain Restoration Projects and Concepts) (USBR 2008b) were also reviewed to provide information for the project identification effort.

Table 3. General restoration strategies and concepts identified in the Tributary Assessment (USBR 2008b). Note that reaches C7, C8, and C9 are not addressed by the USBR.

Reach	General Restoration Strategies *(USBR 2008b, Table 6)*	Primary Restoration Concepts *(USBR 2008b, Table A-5)*	Secondary Restoration Concepts *(USBR 2008b, Table A-5)*
2	Riparian restoration, Side-channel reconnection, Floodplain restoration , LWD restoration	Levee and riprap removal or setback to reconnect a minimum of 4.2 miles of off-channel habitat areas.	Riparian planting and LWD projects in support of Primary Restoration Concepts
3	Riparian restoration, Side-channel reconnection, Road Maintenance, Floodplain restoration , LWD restoration	Small area of riprap removal restoring access to about 0.1 miles of side-channel.	Riprap removal or LWD projects along main channel where possible to a complexity and improve hydraulics.
4	Riparian restoration, Floodplain restoration , LWD restoration	Minor riprap removal between RM 10.4 to 10.5, excavation of fill in cleared areas.	None identified.
5	Riparian restoration, Side-channel reconnection, Floodplain restoration , LWD restoration	Remove or enhance riprap between RM 12.8 to 13 using LWD to reconnect a minimum of 0.5 miles of side channels.	LWD placements in support of Primary Restoration Concepts.
6	None identified	None identified	None identified

Project Prioritization

Projects are prioritized at a coarse-scale based on the hierarchical project prioritization framework described previously (Figure 2). It is important to note that site-specific conditions, such as landowner cooperation, access and infrastructure constraints, often preclude the implementation of the highest priority measures. However, at this stage, projects are not prioritized according to potential feasibility constraints. A finer-scale project prioritization methodology that incorporates feasibility considerations will be conducted as a subsequent phase of this effort.

4.3 Organization

This section of the report is organized on a reach basis, with information presented for each individual reach in separate sections. Reach numbers increase in the upstream direction and are presented in numerical order. Thus, the farthest downstream reach (Reach 2 in this study) is presented first. Reach descriptions include an overview of habitat and fish use, hydrology, geomorphology, and anthropogenic influences operating within the reach. This information is followed by the reach-scale restoration strategy. The sub-unit and project opportunity summary is included next, which presents the bulk of the information in the sub-unit and project table. Unlike reaches, sub-units are numbered in the downstream direction. Thus, the furthest upstream sub-units are presented first and subsequent summaries proceed in the downstream direction within a given reach. The sub-unit and project tables include a sub-unit description, the restoration strategy within each sub-unit, project opportunities that fall within the sub-unit, and potential constraints. Projects are named using their river mile location, with the approximate midpoint used for long projects. An “R” (right bank), “L” (left bank), or “C” (Channel) designation is also included in the name of the project in order to provide ease of locating the project. Reference to river-left or river-right is always oriented facing the downstream direction.

A comprehensive project opportunity list for the study area, which includes project descriptions and photos, is included as Appendix B.

C2a – Reach Assessment

5 C2A REACH ASSESSMENT

5.1 Reach Overview

Reach C2a is a low gradient, meandering, unconfined alluvial reach located between the confluence of Pearygin Creek at RM 2.2 and RM 5.6. Within this area, the channel is actively migrating across a wide floodplain with very few anthropogenic barriers to habitat or process connectivity. There is good current and potential fish habitat in Reach C2a, which has the longest cumulative length of side-channels and floodplain channel networks in the lower 11 miles of the Chewuch (USBR 2008a). Only 17% of the riparian area has been cleared for residential, agricultural, and recreational development. However, the USBR determined that only 1/3 of the reach is currently in functioning condition (USBR 2008b). Restoration work such as levee removal, side-channel enhancement, and culvert improvement would be needed to re-establish habitat connectivity and allow for dynamic physical processes.

Habitat Conditions and Fish Use

Salmonid use of Reach C2a includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. The reach is used for spring Chinook and steelhead spawning, rearing, and migration. Annual steelhead redd counts from 2003 to 2007 from RM 3.3 to Chewuch Bridge (spans most of Reach C2a up through Reach C3a) have an average of 2.6 redds/mile. Spring Chinook redd counts from 2001 to 2007 in the same area have an average of 11.3 redds/mile (data from Snow et al. 2008).

Water temperature is elevated throughout the lower Chewuch River, with numerous exceedances of the state water temperature standard during summer months (USBR 2008a). Instream flows are also a concern during summer months, with two upstream irrigation diversions (the Chewuch Ditch at RM 8.5 and the Skyline Ditch at RM 9.2) that may affect fish passage, temperature, and habitat availability.

Reach C2a had the second highest amount of in-channel LWD during stream surveys of the lower river (RM 0-9.5) in 2008; however, abundance is still considered low (USBR 2008a). Pool quantity was relatively high, comprising 55% of the habitat area in the reach. Side-channel habitat comprises approximately 3% of the reach, which is considered low for the channel type and gradient. Reach C2a has abundant spawning habitat, although the amount of fines (<6mm) is high (22%) (USBR 2008a). A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 4.

Table 4. Reach-Based Ecosystem Indicators (REI) ratings for Reach C2a. See Appendix A for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach C2a Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*At Risk*
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*Adequate*

General Characteristics	General Indicators	Specific Indicators	Reach C2a Condition
	LWD	Pieces per Mile at Bankfull	*Unacceptable*
	Pools	Pool Frequency and Quality	*Adequate*
	Off-Channel Habitat	Connectivity with Main Channel	*At Risk*
Channel	Dynamics	Floodplain Connectivity	*At Risk*
		Bank Stability/ Channel Migration	*Adequate*
		Vertical Channel Stability	*Adequate*
Riparian Vegetation	Condition	Structure	*At Risk*
		Disturbance (Human)	*At Risk*
		Canopy Cover	*Unacceptable*

Hydrology

There are two tributaries in this reach: Pearygin Creek at RM 2.2 and Pete Creek near RM 4.0. These are both small tributaries that contribute a negligible portion of mean annual discharge. Irrigation withdrawals in upstream reaches affect flows in Reach C2a, particularly low flows during summer months. Table 5 presents flood peak estimates for a variety of recurrence intervals calculate for a point near the downstream end of the reach.

Table 5. Flood magnitudes for recurrence intervals from 2 to 100 years at the downstream end of Reach C2a (RM 2.2). Obtained from Methow River Basin GIS hydrology database (USBR 2008b).

		Flood Recurrence Interval (ft^3/sec)					
Location	River Mile	Q2	Q5	Q10	Q25	Q50	Q100
Downstream End	2.2	3,162	4,849	5,943	7,279	8,233	9,151

Geomorphology

Natural constraints on valley width consist of glacial terraces, and in some locations, bedrock. Glaciation in the Chewuch Basin is thought to have extended to its mouth, and glacial deposits compose the majority of the low surface boundary. The remainder of the low surface boundary is bedrock, which consists of relatively easily erodible sedimentary and volcanic rocks (USBR 2008b). Low surface width in Reach C2a is the widest in the lower 11 miles, and extends up to 700 ft in mean width (USBR 2008b). This is still reduced from the geologic width of the low surface, which is up to 230 ft wider at some points (USBR 2008b).

There are few anthropogenic constraints on lateral channel dynamics in this reach. C2a is the only reach in the lower 11 miles that has actively eroded and widened the low surface boundary since 1974. Low surface boundary erosion in this reach accounts for about 2% of the total length of the low surface boundary (USBR 2008b). The channel is the most sinuous in the lower 11 miles (1.25), and is actively migrating, although the magnitude of lateral adjustment has been modest based on aerial photo analysis. Dynamic geomorphic processes have resulted in a complex channel system having a sinuous main channel with primary side-channels and connected floodplain channel networks. The cumulative length of these channel networks and

side-channels, around 25,000 ft, is the longest in the lower 11 miles that was studied by the USBR (2008b).

Bed morphology in this reach is primarily pool-riffle. Pools comprise about 55% of the channel area, with the highest pools/mile ratio in the lower 11 miles of the Chewuch. Pools are mostly formed by scour on the outside of meaner bends. Although there is extensive side-channel length, a relatively small percentage of these channels are active over a wide range of flows; most side-channels are active only at high flow. This may be attributed to a lack of LWD in the reach and/or fine-sediment deposition in side-channels (USBR 2008a). At two USBR pebble count locations, 22% of surface material was smaller than 6 mm.

Human Alterations

Anthropogenic influence on the river corridor is minor in Reach C2a (Figure 3). Major roadways are set back along the toe of bounding hillslopes, outside of the low surface area. Development has been concentrated between RM 2.2 and 2.7 and between RM 3.6 and 4.3 along the west side of the valley. In the downstream area, there is moderate residential development with associated roadways and fill. A 460 ft section of riprap protects houses at the upstream end of this area near RM 2.7. Only small patches of riparian forest clearing have taken place as part of this rural development. At the upstream golf course development, the riparian area has been completely cleared and artificial wetlands have been constructed. The former floodplain surface has been filled and graded, leaving no evidence of high flow channels or off-channel habitat.

Figure 3. Aerial photo showing human features in Reach C2a. Flow is from north to south.

5.2 Reach Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach C2a is included below. The strategy focuses first on protecting existing conditions from further impairment. This objective is followed by reconnecting the fundamental bio-physical processes that will create and maintain habitat conditions over the long-term. Instream and off-channel habitat enhancement (rehabilitation) is also included; these projects occur in conjunction with long-term process reconnection and are also applied in cases where long-term process reconnection is constrained by existing human uses. The USBR (2008b) identifies protection of the channel and floodplain to preserve the integrity of active processes and intact habitat as the primary objective for Reach C2a. USBR restoration objectives include re-connecting side-channel habitat and channel/floodplain processes**.**

1. ***Protect and Maintain***
   - **Prevent Further Degradation**- Opportunities to prevent further degradation should be pursued including purchasing land and water rights in the river corridor, and/or obtaining conservation easements. Water rights acquisition should be focused on increasing instream flow during late summer.
   - **Legal Protection**- Existing enforced legal protection is considered an intrinsic component of all potential projects.

2. ***Reconnect Stream Channel Processes***
   - **Instream Flow**- Continue to identify and carry forward projects that will result in natural timing of runoff recession and increased baseflow. Low baseflow during summer months can create barriers to fish migration that is essential for restoration success throughout the study area. Flow withdrawals also increase the potential for high summer stream temperatures. Increased instream flow between July and October will enhance the success of restoration work that is meant to provide habitat over a wide range of flows including low flow periods. There is one significant diversion upstream of this reach.
   - **Channel Dynamics**- Address loss of multi-thread channel complexity resulting from loss of wood dynamics. LWD jams are important to geomorphic process and their frequency and function have been reduced by past land-use practices. Where feasible, LWD jams can be placed in areas where they would naturally occur and where processes such as bar deposition, pool scour, lateral channel migration, and natural rates of recruitment can be re-established.

3. ***Reconnect Floodplain Processes***
   - **Floodplain Development** – Floodplain development has taken place on the west side of the valley at mid-reach. The development includes clearing and grading. Full floodplain reconnection will require reclamation of floodplain surfaces. Work with appropriate stakeholders to develop long-term solutions to floodplain impacts.

4. ***Riparian Restoration***
   - **Restore Riparian Areas** - There are large cleared areas associated with recreational and agricultural floodplain development. In most areas, there is a moderate riparian corridor maintained along the channel margin. Work should continue to expand riparian buffers.

5. ***In-Stream Habitat Enhancement***
   - **Enhance Habitat Complexity** Instream large wood is a natural component of this system that has been severely reduced by past land-use practices. Wood creates pool scour, cover, and channel complexity. Place wood in configurations and locations that mimic natural wood deposition processes. These projects are not replacements for process restoration, but are meant to provide intermediate habitat enhancement while process restoration matures.

6. ***Off-Channel Habitat Enhancement***
   - **Enhance Off-Channel Habitat Complexity**- Impacts to physical processes has resulted in habitat simplification in some areas. Installation of natural off-channel habitat features can provide an intermediate improvement to aquatic ecology while process restoration matures. Natural activity of beavers can result in enhanced off-channel habitat and may be considered as a restoration option.

5.3 Sub-Unit and Project Opportunity Summary

Eleven sub-units were identified in Reach C2a, including two inner zone sub-units, seven outer zone sub-units, and two disconnected outer zone sub-units (Table 6, Figure 4, Figure 5 Figure 6, Figure 7). The majority of the river corridor is intact; 27% of the outer-zone is disconnected. Current conditions provide substantial opportunity for protection. In addition, restoration efforts have the potential to re-connect large areas of inner and outer zone habitat. Nineteen specific project opportunities have been identified in this reach and are described in the sub-unit summaries in the next section (Table 7).

Table 6. Summary of protection and restoration opportunities for reach C2a.

Sub-Unit	River Mile	Acreage
Outer Zone (OZ-1)	4.9-5.6	24.6
Inner Zone 1 (IZ-1)	3.2-5.6	N/A
Outer Zone 2 (OZ-2)	4.3-4.95	24.8
Outer Zone 3 (OZ-3)	4.5-4.83	7.7
Disconnected Outer Zone 1 (DOZ-1)	3.67-4.27	44.1
Outer Zone 4 (OZ-4)	4.08-4.27	0.93
Outer Zone 5 (OZ-5)	2.7-4.07	99
Outer Zone 6 (OZ-6)	2.76-3.7	21.3
Inner Zone 2 (IZ-2)	2.15-3.25	N/A
Disconnected Outer Zone 2 (DOZ-2)	2.15-2.75	24.2
Outer Zone 7 (OZ-3)	2.15-2.37	4.5

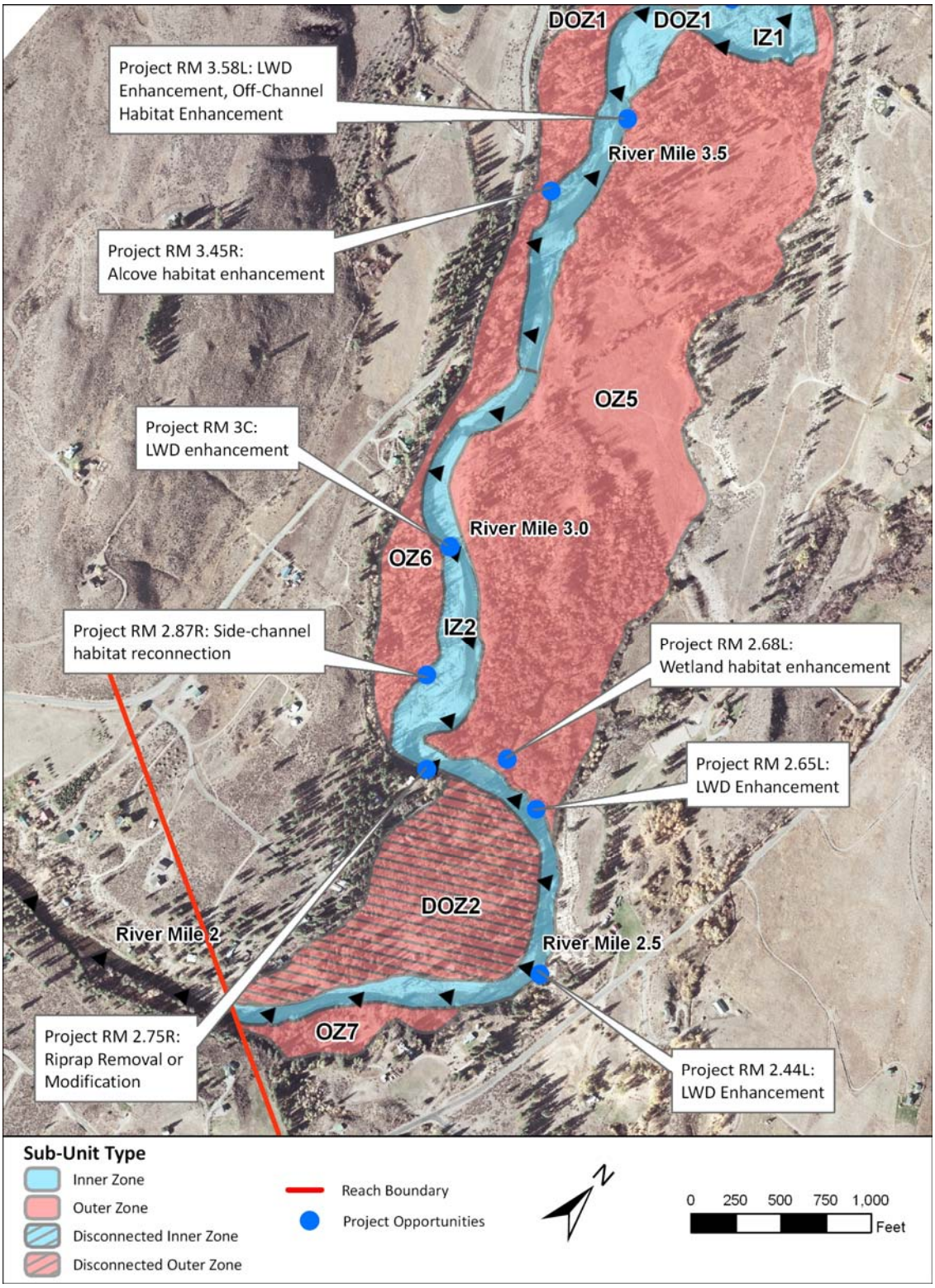

Figure 4. Sub-units and project opportunities in the downstream portion of Reach C2a. Flow is from north to south.

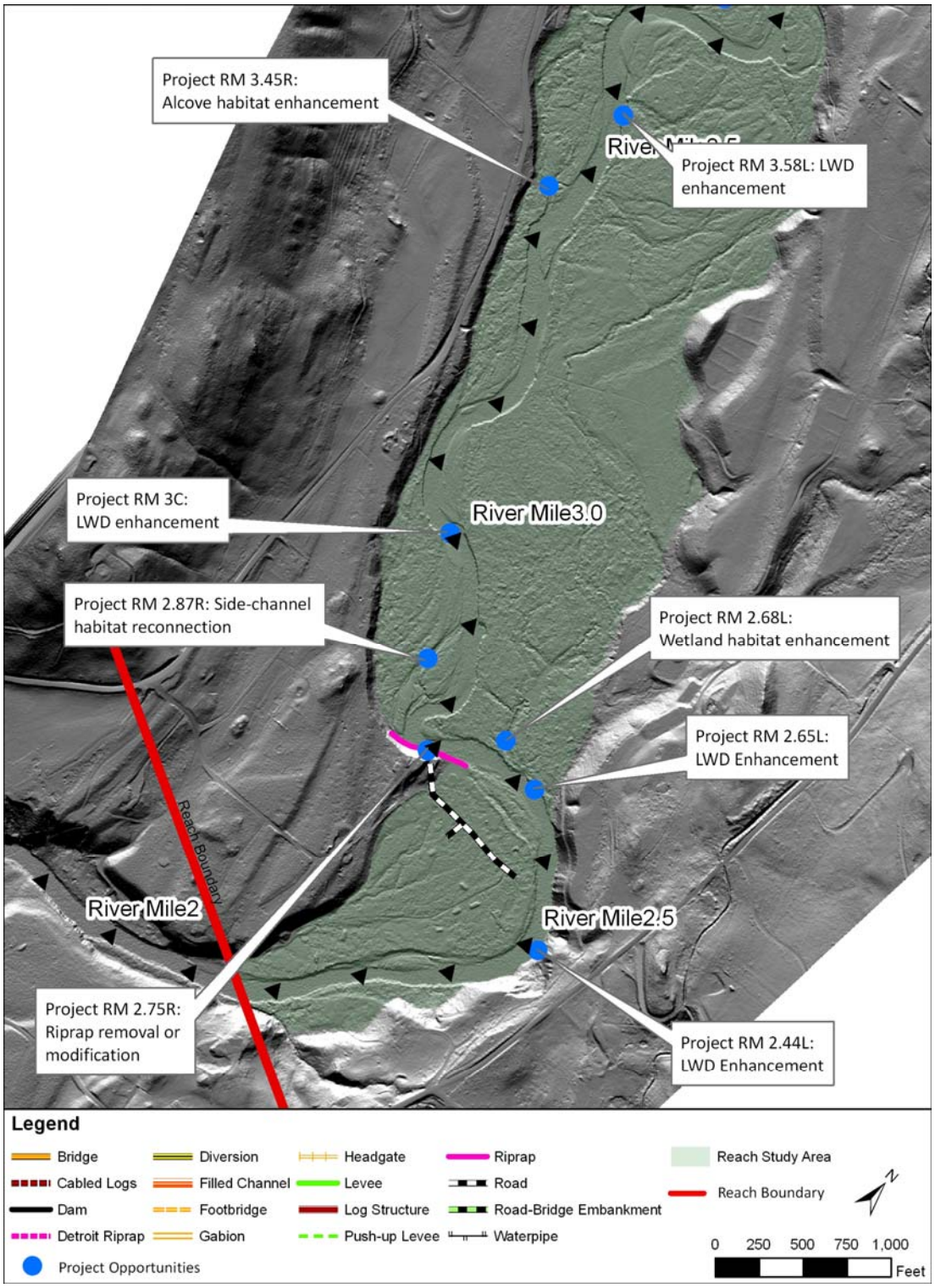

Figure 5. LiDAR hillshade of reach C2a illustrating topography in relation to human features and project locations in the downstream portion of the reach. Flow is from north to south.

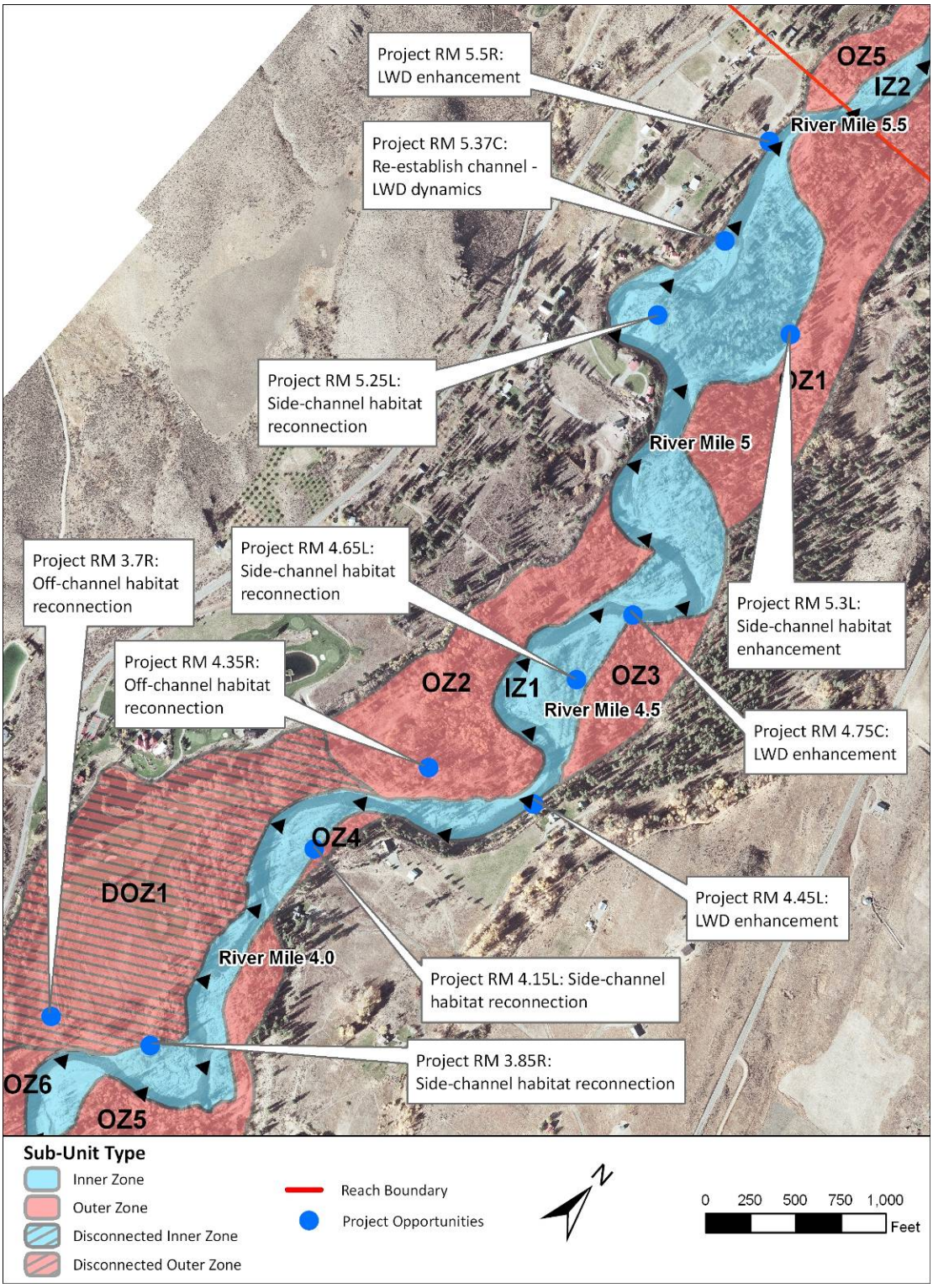

Figure 6. Sub-units and project opportunities in the upstream portion of Reach C2a. Flow is from north to south.

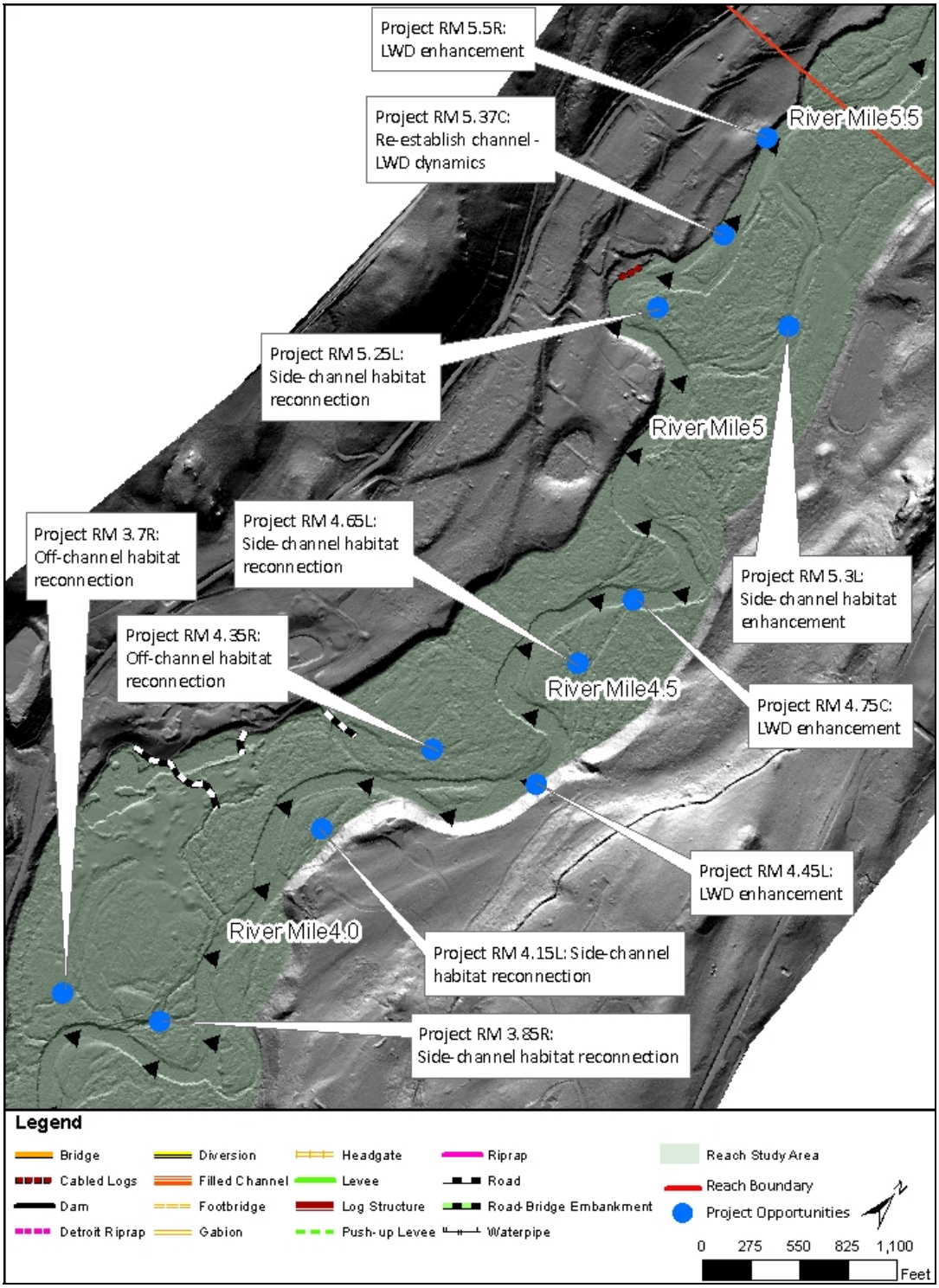

Figure 7. LiDAR hillshade of reach C2a illustrating topography in relation to human features and project locations in the upstream portion of the reach. Flow is from north to south.

Table 7. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C2a.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
OZ-1	This outer zone area is the downstream 24.6 acres of a much larger floodplain that originates upstream in Reach C2b. As with the rest of the surface upstream, OZ-1 contains intact riparian habitat and evidence of active hydrologic and geomorphic connection to the inner zone. LiDAR data shows multiple high-flow channels across the surface, some originating upstream and some within Reach C2a. However, historical aerial photography suggests only a possible high-flow connection in the 1974 photo series, and no other mapped high flow channels in OZ-1. A large inner zone side-channel adjacent to OZ-1 provides the potential for a high flow connection between the channel and floodplain. The intact riparian area, including mature trees along the channel margin, provides a potential LWD recruitment source.	Protect and Maintain		Private Land Ownership
IZ-1	USBR (2008b) reports a reach average sinuosity of 1.25, a channel slope of 0.5%, and a wide average bankfull width of about 70 ft in C2a. Local sinuosity and channel width in IZ-1 are closer to the maximum range within C2a. Meander bends in IZ-1 are tortuous with large gravel point bars depositing on the insides of bends. High flow side-channels create habitat on the inside of almost every meander bend. These geomorphic characteristics suggest a depositional area. There are no anthropogenic constraints on channel processes. The majority of projects in this sub-unit involve enhancing side-channel processes and habitat. These side-channels currently function during high flows as hydraulic	Protect and Maintain Reconnect Stream Channel Processes Instream Habitat Enhancement Off-Channel Habitat Enhancement	***Project RM 5.37C*** Re-establish channel LWD dynamics ***Project RM 5.25L*** Side-channel habitat reconnection ***Project RM 4.65L*** Side-channel habitat reconnection ***Project RM 4.15L*** Side-channel habitat reconnection ***Project M 3.85R*** Side-channel habitat	Golf course development along the west side of the valley between RM 3.7 and 4.25. Light residential and agricultural development on terrace surfaces.

Table 7. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C2a.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
	refugia, but provide very little perennial split flow. The side-channel projects mainly involve increasing low flow volumes. However, a balance must be struck between providing active channel environments and high flow refugia when considering enhancing low-flow connection to side-channels.		reconnection ***Project RM 5.5R*** LWD enhancement. ***Project RM 4.75C*** LWD enhancement ***Project RM 4.45L*** LWD enhancement ***Project RM 3.58L*** LWD enhancement ***Project RM 5.3L*** Side-channel habitat enhancement	
OZ-2	OZ-2 is an outer-zone sub-unit occupying 24.8 acres along the west side of the valley between RM 4.3 and 4.95. OZ-2 contains high-quality riparian habitat with an intact forest that provides a potential LWD recruitment source. Near the downstream end of the sub-unit, LiDAR data shows channel scars which were mapped as the low-flow channel on 1893 cadastral maps. Other than an access road blocking this channel at the USBRder of DOZ-1, there has been minimal development of this surface. A primitive road provides vehicle access near RM 4.66, and some clearing is visible near RM 4.27.	Protect and Maintain Reconnect Floodplain Processes	***Project RM 4.35R*** Off-channel habitat reconnection.	Golf course development downstream.
OZ-3	OZ-3 is a small floodplain sub-unit (7.7 acres) on the east side of the valley between RM 4.5 and 4.83. The floodplain is undisturbed and has an intact riparian forest. There is little geomorphic evidence of inundation. However, there are some small channels near the downstream end that may collect	Protect and Maintain		Private land ownership.

Table 7. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C2a.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
	groundwater seasonally.			
DOZ-1	DOZ-1 is a 44 acre floodplain surface on the west side of the valley between RM 3.67 to 4.27. A golf course has been developed in this sub-unit. Riparian clearing, leveling and extensive landscaping have occurred as part of this development. A buffer of riparian vegetation has been left along the channel margin. LiDAR data suggests that some floodplain topography has been left intact, particularly at the upstream and downstream ends of the sub-unit. This includes channel scars and low areas that were wetted in 1954 and 1964 aerial photographs. Golf course water features occupy some of these locations now. There are no bank modifications or direct barriers to floodplain inundation, and it is possible that larger flow events may inundate low areas in DOZ-1. However the development has fragmented habitat.	Protect and Maintain Reconnect Floodplain Processes Riparian Restoration	***Project RM 3.7R*** Off-channel habitat reconnection *Work with landowners to re-vegetate a riparian buffer along the river corridor*	Golf course development upstream.
OZ-4	OZ-4 is a narrow (0.94 acre) floodplain along the east side of the valley between RM 4.08 and 4.27. OZ-4 is undeveloped and provides a small, intact riparian area. There do not appear to be any off-channel aquatic habitat features or high-flow channels.	Protect and Maintain		Private land ownership.
OZ-5	OZ-5 is the largest floodplain sub-unit in Reach C2a at just over 99 acres, extending along the east side of the valley between RM 2.7 and 4.07. This area has not been developed and provides a large tract of riparian habitat including forest, meadow, and wetlands. Along the channel margin there is	Protect and Maintain Off-Channel Habitat Enhancement	***Project RM 2.68L*** Wetland habitat enhancement	No identified constraints to restoration or preservation.

Table 7. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C2a.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
	opportunity for LWD recruitment, though sinuosity is low and channel migration rates in this area are low. Topographic data shows a complex network of high-flow channels throughout the floodplain. Some of these are channel scars as recent as 1954 and as old as 1893. Near the downstream end of the sub-unit, there is a large open wetland with a surface connection near RM 2.66.			
OZ-6	OZ-6 is a long, narrow floodplain occupying 21.3 acres along the west side of the valley between RM 2.76 and 3.7. This floodplain area has been closely coupled to channel processes over the last century, having been a part of the inner-zone in 1915 and 1945. Existing channel scars do not appear to provide off-channel habitat, but may provide high-flow refugia. The riparian forest is intact and no development has occurred on this surface.	Protect and Maintain Off-Channel Habitat Enhancement	***Project RM 3.45R*** Alcove habitat enhancement	No identified constraints to restoration or preservation.
IZ-2	The inner zone simplifies near RM 3.25, becoming narrower, less sinuous, and with fewer point bars and side-channels. The channel is constrained by riprap at the toe of a glacial terrace at RM 2.75 where the channel is forced east, and by bedrock at RM 2.56 where the channel flows south and west. There is an area between RM 2.75 and RM 3.0 where lateral channel dynamics have resulted in an expanded inner zone and side channel habitat. Aerial photo analysis suggests that up to 500 ft of lateral meander migration has occurred in this area	Protect and Maintain Reconnect Stream Channel Processes In-Stream Habitat Enhancement	***Project RM 2.87R*** Side-channel habitat reconnection ***Project RM 3C*** LWD enhancement. ***Project RM 2.75R*** Riprap removal or modification ***Project RM 2.65L*** LWD enhancement ***Project RM 2.44L*** LWD enhancement	Residential development along the west side of the valley from RM 2.2 to 2.75.

Table 7. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C2a.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
DOZ-2	DOZ-2 is a 24.2 acre, developed floodplain on the west side of the valley between RM 2.15 and 2.75. Light development (including both rural and recreational) has taken place throughout this sub-unit. Riparian clearing has been minimal, with only small areas cleared around structures. Riprap has been installed to protect homes at the upstream end. Driveways and access roads are found across the entire area. Most structures are manufactured or mobile homes placed in low areas near the channel. Though much of the surface has been leveled as part of residential development, LiDAR data shows traces of high-flow channels in some locations, several of which appeared to be secondary channels in 1945 aerial photographs.	Protect and Maintain Reconnect Floodplain Processes	*Work to find opportunities to reconnect channel and floodplain dynamics.*	Rural and recreational residential development throughout the sub-unit.
OZ-7	OZ-7 is a small, 4.5-acre unit along the east side of the valley between RM 2.76 and 3.7. There has been a small amount of riparian clearing and an unimproved road pushed onto the surface. LiDAR data suggests there is fill and grading associated with the road. However, riparian vegetation is mostly intact with a continuous channel margin buffer. There is no evidence of frequent inundation.	Protect and Maintain		Residential development on the adjacent terrace.

[1]*For additional information on specific identified project opportunities, see Chewuch Project Opportunities list in Appendix*

C2b – Reach Assessment

6 C2B REACH ASSESSMENT

6.1 Reach Overview

Reach C2b is an unconfined alluvial reach located between RM 5.6 and the confluence with Cub Creek at RM 7.3. Reach C2b has low gradient (0.7%) and low sinuosity (1.06) (USBR 2008a). Sinuosity appears to have been greater historically, with the channel actively meandering across the width of the low surface. Channel type is pool-riffle, with a bankfull width of 134 feet, the second widest in the lower 11 miles of the Chewuch (USBR 2008a). There are few anthropogenic barriers to habitat or process connectivity. Floodplain development is concentrated in the upstream 0.5 miles and occurs on both sides of the valley. Restoration work such as levee removal, side-channel enhancement, and culvert improvement would be needed to re-establish habitat connectivity and allow for dynamic physical processes.

Habitat Conditions and Fish Use

Salmonid use of Reach C2b includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. The reach is used for spring Chinook and steelhead spawning, rearing, and migration. Annual steelhead redd counts from 2003 to 2007 from RM 3.3 to Chewuch Bridge (spans most of Reach C2a up through Reach C3a) have an average of 2.6 redds/mile. Spring Chinook redd counts from 2001 to 2007 in the same area have an average of 11.3 redds/mile (data from Snow et al. 2008).

Water temperature is elevated throughout the lower Chewuch River, with numerous exceedances of the state water temperature standard during summer months (USBR 2008a). Instream flows are also a concern during summer months, with two upstream irrigation diversions (the Chewuch Ditch at RM 8.5 and the Skyline Ditch at RM 9.2) that may affect fish passage, temperature, and habitat availability.

Reach C2b had the highest amount of in-channel LWD during stream surveys of the lower river (RM 0-9.5) in 2008; however, abundance is still considered low (USBR 2008a). Pool quantity was relatively high, comprising 43% of the habitat area in the reach. Side-channel habitat comprises approximately 1.8% of the reach, which is considered low for the channel type and gradient. Reach C2b has abundant spawning habitat, although the amount of fines (<6mm) is high (16%) (USBR 2008a). A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 8.

