RECLAMATION

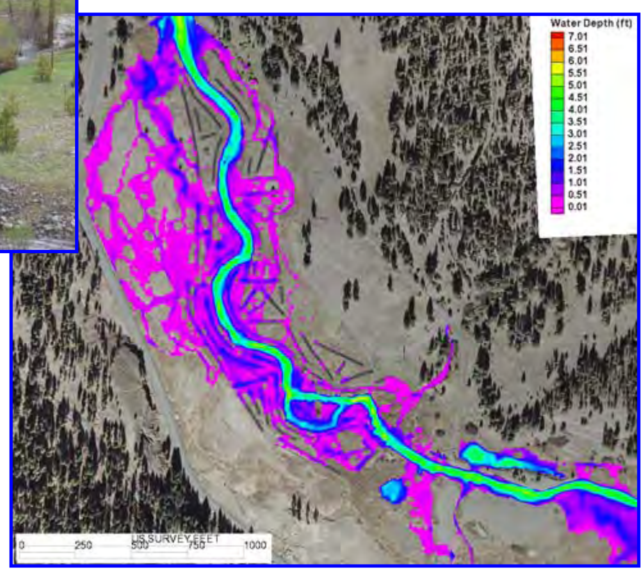
Managing Water in the West

Report Number: SRH-2009-20

Geomorphology and Hydraulic Model Analysis of the Oxbow Conservation Area

Middle Fork John Day River

Grant County, Oregon



U.S. Department of the Interior

Bureau of Reclamation
Pacific Northwest Region
Boise, Idaho

May 2009

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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EXECUTIVE SUMMARY

In compliance with the Federal Columbia River Power System Biological Opinion (NOAA 2008), the Bureau of Reclamation (Reclamation), U.S. Army Corps of Engineers, and Bonneville Power Administration are working to implement salmonid habitat rehabilitation projects in the Columbia River Basin. Reclamation produced this report to help meet tributary habitat commitments contained in the 2008 Federal Columbia River Power System Biological Opinion (NOAA Fisheries 2008). This report provides scientific information to help identify, prioritize, and implement sustainable field projects, in collaboration with Tribal, State, and local partners, that improve survival and lead to the recovery of salmon and steelhead listed under the Endangered Species Act (ESA). These projects focus on the limiting factors for the survival of Endangered Species Act (ESA)-listed fish species and other culturally important fish species within the four general sectors of harvest, hatcheries, hydropower, and habitat, all four of which are likely necessary for recovery of ESA-listed species. Within the habitat sector, Reclamation provides technical assistance for project identification, design, and construction in partnership with States, Tribes, Federal agencies, and other local workgroups. Technical assistance has addressed critical path projects such as stream flow improvement, removal of in-stream barriers, fish screen enhancement projects, and habitat complexity projects.

Along the Middle Fork John Day River, substantial changes to channel processes and associated habitat have occurred over the last century. Ranching, grazing, and timber harvest led to the removal of vegetation from the floodplain and adjacent valley floor. Road and levee construction, channel stabilization, and dredge mining altered the channel and floodplain characteristics dramatically by changing the location, geometry, and planform of the main channel, as well as the number of side channels. As a result, populations of several important fish species, including spring Chinook (*Oncorhynchus tshawytscha*), summer steelhead (*Oncorhynchus mykiss*), and bull trout (*Salvelinus confluentus*), have markedly decreased. Spring Chinook and summer steelhead are of particular importance to the region because the John Day River is managed exclusively for wild fish production (NPCC 2005).

After mining ceased in the Oxbow Conservation Area in the 1940s, the Middle Fork John Day River flow was split between two channels, the North Channel and the South Channel (Figure 1). The South Channel is the remnant of the natural channel to the south of the dredge tailings; the North Channel was constructed through the dredge tailings and across the toe of the Granite Boulder Creek alluvial fan. During high flows, most of the stream flow naturally flows through the South Channel, but during low flows, the hydraulic conditions are reversed due to the conveyance conditions at the bifurcation of the North Channel.

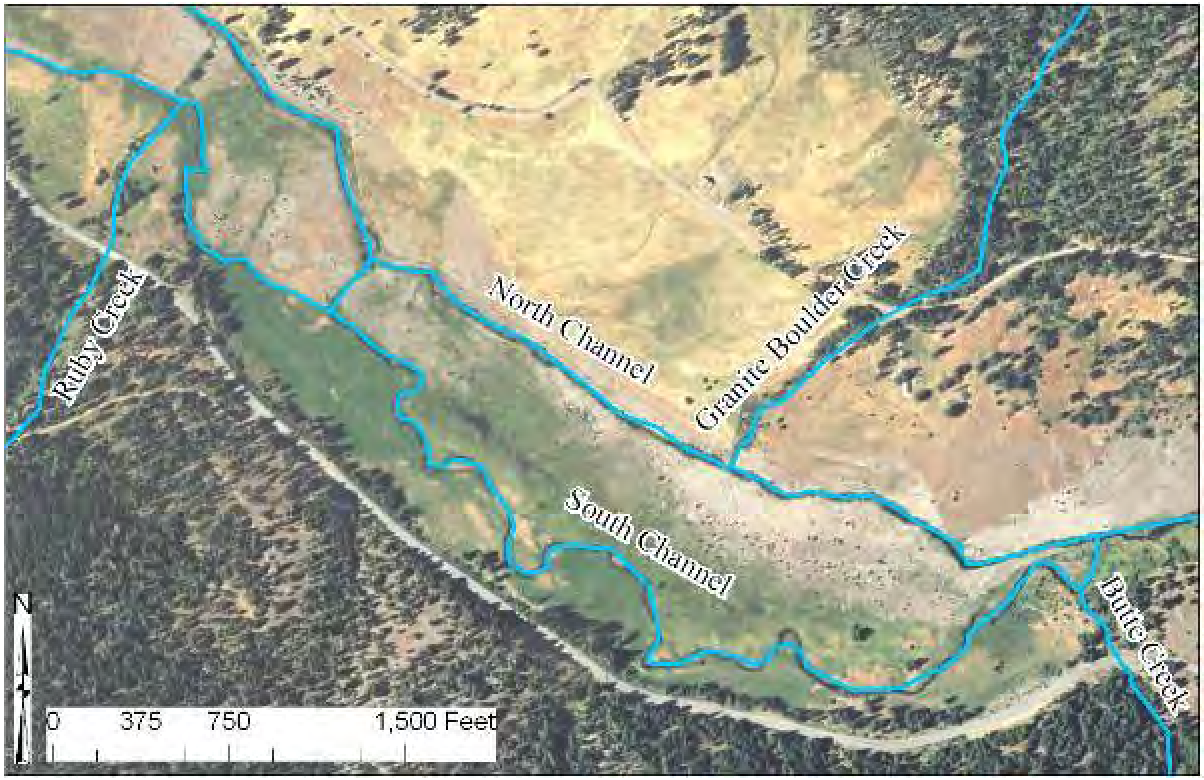

Figure 1 - Aerial image of key features examined in the analyses.

The *Middle Fork and Upper John Day River Tributary Assessments* (*Tributary Assessment*), completed by the Bureau of Reclamation in May 2008, presented an improved understanding of the physical processes acting on the watershed, identified rehabilitation opportunities, and addressed limiting factors of ESA-listed and other culturally important fish species.

Characterization of the biological conditions were also presented, including the fisheries and vegetation ecosystems, the geologic setting, anthropogenic constraints, geomorphic processes, basin hydrology, and hydraulic and sediment transport processes. Local knowledge, compiled data, and modeling results were synthesized to evaluate potential physical and biological response to rehabilitation actions.

Following completion of the *Tributary Assessment* in May, resource managers worked with a technical team to determine where impacts were localized and design work could begin or where a more 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 of the physical processes analyses from the *Tributary Assessment* on the Middle Fork John Day River, combined with landowner preference, led to a refined investigation of rehabilitation opportunities on the 3.5-mile stretch of the Oxbow Conservation Area, which is owned and managed by the Confederated Tribes of the Warm Springs Reservation of Oregon. The refined analysis further investigated the river processes identified in the *Tributary Assessment* in order to move toward the eventual implementation of rehabilitation projects with the greatest potential for success. Questions that needed answers included:

* How severely have mining activities impacted the floodplain connection and lateral channel migration?
* Will returning all flow to the historical South Channel benefit habitat without adversely impacting channel morphology?
* What geomorphic conditions within the reach influence potential rehabilitation options?

Methods

To address these questions about the river processes and provide guidance for future rehabilitation actions, these steps were followed:

1) *Data gap analyses*- An interdisciplinary team comprised of geomorphologists, biologists, ecologists, hydraulic engineers, design engineers, and stakeholders convened to identify missing information necessary to better understand reach processes relative to implementation of rehabilitation actions. Specific items identified were longitudinal and seasonal variations in stream temperature, composition of native vegetation within the riparian corridor, and a refined interpretation of the channel morphology including the hydraulic properties of the river associated with multiple channels, a substantial number of flow splits, a meandering channel, and a channel with extensive point bar and pool-riffle formation.
2) *Geomorphic investigations*- Coarse-scale geologic mapping completed for the *Tributary Assessment* was sharpened 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 collected. 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 describe the character of the sediment comprising the deposits, document the extent of soil formation (an indicator of relative age and landscape stability), and to collect detrital charcoal and sediment samples in an attempt to evaluate the type of vegetation growing adjacent to the river prehistorically.

3) *2D hydraulic model*- The Oxbow Conservation Area is comprised of a complex network of multiple channels and tributaries. A two-dimensional (2D) hydraulic model was developed using Reclamation's Sedimentation and River Hydraulics 2D hydraulic model (SRH-2D; Lai 2006) to gain insight and predictions of floodplain processes, side channel connectivity, and split flow dynamics through the selected reach. Simulations were conducted for the 2- through 100-year peak discharges with inlet flows at the upstream boundary of the model ranging from 881 cubic feet per second (cfs) to nearly 2,700 cfs. In addition, the model was applied to evaluate a "proposed conditions" scenario to examine how hydraulic parameters and habitat features may change following specified rehabilitation actions. Proposed conditions included removing the primary human feature in the study area (not necessarily a selected design option), which blocks off the North Channel downstream from the bifurcation of the South Channel and just upstream of the confluence with Granite Boulder Creek (Figure 1). This section of the North Channel is a relic of the dredge mining activities from the early 1900s.

Following completion of these analyses, results from the geomorphic investigations were linked with results from the hydraulic modeling to better understand pre-disturbance physical processes in the reach, identify potential rehabilitation opportunities, and identify limitations to habitat rehabilitation.

Geomorphology

Several important aspects of the geology, such as how it influences the river geomorphology and river processes, were observed in the Oxbow Conservation Area. Two significant contributors of stream flow and sediment to this reach are Granite Boulder Creek, located downstream from the bifurcation of the North and South Channels, and Ruby Creek, just downstream from the confluence of the North and South Channels (Figure 1). Both tributaries provide substantial physical constraints on the river geomorphology, particularly on lateral channel migration. Additionally, channelization from the dredging activities severely impacted channel position and river function.

In general, the three larger tributaries, Ruby, Butte, and Granite Boulder Creeks, shed alluvial fans into or across the valley that directly influence the channel gradient and channel form immediately upstream of each tributary. In combination with a landslide, the Ruby Creek alluvial fan provides a constraint on the valley width, which controls the channel gradient locally and the channel form immediately upstream. The Granite Boulder Creek alluvial fan constrains the channel position of the South Channel of the Middle Fork John Day River where it pushes this part of the river against the Butte Creek alluvial fan downstream of the split between the North and South Channels.

The valley is significantly wider downstream of Ruby Creek (Figure 1). The historical areal extent of the floodplain was much greater as the Middle Fork John Day River migrated laterally across this area as evidenced by channel scars on the valley floor visible in the 1939 aerial photographs (Figure 10). Older stream terraces preserved along the margins of the valley are indicative of an overall trend of incision by the Middle Fork John Day River into older alluvial valley fill during the last 7,600 years. The wide floodplain and numerous abandoned channels on the valley floor visible in the 1939 photographs suggest that the recent history of the river (at least the last 1,200 years) predominately involved lateral migration (Bandow 2003).

Because vegetation on the valley floor was removed by anthropogenic activities, little is known about the type and extent of historical riparian vegetation on the Oxbow Conservation Area. Thirty-four charcoal samples were collected from four sites on each of the stream terraces and alluvial fan deposits. Samples recovered from terrace deposits along the Middle Fork John Day River are dominated by conifer charcoal. Samples recovered from the floodplain and youngest terrace deposits include material representing riparian species, for example willow (*Salicaceae*) and cottonwood (*Populus*). The youngest terrace and floodplain deposits generally contained charcoal indicative of the diverse riparian ecosystem. While there was diversity in the type of charcoal recovered along the Middle Fork John Day River, the more common riparian species were missing. An interesting finding was the presence of Hemlock (*Tsuga*) charcoal in the older terrace deposits (more than 1,200 years old). Hemlock is not found in the area today.

Two-Dimensional Hydraulics

Profiles of the water surface elevation for the 2- and 100-year flood events were developed for the existing and proposed conditions. Comparisons were made between the existing and proposed conditions (i.e., blocking off the North Channel) based on predicted changes to water surface elevation, depth-averaged velocity, and bed shear stress. These hydraulic parameters were compared along the channel thalweg and across the floodplain.

The most significant reduction in water surface elevation from existing to proposed conditions occurs below Granite Boulder Creek where decreases of 1 foot are predicted for the 2-year peak discharge and 1.2 feet for the 100-year peak discharge. These differences in water surface profiles between existing and proposed conditions are only predicted upstream of the confluence of the North and South Channels near River Mile 57 (Figure 45).

The total area inundated decreased under the North Channel blocked scenario by 2.5 acres, 5.8 acres, and 8.0 acres for the 2-year, 10-year, and 100-year flow events, respectively. Differences in depth, velocity, and bed shear stress between the existing North Channel and the proposed blocked North Channel are most notable between the bifurcation of the North and South Channels and the confluence of Ruby Creek. As the discharge increases in magnitude, the differences between the two scenarios are less pronounced due to the limited capacity of the North Channel.

With the North Channel blocked, the floodplain along the South Channel is characterized by greater depths, which are most pronounced with lower discharges. These results indicate increased floodplain connectivity along the South Channel floodplain when the North Channel is blocked (Figure 2). Evaluation of the changes along the thalweg of the North Channel indicates depth losses greater than 1 foot extending about 0.2 miles downstream from Granite Boulder Creek when the North Channel is blocked. Adding flow from the North Channel to the South Channel has less of an impact on depth differences in the South Channel than decreases predicted in the North Channel. The minimal impact noted in the South Channel is because the additional flow from the North Channel spreads out over the floodplain rather than creating substantial increases in depth within the channel, which results in increased floodplain connection. Furthermore, the South Channel has a much greater capacity than the North Channel and any increases in flow to the South Channel are spread across a greater area. Differences in depth due to blocking off the North Channel are predicted to be between 0 feet to 0.5 feet in the South Channel. The average difference is about 0.25 feet regardless of the flood event. Although substantial additional inundation along the floodplain of the South Slough occurs when the North Channel is blocked, changes to depth in the South Slough are minor due to the limited capacity of the South Slough.

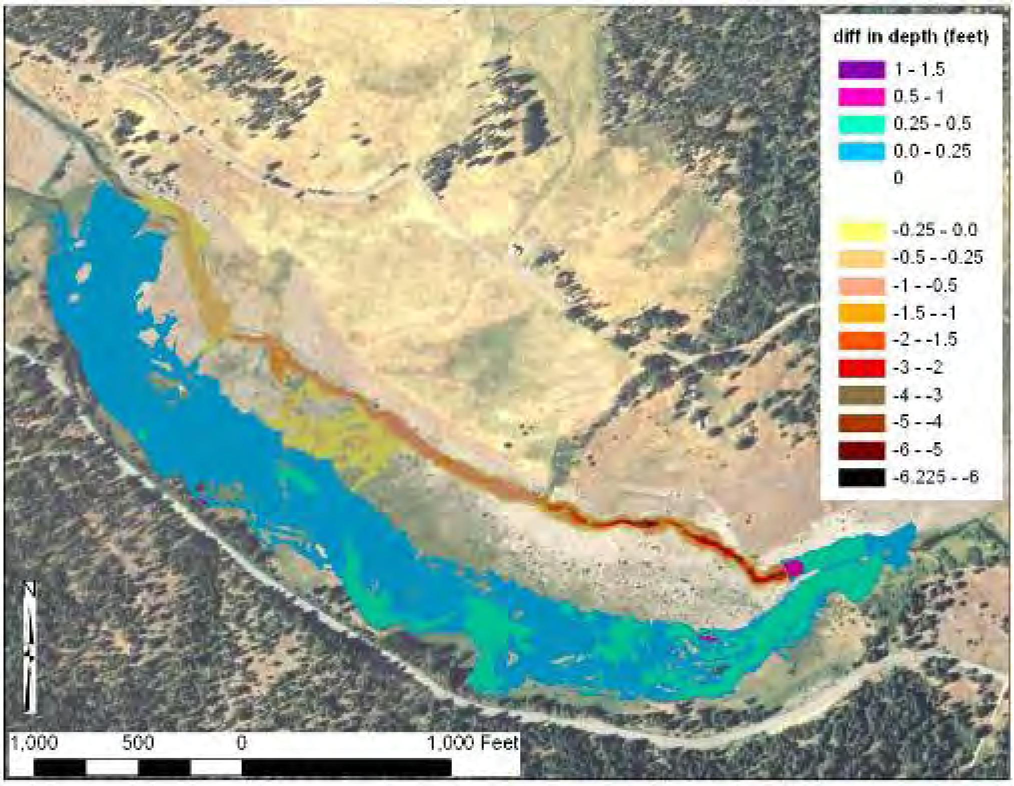

Figure 2 - Differences in flow depth for the 2-year discharge between the existing and proposed conditions. Positive values indicate increases when the North Channel is blocked.

Model results of depth-averaged velocities illustrate minimal increases within the South Channel when the North Channel is blocked (Figure 3). Additional backwater impacts near the downstream end of the South Channel result in slightly reduced velocities in the South Channel in certain locations. At the upstream end of the South Channel, the model predicts decreased velocities in the area just downstream from the bifurcation with the North Channel where active migration into the Butte Creek alluvial is occurring. Changes at the upstream end of the South Channel are related to where the plug is placed in the model in the North Channel (the plug was placed approximately 50 feet downstream of the bifurcation in the model).

Both the areal and longitudinal comparisons clearly predict substantially reduced velocities in the North Channel downstream from Granite Boulder Creek when the North Channel is blocked. Just below the mouth of Granite Boulder, reductions of over 5 feet per second (ft/s) are predicted. Differences of about 1 ft/s are predicted within the North Channel near the confluence with the South Channel. Differences in the channel velocities of the South Channel typically range between -0.5 ft/s to 0.5 ft/s for all flows evaluated, with an average increase of approximately 0.1 ft/s. Although very small changes in velocity magnitudes are experienced in the thalweg of the South Channel, some increases in velocities (up to 2 ft/s) were predicted to occur along the floodplain in the upper part of the South Channel (Figure 3).

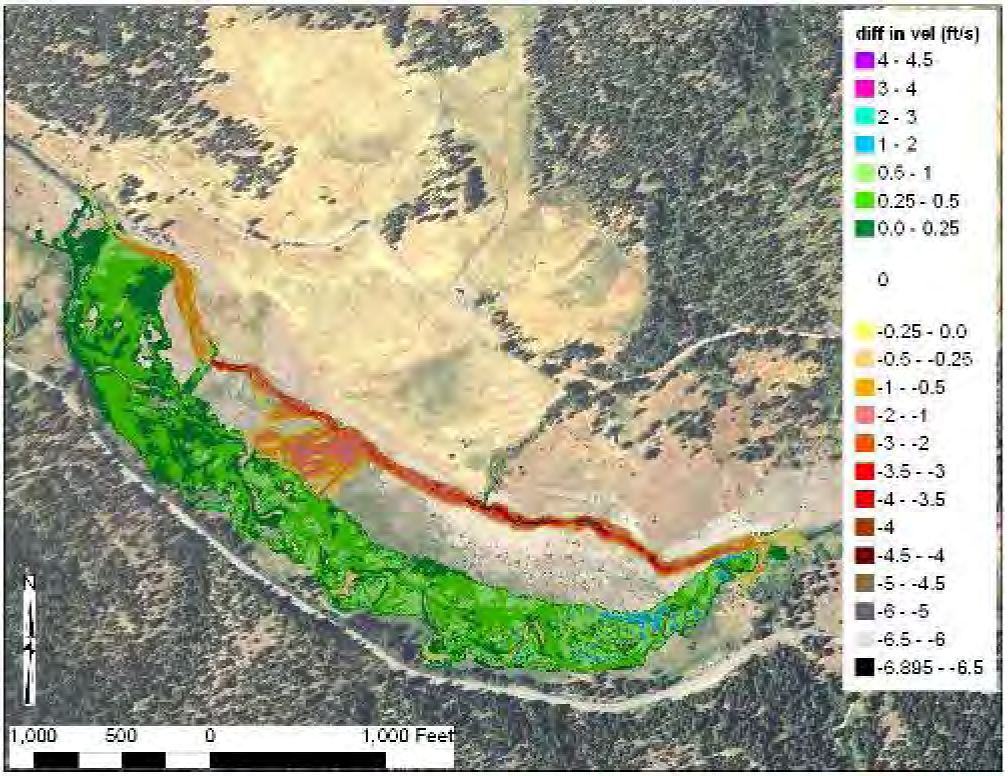

Figure 3 - Difference in velocities for a 2-year discharge between the existing and proposed conditions. A positive value indicates an increase when the North Channel is blocked.

Bed shear stress follows patterns similar to depth-averaged velocities (Figure 4). Increases in shear stress are predicted along the floodplain of the South Channel in areas that are only slightly inundated under existing conditions, which indicates the potential for an increased frequency for floodplain reworking under the proposed conditions. Comparison of channel bed shear stress for existing and proposed conditions in the North and South Channels for all flows indicates minimal increases in the South Channel just downstream of the flow bifurcation. Predicted decreases in the South Channel near the bifurcation are related to backwater resulting from the plug placed in the North Channel in the model and the increased overbank flow at the bifurcation. Changes in bed shear stress are significant in the North Channel downstream of Granite Boulder Creek where reductions of over 1.3 pounds per square foot (lb/sf) are predicted just at the mouth. Under both existing and North Channel blocked conditions, bed shear stress in the North Channel decreases to about 0.16 lb/sf just upstream of the confluence with the South Channel. Despite increasing discharges from the 2- to 100-year recurrence intervals, differences in the bed shear stress between the existing and the proposed blocked North Channel conditions along the South Channel thalweg are similar in magnitude due to increased overbank activation rather than increased main channel flows. Changes along the South Channel thalweg are generally less than 0.10 lb/sf.

Flow split patterns were evaluated to better understand complicated hydraulics between the North and South Channels and through several smaller channels activated during high flow conditions (e.g., abandoned ditches). Model results indicate that the North Channel has a reduced influence on flood conveyance as the peak discharge increases in magnitude. The capacity of the North Channel is estimated to be approximately 450 cfs at a 100-year peak discharge (17 percent of the total), with the remaining flow being conveyed through the South Channel and across the adjacent floodplain.

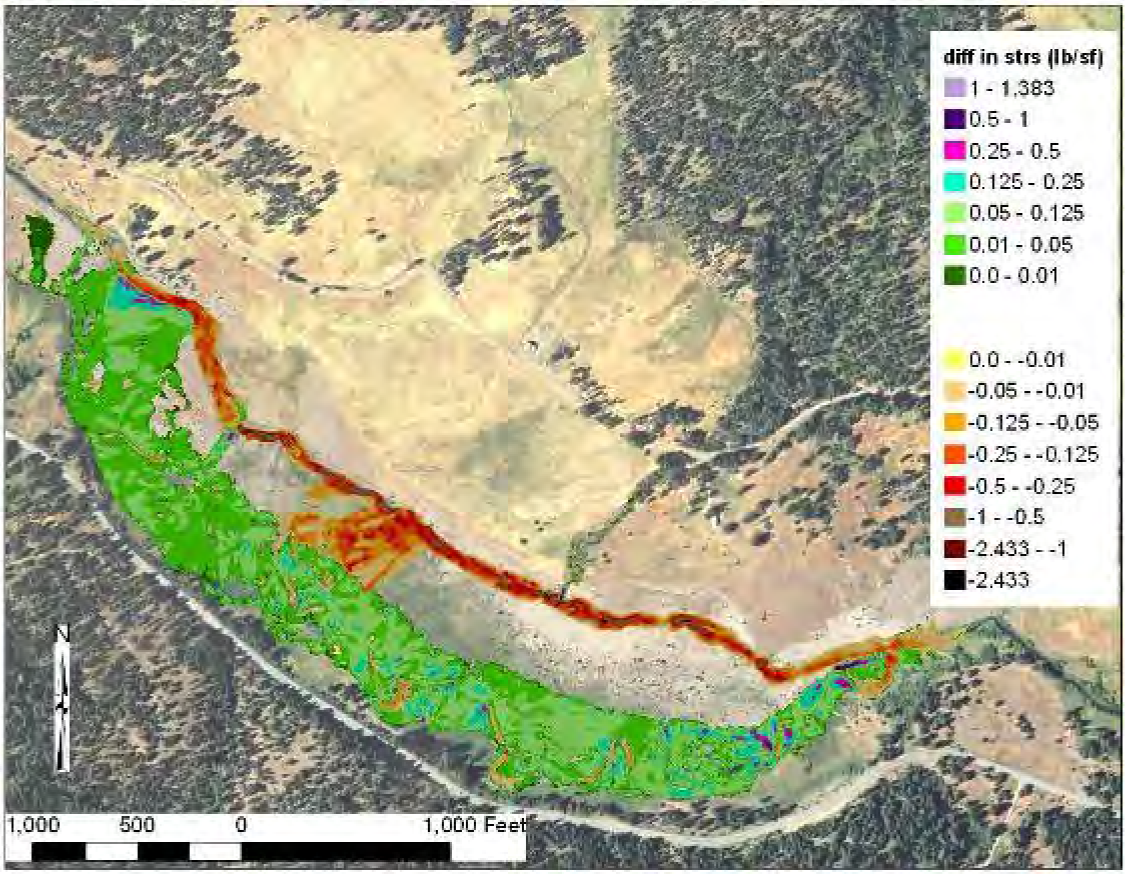

Figure 4 - Difference in shear stress for a 2 year discharge between existing and proposed conditions. A positive value indicates an increase when the North Channel is blocked.

Conclusions

Present floodplain connectivity was determined by quantifying the area of the floodplain outside of the low flow channel that experienced depths exceeding 0.5 feet. Model results predicted substantial floodplain connectivity at the 2-year peak discharge throughout a substantial portion of the study area. Locations not experiencing floodplain connectivity under the peak flows evaluated were channelized portions of the river, which were artifacts of mining activities. The model simulation of the proposed conditions (North Channel blocked) predicted increased floodplain connectivity along the South Channel and, because of the limited capacity of the North Channel, the change in floodplain connectivity decreased in magnitude as the peak discharge increased. At discharges exceeding a 10-year annual exceedance probability, areas of floodplain connectivity lost along the channel margins of the North Channel were greater than those gained along the floodplain of the South Channel, but the potential for reconnecting those floodplain processes in the South Channel is greater than in the North Channel margins.

The model also predicted that almost all of the side channels (distinct channels that can be identified outside of the main channel) present were connected at flows equivalent to the 2-year peak discharge and greater. Side channels that may have been present historically through the dredged areas were drastically altered during the dredging operations of the 1940s. One channel below Ruby Creek on the north side of the valley that appears to have been the main low flow channel in the 1939 aerial photographs begins to convey flow at the 10-year peak discharge and is well connected at the 100-year peak discharge. Across the South Channel floodplain, most flow was not conveyed through distinct side channels, but blocking the North Channel did result in increased overbank flow along the South Channel floodplain.

High-quality high-flow habitat, which was defined as areas experiencing greater than 0.5 feet of flow depth with velocities less than 2 feet per second, accounted for 10 to 17 percent of the floodplain, depending on peak discharge. Blocking the North Channel results in more high-quality high-flow habitat for the 2-year flood, but slightly less for all other discharges evaluated. This is primarily a result of the loss of habitat along the fringes of the North Channel. The maximum decrease is approximately to 2.3 acres of high flow habitat area during a 10-year event.

Low-flow habitat was evaluated using existing information on deep pool locations with respect to historical spring Chinook redd counts and by investigating potential changes in South Channel depths through a one-dimensional model. Analysis of the pool locations suggests that if the North Channel is blocked between the flow bifurcation and the mouth of Granite Boulder Creek, approximately 5 deep pools would be lost. Pool depths in the channel downstream from Granite Boulder Creek would also likely be influenced during low flow conditions. This area has a high density of redds, which are presently partly due to the coarse gravel and cold water flows from Granite Boulder Creek. The one-dimensional model developed for the *Tributary Assessment* was used to capture potential changes in channel depth within the South Channel. Model results indicate that if low flows currently conveyed down the North Channel are instead conveyed down the South Channel, average low-flow hydraulic depths would increase by approximately 25 percent.

Currently, several rehabilitation potential options are being considered on the Oxbow Conservation Area. The first, discussed previously, is focused on blocking the North Channel (the human features on the site) and returning all of the stream flow from the MFJDR into the South Channel. Due to conditions resulting from dredge mining in the area of the bifurcation, concerns have been raised as to the potential impacts of increased depths, velocities, and shear stresses in the South Channel and along the channel bed, banks, and floodplain. Hydraulic modeling results suggest that while localized changes will occur, these parameters will not substantially change from current conditions.

Based on geomorphic characteristics of the river that are visible in the 1939 aerial photography, it is evident that the model simulation removing the anthropomorphic features (block the North Channel) would essentially return the entire river to a position in the valley that it occupied historically. While the current South Channel planform appears to be quite similar to that of the river in 1939, data does not exist to allow comparison of the current channel geometry relative to the geometry of this section of the river in 1939. A dramatic change in the channel morphology of the South Channel is not expected as a result of blocking the North Channel given the results of the hydraulic modeling.

An additional option under consideration is the reconnection of Granite Boulder Creek to the South Channel as a result of a channel reconfiguration. If reconnected, Granite Boulder Creek would serve as an important source of colder water inflow to the Middle Fork John Day River, which could help mitigate high water temperatures not conducive to salmonids. As a result of dredging operations, much of the fine-grained sediment may have been winnowed out of the alluvium in the area between the confluence of Granite Boulder Creek with the North Channel and the South Channel floodplain. Concerns with this reconnection are the potential loss of a surface flow connection due to the disruptions by mining activity in the grain size of the Granite Boulder Creek alluvium. Geomorphic evidence suggests that loss of the surface connection would not be expected due to these three factors:

1) The current course of Granite Boulder Creek flows across tailings for a distance of almost 400 feet and through the North Channel for a distance of more than 2,800 feet with no recognizable loss in surface flow.
2) Sediment data collected four test pits excavated in tailings downstream of Ruby Creek do not appear to be dramatically different from material in the area between the North and South Channels.
3) Ponding of water on the floodplain in the area between the North and South Channels and cooler water temperatures in both the North and South Channel as determined by the TIR survey strongly suggest that there is a groundwater link with Granite Boulder Creek and that the groundwater is relatively high year-round.

