APPENDIX M

Hydraulics

This page intentionally left blank

Table of Contents

Executive Summary 1
1. Overview 3
2. Introduction 3
   2.1 Purpose 3
   2.2 Project Location 4
   2.3 Hydraulic Model 8
3. Topographic Surface Model 8
   3.1 Aerial Survey Data 8
   3.2 Bathymetric Survey Data 10
   3.3 Bridge Survey Data 10
   3.4 Combining Aerial LiDAR and Ground Survey Data 11
4. Hydraulic Model 14
   4.1 River Geometry 14
   4.2 Bridge Crossings 15
   4.3 Manning's n Roughness Values 24
      4.3.1 Reach YF-6 24
      4.3.2 Reach YF-5 26
      4.3.3 Reach YF-4 27
      4.3.4 Reaches YF-3 and YF-2 29
      4.3.5 Reaches JC-2 and JC-1 33
   4.4 Contraction/Expansion Coefficients 35
   4.5 Boundary Conditions 35
   4.6 Model Calibration 35
   4.7 Discharges 38
5. Model Results 40
   5.1 Water Surface Profiles 43
   5.2 Shear Stress 59
   5.3 Velocity 67
   5.4 Flood Inundation Areas 75
6. Discussion 77
   6.1 Reach YF-6 RM 16.3 to 13.2 77
   6.2 Reach YF-5 RM 13.2 to 11.6 78
   6.3 Reach YF-4 RM 11.6 to 9.1 78
   6.4 Reach YF-3 RM 9.1 to 6.9 79
   6.5 Reach YF-2 RM 6.9 to 3.0 80
   6.6 Reach JC-2 RM 4 to 1.4 82
   6.7 Reach JC-1 RM 1.4 to 0 82
7. Literature Cited 83
8. Glossary 85

List of Figures

Figure 1. Yankee Fork Watershed Location Map. 5
Figure 2. Yankee Fork Watershed Tributary Assessment Area. 7
Figure 3. September 2010 Orthophotograph of the West Fork and Yankee Fork confluence. 9
Figure 4. September 2010 Hillshade LiDAR DEM of the West Fork and Yankee Fork confluence. 10
Figure 5. One-foot contour map of the West Fork and Yankee Fork confluence. 11
Figure 6. Bathymetric survey data overlaying aerial photography at the West Fork and Yankee Fork confluence. 12
Figure 7. Bridge survey data overlaying aerial photography at the West Fork and Yankee Fork confluence. 13
Figure 8. Digital Terrain Model at the West Fork and Yankee Fork confluence. 14
Figure 9. Cross Section Cut Lines near RM 14. 15
Figure 10. View looking upstream at the downstream face of Five Mile Bridge. Reach YF-6. RM 14.1. 17
Figure 11. View looking upstream at the downstream face of Custer Bridge. Reach YF-5. RM 12.0. 17
Figure 12. View looking downstream at the upstream face of General's Bridge. Reach YF-4. RM 10.9. 18
Figure 13. View looking downstream at the upstream face of Bonanza Bridge. Reach YF-3. RM 8.3. 18
Figure 14. View looking downstream at the upstream face of Virginia's Bridge. Reach YF-2. RM 6.8. 19
Figure 15. View looking downstream at the upstream face of Cearley Creek Bridge. Reach YF-2. RM 6.5. 19
Figure 16. View looking downstream at the upstream face of Cabin Bridge. Reach YF-2. RM 6.0. 20
Figure 17. View looking upstream at the downstream face of Jerry's Creek Bridge. Reach YF-2. RM 5.7. 20
Figure 18. View looking upstream at the downstream face of Jordan Creek Bridge. Reach JC-2. RM 0.1. 21
Figure 19. View looking upstream at the downstream face of Jordan Creek Bridge JC1. Reach JC-1. RM 0.9. 21
Figure 20. View looking upstream at the downstream face of Jordan Creek Bridge JC2. Reach JC-2. RM 2.1. 22
Figure 21. View looking downstream at the upstream face of Jordan Creek Bridge JC3. Reach JC-2. RM 3.2. 22
Figure 22. View looking downstream at the upstream face of Jordan Creek Bridge JC4. Reach JC-2. RM 3.4. 23
Figure 23. View looking downstream at the upstream face of Jordan Creek Bridge JC5. Reach JC-2. RM 3.6. 23
Figure 24. View looking upstream from Five Mile Bridge. Reach YF-6. RM 14.1. 25
Figure 25. View looking upstream below the confluence with Five Mile Creek. Reach YF-6. RM 13.3. 25

Figure 26. View looking downstream below the confluence with Five Mile Creek. Reach YF-5. RM 13.2. 26
Figure 27. View looking upstream from Custer Bridge. Reach YF-5. RM 12.0. 27
Figure 28. Yankee Fork upstream of the Custer townsite. Reach YF-4. RM 11.5. 28
Figure 29. Yankee Fork downstream of the Custer townsite. Reach YF-4. RM 10.0. ... 28
Figure 30. View looking downstream from Bonanza Bridge. Reach YF-3. RM 8.3..... 29
Figure 31. View looking upstream from Bonanza Bridge. Reach YF-3. RM 8.3. 30
Figure 32. View looking downstream below Jerry's Creek. Reach YF-2. RM 5.2. 30
Figure 33. View looking upstream above Cabin Bridge. Reach YF-2. RM 6.5. 31
Figure 34. View looking upstream at the West Fork (left) and Yankee Fork (right) confluence area. 32
Figure 35. View of the West Fork looking upstream from the confluence area. Reach YF-3. RM 6.9. 33
Figure 36. View looking downstream at upper end of dredged section. Reach JC-1. RM 1.4. 34
Figure 37. View looking downstream below Jordan Creek Bridge JC-3. Reach JC-2. RM 3.2. 34
Figure 38. Yankee Fork Longitudinal Profile of Channel Thalweg and Reach Break Delineation. 41
Figure 39. Jordan Creek Longitudinal Profile of Channel Thalweg and Reach Break Delineation. 42
Figure 40. Yankee Fork RM 17 to RM 15 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge. 44
Figure 41. Yankee Fork RM 15 to RM 13 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge. 45
Figure 42. Yankee Fork RM 13 to RM 11 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge. 46
Figure 43. Yankee Fork RM 11 to RM 9 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge. 47
Figure 44. Yankee Fork RM 9 to RM 7 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge. 48
Figure 45. Yankee Fork RM 7 to RM 5 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge. 49
Figure 46. Yankee Fork RM 5 to RM 3 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge. 50
Figure 47. Jordan Creek RM 4 to RM 3.5 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge. 51
Figure 48. Jordan Creek RM 3.5 to RM 3 - Predicted water surface profiles for he 2-, 10-, and 100-year annual peak discharge. 52
Figure 49. Jordan Creek RM 3 to RM 2.5 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge. 53
Figure 50. Jordan Creek RM 2.5 to RM 2 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge. 54
Figure 51. Jordan Creek RM 2 to RM 1.5 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge. 55
Figure 52. Jordan Creek RM 1.5 to RM 1 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge. 56

Figure 53. Jordan Creek RM 1 to RM 0.5 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge. 57
Figure 54. Jordan Creek RM 0.5 to RM 0 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge. 58
Figure 55. Main channel average shear stress for the 2-year recurrence flood (563 cfs) through Reach YF-6. 60
Figure 56. Main channel shear stress for the 2-year recurrence flood (609 cfs) through Reach YF-5. 61
Figure 57. Main channel shear stress for the 2-year recurrence flood (647 cfs) through Reach YF-4. 62
Figure 58. Main channel shear stress for the 2-year recurrence flood (828 cfs) through Reach YF-3. 63
Figure 59. Main channel shear stress for the 2-year recurrence flood (1,423 cfs) through Reach YF-2. 64
Figure 60. Main channel shear stress for the 2-year recurrence flood (126 cfs) through Reach JC-2. 65
Figure 61. Main channel shear stress for the 2-year recurrence flood (148 cfs) through Reach JC-1. 66
Figure 62. Average velocity of flow in the main channel for the 2-year recurrence flood (563 cfs) through Reach YF-6. 68
Figure 63. Average velocity of flow in the main channel for the 2-year recurrence flood (609 cfs) through Reach YF-5. 69
Figure 64. Average velocity of flow in the main channel for the 2-year recurrence flood (647 cfs) through Reach YF-4. 70
Figure 65. Average velocity of flow in the main channel for the 2-year recurrence flood (828 cfs) through Reach YF-3. 71
Figure 66. Average velocity of flow in the main channel for the 2-year recurrence flood (1,423 cfs) through Reach YF-2. 72
Figure 67. Average velocity of flow in the main channel for the 2-year recurrence flood (126 cfs) through Reach JC-2. 73
Figure 68. Average velocity of flow in the main channel for the 2-year recurrence flood (148 cfs) through Reach JC-1. 74
Figure 69. Flood inundation area during the 10- and 100-year recurrence flood through Reach YF-2. 76

List of Tables

Table 1. Channel reach descriptions. 6
Table 2. Hydraulic Model Extents 15
Table 3. Bridge structure data used in the HEC-RAS model 16
Table 4. Model boundary conditions 35
Table 5. Peak discharge measurements obtained by the Shoshone-Bannock Tribes on June 8, 2011 36

Table 6. June 8, 2011 Calibration results – observed water surface elevations versus predicted at upstream and downstream sides of bridges by Yankee Fork HEC-RAS models. 36
Table 7. Initial Manning's roughness coefficients used in the HEC-RAS models before calibration. 37
Table 8. Final Manning's roughness coefficients used in the HEC-RAS models after calibration. 38
Table 9. Flow change locations and discharges for 1.11- to 100-year flood recurrence intervals 38

This page intentionally left blank

Executive Summary

Results from a steady flow one-dimensional hydraulic model using Hydrologic Engineering Center – River Analysis System (HEC-RAS) were used as a predictive tool to analyze the hydraulic conditions for the Yankee Fork Tributary Assessment area (Appendix M). The model estimated water surface elevation, flood inundation area, shear stress, and velocity along 17 river miles of stream channel including 13 river miles along the Yankee Fork and 4 river miles along Jordan Creek. The objectives of the hydraulic modeling were to:

a. Estimate the water surface elevations for the 2-, 10-, and 100-year recurrence interval flood discharges.

b. Estimate the average channel shear stress for the 2-year recurrence interval flood discharge.

c. Estimate the average velocity of flow in the main channel during the 2-year recurrence interval flood discharge.

d. Estimate the flood inundation areas for the 10- and 100-year recurrence interval flood discharges, approximately equivalent to the valley constraints and the base flood elevation, respectively.

The hydraulic model was calibrated to surveyed water surface elevations near bridge locations using measured stream discharges obtained on June 8, 2011. The stream flow on June 8, 2011 approximately represented the 2-year annual peak discharge. Visual observations of the water surface during stream discharge measurements indicated the flow equaled or exceeded bank full flow with overbank areas partially inundated. The model appears to be well calibrated for the 2-year recurrence discharge with a difference between actual and predicted water surface elevations of less than 3 inches. The model should be applicable for discharges within the 1.11 to 2 year recurrence intervals. At lower and higher flows, the model becomes less useful as those flows are outside the data range used for calibration.

The model area includes five geomorphic reaches on the Yankee Fork and the two geomorphic reaches on Jordan Creek. Model results through each reach were analyzed to determine the presence and extent of natural and anthropogenic controls on river hydraulics.

Within the assessment area, Reaches YF-2, YF-3, and JC-1 have experienced the greatest anthropogenic impact to hydraulic processes. Extensive dredging of the river bed has reduced access to floodplain areas and tributaries. Confining the channel with dredge piles has likely increased in-channel velocities and shear stress, reduced high flow refugia, and isolated overbank areas.

This page intentionally left blank

1. Overview

Established in 1902, the Bureau of Reclamation (Reclamation) is best known for the dams, powerplants, and canals it constructed within the 17 western United States. Today, Reclamation is the largest wholesaler of water in the United States and the second largest producer of hydroelectric power in the western United States. Reclamation's mission is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public. Reclamation's vision is to protect local economies and preserve natural resources and ecosystems through the effective use of water. This vision is achieved through Reclamation's leadership, use of technical expertise, efficient operations, and responsive customer service.

Reclamation and Bonneville Power Administration contribute to the implementation of salmonid habitat improvement projects in the upper Salmon River subbasin to help meet commitments contained in the *2010 Supplemental Federal Columbia River Power System* (FCRPS) *Biological Opinion* (BiOp) (NOAA Fisheries 2010). The BiOp includes a Reasonable and Prudent Alternative (RPA), or a suite of actions, to protect listed salmon and steelhead across their life cycle. Habitat improvement projects in various Columbia River tributaries are one aspect of this RPA. Reclamation provides technical assistance to States, Tribes, Federal agencies, and other local partners for identification, design, and construction of stream habitat improvement projects that primarily address streamflow, access, entrainment, and channel complexity limiting factors. Reclamation's contributions to habitat improvement are all meant to be within the framework of the FCRPS RPA or related commitments.

2. Introduction

This hydraulic assessment provides information on the hydraulic conditions of the Yankee Fork of the Salmon River (Yankee Fork) within the Yankee Fork Tributary Assessment (TA) area. This hydraulic assessment as part of the TA provides improved knowledge of stream corridor and floodplain interactions. The products developed and discussed within this hydraulic assessment inform potential habitat improvement projects and provide necessary tools for potential project planning.

2.1 Purpose

The intent of this TA is to provide a detailed description of existing and historic physical conditions of the Yankee Fork within the TA area such that a comprehensive understanding of historic and existing conditions can be assessed with regards to ESA-listed salmonid habitat conditions. Hydrologic inputs into the Yankee Fork and response hydraulics are primary drivers to physical processes. Therefore, an understanding of the watershed hydrology and river hydraulics is needed to complete the TA.

The objective of this hydraulic assessment is to utilize existing hydrologic information from the Hydrology Assessment (Appendix F) in a one-dimensional hydraulic model to assess existing channel hydraulics and floodplain relationships, and inform the geomorphic analyses with information of current hydraulic conditions. The results of the hydraulic model estimate:

a. The water surface elevations for the 2-, 10-, and 100-year recurrence interval flood discharges.

b. The average channel shear stress for the 2-year recurrence interval flood discharge.

c. The velocity of flow in the main channel during the 2-year recurrence interval flood discharge.

d. The flood inundation areas for the 10- and 100-year recurrence interval flood discharges, approximately equivalent to the valley constraints and the base flood elevation, respectively.

2.2 Project Location

The Yankee Fork, located in central Idaho in the upper Salmon River subbasin of the lower Snake River subregion, is the largest tributary to the Salmon River above Salmon, Idaho from the north. The Salmon River basin drains approximately 14,000 square miles from elevations exceeding 10,000 feet to approximately 900 feet at its confluence with the Snake River. The Salmon River is the second longest undammed river in the Columbia River Basin.

The Yankee Fork watershed boundary within the upper Salmon subbasin is shown in Figure 1.

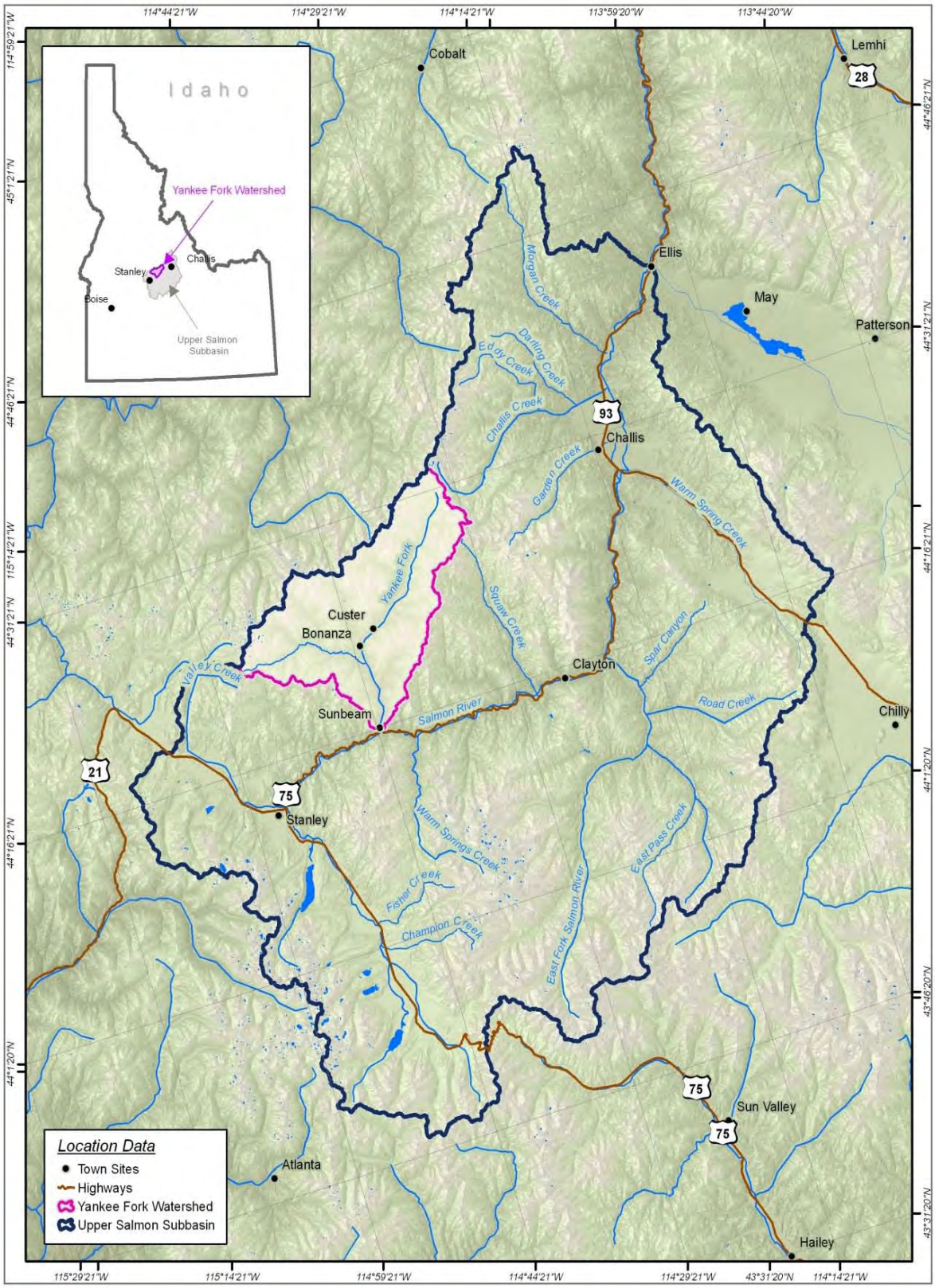

Figure 1. Yankee Fork Watershed Location Map.

The Geomorphology Assessment, Appendix L, delineated five channel reach breaks along the Yankee Fork from river mile (RM) 3 at Pole Flat Camp to RM 16.3 at the confluence with Eight Mile Creek and two channel reaches along Jordan Creek from RM 0 at the confluence with the Yankee Fork to RM 4. A description of each channel reach as defined in the Geomorphology Assessment is provided in Table 1. Additionally, Figure 2 illustrates the TA area with public and private property boundaries, reach breaks, and river miles along the Yankee Fork and Jordan Creek.

Table 1. Channel reach descriptions.

Reach ID	River Mile (RM)	Location	Slope	Geomorphic Description
YF-6	13.2 to 16.3	Eight Mile Creek to Five Mile Creek	0.66%	Unconfined free form alluvial channel, pool-riffle bed-form
YF-5	11.6 to 13.2	End of Bedrock Channel to Five Mile Creek	2.24%	Confined bedrock channel, step-pool cascade bed-form
YF-4	9.1 to 11.6	Jordan Creek to End of Bedrock Channel	1.10%	Moderately confined free form alluvial channel, plane-bed bed-form
YF-3	6.9 to 9.1	West Fork to Jordan Creek	1.00%	Moderately confined free form alluvial channel, plane-bed bed-form
YF-2	3.0 to 6.9	Beginning of Assessment Area to West Fork	0.64%	Confined free form alluvial channel, plane-bed bed-form
JC-2	1.4 to 4.0	End of Dredge Section to End of Assessment Area	2.90%	Moderately confined bedrock channel, plane-bed to pool-riffle bed form
JC-1	0.0 to 1.4	Mouth to End of Dredge Section	2.50%	Moderately confined steep alluvial channel, plane-bed to pool-riffle bed-form

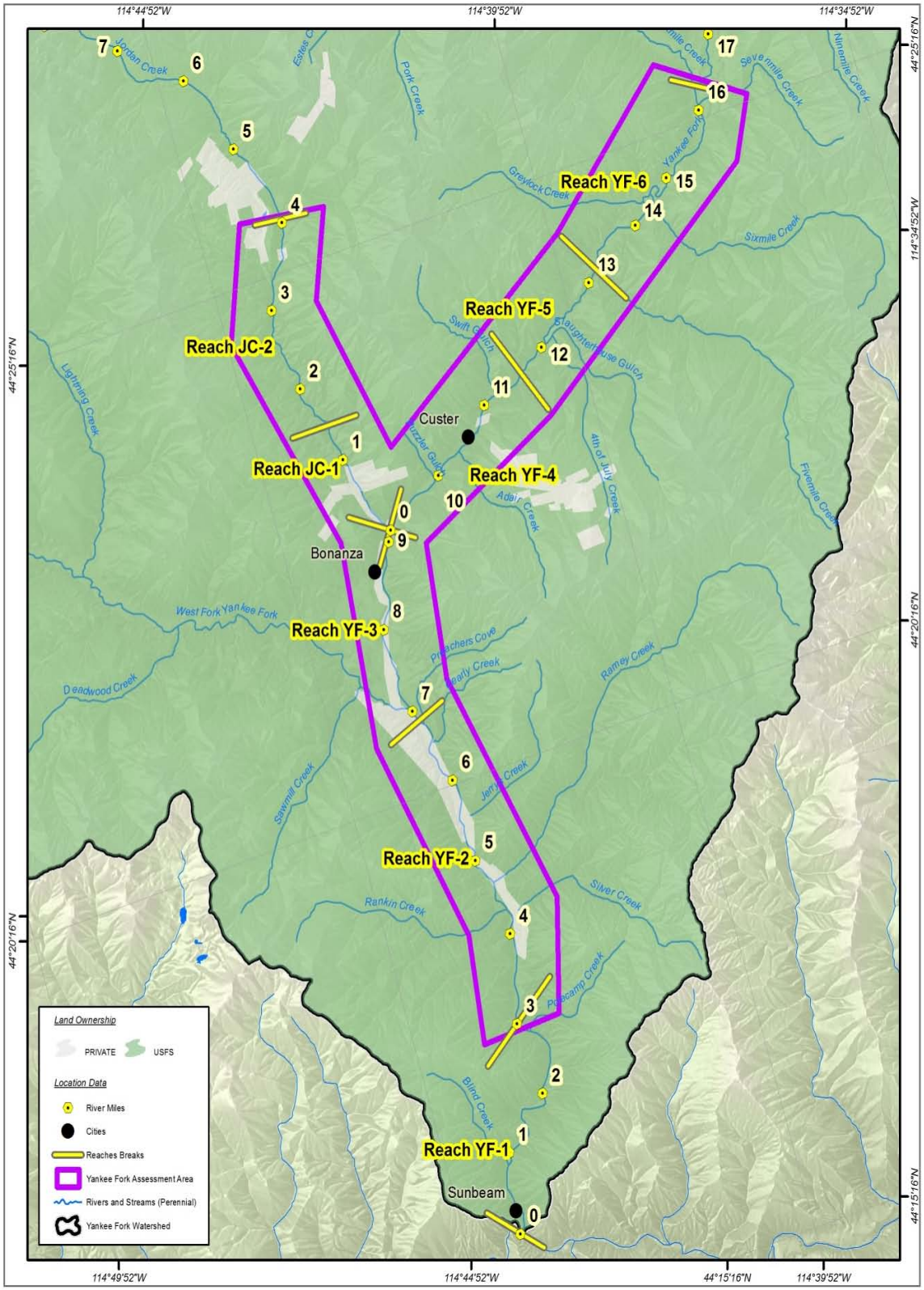

Figure 2. Yankee Fork Watershed Tributary Assessment Area.

2.3 Hydraulic Model

This report summarizes the results of a one-dimensional hydraulic model covering approximately 13 miles of the Yankee Fork of the Salmon River and 4 miles of Jordan Creek. The model results describe the hydraulic responses to watershed inputs (precipitation and snowmelt). River flows at annual discharge probabilities from 90 percent to 1 percent chance of exceedence, 1.11 to 100 year recurrence intervals, respectively, were modeled using the U. S. Army Corps of Engineers Hydrologic Engineering Center – River Analysis System (HEC-RAS) software to depict the physical hydraulic conditions of the Yankee Fork and Jordan Creek in a one-dimensional model.

The HEC-RAS model is a computer application software package developed by the U. S. Army Corps of Engineers (USACE). It is a one-dimensional model that can be used to perform steady and unsteady flow river hydraulic calculations, sediment transport-mobile bed modeling, and water temperature analyses (Brunner 2010). The one-dimensional model defines one space coordinate, the downstream direction, while variables are averaged over the other two directions, width, and depth.

Steady flows in the Yankee Fork were evaluated in HEC-RAS to describe predicted water surface profiles within the TA area. The computational procedure is based on the solution of the one-dimensional energy equation. Energy losses estimated from friction and contraction/expansion losses. The widely accepted model is designed for application in floodplain management, to evaluate floodway encroachment, and for assessing the change in water surface profiles due to channel modifications.

3. Topographic Surface Model

Ground surface topography is required to generate geometric data for use in the HEC-RAS model. For the Yankee Fork, all geometric data was generated using digital terrain modeling (DTM) and HEC-GeoRAS (GeoRAS). The GeoRAS application software package is a set of ArcGIS tools designed to process geospatial data for use with HEC-RAS (Ackerman 2011). The DTM, as created for the Yankee Fork, is represented by a triangulated irregular network and is a continuous surface that includes the bottom of the river channel and the adjacent floodplain. Airborne Light Detection and Ranging (LiDAR) remote sensing is a standard method for the acquisition of topographic data and was utilized for development of the DTM in the Yankee Fork with supplemental topographic and bathymetric surveys as described below.