Table 8. Reach-Based Ecosystem Indicators (REI) ratings for Reach C2b. See Appendix A for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach C2b Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*Adequate*
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*Adequate*
	LWD	Pieces per Mile at Bankfull	*Unacceptable*

General Characteristics	General Indicators	Specific Indicators	Reach C2b Condition
	Pools	Pool Frequency and Quality	*Adequate*
	Off-Channel Habitat	Connectivity with Main Channel	*At Risk*
Channel	Dynamics	Floodplain Connectivity	*At Risk*
		Bank Stability/ Channel Migration	*At Risk*
		Vertical Channel Stability	*Adequate*
Riparian Vegetation	Condition	Structure	*Adequate*
		Disturbance (Human)	*Adequate*
		Canopy Cover	*At Risk*

Hydrology

Cub Creek is the major tributary in this reach, although it contributes a relatively small amount of flow. Upstream diversions reduce instream flows during summer irrigation months. Table 9 presents flood peak estimates for a variety of recurrence intervals calculate for a point near the upstream end of the reach.

Table 9. Flood magnitudes for recurrence intervals from 2 to 100 years at the upstream end of Reach C2b (RM 2.2). Obtained from Methow River Basin GIS hydrology database (USBR 2008b).

Location	River Mile	Flood Recurrence Interval (ft^3/sec)					
		Q2	Q5	Q10	Q25	Q50	Q100
Upstream End	6.9	2,947	4,520	5,540	6,785	7,675	8,531

Geomorphology

This unconfined reach has a narrower low surface width than Reach C2a downstream. The average width of the geologic low surface is 444 ft, 256 ft narrower on average than C2a. Glacial terraces form the majority of the floodplain boundary, although there are also areas bounded by bedrock and alluvial fan deposits. Bedrock is primarily extrusive volcanic, breccias, and sandstone. Cub Creek forms an alluvial fan between RM 6.8 and 7.3 that forces the main channel to the east; just downstream the channel migrates back to the west and reworks the fan deposits.

Although current sinuosity is low (1.06), sinuosity appears to have been much greater historically. Between RM 6.6 and 7.3, there are large channel scars and oxbow wetlands on floodplain surfaces to the east and west. Some of these areas are mapped as the main channel on cadastral maps from 1915, and as overflow or old channels in later aerial photos (1954, 1964, and 1974). Channel position has been stable since 1945. Floodplain width narrows considerably at RM 6.7 where the river flows against a bedrock ridge. The floodplain broadens at RM 6.4, where the bedrock ridge turns to the east. Floodplain channels occur in this broader section downstream to RM 5.95.

The main channel has a bankfull width of 134 ft, which is the second widest average bankfull width in the lower 11 miles of the Chewuch River. Bed morphology is 56% riffle or run, and

43% pools. There are several locations of active split flow, although side-channels are generally short and comprise only 1.8% of the channel area. This reach has a relatively large amount of LWD, most of it in the small size class range, but the reach also has the highest number of large pieces per mile (3.2) in the lower 11 miles of the Chewuch. These LWD densities are likely lower than historical values. Bed material is primarily cobble, which comprises 61% of the bed material. Surface fines (and smaller) cover 16% of the bed.

Human Alterations

Few alterations have been made to the channel and floodplain in Reach C2b (Figure 8, Figure 9). At the upstream end of the reach there are 1,240 ft of riprap along the east side of the channel between RM 7.01 to 7.27. This riprap blocks a historical channel that now contains a large wetland on a private ranch. On the other side of the valley, there is recreational development near the channel adjacent to residential development on the alluvial terrace. Downstream of this, floodplain surfaces are free of development and channel form and channel banks have not been modified.

Figure 8. Aerial photo showing human features in the downstream portion of Reach C2b. Flow is from north to south.

Figure 9. Aerial photo showing human features in the upstream portion of Reach C2b. Flow is from north to south.

6.2 Reach Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach C2b is included below. The strategy focuses first on protecting existing conditions from further impairment. This objective is followed by reconnecting the fundamental bio-physical processes that will create and maintain habitat conditions over the long-term. Instream and off-channel habitat enhancement (rehabilitation) is also included; these projects occur in conjunction with long-term process reconnection and are also applied in cases where long-term process reconnection is constrained by existing human uses. The USBR (2008b) identifies protection of the channel and floodplain to preserve the integrity of active processes and intact habitat as the primary objective for this reach. USBR restoration objectives include re-connecting side-channel habitat and channel/floodplain processes.

1. ***Protect and Maintain***
   - **Prevent Further Degradation**- Opportunities to prevent further degradation should be pursued including purchasing land and water rights in the river corridor, and/or obtaining conservation easements. Water rights acquisition should be focused on increasing instream flow during late summer.
   - **Legal Protection**- Existing enforced legal protection is considered an intrinsic component of all potential projects.

2. ***Reconnect Stream Channel Processes***
   - **Instream Flow**- Continue to identify and carry forward projects that will result in natural timing of runoff recession and increased baseflow. Low baseflow during summer months can create barriers to fish migration that is essential for restoration success throughout the study area. Flow withdrawals also increase the potential for high summer stream temperatures. Increased instream flow between July and October will enhance the success of restoration work that is meant to provide habitat over a wide range of flows including low flow periods. There is one significant diversion upstream of this reach.
   - **Riprap**- Remove features to re-establish dynamic channel processes. There is a substantial amount of riprap armoring the bank on river-left at the upstream end of the reach that limits channel processes and disconnects the channel and floodplain. There are houses protected to the east of the channel that present constraints to removing these barriers. Protective barriers should be assessed to develop a suite of options for removal or modification.
   - **Channel Dynamics**- Address loss of multi-thread channel complexity resulting from loss of wood dynamics. LWD jams are important to geomorphic process and their frequency and function have been reduced by past land-use practices. Where feasible, LWD jams can be placed in areas where they would naturally occur and where processes such as bar deposition, pool scour, lateral channel migration, and natural rates of recruitment can be re-established.

3. ***Reconnect Floodplain Processes***
   - **Floodplain Development** – Floodplain development has taken place on both sides of the valley at the upstream end of the reach. The developments include clearing, bank protection, and grading. Full floodplain reconnection will require reclamation of floodplain surfaces in order to remove constraints to levee removal. Work with appropriate stakeholders to develop long-term solutions to floodplain impacts.

4. ***In-Stream Habitat Enhancement***
   - **Enhance Habitat Complexity** Instream large wood is a natural component of this system that has been severely reduced by past land-use practices. Wood creates pool scour, cover, and channel complexity. Place wood in configurations and locations that mimic natural wood deposition processes. These projects are not replacements for process restoration, but are meant to provide intermediate habitat enhancement while process restoration matures.

5. ***Off-Channel Habitat Enhancement***
   - **Enhance Off-Channel Habitat Complexity**- Impacts to physical processes has resulted in habitat simplification in some areas. Installation of natural off-channel habitat features can provide an intermediate improvement to aquatic ecology while process restoration matures. Natural activity of beavers can result in enhanced off-channel habitat and may be considered as a restoration option.

6.3 Sub-Unit and Project Opportunity Summary

Eight sub-units were identified in Reach C2b, including two inner zone sub-units, five outer zone sub-units, and one disconnected outer zone sub-unit (Table 10, Figure 10, Figure 11, Figure 12, Figure 13). The majority of the river corridor is intact - only 16% of the outer-zone is disconnected. This current condition provides substantial opportunity for protection and conservation. Sixteen specific project opportunities have been identified and are described in the sub-unit summary section (Table 11).

Table 10. Summary of protection and restoration opportunities for reach C2b.

Sub-Unit	River Mile	Acreage
Inner Zone 1 (IZ-1)	5.89-7.3	N/A
Disconnected Outer Zone 1 (DOZ-1)	7.0-7.3	21.6
Outer Zone 1 (OZ-1)	6.05-7.21	35.5
Outer Zone 2 (OZ-2)	6.72-6.95	5.8
Outer Zone 3 (OZ-3)	5.59-6.53	70.1
Outer Zone 4 (OZ-4)	5.87-5.97	0.56
Inner Zone 2 (IZ-2)	5.59-5.89	N/A
Outer Zone 5 (OZ-5)	5.56-5.78	5.4

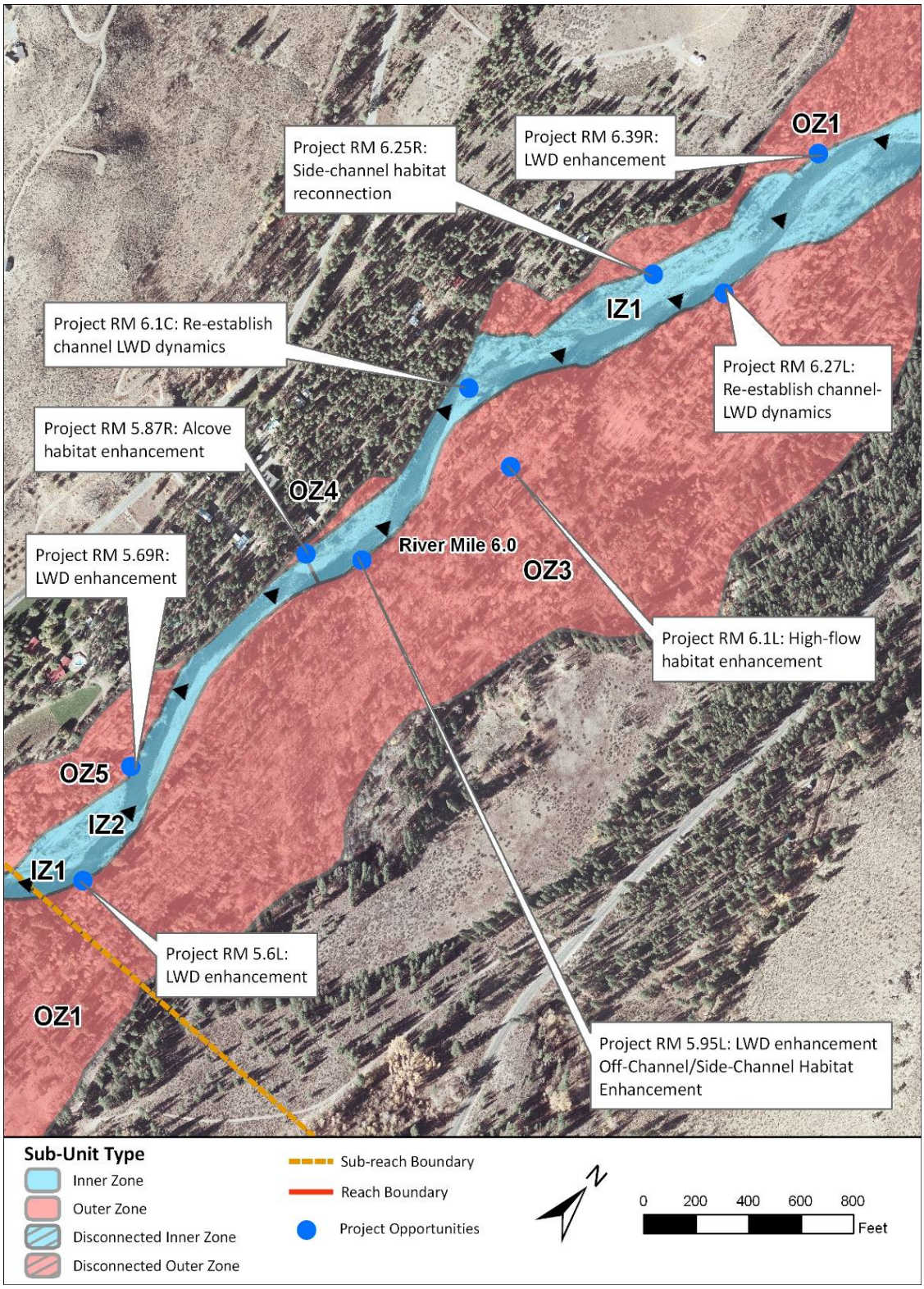

Figure 10. Sub-units and project opportunities at the downstream end of Reach C2b. Flow is from north to south.

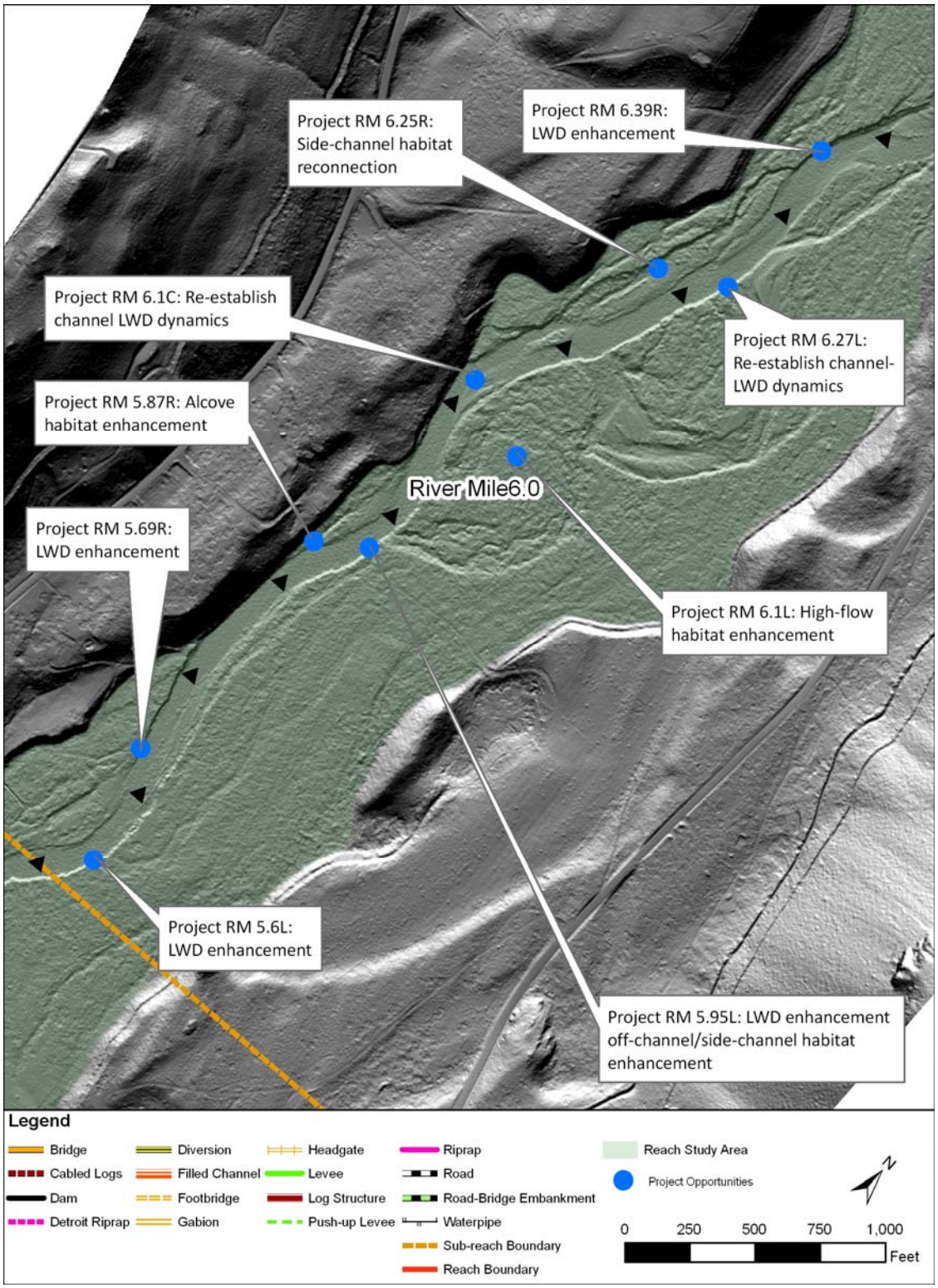

Figure 11. LiDAR hillshade of reach C2b illustrating topography in relation to human features and project locations in the downstream portion of the reach. Flow is from north to south.

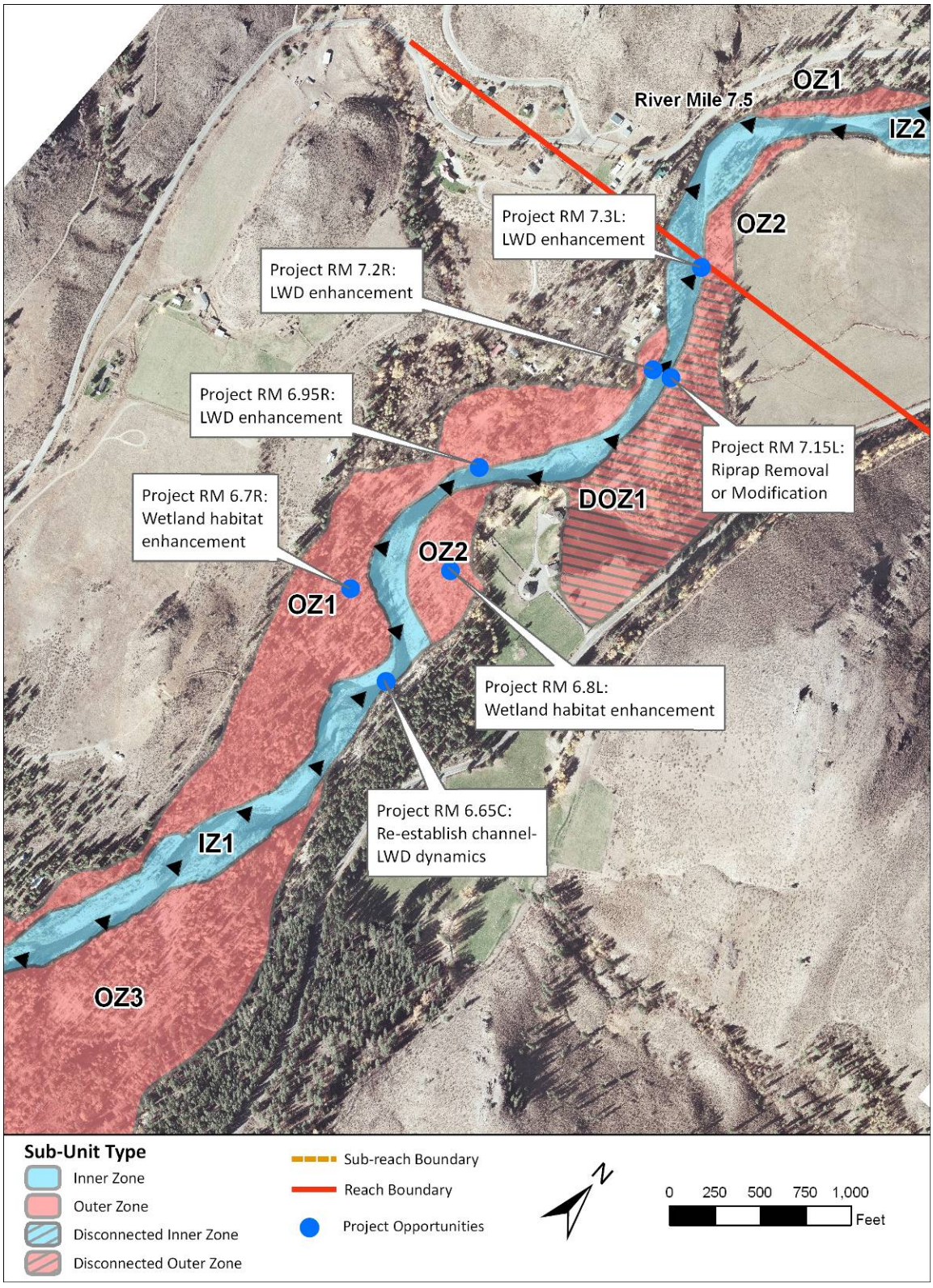

Figure 12. Sub-units and project opportunities at the upstream end of Reach C2b. Flow is from north to south.

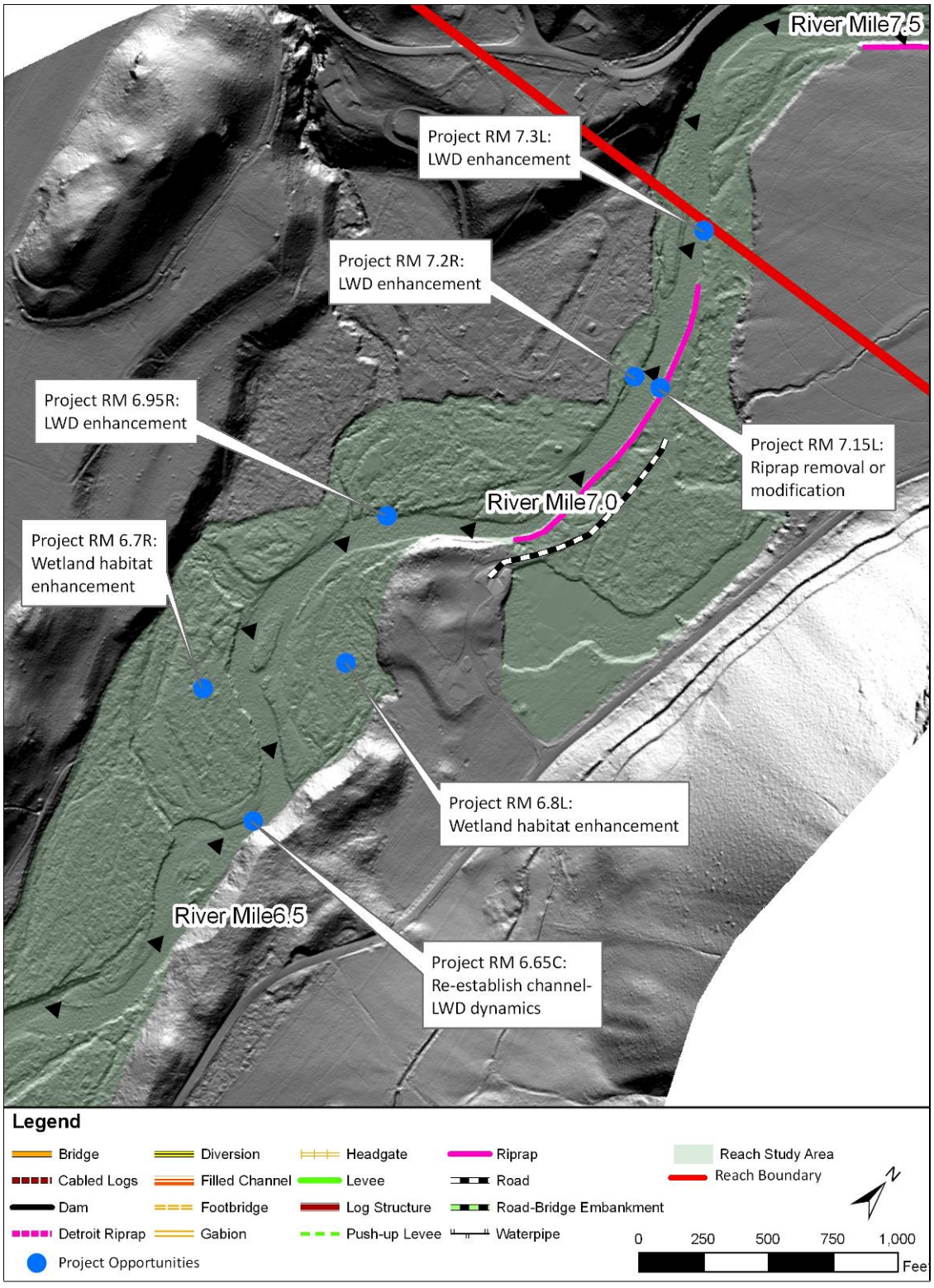

Figure 13. LiDAR hillshade of reach C2b illustrating topography in relation to human features and project locations in the upstream portion of the reach. Flow is from north to south.

Table 11. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C2b.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-1	IZ-1 has the most complex inner zone habitat in Reach C2b. Though the channel is not extremely sinuous there is active point bar formation, split-flow, and side-channel habitat. There are locations with substantial LWD accumulation, primarily on bar apexes. There are several areas of well-connected channel and floodplain processes and habitat, including oxbow ponds and channel scars that are frequently inundated during flood stage. Sediment sources include Cub Creek, which flows into the channel near RM 6.9, and hillslope erosion between RM 6.5 and 6.7. These areas are frequently associated with bar formation and LWD deposition. Riprap has been installed along 1,250 ft of the river-left bank between RM 7.01 and 7.28.	Protect and Maintain Reconnect Stream Channel Processes In-Stream Habitat Enhancement	***Project RM 7.15L*** Riprap removal or modification ***Project RM 6.65C*** Re-establish channel LWD dynamics ***Project RM 6.27L*** Re-establish channel LWD dynamics ***Project RM 6.25R*** Side-channel habitat reconnection ***Project RM 6.1C*** Re-establish channel LWD dynamics. ***Project RM 7.3L*** LWD enhancement ***Project RM 7.2R*** LWD enhancement ***Project RM 6.95R*** LWD enhancement. ***Project RM 6.39R*** LWD enhancement. ***Project RM 5.95L*** LWD enhancement. ***Project RM 5.87R*** Alcove habitat enhancement.	1,250 ft of riprap along river-left between RM 7.01 and 7.28 provides flood protection for private land and residential development in the adjacent floodplain.

Table 11. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C2b.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
DOZ-1	This floodplain area has been disconnected hydrologically and geomorphically from channel and floodplain processes by 1,250 ft of riprap along the entire margin of the low surface. There is a meander scar in this sub-unit that contains large open-water wetlands. This channel scar was wetted on aerial photos from 1964, 1974, and 1985. The ponds have been developed as part of residential landscaping. There is an ephemeral surface connection to a channel that crosses an alluvial fan to the north. The fan surface is used to graze cattle. There are driveways and other roads near the downstream end of the ponds that add to hydrologic disconnection.	Protect and Maintain Off-Channel Habitat Enhancement	***CR_Prj-7*** (USBR 2008b)	Residential and agricultural development. Flood protection provided by 1,250 ft of riprap along the bank between RM 7.01 and RM 7.28.
OZ-1	OZ-1 is a 35.5 acre floodplain sub-unit extending between RM 6.05 and 7.21 along the west side of the valley. There is residential development on the terrace surface near the upstream end of the sub-unit. Cub Creek flows across OZ-1 before its confluence with the main channel near RM 6.9. LiDAR data shows multiple high flow channels and meander scars across OZ-1. The low flow channel was mapped through this area in 1893 and 1915 cadastral maps. Some of the meander scars currently provide hydrologically connected off-channel habitat. There are no anthropogenic constraints to channel/floodplain processes or habitat connectivity, and very little disturbance to riparian vegetation.	Protect and Maintain Off-Channel Habitat Enhancement	***Project RM 6.7R*** Wetland habitat enhancement. ***CR_Prj-7.2*** (USBR 2008b)	Private Land Ownership

Table 11. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C2b.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
OZ-2	OZ-2 is a small, 5.8 acre floodplain on the east side of the valley located on the inside of a meander bend. This surface has been a location of overflow channels throughout the later half of the 20th century. There is some groundwater collected in low areas, but not enough flow accumulation to produce surface outflow. However, a well-defined outflow channel suggests that this surface is inundated by larger flows. The riparian forest is intact except for a swath that has been cleared to accommodate power lines that cross the river near RM 6.87.	Protect and Maintain Off-Channel Habitat Enhancement	***Project RM 6.8L*** Wetland habitat enhancement.	Private land ownership
OZ-3	OZ-3 is a large floodplain sub-unit occupying 70.1 acres along the east size of the valley between RM 5.59 and 6.53. OZ-3 is undeveloped and provides a relatively large expanse of undisturbed riparian and floodplain habitat. There are meander scars and networks of high flow channels between RM 5.96 and 6.3. These channels do not appear to be inundated frequently. Downstream of RM 5.96, there is less topographic evidence of floodplain inundation. There are a few primitive, unmaintained roads on the surface but little associated disturbance.	Protect and Maintain Off-Channel Habitat Enhancement	***Project RM 6.1L*** High-flow habitat enhancement ***Project CR_Prj-6.45*** (USBR 2008b)	Private land ownership
OZ-4	OZ-4 occupies less than an acre of land along the west side of the valley. This small piece of floodplain is isolated and undeveloped. Riparian vegetation is intact.	Protect and Maintain		Private land ownership

Table 11. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C2b.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-2	IZ-2 is a short section of active channel from RM 5.59 to 5.89. The channel is simplified in comparison to IZ-1. There is very little sinuosity, no significant point bar formation, and no side-channels. The channel flows directly against a hillslope near RM 5.87 but is otherwise free to migrate. There are no anthropogenic barriers or alterations to channel form or process.	Protect and Maintain Instream Habitat Enhancement	***Project RM 5.69R*** LWD enhancement ***Project RM 5.6L*** LWD enhancement	No identified constraints to restoration or preservation.
OZ-5	OZ-5 is a small floodplain area that has not been developed. The sub-unit lies on the west side of the valley between RM 5.56 and 5.78. Riparian vegetation is intact aside from a narrow area associated with an unimproved road. There are no anthropogenic barriers to physical or ecological processes or habitat connectivity. LiDAR data indicates the presence of high-flow channels on the surface, though they do not appear to be regularly inundated.	Protect and Maintain		Private land ownership.

[1]*For additional information on specific identified project opportunities, see Chewuch Project Opportunities list in Appendix B.*

C3a – Reach Assessment

7 C3A REACH ASSESSMENT

7.1 Reach Overview

Reach C3a is a moderately steep, moderately confined reach that extends from upstream of the confluence of Cub Creek near RM 7.3 to a valley constriction near RM 8.5. Valley margins are composed of glacial deposits and bedrock. Habitat complexity is fairly low with scarce LWD, few pools, and infrequent side-channel or off-channel habitat. The majority of the channel is riffle or glide morphology with coarse bed material and only a small percentage of spawning sized gravels. Human alteration has a greater affect on channel and floodplain processes in this reach relative to up and downstream reaches and includes a bridge crossing, levees, floodplain clearing, a roadway, and an irrigation diversion at the upstream end.

Habitat Conditions and Fish Use

Salmonid use of Reach C3a includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. The reach is used for spring Chinook and steelhead spawning, rearing, and migration. Annual steelhead redd counts from 2003 to 2007 from RM 3.3 to Chewuch Bridge (spans most of Reach C2a up through Reach C3a) have an average of 2.6 redds/mile. Spring Chinook redd counts from 2001 to 2007 in the same area have an average of 11.3 redds/mile (data from Snow et al. 2008).

Water temperature is elevated throughout the lower Chewuch River, with numerous exceedances of the state water temperature standard during summer months (USBR 2008a). Instream flows are also a concern during summer months, with two upstream irrigation diversions (the Chewuch Ditch at RM 8.5 and the Skyline Ditch at RM 9.2) that may affect fish passage, temperature, and habitat availability.

Reach C3a had scarce amounts of in-channel LWD during stream surveys of the lower river (RM 0-9.5) in 2008, with only 9 pieces of LWD/mile (USBR 2008a). Pool quantity was relatively low, comprising 27% of the habitat area in the reach. There was one, long side-channel within the reach, which contained high quality rearing habitat and LWD. Based on pebble counts, 13% of the bed substrate was fines (<6mm). The reach has limited spawning habitat due to coarse sediments (USBR 2008a). A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 12.

Table 12. Reach-Based Ecosystem Indicators (REI) ratings for Reach 3a. See Appendix A for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach C3a Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*Adequate*
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*Adequate*
	LWD	Pieces per Mile at Bankfull	*Unacceptable*
	Pools	Pool Frequency and Quality	*Adequate*

General Characteristics	General Indicators	Specific Indicators	Reach C3a Condition
	Off-Channel Habitat	Connectivity with Main Channel	*At Risk*
Channel	Dynamics	Floodplain Connectivity	*Unacceptable*
		Bank Stability/ Channel Migration	*At Risk*
		Vertical Channel Stability	*Adequate*
Riparian Vegetation	Condition	Structure	*At Risk*
		Disturbance (Human)	*At Risk*
		Canopy Cover	*Unacceptable*

Hydrology

Diversions in the upstream reach at RM 8.5, and near RM 9.3, directly affect the hydrology of this reach by reducing summer flows. Bank hardening and road building have reduced channel/floodplain connections and flood attenuation capacity. Table 13 provides the results of a flood magnitude estimate for several recurrence intervals derived from a watershed analysis performed by the USBR (2008b).

Table 13. Flood magnitudes for recurrence intervals from 2 to 100 years at the downstream end of Reach C3a (RM 7.6). Obtained from Methow River Basin GIS hydrology database (USBR 2008b).

		Flood Recurrence Interval (ft^3/sec)					
Location	River Mile	Q2	Q5	Q10	Q25	Q50	Q100
Downstream End	7.6	2,893	4,436	5,438	6,660	7,533	8,373

Geomorphology

In Reach C3a natural valley confinement reduces floodplain widths from 1/2 to 1/3 of the floodplain widths downstream (USBR 2008a). Sedimentary and volcanic deposits become more prominent constraints, composing roughly 60 to 70% of the channel margin along the west side of the valley (USBR 2008b). The floodplain is wider to the east where the channel has reworked older channel deposits and material derived from an alluvial fan that originates at a canyon mouth lateral to RM 7.5.

Natural constraints on lateral migration, coarse bed material, and a fairly steep gradient of 0.9% result in a straightened planform geometry with a low sinuosity of 1.10. Channel pattern consists of a single primary thread with active secondary or high-flow channels along the east side of the channel between RM 7.4 and 7.9. Channel pattern and location have been stable throughout the aerial photo record dating back to 1945.

The channel is boulder-bed and dominated by glide habitat units near the upper end of the reach, with some riffle-pool and riffle-glide morphology developing in the downstream half of the reach where cobble bars have formed along the reworked toe of an alluvial fan. The channel is steep and coarse, with about 53% of the bed material in the cobble size range, and only about 13% fines smaller than 6 mm (USBR 2008a). LWD is essentially absent in this reach (1.5

pieces/mile larger than 20 in. diameter) (USBR 2008a). The majority of the wood found in this reach is in high flow side-channel areas and does not play a role in more frequent (annual) flow events.

Human Alterations

Anthropogenic activities play a larger role in this reach than in adjacent downstream or upstream reaches. A bridge crosses the channel at RM 8.3 creating a hydraulic constriction at higher flows (Figure 14). Both banks are protected with riprap up and downstream of the bridge for about 600 ft. East and west side roads laterally bisect the floodplain at this location, with the west side road also running longitudinally through the floodplain. The bank and floodplain alterations result in hydrologic and geomorphic disconnection between the channel and the only substantially wide floodplain in the reach. The floodplain has also been cleared, leveled, and developed on the east side of the valley downstream of the bridge. Downstream of the bridge on the west side of the valley, a road parallels the channel. The road embankment increases lateral constriction between RM 8.0 and 8.2.

Figure 14. View to the south in the downstream direction at the bridge near RM 8.3 (November 2009).

Human modification decreases downstream of RM 8.2. The west side road climbs away from the river corridor and floodplain development on the east side decreases. There are, however, large cleared areas to the east of the channel associated with agricultural development. There is a 430 ft long push-up levee centered on RM 7.95 that creates a barrier to active channel processes. There is no clear object of protection by this levee. Near RM 7.6, the toe of the terrace is protected by riprap along the edge of a large open pasture. Figure 15 shows all human features in Reach C3a.

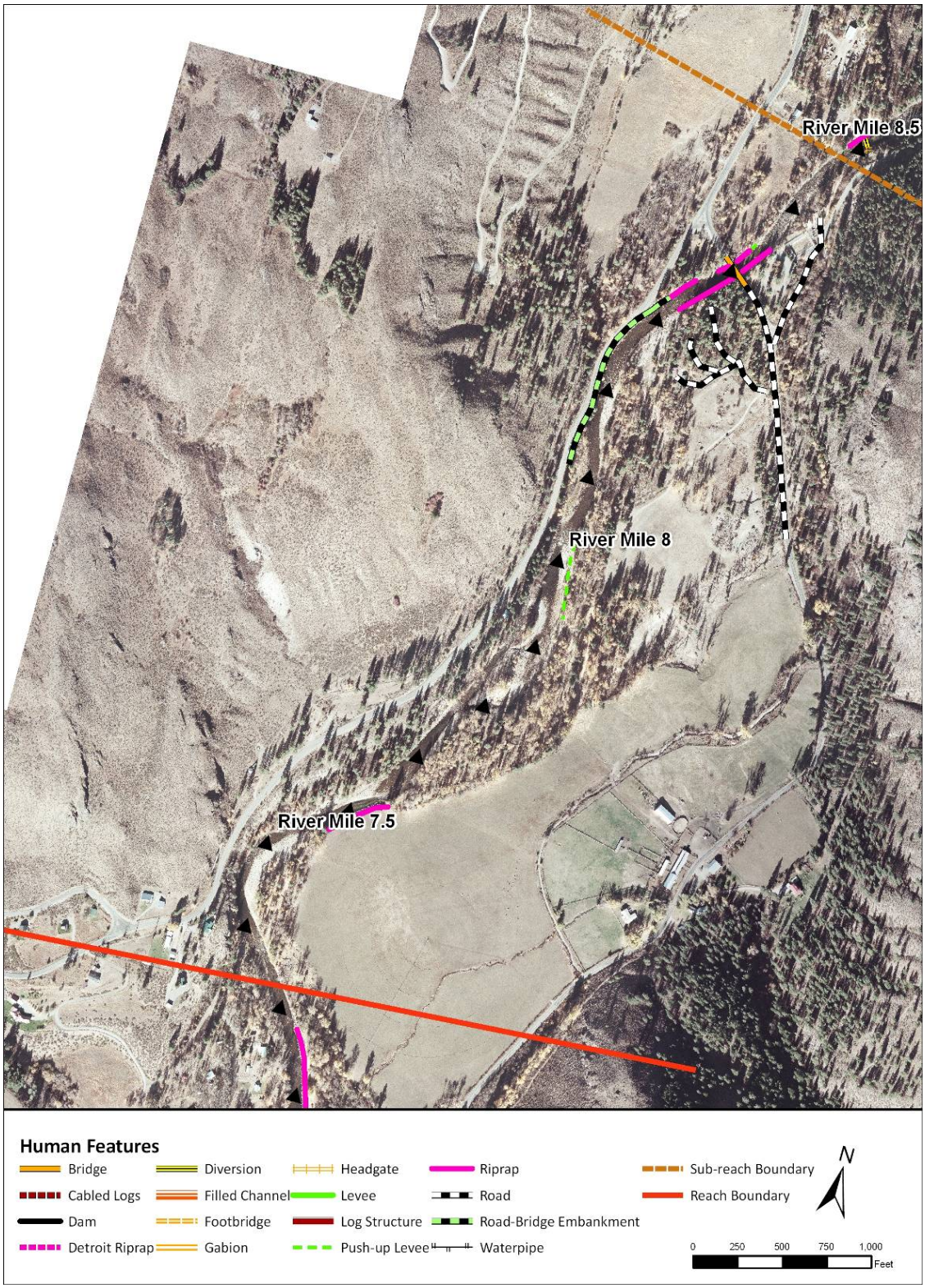

Figure 15. Aerial photo showing human features in Reach C3a. Flow is from north to south.

7.2 Reach Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach C3a is included below. The strategy focuses first on protecting existing conditions from further impairment. This objective is followed by reconnecting the fundamental bio-physical processes that will create and maintain habitat conditions over the long-term. Instream and off-channel habitat enhancement (rehabilitation) is also included; these projects occur in conjunction with long-term process reconnection and are also applied in cases where long-term process reconnection is constrained by existing human uses. The USBR (2008b) identifies protection of the channel and floodplain to preserve the integrity of active processes and intact habitat as the primary objective of this reach. USBR restoration objectives focus on reconnecting floodplain habitat and processes through removal or re-design of bridges and roads and restoring cleared areas on the east side of the upstream end of the reach.

