RECLAMATION
Managing Water in the West

SRH-2013-27

Geomorphology and Hydraulic Modeling of the Forrest Conservation Area

Middle Fork John Day River, Grant County, Oregon

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

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Sedimentation and River Hydraulics Group, 86-68240

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Chapter 1 INTRODUCTION

The Bureau of Reclamation (Reclamation), U.S. Army Corps of Engineers, and Bonneville Power Administration contribute to the implementation of salmonid habitat improvement projects in Columbia River Basin tributaries to help meet commitments contained in the 2008 Federal Columbia River Power System Biological Opinion (NOAA 2008). 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. This report provides scientific information on geomorphology and hydraulic modeling that can be used to help identify, prioritize, and implement sustainable fish habitat improvement projects and to help focus those projects on addressing key limiting factors to protect and improve survival of salmon and steelhead listed under the Endangered Species Act (ESA).

Reclamation has initiated assessments in several tributaries to the Columbia River to develop planning tools that can be used collectively by all partners within a subbasin to focus their resources to identify and prioritize floodplain connectivity and channel complexity rehabilitation/ protection projects. In May 2008, Reclamation completed the Middle Fork and Upper John Day River Tributary Assessment (Tributary Assessment) in which rehabilitation and protection strategies were developed (Reclamation 2008). The primary objective of the Tributary Assessment was to develop an improved understanding of the physical processes acting on the watershed to better identify rehabilitation opportunities and address limiting factors that affect the survival and recovery of ESA-listed and other culturally important fish species. This objective was met through characterization of the biological conditions, including the fisheries and vegetation ecosystems, the geologic setting, anthropogenic constraints, geomorphic processes, subbasin hydrology, and hydraulic and sediment transport processes. Knowledge gained from local scientists and landowners, compiled data, and modeling results were synthesized to evaluate potential physical and biological response to rehabilitation actions. In particular, hydraulic modeling, sediment transport analyses, and geomorphic studies helped define the spatial and temporal scale of river processes and offer a predictive tool to assess proposed actions.

Following completion of the Tributary Assessment in May 2008, resource managers worked with the technical team to determine where impacts were localized and where design work could begin, or alternatively, where a refined analysis within a specific reach of river was needed. The technical team was a small group of experts from various disciplines representing the larger Interdisciplinary Team that provided input and guidance on science and design-driven products developed to address the issues in the John Day basin. Results from the Tributary Assessment of river processes on the Middle Fork John Day River (MFJDR) combined with landowner willingness led to a refined investigation of rehabilitation opportunities within the Forrest Conservation Area (FCA), which is owned and managed by the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO). The key objective of this study was to further investigate hypotheses on river processes identified in the Tributary Assessment and by a working group of stakeholders that would lead to implementation of rehabilitation projects with the greatest potential for success. These hypotheses included effects of (1) remnants of a historical railroad have severely impacted floodplain connection and lateral channel migration, (2) removing the remaining railroad grade and reconnecting flows to the historical channel would benefit habitat without adversely impacting channel morphology, and (3) geomorphic conditions, such as valley confinement, tributary sediment supply, and historical channel position, within the reach influence potential rehabilitation options.

To accomplish the objective, several steps were taken to refine the information generated in the Tributary Assessment. A data gap analysis was completed to help identify missing information needed to better understand reach processes relative to implementation of rehabilitation actions. Coarse-scale geologic mapping completed in the Tributary Assessment was refined to gain a better understanding of geomorphic processes controlling the channel morphology, the history of development, and evolution of the channel over the last several thousand years. In addition, specific information regarding the character of the floodplain, terraces, and deposits from the tributaries was needed. Two-dimensional (2D) hydraulic modeling was completed throughout the Middle Fork Forrest Conservation Area to understand and predict floodplain processes, side channel connectivity, and historical channel reconnection benefits. This report documents the results from the 2D modeling and links those results to geomorphic refinement.

1.1 Background

The John Day River is a tributary to the Columbia River and drains nearly 8,000 square miles. The Middle Fork subbasin originates in the Blue Mountains of the Malheur National Forest and flows 75 miles to its confluence with the North Fork John Day River north of Monument, Oregon. The Tributary Assessment of the Middle Fork examined a 23-mile reach of river located in Grant County, Oregon, from the confluence of Camp Creek to just downstream of the confluence of Crawford Creek (Figure 1). This area has a range of private ownership and Federally-owned national forest lands. Multiple properties are owned by the CTWSRO and by The Nature Conservancy.

Several potential reach assessment and project areas were identified in the Tributary Assessment. The projects that could be completed without additional investigations of the physical processes were initiated upon funding and resource availability. Of the five reach assessments identified on the MFJDR and the Upper Mainstem, the Forrest Conservation

Area was identified as a priority based on the presence of ESA-listed species, rehabilitation potential, stakeholder interest, and ownership by the CTWSRO.

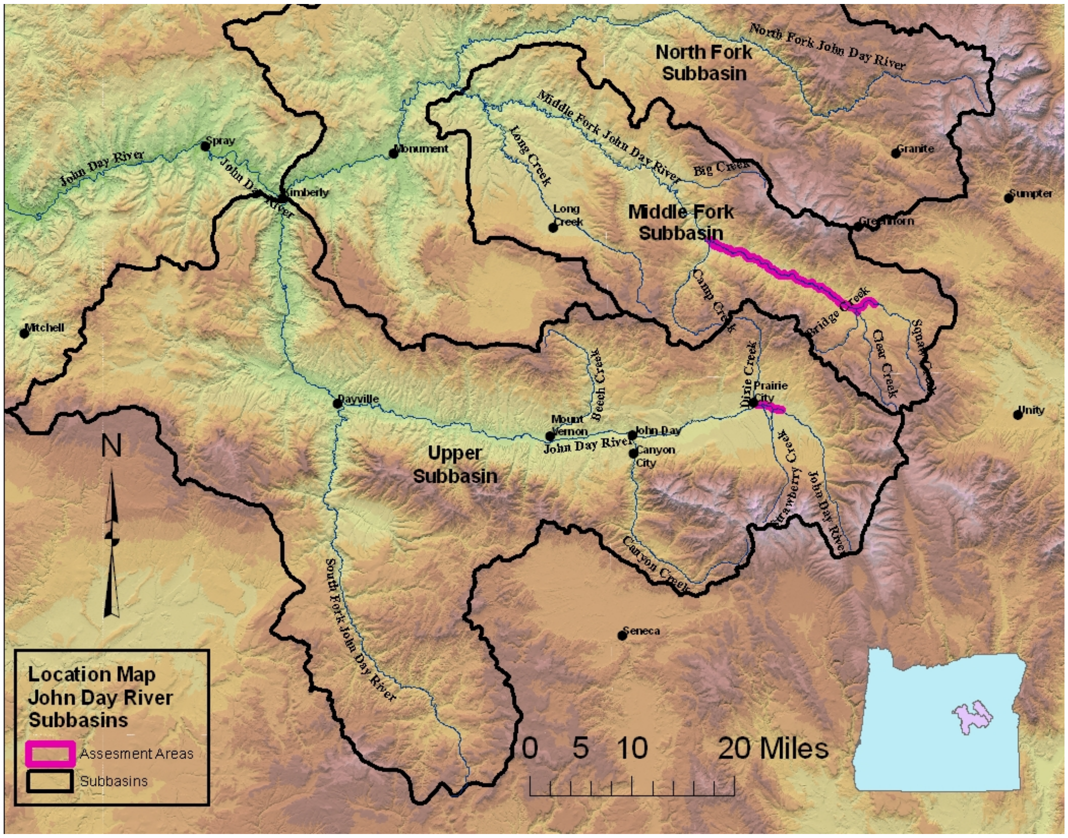

Figure 1. Location Map of Tributary Assessment Areas in the John Day River. This AER is focused on a 4 mile reach of the Tributary Assessment Area of the Middle Fork Subbasin.

1.2 Description of Forrest Conservation Area

The reach modeled as part of this investigation is 4 miles in length and extends from Caribou Creek (RM 63.5) to Bridge Creek (RM 67.5), as shown in Figure 2. The entire FCA lies within a broad valley, the width of which is heavily influenced by multiple tributaries and accompanying alluvial fans. Numerous anthropogenic activities over the past 150 years have influenced the use of the FCA by salmonid fish species. In the early 1900's, Oregon Lumber Company built railroad tracks down the Middle Fork John Day River valley from Bates to Camp Creek and established branch lines up the tributaries to convey logs to the sawmill in Bates (Johns 1997). This rail line was constructed down the center of the floodplain of the FCA on top of a levee. Construction of the railroad through the FCA entailed the reduction of the floodplain width by more than 50 percent in some places, disconnection of several meander bends and re-positioning and straightening of the channel to the north side of the valley. With the development of roads and increasing prevalence of cars in the 1930's, the railroad tracks were removed, but the levees disconnecting historical channels and floodplain remained.

Farming and grazing activities of the FCA also began sometime around the turn of the 20th century. Overtime, irrigation diversions were installed that diverted flows from the Middle Fork John Day River and its tributaries during critical low flow periods, and some ditches may have been excavated to drain floodplain areas for maximum grazing or farming opportunities. In addition to riparian disturbance from farming and grazing activities, flood management practices and beaver trapping further reduced channel complexity due to riprap, rock spur, and levee installations, clearing of channel blockages, including the removal of large wood debris (LWD) and other gravel and debris plugs, and a lack of off-channel beaver ponds. Overall, anthropogenic activities in the FCA have reduced channel and floodplain complexity, disconnected a substantial portion of the floodplain and several side channels, and limited the ability of the channel to migrate laterally. All of these modifications to historical channel processes have likely impacted the ability of the channel to create and maintain suitable spawning, rearing, and migration habitat for salmonids.

Three distinct subreaches were delineated through the modeled section of river on the FCA (Figure 2). These subreaches were determined through input from the Tributary Assessment, geomorphic characteristics, results of the 2D hydraulic model, and a Level 2 Habitat Assessment completed by the US Forest Service (USFS) in 2008. The breaks defined in this assessment may be further refined for future monitoring efforts on the property.

The most upstream subreach, denoted as Bridge Creek to Vinegar Creek, extends from River Mile (RM) 67.5, at the current Bridge Creek confluence with the MFJDR, downstream to RM 66.5, just upstream from Vinegar Creek. Within this subreach, Bridge Creek, Placer Creek, and Davis Creek all contribute flow and sediment to the system. The reach is mostly confined by Placer Gulch alluvial fan between RM 67.5 and 67.2 and by Davis Creek between RM 66.8 and 65.5. A short section of wider valley and side channel development is present between RM 66.8 and 67.2.

The second subreach lies between Vinegar Creek (RM 66.5 and Vincent Creek (RM 65.5), and is denoted in this document as Vinegar Creek to Vincent Creek. This subreach is the widest of the three subreaches, but more than 65 percent of its floodplain is disconnected due to the railroad grade. The existing channel is a straighter, steeper section of river than under pre-disturbance conditions. Oxbows and channel meanders have partially filled in over time, but remain present across the disconnected portion of the floodplain. Both Vinegar and Vincent Creek contribute substantial flows to the system. Vinegar Creek is a substantial contributor of coarse sediment, and historic placer mining in the basin may have some impact on its sediment supply and delivery to the system.

The most downstream reach extends from RM 65.5, just downstream from Vincent Creek to RM 63.5, just downstream from Caribou Creek. This subreach, denoted as Vincent Creek to Caribou Creek, is influenced in a few localized areas by the presence of the historical railroad grade, but not to the extent of the Vinegar to Vincent Creek subreach.

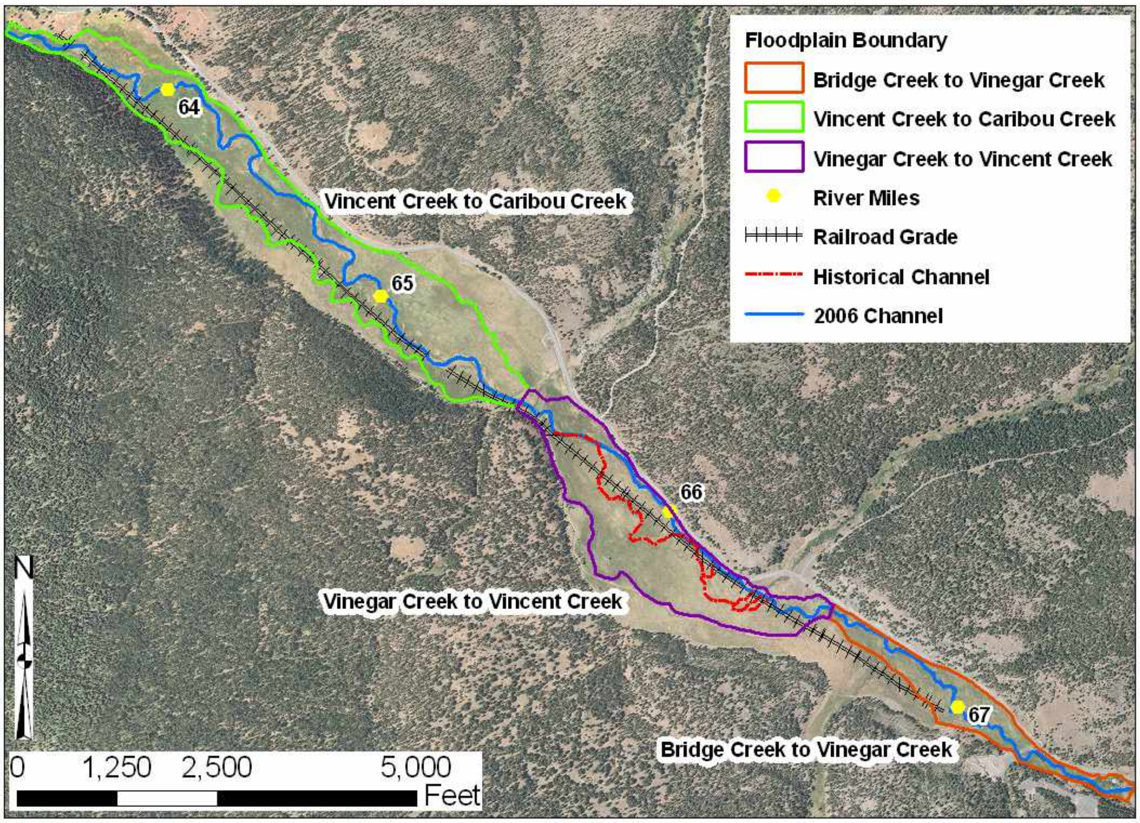

Figure 2. Reach breaks used in this assessment.

1.3 Purpose of Geomorphic Assessment

Coarse-scale geologic mapping completed for the *Tributary Assessment* was refined to gain a better understanding of geomorphic processes controlling the channel morphology, the history of development, and evolution of the channel over the last several thousand years. In addition, specific information regarding the character of the floodplain, terraces, and deposits from the tributaries was needed. A single mapped unit of surficial deposits associated with the river was subdivided into four alluvial units based primarily on surface morphology, relative age, and elevation above the active channel. Shallow pits were excavated on each of the alluvial units to expose the characteristics of the sediment comprising the deposits, document the extent of soil formation (an indicator of relative age and landscape stability of the deposits) and collect sediment samples in an attempt to evaluate the type of vegetation growing adjacent to the river prehistorically from detrital charcoal and pollen recovered from the sediment.

1.4 Purpose of Modeling Effort

The Middle Fork Forrest Conservation Area has been considerably modified from pre-disturbance conditions primarily due to the presence of a historical railroad grade, bank stabilization measures, irrigation infrastructure (diversions and ditches), and channel straightening. A two-dimensional (2D) hydraulic model was developed to increase understanding of floodplain processes, side channel connectivity, tributary inputs under existing conditions and to predict changes to these processes and resulting habitat if anthropogenic features are removed. Hydraulic parameters, including depth-averaged velocity, bed shear stress, and depth were compared across the areal extent of the floodplain for the existing conditions and a “Removed Human Features Scenario”. In addition, potential changes to high quality high flow habitat, floodplain and side channel connectivity, and low flow habitat features were examined to determine how removal of the human features could benefit habitat for salmonid species.

Numerical simulations were conducted for the 2- through 100-year discharges with inlet flows ranging from 560 cfs to nearly 1,740 cfs. In addition to investigating the existing condition, the model was applied to evaluate how hydraulic parameters and habitat features may change following removal of human features. The “Removed Human Feature Scenario” included taking the remnant railroad grade down to the surrounding floodplain elevations and blocking off the channelized sections of river in a few localized areas between Vinegar and Vincent Creeks. In addition, the topography of the model was modified so that the historical channel was more defined in several areas where the historical channels were disconnected or altered by farming and grazing activities. Figure 3 shows the modifications to the topography for the Removed Human Features Scenario between Vinegar and Vincent Creeks. In the upper and lower subreaches, the only modification to the topography included removing the railroad grade.

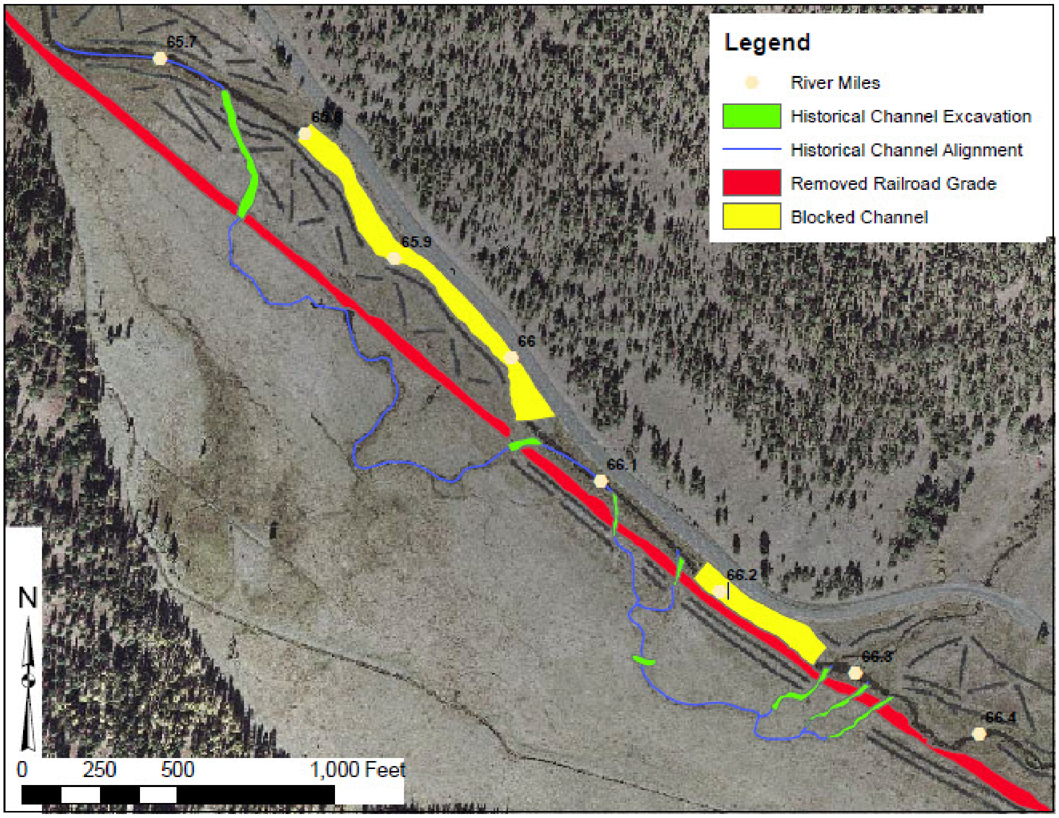

Figure 3. Topographic modifications for the Removed Human Features Scenario between Vinegar and Vincent Creeks.

Chapter 2 GEOMORPHOLOGY

2.1 Methods

2.1.1 Geomorphic methodology

The general methodology followed for evaluating the geomorphology follows the same methodology as used in the Geomorphology and Hydraulic Model Analysis completed for the Oxbow Conservation Area (OCA; see Reclamation, 2009). The surficial geology was mapped in the field using historical aerial photography and recent LiDAR data. The surficial geologic units mapped follow those defined in the OCA study due to their similarities and proximity. The various units were defined based on their visual appearance in the field and their morphology as observed on aerial photographs, topographic maps, and hillshades created from the LiDAR data. The overall physical appearance, or the geomorphology, of a specific unit and the characteristics of the deposit are generally related directly to the processes responsible for the unit's formation and/or deposition (e.g., alluvial fan, colluvium, fluvial terrace). In addition to the mapping, stratigraphic and sedimentological studies were undertaken in the FCA to characterize the physical properties of the materials that comprise the landforms. These physical properties provide information on specific processes responsible for formation of a landform and possible differences to the same types of landforms in the OCA. The age of these deposits is critical to understanding the history of the landscape and the timing of specific landform formation. In this particular case, understanding the timing of the formation of specific landforms and the associated physical processes responsible for their formation (e.g., aggradation and degradation, channel migration across the floodplain, or the development and evolution of side channels) is critical to understanding the river in this reach. For this study, no numerical ages were developed for any of the deposits, but landforms were correlated to those mapped at other sites (e.g., OCA) in the area where numerical ages have been determined (Bandow, 2003). The ages cited in this report are based on these correlations and estimates of the relative ages of the deposits made on the basis of geomorphic characteristics (soil development, surface morphology, vegetation, weathering features, topographic position). Detrital charcoal and pollen samples, materials that are commonly used for determining numerical ages, were collected during this study, but were used to assess specific riverine depositional environments and pre-European settlement vegetation conditions.

2.1.2 Surficial geologic mapping

The 1939, 1956, 1976, 2002, and 2006 aerial photographs were utilized in conjunction with recent 2006 LiDAR, existing topographic data (USGS 7 ½' quadrangles), geologic information (Brown and Thayer, 1966; Jett, 1998; Bandow, 2003; Reclamation, 2009), and field observations to refine the geologic mapping developed during the tributary assessment (Reclamation, 2008). The principle intent of the present mapping was to refine the spatial distribution of the surficial geology and related landforms, and to develop a better understanding of the physical processes that are responsible for the formation of the landforms. This is important in regards to how habitat in the reach was formed and what habitat would be sustainable in this setting. Mapping was completed on the 2002 1:12,000-scale color aerial photographs and LiDAR hillshades; contacts were verified in the field. Physical characteristics were described in the field based on visual observation and were used to delineate each of the map units. These characteristics included morphology, surface texture, and relative elevation and position.

There have been a number of anthropogenic disturbances in the FCA that have modified the surficial deposits or have disrupted geomorphic processes. These include turn-of-century (1900) timber clearing on the valley floor, construction of a railroad that bisects the valley, agricultural practices (grazing and irrigation diversions), and channel realignments and modifications associated with each of these activities. Therefore, the location of surficial unit contacts in some areas may be inferred because of the location of particular disturbances. It is important to note that interpretations for the location of some contacts may include some uncertainty, but natural exposures of the deposits were utilized in the field whenever possible to verify the mapping. This information is considered important background to better understand the pre-disturbance extent and spatial relationship of the deposits and the conditions and processes that might be a goal for any restoration alternatives that would be proposed.

2.1.3 Stratigraphic investigations

Detailed descriptions of the stratigraphic and sedimentological characteristics of the various map units, including the texture and composition of the deposits, soil/stratigraphic relationships, and interpretation of their environment of deposition, were made following methodologies outlined by Soil Survey Division Staff (1993), Birkeland (1999), and Tucker (2003). Many of the descriptions used in this study were made in the field as part of the OCA study (Reclamation, 2009), but sites were described over a broad area along the Middle Fork of the John Day River (MFJDR), including sites on The Nature Conservancy property, on the OCA, and on the FCA. Materials were identified by visual inspection and texture was determined by hand after sieving through a 2-mm screen following U.S. Department of Agriculture classification scheme (Soil Survey Division Staff, 1993). Charcoal that could be used to characterize pre-historical vegetation and environmental conditions was collected. In this study, as in the OCA study (Reclamation, 2009), charcoal and bulk sediment samples for pollen analysis were collected to better understand the vegetative history along the river. All samples were collected in small plastic bags or vials and labeled with unique alpha-numeric identifiers. All the samples collected for charcoal analysis were submitted for macrobotanical identification. This procedure allows for the identification of the material being analyzed to a taxonomic group, generally down to the genus-level and can be useful in providing information on the vegetation that may have been present in the area prehistorically. The laboratory report identifying this material and the procedures followed for the pollen analysis are included in Electronic Appendix 1. Natural exposures were utilized whenever possible in order to reduce impacts on the landscape and to facilitate data collection. Where natural exposures were not available, a soil auger was also used to collect stratigraphic data in lieu of digging soil pits. In the FCA, numerous auger holes were put into floodplain and historical channels to gather samples for pollen analysis and sediment characteristics, including the depth of soil overlaying the historical bed elevation of the main channel.

2.1.4 Geochronology

Ordinarily, organic material in the form of detrital charcoal, shell, or wood, would be collected during stratigraphic studies and submitted for radiocarbon analysis to provide constraints on the ages of the deposits. However, a geochronological scheme for the ages of the alluvium along the MFJDR had been established by Bandow (2003) and used by Turner and others (2009) in OCA. For this study, precise numerical ages for the alluvium was not considered critical to the objective of the study and age estimates were based on relative age indicators (soil development and surface morphology), as well as on a correlation to other sites on the MFJDR (Bandow, 2003). Detrital charcoal and pollen samples were collected as part of the stratigraphic and sedimentologic studies (section 2.1.2), but these samples were used to make qualitative estimates of the vegetation during various periods in the past rather than for assessing the chronology of the deposits.

Additionally, chemical analyses can be undertaken to identify specific tephra (volcanic ash) beds that might be present. No such analyses were undertaken for this study. However, in eastern Oregon the 7,600-year-old Mazama ash is quite common in the region and provides a unique chronostratigraphic marker that can be used to constrain the age of Holocene deposits. The presence of the Mazama ash in soil profiles was reported by Bandow (2003) along the MFJDR and a relatively thick ash bed in Holocene alluvial fans deposits was observed at one locality. While specific geochemical analyses to identify an ash bed in FCA unequivocally as the Mazama were not done as part of this study, the observed ash bed is assumed to be the Mazama given its widespread occurrence in the region and its occurrence locally within Holocene deposits.

2.1.5 Uncertainty

Uncertainties associated with this geomorphic assessment relate to accuracy of mapping, estimates for the age of the surficial geologic units, and with the characterization of soil properties, description of the sedimentology and geomorphology for surficial geologic units and their stratigraphic relationships as determined in the field. Numerical ages are taken from the work of Bandow (2003), which are based on the radiocarbon analyses of charred wood. The type of wood submitted for analysis is unknown as it was not reported; therefore it is not possible to evaluate possible age inheritance issues. All the reported ages were calibrated using a radiocarbon age calibration program (CALIB version 5.0.2). In addition, numerous other problems exist with the radiocarbon age determination methodology that are not addressed in this analysis because the precise age determination and potential errors in the age determinations are not critical to the conclusions of the study.

2.2 Geomorphology, Surficial Geology, and Prehistoric Vegetation

2.2.1 General Geomorphology

The general geomorphic character of the MFJDR is that of long reaches with a meandering channel flowing across broad, flat valleys and low, wide floodplains alternating with short, steep reaches with straight, narrow channels flanked by narrow, high terraces. This overall character of the river is in direct response to constraints imposed on it by the underlying bedrock formations and geologic structure. The course of the MFJDR and its valley generally follows the axis of the Middle Fork Syncline for most of its length (Brown and Thayer, 1966). The syncline is expressed topographically with the axis forming the river valley and the limbs of the syncline forming the adjacent uplands. In general, the bedrock dips into the valley and in a downstream direction. The poorly consolidated, less resistant sedimentary and tuffaceous units within the bedrock are more erodible, which has allowed the river to migrate laterally and form the broad valley sections. In contrast, the more resistant volcanic rocks within these formations restrict the lateral migration and provide vertical control on the channel gradient, resulting in the narrower, steep channel sections. Similarly, the character of the bedrock strongly influences the nature of erosion in the tributary basins, and hence the type and extent of alluvial deposits at their confluence with the main stem MFJDR. In addition, some units within the bedrock are prone to landsliding due to lithologic characteristics of the rock, the general dip of the strata into the valley due to geologic structure. In some areas, these landslides influence the position of the river channel within the valley and the channel slope. This is caused by the movement of material from the valley slopes onto the valley floor thus displacing the channel laterally or by creating a constriction within the valley resulting in localized changes to valley gradient. Downstream of the FCA, a large landslide into the narrow canyon actually dictates the rivers position and gradient.

The character of the river through the FCA generally follows this pattern where the valley downstream of Davis Creek is relatively flat and wide. As in the OCA downstream, the FCA on older aerial photographs of the area appears to be a wet meadow with many secondary and side channels. Water in these channels are now most likely supported by spring flow and a high groundwater table (Figure 4). This interpretation is supported by pollen and micro-channel analyses of samples collected from these channels. This environment was created because the valley is constricted at its downstream end by bedrock, the Caribou Creek alluvial fan, and a massive landslide downstream of Caribou Creek that dramatically flattened the slope of the valley upstream. The morphology of the valley between Davis Creek and Caribou Creek and the position of the river within the valley are largely dictated by alluvial fan deposition at the mouths of the tributaries entering the valley along its northern and southern margins. The basins of these tributary streams are underlain by a variety of intrusive crystalline (primarily granitic), high-grade metamorphic (serpentine), sedimentary (argillite and limestone), and volcanic (basaltic) rocks. Jett (1998) illustrated through a statistical analyses that the morphology of the alluvial fans along the MFJDR was a result of these and other tributary basin characteristics, and that they directly control tributary discharge and sediment supply.

Figure 4. A disconnected historical channel on the floodplain near Vinegar Creek. Water-level in this channel and others on the floodplain in this reach that are separated from the river by the old railroad grade appears to be maintained by groundwater (photo taken on June 17, 2009).

The influence that the alluvial fans have on the overall morphology, position, and geometry of the river is best exhibited where the river meanders between the fans of Davis and Vinegar Creeks (Figure 2). In the FCA, the alluvial fans associated with Davis Creek, Vinegar Creek, Vincent Creek, and Caribou Creek noticeably deflect the river channel towards the opposite side of the valley. Each of these tributaries, with the exception of Davis Creek, has deposited large volumes of coarse-grained sediment into the valley. The Davis Creek fan appears to be comprised of finer-grained material, has a gentler slope, and extends much farther across the valley floor. The MFJDR in the vicinity of the Davis Creek alluvial fan has been deflected against the bedrock along northern side of the valley. This is important not only because of the control these fans exert on the geomorphology of the river channel, but also in regards to the effect the sediment input has on river hydraulics and the formation of specific types of habitat in the FCA.

2.2.2 Surficial Geology

Mapping of the geology along the Middle Fork of the John Day River in a tributary assessment (Reclamation, 2008) defined six major units (see Table 1). The major units are a single undifferentiated bedrock unit, river alluvium mapped as the “Low Surface” and a higher “Terrace” deposit, alluvial-fan deposits, landslides, and an alluvium-colluvium unit. The oldest terrace deposit (Qa1) was not recognized in the FCA. For this analysis, the mapping completed for the tributary assessment was refined in order to develop a better understanding of processes affecting the river geomorphology in the FCA. The present mapping differentiates (1) three floodplain and stream terrace alluvial deposits that were included within the “Low Surface” unit or combined with the alluvium-colluvium map unit, (2) colluvium shed from hillslopes that was combined in the alluvium-colluvium map unit, (3) alluvial-fan deposits of different composition that were previously included in the alluvial-fan deposit map unit, but no distinction was made regarding the age of the deposits, and (4) two bedrock units that were previously mapped as a single unit. In the FCA, the bedrock unit (Tsv) was mapped, but differences in the bedrock elsewhere in the area are described. Additionally, the 7.6-ka Mazama ash (Qma), while present in the valley, was not observed in the FCA; exposures of the Mazama ash were observed downstream of Camp Creek (~RM 48). The ash bed was not mapped on the surficial map for the FCA, but because the ash bed provides an important chronostratigraphic marker that permits age distinctions to be made between some of the surficial deposits, a description of the unit is included here.

Table 1. Correlation chart of geological units.

Tributary Assessment (Reclamation 2008)	This Study (modified from Reclamation 2009)	Bandow (2003)
Low Surface	Qa4	T0
	Qa3	T1
	Qa2	T2 (~7.6 ka)
Terrace	Qa1	T3
Alluvium-colluvim	Qc	-
Alluvial-fan deposit	Qafs Qafg	-
Landslide	Qls	-
-	Qma	Mazama ash (7.6 ka)
Bedrock	Tsv Tc	-

2.2.3 Bedrock (Tsv and Tc)

The bedrock geology underlying the Middle Fork of the John Day River basin is comprised primarily of the Middle Miocene Strawberry Volcanics (Tsv) and the older Eocene Clarno Formation (Tc; see Table 1). The contact between the two formations crosses the valley just downstream of the FCA near the confluence of Deerhorn Creek (Brown and Thayer, 1966). The Strawberry Volcanics, which underlie the FCA, include a gray basaltic andesite interbedded with moderately consolidated light brown-to-white silty ash-rich sediment. Both of these units can be observed in a roadcut exposure immediately upstream of the FCA near the mouth of Bridge Creek (Figure 5). The basaltic andesite is the more resistant of the two units and is the major constituent of the gravel found in the colluvium along the margins of the valley, in the alluvial fan deposits, and in the river alluvium throughout the FCA.

