Lower Twisp River
Reach Assessment

Provided for:

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1 OVERVIEW AND OBJECTIVES

1.1 Overview

This assessment evaluates aquatic habitat conditions in the lower Twisp 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 2008a), 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 lower Twisp River from the mouth to river mile (RM) 7.8 and uses this information to identify restoration and preservation strategies.

This report includes three primary components:

1. Reach Assessment – Reach and Sub-Unit scale evaluation and project opportunity identification
2. Stream Habitat Assessment – Results of stream habitat survey conducted in October 2009.
3. REI Metrics – Reach-Based Ecosystem Indicators

1.2 Study Area

The Twisp River Basin is located on the east slope of the Cascade Mountains in Northern Washington. The Twisp River is a tributary to the Methow River and flows into the Methow River near RM 41. The study area includes the lower Twisp River channel and floodplain from the mouth to RM 7.8. See Figure 1 for a locator map of the study area and the geomorphic subdivisions (reaches) used in this study.

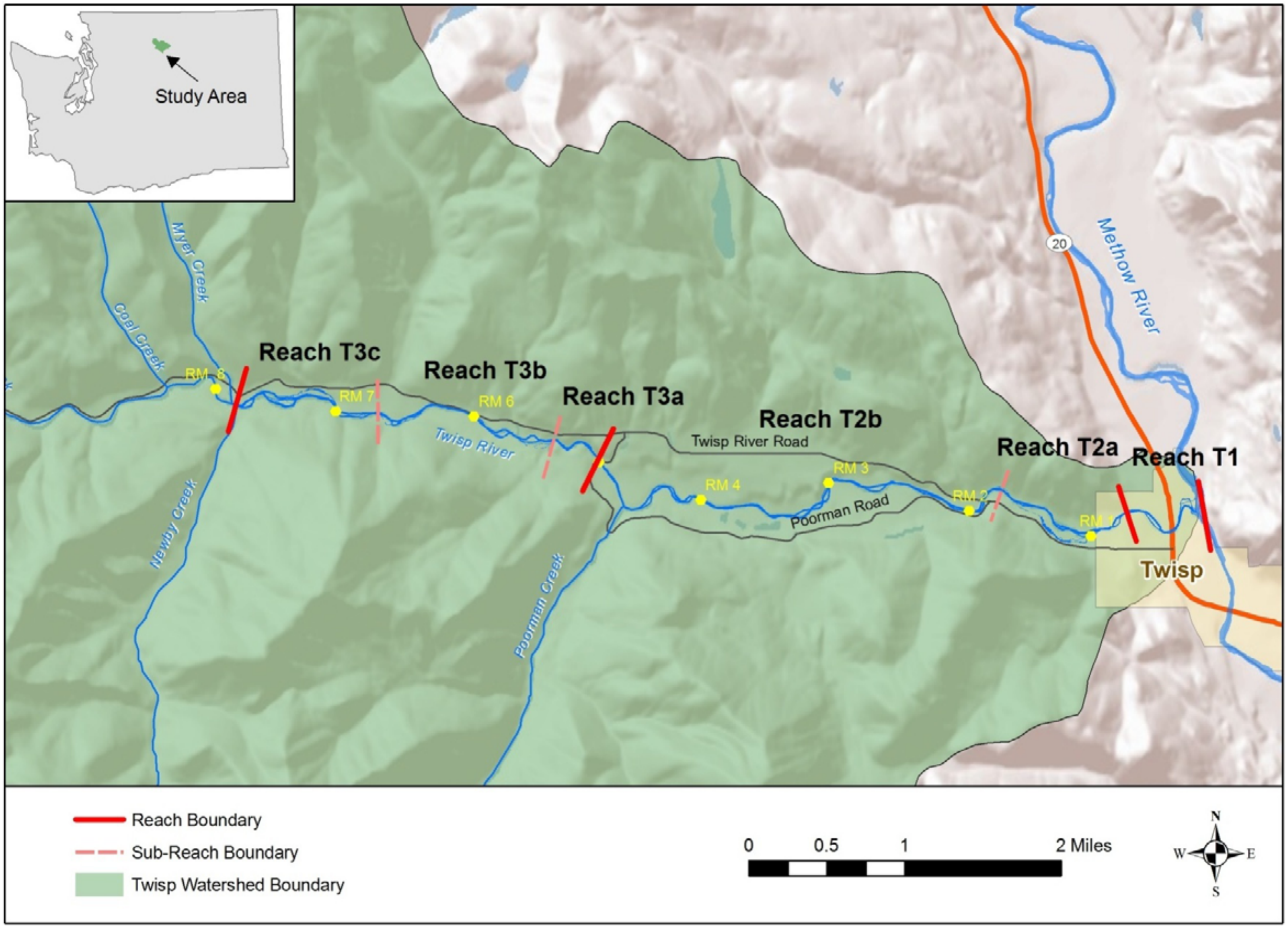

Figure 1. Lower Twisp River Study Area and geomorphic reaches. The study area extends from the confluence with the Methow River to river mile 7.8.

1.3 Goals and Objectives

The Twisp 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:

- Address critical aquatic habitat impairments limiting the productivity of local salmonid populations.
- Protect and restore the dynamic landscape processes that support sustainable riparian and salmonid habitat.
- 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 Lower Twisp River Reach Assessment addresses the Habitat component of the Recovery Plan, with a focus on the lower 7.8 miles of the Twisp 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 Lower Twisp River Basin (*note: these objectives extend beyond the mainstem study area included in this Reach Assessment). 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 Lower Twisp River Basin

- Increase habitat diversity and quantity in the lower Twisp River by restoring riparian habitat, reconnecting side channels and the floodplain (where feasible), and adding instream structures within the river.
- Use practical and feasible means to increase stream flows (within the natural hydrologic regime and existing water rights) in the Twisp River.
- Re-establish connectivity throughout the assessment unit by removing, replacing, or fixing artificial barriers (culverts and diversions).

2 STUDY AREA CHARACTERIZATION

2.1 Setting

The Twisp River Basin is located in Okanogan County in Northern Washington State on the east side of the Cascade Mountains. Headwater drainages in the far western portion of the basin border North Cascades National Park. The total catchment area is 246 square miles. The mainstem Twisp River flows through a broad, glacier-carved valley down to approximately RM 10, which marks the downstream extent of Pleistocene glaciations. Downstream of this point, valley gradient is steeper as the stream has incised through glacial terraces. The study area (RM 0 to 7.8) lies within this steeper and more confined section, except for the lower 0.7 miles where the Twisp River enters the broad Methow River valley. The Twisp River valley is moderately confined throughout the lower 7.8 miles with the exception of an approximately 0.4-mile long confined section near RM 5.0. The major tributaries to the Twisp River within or near the study area include Myer Creek (RM 7.8), Newby Creek (RM 7.8), and Poorman Creek (RM 4.6).

2.2 Salmonid Use and Population Status

Salmonid use of the lower Twisp River includes spring Chinook salmon, 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 lower Twisp 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
Brook Trout	Not listed (non-native)		Present

2.3 Habitat Conditions

Aquatic habitat in the lower Twisp 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 channel straightening, levee construction, bank armoring, and vegetation clearing. Agricultural and residential development has disconnected riparian areas and floodplains due to vegetation clearing, filling and grading, and construction of levees. 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 are discussed in the Stream Habitat Assessment (Appendix A).

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.

Higher priority	**Preservation/Maintenance**
	Protection of existing high quality habitats and processes, and/or allowing no further degradation of altered habitats and processes.
	Restoration/Reconnection
	Restoration of natural process/function that will create and sustain habitats over the long-term. Also includes the reconnection of severed processes, such as floodplain disconnection, as well as reconnection of spatially disconnected habitats (e.g. migration barriers). Includes the principle use of native materials. Dynamic adjustments, such as channel migration, are tolerated. This approach is process-driven and self-sustaining.
	Enhancement
Lower priority	Improvement of habitat without the full restoration of underlying natural processes. Restoration of natural processes is typically limited by past anthropogenic impacts or infrastructure constraints. Dynamic adjustments are only partially tolerated. Includes structure-driven habitat creation that is not necessarily self-sustaining. Habitat may be created in areas where it did not exist historically. An emphasis is placed on native materials but non-native materials may be utilized to some degree.

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 2008a). These same reach delineations were utilized for this Reach Assessment to maintain consistency with tributary-scale assessments.

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 2009). 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 C).

Potential project opportunities were also identified as part of the Methow Subbasin Geomorphic Assessment (aka Tributary Assessment, USBR 2008a). These project opportunities provided a baseline for identification of projects presented in this Reach Assessment. Table 2 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 2008a) were also reviewed to provide information for the project identification effort.

Table 2. General restoration strategies and concepts identified in the Tributary Assessment (USBR 2008a).

Reach	General Restoration Strategies *(USBR 2008a, Table 6)*	Primary Restoration Concepts *(USBR 2008a, Table A-5)*	Secondary Restoration Concepts *(USBR 2008a, Table A-5)*
1	Riparian restoration, Road maintenance, Floodplain restoration	None identified	None identified
2	Riparian restoration, Side-channel reconnection, Road maintenance, Floodplain restoration , LWD restoration	Continue to evaluate MVID West diversion and TR_Prj-4.1 for restoration opportunities; remove or set back levees, riprap and roads that parallel long sections of river and block off 2.3 miles of side channels and floodplain access in TR_Prj-3.3 and 3.15	Restore access to additional floodplain areas and secondary/overflow channels; LWD and riparian planting may be needed in conjunction with side channel reconnections; further evaluate need for restoration strategies along 3% of terrace banks that have been riprapped
3	Riparian restoration, Side-channel reconnection, Floodplain restoration , LWD restoration	Complete TR_Prj-6.65 (Elbow Coulee) where possibly up to 0.3 miles of side channel will be reconnected; evaluate potential to work with heavy development in TR_Prj-7.25 to reconnect a 0.2 mile side channel that would provide off-channel habitat across from a protection and high density spawning are with springs; remove riprap and levees that block upstream and downstream ends of channels in smaller areas	Remove levees to reconnect floodplain areas; further evaluate need for restoration strategies along 9% of terrace banks that have been riprapped

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 1) 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 C.

T1 – Reach Assessment

5 T1 REACH ASSESSMENT

5.1 Reach Overview

T1 begins at the confluence of the Twisp River and the Methow River near the town of Twisp, WA and extends up to RM 0.78, which marks the transition of the Twisp River Valley into the broader Methow River Valley. This reach is within the alluvial fan of the Twisp River and in the past, prior to channelization, would have exhibited a dynamic and complex channel pattern. Modern incision into glacial deposits and development of the town of Twisp pose natural and anthropogenic constraints on floodplain width and channel dynamics. Residential and commercial development has encroached directly to the edge of the channel on both sides throughout the reach, and banks are hardened with riprap. Highway 20 crosses the channel near river mile 0.35.

Habitat Conditions and Fish Use

Salmonid use of Reach T1 includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. A limited amount of spring Chinook and steelhead spawning occurs within the reach; however, the bulk of spawning occurs upstream of the study area (upstream of river mile 12). Annual steelhead redd counts from 2001 to 2007 from the confluence to lower Poorman Bridge (reaches T1 and T2a) ranged from zero to 90. Spring Chinook redd counts over the same period ranged from zero to 10 (Snow et al. 2008). Reach T1 is used by these populations primarily for migration and juvenile rearing. Bull trout primarily use the reach as a migration corridor to access upstream spawning areas.

There is limited spawning and rearing habitat available in Reach T1. Bed substrate is adequately sized but the channel through much of the reach is dynamic and subject to scour and deposition during high flows. There is potential disruption of spawning beds as a result of recreational access, owing to nearby residential areas. Pool quantity within the reach is high although the pools generally have shallow residual depths and very little cover. LWD quantities are moderate, but large key pieces are nearly absent. There are few off-channel rearing areas available. Low flows may be a concern during low flow periods due to upstream irrigation withdrawals (see Appendix A for additional fish habitat information). A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 3.

Table 3. Reach-Based Ecosystem Indicators (REI) ratings for Reach T1. See Appendix B for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach T1 Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*At Risk*
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*Adequate*
	LWD	Pieces per Mile at Bankfull	*Unacceptable*
	Pools	Pool Frequency and Quality	*At Risk*

General Characteristics	General Indicators	Specific Indicators	Reach T1 Condition
	Off-Channel Habitat	Connectivity with Main Channel	*Unacceptable*
Channel	Dynamics	Floodplain Connectivity	*Unacceptable*
		Bank Stability/Channel Migration	*Unacceptable*
		Vertical Channel Stability	*At Risk*
Riparian Vegetation	Condition	Structure	*Unacceptable*
		Disturbance (Human)	*Unacceptable*
		Canopy Cover	*Unacceptable*

Hydrology

The natural hydrologic regime in Reach T1 is driven by snowmelt runoff and low frequency rain-on-snow flood events (Table 4) (USBR 2008a and PWI 2003). Hydrology in Reach T1 is also affected by the TVIP an MVID irrigation diversions upstream. Diversions tend to reduce low flow volume during irrigation season, which typically runs from April through September on the Twisp River. The lower Twisp River has been demonstrated to gain groundwater during late summer, but groundwater gains do not substantially offset diversion volumes (Konrad et al. 2005). Levees and riprap reduce channel/floodplain connection and decrease the water and sediment storage capacity of the floodplain in this reach (PWI 2003).

Table 4. Flood magnitudes for recurrence intervals from 2 to 100 years at the downstream end of Reach T1 (RM 0.05). Obtained from Methow River Basin GIS hydrology database (USBR 2008a).

		Flood Recurrence Interval (ft^3/sec)					
Location	**River Mile**	**Q2**	**Q5**	**Q10**	**Q25**	**Q50**	**Q100**
Downstream end of the Reach near the Mouth of the Twisp River	0.05	2,130	3,169	3,905	4,881	5,640	6,423

Geomorphology

This reach is located at the confluence of the Twisp and Methow Rivers. Reach geomorphology is a function of mainstem/tributary interactions over the last 15,000 years. Valley confinement decreases abruptly as the Twisp River enters the Methow River Valley (Figure 3). The reduction in valley confinement creates a sediment deposition zone that has created a broad alluvial fan over time. Lacustrine deposits between the towns of Twisp and Carlton along the Methow River suggest that the Twisp River may have flowed into the upstream end of a lake at some point during the Pleistocene epoch (Konrad et al. 2005). Since the last glacial retreat about 15,000 years ago, the river has incised the deposits near its mouth, leaving paired-terraces down to river mile 0.45 (USBR 2008a App G). Between these glacial terraces, the river is naturally limited in floodplain width of just over 200 ft, and limited meander migration. Additional limits to planform adjustment have been imposed by levees and riprap. LiDAR data reveals that downstream of river mile 0.45, lateral channel dynamics have created several terraces along river left. These terraces are now developed with residential and commercial development. The mouth of the river downstream of river mile 0.2 is a wide, active, and braided channel with un-vegetated gravel bars that have shifted position during the last 45 years. There has been a recent trend of northward meander migration between river mile 0.0 and 0.2 (Figure 4). The position of the confluence also changes depending on the position of the Methow River, sometimes becoming shorter, and sometimes longer as the Methow meanders across its floodplain.

Figure 3. Low elevation oblique aerial photo looking downstream to the confluence of the Twisp and Methow Rivers (September 2009).

Figure 4. View looking north across the braided channel at the mouth of the Twisp River (November 2009).

Historical channel mapping suggests that channel position has been essentially stable during the 20^{th} century (USBR 2008a). There are two locations that are exceptions to this: the mouth of the channel downstream of RM 0.2 where the channel has been steadily migrating to the north, and between RM 0.45 and 0.6, where the channel has occupied various locations in the past and exhibited split flow conditions in 1985. The active secondary channels in 1985 are now high flow channels (Figure 5).

Figure 5. High-flow channel that was mapped as active side-channel in 1985 (November 2009).

Bed morphology consists primarily of long shallow pools alternating with short riffles (Figure 6). Pools comprise about 56% of the channel area. Natural stream banks through this reach are composed mainly of unconsolidated alluvial deposits and glacial outwash ranging in size from boulders to sand. Bed and bank erosion is limited through much of the reach as a result of bank armoring and hydromodifications. Pebble counts suggest that large gravel and cobbles comprise the majority of bed material (See Habitat Assessment, Appendix A). PWI (2003) found that material smaller than 2mm comprised 12% of the bed, and that 71% of pool features have embedded gravel and cobble.

Figure 6. View looking east in the upstream direction at a riffle-pool section of reach T1 (October 2009).

Human Alterations

Reach T1 has the most concentrated residential development and hydromodifications in the study area (Figure 7). Human development of the historical channel migration zone has resulted in a significant decrease in width of the geologic low-surface. The maximum width has decreased by 58%; mean width has decreased by 65%; and minimum width has decreased by 54% (USBR 2008a). These changes to the maximum and mean widths represent the largest changes in the study area. The floodplain and adjacent terraces have been leveed, cleared, graded, and developed with roads and residences. The right bank of the channel is armored for 2,880 feet, which is essentially the entire length of the reach. Levees along the right bank disconnect 18.5 acres of floodplain. There is less protection along river left, about 870 ft of riprap, which contributes to 6.8 acres of disconnected floodplain. There is one bridge crossing at river mile 0.35 that limits channel migration and floodplain connection.

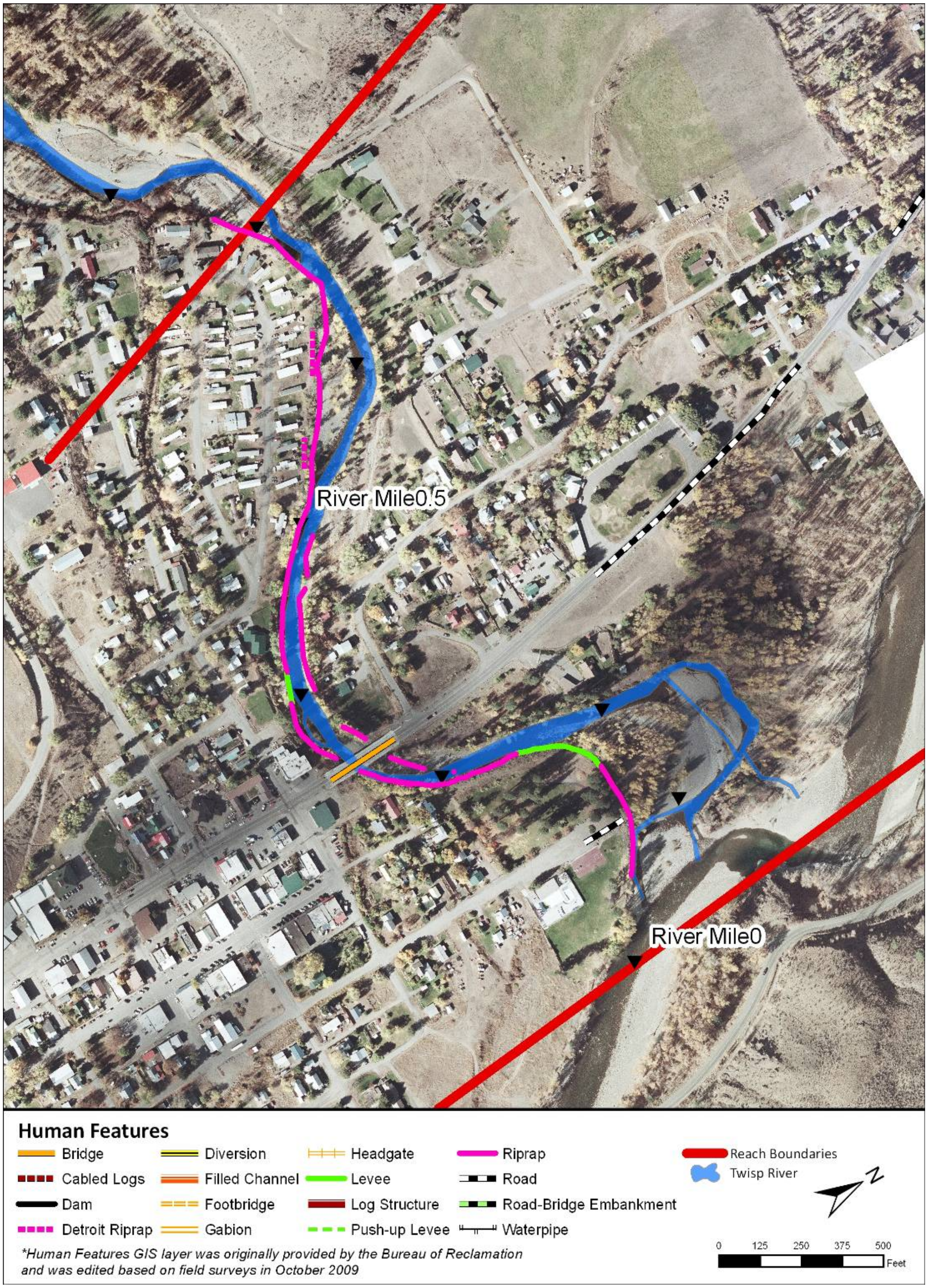

Figure 7. Aerial photo showing human features in Reach T1. Flow is from west to east. Processes are hindered by roadway encroachment, bank hardening, a bridge crossing, and floodplain development.

5.2 Reach-Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach T1 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 (2008) proposes two "restoration with development" areas in the reach corresponding to sub-units IZ-1/DOZ-2 and DOZ3. PWI (2003) suggests a passive restoration approach with community-based riparian planting programs and education outreach.

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.
   - **Riprap and Levees** Remove or modify features to restore dynamic processes. There are barriers to channel/floodplain connection in all but one outer zone. Where feasible, riprap and levees should be removed or modified to increase floodplain and channel migration zone connectivity. The high-concentration of floodplain modification in this reach requires in-depth risk evaluation to assess the potential to modify or remove barriers such as bridge crossings, roadways, levees and developments on adjacent floodplains and terraces.
   - **Highway 20 Bridge** The bridge crossing, and related road fill, near RM 0.35 presents a longitudinal and lateral barrier to floodplain and channel connectivity. The span of the bridge creates a hydraulic constriction as stage increases. Work with appropriate stakeholders to develop long-term solutions to bridge impacts.

3. ***Reconnect Floodplain Processes***
   - **Floodplain Development** The majority of the floodplain in this reach has been developed for residential use. These developments commonly include clearing, fill, and levees or riprap along the channel margin. Full floodplain reconnection will

require reclamation of floodplain surfaces. Work with appropriate stakeholders to develop long-term solutions to floodplain impacts.

- **Levees** Removing or modifying levees, where feasible, will help to restore floodplain processes.

4. ***Riparian Restoration***
   - **Restore Riparian Areas** Loss of riparian forest is extensive in this reach. There is currently only a narrow riparian corridor in this reach that will require significant expansion in order to provide a sustainable source of LWD, thermal shading, natural bank stability, and a 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.

5.3 Sub-Unit and Project Opportunity Summary

Four sub-units were identified in Reach T1, including one inner zone sub-unit and three disconnected outer zone sub-units (Table 5, Figure 8, Figure 9). The inner zone sub-unit in this reach is confined on both sides by armored banks and levees. The Highway 20 Bridge constrains processes and reduces habitat complexity. Near the confluence, the channel is unconfined and complexity is greater, but there is very little wood, pools, or other refugia for rearing fish. Seventy-four percent of the floodplain surfaces in this reach have been converted to residential use. Levees have been placed to protect residences against flooding, and as a result, floodplain connection and habitat have been degraded. The only connected floodplain area is near the confluence of the Methow and Twisp Rivers. Two specific project opportunities are identified for the inner zone in this reach and are presented in the sub-unit summary section below (Table 6).

Table 5. Summary of sub-unit characteristics for Reach T1.

Sub-Unit	River Mile	Acreage
Inner Zone 1 (IZ-1)	0.0 – 0.7	N/A
Disconnected Outer Zone 1 (DOZ-1)	0.42 – 0.78	11.4
Disconnected Outer Zone 2 (DOZ-2)	0.24 – 0.56	6.8
Disconnected Outer Zone 3 (DOZ-3)	0.0 – 0.3	7.1
Outer Zone 1 (OZ-1)	0.0 – 0.2	8.7

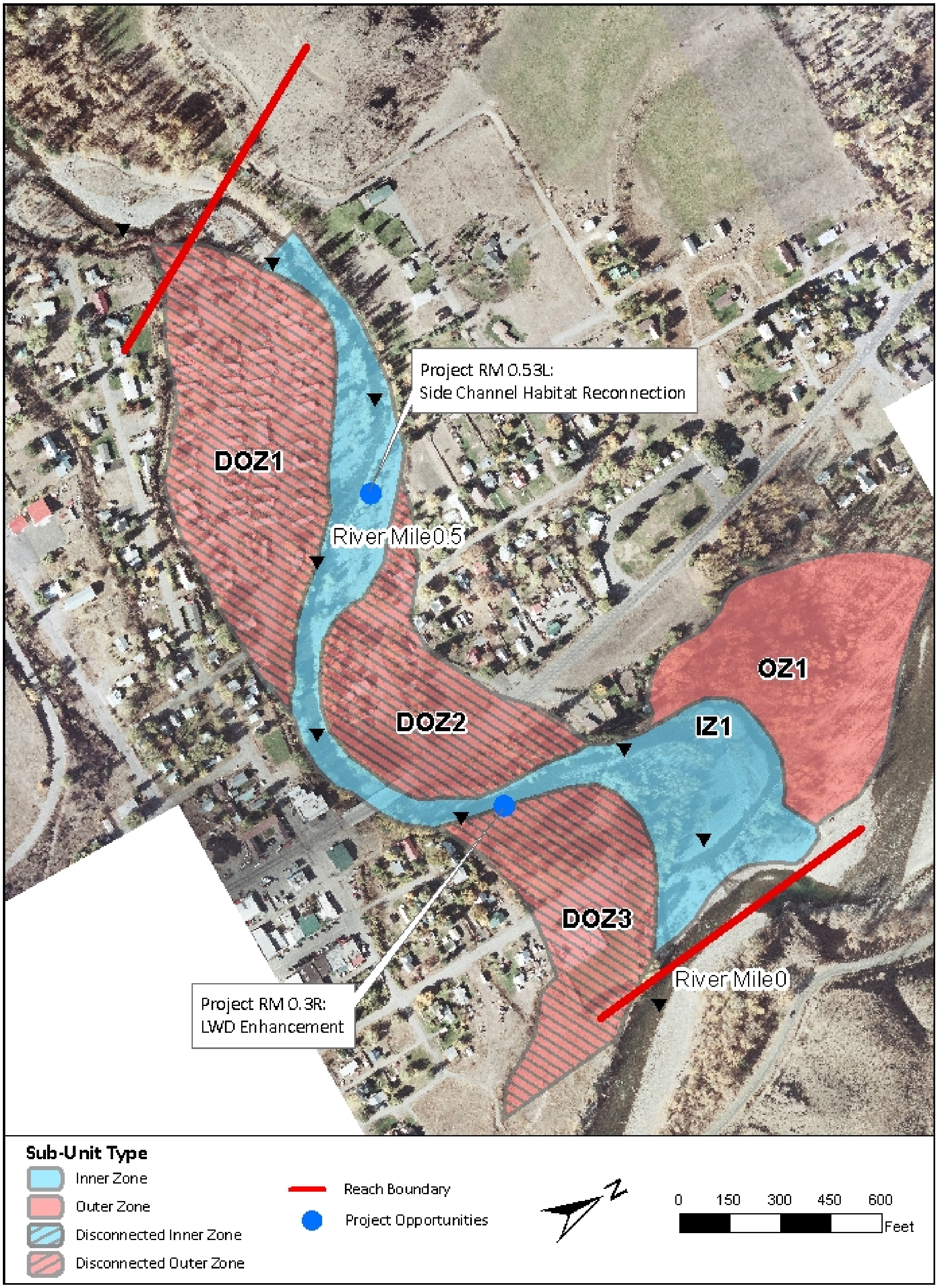

Figure 8. Sub-units and project opportunities in Reach T1. Flow is from west to east.

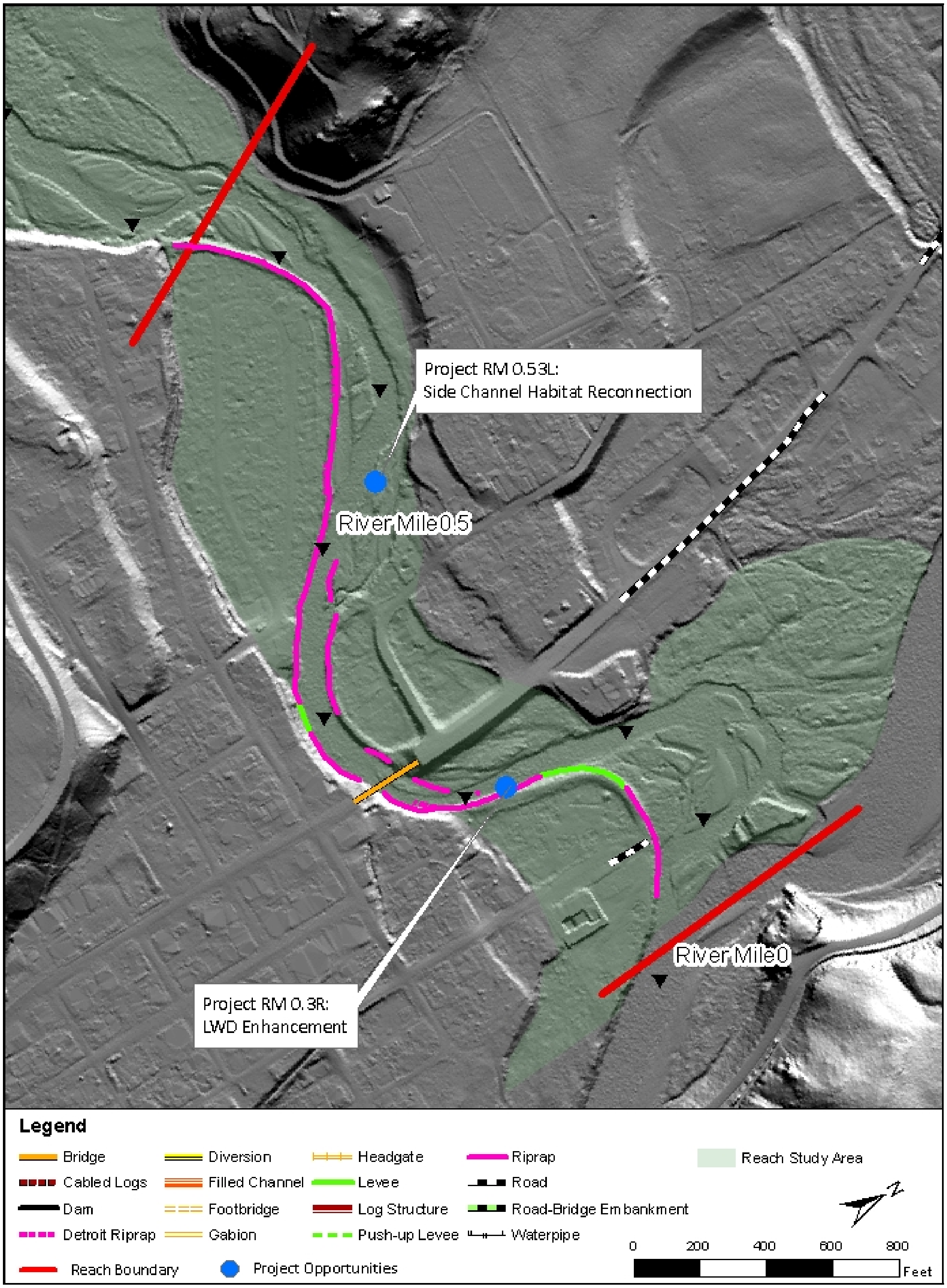

Figure 9. LiDAR hillshade of reach T1 illustrating topography in relation to human features and project locations. Flow is from west to east.

Table 6. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T1.

Sub-Unit	Description	Strategy *(Strategies are listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-1	The channel in this area is subject to the processes of an alluvial fan depositional environment. A large wedge of material has been deposited and subsequently incised by the Twisp River. There are multiple terraces resulting from changes in channel position through time. Almost 75% of floodplain surfaces have been converted to residential development in the town of Twisp, leaving the channel disconnected from the floodplain and decreasing habitat complexity and quality. Bed morphology is alternating pool-riffle sequences with long shallow pools separated by short riffles. Bed material is coarse and is dominated by large gravel and cobble. Large woody debris and other components of habitat complexity are absent.	Protect and Maintain Reconnect Stream Channel Processes Riparian Restoration In-stream Habitat Enhancement	***Project RM 0.53L*** Side-channel habitat reconnection ***Project RM 0.3R*** LWD habitat enhancement. *Work to address impacts related to the highway crossing (e.g. increase span)* *Work with local landowners to identify riparian planting opportunities throughout the reach*	Highway 20 bridge crosses the channel near river mile 0.35. Residential development on both sides of the channel including extensive levees and riprap.
DOZ-1	This sub-unit lies south of the channel and includes 11.4 acres on the inside of a meander bend. This is the largest off-channel sub-unit in the reach. A 1,680-ft long levee separates the entire surface from the inner zone. The surface has been cleared, leveled, and converted to high-density residential use. This disconnected outer zone currently provides no habitat.	Protect and Maintain Reconnect Floodplain Processes	*Work to address impacts of 1,680-foot levee (e.g. removal or selective breaching)*	The levee provides flood protection for high-density residential development.

Table 6. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T1.

Sub-Unit	Description	Strategy *(Strategies are listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
DOZ-2	Anthropogenic development similar to that in DOZ-1 has completely disconnected 6.8 acres of floodplain in DOZ-2. There is riprap protecting the bank, and the floodplain surface has been cleared and developed for residential use, although there are fewer individual dwellings than in DOZ-1. There is no riprap at the upstream end of the unit and the surface may be susceptible to inundation at high-flow; however, there is no off-channel habitat that would be connected during a high-flow event. Highway 20 crosses the sub-unit near its downstream end, creating a longitudinal barrier to habitat and process.	Protect and Maintain Reconnect Floodplain Processes	*Work to identify projects that address riprap, bridge crossing, roadway (e.g. increase bridge span, riprap removal/ modification, road relocation)*	The 450 feet of riprap protects stream banks near residential development. Highway 20 bridge crossing and roadway.
DOZ-3	This surface is located on the alluvial fan deposits south of the channel at the confluence of the Twisp and Methow Rivers. Historical channel processes have been dynamic in this location, including lateral migration, avulsion, and frequent floodplain inundation. However, bank protection, floodplain clearing, and residential development currently limit channel processes and habitat connectivity. Approximately 845 feet of riprap, which protects a school and recreational fields, disconnects 7 acres of floodplain from geomorphic and hydrologic processes. Development of this surface has left no functioning floodplain habitat.	Protect and Maintain Reconnect Floodplain Processes	*Work to address impacts related to riprap and floodplain development (e.g. riprap removal/ modification)*	The 845 feet of riprap provides erosion control and protection to a school and recreational fields.

Table 6. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T1.

Sub-Unit	**Description**	**Strategy** *(Strategies are listed in priority order)*	**Projects**[1] *(specific identified projects are in **bold**)*	**Potential Constraints**
OZ-1	This sub-unit includes 8.7 acres of active floodplain to the north of the channel at the confluence of the Twisp and Methow Rivers. OZ-1 has a relatively robust riparian forest that has not been cleared like other floodplains in the reach. This area retains the dynamic geomorphic and hydrologic processes that occur at river confluences. The surface is frequently inundated and is subject to lateral migration and avulsion by both the Twisp and Methow Rivers.	Protect and Maintain		

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

T2a – Reach Assessment

6 T2A REACH ASSESSMENT

6.1 Reach Overview

Reach T2a begins where the valley width narrows upstream of the alluvial fan of the Twisp River and extends upstream approximately one mile to a point of valley expansion. Glacial outwash deposits form terraces on both sides of the valley. Bedrock outcrops are present in several locations. Sinuosity and floodplain width are naturally limited in this reach, and width is further limited by anthropogenic activities. Low density residential development is present on nearly all floodplain surfaces, although alteration of the riparian forest is relatively minor in comparison to more intensely developed areas downstream. Modification of stream banks is also less than in Reach T1. Nevertheless, levees are present and the majority of outer zone sub-units are disconnected from the main channel. The Twisp River Road parallels the channel to the south, although it is set back against the hill slope and is not a significant factor in outer zone disconnection. A former side channel to the south of the channel now contains constructed off-channel ponds that are owned by the Methow Salmon Recovery Foundation and provide rearing habitat and on seasonal acclimation pond. A diversion located at RM 1.56 provides upstream surface water to this area, and outflow channels return surface water near RM 1.0. There are also old irrigation diversions located at RM 0.8 and 1.3 that have been abandoned.

Habitat Conditions and Fish Use

Salmonid use of Reach T2a includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. A limited amount of spring Chinook and steelhead spawning occurs within the reach; however, the bulk of spawning occurs upstream of the study area (upstream of river mile 12). Annual steelhead redd counts from 2001 to 2007 from the confluence to lower Poorman Bridge (reaches T1 and T2a) ranged from 0 to 90. Spring Chinook redd counts over the same period ranged from 0 to 10 (Snow et al. 2008). Reach T2a is used by these populations primarily for migration and juvenile rearing. Bull trout primarily use the reach as a migration corridor to access upstream spawning areas.

There is a moderate amount of spawning and rearing habitat available in Reach T2a. The dominant substrate in the riffles is cobble (53%) and sub-dominant is gravel (24%). Although limited steelhead and spring Chinook spawning occurs in this reach, many of the pool tail-out areas consist of large cobbles (> 128 mm) that are larger than the ideal size for Chinook (i.e. 13 – 102 mm) and steelhead (6 – 102 mm) spawning (Bjornn and Reiser 1991). However, the coarse bed provides areas of localized velocity refuge that may be utilized for rearing by juvenile steelhead and resident trout. Pool quantity within the reach is high, although the pools generally have shallow residual depths. LWD is relatively abundant although large key pieces are nearly absent. There is a limited amount of accessible off-channel rearing habitat. There are no fish passage barriers in Reach T2a. Low flows may be a concern during low flow periods due to irrigation withdrawals (see Appendix A for additional fish habitat information). A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 7.

Table 7. Reach-Based Ecosystem Indicators (REI) ratings for Reach T2a. See Appendix B for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach T2a Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*At Risk*
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*Adequate*
	LWD	Pieces per Mile at Bankfull	*At Risk*
	Pools	Pool Frequency and Quality	*At Risk*
	Off-Channel Habitat	Connectivity with Main Channel	*At Risk*
Channel	Dynamics	Floodplain Connectivity	*Unacceptable*
		Bank Stability/Channel Migration	*Unacceptable*
		Vertical Channel Stability	*At Risk*
Riparian Vegetation	Condition	Structure	*Unacceptable*
		Disturbance (Human)	*At Risk*
		Canopy Cover	*Unacceptable*

Hydrology

The natural hydrologic regime in Reach T2a is driven by snowmelt runoff and low frequency rain-on-snow flood events (PWI 2003). The current hydrologic regime is augmented by flow diversion at several points upstream, as well as by a diversion near RM 1.55 that supplies restored off-channel rearing ponds and a seasonal acclimation pond to the south of the channel. There is a return flow near RM 1.0. Diversions tend to reduce low flow volume during irrigation season, which typically runs from April through September on the Twisp River. The lower Twisp has been demonstrated to gain groundwater during September, but groundwater gains do not substantially offset diversion volumes (Konrad et al. 2005). Table 8 presents flood peak estimates for a variety of recurrence intervals calculated for a point near the downstream end of the reach.

Table 8. Flood magnitudes for recurrence intervals from 2 to 100 years downstream of Reach T2a (RM 0.05). Obtained from Methow River Basin GIS hydrology database (USBR 2008a).

Location	River Mile	Flood Recurrence Interval (ft^3/sec) Q2	Q5	Q10	Q25	Q50	Q100
Downstream of the Reach Near the Mouth of the Twisp River	0.05	2,130	3,169	3,905	4,881	5,640	6,423

Geomorphology

Reach T2a forms a constriction between the unconfined reach upstream and the Methow River Valley downstream (Figure 10). Hill slopes on both sides of the valley are composed of volcanic breccias inter-bedded with sandstone that can be seen in outcrops in several locations including adjacent to the channel near RM 1.7. Glacial outwash deposits filled the valley during the Pleistocene, were subsequently eroded and incised, and now form terraces on both sides of the valley. The moderate confinement naturally limits mean floodplain width to just less than 500 ft (USBR 2008a).

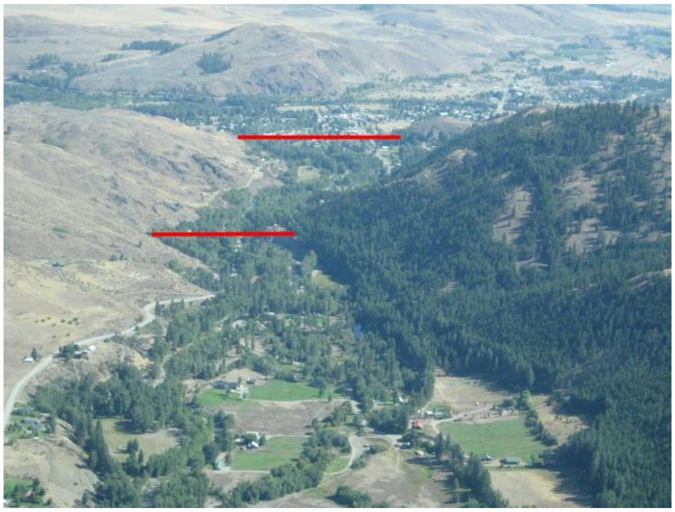

Figure 10. Low elevation oblique aerial photo looking downstream to the east at the transition between reaches T2b (foreground), T2a (mid-ground), and T1a (background) (September 2009).

The historical aerial photo record reveals that Reach T2a has exhibited high planform complexity since the 1940s, including multi-thread channels at all flow levels (USBR 2008a). A significant change in channel planform appears to have occurred after 1964. Pre-1964 photos reveal a channel split from RM 1.05 to RM 1.58. The abandoned channel to the south is now the location of the diversion canal that feeds the off-channel rearing ponds (Figure 11 and Figure 12). The surface return flow from the ponds is at the approximate location where the secondary channel historically rejoined the channel to the north prior to 1964 (Figure 13). Some of the original planform complexity is maintained in the modern channel, which has the highest percentage of side-channel habitat in the study area (See Appendix A: Habitat Assessment). Between RM 1.65 and 1.75, and again between RM 0.95 and 1.2, there is split flow around stable gravel bars. Bar apex jams have been constructed/enhanced in this area and are adding to habitat complexity. Some split flow channels that were mapped around the mid-20th century are now high flow channels that appear to have a frequent recurrence of ground-disturbing flow.

Figure 11. Diversion canal near RM 1.58 that occupies a historical split flow channel that was active prior to 1964 (October 2009).

Figure 12. One of several off-channel rearing ponds developed in the historical secondary channel that was active prior to 1964 (October 2009).

Figure 13. Outflow of "Pond 5" which is a seasonal acclimation pond near RM 1.05 (October 2009).

The channel has a moderate 1% grade. Bed morphology throughout the reach consists primarily of long shallow pools alternating with short riffles (Figure 14). Pools comprise about 47% of the channel area, riffles about 36%, and glides 6%. Natural streambanks through this reach are composed mainly of unconsolidated alluvial deposits and glacial outwash ranging in size from boulders to sand. Reach T2a has the highest percent length of total bank erosion in the study area at 7%. Pebble counts suggest that bed material is comprised primarily of large gravel and cobble size material (See Appendix A: Habitat Assessment).

Figure 14. View looking east in the upstream direction at a riffle-pool transition in reach T2a (October 2009).

Human Alterations

Development in T2a is slightly less intense than in adjacent reaches, perhaps due to the reduced valley width and area suitable to development (Figure 15). Sixty-one percent of the floodplain area is disconnected in this reach. Scattered residences and managed fisheries facilities are the primary human features occupying the floodplain. Bank armoring protects private lands and residential development on both sides of the channel, including about 1,869 ft of the upstream right bank (Figure 16). A diversion through the levee near RM 1.55 provides water to off-channel ponds (Figure 17). This area also includes trails, an observation area, pump houses, a pit tag station, and a screw trap in the channel. The ponds and diversion canal occupy a historical side-channel that was abandoned sometime after 1964. The restoration of the floodplain ponds in this area helps to alleviate some of the floodplain disconnection in this reach and restore off-channel habitat. An additional 630 ft of levee and riprap modifies the banks and disconnects the floodplain along the river left of the channel near the downstream end of the reach. An irrigation diversion near RM 1.3 appears to have been abandoned (Figure 18). A push-up levee on the river-left bank just downstream of the structure disconnects the floodplain from the channel.

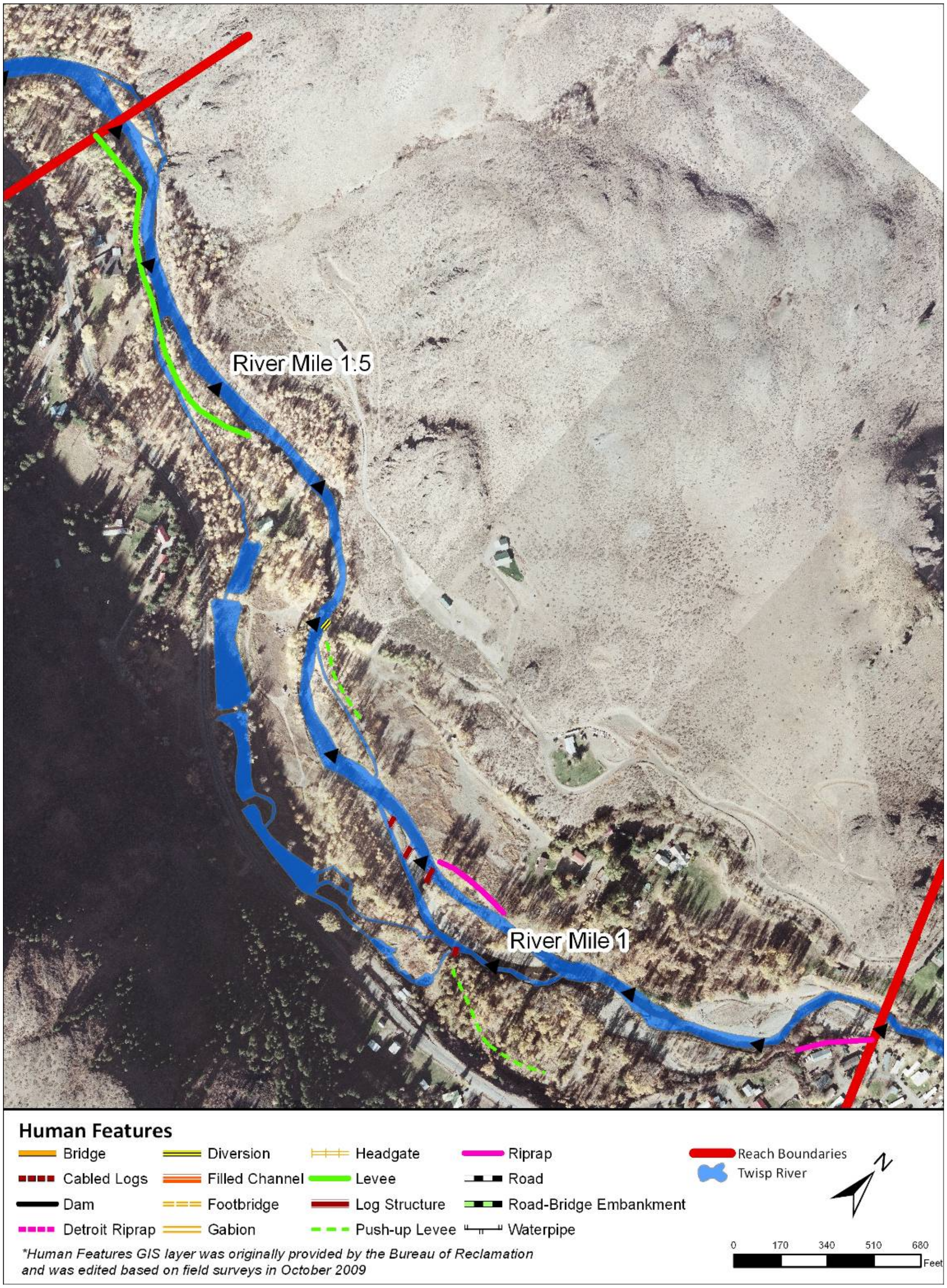

Figure 15. Aerial photo showing human features in Reach T2a. Flow is from west to east. Processes are hindered by bank hardening and development within the floodplain.

Figure 16. View looking downstream toward the west at the levee and development in the floodplain along river-right near RM 1.65 (October 2009).

Figure 17. Diversion structure supplying surface water to restored off-channel ponds along the river-right floodplain (October 2009).

Figure 18. View looking downstream toward the west at the abandoned irrigation diversion on river-left near RM 1.3 (October 2009).

6.2 Reach Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach T2a 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 (2008) sets forth protection and floodplain reconnection as the primary strategies for this reach. PWI (2003) also states that reconnecting side-channel habitat through removal of hydromodifications is a primary restoration goal in 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 diversion in this reach, but that is used to supply off-channel wetlands at a fisheries facility.

- **Riprap and Levees** - Remove or modify features to restore dynamic processes. There are continuous barriers on both sides of the channel at the upstream end of the reach that limit channel processes and disconnect the channel and floodplain. There are houses protected to the south of the channel that present constraints to removing these barriers. There are also several smaller levees throughout the reach. Non-essential barriers to process and habitat connection such as old riprap and unneeded levees should be removed. Protective barriers should be assessed to develop a suite of options for removal or modification.

3. ***Reconnect Floodplain Processes***
   - **Floodplain Development** - There is moderate development of the floodplain on the south side of the valley at the upstream end of the reach. The surface has been subjected to clearing, fill, and levees/riprap along the channel margin. Full floodplain reconnection will require reclamation of floodplain surfaces. Work with appropriate stakeholders to develop long-term solutions to floodplain impacts.
   - **Levees** - Removing or modifying levees, where feasible, will help to restore floodplain processes.