1. ***Protect and Maintain***
   - **Prevent Further Degradation**- Opportunities to prevent further degradation should be pursued including purchasing land and water rights in the river corridor, and/or obtaining conservation easements. Water rights acquisition should be focused on increasing instream flow during late summer.
   - **Legal Protection**- Existing enforced legal protection is considered an intrinsic component of all potential projects.
2. ***Reconnect Stream Channel Processes***
   - **Instream Flow**- Continue to identify and carry forward projects that will result in natural timing of runoff recession and increased baseflow. Low baseflow during summer months can create barriers to fish migration that is essential for restoration success throughout the study area. Flow withdrawals also increase the potential for high summer stream temperatures. Increased instream flow between July and October will enhance the success of restoration work that is meant to provide habitat over a wide range of flows including low flow periods. There is one significant diversion upstream of this reach.
   - **Riprap and Levees**- Remove or modify features to restore dynamic processes. There is a substantial amount of riprap armoring the bank on river both sides of the river at the upstream end of the reach. There are houses protected to the east of the channel and road protected to the west that present constraints to removing these barriers. Where feasible, riprap and levees should be removed or modified to increase floodplain and channel migration zone connectivity.
   - **Roadways and Bridges**- Remove or modify features to restore dynamic processes. The westside road forms the channel margin near RM 8.2 limiting lateral channel dynamics. A bridge crossing near RM 8.4 and road embankments on both sides of the channel limit lateral migration, and alter channel hydraulics. The span of the bridge forms a constriction as stage increases.
   - **Channel Dynamics**- Address loss of multi-thread channel complexity resulting from loss of wood dynamics. LWD jams are important to geomorphic process and their

frequency and function have been reduced by past land-use practices. Where feasible, LWD jams should be placed in areas where they would naturally occur and where processes such as bar deposition, pool scour, lateral channel migration, and natural rates of recruitment can be re-established.

3. ***Reconnect Floodplain Processes***
   - **Floodplain Development** – Floodplain development has taken place on both sides of the valley at the upstream end of the reach. The developments include clearing, bank protection, and grading. Full floodplain reconnection will require reclamation of floodplain surfaces in order to remove constraints to levee removal. Work with appropriate stakeholders to develop long-term solutions to floodplain impacts.
   - **Levees**- There are large floodplain areas that are disconnected by hardened features. Where feasible, riprap and levees should be removed or modified to increase floodplain and channel migration zone connectivity.
   - **Roadways**- Remove or modify features to restore dynamic processes. Floodplain areas to the north and south of the channel are disconnected by roadways. Work should continue to identify options to relocate or modify these roads to provide habitat and process connection in affected floodplain areas.
4. ***Riparian Restoration***
   - **Restore Riparian Areas** - There are large cleared areas associated with recreational and agricultural floodplain development. Commonly there is a moderate riparian corridor maintained along the channel margin in these areas. Work should continue to expand these riparian buffers.
5. ***In-Stream Habitat Enhancement***
   - **Enhance Habitat Complexity** Instream large wood is a natural component of this system that has been severely reduced by past land-use practices. Wood creates pool scour, cover, and channel complexity. Place wood in configurations and locations that mimic natural wood deposition processes. These projects are not replacements for process restoration, but are meant to provide intermediate habitat enhancement while process restoration matures.
6. ***Off-Channel Habitat Enhancement***
   - **Enhance Off-Channel Habitat Complexity**- Impacts to physical processes has resulted in habitat simplification in some areas. Installation of natural off-channel habitat features can provide an intermediate improvement to aquatic ecology while process restoration matures. Natural activity of beavers can result in enhanced off-channel habitat and may be considered as a restoration option.

7.3 Sub-Unit and Project Opportunity Summary

Six sub-units were identified in Reach C3a, including two inner zone sub-units, two outer zone sub-units, and two disconnected outer zone sub-units (Table 14, Figure 16, Figure 17). About 94% of the floodplain is disconnected through anthropogenic disturbance. Inner zone processes and habitat are negatively impacted by flow reduction and levee building. Despite these alterations, there are viable opportunities to improve habitat and function. Seven specific project opportunities are identified and described in the sub-unit summary section (Table 15).

Table 14. Summary of protection and restoration opportunities for reach C3a.

Sub-Unit	River Mile	Acreage
Disconnected Outer Zone 1 (DOZ-1)	8.15-8.5	17.4
Inner Zone 1 (IZ-1)	8.15-8.49	N/A
Disconnected Outer Zone 2 (DOZ-2)	7.7-8.45	51.9
Inner Zone 2 (IZ-2)	7.3-8.15	N/A
Disconnected Inner Zone 1 (DIZ-1)	7.72-8.04	N/A
Outer Zone 1 (OZ-1)	7.48-7.67	2.2
Outer Zone 2 (OZ-2)	7.3-7.5	2.2

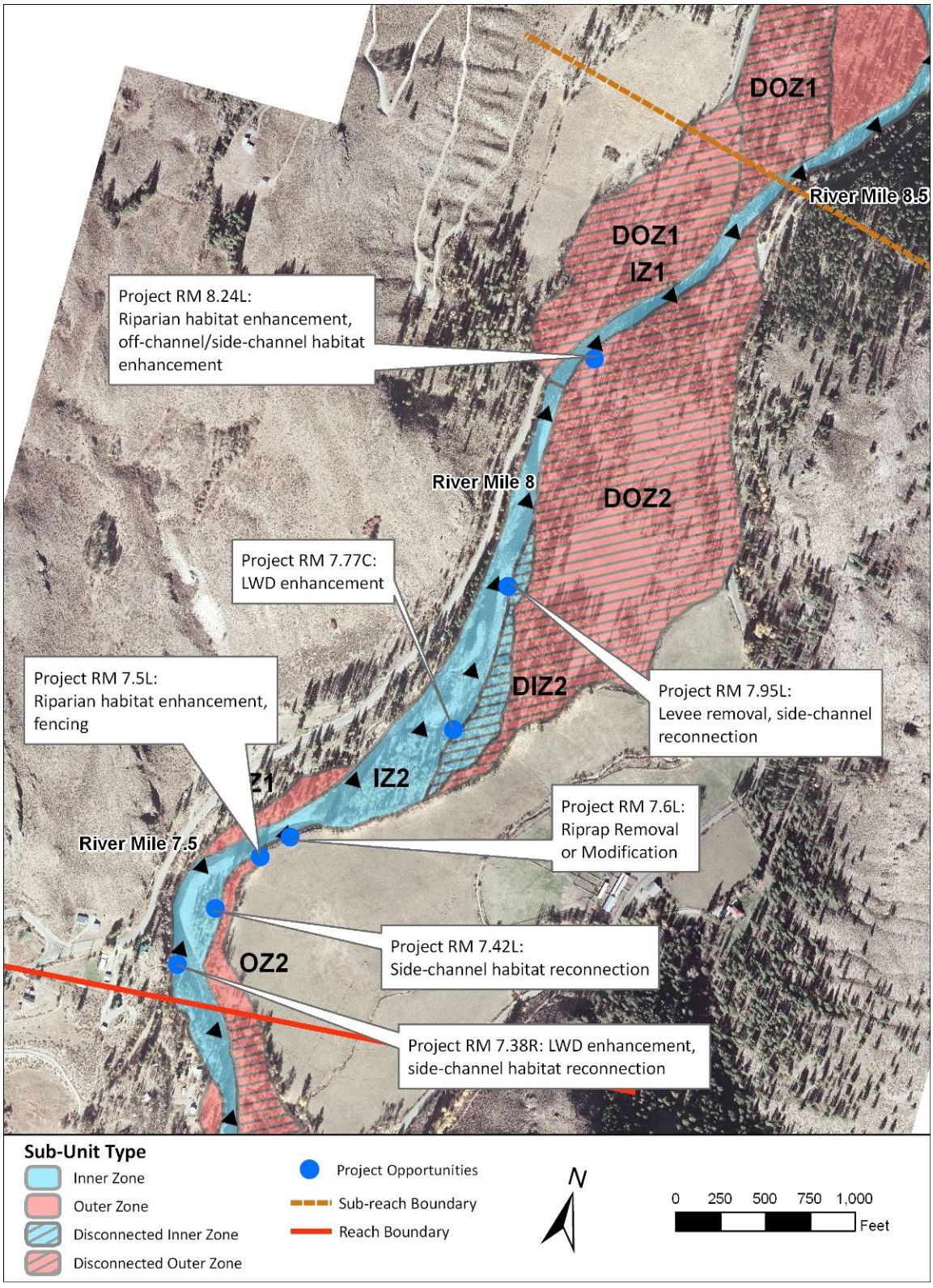

Figure 16. Sub-units and project opportunities in Reach C3a. Flow is from north to south.

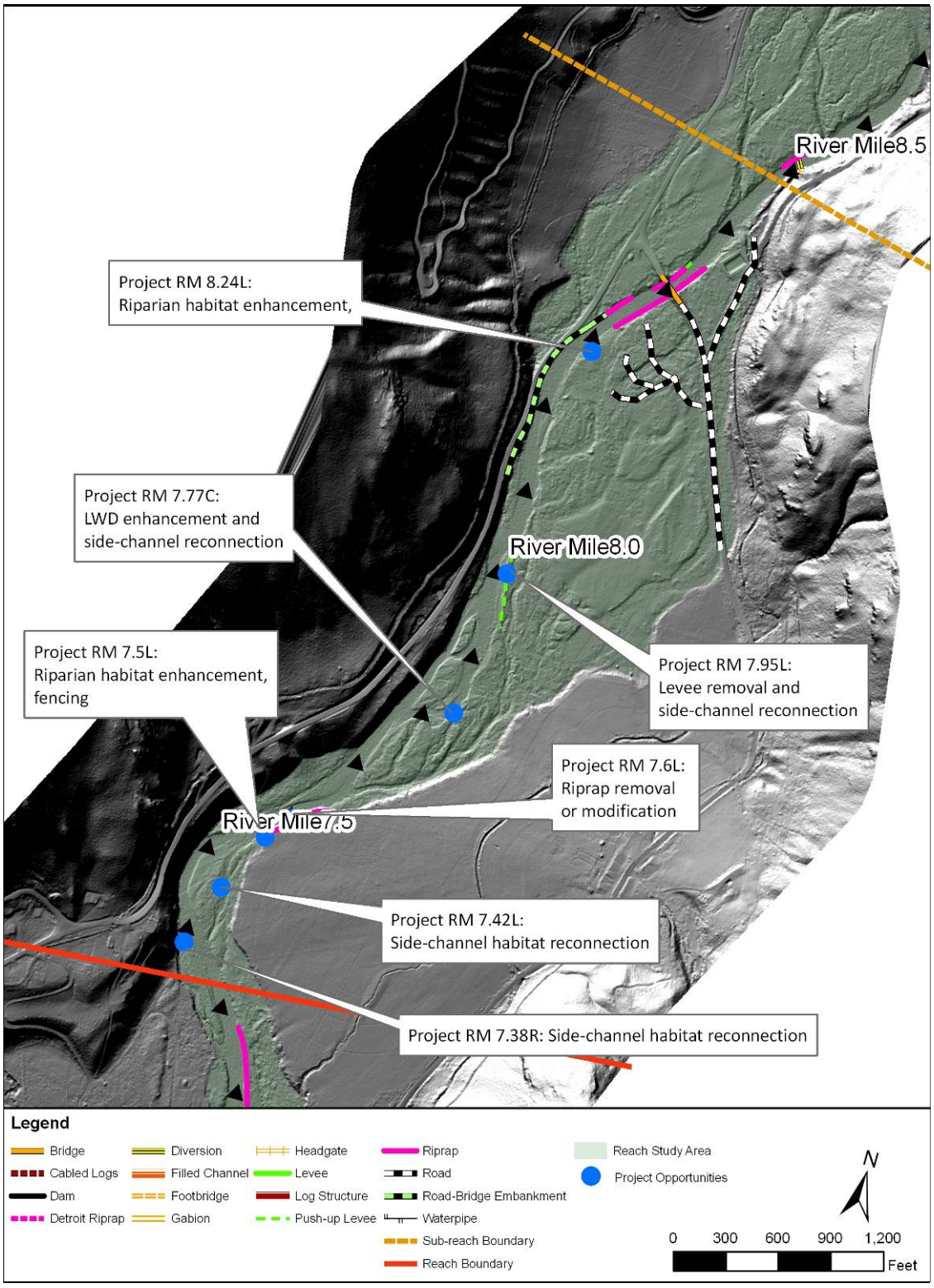

Figure 17. LiDAR hillshade of reach C3a illustrating topography in relation to human features and project locations in the reach. Flow is from north to south.

Table 15. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C3a.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
DOZ-1	DOZ-1 occupies 17.4 acres along the west side of the valley between RM 8.15 and 8.5. A bridge at RM 8.3 and a road that divides the sub-unit along its entire length are barriers to channel/floodplain connection. Both the bridge and the roadway include riprap on adjacent banks, which further disconnects the channel and floodplain. Riparian habitat on the floodplain surface is fragmented by the roadway. The roadway and bridge crossing block a network of high flow channels apparent in LiDAR data.	Protect and Maintain Reconnect Floodplain Processes	*Work to identify projects that address floodplain disconnection*	Bridge crossing at RM 8.3. Roadway through the entire sub-unit. Riprap along the majority of the channel margin.
IZ-1	IZ-1 is a short, straight, steep section of channel with cobble and boulder bed material. Morphology is plane-bed and habitat units are dominated by glides. Although there are significant human alterations along this channel segment, there is little evidence to suggest that channel morphology was much different in the past. The channel morphology may reflect the downstream extent of the effects of the alluvial fan of Boulder Creek. There is little access to overbank floodplain areas due to riprap and levees. Floodplain topography suggests that the channel and floodplain were historically well connected. There is no LWD in this sub-unit and no side-channel habitat. A bridge crossing at RM 8.3 creates a high-flow hydraulic constriction	Protect and Maintain		

Table 15. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C3a.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
DOZ-2	This outer zone sub-unit is the largest floodplain area in Reach C3a at 51.9 acres. LiDAR data reveal extensive high flow channel networks across this surface that are either relic or muted by anthropogenic modification of the floodplain. A roadway runs adjacent to the hillslope toe in the upstream third of the sub-unit before turning west and laterally bisecting the upper corner at the bridge crossing near RM 8.3. There is residential and recreational development upstream and downstream of the bridge crossing with associated clearing, fill, and roadways. There is also substantial agricultural development and associated clearing throughout the sub-unit. There is only a narrow buffer of riparian vegetation along the channel margin.	Protect and Maintain Reconnect Floodplain Processes Off-Channel/Side-Channel Habitat Enhancement	***Project RM 8.24L*** – Riparian habitat enhancement ***CR_Prj-8.5*** (USBR 2008 App. A) *Work to identify projects that address floodplain disconnection*	Bridge crossing at RM 8.3. Roadway and driveways through the upper third of the sub-unit. Residential, recreational, and agricultural development throughout the sub-unit.
IZ-2	The inner zone expands downstream of RM 8.15 and the active channel gains complexity. There are mid-channel bars that provide split flow at moderate to high flows and a few low flow side-channels. Pool-riffle morphology develops around bedrock outcrops and re-worked alluvial fan material. A roadway along the west channel margin creates the only anthropogenic disturbance to channel processes and habitat. However, bedrock on that side of the channel poses similar natural constraints.	Protect and Maintain Reconnect Stream Channel Processes	***Project RM 7.77C*** LWD enhancement and side-channel reconnection ***Project RM 7.6L*** Riprap removal or modification ***Project RM 7.42L*** Side-channel habitat reconnection ***Project RM 7.38R*** Side-channel habitat reconnection	

Table 15. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C3a.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
DIZ-1	A 700 ft push-up levee centered on RM 7.95 blocks the upstream en of a side-channel that extends the entire length of the sub-unit and forms the margin between the inner-zone of the outer zone. The push-up levee is composed of large boulders. The upstream end of the side-channel has cobble and gravel bed material, and multiple log jams built several feet above the stream bed elevation. This suggests that the channel carried a significant flood discharge when it was connected. The downstream end of the side-channel still provides connected alcove habitat. The purpose of the levee is unclear as there is no development on the adjacent floodplain.	Protect and Maintain Reconnect Stream Channel Processes	***Project RM 7.95L*** Levee removal and side-channel reconnection *Work to address disconnection caused by push-up levee*	
OZ-1	This is a small (2.2 acre) floodplain area on the west side of the channel that extends along the toe of the bedrock hillslope. The area has not been developed, probably because of its size and isolated location. There is no low-flow off-channel habitat. The floodplain appears connected at high flows.	Protect and Maintain		Roadway located on the hillslope above the sub-unit for its entire length.
OZ-2	OZ-2 is a small (2.2 acre) floodplain area along the east of the channel creating a riparian buffer between the channel and adjacent uplands that have been converted to agriculture. The preservation of this riparian area between the channel and cleared fields is important for maintaining riparian functions including shade, bank stability, and a source for LWD recruitment.	Protect and Maintain Riparian Restoration	***Project RM 7.5L*** Riparian habitat enhancement, fencing	Agricultural development of the adjacent uplands.

[1]*For additional information on specific identified project opportunities, see Chewuch Project Opportunities list in Appendix B.*

C3b – Reach Assessment

8 C3B REACH ASSESSMENT

8.1 Reach Overview

Reach C3b is moderately confined and extends from a bedrock constriction near RM 8.5 to RM 9.45 just upstream of the confluence of Boulder Creek. At the upstream end of the reach, the channel is bound on the west by bedrock and on the east by the alluvial fan of Boulder Creek. Channel constriction decreases in the downstream direction and a wide inner zone and floodplain develops providing relatively complex habitat with long side channels and LWD. This reach has the lowest percentage of pool habitat in the lower 9.5 miles of the Chewuch River (1.8%) but the highest percentage of side-channel habitat (23%). There is a major diversion near RM 9.2 that reduces flow during irrigation season.

Habitat Conditions and Fish Use

Salmonid use of Reach C3b includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. The reach is infrequently used for steelhead spawning and has limited spawning use by spring Chinook. No steelhead redds were observed in annual redd counts from 2003 to 2007 (2006 was not surveyed) from the Chewuch Bridge to Boulder Creek (approximately the same as Reach C3b). This reach is steep and contains coarse substrate and may be more suitable to steelhead for rearing than spawning. Spring Chinook redd counts from 2001 to 2007 have an average of 8.7 redds/mile (data from Snow et al. 2008) in this area.

Water temperature is elevated throughout the lower Chewuch River, with numerous exceedances of the state water temperature standard during summer months (USBR 2008a). Instream flows are also a concern during summer months, with one upstream irrigation diversion (the Skyline Ditch at RM 9.2) that may affect fish passage, temperature, and habitat availability.

Reach C3b had scarce amounts of in-channel LWD during stream surveys of the lower river (RM 0-9.5) in 2008, with only 7.5 pieces of LWD/mile (USBR 2008a). Pool quantity was low, comprising only 19% of the habitat area in the reach. There was, however, abundant side-channel habitat, comprising approximately 24% of the total habitat area. Based on pebble counts, 7% of the bed substrate was fines (<6mm). The reach has limited spawning habitat due to coarse sediments (USBR 2008a). A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 16.

Table 16. Reach-Based Ecosystem Indicators (REI) ratings for Reach C3b. See Appendix A for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach C3b Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*Adequate*
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*Adequate*
	LWD	Pieces per Mile at Bankfull	*Unacceptable*

General Characteristics	General Indicators	Specific Indicators	Reach C3b Condition
	Pools	Pool Frequency and Quality	*Adequate*
	Off-Channel Habitat	Connectivity with Main Channel	*Adequate*
Channel	Dynamics	Floodplain Connectivity	*Adequate*
		Bank Stability/ Channel Migration	*Adequate*
		Vertical Channel Stability	*Adequate*
Riparian Vegetation	Condition	Structure	*No Data*
		Disturbance (Human)	*Adequate*
		Canopy Cover	*At Risk*

Hydrology

The confluence of Boulder Creek, located near RM 9.35, contributes about 4 to 5 cfs at low flow (USBR 2008a). Channel morphology and sediment size in Boulder Creek, and the debris-flow geomorphology of the Chewuch River downstream of the confluence reflect the significantly higher flow contribute by Boulder Creek during periods of peak discharge (Table 17). The Chewuch Diversion is located near RM 9.2 and feeds water down a constructed side channel to a head gate that supplies the Skyline Canal. During irrigation season, withdrawals into Skyline Canal reduce flows in the Chewuch River. There is another diversion structure within the reach at the downstream boundary near RM 8.5 that consists of a concrete dam with a grouted boulder apron and a fish passage channel along the river right side. There is a fisheries facility just off the point of diversion here that includes a fish screen and return channel, and some older hatchery ponds. Table 17 provides the results of flood magnitude estimates for several recurrence intervals derived from a watershed analysis performed by the USBR (2008b).

Table 17. Flood magnitudes for recurrence intervals from 2 to 100 years for the Chewuch River at point near the upstream end of Reach C3b and for Boulder Creek near its confluence (RM 9.4). Obtained from Methow River Basin GIS hydrology database (USBR 2008b).

Location	River Mile	Flood Recurrence Interval (ft^3/sec) Q2	Q5	Q10	Q25	Q50	Q100
Upstream End	9.4	2,390	3,665	4,492	5,502	6,223	6,917
Boulder Creek at Confluence	9.4	625	938	1160	1456	1688	1927

Geomorphology

The extensive alluvial fan of Boulder Creek on the east pushes the channel against a bed rock hillslope creating high channel confinement between RM 9.0 and 9.45. Below RM 9.0, the hillslope trends away from the channel, and a wider inner zone and floodplain develops. However, the channel abuts bedrock again near RM 8.8 on the east side of the valley and flows against bedrock for the remainder of the reach.

In the confined section of the reach, the large bed material and a steep gradient creates boulder step-pool morphology. As the river flows off of the alluvial fan of Boulder Creek, the material

size and gradient decrease and channel planform transitions to long riffles and poorly developed pools in multiple active low flow split channels and high flow side-channels. Bar apex log jams and side-channel log jams are relatively frequent through this area. The geometry of high flow channels on the floodplain suggests large flood capacities, potentially associated with debris flows out of Boulder Creek.

Human Alterations

Two irrigation diversions are the main anthropogenic alterations affecting Reach C3b. The Chewuch River diversion, located at RM 9.2, includes a constructed side channel on river-right that extends from RM 9.1 to 9.3 (Figure 18). A head gate that takes water into the Skyline Canal during irrigation season is located at RM 9.2 in the diversion channel. At the downstream end of the reach near RM 8.5, a concrete dam creates a head control for another irrigation diversion (river-left) that further reduces flows during the summer months. The dam has been fitted with a grouted boulder apron and a fish-passage channel. Whereas these features reduce the impacts to fish passage of the dam, the structure still alters local hydraulics and channel processes in this reach (Figure 19).

There is minimal floodplain development in this reach. Dispersed camping is found along the northwest side of the valley, mainly on a terrace surface adjacent to an active side-channel. There is residential development on the extreme west side of the valley near RM 8.6. This floodplain is also affected by return flow from the Skyline canal which creates an active floodplain channel that is accessible to fish at the downstream end. Figure 20 shows all human features found in the reach.

Figure 18. View to the southeast in the downstream direction at the Chewuch River diversion near RM 9.3. November 2009.

Figure 19. View to the north in the upstream direction at a diversion near RM 8.5 (November 2009).

Figure 20. Aerial photo showing human features in Reach C3b. Flow is from north to south.

8.2 Reach Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach C3b is included below. The strategy focuses first on protecting existing conditions from further impairment. This objective is followed by reconnecting the fundamental bio-physical processes that will create and maintain habitat conditions over the long-term. Off-channel habitat enhancement (rehabilitation) is also included; these projects occur in conjunction with long-term process reconnection and are also applied in cases where long-term process reconnection is constrained by existing human uses. The USBR (2008b) identifies protection of the channel and floodplain to preserve the integrity of active processes and intact habitat as the primary objective of this reach. USBR restoration objectives focus on reconnecting floodplain processes through removal of riprap and restoring cleared areas on the west side of the downstream end of the reach.

1. ***Protect and Maintain***
   - **Prevent Further Degradation**- Opportunities to prevent further degradation should be pursued including purchasing land and water rights in the river corridor, and/or obtaining conservation easements. Water rights acquisition should be focused on increasing instream flow during late summer.
   - **Legal Protection**- Existing enforced legal protection is considered an intrinsic component of all potential projects.

2. ***Reconnect Stream Channel Processes***
   - **Instream Flow**- Continue to identify and carry forward projects that will result in natural timing of runoff recession and increased baseflow. Low baseflow during summer months can create barriers to fish migration that is essential for restoration success throughout the study area. Increased instream flow between July and October will enhance the success of restoration work that is meant to provide habitat over a wide range of flows including low flow periods. There is one significant diversion within this reach.
   - **Channel Dynamics**- Address loss of multi-thread channel complexity resulting from loss of wood dynamics. LWD jams are important to geomorphic process and their frequency and function have been reduced by past land-use practices. Where feasible, LWD jams can be placed in areas where they would naturally occur and where processes such as bar deposition, pool scour, lateral channel migration, and natural rates of recruitment can be re-established.

3. ***Reconnect Floodplain Processes***
   - **Floodplain Development** – Floodplain development has taken place on the west side of the valley at the downstream end of the reach. The development includes clearing, bank protection, and grading. Full floodplain reconnection will require reclamation of floodplain surfaces. Work with appropriate stakeholders to develop long-term solutions to floodplain impacts.

4. ***Riparian Restoration***
   - **Restore Riparian Areas** - There are cleared areas associated with agricultural floodplain development near the downstream end of the reach. There is a moderate riparian corridor maintained along the channel margin in these areas. Work should continue to expand the riparian buffer.

5. ***Off-Channel Habitat Enhancement***
   - **Enhance Off-Channel Habitat Complexity**- Impacts to physical processes has resulted in habitat simplification in some areas. Installation of natural off-channel habitat features can provide an intermediate improvement to aquatic ecology while process restoration matures. Natural activity of beavers can result in enhanced off-channel habitat and may be considered as a restoration option.

8.3 Sub-Unit and Project Opportunity Summary

Five sub-units were identified in Reach C3b, including three inner zone sub-units one outer zone sub-unit, and one disconnected outer zone sub-unit (Table 18, Figure 21). Two specific project opportunities are identified and described in the sub-unit summary sections (Table 19).

Table 18. Summary of protection and restoration opportunities for Reach C3b.

Sub-Unit	River Mile	Acreage
Inner Zone 1 (IZ-1)	9.1-9.45	N/A
Outer Zone 1 (OZ-1)	8.56-9.1	25
Inner Zone 2 (IZ-2)	8.4-9.1	N/A
Disconnected Outer Zone 1 (DOZ-1)	8.43-8.81	12.4
Inner Zone 3 (OZ-3)	8.5-8.7	N/A

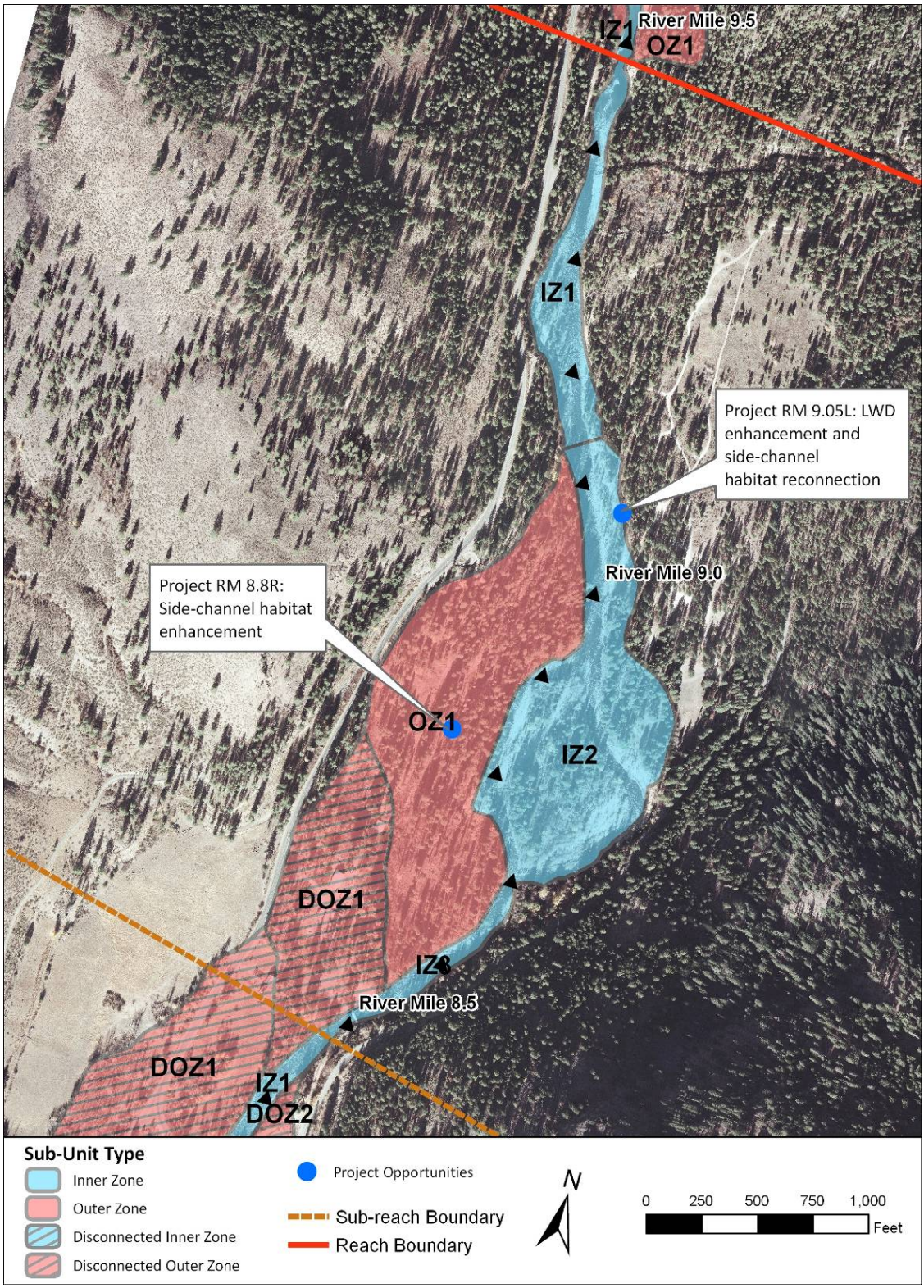

Figure 21. Sub-units and project opportunities in Reach C3b. Flow is from north to south.

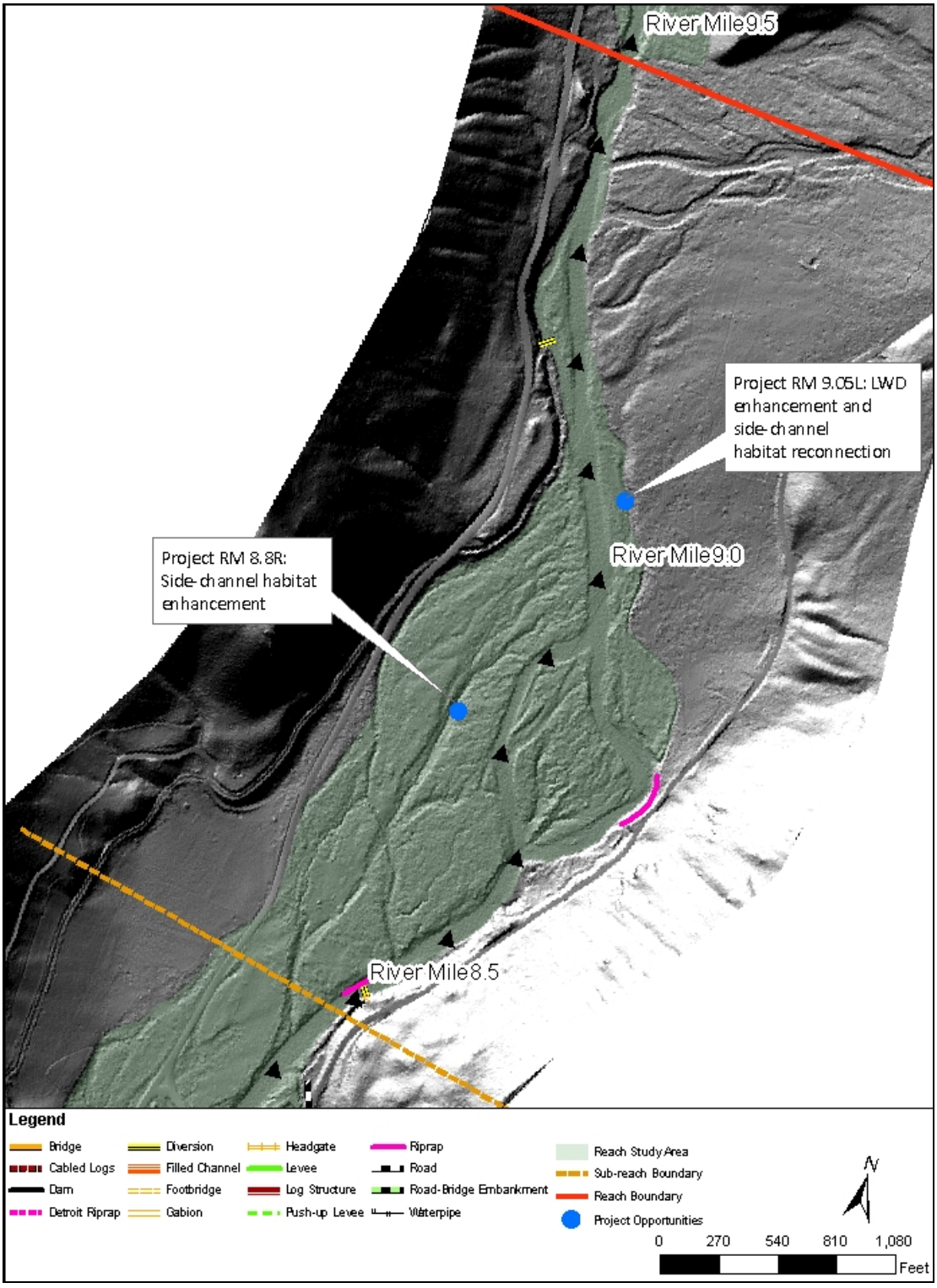

Figure 22. LiDAR hillshade of reach C3b illustrating topography in relation to human features and project locations in the reach. Flow is from north to south.

Table 19. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C3b.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-1	The alluvial fan of Boulder Creek directly impinges on this sub-unit. The fan pushes the channel against the west valley wall (bedrock), creates a locally steep gradient, and adds coarse bed material. The result is a steep boulder-bed channel with long boulder plane-bed sections interspersed with step-pool sequences. There is a side-channel at RM 9.2 created to supply water to the Chewuch diversion.	Protect and Maintain		Irrigation diversion located on river right near RM 9.2.
OZ-1	This 37.5 acre floodplain is west of the channel between RM 8.4-9.1. This is the only outer-zone sub-unit in Reach C3b. Geomorphic evidence suggests that this surface has multiple active high flow channels. The upstream margin of the surface has accumulated LWD along the inlets to the high-flow channels. The bed material ranges from boulders to sand and suggests that a wide range of flows are accommodated by floodplain channels. The scoured floodplain and dynamic overbank flood connection is related to the proximity of the Boulder Creek fan, where bed material inputs and aggradation create a shifting and dynamic channel and floodplain. Irrigation return flow from the Skyline Canal occurs near RM 9.08 and creates a relatively significant floodplain channel that flows along the west side of the sub-unit and returns to the main channel near RM 8.5. The riparian forest is otherwise intact, providing habitat and potential LWD recruitment along the channel margin.	Protect and Maintain Off-Channel Habitat Enhancement	***Project RM 8.8R*** Side-channel habitat enhancement.	Irrigation diversion canal and return (outflow) channel on river-right adjacent to the road/hillslope. Irrigation diversion dam across the channel at RM 8.5. Agricultural and residential development.

Table 19. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C3b.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-2	This inner-zone sub-unit is downstream from the direct effects of the alluvial fan of Boulder Creek, but still owes its morphology to the tributary's flow and sediment contributions. Channel planform transitions from straight single-thread in IZ-1 to sinuous multi-thread in IZ-2. The channel splits around large, stable islands into two fairly equal size channels. There are high-flow channels threading the mid-channel islands as well as paralleling the main channel. Bed material remains large but is organized into step-pool and pool-riffle sequences. There is active bank erosion along the river-right margin and active recruitment of LWD.	Protect and Maintain Re-Connect Stream Channel Processes	***Project RM 9.05L*** LWD enhancement and side-channel habitat reconnection	Irrigation diversion downstream at RM 8.5.
DOZ-1	The floodplain area is a portion of OZ-1 that has undergone development. There is a residence, several large outbuildings and industrial equipment occupying a large cleared and graded area. The irrigation return flow from the Skyline Canal flows to the west of the development. The riparian forest to the east of the development appears to have burned in the recent past.	Protect and Maintain Reconnect Floodplain Processes Off-Channel Habitat Enhancement	***CR_Prj-8.55 (USBR 2008b)*** *Continue to identify projects that address floodplain disconnection*	Residential development.

Table 19. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C3b.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-3	The multi-thread channels of IZ-2 converge near RM 8.7 where the river flows against bedrock along river-left. The channel runs fairly straight downstream of this point and simplifies to boulder-run morphology with no side-channels. There is a diversion dam near RM 8.5 that creates a hydraulic obstruction. The dam has been retrofitted to provide as much natural hydraulics as possible with a grouted boulder apron as opposed to a more abrupt drop-structure. A fish-passage channel has been constructed along the river-right side of the channel.	Protect and Maintain		Irrigation diversion dam across the channel at RM 8.5.

[1]*For additional information on specific identified project opportunities, see Chewuch Project Opportunities list in Appendix B.*

C4A – Reach Assessment

9 C4A REACH ASSESSMENT

9.1 Reach Overview

C4a is a short reach that is confined by bedrock on both sides of the channel. The channel has moderate sinuosity, but very little side-channel habitat and limited overbank connection due to natural limitations in floodplain width. A roadway parallels the channel along the west side of the valley for the entire reach. There is a narrow floodplain between the road and the channel in some locations, and in others the channel runs directly against the road embankment (riprap).

Habitat Conditions and Fish Use

Salmonid use of Reach C4a includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. The reach is heavily used for spring Chinook and steelhead spawning, rearing, and migration. Annual steelhead redd counts from 2003 to 2007 from Boulder Creek to Eightmile Creek (spans Reaches C4a through C4c) have an average of 19.3 redds/mile. Spring Chinook redd counts from 2001 to 2007 in the same area have an average of 30 redds/mile (data from Snow et al. 2008).

Water temperature is elevated throughout the lower Chewuch River, with numerous exceedances of the state water temperature standard during summer months (USBR 2008a). There are no irrigation diversions within or upstream of the reach.

Reaches C4a through C4c had scarce amounts of in-channel LWD during stream surveys in 2008, with only 6 pieces of LWD/mile (USFS 2008). Pools were relatively abundant, and comprised approximately 45% of the habitat area in reaches C4a through C4c. The reach contains good spawning habitat, and is dominated by gravel and small cobble sized substrate. A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 20.