In summary, findings from this technical document for the MFJDR will result in a reach assessment on the Oxbow Conservation Area, a property managed by the Confederated Tribes of the Warm Springs Reservation of Oregon. Due to mining activity, installations of bank protection, water diversions, and vegetation changes related to agriculture and logging, the majority of the study area has experienced dramatic changes in river processes resulting in disconnection of the floodplain, constrained lateral channel migration, and a lack of floodplain and channel complexity. A refined understanding of the geomorphic and hydraulic conditions was applied to the investigation of existing habitat and river processes and how these may be influenced by blocking the artificial North Channel. Comparisons of the channel hydraulics suggest slight improvements to habitat indicators when the North Channel is blocked. Results of the effort also indicate minimal changes in channel depths, velocities, and bed shear stresses along the South Channel and alleviate the concerns regarding potential changes to the morphology of the South Channel and the potential loss of a surface flow connection between Granite Boulder Creek and the South Channel. Additional hydraulic modeling, a refined understanding of geomorphic processes, and collaboration with local partners will be applied in the future to understand the viability of additional potential rehabilitation options within the reach and determine the most suitable actions for habitat improvement.

Chapter 1 INTRODUCTION

In compliance with the Federal Columbia River Power System Biological Opinion (NOAA 2008), the Bureau of Reclamation (Reclamation), U.S. Army Corps of Engineers, and Bonneville Power Administration are working to implement salmonid habitat rehabilitation projects in the Columbia River Basin. Reclamation produced this report to help meet tributary habitat commitments contained in the 2008 Federal Columbia River Power System Biological Opinion (NOAA Fisheries 2008). This report provides scientific information to help identify, prioritize, and implement sustainable field projects, in collaboration with Tribal, State, and local partners, that improve survival and lead to the recovery of salmon and steelhead listed under the Endangered Species Act (ESA). These efforts are focused on limiting factors to protect and improve survival of ESA-listed salmonid fish species and other culturally important salmonid fish species within the four general sectors of harvest, hatcheries, hydropower, and habitat. Implementation of a combination of actions in all four sectors is expected to lead to the recovery of ESA-listed species. Within the habitat sector, Reclamation provides technical assistance for project identification, design, and construction in partnership with States, Tribes, Federal agencies, and other local workgroups. Initially, technical assistance was provided to address site-specific projects such as stream flow improvement, removal of in-stream barriers, and fish screen enhancement projects. More recently, Reclamation has become involved in habitat complexity projects which depend on geomorphic settings and river dynamics for biological success.

Reclamation has initiated assessments in multiple 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 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, 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 Oxbow Conservation Area which is owned and managed by the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO). The key objective of the *Tributary Assessment* was to further investigate hypotheses on river processes identified in the stream 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) mining activities have severely impacted floodplain connection and lateral channel migration, (2) returning all flow to the historical South Channel that would benefit habitat without adversely impacting channel morphology, and (3) geomorphic conditions within the reach that 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 on the multi-channel Oxbow Reach to understand and predict floodplain processes, side channel connectivity, and split flow dynamics through the selected reach. 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. 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 a full understanding 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 Oxbow and Forrest Conservation Areas were given priority based on the presence of ESA-listed species, rehabilitation potential, stakeholder interest, and ownership by the CTWSRO. To expedite the process, all resources for the hydraulic modeling and geomorphic analysis efforts were shifted to the Oxbow Conservation Area in 2009 and construct all or selected parts of the approved design in 2010, depending on the Tribe's funding availability. The Forrest Conservation Area reach assessment will be initiated in the spring or summer of 2009 with the intent to design selected features in 2010 and construct the approved design in 2011, depending on funding availability.

1.2 Description of Oxbow Conservation Area

The 3.5-mile reach of the Oxbow Conservation Area selected for reach-level evaluation has been substantially modified, due primarily to ranching, grazing, timber harvest, road and levee construction, channel stabilization, and dredge mining. The first three activities mentioned led to the removal of vegetation from the floodplain and adjacent valley floor. Road and levee construction resulted in disconnection of floodplain, while bank stabilization structures, principally rock spurs and riprap, have constrained lateral channel migration. Dredge mining activities that occurred during the early 1940s have been the most substantial impact to the reach. This activity altered the channel and floodplain characteristics dramatically by changing the location, geometry, and planform of the main channel, as well as the number of side channels. Dredging operations turned over floodplain deposits, winnowed out available fines, and altered the size of the channel bed and floodplain sediment. After mining ceased, stream flow was split between two channels, the North and South Channels. The South Channel is the remnant of the natural channel to the south of the dredge tailings; the North Channel was constructed through the dredge tailings and across the toe of the Granite Boulder Creek alluvial fan. During discharges that exceed channel capacity, most of the stream flow is routed through the South Channel; however, during low discharges (generally less than 100 cubic feet per second [cfs]), the hydraulic conditions are reversed due to the conveyance conditions at the bifurcation of the North Channel.

All or part of the three reaches identified in the *Tributary Assessment* along the Oxbow Conservation Area were evaluated in this report because the reaches were influenced by similar physical processes prior to dredging impacts. The areas evaluated in this reach assessment include the downstream portion of reach 9, all of reach 8, and almost all of reach 7 (Figure 5). The downstream portion of Middle Fork (MF) reach 9 (MF9) extends from the upstream model boundary to just above the North-South Channel bifurcation. MF7 extends from the confluence of Beaver Creek downstream to a bedrock confinement. MF7 and MF9 are characterized by wide floodplains, relatively low slopes, and high sinuosity and the potential for side channels and frequent floodplain inundation. MF7 and MF9 were distinguished from MF8 by the impacts of the dredge tailings.

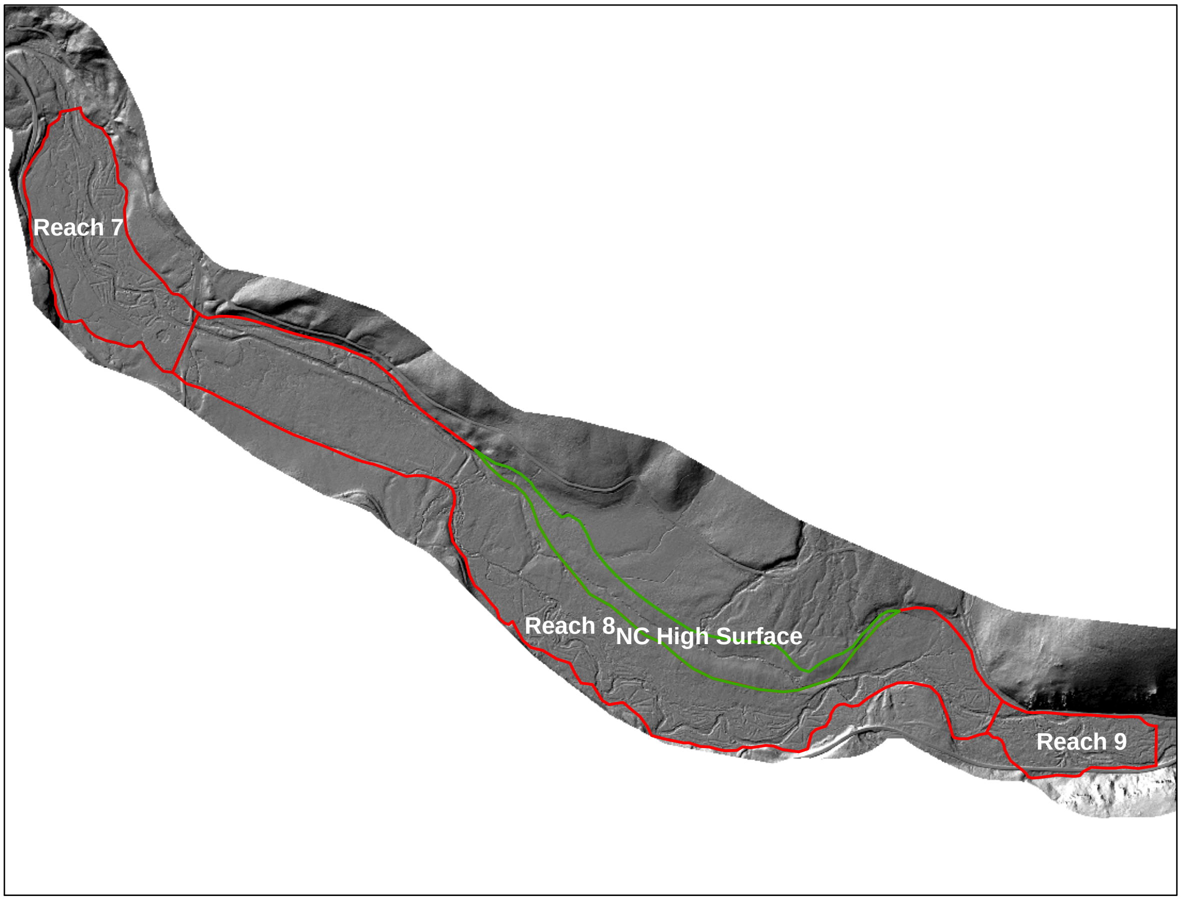

Figure 5 – Delineation of reaches modeled in this analysis.

MF8 extends from just upstream of the North-South Channel bifurcation to just upstream from the Beaver Creek confluence and was greatly modified by dredge mining in the 1940s. Although MF8 does not include the higher surface of the North Channel, which runs across the historic toe of the Granite Boulder Creek alluvial fan, a substantial portion of the channel was heavily channelized as a result of the mining activities. The channelized section has resulted in inhibiting lateral migration and floodplain inundation.

Dredge mining also resulted in increasing the size of bed material in the North Channel and the channelized section of MF8 downstream from Ruby Creek. An in-channel pebble count collected in the North Channel indicates considerably larger material than all other sediment sizes measured in the 23-mile assessment area of the TA (D50~90 millimeter [mm]). Unlike the rest of MF8, the South Channel is located in relatively unmodified floodplain deposits and, with the exception of cleared vegetation, appears to be continuing lateral channel migration and reworking of floodplain deposits. Sediment samples collected in the South Channel and at the confluence of the North and South Channels were comprised of material with median grain sizes of 32 mm and 14 mm, respectively (Reclamation 2008).

Two significant contributors of stream flow and sediment to this reach are Granite Boulder Creek, located downstream from the bifurcation of the North and South Channels, and Ruby Creek, just downstream from the confluence of the North and South Channels (Figure 6). Additionally, both would have provided substantial physical constraints on channel morphology, particularly on lateral channel migration. Parts of each fan were dredged and the creeks have been at least partially diverted into artificial channels that cross these alluvial fans. Channelization resulting from the dredge activities now severely impacts the positions of the tributaries and the main channel, as well as the river function in this area.

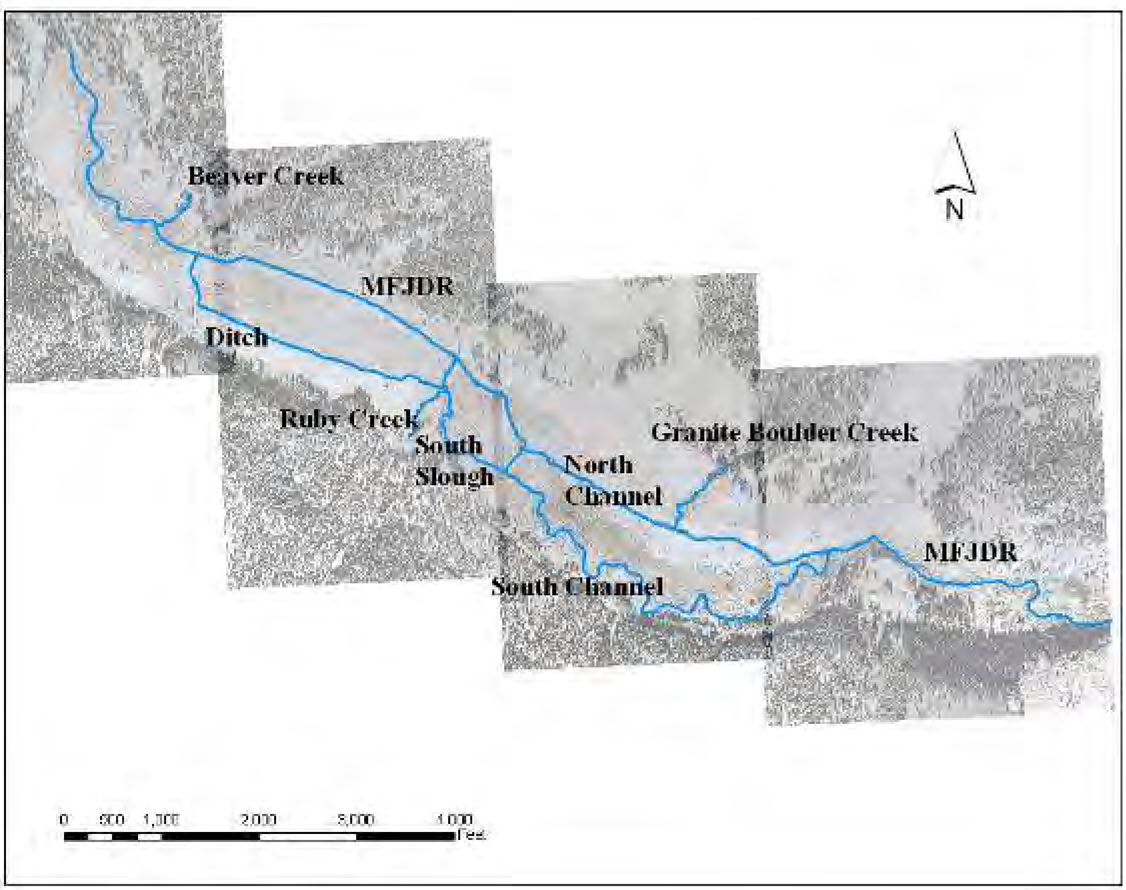

Figure 6 – Oxbow reach study area.

1.3 Purpose of Geomorphic Assessment

Fine-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) and collect detrital charcoal and sediment samples in an attempt to evaluate the type of vegetation growing adjacent to the river prehistorically.

1.4 Purpose of Modeling Effort

The Oxbow reach is comprised of a complex network of multiple channels and tributaries. Therefore, a two-dimensional (2D) hydraulic model was developed to increase understanding of floodplain processes, side channel connectivity, split-flow dynamics through the selected reach, and make predictions of future conditions based on potential options. Baseline hydraulic parameters including depth-averaged velocity, bed shear stress, and depth were compared along the channel thalweg and across the areal extent of the floodplain. In addition, water surface elevation profiles were developed and high quality habitat areas were identified.

1.4.1 Conditions Examined

Numerical simulations were conducted for the 2- through 100-year discharges with inlet flows ranging from 881 cfs to nearly 2,700 cfs. In addition to investigating the existing condition, the model was applied to evaluate potential option scenarios to examine how hydraulic parameters and habitat features may change following a specified rehabilitation action. The potential options included blocking off the North Channel, an artifact of dredge mining downstream from the bifurcation of the historical South Channel and just upstream of the confluence with Granite Boulder Creek, a major tributary of the MFJDR.

Chapter 2 METHODS

2.1 Geomorphic Methodology

The general methodology followed for evaluating the geomorphology is based on mapping the surficial geology, most commonly found on historical aerial photography, then verifying the mapping in the field. The mapped surficial geologic units are typically defined by their physical characteristics and morphology based on aerial photographs, topographic maps, and Light Detection and Ranging (LiDAR) data along with ground surveys. The overall appearance or geomorphology of a specific unit and the physical characteristics of the deposits are generally related directly to the processes responsible for its formation and/or deposition. In addition to mapping, stratigraphic and sedimentological studies are conducted to characterize the physical properties of the materials that comprise the landforms or deposits, which provide information on specific processes responsible for their formation and their relative erodibility. The age (both relative and numerical) of these deposits is critical to understanding the history of the landscape and formation of specific landforms. Understanding the timing associated with specific landforms and the physical processes responsible for their formation (i.e., aggradation and degradation; channel migration across the floodplain; the development and evolution of side channels) is critical to understanding the river system. The age of the deposits can be assessed relatively on the basis of geomorphic characteristics (i.e., soil development, surface morphology, vegetation, weathering features, topographic position) or numerically by collected samples that can be submitted for radiometric analysis. For this study, no numerical ages were developed, but samples of detrital charcoal and pollen were collected to assess past vegetation.

2.1.1 Surficial Geologic Mapping

The 1939, 1956, 1976, 2002, and 2006 aerial photography were utilized in conjunction with recent LiDAR data, existing topographic data (USGS 7.5’ quadrangles), geologic information (Brown and Thayer 1966; Jett 1998; Bandow 2003), and field observations to refine the geologic mapping developed in the *Tributary Assessment* (Reclamation 2008). The principle intent of the mapping was to develop a better understanding of the spatial distribution of the surficial geology, related landforms, and the physical processes that are responsible for their formation, which is important in regard to how habitat in the reach was formed and what would be sustainable in this setting. Mapping was completed on the 2002 1:12.000-scale color aerial photographs using a stereoscope; contacts were verified in the field where possible. Physical characteristics were described in the field based on visual observation and were used to differentiate each of the map units. These characteristics included morphology, surface texture, and relative elevation.

In the Oxbow Conservation Area, much of the alluvium in the valley has been disturbed by dredge mining activity. Wherever possible, the location of alluvial units were mapped based on their position prior to the dredge mining in order to better understand the extent and spatial relationship of the deposits prehistorically. In addition, this information was considered important background to understanding the pre-mining conditions and processes that may be a goal for any potential options.

2.1.2 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 the Soil Survey Division Staff (1993), Birkeland (1999), and Tucker (2003). All descriptions were made in the field as materials were identified by visual inspection and textures were determined by hand after sieving them through 2 mm screen following the U.S. Department of Agriculture classification scheme (Soil Survey Division Staff 1993).

Natural exposures were utilized whenever possible to reduce impacts on the landscape and facilitate data collection. Where natural exposures were not available, soil pits were excavated by hand with shovels and/or picks. The overall dimensions of the pits were generally about 3 feet in length by 2 feet in width with a maximum depth of 3 feet. A soil auger was also used to collect stratigraphic data in lieu of digging soil pits or was used to determine where to locate soil pits.

Numerical ages for specific map units can be determined from a variety of analytical methods. The most common methodology used in studies of younger unconsolidated sediments is the radiocarbon method. Age estimates for the alluvium in this study were based on the results of radiocarbon analyzed (Bandow 2003). In this study, charcoal and pollen were collected and analyzed to better understand the vegetative history along the river, not to determine the age of the deposits. Charcoal and bulk sediment samples for pollen analysis were collected to ascertain the vegetative history along the river. All samples were collected in small plastic bags or vials and labeled with unique alpha-numeric identifiers. All samples collected for charcoal analysis were submitted for macrobotanical identification. This procedure allows for the identification of the sample material and classification to a taxonomic group, generally to the genus-level, which is useful in providing information on vegetation that may have been present in the area prehistorically. The laboratory methodology used to separate and identify this material and the procedures followed for the pollen analysis are included in Appendix C.

2.1.3 Geochronology

Organic material in the form of detrital charcoal, shell, or wood are collected during stratigraphic studies and submitted for radiocarbon analysis to provide estimates of the age of the deposits from which the material was recovered. A rudimentary geochronological scheme for the alluvium had previously been established by Bandow (2003) and provided the needed information regarding the age of the youngest stream terraces along the MFJDR. For this study, precise numerical ages for the older alluvium was not considered critical to the objective of the study and age estimates made based on relative age indicators (soil development and surface morphology), as well as regional correlations, were considered adequate. 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. All of the samples have been retained and can be utilized in the future for radiocarbon analysis if it is deemed necessary.

Chemical analyses can also be conducted to identify specific tephra (volcanic ash), but no such analyses were conducted for this study. 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) and a relatively thick ash bed in Holocene alluvial fans deposits was observed along the MFJDR. While specific geochemical analyses identifying the ash bed unequivocally as the Mazama were not done, given its widespread occurrence in the region and its occurrence locally within Holocene deposits, the observed ash bed is assumed to be the Mazama.

2.2 Hydraulic Modeling Methodology

2.2.1 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 and adopts an approach for coupled modeling of channels and floodplains. 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. Cartesian or raster meshes may also be used.
* 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.

2.2.2 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.

2.2.3 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. The North Channel on the Oxbow Conservation Area was not surveyed at this time due to scheduled recontouring of the dredge tailings within the floodplain.

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.

In October 2006, cross-sectional surveys through the North Channel of the MFJDR on the Oxbow Conservation Area were also collected for the anticipated project designs on the property. Sufficient survey data were obtained between the cross sections such that breaklines of channel features (e.g., top of bank, toe of slope, edge of water, thalweg) could be generated.

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 7.

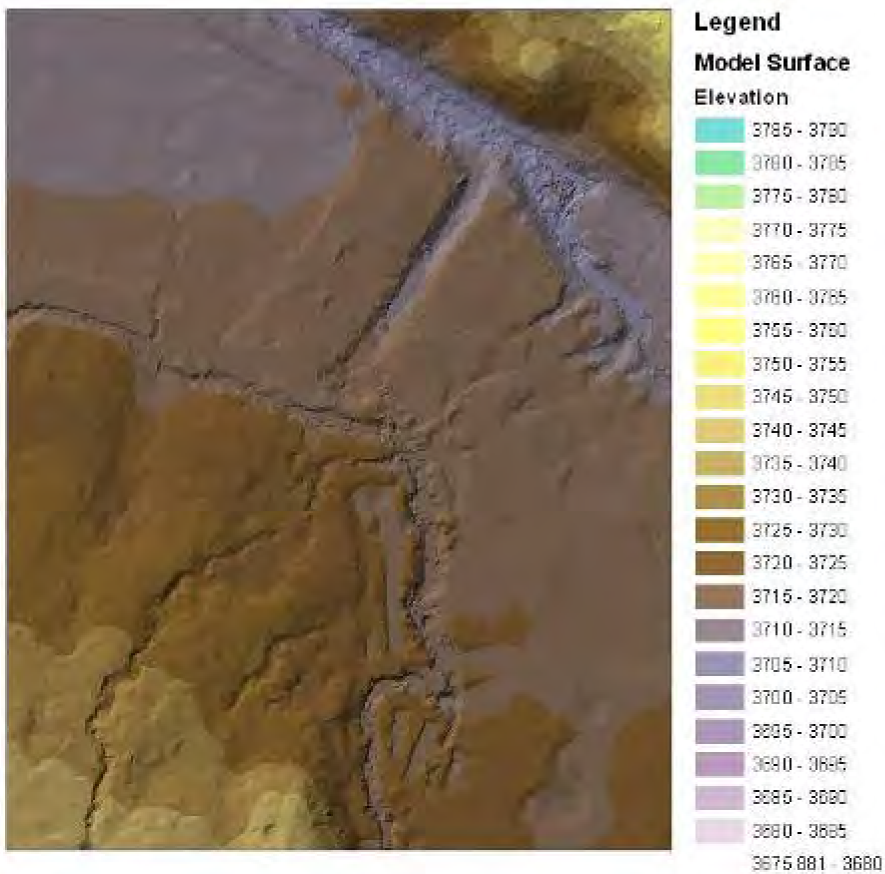

Figure 7 – Example of the surface used as input for the hydraulic model. Elevations are in feet.

2.2.4 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 8 and Figure 9.

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 14 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 200,000 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.

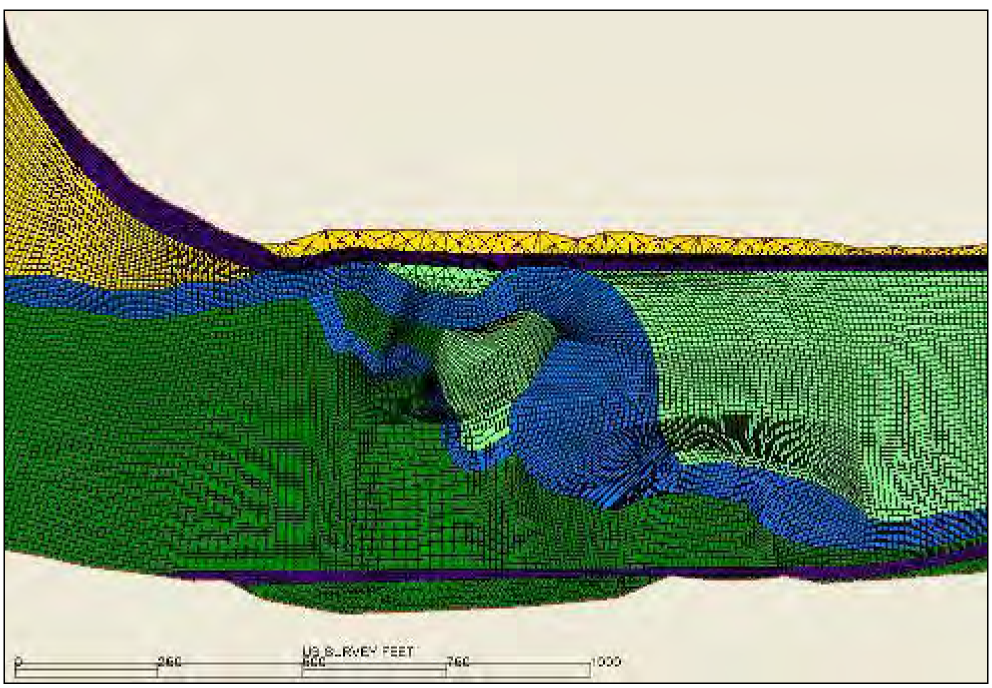

Figure 8 – Example of the numerical mesh constructed in SMS. The various colors represent roughness values (blue = channel, dark green = heavy vegetation, light green = light vegetation, yellow = open areas and grasses, and purple = road).

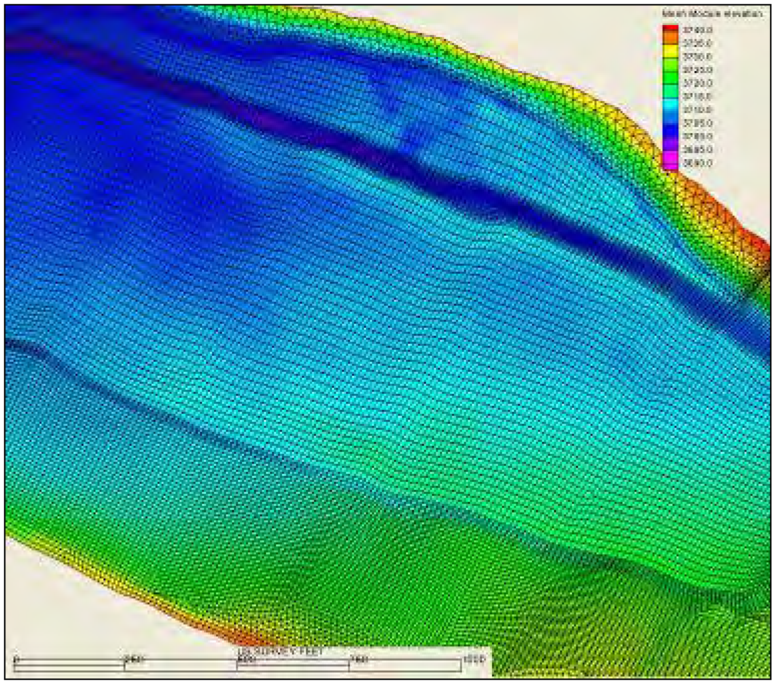

Figure 9 – Example of the numerical mesh showing surface elevations in feet as derived from the terrain surface constructed in ArcGIS.

2.2.5 Roughness Zones and Vegetation

Five classifications of roughness were defined as 1) active channels; 2) open areas and grasses; 3) light vegetation; 4) heavy vegetation; and 5) roadway and bridge embankments (Table 1). Within the extents of the mesh, roughness zones were spatially delineated using the 2006 aerial photographs and the topography data from the model surface. Model sensitivity to in-channel roughness is discussed in section 4.6.1.

Table 1 – Roughness values used in the model and in the sensitivity test.

Run ID	Channel	Open Areas/ Grasses	Light Vegetation	Heavy Vegetation	Road/Bridge
1	0.039	0.045	0.055	0.065	0.045
2	0.044	0.045	0.055	0.065	0.045

2.2.6 Downstream Boundary Conditions

Downstream boundary conditions for the model were derived from a one-dimensional (1D) hydraulic model developed in the TA (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 several 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 4.5).

2.2.7 Upstream Boundary Conditions

Discharges used in the model represent the 2-, 5-, 10-, 25-, 50-, and 100-year return periods (Table 2). 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 Sections 4.1 and 4.5. 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. In addition, refinement of the model mesh may be necessary.

Table 2 – 2- through 100-year discharges in cubic feet per second (cfs) for the Middle Fork John Day River and inlet flows for Granite, Ruby, and Beaver Creeks.

Discharge	Inlet (cfs)	Granite Boulder Creek (cfs)	Ruby Creek (cfs)	Beaver Creek (cfs)	Outlet (cfs)
Q2	881	56	20	20	977
Q5	1,332	80	31	32	1,475
Q10	1,650	98	38	41	1,827
Q25	2,020	118	47	51	2,236
Q50	2,380	137	56	60	2,633
Q100	2,698	156	64	70	2,988

Chapter 3 GEOMORPHOLOGY, SURFICIAL GEOLOGY, AND PREHISTORIC VEGETATION

3.1 General Geomorphology

The general geomorphic character of the MFJDR is that of a meandering channel flowing across broad, flat valley reaches with low, wide floodplains alternating with short, steep sections of straight, narrow channels flanked by narrow, high terraces. In the broad valley reaches, there is an abundance of historical photographs of abandoned channels and meander scars on the floodplain with many secondary or side channels (Figure 10).