4. ***Riparian Restoration***
   - **Restore Riparian Areas** - There are cleared areas throughout the reach that would benefit from planting native riparian vegetation along the river corridor. Several areas only contain a narrow riparian corridor that will require significant expansion in order to provide a sustainable source of LWD, thermal shading, and a 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. There are several natural wood depositional areas in the reach that will support wood structures. 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 is ongoing restoration of off-channel habitat along the south side of the channel by MSRF. Complimentary or additional work could be supported in this reach with cooperation of stakeholders. In some areas, 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

Seven sub-units were identified in Reach T2a, including two inner zone sub-units, three outer zone sub-units, and two disconnected outer zone sub-units (Table 9, and Figure 19, Figure 20). The channel has a meandering planform with multi-thread segments and the highest percentage of side-channel habitat in the study area. Channel habitat is more complex and in better condition than in Reach T1; however, levees, riprap, and development reduce channel/floodplain connection, leaving 97% of the floodplain disconnected. Twelve specific project opportunities are identified in this reach and are presented in the sub-unit summary section. The USBR (2008) identifies one area for restoration, TR_Prj-1.3, with the goal of reconnecting side-channels through levee removal. This area corresponds to DOZ-2 and Project RM1.28L (Table 10). The USBR also identifies one protection area corresponding to DOZ-1 where there is an ongoing project involving management of off-channel ponds for fish acclimation.

Table 9. Summary of protection and restoration opportunities for reach T2a.

Sub-Unit	River Mile	Acreage
Inner Zone 1 (IZ-1)	1.28 – 1.7	N/A
Inner Zone 2 (IZ-2)	0.7-1.28	N/A
Outer Zone 1 (OZ-1)	1.55 – 1.65	1.0
Outer Zone 2 (OZ-2)	1.4 – 1.48	0.9
Disconnected Outer Zone 1 (DOZ-1)	0.85-1.8	14.2
Disconnected Outer Zone 2 (DOZ-2)	0.58 – 1.3	19.6

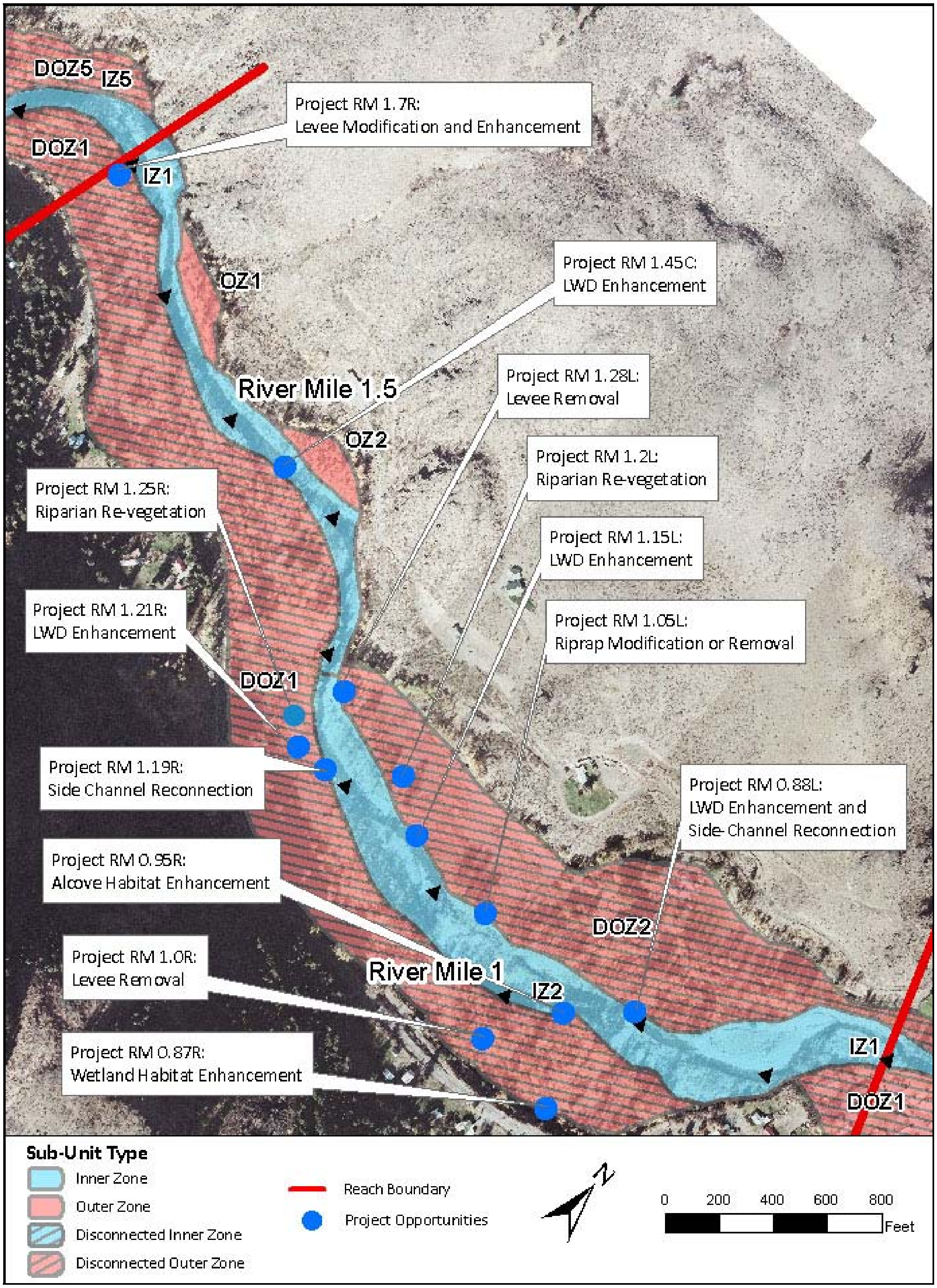

Figure 19. Sub-units and project opportunities in Reach T2a. Flow is from west to east.

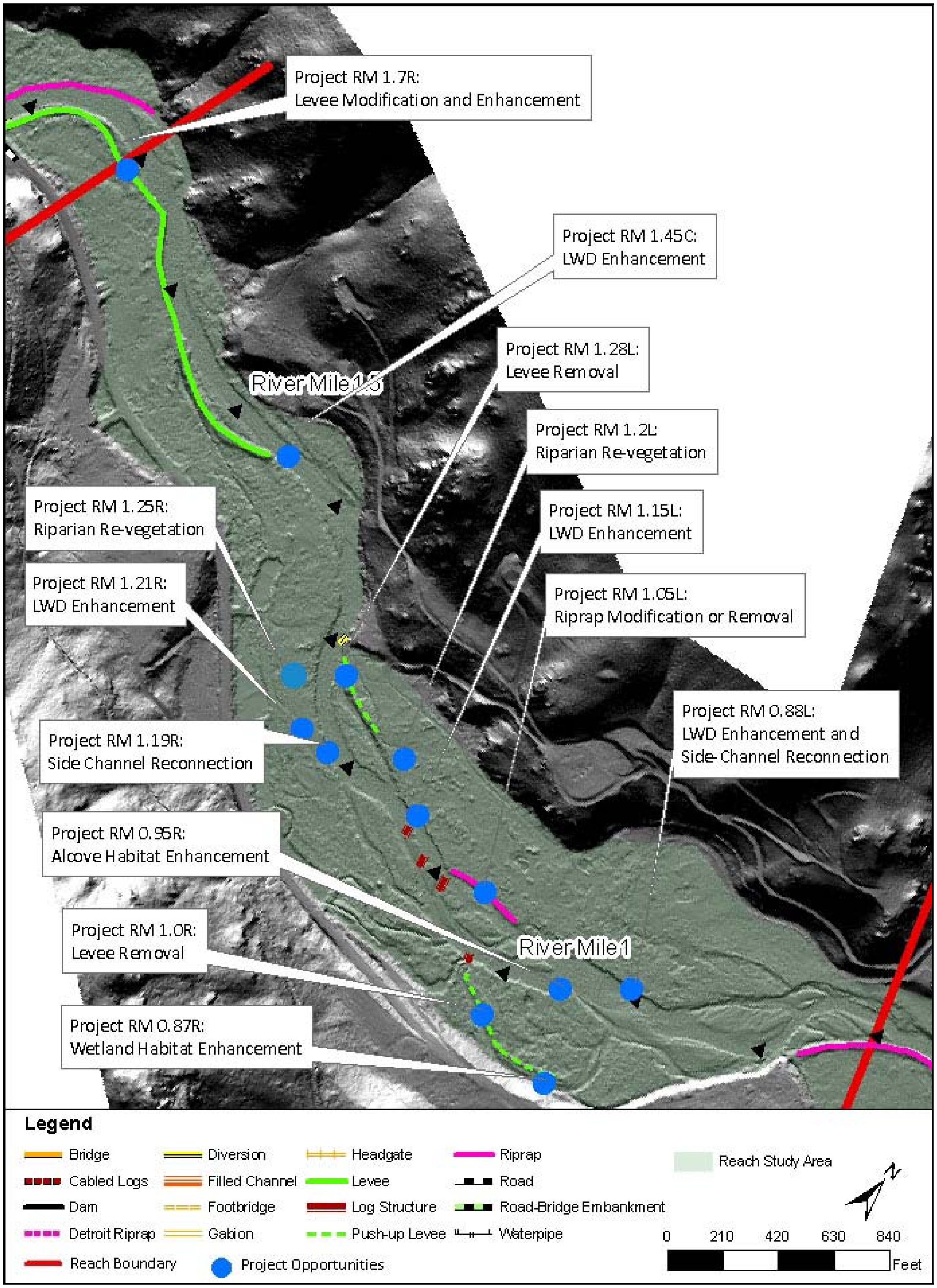

Figure 20. LiDAR hillshade of reach T2a illustrating topography in relation to human features and project locations. Flow is from west to east.

Table 10. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T2a

Sub-Unit	**Description**	**Strategy** *(Strategies are listed in priority order)*	**Projects**[1] *(specific identified projects are in **bold**)*	**Potential Constraints**
IZ-1	Valley confinement naturally limits channel dynamics in this sub-unit. Bedrock outcrops occur along river-left at RM 1.65-1.7 and 1.3-1.4. The adjacent floodplain is more expansive along the right side of the channel, but a levee restricts lateral movement and hydrologic connection. The channel morphology is alternating pool-riffle sequences with long shallow pools separated by short riffles. Bed material is coarse and is composed primarily of large gravel and cobble. Large woody debris and other components of habitat complexity are mostly absent except for near RM 1.1 where wood jams have been placed for habitat enhancement.	Protect and Maintain Reconnect Stream Channel Processes In-stream Habitat Enhancement	***Project RM 1.45C*** LWD Enhancement	Flood protection for a considerable rural residential development in DOZ-1 provided by a levee Diversion structure at RM 1.55 supplying surface flow to acclimation ponds in DOZ-1 and OZ-3 Older irrigation diversion at RM 1.3 (abandoned)
IZ-2	Floodplain width increases along both sides of this sub-unit compared to IZ-1. There are no bedrock controls on the channel and there is less bank hardening than IZ-1. Channel complexity increases, with multiple locations of split flow, a more sinuous channel, active and stable mid-channel gravel bars, and wide point bars with high-flow cut-off channels. The bed morphology is alternating pool-riffle sequences with long shallow pools separated by short riffles. Bed material is coarse and is composed primarily of large gravel and cobble. Large woody debris and other components of habitat complexity increase in this sub-unit relative to IZ-1.	Protect and Maintain Reconnect Stream Channel Processes In-stream Habitat Enhancement Off-Channel Habitat Enhancement	***Project RM 1.19R*** Side-channel reconnection ***Project RM 1.05L*** Riprap modification or removal ***Project RM 0.88L*** LWD enhancement , side-channel reconnection ***Project RM 1.21R*** LWD enhancement ***Project RM 1.15L*** LWD enhancement ***Project RM 0.95R*** Alcove habitat enhancement	In-channel components of managed fisheries facility including a screw trap and P.I.T. tag station Rural residential development in DOZ-2 with discontinuous levees and rip-rap Urban residential development near the downstream end of the sub-unit on river-right with continuous bank hardening beginning at RM 0.78 and extending to the downstream end of the sub-unit

Table 10. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T2a

Sub-Unit	Description	Strategy *(Strategies are listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
OZ-1	OZ-1 is a small, undeveloped floodplain along the north side of the channel near RM 1.6. The riparian forest is relatively undisturbed. A steep hillslope gully drains directly onto this surface and hillslope processes have a large influence on this sub-unit.	Protect and Maintain		Difficult access
OZ-2	OZ-2 is a small, undeveloped floodplain along the north side of the channel near RM 1.3. The sub-unit is undeveloped and the riparian forest is relatively undisturbed. An irrigation canal is aligned along the toe of the adjacent hillslope and remnants of a wood flume are intact on the hillslope just downstream of the sub-unit.	Protect and Maintain		

Table 10. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T2a

Sub-Unit	Description	Strategy *(Strategies are listed in priority order)*	Projects[1] *(specific identified projects are in* ***bold****)*	Potential Constraints
DOZ-1	The 33.8 acre sub-unit encompasses the largest floodplain area in Reach T2a. The upstream half of the sub-unit is disconnected by a levee that extends about 1,870 ft from RM 1.45 to RM 1.85. This levee blocks the upstream inflow of the 1964 active split-flow channel. There is residential development of the floodplain behind the levee and clearing of the riparian forest. The downstream half of the sub-unit consists of several floodplain ponds that are currently managed for juvenile salmon acclimation and release. A diversion located at RM 1.55 supplies surface water to the ponds. The series of ponds provides off-channel habitat. This area of DOZ-1 has been extensively cleared of riparian vegetation. Downstream of the acclimation ponds, floodplain topography suggests a more active connection to overbank flooding. Aerial photography dating from 1964 shows an active split flow channel in the area of the acclimation ponds. It is not clear if abandonment of this channel was natural or if residential development and levees forced flow into a single channel.	Protect and Maintain Reconnect Floodplain Processes Riparian Restoration Off-Channel Habitat Enhancement	***Project RM 1.7R*** Levee removal or set-back ***Project RM 1.0R*** Levee removal ***Project RM 1.25R*** Riparian re-vegetation ***Project RM 0.87R*** Wetland habitat enhancement *Work to address impact of 1,680 foot levee (eg. levee removal/setback*	Managed fisheries infrastructure including acclimation ponds, access roads, and pump-house Rural residential development and 1,870 ft of protective levee

Table 10. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T2a

Sub-Unit	**Description**	**Strategy** *(Strategies are listed in priority order)*	**Projects**[1] *(specific identified projects are in **bold**)*	**Potential Constraints**
DOZ-2	DOZ-2 is a floodplain sub-unit that has been developed for agriculture and residential use. A large portion of the sub-unit has been cleared of riparian vegetation. At the upstream end of the sub-unit, about 320 ft of levee protects an irrigation canal and irrigation diversion. This irrigation diversion does not appear to be actively used, and the canal does not looked regularly maintained. The canal appears to dead-end after about 440 ft in the middle of the cleared floodplain area. There does not appear to be active crop production in this area. Further downstream, riparian vegetation is somewhat intact, but residential development increases. A short section of rip-rap protects houses.	Protect and Maintain Reconnect Floodplain Processes Riparian Restoration	***Project RM 1.28L*** Levee removal ***Project RM 1.2L*** Riparian re-vegetation *Work to identify projects that address riprap, bridge crossing, roadway (eg. Increase bridge span, road relocation, riprap modification/ removal)*	Rural residential development and discontinuous levees and rip-rap posing barriers to hydrologic and geomorphic processes Irrigation diversion and canal beginning near RM 1.3 (abandoned)

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

T2b – Reach Assessment

7 T2B REACH SUMMARY

7.1 Reach Overview

Reach T2b is unconfined and has the widest valley width in the study area. Glacial terraces, alluvial fans, and bedrock provide natural constraints to valley width and channel migration. All floodplain surfaces have been affected by agricultural and rural residential development. The majority of floodplain surfaces are disconnected from active hydrologic and geomorphic processes due to bank hardening, clearing of vegetation, roadways, and fill. Floodplain width is most expansive to the south of the channel. There are extensive wetland ponds throughout the floodplain. The ponds occupy an area that was mapped as an overflow channel in 1954 aerial photographs. Levees limit the connectivity of these features to the channel and floodplain.

Habitat Conditions and Fish Use

Salmonid use of Reach T2b includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. A limited amount of spring Chinook and steelhead spawning occurs within the reach; however, the bulk of spawning occurs upstream of the study area (upstream of river mile 12). Annual steelhead redd counts from 2001 to 2007 from lower Poorman Bridge to upper Poorman Bridge (approximately Reach 2b) ranged from 1 to 46. Spring Chinook redd counts over the same period ranged from 0 to 8 (Snow et al. 2008). Reach T2b is used by these populations primarily for migration and juvenile rearing. Bull trout primarily use the reach as a migration corridor to access upstream spawning areas.

There is limited spawning and rearing habitat available in Reach T2b. The dominant substrate in the riffles is cobble (58%) and sub-dominant is gravel (23%) and boulders (13%). Although the coarse bed is not ideal for spawning, redds were observed during the survey near RM 4.2. The coarse bed provides areas of localized velocity refuge that may be utilized for rearing by juvenile steelhead and resident trout. Pool quantity within the reach is low and the majority of pools (57%) have a residual depth of less than 2 feet. There are eight pools (28% of the reach total) with residual depths greater than 3 feet. LWD frequency is low. There are no fish passage barriers in Reach T2b; however, adequate flows may be a concern during low flow periods due to irrigation withdrawals (see Appendix A for additional fish habitat information). A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 11.

Table 11. Reach-Based Ecosystem Indicators (REI) ratings for Reach T2b. See Appendix B for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach T2b Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*At Risk*
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*Adequate*
	LWD	Pieces per Mile at Bankfull	*Unacceptable*

General Characteristics	General Indicators	Specific Indicators	Reach T2b Condition
	Pools	Pool Frequency and Quality	*Unacceptable*
	Off-Channel Habitat	Connectivity with Main Channel	*At Risk*
Channel	Dynamics	Floodplain Connectivity	*Unacceptable*
		Bank Stability/Channel Migration	*Unacceptable*
		Vertical Channel Stability	*At Risk*
Riparian Vegetation	Condition	Structure	*Unacceptable*
		Disturbance (Human)	*At Risk*
		Canopy Cover	*Unacceptable*

Hydrology

The natural hydrologic regime in Reach T2b is driven by snowmelt runoff and low frequency rain-on-snow flood events (PWI 2003). The lower Twisp has been demonstrated to gain groundwater during September, but groundwater gains do not substantially offset diversion volumes (Konrad et al. 2005). Springs contribute surface flow near RM 4.3, 3.3, 2.8, and 2.0. There is a large irrigation diversion at RM 4.4 that decreases flow during irrigation season (April through September). Table 12 presents flood peak estimates for a variety of recurrence intervals calculated for a point near mid- reach.

Table 12. Flood magnitudes for recurrence intervals from 2 to 100 years for the mid-reach area of T2b (RM 3.4). Obtained from Methow River Basin GIS hydrology database (USBR 2008a).

		Flood Recurrence Interval (ft^3/sec)					
Location	River Mile	Q2	Q5	Q10	Q25	Q50	Q100
Mid-Reach	3.4	2,078	3,092	3,809	4,762	5,502	6,266

Geomorphology

Reach T2b is a wide and unconfined alluvial reach with a mean low surface width of over 1,100 (USBR 2008a). Hill slopes on both sides of the valley are composed of volcanic breccias inter-bedded with sandstone that outcrop near the upstream end of the reach, an several between RM 2.0 an 3.0. Extensive glacial outwash deposits filled the valley during the Pleistocene and now form terraces on both sides of the valley (USBR 2008a). The channel is actively eroding a high terrace near RM 4.6 providing a natural source of sediment ranging in size from sand to boulder (Figure 21).

Figure 21. View to the southeast in the downstream direction at a high glacial terrace that is being actively eroded (October 2009).

Despite the unconstrained valley, Reach T2b has relatively low sinuosity. There is one large-amplitude meander at the upstream end of the reach but the reach is otherwise characterized by low-amplitude meanders with short wavelengths. Aerial photo analysis suggests that the planform pattern and channel location has been relatively stable since about 1945 (USBR 2008a). There has been some meander oscillation between RMs 2.9 and 3.4 and between RMs 4.0 and 4.2. These areas of greater channel dynamics exhibit well-connected side channels and some of the most complex habitat in the reach (Figure 22). The channel gradient is moderate at 1%. Bed morphology is primarily pool-riffle sequences in Reach T2. Reach T2b displays these features, as well as long glides. Bed material is gravel and cobble (See Appendix A: Habitat Assessment).

Figure 22. Side-channel habitat formed in a laterally dynamic area of the reach near RM 3.15 (October 2009).

Human Alterations

There are several areas of channel, bank, and floodplain modification that have disconnected 28% of the inner zone and 74% of the outer zone (Figure 23, Figure 24, and Figure 25). Development occurs mostly on the south side of the channel where the floodplain is more expansive. Habitat and process disconnection results from agricultural and residential development and associated bank hardening, riparian clearing, wetland manipulation, access roads, and fill.

Near the upstream end of the reach, floodplain development is primarily agricultural. Riparian vegetation has been cleared in OZ-1 and thinned in DIZ-1 to accommodate livestock grazing. A 540 ft long push-up levee extending from RM 4.75 to 4.85 is a barrier to hydrologic and geomorphic processes, disconnecting DIZ-1 from the active channel. LiDAR data suggests there are multiple high-flow channels across this surface that would be active in the absence of the levee.

Extensive bank hardening disconnects floodplain surfaces to the north and south of the channel from RM 4.25 to RM 4.5. Riprap extends 650 ft along the river right edge of the channel, disconnecting DOZ-2 from channel/floodplain interactions. This riprap protects irrigation infrastructure along the channel and floodplain. A diversion at RM 4.4 includes a gravel dam extending partially across the channel that blocks a side-channel along river-right. A fish barrier and return structure is located in the interior of the floodplain. Across the river to the north, a 720 ft levee disconnects DOZ-1 from hydrologic and geomorphic processes. The levee protects residential development.

Rural residential development increases on floodplain surfaces to the south of the channel beginning near RM 4.1. Driveways and access roads bisect the floodplain at several locations. Large areas of riparian forest have been cleared for river access and landscaping, and floodplain wetlands have been diked and re-graded. Floodplain clearing, protective levees and riprap, roadways, and fill continue on floodplain surfaces to the south of the channel down to RM 2.0. Discontinuous levees and riprap are found throughout the reach, sometimes providing direct protection to homes near the channel and sometimes disconnecting floodplain or inner zone areas without apparent necessity, as in the levee south of the channel near RM 3.25.

Between RM 2.0 and RM 2.7, Poorman Road longitudinally bisects the floodplain, creating a barrier between a series of wetlands and the river corridor. A mostly plugged culvert provides a surface connection between the wetlands and the channel. Between the channel and the road, the majority of the floodplain has been cleared for rural residential development. A few residences are also located nearer the wetlands, but less clearing has taken place in development of these sites.

To the north of the channel, Twisp River road longitudinally bisects the floodplain between RM 1.95 and 2.2 before climbing onto a terrace. Downstream of the road, the floodplain is disconnected. A bridge crossing at RM 1.85, and 711 ft of riprap along river left between RM 1.7 and 1.8, add to process and habitat disconnection near the downstream end of the reach.

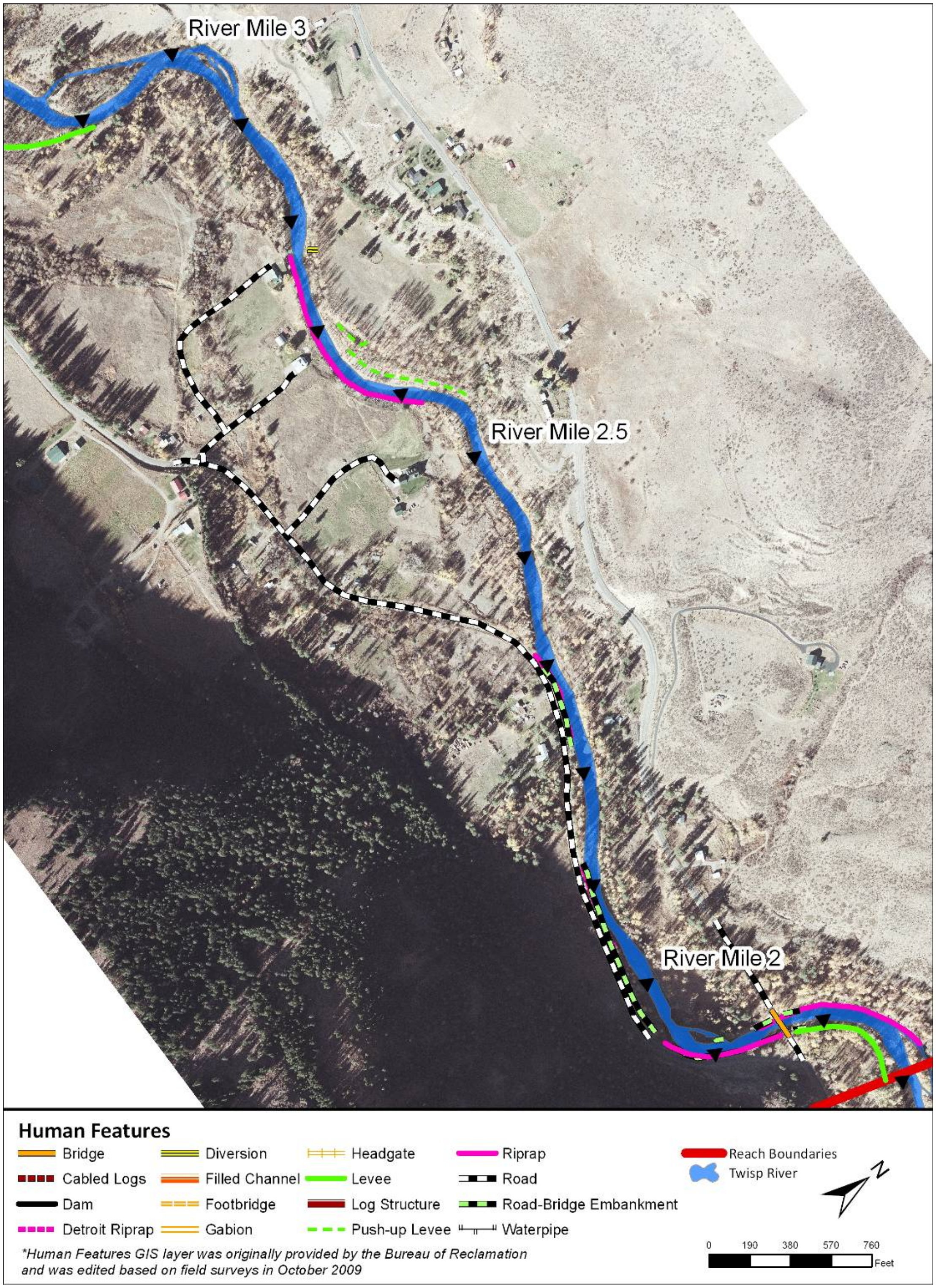

Figure 23. Aerial photo showing human features in Reach T2b in the downstream portion of the reach. Flow is from west to east. Constraints here include roads, a bridge crossing, bank hardening, and floodplain development.

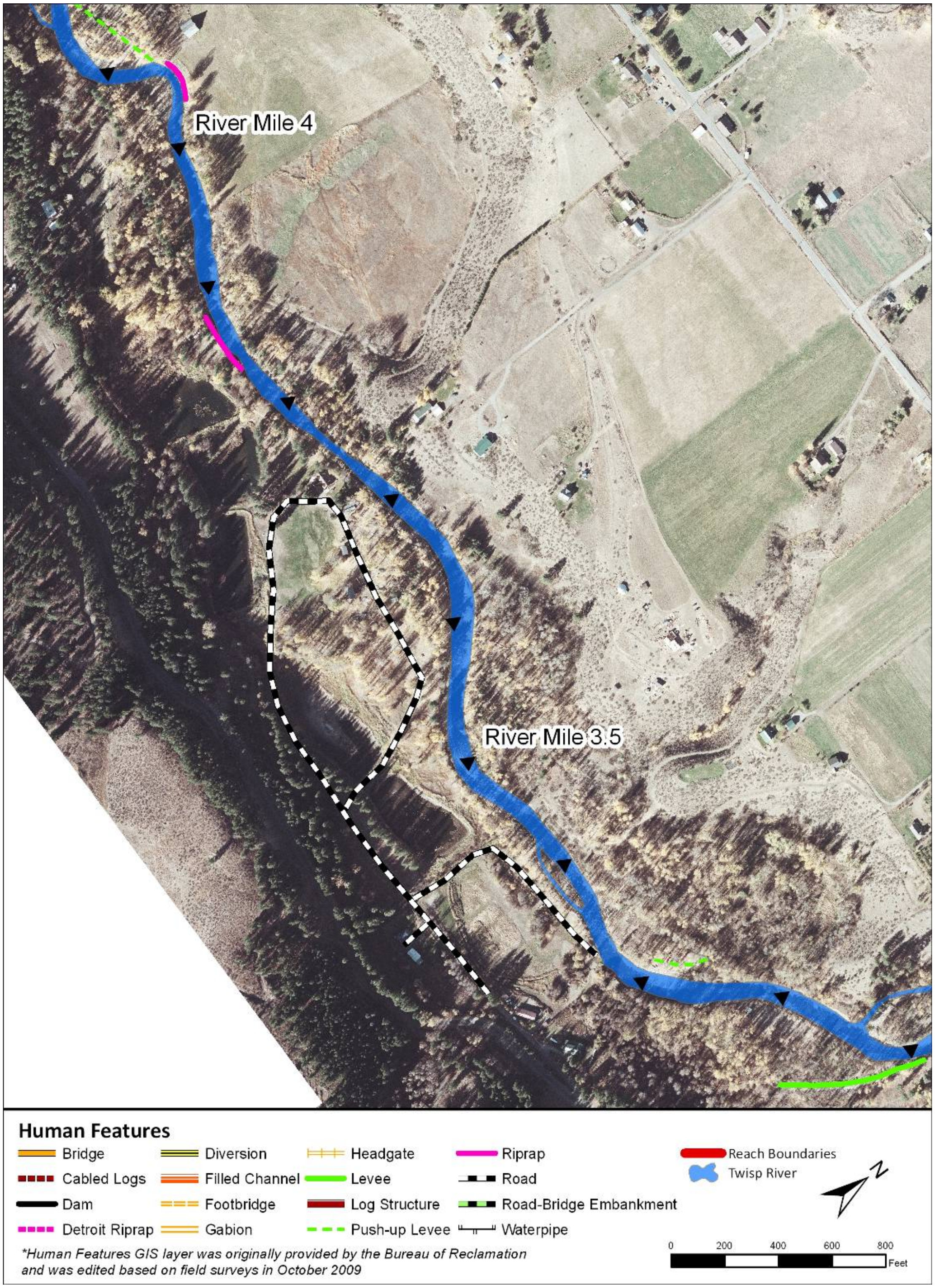

Figure 24. Aerial photo showing human features in Reach T2b in the middle of the reach. Flow is from west to east. Constraints here include roads, bank hardening, and floodplain development.

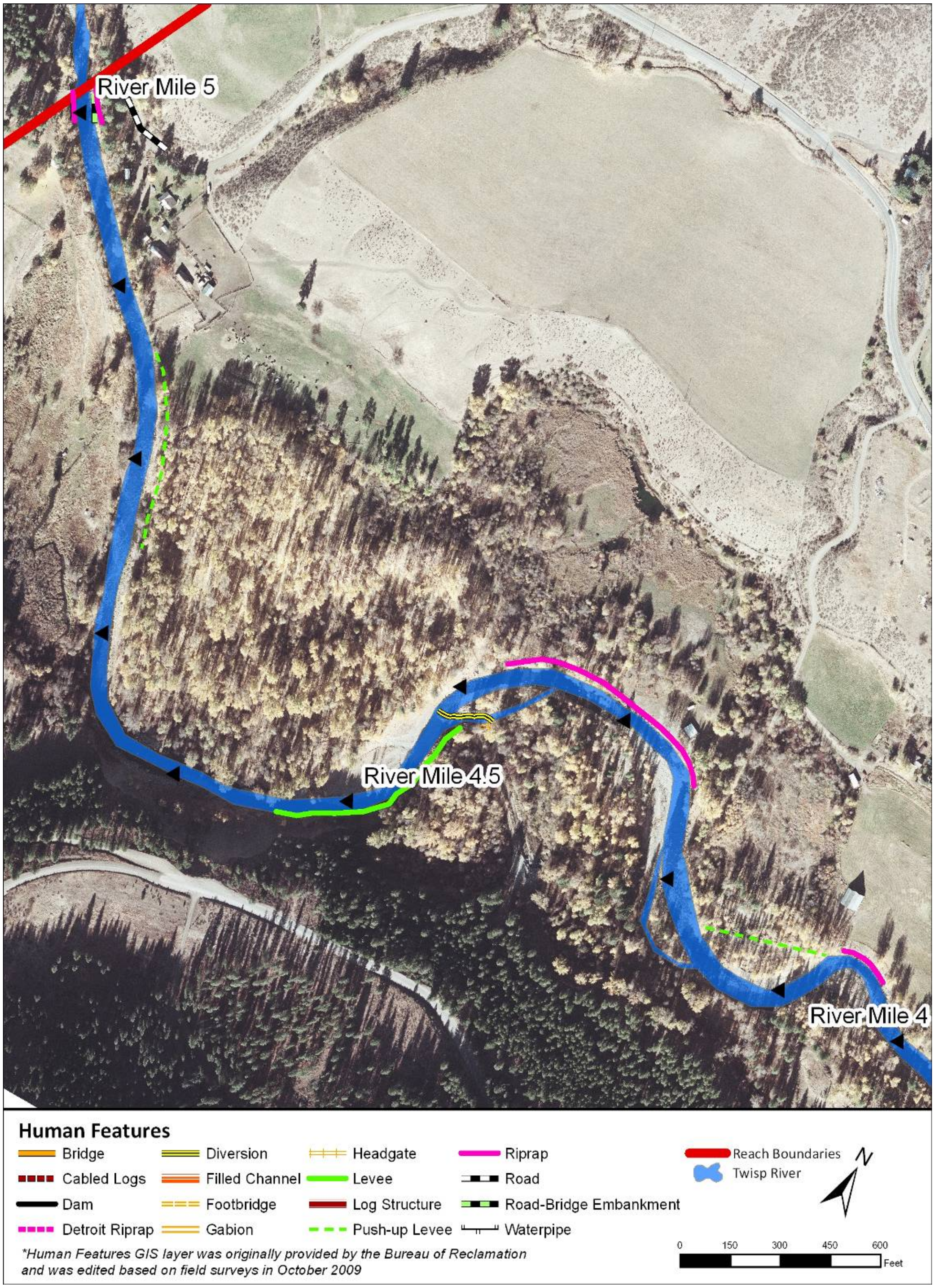

Figure 25. Aerial photo showing human features in Reach T2b at the upstream end of the reach. Flow is from west to east. Constraints here include bank hardening, a diversion, and floodplain development.

7.2 Reach Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach T2b 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. Restoration goals put forth by the USBR focus on re-connecting floodplain habitats and processes. The initial concepts include levee removal, bridge and culvert redesign, and restoration of cleared riparian areas. PWI (2005) states similar restoration goals and strategies for this portion of the Twisp.

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 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 an irrigation diversion in this reach near RM 4.4.
   - **Riprap and Levees -** Remove or modify features to restore dynamic processes, particularly in the upstream end of the reach. There are houses protected to the south of the channel that present constraints to levee removal in the downstream half of the reach. There are also several smaller levees throughout the reach. Non-essential barriers to process and habitat connection such as old riprap and unneeded levees should be removed. Protective barriers should be assessed to develop a suite of options for removal or modification.
   - **Roads and Bridges-** The Twisp River Road and Poorman Road limit channel processes near the downstream end of the reach. A bridge crossing near RM 1.85 and road embankments on both sides of the channel limit lateral migration and alter channel hydraulics. Several options should be considered for alleviating impacts from these features including culverts for limited reconnection, or bridge and road relocation for expanded reconnection.

3. ***Reconnect Floodplain Processes***
   - **<u>Floodplain Development</u>**- There is moderate development of the floodplain throughout the reach. This is mostly residential development, some of which encroaches directly on the channel. Clearing, access roads, and fill are some of the issues created by residential development. Full floodplain reconnection will require reclamation of floodplain surfaces. Reconnection is scalable in some instances, with culverts or bridges allowing limited habitat and process reconnection. Reconnection of floodplain habitat would provide access to large off-channel wetlands on the south side of the valley.
   - **<u>Levees</u>**- There are large floodplain areas that are disconnected by a relatively small number of levees or riprapped banks. Where feasible, riprap and levees should be removed or modified to increase floodplain and channel migration zone connectivity.
   - **<u>Roadways</u>**- At the downstream end of the reach, 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***
   - **<u>Restore Riparian Areas</u>** - There are cleared areas throughout the reach that would benefit from planting native riparian vegetation along the river corridor. Much of this reach contains only a narrow riparian corridor that will require significant expansion in order to provide a sustainable source of LWD, thermal shading, and a riparian buffer.

5. ***In-Stream Habitat Enhancement***
   - **<u>Enhance Habitat Complexity</u>** - 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***
   - **<u>Enhance Off-Channel Habitat Complexity</u>**- There are large off-channel wetlands along the south side of the valley. These features should be assessed for enhancement. Natural activity of beavers can result in enhanced off-channel habitat and may be considered as a restoration option.

7.3 <u>Sub-Unit and Project Opportunity Summary</u>

Twenty sub-units were identified in Reach T2b, including five inner zone sub-units, three disconnected inner-zone sub-units, seven outer zone sub-units, and five disconnected outer zone sub-units (Table 13,Figure 26, Figure 27, Figure 28, Figure 29, Figure 30, Figure 31). The channel has a meandering planform with areas of active split-flow and the highest percentage of side-channel habitat in the study area. Channel habitat is more complex and in better condition that in the adjacent downstream reach. Nevertheless, levees, riprap, and development reduce channel/floodplain connection leaving 78% of the floodplain disconnected. Thirty specific project opportunities are identified in this reach and are presented in the sub-unit summary section (Table 14). The USBR (2008) identifies seven areas with restoration potential. These areas correspond to all connected and disconnected outer zone sub-units, and two of the disconnected inner-zone sub-units.

Table 13. Summary of protection and restoration opportunities for Reach T2b.

Sub-Unit	River Mile	Acreage
Inner Zone 1 (IZ-1)	4.67-5.0	N/A
Disconnected Outer Zone 1 (DOZ-1)	4.1-5.0	24.8
Outer Zone 1 (OZ-1)	4.67-4.95	10.0
Disconnected Inner Zone 1 (DIZ-1)	4.38-4.8	N/A
Inner Zone 2 (IZ-2)	3.97-4.67	N/A
Disconnected Outer Zone 2 (DOZ-2)	4.15-4.5	10.9
Disconnected Inner Zone 2 (DIZ-2)	4.35-4.43	N/A
Disconnected Outer Zone 3 (DOZ-3)	3.1-4.15	47.7
Inner Zone 3 (IZ-3)	3.45-3.97	N/A
Outer Zone 2 (OZ-2)	3.7-3.9	3.0
Outer Zone 3 (OZ-3)	3.19-3.66	16.6
Inner Zone 4 (IZ-4)	2.41-3.45	N/A
Disconnected Outer Zone 4 (DOZ-4)	1.95-3.3	87.0
Outer Zone 4 (OZ-4)	2.78-3.1	7.2
Outer Zone 5 (OZ-5)	2.49-2.91	10.7
Disconnected Inner Zone 3 (DIZ-3)	2.55-2.7	N/A
Outer Zone 6 (OZ-6)	2.31-2.55	4.8
Inner Zone 5 (IZ-5)	1.7-2.41	N/A
Outer Zone 7 (OZ-7)	1.85-2.35	10.7
Disconnected Outer Zone 5 (DOZ-5)	1.71-2.18	8.1

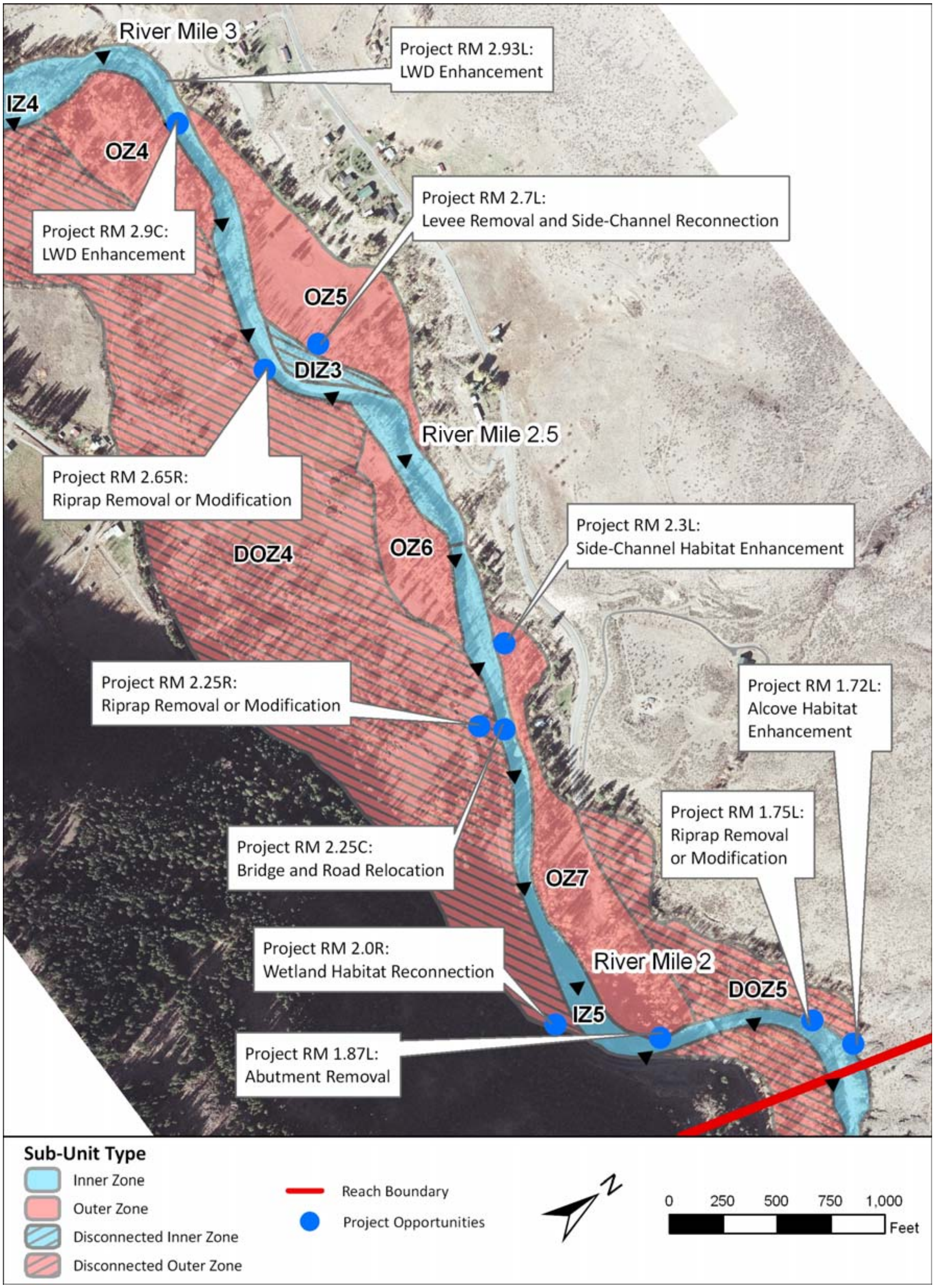

Figure 26. Sub-units and project opportunities in Reach T2b in the downstream end of the reach. Flow is from west to east.

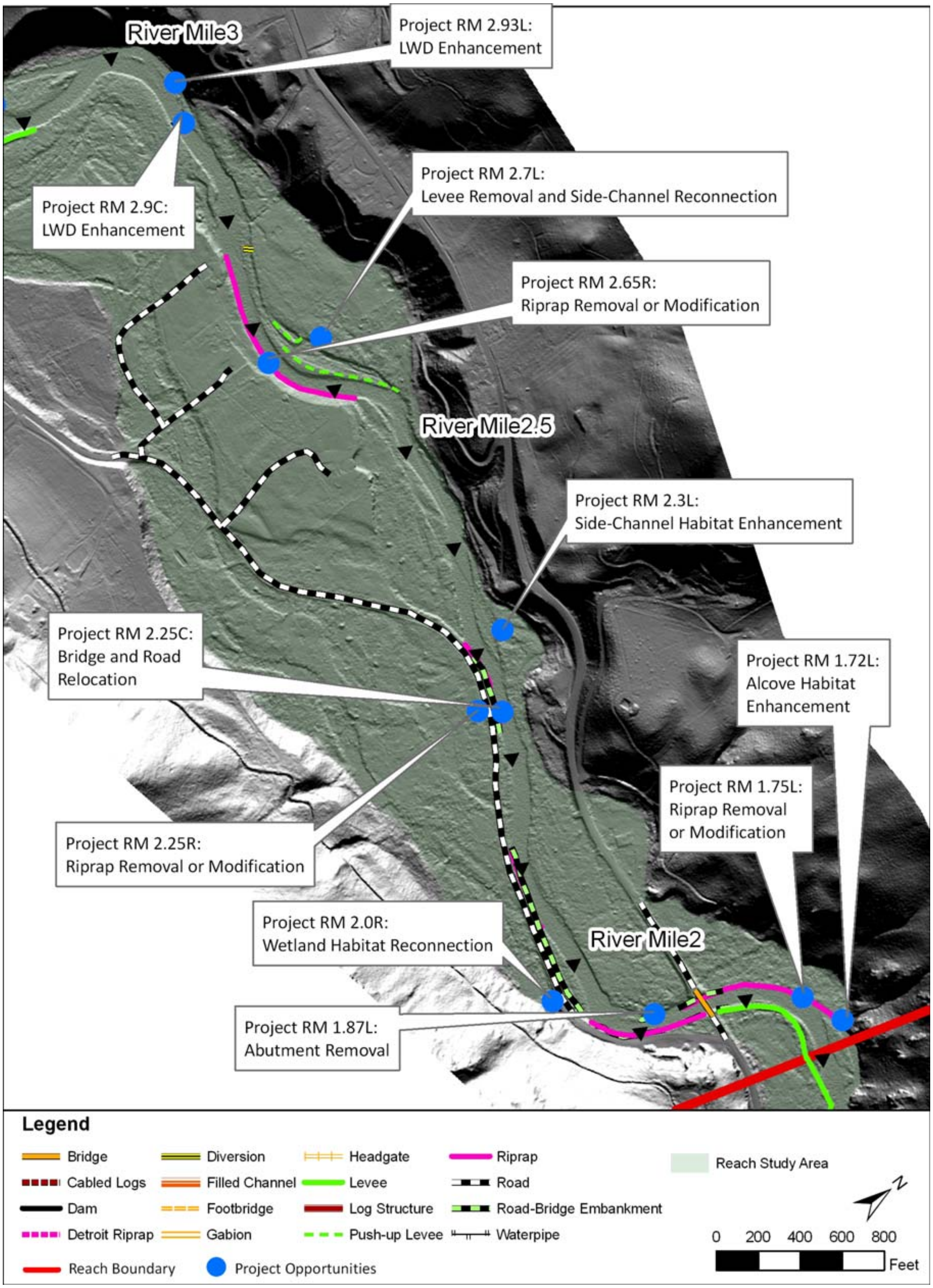

Figure 27. LiDAR hillshade of reach T2b illustrating topography in relation to human features and project locations in the downstream end of the reach. Flow is from west to east.

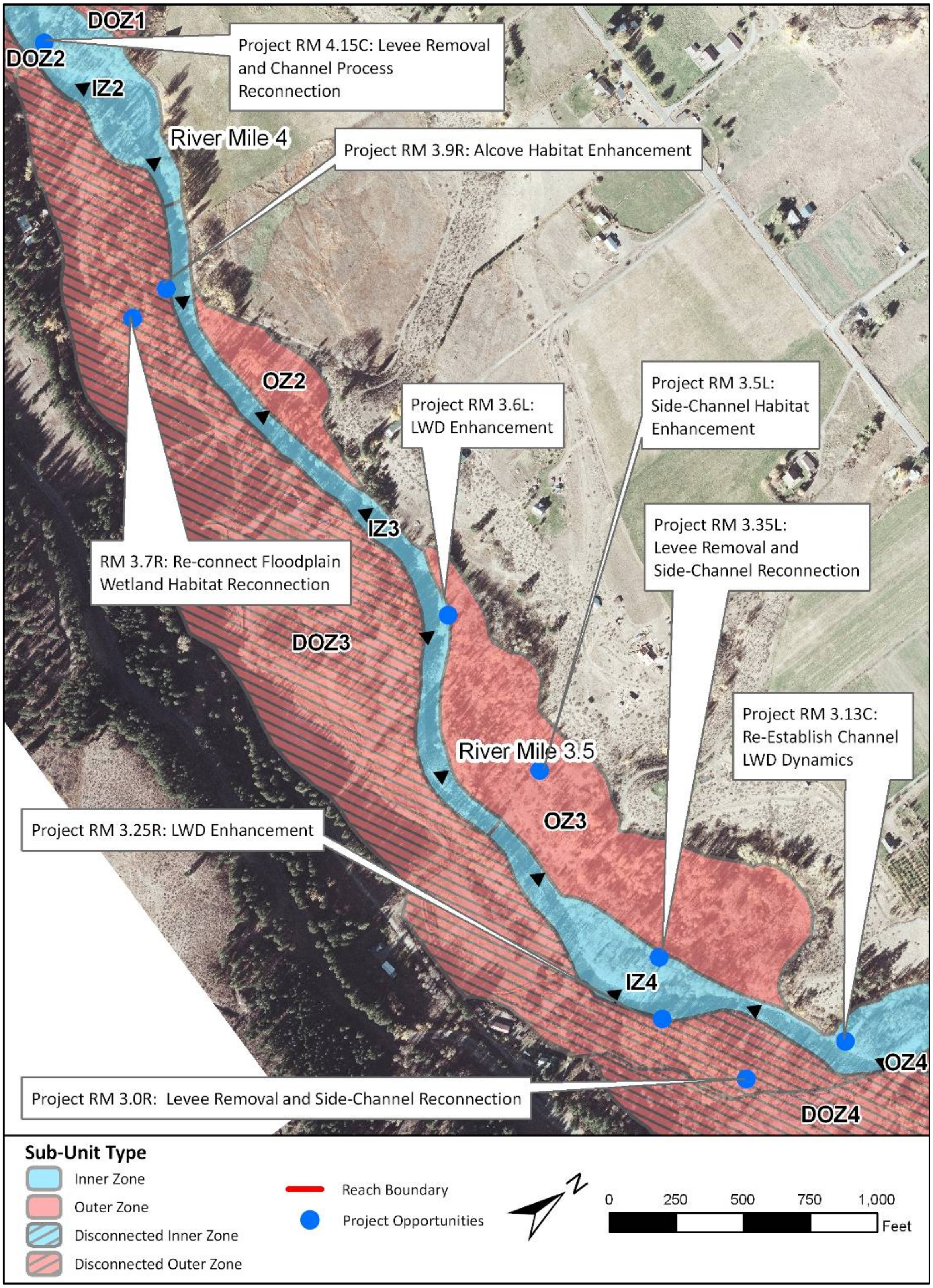

Figure 28. Sub-units and project opportunities in Reach T2b in the middle of the reach. Flow is from west to east.