Table 20. Reach-Based Ecosystem Indicators (REI) ratings for Reach C4a. These REI ratings cover reaches C4a, C4b, and C4c. See Appendix A for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach C4 Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*Adequate*
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*At Risk*
	LWD	Pieces per Mile at Bankfull	*Unacceptable*
	Pools	Pool Frequency and Quality	*Adequate*
	Off-Channel Habitat	Connectivity with Main Channel	*At Risk*
Channel	Dynamics	Floodplain Connectivity	*Unacceptable*
		Bank Stability/ Channel Migration	*At Risk*
		Vertical Channel Stability	*Adequate*
Riparian	Condition	Structure	*No Data*

General Characteristics	General Indicators	Specific Indicators	Reach C4 Condition
Vegetation		Disturbance (Human)	*Adequate*
		Canopy Cover	*Unacceptable*

Hydrology

There are no tributaries or diversions in Reach C4a. The flow in this reach is determined by upstream influences. The narrow valley width and proximity of bedrock suggests that a gaining or parallel flow-through groundwater regime is likely. Table 21 provides the results of flood magnitude estimates for several recurrence intervals derived from a watershed analysis performed by the USBR (2008b).

Table 21. Flood magnitudes for recurrence intervals from 2 to 100 years for a point near the downstream end of Reach C4a (RM 9.4). Obtained from Methow River Basin GIS hydrology database (USBR 2008b).

	River	Flood Recurrence Interval (ft^3/sec)					
Location	Mile	Q2	Q5	Q10	Q25	Q50	Q100
Downstream End	9.4	2,390	3,665	4,492	5,502	6,223	6,917

Geomorphology

This reach is one of the most confined within the Chewuch River study area. There is near-surface bedrock on both sides of the valley that create natural constraints on valley width. The bedrock is draped with glacial deposits along the east side of the valley. The glacial terrace is truncated by the alluvial fan of Boulder Creek near the downstream end of the reach.

Within this narrowly confined reach the channel has developed moderate sinuosity (1.12). Alternating bars have developed throughout the reach. The Boulder Creek fan creates a downstream hydraulic control, which reduces reach gradient and creates depositional areas (bars). The bar material consists of gravel and sand and is much smaller than in Reach C3b downstream. The bed, however, is still coarse, although the percentage of cobble is less and there are few boulders. Bed morphology is pool-riffle or riffle-run.

Human Alterations

The only significant human alteration to the river corridor is the road that runs parallel to the river-right side of the channel for the majority of the reach (Figure 23). The road runs along the hillslope toe and so only provides limited constraints to lateral connectivity. However, the embankment is composed of 588 ft of riprap at the upstream end that alters boundary hydraulics and reduces habitat cover and complexity along the bank.

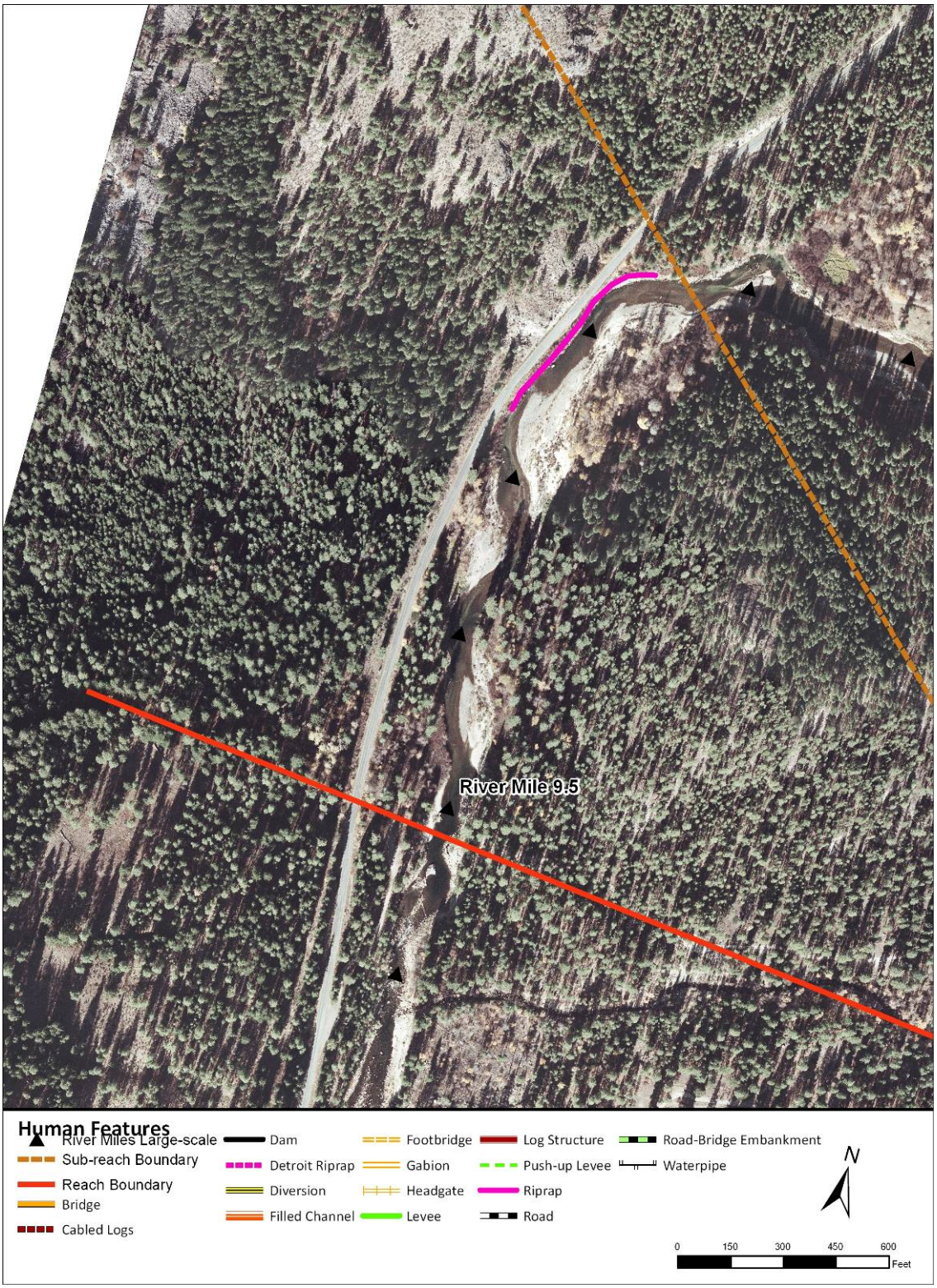

Figure 23. Aerial photo showing human features in Reach C4a. Flow is from north to south.

9.2 Reach Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach C4a is included below. The strategy focuses first on protecting existing conditions from further impairment. Instream and off-channel habitat enhancement (rehabilitation) is also included; these projects occur in conjunction with long-term process reconnection in upstream and downstream reaches and are also applied in cases where long-term process reconnection is constrained by existing human uses. The USBR identifies protection of the channel and floodplain to preserve the integrity of active processes and intact habitat as the primary objective of this reach (USBR 2008b).

1. ***Protect and Maintain***
   - **Prevent Further Degradation**- Opportunities to prevent further degradation should be pursued including purchasing land and water rights in the river corridor, and/or obtaining conservation easements. Water rights acquisition should be focused on increasing instream flow during late summer.
   - **Legal Protection**- Existing enforced legal protection is considered an intrinsic component of all potential projects.

2. ***In-Stream Habitat Enhancement***
   - **Enhance Habitat Complexity** Instream large wood is a natural component of this system that has been severely reduced by past land-use practices. Wood creates pool scour, cover, and channel complexity. Place wood in configurations and locations that mimic natural wood deposition processes. These projects are not replacements for process restoration, but are meant to provide intermediate habitat enhancement while process restoration matures.

3. ***Off-Channel Habitat Enhancement***
   - **Enhance Off-Channel Habitat Complexity**- Impacts to physical processes has resulted in habitat simplification in some areas. Installation of natural off-channel habitat features can provide an intermediate improvement to aquatic ecology while process restoration matures. Natural activity of beavers can result in enhanced off-channel habitat and may be considered as a restoration option.

9.3 Sub-Unit and Project Opportunity Summary

Four sub-units were identified in Reach C4a, including one inner zone sub-unit and three outer zone sub-units (Table 22, Figure 24, Figure 25). There are no disconnected sub-units in this reach, although the inner zone is negatively impacted by the riprap along the road embankment. Natural constraints on floodplain development and channel dynamics limit restoration potential. There are, however, opportunities to improve habitat and process function. Four specific project opportunities are identified in this reach and are described in the sub-unit summary section (Table 23).

Table 22. Summary of protection and restoration opportunities for Reach C4a.

Sub-Unit	River Mile	Acreage
Inner Zone 1 (IZ-1)	9.45-9.8	N/A
Outer Zone 1 (OZ-1)	9.45-9.84	8.9
Outer Zone 2 (OZ-2)	9.55-9.66	0.97
Outer Zone 3 (OZ-3)	9.46-9.51	0.36

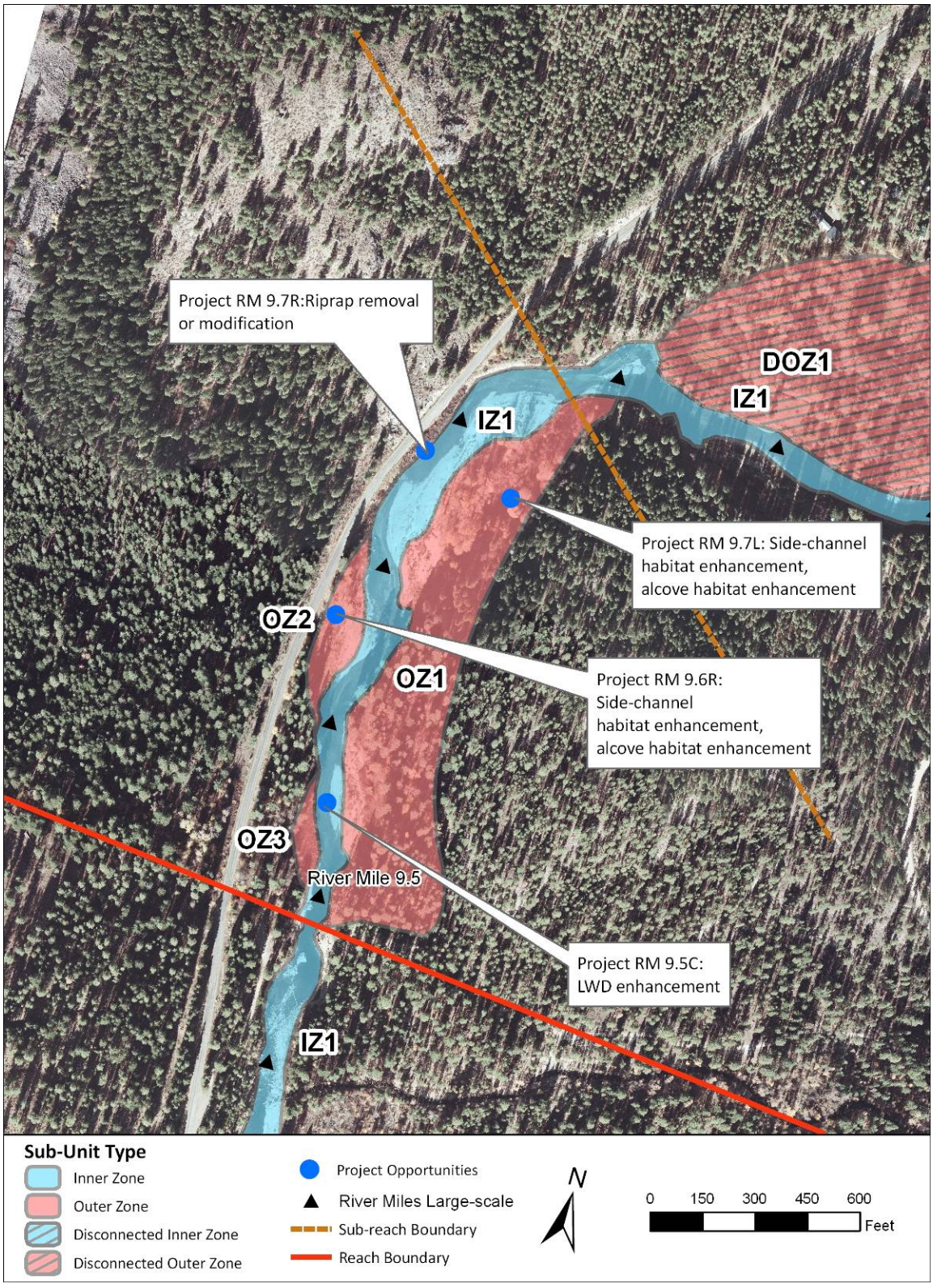

Figure 24. Sub-units and project opportunities in Reach C4a. Flow is from north to south.

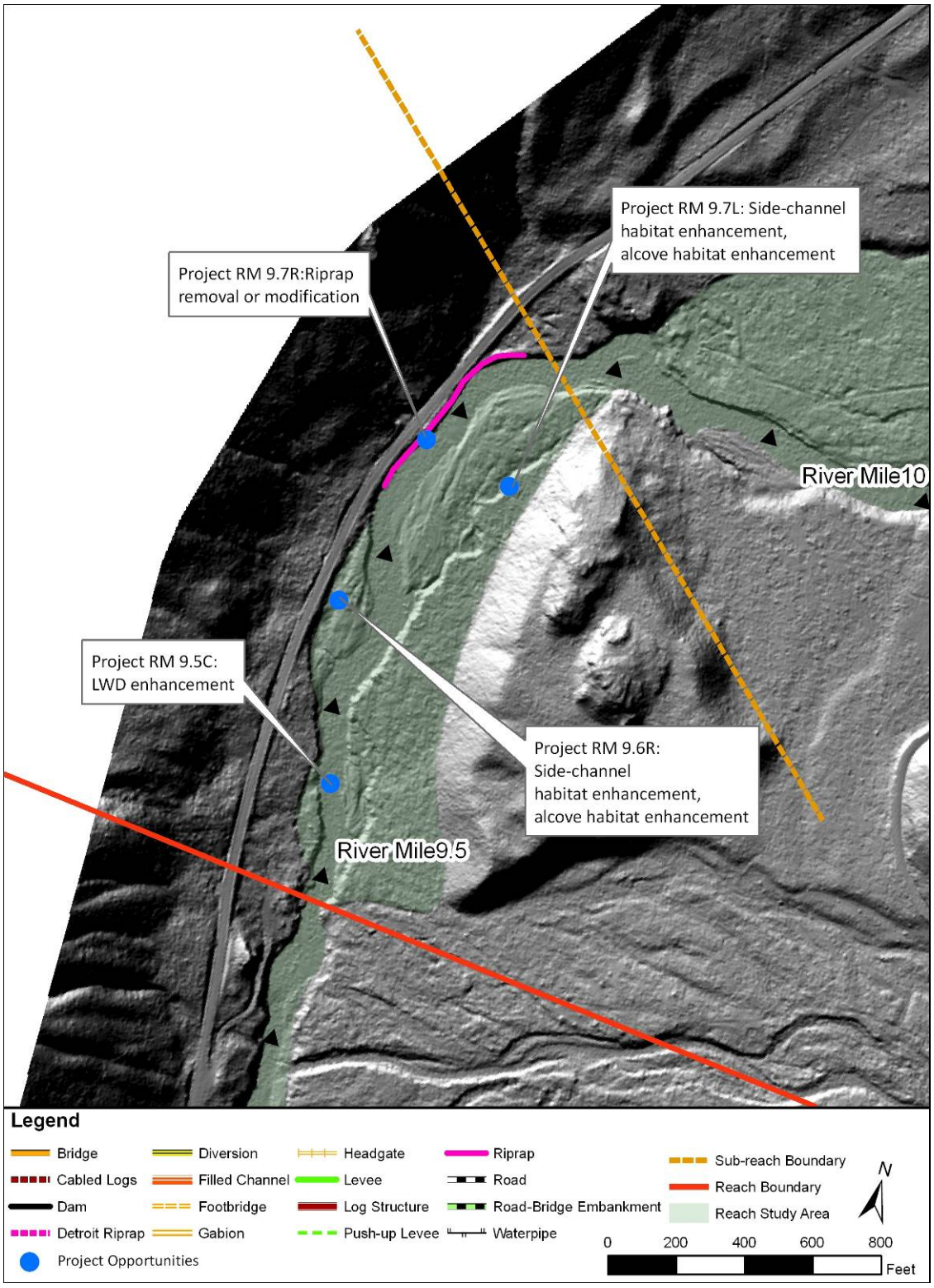

Figure 25. LiDAR hillshade of reach C4a illustrating topography in relation to human features and project locations. Flow is from north to south.

Table 23. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C4a.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-1	IZ-1 comprises the entire length of Reach C4a. This is a moderately sinuous channel with pool-riffle morphology and a gravel/cobble bed. This morphology results from the hydraulic control of the Boulder Creek alluvial fan that reduces the gradient and energy in Reach C4a. There is some LWD recruitment, including one very large cross-channel piece near RM 9.58. Bank erosion along river-left downstream of RM 9.65 provides the opportunity to add more LWD to the channel. Riprap forms the channel margin along river-right between RM 9.66 and 9.76. There is connection to a high-flow channel on river-left between RM 9.65 and 9.82.	Protect and Maintain Reconnect Stream Channel Processes In-Stream Habitat Enhancement	***Project RM 9.7R*** Riprap removal or modification ***Project RM 9.5C*** LWD enhancement.	Road embankment and associated riprap along river-right between RM 9.66 and 9.76.
OZ-1	OZ-1 provides a narrow riparian buffer, occupying 8.9 acres between the channel and hillslopes to the east for the entire length of the reach. The surface is fairly high and there is no evidence of frequent overbank flooding. Riparian vegetation is intact and there is a mature conifer forest that is providing LWD to the channel through active bank erosion. The upstream end of the sub-unit is lower and connected to inner zone processes, providing a short high-flow channel.	Protect and Maintain Off-Channel Habitat Enhancement	***Project RM 9.7L*** Side-channel habitat enhancement, alcove habitat enhancement.	Access for construction would require crossing the main channel.

Table 23. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C4a.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
OZ-2	OZ-2 is a small floodplain surface along the west side of the valley. The sub-unit is on the inside of a meander, where lateral migration has reworked colluvium at the toe of the hillslope. The surface is undeveloped except for the road embankment that USBRders the unit to the west. There appears to be only limited high-flow connection with the channel as evidenced by flood overflow channel scars across the surface.	Protect and Maintain Off-Channel Habitat Enhancement	***Project RM 9.6R*** Side-channel habitat enhancement, alcove habitat enhancement.	A road embankment along the west edge of the entire sub-unit.
OZ-3	This small floodplain is similar to OZ-2 in its location and geomorphic origin. It is isolated and undeveloped. Riparian vegetation in OZ-3 is intact. There is no off-channel habitat provided by this outer-zone.	Protect and Maintain		No apparent constraints to restoration or preservation.

[1]*For additional information on specific identified project opportunities, see Chewuch Project Opportunities list in Appendix B.*

C4b – Reach Assessment

10 C4B REACH ASSESSMENT

10.1 Reach Overview

Reach C4b is a moderately confined reach with moderate sinuosity and channel complexity. Valley width is constrained by bedrock and glacial deposits on both sides of the valley. The channel is relatively homogenous and provides little habitat complexity. Valley width is slightly expanded in comparison to up and downstream reaches. There has been substantial human development of the floodplain, however, riparian vegetation is mostly intact and there are only small areas that have been cleared and leveled for residential development.

Habitat Conditions and Fish Use

Salmonid use of Reach C4b includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. The reach is heavily used for spring Chinook and steelhead spawning, rearing, and migration. Annual steelhead redd counts from 2003 to 2007 from Boulder Creek to Eightmile Creek (spans Reaches C4a through C4c) have an average of 19.3 redds/mile. Spring Chinook redd counts from 2001 to 2007 in the same area have an average of 30 redds/mile (data from Snow et al. 2008).

Water temperature is elevated throughout the lower Chewuch River, with numerous exceedances of the state water temperature standard during summer months (USBR 2008a). There are no irrigation diversions within or upstream of the reach.

Reaches C4a through C4c had scarce amounts of in-channel LWD during stream surveys in 2008, with only 6 pieces of LWD/mile (USFS 2008). Pools were relatively abundant, and comprised approximately 45% of the habitat area in reaches C4a through C4c. The sinuous section of Reach C4b (RM 9.8 to 10.6) was noted as containing some of the more productive spawning habitat for steelhead and spring Chinook in the Chewuch River (USFS 2008). A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 24.

Table 24. Reach-Based Ecosystem Indicators (REI) ratings for Reach C4b. These REI ratings cover reaches C4a, C4b, and C4c. See Appendix A for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach C4 Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*Adequate*
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*At Risk*
	LWD	Pieces per Mile at Bankfull	*Unacceptable*
	Pools	Pool Frequency and Quality	*Adequate*
	Off-Channel Habitat	Connectivity with Main Channel	*At Risk*
Channel	Dynamics	Floodplain Connectivity	*Unacceptable*
		Bank Stability/ Channel Migration	*At Risk*
		Vertical Channel Stability	*Adequate*

General Characteristics	General Indicators	Specific Indicators	Reach C4 Condition
Riparian Vegetation	Condition	Structure	*No Data*
		Disturbance (Human)	*Adequate*
		Canopy Cover	*Unacceptable*

Hydrology

There are no tributaries or diversions that directly change or manipulate the timing or magnitude of flows in Reach C4b. The flow in this reach is determined by upstream influences and local groundwater dynamics. Table 25 provides the results of flood magnitude estimates for several recurrence intervals derived from a watershed analysis performed by the USBR (2008b).

Table 25. Flood magnitudes for recurrence intervals from 2 to 100 years for a point near the downstream end of Reach C4b (RM 9.4). Obtained from Methow River Basin GIS hydrology database (USBR 2008b).

Location	River Mile	Flood Recurrence Interval (ft^3/sec)					
		Q2	Q5	Q10	Q25	Q50	Q100
Downstream End	9.4	2,390	3,665	4,492	5,502	6,223	6,917

Geomorphology

Reach C4b is a moderately confined reach. Bedrock outcrops on both sides of the valley provide the primary constraints on valley width. Glacial deposits overlay the bedrock in most areas and form the low-surface boundary except for at a few locations. The glacial terrace has been eroded and a wide floodplain has developed along the west side of the valley. This surface contains wetlands, but only limited evidence of frequent flood inundation or high flow channels.

The channel forms one large amplitude half-meander. The upstream end of the reach has a large mid-channel bar that creates split flow and pool-riffle development. Downstream, the channel simplifies and is essentially a long run with coarse cobble/boulder bed material. As the channel swings west to complete the half-meander, a deep scour pool is formed on the outside of the bend. At the downstream end of the reach, the channel flows through a tight bedrock constriction where another deep scour pool has formed.

Human Alterations

There is residential development on both sides of the channel at the upstream end of the reach (Figure 26). Streamside riparian vegetation has been cleared and in some areas the banks have been hardened with riprap. There is also residential development of the floodplain along the west side of the valley. A few structures have been built and a long access road is located on the surface. There is relatively little riparian clearing involved with this development. In some locations, streamside vegetation has been removed and improvised riprap has been placed on the bank.

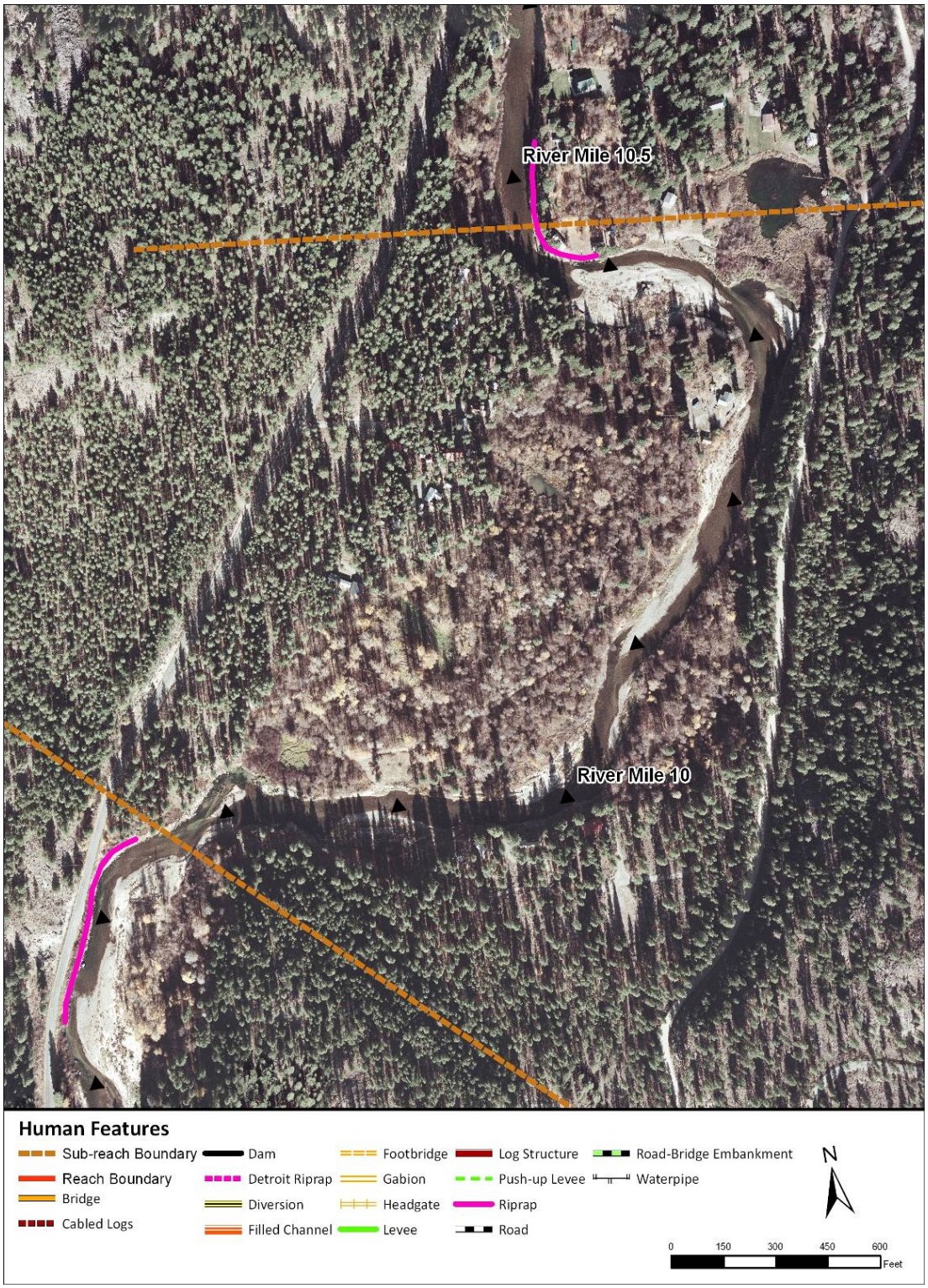

Figure 26. Aerial photo showing human features in Reach C4b. Flow is from north to south.

10.2 Reach Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach C4b is included below. The strategy focuses first on protecting existing conditions from further impairment. This objective is followed by reconnecting the fundamental bio-physical processes that will create and maintain habitat conditions over the long-term. Off-channel habitat enhancement (rehabilitation) is also included; these projects occur in conjunction with long-term process reconnection and are also applied in cases where long-term process reconnection is constrained by existing human uses. The USBR (2008b) suggests taking an active restoration approach in this reach. The primary objectives suggested by the USBR are to "restore wetland or high-flow network", or to "restore primary side channel and wetland". The restoration concepts behind achieving these goals are restoring cleared areas, assessing connectivity, removing riprap, and excavating to enhance side-channel connectivity. The USBR also suggests that addition of LWD throughout the reach may be beneficial.

1. ***Protect and Maintain***
   - **Prevent Further Degradation**- Opportunities to prevent further degradation should be pursued including purchasing land and water rights in the river corridor, and/or obtaining conservation easements. Water rights acquisition should be focused on increasing instream flow during late summer.
   - **Legal Protection**- Existing enforced legal protection is considered an intrinsic component of all potential projects.

2. ***Reconnect Stream Channel Processes***
   - **Riprap**- Remove or modify to restore dynamic processes. There is riprap located at the upstream end of the reach. If feasible, riprap can be removed or modified to increase floodplain and channel migration zone connectivity.
   - **Channel Dynamics**- Address loss of multi-thread channel complexity resulting from loss of wood dynamics. LWD jams are important to geomorphic process and their frequency and function have been reduced by past land-use practices. Where feasible, LWD jams should be placed in areas where they would naturally occur and where processes such as bar deposition, pool scour, lateral channel migration, and natural rates of recruitment can be re-established.

3. ***Reconnect Floodplain Processes***
   - **Floodplain Development** – Floodplain development has taken place on both sides of the channel near the upstream end of the reach. The development includes clearing, bank protection, and grading. Full floodplain reconnection will require reclamation of floodplain surfaces. Work with appropriate stakeholders to develop long-term solutions to floodplain impacts.

4. ***Riparian Restoration***
   - **Restore Riparian Areas** - There are cleared areas associated with residential floodplain development near the upstream end of the reach. Riparian vegetation is

cleared directly along the channel margin. Work should continue to expand the riparian buffer.

5. ***In-Stream Habitat Enhancement***
   - **Enhance Habitat Complexity** Instream large wood is a natural component of this system that has been severely reduced by past land-use practices. Wood creates pool scour, cover, and channel complexity. Place wood in configurations and locations that mimic natural wood deposition processes. These projects are not replacements for process restoration, but are meant to provide intermediate habitat enhancement while process restoration matures.

6. ***Off-Channel Habitat Enhancement***
   - **Enhance Off-Channel Habitat Complexity**- Impacts to physical processes has resulted in habitat simplification in some areas. Installation of natural off-channel habitat features can provide an intermediate improvement to aquatic ecology while process restoration matures. Natural activity of beavers can result in enhanced off-channel habitat and may be considered as a restoration option.

10.3 Sub-Unit and Project Opportunity Summary

Three sub-units were identified in Reach C4b, including one inner zone sub-unit, one outer zone sub-unit, and one disconnected outer zone sub-unit (Table 26, Figure 27, Figure 28). The majority of the outer zone (87%) is disconnected from the channel by riprap and residential development. Eight specific project opportunities are identified in this reach and are presented in the sub-unit summary section below (Table 27).

Table 26. Summary of protection and restoration opportunities for Reach C4b.

Sub-Unit	River Mile	Acreage
Inner Zone 1 (IZ-1)	9.8-10.46	N/A
Disconnected Outer Zone 1 (DOZ-1)	9.85-10.4	21.8
Outer Zone 1 (OZ-1)	10.04-10.19	3.2

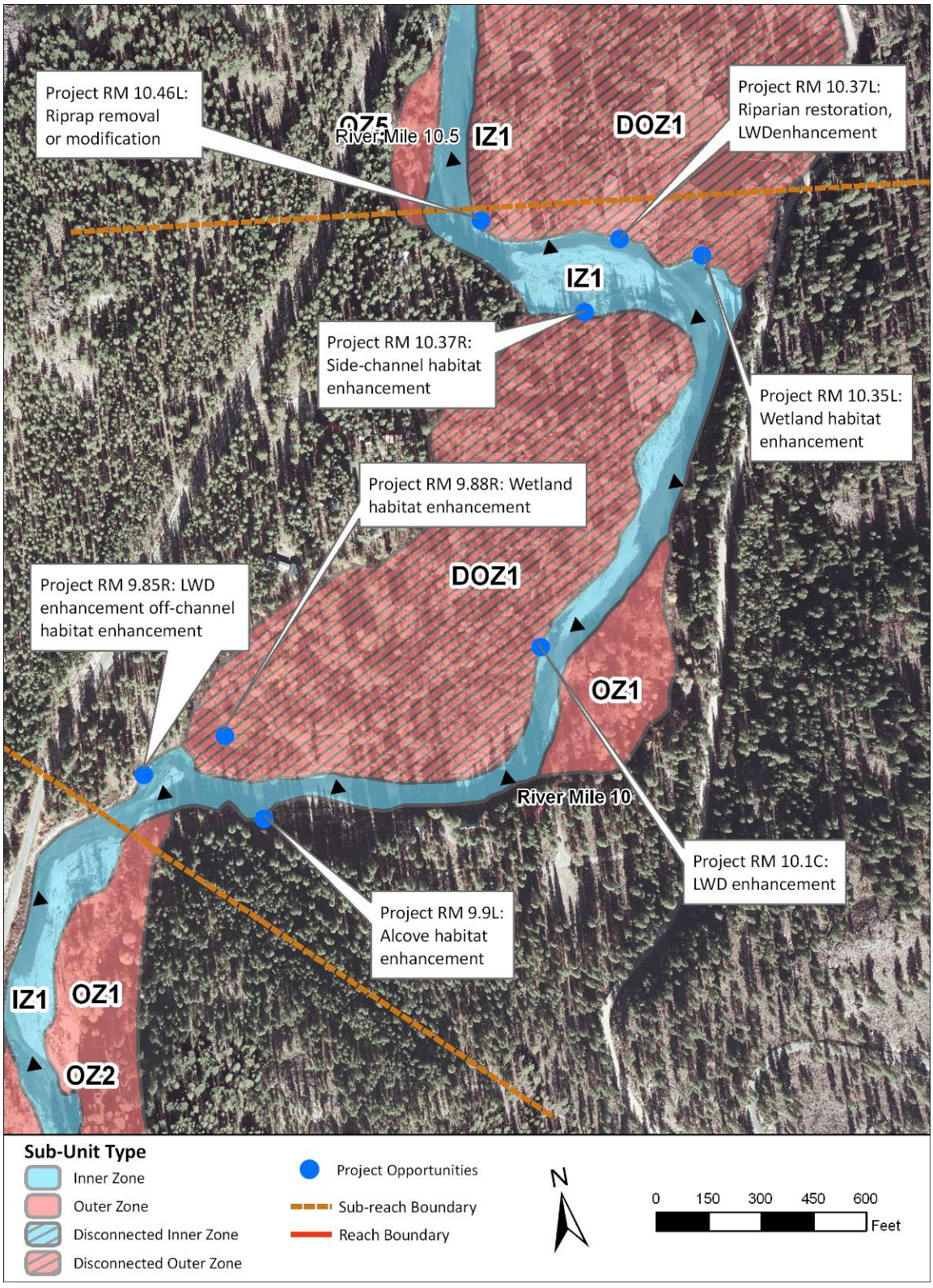

Figure 27. Sub-units and project opportunities in Reach C4b. Flow is from north to south.

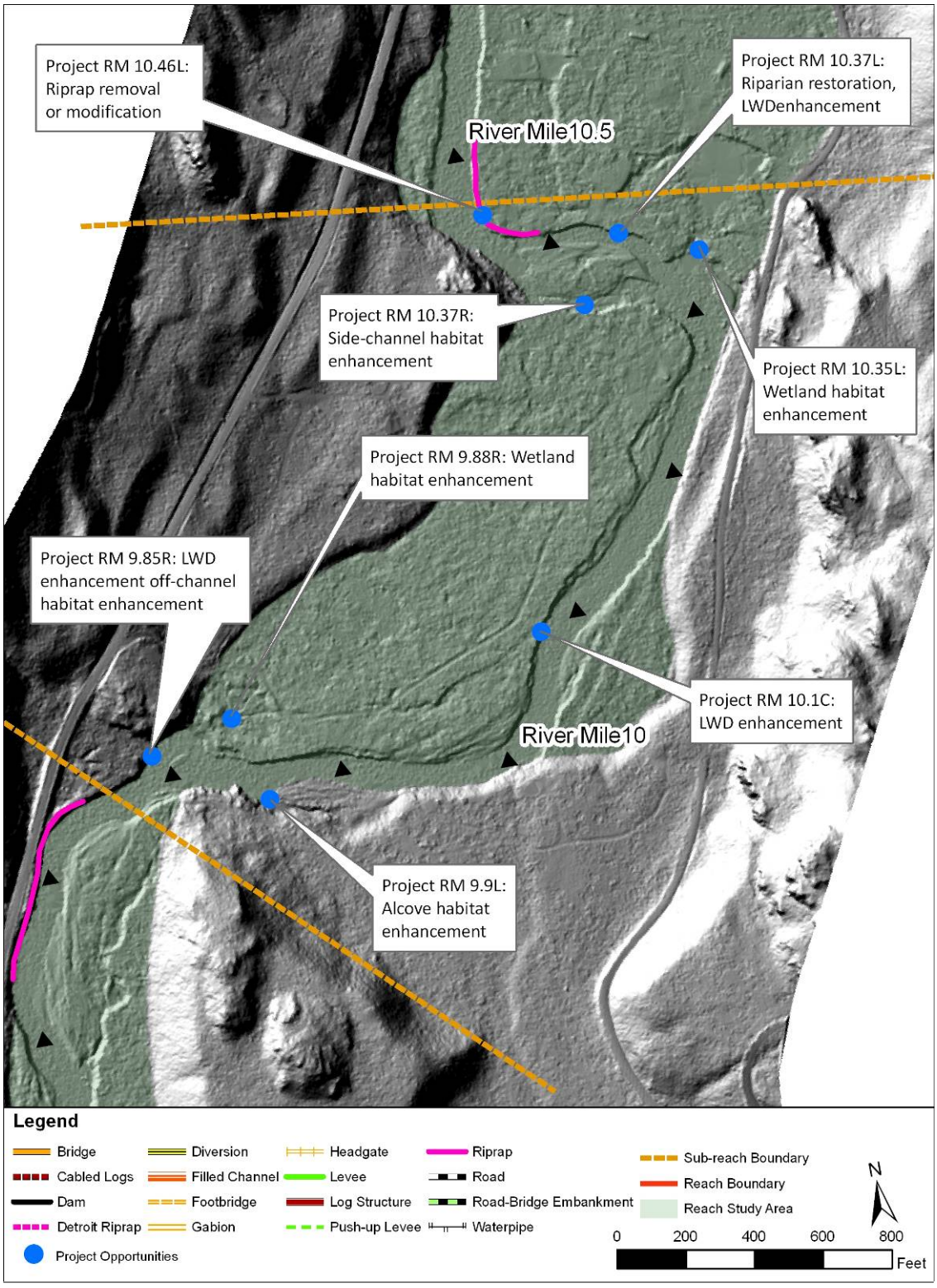

Figure 28. LiDAR hillshade of reach C4b illustrating topography in relation to human features and project locations in the reach. Flow is from north to south.

Table 27. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach 4b.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-1	The inner-zone in Reach C4b is primarily a straight channel with a long riffle-run morphology. The bed material ranges from gravel to cobble. For most of its length, there is very little hydraulic or habitat complexity. Near the upstream and downstream ends of the inner-zone, there are bedrock outcrops in the channel. At each of these locations there is a deep scour pool, and split-flow. The upstream split-flow location provides a significant amount of localized habitat complexity.	Protect and Maintain Reconnect Stream Channel Processes Riparian Restoration In-Stream Habitat Enhancement Off-Channel Habitat Enhancement	***Project RM 10.37L*** Riparian restoration and LWD enhancement ***Project RM 10.46L*** Riprap removal or modification ***Project RM 10.1C*** LWD enhancement ***Project RM 9.85R*** LWD enhancement. ***Project RM 10.37R*** Side-channel habitat enhancement. ***Project RM 10.35L*** Wetland habitat enhancement ***Project RM 9.9L*** Alcove habitat enhancement.	Residential development on both sides of the channel at the upstream end of the reach. Roadway parallel to the channel on the glacial terrace on the east side of the valley.

