LOWER LIBBY CREEK
REACH ASSESSMENT

Prepared for **YAKAMA NATION FISHERIES** | PO BOX 15, FORT ROAD | TOPPENISH, WA 98948

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July 2012

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1 INTRODUCTION

1.1 Purpose

This assessment evaluates geomorphic processes and aquatic habitat conditions in the lower 1.4 miles of Libby Creek and identifies strategies to restore and preserve salmonid habitat and natural river processes. Libby Creek supports populations of salmonids that are currently listed under the Endangered Species Act (ESA), including Upper Columbia River summer steelhead and a small population of spring Chinook salmon. Habitat for these species has been impacted by anthropogenic activities throughout the basin.

Specific goals of this assessment include:

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

1.2 Study Area

Libby Creek is a tributary of the Methow River, joining the Methow River at River Mile (RM) 26.5 near the town of Carlton, WA. Libby Creek is a third-order stream that drains a watershed of approximately 40 square miles. The headwaters of Libby Creek are found in adjacent lakes on Hoodoo Peak in the Lake Chelan-Sawtooth Wilderness. See Figure 1 for a locator map of the basin and the study area for this reach assessment.

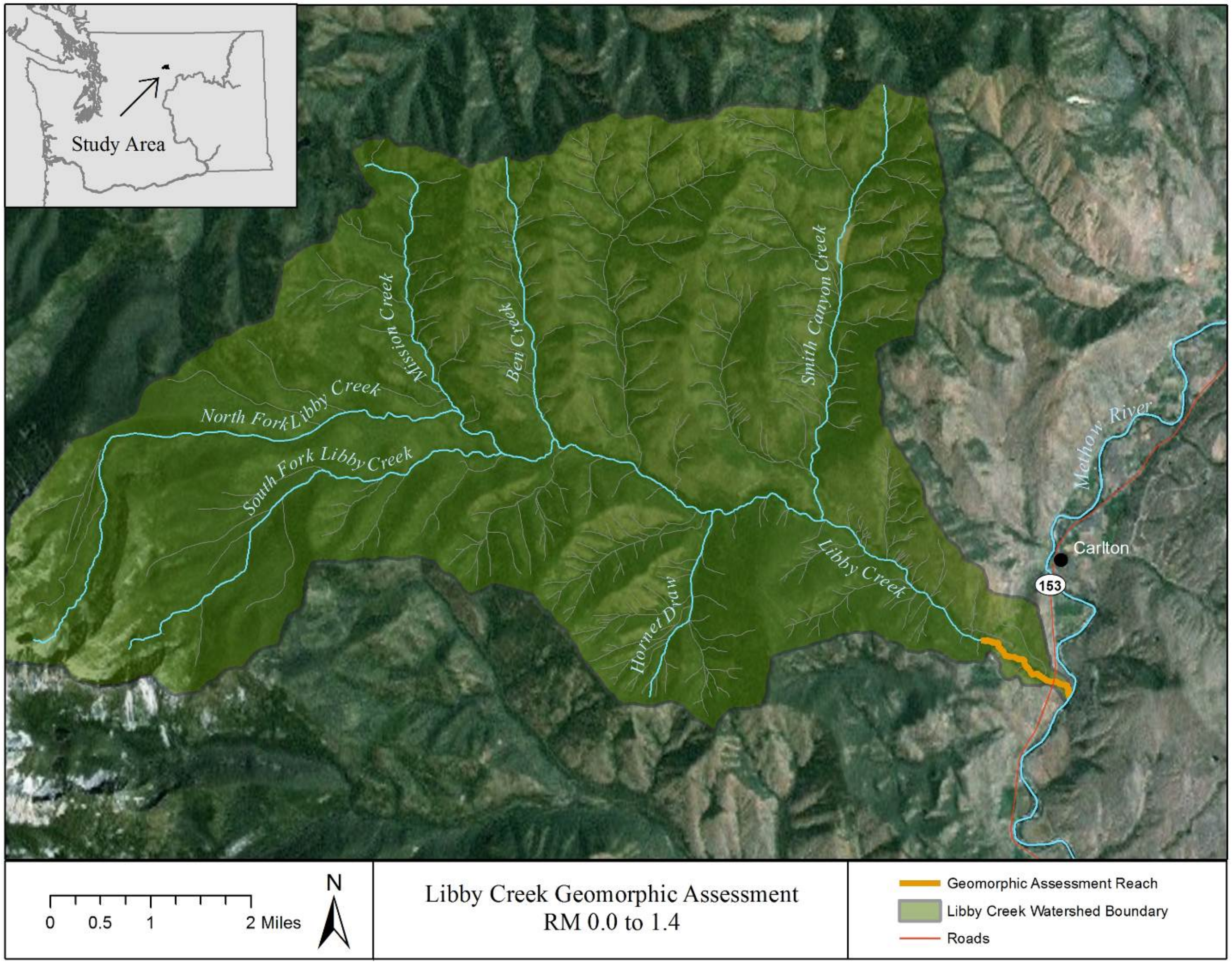

Figure 1. Lower Libby Creek Study Area. The Reach Assessment study area extends from RM 0.0 to RM 1.4.

1.3 Recovery Planning Context

Upper Columbia spring Chinook salmon are listed as Endangered and upper Columbia River steelhead and bull trout are listed as Threatened under the ESA. 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 “H” categories that affect salmon throughout their life history; namely Harvest, Hatchery, Hydropower, and Habitat. This Libby Creek Reach Assessment and its restoration strategies help to address the Habitat component of the Recovery Plan, with a focus on the lower 1.4 miles of the Libby Creek corridor.

The following habitat restoration and preservation objectives were set forth in the Recovery Plan. These objectives apply to spring Chinook, steelhead, and bull trout habitat and are consistent with the Methow 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 Habitat Recovery Actions for the Libby Creek/Gold Creek Basins (UCSRB 2007). These objectives and actions provided a framework and guidance for this Reach Assessment.

Short-Term Regional Objectives

- Protect existing areas where high ecological integrity and natural ecosystem processes persist.
- Restore connectivity (access) throughout the historical range where feasible and practical for each listed species.
- Protect and restore water quality where feasible and practical within natural constraints.
- Increase habitat diversity in the short term by adding instream structures (e.g. large wood, boulders) where appropriate.
- Protect and restore riparian habitat along spawning and rearing streams and identify long-term opportunities for riparian habitat enhancement.
- Protect and restore floodplain function and reconnection, off-channel habitat, and channel migration processes where appropriate and identify long-term opportunities for enhancing these conditions.
- Restore natural sediment delivery processes by improving road networks, restoring natural floodplain connectivity, riparian health, natural bank erosion, and wood recruitment.

Long-Term Regional Objectives

- Protect areas with high ecological integrity and natural ecosystem processes.
- Maintain connectivity through the range of the listed species where feasible and practical.

Habitat Recovery Actions Specific to the Gold and Libby Creek Basins

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

2 METHODS

2.1 Geomorphic Assessment

The geomorphic assessment included the mapping of geomorphic features and the characterization of channel and floodplain processes throughout the study area. The geomorphic assessment utilized a combination of field surveys, aerial photographs, topographic maps, and existing data, where available. Human alterations affecting habitat conditions, channel dynamics, and floodplain processes were identified and mapped. The following were evaluated as part of the geomorphic assessment: 1) sediment transport and response conditions, 2) channel incision and channel evolution trends (erosion and stability), 3) substrate types, distribution, and availability, 4) influence and role of large woody debris, 5) floodplain, channel migration zone, and habitat connectivity, 6) surface and subsurface flow interactions, 7) influence of past and current human structures and activities, and 8) interaction of the stream with riparian ecological processes.

Geomorphic conditions were characterized at the reach as well as subunit scales. Reaches were delineated based on dominant underlying geology, channel gradient, valley confinement, and channel type. Reaches were initially delineated using aerial photographs and topographical maps; appropriate reach divisions were confirmed during the field surveys.

The reaches were further divided into “subunits”, which consist of distinct channel or floodplain units such as an individual floodplain terrace. This scale of analysis is useful for understanding the influence of specific human alterations on geomorphic processes and provides a basis for the identification of site-specific restoration opportunities. Each subunit is mapped and is given a designation based on whether it is located within a segment of active channel, referred to as an “inner zone (IZ),” or if it is located within the floodplain, referred to as an “outer zone (OZ)”.

The patterns and processes at work at the subunit scale are described, and are used to inform the project identification and prioritization process.

An inner zone subunit is defined as the wetted low-flow channel and all related areas that annually experience ground-disturbing flow (e.g. secondary channels and active bars). An outer zone subunit is defined as the low-lying area adjacent to the channel that may become inundated at higher flow but does not normally experience ground disturbing flow (USBR 2009a). Inner zone subunits were delineated using breaks in geomorphic control such as bedrock constrictions, changes in geomorphic patterns (e.g. step-pool to riffle-run), or roadways that result in variations in channel pattern and channel type. Outer zone subunits were delineated as discrete floodplain areas separated by natural breaks, variation in the dominant ecology, or anthropogenic barriers.

Inner and outer zones may further be designated as “disconnected”, denoted with a “D” before the IZ (inner zone) or OZ (outer zone) identifier. A designation of “disconnected” indicates that a zone’s historical pattern and processes have been severed due to anthropogenic alterations. An example of a disconnected inner zone is an area of active channel that has been blocked by a levee. 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.

2.2 Stream Habitat Assessment

A habitat assessment was conducted on lower Libby Creek in 2011 using the US Forest Service (USFS) Level II stream habitat survey protocol. Results of this assessment are included in Appendix A. The habitat assessment included measurements of habitat unit type, channel dimensions, bed substrate, large wood, and riparian conditions. See Appendix A for complete methods and results of this assessment.

2.3 Identification of Project Opportunities

Potential project opportunities were identified through a combination of methods, including: 1) assessment of existing geomorphic conditions, 2) field surveys of project opportunities, and 3) remote sensing using aerial photography. Location information, general site conditions, and photographs were acquired for each project opportunity area. A summary of project opportunities for the entire study area is presented in Section 4. Project locations and types by reach are provided in the tables and maps for each reach description, in Section 5. Detailed project descriptions and site photos are included in the list of project opportunities (Appendix B).

2.4 Process-based Restoration Strategy

Restoration and preservation activities are identified and 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). As illustrated by Figure 2, the framework used in this assessment emphasizes preservation and process-based restoration as the highest priority, followed by habitat enhancement and stabilization.

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. (2010).

All of the projects identified within this assessment are categorized by project type. The project types are included below with a brief description and examples for each type. Each project type is explained in detail below and is listed in priority order based on the hierarchical strategy described in Figure 2. Project priorities are based on geomorphic analysis and do not account for feasibility considerations (e.g. landowner permissions, access).

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.

<u>Reconnect Stream Channel Processes.</u> 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 riprap 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 large wood jam where wood recruitment rates have been reduced to promote active lateral channel dynamics, such as development of a multi-thread channel system.

<u>Reconnect Floodplain Processes.</u> 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 to enhance floodplain connectivity.
- Removal of floodplain infrastructure or fill that limits floodplain connectivity.

<u>Riparian Restoration.</u> Riparian restoration projects are located in areas where native riparian vegetation communities have been significantly impacted by anthropogenic activities such that riparian functions and connections with the stream are compromised. Restoration actions are focused on restoring native riparian vegetation communities in order to reestablish natural stream stability, stream shading, nutrient exchange, and large wood recruitment. Even though it is not 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 large wood jam).

Examples:

- Construction of a log-jam to increase in-channel habitat complexity.
- Placement of boulders or individual logs to increase cover and hiding habitat for juvenile salmonid rearing..

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 large wood cover and complexity in an existing off-channel area.

3 STUDY AREA CHARACTERIZATION

3.1 Setting

Libby Creek is a tributary to the Methow River and drains a watershed of approximately 40 square miles (25,000 acres). Libby Creek is located in Okanogan County in Northern Washington State, on the east side of the Cascade Mountains. Although the majority of the Libby Creek subbasin is within the Okanogan National Forest (~85%), the lower reach of the mainstem and the majority of streamside areas in the lower basin are privately owned.

Libby Creek is approximately 14 miles long and flows into the Lower Methow River along the right bank at Methow RM 26.5. The headwaters of the north and south forks of Libby Creek are found in adjacent lakes on Hoodoo Peak in the Lake Chelan-Sawtooth Wilderness. Libby Creek has six tributaries, three fish-bearing, and three that are non-fish-bearing. Fish-bearing streams include Smith Canyon (entering at the left bank at RM 3.33), Ben Creek (left bank at RM 6.5), and Mission Creek (left bank at RM 7.93). Non fish-bearing tributaries of Libby Creek include Hornet Draw (right bank at RM 4.6), Chicamun Canyon (left bank at RM 5.6), and Nickel Canyon (right bank at RM 7.2).

3.2 Salmonid Use and Population Status

Salmonid use of Lower Libby Creek includes spawning and rearing for Upper Columbia River summer steelhead and spring Chinook salmon. A single bull trout has been documented in Libby Creek (USFS 2010). Brook trout are also present in the basin; their removal is listed as a Tier 4 recommended habitat action in the Biological Strategy (UCRTT 2008). Life-stage usage and ESA status for each species relevant to Libby creek are summarized in Table 1.

Table 1. Species usage in Libby Creek. Adapted from the USFS Libby Creek Stream Survey Report (2010).

Species	ESA Status	Life Stages	
		High density or abundant use	**General use**
Summer steelhead	Threatened	Migration	Spawning Rearing
Spring Chinook	Endangered	Migration	Spawning Rearing
Bull trout*	Threatened	Unknown	Unknown
Brook trout	None	Stocked	Spawning, Rearing

* Only one Bull trout has been recorded in Libby Creek (captured by the USGS in 2005 (USFS 2010))

3.3 Habitat Conditions

*See Appendix A for a full description of habitat conditions in lower Libby Creek.

Habitat in Lower Libby Creek has been impacted by a number of historical and on-going land-use activities within the subbasin. These land use activities have directly impacted Libby Creek's instream habitat, riparian areas, floodplains, and the physical processes that create and maintain the habitat conditions to which aquatic species have adapted to over time.

Timber harvesting has reduced hydrologic regulation and increased fine sediment loads within the subbasin. Since 1963, eleven timber sales over a total area of 16,670 acres were harvested and sold. Approximately 10,000 of these acres were tractor logged which has led to soil compaction (USFS 1999c, Andonaegui 2000). A majority of the sediment in Libby Creek has been linked to the creation/presence of logging roads and slope failures induced by timber harvesting. The increase in sediment load was evidenced by a 1999 pebble count above this study area which found that 27% of stream substrate was fine sediments (USFS 1999a). Increases in fine sediments to a system can alter stream temperatures, diminish water quality, and make it difficult for juvenile salmonid species to find food.

Road building has altered the river corridor through bank armoring, vegetation clearing, installation of undersized culverts, and accelerated sediment delivery. Road density in the watershed is 2.1 miles/square mile and 4.6 miles/square mile in the riparian area. Nearly every stream in the Libby Creek basin is paralleled by a road. Riparian areas have been cleared along streams as part of residential development or agricultural land use.

Agricultural uses appear to have impacted floodplains and wetlands through grazing and vegetation clearing. Water withdrawals (see Section 3.5) from Libby Creek also may be impacting the stream's natural processes. Modeling of Libby Creek suggests that withdrawal rates may exceed late summer baseflows (August, September), but local residents indicate that the stream has remained wet year round for at least the past 10 years (USFS 2010, Methow Valley Water Pilot Planning Project Committee 1994). Three small riparian planting projects and a riparian fencing project to reduce livestock grazing were completed in 2010 on private property. Projects such as these are beneficial to habitat conservation.

Trapping and removal of beaver has had a major impact on the pattern and process of low gradient streams throughout the Methow Basin, including Libby Creek. Historically, beaver built numerous dams throughout streams in the Methow Basin (Methow Basin Planning Unit 2005, Knudsen 1962; Parker 1986). In addition to mimicking a step-pool geomorphic structure, these dams retain sediment, impound organic material, establish wetlands and bogs, alter nutrient cycling, and slow the hydrograph by storing water as groundwater, which is then slowly released back into the stream throughout the year (Naiman et al. 1988). Although some beaver activity was observed as part of this assessment, this activity is a fraction of historical beaver activity in the system. Areas where beaver activity was observed exhibited the most complex habitat, including gravel recruitment, deep pools, large wood for cover, and the development of point and mid-channel bars.

Specific conditions with respect to hydrology, geomorphology, and human alterations are discussed in the individual reach profile summaries in Section 5.

3.4 Hydrology

Hydrology in the Libby Creek watershed is driven by snowmelt, groundwater seeps, and precipitation. The high elevation headwaters of Libby Creek's North Fork provides consistent flows from snowpack for much of the spring and summer season. Flow from Libby Creek is also augmented by the entry of significant tributaries that include Smith Canyon (entering at RM 3.33), Hornet Draw (right bank at RM 4.6), Chicamun Canyon (left bank at RM 5.6), Ben Creek (left bank at RM 6.5), Mission Creek (left bank at RM 7.93), and Nickel Canyon (right bank at RM 7.2). There are also multiple unnamed ephemeral drainages that contribute to Libby Creek's flow.

Libby Creek's mean annual discharge is estimated at 15 cfs (Mullan et al. 1992). Summer baseflows in Libby Creek are estimated at 3 cfs (Mullan et al. 1992).

Table 2. Available Libby Creek Flow Measurements. Flow Data from 1992, 1998, and 2010 (adapted from USFS 2010)

Measurement Location	Date of Discharge Measurement	Flow	Corresponding flow at Methow River at Twisp Gage (USGS 12449500)
RM 0.1	September 10, 1992	2.4 cfs	238 cfs
RM 6.4	August 08, 1998	9.8 cfs	568 cfs
RM 6.4	July 30, 2010	11.2 cfs	1,050 cfs

At the time of the survey (September 2011), a scour line was observed at the low flow water surface elevation (i.e. an ordinary low water line). This indicates that Libby Creek's summer baseflow is very consistent between years, and suggests hydrology is driven by springs and/or snowpack. This was further supported by a secondary vegetation line (primarily mosses) and a well-defined cross-sectional area set within the channel's ordinary high water geometry.

3.5 Water Rights

The Libby Creek Watershed was adjudicated in the 1920s and has 776 acres listed as 'acres under rights' with monthly water rights listed as 17.37 cfs (USFS 1999b). This flow could potentially exceed modeled baseflows in August and September, but observations by local residents indicate that over the past 10 years Libby Creek stays wet all year round.

3.6 Geomorphology overview

Libby Creek flows through a semi-confined valley, incising into andesite, schist and historical alluvial terraces. The valley-wall confinement of Libby Creek increases in the upstream direction. Holocene-aged alluvium deposited by both Libby Creek and the Methow River frame much of lower Libby Creek. Initial reworking by Libby Creek of these deposits resulted in the

Holocene-aged alluvial fan that borders the lower 0.3 miles of the channel. Incision into the Holocene deposits has resulted in diverse sets of historical floodplain surfaces throughout the study area.

Evidence of channelization exists throughout the study area, although the creek increases in complexity in the upstream direction. Evidence of human-induced channelization is most prevalent in Reach 1. Within this portion of the study area, field observations indicate that natural incision has been accelerated by human activities. The accelerated incision throughout Libby Creek results from a combination of logging Libby Creek and its subbasins, building of roads along almost every major tributary, channelization through excavation and bank hardening, and the removal of beaver. In Reach 2, visible bedrock indicates that the creek has reached its grade control elevation. Localized accumulations of large wood and evidence of beaver activity have slowed the rate of incision by promoting gravel recruitment in Reach 2.

A summary of geomorphic and habitat conditions in Libby Creek can be found in Table 3, along with an overview map in Figure 3.

Table 3. Summary of geomorphic and habitat conditions among reaches in Lower Libby Creek.

	Metric	Reach One	Reach Two
Channel	River Miles	0.0 to 0.58	0.58 to 1.4
	Gradient	2.11%	2.95%
	Sinuosity	1.30	1.42
	Dominant Channel Morphology	Pool-riffle	Pool-riffle
	Average Bankful Width (ft)	22.6	31.6
Floodplain	Average Floodprone Width (ft)	174	205.7
	% Floodplain Disconnected*	95.8%	79.7%
	% Floodplain Connected*	4.2%	20.3%
% Habitat Area	Pool	12%	11%
	Riffle	80%	80%
	Glide	8%	8%
	Side Channel	0%	1%

*for an explanation of what constitute a disconnected or connected floodplain see Section 2.1.

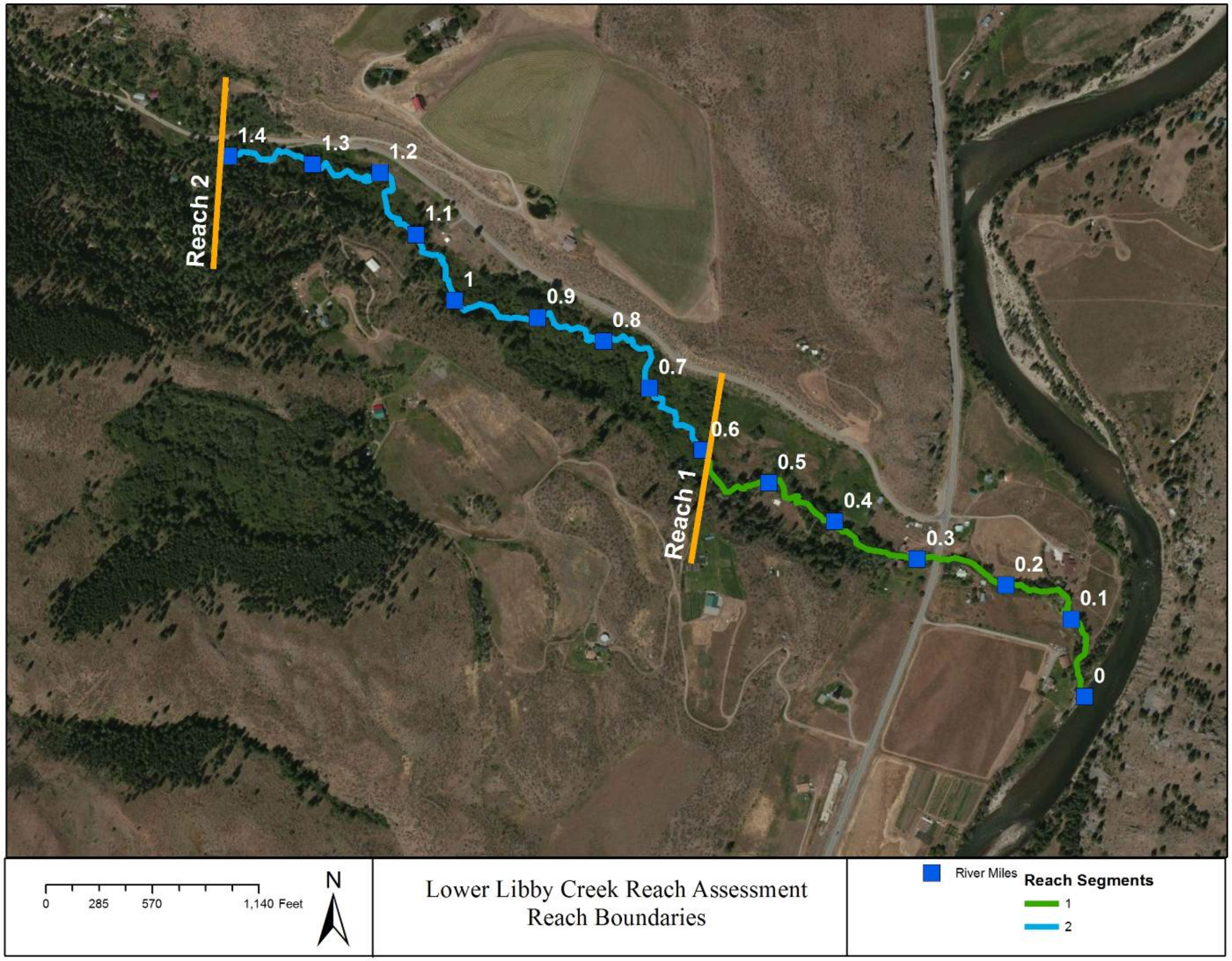

Figure 3. Reach delineation map for Libby Creek Study Area.

