WATERSHED AND REACH SCALE INVESTIGATION OF EXISTING CONDITIONS

MANASTASH CREEK CORRIDOR HABITAT ENHANCEMENT AND FLOOD HAZARD REDUCTION PLAN

Prepared for
Kittitas County Conservation District

Prepared by
Herrera Environmental Consultants, Inc.
and
Watershed Science & Engineering, Inc.

WATERSHED
Science & Engineering

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Prepared for
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LIST OF ABBREVIATIONS AND ACRONYMS

dbh	diameter at breast height
ESA	Endangered Species Act
GIS	geographic information system
KCCD	Kittitas County Conservation District
KRD	Kittitas Reclamation District
LWD	large woody debris
m	meter(s)
mi./sq. mi.	mile(s) per square mile
mm	millimeter(s)
MWDA	Manastash Water Ditch Association
NOAA Fisheries	National Oceanic and Atmospheric Administration, National Marine Fisheries Service
Reach BC	Bullfrog Confined Reach
Reach CY	Canyon Reach
Reach FA	Fan Apex Reach
Reach FC	Fan Contraction Reach
Reach FE	Fan Expansion Reach
Reach SC	Swauk Confined Reach
Reach YC	Yakima Confluence Reach
REI	reach-based ecosystem indicator
RM	River Mile
USGS	US Geological Survey
WDFW	Washington Department of Fish and Wildlife
WSE	Watershed Science & Engineering, Inc.

EXECUTIVE SUMMARY

Purpose/Background

The Kittitas County Conservation District (KCCD) is conducting a reach-scale assessment (also referred to herein as the project) of Manastash Creek that seeks to identify opportunities to improve aquatic habitat and reduce flood hazards. The project will:

- Identify factors within Manastash Creek that limit salmonid productivity
- Identify existing flood and erosion hazards in the Manastash Creek floodplain
- Identify opportunities to protect and restore dynamic fluvial and landscape processes that will sustain healthy salmonid populations and improve water quality
- Identify opportunities to reduce flood and erosion damage to private property and public infrastructure without affecting riparian or aquatic habitat
- Engage landowners, resource managers, and others in collaborative efforts that contribute to the success of restoration and flood protection efforts

The outcome of this effort will be a focused strategy and a list of viable projects that can be cooperatively implemented to improve aquatic habitat and reduce the impacts of flooding and erosion along Manastash Creek.

This report describes the existing conditions in the project area with respect to riparian and aquatic habitat quality and flood and erosion hazards. This report combines the results of a habitat conditions assessment conducted by Herrera Environmental Consultants, Inc., (Herrera) and a flood and erosion hazard assessment conducted by Watershed Science and Engineering, Inc. (WSE). Future phases of the project will involve identification and prioritization of opportunities for habitat improvement and flood and erosion hazard reduction, and development of a plan for implementing these project opportunities.

Results of the Habitat Condition Assessment

In general, the study area has a wide range of habitat conditions that depend largely on: 1) location relative to instream diversions, 2) modifications to floodplain geomorphology, and 3) the extent of riparian clearing.

With regard to riparian vegetation, conditions varied widely throughout the study area based largely on the combination of land use and environmental conditions. Relatively intact areas that have not been cleared through development or agricultural activities display a range of vegetation types that appear to be driven primarily by seasonal water availability; vegetation types range from shrub-steppe (dry) to deciduous forest (moist), to wetland habitats (wet).

Areas that have been cleared for development or agricultural purposes generally fall under the grass, bare ground, building, or road landcover types.

Channel hydrology is a primary limiting factor to habitat forming, maintenance, and overall quality and fish habitat use and accessibility. Irrigation diversions led to dry channel conditions from the Reed diversion to West Side Canal spill during the summer and fall, and reduced stream flow downstream of the West Side Canal spill.

Water quality is also a concern related to irrigation diversion and return flows. Elevated water temperatures and turbid water occurs downstream of the West Side Canal spill. Lack of riparian vegetation throughout portions of the lower 6 miles of Manastash Creek also likely increases stream temperature due to greater sun exposure.

Levees constructed in the vicinity of Serenity Lane and Cove Road, and to lesser degrees elsewhere along Manastash Creek, confine stream flows to the channel and reduce floodplain storage, which can exacerbate downstream flooding and impact water quality and habitat. This channel confinement also affects sediment transport processes and leads to excessive deposition and channel migration in adjacent portions of the system. The channel is also confined at many undersized crossings in the project area, including at Serenity Lane, Cove Road, and at multiple crossings in Manastash Canyon.

Many reaches in the lower 6 miles of Manastash Creek have limited habitat complexity and low density of large woody debris (LWD) in the channel. Active floodplain processes provide flood storage and reduce velocity in the stream channel. Large wood in the stream channel leads to sediment transport and gravel sorting that provides spawning habitat and pools for fish rearing. Reaches with intact riparian vegetation tend to have greater LWD density and habitat complexity.

Habitat improvement measures to be considered will include preservation and conservation of existing higher quality habitat areas, as well as restoration and enhancement of areas with more degraded conditions. Restoration measures will be developed and evaluated from the perspective of restoring natural function to the system rather than creating habitat forms in the system directly. Some of the restoration measures to be considered include:

- **Preservation and conservation.** Where habitat quality is high but could potentially be compromised in the future, measures such as conservation easements could be considered for protection of the resource.

- **Floodplain reconnection.** Where levees confine the stream channel but are not critical for flood control, removing or setting back the levees could provide valuable flood storage and habitat function to Manastash Creek floodplain areas.

- **Stream crossing modification or removal.** Where road or other crossings confine the channel and block floodplain flow, widening of the opening or removal of the crossing could decrease the negative impact on sediment transport, erosion, and habitat. Upsizing or removing crossings could also reduce flooding potential and the need for dredging and emergency repairs.

- **LWD placement.** In portions of Manastash Creek where there is a lack of channel habitat structure, placement of stable LWD could provide benefits to local habitat by sorting deposited sediment and inducing deep pools.
- **Instream flow restoration.** Because reduced summer base flows impair habitat in a large portion of Manastash Creek, irrigation water conservation and diversion consolidation measures that are being implemented should be continued. In addition, given that field observation indicated the presence of irrigation return flows through groundwater/hyporheic input within the Swauk Confined Reach (Reach SC), this provides an analog to study the feasibility of infiltrating into the ground the discharges from irrigation return ditches as a potential restoration strategy.
- **Revegetation of the riparian zone.** Where the riparian forest has been removed or modified, re-establishment of a healthy vegetated community can provide a dramatic improvement in geomorphic function and habitat quality. In the reaches of Manastash Creek where no summer base flow persists, it will be important to ensure that groundwater exists at a shallow enough depth to support the establishment of trees in this zone. Alternatively, infiltrated discharges from irrigation return ditches could be used in areas of where trees are planted.

Results of Flood and Erosion Hazard Assessment

In general, flood, erosion, and sedimentation hazards are present throughout the project area due to the volume of sediment moving through the system, development within the floodplain, lack of riparian vegetation, and confined channel reaches and roadway crossings.

At the Yakima River confluence, flood hazards are significant. Extreme care must be exercised for any proposed development within this reach. The downstream half of the reach is dynamic; because Manastash Creek actively floods and deposits sediment in that area, the hazards are significant. The upstream half of the delta is partially protected by an earthen levee along the edge of the Yakima River, and it is the river that poses the greatest threat to that part of the delta, not Manastash Creek.

Between Serenity Lane and the Yakima River confluence, flood risk is generally confined to the narrow, entrenched floor of the reach. Fortunately, few structures have been built on the entrenched channel floor and, therefore, the potential for costly flood damage in most of this reach is low. Other features that could sustain damage include two county road bridges, an irrigation siphon crossing, and driveway road fill. Lateral erosion is of concern as there are several places where the stream is eroding the toe of the entrenched terrace wall. Structures currently do not appear at risk from such lateral erosion, but it should be monitored in this reach where structures are present.

Between Cove Road and Serenity Lane, flood hazards are highly dependent upon the capacity of the Cove Road Bridge. If the bridge remains open, then flood, erosion, and sedimentation risks along the main channel would be high. If the bridge clogs with sediment, flood risk would decrease within the main channel, but it would increase within the network of historical swales and irrigation ditches that would carry the water downstream. A major concern is the potential for increased erosion along the main channel where little to no vegetation covers the banks. Significant erosion would introduce large quantities of sediment to the stream. The material would deposit downstream where it would likely aggravate erosion and flooding. Efforts should continue to restore year-round stream flows so that healthy vegetation can be established along the stream banks.

Flood risk is high between KRD South Branch Road and Cove Road. The extent of flooding will depend upon main channel capacity. If the channel fills with sediment or debris, flow would find its way downstream through the network of historical swales and irrigation ditches. Lateral erosion is likely to continue within the reach between the Cove Road Bridge and the Reed diversion, where there is little to no vegetation on the banks. As noted above, efforts should continue to re-establish year-round stream flows and bank vegetation. Sediment deposition is and will continue to be a concern, especially in the vicinity of the Cove Road Bridge. Avulsion potential is moderate because there are a number of significant distributary swales that connect to the channel along the reach.

Flood hazards are significant within Manastash Canyon, but most are confined to the active floodplain. Fortunately, most residences and structures are located outside of the active floodplain. Facilities most at risk are driveway bridges and Manastash Road where it is adjacent to the stream. Opportunities to reduce flood hazard risk within Manastash Canyon will need to be addressed on a site-by-site basis, as there appear to be few reach-scale opportunities for flood hazard reduction.

Some of the flood and erosion hazard management strategies to be considered include:

- **Monitor structures between Serenity Lane and the Yakima River confluence.** The structures currently do not appear at risk, but lateral erosion should be monitored in this reach.

- **Sediment Management.** A sediment management plan is needed for the channel in the vicinity of the Cove Road Bridge to provide reasonable assurance that the bridge would pass an acceptable portion of the flow during major floods.

- **Restore Year-Round Flows.** Efforts should continue to restore year-round stream flows so that healthy vegetation can be established along the stream banks.

- **Bridge Replacement.** The Serenity Lane Bridge is too narrow and the abutments are in extremely poor condition. It should be replaced with a wider crossing. In addition, other undersized channel crossings (Cove Road, KRD South Branch Road, and KRD 13.8) should be considered for modification or replacement.

- **Manastash Canyon**. Identify and study opportunities to reduce flood hazard risk within Manastash Canyon on a site-by-site basis.

INTRODUCTION

The Kittitas County Conservation District (KCCD) is conducting a reach-scale assessment (also referred to herein as the project) of Manastash Creek that seeks to identify opportunities to improve aquatic habitat and reduce flood hazards. The project will:

- Identify factors within Manastash Creek that limit salmonid productivity
- Identify existing flood and erosion hazards in the Manastash Creek floodplain
- Identify opportunities to protect and restore dynamic fluvial and landscape processes that will sustain healthy salmonid populations and improve water quality
- Identify opportunities to reduce flood and erosion damage to private property and public infrastructure without affecting riparian or aquatic habitat
- Engage landowners, resource managers, and others in collaborative efforts that contribute to the success of restoration and flood protection efforts

The outcome of this effort will be a focused strategy and a list of viable projects that can be cooperatively implemented to improve aquatic habitat and reduce the impacts of flooding and erosion along Manastash Creek.

This report describes the existing conditions in the project area with respect to riparian and aquatic habitat quality and flood and erosion hazards. This report combines the results of a habitat conditions assessment conducted by Herrera Environmental Consultants, Inc., (Herrera) and a flood and erosion hazard assessment conducted by Watershed Science and Engineering, Inc. (WSE). Future phases of the project will involve identification and prioritization of opportunities for habitat improvement and flood and erosion hazard reduction, and development of a plan for implementing these project opportunities.

Background

The project is being conducted because Manastash Creek has been designated as critical habitat for the Mid-Columbia Summer Steelhead, a species listed as threatened under the Endangered Species Act (ESA). Effective use of fish habitat in Manastash Creek is limited by excessive sedimentation, low stream flows during the summer and fall, and lack of fish access to upper portions of the system. In response to the ESA listing, the KCCD has been actively working with the local agricultural community to improve habitat conditions and avoid or minimize potential impacts associated with agriculture practices along the lower 6 miles of the stream. Past activities have included installation of fish screens at irrigation diversions, removal of fish passage barriers, and efforts to improve stream flow conditions. There are three unscreened fish diversions and one large fish passage barrier remaining, and they are slated for improvement.

The project is also being undertaken because flood and erosion damage continues to adversely affect private property and public infrastructure. For years, flood damage reduction activities have taken place in an ad hoc fashion, often with little regard for potential impacts on habitat. A comprehensive strategic plan is needed to implement projects that will reduce flood and erosion damage while preserving or enhancing aquatic habitat.

The project is being led by the KCCD in partnership with Kittitas County (County). Funding is provided by the State of Washington Salmon Recovery Funding Board (SRFB), the Washington State Conservation Commission, the Bureau of Reclamation's Yakima River Water Enhancement Program, and Kittitas County Public Works.

Project Description

This report documents the existing conditions assessment of Manastash Creek conducted in 2012. It provides baseline information for the two primary issues being addressed by the overall project:

- Riparian and aquatic habitat conditions in Manastash Creek
- Flood and erosion hazards in the Manastash Creek floodplain

This report focuses on the physical and biological processes that create and influence habitat and flood and erosion hazards. Those physical and biological processes are water flow (hydrology), stream channel changes (geomorphology), and sediment and wood transport.

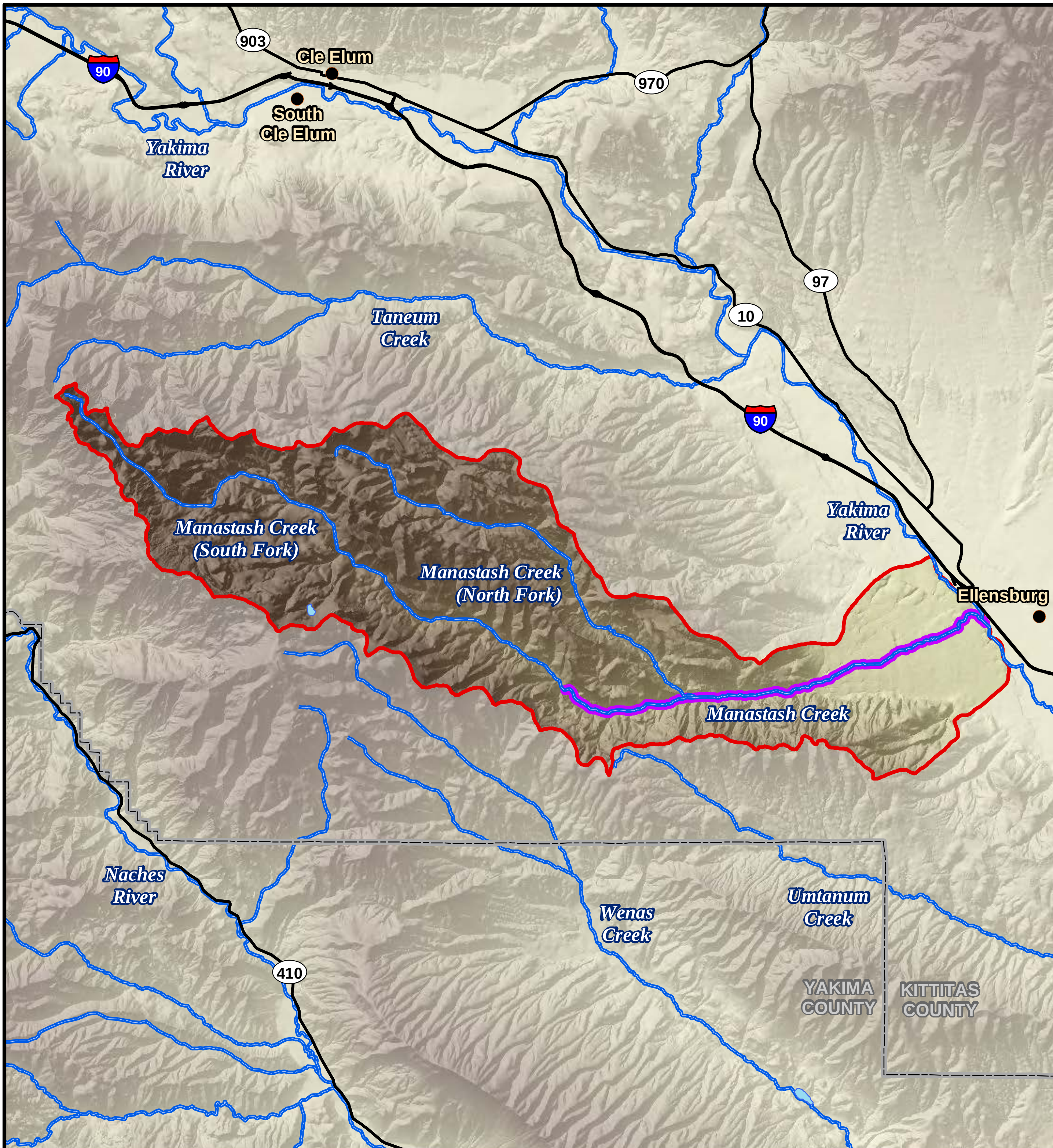
This report provides a summary description of the Manastash Creek watershed and more detailed descriptions of habitat and flood and erosion hazards on a reach scale. The report is organized in the following major sections:

1. **Historic and Existing Watershed Conditions**
2. **Existing Reach-Scale Habitat Conditions**
3. **Existing Flood and Erosion Hazards**

In the next phase of the project, potential project opportunities will be developed with the goal of preserving or improving habitat, and reducing flood and erosion risks in the Manastash Creek corridor.

Project Study Area

The Manastash Creek flows within a narrow canyon for most of its course before reaching a broad alluvial fan, and from there, the Yakima River. The study area for the existing conditions assessment includes a focus area of approximately 6 miles from the confluence with the Yakima River to the mouth of Manastash canyon at the apex of the fan, and an additional 7 miles of the main stem and South Fork Manastash Creek. The lower 6 miles of Manastash Creek is the portion most impacted by irrigation water diversion and floodplain encroachment by residential and agricultural development. Figure 1 shows the Manastash Creek watershed boundary and project study area. The study area for the flood and erosion hazard assessment also includes the lower portion of North Fork Manastash Creek.



Legend

- City
- Highway
- County boundary
- River
- Project study area
- Watershed boundary

Figure 1. Manastash Creek watershed location map.

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0 9,500 19,000 38,000

Feet

HERRERA WATERSHED Science & Engineering

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HISTORIC AND EXISTING WATERSHED CONDITIONS

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Methods of Assessment

Watershed conditions were investigated by reviewing existing data, collecting additional data, analyzing stream gauge data, and collecting sediment gradation information. The following data were reviewed as a part of the existing conditions assessment:

- Lidar data of the lower 6 miles of Manastash Creek collected by FEMA, April 2011
- Lidar data of the project study area collected as a part of this project by 3DiWest, Inc., May 2012
- Geographic information system (GIS) data, including stream features, irrigation system features, and watershed boundary, provided by the KCCD
- Orthophotography of the project study area collected as a part of this project by 3DiWest, Inc., May 2012
- Historical aerial photos available online at Central Washington University's web site: http://www.gis.cwu.edu/geog/historic_airphotos/index.htm
- Fish survey data from the Washington Department of Fish and Wildlife (WDFW) at Barnes Road stations, and at other Manastash Creek stations for Yakima River Species Interactions Studies from 1990 through 2005 (WDFW 2012)
- Flood history information provided by the KCCD
- Personal interviews with local residents about experiences with flooding and bank erosion conducted by WSE in June – August 2011
- Hydrologic monitoring reports for flow studies conducted in 2006 and 2007 (HDR/Fishpro 2007, 2009)
- Watershed assessment of Manastash and Taneum Creeks (USFS 1995)
- Geologic maps of Manastash watershed area (Tabor et al. 1982; Walsh 1986)
- Forest road analysis documenting existing conditions of national forest areas in the upper Manastash Creek watershed and impacts on sediment delivery (USFS 2004)

An analysis of mean daily flows throughout the year was conducted based on the Washington Department of Ecology Gauge (Gauge Number 39J090; Ecology 2009) at Manastash Road. Data are available for the period April 2005 through September 2009.

Sediment characterization within Manastash Creek was performed at a number of locations using Wolman pebble counts. Sediment sampling was done within the channel at Cove Road (RM 4.0), at RM 4.4, and within the Canyon Reach (RM 6.4). Sampling at RM 4.4 included three separate measurements to classify material within the main channel (dry at the time), larger material eroded from the channel banks, and sediment deposited along overbank bars during high flow.

Results

Regional and Watershed Geology

The Manastash Creek basin is in the Yakima Fold and Thrust Belt, a highly deformed region on the west edge of the Columbia Basin (Tabor et al. 1982). The surface of the region is composed of Columbia River basalts, primarily the Grand Ronde basalt, which also serves as bedrock in nearly the entire study area. The “folds” in the belt define the upper basin of the creek with generally east-west trending ridges. Within the Kittitas Valley itself, the folds are buried by Yakima River deposits. Those deposits are exposed as broad terraces across the valley that are composed of sediment delivered to the area from erosion of the Cascades Mountains over the last three million years. Most likely, the peaks in sediment discharge that define the terraces are primarily glacial (outwash) in origin; however, impoundment, over geologic time, of the Yakima River by Manastash Ridge plays a secondary role. In the study area, two terraces have been clearly identified: a terrace approximately 130,000 to 140,000 years old called the Swauk Prairie subdrift and a younger, 18,000-year-old terrace, called the Bullfrog subdrift, which coincided with the last glacial maximum in the greater Yakima Basin (Tabor et al. 1982; Walsh 1986).

It appears that water flow, in the geologic past, spanned the area from the Ellensburg Golf & Country Club to south of Manastash Road because of the numerous swales and draws in the general area. However, sedimentologically speaking, the alluvial fan is quite limited in extent. For much of the apparent fan’s length, creek-derived sediments extend less than one-quarter mile on each side of the active channel. Therefore, the fan is widest not at its base at the confluence with the Yakima River but, rather, near Cove Road, which is only about one-third of the way down the apparent fan. Moving downstream, the fan widens from its apex to the limit of tributary sediments along Manastash Ridge near Cove Road. Downstream of Cove Road, flow and sediments, including the primary historic side channel, converge to a narrow, shallow valley that incises through historic Yakima River sediments.

Watershed Hydrology

Manastash Creek drains an area of approximately 97 square miles, dropping more than 4,500 feet over 30 miles as it flows from its headwaters in the Wenatchee National Forest to its terminus at the Yakima River near Ellensburg, Washington. The creek flows within a narrow canyon for most of its course before reaching the alluvial fan. Channel slopes range from 3.5 percent in the upper canyon to less than 2 percent along the alluvial fan and within most of the study reach.

The upper basin of Manastash Creek consists of mountainous terrain that varies in elevation from 2,000 to 5,500 feet (Montgomery and McDonald 2002). Manastash Creek flows are greatest in the spring during snowmelt conditions and lowest in late summer and early fall. However, large late fall and winter rain-on-snow events are expected to become dominant within 50 years as a result of climate change (Elsner et al. 2010). From approximately late June/early July until late October/early November, a portion of lower Manastash Creek between the Reed Ditch diversion and the West Side Canal crossing (between River Mile [RM] 4.8 and RM 1.5) dries up entirely (KCCD 2007).

Flow monitoring has been conducted in Manastash Creek, primarily in the lower 6 miles of the system. The KCCD conducted a hydrologic monitoring study of Manastash Creek and select irrigation ditches to evaluate water flow during the critical summer irrigation periods in 2006 and 2007 (HDR/Fishpro 2007, 2009). That study documented losses and gains in discharge in reaches between irrigation diversion and spill locations. Gains and losses were found to be highly variable and subject to fluctuation based on many factors, potentially including seasonal change, hydrologic variability, groundwater exchange, and physical variation in subsurface conditions and channel morphology (HDR/Fishpro 2009). In general, Manastash Creek downstream of the Anderson diversion (RM 3.39) was found in 2006 to be a gaining reach, while the portion between the Reed diversion (RM 4.8) and the Anderson diversion was found to be a losing reach (HDR/Fishpro 2007).

Annual Instantaneous Peak Flood Flows and Frequencies

In the absence of long-term stream gauge data, peak flows along Manastash Creek were determined using regional regression equations developed by the US Geological Survey (USGS) (Sumioka et al. 1998). Estimated discharge quantiles are presented in Table 1 for seven locations along Manastash Creek.

Table 1. Computed Flood Frequency Discharges in Cubic Feet per Second for Manastash Creek.

Return Period	Location Along Manastash Creek					
	Mouth Near Yakima River	Manastash Road	Confluence of North & South Forks	Mouth of North Fork	Mouth of South Fork	Upstream Extent of Study Reach
2-yr	520	500	470	180	350	300
10-yr	1,090	1,070	1,000	390	750	650
25-yr	1,440	1,410	1,320	520	1,000	870
50-yr	1,730	1,690	1,590	630	1,200	1,050
100-yr	2,040	2,000	1,870	750	1,420	1,240
500-yr	2,860	2,800	2,620	1,050	1,990	1,740

To put these estimated discharge quantiles into perspective, HDR estimated May 2011 peak flows at the Manastash Water Ditch Association (MWDA) consolidated diversion site to be 1,180 cubic feet per second (cfs) in the channel, and 1,780 cfs with the inclusion of overbank flow. HDR also concluded that the return period of the flood was in the range of 78 to

100 years. As part of an investigation of flood and sedimentation issues at Cove Road, WSE estimated an in-channel peak flow of 1,000 to 1,200 cfs upstream of the Cove Road Bridge (WSE 2012). These data show that the May 2011 flood was a significant and statistically infrequent event that should provide a reasonable representation of extreme flood impacts along Manastash Creek.

Annual Mean Daily Flows

Seasonal stream flow patterns in Manastash Creek are influenced by rainfall in the fall and winter and snowmelt runoff in the late spring. Mean daily flows in Manastash Creek calculated from April 2005 through September 2009 at the Washington Department of Ecology Gauge 39J090 at Manastash Road generally peak between mid-March and early July (see Figures 2 and 3) with the highest mean monthly flow occurring in May (220 cfs for the 2005–2009 period). Spring snowmelt flows in the March-through-July period generally average 100 to 300 cfs, with maximum mean daily flows through the period of record of just over 500 cfs (see Figures 2 and 3). Flows in the winter period (mid-October through March) are generally less than 100 cfs with occasional brief spikes approaching 200 cfs due to rain or rain-on-snow events. Mean daily flows in the late summer and early fall (August through mid-October) are generally less than about 40 cfs and as low as 10 cfs in some years. Downstream from the Manastash Road Bridge, irrigation withdrawals can significantly alter or, in some cases, eliminate instream flow.

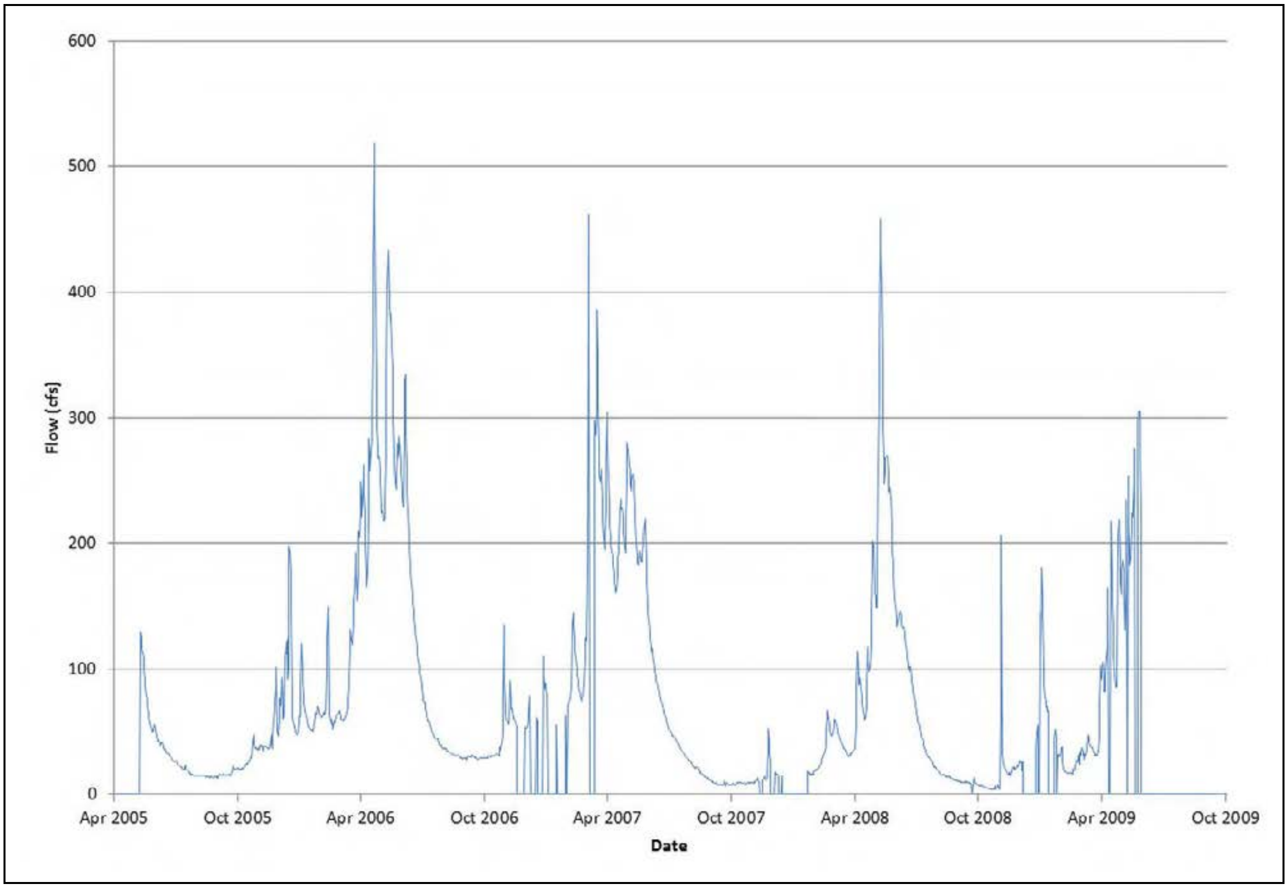


Figure 2. Mean Daily Flow Record for Manastash Creek at Manastash Road (2005-2009).

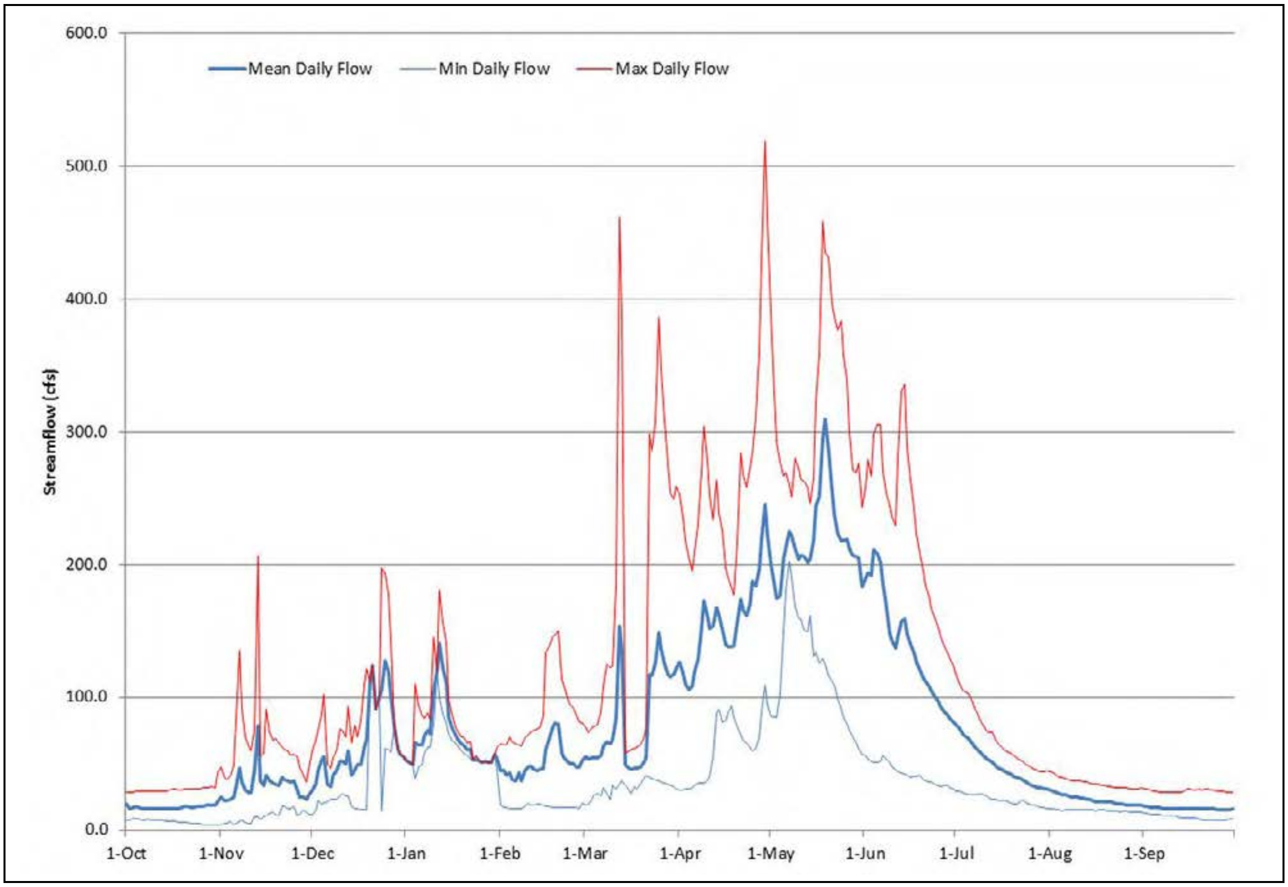


Figure 3. Mean Daily low Statistics for Manastash Creek at Manastash Road (2005-2009).

Irrigation Withdrawals and Impacts to Stream Flows

Diversion Points

Water is collected from Manastash Creek at six major diversion points for the purpose of irrigation:

- Manastash Ditch (RM 5.6)
- Keach Jensen Ditches (RM 5.5)
- Hatfield Ditch (RM 5.3)
- Reed Ditch (RM 4.8)
- Anderson Ditch (RM 3.4)
- Barnes Road Ditch (RM 1.4)

In addition to these diversion points, there are two locations where surface irrigation return flow is spilled back into Manastash Creek:

- Kittitas Reclamation District (KRD) spill (RM 5.4)
- West Side Canal spill (RM 1.7)

Some of the irrigation-return flows also flows back to the main stem via groundwater recharge near the surface irrigation return flow points, although quantities and extents of that process are unknown.

The KCCD, as part of the Manastash Creek Restoration Project, is implementing a restoration project to improve instream flows within the lower 6 miles of Manastash Creek. That project involves decommissioning and consolidating irrigation diversions, piping of ditched irrigation canals, improving irrigation efficiency (sprinkler systems), and purchasing water rights from willing landowners.

A new Manastash Water Ditch Association (MWDA) diversion facility was constructed at RM 5.6. This new diversion includes a rock weir fish passage structure. The KCCD plans to remove the Reed Ditch diversion dam and consolidate that diversion at the MWDA diversion. A new Keach Jensen Ditches diversion structure was constructed with a rock weir fish passage structure. The Anderson and Hatfield diversions are also slated for consolidation with the new MWDA diversion facility as well as decommissioning the diversions.

Flow Diversion Impacts

The newly constructed diversions at MWDA/Consolidated, Keach Jensen, and Barnes are measuring and recording diversionary amounts. In addition, withdrawals and instream flows are also measured as part of the KCCD's flow monitoring network at Hatfield Ditch, Reed Ditch, and Anderson Ditch. The MWDA diversion and the Keach Jensen diversion operate year round, delivering stockwater November 1 thru March 31.

By mid-June of each year, the amount of water in Manastash Creek has greatly diminished and only first- and second-class water rights can be met; all rights are reduced by 50 percent on July 1 (KCCD 2007). From late June/early July to late October/early November, Manastash Creek is often dry in the 3.25-mile reach between the Reed Ditch diversion and the intersection of West Side Canal and Manastash Creek. There is ongoing work by the KCCD to improve instream flow through voluntary water conservation projects and water acquisition with willing water right holders. More detailed information concerning the individual irrigation diversions are available in the *Manastastash Creek Restoration Project Instream Flow Enhancement Implementation Plan* (KCCD 2007).

Flow diversion impacts on fish passage are discussed under the Fish Habitat, Use, and Passage section later in this report.

Sediment Sources and Delivery

Nearly the entire Manastash Creek basin above the alluvial fan is composed of Grand Ronde Basalt. The basalt has been naturally altered, primarily through folding in the Yakima Fold Belt. The alteration has left the rock in the basin heavily fractured and erodible. Sediment is delivered to the creek via numerous small talus piles that were over-steepened over time by the ongoing folding (Figure 4). There are also numerous large landslides in the upper basin that encroach into the channel (Tabor et al. 1982; Walsh 1986). Finally, the largest source of sediment is stream floodplain alluvium and older Yakima River terrace alluvium which enters the stream through lateral erosion of the channel banks. All of these processes contribute a significant volume of sediment to the stream. These sediments deposit in areas where velocities slow and discharge intensity is reduced, typically due to loss of channel confinement, reduction in channel slope, or the presence of a natural or anthropogenic impediment.

Figure 4. Photograph of Active Sediment Delivery in Manastash Canyon.

Figure 5 shows sediment size distribution calculated for samples collected at RM 4.4 and RM 6.4. The mean particle size (D_{50}) of material actively transported by the creek are cobble in the range of 80 to 120 millimeters (mm) (approximately 3 to 5 inches). The largest particles moved by the stream appear to be small boulders ranging from 250 to 300 mm (approximately 10 to 12 inches). At RM 4.4, the channel has eroded laterally into a glacial terrace deposit of oversized boulders. The bed near the bank is covered by a relatively immobile armor layer that is dominated by these large stones. These stones range from 100 to 500 mm (approximately 4 to 20 inches).

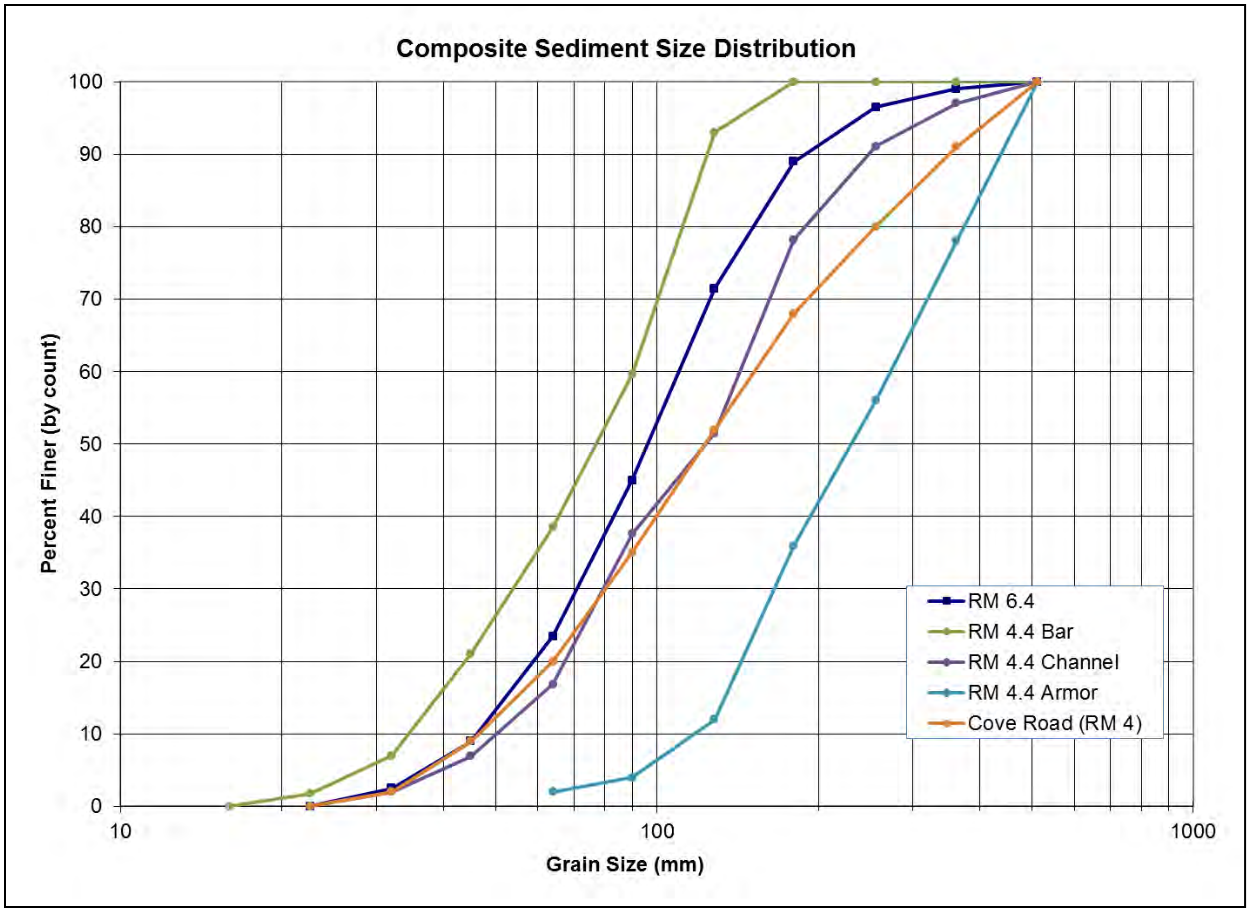


Figure 5. Manastash Creek Sediment Size Distribution Determined by Wolman Pebble Count.

Fish Habitat, Use, and Passage

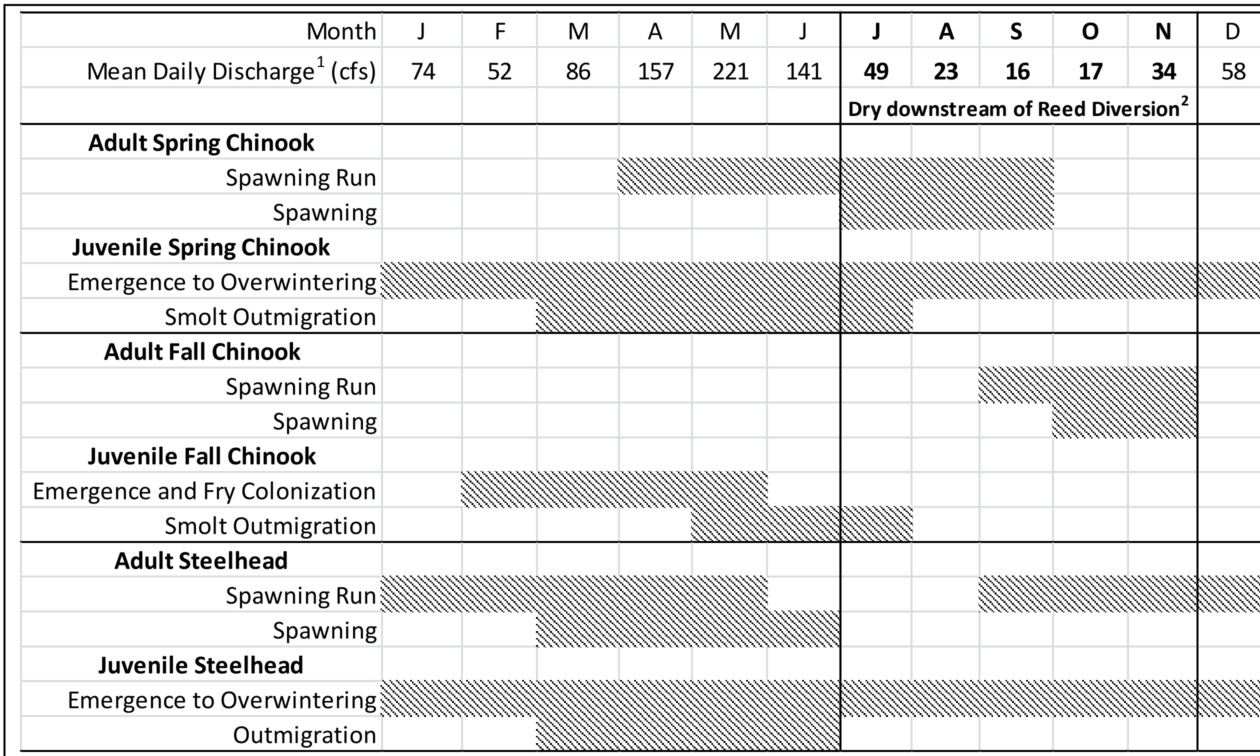
The Yakima Subbasin Fish and Wildlife Planning Board has identified six focal species for subbasin planning purposes (NPCC 2004):

- **Bull trout (*Salvelinus confluentus*)** – Resident species listed as threatened under the ESA by the US Fish and Wildlife Service (USFWS).
- **Steelhead/rainbow trout (*Oncorhynchus mykiss*)** – Anadromous (migratory) and resident forms. Middle Columbia Steelhead Distinct Population Segment (DPS; anadromous form only) listed as a threatened species under the ESA by the National

Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA Fisheries).

- **Spring Chinook salmon (*Oncorhynchus tshawytscha*)** – Anadromous salmonid species not listed as threatened or endangered under the ESA.
- **Fall Chinook salmon (*Oncorhynchus tshawytscha*)** – Anadromous salmonid species not listed as threatened or endangered per the ESA.
- **Sockeye salmon (*Oncorhynchus nerka*)** – Anadromous salmonid that was historically present in the Yakima subbasin but has not been present since the late 1910s and early 1920s due to the construction of impassable storage dams.
- **Pacific lamprey (*Entosphenus tridentatus*)** – Anadromous species not listed as threatened or endangered under the ESA.

The Yakima Steelhead Plan (YBFWRB 2009) identifies Manastash Creek as likely to have supported steelhead, but it is currently blocked by impassable dams and dry stream reaches. Results of an intrinsic potential analysis were presented in the Yakima Steelhead Plan, indicating medium to high quality habitat potential in the Manastash Creek system. Figure 6 shows the life history of summer steelhead, fall Chinook salmon, and spring Chinook salmon in the Yakima River basin along with flow conditions in Manastash Creek.



[1] *Discharge from Manastash Road gauge upstream of irrigation diversions*

[2] *Months shown in **boldface** (July through November) represent the general time period when Manastash Creek is dry between Reed diversion and West Side Canal spill.*

Source: YBFWRB (2009)

Figure 6. Mean Daily Discharge and Yakima River Tributary Salmonid Life Stages by Month.

The Yakima steelhead population is classified as summer steelhead based on their migration timing. Returning adult steelhead generally migrate upstream into the Yakima River basin in the fall to spawn in the river and tributaries between late January and mid-May (YBFWRB 2009). Juvenile steelhead rear in the Yakima River and tributaries for 1 to 3 years before migrating to the ocean.

Three main factors limiting salmonid production in Manastash Creek were reported by the Washington State Conservation Commission (2001) to be:

- Barriers to upstream fish passage
- Unscreened irrigation diversions
- Low stream flows during the summer and early fall

Fish monitoring has been conducted in Manastash Creek by WDW/WDFW starting in 1989 as a part of a species interaction study (WDFW 2012). Additional monitoring was conducted by WDFW during 2007, 2008, 2009, and 2010 at Barnes Road and upstream of Manastash diversion. Salmon and trout species observed include rainbow trout, brook trout (*Salvelinus fontinalis*), cutthroat trout (*Onchorhyncus clarkii*), spring Chinook, and coho salmon (*O. kisutch*). In April 2012, KCCD and HDR Engineering observed and documented adult steelhead trout attempting to jump upstream at the Reed Ditch diversion dam (Anna Lael, personal communication, April 20, 2012).

Irrigation water diversion points throughout the lower reaches of Manastash Creek historically functioned as passage barriers for migratory fish. Of the six diversions listed in the *Watershed Hydrology* section above, three diversion points (Manastash Ditch, Keach Jensen Ditches, and Barnes Road Ditch) have been reconstructed to provide fish passage and screening. The KCCD plans to consolidate the remaining three diversions (Reed, Hatfield, and Anderson) up to the newly constructed MWDA/Consolidated diversion and to restore fish passage at those diversions.

Watershed Development and Floodplain Encroachment

In addition to irrigation diversions on Manastash Creek, other human activities have affected the channel and floodplain processes of Manastash Creek in ways that affect habitat, flooding, and bank erosion. In the upper watershed, logging has occurred historically on US Forest Service land. The change in forest cover and existence of logging roads can affect hydrology of the system by reducing rainfall interception and evapotranspiration, and can lead to increased surface erosion and delivery of fine sediments to downstream reaches. In the lower Manastash canyon, on the alluvial fan and downstream to the Yakima River, rural residential and agricultural development has led to changes in riparian vegetation, channel road crossings that constrict channel migration and floodplain function, channel bank hardening (revetments), and disconnection of the historic floodplain (dikes).

EXISTING REACH-SCALE HABITAT CONDITIONS

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Methods of Assessment

Two approaches were used to assess existing habitat conditions at the reach scale in the Manastash Creek project study area. A detailed reach assessment methodology was applied to the lower 6 miles of the system where habitat conditions are known to be in the most need of improvement. A qualitative assessment method was applied to the upper 7 miles of the system because understanding of the watershed-scale conditions is critical to provide a more holistic assessment of the project area.

The habitat assessment entailed a two-step process. First, existing data were reviewed in the office. Then field assessments were conducted at specific locations. Field assessments focused on verifying results of the in-office assessment and on documenting habitat conditions at each representative sampling location. The documentation was used to help evaluate habitat metrics, prepare subreach descriptions relative to indicators (described below), further characterize limiting factors, and identify habitat restoration opportunities.

Existing data reviewed as part of the reach scale habitat assessment include:

- Aerial photography (3Di 2012)
- Lidar data (3Di 2012)
- US Fish and Wildlife Service National Wetland Inventory digital data (USFWS 2012)
- Natural Resources Conservation Service soil survey (NRCS 2012)
- SalmonScape fish passage barrier information (WDFW 2012)

These data were analyzed/reviewed in GIS, enabling Herrera staff to determine reach breaks and digitize geomorphic and floodplain features (e.g., side channels, off-channel wetlands), potential in-channel habitat features (e.g., large woody debris [LWD]), human modifications (e.g., levees, bridges, diversions), and riparian vegetation characteristics (i.e., vegetation types) for inclusion on field maps. The field maps were then used as a basis for the field assessment, which was conducted between July 30 and August 2, 2012.

Existing habitat conditions were assessed using a methodology based partially on Bureau of Reclamation reach assessment guidance (Bureau of Reclamation 2009). In keeping with those previous investigations, this assessment applied principles from the Matrix of Pathways and Indicators developed by the US Fish and Wildlife Service and NOAA Fisheries to assess habitat quality as represented by Reach-based Ecosystem Indicators (REIs) relative to fish species requirements (NMFS 1996; USFWS 1998).

Reach Determination

This subsection describes the approach for dividing the study area into reaches and subreaches and provides associated descriptions. For purposes of assessing habitat quality, the project was divided into two major areas. The lower 6 miles of Manastash Creek has the most varied geomorphic conditions, the most substantial habitat impacts, and represents a barrier to accessibility of fish species to the generally higher quality habitat present in the upper watershed. The upper 7 miles of the project study area in Manastash Canyon has more homogeneous geomorphic and habitat conditions, and has been less affected by human development.

The lower 6 miles of Manastash Creek consists of 6 distinct reaches based on geologic and geomorphic conditions. GIS and lidar data were used to further refine these 6 reaches into 19 more specific geomorphic subreaches based on significant changes in channel slope, planform, width, and/or riparian conditions. Subreach breaks typically coincided with anthropogenic impact points such as irrigation diversions, road bridges, or abrupt changes in land use. Field assessments were conducted within each subreach where accessible to ensure a comprehensive characterization of habitat conditions within each subreach could be developed.

The upper 7 miles of the project area was assessed as a single reach primarily in the office using GIS and lidar data. Field observations were made at several locations in this reach, but field access was limited.

From downstream to upstream, the reaches in the study area for the habitat conditions assessment include:

1. **Reach YC – Yakima Confluence Reach (River Mile [RM] 0 – 0.4):** This reach is extremely short—about 750 feet from the confluence with the active Yakima River channel upstream to the wall of the modern Yakima River valley. This reach is dominated by the dynamics of the Yakima River.
2. **Reach BC – Bullfrog Confined Reach (RM 0.4 – 1.5):** This reach extends from the modern Yakima River valley wall upstream to the Barnes Road Bridge. Flow in this reach is confined to a narrow and entrenched, but shallow in places, floodplain. Bullfrog refers to the Bullfrog subdrift geologic deposit that Manastash Creek is present in within this reach.
3. **Reach SC – Swauk Confined Reach (RM 1.5 – 2.5):** This reach is confined by the Swauk Prairie subdrift and extends from the Barnes Road Bridge upstream to the Serenity Lane Bridge. It appears to be the most historically confined portion of the fan because the Swauk Prairie terrace, into which it is incising, is quite large. Like in the Bullfrog confined reach, flow is confined to a narrow and entrenched, but shallow in places, floodplain. Swauk refers to the Swauk Prairie subdrift geologic deposit that Manastash Creek is present in within this reach.
4. **Reach FC – Fan Contraction Reach (RM 2.5 – 4.0):** This reach extends from the Serenity Lane Bridge upstream to the Cove Road Bridge. It is likely that overtopping at the fringes of this zone occurred in the geologic past, but those overtopping events were rare and ephemeral. Most of the flow and all of the sediment in this reach converge to a narrow, shallow valley through historic terraces of the Yakima River.
5. **Reach FE – Fan Expansion Reach (RM 4.0 – 5.4):** This reach extends from Cove Road upstream to the Manastash Road curve. This reach is likely the most historically

dynamic portion of the study area, with historic deposition likely being highest at the Cove Road Bridge. The constriction of the road crossing likely increases this deposition.

