To: Chelan County Natural Resource Department

From: Shawn Higgins, Mike (Rocky) Hrachovec, John Soden, Tim Abbe, and Kelvin Andrews, Natural Systems Design

Date: October 26, 2015

Re: Baseline Reach Characteristics: Peshastin Creek at RM 8.8 Project Site

BACKGROUND

The Peshatin Creek RM 8.8 project site is located between river miles (RM) 8.4 and 9.2 on Peshastin Creek in Chelan County, Washington. The project reach was channelized into a straightened alignment parallel to SR 97 as part of highway construction in the late 1950s. Prior to channelization, the historical channel followed a more sinuous flowpath and had greater connectivity with the adjacent floodplain. Reconnection of the historical channel alignment at the RM 8.8 site was previously identified as a priority habitat restoration project within Peshastin Creek (Inter-Fluve, 2010). Natural Systems Design, Inc. (NSD) is developing design plans for reconnection of the historical channel under contract to, and in coordination with, the Chelan County Natural Resource Department (CCNRD).

This memorandum presents a synthesis of baseline reach characteristics at the RM 8.8 project site. The Tributary and Reach Assessment for Lower Peshastin Creek (Inter-Fluve, 2010) previously evaluated basin- and reach-scale conditions as part of a planning level assessment to identify restoration opportunities. Findings from this previous assessment are synthesized here and augmented by observations from NSD's field reconnaissance of the project reach on September 15, 2015, GIS data analysis using the 2006 LiDAR DEM, and hydraulic model simulations.

Baseline Reach Characteristics

NSD developed a geomorphic map of the project reach using relative elevations derived from the 2006 LiDAR DEM to highlight valley topography and landforms (Map 1). This map, along with other GIS outputs from this assessment are attached to this memorandum as Appendix A. Site photos collected during field reconnaissance are attached as Appendix B. An overview of reach characteristics are presented below in Table 1 and followed by a narrative summary.

Valley Setting

The RM 8.8 project site is located in a dynamic setting immediately downstream of the confluence of Peshastin Creek and Ingalls Creek (Figure 1). Valley topography and landforms are shown in Map 1 with elevation relative to the active channel derived from a 2006 LiDAR Digital Elevation Model (DEM). A series of tectonic faults (Leavenworth Fault Zone) cross the valley both up- and downstream of the RM 8.8 project site. Hillslope areas flanking the site are underlain by geologic units of the Ingalls Tectonic Complex (late Jurassic to early Cretaceous). During the Pleistocene, alpine glaciers from the Ingalls Creek subbasin turned north at the confluence with Peshastin Creek and reshaped the valley. Deposits from the most recent glaciation, approximately 18,000 years ago, confine the valley just downstream of the confluence forming bluffs that rise approximately 60 feet above the valley floor. The till forming these deposits is a poorly sorted mixture of sediment ranging in size from sand to boulders a large as 2 meters (6.5 feet) in diameter. Valley width is confined to approximately 400 feet between the glacial deposits downstream of the confluence, then widens to over 1,000 feet across downstream of RM 8.9. Another exposure of glacial till crops out along the east side of the valley between RM 8.5 and 8.8. Alluvial fan deposits from Hansel Creek project into the valley from the west between RM 8.3 and 8.7. Across the valley, a smaller alluvial fan is present at the outlet of the unnamed right bank tributary near RM 8.5.

Hydrology

The watershed upstream of the RM 8.8 project site drains an area of 102 square miles. Flow at the upper end of the reach is split between subbasins draining Ingalls Creek and Upper Peshastin Creek (Table 2). The Upper Peshastin subbasin drains an area about 62% greater than Ingalls Creek, however, the Ingalls Creek subbasin is about 48% wetter than Upper Peshastin. As such, the annual flow distribution is probably closer to an even split. Tributary inflow within the project reach includes Hansel Creek and two unnamed tributaries that drain hillslope areas from the east. The Hansel Creek subbasin accounts for about 4% of the total drainage area contributing flow to the project reach. The unnamed tributaries from the eastern hillslope account for less than 1% of the contributing drainage area.

Table 1. Baseline reach characteristics of Peshastin Creek from RM 8.3 to 9.1 (RM 8.8 Project Site)

Metric	Value	Data Source and Notes
Watershed Characteristics		
Drainage Area	102 sq mi	USGS Topographic Maps
Mean Annual Precipitation	41 in	PRISM Climate Group, OSU
Mean Annual Streamflow	140 cfs	ECY gage 45F070; adj for drainage area
2-yr Peak Flow (Q_2)	900 cfs	Reclamation (2008)
100-yr Peak Flow (Q_{100})	3,310 cfs	" "
Channel and Floodplain Geometry		
Channel Length	4,300 ft	2006 LiDAR DEM;
Sinuosity	1.01	Channel length / valley length.
Channel Gradient	0.024 ft/ft	Reach avgerage. Ranges between 0.018 and 0.030 ft/ft.
Bankfull Width	50 ft	Range between 40 and 65 ft.
Mean Depth	2.3 ft	Range between 1.8 and 3.1 ft.
Width/Depth Ratio	25	
Valley Width	400-1,100 ft	Moderately confined by glacial deposits near RM 9.
Confinement Ratio	8-22	Valley width / channel width (< 4 is confined).
Q100 Wetted Width	65 ft	Average from hydraulic model simulations.
Entrenchment Ratio	1.3	Floodprone (Q100) width/channel width (<1.4 is entrenched).
Bed Material		
Median Grain Size (D_{50})	128 mm	Medium Cobble
10^{th} Percentile Grain Size (D_{10})	12 mm	Medium Gravel
90^{th} Percentile Grain Size (D_{90})	512 mm	Boulder
Wood		
Key pieces	0 pieces	No stable wood observed in 2015 field reconnaissance
Hydraulic Parameters		
Q_2 Cross-Sectional Area	120 ft^2	Simulated wse and channel geometry from LiDAR DEM.
Q_2 Avg Velocity	9 ft/sec	Range between 7 and 12.5 ft/sec.

Metric	Value	Data Source and Notes
Q_2 Total Shear Stress (τ_0)	3.4 lb/sq ft	Based on reach average gradient and hydraulic depth.
Q_2 Grain Stress (τ')	2.3 lb/sq ft	Wilcok (2009) calculation of drag partition
Critical Shear Stress (τ_c) for D_{50}	2 lb/sq ft	Mobility of bed material when $\tau' > \tau_c$
Q_{100} Avg Velocity	15 ft/sec	Range between 11 and 19.5 ft/sec.
Q_{100} Total Shear Stress (τ_0)	6.9 lb/sq ft	Based on reach average gradient and hydraulic depth.
Q_{100} Grain Stress (τ')	5 lb/sq ft	Not competent to mobilize D_{90} (512 mm).