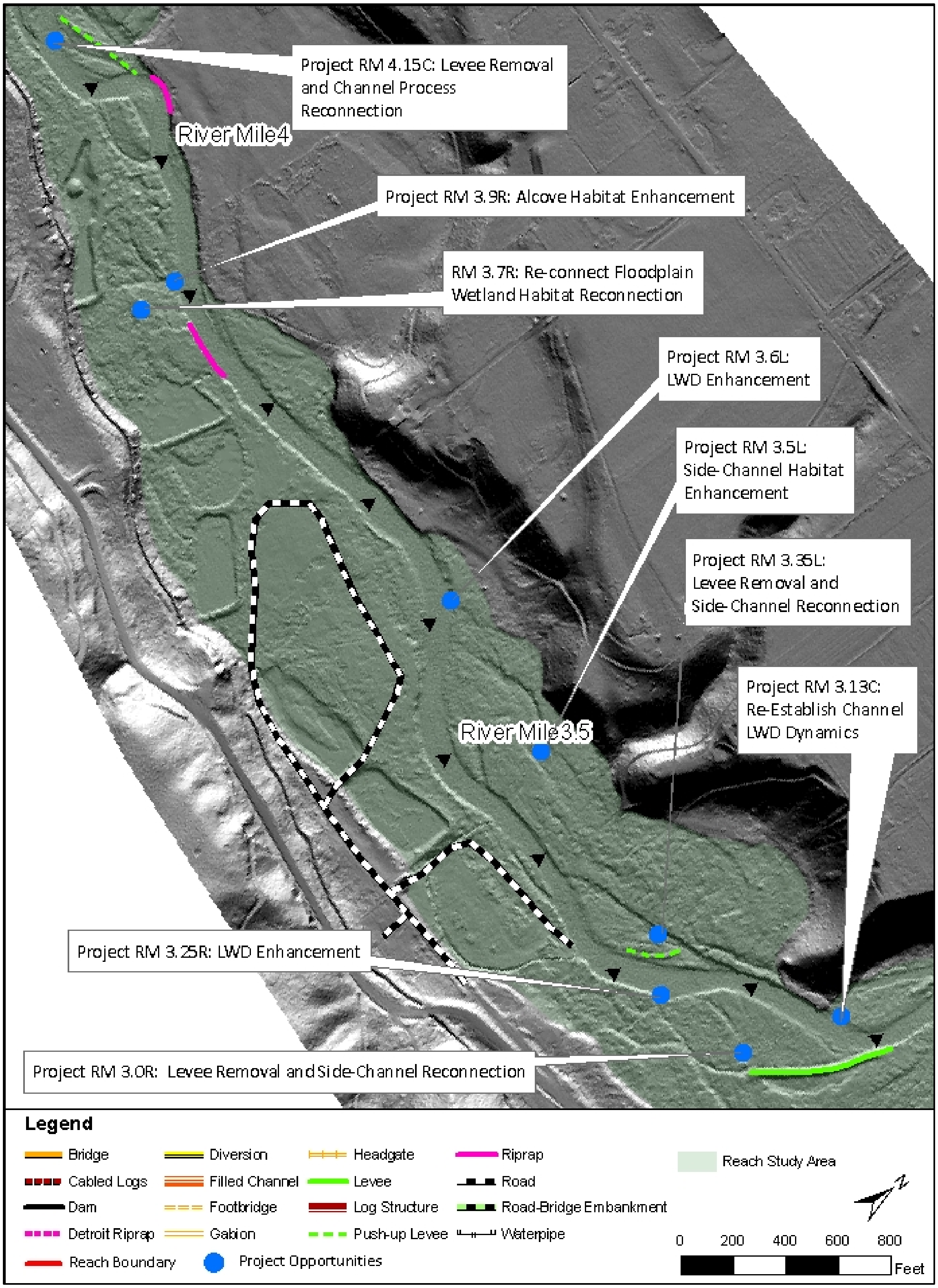

Figure 29. LiDAR hillshade of reach T2b illustrating topography in relation to human features and project locations in the middle of the reach. Flow is from west to east.

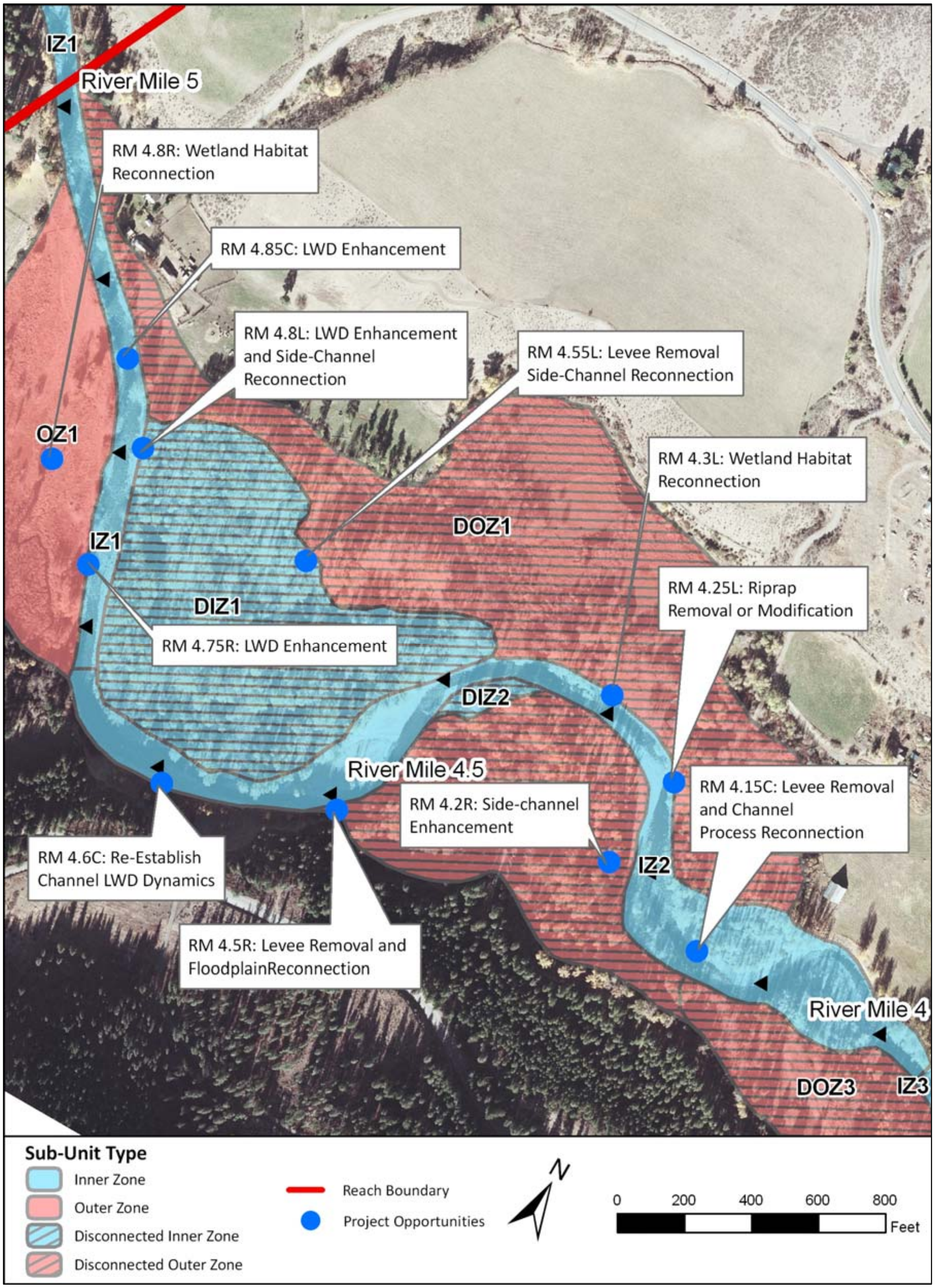

Figure 30. Sub-units and project opportunities in Reach T2b in the upstream end of the reach. Flow is from west to east.

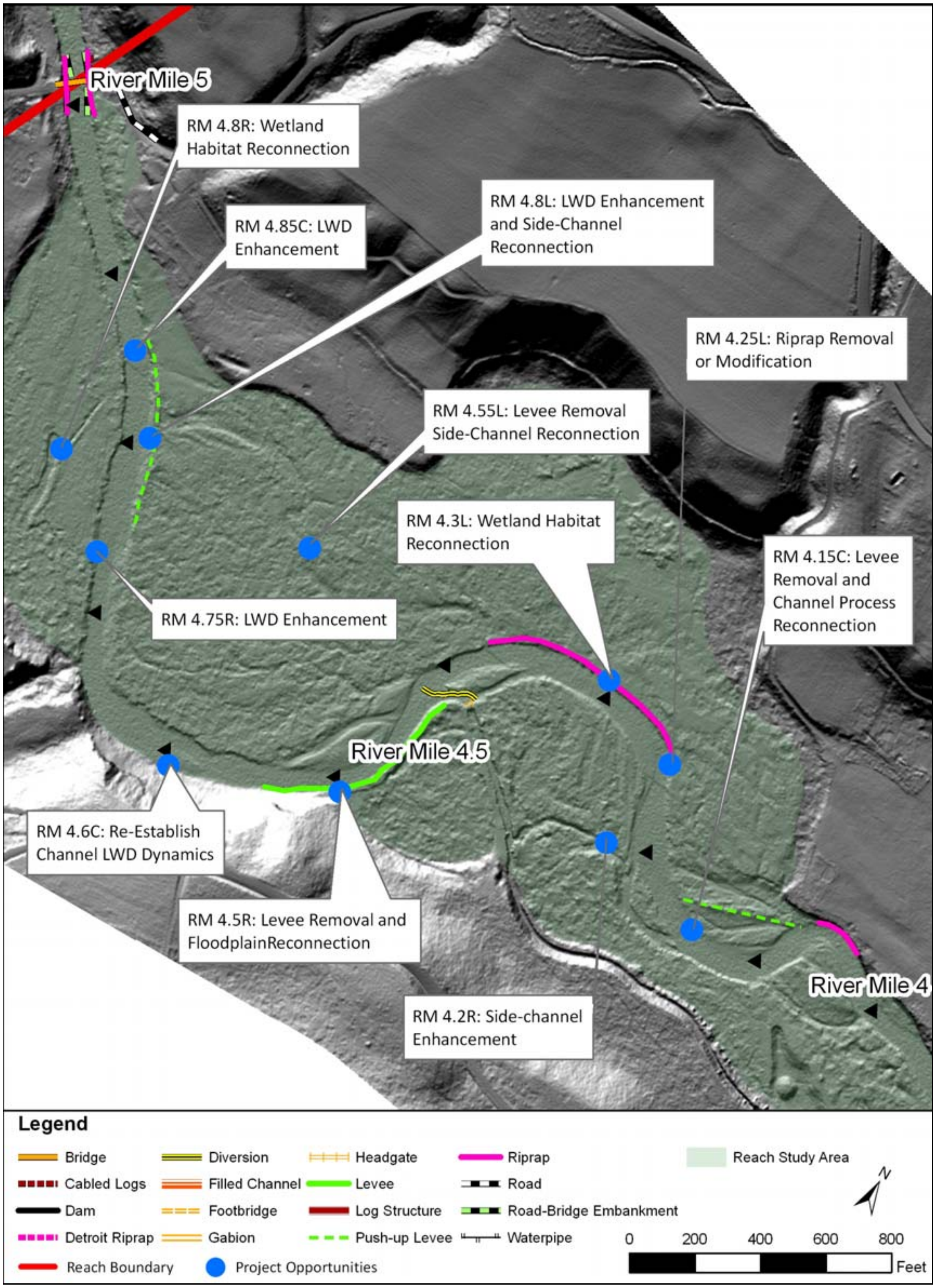

Figure 31. LiDAR hillshade of reach T2b illustrating topography in relation to human features and project locations in the upstream end of the reach. Flow is from east to west.

Table 14. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T2b

Sub-Unit	**Description**	**Strategy** *(Strategies are listed in priority order)*	**Projects**[1] *(specific identified projects are in **bold**)*	**Potential Constraints**
IZ-1	The upstream end of the reach begins at a bridge crossing. There is bedrock in the banks and bed of the channel just downstream of the bridge. IZ-1 is straight, with plane-bed morphology and very little channel complexity or in-stream habitat. Large boulders create limited habitat complexity in some areas. Bed substrate is cobble/boulder and banks are composed of similar alluvial material ranging in size from cobble to sand. There is evidence of cattle grazing along the banks of the channel. At least one location shows signs of cattle accessing the channel for water; the bank is destabilized and riparian vegetation is damaged at this area. There is a narrow riparian buffer along both banks, which provides solar shading but no active LWD recruitment.	Protect and Maintain Reconnect Stream Channel Processes In-Stream Habitat Enhancement	***Project RM 4.8L*** LWD enhancement and side-channel reconnection ***Project RM 4.85C*** LWD enhancement ***Project RM 4.75R*** LWD enhancement	Agricultural and rural residential development along both sides of the channel Bridge crossing at the upstream end of the sub-unit

Table 14. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T2b

Sub-Unit	Description	Strategy *(Strategies are listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
DOZ-1	This outer zone sub-unit encompasses 24.8 acres to the north of the channel. Rural residential and agricultural developments are the main mechanisms for disconnection of hydrologic and geomorphic processes and habitat continuity. Most residential development occurs at the narrow upstream end of the sub-unit. As the sub-unit widens, development decreases, although livestock grazing is still apparent. Portions of the riparian forest have been cleared. There are intact wetlands in the sub-unit near RM 4.35. These wetlands occur along the toe of the glacial terrace and have a surface flow connection to the channel; however, the surface connection is degraded by a riprap bank and the water flows steeply down a 5 ft high embankment providing no fish access to the off-channel habitat. Hydrologic and geomorphic processes and channel/floodplain habitat are disconnected by a 585 ft push-up levee that also disconnects a large inner zone area.	Protect and Maintain Reconnect Floodplain Processes	***Project RM 4.3L*** Wetland Habitat Reconnection *Work to address impacts related to riprap and floodplain development (eg. riprap removal, levee removal, restoration of converted floodplain)*	Residential and agricultural development Extensive riprap along the channel margin blocking habitat and process connection at the outflow Push up levee blocking hydrologic and geomorphic connection upstream
OZ-1	OZ-1 is a 10 acre floodplain sub-unit to the south of the channel between RM 4.67 and 5.1. Most of this floodplain has been cleared of riparian vegetation and is used for livestock grazing. There is a narrow riparian buffer. The downstream half of the sub-unit is a wetland that appears to have been improved for livestock watering. There is an active surface outflow near RM 4.67, just upstream of the confluence with Poorman Creek.	Protect and Maintain Reconnect Floodplain Processes	***Project RM 4.8R*** Wetland habitat reconnection	Agricultural development.

Table 14. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T2b

Sub-Unit	**Description**	**Strategy** *(Strategies are listed in priority order)*	**Projects**[1] *(specific identified projects are in **bold**)*	**Potential Constraints**
DIZ-1	DIZ-1 is the largest disconnected inner zone sub-unit in the study area, occupying the inside of a meander bend from RM 4.38-4.8. The riparian forest has been thinned at the upstream end, with almost no undergrowth remaining; widely spaced cottonwoods provide canopy cover. There is abandoned farm equipment in this area. Thinning decreases in the downstream direction, improving the quality of the riparian forest. A 585 ft long push-up levee blocks process and habitat connection at the upstream end of the sub-unit. LiDAR data suggests that this surface has had a strong connection to active channel processes in the past. There are channel scars that match active channel locations mapped on cadastral maps dating to 1919 and earlier. Removal of the push-up levee would re-establish active channel processes in this area, including active side-channels that experience frequent ground disturbing flows as part of the inner zone. Process and habitat disconnection of this sub-unit creates disconnection of the DOZ-1 as well.	Protect and Maintain Reconnect Stream Channel Processes	***Project RM 4.55L*** Levee removal, side-channel reconnection *Work to address impacts related to the 585 foot levee and agricultural development (eg. levee removal)*	Flood protection provided by push-up levee along the upstream inlet to high flow channels Agricultural development

Table 14. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T2b

Sub-Unit	**Description**	**Strategy** *(Strategies are listed in priority order)*	**Projects**[1] *(specific identified projects are in **bold**)*	**Potential Constraints**
IZ-2	Channel complexity increases in this sub-unit relative to the straight plane-bed morphology of IZ-1 upstream. This is the most sinuous inner zone sub-unit in Reach T2b, and the most laterally dynamic. At the upstream end of the sub-unit, the channel is eroding the toe of a glacial terrace along river right, providing a sediment source to the channel. Historical channel mapping shows several locations of active meander migration and split flow downstream of this sediment source. These geomorphically active areas currently support side-channel habitat. The potential for high-quality habitat and dynamic processes is high in this sub-unit. However, development of adjacent floodplains and bank protection create barriers that leave the channel and floodplain disconnected throughout most of the sub-unit. There is a 688 ft levee along river right between RM 4.45 and 4.55. A gravel dam extends partway into the channel forming a backwater for an irrigation diversion at RM 4.4. The gravel dam blocks the upstream end of a side channel at that location. Another 725 ft of riprap extends along river left between RM 4.25 and 4.37. This riprap may be contributing to downstream bank erosion along river-right and potential channel instability between RM 4.0 and 4.2.	Protect and Maintain Reconnect Stream Channel Processes	***Project RM 4.6C*** Re-establish channel LWD dynamics ***Project RM 4.25L*** Riprap removal or modification ***Project RM 4.15C*** Levee removal and channel process reconnection	Flood protection provided by several hundred feet of levees and riprap on both sides of the channel Irrigation diversion and associated infrastructure at RM 4.4

Table 14. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T2b

Sub-Unit	Description	Strategy *(Strategies are listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
DOZ-2	DOZ-2 occupies 10.9 acres on the inside bend of a large amplitude meander between RM 4.15-4.5. The upstream channel margin of the sub-unit is protected with a 688 ft long levee. A diversion canal begins near RM 4.4 and runs about 390 ft southeast to a fish screen. A diversion overflow and fish return channel extends from the fish screen location to the mainstem at RM 4.2. The cumulative effect of these structures disconnects the floodplain from natural hydrologic, geomorphic, and ecological processes.	Protect and Maintain Reconnect Floodplain Processes Off-Channel Habitat Enhancement	***Project RM 4.5R*** Levee removal and floodplain reconnection ***Project RM 4.2R*** Side-channel enhancement *Work to address impacts related to the 688 foot levee and irrigation diversion (eg. levee removal)*	Levee protecting irrigation diversion. Irrigation diversion at RM 4.4.
DIZ-2	This inner zone sub-unit includes a small side-channel between RM 4.35 and 4.4 that is blocked by a gravel dam diversion. A berm that has been created out of native bed material completely blocks the side-channel. A backwater is created behind the berm and water seeps through the gravel and flows into the side-channel. Without the presence of the gravel berm, the side-channel would provide well-connected habitat. This sub-unit would benefit from the actions proposed in Project RM 4.5R that involves moving the point of diversion and dam upstream near RM 4.5.	Protect and Maintain		Irrigation diversion near RM 4.4.

Table 14. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T2b

Sub-Unit	Description	Strategy (*Strategies are listed in priority order*)	Projects[1] (*specific identified projects are in* ***bold***)	Potential Constraints
DOZ-3	DOZ-3 is a large (47.7 acre) floodplain sub-unit that extends along the south side of the valley between RM 3.1 and 4.15. A series of open water ponds, known locally as the Chain of Lakes, are located in an area that is mapped as overflow channels in 1954 and 1964 aerial photos. Wetlands such as these provide valuable off-channel habitat under natural conditions. The ponds are currently disconnected from hydrologic processes by dikes, roads, and fill. There is a small surface outflow channel that meets the main channel near RM 3.31. Fish access into this off-channel habitat is limited by a culvert. There are houses located in the floodplain near RM 3.7. Other development includes riparian clearing, fill, and roads that contribute to habitat disconnection. About 30% of the riparian forest has been cleared, mainly near houses. Riparian vegetation on the remaining 70% is relatively intact. There is a narrow riparian buffer along the entire channel. DOZ-3 would be part of a large, continuous floodplain area except for the presence of a levee at RM 3.2 that breaks up longitudinal continuity with downstream outer zone sub-units. Re-connection of habitat and processes in this sub-unit would enhance a large amount of potentially high-quality habitat.	Protect and Maintain Reconnect Floodplain Processes Off-channel Habitat Enhancement	***Project RM 3.9R*** Alcove habitat enhancement ***Project RM 3.7R*** Wetland habitat enhancement *Work to address impacts related to levee, residential development (ef. Levee removal, floodplain habitat restoration, riparian restoration*)	Residential development and associated fill, roads, and riparian clearing. Pond manipulation including dikes, roads, and culverts. A 550 ft levee disconnecting several floodplain sub-units.

Table 14. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T2b

Sub-Unit	Description	Strategy *(Strategies are listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-3	This is a short sub-unit with relatively low channel complexity. Channel position appears naturally stable through the latter half of the 20th century. The channel is single thread, without side-channels or split flow. Bed morphology is plane-bed and pool-riffle. Streamside vegetation has been cleared in some areas near residential development, which compromises thermal shading, LWD recruitment, and bank stability.	Protect and Maintain In-Stream Habitat Enhancement	***Project RM 3.6L*** LWD enhancement	Adjacent residential development.
OZ-2	OZ-2 is a small 3-acre floodplain that is undeveloped. The surface has formed where channel migration has re-worked an older floodplain terrace and the toe of the glacial terrace to the north of the channel. High-flow channels across the terrace were mapped as overflow channels in 1954 and 1964 aerial photos, but not in subsequent photo series, suggesting a diminishing hydrologic connection with the channel. There is no agricultural or residential development and riparian vegetation is mostly intact. There is one primitive roadway within the floodplain.	Protect and Maintain		No identified constraints to restoration or preservation

Table 14. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T2b

Sub-Unit	**Description**	**Strategy** *(Strategies are listed in priority order)*	**Projects**[1] *(specific identified projects are in **bold**)*	**Potential Constraints**
OZ-3	OZ-3 is 16 acres and is located along the toe of the glacial terrace where the river has reworked glacial deposits and established a floodplain with a width up to 500 ft. Its location is relatively isolated and there is no residential or agricultural development of the floodplain. Vegetation is intact in OZ-3, providing one of the larger intact riparian and floodplain vegetation patches in the reach. There are some protected plantings in this area. There is an inactive high-flow channel across this surface that was mapped as an overflow channel in 1954. Currently, the channel does not appear to receive regular inundation as evidenced by well-established upland vegetation in the channel.	Protect and Maintain Off-Channel Habitat Enhancement	***Project RM 3.5L*** Side-channel habitat enhancement	No identified constraints to restoration or preservation.
IZ-4	Channel complexity increases in IZ-4 relative to IZ-3 upstream. Meander migration has been relatively dynamic in this sub-unit based on aerial photograph interpretation. The meander sequence between RM 3.1 and 3.4 has experienced up to 200 ft of lateral movement in the position of the low-flow channel since 1964. As a result, there are multiple locations of side-channel that appear active during annual high flow events and several locations of split flow that are active at all flow levels. These features result in some of the highest quality habitat in the reach.	Protect and Maintain Reconnect Stream Channel Processes In-Stream Habitat Enhancement	***Project RM 3.13C*** Re-establish channel LWD dynamics ***Project RM 2.65R*** Riprap removal or modification ***Project RM 3.35L*** Levee removal and side-channel reconnection ***Project RM 3.25R*** LWD enhancement ***Project RM 2.93L*** LWD enhancement ***Project RM 2.9C*** LWD enhancement	Residential development on adjacent floodplains and terraces. Flood protection provided by levees and riprap in the channel and along the channel margin.

Table 14. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T2b

Sub-Unit	**Description**	**Strategy** *(Strategies are listed in priority order)*	**Projects**[1] *(specific identified projects are in* ***bold****)*	**Potential Constraints**
DOZ-4	DOZ-4 is the largest (87 acres) and most intensely developed floodplains in Reach T2b. Ecologic, hydrologic, and geomorphic disconnections result from levees, riprap, riparian clearing, fill, residential development, and transportation corridors. Without the presence of these features, DOZ-3, OZ-4, and DOZ-4 would comprise a large continuous floodplain corridor. Continuity of habitat and processes between these fragmented areas can potentially be regained through habitat enhancement activities. There are wetlands that occupy channel scars and oxbows throughout much of the sub-unit. These channels were overflow channels or old mainstem channels in the 1954 aerial photographs. The wetland areas support open water ponds between RM 2.0 and 2.4 at the far southern edge of the sub-unit along the toe of the hillslope. Poorman Road is a barrier to surface connection between the channel and this potential off-channel habitat. Residential development is another contributing factor to disconnection. Riparian clearing, fill, and road building affect the majority of the sub-unit north of Poorman Road. Smaller developments occur to the south of the road near the wetlands. At the upstream margin of the sub-unit, the levee described in the DOZ-3 summary disconnects high flow channels and wetlands in the western extent of DOZ-4 from DOZ-3 and OZ-4.	Protect and Maintain Reconnect Floodplain Processes Reconnect Stream Channel Processes	***Project RM 3.0R*** Levee removal, side-channel reconnection ***Project RM 2.0R*** Wetland habitat reconnection ***Project RM2.25C*** Bridge and road relocation *Work to address impacts related to levee, road corridor, development (eg. levee removal/setback, road relocation)*	Residential development including fill, roads, and bank protection. Poorman Road corridor. Flood protection provided by levee at the upstream end of the sub-unit.

Table 14. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T2b

Sub-Unit	Description	Strategy *(Strategies are listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
OZ-4	OZ-4 is a 7.2 acre remnant of a much larger floodplain corridor that included DOZ-3 and DOZ-4 as continuous floodplain habitat containing high-flow channels, wetlands, and off-channel habitat. Floodplain development along the south side of the valley has reduced channel/floodplain connection and has fragmented habitat. Because the adjacent floodplain areas are disconnected, process dynamics and habitat quality are also degraded in OZ-4. However, there is no development and no direct barriers to channel/floodplain connection in the sub-unit. There are multiple high-flow channels across the surface that provide wetland and off-channel habitat. Standing water and wetland vegetation suggest a strong groundwater connection. The levee described in the DOZ-3 summary degrades surface connection of high-flow channels. This levee intercepts several high-flow channels in DOZ-3, severing surface flow connection with high-flow channels downstream in OZ-4 and DOZ-4. This sub-unit woul benefit from actions propose in Project RM 3.0R.	Protect and Maintain		No identified constraints to restoration or preservation.
OZ-5	OZ-5 occupies 10.7 acres on the inside of a meander bend between RM 2.5 and 2.9. The surface has been cleared and developed for agricultural purposes. There is a narrow buffer of riparian vegetation along the channel margin at both ends of the sub-unit. The surface has been filled and leveled. LiDAR data does not show any surface expression of high-flow channels or off-channel habitat.	Protect and Maintain Reconnect Stream Channel Processes		Agricultural development and associated riparian clearing and surface leveling.

Table 14. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T2b

Sub-Unit	**Description**	**Strategy** *(Strategies are listed in priority order)*	**Projects**[1] *(specific identified projects are in **bold**)*	**Potential Constraints**
DIZ-3	DIZ-3 lies at the interface between OZ-5 and IZ-4. Under natural conditions this sub-unit would be an active gravel bar with a high-flow cut-off channel defining the floodplain margin. This high-flow cut-off channel has been appropriated for agricultural use. Beginning at around RM 2.76, the bottom of the high-flow channel has been lined with plastic to reduce groundwater loss and maximize flow into a catch basin that has been built near the upstream end of the gravel bar near RM 2.7. Downstream of this catch basin, a 575 ft long push-up levee disconnects the remainder of the gravel bar and side-channel from inner-zone processes and habitat.	Protect and Maintain Reconnect Stream Channel Processes	***Project RM 2.7L*** Levee removal and side-channel reconnection *Work to address impacts of development and levee (eg. levee setback/removal, reconnect secondary channel)*	Catch basin and levee disconnecting inner zone processes.
OZ-6	OZ-6 is a 4.8 acre floodplain area on the margin of the much larger disconnected floodplain of DOZ-4. There is some riparian clearing near the upstream end of the sub-unit, but otherwise the riparian forest is intact. LiDAR data suggests that there are high flow channels near the downstream end. An overflow channel on this floodplain is visible in the 1954 aerial photos.	Protect and Maintain		Private land ownership.

Table 14. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T2b

Sub-Unit	Description	Strategy *(Strategies are listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-5	IZ-5 has low planform complexity and high stability. Sinuosity is low and there is no split flow or side-channel habitat. Bed morphology is plane-bed and pool-riffle. There is limited cover, no deep pools, and scarce LWD. The embankment of Poorman road forms the river-right bank for most of the length of the sub-unit between RM 1.87 and 2.3. This forms a barrier to inner zone processes and channel/floodplain connection between IZ-5 and DOZ-4. Under natural conditions, high-flow channels and off-channel habitat would have a hydrologic and ecologic connection to channel processes. There is a bridge crossing for Twisp River Road at RM 1.85. This structure is a hydraulic constraint and limits channel dynamics. Downstream of the bridge, both sides of the channel are protected with riprap and levees and channel processes are further limited.	Protect and Maintain Reconnect Stream Channel Processes	***Project RM 1.87L*** Abutment removal. ***Project RM 1.75L*** Riprap removal or modification ***Project RM 2.25R*** Riprap removal or modification	Poorman Road to the south of the channel between RM 1.9 and 2.3. Residential development in adjacent floodplain sub-units to the south of the channel. Bridge crossing at RM 1.85. Flood protection provided by riprap and levees on both sides of the channel from RM 1.85 to the downstream extent of the reach at RM 1.7.
OZ-7	The Twisp River Road bisects the floodplain between RM 1.85 and 2.15. OZ-7 is south of the road and is connected to floodplain and channel processes and habitat, although the presence of the road affects connectivity to some degree. The riparian forest is largely intact in this 10.7 acre sub-unit. There is a primitive road on the floodplain and small patches of clearing.	Protect and Maintain Off-Channel Habitat Enhancement	***Project RM 2.3L*** Side-channel habitat enhancement	Twisp River Road corridor.

Table 14. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T2b

Sub-Unit	**Description**	**Strategy** *(Strategies are listed in priority order)*	**Projects**[1] *(specific identified projects are in **bold**)*	**Potential Constraints**
DOZ-5	This 8 acre floodplain sub-unit is north of the Twisp River Road and is disconnected from channel/floodplain processes and habitat. The roadway, bridge crossing at RM 1.85, and riprap along the channel margin between RM 1.7 and 1.85 create barriers to ecological and physical processes. There is also residential development of this surface and associated riparian clearing, fill, and road building. The riparian forest is otherwise intact and provides fragmented riparian habitat.	Protect and Maintain Reconnect Floodplain Processes Off-Channel/Side-Channel Habitat Enhancement	***Project RM 1.72L*** Alcove habitat enhancement	Twisp River road corridor. Riprap between RM 1.7 and 1.85. Bridge crossing at RM 1.85. Residential development.

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

T3a – Reach Assessment

8 T3A REACH ASSESSMENT

8.1 Reach Overview

Reach T3a is a short, confined reach located between RM 5.0 and 5.4. Bedrock confines the channel on both sides for the majority of the reach. Natural channel confinement limits floodplain formation and habitat complexity, but also limits human development. There are essentially no anthropogenic features within the reach.

Habitat Conditions and Fish Use

Salmonid use of Reach T3a includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. A limited amount of spring Chinook and steelhead spawning occurs within the reach; however, the bulk of spawning occurs upstream of the study area (upstream of river mile 12). Annual steelhead redd counts from 2001 to 2007 from upper Poorman Bridge to the fish weir (corresponds to Reaches 3a, 3b, and part of 3c) ranged from 3 to 88. Spring Chinook redd counts over the same period ranged from 0 to 21 (Snow et al. 2008). Reach T3a is used by these populations primarily for migration and juvenile rearing. Bull trout primarily use the reach as a migration corridor to access upstream spawning areas.

There is good spawning and rearing habitat in Reach T3a. Although substrate is generally coarse (cobbles and boulders), a few of the long tail-outs at the bedrock-formed pools provide potential for high quality spring Chinook and steelhead spawning. The deep pools also provide good adult holding and juvenile rearing habitat for multiple salmonid species.

The dominant substrate in riffles is cobble (45%) and sub-dominant is boulders (23%) and gravels (22%). Pool quantity within the reach is much higher in this reach than other reaches in the study area, with 23.7 pools/mi compared to 8.9 - 25.7 pools/mi in the other reaches. Twenty-two percent of the pools have a residual depth of less than 2 feet. Forty-four percent have residual depths greater than 3 feet. LWD frequency is moderate compared to the other reaches, but is low overall. Pools provide most of the protection and cover within the reach. There are no fish passage barriers in Reach T3a; however, adequate flows may be a concern during low flow periods due to irrigation withdrawals (see Appendix A for additional fish habitat information). A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 15.

Table 15. Reach-Based Ecosystem Indicators (REI) ratings for Reach T3a. See Appendix B for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach T3a Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*At Risk*
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*Adequate*
	LWD	Pieces per Mile at Bankfull	*Unacceptable*

General Characteristics	General Indicators	Specific Indicators	Reach T3a Condition
	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 Vegetation	Condition	Structure	*Adequate*
		Disturbance (Human)	*Adequate*
		Canopy Cover	*Unacceptable*

Hydrology

The natural hydrologic regime in Reach T3a is driven by snowmelt runoff and low frequency rain-on-snow flood events (PWI 2003). This natural hydrologic pattern is altered by the TVPI diversion upstream near RM 7.4 that appreciably decreases in-stream flow during the later summer. The lower Twisp gains groundwater during September, but groundwater gains do not substantially offset diversion volumes (Konrad et al. 2005). Table 16 presents flood peak estimates for a point near the downstream end of the reach.

Table 16. Flood magnitudes for recurrence intervals from 2 to 100 years for the downstream end of T3a (RM 4.7). Obtained from Methow River Basin GIS hydrology database (USBR 2008a).

Location	River Mile	Flood Recurrence Interval (ft^3/sec)					
		Q2	Q5	Q10	Q25	Q50	Q100
Downstream of the Reach	4.7	1,945	2,895	3,567	4,459	5,151	5,867

Geomorphology

Reach T3a is a confined canyon reach created by incision through volcanic breccia interbedded with sandstone. Mean low-surface width is the narrowest in the study area at just under 200 ft (USBR 2008a). The canyon creates a geomorphic constriction for the channel directly upstream. The constrained valley width sets natural limits on channel pattern complexity. The reach consists of one meander sequence that has been stable throughout the aerial photo record (USBR 2008a). There are no split-flow locations, side-channels, or off-channel features. Bed morphology consists primarily of plane-bed segments, bedrock pools, and boulder step-pool sequences. There is very little LWD in this reach.

Human Alterations

Reach T3a has seen very little human alteration due to the isolated location and lack of a developable floodplain (Figure 32). Near the downstream end of the reach, there is a small terrace that has formed where the canyon begins to widen into Reach T2b. This terrace has been cleared and developed for a seasonal RV site. The downstream end of the reach is marked by a bridge crossing. The bridge creates a hydraulic constriction; however, there are also significant natural limits on lateral channel dynamics at this location.

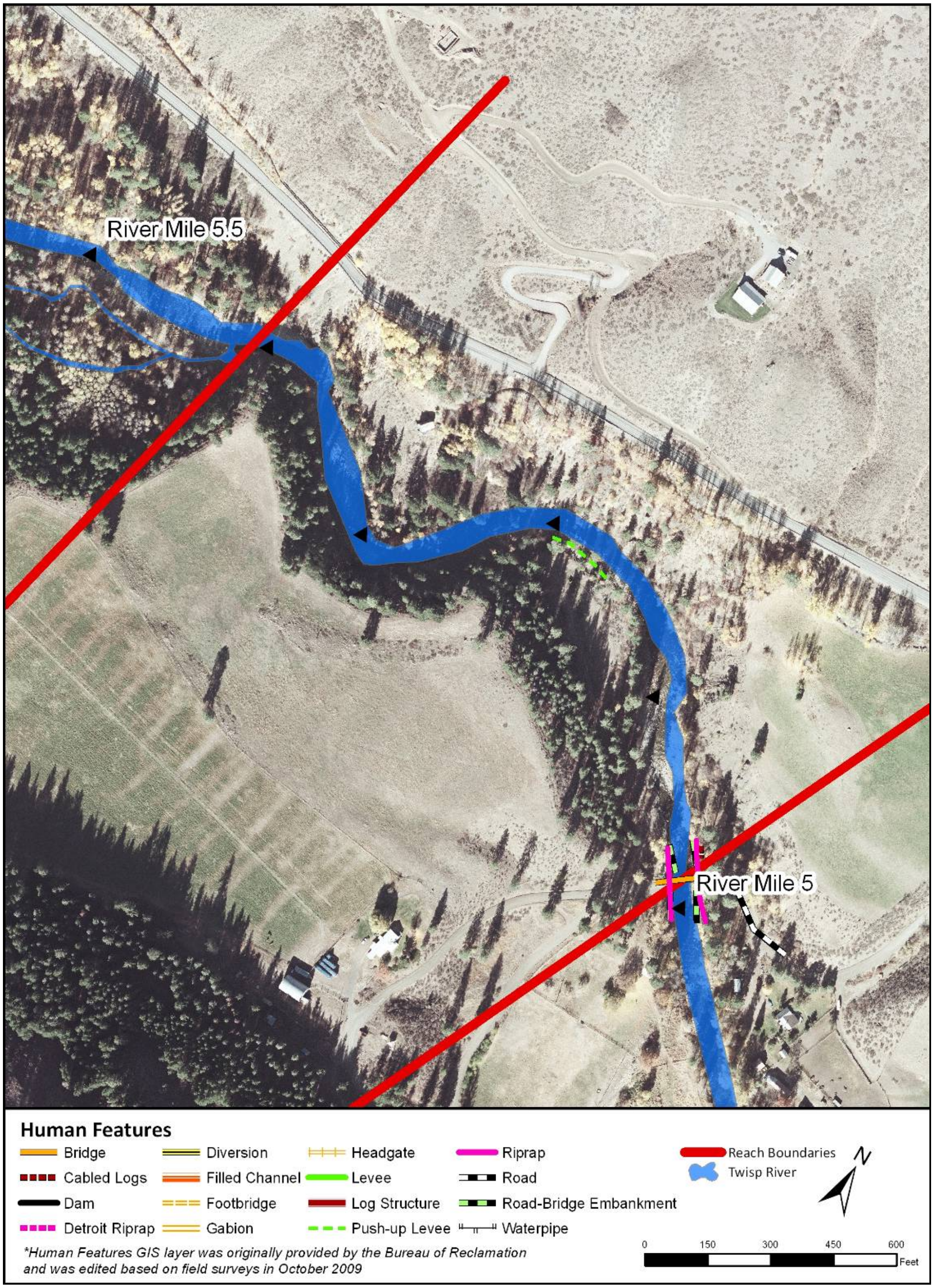

Figure 32. Aerial photo showing human features in Reach T3a. Flow is from west to east.

8.2 Reach Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach T3a is included below. The strategy focuses on protecting existing conditions from further impairment. The confined geomorphology of this reach precludes many of the direct disturbances and subsequent biophysical reconnection actions that are the pattern in other reaches. However, upstream irrigation withdrawals impact this reach and increasing instream flow is included in the reach level strategy. Instream habitat enhancement (rehabilitation) is also included; these projects occur in conjunction with long-term process reconnection in up and downstream reaches and are also applied in cases where long-term process reconnection is constrained by existing human uses. The USBR (2008) has not identified any restoration or protection opportunities in this reach. PWI (2003) suggests that monitoring and stewardship are the approaches to take in Reach T3a.

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 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 are two irrigation diversions upstream of this reach.

3. ***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.

8.3 Sub-Unit and Project Opportunity Summary

Only one inner zone sub-unit and no outer-zone sub-units were identified (Table 17, Figure 33, Figure 34). Valley confinement and bedrock result in the single, relatively uniform inner zone sub-unit. The single location where bedrock does not directly border the channel is a terrace that is developed for recreational use. Natural constraints have protected the reach from significant human alteration. One specific project was identified in this reach (Table 18).

Table 17. Summary of protection and restoration opportunities for reach T3a.

Sub-Unit	River Mile	Acreage
Inner Zone 1 (IZ-1)	5.0-5.4	N/A

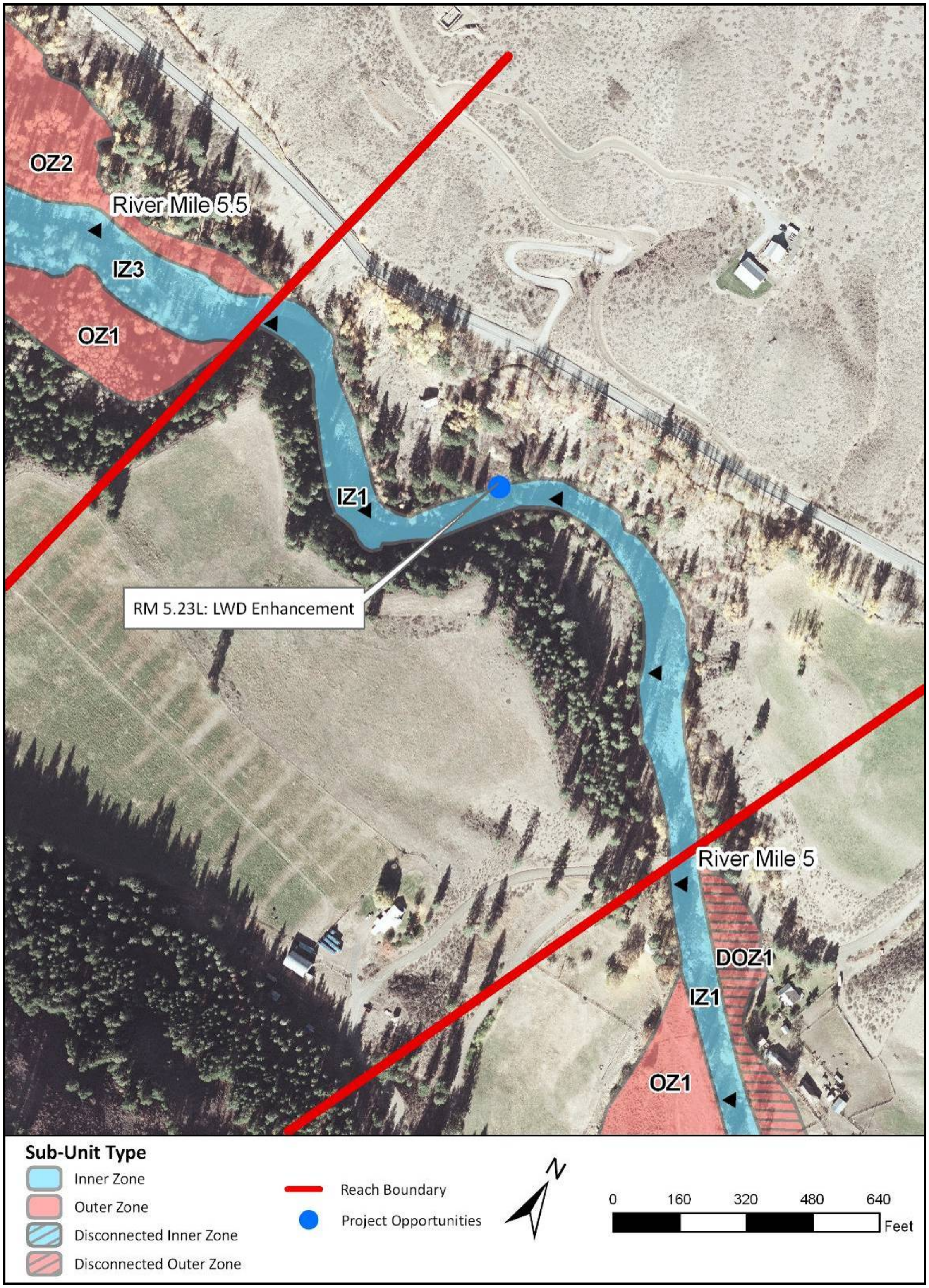

Figure 33. Sub-units and project opportunities in Reach T3a. Flow is from west to east.

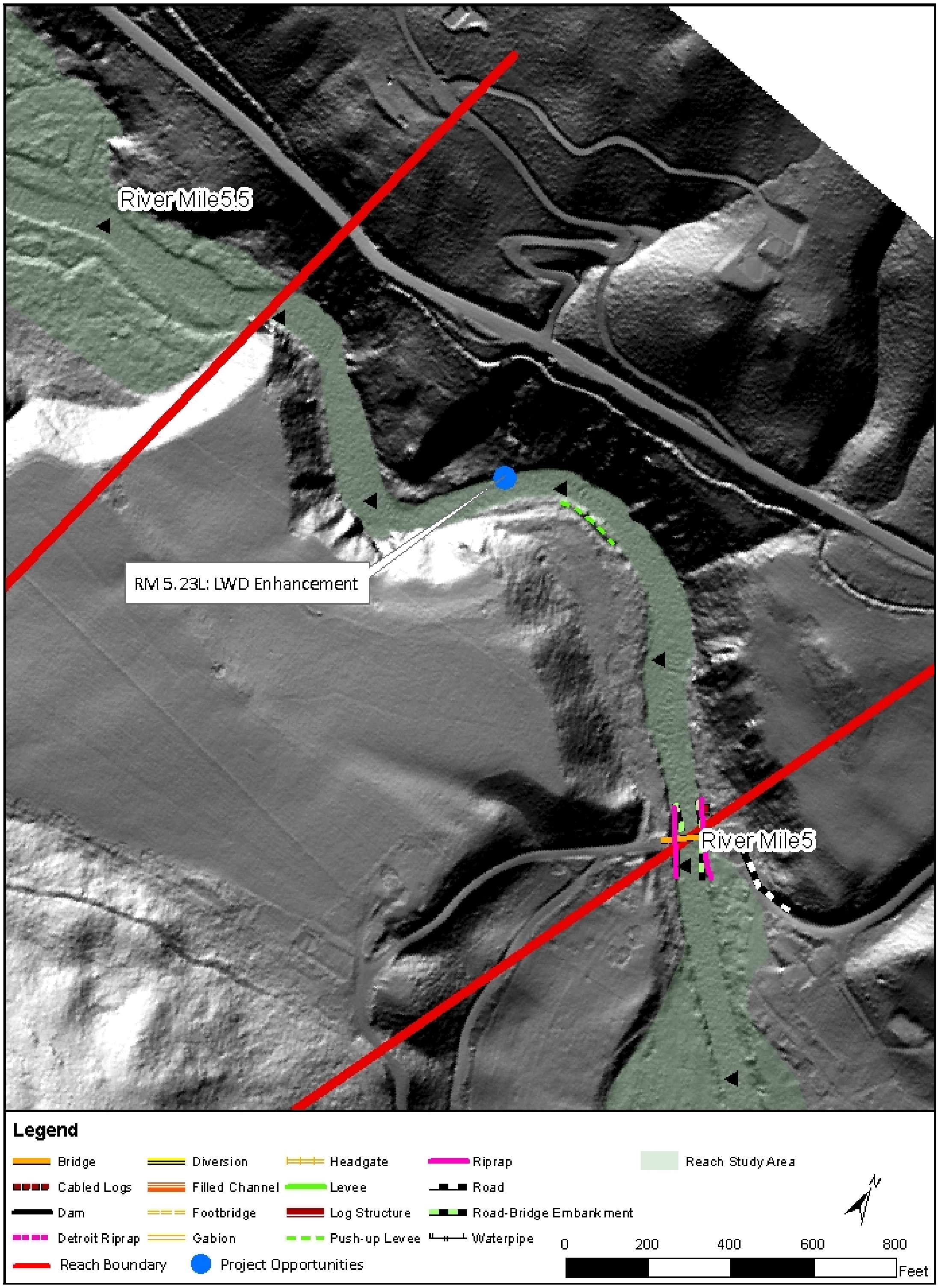

Figure 34. LiDAR hillshade of reach T3a illustrating topography in relation to human features and project locations. Flow is from west to east.

Table 18. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T3a

Sub-Unit	**Description**	**Strategy** *(Strategies are listed in priority order)*	**Projects**[1] *(specific identified projects are in **bold**)*	**Potential Constraints**
IZ-1	IZ-1 is a steep bedrock controlled channel with a cobble/boulder bed organize in step-pool or riffle-pool sequences. Lateral migration is limited to the width of the canyon. This has resulted in no effective floodplain formation adjacent to the inner-zone. Pool habitat has benefitted from bedrock outcrops and boulders that create deep holes in a few locations.	Protect and Maintain In-Stream Habitat Enhancement	***Project RM 5.23L*** LWD enhancement	Bridge crossing at the downstream end of the sub-unit near RM 5.0. Recreational development on adjacent terrace near RM 5.15.