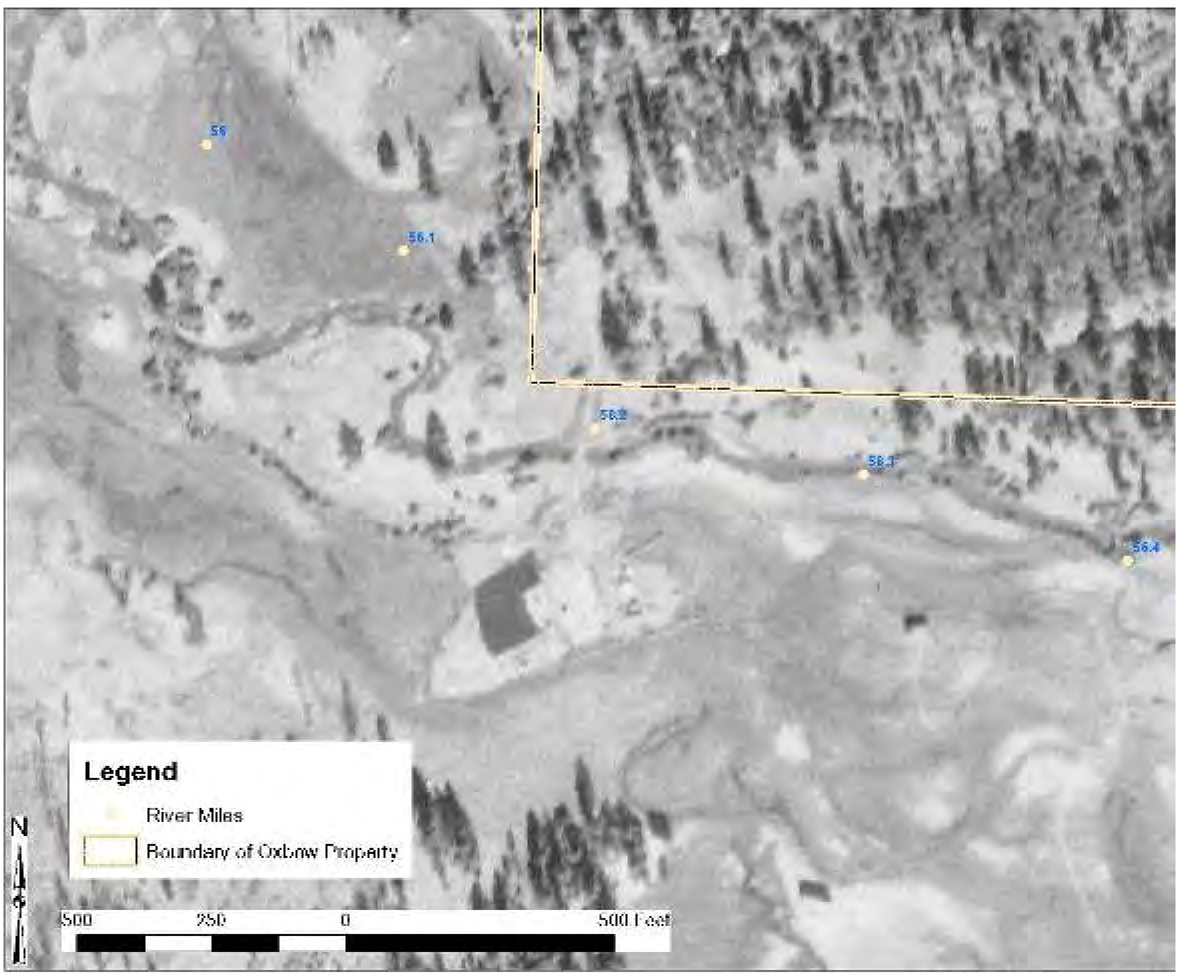

Figure 10 – Portion of 1939 aerial photograph near the mouth of Beaver Creek showing the meandering form of the main channel, the numerous secondary and side channels, and meander scars on the floodplain.

This general character of the river is in direct response to constraints imposed by the underlying bedrock formations and geologic structure. The course of the MFJDR and its valley are controlled by the geologic structure as it follows the axis of the Middle Fork Syncline for most of its length (Brown and Thayer 1966; maps may be found in Appendix A of the *Tributary Assessment*). The poorly consolidated, less resistant sedimentary units within the bedrock are more erodible, which has allowed the river to migrate laterally and form broad valleys. In contrast, the more resistant volcanic rocks within these formations restrict the lateral migration and provide vertical control on the channel gradient, which has created narrow steep channels. In addition, some units within the bedrock are prone to landsliding due to lithologic characteristics of the rock, the general dip of the strata relative to the valley, and the overall geologic structure. In some areas, these landslides influence the position of the river channel within the valley or actually dictate its position.

The character of the river through the Oxbow Conservation Area follows this pattern, with the valley downstream of Ruby Creek being relatively flat and wide. On historical aerial photographs, this area is seen as a wet meadow with many secondary and side channels, mostly likely supported by spring flow and a high groundwater table. This environment would have been established by a constriction formed by bedrock at the downstream end of the valley, a large alluvial fan at Ragged Creek, and a number of small landslides along the northern side of the valley.

The morphology of the valley and the position of the river within the valley upstream of Ruby Creek are largely dictated by alluvial fan deposition at the mouths of the larger tributaries. The subbasins 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 statistical analyses that the morphology of the alluvial fans was a result of the tributary subbasin characteristics, which directly control tributary discharge and sediment supply. In the Oxbow Conservation Area, the largest alluvial fans that deflect the river channel are associated with Ragged Creek, Ruby Creek, Granite Boulder Creek, and Butte Creek (Appendix A). The sediment supplied by these streams to the margins of the valley is primarily of granitic and basaltic composition and forms large gravelly alluvial fans. All of the major tributaries in the Oxbow Conservation Area, with the exception of Beaver Creek, have deposited large volumes of coarse-grained sediment into the valley. This is important not only because of the control these fans exert on the geomorphology of the river channel, but also in regard to effect the sediment input has on river hydraulics and the formation of specific habitat in the Oxbow Conservation Area.

3.2 Surficial Geology

In the *Tributary Assessment*, mapping of the geology along the MFJDR defined five major units: a single undifferentiated bedrock unit; river alluvium mapped as the low surface; alluvial fan deposits; landslides; and an alluvium-colluvium unit (Table 3; Reclamation 2008). Abbreviations used to denote geologic units described in this study and how they correlate to previous mappings are outlined in Table 3. Within the Oxbow Conservation Area, a small remnant of an older terrace was also recognized and mapped.

For this analysis, the mapping completed for the *Tributary Assessment* was refined in order to better understand the processes affecting the river geomorphology in the Oxbow Conservation Area. Major differences in the mapping included differentiation of the floodplain and stream terraces within the low surface and in the alluvium-colluvium of the *Tributary Assessment*; refined mapping of the landslide deposits within the Oxbow Conservation Area; and detailed descriptions of the alluvial fans deposition shed into the valley by tributary streams. A single bedrock unit was still mapped, but distinctions between the bedrock in the Oxbow Conservation Area and elsewhere in the area are described in the following subsections. Additionally, the 7.6-kilo annum (ka) Mazama ash (Qma) was recognized (Bacon 1983). Exposures of the Mazama ash in the area are limited, but the ash bed provides an important chronostratigraphic marker that permits age distinctions to be made between some of the surficial deposits. Stumps of old growth trees on older stream terraces also provide minimum age constraints for the alluvial deposits.

Table 3 – Correlation chart of geologic units.

Deposit	*Tributary Assessment*[1]	This Study	Bandow (2003)
Bedrock	Bedrock	Tc Tsv	-
Landslide	Landslide	Qls	-
Alluvial fan	Alluvial-fan deposit	Qafs Qafd	-
Alluvium	Low Surface Terrace	Qa4 Qa3 Qa2 Qa1	T0 T1 T2 T3
Colluvium	Alluvium-colluvim	Qc	-
Mazama ash	-	Qma	-

[1]Reclamation 2008

3.2.1 Bedrock (Tc and Tsv)

The bedrock geology underlying the MFJDR subbasin is comprised primarily of the Middle Miocene Strawberry Volcanics (Tsv) and the older Eocene Clarno Formation (Tc; Table 3). The contact between the two formations crosses the valley just upstream of the Oxbow Conservation Area at about RM 62.7 (Brown and Thayer 1966). The Strawberry Volcanics include a gray basaltic andesite interbedded with moderately consolidated light brown-to-white silty ash-rich sediment (Figure 11). The basaltic andesite is the more resistant of the two units and is the major constituent in the colluvium found along the margins of the valley and the gravel in the alluvial fans and river alluvium upstream of the Oxbow Conservation Area.

The valley in the Oxbow Conservation Area is completely underlain by the Eocene Clarno Formation, which is comprised of andesitic volcanic flows interbedded with tuff; volcanic breccia and conglomerate; and lenses of water-laid ash and silt (Brown and Thayer 1966). The very diverse nature of the Clarno Formation and the characteristics of these units is one of the reasons the formation is prone to landsliding. A very large landslide within the Clarno Formation that covers an area of more than a square mile forms the southwestern margin of the river valley between the Forrest and Oxbow reaches (RM 61.35 to 62.35).

Other bedrock types present in the MFJDR subbasin include the intrusive crystalline, metamorphic, sedimentary, and volcanic rocks described previously (Section 3.1). These rocks are present only in the tributary subbasins and are limited in their extent to the higher terrain that forms the margins of the subbasin (Brown and Thayer 1966). The intrusive crystalline rocks include diorite and gabbro and occur primarily in the tributaries north of the Oxbow Conservation Area (e.g., Granite Boulder Creek). The tributary subbasins south of the MFJDR are primarily underlain by older Paleozoic sedimentary rocks including argillite, quartzite, limestone, and conglomerate with small areas of diorite. The differences in distribution of rock types in the tributaries control in large part the mechanism responsible for sediment delivery to the main stem MFJDR. In the Oxbow Conservation Area, the three largest alluvial fans on the south side of the valley, Ragged Creek, Ruby Creek, and Butte Creek, are formed primarily by debris flows. Material comprising the alluvial fan deposits is very poorly-sorted and includes blocky, angular boulders in a fine-grained matrix of silt and mud. The alluvial fan from Granite Boulder Creek on the northern side of the valley is primarily the product of stream flow. Relatively, the Granite Boulder Creek alluvial fan is better-sorted, contains more subrounded and rounded gravel with coarser-grained sand matrix.

Figure 11 – Exposure of the Strawberry Volcanics in a road cut near the confluence of Bridger Creek with the Middle Fork John Day River.

3.2.2 Landslide (Qls)

Landslides and shallow soil slumps are relatively widespread and play a large role in the regional geomorphology. Some of the landslides are quite extensive and have even altered the course of the river (Thayer 1972). As described in Section 3.2.1, a very large landslide that extends for about a mile along the river between the Forrest Conservation Area and Oxbow Conservation Area (RM 61.35 to 62.35) directly controls the position of the river channel. This landslide also results in a dramatically narrower and steeper valley segment than both upstream and downstream of the slide. Numerous smaller landslides are present along the northern valley margin through much of the Oxbow Conservation Area between Ragged Creek and Granite Boulder Creek.

3.2.3 Alluvial Fan (Qafs and Qafd)

All of the alluvial fan deposits in the Oxbow Conservation Area have been shed either onto the valley floor, thereby impinging directly on the river channel, or onto and across fluvial terraces along the margins of the valley where they do not directly influence the present channel. Two distinct types of alluvial fan deposits are defined based on the dominant mode of deposition responsible for their formation; stream-dominated deposits (Qafs) are the result of stream flow in wide, shallow channels whereas the debris-flow (Qafd) deposits are the result of debris flows in the narrow, steep channels. The stream-laid alluvial fans are composed of moderately-sorted, subrounded and rounded gravel with coarse-grained sand matrix (Figure 12). The morphology of the fan surface on stream-laid alluvial fans is generally much smoother and in the case of Granite Boulder Creek, is much broader in its areal extent and volume. Debris-flow dominated alluvial fan deposits are present along the south margin of the valley, have very rough fan surfaces, and are smaller both volumetrically and in their areal extent.

The bedrock types underlying the debris flow dominated alluvial fans in the Oxbow Conservation Area are composed principally of volcanic rocks of the Clarno Formation and older sedimentary rocks, including argillite, quartzite, limestone, and conglomerate, with minor amounts of intrusive crystalline rocks. The bedrock underlying much of the Granite Boulder Creek alluvial fan is predominantly crystalline bedrock, including diorite, gabbro, and serpentine, with minor amounts of sedimentary rock. Jett (1998) outlines specific subbasin variables in the MFJDR subbasin that support this distinction between stream-laid and debris-flow dominated alluvial fans; however, in his analysis, only 2 of the 21 variables he analyzed were related to bedrock characteristics within the tributary subbasin: lithologic competency and degree of fracture. In the case of the alluvial fans in the Oxbow Conservation Area, factors from his analysis that correlate well with the stream-laid and debris flow alluvial fans observed at Ruby Creek, Granite Boulder Creek and Butte Creek are the drainage area, the subbasin and stream length, and the areal extent of the fan on the valley floor. In the Oxbow Conservation Area, the areal extent of stream-laid alluvial fans is generally greater than the debris flow dominated alluvial fans; in the case of the Granite Boulder Creek fan (Qafs), the fan is a factor of eight times greater than the Butte Creek fan, the largest debris flow dominated fan (Jett 1998).

The uppermost part of the Granite Boulder Creek drainage was glaciated during the latest Pleistocene. This would have contributed to a greater overall sediment load in the drainage at the time when the headwaters were occupied by ice. Much of this sediment remains stored, particularly in the lower part of the basin and south of the current course of Granite Boulder Creek. The current size of the alluvial fan and the character of the deposits, which plays a large role in the recent history and evolution of the river, are primarily a function of the drainage basin area and lithology of the basin.

Figure 12 – Sandy gravel alluvial fan deposit near the confluence of Granite Boulder Creek and the North Channel near RM 57.4.

3.2.4 Alluvium (Qa4 – Qal)

In the *Tributary Assessment* (Reclamation 2008), two units were mapped that were associated in part with fluvial deposition: the low surface and an alluvium-colluvium unit. The low surface incorporated many of the deposits on the valley floor but did not differentiate the floodplain deposits from terrace deposits of several different ages (Bandow 2003; Table 3) except for a small remnant of an older terrace just upstream of Ragged Creek near RM 55.7. Similarly, the alluvium-colluvium unit mapped in the *Tributary Assessment* includes deposits that, in many cases, could be associated with the river, but were not differentiated from colluvium shed off of the adjacent hillslopes. For this analysis, four distinct deposits that could be attributed directly to deposition or reworking by the river, including floodplain deposits and three terraces, were mapped (Table 3). 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 equates to unit T0 of Bandow (2003; Table 3) and on the basis of three radiocarbon ages Qa4 formed in the last 1,000 years. Based on hydraulic modeling results, a majority of the floodplain in the area of Granite Boulder Creek is inundated by the 2-year peak discharge. In addition to being located immediately adjacent to the active channel or side channels, the surface of the floodplain is formed by unweathered sediment and exhibits primary deposition forms (e.g., bars and swales) as well as sedimentologic characteristics, such as clast imbrication, bedding, and grading. The floodplain can also be distinguished on the basis of the vegetation or the lack of vegetation growing on the deposits.

The floodplain in the Oxbow Conservation Area is inset into slightly older but distinct terrace deposit (Qa3). The terrace surface ranges from 3 to 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 very infrequent inundation or by flow emanating from springs along the valley margins. Quite often these channels are muted due to infilling by fine-grained overbank sediment. 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 13). This thin 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 3) who reported the surface as being abandoned by the river about 1,000 to 1,200 years ago. This interpretation is based on a single radiocarbon age from the gravel at the base of the deposit. Given the surface morphology of the terrace and the nature of the soil formed on the deposits (Appendix B), it is likely that the surface is inundated by large infrequent floods. Results of the hydraulic modeling routing the 100-year peak discharge indicate this surface being inundated in some areas.

Figure 13 – Bank exposure of Qa3 alluvium. Note the thick bed of fine-grained sediment (overbank deposits) overlying the sandy gravel visible at the base of the exposure.

The older terrace deposits, Qa2 and Qa1, are characterized by a noticeably smoother and planar surface that is 6 to 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 Forrest Conservation Area were approaching 400 years old when they were cut, presumably in the late 1800s, and provide a minimum age for the terrace surface. Detrital charcoal and pollen recovered from soil pits excavated on the surfaces of these terraces are predominately conifer species that support this observation (Appendix C). Bandow (2003) reports the Mazama ash interbedded with overbank sediments in his unit T2 (Qa2 deposits of this study). No numerical ages have been developed for the Qa2 deposits along the MFJDR, but an age estimate of 5 to 7 ka for the abandonment of the terrace was made by Bandow (2003) based on the presence of the Mazama ash, but the presence of the ash may not represent the age of the terrace. For example, at a location along the Powder River near Sumpter (Klinger 2003; unpublished data), the age of a terrace surface containing a 0.5 meter thick bed of Mazama ash is estimated to be a minimum of 1,800 years old based on radiocarbon analysis of detrital charcoal recovered from the overlying soil. It was determined that the Mazama ash present in terrace deposits was not primary air-fall and it was speculated that it may have been reworked from the landscape at a later date. The thickness and relative purity of the ash in the deposit may be the function of several factors including the abundance of the ash on the landscape or the tendency of the ash to become segregated in overbank sediments due to its lower density. Thick ash beds in terrace deposits are commonly recognized at numerous locations in eastern Oregon (Levish and Ostenaa 1996); therefore, the presence of the Mazama ash in fluvial deposits may not be a reliable indicator of age and must be carefully evaluated.

The oldest and highest terrace, Qa1, is relatively well-preserved at several locations in the Oxbow Conservation Area. It also displays a smooth planar surface that overlies thin fine-grained sandy sediment interpreted as overbank deposits and a thick sequence of sandy gravel (Figure 10). In a soil pit on the Qa1 deposit downstream of Beaver Creek (MJD4; Appendix B), the fine-grained overbank deposit is about 0.3 meters thick (about 1 foot) and interfingers with angular gravelly colluvium that prograded across the terrace surface from the nearby hillslope shortly after the terrace was abandoned. Again, no numerical ages have been developed for the Qa1 deposits along the MFJDR, but an age estimate of 8 to 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.

Figure 14 – Exposure of the Qal terrace deposit just upstream of Butte Creek near RM 57.9.

3.2.5 Colluvium (Qc)

In the *Tributary Assessment*, an alluvium-colluvium unit was mapped (Reclamation 2008). This unit did not differentiate between colluvium shed off the hillslope and 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. As illustrated in the soil pit excavated on the Qa1 deposits (Section 3.2.4), the colluvium can and probably does interfinger with alluvium quite often along the valley margins. This can make it quite difficult to distinguish between the deposits without a clear exposure. In this analysis, colluvium was differentiated from the alluvium in the field solely on the basis of ground surface slope. It was reasoned that at the point where the ground surface transitioned from the hillslope to near-horizontal constituted the contact between the colluvium and alluvium. In doing this, it should be noted that the areal extent of colluvium in the valley is greatly reduced from what was mapped in the *Tributary Assessment* (Reclamation 2008).

In general, the colluvium is limited to a narrow band along the margin of the valley and in outcrops, it is distinguished from the fluvial deposits by their more angular, poorly-sorted character and the generally steeper slope of the ground surface overlying the deposits described above. In a few areas where the valley margins are quite steep, talus formed almost exclusively of angular rock 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.

3.2.6 Mazama Ash (Qma)

The Mazama is a light gray to white glassy ash that was erupted from the caldera (Mt. Mazama) that now forms Crater Lake in south-central Oregon. The age of the ash is about 7.6 ka and fairly well-constrained by numerous radiocarbon ages from widespread locations in the western United States. (Sarna-Wojcicki and Davis 1991). The thickness of the ash is dependent on its location relative to the eruptive center. In this area of eastern Oregon, the primary air-fall may form beds only a few inches thick, but beds many feet thick exist where the ash has been reworked from the landscape and ponded in hollows. 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 within the last few hundred to several thousand years; consequently, 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. Along the MFJDR, the Mazama ash has been reported in terrace deposits (Bandow 2003) and observed in alluvial fan deposits in road cuts along Highway 20.

3.3 Geologic History

As described in Section 3.2.1, a variety of bedrock types underlie the MFJDR subbasin. The type of bedrock and its impact on subbasin hydrology and vegetation; the lithologic characteristics of the bedrock and their effects 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. The most important aspect of the geologic history on the development and evolution of the river with regard 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.

3.3.1 Deposition/Formation of Specific Geomorphic Units

The history and formation of three specific geomorphic units present along the MFJDR are either directly related to the river or exert some influence on its development and evolution. These units include, in order of increasing importance, landslides (unit Qls in Table 3 and described in Section 3.2.2), the alluvial fans (units Qafs and Qafd in Table 3 and described in Section 3.2.3), and the floodplain and stream terraces (units Qa4-Qa1 in Table 3 and described in Section 3.2.4). The large landslide that extends for about a mile along the river between the Forrest Conservation Area and Oxbow Conservation Area (RM 61.35 to 62.35) is a dominant factor in controlling the geomorphology of the river at that location and it has had some impact on the river both upstream and downstream. In the Oxbow Conservation Area, landslides have been a much smaller factor. The most significant landslide is located north of the confluence of Ruby Creek with the MFJDR at RM 56.8. This landslide is most likely the result of the river undercutting the toe of the slope where the river was forced north by the Ruby Creek alluvial fan.

The precise age of each landslide in the Oxbow Conservation Area is unknown, but certainly the landslide near Ruby Creek is middle to late Holocene-aged (less than 7,600 years) based on its surface morphologic characteristics of sharp hummocky topography and its stratigraphic relationship to stream terrace deposits (overlies Qa3 terrace; topographically lower than Qa2 terrace). The age of some of the smaller landslides in the downstream part of the Oxbow Conservation Area near Beaver and Ragged Creeks may be somewhat older as the morphology is more muted and the relationship to the river is less clear. Several of the landslides in this area appear to have been deposited onto the margins of the Qa1 terrace. In many areas of the western United States, the timing of widespread landslide activity has been linked to climatic factors, principally that the rate of landslide activity rate increases during periods when the climate is wetter than present. In specific areas of the west, climate is less a factor where landslides are controlled more by rock type and geologic structure. In the case of the MFJDR, the bedrock is certainly a factor just as landslides and other mass-wasting features are common and widespread. As a result, landslides represent a key element in the MFJDR system for delivering large volumes of sediment to the river and more often via the many tributaries.

Alluvial fans are the principal source of sediment in the MFJDR, as well as controls on the morphology of the river. This influence on the morphology is the result of not only the type of sediment they deliver to the mainstem, but the rate, volume, and manner of sediment delivery to the river. These factors were described in Section 3.2.3 and formed the basis for thesis work completed in the MFJDR subbasin 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 subbasin other than relating the influence that changes in climate have on their 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. The most important factor pertaining to the deposition and formation of alluvial fans in the MFJDR subbasin is that the supply of sediment delivered to the river is at or slightly exceeds the ability of the river to transport this material downstream. This condition is termed transport-limited and based on the history of river incision and lateral migration (Bandow 2003). This has been the situation for perhaps the last several thousand years.

The most important geomorphic unit in regard to the fluvial system along the MFJDR is the alluvium that forms floodplain and stream terraces (units Qa4-Qa1 in Table 3 and described in Section 3.2.4). 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 surficial mapping was in distinguishing the between the four alluvial units within the low surface unit 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 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 7,600 years. The wide floodplain and numerous abandoned channels on the valley floor (unit Qa3) visible in the 1939 photographs suggest that the recent history of the river has been predominately of lateral migration for at least the last 1,200 years (Bandow 2003). It is unclear exactly why the change in process on the river went from one of incision to one of primarily lateral migration. Bandow (2003) suggests climatic factors, but there is some evidence that it may in part be related to local base level control (bedrock channel), current hydrology (climate), and sediment supply (various mechanisms).

3.3.2 Influence of Specific Units on River Morphology and Evolution

The most influential geomorphic unit on the morphology of the MFJDR is the alluvial fans and there are several important aspects of the physiography that influence the evolution of the alluvial fans. In the Oxbow Conservation Area, there are four large tributary alluvial fans that directly impact the morphology of the river: Butte Creek, Granite Boulder Creek, Ruby Creek, and Ragged Creek located from upstream to downstream in the reach. The Butte Creek alluvial fan is relatively small compared to the Granite Boulder Creek fan located immediately downstream, but it exerts some control on the position of the river due to its location opposite the Granite Boulder Creek drainage and as a result, affects the channel gradient upstream. As described in Section 3.2.3, the Granite Boulder Creek alluvial fan is the largest in terms of its areal extent, therefore, it exerts a lot of control on the position of the MFJDR in the valley as well as supplying a tremendous volume of sediment to the system locally. The Ruby Creek alluvial fan, while being significantly smaller than the Granite Boulder Creek alluvial fan, constrains the width of the valley, dictates the position of the river on the valley floor, controls the gradient of the channel upstream, and has contributed to the formation of a small landslide that is impinging on the river from the north (see surficial geologic map; Appendix B). At the downstream-most end of the reach, the Ragged Creek alluvial fan works in combination with a resistant member of the Clarno Formation to control not only the position of the river, but its gradient.

Material shed onto the valley by Ruby Creek and Butte Creek is in general very coarse (bouldery) and primarily of volcanic composition. This material is predominately delivered to the fan surfaces and the valley margin by debris flows. As a consequence, both alluvial fans have a strong influence on the position of the MFJDR in the valley, pushing it generally northeastward. In combination with a landslide opposite Ruby Creek, the Ruby Creek alluvial fan provides a constraint on the valley width at RM 56.8 and as a result, controls the channel gradient locally and channel form immediately upstream. The morphology of valley downstream of Ruby Creek is significantly wider. As a consequence of the bedrock control in the channel near Ragged Creek at RM 55.3, the areal extent of the floodplain is greater as the MFJDR migrated laterally across this area, most likely in response to balancing slope and sediment load. Evidence for this is provided by channel scars visible on the valley floor in the 1939 aerial photographs (Figure 6). This area is in the location of the dredge tailings mapped in the *Tributary Assessment* (Reclamation 2008).

Based on the extent of its alluvial fan, it is apparent that the Granite Boulder Creek drainage is a major contributor of coarse-grained gravelly sediment to the MFJDR. Material shed onto the valley floor from Granite Boulder Creek is very coarse, primarily of granitic composition. This is in contrast to the volcanic composition of the alluvial fans on the southern side of the valley. The Granite Boulder Creek alluvial fan also has a strong influence on the position of the river in the valley by pushing it to the south. Unlike the Ruby Creek fan, its extent is significantly larger and the distal portion of the alluvial fan (toe) appears to have been modified by flooding on the MFJDR. Evidence for this is present in the form of patterns in the vegetation, the abandoned channel scars, and other lineations that are subparallel to the course of the river. The Granite Boulder Creek alluvial fan constrains the channel position of the river between RM 57.6 and 57.8 where it pushes the river against the Butte Creek alluvial fan near the present day split between the North and South Channels.

Lastly, similar aspects of the geology, how it influences the river geomorphology, and the processes controlling it can be observed at Butte Creek, but they are much less obvious than those observed downstream at Ruby and Granite Boulder Creeks. Material shed onto the valley floor from Butte Creek is very coarse (bouldery) debris flows and, as with Ruby Creek, primarily of volcanic composition. The Butte Creek alluvial fan is small in terms of areal extent relative to Granite Boulder Creek; however, its steep gradient, which is similar to that of the Ruby Creek alluvial fan, allows very coarse-grained material to be delivered from its subbasin directly to the margin of the valley. This allows the Butte Creek alluvial fan to exert some influence on the position of the river by pushing it northward against the toe of the Granite Boulder Creek fan. The Butte Creek alluvial fan is also located at the downstream end of a remnant Qa1 terrace and thereby buttressing the older terrace. It appears that the Qa1 terrace surface at this location is cut into and formed on older Butte Creek alluvium.

3.4 Prehistoric Vegetation Investigation and Evaluation

3.4.1 Charcoal Analysis

Thirty-four charcoal samples were collected from four soil pits excavated on the stream terraces and alluvial fan deposits along the MFJDR. Each charcoal sample was identified to family and genus level if possible (Appendix C). The results show several trends in the type and distribution of paleobotanical material recovered. Twenty-six of the 34 total samples were some variety of conifer charcoal; only a single fragment of Alder (Alnus) charcoal was recovered (Table 4). While the conifer charcoal was more common in the older deposits, it was present in deposits of every age. 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 vegetation species, specifically willow (Salicaceae) and cottonwood (Populus), is completely missing. Given that these species are present in other areas of the subbasin, the reason for their absence from this record is unclear. Another interesting finding is that hemlock (Tsuga) charcoal is present in only the oldest deposits (Qa1 and Qafs; Table 4). Hemlock (Tsuga) is not presently growing in the area.

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. The vegetation conditions in certain locations on the 1939 aerial photography appear to be much better than 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 vegetation. The trend indicated by these charcoal analyses results in no way represents a statistically valid analysis.

Table 4 – Frequency distribution of detrital charcoal in alluvial deposits.

Type of Material[1]	Qa3	Qa2	Qa1	Qafs	Total
Alnus	1	0	0	0	1
Larix	1	2	1	0	4
Pinus	1	3	1	2	7
Tsuga	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.

3.4.2 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 (Appendix C). The results show similar trends to the charcoal analyses 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 Appendix C). Pine (Pinus) pollen and charcoal was common in samples MJD1 through MJD10 (B1 horizon; interval 25 to 40 cm) and MJD3 through MJD7 (Bb horizon; interval 65 to 70 cm), but lacking in sample MJD1 through MJD9 (B2 horizon; interval 45 to 60 cm). This plus the relatively small concentration of pollen in general in sample MJD1 through MJD9 are interpreted to represent a period of very rapid deposition. The lack of pine pollen may also be indicative of missing or decreased numbers of pines locally. The rapid deposition of sediment in the interval of 45 to 60 cm may correlate to the denudation of the landscape of vegetation, perhaps due to fire, which also explains the lack of pine pollen. Generally, samples MJD1 through MJD10 and MJD3 through MJD7 have greater concentrations of pollen and microscopic charcoal indicative of a period of slower deposition, which is in contrast to sample MJD1-9. In samples MJD3 through MJD7, the interpretation of slow deposition is consistent with the formation of a B horizon on gravelly alluvium, suggesting a period of relative landscape stability. Low concentrations of Alder (Alnus) pollen and other vegetation 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, but is present in much smaller concentrations. 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 subbasin. The USFS habitat assessment did not specifically identify hemlock, but the current climate conditions in the higher elevations of the MFJDR basin appear to be adequate to support hemlock. The mean annual precipitation ranges up to 40 inches a year, whereas hemlock requires a minimum of about 30 to 32 inches per year. Hemlock pollen is present in younger alluvium (Qa2 and Qa3) suggesting its presence in the basin. The current lack of hemlock along the river corridor may be the result of changing climatic conditions, but it is believed to missing be due to logging pressure over the last 150 years. Hemlock is a prized species by the timber industry.

3.5 Stream Temperature, Springs, and Groundwater Monitoring

In August 2003, the Oregon Department of Fisheries and Wildlife and 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 15). 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. The first survey was conducted on August 14 and the air temperature during the flight ranged from 31.1°C to 34.4°C (88.0°F to 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 to 75.9°F). This difference in the air temperature resulted in a change in the median water temperature in the Oxbow Conservation Area (1°C to 1.5°C) suggesting that the water temperature on the MFJDR is strongly influenced by the air temperature (Figure 15). This is not the case in all areas of the MFJDR and may be linked to specific physical conditions of the channel within particular reaches such as the relationship of these reaches to the locations of springs, the groundwater-river interaction (hyporheic zones), tributary inflow, and shading of the channel by vegetation. These potential differences were not addressed in this study.