Figure 5. Exposure of the Strawberry Volcanics in a roadcut near the confluence of Bridge Creek just upstream of the Forrest Conservation Area.

The Clarno Formation is comprised of andesitic volcanic flows interbedded with tuff, volcanic breccias and conglomerate, and lenses of water-laid ash and silt (Brown and Thayer, 1966). The diverse nature of the formation and the individual characteristics of some of the units within the formation are responsible in large part why the Clarno Formation is highly prone to landsliding. While the Clarno Formation does not underlie the FCA, a large landslide within the Clarno Formation that covers an area of more than a square mile forms the southwestern margin of the river valley immediately downstream of the FCA (RM 61.35 to 62.35) and dramatically influences the geomorphology of the MFJDR upstream to Caribou Creek.

Other bedrock types present in the higher terrain that form the headwaters of the tributaries to MFJDR include the intrusive crystalline, metamorphic, sedimentary, and volcanic rocks and are limited in their extent (Brown and Thayer, 1966). The tributaries along the southern margin of the basin (e.g., Davis Creek) are underlain by crystalline dioritic intrusive and metamorphic rocks. The tributaries north of the FCA include serpentine and meta-volcanic rocks (e.g., Vinegar and Vincent Creeks). The distribution of the different rock types in the tributaries control in large part the mechanism responsible for sediment delivery to the main stem MFJDR. For example, tributary basins that contain the Clarno Formation, and other relatively erodible rock types, may have higher delivery rates of finer-grained sediment than basins underlain by more resistant rock types. In the FCA, the largest alluvial fan is formed at the mouth of Davis Creek. The bulk of this alluvial fan is finer-grained than the fans shed into the valley by Vinegar, Vincent, and Caribou Creeks.

2.2.4 Landslide (Qls)

Landslides and shallow soil slumps are widespread and play a large role in the geomorphology elsewhere on the MFJDR but not within the FCA. Some of the landslides are quite extensive and have even altered the course of the river (Thayer, 1972). An example is provided by a very large landslide within the Clarno Formation that extends for about a mile along the river between the FCA and OCA (RM 61.35 to 62.35) and directly controls the width and slope of the river channel and of the valley both up- and downstream of the slide. While no landslides were observed within the FCA, and hence were not mapped on the surficial map of the FCA, the unit is described here because of the widespread influence the unit has on the river geomorphology locally.

2.2.5 Alluvial fan (Qafs and Qafg)

Two distinct types of alluvial fan deposits recognized by Turner and others (2009) were described as the result of two distinct processes: stream flow in wide, shallow channels, and debris flows in the narrow, steep channels. For this study, the two types of alluvial fan deposits were differentiated based on the sediment type comprising the deposit: sand-dominated or gravel-dominated (Table A; Qafs and Qafg, respectively). This distinction in the alluvial fan deposits was made primarily due to the importance of the type of sediment on the alluvial fan morphology and on the influence the type of sediment has on the morphology of the MFJDR. While the Qafs fans are dominated by sand deposition (Figure 6), gravel is present in the deposit and is common closer to the apex of the fan. The only large sand-dominated alluvial fan in the FCA is at Davis Creek. The morphology of the fan surface on sand-dominated alluvial fans is generally much smoother and in the case of Davis Creek, is much broader in its areal extent and volume than the gravel-dominated alluvial fans in the FCA. In the tributary assessment, an older alluvial fan deposit was recognized, but was not differentiated in this study because a significantly older deposit was not recognized in the FCA and the emphasis was placed on the character of the deposits due to their influence on the river processes and morphology.

Figure 6. Sandy alluvial fan deposit of the Davis Creek alluvial fan (near RM 66.5).

The gravel-dominated alluvial fans are composed primarily of poorly-sorted, angular gravel with a sand matrix (Figure 7). The three largest gravel-dominated alluvial fans in the FCA are present primarily along the northern margin of the valley formed by Caribou, Vincent, and Vinegar Creeks, but a smaller gravel-dominated fan is present at Dead Cow Creek, which is along the southern margin of the valley. The gravel-dominated alluvial fan deposits have very rough fan surfaces, common debris flow levees, steeper fan surface gradients, and smaller areal extents. In the case of Caribou Creek, the debris flows on the fan surface control the position of the tributary drainage.

Figure 7. Gravelly alluvial fan deposit at the mouth of Vinegar Creek with its confluence with the MFJDR (near RM 66.3).

Most of the alluvial fan deposits in the FCA have been shed onto the valley floor thereby impinging directly on the channel of the MFJDR. Several of the smaller tributaries have shed their fans onto and across fluvial terraces along the margins of the valley, so that these fans are in positions where they do not directly influence the position of the present-day channel of the MFJDR. While this difference could be attributed to the age of the alluvial fan deposits, in this case may just as likely be due to the size of the tributary and the position of the main stem channel in the valley relative to the tributary. The bedrock types underlying the drainage basins of the gravel-dominated alluvial fans in the FCA are principally the volcanic rocks of the Strawberry Formation but include the Clarno Formation and a variety of older metamorphic rocks in the upper portions of the basin. There are also minor amounts of intrusive crystalline rocks in the upper parts of both Vincent and Vinegar Creeks, and the alluvium within these tributaries was mined for placer deposits in the first half of the 1900s. The effects of that mining are still quite evident and certainly have influenced sediment supply to the MFJDR.

Jett (1998) outlined several basin variables in the MFJDR basin that support a distinction between stream-laid and debris-flow dominated alluvial fans described by Turner and others (2009). However, in his analysis, only two of the 21 variables Jett analyzed were related to bedrock characteristics within tributary basins: lithologic competency and degree of fracture. In the case of the alluvial fans in the FCA, the basin factors that correlate the best with the characteristics of the alluvial fans at Caribou Creek, Vincent Creek and Vinegar Creek are drainage area, basin relief, and stream length. In the FCA, the Davis Creek alluvial fan has the largest areal extent, but the basin area is not significantly larger than that of other basins with smaller alluvial fans (Jett, 1998). It would appear that lithologic competency may be a more important factor in the case of the Davis Creek fan (Qafs), but basin relief may play a role as the gradient in the lower part of the basin is lower and may not be as efficient at moving coarser-grained sediment out of the basin and onto the alluvial fan.

An additional aspect of the alluvial fans along the MFJDR in general touched upon above is the location of the alluvial fan relative to the river. Where alluvial fans impinge on the margins of the channel they directly influence the position of the channel on the valley floor. This interaction can also affect the channel geometry locally and the character of the channel and stream flow both upstream and downstream of these intersection points. Not surprisingly, this interaction can also impact the geomorphology of the alluvial fans. In areas where the river channel flows directly against the alluvial fan deposits, the channel cuts into these deposits often creating large cutbanks. These situations may be induced by either migration of the channel into the alluvial fan deposits or by direct erosion of the channel into the alluvial fans due to locate conditions that confine the valley width or direct the channel into the alluvial fan (see Figures C and D as examples). These cutbanks are often cited as evidence of channel incision due to their appearance; however given the geomorphic setting of these sites it appears that these tall cutbanks are the function of lateral migration rather than of incision.

2.2.6 Alluvium (Qa4-Qa1)

In the tributary assessment (Reclamation, 2008), three alluvial units were mapped that were associated in part with fluvial deposition: a Low Surface unit, the Terrace unit, and an alluvium-colluvium unit. The Low Surface unit incorporated many of the deposits on the valley floor and did not differentiate between the floodplain deposits from terrace deposits of several different ages (as per Bandow, 2003; see Table 1). Similarly, the alluvium-colluvium unit mapped in the tributary assessment did not differentiate deposits associated with the river from colluvium shed off of the adjacent hillslopes. For this analysis, the Terrace unit was subdivided into four distinct fluvial deposits (see Table 1) that could be attributed directly to deposition or reworking by the river, including floodplain deposits and three terraces, were mapped. The four units can be differentiated in the field on the basis of their elevation relative to the active channel and on the characteristics of the surface overlying the deposits. The floodplain (Qa4) includes those deposits that are inundated and reworked regularly. This unit correlates to unit T0 of Bandow (2003; Table 1), and on the basis of three radiocarbon ages, Qa4 formed within the last 1000 years. In addition to being located immediately adjacent to the active main channel or side channels, the surface of the floodplain is formed of unweathered sediment and exhibits primary depositional forms (e.g., bars and swales; Figure 8). It also exhibits sedimentologic characteristics, such as clast imbrication, planar bedding, and grading. The floodplain can also be distinguished on the basis of the vegetation, or the lack thereof, growing on the deposits.

The floodplain in the FCA is inset into a slightly older, but distinct terrace deposit (Qa3). The terrace surface ranges from 3-5 feet above the active channel depending on location and is marked by a much more planar surface than the active floodplain. It lacks clearly visible bar and swale morphology although it may exhibit narrow, shallow channels and/or scars of abandoned channel meanders (relict oxbows). In places these shallow channels may be maintained in part by relatively infrequent inundation or by flow emanating from springs along the valley margins. At the upstream end of the FCA, it appears that some of these channels were periodically utilized by Davis Creek as its connection to the MFJDR. These channels are muted due to infilling by fine-grained overbank sediment (see Figure 4). The deposits underlying the surface are typically coarse-grained sandy gravel overlain by a thick layer of fine-grained silty sand that contains very little or no gravel (Figure 9). This layer of fine-grained sediment forms the medium for vegetative growth and represents the initial stages of soil formation. This unit equates to the T1 deposit of Bandow (2003; Table 1) who reported the surface as being abandoned by the river about 1000-1200 years ago. This interpretation is based on a single radiocarbon age from the gravel at the base of the deposit. However, given the surface morphology of the terrace, the nature of the soil formed on the deposits (see Electronic Appendix 1), and the results of paleoflood studies in the area (Ort, 1998), it is likely that the surface is inundated by larger but infrequent floods. In fact, large parts of the Qa3 terrace were shallowly inundated in the May 2011 flooding (estimated to be about 1,740 ft3/s in the FCA) and was projected as being close to the 100-year peak discharge (between 4,000-5,000 ft3/s) at the Ritter gage downstream (USGS station #14044000).

Figure 8. The Qa4 alluvium is composed primarily of sandy gravelly alluvium that forms the active channel and associated bars. Finer-grained sand facies of the Qa4 alluvium is found in pools and side channels.

The older terrace deposits (Qa2 and Qa1) are characterized by noticeably smoother and planar surfaces that are 6-9 feet above the active channel and once supported extensive stands of conifers. Numerous stumps of old trees in growth position that are present on the Qa2 surface in the FCA were approaching 400 years old when they were cut (presumably in the late 1800s) and provide a minimum age for the terrace surface (Figure 10). Detrital charcoal and pollen recovered from soil pits excavated on the surfaces of these terraces are from predominately conifer species, which supports this observation. Bandow (2003) reports the Mazama ash is interbedded with overbank sediments in his unit T2 (Qa2 deposits of this study). In a soil pit on the Qa2 deposit downstream of Dead Cow Gulch (MJD5; Electronic Appendix 1), the fine-grained surface deposit is more than 0.8 meters thick (almost 3 feet). No numerical ages were developed for the Qa2 deposits along the MFJDR, but an age estimate of 5,000-7,000 years was made for the abandonment of the terrace by Bandow (2003) based on the presence of the Mazama ash.

Figure 9. Bank exposure of Qa3 alluvium. Note the thick bed of fine-grained sediment (overbank deposits) overlying the sandy gravel alluvium (bedload).

The oldest and highest terrace (Qa1) is relatively well-preserved at several locations along the MFJDR, but is not present in the FCA. It too displays a smooth planar surface that overlies fine-grained sandy sediment interpreted as overbank deposits and a thick sequence of sandy gravel. No numerical ages were developed for the Qa1 deposits along the MFJDR, but an age estimate of 8-10 ka for the abandonment of the terrace was made by Bandow (2003) based on a qualitative assessment of pedogenic development, which he ties loosely to variations in the climate.

2.2.7 Colluvium (Qc)

In the tributary assessment (Reclamation, 2008), a combined alluvium-colluvium unit was mapped. This unit did not differentiate between colluvium shed off of the hillslope, alluvium deposited by tributaries, or alluvium associated with the river. In this analysis, the colluvium was mapped as a separate unit due to the importance of delineating these deposits from those specifically associated with the river. On the OCA (Reclamation, 2009), the colluvium was found to interfinger with the Qa1 alluvium on a terrace along the valley margins. This can make it quite difficult to distinguish between the alluvial and colluvial deposits without a clear exposure of the deposits and their relationship to each other. In this analysis, colluvium was differentiated from the alluvium in the field solely on the basis of ground surface slope and the angularity of the gravel on the ground surface. It was reasoned that the point where the slope of the ground surface transitioned from the hillslope to near-horizontal constituted the contact between the colluvium and alluvium. Similar to the findings of Reclamation (2009), it was found that the areal extent of colluvium in the valley was found to be different from what was mapped in the tributary assessment (Reclamation, 2008).

Figure 10. A Qa2 terrace located just upstream of Caribou Creek (near RM 64.5). Note the stumps of trees in growth position. The trees were about 400 years old when they were cut down in the late 1800s.

In general, the colluvium is limited to a narrow band along the margins of the valley and in outcrop is distinguished from the fluvial deposits by more angular gravel and the poorly-sorted character of the sediment. Colluvium generally exhibits a steeper surface slope than the alluvial deposits as described above. In a few areas where the valley margins are quite steep, talus formed almost exclusively of angular rock with little fine matrix has been deposited at the angle of repose. Colluvium and talus are primarily the product of mass wasting and the downslope movement of material under the influence of gravity. The deposition of colluvium along the MFJDR has little influence on the character of the river other than providing a source of coarse sediment in those cases where the river channel impinges on the valley margins as it does upstream of both Vinegar Creek opposite the Davis Creek alluvial fan (RM 66.5 to 66.8) and at Caribou Creek.

2.2.8 Mazama ash (Qma)

The Mazama ash is a light gray to white glassy ash that was erupted from Mt. Mazama, the caldera that now forms Crater Lake in south-central Oregon. The age of the ash is about 7,600 years old, which is fairly well-constrained by numerous radiocarbon ages from widespread locations in the western U.S. (Bacon and Lanphere, 2006). The thickness of the ash is of course dependent on its location relative to the eruptive center. In this area of eastern Oregon, primary air-fall may form beds only a few inches thick, but ash that has been reworked from the landscape and ponded in hollows may exist in beds many feet thick. Because of the widespread occurrence of the Mazama ash in the region and the volume of ash that is present on the landscape, it is important to note that the ash may have been reworked and redeposited on the landscape at any time after its deposition, and therefore its use as an age indicator should be carefully evaluated. Despite this potential complication, the Mazama ash is an important chronostratigraphic marker because it provides a maximum limit for the age of associated deposits and can be utilized when the depositional nature of the ash is discerned. The Mazama ash has been reported in terrace deposits at other locations in the John Day basin (Qa2 of this study or T2 of Bandow, 2003) and has been observed in alluvial fan deposits in road cuts along Highway 20 downstream of Camp Creek.

2.3 Geologic History

As described in Section 2.2.3, a variety of bedrock types underlie the MFJDR basin. The type of bedrock and its impact on basin hydrology and vegetation, the lithologic characteristics of the bedrock and their effect on sediment production, and the geologic structure and the control it exerts on the topography all play a vital role in the geomorphology of the river. However, the most important aspect of the geologic history on the development and evolution of the river in regards to fish habitat is the relationship and effect of the geology on the geomorphic processes responsible for the conditions that have formed over the last several hundreds to many of thousands of years.

2.3.1 Deposition/Formation of Specific Geomorphic Units

The history and formation of two specific types of geomorphic units present along the MFJDR in the FCA are either directly related to the river or exert some influence on its development and evolution. These units include the alluvial fans (units Qafs and Qafg in Table 1 and described in Section 2.2.5), and the floodplain and stream terraces (units Qa4-Qa1 in Table 1 and described in Section 2.2.6). While the large landslide that extends for about a mile along the river between the FCA and OCA (RM 61.35 to 62.35) is a dominant factor in controlling the geomorphology of the river at that location and landslides certainly have had some impact on the river in the OCA, landslides are much less a factor in the FCA.

The principle source of sediment in the MFJDR as well as main control on the morphology of the river is the alluvial fans. The influence of the alluvial fans on river morphology is the result of not only the type of sediment they deliver to the mainstem, but also the rate, volume, and the manner in which the sediment is delivered to the river. These factors were described in Section 2.2.5 and formed the basis for thesis work completed in the MFJDR basin by Jett (1998). Unfortunately, his work focused primarily on the various landscape variables that affect the formation of the alluvial fans and did not address the history of alluvial fan deposition in the MFJDR basin other than relating the influence that changes in climate have on alluvial-fan formation. For the most part, sediment is more or less delivered on a continuous basis to the mainstem by tributaries, but the rate fluctuates through time given some of the variables, including climate, that control sediment formation and fan deposition. In addition, placer mining in the MFJDR basin, and specifically along Vincent and Vinegar Creeks in the FCA, may have historically increased the rate of sediment delivery to the main stem. The most important factor pertaining to the deposition and formation of alluvial fans along the MFJDR is that the supply of sediment delivered to the river has been at or slightly exceeded the ability of the river to transport this material downstream. This condition is termed transport-limited, and based on the overall history of river incision and lateral migration (Bandow, 2003), this has been the situation for perhaps the last several thousand years. This condition has been influenced historically locally by the railroad and agricultural and mining activities and along several reaches in and near the FCA the river has the ability to locally move sediment supplied to it due to channelization. For example, at the mouth of and downstream of Vinegar Creek (RM 66.0 and 66.4), the river channel has been confined along the northeast side of the valley between the railroad grade and bedrock that forms the valley margin. Immediately upstream, the channel position is dictated by sediment of the Davis Creek alluvial fan. It is important to recognize the geomorphic change in the temporal context of natural processes and the local effects of anthropogenic impacts.

The most important geomorphic unit in regards to the fluvial system along the MFJDR is the alluvium that forms the floodplain and stream terraces (units Qa4-Qa1 in Table 1. Correlation Chart of Geological Units and described in Section 2.2.6). These deposits form in response to stream flow and the delivery of sediment to the river and represent how sediment is transported downstream or stored in the channel and on the floodplain and terraces. The principle refinement in the differentiation of the surfical geological units was in distinguishing four alluvial units within the Low Surface and Terrace units of the tributary assessment (Reclamation, 2008). The presence of multiple stream terraces and a wide floodplain marked by numerous side channels and meander scars represents a complex history of deposition, erosion, and lateral migration. Describing this history forms the basis of thesis work completed by Bandow (2003). Simply stated, the alluvial history of the MFJDR has been one of incision followed by a period of lateral migration of the main channel across the valley floor. Older stream terraces (units Qa1 and Qa2) preserved along the margins of the valley are indicative of an overall trend of incision into older alluvial valley fill during the last 7600 years. The wide floodplain and numerous abandoned channels on the valley floor (units Qa3 and Qa4) visible in the 1939 photographs suggest that the recent history of the river (for at least the last 1200 years; Bandow, 2003) has been dominated by lateral migration. It is unclear exactly why the period of incision changed to a period of primarily lateral migration. Bandow (2003) suggests climatic factors, but there is some evidence that the change may in part be related to changes in several factors, including local base level control (bedrock channel), current hydrology (climate), and sediment supply.

2.3.2 Influence of Specific Units on River Morphology and Evolution

Several important aspects of the geology and how it influences the river morphology can be observed on historical aerial photography as well as on the ground. In the FCA, there are four large tributary streams whose alluvial fans directly impact the morphology of the main stem MFJDR: Davis Creek, Vinegar Creek, Vincent Creek, and Caribou Creek. The Davis Creek alluvial fan works in combination with the alluvial fan of Vinegar Creek to control the position and gradient of the river in the upstream end of the reach. As described in Section 2.2.5, the Davis Creek alluvial fan is the largest in terms of its areal extent and therefore exerts a lot of control on the position of the MFJDR in the valley. In combination with Davis Creek alluvial fan, the Vinegar Creek alluvial fan provides a constraint on the valley width between RM 66.9 and 66.4, and as a result, controls the channel gradient and the channel form locally (Figure 11). Upstream of Vinegar Creek, the Davis Creek alluvial fan has forced the river against the bedrock that forms the northern valley margin. The Vinegar Creek alluvial fan is significantly smaller and enters the valley immediately downstream of the Davis Creek alluvial fan. Both alluvial fans effectively constrain the width of the valley, dictate the position of the river on the valley floor, and control the gradient of the channel. As a consequence, the channel slope upstream of Davis Creek is significantly reduced and the areal extent of the floodplain is greater as the MFJDR has migrated laterally across this area. The presence of numerous secondary and side channels preserved on the floodplain and on the surface of the Qa3 terraces is most likely due to flooding in response to balancing slope, discharge, and sediment load. This idea is supported by the channel scars on the valley floor visible in the 1939 aerial photographs (Figure 11).

Material shed into the valley by Vinegar, Vincent, and Caribou Creeks is very coarse (bouldery), and primarily of volcanic composition. This material is predominately delivered to the fan surfaces and the valley margin by debris flows. Prominent debris flow levees are preserved near the mouth of the Caribou Creek and control the position of the tributary drainage on the alluvial fan. As a consequence, each of these coarser-grained alluvial fans has a strong influence on the position of the MFJDR in the valley pushing the main channel generally southward.

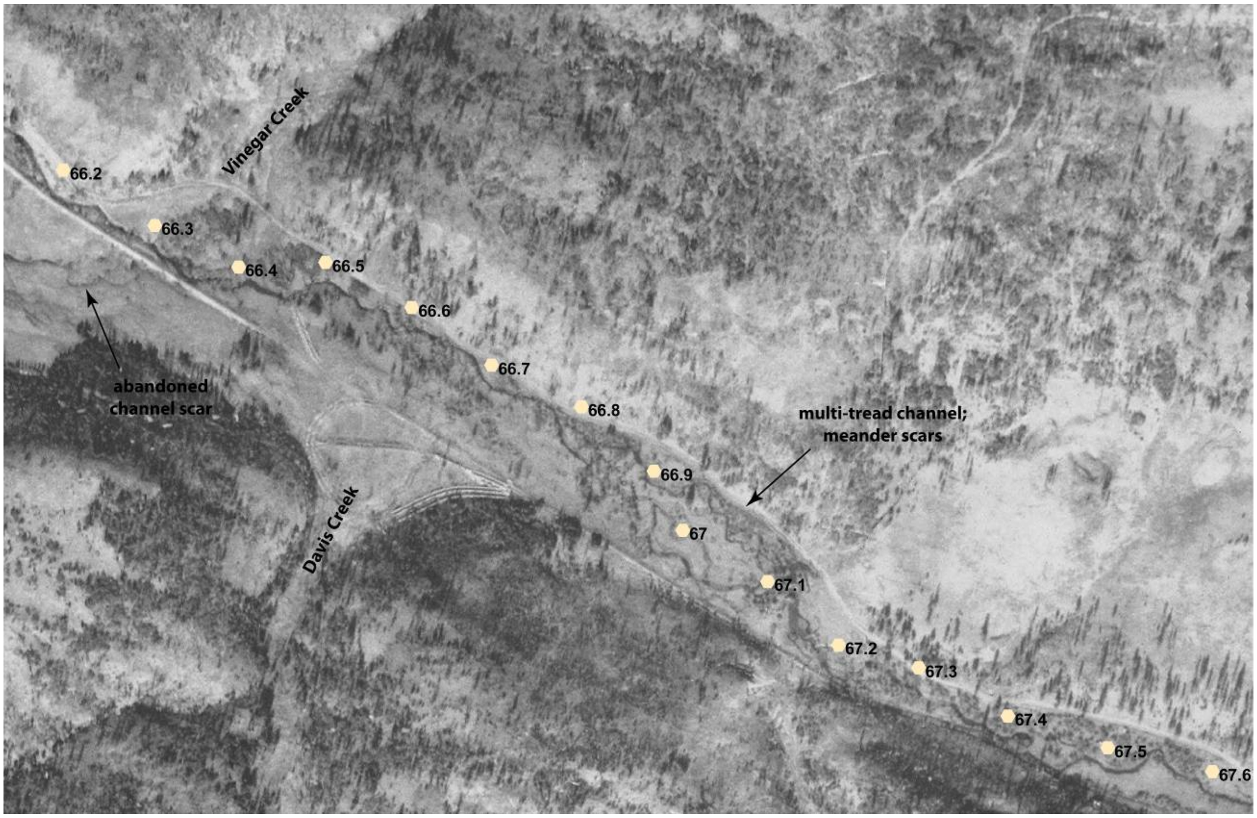

Figure 11. 1939 vertical aerial photograph of the MFJDR near Davis Creek (RM 66.7) and Vinegar Creek (RM 66.3). Note the abandoned channel scar downstream of Vinegar Creek due to channelization by railroad, the single entrenched channel at the Davis Creek alluvial fan, and the multi-tread character upstream.

Based on the extent of its alluvial fan, it is apparent that the Davis Creek drainage is one of several major contributors of sediment to the MFJDR. Material shed onto the valley floor from Davis Creek appears to be finer-grained (see Figure 6) than the sediment delivered by Vinegar Creek, Vincent Creek, and Caribou Creek, which is significantly coarser (see Figure 7). The extent of the Davis Creek alluvial fan is significantly larger than that of the adjacent Vinegar Creek and the distal portion of its fan (e.g., its toe) appears to have been modified by flooding on the MFJDR. Evidence for this is present on the 1939 photography in the form of patterns in the vegetation and the abandoned channel scars and other lineations that are subparallel to the course of the main stem MFJDR (Figure 11). The influence that the alluvial fans have on the overall morphology of the valley and the position and geometry of the river is best exhibited where the river meanders between the alluvial fans of Davis and Vinegar Creeks. The Davis Creek alluvial fan constrains the channel position of the river between RM 66.5 and 67.0 by pushing the river against the bedrock along the northern valley margin. The river then shifts towards the south where it encounters the Vinegar Creek alluvial fan near RM 66.5 (Figure 11).

Lastly, aspects of the geology, how it influences the river geomorphology and controls fluvial processes can be observed at Caribou Creek. Material shed onto the valley floor from Caribou Creek is again very coarse debris flows. The Caribou Creek alluvial fan is small in terms of areal extent relative to the fans farther upstream in the FCA reach (Jett, 1998). However, the steep gradient of the Caribou Creek alluvial fan and the confined character of the valley allow very coarse-grained material to be delivered directly onto the valley floor. This allows the Caribou Creek alluvial fan to exert some influence on the position of the main stem MFJDR by pushing it southward against the bedrock forming the valley margin. The Caribou Creek alluvial fan is located just upstream of a very large landslide that further restricts the width of the valley and the channel slope locally. The valley floor in this area also appears to have been dredge-mined (between about RM 63.2 and 63.4) and the channel may have been relocated by the mining activity and to a lesser extent by the railroad construction. Based on the presence of abandoned channels on the flood plain (RM 63.0 to 63.2), it appears that the landslide may have pushed the position of the river channel to the north and the mining activity has removed the evidence for the natural position of the channel

Again, it is important to distinguish the difference between long-term (thousands of years) natural geomorphic response of the river to the geology and surficial processes that exert control on the character of the river and the short-term historical impacts (tens to hundreds of years) of anthropogenic activity (mining, agriculture, and the railroad). Unlike the OCA where the mining activity had the most obvious impact on the river and its floodplain, in the FCA the greatest impact seems to be related to the construction and remaining presence of the railroad grade. In numerous locations within the FCA, remnants of the railroad grade continue to isolate large areas of the floodplain from the river. While the short-term impacts leave a clear and recognizable record that can have tremendous influence on the river locally (e.g., mining in the OCA and the railroad in the FCA), the longer-term controls provided by bedrock types and structure, the size, style, and composition of the alluvial fill influence the overall character of the river.

2.4 Prehistoric Vegetation Investigation and Evaluation

Charcoal and pollen samples were collected from excavated soil pits, from natural exposures, and from auger holes in the alluvium (Qa4-Qa1) and alluvial fan (Qafs and Qafg) deposits along the MFJDR and in the FCA. These samples were submitted for macrobotanical analysis, were identified to a taxonomic group, and tabulated on the basis their relative frequency stratigraphically. The findings are based on a reconnaissance-level inquiry and are only intended to explore the possibility of using detrital charcoal and pollen in this area to develop a better understanding of the type and distribution of vegetation present in the area prehistorically. Specifically, to what extent did European settlement and the effects of ranching, mining, and the railroad construction alter the existing vegetation populations and distribution patterns.

2.4.1 Charcoal Analysis

Thirty-four charcoal, pollen, and wood samples were collected from the stream terraces and alluvial fan deposits along the MFJDR. Each sample was identified to family and genus level if possible (Electronic Appendix 2). The results show several trends in the type and distribution of paleobotanical material recovered. Twenty-six of the 34 total samples are some variety of conifer charcoal; only a single fragment of Alder (Alnus) charcoal was recovered (see Table B). While the conifer charcoal was more common in the older deposits, it was present in all four deposits. Generally, samples recovered from the youngest deposits (in this case the Qa3 deposits) are relatively diverse and include material representative of a wide distribution of species. This was the case for the samples from the Qa3 deposits, where seven different types of charcoal are represented. The single fragment of alder (*Alnus*) was recovered from the Qa3 deposits; however, charcoal from other riparian species, specifically willow (*Salicaceae*) and cottonwood (*Populus*), is completely missing from all the deposits. These species are present in other areas of the MFJDR basin, so the reason for their absence from the FCA is unclear. Another interesting finding is that hemlock (*Tsuga*) charcoal is present in only the oldest alluvium deposits (Qa1) and in alluvial fan deposits (Qafs; Table 2). It remains to be verified, but apparently hemlock (*Tsuga*) is not presently growing in the FCA or anywhere within the drainage basin upstream.

These findings are based on a reconnaissance-level inquiry and are only intended to explore the possibility of using detrital charcoal in this area to develop an understanding of the possible type and distribution of vegetation present in the area prehistorically. From the historical aerial photographs, the riparian conditions in certain locations within the FCA (and elsewhere on the MFJDR) appear to have been much better in 1939 than they are at present. However, it is unclear how the conditions in 1939 varied from pre-1939 conditions or what widespread effects European settlement in the late 1800s had on the riparian vegetation, which may have already been impacted by 1939. One important factor to remember is that the trend indicated by these results in no way represents a statistically valid analysis.

Table 2. Frequency Distribution of Detrital Charcoal in Alluvial Deposits.

Type of Material[1]	Qa3	Qa2	Qa1	Qafs	Total
Alnus (Alder)	1	0	0	0	1
Larix (Larch)	1	2	1	0	4
Pinus (Pine)	1	3	1	2	7
Tsuga (Hemlock)	0	0	1	4	5
Undifferentiated conifer	1	6	1	2	10
Unidentified hardwood	0	1	1	0	2
Amaranthus (floret)	1	0	0	0	1
Poaceae (seed, leave)	1	0	0	1	2
Unidentified bark	1	1	0	0	2
Total	7	13	5	9	34

[1] detrital charcoal unless otherwise noted.

2.4.2 Pollen Analysis

Three bulk sediment samples for pollen analysis were collected from the Qa2 and Qa3 alluvium. Pollen in each sample was identified to family, genus, and species when possible (Electronic Appendix 2). The results show similar trends to the charcoal analysis in the type and distribution of paleobotanical material recovered, particularly in the distribution of conifer pollen and in the apparent lack of cottonwood (*Populus*) and willow (*Salicaceae*) pollen (see Figure 1 in Electronic Appendix 2). Pine (*Pinus*) pollen and charcoal were common in general throughout most samples, but is lacking in sample MJD1-9 (B2 horizon; interval 45-60 cm). The commonality of *Pinus* in general is recognized, however the relatively small concentration of pollen in sample MJD1-9 within the same Qa2 deposit is interpreted to represent a period of very rapid deposition. The absence of pine pollen at site MJD1-9 may also be indicative of missing or decreased numbers of pines locally. The rapid deposition of sediment in the interval of 45-60 cm may correlate to the denudation of the landscape of vegetation, perhaps due to fire, also explaining the lack of pine pollen. Generally, samples MJD1-10 and MJD3-7 have greater concentrations of pollen and microscopic charcoal indicative of a period of slower deposition, counter to sample MJD1-9. In sample MJD3-7, the interpretation of slow deposition is consistent with the formation of a B horizon on gravelly alluvium suggesting a period of relative landscape stability either due to migration of the channel away from this location or by the lack of inundation from floods. Low concentrations of Alder (*Alnus*) pollen and other riparian species are also similar to trends recognized in the distribution detrital charcoal. Hemlock (Tsuga) pollen is present in younger alluvium (Qa3), unlike the results of the charcoal analysis where it is present only in the older two terraces, but is present in much smaller concentrations in the Qa3 alluvium. Given the durability of conifer pollen in general, it is possible that the hemlock pollen may have been reworked from older sediment or transported from other parts of the basin. Again, it remains to be verified if hemlock (*Tsuga*) is presently growing anywhere in the basin.

2.5 Stream Temperature, Springs, and Groundwater Monitoring

In August 2003, the Oregon Department of Fisheries and Wildlife and the Bureau of Reclamation contracted with Watershed Sciences to perform an airborne thermal infrared (TIR) survey of stream temperature on the MFJDR. The methodology used to collect these data and the results of the survey are included in a final technical report (Watershed Sciences, 2008). The river was actually surveyed twice over the course of several days due to the flight conditions in the region (Figure 12). Differences in air and water temperature between the two surveys are notable and provide additional information related to stream temperature that might not have been recognized from the results of a single survey.