Table 27. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach 4b.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
DOZ-1	DOZ-1 is the largest floodplain surface in all of the C4 reaches. The 21.8 acre sub-unit is formed on the inside of a large amplitude half-meander. There is only limited topographic evidence of high-flow connectivity such as flood overflow channels. There are, however, wetlands at the up and downstream ends of the sub-unit. A low area exists between the channel and the downstream wetland that could provide access to off-channel habitat during high flows. There is residential development, clearing, and road building on the surface. Further investigation is needed to determine if roadways or fill block potential high flow connectivity.	Protect and Maintain Reconnect Floodplain Processes Off-Channel Habitat Enhancement	***Project RM 9.88R*** Wetland habitat enhancement. ***CR_Prj-10.4R (USBR 2008b)*** ***CR_Prj-10.1 (USBR 2008b)*** *Work to address floodplain disconnection*	Residential development within the sub-unit including clearing, fill, and roads.
OZ-1	The margin of the glacial terrace has been eroded and a 3.2 acre floodplain has formed just upstream of a sharp bend in the river. Riparian habitat in OZ-1 is intact and connected to the inner zone. There is no off-channel habitat provided by OZ-1, but there is topographic evidence of high-flow connectivity.	Protect and Maintain	***CR_Prj-10.2 (USBR 2008b)***	Residential development on the adjacent terrace.

[1]*For additional information on specific identified project opportunities, see Chewuch Project Opportunities list in Appendix B.*

C4c – Reach Assessment

11 C4c Reach Assessment

11.1 Reach Overview

In reach C4c, the channel is confined by glacial deposits, bedrock, and the alluvial fan of Eightmile Creek at the upstream end of the reach. The channel is fairly straight and somewhat incised with a glacial or alluvial terrace. The floodplain expands in the downstream third of the reach. Habitat complexity is low, with few side-channels, scarce LWD, and no connectivity to off-channel habitat. Anthropogenic disturbance includes a roadway along the east side of the valley with an occasional riprap bank where the river flows directly against the road embankment. There is residential development along river-left at the downstream end of the reach.

Habitat Conditions and Fish Use

Salmonid use of Reach C4c includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. The reach is heavily used for spring Chinook and steelhead spawning, rearing, and migration. Annual steelhead redd counts from 2003 to 2007 from Boulder Creek to Eightmile Creek (spans Reaches C4a through C4c) have an average of 19.3 redds/mile. Spring Chinook redd counts from 2001 to 2007 in the same area have an average of 30 redds/mile (data from Snow et al. 2008).

Water temperature is elevated throughout the lower Chewuch River, with numerous exceedances of the state water temperature standard during summer months (USBR 2008a). There are no irrigation diversions within or upstream of the reach.

Reaches C4a through C4c had scarce amounts of in-channel LWD during stream surveys in 2008, with only 6 pieces of LWD/mile (USFS 2008). Pools were relatively abundant, and comprised approximately 45% of the habitat area in reaches C4a through C4c. The reach contains good spawning habitat, and is dominated by gravel and small cobble sized substrate. A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 28.

Table 28. Reach-Based Ecosystem Indicators (REI) ratings for Reach C4c. These REI ratings cover reaches C4a, C4b, and C4c. See Appendix A for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach C4 Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*Adequate*
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*At Risk*
	LWD	Pieces per Mile at Bankfull	*Unacceptable*
	Pools	Pool Frequency and Quality	*Adequate*
	Off-Channel Habitat	Connectivity with Main Channel	*At Risk*
Channel	Dynamics	Floodplain Connectivity	*Unacceptable*
		Bank Stability/ Channel Migration	*At Risk*

General Characteristics	General Indicators	Specific Indicators	Reach C4 Condition
		Vertical Channel Stability	*Adequate*
Riparian Vegetation	Condition	Structure	*No Data*
		Disturbance (Human)	*Adequate*
		Canopy Cover	*Unacceptable*

Hydrology

Eightmile Creek flows into the Chewuch at the upstream end of the reach. This tributary contributes flow and coarse sediment to the channel, impacting channel form and hydrology. This reach is above all major diversions on the Chewuch and displays a natural hydrologic pattern typical of snowmelt streams in the northeastern Cascades. Table 29 provides the results of flood magnitude estimates for several recurrence intervals derived from a watershed analysis performed by the USBR (2008b).

Table 29. Flood magnitudes for recurrence intervals from 2 to 100 years for a point near the upstream end of Reach C4c (RM 11.9). Obtained from Methow River Basin GIS hydrology database (USBR 2008b).

Location	River Mile	Flood Recurrence Interval (ft^3/sec)					
		Q2	Q5	Q10	Q25	Q50	Q100
Upstream End	11.9	2,088	3,202	3,925	4,807	5,437	6,044

Geomorphology

Unlike the other two sub-reaches of C4, C4c is constrained primarily by alluvial deposits rather than bedrock. The width of the valley floor between bedrock hillslopes actually provides a moderately wide valley. However, channel incision into glacial terraces and alluvial fan deposits create a confined channel condition. Eightmile Creek creates a large alluvial fan at the upstream end of the reach that pushes the channel east against bedrock, creating a locally steep, confined channel. The channel flows southwest away from the bedrock, but incises glacial deposits and remains straight and confined. Near the downstream end of the reach, the channel flows against bedrock slopes on the west side of the valley.

Planform geometry is simple, with a low sinuosity of 1.10. There is one large-amplitude half-meander at the upstream end of the reach; the channel is essentially straight for the remainder of its length. There are no split-flow locations and few high-flow or seasonal side-channels. Aside from the influence of Eightmile Creek at the upstream end, the gradient is relatively low. Channel morphology varies from boulder step-pool at the upstream end to long runs near the downstream end. Future LWD recruitment is low due to a number of factors: clearing of the majority of the terrace surface on the west side of the valley, coarse banks that erode slowly, and residential development near the downstream end of the reach.

Human Alteration

Human alterations in C4c are relatively negligible in comparison to natural constraints on channel form, gradient, and lateral dynamics in this reach (Figure 29). There are short sections

of riprap along river-left at several locations and clearing on the high terrace along the west side of the valley in the upstream half of the reach. Perhaps the most deleterious human action in Reach C4c was LWD clearing following large floods in 1948 and 1972 (USBR 2008b). There is little potential for future recruitment due to riparian clearing and natural constraints on lateral channel adjustments. There is residential development on the most expansive floodplain surface in the reach, which is on the east side of the valley between RM 10.46 and 10.93. Riparian vegetation has been cleared along portions of the channel margin and the banks are hardened with riprap.

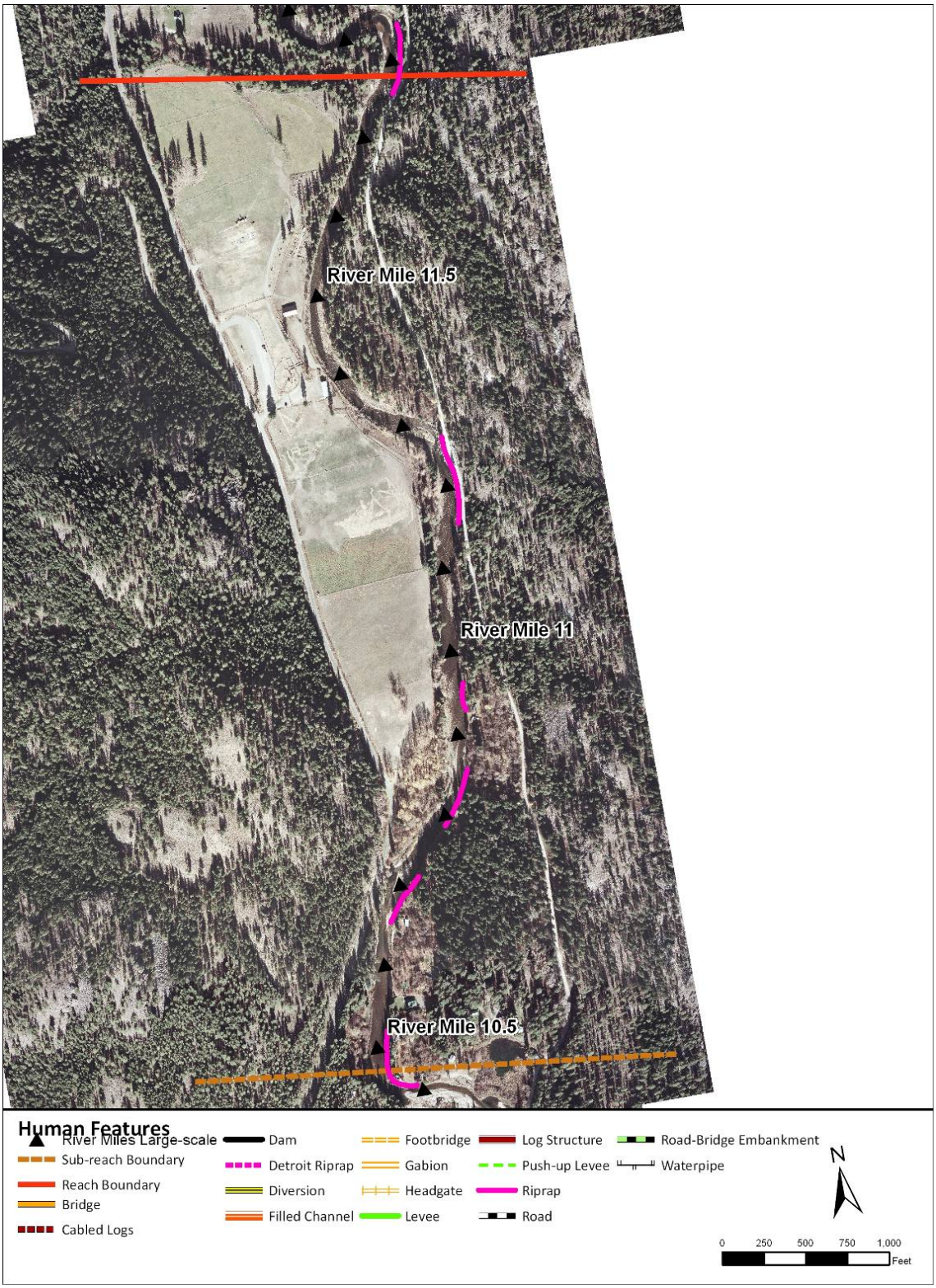

Figure 29. Aerial photo showing human features in Reach C4c. Flow is from north to south.

11.2 Reach Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach C4c is included below. The strategy focuses first on protecting existing conditions from further impairment. This objective is followed by reconnecting the fundamental bio-physical processes that will create and maintain habitat conditions over the long-term. Off-channel habitat enhancement (rehabilitation) is also included; these projects occur in conjunction with long-term process reconnection and are also applied in cases where long-term process reconnection is constrained by existing human uses. The Tributary Assessment (USBR 2008b) suggests taking an active restoration approach in this reach. The primary objectives suggested by the USBR are to "restore wetland or network", or to "restore primary side channel and wetland". The restoration concepts behind achieving these goals are restoring cleared areas, assessing connectivity, removing riprap, and excavating to enhance side-channel connectivity. The USBR also suggests that addition of LWD throughout the reach may be beneficial.

1. ***Protect and Maintain***
   - **Prevent Further Degradation**- Opportunities to prevent further degradation should be pursued including purchasing land and water rights in the river corridor, and/or obtaining conservation easements. Water rights acquisition should be focused on increasing instream flow during late summer.
   - **Legal Protection**- Existing enforced legal protection is considered an intrinsic component of all potential projects.

2. ***Reconnect Stream Channel Processes***
   - **Riprap**- Remove or modify features to restore dynamic processes. There are barriers to channel/floodplain connection on river left throughout the reach. Where feasible, riprap and levees should be removed or modified to increase floodplain and channel migration zone connectivity.
   - **Channel Dynamics**- Address loss of multi-thread channel complexity resulting from loss of wood dynamics. LWD jams are important to geomorphic process and their frequency and function have been reduced by past land-use practices. Where feasible, LWD jams can be placed in areas where they would naturally occur and where processes such as bar deposition, pool scour, lateral channel migration, and natural rates of recruitment can be re-established.

3. ***Reconnect Floodplain Processes***
   - **Riprap** – Removing or modifying hardened banks, where feasible, will help to restore floodplain processes.

4. ***Riparian Restoration***
   - **Restore Riparian Areas** – Riparian clearing on the west sie of the valley is extensive. Riparian vegetation is cleared directly along the river right channel margin for the majority of the reach. Work should continue to expand the riparian buffer.

5. ***In-Stream Habitat Enhancement***
   - **Enhance Habitat Complexity**- Instream large wood is a natural component of this system that has been severely reduced by past land-use practices. Wood creates pool scour, cover, and channel complexity. Place wood in configurations and locations that mimic natural wood deposition processes. These projects are not replacements for process restoration, but are meant to provide intermediate habitat enhancement while process restoration matures.

6. ***Off-Channel Habitat Enhancement***
   - **Enhance Off-Channel Habitat Complexity**- Impacts to physical processes has resulted in habitat simplification in some areas. Installation of natural off-channel habitat features can provide an intermediate improvement to aquatic ecology while process restoration matures. Natural activity of beavers can result in enhanced off-channel habitat and may be considered as a restoration option.

11.3 Sub-Unit and Project Opportunity Summary

Eight sub-units were identified in Reach C4c, including one inner zone sub-unit, five outer zone sub-units, and two disconnected outer zone sub-units (Table 30, Figure 30, Figure 31). The majority of the outer zone (81%) is disconnected from the channel by riprap and residential development. Seven specific project opportunities are identified in this reach and are presented in the sub-unit summary section (Table 31).

Table 30. Summary of protection and restoration opportunities for Reach C4c.

Sub-Unit	River Mile	Acreage
Inner Zone 1 (IZ-1)	10.46-11.7	N/A
Outer Zone 1 (OZ-1)	11.6-11.68	0.6
Outer Zone 2 (OZ-2)	11.24-11.54	6.6
Outer Zone 3 (OZ-3)	11.08-11.25	1.3
Outer Zone 4 (OZ-4)	11.0-11.08	0.5
Disconnected Outer Zone 1 (DOZ-1)	10.32-10.93	39.3
Disconnected Outer Zone 2 (DOZ-2)	10.7-10.92	3.4
Outer Zone 5 (OZ-5)	10.46-10.59	1.0

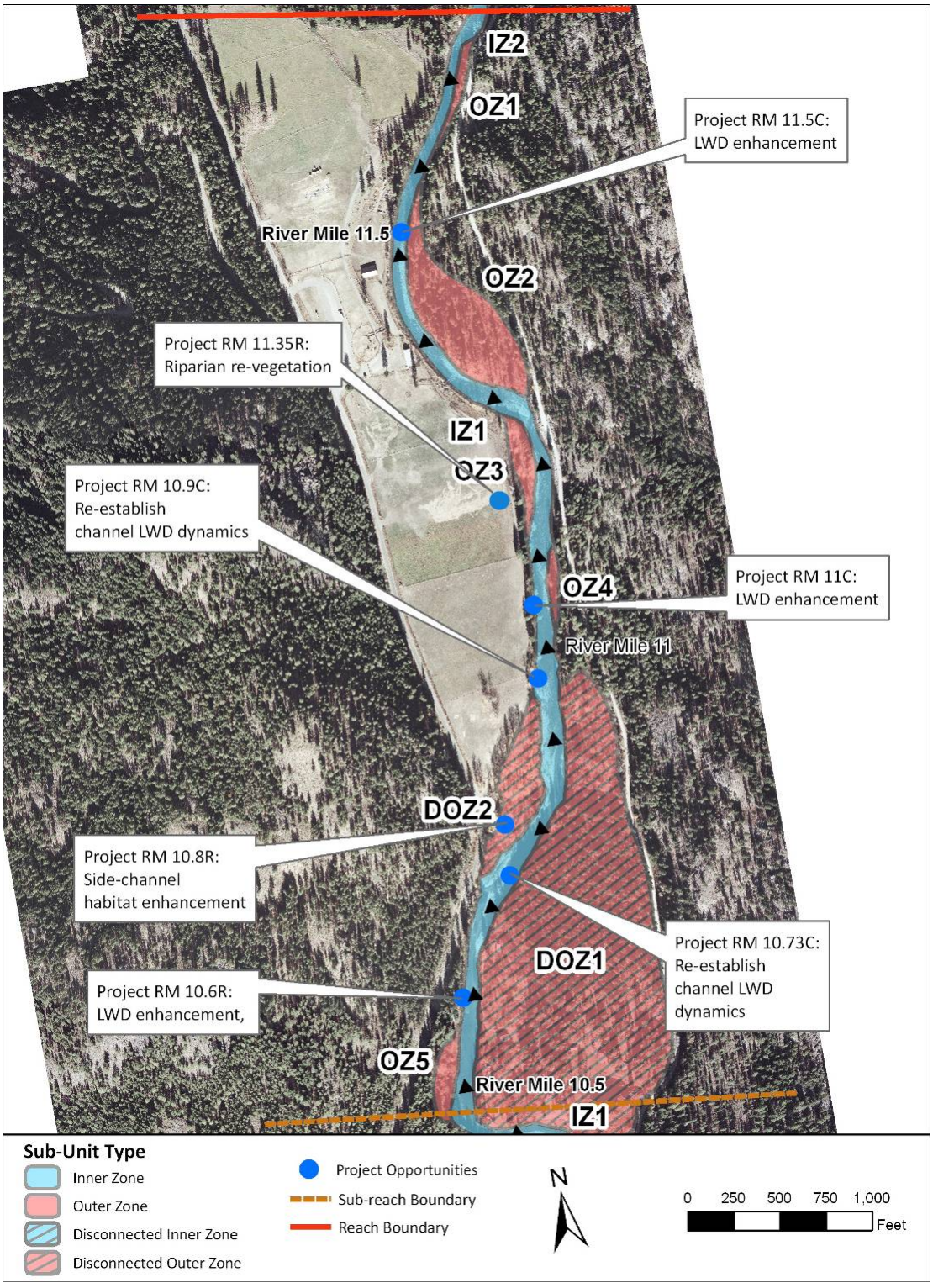

Figure 30. Sub-units and project opportunities in Reach C4c. Flow is from north to south.

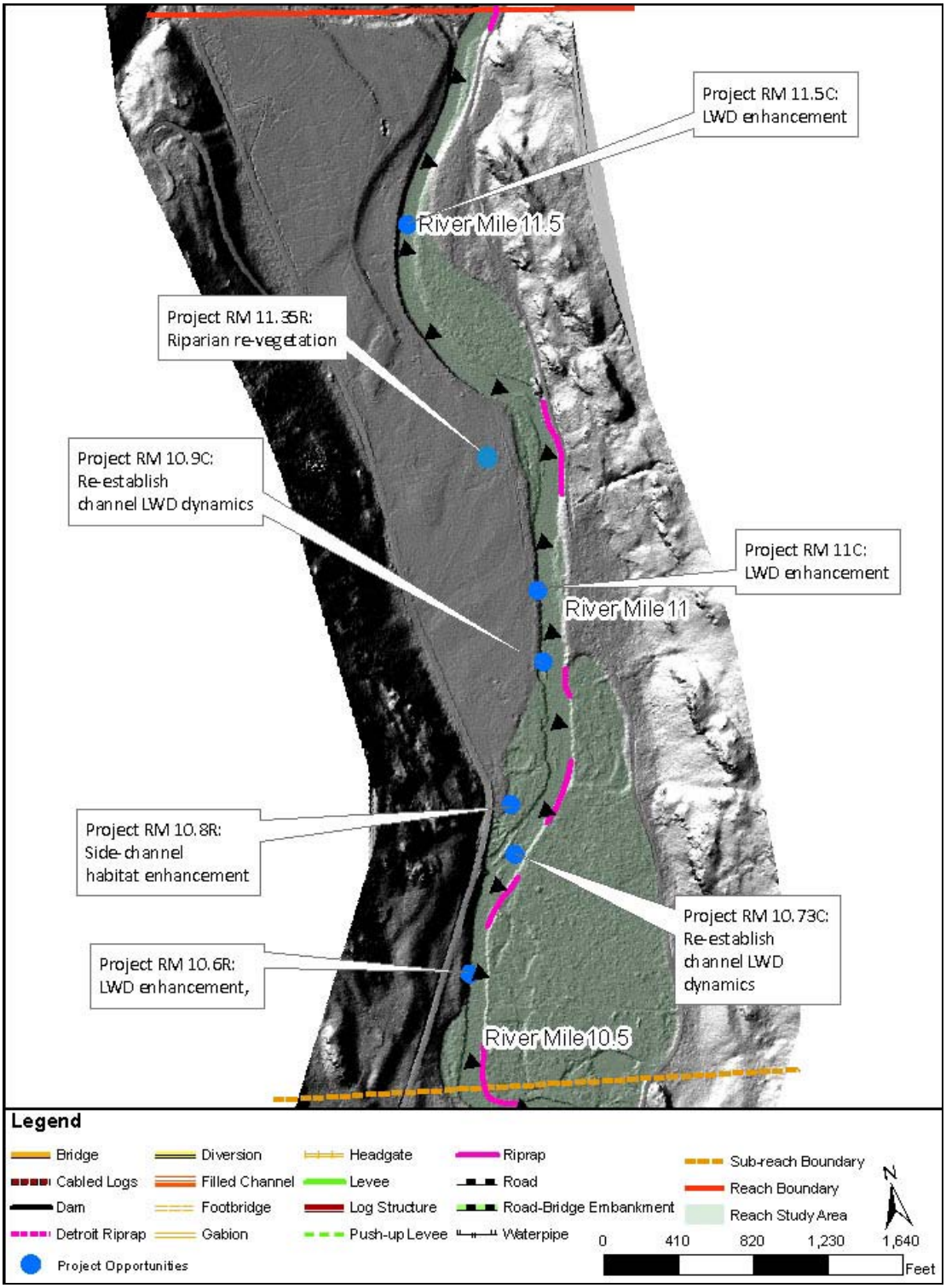

Figure 31. LiDAR hillshade of reach C4c illustrating topography in relation to human features and project locations in the reach. Flow is from north to south.

Table 31. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C4c.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-1	IZ-1 includes the entire inner zone of Reach C4c. IZ-1 is a cobble/gravel channel with low sinuosity and poorly developed riffle-pool sequences. Pools are shallow and sediment contributed by Eightmile Creek has resulted in downstream substrate embededness (USFS 2008). There is very little LWD in IZ-1.	Protect and Maintain Reconnect Stream Channel Processes Riparian Restoration In-Stream Habitat Enhancement	***Project RM 10.9C*** Re-establish channel LWD dynamics ***Project RM 10.73C*** Re-establish channel LWD dynamics ***Project RM 11.5C*** LWD enhancement. ***Project RM 11C*** LWD enhancement. ***Project RM 10.6R*** LWD enhancement.	Upland agricultural development west of the channel in the upstream half of the reach. Roadway parallel to the channel on east side of the valley, directly impinging on the channel in several locations. Residential development with associated bank hardening along river left in the downstream third of the reach.
OZ-1	OZ-1 is a small, 0.6-acre floodplain that provides a narrow riparian buffer at the toe of the hillslope. Terrestrial habitat is provided by intact riparian vegetation, but there is no off-channel aquatic habitat provided.	Protect and Maintain		A roadway parallels the hillslope side of the sub-unit for its entire length.
OZ-2	At 6.6 acres, OZ-2 is the largest connected floodplain sub-unit in Reach C4c. The floodplain has formed on the inside of a meaner bend where the channel is migrating to the west and eroding an adjacent glacial terrace. There is no topographic evidence of a strong high flow connection to inner-zone processes such as a high-flow channel network. There are no off-channel habitat features. The riparian forest is intact and provides thermal shading and the potential for LWD recruitment.	Protect and Maintain		A roadway parallels the hillslope side of the sub-unit for its entire length.

Table 31. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C4c.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
OZ-3	OZ-3 is another small (1.3 acre) and undeveloped floodplain that has formed on the inside of a low amplitude meander centered on RM 11.2. Though small, this floodplain provides the only evidence of a connected high-flow channel and the potential for connected off-channel habitat.	Protect and Maintain	***Project RM 11.35R*** Riparian re-vegetation	Agricultural development of the adjacent terrace.
OZ-4	OZ-4 is similar to OZ-1 in its location and morphology. The sub-unit provides a 0.5 acre riparian buffer at the toe of a glacial terrace. Terrestrial habitat is provided by intact riparian vegetation but there is no off-channel aquatic habitat provided.	Protect and Maintain		A roadway parallels the hillslope side of the sub-unit for its entire length.
DOZ-1	DOZ-1 is the largest (39.3) floodplain area in Reach C4c. As with other large, accessible floodplains along the Chewuch, this area has been developed. The primary use is residential, with most of the development located at the downstream end of the sub-unit. There has been significant riparian clearing along the edge of the channel adjacent to residences. The stability created by vegetation has been replaced with riprap in many locations. The potential for LWD recruitment is greatly reduced. There is a large wetland at the downstream end of the sub-unit. The wetland currently has a surface connection to the channel and provides off-channel habitat that is rare in this reach.	Protect and Maintain Reconnect Floodplain Processes	*Work to address disconnected floodplain (eg. Riprap modification, removal, off-channel habitat restoration).*	Residential development throughout the sub-unit. Riprap in several locations along the channel margin protecting residences.

Table 31. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C4c.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
DOZ-2	Though classified as disconnected, there is geomorphic evidence that OZ-2 shares a hydrologic connection with the inner-zone at high flow. There is one fairly well-defined high flow channel on the surface. This channel does not look frequently scoured but may become seasonally wet and provides outflow at the downstream end of the sub-unit. The disconnection in this sub-unit is derived from spoil piles that are found near the road paralleling the sub-unit. The piles run along the shared margin between the floodplain and the agriculturally developed uplands and disrupt the flow path between the floodplain and channel.	Protect and Maintain Reconnect Floodplain Processes Off-Channel Habitat Enhancement	***Project RM 10.8R*** Off-channel habitat enhancement *Work to address disconnected floodplain (eg. removal/modification of spoil piles).*	A roadway parallels the hillslope side of the sub-unit for its entire length. Agricultural development of the adjacent terrace.
OZ-5	OZ-5 is similar to the other small (1.0 acre) floodplains that are formed where the channel has eroded and migrated across the margin of a terrace. However, this small area has some residential development that includes leveling of the surface and clearing riparian vegetation at the upstream end of the sub-unit. There is no off-channel habitat or high-flow channels in this sub-unit.	Protect and Maintain		A roadway parallels the hillslope side of the sub-unit for its entire length. Residential development near the upstream end.

[1]*For additional information on specific identified project opportunities, see Chewuch Project Opportunities list in Appendix B.*

C5a – Reach Assessment

12 C5A REACH ASSESSMENT

12.1 Reach Overview

Reach C5a is unconfined. Sinuosity is low; however there are well-connected floodplain channels and active side-channels providing high quality habitat and complexity. Human alteration is minor and primarily includes a roadway that parallels the channel along the east side of the reach along the hillslope toe. There are also camping areas on terraces and in the floodplain.

Habitat Conditions and Fish Use

Salmonid use of Reach C5a includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. The reach is heavily used for spring Chinook and steelhead spawning, rearing, and migration. Annual steelhead redd counts from 2003 to 2007 from Eightmile Creek to Falls Creek Campground (spans Reaches C5a through C6) have an average of 6.4 redds/mile. Spring Chinook redd counts from 2001 to 2007 in the same area have an average of 23.9 redds/mile (data from Snow et al. 2008).

Water temperature is elevated throughout the lower Chewuch River, with numerous exceedances of the state water temperature standard during summer months (USBR 2008a). There are no irrigation diversions within or upstream of the reach.

Reaches C5a through C6 had relatively abundant amounts of in-channel LWD during stream surveys in 2008, with 17.6 pieces of LWD/mile (USFS 2008). Pools were also relatively abundant, comprising approximately 46% of the habitat area. The surveys found excellent spawning gravel and noted that these reaches were some of the most productive in the Chewuch River for steelhead and spring Chinook. A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 32.

Table 32. Reach-Based Ecosystem Indicators (REI) ratings for Reach C5a. These REI ratings cover reaches C5a, C5b, and C6. See Appendix A for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach C5/6 Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*Adequate*
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*At Risk*
	LWD	Pieces per Mile at Bankfull	*Unacceptable*
	Pools	Pool Frequency and Quality	*Adequate*
	Off-Channel Habitat	Connectivity with Main Channel	*Adequate*
Channel	Dynamics	Floodplain Connectivity	*At Risk*
		Bank Stability/ Channel Migration	*Adequate*
		Vertical Channel Stability	*Adequate*

General Characteristics	General Indicators	Specific Indicators	Reach C5/6 Condition
Riparian Vegetation	Condition	Structure	*No Data*
		Disturbance (Human)	*Adequate*
		Canopy Cover	*At Risk*

Hydrology

There are no major surface water inputs in this reach. Falls Creek is the nearest upstream tributary near RM 14. There is abundant open water on the floodplain in this reach around RM 12.3, suggesting a near surface groundwater table and potentially strong groundwater/surface water connection. Table 33 provides the results of flood magnitude estimates for several recurrence intervals derived from a watershed analysis performed by the USBR (2008b).

Table 33. Flood magnitudes for recurrence intervals from 2 to 100 years for a point near the downstream end of Reach C5a (RM 11.9). Obtained from Methow River Basin GIS hydrology database (USBR 2008b).

Location	River Mile	Flood Recurrence Interval (ft^3/sec)					
		Q2	Q5	Q10	Q25	Q50	Q100
Downstream End	11.9	2,088	3,202	3,925	4,807	5,437	6,044

Geomorphology

Natural constraints on valley and floodplain width in C5a are similar to more confined reaches downstream. The distance between bounding bedrock hills is similar and the valley is filled with glacial and alluvial fan deposits. From RM 12.2 to 12.7, lateral channel migration has eroded the margins of glacial terraces and has formed a wide floodplain surface. Channel slope is locally controlled by the alluvial fan of Eightmile Creek. Slope is steeper downstream of the fan, creating a straight, coarse bed channel that adjusts vertically. Upstream of the fan the gradient is flatter and the channel accumulates sediment and adjusts laterally.

Sinuosity in C5a is 1.19. The upstream end of the reach has low amplitude, long wavelength meanders. In the downstream half of the reach, beginning near RM 12.4, the channel has been actively migrating over the past 100 years. At one location, a tight meaner lobe that was the low-flow channel in 1985 was cut-off and now contains floodplain wetlands. The modern active channel has multiple locations of split-flow and large backwaters. The bed of the channel is composed of gravel and cobble organized in riffle-pool and riffle-run sequences. Above Eightmile Creek there are fewer fines on the bed, and gravels are not as embedded and provide good spawning gravels (USFS 2008).

Human Alteration

Channel processes, floodplain processes, and habitat are in a relatively naturally functioning state in this reach (Figure 32). There are no direct modifications to the channel and there appears to be well-connected floodplains and active lateral channel dynamics. The channel flows against a road embankment at some locations along the east side of the valley. However, the road is set on

a bedrock hillslope that provides a natural lateral constraint. There is some semi-maintained camping on the west side of the valley in the widest portion of the floodplain near RM 12.5. Some of the campsites and access roads block floodplain channels and seasonal wetlands (USBR 2006). There are approximately 430 ft of riprap along river-left at the downstream end of the reach.

Figure 32. Aerial photo showing human features in Reach C5a. Flow is from north to south.

12.2 Reach Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach C5a is included below. The strategy focuses first on protecting existing conditions from further impairment. This objective is followed by reconnecting the fundamental bio-physical processes that will create and maintain habitat conditions over the long-term. Off-channel habitat enhancement (rehabilitation) is also included; these projects occur in conjunction with long-term process reconnection and are also applied in cases where long-term process reconnection is constrained by existing human uses. The USBR (2008b) suggests taking an active restoration approach in this reach. The primary objectives suggested by the USBR are to "reconnect the low surface" and to "reconnect primary side-channels". The restoration concepts behind achieving these goals are removing riprap and excavating to enhance side-channel connectivity.

1. ***Protect and Maintain***
   - **Prevent Further Degradation**- Opportunities to prevent further degradation should be pursued including purchasing land and water rights in the river corridor, and/or obtaining conservation easements. Water rights acquisition should be focused on increasing instream flow during late summer.
   - **Legal Protection**- Existing enforced legal protection is considered an intrinsic component of all potential projects.

2. ***Reconnect Stream Channel Processes***
   - **Riprap**- Remove or modify features to restore dynamic processes. There are barriers to channel/floodplain connection on river left throughout the reach. Where feasible, riprap and levees should be removed or modified to increase floodplain and channel migration zone connectivity.
   - **Channel Dynamics**- Address loss of multi-thread channel complexity resulting from loss of wood dynamics. LWD jams are important to geomorphic process and their frequency and function have been reduced by past land-use practices. Where feasible, LWD jams can be placed in areas where they would naturally occur and where processes such as bar deposition, pool scour, lateral channel migration, and natural rates of recruitment can be re-established.

3. ***Reconnect Floodplain Processes***
   - **Floodplain Development**- Modest recreational floodplain development has taken place to the west of the channel near RM 12.5. This includes state managed camping and sportsman's access in the floodplain. Impacts from this development include unculverted roads and clearing. Work with appropriate stakeholders to develop long-term solutions to floodplain impacts.

4. ***Riparian Restoration***
   - **Restore Riparian Areas** – Riparian clearing on the west side of the valley occurs near the downstream end of the reach. There is a riparian buffer left along the channel margin that provides some shade and potential LWD recruitment. However,

the narrow buffer does not provide significant riparian habitat. Work should continue to expand the riparian buffer.

5. ***In-Stream Habitat Enhancement***
   - **Enhance Habitat Complexity**- Instream large wood is a natural component of this system that has been reduced by past land-use practices. Wood creates pool scour, cover, and channel complexity. Place wood in configurations and locations that mimic natural wood deposition processes. These projects are not replacements for process restoration, but are meant to provide intermediate habitat enhancement while process restoration matures.

6. ***Off-Channel Habitat Enhancement***
   - **Enhance Off-Channel Habitat Complexity**- There are multiple off-channel features in this reach. Low cost restoration could potentially provide large habitat improvements. Natural activity of beavers can result in enhanced off-channel habitat and may be considered as a restoration option.

12.3 Sub-Unit and Project Opportunity Summary

Six sub-units were identified in Reach C5a, including two inner zone sub-units and four outer zone sub-units (Table 34, Figure 33, Figure 34). There are no disconnected inner or outer zone sub-units in this reach. Thirteen specific project opportunities are identified in this reach and are presented in the sub-unit summary section (Table 35).

Table 34. Summary of protection and restoration opportunities for Reach C5a.

Sub-Unit	River Mile	Acreage
Inner Zone 1 (IZ-1)	12.4-12.97	N/A
Outer Zone 1 (OZ-1)	12.6-13.2	9.2
Outer Zone 2 (OZ-2)	11.93-12.98	54.5
Inner Zone 2 (IZ-2)	11.7-12.4	N/A
Outer Zone 3 (OZ-3)	12.18-12.32	3.0
Outer Zone 4 (OZ-4)	11.83-12.12	5.4

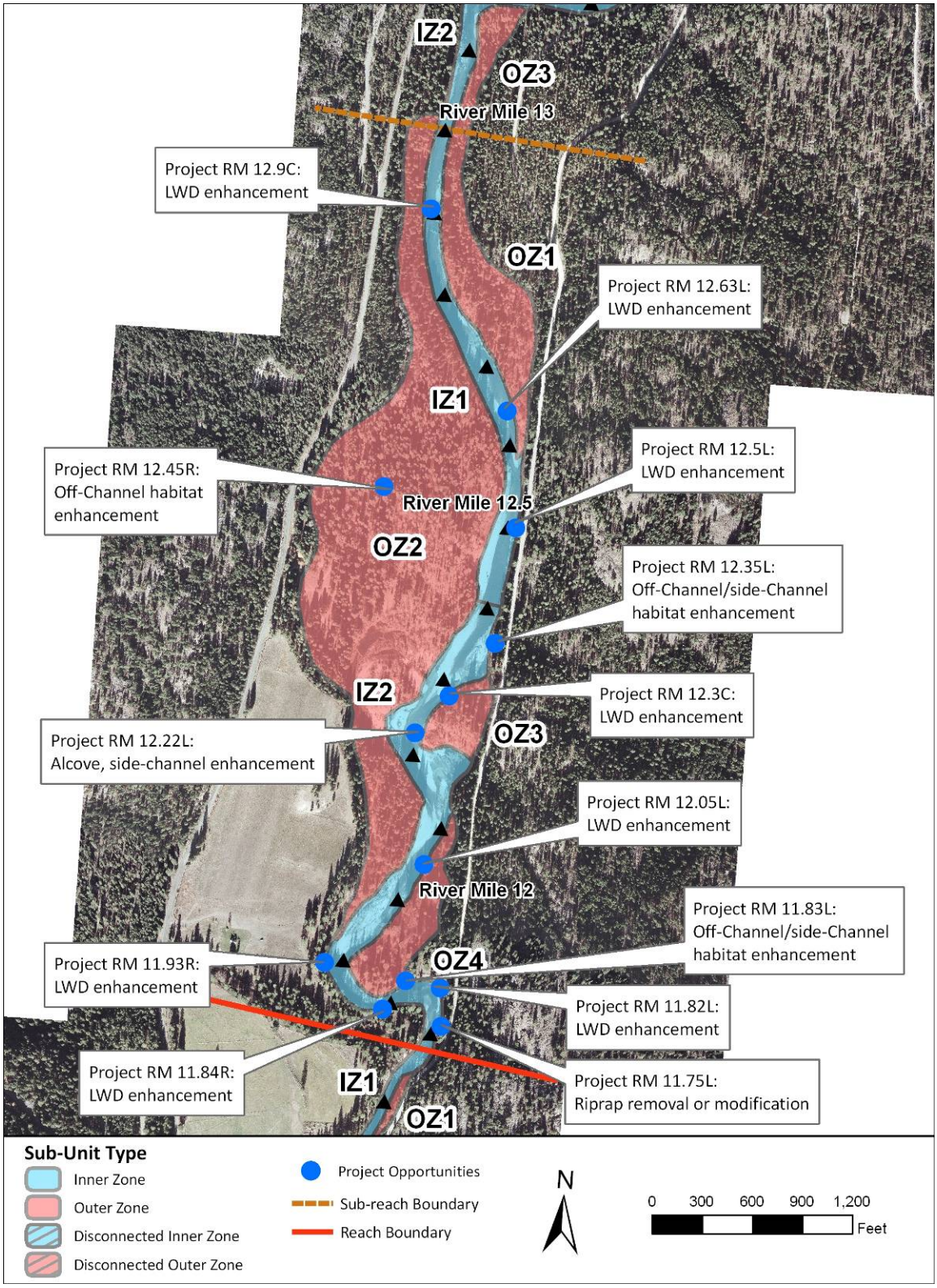

Figure 33. Sub-units and project opportunities in Reach C5a. Flow is from north to south.