4 SUMMARY OF PROJECT OPPORTUNITIES

The restoration strategy and project opportunities for each reach are presented in Section 5 and in Appendix B. This section presents an overview and summary of the project opportunities for the entire study area.

This reach assessment identified twenty-three project opportunities in the lower 1.4 miles of Libby Creek. 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. The Protect and Maintain category is applied to any existing and connected floodplain, as functioning floodplain is extremely limited throughout the reach, and preventing any further degradation of current conditions should be prioritized. Further, all opportunities to protect, conserve, and monitor the river corridor should be investigated. The highest priority action, reconnecting stream channel processes, has the highest proportion of potential projects with eight potential opportunities. For Libby Creek, these projects primarily involve the removal of riprap or bridge abutments and the placement of complex large wood projects to promote floodplain development and aggradation. Instream habitat enhancement comprises the second largest proportion of project opportunities with seven potential projects. All of these projects involve placing smaller large wood complexes in the system. Re-establishing natural wood loading patterns will enhance the entire ecosystem over time through sustained formation of a wide variety of instream and off-channel habitats. Riparian restoration was the third ranking project type at four total projects. Reestablishing native riparian cover will reduce stream temperatures, provide future sources of large wood material, and increase channel roughness to regulate channel hydraulics. Two project opportunities are focused on reconnecting floodplain processes. This low number is due to the significant disconnection of Libby Creek from historical floodplain surfaces and limited opportunities for floodplain reconnection projects due to residential development.

Table 4 . Summary of projects identified for each reach in the study area.

Reach	Reconnect Stream Channel Processes	Reconnect Floodplain Processes	Riparian Restoration	Instream Habitat Enhancement	Off-Channel Habitat Enhancement	Totals
1	6	2	1	4	0	13
2	2	0	3	3	0	10

5 Reach Descriptions

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 in this study) is presented first, followed by the most upstream reach, Reach 2. Reach descriptions include an overview of geomorphology, floodplain condition, and anthropogenic influences operating within the reach. This information is followed by the reach-scale restoration strategy, which presents the bulk of the information in tabular format. Unlike reaches, subunits are numbered in the downstream direction. Thus, the furthest upstream subunits are presented first in alphabetical order by subunit type (DOZ, IZ, OZ) and subsequent summaries proceed in the downstream direction within a given reach. The subunit tables include a subunit description, the restoration strategy within the subunit, and a list of the project opportunities that fall within the subunit. 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 may also be included if a location has multiple distinct projects. Reference to river-left or river-right is always oriented facing the downstream direction.

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

Libby Creek was broken into two distinct reaches based on underlying geology and geomorphic observation. Reaches are designated from the downstream to upstream direction, with Reach 1 extending from the confluence of the Methow River (RM 0.0) to RM 0.58 and Reach 2 extending from RM 0.58 to RM 1.4. Figure 4 shows the reaches in the study area. The defining characteristics of each reach, and their geomorphology, floodplain condition, and extent of human alteration are described in detail in the subsequent sections.

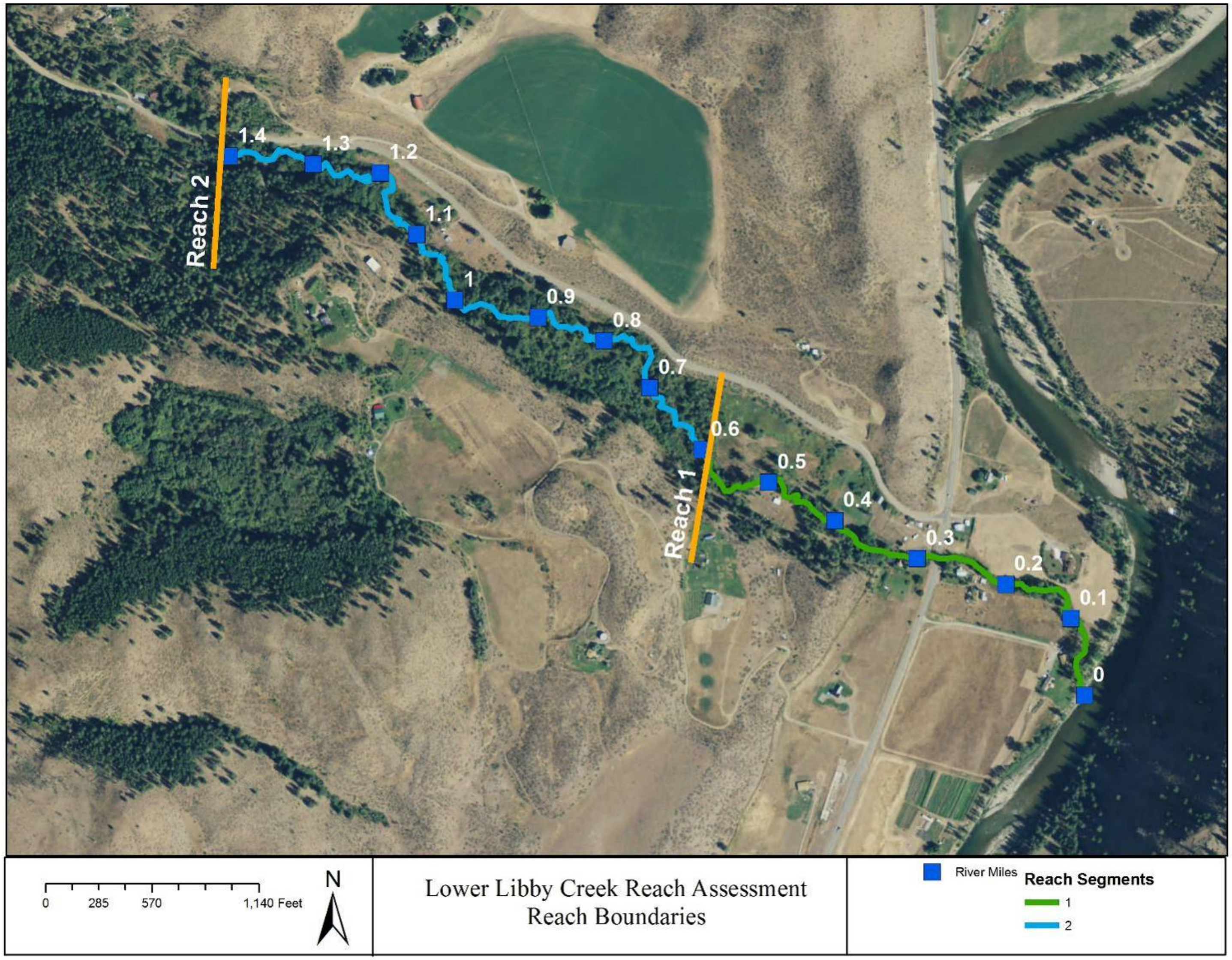

Figure 4. Libby Creek reaches and river mile stationing (RM 0.0 to RM 1.4)

5.1 Reach 1

Reach Overview

Reach 1 is a semi-confined reach that extends 0.58 RM from the confluence of the Methow River. This reach is mostly inset into Holocene-aged alluvial deposits of the Methow River and Libby Creek. Field observation and historical information indicate that Libby Creek's entrenchment into the Holocene alluvial deposits is a natural geomorphic process that has been accelerated by anthropogenic activities. Incision into the historic alluvial fan and further human-induced channelization limits channel processes and mobility. Residential and agricultural development have further accelerated rates of incision. The bed morphology is largely riffle-glide and step-pool. Access to off-channel habitats is limited in Reach 1.

Geomorphology

Bed morphology throughout Reach 1 shifts between riffle-glide and step-pool. Bed substrate is dominated by gravels and cobbles with boulders scattered throughout the reach. The reach has a sinuosity of 1.30 and a gradient of 2.11%. Libby Creek has a modern steep small alluvial fan at its mouth where it enters the Methow River.

Modern channel form and substrate are greatly influenced by the historical alluvial terraces that Libby Creek is entrenched into. Natural incision into the terraces likely began as a result of changes in climate, hydraulic regime, and sediment supply of the early Holocene. Since that time Libby Creek has gradually and naturally lowered its bed elevation by incising into the historical alluvial deposits. Over the last 150 years Lower Libby Creek has been ditched and straightened (USDA 1999a, Andonaegui 2000), riparian vegetation has been altered, roads have been built adjacent to stream channels, and banks have been armored. Further, timber harvest of over 16,000 acres since the early 1960s (Andonaegui 2000) has likely altered the hydrologic regime by increasing flashy flows. Each of these alterations have reduced channel length, removed hydraulic roughness and increased bed shear -- all of which promote incision. Evidence of incision is based on field investigations of the modern geomorphic processes of the channel. The exact influence of anthropogenic activities on incision rates is not known for this reach. Determining modern incision rates will require an analysis of sediment transport competence and effective discharge.

Despite anthropogenic influences on the study area localized rates of incision have appeared to have slowed enough for development of small modern floodplain surfaces at the current base elevation. In the lower portion of Libby Creek reduced incision rates may be influenced by the abundance of relatively large sized substrate (cobbles and boulders) on the channel bed.

In Reach 1, channel gradient, lack of large wood, and anthropogenic channelization all prevent the recruitment of finer-grained sediment. This has led to excessive sediment transport, and although the rate of incision appears to have slowed, further bed incision remains a concern.

Lateral channel dynamics have been inhibited by the entrenchment of lower Libby Creek but not stopped, especially in the upper portion of Reach 1. The rate at which lateral migration occurs is dependent upon the bed and bank composition as well as riparian roughness. In areas were bank materials are easily erodible (e.g. unarmored gravels, lacking mature riparian vegetation) lateral migration will likely continue.

A short section of partial channel aggradation occurs at mid-reach. This is an expected result of upstream incision processes transporting scoured bed material downstream and depositing it. This process commonly occurs in degrading systems as a cyclic channel response.

Only minor wood inputs and accumulations were observed in this reach. Where these accumulations are present, the channel has responded with localized pool development, some sediment retention, reduced gradient, increased sinuosity, and increased complexity.

Floodplain

Connected modern floodplain areas account for 4.2% percent of the total Reach 1 subunit area. The connected floodplains that do exist are found in small, discrete pockets with the largest floodplain subunit spanning just 0.21 acres and the majority being below 0.05 acres. Floodplains and terraces near the river are mostly vegetated, with the exception of some areas along the left bank. Vegetation is dominated by cottonwood, willow, dogwood, and rose. Both the active floodplain and historical floodplain surface as well as the bordering terrace surfaces have been altered by human land use practices.

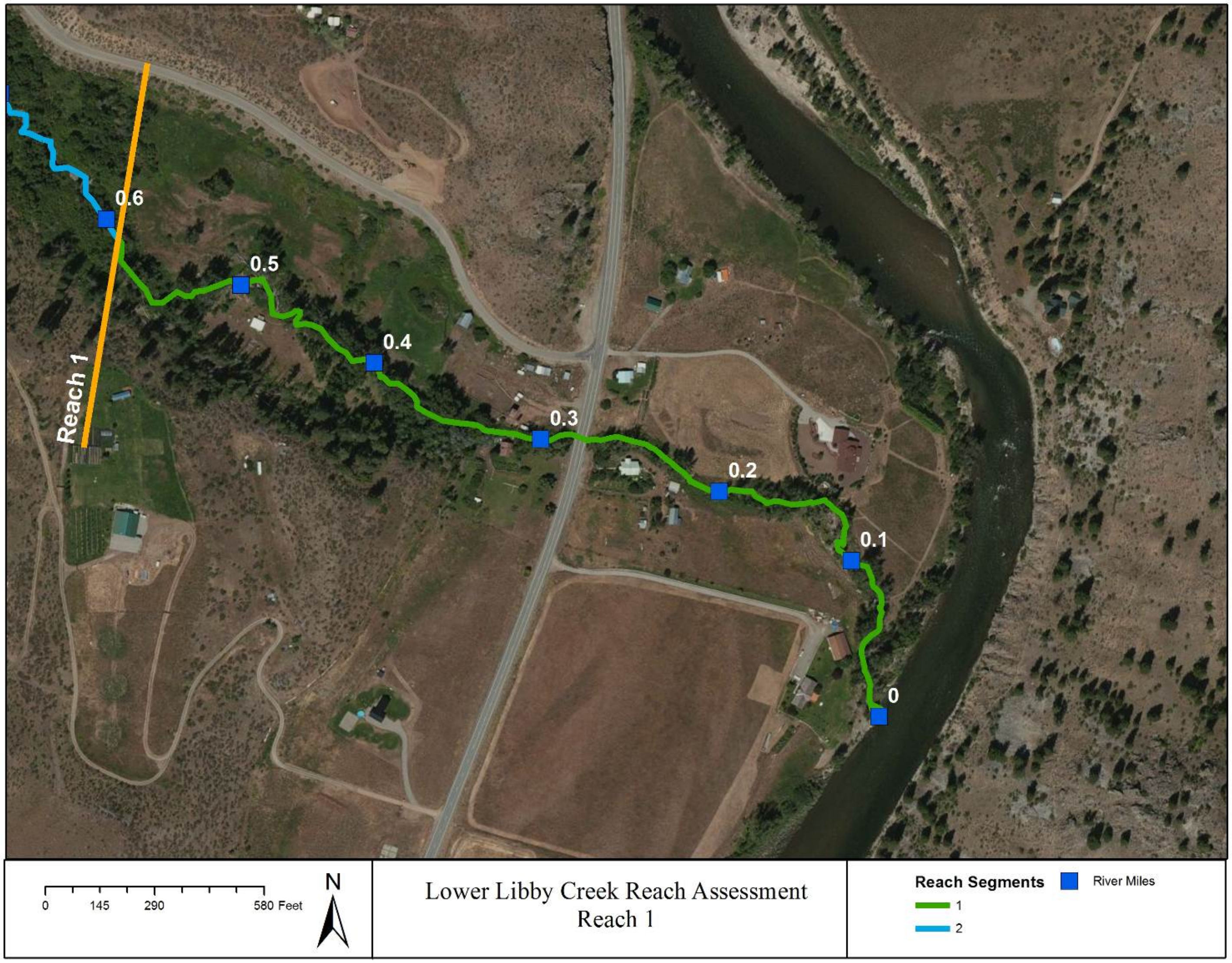

Figure 5. Reach 1 overview. Reach 1 extends from the confluence of Libby Creek and the Methow River (RM 0.0) upstream to RM 0.6.

Human Alterations

Anthropogenic influence on the river corridor is extensive throughout Reach 1. Limited residential development and agriculture is present throughout the reach along both banks, but historically the Creek has been channelized and basin-scale activities have accelerated incision processes. This development has resulted in floodplain alterations, instream alterations, and modifications to the riparian corridor. Each category is expanded upon below and distribution of these features is presented in Figure 8.

Floodplain Alterations

The most notable floodplain alteration is the lack of accessible floodplain surfaces, due to accelerated incision processes. Moderate residential development has taken place along both banks throughout the reach. This is low-density rural development and there have been limited additions of impervious surfaces. The development includes some grading of lawns and structures on historical floodplain surfaces.

Riparian Alterations

Riparian vegetation has been cleared or altered at multiple points throughout the reach. Metal mesh fencing has been placed around the base of larger trees (mostly cottonwood) throughout the lower portion of the reach, presumably to prevent beaver activity. This has prevented beaver from using riparian vegetation to build dams, which would provide valuable habitat complexity, recruit gravel substrate, and provide pool habitat.

Instream Alterations

There are multiple instream alterations present throughout Reach 1. Two of the most significant alterations within Reach 1 are a 42-ft long riprap wall that has been installed along the river left bank at RM 0.11 (Figure 6) and the Highway 153 bridge (Figure 7).

Figure 6. Riprap wall near RM 0.11. The top elevation is approximately 5.5 ft above OWH.

Figure 7. Highway 153 bridge facing upstream.

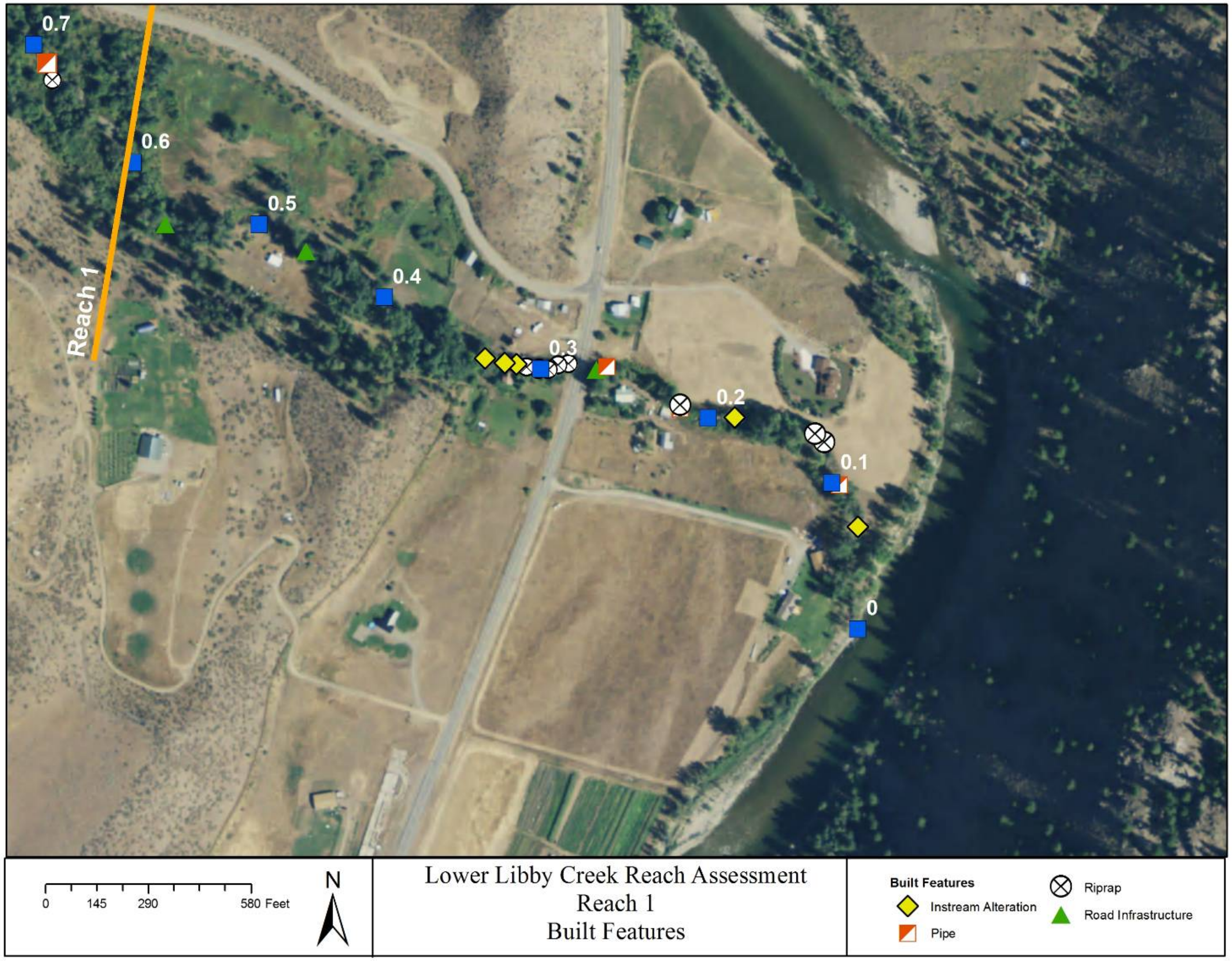

Figure 8. Human alterations in Reach 1.

Restoration Strategy Overview

This reach is largely confined, lacks access to the floodplain, and has minimal off-channel habitat. Opportunities to reduce incision processes and reconnect the channel with modern floodplain surfaces should be prioritized. Riprap should be removed throughout the reach and vegetated riparian buffers along developed areas should be restored and/or widened. Further, the lack of wood throughout the reach should be alleviated by the addition of small wood jams wherever possible. The addition of large wood will promote the development of pool habitat, provide hydraulic complexity, and will recruit spawning gravels.

Thirty six subunits were identified in Reach 1, including seven disconnected outer zones, sixteen inner zones, and thirteen outer zones (Table 5, Figure 9, and Figure 10). The majority (95.8%) of the river's historical floodplain surfaces have become disconnected through a combination of natural and human-accelerated incision of Libby Creek and riprap channelization. Connected outer zones are small, discrete floodplain pockets (less than 0.2 acres) that provide space for overland flow.

The restoration strategy for each subunit is presented in Table 5. Thirteen specific project opportunities that are included in Table 5 have been identified in this reach and are mapped in Figure 11 and Figure 12. Additional project detail is provided in Appendix B.

Table 5. Subunit scale restoration strategy for Reach 1. Individual projects are listed under their respective restoration strategy category. Additional detail on projects is included in Appendix B.

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
01-DOZ-01	DOZ	6.26	• This is an historical floodplain surface that has become abandoned from incision • Surface is mostly pasture used for grazing; Vegetation has been cleared and fencing has been installed • Surface extends from the top of bank to Libby Creek Road • Contains spring and small wetland pockets with patches of aspen groves and willow.	Reconnect Floodplain Processes • Project RM 0.41 - Floodplain Reconnection • Project RM 0.41 - Floodplain Reconnection
01-DOZ-02	DOZ	0.36	• This is a well-vegetated surface along the right bank • This is an historical floodplain surface that has become abandoned from incision • surface extends from the top of bank to the valley's confining hillslope • The DOZ is bisected by an ephemeral tributary that connects to Libby Creek	
01-DOZ-03	DOZ	1.85	• This is an historical floodplain surface that has become abandoned from incision • A residential trailer is located on river right at the upstream end • The boundaries of this subunit are marked by aspen and cottonwood	Reconnect Stream Channel Processes • Project RM 0.41 - Floodplain Reconnection • Project RM 0.41 - Floodplain Reconnection
01-DOZ-04	DOZ	0.37	• This is an historical floodplain surface that has become abandoned from incision • Banks are steeply sloping • Composed of cobble to sands • The land has been cleared for pasture and residential development • The downstream end of this unit is bounded by Highway 153	
01-DOZ-05	DOZ	0.63	• This is an historical floodplain surface that has become abandoned from incision • Alluvium of cobbles to sands are expansive along this DOZ	
01-DOZ-06	DOZ	2.89	• This is an alluvial terrace that has become abandoned from incision • Surface is a well-vegetate near channel margins; including aspen, rose, alder, and cottonwood	Riparian Restoration • Project RM 0.06 (Left Bank) - Riparian Restoration

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
			• The floodplain has been cleared for pasture • The surface appears to be inundated very rarely • Large rounded boulders and minor racked material are scattered across the surface	
01-DOZ-O7	DOZ	3.74	• This is an alluvial terrace that has become abandoned from incision • Surface is a well-vegetate; including aspen, rose, alder, and cottonwood near the channel margins • The floodplain has been cleared for pasture • The surface appears to be inundated very rarely • Contains multiple homesites, and is bisected by a private road	
01-IZ-01	IZ	0.08	• Step-pool channel morphology • Steps are been made of large boulders • Banks are well vegetated with a dense mix of cottonwood, alder, and willow • Small wood accumulations are evident on the channel margins, but are absent on floodplain surfaces • An ephemeral drainage joins the right bank but was not wetted on the date of the survey • One channel-spanning Large Wood jam was evident on the date of the survey and was accumulating gravels	
01-IZ-02	IZ	0.11	• a long straight riffle • minimal lateral migrating, but still maintains a gully-like appearance • The banks are largely cobbles at the base with gravel and sand at the top	
01-IZ-03	IZ	0.09	• This subunit is defined by a series of channel-spanning Large Wood jams that create a step-pool sequence • Inadequate riparian cover • Large Wood jams reduce channel gradient, add complexity, and raise the water table • Noticeably more gravel and sand throughout • Evidence of beaver activity throughout	Instream Habitat Enhancement • Project RM 0.15 - Large Wood Enhancement
01-IZ-04	IZ	0.05	• steep-pool sequence morphology with large boulder steps • Substrate ranges from large boulders to sands in pool	