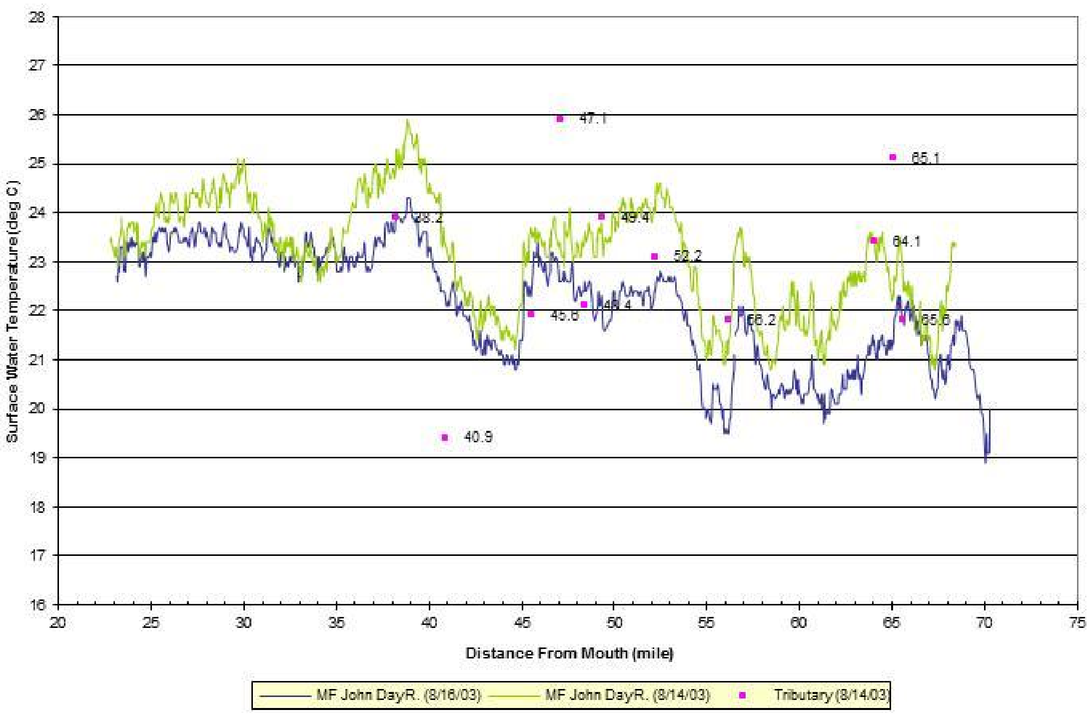

Figure 12. Comparison of the median channel temperature as measured on August 14, 2003 and August 16, 2003 plotted by river mile for the Middle Fork John Day River. The FCA is located between about RM 61.3 to 65.3; the tributary at RM 64.1 is Vinegar Creek. Note that the river miles shown on this plot (taken from Watershed Sciences, Inc., 2008) may not correlate directly to river miles used in other reports.

The first survey was conducted on August 14 and the air temperature during the flight ranged from 31.1 to 34.4°C (88.0-94.0°F). The air temperature during the survey on August 16 was markedly cooler ranging from 22.9°C to 24.4°C (73.2°F -75.9°F). This difference in the air temperature resulted in a change in the water surface temperature of up to almost 2.0°C (3.6°F) in areas along the MFJDR (Figure 12) suggesting that the water temperature is strongly influenced by the air temperature. A similar change in the water temperature was documented at several other sites on the MFJDR by researchers at Oregon State University using fiber optic technology that showed diurnal fluctuations in water temperature that could be related in part to solar gain. However, the change in the water surface temperature cannot be linked directly to solar gain in all cases. Areas of the MFJDR appear to be strongly influenced by specific physical conditions of the channel such as its relationship to geologic structure and proximity to springs, the groundwater-river interaction (hyporheic zones), tributary inflow, and the alluvial architecture of the valley fill (see detailed maps of thermal imagery in Electronic Appendix 3).

Data collected during the TIR survey and illustrated in the longitudinal temperature profile (Figure 12) illustrate the complex relationship that exists between the river system, physical attributes of its setting, and water temperature. In general, the water temperature appears to increase through the steeper gradient, more confined, bedrock-controlled reaches and decreases through the wider, alluvial-filled valley sections (Figure 1). This may seem counter intuitive, but seems to be related to fact that the water in the channel crossing the valley segments has greater capacity to interact with colder groundwater, therefore effectively reducing temperatures. Thermal infrared data from the FCA provides an example where riparian vegetation is currently non-existent, the channel meanders across a wide, flat-bottomed valley, and tributary inflows during the summer months when the survey was undertaken was limited, yet the temperature decreases steadily in a downstream direction (Figure 13). This trend was also recognized by Huff (2009) where decreasing temperature was linked to groundwater and hyporheic interaction during the summer months over the two-year period (2008-2009) of her monitoring effort. Further, a sensitivity analysis of her stream temperature model indicated that solar radiation had the lowest effect on stream temperature when considering stream flow velocity, air temperature, relative humidity, and groundwater inflow.

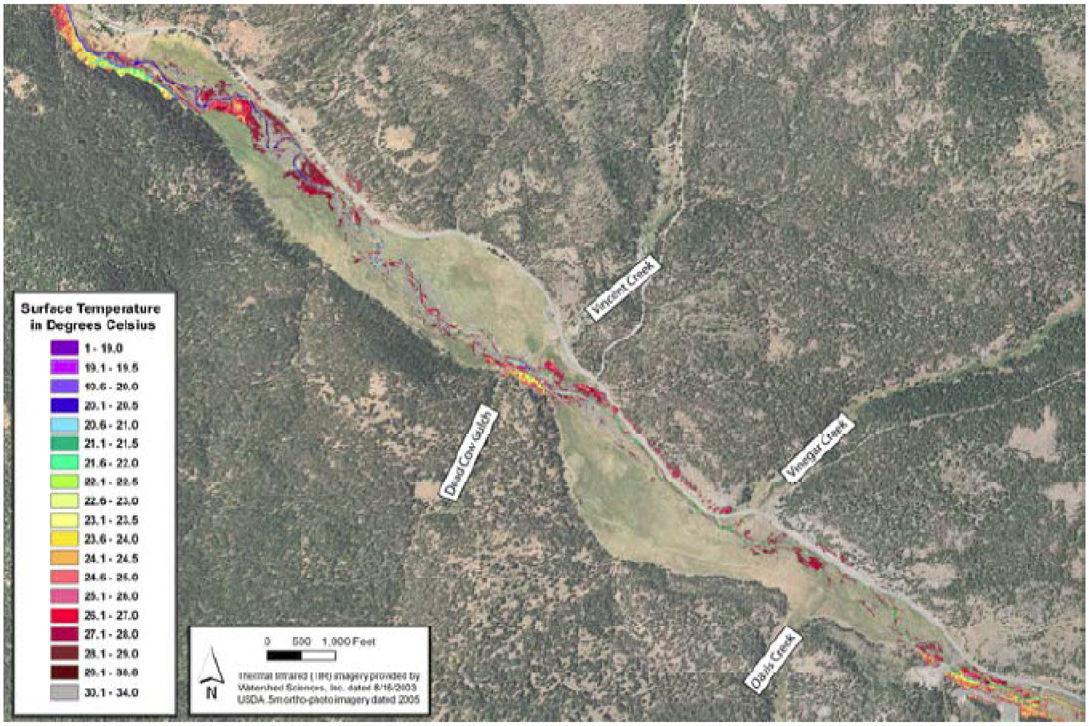

Figure 13. Thermal infrared image of the Forrest Conservation Area. Placer Creek (unlabeled; joins the MFJDR at lower right corner) and Caribou Creek (unlabeled; joins the MFJDR at the upper left corner).

Several aspects of the TIR survey findings have important implications in regards to fish habitat in the FCA. The most important aspect of the survey is the marked decrease in the median stream temperature across the property in a downstream direction (Figure 13). In the FCA, the MFJDR flows across a wide, relatively flat, treeless alluvial valley and is joined by six tributaries of significance: Placer Creek, Davis Creek, and Dead Cow Gulch on the south side of the valley and Vinegar Creek, Vincent Creek and Caribou Creek on the north side of the valley (Figure 13). All of these tributaries join the MFJDR in the upstream half of the reach with the exception of Caribou Creek, which is located at the downstream end of the property. At the time of the survey (August 2003), inflow from these tributaries would be expected to be at its seasonal minimum. There was no riparian vegetation of any significance along the channel at the time of the survey, and yet the thermal data indicate a more than 2.0ºC decrease in stream temperature. It is equally clear based on the longitudinal profile that the temperature fluctuates greatly from reach to reach independent of solar exposure. Resolving the cause of this difference is however outside the scope of this analysis and is the focus of continuing research at Oregon State University.

Chapter 3 HYDRAULIC MODELING

3.1 Hydraulic Modeling Methodology

3.1.1 Model Selection

The model selected for this analysis was SRH-2D (Lai 2006), a depth-averaged, two-dimensional model that simulates hydraulics and was developed primarily for use by engineers to solve various hydraulic and sedimentation problems. The SRH-2D model has the capability of computing mobile bed sediment transport conditions and net volumes of aggradation and degradation but the model size, computation times, and data processing are much more time consuming and costly. For this analysis, the fixed bed version of the model was selected and no sediment transport computations were performed. The fixed-bed version adequately addressed the study questions. Notable capabilities of SRH-2D, taken from Lai (2006), are as follows:

- SRH-2D solves the 2D form of the diffusive wave or dynamic wave equations. The dynamic wave equations are the standard St. Venant depth-averaged equations.
- Both diffusive wave and dynamic wave solvers use the implicit scheme so that solution robustness and efficiency may be achieved for the majority of applications.
- Both steady and unsteady flows may be simulated.
- Unstructured or structured 2D meshes, with arbitrary element shapes, may be used. In most applications, a combination of quadrilateral and triangular meshes works the best.
- All flow regimes, i.e., subcritical, transcritical, and supercritical flows, are simulated simultaneously.
- Solution domain may include a combination of main channels, overland flow, and floodplains.

3.1.2 Model Input

This report section describes the development of model input data, which includes the following steps:

1. Development of a topographic surface based on survey data and Light Detection and Ranging (LiDAR) data.

2. Development of a mesh that represents topographic features of interest.

3. Delineation of polygons to represent the variation in roughness (resistance to flow such as vegetation).

4. Determination of downstream water surface elevations for various flow scenarios.

5. Determination of which flows are available for calibration.

3.1.3 Development of the Model Surface

The first step in constructing the hydraulic model was to obtain topographic data in a known survey datum for both above water topography and bathymetry. Topographic and bathymetric ground surveys were performed in 2005 and 2006 and topographic LiDAR data were acquired in October 2006.

Ground Surveys

Between August and December of 2005, topographic surveys were collected on the Oxbow and Forrest Conservation Areas of the MFJDR by a contractor (Thomas/Wright, Inc.) to Reclamation. These surveys involved total station surveys of detailed cross sections through the river and onto the floodplain with sufficient points between cross sections to generate breaklines and 2-foot contours in the areas of specific project locations.

Following identification of the need for a larger-scale geomorphic assessment in early 2006, additional ground surveys were completed by a different contractor to Reclamation (David Evans and Associates) to develop a longitudinal profile through the extents of the Tributary Assessment area, which encompasses the specific project sites on the Oxbow and Forrest Conservation Areas and several miles upstream and downstream of each of the sites. In October 2006, longitudinal profile surveys were collected along the active channel thalweg spaced such that the bottom of each pool and the top of each riffle were identified with a maximum distance of 100 feet between points. Survey data collected by David Evans and Associates included a combination of GPS and total station methods.

A substantial spring runoff event occurred in 2006, potentially modifying previously existing ground surface features as surveyed in the 2005 surveys. As a result, several cross sections needed to be resurveyed to record changes that may have occurred. On each of the Oxbow and Forrest Conservation Areas, a minimum of two cross sections across the river were resurveyed.

LiDAR

LiDAR survey data were acquired in October 2006 to identify ground surface elevations, infrastructure, and vegetation within the floodplain of the study area (Watershed Sciences 2006). Quality control data were collected within the project area using a ground-based real-time kinematic (RTK) survey and were compared to the processed LiDAR data to evaluate LiDAR accuracy across the project area. The root mean square error was reported as 0.069 meters based on a comparison of the LiDAR and RTK surveys. An example of the model surface can be seen in Figure 14.

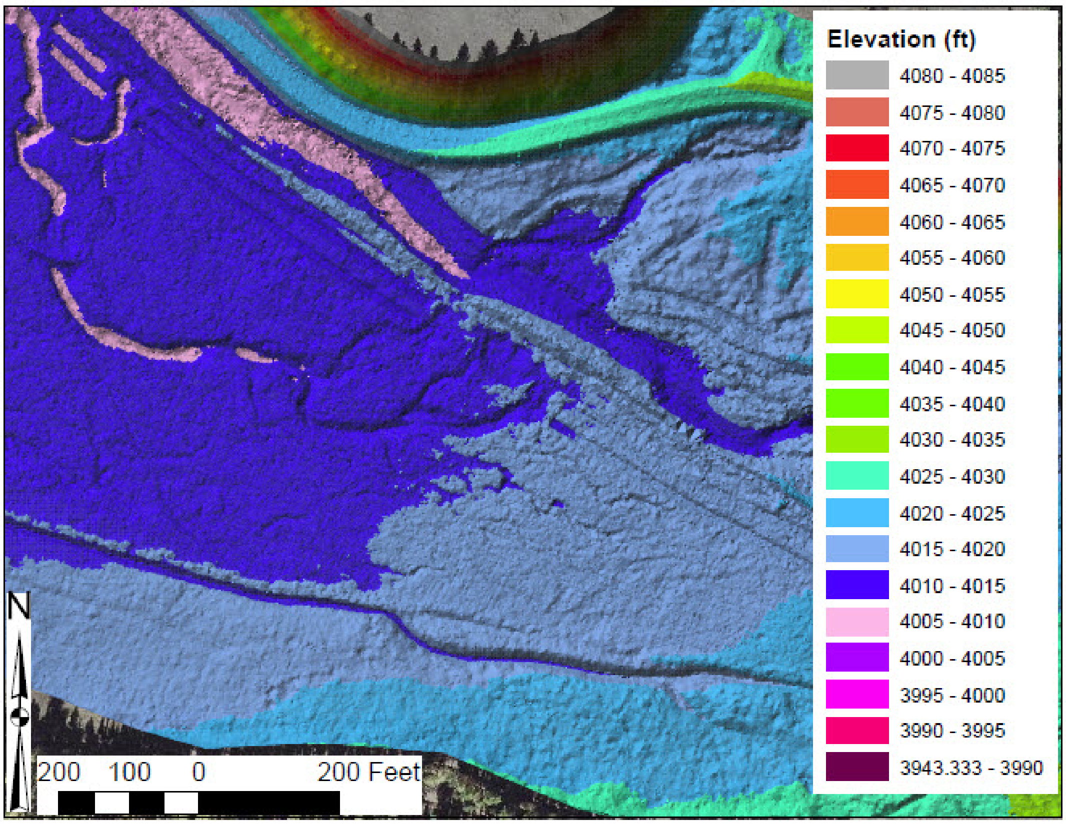

Figure 14. Example of the surface used as input for the hydraulic model. Elevations are in feet.

3.1.4 Construction of the Modeling Mesh

The computational mesh was constructed using the Surface-Water Modeling System (SMS) software Version 10.0.0 (SMS 2008). The mesh contains elevation information at each node and roughness data for each cell (see next section for more information on establishing roughness parameters). Examples of the mesh are shown in Figure 15 and Figure 16.

The cell size of the mesh was varied based on the location of the cell. Within the channel and across other important topographic features (e.g., road embankment, levees, side channels, riprap), cells were limited to approximately 5 feet in the lateral direction (cross-stream) and approximately 10 to 15 feet in the longitudinal direction (downstream). The shorter dimension in the lateral direction is used to capture the more rapidly changing topography transverse to the stream flow with respect to horizontal distance. In the floodplain, cells were limited to 10 to 20 feet in both directions depending on the uniformity of the topography. The mesh consists primarily of quadrilateral elements, with triangular elements making up less than 20 percent of the entire mesh. The cell size of the channel was selected to maximize model computation efficiency by minimizing the number of cells to balance run time with model accuracy. Cell sizes throughout the modeled area were varied to ensure that important breaks in elevation were represented. Approximately 170,000 grid cells were used in the mesh.

The mesh boundaries in the lateral direction were digitized to at least capture all of the area inundated by a 100-year discharge. The channel margins and other significant breaks in the topography were also digitized into the mesh to ensure that mesh boundaries align with elevation changes. Key topographic features represented in the mesh included road and bridge embankments, channel margins, side channels, and tributaries.

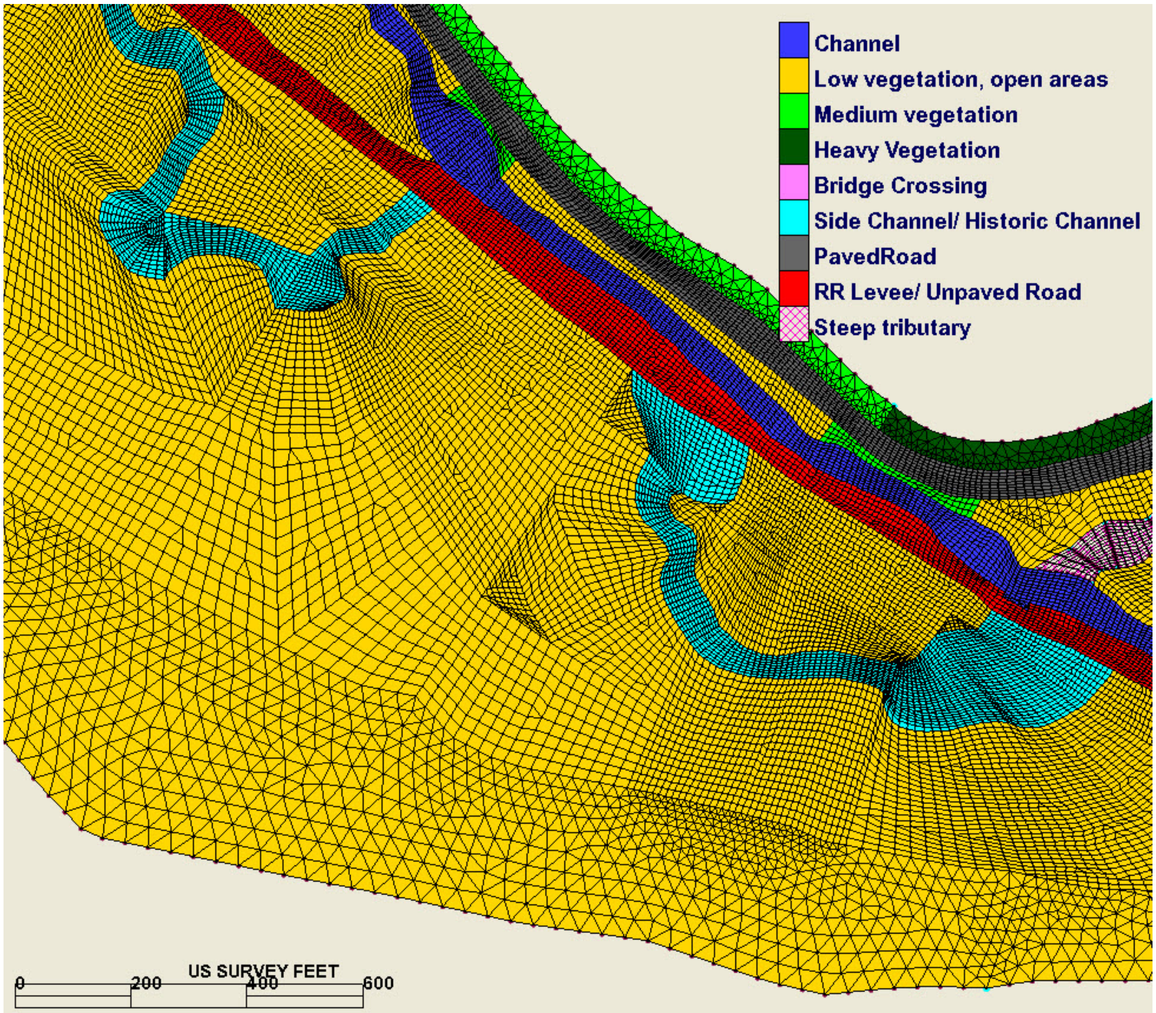

Figure 15. Example of the numerical mesh constructed in SMS. The various colors represent roughness values.

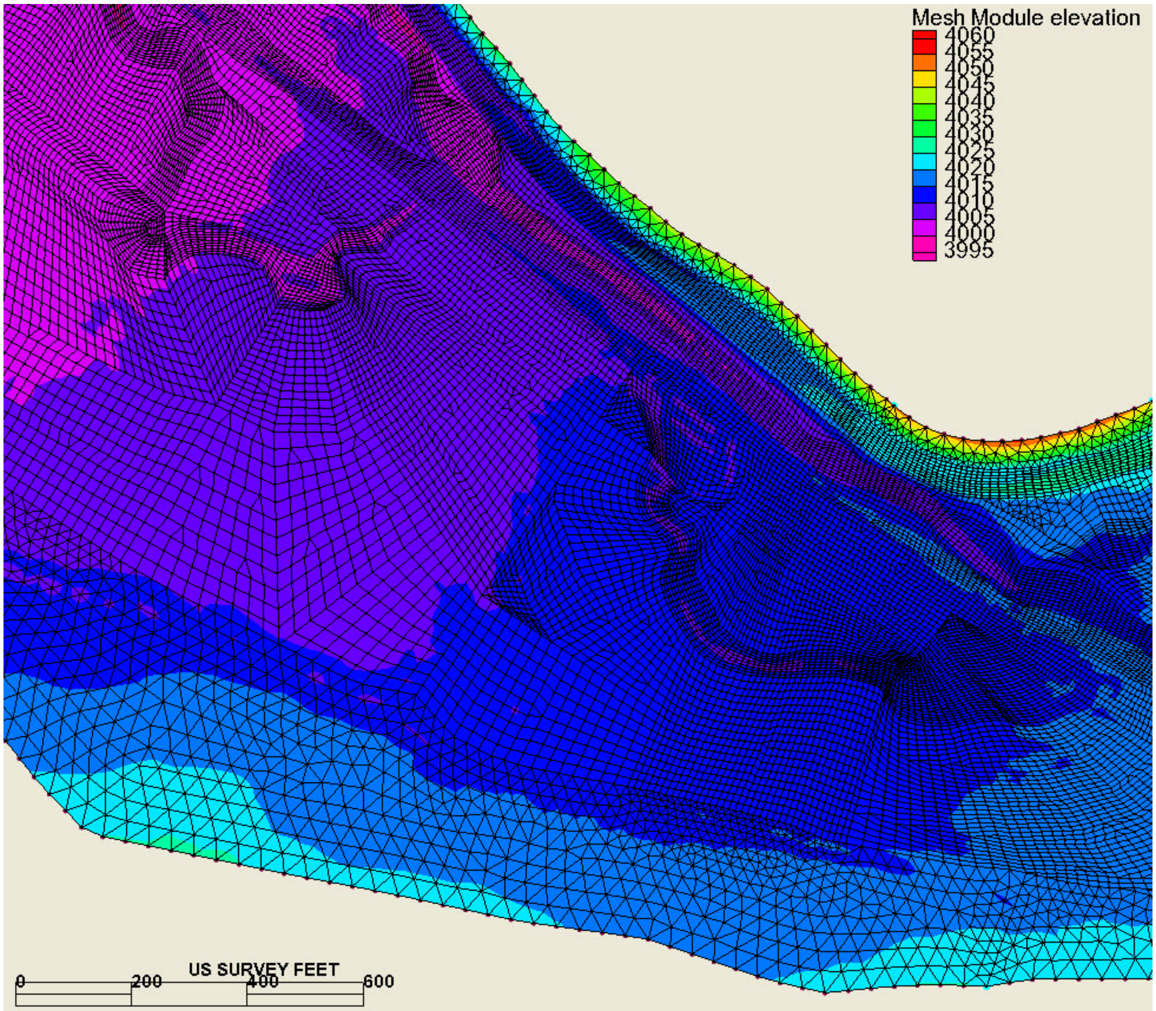

Figure 16. Example of the numerical mesh showing surface elevations in feet as derived from the terrain surface constructed in ArcGIS.

3.1.5 Roughness Zones and Vegetation

Nine classifications of roughness were used to represent the study area. Within the extents of the mesh, roughness zones were spatially delineated using the 2006 aerial photographs and the topography data from the model surface. Each roughness zone was assigned an appropriate Manning's n value for input to the 2D model. These values were adjusted for qualitative model calibration and also to examine the model sensitivity to variations in roughness. The sensitivity run values were determined by adding or subtracting .005 to or from the adjusted roughness value.

Table 3. Roughness values used in the model development and in the sensitivity test.

	Manning's Roughness Coefficient			
Roughness Classification	**Initial Value**	**Adjusted Value**	**High Sensitivity Run**	**Low Sensitivity Run**
Channel	0.039	0.039	0.044	0.034
Light Vegetation	0.043	0.045	0.050	0.040
Medium Vegetation	0.053	0.055	0.060	0.050
Heavy Vegetation	0.063	0.065	0.070	0.060
Bridge	0.039	0.039	0.044	0.034
Side Channel/Historical Main Channel/Tributary	0.039	0.042	0.047	0.037
Road and embankment	0.050	0.050	0.055	0.045
Levee	0.043	0.043	0.048	0.038
Steep Tributary with larger bed material than main channel	0.043	0.043	0.048	0.038

3.1.6 Downstream Boundary Conditions

Downstream boundary conditions for the model were derived from a one-dimensional (1D) hydraulic model developed in the Tributary Assessment (Reclamation 2008). Results of the 1D model were used to determine the water surface elevation at the downstream boundary of the 2D model. The 1D model extends more than 10 miles below the downstream boundary for the 2D model and was run with downstream boundary conditions based on normal depth. To evaluate potential impacts of the downstream boundary condition on model results, a sensitivity analysis on the downstream boundary condition of the 2D model was completed for the 2-year peak discharge (Section 3.4.4).

3.1.7 Upstream Boundary Conditions

Discharges used in the model represent the 2-, 5-, 10-, 25-, 50-, and 100-year return periods (Table 4). Flows were based on a hydrologic analysis conducted by Reclamation (2008), in which the National Flood Frequency equations were coupled with gaged data from the United State Geologic Survey (USGS) gage on the Middle Fork John Day River at Ritter (14044000). Additional overbank discharges were evaluated for qualitative comparison of model results with high flow photographs, as described in Section 3.2.1. No seepage losses were accounted for throughout the length of the reach. The model was developed to evaluate lateral floodplain processes under high flows. Low flow analyses would require additional bathymetric data to more accurately represent localized hydraulic conditions and refinement of the model mesh to capture small changes in channel topography.

Table 4. 2- through 100-year discharges in cubic feet per second (cfs) for the Middle Fork John Day River and tributaries located in the study reach.

Flow Input Location	Discharge (cfs)					
	Q2	Q5	Q10	Q25	Q50	Q100
Model Inlet	562	857	1,064	1,304	1,542	1,744
Bridge Creek	78	117	144	176	207	235
Placer Creek	11	17	21	27	32	37
Davis Creek	23	34	43	52	61	70
Vinegar Creek	54	81	100	122	142	162
Vincent Creek	41	60	73	88	103	116
Model Outlet	769	1,166	1,445	1,769	2,087	2,364

3.2 Model Validation and Results

No surveyed water surface elevations combined with flow measurements were available for the same time period for model calibration. In May 2008, ground photographs were taken and high water marks following high flows were surveyed, but no corresponding flow measurements were acquired. The nearest stream gage to the Forrest Conservation Area is the Middle Fork at Ritter gage, which is located more than 50 miles downstream. More reliable information consists of ground photographs corresponding to measured flows during a high flow discharge on May 7, 2009. However, no high water marks of this discharge were ever surveyed. All of the available information was utilized to the extent possible to compare model results and adjust roughness values to calibrate the existing conditions model. In this section, we present the data available and the corresponding model results. The intended use of the model is to establish baseline hydraulic conditions and investigate potential increases in habitat value following removal of human features. Although the final model does not have a substantial amount of quantitative data for calibration, the validity of comparisons of the existing conditions with removed human features conditions should be unaffected. Furthermore, a sensitivity analysis of Manning's coefficient n was conducted (see section 3.4.4) to evaluate how modifications to the roughness values affect the model results.

3.2.1 Existing Conditions Model Comparison with High Flow Photographs- Spring 2008 High flows

Hydrology

In 2008, Reclamation completed a hydrologic analysis of the Middle Fork John Day Basin to estimate ungaged drainage areas using the National Flood Frequency Equations for Eastern Oregon (Reclamation 2008). The Middle Fork of the John Day River at Ritter is the closest USGS gage on the mainstem of the Middle Fork. Results from the hydrologic analysis are compared with an analogous study conducted by the State of Oregon in 2006 (Table 5). Both the regional regression formulas used in the USBR study and the State of Oregon study predict similar high flow discharges for the Ritter gage. The regional regression equation applied in the USBR study was used to estimate discharges for the 2- through 100-year discharges on the Forrest Conservation Area. The values for the Forrest Conservation Area were used to estimate flows for ground photographs and high water marks acquired during the 2008 high flows.

Based on provisional data from the Ritter gage, the peak discharge for 2008 occurred on May 19 with an instantaneous discharge of 2,300 cfs (Figure 17). The following day, several staff from Reclamation visited the MFJDR when the average daily discharge at the Ritter gage was 1,910 cfs. Measured discharge fluctuated between instantaneous values of 1,800 and 2,060 cfs. This range of discharges corresponds to a return period between 2- and 5-years at Ritter (Table 5). Taking into account the travel time from the Forrest Conservation Area to the Ritter gage (over 50 river miles), the discharge through the Forrest Conservation Area was estimated to be approximately equivalent to a 2-year return discharge of 769 cfs (Table 5). However, no discharge measurements were collected to compare to this assumed discharge.

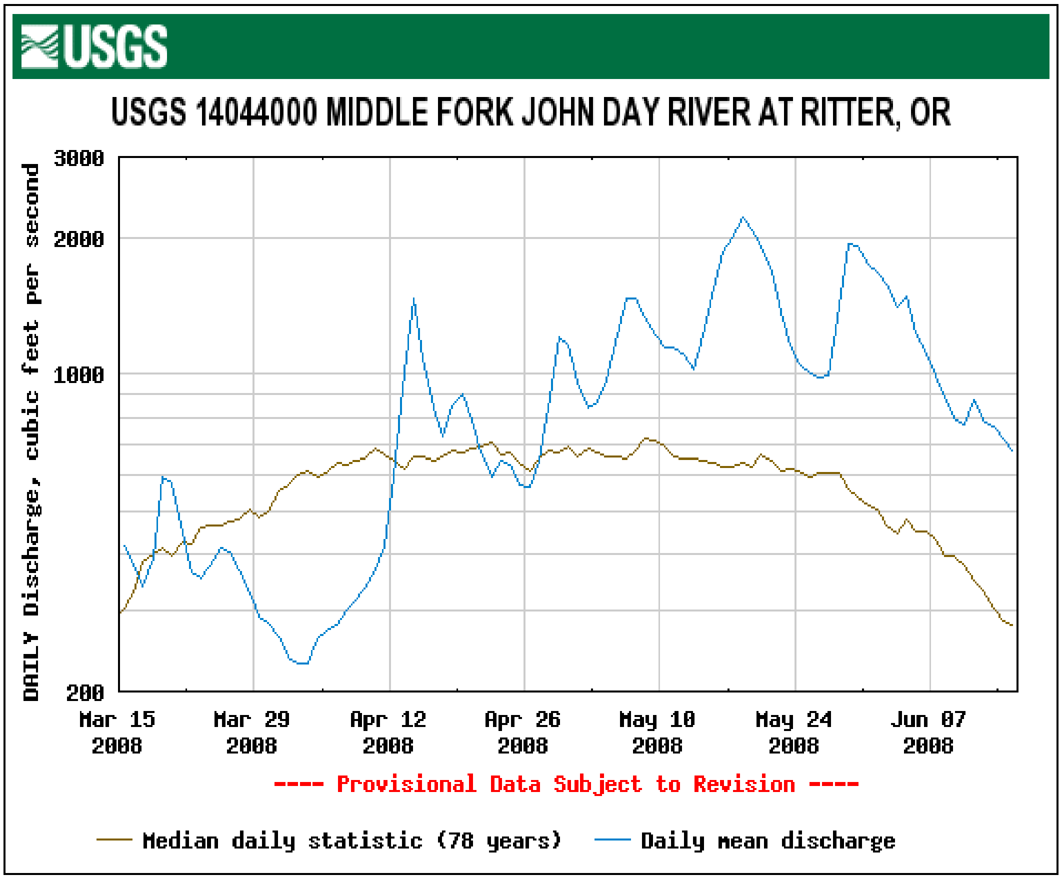

Figure 17. Gage data at Ritter for the Middle Fork John Day River, Spring 2008.

Table 5. Predicted high flows at the Ritter Gage and at the outlet of the Forrest Conservation property.