3.1 Aerial Survey Data

Aerial survey LiDAR data acquisition within the Yankee Fork TA area occurred during two time frames. Jordan Creek and the Yankee Fork upstream of the confluence with Jordan Creek was surveyed on November 5 and 6, 2009 (Watershed Sciences 2010a). On

September 23, 2010, aerial survey LiDAR data was collected along the main stem of the Yankee Fork from Pole Flat Camp to the Custer townsite as well as true-color orthophotographs of the 2009 and 2010 survey areas (Watershed Sciences 2010b). For both surveys, Watershed Sciences provided the raw data point files and a digital elevation model (DEM) with 1-meter resolution in ESRI GRID format. The horizontal projection was UTM Zone 11, NAD 83, the vertical datum was NAVD 88, and the units were in meters. An example of the orthophotography provided by Watershed Sciences at the confluence of the West Fork with the Yankee Fork is shown in Figure 3.

Figure 3. September 2010 Orthophotograph of the West Fork and Yankee Fork confluence.

A hillshade was created to enhance visual representation of the DEM using spatial analyst in ArcGIS. An example hillshade representation of the LiDAR DEM at the confluence of the West Fork with the Yankee Fork is shown in Figure 4.

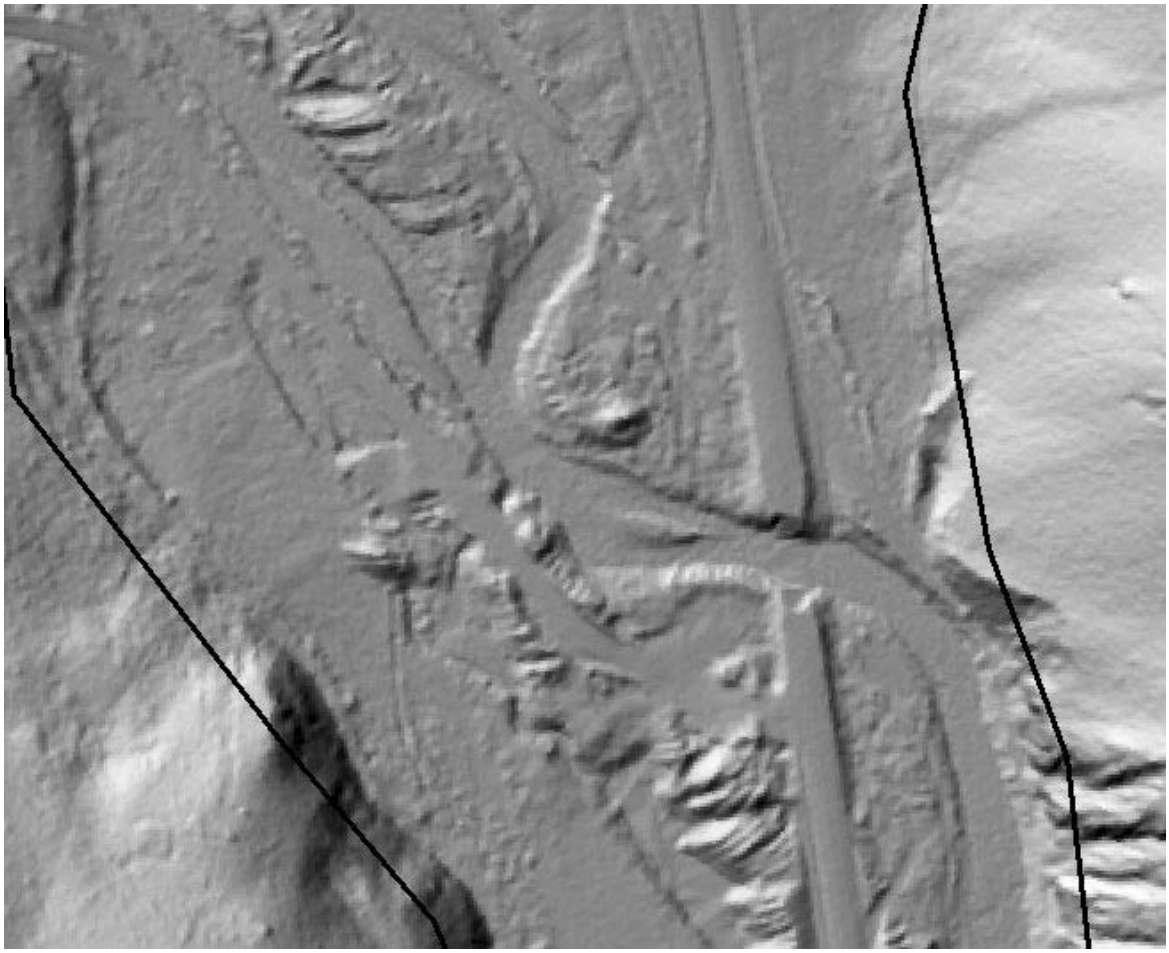

Figure 4. September 2010 Hillshade LiDAR DEM of the West Fork and Yankee Fork confluence.

3.2 Bathymetric Survey Data

Bathymetric survey data collected during previous studies (CH2M Hill 2008) along the Yankee Fork from RM 3 to RM 9 was obtained from the Shoshone-Bannock (Sho-Ban) Tribes. The bathymetric surveys were conducted between September 17 and 21, 2007 between Pole Flat Camp and the confluence with Jordan Creek. CH2M Hill (2008) surveyors used real-time kinematic (RTK) geodetic position system (GPS) techniques to survey the toes of each slope below the water surface, the thalweg, and 22 cross sections of the active channel.

3.3 Bridge Survey Data

Additional surveys were conducted on October 26 and 27, 2010 by Reclamation to collect data on bridge structures crossing the Yankee Fork and Jordan Creek and to collect additional bathymetric data. Reclamation surveyors used conventional survey techniques using a Leica Total Station and data collector to survey 6 bridges and 27 cross sections of

the active channel. All surveys were collected using an assumed local vertical datum and assumed local horizontal control. All horizontal and vertical units were in feet.

3.4 Combining Aerial LiDAR and Ground Survey Data

The DEM is represented by one-foot contours in Idaho State Plane Central coordinate system. An example of the one-foot contour map with five-foot index contours developed from the LiDAR DEM at the confluence of the West Fork with the Yankee Fork is shown in Figure 5.

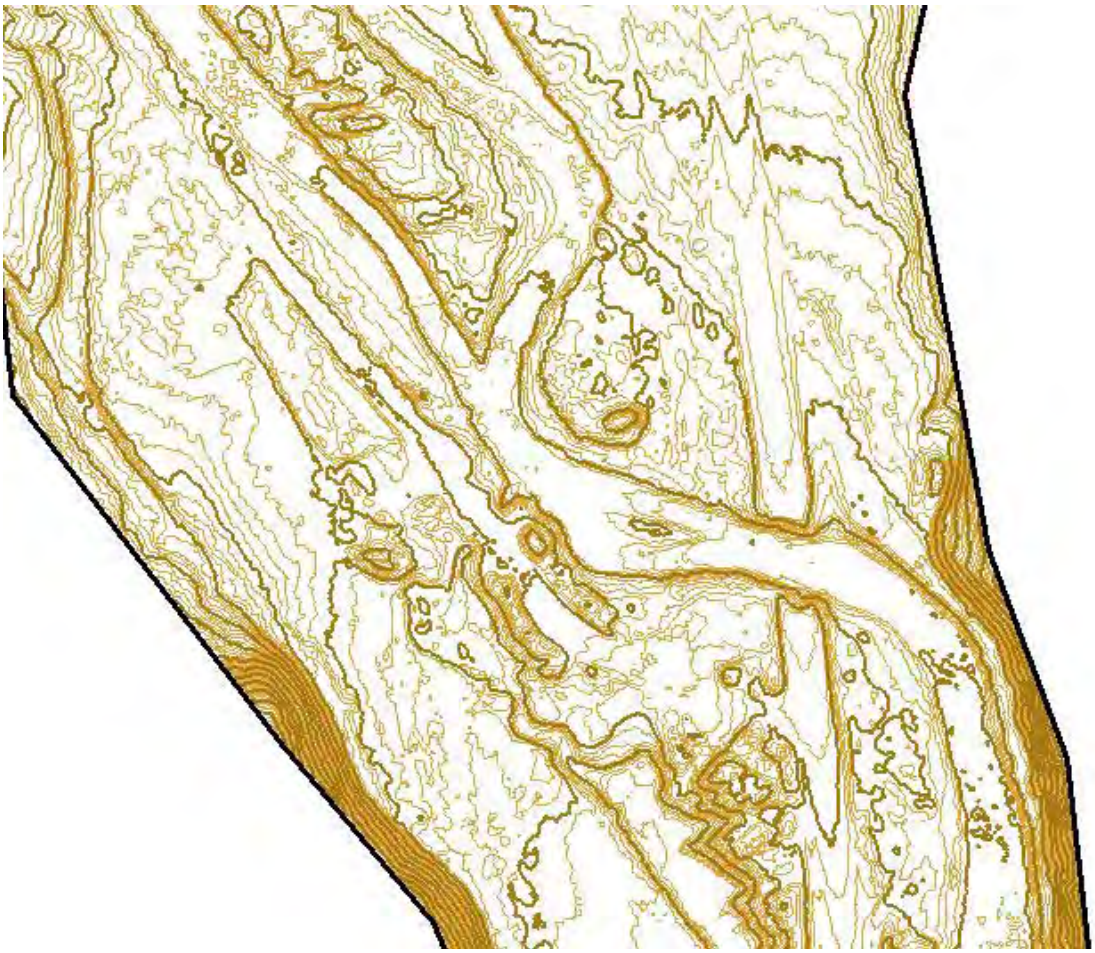

Figure 5. One-foot contour map of the West Fork and Yankee Fork confluence.

The bathymetric survey points were grouped together and moved to overlay the aerial photograph of the Yankee Fork. The overlay process was a visual exercise to match the points with the river alignment in the orthophotographs. An example of the bathymetric survey data collected in September 2007 by CH2M Hill (2008) overlaying the September 2010 orthophotograph at the confluence of the West Fork with the Yankee Fork is shown in Figure 6.

Figure 6. Bathymetric survey data overlaying aerial photography at the West Fork and Yankee Fork confluence.

The bridge survey data was also incorporated into the model using the same methods described above for the bathymetric survey data. An example of the bridge survey data collected by Reclamation in October 2010 overlaying the September 2010 orthophotograph at the confluence of the West Fork with the Yankee Fork is shown in Figure 7.

Figure 7. Bridge survey data overlaying aerial photography at the West Fork and Yankee Fork confluence.

One-foot contours from the DEM where combined with the bathymetric and bridge survey data into a seamless surface DTM. Segregating the YF study area into smaller subsets was necessary to reduce the data sets to manageable file sizes. A total of four DTMs were created: Yankee Fork from RM 3.0 to 6.7 including the lower section of Ramey Creek, Yankee Fork from RM 6.7 to 8.2 including the lower section of the West Fork, Yankee Fork from RM 8.2 to 11.7 and Jordan Creek from RM 0.0 to 4.0, and Yankee Fork from RM 11.7 to 16.6 including the lower sections of Five Mile and Eight Mile creeks. An example of the triangulated irregular network DTM at the confluence of the West Fork with the Yankee Fork is shown in Figure 8.

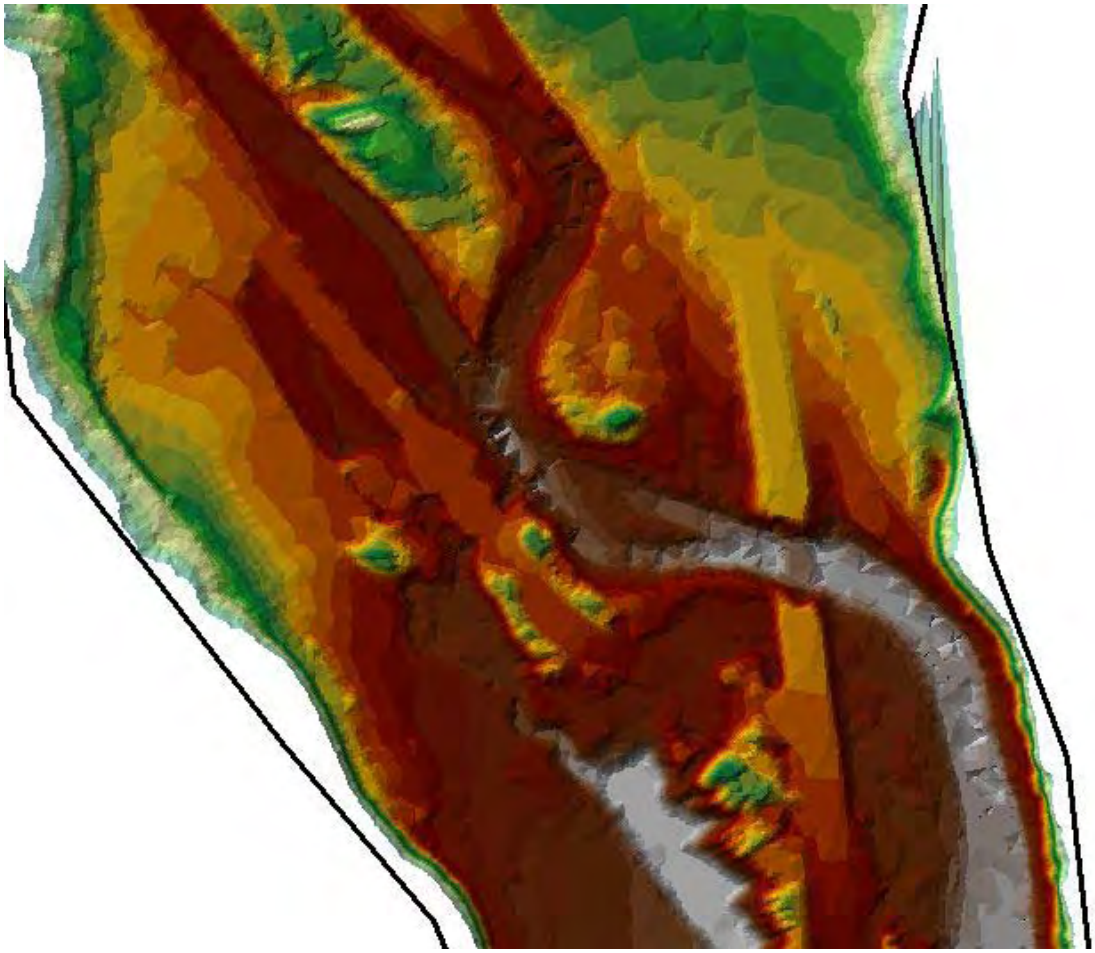

Figure 8. Digital Terrain Model at the West Fork and Yankee Fork confluence.

4. Hydraulic Model

GeoRAS is a set of procedures, tools, and utilities for processing geospatial data in ArcGIS for use in the preparation and application of HEC-RAS. The GeoRAS (version 4.2.93) extension for use with ArcGIS 9.3 was used to create inputs to HEC-RAS describing the main channel centerline, cross sections, main channel banks, and bridge locations along the modeled reaches. Additionally, GeoRAS was used to develop floodplain maps for the YF from model output by HEC-RAS.

4.1 River Geometry

Four separate HEC-RAS models as described in Table 2 were created for this assessment due to data limitations of the DTM when using GeoRAS. Geometric inputs to the four HEC-RAS models included 765 cross-sections, a channel centerline, river bank lines and bridge details at 15 bridge locations throughout the 17 river miles modeled. Each model was constructed from its own DTM by extraction of geometric features based upon delineation in ArcGIS as shown in Figure 9.

Figure 9. Cross Section Cut Lines near RM 14.

Data files generated from GeoRAS were imported to the HEC-RAS program geometric data editor. Data describing the stream centerline, cross sections, bank points, and bridge locations were then verified and corrected as necessary.

Table 2. Hydraulic Model Extents

Model Parameters	Reach (Model)				
	YF-2 (Lower)	YF-3 (West Fork)	YF-4 (Middle)	YF-5 & 6 (Upper)	JC-1 & 2 (Middle)
Distance, miles	3.7	1.8	3.6	5.5	4.0
River Mile From	3.0	6.6	8.2	11.5	0.0
River Mile To	6.7	8.4	11.8	17.0	4.0
# of Cross Sections	100	55	135	228	260
# of Stream Junctions	0	1	1	2	0
# of Bridge Crossings	3	2	1	3	6

4.2 Bridge Crossings

Bridge structure surveys were completed on the Custer, Jordan Creek, Bonanza, Virginia's, Cearly, and Jerry's bridges by Reclamation in October 2010. Where survey data was not obtained, the bridge details were based on interpretation of aerial

photographs and LiDAR. For non-surveyed bridges, deck elevations were determined from the DTMs. The width of each bridge deck in the direction of flow and the opening width perpendicular to the direction of flow was estimated from orthophotographs using ArcGIS. For bridges that were not surveyed, the thickness of the bridge deck was assumed to be 2.5 feet. A weir coefficient of 3.2 was used for overflow at all bridge structures. A summary of the bridge structure data used in the HEC-RAS model is provided in Table 3. Additionally, photographs of each bridge are shown in Figures 10 through 23.

Table 3. Bridge structure data used in the HEC-RAS model

Bridge	River Mile	Top Elevation, feet	Bottom Elevation, feet	Opening Width, feet	Bridge Width, feet[1]
Eight Mile	16.5	6,829	6,827.5	30	16
Five Mile	14.1	6,750	6,748.25	30	16
Custer[2]	12.0	6,552	6,549.5	36	18
General's	10.9	6,482	6,479.5	45	13
Jordan Creek[2]	0.1[3]	6,382	6,378	28	30
JC1	0.9[3]	6,476	6,473.5	20	16
JC 2	2.1[3]	6,656	6,653.5	20	20
JC 3	3.2[3]	6,835	6,832.5	20	20
JC 4	3.4[3]	6,866	6,863.5	20	40
JC 5	3.6[3]	6,900	6,897.5	20	20
Bonanza[2]	8.3	6,345	6,341	100	30
Virginia's[2]	6.8	6,260	6,256.5	100	30
Cearley[2]	6.5	6,253	6,249.5	100	50
Cabin	6.0	6,234	6,230.5	100	36
Jerry's[2]	5.7	6,229	6,225.5	100	30

Notes: [1] Bridge width in the direction of flow
[2] Surveyed by Reclamation
[3] Jordan Creek River Miles

Figure 10. View looking upstream at the downstream face of Five Mile Bridge. Reach YF-6. RM 14.1. Stream discharge is approximately 460 cfs as measured by Sho-Ban Tribes. Bureau of Reclamation photograph by Paul Drury, June 8, 2011.

Figure 11. View looking upstream at the downstream face of Custer Bridge. Reach YF-5. RM 12.0. Bureau of Reclamation photograph by Paul Drury, June 6, 2011.

Figure 12. View looking downstream at the upstream face of General's Bridge. Reach YF-4. RM 10.9. Bureau of Reclamation photograph by Paul Drury, October 27, 2010.

Figure 13. View looking downstream at the upstream face of Bonanza Bridge. Reach YF-3. RM 8.3. Stream discharge is approximately 678 cfs as measured by Sho-Ban Tribes. Note the hydraulic contol imparted by the bridge pier. Bureau of Reclamation photograph by Paul Drury, June 8, 2011.

Figure 14. View looking downstream at the upstream face of Virginia's Bridge. Reach YF-2. RM 6.8. June 8, 2011 stream discharge is 1,357 cfs as measured by Sho-Ban Tribes. Bureau of Reclamation photograph by Paul Drury, June 7, 2011.

Figure 15. View looking downstream at the upstream face of Cearley Creek Bridge. Reach YF-2. RM 6.5. Bureau of Reclamation photograph by Paul Drury, June 7, 2011.

Figure 16. View looking downstream at the upstream face of Cabin Bridge. Reach YF-2. RM 6.0. Bureau of Reclamation photograph by Paul Drury, June 7, 2011.

Figure 17. View looking upstream at the downstream face of Jerry's Creek Bridge. Reach YF-2. RM 5.7. Bureau of Reclamation photograph by Paul Drury, June 7, 2011.

Figure 18. View looking upstream at the downstream face of Jordan Creek Bridge. Reach JC-2. RM 0.1. June 8, 2011 stream discharge is approximately 168 cfs as measured by Sho-Ban Tribes. Bureau of Reclamation photograph by Paul Drury, June 6, 2011.

Figure 19. View looking upstream at the downstream face of Jordan Creek Bridge JC1. Reach JC-1. RM 0.9. Bureau of Reclamation photograph by Paul Drury, June 7, 2011.

Figure 20. View looking upstream at the downstream face of Jordan Creek Bridge JC2. Reach JC-2. RM 2.1. Bureau of Reclamation photograph by Paul Drury, June 7, 2011.

Figure 21. View looking downstream at the upstream face of Jordan Creek Bridge JC3. Reach JC-2. RM 3.2. Bureau of Reclamation photograph by Paul Drury, June 7, 2011.

Figure 22. View looking downstream at the upstream face of Jordan Creek Bridge JC4. Reach JC-2. RM 3.4. Bureau of Reclamation photograph by Paul Drury, June 7, 2011.

Figure 23. View looking downstream at the upstream face of Jordan Creek Bridge JC5. Reach JC-2. RM 3.6. Bureau of Reclamation photograph by Paul Drury, June 7, 2011.

4.3 Manning's n Roughness Values

Manning's roughness values ("n") for the main channel and the left and right overbank areas were entered into data tables within the HEC-RAS geometric data editor. Initial estimates for Manning's roughness values were selected using professional judgment and reference photographs based on published values determined in other similar river systems (Barnes 1967), previous modeling efforts by CH2M Hill (2008), and guidance presented by NRCS (SCS 1963), Arcement and Schneider (1989), and USACE (1993).

Manning's roughness values represent the surface roughness of the channel and vary with river bed form, material, and discharge. In natural alluvial stream channels of coarse noncohesive gravel and cobbles, in-channel roughness values are directly proportional to the median size of the bed material (Henderson 1966). In-channel roughness values for alluvial streams decline with rising flow and depth (USACE 1993) and increase with channel irregularities, obstructions, vegetation, and degree of meandering (Arcement and Schneider 1989).

Final Manning's roughness values for the channel at bank full flow were confirmed by model calibration, described subsequently, using measured stream discharges and surveyed water surface elevations. The following sections detail in-channel Manning's roughness values at bankfull conditions used for each modeled reach. Roughness values for the overbank floodplain areas were determined separately based upon the composition, physical shape, and vegetation along the riparian corridor and whether the channel was confined or unconfined.

4.3.1 Reach YF-6

Reach YF-6, from Eight Mile Creek to Five Mile Creek has an average slope of 0.66 percent. The channel is a riffle-pool channel with sand and gravel substrate and significant channel cross section variation primarily caused by woody debris obstructions. An initial in-channel Manning's n value of 0.059 was selected for this reach. Figures 24 and 25 are representative photographs of the river channel and floodplain in this reach.

Figure 24. View looking upstream from Five Mile Bridge. Reach YF-6. RM 14.1. Bureau of Reclamation photograph by Paul Drury, June 8, 2011.

Figure 25. View looking upstream below the confluence with Five Mile Creek. Reach YF-6. RM 13.3. Bureau of Reclamation photograph by Paul Drury, June 8, 2011.

4.3.2 Reach YF-5

Reach YF-5, from Five Mile Creek to the reach break at RM 11.6, has an average slope of 2.24 percent. The channel cascades through a confined boulder strewn narrow canyon with significant channel obstructions and cross section variation. An initial in-channel Manning's n value of 0.072 was selected for this reach. Figures 26 and 27 are representative photographs of the river channel in this reach.

Figure 26. View looking downstream below the confluence with Five Mile Creek. Reach YF-5. RM 13.2. Bureau of Reclamation photograph by Paul Drury, June 8, 2011.

Figure 27. View looking upstream from Custer Bridge. Reach YF-5. RM 12.0. Bureau of Reclamation photograph by Paul Drury, June 6, 2011.

4.3.3 Reach YF-4

Reach YF-4, from RM 11.6 to Jordan Creek at RM 9.1 has an average slope of 1.1 percent and is a fairly straight and uniform plane bed channel with significant stream bank vegetation. Channel substrate consists of mostly cobble-sized alluvium intermixed with some small boulders. An initial in-channel Manning's n value of 0.051 was selected for this reach. Figures 28 and 29 are representative photographs of Reach YF-4.

Figure 28. Yankee Fork upstream of the Custer townsite. Reach YF-4. RM 11.5. Bureau of Reclamation photograph by Dave Walsh, September 2, 2010.

Figure 29. Yankee Fork downstream of the Custer townsite. Reach YF-4. RM 10.0. Bureau of Reclamation photograph by Dave Walsh, September 2, 2010.

4.3.4 Reaches YF-3 and YF-2

Reach YF-3 from Jordan Creek to the confluence with the West Fork has an average slope of one percent. Reach YF-2 from the confluence with the West Fork to Pole Flat Camp has an average slope of 0.64 percent. The channel in both reaches is a fairly straight and uniform alluvial channel that is confined by dredge spoils. Stream banks are slightly vegetated and substrate consists of mostly gravel and cobble-sized alluvium. An initial in-channel Manning's n value of 0.043 was selected for this reach. Figures 30 and 31 are representative photographs of Reach YF-3and Figure 32 and Figure 33 are representative photographs of Reach YF-2.

Figure 30. View looking downstream from Bonanza Bridge. Reach YF-3. RM 8.3. Bureau of Reclamation photograph by Paul Drury, June 6, 2011.

Figure 31. View looking upstream from Bonanza Bridge. Reach YF-3. RM 8.3. Bureau of Reclamation photograph by Paul Drury, June 6, 2011

Figure 32. View looking downstream below Jerry's Creek. Reach YF-2. RM 5.2. Bureau of Reclamation photograph by Paul Drury, June 6, 2011.

Figure 33. View looking upstream above Cabin Bridge. Reach YF-2. RM 6.5. Bureau of Reclamation photograph by Paul Drury, June 7, 2011**.**

The lower section of the West Fork of the Yankee Fork with its confluence near RM 6.8 has similar physical characteristics to the dredge section of the Yankee Fork. An initial in-channel Manning's n value of 0.043 was selected for this reach. Figures 34 and 35 are representative photographs of the West Fork of the Yankee Fork near its confluence with the Yankee Fork.

Figure 34. View looking upstream at the West Fork (left) and Yankee Fork (right) confluence area. Bureau of Reclamation photograph by Paul Drury, June 6, 2011**.**

Figure 35. View of the West Fork looking upstream from the confluence area. Reach YF-3. RM 6.9. Bureau of Reclamation photograph by Paul Drury, June 7, 2011**.**

4.3.5 Reaches JC-2 and JC-1

Jordan Creek from RM 4 to 1.4 (Reach JC-2) is a fairly steep cascading stream through a narrow canyon with an average slope of 2.9 percent. The lower section of Jordan Creek from RM 1.4 to its confluence with the Yankee Fork (Reach JC-1) with an average slope of 2.5 percent is confined by dredge tailings and has limited riparian vegetation. An initial in-channel Mannings n value of 0.065 and 0.043 was chosen for Reach JC-2 and JC-1, respectively. Figures 36 and 37 are representative photographs of Jordan Creek.