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
			• Right bank vegetation is altered and has been thinned • Large Wood jam creates mid-channel complexity • Right bank is vertical; </= eight feet above channe l	
01-IZ-05	IZ	0.24	• Long extended riffles with short, small pools • Substrate is cobble to gravel • The banks are vertical but have dense riparian cover that offer good canopy cover • Channel is incised	
01-IZ-06	IZ	0.06	• A constructed step-pool sequence near a homesite • Right bank vegetation has been altered for residential development • One galvanized 4'' pipe and one 3'' plastic pipe spans the channel	Reconnect Stream Channel Processes • Project RM 0.33 - Transverse Bar Construction
01-IZ-07	IZ	0.11	• Step-pool morphology with boulder substrate • Confined by large boulder riprap and vertical banks • Downstream end is confined by Highway 153 Bridge	Reconnect Stream Channel Processes • Project RM 0.3 - Riprap removal & grade control
01-IZ-08	IZ	0.07	• Step-pool morphology with boulder steps • Upstream end is laterally confined by Highway 153 Bridge • Banks are composed of partially cemented conglomerate alluvium • Substrate has become armored throughout this IZ. This condition is likely caused by scour from the bridge constriction	Reconnect Stream Channel Processes • Project RM 0.29 - Replace Highway 153 Bridge
01-IZ-09	IZ	0.03	• Pool-riffle channel morphology • Substrate is dominated by sand ; less gravels as compared with upstream unit (IZ-08) • Thick overhanging vegetation throughout	Reconnect Stream Channel Processes • Project RM 0.21-C - Remove Channel Spanning Wood Bridge and Replace with Channel-spanning jam
01-IZ-10	IZ	0.07	• Riffle-glide channel morphology • Substrate is gravel to cobbles • Dense riparian canopy continues throughout • Floodplain connectivity has increased; some aggradation is visible throughout the left bank	Reconnect Stream Channel Processes • Project RM 0.12 – Remove Riprap
01-IZ-11	IZ	0.02	• This subunit is made up of a short cascade and step-pool sequence	

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
			• Steps are approximately 1- to 2-feet high • Substrate ranges from cobbles to very coarse sands • Limited connectivity to floodplain	
01-IZ-12	IZ	0.05	• Channel is narrow and flume-like through this stretch • High gradient riffle morphology • Banks are vertical and range from 1 to 2 feet • A deep pool is associated with a large downed cottonwood root wad, which is accumulating Large Wood material	
01-IZ-13	IZ	0.03	• Riffle-glide channel morphology • Lower gradient IZ than IZ-12 • Substrate ranges from cobbles to very coarse sands • The right bank is gradually sloping away from vertical	
01-IZ-14	IZ	0.07	• Step-pool channel morphology • Substrate is cobbles to small gravels • The channel lacks sinuosity through this IZ • Vertical banks (approximately 2' high) line the channel on both sides of the channel	
01-IZ-15	IZ	0.07	• Low gradient riffle-glide unit • Substrate is cobble to coarse sand • Gradual sloping banks	Instream Habitat Enhancement • Project RM 0.04 – Large wood enhancement
01-IZ-16	IZ	0.03	• Confluence of Libby Creek and Methow River • Channel flow has split into two short, steep riffles that flow out of an area dammed by beaver activity • Sediment (sand to cobble) is accumulating at the mouth and the toe of the fan is steeply sloped and drops 2 to 3 feet at approximately a 10% grade at the confluence • Willows have established along the toe of the fan	Instream Habitat Enhancement • Project RM 0.0 - Monitor and maintain fish passage at low flow
01-OZ-01	OZ	0.04	• This floodplain pocket appears to be regularly inundated • Evidence of fresh deposits of large wood and sand • Surface is composed of cobbles to sand	Protect & Maintain

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
			• Thick vegetative cover of cottonwood and alder	
01-OZ-02	OZ	0.01	• Small area of active floodplain • Surface is approximately 3 ft above channel invert • Dense vegetation that includes cottonwood and alder • Fresh sand deposits on the surface indicate recent deposition on this surface	Protect & Maintain
01-OZ-03	OZ	0.05	• Along the right bank of the channel this floodplain pocket appears to be regularly inundated • Evidence of fresh deposits of large wood and sand • Surface is composed of cobbles to sand • Thick vegetative cover of cottonwood and alder	Protect & Maintain Reconnect Floodplain Processes • Project RM 0.38 – Floodplain excavation and restoration
01-OZ-04	OZ	0.02	• Surface is composed of cobbles to sand • Thick vegetative cover of cottonwood and alder but inland portion has a small patch of blackberry and reed canary grass	Protect & Maintain
01-OZ-05	OZ	0.14	• Vegetated with horsetail, cottonwood, and dogwood • Evidence of fresh deposits of large wood and sand • Surface is composed of cobbles to sand • Wire fencing around base of larger trees to prevent beaver chewing • This unit is more aggradational than the units downstream	Protect & Maintain
01-OZ-06	OZ	0.21	• This is a low elevation surface • Evidence of fresh deposits of large wood and sand	Protect & Maintain
01-OZ-07	OZ	0.01	• Evidence of fresh deposits of large wood and sand • Surface is composed of cobbles to sand • Vegetation dominated by dogwood	Protect & Maintain
01-OZ-08	OZ	0.01	• This floodplain pocket appears to be regularly inundated • Evidence of fresh deposits of large wood and sand • Surface is composed of cobbles to boulders • Thick vegetative cover of cottonwood and alder	Protect & Maintain
01-OZ-09	OZ	0.03	• This is a low elevation surface (approximately 2 feet off of the channel) • Single log bridge lying across the floodplain that is accumulating wood	Protect & Maintain

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
01-OZ-10	OZ	0.03	• Deposition of cobbles to sands • Minor areas of gravel and cobble accumulation present • Recent scour evident on alluvial fan • Vegetation is primarily alder and cottonwood	Protect & Maintain
01-OZ-11	OZ	0.13	• Scouring evident • Riparian area vegetated with cottonwood • Entire area could not be surveyed because of landowner access restrictions	Protect & Maintain
01-OZ-12	OZ	0.02	• This is an alluvial fan near the confluence with the Methow River • Substrate is cobble to sand • Sparsely vegetated with willow • Dynamic surface evidenced by recent scouring flows (deposition of sands and large wood material)	Protect & Maintain

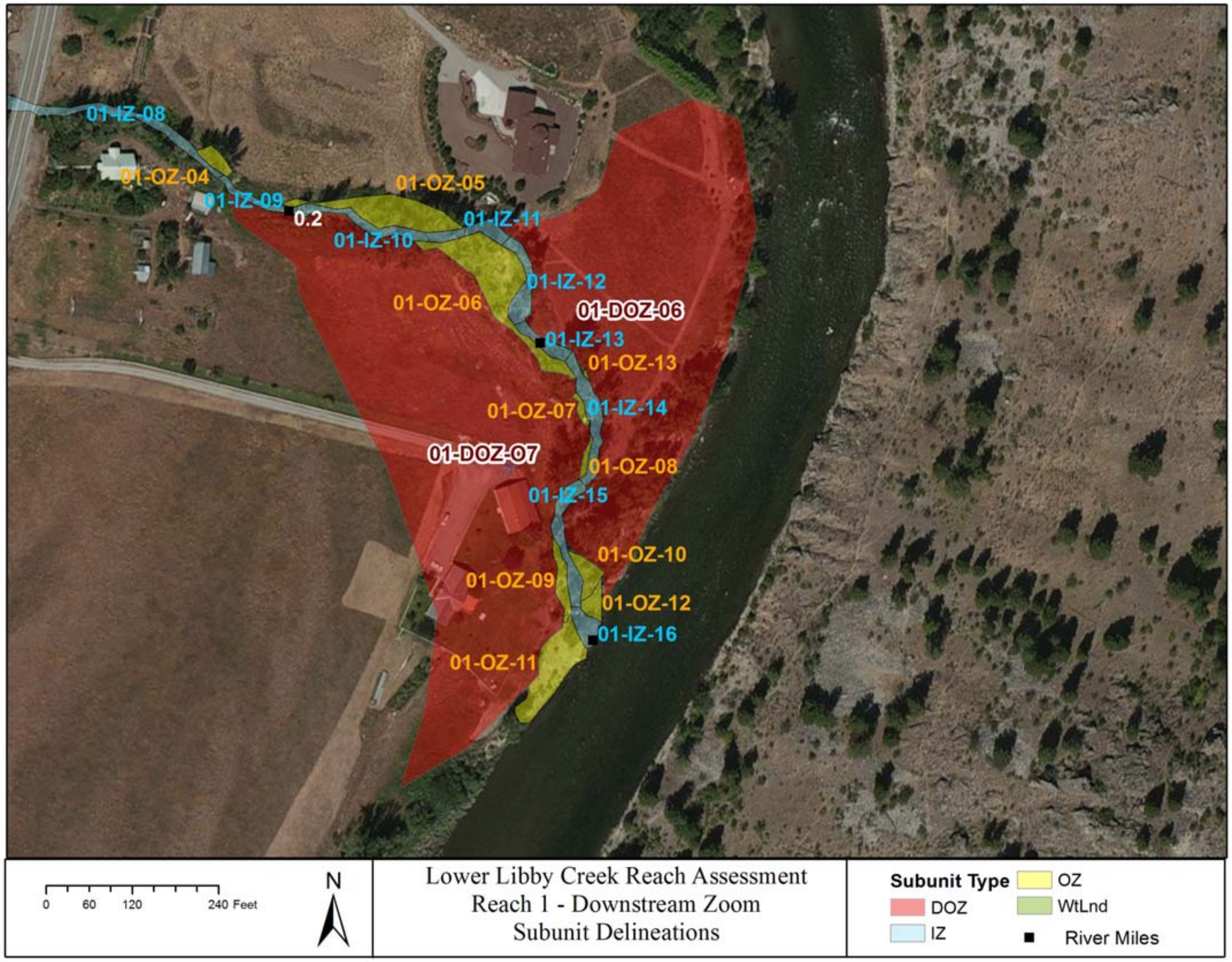

Figure 9. Subunit delineations in the downstream portion of Reach 1. Flow is from northwest to southeast.

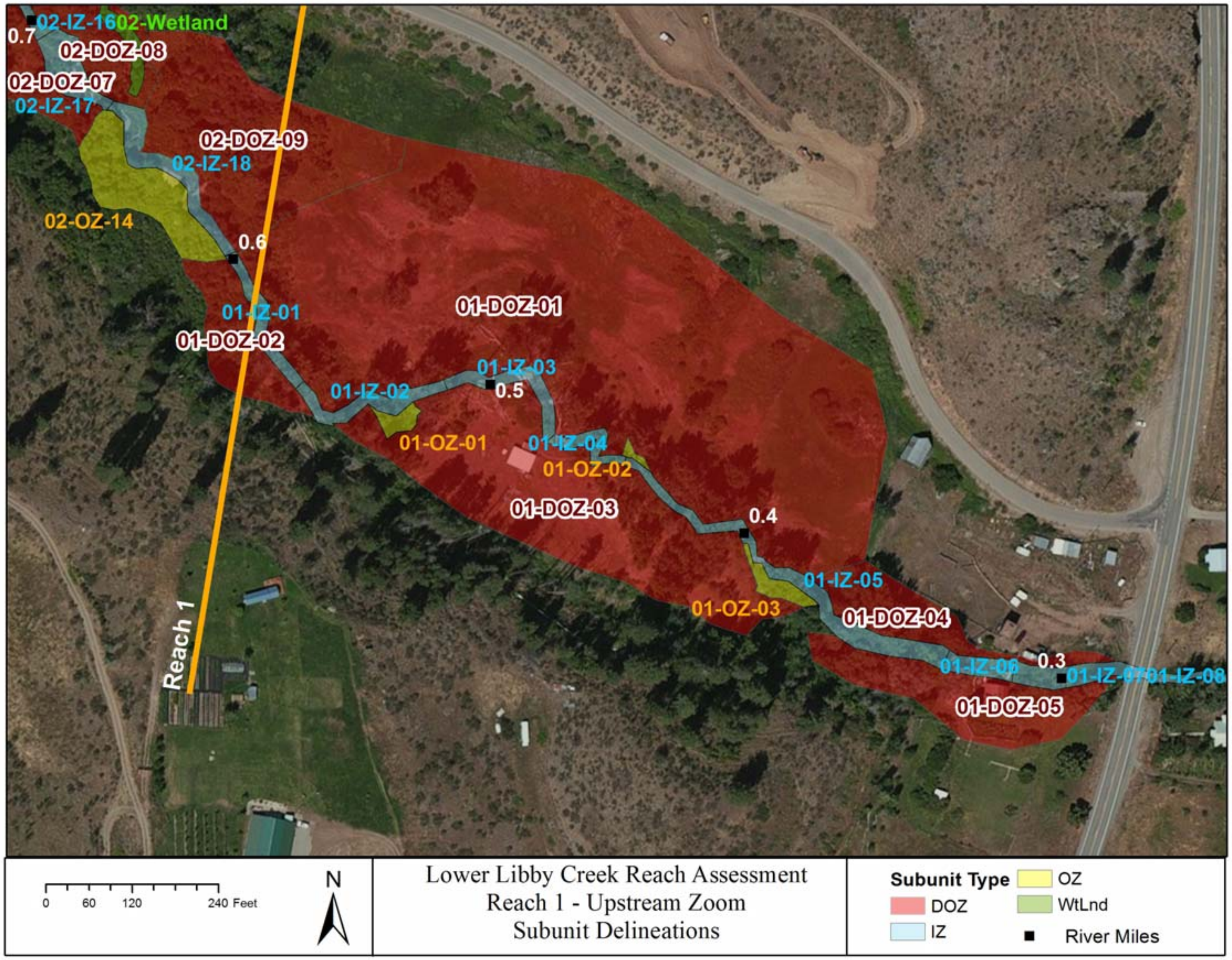

Figure 10. Subunit delineations in the upstream portion of Reach 1. Flow is from northwest to southeast.

Figure 11. Potential project locations in the downstream portion of Reach 1. Project photographs are provided for selected sites to illustrate the types of project opportunities that are available throughout the reach. Additional project detail is included in Appendix B.

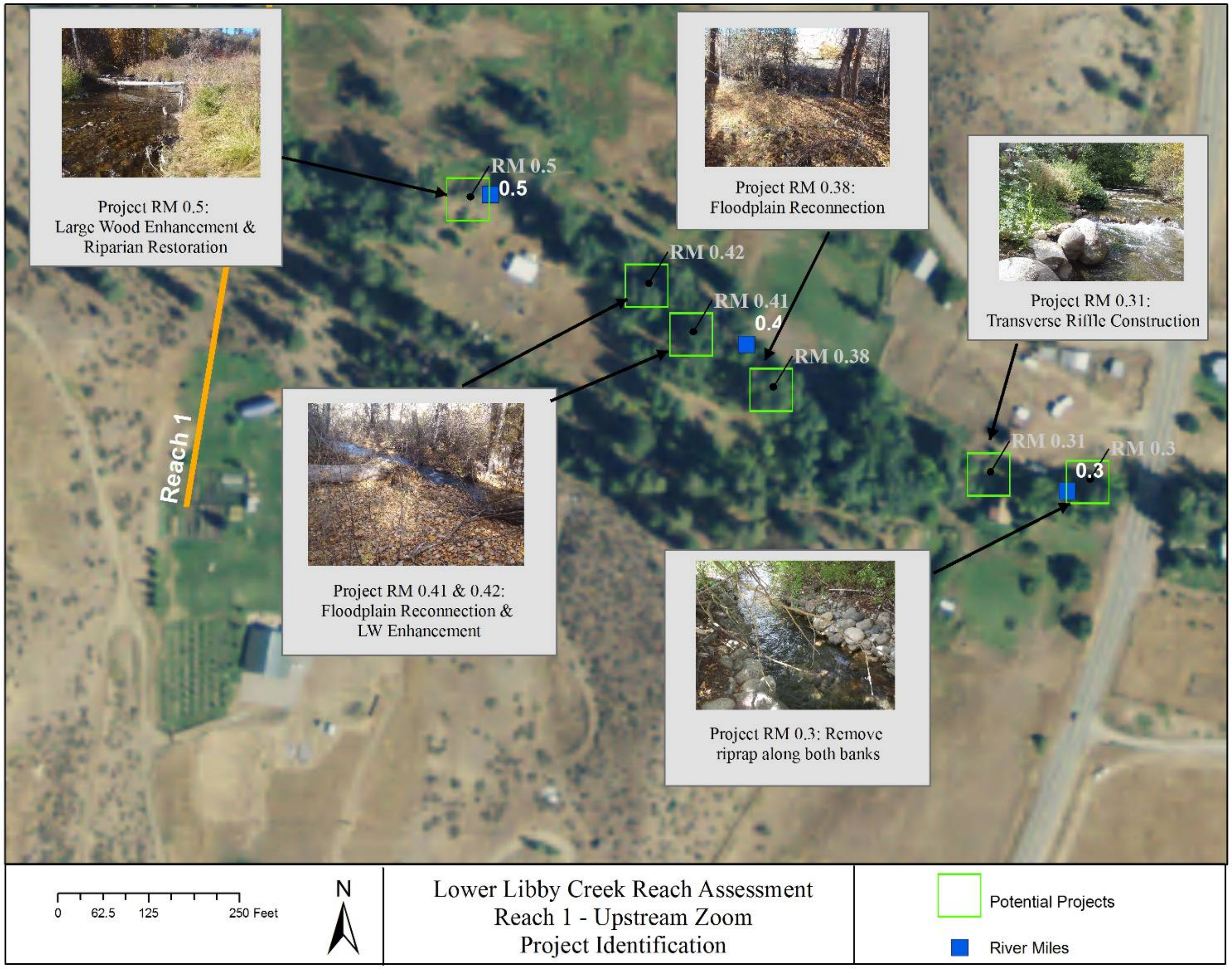

Figure 12. Potential project locations in the upstream portion of Reach 1. Additional project detail is included in Appendix B.

5.2 Reach 2

Reach Overview

Reach 2 begins at RM 0.58 and extends upstream to the end of the survey reach at River Mile 1.42 (RM 1.4). This section of Libby Creek has a slightly steeper gradient (increasing from 2.11% to 2.95%) than Reach 1 and enters into a semi-confined valley between Libby Creek Road (to the north of the channel) and a hillslope terrace (to the south of the channel). The sinuosity increased from 1.30 to 1.42, and the overall canopy cover increased compared to Reach 1.

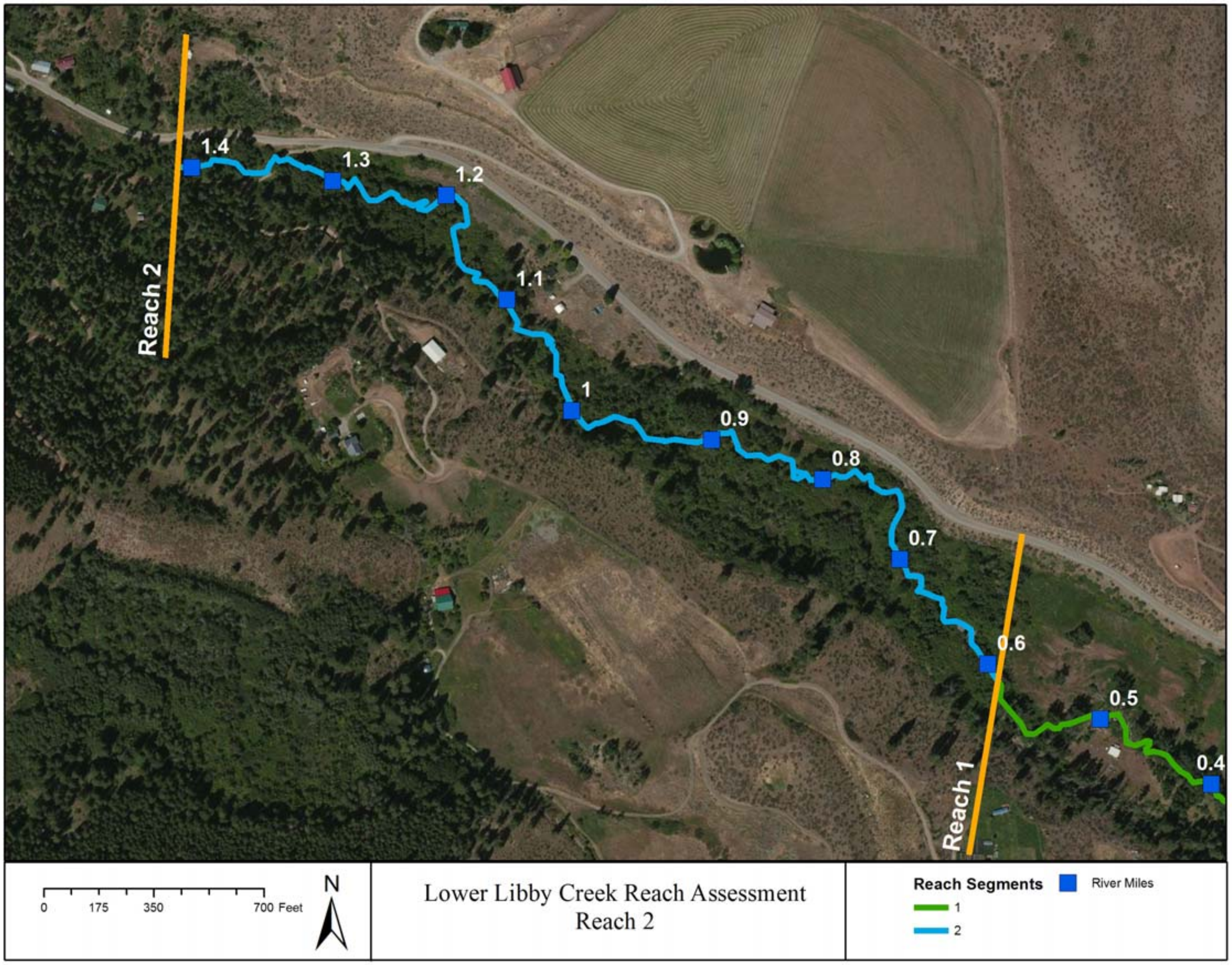

Figure 13. Reach 2 overview. Reach 2 extends from RM 0.58 upstream to RM 1.4.

Geomorphology

The channel through this reach is dominated by sequences of steep, extended riffles and pools. Smaller sequences of step-pools are interspersed throughout the reach. The lateral migration of the creek is constrained by Libby Creek Road to the north and the hillslope to the south. Bed substrate throughout this reach was predominantly gravels and cobbles, although boulders and sand were prevalent in the step-pool sequences.

The channel becomes increasingly complex throughout this reach. The channel transitions from incising to alternating sequences of aggradation and incision. This is evident from the development of point bars and mid-channel bars at aggradation sequences within the reach. This aggradation is most dominant in areas of beaver activity and large wood accumulation and is promoting localized areas of lateral migration within the channel. Large wood accumulations create complex step-pool sequences and reduce stream gradient, promote aggradation, increase complexity (both habitat and geomorphic), increase floodplain connections, and minimize incision.

Floodplain

As Libby Creek works to reestablish lateral migration inset within historical alluvial surfaces, it has formed new floodplain surfaces at its current incised channel elevation. These modern floodplain surfaces range from six to twelve feet below the historical floodplain surface at the creek's current baseflow elevation. Development of modern floodplain surfaces appears to be in areas of large wood accumulations. These large wood accumulations induce recruitment of gravels upon which vegetation establishes and a floodplain develops. In other locations, large wood has led to channel avulsion and the historical channel locations have subsequently become floodplain. This is evident in areas where even-aged alder stands have developed on inset floodplains in the upstream portions of Reach 2.

Floodplains and terraces near the river are mostly vegetated and vegetation is dominated by alder, cottonwood, willow, dogwood, and rose. Historical floodplain surfaces alternate between well-vegetated to pasture. A county owned property extends from RM 0.6 to RM 1.0 and provides forest cover along this abandoned terrace for 200 feet along the left and right banks. Conversely, segments of the historical floodplain surface up and downstream of this preserve have been cleared for residential development. This includes the removal of riparian canopy and apparent streamside grazing.

A 0.06-acre area of a perched spring bisects an historical floodplain surface (02-DOZ-01). This wetland complex runs along the base of the hillslope on river-left and is likely fed by groundwater and/or spring seeps. This is a functioning wetland system with cool standing water and a diverse mix of vegetation. The shape and inland terrace boundary of the wetland indicates that it is located in an abandoned channel.

Human Alterations

The current state of anthropogenic influence on the river corridor throughout Reach 2 is moderate. Large wood accumulations, bedrock control, and limited bank armoring have allowed the creek to generate increased complexity as compared with Reach 1. However, limited residential development and agriculture is present throughout the reach along both banks below RM 0.6 and upstream of RM 1.0. This development has resulted in floodplain alterations, instream alterations, and modifications to the riparian corridor. Each category is expanded upon below and distribution of these features is presented in Figure 14.