Hydrology at Ritter Gage	**Flows for discharges with specific recurrence intervals (CFS)**						
	2 year	5 year	10 year	25 year	50 year	100 year	Parameters used
USBR Log-Pearson III high[1]	1,918	2,922	3,630	4,548	5,242	5,941	
USBR Log-Pearson III mid[1]	1,746	2,599	3,165	3,873	4,394	4,908	
USBR Log-Pearson III low[1]	1,591	2,348	2,823	3,399	3,813	4,214	
USBR regional regression[1]	1,648	2,584	3,277	4,121	4,906	5,681	drainage area, mean annual precipitation, percent forest cover
State of Oregon systematic and historical record[2]	1,720	2,570	3,160	3,910	5,040	6,380	
State of Oregon regional regression[2]	1,690	2,570	3,180	3,980	5,210	6,680	
State of Oregon weighted average[2]	1,720	2,570	3,160	3,910	5,050	6,400	drainage area, mean watershed slope, mean January precipitation, mean minimum January temperature, soil depth
USBR Regional Regression for Forrest Property (outlet)[1]	769	1,166	1,445	1,769	2,087	2,364	

[1] Reclamation (2008)
[2] Cooper, R.M. (2006)

High Water Marks

In August 2008, high water marks were collected by Oregon State University between RM 66.6 and 67.2. Students surveyed elevations where the top of flotsam was visible on the ground, on vegetation, and on fencing. Assuming flows at the downstream end of the Forrest Conservation Area reached the estimated 2-year discharge of 769 cfs, the measured high water marks were compared with the modeled depths (at inlet and outlet flows shown in Table 4 for 2-year discharge). Two sets of high water mark data were acquired: one was collected using a total station, which is expected to have the highest accuracy; and the other was collected using an autolevel and shooting back to a known control point for vertical accuracy and a GPS for horizontal accuracy. The horizontal precision of the GPS ranged between 0 and 0.45 meters with an average precision of 0.3 meters (~ 1 foot). Depths were determined from the high water marks by subtracting the ground elevation at the location of each surveyed high water mark. A total of 61 high water marks were surveyed. However, 5 were removed because the measured elevations had values that were less than the corresponding ground elevations.

A comparison of modeled versus measured depths, illustrated in Figure 18, suggests that the model tends to predict slightly greater depths than those determined from the high water marks. A line of equivalence shown in Figure 18 denotes the point at which the modeled depths and the measured depths would be equal to one another. The total station high water marks tend to fit more closely to the line of equivalence than the auto level high water marks. Differences between the modeled and measured depths are depicted in Figure 19. While the average difference between the total station points and the modeled depths is 0.2 feet, the average difference between the autolevel points and the modeled depths is 0.5 feet. For the total station data set, 70% of the measured depths are within 0.5 feet of the modeled depths, and 95% are within 1 foot. For the autolevel data set, only 40% of the depths measured from the high water marks are within 0.5 feet of the modeled depths, and 90% are within 1 foot. Considering accuracies of surveyed high water mark elevations and ground elevations used to determine the depths from the high water marks, these results indicate that the high water marks and the modeled depths for the 2-year discharge compare relatively well. A known flow corresponding with the high water marks would improve the ability to determine the model’s prediction capability.

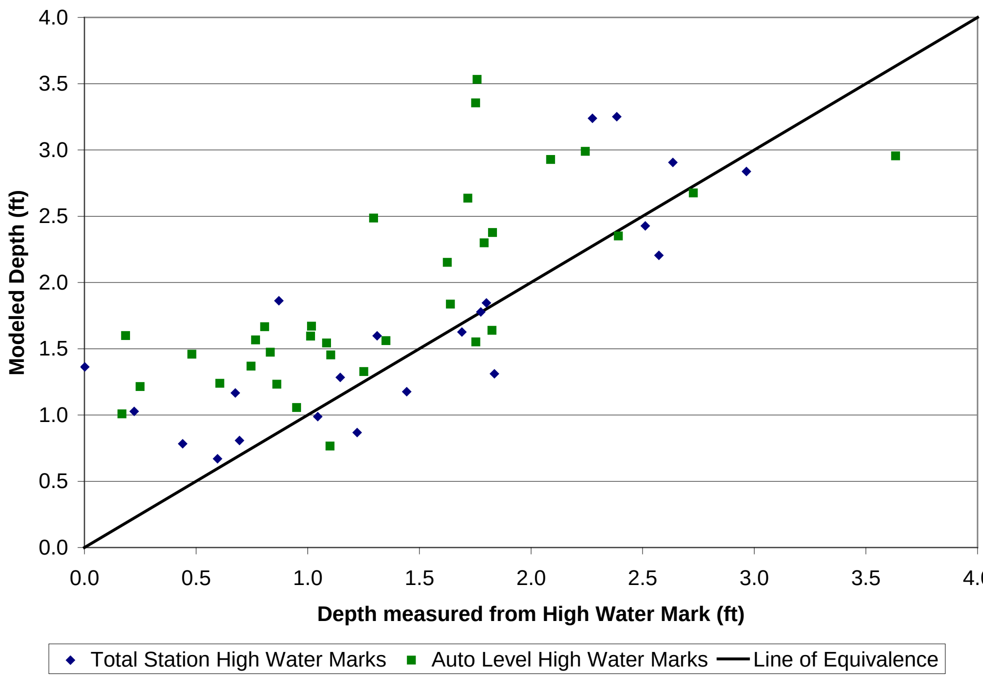

Figure 18. Comparison of depths modeled at 769 CFS with depths measured from high water marks in August 2008.

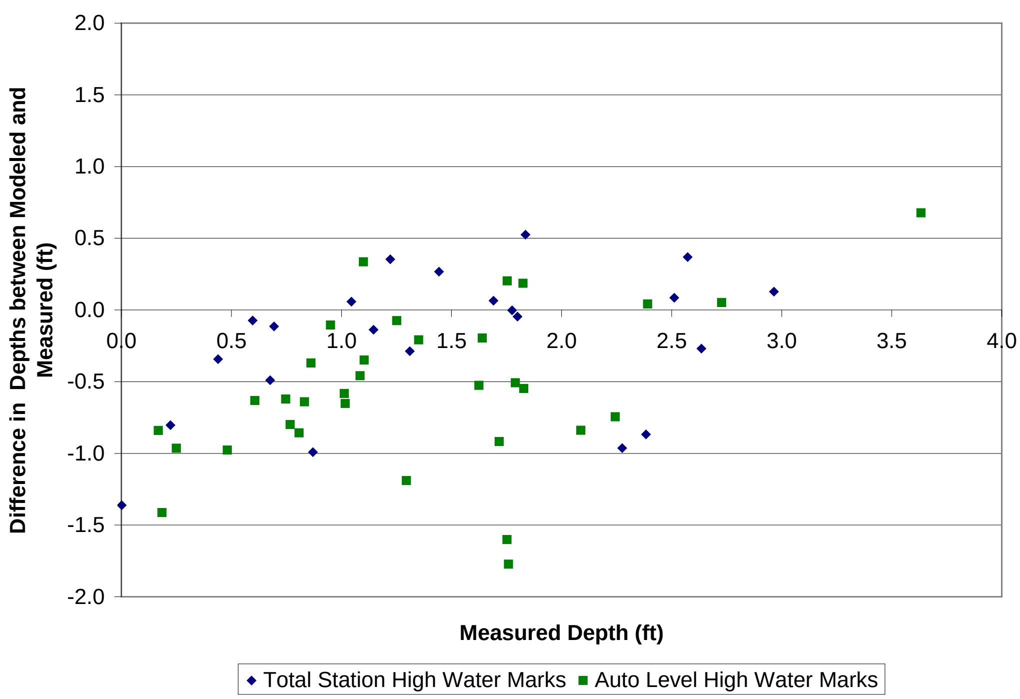

Figure 19. Differences between modeled depths at 769 cfs and depths measured from high water marks collected in August 2008.

Ground Photo Comparison

Ground photos of the flood event on May 20, 2008 are compared with model results in Figure 20 through Figure 29. Modeled discharge in these figures is 769 cfs. Comparisons of the photographs suggest that either flows on May 20 were less than the modeled 769 cfs or that the model slightly overpredicts water depths in some areas (typically by less than 0.5 feet). Without a measured discharge, determining which of these factors is responsible for the discrepancies is difficult. However, ground photographs in the same locations during a measured discharge of less than 500 cfs on May 7, 2009 show similar and sometimes more inundation than that observed on May 20, 2008. This would support a flow of less than 769 cfs on the Forrest Conservation Property on May 20, 2008.

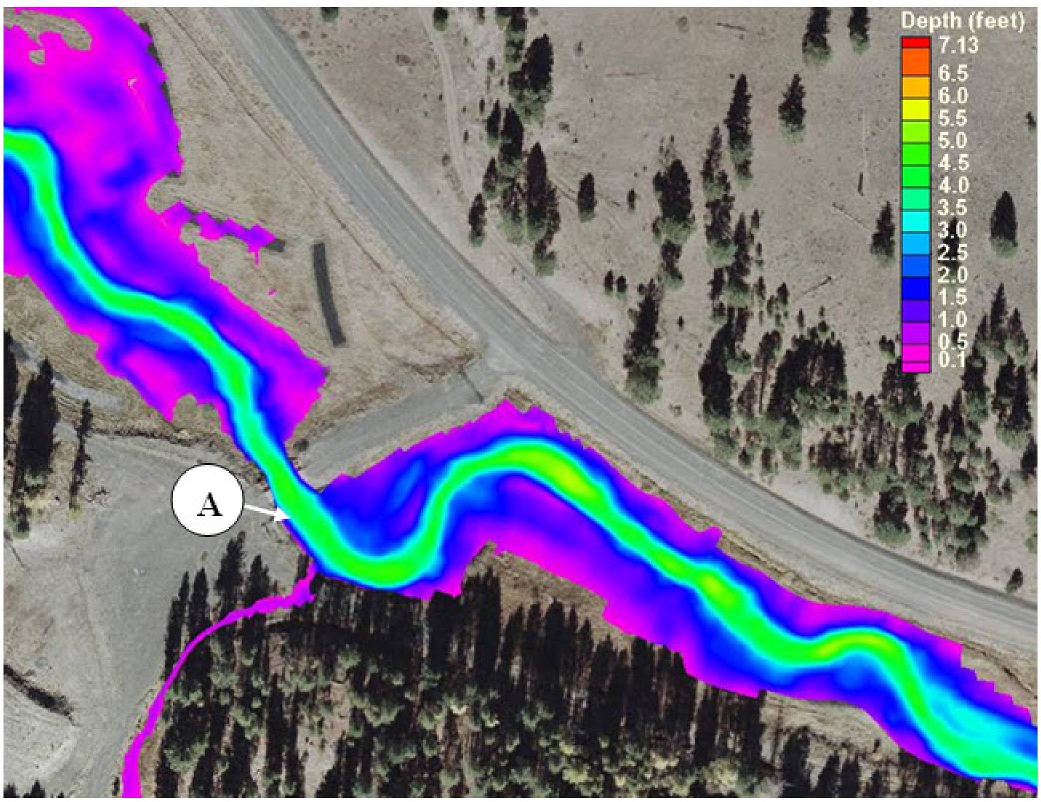

Figure 20. Model results of the 2-year discharge showing water depth in feet at Placer Gulch confluence. Flow is from right to left. Corresponding photograph of high flow on May 20, 2008 is shown in Figure 21. The arrow indicates the direction of the photograph.

Figure 21. Photograph taken from location A as shown in Figure 20.

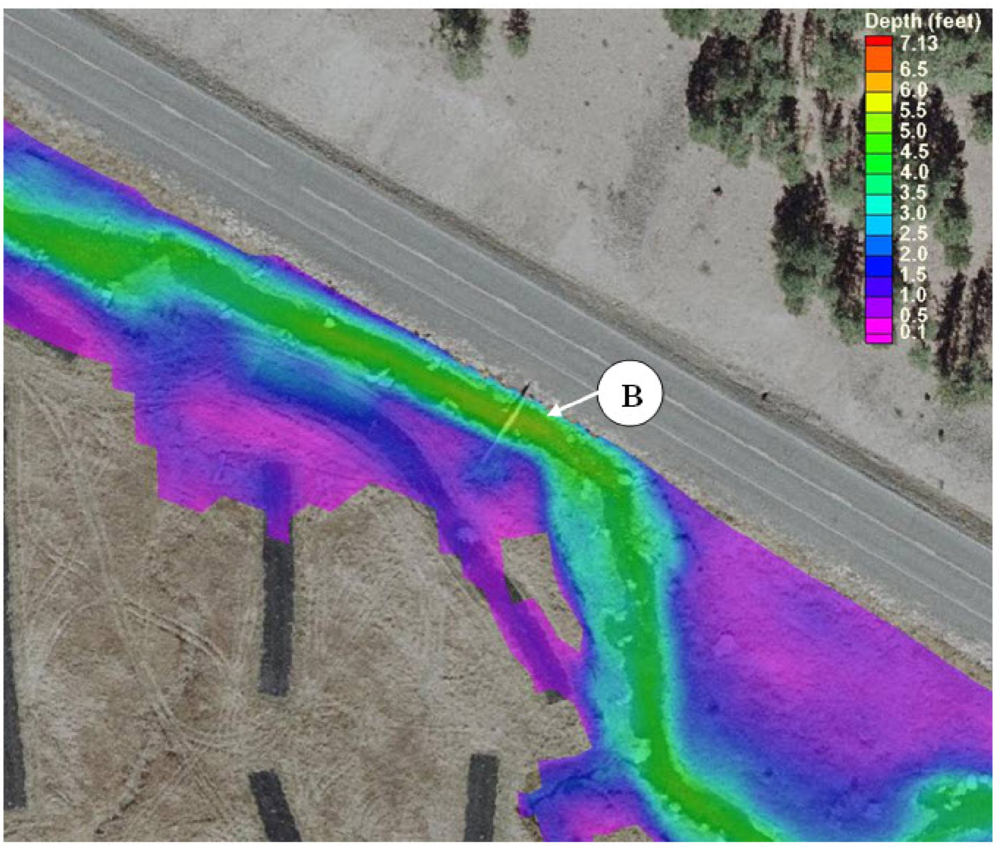

Figure 22. Model results of the 2-year discharge showing water depth in feet near foot bridge (RM 66.7). Flow is from right to left. Corresponding photograph of high flow on May 20, 2008 is shown in Figure 23. The arrow indicates the direction of the photograph.

Figure 23. Photograph taken from location B as shown in Figure 22.

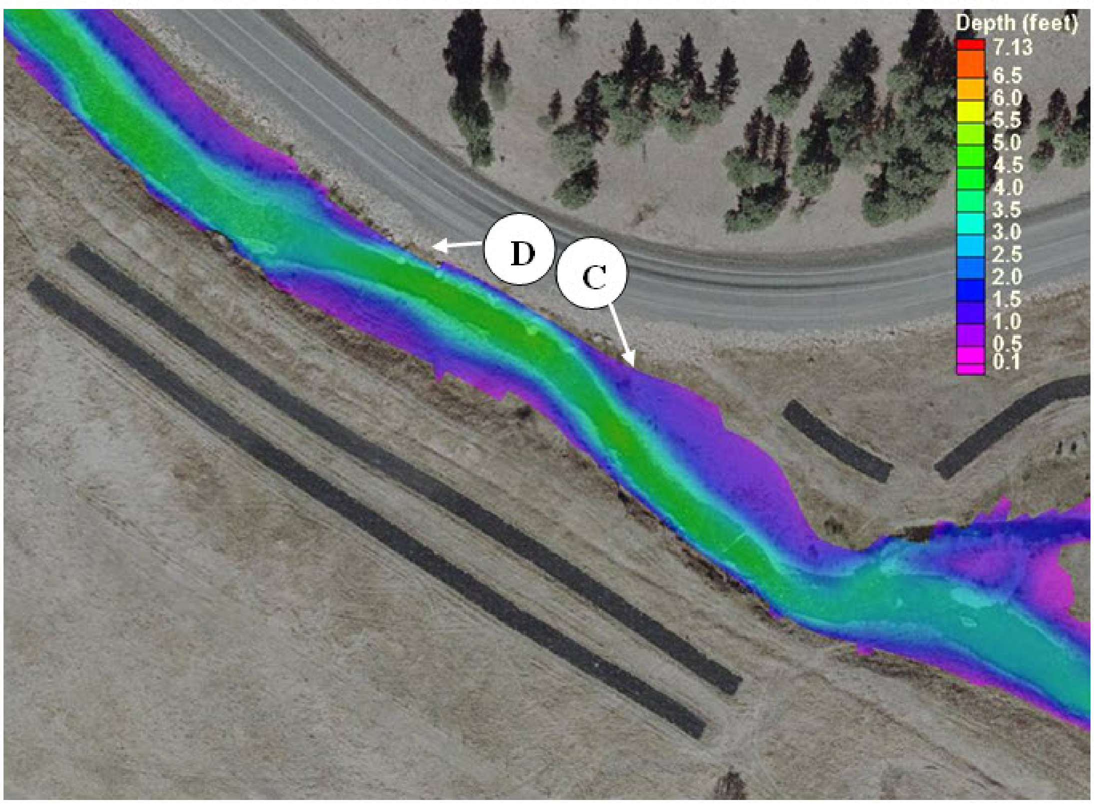

Figure 24. Model results of the 2-year discharge showing water depth in feet downstream of Vinegar Creek. Flow is from right to left. Corresponding photographs of high flow on May 20, 2008 are shown in Figure 25 and Figure 26. The arrows indicate the direction of the photograph.

Figure 25. Photograph taken from location C as shown in Figure 24.

Figure 26. Photograph taken from location D as shown in Figure 24.

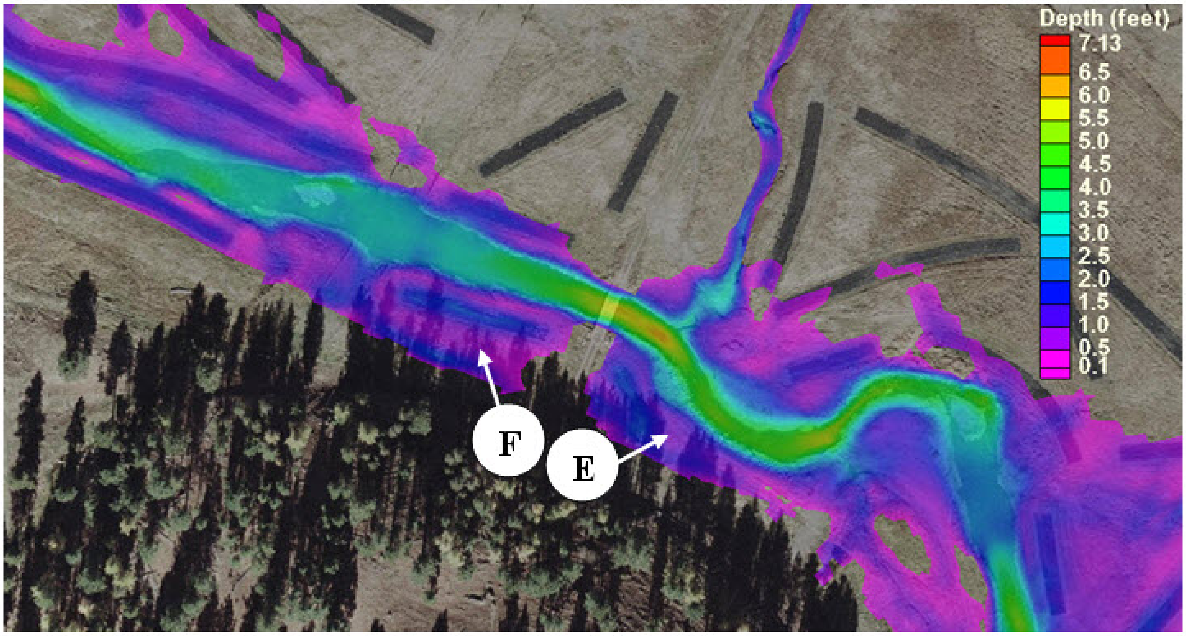

Figure 27. Model results of the 2-year discharge showing water depth in feet at Vincent Creek confluence. Flow is from right to left. Corresponding photographs of high flow on May 20, 2008 are shown in Figure 28 and Figure 29. The arrows indicate the direction of the photograph.

Figure 28. Photograph taken from location E as shown in Figure 27.

Figure 29. Photograph taken from location F as shown in Figure 27.

3.2.2 Existing Conditions Model Comparison with High Flow Photographs- May 7, 2009

Hydrology

On May 7th, 2009, discharge measurements of the Middle Fork John Day River were collected on the FCA from the Placer Gulch Bridge (RM 67.2) and then also from the Dead Cow Gulch Bridge (RM 65.5). A flow of 391 cfs was measured just downstream from Placer Gulch, and a flow of 496 was measured just downstream of Vincent Creek. The measured flow values were plotted against flows measured at the Ritter gage during the same time period (Figure 30) and were also compared with the regional regression equations used as estimates for the Spring 2008 flows. Figure 30 shows that although the Ritter gage was close to a 2-year discharge on May 7th, the Forrest Conservation Area measurements are approximately 200 cfs lower than the estimated 2-year discharge using regional regression equations. However, another slightly higher discharge occurred just three weeks prior to the May 7th high flow (Figure 31). Timing of the snowmelt and runoff from tributaries is partially responsible for variations in the regression equations and the measured flows. Over time, if this graph continues to be populated, a cloud of points around the regional regression points for a 2-year discharge would be expected.

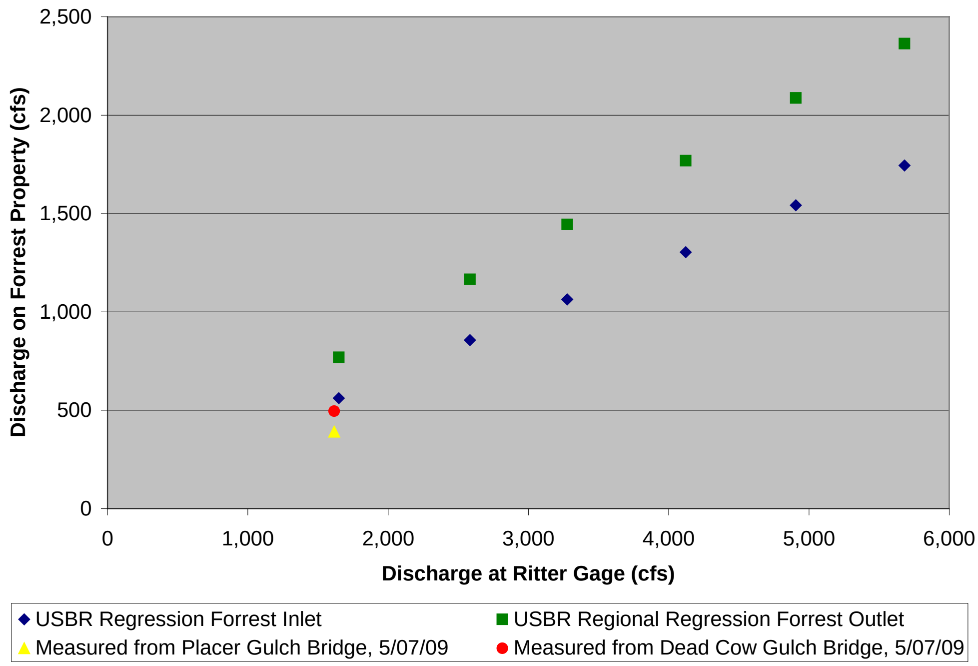

Figure 30. Comparison of flows measured at the Ritter gage with flow measurements conducted on the Forrest Conservation Property.

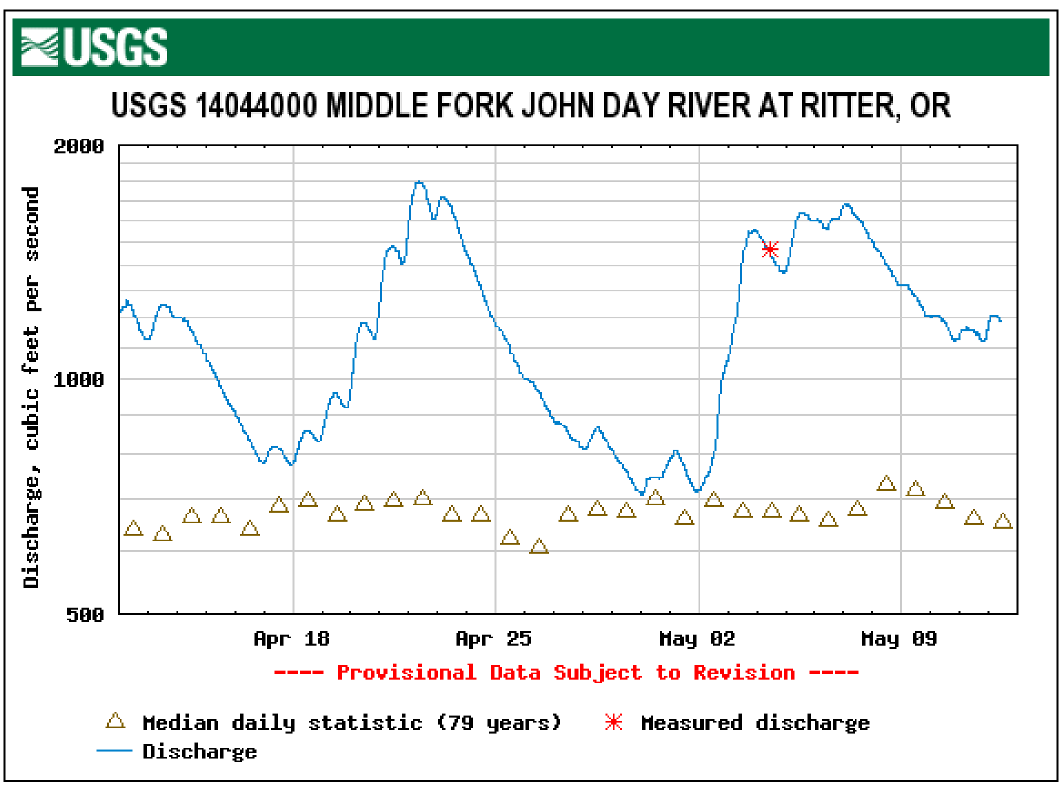

Figure 31. Spring 2009 discharge measurements at the Ritter gage.

Ground Photo Comparison

A qualitative evaluation of the model's ability to match ground photos from May 7th, 2009 was completed. The model was simulated with a flow of 331 cfs at the inlet and 496 cfs at the outlet, and discharges from the tributaries were scaled to most closely match the measured discharges of 391 cfs just downstream from Placer Gulch and 496 cfs just downstream from Vincent Creek. Ground photos of the observed discharge are compared with model results in Figure 20 through Figure 29. Vegetation mats elevations appear lower than the true ground surface, which may be due to the LiDAR returns. Therefore, vegetation mats are frequently wetted in model when not actually wetted during the observed flows. Side channel inundation appears to be accurately represented by the model. Overall, the model results compare well with the observed ground photographs. This information was the most useful in determining the final roughness values used for the high flow model.

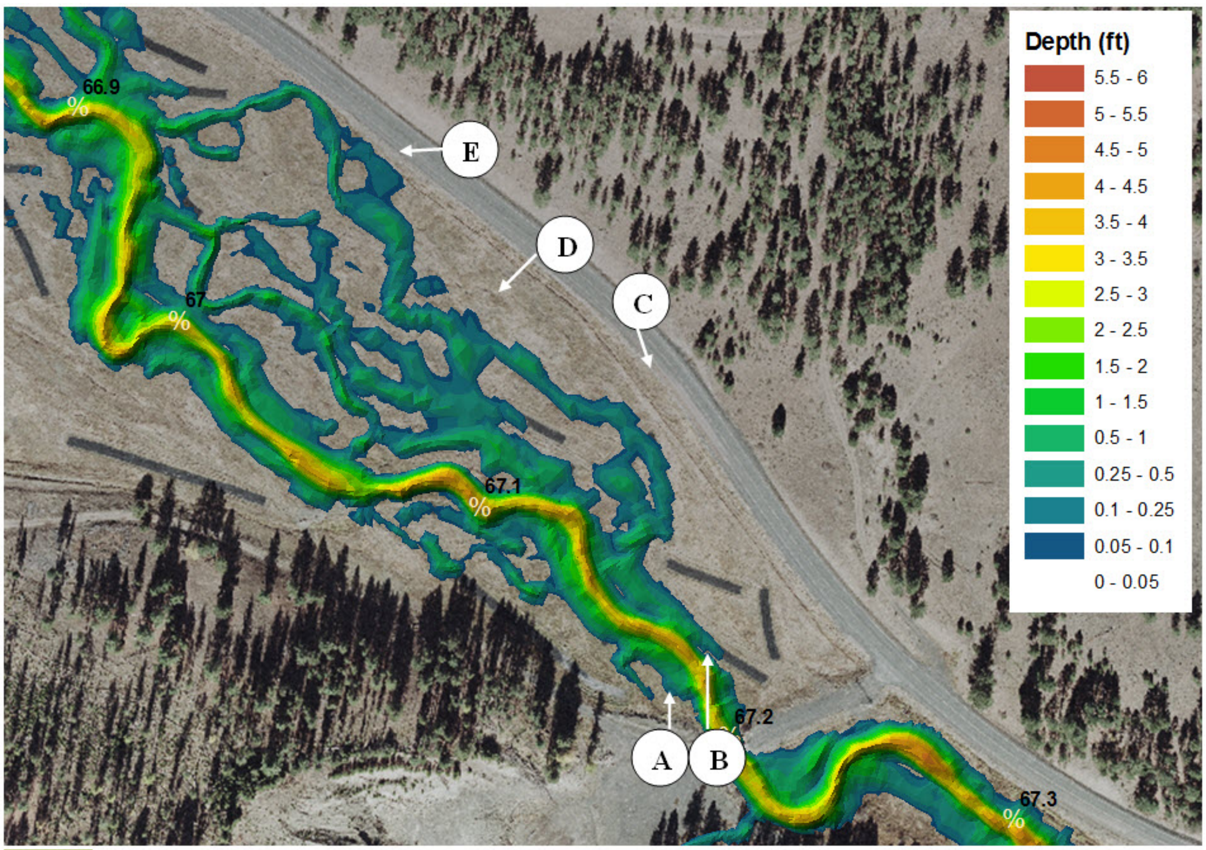

Figure 32. Model results of an inlet flow of 391 cfs showing water depth in feet near Placer Gulch confluence. Flow is from right to left. Corresponding photographs of flow on May 7, 2009 are shown in Figure 33 through Figure 37. The arrows indicate the direction of the photographs.

Figure 33. Photograph taken from location A as shown in Figure 32.

Figure 34. Photograph taken from location B as shown in Figure 32.

Figure 35. Photograph taken from location C as shown in Figure 32.

Figure 36. Photograph taken from location D as shown in Figure 32.

Figure 37. Photograph taken from location E as shown in Figure 32.

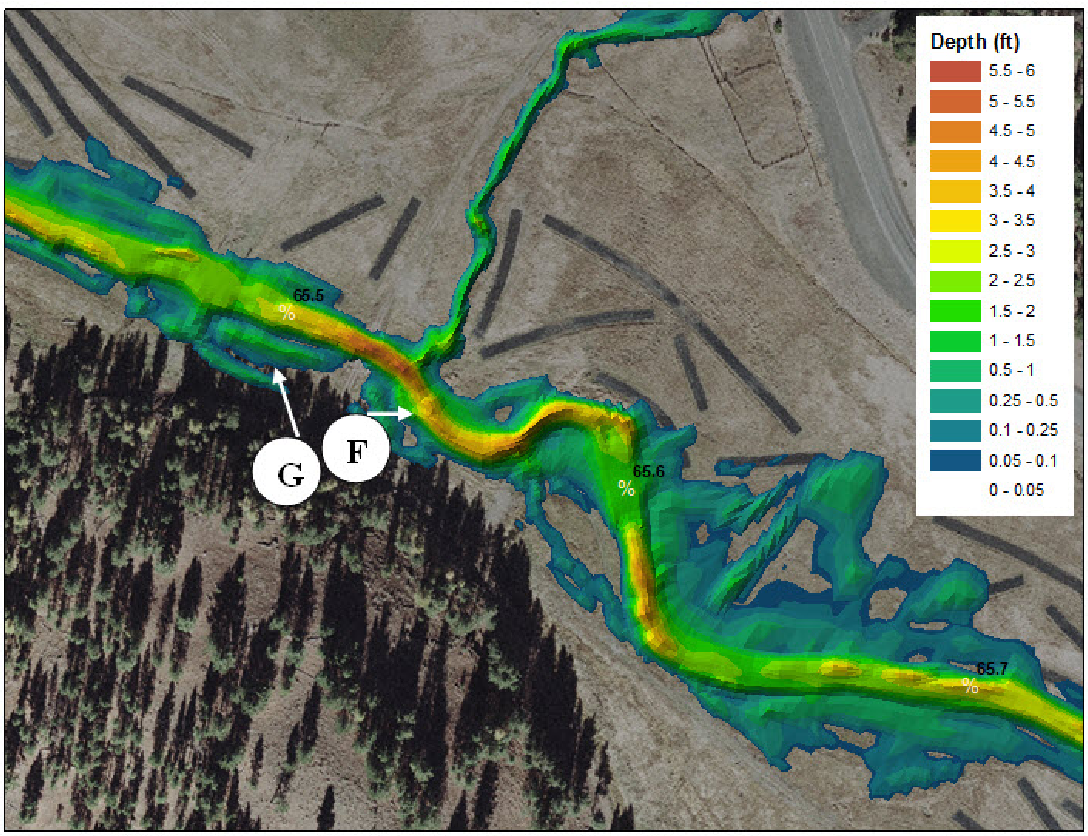

Figure 38. Model results of an inlet flow of 391 cfs showing water depth in feet at Vincent Creek confluence. Flow is from right to left. Corresponding photographs of flow on May 7, 2009 are shown in Figure 39 through Figure 40. The arrows indicate the direction of the photographs.