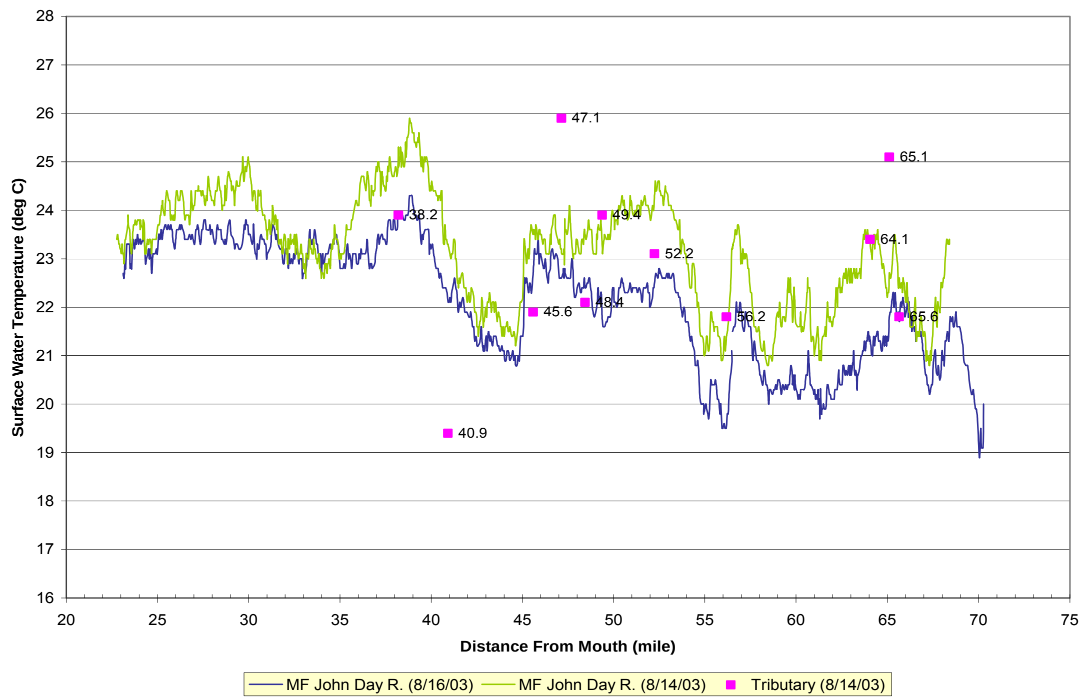

Figure 15 - Comparison of the median channel temperature as measured on August 14, 2003 and August 16, 2003 plotted by river mile for the Middle Fork John Day River (taken from Watershed Sciences, Inc. 2008). The Oxbow Conservation Area is between RM 58.4 and 54.9, Granite Boulder Creek is located at RM 56.2, the Forrest Conservation Area is between 63.5 and 67.4 on this plot (river miles in the Watershed Sciences report do not correlate directly to river miles used in this report).

Several other aspects of the survey findings have important implications in regards to fish habitat and for the Oxbow Conservation Area specifically. The most important aspect of the survey is the marked decrease in the median temperature of the MFJDR that results from the influx of relatively cold water from Granite Boulder Creek (RM 56.2 in Figure 15). Median temperature values drop about 2.5°C in the area immediately adjacent to Granite Boulder Creek. At the upstream end of the Oxbow Conservation Area, the temperature ranges from about 21.5°C to 22.5°C (70.7°F to 72.5°F; Figure 16). Downstream of the bifurcation of the channel into the North and South Channels, the median temperature in the North Channel drops to about 19°C (66.2°F). Because this change occurs upstream of the confluence with Granite Boulder Creek, it is apparent that there is a subsurface connection between the North Channel and Granite Boulder Creek.

It also becomes apparent that this linkage of groundwater with the main stem is strongly influenced by the site geology and geomorphology. Surficial mapping indicates that the area is largely comprised of gravelly alluvial fan deposits (Appendix A). While the area immediately adjacent to the North Channel was disturbed by dredge mining, this activity does not appear to have had an adverse impact on the linkage between the groundwater and the North Channel. Based on the assumption that the fine-grained interstitial materials were removed from the alluvium as a result of the mining activity, it seems logical that the porosity and transmissivity of the tailings would be increased, thereby enhancing the interaction between groundwater and the main channel. However, data collected in test pits in tailings downstream of Ruby Creek that show an abundance of fine-grained interstitial material (McAffee 2008) suggest that this assumption may not be correct.

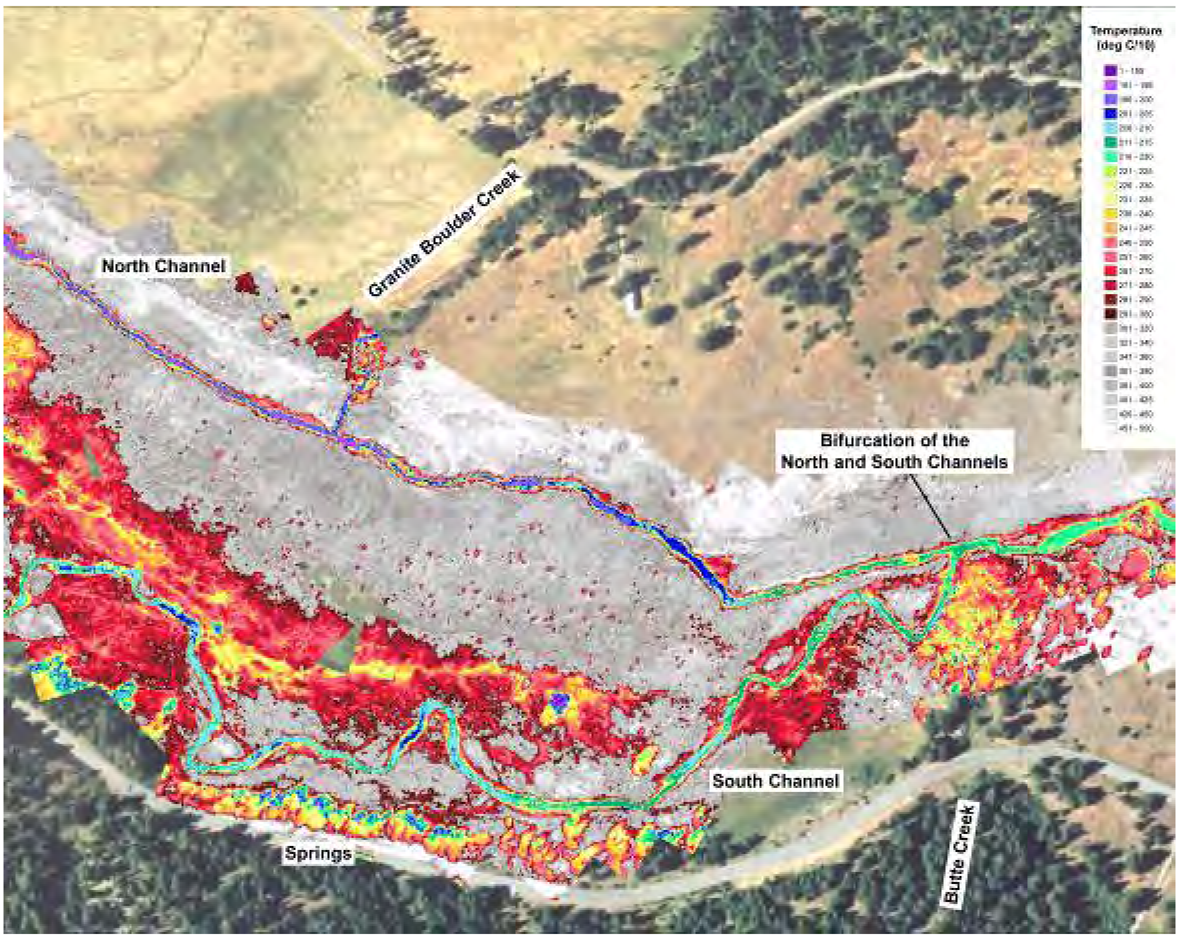

Figure 16 - Thermal infrared image of the area at the bifurcation of the North and South Channels and the confluence of Granite Boulder Creek with the North Channel.

In addition to the decrease in the median temperature of the North Channel, there was also a decrease in the temperature of the South Channel that corresponds with its position relative to the Granite Boulder Creek alluvium and springs along the southern margin of the valley (Figure 16). While the difference is not as significant or consistent as the temperature decrease in the North Channel, the temperature in the South Channel decreased from about 21.5°C to 22.0°C (70.7°F to 71.6°F) just downstream of the bifurcation to 20.5°C to 21.0°C (68.9°F to 69.8°F) in the South Channel opposite the confluence of Granite Boulder Creek. The temperatures in areas of the South Channel were as low as 20.0°C (68.0°F) and may correspond with the location of pools or cold water seeps that have been previously identified along the southern margin of the valley (Torgersen 1996; Figure 16). Localized wetted areas on the flood plain between the North and South Channels also had temperatures as low as 19.5°C to 20.0°C (67.1°F to 68.0°F; Figure 16 and Figure 17). The location of these cooler off-channel sites between the North and South Channels further supports a groundwater linkage to Granite Boulder Creek.

In the area of the valley downstream of Granite Boulder Creek, localized decreases in the median channel water temperature were also noted in association with the Ruby Creek alluvial fan (Figure 17). Temperatures in the South Slough at the departure from the South Channel decreased rapidly from about 22.0°C (71.6°F) to less than 20.0°C (68.0°F) where the channel flanks the upstream edge of the Ruby Creek alluvial fan. This area also has numerous springs located along the southern margin of the valley that correlate directly to the contact between the bedrock and alluvium (Torgersen 1996; Appendix B; Figure 17).

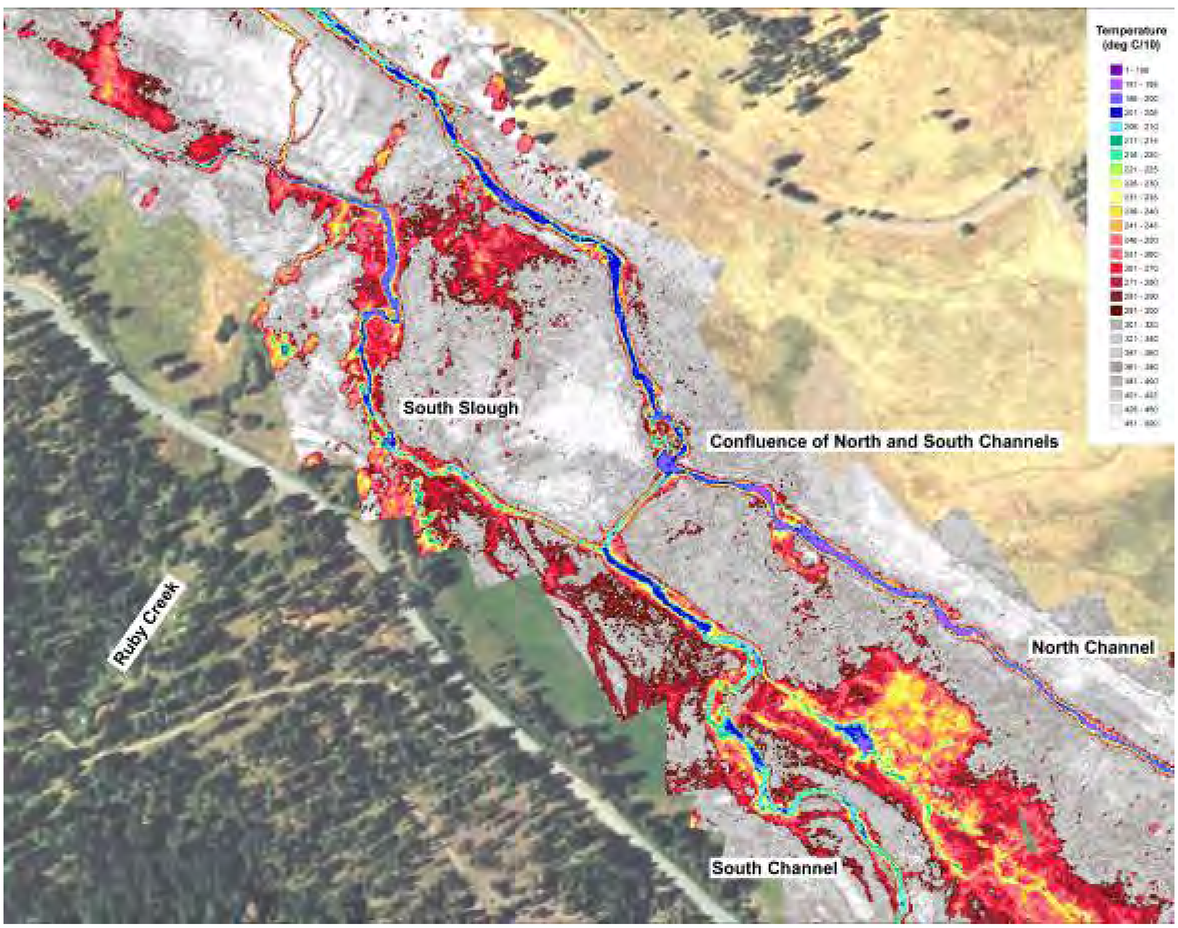

Figure 17 - Thermal infrared image of the area upstream of Ruby Creek showing the South Slough and the confluence of the South Channel with the North Channel.

In the area of the valley between Ruby Creek and Beaver Creek, the main stem channel is straight and deep relative to the channel geometry of the South Channel and the reach of the river from Beaver Creek to Ragged Creek. Within this channelized section of river, the water temperature remained relatively cool (19.5°C to 20.5°C; 67.1°F to 68.9°F) which may be due to the draining of cooler groundwater from the adjacent alluvium (Figure 18). Thermal data shows a slight cooling trend in the area immediately upstream of and adjacent to Beaver Creek. Temperatures begin to warm steadily downstream of Beaver Creek, reaching about 22.5°C to 23.0°C (72.5°F to 73.4°F) as the channel becomes confined between bedrock at the highway bridge and the alluvium of Ragged Creek on the west side of the river and the landslide deposits along the eastern side of the valley (Figure 19).

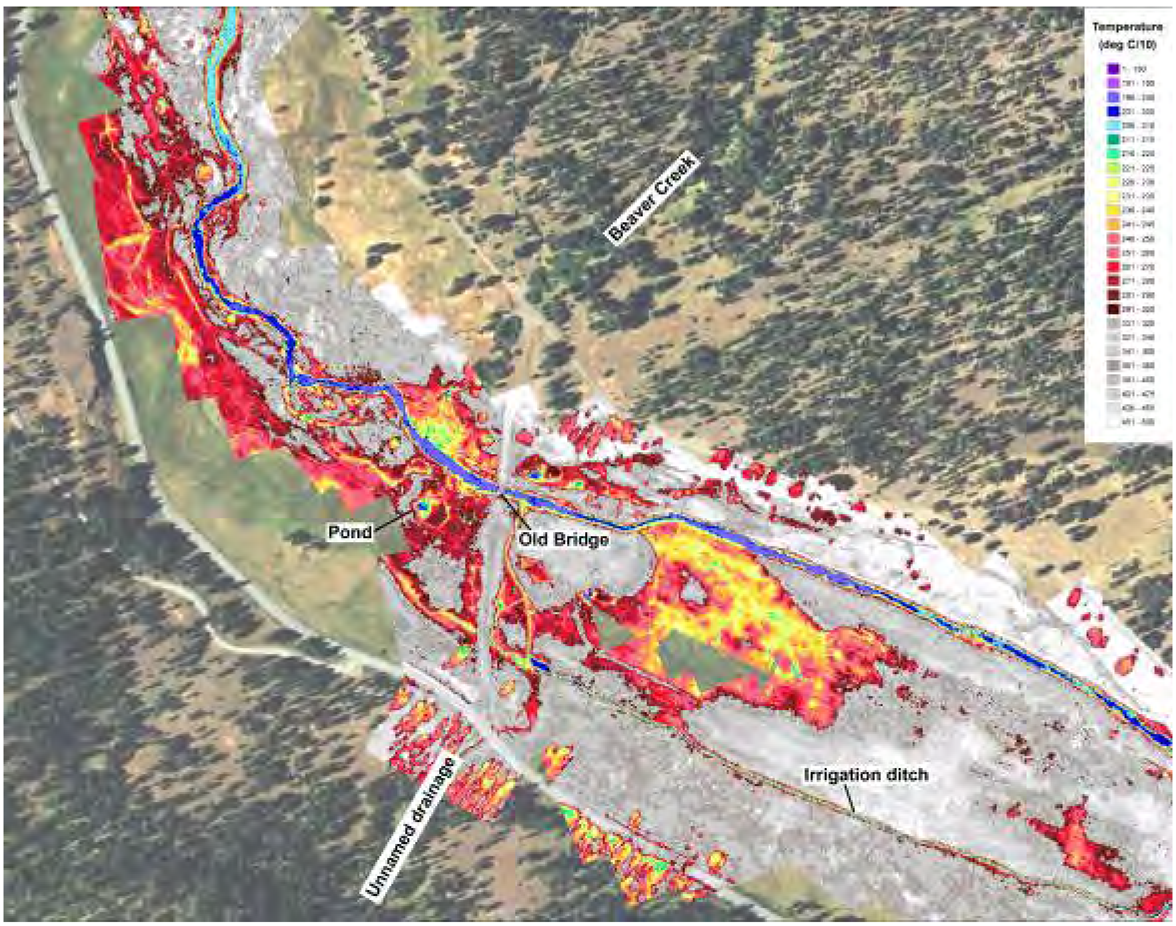

Figure 18 - Thermal infrared image of the area near the Old Bridge at Beaver Creek showing the North Channel and the irrigation ditch.

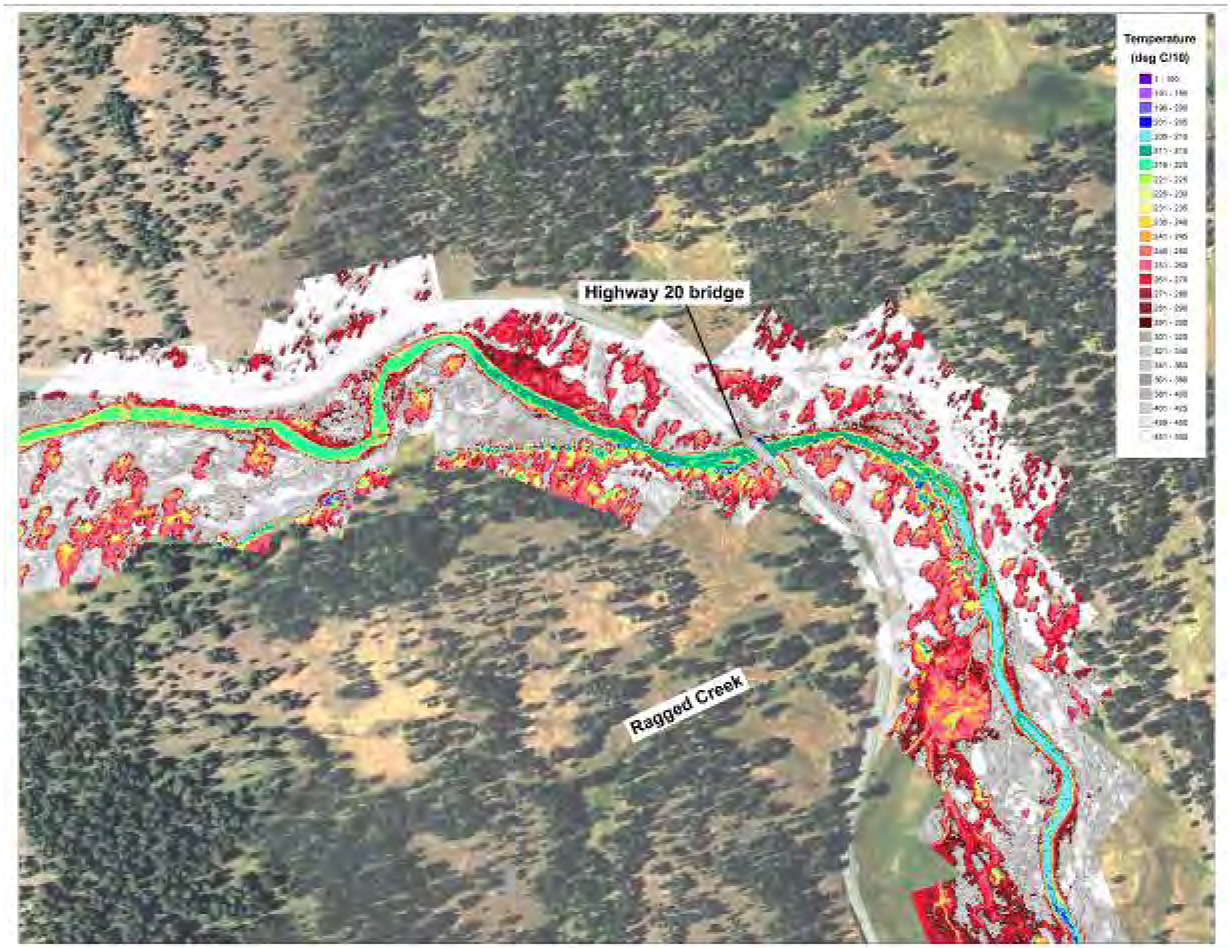

Figure 19 - Thermal infrared image at the downstream end of the Oxbow Conservation Area near Ragged Creek and the Highway 20 bridge.

There are several off-channel areas that are noteworthy in regards to colder water. In addition to the areas on the floodplain near Granite Boulder Creek described previously, there are two other areas near the former access road and the old bridge just upstream of Beaver Creek with markedly cooler temperatures: a pond downstream of the old bridge and an area at the downstream end of the irrigation ditch up valley of the former access road (Figure 18). In both of these areas the water temperature was about 19.5°C to 20.5°C (67.1°F to 68.9°F). The pond is particularly noteworthy as it is not linked directly by surface flow to the main channel indicating that both water in the pond and the temperature of the water are controlled by ground water upwelling. In all likelihood, the lower temperatures at the downstream end of the diversion ditch have a similar connection to ground water, but may be linked by surface flow to the unnamed tributary drainage to the south (Figure 18). A small alluvial fan deposited by this tributary is present along the margin of the valley and small spring brooks formed on the surface of the Qa3 alluvium originate at springs along the toe of this alluvial fan (Appendix B). The lower temperatures, both in the main channel, the pond, and diversion ditch, suggest that the unnamed tributary along the southern margin of the valley and Beaver Creek, in combination with Granite Boulder Creek and Ruby Creek upstream are important factors of the physical system that contribute to the establishment and maintenance of cooler water habitat in this reach of the valley. These data, in combination with the findings of the pollen analysis suggesting a wet meadow environment, indicate that water temperature may not be as reliant on riparian vegetation shading the channel as it is on the geomorphic controls and the associated groundwater connection.

In addition to the thermal survey that was conducted in August of 2003, five piezometers were installed in wells during September 2006 to monitor groundwater levels in the reach between Beaver Creek and Ruby Creek. Data from these wells complement staff gage measurements of flow in the channel (Figure 20) and can be used to evaluate the interaction of groundwater with the river and the magnitude of seasonal changes in the groundwater levels on the Oxbow Conservation Area. The five wells were installed in test pits (TP1 to TP5) and are referenced by their position relative to each other (North, West, East, South, and Center; Figure 20). Four of the five wells are located in dredge-mining tailings; the North well (TP1) is the only well sited in undisturbed alluvium of the 1939 historical channel (Qa4 of this study). The sedimentological characteristics of the alluvium at each site were described when the wells were installed (McAffee 2006) and indicate that despite the disturbance by dredge-mining, the alluvium is in general poorly-sorted with the grain size ranging from silt and sand to gravel (GP-GM; Unified Soil Classification).

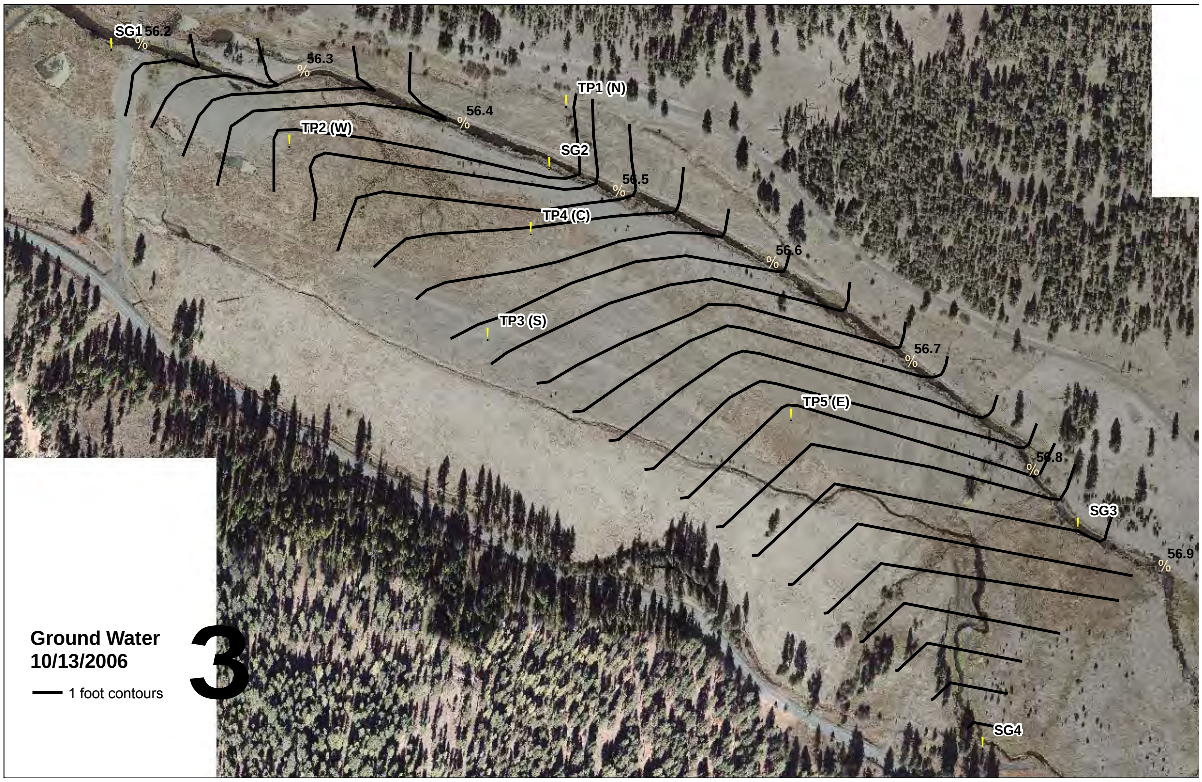

Figure 20 - Area between Ruby Creek and Beaver Creek on the Oxbow Conservation Area showing the locations of groundwater wells (TP) and staff gages (SG). Contours show the elevation of the groundwater table on October 13, 2006 and were smoothed to reflect the interpretation of data from wells and staff gages shown.

The most notable difference between the tailings and stratified fluvial deposits observed elsewhere along the MFJDR (Qa1-Qa4) is not with the grain size, but with the loss of stratification. Undisturbed river alluvium generally consists of distinct stratified beds of gravelly sand and sand commonly overlaid by beds of silty fine sand. Photographs and descriptions of the test pits excavated in the tailings (Figure 21; McAffee 2006) indicate the same overall composition as undisturbed deposits, except that the stratification has been destroyed and the deposits are more homogeneous.

Figure 21 - Exposure in TP4 (C) showing the sedimentological character of the dredge tailings. Material was described as poorly graded gravel with sand, cobbles and boulders with 30 percent of the sediment being sand and non-plastic fines. Note the presence of water in the bottom of the pit (photograph taken by R. McAffee, 2008).

Measured groundwater levels in all five wells show fluctuations seasonally as would be expected but the magnitude of the fluctuation varies between wells and with the position of the well in the valley. The water level in the Center well (TP4; Figure 20) shows the greatest deviation on a seasonal basis (Figure 22). This probably reflects the fact that the well is located in tailings, is very close to the channel thereby reflecting the seasonal fluctuation in stream flow, and in a position farthest away from groundwater sources (springs, tributaries, or the unlined irrigation ditch). However, the North and West wells are located similarly near the channel, but do not show the same degree of fluctuation in water levels seasonally. The lack of fluctuation in the North well might be explained by the fact it was sited in undisturbed alluvium (Qa4) of the historical 1939 channel, but it is also topographically lower being at a similar elevation to the main channel and is likely still linked in the subsurface to the main channel (). The West well shows the least amount of fluctuation of all the wells on a seasonal basis and is also sited in dredge tailings. This may be a reflection of its position at a location farthest downstream and in an area that is strongly influenced by tributary and spring inflow from Beaver Creek, and the unnamed tributary along the southwestern margin of the valley (Figure 18). The East well is also located in tailings, but is about twice the distance of the West, North, and Center wells from the main channel. The data for the East well show that the seasonal fluctuation is potentially quite similar to that of the North and West wells. This may reflect the fact the East well is located closer to Ruby Creek (tributary inflow) and down slope of the diversion ditch, which may in part buffer the magnitude of fluctuation. On the basis of the limited available data, the groundwater levels and seasonal fluctuations appear to be linked to the well locations relative to groundwater source area (i.e., tributaries, springs). Differences in sediment characteristics (undisturbed alluvium versus tailings) seem to have little or no influence. Additional data collected as part of the ongoing monitoring will be helpful in resolving this question.

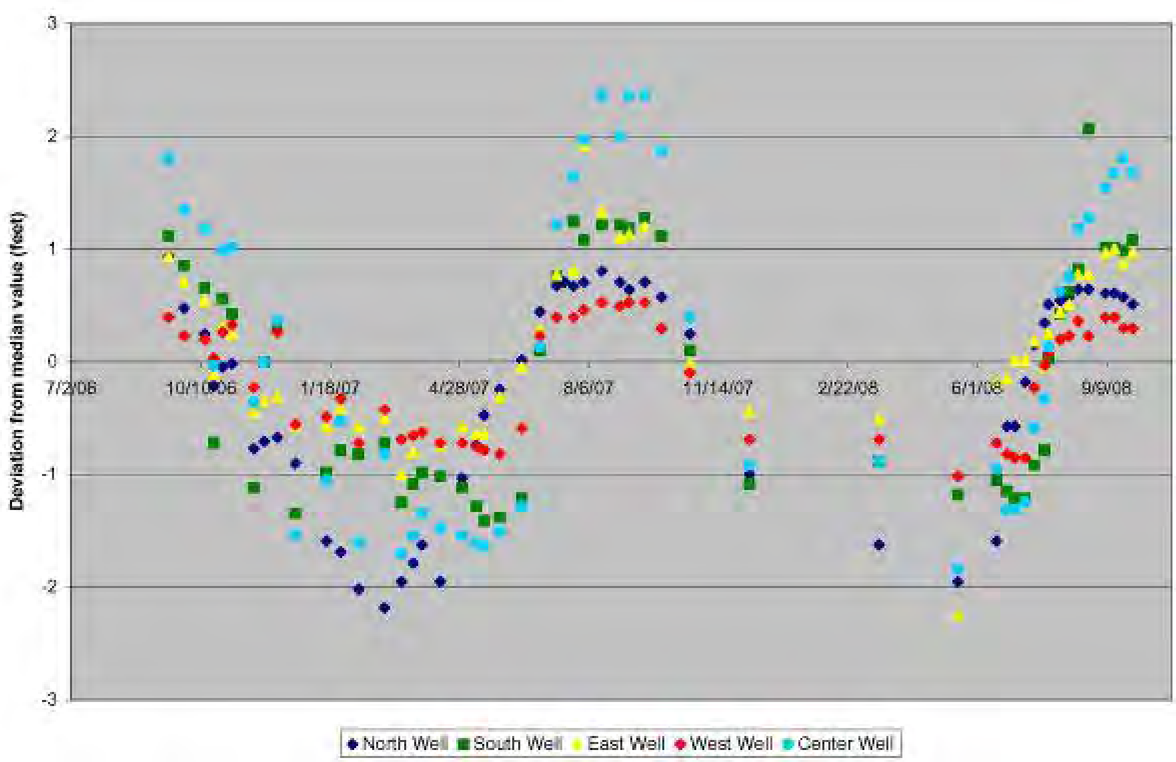

Figure 22 - Deviation of groundwater from the median value of depth in feet below the ground surface measured for the period between September 15, 2006 and September 29, 2008.