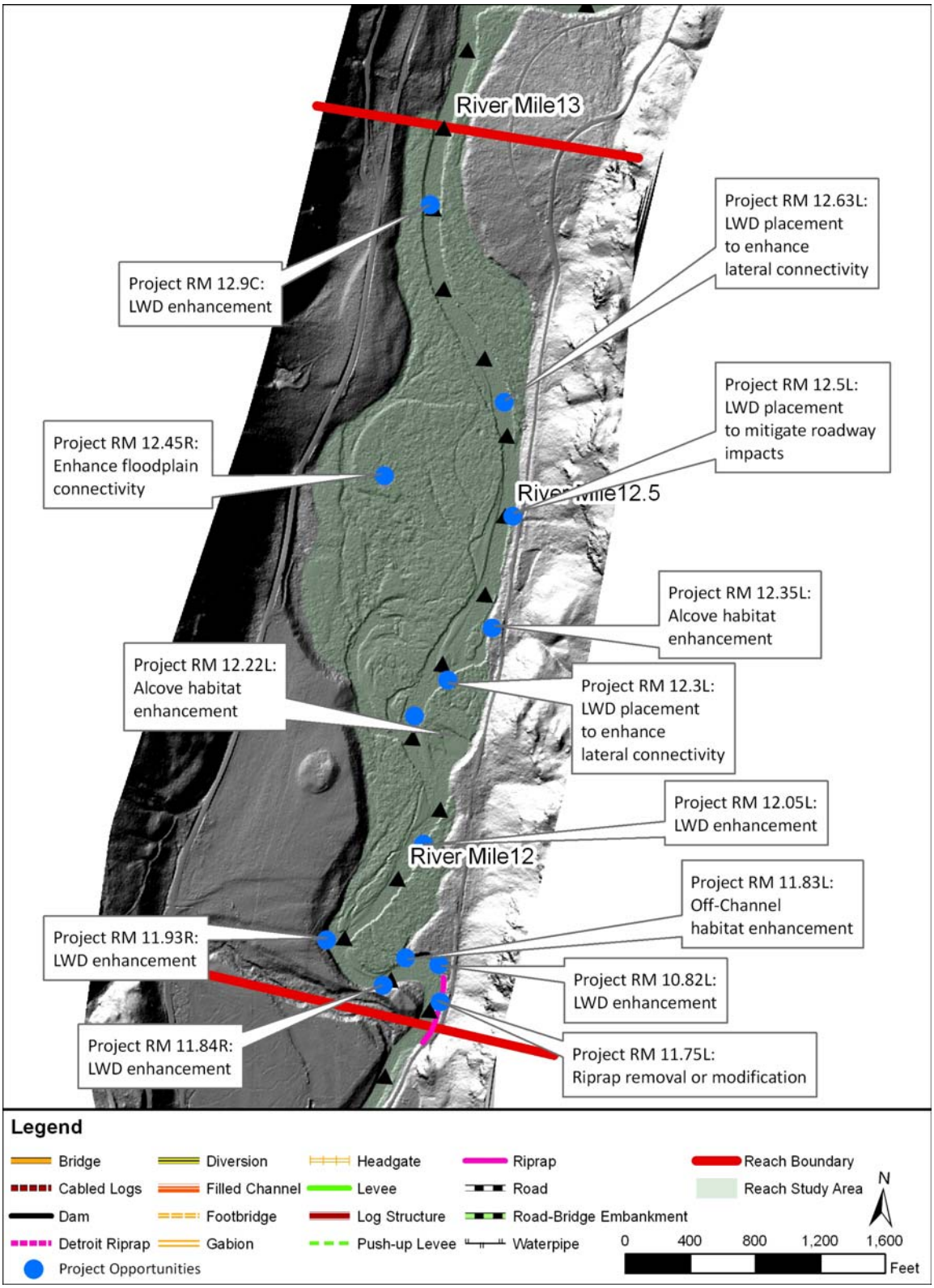

Figure 34. LiDAR hillshade of reach C5a illustrating topography in relation to human features and project locations in the reach. Flow is from north to south.

Table 35. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C5a.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-1	IZ-1 is confined in its upper portion by an alluvial fan to the east and a glacial terrace to the west. Moving downstream, the channel has eroded out segments of glacial terrace constructing a relatively wide floodplain surface that shows evidence of historical meander migration and current high-flow connection. Currently, the channel is located at the extreme east side of the valley against the hillslope, which limits further eastward migration. The bed morphology is a long run with gravel and cobble bed material. There is notable bank erosion in this sub-unit.	Protect and Maintain Reconnect Stream Channel Processes In-Stream Habitat Enhancement	***Project RM 12.63L*** LWD placement to enhance lateral connectivity. ***Project RM 12.5L*** LWD placement to mitigate roadway impacts. ***Project RM 12.9C*** LWD enhancement.	Roadway parallel to the channel on east side of the valley, directly impinging on the channel near the downstream end of the sub-unit.
OZ-1	OZ-1 is a 9.2 acre floodplain area formed along the toe of an alluvial fan along the east side of the valley. The surface is narrow at the upstream end and expands in the downstream direction. There are no high-flow channels or off-channel habitat in this sub-unit. However, the riparian forest is intact and provides a buffer between channel and hillslope processes. There is good potential for recruitment of LWD.	Protect and Maintain		A roadway parallels the hillslope side of the sub-unit near its downstream end.

Table 35. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C5a.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
OZ-2	At 54.5 acres, OZ-2 is the largest floodplain surface in Reach C5a. OZ-2 is actively connected to inner zone processes. There is topographic evidence of recent lateral channel migration and floodplain formation. These processes have left a floodplain with high-flow channel networks, meander scars, and large oxbow wetlands providing off-channel habitat. At RM 12.4 there is a developed recreation area and roads lead to several unimproved campsites in the floodplain. These roads block several high flow channels and there is vegetation clearing throughout the camping area. Aside from this, the riparian forest is intact in OZ-2.	Protect and Maintain Reconnect Floodplain Processes	***Project RM 12.45R*** Enhance floodplain connectivity.	Developed camping on state lands.

Table 35. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C5a.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-2	Channel complexity increases in IZ-2. Based on the aerial photo record, an avulsion occurred here between 1985 and 2004,leaving multiple split flow channels, a large backwater, and connected off-channel habitat. Sinuosity increases in the downstream direction, with large active gravel bars and associated riffle-pool sequences. Active bank erosion and intact riparian forests provide the means and source for future in channel LWD.	Protect and Maintain Reconnect Stream Channel Processes In-Stream Habitat Enhancement Off-Channel Habitat Enhancement	***Project RM 12.3C*** LWD placement to enhance lateral connectivity. ***Project RM 12.05L*** LWD enhancement. ***Project RM 11.93R*** LWD enhancement ***Project RM 11.84R*** LWD enhancement ***Project RM 11.82L*** LWD enhancement ***Project RM 11.75L*** Riprap removal or modification ***Project RM 12.35L*** Alcove habitat enhancement ***Project RM 12.22L*** Alcove and side-channel habitat enhancement.	A roadway parallels the entire length of the sub-unit along the east side of the valley.
OZ-3	Prior to the channel avulsion that occurred between 1985 and 2004, this floodplain area was the inside of a large, tortuous meander bend. The avulsion truncated the meander, isolating this smaller (3.0 acres) floodplain area. OZ-3 provides a connection between channel and floodplain processes; there is a high flow channel that connects backwater areas up and downstream of OZ-3.	Protect and Maintain		A roadway parallels the hillslope side of the sub-unit for its entire length.

Table 35. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C5a.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
OZ-4	OZ-4 is a 5.4 acre floodplain that is forming through lateral floodplain accretion as a tight meander migrates down valley into the alluvial fan of Eightmile Creek. The riparian forest is currently undisturbed but the adjacent terrace has dispersed camping where wood gathering and river access pose risks to riparian vegetation an bank stability if not monitored and maintained.	Protect and Maintain Off-Channel Habitat Enhancement	***Project RM 11.83L*** Off-channel habitat enhancement	A roadway parallels the hillslope side of the sub-unit for its entire length. There is dispersed camping on the adjacent terrace.

[1]*For additional information on specific identified project opportunities, see Chewuch Project Opportunities list in Appendix B.*

C5b – Reach Assessment

13 C5B REACH ASSESSMENT

13.1 Reach Overview

Reach C5b is unconfined, low gradient (0.3%), sinuous, and actively meandering across a broad, flat valley with width ranging from 1,200 to 1,700 ft. Glacial terraces bound the valley on both sides. There is very little human development in the reach. Riparian forests are intact except for some agricultural clearing near the upstream end of the reach. Roads parallel the channel on both sides of the valley, but are located on hillslopes above the floodplain.

Habitat Conditions and Fish Use

Salmonid use of Reach C5b includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. The reach is heavily used for spring Chinook and steelhead spawning, rearing, and migration. Annual steelhead redd counts from 2003 to 2007 from Eightmile Creek to Falls Creek Campground (spans Reaches C5a through C6) have an average of 6.4 redds/mile. Spring Chinook redd counts from 2001 to 2007 in the same area have an average of 23.9 redds/mile (data from Snow et al. 2008).

Water temperature is elevated throughout the lower Chewuch River, with numerous exceedances of the state water temperature standard during summer months (USBR 2008a). There are no irrigation diversions within or upstream of the reach.

Reaches C5a through C6 had relatively abundant amounts of in-channel LWD during stream surveys in 2008, with 17.6 pieces of LWD/mile (USFS 2008). Pools were also relatively abundant, comprising approximately 46% of the habitat area. The surveys found excellent spawning gravel and noted that these reaches were some of the most productive in the Chewuch River for steelhead and spring Chinook. A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 36.

Table 36. Reach-Based Ecosystem Indicators (REI) ratings for Reach C5b. These REI ratings cover reaches C5a, C5b, and C6. See Appendix A for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach C5/6 Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*Adequate*
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*At Risk*
	LWD	Pieces per Mile at Bankfull	*Unacceptable*
	Pools	Pool Frequency and Quality	*Adequate*
	Off-Channel Habitat	Connectivity with Main Channel	*Adequate*
Channel	Dynamics	Floodplain Connectivity	*At Risk*
		Bank Stability/ Channel Migration	*Adequate*
		Vertical Channel Stability	*Adequate*
Riparian	Condition	Structure	*No Data*

General Characteristics	General Indicators	Specific Indicators	Reach C5/6 Condition
Vegetation		Disturbance (Human)	*Adequate*
		Canopy Cover	*At Risk*

Hydrology

There are no major tributaries, or other surface inputs or outputs in Reach C5b. Groundwater dynamics are unknown. The reach is above all major diversions and is therefore connected to a natural snowmelt hydrologic regime. Table 37 provides the results of flood magnitude estimates for several recurrence intervals derived from a watershed analysis performed by the USBR (2008b).

Table 37. Flood magnitudes for recurrence intervals from 2 to 100 years for a point near the uptream end of Reach C5b (RM 14.3). Obtained from Methow River Basin GIS hydrology database (USBR 2008b).

Location	River Mile	Flood Recurrence Interval (ft^3/sec)					
		Q2	Q5	Q10	Q25	Q50	Q100
Upstream End	14.3	1,891	2,900	3,555	4,355	4,925	5,474

Geomorphology

The floodplain in Reach C5b is consistently wide due to the space between glacial terraces and the distance between hillslopes. The only natural limitation on valley width is an alluvial fan on the east side of the valley at the downstream end of the reach. The aerial photo record is not extensive in this part of the Chewuch, but available photos show a stable channel location since 1985. However, there is geomorphic evidence of lateral channel migration in the form of channel scars near the downstream end of the reach. High-flow channel networks on the west side of the valley suggest a strong connection between the main channel and floodplain in that area. The active channel is complex and includes several locations of split flow, side channels, and backwater areas. Large gravel point bars create riffle-pool sequences. The bed is composed of gravel and cobble.

Human Alteration

Human alteration of the river corridor in Reach C5b is minimal (Figure 35). There is no manipulation of the channel. There is some clearing of the low surface along the west side of the valley near the upstream end of the reach. The floodplain is otherwise intact. Roads are set on hillslopes above the low surface and have no direct impact on physical or ecological processes.

Figure 35. Aerial photo showing human features in Reach C5b. Flow is from north to south.

13.2 Reach Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach C5b is included below. The strategy focuses first on protecting existing conditions from further impairment. This objective is followed by reconnecting the fundamental bio-physical processes that will create and maintain habitat conditions over the long-term. Off-channel habitat enhancement (rehabilitation) is also included; these projects occur in conjunction with long-term process reconnection and are also applied in cases where long-term process reconnection is constrained by existing human uses. The USBR (2008b) suggests that protection and monitoring are the main objectives in this reach. One restoration area is identified by the USBR with the primary goal being "reconnect the low surface" along the east side of the valley at the downstream end of the reach. The restoration concept behind achieving this goal is removing riprap.

1. ***Protect and Maintain***
   - **Prevent Further Degradation**- Opportunities to prevent further degradation should be pursued including purchasing land and water rights in the river corridor, and/or obtaining conservation easements. Water rights acquisition should be focused on increasing instream flow during late summer.
   - **Legal Protection**- Existing enforced legal protection is considered an intrinsic component of all potential projects.

2. ***Reconnect Stream Channel Processes***
   - **Channel Dynamics**- Address loss of multi-thread channel complexity resulting from loss of wood dynamics. LWD jams are important to geomorphic process and their frequency and function have been reduced by past land-use practices. Where feasible, LWD jams should be placed in areas where they would naturally occur and where processes such as bar deposition, pool scour, lateral channel migration, and natural rates of recruitment can be re-established.

3. ***Reconnect Floodplain Processes***
   - **Floodplain Development**- Floodplain development has taken place to the west of the channel near the upstream end of the reach. Clearing is the primary impact of this development. Work with appropriate stakeholders to develop long-term solutions to floodplain impacts.

4. ***Riparian Restoration***
   - **Restore Riparian Areas** – Riparian clearing on the west side of the valley occurs near the upstream end of the reach. There is a riparian buffer left along the channel margin that provides some shade. However, the narrow buffer does not provide a sustainable source of LWD or significant riparian habitat. Work should continue to expand the riparian buffer.

5. ***In-Stream Habitat Enhancement***
   - **Enhance Habitat Complexity**- Instream large wood is a natural component of this system that has been reduced by past land-use practices. Wood creates pool scour, cover, and channel complexity. Place wood in configurations and locations that mimic natural wood deposition processes. These projects are not replacements for process restoration, but are meant to provide intermediate habitat enhancement while process restoration matures.

6. ***Off-Channel Habitat Enhancement***
   - **Enhance Off-Channel Habitat Complexity**- There are multiple off-channel features in this reach. Low cost restoration could potentially provide large habitat improvements. Natural activity of beavers can result in enhanced off-channel habitat and may be considered as a restoration option.

13.3 Sub-Unit and Project Opportunity Summary

Six sub-units were identified in Reach C5a, including two inner zone sub-units, three outer zone sub-units, and one disconnected outer zone sub-unit (Table 38, Figure 36). The majority of the outer zone is connected, with only 24% disconnected due to agricultural development. Eight specific project opportunities are identified in this reach and are presented in the sub-unit summary section (Table 39).

Table 38. Summary of protection and restoration opportunities for Reach C5b.

Sub-Unit	River Mile	Acreage
Inner Zone 1 (IZ-1)	13.34-14.1	N/A
Outer Zone 1 (OZ-1)	13.4-14.7	24.2
Disconnected Outer Zone 1 (DOZ-1)	13.57-14.1	16.2
Outer Zone 2 (OZ-2)	13.1-13.57	23.3
Inner Zone 2 (IZ-2)	12.97-13.34	N/A
Outer Zone 3 (OZ-3)	12.97-13.18	2.5

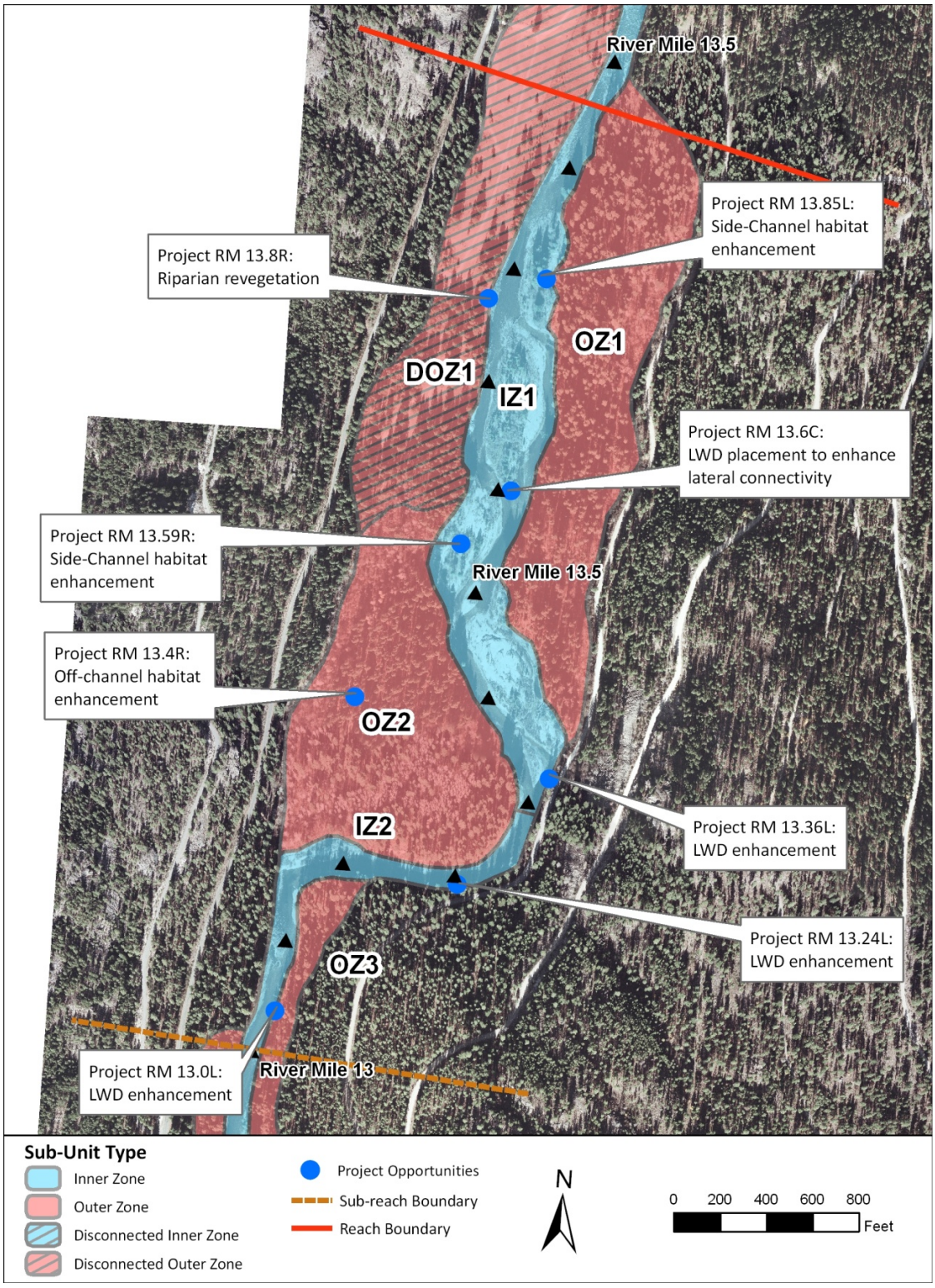

Figure 36. Sub-units and project opportunities in Reach C5b. Flow is from north to south.

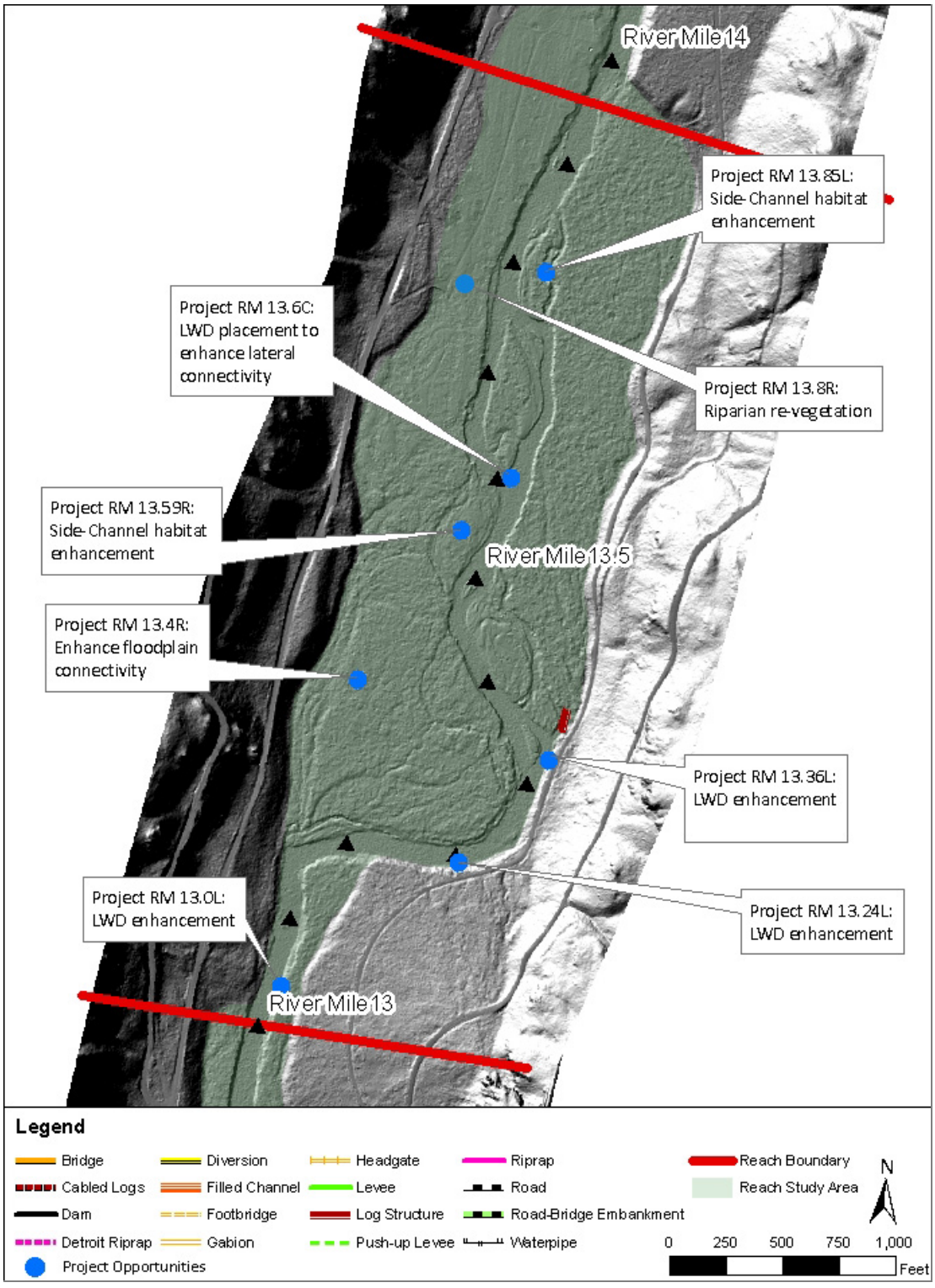

Figure 37. LiDAR hillshade of reach C5b illustrating topography in relation to human features and project locations in the reach. Flow is from north to south.

Table 39. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C5b.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-1	The active channel of IZ-1 is wide, sinuous, and complex and includes multiple locations of split flow around stable vegetated islands and high flow channels. This pattern has been stable since at least 1985. Bed morphology is riffle-pool with gravel and cobble bed material. There is a substantial amount of LWD, particularly at bar apex locations. Active erosion provides a potential for future recruitment of LWD. The sub-unit is unconfined except for a small portion at the downstream end of the reach where the channel flows against the bedrock hillslope. There is a road on the slope and some natural revetment in the form of a log structure near RM 13.37 on river-left.	Protect and Maintain Reconnect Stream Channel Processes In-Stream Habitat Enhancement Off-Channel Habitat Enhancement	***Project RM 13.6C*** LWD placement to enhance lateral connectivity ***Project RM 13.36L*** LWD enhancement. ***Project RM 13.85L*** Side-Channel habitat enhancement ***Project RM 13.59R*** Side-Channel habitat enhancement.	Roadway parallel to the channel on east side of the valley, directly impinging on the channel near the downstream end of the sub-unit.
OZ-1	OZ-1 is the largest floodplain area in Reach C5b at 24.2 acres. There are no active high-flow channels or off-channel habitat. However, the sub-unit is undisturbed and provides quality riparian habitat and function. There is active LWD recruitment along the channel margin.	Protect and Maintain		A roadway parallels the hillslope side of the sub-unit for its entire length.
DOZ-1	DOZ-1 is a 23.3 acre floodplain area on the west side of the valley between RM 13.57 and 14.1. Agricultural development of this sub-unit has resulted in degraded riparian conditions. The most intense clearing is at the upstream end of the sub-unit. Riparian vegetation is essentially gone, and there is a road across the surface down to approximately RM 13.7. There is less clearing at the downstream end of DOZ-1, where the floodplain transitions into a connected outer zone.	Protect and Maintain Reconnect Floodplain Processes Riparian Restoration	***Project RM 13.8R*** Riparian re-vegetation. *Continue to identify opportunities to reconnect floodplain, restore riparian vegetation.*	Agricultural development and unmaintained camping.

Table 39. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C5b.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
OZ-2	OZ-2 is the undeveloped continuation of DOZ-1. The sub-unit is 16.2 acres located along the west side of the valley. Starting along the margin of DOZ-1, there are multiple high flow channel networks across the entire surface. The riparian forest is undisturbed and provides potential LWD recruitment. The downstream outlet of the high-flow network flows into a sheltered side-channel within IZ-2 near RM 13.15.	Protect and Maintain Reconnect Floodplain Processes	***Project RM 13.4R*** Enhance floodplain connectivity	A roadway parallels the hillslope side of the sub-unit for its entire length.
IZ-2	As the river flows against hillslope deposits on the east side of the valley near RM 13.35, the inner zone loses complexity. The channel goes from a multi-thread pattern to a single-thread pattern. Sinuosity is maintained and there is some side-channel habitat. However, the channel is more confined and not as laterally dynamic.	Protect and Maintain In-Stream Habitat Enhancement	***Project RM 13.24L*** LWD enhancement. ***Project RM 13.0L*** LWD enhancement.	A roadway parallels the entire length of the sub-unit along the east side of the valley and at the downstream end of the sub-unit on the west side.
OZ-3	OZ-3 is a narrow sub-unit occupying 2.5 acres along the west side of the valley. The floodplain has formed where the channel has re-worked alluvial fan deposits. The sub-unit is continued in Reach C5a. OZ-3 is undisturbed, providing quality riparian habitat, a buffer between channel and hillslope processes, and a source of LWD.	Maintain and Protect Reconnect Floodplain Processes	***CR_Prj-13.3*** (USBR 2008b)	A roadway parallels the hillslope side of the sub-unit for its entire length. There is dispersed camping on the adjacent terrace.

[1]*For additional information on specific identified project opportunities, see Chewuch Project Opportunities list in Appendix B.*

C6 – Reach Assessment

14 C6 REACH ASSESSMENT

14.1 Reach Overview

Reach C6 is a short (0.4 mile), confined reach that extends from RM 13.98 up to near the confluence with Falls Creek. The channel is relatively straight, with coarse bed material and little habitat complexity. Human disturbance occurs mainly on the alluvial fans to the east and west of the channel in the form of campgrounds and roads.

Habitat Conditions and Fish Use

Salmonid use of Reach C6 includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. The reach is heavily used for spring Chinook and steelhead spawning, rearing, and migration. Annual steelhead redd counts from 2003 to 2007 from Eightmile Creek to Falls Creek Campground (spans Reaches C5a through C6) have an average of 6.4 redds/mile. Spring Chinook redd counts from 2001 to 2007 in the same area have an average of 23.9 redds/mile (data from Snow et al. 2008).

Water temperature is elevated throughout the lower Chewuch River, with numerous exceedances of the state water temperature standard during summer months (USBR 2008a). There are no irrigation diversions within or upstream of the reach.

Reaches C5a through C6 had relatively abundant amounts of in-channel LWD during stream surveys in 2008, with 17.6 pieces of LWD/mile (USFS 2008). Pools were also relatively abundant, comprising approximately 46% of the habitat area. The surveys found excellent spawning gravel and noted that these reaches were some of the most productive in the Chewuch River for steelhead and spring Chinook. A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 40.

Table 40. Reach-Based Ecosystem Indicators (REI) ratings for Reach C6. These REI ratings cover reaches C5a, C5b, and C6. See Appendix A for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach C5/6 Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*Adequate*
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*At Risk*
	LWD	Pieces per Mile at Bankfull	*Unacceptable*
	Pools	Pool Frequency and Quality	*Adequate*
	Off-Channel Habitat	Connectivity with Main Channel	*Adequate*
Channel	Dynamics	Floodplain Connectivity	*At Risk*
		Bank Stability/ Channel Migration	*Adequate*
		Vertical Channel Stability	*Adequate*
Riparian	Condition	Structure	*No Data*

General Characteristics	General Indicators	Specific Indicators	Reach C5/6 Condition
Vegetation		Disturbance (Human)	*Adequate*
		Canopy Cover	*At Risk*

Hydrology

The hydrology of this reach is affected by the inflow of Falls Creek, which is a relatively large tributary to the Chewuch River contributing about 4 cfs during low flow periods. The reach is above any major diversions, so the hydrology is a natural snowmelt runoff regime. Table 41 provides the results of flood magnitude estimates for several recurrence intervals derived from a watershed analysis performed by the USBR (2008b).

Table 41. Flood magnitudes for recurrence intervals from 2 to 100 years for a point near the upstream end of Reach C6, and for the mouth of Falls Creek (RM 14.3). Obtained from Methow River Basin GIS hydrology database (USBR 2008b).

Location	River Mile	Flood Recurrence Interval (ft^3/sec)					
		Q2	Q5	Q10	Q25	Q50	Q100
Upstream End	14.3	1,891	2,900	3,555	4,355	4,925	5,474
The mouth of Falls Creek	14.3	206	310	383	481	558	637

Geomorphology

This reach is narrowly confined by alluvial fans on both sides of the valley. Falls Creek forms the fan to the west of the channel. This is an active tributary contributing sediment and flow to the main channel of the Chewuch. There are multiple channels on the fan that could be activated at varying flow levels. The fan of Butte Creek has formed to the east of the channel. Butte Creek is an ephemeral tributary. There are no well defined channels on this inactive fan. Within this confinement, the channel is fairly straight and simple. There are side-channels and the bed morphology is mainly long glides.

Human Alteration

What little floodplain area there is in this reach has been cleared and developed for recreation and agriculture (Figure 38). There are unimproved camping and grazing areas, as well as roads across the surface. There are no direct alterations to the channel.

Figure 38. Aerial photo showing human features in Reach 6. Flow is from north to south.

14.2 Reach Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach C6 is included below. The strategy focuses on protecting existing conditions from further impairment. Project RM 13.8 in Reach C5b will involve work in OZ-1 of this reach.

1. ***Protect and Maintain***
   - **Prevent Further Degradation**- Opportunities to prevent further degradation should be pursued including purchasing land and water rights in the river corridor, and/or obtaining conservation easements. Water rights acquisition should be focused on increasing instream flow during late summer.
   - **Legal Protection**- Existing enforced legal protection is considered an intrinsic component of all potential projects.

14.3 Sub-Unit and Project Opportunity Summary

Two sub-units were identified in Reach C6, including one inner zone sub-unit and one outer zone sub-unit (Table 42, Figure 39). The small area of outer zone in this reach is disconnected due to clearing and grading to support recreational uses. No project opportunities were identified in this reach (Table 43).

Table 42. Summary of protection and restoration opportunities for Reach C6.

Sub-Unit	River Mile	Acreage
Inner Zone 1 (IZ-1)	13.9-14.3	N/A
Outer Zone 1 (OZ-1)	13.9-14.12	5.9

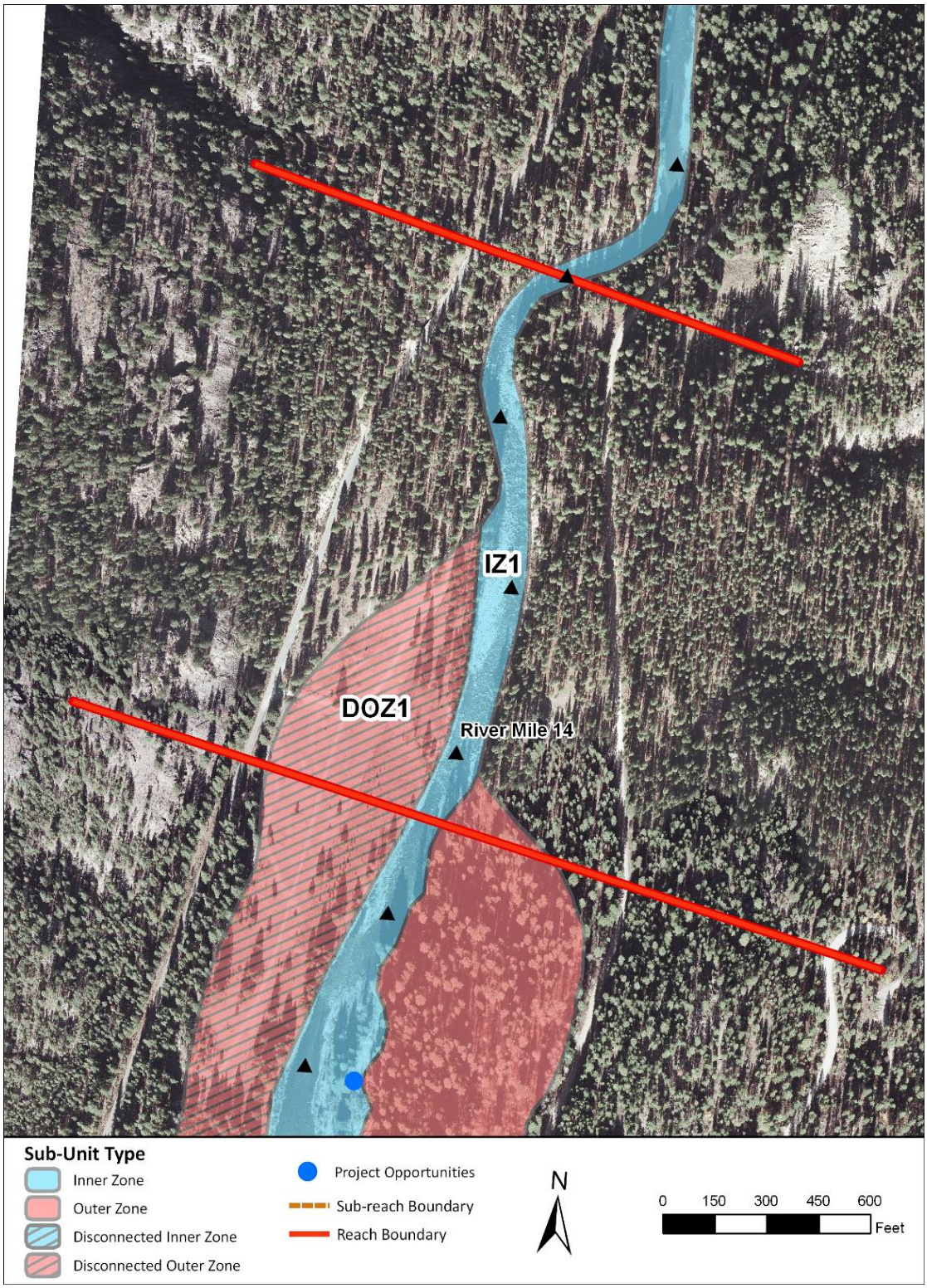

Figure 39. Sub-units in Reach C6. Flow is from north to south.

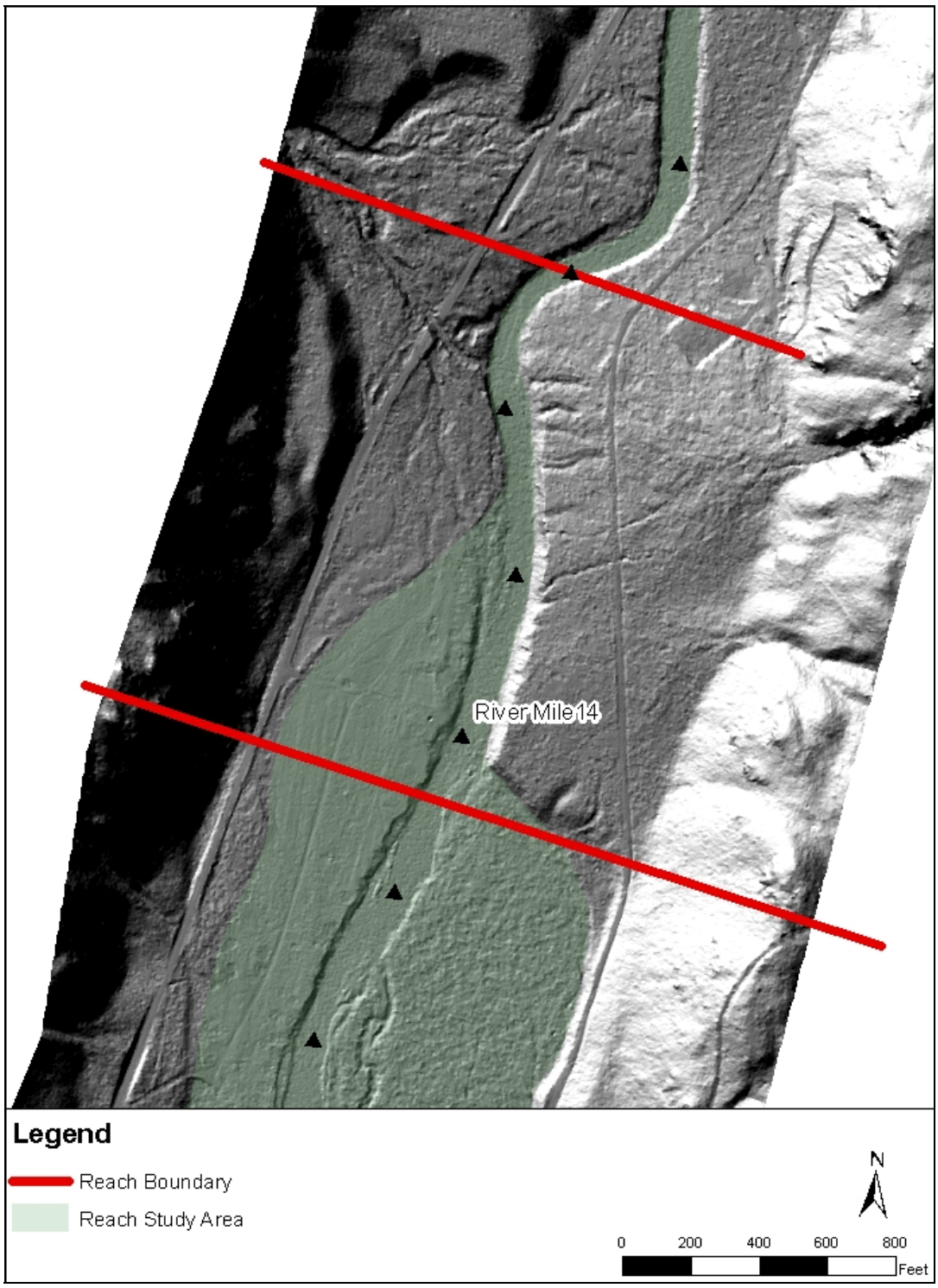

Figure 40. LiDAR hillshade of reach C6 illustrating topography in relation to human features and project locations in the reach. Flow is from north to south.

Table 43. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C6.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-1	IZ-1 is highly confined between alluvial fan deposits that impinge upon both sides of the channel. The Falls Creek alluvial fan forms the left bank of the Chewuch through the reach. It is a high, actively eroding bank that supplies sand up to boulder size sediment to the Chewuch. The Butte Creek fan, which is older and more stable, forms the right bank. Though it appears the channel has re-worked the toe of the deposit, it is not actively eroding at this time. The influence of alluvial fan processes on both sides of the channel dominates the geomorphology in this sub-unit. The channel is straight, aside from a small meander at the upstream end. Channel morphology is step-pool and boulder run with cobble bed material and frequent boulders.	Protect and Maintain		No apparent constraints.
OZ-1	This is the upstream portion of a floodplain that continues into the downstream reach along the west side of the valley. This 5.9 acre area has been completely cleared except for some trees along the channel. There is a network of unimproved roads on the floodplain surface. Topographic evidence suggests that this area is influenced by alluvial fan processes as well as river processes. Project RM 13.8R described in Reach C5b will work to re-vegetate the native riparian community in this sub-unit.	Protect and Maintain		Agricultural and recreational development throughout the sub-unit.