Figure 39. Photograph taken from location F as shown in Figure 38.

Figure 40. Photograph taken from location G as shown in Figure 39.

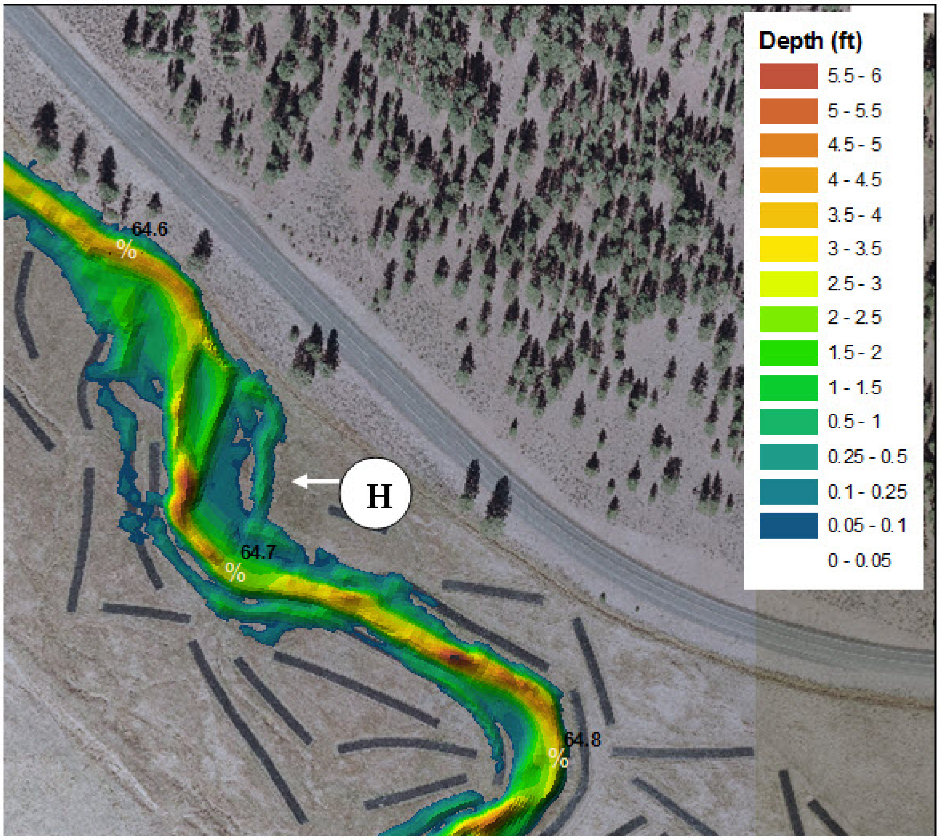

Figure 41. Model results of an inlet flow of 391 cfs showing water depth in feet. Flow is from right to left. Corresponding photograph is shown in Figure 42. The arrow indicates the direction of the photograph.

Figure 42. Photograph taken from location H as shown in Figure 41. Photograph taken one day prior to measured inlet flow of 391 cfs.

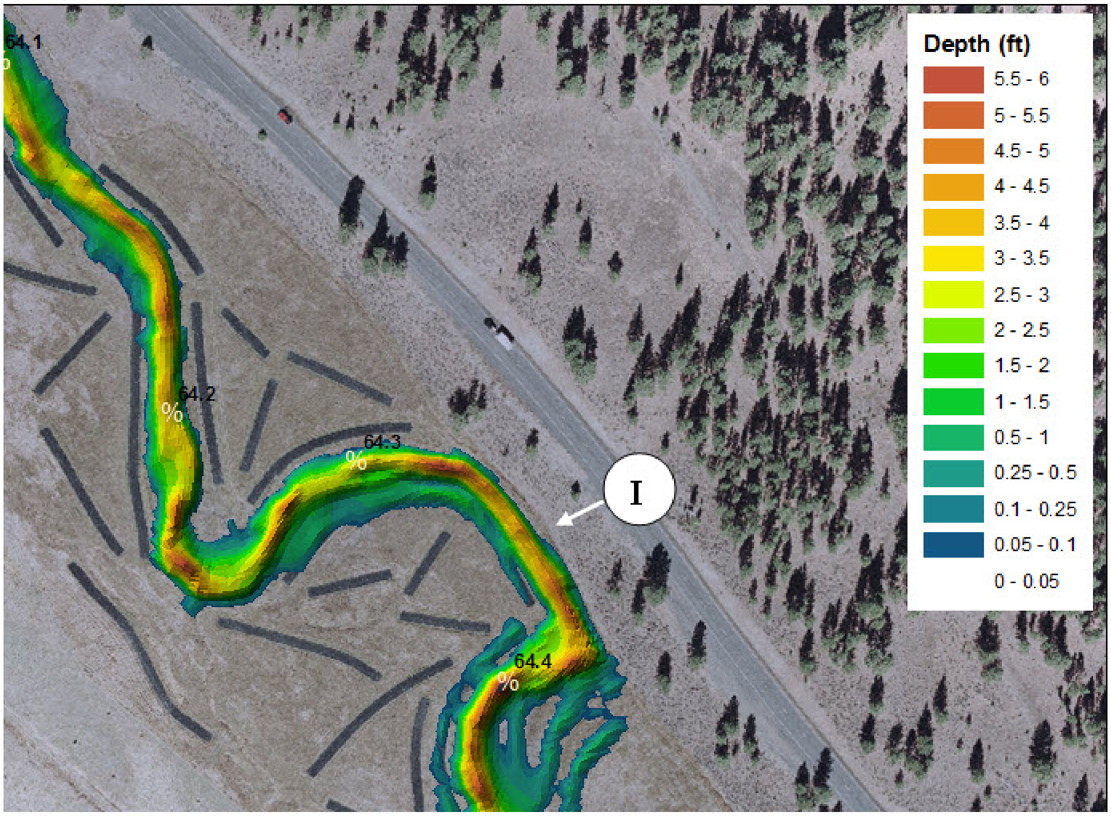

Figure 43. Model results of an inlet flow of 391 cfs showing water depth in feet. Flow is from right to left. Corresponding photograph is shown in Figure 44. The arrow indicates the direction of the photograph.

Figure 44. Photograph taken from location I as shown in Figure 43. Photograph taken one day prior to measured inlet flow of 391 cfs.

3.3 Water Surface Elevation Profiles

Profiles of the water surface elevation for the 2-year discharge were developed along the existing and historical channel thalwegs for the existing conditions scenario and the Removed Human Feature scenario. The thalweg alignments differ between Vinegar and Vincent Creeks as shown in Figure 45. Figure 46 illustrates that differences in the water surface elevations along the channel thalweg are only notable between Vinegar and Vincent Creeks. A more focused view of the profile between Vinegar and Vincent Creeks (Figure 47) indicates that reductions in the water surface elevations are predicted under the Removed Human Features scenario. However, backwater caused by abrupt blockages to flow in the Removed Human Features model ultimately results in increased water surfaces just upstream of the blockages and overland flow across the blocked portions of the channel. Along the historical channel thalweg, the profiles suggest that the bed elevations of the historical channel have filled-in over time and create subtle fluctuations in the water surface profile of the Removed Human Features scenario (Figure 48). Flow is only present in the existing conditions model in areas where the historical channel alignment overlaps with the existing channel alignment. In these areas, abrupt drops in the elevation of the bed cause steep drops in the water surface elevation of the Removed Human Features scenario. After flow is actually introduced to the historical channel, it is expected that sediment transport will smooth the bed profile and result in a relatively smooth water surface elevation compared with the current simulation results.

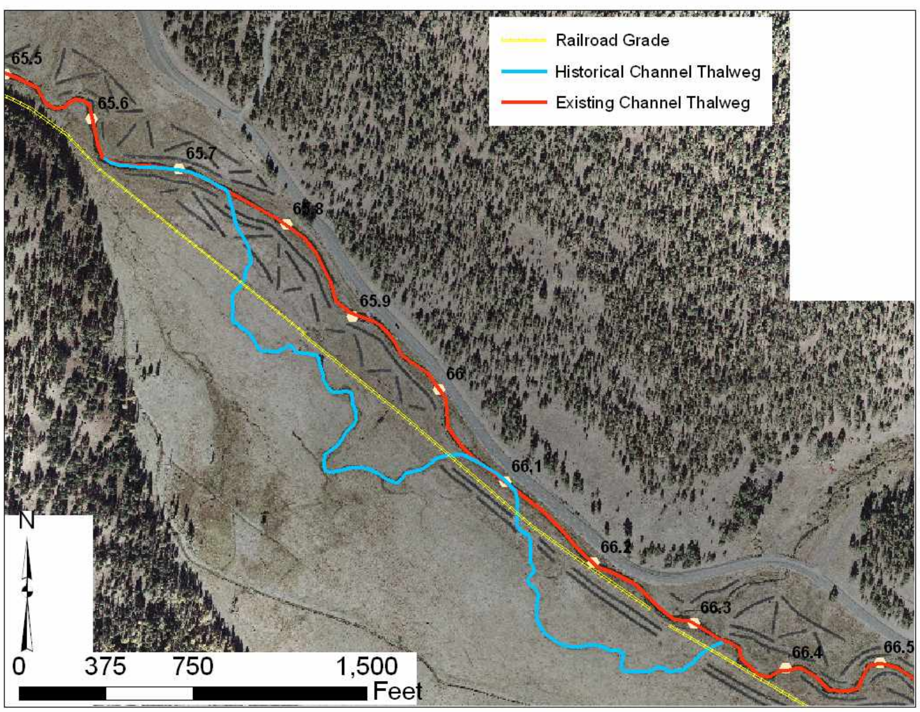

Figure 45. Existing and historical channel thalweg alignments between Vinegar and Vincent Creeks.

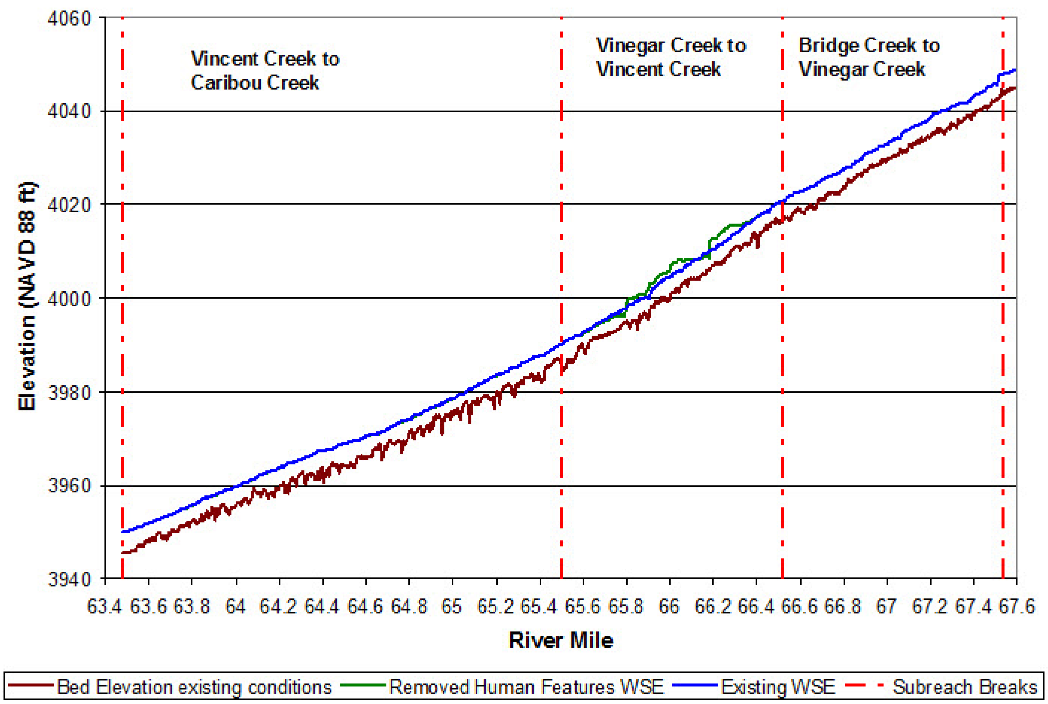

Figure 46. Bed and water surface elevation along the existing channel thalweg for a 2-year discharge.

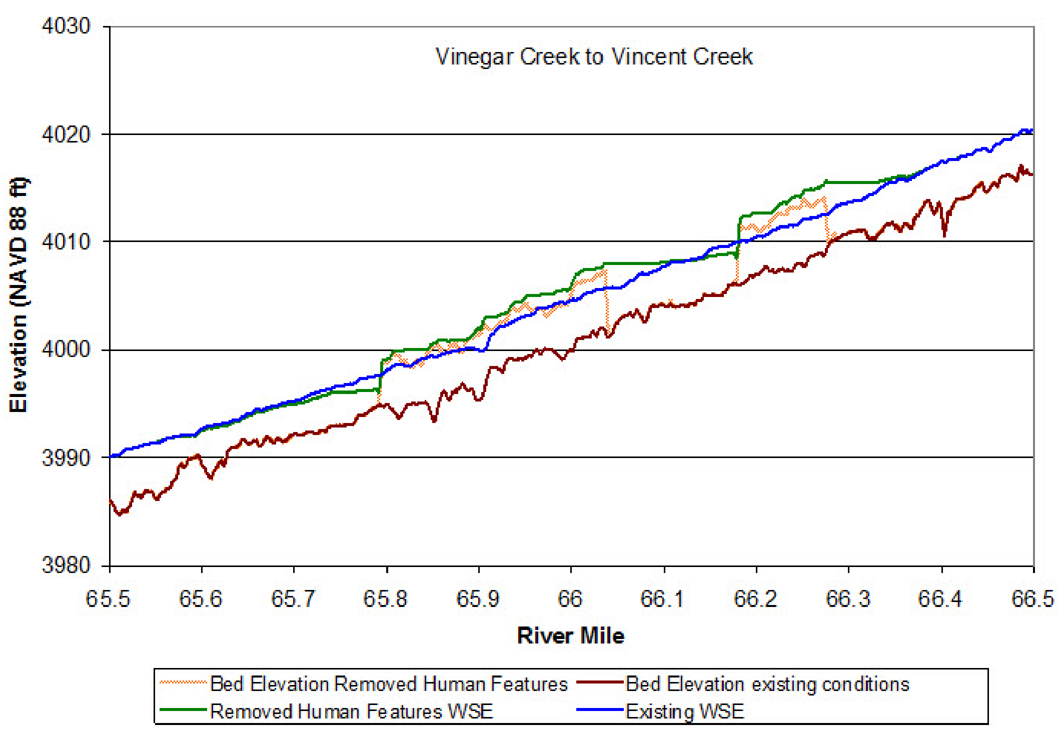

Figure 47. Zoomed in view of water surface and bed elevations along the existing channel thalweg for a 2-year discharge.

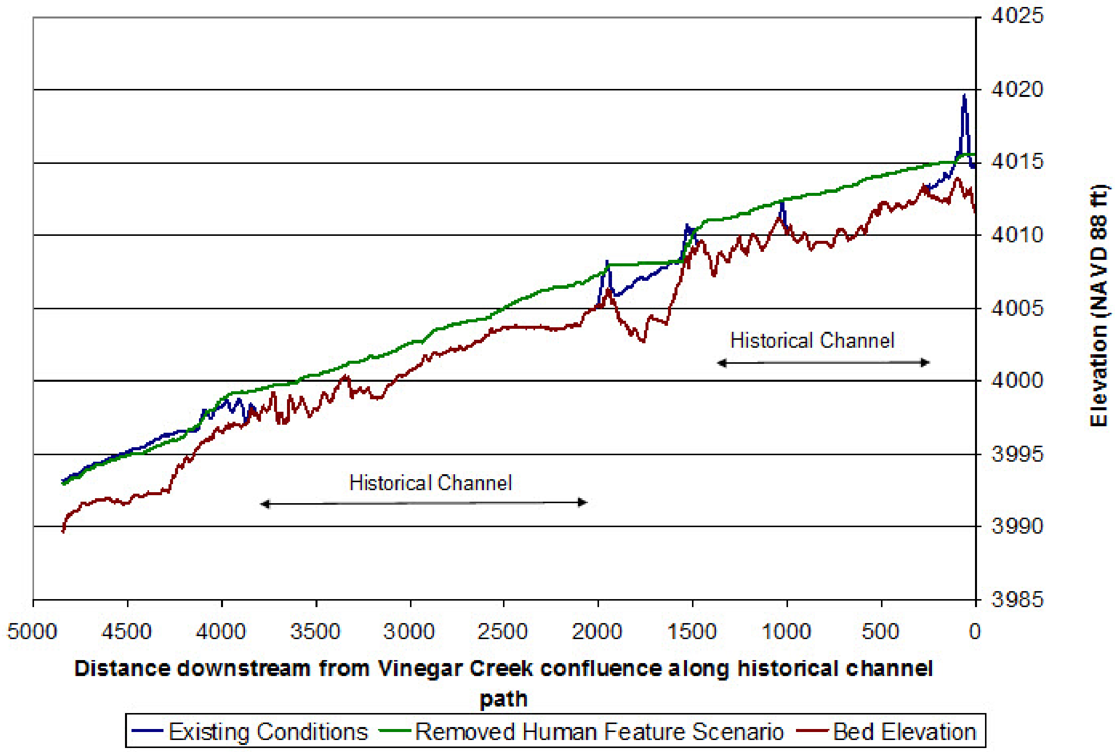

Figure 48. Bed and water surface elevation profiles along the historical channel thalweg between Vinegar and Vincent Creeks for a 2-year discharge. Locations noted as historical channel on the graph are blocked under existing conditions due to the railroad grade.

3.4 Hydraulic Parameters

Hydraulic parameters (flow depth, bed shear stress, and depth averaged velocity) were evaluated longitudinally along the channel thalweg and also based on area across the channel and floodplain. Longitudinal and areal distributions of hydraulic parameters were examined to determine how the values change between existing conditions and the Removed Human Feature Scenario. Longitudinal changes in the parameters were examined by digitizing a line along the existing and historical channel thalwegs and extracting values from the model results along the line at intervals of about 1 foot in ArcGIS.

To evaluate the areal distributions, Triangulated Irregular Networks (TINs) of depth, velocity, and bed shear stress were created in ArcGIS for both conditions. A module was used to divide the TIN surfaces into specified bins and compute the surface area within each bin. Distributions were evaluated for the 2- through 100-year peak discharges. The aerial distributions provide insight into changes in the spatial distribution of the hydraulic parameters such as where and how hydraulic parameters increase or decrease from one scenario to the next. Spatial comparisons were completed by quantifying changes in distributions for each parameter for each modeled discharge. In addition, the magnitude of the differences within each cell was plotted for the 2-, 10-, and 100-year discharge by intersecting the TINs between the existing conditions and Removed Human Features Scenario. The following sections describe the model results of flow depth, depth-averaged velocity, and bed shear stress.

3.4.1 Flow Depth

The total area inundated increased under the Removed Human Features Scenario by 54 acres, 45 acres, and 8.0 acres for the 2-year, 10-year, and 100-year flow events, respectively. Differences in flow depth between the existing conditions and the Removed Human Features Scenario are most notable in between the Vinegar and Vincent Creeks as shown in Figure 49 and Figure 50. Almost no changes in flow depth are present upstream of Vinegar Creek for any of the flows modeled. With the railroad removed and portions of the channelized section of the river blocked, the floodplain along the south western side of the valley is characterized by greater depths, and the historic channel becomes activated. Reduced depths are noted in the existing channel that was blocked under the Removed Human Features Scenarios. Depth reductions are also apparent in some localized floodplain areas due to an increase in accessible floodplain area. In other words, as more flow can access and inundate a greater area due to removal of the railroad, the depth of the previously inundated area is reduced and spread across a greater area. These results indicate increased floodplain connectivity across the floodplain of the middle subreach, between Vinegar and Vincent Creeks, under the Removed Human Features Scenario. Within the downstream subreach, changes in flow depth occurred in a few localized areas as shown in Figure 51 and Figure 52. In these areas, flow depths on the floodplain adjacent to the channel are generally reduced due to an increase in the total accessible floodplain area resulting from removal of the railroad grade. With the railroad grade removed, increases in the flow depth occur in previously disconnected floodplain areas, including along the railroad grade.

Evaluation of longitudinal changes in depth along the existing channel thalweg indicates substantial decreases in depth between Vinegar and Vincent Creeks under the Removed Human Features Scenario (Figure 53). Depths drop to less than one foot for a 2-year discharge where the existing channel is blocked. Just upstream from where the channel is blocked, however, short distances of dramatically increased depths were simulated due to back water impacts from the blocked section of the channel. Figure 54 illustrates depths along the historical channel thalweg, portions of which are not activated for a 2-year discharge under existing conditions. These areas become activated with depths between 1 and 4 feet when the railroad grade is removed.

Distribution graphs indicate that the total area characterized by depths greater than 3 feet tends to decrease under the Removed Human Features Scenario for all discharges evaluated.

With the railroad grade removed, more floodplain total area is characterized by depths between 0 to 2.5 feet. For a 2- to 10-year discharge, most increases in floodplain area occur along the south west side of the railroad grade and have depths ranging between 0 and 1.0 feet. For the 100-year discharge, the floodplain area with depths between 0 to 0.5 feet decreases when the railroad grade was removed, mostly because depths in those areas increased above 0.5 feet. The total area with depths greater than 3.0 feet is reduced with the railroad grade removed for the 2- to 10-year discharges, and the total area with depths greater than 4.0 feet is reduced for the 100-year discharge. Maps showing the results for the 2-, 10-, and 100-year peak discharge are presented in the Electronic Appendix 4.

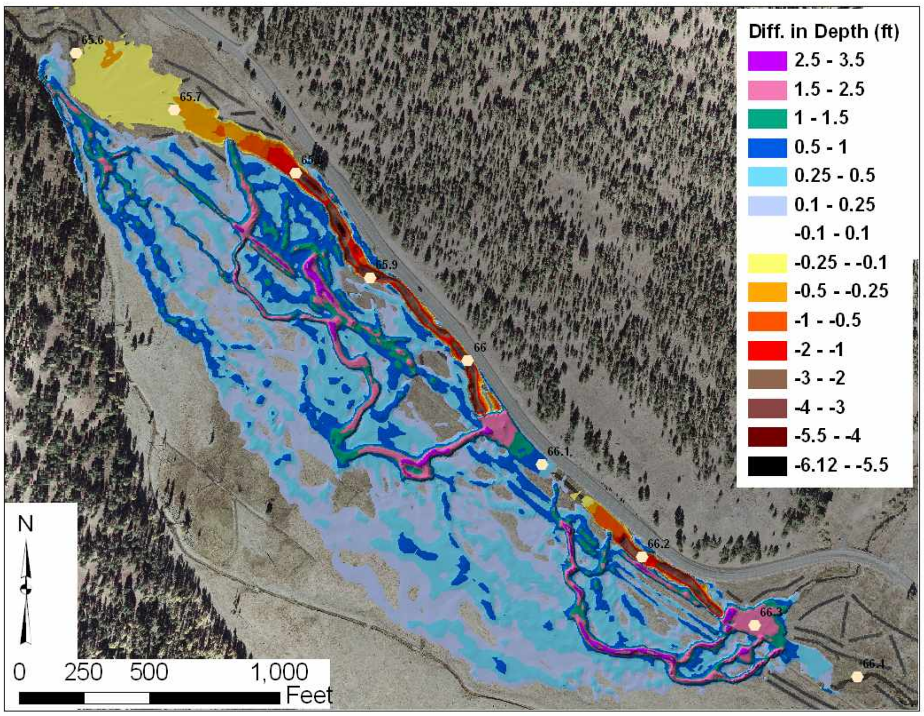

Figure 49. Difference in depth in the middle subreach between existing conditions and Removed Human Features Scenario for a 2-year discharge. A positive value indicates an increase when the railroad grade is removed.

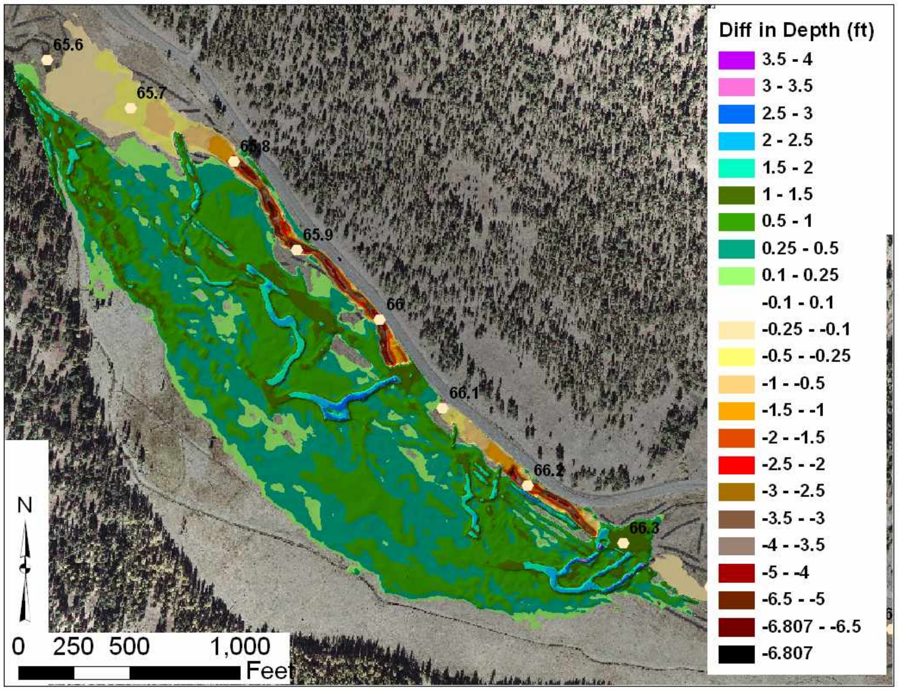

Figure 50. Difference in Depth in the middle subreach between existing conditions and Removed Human Features Scenario for a 10-year discharge. A positive value indicates an increase when the railroad grade is removed.

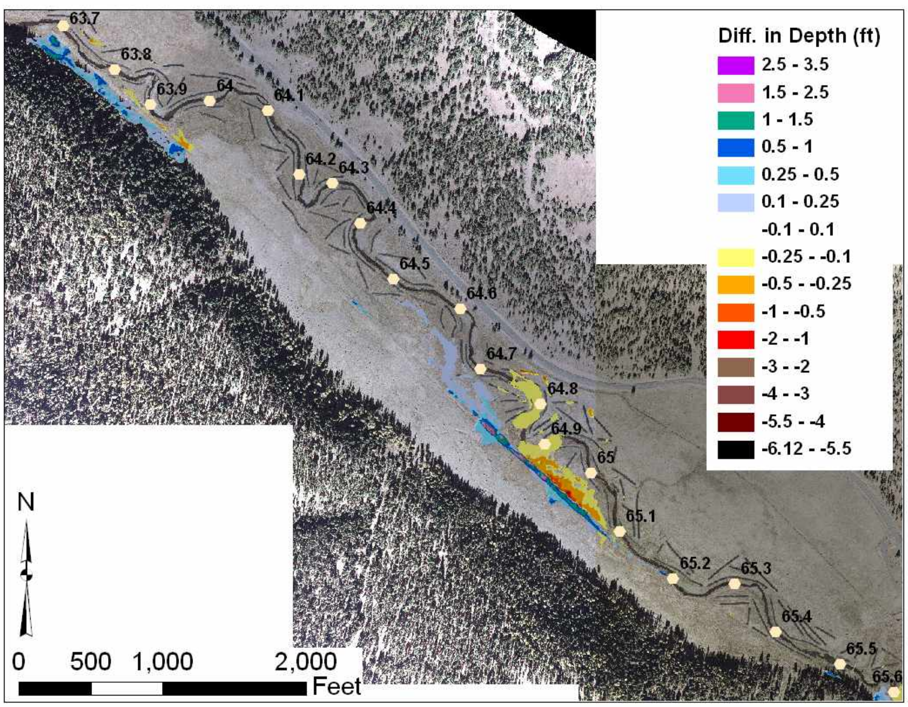

Figure 51. Difference in depth in the downstream subreach between existing conditions and Removed Human Features Scenario for a 2-year discharge. A positive value indicates an increase when the railroad grade is removed.

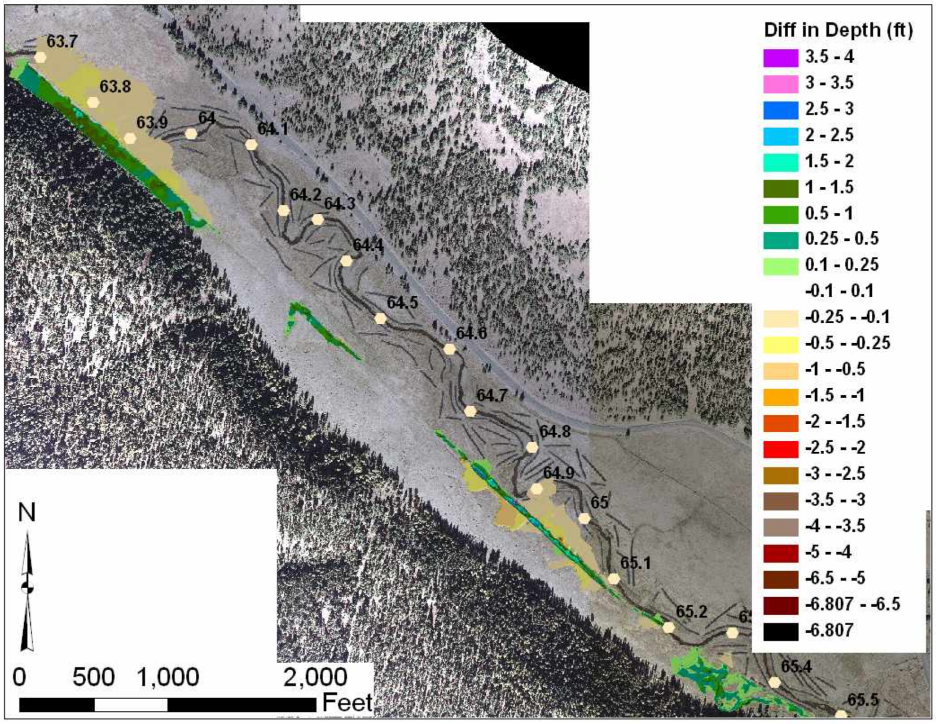

Figure 52. Difference in depth in the downstream subreach between existing conditions and Removed Human Features Scenario for a 10-year discharge. A positive value indicates an increase when the railroad grade is removed.

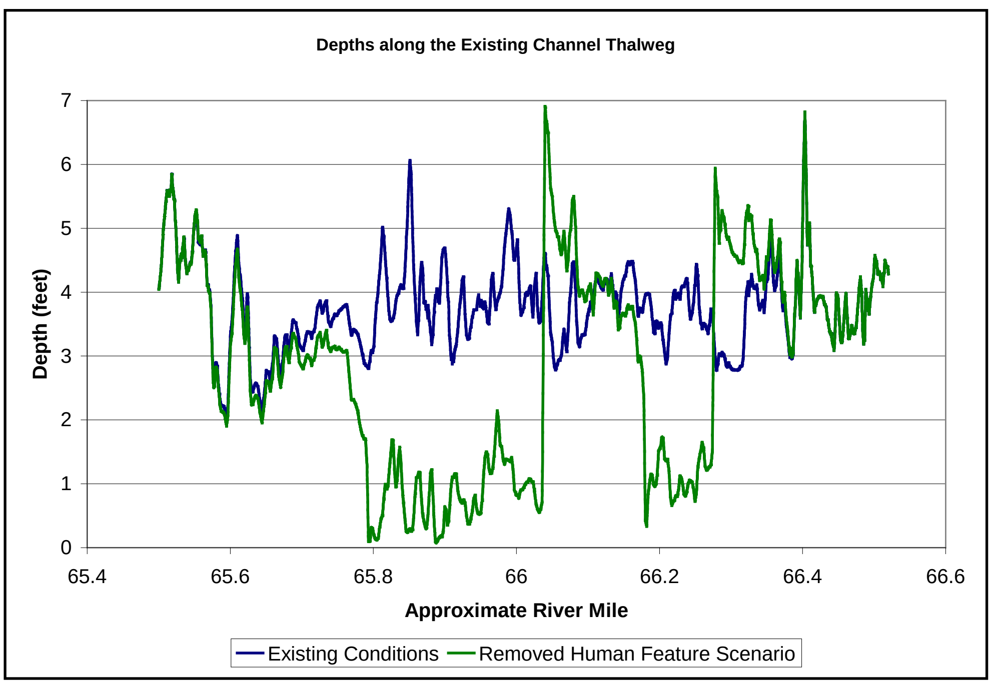

Figure 53. Comparison of channel depths in the middle subreach along the existing channel thalweg for the existing conditions and Removed Human Feature Scenario at a 2-year discharge.