Floodplain

Similar to Reach 1, the most notable floodplain alteration is the disconnection of historical floodplain surfaces throughout the reach. Natural incision processes have been accelerated by human-induced activities such a timber harvest, road building, and beaver removal. As previously mentioned, upstream of RM 1.0 and downstream of RM 0.6, historical floodplain surfaces have been cleared and altered. These areas are primarily being used for grazing or low density rural development.

Riparian

Similar to Reach 1, riparian vegetation has been cleared or altered at multiple points throughout the reach. There are small segments where the riparian canopy has been completely removed.

Instream

At the downstream end of the reach, Libby Creek has been channelized and confined through riprap bank protection. This has accelerated incision throughout this portion of the channel. Humans have further modified the channel bed by constructing step-pools and digging out of areas of the channel bed. At the upstream end of the reach, riprap and bridge abutments confine the channel and there is evidence of channel incision. A private road continues from Libby Creek Road, over the bridge, and then along the right bank. The road fill confines the channel by limiting lateral migration.

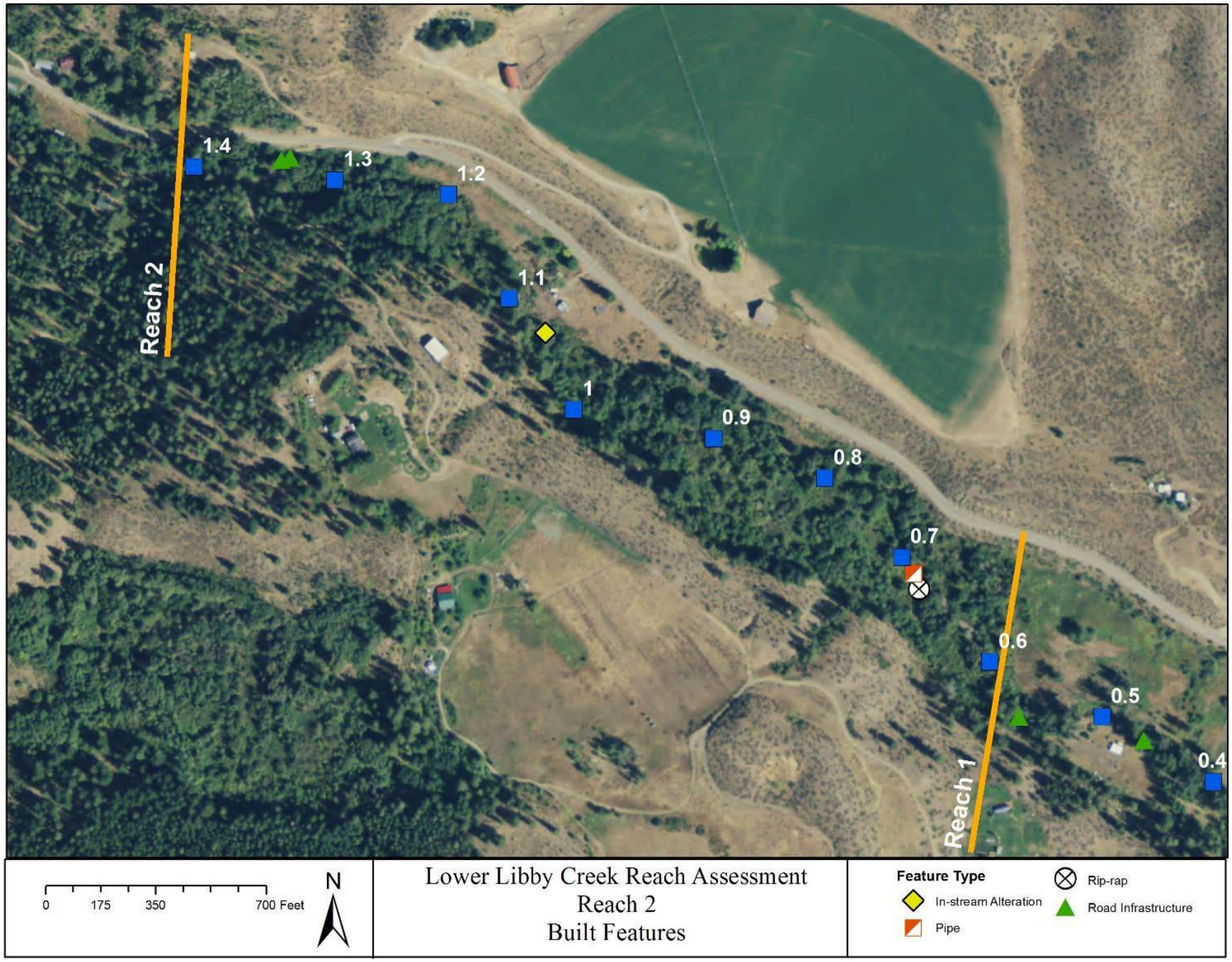

Figure 14. Aerial photo showing human features in Reach 2.

Restoration Strategy Overview

Overall, the geomorphic and habitat complexity is improved from Reach 1. Large wood accumulations are promoting lateral channel dynamics, pool scour, recruitment of gravels, and development of new floodplains at the creek's current baseflow elevation. Locations that lack large wood and habitat diversity within the reach should be alleviated through the addition of large wood to further encourage floodplain development and habitat diversity within the channel.

Forty-two subunits were identified in Reach 2, including nine disconnected outer zones, eighteen inner zones, and fourteen outer zones (Table 6, Figure 15, Figure 16). The majority of the historical floodplain is disconnected (80%), with only small, discrete active floodplain areas remaining. This current condition provides substantial opportunity for restoration and enhancement. The lack of active floodplain and off-channel habitat should be mitigated wherever possible.

The restoration strategy for each subunit is presented in Table 6. Eight specific project opportunities have been identified in this reach and these are included in the table and are mapped in Figure 17 and Figure 18. Additional project detail is provided in Appendix B.

Table 6. Subunit scale restoration strategy for Reach 2. Individual projects are listed under their respective restoration strategy category. Additional detail on projects is included in Appendix B.

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
02-DOZ-01	DOZ	0.12	• An historical floodplain surface that has become abandoned from incision and road construction • Vegetation has been altered by the construction of a gravel road; dust from the road is adding fines to the stream	Riparian Restoration • Project RM 0.62 - Riparian restoration (right bank)
02-DOZ-02	DOZ	0.37	• An historical floodplain surface that has become abandoned from incision • Very well vegetated	
02-DOZ-03	DOZ	0.44	• An historical floodplain surface that has become abandoned from incision • Very well vegetated	
02-DOZ-04	DOZ	0.80	• An historical floodplain surface that has become abandoned from incision and home construction • Anthropogenic activities have altered the streambank and riparian vegetation	
02-DOZ-05	DOZ	0.07	• An historical floodplain surface that has become abandoned from incision • Very well vegetated	
02-DOZ-06	DOZ	2.55	• An historical floodplain surface that has become abandoned from incision • Very well vegetated • Provides vegetated buffers to perched wetland	Protect & Maintain
02-DOZ-07	DOZ	2.99	• An historical floodplain surface that has become abandoned from incision • Very well vegetated	Riparian Restoration • Project RM 0.7 - Riparian Restoration
02-DOZ-08	DOZ	0.43	• Dominated by a well-functioning, but perched, spring-fed wetland complex. • Located in an abandoned channel on an historical floodplain surface • There is no evidence of recent inundation • No evidence of connection to the channel and the complex	Protect & Maintain

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
			is perched ~ 8 feet above the channel's surface at its downstream end • The water is cool and clear • Evidence of some beaver activity • Some fill has been deposited at the upstream end of the unit • Evidence of an old berm connected to a derelict culvert exists, likely used to drain the wetland historically • Dense vegetation exists throughout the unit including alder, dogwood, willow, aspen and emergent wetland vegetation • Provides vegetated buffer to perched wetland	
02-DOZ-09	DOZ	1.31	• An historical floodplain surface that has become abandoned from incision • Unit extends from top of bank to Libby Creek Road • Includes additional areas of perched wetland complex, which has become disconnected from the channel due to incision • The upstream portion of the unit has wetted areas that appear to be spring fed • Area has been cleared and leveled to be used as pasture	
02-IZ-01	IZ	0.05	• Subtle step-pool morphology • Substrate is small boulders and large cobbles • Vegetation is removed for a gravel road	
02-IZ-02	IZ	0.05	• Riffle-pool morphology • Sparse boulders to cobbles • Banks are well-vegetated • A few undercut banks are present throughout, providing small amounts of cover	Reconnect Stream Channel Processes • Project RM 1.35 - Bridge Replacement
02-IZ-03	IZ	0.07	• Riffle-pool morphology; with one cascade over large boulders • Substrate is cobbles with sparse boulders • Both banks through are well-vegetated and offer good canopy cover	Reconnect Stream Channel Processes • Project RM 1.35 - Bridge Replacement

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
02-IZ-04	IZ	0.04	• Riffle-pool morphology • Substrate is cobble to gravels • The right bank has been disconnected from incision • Two large wood material jams were present at the time of survey	
02-IZ-05	IZ	0.03	• Step-pool morphology; steps are defined by boulders • Substrate is boulders (steps) to sands (located in pools) • Small point bars are forming on the inside of meander bends, which is expanding the connected floodplain OZs (OZ-04, OZ-05) along both banks	
02-IZ-06	IZ	0.16	• Riffle-pool morphology • Substrate is cobbles with sparse gravels and sand • The right bank floodplain is connected, and the left bank slopes up sharply to an abandoned alluvial terrace approximately 3 feet above the channel's elevation • Both banks are well vegetated and provide excellent canopy cover • Deposition (of cobbles, gravels) on the inside of meander bends is more subtle than in IZ-05	Reconnect Stream Channel Processes • Project RM 1.18 - Large Wood Enhancement
02-IZ-07	IZ	0.07	• Cascade-pool morphology • Substrate of pools is cobles and gravels, banks are composed of cobbles and sand • Left bank (DOZ 04) has had vegetation cleared for residential development	
02-IZ-08	IZ	0.07	• Step-pool morphology; steps are a mix of cobbles and boulders • Canopy cover throughout is >90% • A secondary high-flow channel has formed through this IZ, at the time of survey it was not wetted, and was disconnected from a large material jam forming at divergence	
02-IZ-09	IZ	0.04	• Step-pools morphology created by Large Wood jams • Substrate is primarily sand, with large cobbles and sparse	

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
			gravels • Both banks throughout are well-vegetated with dense overhanging vegetation that offers good canopy cover	
02-IZ-10	IZ	0.05	• High gradient riffles morphology with short, intermittent glides • Dense vegetation along both banks • Intermittent undercut banks throughout	
02-IZ-11	IZ	0.10	• Riffle-pool morphology • Substrate is cobble to sand, with a few sparse boulders • A cool spring seep source enters the channel here • Bedrock exposure is evident at spring seep location • Channel-spanning overhanging vegetation is present (primarily dogwood)	
02-IZ-12	IZ	0.14	• Riffle-pool morphology • Substrate is cobble to gravel • Point bars deposits of gravel are forming on the inside of meander bends • Occasional mid-channel bars are forming	
02-IZ-13	IZ	0.06	• Riffle pool morphology • Substrate is cobbles to coarse sand, sparse boulders are present • Channel has access to smaller connected floodplains (OZ-09, 0Z-10), which are inset below higher, disconnected alluvial terraces	
02-IZ-14	IZ	0.09	• Riffle-pool morphology • Substrate is cobbles to coarse sand, sparse boulders are present • Channel has access to smaller connected floodplains (OZ-09, 0Z-10), which are inset below higher, disconnected alluvial terraces	Instream Habitat Enhancement • Project RM 0.9- Large Wood Enhancement
02-IZ-15	IZ	0.06	• Riffle-run-pool morphology • Substrate is cobble to sand	Instream Habitat Enhancement • Project RM 0.75 - Large Wood Enhancement

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
			• Gravel accumulations on the inside of meander bends forms point bars • Riffle is lower gradient than upstream (IZ-14) • Three channel-spanning jams are accumulating gravel and sands	
02-IZ-16	IZ	0.02	• Long riffles with short pool morphology • Substrate is cobble to sand with a few small boulders • No point bars forming on the margins • Banks are well vegetated	Instream Habitat Enhancement • Project RM 0.71 - Large Wood Enhancement
02-IZ-17	IZ	0.12	• Step-pool morphology • Substrate is cobbles to very coarse sand • Large Wood accumulations are present • Small gravels to small cobbles are accumulating along the inside of meander bends • Dense vegetation along both banks • Banks are cobbles to sand at base, with sandy loam along the tops of banks	Instream Habitat Enhancement • Project RM 0.7 - Large Wood Enhancement
02-IZ-18	IZ	0.15	• Riffle-pool braided morphology • Channel is aggrading • Substrate is cobble to sand • Mid-channel point bars are dominated by gravels and sands, and some vegetation has established on them	
02-OZ-01	OZ	0.03	• Evidence of overland flow (sand deposition, Large Wood racked in vegetation) • Well-vegetated with thick shrubs and trees	Protect & Maintain
02-OZ-02	OZ	0.05	• Evidence of overland flow (sand deposition, Large Wood racked in vegetation) • Well-vegetated with thick shrubs and trees	Protect & Maintain
02-OZ-03	OZ	0.07	• Well-vegetated with mostly alder	Protect & Maintain
02-OZ-04	OZ	0.30	• Vegetation has been cleared along bank for residential development	Protect & Maintain Riparian Restoration

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
				• Project RM 1.07 - Riparian Restoration
02-OZ-05	OZ	0.06	• Dense stand of even-aged alders- indicates channel has realigned through avulsion, or human induced realignment	Protect & Maintain
02-OZ-06	OZ	0.23	• Low elevation surface- seems to be inundated regularly throughout the high-flow season • Point bar is developing at downstream end	Protect & Maintain Reconnect Floodplain Processes • Project RM 1.18 - Large Wood Enhancement
02-OZ-07	OZ	0.13	• Well-vegetated floodplain surface (largely dogwood, cottonwood, and horsetail) • Surface is sand to cobbles	Protect & Maintain Reconnect Stream Channel Processes • Project RM 0.9- Large Wood Enhancement & Fill Removal
02-OZ-08	OZ	0.19	• Sparse vegetation (alders, horsetails) • This modern floodplain has multiple terrace levels, which have been created from episodic incision of Libby Creek	Protect & Maintain
02-OZ-09	OZ	0.04	• Connected floodplain that has formed inset to historical disconnected floodplain surface • Large wood jam at upstream end is orienting flow over the surface. This has created a secondary channel that is wetted at the downstream end. Flow at the upstream end is hyporheic.	Protect & Maintain
02-OZ-10	OZ	0.30	• Extremely dense vegetation (dominated by dogwood) • North/northeast boundary of surface abuts area that has been altered by road fill and becomes DOZ-06	Protect & Maintain
02-OZ-11	OZ	0.11	• Extends from channel to road fill boundary (north/northeast boundary of OZ) • Well vegetated with dogwood, alder, and horsetail • Piles of trash along north/northeast boundary where trash is thrown from road	Protect & Maintain
02-OZ-12	OZ	0.04	• Evidence of recent inundation (sand, debris) • Well-vegetated	Protect & Maintain
02-OZ-13	OZ	0.16	• Connected to DOZ-08; channel appears to be incising, which has disconnected DOZ-08	Protect & Maintain

Subunit	Type	Area (acres)	Description & Notable Features	Restoration Strategy
			• A wetland complex (02-Wetland) spans DOZ-08 and OZ-13. • Downstream boundary is altered by road grade and an old abandoned culvert runs from the road grade into the channel. The culvert is plugged with sediment.	
02-OZ-14	OZ	0.36	• Large wood accumulations along the bank • Very well vegetated with a mix of trees and shrubs • Area appears to receive more inundation than other OZs	Protect & Maintain
02-Wetland	Wetland Area	0.06	• A large complex of small, interconnected wetlands • Water surface elevation is approximately 8 feet above the water Surface elevation of Libby Creek • There may be hyporheic connection between Libby Creek and the wetland complex • Wetlands are likely sourced from hillslope seeps • Evidence of beaver activity throughout the wetland	Protect & Maintain

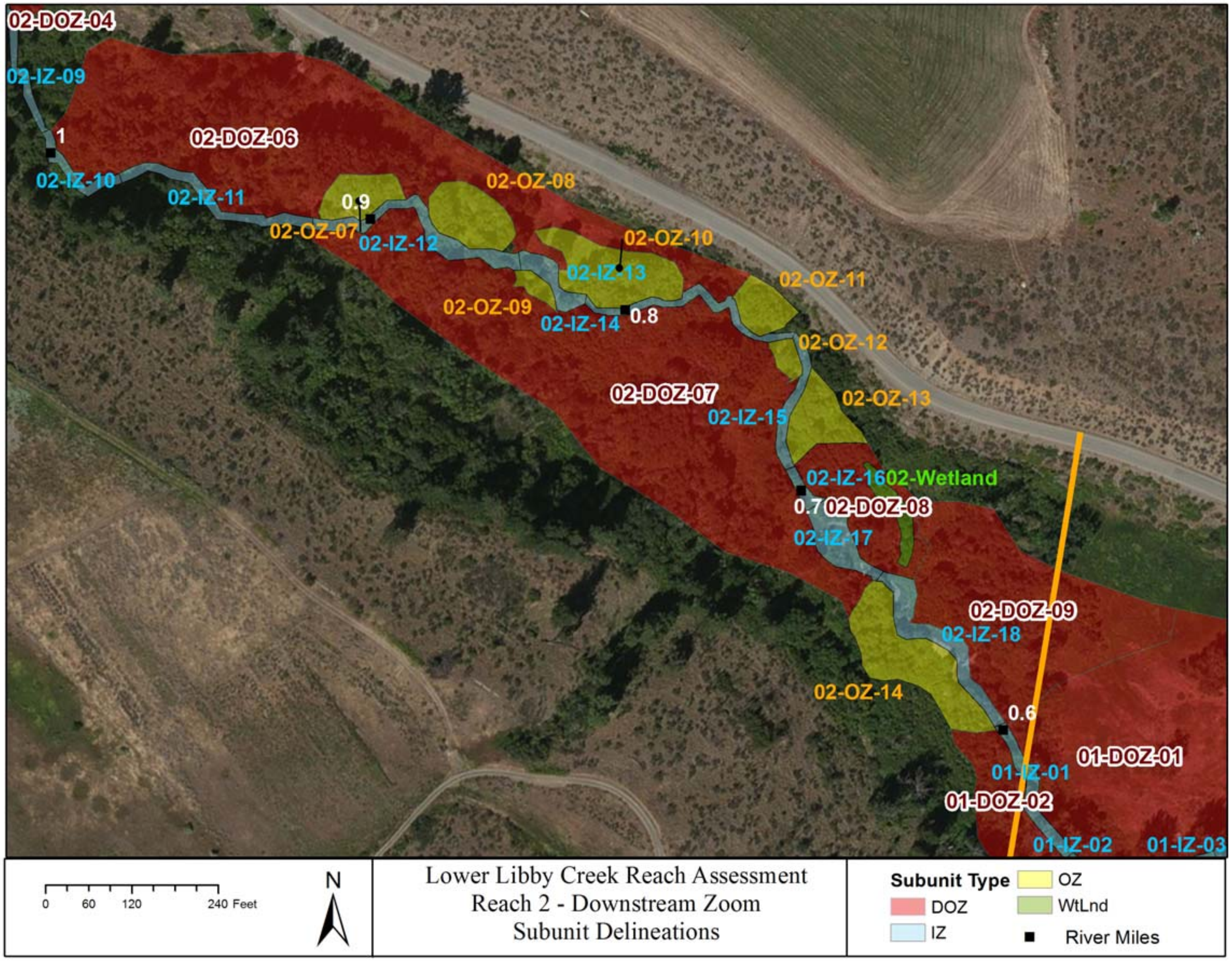

Figure 15. Subunit delineations in the downstream portion of Reach 2. Flow is from northwest to southeast.

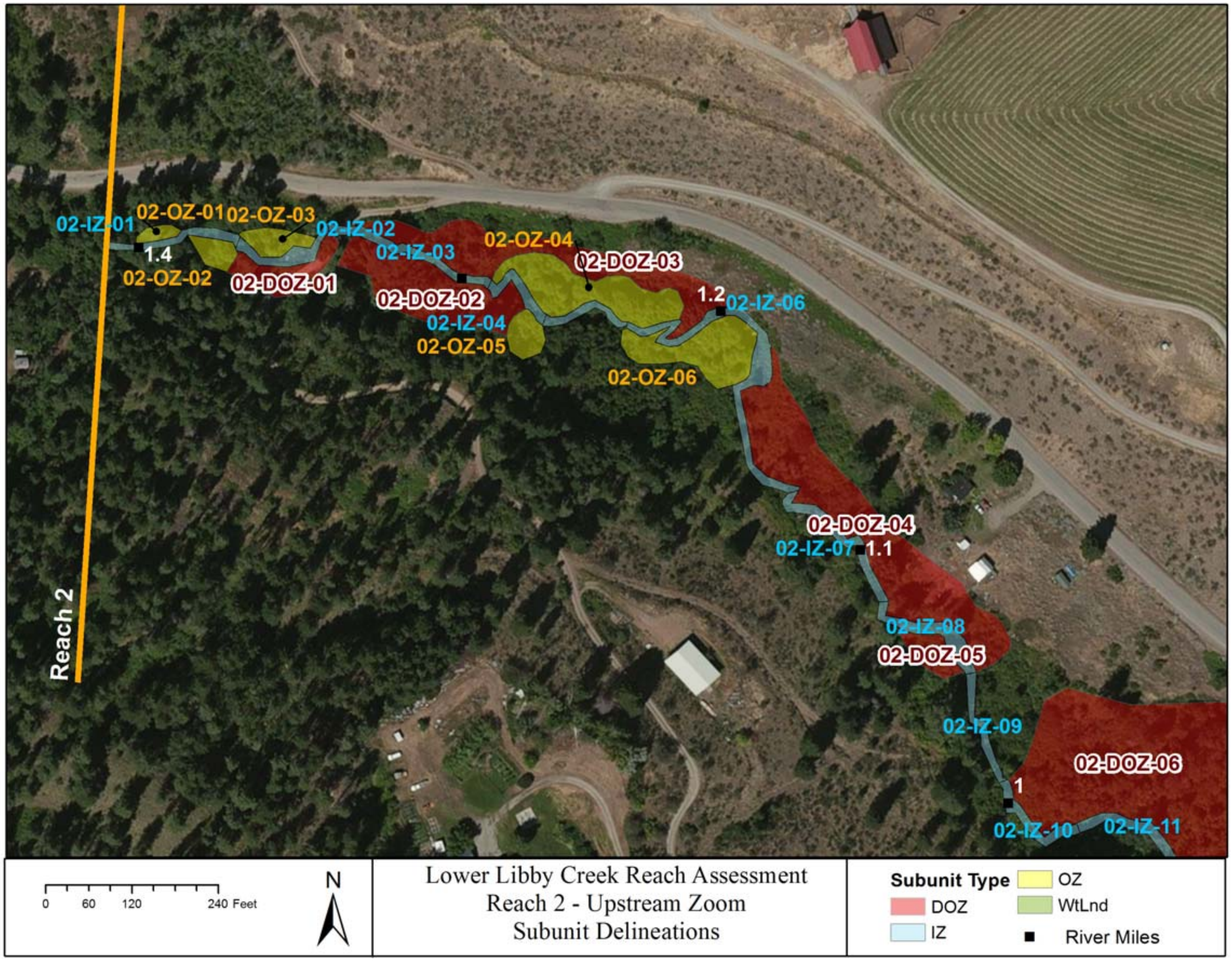

Figure 16. Subunit delineations in the upstream portion of Reach 2. Flow is from northwest to southeast.