6. **Reach FA – Fan Apex Reach (RM 5.4 – 6.2):** This reach extends roughly from the Manastash Road curve upstream to the Manastash Road Bridge at the mouth of the canyon proper. This reach is the transition zone from a purely alluvial, steep, mountain stream to a braided, highly depositional fan environment. Therefore, its extents are somewhat diffuse.
7. **Reach CY – Canyon Reach (RM 6.2 – 13):** This reach extends from the apex of the alluvial fan and mouth of the canyon to a point 7 miles upstream along South Fork Manastash Creek.

Figure A-1, in Appendix A, shows the reach and subreach boundary locations within the study area.

Collecting representative data for all subreaches in the lower 6 river miles and observations of channel conditions in the upper 7 river miles were limited by access to private properties. Project field crews only visited portions of Manastash Creek where property owners had provided explicit permission for access. This limited the sampling extent of several reaches. In addition, some of the geomorphic reaches were less than 1,000 feet in length. As a result, the actual length of sampling reaches varied from 320 to approximately 1,200 feet in length. Two geomorphic reaches, FC3 and FA3, were not sampled at all due to access considerations.

Field crews sought to conduct data collection on 1,000-foot long sampling reaches within each geomorphic subreach. The conditions within a sampling reach were assumed to represent conditions in the overall geomorphic subreach. The 1,000-foot sampling reach length was based on 30-times bankfull channel width for the Manastash Creek channel, which, based on interpretation of lidar data, averages between 18 and 50 feet with an average bankfull with of around 30 to 35 feet.

Assessment of Reach-based Ecosystem Indicators

This subsection discusses the methodology for assessing each of the REIs, including a description of the indicators themselves and the detailed approach for their characterization. The indicators evaluated as part of this study, the range of ratings for each indicator, and the criteria/definition for indicator ratings are presented in Table 2.

Geomorphology

The following metrics were used to describe channel type and process in each reach of Manastash Creek:

- Reach type (Montgomery and Buffington 1998) – source, transport, or response
- Channel gradient – measured form lidar-derived channel profile
- Channel dimensions – bankfull width, depth, and flood prone width (Rosgen 1996)
- Montgomery and Buffington channel type (Montgomery and Buffington 1998)

- Rosgen channel type (Rosgen 1996)
- Active channel process stage – channel evolution stage (Simon 1995)
- Sinuosity – estimated in field
- Substrate material – primary and secondary
- Riffle/gravel cementation (Comings et al. 2000)
- Riffle/gravel embeddedness (Comings et al. 2000)
- Bank material – primary and secondary
- Active bank erosion – none, right, left, or both banks
- Percent eroded banks (US Environmental Protection Agency 2001)
- Bank stability (Booth and Henshaw 2001)

Table 2 describes in more detail how these metrics were used as REIs to assess specific elements of habitat quality.

Riparian Vegetation

As mentioned, three indicators provide a qualitative estimate of riparian vegetation condition: 1) structure, 2) level of disturbance, and 3) canopy cover. These indicators were evaluated primarily based on vegetation type/landcover type composition (percent composition) within the riparian zone of Manastash Creek, which was defined as 100 feet from each streambank (as in Interfluve 2010). Using the standard approach for Bureau of Reclamation reach assessments, the qualitative value for each metric is based on a quantification of the overall cover for intact vegetation types (and particularly forested areas) as compared to modified areas within each subreach (see Table 2).

Vegetation types (and landcover types for modified areas) within the riparian corridor of Manastash Creek were digitized in GIS. The vegetation types were spot-checked at accessible locations during field work to ensure the digitized polygons accurately represented on-the-ground conditions. The following vegetation types/landcover types were mapped within the riparian zone of Manastash Creek:

- **Deciduous forest** – forested areas dominated by deciduous (hardwood) tree species, such as black cottonwood and Pacific willow. Other common plant species include red alder, mountain alder, quaking aspen, Scouler’s willow, chokecherry, serviceberry, snowberry, red osier dogwood, and reed canarygrass. This vegetation type is most common in close proximity to the stream or other areas exhibiting moist soils (e.g., irrigation drainages) throughout the project area. Trees sizes of the dominant species vary widely from approximately 6 inches diameter breast height (dbh) to over 30 inches dbh, and canopy cover also varies significantly from 50 to 100 percent, with both characteristics depending primarily on level of previous disturbance and proximity to water source. However, average dominant tree sizes are approximately 12 to 24 inches (medium to large) and average canopy cover is approximately 60 to 80 percent.

Table 2. Reach-Scale Ecosystem Indicators (REIs) Evaluated for Manastash Creek.

General Characteristics	General Indicators	Specific Indicators	Adequate Condition	At-Risk Condition	Unacceptable Risk Condition
Habitat Access	Physical Barriers	Main channel barrier in reach or downstream. Includes full dewatering of the channel and thermal barriers.	No manmade barriers present in the main stem that limit upstream of downstream migration at any flow.	Manmade barriers present in the main stem that prevent upstream or downstream migration at some flows that are biologically significant.	Manmade barriers present in the main stem that prevent upstream or downstream migration at multiple or all flows.
Hydrology	Stream flow	Alteration of peak or base flows	Magnitude, timing, duration, and frequency of peak/base flows within a watershed are not altered relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.	Some evidence of altered magnitude, timing, duration, and/or frequency of peak/base flows relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.	Pronounced changes in magnitude, timing, duration, and/or frequency of peak/base flows relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.
Water Quality	Temperature, Turbidity, and Nutrients	Field observations, including warm, turbid water, and nuisance algae growth	Existing data and field observations do not suggest any water quality issues in the reach.	Existing data and observations indicate elevated temperatures, turbidity, and/or nutrient concerns may impair in-stream habitat quality, or water was not observed in the channel, and the presence of irrigation diversions and return flows suggest that water quality is impaired	Existing data and observations indicate elevated temperatures, turbidity, and/or nutrient concerns impair in-stream habitat quality
Habitat Quality	Substrate	Dominant substrate/fine sediment	Gravels or small cobbles make up >50% of the bed materials in spawning areas. Reach embeddedness in rearing areas <20%. ≤12% fines (<0.85mm) in spawning gravel or 12% surface fines of ≤6mm.	Gravels or small cobbles make-up 30-50% of the bed materials in spawning areas. Reach embeddedness in rearing areas 20-30%. 12-17% fines (<0.85mm) in spawning gravel or 12-20% surface fines of ≤6mm.	Gravels or small cobbles make-up <30% of the bed materials in spawning areas. Reach embeddedness in rearing areas >30%. >17% fines (<0.85mm) in spawning gravel or >20% surface fines of ≤6mm.
	Large Woody Debris	Pieces per mile	>20 pieces/mile >12" diameter > 35 ft. length; and adequate sources of LWD available for both long- and short-term recruitment.	Currently levels are being maintained at minimum levels desired for "adequate," but potential sources for long-term LWD recruitment is lacking to maintain these minimum values.	Current levels are not at those desired values for "adequate," and potential sources of LWD for short- and/or long-term recruitment are lacking.
	Pools	Frequency and quality	Pool frequency: Number of pools/mile for a given channel width. Channel width 30-35 ft. = 18 pools per mile. Channel width 35-40 ft. = 10 pools per mile. Pools have good cover and cool water and only minor reduction in pool volume by fine sediment. Each reach has many large pools >1 m deep with good fish cover.	Pool frequency is similar to values in "functioning adequately," but pools have inadequate cover/temperature and/or there has been a moderate reduction of pool volume by fine sediment. Reaches have few large pools (>1m deep) present with good fish cover.	Pool frequency is considerably lower than values for "adequate condition," also cover/temperature is inadequate, and there has been a major reduction of pool volume by fine sediment. Reaches have no deep pools (>1m) with good fish cover.
	Complexity	Variability and heterogeneity of habitat units	Significant number and variety of habitat elements in the reach. Regular changes between habitat elements along the longitudinal profile.	Moderate or reduced number and variety of habitat elements in the reach. Fewer pools and less frequent changes between habitat elements along the longitudinal profile.	Few or greatly reduced number and variety of habitat elements in the reach. Few pools and extremely infrequent changes between habitat elements along the longitudinal profile.
	Off-Channel Habitat	Connectivity with main channel	Reach has many ponds, oxbows, backwaters, and other off-channel areas with cover, and side channels are low energy areas. No manmade barriers present along the main stem that prevent access to off-channel areas.	Reach has some ponds, oxbows, backwaters, and other off-channel areas with cover, and side channels are high energy areas. Manmade barriers present that prevent access to off-channel habitat at some flows that are biologically significant.	Reach has few or no ponds, oxbows, backwaters, and other off-channel areas. Manmade barriers present that prevent access to off-channel habitat at multiple or all flows.
Channel	Dynamics	Floodplain connectivity	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession.	Reduced linkage of wetland, floodplains, and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession.	Sever reduction in hydrologic connectivity between off-channel, wetland, floodplain and riparian areas; wetland extent drastically reduced and riparian vegetation/succession altered significantly.
		Bank stability/channel migration	Channel is migrating at or near natural rates.	Limited amount of channel migration is occurring at a fasteror slower rate relative to natural rates, but significant change in channel width or planform is not detectable; LWD is still being recruited.	Little or no channel migration is occurring because of human actions preventing reworking of the floodplain and LWD recruitment; or channel migration is occurriing at an accelerated rate such that channel width has at least doubled, possibly resulting in a channel planform change, and sediment supply has noticeably increased from bank erosion.

Table 2 (continued). Reach-Scale Ecosystem Indicators (REIs) Evaluated for Manastash Creek.					
General Characteristics	**General Indicators**	**Specific Indicators**	**Adequate Condition**	**At-Risk Condition**	**Unacceptable Risk Condition**
Channel (cont'd)		Vertical channel stability	No measurable trend of aggradation or incision and no visible change in channel planform.	Measureable trend of aggradation or incision that has the potential to, but has not yet caused, disconnection of the floodplain or a visible change in channel planform (e.g. single thread to braided).	Enough incision that the floodplain and offchannel habitat areas have been disconnected; or, enough aggradation that a visible change in channel planform has occurred (e.g. single thread to braided).
		Resiliency to Disturbance	Intact riparian vegetation, channel, and floodplain process/conditions allow habitat value to remain intact following disturbance from large flood events that carry significant bedload.	Human-caused degradation of riparian vegetation, channel, and floodplain process and conditions limits the ability of habitat value to remain intact following disturbance from large flood events that carry significant bedload. Flood events do not result in positive feedback loops and further reduce the channel's resiliency to disturbance.	Human-caused degradation of riparian vegetation, channel, and floodplain process/conditions makes retention of habitat value impossible following disturbance from large flood events that carry significant bedload.
Riparian Vegetation	Condition	Structure	>80% species composition, seral stage, and structural complexity are consistent with potential native community in the riparian buffer zone (defined as a 30 m belt along each bank).	50-80% species composition, seral stage, and structural complexity are consistent with potential native community.	<50% species composition, seral stage, and structural complexity are consistent with potential native community.
		Disturbance (Human)	>80% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; <20% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); <2 mi./sq. mi. road density in the floodplain.	50-80% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; 20-50% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); 2-3 mi./sq. mi. road density in the floodplain.	<50% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; >50% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); >3 mi./sq. mi. road density in the floodplain.
		Canopy Cover	Trees (forested vegetation types)within potential tree height distance or 10 m riparian buffer zone have >80% canopy cover that provides thermal shading to the river.	Trees and shrubs within one site potential tree height distance or 10 m buffer zone have 50-80% canopy cover that provides thermal shading to the river.	Trees and shrubs within one site potential tree height distance or 10 m buffer zone have <50% canopy cover that provides thermal shading to the river.

LWD = large woody debris
m = meters
mi./sq. mi. = miles per square mile
mm = millimeters

- **Mixed forest** – forested areas dominated by both coniferous and deciduous tree species, such as black cottonwood and Ponderosa pine. Other common plant species include chokecherry, creeping Oregon grape, serviceberry, Douglas maple, Woods' rose, snowberry, and wax currant. This vegetation type is found primarily in the Fan Expansion and Canyon reaches. Knapweed (spotted and diffuse) occurs sporadically in this vegetation type. Canopy cover is lower in this vegetation type than deciduous forest areas and ranges from approximately 20 to 50 percent. Trees sizes vary from approximately 12 to 24 inches dbh (medium to large).

- **Shrub-steppe** – upland areas exhibiting sparse, native shrub cover intermixed with dryland grasses. Common species include wax currant, rabbitbrush, big sagebrush, Idaho fescue, and cheatgrass. Knapweed was also commonly observed in this vegetation type. This vegetation type is found primarily in the Fan Expansion reach.

- **Shrub** – areas dominated primarily by shrub species, such as Woods' rose, chokecherry, wax currant, rabbitbrush, serviceberry, oceanspray, and creeping Oregon grape. Percent cover of vegetation is moderate to high, as soils are likely moist enough to support relatively dense shrub growth (unlike shrub-steppe habitats). This vegetation type is found primarily as part of residential landscaping throughout the project area and in the Fan Expansion reach in areas where trees have been removed.

- **Forested wetland**[1] – wetland areas dominated by tree species tolerant of saturated soil conditions, such as black cottonwood and Pacific willow. Other common species include red osier dogwood, red alder, quaking aspen, salmonberry, coyote willow, Mackenzie willow, and reed canarygrass. This vegetation type occurs throughout the project area in low-lying floodplain areas adjacent to Manastash Creek.

- **Scrub-shrub wetland**[1] – wetland areas dominated by shrubs and small trees tolerant of saturated soil conditions, such as red osier dogwood, coyote willow, Mackenzie willow, salmonberry, reed canarygrass, and Pacific willow and black cottonwood seedlings. This vegetation type is relatively rare within the study area, occurring most commonly in the Fan Apex reach where Manastash Creek occupies an extensive/broad floodplain area.

- **Emergent wetland**[1] – wetland areas dominated by herbaceous plant species, such as reed canarygrass, fowl bluegrass, soft rush or other grasses, sedges, rushes, or forbs tolerant of saturated soil conditions and/or flooding. This vegetation type occurs primarily in the Fan Apex reach where Manastash Creek occupies an extensive/broad floodplain area.

- **Pond** – areas of open water not exhibiting a surface water connection to the stream. Ponds observed within the project area appear to be exclusively manmade features constructed for livestock watering and landscaping purposes.

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[1] These areas were distinguished from upland habitats during GIS digitizing by their location in low-lying floodplain or in-channel areas and/or evidence of inundation or seasonal ponding in aerial photographs.

- **Irrigation canal** – areas of open water associated with the multiple systems of irrigation canals within the project study area
- **Grass** – areas dominated by grasses and forbs, which are generally pastures, lawns, or other cleared areas. This vegetation type is common throughout the study area
- **Gravel/cobble** – unvegetated areas of gravel and/or cobble associated with the stream channel, including dredge spoils
- **Bare ground** – areas that appear to be cleared/disturbed and are not currently supporting vegetation
- **Road** – paved or gravel roads
- **Building** – residences, barns, outbuildings, and other structures

Physical Habitat Conditions

The following indicators/metrics were used to describe and assess physical habitat in each reach of Manastash Creek:

- **Stream complexity** (McBride 2001)
- **Functional LWD** (adapted from Ralph et al. 1994; Beechie and Sibley 1997; Fox and Bolton 2007)
- **Typical pool conditions** – forming feature, dimensions, overhead cover, complexity, and fine sediment
- **Habitat unit delineation** (Flosi et al. 1998) **-** riffle, pool, flat water, pocket water
- **LWD survey**

Table 2 describes in more detail how these metrics were used as REIs to assess specific elements of habitat quality.

Human Alterations

Human alterations and impacts were assessed by mapping levees and bank armoring, and observing conditions in the field with respect to physical alterations and water quality and flow impacts of irrigation diversions. Water quality was not assessed in detail for this study, but observations were made of stream temperature and visible quality in reaches where water was present, and professional judgment was used to estimate the level of disturbance that water quality has on in-stream habitat.

Results of the Habitat Condition Assessment

In general, the study area has a wide range of habitat conditions that depend largely on: 1) location relative to instream diversions, 2) modifications to floodplain geomorphology, and 3) the extent of riparian clearing.

With regard to riparian vegetation, conditions varied widely throughout the study area based largely on the combination of land use and environmental conditions. Relatively intact areas that have not been cleared through development or agricultural activities display a range of vegetation types that appear to be driven primarily by seasonal water availability; vegetation types range from shrub-steppe (dry) to deciduous forest (moist), to wetland habitats (wet). Areas that have been cleared for development or agricultural purposes generally fall under the grass, bare ground, building, or road landcover types.

Channel hydrology is a primary limiting factor to both habitat accessibility and habitat quality. Irrigation diversions led to dry channel conditions from the Reed diversion to West Side Canal spill during the summer and fall, and reduced stream flow downstream of the West Side Canal spill.

Water quality is also a concern related to irrigation diversion and return flows. Elevated water temperatures and turbid water was observed downstream of the West Side Canal spill. Lack of riparian vegetation throughout portions of the lower 6 miles of Manastash Creek also increases stream temperature through greater sun exposure.

Levees constructed in the vicinity of Serenity Lane and Cove Road, and to lesser degrees elsewhere along Manastash Creek, confine stream flow to the channel and reduce floodplain storage. This channel confinement affects sediment transport processes and leads to excessive deposition and channel migration in adjacent portions of the system. The channel is also confined at undersized crossings at Serenity Lane, Cove Road, and at multiple crossings in Manastash Canyon.

Many reaches in the lower 6 miles of Manastash Creek have limited habitat complexity and LWD in the channel. Large wood and active floodplain processes lead to sediment transport and sorting that provides spawning habitat and pools for fish rearing. Reaches with intact riparian vegetation tend to have greater LWD density and habitat complexity.

The following subsections describe general habitat conditions for each subreach, including assessments of the REIs. Figures showing habitat features of each reach are included in Appendix A. Detailed tables of reach-based indicators are included in Appendix B. Appendix C includes charts showing the composition of riparian vegetation communities in each reach. Photographs showing habitat conditions are in Appendix D. Habitat data collected in the field are included in Appendix E.

Reach YC – Yakima Confluence

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The Yakima Confluence Reach of Manastash Creek remains geomorphically consistent throughout its approximately 750-foot length from where it exits the confined reach upstream onto the Yakima River floodplain down to its shifting confluence with the Yakima River. Habitat conditions are described below and summarized in Table 3. Detailed information on habitat conditions in the reach based on REIs is provided in Appendix B. Habitat and disturbance features are shown in Figure A-2.

Table 3. Yakima Confluence (Reach YC) Habitat Conditions.

General Characteristics	General Indicators	Specific Indicators	Reach YC Condition
Habitat Access	Physical Barriers	Main channel barrier in reach or downstream	***At Risk***
Hydrology	Stream flow	Alteration of peak or base flows	***Unacceptable Risk***
Water Quality	Temperature; Turbidity and Nutrients	Field observations, including warm, turbid water, and nuisance algae growth	***At Risk***
Habitat Quality	Substrate	Dominant substrate/fine sediment	***Unacceptable Risk***
	Large Woody Debris	Pieces per mile	***Adequate***
	Pools	Frequency and quality	***Adequate***
	Complexity	Variability and heterogeneity of habitat units	***Adequate***
	Off-Channel Habitat	Connectivity with main channel	***Adequate***
Channel	Dynamics	Floodplain connectivity	***Adequate***
		Bank stability/channel migration	***Adequate***
		Vertical channel stability	***Adequate***
		Resiliency to Disturbance	***Adequate***
Riparian Vegetation	Condition	Structure	***Adequate***
		Disturbance (Human)	***Adequate***
		Canopy Cover	***Adequate***

In summary, the factors that limit habitat quality in this reach include:

- **Hydrology** (reduced baseflow during summer months limiting habitat development and maintenance as well as fish habitat use and accessibility)
- **Water quality** (temperature, turbidity, and nutrients during low flow due to irrigation return flows)

Geomorphology

Manastash Creek splits into a multi-thread, distributary channel network in Reach YC, a delta that has formed at the confluence with the Yakima River. The channel in this reach exhibits highly variable dimensions. Reach YC is a response reach (Montgomery and Buffington 1998) where morphological adjustments occur in response to increased sediment supply and influence of past Yakima River sedimentation. Overall channel gradient is just under 1 percent, and the sinuosity of individual channel threads is low (1.0 to 1.2). Channel substrate is primarily gravel, with fine sediment secondary. Banks are composed primarily of fine sediment mixed with gravel and stabilized by riparian vegetation. Individual channel threads exhibited a pool/riffle channel type (Montgomery and Buffington 1998). The creek was visually classified as a Rosgen Type Da4 (Rosgen 1996).

Channel processes in Reach YC are dominated by the Yakima River. Deposition of bedload from Manastash Creek and suspended load from the Yakima River result in bed aggradation. Channel braiding and avulsions are commonplace in this reach. Bank erosion is present but minimal. There is significant LWD in the channels through the reach and intact riparian forest. High flows regularly inundate the floodplain.

Riparian Vegetation

In general, riparian vegetation condition within Reach YC is adequate in terms of structure, disturbance, and canopy cover (Table 3). The overall composition of the riparian zone in this reach is shown on a chart in Appendix C.

Riparian vegetation in Reach YC is largely intact and represents one of the best large-scale examples of pre-development floodplain conditions in the project area. A large, mature, forested mosaic wetland complex (i.e., areas with an integrated combination of wetland and upland areas) occupies the floodplain in the reach, dominated by a dense canopy of large to very large black cottonwoods and Pacific willows. An extensive network of channels supports a dense, diverse understory, dominated by a variety of shrub species (e.g., red osier dogwood, chokecherry, willows) and herbaceous species (e.g., cow parsnip, stinging nettle, field mint, water sedge, small-fruited bulrush, variety of grasses).

In the one developed portion of the floodplain within this reach, riparian vegetation has been cleared and replaced with a residence and surrounding lawn and landscaping.

Physical Habitat Conditions

Habitat conditions in Reach YC are good, with minimal human impact on the riparian area. Pools are highly variable in dimension and generally have high amounts of overhead cover and complexity provided by LWD and riparian vegetation. Spawning-sized gravels were observed in some of the pool tailouts and adjacent riffles. Rearing habitat is excellent due to the complexity of the channel network, backwater areas, and floodplain connectivity, though the quantity and quality of summer rearing habitat is limited by severely reduced stream flows (see *Human Alterations* section, below). No barriers to fish migration are located in Reach YC.

Human Alterations

The channel and riparian zone in Reach YC has minimal human alterations. One short portion of the left bank is clear of vegetation near the upstream end of the reach, and a house is built on the floodplain. Some bank erosion is occurring in the area, and more habitat impacts at this location are expected over time due to further erosion. Quality of habitat is affected in summer months by irrigation withdrawals and return flows.

Restoration Opportunities

Conditions would be improved during the summer months if base flows in Manastash Creek were increased and the water quality (temperature, turbidity, and nutrients) of irrigation return flows was improved. Because habitat conditions are relatively good in Reach YC, a restoration strategy should be conservation and preservation. Due to population growth in the greater Ellensburg area, development is occurring in and near Reach YC and will likely continue. Conservation and preservation is recommended to maintain good aquatic habitat in this reach. In addition, a protected, quality habitat area near Ellensburg could be used as teaching tool, illustrating to the community what quality habitat looks like and what functions it provides compared to more altered stream reaches. One home is currently developed in the floodplain of the reach, with cleared riparian vegetation to the top of banks. Revegetation and education of the landowners is recommended to prevent potential habitat damage and channel avulsion through the property.

Reach BC – Bullfrog Confined

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Reach BC extends from the modern Yakima River valley wall upstream to the Barnes Road Bridge. Like the Swauk Confined reach upstream (see Reach SC description, below), flow is confined to a narrow, sometimes shallow, floodplain. The Bullfrog Confined Reach of Manastash Creek was separated into three distinct geomorphic subreaches (BC1, BC2, and BC3, from downstream to upstream) for the purposes of assessing habitat quality. Habitat conditions are described below and summarized in Table 4. Detailed information on habitat conditions in the reach based on REIs is provided in Appendix B. Habitat and disturbance features are shown in Figure A-2 in Appendix A.

Table 4. Bullfrog Confined (Reach BC) Habitat Conditions.

General Characteristics	General Indicators	Specific Indicators	Subreach BC1 Condition	Subreach BC2 Condition	Subreach BC3 Condition
Habitat Access	Physical Barriers	Main channel barrier in reach or downstream	***At Risk***	***At Risk***	***At Risk***
Hydrology	Stream flow	Alteration of peak or base flows	***Unacceptable Risk***	***Unacceptable Risk***	***Unacceptable Risk***
Water Quality	Temperature, Turbidity, and Nutrients	Field observations, including warm, turbid water, and nuisance algae growth	***At Risk***	***At Risk***	***Unacceptable Risk***
Habitat Quality	Substrate	Dominant substrate/fine sediment	***At Risk***	***At Risk***	***At Risk***
	Large Woody Debris	Pieces per mile	***Adequate***	***Unacceptable Risk***	***Unacceptable Risk***
	Pools	Frequency and quality	***Adequate***	***Adequate***	***Adequate***
	Complexity	Variability and heterogeneity of habitat units	***Adequate***	***At Risk***	***At Risk***
	Off-Channel Habitat	Connectivity with main channel	***Adequate***	***At Risk***	***Unacceptable Risk***
Channel	Dynamics	Floodplain connectivity	***Adequate***	***Adequate***	***At Risk***
		Bank stability/channel migration	***Adequate***	***At Risk***	***Adequate***
		Vertical channel stability	***At Risk***	***At Risk***	***At Risk***
		Resiliency to Disturbance	***Adequate***	***At Risk***	***Adequate***
Riparian Vegetation	Condition	Structure	***At Risk***	***At Risk***	***At Risk***
		Disturbance (Human)	***At Risk***	***At Risk***	***Unacceptable Risk***
		Canopy Cover	***Adequate***	***At Risk***	***Adequate***

In summary, the factors that limit habitat quality in Reach BC include:

- **Hydrology** (reduced baseflow during summer months limiting habitat creation and maintenance as well as fish habitat use and accessibility)
- **Water quality** (temperature, turbidity, and nutrients during low flow due to irrigation return flows)
- **Floodplain connectivity** (levees confining stream flow in main channel)
- **Riparian vegetation** (lack of vegetation in subreach BC2)

Geomorphology

Subreach BC1 of Manastash Creek is primarily single-threaded, with several high flow channels and occasional side channels. The bankfull channel is, on average, 35 feet wide and 2.5 to 3 feet deep, with a flood prone width (Rosgen 1996) of approximately 150 feet. Subreach BC1 is a response reach (Montgomery and Buffington 1998) where morphological adjustments occur in response to increased sediment supply. Overall channel gradient is 1.8 percent, and the sinuosity of individual channel threads is low (1.0 to 1.2). Channel substrate is primarily cobble, with gravel secondary. Banks are composed primarily of cobble mixed with gravel and stabilized by riparian vegetation. The channel exhibited a pool/riffle channel type (Montgomery and Buffington 1998), and the creek was visually classified as a Rosgen Type C3 (Rosgen 1996).

Channel processes in Subreach BC1 are dominated by Bullfrog subdrift terrace (historic Yakima River sediment) confinement, LWD, and bedload influx from upstream. Deposition of bedload during the 2011 flood event, particularly upstream of channel-spanning debris jams, resulted in significant bed aggradation and at least one instance of channel avulsion on the inset floodplain. Channel braiding and avulsions are not unexpected in this geomorphic setting. Significant bank erosion is present but appears to be primarily associated with the large flood event of 2011 and is currently in a state of restabilization. There is a large amount of LWD in the channels through the reach, and intact riparian forest and high flows are able to inundate the floodplain.

Subreach BC2 of Manastash Creek is primarily a multi-threaded channel network, with several high flow channels and side channels. The bankfull channel is highly variable but, on average, is 30 feet wide and 2 feet deep, with a flood prone width (Rosgen 1996) of greater than 150 feet. This is a response reach (Montgomery and Buffington 1998) where morphological adjustments occur in response to increased sediment supply. Overall channel gradient is 1.6 percent, and the sinuosity of individual channel threads is low (1.0 to 1.2). Channel substrate is primarily cobble, with gravel secondary. Banks are composed primarily of cobble mixed with gravel. The channel exhibited a pool/riffle channel type (Montgomery and Buffington 1998), and the creek was visually classified as a Rosgen Type D3 or D4 (Rosgen 1996).

Channel processes in Subreach BC2 are dominated by terrace confinement and bedload influx from upstream. Significant deposition of bedload occurred during the 2011 flood event, resulting in significant bed aggradation and at least one instance of channel avulsion on the inset floodplain. Channel braiding and avulsions are not unexpected in this geomorphic setting. However, habitat suffered here because the channel avulsed into a portion of the floodplain with little to no vegetation. Some bank erosion is present, but it appears to be primarily associated with the large flood event of 2011 and is currently in a state of restabilization, except in areas of the channel that do not have channel stabilizing vegetation. There is significant amount of small woody debris in Subreach BC2 but an overall lack of large, key pieces that could form the basis of larger stable log jams.

Subreach BC3 of Manastash Creek is single-threaded, with no high-flow channels or side channels. The bankfull channel is, on average, 30 to 35 feet wide and 2.5 to 3 feet deep; it has a flood prone width (Rosgen 1996) of approximately 150 feet. This is a response reach (Montgomery and Buffington 1998) where morphological adjustments occur in response to increased sediment supply. Overall channel gradient is 1.5 percent, and the sinuosity of individual channel threads is low (1.0 to 1.2). Channel substrate is primarily cobble, with gravel secondary. Banks are composed primarily of cobble mixed with gravel and stabilized by riparian vegetation. The channel exhibited a pool/riffle channel type (Montgomery and Buffington 1998). The creek was visually classified as a Rosgen Type C3 or C4 (Rosgen 1996).

Channel processes in Subreach BC3 are dominated by riparian vegetation and bedload influx from upstream. This reach is less confined by terraces than those downstream. Some deposition of bedload occurred during the 2011 flood event, although bed aggradation was not significant enough to affect channel planform. A lack of LWD in the reach reduces hydraulic complexity and limits habitat complexity. Bank erosion is relatively low; banks are stabilized by dense riparian vegetation.

Riparian Vegetation

In general, riparian vegetation condition within Reach BC is at risk in terms of structure, disturbance, and canopy cover (Table 3). The overall composition of the riparian zone in this reach is provided in Appendix C. Riparian vegetation in Reach BC is composed primarily of deciduous forest and is mostly intact within approximately 50 to 150 feet on either side of the stream channel. An exception to this generality is in Subreach BC2, where portions of the floodplain currently lack shrub and tree canopy cover over the network of side channels that flow through the area.

Although Reach BC is naturally confined, forested wetland habitats occupy low-lying floodplain areas and in-channel riparian fringe benches, which experience frequent inundation and high connectivity with the main stream flow. Tree canopy cover throughout the reach is high (except just upstream of Brown Road, as mentioned above), and the dominant tree species are medium to large black cottonwoods and Pacific willows. The understory is moderately dense and is dominated by red osier dogwood, Woods' rose, snowberry, mountain alder, water horsetail, chokecherry, serviceberry, and reed canarygrass. Large masses of milfoil and algae were observed within the upstream end of this reach. These aquatic plants suggest the potential for compromised water quality conditions (eutrophication due to high concentration of nutrients) locally and/or in upstream areas that may be serving as the source for downstream transport of the plants (for example, milfoil appeared to have been transported downstream following irrigation facility clean-outs). This large mass of aquatic vegetation has the potential to affect salmonid spawning habitat, given the altered state of the system hydrology. For example, it is likely that this and other subreaches may not experience channel flushing or maintenance flows, which are critical to remove excessive organic material, fines, and vegetation from spawning grounds as well as resort gravels prior to salmonid spawning.

Physical Habitat Conditions

Physical habitat conditions in Subreach BC1 are very good, with minimal impact on the riparian area by humans. Pools are relatively deep, numerous, and generally have high amounts of overhead cover and complexity provided by LWD and riparian vegetation. Spawning-sized gravels are observed in some limited areas, but cobbles are the dominant substrate. Rearing habitat is excellent due to the complexity of the channel network, backwater areas, and floodplain connectivity, although the quality of summer rearing habitat is somewhat limited by severely reduced stream flows (see *Human Alterations* section, below). No barriers to fish migration are located in Subreach BC1 or downstream.

Physical habitat conditions in Subreach BC2 are good but degrading due to the lack of riparian vegetation. Pools are relatively numerous and generally had high amounts of overhead cover and some complexity provided by LWD and riparian vegetation, but they are relatively shallow. Spawning-sized gravels were observed in very limited areas, but cobbles are the dominant substrate, and sorting is not common. Rearing habitat is good due to the complexity of the channel network, backwater areas, and floodplain connectivity; however, the quality of habitat in the side channel that now flows through the logged left-bank floodplain is very poor. Summer rearing habitat is somewhat limited by severely reduced stream flows (see *Human Alterations*, below). No barriers to fish migration are located in this reach or downstream.

Habitat conditions in Subreach BC3 are fair, but quality and complexity are limited by an overall lack of LWD. Pool density is adequate and overhead cover is high, provided by dense riparian vegetation canopy. Spawning-sized gravels were not observed in key areas, and cobbles are the dominant substrate. Rearing habitat is limited by the lack of side channels and backwater areas. Summer rearing habitat is somewhat limited by severely reduced stream flows (see *Human Alterations*, below). There are no barriers to fish migration in this reach or downstream.

Human Alterations

Human alterations in Subreach BC1 are fairly minimal in terms of impact on habitat. One levee reduces floodplain connectivity and prevents flooding on the left bank at the upstream end of the reach. Downstream of there, the reach is confined naturally and the channel and riparian areas remain in natural condition.

The left-bank floodplain in Subreach BC2 is clear of vegetation. Floodplain connectivity remains high in the reach, with bank armoring and levees absent. Reduction of stream flows for irrigation limits quantity and quality of habitat in summer months, and lack of vegetated cover can increase stream temperatures.

Human alterations in Subreach BC3 include removal of LWD and presence of levees that reduce floodplain connectivity, particularly in the downstream half of the reach. Water quality may also be a concern in Subreach BC3. Field crews observed turbid, warm water in Subreach BC3 from irrigation return flows.

Restoration Opportunities

Restorations opportunities in Reach BC should focus on preserving existing areas with mature or intact riparian vegetation, and improving in channel habitat conditions through the addition of stable LWD key members to promote formation of log jams where flood risk is not present due to the confined nature of the stream/valley. Revegetation and restoration of Subreach BC2 is encouraged.

Reach SC – Swauk Confined

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Reach SC is confined by Swauk Prairie subdrift and extends from the Barnes Road Bridge upstream to the Serenity Lane Bridge. It appears to be the most historically confined portion of the lower 6 miles of Manastash Creek because the Swauk Prairie terrace, into which it is incising, is quite large. The Swauk Confined Reach of Manastash Creek is separated into two distinct geomorphic subreaches (SC1, and SC2, from downstream to upstream) for habitat assessment purposes. Habitat conditions are described below and summarized in Table 5. Detailed information on habitat conditions in the reach based on REIs is provided in Appendix B. Habitat and disturbance features are shown in Figure A-3 in Appendix A.

Table 5. Swauk Confined (Reach SC) Habitat Conditions.

General Characteristics	General Indicators	Specific Indicators	Subreach SC1 Condition	Subreach SC2 Condition
Habitat Access	Physical Barriers	Main channel barrier in reach or downstream	***At Risk***	***At Risk***
Hydrology	Stream flow	Alteration of peak or base flows	***Unacceptable Risk***	***Unacceptable Risk***
Water Quality	Temperature, Turbidity, Nutrients	Field observations, including warm, turbid water, and nuisance algae growth	***Unacceptable Risk***	***At Risk***
Habitat Quality	Substrate	Dominant substrate/fine sediment	***At Risk***	***At Risk***
	Large Woody Debris	Pieces per mile	***Unacceptable Risk***	***At Risk***
	Pools	Frequency and quality	***At Risk***	***At Risk***
	Complexity	Variability and heterogeneity of habitat units	***Unacceptable Risk***	***At Risk***
	Off-Channel Habitat	Connectivity with main channel	***Unacceptable Risk***	***At Risk***
Channel	Dynamics	Floodplain connectivity	***Unacceptable Risk***	***Unacceptable Risk***
		Bank stability/channel migration	***Unacceptable Risk***	***At Risk***
		Vertical channel stability	***Unacceptable Risk***	***Unacceptable Risk***
		Resiliency to Disturbance	***At Risk***	***At Risk***
Riparian Vegetation	Condition	Structure	***Unacceptable Risk***	***Unacceptable Risk***
		Disturbance (Human)	***Unacceptable Risk***	***Unacceptable Risk***
		Canopy Cover	***At Risk***	***Unacceptable Risk***

In summary, the factors that limit habitat quality in this reach include:

- **Hydrology** (reduced baseflow during summer months limiting habitat formation and maintenance as well as fish habitat use and accessibility)
- **Water quality** (temperature, turbidity, and nutrients during low flow due to irrigation return flows)
- **Channel confinement** (revetments preventing channel migration)
- **Floodplain connectivity** (levees confining stream flow in main channel)
- **Habitat structure** (lack of LWD)
- **Riparian vegetation** (lack of vegetation in Subreach BC2)

Geomorphology

Subreach SC1 is single-threaded, with no high-flow channels or side channels. The bankfull channel is, on average, 35 to 42 feet wide and 2 feet deep, with a flood prone width (Rosgen 1996) of approximately 200 feet where the channel is not artificially confined by levees and bank armoring. Human alterations (straightening of the channel and removal of LWD) have made this a transport reach (Montgomery and Buffington 1998) where sediment inputs are rapidly conveyed through the reach. Overall channel gradient is 1.6 percent, and the sinuosity of individual channel threads is low (1.0 to 1.2). Channel substrate is primarily cobble, with gravel as secondary. Banks are composed primarily of cobble mixed with gravel and stabilized by armoring in many areas. The channel exhibited a pool/riffle channel type, bordering on plane bed (Montgomery and Buffington 1998). The creek was visually classified as a Rosgen Type C3 or C4 (Rosgen 1996).

Channel processes in Subreach SC1 are limited by human alterations to the channel. Mechanical straightening and removal of LWD maintain this as a transport reach. Some channel response is apparent near the downstream end of the reach, where meanders are beginning to reform and erode alternating banks. Bank erosion is relatively low, though it is primarily due to armoring and channel manipulation.

Subreach SC2 is single-threaded, with very few high-flow channels and no side channels. The bankfull channel is, on average, 30 to 35 feet wide and 2.5 to 3 feet deep, with a flood prone width (Rosgen 1996) of approximately 50 to 75 feet. This is a response reach (Montgomery and Buffington 1998) where morphological adjustments occur in response to increased sediment supply and deposition, though the degree of response is limited by its incised nature. Overall channel gradient is 1.7 percent, and the sinuosity of individual channel threads is low (1.0 to 1.2). Channel substrate is primarily cobble, with small boulders as secondary. Banks are composed primarily of cobble mixed with fines. The channel exhibited a plane bed type in the upper portion of the reach and transitioned to a pool/riffle type downstream (Montgomery and Buffington 1998). The creek was visually classified as a Rosgen Type G3 (Rosgen 1996).

Though some response to bedload deposition occurs during large flow events, channel processes in Subreach SC2 are limited by human alterations to the channel. Mechanical straightening, dredging, and levee construction limit response in the upper portion of this reach. Alluvial channel response is apparent downstream of the private road bridge, where meanders are eroding alternating banks. Bank erosion is relatively low to moderate, with many of the banks composed of relatively erosion resistant sediments that are cemented to some degree.

Riparian Vegetation

In general, riparian vegetation condition within Reach SC is at unacceptable risk in terms of structure and disturbance, and at risk in terms of canopy cover (Table 5). The overall composition of the riparian zone in this reach is shown in Appendix C.

Riparian vegetation in Reach SC provides less cover than in the downstream reaches, and the intact riparian zone is much narrower (i.e., averaging approximately 10 to 50 feet wide). Riparian vegetation is dominated by deciduous forest, landscaping, and agricultural fields (i.e., Timothy hay, pasture). Forested areas are characterized primarily by medium to large black cottonwoods and Pacific willows, with several very large trees observed in a few locations at the downstream end of the reach. Abundant black cottonwood seedlings comprise the majority of understory vegetation in many areas.

Some narrow riparian fringe wetlands (similar species composition as in the Bullfrog Confined Reach) are present in areas where the channel is less confined and some small floodplain wetland areas are present (primarily in the middle of the reach). Knapweed, an invasive species, was observed on stream banks at many locations, and large clumps of milfoil and algae were also present, particularly at the downstream end of the reach (downstream of the West Side Canal spill, just upstream of Barnes Road). These aquatic plants suggest eutrophication and the potential for compromised water quality conditions locally and/or in upstream areas that may be serving as the source for downstream transport of the plants.

Physical Habitat Conditions

Physical habitat conditions in Subreach SC1 are generally poor. Pools are present, but quality and complexity are low due to an overall lack of LWD and riparian vegetation. Spawning-sized gravels were not observed, with cobbles and small boulders being the dominant substrate. Rearing habitat is severely limited by the lack of side channels and backwater areas. Floodplain connectivity is almost completely cut off by human alterations. Summer rearing habitat is limited by severely reduced stream flows (see *Human Alterations* section, below) and water quality is affected by irrigation return flows. No barriers to fish migration are located in Subreach SC1 or downstream.

Physical habitat conditions in Subreach SC2 are fair to poor. Pools are present, but quality and complexity are low due to an overall lack of LWD and riparian vegetation. Spawning-sized gravels were not observed, with cobbles and small boulders being the dominant substrate. Rearing habitat is severely limited by the lack of side channels and backwater areas. Summer rearing habitat is limited by severely reduced stream flows (see *Human Alterations,* below). No barriers to fish migration are located in this reach or downstream.

The exception to the generally poor conditions is a small forested area in Subreach SC2 downstream of the Serenity Lane Bridge, which receives groundwater (hyporheic) input from the irrigation return flows immediately downstream of it. Juvenile fish were observed in concentrated quantities in this location likely due to the presence of upwelling hyporheic flows. This area of high-quality habitat was limited by severe channel modifications both upstream and downstream from this point.

Human Alterations

Human alterations significantly affect habitat in Subreach SC1. Alterations include mechanical straightening, levee construction limiting floodplain connectivity, riparian vegetation removal, LWD removal, and bank armoring that limits natural channel process and LWD recruitment. Water quality may also be a concern here. Field crews observed turbid, warm water in Subreach SC1 from ditch return flows.

Human alterations also significantly affect habitat in Subreach SC2. Though applied to a lesser degree than in Subreach SC1, alterations include mechanical straightening, levee construction limiting floodplain connectivity, LWD removal, and bank armoring that limits natural channel process and LWD recruitment.

Quality of habitat in both Subreach SC1 and SC2 is affected in summer months by irrigation withdrawals. Field crews observed dry channel conditions at the upstream end of Subreach SC2. Conditions would be greatly improved during the summer months if base flows in Manastash Creek were increased.

Restoration Opportunities

Although Reach SC is heavily impacted by alterations, it serves an excellent site for restoration activities because it is one of the few reaches that has groundwater/hyporheic input (from irrigation return flows). In fact, the presence of irrigation return flows through groundwater/hyporheic input provides an analog that should be evaluated as a potential restoration strategy for the pertinent subreaches of the project study area (i.e., study the feasibility of infiltrating into the ground the discharges from irrigation return). The degree of human impacts (e.g., channel straightening) also means that restoration of more natural channel conditions could provide a significant ecological uplift, building on the isolated area of high-quality rearing habitat downstream of Serenity Lane Bridge. Restoring vegetative cover in this reach presents an easy, straightforward opportunity to improve conditions that would have a net benefit to fish and would help to manage out-of-bank flooding.

Reach FC – Fan Contraction

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Reach FC extends from the Serenity Lane Bridge upstream to the Cove Road Bridge. It is likely that overtopping at the fringes of this zone occurred in the geologic past, but those overtopping events were rare and ephemeral. Most of the flow and all of the sediment in this reach converge to a narrow, shallow valley through historic terraces of the Yakima River. Several historical distributary swales are present in the floodplain and receive flow during flood events. The Fan Contraction Reach of Manastash Creek is separated into five distinct geomorphic subreaches (FC1, FC2, FC3, FC4, and FC5, from downstream to upstream) for purposes of habitat assessment. Habitat conditions are described below and summarized in Table 6. Detailed information on habitat conditions in the reach based on REIs is provided in Appendix B. Habitat and disturbance features are shown in Figure A-4 in Appendix A.

In summary, the factors that limit habitat quality in this reach include:

- **Hydrology** (reduced baseflow during summer months limiting habitat formation and maintenance and fish habitat use accessibility)
- **Channel confinement** (revetments preventing channel migration and undersized crossings)
- **Floodplain connectivity** (levees confining stream flow in main channel)
- **Habitat structure** (lack of LWD and spawning-sized substrate)
- **Riparian vegetation** (lack of vegetation)

Geomorphology

Subreach FC1 is single-threaded, with no high-flow channels or side channels. The bankfull channel is, on average, 35 feet wide and 2 to 2.5 feet deep, with a flood prone width (Rosgen 1996) of approximately 100 feet. The channel is confined at the downstream end of the subreach by an undersized crossing at Serenity Lane. Subreach FC1 is a response reach (Montgomery and Buffington 1998) where morphological adjustments occur in response to increased sediment supply. Overall channel gradient was determined from lidar data to be 1.6 percent, and the sinuosity of individual channel threads is low (1.0 to 1.2). Channel substrate is primarily cobble, with boulder secondary. Banks are composed primarily of cobble mixed with fines and are very unstable. The channel exhibits an excavated/constructed channel type with both banks of the current active channel being composed of material excavated from the stream channel and piled into berms or piled along the existing banks. The creek was visually classified as a Rosgen Type D3 (Rosgen 1996).

Channel processes in Subreach FC1 are limited by human alterations to the channel, constriction at the Serenity Lane Bridge, and lack of riparian vegetation. Unnatural rates of bedload deposition result due to the backwater effect of the undersized crossing. That, in combination with highly erodible bank material and a lack of bank stabilizing riparian vegetation, has resulted in extreme lateral migration/expansion rates of the channel, including the undermining of the bridge itself. In its current, deteriorated condition, the

Table 6. Fan Contraction (Reach FC) Habitat Conditions.

General Characteristics	General Indicators	Specific Indicators	Subreach FC1 Condition	Subreach FC2 Condition	Subreach FC3 Condition	Subreach FC4 Condition	Subreach FC5 Condition
Habitat Access	Physical Barriers	Main channel barrier in reach or downstream	***At Risk***	***At Risk***	***At Risk***	***At Risk***	***At Risk***
Hydrology	Stream flow	Alteration of peak or base flows	***Unacceptable Risk***	***Unacceptable Risk***	***Unacceptable Risk***	***Unacceptable Risk***	***Unacceptable Risk***
Water Quality	Temperature, Turbidity, Nutrients	Field observations, including warm, turbid water, and nuisance algae growth	***At Risk***	***At Risk***	***At Risk***	***At Risk***	***At Risk***
Habitat Quality	Substrate	Dominant substrate/fine sediment	***At Risk***	***At Risk***	Not Assessed	***At Risk***	***At Risk***
	Large Woody Debris	Pieces per mile	***Unacceptable Risk***	***Unacceptable Risk***	Not Assessed	***Unacceptable Risk***	***Unacceptable Risk***
	Pools	Frequency and quality	***Unacceptable Risk***	***At Risk***	Not Assessed	***Unacceptable Risk***	***Unacceptable Risk***
	Complexity	Variability and heterogeneity of habitat units	***Unacceptable Risk***	***At Risk***	Not Assessed	***Unacceptable Risk***	***Unacceptable Risk***
	Off-Channel Habitat	Connectivity with main channel	***Unacceptable Risk***	***Unacceptable Risk***	Not Assessed	***Unacceptable Risk***	***Unacceptable Risk***
Channel	Dynamics	Floodplain connectivity	***Unacceptable Risk***	***Unacceptable Risk***	Not Assessed	Not Assessed	***Unacceptable Risk***
		Bank stability/channel migration	***Unacceptable Risk***	***At Risk***	Not Assessed	***At Risk***	***Unacceptable Risk***
		Vertical channel stability	***Unacceptable Risk***	***Unacceptable Risk***	Not Assessed	Not Assessed	***Unacceptable Risk***
		Resiliency to Disturbance	***Unacceptable Risk***	***At Risk***	Not Assessed	***Unacceptable Risk***	***Unacceptable Risk***
Riparian Vegetation	Condition	Structure	***At Risk***	***At Risk***	***At Risk***	***At Risk***	***Unacceptable Risk***
		Disturbance (Human)	***Unacceptable Risk***	***At Risk***	***At Risk***	***At Risk***	***Unacceptable Risk***
		Canopy Cover	***Unacceptable Risk***	***Unacceptable Risk***	***At Risk***	***Unacceptable***	***Unacceptable Risk***

bridge is unlikely to survive another extreme flood. As a result, improving or replacing the Serenity Lane Bridge would benefit fish and improve access for the community.

Subreach FC2 is single-threaded channel that is deeply incised and is actively incising and widening. The bankfull channel is, on average, 18 to 22 feet wide and 2 to 2.5 feet deep, with a flood-prone width (Rosgen 1996) of 25 to 35 feet. The channel is confined in at least one location by an undersized private crossing. This is primarily a transport reach due to its incised and confined nature (Montgomery and Buffington 1998), but some indications of channel response to alluvial processes were observed. Overall channel gradient is 1.6 percent, and the sinuosity of individual channel threads is low (1.0 to 1.2). Channel substrate is primarily cobble, with boulder secondary. Banks are composed primarily of cobble mixed with fines and are moderately unstable. The channel exhibits a pool/riffle channel type (Montgomery and Buffington 1998), and the creek was visually classified as a Rosgen Type G3 (Rosgen 1996).

Subreaches FC3 and FC4 were not assessed in the field due to limited site access. Subreach FC3 was assessed only based on aerial photography and lidar data. Subreach FC4 was assessed additionally by field observations from the adjacent Subreach FC5.

Subreach FC3 is a multi-threaded channel that is actively widening and meandering. This is a response reach (Montgomery and Buffington 1998) where morphological adjustments occur in response to increased sediment supply. Overall channel gradient was determined from lidar data to be 1.8 percent, and the sinuosity of individual channel threads is low (1.0 to 1.2).

Subreach FC4 is primarily a single-threaded channel with high-flow channels evident in the floodplain. The bankfull channel is, on average, 35 feet wide and 2.5 feet deep, with a flood prone width (Rosgen 1996) of approximately 150 feet. This is a response reach (Montgomery and Buffington 1998) where morphological adjustments occur in response to increased sediment supply. Overall channel gradient is 1.8 percent, and the sinuosity of individual channel threads is low (1.0 to 1.2). Channel substrate is primarily cobble, with boulder secondary. Banks are composed primarily of fines mixed with cobbles and are moderately unstable. The channel exhibits a pool/riffle channel type (Montgomery and Buffington 1998), and the creek was visually classified as a Rosgen Type C3 (Rosgen 1996).

Subreach FC5 is single-threaded, with substantial impacts from the May 2011 flood event and subsequent levee construction on both banks. The bankfull channel is, on average, 35 feet wide and 2 to 2.5 feet deep, with a flood prone width (Rosgen 1996) of approximately 150 feet. The channel is confined at the upstream end of the subreach by an undersized crossing at Cove Road. This is a response reach (Montgomery and Buffington 1998) where morphological adjustments occur in response to increased sediment supply. Overall channel gradient is 1.7 percent. The sinuosity of individual channel threads is low (1.0 to 1.2). Channel substrate is primarily cobble, with boulder secondary. Banks are composed primarily of fines mixed with cobble and are very unstable. The channel exhibits an excavated/constructed channel type (Montgomery and Buffington 1998) and is leveed on both banks for almost the entire length of the reach. The creek was visually classified as a Rosgen Type C3 or D3 (Rosgen 1996).

Riparian Vegetation

In general, riparian vegetation condition within the Fan Contraction Reach is at risk in terms of structure, at risk in terms of disturbance, and at unacceptable risk in terms of canopy cover (Table 6). The overall composition of the riparian zone in this reach is shown on a chart in Appendix C.

Riparian vegetation conditions in Reach FC are overall generally poor, with the intact riparian zone averaging 0 to 30 feet wide in most places. Canopy cover is generally low, which is likely partially attributable to lower soil moisture caused by dewatering in the reach and channel incision resulting in floodplain disconnection. There is evidence of widespread tree dieback, with many dead-topped medium to large black cottonwoods throughout the reach. This may be related to the lack of water in Manastash Creek during the summer and fall months. It also appears that trees and shrubs have been cleared in many areas for agriculture or residential development. Several sections of the stream banks are in an unvegetated cutbank state or are supporting only invasive weed species (e.g., knapweed). In many areas, in-channel gravel bars have been colonized almost exclusively by knapweed and white sweetclover. Riparian conditions adjacent to sections of the stream that have been dredged are exceptionally poor, as these areas have virtually no trees or shrubs to provide instream cover.

The patches of deciduous forest that are present are dominated by medium black cottonwoods and Pacific willows with an understory of quaking aspen and black cottonwood seedlings, Woods' rose, Douglas' maple, oceanspray, and coyote willow near the shoreline. There are several areas where upland shrubs are dominant, including species such as snowberry, Woods' rose, wax currant, chokecherry, mock orange, blue elderberry, and deerbrush.

Physical Habitat Conditions

Physical habitat conditions in Subreach FC1 are generally poor. Pools are present, but quality and complexity are low due to an overall lack of LWD and riparian vegetation. Some groundwater flow was observed in the lower half of Subreach FC1, while the upper half of the subreach was completely dewatered at the time of field work. No spawning-sized gravels were observed; cobbles and small boulders are the dominant substrate. Rearing habitat is severely limited by the lack of side channels and backwater areas. Floodplain connectivity is limited, cut off by human alterations and undersized crossings, but there is evidence of floodplain flow during extreme flow events. Summer rearing habitat is limited by severely reduced stream flows (see *Human Alterations,* below). No physical barriers to fish migration are located in this reach or downstream. However, Subreach FC1 was entirely dry during the site visit, representing a fish barrier during low flow periods.