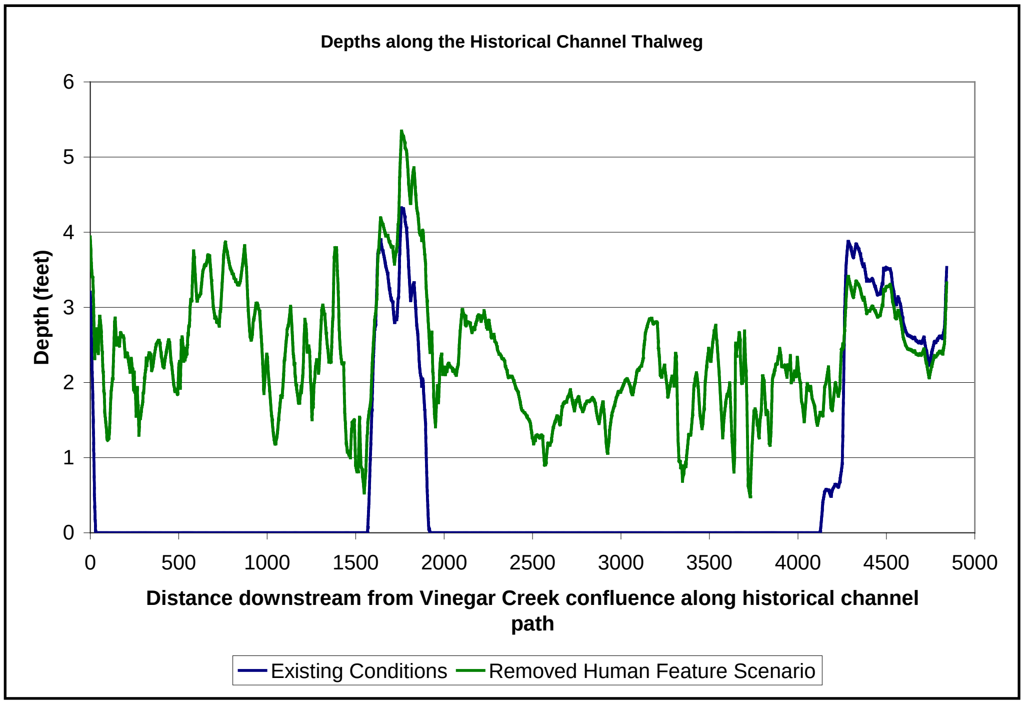

Figure 54. Comparison of channel depths in the middle subreach along the historical channel thalweg for the existing conditions and Removed Human Feature Scenario at a 2-year discharge.

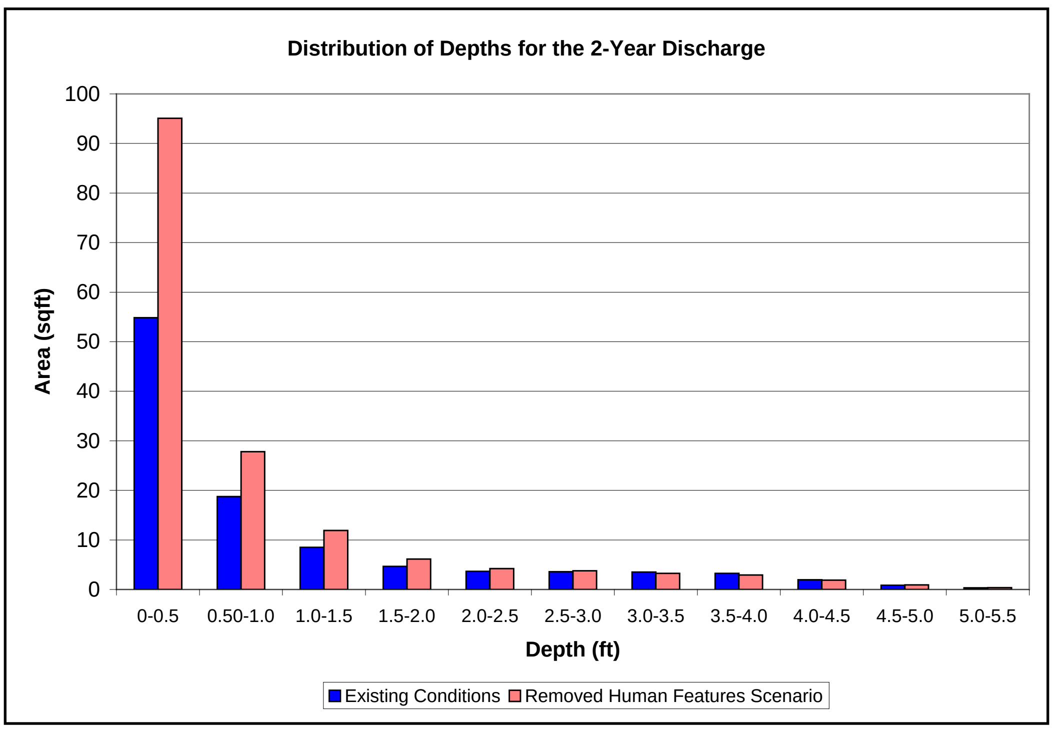

Figure 55. Distribution of depth for a 2-year discharge for the entire modeled reach under existing and proposed conditions.

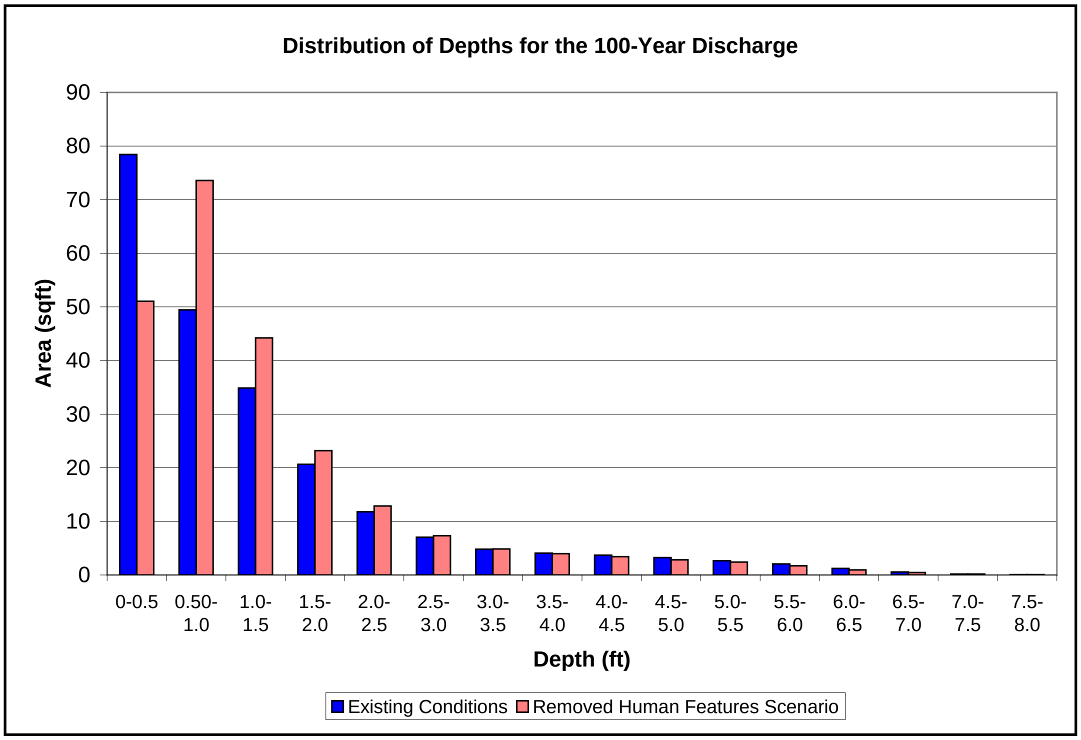

Figure 56. Distribution of depth for a 100-year discharge for the entire modeled reach under existing and proposed conditions.

3.4.2 Depth-Averaged Velocity

Similar to changes in flow depths, spatial changes in velocities are primarily present between Vinegar Creek and Vincent Creeks (Figure 57 to Figure 60) with small areas of localized changes between Vincent Creek and Caribou Creek. Both the areal and longitudinal comparisons clearly predict substantially reduced velocities in the existing channel between Vincent and Vinegar Creeks. Reductions of 5 ft/s are predicted in channelized portion of the existing channel that was blocked under the Removed Human Features Scenario. Within the historical channel, velocities increase up to 5 ft/s when the railroad grade is removed and the channel becomes activated. For a 2-year discharge, velocities along the floodplain adjacent to the historical channel typically increase by 0.25 to 2 ft/s, and increases for a 10-year discharge typically range between 1 and 2 ft/s. Along the historical channel thalweg, velocities are generally between 1 and 5 ft/s during a 2-year discharge for the Removed Human Features Scenario. Along the existing channel thalweg, high peaks in velocities occur near RM 65.8, RM 66, and RM 66.2 under the Removed Human Features Scenario. These peaks are artifacts of abrupt changes in topography where the existing channel was blocked and would not likely exist if smooth transitions are constructed between the blocked and unblocked portions of the existing channel.

Graphs of the distributions of velocity suggest that the total floodplain area experiencing velocities less than 4 feet per second is increased under the Removed Human Features Scenario for all modeled discharges. Floodplain area with velocities ranging between 0.5 and 1.5 ft/s experiences the greatest increase in area when the railroad grade is removed for a 2-year discharge. The floodplain area with velocities between 1.0 and 3.0 ft/s increases the most for a 10-year discharge, and between 1.5 and 3.0 ft/s for a 100-year discharge. A reduction in the total area experiencing velocities exceeding 5 ft/s is also noted across all modeled discharges.

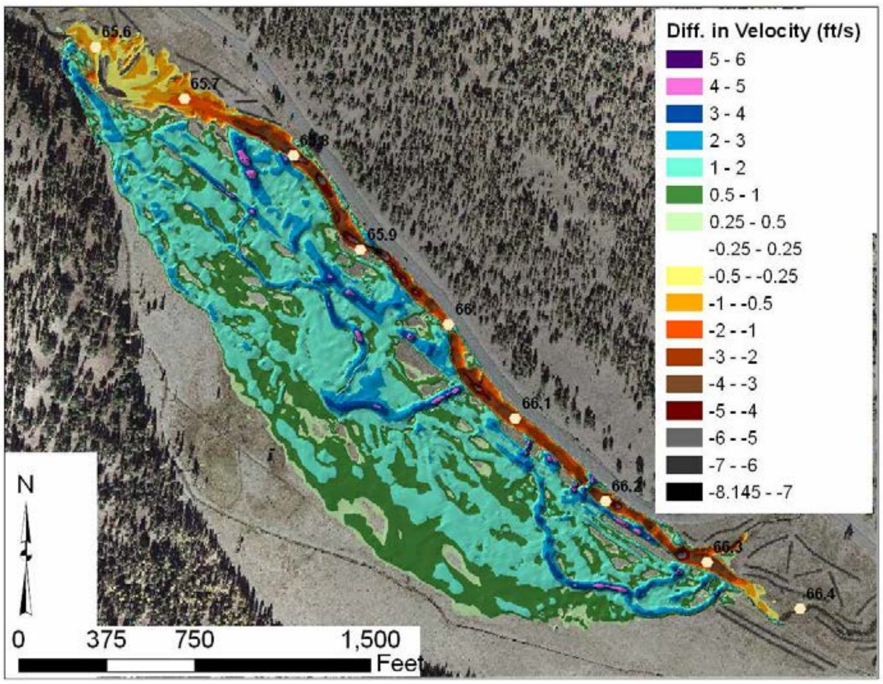

Figure 57. Difference in velocity in the middle subreach between existing conditions and Removed Human Features Scenario for a 2-year discharge. A positive value indicates an increase when the railroad grade is removed.

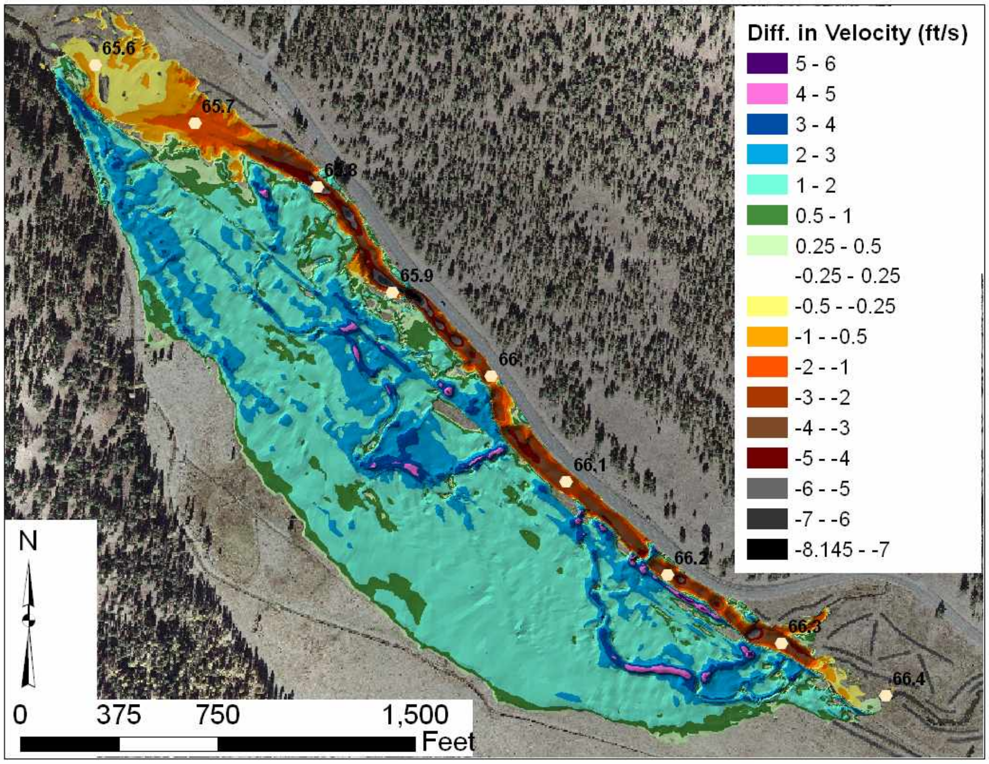

Figure 58. Difference in velocity in the middle subreach between existing conditions and Removed Human Features Scenario for a 10-year discharge. A positive value indicates an increase when the railroad grade is removed.

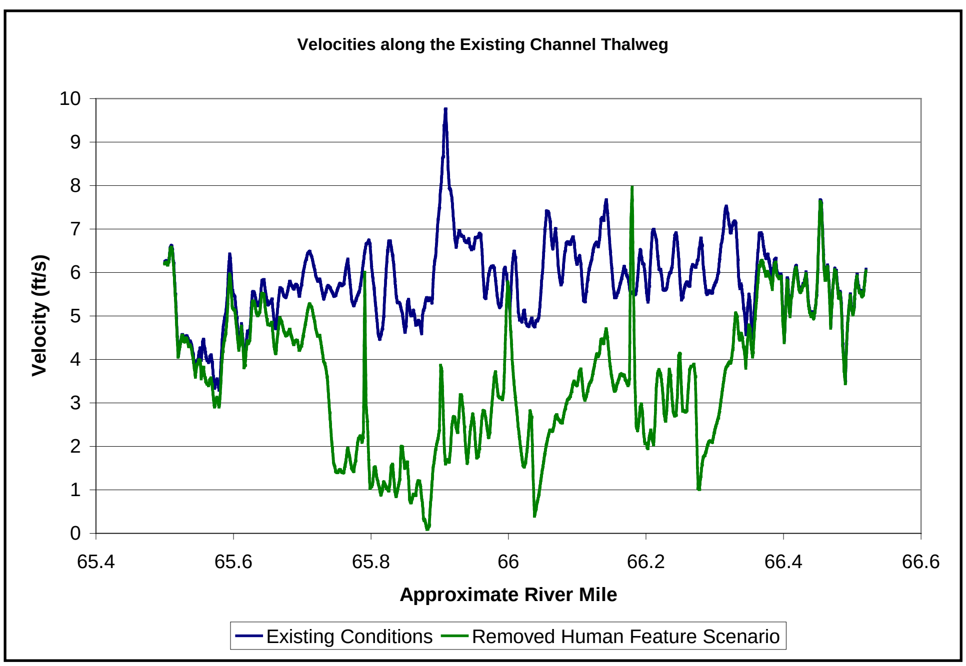

Figure 59. Comparison of velocities in the middle subreach along the existing channel thalweg for the existing conditions and Removed Human Feature Scenario at a 2-year discharge.

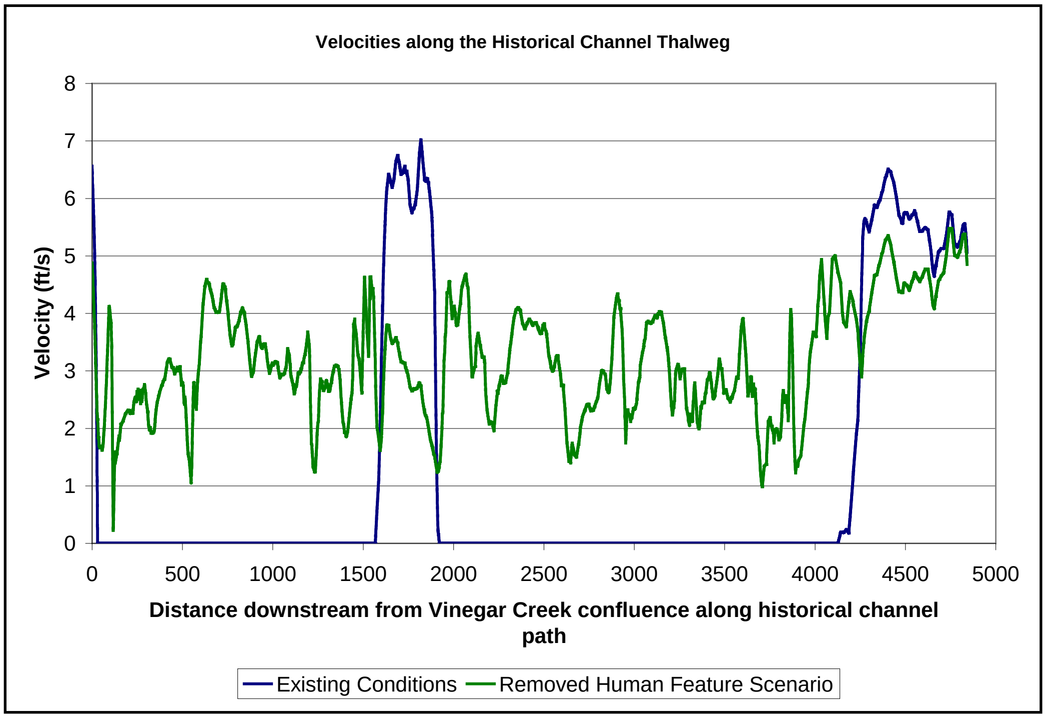

Figure 60. Comparison of velocities in the middle subreach along the historical channel thalweg for the existing conditions and Removed Human Feature Scenario at a 2-year discharge.

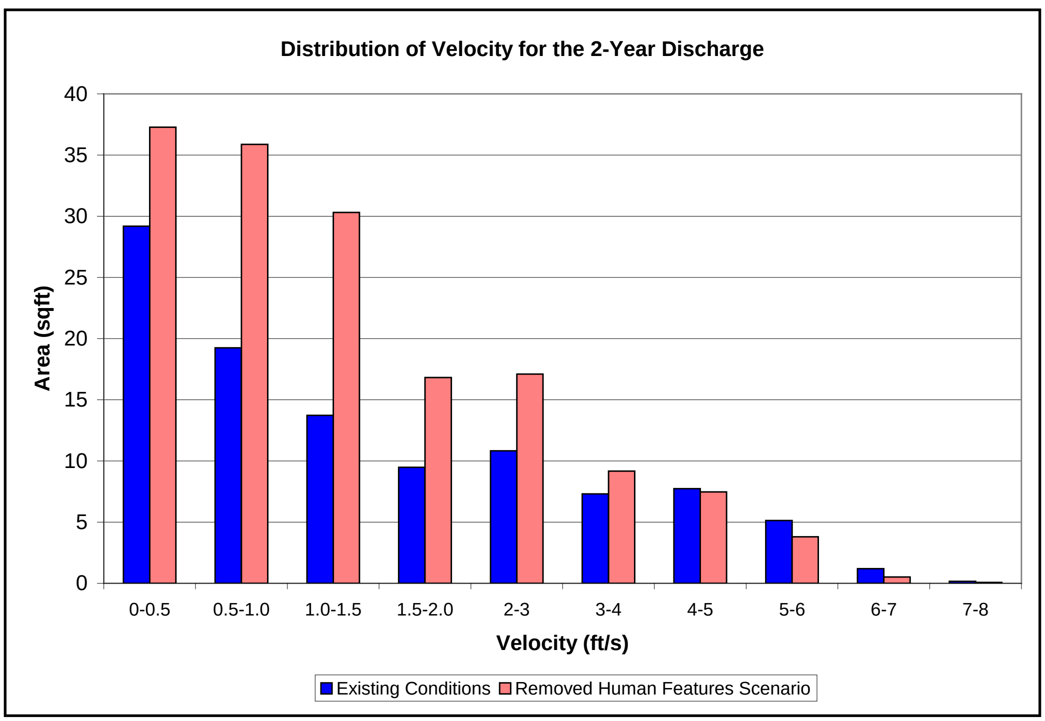

Figure 61. Distribution of velocity for a 2-year discharge for the entire modeled reach under existing and proposed conditions.

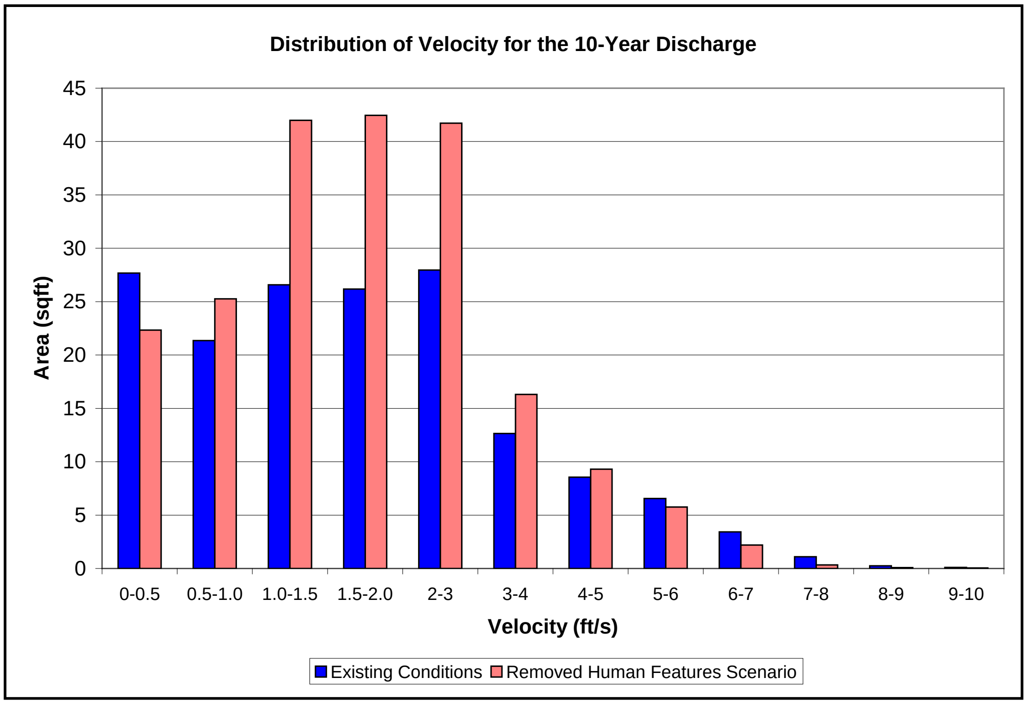

Figure 62. Distribution of velocity for a 10-year discharge for the entire modeled reach under existing and proposed conditions.

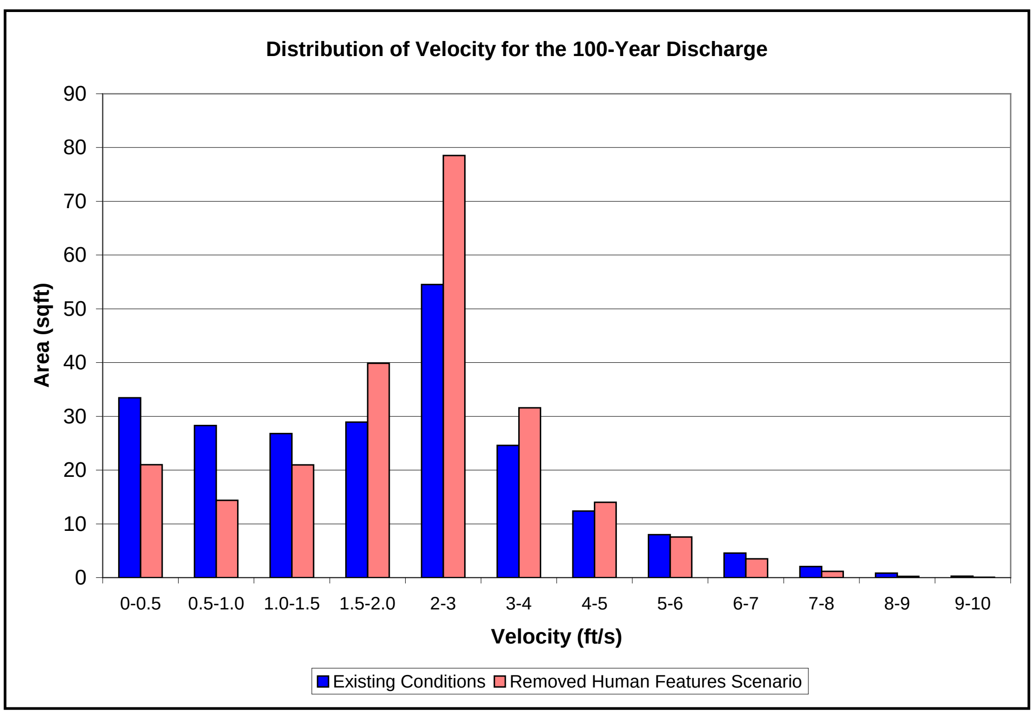

Figure 63. Distribution of velocity for a 100-year discharge for the entire modeled reach under existing and proposed conditions.

3.4.3 Bed Shear Stress

Bed shear stress follows patterns similar to depth-averaged velocities with most changes noted between Vinegar and Vincent Creeks (Figure 67 and Figure 68). Under existing conditions, the existing channel between Vinegar and Vincent Creeks acts as a transport reach, in which all incoming sediment is transported through the reach to the next downstream reach (Reclamation, 2008). This is primarily due to the fact that compared with historical conditions, the channel slope has increased; the channel entrenchment has substantially increased, and velocities through this short reach are greater. These conditions indicate that the channel is generally supply-limited between Vinegar and Vincent Creek under existing conditions. Bed shear stresses between Vinegar and Vincent Creeks average just over 1 lb/sf during a 2-year discharge under existing conditions, indicating that the channel could mobilize small cobbles. However, the capacity of the existing channel to transport sediment exceeds the actual sediment supplied to the reach because of the modifications from the historical meandering pattern of the channel. Bed shear stresses along the historical channel thalweg average close to 0.4 lb/sf during a 2-year discharge when the railroad grade is removed, which would mobilize coarse gravels. These results suggest that removing the railroad and routing flows through the historical channel could promote a transport-limited condition, thereby increasing the lateral channel migration (dynamic erosion and depositional processes) associated with historical channel and adjacent floodplain.

Similar to results for velocities, high peaks in shear stresses occur along the existing channel thalweg near RM 65.8, RM 66, and RM 66.2 under the Removed Human Features Scenario. These peaks result from abrupt changes in topography where the existing channel was blocked. Final design and construction techniques, such as developing ramp-like features between the blocked and unblocked portions of the existing channel would prevent the sharp changes in topography and reduce shear stresses experienced on the channel bed.

No noteworthy changes in shear stress were modeled upstream of Vinegar Creek. Some localized changes in shear stress along the floodplain between Vincent Creek and Caribou Creek were simulated under the Removed Human Features Scenario as shown in Figure 66. Increases in shear stress are notable where the railroad was removed along the south side of the floodplain, which resulted in slight decreases in shear stresses across other portions of the floodplain where flow is confined under existing conditions.

Distribution plots illustrate an increase in area with shear stresses less than 1 lb/sf under the Removed Human Features scenario for a 2-year discharge. The increased area with shear stresses less than 1 lb/sf generally corresponds to the increased area inundated along the floodplain of the historical channel. Areas characterized by shear stresses exceeding 1 lb/sf, which were generally localized to the existing channel, decreased from existing conditions to Removed Human Feature conditions. Example plots of bed shear stress distributions for the 2- and 100-year discharges are illustrated in Figure 69 and Figure 70.

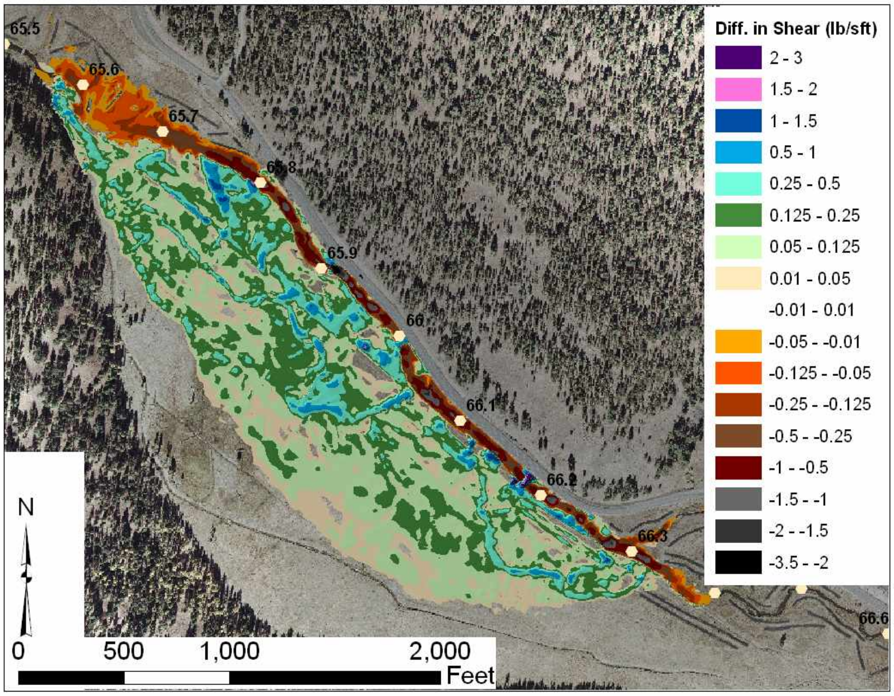

Figure 64. Difference in shear stress in the middle subreach between existing conditions and Removed Human Features Scenario for a 2-year discharge. A positive value indicates an increase when the railroad grade is removed.

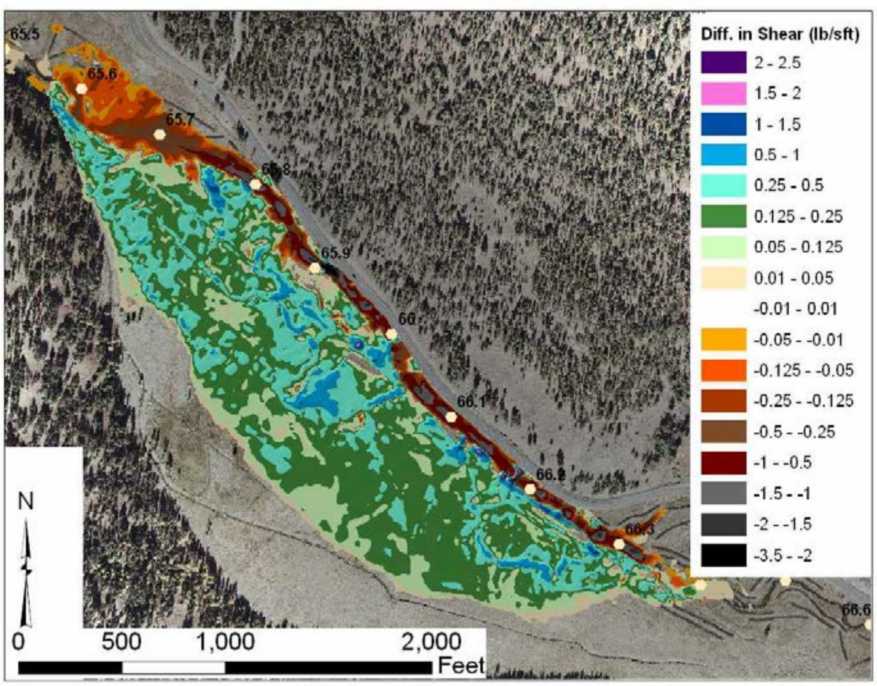

Figure 65. Difference in shear stress in the middle subreach between existing conditions and Removed Human Features Scenario for a 10-year discharge. A positive value indicates an increase when the railroad grade is removed.