Table 2. Subbasin characteristics of the contributing drainage areas upstream of the RM 8.8 project site and near the watershed outlet.

Basin	Drainage Area (square miles)	Mean Annual Precipitation* (inches)
Peshastin Creek above Ingalls Creek Road (RM 8.3)	**102**	**41**
Upper Peshastin Creek	60	35
Ingalls Creek	37	52
Hansel Creek	4	35
Right Bank Tributaries (RM 8.5-9)	0.8	31
Peshastin Creek at Watershed Outlet	**134**	**38**

* PRISM Climate Group, Oregon State University

The seasonal flow regime is characterized by a rainfall dominated period during fall, a snowfall dominated period during winter, snowmelt runoff during spring and early summer, and a period of low streamflow as snowmelt recedes in August and September. Peak flows occur with spring/summer snowmelt during most years. Extreme flood events; however, tend to occur in fall or winter in response to atmospheric river storm events that are associated with relatively warm temperatures that raise freezing levels and heavy rainfall that combines with melting snow to produce large amounts of runoff. The three largest floods recorded for the Wenatchee Basin in recent decades (Nov. 1990, Nov. 1995, and Nov. 2006) all were caused by large atmospheric river storms with substantial rain-on-snow contributions.

Washington Department of Ecology (Ecology) monitors streamflow at a gaging station near RM 1.4 at Green Bridge Road (site 45F070). The contributing drainage area upstream of the gage site encompasses 134 square miles. Data at the Ecology gage cover the period from September 2002 to present (13 years). Annual hydrographs of streamflow data from the gaging station at Green Bridge Road are presented in Figure 2. Ecology collected periodic streamflow measurements at additional gage sites upstream (site 45F110) of the Ingalls Creek confluence and at the Ingalls Creek Road Bridge (site 45F100) over the period 2003-2009; however, gage readings were recorded manually at these sites (approximately 10-40 readings per year) and do not form a continuous record.

Figure 2 shows the seasonal variation of streamflow from two representative water years (WY) using streamflow data from the Ecology gage near RM 1.4. WY 2011 was the wettest year over the period of record and WY 2013 had an annual flow that approximated the average value over the period of record. The hydrograph for WY 2011 includes an example of a rain-on-snow driven flood in January. No such rain-on-snow driven peaks occurred in winter of 2013. WY 2011 had a relatively average snowpack in spring and a sustained snowmelt runoff period. WY 2013, in contrast, had a relatively low snowpack and streamflow receded rapidly in July. The extended baseflow period shown for WY 2013 is likely to be a more typical flow regime given projected climate change with increased temperatures and reduced snowfall accumulation in future decades. Summer baseflows reported for the Ecology gage site at Ingalls Creek Road Bridge show a range of 25-30 cfs is commonly observed during late summer in the project reach. NSD measured a flow of 14 cfs during field reconnaissance on 9/15/2015 following a winter with record low snowfall totals in the Cascades.

Peak Flows

Data from the Department of Ecology gaging stations in Peshastin Creek are useful for describing the general streamflow characteristics; however, the gage data are not sufficient for calculation of flood frequency magnitudes in the watershed due to the limited record and operational failures during large floods. The records contain no data for the annual peak flow during 4 of the 13 years over the period of record. As such, characterizing flood frequency statistics to inform design criteria for project actions requires an estimate based on data from adjacent watersheds. The Bureau of Reclamation (2008) has developed a regression based tool to estimate flood frequency statistics for ungaged streams in the Wenatchee River Basin (Table 3). The flood in January 2011 (2780 cfs) was the largest recorded peak flow at the gage and is estimated as greater than a 10-year recurrence interval flood based on the Reclamation (2008) flood frequency statistics. Other floods of greater magnitude occurred in November 2006 and in January 2009; however, those peaks were not recorded at the gage.

Table 3. Estimated flood frequency statistics for Peshastin Creek produced (Reclamation, 2008; as cited by Inter-Fluve, 2010).

Basin	Estimated Peak Flow (cfs)					
	Q2	Q5	Q10	Q25	Q50	Q100
Peshastin Creek above Camas Creek*	**900**	**1,370**	**1,750**	**2,310**	**2,780**	**3,310**
Peshastin Creek at Watershed Outlet	1,210	1,860	2,370	3,120	3,770	4,490

*Used for project reach

Hydraulic Analysis

The primary objective of NSD's hydraulic analysis was to evaluate flow patterns, hydraulic parameters, and inundation extents to characterize current riverine conditions within the project area and to compare with proposed conditions model simulations. The hydraulic analysis was conducted for the 2- and 100-year peak flow discharges described in the preceding section. All model runs were performed in steady state (discharge does not vary with time) with a non-deformable bed (no adjustments for scour, sediment transport or deposition). Hydraulic models were created representative of existing conditions using Hydronia's RiverFlow-2D Plus GPU and Aquaveo's Surface-water Modeling System (SMS) v11.2 computer software. RiverFlow-2D is a two-dimensional finite volume computer model that provides depth-averaged hydraulic parameters at nodes within a triangular model mesh domain by solving the shallow water equations resulting from integration of the Navier-Stokes equation. The Navier Stokes equation is derived from applying Newton's Second Law (Force = mass*acceleration) to fluid motion, and is generally expressed as:

$$\overbrace{\rho\Big(\underbrace{\frac{\partial \mathbf{v}}{\partial t}}_{\substack{\text{Unsteady}\\\text{acceleration}}} + \underbrace{\mathbf{v}\cdot\nabla\mathbf{v}}_{\substack{\text{Convective}\\\text{acceleration}}}\Big)}^{\text{Inertia (per volume)}} = \overbrace{\underbrace{-\nabla p}_{\substack{\text{Pressure}\\\text{gradient}}} + \underbrace{\mu\nabla^2\mathbf{v}}_{\text{Viscosity}}}^{\text{Divergence of stress}} + \underbrace{\mathbf{f}}_{\substack{\text{Other}\\\text{body}\\\text{forces}}}.$$

Where ρ = fluid density

μ = dynamic viscosities

p = pressure

$\nabla =$ del operator (abbreviation for derivative (gradient) of 3D vector field)

f = term representing body forces acting on the fluid (per unit volume)

SMS is a GIS-based program that creates the triangular model mesh, model input files, and displays model results. The following sections provide more in-depth information on specific components of our hydraulic analysis, data development, and results. Model results are summarized in Table 1 and inundation and velocity maps are provided in Appendix A.