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

T3b – Reach Assessment

9 T3B REACH ASSESSMENT

9.1 Reach Overview

Reach T3b is a moderately confined reach extending from RM 5.4 to RM 6.8. Development of the floodplain is primarily agricultural and includes land clearing, irrigation diversions, and levees to protect against erosion and flooding. These hydromodifications have resulted in the disconnection of many former components of the channel network. Multiple habitat actions are possible in this reach to re-connect inner and outer-zone habitats.

Habitat Conditions and Fish Use

Salmonid use of Reach T3b includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. A limited amount of spring Chinook and steelhead spawning occurs within the reach; however, the bulk of spawning occurs upstream of the study area (upstream of river mile 12). Annual steelhead redd counts from 2001 to 2007 from upper Poorman Bridge to the fish weir (corresponds to Reaches T3a, T3b, and part of 3c) ranged from 3 to 88. Spring Chinook redd counts over the same period ranged from 0 to 21 (Snow et al. 2008). Reach T3a is used by these populations primarily for migration and juvenile rearing. Bull trout primarily use the reach as a migration corridor to access upstream spawning areas.

Although steelhead and spring Chinook spawning occurs in this reach, many of the riffle and pool tail-outs consist of large cobbles (> 128 mm) that are larger than the ideal size for Chinook and steelhead spawning. However, the coarse bed provides areas of localized velocity refuge that may be utilized for rearing by juvenile steelhead and resident trout. Pool quantity within the reach is low and the majority of pools have a residual depth of less than 2 feet. LWD cover is relatively abundant compared to adjacent reaches but is low overall, especially with respect to large key pieces necessary for forming jams. Fish passage is mostly unrestricted in Reach T3b; however, adequate flows may be a concern during low flow periods due to irrigation withdrawals (see Appendix A for additional fish habitat information). A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 19.

Table 19. Reach-Based Ecosystem Indicators (REI) ratings for Reach T3b. See Appendix B for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach 3b Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*Unacceptable*
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*At Risk*
	LWD	Pieces per Mile at Bankfull	*At Risk*
	Pools	Pool Frequency and Quality	*At Risk*
	Off-Channel Habitat	Connectivity with Main Channel	*Unacceptable*
Channel	Dynamics	Floodplain Connectivity	*Unacceptable*

General Characteristics	General Indicators	Specific Indicators	Reach 3b Condition
		Bank Stability/Channel Migration	*Unacceptable*
		Vertical Channel Stability	*Unacceptable*
Riparian Vegetation	Condition	Structure	*Unacceptable*
		Disturbance (Human)	*Unacceptable*
		Canopy Cover	*Unacceptable*

Hydrology

The natural hydrologic regime in Reach T3b is driven by snowmelt runoff and low frequency rain-on-snow flood events (Table 20) (PWI 2003). This natural hydrologic pattern is altered by the TVPI diversion upstream near RM 7.4 and a small diversion within the reach near RM 6.5 (Figure 35). Irrigation diversion appreciably decreases in-stream flow during the later summer. The lower Twisp has been demonstrated to gain groundwater during late summer when diversion rates are high, but groundwater gains do not substantially offset diversion volumes (Konrad et al. 2005). There are two floodplain areas, near RM 6.45 and 6.55, where wetlands may contribute surface flow to the channel seasonally. Table 20 presents flood peak estimates for a variety of recurrence intervals calculated for a point near the upstream end of the reach.

Table 20. Flood magnitudes for recurrence intervals from 2 to 100 years for the upstream end of T3b (RM 6.68). Obtained from Methow River Basin GIS hydrology database (USBR 2008a).

		Flood Recurrence Interval (ft^3/sec)					
Location	River Mile	Q2	Q5	Q10	Q25	Q50	Q100
Upstream end of the Reach	6.68	1,888	2,810	3,461	4,327	4,999	5,604

Figure 35. View to the southwest in the upstream direction at an irrigation diversion in a side-channel near RM 6.5 (October 2009).

Geomorphology

Reach T3b is moderately confined by glacial terraces and small alluvial fan deposits. Following Pleistocene deposition, the river incised glacial outwash leaving multiple terrace elevations above the current floodplain surface. Erosion of glacial deposits continues at some locations along the valley margin (e.g. near RM 6.55), contributing sediment to the channel.

Within the bounds of the incised glacial deposits, the mean floodplain width is just over 600 ft. The average channel grade is about 1% (See Appendix A: Habitat Assessment). This reach contains numerous side-channels, flood overflow channels, and abandoned channels. The modern planform pattern and channel location has been stable since about 1945 except between RM 5.4 and 5.8, where natural deposition upstream of a valley constriction increases lateral migration. Near RM 5.55, up to 300 ft of lateral migration has taken place since 1964 (USBR 2008a).

Human Alterations

As with other moderately confined or unconfined reaches in the study area, Reach T3b has experienced substantial human modification. Habitat and process disconnection affects 20% of the inner zone and 72% of the outer zone. Agricultural development, roads, and levees are the primary impacts that cause disconnection of geomorphic processes and habitat.

Near RM 6.65, a 330 ft long push up levee along river-left disconnects several secondary and high-flow channels across the point bar (Figure 36). Enhancement work at the site includes a small breach in the levee to enhance activation of high flow channels. Because of the disconnection of the inner-zone, the adjacent outer-zone to the north is also hydrologically and geomorphically disconnected. Wetlands and off-channel features in the floodplain do not have an active connection to channel processes, including seasonal flooding. Inner zone processes are also affected by a diversion near RM 6.5 (Figure 35). Although there is not a permanent diversion structure or dam, a berm is constructed to divert surface flow to an irrigation ditch. The secondary channel continues to be active during high flows, but low-flow connectivity is compromised.

There is more extensive channel and bank modification between RM 6.3 and 5.9. Near RM 6.3, a 240 ft long levee blocks an inner zone side channel and reduces channel/floodplain connection to the south of the channel. The floodplain in this area has been cleared for agriculture. There is a small amount of rural residential development on the floodplain near RM 6.08. Access to the house is provided by a bridge crossing that includes about 100 ft of riprap upstream and downstream of the crossing. The Twisp River Road embankment forms the river-left channel margin between RM 6.0 and 6.28. The bank is protected with riprap along most of this length. Figure 37 shows all human features in reach T3b.

Figure 36. View to the southeast in the downstream direction at a push-up levee near RM 6.65 (October 2009).

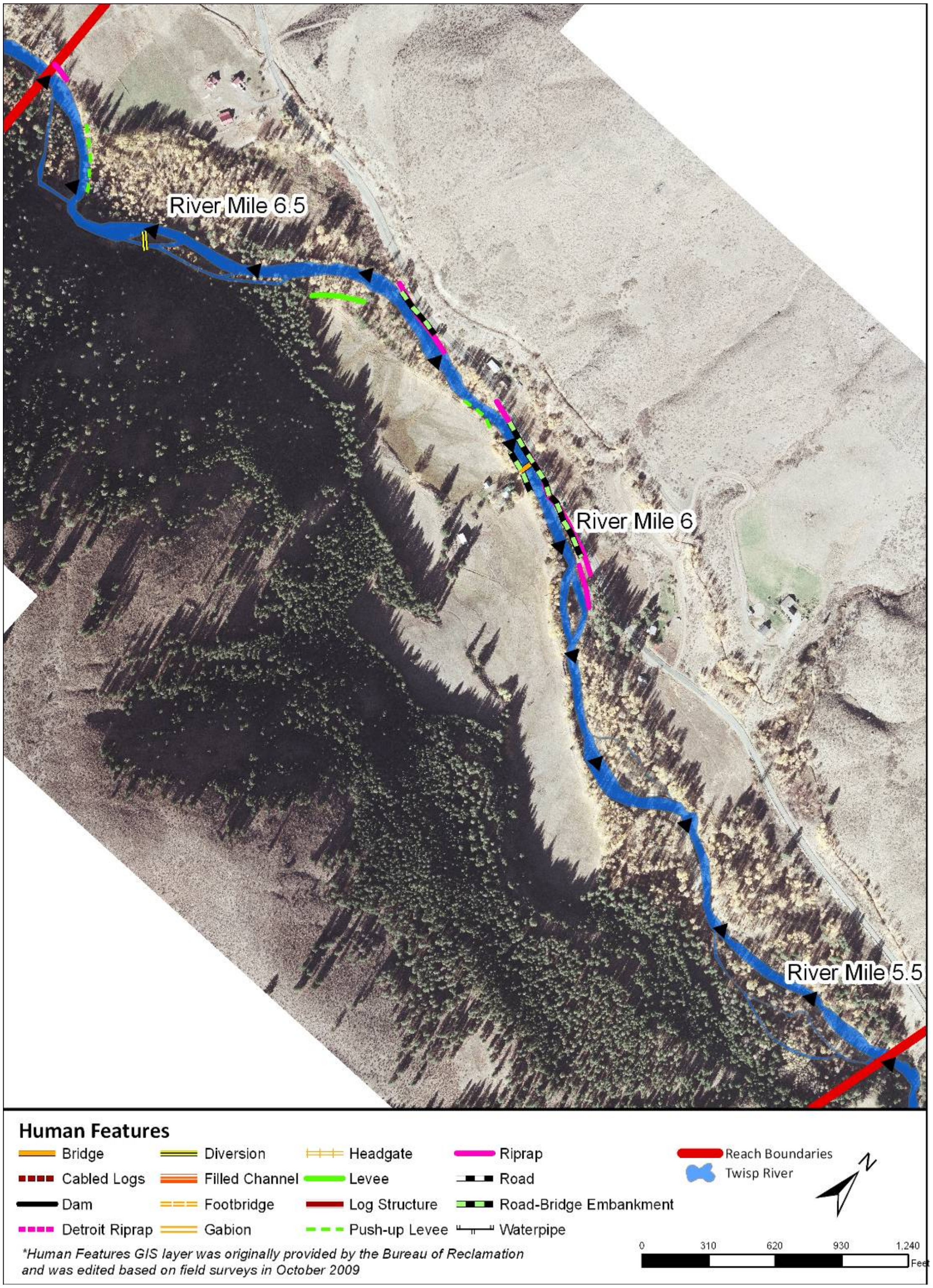

Figure 37. Aerial photo showing human features in Reach T3b. Flow is from west to east. Constraints include roads, a bridge crossing, bank hardening, and floodplain development.

9.2 Reach-Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach T3b 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. Restoration goals for USBR (2008) projects focus on reconnecting floodplain habitat and processes by removing barriers such as levees, and re-vegetating cleared areas. PWI (2003) identifies similar potential restoration projects and goals, and stresses the need for stewardship, education, and conservation. The restoration efforts presented here complement and reflect these other efforts.

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 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 diversion located within this reach and at least one diversion upstream of this reach.
   - **Riprap and Levees-** Remove or modify features to restore dynamic processes. There are barriers to channel processes and channel/floodplain connection throughout the reach. Where feasible, riprap and levees should be removed or modified to increase floodplain and channel migration zone connectivity.
   - **Bridge Crossing-** The bridge crossing, and related bank protection, near RM 6.08 presents a longitudinal and lateral barrier to channel processes and habitat connectivity. The span of the bridge creates a hydraulic constriction as stage increases. Work with appropriate stakeholders to develop long-term solutions to bridge impacts.
   - **Twisp River Road-** A 0.25 mile stretch of the Twisp River Road creates a hardened channel margin and disconnects the channel and floodplain between RM 5.9 and 6.15 along river-left. Options for relocating or modifying this roadway should be developed with the appropriate stakeholders.

3. ***Reconnect Floodplain Processes***
   - **Floodplain Development**- The majority of the floodplain in this reach is associated with agricultural use and commonly includes clearing, grazing, and levees or riprap along the channel margin. Full floodplain reconnection will require reclamation of floodplain surfaces. Work with appropriate stakeholders to develop long-term solutions to floodplain impacts.
   - **Levees**- Removing or modifying levees, where feasible, will help to restore floodplain processes.
   - **Twisp River Road**- A 0.25 mile stretch of the Twisp River Road between RM 5.9 and 6.15 along river left creates a barrier to hydrologic and geomorphic processes that connect the channel and floodplain. Options for relocating or modifying this roadway should be developed with the appropriate stakeholders.

4. ***Riparian Restoration***
   - **Restore Riparian Areas**- Large areas of riparian forest have been cleared for agricultural development in this reach. In other areas, the riparian forest is relatively intact. Cleared areas should be replanted along the river corridor in order to provide a sustainable source of LWD, thermal shading, natural bank stability, and a riparian buffer. Forested areas should be maintained.

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**- Side-channels and off-channel wetlands in this reach can be enhanced in terms of their connectivity and habitat complexity. Natural elements such as wood and vegetation can be used to increase the habitat quality. 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

Ten sub-units were identified in Reach T3b, including three inner zone sub-units, two disconnected inner-zone sub-units, two outer zone sub-units, and three disconnected outer zone sub-units (Table 21, Figure 38, Figure 39). Levees, riprap, and development reduce channel/floodplain connection leaving 72% of the floodplain disconnected. Thirteen specific project opportunities are identified in this reach and are presented in the sub-unit summary section (Table 22). The USBR (2008) has identified two areas in the reach with restoration potential, and three areas for protection and monitoring.

Table 21. Summary of protection and restoration opportunities for Reach T3b.

Sub-Unit	River Mile	Acreage
Inner Zone 1 (IZ-1)	6.2-6.7	N/A
Disconnected Inner Zone 1 (DIZ-1)	6.42-6.65	N/A
Disconnected Outer Zone 1 (DOZ-1)	6.28-6.65	8.6
Disconnected Outer Zone 2 (DOZ-2)	5.7-6.4	19.9
Disconnected Inner Zone 2 (DIZ-2)	6.19-6.35	N/A
Inner-Zone 2 (IZ-2)	5.96-6.19	N/A
Disconnected Outer Zone 3 (DOZ-3)	5.87-6.18	5.9
Inner Zone 3 (IZ-3)	5.4-5.96	N/A
Outer Zone 1 (OZ-1)	5.41-5.78	7.1
Outer Zone 2 (OZ-2)		6.0

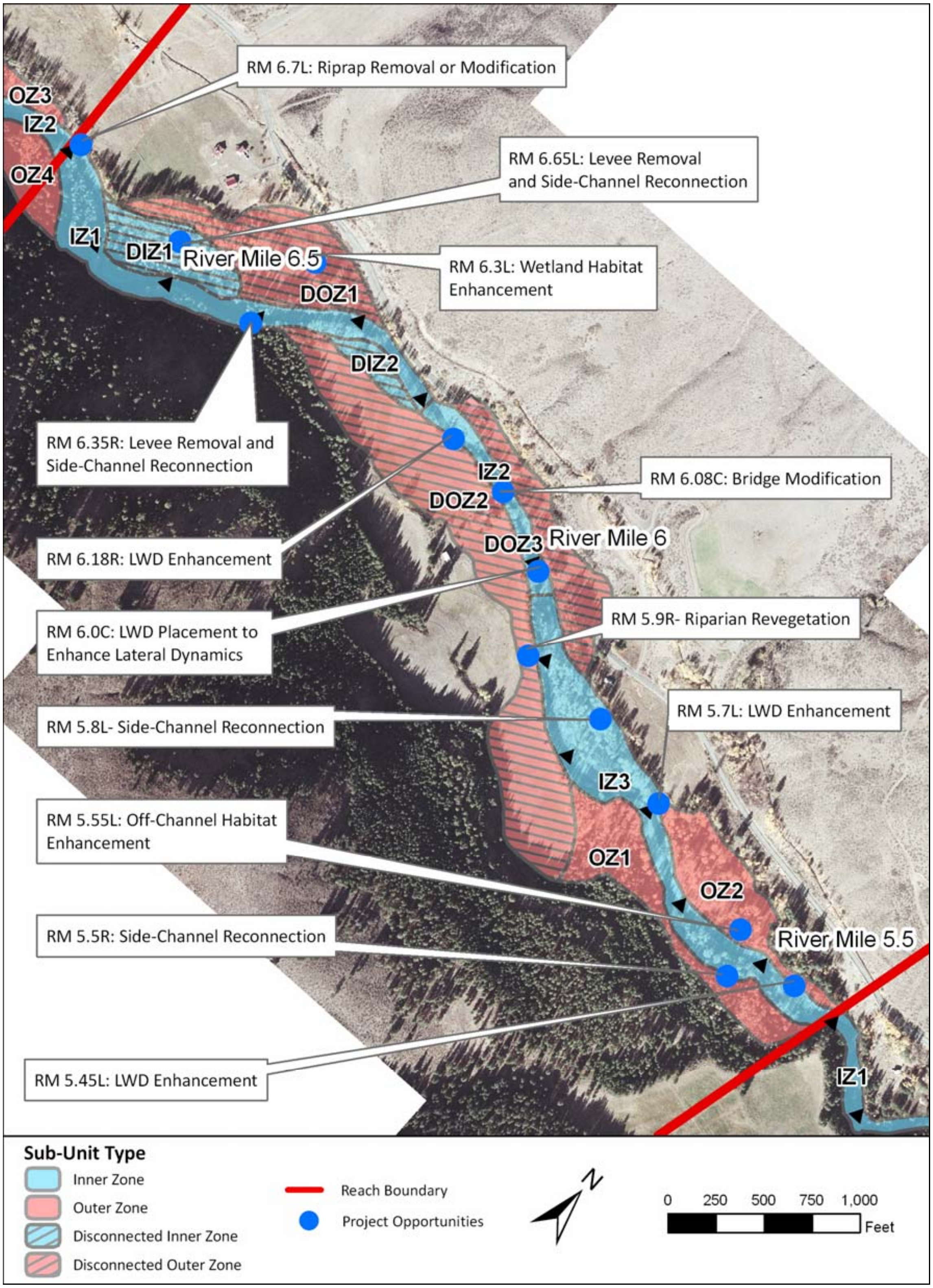

Figure 38. Sub-units and project opportunities in Reach T3b. Flow is from west to east.

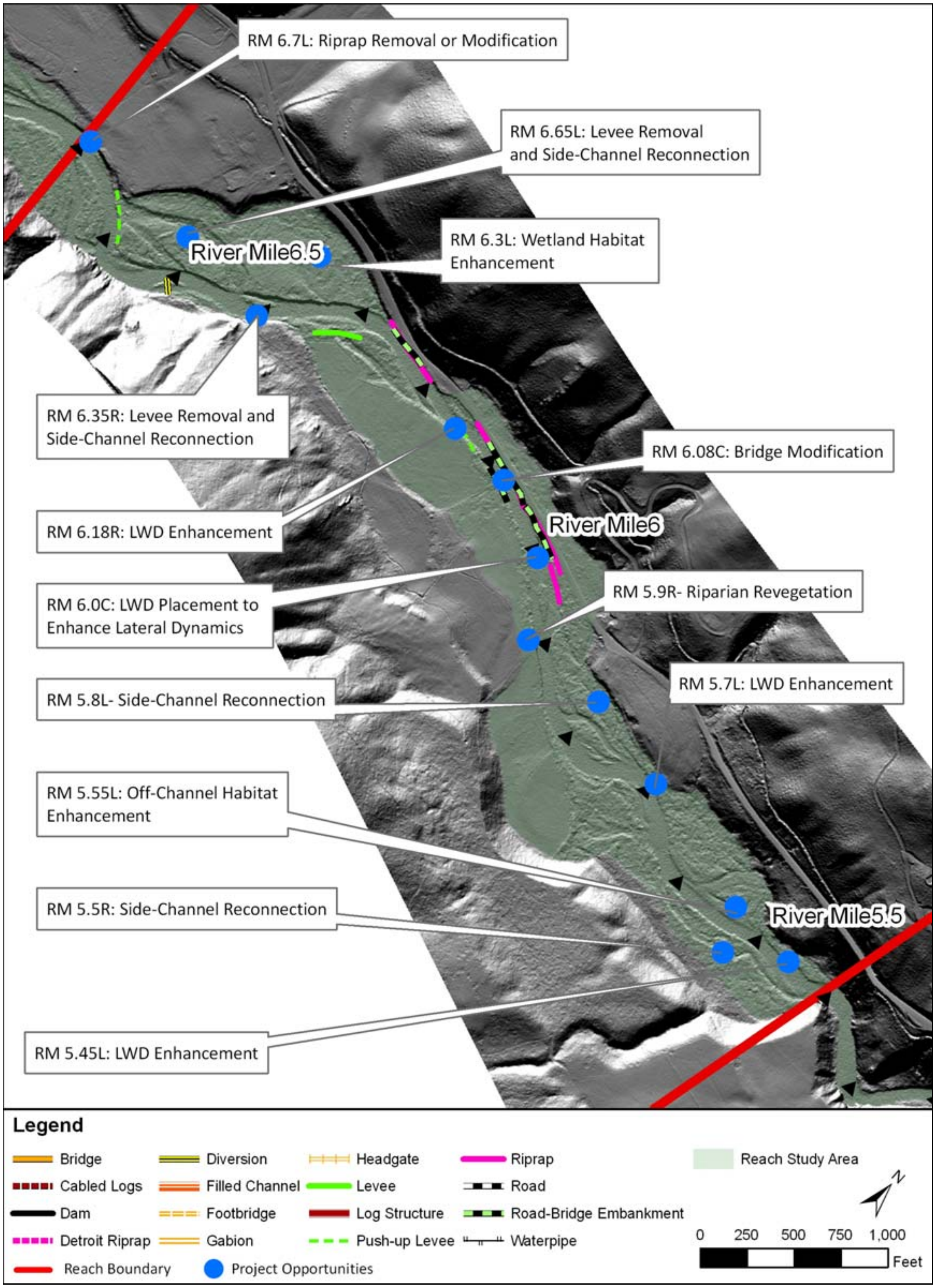

Figure 39. LiDAR hillshade of reach T3b illustrating topography in relation to human features and project locations. Flow is from west to east.

Table 22. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T3b

Sub-Unit	Description	Strategy *(Strategies are listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
IZ-1	IZ-1 is a relatively complex section of channel with multiple active side-channels, networks of flood overflow channels, and off-channel habitat. The floodplain overflow channels located to the north of the inner-zone have been disconnected by levee construction; however, there have been efforts to re-establish hydrologic connection. IZ-1 begins where the river takes a southern bend and flows directly against the hillslope toe near RM 6.6; this eroding hillslope provides a large source of sediment to the channel. A large gravel bar and side-channel has formed along river-right just downstream of the sediment source. Low-flow connectivity between the main channel and the side-channel is currently affected by an irrigation diversion near RM 6.52. Another side-channel is also disconnected by a 240 ft levee near RM 6.3. Near the downstream end of the sub-unit, the river-left side abuts the Twisp River Road embankment.	Protect and Maintain Reconnect Stream Channel Processes	***Project RM 6.7L*** Riprap modification ***Project RM 6.35R*** Levee removal and side-channel reconnection	Flood protection for agricultural and residential development along the north side of the channel provided by a levee. Irrigation diversion near RM 6.5. Twisp River Road along the north side of the channel between RM 6.2 and 6.28.
DIZ-1	Several high-flow channels are located in this sub-unit including a large channel that traces the boundary of the sub-unit along the margin of the adjacent outer zone. These channels provide high-flow cut-off across the inside of a meander bend. 1954 aerial photos indicate an active side-channel in this area. The existing high flow channels are currently blocked by a levee between RM 6.6 and 6.65. The levee effectively disconnects the adjacent outer zone to the north. The levee has recently been breached/lowered in one location as part of an enhancement project.	Protect and Maintain Reconnect Stream Channel Processes	***Project RM 6.65L*** Levee removal and side-channel reconnection	Agricultural development and bank protection.

Table 22. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T3b

Sub-Unit	**Description**	**Strategy** *(Strategies are listed in priority order)*	**Projects**[1] *(specific identified projects are in **bold**)*	**Potential Constraints**
DOZ-1	This 8.6 acre outer-zone sub-unit extends along the north of the channel from RM 6.28-6.65. Floodplain connectivity is reduced due to the levee between RM 6.6 and 6.65. This floodplain appears to have been well-connected to inner-zone processes in the recent past as evidenced by overflow channels that have been mapped from historical aerial photos (USBR 2008a). Wetlands are located along these overflow channel paths and within old meander scars.	Protect and Maintain Reconnect Floodplain Processes Off-Channel Habitat Enhancement	***Project RM 6.3L*** Wetland habitat enhancement *Work to address impacts of levee (eg. levee removal or breaching).*	Flood protection provided by a levee that limits connectivity of the adjacent inner zone (DIZ-1).
DOZ-2	At 19.9 acres, this is the largest area of floodplain in Reach T3b. A levee at the upstream end of the sub-unit near RM 6.35 creates a barrier to channel/floodplain connection at a point where overbank flow and floodplain inundation would otherwise occur. The entire surface has been cleared for pasture, eliminating riparian habitat. There is a narrow band of riparian vegetation along the bank of the channel that provides thermal shading, but there is limited potential for any significant recruitment of LWD. Clearing and grading has removed evidence of overbank flow paths; however, channel mapping using the 1964 aerial photographs (USBR 2008a) suggests the presence of overflow channels. There is a small rural residential development accessed by a bridge at RM 6.08. Suggested habitat actions in IZ-1 at Project RM 6.35R would potentially benefit DOZ-2 as well.	Protect and Maintain Reconnect Floodplain Processes Riparian Restoration	***Project RM 5.9R*** Riparian re-vegetation *Work to address impacts of development, levee, bridge crossing (eg. riparian and off-channel habitat restoration, levee removal or breaching, increase bridge span).*	Agricultural and residential development including riparian and floodplain clearing and grading. Flood protection provided by levee near RM 6.35. Bridge crossing near RM 6.08.

Table 22. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T3b

Sub-Unit	Description	Strategy *(Strategies are listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
DIZ-2	This sub-unit is located on the inside of a meander bend between RM 6.19 and 6.35. A high-flow cut-off channel extends along the edge of the floodplain. A levee blocks this channel and reduces floodplain connectivity. The sub-unit is otherwise undeveloped and riparian vegetation is intact. DIZ-2 would potentially be re-connected by the habitat actions suggested in Project RM 6.35R in IZ-1.	Protect and Maintain Reconnect Stream Channel Processes	*Work to address impacts of development(eg. levee setback/removal, riparian restoration, off-channel habitat restoration).*	Agricultural and residential development including riparian clearing in the adjacent outer-zone. Flood protection provided by levee near RM 6.35.
IZ-2	In IZ-2, the inner zone transitions from a relatively complex and sinuous pool-riffle channel into a uniform plane-bed channel with limited habitat complexity. The channel is constricted by Twisp River Road on the left and a developed floodplain on the right. There is considerable bank hardening along both sides of the channel that limits channel dynamics. A bridge crossing at RM 6.08 creates a hydraulic constriction that limits lateral channel dynamics.	Protect and Maintain Reconnect Stream Channel Processes In-Stream Habitat Enhancement	***Project RM 6.08C*** Bridge modification ***Project RM 6.0C*** LWD placement to enhance lateral dynamics ***Project RM 6.18R*** LWD enhancement	Agricultural and residential development including riparian clearing in the adjacent outer-zone to the south. The embankment of the Twisp River Road parallels the sub-unit for its entire length. Bridge crossing at RM 6.08.
DOZ-3	This is a small (6 acres) and narrow outer zone unit between the river and the hillslope toe between RM 5.87 and 6.18. Twisp River Road creates a barrier between the channel and the floodplain for most of the length of the sub-unit. There is a small portion of DOZ-3 to the south of the road, but riprap extends along much of the bank. The area to the north of the road has been cleared, filled, and developed for residential use.	Protect and Maintain Reconnect Floodplain Processes	*Work to address impacts of development, roads, bridge (eg. riparian restoration, road relocation, increase bridge span)*	Agricultural and residential developments including riparian clearing, fill, and access roads on both sides of the channel. Twisp River Road and associated bank hardening along the channel margin to the north. A Bridge Crossing near RM 6.08.

Table 22. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T3b

Sub-Unit	**Description**	**Strategy** *(Strategies are listed in priority order)*	**Projects**[1] *(specific identified projects are in **bold**)*	**Potential Constraints**
IZ-3	IZ-3 is similar to IZ-1 in planform and habitat complexity. There are multiple locations of split flow and connection to high-flow channels. One of the most complex connected inner-zone areas in Reach T3b is located near the upstream end of IZ-3 between RM 5.7 and 5.9. An alluvial fan impinges on the channel from the north and local aggradation has occurred upstream of the fan, creating a mid-channel bar, active split flow, and several high-flow channels through the fan deposits. The bed morphology through this area is pool-riffle. Another connected side-channel extends between RM 5.41 and 5.5. IZ-3 is well-connected to adjacent floodplain surfaces. Altogether, this creates some of the best habitat in the downstream 1/3 of Reach T3b.	Protect and Maintain Reconnect Stream Channel Processes In-Stream Habitat Enhancement	***Project RM 5.8L*** Side-channel reconnection. ***Project RM 5.5R*** Side-channel reconnection ***Project RM 5.7L*** LWD enhancement ***Project RM 5.45L*** LWD enhancement	Agricultural and residential development including riparian clearing in the adjacent outer-zone to the south (DOZ-2). Twisp River Road parallels the sub-unit for the upper 330 ft and riprap has been placed on the bank.
OZ-1	This outer-zone sub-unit is a 7-acre extension of DOZ-2. The riparian and floodplain forest is intact and LiDAR data suggests that high-flow inundates this surface. However, historical channel mapping (USBR 2008a) does not place any channels on this surface during the 20th century. Anthropogenic impacts in DOZ-2 upstream may affect connectivity of this sub-unit to some degree. Nevertheless, there are no significant barriers to channel/floodplain connection and there is the potential for this sub-unit to provide valuable outer-zone processes such as overbank flooding.	Protect and Maintain		Agricultural and residential development including riparian clearing in the adjoining floodplain upstream.

Table 22. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T3b

Sub-Unit	Description	Strategy *(Strategies are listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
OZ-2	Historical channel mapping (USBR 2008a) indicates a tortuous main channel meander bend in this sub-unit in 1954, 1964, and 1985. The abandoned channel scar now supports a wetland and a high quality floodplain forest. Under current conditions, the abandoned channel is likely well-connected as a flood overflow channel.	Protect and Maintain Off-Channel Habitat Enhancement	***Project RM 5.55L*** Off-channel habitat enhancement	There are no significant constraints to restoration or preservation activities.

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

T3c – Reach Assessment

10 T3c Reach Assessment

10.1 Reach Overview

Reach T3c is a moderately confined reach extending from RM 6.7 (Elbow Coulee) to 7.8 (Newby Creek). The Twisp River Road parallels the reach to the north. The Twisp Valley Power and Irrigation ditch (TVPI) is located near RM 7.4 on the north bank. There is a fish weir that is operated seasonally at RM 7.25.

Habitat Conditions and Fish Use

Salmonid use of Reach T3c includes spring Chinook, steelhead, bull trout, westslope cutthroat trout, and non-native brook trout. A limited amount of spring Chinook and steelhead spawning occurs within the reach; however, the bulk of spawning occurs upstream of the study area (upstream of river mile 12). Annual steelhead redd counts from 2001 to 2007 from upper Poorman Bridge to the fish weir (corresponds to Reaches T3a, T3b, and part of T3c) ranged from 3 to 88. Spring Chinook redd counts in the same reach over the same period ranged from 0 to 21 (Snow et al. 2008). Steelhead redd counts from the fish weir to Little Bridge Creek (includes upstream half of Reach 3c) ranged from 13 to 194. Spring Chinook redd counts in this upper reach ranged from 0 to 25. Reach T3c is used by these populations primarily for migration and juvenile rearing. Bull trout primarily use the reach as a migration corridor to access upstream spawning areas.

Although steelhead and spring Chinook spawning occurs in this reach, many of the riffle and pool tail-outs consist of large cobbles (> 128 mm) that are larger than the ideal size for Chinook and steelhead spawning. However, the coarse bed provides areas of localized velocity refuge that may be utilized for rearing by juvenile steelhead and resident trout. Pool quantity within the reach is low and the majority of pools have a residual depth of less than 2 feet. LWD cover is relatively abundant compared to adjacent reaches but is low overall, especially with respect to large key pieces necessary for forming jams.

The fish weir at RM 7.25 likely presents a passage barrier for upstream migrating juveniles during low flows. A 2.5-ft tall concrete dam located just downstream of the irrigation diversion on a side-channel at RM 7.6 may limit fish passage, especially during summer low flow periods. Adequate flows may be a concern during low flow periods due to irrigation withdrawals (see Appendix A for additional fish habitat information). A summary of the Reach-Based Ecosystem Indicators (REI) is included in Table 23.

Table 23. Reach-Based Ecosystem Indicators (REI) ratings for Reach T3c. See Appendix B for the complete REI analysis.

General Characteristics	General Indicators	Specific Indicators	Reach 3c Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*At Risk*

General Characteristics	General Indicators	Specific Indicators	Reach 3c Condition
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*At Risk*
	LWD	Pieces per Mile at Bankfull	*At Risk*
	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	*At Risk*
Riparian Vegetation	Condition	Structure	*At Risk*
		Disturbance (Human)	*At Risk*
		Canopy Cover	*At Risk*

Hydrology

The natural hydrologic regime in Reach T3c is driven by snowmelt runoff and low frequency rain-on-snow flood events (Table 20) (PWI 2003). This natural hydrologic pattern is altered by the TVPI diversion near RM 7.4. Irrigation diversion appreciably decreases in-stream flow during the later summer. This area of the Twisp River has been shown to gain groundwater during the irrigation season (Konrad et al. 2005). There is one floodplain areas near RM 7.08 where surface outflow from floodplain wetlands contributes to flow in the main channel (Figure 40). Table 24 presents flood peak estimates for a variety of recurrence intervals calculated for a point near the upstream end of the reach.

Table 24. Flood magnitudes for recurrence intervals from 2 to 100 years for the upstream end of T3c (RM 7.75). Obtained from Methow River Basin GIS hydrology database (USBR 2008a).

		Flood Recurrence Interval (ft^3/sec)					
Location	**River Mile**	**Q2**	**Q5**	**Q10**	**Q25**	**Q50**	**Q100**
Upstream end of the Reach	7.75	1,838	2,735	3,370	4,212	4,867	5,543

Figure 40. View to the north at the outflow of a floodplain wetland near RM 7.08 (October 2009).

Geomorphology

The maximum extent of glaciation in the Twisp drainage is thought to be somewhere near RM 10.0, a few miles upstream of Reach T3c (USBR 2008a). Downstream of the major slope break at RM 10.0, channel slope increases and valleys are narrower. These morphological differences are thought to be the result of glacial erosion upstream of RM 10.0 and glacial deposition downstream of RM 10.0. Thus, much of the valley confinement in Reach T3c (mean low surface width is under 700 ft) is caused by bounding glacial terraces that formed as the river incised outwash deposits. Alluvial fans impinge on the channel from the north at the extreme upstream end of the reach and at the extreme downstream end of the reach. There is bedrock along the river-right channel margin between RM 6.9 and 7.0.

The channel near the upstream end of the reach (RM 7.3 to 7.8) is multi-thread with active split-flow around stable, vegetated islands. Sediment inputs from Newby Creek likely contribute to channel planform conditions here. In contrast, the channel downstream of RM 7.3 is mostly single-thread with very limited side-channel habitat. Bed morphology follows a similar pattern to planform morphology, with a distinct difference up and downstream of RM 7.3. In the multi-thread portion of the reach, bed morphology is pool-riffle and provides complex habitat. Downstream of RM 7.3, the bed transitions to plane-bed and habitat complexity is reduced. Near RM 7.0 the channel bends south against a bedrock hill slope and a deep pool has formed.

Human Alterations

The majority of human alteration to the river corridor in Reach T3c occurs along the north side of the valley where Twisp River Road provides easy access to residential and agricultural development (Figure 41). Near the upstream end of the reach, high flow channels flow directly against the roadway near RM 7.6. Just downstream as the river turns south, a 200 ft long push-up levee creates a barrier to channel/floodplain connection near RM 7.56.

The outer-zone downstream of this levee has been cleared of riparian vegetation for agricultural and residential development; there is no geomorphic evidence of recent floodplain inundation. The TVPI irrigation diversion at RM 7.45 supplies a ditch that follows the channel margin down to RM 7.08 before contouring away from the channel. Multiple sections of push-up levee protect the ditch and block inner-zone processes between RM 7.1 and 7.3 along the north side of the channel.

There is an adult fish collection weir at RM 7.25. There is an access road to the fish weir that bisects the inner zone. A private drive continues downstream from near the fish weir and follows a levee that parallels the channel down to the bridge at RM 7.16. There are wetlands in a disconnected inner zone area to the north of the road and the levee. The road and bridge access residential development on the terrace to the south of the channel. The bridge span creates a hydraulic constriction at high flows and riprap abutments alter local hydraulics and channel dynamics. The residential development to the south is located on older alluvial terraces and provides little impact to channel or floodplain processes. Near RM 7.05, the river flows directly against the toe of a terrace where 130 ft of riprap protects nearby homes located near the bank along river-left. A similar situation occurs near RM 6.7 where a short section of riprap protects the toe of a terrace where a home has been built near the stream edge.

Figure 41. Aerial photo showing human features in Reach T3c. Flow is from west to east. Constraints include roads, levees, bank hardening, a diversion, and floodplain development.

10.2 Reach Scale Restoration Strategy

The prioritized reach-scale restoration and preservation strategy for Reach T3c 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 restoration goals propose by the USBR (2008) focus on re-connecting off-channel/side-channel habitats in OZ-3, DIZ-1, and IZ-1. Protection focuses on OZ-1 an OZ-2. PWI (2003) also proposes the reconnection of floodplain processes as a primary restoration goal for 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 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 an irrigation diversion in this reach near RM 7.4.
   - **Riprap and Levees -** Remove or modify features to restore dynamic processes, particularly in the upstream portion of the reach. The most extensive levees in this reach are along river-left between RM 7.1 and 7.3. These features protect an irrigation ditch, access road, and fisheries facilities to the north of the channel. Protection of these features presents a constraint to removal, and further assessment will be needed to develop a suite of options for removal or modification.
   - **Bridges-** A bridge crossing near RM 7.16 and road embankments on both sides of the channel limit lateral migration, and alter channel hydraulics. The span of the bridge is a constriction as stage increases. Work with appropriate stakeholders to develop long-term solutions to bridge impacts.

3. ***Reconnect Floodplain Processes***
   - **Floodplain Development**- There is moderate development of the floodplain throughout the reach, mostly related to agricultural uses. Clearing, access roads, and

fill are some of the issues associated with development. Full floodplain reconnection will require reclamation of floodplain surfaces. Reconnection of floodplain habitat would provide access to large off-channel wetlands on the north side of the valley.

- **Levees**- Where feasible, riprap and levees should be removed or modified to increase floodplain and channel migration zone connectivity.

4. ***Riparian Restoration***
    - **Restore Riparian Areas** – Riparian clearing is moderate in this reach, and is concentrated primarily to the north of the channel between RM 7.3 and 7.6. There is currently only a narrow riparian corridor in this area that will require significant expansion in order to provide a sustainable source of LWD, thermal shading, and a 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**- There are large off-channel wetlands along the north side of the valley. These features should be assessed for enhancement. Natural activity of beavers can result in enhanced off-channel habitat and should be considered as a restoration option.

10.3 Sub-Unit and Project Opportunity Summary

Eight sub-units were identified in Reach T3c, including two inner zone sub-units, one disconnected inner-zone sub-unit, four outer zone sub-units, and one disconnected outer zone sub-unit (Table 25, Figure 42, Figure 43). Although there are areas of intense human alteration, this reach has the lowest percent of disconnected floodplain in the study area at 31%. A proportionately large area of the inner-zone in the reach is disconnected accounting for about 20% of the total inner-zone area. Eleven specific project opportunities are identified in this reach and are described in the sub-unit summaries in the next section (Table 26). The USBR (2008) identified three areas for restoration in this reach, and one area for protection and monitoring.

Table 25. Summary of protection and restoration opportunities for reach T3c.

Sub-Unit	River Mile	Acreage
Inner Zone 1 (IZ-1)	7.3-7.8	N/A
Outer Zone 1 (OZ-1)	7.42-7.7	7.5
Disconnected Outer Zone 1 (DOZ-1)	7.26-7.6	11

Sub-Unit	River Mile	Acreage
Disconnected Inner Zone 1 (DIZ-1)	7.06-7.35	N/A
Outer Zone 2 (OZ2-2)	7.0-7.35	7.4
Inner Zone 2 (IZ-2)	6.7-7.3	N/A
Outer Zone 3 (OZ-3)	6.71-7.01	6.3
Outer Zone 4 (OZ-4)	6.62-6.8	3.3

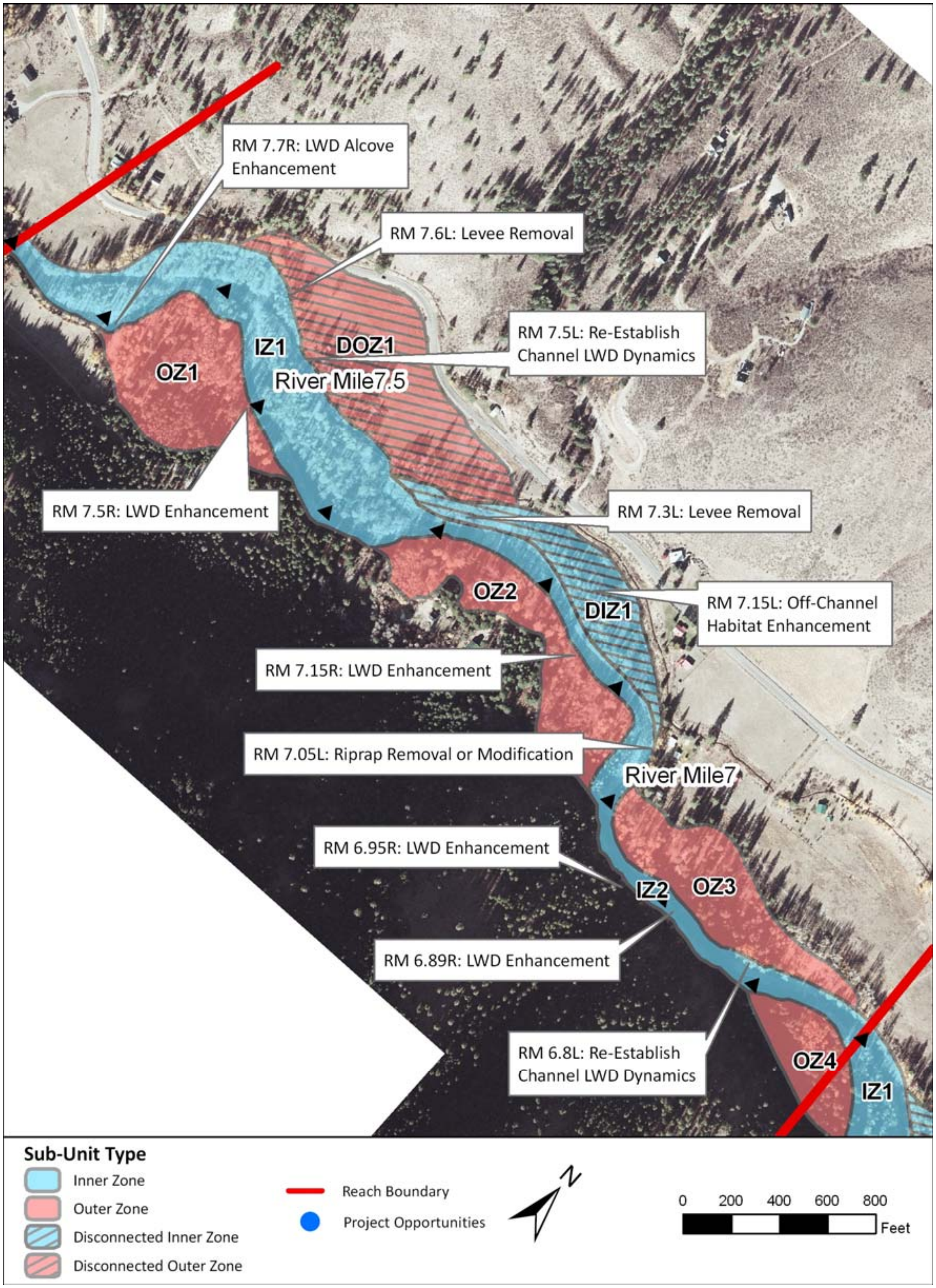

Figure 42. Sub-units and project opportunities in Reach T3c. Flow is from west to east.

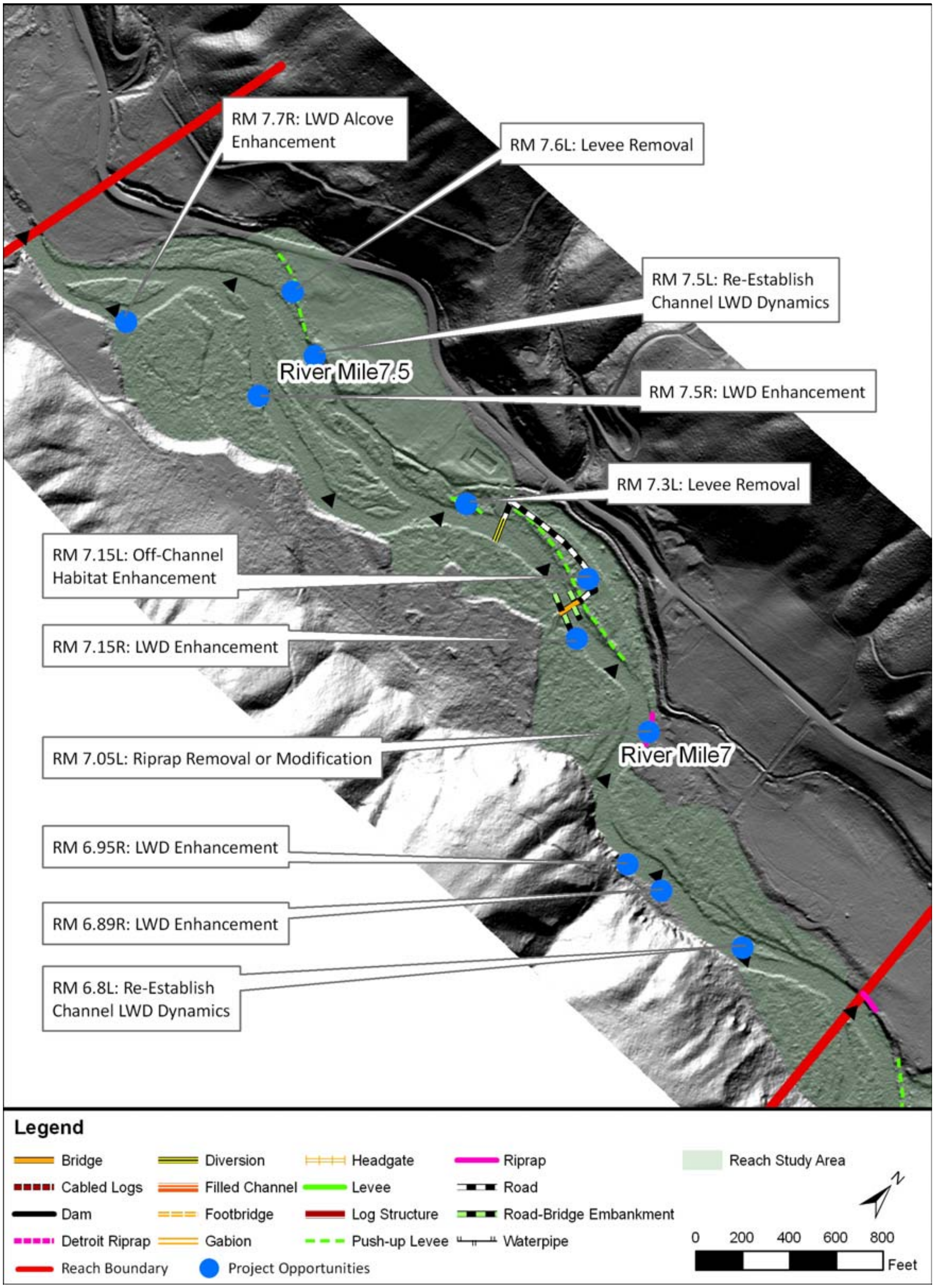

Figure 43. LiDAR hillshade of reach T3c illustrating topography in relation to human features and project locations. Flow is from west to east.

Table 26. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T3c

Sub-Unit	**Description**	**Strategy** *(Strategies are listed in priority order)*	**Projects**[1] *(specific identified projects are in **bold**)*	**Potential Constraints**
IZ-1	IZ-1 provides the most complex inner-zone habitat in the study area. The channel displays a multi-thread planform with active side-channels, stable mid-channel islands, connected high-flow channels, LWD jams, and potential LWD recruitment. IZ-1 begins at the confluence of Newby Creek, a small perennial tributary that flows in from the south. On the opposite side of the valley, an alluvial fan has pushed the channel to the south. These two features provide sources of sediment for the channel, accounting for the multi-thread channel just downstream.	Protect and Maintain Reconnect Stream Channel Processes Reconnect Floodplain Processes In-Stream Habitat Enhancement	***Project RM 7.5L*** Re-establish channel LWD dynamics ***Project RM 7.6L*** Levee removal. ***Project RM 7.7R*** LWD alcove enhancement. ***Project RM 7.5R*** LWD enhancement	Flood protection for agricultural and residential development along the north side of the channel provided by levee. Twisp River Road along the north side of the inner-zone near RM 7.6. Irrigation diversion near RM 7.4.
OZ-1	OZ-1 is a 7.5-acre floodplain on the inside of a meaner bend. It is mostly isolated from human activity, retains an intact riparian forest, and has not been developed. The riparian forest provides thermal shading and potential LWD recruitment. There is residential development on the glacial terrace to the south of OZ-1 and a small recreational area has been cleared near RM 7.7. Although the potential exists for a strong channel/floodplain connection in this area, there is no topographic evidence of active high-flow channels.	Protect and Maintain		There are no significant constraints to restoration or preservation activities.