Figure 36. View looking downstream at upper end of dredged section. Reach JC-1. RM 1.4. Bureau of Reclamation photograph by Paul Drury, June 7, 2011.

Figure 37. View looking downstream below Jordan Creek Bridge JC-3. Reach JC-2. RM 3.2. Bureau of Reclamation photograph by Paul Drury, June 7, 2011.

4.4 Contraction/Expansion Coefficients

Default values for the contraction and expansion coefficients of 0.1 and 0.3 were used at all sections except upstream and downstream of the bridges. At bridge locations, 0.3 for the contraction coefficient and 0.5 for the expansion coefficient was applied to cross sections immediately upstream and downstream of the bridge.

4.5 Boundary Conditions

Boundary conditions were assumed to be normal depth flow conditions approximated by the channel slope at the upstream and downstream end of the lower model boundary. The predicted upstream water surface elevation of the lower model was then used as the downstream boundary condition for the next upstream model. Channel slopes at upstream and downstream locations were calculated from DTMs as the measured distance between contour intervals and are shown in Table 4.

Table 4. Model boundary conditions

HEC-RAS Model	River Location	River Mile	Channel Slope, ft/ft	
			Upstream	Downstream
Upper	Yankee Fork	17.0	0.012	--
	Eight Mile Creek	--	0.016	--
	Five Mile Creek	--	0.045	--
	Yankee Fork	11.5	--	--[1]
Middle	Yankee Fork	11.8	0.013	--
	Jordan Creek	4.0	0.048	--
	Yankee Fork	8.2	--	--[1]
West Fork	Yankee Fork	8.4	0.010	--
	West Fork	--	0.008	--
	Yankee Fork	6.8	--	--[1]
Lower	Yankee Fork	6.7	0.004	--
	Yankee Fork	3.0	--	0.018

[1] Downstream boundary condition equals the predicted upstream water surface elevation from the next downstream model

4.6 Model Calibration

Calibration data for the HEC-RAS model was obtained by Reclamation with assistance from the Shoshone-Bannock Tribes on June 8, 2011. Calibration data consisted of measured stream discharge along with surveyed water surface points. Peak discharge measurements were obtained by the Shoshone-Bannock Tribes and observed by

Reclamation on June 8, 2011. Measurements were obtained using a SonTek™ RiverSurveyor-S5 acoustic Doppler velocity meter. Measured peak discharge values are shown in Table 5.

Table 5. Peak discharge measurements obtained by the Shoshone-Bannock Tribes on June 8, 2011

Location	date	Time	CFS	Std Dev +/-	covariance/ error	width ft	area ft2	mean speed ft/s
Five Mile Bridge at RM 14.1	6/8/2011	2:30-2:45	460.45	22.6	4.90%	46.31	101	4.568
Bonanza Bridge at RM 8.3	6/8/2011	1:14-1:30	677.75	19.57	2.90%	50.97	142.8	4.758
YF below WF at RM 6.8	6/8/2011	11:49-12:16	1356.86	56.63	4.20%	59.3	255.2	5.316
Flat Rock Bridge at RM 1.9	6/8/2011	10:08-10:25	1549.91	80.66	5.20%	55.09	243.5	6.369
Jordan Creek AT RM 0.1	6/8/2011	3:22-3:36	167.39	8.49	5.10%	21.28	36.3	4.617

High water was marked by Reclamation at accessible bridge locations with temporary stakes on June 8, 2011 and the elevation and horizontal position of each stake was surveyed by Reclamation on June 16, 2011. HEC-RAS model runs were then conducted using the June 8, 2011 peak flow measurements. To calibrate, Manning's roughness values were adjusted until the predicted water surface elevations were within approximately 4 inches of the surveyed water surface elevations. The observed water surface elevations (surveyed), predicted water surface elevations, and the differences between the two are shown in Table 6.

Table 6. June 8, 2011 Calibration results – observed water surface elevations versus predicted at upstream and downstream sides of bridges by Yankee Fork HEC-RAS models.

Location	Elevation, feet					
	Upstream			Downstream		
	Surveyed	Predicted	Difference	Surveyed	Predicted	Difference
Five Mile Bridge	6,747.22	6,747.56	-0.34	6,745.85	6,746.16	-0.31
Custer Bridge	6,548.91	6,548.89	0.02	6,546.92	6,546.70	0.22
Bonanza Bridge	6,333.04	6,332.97	0.07	6,331.85	6,331.64	0.21
Virginias Bridge	6,255.92	6,255.71	0.21	6,253.78	6,253.97	-0.19

Location	Elevation, feet					
	Upstream			Downstream		
	Surveyed	Predicted	Difference	Surveyed	Predicted	Difference
Cearley Bridge	6,248.82	6,249.09	-0.27	6,248.06	6,248.33	-0.27
Cabin Bridge	6,234.19	6,234.17	0.02	6,229.92	6,229.58	0.34
Jerrys Bridge	6,221.60	6,221.36	0.24	6,220.93	6,220.84	0.09
Jordan Creek Confluence	6,381.24	6,381.37	-0.13	6373.87	6,374.11	-0.24

Initial Manning's roughness coefficients used in the Yankee Fork HEC-RAS models before calibration are shown in Table 7. The final Manning's roughness coefficients used in the Yankee Fork HEC-RAS models after calibration are shown in Table 8.

Table 7. Initial Manning's roughness coefficients used in the HEC-RAS models before calibration.

River Location	Reach	River Mile		Manning's n value		
		From	To	Left Overbank	Channel	Right Overbank
Yankee Fork above Eight Mile Creek	Y7-7	16.8	16.4	0.075	0.059	0.075
Yankee Fork from Eight Mile to Five Mile Creek	YF-6	16.4	13.3	0.075	0.059	0.075
Yankee Fork from Five Mile to Reach Break	YF-5	13.3	11.6	1.1	0.072	1.1
Yankee Fork from Reach Break to Jordan Creek	YF-4	11.6	9.1	0.068	0.051	0.068
Jordan Creek Upper	JC-2	4.0	1.5	0.08	0.065	0.08
Jordan Creek Lower	JC-1	1.4	0.0	0.055	0.043	0.055
Yankee Fork from Jordan Creek to West Fork	YF-3	9.1	6.8	0.055	0.043	0.055
Yankee Fork from West Fork to Pole Flat Camp	YF-2	6.8	3.2	0.055	0.043	0.055

Table 8. Final Manning's roughness coefficients used in the HEC-RAS models after calibration.

River Location	Reach	River Mile		Manning's n value		
		From	To	Left Overbank	Channel	Right Overbank
Yankee Fork above Eight Mile Creek	Y7-7	16.8	16.4	0.043	0.032	0.043
Yankee Fork from Eight Mile to Five Mile Creek	YF-6	16.4	13.3	0.041	0.029	0.041
Yankee Fork from Five Mile to Reach Break	YF-5	13.3	11.6	0.055	0.045	0.055
Yankee Fork from Reach Break to Jordan Creek	YF-4	11.6	9.1	0.06	0.045	0.06
Jordan Creek Upper	JC-2	4.0	1.5	0.065	0.055	0.065
Jordan Creek Lower	JC-1	1.4	0.0	0.055	0.041	0.055
Yankee Fork from Jordan Creek to West Fork	YF-3	9.1	6.8	0.065	0.051	0.065
Yankee Fork from West Fork to Pole Flat Camp	YF-2	6.8	3.2	0.065	0.051	0.065

4.7 Discharges

Discharges were developed for external and internal boundary conditions throughout the assessment area as described in the Hydrologic Assessment (Appendix D). Discharges were developed for flow change locations to include major tributary inputs to the Yankee Fork. Minor tributary inputs to the Yankee Fork were neglected for this analysis. Discharges were developed for return intervals ranging between the 1.11- to 100-year events as shown in Table 9.

Table 9. Flow change locations and discharges for 1.11- to 100-year flood recurrence intervals

River Location	Reach	River Mile		Total Drainage Area, square miles	Discharge, cfs				
		From	To		1.11 year	2 year	10 year	50 year	100 year
Yankee Fork above Eight Mile Creek	--	16.8	16.5	44	190.8	368.9	679.4	959.4	1,079.3
Eight Mile Creek	--	--	--	--	56.6	109.4	201.5	284.5	320.0
Yankee Fork from Eight Mile to Greylock Creek	YF-6	16.4	14.6	58	247.4	478.3	880.9	1,243.9	1,399.4

River Location	Reach	River Mile		Total Drainage Area, square miles	Discharge, cfs				
		From	To		1.11 year	2 year	10 year	50 year	100 year
Greylock Creek	--	--	--	- -	43.9	84.8	156.2	220.6	248.1
Yankee Fork from Greylock to Five Mile Creek	YF-6	14.5	13.4	69	291.3	563.1	1,037.1	1,464.5	1,647.5
Five Mile Creek	--	--	--	--	23.7	45.9	84.6	119.4	134.3
Yankee Fork from Five Mile to 4th of July	YF-5	13.3	12.2	75	315.0	609.0	1,121.6	1,583.9	1,781.8
4th of July Creek	--	--	--	--	19.7	38.1	70.2	99.1	111.4
Yankee Fork from 4th of July to Jordan	YF-4	12.1	9.2	80	334.7	647.1	1,191.8	1,682.9	1,893.3
Jordan Creek Upper	JC-2	4.0	1.5	14	65.0	125.7	231.6	327.0	367.9
Unnamed Tributary	--	--	--	--	11.3	21.8	40.2	56.8	63.9
Jordan Creek Lower	JC-1	1.4	0.0	16.6	76.3	147.6	271.8	383.8	431.7
Yankee Fork from Jordan Creek to West Fork	YF-3	9.1	6.9	104	428.3	828.1	1,525.1	2,153.6	2,422.8
West Fork	--	--	--	--	228.9	442.6	815.0	1,150.9	1,294.8
Yankee Fork from West Fork to Jerry's Creek	YF-2	6.8	5.1	164	657.2	1,270.7	2,340.1	3,304.5	3,717.6
Jerry's Creek	--	--	--	--	15.1	29.1	53.6	75.7	85.2
Yankee Fork from Jerry's Creek to Ramey Creek	YF-2	5.1	4.6	168	672.3	1,299.8	2,393.7	3,380.2	3,802.8
Ramey Creek	--	--	--	--	33.8	65.4	120.4	170.0	191.2
Yankee Fork from Ramey Creek to Rankin Creek	YF-2	4.5	4.3	177	706.1	1,365.2	2,514.1	3,550.2	3,994.0
Rankin Creek	--	--	--	--	30.0	57.9	106.7	150.6	169.5

River Location	Reach	River Mile		Total Drainage Area, square miles	Discharge, cfs				
		From	To		1.11 year	2 year	10 year	50 year	100 year
Yankee Fork from Rankin Creek to Pole Flat Camp	YF-2	4.3	3.2	185	736.0	1,423.1	2,620.8	3,700.8	4,163.4
Yankee Fork from Pole Flat Camp to USGS 19326000	YF-1	3.1	0.5	189	751.0	1,452.0	2,674.0	3,776.0	4,248.0

5. Model Results

The longitudinal profile of the channel thalweg and location of reach breaks along the Yankee Fork and Jordan Creek tributary assessment areas are shown in Figure 38 and Figure 39, respectively.

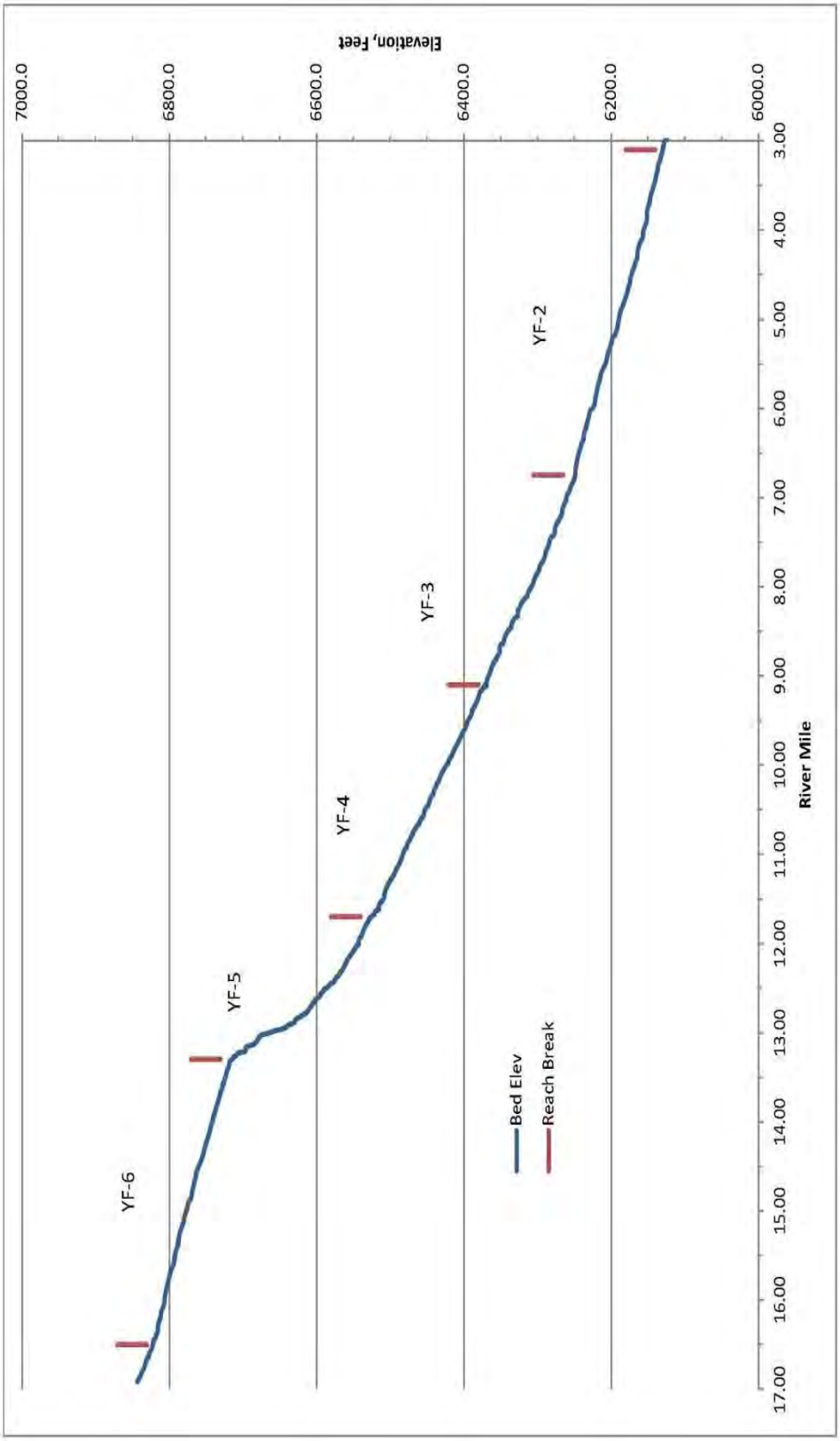

Figure 38. Yankee Fork Longitudinal Profile of Channel Thalweg and Reach Break Delineation.

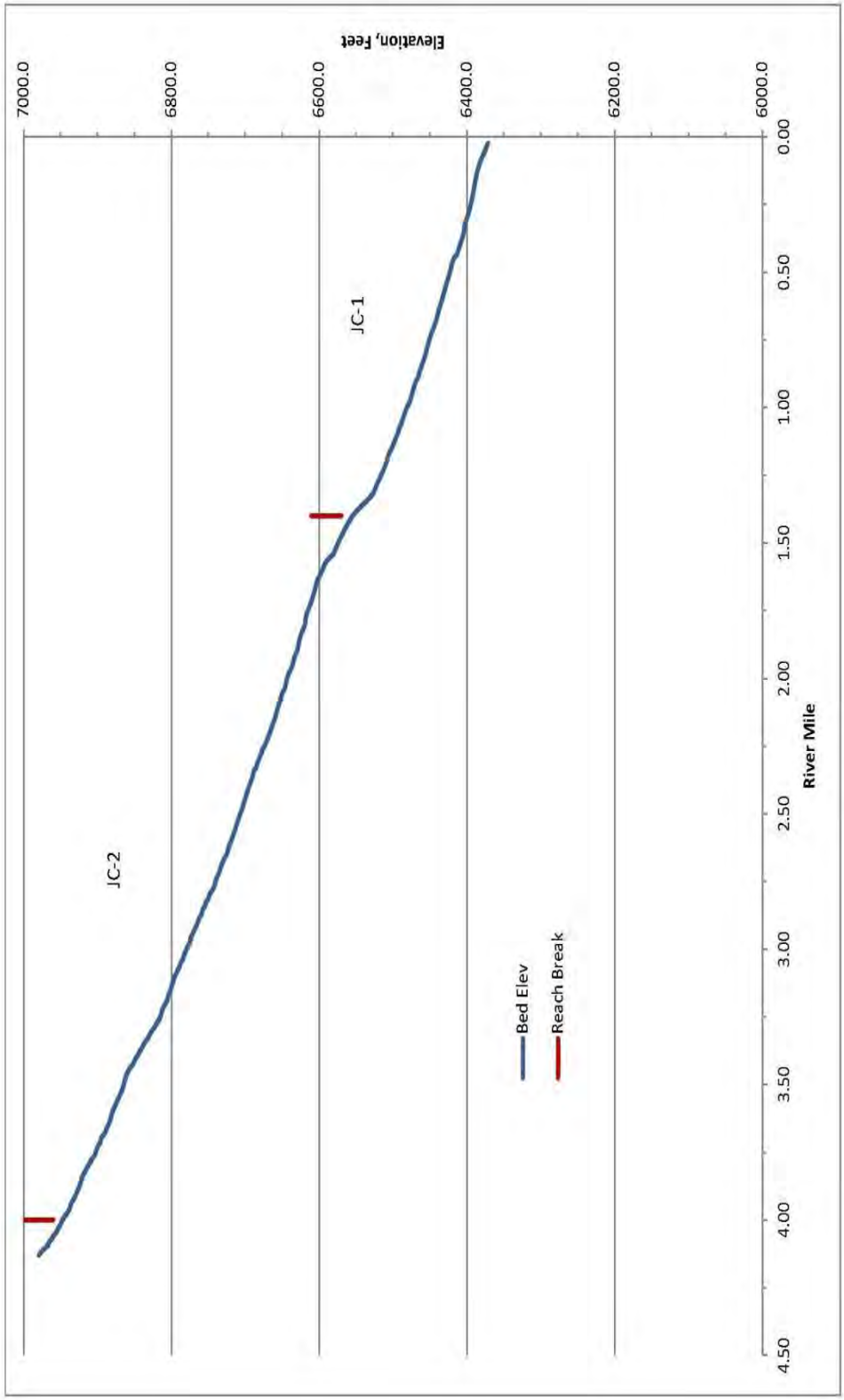

Figure 39. Jordan Creek Longitudinal Profile of Channel Thalweg and Reach Break Delineation.

5.1 Water Surface Profiles

Water surface elevation results were exported from HEC-RAS to generate the following water surface profile figures for the 2-, 10-, and 100-year annual peak flood discharge (Figures 40 through 54).

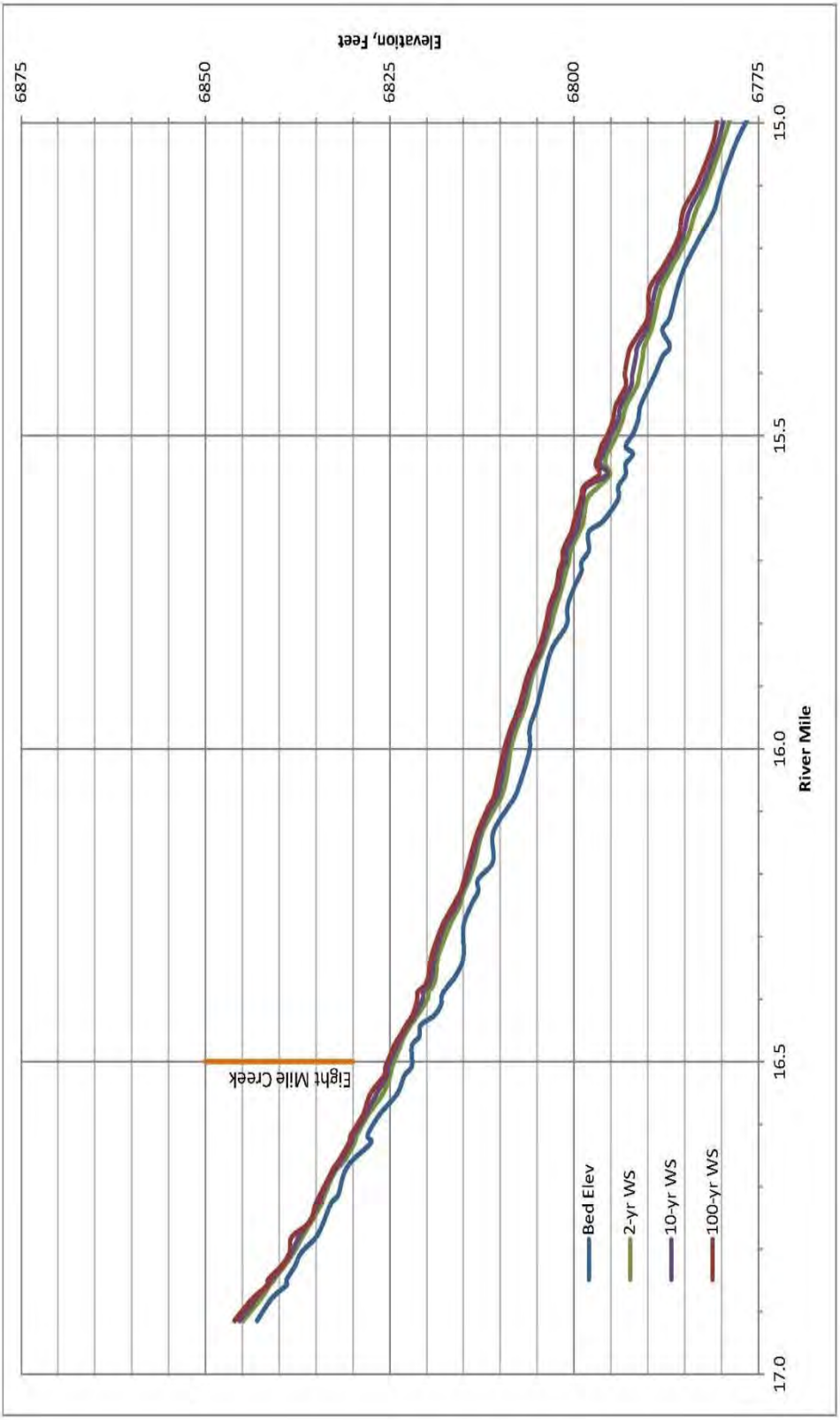

Figure 40. Yankee Fork RM 17 to RM 15 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge (note - locations of bridges and major tributaries shown).

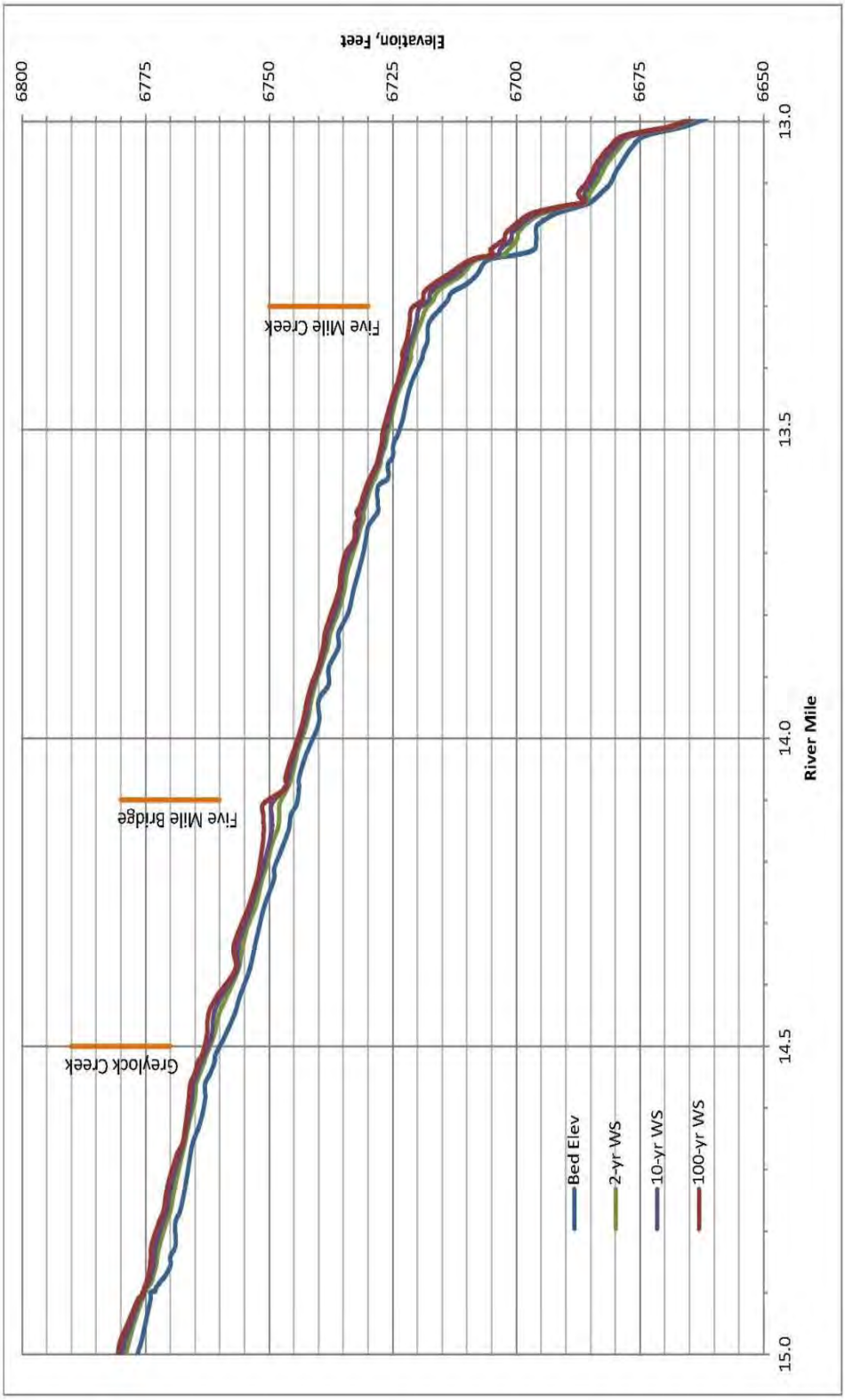

Figure 41. Yankee Fork RM 15 to RM 13 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge (note - locations of bridges and tributaries shown).