Physical habitat conditions in Subreach FC2 are fair to poor. Pools are present in greater frequency than in Subreach FC1, but quality and complexity are low due to an overall lack of LWD and riparian vegetation. Some groundwater-fed flow was observed in this subreach, and isolated pools held juvenile and smaller adult salmonids. Spawning-sized gravels were not observed, with cobbles and small boulders being the dominant substrate. Rearing habitat is severely limited by the lack of side channels and backwater areas. Summer rearing habitat is limited by severely reduced stream flows (see *Human Alterations,* below). No barriers to fish migration are located in Subreach FC2 or downstream, although the subreach was entirely dry during the site visit and represents a fish barrier during low flow periods.

Physical habitat conditions in Subreaches FC3 and FC4 were not directly assessed in the field but are expected to be fair to poor. Some LWD was observed in aerial photos of the subreaches, but summer rearing habitat is limited by severely reduced stream flows (see *Human Alterations*, below). No complete barriers to fish migration are located in these subreaches or downstream. While the Anderson Diversion dam was not inspected during field work, it is understood to be a partial fish passage barrier depending on flow rate. The Abandoned dam was previously considered a fish passage barrier, but was breached during the May 2011 storm event and is now considered passable. However, both subreaches were entirely dry during the site visit and represent a fish barrier during low flow periods.

Physical habitat conditions in Subreach FC5 are poor. Pools are very infrequent, and quality and complexity are low due to an overall lack of LWD, lack of riparian vegetation, and mechanical alterations to the channel. Spawning-sized gravels were not observed, with cobbles and small boulders being the dominant substrate. Rearing habitat is severely limited by the lack of side channels and backwater areas. Summer rearing habitat is limited by severely reduced stream flows (see *Human Alterations*, below). There are no barriers to fish migration in Subreach FC5 or downstream, although this subreach was entirely dry during the site visit and represents a fish barrier during low flow periods.

Human Alterations

Human alterations significantly affect habitat in Reach FC. Alterations include undersized channel crossings in Subreaches FC1, FC2, and FC5; mechanical dredging and levee construction limiting floodplain connectivity (partly required and exacerbated by the undersized crossing), riparian vegetation removal by both people and natural erosive processes from other human alterations, LWD removal, and bank armoring that limits natural channel process and LWD recruitment.

Quality of habitat in all subreaches of Reach FC is affected in summer months by irrigation withdrawals. Field crews observed dry channel conditions through most of Reach FC, and it is, therefore, an effective low flow fish passage barrier. Conditions would be greatly improved during the summer months if base flows in Manastash Creek were increased.

Restoration Opportunities

Chronic dewatering is a major limiting factor to habitat in this reach, and maintaining instream flow should be a top priority. The level of human alterations and its relative proximity to higher quality areas downstream mean that Reach FC is also an excellent target for restoration. In particular, the undersized Serenity Lane Bridge, which is a cause of channel aggradation and flooding, will require repairs in the near future, at which time habitat improvements could also be made. These improvements would lessen the geomorphic ramifications of the existing crossing and also lessen the need for subsequent armoring. Large scale restoration efforts will need to be balanced with flood risk. Finally restoring vegetative cover in this reach presents an easy, straightforward opportunity to improve conditions that would have a net benefit to fish and serve to manage out-of-bank flooding.

Reach FE – Fan Expansion

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Reach FE extends from Cove Road upstream to the Manastash Road curve at RM 5.4. This reach is likely the most historically dynamic portion of the study area, with historic deposition likely being highest at Cove Road. The constriction of the road crossing likely increases this deposition. Several historical distributary swales are present in the floodplain and receive flow during flood events. The Fan Expansion Reach is separated into four distinct geomorphic subreaches (FE1, FE2, FE3, and FE4, from downstream to upstream) for the purposes of habitat assessment. Habitat conditions are described below and summarized in Table 7. Detailed information on habitat conditions in the reach based on REIs is provided in Appendix B. Habitat and disturbance features are shown in Figure A-5 in Appendix A.

In summary, the factors that limit habitat quality in this reach include:

- **Hydrology** (reduced baseflow during summer months limiting habitat creation and maintenance as well as fish habitat use and accessibility)
- **Channel confinement** (revetments preventing channel migration and undersized crossing at Cove Road)
- **Floodplain connectivity** (levees confining stream flow at downstream extent of reach)
- **Fish passage barrier** (Reed Ditch diversion)
- **Habitat structure** (lack of LWD and spawning-sized substrate)
- **Riparian vegetation** (lack of vegetation)

Geomorphology

Subreach FE1 is single-threaded, with no high-flow channels or side channels. The bankfull channel is, on average, 25 feet wide and 3 feet deep, with a flood prone width (Rosgen 1996) of approximately 150 feet. The channel is confined at the downstream end of the subreach by an undersized crossing at Cove Road and was mechanically dredged after the flood event of May 2011. Subreach FE1 is a response reach (Montgomery and Buffington 1998) where morphological adjustments occur in response to increased sediment supply. Sediment deposition is expected in alluvial fan environments, but rates of deposition are likely increased above normal in this subreach by the backwater effect of the undersized Cove Road crossing. Overall channel gradient is 1.7 percent, and the sinuosity of individual channel threads is low (1.0 to 1.2). Channel substrate is primarily cobble, with boulder secondary. Banks are composed primarily of cobble mixed with fines and are slightly unstable. The channel exhibits plane bed (cobble, boulder) and excavated/constructed channel types (Montgomery and Buffington 1998), and the creek was visually classified as a Rosgen Type B3 or C3 (Rosgen 1996).

Subreach FE2 is multi-threaded in some areas, with some high-flow channels and side channels present. The bankfull channel is, on average, 40 to 50 feet wide and 2 to 2.5 feet deep, with a flood prone width (Rosgen 1996) of approximately 150 feet. Subreach FE2 is a response reach (Montgomery and Buffington 1998) where morphological adjustments occur in

Table 7. Fan Expansion (Reach FE) Habitat Conditions.

General Characteristics	General Indicators	Specific Indicators	Subreach FE1 Condition	Subreach FE2 Condition	Subreach FE3 Condition	Subreach FE4 Condition
Habitat Access	Physical Barriers	Main channel barrier in reach or downstream	***At Risk***	***At Risk***	***At Risk***	***Unacceptable Risk***
Hydrology	Stream Flow	Alteration of peak or base flows	***Unacceptable Risk***	***Unacceptable Risk***	***Unacceptable Risk***	***Unacceptable Risk***
Water Quality	Temperature, Turbidity, Nutrients	Field observations, including warm, turbid water, and nuisance algae growth	***At Risk***	***At Risk***	***At Risk***	***At Risk***
Habitat Quality	Substrate	Dominant substrate/fine sediment	***At Risk***	***At Risk***	***At Risk***	***At Risk***
	Large Woody Debris	Pieces per mile	***Unacceptable Risk***	***Unacceptable Risk***	***Unacceptable Risk***	***Adequate***
	Pools	Frequency and quality	***At Risk***	***At Risk***	***At Risk***	***Adequate***
	Complexity	Variability and heterogeneity of habitat units	***Unacceptable Risk***	***Unacceptable Risk***	***At Risk***	***Adequate***
	Off-Channel Habitat	Connectivity with main channel	***Unacceptable Risk***	***At Risk***	***Unacceptable Risk***	***Unacceptable Risk***
Channel	Dynamics	Floodplain connectivity	***Unacceptable Risk***	***At Risk***	***Unacceptable Risk***	***Adequate***
		Bank stability/channel migration	***Unacceptable Risk***	***Unacceptable Risk***	***Unacceptable Risk***	***Adequate***
		Vertical channel stability	***Unacceptable Risk***	***Unacceptable Risk***	***Unacceptable Risk***	***Adequate***
		Resiliency to Disturbance	***Unacceptable Risk***	***Unacceptable Risk***	***Adequate***	***Adequate***
Riparian Vegetation	Condition	Structure	***Adequate***	***Adequate***	***Adequate***	***Unacceptable***
		Disturbance (Human)	***Adequate***	***Adequate***	***At Risk***	***Unacceptable***
		Canopy Cover	***Adequate***	***Adequate***	***Unacceptable***	***Unacceptable***

response to increased sediment supply. The channel is less incised in this subreach than in Subreach FE1, and it exhibits more meandering and floodplain connectivity. Bedload deposition is naturally expected in this alluvial fan environment. That, in combination with highly erodible bank material and a lack of bank stabilizing riparian vegetation, has resulted in extreme lateral migration/expansion rates of the channel. Overall channel gradient is 1.8 percent, and the sinuosity of individual channel threads is low (1.0 to 1.2). Channel substrate is primarily cobble, with fines secondary. Banks are composed primarily of cobble mixed with fines and are moderately to completely unstable. The channel exhibits pool/riffle channel type (Montgomery and Buffington 1998), and the creek was visually classified as a Rosgen Type C3 (Rosgen 1996).

Subreach FE3 is a single-thread channel located immediately downstream of the Reed Ditch diversion. The bankfull channel is, on average, 20 feet wide and 3 feet deep, with a flood prone width (Rosgen 1996) of approximately 32 feet. The channel is incised deeply below the floodplain. Subreach FE3 is a transport reach (Montgomery and Buffington 1998) where sediment inputs are rapidly conveyed through the reach. Overall channel gradient is 1.9 percent, and the sinuosity of individual channel threads is low (1.0 to 1.2). Channel substrate is primarily cobble, with boulder secondary. Banks are composed primarily of cobble mixed with fines and are slightly unstable. The channel exhibits plane bed (cobble, boulder) channel type, bordering on step pool morphology (Montgomery and Buffington 1998). The creek was visually classified as a Rosgen Type A2 or A3 (Rosgen 1996).

Subreach FE4 is primarily single-threaded, with high stream complexity. The bankfull channel is, on average, 28 to 35 feet wide and 1.5 to 2.0 feet deep, with a flood prone width (Rosgen 1996) of greater than 300 feet. Channel grade is controlled on the downstream end by the Reed Ditch diversion. Subreach FE4 is a response reach (Montgomery and Buffington 1998) where morphological adjustments occur in response to increased sediment supply. Overall channel gradient is 1.6 percent, and the sinuosity of individual channel threads is low (1.0 to 1.2). Channel substrate is primarily cobble, with gravel and boulder secondary. Banks are composed primarily of cobble mixed with fines and are slightly unstable. The channel exhibits pool/riffle channel type (Montgomery and Buffington 1998), and the creek was visually classified as a Rosgen Type C3 (Rosgen 1996).

Riparian Vegetation

In general, riparian vegetation condition within Reach FE is at risk in terms of structure, disturbance, and canopy cover (Table 7). The overall composition of the riparian zone in this reach is provided in Appendix C.

Riparian vegetation in Reach FE displays a range of conditions (from high to low), with a stark transition at the Reed Ditch diversion. Immediately upstream of the Reed Ditch diversion, the artificial grade control caused by the diversion has produced exceptionally high floodplain connectivity, resulting in the development of dense riparian vegetation and floodplain forested wetland habitats. This area is characterized by high overhanging tree and shrub cover, dominated by medium black cottonwood (and abundant seedlings),Pacific willow, red alder, quaking aspen, mountain alder, red osier dogwood, Woods' rose, Douglas' maple, creeping Oregon grape, and Mackenzie willow, with small-fruited bulrush, water horsetail, and water sedge observed in several areas. The lush riparian vegetation condition extends along the Reed Ditch diversion as it diverges from Manastash Creek; however, the banks of the ditch are contrastingly steep, and it lacks instream and bank complexity.

Downstream of the Reed Ditch diversion, there is evidence of widespread deciduous tree dieback similar to that observed in the Fan Contraction reach, with many dead-topped medium to large black cottonwoods throughout the lower portion of the reach (Subreaches FE1 and FE2). This may be related to the lack of water in Manastash Creek during the summer and fall months. Many areas have been cleared for residential landscaping and livestock, particularly in the lower portion of the reach. However, some areas have retained somewhat intact deciduous forest, and other areas display an open mixed forest or shrub-steppe vegetation type (i.e., naturally low vegetative cover).

Deciduous forest areas are dominated by medium to large black cottonwood, while mixed forest areas are co-dominated by medium to large black cottonwood and large Ponderosa pine. The understory in Reach FE is moderately dense to sparse (depending on soil moisture), and common species include chokecherry, Woods' rose, mock orange, creeping Oregon grape, with Mackenzie willow, coyote willow, and red osier dogwood common on stream banks. Dense stands of black cottonwood seedlings dominated the understory at many locations within the reach.

Many streambank areas and gravel bars within the reach have been colonized by invasive weeds, such as knapweed, white sweetclover, reed canarygrass, and mullein.

Physical Habitat Conditions

Physical habitat conditions in Subreach FE1 are generally poor. Pools are present, but quality and complexity are low due to modified channel bed and banks and an overall lack of LWD and riparian vegetation. Spawning-sized gravels were not observed, with cobbles and small boulders being the dominant substrate. Rearing habitat is severely limited by the lack of side channels and backwater areas. Summer rearing habitat is limited by severely reduced stream flows (see *Human Alterations* section, below). Floodplain connectivity is limited by berms constructed along channel banks and the undersized crossing at Cove Road, but there is evidence of floodplain flow during extreme flow events. No physical barriers to fish migration are located in Subreach FE1 or downstream, although this subreach was entirely dry during the site visit and represents a fish barrier during low flow periods.

Physical habitat conditions in Subreach FE2 are fair to poor. Pools are present, but quality and complexity are moderate to low due to lack of LWD and riparian vegetation. Spawning-sized gravels were not observed, with cobbles and small boulders being the dominant substrate. Juvenile salmonids were observed in one pool in the subreach. Rearing habitat is limited by low quality side channels and backwater areas. There is moderate floodplain connectivity in this reach, and the channel has meandered substantially within the largely unvegetated riparian zone. Summer rearing habitat is limited by severely reduced stream flows (see *Human Alterations,* below). Although no physical barriers to fish migration are located in Subreach FE2 or downstream, this subreach was entirely dry during the site visit and represents a fish barrier during low flow periods.

Physical habitat conditions in Subreach FE3 are fair to poor. Pools are present in adequate numbers, and quality and complexity are moderate. Spawning-sized gravels were not observed, with cobbles and small boulders being the dominant substrate. Rearing habitat is limited by the straight, entrenched nature of the channel. There is little floodplain connectivity in this incised subreach; however, the channel is shaded by riparian vegetation. Summer rearing habitat is limited by severely reduced stream flows (see *Human Alterations,* below). The Reed Ditch diversion at the upstream end of Subreach FE3 constitutes a physical barrier to fish migration. In addition, this subreach was entirely dry during the site visit and represents a fish barrier during low flow periods.

Physical habitat conditions in Subreach FE4 are good to fair. Pools are present in adequate numbers, and quality and complexity are moderate to high. Spawning-sized gravels were observed among the cobbles, and small boulders that dominate the substrate. While the channel in this subreach provides generally high quality habitat with good shading from riparian vegetation, side channel and off-channel (riparian wetland) rearing habitat areas are limited. There is generally good floodplain connectivity in this subreach, with the exception of areas with levees at the downstream end at the Reed Ditch diversion. Subreach FE4 is less affected by reduced summer stream flows than downstream portions of Manastash Creek, and typically has flow year round. The Reed Ditch diversion at the downstream end of this subreach constitutes a physical barrier to upstream fish migration at all flows.

Human Alterations

Human alterations significantly affect habitat in Reach FE. There is an undersized channel crossing at Cove Road in Subreach FE1. Mechanical dredging and levee construction limits floodplain connectivity upstream of Cove Road, and riparian vegetation alterations in Subreaches FE1 and FE2 reduce habitat complexity and cover.

Quality of habitat in all subreaches within Reach FE is affected in summer months by irrigation withdrawals, but to a lesser degree in Subreach FE4, which is located above the Reed Ditch diversion. Field crews observed dry channel conditions through portions of Reach FE. Conditions would be greatly improved during the summer months if base flows in Manastash Creek were increased.

The Reed Ditch diversion located at the Subreach FE3/FE4 boundary constitutes the last physical fish passage barrier on the Manastash Creek main stem.

Restoration Opportunities

Chronic dewatering is a major limiting factor to habitat in this reach, and maintaining instream flow should be a top priority. The largest restoration opportunity aside from the already-planned Reed Ditch diversion removal is the modification or replacement of the Cove Road Bridge opening at the downstream end of Subreach FE1. This bridge is undersized for the dynamic environment found at the crossing, and may limit throughput of sediment, which is exacerbating sediment deposition, flooding and channel migration upstream. Improving the crossing at Cove Road and improving the upstream and downstream channel to allow sediment throughput would also reduce the need for emergency dredging in the future. In addition, revegetation of areas damaged in the 2011 flood could build up the resilience of the reach to future flooding, while improving habitat conditions. Restoring vegetative cover in this reach presents an easy, straightforward opportunity to improve conditions that would have a net benefit to fish and serve to manage out-of-bank flooding. Lastly, some portions of this reach currently have good habitat (Subreach FE4), and protection and conservation from additional development or armoring should be encouraged.

Reach FA – Fan Apex

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Reach FA extends roughly from the Manastash Road curve upstream (R.M. 5.4) to the Manastash Road Bridge at the mouth of the canyon proper. This reach is the transition zone from an alluvial, mountain stream to a braided, highly depositional fan environment. However, because there is significant deposition in the canyon both from interglacial periods and in the present day and there is very little slope change from the canyon to the fan, its extents are somewhat diffuse.

The Fan Apex Reach of Manastash Creek is separated into four distinct geomorphic subreaches (FA1, FA2, FA3, and FA4, from downstream to upstream), each characterizing a transition from canyon confinement to open fan conditions. These subdivisions are useful for the purposes of assessing habitat conditions.

Habitat conditions are described below and summarized in Table 8. Detailed information on habitat conditions in the reach based on REIs is provided in Appendix B. Habitat and disturbance features are shown in Figure A-6 in Appendix A.

In summary, the factors that limit habitat quality in Reach FA include:

- **Hydrology** (reduced baseflow during summer months limiting habitat forming and maintenance as well as fish habitat use and accessibility)
- **Channel confinement** (crossing at KRD South Branch Rd in Subreach FA1) and revetments preventing channel migration in Subreach FA2)
- **Floodplain connectivity** (levees confining stream flow at in Subreaches FA2 and FA4)
- **Habitat structure** (lack of LWD and spawning-sized substrate)
- **Riparian vegetation** (lack of vegetation)

Geomorphology

Subreach FA1 is primarily a single-threaded, highly complex channel with high-flow channels and occasional side channels. The bankfull channel is, on average, 35 feet wide and 2.5 feet deep, with a flood prone width (Rosgen 1996) of greater than 100 feet. The channel is confined at the upstream end of the subreach by a crossing at KRD South Branch Road and KRD irrigation canal siphon, which serves as grade control. Subreach FA1 is a response reach (Montgomery and Buffington 1998) where morphological adjustments occur in response to increased sediment supply. Overall channel gradient is 1.6 percent, and the sinuosity of individual channel threads is low to appreciable (1.0 to 1.5). Channel substrate is primarily cobble, with gravel and boulder secondary. Banks are composed primarily of cobble mixed with fines and are slightly unstable. The channel exhibits pool/riffle channel type (Montgomery and Buffington 1998), and the creek was visually classified as a Rosgen Type C3 or C4 (Rosgen 1996).

Subreach FA2 is a single-threaded, confined channel with no off-channel habitat. The bankfull channel is, on average, 28 to 32 feet wide and 2.5 feet deep, with a flood prone width

Table 8. Fan Apex (Reach FA) Habitat Conditions.

General Characteristics	General Indicators	Specific Indicators	Subreach FA1 Condition	Subreach FA2 Condition	Subreach FA3 Condition	Subreach FA4 Condition
Habitat Access	Physical Barriers	Main channel barrier in reach or downstream.	***At Risk***	***At Risk***	***At Risk***	***At Risk***
Hydrology	Stream flow	Alteration of peak or base flows	***Unacceptable Risk***	***Unacceptable Risk***	***Adequate***	***Adequate***
Water Quality	Temperature	Field observations, including warm, turbid water, and nuisance algae growth	***At Risk***	***At Risk***	Not Assessed	***Adequate***
Habitat Quality	Substrate	Dominant substrate/fine sediment	***At Risk***	***At Risk***	Not Assessed	***At Risk***
	Large Woody Debris	Pieces per mile	***Adequate***	***Unacceptable Risk***	Not Assessed	***Unacceptable Risk***
	Pools	Frequency and quality	***Adequate***	***Unacceptable***	Not Assessed	***At Risk***
	Complexity	Variability and heterogeneity of habitat units	***Adequate***	***At Risk***	Not Assessed	***At Risk***
	Off-Channel Habitat	Connectivity with main channel	***At Risk***	***Unacceptable***	Not Assessed	***At Risk***
Channel	Dynamics	Floodplain connectivity	***At Risk***	***Unacceptable***	Not Assessed	***At Risk***
		Bank stability/channel migration	***Adequate***	***Unacceptable Risk***	Not Assessed	***Unacceptable Risk***
		Vertical channel stability	***At Risk***	***Unacceptable Risk***	Not Assessed	***At Risk***
		Resiliency to Disturbance	***Adequate***	***At Risk***	Not Assessed	***At Risk***
Riparian Vegetation	Condition	Structure	***At Risk***	***Adequate***	***Unacceptable***	***Adequate***
		Disturbance (Human)	***Unacceptable***	***At Risk***	***Unacceptable***	***Adequate***
		Canopy Cover	***At Risk***	***At Risk***	***At Risk***	***Adequate***

(Rosgen 1996) of greater than 100 feet. The channel is confined throughout subreach by armored revetments for stream banks. There are two recently constructed diversion structures in this reach (MWDA and Keach Jensen) with rock weir fish passage structures. Subreach FA2 is a transport reach (Montgomery and Buffington 1998) where sediment inputs are rapidly conveyed through the reach. Overall channel gradient is 1.9 percent, and the sinuosity of individual channel threads is low (1.0 to 1.2). Channel substrate is primarily cobble, with gravel secondary. Banks are composed primarily of cobble mixed with fines where the banks are not armored. The channel exhibits plane bed (cobble, boulder) channel type (Montgomery and Buffington 1998), and the creek was visually classified as a Rosgen Type B4 or C4 (Rosgen 1996).

Subreach FA3 was not assessed in the field due to limited access.

Subreach FA4 is multi-threaded with high floodplain connectivity. Bankfull channel dimensions were estimated to be 35 feet wide and 2.5 feet deep on average, but constructed channels and the degree of disturbance by sediment aggradation made accurate measurement difficult. This is a response reach (Montgomery and Buffington 1998) where morphological adjustments occur in response to increased sediment supply. Subreach FA4 experienced substantial sediment deposition during the May 2011 flood event. Its location, at the head of the fan apex, makes it an expected location for significant natural sediment deposition. Landowners also report significant ice jam formation annually. Overall channel gradient is 1.6 percent, and the sinuosity of individual channel threads is low (1.0 to 1.2). Channel substrate is primarily cobble, with fines as secondary. Banks are composed primarily of cobble mixed with fines and are moderately unstable. Significant bank erosion is present but appears to be primarily associated with the large flood event of 2011 and is currently in a state of restabilization. The channel exhibits pool/riffle channel type (Montgomery and Buffington 1998), although the majority of the channel network, including side channels, have been excavated or constructed in an attempt to increase channel capacity and decrease flood risk to landowners on the developed, right-bank floodplain. The creek was visually classified as a Rosgen Type C3 or D3 (Rosgen 1996).

Riparian Vegetation

In general, riparian vegetation condition within Reach FA is at risk in terms of structure, disturbance, and canopy cover (Table 8). The overall composition of the riparian zone in this reach is provided in Appendix C. Riparian vegetation in Reach FA is intact in many areas, which are generally dominated by deciduous forest and forested wetland habitats. Some areas have been cleared to the shoreline for lawns/residential landscaping, and livestock use. The intact riparian zone within the reach ranges from 0 to 300 feet wide.

The lower end of the reach (Subreach FA1, immediately downstream of the KRD canal) is characterized by excellent riparian cover, as a large stand of medium to large black cottonwoods and quaking aspen occupy a broad, low-lying portion of the floodplain. Cover in Subreaches FA2 and FA3 is also generally high (except in the vicinity of the diversions), but the riparian zone is much narrower (e.g., 20 to 50 feet wide). The riparian understory in intact forested areas is dense and diverse, dominated by black cottonwood seedlings, mountain alder, Pacific willow, Mackenzie willow, Douglas’ maple, red osier dogwood, snowberry, and mock orange. The riparian zone in the vicinity of the diversion facilities has been largely cleared of trees and shrubs, and some stream bank areas there lack vegetative cover.

An extensive forested/scrub-shrub wetland complex occupies the left-bank floodplain in Subreach FA4. The area is dominated by medium to large black cottonwoods, and a dense understory of red osier dogwood, Mackenzie willow, coyote willow, water horsetail, fowl bluegrass, reed canarygrass, and other wetland plant species. The right-bank riparian zone in this area has been compromised by residential development and landscaping, with lawns extending up to the shoreline (and experiencing flooding in places).

Several stream bank areas and gravel bars within the reach have been colonized by invasive weeds, such as knapweed, white sweetclover, reed canarygrass, and mullein.

Physical Habitat Conditions

Physical habitat conditions in Subreach FA1 are generally good and represent the highest quality habitat observed in the lower 6 miles of Manastash Creek. Pools are present, with high quality and complexity provided by LWD. Spawning-sized gravels were observed amongst the cobbles and small boulders that dominate the substrate. High quality rearing habitat is somewhat limited, and there are historic high flow channels and ditches that have been cut off by human alteration. Floodplain connectivity is fair, as the channel is incised at the upstream end. Incision decreases moving downstream in the reach. Subreach FA4 is less affected by reduced summer stream flows than downstream portions of Manastash Creek and typically has flow year round. No physical barriers to fish migration are located in this subreach, but it is isolated from downstream reaches at the Reed Ditch diversion in Reach FE.

Physical habitat conditions in Subreach FA2 are generally poor due to the confined nature of the channel. Pools are present in low numbers and are primarily associated with irrigation diversion infastructure. The observed pools have limited quality and complexity. Spawning-sized gravels were observed amongst the cobbles that dominate the substrate. No off-channel habitat is present in this subreach, and no LWD was observed. Floodplain connectivity is poor due to constructed levees and armoring of the streambanks. Subreach FA2 is less affected by reduced summer stream flows than downstream portions of Manastash Creek and typically has flow year round. No physical barriers to fish migration are located in this subreach, but it is isolated from downstream reaches at the Reed Ditch diversion in Reach FE.

Habitat conditions were not assessed in Subreach FA3 due to limited access.

Physical habitat conditions in Subreach FA4 are generally fair due to the low habitat complexity and lack of LWD resulting from continued mechanical alteration of the channel. Pools are present with limited quality and complexity and are primarily associated with bank armoring or rock barbs. Spawning-sized gravels were observed amongst the cobbles that dominate the substrate. Some low to moderate quality off-channel habitat (floodplain wetland areas) is present in this subreach. Floodplain connectivity is moderate to high in spite of constructed levees and armoring of the stream banks, and flooding is a continuous source of concern for those with homes on the floodplain. Summer base flow in this subreach is not affected by irrigation diversions, as it is upstream of all major diversion points, and it typically has flow year round. No physical barriers to fish migration are located in Subreach FA4, but it is isolated from downstream reaches at the Reed Ditch diversion in Reach FE.

Human Alterations

Human alterations significantly affect habitat in Reach FA. Alterations include the KRD road crossing at the break between Subreaches FA1 and FA2, the confined channel in Subreach FA2, and the developed floodplain and revetments and levees constructed in Subreach FA4. Channel grade is controlled at the KRD South Branch Road crossing and siphon and at the fish passage structures at the MWDA diversion and Keach Jensen diversion.

Quality of habitat in Subreaches FA1 and FA2 are affected in summer months by irrigation withdrawals, but Subreaches FA3 and FA4 are upstream of all major diversions.

Restoration Opportunities

Habitat conditions are relatively good in portions of the reach (Subreach FA1), so a strategy of conservation and preservation should be encouraged. In other areas, balancing flood risk with channel restoration activities could provide win-win solutions. Where riparian vegetation has been cleared, restoring vegetative cover presents an easy, straightforward opportunity to improve conditions that would have a net benefit to fish and serve to manage out-of-bank flooding.

Reach CY - Canyon

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Reach CY extends approximately 7 miles, from the Manastash Road Bridge at the mouth of the canyon proper upstream to approximately RM 13.6, the upstream extent of lidar coverage for the project study area. Reach CY is shown on Figures A-7 through A-10 in Appendix A. For this study, the Canyon Reach of Manastash Creek is treated as a single unit, although there is significant variation in geomorphology within the reach. The degree of field survey was also less rigorous in the Canyon Reach than in the lower 6 miles of study area. The primary method of analysis was through remote sensing data, coupled with observations from individual sites through the canyon reach where access was granted. No formal channel or habitat surveys were conducted, though isolated portions (when publically owned and at Lazy F Ranch) of the stream were accessed.

Geomorphology

The Canyon Reach is primarily single-threaded, with numerous high-flow channels and occasional side channels. Reach CY is a response reach (Montgomery and Buffington 1998) where morphological adjustments occur in response to deposition from increased sediment supply. Overall channel gradient was determined from lidar data, and varied from approximately 2.4 percent in the upstream quarter of the reach, gradually decreasing to 1.79 percent in the downstream quarter of the reach. Sinuosity trends toward the high end of the low range (1.0 to 1.2). Where observed, channel substrate is primarily cobble, with secondary substrate trending between gravel and small boulders depending on the location. An accurate assessment of bank stability is not possible given the limited access to the channel in the reach. The Canyon Reach exhibits pool/riffle channel type (Montgomery and Buffington 1998). The reach is typified by small and large slope failures on both banks, which are composed of degraded Grande Ronde basalt (see Figure 4).

Riparian Vegetation

Riparian vegetation throughout the Canyon Reach is largely intact with high in-channel cover, except for the Manastash Road corridor and sporadic areas of residential and agricultural development. The dominant vegetation type in the canyon is mature mixed forest, with many occurrences of floodplain forested wetland in areas where the canyon widens (e.g., Lazy F Ranch, confluence with North Fork). The lateral extent of the intact riparian zone throughout this reach generally ranges from 50 to 300 feet from the stream channel.

Mixed forest areas are dominated by medium to large black cottonwood, Ponderosa pine, and Douglas-fir trees, with a dense understory composed of mountain alder, Mackenzie willow, chokecherry, serviceberry, red osier dogwood, Douglas maple, snowberry, Woods' rose, oceanspray, creeping Oregon grape, and thimbleberry. Reed canarygrass, water sedge, and water horsetail were common at the toe of streambanks throughout much of the reach.

Floodplain wetland habitats, such as at the Lazy F Ranch, are dominated by medium to large black cottonwood, red alder, and quaking aspen trees, with a dense and diverse understory of hydrophytic vegetation, including red osier dogwood, water parsley, small-fruited bulrush, fowl mannagrass, water horsetail, reed canarygrass, black cottonwood and quaking aspen seedlings, coyote willow, and Mackenzie willow. Many occurrences of forested mosaic wetlands are present in portions of the canyon where the floodplain broadens and complex channel networks (i.e., braiding) have developed.

Physical Habitat Conditions

Physical habitat conditions were not surveyed in detail within Reach CY. Where observed, and based on assessment of the aerial photos, physical habitat conditions in Reach CY are generally fair to good due to the presence of dense riparian vegetation along most of the reach and relatively intact habitat forming processes (e.g., large wood transport and accumulation, sediment deposition and sorting). Spawning-sized gravels were observed amongst the cobbles that dominate the substrate. Numerous high flow channels provide quality off-channel habitat is present in the reach. Floodplain connectivity is moderate in spite of numerous private crossings and armoring of the stream banks. Floodplain connectivity and habitat would likely improve with modification of bridges and addition of LWD to the channel. Summer base flow in the Canyon Reach is not severely affected by irrigation diversions because it is upstream of all major diversion points. The reach typically has flow year round, as was observed during the field work. There are no physical barriers to fish migration in the reach, but it is isolated from downstream reaches at the Reed Ditch diversion in Reach FE.

Human Alterations

Human alterations significantly affect floodplain connectivity and habitat quality in portions of the Canyon Reach. The most prominent human factors are undersized private road crossings and associated bank armoring (riprap) that locally inhibit lateral migration and significantly reduce floodplain continuity/connectivity. The Manastash Road County bridge crossing is also undersized. Floodplain development for agriculture and residential uses has resulted in removal of riparian vegetation in some areas, reducing overhead cover and a source of LWD. Some landowners also remove LWD from the creek to improve conveyance, at the detriment of habitat. In at least two locations, Manastash Road is interfering with the natural dynamics of the creek, and large bank armoring projects (riprap) have been installed.

Restoration Opportunities

The primary impact to habitat conditions in Reach CY is the presence of numerous small road crossings that locally constrict flow and limit hydraulic connectivity with the floodplain. It is likely that some of these could be removed or consolidated. For the armoring impacts associated with Manastash Road, wood structures could be used in place of the riprap. Finally, there are conservation and preservation opportunities that could protect some of the quality habitat in the reach, particularly near the confluence of the two forks.

Target Conditions and Restoration Strategies

One of the next steps for the Manastash Creek project is to identify potential habitat improvements for the project study area. To effectively develop a habitat restoration strategy, it is important to understand the limitations to restoration in the project area. Target habitat conditions must take into account the realities of continued irrigation in the Manastash Creek area and human land uses in the vicinity of the stream and floodplain. Human impacts are greatest in the lower 6 miles of the project study area. While there are limitations to do restoration in the lower 6 miles, it is the part of the project area with the greatest habitat improvement potential.

As the next phase of this project, habitat improvement opportunities will be identified based on the existing habitat conditions described in this report. They will be evaluated using a number of criteria including cost, potential ecological benefit, landowner willingness and cooperation, and potential impact on flood and erosion hazards.

Habitat improvement measures to be considered will include preservation and conservation of existing higher quality habitat areas, as well as restoration and enhancement of areas with more degraded conditions. Restoration measures will be developed and evaluated from the perspective of restoring natural function to the system rather than creating habitat forms in the system directly. Some of the restoration measures to be considered include:

- **Preservation and conservation.** Where habitat quality is high but could potentially be compromised in the future, measures such as conservation easements could be considered for protection of the resource.

- **Floodplain reconnection.** Where levees confine the stream channel but are not critical for flood control, removing or setting back the levees could provide valuable flood storage and habitat function to Manastash Creek floodplain areas.

- **Stream crossing modification or removal.** Where road or other crossings confine the channel and block floodplain flow, widening of the opening or removal of the crossing could decrease the negative impact on sediment transport, erosion, and habitat. Upsizing or removing crossings could also reduce flooding potential, and the need for dredging and emergency repairs.

- **LWD placement.** In portions of Manastash Creek where there is a lack of channel habitat structure, placement of stable LWD could provide benefits to local habitat by sorting deposited sediment and inducing deep pools.

- **Instream flow restoration.** Because reduced summer base flows impair habitat in a large portion of Manastash Creek, irrigation water conservation and diversion consolidation measures that are being implemented should be continued. In addition, given that field observation indicated the presence of irrigation return flows through groundwater/hyporheic input within Reach SC, this provides an analog to study the feasibility of infiltrating into the ground the discharges from irrigation return ditches as a potential restoration strategy.

- **Revegetation of the riparian zone.** Where the riparian forest has been removed or modified, re-establishment of a healthy vegetated community can provide a dramatic improvement in geomorphic function and habitat quality. In the reaches of Manastash Creek where no summer base flow persists, it will be important to ensure that groundwater exists at a shallow enough depth to support the establishment of trees in this zone.

EXISTING FLOOD AND EROSION HAZARDS

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Flood Hazard Reaches Based upon Morphology and Topography

Flood, erosion, and sedimentation hazards along Manastash Creek are highly dependent upon local topographic and geomorphic characteristics. The project study area can be divided into five distinct reaches for the purposes of assessing flood and erosion hazards, each possessing unique landscape attributes and fluvial processes that influence flood hazard severity. These reaches differ somewhat from the reaches delineated for the habitat conditions assessment described in the previous sections of this report, although they share some common boundaries. Flood hazard reaches are listed below and identified in Figure F-1 (Appendix F), with flood hazard characteristics discussed in the following pages.

The Flood hazard reaches used for this study include:

1. **Yakima Confluence Reach (RM 0 to RM 0.4)** – this is the same as Reach YC of the habitat conditions assessment
2. **Entrenched Terrace Reach (RM 0.4 to RM 2.5)** – this comprises Reach BC and Reach SC of the habitat conditions assessment
3. **Fan Contraction Reach (RM 2.5 to RM 4)** – this is the same as Reach FC of the habitat conditions assessment
4. **Fan Expansion Reach (RM 4 to RM 6)** – this encompasses Reach FE and a portion of Reach FA (Subreaches FA1, FA2, and FA3) of the habitat conditions assessment
5. **Canyon Reach (RM 6 to RM 13)** – this includes a portion of Reach FA (Subreach FA4) and Reach CY of the habitat conditions assessment, as well the lower reach of North Fork Manastash Creek.

The flood and erosion hazards study was prepared by WSE. WSE staff made observations during site visits in July 2012. Many flood hazard insights described in this section are also based upon direct observation by residents and agency staff during flooding in May 2011. Figures F-2 through F-23 help to illustrate those observations, showing approximate inundation limits, lateral erosion sites, and areas of sedimentation associated with the May 2011 flood, which was the largest flood experienced along Manastash Creek in at least 70 years, according to residents that have lived along the stream during that time.

Yakima Confluence Reach

Extending upstream from the Yakima River to the mouth of Manastash Creek is the Yakima Confluence Reach (Figure F-1). In this reach, the stream flows across a large alluvial delta before entering the Yakima River (Figures F-2 and F-3). Manastash Creek flows across the southern portion of the delta (downstream with respect to the Yakima River) and does not affect the northern portion due to obstructions at the outlet of the upstream entrenched reach. The delta is covered with a mature cottonwood forest in the area where Manastash Creek is active. The northern portion of the delta has been partially cleared for agriculture and livestock grazing, and did not contain residences until one was built near the middle of the delta within the past year (Figures F-2 and F-3).

Field Visit and Landowner Observations

Field staff did not inspect the delta during the site visit because flood and erosion risk associated with Manastash Creek was not identified as a significant concern by agency personnel or landowners. However, now that a residence has been built on the delta, flood hazard risk may become a concern.

Inventory of Anthropogenic Features that Affect Flooding, Erosion, and Sedimentation

Flood risk is reduced by a large earthen levee that borders the Yakima River along the northern portion of the delta (Figures 2 and 3). It was not within the scope of this study to examine the level of protection provided by the levee because it reduces flooding from the Yakima River, not Manastash Creek.

Earthen fills extend into the floodplain from both banks at the outlet from the upstream entrenched reach (Figures F-2 and F-3). They may be approach fills from a historic stream crossing. The fills aid in directing Manastash Creek toward the southern portion of the delta. No other significant features appear to have a major influence on flood and erosion risk on the delta.

Geomorphic Characteristics that Influence Flood Hazard Risk within Reach

Channel Planform

Field staff did not inspect the delta; therefore, specific channel planform characteristics are unknown. As shown in Figure F-3, it appears the channel is entrenched as it leaves the upstream portion of the Yakima Confluence Reach, giving way to an unconfined, irregular, meandering /braided pattern along the lower half of the reach.

Channel Slope

The channel maintains an average slope of 1.1 percent throughout the reach, however, there is a steeper portion located near the middle of the reach. If this is a nick-point, it would suggest that the channel profile is adjusting to some form of downstream base level change. This, however, seems unlikely and therefore, probably is a step in the profile created by sediment and debris that has deposited upstream from a large woody debris jam (see Figure F-24).

Hydraulic Characteristics

It appears that water will inundate both the southern portion of the delta and the low-lying area near the middle of the delta during major floods on Manastash Creek (Figures F-2 and F-3 and Photo 1YC).

Sediment Transport and Deposition

The entire downstream half to the delta is prone to sediment deposition.

Bank Vegetation

Manastash Creek flows through a large cottonwood forest on the delta. A detailed description of the vegetative community is provided in the *Existing Reach-Scale Habitat Assessment* section of this report.

Large Woody Debris

Large woody debris is abundant within the stream channel.

Conclusions Regarding Flood Hazard Risk

Flood, erosion, and sedimentation risks associated with Manastash Creek are extremely high on the portion of the delta where Manastash Creek is active (the southern portion and low-lying area near the middle of the delta). To limit flood risk, future development within those areas should be discouraged and conservation should be attempted where feasible. Flood risk on the northern portion of the delta is primarily from the Yakima River, although risks are reduced by the earthen levee that borders the river. Until recently, there were no residences on the delta and, therefore, flood hazard risk has not been a significant concern. If further development is proposed, flood risk should be thoroughly examined.

Entrenched Terrace Reach

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The Entrenched Terrace reach extends upstream from the Yakima Confluence reach to the Serenity Lane Bridge (see Figure F-1). Upstream from the Yakima Confluence reach, Manastash Creek has incised into deposits of glacial drift outwash, i.e., coarse sediments that were deposited within the Yakima River valley during periods of past glacial activity (see Figures F-2 through F-5). Entrenchment is deepest near the downstream end of the Entrenched Terrace Reach, where the streambed has incised itself 15 to 20 feet below the surface of the terrace. The degree of incision gradually shallows upstream, and the entrenchment ends a short distance downstream from the Serenity Lane Bridge. The channel and narrow floodplain incised below the terrace in this reach is referred to as the floor.

Field Visit and Landowner Observations

During the site visit, field staff examined creek conditions at several sites within the Entrenched Terrace Reach. Photographs of key features observed during the site inspection and of damage caused by the May 2011 flood are included in Appendix G (Photos 1ER to 5ER).

Figures F-2 through F-5, in Appendix F, show approximate areas of inundation and channel adjustment, including bank erosion and sediment deposition caused by the May 2011 flood.

Key field staff, landowner, and agency staff observations include:

- Reported flooding issues in May 2011 were generally limited to the floor of the Entrenched Terrace Reach (Photo 1ET).
- Large quantities of woody debris and sediment were deposited within the channel downstream from Brown Road (Photo 2ET) and within the channel and on the floodplain a short distance downstream from Serenity Lane.
- Relatively minor lateral erosion along the stream banks occurred at a number of sites along the reach.
- Erosion along the toe of the entrenched valley wall occurred at several locations. Most are bordering agricultural lands, and the amount of land lost due to erosion was small. However, at one of the eroded locations, near the end of Camas Drive, a residence and garage sit atop the terrace and are relatively close to the edge of the valley wall. There does not appear to be an immediate concern at this location. However, future development on top of the terrace near the edge of the valley wall must be done with care.
- The upstream left-bank abutment of Barnes Road was damaged during the May 2011 flood (Photo 3ET); it has since been repaired and revetted. Brown Road Bridge was not damaged during the flood.
- A residence located just downstream from Brown Road along the left (north) bank, was flooded (Photo 4ET) in May 2011. It is one of the few residences built within the floor of the entrenched reach. While not necessarily good for fish habitat, driveway fills along the stream side of the residence help reduce flood risk, and a recently constructed concrete floodwall may provide additional protection against future flooding.

Inventory of Anthropogenic Features that Affect Flooding, Erosion, and Sedimentation

Figures F-2 through F-5 highlight the human alterations that affect flooding, erosion, and sedimentation along the Entrenched Terrace Reach. They include erosion control revetments, irrigation diversions and facilities, road and driveway fills, and bridges. Noteworthy features include:

- Local bank protection berms, many of which appear to be spoil piles from channel dredging (red dashed lines in Figures F-2 through F-5). Berms line much of the stream channel between the West Side Canal siphon and spill and Serenity Lane. Two additional berms are located between Brown and Barnes roads.
- Two county roads: Brown Road and Barnes Road. Brown Road and its bridge have little impact on flooding and erosion. Barnes Road and its bridge restrict channel movement, providing a stable channel and consistent flow path, which while may impair habitat

forming processes and thus affect fish, are important for the operation of the Barnes Road diversion facility located downstream from the bridge. The Barnes Road Bridge is relatively narrow and moderately constricts flow during major floods. When the bridge reaches the end of its functional life, the County should consider replacing it with a longer crossing.

- An irrigation canal siphon (West Side Canal siphon and spill) crosses under the stream approximately 1,000 feet upstream from Barnes Road.
- Road and driveway fills upstream of the Barnes Road Bridge (within Reach SC) cross the floor of the Entrenched Terrace Reach and obstruct portions of the floodplain. Typically, however, they are low and have limited impact on reach dynamics or flooding.
- The Barnes Road diversion structure that was recently built immediately downstream from the Barnes Road Bridge has little impact on the channel because it is tucked into the bank downstream from the south bridge abutment. The diversion structure's north wall forms the south bank of the stream. Velocities will be swift along this "smooth" bank and could cause scour along the streambed or erosion along the downstream natural channel bank.

Geomorphic Characteristics that Influence Flood Hazard Risk within Reach

Channel Planform

The stream channel generally maintains an irregular meandering planform that is constrained by the walls of the entrenched floor, road and driveway crossings, rock revetments, and dredging spoil pile berms.

It appears that, many years ago, a significant portion of the channel was straightened and relocated. The longest straight reach begins approximately 2,000 feet upstream from Brown Road and extends to the West Side Canal siphon and spill upstream from Barnes Road (see Figures 2 to 5). The reach is unnaturally straight and is located along the southern edge of the entrenched valley floor, possibly placed there to maximize the size of the pastures that occupy the valley floor to the north. The channel is also unnaturally straight and has subtle berms downstream from Serenity Lane, suggesting that it has been altered by human activity.

Channel Slope

The average slope of the channel is 1.6 percent through the Entrenched Terrace Reach (Figure F-24). There is a significant nick-point (step) in the profile downstream from Brown Road. Field staff did not examine this feature during the site visit; therefore, the characteristics of the nick-point are unknown. Within the vicinity of Barnes Road, the channel slope is slightly flatter than the reach average because the channel contains numerous natural meanders.

Hydraulic Characteristics

The channel is relatively steep in the Entrenched Terrace Reach. With the exception of the meandering reach near Brown Road, the channel is also relatively straight and clear of debris. Velocities, erosive forces, and sediment transport would be high during major floods. Within the meandering reach near Brown Road, the slope flattens and more LWD is present. This will encourage sediment deposition and channel migration.

Sediment Transport and Deposition

Straightening a stream increases channel slope, which increases sediment transport capacity. Straight reaches contain fewer gravel bars and less wood and, therefore, are generally more stable than reaches that meander and contain significant wood. Such stability can limit the habitat forming process. The straight reach immediately downstream from the Serenity Lane Bridge is incised and readily transports sediment. Many of the sediments carried through the bridge deposit in the floodplain north of the channel approximately 800 feet downstream from the bridge (Photo 5ET). The relatively undisturbed meander portion of the channel that begins approximately 2,000 feet upstream from the Brown Road Bridge and extends downstream to the Yakima Confluence Reach contains numerous active gravel bars and LWD, which initiate lateral erosion and channel movement.

Bank Vegetation

Abundant and healthy tree and brush vegetation buffers the channel from the Yakima Confluence Reach upstream to the Barnes Road Bridge (that is, within Reach BC of the habitat conditions assessment). Mature and healthy trees generally line both banks upstream from Barnes Road, although the width of the riparian buffer tends to be much narrower. See a detailed discussion of the vegetative community in the *Existing Reach-Scale Habitat Assessment* section, above.

Large Woody Debris

Downstream from Barnes Road (in Reach BC of the habitat conditions assessment) the channel has a wide vegetated buffer and there is significant LWD in the channel. Upstream from Barnes Road (in Reach SC of the habitat conditions assessment), the buffer is narrower and there is less LWD in the channel, especially where landowners have cleared the underbrush to the channel edge.

Conclusions Flood Hazard Risk

- **Flooding:** Flooding is confined to the floor of the Entrenched Terrace Reach where few structures have been constructed. However, those structures that are located on the floor are highly susceptible to damage. Restricting future construction within the floodplain is the most effective way to limit the potential for future flood damages. At a minimum, landowners should be made aware of the risks and encouraged to incorporate appropriate safeguards and countermeasures in site development design.

- **Erosion:** Lateral erosion is a concern not only for properties and facilities located on the floor of the entrenched reach, but also for structures built on top of the terrace near the edge of the entrenched wall. Velocities within the channel will be high during major floods and, therefore, lateral erosion is possible along unprotected banks, especially in those areas where gravel bars or LWD deflect stream flows toward the entrenched valley wall or stream bank. To reduce potential erosion-related damage and protect aquatic habitat, new structures should not be built adjacent to the stream where lateral erosion is likely or adequate erosion prevention countermeasures should be included in site development design. Structures built on top of the terrace should be set back an adequate distance from the terrace edge.

- **Sedimentation:** Sediment tends to be transported through straight reaches, but is both deposited and transported within the reaches that naturally meander and contain significant LWD.

- **Avulsion Potential:** None, because the channel is confined by the walls of the terrace entrenchment.

Fan Contraction Reach

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Extending upstream from Serenity Lane to Cove Road is the Fan Contraction Reach (see Figure F-1). Within this reach, floodwaters can reach numerous distributary swales and irrigation channels covering broad areas of the fan; however, most of these features converge near Serenity Lane (Photo 1FC) before entering the downstream Entrenched Terrace Reach (Figures F-4 through F-7).

Field Visit and Landowner Observations

During the site visit, field staff examined creek conditions at several locations within the Fan Contraction Reach. Photographs of key features observed during the site visit and of damage caused by the May 2011 flood are included in Appendix G (Photos 1FC to 5FC). Figures F-4 through F-7 show approximate areas of inundation and channel adjustment, including bank erosion and sediment deposition caused by the May 2011 flood.

Key field staff and landowner observations include:

- Severe lateral erosion occurred immediately upstream from the Serenity Lane Bridge, and the bridge abutment foundations were partially undermined (Photos 2FC and 3FC). Repairs are needed.

- An abandoned irrigation diversion dam located near the middle of the reach at RM 3.1 was broken apart by an excavator during the flood, which removed the channel obstruction created by the old concrete structure.

- Significant sediment deposition occurred in the vicinity of Cove Road. It reduced channel capacity, clogged the bridge waterway, and caused significant overbank flooding particularly on the north floodplain (Photos 4FCto 5FC). Sediment accumulated in approximately 700 feet of channel downstream and 400 feet upstream from Cove Road.

- Floodwaters that left the stream channel at Cove Road made their way downstream by following numerous historical swales and irrigation ditches (see Photo 5FC). Due to years of agricultural cultivation, many of the historical swales are difficult to distinguish; therefore, some local landowners were surprised when flow entered their property.

- Relatively minor lateral erosion and sediment deposition occurred at a number of other sites along the reach (see Figures F-4 through F-7).

Inventory of Anthropogenic Features that Affect Flooding, Erosion, and Sedimentation

Figures F-4 through F-7 show the human alterations that affect flooding, erosion, and sedimentation along the Fan Contraction Reach. They include erosion control revetments, irrigation diversions and facilities, road and driveway fills, and bridges. Specific features include:

- Bridges at Serenity Lane and Cove Road. The Serenity Lane Bridge is so narrow (19 feet wide) that it creates a severe constriction during major floods. This causes sediment to deposit upstream, which pushes the flow toward the banks and results in erosion (Photo 3FC). The bridge also throttles flow, which causes incision and scour in the reach immediately downstream. As noted above, the Cove Road Bridge sits within a natural depositional reach and, therefore, the waterway tends to clog with sediment during large floods.

- Hanson Road cuts off and intercepts numerous historical floodplain swales. The water carried by those swales collects within a roadside ditch that runs along the south side of Hanson Road. During the May 2011 flood, so much water collected within the ditch that severe erosion undermined portions of the road and damaged several driveways. Hanson Road is the primary reason that flow on the north floodplain is redirected into the Entrenched Terrace Reach. If the road did not exist, water would follow the swales that bypass the Entrenched Terrace Reach and would join the Yakima River upstream of Manastash Creek.

- The abandoned diversion dam lies within the channel at approximately RM 3.1 (see Figures F-6 and F-7). A large section of the dam was removed by an excavator during the May 2011 flood. As a result, the dam now has little influence on channel processes.

- Intermittent earthen spoil pile berms scattered along the reach have cut off natural overbank flow paths, resulting in increased flood volume downstream. This limits floodplain connectivity (and thus habitat formation processes) and may have adverse impacts along downstream properties.

- Only two driveway bridges cross the stream channel within the Fan Contraction Reach. Both are a short distance upstream from Serenity Lane.

Geomorphic Characteristics that Influence Flood Hazard Risk within Reach

Channel Planform

The stream channel generally maintains an irregular meandering planform except within the reach extending approximately 2,500 feet upstream from Serenity Lane. The reach is unnaturally straight and is bordered by spoil pile berms, suggesting that it was straightened in the past.

Channel Slope

The average slope of the channel through this reach is 1.8 percent (see Figure F-25). The most noteworthy feature revealed by the profile is the significant concave dip downstream from the abandoned Anderson Ditch diversion dam. The immediate area around the former dam was likely starved of sediment due to deposition upstream from the dam, and the channel responded with incision.

Hydraulic Characteristics

Hydraulic forces within the Fan Contraction Reach are dependent upon what occurs at Cove Road. If the Cove Road Bridge waterway remains open and can convey large flows, then the main channel within the reach would experience significant erosional forces. If the bridge waterway clogs, then the main channel would carry significantly less flow and forces would be reduced. In the latter case, most of the water would be carried by floodplain swales, which can produce significant erosional forces, especially when they converge with other swales and encounter an obstruction like Hanson Road.

Sediment Transport and Deposition

Significant sediment deposition occurred immediately upstream from Serenity Lane and downstream from Cove Road during the May 2011 flood. (Note: the deposition does not appear in Figure F-4 or F-5 because the channel upstream from Serenity Lane had been modified before the recent lidar data were collected). The heightened deposition at Serenity Lane was caused by backwater associated with the bridge constriction. The deposition downstream from Cove Road (see Figure F-6) was due to a lack of channel confinement. The 2,500-foot-long straight reach upstream from Serenity Lane appears to be a transport reach, while the remainder of the channel appears to maintain a relatively reasonable balance between transport and deposition. Now that the abandoned irrigation dam has been breached, sediment will likely begin to fill the incised reach downstream.