An additional aspect of the groundwater that can be analyzed from well and staff gage data is the effect of channelization and lowering of the stream bed elevation as a result of the dredge-mining activities. Data from each of the staff gages in the reach and the depth of the groundwater in the wells on October 13, 2006 were contoured in an effort to better understand the potential extent of groundwater lowering. In the case of the area between Ruby and Beaver Creeks, the deepening of the channel (reduction of the bed elevation) and the increase in the channel gradient (shortening of channel length) immediately downstream of Ruby Creek imposed by channelization has effectively lowered the groundwater levels. This can be seen in the contoured groundwater surface where contours are at high angles to the main channel (e.g., between TP4 and main channel; (Figure 20). The drop in the groundwater is interpreted to be less in areas where the contoured data parallels the main channel (e.g., between TP2 and SG2; Figure 20). The lowering of groundwater levels is especially evident in the reach immediately upstream of SG2 where the gradient in the groundwater is must steeper than in the downstream part of the reach (Figure 20).

Chapter 4 Discussion of Model Results and Link to Geomorphology

4.1 Existing Conditions Model Comparison with High Flow Photographs

No surveyed water surface elevations or high water marks are available with which to calibrate the numerical model. Instead, results were qualitatively validated by comparing them to discharge patterns visible in oblique aerial and ground photographs taken on May 25, 2006 and May 20, 2008. Average daily discharges on these dates were estimated to be 390 and 977 cfs, respectively. Estimating discharge through the modeled reach was necessary due to the absence of nearby stream gages. These estimates were based upon National Flood Frequency (NFF) equations for peak discharges in Eastern Oregon (Reclamation 2008) and on measured flows at the Ritter Gage located approximately 41 miles downstream from the Oxbow Conservation Area. Because flow through the area on May 25, 2006 was less than a 2-year peak discharge, an analysis of the flow contribution from the Oxbow Conservation Area to measured flows at the Ritter Gage for a 2-year peak discharge was performed. The results of the comparison indicate that flow exiting the modeled reach of the Oxbow Conservation Area accounts for 59 percent of the flow measured at the Ritter gage during a 2-year discharge. This percentage was used to estimate flow exiting the modeled reach on May 25, 2006.

4.1.1 Spring 2006 High Flows

The peak discharge for 2006 occurred on April 6 and measured just under a 5-year discharge at Ritter according to multiple methods by Reclamation (2008) and the State of Oregon (Cooper 2006) (Figure 23; Table 5); however, aerial photographs were not acquired until May 25, 2006 following a smaller storm event. The peak of this storm occurred on May 20, 2006 and was measured just under a 2-year peak discharge at the Ritter gage. The photographs acquired on May 25, 2006 represent conditions for the falling limb of that storm. The daily mean discharge of the flow at Ritter on the day the aerial photos were taken (May 25, 2006) was 657 cfs. Instantaneous discharge measurement ranged between 621 cfs and 694 cfs. This range of discharges is approximately 1,000 cfs less than a 2-year event. Using a percent contribution of 59 percent from the Oxbow Conservation Area, flow through the modeled reach was estimated as 390 cfs on May 25, 2006.

In Figure 24 through Figure 31, several oblique aerial photographs acquired on May 25, 2006 are compared with model results for an estimated flow through the Oxbow Conservation Area of 390 cfs. Each of the following figures that illustrate model results is followed with a photograph of the conditions observed on May 25, 2006. The model results tend to predict similar flow patterns evidenced during the observed discharge. This is especially apparent near the Ruby Creek confluence where complex flow patterns are present for flows of this magnitude. In some locations, wetted areas may remain from higher flows on previous days.

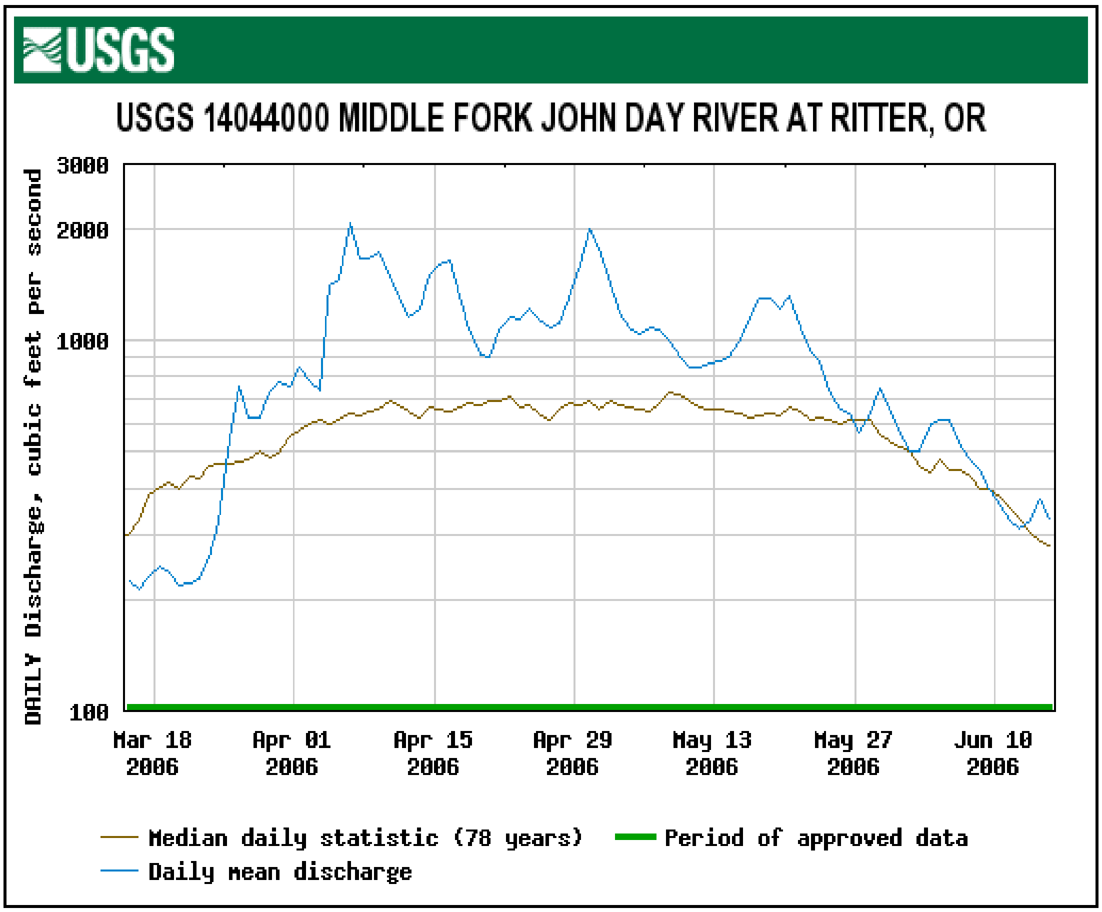

Figure 23 – Gage data at Ritter for the Middle Fork John Day River, Spring 2006.

Hydrology at Ritter Gage	Discharge for selected return periods (CFS)						Parameters Used
	2-year	5-year	10-year	25-year	50-year	100-year	
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 OCA (outlet)[1]	977	1,475	1,827	2,236	2,633	2,988	

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

Table 5 – Predicted high flow events at the Ritter Gage and at the inlet to the Oxbow Conservation Area.

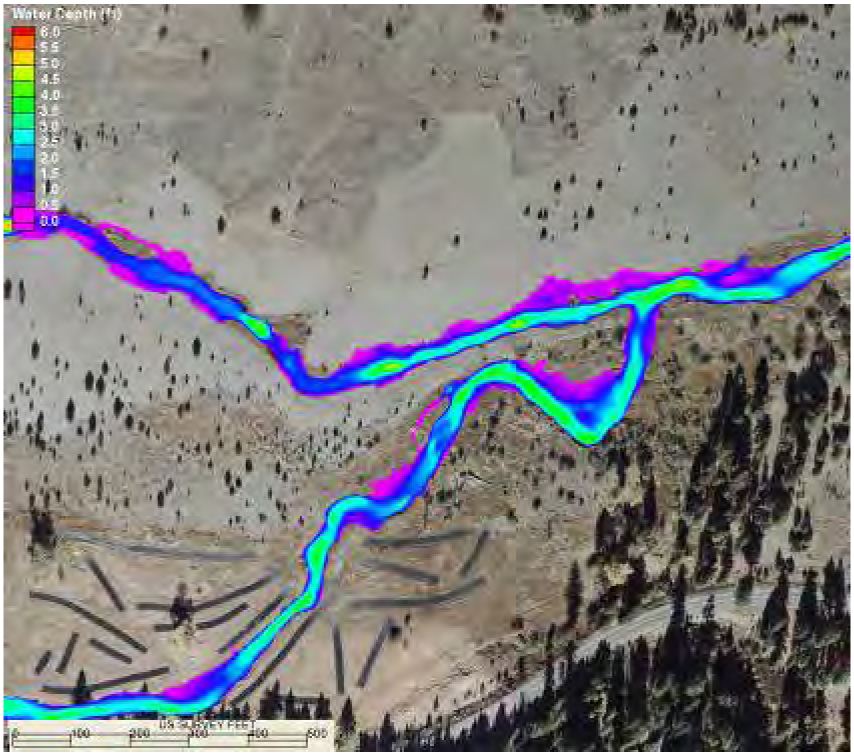

Figure 24 – Model results at the bifurcation of North and South Channels at an estimated discharge of 390 cfs. Flow is from right to left. A corresponding aerial photograph on May 25, 2006 is shown in Figure 13.

Figure 25 – Middle Fork John Day River at bifurcation of North and South Channels on May 25, 2006. Flow is from right to left. Photo corresponds to model results shown in Figure 12.

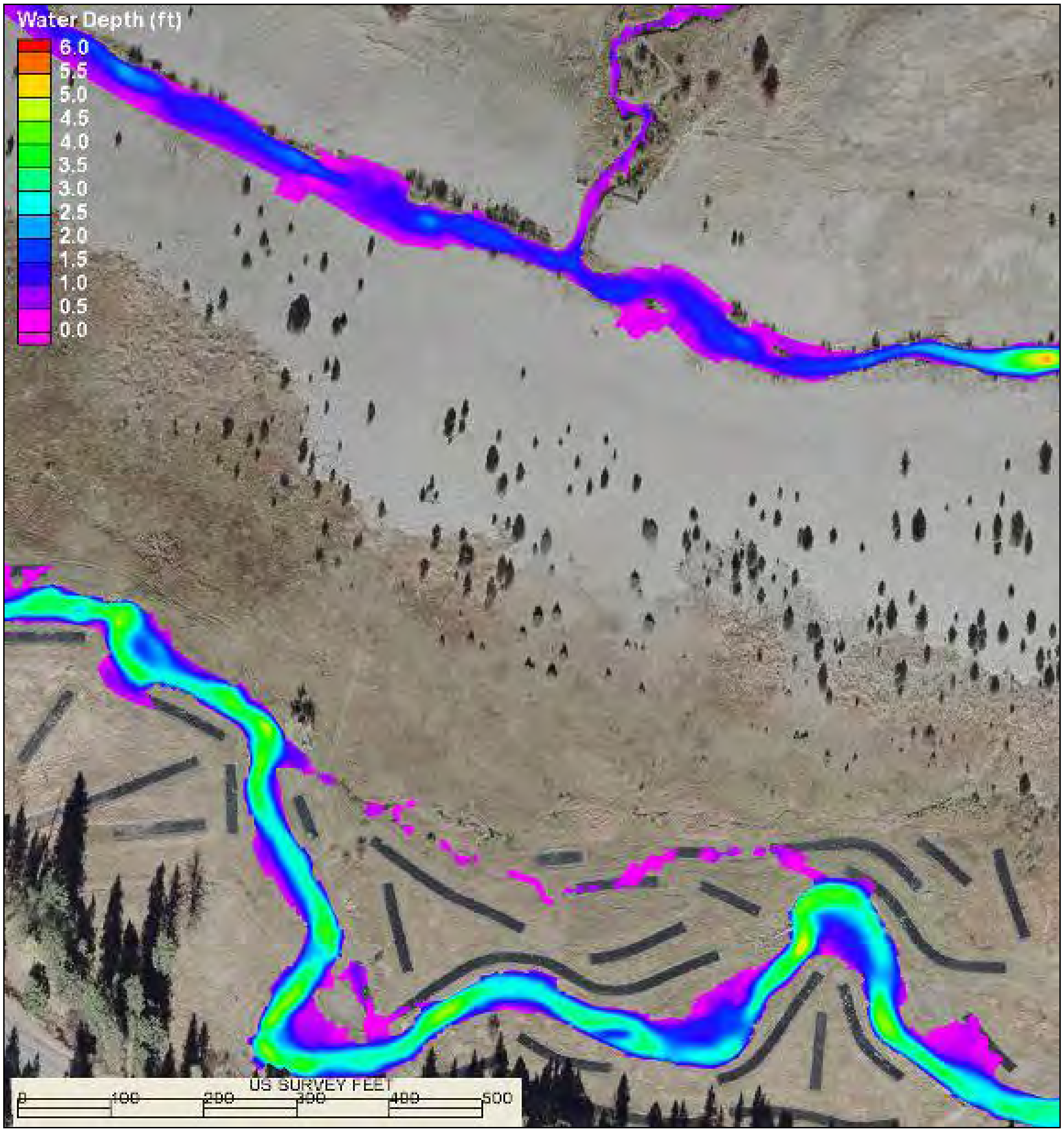

Figure 26 – Model results at the confluence of Granite Boulder Creek at an estimated discharge of 390 cfs. Flow is from lower right to upper left. A corresponding aerial photograph on May 25, 2006 is shown in Figure 15.

Figure 27 – Confluence of Granite Boulder Creek on May 25, 2006. Flow is from right to left. Photo corresponds to model results shown in Figure 14.

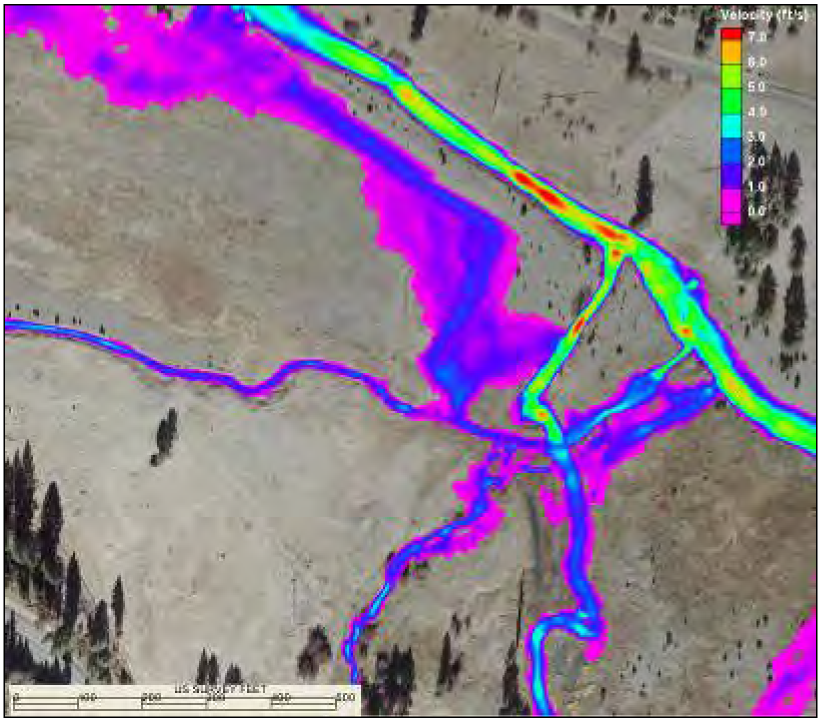

Figure 28 – Model results at the confluence of Ruby Creek at an estimated discharge of 390 cfs. Flow is from lower right to upper left. A corresponding aerial photograph on May 25, 2006 is shown in Figure 17.

Figure 29 – Confluence of Ruby Creek with the Middle Fork John Day River on May 25, 2006. Flow is from lower right to upper left. Photo corresponds to model results shown in Figure 15.

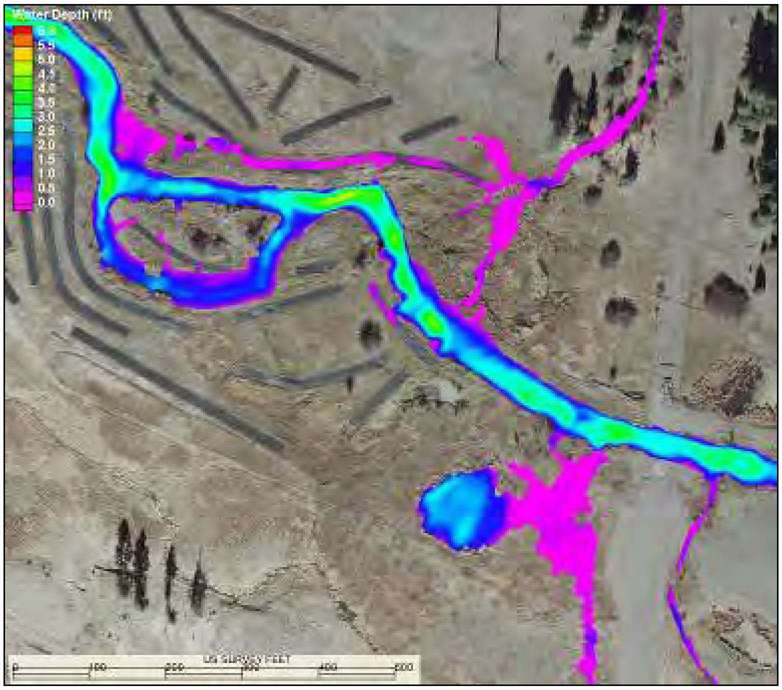

Figure 30 – Model results at the confluence of Beaver Creek just downstream from Old Bridge Crossing at an estimated discharge of 390 cfs. Flow is from lower right to upper left. A corresponding aerial photograph taken on May 25, 2006 is shown in Figure 19.

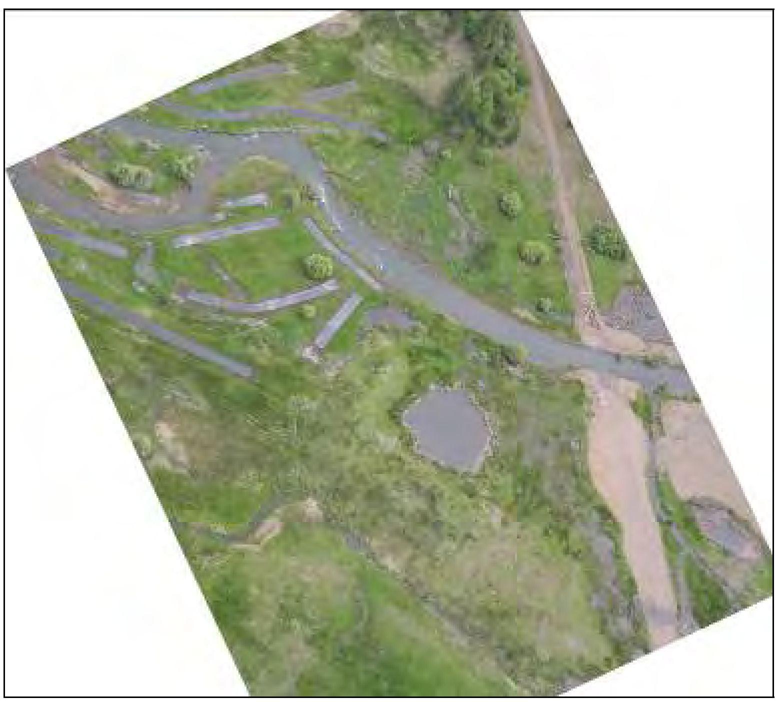

Figure 31 – Aerial photograph just downstream of Beaver Creek and Old Bridge Crossing taken on May 25, 2006. Flow is from lower right to upper left. Photograph corresponds to model results shown in Figure 18.

4.1.2 Spring 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 32). 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 Oxbow Conservation Area to the Ritter gage (approximately 41 river miles), the discharge through the Oxbow Conservation Area was estimated to be approximately equivalent to a 2-year return discharge of 977 cfs (Table 5).

Ground photos of the flood event on May 20, 2008 are compared with model results in Figure 21 through Figure 32. Modeled discharge in these figures is 977 cfs. Assuming the modeled discharge is representative of the observed discharge in the photographs, the model reasonably predicts the wetted areas for a 2-year discharge based on visual comparisons.

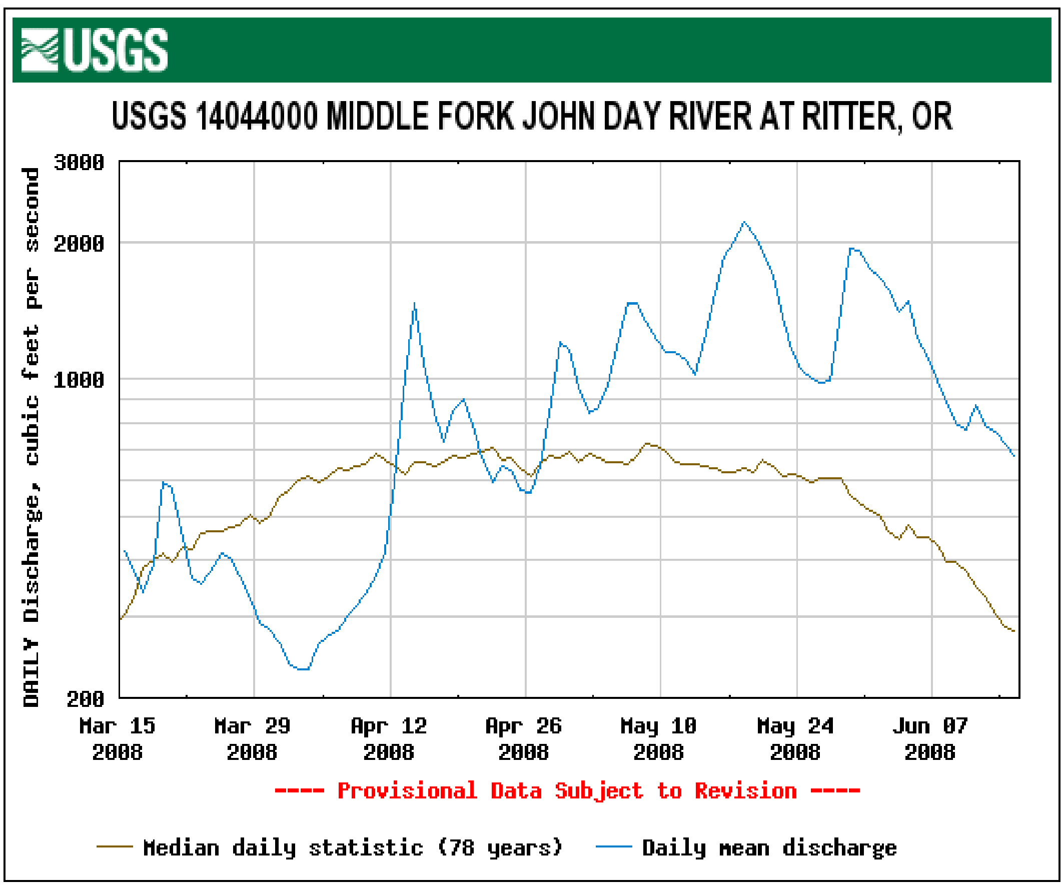

Figure 32 – Gage data at Ritter for the Middle Fork John Day River, Spring 2008.

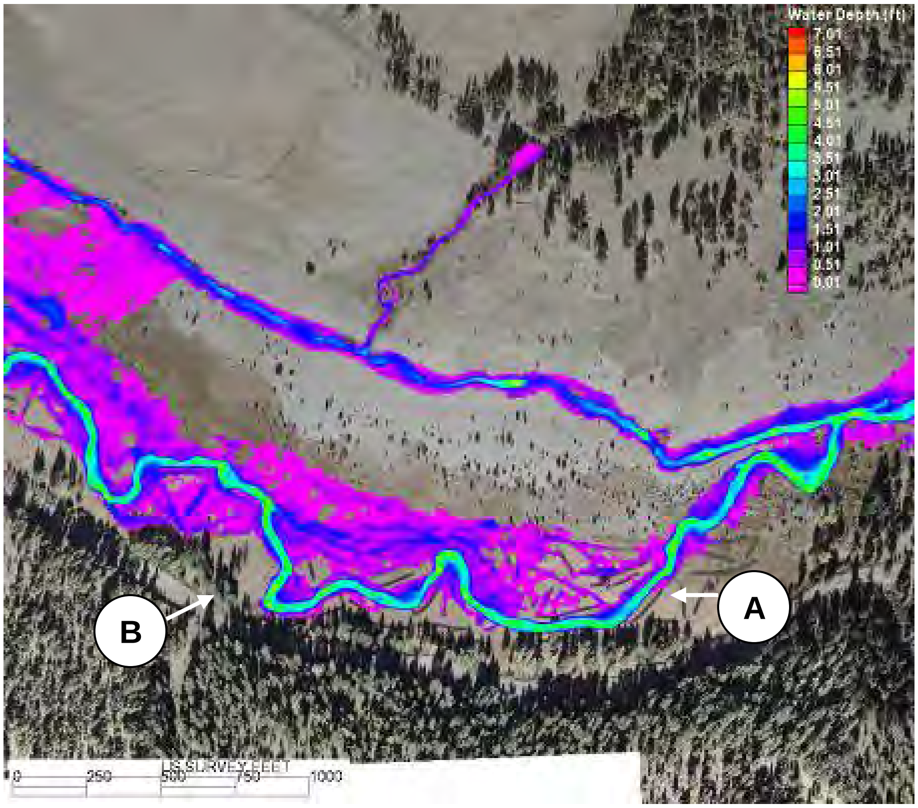

Figure 33 – Model results of the 2-year discharge showing water depth in feet, downstream of bifurcation. Flow is from right to left. Photographs of observed discharge are shown in Figure 22 and Figure 23. The arrows indicate direction of the photographs.

Figure 34 – Photograph taken from location A as shown in Figure 21.

Figure 35 - Photograph taken from location B as shown in Figure 21.

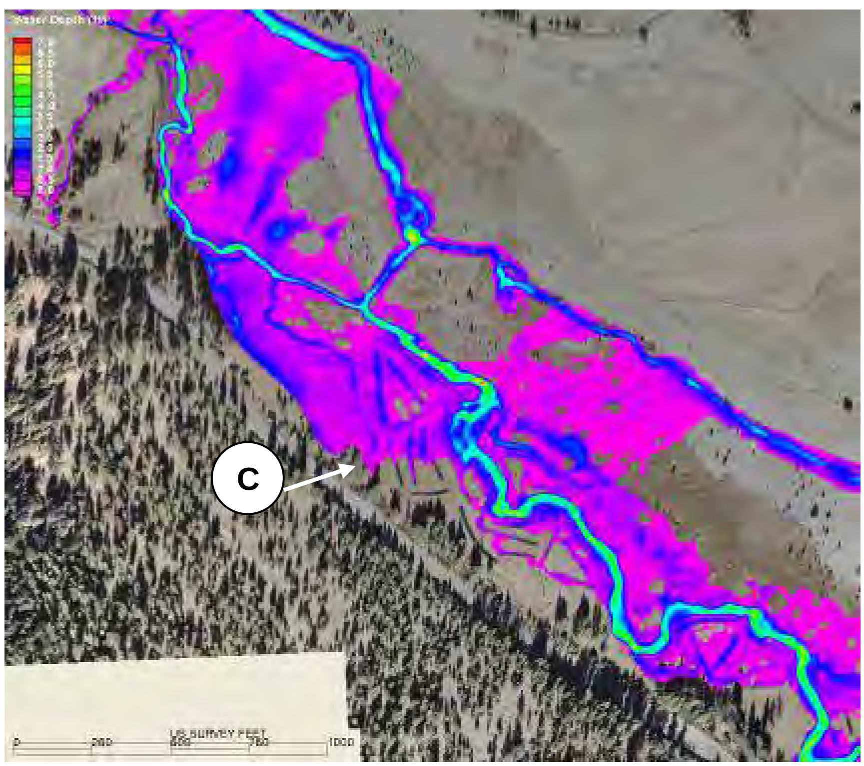

Figure 36 – Model results of the 2-year peak discharge showing water depth in feet upstream of Ruby Creek. Photograph of observed discharge is shown in Figure 25. The arrow indicates the direction of the photograph.

Figure 37 – Photograph taken from location C as shown in Figure 24.

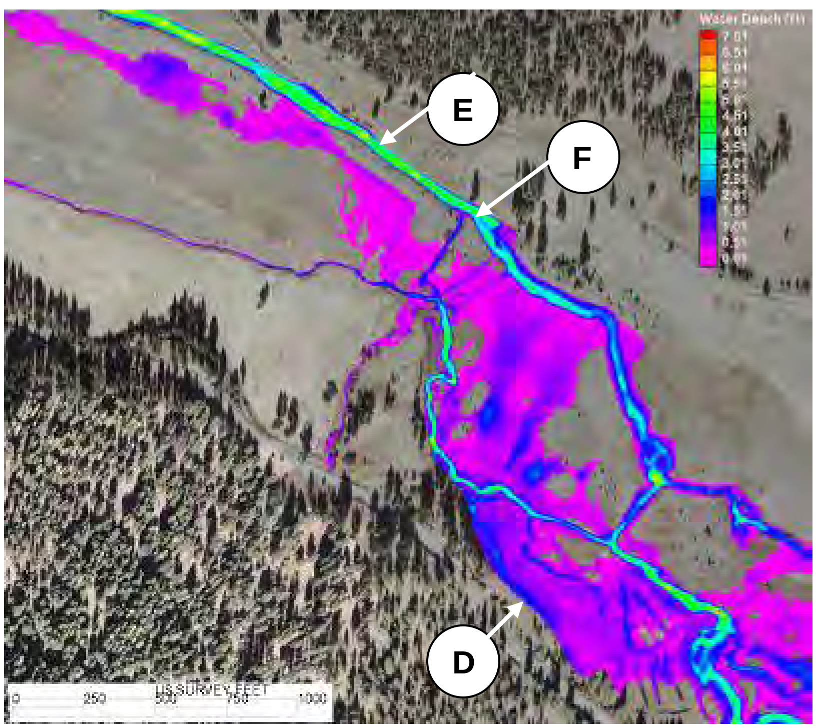

Figure 38 – Model results of the 2-year peak discharge showing water depth in feet at Ruby Creek confluence with the Middle Fork John Day River. Observed photographs are shown in Figure 27, Figure 28, and Figure 29. The arrows indicate the direction of the photographs.