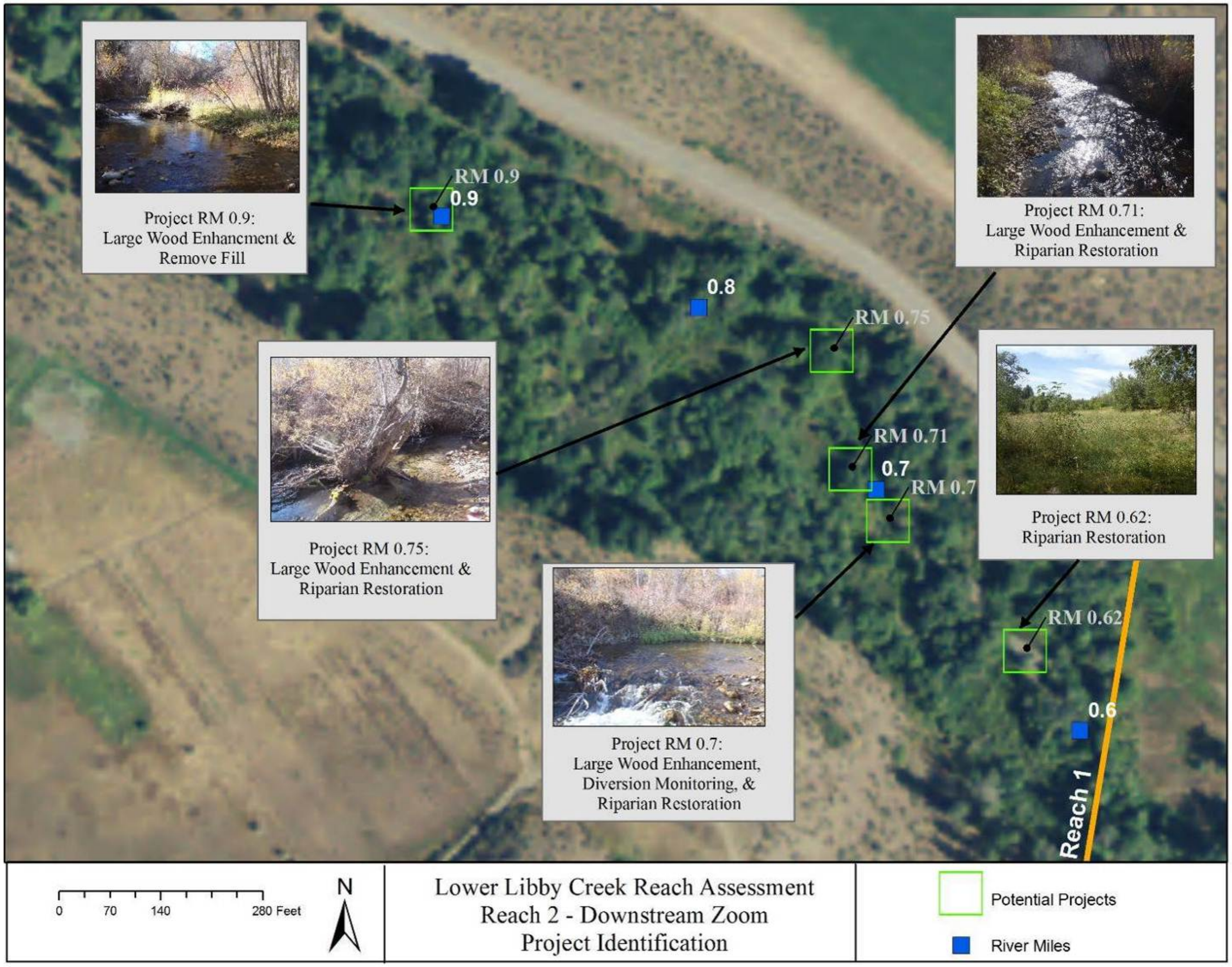

Figure 17. Potential project locations in the downstream portion of Reach 2. Project photographs are provided for selected sites to illustrate the types of project opportunities that are available throughout the reach. Additional project detail is included in Appendix B.

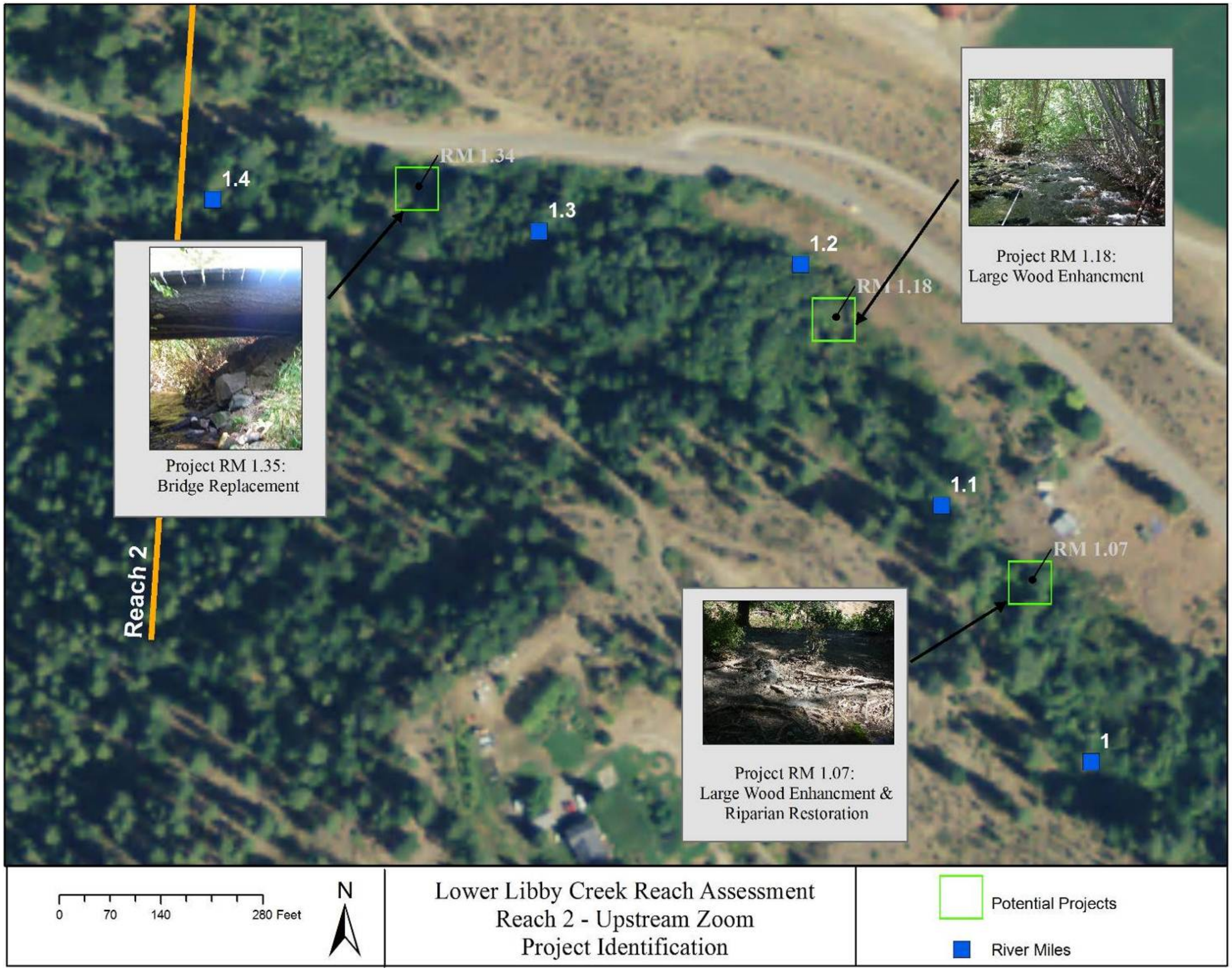

Figure 18. Potential project locations in the upstream portion of Reach 2. Flow is from northwest to southeast. Additional project detail is included in Appendix B.

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APPENDIX A

Lower Libby Creek
Stream Habitat Assessment
River Mile 0 to 1.4

Survey: September 2011

TABLE OF CONTENTS

1 Introduction

Libby Creek is located in Okanogan County, Washington. It is a tributary to the Methow River that enters the Methow at river mile (RM) 26.5, near the unincorporated community of Carlton. A habitat survey was conducted along lower Libby Creek from RM 0 to approximately RM 1.4 on September 22 and 23, 2011 (Figure 1). There is no streamflow data available for Libby Creek; however, an average annual flow of 18 cfs has been estimated by WDFW (2011). On the Twisp River, a larger Methow tributary located further upstream in the basin, streamflow during the survey period ranged between 60 to 63 cfs (USGS Gage #12448998).

The objective of the Habitat Assessment is to characterize the habitat quantity and quality for salmonid species native to Libby Creek 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, summer Chinook, reintroduced coho, summer steelhead, rainbow trout, bull trout, and westslope cutthroat trout are salmonid species found throughout the Methow Valley that potentially utilize Libby Creek for some portion of their life history. Libby Creek was given an “average” score for fish status and utilization in a recent Columbia River Instream Atlas Report for the Methow Basin (WDFW 2011). In this report, seven fish stocks limit their utilization to juvenile rearing only. One exception to this utilization is summer steelhead, which use Libby Creek for spawning, juvenile migration, and juvenile and adult rearing (WDFW 2011). Throughout the Methow Basin, wild summer steelhead currently sustain themselves only at a threshold population size (NW Councils 2004). Steelhead were listed as Endangered under the ESA on August 18, 1997 but were upgraded to Threatened on January 5, 2006.

In general, fish habitat in lower Libby Creek 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 and are intended to provide information for establishing objectives and performance targets to guide restoration and preservation activities.

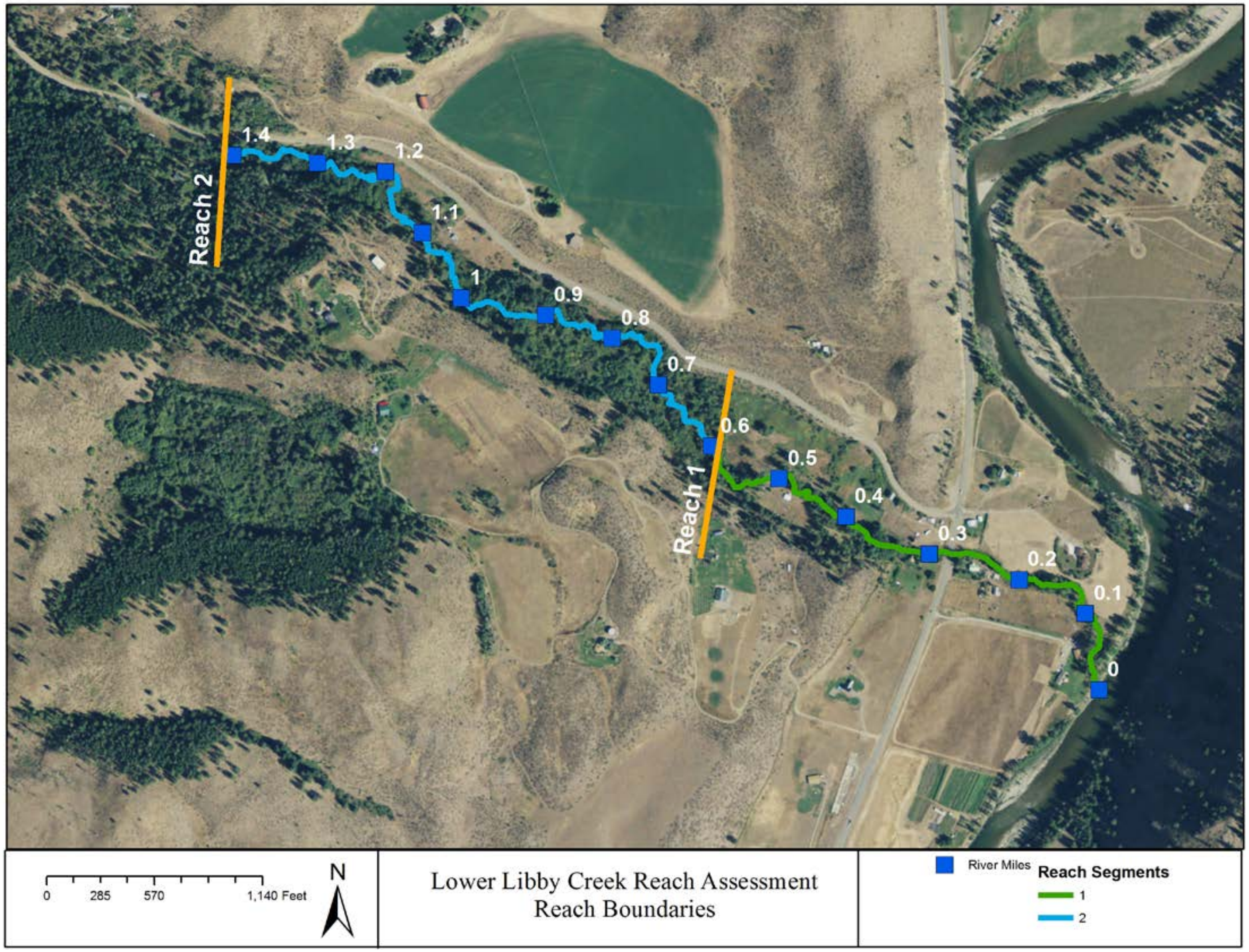


Figure 1. Locator map of the Habitat Assessment area showing the habitat survey reaches used in the assessment.

2 Methods

Two geomorphic reaches have been delineated as part of the reach assessment. These same reaches were used for both the stream habitat assessment and geomorphology assessment to maintain consistency for this and future inventories. Data collected in this survey is intended to compliment preexisting data for the Methow Basin.

Field methods for the habitat survey used the USFS Region 6 Level II Stream Survey Protocol Version 2.6 (USDA Forest Service 2006). A modification was made to the protocol with respect to the nth unit measurement frequency. The protocol indicates that nth unit measurements should occur at no less than a 10% sampling frequency with a minimum of 10 nth 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 nth units than was possible given time constraints. As a compromise, the minimum nth unit sampling frequency was increased to 20% with no minimum number of nth 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 nth units in order to determine if correction of the ocular estimates was necessary. The average difference between the actual and ocular values was 3.1 feet. As a result, ocular estimates were not corrected and are considered generally accurate to within +/- 5 feet.

Visual (ocular) estimates of bed sediment composition (considered a "forest option" in the USFS protocol) were recorded for every fast water unit (i.e. riffles and glides). Wolman (1952) pebble counts were recorded at 2 representative riffles per reach. Riparian vegetation was quantified by percent total of riparian inner zones and riparian outer zones for each unit. Additionally, the length of unstable banks were visually estimated for every unit in the study area.

3 Summary of Results

This section summarizes the results across both reaches. Detailed reach summaries with reach-specific results are included in Section 5.

3.2 Channel Morphology

Lower Libby Creek reaches were dominated by pool-riffle morphology. Channel bed substrate consisted primarily of gravel and cobble, with a high frequency of sand. Boulders and bedrock were rarely observed.

Bankfull widths did not vary substantially between stream reaches but did decrease in the downstream direction. This may be attributed to a large degree of artificial channel confinement that affects stream width in scattered locations throughout the study area. Mean bankfull widths were 27.8 feet (stdev 8.3ft). Bankfull depths varied only slightly between reaches. Mean bankfull depth was 2.3 feet (stdev 0.3ft). Mean floodprone widths for Reach 1 and 2 ranged from 174 to 206 feet.

3.3 Habitat Unit Composition

Riffles were the dominant habitat unit type, making up 80% of the total habitat area. Pools and glides comprised approximately 12% and 8% of the total habitat area, respectively. Side-channel habitat was less than 0.5% of the survey area (Figure 2).

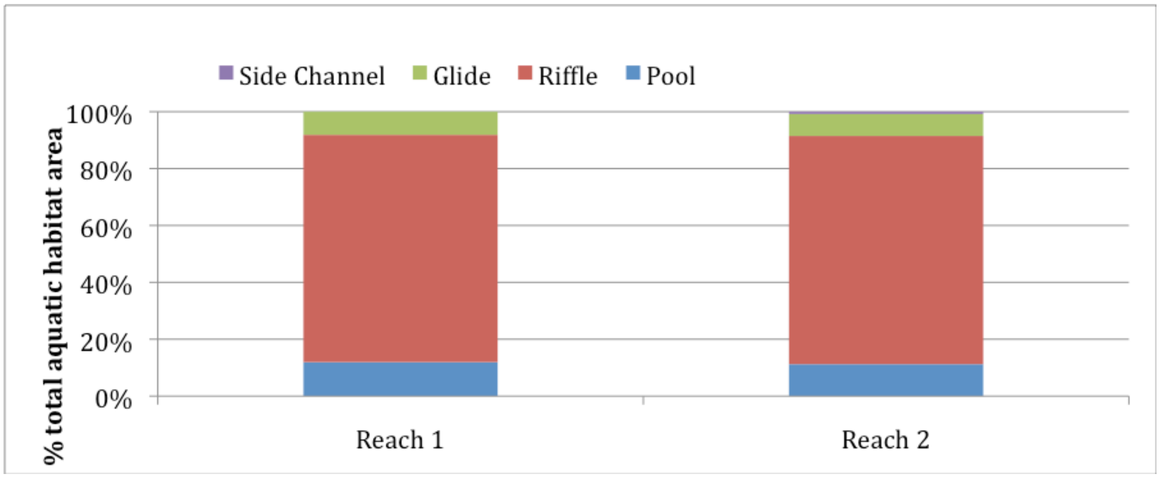


Figure 2. Proportion of habitat types in Reaches 1 and 2 in lower Libby Creek.

Pool frequency ranged from 20.1 to 21.5 pools/mile, with mean pool spacing of 16.6 to 19.0 channel widths per pool. Both reaches had nearly identical habitat unit composition, with the exception of two side-channels in Reach 2. Reach 1 had a slightly greater proportion of pool habitat due to the presence of both scour and plunge pools, whereas Reach 2 was dominated by short plunge pools. Reach 2 had a slightly greater number of deep pools, with one residual depth exceeding 3 feet. The majority of the pools throughout the study area were relatively shallow, with residual depths of 1-2 feet (77% of the pools).

Mean wetted width was 14.5 feet (stdev 5.1ft) for the survey area. Mean riffle depths were 0.7 feet (stdev 0.2ft) with mean maximum depths of 1.3 feet (stdev 0.4 ft). Shallow riffle depths can limit adult salmonid passage. Minimum depths of 0.8 feet and 0.6 feet have been reported as necessary to maintain adult Chinook and steelhead passage, respectively (Thompson 1972). However, steelhead adults likely migrate during periods of higher water than was observed during the survey.

Average unit lengths for the three habitat types (pools, riffles, and glides) are presented in Figure 3. Reach 1 had slightly longer pools, as they are predominately scour pools versus the plunge pools that dominate Reach 2. Reach 2 had longer riffles and slightly longer glides.

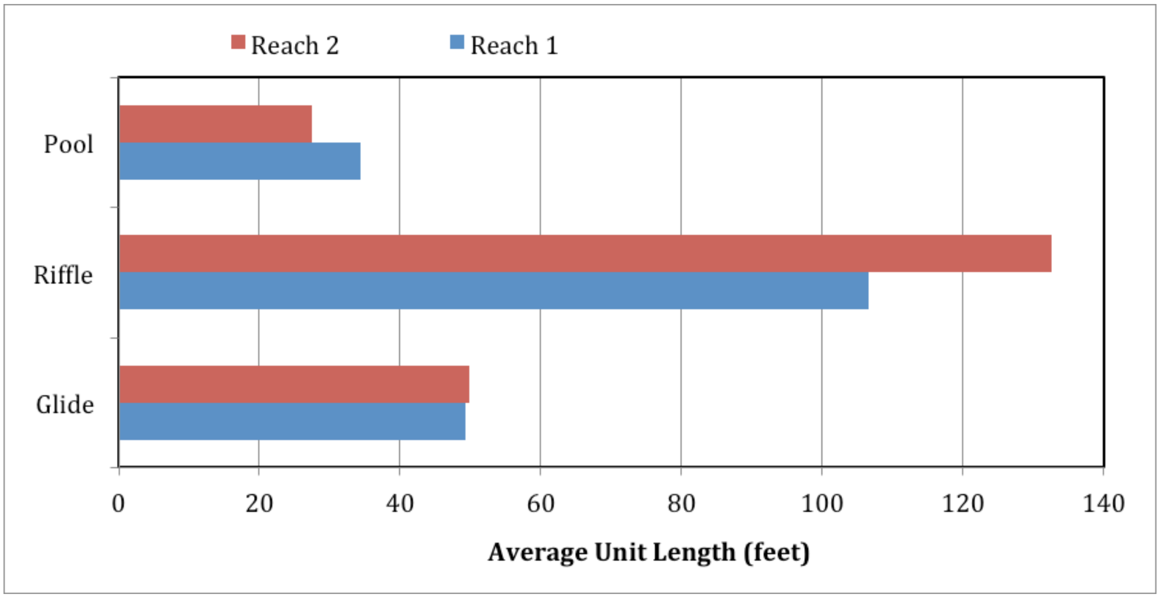


Figure 3. Comparison of average habitat unit lengths for Reaches 1 and 2 in lower Libby Creek.

3.4 Off-Channel Habitat

Side-channel habitat accounted for approximately 0.4% of the surveyed length along the lower 1.4 miles of Libby Creek (Figure 2). A total of 2 wetted side-channels were measured during the survey, both within Reach 2. An abandoned irrigation diversion in Reach 2 was not included in this count, as no active flow was observed at the time of the survey. Reach 2 had one side-channel pool and one side-channel riffle. The side-channel pool occupied a greater area than the side-channel riffle.

Artificial confinement significantly limited off channel habitat in Reach 1, which was at an “unacceptable risk” level based on thresholds from USFWS (1998). Reach 2 was moderately confined by both natural and artificial means. In addition to side-channels, Reach 2 had two groundwater springs (Tributary 1 and 2) and one slope wetland that have the potential to develop into off channel refuge and rearing habitat. Reach 2 is connected to a narrow floodplain for the majority of the reach.

3.5 Large Wood

A total of 268 pieces of wood were counted in lower Libby Creek, with an average of 211 pieces of wood per mile. Of these, 63% of these were “small” pieces with diameters between 6 and 12 inches and lengths greater than 20 feet (Figure 4). Reach 1 had the highest number of “large” pieces per mile (41), compared to 11 large pieces per mile in Reach 2. Large pieces were often stabilizing jams with numerous small, medium, and uncountable (too small) pieces that formed the total volume of complex woody structures. However, there were very few pieces that would meet the criteria for “key” pieces as defined by Schuett-Hames et. al. (1999).

The total number of wood pieces counted was 104 in Reach 1 and 164 in Reach 2. The average wood frequency in lower Libby Creek (both reaches combined) was 211 pieces/mile. As a reference, median wood loading on “undisturbed” streams of comparable size in the Douglas-Fir/ponderosa pine forest zones in Washington State is 274 pieces/mile (Fox and Bolton 2007). When making these comparisons, it should be noted that the size criteria for large wood used by Fox and Bolton (2007) is based on the WA State Timber Fish & Wildlife criteria, which is smaller (4 inches diameter and 6.6 feet long) than the size criteria used for the USFS Level II surveys (6 inches diameter and 20 feet long).

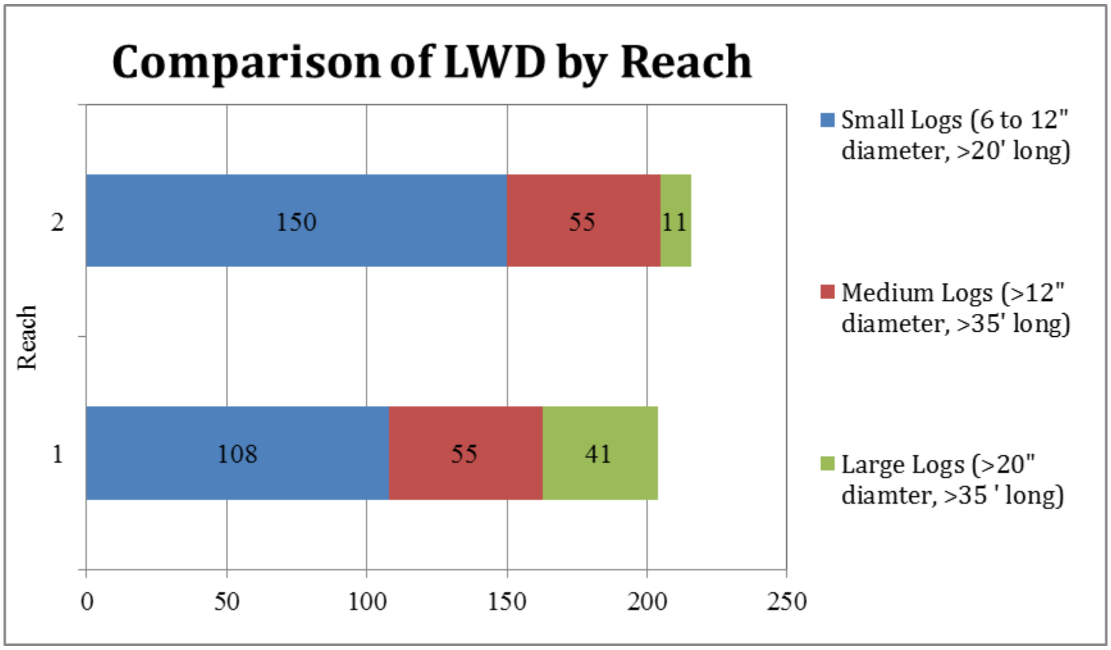


Figure 4. Small and medium/large wood pieces/mile for each reach.