Bank Vegetation

Bank vegetation is relatively sparse in the 1,500-foot-long reach immediately upstream from Serenity Lane and in the 2,500-foot long reach downstream from Cove Road. The stream is buffered by a relatively wide and healthy riparian forest in the middle 3,500 feet of the reach (see Figures F-4 and F-6). A detailed discussion of the vegetative community is in the *Existing Reach-Scale Habitat Assessment* section of this document.

Large Woody Debris

Field staff did not inspect the forested portion of the reach, but no LWD was visible in the channel in the vicinity of Serenity Lane or Cove Road. There were large piles of debris deposited by the May 2011 flood on the floodplain downstream from both Serenity Lane and Cove Road, suggesting that significant quantities of LWD are carried by the stream through this reach during large floods.

Conclusions Regarding Flood Hazard Risk

- **Flooding:** Flood extents within the Fan Contraction Reach are highly dependent upon the capacity of the Cove Road Bridge. If the bridge clogs with sediment as it did in May 2011, then most of the flow would leave the channel and find its way downstream through the network of historical swales and irrigation ditches, many of which are intercepted by Hanson Road. If the bridge waterway remains open, then significantly more flow would follow the main channel than did in May 2011. That would lead to more erosion and sediment deposition along the channel downstream of the bridge. A sediment management plan is needed for the channel in the vicinity of Cove Road to provide a consistent opening under the bridge and, therefore, a predictable flow downstream.

- **Erosion:** As noted above, if the bridge waterway remains open at Cove Road during future major floods, erosive forces would be higher in the main channel and bank erosion would likely increase. Fortunately, most structures are set back from the channel and, other than loss of land, damages should be limited. The primary concern would be the stability of the two driveway bridges that cross the channel upstream from Serenity Lane and the Serenity Lane Bridge itself. Serenity Lane Bridge is too narrow and the abutments are in extremely poor condition. It should be replaced with a wider bridge that rests on secure foundations outside of the active channel.

  One major concern is the potential for increased erosion along the reaches where little to no vegetation covers the stream banks, such as the 1,500-foot-long reach upstream of the Serenity Lane Bridge and the 2,500-foot-long reach downstream of the Cove Road Bridge. Efforts should be made to restore healthy vegetation along those banks as soon as possible. If significant erosion were to occur within these reaches, large quantities of coarse bedload sediment would be introduced to the stream, which would be transported and deposited downstream where it may initiate or worsen erosion and flooding.

  Erosion is also possible along Hanson Road if the road were to intercept significant flow. However, the repairs that are currently being developed by Kittitas County for Hanson Road are to include erosion protection.

- **Sedimentation:** Sediment deposition is and will continue to be a concern downstream from Cove Road. It will remain a concern at the Serenity Lane Bridge until the bridge is replaced with a wider crossing. As noted above, significant bank erosion and sediment transport and deposition could occur if the stream banks are not revegetated.

- **Avulsion Potential:** Low to moderate, but it will depend upon the quantity of coarse bedload sediment and woody debris that is transported into and deposited within the main channel.

Fan Expansion Reach

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Extending upstream from Cove Road to the apex of the alluvial fan is the Fan Expansion Reach (see Figures F-8 through F-11). In this reach, floodwater can spread across a broad alluvial fan floodplain. Numerous historical distributary swales diverge from the stream due to the convex topography of the alluvial fan surface.

Field Visit and Landowner Observations

During the site visit, field staff examined creek conditions at several locations within the Fan Expansion Reach. Photographs of key features observed during the site inspection and of damage caused by the May 2011 flood are included in Appendix G (Photos 1FE to 7FE). Figures F-8 through F-11 in Appendix F show areas of inundation and channel adjustment, including bank erosion and sediment deposition caused by the May 2011 flood. Streambed surface material pebble counts were completed just upstream from the Cove Road Bridge (RM 4) and on the private property where access was granted near RM 4.4.

Key field staff and landowner observations include:

- As noted previously, during the May 2011 flood, significant sediment deposition occurred in the vicinity of Cove Road, starting approximately 700 feet downstream and extending approximately 400 feet upstream from the bridge (see Figures F-6 through F-9). This reduced channel capacity and clogged the Cove Road Bridge waterway, causing severe overbank flooding (Photos 5FC and 1FE).
- Water escaping the channel in May 2011 tended to enter historical channel swales and irrigation ditches (see Photos 2FE and 4FE). Due to years of agricultural cultivation, many of these historical swales are difficult to distinguish.
- Bank erosion was particularly severe in the middle of the reach between Cove Road and the Reed Ditch diversion (Figures F-8 and F-9 and Photos 2FE and 3FE). The banks in this area are vulnerable because the vegetation that once reinforced them has either died or decayed due to a lack of water during the summer agricultural irrigation season. Sediment derived from the banks is the primary source of material deposited at the Cove Road Bridge. Upstream from the Reed Ditch diversion, the vegetation bordering the stream banks appears to be much healthier and the banks appear stable.
- In many locations, the streambed is covered by boulders, many of which are too large to be moved a significant distance by the stream (Photo 3FE). The boulders are exposed in eroded stream banks and are glacial drift outwash, not stream alluvium (Photo 5FE).
- A narrow and deeply entrenched reach begins at the Reed Ditch diversion and extends approximately 1,500 feet downstream (Photo 6FE). Due to this entrenchment, the

Reed Ditch diversion has been severely undermined and is perched approximately 10 feet above the bed of the downstream channel (Photo 7FE).

- Extending approximately 1,000 feet upstream from the Reed Ditch diversion, sediment has deposited in and reduced the capacity of the stream channel. This was a major contributor to significant flow overtopping the right (south) bank during the May 2011 flood (Figures F-8 and F-9 and Photo 4FE).

- Numerous historical swales connect to and diverge from the stream channel along the Fan Expansion Reach (Figures F-9 and F-1). Some of the swales represent possible avulsion pathways.

Inventory of Physical Features that Affect Flooding, Erosion, and Sedimentation

Figures F-8 through F-11 show the human alterations that affect flooding, erosion, and sedimentation along the Fan Expansion Reach. They include erosion control revetments, irrigation diversions and facilities, road and driveway fills, and bridges. Specific features include:

- The Cove Road and KRD road bridges. As described previously, the Cove Road Bridge tends to clog with sediment, which can have a major impact on flooding at and downstream from Cove Road. The KRD bridge is narrow; however, during major floods, water will overtop a levee upstream from the bridge and will bypass the bridge by flowing over the at-grade gravel approach road south of the bridge.

- Flow conditions created by Reed Ditch diversion have encouraged sediment deposition upstream of the dam while promoting scour and entrenchment downstream.

- Intermittent earthen spoil pile berms upstream from the Cove Road Bridge have cut off natural overbank flooding, resulting in increased flood volume downstream.

- A levee just upstream from the KRD road crossing limits overbank flooding, but it will overtop during major flood event as it did in May 2011.

- Only one driveway bridge crosses the stream in this reach; it is approximately 750 feet upstream from the Reed Ditch diversion. The road leading to the bridge appears to be at grade and, therefore, is not an obstruction to floodplain flow. The bridge itself has caught ice and debris during high flow events.

Geomorphic Characteristics that Influence Flood Hazard Risk within Reach

Channel Planform

The stream channel generally maintains an irregular meandering planform that follows a natural path down the fan. It does not appear that significant sections of the stream have been straightened or moved.

Channel Slope

The channel slope has a break point in it at the Reed diversion. Downstream from the diversion, the channel has an average slope of 1.9 percent; upstream, it is slightly flatter at 1.7 percent (Figure F-26). Significant incision has occurred downstream from the Reed diversion, similar to what occurred at the abandoned diversion dam in the Fan Contraction Reach. Upstream sediment has filled the channel, flattening the slope and reducing flow capacity.

There is a notable dip in the profile downstream from the Keach Jensen diversion. This is due to confinement of flow to the channel by the right-bank levee. The levee increases the discharge intensity within the channel, leading to scour and incision.

Hydraulic Characteristics

It is difficult to predict with certainty how much water, during large floods, would remain the channel and how much would leave the channel to follow one of the many swales that diverge from the stream. The distribution of flow would dictate the hydraulic forces that would develop within the main channel and within the swales. Within the channel, the slope is steep, and velocities and erosive forces would be high during major floods.

Sediment Transport and Deposition

As noted previously, major sediment deposition occurred in the vicinity of the Cove Road Bridge during the May 2011 flood. Large quantities of sediment also deposited mid-reach in the area that experienced significant bank erosion. It is likely that the deposition was partly a redistribution of the eroded bank sediment rather than solely due to deposition of material transported from upstream.

Significant sediment has accumulated in the reach upstream from the Reed diversion. It has reduced channel capacity and is likely the reason water left the channel along the right (south) bank upstream from the dam during the May 2011 flood (see Figures F-8 and F-9).

Bank Vegetation

Bank vegetation does not exist, or is generally in poor condition, between the Cove Road Bridge and the Reed diversion. That is because this reach typically does not contain water during the summer irrigation season. Upstream of the Reed diversion, vegetation is much healthier and the channel is surrounded by a wide riparian corridor. A detailed description of the vegetative community is provided in the *Existing Reach-Scale Habitat Assessment* section of this report.

Large Woody Debris

In-channel LWD is generally scarce within the reach between the Cove Road Bridge and the Reed diversion, but it is abundant in the area upstream from the Reed diversion.

Conclusions Regarding Flood Hazard Risk

- **Flooding:** Flood extents within the Fan Expansion Reach are highly dependent upon the capacity of the stream channel. If the channel fills with sediment or debris, flow would leave the channel and find its way downstream through the network of historical swales and irrigation ditches.

- **Erosion:** Lateral erosion is likely to continue within the reach between the Cove Road Bridge and the Reed diversion, where there is little to no vegetation on the banks. Efforts should continue to reestablish year-round stream flows and to restore a health vegetation corridor along the stream.

- **Sedimentation:** Sediment deposition is, and will continue to be, a concern in the vicinity of the Cove Road Bridge. As noted above, there is potential for significant bank erosion and sediment transport upstream from the Cove Road crossing as long as the stream banks remain devoid of healthy vegetation and the bridge remains overly confined.

- **Avulsion Potential:** Moderate. Blockage of the channel by debris and sediment just downstream from the entrance to one of the distributary swales, particularly those located along the north side of Manastash Creek, could cause the channel to avulse and find a new path down the fan. The area of greatest concern is at and upstream from the Reed diversion. Here, the existing channel has limited capacity due to sediment deposition and a channel jam could easily divert most if not all of the flow into the Reed Ditch or an adjacent swale that connects to the ditch. The Reed diversion dam is intended to be removed, and the diversion point consolidated with an upstream diversion structure. Removal of the dam will require restoration of the channel both upstream and downstream. The restoration design should consider avulsion potential and seek opportunities to reduce the risk. For example, restoring capacity to the upstream channel alone will help reduce the risk. In the interim, the location and size of debris jams should be monitored within this reach and, if it is determined that they pose an avulsion risk, it may prudent to break the jam apart or remove it from the channel before the next flood.

Canyon Reach

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Extending approximately 7 miles upstream from the apex of the alluvial fan to the border of the public lands is the Canyon Reach (see Figure F-1). The Canyon Reach is a long, linear segment that is confined to a canyon of relatively uniform width bordered by vertical basalt walls and sloping basalt talus slopes. The valley floor varies between about 400 and 800 feet in width, with the active floodplain typically covering less than half the width. Throughout the valley, large sections of the floodplain are maintained as open fields for livestock and agriculture; however, the stream channel is generally bordered by mature cottonwood trees.

Field Visit and Landowner Observations

During the site visit, field staff examined creek conditions at several locations within the Canyon Reach. Photographs of key features observed during the site visit and of damage caused by the May 2011 flood are included in Appendix G (Photos 1C to 7C). Figures F-10 through F-23 show approximate areas of inundation and channel adjustment, including bank erosion and sediment deposition caused by the May 2011 flood. Streambed surface material pebble counts were completed in an abandoned meander bend at approximately RM 6.4 (see Photo 5C).

Key field staff and landowner observations include:

- During the May 2011 flood, significant sediment deposition occurred within the channel and on the floodplain at numerous locations. In response, flood water was forced out of the channel and flowed through low-lying areas, some of which were occupied by barns, sheds, or other structures (Photos 1C and 4C). Structures built within the active floodplain are at risk of inundation, and those near the channel may be at risk of damage by lateral erosion.

- One area particularly hard hit by the May 2011 flood was near the mouth of the canyon between the MWDA consolidated diversion and the Manastash Road Bridge (Photos 1C and 2C). At least five residences in that reach were affected by flooding, erosion, and sediment deposition.

- Numerous driveways cross the floodplain in the Canyon Reach; they are elevated above Manastash Creek on one-lane bridges. In most cases, floodwater is free to flow around the bridge because the driveways are not elevated or are elevated only slightly above the natural grade. Many of the driveway bridges and their abutments were not designed to withstand the hydraulic and scour forces that develop within Manastash Creek during major floods, especially when those forces are increased by woody debris accumulating at crossings. Many bridges failed or were severely damaged during the May 2011 flood.

Inventory of Physical Features that Affect Flooding, Erosion, and Sedimentation

Figures F-10 through F-23 show the human alterations that affect flooding, erosion, and sedimentation along the Canyon Reach. They include erosion control revetments, irrigation diversions and facilities, road and driveway fills, and bridges and culverts. Specific features include:

- Driveway fills and bridges are the primary manmade features that affect flooding within the Canyon Reach. As shown in Figures F-10 through F-23, numerous driveways extend into the floodplain and some of them cross the stream channel. Fortunately, most driveways are elevated only slightly above the natural grade and, therefore, do not obstruct flow. Driveway crossings are on single-lane bridges, many of which are elevated high above the stream channel and have short and steep approach fills to elevate the driveway to the bridge deck.

- Manastash Road crosses the stream at three locations: one near the mouth of the canyon, one upstream from the Lazy F Ranch near RM 12, and one near the upstream project reach boundary near RM 13. All three performed reasonably well during the May 2011 flood, although rip rap was placed at the abutments of the Manastash Road county bridge. Just upstream from the bridge near the canyon mouth, the stream channel is confined between Manastash Road and south wall of the canyon. Velocities within that confined reach will be very high during major floods. Upstream from that confined reach, the road crosses the valley floor and creates a slight obstruction to flow moving down the floodplain. Because the road is elevated only slightly above the floodplain, floodwater can overtop the road during major floods.

- Manastash Road is adjacent to the stream in several areas. The County has placed riprap in those areas to protect the road (Photo 3C).
- Manastash Road crosses over the North Fork of Manastash Creek immediately upstream of the confluence near RM 11.7. The crossing is a corrugated metal pipe (CMP) culvert, which did not have the capacity to pass the May 2011 North Fork flood. Floodwater bypassed the culvert and crossed the road to the east. The road sustained major erosion damage.
- The Keach Jensen and MWDA diversions are relatively new structures that are adjacent to the channel. At both diversions, a series of cross-channel weirs were installed to provide fish passage, grade control and to maintain predictable water levels for irrigation withdrawals. The intake facilities at both diversions were overtopped during the May 2011 flood (Photos 6C and 7C).

Geomorphic Characteristics that Influence Flood Hazard Risk within Reach

Channel Planform

The stream channel generally maintains a natural meandering planform in the Canyon Reach. However, there are reaches that appear to have been straightened or moved in the past (see Photo 3C, which shows an area near RM 10).

Channel Slope

Figures F-27, F-28, and F-29 show the channel profile within the Canyon Reach. As expected, the slope of the stream gradually steepens upstream. It maintains a slope of approximately 1.8 percent near the mouth of the canyon, increasing to about 2.3 percent at the upstream end of the project reach. The only notable feature revealed by the profile is a small nick-point, rock cascade, or log jam about 1,500 feet upstream from the bridge near Lazy F Ranch. Field staff did not inspect the site and cannot confirm what the feature is.

Hydraulic Characteristics

The channel slope is steep. Therefore, channel velocities will be high during major floods.

Sediment Transport and Deposition

Within the Canyon Reach, it is difficult to identify areas of May 2011 sediment deposition. Downstream from the canyon, areas of flood sediment deposition were identified by comparing two different sets of lidar data, one collected before the flood and one after. Pre-flood lidar data are not available for the Canyon Reach; therefore, this technique could not be used. The incomplete and limited number of sediment deposition sites identified in

Figures F-10 through F-23 is based upon anecdotal information provided by landowners and agency personnel, and field staff observations during the site visit. Based upon discussions with landowners, it is clear that numerous sites throughout the Canyon Reach were affected by significant sediment deposition during the May 2011 flood.

Bank Vegetation

Within the Canyon Reach, the stream generally remains within a wide and healthy vegetated corridor. More description of the vegetative community is provided in the *Existing Reach-Scale Habitat Assessment* section of this document.

Large Woody Debris

Large woody debris is abundant within the Canyon Reach. There were reports of numerous debris jams forming within the channel during the May 2011 flood, some of which damaged bridges, diverted the stream into old channel scars, or deflected the flow toward banks, causing them to erode.

Conclusions Regarding Flood Hazard Risk

Flood, erosion, sedimentation, and log jams are all significant concerns within the Canyon Reach, but most hazards are confined to the floor of active floodplain. However, flood flows and log jams are critical for habitat forming purposes and the wood associated with such jams provides valuable habitat. Fortunately, many (but not all) residences and structures within the reach are located at the edge of the valley floor where ground elevations are above the level of the active floodplain. The facilities most at risk are driveways that cross the active floodplain and bridges that elevate driveways across the stream. Manastash Road is vulnerable in those areas where it is adjacent to the stream. The North Fork of Manastash Creek continues to pose a risk to Manastash Road, but the County is planning to make improvements to the crossing to reduce the risk. Opportunities to reduce flood hazard risk within the Canyon Reach will likely to need to be addressed on a site-by-site basis, as there appear to be few reach-scale opportunities to reduce flood hazards.

Flood, Erosion, and Sedimentation Summary

Flood, erosion, and sedimentation hazards within each of the five reaches defined for this flood hazard study are summarized as follows.

- Within the Yakima Confluence Reach, flood hazards are significant. Extreme care must be exercised for any proposed development within this reach. The downstream half of the reach is dynamic; because Manastash Creek actively floods and deposits sediment in that area, the hazards are significant. The upstream half of the delta is partially protected by an earthen levee along the edge of the Yakima River, and it is the river that poses the greatest threat to this part of the delta, not Manastash Creek. Analyzing the risk associated with the Yakima River and the level of protection provided by the levee are beyond the scope of this project.
- Within the Entrenched Terrace Reach, flood risk is generally confined to the floor of the reach. Fortunately, few structures have been built on the floor and, therefore,

the potential for costly flood damage is low. There is one residence, downstream from Brown Road that is located on the floor; it was inundated during the April and May 2011 flood. Other features that could sustain damage include two county road bridges, an irrigation siphon crossing, and driveway road fill. Lateral erosion is of concern as there are several places where the stream is eroding the toe of the entrenched terrace wall. At one of those locations, a residence and associated out buildings sit on top of the terrace above the erosion site. The structures currently do not appear at risk, but lateral erosion of this type should be monitored in this reach where structures are present.

- Within the Fan Contraction Reach, flood hazards are highly dependent upon the capacity of the Cove Road Bridge. If the bridge remains open, then flood, erosion, and sedimentation risks along the main channel would be high. If the bridge clogs with sediment, flood risk would decrease within the main channel, but it would increase within the network of historical swales and irrigation ditches that would carry the water downstream. A sediment management plan is needed for the channel in the vicinity of the Cove Road Bridge to provide reasonable assurance that the bridge would pass an acceptable portion of the flow during major floods.
- A major concern is the potential for increased erosion along the main channel where little to no vegetation covers the banks. Significant erosion would introduce large quantities of sediment to the stream. The material would deposit downstream where it would likely aggravate erosion and flooding. Efforts should continue to restore year-round stream flows so that healthy vegetation can be established along the stream banks.
- The Serenity Lane Bridge is too narrow and the abutments are in extremely poor condition. It should be replaced with a wider crossing.
- Flood risk is high within the Fan Expansion Reach. The extent of flooding will depend upon main channel capacity. If the channel fills with sediment or debris, flow would find its way downstream through the network of historical swales and irrigation ditches. Lateral erosion is likely to continue within the reach between Cove Road Bridge and the Reed diversion, where there is little to no vegetation on the banks. As noted above, efforts should continue to re-establish year-round stream flows and bank vegetation. Sediment deposition is and will continue to be a concern, especially in the vicinity of the Cove Road Bridge. Avulsion potential is moderate because there are a number of significant distributary swales that connect to the channel along the reach.
- Flood hazards are significant within the Canyon Reach, but most are confined to the active floodplain. Fortunately, most residences and structures are located outside of the active floodplain. Facilities most at risk are driveway bridges and Manastash Road where it is adjacent to the stream. The North Fork of Manastash Creek continues to pose a risk to Manastash Road, but the County is planning to make improvements to the crossing to reduce the risk. Opportunities to reduce flood hazard risk within the Canyon Reach will need to be addressed on a site-by-site basis, as there appear to be few reach-scale opportunities for flood hazard reduction.

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APPENDIX A

Habitat Assessment Figures

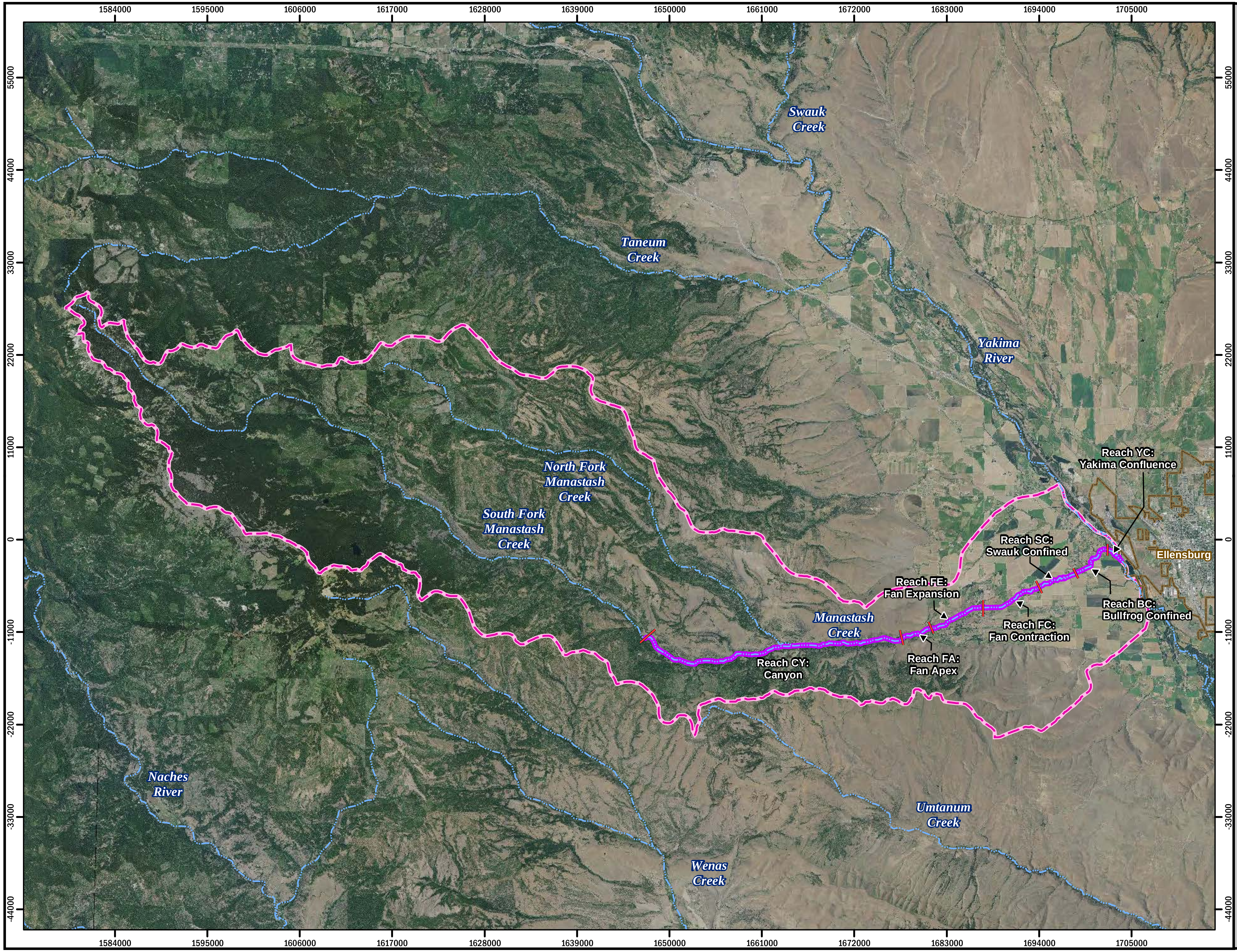


Figure A1.
Project extents and reach boundaries.

Legend

- Project study area
- Reach break
- Watershed boundary
- River
- City limits

N

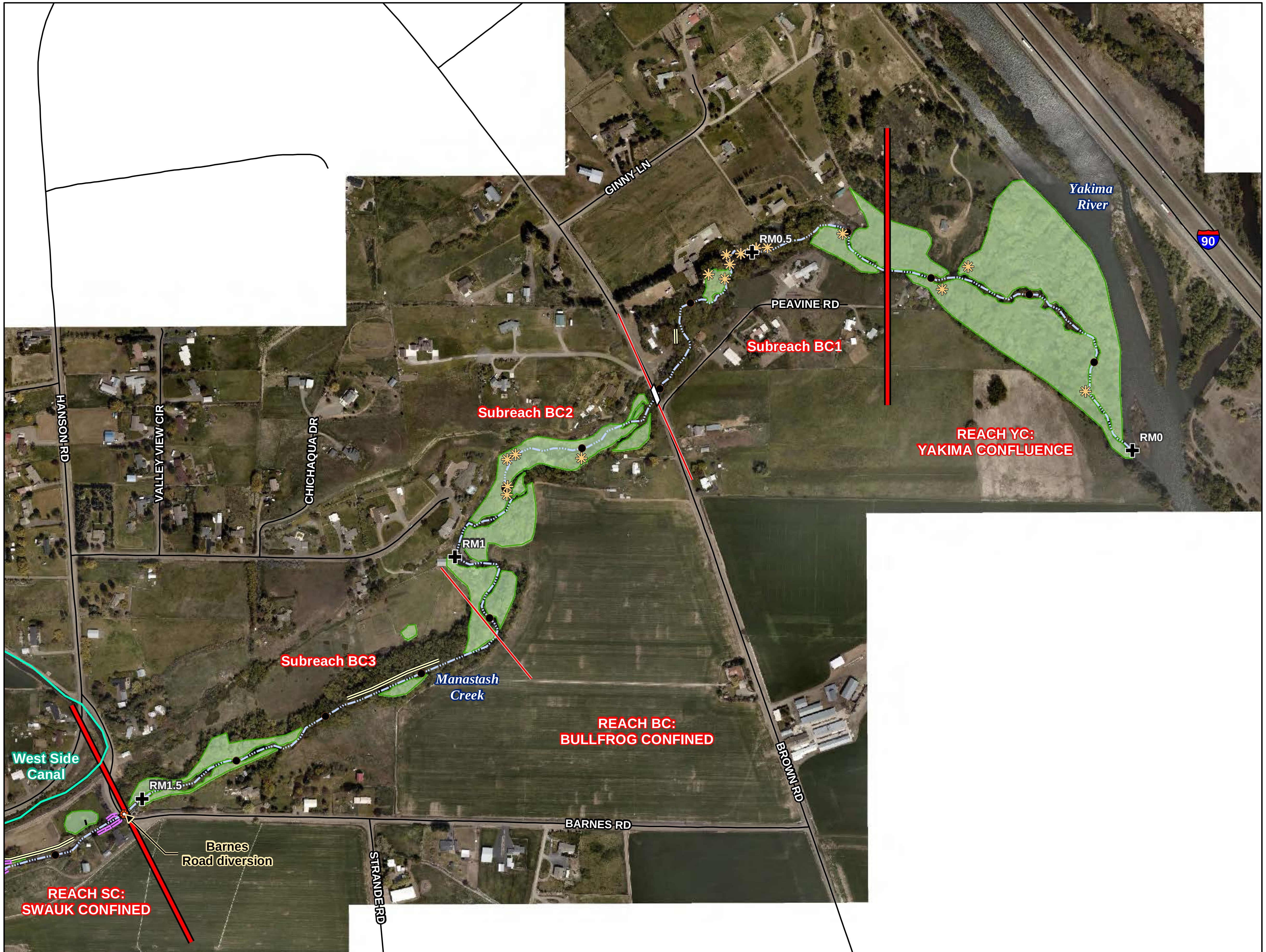
0 5,500 11,000 22,000
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: USDA (2009)

Produced By: GIS
Project: K:\Projects\12-05295-000\Project\project_extents_and_reach_boundaries.mxd (9/12/2012)

Figure A2.
Yakima Confluence (Reach YC) and Bullfrog Confined (Reach BC) habitat conditions.



Legend

- Subreach break
- Reach break
- Irrigation system
- Bridge
- Irrigation diversion
- Culvert
- Half river mile
- Large woody debris (LWD)
- 1/10th river mile
- Manastash Creek
- Bank armor
- Levee
- Potential wetland habitat

N

0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 3DiWest (May 2012)

Produced By: GIS
Project: K:\Projects\12-05295-000\Project\reach_detail_sheets.mxd (9/11/2012)

Figure A3.
Swauk Confined (Reach SC) habitat conditions.

Legend

- Subreach break
- Reach break
- Irrigation system
- Bridge
- Irrigation diversion
- Culvert
- Half river mile
- Large woody debris (LWD)
- 1/10th river mile
- Manastash Creek
- Bank armor
- Levee
- Potential wetland habitat

N

0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 3DiWest (May 2012)

Produced By: GIS
Project: K:\Projects\12-05295-000\Project\reach_detail_sheets.mxd (9/11/2012)

Figure A4.
Fan Contraction (Reach FC) habitat conditions.

Legend

- Subreach break
- Reach break
- Irrigation system
- Bridge
- Irrigation diversion
- Culvert
- Half river mile
- Large woody debris (LWD)
- 1/10th river mile
- Manastash Creek
- Bank armor
- Levee
- Potential wetland habitat

N

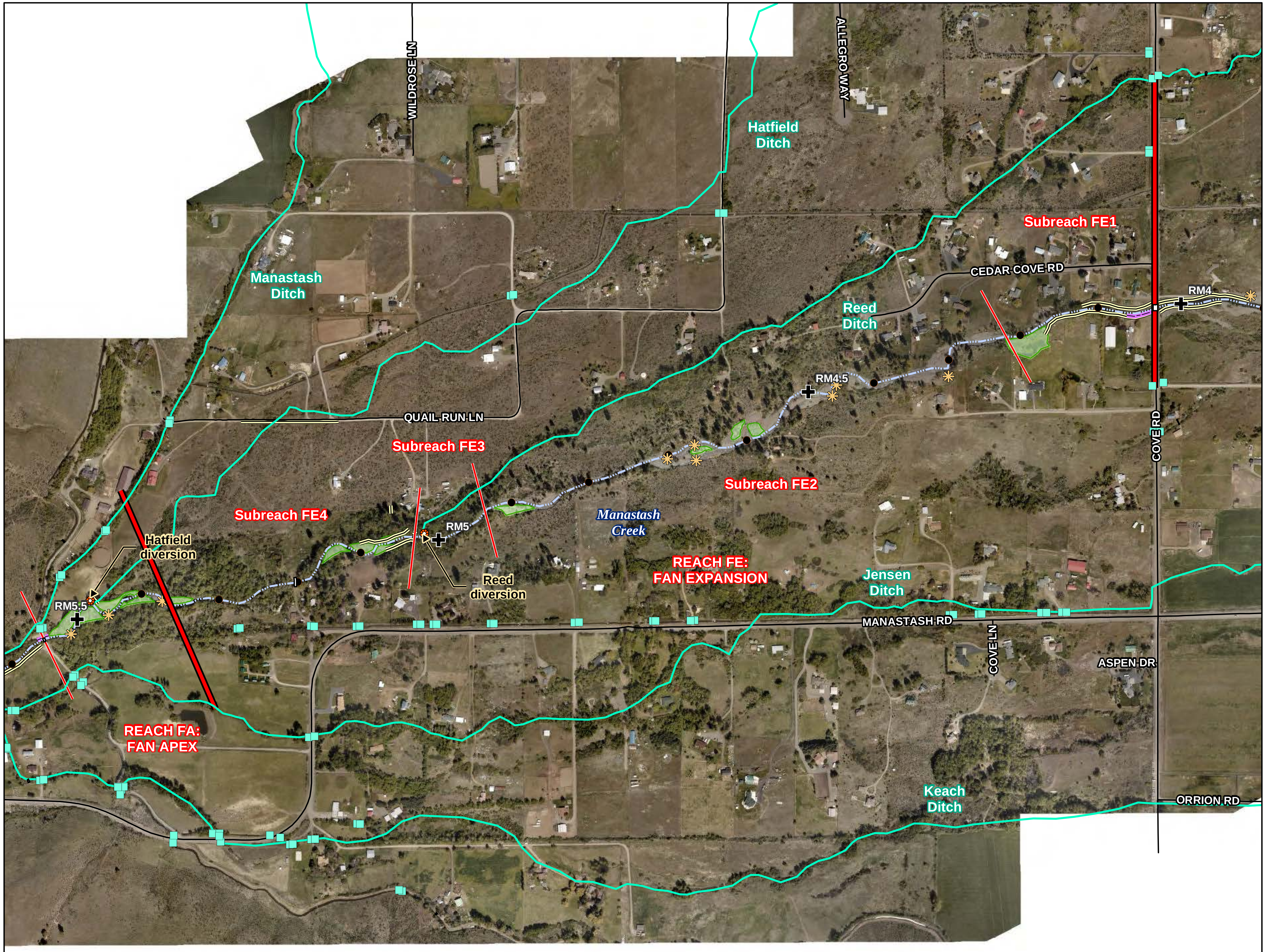
0 312.5 625 1,250
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 3DiWest (May 2012)

Produced By: GIS
Project: K:\Projects\12-05295-000\Project\reach_detail_sheets.mxd (9/11/2012)

Figure A5.
Fan Expansion (Reach FE) habitat conditions.



Legend

- Subreach break
- Reach break
- Irrigation system
- Bridge
- Irrigation diversion
- Culvert
- Half river mile
- Large woody debris (LWD)
- 1/10th river mile
- Manastash Creek
- Bank armor
- Levee
- Potential wetland habitat

N

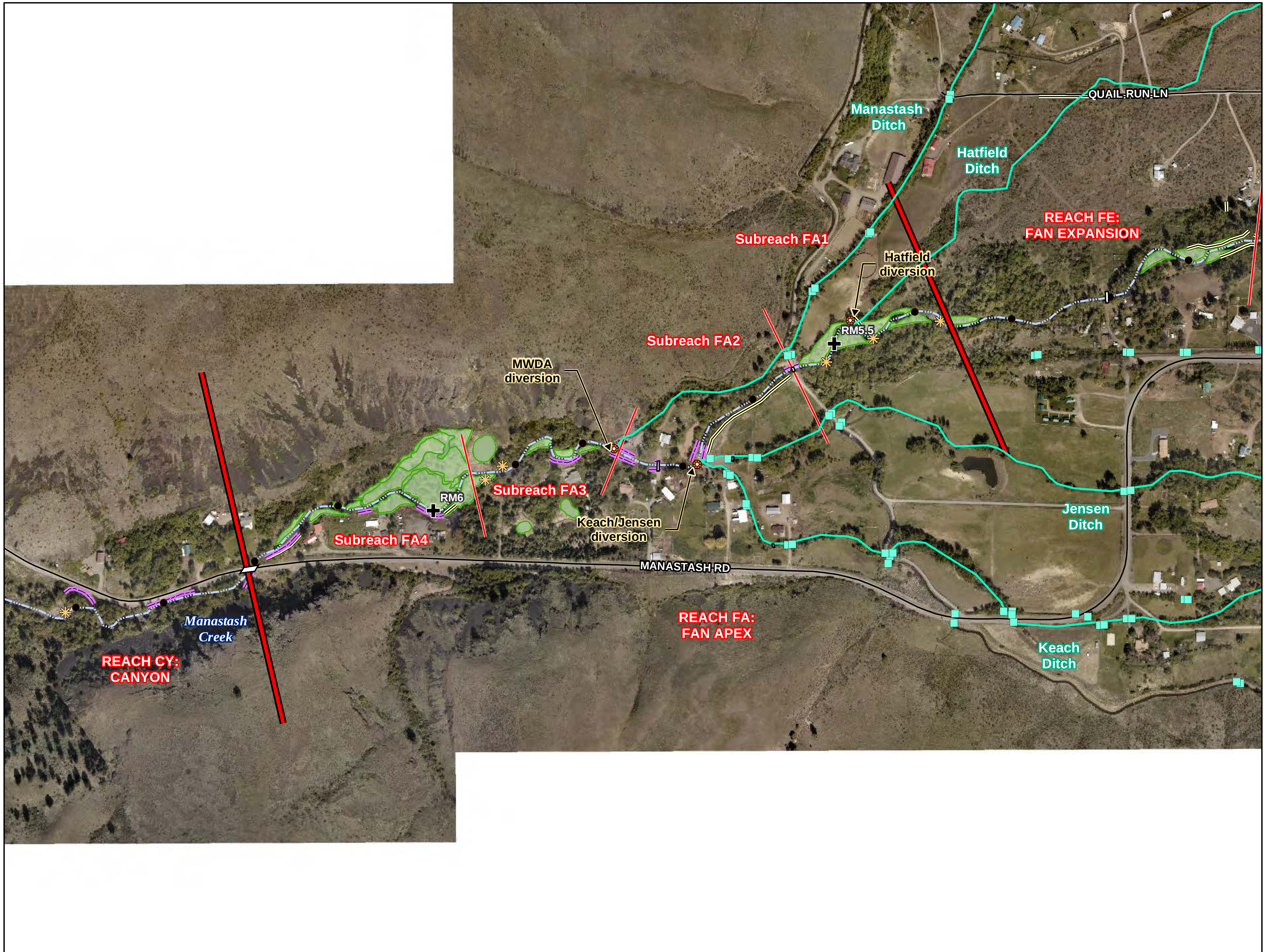
0 312.5 625 1,250
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 3DiWest (May 2012)

Produced By: GIS
Project: K:\Projects\12-05295-000\Project\reach_detail_sheets.mxd (9/11/2012)

Figure A6.
Fan Apex (Reach FA) habitat conditions.



Legend

- Subreach break
- Reach break
- Irrigation system
- Bridge
- Irrigation diversion
- Culvert
- Half river mile
- Large woody debris (LWD)
- 1/10th river mile
- Manastash Creek
- Bank armor
- Levee
- Potential wetland habitat

N

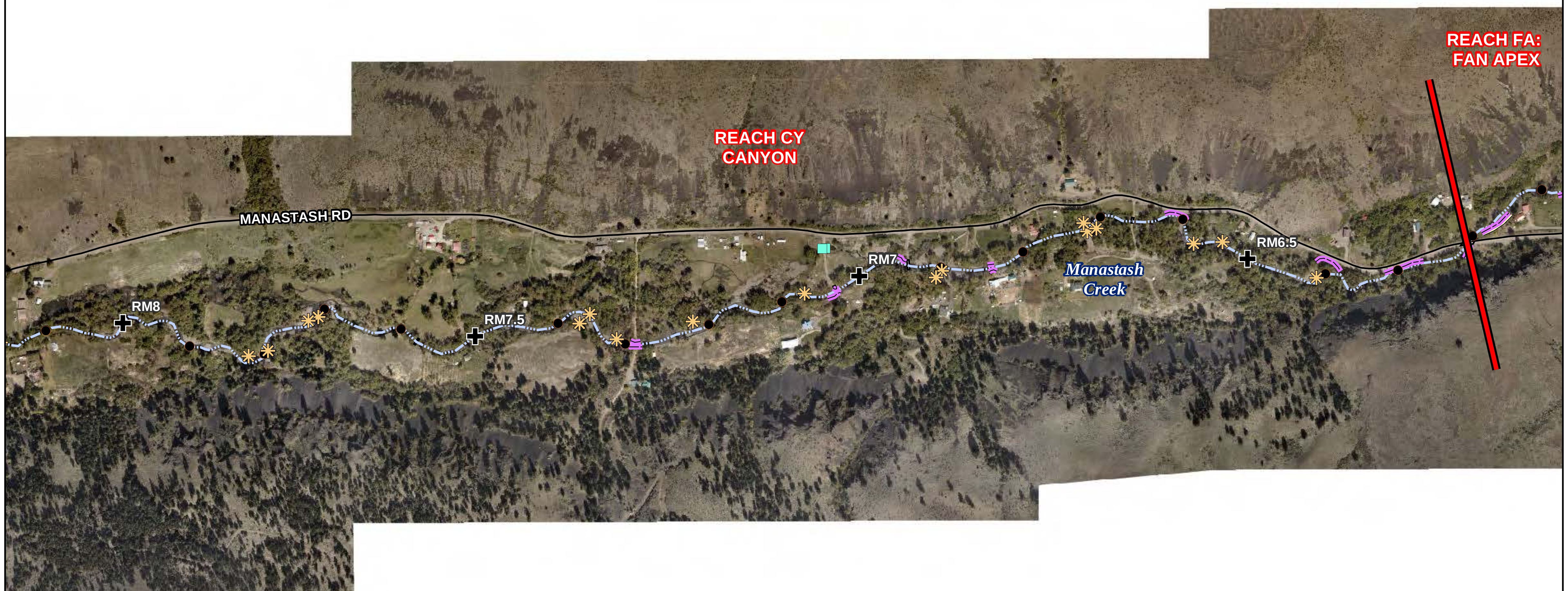
0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 3DiWest (May 2012)

Produced By: GIS
Project: K:\Projects\12-05295-000\Project\reach_detail_sheets.mxd (9/11/2012)

Figure A7.
Canyon (Reach CY) habitat conditions (Sheet 1 of 4).



Legend

- Reach break
- Large woody debris (LWD)
- Irrigation diversion
- Culvert
- Bridge
- Bank armor
- Levee
- 1/10th river mile
- Half river mile
- Manastash Creek

N

0 375 750 1,500
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 3DiWest (May 2012)

Produced By: GIS
Project: K:\Projects\12-05295-000\Project\reach_detail_sheets_canyon.mxd (9/12/2012)

Figure A8.
Canyon (Reach CY) habitat conditions (Sheet 2 of 4).

Legend

- Reach break
- Large woody debris (LWD)
- Irrigation diversion
- Culvert
- Bridge
- Bank armor
- Levee
- 1/10th river mile
- Half river mile
- Manastash Creek

N

0 375 750 1,500

Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 3DiWest (May 2012)

Produced By: GIS
Project: K:\Projects\12-05295-000\Project\reach_detail_sheets_canyon.mxd (9/12/2012)

Figure A9.
Canyon (Reach CY) habitat conditions (Sheet 3 of 4).

Legend

- Reach break
- Large woody debris (LWD)
- Irrigation diversion
- Culvert
- Bridge
- Bank armor
- Levee
- 1/10th river mile
- Half river mile
- Manastash Creek

N

0 375 750 1,500
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 3DiWest (May 2012)

Produced By: GIS
Project: K:\Projects\12-05295-000\Project\reach_detail_sheets_canyon.mxd (9/12/2012)

Figure A10.
Canyon (Reach CY) habitat conditions (Sheet 4 of 4).

Legend

- Reach break
- Large woody debris (LWD)
- Irrigation diversion
- Culvert
- Bridge
- Bank armor
- Levee
- 1/10th river mile
- Half river mile
- Manastash Creek

N

0 375 750 1,500
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 3DiWest (May 2012)

Produced By: GIS
Project: K:\Projects\12-05295-000\Project\reach_detail_sheets_canyon.mxd (9/12/2012)

APPENDIX B

Habitat Conditions Described by Reach-Based Ecosystem Indicators

Table B-1. Habitat Conditions of Reach YC (Yakima Confluence Reach).			
General Characteristics	**General Indicators**	**Specific Indicators**	**Reach YC Condition**
Habitat Access	Physical Barriers	Main channel barrier in reach or downstream. Includes full dewatering of the channel and thermal barriers	***At Risk Condition*** There are no anthropogenic barriers to fish migration in this reach. Access from upstream of reach SC1 is limited by low flow or dewatered conditions during periods of heavy irrigation water withdrawals.
Hydrology	Stream flow	Alteration of peak or base flows	***Unacceptable Risk Condition*** Low/base flows are adversely affected by irrigation withdrawals at numerous diversion points upstream of this reach. This reach is known to have year-round base flow due to return from the West Side Irrigation Canal return at the upstream end of the reach. Significant changes to peak flow timing, magnitude, duration, and frequency cannot be determined from the available stream flow record on Manastash Creek. However, many of the land use activities documented in the Manastash Creek basin are known to affect peak flow hydrology.
Water Quality	Temperature, Turbidity, Nutrients	Field observations, including warm, turbid water, and nuisance algae growth	***At Risk Condition*** Water quality limited by irrigation withdrawals and return flows.
Habitat Quality	Substrate	Dominant substrate/fine sediment	***Unacceptable Risk Condition*** Substrate character is highly variable throughout the multi-thread channel network in this reach. Most active channels had substrate predominantly in the gravel size classes, while newly cut, abandoned, or less frequently activated channels had substrate in the sand and fines size classes. Cementation was fair, and embeddedness was 50-75% in this low-gradient, depositional environment.
	Large Woody Debris	Pieces per mile	***Adequate Condition*** Numerous and significant accumulations of large (20” x 35’), medium (12” x 35’) and small (6” x 20’) woody debris were observed in a multi-thread, distributary fan setting. Mature riparian forest and significant LWD in upstream reaches provides adequate recruitment source. Rated as properly functioning for LWD based on adaptation of Ralph et al. 1994, Beechie and Sibley 1997, and Fox and Bolton 2007.
	Pools	Frequency and quality	***Adequate Condition*** Though no formal pool count or habitat survey was conducted for this reach, numerous and highly variable pool environments were present throughout the distributary channel network in this reach. Observed pools ranged in size from approximately 5’x5’x2’deep to 50’x25’x5’ deep, trending towards the smaller side. Overhead cover and complexity were both high, and the amount of fines in the pool bottoms varied significantly.
	Complexity	Variability and heterogeneity of habitat units	***Adequate Condition*** Although no formal pool count or habitat survey was conducted for this reach, numerous and highly variable habitat unit environments were present throughout the distributary channel network in this reach. Abundant LWD provides significant overhead cover and complexity to habitat units.
	Off-Channel Habitat	Connectivity with main channel	***Adequate Condition*** This reach has numerous distributary channels, abandoned channels, and low energy areas with significant LWD and overhead cover from vegetation. Off-channel areas are accessed by high flows of both Manastash Creek and the Yakima River. In addition, no anthropomorphic barriers limit access to off-channel habitat.
Channel	Dynamics	Floodplain connectivity	***Adequate Condition*** Observation of indicators of overland flow on the floodplain and in high flow channels, as well as areas of floodplain wetlands and dense riparian vegetation, suggests that the floodplain is frequently inundated by Manastash Creek and/or the Yakima River.
		Bank stability/channel migration	***Adequate Condition*** Bank erosion was observed on <5% of banks and riparian vegetation is abundant and of high quality. Bank stability was rated as stable (Booth and Henshaw 2001).
		Vertical channel stability	***Adequate Condition*** Observed channel dynamics in this reach were within the normal range for a distributary fan environment at a confluence.
		Resiliency to Disturbance	***Adequate Condition*** Significant and dense riparian forest, numerous LWD, and a wide active floodplain make this reach fairly resilient to disturbance from large flood events that carry significant bedload.
Riparian Vegetation	Condition	Structure	***Adequate Condition*** Natural structure of 93% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.
		Disturbance (Human)	***Adequate Condition*** 91% medium to large wood available in the riparian buffer; 7% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); no roads in riparian buffer.
		Canopy Cover	***Adequate Condition*** 93% medium to large wood available in the riparian buffer.

Table B-2. Habitat Condition Assessment of Reach BC (Bullfrog Confined Reach).					
General Characteristics	**General Indicators**	**Specific Indicators**	**Subreach BC1 Condition**	**Subreach BC2 Condition**	**Subreach BC3 Condition**
Habitat Access	Physical Barriers	Main channel barrier in reach or downstream. Includes full dewatering of the channel and thermal barriers.	***At Risk Condition*** There are no anthropogenic barriers to fish migration in this reach or on the main channel downstream of this reach. Access from upstream of Subreach SC1 is limited by low flow or dewatered conditions during periods of heavy irrigation water withdrawals.	***At Risk Condition*** There are no anthropogenic barriers to fish migration in this reach or on the main channel downstream of this reach. Access from upstream of Sub reach SC1 is limited by low flow or dewatered conditions during periods of heavy irrigation water withdrawals.	***At Risk Condition*** There are no anthropogenic barriers to fish migration in this reach or on the main channel downstream of this reach. Access from upstream of reach SC1 is limited by low flow or dewatered conditions during periods of heavy irrigation water withdrawals.
Hydrology	Stream flow	Alteration of peak or base flows	***Unacceptable Risk Condition*** Low/base flows are adversely affected by irrigation withdrawals at numerous diversion points upstream of this reach. This reach is known to have year-round base flow due to return from the West Side Irrigation Canal return at the upstream end of the reach. Significant changes to peak flow timing, magnitude, duration, and frequency cannot be determined from the available stream flow record on Manastash Creek. However, many of the land use activities documented in the Manastash Creek basin are known to affect peak flow hydrology.	***Unacceptable Risk Condition*** Low/base flows are adversely affected by irrigation withdrawals at numerous diversion points upstream of this reach. This reach is known to have year-round base flow due to return from the West Side Irrigation Canal return at the upstream end of the reach. Significant changes to peak flow timing, magnitude, duration, and frequency cannot be determined from the available stream flow record on Manastash Creek. However, many of the land use activities documented in the Manastash Creek basin are known to affect peak flow hydrology.	***Unacceptable Risk Condition*** Low/base flows are adversely affected by irrigation withdrawals at numerous diversion points upstream of this reach. This reach is known to have year-round base flow due to return from the West Side Irrigation Canal return at the upstream end of the reach. Significant changes to peak flow timing, magnitude, duration, and frequency cannot be determined from the available stream flow record on Manastash Creek. However, many of the land use activities documented in the Manastash Creek basin are known to affect peak flow hydrology.
Water Quality	Temperature, Turbidity, Nutrients	Field observations, including warm, turbid water, and nuisance algae growth	***At Risk Condition*** Water quality limited by irrigation withdrawals and return flows.	***At Risk Condition*** Water quality limited by irrigation withdrawals and return flows.	***Unacceptable Risk Condition*** Water quality limited by irrigation withdrawals and return flows. Field crews observed turbid, warm water in the reach from ditch return flows
Habitat Quality	Substrate	Dominant substrate/fine sediment	***At Risk Condition*** Primary substrate is medium cobble. Secondary substrate is large gravel. Reasonable diversity of substrate characteristics associated with sorting at LWD accumulations. Cementation was good and embeddedness was 25-50%.	***At Risk Condition*** Primary substrate is medium cobble. Secondary substrate is large gravel. Reasonable diversity of substrate characteristics associated with sorting at woody debris accumulations. Cementation was good and embeddedness was 0-25% in this reach. Substrate in the side channel that avulsed into the logged portion of the riparian area was predominantly fines, and the channel is a significant source of fine sediment to the creek.	***At Risk Condition*** Primary substrate is large cobble. Secondary substrate is large gravel. Minimal diversity of substrate associated with sorting and hydraulic complexity. Cementation was good and embeddedness was 25-50% in this reach.
	Large Woody Debris	Pieces per mile	***Adequate Condition*** 1 piece of large (20” x 35’), 10 pieces of medium (12” x 35’) and >50 and perhaps greater than 100 pieces of small (6” x 20’) woody debris were observed in the sampling reach, which equates to 82 pieces (>12” diameter and 35’ length) per mile. Numerous debris jams in reach. Mature riparian forest provides adequate recruitment source. Rated as properly functioning for LWD based on adaptation of Ralph et al. 1994, Beechie and Sibley 1997, and Fox and Bolton 2007.	***Unacceptable Risk Condition*** 0 pieces of large (20” x 35’), 0 pieces of medium (12” x 35’) and 15 pieces of small (6” x 20’) woody debris with more hidden in debris accumulations were observed in the sampling reach, which equates to 0 pieces (>12” diameter and 35’ length) per mile. There was a significant quantity of woody debris that was very small, less than 6” diameter and less that 20’ long, and accumulated in large jams in the mature floodplain vegetation. Sources of natural LWD recruitment greatly reduced by riparian logging. Rated as not properly functioning for LWD based on adaptation of Ralph et al. 1994, Beechie and Sibley 1997, and Fox and Bolton 2007.	***Unacceptable Risk Condition*** 0 pieces of large (20” x 35’), 0 pieces of medium (12” x 35’) and 3 pieces of small (6” x 20’) woody debris were observed in the sampling reach, which equates to 0 pieces (>12” diameter and 35’ length) per mile. Mature riparian forest provides adequate recruitment source. Rated as not properly functioning for LWD based on adaptation of Ralph et al. 1994, Beechie and Sibley 1997, and Fox and Bolton 2007.