Figure 39 – Photograph Taken from location D as shown in Figure 26.

Figure 40 – Photograph taken from location E, looking downstream as shown in Figure 26.

Figure 41 – Photograph taken of Ruby Creek confluence with the Middle Fork John Day River from location F as shown in Figure 26.

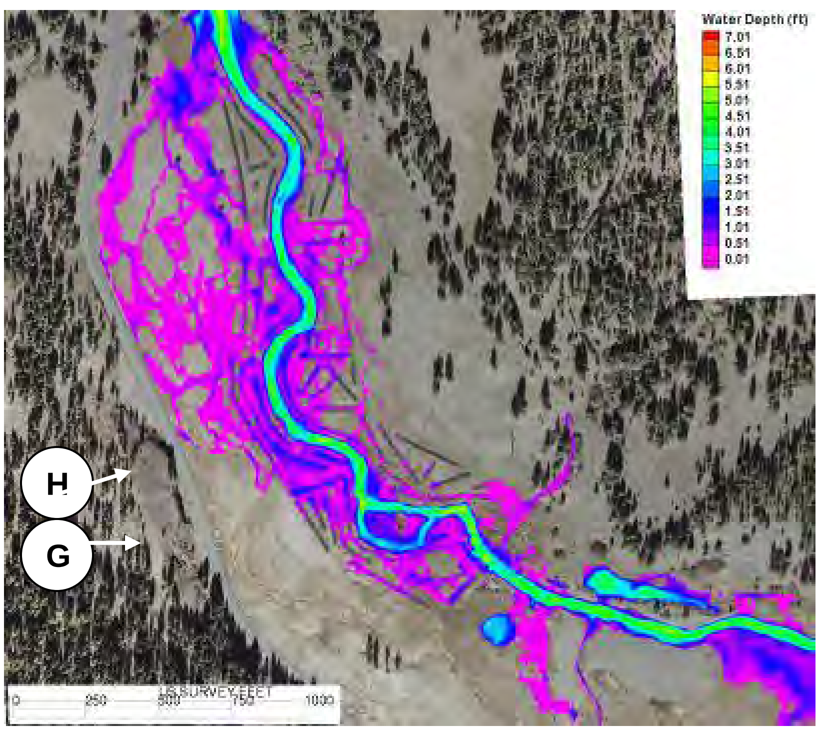

Figure 42 – Model results of the 2-year peak discharge water depth in feet downstream of the tailings. Observation photographs are shown in Figure 31 and Figure 32. The arrows indicate the direction of the photographs.

Figure 43 – Photograph looking upstream taken from location G as shown in Figure 30.

Figure 44 – Photograph looking downstream taken from location H as shown in Figure 30.

4.2 Water Surface Elevation Profiles of Existing and Proposed Conditions

Profiles of the water surface elevation for the 2- and 100-year peak discharges were developed for the existing and proposed conditions. The most significant reduction in water surface elevation change between existing and proposed conditions occurs downstream of Granite Boulder Creek below approximately River Mile 57.4 where decreases of up to 1 foot are predicted in the 2-year discharge and up to 1.2 feet in the 100-year discharge (Figure 45). These differences in water surface profiles between existing and proposed conditions are only predicted upstream of the confluence of the North Channel and South Channel near River Mile 57 (Figure 46).

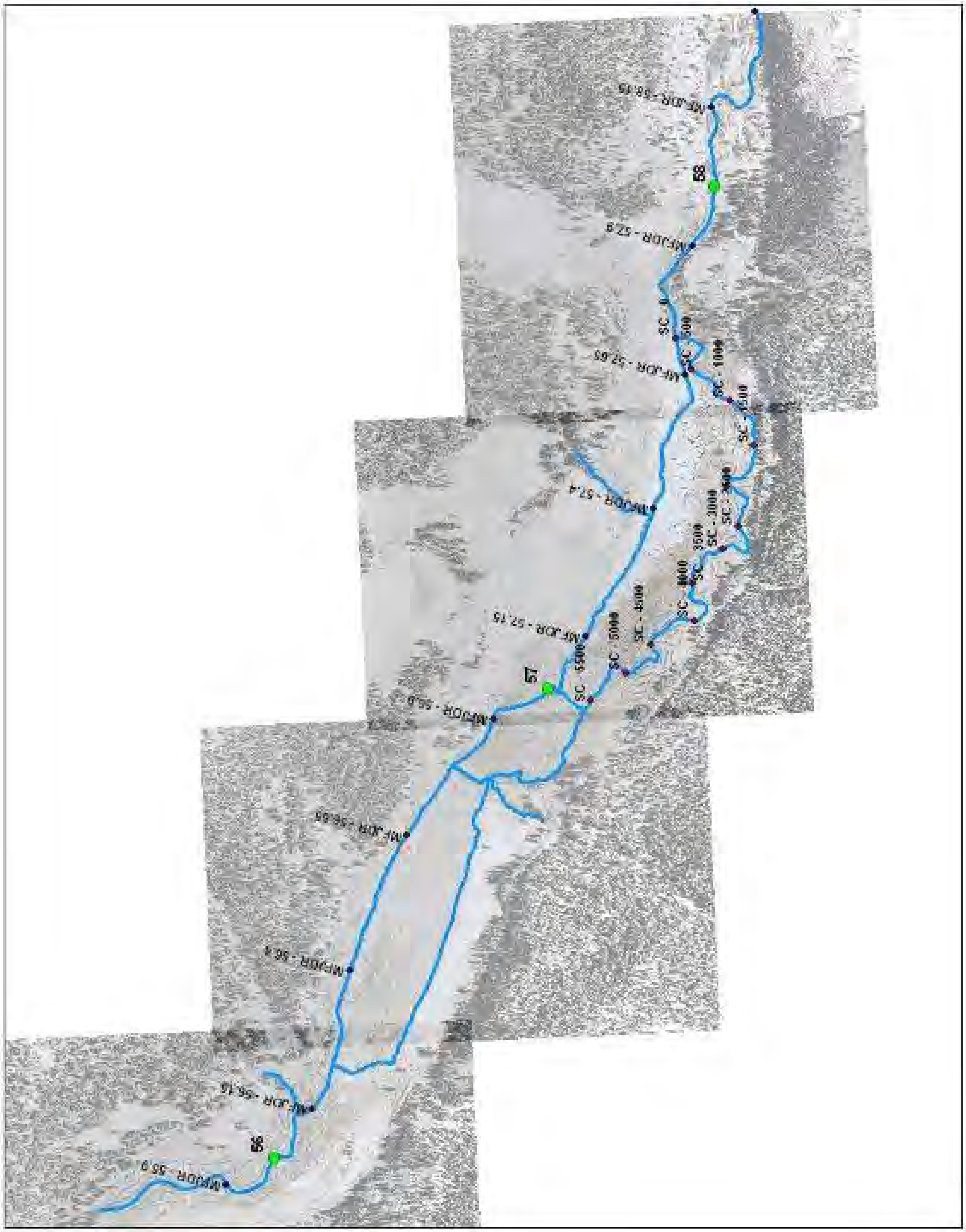

Figure 45 – Stationing of the Middle Fork John Day River in River Miles and the South Channel in feet.

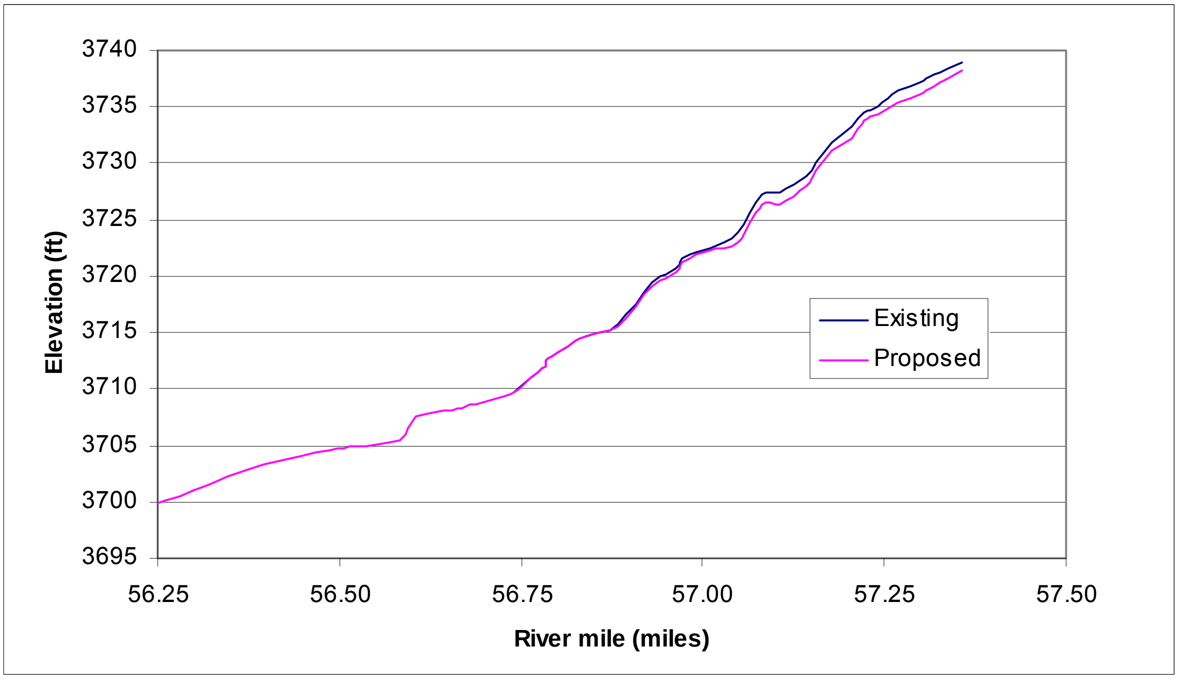

Figure 46 – 2-year discharge water surface profiles of the existing and proposed conditions in the North Channel beginning at the mouth of Granite Boulder Creek.

4.3 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 and proposed conditions. Longitudinal changes in the parameters were examined by digitizing a line along an approximated channel thalweg and extracting values from the model results along the line at intervals of about 100 feet 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-year event by intersecting the TINs between the existing and proposed conditions. The following sections describe the model results of flow depth, depth-averaged velocity, and bed shear stress.

4.3.1 Flow Depth

The total area inundated decreased under the proposed conditions scenario by 2.5 acres, 5.8 acres, and 8.0 acres for the 2-year, 10-year, and 100-year flow events, respectively. As the discharge increases in magnitude, the differences in depths between the two scenarios are less pronounced due to the limited capacity of the North Channel. Differences in water depth between the existing and proposed conditions are most notable between the bifurcation of the North Channel and South Channel the confluence with Ruby Creek. Under the proposed condition, the floodplain along the South Channel is characterized by greater depths, which are most pronounced with lower discharges. These results indicate increased floodplain connectivity along the South Channel floodplain when the North Channel is blocked (Figure 47).

Evaluation of depth changes along the thalweg of the North Channel indicates decreases greater than 1 foot downstream from Granite Boulder Creek between RM 57.4 and 57.2 when the North Channel is blocked (Figure 48 and Figure 49). The depth changes near RM 57.4 are likely due to inflow from Granite Boulder Creek. Cyclical patterns on these and other thalweg graphs are likely indicative of bathymetric changes in channel grade.

Diverting flow from the North Channel to the South Channel has less of an impact on depth differences in the South Channel than decreases predicted in the North Channel (Figure 50 and Figure 51). The minimal impact noted in the South Channel results from additional floodplain flow along the South Channel rather than substantial increases in depth within the channel, which results in increased floodplain connection. Furthermore, the South Channel has a much greater capacity than the North Channel, and any increases in flow to the South Channel are spread across a greater area. Differences in depth due to blocking off the North Channel are predicted to be between 0 feet to 0.5 feet in the South Channel. The average difference is about 0.25 feet regardless of the flood event. Changes in depth along the South Channel are predicted to occur upstream of the South Slough (see Figure 6 for the location of the South Slough). Although substantial additional inundation of flow along the floodplain of the South Slough occurs when the North Channel is blocked, changes to depth within the South Slough are minor due to the limited capacity of the South Slough (Figure 1).

A comparison of the distribution graphs (Figure 52 through Figure 54; Table 6) indicates that the total area characterized by depths greater than 4 feet tends to increase under the proposed conditions for all discharges evaluated. During a 2-year event with the North Channel blocked, less floodplain area is characterized by depths between 0 to 0.5 feet and more floodplain area is characterized by depths between 0.5 to 1.5 feet. This increase is occurring predominantly along the South Channel floodplain. Figure 55 through Figure 57 illustrate examples of the model results of depth for the 2-year peak discharge. Results for the 2-, 10-, and 100-year peak discharge are presented in the Appendix D.

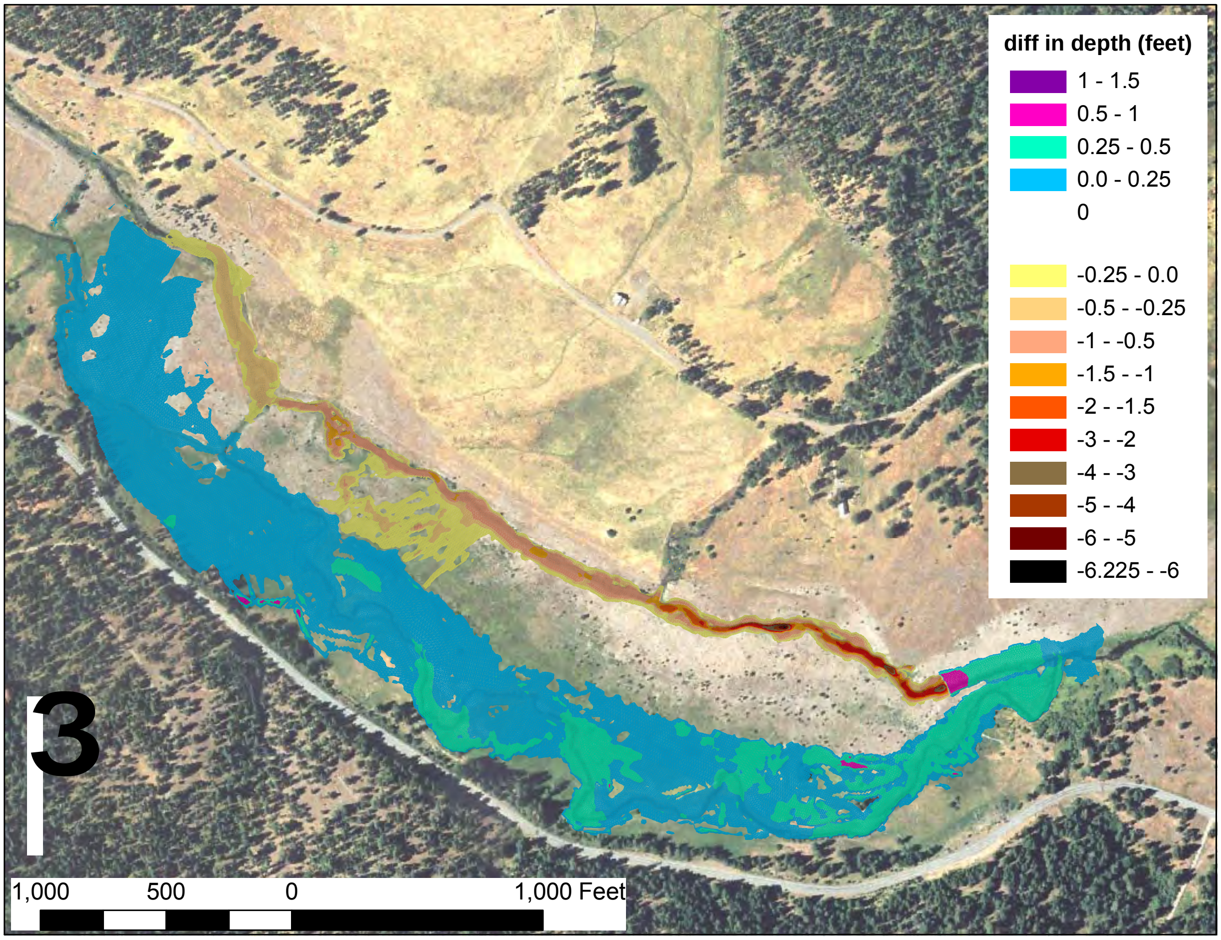

Figure 47 – Differences in flow depth for the 2-year peak discharge between the existing and proposed conditions. Positive values indicate depth increases when the North Channel is blocked.

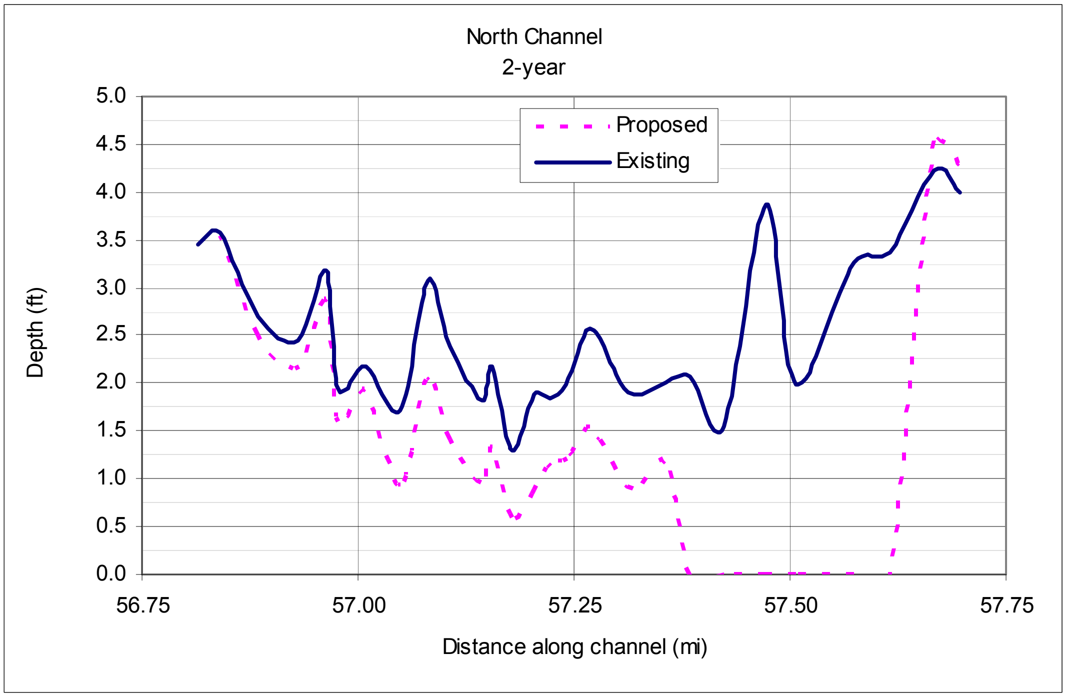

Figure 48 – Comparison of depth in existing and proposed conditions in the North Channel along the thalweg for the 2-year flow event. RM 57.7 corresponds to the bifurcation of the North Channel and the South Channel.

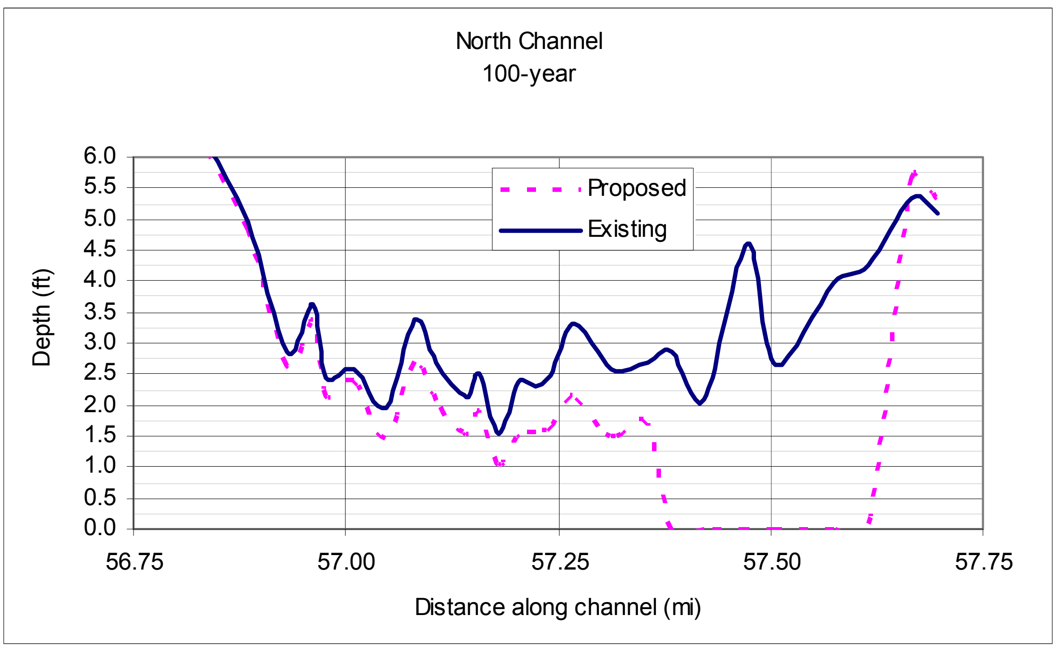

Figure 49 – Comparison of depth in existing and proposed conditions in the North Channel along the thalweg for the 100-year flow event. RM 57.7 corresponds to the bifurcation of the North Channel and the South Channel.

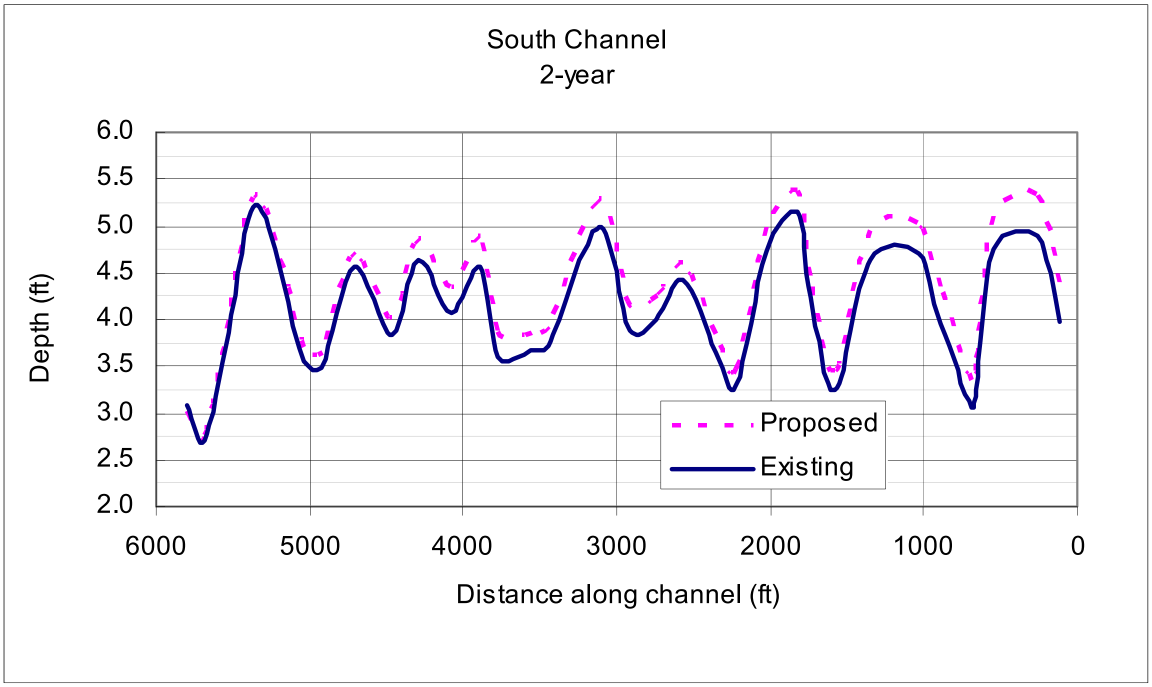

Figure 50 – Comparison of depth in existing and proposed conditions in the South Channel along the thalweg for the 2-year peak discharge. Zero feet corresponds to the bifurcation of the North Channel and the South Channel.

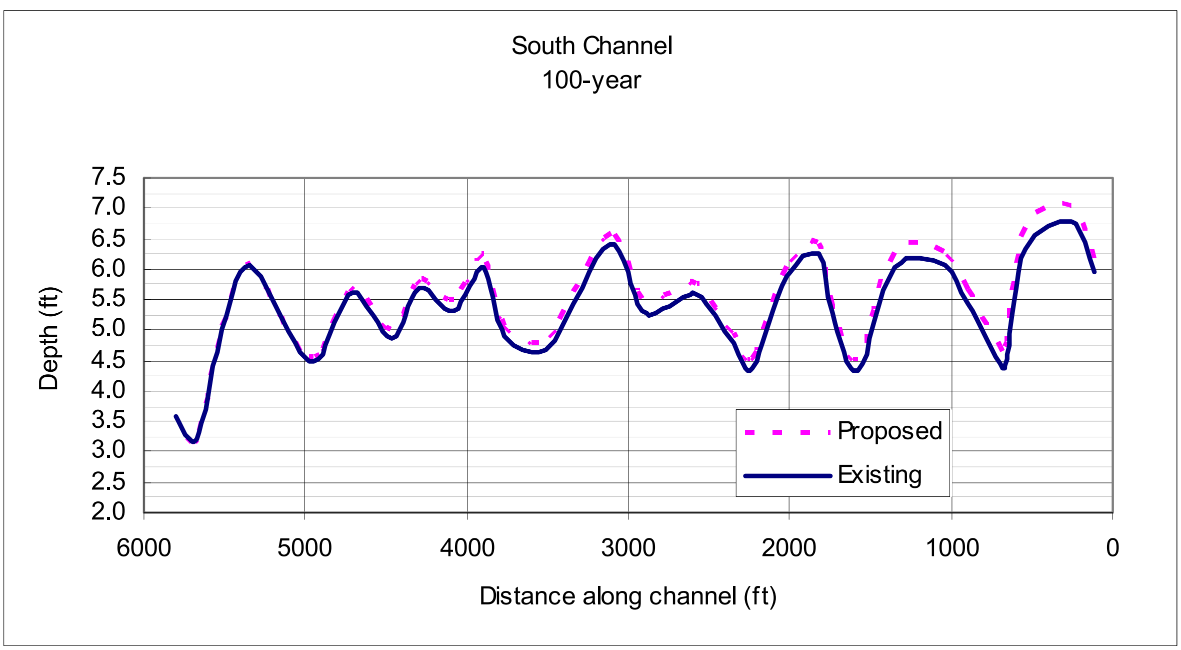

Figure 51 – Comparison of depth in existing and proposed conditions in the South Channel along the thalweg for the 100-year peak discharge. Zero feet corresponds to the bifurcation of the North Channel and the South Channel.

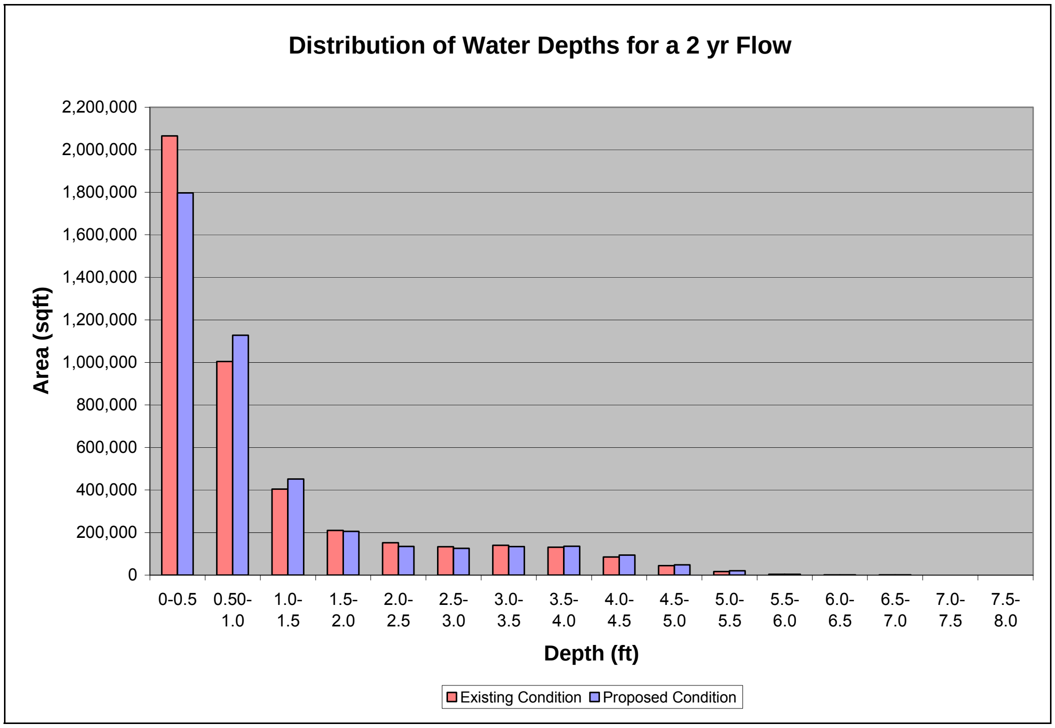

Figure 52 – Distribution of depths for a 2-year peak discharge for the entire reach under existing and proposed conditions.

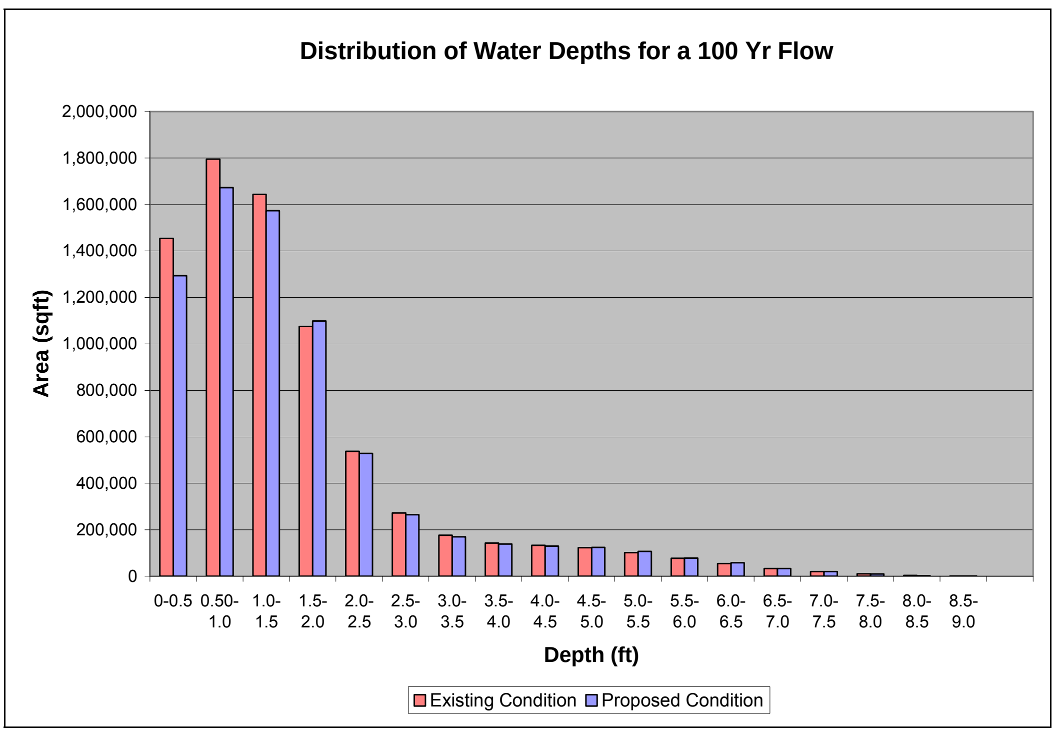

Figure 53 – Distribution of depths for a 100-year peak discharge for the entire reach under existing and proposed conditions.