[1]*For additional information on specific identified project opportunities, see Chewuch Project Opportunities list in Appendix B.*

C7 – Reach Assessment

15 C7 REACH ASSESSMENT

15.1 Reach Overview

Reach C7 is a confined reach flowing between alluvial fan deposits to the east and bedrock and glacial deposits to the west. Habitat complexity is low in this reach, with few pools, no side-channels, and reduced fish production in comparison to the C5 reaches (USFS 2008). There is very little human activity affecting the channel or floodplain areas. There are roads that parallel the river corridor on both sides of the valley for the entire length of the reach, but they do not impinge on the channel or floodplain except for short distances.

Habitat Conditions and Fish Use

Salmonid use of Reach C7 includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. The reach is used for spring Chinook and steelhead spawning, rearing, and migration. Annual steelhead redd counts from 2003 to 2007 from Falls Creek Campground to Chewuch Campground (spans Reaches C7 and C8) have an average of 3.5 redds/mile. Spring Chinook redd counts from 2001 to 2007 in the same area have an average of 12.6 redds/mile (data from Snow et al. 2008).

Water temperature is elevated throughout the lower Chewuch River, with numerous exceedances of the state water temperature standard during summer months (USBR 2008a). There are no irrigation diversions within or upstream of the reach.

Reach C7 had scarce amounts of in-channel LWD during stream surveys in 2008, with only 4.4 pieces of LWD/mile (USFS 2008). Pools comprised approximately 35% of the habitat area. The substrate is relatively coarse and limits the availability of productive spawning habitat for steelhead and spring Chinook. A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 44.

Table 44. Reach-Based Ecosystem Indicators (REI) ratings for Reach 7. See Appendix A for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach C7 Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*Adequate*
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*Adequate*
	LWD	Pieces per Mile at Bankfull	*Unacceptable*
	Pools	Pool Frequency and Quality	*At Risk*
	Off-Channel Habitat	Connectivity with Main Channel	*Adequate*
Channel	Dynamics	Floodplain Connectivity	*Adequate*
		Bank Stability/ Channel Migration	*Adequate*
		Vertical Channel Stability	*Adequate*
Riparian	Condition	Structure	*No Data*

General Characteristics	General Indicators	Specific Indicators	Reach C7 Condition
Vegetation		Disturbance (Human)	*Adequate*
		Canopy Cover	*At Risk*

Hydrology

There are no major tributaries or other surface inputs or outputs in Reach C7. The reach is above all major diversions and is therefore connected to a natural snowmelt hydrologic regime. Table 45 provides the results of flood magnitude estimates for several recurrence intervals derived from a watershed analysis performed by the USBR (2008b).

Table 45. Flood magnitudes for recurrence intervals from 2 to 100 years for a point near the mile of Reach C7 (RM 15.2). Obtained from Methow River Basin GIS hydrology database (USBR 2008b).

Location	River Mile	Flood Recurrence Interval (ft^3/sec)					
		Q2	Q5	Q10	Q25	Q50	Q100
Mid-Reach	15.2	1,871	2,869	3,517	4,307	4,872	5,415

Geomorphology

Valley width is narrow, ranging from 220 to 800 ft. Large alluvial fans to the east push the channel to the west side of the valley against hillslopes and glacial terraces. This natural confinement has kept the channel relatively simple. Sinuosity is very low at 1.05 with only one sharp bend near the middle of the reach. Floodplain development is limited with an average flood-prone width of only 114 ft. The majority of the channel is riffle and run morphology with cobble size material dominating the channel (USFS 2008). The only location where the morphology is distinctly different is at the upstream end of the reach, where a wider floodplain has formed in the upstream reach. There are floodplain channels and wetlands that are connected to inner zone processes. The channel is wider with active gravel bar formation.

Human Alteration

Roads are the only human features that create a disturbance in Reach C7 (Figure 41). For the most part, the roads are located on upland slopes out of the river corridor. However, the westside road embankment creates the channel margin between RM 15.06 and 15.15 and at locations near RM 14.68 and 14.53. The eastside road creates the floodplain margin between RM 14.78 and 15.03.

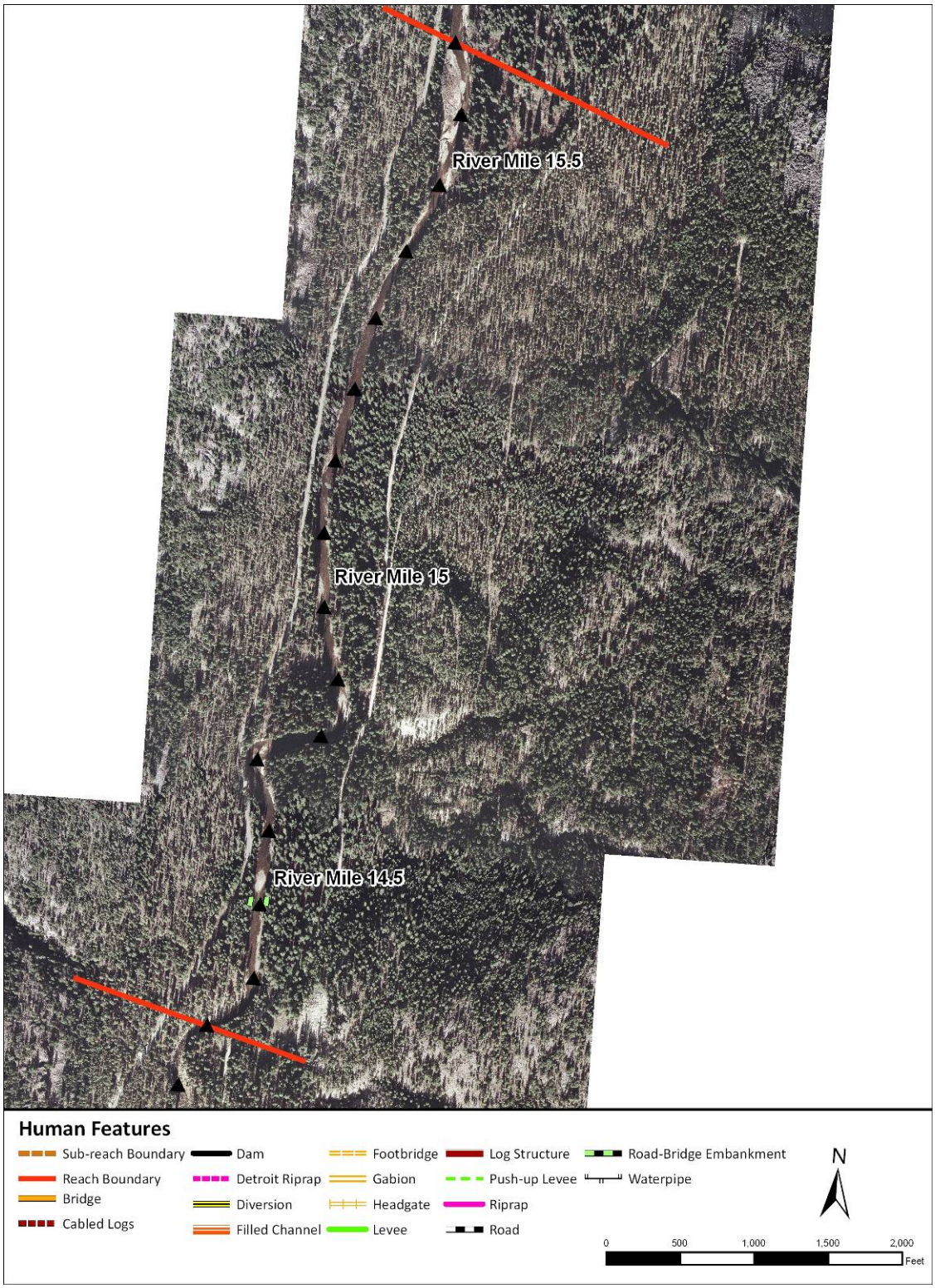

Figure 41. Aerial photo showing human features in Reach C7. Flow is from north to south.

15.2 Reach Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach C7 is included below. The strategy focuses first on protecting existing conditions from further impairment. This objective is followed by reconnecting the fundamental bio-physical processes that will create and maintain habitat conditions over the long-term. Off-channel habitat enhancement (rehabilitation) is also included; these projects occur in conjunction with long-term process reconnection and are also applied in cases where long-term process reconnection is constrained by existing human uses. The USBR (2008b) suggests that protection and monitoring are the main objectives in this reach. The USFS (2008) recommendations include several monitoring tasks; signage to reduce LWD cutting and management practices to reduce road related fine sediment.

1. ***Protect and Maintain***
   - **Prevent Further Degradation**- Opportunities to prevent further degradation should be pursued including purchasing land and water rights in the river corridor, and/or obtaining conservation easements. Water rights acquisition should be focused on increasing instream flow during late summer.
   - **Legal Protection**- Existing enforced legal protection is considered an intrinsic component of all potential projects.

2. ***Reconnect Stream Channel Processes***
   - **Channel Dynamics**- Address loss of multi-thread channel complexity resulting from loss of wood dynamics. LWD jams are important to geomorphic process and their frequency and function have been reduced by past land-use practices. Where feasible, LWD jams can be placed in areas where they would naturally occur and where processes such as bar deposition, pool scour, lateral channel migration, and natural rates of recruitment can be re-established.
   - **Abandoned Bridge**- Removal of feature to re-establish natural hydraulics and geomorphic processes.

3. ***In-Stream Habitat Enhancement***
   - **Enhance Habitat Complexity**- Instream large wood is a natural component of this system that has been reduced by past land-use practices. Wood creates pool scour, cover, and channel complexity. Place wood in configurations and locations that mimic natural wood deposition processes. These projects are not replacements for process restoration, but are meant to provide intermediate habitat enhancement while process restoration matures.

15.3 Sub-Unit and Project Opportunity Summary

Six sub-units were identified in Reach C7, including two inner zone sub-units and four outer zone sub-units (Table 46, Figure 42, Figure 43). There are no disconnected areas in the reach. Eight specific project opportunities are identified in this reach and are presented in the sub-unit summary section (Table 47).

Table 46. Summary of protection and restoration opportunities for Reach C7.

Sub-Unit	River Mile	Acreage
Inner Zone 1 (IZ-1)	15.48-15.72	N/A
Outer Zone 1 (OZ-1)	15.63-15.7	0.28
Inner Zone 2 (IZ-2)	14.3-15.48	N/A
Outer Zone 2 (OZ-2)	15.34-15.79	11.3
Outer Zone 3 (OZ-3)	14.68-15.0	5.9
Outer Zone 4 (OZ-4)	14.63-14.72	0.9

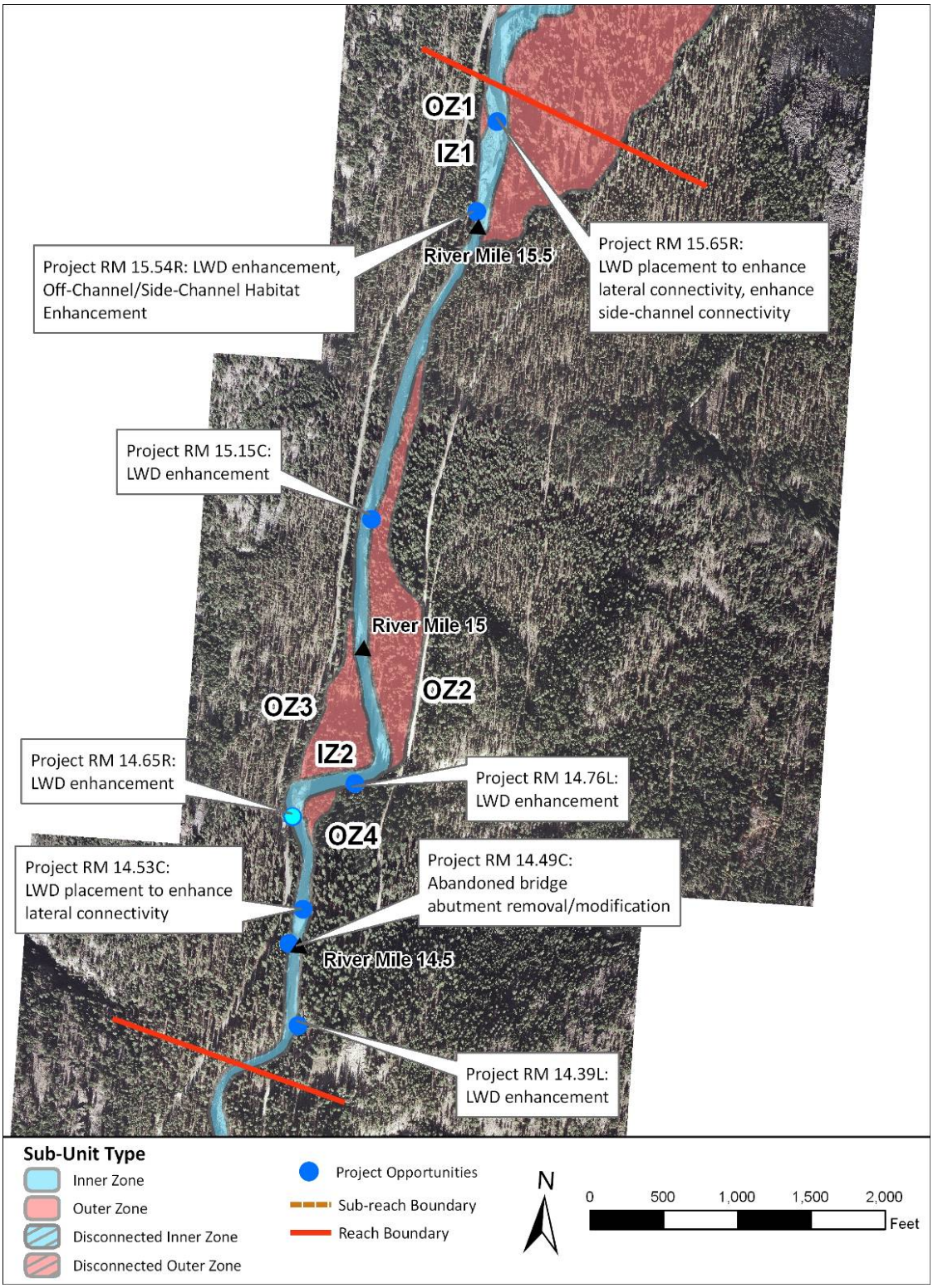

Figure 42. Sub-units and project opportunities in Reach C7. Flow is from north to south.

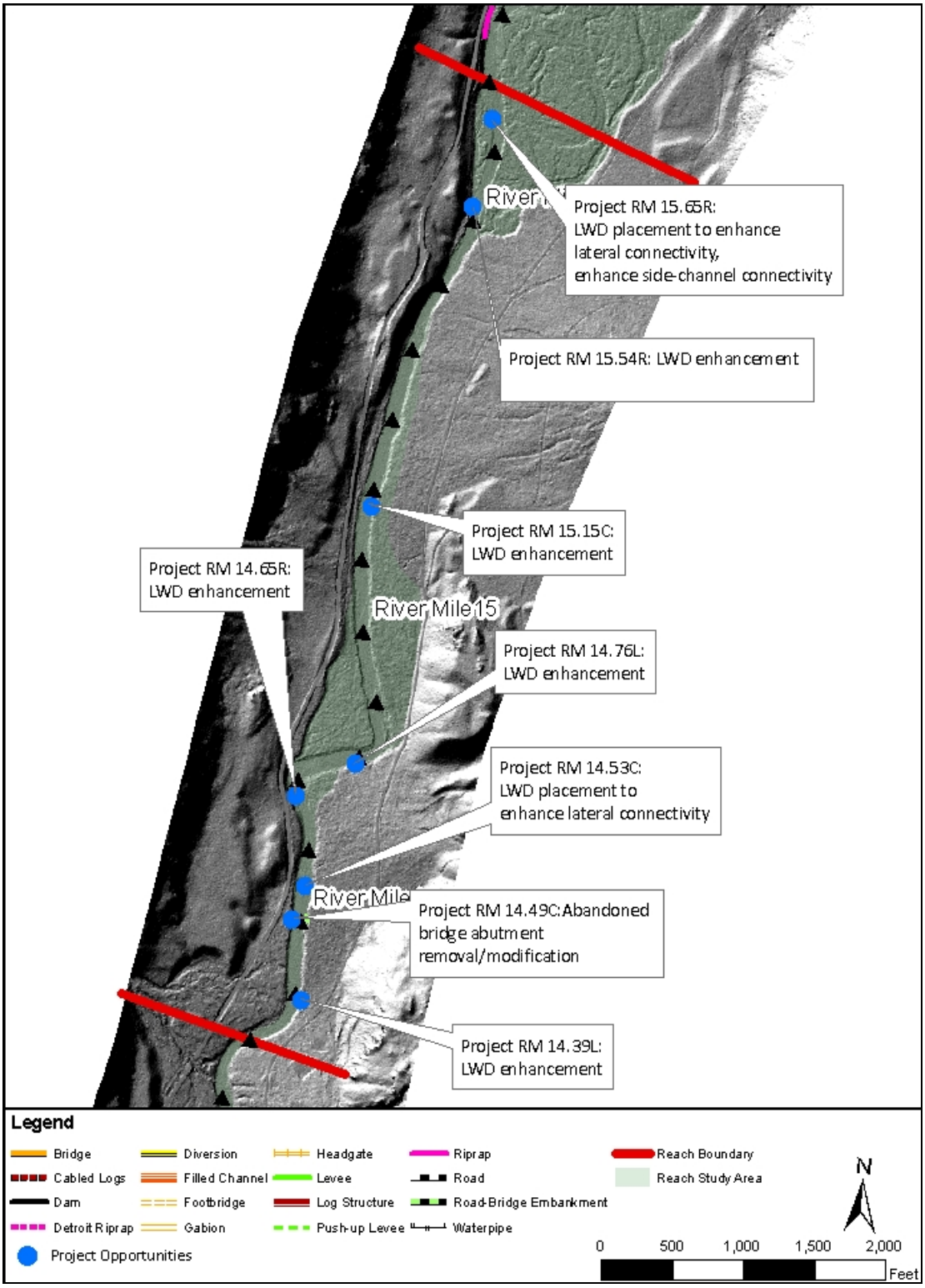

Figure 43. LiDAR hillshade of reach C7 illustrating topography in relation to human features and project locations in the reach. Flow is from north to south.

Table 47. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C7.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-1	Inner Zone 1 (IZ-1) has more similarities to the inner zone of upstream reach C8 than to the rest of the inner zone in Reach C7. The channel is wider and contains a large gravel bar with a high-flow cut-off channel that provides an off-channel backwater during low flow periods. Channel morphology is pool-riffle. Channel and floodplain habitat and processes are connected at the downstream end of the floodplain east of the channel. To the west, the channel flows against a glacial terrace.	Protect and Maintain Reconnect Stream Channel Processes In-Stream Habitat Enhancement	***Project RM 15.65R*** LWD placement to enhance lateral connectivity, enhance side-channel connectivity ***Project RM 15.54R*** LWD enhancement	Roadway parallel to the channel on the west side of the valley for the entire length of the sub-unit.
OZ-1	This is a very small (0.28 acre) floodplain area that is forming as the channel migrates east. There is no disturbance to this area. This unit provides a small pocket of riparian habitat between the channel and the hillslope.	Protect and Maintain		A roadway parallels the floodplain for the entire length of the sub-unit.

Table 47. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C7.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-2	IZ-2 is bounded by an alluvial fan on the east side of the valley, truncating the upstream floodplain and confining the channel against a high glacial terrace to the west. At this location, the inner zone transitions to a straight, narrow channel with low complexity. The channel is relatively straight except for sharp bends at RM 14.8 and RM 14.7, where there is point bar formation and pool-riffle sequences. Otherwise, the majority of the channel is long riffle and glide morphology with gravel and cobble bed material.	Protect and Maintain Reconnect Stream Channel Processes In-Stream Habitat Enhancement	***Project RM 14.53C*** LWD placement to enhance lateral connectivity. ***Project RM 14.49C*** Abandoned bridge abutment removal/modification ***Project RM 15.15C*** LWD enhancement ***Project RM 14.76L*** LWD enhancement. ***Project RM 14.65R*** LWD enhancement ***Project RM 14.39L*** LWD enhancement	Roadways parallel to the channel on both sides of the valley directly impinge on the channel at several locations.
OZ-2	OZ-2 is the largest floodplain area in Reach C7 (11.3 acres). OZ-2 is a long, narrow area along the re-worked toe of a large alluvial fan on the east side of the valley. At the upstream end, the floodplain grades into the alluvial fan and is close to being at a terrace elevation. The surface expands in the downstream direction and appears to be more closely coupled with inner zone processes (i.e. flooding, lateral channel migration). There are traces of high-flow channels, but no well defined off-channel habitat or side-channels. Riparian vegetation is undisturbed through most of the sub-unit, providing a source of LWD. There is dispersed camping in the downstream corner of the sub-unit.	Protect and Maintain		Camping at the downstream end of the sub-unit.

Table 47. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C7.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
OZ-3	This floodplain surface is located on the inside of a 90-degree bend in the river. This is the only sinuous stretch of channel found in Reach C7 and includes a gravel point bar and lateral floodplain accretion. There is topographic evidence of periodic inundation of this surface. Riparian vegetation is undisturbed and there is the potential for seasonal off-channel habitat with high flows along the downstream edge of the sub-unit.	Protect and Maintain		A roadway parallels the entire length of the sub-unit along the east side of the valley and at the downstream end of the sub-unit on the west side.
OZ-4	This floodplain is the counterpart to OZ-3 on the inside of the opposite meander. As with OZ-3, there is a gravel bar depositing on the inside of the bend laterally accreting the floodplain surface as the bar builds and the channel migrates. The sub-unit is undisturbed and provides quality riparian habitat but no off-channel or high-flow connectivity.	Protect and Maintain		A roadway parallels the hillslope side of the sub-unit for its entire length.

[1]*For additional information on specific identified project opportunities, see Chewuch Project Opportunities list in Appendix B*

C8 – Reach Assessment

16 C8 REACH ASSESSMENT

16.1 Reach Overview

Reach C8 is moderately confined. There are large, well-connected floodplain areas providing off-channel habitat. There is relatively high sinuosity, low gradient, and high channel and habitat complexity. There is localized confinement at the upstream end of the reach where alluvial fans come in from the east and the west. The only sources of human disturbance in the reach are roads with riprap along the channel margin at a few locations on the west side of the valley.

Habitat Conditions and Fish Use

Salmonid use of Reach C8 includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. The reach is used for spring Chinook and steelhead spawning, rearing, and migration. Annual steelhead redd counts from 2003 to 2007 from Falls Creek Campground to Chewuch Campground (spans Reaches C7 and C8) have an average of 3.5 redds/mile. Spring Chinook redd counts from 2001 to 2007 in the same area have an average of 12.6 redds/mile (data from Snow et al. 2008).

Water temperature is elevated throughout the lower Chewuch River, with numerous exceedances of the state water temperature standard during summer months (USBR 2008a). There are no irrigation diversions within or upstream of the reach.

Reach C8 had a moderate abundance of in-channel LWD during stream surveys in 2008, comprising 17 pieces of LWD/mile (USFS 2008). Pools comprised approximately 35% of the habitat area. The substrate is dominated by cobbles, which limits the availability of productive spawning habitat for steelhead and spring Chinook. Side-channel habitat was relatively abundant at 3.9% of the total habitat area, but there was some concern with filling of off-channel areas with sediment (USFS 2008). A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 48.

Table 48. Reach-Based Ecosystem Indicators (REI) ratings for Reach C8. See Appendix A for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach C8 Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*Adequate*
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*Adequate*
	LWD	Pieces per Mile at Bankfull	*Unacceptable*
	Pools	Pool Frequency and Quality	*Adequate*
	Off-Channel Habitat	Connectivity with Main Channel	*Adequate*
Channel	Dynamics	Floodplain Connectivity	*Adequate*
		Bank Stability/ Channel Migration	*Adequate*
		Vertical Channel Stability	*Adequate*

General Characteristics	General Indicators	Specific Indicators	Reach C8 Condition
Riparian Vegetation	Condition	Structure	*No Data*
		Disturbance (Human)	*Adequate*
		Canopy Cover	*Unacceptable*

Hydrology

This reach is above all major diversions and is subject to a natural snowmelt runoff hydrologic regime. A small ephemeral tributary, Doe Creek, comes in from the west at the upstream reach boundary. Flow patterns from this small drainage are unrecorded. Table 49 provides the results of flood magnitude estimates for several recurrence intervals derived from a watershed analysis performed by the USBR (2008b).

Table 49. Flood magnitudes for recurrence intervals from 2 to 100 years for a point near upstream end of Reach C8 (RM 17.8). Obtained from Methow River Basin GIS hydrology database (USBR 2008b).

Location	River Mile	Flood Recurrence Interval (ft^3/sec)					
		Q2	Q5	Q10	Q25	Q50	Q100
Upstream End	17.8	1,814	2,782	3,410	4,177	4,725	5,251

Geomorphology

Reach C8 is moderately confined with valley widths ranging from 700 to 1,600 ft (USFS 2008). Natural constraints consist of large alluvial fans on both sides of the valley at the upstream end of the reach and glacial deposits at the downstream end. The alluvial fans create a constricted section with very little floodplain development. Floodplain area increases downstream with an average floodprone width of 362 ft (USFS 2008). Channel scars and oxbow wetlands suggest that the active channel has migrated across much of the valley within the downstream half of the reach, eroding glacial deposits and forming terraces at the valley margins over time.

Sinuosity and channel complexity follow similar patterns, increasing in the downstream direction. There are gravel bars and side-channels near the top of the reach but they become more frequent in the downstream half. Riffles and runs are the dominant bed morphology in the reach, together comprising about 61% of the channel area (USFS 2008). The channel transitions from a riffle-run morphology to a riffle-pool morphology in the downstream direction. There is a moderate amount of woody debris in the reach (40.6 pieces per mile) but only 2.2 pieces per mile are large (USFS 2008).

Human Alteration

There is very little anthropogenic disturbance in this reach (Figure 44). There is no residential or agricultural development. The road on the west side of the valley creates two points of bank modification on river-right. There are 950 ft of riprap and road embankment along the channel and floodplain margin centered on RM 17.4; and 200 ft of riprap near RM 15.8. The east side road does not impinge on the channel or floodplain. Both roads provide access to dispersed camping at several locations. Most camps are on terrace or upland surfaces, but river access

points decrease bank stability in some locations. Some of the camping areas show signs of recent improvements such as fencing and boulder placements to limit vehicle disturbance.

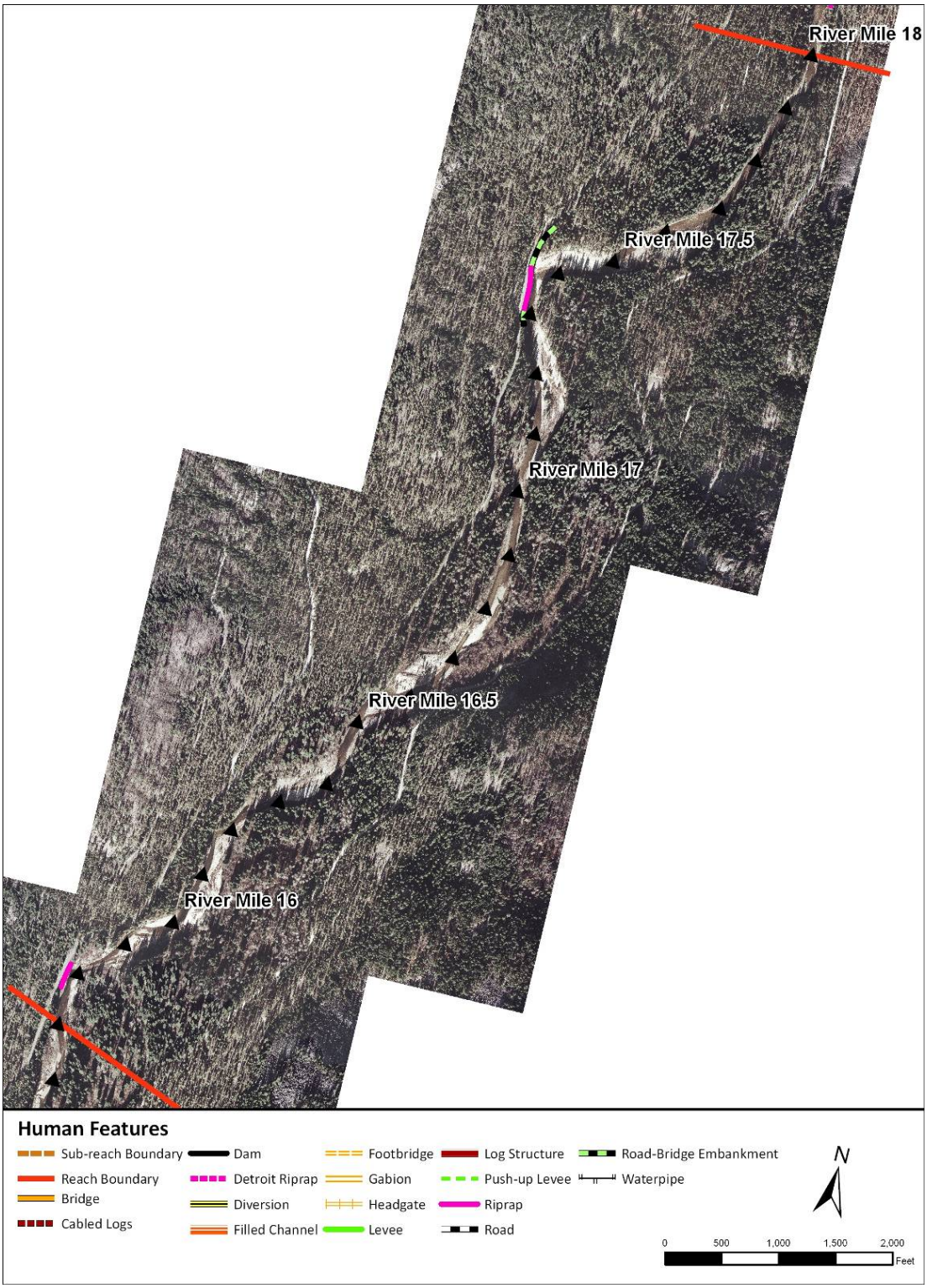

Figure 44. Aerial photo showing human features in Reach C8. Flow north to south.

16.2 Reach Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach C8 is included below. The strategy focuses first on protecting existing conditions from further impairment. This objective is followed by reconnecting the fundamental bio-physical processes that will create and maintain habitat conditions over the long-term. Off-channel habitat enhancement (rehabilitation) is also included; these projects occur in conjunction with long-term process reconnection and are also applied in cases where long-term process reconnection is constrained by existing human uses. The USBR (2008b) recommend protection and monitoring as the main objectives in this reach. The USFS (2008) recommendations also include several monitoring tasks, as well as signage to reduce LWD cutting and reducing sedimentation from roadways.

1. ***Protect and Maintain***
   - **Prevent Further Degradation**- Opportunities to prevent further degradation should be pursued including purchasing land and water rights in the river corridor, and/or obtaining conservation easements. Water rights acquisition should be focused on increasing instream flow during late summer.
   - **Legal Protection**- Existing enforced legal protection is considered an intrinsic component of all potential projects.

2. ***Reconnect Stream Channel Processes***
   - **Channel Dynamics**- Address loss of multi-thread channel complexity resulting from loss of wood dynamics. LWD jams are important to geomorphic process and their frequency and function have been reduced by past land-use practices. Where feasible, LWD jams can be placed in areas where they would naturally occur and where processes such as bar deposition, pool scour, lateral channel migration, and natural rates of recruitment can be re-established.
   - **Riprap**- Remove features to re-establish dynamic channel processes. There are short sections of riprap armoring the bank on river right where the road embankment coincides with the channel margin at the upstream and downstream end of the reach. These areas should be assessed to develop a suite of options for removal or modification.

3. ***Reconnect Floodplain Processes***
   - **Isolated Habitat**- Address issues creating disconnection of off-channel features including excess sedimentation or channel incision. Provide intermediate means of habitat reconnection while process disturbance is corrected over the long-term.

4. ***In-Stream Habitat Enhancement***
   - **Enhance Habitat Complexity**- Instream large wood is a natural component of this system that has been reduced by past land-use practices. Wood creates pool scour, cover, and channel complexity. Place wood in configurations and locations that mimic natural wood deposition processes. These projects are not replacements for

process restoration, but are meant to provide intermediate habitat enhancement while process restoration matures.

5. ***Off-Channel Habitat Enhancement***
   - **Enhance Off-Channel Habitat Complexity**- There are multiple off-channel features in this reach. Low cost restoration could potentially provide large habitat improvements. Natural activity of beavers can result in enhanced off-channel habitat and may be considered as a restoration option. Natural activity of beavers can result in enhanced off-channel habitat and may be considered as a restoration option.

16.3 Sub-Unit and Project Opportunity Summary

Twelve sub-units were identified in Reach C8, including two inner zone sub-units and 10 outer zone sub-units (Table 50, Figure 45, Figure 46). There are no disconnected sub-units in the reach. Seventeen specific project opportunities are identified in this reach and are presented in the sub-unit summary section (**Table 51**). Many of the potential LWD enhancement projects encompass several possible log jam locations in one project description, making the total number of possible projects much greater.

Table 50. Summary of protection and restoration opportunities for Reach C8.

Sub-Unit	River Mile	Acreage
Inner Zone 1 (IZ-1)	17.68-18.0	N/A
Outer Zone 1 (OZ-1)	17.92-18.0	0.7
Outer Zone 2 (OZ-2)	17.52-17.83	3.7
Inner Zone 2 (IZ-2)	15.72-17.68	N/A
Outer Zone 3 (OZ-3)	17.37-17.44	0.8
Outer Zone 4 (OZ-4)	17.16-17.52	7.3
Outer Zone 5 (OZ-5)	16.64-17.22	15.9
Outer Zone 6 (OZ-6)	16.53-17.14	33.6
Outer Zone 7 (OZ-7)	16.24-16.56	6.9
Outer Zone 8 (OZ-8)	15.53-16.47	68.2
Outer Zone 9 (OZ-9)	15.94-16.02	0.5
Outer Zone 10 (OZ-10)	15.79-15.87	0.6

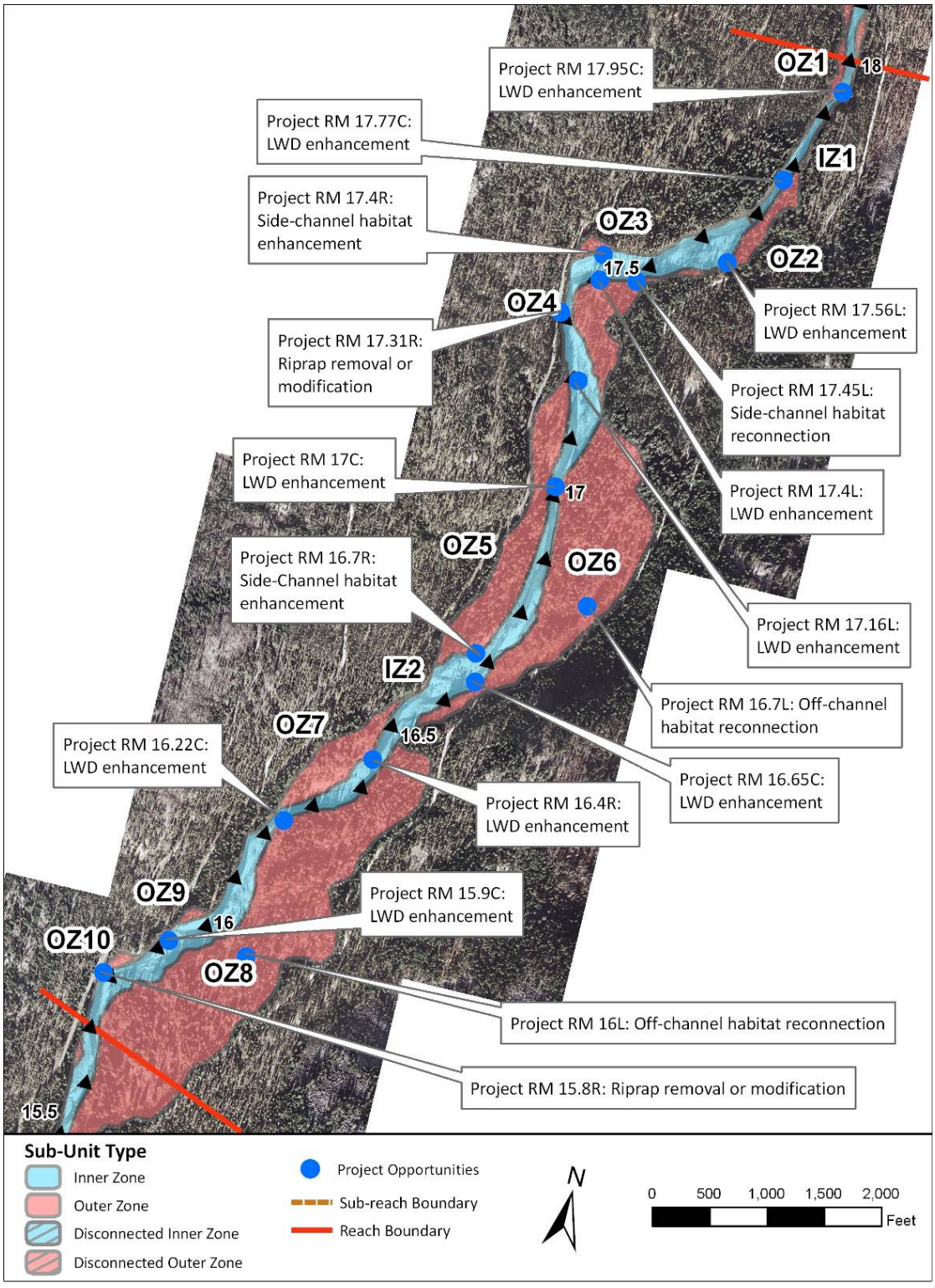

Figure 45. Sub-units and project opportunities in Reach C8. Flow is from north to south.