Table B-2 (continued). Habitat Condition Assessment of Reach BC (Bullfrog Confined Reach).					
General Characteristics	**General Indicators**	**Specific Indicators**	**Subreach BC1 Condition**	**Subreach BC2 Condition**	**Subreach BC3 Condition**
Habitat Quality (cont'd)	Pools	Frequency and quality	***Adequate Condition*** Pool frequency is 45 pools per mile (extrapolated from the sampling reach data). Typical pools in the reach were formed by scour at LWD accumulations. Average dimensions were 25' long x 10' wide x 3' residual depth. Overhead cover and complexity were both high, and the amount of fines in the pool bottoms was low.	***Adequate Condition*** Pool frequency is 42 pools per mile (extrapolated from the sampling reach data). Typical pools in the reach were formed by scour at LWD accumulations or at tree roots in side channels/braids. Average dimensions were 15-20' long x 3-6' wide x 1.5-2.5' residual depth. Overhead cover was high and complexity was moderate, and the amount of fines in the pool bottoms was low.	***Adequate Condition*** Pool frequency is 22 pools per mile (extrapolated from the sampling reach data). Typical pools in the reach were formed by scour at tree root hard points. Average dimensions were 25' long x 8' wide x 2-2.5' residual depth. Overhead cover was high and complexity was moderate, and the amount of fines in the pool bottoms was low.
	Complexity	Variability and heterogeneity of habitat units	***Adequate Condition*** Habitat unit density is good, 135 habitat units per mile. Abundant LWD provides significant overhead cover and complexity to habitat units.	***At Risk Condition*** Habitat unit density is very good, 177 habitat units per mile. However, lack of LWD in the reach and logged portions of the floodplain limit the overhead cover and complexity to habitat units.	***At Risk Condition*** Habitat unit density is good,140 habitat units per mile. Abundant riparian vegetation provides overhead cover and tree roots provide complexity to habitat units, but overall lack of LWD limits complexity overall.
	Off-Channel Habitat	Connectivity with main channel	***Adequate Condition*** This reach has several high-flow channels, alcoves, and off-channel areas. Habitat features have significant LWD and overhead cover from vegetation. Off-channel areas are accessed by high flows, particularly where LWD accumulations create significant hydraulic roughness. In addition, no anthropomorphic barriers limit access to off channel habitat.	***At Risk Condition*** This reach has several channels, and off channel areas. Habitat features have minimal LWD and overhead cover from vegetation is limited in large portions of the reach. Some of the side channels flow directly through areas with limited vegetation, and habitat in those areas is severely degraded. Off channel areas are accessed by high flows, particularly where LWD accumulations create significant hydraulic roughness. In addition, no anthropomorphic barriers limit access to off channel habitat.	***Unacceptable Risk Condition*** Off channel habitat is primarily confined to wooded floodplain areas immediately adjacent to the channel. Few ponds, oxbows, or backwaters were observed. Channel is single threaded in this reach. No manmade barriers limiting access to habitat.
Channel	Dynamics	Floodplain connectivity	***Adequate Condition*** Active high-flow channels and evidence of regular floodplain inundation were observed in the reach. Natural dynamics of aggradation and incision vary the degree of floodplain inundation.	***Adequate Condition*** Active high and low flow side channels and evidence of regular floodplain inundation were observed in the reach. Natural dynamics of aggradation maintain floodplain connectivity.	***At Risk Condition*** Floodplain inundation frequency is reduced somewhat due lack of hydraulic roughness from LWD accumulations in the channel. Still, evidence of floodplain activation was observed. Riparian vegetation is well supported.
		Bank stability/channel migration	***Adequate Condition*** Bank erosion was observed on 30-60% of banks. It is suspected that the majority of the erosion occurred during the large flood event of 2011. Still, riparian vegetation is abundant and of high quality and the erosion recruited large amounts of LWD to the channel, positively influencing habitat. Bank stability was rated as slightly unstable (Booth and Henshaw 2001).	***At Risk Condition*** Bank erosion was observed on 5-30% of banks. It is suspected that the majority of the erosion occurred during the large flood event of 2011. Still, riparian vegetation is abundant in much of the subreach. Bank stability was rated as slightly unstable (Booth and Henshaw 2001). The risk of channel avulsion resulting in severe bank erosion and habitat degradation is significant in portions of the subreach that lack substantial vegetation.	***Adequate Condition*** Bank erosion was observed on 5-30% of banks. It is suspected that the majority of the erosion occurred during the large flood event of 2011, and banks are currently restabilizing. Riparian vegetation is abundant. Bank stability was rated as slightly unstable (Booth and Henshaw 2001).
		Vertical channel stability	***At Risk Condition*** Both aggradation and incision processes were evident in this reach. Significant aggradation was observed in the upstream portion of the reach, primarily as a result of a large channel spanned LWD jam. The downstream portion of the reach was more incised. Floodplain disconnection or large scale changes in channel planform were not observed.	***At Risk Condition*** Aggradation processes are evident in this reach resulting in a multi thread channel network. This is believed to be natural and expected and not in response to significant watershed disturbance.	***At Risk Condition*** Evidence of aggradation is present in the reach, but no visible change in channel planform has resulted. It is suspected that the majority of the aggradation occurred during the large flood event of 2011.

Table B-2 (continued). Habitat Condition Assessment of Reach BC (Bullfrog Confined Reach).					
General Characteristics	**General Indicators**	**Specific Indicators**	**Subreach BC1 Condition**	**Subreach BC2 Condition**	**Subreach BC3 Condition**
Channel (cont'd)	Dynamics (cont'd)	Resiliency to Disturbance	***Adequate Condition*** Significant and dense riparian forest, numerous LWD, and a moderately wide active floodway make this reach fairly resilient to disturbance from large flood events that carry significant bedload.	***At Risk Condition*** This reach shows strong resiliency to large flood events that carry significant bedload in areas with significant and dense riparian forest, but portion of the reach impacted by riparian logging have extremely low resiliency. Habitat in logged areas is poor and in danger of degrading even more.	***Adequate Condition*** This reach shows strong resiliency to large flood events that carry significant bedload due to the presence of significant and dense riparian forest.
Riparian Vegetation	Condition	Structure	***At Risk Condition*** Natural structure of 73% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.	***At Risk Condition*** Natural structure of 73% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.	***At Risk Condition*** Natural structure of 72% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.
		Disturbance (Human)	***At Risk Condition*** 73% medium to large wood available in riparian buffer; 27% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); 1.6 mi/mi^2 roads in riparian buffer.	***At Risk Condition*** 46% medium-large wood available in riparian buffer; 27% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); 0.5 mi/mi^2 roads in riparian buffer.	***Unacceptable Risk Condition*** 64% medium-large wood available in riparian buffer; 28% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); 8 mi/mi^2 roads in riparian buffer.
		Canopy Cover	***Adequate Condition*** 94% medium to large wood available in riparian buffer.	***At Risk Condition*** 66% medium-large wood available in riparian buffer.	***Adequate Condition*** 86% medium-large wood available in riparian buffer.

Table B-3. Habitat Condition Assessment of Reach SC (Swauk Confined Reach).

General Characteristics	General Indicators	Specific Indicators	Subreach SC1 Condition	Subreach SC2 Condition
Habitat Access	Physical Barriers	Main channel barrier in reach or downstream. Includes full dewatering of the channel and thermal barriers.	***At Risk Condition*** There are no anthropogenic barriers to fish migration in this reach or on the main channel downstream of this reach. The exposed siphon pipe in the stream bed may act as a fish passage barrier to juvenile fish at extreme low flow conditions. Year-round base flow returns at the upstream end of this reach at the West Side Irrigation Canal return. Access from upstream of Subreach SC1 is limited by low flow or dewatered conditions during periods of heavy irrigation water withdrawals.	***At Risk Condition*** There are no anthropogenic barriers to fish migration in this reach or on the main channel downstream of this reach. Access from downstream may be adversely affected by low flow conditions during some periods of heavy water withdrawals for irrigation. Year-round base flow returns at the downstream end of this reach at the West Side Irrigation Canal return. Access from upstream is limited by low flow or dewatered conditions during periods of heavy irrigation water withdrawals.
Hydrology	Stream flow	Alteration of peak or base flows	***Unacceptable Risk Condition*** Low/base flows are adversely affected by irrigation withdrawals at numerous diversion points upstream of this subreach. Thissub reach is known to have year-round base flow due to return from the West Side Irrigation Canal return at the upstream end of the reach. Significant changes to peak flow timing, magnitude, duration, and frequency cannot be determined from the available stream flow record on Manastash Creek. However, many of the land use activities documented in the Manastash Creek basin are known to affect peak flow hydrology.	***Unacceptable Risk Condition*** Low/base flows are adversely affected by irrigation withdrawals at numerous diversion points upstream of this reach. This reach is known to become completely dewatered during periods of heavy irrigation water withdrawals. Significant changes to peak flow timing, magnitude, duration, and frequency cannot be determined from the available stream flow record on Manastash Creek. However, many of the land use activities documented in the Manastash Creek basin are known to affect peak flow hydrology.
Water Quality	Temperature, Turbidity, Nutrients	Field observations, including warm, turbid water, and nuisance algae growth	***Unacceptable Risk Condition*** Water quality limited by irrigation withdrawals and return flows. Field crews observed turbid, warm water in the reach from ditch return flows	***At Risk Condition*** Water quality limited by irrigation withdrawals and return flows.
Habitat Quality	Substrate	Dominant substrate/fine sediment	***At Risk Condition*** Primary substrate is large cobble. Secondary substrate is large gravel. Minimal diversity of substrate associated with sorting and hydraulic complexity. Cementation was good and embeddedness was 0-25% in this reach.	***At Risk Condition*** Primary substrate is large cobble. Secondary substrate is small boulders. Minimal diversity of substrate associated with sorting and hydraulic complexity. Cementation was excellent and embeddedness was 0-25% in this reach.
	Large Woody Debris	Pieces per mile	***Unacceptable Risk Condition*** 1 piece of large (20" x 35'), 0 pieces of medium (12" x 35') and 0 pieces of small (6" x 20') woody debris were observed in the sampling reach, which equates to 5 pieces (>12" diameter and 35' length) per mile. The one piece of LWD was placed by humans as bank toe scour protection and it provides little or no habitat value. Sources of natural LWD recruitment are minimal due to lack of mature riparian vegetation and a straightened/armored channel. Rated as not properly functioning for LWD based on adaptation of Ralph et al. 1994, Beechie and Sibley 1997, and Fox and Bolton 2007.	***At Risk Condition*** 0 pieces of large (20" x 35'), 9 pieces ofmMedium (12" x 35') and 10 pieces of small (6" x 20') woody debris were observed in the sampling reach, which equates to 46 pieces (>12" diameter and 35' length) per mile. The small pieces of woody debris were mainly distributed as single pieces rather than in debris jams.. Sources of natural LWD recruitment are minimal due to lack of mature riparian vegetation and a relatively confined channel. Rated as not properly functioning for LWD based on adaptation of Ralph et al. 1994, Beechie and Sibley 1997, and Fox and Bolton 2007.
	Pools	Frequency and quality	***At Risk Condition*** Pool frequency is 15 pools per mile (extrapolated from the sampling reach data), which falls at the low end of the acceptable range. Typical pools in the reach were part of unforced riffle/pool sequences. Average dimensions of the 3 pools observed were 45' long x 15' wide x 2.5' residual depth. Overhead cover, complexity, and the amount of fines in the pool bottoms were all low.	***At Risk Condition*** Pool frequency is 26 pools per mile (extrapolated from the sampling reach data), in the acceptable range, but overall quality is low. Typical pools in the reach were located at tree root or other bank hard points. Average dimensions of the pools observed were 50' long x 20' wide x 1.5' residual depth. Overhead cover, complexity, and the amount of fines in the pool bottoms were all low.

Table B-3 (continued). Habitat Condition Assessment of Reach SC (Swauk Confined Reach).				
General Characteristics	**General Indicators**	**Specific Indicators**	**Subreach SC1 Condition**	**Subreach SC2 Condition**
Habitat Quality (cont'd)	Complexity	Variability and heterogeneity of habitat units	***Unacceptable Condition*** Habitat unit density is a relatively low 44 habitat units per mile. Lack of LWD in the reach and sparse mature riparian vegetation limit the overhead cover and complexity to habitat units.	***At Risk Condition*** Habitat unit density is a relatively low 57 habitat units per mile. However, only riffles and pools were able to be logged because most of the sampling reach was completely dewatered at the time of sampling. Modest amounts of LWD in the reach and a limited corridor of mature riparian vegetation limit the overhead cover and complexity to habitat units.
	Off-Channel Habitat	Connectivity with main channel	***Unacceptable Risk Condition*** Off-channel habitat is almost completely absent. One small alcove with limited vegetation exists on the right bank. One constructed pond on the left bank floodplain excluded from the stream by levees. Channel is straightened and single-threaded in this reach. Bank armoring and levees limit high flow access to the floodplain.	***At Risk Condition*** Several historic high flow channels that have mature vegetation along them are visible along this reach within the somewhat naturally confined floodway. However, channel incision appears to have limited or disconnected these channels at all but the highest peak flows.
Channel	Dynamics	Floodplain connectivity	***Unacceptable Risk Condition*** Channel has been mechanically straightened, and cleaned of LWD. Significant portions of the reach have been leveed, and many banks have been armored, severely reducing hydrologic connectivity between the channel and floodplain and riparian areas.	***Unacceptable Risk Condition*** Portions of the channel have been mechanically straightened, and leveed, and many banks have been armored. Channel incision is reducing hydrologic connectivity between the channel and historic high flow channels, floodplain and riparian areas is many areas. At one location I the reach a large debris jam resulted in significant flow of water and bedload onto the left bank floodplain.
		Bank stability/channel migration	***Unacceptable Risk Condition*** Bank erosion was observed on 5-30% of banks. Channel has been mechanically straightened, and bank armoring and levees maintain this generally stable configuration, limiting natural channel migration and LWD recruitment. There is some bank erosion in the downstream portion of the reach where the channel is beginning to naturally increase its sinuosity in areas where banks have not been armored. Bank stability was rated as slightly unstable (Booth and Henshaw 2001).	***At Risk Condition*** Bank erosion was observed on 5-30% of banks. Channel has been mechanically straightened in portions but natural channel migration and mature riparian vegetation still exists in quantities to recruit new LWD to the channel. Over time, without improvement in floodplain connectivity, natural LWD debris recruitment sources will be exhausted as the channel migrates into adjacent agricultural fields. Bank stability was rated as slightly unstable (Booth and Henshaw 2001).
		Vertical channel stability	***Unacceptable Risk Condition*** Channel has been mechanically modified in this reach to limit access of high flows to the floodplain. The current condition is vertically stable but incised.	***Unacceptable Risk Condition*** Channel incision has resulted in significant disconnection of floodplain and off channel habitat areas.
		Resiliency to Disturbance	***At Risk Condition*** This subreach has been mechanically altered and armored to be resilient to large flood events that carry significant bedload. However, minimal habitat or natural, dynamic processes are at work in this subreach.	***At Risk Condition*** This reach has incised and been altered in a way that habitat resiliency to large flood events that carry significant bedload has been reduced. As riparian conditions continue to degrade, resiliency will decrease even further.
Riparian Vegetation	Condition	Structure	***Unacceptable Risk Condition*** Natural structure of 38% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.	***Unacceptable Risk Condition*** Natural structure of 14% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.
		Disturbance (Human)	***Unacceptable Risk Condition*** 34% medium to large wood available in riparian buffer; 62% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); 0.4 mi/mi^2 roads in riparian buffer.	***Unacceptable Risk Condition*** 9% medium-large wood available in riparian buffer; 86% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); 3.2 mi/mi^2 roads in riparian buffer.
		Canopy Cover	***At Risk Condition*** 63% medium to large wood available in riparian buffer.	***Unacceptable Risk Condition*** 233% medium-large wood available in riparian buffer.

Table B-4. Habitat Condition Assessment of Reach FC (Fan Contraction Reach).							
General Characteristics	General Indicators	Specific Indicators	Subreach FC1 Condition	Subreach FC2 Condition	Subreach FC3 Condition	Subreach FC4 Condition	Subreach FC5 Condition
Habitat Access	Physical Barriers	Main channel barrier in reach or downstream. Includes full dewatering of the channel and thermal barriers.	***At Risk Condition*** There are no anthropogenic barriers to fish migration in this reach or on the main channel downstream of thissub reach. Access from upstream and downstream is limited by low flow or dewatered conditions during periods of heavy irrigation water withdrawals.	***At Risk Condition*** There are no anthropogenic barriers to fish migration in this reach or on the main channel downstream of this reach. Access from upstream and downstream is limited by low flow or dewatered conditions during periods of heavy irrigation water withdrawals.	***At Risk Condition*** There are no anthropogenic barriers to fish migration in this reach or on the main channel downstream of this reach. Access from upstream and downstream is limited by low flow or dewatered conditions during periods of heavy irrigation water withdrawals.	***At Risk Condition*** There are no anthropogenic barriers to fish migration in this reach or on the main channel downstream of this reach. Access from upstream and downstream is limited by low flow or dewatered conditions during periods of heavy irrigation water withdrawals.	***At Risk Condition*** There are no anthropogenic barriers to fish migration in this reach or on the main channel downstream of this reach. Access from upstream and downstream is limited by low flow or dewatered conditions during periods of heavy irrigation water withdrawals.
Hydrology	Stream flow	Alteration of peak or base flows	***Unacceptable Risk Condition*** Low/base flows are adversely affected by irrigation withdrawals at numerous diversion points upstream of this reach. This reach is known to become completely dewatered during periods of heavy irrigation water withdrawals. Significant changes to peak flow timing, magnitude, duration, and frequency cannot be determined from the available stream flow record on Manastash Creek. However, many of the land use activities documented in the Manastash Creek basin are known to affect peak flow hydrology	***Unacceptable Risk Condition*** Low/base flows are adversely affected by irrigation withdrawals at numerous diversion points upstream of this reach. This reach is known to become completely dewatered during periods of heavy irrigation water withdrawals. Significant changes to peak flow timing, magnitude, duration, and frequency cannot be determined from the available stream flow record on Manastash Creek. However, many of the land use activities documented in the Manastash Creek basin are known to affect peak flow hydrology.	***Unacceptable Risk Condition*** Low/base flows are adversely affected by irrigation withdrawals at numerous diversion points upstream of this reach. This reach is known to become completely dewatered during periods of heavy irrigation water withdrawals. Significant changes to peak flow timing, magnitude, duration, and frequency cannot be determined from the available stream flow record on Manastash Creek. However, many of the land use activities documented in the Manastash Creek basin are known to affect peak flow hydrology.	***Unacceptable Risk Condition*** Low/base flows are adversely affected by irrigation withdrawals at numerous diversion points upstream of this reach. This reach is known to become completely dewatered during periods of heavy irrigation water withdrawals. Significant changes to peak flow timing, magnitude, duration, and frequency cannot be determined from the available stream flow record on Manastash Creek. However, many of the land use activities documented in the Manastash Creek basin are known to affect peak flow hydrology.	***Unacceptable Risk Condition*** Low/base flows are adversely affected by irrigation withdrawals at numerous diversion points upstream of this reach. This reach is known to become completely dewatered during periods of heavy irrigation water withdrawals. Significant changes to peak flow timing, magnitude, duration, and frequency cannot be determined from the available stream flow record on Manastash Creek. However, many of the land use activities documented in the Manastash Creek basin are known to affect peak flow hydrology.
Water Quality	Temperature, Turbidity, Nutrients	Field observations, including warm, turbid water, and nuisance algae growth	***At Risk Condition*** Water quality limited by irrigation withdrawals and return flows. Little to no flow observed.	***At Risk Condition*** Water quality limited by irrigation withdrawals and return flows. Little to no flow observed.	***At Risk Condition*** Water quality limited by irrigation withdrawals and return flows.	***At Risk Condition*** Water quality limited by irrigation withdrawals and return flows. Little to no flow observed	***At Risk Condition*** Water quality limited by irrigation withdrawals and return flows. Little to no flow observed
Habitat Quality	Substrate	Dominant substrate/fine sediment	***At Risk Condition*** Primary substrate is large cobble. Secondary substrate is small boulder. Minimal diversity of substrate associated with sorting and hydraulic complexity. Cementation was good and embeddedness was 0-25% in this reach.	***At Risk Condition*** Primary substrate is large cobble. Secondary substrate is small boulder. Minimal diversity of substrate associated with sorting and hydraulic complexity. Cementation was excellent and embeddedness was 0-25% in this reach.	Substrate was not surveyed in this subreach due to access restriction.	***At Risk Condition*** Primary substrate is large cobble. Secondary substrate is small boulder. Minimal diversity of substrate associated with sorting and hydraulic complexity. Cementation was good and embeddedness was 0-25% in this reach.	***At Risk Condition*** Primary substrate is large cobble. Secondary substrate is small boulder. Minimal diversity of substrate associated with sorting and hydraulic complexity. Cementation was good and embeddedness was 0-25% in this reach.

Table B-4 (continued). Habitat Condition Assessment of Reach FC (Fan Contraction Reach).							
General Characteristics	General Indicators	Specific Indicators	Subreach FC1 Condition	Subreach FC2 Condition	Subreach FC3 Condition	Subreach FC4 Condition	Subreach FC5 Condition
Habitat Quality (cont'd)	Large Woody Debris	Pieces per mile	***Unacceptable Risk Condition*** 0 pieces of large (20" x 35'), 0 pieces of medium (12" x 35') and 0 pieces of small (6" x 20') woody debris were observed in the sampling reach, which equates to 0 pieces (>12" diameter and 35' length) per mile. Sources of natural LWD recruitment are absent due to lack of mature riparian vegetation. Rated as not properly functioning for LWD based on adaptation of Ralph et al. 1994, Beechie and Sibley 1997, and Fox and Bolton 2007.	***Unacceptable Risk Condition*** 0 piece of large (20" x 35'), 1 pieces of medium (12" x 35') and 1 pieces of small (6" x 20') woody debris were observed in the sampling reach, which equates to 5 pieces (>12" diameter and 35' length) per mile. Sources of natural LWD recruitment are minimal due to lack of mature riparian vegetation and a straightened channel. Rated as not properly functioning for LWD based on adaptation of Ralph et al. 1994, Beechie and Sibley 1997, and Fox and Bolton 2007.	LWD was not surveyed in this subreach due to access restriction.	***Unacceptable Risk Condition*** LWD was not surveyed in this subreach due to access restriction. Sources of natural LWD recruitment are minimal due to lack of mature riparian vegetation. Rated as not properly functioning for LWD via remote observation based on adaptation of Ralph et al. 1994, Beechie and Sibley 1997, and Fox and Bolton 2007.	***Unacceptable Risk Condition*** 0 piece of large (20" x 35'), 0 pieces of medium (12" x 35') and 1 piece of small (6" x 20') woody debris were observed in the sampling reach, which equates to 0 pieces (>12" diameter and 35' length) per mile. Sources of natural LWD recruitment are absent due to lack of mature riparian vegetation. Rated as not properly functioning for LWD based on adaptation of Ralph et al. 1994, Beechie and Sibley 1997, and Fox and Bolton 2007.
	Pools	Frequency and quality	***Unacceptable Risk Condition*** Pool frequency is 19 pools per mile (extrapolated from the sampling reach data), which falls at the low end of the acceptable range. Typical pools in the reach were associated with riprap or rock groins. Average dimensions of the pools observed were 30' long x 15' wide x 1.5-2' residual depth. Overhead cover, complexity, and the amount of fines in the pool bottoms were all low.	***At Risk Condition*** Pool frequency is 36 pools per mile (extrapolated from the sampling reach data). Typical pools in the reach were associated with the naturally forming pool/riffle sequence and relatively erosion resistant, consolidated bank materials. Average dimensions of the pools observed were 40' long x 15' wide x 1.5' residual depth. Overhead cover, complexity, and the amount of fines in the pool bottoms were all low.	Pools and habitat units were not surveyed in this subreach due to access restriction.	***Unacceptable Risk Condition*** Habitat units and pool frequency/quality were not surveyed directly in this subreach due to access restriction . Estimates of pool frequency based on aerial imagery suggest that pool frequency is approximately 20-25 pools per mile. Based on observations in adjacent reaches, it is assumed that overhead cover, complexity, and the amount of fines in the pool bottoms were all low.	***Unacceptable Risk Condition*** Pool frequency is 7 pools per mile (extrapolated from the sampling reach data), which falls well below the acceptable range. The only pool observed in the reach was associated with a tree root hard point. Average dimensions of the pools observed were 35' long x 18' wide x 4' residual depth. Overhead cover, complexity, and the amount of fines in the pool bottoms were all low.
	Complexity	Variability and heterogeneity of habitat units	***Unacceptable Risk Condition*** Habitat unit density is a relatively low 48 habitat units per mile. Lack of LWD in the reach and a nearly total absence of mature riparian vegetation limit the overhead cover and complexity to habitat units.	***At Risk Condition*** Habitat unit density is a moderate 82 habitat units per mile. Lack of LWD in the reach, and reduced levels of mature riparian vegetation limit the overhead cover and complexity to habitat units.	Habitat units were not surveyed in this subreach due to access restriction.	***Unacceptable Risk Condition*** Habitat units and pool frequency/quality were not surveyed directly in this subreach due to access restriction . Risk condition has been assigned based on aerial imagery and comparison with conditions in adjacent reaches that were surveyed.	***Unacceptable Risk Condition*** Habitat unit density is an extremely low 20 habitat units per mile. Dredging, other mechanical channel alterations, and a lack of LWD in the reach limit habitat diversity. A near total absence of mature riparian vegetation limits the overhead cover and complexity to habitat units.

Table B-4 (continued). Habitat Condition Assessment of Reach FC (Fan Contraction Reach).							
General Characteristics	**General Indicators**	**Specific Indicators**	**Subreach FC1 Condition**	**Subreach FC2 Condition**	**Subreach FC3 Condition**	**Subreach FC4 Condition**	**Subreach FC5 Condition**
Habitat Quality (cont'd)	Off-Channel Habitat	Connectivity with main channel	***Unacceptable Risk Condition*** Off channel habitat is completely absent. Channel is mechanically altered, straightened, and single threaded in this reach. Bank armoring and levees constructed from dredge spoils limit high flow access to the floodplain.	***Unacceptable Risk Condition*** While a couple of historic high flow channels are visible in the lidar data along this reach, they exist exclusively outside of the modern floodway. Mechanical channel alterations and channel incision have disconnected these off channel habitats.	Off channel habitat could not be accurately assessed in this subreach due to access restriction.	***Unacceptable Risk Condition*** Based on analysis of lidar data and aerial imagery, off channel habitat areas with significant cover and complexity are extremely limited. Only one side channel is apparent in the reach.	***Unacceptable Risk Condition*** Off channel habitat is completely absent. Channel is mechanically altered, straightened, and single threaded in this reach. Levees constructed from dredge spoils limit high flow access to the floodplain.
Channel	Dynamics	Floodplain connectivity	***Unacceptable Risk Condition*** Channel has been mechanically straightened, and cleaned of LWD. Significant portions of the reach have been dredged, leveed, and some banks have been armored, severely reducing hydrologic connectivity between the channel and floodplain and riparian areas. The severely undersized bridge at Serenity Lane causes a major discontinuity in the system.	***Unacceptable Risk Condition*** Portions of the channel have been mechanically straightened in the past. Channel incision is reducing hydrologic connectivity between the channel and historic high flow channels, and floodplain, severwely limiting the extent of riparian areas throughout the reach.	Floodplain connectivity could not be accurately assessed in this subreach due to access restriction.	Unable to adequately assess floodplain connectivity due to access restriction.	***Unacceptable Risk Condition*** Channel has been mechanically straightened, and cleaned of LWD. The reach has been dredged and leveed, severely reducing hydrologic connectivity between the channel and floodplain and riparian areas.
		Bank stability/channel migration	***Unacceptable Risk Condition*** Bank erosion was observed on 60-100% of banks. Channel has been mechanically straightened, and is dredged in an attempt to maintain capacity and mitigate for aggradation caused by the undersized bridge at Serenity Lane. The constriction, associated aggradation, and the overall lack of bank stabilizing riparian vegetation have created highly unstable conditions. Bank stability was rated as completely unstable (Booth and Henshaw 2001).	***At Risk Condition*** Bank erosion was observed on 30-60% of banks. Channel has been mechanically straightened in portions, limiting natural channel migration. Significantly reduced extent of mature riparian vegetation limits recruitment of new LWD to the channel. Over time, without improvement in dynamic channel processes and floodplain connectivity, natural LWD debris recruitment sources will be exhausted. Channel migration rate may then increase as the channel migrates into adjacent agricultural areas. Bank stability was rated as moderately unstable (Booth and Henshaw 2001).	Bank stability was not surveyed in this subreach due to access restriction.	***At Risk Condition*** Bank conditions were observed in a portion of this reach from the adjacent reach. Bank erosion appeared to be active on 30-60% of banks. Significantly reduced extent of mature riparian vegetation limits recruitment of new LWD to the channel. Over time, without improvement in dynamic channel processes and floodplain connectivity, natural LWD debris recruitment sources will be exhausted. Channel migration rate may then increase as the channel migrates into adjacent agricultural areas. Bank stability was rated as moderately unstable (Booth and Henshaw 2001).	***Unacceptable Risk Condition*** Bank erosion was observed on 60-100% of banks. Channel has been mechanically straightened, and is dredged in an attempt to maintain capacity and mitigate for aggradation downstream of the Cove Rd bridge. The aggradation, and the overall lack of bank stabilizing riparian vegetation has created highly unstable conditions. Bank stability was rated as completely unstable (Booth and Henshaw 2001).

Table B-4 (continued). Habitat Condition Assessment of Reach FC (Fan Contraction Reach).							
General Characteristics	**General Indicators**	**Specific Indicators**	**Subreach FC1 Condition**	**Subreach FC2 Condition**	**Subreach FC3 Condition**	**Subreach FC4 Condition**	**Subreach FC5 Condition**
Channel (cont'd)	Dynamics (cont'd)	Vertical channel stability	***Unacceptable Risk Condition*** Unnatural rates of bed aggradation in this reach are the result of the undersized bridge at Serenity Lane. This has forced the channel to respond by expanding laterally at unnatural rates, and landowners have combatted this undesirable scenario by dredging the channel.	***Unacceptable Risk Condition*** Channel incision has resulted in significant disconnection of floodplain and off channel habitat areas, though the channel may be vertically stable in its current configuration.	Vertical channel stability could not be accurately assessed in this subreach due to access restriction.	Unable to adequately assess vertical channel stability due to access restriction.	***Unacceptable Risk Condition*** Unnatural rates of bed aggradation in this reach are the result of the rapid decrease in sediment transport capacity downstream of the Cove Rd bridge. Landowners have combatted this scenario, which increases local flooding risk, by dredging the channel.
		Resiliency to Disturbance	***Unacceptable Risk Condition*** Near total lack of bank stabilizing, mature riparian vegetation, coupled with the effects of the undersized crossing at Serenity Lane severely limit this reach's resiliency to large flood events that carry significant bedload.	***At Risk Condition*** This reach has incised and been altered in a way that habitat resiliency to large flood events that carry significant bedload has been reduced. As riparian conditions continue to degrade, resiliency will decrease even further.	Resiliency to disturbance could not be accurately assessed in this subreach due to access restriction.	***Unacceptable Risk Condition*** Based on analogs of similar reaches, near total lack of bank stabilizing, mature riparian vegetation severely limits this reach's resiliency to large flood events that carry significant bedload.	***Unacceptable Risk Condition*** Near total lack of bank stabilizing, mature riparian vegetation, coupled with the effects of localized reduction of sediment transport capacity downstream of Cove Road, severely limits this reach's resiliency to large flood events that carry significant bedload.
Riparian Vegetation	Condition	Structure	***At Risk Condition*** Natural structure of 67% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.	***At Risk Condition*** Natural structure of 55% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.	***At Risk Condition*** Natural structure of 74% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.	***At Risk Condition*** Natural structure of 62% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.	***Unacceptable Risk Condition*** Natural structure of 35% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.
		Disturbance (Human)	***Unacceptable Risk Condition*** 3% medium-large wood available in riparian buffer; 33% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); 7 mi/mi^2 roads in riparian buffer.	***At Risk Condition*** 29% medium-large wood available in riparian buffer; 46% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); no roads in riparian buffer.	***At Risk Condition*** 47% medium-large wood available in riparian buffer; 26% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); 7 mi/mi^2 roads in riparian buffer.	***At Risk Condition*** 22% medium-large wood available in riparian buffer; 38% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); no roads in riparian buffer.	***Unacceptable Risk Condition*** 3% medium-large wood available in riparian buffer; 65% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); 6 mi/mi^2 roads in riparian buffer.
		Canopy Cover	***Unacceptable Risk Condition*** 9% medium-large wood available in riparian buffer.	***Unacceptable Risk Condition*** 44% medium-large wood available in riparian buffer.	***At Risk Condition*** 64% medium-large wood available in riparian buffer.	***Unacceptable Risk Condition*** 32% medium-large wood available in riparian buffer.	***Unacceptable Risk Condition*** 9% medium-large wood available in riparian buffer.

Table B-5. Habitat Condition Assessment of Reach FE (Fan Expansion Reach).

General Characteristics	General Indicators	Specific Indicators	Subreach FE1 Condition	Subreach FE2 Condition	Subreach FE3 Condition	Subreach FE4 Condition
Habitat Access	Physical Barriers	Main channel barrier in reach or downstream. Includes full dewatering of the channel and thermal barriers.	***At Risk Condition*** There are no anthropogenic barriers to fish migration in this reach or on the main channel downstream of this reach. This reach is known to become severely or completely dewatered during periods of heavy irrigation water withdrawals, limiting upstream and downstream passage.	***At Risk Condition*** There are no anthropogenic barriers to fish migration in this reach or on the main channel downstream of this reach. This reach is known to become severely or completely dewatered during periods of heavy irrigation water withdrawals, limiting upstream and downstream passage.	***At Risk Condition*** The Reed diversion Dam marks the upstream end of this subreach and is a known barrier to upstream passage for all life stages of salmonids. This reach is known to become severely or completely dewatered during periods of heavy irrigation water withdrawals, limiting downstream passage.	***Unacceptable Risk Condition*** The Reed diversion dam marks the downstream end of this subreach and is a known barrier to upstream passage for all life stages of salmonids. In addition, Manastash Creek is known to run dry downstream of the Reed diversion during periods of heavy irrigation water withdrawals.
Hydrology	Stream flow	Alteration of peak or base flows	***Unacceptable Risk Condition*** Base flows are adversely affected by irrigation withdrawals at numerous diversion points upstream of this reach. This reach is known to become completely dewatered during periods of heavy irrigation water withdrawals. Significant changes to peak flow timing, magnitude, duration, and frequency cannot be determined from the available stream flow record on Manastash Creek. However, many of the land use activities documented in the Manastash Creek basin are known to affect peak flow hydrology.	***Unacceptable Risk Condition*** Base flows are adversely affected by irrigation withdrawals at numerous diversion points upstream of this reach. This reach is known to become completely dewatered during periods of heavy irrigation water withdrawals. Significant changes to peak flow timing, magnitude, duration, and frequency cannot be determined from the available stream flow record on Manastash Creek. However, many of the land use activities documented in the Manastash Creek basin are known to affect peak flow hydrology.	***Unacceptable Risk Condition*** Base flows are adversely affected by irrigation withdrawals at numerous diversion points upstream of this reach. This reach is known to become completely dewatered during periods of heavy irrigation water withdrawals. Significant changes to peak flow timing, magnitude, duration, and frequency cannot be determined from the available stream flow record on Manastash Creek. However, many of the land use activities documented in the Manastash Creek basin are known to affect peak flow hydrology.	***Unacceptable Risk Condition*** Base flows are adversely affected by irrigation withdrawals at numerous diversion points upstream of this reach. This reach is known to retain at least some base flow year round, however. Significant changes to peak flow timing, magnitude, duration, and frequency cannot be determined from the available stream flow record on Manastash Creek. However, many of the land use activities documented in the Manastash Creek basin are known to affect peak flow hydrology.
Water Quality	Temperature, Turbidity, Nutrients	Field observations, including warm, turbid water, and nuisance algae growth	***At Risk Condition*** Water quality limited by irrigation withdrawals and return flows. Little to no flow observed.	***At Risk Condition*** Water quality limited by irrigation withdrawals and return flows. Little to no flow observed.	***At Risk Condition*** Water quality limited by irrigation withdrawals and return flows. Little to no flow observed.	***At Risk Condition*** Water quality limited by irrigation withdrawals and return flows. This subreach is upstream of the Reed diversion, and flow was observed in the channel.
Habitat Quality	Substrate	Dominant substrate/fine sediment	***At Risk Condition*** Primary substrate is large cobble. Secondary substrate is small boulder. Minimal diversity of substrate associated with sorting and hydraulic complexity. Cementation was excellent and embeddedness was 0-25% in this reach.	***At Risk Condition*** Primary substrate is large cobble. Secondary substrate is small boulder. Minimal diversity of substrate associated with sorting and hydraulic complexity. Cementation was good and embeddedness was 0-25% in this reach.	***At Risk Condition*** Primary substrate is large cobble. Secondary substrate is boulder. Cementation was excellent and embeddedness was 0-25% in this reach.	***At Risk Condition*** Primary substrate is large cobble. Secondary substrate is gravel and small boulder. Reasonable diversity of substrate associated with sorting and hydraulic complexity. Cementation was excellent and embeddedness was 0-25% in this reach.

Table B-5 (continued). Habitat Condition Assessment of Reach FE (Fan Expansion Reach).						
General Characteristics	**General Indicators**	**Specific Indicators**	**Subreach FE1 Condition**	**Subreach FE2 Condition**	**Subreach FE3 Condition**	**Subreach FE4 Condition**
Habitat Quality (cont'd)	Large Woody Debris	Pieces per mile	***Unacceptable Risk Condition*** 0 pieces of large (20" x 35'), 0 pieces of medium (12" x 35') and 1 piece of small (6" x 20') woody debris were observed in the sampling reach, which equates to 0 pieces (>12" diameter and 35' length) per mile. Sources of natural LWD recruitment are minimal due to lack of mature riparian vegetation and a straightened/armored channel. Rated as not properly functioning for LWD based on adaptation of Ralph et al. 1994, Beechie and Sibley 1997, and Fox and Bolton 2007.	***Unacceptable Risk Condition*** 0 piece of large (20" x 35'), 1 piece of medium (12" x 35') and 4 pieces of small (6" x 20') woody debris were observed in the sampling reach, which equates to 9 pieces (>12" diameter and 35' length) per mile. Sources of natural LWD recruitment are minimal due to lack of mature riparian vegetation and a straightened/armored channel. Rated as not properly functioning for LWD based on adaptation of Ralph et al. 1994, Beechie and Sibley 1997, and Fox and Bolton 2007.	***Unacceptable Risk Condition*** 1 piece of large (20" x 35'), 0 pieces of medium (12" x 35') and 2 pieces of small (6" x 20') woody debris were observed in the sampling reach, which equates to 10 pieces (>12" diameter and 35' length) per mile. Sources of natural LWD recruitment are present. Rated as not properly functioning for LWD based on adaptation of Ralph et al. 1994, Beechie and Sibley 1997, and Fox and Bolton 2007.	***Adequate Condition*** 0 pieces of large (20" x 35'), 4 pieces of medium (12" x 35') and 5 pieces of small (6" x 20') woody debris were observed in the sampling reach, which equates to 32 pieces (>12" diameter and 35' length) per mile. Sources of natural LWD recruitment are present, and there is significant LWD in parts of the reach, but the reach is cleaned of LWD to reduce potential issues at the Reed diversion. Rated as not properly functioning for LWD based on adaptation of Ralph et al. 1994, Beechie and Sibley 1997, and Fox and Bolton 2007.
	Pools	Frequency and quality	***At Risk Condition*** Subreach habitat was observed while the channel was dry, therefore pool dimensions were estimated based on channel bed topography. Pool frequency is 32 pools per mile (extrapolated from the sampling reach data), which falls within acceptable range. However, the short sampling reach (due to access limitations) may skew the results to look more favorable than the reality. Typical pools in the reach were associated with riprap or rock groins. Average dimensions of the 3 pools observed were 25' long x 10' wide x 1.5' residual depth. Overhead cover, complexity, and the amount of fines in the pool bottoms were all low.	***At Risk Condition*** Pool frequency is 35 pools per mile (extrapolated from the sampling reach data), which falls within acceptable range. Typical pools in the reach were associated with tree roots and other natural hard points. Average dimensions of the 3 pools observed were 35' long x 17' wide x 1.6' residual depth. Overhead cover, complexity, and the amount of fines in the pool bottoms were all low.	***At Risk Condition*** Pool frequency is 52 pools per mile (extrapolated from the sampling reach data), which falls within acceptable range. Typical pools in the reach were associated with bank hard points. Average dimensions of the pools observed were 25' long x 10' wide x 2-2.5' residual depth. Overhead cover, and complexity are medium. The amount of fines in the pool bottoms was low.	***Adequate Condition*** Pool frequency is 56 pools per mile (extrapolated from the sampling reach data), which falls within acceptable range. Typical pools in the reach were associated with tree root bank hard points. Average dimensions of the pools observed were 20' long x 8-10' wide x 2-3' residual depth. Overhead cover was high. Complexity was medium. The amount of fines in the pool bottoms was low.
	Complexity	Variability and heterogeneity of habitat units	***Unacceptable Risk Condition*** Habitat unit density was calculated at a moderate 82 habitat units per mile, though the short sampling reach (due to access limitations) may skew the results to look more favorable than the reality. Lack of LWD in the reach, widespread mechanical channel alterations, dredging, and reduced levels of mature riparian vegetation limit the overhead cover and complexity to habitat units.	***Unacceptable Risk Condition*** Habitat unit density was calculated at a moderate 87 habitat units per mile, though the short sampling reach (due to access limitations) may skew the results to look more favorable than the reality. Lack of LWD in the reach, extreme rates of lateral channel migration, and reduced levels of mature riparian vegetation limit the overhead cover and complexity to habitat units.	***At Risk Condition*** Habitat unit density is good, 145 habitat units per mile, despite the channelized and confined nature of the reach. Lack of LWD in the reach limit the overhead cover and complexity to habitat units to some extent.	***Adequate Condition*** Habitat unit density is very good, 175 habitat units per mile. Riparian vegetation is relatively intact and LWD is present, providing significant complexity and cover.

Table B-5 (continued). Habitat Condition Assessment of Reach FE (Fan Expansion Reach).						
General Characteristics	**General Indicators**	**Specific Indicators**	**Subreach FE1 Condition**	**Subreach FE2 Condition**	**Subreach FE3 Condition**	**Subreach FE4 Condition**
Habitat Quality (cont'd)	Off-Channel Habitat	Connectivity with main channel	***Unacceptable Risk Condition*** The entirety of off channel habitat in the reach is represented by a single cutoff meander. Analysis of the lidar data suggests that the area is no longer connected to the main channel at high flows. Mechanical channel alterations and channel incision have disconnected these off channel habitats.	***At Risk Condition*** Rapid rates of later channel migration and aggradation in this reach have resulted in the development of significant braiding of the channel. Unfortunately, lack of LWD and riparian vegetation in the active floodplain and on bars within the braided channel network severely limit the quality of habit in side channels and off channel habitat. Dewatering of the reach during summer months may be impeding the ability of vegetation to become established.	***Unacceptable Risk Condition*** This straight, entrenched reach has no off channel habitat. With significant effort, the Reed Ditch could potentially be reconnected to the Manastash Creek channel downstream of this reach, allowing the decommissioned ditch to serve as artificial side channel habitat.	***Unacceptable Risk Condition*** Despite good in channel conditions, limited amounts of off-channel habitat exist in this reach. This is likely the result of residential development in the floodplain. While few/no high flow channels, oxbows, and backwater areas are apparent from the lidar data, the floodplain and riparian areas at least remain densely vegetated along most of the reach. Levees limit floodplain inundation immediately upstream of the Reed diversion.
Channel	Dynamics	Floodplain connectivity	***Unacceptable Risk Condition*** Channel has been mechanically straightened, and cleaned of LWD. Significant portions of the reach have been dredged and leveed, severely reducing hydrologic connectivity between the channel and floodplain and riparian areas.	***At Risk Condition*** Extreme widening of the active floodway and channel in response to large flow events has left a situation where the inset floodplain can be frequently activated by high flows, but the state of riparian vegetation is highly degraded or disturbed.	***Unacceptable Risk Condition*** Channel appears to have been mechanically straightened in the past and is extremely incised below the historic floodplain, starting at the longitudinal profile discontinuity at the Reed diversion. Even the highest flood flows are unable to access overbank areas from this reach. Some out of bank flows likely occur on the left bank when if flood flows are able to enter the Reed Ditch.	***Adequate Condition*** While levees limit floodplain inundation immediately upstream of the Reed diversion, upstream landowners report overbank flows at regular intervals, though perhaps not every year. Channel and floodplain/riparian areas are in relatively good condition. Connectivity would likely improve if the practice of LWD removal was halted in the reach, though the existence of homes on the floodplain may make this infeasible from a flood risk standpoint. Private bridge may also limit floodplain connectivity to some extent.
		Bank stability/channel migration	***Unacceptable Risk Condition*** Bank erosion was observed on <5% of banks. Channel has been mechanically straightened, and is dredged in an attempt to maintain capacity and mitigate for aggradation caused by the Cove Road Briadge constriction. Mechanical armoring of the banks accounts for the lack of natural channel migration. Bank stability was rated as slightly unstable (Booth and Henshaw 2001).	***Unacceptable Risk Condition*** Bank erosion was observed on 60-100% of banks. Bed aggradation, highly erodible bank materials, and the overall lack of bank stabilizing riparian vegetation has created highly unstable conditions and a wide, largely unvegetated floodway. Rates of lateral cahnnel migration greatly exceed natural rates. Bank stability was rated as moderately unstable, with banks being held only by occasional hardpoints at tree roots and (Booth and Henshaw 2001).	***Unacceptable Risk Condition*** Bank erosion was observed on 30-60% of banks. Erosion was typically not severe and little or no lateral migration is occurring in the reach, but banks were raw still from the effects of the 2011 flood. Channel has been mechanically straightened, limiting natural channel migration and LWD recruitment. Bank stability was rated as slightly unstable (Booth and Henshaw 2001).	***Adequate Condition*** Bank erosion was observed on 5-30% of banks – in the low end of this range. The majority of the erosion occurred during the large flood event of 2011, and is associated with areas where bank vegetation was mechanically removed. Riparian vegetation is abundant and normal rates of channel migration recruit new LWD to the channel, though it is often removed. Bank stability was rated as slightly unstable (Booth and Henshaw 2001).

Table B-5 (continued). Habitat Condition Assessment of Reach FE (Fan Expansion Reach).						
General Characteristics	**General Indicators**	**Specific Indicators**	**Subreach FE1 Condition**	**Subreach FE2 Condition**	**Subreach FE3 Condition**	**Subreach FE4 Condition**
Channel (cont'd)		Vertical channel stability	***Unacceptable Risk Condition*** Unnatural rates of bed aggradation in this reach appear to be the result of the constriction at the Cove Road bridge combined with the fact that this is a naturally depositional alluvial fan reach. Landowners have combatted this undesirable scenario which increases flooding risk, by dredging the channel.	***Unacceptable Risk Condition*** Aggradation is expected in the reach as it is located in a naturally depositional alluvial fan environment. However, due to an overall lack of mature riparian vegetation, rates of bed aggradation along with unchecked lateral migration rates, are negatively influencing habitat conditions.	***Unacceptable Risk Condition*** This reach is confined and straightened reach as a result of mechanical alterations and the Reed diversion. The reach is likely still incision, though it is doing so ate slow rates. At this point, the reach has incised enough that historic floodplain and off channel areas visible on the lidar coverage have been hydraulically disconnected.	***Adequate Condition*** This reach shows some signs of aggradation, but not to a degree disproportionate with natural processes expected on a depositional alluvial fan. Human caused incision into the reach from downstream is blocked by the grade control provided by the Reed Ditch diversion structure. Removal of that structure without regard to channel slope equilibrium could result in severe habitat degradation in this reach.
		Resiliency to Disturbance	***Unacceptable Risk Condition*** Extreme reduction of bank stabilizing, mature riparian vegetation, coupled with the effects of the Cove Road crossing severely limit this reach's resiliency to large flood events that carry significant bedload.	***Unacceptable Risk Condition*** Extreme reduction of bank stabilizing, mature riparian vegetation in a naturally depositional alluvial fan environment has all but eliminated this reach's resiliency to large flood events that carry significant bedload.	***Adequate Condition*** In its current state, both peak flood flows and bedload are transported through this confined reach into the reach below. Habitat may be limited to some degree by the incised state, but the reach remains resilient to the effect of large flood events that carry significant bedload.	***Adequate Condition*** Significant and dense riparian forest and an active floodplain make this reach fairly resilient to disturbance from large flood events that carry significant bedload. Encroachment of residential development on the channel may threaten this in time.
Riparian Vegetation	Condition	Structure	***Adequate Condition*** Natural structure of 82% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.	***Adequate Condition*** Natural structure of 98% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.	***Adequate Condition*** Natural structure of 90% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.	***Unacceptable Risk Condition*** Natural structure of 28% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.
		Disturbance (Human)	***Adequate Condition*** 79% medium-large wood available in riparian buffer; 18% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); no roads in riparian buffer.	***Adequate Condition*** 85% medium-large wood available in riparian buffer; 2% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); no roads in riparian buffer.	***At Risk Condition*** 23% medium-large wood available in riparian buffer; 10% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); no roads in riparian buffer.	***Unacceptable Risk Condition*** 9% medium-large wood available in riparian buffer; 73% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); no roads in riparian buffer.
		Canopy Cover	***Adequate Condition*** 95% medium-large wood available in riparian buffer.	***Adequate Condition*** 100% medium-large wood available in riparian buffer.	***Unacceptable Risk Condition*** 29% medium-large wood available in riparian buffer.	***Unacceptable Risk Condition*** 33% medium-large wood available in riparian buffer.

Table B-6. Habitat Condition Assessment of Reach FA (Fan Apex Reach).						
General Characteristics	**General Indicators**	**Specific Indicators**	**Subreach FA1 Condition**	**Subreach FA2 Condition**	**Subreach FA3 Condition**	**Subreach FA4 Condition**
Habitat Access	Physical Barriers	Main channel barrier in reach or downstream. Includes full dewatering of the channel and thermal barriers.	***At Risk Condition*** There are no documented anthropogenic barriers to fish migration in this reach. The siphon crossing at the upstream end of this reach may act as a partial barrier to juvenile salmonids at very low flow conditions. However, there is a total barrier to upstream migration on the main channel downstream of this reach (Reed diversion).	***At Risk Condition*** There are no anthropogenic barriers to fish migration in this reach. The siphon crossing at the downstream end of this reach may act as a partial barrier to juvenile salmonids at very low flow conditions. However, there is a total barrier to upstream migration on the main channel downstream of this reach (Reed diversion).	***At Risk Condition*** There are no anthropogenic barriers to fish migration in this reach. However, there is a total barrier to upstream migration on the main channel downstream of this reach (Reed diversion).	***At Risk Condition*** There are no anthropogenic barriers to fish migration in this reach. However, there is a total barrier to upstream migration on the main channel downstream of this reach (Reed diversion).
Hydrology	Stream flow	Alteration of peak or base flows	***Unacceptable Risk Condition*** Base flows are adversely affected by irrigation withdrawals at numerous diversion points upstream of this reach. This reach is known to have year-round base flow due to return from the West Side Irrigation Canal return at the upstream end of the reach. Significant changes to peak flow timing, magnitude, duration, and frequency cannot be determined from the available stream flow record on Manastash Creek. However, many of the land use activities documented in the Manastash Creek basin are known to affect peak flow hydrology.	***Unacceptable Risk Condition*** Base flows are adversely affected by irrigation withdrawals at numerous diversion points upstream of this reach. This reach is known to have year-round base flow due to return from the West Side Irrigation Canal return at the upstream end of the reach. Significant changes to peak flow timing, magnitude, duration, and frequency cannot be determined from the available stream flow record on Manastash Creek. However, many of the land use activities documented in the Manastash Creek basin are known to affect peak flow hydrology.	***Adequate Condition*** No major diversions upstream of this reach	***Adequate Condition*** No major diversions upstream of this reach
Water Quality	Temperature, Turbidity, Nutrients	Field observations, including warm, turbid water, and nuisance algae growth	***At Risk Condition*** Water quality limited by irrigation withdrawals and return flows. This subreach is upstream of the Reed diversion, and flow was observed in the channel	***At Risk Condition*** Water quality limited by irrigation withdrawals and return flows. This subreach is upstream of the Reed diversion and the KRD spill, and flow was observed in the channel	***Adequate Condition*** No major diversions upstream of this reach	***Adequate Condition*** No major diversions upstream of this reach
Habitat Quality	Substrate	Dominant substrate/fine sediment	***At Risk Condition*** Primary substrate is large cobble. Secondary substrate is small boulder and gravel. Cementation was excellent and embeddedness was 0-25% in this reach.	***At Risk Condition*** Primary substrate is large cobble. Secondary substrate is gravel. Minimal diversity of substrate associated with sorting and hydraulic complexity. Cementation was good and embeddedness was 25-50% in this reach.	Substrate was not surveyed in this subreach due to access restriction.	***At Risk Condition*** Primary substrate is large cobble. Secondary substrate is gravel. Minimal diversity of substrate associated with sorting and hydraulic complexity. Cementation was good and embeddedness was 0-25% in this reach.