3.6 Substrate and Fine Sediment

Bed substrate was based on ocular estimates at each fast water unit and pebble counts at two representative riffle locations within each of the two reaches. Pebble counts suggested that ocular estimates in Reach 1 slightly underestimated sand and gravel, and slightly underestimated gravel in Reach 2 (Figure 5).

Gravels and cobbles were dominant in lower Libby Creek, with sand a subdominant substrate type (Figure 5 and Figure 6). Boulders were observed infrequently and were more common in riffle habitat towards the upstream end of the survey area. Bedrock was rare and was only observed in two riffles in Reach 2. Generally, Reach 1 had smaller bed substrate than Reach 2.

Sediment measurements indicated that the presence of fine sediment (<2mm) was moderate and on the border of being a concern in the study area. Generally, bed substrate was composed of more than 12% sand.

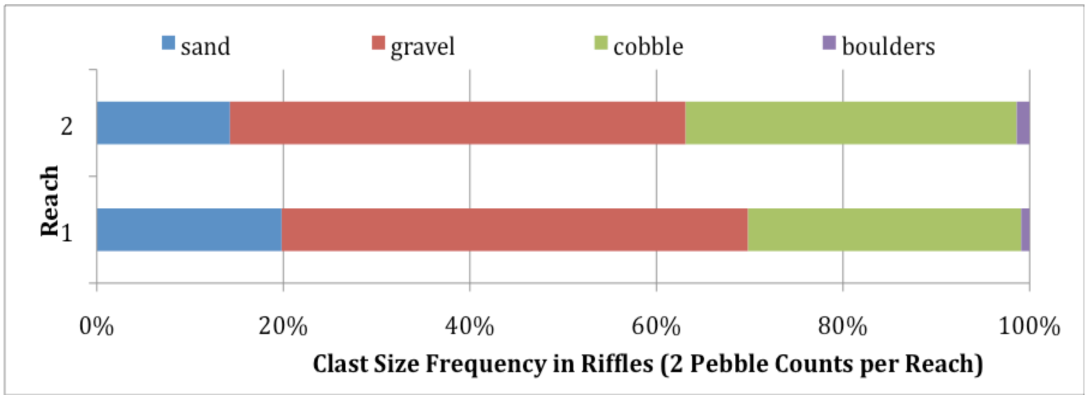


Figure 5. Pebble count classification of substrate by reach for lower Libby Creek (frequency values are derived by pooling the 2 pebble counts per reach).

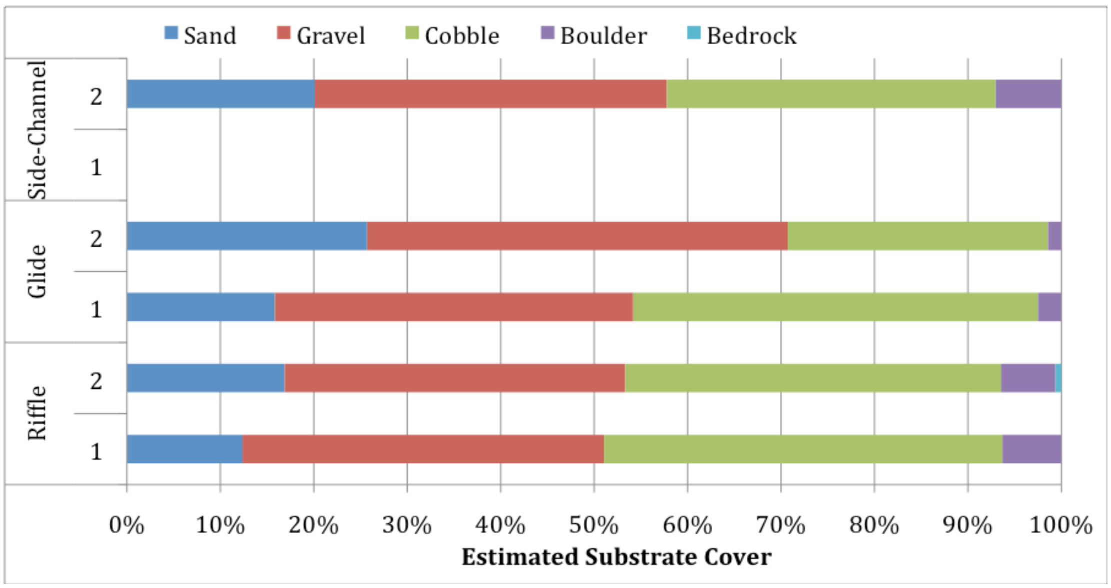


Figure 6. Ocular estimates of substrate by habitat unit type and reach for lower Libby Creek.

3.7 Instability and Disturbance

There was moderate human disturbance to the channel, riparian corridor, and floodplains throughout lower Libby Creek. These alterations are related to past and ongoing land-uses including timber harvest, gravel mining, agricultural use of floodplains, road building, and residential development. Artificial channel confinement in the form of bridges, floodplain fill, irrigation diversions, and bank armoring affects channel and floodplain dynamics within the study area.

Bank instability was present near areas affected by human disturbance and channel confinement.

In total, 7% of the streambanks (373 feet) along Reach 1 were actively eroding. Erosion and instability in this reach has primarily been caused by bank armoring or large wood accumulations that transfer stream energy into streambanks.

Reach 2 bank erosion was higher with a total of 11% of the mainstem streambanks (905 feet) showing signs of active erosion (Figure 7). Erosion in this reach can be attributed to natural conditions as well as land uses including livestock grazing. Eroded areas were characterized by loam soils with fewer instances of cobble banks than was observed in Reach 1.

Bank erosion occurred in all habitat types; however, it was most frequently observed in riffle and glide habitats (Figure 8). In portions of Reach 1, streambank erosion is limited by the presence of riprap armoring near residential development. Plywood riprap lines a small (10 feet) section in Reach 2 near an abandoned irrigation diversion along river-right.

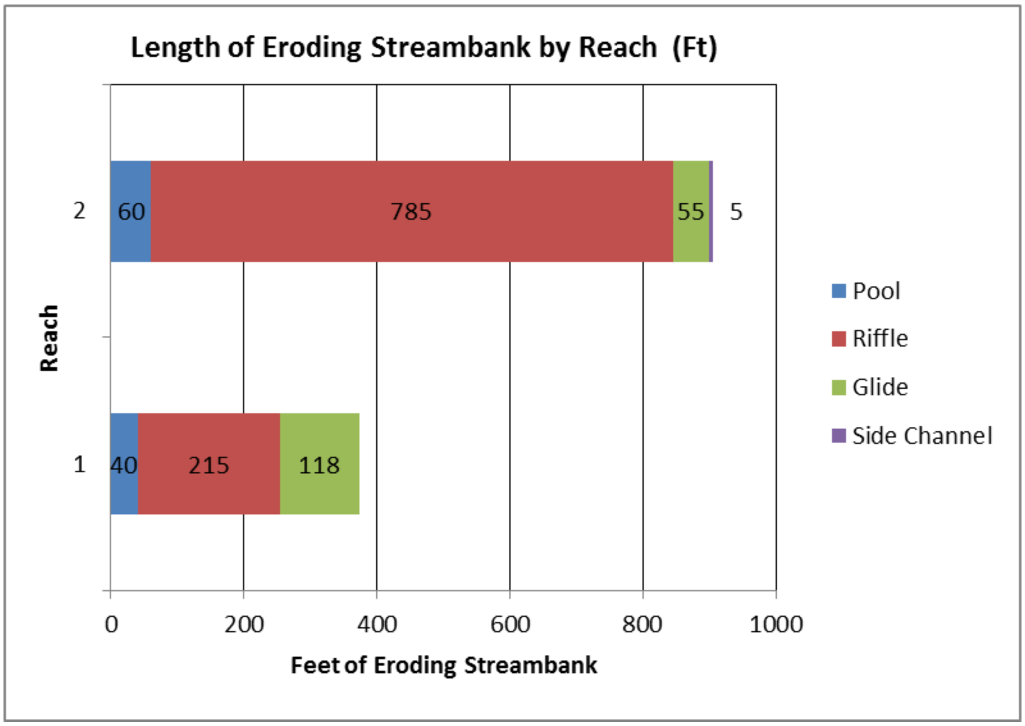


Figure 7. Length of bank erosion by habitat type and reach along lower Libby Creek.

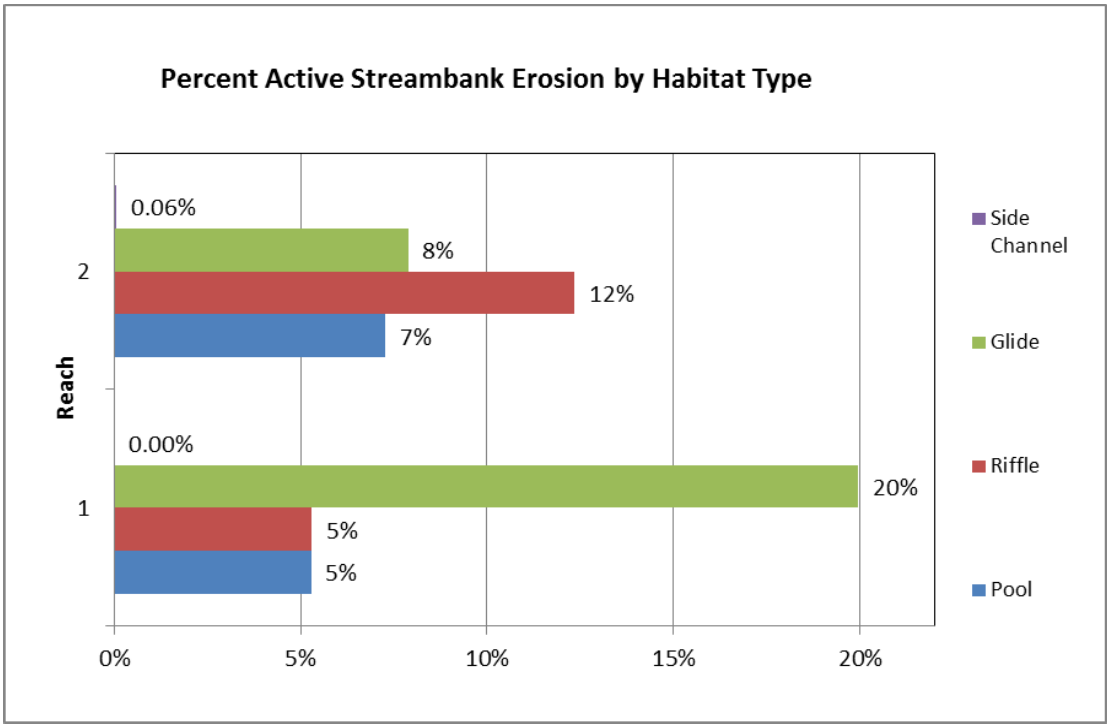


Figure 8. Percent active erosion of each habitat type along lower Libby Creek.

3.8 Fish Passage Barriers

There were no significant fish passage barriers in the study area. Adult passage may be challenging near a series of channel spanning rock weirs in Reach 1 and throughout the entire survey area during periods of low flow. Beaver dams and plunge pools throughout both reaches have the potential to challenge upstream migration for juvenile fish.

3.9 Riparian Corridor

Survey methods dictate defining a dominant size class of vegetation (e.g. large trees, small trees, shrubs, etc) for the inner and outer zones, then defining the dominant species observed in the over and understory within both the inner and outer zones.

Riparian inner zones were typically dominated by small trees (54% of units) or shrubs (27% of units); large trees were dominant in only 12% of units (Figure 9). Outer zones were typically dominated by shrubs (48%) or grass/forbs (26%). Small trees dominated 16% and large trees dominated only 10% of units. Many of the outer zones were within areas that had been cleared for agricultural or residential uses.

The species composition of riparian areas was dominated by deciduous species (Figure 10). The inner zone understory was typically dogwood or grass/forbs. The inner zone overstory was typically either cottonwood, dogwood, alder, or birch. The outer zone understory was typically grass/forbs but the overstory varied considerably.

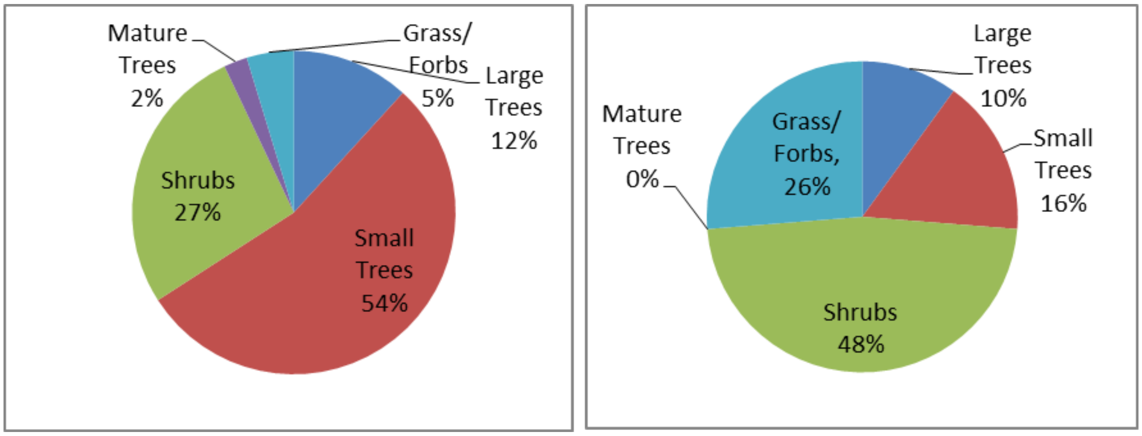


Figure 9. Libby Creek Inner Zone Distribution (left) and Outer Zone Distribution (right) of the dominant diameter class category for the riparian zones in lower Libby Creek (RM 0.0 to RM 1.3).

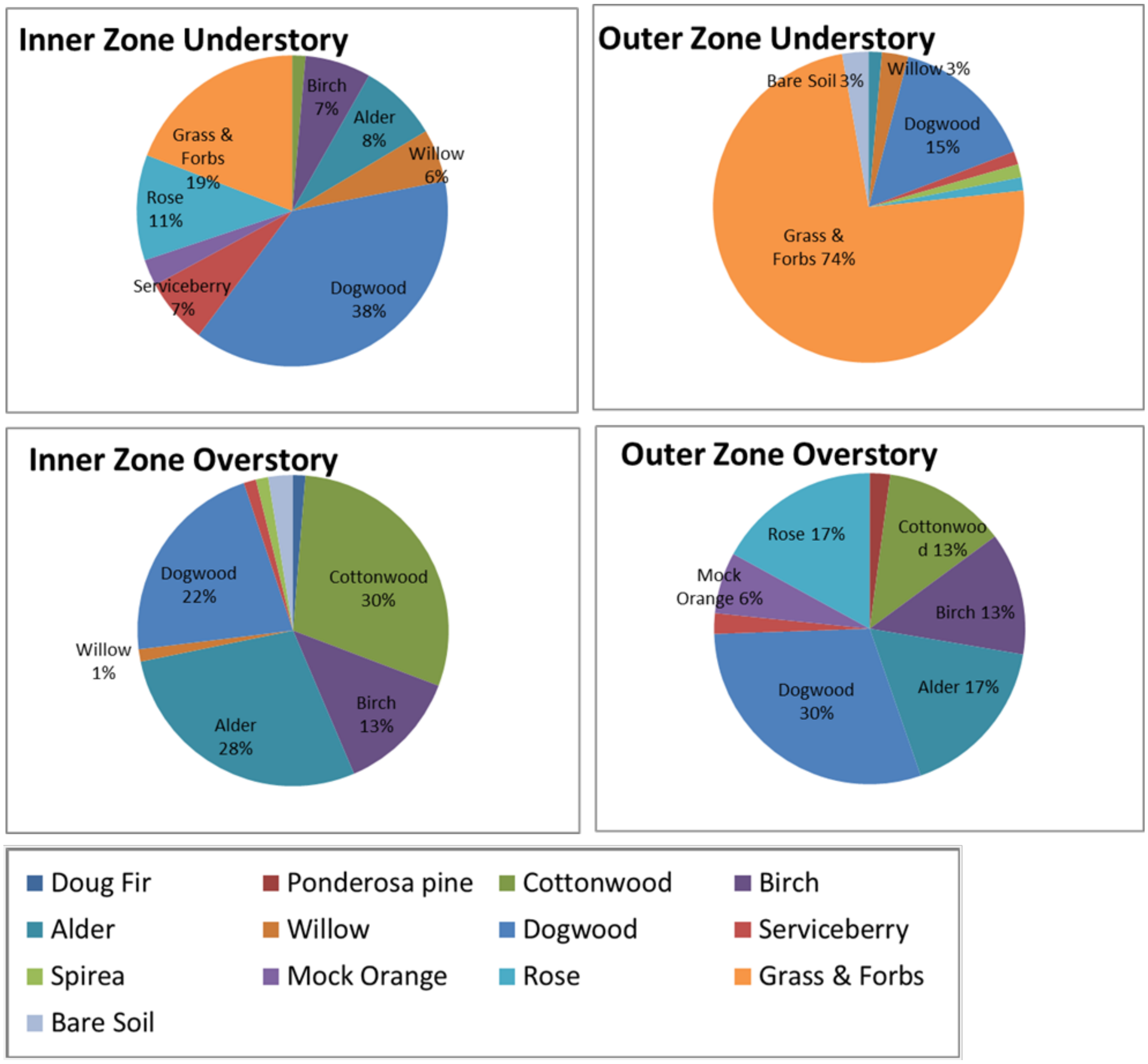


Figure 10. Proportions of vegetation cover in lower Libby Creek. The dominant species of grasses and forbs were not determined, however curly dock, Canada thistle, burdock, slough sedge, nettles and reed canary grass were observed.

4 Summary Data Tables

Libby Creek Data Summary: RM 0 to RM 1.4.

		Total	Reach 1	Reach 2
Reach Mileage Boundaries		0 – 1.4	0 – 0.6	0.6 – 1.4
Channel Morphology			Pool-riffle	Pool-riffle
Slope			2.11%	2.95%
Wetted Width (ft)				
Pool				
	Mean	15.4	14.8	15.8
	Median	15.5	16.0	15.0
	StDev	5.5	5.2	5.9
Riffle				
	Mean	15.0	16.8	13.6
	Median	14.0	16.0	12.5
	StDev	4.6	4.6	4.1
Glide				
	Mean	12.4	12.8	12.0
	Median	11.0	13.0	11.0
	StDev	4.5	5.5	3.8
Water Depth (ft)				
Pool Maximum Depth (ft)				
	Mean	2.4	2.4	2.5
	Median	2.3	2.3	2.3
	StDev	0.5	0.4	0.6
Pool Residual Depth (ft)				
	Mean	1.6	1.4	1.7
	Median	1.5	1.2	1.6
	StDev	0.6	0.5	0.6
Maximum Riffle Depth				
	Mean	1.3	1.2	1.4
	Median	1.2	1.1	1.3
	StDev	0.4	0.4	0.5
Average Riffle Depth				
	Mean	0.7	0.7	0.6
	Median	0.6	0.7	0.6
	StDev	0.2	0.2	0.2

Reach Mileage Boundaries		**Total** 0 – 1.4	**Reach 1** 0 – 0.6	**Reach 2** 0.6 – 1.4
Maximum Glide Depth				
	Mean	1.7	1.8	1.7
	Median	1.8	1.8	1.8
	StDev	0.3	0.2	0.3
Average Glide Depth				
	Mean	0.9	0.9	0.9
	Median	0.9	1.0	0.9
	StDev	0.2	0.2	0.1
Bankfull Characteristics				
Width (ft)				
	Mean	27.8	22.6	31.6
	StDev	8.3	8.6	6.0
Depth (ft) Averaged over 3 depth measurements				
	Mean	2.3	2.2	2.3
	StDev	0.3	0.3	0.3
Maximum Depth (ft)				
	Mean	3.0	2.8	3.2
	StDev	0.6	0.3	0.7
Width:Depth Ratio				
	Mean	12.6	10.5	14.1
	StDev	4.4	4.1	4.2
Floodprone Width (ft)				
	Mean	192.5	174	205.7
	StDev	110.5	138.5	95.4
Habitat Area %				
Pool		12%	12%	11%
Riffle		80%	80%	80%
Glide		8%	8%	8%
Side Channel		0%	0%	1%
Pools				
Pools per Mile		20.7	21.5	20.1
Residual Depth (% of pools)				
	Pools < 1 ft	4%	9%	0%
	Pools 1-2 ft	77%	73%	80%
	Pools 2-3 ft	15%	18%	13%
	Pools > 3 ft	4%	0%	7%
Riffle:Pool Ratio		1.7	1.7	1.6

Reach Mileage Boundaries	**Total** 0 – 1.4	**Reach 1** 0 – 0.6	**Reach 2** 0.6 – 1.4
Mean Pool Spacing (channel widths per pool)	17.9	16.6	19.0
Large Wood			
Number Pieces			
Totals	268	104	164
Small (6 in x 20 ft)	169	55	114
Medium (12 in x 35 ft)	70	28	42
Large (20 in by 35 ft)	29	21	8
Number of Pieces/Mile			
Totals	211	204	216
Small (6 in x 20 ft)	258	108	150
Medium (12 in x 35 ft)	110	55	55
Large (20 in by 35 ft)	52	41	11
Bank Erosion (% eroding banks)			
Totals	10%	7%	11%
Pool	6%	5%	7%
Riffle	10%	5%	12%
Glide	13%	20%	8%
Side Channel Pools	0%		0%
Side Channel Riffles	0%		0%
Substrate (Ocular Estimate)			
Total			
% Sand	17%	13%	19%
% Gravel	38%	39%	38%
% Cobble	40%	43%	37%
% Boulder	5%	5%	5%
% Bedrock	0%	0%	1%
Riffle			
% Sand	15%	12%	17%
% Gravel	37%	39%	36%
% Cobble	41%	43%	40%
% Boulder	6%	6%	6%
% Bedrock	0%	0%	1%
Glide			
% Sand	21%	16%	26%
% Gravel	42%	38%	45%
% Cobble	35%	43%	28%
% Boulder	2%	3%	1%

Reach Mileage Boundaries		**Total** 0 – 1.4	**Reach 1** 0 – 0.6	**Reach 2** 0.6 – 1.4
	% Bedrock	0%	0%	0%
Side Channel Pools				
	% Sand	10%		10%
	% Gravel	35%		35%
	% Cobble	45%		45%
	% Boulder	10%		10%
	% Bedrock	0%		0%
Side Channel Riffles				
	% Sand	30%		30%
	% Gravel	40%		40%
	% Cobble	25%		25%
	% Boulder	5%		5%
	% Bedrock	0%		0%
Riffle Pebble Count (*2 pebble counts per reach*)				
	% Sand	17%	20%	14%
	% Gravel	49%	50%	49%
	% Cobble	32%	29%	35%
	% Boulder	1%	1%	1%
	% Bedrock	0%	0%	0%
Vegetation (% of sampled units)				
Riparian Inner Zone				
	Grass/Forbs	5%	3%	6%
	Shrubs	27%	25%	29%
	Small trees	54%	56%	53%
	Large trees	12%	11%	12%
	Mature Trees	2%	6%	0%
Riparian Outer Zone				
	Grass/Forbs	26%	34%	19%
	Shrubs	48%	54%	43%
	Small trees	16%	6%	26%
	Large trees	10%	6%	13%
	Mature Trees	0%	0%	0%

5 Reach Reports

5.2 Reach 1

Location: River mile 0 to River mile 0.6

Survey Date: September 22, 2011

Survey Crew: Christa Strickwerda Heller and Adrianne Zuckerman (Inter-Fluve)

*A staff gage and PIT Tag antenna are located upstream of the Hwy 153 Bridge (RM 0.3).