Model Topography

All hydraulic models utilized the October 2006 LiDAR data collected by Watershed Sciences to represent channel and floodplain topography. The horizontal and vertical datum of all data utilized and referenced in the hydraulics is NAD 1983 Washington State Plane North feet and NAVD88 feet, respectively. Due to the limited light penetrating abilities of near infrared (NIR) LiDAR scanners, channel topography utilizing only NIR LiDAR is representative of the water surface at the time of LiDAR acquisition, not the channel bottom. Review of the 2006 LiDAR data indicates that the channel bathymetry is not well represented but the majority of out of water areas (gravel bars, floodplain, etc.) are representative of current conditions. The existing conditions model simulations utilized a point cloud derived directly from the ground and water surface points delivered in the raw LiDAR data. If model runs of low flows are requested in future phases of this project, we would recommend channel survey data be acquired at key locations to increase the accuracy of model results.

Mesh

A mesh or wireframe is a key component to any 2D hydraulic model. The model derives one depth-averaged flow velocity (direction and magnitude) at each node of the 2D (x-y) mesh. To predict vertical variations in flow within the water column would require a 3D model. The mesh is composed of nodes and elements that are coded with elevation and roughness values needed to run the computational routine. RiverFlow-2D utilizes a flexible tri-angular mesh to solve for volume conservation and momentum in the x and y directions at each node (representing depth average). The model mesh begins near the confluence with Ingalls Creek and extends approximately 0.9 miles downstream to RM 8.2. For this project the model mesh utilized 80,755 triangular elements and 40,971 nodes. The governing equations are applied at each node in an iterative routine until converging on a solution that achieves conservation of mass and energy to within an acceptable error.

To create the model mesh, a map consisting of arcs and regions delineating the channel, floodplain features, and material types was developed using Aquaveo's SMS software. Arcs were drawn along significant topographic features (top of bank, bars, roadways) and changes in roughness (ground cover type, mean vegetation height). Arcs function as breaklines during the mesh creation process to ensure the model mesh is an accurate representation of the channel/floodplain topography and to create regions within the map to which different roughness values can be assigned.

Roughness

Hydraulic analyses require an assessment of the resistance (drag force) the ground surface and other physical features exert against the movement of water. This drag force is commonly referred to as roughness. The most accepted method to assess roughness uses the Manning's n resistance factor (Chow, 1959). Common factors that affect roughness values include: channel sediment size, gradation, and shape; channel shape, channel meandering, bank and floodplain vegetation, obstructions to flow, flow depth, and flow rate. 2D hydraulic models explicitly calculate momentum losses caused by channel shape, meandering, and floodplain topography not normally accounted for in 1D hydraulic models. As such, Manning's n values in 2D models can generally be lower (up to 30%) than those normally used for 1D hydraulic models (Hydronia, 2012). Manning's n values for this project were assigned to different roughness types using a hillshade image derived from the 2006 LiDAR and 2015 aerial imagery from Google Earth and in accordance with standard hydraulic reference manuals (Chow, 1959; Barnes, 1967; Hicks and Mason, 1998). An adjustment for hydraulic radius was then applied for variability between the 2- and 100-year flows according to the Limerinos equation. Model roughness values are shown in Table 4 below.

Table 4. Model Roughness Values

Roughness Type	Manning's N Value	
	2 year	100 year
building	0.2	0.2
channel main	0.046	0.041
forest	0.12	0.12
gravel bar	0.046	0.041
gravel bar-vegetated	0.09	0.09
road-gravel	0.014	0.014
road-pavement	0.01	0.01
shrub	0.09	0.09
slough	0.02	0.02

Boundary Conditions

All hydraulic models require the user to input a known boundary condition at the upstream and downstream extents to begin the computational routine. The upstream boundary condition for all model runs was set to the corresponding peak flow rate described in the hydrology section of this assessment for the 2- and 100-yr recurrence interval flows. The downstream boundary condition for all model runs was set to a free outflow, which enables the model to calculate velocities and WSE based on the same iterative routines applied throughout the model domain. Model boundary condition values are shown in Table 5.

Table 5. Model Boundary Conditions

Recurrence Interval	Discharge (cfs)	Downstream Boundary Condition
2 year	900	Free Outflow
100 year	3310	Free Outflow

Existing Conditions Hydraulic Results

Results from the existing conditions model simulations are summarized in Table 1 and attached to this report in Appendix A. Completed model runs were initially reviewed in SMS to verify accuracy of results and then exported to a GIS compatible data file. GIS files include data for each node and hydraulic parameter within the model mesh (bed elevation, water surface, flow depth, velocity, shear stress, etc.) to facilitate development of raster grids representing the model results.

Channel Planform and Profile

The active channel alignment follows a straight alignment parallel to SR 97 through the project reach. A reach average gradient of 0.024 ft/ft (2.4%) was calculated from the 2006 LiDAR DEM (Figure 3). At the downstream end of the project reach Peshastin Creek is crossed by a bridge with an approximately 75 foot span and two concrete piers (Photo 1). The gradient steepens immediately upstream of the bridge (2.8%) due to the historical cutoff of a meander bend between RM 8.3 and 8.5. The channel is confined by the road embankment for SR 97 on the right and an approximately 25-foot high bluff composed of alluvial fan deposits along the left bank (Photo 2). Gradient decreases to about 2% upstream of RM 8.5 to about RM 8.9. At RM 8.9, the channel is confined between the road embankment on the right and a high bluff underlain by glacial deposits on the left (Photo 11). As the channel traverses along this glacial deposit gradient increases to 2.7% and continues at this grade upstream to the Ingalls Creek confluence. Upstream of the confluence, Peshastin Creek steepens to a grade of approximately 3.7%. Ingalls Creek has a gradient of approximately 3.1% for a distance of 2,500 upstream of the confluence then steepens to approximately 4.6% as the valley narrows upstream.

Right of way (ROW) maps prepared for construction of SR 97 in the late 1950s show the channel in the historic alignment prior to channelization. The ROW map is overlaid with existing topography in Map 3; however, there is an unresolved georeferencing issue near the take-out point at the upstream end as the ROW map shows the channel intersecting the high glacial deposit. We have adjusted the alignment in this location using the existing topography as a guide and included an overlay of the historical alignment with the Relative Elevation Map (REM) shown in Map 1. The pre-channelization alignment is slightly more sinuous than the existing alignment with an additional 500 feet of primary channel over the project reach and approximately 1,200 feet of secondary channels shown in the ROW maps. Note, however, that the channel condition in the 1950s is not necessarily representative of a "natural" condition and had been affected by decades of human impacts such as timber harvest and road construction earlier in the historical period.