Table 26. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T3c

Sub-Unit	Description	Strategy *(Strategies are listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
DOZ-1	DOZ-1 is 11 acres and is the largest floodplain unit in Reach T3c. There is little remaining habitat or process connection to this floodplain. The surface has been almost entirely cleared of vegetation, filled, leveled, and roads built for agricultural, residential, or fisheries management use. Along the outer-zone margin near the house at RM 7.5, car bodies have been used for bank protection. There is an irrigation diversion that originates near RM 7.4 and the ditch follows the floodplain margin down to near RM 7.25. There is a fish screen and fish return channel located near the adult weir at RM 7.25. The levee, roadway, and bridge near RM 7.2 sever connections between the main channel and the abandoned side-channel to the north. Habitat actions suggested in Project RM 7.6L would also benefit DOZ-1.	Protect and Maintain Reconnect Floodplain Processes	*Work to address impacts of development, bank protection, levee (eg. levee setback/removal, riparian restoration, off-channel habitat restoration).*	Agricultural and residential development and bank protection Irrigation diversion and canal Fisheries facilities Levee and private drive.

Table 26. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T3c

Sub-Unit	Description	Strategy *(Strategies are listed in priority order)*	Projects[1] *(specific identified projects are in **bold**)*	Potential Constraints
DIZ-1	This sub-unit includes an old channel scar to the north of the channel on the outside of a meander bend. These wetlands have the potential to provide valuable off-channel habitat. Currently, there are several obstructions limiting the connection of these wetlands to the main channel. There is a 150-ft long push up levee near RM 7.28 and a longer push-up levee from RM 7.1 to RM 7.25. This larger levee disconnects the main channel from the oxbow wetlands to the north. This levee also protects a roadway that crosses the bridge at RM 7.15 and provides access to residential development south of the river. There is an outlet channel that connects the wetlands to the main channel at the downstream end of the sub-unit. The outflow does not appear to provide fish passage at low flows.	Protect and Maintain Reconnect Stream Channel Processes Off-Channel Habitat Enhancement	***Project RM 7.3L*** Levee removal ***Project RM 7.15L*** Off-channel habitat enhancement.	Fisheries and irrigation facilities. Access road for homes to the south of the river. Bridge crossing at RM 7.15. Flood protection provided by levees.
OZ-2	This 7.4 acre floodplain surface is located on the inside of a meaner bend between RM 7.0 and 7.35. This outer-zone sub-unit is undeveloped and exhibits intact floodplain/riparian habitat and potential LWD recruitment. There is no geomorphic evidence of frequent overbank flooding, high-flow channels, or other active connection to channel processes. There is some residential development of the terrace to the south and a bridge and access road near RM 7.15.	Protect and Maintain		Bridge and road near RM 7.15.

Table 26. Summary of Sub-Unit Descriptions, Restoration Strategies, Projects and Constraints for Reach T3c

Sub-Unit	Description	Strategy *(Strategies are listed in priority order)*	Projects[1] *(specific identified projects are in* ***bold****)*	Potential Constraints
IZ-2	In IZ-2, channel form simplifies to single-thread with plane-bed morphology. The upstream half of the sub-unit is constrained by human alteration, primarily to the north of the channel. There is a several hundred foot long push-up levee along the edge of the channel between RM 7.1 and 7.3. There is a fish collection weir across the entire width of the channel at RM 7.25. A bridge crosses the channel at RM 7.15 and there is riprap along both sides of the channel protecting the abutments. Riprap is also located on the outside of the bend near RM 7.05 to protect houses near the bank. Anthropogenic constraints decrease in the downstream direction. Bedrock affects channel dynamics between RM 6.9 and 7.0.	Protect and Maintain Reconnect Stream Channel Processes In-Stream Habitat Enhancement	***Project RM 7.05L*** Riprap removal or modification ***Project RM 6.8L*** Re-establish channel LWD dynamics. ***Project RM 7.15R*** LWD enhancement ***Project RM 6.95R*** LWD enhancement ***Project RM 6.89R*** LWD enhancement	Agricultural and residential development along the north side of the channel and associated bank hardening. Fisheries facilities near RM 7.25. Bedrock on river-right near RM 6.97.
OZ-3	OZ-3 is a 7.3-acre floodplain area to the north of the channel between RM 6.71 and 7.01. There is residential development in OZ-3 but it has relatively little impact on the channel or floodplain. The riparian forest is generally intact and there are no significant barriers to habitat connection or process. LiDAR data reveal high-flow channels near the downstream end of the sub-unit.	Protect and Maintain		Rural residential development.
OZ-4	OZ-4 is 3.3 acres and is the smallest floodplain unit in Reach T3c. The sub-unit is isolated, without road access. It remains undeveloped with an intact riparian forest and the potential to contribute LWD to the channel. There are no barriers to habitat connection or physical processes. There is no geomorphic evidence of high-flow across this surface and there is no off-channel habitat.	Protect and Maintain		There are no significant constraints to restoration or preservation activities.

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

11 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 44, Table 27). Reconnect Stream Channel Processes is the majority opportunity type in the study area, comprising 41% of the project opportunities. These projects include levee modifications, side-channel reconnections, and re-establishing natural densities of channel LWD to restore dynamic geomorphic processes. Instream Habitat Enhancement, which is mainly LWD placements for cover and structure, comprises the next largest share of habitat actions at 28%. Reconnecting Floodplain Processes and Off-Channel Habitat Enhancement both make up 13% of the total distribution of projects. Reconnecting floodplain processes usually entails levee modification, and in some cases road and culvert modification. Off-channel habitat enhancements can include wetland, alcove, or side-channel enhancement. Riparian Restoration projects make up a small portion of the project distribution at 4%. 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.

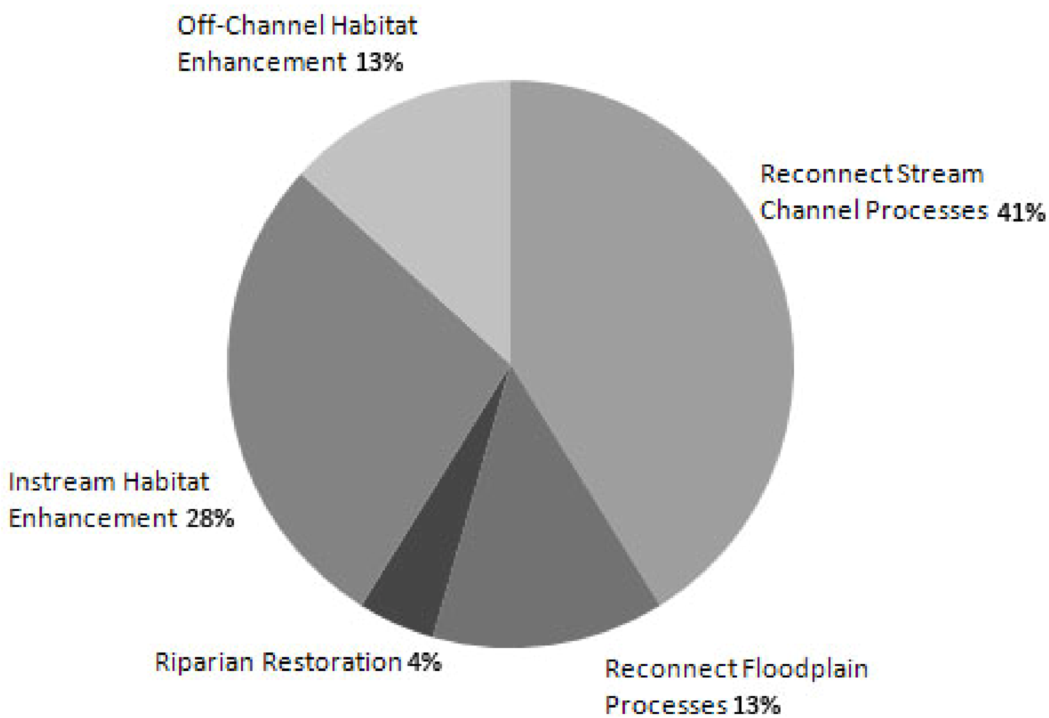

Figure 44. Comparison of the distribution of project types in the study area.

Table 27. Summary of projects identified for each reach in the study area.

Reach	Protect an Maintain	Reconnect Stream Channel Processes	Reconnect Flooplain Processes	Riparian Restoration	Instream Habitat Enhancement	Off-Channel Habitat Enhancement	Totals
T1		1			1		2
T2a		3	3	2	3	2	13
T2b		13	5		6	6	30
T3a					1		1
T3b		7	0	1	3		11
T3c		4	1		5	1	11
Totals	0	28	9	3	19	9	68

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Appendix A

Twisp River

Stream Habitat Assessment

River Mile 0 to 7.8

Survey: October 2009

Table of Contents

1 Introduction

The Twisp River is located in Okanogan County, WA. The Twisp River flows into the Methow River near river mile (RM) 41, near the town of Twisp. A habitat survey was conducted along the lower Twisp River from RM 0 to approximately RM 7.8 from October 5 to October 10, 2009 (Figure 1).

The objective of the Habitat Assessment is to characterize the habitat quantity and quality for salmonid species native to the Twisp River by quantifying in-channel morphologic features, qualitatively describing riparian conditions, and identifying anthropogenic features influencing aquatic habitat. This information is used to inform potential restoration/preservation actions and will provide a baseline for evaluating future habitat trends and for measuring the effectiveness of restoration efforts.

Spring Chinook salmon, Coho salmon, steelhead trout, rainbow trout, bull trout, and west slope cutthroat trout are native salmonid species to the Twisp River. The lower Twisp River is utilized primarily as a migration corridor for steelhead and spring Chinook salmon, but is also used to some degree for spawning and rearing. Bull trout use the lower Twisp River for migration and rearing (BOR 2008). Spawning, rearing, and adult migration habitat is limited by anthropogenic impacts including road building, land clearing, agriculture, and development. These activities have resulted in channel confinement, bank armoring, channel simplification, and reduced quantities of large woody debris (LWD).

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

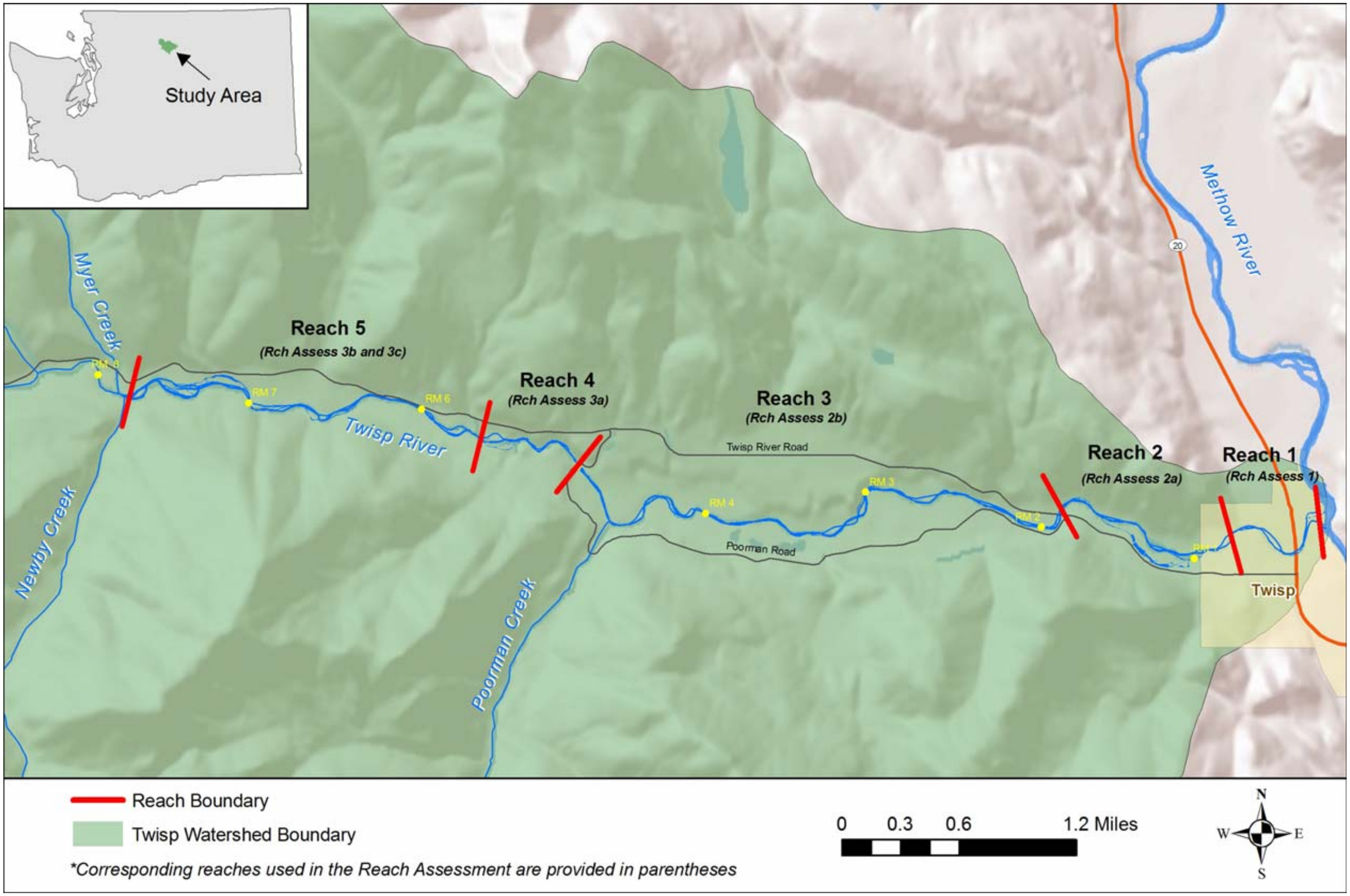

Figure 1. Locator map of the Habitat Assessment area showing the habitat survey reaches used in the assessment. Reaches conform to past habitat surveys to maintain consistency. The relationship to the reach designations used in the Bureau of Reclamation Tributary Assessment (USBR 2008) are provided in parentheses.

2 Methods

Five geomorphic reaches have been previously delineated and used for habitat assessment work in the study area by the Pacific Watershed Institute (PWI 2003) and the U.S. Forest Service (USFS 2001). These same reaches were used for the stream habitat assessment to maintain consistency with these previous efforts. It is important to note, however, that these reaches differ from the reach nomenclature used in the Reach Assessment portion of this report (see Figure 1 for a comparison of reaches).

Field methods for the habitat survey used the USFS Region 6 Level II Stream Survey Protocol Version 2.6 (USFS 2006). A modification was made to the protocol with respect to the n^{th} unit measurement frequency. The protocol indicates that n^{th} unit measurements should occur at no less than a 10% sampling frequency with a minimum of 10 n^{th} unit samples of each unit type per reach. Due to long habitat units relative to reach length, this would have required the measurement of more n^{th} units than was possible given time constraints. As a compromise, the minimum n^{th} unit sampling frequency was increased to 15% with no minimum number of n^{th} units per reach.

Following the Level II Stream Survey Protocol, we compared the ocular (visual) estimates of wetted width performed for every unit with the measured values at n^{th} units in order to determine if correction of the ocular estimates was necessary. The average difference between the actual and ocular values was 4.8 feet, evenly distributed ab. As a result, ocular estimates were not corrected and are considered generally accurate to within +/- 5 feet.

3 Summary of Results

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

3.1 Channel Morphology

Lower Twisp River reaches are dominated by pool-riffle morphology. Channel bed substrate consists primarily of cobbles and gravel, with a high frequency of boulders in some reaches. Bedrock and sand occur relatively infrequently.

Channel widths do not vary substantially between stream reaches and do not increase in the downstream direction as might be expected (Figure 2). This may be attributed to a large degree of artificial channel confinement that affects stream width in various locations throughout the study area. Mean bankfull widths are 74.4 ft (stdev 17.6). Bankfull depths do not vary substantially among reaches (Figure 3). Median bankfull depths range from 2.8 to 3.3 feet with the largest bankfull depths occurring, on average, in Reaches 2 and 5. Median floodprone widths in reaches 1, 3, 4, and 5 range from 121 to 184 feet (Figure 4). Reach 2 has a wider active floodplain, with a floodprone width of 400 feet.

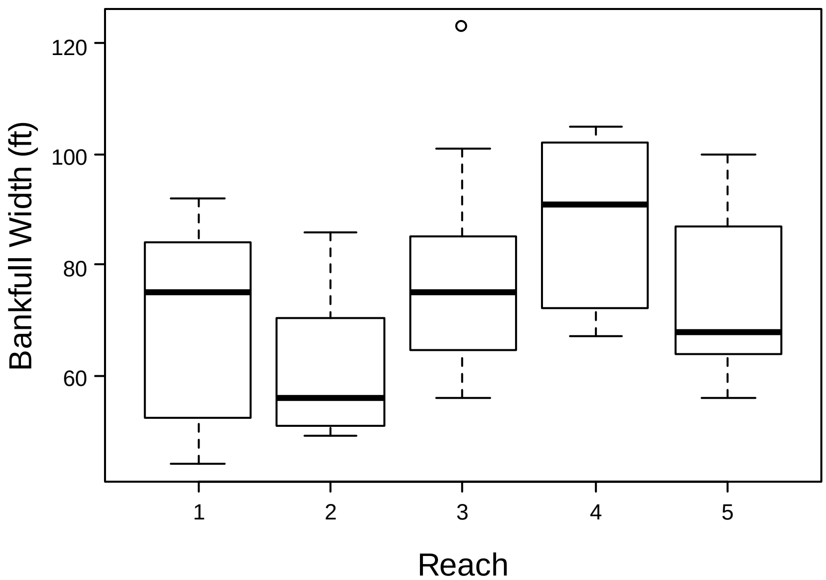

Figure 2. Boxplot of bankfull widths for each reach in feet.

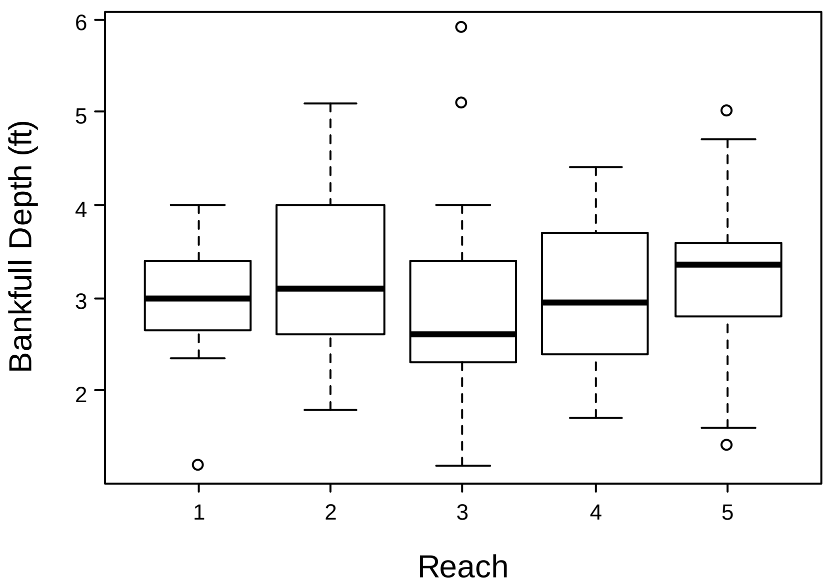

Figure 3. Boxplots of bankfull depths in feet. Each value is an average of three individual measurements taken at each n[th] riffle unit in each reach.

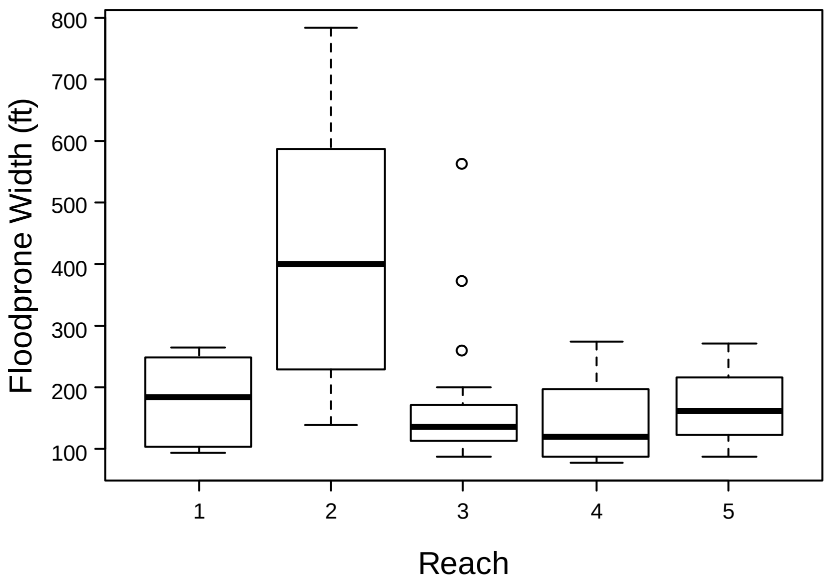

Figure 4. Boxplots of floodprone width in feet.

3.2 Habitat Unit Composition

Riffles are the predominant habitat unit type and make up 51% of the total habitat area. Pools comprise approximately 33% and glides comprise approximately 8% of the total habitat area. The remaining 8% is side channel habitat (Figure 5).

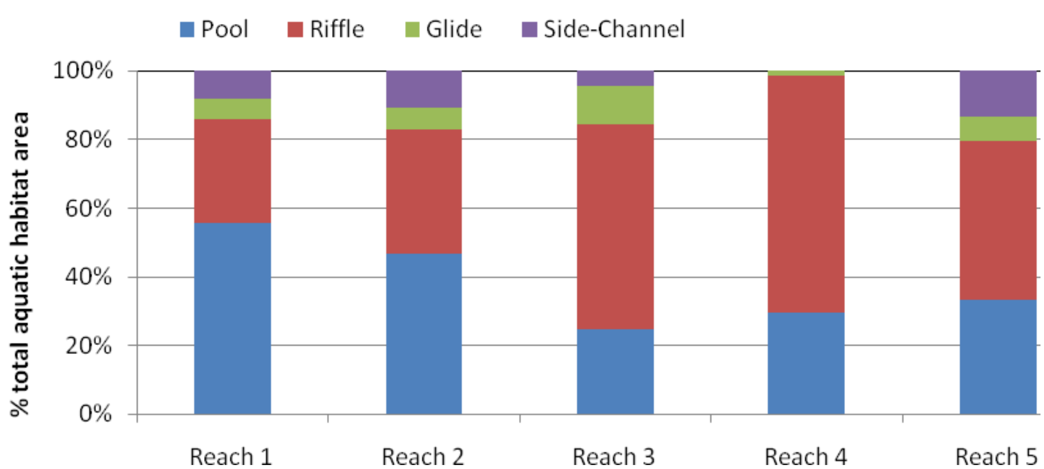

Figure 5. Proportion of habitat types by length in Reaches 1 through 5 on the mainstem Twisp River.

Pool frequency ranges from 8.9 to 23.7 pools/mile, with a mean pool spacing of 305 ft, or a pool approximately every 4 bankfull widths. Reach 1 has the greatest proportion of habitat in pools (56%), although Reach 4 has the greatest number of pools/mile (23.7). Reaches 1 and 2 have the shortest pool spacing (151 ft and 173 ft, respectively). Reach 4 has the greatest number of deep pools (44% of residual depths exceed 3 ft in several pools), owing to its natural confinement and frequency of bedrock-formed pools. The majority of the pools throughout the study site are relatively shallow, with residual depths of 1-2 ft commonly comprising between one-half to three-quarters of the pools.

Mean wetted widths are 51.3 feet (st. dev. 14.1 ft) and riffles are 5.7 feet wider than pools on average. Mean riffle depths are 0.7 feet (st. dev. 0.1 ft) with mean maximum depths of 1.4 feet (st. dev. 0.3 ft). Minimum depths of 0.8 feet and 0.6 feet have been reported as necessary to maintain Chinook and large trout passage, respectively (Thompson 1972). Shallow riffle depths may limit passage for spring Chinook and steelhead at summer low flow periods; however, many adults will migrate through this area during higher spring or fall flows.

Average unit lengths for the three habitat types (pools, riffles, and glides) are presented in Figure 6. Reaches 1 and 5 have the longest pools. Reaches 3, 4, and 5 have the longest riffles and Reaches 3 and 5 have the longest glides. Reaches 3 and 5 tend to have longer habitat units in general, mostly long riffles and glides.

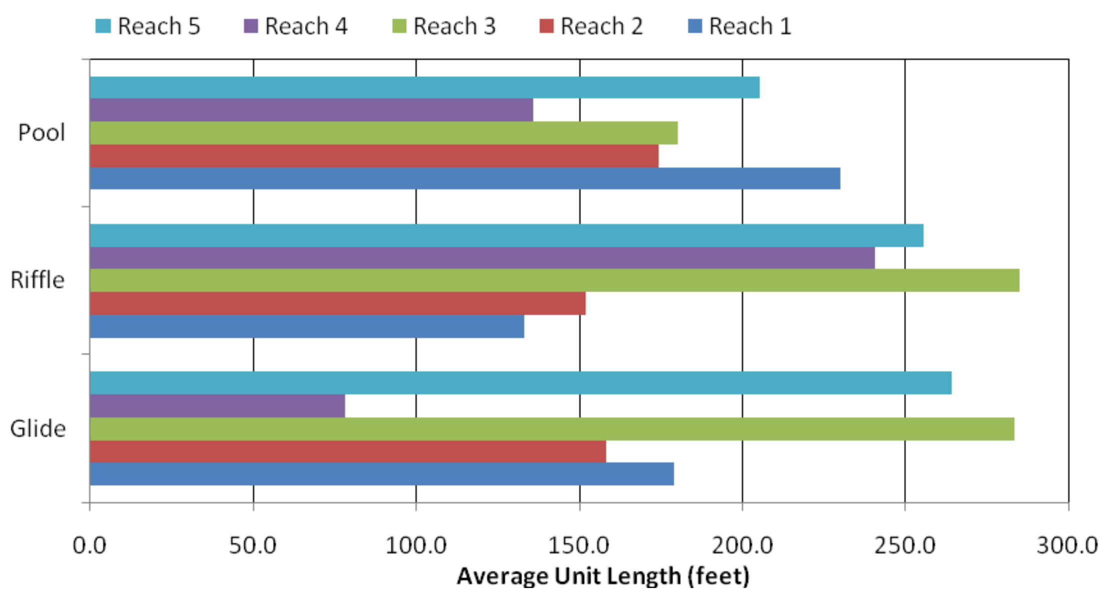

Figure 6. Comparison of average habitat unit lengths for Reaches 1-5 in the mainstem Twisp River.

3.3 Off-Channel Habitat

Side-channel habitat accounts for approximately 8% of the surveyed length along the lower 7.8 miles of the Twisp River (Figure 5). A total of 35 wetted side-channel habitat units were measured during the survey. Reach 5 has the greatest amount of side-channel habitat and Reach 4 has no side-channel habitat. The irrigation diversion and return flow in Reach 5 was considered a side-channel because of active flow during the survey. The diversion into the coho acclimation ponds in Reach 2 was also considered a side-channel during the survey.

Reaches 3 and 5 contained the greatest number of side-channel habitat units, with 8 and 15 side-channels, respectively. Side-channel pools were larger in area for Reaches 2 and 5 and greater in depth for Reaches 1 and 2. Side-channel pools occupied a greater area than side-channel riffles in Reaches 1-3.

Natural confinement as well as artificial confinement caused by hydromodifications limit side-channel habitat throughout the study area. Natural confinement limits side-channels in Reach 4. In reaches 1, 2, 3, and 5, there are areas where roads, bank armoring, levees, and channel/floodplain filling have reduced the abundance and connectivity of side-channels and off-channel habitat.

3.4 Large Wood

An average of 104 pieces of wood per mile were counted in the Twisp River; 81% of these were "small" pieces with diameters between 6 and 12 inches and lengths greater than 20 feet (Figure 7). Reaches 2 and 5 had the highest number of "large" pieces per mile (6 and 7, respectively), and overall these two reaches also contained the highest frequencies of LWD at 116 and 165 pieces per mile, respectively. The number of pieces per mile in each reach ranged from 65 to 165.

Median wood loading on "undisturbed" streams of comparable size and type in the region is 274 pieces/mile and the 25th percentile is 80 pieces/mile (Fox and Bolton 2007). The average wood frequency in the lower Twisp River (all reaches combined) is 104 pieces/mile, which is well below the median but exceeds the 25th percentile.

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

3.5 Substrate and Fine Sediment

Bed substrate is based on ocular estimates at each habitat unit and pebble counts at two representative locations within each of the five reaches. The ocular estimates and pebble counts closely agree with percent coverage of gravel, cobble, and boulder. In general, bed substrate in the lower Twisp River is gravel, cobble, and boulder with smaller amounts of bedrock and sand

(Figure 8 and Figure 9). Generally, more sand and boulders are found in the upstream reaches and a greater proportion of the substrate is gravels in the downstream reaches.

Sediment measurements indicate that the presence of fine sediment is low and an excess of fine sediment (<2mm) does not appear to be a significant concern in the study area. Sand accounts for less than 12% of the bed in mainstem habitat units and bed substrate was not considered to be embedded. Side-channels contained a greater abundance of fine sediments, ranging from 5% to 45% sand or fines.

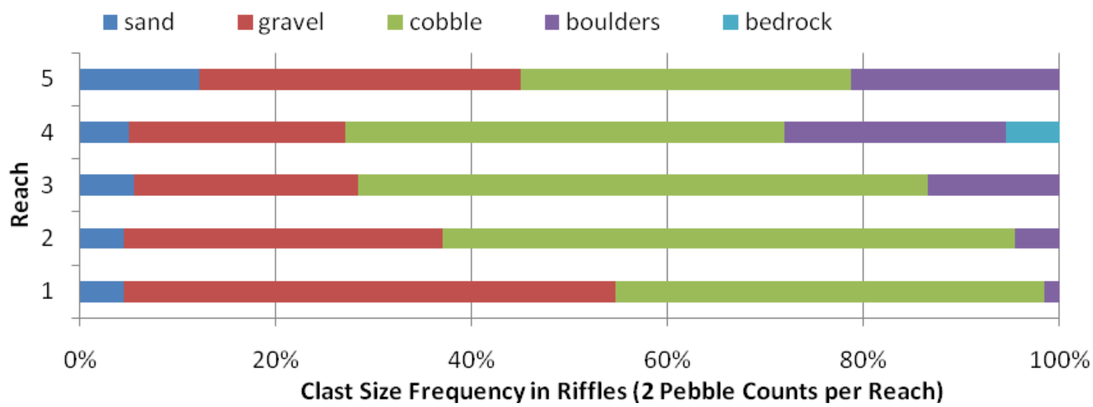

Figure 8. Pebble count classification of substrate by habitat unit type and reach for the Twisp River.

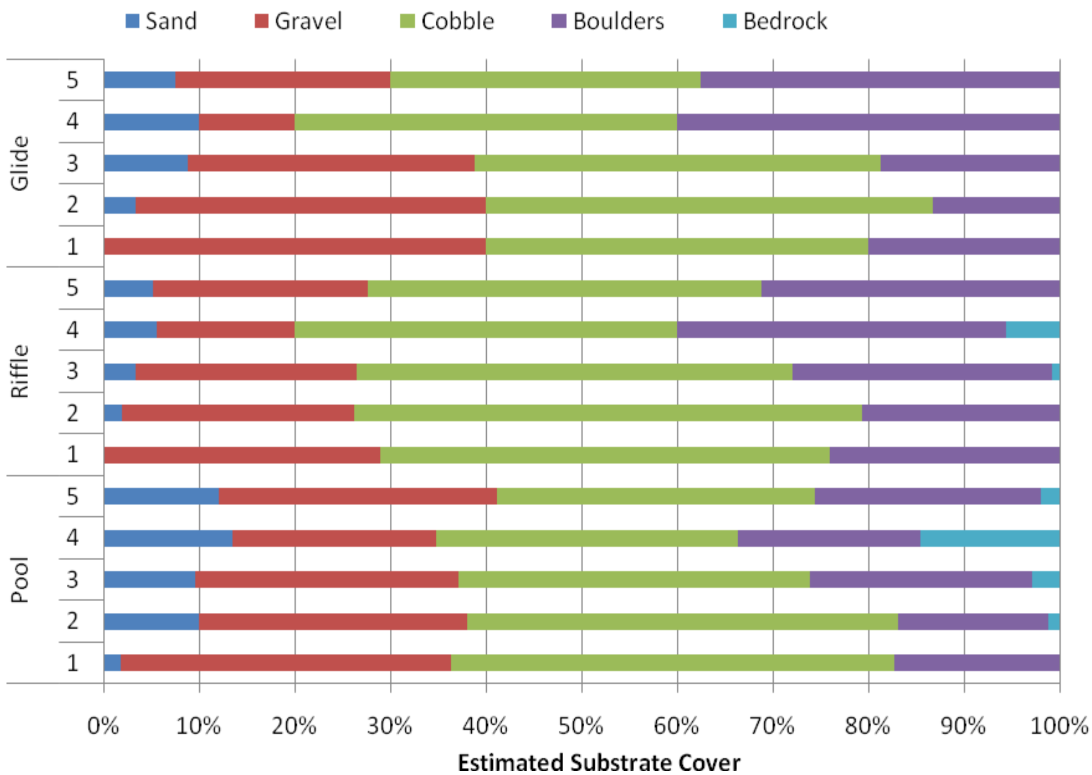

Figure 9. Ocular estimates of substrate by habitat unit type and reach for the Twisp River.

3.6 Instability and Disturbance

There has been significant human alteration along portions of the channel, riparian zone, and floodplain throughout the study area. These alterations are related to past and ongoing land-uses in the lower Twisp River Valley, including timber harvest, gravel mining, agriculture, road building, and residential development. Artificial channel confinement in the form of bridges, floodplain fill, levees, and bank armoring affects channel and floodplain dynamics in many areas. Reach 1, which flows through the town of Twisp, has the greatest proportion of hydromodifications that alter channel and floodplain processes. The other 4 reaches have moderate amounts of human disturbance, except for Reach 4, which has relatively little disturbance as a result of natural valley confinement.

On average, only 3% of the streambanks along the lower 7.8 miles of the Twisp River are actively eroding. The greatest amount of bank erosion was observed in Reach 2, where an average of 7% of the mainstem streambanks displayed active erosion. The other four reaches contained only 2% to 3% bank erosion overall.

Bank erosion occurs in all habitat unit types (Figure 10). Ninety percent of the river-left bank along Reach 2 was eroding, but overall, the lower Twisp does not exhibit excessive erosion. In some areas, streambank erosion is prevented by riprap and boulder weirs.

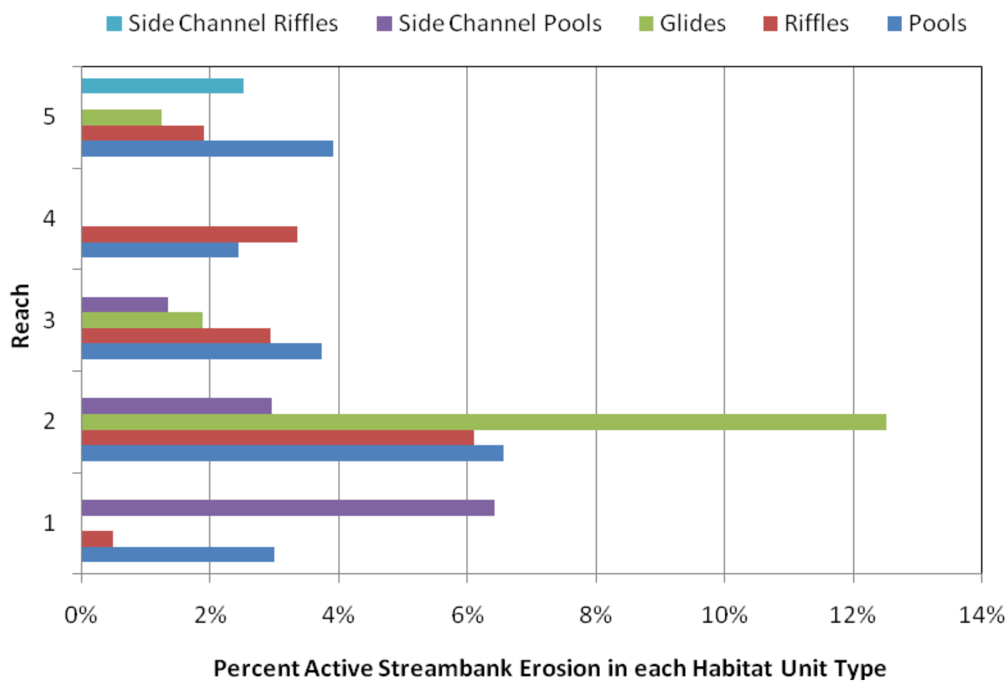

Figure 10. Percent active streambank erosion in each habitat unit type.

3.7 Fish Passage Barriers

There are no significant fish passage barriers in the study area. The adult weir near RM 7.25 may provide a barrier for upstream migrating juveniles under some conditions. A small-head concrete diversion dam at the irrigation diversion near RM 7.4 may limit passage in the river-left side-channel. Low flows, especially during low water years and times of high irrigation diversion, may impact adult fish passage in some areas.

3.8 Riparian Corridor

The inner riparian zones are typically dominated by small trees (76% of measured units); large trees are dominant in 24% of units (Figure 11). Inner zone overstories are almost all hardwoods (95%) (Figure 13) and cottonwood is the dominant overstory species. The understory is mostly hardwood (85%) and exhibits greater species diversity than the overstory; species include river birch, alder, quaking aspen, chokecherry, red-osier dogwood, and willows.

The majority of the riparian outer zones (i.e. floodplain areas) are dominated by large trees (60%), although a significant portion (38%) are dominated by small trees and a few (2%) are dominated by grass/forbs (Figure 12). The outer zone overstory is typically dominated by either conifers (53%) or hardwoods (45%) (Figure 13). The outer zone understory is mostly grass/forbs (53%), although hardwoods (33%) and conifers (12%) also dominate in some areas (Figure 13).

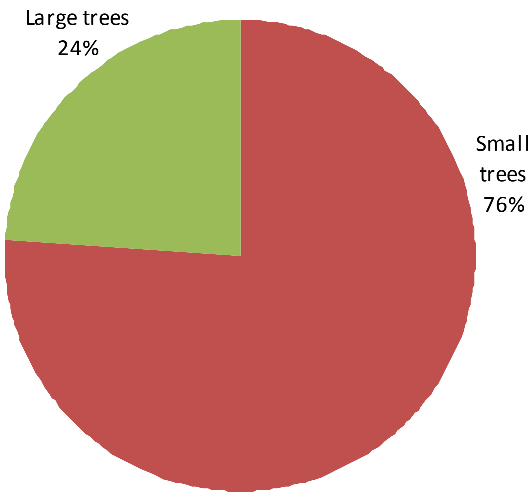

Figure 11. Distribution of the dominant size class category for the riparian inner zones, all reaches combined.

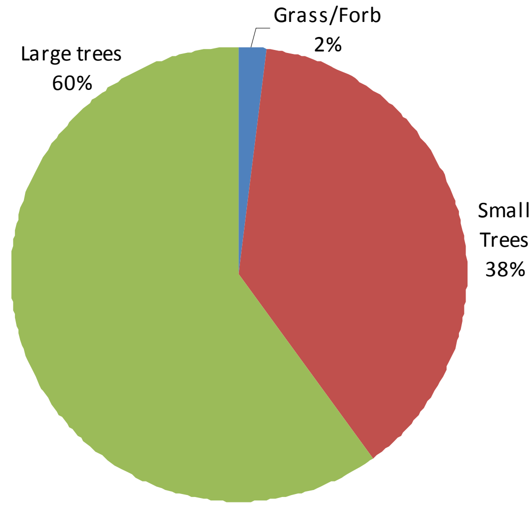

Figure 12. Distribution of the dominant size class category for the riparian outer zones, all reaches combined.

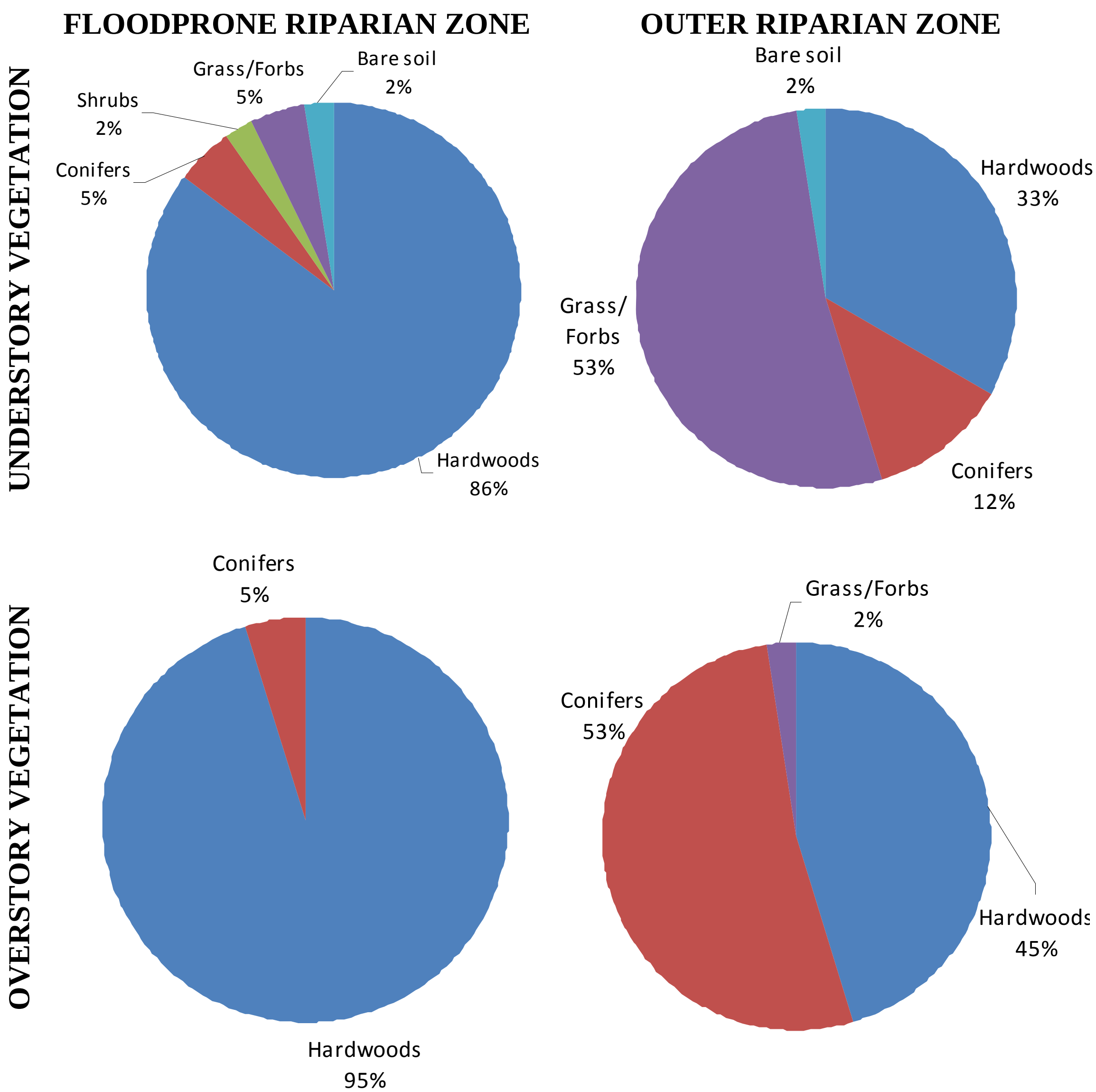

Figure 13. Proportions of vegetation cover types in the riparian zone along the lower 7.8 miles of the Twisp River.

Table 1. Twisp River Data Summary: RM 0 to RM 7.8.

		Total	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
Reach Mileage Boundaries (based USBR mileage locations)		0 - 7.8	0 - 0.7	0.7 - 1.9	1.9 - 5.0	5.0 - 5.6	5.6 - 7.8
Channel Morphology			Pool-riffle	Pool-riffle	Pool-riffle	Pool-riffle	Pool-riffle
Slope							
Average (USFS 2001)		1.2%	1.2%	0.6%	1.0%	1.7%	1.3%
Wetted Width (ft)							
Pool							
	Mean	45.6	34.7	46.2	48.4	43.9	47.6
	Median	45.0	35.0	45.0	45.5	42.0	47.0
	StDev	10.4	11.2	12.0	7.4	13.0	8.2
Riffle							
	Mean	51.3	36.5	43.0	56.6	60.2	51.6
	Median	51.0	31.0	41.0	56.0	60.0	48.0
	StDev	14.1	18.4	15.2	10.5	8.6	11.1
Glide							
	Mean	47.3	50.0	43.0	49.0	35.0	50.5
	Median	47.5	50.0	45.0	47.5	35.0	50.5
	StDev	10.5	n=1	13.9	9.9	n=1	10.4
Water Depth (ft)							
Pool Maximum Depth (ft)							
	Mean	2.9	2.7	2.8	3.1	3.6	2.7
	Median	2.5	2.4	2.5	2.8	3.2	2.3
	StDev	1.1	0.9	0.8	1.1	1.4	1.2
Pool Residual Depth (ft)							
	Mean	2.1	2.0	2.0	2.2	2.8	1.9
	Median	1.8	1.7	1.7	1.9	2.4	1.5
	StDev	1.1	0.9	0.9	1.1	1.4	1.1
Maximum Riffle Depth							
	Mean	1.4	1.2	1.2	1.4	1.6	1.6
	Median	1.3	1.1	1.2	1.3	1.6	1.5
	StDev	0.3	0.1	0.2	0.3	0.4	0.3
Average Riffle Depth							
	Mean	0.7	0.7	0.8	0.7	0.8	0.8
	Median	0.7	0.7	0.7	0.7	0.8	0.8
	StDev	0.1	0.1	0.2	0.1	0.1	0.1

		Total	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
Reach Mileage Boundaries (based USBR mileage locations)		0 - 7.8	0 - 0.7	0.7 - 1.9	1.9 - 5.0	5.0 - 5.6	5.6 - 7.8
Maximum Glide Depth							
	Mean	1.6	1.1	1.4	1.6	2.0	1.8
	Median	1.6	1.1	1.5	1.6	2.0	1.8
	StDev	0.2	n=1	0.1	0.2	n=1	0.1
Average Glide Depth							
	Mean	1.0	0.8	1.1	0.9	1.2	1.1
	Median	1.0	0.8	1.0	0.9	1.2	1.1
	StDev	0.2	n=1	0.2	0.1	n=1	0.1
Bankfull Characteristics							
Width (ft)							
	Mean	74.4	69.5	62.0	76.9	88.0	73.7
	StDev	17.6	20.5	15.2	17.8	15.7	14.6
Depth (ft) Averaged over 3 depth measurements							
	Mean	3.0	3.0	3.2	2.8	3.0	3.3
	StDev	0.6	0.3	0.6	0.7	0.4	0.5
Maximum Depth (ft)							
	Mean	3.7	3.5	3.9	3.6	3.7	4.0
	StDev	0.9	0.5	1.0	1.1	0.7	0.7
Width:Depth Ratio							
	Mean	25.9	23.9	20.6	29.2	30.5	22.8
	StDev	9.4	7.8	9.6	10.8	8.2	6.1
Floodprone Width (ft)							
	Mean	212	178	422	180	147	167
	StDev	160	80	254	129	76	57
Habitat Area %							
Pool		33%	56%	47%	25%	29%	33%
Riffle		51%	30%	36%	60%	69%	46%
Glide		8%	6%	6%	11%	1%	7%
Side Channel		8%	8%	11%	4%	0%	13%
Pools							
Pools per mile		11.5	15.7	15.2	8.9	23.7	10.5
Residual Depth (% of pools)							
	Pools< 1 ft	4%	9%	6%	0%	0%	8%
	Pools 1-2 ft	57%	45%	65%	57%	33%	64%
	Pools 2-3 ft	17%	36%	12%	14%	22%	12%
	Pools > 3 ft	22%	9%	18%	29%	44%	16%
Riffle:Pool Ratio		1.1	0.9	0.9	1.3	1.0	1.0

	Total	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
Reach Mileage Boundaries (based USBR mileage locations)	0 - 7.8	0 - 0.7	0.7 - 1.9	1.9 - 5.0	5.0 - 5.6	5.6 - 7.8
Mean Pool Spacing	305	151	173	460	280	298
Mean Pool Spacing/Mean Bankfull Width	4	2	3	6	3	4
Large Wood						
Total Number Pieces						
Small (6 in x 20 ft)	659	41	96	184	29	309
Medium (12 in x 35 ft)	132	8	27	17	4	76
Large (20 in by 35 ft)	23	2	7	5	3	6
Number of Pieces/Mile						
Small (6 in x 20 ft)	85	59	86	58	76	130
Medium (12 in x 35 ft)	17	11	24	5	11	32
Large (20 in by 35 ft)	3	3	6	2	8	3
Bank Erosion (% eroding banks)						
Mainstem	3%	2%	7%	3%	3%	3%
Pool	4%	3%	7%	4%	2%	4%
Riffle	3%	0%	6%	3%	3%	2%
Glide	3%	0%	13%	2%	0%	1%
Side Channel Pools	4%	6%	3%	1%	0%	0%
Side Channel Riffles	2%	0%	0%	0%	0%	3%
Substrate (Ocular Estimate)						
Total						
% Sand	9%	2%	7%	7%	10%	15%
% Gravel	27%	34%	29%	27%	17%	26%
% Cobble	40%	45%	47%	41%	36%	34%
% Boulder	22%	20%	16%	23%	28%	25%
% Bedrock	2%	0%	1%	1%	10%	1%
Pool						
% Sand	9%	2%	10%	10%	13%	12%
% Gravel	28%	35%	28%	28%	21%	29%
% Cobble	39%	46%	45%	37%	31%	33%
% Boulder	20%	17%	16%	23%	19%	24%
% Bedrock	4%	0%	1%	3%	15%	2%
Riffle						
% Sand	3%	0%	2%	3%	6%	5%
% Gravel	23%	29%	24%	23%	14%	22%
% Cobble	45%	47%	53%	45%	40%	41%
% Boulder	27%	24%	21%	27%	34%	31%
% Bedrock	1%	0%	0%	1%	6%	0%

	Total	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
Reach Mileage Boundaries (based USBR mileage locations)	0 - 7.8	0 - 0.7	0.7 - 1.9	1.9 - 5.0	5.0 - 5.6	5.6 - 7.8
Glide						
% Sand	6%	0%	3%	9%	10%	8%
% Gravel	28%	40%	37%	30%	10%	23%
% Cobble	40%	40%	47%	43%	40%	33%
% Boulder	26%	20%	13%	19%	40%	38%
% Bedrock	0%	0%	0%	0%	0%	0%
Side Channel Pools						
% Sand	17%	5%	15%	12%	-	27%
% Gravel	40%	55%	43%	47%	-	29%
% Cobble	33%	35%	33%	35%	-	30%
% Boulder	9%	5%	5%	7%	-	14%
% Bedrock	1%	0%	5%	0%	-	0%
Side Channel Riffles						
% Sand	27%	5%	10%	5%	-	45%
% Gravel	31%	30%	30%	30%	-	32%
% Cobble	29%	40%	60%	45%	-	15%
% Boulder	13%	25%	0%	20%	-	8%
% Bedrock	0%	0%	0%	0%	-	0%
Pebble Count (*Riffle*)						
% Sand	6%	4%	5%	5%	5%	12%
% Gravel	32%	50%	33%	23%	22%	33%
% Cobble	48%	44%	59%	58%	45%	34%
% Boulder	13%	1%	5%	13%	23%	21%
% Bedrock	1%	0%	0%	0%	5%	0%
Vegetation (% of sampled units)						
Riparian Inner Zone						
Small trees	76%	80%	86%	73%	100%	56%
Large trees	24%	20%	14%	27%	-	44%
Hardwoods	95%	100%	100%	100%	100%	78%
Conifers	5%	-	-	-	-	22%
Riparian Outer Zone						
Grass/Forb	2%	-	-	-	-	11%
Small Trees	38%	-	71%	47%	17%	33%
Large trees	60%	100%	29%	53%	83%	56%
Hardwoods	45%	20%	100%	60%	-	22%
Conifers	53%	80%	-	40%	100%	67%

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ATTACHMENT A STREAM HABITAT REACH REPORTS

Table of Contents

A-1 REACH 1 (same as Reach Assessment Reach 1)

Location: River mile 0 to River mile 0.7

Survey Date: October 5, 2009

Survey Crew: Robin Jenkinson and Emily Plummer (Inter-Fluve)

A-1.1 Reach Overview

Reach 1 is located on the Twisp River alluvial fan as it enters the broad Methow River Valley. The reach extends from RM 0 to RM 0.7 and flows through the town of Twisp, WA. There is considerable development and human infrastructure in the reach, including houses, commercial development, parks, roadways, bank armoring, and levees (see aerial photo in Figure 3).