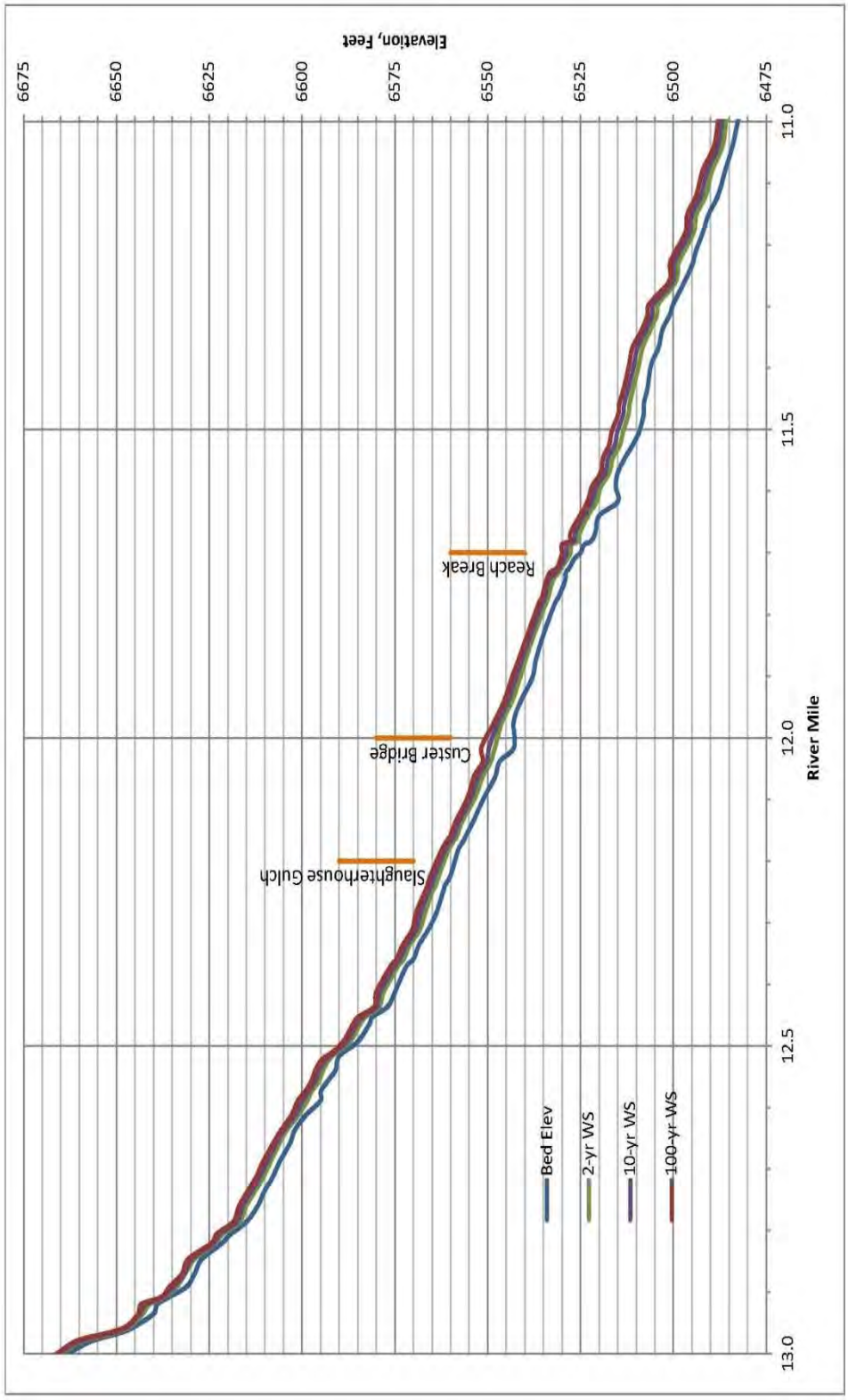

Figure 42. Yankee Fork RM 13 to RM 11 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge (note - locations of bridges and tributaries shown).

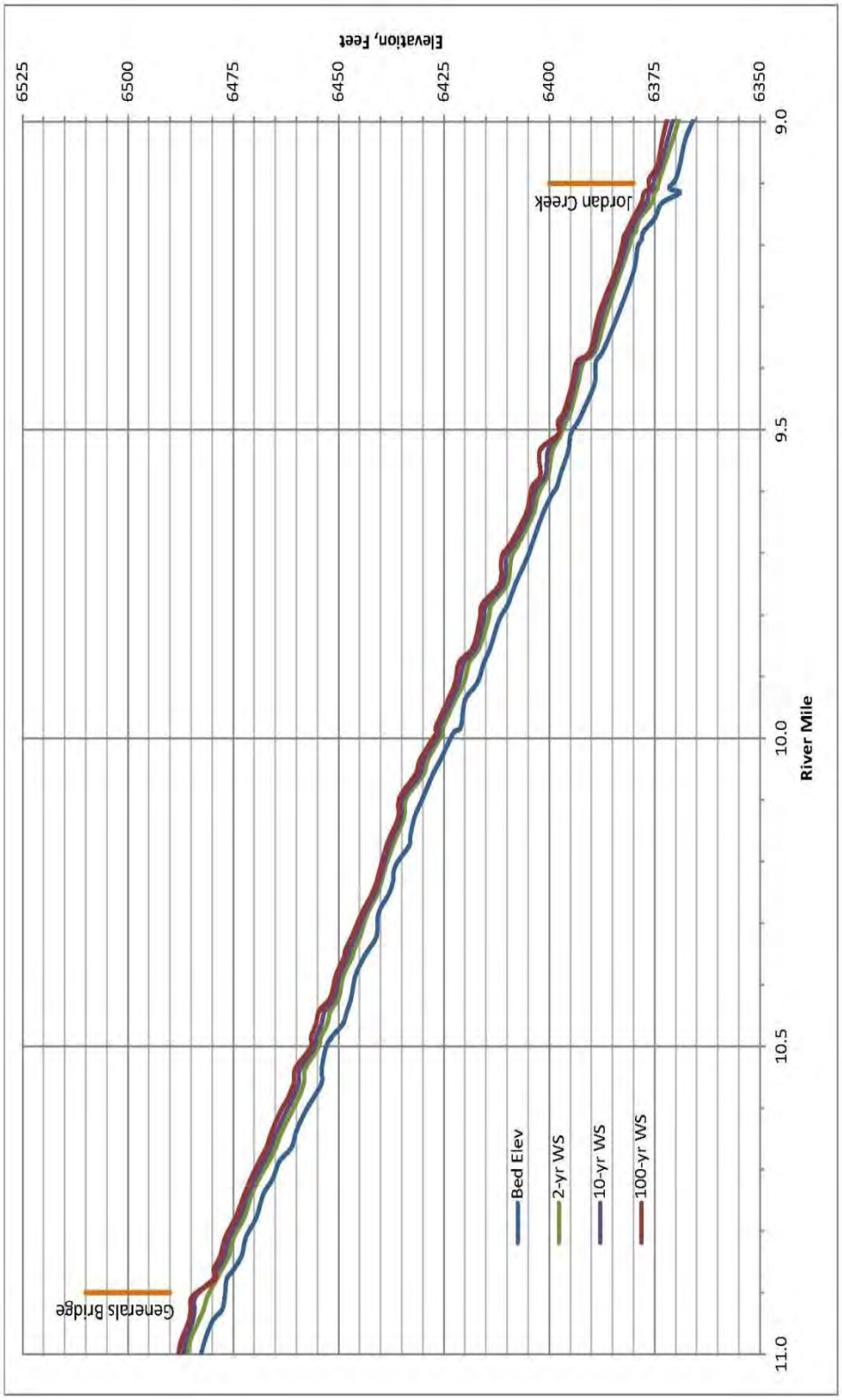

Figure 43. Yankee Fork RM 11 to RM 9 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge (note - locations of bridges and tributaries shown).

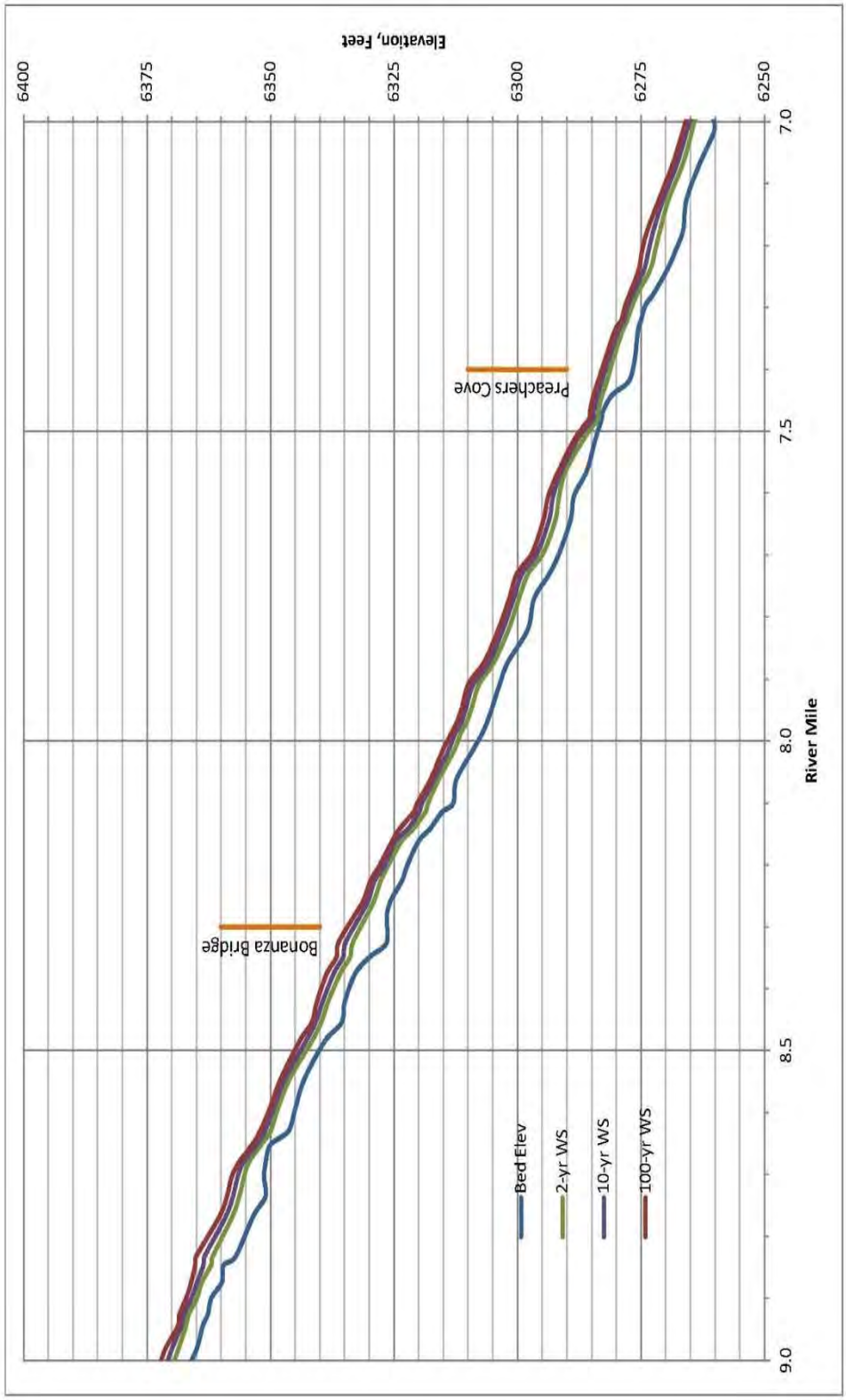

Figure 44. Yankee Fork RM 9 to RM 7 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge (note - locations of bridges and tributaries shown).

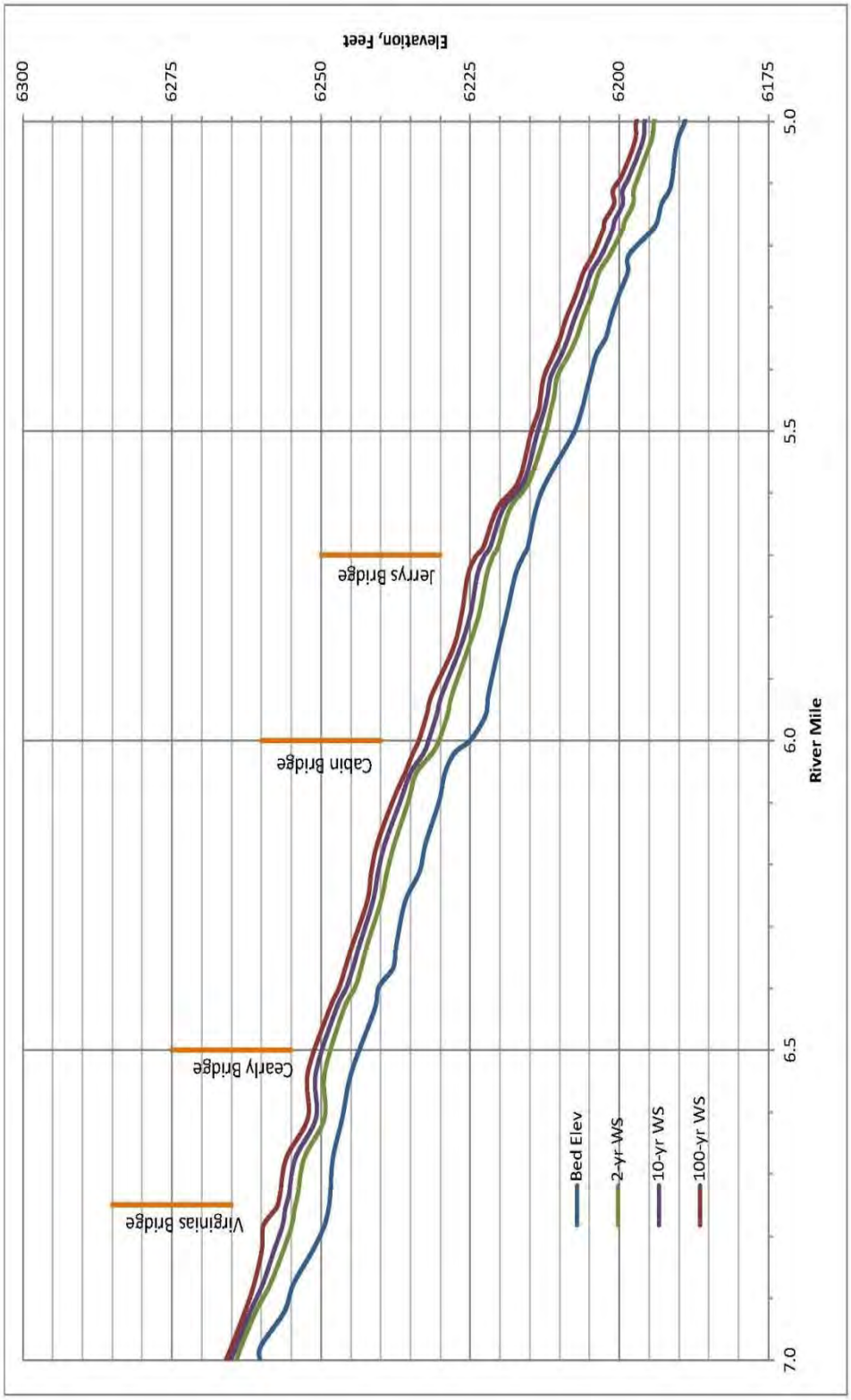

Figure 45. Yankee Fork RM 7 to RM 5 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge (note - locations of bridges and tributaries shown).

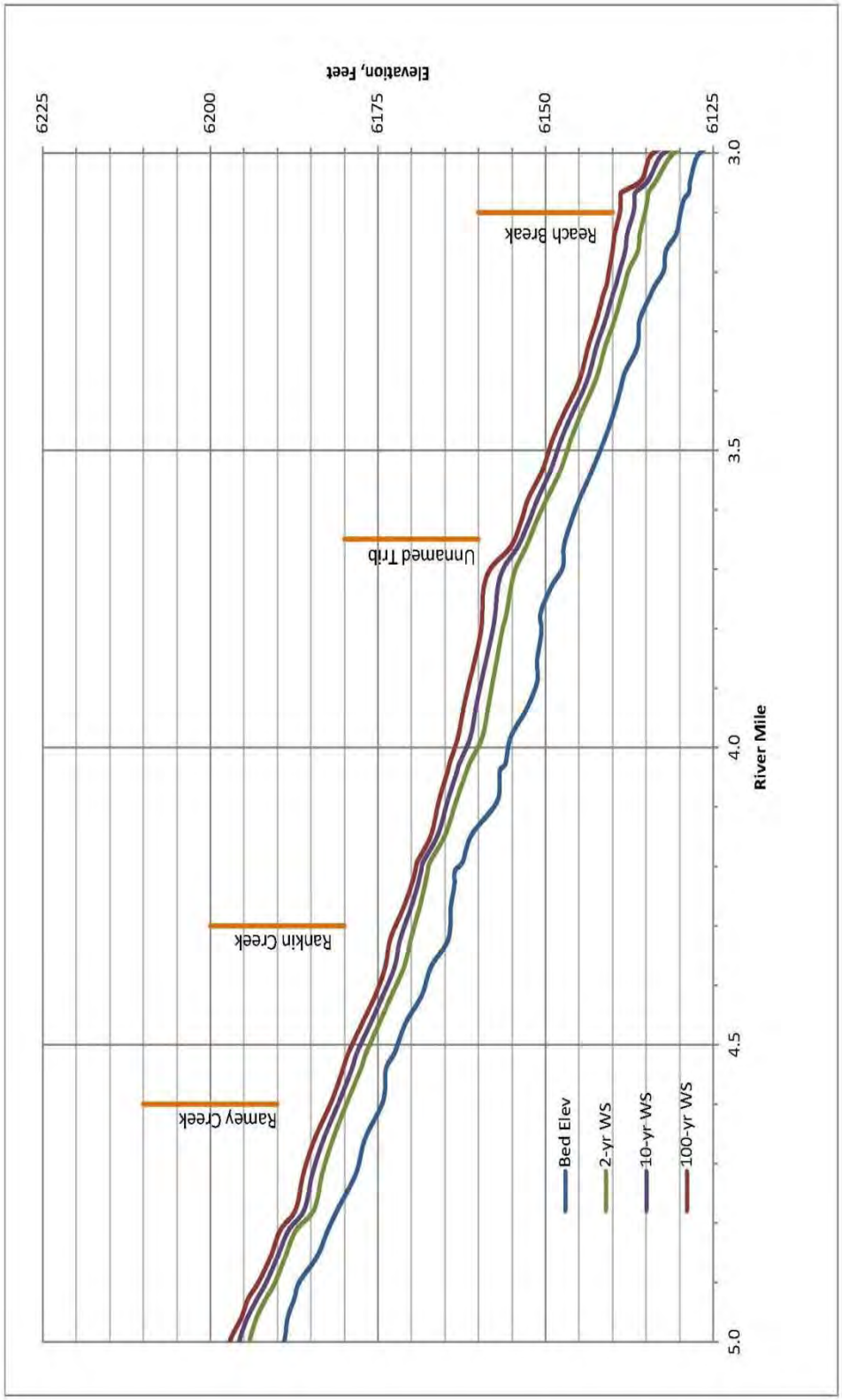

Figure 46. Yankee Fork RM 5 to RM 3 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge (note - locations of bridges and tributaries shown).

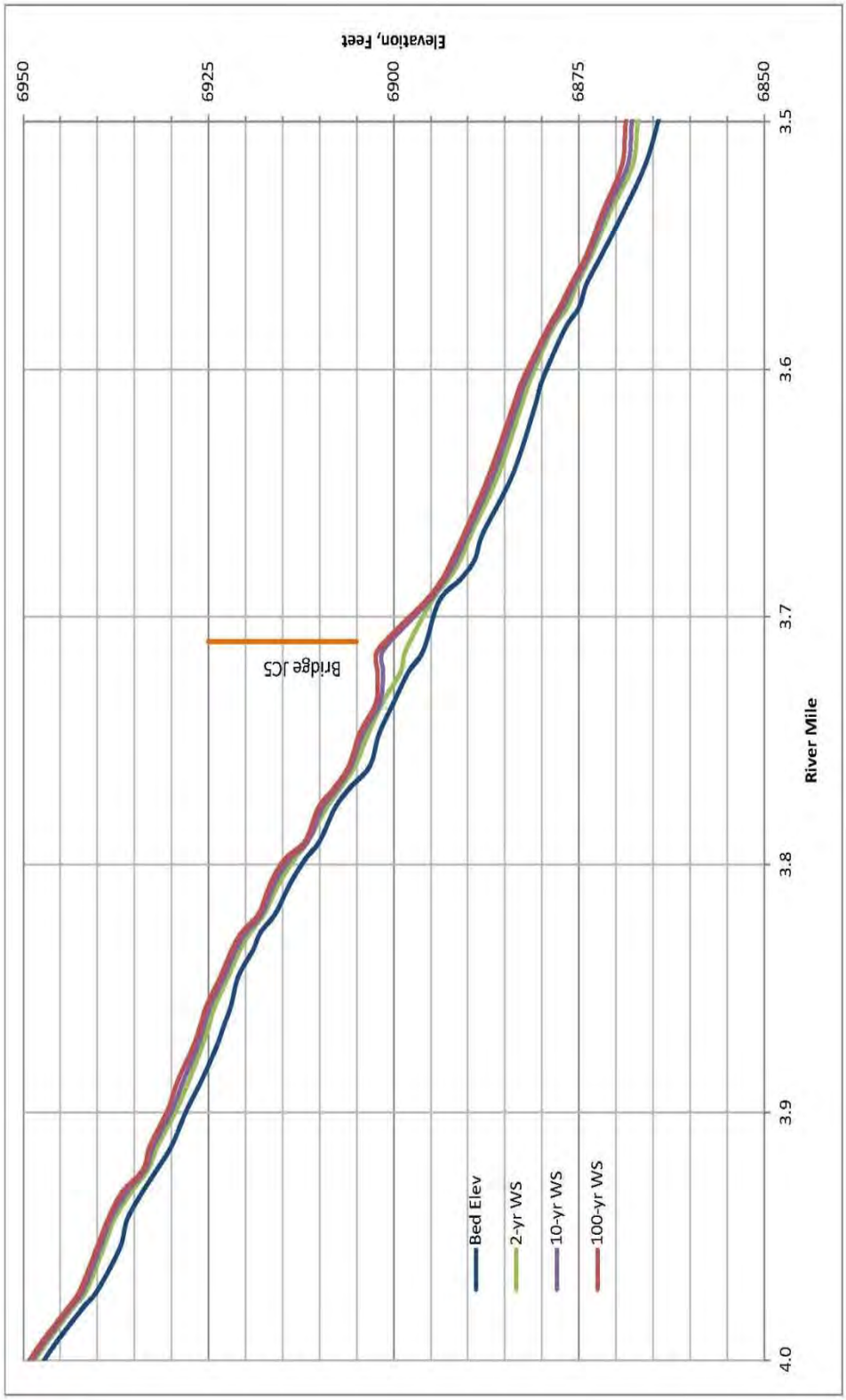

Figure 47. Jordan Creek RM 4 to RM 3.5 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge (note - locations of bridges and tributaries shown).

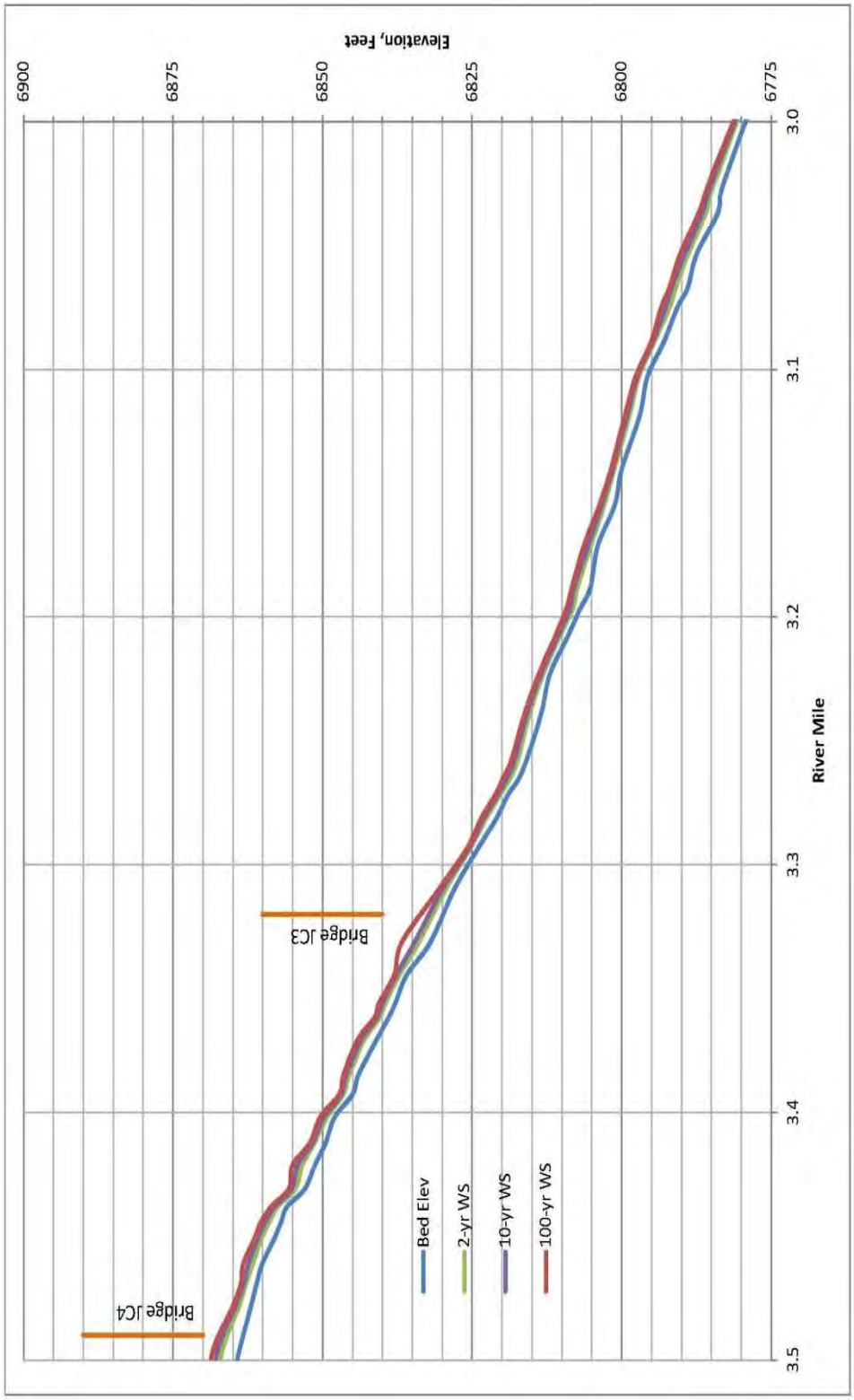

Figure 48. Jordan Creek RM 3.5 to RM 3 - Predicted water surface profiles for he 2-, 10-, and 100-year annual peak discharge (note - locations of bridges and tributaries shown).