Cross-Sectional Geometry and Floodplain Connectivity

A series of four representative cross-sections extracted from the 2006 LiDAR DEM are presented in Figure 4 to Figure 7. The channelized alignment has a cross-section geometry with near-bankfull channel widths ranging between 42 and 65 feet (typical section is approximately 50 feet wide). The channel is artificially confined by the SR97 road embankment to the east and by large spoils piles that flank the west side of the channel for much of its length. Regional regression equations by Castro and Jackson (2001) relating bankfull channel dimensions to streamflow characteristics predict a bankfull width of approximately 60 to 65 feet. There is a short section near RM 9.1 that is upstream of the channelization project and downstream of the Ingalls Creek confluence where NSD measured bankfull width of 62 feet.

Hydraulic model simulations of the project reach show that there is effectively no floodplain connectivity under baseline conditions. There is one limited exception near RM 8.75 where there is an approximately 40 foot wide bench surface flanking the left side of the channel that has a cobble-dominated substrate with localized areas of sand deposition and some small wood racked up against vegetation (Photo 7). This surface is inundated in the simulated 2-year flood discharge (Map 4). The 100-year flood simulation shows an increase in depth without any substantial overbank flow due to the highly confined nature of the existing channel (Map 5). Predicted water surface elevations from the two model simulations are overlain with the representative cross-sections in Figure 4 to Figure 7.

Comparison of the existing channel geometry with that of the historical channel on the east side of the valley suggests that there has not been substantial incision since the channelization project. The existing channel is actually at a higher elevation than the historical channel when compared in cross-section transects.

Bed Material

Peshastin Creek has a bed composed of coarse material given the geomorphic setting and relatively steep channel profile. NSD collected pebble count samples (surface) in the channnelized reach of the active channel near RM 8.6 and in a short, unconfined reach just downstream of Ingalls Creek near RM 9.1 (Figure 8). In the confined segment near RM 8.6, the bed has a median grain size (D_{50}) of approximately 128 mm (5 inches) and 90 percent of the bed material is finer than (D_{90}) 512 mm (20 inches). Fine sediment less than 2 mm, sand-sized particles or smaller, composed less than 6% of the bed material.

Sediment sources to the project reach include tributary inputs from the upper watershed, hillslope inputs, and remobilization of bed and bank materials. The upper watershed is steep and prone to landsliding in some locations. The Ruby Creek slide upstream of the project reach near RM 10.4 released a large pulse of sediment during the 1996 flood and is likely a significant source of sediment to the project reach. The glacial deposits near the upper end of the porject reach and along the valley margin contribute abundant sediment loads including large boulders.

Hydraulic parameters from the baseline hydraulic model were utilized to estimate shear stress and sediment transport capacity. A relation from Wilcock et al. (2009) was used to estimate the drag partition, or grain stress (τ'), representing the partition of the total applied shear stress that is acting on the sediment grains and available for sediment transport as:

$$\tau' = 17(SD_{65})^{1/4}U^{3/2}$$

Where S = slope of the energy grade line

D_{65} = 65th percentil of the sediment grain size distribution

U = velocity

The calculated grain stress for the 2-year recurrence interval peak flow (2.3 lbs/sq ft) is slightly greater than the critical shear stress for entrainment of the median grain size (2 lbs/sq ft) verifying the assumption that the surface layer of bed material is mobilized by near-bankfull flow. Comparing the calculated shear stress to critical shear stress for entrainment of the coarse fraction of the grain size distibution (represented by D_{90}) suggest that the larger boulders observed in the bed are derived from the adjacent hillslope areas and not mobilized by large flows such as the 100-year flood.

Channel Type and Bedforms

The project reach is predominantly a plane-bed channel lacking developed bedforms. No functional wood was observed in the channel. Localized areas include aggregations of boulders to form a step that results in plunging flow and scour on the downstream end. Other mechanisms of bedform development include localized scour around large boulders. Field reconnaissance noted locations of approximately three small pools over the reach length (approximately 3 pools/mile); however, even these were very shallow and had no cover to function as good pool habitat.

Riparian Conditions and Wetlands

NSD staff conducted field work to assess existing habitat conditions on September 15, 2015. During this site visit, four main vegetation areas were identified: a) forested riparian edge and floodplain, b) wetland, c) forested upland and clearings, d) un-vegetated, heavily-utilized gravel borrow-pit and storage-pile areas. In general, a scarcity of large trees was observed in the forested riparian and floodplain areas. The wetland areas were all ponded with mature wetland species present. Lastly, the un-vegetated gravel-pit and storage areas will require significant restoration design work in order to re-engage them as a part of the restored Peshastin Creek habitat. Detailed existing conditions and design considerations are described below.

Within the project area, trees line almost the entire riparian edge of the existing creek channel. However, in many places, this riparian buffer is just one or two trees deep, with large areas of cleared open space behind. In the areas with continuous tree cover, from river edge to road, the forest composition is dominated by young cottonwood trees and saplings. There are some mature and sapling Pondersa pine, Douglas fir, big leaf maple, and western red cedar scattered along the riparian edge and into the adjacent floodplain. Willow, red-osier dogwood, and mountain alder represent the shrub layer in the understory, mostly along the riparian edge.

Photo 1 Forested Riparian Edge, Peshastin Creek (NSD, 9/2015)

Photo 2. Upland clearings, (NSD, 9/2015)

Wetlands onsite are limited to the historical channel alignment. No wetlands were identified within floodplain areas. Wetland hydrology is provided by hillside runoff and likely a shallow groundwater table. These wetlands have a diversity of plant species including western red cedar, red-osier dogwood, big leaf maple, willow, mountain alder, smallfruit bulrush, horsetail, and cattail, among others. Reed canarygrass was observed in some areas but, it was not growing as a monoculture.