In the past, Native American camps of greater than 200 teepees used this confluence area, as well as a fish hatchery (Figure 1 and Figure 2). Today, the Twisp City Park borders the river on the river-right bank, which is hardened with riprap.

Figure 1. Fish hatchery located near the Twisp River – Methow River confluence at the turn of the 19th-20th centuries.

Figure 2. Native American camps at the Twisp River – Methow River confluence in 1927.

Figure 3. Reach 1 habitat unit composition map.

A-1.2 Channel Morphology

Reach 1 is located on the Twisp River alluvial fan as it enters the broad Methow River Valley. The reach is low gradient (1.2%) and the valley is unconfined. The channel itself is artificially confined due to human alterations. The channel type is pool-riffle. There is a deep, bedrock-formed pool in the Methow River just upstream of the Twisp confluence (Figure 1Figure 4). At the confluence, the Twisp River flows across a broad cobble and boulder delta (Figure 5). Small cottonwoods and willows grow in some locations on this alluvial deposit and occasional LWD is located throughout the delta.

The historical natural depositional environment in this reach has been impacted by development in and around the town of Twisp, including bank armoring, roadways, bridges, and associated channel incision and constraints on lateral channel dynamics. Due to artificial confinement, bed material is transported more readily through the upper portion of this reach than would have been expected under historical conditions.

Figure 4. View looking upstream on the Methow River from the Twisp River confluence (October 2009).

Figure 5. Looking upstream on the Twisp River from the confluence with the Methow River (October 2009).

A-1.3 Habitat Unit Composition

Reach 1 consists of 56% pools, 30% riffles, 6% glides, and 8% side-channels (Figure 6 and Figure 7). Pool frequency is 15.7 pools/mile or 1 pool every 2 bankfull widths. This was the tightest pool spacing of all the reaches in the survey. Average residual pool depth is 2.0 feet. Average maximum pool depth is 2.7 feet.

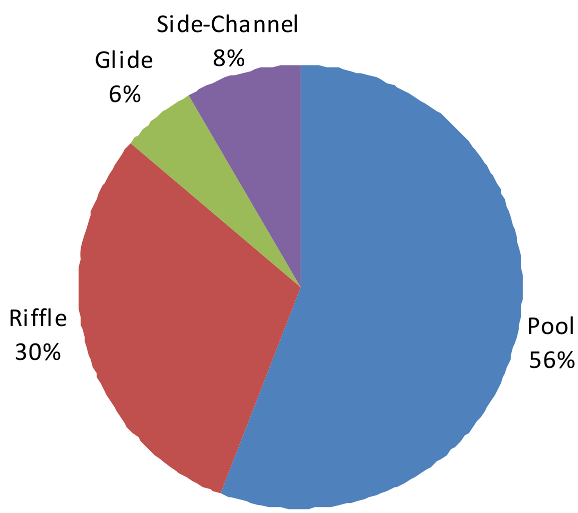


Figure 6. Habitat unit composition for Reach 1.

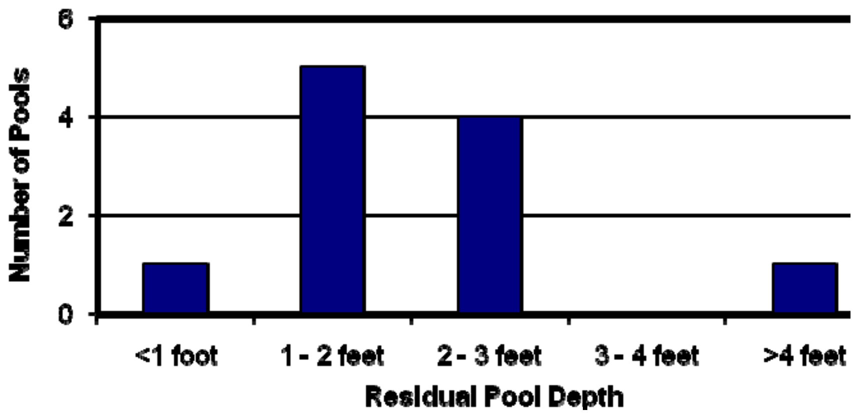


Figure 7. Reach 1 residual pool depths.

A-1.4 Off-Channel Habitat

Four side channels were observed in Reach 1. Two of the side-channels were distributary channels that flowed directly into the Methow River (Figure 8). The downstream 0.2 miles of the reach is a dynamic section of channel and has experienced shifting channel locations of the mainstem Twisp River, Twisp distributary channels, and Methow River channels in the past. Off-channel complexity is high in this section of the river. Off-channel availability in the upstream portion of the reach through the town of Twisp is limited due to artificial confinement, bank armoring, and fill. This area likely had high historical off-channel complexity that has been severely reduced as a result of development and river management.

Figure 8. High-flow distributary side-channel that flows directly into the Methow River at the confluence (October 2009).

A-1.5 Large Woody Debris

LWD plays a moderate role in Reach 1, including sediment sorting, habitat cover, and channel complexity (Table 1and Figure 9). Wood is an important component of pool formation. Large wood frequency is 73 pieces/mile, with "small" pieces comprising 80% of all large woody debris counted in the reach. "Large" wood pieces only accounted for 5% of all large woody debris counted in the reach.

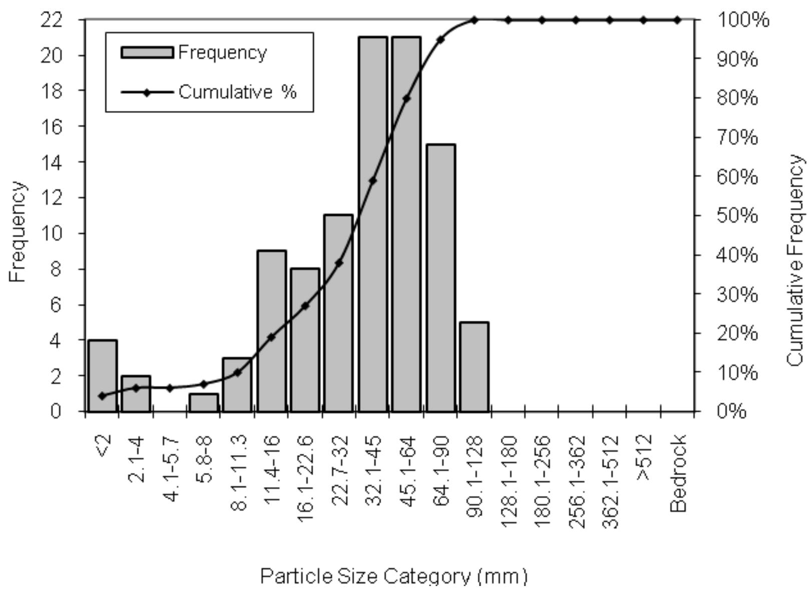
Table 1. Large woody debris quantities in Reach 1.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in by 35 ft)	Total
Number of Pieces	41	8	2	51
Number of Pieces/Mile	59	11	3	73

Figure 9. Large woody debris jam in Reach 1 (October 2009).

A-1.6 Substrate and Fine Sediment

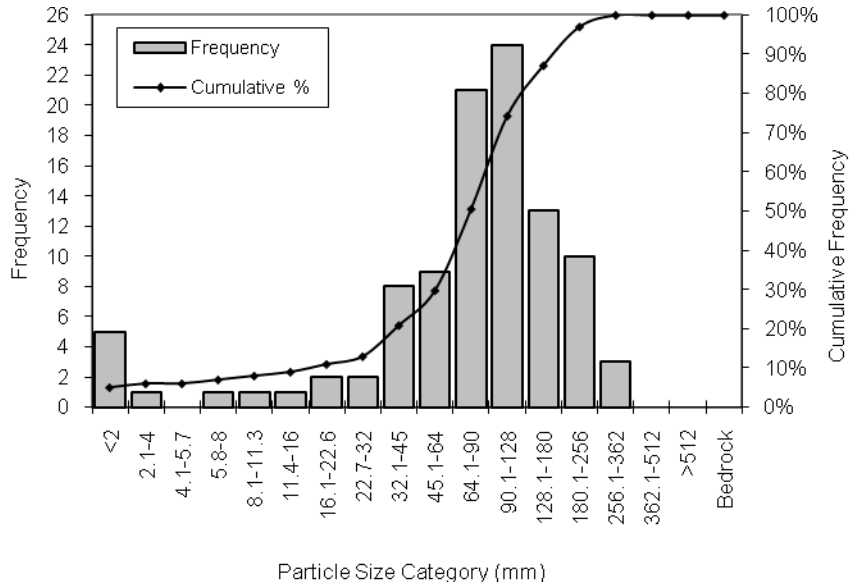
Bed substrate is dominated by gravels and cobbles. Boulders are subdominant. No bedrock was observed during stream surveys. Sand makes up less than 5% of the distribution. The pebble count and size class data are depicted in Figure 10, Figure 11, and Figure 12.



Material	Percent Composition
Sand	4%
Gravel	76%
Cobble	20%
Boulder	0%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	3
D16	14
D50	39
D84	71
D95	90

Figure 10. Grain size distribution and particle size classes from pebble count taken at RM 0.15.



Material	Percent Composition
Sand	5%
Gravel	25%
Cobble	67%
Boulder	3%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	2
D16	37
D50	90
D84	167
D95	240

Figure 11. Grain size distribution and particle size classes from pebble count taken at RM 0.55.

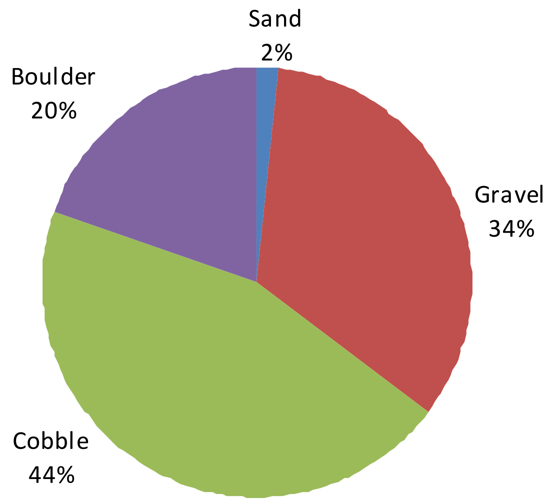


Figure 12. Percent composition of bed substrate based on ocular estimates, Reach 1.

A-1.7 Instability and Disturbance

There has been considerable human alteration to the channel and floodplain throughout Reach 1. Channel straightening, bank armoring, artificial confinement (levees), and incision have reduced dynamic channel adjustments that would have existed historically. The Highway 20 Bridge crosses the reach at RM 0.35. Riprap lines almost the entire river-right (southern) bank of the reach and portions of the river-left bank. Car bodies have also been used in places to provide bank stabilization (Figure 13). Residential development is protected by a levee on the river-right bank from RM 0.4 to 0.8. Houses with lawns and recreational access points occur frequently from RM 0.3 to RM 0.6 (Figure 14).

As a result of widespread bank armoring, actively eroding streambanks are uncommon in Reach 1 and only occur on approximately 165 feet of streambank.

Figure 13. Old car bodies ("detroit riprap") have been incorporated into streambanks in several locations (October 2009).

Figure 14. Residential development within the riparian corridor in Reach 1 (October 2009).

A-1.8 Available Spawning and Rearing Habitat

There is limited spawning and rearing habitat available in Reach 1. Bed substrate is adequately sized but the channel through much of the reach is dynamic and subject to scour and deposition during high flows. There is also potential disruption of spawning beds as a result of recreational access. Pool quantity within the reach is high although the pools generally have shallow residual depths and very little cover. LWD is moderately abundant and there are a number of off-channel rearing areas available.

A-1.9 Fish Passage Barriers

There are no fish passage barriers in Reach 1. Mean riffle thalweg depth is 0.7 feet, just under the 0.8-ft threshold cited for spring Chinook by Thompson (1972). Adult passage may be a concern during very low flow periods.

A-1.10 Riparian Corridor

The forested riparian corridor in Reach 1 is narrow and contains fewer species of trees and shrubs than upstream reaches. The riparian tree canopy is comprised primarily of cottonwood and ponderosa pine. Reed canary grass dominates the floodplain near the confluence.

Small trees are typically dominant within the riparian inner zone (80% of measured units) and nearly all inner zone areas are dominated by hardwoods (Figure 15). Riparian outer zone units are typically dominated by large trees (100% of measured units). Eighty percent of outer zones were dominated by conifers and 20% by hardwoods.

Relatively healthy riparian and floodplain forest vegetation is found downstream of RM 0.2 where active channel dynamics have created a patchwork mosaic of species and stand ages. Reed canary grass, however, is prevalent in this area.

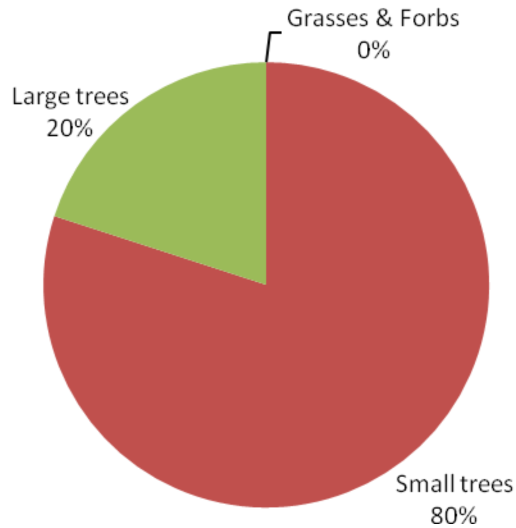


Figure 15. Distribution of the dominant size class category for the riparian inner zone, Reach 1.

A-2 REACH 2 (same as Reach Assessment Reach 2a)

Location: River mile 0.7 to River mile 1.9. *Note: This reach corresponds to BOR Reach 2a (BOR 2008).

Survey Date: October 6, 2009

Survey Crew: Robin Jenkinson and Emily Plummer (Inter-Fluve)

*A staff gage and antenna are located downstream of the Twisp River bridge (RM 1.85) on the river-left bank.

A-2.1 Reach Overview

Reach 2 is located just upstream of the town of Twisp (Figure 17). The reach is low gradient (0.6%) and flows through a moderately confined valley. The reach lies within a more confined valley than adjacent reaches. Land use is rural residential and agriculture. A portion of the floodplain on the south side of the river consists of a series of former gravel ponds that are currently utilized as a salmon acclimation and release facility. There is a levee on the river-right bank and riprap on the river-left bank below the Twisp River Road bridge (Figure 16) that disconnect much of the upstream portion of the reach from the floodplain. Small sections of riprap and push-up levees are located in the downstream portion of the reach but these have a relatively minor effect on channel processes and floodplain connection.

Figure 16. Looking upstream at the Twisp River Road bridge (October 2009). The stream gage is visible on the right.

Figure 17. Reach 2 locator and habitat unit composition map.

A-2.2 Channel Morphology

Reach 2 is a low gradient (0.6%) pool-riffle channel. The reach flows through a moderately confined valley. The channel and floodplain are artificially confined by the Twisp River bridge at the upstream end of the reach. A long right-bank levee and left-bank riprap just downstream of the bridge also disconnect channel and floodplain processes. The downstream portion of the reach (RM 0.7 – 1.4) is impacted by short sections of riprap and push-up levees, but in general is better connected to channel and floodplain processes than the upstream 0.4 miles.

A-2.3 Habitat Unit Composition

Reach 2 consists of 47% pools, 36% riffles, 6% glides, and 11% side-channels (Figure 18 and Figure 19). Pool frequency is 15.2 pools/mile or 1 pool every 3 bankfull widths. Average residual pool depth is 2.0 feet. Average maximum pool depth is 2.8 feet.

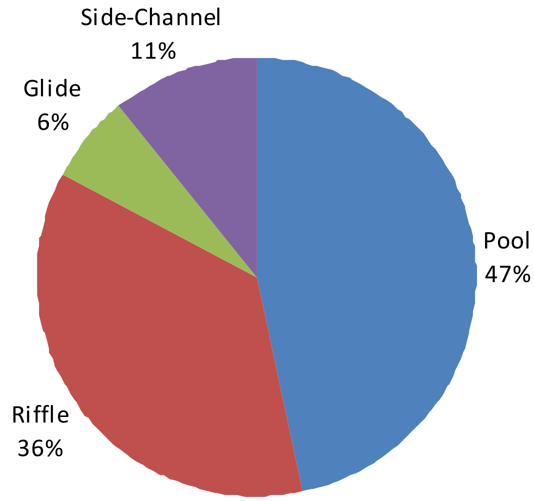


Figure 18. Habitat unit composition for Reach 2.

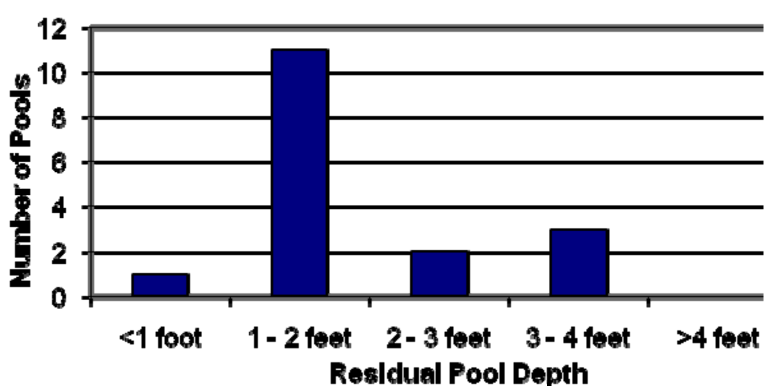


Figure 19. Reach 2 residual pool depths.

A-2.4 Off-Channel Habitat

There are five side-channels in Reach 2. One of the side-channels is a diversion ditch controlled with a headgate at RM 1.3 (Figure 20). This headgate is currently closed and abandoned. In addition to the five side-channels, there is a diversion at RM 1.5 that waters the Methow Salmon Recovery Foundation and Yakama Tribe's coho acclimation ponds located to the south of the main channel. The diversion is a large concrete headgate with a hand-built rock dam used to help divert water (Figure 21). The acclimation ponds are former gravel pits that have been connected to allow for juvenile fish passage through the ponds and out into the mainstem Twisp River. Flow from the ponds enters a side channel at RM 1.0.

Figure 20. Headgate on river-left at RM 1.3 (October 2009).

Figure 21. Diversion near RM 1.5 on river-right that sources acclimation ponds (October 2009).

A-2.5 Large Woody Debris

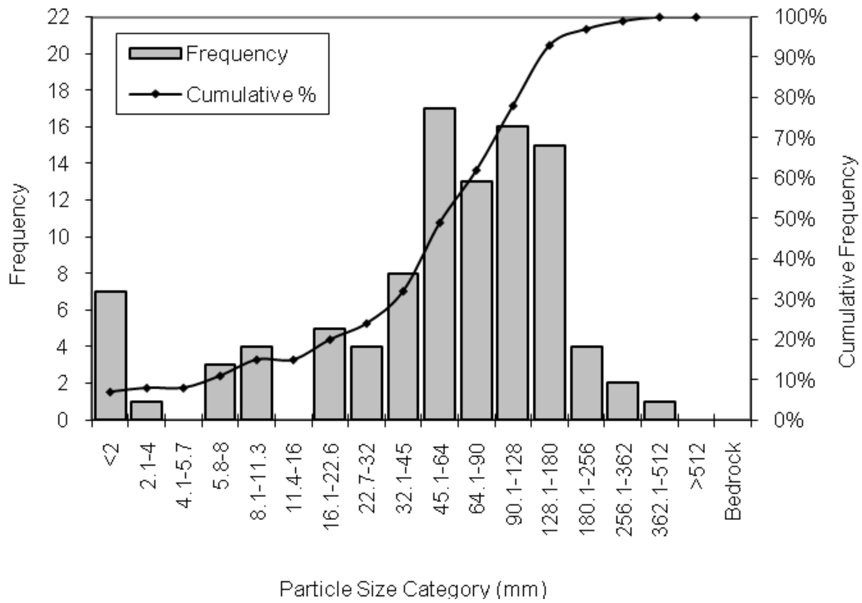
LWD plays an important role in Reach 2, including sediment sorting, habitat cover, and channel complexity. Wood is an important component of pool formation. Large wood frequency is 116 pieces/mile, with "small" pieces comprising 74% of all large wood counted in the reach. "Large" wood pieces only accounted for 5% of all large wood counted in the reach.

Table 2. Large woody debris quantities in Reach 2.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in by 35 ft)	Total
Number of Pieces	96	27	7	130
Number of Pieces/Mile	86	24	6	116

A-2.6 Substrate and Fine Sediment

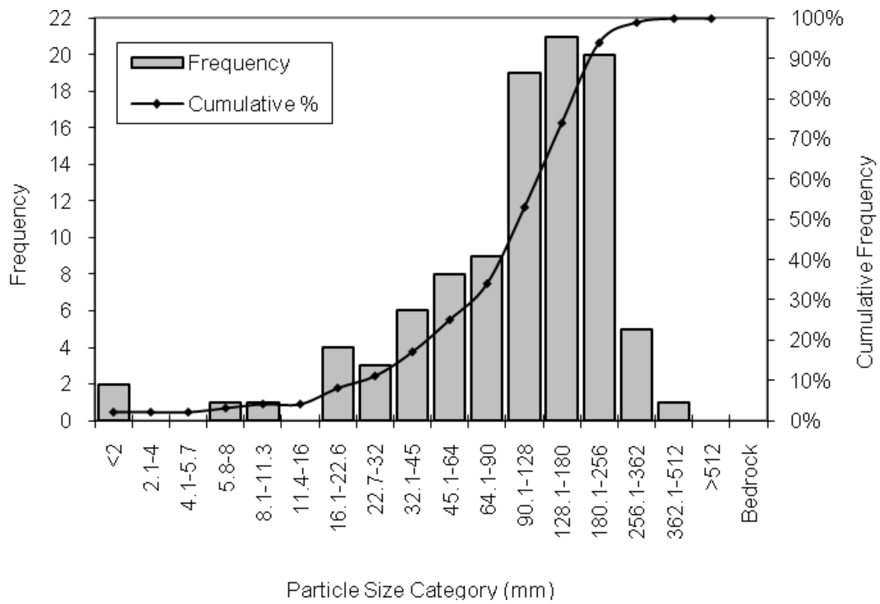
Bed substrate is dominated by gravels and cobbles. Bedrock and boulders are uncommon, although bedrock pools are located near RM 1.4 (Figure 25) and the side-channel at RM 1.7. Sand makes up less than 10% of the distribution. The pebble count and size class data are depicted in Figure 22, Figure 23, and Figure 24.



Material	Percent Composition
Sand	7%
Gravel	42%
Cobble	48%
Boulder	3%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	2
D16	17
D50	66
D84	149
D95	218

Figure 22. Grain size distribution and particle size classes from pebble count taken at RM 0.9.



Material	Percent Composition
Sand	2%
Gravel	23%
Cobble	69%
Boulder	6%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	18
D16	36
D50	122
D84	218
D95	277

Figure 23. Grain size distribution and particle size classes from pebble count taken at RM 1.7.

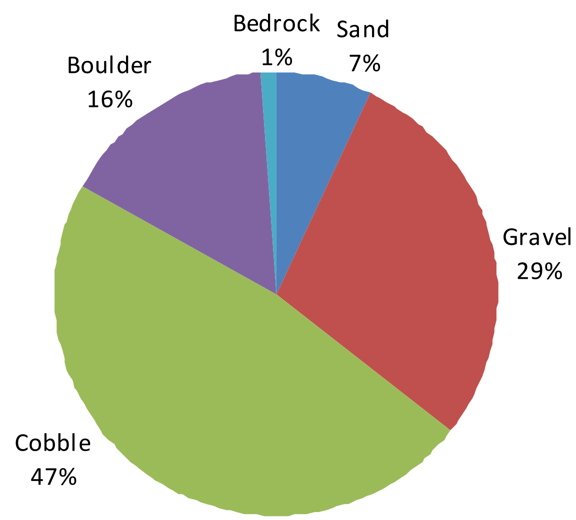


Figure 24. Percent composition of bed substrate based on ocular estimates, Reach 2.

Figure 25. View looking downstream at bedrock pool and boulder vein at RM 1.37 (March 2010).

A-2.7 Instability and Disturbance

Human activities have modified the channel, floodplain, and associated riparian corridor within the reach. The Twisp River bridge constrains channel processes at the upstream end of the reach. A levee extends along the river-right bank below the bridge for 2,000 feet and riprap extends along river-left for 700 feet (Figure 26). A boulder vein extends out from the river-right bank near RM 1.37 (see Figure 25). A right-bank levee affects side-channel connectivity near RM 1.0. There are other short sections of riprap and push-up levees that affect channel and floodplain processes throughout the reach.

There is active bank erosion in several locations. In some areas, erosion is associated with a lack of a mature streambank vegetation. This is particularly evident on both banks between RM 1.1 and 1.3 (Figure 27).

Washington Department of Fish and Wildlife maintains a smolt trap at RM 1.25. PIT tag antennae are located just downstream of the trap. The coho acclimation ponds are located in the right bank floodplain from RM 1.1 to 1.3. The outlets from these ponds are located near RM 1.0; an observation deck and trails are also located in this area.

Habitat enhancement activities in the reach include constructed log jams along the river-right bank at RM 0.95 and 1.05 and enhancement/construction of a series of bar apex log jams near RM 1.1 (Figure 28).

Figure 26. View looking upstream near RM 1.75 at riprap on river-left bank (March 2010).

Figure 27, View looking downstream at eroding river-left bank and cleared riparian zone near RM 1.15 (March 2010).

Figure 28. Constructed/enhanced bar apex log jam at RM 1.1 (March 2010).

A-2.8 Available Spawning and Rearing Habitat

There is a moderate amount of spawning and rearing habitat available in Reach 2. The dominant substrate in the riffles is cobble (53%) and sub-dominant is gravel (24%). Although steelhead and spring Chinook spawning occurs in this reach, many of the pool tail-out areas consist of large cobbles (> 128 mm) that are larger than the ideal size for Chinook (i.e. 13 – 102 mm) and steelhead (6 – 102 mm) spawning (Bjornn and Reiser 1991). However, the coarse bed provides areas of localized velocity refuge that may be utilized for rearing by juvenile steelhead and resident trout. Pool quantity within the reach is high although the pools generally have shallow residual depths. There are only three pools (6% of reach total) with residual depths greater than 3 feet. LWD is abundant and there are a number of off-channel rearing areas available.

A-2.9 Fish Passage Barriers

There are no fish passage barriers in Reach 2. Mean riffle thalweg depth is 0.8-ft, which meets the minimum threshold depth for passage of spring Chinook (Thompson 1972) and exceeds the threshold for bull trout passage. Adequate flow depths in riffles during summer low flow could be a potential constraint on passage of in-migrating spring Chinook under some conditions.

A-2.10 Riparian Corridor

The presence and width of a forested riparian buffer varies along the reach. Past land clearing for agriculture results in an absence of a forested riparian zone on portions of both sides of the stream between RM 1.1 and 1.3. The remainder of the reach generally has a forested riparian area although riprap and levees affect streambank vegetation in several areas. The stream receives minimal shading from riparian vegetation due to a lack of large trees in the riparian zone and past clearing. Topographic shading may be provided in some locations by the south valley wall.

In the riparian inner zone (near-channel), small trees were the dominant size class (86%) in all measured units (Figure 29), and all of the units were dominated by hardwoods. In the riparian outer zone, 71% of the units were dominated by small trees (Figure 30) and all units were dominated by hardwoods. The most abundant hardwoods in the reach include dogwood, cottonwood, birch, aspen, and chokecherry. There is a greater diversity of riparian vegetation near the downstream end of the reach (Figure 31).

Near-term LWD recruitment potential is low due to a lack of large, mature trees in the riparian area and due to anthropogenic constraints on lateral channel dynamics (e.g. bridge, levees, and riprap). Beaver activity was observed during the survey at several locations.

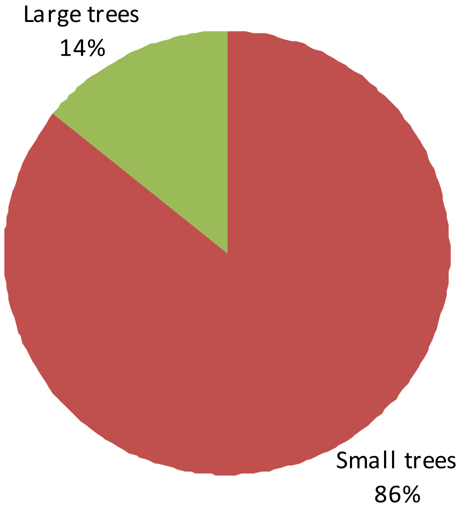


Figure 29. Distribution of the dominant size class category for the riparian inner zones, Reach 2.

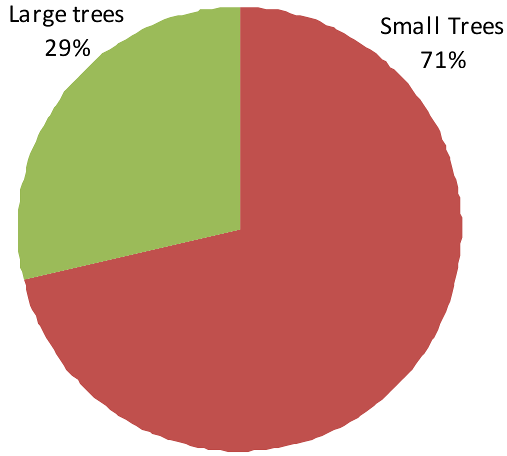


Figure 30. Distribution of the dominant size class category for the riparian outer zones, Reach 2.

Figure 31. Diverse riparian vegetation near downstream end of Reach 2 (October 2009).

A-3 REACH 3 (same as Reach Assessment Reach 2b)

Location: River mile 1.9 to River mile 5.0

Survey Date: October 7 and 8, 2009

Survey Crew: Robin Jenkinson and Emily Plummer (Inter-Fluve)

A-3.1 Reach Overview

Reach 3 extends 3.1 miles upstream from RM 1.9 to the Poorman Creek Cut-off Road Bridge (Figure 32). The reach flows through an unconfined alluvial valley. Levees and riprap banks occur periodically throughout the reach. There are several areas with floodplain wetlands although most have poor surface connection to the main channel. Seven small tributaries enter the channel along the reach including Poorman Creek at RM 4.7. There are also numerous side channels and several springs along the reach. Long, straight, and turbulent riffles are the dominant habitat type. Pools are less frequent in Reach 3 than the other reaches in the study area.

Land use in Reach 3 is predominantly rural residential and agriculture. There are several residences in the floodplain; some with lawns extending to the top of bank. Grazing and watering of livestock also occur in portions of the reach.

Figure 32. Reach 3 – Downstream Portion. Reach locator and habitat unit composition map.

Figure 33. Reach 3 – Upstream Portion. Reach locator and habitat unit composition map.

A-3.2 Channel Morphology

Reach 3 flows within an unconfined alluvial valley. Channel gradient is 1.0%.
The geomorphic low surface is bounded on both sides by glacial terraces. The reach alternates between pool-riffle and plane-bed morphology. Riffles are the dominant habitat unit type. There are many long, uniform riffles with few depositional features.

A-3.3 Habitat Unit Composition

Reach 3 consists of 25% pools, 60% riffles, 11% glides, and 4% side-channels (Figure 34 and Figure 35). Pool frequency is 8.9 pools/mile or 1 pool every 6 bankfull widths. Average residual pool depth is 2.2 feet. Average maximum pool depth is 3.1 feet.

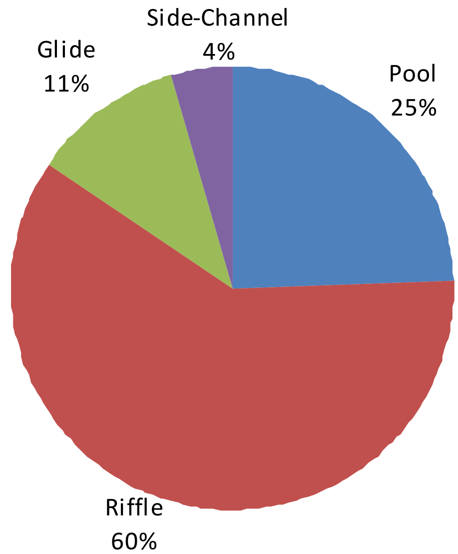


Figure 34. Habitat unit composition, Reach 3.

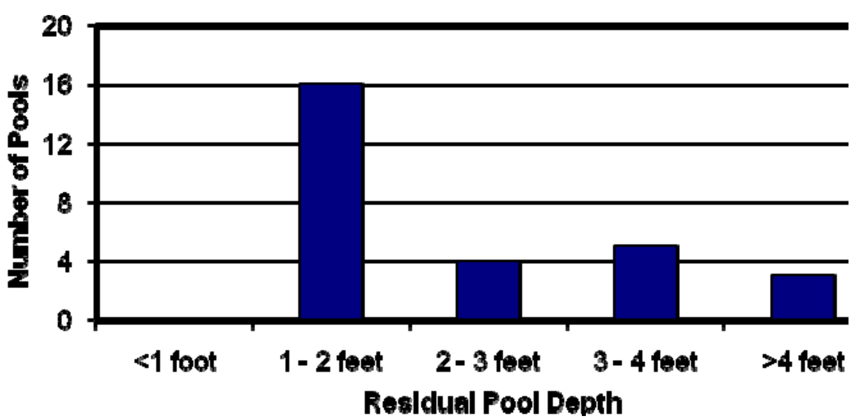


Figure 35. Reach 3 residual pool depths.

A-3.4 Off-Channel Habitat

Eight side channels were observed in Reach 3. One of the side-channels is a diversion ditch controlled with a headgate at RM 4.4 (Figure 36). Approximately half of the side channels were dry or partially dry at the time of the survey.

Figure 36. Irrigation diversion and headgate near RM 4.4 (October 2009).

A-3.5 Large Woody Debris

LWD counts were low for Reach 3 compared with the other reaches. Large wood frequency is 65 pieces/mile, with "small" pieces comprising 89% of all LWD counted in the reach. "Large" wood pieces only accounted for 3% of the LWD in the reach.

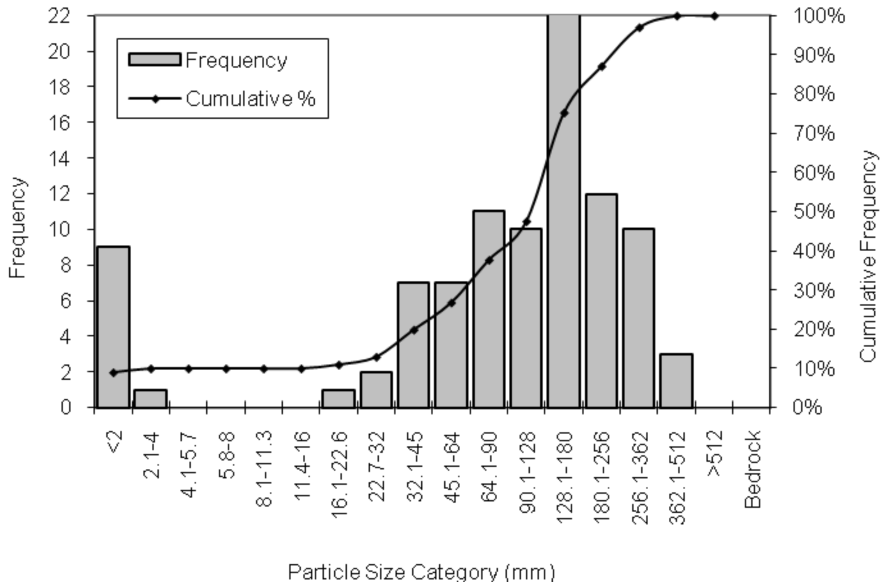
Beaver activity was observed at several locations along the reach and may contribute to LWD recruitment and channel complexity in some locations.

Table 3. Large woody debris quantities in Reach 3.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in by 35 ft)	Total
Number of Pieces	184	17	5	206
Number of Pieces/Mile	58	5	2	65

A-3.6 Substrate and Fine Sediment

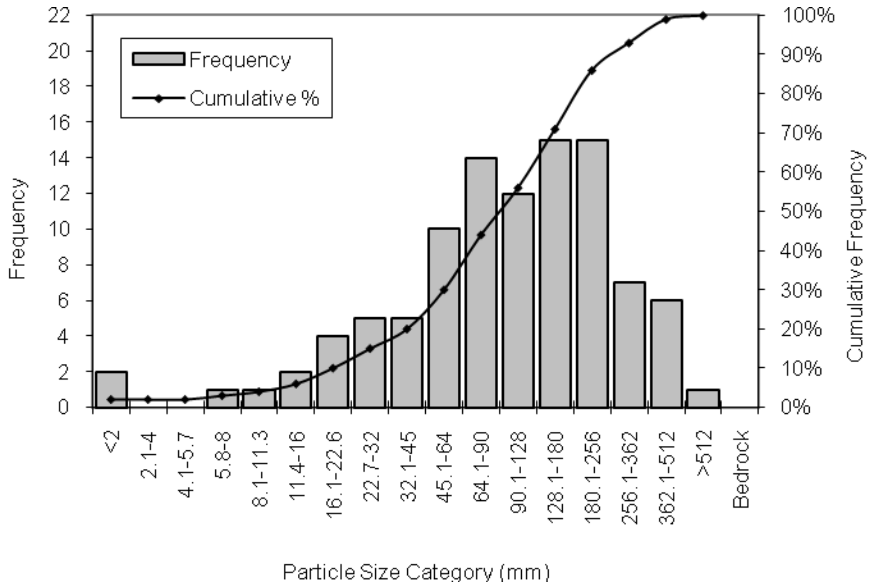
Bed substrate is dominated by cobbles, with gravels and boulders sub-dominant. Much of the low-flow channel bed consists of coarse material, with smaller gravels and cobbles in depositional areas. Bedrock is relatively uncommon and was only observed at a few locations along the reach. Sand makes up less than 10% of the grain-size distribution based on pebble count data. The pebble count and size class data are depicted in Figure 37, Figure 38, and Figure 39.



Material	Percent Composition
Sand	9%
Gravel	18%
Cobble	60%
Boulder	13%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	2
D16	38
D50	133
D84	236
D95	260

Figure 37. Grain size distribution and particle size classes from pebble count taken at RM 2.6.



Material	Percent Composition
Sand	2%
Gravel	28%
Cobble	56%
Boulder	14%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	14
D16	35
D50	109
D84	246
D95	412

Figure 38. Grain size distribution and particle size classes from pebble count taken at RM 4.6.

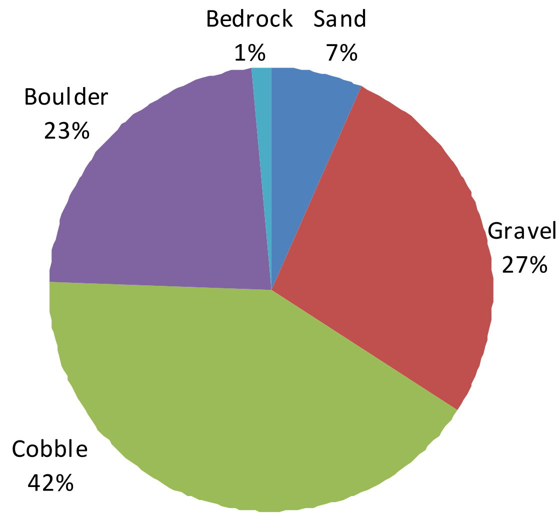


Figure 39. Percent composition of bed substrate based on ocular estimates, Reach 3.

A-3.7 Instability and Disturbance

Levees, riprap, and boulder weirs are used to stabilize banks and control flooding in several locations. Long sections of riprap (>1,000 ft) are located along both banks near RM 2.6. Smaller sections of riprap and levees are located intermittently between RM 4.0 and 4.5. There is 600 feet of riprap along the river-right bank just upstream of the bridge at RM 1.9 where Poorman Creek Road abuts the channel. An old concrete abutment is located just upstream of the Twisp River Road bridge at RM 1.9 (Figure 40).

Culverts discharge into the channel at RM 1.95, RM 2.3, and RM 3.8. The culvert at RM 1.95 discharges flow from the series of abandoned gravel pits (aka "chain of lakes") located along the southern floodplain terrace. This culvert is mostly plugged and was not flowing during surveys in March 2010 (Figure 41). Neither of the other culverts were flowing at the time of the October 2009 survey. Two irrigation pumps are located at RM 2.7, one on the right bank and one on the left bank. Both pumps are screened.

Active bank erosion was also evident in several locations. Bank erosion was associated with clearing of riparian vegetation at several locations between RM 3.2 and 3.5 (Figure 42). There is also considerable erosion of the high glacial terrace near RM 4.6.

There are numerous residences within the floodplain; some with lawns extending to the top of bank and recreational access to the river. Grazing and watering of livestock is also evident along sections of the reach (Figure 43).

Figure 40. Old concrete footing/abutment near RM 1.9 (October 2009).

Figure 41. Culvert (mostly plugged) draining floodplain ponds at RM 1.95 (river-right bank) (March 2010).

Figure 42. Erosion on river-left (north) bank near RM 3.2 (October 2009).

Figure 43. Livestock access to the stream near RM 4.9 (October 2009).

A-3.8 Available Spawning and Rearing Habitat

There is limited spawning and rearing habitat available in Reach 3. The dominant substrate in the riffles is cobble (58%) and sub-dominant is gravel (23%) and boulders (13%). Although the coarse bed is not ideal for spawning, redds were observed during the survey near RM 4.2.

The coarse bed provides areas of localized velocity refuge that may be utilized for rearing by juvenile steelhead and resident trout. Pool quantity within the reach is low and the majority of pools (57%) have a residual depth of less than 2 feet. There are eight pools (28% of the reach total) with residual depths greater than 3 feet. LWD frequency is low.

A-3.9 Fish Passage Barriers

There are no fish passage barriers in Reach 2. Mean riffle thalweg depth is 0.7 feet. The minimum threshold depth for passage by spring Chinook is 0.8 feet (Thompson 1972). Shallow depths during summer low flow could be a potential constraint on passage under some conditions for in-migrating spring Chinook.

A-3.10 Riparian Corridor

The native riparian forest has been affected by roadways, residential uses, bank armoring, and agriculture. In some areas, the vegetated riparian buffer is narrow due to the proximity of the valley wall. Poorman Creek Road, residential uses, and grazing have reduced the width of the riparian corridor in several locations.

In the riparian inner zone, small trees were the dominant size class (73%) in all measured units; large trees made up the remainder (Figure 44). All inner zones were dominated by hardwoods, mostly cottonwoods with smaller amounts of willow, birch, and alder. There is a mature grove of quaking aspens at RM 3.9. In the riparian outer zone, large trees were dominant in 53% of the units and small trees were dominant in 47% (); 60% of units were dominated by hardwoods and 40% were dominated by conifers. Hardwoods in the riparian outer zones were mostly willow, cottonwood, birch, alder, and aspen. Conifers within the reach included ponderosa pine and Douglas fir.

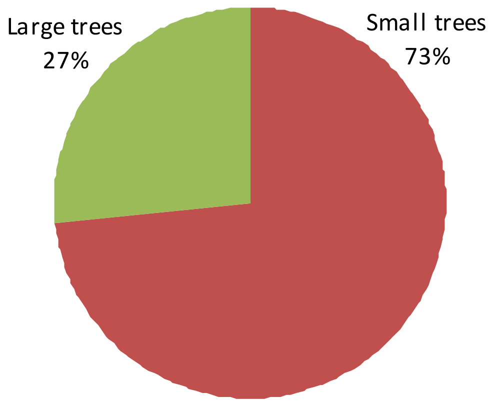


Figure 44. Distribution of the dominant size class category for the riparian inner zones, Reach 3.

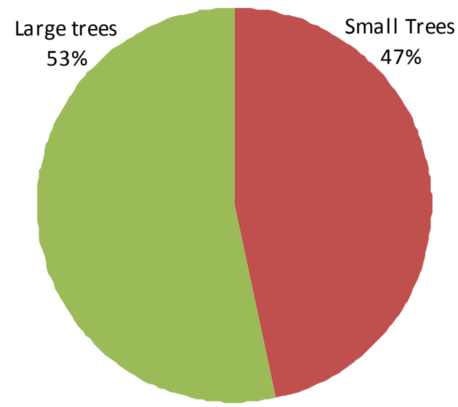


Figure 45. Distribution of the dominant size class category for the riparian outer zones, Reach 3.

A-4 REACH 4 (same as Reach Assessment Reach 3a)

Location: River mile 5.0 to River mile 5.6

Survey Date: October 8, 2009

Survey Crew: Robin Jenkinson and Emily Plummer (Inter-Fluve)

A-4.1 Reach Overview

Reach 4 extends 0.6 miles from Poorman Creek Cut-off Road Bridge upstream to the end of the bedrock gorge (Figure 46). Land use is rural residential and agriculture, although much of the reach has a forested riparian buffer. Most of the homes are located well above the floodplain. A swimming area, trail, and picnic table are located near RM 5.2.

Figure 46. View looking upstream near RM 5.1. Typical bedform with coarse substrate and bedrock outcrops (October 2009).

A-4.2 Channel Morphology

Reach 4 is a transport reach that flows through a deeply entrenched gorge bounded by high glacial terraces and bedrock outcrops. The gradient is low to moderate (1.7%). The valley width and floodprone width are both approximately 150 feet. The reach is pool-riffle, with long, plane-bed riffles and several deep bedrock-formed pools. Hillslope seeps enter the river along the river-left bank near RM 5.2. There is a tributary (waterfall) that enters the river on the river-left bank at RM 5.4.

A-4.3 Habitat Unit Composition

Reach 4 consists of 29% pools, 69% riffles, 2% glides, and 0% side channels (Figure 47 and Figure 48). Pool frequency is 23.7 pools/mile or 1 pool every 3 bankfull widths. Average residual pool depth is 2.8 feet. Average maximum pool depth is 3.6 feet. Most of the pools in the reach are formed by bedrock constrictions at the beds in the river (Figure 49). Most of the riffles form long and uniform plane-bed segments (Figure 50).

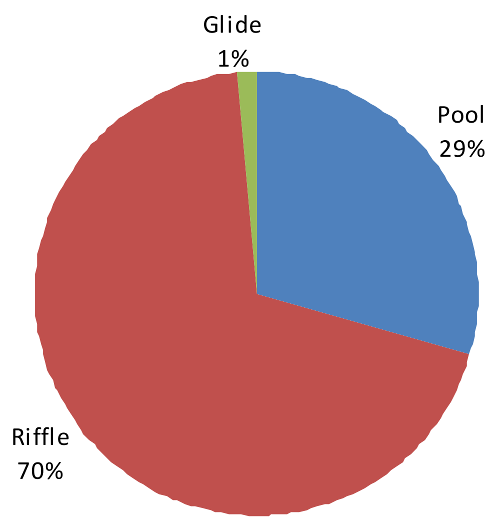


Figure 47. Habitat unit composition, Reach 4.