5.2.1 Reach Overview

Reach 1 is located on the Libby Creek alluvial fan as it enters the lower Methow River valley. The confluence with the Methow River is on the river-right bank at RM 26.5. The reach extends from Libby Creek RM 0 to RM 0.6, flowing under Highway 153 and through residential, agricultural and livestock grazing lands. There is considerable habitat alteration and human infrastructure in the reach, including houses, hobby farms, horse fords, roads, bank armoring, and grade control structures (rock weirs) (Figure 11 and Figure 12). These alterations have confined Reach 1 to a narrow riparian corridor with little canopy cover and no off-channel habitat.

Figure 11. Bank armoring and scour along lower Libby Creek (September 2011).

Figure 12. Habitat alteration and channel confinement at the Hwy 153 Bridge (RM 0.3).

5.2.2 Channel Morphology

Reach 1 is located on the Libby Creek alluvial fan as it enters the lower Methow River valley. Just upstream of the confluence, Libby Creek forks into a short braided riffle that flows out of a beaver-dammed pool (Figure 13 and Figure 14). Young willows grow along the alluvial deposit with small woody debris accumulating throughout the delta.

The reach has a moderate gradient (2.11%) and the valley is moderately confined by residential and agricultural land uses. The stream itself is channelized and artificially confined due to human alterations. The channel type is pool-riffle.

The historical natural depositional environment in this reach has been impacted by development in and around the agricultural community of Carlton, including bank armoring, roadways, and bridges. Due to artificial confinement, bed material is transported more readily through this reach than would have been expected under historical conditions.

Figure 13. Confluence of Libby Creek looking downstream towards the Methow River. Young willows are growing along the alluvial deposits (September 2011).

Figure 14. Looking upstream from the mouth of Libby Creek at a beaver-dammed pool (September 2011).

5.2.3 Habitat Unit Composition

Reach 1 consisted of 12% pools, 80% riffles, 8% glides, and 0% side-channels (Figure 15 and Figure 16). Pool frequency was 21.5 pools per mile, with mean pool spacing of 16.6 channel widths per pool. Reach 1 had slightly more pools per mile than Reach 2. Reach 1 would be considered "functioning at risk" with respect to pool spacing based on USFWS (1998). Average residual pool depth was 1.4 feet. Average maximum pool depth was 2.4 feet. Scour pools were the dominant pool type (e.g. Figure 17).

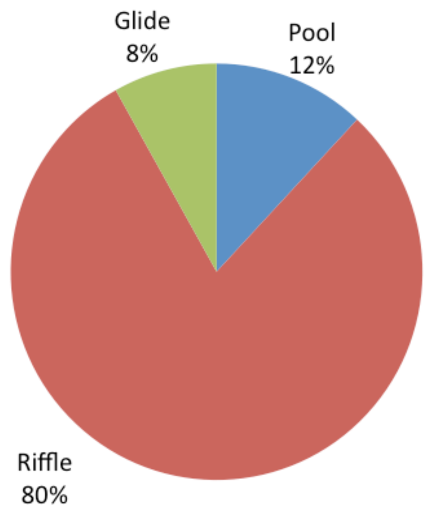


Figure 15. Habitat unit composition for Reach 1.

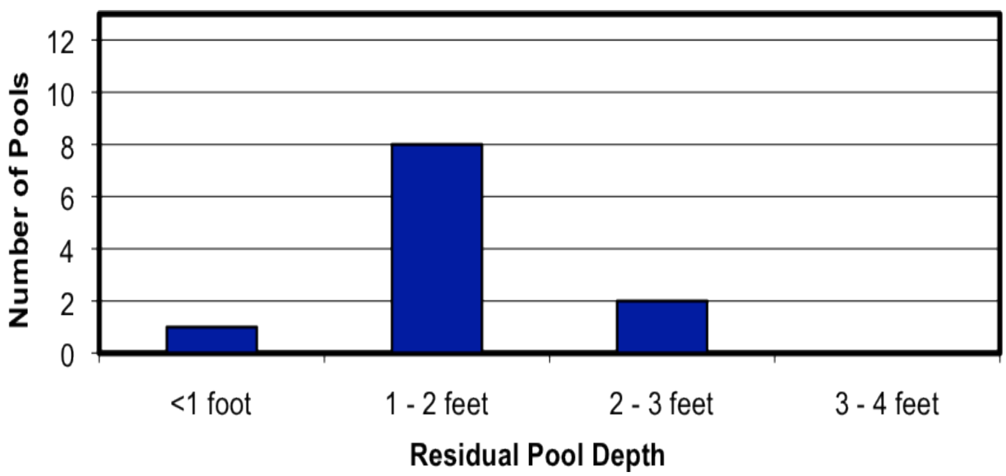


Figure 16. Reach 1 residual pool depths.

Figure 17. Scour pool near the mouth of Libby Creek. This is a representative slow water unit (pool) observed in Reach 1 (September 2011).

5.2.4 Off-Channel Habitat

No side channels were observed in Reach 1. Artificial confinement, bank armoring, and fill prevent access to off-channel and floodplain habitats. Reach 1 likely had high historical off-channel complexity that has been severely reduced as a result of land uses.

5.2.5 Large Woody Debris

Wood plays a moderate role in Reach 1, including sediment sorting, habitat cover, and channel complexity (Table 1 and Figure 18). The number of LWD pieces in Reach 1 was higher than in Reach 2. LWD frequency was 104 pieces/mile, with "large" pieces comprising 20% of all LWD in the reach. "Medium" wood pieces accounted for 27% of all LWD in the reach, and "small" pieces accounted for 53%. Black cottonwood is the most abundant species of LWD. Wood quantities averaged 204 pieces per mile in Reach 1, less than the recommended quantities of 274 pieces/mile for median wood loading in unmanaged stream systems of comparable size and type (Fox and Bolton 2007). When making these comparisons, it should be noted that the size criteria for large wood used by Fox and Bolton (2007) is based on the WA State Timber Fish & Wildlife criteria, which is smaller (4 inches diameter and 6.6 feet long) than the size criteria used for the USFS Level II surveys (6 inches diameter and 20 feet long).

The potential for woody debris recruitment is limited in this reach due to bank armoring that limits lateral erosion, past riparian clearing, and use of chicken wire to protect riparian trees from beaver activity.

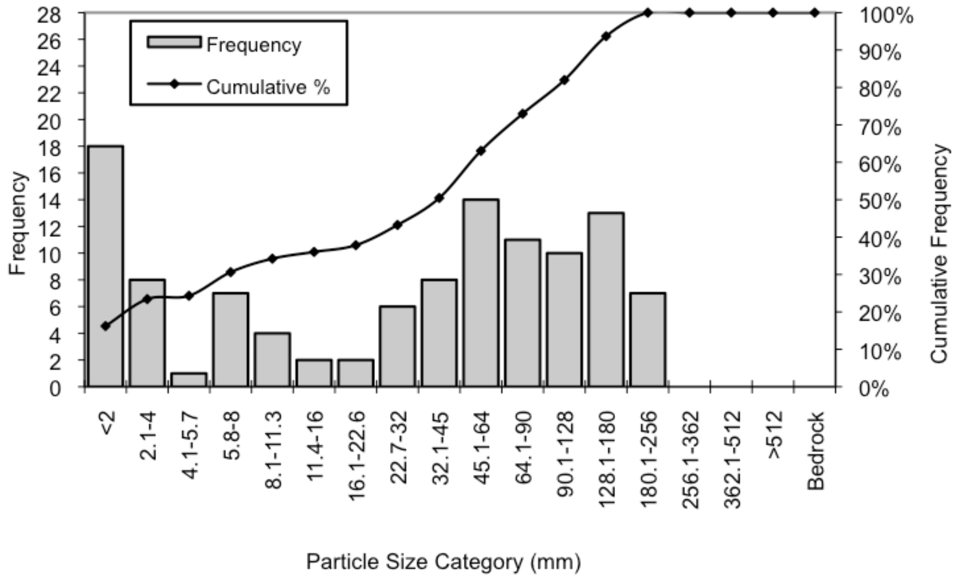
Table 1. Large woody debris quantities in Reach 1.

Reach 1	Small (6 in x 20 ft)	Medium (12in x 35 ft)	Large (20in x 35 ft)	Total
Number of Pieces	55	28	21	104
Number of Pieces/Mile	108	55	41	204

Figure 18. Large woody debris jam in Reach 1 (September 2011).

5.2.6 Substrate and Fine Sediment

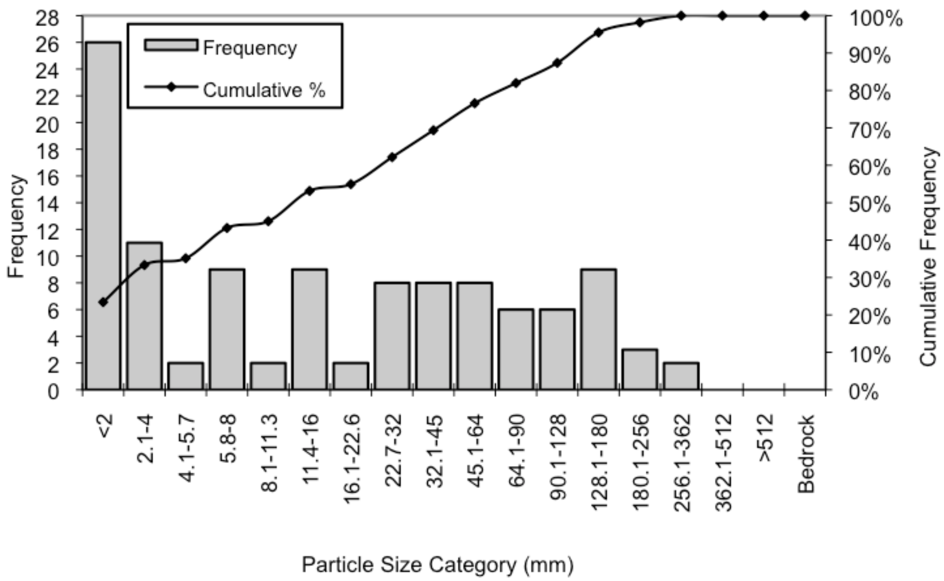
Bed substrate was dominated by gravels and cobbles. Sand was subdominant. No bedrock was observed in Reach 1 and boulders made up no greater than 5% of the distribution. Percent fines (<2mm) were relatively high (13-23%) based on the ocular estimates and pebble counts. Reach 1 would be considered "functioning at risk" with respect to fines in gravel (near areas of spawning and incubation) based on USFWS (1998). The pebble count and size class data are depicted in Figure 19, Figure 20, and Figure 21.



Material	Percent Composition
Sand	16%
Gravel	47%
Cobble	37%
Boulder	0%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	<2
D16	2
D50	44
D84	137
D95	196

Figure 19. Grain size distribution and particle size classes from pebble count taken at RM 0.22.



Material	Percent Composition
Sand	23%
Gravel	53%
Cobble	22%
Boulder	2%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	<2
D16	<2
D50	14
D84	104
D95	177

Figure 20. Grain size distribution and particle size classes from pebble count taken at RM 0.46.

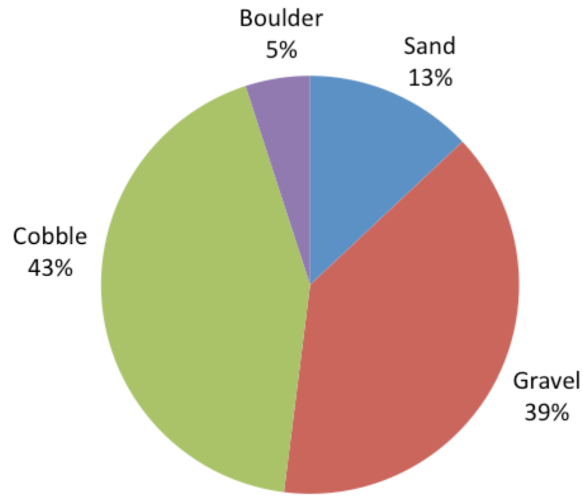


Figure 21. Percent composition of bed substrate based on ocular estimates, Reach 1.

5.2.7 Instability and Disturbance

Human activities have modified the channel, floodplain and riparian corridor in Reach 1. Erosion was minimal, with 7% (373 feet total) of actively eroding streambank measured along both banks (Figure 22). Floodplain connectivity and natural channel processes, including lateral channel dynamics, were limited by residential development, agricultural practices, and bank armoring (Figure 23).

Hwy 153 crosses Libby Creek at RM 0.3. The bridge abutments and adjacent riprap confine the channel, limit meandering, increase water velocities, and contribute to channel incision.

In some areas, bank erosion was associated with a lack of riparian vegetation due to livestock grazing (RM 0.3) and residential development (RM 0.5) (Figure 24). Riparian plantings would help provide natural stability to streambanks and floodplain areas.

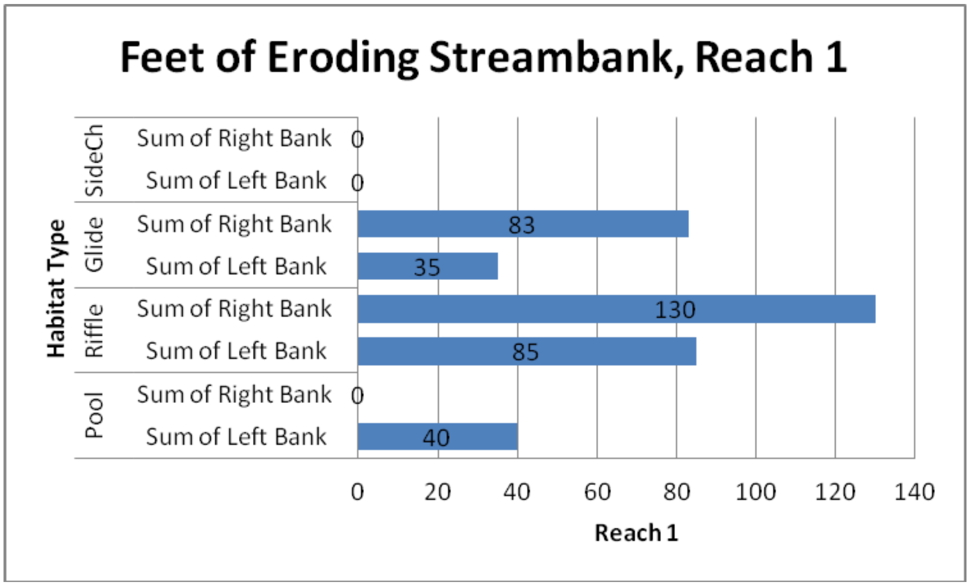


Figure 22. Lineal distance of erosion (above the bankfull channel) according to left or right bank and habitat unit type in Reach 1.

Figure 23. Riprap armoring limits floodplain connectivity and lateral channel dynamics near RM 0.3, Reach 1 (September 2011).

Figure 24. Vegetation clearing and development in the riparian zone near RM 0.5, Reach 1 (September 2011).

5.2.8 Available Spawning and Rearing Habitat

There was minimal spawning and moderate rearing habitat available in Reach 1. Bed substrate was adequately sized, with riffles having 39% gravel and 41% cobble. Gravels and cobbles were embedded with fines in many potential spawning riffles (Figure 25).

Pool quantity and quality was below “functioning adequately” conditions (USFWS 1998) with the reach having shallow residual depths and no pools with residual depths greater than 3 feet.

Canopy cover and riparian vegetation was sparse and limited to a narrow corridor. LWD was below acceptable levels and the short and long-term recruitment potential for woody debris is lacking.

Steelhead and trout primarily use this reach as a migration corridor to access upstream habitat closer to the Okanogan National Forest boundary. WDFW collects PIT (Passive Integrated Transponder) tag data from steelhead and other salmonids migrating through Reach 1 (Bob Jateff, WDFW, personal communication, Oct. 19, 2011). An instream PIT tag detection antenna is located at RM 0.3, just upstream from the Hwy 153 Bridge (Figure 26).

Figure 25. Riffle habitat in Reach 1 with sparse canopy cover and embedded substrate (September 2011).

Figure 26. Instream PIT tag detection antenna in Lower Libby Creek at RM 0.3 (September 2011).

5.2.9 Fish Passage Barriers

Adult passage may be a concern during low flow periods. Mean riffle thalweg depth was 0.7 feet, just under the 0.8-ft threshold cited for spring Chinook by Thompson (1972). A small beaver dam, just upstream of the confluence with the Methow River (Figure 3), may act as a migration barrier during times of low flow. The beaver dam had a 2-ft difference in water surface elevation that could hinder upstream migration during the summer and fall. At approximately RM 0.35, several channel spanning rock weirs that protect a river-right home and horse ford may prevent the upstream colonization of juvenile fish at times of very low flow (Figure 17).

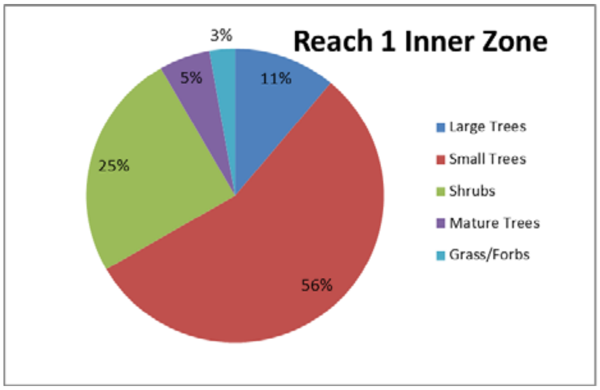
Figure 27. Rock weirs (located at RM 0.35) may prevent upstream colonization by juvenile fish during low water years (September 2011).

5.2.10 Riparian Corridor

The riparian corridor in Reach 1 was forested, with less diversity of trees and shrubs than upstream reaches. The riparian canopy was comprised primarily of cottonwoods with a smaller amount of young ponderosa pines. Willows were abundant along the streambanks and on cobble bars near the mouth. Shrubs and other herbaceous plants were dominant on the floodplain terrace extending beyond the inner riparian zone.

Small trees were typically dominant within the riparian inner zone (56% of measured units) (Figure 28) and nearly all inner zone areas were dominated by hardwood species including alder, cottonwood, and birch. Riparian outer zone units were typically dominated by shrubs (54% of measured units) including rose, willow, mock orange, and serviceberry. Grass, forbs and other herbaceous plants were abundant throughout the outer zone (34%).

Near the mouth of Libby Creek, mature cottonwoods dominate the riparian zone and understory vegetation was sparse (Figure 29). The riparian overstory in the upper portion of Reach 1 was dominated by small trees (including alder, birch, and cottonwood), yet some areas lack substantial overstory vegetation aside from dense thickets of red-osier dogwood (12-20 ft tall). In other sections, small alders were dominant, providing valuable stream shade and future woody debris. The floodplain terraces in Reach 1 were primarily unmanaged pasture lands sparsely vegetated with hardwood shrubs or herbaceous vegetation.



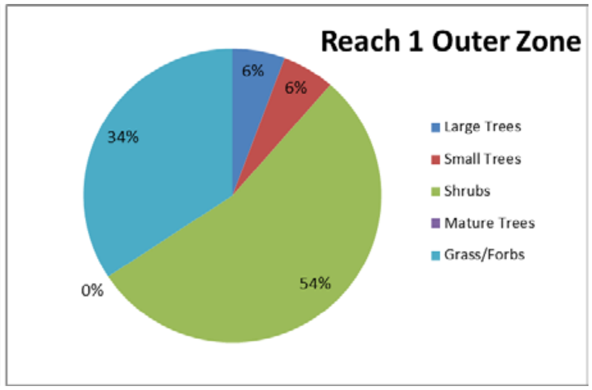


Figure 28. Distribution of vegetation size class categories for the riparian inner and outer zones in Reach 1.

Figure 29. Dominant vegetation observed in Reach 1 near RM 0.2 (September 2011).

5.3 Reach 2

Location: River mile 0.6 to River mile 1.4

Survey Date: September 22 and 23, 2011

Survey Crew: Christa Strickwerda Heller and Adrianne Zuckerman (Inter-Fluve)

5.3.1 Reach Overview

Reach 2 begins approximately 0.3 RMs upstream of Hwy 153. This section of Libby Creek has a low gradient and is moderately confined between a hillside along the river-right bank and by Libby Creek Road along the left bank. Land use is residential and agriculture. Larger private parcels are more frequent towards the upper end of the reach. Beyond the reach boundary at RM 1.4, Libby Creek flows through Okanogan National Forest lands.

5.3.2 Channel Morphology

Reach 2 is a moderate gradient (2.95%) pool-riffle channel. The reach flows through a moderately confined valley. The channel and floodplain are artificially confined in portions of the reach that lie adjacent to Libby Creek Road and developed lands. Several failed wooden bridges and an abandoned irrigation diversion (right bank at RM 0.7) are located in the reach. The reach is relatively unconstrained and meanders through a narrow floodplain (Figure 30). There are high flow channels, slope wetlands, and beaver activity. Channel gradient increases at RM 1.2 and the dominant habitat type transitions to cascading riffles.

Figure 30. Reach 2 flows through a narrow floodplain and has a greater wood supply than Reach 1. The channel is moderately confined between the right bank hillside (observed in the photo) and a left bank road (September 2011).

5.3.3 Habitat Unit Composition

Reach 2 consisted of 11% pools, 80% riffles, 8% glides, and 1% side-channels (Figure 31). Residual pool depths ranged from 1 to 4 feet (Figure 32). Average residual pool depth was 1.7 feet. Average maximum pool depth was 2.5 feet. Plunge pools formed by channel spanning LWD and/or woody debris jams were the dominant slow water units (e.g. Figure 33). Pool frequency was 20.1 pools per mile, with mean pool spacing of 19.0 channel widths per pool. Reach 2 would be considered “functioning at risk” with respect to pool spacing based on USFWS (1998).

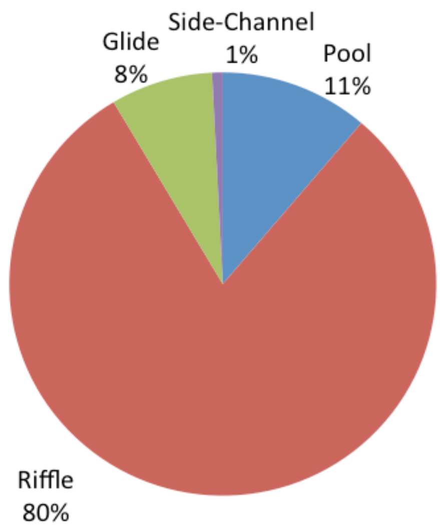


Figure 31. Habitat unit composition for Reach 2.

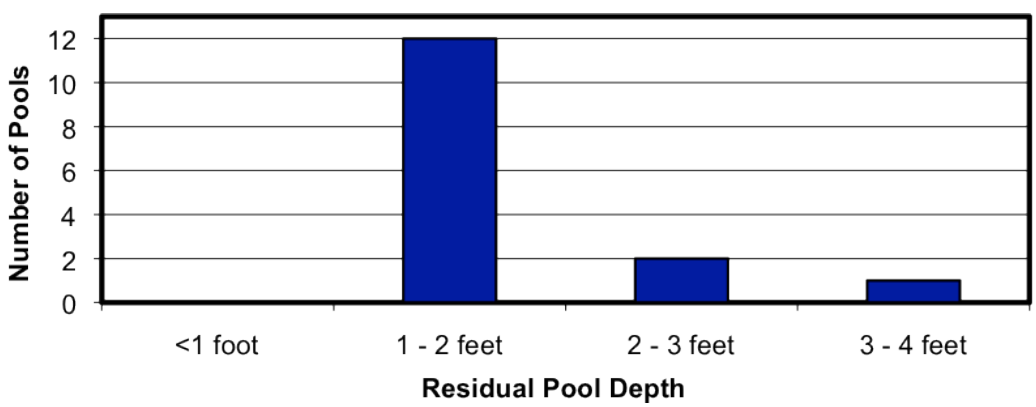


Figure 32. Reach 2 residual pool depths.