Photo 3. Wetland within historical channel alignment (NSD, 9/2015)

FIGURES

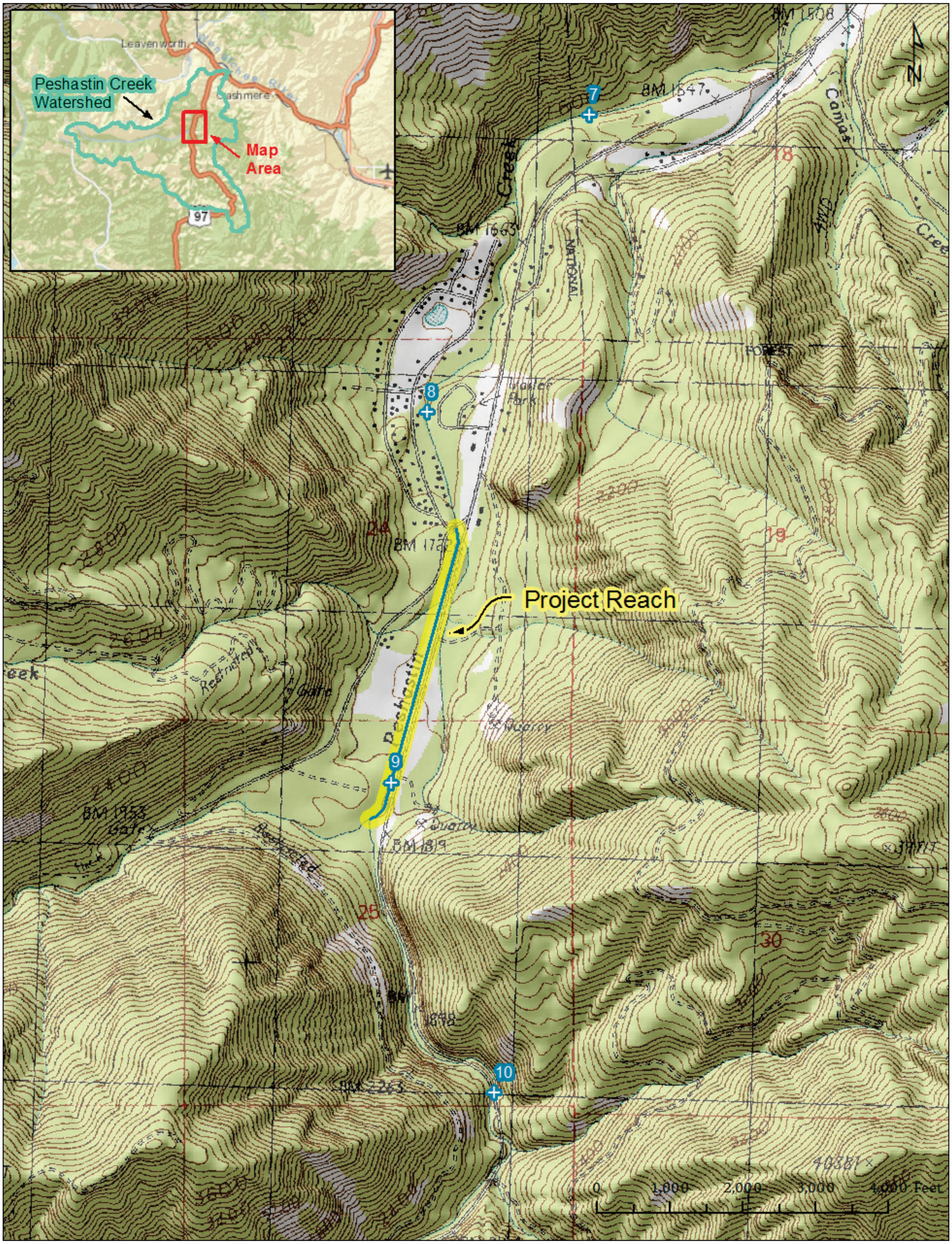

Figure 1. Project location map.

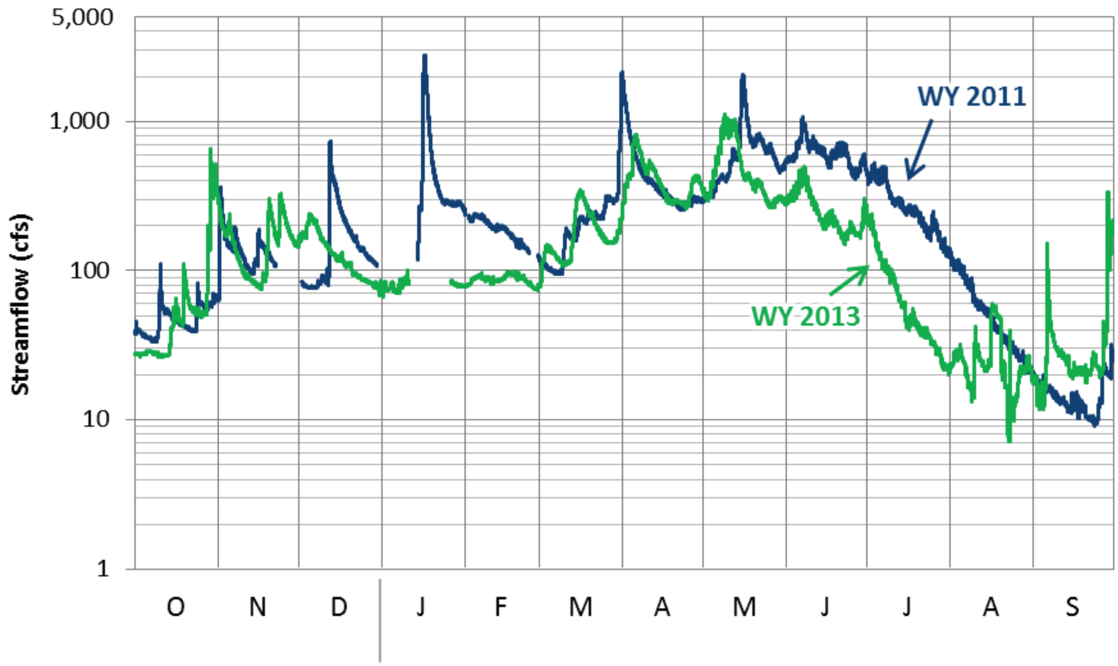

Figure 2. Annual hydrographs for Peshastin Creek at Green Bridge Road (site 45F070) during WY 2011 (blue) and WY 2013 (green).