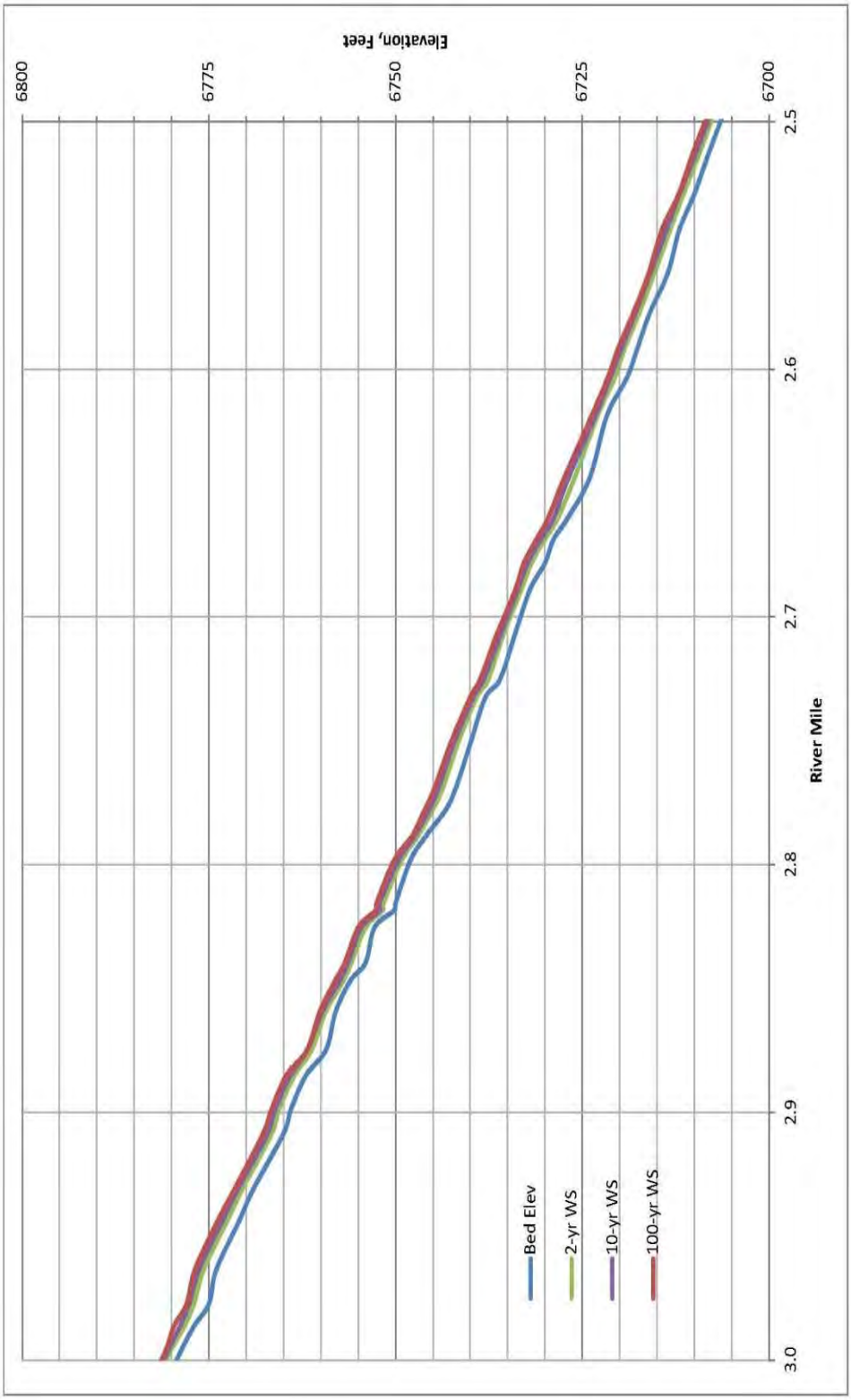

Figure 49. Jordan Creek RM 3 to RM 2.5 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge (note - locations of bridges and tributaries shown).

Figure 50. Jordan Creek RM 2.5 to RM 2 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge (note - locations of bridges and tributaries shown).

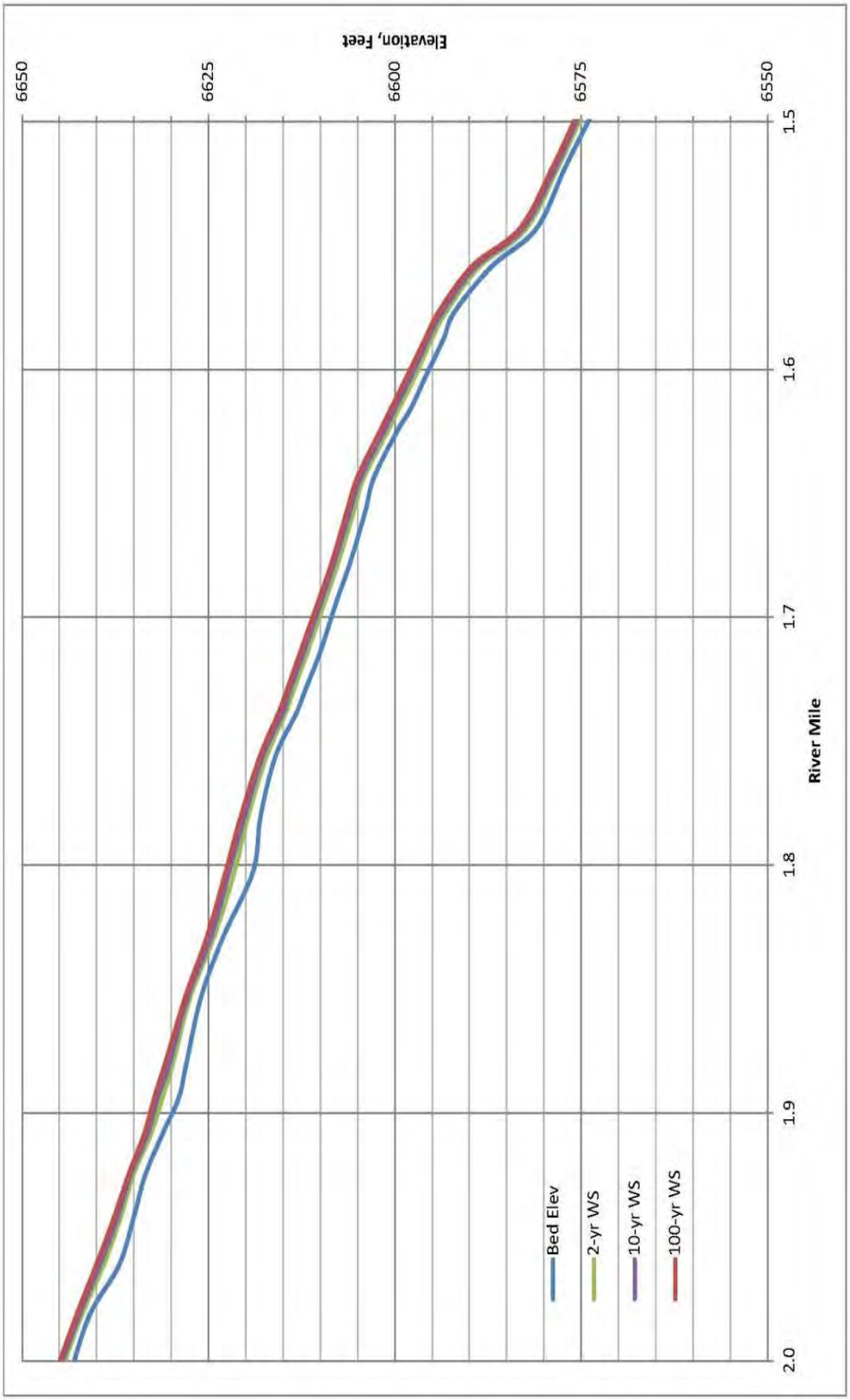

Figure 51. Jordan Creek RM 2 to RM 1.5 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge (note - locations of bridges and tributaries shown).

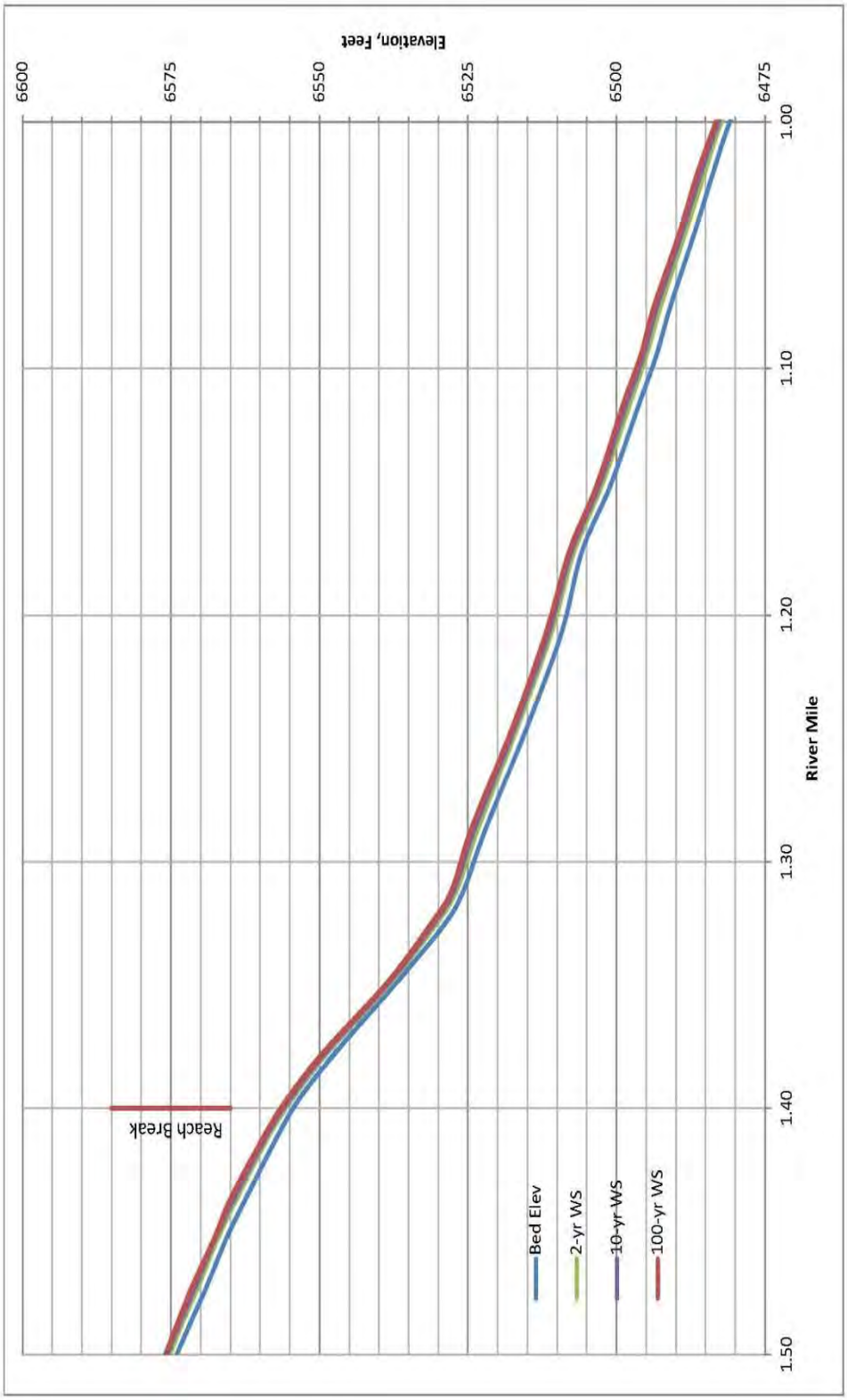

Figure 52. Jordan Creek RM 1.5 to RM 1 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge (note - locations of bridges and tributaries shown).

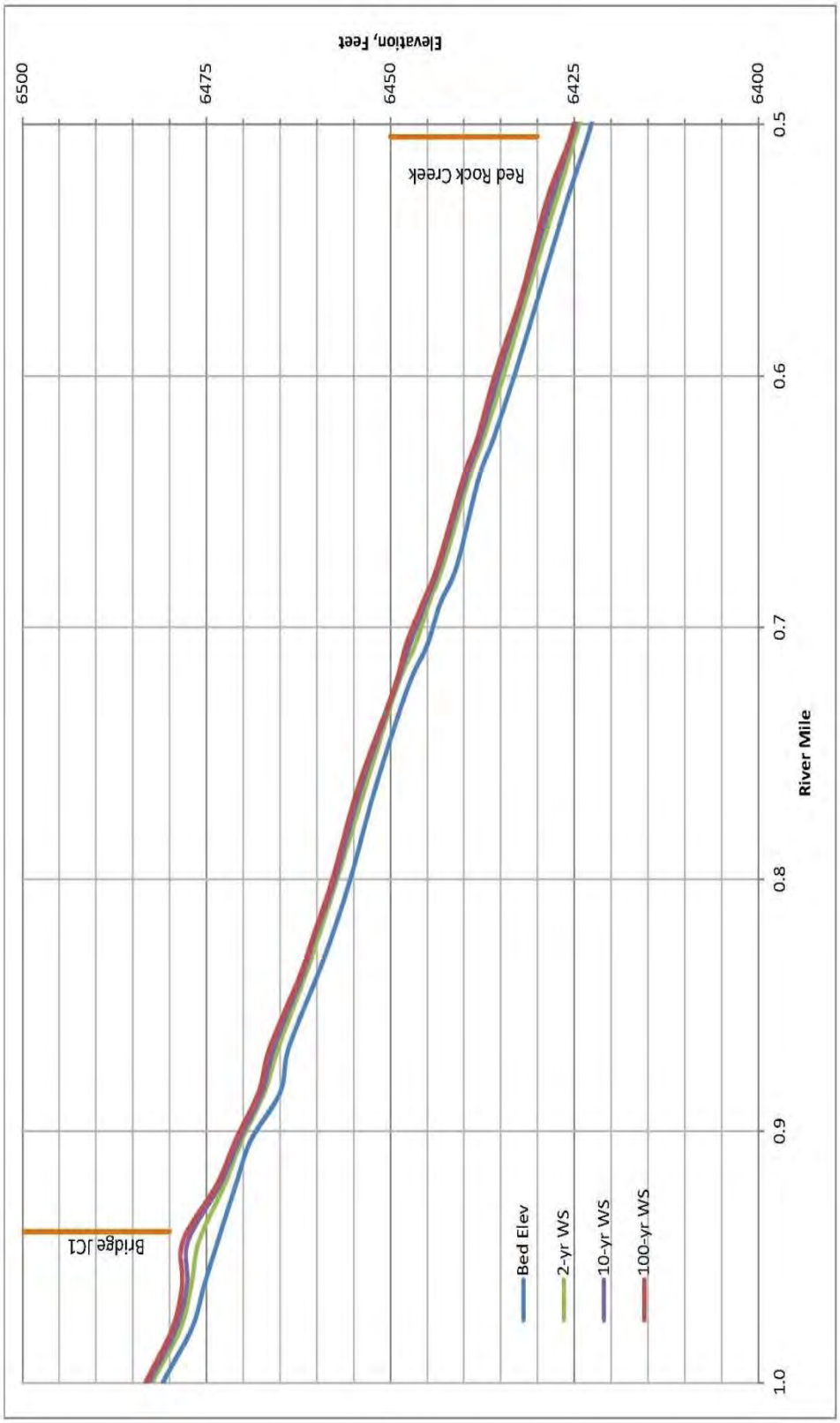

Figure 53. Jordan Creek RM 1 to RM 0.5 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge (note - locations of bridges and tributaries shown).

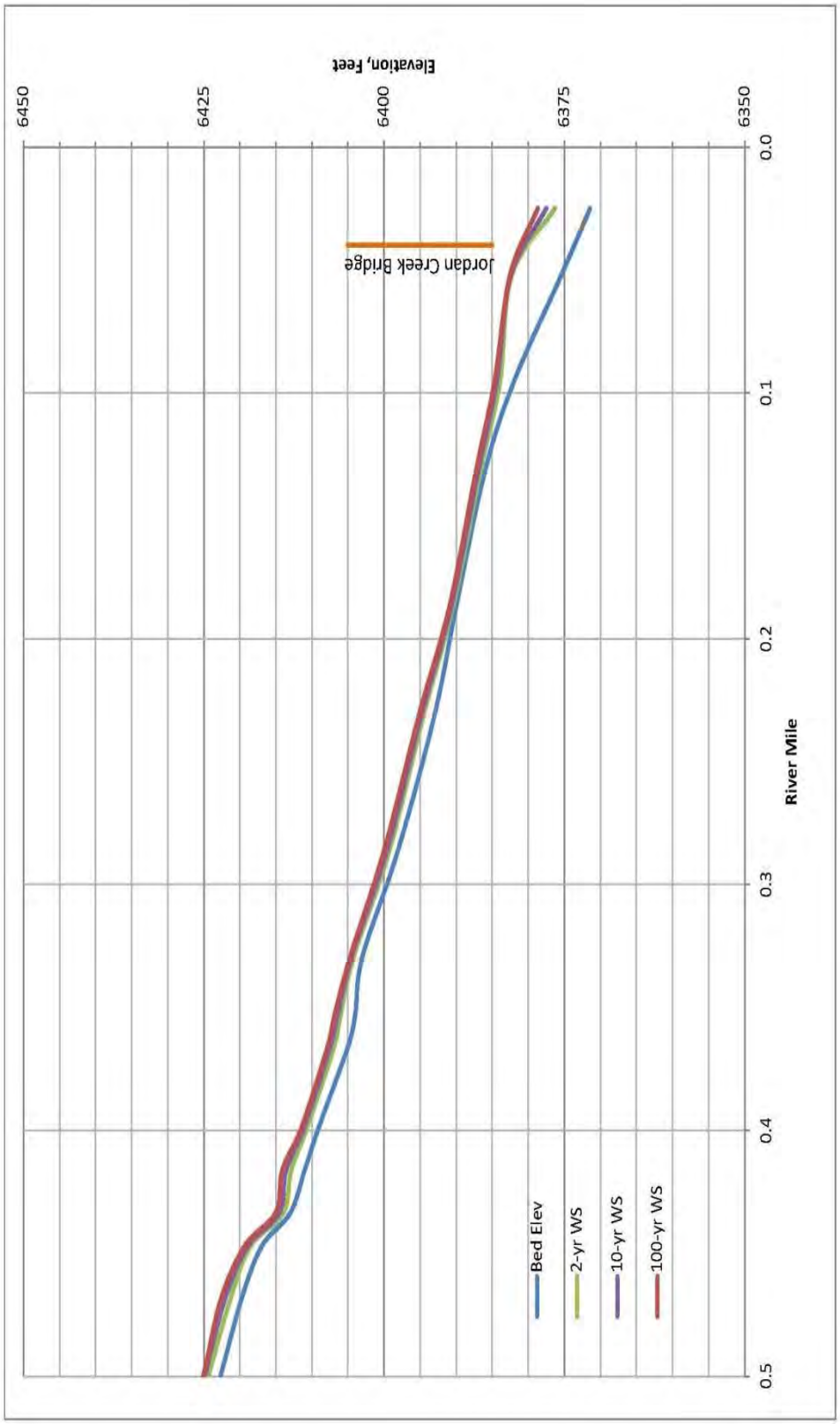

Figure 54. Jordan Creek RM 0.5 to RM 0 - Predicted water surface profiles for the 2-, 10-, and 100-year annual peak discharge (note - location of bridges and tributaries shown).

5.2 Shear Stress

Shear stress predicted by HEC-RAS is used with the Shields critical mobility parameter to estimate the size of sediment that is moving along the channel bed. Using a Shields mobility factor of 0.045 for rough, turbulent flow characteristics of gravel-bedded rivers, the size of sediment in motion along the stream bed can be estimated.

Shear stress in the main channel and the estimated size of sediment in motion along the stream bed for the 2-year recurrence interval flood discharge through each reach of the Yankee Fork and Jordan Creek is shown on Figures 55 through 61.

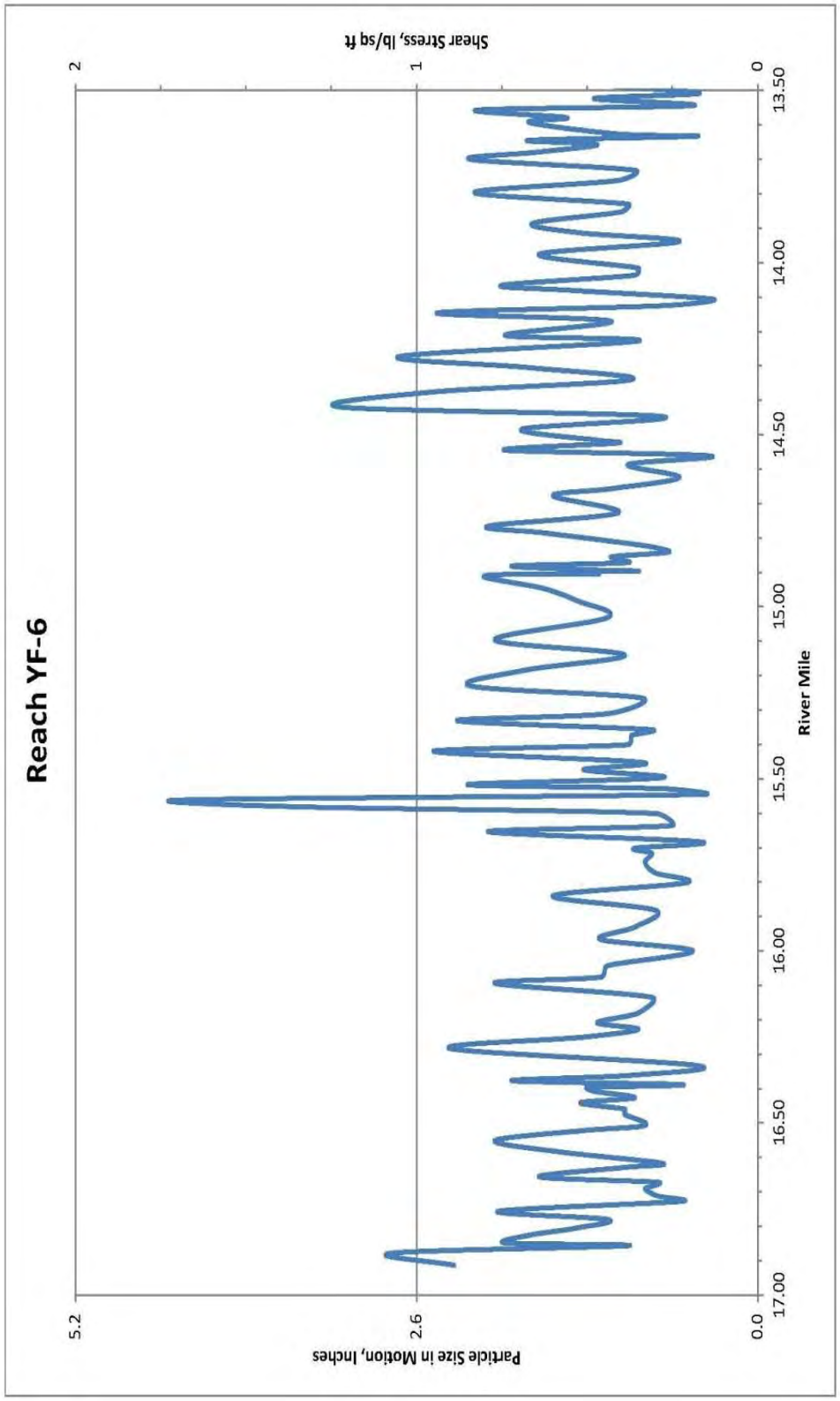

Figure 55. Main channel average shear stress for the 2-year recurrence flood (563 cfs) through Reach YF-6.