Figure 33. Representative plunge pool in Reach 2 (September 2011).

5.3.4 Off-Channel Habitat

There were two side-channels in Reach 2. Both side-channels were short and had collected small LWD along the upstream side of the island separating the unit from the main channel.

In addition to the two side-channels, there was an abandoned irrigation diversion at RM 0.7 along the right bank. The diversion had a large concrete headgate (Figure 34) with a cobble lined channel that had been filled with smaller gravels and fines. The main channel had been armored with plywood at the upstream end of the diversion to protect the closed headgate and channel (Figure 35).

Opposite the abandoned irrigation diversion, and confined between the left bank and Libby Creek Road, was a wetland complex perched on a bench above the main channel. The wetland was currently isolated from the main channel. Further upstream, at RM 0.8 and 1.2, were two separate tributaries that originate from groundwater springs along the river-right hillside (Figure 36). The wetland and one of the tributaries had evidence of beaver activity.

Figure 34. Headgate in an abandoned irrigation diversion at RM 0.7 (September 2011).

Figure 35. Plywood armoring along river-right near the downstream end of Reach 2 (September 2011).

Figure 36. Spring-origin tributary entering the channel from river-right (September 2011).

5.3.5 Large Woody Debris

Instream wood plays a moderate role in Reach 2, including sediment sorting, habitat cover, flood refuge habitat, and channel complexity (Table 2). Wood was an important component of plunge pool formation observed in Reach 2 (Figure 37). Most wood jams were comprised principally of small material that had accumulated behind larger stable pieces. The jams had captured fallen leaves, needles, and other stream detritus, improving habitat cover and providing food for macroinvertebrates and fish.

LWD frequency totaled 164 pieces with 216 pieces/mile and "small" pieces comprising 70% of all LWD counted in the reach. "Large" pieces accounted for only 5% of the LWD. Reach 2 appeared to have adequate LWD recruitment potential due to numerous mature riparian trees within the narrow floodplain (Figure 38).

Table 2. Large woody debris quantities in Reach 2.

Reach 2	**Small** (6 in x 20 ft)	**Medium** (12in x 35 ft)	**Large** (20in x 35 ft)	**Total**
Number of Pieces	114	42	8	164
Number of Pieces/Mile	150	55	11	216

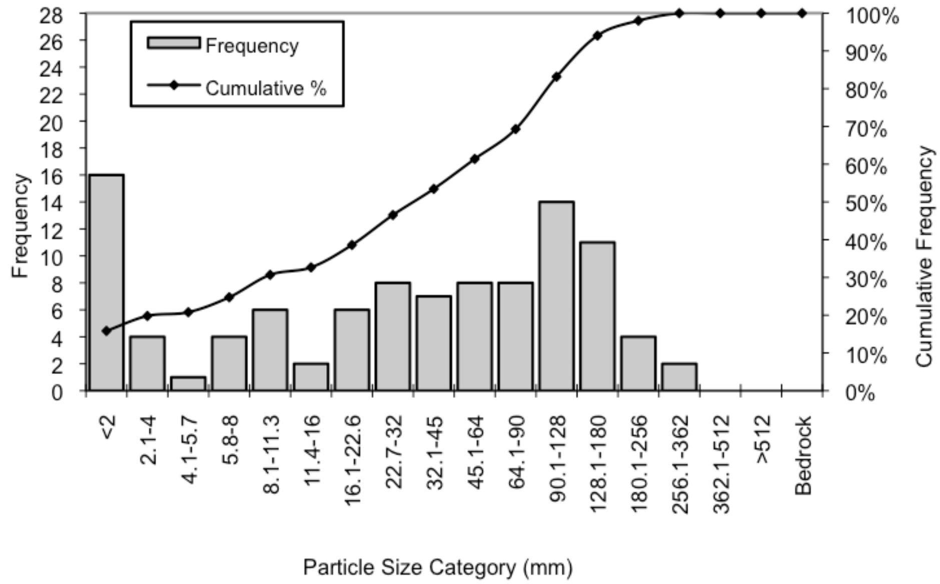
Figure 37. Characteristic plunge pool formed by channel-spanning LWD, Reach 2 (September 2011).

Figure 38. Narrow floodplain with large cottonwoods and high flow channel along river-left (September 2011).

5.3.6 Substrate and Fine Sediment

Bed substrate was dominated by gravels and cobbles. Bedrock and boulders were rare, although large boulders become more prevalent above RM 1.2 (Figure 39). The percentage of fine sediment (<2mm) was relatively high, making up approximately 13-19% of the substrate distribution. Reach 2 would be considered “functioning at risk” with respect to fines in gravel (near areas of spawning and incubation) based on USFWS (1998). The pebble count data and ocular estimates are presented in Figure 40, Figure 41, and Figure 42.

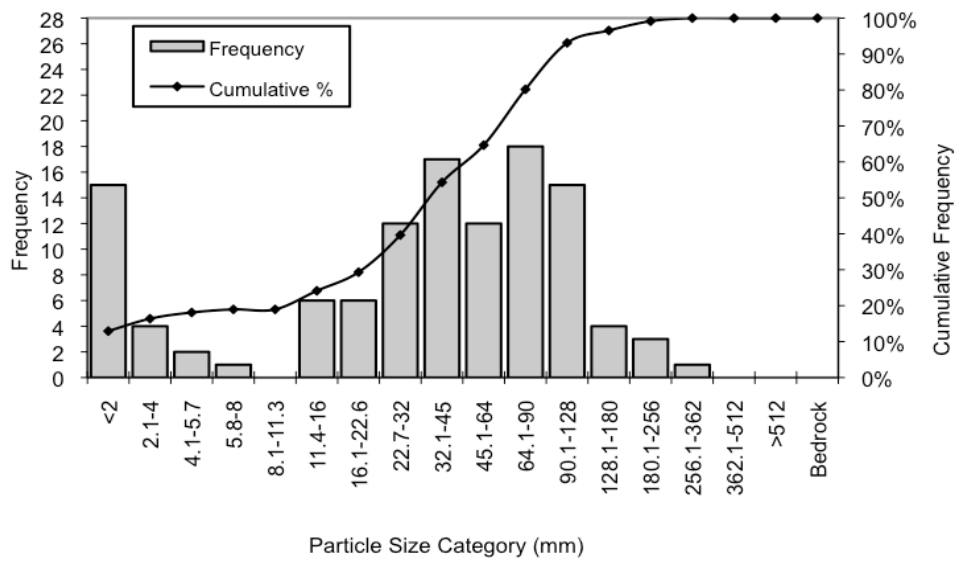
Figure 39. Boulders were observed towards the upstream end of Reach 2 (September 2011).



Material	Percent Composition
Sand	16%
Gravel	46%
Cobble	37%
Boulder	2%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	<2
D16	2
D50	39
D84	132
D95	198

Figure 40. Grain size distribution and particle size classes from pebble count taken at RM 0.7.



Material	Percent Composition
Sand	13%
Gravel	52%
Cobble	34%
Boulder	1%
Bedrock	0%

Size Class	Size percent finer than (mm)
D5	<2
D16	4
D50	41
D84	101
D95	157

Figure 41. Grain size distribution and particle size classes from pebble count taken at RM 1.0.

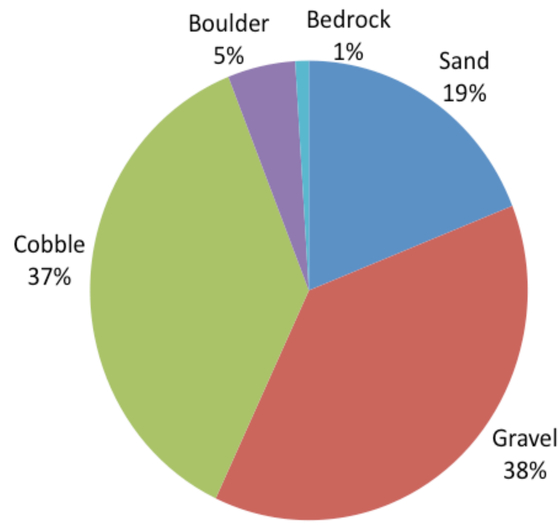


Figure 42. Percent composition of bed substrate based on ocular estimates, Reach 2.

5.3.7 Instability and Disturbance

Human activities have modified the channel, floodplain, and riparian corridor. Although residential development in Reach 2 was less than Reach 1, channel modifications and bank instability were more prevalent in Reach 2. Reach 2 had 905 feet of actively eroding streambank, making up 11% of total reach erosion (Figure 43).

The channel was naturally confined along river-right. Loam soils were exposed in a few incised channel sections (Figure 44). Past land use practices (including logging and road building) may have contributed to these conditions.

There were several small channel-spanning bridges throughout Reach 2; however, most were located above the active channel and did not include bank armoring. A bridge at the upper end of the reach (near RM 1.3) was located downstream of a right bend where riprap and gabions affected channel hydraulics and lateral channel dynamics. There was also a small failed footbridge that had accumulated woody material and created a downstream plunge pool.

A failed irrigation diversion was located at RM 0.7. The channel was likely altered in this area to divert water into the irrigation canal. The system was no longer functional; however, flows continue to be affected by the diversion structure and are causing erosion along the river-right bank.

Livestock grazing along the riparian corridor (Figure 45) has resulted in exposed streambanks that were contributing fine sediment and animal waste during rains and high flow events. Bank vegetation was limited where livestock had access to the stream. Exclusion fencing and riparian plantings would be beneficial in these areas.

A non-functional culvert was located instream near RM 0.7 (Figure 46). This culvert may have been used to drain the slope wetland located within the river-left floodplain bench.

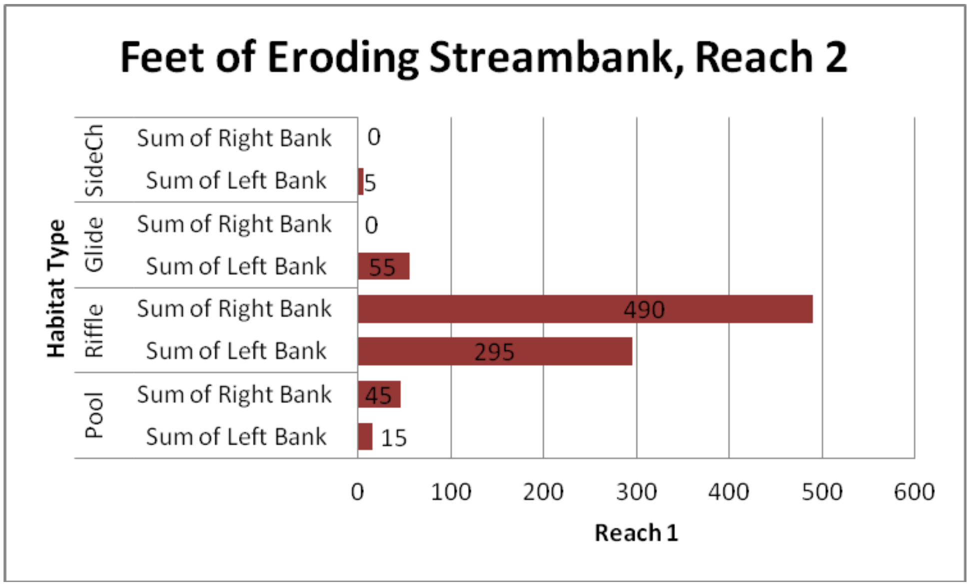


Figure 43. Length of eroding streambank in feet.

Figure 44. Channel incision observed in the upper portion of Reach 2 (September 2011).

Figure 45. Riparian grazing, Reach 2 (September 2011).

Figure 46. Remnant culvert in Reach 2 (September 2011). This culvert may have been used to drain the river-left wetland at RM 0.7.

5.3.8 Available Spawning and Rearing Habitat

A moderate amount of spawning and rearing habitat was available in Reach 2. Cobble was the dominant substrate in riffles (40%) and gravel was sub-dominant (36%). Steelhead spawn throughout this reach (Figure 47). Many of the pool tail-out areas were composed of gravels and small cobbles that are within the optimum range for spawning steelhead (6 – 102 mm, Bjornn and Reiser 1991). The coarse bed at the upstream end of this reach provides areas of localized velocity refuge that may be utilized for rearing by juvenile steelhead and resident trout.

Pool quantity within the reach was low to moderate and the pools generally had shallow residual depths. There was only one pool with a residual depth greater than 3 feet. Reach 2 pool quantity would be considered below "functioning adequately" conditions based on USFWS (1998).

LWD was below adequate levels but there are good future potential recruitment sources.

Figure 47. Riffle where steelhead spawning has been observed during past spawning surveys (September 2011).

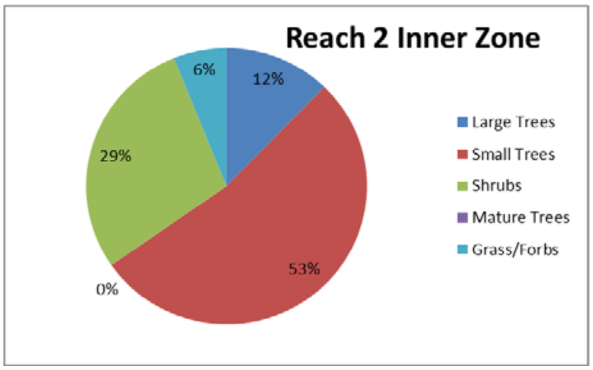
5.3.9 Fish Passage Barriers

There were no fish passage barriers in Reach 2. Several plunge pools have the potential to limit upstream passage for juvenile steelhead and trout during low flow periods. Mean riffle thalweg depth was 0.6 ft, which is below the minimum threshold depth for passage for spring Chinook (Thompson 1972). However, spring snowmelt flows would allow for easy upstream passage by adult summer steelhead.

5.3.10 Riparian Corridor

Reach 2 was generally forested but there continues to be impacts related to past riparian clearing and grazing. Riparian cover was more diverse and provided more stream shade than Reach 1. Hardwoods were more abundant than conifers and included alder, birch, cottonwood, and thickets of red osier dogwood. There were a few ponderosa pines toward the upstream end of the reach. There was also greater diversity of shrubs in Reach 2, which included serviceberry, mock orange, bald hip rose, Douglas spirea, Columbia hawthorne, and snowberry. Columbia clematis was abundant in areas where the canopy provided filtered or full sunlight. Clematis may impact the growth and vigor of more desirable overstory vegetation due to its abundance and its ability to shade out young seedlings.

In the riparian inner zone (near-channel), small trees were the dominant size class (53%) (Figure 48) and shrubs were sub-dominant (29%). In the riparian outer zone, 43% of the units were dominated by shrubs, including red osier dogwood, hawthorne, spirea, and sagebrush. The stream is naturally confined by the valley wall along river-right, which shades the stream in the afternoon.



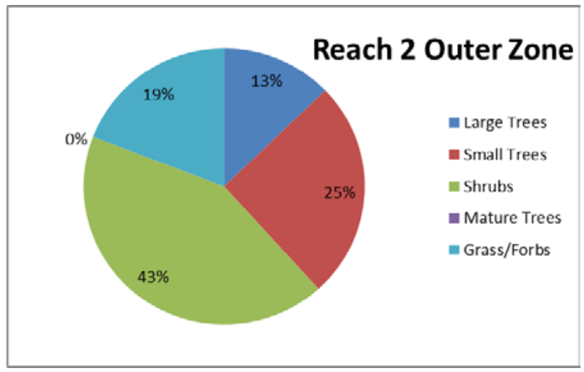


Figure 48. Distribution of vegetation size class categories for the riparian inner and outer zones in Reach 2.

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APPENDIX B LIBBY CREEK PROJECT OPPORTUNITIES

Reach	Sub-Unit	Project Number	Strategy Category	Project Name	Description	Photo
1	IZ-16	Project RM 0.0	Instream Habitat Enhancement	Confluence Maintenance	A Low flow passage problem currently exists at the confluence of Libby Creek and the Methow River. There is currently a short, steep riffle to connect the base flow elevation of Libby Creek to the base flow water surface elevation of the Methow River. This may present a passage problem for juveniles at low flow. This location should be monitored, and if necessary, grade control should be installed to ensure fish passage at all flows.	
1	IZ-15	Project RM 0.04	Instream Habitat Enhancement	LW Enhancement	This project would include a lateral log-jam along the right bank of the channel. The goal of the wood placement would be to provide adult holding and juvenile rearing habitat. Large wood would promote lateral channel dynamics, recruit spawning gravels, initiate pool scour, and provide cover for habitat. This location benefits from having few infrastructure constraints; this project would also promote overland flow on one of the few connected OZs	
1	DOZ-06	Project RM 0.06 (Left Bank)	Riparian Restoration	Expand Riparian Buffer (left bank).	A very narrow band of riparian forest extends along the left bank. This project would plant high density native riparian forest vegetation within a 150 foot buffer in order to restore riparian functions including stream shade, bank stabilization, and futures sources of LWM.	

Reach	Sub-Unit	Project Number	Strategy Category	Project Name	Description	Photo
1	IZ-13	Project RM 0. 1	Instream Habitat Enhancement	Monitor Instream Flow & Withdrawal Rates	This project includes monitoring instream flows to ensure flow is meeting the requirements for fish passage and habitat. If necessary, investigate opportunities for reducing withdrawals during low flow periods to increase instream flows.	
1	IZ-10	Project RM 0.12 (Left Bank).	Reconnect Stream Channel Processes	Remove Riprap	This project involves the removal of approximately 75 feet of riprap along the left bank. Riprap removal would restore lateral channel dynamics and would reduce the rate of incision within Libby Creek. A small jam could be placed along the right bank to promote habitat diversity and inundation along the left floodplain.	
1	IZ-03	Project RM 0.15	Instream Habitat Enhancement	LW Enhancement	This project involves placement of large wood to promote channel process and to provide cover for habitat that is extremely limited in this reach. The project would include a lateral bank jam and cover wood along the right bank into existing pool/glide habitat.	

Reach	Sub-Unit	Project Number	Strategy Category	Project Name	Description	Photo
1	IZ-09	Project RM 0.21-L	Instream Habitat Enhancement	Monitor Instream Flow & Withdrawal Rates	This project includes monitoring instream flows to ensure flow is meeting the requirements for fish passage and habitat. If necessary, investigate opportunities for reducing withdrawals during low flow periods to increase instream flows.	
1	IZ-09	Project RM 0.21-C	Reconnect Stream Channel Processes	Remove Channel Spanning Wood Bridge and Replace with Channel-spanning Log Jam.	The existing channel-spanning wood bridge could be removed and replaced with LW material. A channel-spanning jam could be tied into the banks where the existing bridge abutments are located. This would promote vertical stability of the Libby Creek channel.	
1	IZ-08	Project RM 0.29	Reconnect Stream Channel Processes	Replace Highway 153 Bridge	The existing Highway 153 bridge is undersized – it is currently only equivalent to 1.25 channel widths at low flow. The bridge is acting as a hydraulic constriction and limiting lateral migration of the channel. Additionally, it is causing scour downstream of the bridge. The bridge should be replaced with a wider and higher structure to allow for the lateral and vertical expansion of Libby Creek.	

Reach	Sub-Unit	Project Number	Strategy Category	Project Name	Description	Photo
1	IZ-07	Project RM 0.3	Reconnect Stream Channel Processes	Riprap Removal & Grade Control	Libby Creek has been channelized and riprap has been placed along both the left and right banks. Riprap begins 40 feet upstream of the Highway 153 Bridge and extends along both banks for 116 feet. This project would include the removal or modification of the riprap to enhance channel margin habitat and to restore lateral channel dynamics. If necessary, wood jams and grade control could be placed to protect property.	
1	IZ-06	Project RM 0.33	Reconnect Stream Channel Processes	Transverse Bar Construction	Instream alterations have been made to create a step-pool sequence. These alterations extend 100 feet upstream of the riprap at RM 0.3. The steps could be removed and replaced with constructed transverse riffles/bars to improve habitat conditions for spawning, rearing, and insect production. This would introduce more lateral movement within the stream and would promote scour pool development. Large wood could be added for habitat enhancement within the pools. It would be necessary to work closely with the landowners to ensure maintenance of aesthetics and adjacent uses.	
1	OZ-03	Project RM 0.38	Reconnect Floodplain Processes	Floodplain Reconnection	The incision of Libby Creek has resulted in extremely limited connected floodplain throughout the survey reach. This location presents adequate space to lower floodplain surfaces on either side and install alternating large wood jams. This would promote increased hydraulic and hydrologic connectivity with floodplain surfaces on either side, as well as provide habitat diversity throughout the reach.	

Reach	Sub-Unit	Project Number	Strategy Category	Project Name	Description	Photo
1	DOZ-03 and DOZ-01	Project RM 0.41	Reconnect Floodplain Processes	Floodplain Reconnection	The left and right bank throughout this area provide space to lower floodplain elevations to create an active floodplain. Floodplains would be treated with large wood to increase complexity and provide roughness throughout the reach. Large wood would promote gravel recruitment and pool scour over time.	
1	DOZ-03 and DOZ-01	Project RM 0.42	Reconnect Stream Channel Processes	LW Enhancement	This project would be paired with RM 0.41 if possible. This project would include creating alternating channel margin log jams to reintroduce lateral migration into Libby Creek and slow its rate of incision.	
1	IZ-03	Project RM 0.5	Instream Habitat Enhancement	LW Enhancement	This project would involve the placement of two large log jams (one along the right bank at the downstream end, and one along the right bank at the upstream end) that extend out into the channel. This would promote lateral channel dynamics, pool scour, gravel recruitment, and cover enhancement. These actions would be paired with dense plantings of riparian vegetation along both banks.	

Reach	Sub-Unit	Project Number	Strategy Category	Project Name	Description	Photo
2	DOZ-09	Project RM 0.62	Riparian Restoration	Riparian Restoration (right bank)	Approximately 150 feet of the right bank is unvegetated along this reach. Native replanting would improve shade, natural stability, and provide future sources of large wood.	
2	IZ 17	Project RM 0.7	Instream Habitat Enhancement and Riparian Restoration	LW Enhancement, Riparian Restoration, and Diversion Monitoring	Large wood could be keyed into the right bank to provide overhanging cover, recruit gravels, and promote pool scour. This would be paired with riparian restoration along the right bank to provide shade, natural stability, and future sources of large wood material.	
2	IZ-16	Project RM 0.71	Reconnect Stream Channel Processes	LW Enhancement	Alternating jams would be placed along the left and right banks throughout this long riffle. This would promote lateral migration of the channel as well as initiate gravel recruitment and pool scour. This would provide habitat complexity in this long, uniform riffle.	

Reach	Sub-Unit	Project Number	Strategy Category	Project Name	Description	Photo
2	IZ-15	Project RM 0.75	Instream Habitat Enhancement	LW Enhancement	A small jam could be built into the right bank along this reach. The goal of the jam would be to add complexity and cover.	
2	IZ-12 and OZ 07	Project RM 0.9	Instream Habitat Enhancement and Reconnect Stream Channel Processes	LW Enhancement and Fill Removal	The location of a connected outer zone (OZ-07) along the left bank makes this an excellent location for a channel- and valley-spanning jam. A large jam complex here would promote floodplain connectivity and habitat complexity. Fill along the floodplain would need to be removed and portions of the floodplain may also need to be regraded. An additional log jam could also be installed along the left bank approximately 100 feet downstream.	
2	DOZ -04	Project RM 1.07	Riparian Restoration	Riparian Restoration	The right bank is sparsely vegetated from RM 1.07 to RM 1.14. The shoreline has been altered, regraded, and cleared for residential development along the banks. This project would replant banks with native riparian seedlings and regrade where necessary.	

Reach	Sub-Unit	Project Number	Strategy Category	Project Name	Description	Photo
2	IZ-06 and OZ-06	Project RM 1.18	Reconnect Stream Channel Processes	LW Enhancement	The left and right banks throughout this reach are relatively well connected floodplains. Large, alternating, left and right bank jams could be placed to promote lateral channel migration, gravel recruitment, and pool habitat formation.	
2	IZ-02 and IZ-03	Project RM 1.35	Reconnect Stream Channel Processes	Bridge Replacement	The left and right abutments of this bridge are limiting Libby Creek's lateral channel dynamics and are acting as a hydraulic constriction. Replacing the bridge with a larger bridge would restore channel processes.