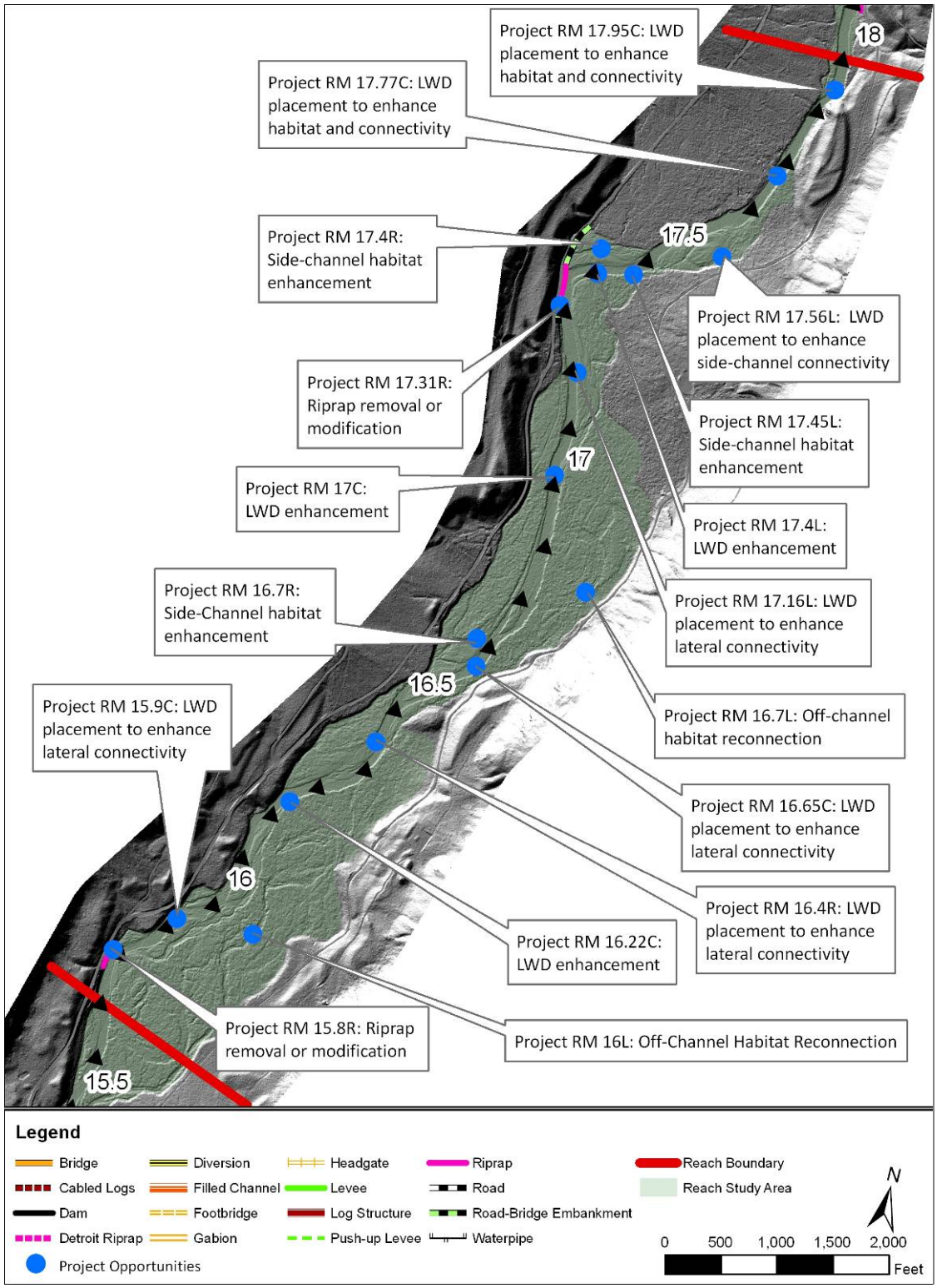

Figure 46. LiDAR hillshade of reach C8 illustrating topography in relation to human features and project locations in the reach. Flow is from north to south.

Table 51. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C8.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-1	IZ-1 is a short section of the inner zone at the upstream end of the reach where a large alluvial fan confines the channel against glacial deposits on the east side of the valley. The channel is a straight, long, cobble run. There are no side-channels and no connection to floodplain processes or habitat. There is active bank erosion, and with it, the potential to recruit large wood.	Protect and Maintain Reconnect Stream Channel Processes	***Project RM 17.95C*** LWD placement to enhance habitat and connectivity ***Project RM 17.77C*** LWD placement to enhance lateral connectivity	No identified constraints to restoration or preservation.
OZ-1	This 0.6 acre low surface is the downstream end of a floodplain that extends into the upstream reach. OZ-1 has formed along the toe of the alluvial fan where the channel has re-worked fan deposits and created an inset floodplain. OZ-1 has intact riparian vegetation but no off-channel aquatic habitat.	Protect and Maintain		No identified constraints to restoration or preservation.
OZ-2	OZ-2 is a narrow low surface occupying 3.7 acres along the toe of the alluvial fan on the east side of the upstream end of the valley. The bank is high at the upstream end of the sub-unit, but gradually lowers to an elevation that allows more frequent inundation at the downstream end. There is geomorphic evidence of high energy flow in OZ-2 in the form of overflow channels at the inner zone margin. Riparian vegetation is intact, and active bank erosion appears to be close to recruiting several trees as channel debris.	Protect and Maintain		No identified constraints to restoration or preservation.

Table 51. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C8.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-2	IZ-2 comprises the majority of the inner zone in Reach C8. The character of the inner zone changes dramatically near RM 17.7. The active channel widens and includes large active bars with high flow cut-off channels and low flow side-channels. Channel floodplain connection increases as evidenced by high flow channels and wetlands with surface connection that provide off-channel aquatic habitat. Sinuosity is still low until about RM 16.8 where meander amplitude increases, mid-channel bars and alternating point bars are more frequent, and split flow conditions exist at low flows. IZ-2 has some LWD, including a few large trees.	Protect and Maintain Reconnect Stream Channel Processes In-Stream Habitat Enhancement	***Project RM 17.56L*** LWD placement to enhance side-channel connectivity ***Project RM 17.31R*** Riprap removal or modification ***Project RM 17.16L & Project RM 16.65C*** LWD placement to enhance lateral connectivity ***Project RM 16.4R*** LWD placement to enhance lateral connectivity ***Project RM 15.9C*** LWD placement to enhance lateral connectivity ***Project RM 15.8R*** Riprap removal or modification ***Project RM 17.4L, Project RM 17C & Project RM 16.22C*** LWD enhancement ***Project RM 17.4R*** Side-channel habitat enhancement. ***Project RM 16.7R*** Side-channel habitat enhancement	Roadways parallel to the channel on both sides of the valley, directly impinging on the channel at a few locations on river-right.

Table 51. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C8.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
OZ-3	OZ-3 is a small, 0.8 acre floodplain located at the far downstream edge of the alluvial fan on the west side of the valley. The surface is only slightly lower than the fan itself, and may be an older re-worked surface that is poorly connected to the channel under current conditions. A road embankment runs along the hillslope side of the sub-unit and continues downstream along the channel margin. Vegetation is undisturbed.	Protect and Maintain		Roadway along the hillslope side of the sub-unit.
OZ-4	OZ-4 is a moderately large floodplain formed where the channel has reworked the toe of the alluvial fan on the east side of the valley. The surface appears well connected to channel processes. There is a well defined high flow channel that runs along the floodplain/upland margin and has a low flow surface connection at the downstream end. There is strong connectivity to off-channel habitat in OZ-4. Riparian vegetation is undisturbed. Recruitment of LWD is a possibility.	Protect and Maintain Reconnect Stream Channel Processes	***Project RM 17.45L*** Side-channel habitat reconnection.	There are no apparent constraints.
OZ-5	OZ-5 is a moderately large (15.9 acres), long, and narrow floodplain located on the west side of the valley. At the upstream end, there is an old road, some dispersed camping, and forest clearing. Disturbance decreases at the downstream end of the sub-unit. There is a high-flow channel with a well-defined outflow, and surface connection to an inner zone side-channel. This connection creates continuity between the channel and off-channel habitat.	Protect and Maintain		Some clearing, dispersed camping, and an abandoned road in the upstream third of the sub-unit.

Table 51. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C8.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
OZ-6	OZ-6 is a large (33.9 acre) floodplain on the east side of the valley. The sub-unit appears to have been formed as the result of a channel avulsion and straightening at some point in the past. There are well-defined channel scars that suggest formation by a sinuous channel while the modern channel is fairly straight through this reach. This process has left behind high quality floodplain habitat with wetlands that have surface connection to the channel at the downstream end of the sub-unit. There is an old road across the upper half of the floodplain and some older cleared areas that have begun to recover.	Protect and Maintain Reconnect Floodplain Processes	***Project RM 16.7L*** Off-channel habitat reconnection.	No identified constraints to restoration or preservation.
OZ-7	OZ-7 is a 6.9-acre floodplain that appears to be connected to inner zone processes via a network of high flow channels. The upstream channel margin is actively eroding, providing a source of woody debris to the channel. Vegetation is undisturbed and riparian habitat quality is high.	Protect and Maintain		No identified constraints to restoration or preservation.
OZ-8	At 68.2 acres, OZ-8 is the largest floodplain sub-unit in Reach C8. OZ-8 is similar to OZ-6 in its connection to inner zone processes (e.g. overbank flooding and channel migration). The laterally expansive floodplain bears topographic expression of several meander scars, some of which are now oxbow ponds. There is a long high-flow channel with areas of standing water and a downstream connection to the channel. There is some evidence of historical disturbance such as an abandoned road and stumps, but the riparian forest is currently intact and high quality.	Protect and Maintain Reconnect Floodplain Processes	***Project RM 16L*** Off-channel habitat reconnection.	No identified constraints to restoration or preservation.

Table 51. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C8.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
OZ-9	OZ-9 is a very small floodplain area located on the west side of the valley where the migrating channel has eroded the glacial terrace and then moved east again. The surface is undisturbed	Protect and Maintain		No identified constraints to restoration or preservation.
OZ-10	OZ-10 is the same as OZ-9 in location, origin, and condition. The hillslope margin (and roadway) at the downstream end of the sub-unit is protected with riprap.	Protect and Maintain		No identified constraints to restoration or preservation.

[1]*For additional information on specific identified project opportunities, see Chewuch Project Opportunities list in Appendix B.*

C9 – Reach Assessment

17 C9 REACH ASSESSMENT

17.1 Reach Overview

Reach C9 is confined between coalescing alluvial fans to the east and bedrock to the west. The channel has low sinuosity and low geomorphic complexity. However, there is a large amount of LWD in the reach and a substantial amount of side-channel habitat. Overall use by native fish is limited due to lack of spawning and rearing habitats. There is very little human disturbance in the reach (USFS 2008).

Habitat Conditions and Fish Use

Salmonid use of Reach C9 includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. The reach is used for spring Chinook and steelhead spawning, rearing, and migration. Annual steelhead redd counts from 2003 to 2007 from Chewuch Campground to Camp 4 (includes Reach C9 and upstream another one-half mile) have an average of 2.5 redds/mile. Spring Chinook redd counts from 2001 to 2007 in the same area have an average of 8.8 redds/mile (data from Snow et al. 2008).

Water temperature is elevated throughout the lower Chewuch River, with numerous exceedances of the state water temperature standard during summer months (USBR 2008a). There are no irrigation diversions within or upstream of the reach.

Reach C9 (data reported here includes C9 as well as 2 miles upstream) had a low abundance of in-channel LWD during stream surveys in 2008, comprising 11.4 pieces of LWD/mile (USFS 2008). Pools comprised approximately 25% of the habitat area. The substrate is dominated by cobbles, which limits the availability of productive spawning habitat for steelhead and spring Chinook. Fines comprised an average of 12% of the bed substrate based on 2 pebble counts. Side-channel habitat was abundant at 11.5% of the total habitat area, but the "No Snake" side-channel upstream of Reach C9 (but within the USFS survey reach) comprised much of the side-channel habitat area. A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 52.

Table 52. Reach-Based Ecosystem Indicators (REI) ratings for Reach C9. See Appendix A for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach C9 Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*Adequate*
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*Adequate*
	LWD	Pieces per Mile at Bankfull	*Adequate*
	Pools	Pool Frequency and Quality	*At Risk*
	Off-Channel Habitat	Connectivity with Main Channel	*Adequate*
Channel	Dynamics	Floodplain Connectivity	*Adequate*

General Characteristics	General Indicators	Specific Indicators	Reach C9 Condition
		Bank Stability/ Channel Migration	*Adequate*
		Vertical Channel Stability	*Adequate*
Riparian Vegetation	Condition	Structure	*No Data*
		Disturbance (Human)	*Adequate*
		Canopy Cover	*Unacceptable*

Hydrology

This reach is above all major diversions and is subject to a natural snowmelt runoff hydrologic regime. Twentymile Creek flows into the Chewuch River at the top of the reach contributing about 10-15% of the low flow volume (USFS 2008). Table 53 provides the results of flood magnitude estimates for several recurrence intervals derived from a watershed analysis performed by the USBR (2008b).

Table 53. Flood magnitudes for recurrence intervals from 2 to 100 years for a point near upstream end of Reach C9, and for Twentymile Creek at its mouth (RM 19.8). Obtained from Methow River Basin GIS hydrology database (USBR 2008b).

Location	River Mile	Flood Recurrence Interval (ft^3/sec)					
		Q2	Q5	Q10	Q25	Q50	Q100
Upstream End	19.8	1,522	2,334	2,861	3,504	3,964	4,405
Mouth of Twentymile Creek	19.8	318	477	590	741	859	981

Geomorphology

The geomorphology of Reach C9 is influenced by large alluvial fans generated from drainages along the eastern edge of the valley. One is the active alluvial fan of Twentymile Creek. The fan deposits push the channel to the far west side of the valley against the hillslope. Very little floodplain formation has occurred in this reach; there are only small low surface areas near the downstream end. The channel is fairly simple as well, with about 63% of the channel area in riffle or run morphology (USFS 2008). There are active lateral and mid-channel cobble bars at the upstream end and again at the downstream end where the the channel has avulsed (USFS 2008).

Human Alteration

There is little human disturbance in this reach (Figure 47). The main alteration is the road along the west side of the valley. Although the road is located on the hillslope above the channel and low surface, the embankment often forms the channel margin, creating requirements of protection and maintenance that affect channel migration, erosion, and streambank habitat.

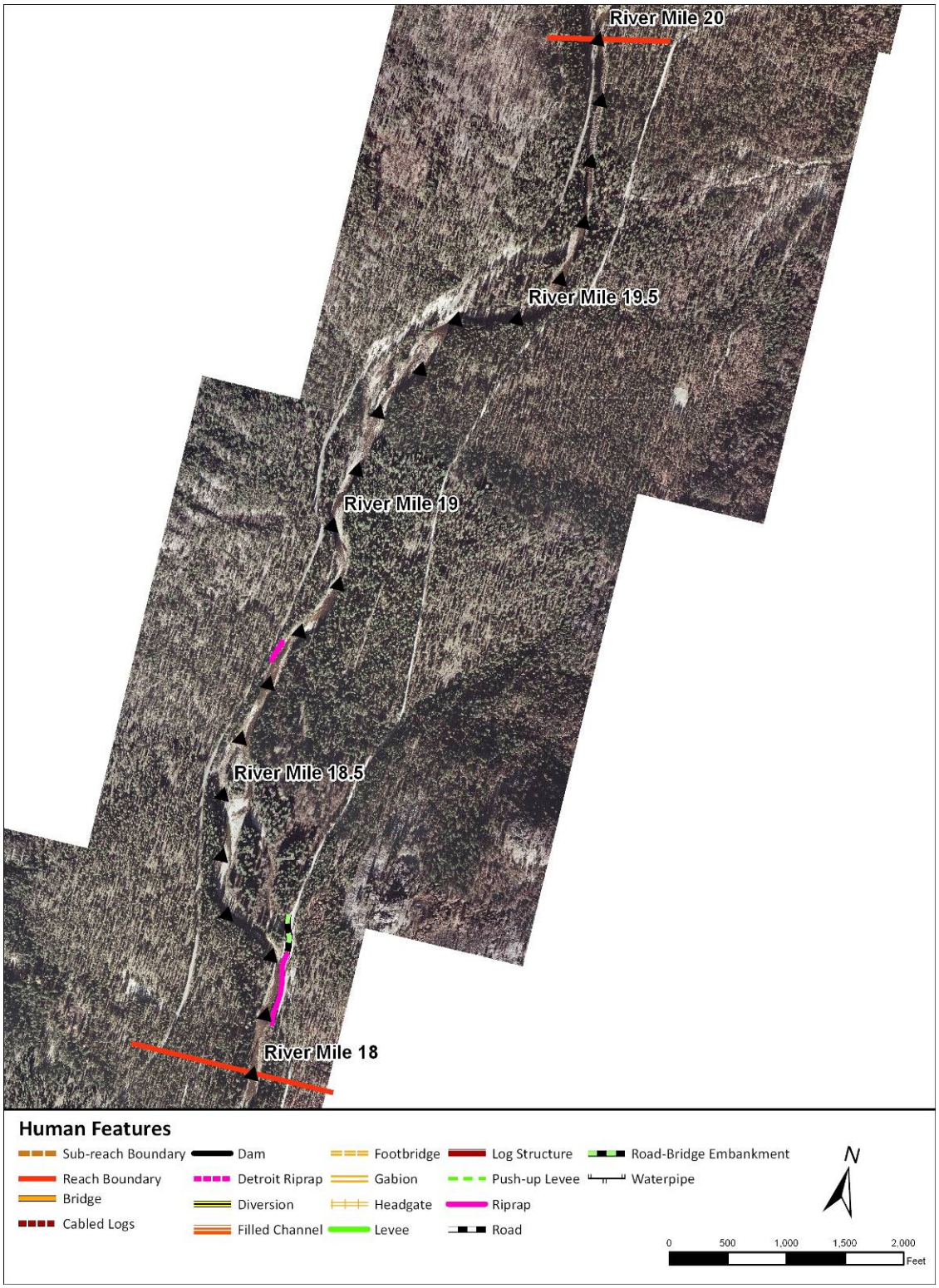

Figure 47. Aerial photo showing human features in Reach C9. Flow is from north to south.

17.2 Reach-Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach C9 is included below. The strategy focuses first on protecting existing conditions from further impairment. This objective is followed by reconnecting the fundamental bio-physical processes that will create and maintain habitat conditions over the long-term. Off-channel habitat enhancement (rehabilitation) is also included; these projects occur in conjunction with long-term process reconnection and are also applied in cases where long-term process reconnection is constrained by existing human uses. The USFS (2008) recommendations include several monitoring tasks, signage to reduce LWD cutting, and reducing sedimentation from roadways**.**

1. ***Protect and Maintain***
   - **Prevent Further Degradation**- Opportunities to prevent further degradation should be pursued including purchasing land and water rights in the river corridor, and/or obtaining conservation easements. Water rights acquisition should be focused on increasing instream flow during late summer.
   - **Legal Protection**- Existing enforced legal protection is considered an intrinsic component of all potential projects.

2. ***Reconnect Stream Channel Processes***
   - **Channel Dynamics**- Address loss of multi-thread channel complexity resulting from loss of wood dynamics. LWD jams are important to geomorphic process and their frequency and function have been reduced by past land-use practices. Where feasible, LWD jams can be placed in areas where they would naturally occur and where processes such as bar deposition, pool scour, lateral channel migration, and natural rates of recruitment can be re-established.
   - **Abandoned Bridge**- Removal of feature to re-establish natural hydraulics and geomorphic processes.
   - **Riprap**- Remove features to re-establish dynamic channel processes. There are short sections of riprap armoring the bank on river right where the road embankment coincides with the channel margin at the upstream and downstream end of the reach. These areas should be assessed to develop a suite of options for removal or modification.

3. ***In-Stream Habitat Enhancement***
   - **Enhance Habitat Complexity**- Instream large wood is a natural component of this system that has been reduced by past land-use practices. Wood creates pool scour, cover, and channel complexity. Place wood in configurations and locations that mimic natural wood deposition processes. These projects are not replacements for process restoration, but are meant to provide intermediate habitat enhancement while process restoration matures.

4. Off-Channel Habitat Enhancement

- **Enhance Off-Channel Habitat Complexity**- There are multiple off-channel features in this reach. Low cost restoration could potentially provide large habitat improvements. Natural activity of beavers can result in enhanced off-channel habitat and may be considered as a restoration option.

17.3 Sub-Unit and Project Opportunity Summary

Eight sub-units were identified in Reach C9, including two inner zone sub-units and six outer zone sub-units (Table 54, Figure 48, Figure 49). There are no disconnected sub-units in the reach. Fifteen specific project opportunities are identified in this reach and are presented in the sub-unit summary section (Table 55).

Table 54. Summary of protection and restoration opportunities for Reach C9.

Sub-Unit	River Mile	Acreage
Inner Zone 1 (IZ-1)	19.7-20.0	N/A
Inner Zone 2 (IZ-2)	18.0-19.7	N/A
Outer Zone 1 (OZ-1)	19.4-19.5	0.9
Outer Zone 2 (OZ-2)	19.18-19.2	0.3
Outer Zone 3 (OZ-3)	18.8-19.15	3.8
Outer Zone 4 (OZ-4)	18.33-18.75	13.6
Outer Zone 5 (OZ-5)	17.95-18.33	3.1
Outer Zone 6 (OZ-6)	18-18.05	0.5

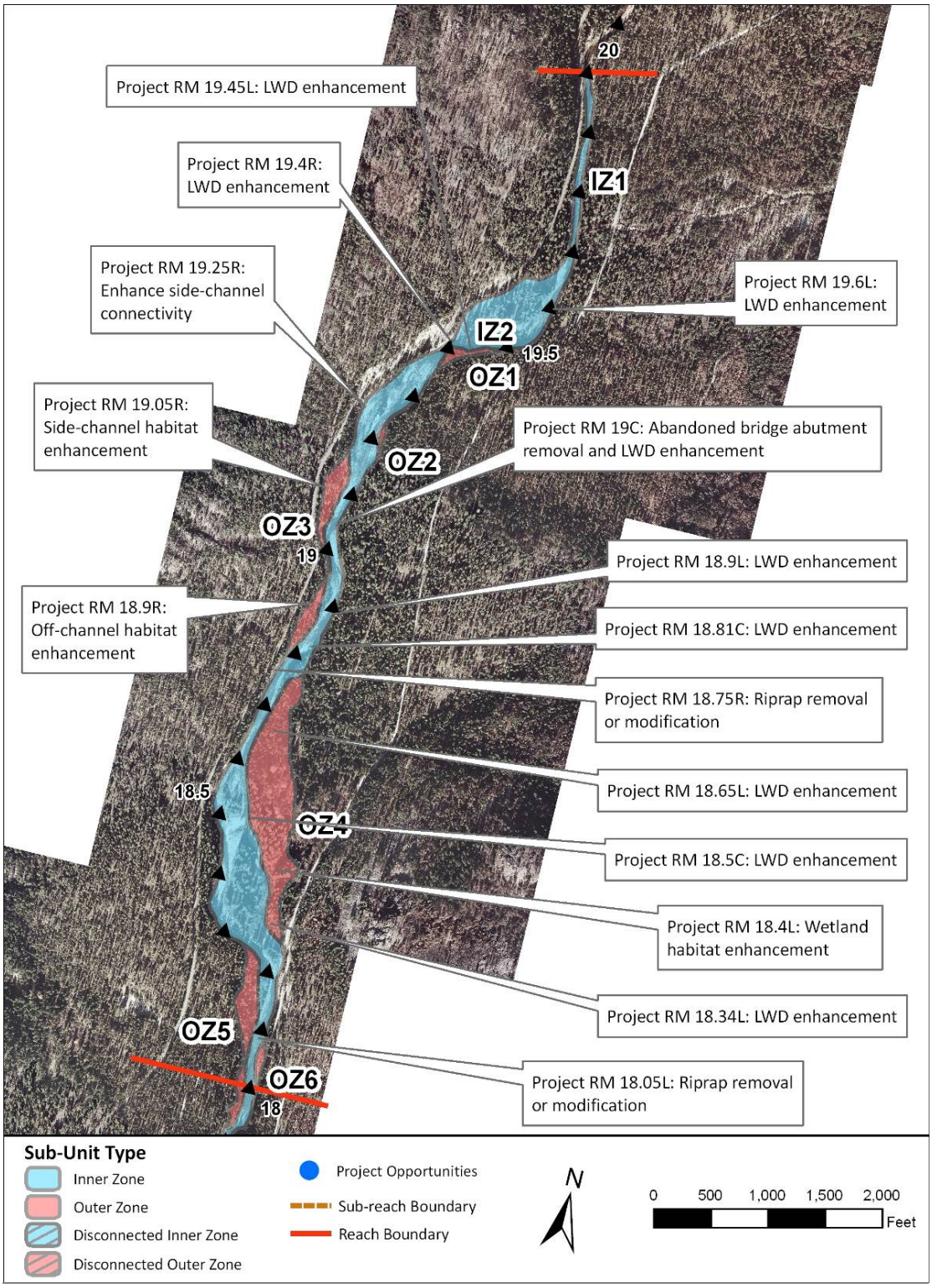

Figure 48. Sub-units and project opportunities in Reach C9. Flow is from north to south.

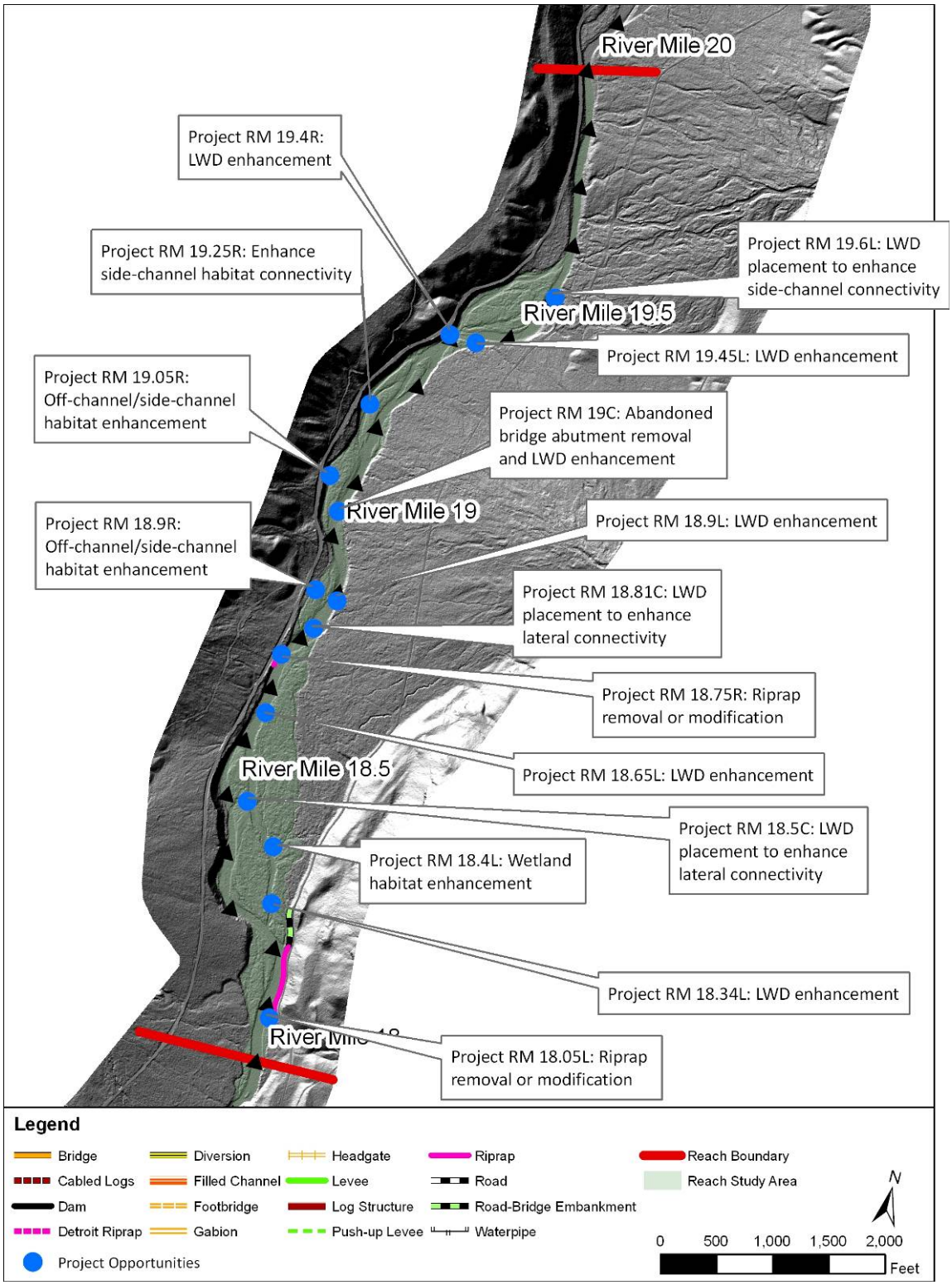

Figure 49. LiDAR hillshade of reach C9 illustrating topography in relation to human features and project locations in the reach. Flow is from north to south.

Table 55. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C9.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-1	This is a short section of the inner zone just downstream of the confluence of Twentymile Creek. The alluvial fan of Twentymile Creek pushes the channel against bedrock to the west and the river is highly confined and essentially straight. Bed material is cobble and boulder with step-pool morphology and long riffles. There is a large percentage of sand in the bed, potentially generated from wildfires in tributary watersheds upstream. This smaller material embeds the cobbles that form the dominant substrate.	Protect and Maintain		No apparent constraints.

Table 55. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C9.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-2	Downstream of the alluvial fan created by Twentymile Creek, the inner zone becomes sinuous, less confined, and much more complex. There are multiple locations of split-flow around stable vegetated islands. Long side-channels carry flow at all discharge levels and high-flow networks activate at flood stage and provide moderate connectivity between the channel and floodplain. There is a high concentration of LWD recruitment at locations where the channel is re-working the toe of the fan and in areas that have undergone channel avulsion. Naturally occurring log jams help create bars, riffle-pool sequences, and deposition of gravel that is suitable for spawning.	Protect and Maintain Reconnect Stream Channel Processes In-Stream Habitat Enhancement	***Project RM 19.6L*** LWD placement to enhance side-channel connectivity ***Project RM 19.25R*** Enhance side-channel habitat connectivity ***Project RM 19C*** Abandoned bridge abutment removal and LWD enhancement ***Project RM 18.81C*** & Project RM 18.5C LWD placement to enhance lateral connectivity ***Project RM 18.75R*** Riprap removal or modification ***Project RM 18.05L*** Riprap removal or modification ***Project RM 19.45L***. ***Project RM 19.4R, Project RM 18.9L, Project RM 18.65L,*** & ***Project RM 18.34L*** LWD enhancement.	Roadways parallel the channel on both sides of the valley, directly impinging on the channel at a few locations.

Table 55. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C9.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
OZ-1	OZ-1 is a narrow floodplain occupying 0.88 acres between the inner zone and an alluvial fan to the southeast. The floodplain has formed where the alluvial fan has been reworked as the channel migrates from east to west. There is no off-channel or side-channel habitat provided in OZ-1, but the riparian forest is intact and provides a buffer between the channel and hillslope processes.	Protect and Maintain		No identified constraints to restoration or preservation.
OZ-2	OZ-2 is a 0.27-acre floodplain area along river-left where the toe of the alluvial fan has been re-worked through lateral channel migration. Riparian vegetation is intact, providing a potential source of LWD.	Protect and Maintain		No identified constraints to restoration or preservation.
OZ-3	OZ-3 occupies 3.8 acres along a narrow margin on the west side of the valley. The channel has eroded and re-worked the toes of two small alluvial fans and formed this floodplain surface. There are poorly connected high-flow channels throughout this sub-unit. These channels may also be subject to debris flows from the alluvial fans. However, a roadway forms a barrier between alluvial fan processes and this outer-zone area. The intact forest provides good riparian habitat.	Protect and Maintain Off-Channel Habitat Enhancement	***Project RM 19.05R*** Off-channel/side-channel habitat enhancement. ***Project RM 18.9R*** Off-channel/side-channel habitat enhancement	Roadway along the hillslope side of the sub-unit.

Table 55. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach C9.

Sub-Unit	Description	Strategy *(Strategies listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
OZ-4	OZ-4 is the largest floodplain area in Reach C9, providing 13.6 acres of intact floodplain forest. The floodplain contains small wetlands near its downstream end. These features do not share a strong connection to inner-zone habitat or processes. High-flow channel networks in OZ-4 appear abandoned and rarely inundated. The channel margin along the majority of the sub-unit is a fairly high bank.	Protect and Maintain Off-Channel Habitat Enhancement	***Project RM 18.4L*** – Wetland habitat enhancement	No identified constraints to restoration or preservation.
OZ-5	OZ-5 creates a 3.1-acre riparian buffer between the channel and an alluvial fan. Riparian vegetation is intact but there are no off-channel aquatic habitats in the sub-unit.	Protect and Maintain		Some clearing, dispersed camping, and an abandoned road in the upstream third of the sub-unit.
OZ-6	OZ-6 is a small 0.47-acre floodplain that provides intact riparian habitat along the east side of the channel at the downstream end of the reach.	Protect and Maintain		No identified constraints to restoration or preservation.

[1]*For additional information on specific identified project opportunities, see Chewuch Project Opportunities list in Appendix B.*

18 SUMMARY OF PROJECT OPPORTUNITIES

The spatial distribution and types of projects in the study area are dependent on the condition of biophysical processes, the level of human disturbance, and specific opportunities that are available for restoration (Figure 50, Table 56). The Protect and Maintain category is applied as an inherent objective for the entire study area. All opportunities to protect, conserve, and monitor the river corridor should be investigated. Protection in perpetuity will be a vital component of any proposed restoration project. The highest priority action, reconnecting stream channel processes, comprises the greatese share of project opportunities at 37%. These projects often involve re-connecting side-channel habitats and processes. In-stream habitat enhancement comprises a large proportion of project opportunities as well with 34% of the total projects. All of these projects involve replacing LWD in the system. REI analysis shows that general levels of LWD are at unacceptable risk conditions in most reaches of the study area. Re-establishing natural wood loading patterns can enhance the entire ecosystem over time through sustained formation of a wide variety of in- and off-channel habitats. So, even though in-stream habitat enhancements are not the highest priority actions, many of these projects stand to improve several important elements of the river system. Enhancement of off-channel habitats represents the third largest portion of projects at 20%. Project opportunities focused on reconnecting floodplain channel processes make up 5% of the habitat actions in the reach. This low number reflects the few locations where floodplain processes are hindered by anthropogenic activities. Riparian Restoration projects make up a small portion of the project distribution at 4%.

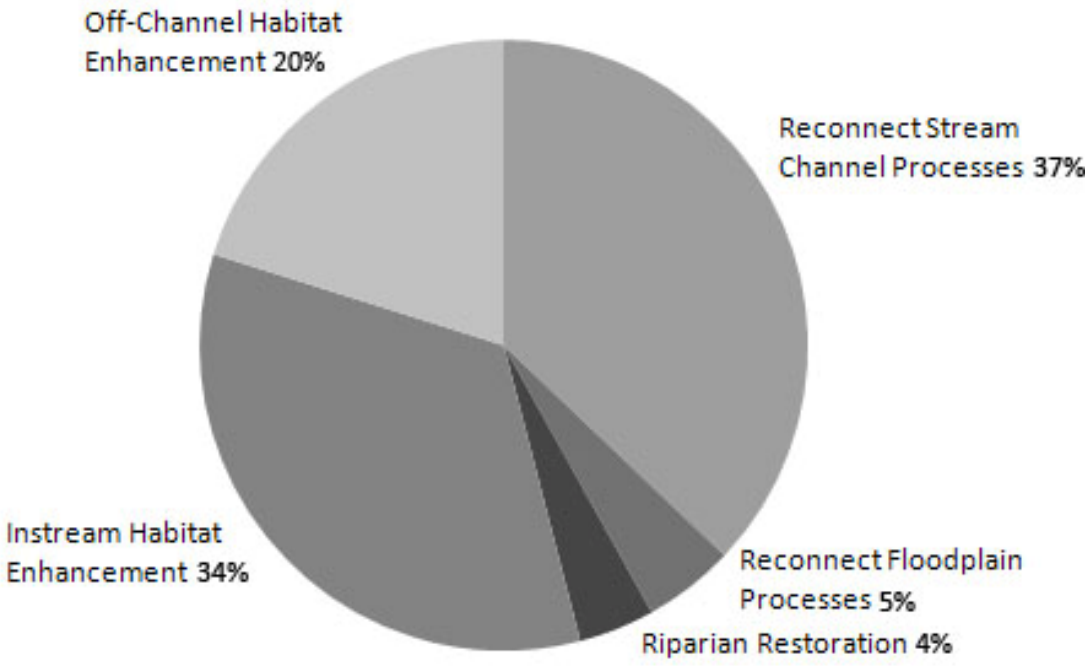

Figure 50. Comparison of the distribution of project types in the study area.

Table 56. Summary of projects identified for each reach in the study area.

Reach	Protect and Maintain	Reconnect Stream Channel Processes	Reconnect Floodplain Processes	Riparian Restoration	Instream Habitat Enhancement	Off-Channel Habitat Enhancement	Totals
C2a		7	2		7	3	19
C2b		5			7	4	16
C3a		5		2			7
C3b		1				1	2
C4a					2	2	4
C4b		1		1	2	4	8
C4c		2		1	3	1	7
C5a		4	1		5	3	13
C5b		1	1	1	3	2	8
C6							0
C7		3			5		8
C8		10	2		3	2	17
C9		7			5	3	15
Totals		46	6	5	42	25	124

19 REFERENCES

Gillilan, S., K. Boyd, T. Hoitsma, and M. Kauffman. 2005. Challenges in developing and implementing ecological standards for geomorphic river restoration projects: a practitioner's response to Palmer et al. Journal of Applied Ecology. 42:223-227.

KWA. 2004. Methow Subbasin Plan. Prepared by KWA Ecological Sciences Ltd. under contract for Washington Department of Fish and Wildlife and funded by the Northwest Power and Conservation Council. April 23, 2004; 463 p.

Lyon, E. Jr. 2006. Lower Eightmile Project , Chewuch River, Okanogan County, Washington: U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Regional Office, Boise, Idaho, 5 p.

Lyon, E. Jr., and Maguire, T. 2008. Big Valley Reach Assessment, Methow River, Okanogan County, Washington: U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Regional Office, Boise, Idaho, 41 p. plus appendices.

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

Roni, P.; Hanson, K.; Beechie, T.; Pess, G.; Pollock, M.; Bartley, D.M. 2005. Habitat rehabilitation for inland fisheries. Global review of effectiveness and guidance for rehabilitation of freshwater ecosystems. FAO Fisheries Technical Paper. No. 484. Rome, FAO. 116p.

Skidmore, P. B., C. R. Thorne, B. Cluer, G. R. Pess, J. Castro, T. J. Beechie, and C.C. Shea. In review 2009. Science base and tools for evaluating stream engineering, management, and restoration proposals. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC.

Upper Columbia Regional Technical Team (UCRTT). 2008. A Biological Strategy to Protect and Restore Salmonid Habitat in Upper Columbia Region (revised). A Report to the Upper Columbia Salmon Recovery Board from the Upper Columbia Regional Technical Team.

Upper Columbia Salmon Recovery Board (UCSRB). 2007. Upper Columbia spring Chinook salmon, steelhead, and bull trout recovery plan: Upper Columbia Salmon Recovery Board, Wenatchee, Washington, 300 pp. Web site: http://www.ucsrb.com/plan.asp

US Bureau of Reclamation (USBR). 2008a. Chewuch River Habitat Assessment – Mouth to Boulder Creek. October 2008 Draft.

US Bureau of Reclamation (USBR). 2008b. Methow Subbasin Geomorphic Assessment (including 19 technical appendices). February 2008. Prepared by Technical Service Center, Sedimentation and River Hydraulics Group, Denver, Colorado in cooperation with Pacific Northwest Regional Office, Boise, Idaho and Methow Field Station, Winthrop, Washington.

US Bureau of Reclamation (USBR). 2009a. Lower White Pine Reach Assessment Nason Creek, Chelan County, WA. USDI USBR Pacific Northwest Region, Boise, ID.

US Bureau of Reclamation (USBR). 2009b. Preston Reach Assessment Entiat River, Chelan County, WA. USDI USBR Pacific Northwest Region, Boise, ID.

US Forest Service (USFS). 2008. Chewuch River Stream Survey Report 2008. Okanogan-Wenatchee National Forest - Methow Valley Ranger District.

Washington Forest Practices Board (WFPB), 1993. Standard Methodology for Conducting Watershed Analysis.