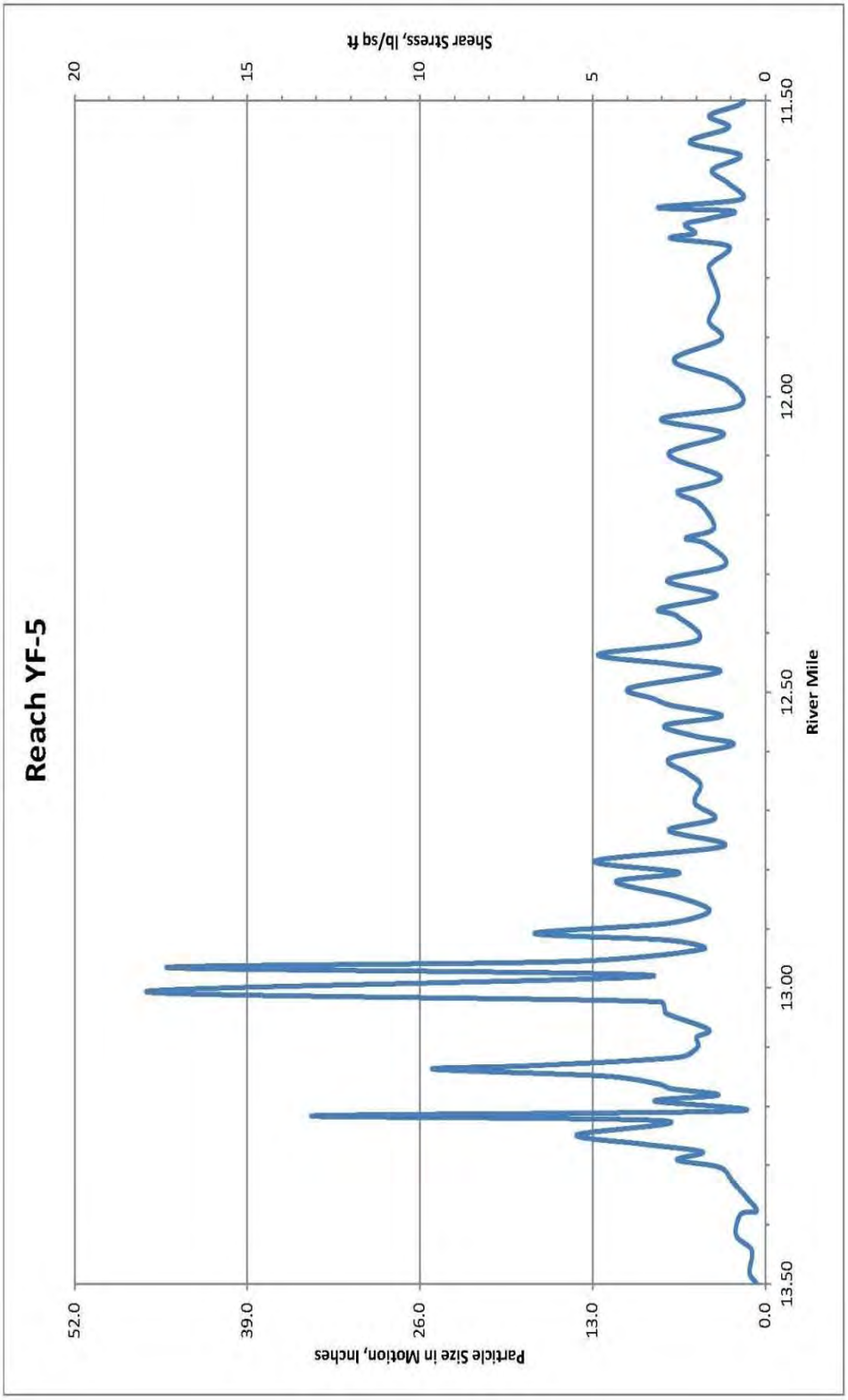

Figure 56. Main channel shear stress for the 2-year recurrence flood (609 cfs) through Reach YF-5.

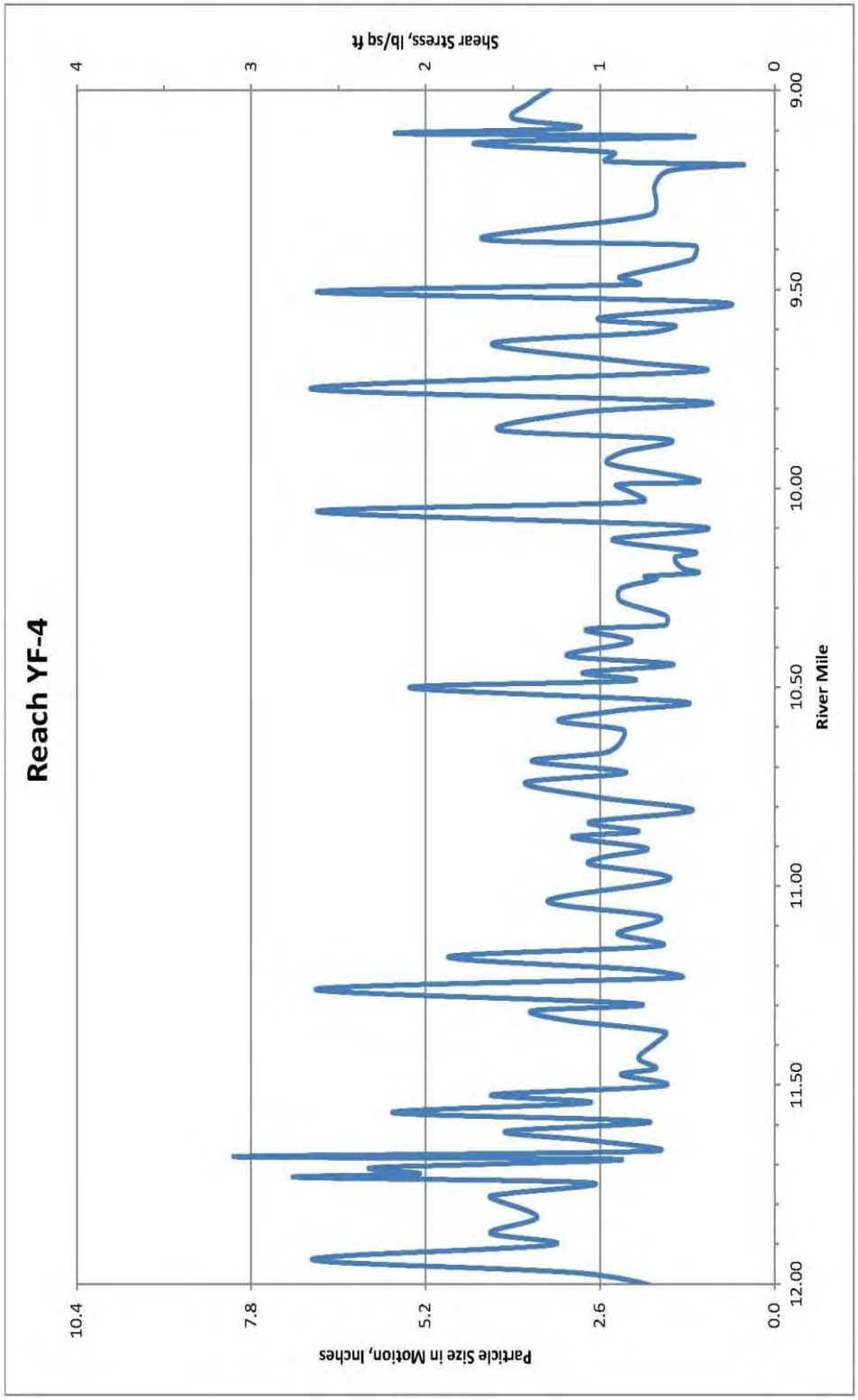

Figure 57. Main channel shear stress for the 2-year recurrence flood (647 cfs) through Reach YF-4.

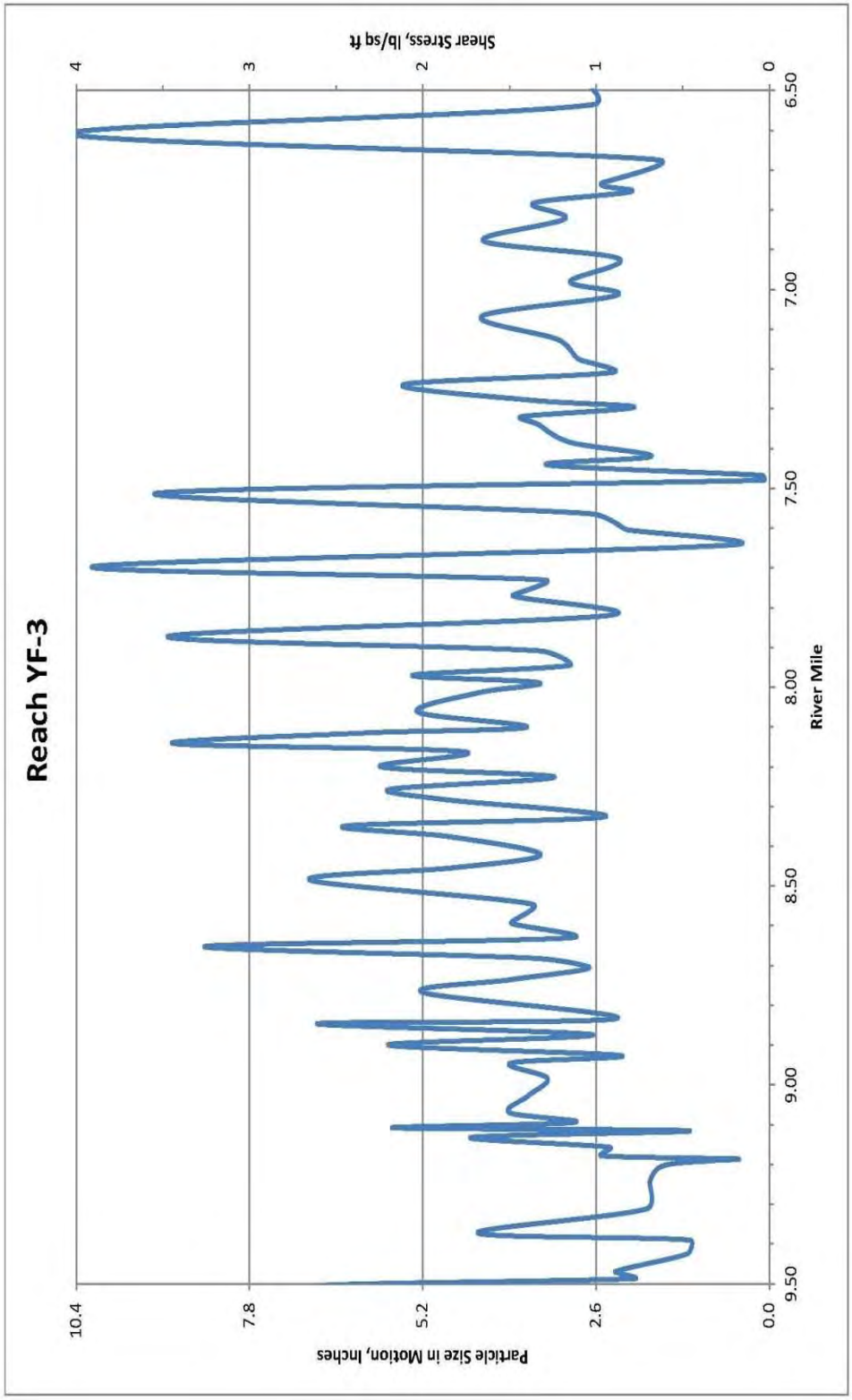

Figure 58. Main channel shear stress for the 2-year recurrence flood (828 cfs) through Reach YF-3.

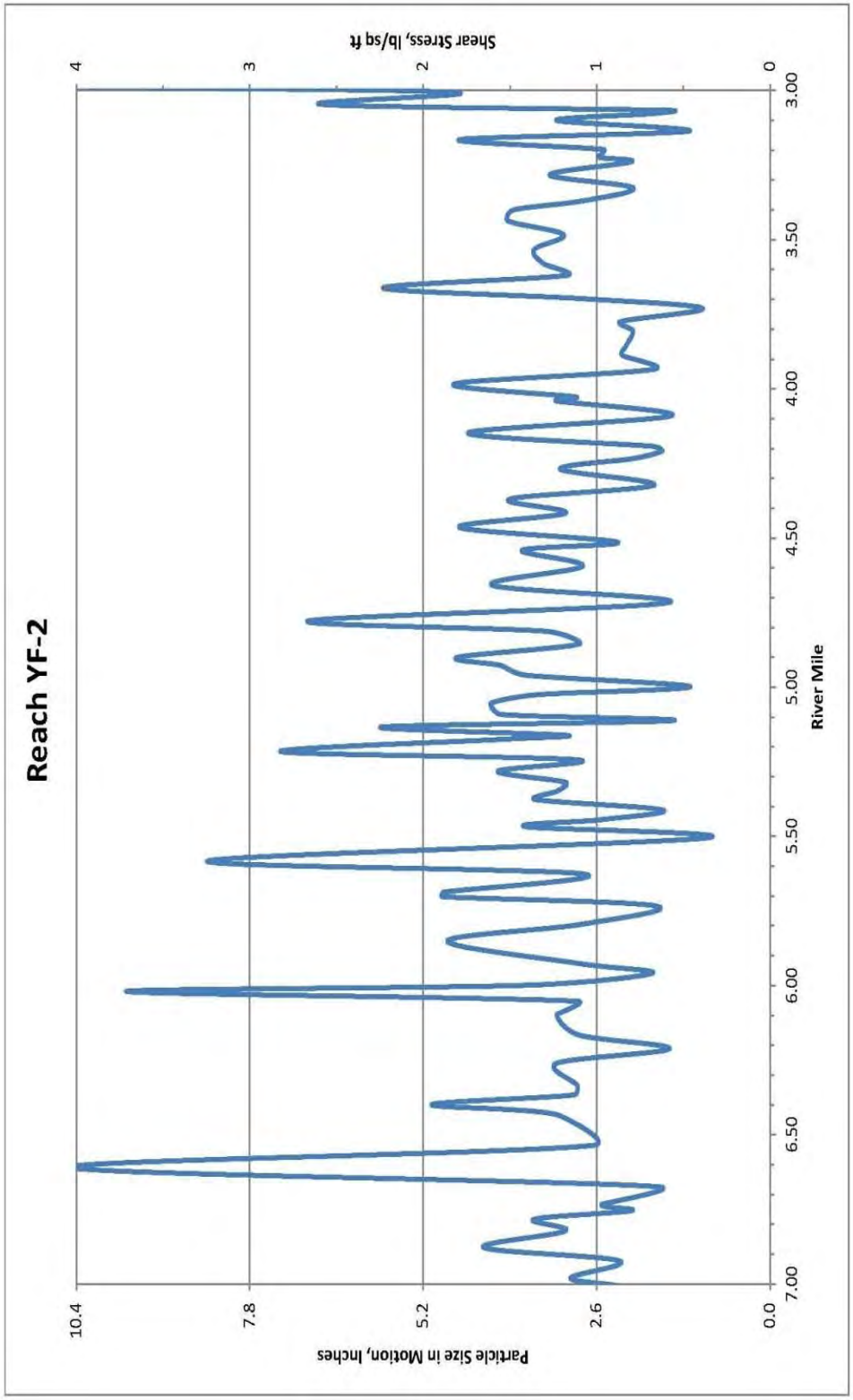

Figure 59. Main channel shear stress for the 2-year recurrence flood (1,423 cfs) through Reach YF-2.

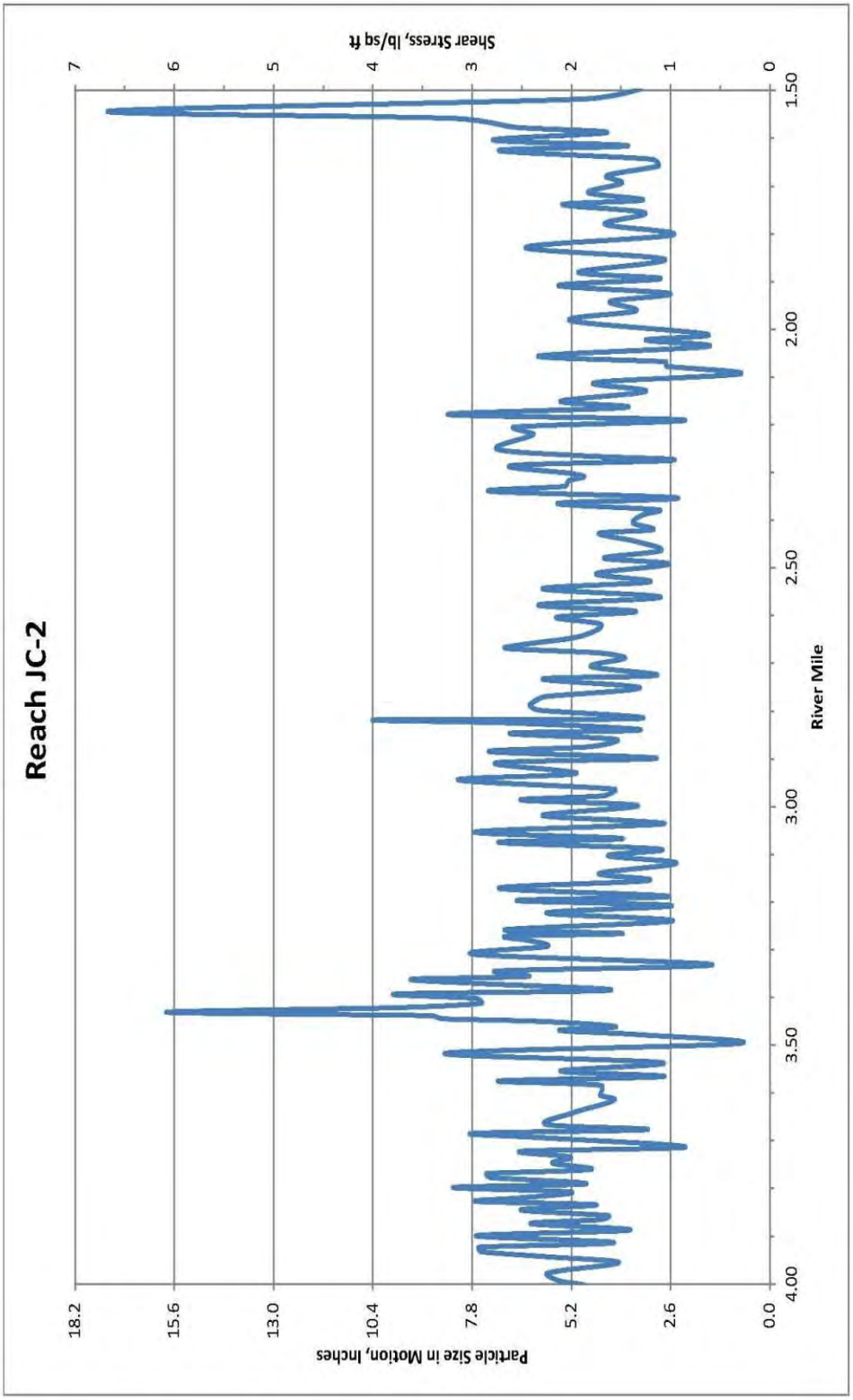

Figure 60. Main channel shear stress for the 2-year recurrence flood (126 cfs) through Reach JC-2.

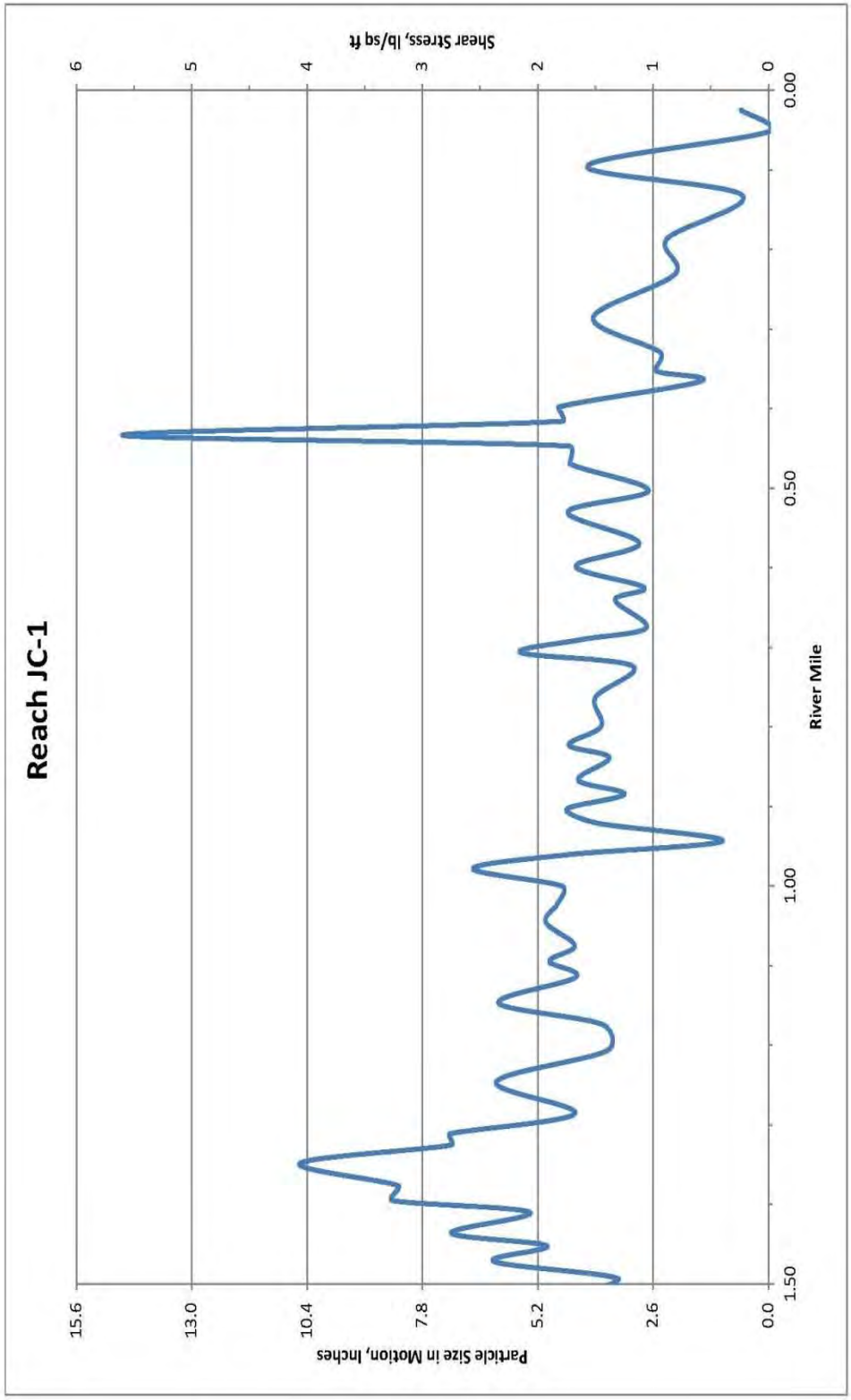

Figure 61. Main channel shear stress for the 2-year recurrence flood (148 cfs) through Reach JC-1.

5.3 Velocity

Water velocities predicted by HEC-RAS can provide an indication of potential barriers to Juvenile upstream migration in the Yankee Fork. Juvenile Chinook salmon prefer pool or protected habitats with velocities less than 2 feet per second (fps) (Maret et al. 2006). Maximum water velocities for juvenile upstream fish passage facilities are recommended to be less than 2.5 fps (NOAA Fisheries 2008).

Predicted average water velocities from HEC-RAS in the main channel for the 2-year recurrence interval flood discharge through each reach of the Yankee Fork and Jordan Creek is shown on Figures 62 through 68.

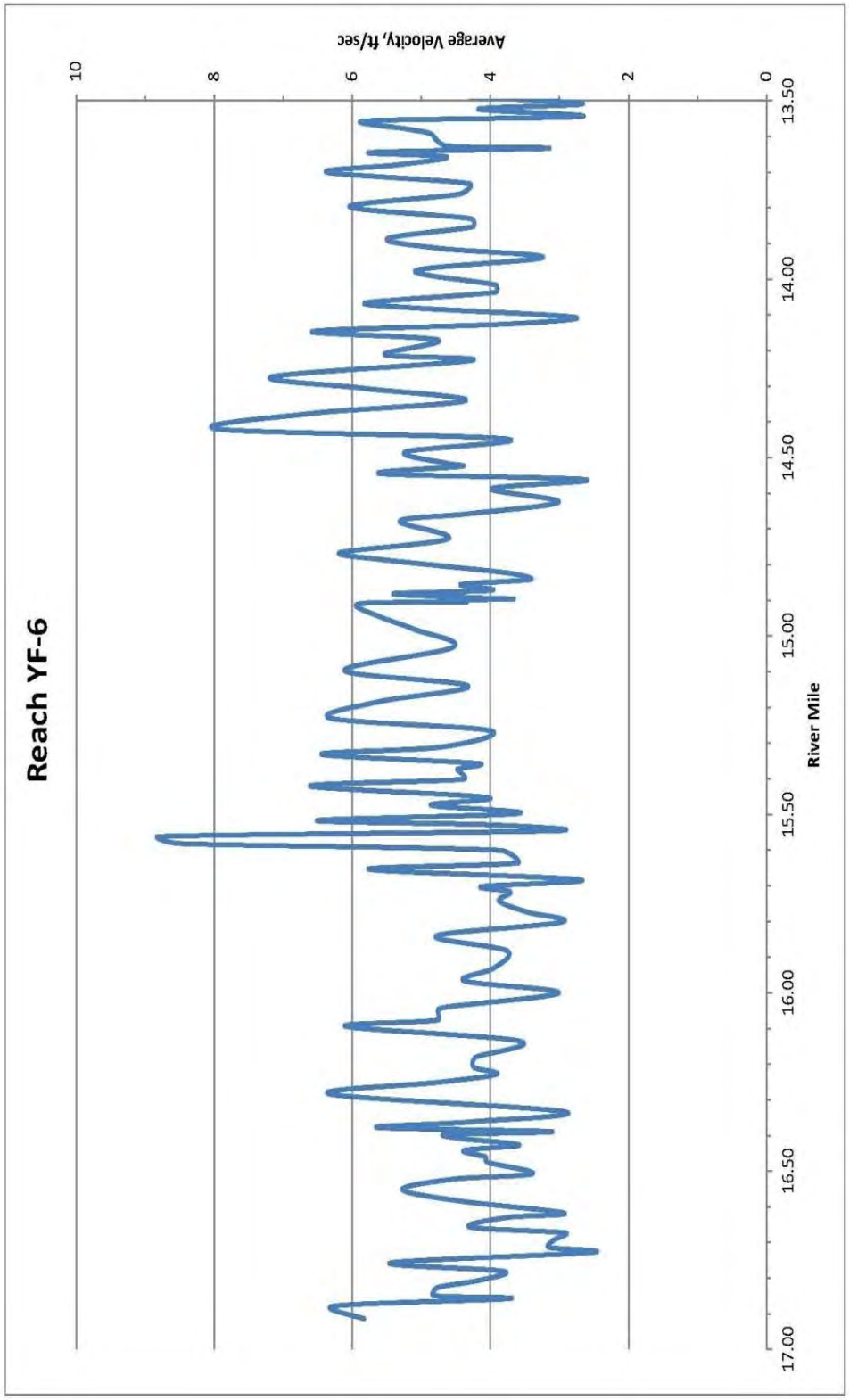

Figure 62. Average velocity of flow in the main channel for the 2-year recurrence flood (563 cfs) through Reach YF-6.