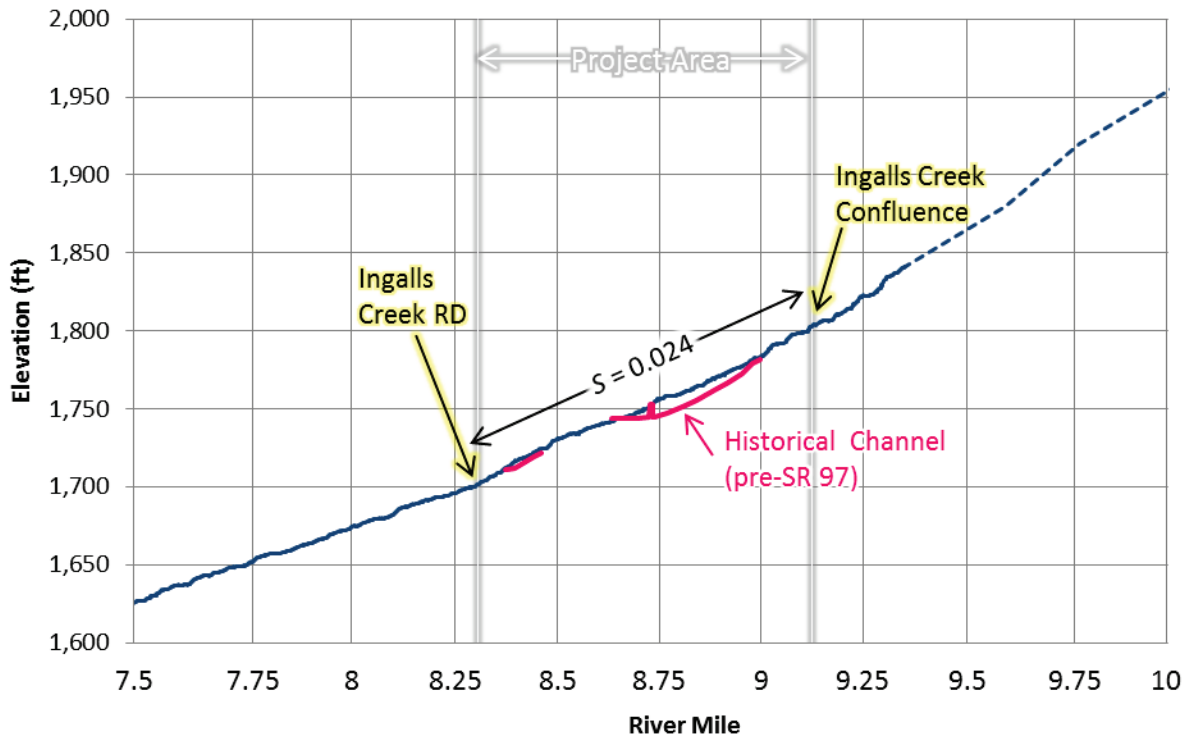

Figure 3. Longitudinal profile of Peshastin Creek derived from 2006 LiDAR DEM. Profile extended upstream of RM 9.5 (dashed blue line) using elevation contours from USGS 1:24,000 scale map. Profile of the pre-SR 97 channel alignment (pink) is projected onto the stationing of the active channel alignment.

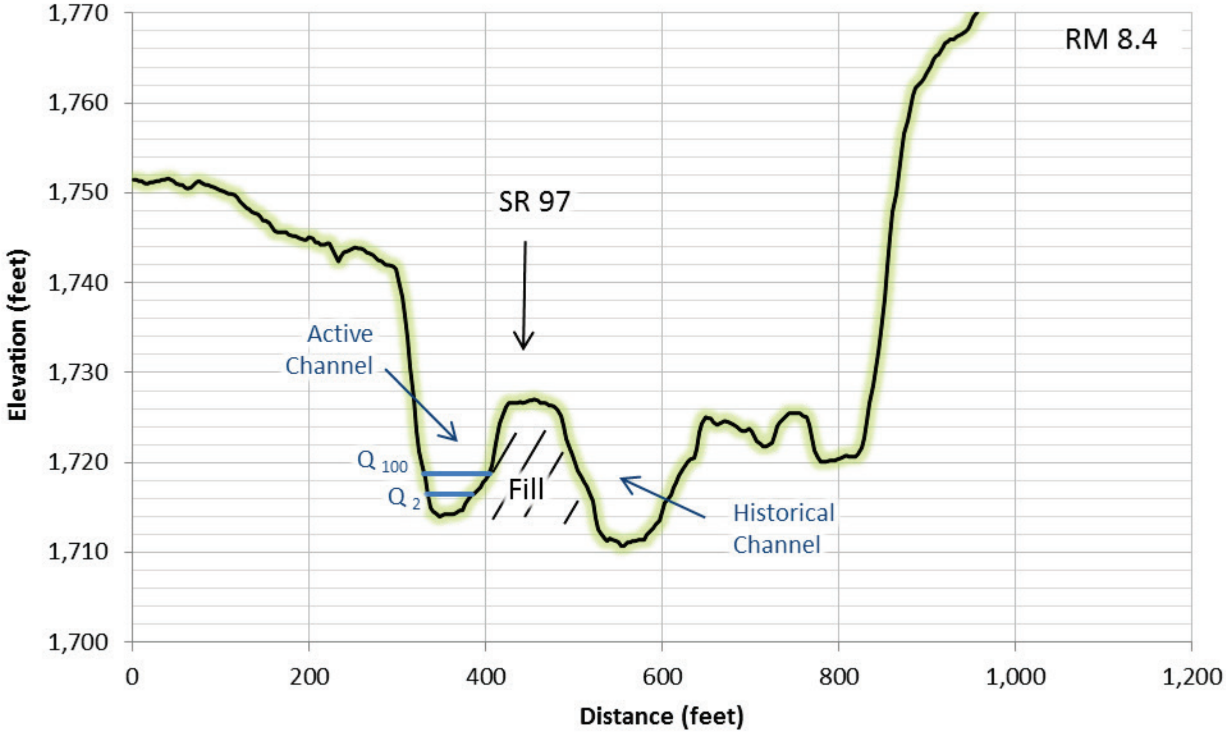

Figure 4. Cross-section A-A' near RM 8.4, just upstream of the Ingalls Creek Road Bridge (source: 2006 LiDAR DEM).