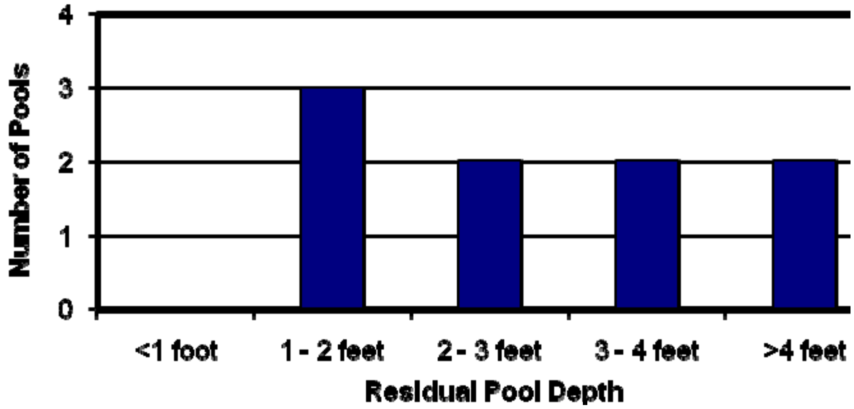


Figure 48. Reach 4 residual pool depths.

Figure 49. Deep bedrock-formed pool near RM 5.4 (October 2009).

Figure 50. Typical high gradient riffle near RM 5.3 (October 2009).

A-4.4 Off-Channel Habitat

There are no active low-flow side channels in Reach 4. A high-flow side-channel is located on the river-right between RM 5.4 and 5.6. The side channel had moist pools at the time of the survey and abundant LWD.

A-4.5 Large Woody Debris

LWD frequency is low in Reach 4. LWD frequency is 95 pieces/mile, with "small" pieces comprising 81% of all LWD counted in the reach. "Large" wood pieces only accounted for 8% of the LWD in the reach (Table 4). Wood is likely readily transported through this reach during floods.

Logs are anchored into the right bank with metal rods between RM 5.0 and RM 5.1. One of the logs is anchored in near the Poorman Creek Cut-off Road Bridge. Two additional logs are anchored with cable at RM 5.1, one to the right-bank and one to the left-bank.

Mature riparian timber, the prevalence of large confers in the riparian zone, and steep hillslope topography provides stream shade and LWD recruitment potential. A burned area on the river-left bank near RM 5.2 has the potential to contribute LWD to the channel in the short-term (Figure 51).

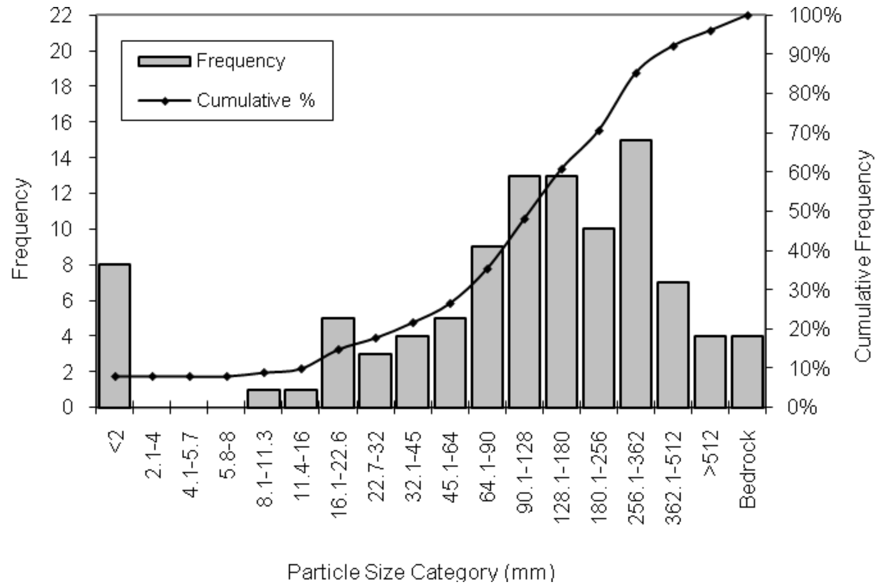
Table 4. Large woody debris quantities in Reach 4.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in by 35 ft)	Total
Number of Pieces	29	4	3	36
Number of Pieces/Mile	76	11	8	95

Figure 51. Burned area near RM 5.2 has the potential to provide short-term LWD recruitment (October 2009).

A-4.6 Substrate and Fine Sediment

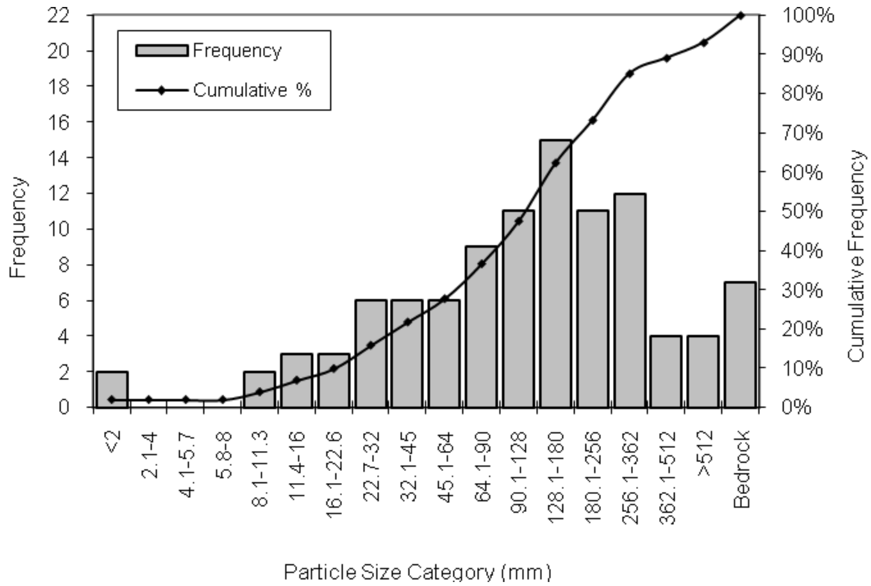
Large cobbles and small boulders are the dominant substrate type throughout the reach. Bedrock is prevalent along the channel margins and in portions of the channel itself, but bedrock consists 10% or less of the total bed composition. Bank erosion at the burned area is a potential source of substrate in the reach (Figure 51). The pebble count data and the results of the ocular substrate measures are depicted in Figure 52, Figure 53, and Figure 54.



Material	Percent Composition
Sand	8%
Gravel	19%
Cobble	44%
Boulder	25%
Bedrock	4%

Size Class	Size percent finer than (mm)
D5	2
D16	27
D50	136
D84	353
D95	883

Figure 52. Grain size distribution and particle size classes from pebble count taken near RM 5.25.



Material	Percent Composition
Sand	2%
Gravel	26%
Cobble	46%
Boulder	20%
Bedrock	7%

Size Class	Size percent finer than (mm)
D5	13
D16	32
D50	137
D84	352
D95	1024

Figure 53. Grain size distribution and particle size classes from pebble count taken at RM 5.38.

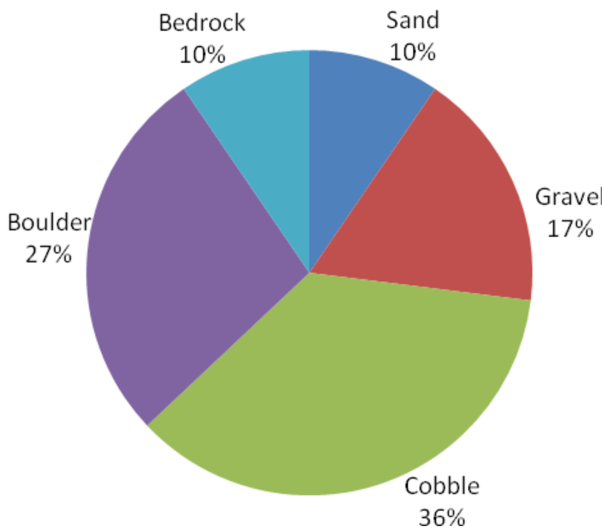


Figure 54. Percent composition of bed substrate based on ocular estimates, Reach 4.

A-4.7 Instability and Disturbance

There are approximately 20 feet of riprap on both banks upstream of the Poorman Cut-off Road Bridge. There are no other significant alterations to channel or floodplain processes in the reach. Human activities mainly consist of recreation access. There is a swimming area, trail, and picnic table on the river-right bank at RM 5.2. Most of the homes are located well above the floodplain.

A-4.8 Available Spawning and Rearing Habitat

There is good spawning and rearing habitat in Reach 4. Although substrate is generally coarse (cobbles and boulders), a few of the long tail-outs at the bedrock-formed pools provide high quality potential for spring Chinook and steelhead spawning. The deep pools also provide good adult holding and juvenile rearing habitat for multiple salmonid species.

The dominant substrate in the riffles is cobble (45%) and sub-dominant is boulders (23%) and gravels (22%). Pool quantity within the reach is much higher in Reach 4 than any of the other reaches, with 23.7 pools per mile compared with 8.9 to 25.7 pools per mile in the other reaches. Twenty-two percent of the pools have a residual depth of less than 2 feet. Forty-four percent have residual depths greater than 3 feet. LWD frequency is moderate compared to the other reaches. Pools provide most of the protection and cover within the reach.

A-4.9 Fish Passage Barriers

There are no fish passage barriers in Reach 4. Mean riffle thalweg depth is 0.8 feet, which is the minimum threshold depth for passage of spring Chinook (Thompson 1972). Flow depths in some years may present passage limitations for Chinook.

A-4.10 Riparian Corridor

The riparian area is generally in good condition due to the steep slopes and limited access to streambanks (Figure 56). A recent burned area was located within the riparian zone and adjacent hillslope near RM 5.2 (Figure 51).

In the riparian inner zone, small trees were the dominant size class (100%) in all measured units, and all units were dominated by hardwoods, mostly cottonwoods, alder, and dogwood. In the riparian outer zone, large trees were dominant in the majority of units (83%), followed by small trees (17%) (Figure 55). All of the measured outer zones were dominated by conifers, primarily ponderosa pine.

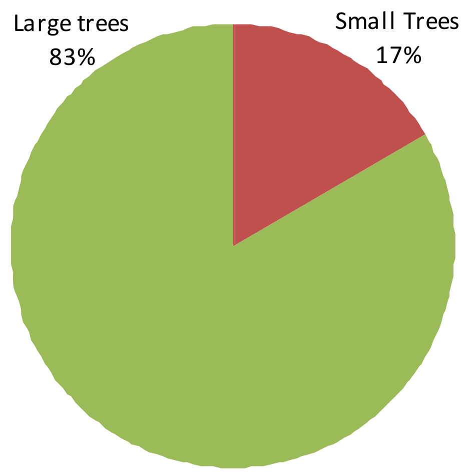


Figure 55. Distribution of the dominant size class category for the riparian outer zones, Reach 4.

Figure 56. Mature conifers in the riparian area near RM 5.1 (October 2009).

A-5 REACH 5 (same as Reach Assessment Reach 3b and 3c)

Location: River mile 5.6 to River mile 7.8

Survey Date: October 8-10, 2009

Survey Crew: Robin Jenkinson and Emily Plummer (Inter-Fluve)

* A staff gage is located at RM 6.6. The gage read 0.8 feet at the time of the survey.

A-5.1 Reach Overview

Reach 5 extends from the bedrock gorge upstream 2.1 miles to Newby Creek (Figure 57 and Figure 58). The reach is low gradient and flows through a wide, moderately confined valley. Development of the floodplain is primarily agricultural and rural residential and includes land clearing, irrigation diversions, and levees to protect against erosion and flooding. The Twisp River Road parallels the reach to the north. There are screened irrigation diversions at two locations: (1) near RM 7.4 on the north bank (Twisp River Power and Irrigation Ditch) and (2) near RM 6.4 on the south bank. There is also a fish weir that is operated seasonally at RM 7.25.

Figure 57. Reach 5 – Downstream Portion. Reach locator and habitat unit composition map.

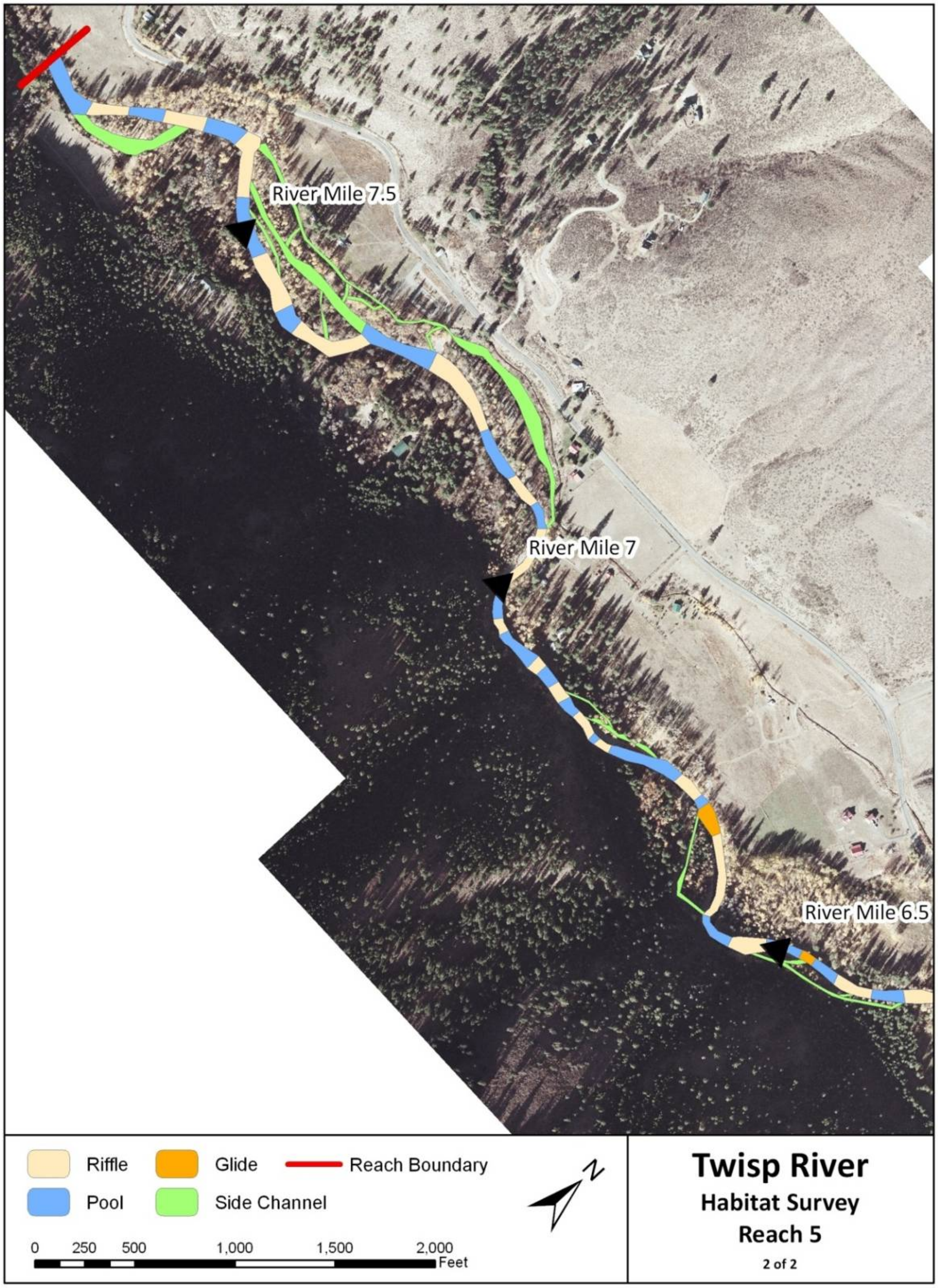


Figure 58. Reach 5 – Upstream Portion. Reach locator and habitat unit composition map.

A-5.2 Channel Morphology

Reach 5 is low gradient (1.3%) and flows through a wide, moderately confined valley. The reach is mostly pool-riffle with several multiple-thread sections with side-channels. Several long plane-bed sections are located within the reach (Figure 60). The reach is bounded by glacial terraces and tributary alluvial fan deposits. There is generally good connectivity with floodplains with the exception of several locations where levees, bank armoring, bridges, and/or floodplain fill have artificially confined channels and have limited floodplain connections.

Figure 59. View looking upstream at a long plane-bed section near RM 6.3 (October 2009).

A-5.3 Habitat Unit Composition

Reach 5 consists of 34% pools, 46% riffles, 7% glides, and 13% side-channels (Figure 60 and Figure 61). Pool frequency is 10.5 pools/mile or 1 pool every 4 bankfull widths. Average residual pool depth is 1.9 feet. Average maximum pool depth is 2.7 feet.

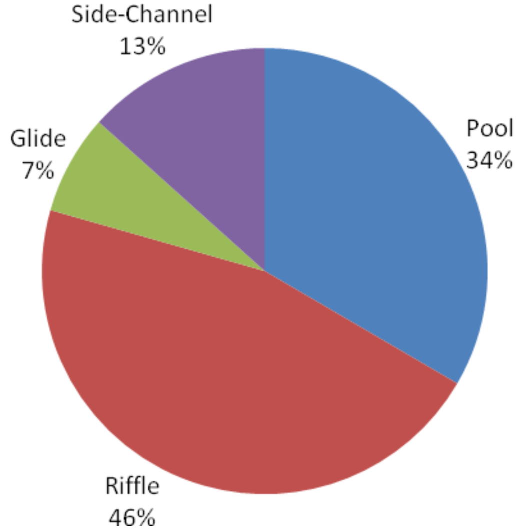


Figure 60. Habitat unit composition, Reach 5.

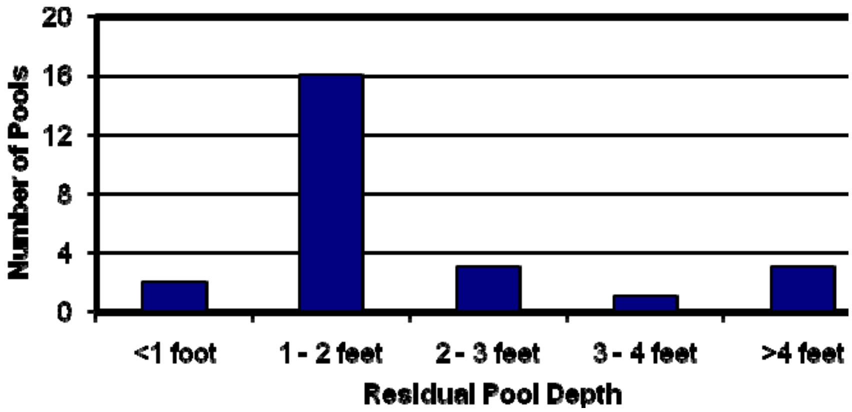


Figure 61. Reach 5 residual pool depths.

A-5.4 Off-Channel Habitat

Reach 5 has the greatest amount of side-channel habitat of all the reaches in the study area. Fifteen side channels were observed in Reach 5, which accounts for 13% of the habitat area in the reach. Several of these side-channels were only partially flowing at the time of the survey. Two of the side channels (RM 6.5 and 7.6) are irrigation diversions with return flow to the river. Several of the side-channels are not active at summer low-flow periods. There are floodplain wetlands to the north of the main channel near RM 6.3 that have limited or no connectivity to the main channel during low flow periods.

A-5.5 Large Woody Debris

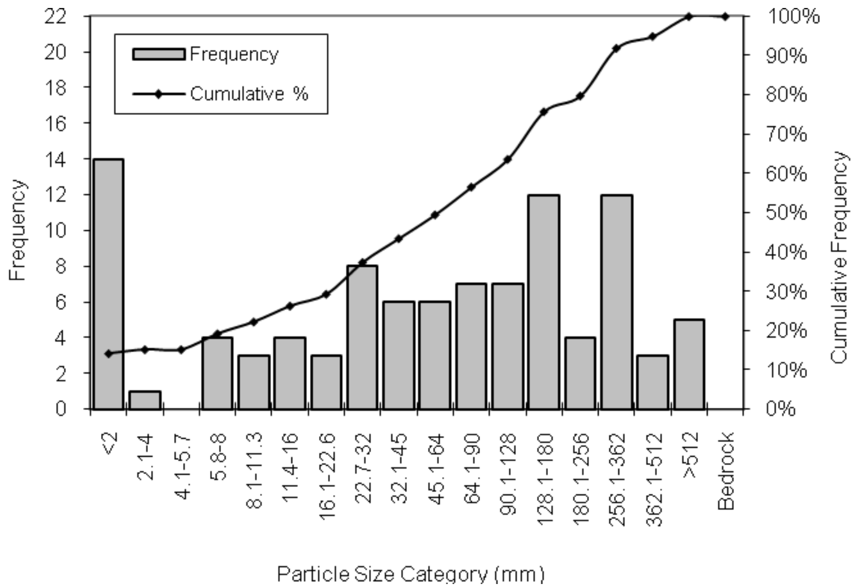
LWD quantities are high for Reach 5 compared to other reaches in the study area. LWD frequency is 165 pieces/mile, with "small" pieces comprising 79% of all LWD counted in the reach (Table 5). "Large" wood pieces are relatively scarce and only account for 2% of the LWD in the reach.

Table 5. Large woody debris quantities in Reach 5.

	Small (6 in x 20 ft)	Medium (12 in x 35 ft)	Large (20 in by 35 ft)	Total
Number of Pieces	309	76	6	391
Number of Pieces/Mile	130	32	3	165

A-5.6 Substrate and Fine Sediment

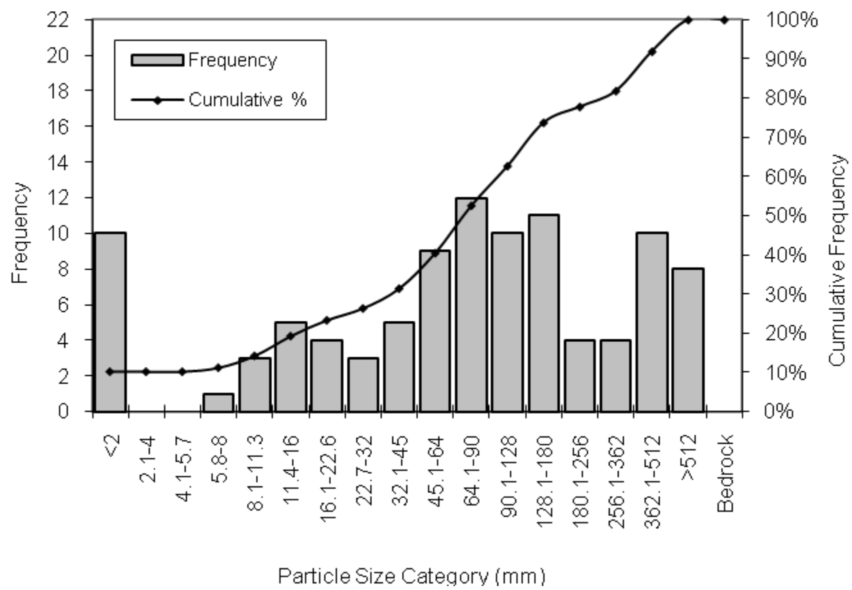
Bed substrate is dominated by gravels and cobbles, with boulders sub-dominant. Bedrock is relatively uncommon although bedrock outcrops were observed at a few locations along the reach. Sand, which is more common in Reach 5 than in other reaches, comprises up to 15% of the distribution. The pebble count and size class data are depicted in Figure 62, Figure 63, and Figure 64.



Material	Percent Composition
Sand	14%
Gravel	35%
Cobble	30%
Boulder	20%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	2
D16	6
D50	66
D84	991
D95	512

Figure 62. Grain size distribution and particle size classes from pebble count taken at RM 5.6.



Material	Percent Composition
Sand	10%
Gravel	30%
Cobble	37%
Boulder	22%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	2
D16	26
D50	85
D84	394
D95	707

Figure 63. Grain size distribution and particle size classes from pebble count taken at RM 7.65.

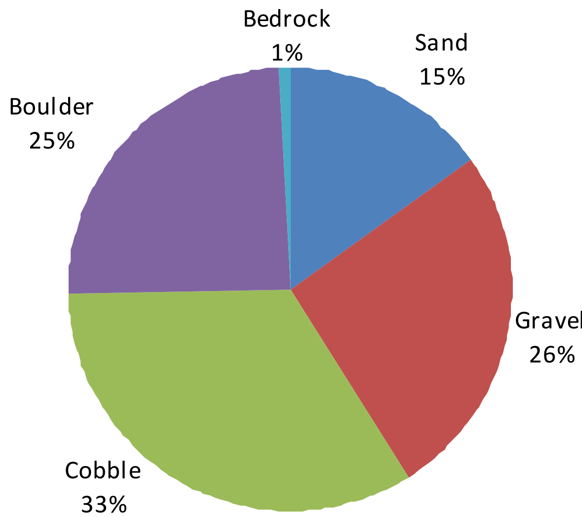


Figure 64. Percent composition of bed substrate based on ocular estimates, Reach 5.

A-5.7 Instability and Disturbance

Human activities have modified the channel, floodplain, and associated riparian corridor within the reach. The primary elements of disturbance to the channel include riprap, levees, road embankments, and irrigation diversions. The two areas of greatest impact are where the Twisp River Road abuts the channel for approximately 1,600 feet near RM 6.1 and near RM 7.2 where a private bridge, fish weir, levee, and diversion canal constrain channel processes. Other shorter sections of levee and riprap are located throughout the reach. Two private bridges cross the river, one at RM 6.1 and another at RM 7.15.

Land use is rural residential and agriculture. There are several private residences located within the floodplain or on adjacent terraces (Figure 65); many of these areas have streambanks protected with riprap. There is cleared pasture land at several locations, including a long section along the south bank from RM 5.8 to 6.3, where there is only a narrow forested riparian buffer (less than 50 feet in most locations) (Figure 66).

Active bank erosion is evident along the reach, often associated with land clearing for agriculture, residential uses, or roadways. Active erosion of the glacial terrace also occurs in several places, including at RM 6.9 and RM 6.55 (Figure 67).

Figure 65. House adjacent to main channel near RM 6.75 (October 2009).

Figure 66. View looking upstream at the narrow forested buffer separating the main channel from pasture land near RM 5.9 (October 2009).

Figure 67. Exposure of bedrock and erosion of glacial material near RM 6.55 (October 2009).

A-5.8 Available Spawning and Rearing Habitat

There is moderate spawning and rearing habitat available in Reach 5. The dominant substrates are cobbles and gravels; boulders are sub-dominant. Although steelhead and spring Chinook spawning occurs in this reach, many of the riffle and pool tail-out areas consist of large cobbles (> 128 mm) that are larger than the ideal size for Chinook (i.e. 13 – 102 mm) and steelhead (6 – 102 mm) spawning (Bjornn and Reiser 1991). However, the coarse bed provides areas of localized velocity refuge that may be utilized for rearing by juvenile steelhead and resident trout.

Pool quantity within the reach is low and the majority of pools (72%) have a residual depth of less than 2 feet. There are three pools (12% of the reach total) with residual depths greater than 3 feet. LWD cover is relatively abundant along the reach.

A-5.9 Fish Passage Barriers

Fish passage is mostly unrestricted in Reach 5. Mean riffle thalweg depth is 0.8 feet, which meets the minimum threshold depth for passage of spring Chinook (Thompson 1972) and exceeds the threshold for bull trout passage. The absence of adequate flow depths in riffles during summer low flow could be a potential concern in very dry years.

The fish weir at RM 7.25 likely presents a passage barrier for upstream migration juveniles during low flows (Figure 68). A 2.5-ft tall concrete dam located just downstream of the irrigation diversion on a side-channel at RM 7.6 may limit fish passage, especially during summer low flow periods (Figure 69).

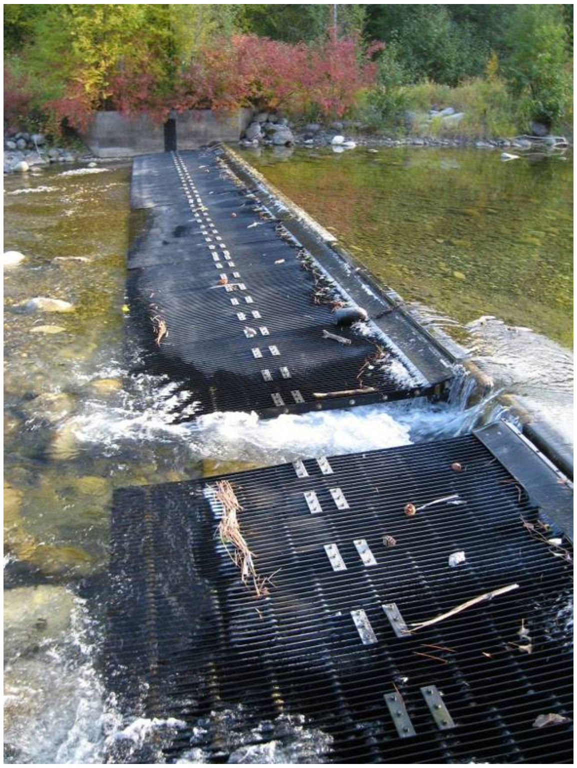


Figure 68. Adult fish weir at RM 7.25 (October 2009).

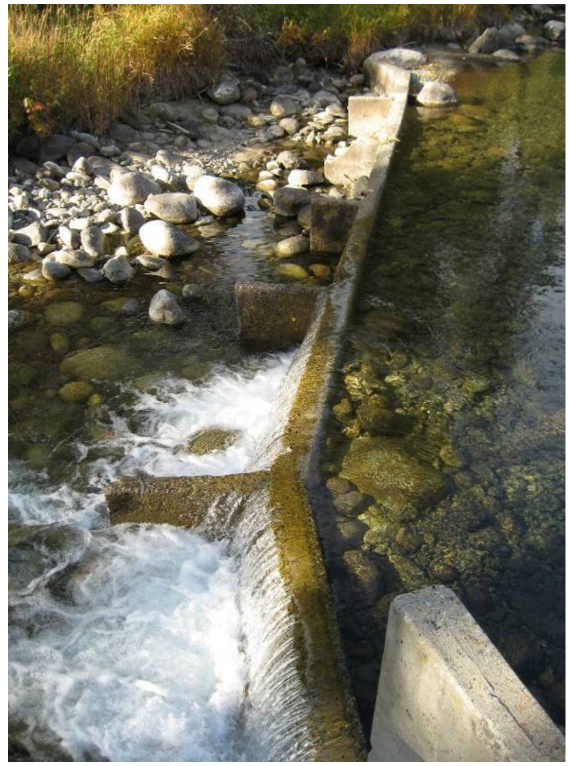


Figure 69. Concrete diversion weir at RM 7.6 used to divert flow into an irrigation canal (October 2009).

A-5.10 Riparian Corridor

The presence and width of a forested riparian buffer varies within the reach. Past land clearing for agriculture and the Twisp River Road embankment results in a narrow forested riparian buffer (less than 50 feet wide) on portions of the right and left banks between RM 5.8 and RM 6.2. There are other areas of localized clearing of riparian vegetation due primarily to residential uses.

Most of the riparian inner zones are dominated by small trees (56%) (Figure 70), and mostly consist of hardwoods (78% hardwood; 22% conifer). Cottonwoods, alder, and dogwood are the most prevalent inner zone species. The majority of riparian outer zones are dominated by large trees (56%), followed by small trees (33%) and grass/forbs (11%) (Figure 71). Conifers are the dominant tree in outer zones (22% hardwood; 67% conifer). Outer zones include ponderosa pine, cottonwoods, shrubs, and grasses (i.e. pasture and lawns).

The level of stream shade provided by the riparian canopy varies throughout the reach. Topographic shading is provided by the steep southern valley wall in the middle portion of the reach (RM 6.4 – 7.0).

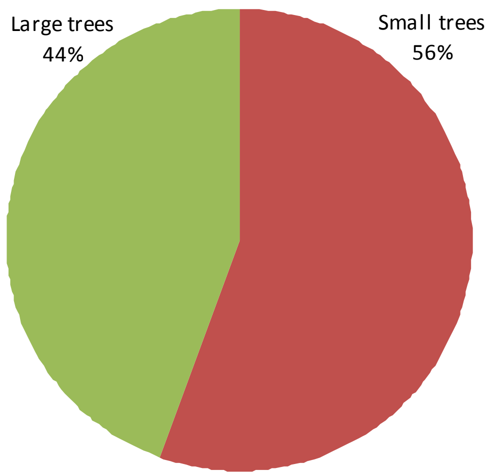


Figure 70. Distribution of the dominant size class category for the riparian inner zones, Reach 5.

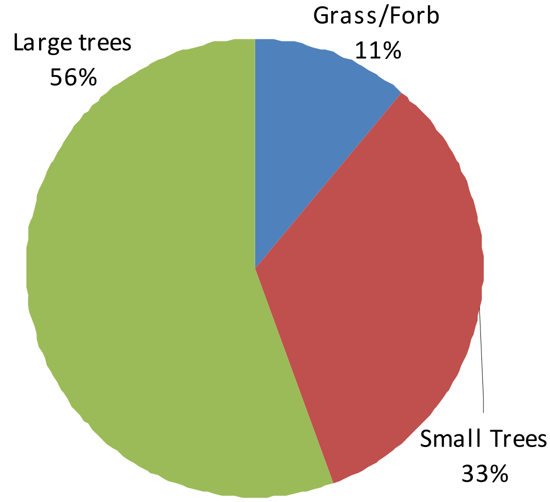


Figure 71. Distribution of the dominant size class category for the riparian outer zones, Reach 5.

Appendix B

Twisp River

REI Metrics

REACH-BASED ECOSYSTEM INDICATORS (REI) ASSESSMENT

REI metrics provide a consistent means of evaluating biological and physical conditions of a watershed in relation to regional standards and known habitat requirements for aquatic biota. These metrics, along with other scientific evaluations, describe the current quality of stream biophysical conditions and can help guide restoration priorities and alternatives. The REI evaluation for the Twisp River watershed was conducted using field data, observations, and applicable studies produced for the Twisp River, the Methow Basin, and other regional watersheds. The indicators used in this REI assessment were adapted from previous assessments conducted by the BOR for the White Pine Reach of Nason Creek (2009) and from the Preston Reach of the Entiat River (2009). The complete list of REI Metrics and threshold values used in this assessment are included in Table 1.

A total of four REI general indicators were assessed at the tributary scale (Table 2). One metric was found to be in an 'adequate condition': effective drainage network and watershed road density. This rating might change if more data were available. Two metrics were in an 'unacceptable condition': stream flow and water temperature. Low flow conditions in the Twisp River, mainly attributed to irrigation diversion, impair habitat conditions for migrating, spawning, and rearing anadromous fish (KWA 2004, PWI 2003). The disturbance regime metric was in an at risk condition.

A total of 11 REI general indictors were assessed at the reach scale (Table 3). In Reach T1, six of the 11 indicators were in an 'unacceptable risk' condition including some habitat quality, channel dynamics, and riparian vegetation characteristics. This reach is completely within the town of Twisp and has undergone extensive floodplain development and channel modification. Two categories, habitat access and substrate, were found in 'adequate condition'. In Reach T2a, four indicators were rated as 'unacceptable condition' with the most impaired characteristics being channel dynamics and riparian vegetation. LWD and channel substrate were in 'adequate condition'. In Reach T2b, five indicators were rated in an 'unacceptable risk' condition. These fell in the habitat quality, channel dynamics, and riparian vegetation categories. Substrate characteristics were in an 'adequate condition' and all other characteristics were 'at risk'. In Reach T3a, there were only two 'unacceptable risk' conditions given: LWD and canopy cover. This reach was given seven 'adequate condition' ratings, the most of any reach in the study area. This is mainly due to natural confinement that limits human impacts on habitat and channel dynamics. In Reach T3b, eight 'unacceptable risk' ratings were given. This is the most impaired reach in the study area. Every category has some characteristics that were in an unacceptable condition. Every category in the channel dynamics and riparian vegetation categories was found to be unacceptable. There were no characteristics that were in an 'adequate condition'. Reach T3c was the only reach where no 'unacceptable condition' ratings were given, however, most categories were 'at risk', with only two 'adequate condition' ratings. Without some protection or restoration, many of these characteristics could be in 'unacceptable condition' in the near future.

Table 1. REI Metrics used in the Twisp River Assessment including criteria for condition ratings.

General Characteristics	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Tributary Scale					
Watershed condition	Effective Drainage Network and Watershed Road Density	Increase in Drainage Network/Road Density	Zero or minimum increases in active channel length correlated with human caused disturbance. And road density <1 miles/miles^2	Low to moderate increase in active channel length correlated with human caused disturbances. And road density <1 miles/miles^2	Greater than moderate increase in active channel length correlated with human cuased distrubances. And road density >2.4 miles/miles^2
	Disturbance Regime	Natural/Human Caused	Environmental disturbance is short lived; predictable hydrograph, high quality habitat and watershed complexity providing refuge and rearing space for all life stages or multiple life-history forms. Natural processes are stable.	Scour events, debris torrents, or catastrophic fires are localized events that occur in several minor parts of the watershed. Resiliency of habitat to recover from environmental disturbance is moderate.	Frequent flood or drought producing highly variable and unpredictable flows, scour evnets, debris torrents, or high probability of catastrophic fire exists throughout a major portion of the watershed. The channel is simplified, providing little hydraulic complexity in the form of pools or side channels. Natural processes are unstable.
Flow/ Hydrology	Streamflow	Change in Peak/Base Flows	Magnitude, timing, duration, and frequency of peak flows within a watersed are not altered relative to natural conditions of an undistrubed watershed of similar size, geology, and geography.	Some evidence of altered magnitude, timing, duration, and/or frequency of peak flows relative to natural conditions of an undisturbed watersed of similar size, geology, and geography.	Pronounced changes in magnitude, timing, duration, and/or frequency of peak flows relative to natural conditions of an undisturbed watersed of similar size, geology, and geography.
Water Quality	Temperature	Daily maximum, and 7-day mean maximum temperatures	Bull Trout: Incubation 2-5°C, rearing: 4-10°C, spawning: 1-9°C. Salmon and Steelhead: Spawning June-Sept 15°C, Sept-May 12°C; rearing 15°C, migration 15°C, adult holding 15°C. Or 7-day daily maximum temperature perfromance standards: Salmon spawning 13°C, core summer salmonid habitat 16°C. Salmonid spawning, rearing and migration 17.5°C. Salmonid rearing and migration only 17.5°C.	MWMT in reach during the following life history stages: Incubation <2°C or >6°C; rearing <4°C or >13-15°C; spawning <4°C or >10°C. Temperatures in areas used by adults during the local spawning migration sometimes exceed 15°C. Or 7-day average daily maximum temperature standards exceeded by ≤15%.	MWMT in reach during the following life history stages: Incubation <1°C or >6°C; rearing >15°C; spawning <4°C or >10°C. Temperatures in areas used by adults during the local spawning migration sometimes exceed 15°C. Or 7-day average daily maximum temperature standards exceeded by >15%.
	Turbidity	Turbidity NTU's	Performance Standard: Acute <70 NTU Chronic <50 NTU For streams that naturally exceed these standards: Turbidity should not exceed natural baseline levels at the 95% CL. <15% exceedance., Or Turbidity shall not exceed: 5 NTU over background when the background is 50 NTU or less; or a 10 percent increase in turbidity when the backgorund turbidity is more tha 50 NTU (WDOE -173-201A-200).	15-50% exceedance.	>50% exceedance.

Table 1 continued.

General Characteristics	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
	Chemical Contamination/ Nutrients	Metals/ Pollutants, pH, DO, Nitrogen, Phosphorous	Low levels of chemical contamination from landuse sources, no excessive nutrients, no CWA 303d designated reaches., Or Washington State Department of Ecology standards - 173-201A-200.	Moderate levels of chemical contamination from landuse sources, some excess nutrients, one CWA 303d designated reach.	High levels of chemical contamination from landuse sources, high levels of excess nutrients, more than one CWA 303d designated reach.
Reach-Scale					
Habitat Access	Physical Barriers	Main Channel Barriers	No man-made barriers present in the mainstem that limit upstream of downstream migration at any flow.	Mand-made barriers present in the mainstem that prevent upstream or downstream migration at some flows that are biologically significant.	Man-made barriers present in the mainstem that prevent upstream or downstream migration at multiple or all flows.
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	Gravels or small cobbles make-up >50% of the bed materials in spawning ares. Reach embeddedness in rearing areas <20%. ≤12% fines (<0.85mm) in spawning gravel or 12% surface fines of ≤6mm	Gravels or small cobbles make-up 30-50% of the bed materials in spawning ares. Reach embeddedness in rearing areas 20-30%. 12-17% fines (<0.85mm) in spawning gravel or 12-20% surface fines of ≤6mm	Gravels or small cobbles make-up <30% of the bed materials in spawning ares. Reach embeddedness in rearing areas >30%. >17% fines (<0.85mm) in spawning gravel or >20% surface fines of ≤6mm
	LWD	Pieces per Mile at Bankfull	>20 pieces/mile >12" diameter > 35 ft length; and adequate sources of woody debris available for both long- and short-term recruitment.	Currenlty levels are being maintained at minimum levels desired for "adequate", but potential sources for long-term woody debris recruitment is lacking to maintain these minimum values.	Current levels are not at those desired values for "adequate", and potential sources of woody debris for short- and/or long-term recruitment are lacking.
	Pools	Pool Frequency and Quality, presence of large pools.	Pool frequency: Number of pools/mile for a given channel width. Channel width between 30-35 ft = 18 pools/mile. Channel width 35-40 ft = 10 pools per mile. Pool have good cover and cool water and only minor reduction in pool volume by fine sediment. Each reach has many large pools >1 m deep with good fish cover.	Pool frequency is similar to values in "functioning adequately", but pools have inadequate cover/temperature and/or there has been a moderate recution of pool volume by fine sediment. Reaches have few large pools (>1m) present with good fish cover.	Pool frequency is considerably lower than values for "adequate condition", also cover/temperature is inadequate, and there has been a major recudtion of pool volume by fine sediment. Reaches have no deep pools (>1m) with good fish cover.
	Off-Channel Habitat	Connectivity with Main Channel	Reach has many ponds, oxbows, backwaters, and other off-channel areas with cover, and side channels are low energy areas. No manmade barriers present along the mainstem that prevent access to off-channel areas.	Reach has some ponds, oxbows, backwaters, and other off-channel areas with cover, and side channels are high energy areas. Manmade barriers present that prevent access to off-channel habitat at some flows that are biologically significant.	Reach has few or no ponds, oxbows, backwaters, and other off-channel areas. Manmade barriers present that prevent access to off-channel habitat at multiple or all flows.

Table 1 continued.

General Characteristics	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Channel	Dynamics	Floodplain Connecivity	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession.	Reduced linkage of wetland, floodplains and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession.	Sever reduction in hydrologic connectivity between off-channel, wetland, floodplain and riparian areas; wetland extent drastically reduced and riparian vegetation/succession altered significantly.
		Bank Stability/Channel Migration	Channel is migrating at or near natural rates.	Limited amount of channel migration is occurring at a faster/slower rate relative to natural rats, but significant change in channel width or planform is not detectable; large woody debris is still being recruited.	Little or no channel migration is occurring because of human actions preventing reqorking of the floodplain and large woody debris recruitment; or channel migration is occurring at an accelerated rate such that channel width has at least doubled, possibly resulting in a channel planform change, and sediment supply has noticeably increased from bank erosion.
		Vertical Channel Stability	No measurable trend of aggradation or incision and no visible change in channel planform.	Measureable trend of aggradation or incision that has the potential to, but not yet caused, disconnection of the floodplain or a visible change in channel planform (e.g. single thread to braided)	Enough incision that the floodplain and off-channel habitat areas have been disconnected; or, enough aggradation that a visible change in channel planform has occurred (e.g. single thread to braided).
Riparian Vegetation	Condition	Structure	>80% species composition, seral stage, and structural complexity are consistent with potential native community.	50-80% species composition, seral stage, and structural complexity are consistent with potential native community.	<50% species composition, seral stage, and structural complexity are consistent with potential native community.
		Disturbance (Human)	>80% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; <20% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); <2 mi/mi^2 road density in the floodplain.	50-80% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; 20-50% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); 2-3 mi/mi^2 road density in the floodplain.	<50% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; >50% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); >3 mi/mi^2 road density in the floodplain.
		Canopy Cover	Trees and shrubs within one site potential tree height distance or 10 m buffer zone have >80% canopy cover that provides thermal shading to the river.	Trees and shrubs within one site potential tree height distance or 10 m buffer zone have 50-80% canopy cover that provides thermal shading to the river.	Trees and shrubs within one site potential tree height distance or 10 m buffer zone have <50% canopy cover that provides thermal shading to the river.

Table 2. REI Ratings for Tributary-Scale Metrics.

Characteristics	General Indicators	Specific Indicators	Rating	Discussion
Watershed Condition	Effective Drainage Network and Watershed Road Density	Increase in Drainage Network/Road Density	*Adequate Condition*	There are 220 miles of roads in the watershed, 70 miles of which are within 200 ft of the mainstem or tributary streams creating a road density of 0.28 miles/miles^2 (USFS 2005). This includes paved primary transportion roadways, as well as unpaved roads providing residential, recreational, logging, and mining access throughout the watershed. A study of the effects of road density on the effective length of the active channel has not been completed for the Twisp Watershed. The determination of an increase in effective drainage network due to road density would change this rating.
	Disturbance Regime	Natural/Human Caused	*At Risk Condition*	Anthropogenic disturbance is present throughout the watershed in the form of roads, riparian clearing, logging, mining, grazing, agriculture, and residential development. These activities have been shown to create channel instability, and also decrease the ability of the system to respond to natural disturbance regimes such as fire or floods. The watershed has a naturally frequent fire regime, annual snowmelt flooding and infrequent rain-on-snow floods, and active tributary alluvial fans (BOR 2008 App J, L and N). The channel has a documented decrease in complexity and floodplain connection, and is shown to be incising in some areas and aggrading in others (PWI 2003, NWP and C 2000).
Flow/Hydrology	Streamflow	Change in Peak/Base Flows	*Unacceptable Risk Condition*	Low flows are adversely affected by the 7 irrigation diversions found on the Twisp River (NWCandP 2000). This is especially true on the receding limb of the hydrograph that coincides with irrigation season. Some years withdrawals can account for up to 60% of the total flow during irrigation season (PWI 2003). The Twisp River was placed on the Washington State 303(d) list in 1998 for insuficient flow and temperature exceedance (NWC and P 2000). A significant change in peak flow frequency, duration, magnitude, or timing cannot be determined from the streamflow record that exists for the Twisp River (PWI 2005). However, many of the land-use activities and channel alterations affecting the Twisp have been shown to change one or all of the above mentioned attributes of peak flows in other basins.
Water Quality	Temperature	Daily maximum, and 7-day mean daily maximum temperatures	*Unacceptable Risk Condition*	Two excursions above temperature threshold limits in 1989 resulted in the original listing of the Twisp River on the 1996 Washington state 303(d) list (NWC and P 2000). The Twisp is currently listed as "waters of concern" by the Department of Ecology. More recent measurements show that the Twisp River continues to have high temperatures throughout the summer months. Near the mouth of the Twisp the highest 7-day average daily maximum temperature recorded during the summer exceeded 16°C by about 26% in 2001 and 30% in 2005. Threshold criterion were also exceeded by over 15% at two other locations in those years (BOR 2009 App I). Temperature data from 2008 and 2009 show 7-day average daily maximum temperatures with over 15% exceedance of 16°C consistently from mid-July through mid-September.
	Turbidity	Turbidity NTU's	*N/A*	Data was unavailable.
	Chemical Contamination/Nutrients	Metals/ Pollutants, pH, DO, Nitrogen, Phosphorous	*N/A*	Data was unavailable.

Table 3. REI Metrics for Reach-Scale Metrics.

General Characteristics	General Indicators	Specific Indicators	Reach 1 Condition	Reach 2a Condition	Reach 2b Condition	Reach 3a Condition	Reach 3b Condition	Reach 3c Condition
Habitat Access	Physical Barriers	Main Channel Barriers	*At Risk Condition*	*At Risk Condition*	*At Risk Condition*	*At Risk Condition*	*Unacceptable Condition*	*At Risk Condition*
			There are no anthropogenic barriers in the main channel in Reach 1. However, connectivity is adversely affected by critically low-flow conditions due to upstream irrigation diversions.	Irrigation diversion at RM 1.5 poses a potential barrier at low flow. Riprap has cut off connectivity between side channel and main channel habitats.	No barriers in the reach, though downstream barriers limit access to this reach.	There are no physical barriers in Reach 3a, though downstream barriers limit access in this reach.	Irrigation diversion at RM 6.5 blocks low flow access to side-channel, push-up levee at RM 6.6 and riprap at RM 6.3 block side-channel and off-channel access.	Channel-spanning fish collection wier at RM 7.25 creates a potential low flow barrier, an irrigation diversion at RM 7.35 creates a side-channel barrier.
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	*Adequate Condition*	*Adequate Condition*	*Adequate Condition*	*Adequate Condition*	*At Risk Condition*	*At Risk Condition*
			Based on pebble counts, gravel and cobble are the dominant substrate (92 - 96%), while sand makes up <5% of surface sediment.	Based on pebble counts, >50% of the bed substrate is in the gravel or small cobble size classes (D50 64-43 mm). At one site there was 7% sand and 88% gravel/cobble composition.	Based on pebble counts, sand comprises only 9% of bed sediments, while gravel and cobble account for 78%.	Based on pebble counts, 63 - 72% of the bed substrate is in the gravel or cobble size classes, and 2 - 8% sand was found.	Based on pebble counts, 65% of the bed substrate is in the gravel or cobble size classes and sand composition is 14%.	Based on pebble counts, 67% of the bed substrate is in the gravel or cobble size classes and sand composition is 10%.
	LWD	Pieces per Mile at Bankfull	*Unacceptable Condition*	*At Risk Condition*	*Unacceptable Condition*	*Unacceptable Condition*	*At Risk Condition*	*At Risk Condition*
			A total of 73 pieces/mile were found (3 large, 11 medium, and 59 small pieces/mile). The majority of the wood was small, and due to the urbanization of the historic floodplain, recruitment sources are limited in this reach.	6 pieces per mile large wood, 24 pieces per mile medium wood, 86 pieces per mile are small. Total 30 pieces per mile medium or larger wood with limited potential for future recruitment of large pieces.	65 pieces per mile large wood, 2 large pieces/mile, 5 medium pieces/mile and 58 small pieces/mile.	8 pieces per mile large wood, 11 pieces per mile medium wood, 76 pieces per mile small wood. Total 19 pieces per mile medium or larger wood with moderate recruitment sources.	A total of 105 pieces of wood per mile, composed of 85 pieces per mile small, 15 pieces of medium, 5 pieces per mile large wood. Total 20 pieces per mile medium or larger wood with limited potential for future recruitment.	180 pieces per mile small wood, 51 pieces medium, but no large wood. Riparian conitions allow for limited potential recruitment of LWD
	Pools	Pool Frequency and Quality	*At Risk Condition*	*At Risk Condition*	*Unacceptable Condition*	*At Risk Condition*	*At Risk Condition*	*Adequate Condition*
			There is a less than adequate amount of pool habitat: 15.7 pools/mile.	15 pools per mile, adequate for a 40 ft wetted width.	8.9 pools per mile, Unacceptable for an average 49 ft wetted width. 57% of pools have residual depths of less than 2 ft.	23.7 pools per mile, adequate for an average 51 ft wetted width.	8.5 pools per mile, which is less than minimum of 10 pools per mile for wetted width of 41 ft.	12.7 pools per mile, adequate for 42 ft average wetted width.