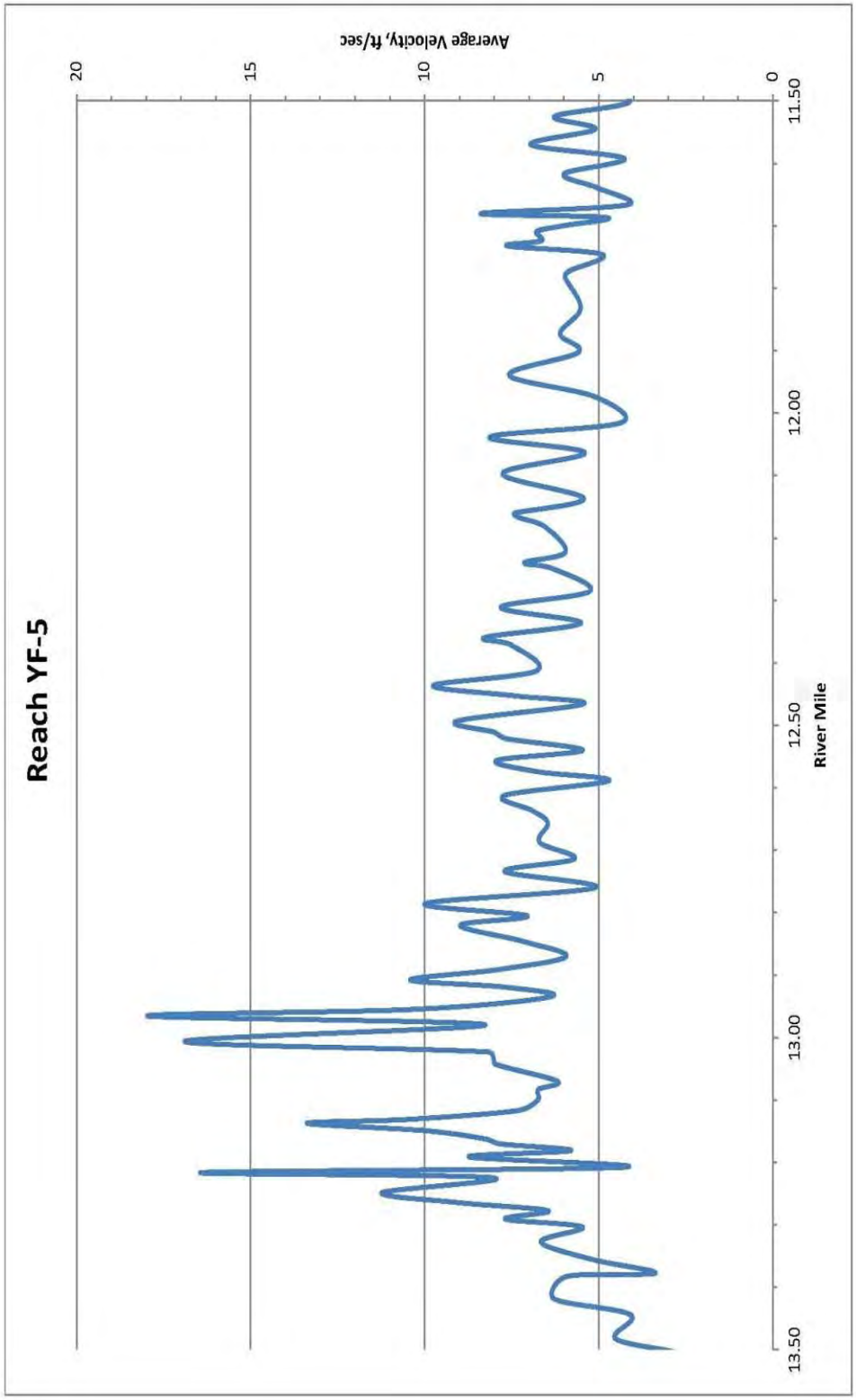

Figure 63. Average velocity of flow in the main channel for the 2-year recurrence flood (609 cfs) through Reach YF-5.

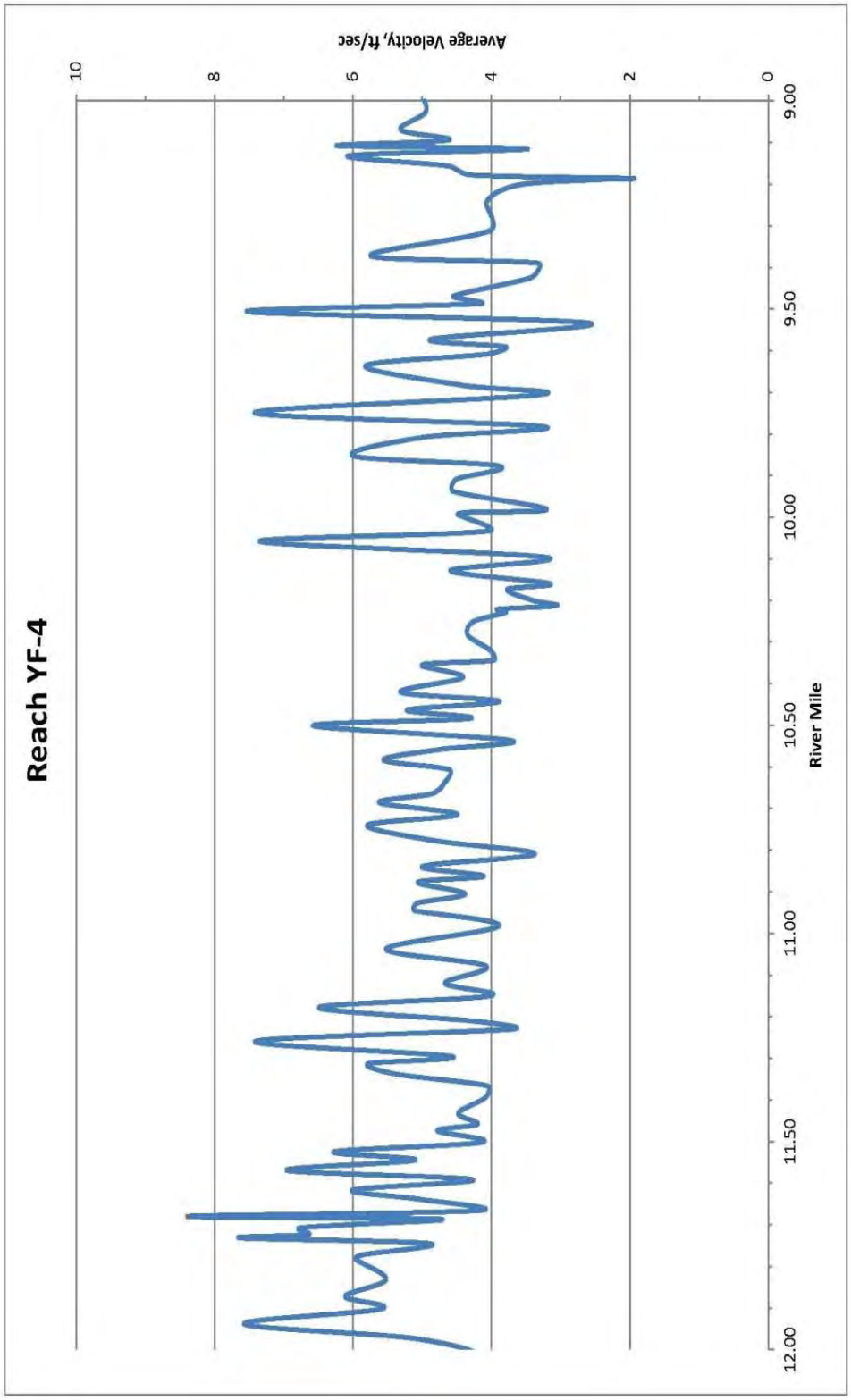

Figure 64. Average velocity of flow in the main channel for the 2-year recurrence flood (647 cfs) through Reach YF-4.

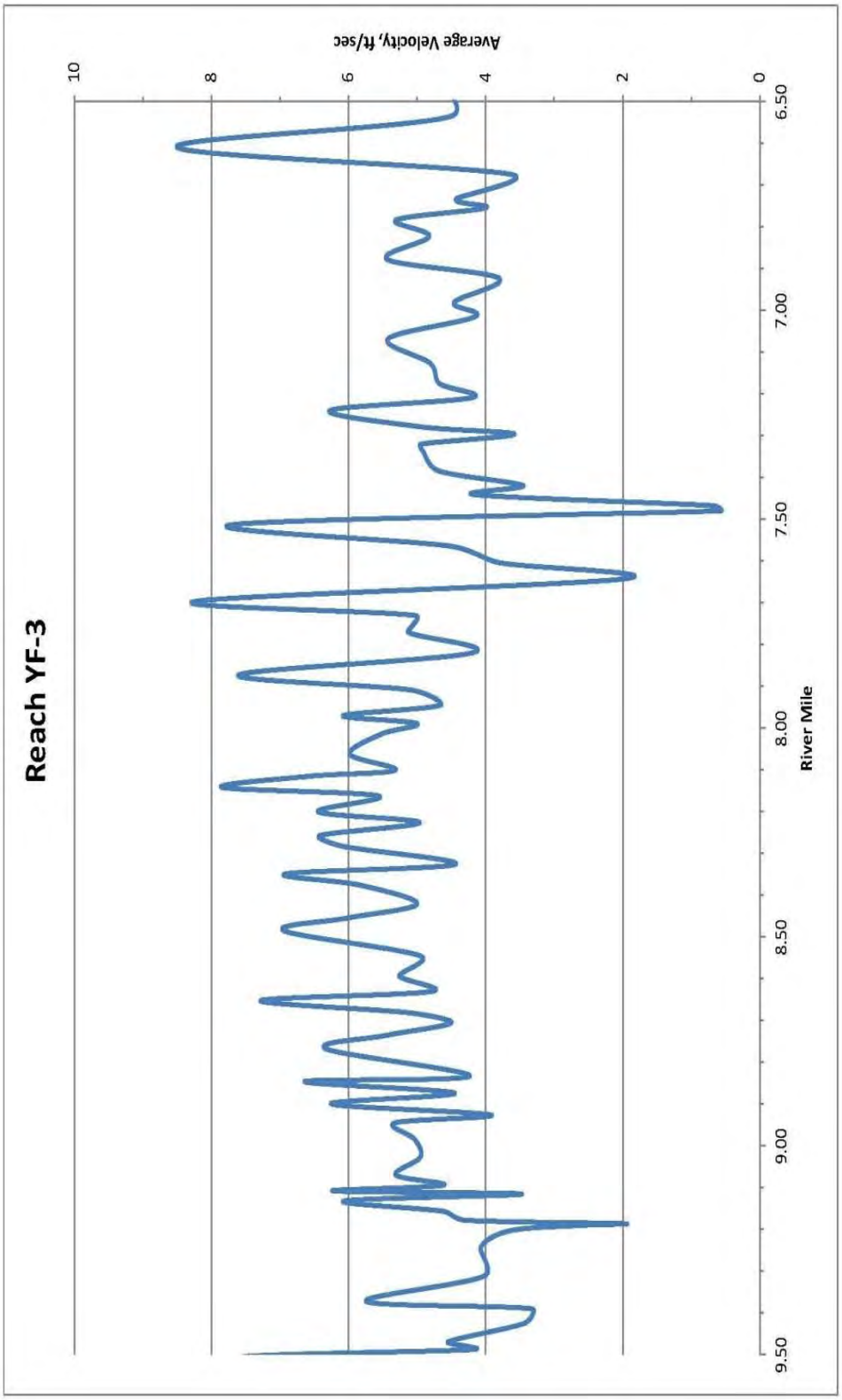

Figure 65. Average velocity of flow in the main channel for the 2-year recurrence flood (828 cfs) through Reach YF-3.

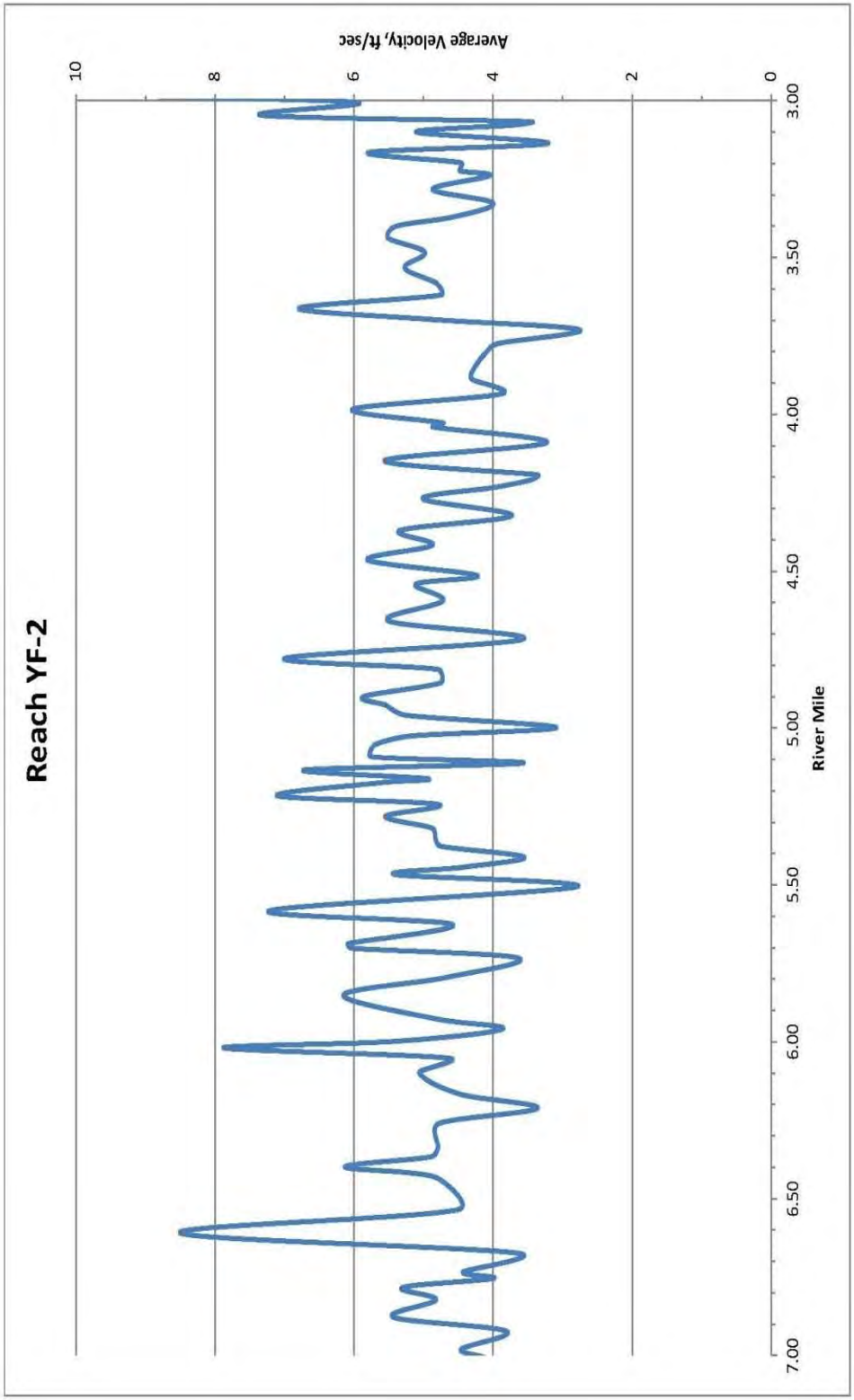

Figure 66. Average velocity of flow in the main channel for the 2-year recurrence flood (1,423 cfs) through Reach YF-2.

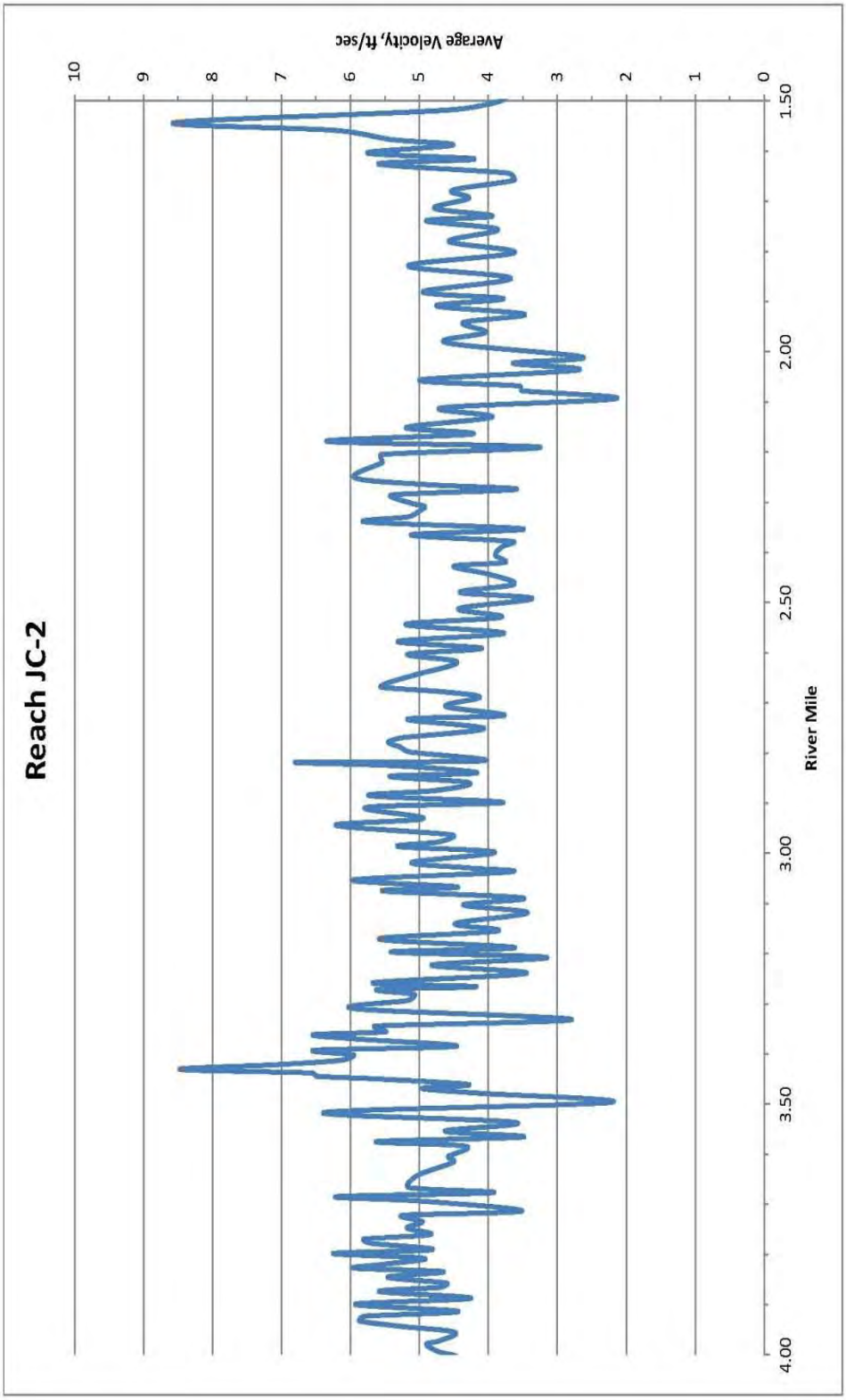

Figure 67. Average velocity of flow in the main channel for the 2-year recurrence flood (126 cfs) through Reach JC-2.

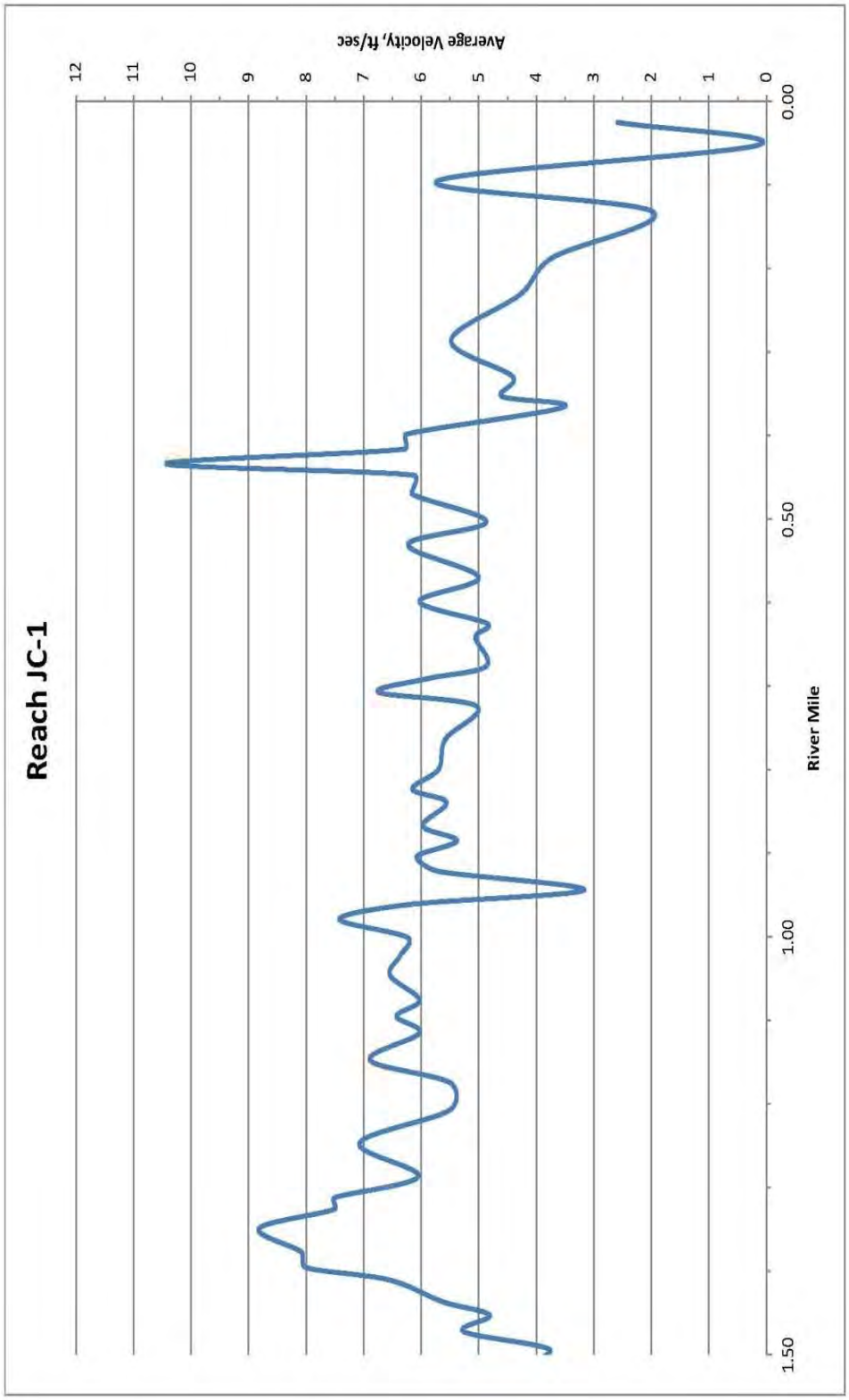

Figure 68. Average velocity of flow in the main channel for the 2-year recurrence flood (148 cfs) through Reach JC-1.

5.4 Flood Inundation Areas

Predicted water surface elevations were imported from the results of the HEC-RAS model into the GeoRAS application to map the spatial extent of flood inundation in ArcGIS. The flood inundation area during the 10- and 100-year recurrence interval flood event through Reach YF-2 is shown on Figure 69. Flood inundation maps for the 10- and 100-year recurrence interval flood events through each reach of the Yankee Fork and Jordan Creek are available in the Map Atlas of the Yankee Fork Tributary Assessment.

Only lower elevation areas with surface connections to the mainstem channel are shown to be inundated. Other areas not connected to the mainstem channel but have ground surface elevations lower than the respective water surface elevations are not shown to be inundated. These areas may actually be inundated with ground water. For the purposes of this assessment, the parallel ponds through Reach YF-2 were assumed to be disconnected from the main channel and are not shown to be inundated. These parallel ponds are expected to have water surface elevations approximating the main channel water surface elevations.

This analysis was not done in strict compliance with Federal Emergency Management Agency flood insurance rate studies and the flood inundation maps are not intended to be used as flood insurance maps.

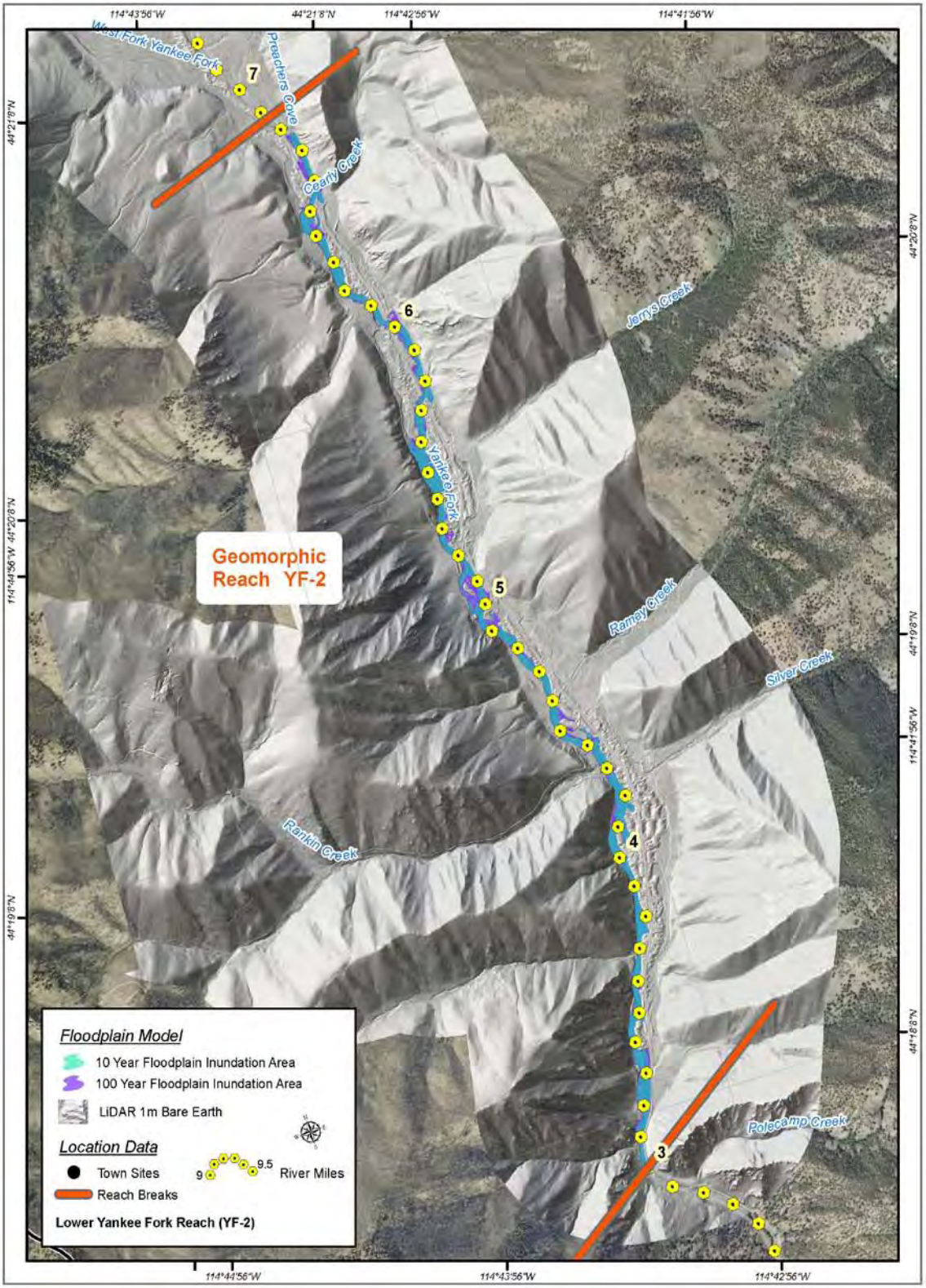

Figure 69. Flood inundation area during the 10- and 100-year recurrence flood through Reach YF-2.