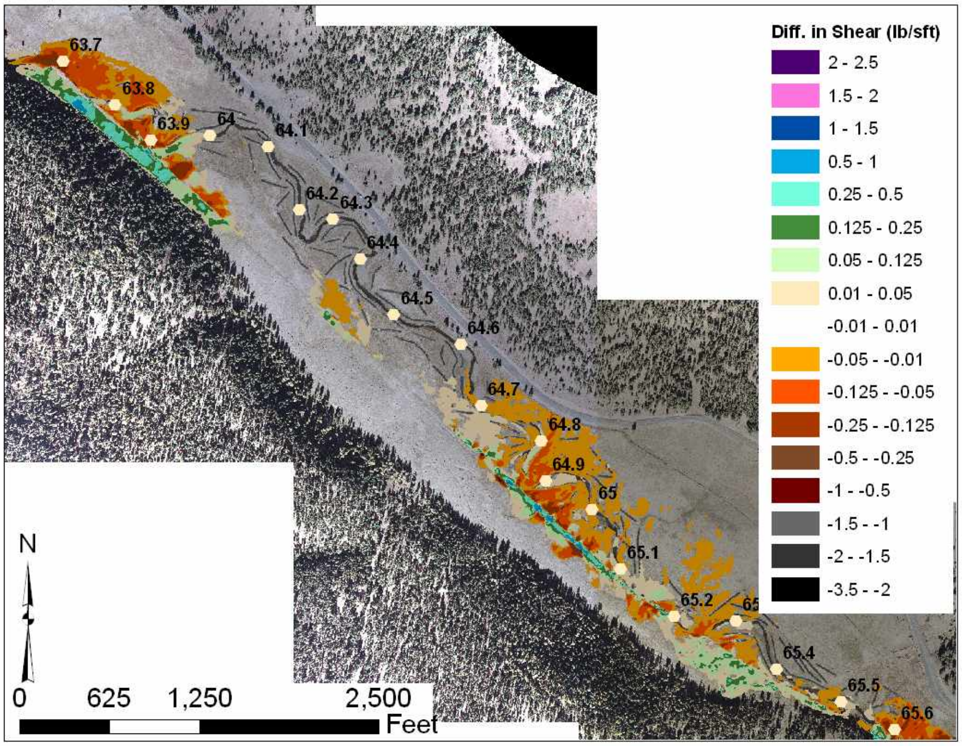

Figure 66. Difference in shear stress in the downstream subreach between existing conditions and Removed Human Features Scenario for a 10-year discharge. A positive value indicates an increase when the railroad grade is removed.

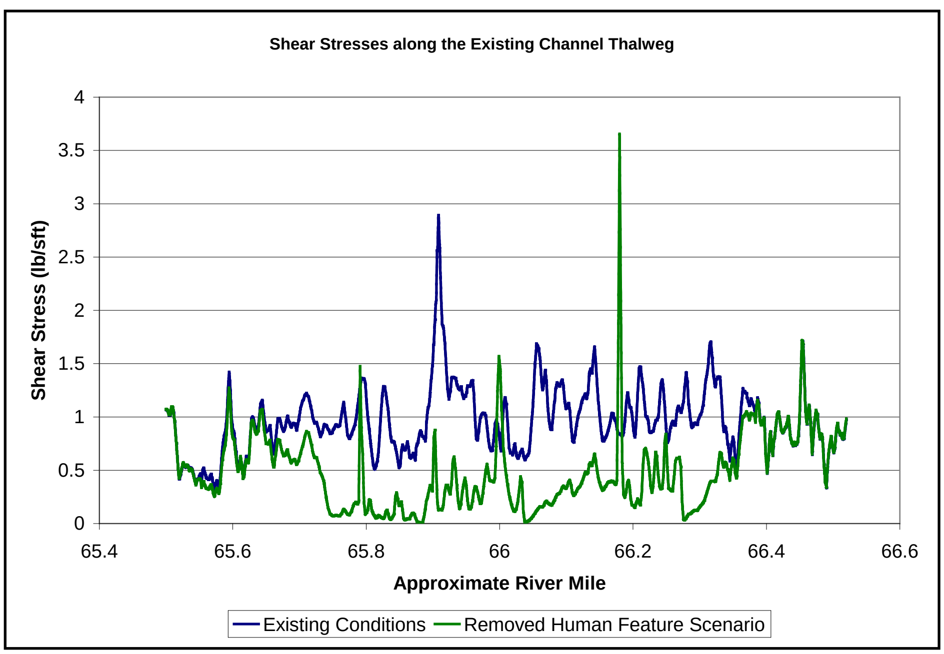

Figure 67. Comparison of shear stresses in the middle subreach along the existing channel thalweg for the existing conditions and Removed Human Feature Scenario at a 2-year discharge.

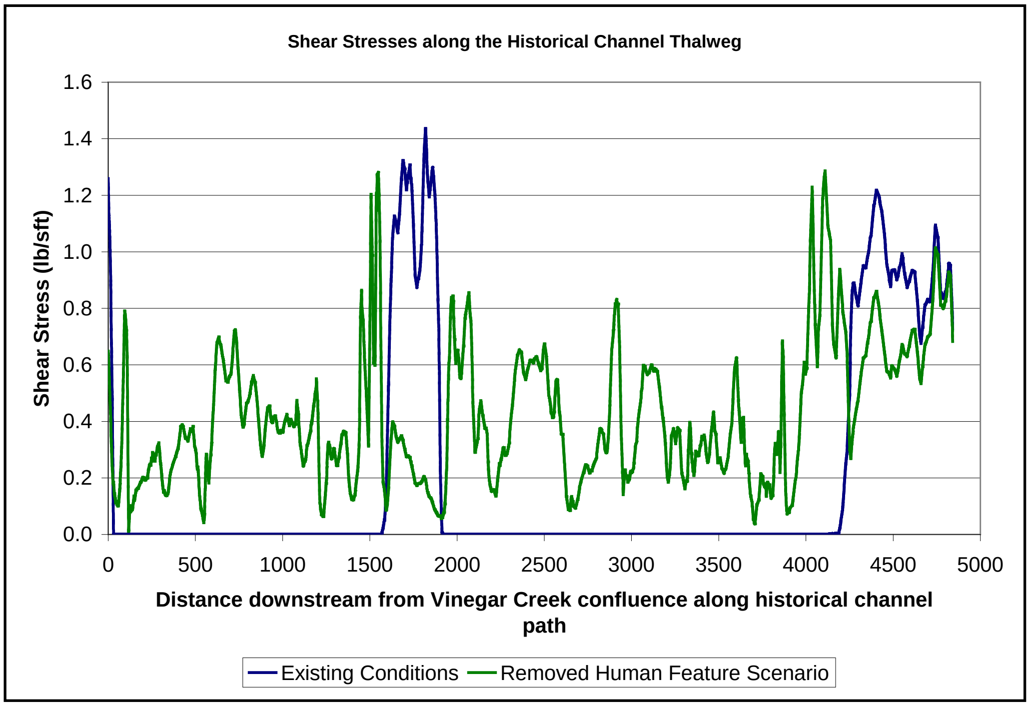

Figure 68. Comparison of shear stresses in the middle subreach along the historical channel thalweg for the existing conditions and Removed Human Feature Scenario at a 2-year discharge.

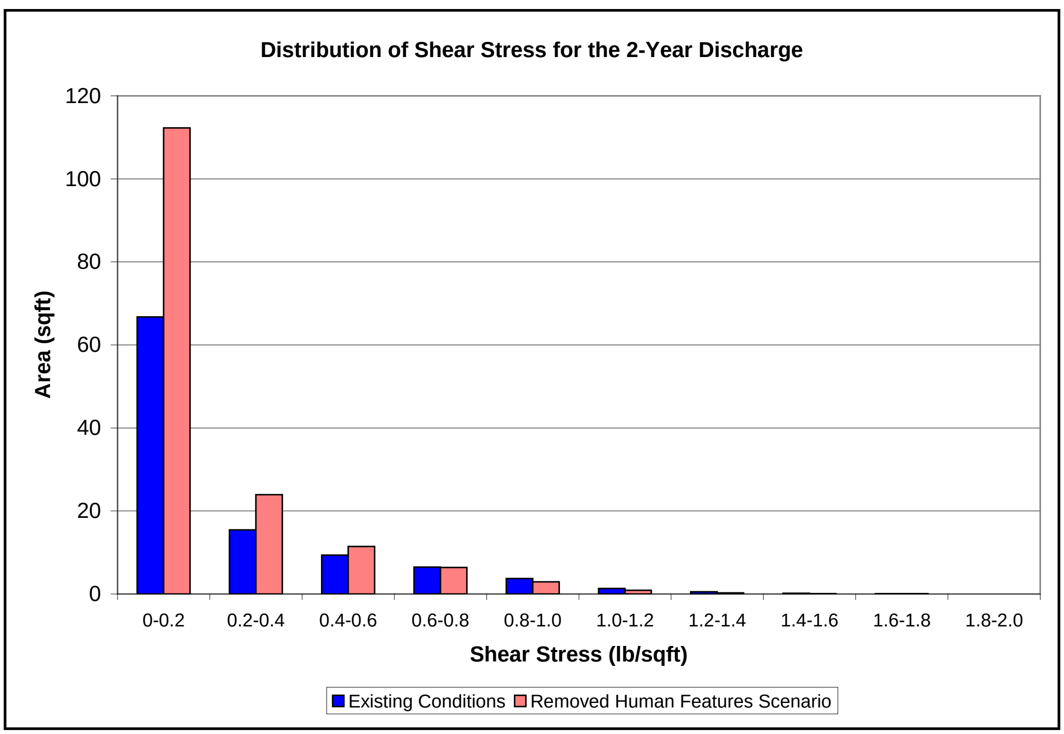

Figure 69. Distribution of shear stress for a 2-year discharge for the entire modeled reach under existing and proposed conditions.

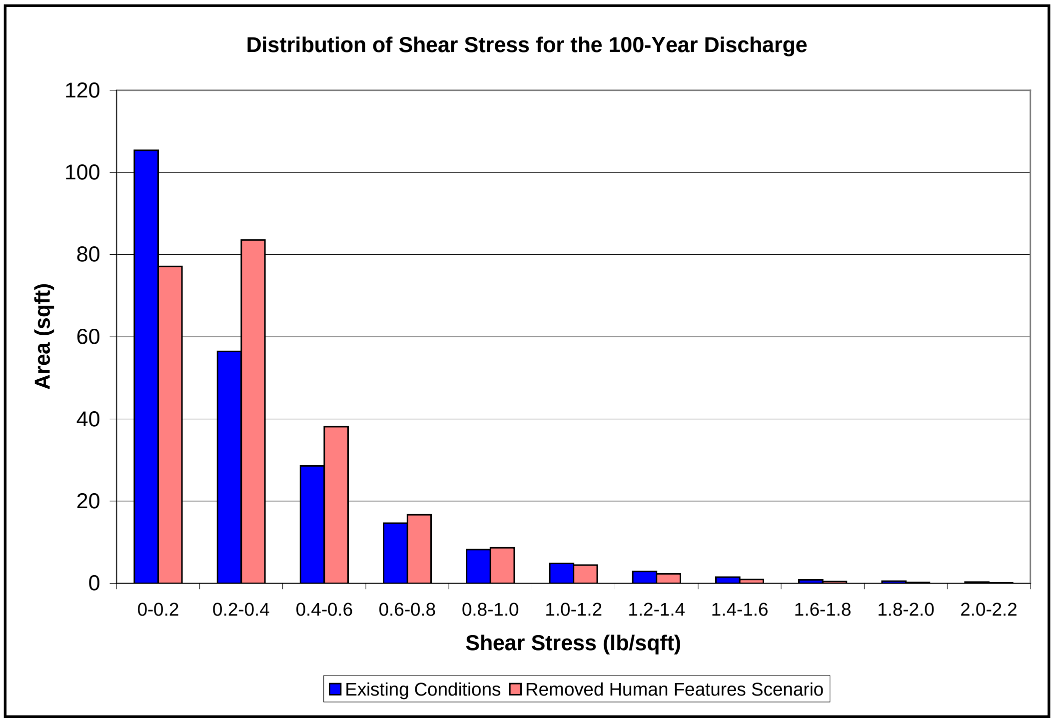

Figure 70. Distribution of shear stress for a 100-year discharge for the entire modeled reach under existing and proposed conditions.

3.4.4 Limitations Due to Sensitivity and Variability

Limitations of Model Analysis

Low Flow Conditions

The surface topography outside of the active channel was developed from LiDAR data with a close spacing. However, within the active channel area, survey data were used with a much wider spacing, typically sufficient to create 2-foot contours. While this spacing is sufficient to capture the area of the channel, subtle changes in the surface topography are not detectable with this level of bathymetric data. As a result, the models developed are capable of capturing two-dimensional hydraulics through the channel for flows that are close to or exceeding bankfull. Lower flows could be modeled through the reach. However, the ability of the hydraulic model to capture two-dimensional hydraulics resulting from small topographic changes, such as the presence of boulders or wood in the channel, is limited. This model was developed to capture higher magnitude flows and to use as a tool for comparison between different scenarios at those flows. Flows having a magnitude of a 2-year discharge and greater are typically responsible for the channel forming processes and for the formation and maintenance of floodplain habitat.

Calibration

A qualitative comparison of ground photos with model results for flows measured during May 2009 demonstrated that inundation areas were represented well by the model. Following the initial model runs, hydraulic roughness values in the side and overbank areas were slightly adjusted to better represent the inundated areas. However, no quantitative calibration information of hydraulic parameters, such as depths, was available with which to compare model results. While values of depth and velocity at any one location in the model may vary slightly from measured results, this model is well suited for comparisons between and among various discharges and potential rehabilitation option scenarios. Better model calibration and validation data of existing conditions could reduce potential variability between the model results and measured conditions.

Flow Estimates

This model was developed to investigate high flows on the Middle Fork John Day River through the Forrest Conservation Area. The 2-year through 100-year peak flows for the inlet conditions of the FCA were determined using a regional regression equation based on drainage area, mean annual precipitation, and percent forest cover (Reclamation 2008). Inlet flow for the Vinegar Creek, Vincent Creek, Placer Creek, Davis Creek, and Bridge Creek were determined based on their increased drainage area contributions to the Middle Fork John Day River and do not represent the 2-year through 100-year discharges in each of the tributaries. As such, a 2-year discharge is only representative of a 2-year discharge through the Middle Fork John Day River and not a 2-year discharge on all tributaries and the Middle Fork John Day River. Modeling a 2-year discharge simultaneously in all of the tributaries would result in a discharge exceeding a 2-year recurrence interval along the mainstem of the Middle Fork John Day River. Measured discharges in the tributaries and main channel in combination with surveyed water surface elevations could improve calibration of this model and corresponding estimates for the hydraulic parameters evaluated in this report.

Hydraulic Modeling Sensitivity

To more clearly understand how sensitive the model is to changes in various model input parameters, sensitivity analyses were conducted on the downstream boundary condition and the hydraulic roughness using the 2-year SRH-2D existing conditions model. These values are typically modified during a model calibration process.

The original downstream boundary water surface elevation for each modeled discharge was based on results of the 1D model developed in the Tributary Assessment. To determine the sensitivity of the downstream boundary condition on the model results, the 2D model was run by varying the downstream water surface elevation ± 0.5 feet from the condition calculated from the 1D model. This sensitivity analysis was conducted for the 2-year discharge to understand how far upstream the downstream boundary condition impacts the hydraulic model results. Using the 1D model generated in the Tributary Assessment, the downstream stage for a 2-year discharge was 3948.68 feet. Varying the downstream boundary condition resulted in changes in water depths for approximately 700 feet upstream from the downstream boundary (Figure 71). For flows exceeding a 2-year discharge, the extent of the downstream boundary may increase further upstream but the difference in the depths will be small (less than 0.1 feet).

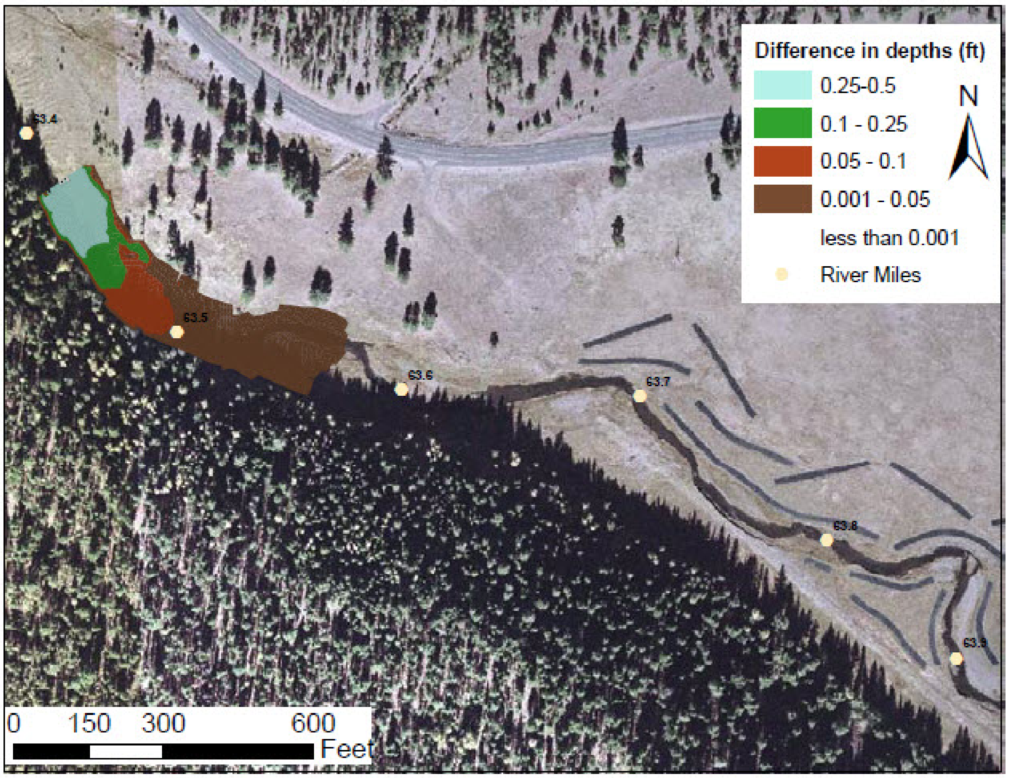

Figure 71. Difference in depths between the initial downstream boundary (3948.68 feet) and the higher downstream boundary (3949.18 feet).

The sensitivity of hydraulic roughness was tested by varying Manning's n in the 10-year existing conditions model. This discharge was selected to capture potential differences within the channel and across the floodplain and side channels. Results presented in the report thus far are based on a Manning's n value of 0.039 in the channel and values ranging between 0.045 and 0.065 along the floodplain and adjacent heavily vegetated terraces. During the sensitivity runs, the values were increased and decreased by 0.05 to investigate potential modifications to the results from differing hydraulic roughness coefficients (Table 6; Figure 73). The sensitivity simulations predicted changes in depths typically less than 0.2 feet in the channel and along the floodplain based on increased and decreased Manning's n values. The greatest changes were close to 0.3 feet and located within the channelized portion of the existing channel between Vinegar and Vincent Creek.

Table 6. Hydraulic roughness values used in the model development and in the sensitivity test.

	Manning's Roughness Coefficient			
Roughness Classification	**Initial Value**	**Adjusted Value***	**High Sensitivity Run**	**Low Sensitivity Run**
Channel	0.039	0.039	0.044	0.034
Light Vegetation	0.043	0.045	0.050	0.040
Medium Vegetation	0.053	0.055	0.060	0.050
Heavy Vegetation	0.063	0.065	0.070	0.060
Bridge	0.039	0.039	0.044	0.034
Side Channel/ Historical Main Channel/ Tributary	0.039	0.042	0.047	0.037
Road and embankment	0.050	0.050	0.055	0.045
Levee	0.043	0.043	0.048	0.038
Steep Tributary with larger bed material than main channel	0.043	0.043	0.048	0.038

* Hydraulic roughness adjusted in final model runs based on qualitative calibration of model results.

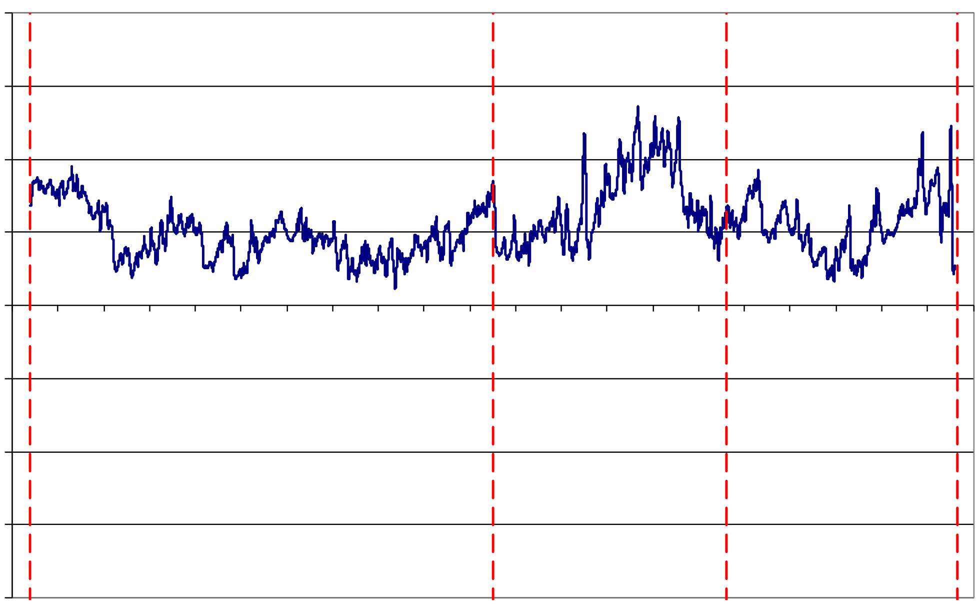

Figure 72. Deviations in water surface elevations along the existing channel thalweg with hydraulic roughness values increased or decreased by 0.005 from the model results.

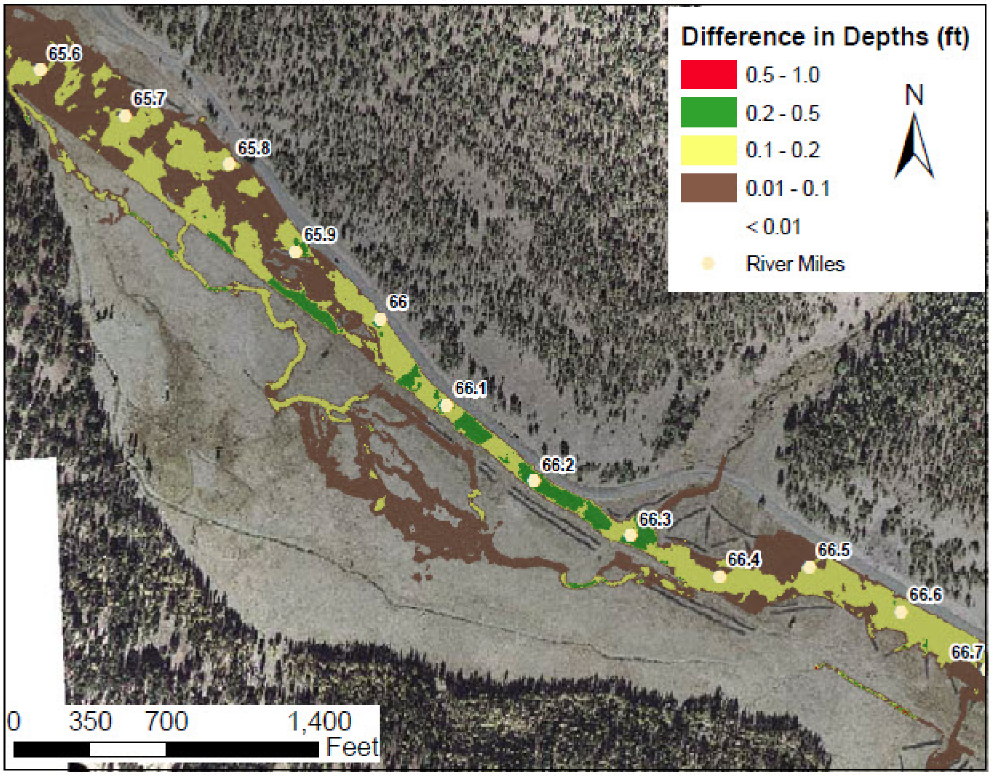

Figure 73. Difference in predicted depths between the final modeled roughness values and the increased roughness values.

Chapter 4 LINKING HYDRAULIC MODEL RESULTS TO GEOMORPHOLOGY AND HABITAT

Using the results of the 2D model, several habitat indicators, including side channel access, floodplain connectivity, high-quality high-flow habitat, and low flow habitat were investigated. Comparisons were made between existing conditions and Removed Human Features Scenario based on predicted changes to inundation depths, side channel activation, velocities, and also based on measured low flow habitat features.

4.1 Existing and Potential Floodplain Connectivity

To evaluate floodplain connectivity, the study area was analyzed on a subreach basis. For the purposes of this analysis, connected floodplain was defined as the area with depth exceeding 0.5 feet outside of the low flow channel, including side channels with depths exceeding 0.5 feet. These criteria were evaluated for all discharges modeled. Under existing conditions, the subreach between Bridge Creek and Vinegar Creek and the subreach between Vincent and Caribou Creek are fairly well inundated during most flood events with 18 to 32 percent of floodplain connected during a 2-year discharge, 35 to 50 percent of the floodplain connected during a 5-year discharge, and 46 to 60 percent of the floodplain connected during a 10-year discharge (Figure 74). Floodplain connectivity between Vinegar and Vincent Creeks is much more limited under existing conditions, with only 8 to 18 percent of the floodplain connected for a 2- to 10-year discharge, respectively.

Under the Removed Human Features scenario, slight increases in the total area of floodplain connected (typically less than 1 acre) are predicted between Bridge Creek and Vinegar Creek and between Vincent Creek and Caribou Creek. However, the greatest improvements to floodplain connectivity were simulated in the most heavily impacted subreach between Vinegar and Vincent Creeks. By removing the historical railroad grade and allowing flow to access the disconnected portion of the floodplain, the area of connected floodplain between Vinegar and Vincent Creeks increases by more than 200% for the flows modeled.

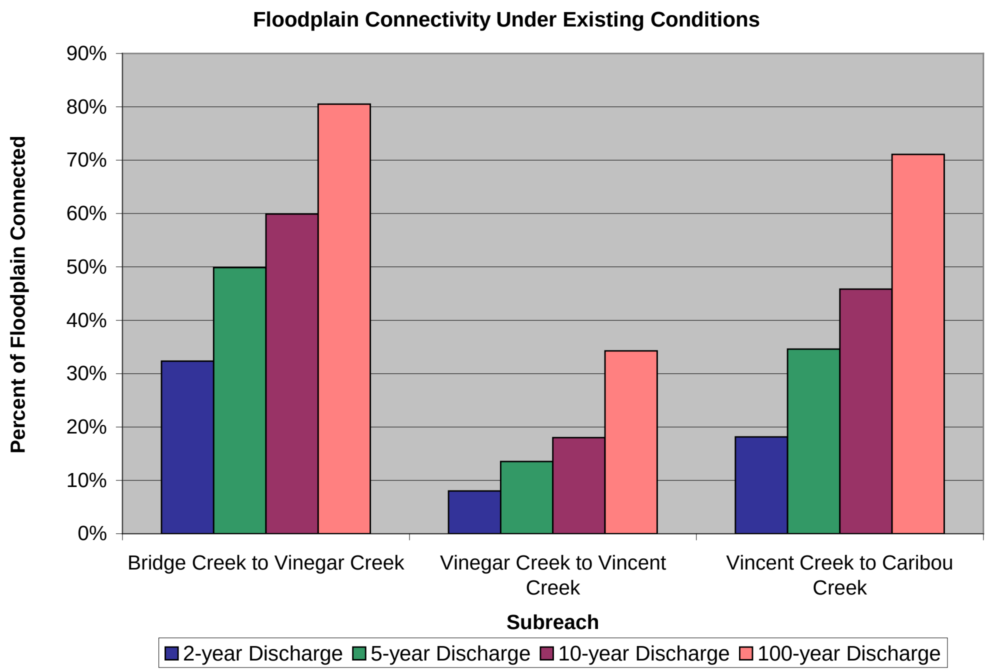

Figure 74. Percent of floodplain area meeting criteria for connectivity for each subreach under existing conditions.

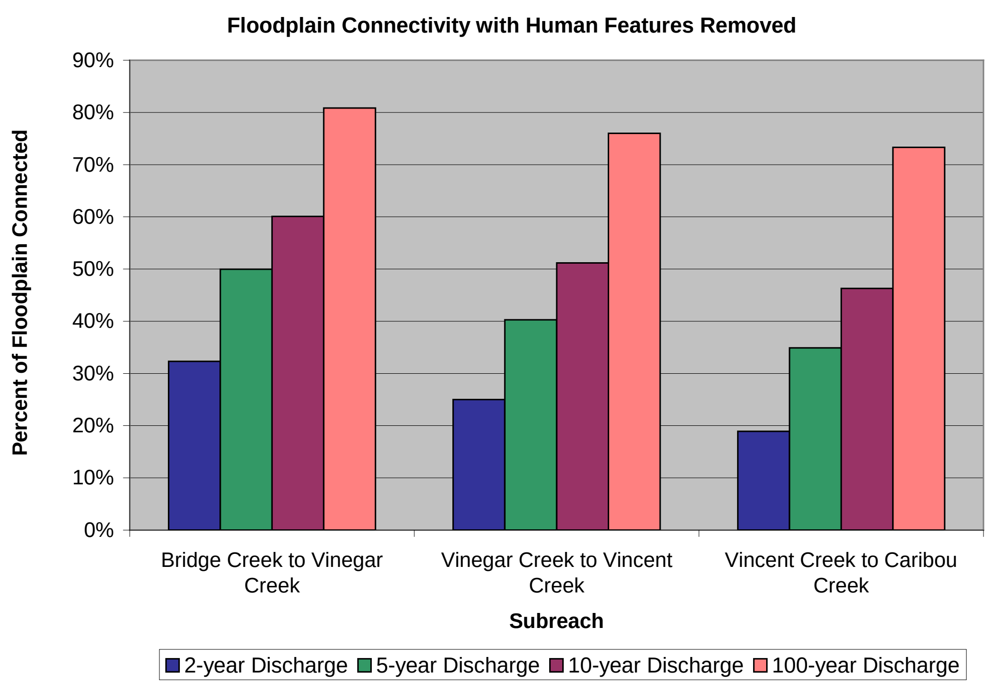

Figure 75. Percent of floodplain area meeting criteria for connectivity for each subreach under the Removed Human Features scenario.

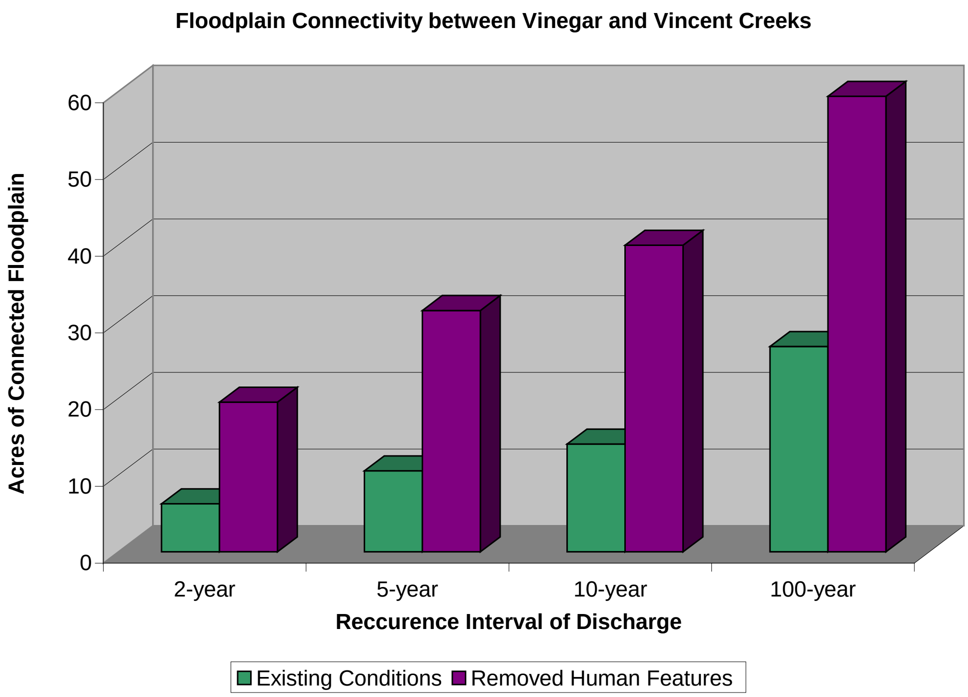

Figure 76. Acres of floodplain connected under existing conditions and the Removed Human Features scenario between Vinegar and Vincent Creeks.

4.2 Side Channel Connectivity

Side channel connectivity was evaluated for the existing conditions and the Removed Human Features scenario. Within the FCA, side channels are often comprised of a network of multiple, interconnected channels rather than one distinct channel path. Distinctly connected channels at flows between the 2- and 10-year discharges located outside of the main channel were mapped within each subreach based on the model results. Additional verification of side channel connectivity could be accomplished through field investigations during high flows for increased confidence in the existing and potential side channel activation. Results of the model suggest that most side channels are activated under existing conditions between Bridge Creek and Vinegar Creek and also between Vincent Creek and Caribou Creek. Side channel connectivity was predicted to experience the greatest increase from existing to Removed Human Feature conditions between Vinegar and Vincent Creeks.