Table B-6 (continued). Habitat Condition Assessment of Reach FA (Fan Apex Reach).						
General Characteristics	**General Indicators**	**Specific Indicators**	**Subreach FA1 Condition**	**Subreach FA2 Condition**	**Subreach FA3 Condition**	**Subreach FA4 Condition**
Habitat Quality (cont'd)	Large Woody Debris	Pieces per mile	***Adequate Condition*** 1 piece of large (20" x 35'), 10 pieces of medium (12" x 35') and 16 pieces of small (6" x 20') woody debris were observed in the sampling reach, which equates to 55 pieces (>12" diameter and 35' length) per mile. Mature riparian vegetation provides adequate LWD sources. Rated as properly functioning for LWD based on adaptation of Ralph et al. 1994, Beechie and Sibley 1997, and Fox and Bolton 2007.	***Unacceptable Risk Condition*** 0 pieces of large (20" x 35'), 0 pieces of medium (12" x 35') and 2 pieces of small (6" x 20') woody debris were observed in the sampling reach, which equates to 0 pieces (>12" diameter and 35' length) per mile. Sources of natural LWD recruitment are present, but armored bank conditions and active removal of LWD in reach limit function. Rated as not properly functioning for LWD based on adaptation of Ralph et al. 1994, Beechie and Sibley 1997, and Fox and Bolton 2007.	LWD was not surveyed in this subreach due to access restriction.	***Unacceptable Risk Condition*** 0 pieces of large (20" x 35'), 2 pieces ofmMedium (12" x 35') and 1 piece of small (6" x 20') woody debris were observed in the sampling reach, which equates to 9 pieces (>12" diameter and 35' length) per mile. Sources of natural LWD recruitment are present, but recruitment is limited by bank armoring that reduces channel migration. Rated as not properly functioning for LWD based on adaptation of Ralph et al. 1994, Beechie and Sibley 1997, and Fox and Bolton 2007.
	Pools	Frequency and quality	***Adequate Condition*** Pool frequency is 50 pools per mile (extrapolated from the sampling reach data), which falls within acceptable range. Typical pools in the reach were associated with LWD jams. Average dimensions of the pools observed were 40' long x 12' wide x 3-4' residual depth. Overhead cover and complexity were high, while the amount of fines in the pool bottoms was low.	***Unacceptable Condition*** Pool frequency is 13 pools per mile (extrapolated from the sampling reach data), which is below acceptable range. Typical pools in the reach were associated with riprap/rock groin. Average dimensions of the pools observed were 45' long x 15' wide x 1.5' residual depth. Overhead cover was medium. Complexity and the amount of fines in the pool bottoms were low.	Pools and habitat units were not surveyed in this subreach due to access restriction.	***At Risk Condition*** Pool frequency is 23 pools per mile (extrapolated from the sampling reach data), which is within acceptable range. Typical pools in the reach were associated with riprap/rock groin. Average dimensions of the pools observed were 50' long x 15' wide x 2.5' residual depth. Overhead cover and complexity were medium. The amount of fines in the pool bottoms was low.
	Complexity	Variability and heterogeneity of habitat units	***Adequate Condition*** Habitat unit density is very good, 155 habitat units per mile. Riparian vegetation is intact and LWD is abundant, providing significant complexity and cover.	***At Risk Condition*** Habitat unit density was calculated at a moderate 76 habitat units per mile. Lack of LWD in the reach, and reduced levels of mature riparian vegetation limit the overhead cover and complexity to habitat units.	Habitat units were not surveyed in this subreach due to access restriction.	***At Risk Condition*** Habitat unit density was calculated at a low to moderate 63 habitat units per mile. Lack of LWD in the reach, and reduced levels of mature riparian vegetation associated with residential development on the right bank limit the overhead cover and complexity to habitat units.
	Off-Channel Habitat	Connectivity with main channel	***At Risk Condition*** Some backwater areas and excellent riparian/floodplain vegetation make the limited off-channel habitat in the reach very high quality. Two historic high flow channels/ditches on the left bank have been cut off by human alterations.	***Unacceptable Condition*** No off-channel habitat exists in this reach due to development of the floodplain and maintenance of the channel for irrigation water diversion and high flow conveyance.	Off channel habitat could not be accurately assessed in this subreach due to access restriction.	***At Risk Condition*** High flow channel constructed for flood relief provide some low to moderate quality off-channel habitat in the reach, along with a large wetland/beaver complex on the left bank floodplain. However, residential development and manmade alterations have destroyed or cut off any off channel habitat that was present on the right bank floodplain.

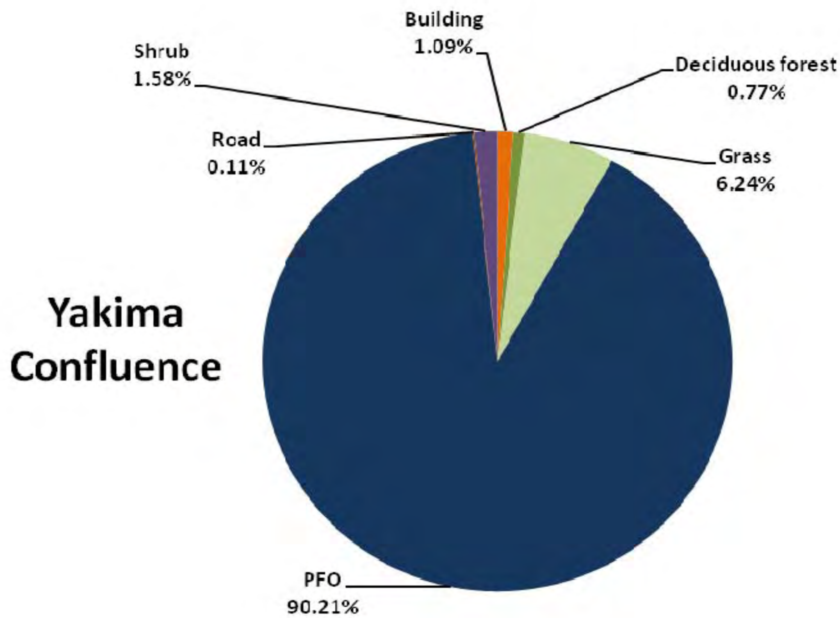
Table B-6 (continued). Habitat Condition Assessment of Reach FA (Fan Apex Reach).						
General Characteristics	**General Indicators**	**Specific Indicators**	**Subreach FA1 Condition**	**Subreach FA2 Condition**	**Subreach FA3 Condition**	**Subreach FA4 Condition**
Channel	Dynamics	Floodplain connectivity	***At Risk Condition*** Reach is somewhat incised the upstream end. Incision reduces and floodplain connectivity improves as it continues downstream. Floodplain inundation does occur, though not likely at Q2 or lower. Riparian/floodplain vegetation is in excellent condition.	***Unacceptable Condition*** Mechanical alterations and maintenance of the channel in this reach all but eliminates overbank flows, and floodplain habitat has been degraded as a result of land use. The right bank floodplain floods from upstream Subreaches FA3 and FA4, according to landowners.	Floodplain connectivity could not be accurately assessed in this subreach due to access restriction.	***At Risk Condition*** Homeowners report regular overbank flows in this reach in areas where levees do not prevent overtopping. Significant channel modifications have been made in an attempt to increase flood flow capacity and direct high flows away from the houses on the right bank. However, natural processes of channel aggradation have worked against many of the attempts to reduce floodplain connectivity on the right bank. Riparian vegetation and wetland function remain in good condition where alterations have not isolated them hydraulically.
		Bank stability/channel migration	***Adequate Condition*** Bank erosion was observed on 5-30% of banks. It is suspected that the majority of the erosion occurred during the large flood event of 2011. Still, riparian vegetation is abundant and of high quality and the erosion recruited large amounts of LWD to the channel, positively influencing habitat. Bank stability was rated as slightly unstable (Booth and Henshaw 2001).	***Unacceptable Risk Condition*** Bank erosion was observed on <5% of banks. The channel in this reach is highly modified and maintained for irrigation water diversion and high flow conveyance. It has been mechanically straightened, and many banks have been armored, eliminating natural channel migration and LWD recruitment. Bank stability was rated as armored (Booth and Henshaw 2001).	Bank stability was not surveyed in this subreach due to access restriction.	***Unacceptable Risk Condition*** Bank erosion was observed on 30-60% of banks. Erosion was concentrated in areas where riparian vegetation was removed. Bank erosion and flooding concerns by homeowners in this dynamic reach have prompted significant channel modification in the form of bank armoring and construction of new channels to increase flood capacity. Channel has been mechanically straightened, limiting natural channel migration and LWD recruitment. Bank stability was rated as moderately unstable (Booth and Henshaw 2001).
		Vertical channel stability	***At Risk Condition*** This reach experiences some aggradation during flow events that mobilize significant bedload. Rates remain within levels that are not unexpected given the reach location in depositional alluvial fan. Extreme changes in planform are not evident and habitat forming processes are at work in the reach.	***Unacceptable Risk Condition*** This reach is confined and straightened as a result of mechanical alterations and maintenance of the channel for irrigation water diversion and high flow conveyance. The reach at this point appears to be vertically stable due to grade control at the irrigation diversion structures and the siphon crossing at the downstream end of the reach. At this point, the majority of the reach is incised enough that historic floodplain and off channel areas that once existed have been hydraulically disconnected.	Vertical channel stability could not be accurately assessed in this subreach due to access restriction.	***At Risk Condition*** This reach experiences regular aggradation during flow events that mobilize significant bedload. Rates remain within levels that are not unexpected given the reach location at the apex of a depositional alluvial fan. Landowners have combatted this undesirable scenario which increases flooding risk, by dredging the channel, excavating additional high flow channels on the left bank, and armoring banks to limit lateral migration in response to natural channel aggradation.

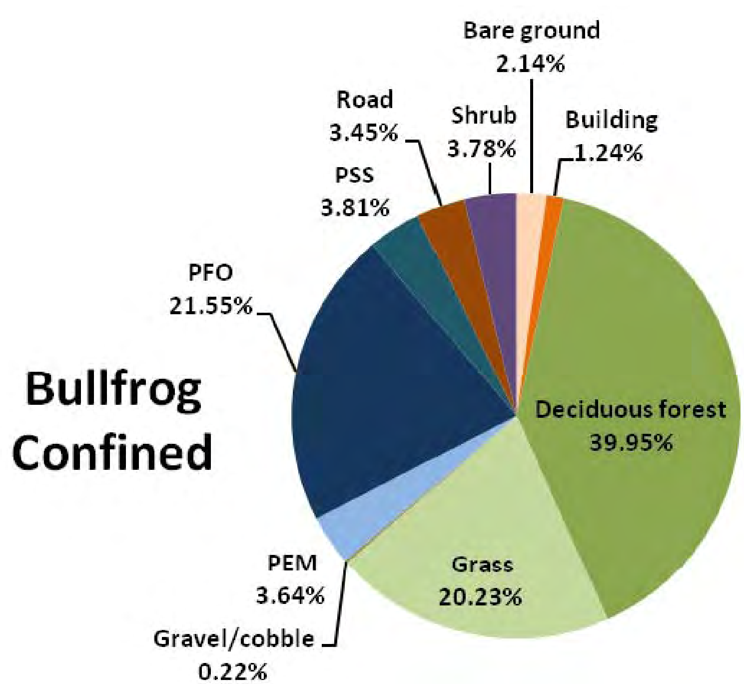
Table B-6 (continued). Habitat Condition Assessment of Reach FA (Fan Apex Reach).						
General Characteristics	**General Indicators**	**Specific Indicators**	**Subreach FA1 Condition**	**Subreach FA2 Condition**	**Subreach FA3 Condition**	**Subreach FA4 Condition**
Channel (cont'd)		Resiliency to Disturbance	***Adequate Condition*** Significant and dense riparian forest, numerous LWD, and a moderately wide active floodway make this reach fairly resilient to disturbance from large flood events that carry significant bedload.	***At Risk Condition*** Human channel alterations have all but eliminated natural habitat forming processes in this reach. The leveed and confined nature of the reach effectively transports peak flows and bedload through the reach, eliminating the chance for the channel and floodplain to respond. Habitat is limited by human alterations, but the existing bed and banks remainartificially resilient to the effect of large flood events that carry significant bedload.	Resiliency to disturbance could not be accurately assessed in this subreach due to access restriction.	***At Risk Condition*** Removal of riparian vegetation and channel modifications associated with residential development on the right bank floodplain limit resiliency to disturbance by to large flood events that carry significant bedload.
Riparian Vegetation	Condition	Structure	***At Risk Condition*** Natural structure of 63% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.	***Adequate Condition*** Natural structure of 85% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.	***Unacceptable Risk Condition*** Natural structure of 41% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.	***Adequate Condition*** Natural structure of 82% (total composition less roads, bare ground, grass, irrigation canals, and buildings) in riparian buffer.
		Disturbance (Human)	***Unacceptable Risk Condition*** 49% medium-large wood available in riparian buffer; 37% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); 4 mi/mi^2 roads in riparian buffer.	***At Risk Condition*** 55% medium-large wood available in riparian buffer; 15% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); no roads in riparian buffer.	***Unacceptable Risk Condition*** 39% medium-large wood available in riparian buffer; 59% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); no roads in riparian buffer.	***Adequate Condition*** 82% medium-large wood available in riparian buffer; 18% disturbed cover (roads, bare ground, grass, irrigation canals, and buildings); no roads in riparian buffer.
		Canopy Cover	***At Risk Condition*** 66% medium-large wood available in riparian buffer.	***At Risk Condition*** 76% medium-large wood available in riparian buffer.	***At Risk Condition*** 54% medium-large wood available in riparian buffer.	***Adequate Condition*** 93% medium-large wood available in riparian buffer.

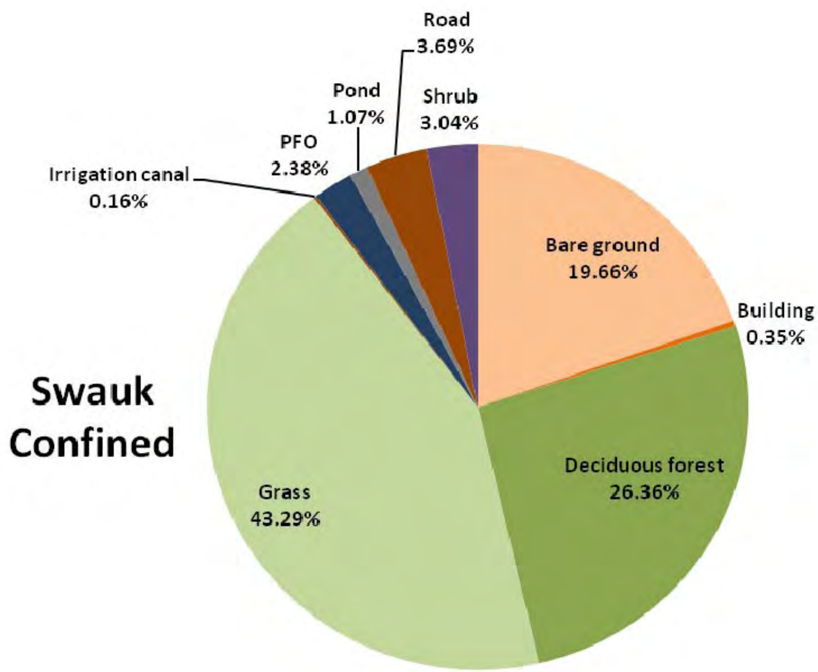
APPENDIX C

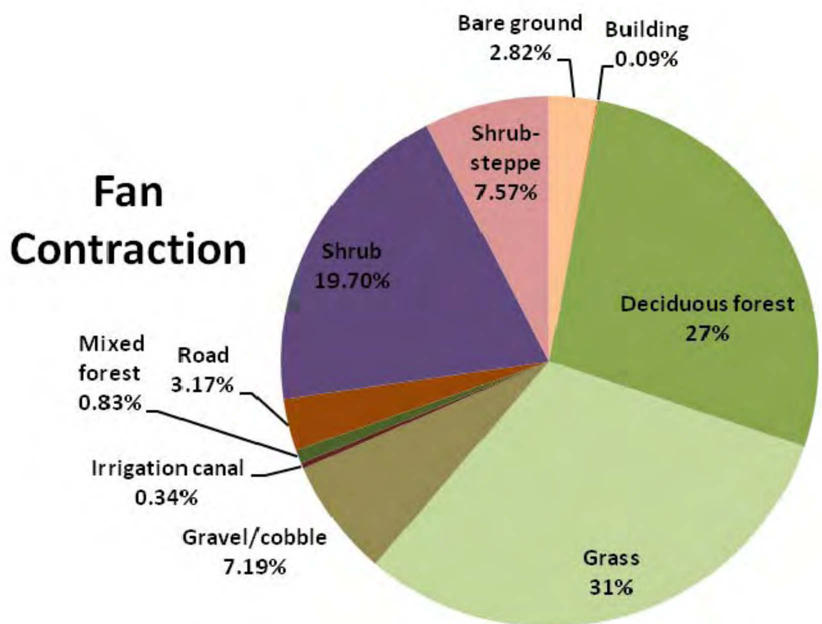
Vegetation Community Composition in Riparian Zone

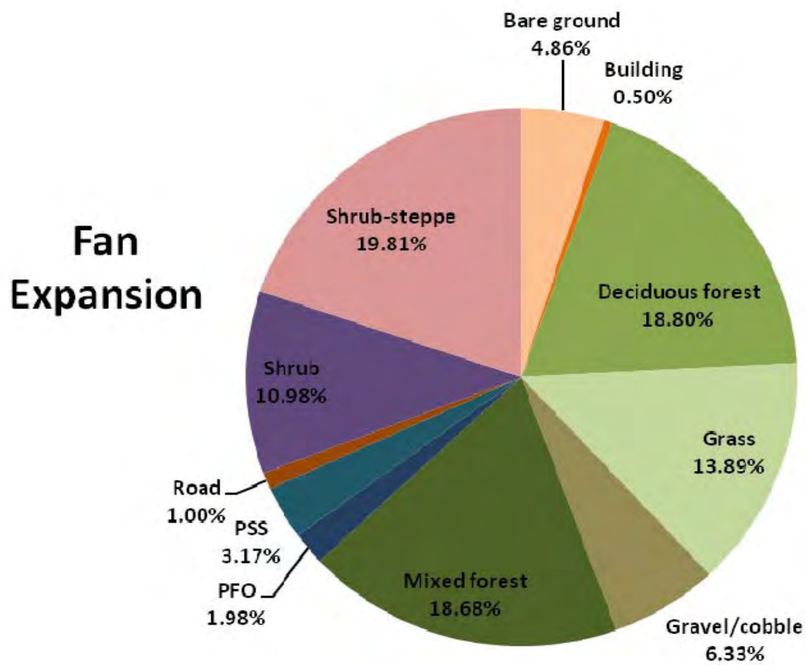
Riparian zone composition (within 30 meter belt along each bank) for each non-canyon reach in the Manastash Creek Corridor Habitat Enhancement and Flood Hazard Reduction Plan. [PFO = forested wetland; PSS = scrub-shrub wetland; PEM = emergent wetland (Cowardin et al. 1979)]. See main text for definition of vegetation types and constituent species.

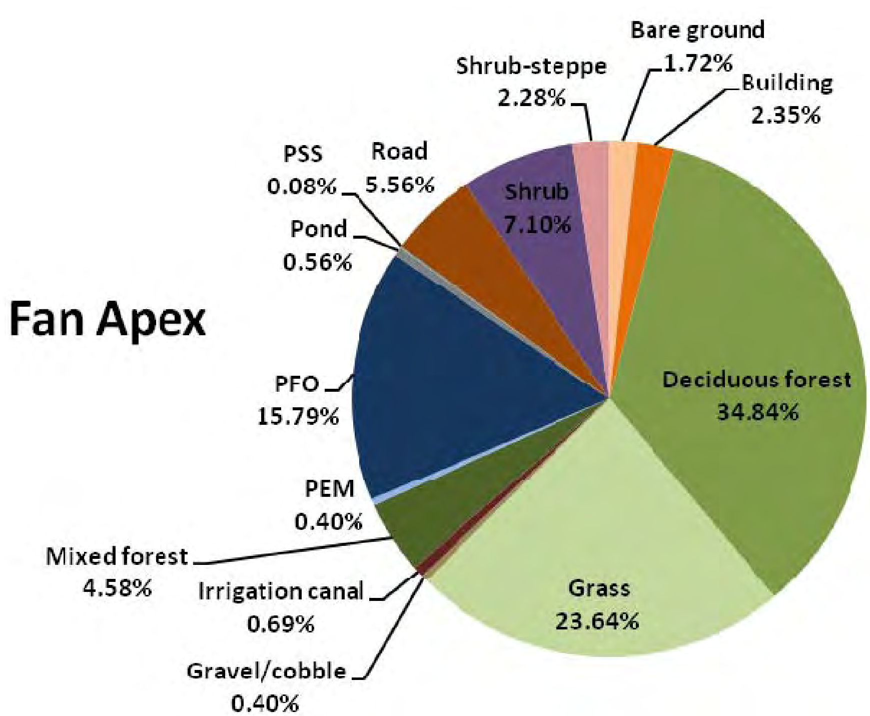





Swauk
Confined
Road
3.69%
Pond
1.07%
Shrub
3.04%
PFO
2.38%
Irrigation canal
0.16%
Bare ground
19.66%
Building
0.35%
Deciduous forest
26.36%
Grass
43.29%


Fan
Contraction
Bare ground
2.82%
Building
0.09%
Shrub-
steppe
7.57%
Shrub
19.70%
Deciduous forest
27%
Mixed
forest
0.83%
Road
3.17%
Irrigation canal
0.34%
Gravel/cobble
7.19%
Grass
31%


Fan Expansion
Bare ground 4.86%
Building 0.50%
Deciduous forest 18.80%
Grass 13.89%
Gravel/cobble 6.33%
Mixed forest 18.68%
PFO 1.98%
PSS 3.17%
Road 1.00%
Shrub 10.98%
Shrub-steppe 19.81%


Fan Apex
Bare ground 1.72%
Building 2.35%
Shrub-steppe 2.28%
Shrub 7.10%
Road 5.56%
PSS 0.08%
Pond 0.56%
PFO 15.79%
PEM 0.40%
Mixed forest 4.58%
Irrigation canal 0.69%
Gravel/cobble 0.40%
Grass 23.64%
Deciduous forest 34.84%

APPENDIX D

Photographic Documentation of Habitat Conditions

YAKIMA CONFLUENCE REACH

Photo D1. Stream channel and riparian habitat conditions in Reach YC.

Bullfrog Confined Reach

Photo D2. Stream channel and riparian habitat conditions in Reach BC1 downstream of Brown Road.

Photo D3. Large wood accumulation in Reach BC1.

Photo D4. Algae growth in stream channel and riparian habitat conditions in Subreach BC3.

SWAUK CONFINED REACH

Photo D5. Turbid water and algae in stream channel in Subreach SC1.

Photo D6. Dry stream channel conditions in Subreach SC2.

FAN CONTRACTION REACH

Photo D7. Dry stream channel, gravel berms, and unvegetated riparian conditions in Subreach FC1.

Photo D8. Groundwater fed base flow within confined stream channel in Subreach FC2.

Photo D9. Dry stream channel and riparian habitat conditions in Subreach FC4.

Photo D10. Dry stream channel and riparian habitat conditions in Subreach FC5.

FAN EXPANSION REACH

Photo D11. Dry stream channel and berm/revetment upstream of Cove Road in Subreach FE1.

Photo D12. Stream channel and riparian habitat conditions in Subreach FE2.

Photo D13. Entrenched stream channel and riparian habitat conditions downstream of Reed diversion in Subreach FE3.

Photo D14. Stream channel and riparian habitat conditions in Subreach FE4.

FAN APEX REACH

Photo D15. Stream channel and riparian habitat conditions in Subreach FA1.

Photo D16. Stream channel and bridge in Subreach FA2.

Photo D17. Stream channel and riparian habitat conditions in Subreach FA4.

CANYON REACH

Photo D18. Stream channel and riparian habitat conditions in Reach CY.

Photo D19. Stream channel and riparian habitat conditions in Reach CY.


Photo D20. Gravel berm along Manastash Road in Reach CY.

APPENDIX E

Habitat Assessment Field Data

Reach ID	YC 1	BC 1	BC 2	BC 3	SC 1
Channel Morphology					
Reach Type	Response	Response	Response	Response	Transport - forced by straightening, Response - should be naturally
Channel Gradient	<1%	1-2%	1-2%	1-2%	1-2%
Channel Dimensions					
Bankfull Width (ft)	variable	35	30-150	30-35	35-42
Bankfull Depth (ft)	variable	2.5-3	2	2.5-3	2
Flood Prone Width (ft)	>300'	150	>150	150	200
Montgomery & Buffington Channel Type	Pool/Riffle, Distributary	Pool/Riffle	Pool/Riffle	Pool/Riffle, Borderline Plane/Bed	Excavated/Constructed
Rosgen Channel Type					
Type	Da	C	D	C	C
Substrate	4	3	3, 4	3,4	3
Active Channel Process Stage	Aggrading, Depositional Distributary Fan	Incising, Aggrading (restabilizing), Alternating	Aggrading	Stable, Aggrading	Forced Stable, Widening - where bank erosion is occuring
Stream Complexity	Excellent/Complex	Excellent/Complex	Good	Fair	Poor/Simple
Sinuosity	Low/Minor (1.0-1.2)	Low/Minor (1.0-1.2)	Low/Minor (1.0-1.2)	Low/Minor (1.0-1.2)	Straight (1.0)
Functional LWD	Properly Functioning	Properly Functioning	Not Properly Functioning - jams of small debris only	Not Properly Functioning	Not Properly Functioning
Substrate Material					
Primary	Gravel	Cobble	Cobble	Cobble	Cobble
Secondary	Fines	Gravel	Gravel	Gravel	Gravel
Riffle/Gravel Cementation	Fair	Good	Good	Good	Good
Riffle/Gravel Embeddedness	50-75%	25-50%	0-25%	25-50%	0-25%
Bank Description					
Bank Material					
Primary	Fines	Cobble	Cobble	Cobble	Cobble
Secondary	Gravel	Gravel	Gravel	Gravel	Fines
Active Bank Erosion	Both Banks	Both Banks	Both Banks	Both Banks	Right Bank
Percent Eroded Banks	<5%	30-60%	5-30%	5-30%	5-30%
Bank Stability	Stable	Slightly Unstable	Slightly Unstable	Slightly Unstable	Slightly Unstable
Project Potential					
Alterations/Impacts	Minimal impact. Intact riparian forest. One cleared area near house -> reveg education	Fairly minimum, consider adding LWD key pieces in incised area downstream of huge debris pile jam	Riparian area on LB has limited vegetation. Reveg, add LWD key members. Reroute flow out of unvegetated area into trees.	Potential flood risk on RB (Wright)	Straightened. Siphon pipe exposed (may become a barrier at some point). WQ - dithc return flow observed (warm, silty, aquatic veg). Adding wood - catch 22, flood risk.
Potential Projects	riparian habitat/reveg, parcel acquisition, conserve/protect	parcel acquisition for flood mitigation (property US, RB)	stream habitat/LWD, riparian habitat/reveg	stream habitat/LWD	stream habitat/LWD, bank stabilization/halt sed source, riparian habitat/reveg
Typical Pool Conditions					
Formed By	LWD Jam	LWD Jam	LWD Jam	Tree Hardpoint	Unforced Riffle/Pool
Dimensions					
Length (ft)	5-50	25	15-20	25	45
Width (ft)	5-25	10	3-6	8	15
Residual Depth (ft)	2-5	3	1.5-2.5	2-2.5	2.5
Quality					
Overhead Cover	High	High	High	High	Low
Complexity	High	High	Med	Med	Low
Fines	Low, Med, High	Low	Low	Low	Low
Photos	6107-6114	6060-6071	6084-6106	6072-6083	6137-6155
General Notes/Comments	Highly variable, multi-thread, distributary channel network. Highly dynamic channel. Good habitat. Grogan allowed to dig/pump water right since they were excluded from the surface diversion @ Barnes Rd.	May warrant a bubreach break at huge debris jam -> US channel aggraded, DS incised. Lots of evidence of recent flood: deposition downed trees, large debris jam, disturbed channel conditions make characterization challenging.	Channel highly affected by toll flood - braided ?? Channels of different size. Confirm with lidar.	Reach DS of diversion for 750. Significant deposition, ?"? Formation in flood. Possible flood risk on RB. Minimal LWD/?? Habitat. Excellent shade from riparian vegetation. Significant algae. Nutrient issue? Ditch return flows?	No decent habitat. No LWD: rough restoration scenario with developed/developing FP on LB (pond, orchard?); no flood evidence on LB FP surprisingly - transport maximized in reach

Reach ID	SC 2	FC 1	FC 2	FC 4	FC 5
Channel Morphology					
Reach Type	Response	Response	Transport, some minor Response	Response	Response
Channel Gradient	1-2%	1-2%	1-2%	1-2%	1-2%
Channel Dimensions					
Bankfull Width (ft)	30-35	35	18-22	35	35
Bankfull Depth (ft)	2.5-3	2-2.5	2.0-2.5	2.5	2-2.5
Flood Prone Width (ft)	50-75	100	25-35	150	150 - manmade/dredged
Montgomery & Buffington Channel Type	Planebed (cobble boulder) - US of big jam, Pool/Riffle - DS of big jam	Excavated/Constructed	Pool/Riffle - inside, Excavated/Constructed - originally	Pool/Riffle	Excavated/Constructed
Rosgen Channel Type					
Type	G	D	G	C	C,D
Substrate	3	3	3	3	3
Active Channel Process Stage	Widening	Widening, Aggrading	Incising and Widening	Widening, Aggrading	Widening, Aggrading
Stream Complexity	Poor/Simple	Poor/Simple	Fair	Fair	Poor/Simple
Sinuosity	Low/Minor (1.0-1.2)	Low/Minor (1.0-1.2)	Low/Minor (1.0-1.2)	Low/Minor (1.0-1.2)	Low/Minor (1.0-1.2)
Functional LWD	Not Properly Functioning	Not Properly Functioning	Not Properly Functioning	Not Properly Functioning	Not Properly Functioning
Substrate Material					
Primary	Cobble	Cobble	Cobble	Cobble	Cobble
Secondary	Boulder	Boulder	Boulder	Boulder	Boulder
Riffle/Gravel Cementation	Excellent	Good	Excellent	Good	Good
Riffle/Gravel Embeddedness	0-25%	0-25%	0-25%	0-25%	0-25%
Bank Description					
Bank Material					
Primary	Cobble	Cobble	Cobble	Fines	Fines
Secondary	Fines	Fines	Fines	Cobble	Cobble
Active Bank Erosion	Both Banks	Both Banks	Both Banks	Both Banks	Both Banks
Percent Eroded Banks	5-30%	60-100%	30-60%	30-60%	60-100%
Bank Stability	Slightly Unstable	Completely Unstable	Moderately Unstable	Moderately Unstable	Completely Unstable
Project Potential					
Alterations/Impacts	Tough call, real conflict between instream habitat (log jam) and flood risk. Levees below Serenity Ln. Narrow bridges. Some unvegetated banks. Dewatered!	Replace bridge (too narrow, failing abutments). Tricky instream porjects due to flood risk. Instream flow. Construsted ?? dykes due to aggraded material.	Historically channelized, very incised, badly dewatered: different restoration scenario - try improving in-channel habitat without increasing flood risk.	Lack of vegetation and LWD	Dredged post flood, levees/spoil piles on both sides. High flood risk. No instream habitat.
Potential Projects	stream habitat/LWD, bank stabilization/halt sed source, riparian habitat/reveg	stream habitat/LWD, bank stabilization/halt sed source, riparian habitat/reveg, structural removal, no water	stream habitat/LWD, bank stabilization/halt sed source, riparian habitat/reveg, more water	stream habitat/LWD, riparian hanitat/reveg	stream habitat/LWD, bank stabilization/halt sed source, riparian habitat/reveg, water
Typical Pool Conditions					
Formed By	LWD Jam	Riprap/Rock Groin	Unforced Riffle/Pool	Unforced Riffle/Pool	Tree Hardpoint
Dimensions					
Length (ft)	50	30	40	No Access	35
Width (ft)	20	15	15	No Access	18
Residual Depth (ft)	1.0-1.5	1.5-2	1.5	No Access	4
Quality					
Overhead Cover	Low	Low	Low	No Access	Low
Complexity	Low	Low	Low	No Access	Low
Fines	Low	Low	Low	No Access	Low
Photos	6115-6135	6177-6198	6156-6178	6220-6221	6199-6216
General Notes/Comments	Some GW ?? Lower 1/2 of surveyed reach, completely dry above: incised/confined but able to access FP in large events as evidences by splays. Likely requires debris jams, large splay/overtopping on LB damaged as caused by debris jams - only good pool in reach (3-4' deep with cover).	Reach experiences significant aggradation/widening in RB during last flood. Serenity Ln bridge is undersized construction between FC2 &SC2 transport reaches.	Observed GW/?? flow only: many juvenile and smaller adult solmonids (ro 10") present in reach. Trapped. Erosions resistant banks allow for regular pool/riffle sequence. Flood flow depth ~ 6 ft deep in reach.	Not able to access channel in this reach. All data estimated from adjacent property. Visual of channel from adjacent property suggest similar to FC 5 without the dredge tailing levees.	?? bridge ??: lateral widening in response to bedload deposition - bank not resistant to erosions like DS (FC 1-2). Bed more resistant to erosion than banks.

Reach ID	FE 1	FE 2 - DS of Reed	FE 2 - Carns	FE 3	FE 4
Channel Morphology					
Reach Type	Response	Response	Response	Transport	Response
Channel Gradient	1-2%	1-2% ~	1-2%	1-2%	1-2%
Channel Dimensions					
Bankfull Width (ft)	25	40-50	56	20	28-35
Bankfull Depth (ft)	3	2-2.5	2.5	3	2.0-1.5
Flood Prone Width (ft)	150	150	150	32	>300
Montgomery & Buffington Channel Type	Planebed (cobble, boulder), Excavated/Constructed	Pool/Riffle	Pool/Riffle	Planebed (cobble/boulder)	Pool/Riffle
Rosgen Channel Type					
Type	B,C	C	C,D	A	C
Substrate	3	3	3	2,3	3
Active Channel Process Stage	Aggrading (restabilizing)	Widening, Aggrading	Widening, Aggrading	Incising	Stable
Stream Complexity	Poor/Simple	Fair ~ Poor/Simple	Poor/Simple	Fair	Excellent/Complex
Sinuosity	Low/Minor (1.0-1.2)	Low/Minor (1.0-1.2)	Low/Minor (1.0-1.2)	Low/Minor (1.0-1.2)	Low/Minor (1.0-1.2)
Functional LWD	Not Properly Functioning	Not Properly Functioning	Not Properly Functioning	Not Properly Functioning	Not Properly Functioning
Substrate Material					
Primary	Cobble	Cobble	Cobble	Cobble	Cobble
Secondary	Boulder	Boulder	Boulder	Boulder	Gravel, Boulder
Riffle/Gravel Cementation	Excellent	Good	Excellent	Excellent	Excellent
Riffle/Gravel Embeddedness	0-25%	0-25%	0-25%	0-25%	5-30%
Bank Description					
Bank Material					
Primary	Cobble	Cobble	Cobble	Cobble	Cobble
Secondary	Fines	Fines	Fines	Fines	Fines
Active Bank Erosion	Both Banks	Both Banks	Both Banks	Both Banks	Both Banks
Percent Eroded Banks	<5%	60-100%	60-100%	30-60%	5-30%
Bank Stability	Slightly Unstable	Moderately Unstable	Completely Unstable	Slightly Unstable	Slightly Unstable
Project Potential					
Alterations/Impacts	Tough to balance flood risk. Reveg.	Some wider FP, less incised, good reveg opportunity, also adding instream structure (had points for pool formation)	Destabilized banks, no resiliency to high energy from vegetation. Dewatered every summer - related to lack of veg?	Incised, impacted by Reed diversion (barrier). Potential to improve instream habitat without increasing flood risk.	Not incised. Habitat quite good. Project potential limited by flood risk. Barrier at DS end of reach forcing grade (limits incision).
Potential Projects	riparian habitat/reveg, structure removal, replace undersized bridge, water	stream habitat/LWD, bank stabilization, riparian habitat/reveg, floodplain/wetland reconnection, water	stream habitat/LWD, bank stabilization/halt sed source, riparian habitat/reveg	fish barrier removal, stream habitat/LWD, halt incision - probably with boulders instead of LWD, structure removal - screen inlet at least	fish barrier removal, stream habitat/LWD, bank stabilization, riparian habitat/reveg, parcel acquisition, limited reveg & bank stabilization stability at properties
Typical Pool Conditions					
Formed By	Riprap/Rock Groin	Hardpoint Roots - Natural hardpan	Unforced Riffle/Pool	Step/Hardpoint	Bank Hardpoints/Roots
Dimensions					
Length (ft)	25	25	50	25	20
Width (ft)	10	15	20	10	8-10
Residual Depth (ft)	1.5	1.7	1.5	2-2.5	2-3
Quality					
Overhead Cover	Low	Low	Low	Med	High
Complexity	Low	Low	Low	Med	Med
Fines	Low	Low	Low	Low	Low
Photos	6326-6334	6236-6250	6335-6340	6222-6235, 6251-6253 (Reed ditch)	6254-6272
General Notes/Comments	Leveed & impacted by small bridge. Stable banks. Minimal/no habitat. Observed dry.	Response reach. Not badly incised like upstream. Habitat and bank stability directly realted to woody vegetation (cottonwood mainly, some conifer). Reach is known to go dry at Reed Diversion. A few Juvi - 10" RBT/Steel spotted in deepest, most shaded/complete pool in sample reach.	Completely dewatered. Poor veg. Extreme widening in response to flood/deposition. Banks not erosion resistant. No habitat survey done - access to only 1 parcel in reach.	Reed diversion = barrier. Incising above, not below. Steep plane bed verging on step pool morphology. Some decent forced pools at the tree roots. Bank hard. Very incised. Nicely shaded. Reach known to go dry at Reed Diversion. A few sighted ?? RBT/steel.	Reed diversion = grade control halting incision in reach. Godd floodplain connectivity & vegetation. Good habitat complexity. Presumably ?? watered. Good sorting of bedload. Not much spawning gravel deposits in sample reach. Landowner noted large channel response to flood, yet habitat remains good. Resiliense of stream to flood increased by mature vegetation and access to FP.

Reach ID	FA 1	FA 2	FA 4
Channel Morphology			
Reach Type	Response	Transport	Response
Channel Gradient	1-2%	1-2%	1-2%
Channel Dimensions			
Bankfull Width (ft)	35	28-32	35 *
Bankfull Depth (ft)	2.5	2.5	2.5 *
Flood Prone Width (ft)	>100	>100	*hard to classify after massive aggradation
Montgomery & Buffington Channel Type	Pool/Riffle	Planebed (cobble, boulder), Excavated/Constructed	Pool/Riffle
Rosgen Channel Type			
Type	C	B,C	C,D
Substrate	3,4	4	3
Active Channel Process Stage	Stable	Forced Stable	Aggrading
Stream Complexity	Excellent/Complex	Poor/Simple	Fair
Sinuosity	Low/Minor (1.0-1.2), Appreciable (1.2-1.5)	Low/Minor (1.0-1.2)	Low/Minor (1.0-1.2)
Functional LWD	Properly Functioning	Not Properly Functioning	Not Properly Functioning
Substrate Material			
Primary	Cobble	Cobble	Cobble
Secondary	Gravel, Boulder	Gravel	Gravel
Riffle/Gravel Cementation	Excellent	Good	Good
Riffle/Gravel Embeddedness	0-25%	25-50%	0-25%
Bank Description			
Bank Material			
Primary	Cobble	Cobble	Cobble
Secondary	Fines	Fines, Other (armor)	Fines
Active Bank Erosion	Both Banks	Both Banks	Both Banks
Percent Eroded Banks	5-30%	<5%	30-60%
Bank Stability	Slightly Unstable	Armored/Revetment	Moderately Unstable
Project Potential			
Alterations/Impacts	Relatively good: look at passage as ??/bridge. Some reveg where lacking large woody trees. Consider protecting this area as undeveloped. Room for FP work on RB	Channel form controlled by diversions, siphon. Opportunities limited by structures/development. Substrate coarser where not impacted by structures.	Massive human channel alterations after flood. Aggradation & ice jams.
Potential Projects	fish barrier removal, riparian habitat/reveg, floodplain/wetland reconnection/storage, parcel acquisition	riparian habitat/reveg	floodplain/wetland reconnection
Typical Pool Conditions			
Formed By	LWD Jam	Riprap/Rock Groin	Riprap/Rock Groin
Dimensions			
Length (ft)	40	45	50
Width (ft)	12	15	15
Residual Depth (ft)	3-4	1.5	2-2.5
Quality			
Overhead Cover	High	Med	Low
Complexity	High	Low	Low
Fines	Low	Low	Med
Photos	6288-6308	6273-6287	6309-6325
General Notes/Comments	Some of the best habitat we've seen. Good sorting due to hydraulic complexity & LWD. Great riparian. Not badly incised. Protect.	2 diversion up top, siphon at bridge at DS end. FP connectivity intentionally/mechanically limited. Overbank area floods from upstream reach.	Reach experienced major aggradation/deposition in flood. Landowners got permits to dry channels on LB FP. Water somewhat at 1' freeboard at Berger. Landowners note significant ice accumulations in reach as well.

Manastash Creek Habitat Assessment
Herrera Environmental Consultants

Survey Date	7/30/2012
Reach	BC 1
Starting Station	0
Survey Direction	DS to US

Habitat Delineation

Feature	**Starting Station**	**End Station**	**Length**
Riffle	0	15	15
Pool	15	40	25
Riffle	40	70	30
Pool	70	95	25
Riffle	95	135	40
Pool	135	145	10
Riffle	145	205	60
Flatwater	205	235	30
Pool	235	245	10
Riffle	245	295	50
Flatwater	295	445	150
Debris Jam	445	445	
Pool	445	465	20
Riffle	465	495	30
Flatwater	495	515	20
Riffle	515	535	20
Pool	535	590	55
Riffle	590	655	65
Flatwater	655	705	50

# Pools =	6	**Pools/Mile =**	45		**Habitat units/Mile =**	135

LWD Survey

Small - 6” x 20’	>50, likely >100			
Medium - 12” x 35	10		Med + Lg =	11
Large 20” x 35’	1		Pcs / Mile =	82

General Notes

Part incised, part aggraded US of huge debris jam. Flooding issues in property at US end of sample reach.

Manastash Creek Habitat Assessment
Herrera Environmental Consultants

Survey Date	7/30/2012					
Reach	BC 2					
Starting Station	0					
Survey Direction	DS to US					

Habitat Delineation

Feature	**Starting Station**	**End Station**	**Length**			
Riffle	0	15	15			
Pool	15	45	30			
Riffle	45	70	25			
Flatwater	70	100	30			
Riffle	100	175	75			
Pool	175	190	15			
Riffle	190	235	45			
Flatwater	235	250	15			
Riffle	250	360	110			
Pool	360	380	20			
Flatwater	380	410	30			
Riffle	410	430	20			
Pool	430	440	10			
Debris Jam	440	490	50			
Pool	490	505	15			
Riffle	505	525	20			
Pool	525	535	10			
Riffle	535	605	70			
Flatwater	605	615	10			
Riffle	615	645	30			
Flatwater	645	665	20			
Riffle	665	670	5			
Flatwater	670	730	60			
Riffle	730	745	15			
Pool	745	775	30			
Riffle	775	805	30			
Flatwater	805	865	60			
Riffle	865	900	35			
Flatwater	900	915	15			
Riffle	915	930	15			
Pool	930	950	20			
Riffle	950	955	5			
Flatwater	955	980	25			
Riffle	980	1005	25			
Flatwater	1005	1025	20			
Riffle	1025	1085	60			
Pool	1085	1110	25			
Riffle	1110	1135	25			
# Pools =	9	**Pools/Mile =**	42		**Habitat units/Mile =**	177

LWD Survey

Small - 6” x 20’	15	unknown # in jams		
Medium - 12” x 35’	0		Med + Lg =	0
Large 20” x 35’	0		Pcs / Mile =	0

General Notes						
LB FP logged. Flood resulted in significant aggradation and braiding:						
Some good micro habitat where riparian veg is intact. RB logged area is very bad shape.						

Manastash Creek Habitat Assessment
Herrera Environmental Consultants

Survey Date	7/30/2012					
Reach	BC 3					
Starting Station	0					
Survey Direction	US to DS					

Habitat Delineation

Feature	**Starting Station**	**End Station**	**Length**			
Flatwater	705	715	10			
Riffle	675	705	30			
Flatwater	635	675	40			
Riffle	575	635	60			
Flatwater	560	575	15			
Pool	535	560	25			
Riffle	505	535	30			
Flatwater	470	505	35			
Riffle	450	470	20			
Pool	430	450	20			
Riffle	395	430	35			
Flatwater	335	395	60			
Riffle	240	335	95			
Flatwater	215	240	25			
Riffle	185	215	30			
Flatwater	155	185	30			
Riffle	120	155	35			
Pool	85	120	35			
Riffle	0	85	85			
# Pools =	3	**Pools/Mile =**	22		**Habitat units/Mile =**	140

LWD Survey

Small - 6” x 20’	3			
Medium - 12” x 35’	0		Med + Lg =	0
Large 20” x 35’	0		Pcs / Mile =	0

General Notes

Manastash Creek Habitat Assessment						
Herrera Environmental Consultants						
Survey Date	7/31/2012					
Reach	SC 1					
Starting Station	0					
Survey Directior	US to DS					
Habitat Delineation		Starting at Siphon Pipe exposed in bed				
Feature	**Starting Station**	**End Station**	**Length**			
Pool	1055	1075	20			
Flatwater	990	1055	65			
Riffle	630	990	360			
Pool	605	630	25			
Riffle	275	605	330			
Pool	230	275	45			
Riffle	165	230	65			
Flatwater	95	165	70			
Riffle	0	95	95			
# Pools =	3	**Pools/Mile =**	15		**Habitat units/Mile =**	44
LWD Survey						
Small - 6” x 20’	0					
Medium - 12” x 35	0		Med + Lg =	1		
Large 20” x 35’	1	human placed	Pcs / Mile =	5		
General Notes						
Almost no diversity of habitat - excavated channel, transport reach until DS end where some widening						
occurs and one riffle pool sequence results.						

Manastash Creek Habitat Assessment						
Herrera Environmental Consultants						
Survey Date	7/31/2012					
Reach	SC 2					
Starting Station	0					
Survey Directior	US to DS					
Habitat Delineation		Dry Channel - Logged Pool and Riffle only				
Feature	**Starting Station**	**End Station**	**Length**			
Riffle	525	1025	500			
Pool	475	525	50			
Riffle	400	475	75			
Pool	360	400	40			
Riffle	310	360	50			
Pool	255	310	55			
Riffle	215	255	40			
Pool	165	215	50			
Riffle	125	165	40			
Pool	75	125	50			
Riffle	0	75	75			
# Pools =	5	**Pools/Mile =**	26		**Habitat units/Mile =**	57
LWD Survey						
Small - 6” x 20’	10	mainly single pieces				
Medium - 12” x 3!	9		Med + Lg =	9		
Large 20” x 35’	0		Pcs / Mile =	46		
General Notes						
Pool quality very poor - shallow, no cover.						

Manastash Creek Habitat Assessment						
Herrera Environmental Consultants						
Survey Date	7/31/2012					
Reach	FC 1					
Starting Station	0					
Survey Direction	US to DS					
Habitat Delineation		Dry Channel - Logged Pool and Riffle only				
Feature	**Starting Station**	**End Station**	**Length**			
Riffle	500	555	55			
Pool	460	500	40			
Riffle	385	460	75			
Pool	360	385	25			
Riffle	0	360	360			
# Pools =	2	**Pools/Mile =**	19		**Habitat units/Mile =**	48
LWD Survey						
Small - 6" x 20'	0					
Medium - 12" x 35'	0		Med + Lg =	0		
Large 20" x 35'	0		Pcs / Mile =	0		
General Notes						
No habitat complexity, no water.						

Manastash Creek Habitat Assessment
Herrera Environmental Consultants

Survey Date	7/31/2012					
Reach	FC 2					
Starting Station	0					
Survey Direction	US to DS					
Habitat Delineation		Dry Channel - Logged Pool and Riffle only				
Feature	**Starting Station**	**End Station**	**Length**			
Riffle	880	1025	145			
Pool	845	880	35			
Riffle	830	845	15			
Pool	800	830	30			
Riffle	720	800	80			
Pool	680	720	40			
Riffle	630	680	50			
Pool	610	630	20			
Riffle	505	610	105			
Bridge	505	505				
Riffle	405	505	100			
Pool	365	405	40			
Riffle	270	365	95			
Pool	235	270	35			
Riffle	140	235	95			
Pool	100	140	40			
Riffle	0	100	100			
# Pools =	7	**Pools/Mile =**	36		**Habitat units/Mile =**	82
LWD Survey						
Small - 6” x 20’	1					
Medium - 12” x 35’	1		Med + Lg =	1		
Large 20” x 35’	0		Pcs / Mile =	5		
General Notes						
Regular pool/riffle sequence in badly incised (excavated) channel.						
Banks resistant to erosion, consolidated alluvium.						

Manastash Creek Habitat Assessment						
Herrera Environmental Consultants						
Survey Date	7/31/2012					
Reach	FC 5					
Starting Station	0					
Survey Directior	US to DS					
Habitat Delineation		Dry Channel - Logged Pool and Riffle only				
Feature	**Starting Station**	**End Station**	**Length**			
Riffle	710	795	85			
Pool	675	710	35			
Riffle	0	675	675			
# Pools =	1	**Pools/Mile =**	7		**Habitat units/Mile =**	20
LWD Survey						
Small - 6” x 20’	1					
Medium - 12” x 35	0		Med + Lg =	0		
Large 20” x 35’	0		Pcs / Mile =	0		
General Notes						
Almost no habitat variation, entire reach dredged, spoil pile leaves on both banks. No water.						

Manastash Creek Habitat Assessment						
Herrera Environmental Consultants						
Survey Date	8/2/2012					
Reach	FE 1					
Starting Station	0					
Survey Directior	US to DS					
Habitat Delineation		Dry Channel - Logged Pool and Riffle only				
Feature	**Starting Station**	**End Station**	**Length**			
Riffle	135	330	195			
Pool	115	135	20			
Riffle	50	115	65			
Pool	20	50	30			
Riffle	0	20	20			
# Pools =	2	**Pools/Mile =**	32		**Habitat units/Mile =**	80
LWD Survey						
Small - 6” x 20’	1					
Medium - 12” x 35	0		Med + Lg =	0		
Large 20” x 35’	0		Pcs / Mile =	0		
General Notes						

Manastash Creek Habitat Assessment
Herrera Environmental Consultants

Survey Date	8/1/2012
Reach	FE 2
Starting Station	0
Survey Direction	US to DS

Habitat Delineation

Feature	**Starting Station**	**End Station**	**Length**			
Riffle	360	605	245			
Pool	325	360	35			
Riffle	230	325	95			
Pool	215	230	15			
Riffle	180	215	35			
Pool	155	180	25			
Riffle	130	155	25			
Pool	105	130	25			
Flatwater	70	105	35			
Riffle	0	70	70			
# Pools =	4	**Pools/Mile =**	35		**Habitat units/Mile =**	87

LWD Survey

Small - 6” x 20’	4			
Medium - 12” x 35’	1		Med + Lg =	1
Large 20” x 35’	0		Pcs / Mile =	9

General Notes

Habitat units directly associated in bank hard points (vegetation primarily, some geologic).
Channel narrows & habitat improves where large woody riparian veg is present.

Manastash Creek Habitat Assessment
Herrera Environmental Consultants

Survey Date	8/1/2012					
Reach	FE 3					
Starting Station	0					
Survey Direction	US to DS					

Habitat Delineation

Feature	**Starting Station**	**End Station**	**Length**			
Pocket	365	510	145			
Riffle	355	365	10			
Pool	335	355	20			
Riffle	320	335	15			
Flatwater	300	320	20			
Pocket	200	300	100			
Riffle	180	200	20			
Pool	145	180	35			
Riffle	135	145	10			
Pool	110	135	25			
Pocket	70	110	40			
Pool	55	70	15			
Riffle	40	55	15			
Pool	0	40	40			
# Pools =	5	**Pools/Mile =**	52		**Habitat units/Mile =**	145

LWD Survey

Small - 6" x 20'	2			
Medium - 12" x 35'	0		Med + Lg =	1
Large 20" x 35'	1		Pcs / Mile =	10

General Notes

Manastash Creek Habitat Assessment						
Herrera Environmental Consultants						
Survey Date	8/1/2012					
Reach	FE 4	US of Reed Diversion				
Starting Station	0					
Survey Direction	US to DS					
Habitat Delineation		End just US of Reed Division				
Feature	**Starting Station**	**End Station**	**Length**			
Riffle	635	665	30			
Flatwater	610	635	25			
Pool	560	610	50			
Riffle	525	560	35			
Pool	485	525	40			
Riffle	480	485	5			
Pool	455	480	25			
Flatwater	440	455	15			
Riffle	410	440	30			
Flatwater	395	410	15			
Pool	365	395	30			
Flatwater	300	365	65			
Riffle	280	300	20			
Pool	265	280	15			
Riffle	250	265	15			
Pool	230	250	20			
Riffle	220	230	10			
Flatwater	195	220	25			
Riffle	185	195	10			
Pool	140	185	45			
Flatwater	80	140	60			
Riffle	0	80	80			
# Pools =	7	**Pools/Mile =**	56		**Habitat units/Mile =**	175
LWD Survey						
Small - 6” x 20’	5					
Medium - 12” x 35	4		Med + Lg =	4		
Large 20” x 35’	0		Pcs / Mile =	32		
General Notes						
Most LWD and trees removed by irrigation district after flood based on landowner account. Levees US of diversion.						

Manastash Creek Habitat Assessment
Herrera Environmental Consultants

Survey Date	8/1/2012
Reach	FA 1
Starting Station	0
Survey Direction	US to DS

Habitat Delineation — Start at Siphon Return

Feature	**Starting Station**	**End Station**	**Length**
Pocket	1000	1055	55
Pool	975	1000	25
Riffle	900	975	75
Pool	840	900	60
Flatwater	815	840	25
Riffle	790	815	25
Pool	755	790	35
Riffle	725	755	30
Pool	660	725	65
Flatwater	635	660	25
Riffle	615	635	20
Pool	565	615	50
Flatwater	550	565	15
Riffle	530	550	20
Pool	505	530	25
Riffle	480	505	25
Pool	420	480	60
Riffle	395	420	25
Flatwater	370	395	25
Pool	340	370	30
Riffle	315	340	25
Flatwater	280	315	35
Riffle	255	280	25
Flatpan	215	255	40
Riffle	190	215	25
Flatwater	150	190	40
Riffle	125	150	25
Pool	105	125	20
Riffle	60	105	45
Flatwater	45	60	15
Pool	0	45	45

# Pools =	10	**Pools/Mile =**	50	**Habitat units/Mile =**	155

LWD Survey

Small - 6” x 20’	16		
Medium - 12” x 35	10	Med + Lg =	11
Large 20” x 35’	1	Pcs / Mile =	55

General Notes

Quite diverse. Signs of flood (large deposits) but great habitat. Resilience in disturbance from woody veg/trees.