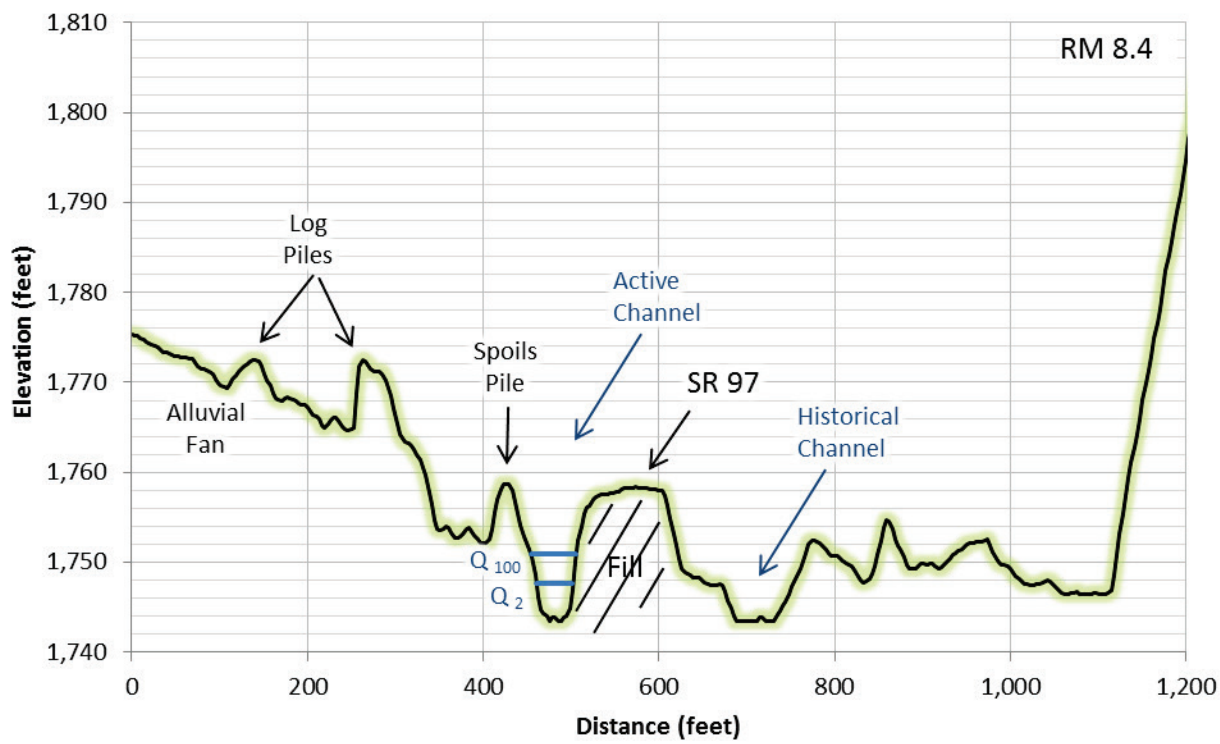

Figure 5. Cross-section B-B' near RM 8.6, just upstream of the Hansel Creek confluence (source: 2006 LiDAR DEM).

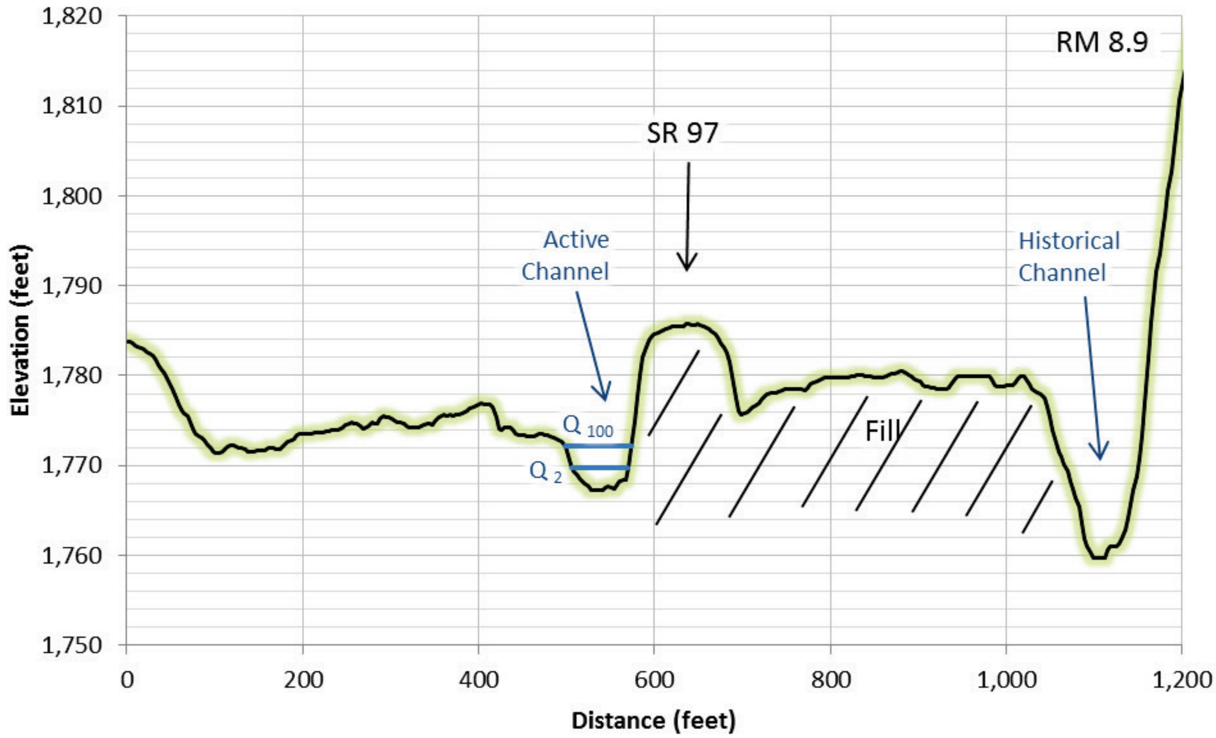

Figure 6. Cross-section C-C' near RM 8.7 (source: 2006 LiDAR DEM).