Between Bridge Creek and Vinegar Creek, a short section (0.4 miles) of unconfined floodplain is separated from upstream and downstream portions of the subreach where the floodplain is heavily constricted by bedrock or alluvial fan deposits. Under existing conditions, this area is well inundated and consists of several interconnected side channels during a 2-year discharge. This area is unaffected by the Removed Human Features Scenario.

The total length of potential side channel connectivity in this subreach is estimated to be approximately 0.7 miles.

Under existing conditions, side channel connectivity in the subreach between Vinegar and Vincent Creeks is limited to one small area with approximately 660 feet of side channel just upstream of the Vinegar Creek confluence. However, the total length of accessible side channel connectivity increases to almost 1.8 miles with the railroad grade removed. Most of these side channels are interlinked and lie along the southwest side of the historical channel and floodplain.

Downstream of Vincent Creek, the floodplain is well-connected under existing conditions, and therefore existing side channels are also well-connected. The total length of side channels activated during flows with a magnitude of a 10-year discharge or less is approximately 2 miles under existing conditions. Approximately 1,800 feet of mapped side channels appear to be remnant drainages that formed along the historical railroad grade either through natural or artificial means. Following removal of the railroad grade, one substantially improved area of side channel connectivity is predicted between RM 65.2 and RM 65.4. These additional side channels add approximately 1,600 feet or 13 percent additional length to the total length of potential side channel connectivity through the subreach.

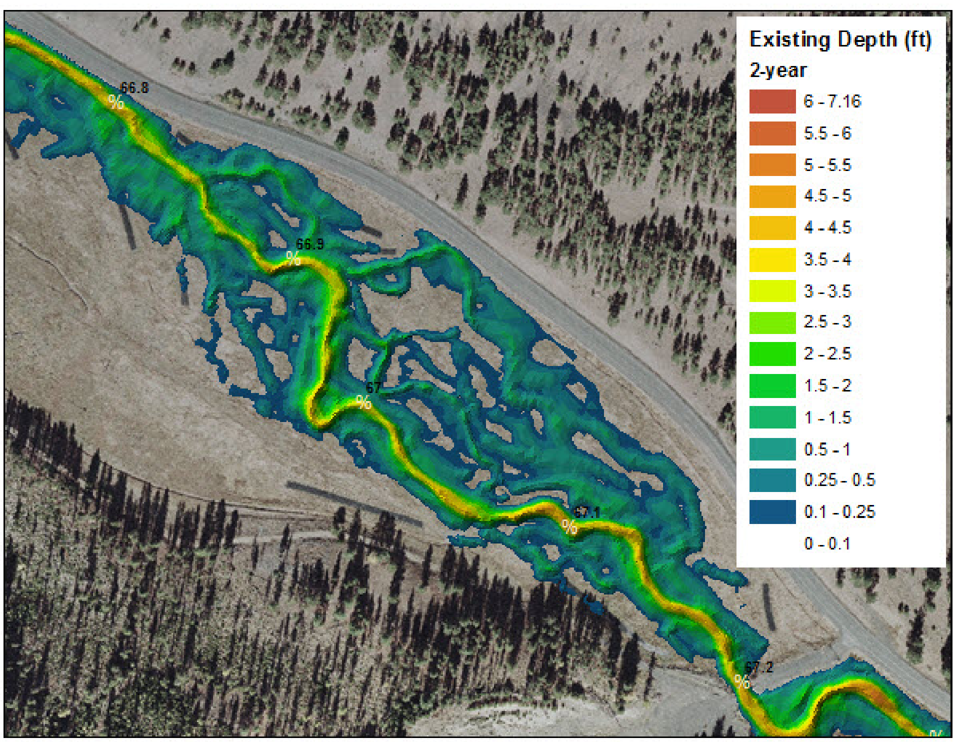

Figure 77. Well-connected area of floodplain between Bridge Creek and Vinegar Creek where a network of side channels exists.

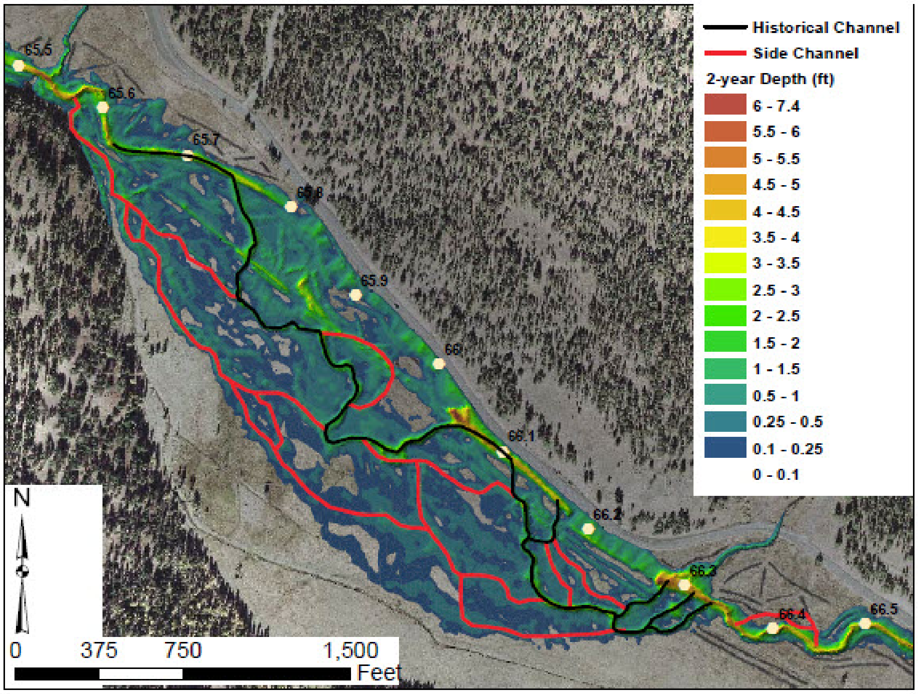

Figure 78. Side channel locations between Vinegar and Vincent Creek following removal of railroad grade.

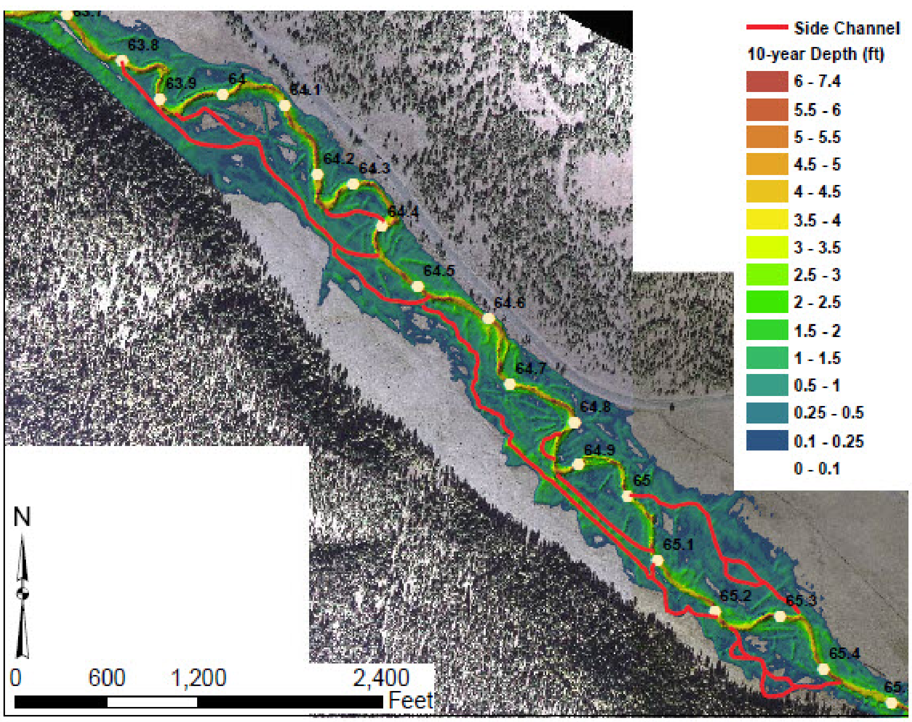

Figure 79. Side channel locations between Vincent and Caribou Creeks following removal of the railroad grade.

4.3 Locations of High-Quality High-Flow Habitat

High-quality high-flow habitat was defined as areas experiencing greater than 0.5 feet of flow depth with velocities less than 2 ft/s. Areas meeting these criteria accounted for 2 to 33 percent of the floodplain area under existing and Removed Human Features conditions depending on the discharge simulated and the reach analyzed. In comparing the floodplain area meeting the criteria in the existing and Removed Human Features conditions, the most notable changes were predicted between Vinegar and Vincent Creeks with smaller areas of localized changes between Vincent and Caribou Creeks. Within the subreach between Vinegar and Vincent Creeks, total high-quality high-flow habitat area increased from 2 to 11 acres during a 2-year discharge, from 4 to 16 acres during a 5-year discharge, from 5.5 to 18 acres during a 10-years discharge, and from 9 to 15 acres during a 100-year discharge. Increases in the subreach between Vincent to Caribou Creek were less than 1 acre for the 2-, 5-, and 10-year discharges and 1.75 acres for a 100-year discharge. Almost no changes were predicted between Bridge and Vinegar Creeks. Figure 80 through Figure 82 illustrate how the total floodplain area (in acres) meeting the criteria differs between the existing and Removed Human Features conditions. Figure 83 through Figure 84 demonstrate differences in the locations of high-flow habitat between existing and Removed Human Feature conditions for the 5-year peak discharge downstream from Vinegar Creek.

The area meeting the criteria for high-quality, high flow habitat tended to decrease from a 10-year to a 100-year discharge. Although the area with depths exceeding 0.5 feet did not decrease, the velocities in these areas exceeded the 2 ft/s velocity criteria more frequently during a 100-year discharge than during a 10-year discharge. The one exception was in the subreach from Vinegar to Vincent Creeks under existing conditions, where flows were more likely to overtop portions of the railroad grade and access the disconnected floodplain during a 100-year discharge than during a 10-year discharge.

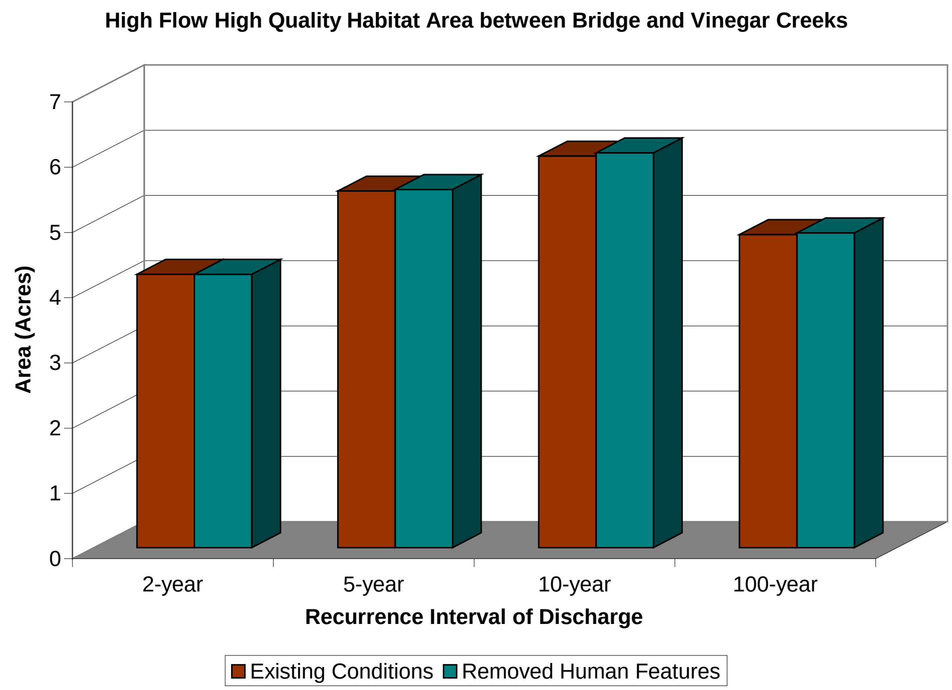

Figure 80. Changes in the area (acres) of high-quality high-flow habitat between Bridge and Vinegar Creeks.

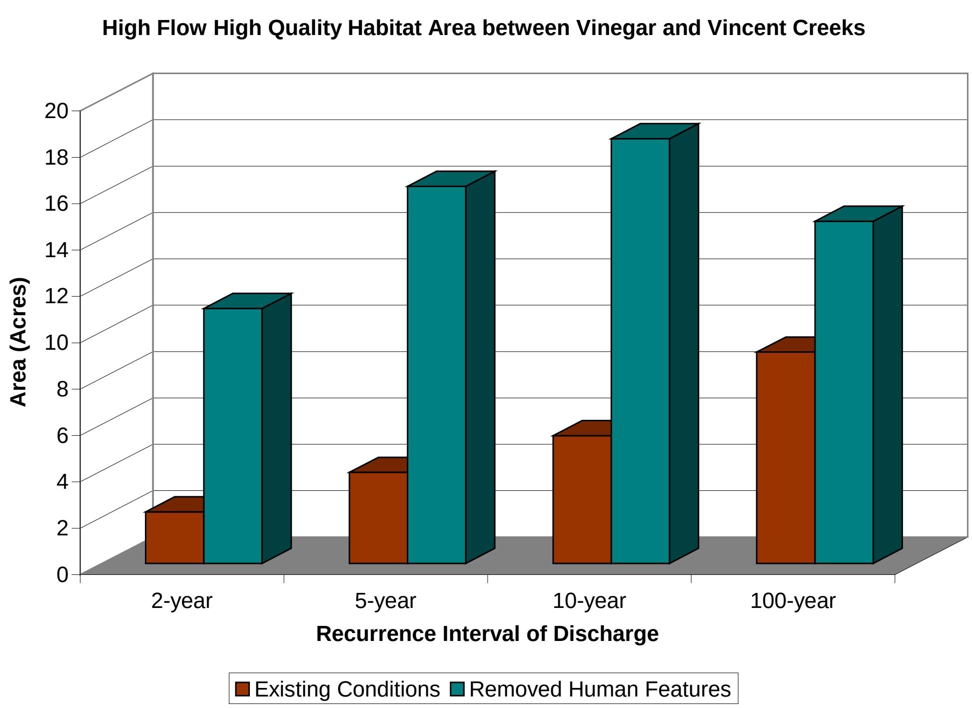

Figure 81. Changes in the area (acres) of high-quality high-flow habitat between Vinegar and Vincent Creeks.

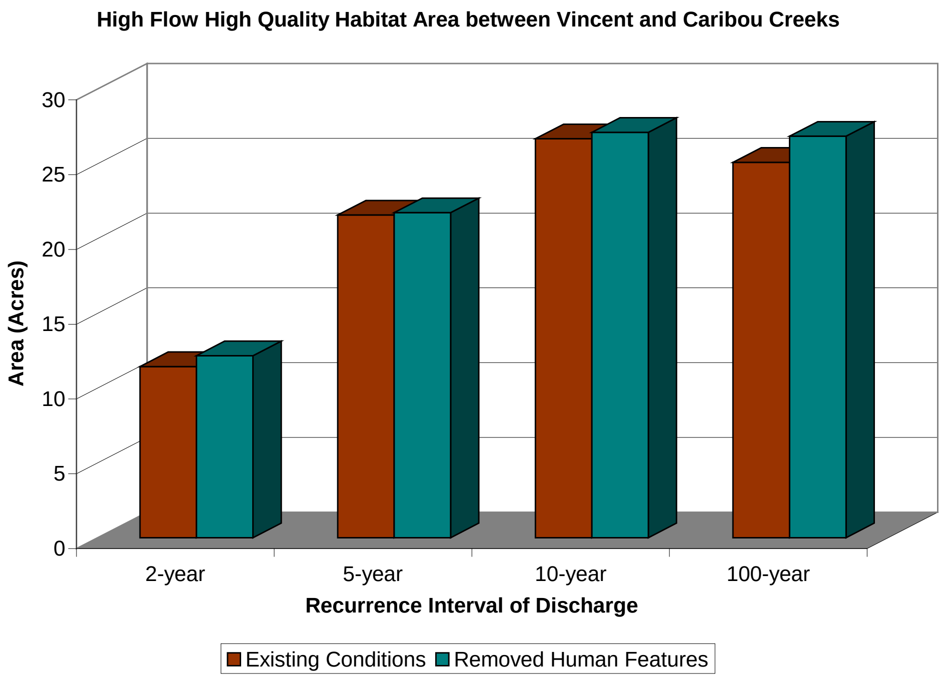

Figure 82. Changes in the area (acres) of high-quality high-flow habitat between Vincent and Caribou Creeks.

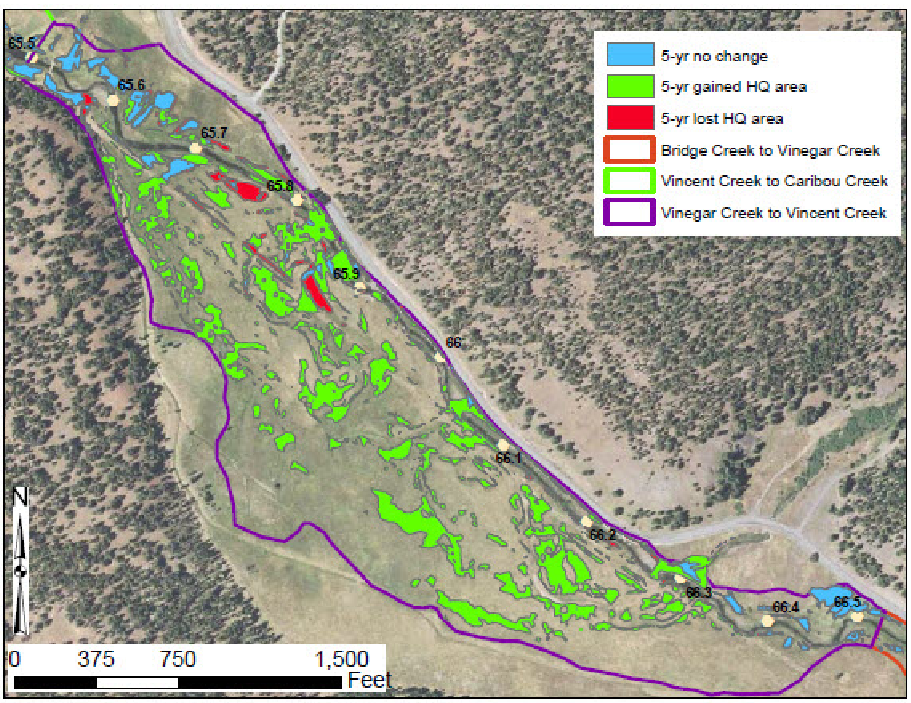

Figure 83. Difference in high-quality high-flow habitat between existing and Removed Human Feature conditions for a 5-year discharge between Vinegar and Vincent Creeks.

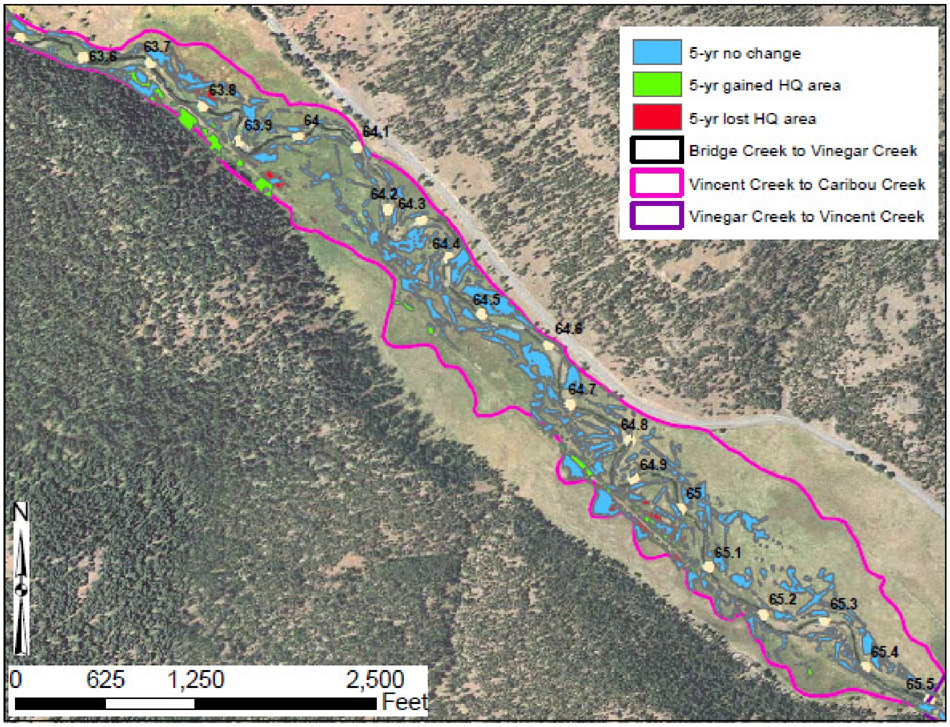

Figure 84. Difference in high-quality high-flow habitat between existing and Removed Human Feature conditions for a 5-year discharge between Vincent and Caribou Creeks.

4.4 Low Flow Habitat

Low-flow habitat is a primary concern in the MFJDR due to the limiting factor of high summer temperatures. A Level II habitat assessment was conducted by the U.S. Forest Service (USFS) on the Forrest Conservation Area in July of 2008 (USFS 2008). While the habitat assessment provides indicators of the quality of existing habitat, potential changes with the proposed scenario were evaluated by plotting the locations of deep pools identified during the habitat assessment and historical spring Chinook redd data.

4.4.1 Deep Pool Locations

Measured flow rates on the day of the survey (July 7, 2008) ranged between 21 cfs upstream of the confluence with Bridge Creek (RM 67.5) to 37 cfs just upstream of the confluence with Deerhorn Creek (RM 62.5). In addition to typical habitat assessment procedures, Reclamation requested the USFS to collect GPS points for all pools greater than 3 feet deep. Within the FCA, deep pools exist and may be used as holding habitat during migration, potentially provide thermal refugia during summer months, and offer cover for juvenile rearing. Investigation of low flow habitat for multiple life stage use (holding and potentially rearing) can be accomplished by plotting the locations of deep pools. Pool locations estimated by USFS to be close to or exceeding 3 feet were plotted to examine the spatial distribution of the pools.

Forty-seven pools exceeding 3 feet in depth were identified throughout the modeled reach of FCA, most of which were located between Vincent Creek and Caribou Creek. Of the forty-seven deep pools measured, ten were located within the Vinegar to Vincent Creek subreach. Figure 85 illustrates that if the existing channel is blocked and the historical channel conveys the majority of low flows, approximately 5 deep pools would be lost. However, a dynamic channel is anticipated to develop through the historical channel, in which deep pools are established due to resulting hydraulics.

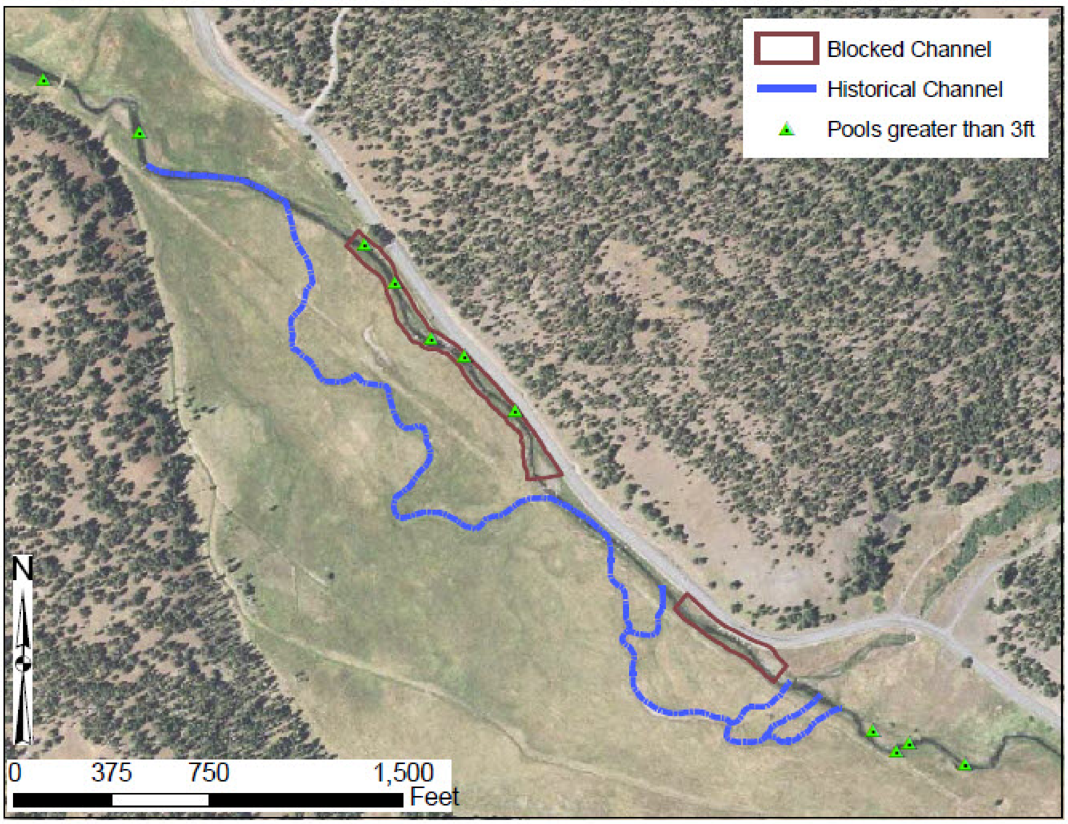

Figure 85. Pools between Vinegar and Vincent Creeks identified by USFS as approximately 3 feet deep or deeper on July 7, 2008.

4.4.2 Redd Locations

The presence of redds offers insight into the value of certain areas in the channel with respect to spawning habitat, particularly that which is often threatened by low flows in late summer and early fall. The FCA offers some of the most productive spawning habitat of the MFJDR as measured through the presence of spring Chinook redds. Oregon Department of Fish and

Wildlife spring Chinook redd data from 2002 to 2009 were plotted to evaluate the spatial distribution of redds identified in the study area. Portions of the channelized section of river between Vinegar and Vincent Creeks were blocked for analysis of the Removed Human Features scenario. Within the downstream section of channel blocked, numerous redds were established between 2002 and 2009. While blocking this section of channel will impact the ability for potential establishment of future redds, multiple areas of suitable spawning habitat are expected to develop in the historical channel alignment over time if the railroad grade is removed. Evaluation of shear stress values under the Removed Human Features Scenario indicates that the historical channel will likely retain medium to coarse sized gravels, which are suitable for spawning Chinook and Steelhead.

Input from biologists is necessary to determine the potential for low flow habitat within the historical channel. Sediment and flow inputs from Vinegar Creek are not anticipated to change if flows are routed through the historical channel alignment. However, the decreased channel slope and velocities combined with the less channelized geometry of the historical channel is anticipated to retain more spawning-sized gravel material than is present in the current channel and rework floodplain deposits on a more frequent basis, thereby increasing the potential for development of diverse sediment deposits and spawning grounds.

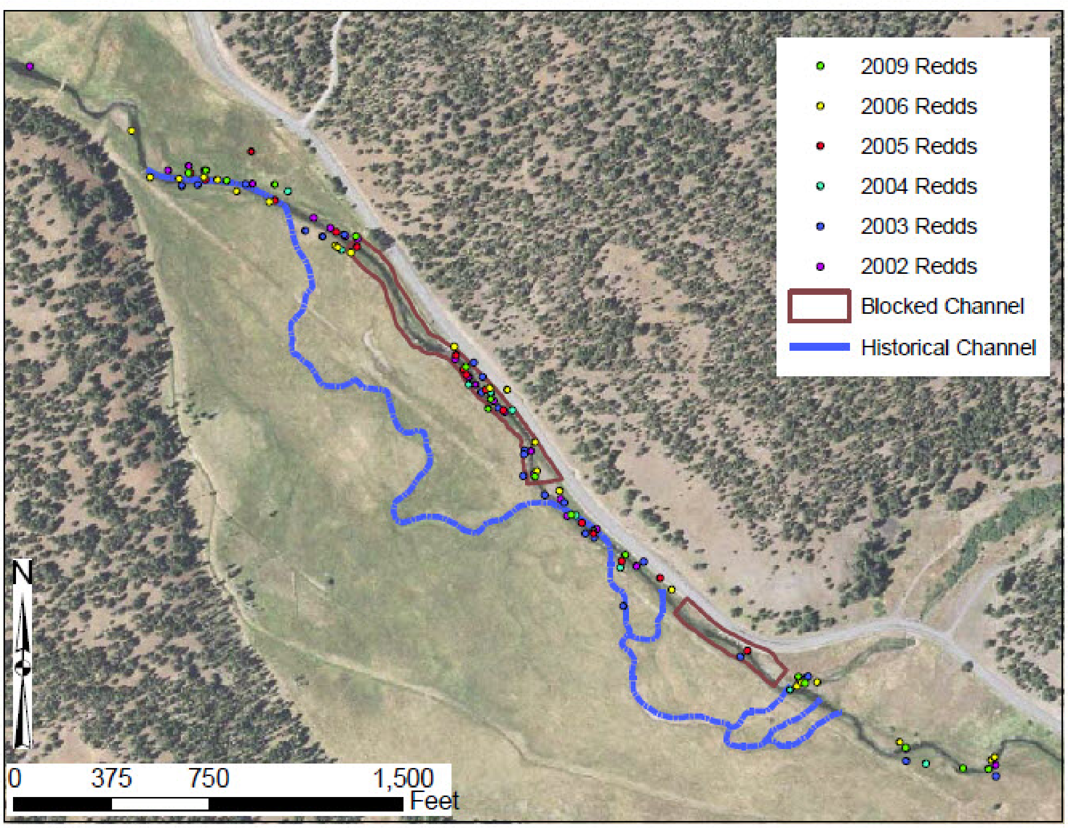

Figure 86. Historical spring Chinook redd locations between Vinegar and Vincent Creek.

Chapter 5 CONCLUSIONS-LINKING RESULTS OF THE ASSESSMENTS TO REHABILITATION OPTIONS

In combination with a geomorphic assessment, a two-dimensional hydraulic model was utilized to evaluate existing hydraulic conditions and resultant habitat for high flows on the Forrest Conservation Area of the Middle Fork John Day River. The analyses were conducted to investigate the potential for increased habitat following the removal of a railroad grade, reconnection of a historical channel, and blockage of an existing channelized portion of the river. Several key conclusions can be drawn from the geomorphic evaluation and modeling results, including:

1. The geomorphic character of the MFJDR in the FCA is strongly controlled by bedrock structure and the alluvial fill within the valley. The MFJDR generally follows the axis of a syncline formed in the bedrock. The narrower canyon and wide valleys reaches are the result of interbedded nature of more resistant rock types (volcanic flows) with more erodible types (breccia, conglomerate, and poorly-consolidated volcanoclastic sediment) respectively.

2. Sediment delivered to the MFJDR from its tributaries has formed alluvial fans along the valley margins, and due to the generally transport-limited capability of the river to move this sediment, the channel pattern on the valley floor is controlled largely by these alluvial fans.

3. Bedrock types and a large landslide at the downstream end of the FCA, which in addition to local control provided by sediment shed across the valley floor by alluvial fans, provides control on the overall channel slope through the reach.

4. With the slope of the reach being bedrock controlled and with the influx of coarse-grained sediment from tributaries that form numerous alluvial fans and underlie the valley, it appears that the general geologic architecture of the FCA plays a large role in controlling the overall water temperature of the river.

5. Based on charcoal and pollen analyses that were undertaken to better understand possible types and distribution of vegetation it appears that the ecosystem within the FCA may have been represented by more of a wet meadow environment. This is supported by geomorphic evidence of abandoned channels widespread on the valley floor and floodplain. While there is some basis for temperature being controlled by the geomorphic character of the FCA, it is unclear from this analysis how much influence vegetation that was present in the past could have on current conditions.

6. It is clear from both the geomorphic and hydraulic analyses that the most adverse impact on the MFJDR in the FCA is related to the isolation of large areas of floodplain from the river by remnants of the railroad grade.

7. The area of greatest impact from human features lies between Vinegar and Vincent Creeks. Removing the railroad grade in this location and blocking portions of the existing channelized river will force flow into its historical channel and result in substantially increased floodplain connectivity, side channel connectivity, and high-flow high quality habitat.

8. The two subreaches between Bridge and Vinegar Creeks and Vincent and Caribou Creeks have well-connected floodplains under existing conditions. Removal of human features has almost no impact on the Bridge to Vinegar Creek subreach. Small, localized areas of floodplain and habitat may benefit from removal of the railroad downstream between Vincent and Caribou Creek, but the amount of increased off-channel habitat is predicted to be small relative to the subreach between Vinegar and Vincent Creeks.

9. Model results can be used to assist the landowners, managers, and other stakeholders in deciding where to prioritize rehabilitation efforts in order to realize the greatest biological benefit. Currently, the railroad grade through the FCA is listed on the National Register of Historical Places. While it is recognized that the railroad grade has historical significance through the property, it also limits habitat for ESA-listed and other culturally important fish species in the region. The model results may be used to identify (1) locations where the railroad grade has the greatest impact on habitat and could be removed or breached as a rehabilitation action and (2) locations where the railroad grade has relatively little impact on channel dynamics and floodplain connectivity through the reach and could remain intact without further limiting habitat.

Results from the 2D model will continue to be evaluated in conjunction with a geomorphic analysis and used as tools to investigate additional rehabilitation actions and subsequent results on habitat.

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