Table 6 – Magnitude of differences in areal distribution of depth from existing to proposed channel conditions. Negative values indicate a reduction in area of the specified amount.

Difference in Areal Distribution of Depths from Existing to Proposed Conditions			
Depth Bins (feet)	2-Year difference (square feet)	10-Year difference (square feet)	100-Year difference (square feet)
0-0.5	-267,904	-268,505	-160,306
0.50-1.0	122,687	-96,473	-122,096
1.0-1.5	46,782	78,832	-70,027
1.5-2.0	-4,912	27,853	23,508
2.0-2.5	-17,147	846	-8,701
2.5-3.0	-6,587	-8,618	-7,677
3.0-3.5	-5,820	-4,792	-6,868
3.5-4.0	4,465	-4,134	-3,936
4.0-4.5	8,961	2,778	-3,748
4.5-5.0	4,229	7,013	1,119
5.0-5.5	3,641	4,513	5,709
5.5-6.0	27	3,261	1,225
6.0-6.5	-25	2,847	2,538
6.5-7.0	12	31	-7

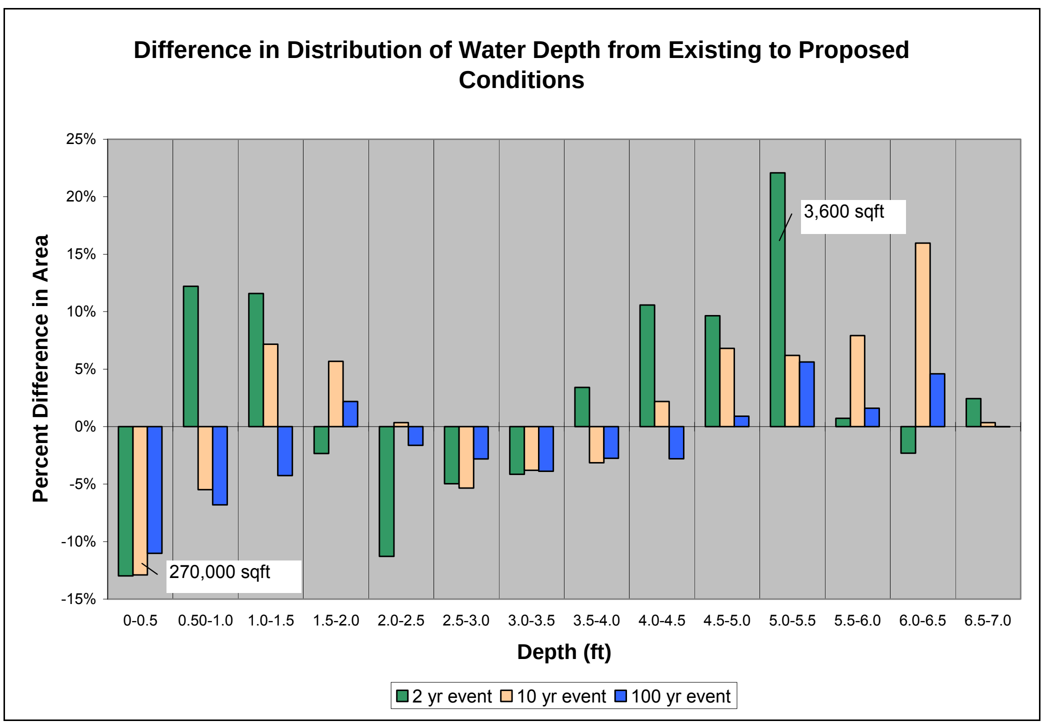

Figure 54 – Difference in distribution of water depths for dins of 0.5 feet. A negative difference represents a decrease from existing conditions.

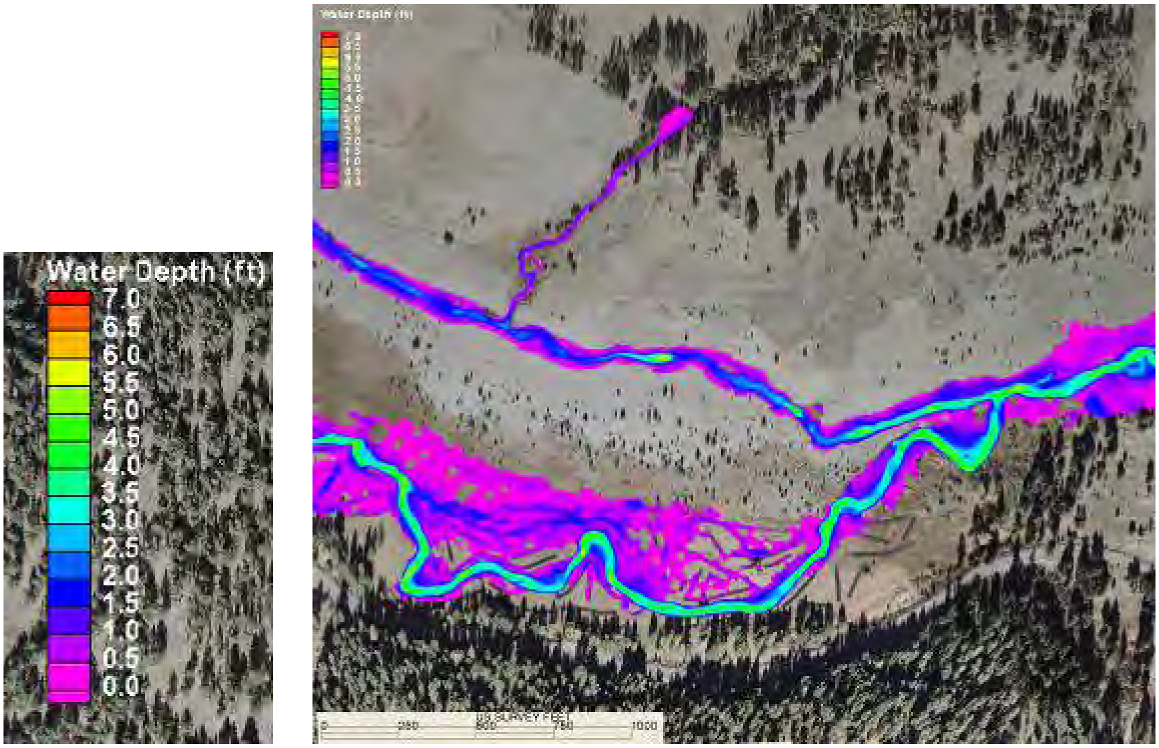

Figure 55 – Model results showing depths for the 2-year peak discharge under existing and proposed conditions downstream of bifurcation of North and South Channels. Legend shown at left.

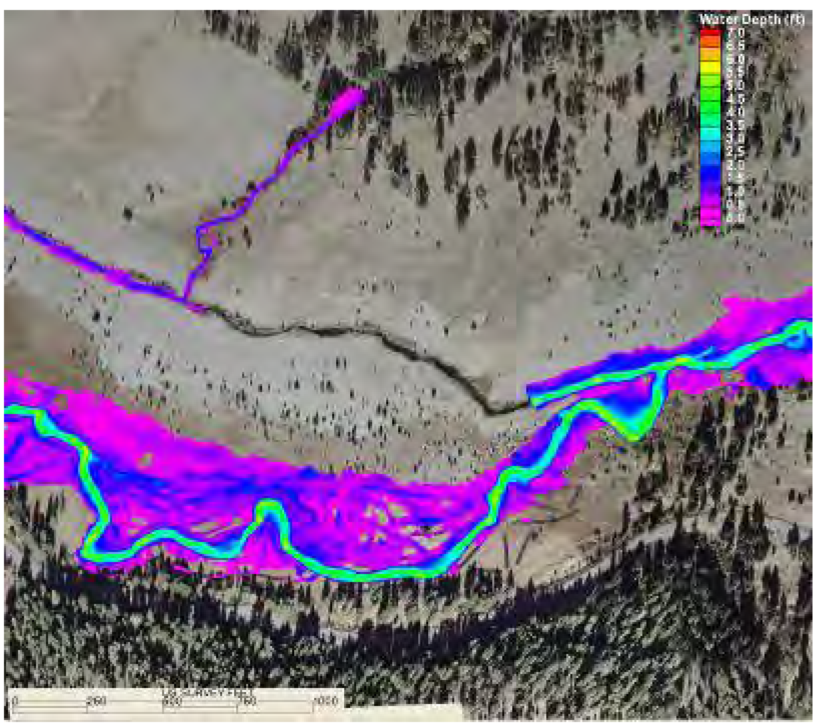

Figure 56 – Model results showing depth for the 2-year peak discharge with the North Channel blocked downstream of bifurcation of North and South channels.

4.3.2 Depth-Averaged Velocity

Similar to changes in flow depths, spatial changes in velocities are only detectable between the bifurcation of the North and South channels downstream to the confluence with Ruby Creek (Figure 57). Model results of depth-averaged velocities illustrate minimal increases within the South Channel when the North Channel is blocked. Additional backwater impacts near the downstream end of the South Channel result in slightly reduced velocities in the South Channel in certain locations. At the upstream end of the South Channel, the model predicts decreased velocities in the area just downstream from the bifurcation with the North Channel, where active migration into the Butte Creek alluvium is occurring. Changes at the upstream end are related to the location of the plug placed in the North Channel.

Both the areal and longitudinal comparisons clearly predict substantially reduced velocities in the North Channel downstream from Granite Boulder Creek when the North Channel is blocked. Just below the mouth of Granite Boulder, reductions of over 5 feet per second (ft/s) are predicted (Figure 58 and Figure 59). Differences of about 1 ft/s are predicted within the North Channel near the confluence with the South Channel. Differences in the channel velocities of the South Channel typically range between -0.5 ft/s to 0.5 ft/s for all flows evaluated, with an average increase of approximately 0.1 ft/s (Figure 60 and Figure 61). Although very small changes in velocity magnitudes are experienced in the South Channel, a considerable increase in velocities occurs along the floodplain of the South Channel. Graphs of the distributions of velocity suggest that the total floodplain area experiencing velocities less than 2 feet per second is reduced under North Channel blocked conditions (Figure 62 through Figure 64; Table 7). A reduction in the total floodplain area experiencing velocities between 4 and 8 ft/s is also noted.

Velocity vectors shown in Figure 65 through Figure 70 illustrate the direction of flow and are helpful in discerning predicted overbank flow patterns. Under existing conditions, flow from the North Channel downstream from Granite Boulder Creek is conveyed overbank toward the South Channel with a 2-year event. With the North Channel blocked, flow does not spill over the bank until a 5-yr event occurs, which in that case, the area inundated is smaller. A substantial portion of flow from Ruby Creek is intercepted by the ditch under both existing and blocked channel scenarios. This flow is conveyed across the floodplain with some flow returning to the main Ruby Creek channel and the rest returned to the North Channel at some point downstream. Flow patterns in this region are affected by a channel blockage of some type (possibly a plug, a diversion, or an artificial berm) that is visible in the LiDAR data. While the actual feature requires field verification, high-flow ground photographs indicated similar flow patterns across the floodplain north of the ditch.

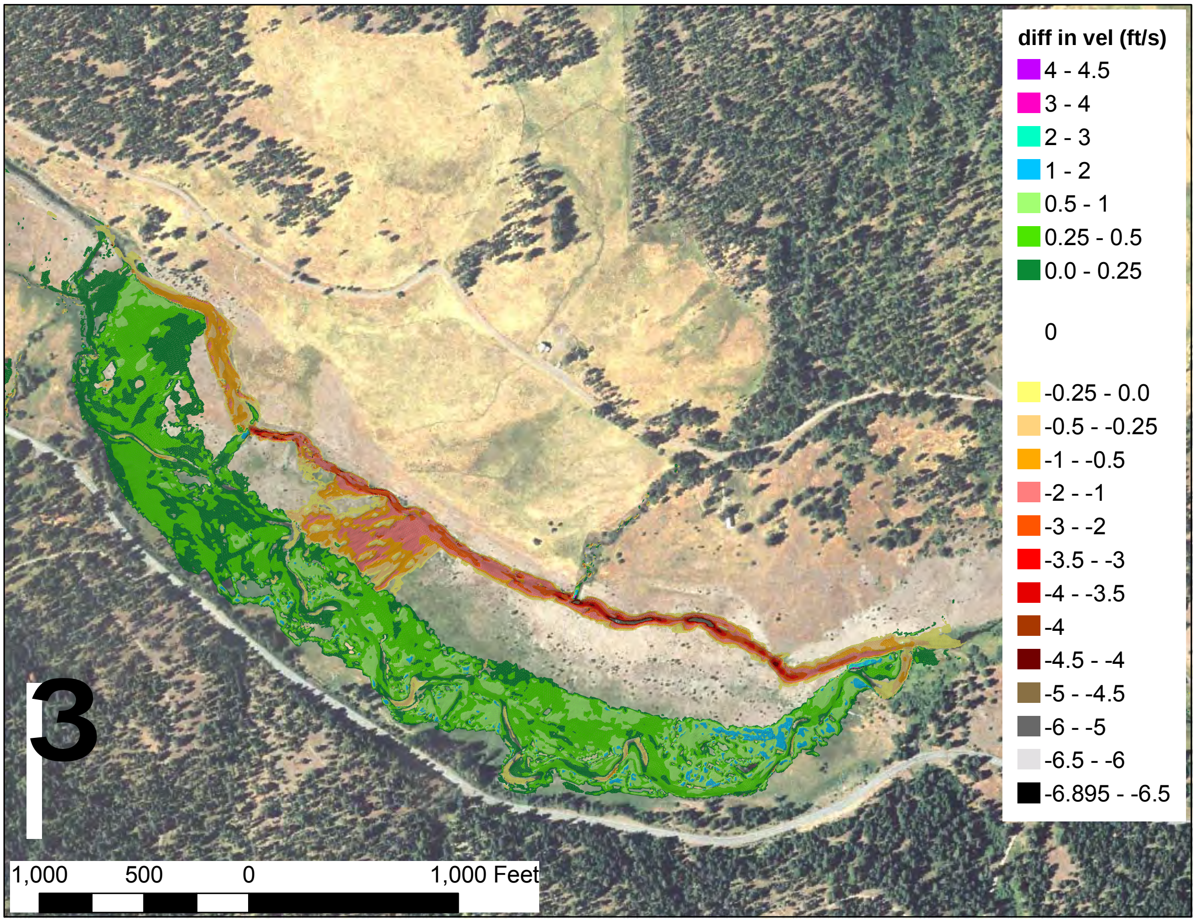

Figure 57 - Difference in velocities for a 2-year peak discharge between the existing and proposed conditions. A positive value indicates an increase when the North Channel is blocked.

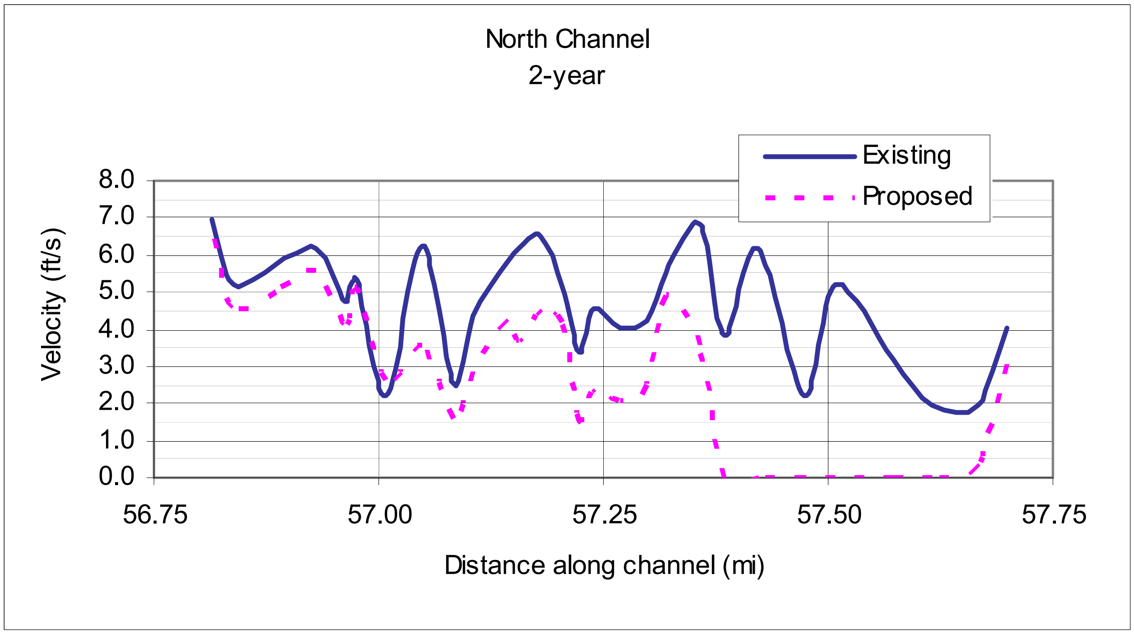

Figure 58 - Comparison of centerline velocity in existing and proposed conditions in the North Channel for the 2-year peak discharge. RM 57.7 corresponds to the bifurcation of the North Channel and the South Channel.

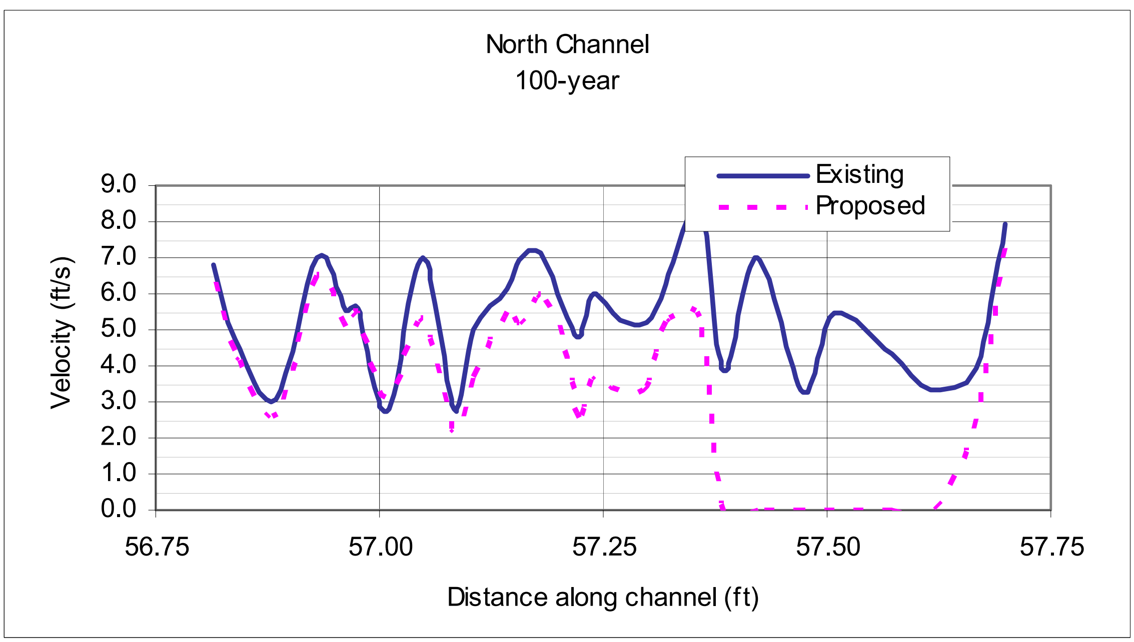

Figure 59 - Comparison of centerline velocity in existing and proposed conditions in the North Channel for the 100-year peak discharge. RM 57.7 corresponds to the bifurcation of the North Channel and South Channel.

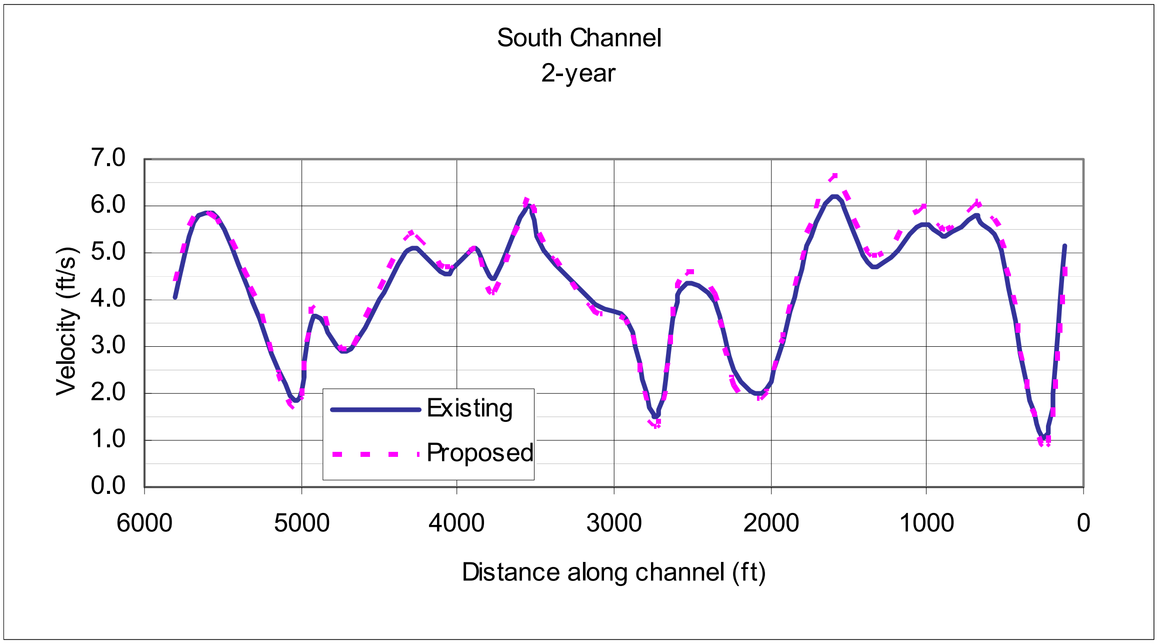

Figure 60 - Comparison of centerline velocity in existing and proposed conditions in the South Channel for the 2-year peak discharge. Zero feet corresponds to the bifurcation of the North Channel and South Channel.

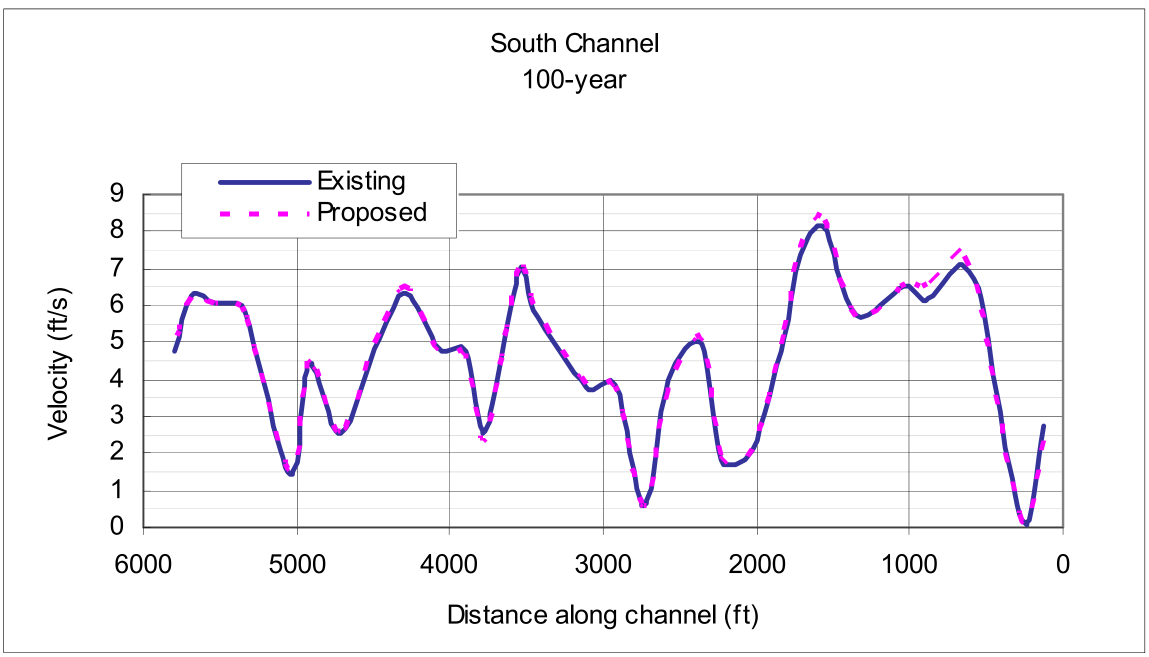

Figure 61 - Comparison of centerline velocity in existing and proposed conditions in the South Channel for the 100-year peak discharge. Zero feet corresponds to the bifurcation of the North Channel and South Channel.

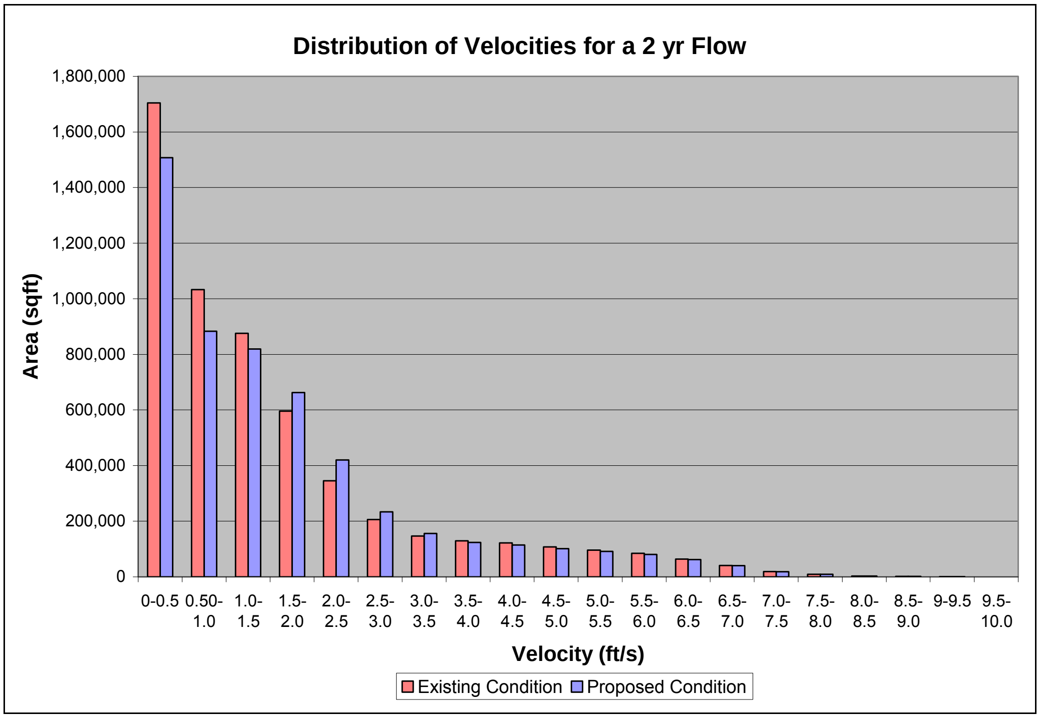

Figure 62 - Distribution of velocities for a 2-year peak discharge for the entire reach under existing and proposed conditions.

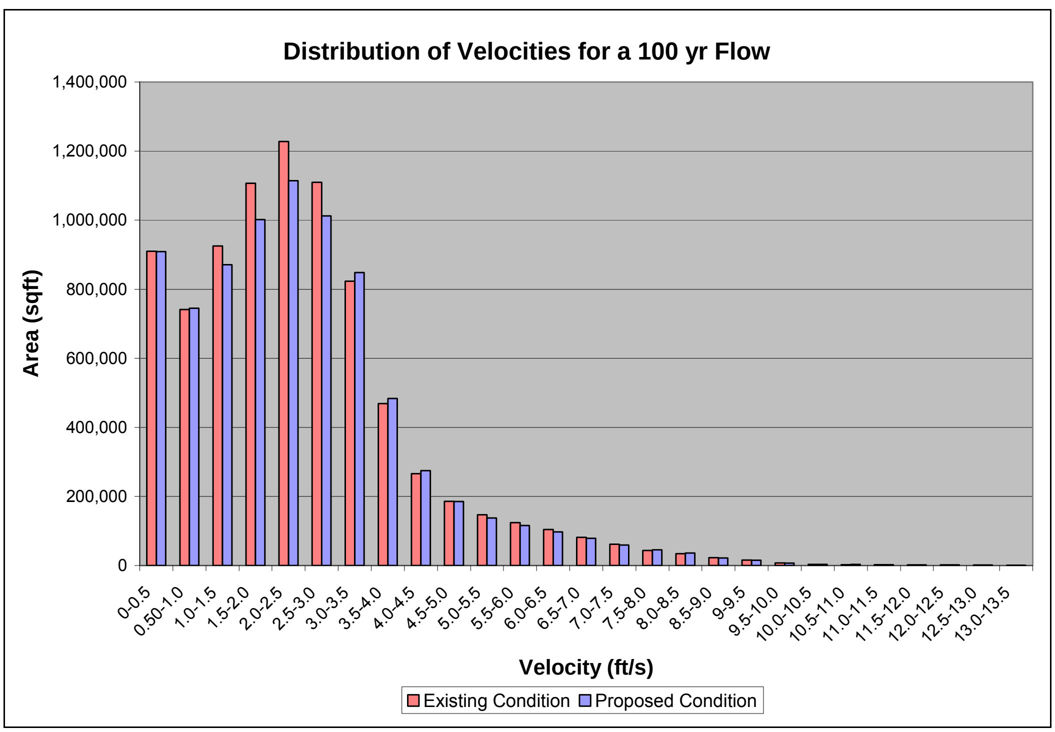

Figure 63 - Distribution of velocities for a 100 year peak discharge for the entire reach under existing and proposed conditions.