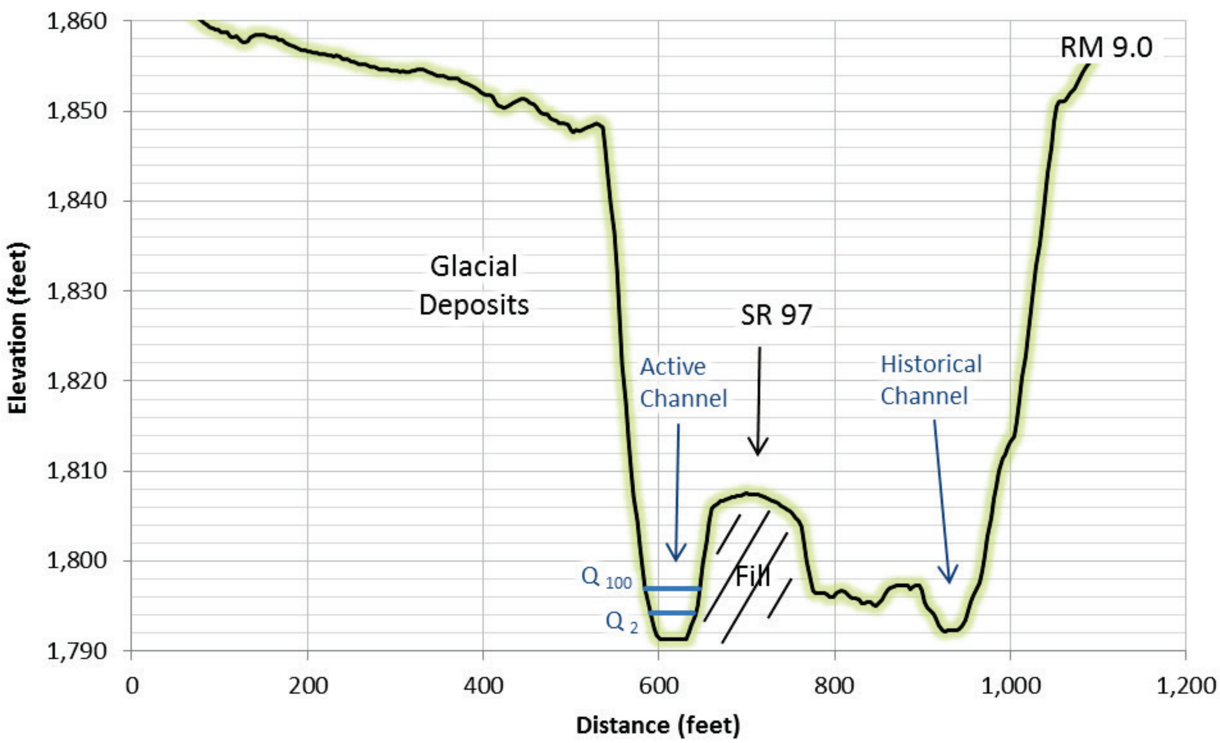

Figure 7. Cross-section D-D' near RM 9, just downstream of Ingalls Creek confluence (source: 2006 LiDAR DEM).

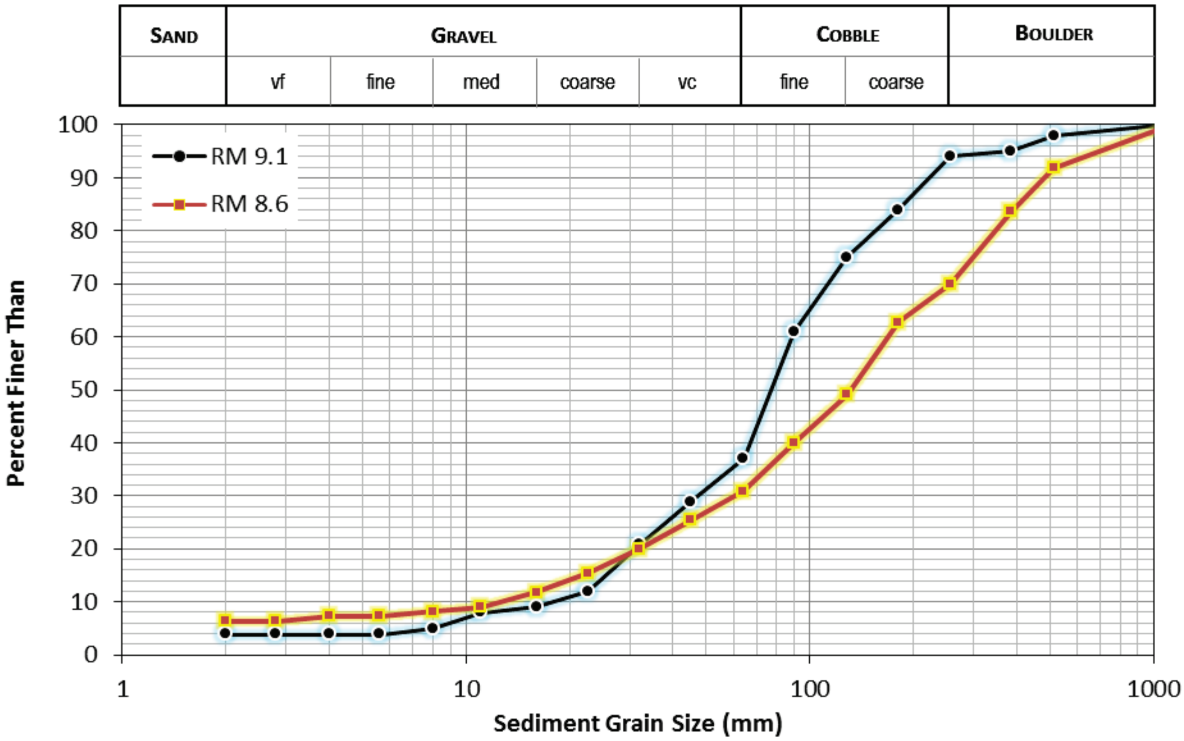

Figure 8. Sediment grain size distributions for two pebble count samples in Peshastin Creek. The sample at RM 8.6 is representative of the confined channel segment parallel to SR97 and has a larger proportion of coarse bed materials. The sample at RM 9.1 is downstream of the Ingalls Creek confluence and upstream of the late 1950s channelization project.

REFERENCES

Barnes, H.H. 1967. Roughness Characteristics of Natural Channel. U.S. Geological Survey, Water Supply Paper 1849, Washington D.C.

Castro, J.M., Jackson, P.L., 2001. Bankfull discharge recurrence intervals and regional hydraulic geometry relationships: patterns in the Pacific Northwest, USA. JAWRA Journal of the American Water Resources Association, 37(5), 1249-1262.

Chow, V.T., 1959. Open Channel Hydraulics, McGraw-Hill Book Company, NY.

Hicks, D.M., Mason, P.D., 1998. Roughness Characteristics of New Zealand Rivers, Water Resource Survey. Wellington, New Zealand.

Hydronia. 2012. RiverFLO-2D v3 Two-Dimensional Finite-Element River Dynamics Model User's Guide.

Inter-Fluve, 2010. Lower Peshastin Creek Tributary and Reach Assessment, Prepared for the Yakama Nation Fisheries Program.

Wilcock, P.R., Pitlick, J., Cui, Y., 2009. Sediment transport primer: estimating bed-material transport in gravel-bed rivers.