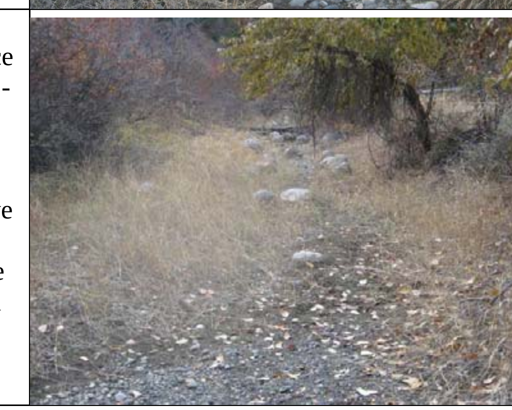
Table 3 continued.

General Characteristics	General Indicators	Specific Indicators	Reach 1 Condition	Reach 2a Condition	Reach 2b Condition	Reach 3a Condition	Reach 3b Condition	Reach 3c Condition
Habitat Quality	Off-Channel Habitat	Connectivity with Main Channel	*Unacceptable Condition*	*At Risk Condition*	*At Risk Condition*	*Adequate Condition*	*Unacceptable Condition*	*At Risk Condition*
			The side channels are largely limited to the Twisp - Methow confluence, three of which are likely disconnected at base flow. <30% of the reach has side channel habitat, which is due to the urbanization along the river corridor in this reach.	Five side channels are present, however diversion ditches and riprap have reduced their accessability to fish.	Eight side channels observed during the habitat survey, half of which were dry. It is possible that downcutting has decreased connectivity between the main channel and off-channel habitats.	There are naturally limited side channel habitats due to the canyon character of this reach. There is one high flow side channel, and one low flow side channel.	There is one side-channel that is active at low flow. There are three other side-channels that are connected at higher-flows. Levees and riprap block extensive side-channel networks.	There are 11 side channels in the reach. Three are active at all flow levels. Six are active only at higher flows. The longest side-channel contains large wetlands, but is blocked at the upstream end by a road and an irrigation diversion.
Channel	Dynamics	Floodplain Connecivity	*Unacceptable Condition*	*Unacceptable Condition*	*Unacceptable Condition*	*Adequate Condition*	*Unacceptable Condition*	*At Risk Condition*
			54% of the floodplain has been disconnected due to a variety of alterations to the land surface and river system.	72% of the floodplain has been disconnected.	Also 65% of the floodplain has been disconnected due to a variety of alterations to the land surface and river system.	100% of the floodplain is connected, although due to the confined nature of this reach, the lateral extent of the floodplain is limited.	53% of the floodplain has been disconnected by a variety of modifications to the land surface and river system.	26% of the floodplain is disconnected due to alteration of the land surface, road construction, levees, etc.
		Bank Stability/Channel Migration	*Unacceptable Condition*	*Unacceptable Condition*	*Unacceptable Condition*	*Adequate Condition*	*Unacceptable Condition*	*At Risk Condition*
			Only 2% of banks are eroding, due to the high level of bank protection that has been installed.	Riprap, boulders, concrete and rock gabions have been installed to prevent erosion. Moderate LWD recruitment may be driven by cottonwood stands.	Channel migration is limited by extensive bank protection on the oustide of most large bends. Only 3% of banks in the reach are eroding.	Despite riprap installed upstream of the Poorman Cut Off Rd. bridge, the majority of the banks in this reach have not been armored to limit erosion. The natural rate of channel migration is likely very low due to the level of confinement.	Historical trends indicate sinuosity in the reach is decreasing, there are long sections of bank protection and levees in the upstream half of the reach that limit meander migration.	The upstream half of the reach is laterall dynamic and has the potential for long-term wood recruitment. However, there are levees and riprap in the downstream half of the reach that limit meander migration.

Table 3 continued.

General Characteristics	General Indicators	Specific Indicators	Reach 1 Condition	Reach 2a Condition	Reach 2b Condition	Reach 3a Condition	Reach 3b Condition	Reach 3c Condition
Channel	Dynamics	Vertical Channel Stability	*At Risk Condition*	*At Risk Condition*	*At Risk Condition*	*Adequate Condition*	*Unacceptable Condition*	*At Risk Condition*
			Current bed elevation has been influenced by channel simplification and armoring of banks, forcing stream energy down into the bed rather than laterally across the floodplain.	A rock dam and a constructed log jam influence vertical channel stability in this reach. There are some high, eroding banks that suggest that incision may be ongoing. However, there are several connecte side-channels.	Bedrock outcrops control grade and vertical stability at several points in the downstream half of the reach. In the upstream half, bank protection has decreased flood attentuation and concentrated energy in the channel at higher flows. This creates the potential for downcutting.	Bedrock and other boundaries that confine Reach 3a make the reach naturally more likely to incise rather than migrate laterally.	Evience of incision exists in the historical aerial photo record that shows meander straightening at the downstream end of the reach. Also, there are several side channels that were connected in older aerial photos, and are not connected now.	Though there are several well-connected side-channels, some of the larger side channels are no longer connected. There is very little channel/floodplain connection. However, there are no indications of increased rates of aggradation or incision.
Riparian Vegetation	Condition	Structure	*Unacceptable Condition*	*Unacceptable Condition*	*Unacceptable Condition*	*Adequate Condition*	*Unacceptable Condition*	*At Risk Condition*
			Intact riparian areas have <50% species composition, seral stage, and low complexity compared with the potential of the native community	A narrow band of riparian vegetation is present, providing little shading. There is <50% species composition, serval stage, an low complexity compare with the potential of the native community.	Intact riparian areas have <50% species composition, seral stage, and low complexity compared with the potential of the native community	There is naturally limited with for riprian forest growth and development. Aside from a recently burned area, the existing riparian habitats are consistent with adequate conditions.	Intact riparian areas have <50% species composition, seral stage, and low complexity compared with the potential of the native community	Intact riparian areas have 5-80% species composition, seral stage, and low complexity compared with the potential of the native community
		Disturbance (Human)	*Unacceptable Condition*	*At Risk Condition*	*At Risk Condition*	*Adequate Condition*	*Unacceptable Condition*	*At Risk Condition*
			>50% disturbance in the riparian area due to roads, bridges, and development. The majority of riparian habitats have been converted to other land uses, and more than 40% has been hydrologically disconnected.	<50% disturbance in the riparian area from roads, bridges and development.	>40% disturbance in the floodplain.	<30% distrubance in the floodplain.	>50% disturbance in the riparian area due to roads and development.	<40% disturbance in the floodplain due to development and road construction.
		Canopy Cover	*Unacceptable Condition*	*Unacceptable Condition*	*Unacceptable Condition*	*Unacceptable Condition*	*Unacceptable Condition*	*At Risk Condition*
			<20% canopy cover is provided by trees and shrubs producing minimal thermal shading to the river.	<40% canopy cover is provided by trees and shrubs producing minimal thermal shading to the river.	<50% canopy cover is provided by trees and shrubs producing some thermal shading to the river.	<50% canopy cover is provided by trees and shrubs producing some thermal shading to the river.	<50% canopy cover is provided by trees and shrubs producing minimal thermal shading to the river.	>50% canopy cover is provided by trees and shrubs producing minimal thermal shading to the river.

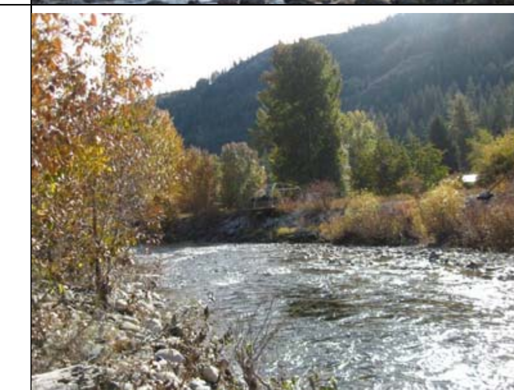
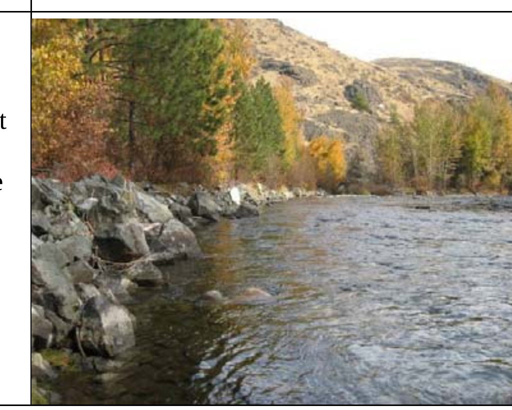
Appendix C: Lower Twisp Project Opportunities

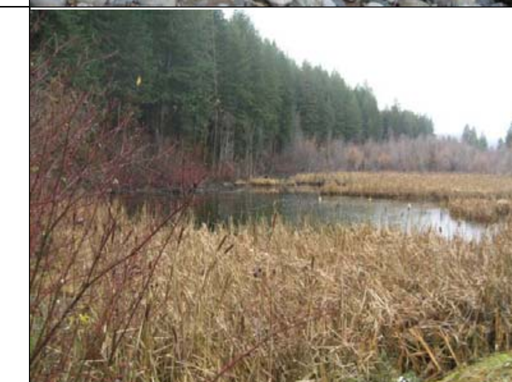
Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo
1	Project RM 0.3R	Inner Zone 1 (IZ-1)	In-stream Habitat Enhancement	LWD habitat enhancement	The bank in this area has been protected with riprap beginning at the bridge and extending down to RM 0.25. The riprap is currently protecting residences built in DOZ-3. Riprap limits geomorphic connectivity (e.g. channel migration), riparian function, and habitat complexity. Bank protection should be maintained for safety, but could be enhanced with LWD to enhance in-stream habitat cover/complexity.	 Looking downstream to the northeast at the river-right bank near RM 0.3 where LWD could enhance a riprap protected bank (October 2009).
1	Project RM 0.53L	Inner Zone 1 (IZ-1)	Reconnect Stream Channel Processes	Side-channel habitat reconnection	In 1985, this side-channel was mapped as active split flow. Currently, the channel is scoured and contains un-vegetated alluvial material indicating a frequent high-flow connection; however, there is no active flow when water levels are low. A low-flow connection could be enhanced to provide a perennial split flow channel. Protection of adjacent residences would be a primary consideration. A small portion of riprap near the downstream outlet could be moved to the margin of the floodplain surface.	 View looking upstream toward the northwest at a small high-flow channel that could be enhanced to provide side-channel habitat at all flow levels (October 2009).
2a	Project RM 0.87R	Disconnected Outer Zone 1 (DOZ-1)	Off-Channel Habitat Enhancement	Wetland habitat enhancement	The downstream outlet of the acclimation ponds is near RM 1.05. Downstream of that point, there is topographic and vegetative evidence of a more active hydrologic connection between the channel and DOZ-1. This area is also managed by MSRF. MSRF breached the levee in several places, allowing for semi-annual flooding. Groundwater investigation by MSRF does not support a flow augmentation here. This channel could be developed with a surface connection to an active side-channel near RM 0.9, enhancing connectivity between channel and floodplain processes and habitats. There is also potential to create an active low-flow side-channel through this area in combination with Project RM 1.0R.	 Floodplain channel near RM 0.9. This channel is continuous across the surface but is currently not well-connected (October 2009).

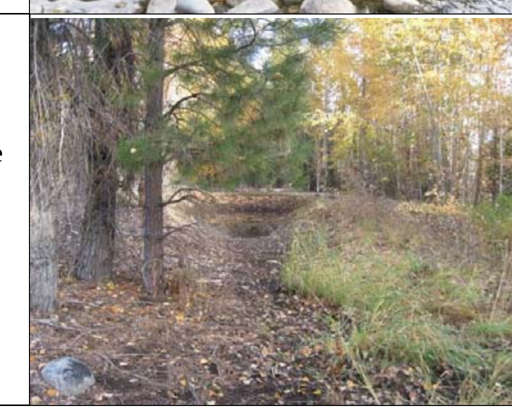
Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo	
2a	Project RM 0.88L	Inner Zone 2 (IZ-2)	Reconnect Stream Channel Processes	LWD enhancement and side-channel reconnection	LWD jams at this location would enhance LWD that is naturally being deposited in this area and could enhance flows into adjacent high-flow channels. Downstream near RM 0.86, a bar apex log jam would be used to enhance a gravel bar high-flow cut-off. The cut-off channel is scoured and appears active. The purpose of the jam would be to increase scour, increase low flow discharge in the channel, and provide improve habitat.		View looking upstream toward the west at LWD near RM 0.9 (October 2009).
2a	Project RM 0.95R	Inner Zone 2 (IZ-2)	Off-Channel Habitat Enhancement	Alcove habitat enhancement	This wood structure would enhance an existing backwater pool that has above average residual depth, providing cover and habitat complexity.		View looking downstream toward the east at an alcove near RM 0.95 (October 2009).
2a	Project RM 1.0R	Disconnected Outer Zone 1 (DOZ-1)	Reconnect Floodplain Processes	Levee removal	There is a 560 ft long push-up levee that creates a barrier to downstream connection to high-flow across the floodplain, and to the connectivity of off-channel and floodplain side-channel habitat. The levee does not appear to provide protection to vital infrastructure and could be removed to re-establish floodplain connectivity.		View looking east in the downstream direction at an old irrigation ditch in the center of the photo protected by a levee on the right (October 2009).

Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo	
2a	Project RM 1.05L	Inner Zone 2 (IZ-2)	Reconnect Stream Channel Processes	Riprap modification or removal	A 300 ft levee is located on the left bank of the river centered on RM 1.05. There are houses on the floodplain about 200 ft to the north. This levee could be set back to provide protection to the structure while allowing more dynamic inner zone processes to take place. Or the current location of the revetment could be maintained, but replaced/enhanced with LWD.		View looking towards the left bank at a levee near RM 1.05 (October 2009).
2a	Project RM 1.15L	Inner Zone 2 (IZ-2)	In-Stream Habitat Enhancement	LWD enhancement	This project would involve the placement of several log jams along the river-left bank in order to control erosion and provide cover to improve habitat quality.		View looking towards the left bank at eroding bank near RM 1.15 (October 2009).
2a	Project RM 1.19R	Inner Zone 2 (IZ-2)	Reconnect Stream Channel Processes	Side-channel reconnection	An existing side-channel would be enhanced with placement of an apex wood jam. There is an existing jam at this location that would be enhanced.		View looking downstream at point bar with potential for apex jam placement near RM 1.19 (October 2009).

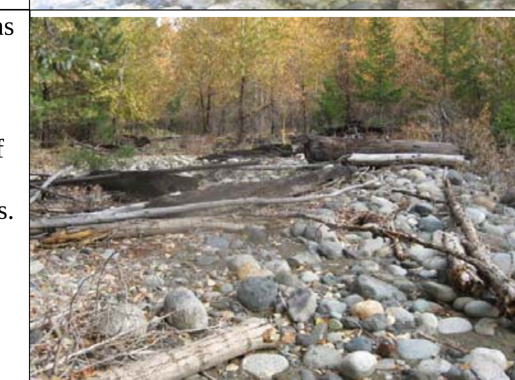
Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo
2a	Project RM 1.21R	Inner Zone 2 (IZ-2)	In-Stream Habitat Enhancement	LWD enhancement	This project includes placement of several log jams along the river right bank to control erosion and increase cover for habitat enhancement.	 View looking upstream at eroding bank on river-right near RM 1.21. Smolt trap in background (October 2009).
2a	Project RM 1.25R	Disconnected Outer Zone 1 (DOZ-1)	Riparian Habitat Enhancement	Riparian re-vegetation	Several acres of riparian forest have been cleared on the south side of the valley for residential an agricultural development. There is no active agricultural or residential use for this cleared area, and the potential exists to re-plant native riparian vegetation to enhance habitat quality. The land is currently under protection and slated for riparian restoration.	 View to the south at a cleared floodplain area near RM 1.25 (October 2009).
2a	Project RM 1.2L	Disconnected Outer Zone 2 (DOZ-2)	Riparian Restoration	Riparian re-vegetation	Several acres of riparian forest have been cleared north of the channel between RM 1.0 and 1.3. This clearing was originally agricultural, but now appears to be fallow. The land is under protection and is slated for riparian restoration. Re-planting native riparian vegetation would enhance habitat quality and stream processes by increasing solar shading of the channel, and eventually providing a source for large woody debris.	
2a	Project RM 1.28L	Disconnected Outer Zone 2 (DOZ-2)	Reconnect Floodplain Processes	Levee removal	Along the channel margin at the upstream end of DOZ-2, a levee protects an abandoned irrigation canal. Without the need to protect the canal, the level could be removed to re-establish channel/floodplain connection between processes and habitat.	 View looking east in the downstream direction at an old irrigation ditch in the center of the photo protected by a levee on the right (October 2009).

Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo
2a	Project RM 1.45C	Inner Zone 1 (IZ-1)	In-Stream Habitat Enhancement	LWD enhancement	Between RM 1.4 and 1.5 there are several opportunities for placement of LWD on both sides of the channel. These structures would increase habitat cover and complexity.	 View looking east in the downstream direction near RM 1.45 where both sides of the channel provide opportunities for LWD enhancement (October 2009).
2a	Project RM 1.7R	Disconnected Outer Zone 1 (DOZ-1)	Reconnect Floodplain Processes	Levee removal or set-back	At the upstream end of the reach, a levee runs along the right bank of the channel for approximately 1,869 feet. Residential development does not begin for several hundred feet downstream. The levee could be set back farther on the floodplain to provide more direct protection for residential development, and re-establish a connection between channel/floodplain processes and habitats.	 View looking downstream towards the east at a levee along river-right (October 2009).
2b	Project RM 1.72L	Disconnected Outer Zone 5 (DOZ-5)	Off-Channel/Side-Channel Habitat Enhancement	Alcove habitat enhancement	This project would create an off-channel backwater/alcove at the upstream end of the north channel of the split-flow area between RM 1.68 and 1.73. The backwater would provide high-flow refugia for fish in the active channel and provide connectivity between channel and floodplain habitat.	
2b	Project RM 1.75L	Inner Zone 5 (IZ-5)	Reconnect Stream Channel Processes	Riprap removal	Downstream of the bridge at RM 1.85, the river-left channel is protected by riprap for over 700 feet. There is no residential development or other infrastructure in the adjacent floodplain. The riprap could be removed and replaced with LWD in order to reconnect stream channel and floodplain processes and to increase habitat cover and complexity. Alternatively, the riprap could remain in place and be enhanced with LWD additions.	 Northeast view in the downstream direction of riprap bank along river-left downstream of the bridge at RM 1.87 extending to RM 1.71 (October 2009).

Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo
2b	Project RM 1.87L	Inner Zone 5 (IZ-5)	Reconnect Stream Channel Processes	Abutment removal	An old bridge abutment is located along the river-left channel margin. The abutment currently serves no purpose, but creates a process barrier. Removal would enhance inner zone processes.	 Northeast view in the downstream direction at an old bridge abutment along river-left near RM 1.87 (October 2009).
2b	Project RM 2.0R	Disconnected Outer Zone 4 (DOZ-4)	Reconnect Floodplain Processes	Wetland habitat reconnection	A larger effort to reconnect habitat and process throughout DOZ-4 would require several culverts on Poorman road, multiple private roads, and multiple landowner approval. This approach is mentioned by the BOR as the "Spokane Grade" project (BOR 2008). The effort faces too many constraints to be considered here. A scaled-back approach with one culvert to connect floodplain wetlands at the downstream end is described here. This project involves replacing a culvert at RM 2.0 in order to re-connect off-channel habitat south of Poorman Road between RM 2.0 and 2.4.	 View to the west in the upstream direction at wetlands south of Poorman Road in DOZ-4 (November 2009).
2b	Project RM 2.25C	Disconnected Outer Zone 4 (DOZ-4)	Reconnect Floodplain Processes	Bridge and road relocation	The Twisp River Road and Poorman Road corridor create disconnected outer zone areas and limit channel processes through the downstream en of the reach. Limited reconnection can be achieved by installing culverts or bridges as described in Project RM 2.0L. However greater physical an ecological connectivity could be gained by a large scale relocation of the road junction. Several options exist for this modification. The greatest benefit may be gained by removing the bridge at RM 1.85, and decommissioning Twisp River Road between RM 1.85 and 2.2. This, along with riprap removal on river left near RM 1.8, would reconnect DOZ5. Poorman road between RM 1.85 and 2.7 would be move south against the hillslope, thus reconnecting a large portion of DOZ4. The bridge would be moved near RM 2.25 with multiple culverts providing hydrologic connection through Twisp River Road as it traverses DOZ4 and then climbs out of the floodplain onto the terrace to the north of the channel.	

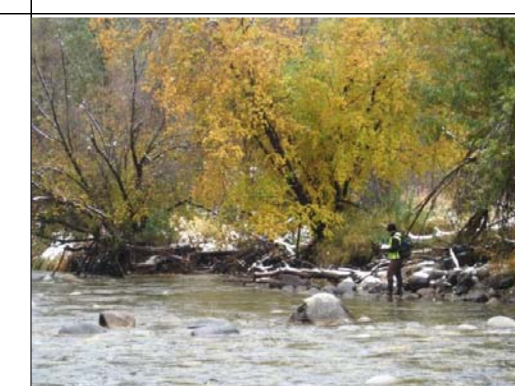
Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo	
2b	Project RM 2.25R	Inner Zone 5 (IZ-5)	Reconnect Stream Channel Processes	Riprap modification or removal	This project involves incorporation of LWD along the riprap bank with the goal of increasing habitat complexity and quality. There is a backwater created by the crest of a riffle. A LWD structure could provide enhanced pool habitat in this area.		Northwest view in the upstream direction at a potential LWD location along river-right near RM 2.25 (October 2009).
2b	Project RM 2.3L	Outer Zone 7 (OZ-7)	Off-Channel Habitat Enhancement	Side-channel habitat enhancement	An existing meander scar could be excavated and opened up to create a floodplain channel. There is no evidence that the feature is frequently inundated. The downstream end of the channel could be widened to create a backwater/alcove connected to the active channel.		
2b	Project RM 2.65R	Inner Zone 4 (IZ-4)	Reconnect Stream Channel Processes	Riprap modification or removal	This project involves in-channel work over a 640 ft section of the river-right bank centered on RM 2.65. The bank is hardened to protect homes on the terrace near the channel margin. The riprap could be replaced with, or enhanced by, LWD structures in order to provide increased habitat complexity, enhanced inner zone process, and to maintain bank stability and protection. At the downstream end of the bank protection there is an area of deep slow moving water along the edge of the riprap. An LWD structure here could enhance this slack water forming a pool with higher habitat value.		Southeast view in the downstream direction at a portion of the riprap that extends along river right between RM 2.58-2.75 (October 2009).
2b	Project RM 2.7L	Disconnected Inner Zone 3 (DIZ-3)	Reconnect Stream Channel Processes	Levee removal and side-channel reconnection	This project involves removing anthropogenic features to reconnect inner zone processes. A portion of the high flow channel is currently ditched, lined, and routed into a catch basin near RM 2.7. There are also two push-up levees in this area that limit connectivity of channel and floodplain processes. These features could be removed to enhance floodplain and side-channel connectivity.		View to the east in the downstream direction at a catch basin that has been built to capture high-flow from a side-channel near RM 2.7 (October 2009).

Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo	
2b	Project RM 2.9C	Inner Zone 4 (IZ-4)	In-Stream Habitat Enhancement	LWD enhancement.	LWD structures on both sides of the channel would increase habitat cover, pool scour, and complexity		Northeast view in the downstream direction at a potential LWD location along river-right near RM 2.9. The left side of the channel provides a similar opportunity (October 2009).
2b	Project RM 2.93L	Inner Zone 4 (IZ-4)	In-Stream Habitat Enhancement	LWD enhancement	This is a location where LWD could be added to the channel along river-left near RM 2. This project is located in an active side-channel. The log jam would provide habitat complexity in the side channel.		View to the northwest in the upstream direction at a side channel near RM 2.93 (October 2009).
2b	Project RM 3.0R	Disconnected Outer Zone 4 (DOZ-4)	Reconnect Floodplain Processes	Levee removal, side-channel reconnection	Habitat actions proposed for this project would re-connect several floodplain sub-units and the active channel. Currently a large levee extends 550 ft between RM 3.1 and 3.2. The levee creates a process and habitat barrier between DOZ-3, DOZ-4, and OZ-4. High-flow channels and wetlands occupying older channel scars intersect the levee and terminate, with the water entering the levee prism and going sub-surface. LiDAR data suggests that these high flow channels historically extended beyond the levee connecting with wetland features in DOZ-4. The levee does not appear to serve a protection purpose; there is no residential development or transportation corridor nearby. In addition to removing the levee, high flow channels and off-channel habitat would be enhanced to re-establish historical floodplain connections and functions in the system.		Northeast view along the top of the levee near RM 3.2 that creates an ecological and physical barrier between multiple floodplain sub-units (October 2009).

Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo	
2b	Project RM 3.13C	Inner Zone 4 (IZ-4)	Reconnect Stream Channel Processes	Re-establish channel LWD dynamics	This project entails enhancing an existing apex jam in order to increase channel complexity, and enhance an existing side-channel by encouraging split-flow at all flow levels. The side-channel currently sees active flow during annual high-flow events. Creating a split-flow condition would increase habitat complexity. Habitat features could be installed throughout the side-channel as well.		View to the northeast in the downstream direction at a side-channel near RM 3.13 (October 2009).
2b	Project RM 3.25R	Inner Zone 4 (IZ-4)	In-Stream Habitat Enhancement	LWD enhancement	A LWD meander bend jam would improve local habitat and cover. Existing riparian vegetation is in good condition along the bank and enhancing lateral channel adjustment processes could drive future LWD recruitment		Northeast view in the downstream direction at a potential LWD jam location on river-right near RM 3.25 (October 2009).
2b	Project RM 3.35L	Inner Zone 4 (IZ-4)	Reconnect Stream Channel Processes	Levee removal and side-channel reconnection	This project involves enhancement of a river-left side-channel that runs between RM 3.22 and 3.38. This side-channel was the active channel location in 1954 and 1964 aerial photos. Geomorphic and vegetative evidence suggests an active connection to inner zone processes that could be enhanced through a combination of actions. Enhancement of an existing bar apex jam would encourage flow into the side-channel.The existing jam is limited by current wood recruitment levels. A 200 ft long push-up levee currently creates a flow barrier between the main channel and the side-channel at the downstream end. Removing this levee would allow inner zone processes to proceed unimpeded.		Northeast view in the downstream direction at a small LWD jam at a bar apex near RM 3.38 (October 2009).
2b	Project RM 3.5L	Outer Zone 3 (OZ-3)	Off-Channel Habitat Enhancement	Side-channel habitat enhancement	This project involves re-activating a high-flow channel between RM 3.3 and 3.6. Currently, the channel does not appear to be regularly inundated, but cross-section geometry suggests that moderate flows were historically accommodated in this channel. Excavation would be required to lower the upstream end of the channel and activate flow at a 1.5-2 yr frequency. The channel is well defined in its upstream half and would require minimal mechanical enhancement to accommodate flow. Excavation is needed to construct a channel and outlet at the downstream end of the project. Dry ground and upland vegetation suggest that groundwater would not be a significant contributor to flow in this channel.		Northeast view in the downstream direction at the historical high-flow channel found between RM 3.3 and 3.6 in OZ-3 (October 2009).

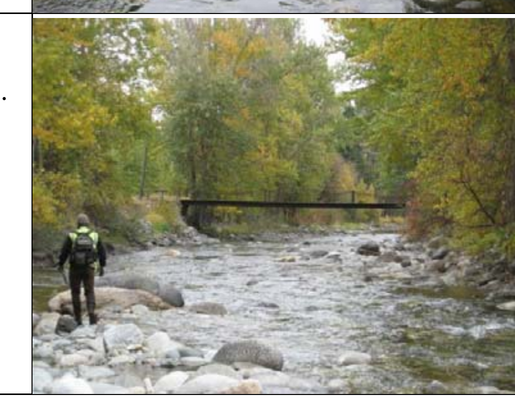
Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo
2b	Project RM 3.6L	Inner Zone 3 (IZ-3)	In-Stream Habitat Enhancement	LWD enhancement	The project includes a LWD bank structure on the outside of a bend in the river. Several pieces could be placed to enhance cover and habitat, and drive pool formation on the outside of the meander.	 East looking view of the river left bank of the channel near RM 3.6 where a LWD structure would enhance habitat and re-establish inner-zone processes (October 2009).
2b	Project RM 3.7R	Disconnected Outer Zone 3 (DOZ-3)	Off-Channel Habitat Enhancement	Wetland habitat enhancement	The overall goal of this project is to re-connect the "Chain of Lakes", a large area of off-channel habitat, and re-establish hydrologic and geomorphic connection between DOZ-3 and the main channel. Fish access to this off-channel habitat would be enhanced by developing up and downstream surface connections and by improving culvert passability between wetlands to create a well-connected longitudinal system. The upstream surface connection could be developed off an active side-channel near RM 4.05. This side-channel is proposed for enhancement under Project RM 4.1C. Culvert passability through 6 dikes would need to be addressed to ensure flow-through connection between each of the ponds. Currently there are several downstream drainage points. Some of the ponds appear completely blocked at the downstream end and surface flow is diverted to the channel. This occurs at RM 3.85 and 3.9. Neither of these outflows provides habitat connection between the channel and off-channel locations. The downstream-most outlet locations are at RM 3.32 and 3.45. One or all of these outlets would be enhanced to allow connection to the channel. Water quality and presence of non-native fish would be of concern.	
2b	Project RM 3.9R	Disconnected Outer Zone 3 (DOZ-3)	Off-Channel Habitat Enhancement	Alcove habitat enhancement	At RM 3.9, there is a low area on the channel margin that forms the drainage point for the upstream end of the "Chain of Lakes" (Figure 20). Despite the berms that surround the wetlands, and the lack of natural drainage, there is a small surface discharge into the channel. This topographic low point could be excavated into the floodplain to create an off-channel alcove that connects channel and floodplain habitats.	 View to the southwest toward the outlet of the upstream end of the "Chain of Lakes" near RM 3.9 (October 2009).

Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo
2b	Project RM 4.15C	Inner Zone 2 (IZ-2)	Reconnect Stream Channel Processes	Levee removal and channel process reconnection	Between RM 4.0 and 4.2 there are several side-channels that provide the opportunity to encourage split flow processes, increase side-channel habitat, and reduce shear stress that may be responsible for observe bank erosion. Placement of a bar-apex LWD jam on river right at RM 4.18 could increase side-channel flow, enhance channel processes, and improve in-stream habitat. A bar-apex LWD jam placed on river left near RM 4.2 would encourage split flow between RM 4.05 and 4.2 at all flow levels. A push up levee located down the middle of the gravel bar could be removed to re-establish natural channel processes in this area. Increased channel width and cross-sectional area would decrease flow velocity for a given discharge, and could alleviate some of the erosion problems that are necessitating riprap just downstream. An LWD jam at 4.1 would enhance split flow into an existing side-channel on river right between RM 4.0 and 4.1.	
2b	Project RM 4.2R	Disconnected Outer Zone 2 (DOZ-2)	Off-Channel Habitat Enhancement	Off-Channel Habitat Enhancement at fish return channel	The fish return channel from the fish screen near RM 4.2 could be developed to provide access to off-channel habitat. The channel currently provides some off-channel habitat, but placement of habitat features would increase the quality of habitat components in the channel.	
2b	Project RM 4.25L	Inner Zone 2 (IZ-2)	Reconnect Stream Channel Processes	Riprap modification or removal	This project involves the removal or modification of large riprap and installation of LWD structures to maintain bank stability while allowing for greater connection of process and enhanced in-stream habitat.	 Looking east in the downstream direction at riprap along river-left near RM 4.25 (October 2009).
2b	Project RM 4.3L	Disconnected Outer Zone 1 (DOZ-1)	Reconnect Floodplain Processes	Wetland Habitat Reconnection	This project involves reconnecting wetland habitats to inner zone habitats, and re-establishing channel/floodplain connection. Groundwater fed wetlands provide potentially valuable off-channel habitat, but lack passable fish access. The outflow channel is blocked by fill, garbage, and riprap at the channel margin creating a steep fall into the channel that is impassible except at very high flows. The outflow channel could be opened up to allow fish passage into off-channel habitat. The wetlands themselves could be enhanced to provide increased quality of fish habitat	 Wetland outflow channel that has been altered with floodplain fill behind riprap. The channel does not currently provide habitat connection at any flow level except high flows (October 2009).

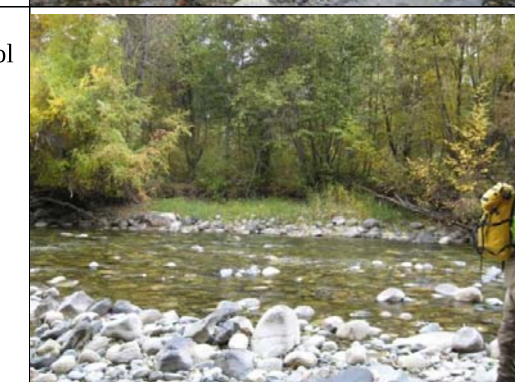
Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo
2b	Project RM 4.5R	Disconnected Outer Zone 2 (DOZ-2)	Reconnect Floodplain Processes	Levee removal and floodplain reconnection	The goal of this project is to re-connect the floodplain and the channel. Explore opportunities to re-locate the irrigation diversion and dam upstream to near RM 4.5 adjacent to the hillslope toe and remove or set-back the levee that forms the upstream boundary of DOZ-2. Given the amount of alteration to the sub-unit, the constraints are considerable (Figure 19). The irrigation canal and fish screen depend on protection from this levee.	 Looking southwest in the upstream direction at a levee that is a process and habitat barrier for DOZ-2 (October 2009).
2b	Project RM 4.55L	Disconnected Inner Zone 1 (DIZ-1)	Reconnect Stream Channel Processes	Levee removal, side-channel reconnection	This project involves removing or modifying the push-up levee between RM 4.75 and 4.85. LWD enhancement near inlet locations of disconnected side-channels could direct high-flow into high flow channels, re-establishing process and enhancing habitat connection. Downstream outlets of the high flow channels are unimpeded, and would not require and mechanical enhancement.	 Southeast view of DIZ-1 looking across a push-up levee into the thinned riparian forest (October 2009).
2b	Project RM 4.6C	Inner Zone 2 (IZ-2)	Reconnect Stream Channel Processes	Re-establish channel LWD dynamics	This portion of the inner zone is geomorphically active. The channel is eroding into a glacial terrace to the south and forming a gravel bar with the eroded material. Large wood is being deposited at the apex of this gravel bar. There are large boulders in the channel creating a scour pool. A large, channel spanning wood jam here would increase pool scour, provide cover, and re-establish large wood and lateral channel dynamics.	
2b	Project RM 4.75R	Inner Zone 1 (IZ-1)	In-Stream Habitat Enhancement	LWD enhancement	Existing root wads and small wood could be enhanced with a LWD bank structure to increase the quality of pool habitat	 Potential LWD location along river right near RM 4.75. Existing woody bank structure could be enhanced to provide increased habitat quality (October 2009).

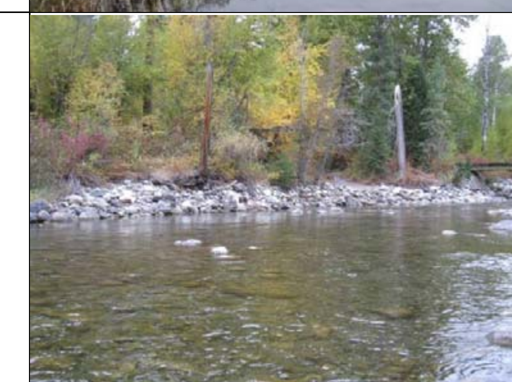
Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo
2b	Project RM 4.8R	Outer Zone 1 (OZ-1)	Reconnect Floodplain Processes	Wetland Habitat Reconnection	At the downstream end of the sub-unit there is a long, narrow wetland that has been developed for stock watering. The upstream end of the wetland has been extended and bermed to allow storage for stock water. The downstream en rains to the channel near RM 4.7 and the confluence of Poorman Creek. Connection to the wetland could be enhanced by excavating the downstream end to make the feature passable during certain biologically significant flows.	
2b	Project RM 4.8L	Inner Zone 1 (IZ-1)	Reconnect Stream Channel Processes	LWD enhancement and side-channel reconnection	At this location, there is some natural LWD accumulation near the upstream inlets to several high flow channels across DIZ-1. LWD supplementation could encourage overbank flow into DIZ-1, re-establishing inner-zone processes, enhancing side-channel habitat, and supporting Project RM 4.55L.	 LWD jam on river left near RM 4.8. Enhancement of this LWD could encourage overbank flow into DIZ-1, as well as improve pool habitat (October 2009).
2b	Project RM 4.85C	Inner Zone 1 (IZ-1)	In-Stream Habitat Enhancement	LWD enhancement	There are several potential locations on both sides of the channel where placements of meander bend log jams can enhance in-stream habitat and re-establish natural geomorphic conditions	 Looking toward the southeast in the downstream direction where LWD placements on both sides of the channel could increase habitat quality and diversity (October 2009).
3a	Project RM 5.23L	Inner Zone 1 (IZ-1)	In-Stream Habitat Enhancement	LWD enhancement	There is an existing boulder step-pool and bedrock outcrop in the channel. The pool has good residual depth but lacks cover. This project entails placing a meander-bend LWD jam to increase the amount of cover and quality of habitat provided in this deep pool.	 View to the northeast in the downstream direction at a deep bedrock pool near RM 5.23 (October 2009).

Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo
3b	Project RM 5.45L	Inner Zone 3 (IZ-3)	In-Stream Habitat Enhancement	LWD enhancement	Similar to Project RM 5.7L, this is a location where an existing root mass and pool could be enhanced with a LWD meander-bend jam.	 View to the west in the upstream direction at an overhanging root mass on the left bank near RM 5.45 (October 2009).
3b	Project RM 5.5R	Inner Zone 3 (IZ-3)	Reconnect Stream Channel Processes	Side-channel reconnection	A high-flow channel between RM 5.4 and 5.6 appears to be inundated and scoured on an annual recurrence. This channel could be enhanced to provide side-channel habitat at a wider range of flows. LWD structures and select excavation would be used to provide low-flow access to the side-channel and to increased habitat complexity and quality.	 View to the east in the downstream direction at an active high-flow channel near RM 5.5 (October 2009).
3b	Project RM 5.55L	Outer Zone 2 (OZ-2)	Off-Channel Habitat Enhancement	Off-channel habitat enhancement	This project involves increasing the availability and connectivity of off-channel habitat. A low-flow channel could be created to connect floodplain wetlands to the main channel.	
3b	Project RM 5.7L	Inner Zone 3 (IZ-3)	In-Stream Habitat Enhancement	LWD enhancement	There is an existing overhanging root mass and scour pool at an outside bend. Placement of a LWD meander-bend log jam would increase cover, pool scour, and complexity. Planting of the riparian area should be a part of project work at this location.	 View to the north at the river-left bank near RM 5.7 (October 2009).

Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo
3b	Project RM 5.8L	Inner Zone 3 (IZ-3)	Reconnect Stream Channel Processes	Side-channel reconnection	This project involves enhancing the active side-channel and high-flow channels that have developed in the re-worked deposits of an alluvial fan between RM 5.7 and 5.9. LWD apex jams near the upstream end at RM 5.9 would enhance inundation of high-flow channels. Select excavation could be used to create a low flow side-channel. High-flow channel outlets could be enhanced to allow for habitat connection throughout the project area.	 View to the southeast in the downstream direction at the upstream inlet to a network of high flow channels located along river-left between RM 5.7 and 5.9 (October 2009).
3b	Project RM 5.9R	Disconnected Outer Zone 2 (DOZ-2)	Riparian Restoration	Riparian re-vegetation	There is only a narrow forested riparian buffer (10 – 50 ft wide) on river-right between RM 5.8 and RM 6.2. This project would involve reforestation of the riparian zone up to 100 feet (or greater if possible) from the channel. Address livestock access if it is an issue on this parcel.	
3b	Project RM 6.0C	Inner Zone 2 (IZ-2)	Reconnect Stream Channel Processes	LWD placement to enhance lateral dynamics	This location is just upstream of the transition from IZ-2 to IZ-3 where the channel width begins to expand and flow splits around a mid-channel bar. This project would involve placing LWD jams on point bars and mid-channel bar apexes to enhance split flow conditions.	 Downstream view to the east at an apex log jam on a mid-channel bar. LWD jams in this area would enhance lateral channel dynamics and improve habitat cover and complexity (October 2009).
3b	Project RM 6.08C	Inner Zone 2 (IZ-2)	Reconnect Stream Channel Processes	Bridge modification	The bridge at RM 6.08 creates a hydraulic constriction at high flows. An improvement of the bridge with a wider span could alleviate hydraulic effects of increased energy in the channel during high flows.	 View to the east in the downstream direction at a bridge crossing near RM 6.08. As stage increases, the bridge becomes a hydraulic constriction (October 2009).

Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo	
3b	Project RM 6.18R	Inner Zone 2 (IZ-2)	In-Stream Habitat Enhancement	LWD enhancement	At this location an existing root mass creates an area of cover along the river-right. A lateral meander-bend LWD jam on the river-right bank could enhance the existing habitat and encourage pool scour.		View to south at the right bank of the channel near RM 6.18. The undercut root mass could be enhanced to provide increased habitat quality and enhance inner-zone processes (October 2009).
3b	Project RM 6.3L	Disconnected Outer Zone 1 (DOZ-1)	Off-Channel Habitat Enhancement	Wetland habitat enhancement	This project is described in the DIZ-1 sub-unit summary, but also involves habitat found in DOZ-1. There are wetlands in DOZ-1 that would provide valuable off-channel habitat if access were created. As part of Project RM 6.65L, surface connection between inner-zone side-channels and outer-zone off channel habitat could be enhanced. This would require some excavation to create channels providing low-flow pathways.		Floodplain wetlands located in DOZ-1 that could be re-connected to inner-zone processes and habitat (October 2009).
3b	Project RM 6.35R	Inner Zone 1 (IZ-1)	Reconnect Stream Channel Processes	Levee removal and side-channel reconnection	This project involves reconnecting the two main areas of side-channel habitat in this sub-unit. Both side-channels are located on river-right. The upstream side-channel is centered on RM 6.5; the downstream side-channel is centered on RM 6.25. A narrow high flow channel runs along the toe of the hillslope and connects the two side-channels. This connecting channel is being as an irrigation diversion. As part of the project, the diversion would be re-engineered to re-connect the upstream side-channel to inner–zone processes and habitat. A levee blocks the downstream side-channel. This levee would be removed to promote reconnection of inner-zone processes		View to the southwest in the upstream direction at the diversion dam near RM 6.51. Removal of the dam would enhance side-channel habitat (October 2009).
3b	Project RM 6.65L	Disconnected Inner Zone 1 (DIZ-1)	Reconnect Stream Channel Processes	Levee removal and side-channel reconnection	This project would involve levee removal between RM 6.6 and 6.65. The levee currently blocks one large side-channel and several smaller high flow channels across the inside of a meander bend). Removal of the levee would re-establish active inner zone processes in the sub-unit. Excavation at the upstream end of the primary side-channel could provide side-channel habitat at all flow levels. LWD jams could be used to push flow into the high-flow channel network. Once this inner-zone sub-unit is reconnected, it becomes possible to provide access to off-channel habitat in DOZ-1. Coordination with ongoing restoration efforts would be necessary.		View to the southeast in the downstream direction at a push-up levee near RM 6.4. The levee has been breached / lowered as part of an enhancement project (October 2009).

Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo
3b	Project RM 6.7L	Inner Zone 1 (IZ-1)	Reconnect Stream Channel Processes	Riprap modification	A short length of bank has been protected with riprap adjacent to new residential construction. The riprap could be replaced or enhanced with LWD jams to provide commensurate protection as well as provide enhanced channel habitat.	 View to the north in the downstream direction at a short section of riprap that could be enhanced with LWD (October 2009).
3c	Project RM 6.8L	Inner Zone 2 (IZ-2)	Reconnect Stream Channel Processes	Re-establish channel LWD dynamics	This site consists of a left-bank high-flow side channel between RM 6.78 and 6.8. Placement of bar apex jams at this location would enhance lateral channel dynamics and side-channel activation at lower flows.	 View to the east in the downstream direction at a high-flow side-channel near RM 6.8 (October 2009).
3c	Project RM 6.89R	Inner Zone 2 (IZ-2)	In-Stream Habitat Enhancement	LWD enhancement	There is another good location for LWD enhancement on river-left at RM 6.89. Construction of a meander-bend log jam would increase pool scour, cover, and habitat complexity.	 View to the north at river-left near RM 6.89 where LWD would enhance in-channel habitat (October 2009).
3c	Project RM 6.95R	Inner Zone 2 (IZ-2)	In-Stream Habitat Enhancement	LWD enhancement	This project opportunity involves placement of LWD along the margins of an existing bedrock pool to increase habitat cover and complexity.	 View to the southeast in the downstream direction at a potential LWD placement location along river-right near RM 6.95 (October 2009).

Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo
3c	Project RM 7.05L	Inner Zone 2 (IZ-2)	Reconnect Stream Channel Processes	Riprap modification	There are approximately 200 feet of riprap along the river-left bank between RM 7 and 7.1. The riprap could be modified through removal and replacement with LWD meander-bend jams that would enhance habitat while also providing bank protection. Alternatively, the riprap could be modified in situ through incorporation of LWD to provide habitat cover and complexity.	 View to the east in the downstream direction at riprap along the river-left bank near RM 7.05 (October 2009).
3c	Project RM 7.15L	Disconnected Inner Zone 1 (DIZ-1)	Off-Channel Habitat Enhancement	Off-channel habitat enhancement	The oxbow wetlands in this sub-unit provide the potential for valuable habitat that is rare in Reach T3c. This project would re-establish/enhance the connection between the wetlands and main channel habitats while maintaining protection of the irrigation diversion, fisheries facilities, and residential access. Improved culverts at the upstream road crossing could provide a stronger high-flow connection with the main channel. Culverts under the access road are either completely overgrown or non-existent. The downstream outlet could be enhanced to ensure low flow fish access to the ponds.	 Oxbow pond located near RM 7.15 that provides valuable, although largely disconnected, off-channel habitat (October 2009).
3c	Project RM 7.15R	Inner Zone 2 (IZ-2)	In-Stream Habitat Enhancement	LWD enhancement	This location is just downstream of the bridge crossing at RM 7.15. Installation of LWD would enhance cover and habitat along the right bank. Currently, the bank is protected with riprap and large alluvial material. LWD would increase pool scour, cover, and habitat complexity.	 View to the west in the upstream direction at a potential LWD jam location along river-right near RM 7.15 (October 2009).
3c	Project RM 7.3L	Disconnected Inner Zone 1 (DIZ-1)	Reconnect Stream Channel Processes	Levee removal	This project involves removing 150 ft of push-up levee that has been constructed out of local alluvium. The levee may provide some protection for the TVIP canal. The levee could be set-back to provide more direct protection to the canal while re-connecting inner zone processes.	

Reach	Project Number	Sub-Unit	Strategy Category	Project Name	Description	Photo	
3c	Project RM 7.5L	Inner Zone 1 (IZ-1)	Reconnect Stream Channel Processes	Re-establish channel LWD dynamics	There are several LWD jams along the banks and at island apexes near RM 7.5 in the north split-channel. This project would enhance existing and create new jams to enhance active channel dynamics including split-flow and pool scour.		View the east in the downstream direction near RM 7.5 (October 2009).
3c	Project RM 7.5R	Inner Zone 1 (IZ-1)	In-Stream Habitat Enhancement	LWD enhancement	This project involves constructing a LWD jam along the right bank of the south split-channel near RM 7.5. The location is in a backwater just upstream of a riffle crest where the grade breaks and steepens. LWD would provide cover in the pool and increase local habitat complexity.		View to the east in the downstream direction at a potential LWD jam location along river-right near RM 7.5 (October 2009).
3c	Project RM 7.6L	Inner Zone 1 (IZ-1)	Reconnect Floodplain Processes	Levee removal	An older push-up levee starts at the edge of the active channel near RM 7.58 and extends about 190 ft. along the inner/outer-zone margin. Removal of the levee would enhance floodplain connectivity to DOZ-1. Appliances have also been dumped in this area and could be removed as part of enhancement work.		View of an older, vegetated push-up levee near RM 7.6 that could be removed to re-connect channel/floodplain processes (October 2009).
3c	Project RM 7.7R	Inner Zone 1 (IZ-1)	In-Stream Habitat Enhancement	LWD alcove enhancement	This project involves placing LWD along river-right near RM 7.7. The placement is in a backwater just upstream of a break in slope where the channel steepens. Some large trees have been cut down and cleared along the stream edge. Installing LWD could replace some of the bank stability and habitat complexity lost by the riparian clearing.		View to the northeast in the downstream direction at a potential LWD structure location along river-right near RM 7.7 (October 2009).