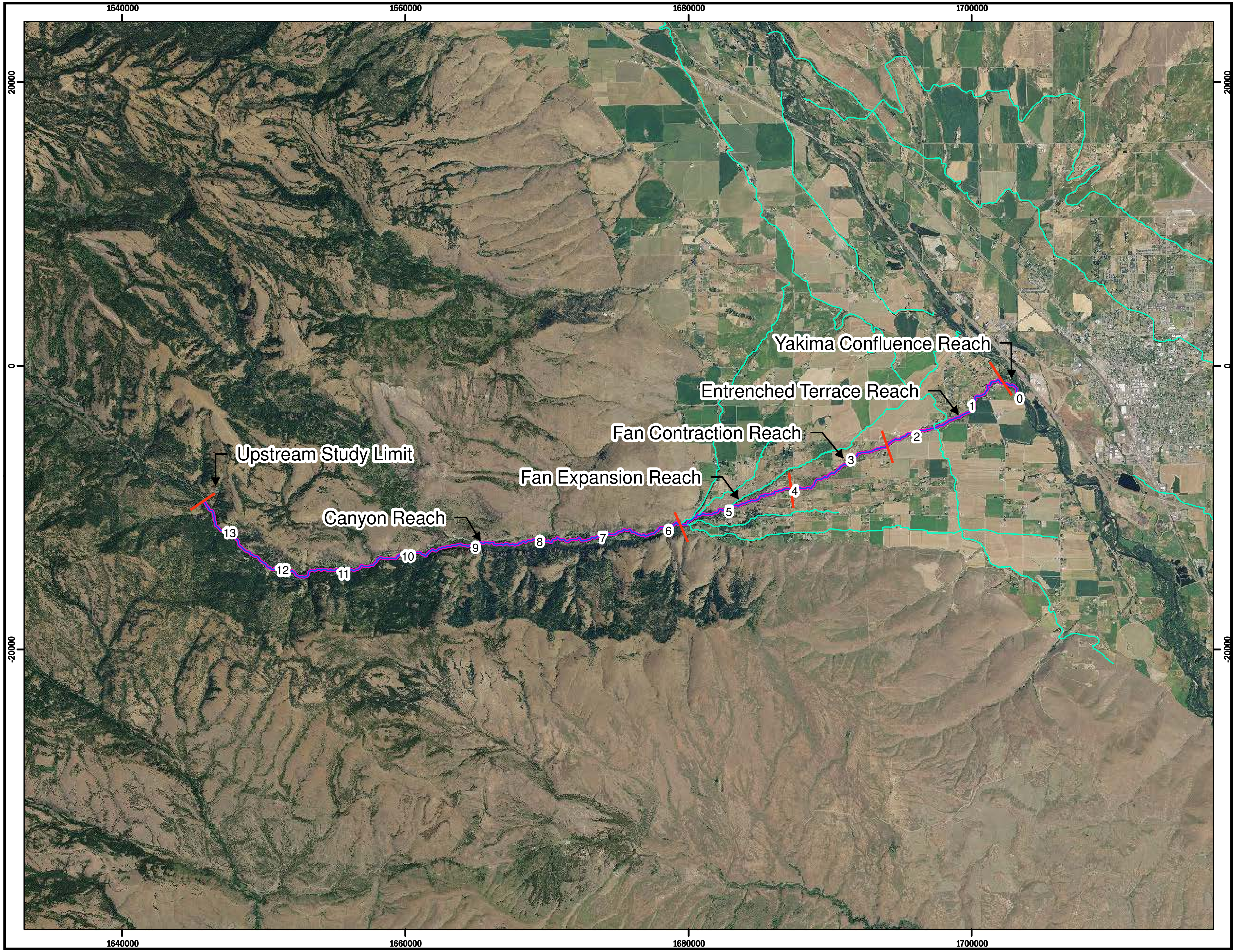
Manastash Creek Habitat Assessment						
Herrera Environmental Consultants						
Survey Date	8/1/2012					
Reach	FA 2					
Starting Station	0					
Survey Direction	US to DS					
Habitat Delineation		Start at top of upper division				
Feature	**Starting Station**	**End Station**	**Length**			
Steppool ladder	1050	1185	135			
Flatwater	1005	1050	45			
Riffle	980	1005	25			
Flatwater	905	980	75			
Riffle	810	905	95			
Pool	770	810	40			
Flatwater	760	770	10			
Pool	715	760	45			
Steppool ladder	590	715	125			
Pocket	490	590	100			
Pool	450	490	40			
Riffle	390	450	60			
Flatwater	315	390	75			
Pocket	215	315	100			
Riffle	185	215	30			
Flatwater	85	185	100			
Riffle	0	85	85			
# Pools =	3	**Pools/Mile =**	13		**Habitat units/Mile =**	76
LWD Survey						
Small - 6” x 20’	2					
Medium - 12” x 35	0		Med + Lg =	0		
Large 20” x 35’	0		Pcs / Mile =	0		
General Notes						

Manastash Creek Habitat Assessment						
Herrera Environmental Consultants						
Survey Date	8/1/2012					
Reach	FA 4					
Starting Station	0					
Survey Direction	US to DS					
Habitat Delineation		Start at top of upper division				
Feature	**Starting Station**	**End Station**	**Length**			
Riffle	1140	1170	30			
Pool	1110	1140	30			
Flatwater	1090	1110	20			
Riffle	900	1090	190			
Pool	835	900	65			
Riffle	700	835	135			
Pool	640	700	60			
Riffle	630	640	10			
Pool	605	630	25			
Riffle	565	605	40			
Flatwater	490	565	75			
Riffle	465	490	25			
Pool	390	465	75			
Riffle	0	390	390			
# Pools =	5	**Pools/Mile =**	23		**Habitat units**	63
LWD Survey						
Small - 6” x 20’	1					
Medium - 12” x 35	2		Med + Lg =	2		
Large 20” x 35’	0		Pcs / Mile =	9		
General Notes						
Human impacts - attempts at controlling sediment and water.						

APPENDIX F

Flood and Erosion Hazard Figures

Figure F1
Flood and Erosion
Sub-Reach Index



Legend

- Reach Limits
- Irrigation
- Manastash Creek
- River Mile

N

0 3,000 6,000 12,000
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 2011 NAIP

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure1.mxd (11/5/2012)

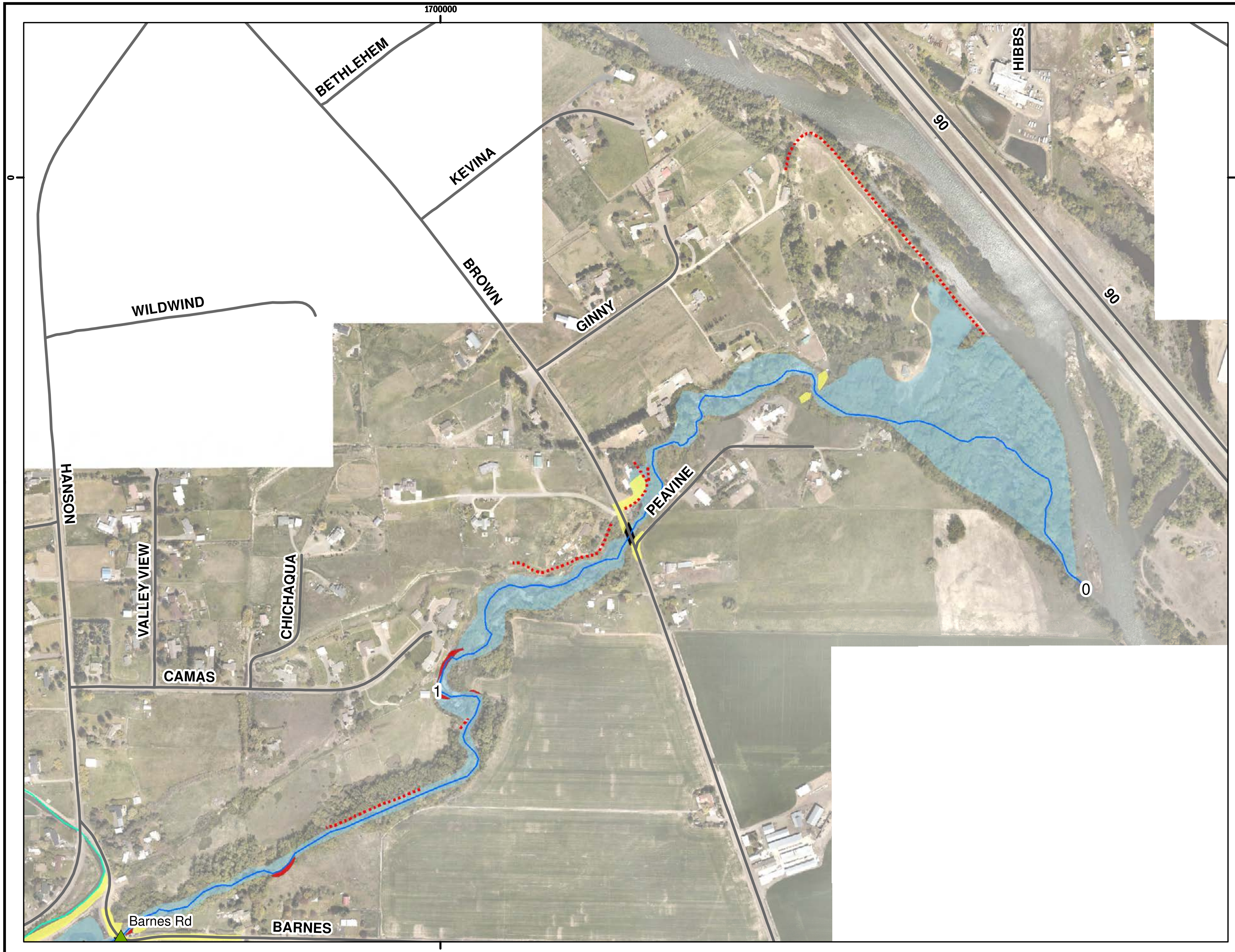


Figure F2
Flood and Erosion Overview
Yakima Confluence
and Entrenched Terrace Reaches

Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 2012 3Di West

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

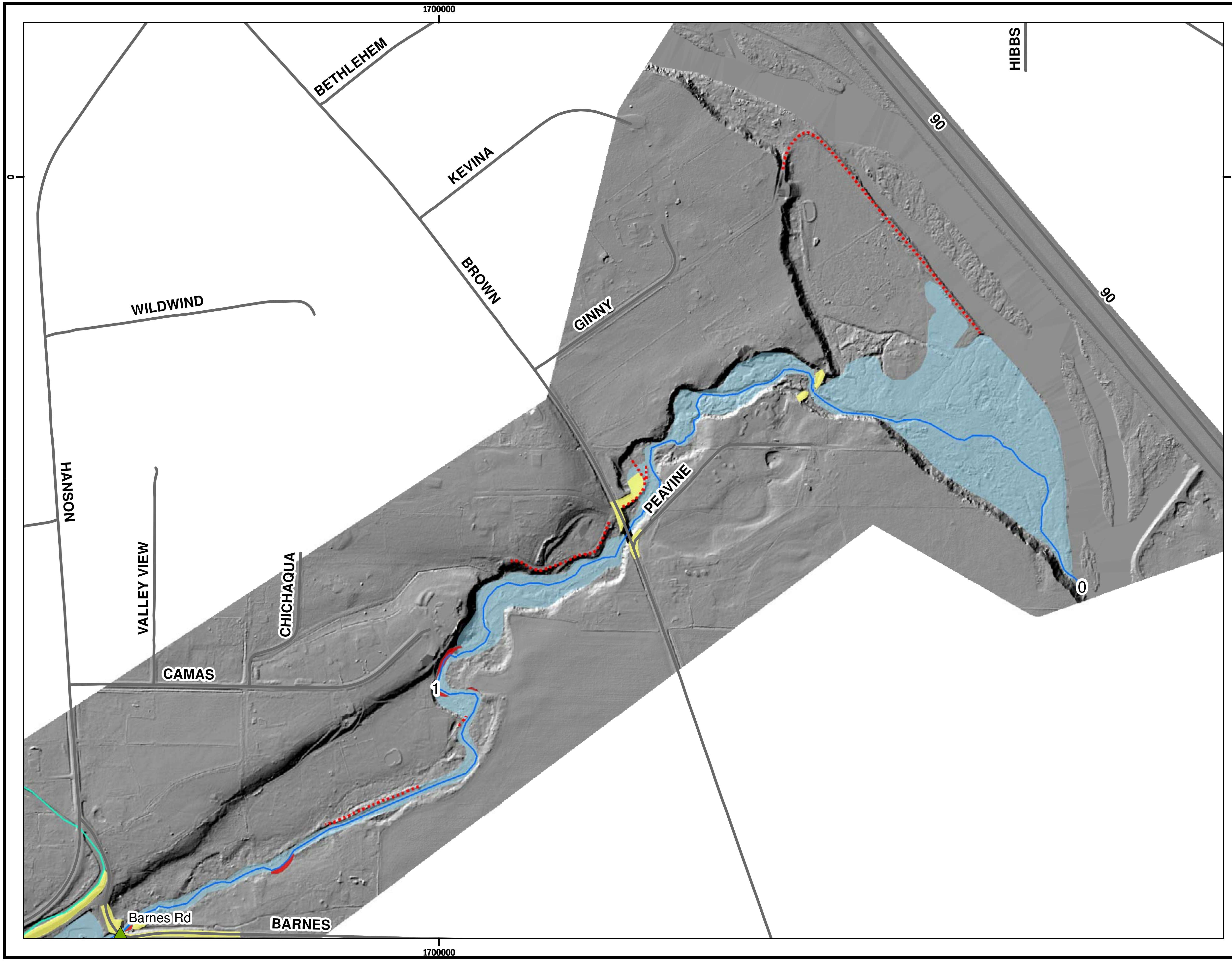


Figure F3
Hillshade
Yakima Confluence
and Entrenched Terrace Reaches

Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

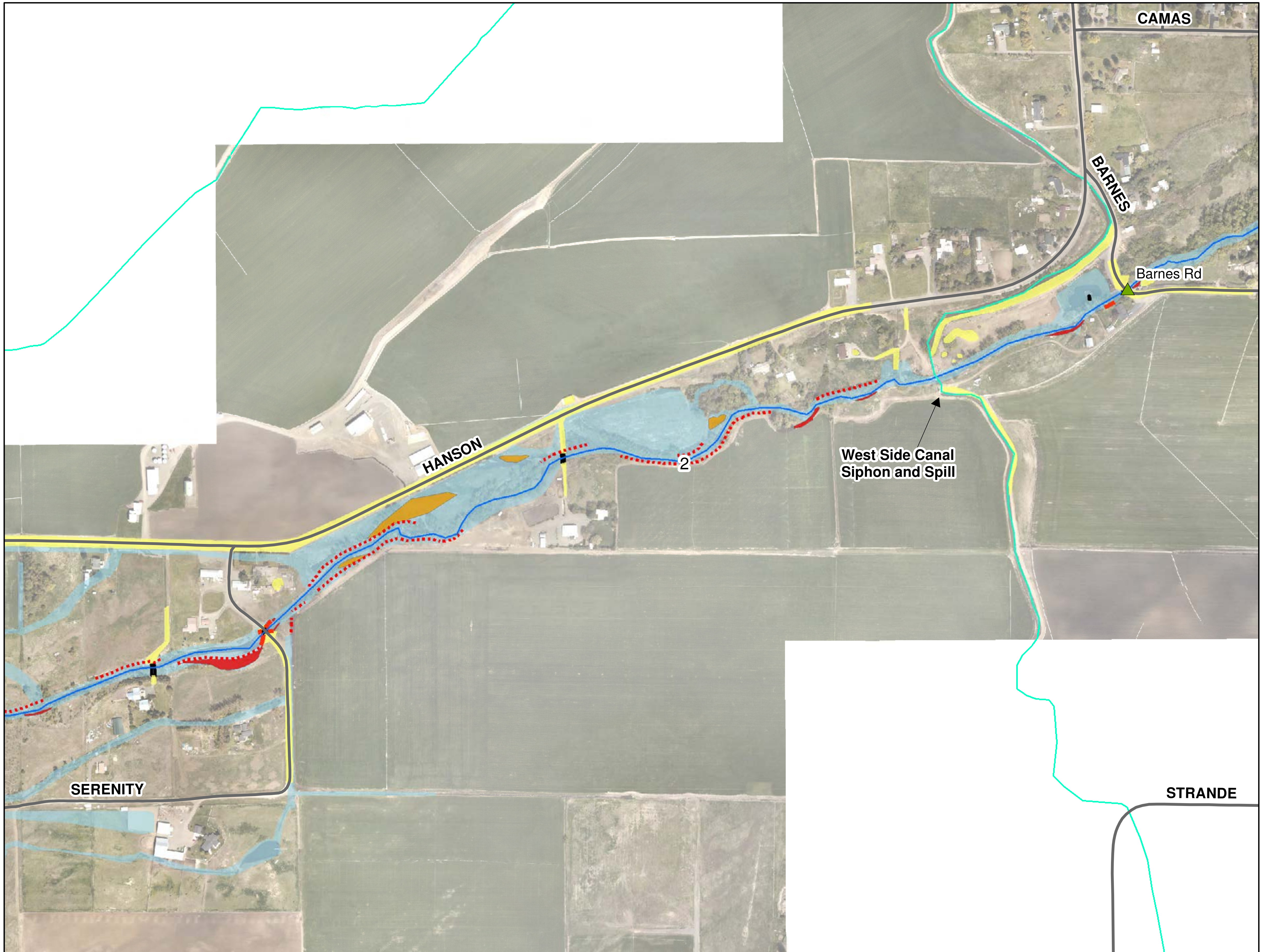
0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Hillshade: 2012 Herrera from 3Di West LiDAR

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

Figure F4
Flood and Erosion Overview Entrenched Terrace and Fan Contraction Reaches



Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

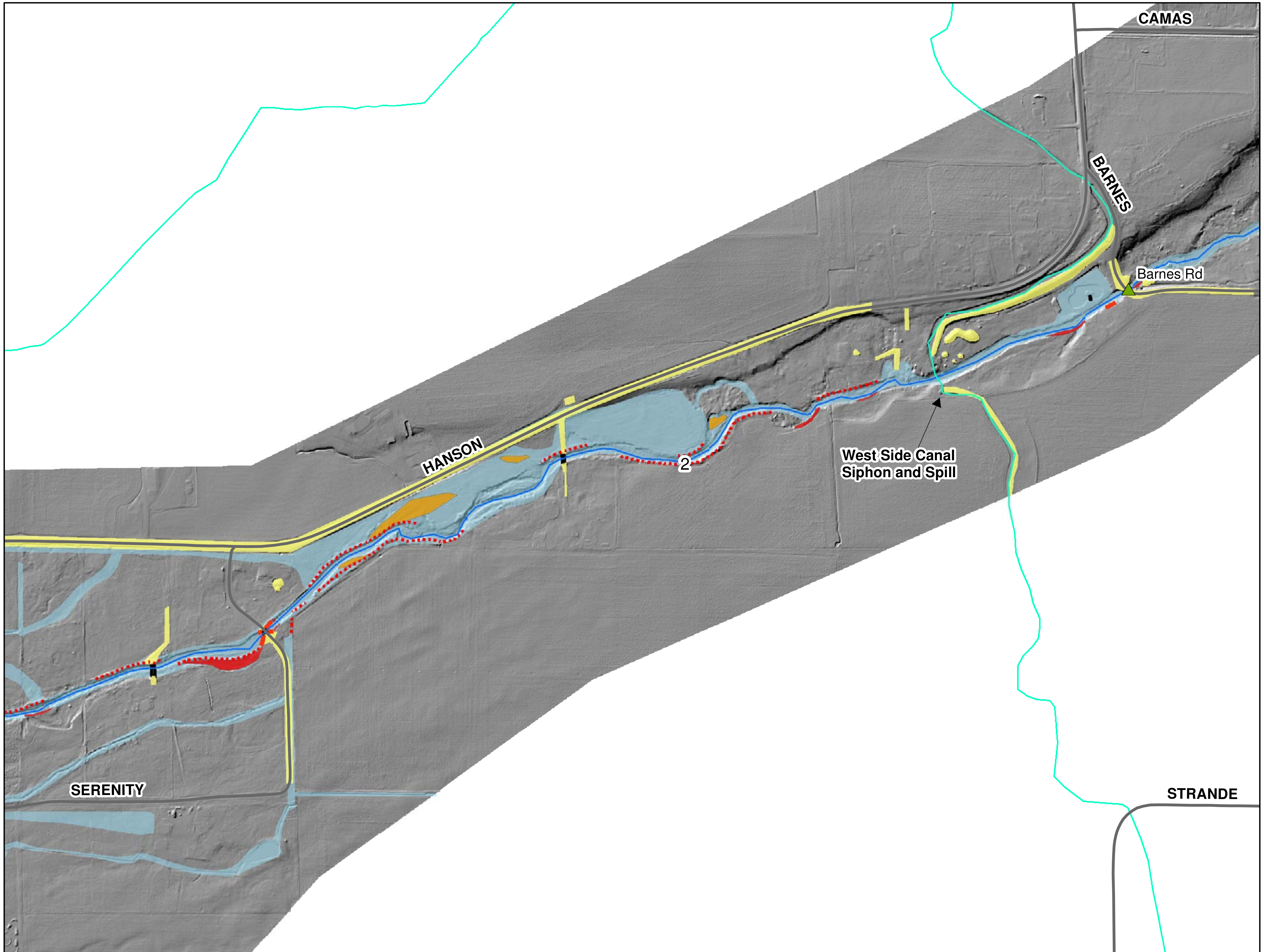
0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 2012 3Di West

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

Figure F5
Hillshade
Entrenched Terrace
and Fan Contraction Reaches

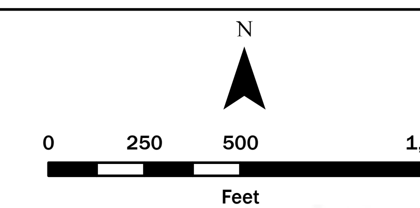


Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

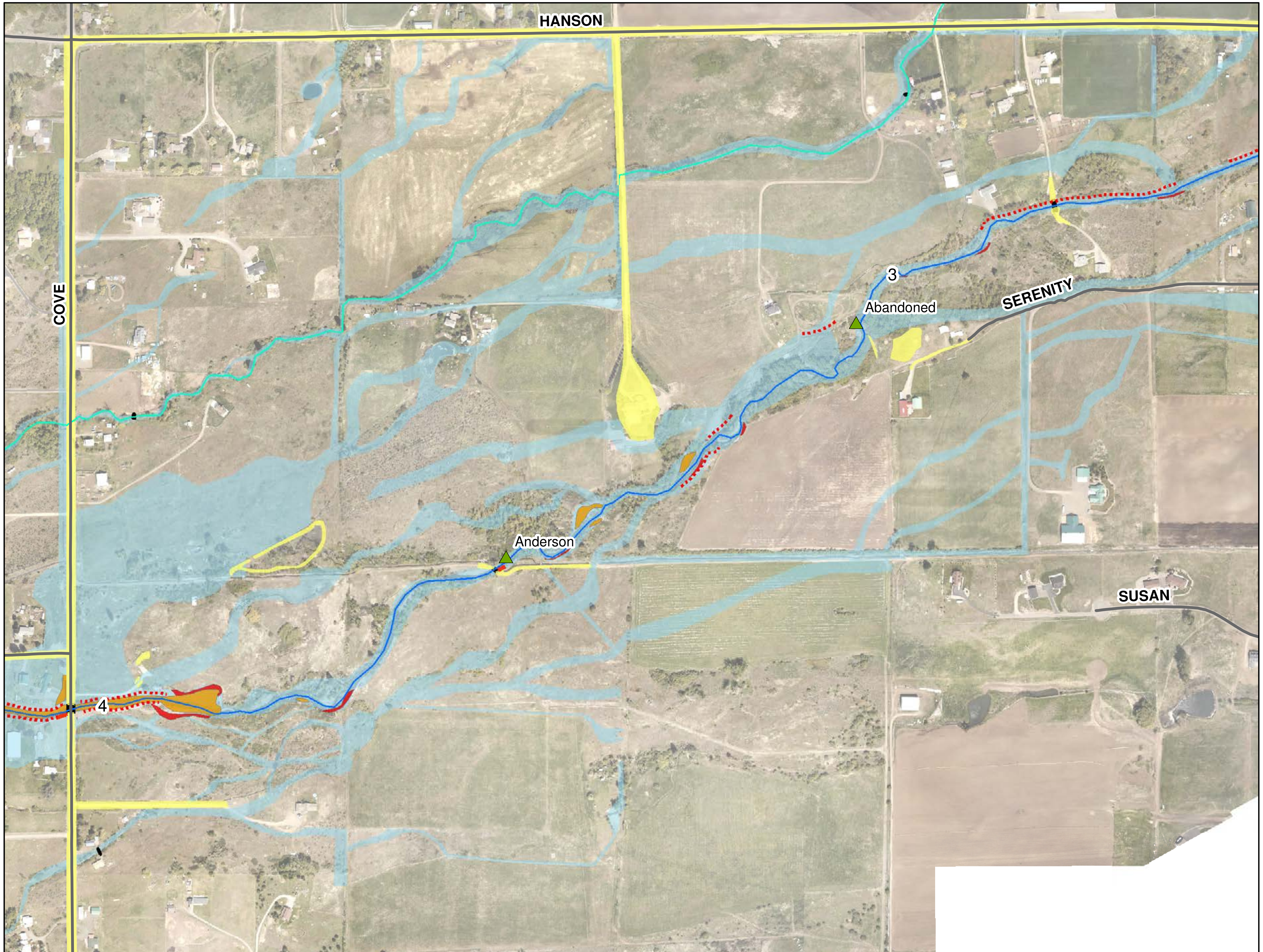


HERRERA WATERSHED Science & Engineering

Hillshade: 2012 Herrera from 3Di West LiDAR

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

Figure F6
Flood and Erosion Overview
Fan Contraction Reach



Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

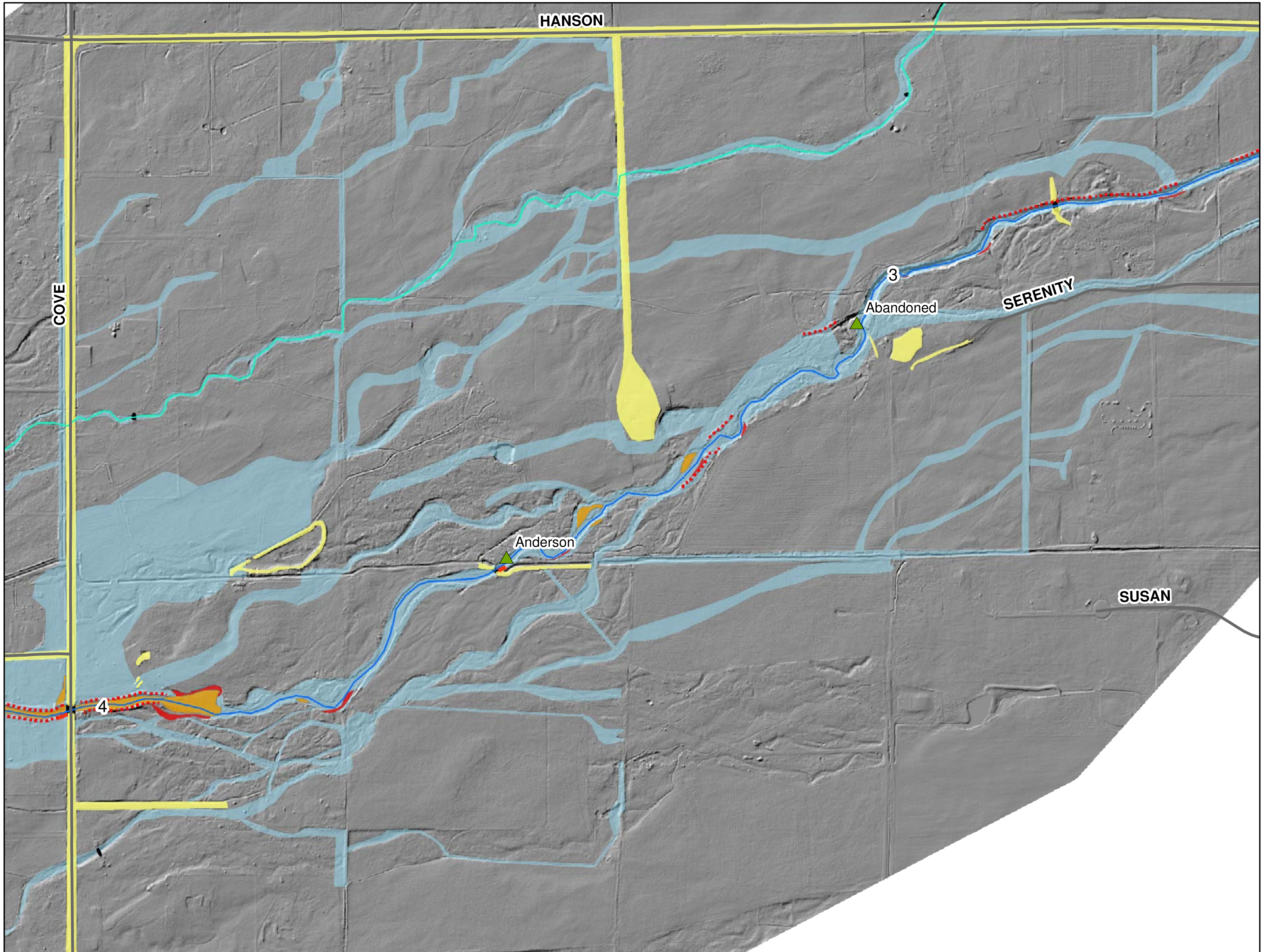
0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 2012 3Di West

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

Figure F7
Hillshade
Fan Contraction Reach



Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

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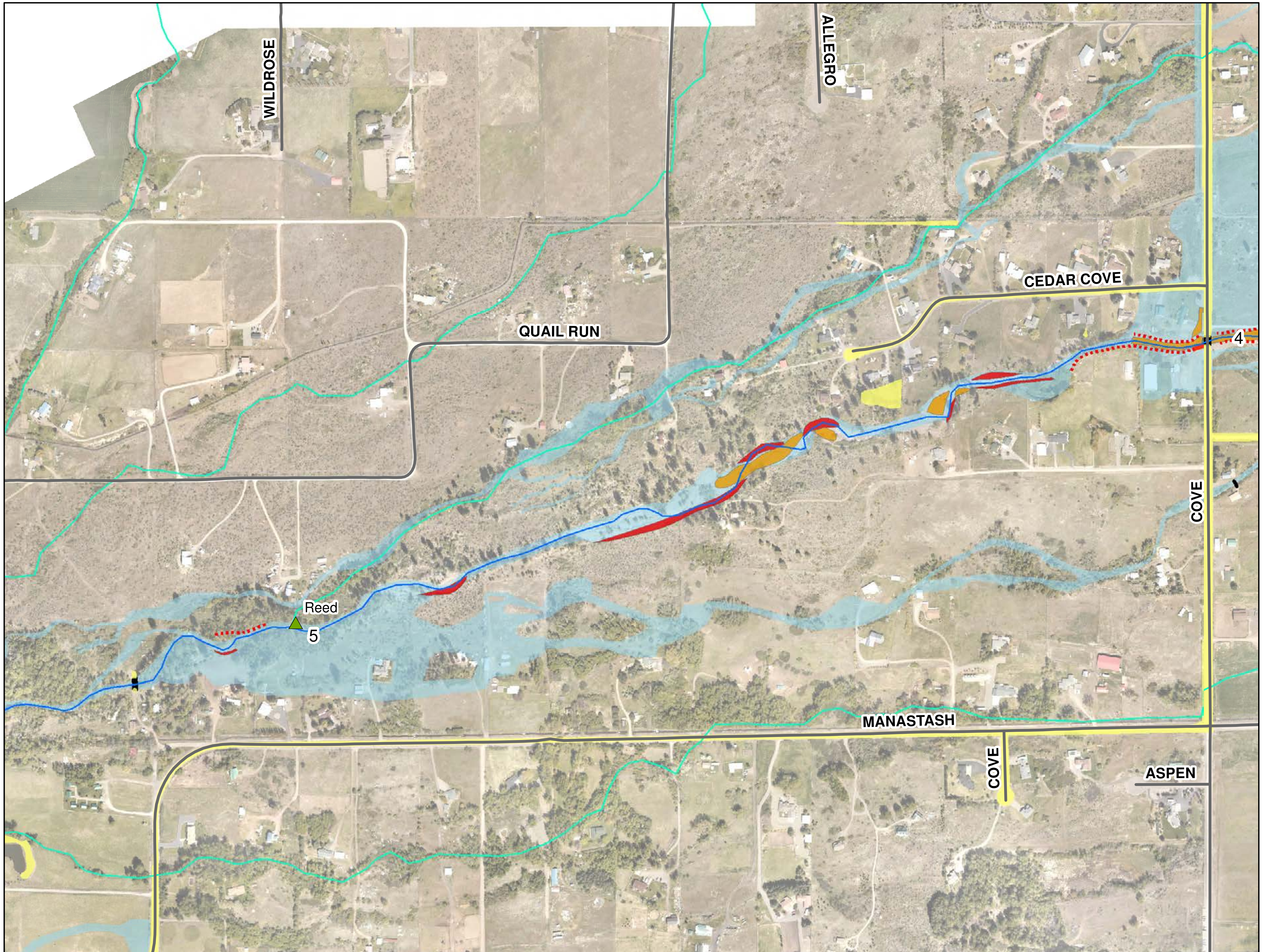
Hillshade: 2012 Herrera from 3Di West LiDAR

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

Figure F8
Flood and Erosion Overview
Fan Expansion Reach



Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 2012 3Di West

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

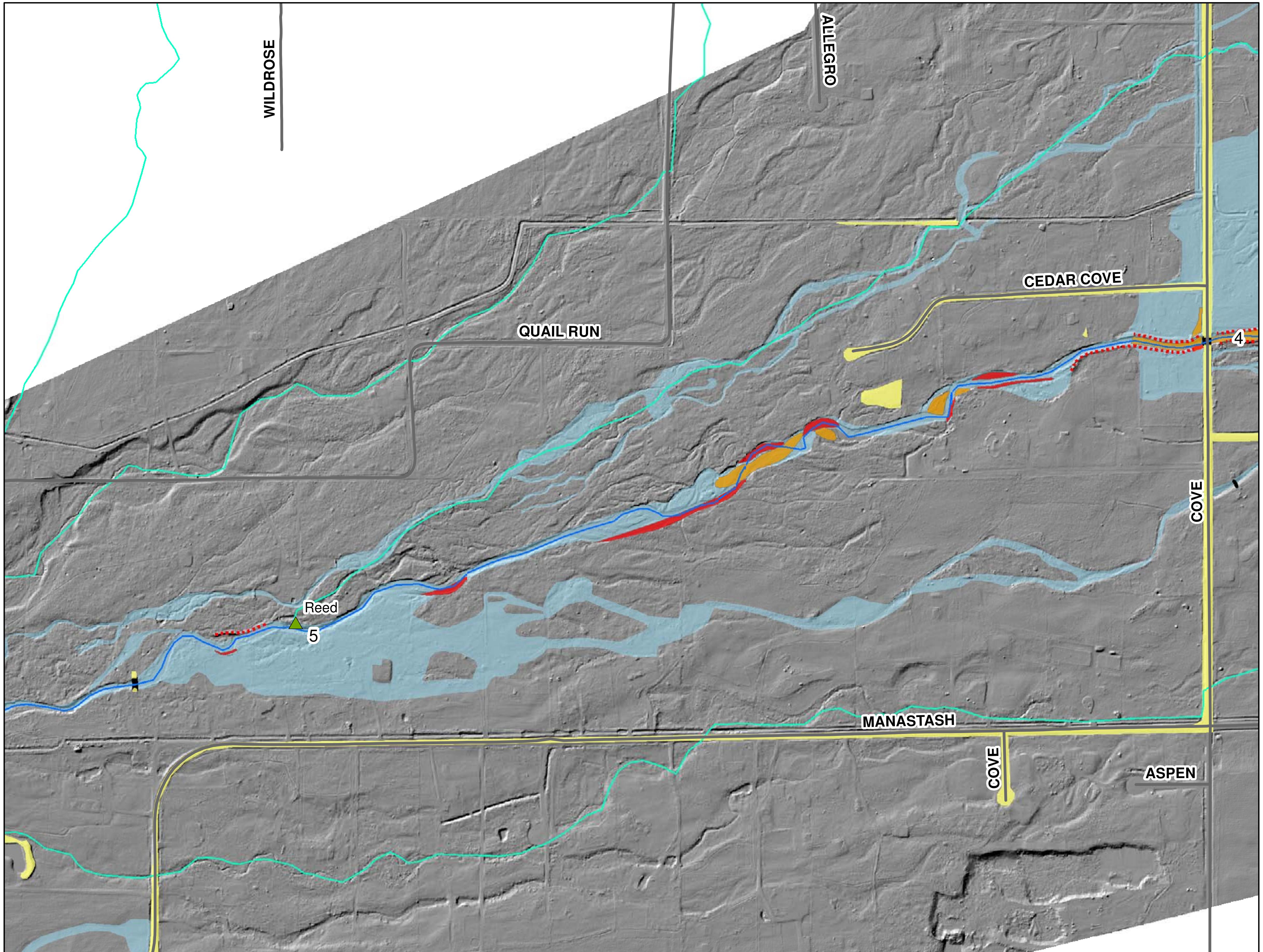


Figure F9
Hillshade
Fan Expansion Reach

Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

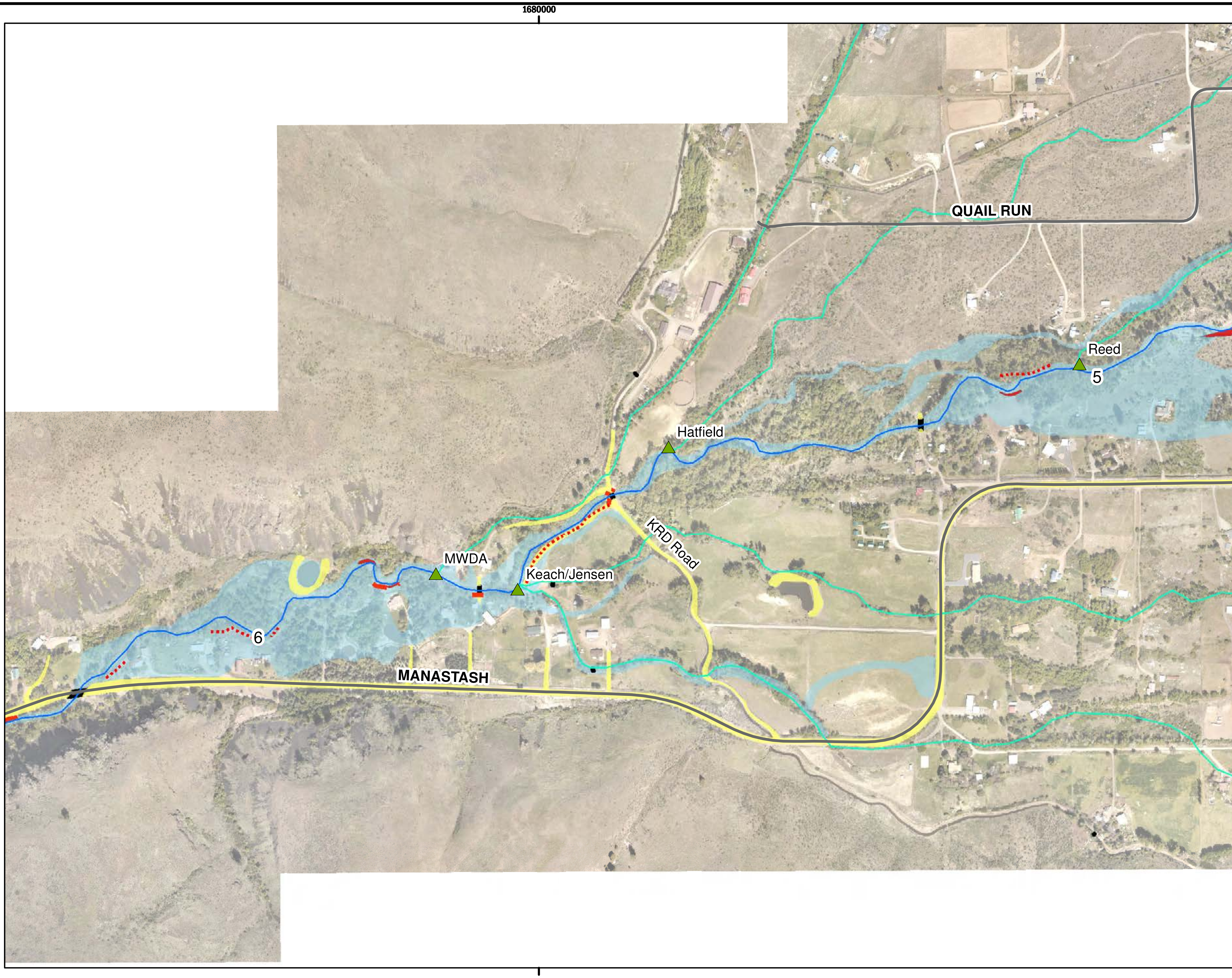
0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Hillshade: 2012 Herrera from 3Di West LiDAR

Produced By: GIS
Project: F:\12-016 Manastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

Figure F10
Flood and Erosion Overview
Canyon and Fan
Expansion Reaches



Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

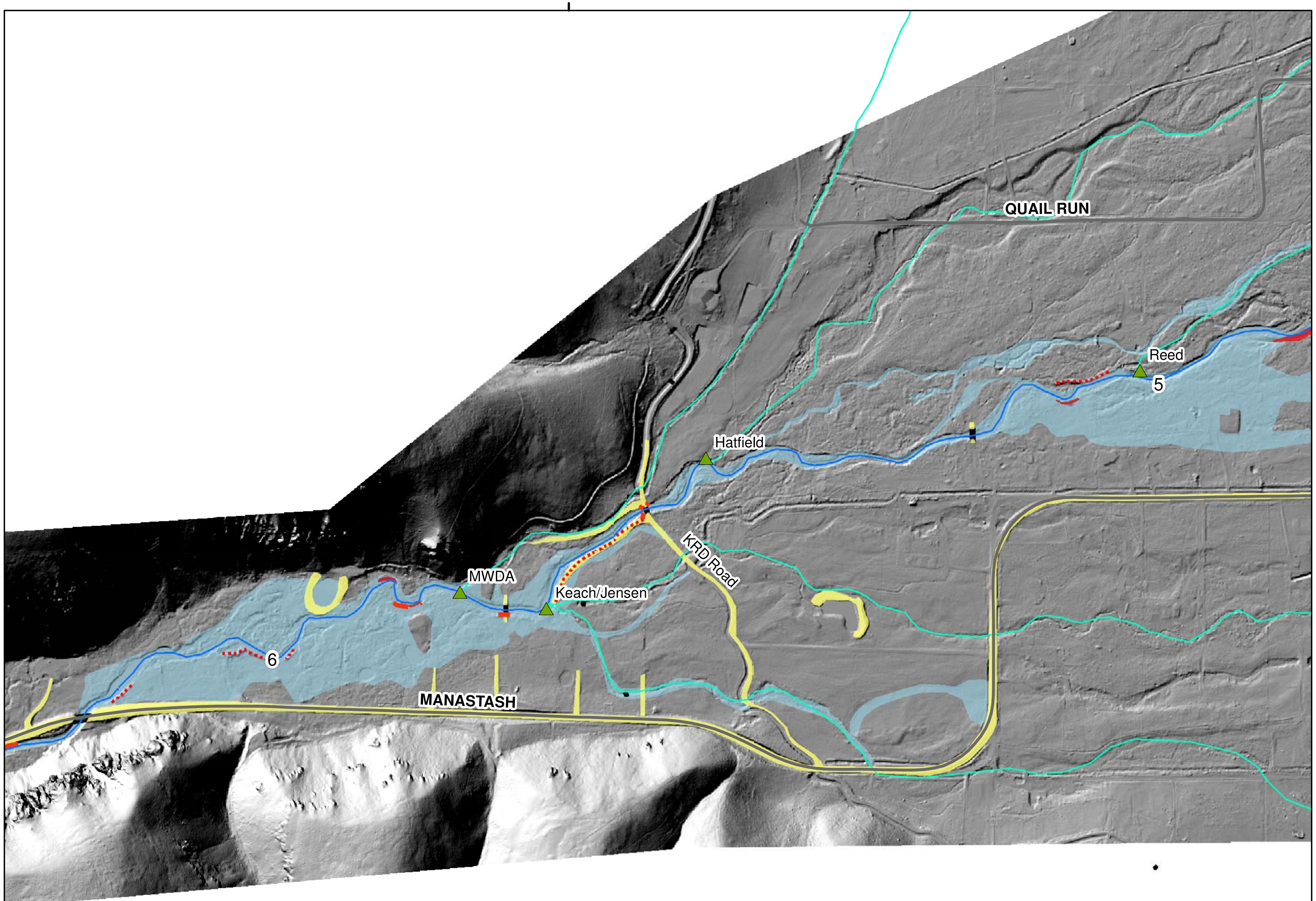
0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 2012 3Di West

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

1680000



1680000

Figure F11
Hillshade
Canyon and Fan
Expansion Reaches

Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

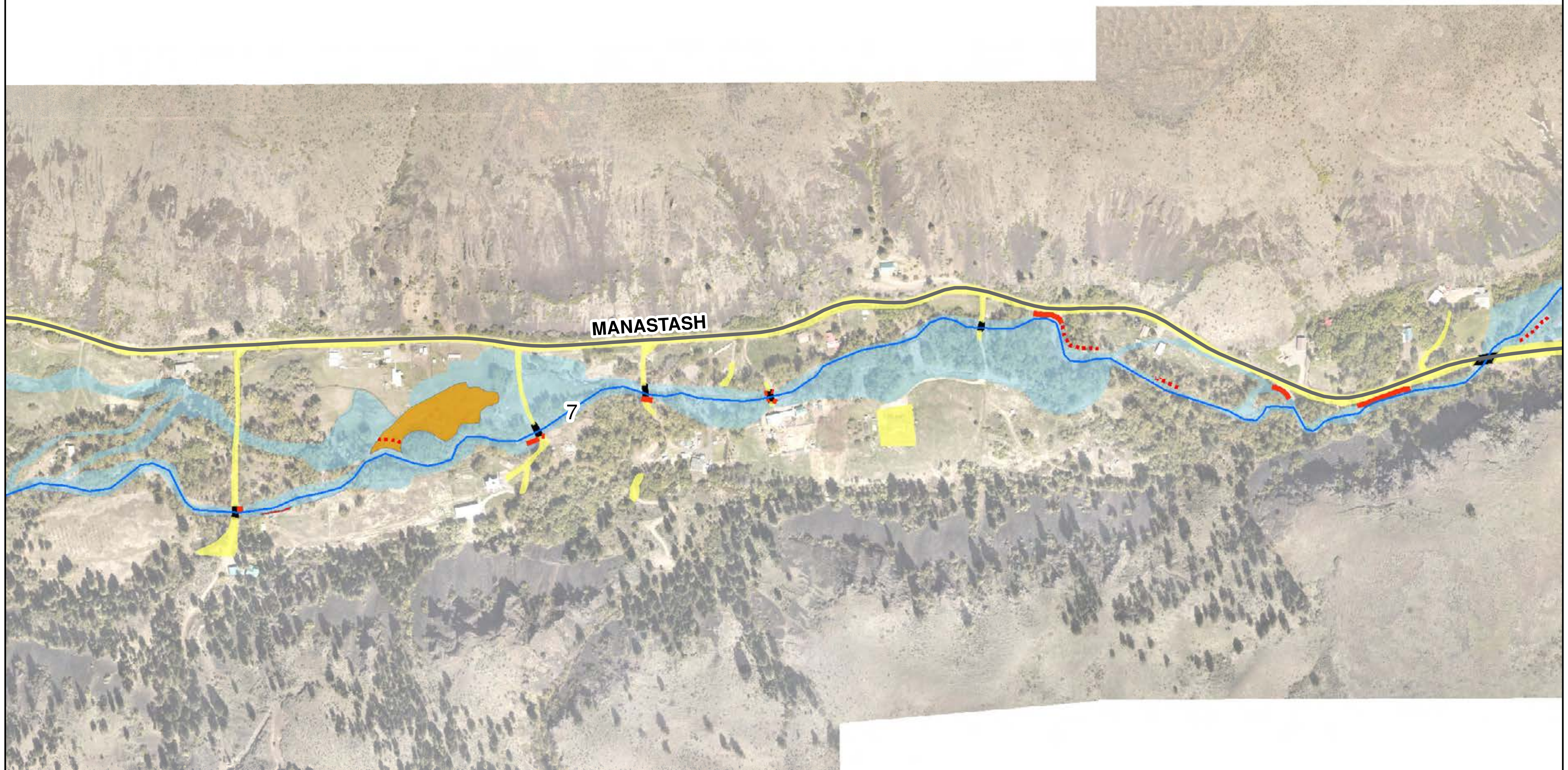
0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Hillshade: 2012 Herrera from 3Di West LiDAR

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

Figure F12
Flood and Erosion Overview
Canyon Reach



Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

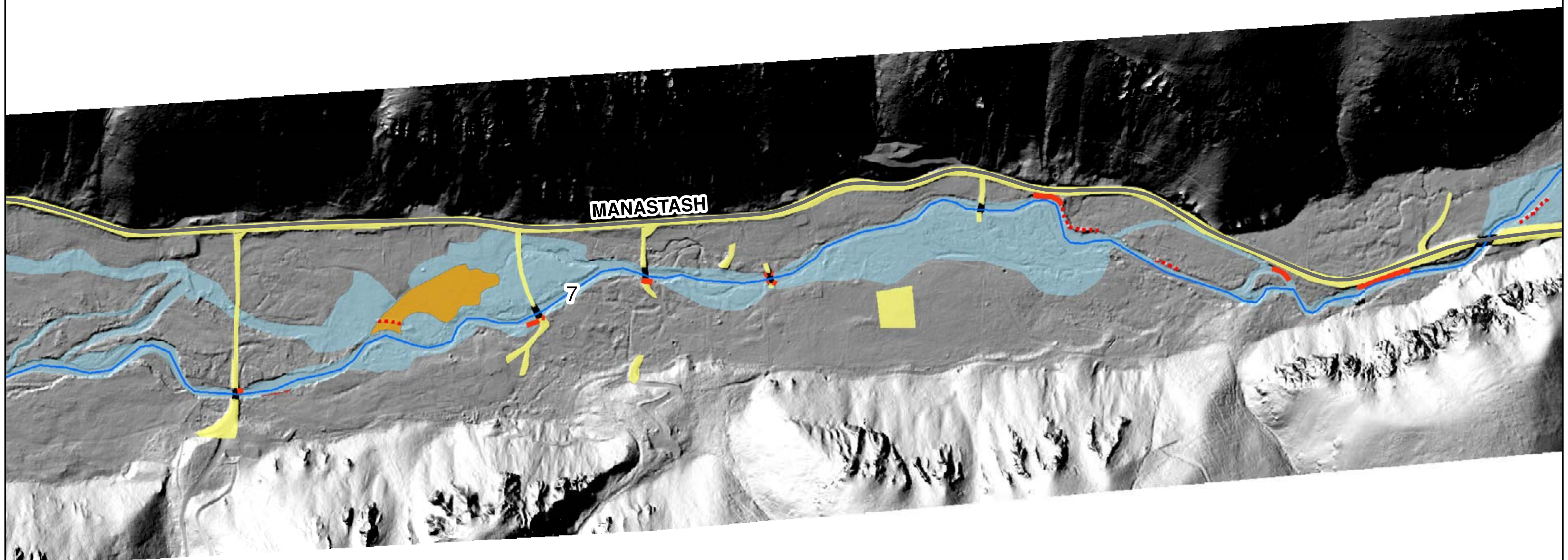
0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 2012 3Di West

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

Figure F13
Hillshade
Canyon Reach



Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Hillshade: 2012 Herrera from 3Di West LiDAR

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

Figure F14
Flood and Erosion Overview
Canyon Reach Continued

Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 2012 3Di West

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

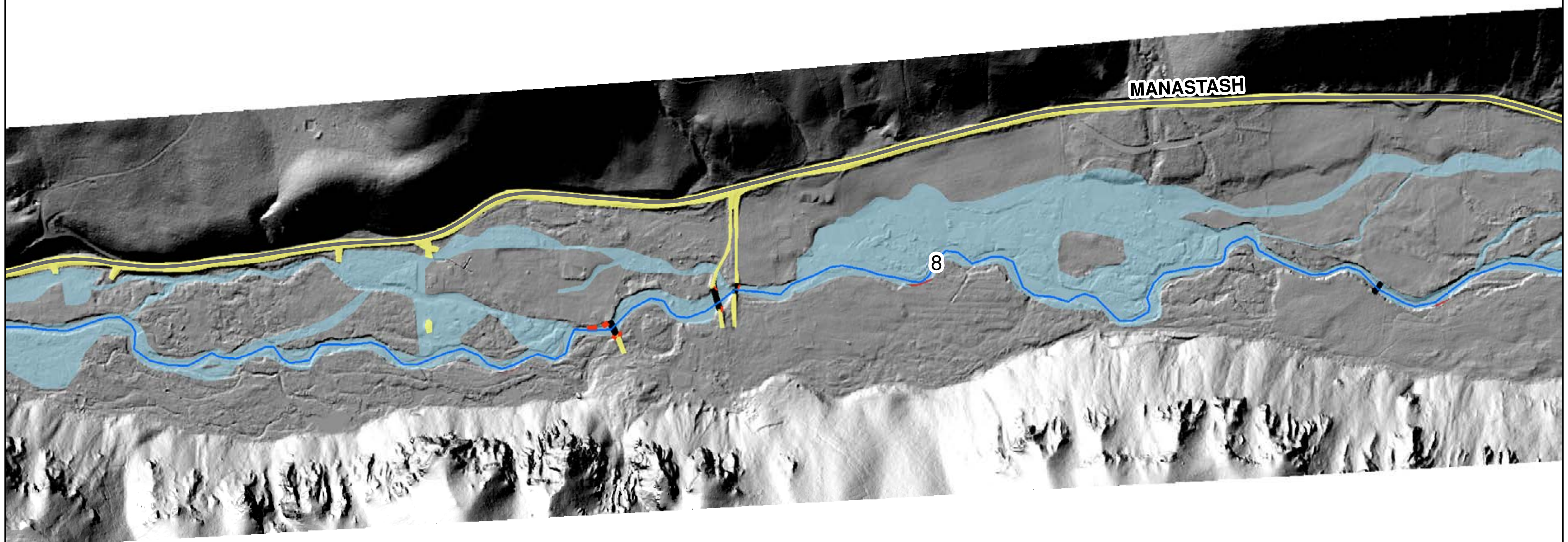


Figure F15
Hillshade
Canyon Reach Continued

Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Hillshade: 2012 Herrera from 3Di West LiDAR