6. Discussion

Hydraulic modeling using HEC-RAS included discharges for the 1.11-, 2-, 10-, 50-, and 100-year annual peak recurrence interval events. The hydraulic model was calibrated to surveyed water surface elevations near bridge locations using measured stream discharges obtained on June 8, 2011. The stream flow on June 8, 2011 approximately represented the 2-year annual peak discharge. Visual observations of the water surface during stream discharge measurements indicated the flow equaled or exceeded bank full flow with overbank areas partially inundated. The model appears to be well calibrated for the 2-year recurrence discharge with a difference between actual and predicted water surface elevations of less than 3 inches. The model should be applicable for discharges within the 1.11 to 2 year recurrence intervals. At lower and higher flows, the model becomes less useful as those flows are outside the data range used for calibration.

The one-dimensional model was chosen to represent broad scale river hydraulics. The model is limited to one-dimension providing results for longitudinal changes in channel hydraulics resulting from channel geometry, structures, and flow rate. Limitations of the current model include a lack of bathymetric survey data, survey data not tied to a datum, lack of calibration data for low and high stream discharges, and the exclusion of the parallel pond series through Reach YF-2.

The model area includes five geomorphic reaches on the Yankee Fork and the two geomorphic reaches on Jordan Creek. Discussion of the existing hydraulic characteristics through each geomorphic reach follows:

6.1 Reach YF-6 RM 16.3 to 13.2

The Yankee Fork through Reach YF-6 meanders through a broad valley from the confluence with Eight Mile Creek to the confluence with Five Mile Creek. The overall channel slope is fairly constant at approximately 0.6 percent with local streambed changes through the riffle-pool reach. The channel is constrained intermittently by valley walls and channel embankments. Model results indicate that stream flows begin to access adjacent floodplains, oxbows, and side channels at the 1.11-year recurrence discharge. Greylock Creek appears to contribute sediment to the river as indicated by the change in bed profile at RM 14.5. Five Mile Bridge appears to impart hydraulic controls at the 2-year and above recurrence floods as indicated by the backwater condition on the water surface profile at RM 14.1.

The average shear stress in the main channel through Reach YF-6 during the 2-year recurrence discharge is approximately 0.5 pounds per square foot (lb/sq ft). This indicates that the stream has the ability to at minimum move small gravel (approximately 1.3-inch) on average in this reach. A peak in velocity and shear stress occurs at RM 15.65 where

the channel is constrained on the right bank by the Custer Motorway. Visual observations from the road confirm a scour pool along the road embankment.

In terms of hydraulics, natural processes appear to be functioning through Reach YF-6 with the exception of minor anthropogenic impacts from road and bridge construction that constrict flood flows and alter natural hydraulic function. Interactions between the main channel and the side channels, floodplains, and oxbows appear active and dynamic.

6.2 Reach YF-5 RM 13.2 to 11.6

The Yankee Fork through Reach YF-5 flows through a steep and narrow canyon between the confluence with Five Mile Creek and the reach break at RM 11.6. This reach of the Yankee Fork is steeper than upstream and gradually reduces in slope through the reach. Channel slope increases from 0.6 to 3.8 percent at the geologic control between Reaches YF-6 and YF-5. Channel slope then decreases to 1.7 percent near RM 12.8 at the lower end of the canyon segment upstream of Slaughterhouse Gulch and finally decreases to 1.2 percent from Custer Bridge at RM 12 to the break at Reach YF-4. The channel is constrained throughout this reach by valley walls. Slaughterhouse Gulch at RM 12.2 appears to contribute only minor hydrologic and sediment inputs to the Yankee Fork. At higher flows, Custer Bridge appears to create a backwater condition by imparting hydraulic controls during the 10-year and higher recurrence flood event and only minor hydraulic influences during the 2-year recurrence discharge.

Average channel shear stresses vary through YF-5 as slope changes occur. The average shear stress in the main channel through Reach YF-5 during the 2-year recurrence discharge is approximately 3.1 lb/sq ft. This indicates that the stream has the ability to at minimum move large cobble to small boulder sized material (approximately 8-inch) on average through much of the reach. However, during the 2-year peak flow, average shear stress exceeds 5 lb/sq ft as the Yankee Fork flows through the steep canyon segment of Reach YF-5, which indicates, that on average, this subreach is capable of moving boulders (13 –inch) and shear stress declines to less than 2 lb/sq ft at the lower end of the reach indicating the ability to move cobble sized material (5-inch) on average at the lower end of YF-5.

In terms of hydraulics, natural processes appear to be functioning through Reach YF-5. Overbank areas are limited and the Yankee Fork is confined within in its channel banks throughout Reach YF-5. Custer Bridge appears to be the only anthropogenic disturbance to hydraulic processes at the 10-year and above recurrence discharge in the reach.

6.3 Reach YF-4 RM 11.6 to 9.1

Reach YF-4 of the Yankee Fork flows in a moderately confined channel through the townsite of Custer with a slope of 1.1 percent from the reach break at RM 11.6 to the

confluence with Jordan Creek at RM 9.1. There are no significant tributary inputs in this reach. The channel is confined within its banks in the upper segment between RM 11.6 and 11.0. Hydraulic modeling indicates that the Yankee Fork begins to access adjacent floodplains between RM 11.0 and 9.1 during the 1.11-year recurrence discharge.

The General Custer Mill site is on river left between RM 11.2 and 10.9 and the townsite of Custer on river right between RM 10.9 and 10.3. The abutments for General's Bridge at RM 10.9 encroach into the floodplain and appear to only exert hydraulic control at 10-year and greater recurrence floods.

The average shear stress in the main channel through Reach YF-4 during the 2-year recurrence discharge is approximately 1.0 lb/sq ft. This indicates that the stream has the ability to at minimum move gravels (approximately 2.6-inch) on average in this reach. There are five locations where average shear stresses can exceed 2 lb/sq ft; at RM 11.3 and 10.5 the channel is constrained by the valley wall on river left; at RM 10.1 and RM 9.7 the channel is constrained by the Custer Motorway on river right; and at RM 9.5 the valley wall encroaches into river left. It appears that earth fill may have been placed at the dispersed camping site on river right at RM 9.5 potentially constraining the channel further in this segment.

In terms of hydraulics, natural processes appear to be functioning through the upper part of this reach from RM 11.6 to 11.2. Overbank areas are naturally limited and the channel is confined within in its banks. Hydraulic results indicate natural processes through the lower part of this reach from RM 11.2 to 9.1 have been modified by anthropogenic impacts resulting in channel realignment and potential scour.

6.4 Reach YF-3 RM 9.1 to 6.9

In Reach YF-3, the Yankee Fork flows through a dredged segment from the confluence with Jordan Creek at RM 9.1 to the confluence with the West Fork at RM 6.9. The channel slope is fairly constant at 1.0 percent. Jordan Creek is a major tributary at the upstream end of Reach YF-3. There are no additional significant tributary inputs in this reach. Bonanza Bridge appears to exert hydraulic control at the 2-year and above recurrence floods. Overbank areas are naturally limited by valley walls and constrained by artificial dredge piles.

The Yankee Fork is confined within it banks naturally by valley walls and through anthropogenic alternations at dredge piles throughout Reach YF-3. A levee between RM 8.9 and RM 8.6 on river right protecting a gravel mining operation contributes to river confinement. Fill placed at an abandoned road crossing at RM 8.0 encroaches into the floodplain area on river left and river right. Dredge piles disconnect floodplain areas from the river channel on river right resulting in channel realignment and potential scour between RM 7.8 and RM 6.9 above the confluence with the West Fork. The Yankee Fork

and West Fork confluence area has been displaced downstream with the two channels realigned and isolated from each other by dredge piles between RM 7.2 and 6.9.

The average shear stress in the main channel through Reach YF-3 during the 2-year recurrence discharge is approximately 1.5 lb/sq ft. This indicates that the stream has the ability to at minimum move large gravels to small cobbles (approximately 3.9-inch) on average in this reach. There are five locations where average channel shear stress is greater than 3 lb/sq ft and average channel velocity approaches 8 fps exceeding juvenile fish swimming capability; at RM 8.6 the channel is constrained by levees on river right; at RM 8.1 downstream of Bonanza Bridge the channel is constrained by the valley wall on river right and dredge piles on river left; at RM 7.9 downstream of the abandoned bridge crossing the channel is constrained by the valley wall on river right; at RM 7.7 the channel is constrained by dredge piles on river right and a topographic constraint created by an earth fill embankment on river left; and at RM 7.5 the channel is constrained by dredge piles on river right.

In term of hydraulics, natural processes appear to have been modified by anthropogenic alterations throughout Reach YF-3. Anthropogenic alterations are primarily the result of dredging operations that realigned and confined the channel and segregated the West Fork from the main channel displacing the confluence area to a downstream location. Hydraulic impacts likely include increased velocities and shear stresses both localized at several locations as shown in hydraulic modeling results and on average through the reach. Increases in stream energy within this reach would have the effect of altering geomorphic properties including sediment transport and composition of the reach.

6.5 Reach YF-2 RM 6.9 to 3.0

The Yankee Fork continues to flow in a channel naturally confined by valley walls and artificially constrained by dredge piles through Reach YF-2 from the confluence with the West Fork at RM 6.9 to the end of the reach at RM 3.0. The channel slope is fairly constant at approximately 0.6 percent. The Custer Motorway crosses the Yankee Fork in four locations within Reach YF-2. Virginia's Bridge at RM 6.8 appears to exert hydraulic control at the 100-year recurrence flood. Cearley Creek Bridge at RM 6.5 does not appear to exert hydraulic control at the 2-year or higher recurrence floods. Cabin Bridge at RM 6.0 appears to impart hydraulic controls during the 2-year and above recurrence discharge. Jerry's Bridge at RM 5.7 appears to exert hydraulic control at the 100-year recurrence discharge. The debris slide at the unnamed tributary at RM 3.8 appears create a backwater condition at the 2-year and higher recurrence floods.

Surface water connections of tributaries have been altered throughout this reach. Surface connections of tributaries including Cearley Creek on river left near RM 6.5, an unnamed tributary on river right near RM 6.0, Jerry's Creek on river left near RM 5.7, and Silver Creek on river left near RM 4.2 have been disconnected from the main Yankee Fork

channel by dredge piles. Surface connection of Ramey Creek on river left near RM 4.6 has also been realigned and confined in an artificial channel through a residential subdivision area.

As a result of dredge operations and subsequent habitat improvement projects conducted during the 1980s (Reiser and Ramey 1987), multiple ponds are found in the valley bottom within YF-2. Parallel to the Yankee Fork and on the opposite side of the valley from the main channel are four series of dredge ponds. Pond series 4 begins upstream of Virginia's Bridge near RM 6.8. A diversion structure on river right directs surface water into a series of dredge ponds and surface water returns to the Yankee Fork downstream of Cearley Creek Bridge near RM 6.4. Pond series 3 begins upstream of Cearley Creek Bridge at RM 6.5 with a diversion structure on river right. Water flow from these ponds returns to the Yankee Fork downstream of Cabin Bridge near RM 5.9. Pond series 2 begins with a diversion structure on river right near RM 6.0 upstream of Cabin Bridge and returns to the Yankee Fork downstream of Jerry's Bridge near RM 5.5. Pond Series 1 begins downstream of Silver Creek with no surface water diversion and returns to the Yankee Fork on river right through a culvert under Custer Motorway near RM 3.5. Water flow into these series of ponds is from tributaries, groundwater flow, and surface water diversion with hydraulic control structures from the Yankee Fork. Dredge ponds that are disconnected from the main channel, including the four pond series, have been excluded from this hydraulic analysis and flood inundation mapping. Without hydraulic modeling, it is assumed that the dredge ponds will have water surface elevations approximately equal to the water surface profile in the main channel but do not affect hydraulic processes within the main channel. Only those floodplain areas that are directly connected to the main channel have been included.

The average shear stress in the main channel through Reach YF-2 during the 2-year recurrence discharge is approximately 1.3 lb/sq ft. This indicates that the stream has the ability to at minimum move large gravels (approximately 3.4-inch) on average in this reach. There are six locations where local average channel shear stress is greater than 2 lb/sq ft and average channel velocity approaches 8 fps exceeding juvenile fish swimming capability; at RM 6.6 downstream of the confluence with the West Fork and Virginia's Bridge the channel is confined by the valley wall on river left; at RM 6.0 the channel is approaching Cabin Bridge with rock riprap placed on river right; at RM 5.6 the channel is constrained by dredge piles on river left; at RM 5.2 the channel is confined by the valley wall on river right; at RM 4.8 the channel is constrained by dredge piles on river right; and at RM 3.7 the channel is constrained by dredge piles on river left and a debris flow from an unnamed tributary on river right.

Natural hydraulic stream processes appear to have been modified by anthropogenic impacts throughout Reach YF-2. Apparent impacts to natural stream hydraulics appear to be the result of dredging operations that realigned and constrained the channel with additional impacts caused by the Custer Motorway and four poorly aligned bridge

crossings over the Yankee Fork. Impacts to stream hydraulics have likely created increases in shear stress and stream velocity both locally at several locations and throughout the reach on average.

6.6 Reach JC-2 RM 4 to 1.4

Jordan Creek flows through Reach JC2 from Grouse Creek Mine at RM 4 to the reach break at RM 1.4. There are three minor slope breaks in Jordan Creek Reach JC-2. The channel slope is approximately 3.3 percent from RM 4 to 3.3, 2.6 percent from RM 3.3 to 1.8, and 3.1 percent from RM 1.8 to 1.4. There are four bridges that cross Jordan Creek in this reach. Bridge JC5 appears to exert hydraulic control during the 10-year and greater recurrence flood. Bridge JC4 does not appear to exert hydraulic control at flows less than or equal to the 100-year recurrence discharge. Bridge JC3 does not appear to exert hydraulic control at flows less than or equal to the 10-year recurrence discharge but does appear to exert hydraulic control during the 100-year recurrence flood. Bridge JC2 appears to exert hydraulic control at the 2-year recurrence discharge and greater with the backwater extending further upstream at higher discharges. There are no significant tributary inputs to Jordan Creek through this reach.

Overbank areas are naturally limited and Jordan Creek is generally confined within in its channel banks through Reach JC-2. There are small floodplain areas that Jordan Creek begins to access during the 2-year recurrence discharge and above near RM 3.6 to 3.4, RM 3.2 to 3.0, RM 2.6 to 2.4, and RM 2.1 to 1.7.

The average shear stress in the main channel through Reach JC-2 during the 2-year recurrence discharge is approximately 2.0 lb/sq ft. This indicates that the stream has the ability to at minimum move cobble sized material (approximately 5-inch) on average in this reach. There are three locations where shear stress is locally greater than 4 lb/sq ft; at RM 3.4 and RM 2.8 the channel is confined by the valley wall on river left and the Loon Creek Road on river right; and at RM 1.5 the channel is confined by the valley wall on river right.

In terms of hydraulics, natural processes appear to be functioning through Reach JC-2 with the exception of minor anthropogenic impacts from road and bridge construction. Stream hydraulics do not appear to be altered by the bridges in this reach due to the confined nature and gradient of the stream channel.

6.7 Reach JC-1 RM 1.4 to 0

Jordan Creek flows through Reach JC1 from RM 1.4 to the confluence with the Yankee Fork. From RM 1.4 to 0.4 Jordan Creek flows through a dredged segment with two slope breaks. The channel slope is approximately 5.5 percent from RM 1.4 to 1.3 and 2.4 percent from RM 1.3 to 0.4. From RM 0.4 to the mouth Jordan Creek flows through a

habitat rehabilitation project area developed as part of mitigation for the Grouse Creek Mine with a slope of 1.8 percent. There are two bridges that cross Jordan Creek in this reach. Bridge JC1 near RM 0.9 appears to access private land and exerts backwater hydraulic control at the 10-year recurrence discharge and above with no control at the 2-year recurrence discharge. Jordan Creek Bridge on the Custer Motorway near RM 0.1 does not appear to exert hydraulic control as modeled. One tributary within this reach, Red Rock Creek, enters Jordan Creek on river right near RM 0.5.

Overbank areas are artificially limited and Jordan Creek is constrained within its channel banks by dredge piles through the upper mile of Reach JC-1. The stream channel from RM 0.4 to the Jordan Creek Bridge at RM 0.05 encompasses a habitat rehabilitation project that increased the floodplain area in this segment. Jordan Creek begins to access adjacent floodplains during the 1.11-year recurrence discharge through this segment. The hydraulic control upstream of Jordan Creek Bridge is the result of the habitat rehabilitation project and not the bridge itself.

The shear stress in the main channel through Reach JC-1 during the 2-year recurrence discharge is approximately 1.7 lb/sq ft. This indicates that the stream has the ability to at minimum move small cobble (approximately 4.4-inch) on average in this reach. There are two locations where shear stress is greater than 3 lb/sq ft and average channel velocity exceeds 8 fps exceeding juvenile fish swimming capability; at RM 1.3 the channel is constrained by dredge piles on both river right and river left; and at RM 0.4 the channel is constrained by dredge piles on river right and the Loon Creek Road on river left.

Hydraulic processes appear to have been modified by anthropogenic impacts through the upper segment of Reach YF-1 from RM 1.4 to 0.4. Primary impacts appear to be the result of dredging operations that realigned and confined the channel and the Loon Creek Road and two bridge crossings over Jordan Creek. In terms of hydraulics, natural stream processes appear to be functioning through the habitat rehabilitation segment from RM 0.4 to 0.1. Downstream of the habitat rehabilitation segment to the confluence with the Yankee Fork, Jordan Creek in channelized and confined between dredge piles.

7. Literature Cited

Parenthetical Reference	Bibliographic Citation
Ackerman 2011	Ackerman, C.T. 2011. *HEC-GeoRAS GIS Tools for Support of HEC-RAS using ArcGIS User's Manual Version 4.3.93*. U.S. Army Corps of Engineers Institute for Water Resources, Hydrologic Engineering Center, Davis, CA. 244p.
Arcement and Schneider 1989	Arcement Jr., G.J. and V.R. Schneider. 1989. "Guide for Selecting Manning's roughness coefficients for natural channels and floodplains." U.S. Geological Survey Water Supply Paper 2339. 38p.

Parenthetical Reference	Bibliographic Citation
Barnes 1967	Barnes, H.H. 1967. "Roughness Characteristics of Natural Channels." U.S. Geological Survey Water-Supply Paper 1849. 213p.
Brunner 2010	Brunner, G.W. 2010. *HEC-RAS River Analysis System User's Manual Version 4.1*. U.S. Army Corps of Engineers Institute for Water Resources, Hydrologic Engineering Center, Davis, CA. 790p.
Buffington and Montgomery 1997	Buffington, J.M. and D.R. Montgomery. 1997. "A Systematic Analysis of Eight Decades of Incipient Motion Studies, With Special Reference to Gravel-Bedded Rivers." *Water Resources Research, Vol. 33, No. 8*, Pages 1993-2029.
CH2M Hill 2008	CH2M Hill. 2008. *Final Report Yankee Fork Floodplain Restoration Project: Alternatives Analysis and Evaluation*. Prepared for: Shoshone-Bannock Tribes. 36p.
Henderson 1966	Henderson, F.M. 1966. *Open Channel Flow*. Macmillan Publishing Co. Inc. New York.
Maret et al. 2006	Maret, T.R., Hortness, J.E., and Ott, D.S., 2006. *Instream Flow Characterization of Upper Salmon River Basin Streams, Central Idaho, 2005*. U.S. Geological Survey Scientific Investigations Report 2006-5230, 110 p.
NOAA Fisheries 2008	NOAA National Marine Fisheries Service. 2008. *Anadromous Salmonid Passage Facility Design*. NMFS, Northwest Region, Portland, Oregon. 137 p.
NOAA Fisheries 2010	NOAA National Marine Fisheries Service. 2010. *Supplemental Consultation on Remand for Operation of the Federal Columbia River Power System, 11 Bureau of Reclamation Projects in the Columbia Basin and ESA Section 10(a)(1)(A) Permit for Juvenile Fish Transportation Program*. May 20, 2010, F/NWR/2010/0209.
Reiser and Ramey 1987	Reiser, D.H. and M.P. Ramey. 1987. *Feasibility Plan for the Enhancement of the Yankee Fork of the Salmon River, Idaho*. Shoshne-Bannock Tribes, Fort Hall, Idaho.
SCS 1963	Soil Conservation Service. 1963. *Guide for Selecting Roughness Coefficient 'n' Values for Channels*. U.S. Department of Agriculture. 46p.
USACE 1993	Army Corps of Engineers. 1993. *Engineering and Design River Hydraulics Engineer Manual 1110-2-1416*. U.S. Department of the Army. Washington, DC. 176 p.
Watershed Sciences 2010a	Watershed Sciences. 2010a. *LiDAR Remote Sensing Data Collection: Yankee Fork Tributaries, Idaho*. Corvallis, OR. 22 pp.
Watershed Sciences 2010b	Watershed Sciences. 2010b. *LiDAR Remote Sensing & True-Color Orthophotographs: Yankee Fork Idaho*. Corvallis, OR. 29 pp.

8. Glossary

TERM	DEFINITION
bank	The margins of a channel. Banks are called right or left as viewed facing in the direction of the flow.
boundary conditions	Definition or statement of conditions at the boundaries. Water level, flow rate, or concentration etc. that are applied at the boundaries of the area being modeled.
cfs	The flow rate or discharge equal to one cubic foot (of water, usually) per second. This rate is equivalent to approximately 7.48 gallons per second. This is also referred to as a second-foot.
calibration	Adjustment of a model's parameters such as roughness so that the model reproduces observed data to acceptable accuracy.
channel	A natural or artificial waterway which periodically or continuously contains moving water.
cross section	Depicts the shape of the channel in which a stream flows. Measured by surveying the stream bed elevation across the channel on a line perpendicular to the flow.
discharge	The rate at which water passes a given point. Discharge is expressed in a volume per time. Discharge is often used interchangeably with streamflow.
drainage basin	The area tributary to or draining into a lake, stream, or measuring site.
floodplain	That portion of a river valley, adjacent to the channel, which is built of sediments deposited during the present regimen of the stream and is covered with water when the river overflows its banks at flood stages.
fluvial	Produced by the action of a river or stream. Also used to refer to something relating to or inhabiting a river or stream. Fish that migrate between rivers and streams are labeled "fluvial".
geologic control	A local rock formation or clay layer that limits the vertical and/or lateral movement of a stream at a particular point.
hydraulic model	A physical scale or computation model of a river used for engineering studies.
hydraulics	The study and computation of the characteristics (depth, velocity, slope) of water flowing in a stream or river.

TERM	DEFINITION
hydrology	The applied science concerned with the waters of the earth, their occurrences, distribution, and circulation through the unending hydrologic cycle of: precipitation, consequent runoff, infiltration, and storage; eventual evaporation; and so forth. It is concerned with the physical and chemical reaction of water with the rest of the earth, and its relation to the life of the earth.
Manning's n value	n is a coefficient of roughness accounting for the energy loss due to friction between the bed and the water. In fluvial hydraulics the Manning's n value includes the effects of grain roughness, form roughness, bank irregularities, vegetation, bends, and junctions.
model	A representation of a physical process that can be used to predict the process's behavior or state.
network	A network of computation points (nodes) linked together to form a digital representation of the model area's geometry.
node	The location in a numerical network where computations are performed and/or output requested.
one-dimensional model	Model defines one space coordinate, the downstream direction, while variables are averaged over the other two directions, width and depth.
overbank	In a river reach, the area between the bank of the main channel and the limits of the floodplain.
reach	The distance between two specific points outlining a portion of the stream, or river.
Reclamation	U.S. Department of the Interior, Bureau of Reclamation. The Federal agency whose mandate was to reclaim the arid west of the United States. Operating in 17 western states, this agency builds, operates, and maintains a variety of irrigation, power, and flood control projects.
recurrence interval	The average amount of time between events of a given magnitude. For example, there is a 1 percent chance that a 100-year flood will occur in any given year.
river mile (RM)	Miles measured in the upstream direction beginning from the mouth of a river or its confluence with the next downstream river.
roughness	The roughness of the bed and banks of a stream or channel. The greater the roughness, the greater the frictional resistance to flow; and hence, the greater the water surface elevation for a given discharge.
runoff	That part of precipitation that flows toward the streams on the surface of the ground or within the ground. Runoff is composed of baseflow and surface runoff.

TERM	DEFINITION
sediment	Particles derived from rocks or biological materials that have been transported by a fluid.
shear stress	Frictional force per unit of bed area exerted on the bed by the flowing water.
thalweg	The line following the lowest part of a valley, whether under water or not. Usually the line following the deepest part, or middle, of the bed or channel of a river.
transport capacity	The ability of a stream to transport a given volume or weight of sediment material of a specific size per unit time for a given flow condition.
tributary	A watercourse flowing into a larger watercourse or into a lake.
watershed	The area of land from which rainfall and/or snow melt drains into a stream or other water body. Watersheds are also sometimes referred to as drainage basins. Ridges of higher ground form the boundaries between watersheds. At these boundaries, rain falling on one side flows toward the low point of one watershed, while rain falling on the other side of the boundary flows toward the low point of a different watershed.

This page intentionally left blank