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

Figure F16
Flood and Erosion Overview
Canyon Reach Continued

Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

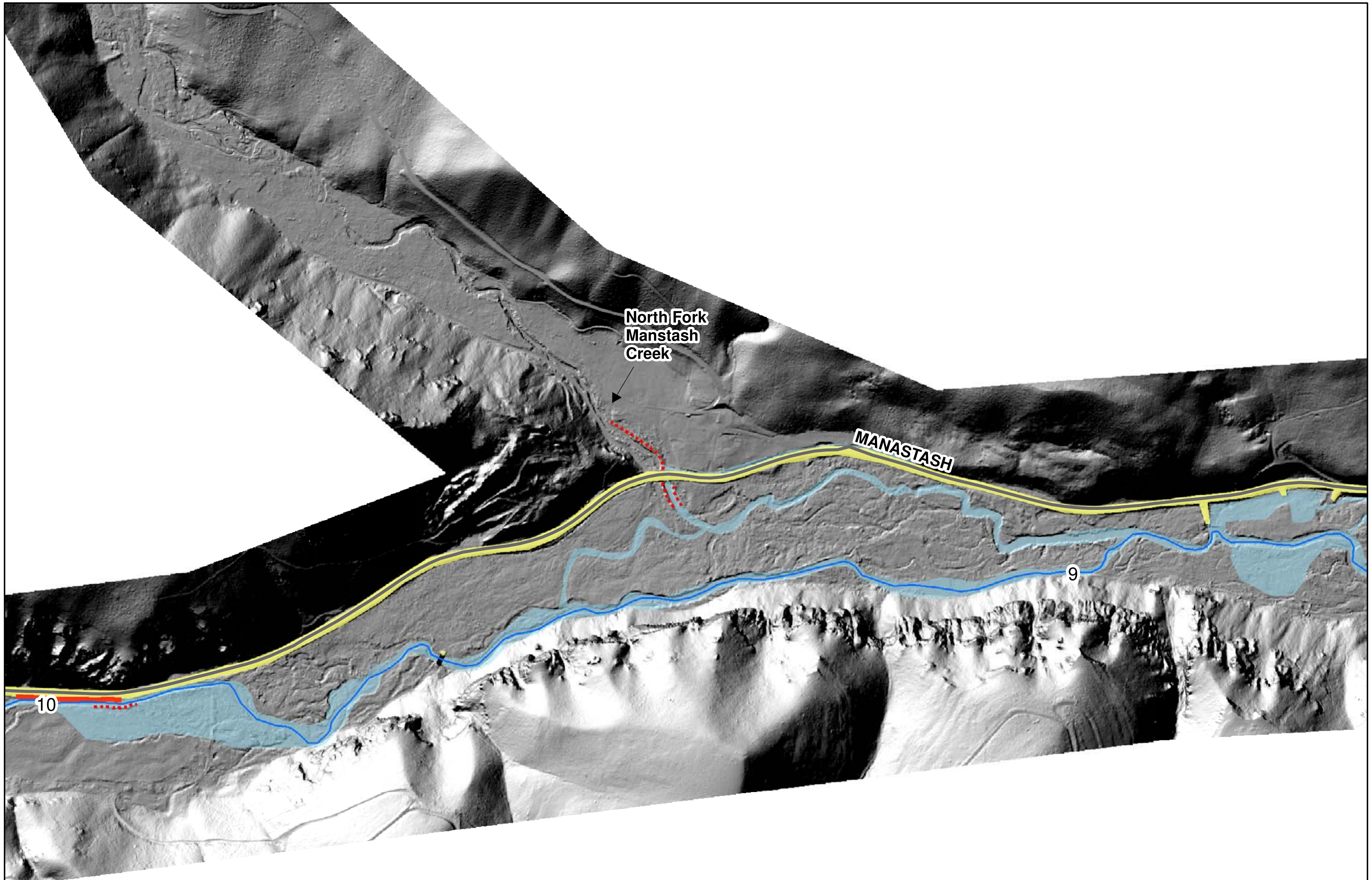
0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 2012 3Di West

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

Figure F17
Hillshade
Canyon Reach Continued



Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

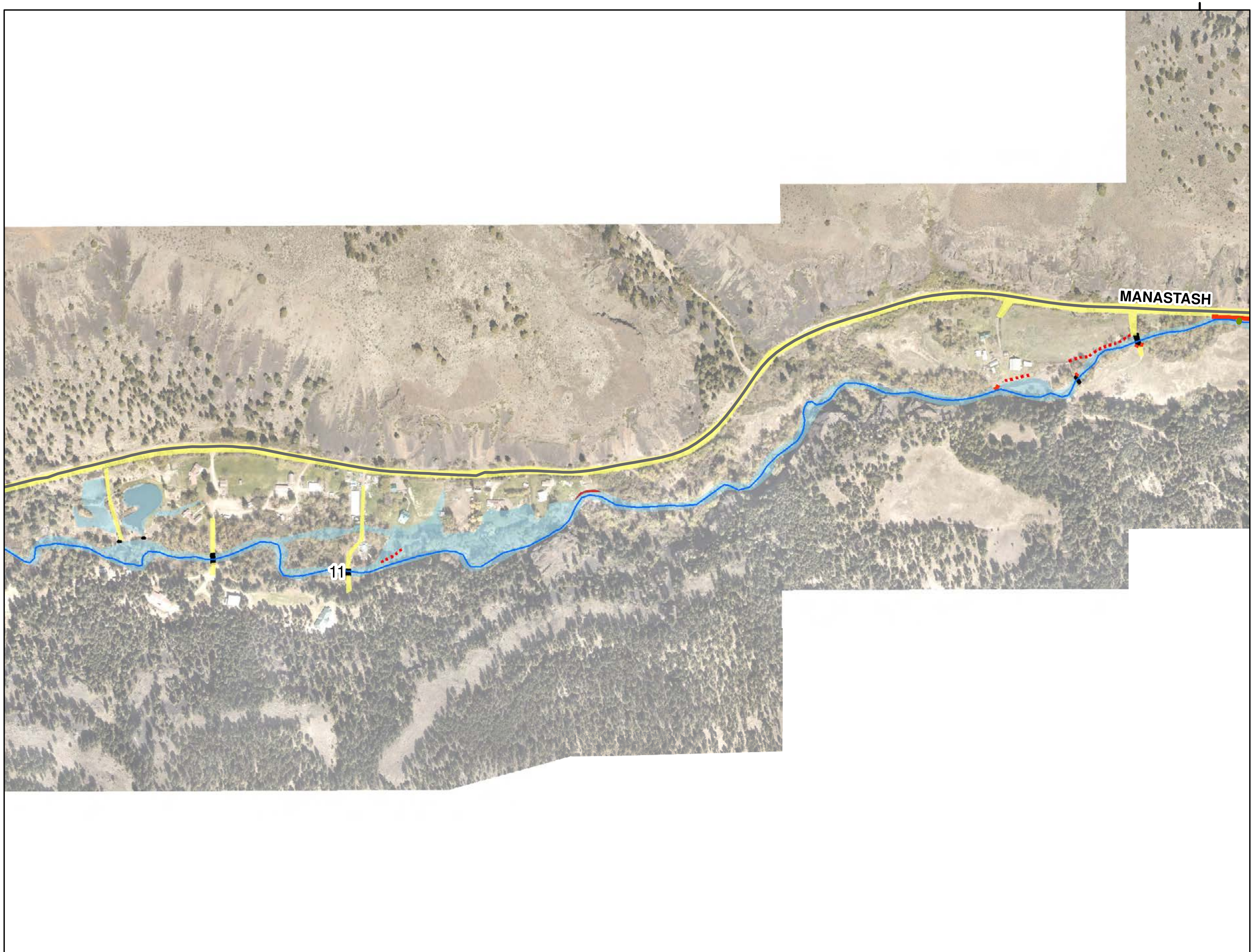
0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Hillshade: 2012 Herrera from 3Di West LiDAR

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

Figure F18
Flood and Erosion Overview
Canyon Reach Continued



Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 2012 3Di West

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

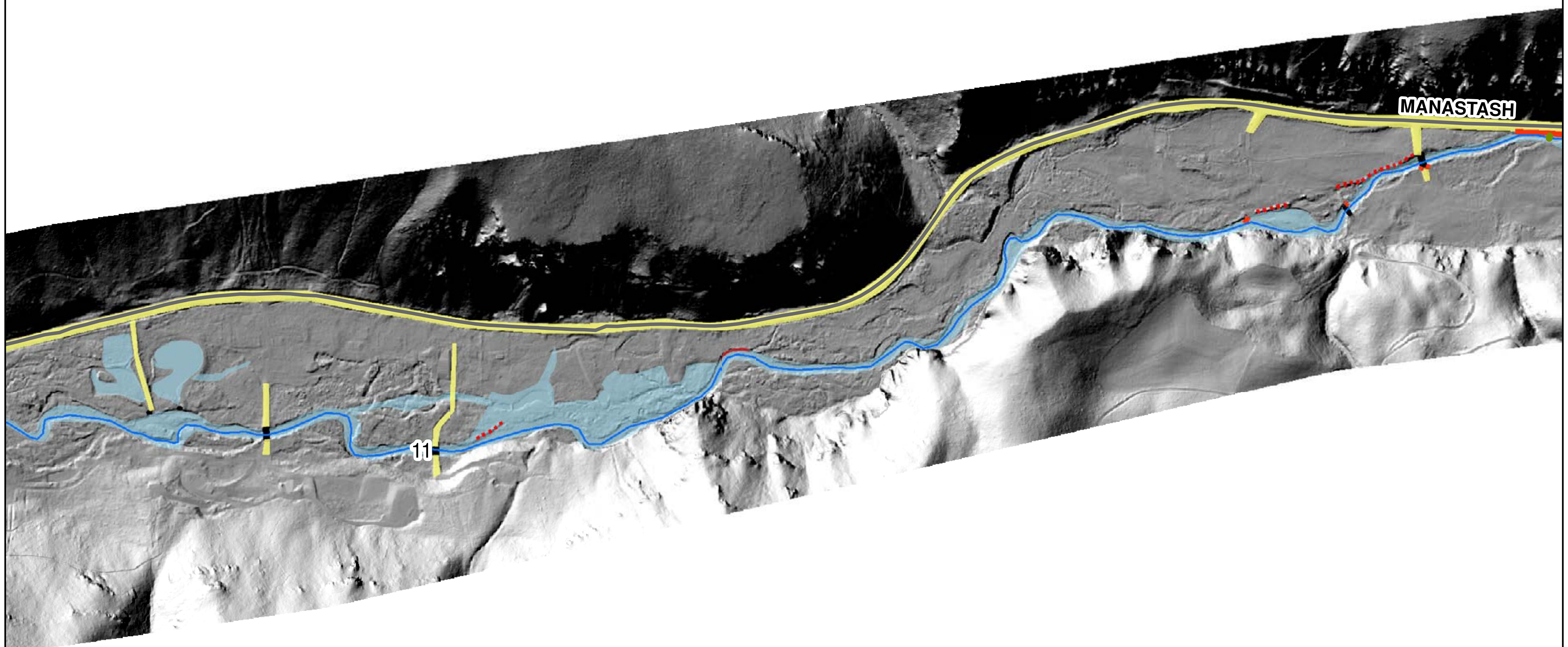


Figure F19
Hillshade
Canyon Reach Continued

Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

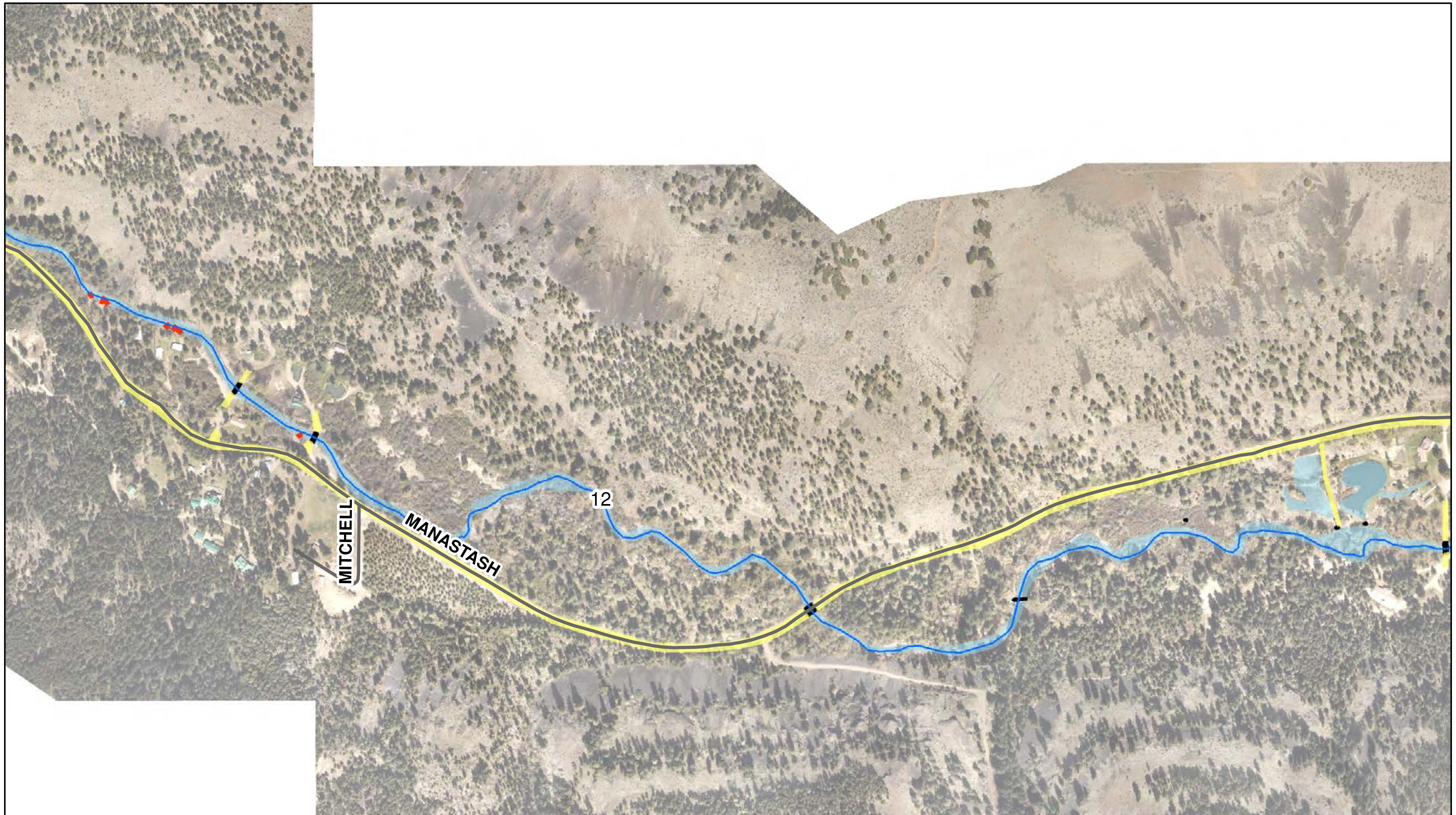
0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Hillshade: 2012 Herrera from 3Di West LiDAR

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

Figure F20
Flood and Erosion Overview
Canyon Reach Continued



Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

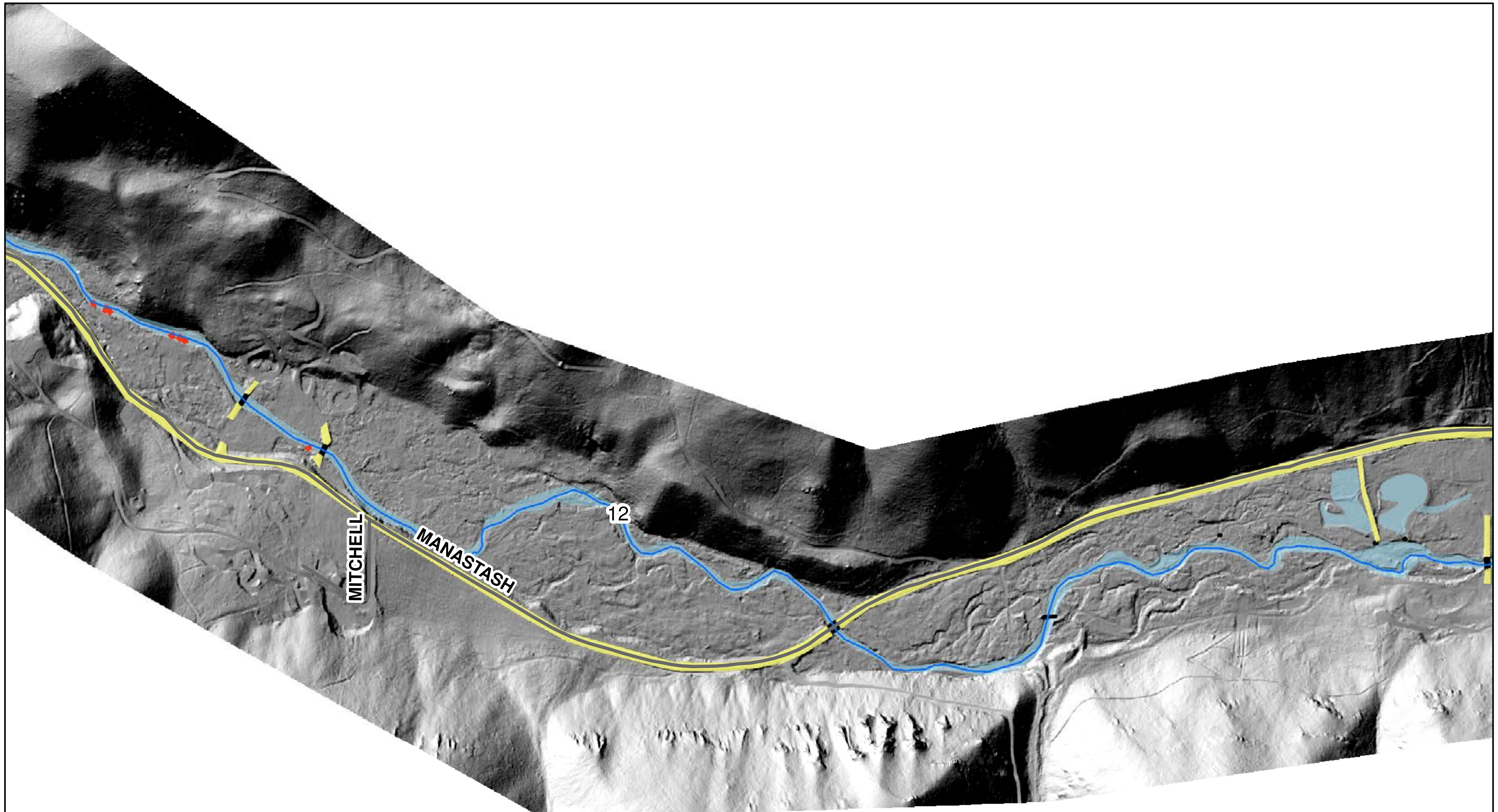
0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 2012 3Di West

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

Figure F21
Hillshade
Canyon Reach Continued



Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Hillshade: 2012 Herrera from 3Di West LiDAR

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

Figure F22
Flood and Erosion Overview
Canyon Reach Continued

Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

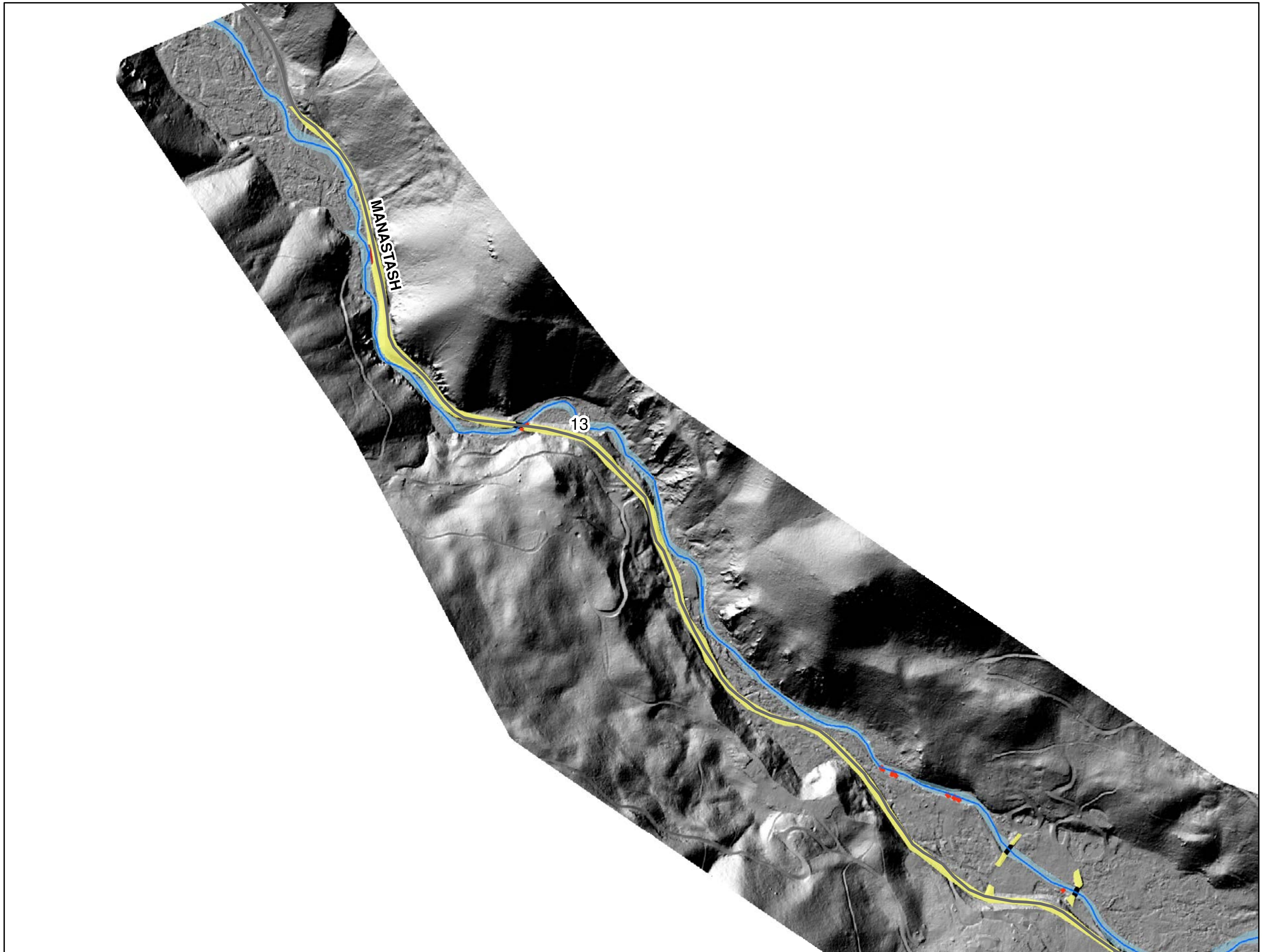
0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Aerial Photography: 2012 3Di West

Produced By: GIS
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)

Figure F23
Hillshade
Canyon Reach Continued



Legend

- Diversions
- County Roads
- Irrigation
- Manastash Creek
- Berm
- Revetment
- Fill
- Bridges
- May 2011 Erosion
- May 2011 Sediment
- May 2011 Flooding
- River Mile

Note:
Layers including Berms, Revetments, Fill, Erosion, Sediment, and Flooding are approximations based on available aerial photos and topography and will not be accurate or complete in all areas.

River mile stationing included along Manastash centerline.

N

0 250 500 1,000
Feet

HERRERA WATERSHED Science & Engineering

Hillshade: 2012 Herrera from 3Di West LiDAR

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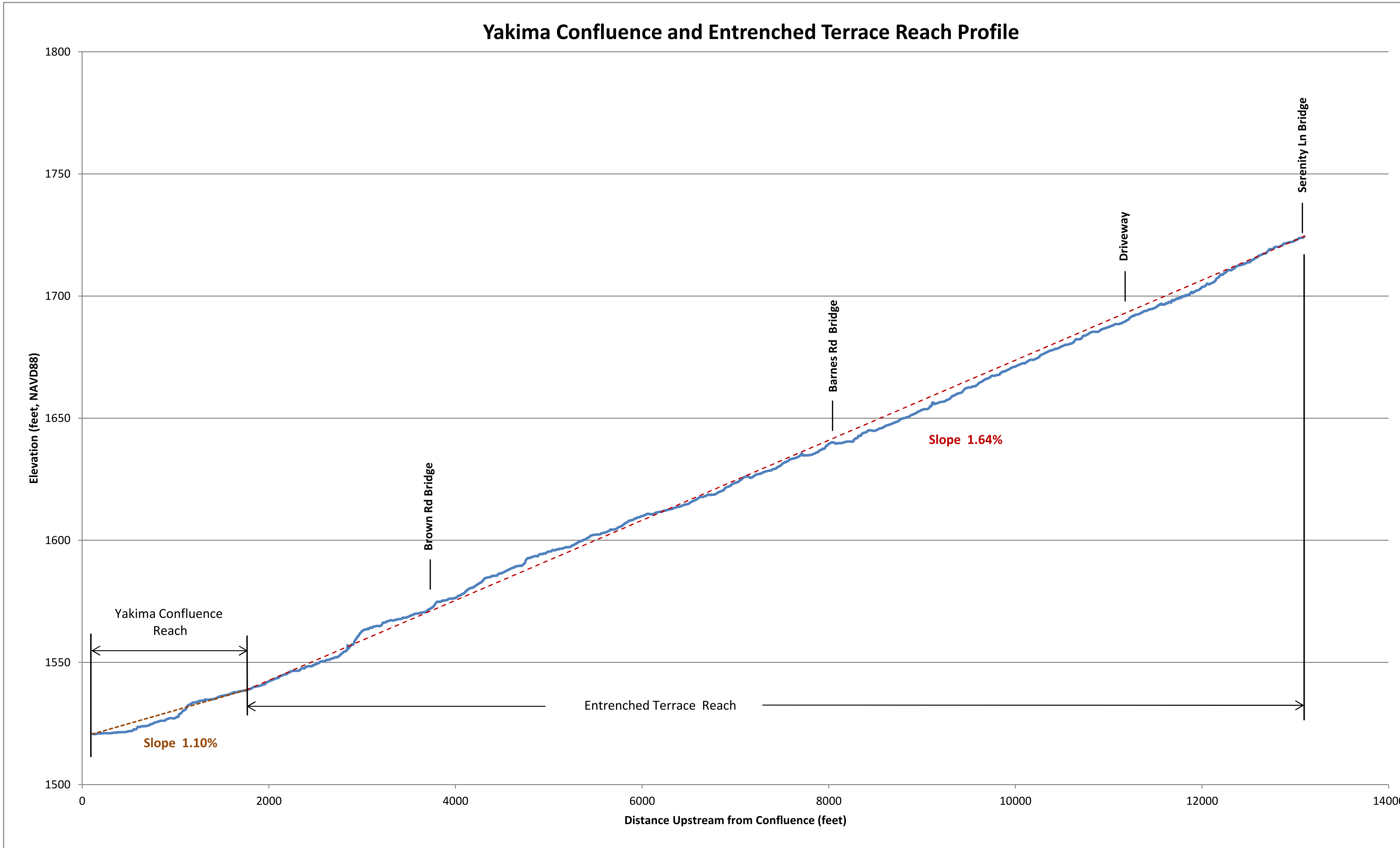
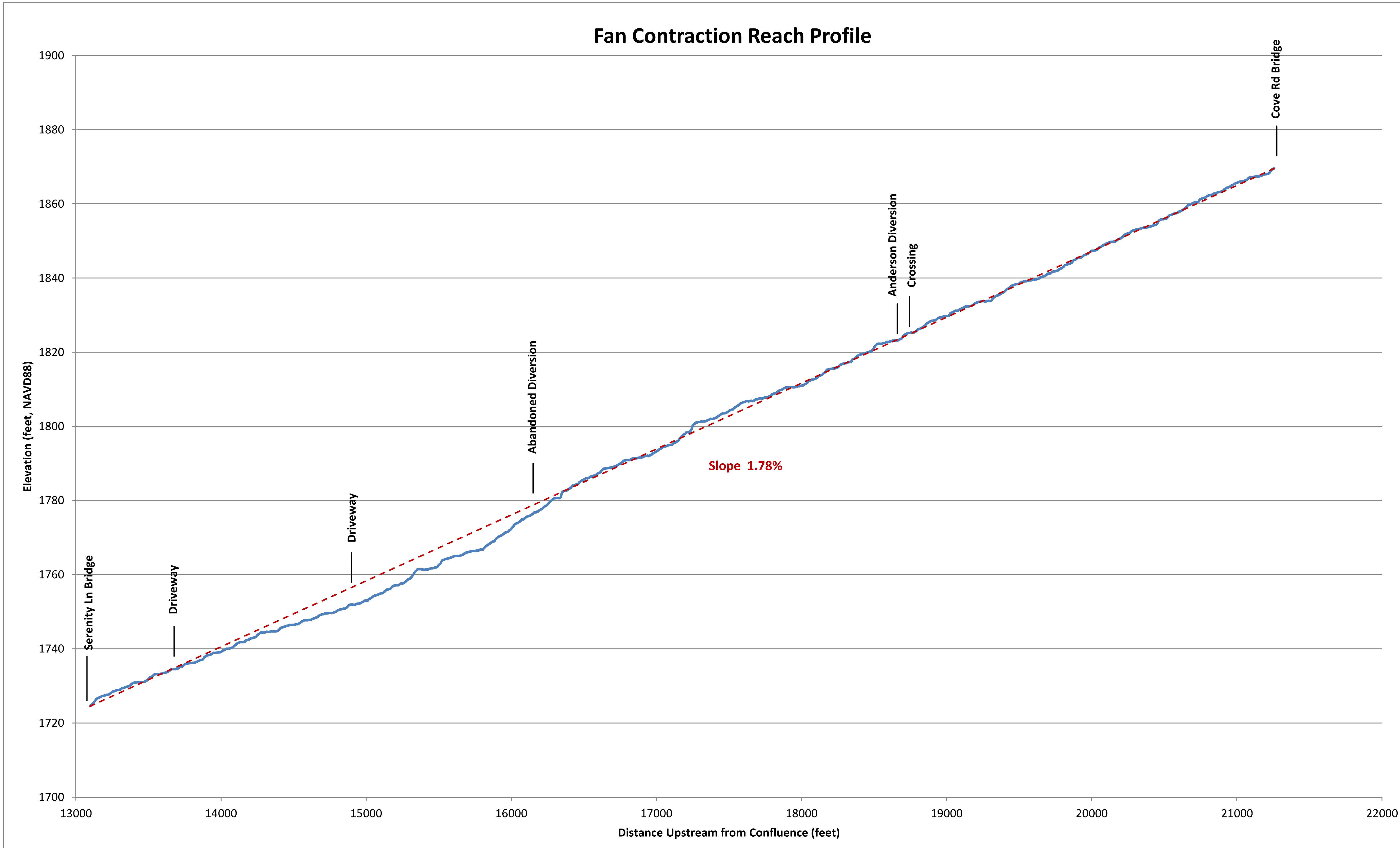
Project: F:\12-016 Monastash Corridor\GIS\Manastash_Figure2to23.mxd (9/11/2012)



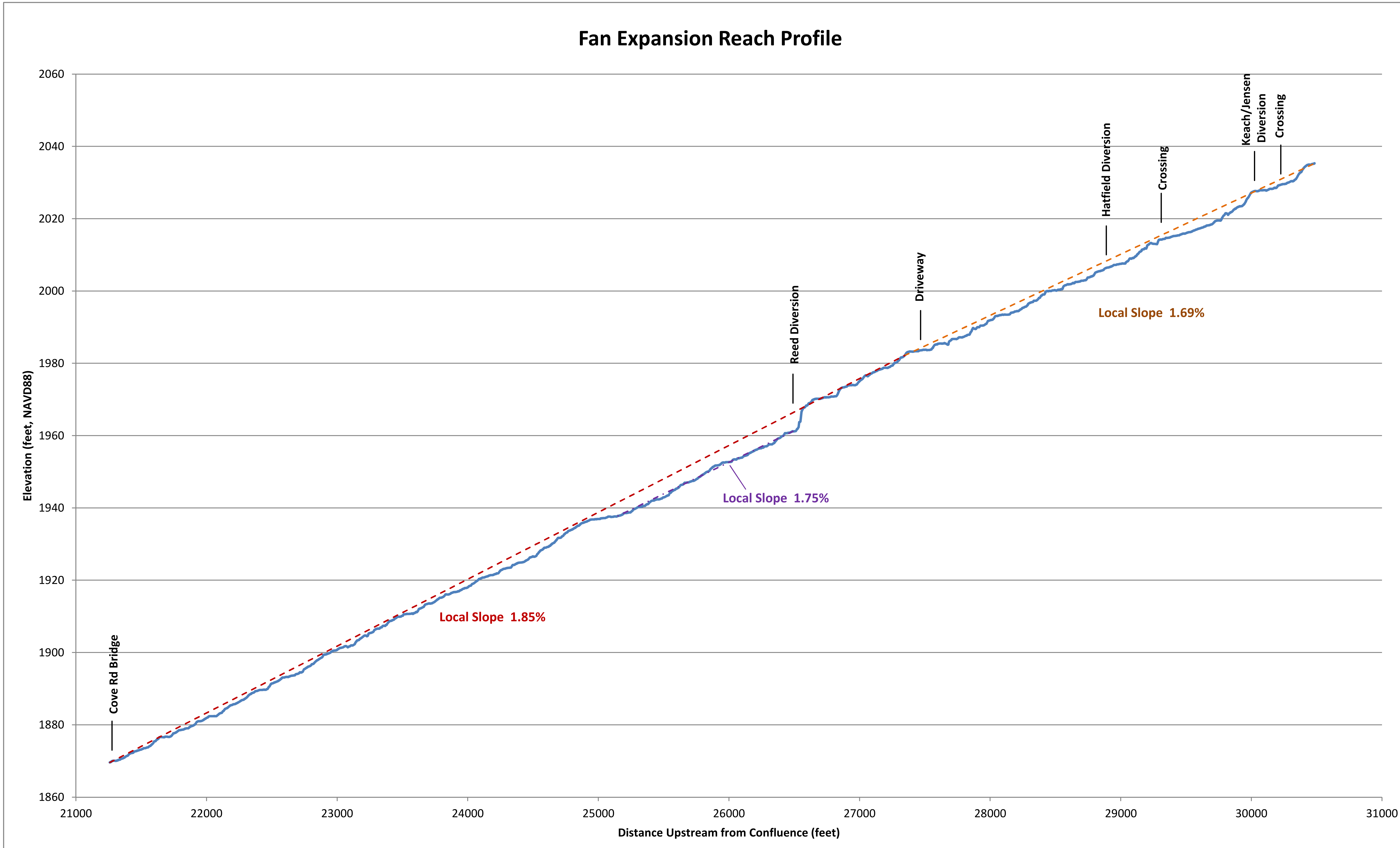
Yakima Confluence and Entrenched Terrace Reach Profile
Elevation (feet, NAVD88)
1800
1750
1700
1650
1600
1550
1500
0
2000
4000
6000
8000
10000
12000
14000
Distance Upstream from Confluence (feet)
Serenity Ln Bridge
Driveway
Barnes Rd Bridge
Brown Rd Bridge
Slope 1.64%
Yakima Confluence Reach
Entrenched Terrace Reach
Slope 1.10%

Figure F24



Fan Contraction Reach Profile
Elevation (feet, NAVD88)
Distance Upstream from Confluence (feet)
1900
1880
1860
1840
1820
1800
1780
1760
1740
1720
1700
13000
14000
15000
16000
17000
18000
19000
20000
21000
22000
Serenity Ln Bridge
Driveway
Driveway
Abandoned Diversion
Anderson Diversion
Crossing
Cove Rd Bridge
Slope 1.78%

Figure F25



Fan Expansion Reach Profile
Elevation (feet, NAVD88)
Distance Upstream from Confluence (feet)
2060
2040
2020
2000
1980
1960
1940
1920
1900
1880
1860
21000
22000
23000
24000
25000
26000
27000
28000
29000
30000
31000
Cove Rd Bridge
Reed Diversion
Driveway
Hatfield Diversion
Crossing
Keach/Jensen Diversion
Crossing
Local Slope 1.85%
Local Slope 1.75%
Local Slope 1.69%

Figure F26

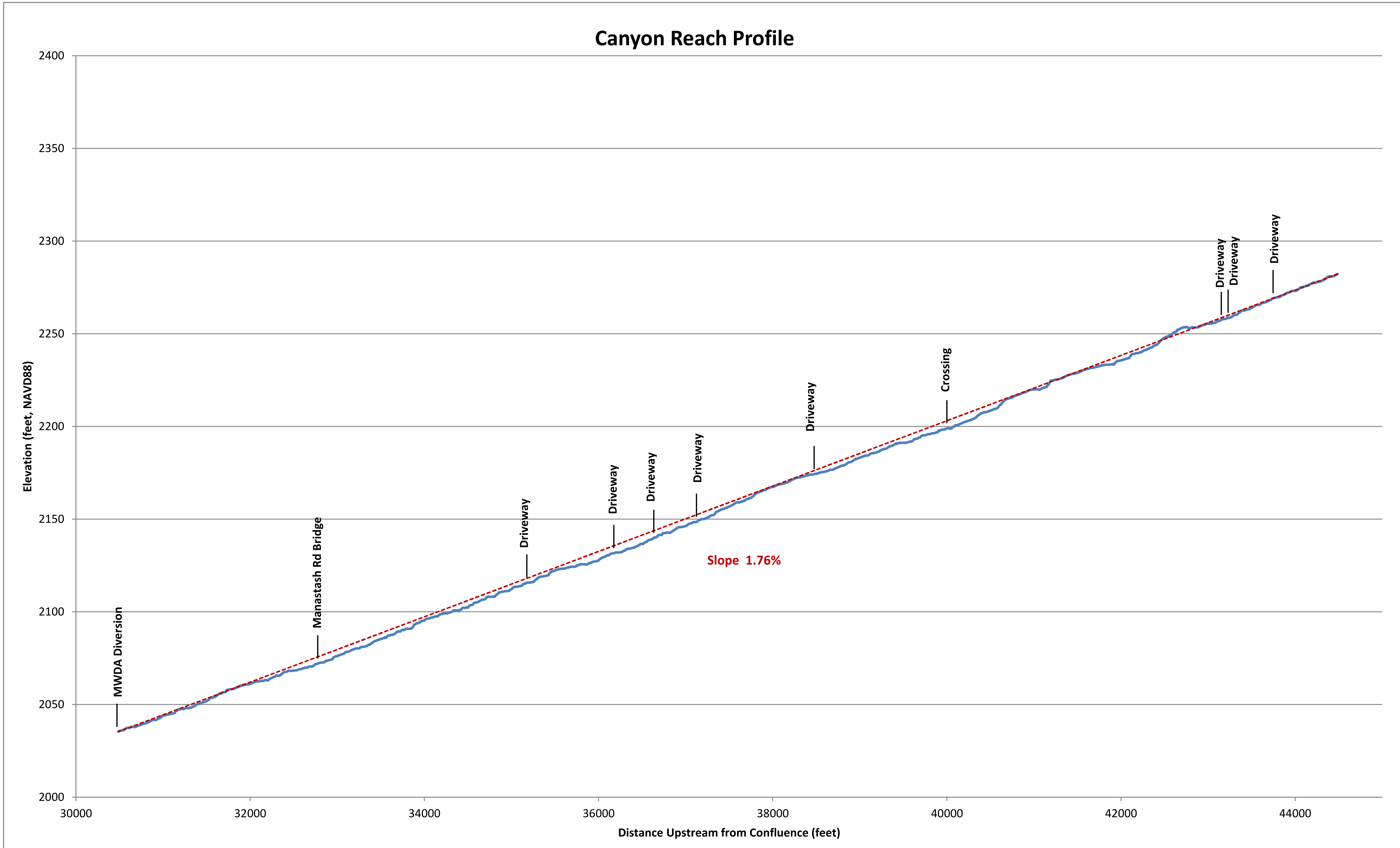

Canyon Reach Profile
Elevation (feet, NAVD88)
Distance Upstream from Confluence (feet)
2400
2350
2300
2250
2200
2150
2100
2050
2000
30000
32000
34000
36000
38000
40000
42000
44000
MWDA Diversion
Manastash Rd Bridge
Driveway
Driveway
Driveway
Driveway
Driveway
Crossing
Driveway
Driveway
Driveway
Slope 1.76%

Figure F27

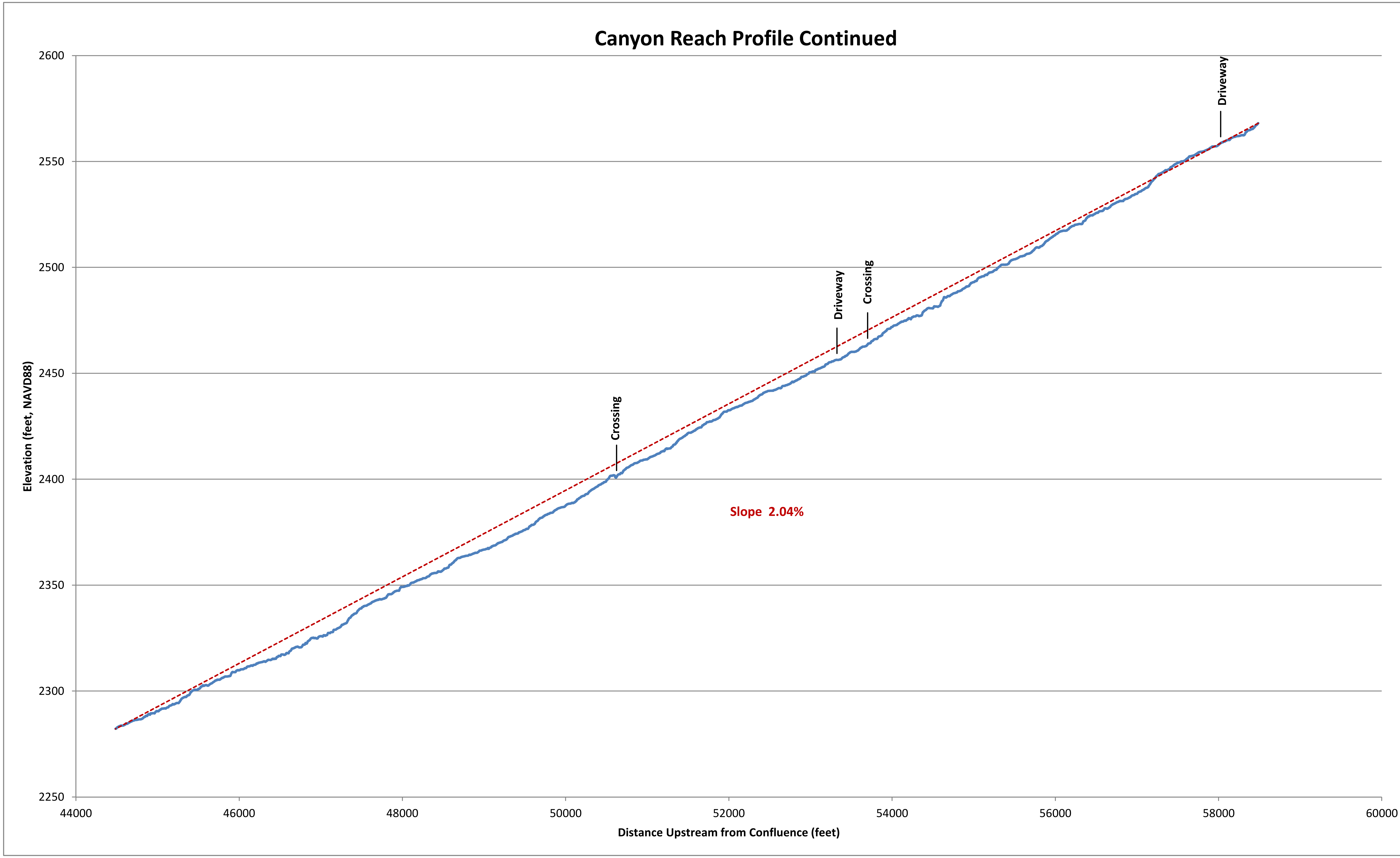

Canyon Reach Profile Continued
Elevation (feet, NAVD88)
Distance Upstream from Confluence (feet)
2600
2550
2500
2450
2400
2350
2300
2250
44000
46000
48000
50000
52000
54000
56000
58000
60000
Crossing
Driveway
Crossing
Driveway
Slope 2.04%

Figure F28

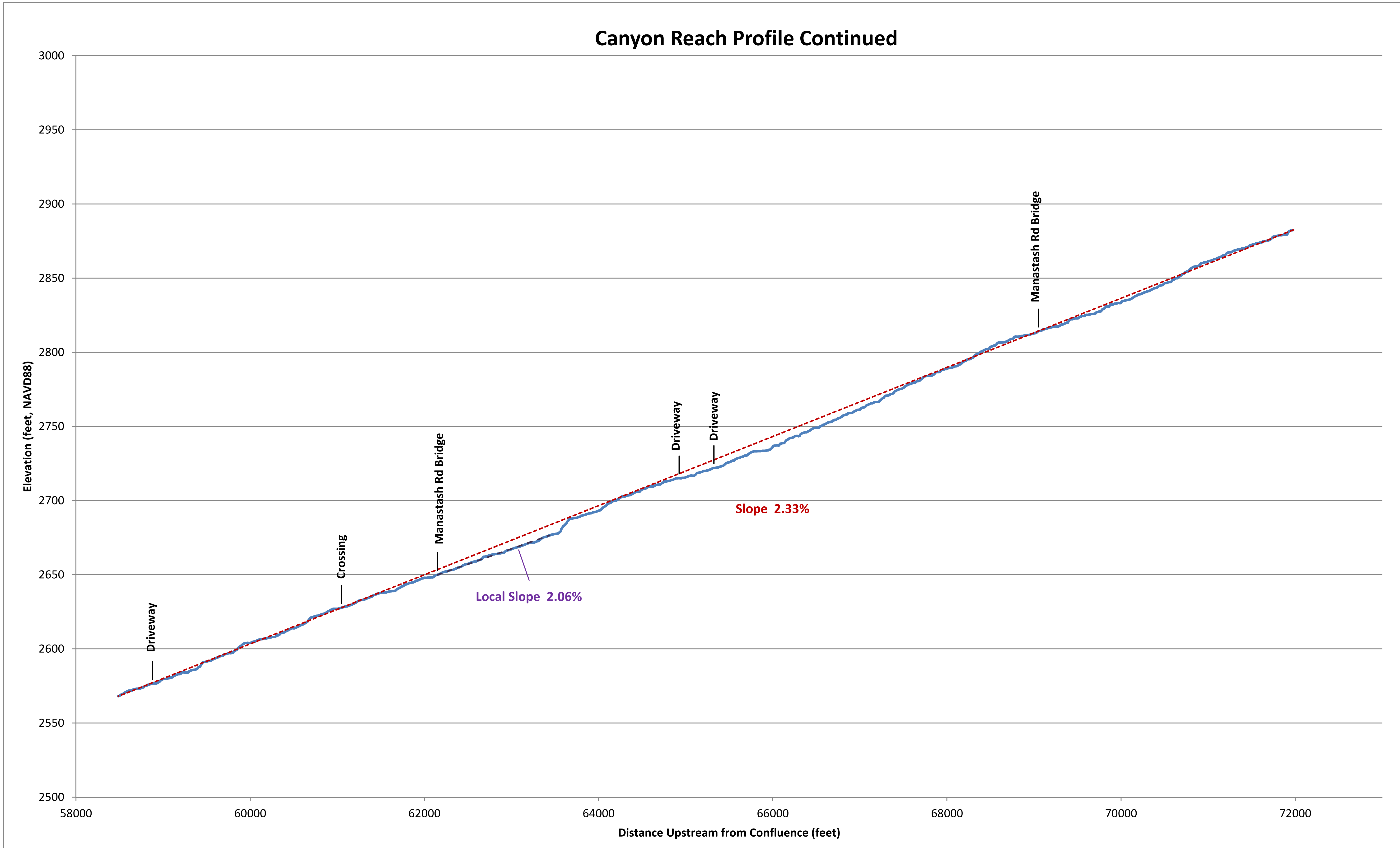

Canyon Reach Profile Continued
Elevation (feet, NAVD88)
Distance Upstream from Confluence (feet)
3000
2950
2900
2850
2800
2750
2700
2650
2600
2550
2500
58000
60000
62000
64000
66000
68000
70000
72000
Driveway
Crossing
Manastash Rd Bridge
Driveway
Driveway
Manastash Rd Bridge
Slope 2.33%
Local Slope 2.06%

Figure F29

APPENDIX G

Photographic Documentation of Flood and Erosion Hazards

YAKIMA CONFLUENCE REACH

Photo 1YC. Viewing south along Yakima Confluence Reach during May 2011 flooding. The Yakima River is to the right and is flowing toward the top of the photograph (County photo).

ENTRENCHED TERRACE REACH

Photo 1ET. Viewing south over Manastash Creek at Barnes Road Bridge (right of center) during May 2011 flood. Water is generally confined within the treed corridor (County photo).

Photo 2ET. Example of debris jam within the entrenched reach.

Photo 3ET. Barnes Road upstream left bank damage May 2011 flood.

Photo 4ET. Water on the Wise property downstream of Brown Road during May 2011 flooding. This is one of the few structures located on the floor of the entrenched reach. Ecology blocks were used to construct a levee during/following flooding.

Photo 5ET. Viewing south to the entrenched reach during May 2011 flooding. The straight reach dowsntream of Serenty Lane (right center) carried sediment and wood which deposited in the innundated field and trees approximately 800 ft downstream (County photo).

FAN CONTRACTION REACH

Photo 1FC. Viewing south to flowpaths converging at Serenity Lane bridge (left of center) during May 2011 Flood. Hanson Road, in foreground, intercepted a significant portion of overbank flow and funneled it back to the creek at this location (County photo).

Photo 2FC. Viewing north to the downtream left bank abutment of Serenity Road bridge. Bridge abutments have been undermined and are in need of repair (July 25, 2012).

Photo 3FC. Viewing upstream from Serenity Lane Bridge after the May 2011 Flooding.


Photo 4FC. Viewing upstream (west) to Cove Road Bridge (July 25, 2012).


Photo 5FC. Flow escaping the channel at Cove Road during May 2011 flooding. Historical floodplain swales are highlighted by water working its way down the fan (County photo).

FAN EXPANSION REACH

Photo 1FE. Flooding at Cove Road during May 2011 flooding (County photo).

Photo 2FE. Viewing south over Quail Run and Cedar Cove Roads during May 2011 Flooding. Scour and deposition occurred within the main channel (center), and flow has entered the Reed Ditch (foreground) and an overflow path south of the creek (background) (County Photo).

Photo 3FE. Scoured channel bank along Carns Property near RM 4.4. Notice change in gradation between material near the bank and within the channel Photo taken July 26, 2012 during sediment sampling. Weak creekside vegetation allowed significant bank erosion within this reach.

Photo 4FE. Viewing south in the vicinity of the Reed Diversion Dam during May 2011 Flooding. The stream is in the middle of the treeded corridor. Flow has entered the Reed Ditch (foreground) and the south floodplain (background) (County Photo).

Photo 5FE. Large material eroded from the channel bank on the Carns property (July 25, 2012). This is glacial drift outwash and many of the stones are too large to be transported downstream.

Photo 6FE. Viewing downstream to the incised reach below Reed Dam (July 25, 2012).

Photo 7FE. Water flowing over the dam at Reed Dam on July 25, 2012. Severe incision has resulted in erosion beneath the structure leaving the dam perched above the channel.

CANYON REACH

Photo 1C. Viewing south just upstream from the mouth of the canyon during the May 2011 flooding within the Sienia, Kinnan, Berger and Bradley properties (County Photo).

Photo 2C. Viewing upstream to overbank flooding on the Berger property which is near the mouth of the Canyon in the area shown in Photo 1C. The main channel is located to the right of the photo, and overflow water seen in the foreground continued down the valley floor to flood downstream landowners.

Figure 3C. Straightened channel along Manastash Road within the canyon reach near River Mile 10. Note riprap placed to protect road. Photo taken July 25, 2012.

Figure 4 C. Viewing creek overflow/avulsion through Bauman property during the May 2011 flood. The head of this overflow path was later manually blocked by a berm constructed using sediment deposited on the Bauman property (County Photo).

Figure 5C. Conducting a pebble count on an abandoned meander bend along the Cayon Reach approximately RM 6.4 (July 26, 2012).

Figure 6C. MWDA diversion fooking upstream during May 2011 flooding (KCCD photo).

Figure 7C. Water overflowing the Keach-Jensen diversion during May 2011 flooding (KCCD photo).