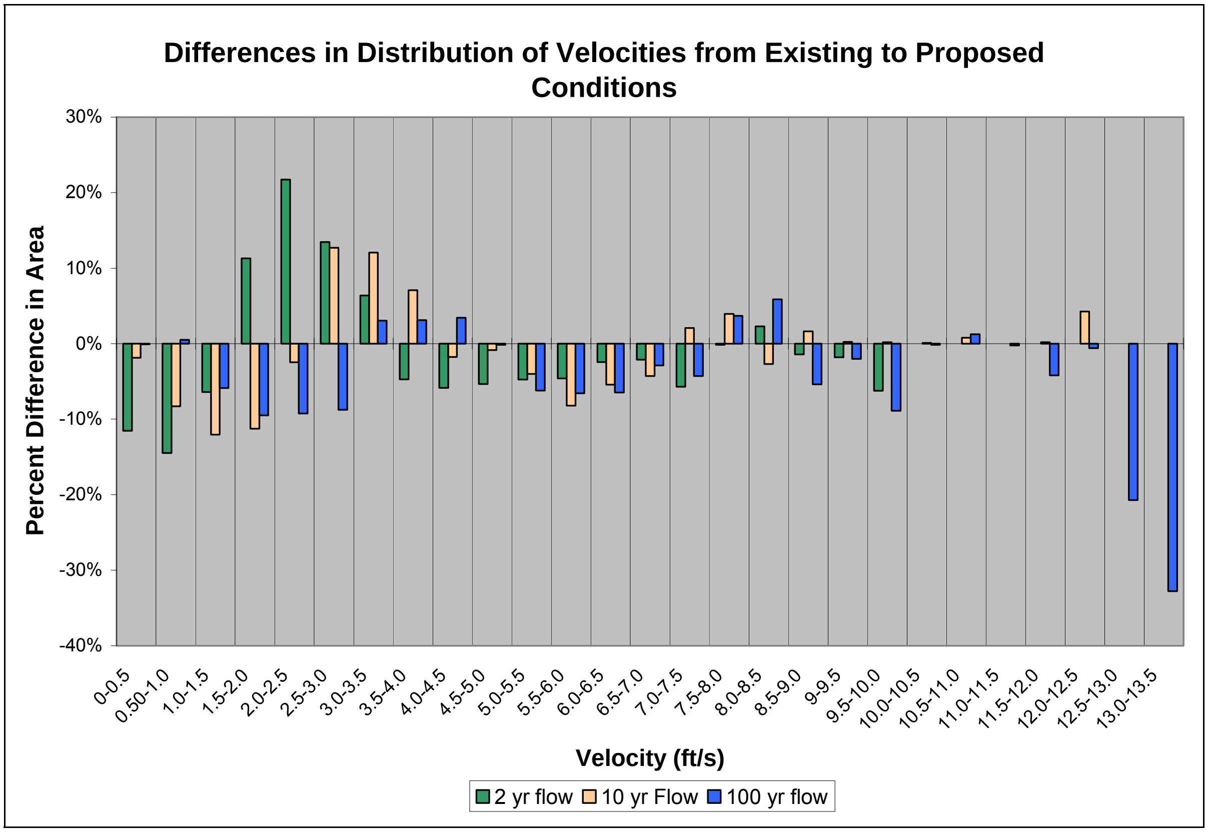

Figure 64 - Difference in areal distribution of velocities for bins of 0.5 feet/second. A negative difference represents a decrease from existing conditions. Values are shown in the following table.

Table 7 - Magnitude of differences in the distribution of velocities from existing to proposed conditions. Negative values indicate a reduction in area of the specified velocity bin.

Difference in Areal Distribution of Velocities from Existing to Proposed Conditions			
Velocity Bin (feet/second)	2-Year difference (square feet)	10-Year difference (square feet)	100-Year difference (square feet)
0-0.5	-196,802	-23,179	-920
0.50-1.0	-149,327	-82,829	3,675
1.0-1.5	-56,223	-138,060	-54,410
1.5-2.0	67,259	-126,820	-105,037
2.0-2.5	74,990	-23,439	-113,465
2.5-3.0	27,737	76,420	-97,289
3.0-3.5	9,342	40,515	24,987
3.5-4.0	-6,140	14,131	14,587
4.0-4.5	-7,124	-2,727	9,131
4.5-5.0	-5,734	-1,120	-274
5.0-5.5	-4,604	-4,706	-9,143
5.5-6.0	-3,870	-8,520	-8,173
6.0-6.5	-1,547	-4,410	-6,727
6.5-7.0	-862	-2,777	-2,352
7.0-7.5	-1,099	1,003	-2,659
7.5-8.0	-13	1,253	1,606
8.0-8.5	65	-549	2,013
8.5-9.0	-16	191	-1,233
9-9.5	-11	11	-320
9.5-10.0	-7	5	-666
10.0-10.5	0	2	-5
10.5-11.0	0	4	37
11.0-11.5	0	0	-6
11.5-12.0	0	0	-94
12.0-12.5	0	0	-12
12.5-13.0	0	0	-364
13.0-13.5	0	0	-201

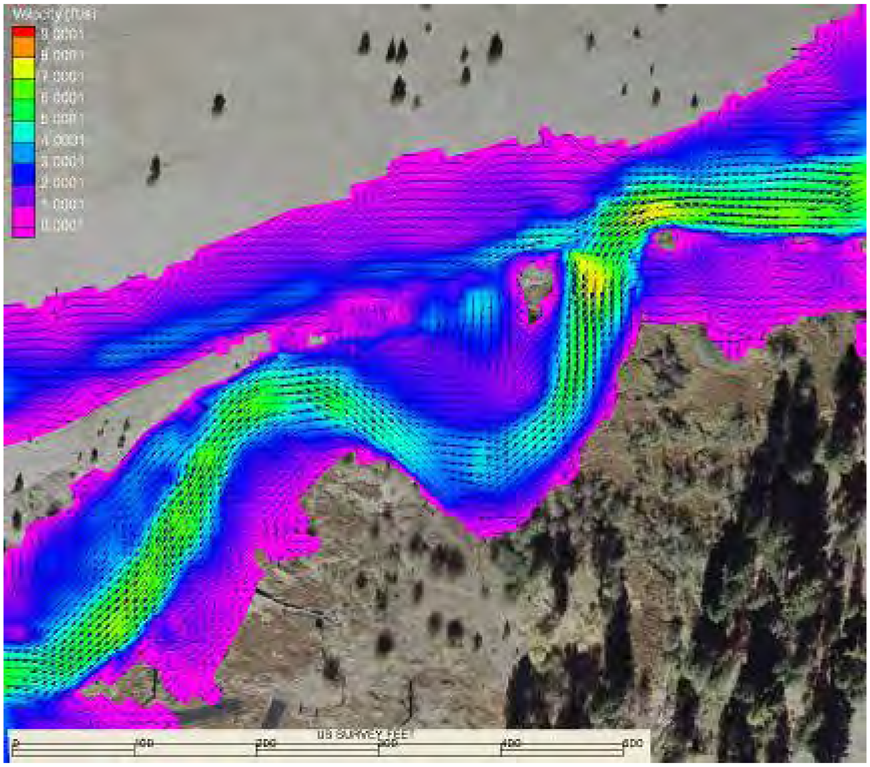

Figure 65 - Velocity vectors for 2-year discharge under existing conditions at bifurcation.

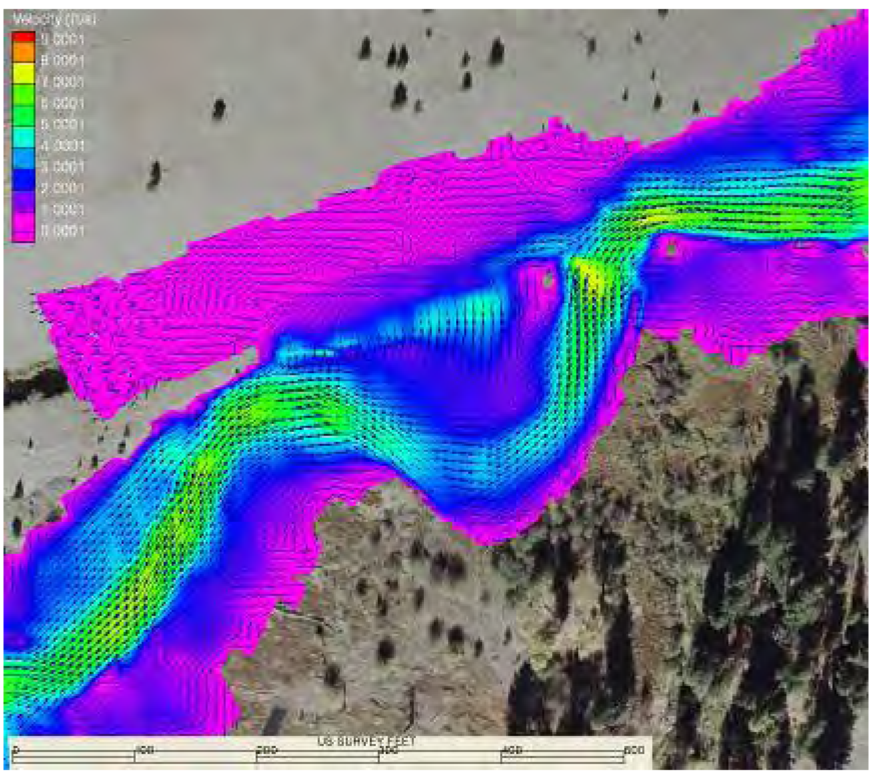

Figure 66 - Velocity vectors for 2-year discharge under proposed conditions at bifurcation.

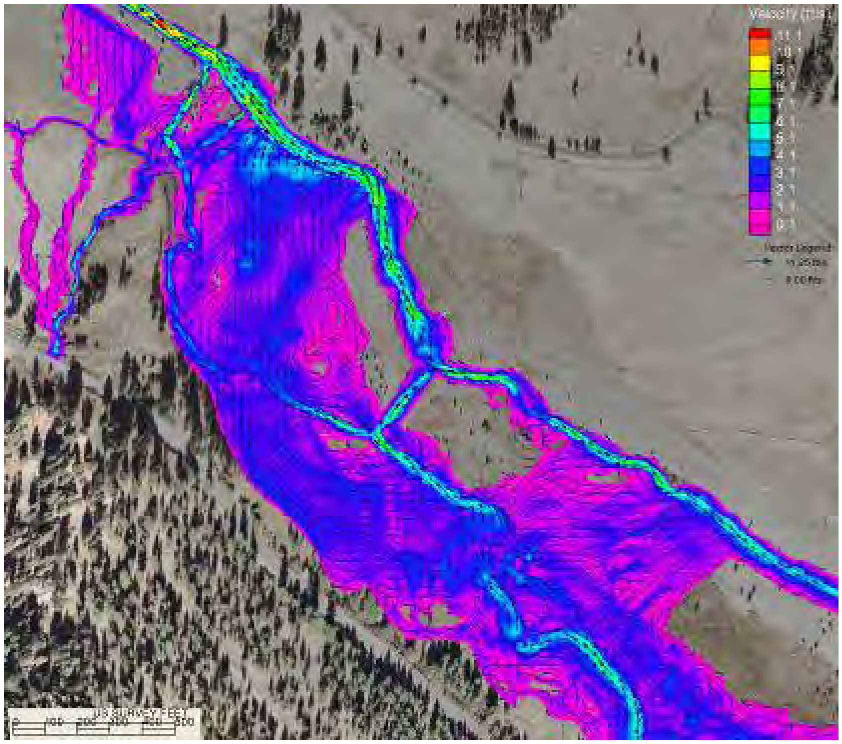

Figure 67 - Velocity vectors for 5-year discharge under existing conditions upstream from Ruby Creek.

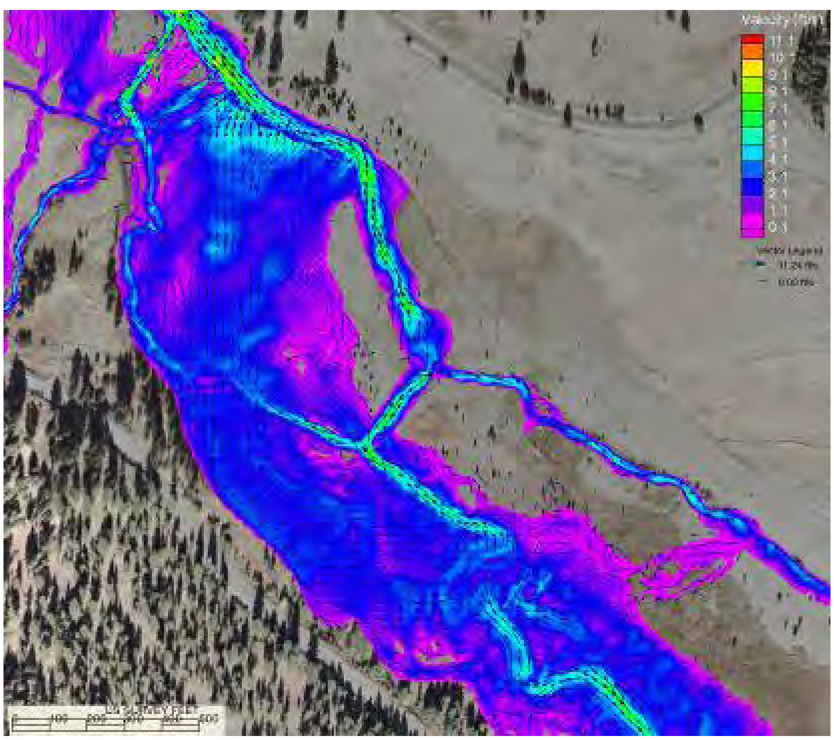

Figure 68 - Velocity vectors for 5-year discharge under proposed conditions upstream from Ruby Creek.

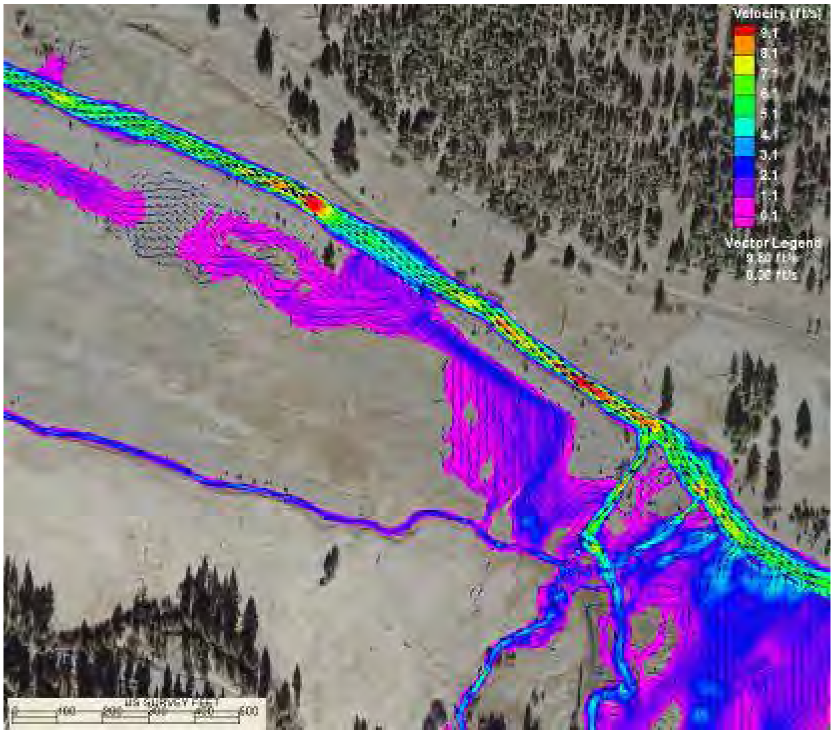

Figure 69 - Velocity vectors for 2-year discharge under existing conditions at Ruby Creek confluence.

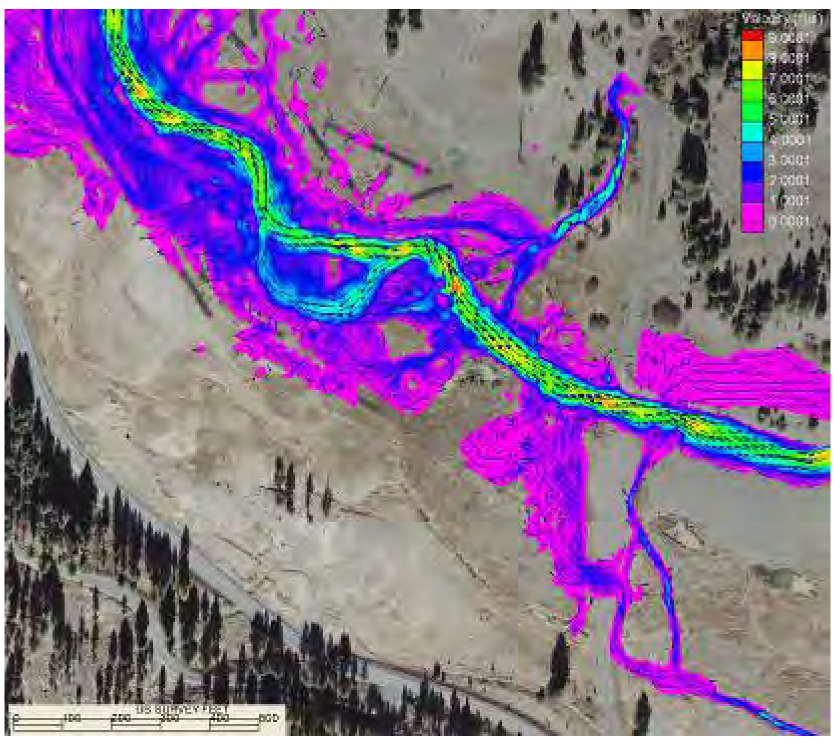

Figure 70 - Velocity vectors for 2-year discharge under existing conditions at Beaver Creek confluence.

4.3.3 Bed Shear Stress

Bed shear stress follows patterns similar to depth-averaged velocities. In the South Channel under existing conditions, bed shear stress averages around 0.6 pounds per square foot (lb/sf) at a 2-year peak discharge, which corresponds to threshold mobilization of particles between 32 and 45 mm in diameter (Julien 1998). Bed shear stress values close to 1.5 lb/sf under existing conditions and not exceeding 100 feet in length are found in very localized areas within the South Channel near its entrance, across a few riffles, and along the outside of a meander bend, which corresponds to threshold mobilization of approximately 80 to 100 mm particle diameters. Geomorphic conditions indicate that the reach is transport-limited.

Similar to depth and velocity, changes in shear stress are only detectable between the bifurcation of the North and South Channels and the confluence of Ruby Creek (Figure 71). Comparison of channel bed shear stress for existing and proposed conditions in the North and South Channels for all flows indicates minimal increases in the South Channel just downstream of the flow bifurcation (Figure 72). Increases in shear stress are predicted along the floodplain of the South Channel in areas that are only slightly inundated under existing conditions, which indicates the potential for an increased frequency for floodplain reworking under the proposed conditions. Predicted decreases in the South Channel near the bifurcation are related to backwater resulting from the plug in the North Channel and the increased overbank flow at the bifurcation. Changes in bed shear stress are significant in the North Channel downstream of Granite Boulder where reductions of over 1.3 lb/sf are predicted only at the mouth (Figure 73 to Figure 76). Under both existing and proposed conditions, bed shear stress in the North Channel decreases to about 0.16 lb/sf just upstream of the confluence with the South Channel. Despite increasing discharges from the 2- to 100-year recurrence intervals, differences in the bed shear stress between the existing and proposed conditions along the South Channel thalweg are similar in magnitude due to increased overbank activation rather than increased main channel flows. Within the channel, a maximum increase of 0.19 lb/sf is predicted for a 5-year peak discharge at approximately Station 1621, but generally changes are less than 0.10 lb/sf.

Distribution plots illustrate that the total area experiencing shear stresses between 0 and 0.2 lb/sf decreased under all modeled discharges (Figure 77 to Figure 79; Table 8). For a 2-year event, there is a general reduction in shear stresses between 1.4 and 2.4 lb/sf when the North Channel is blocked. The greatest shear stress differences between existing and proposed conditions occur for values less than 1.0 lb/sf (Table 8). Although the percent differences for shear stress values greater than 1.0 lb/sf approach -15 percent, the magnitude of the differences (the actual change in area in square feet) is small (Figure 78). Overall, because the total area inundated is smaller under proposed conditions, the total area experiencing shear stress is reduced. The reductions are most notable in areas experiencing small shear stress values (less than 0.2 lb/sf). Example plots of the spatial distributions of bed shear stress for the 2-year discharge under existing and proposed conditions are illustrated in Figure 80 through Figure 81.

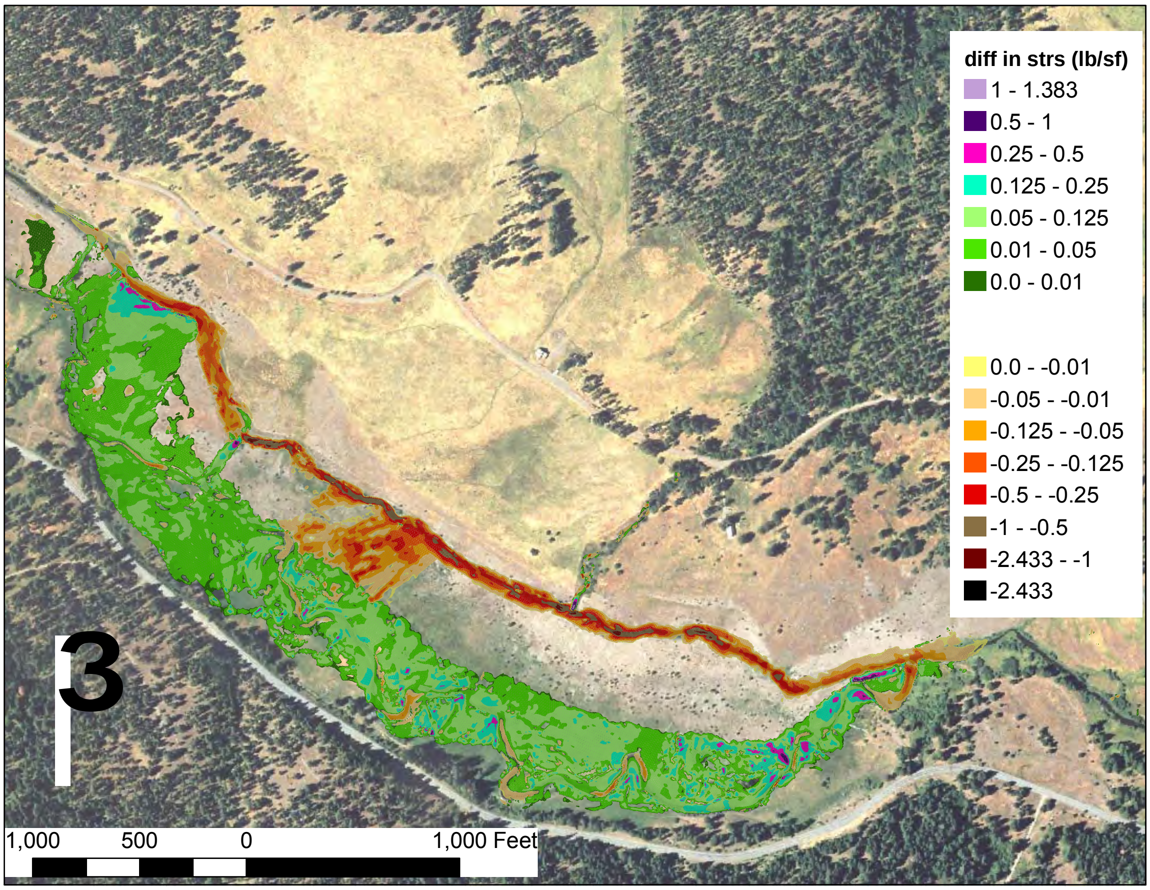

Figure 71 - Difference in shear stress between existing and proposed conditions. A positive value indicates an increase when the North Channel is blocked.

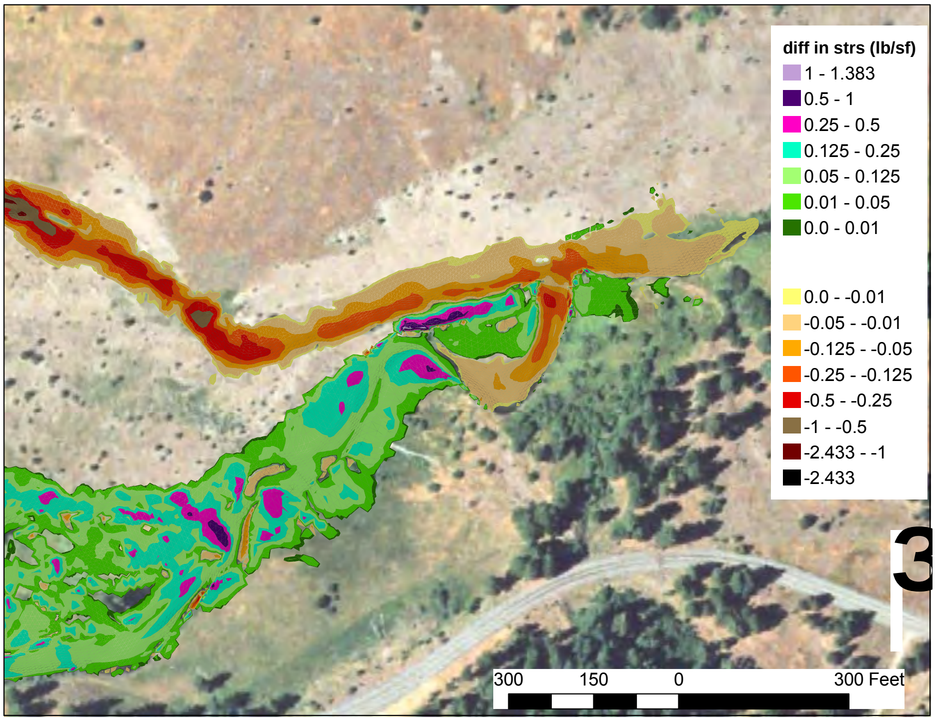

Figure 72 - Differences in shear stress near the bifurcation of the North Channel and South Channel. A positive value indicates an increase when the North Channel is blocked.

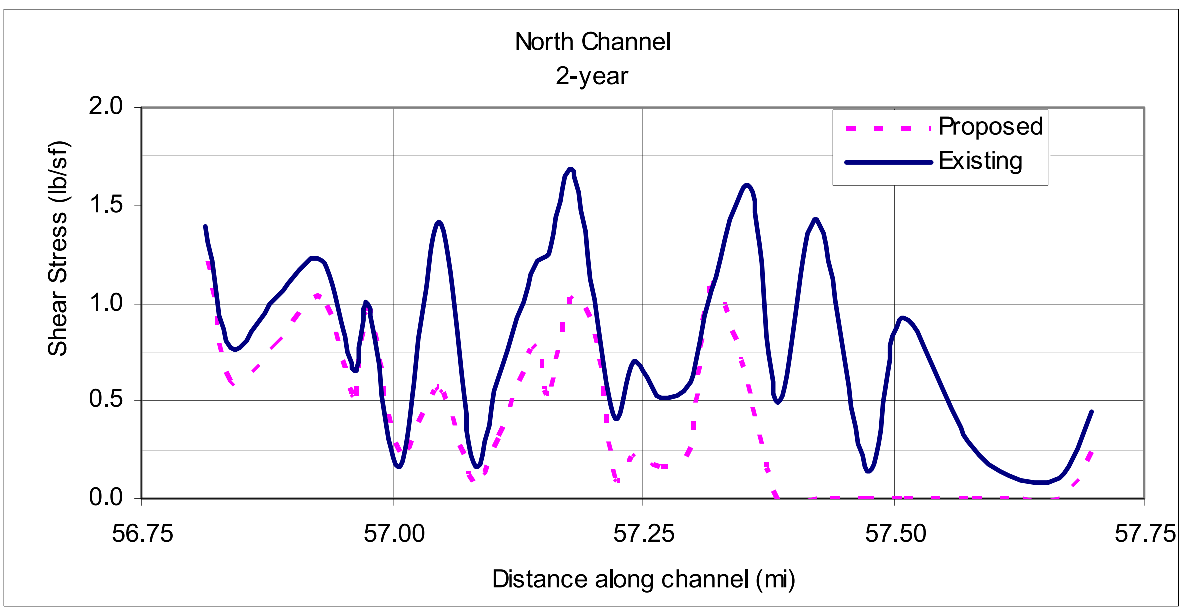

Figure 73 - Comparison of bed shear stress in existing and proposed conditions in the North Channel along the thalweg for the 2-year discharge. RM 57.7 corresponds to the bifurcation of the North Channel and South Channel.

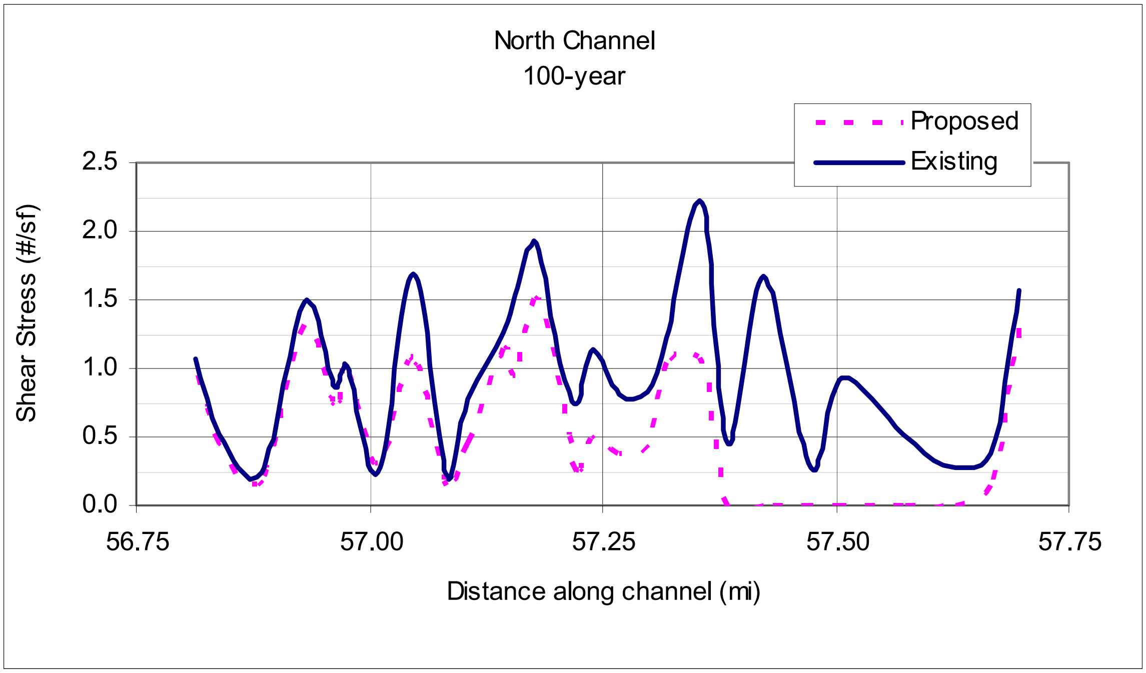

Figure 74 - Comparison of bed shear stress in existing and proposed conditions in the North Channel along the thalweg for the 100-year discharge. RM 57.7 corresponds to the bifurcation of the North Channel and South Channel.

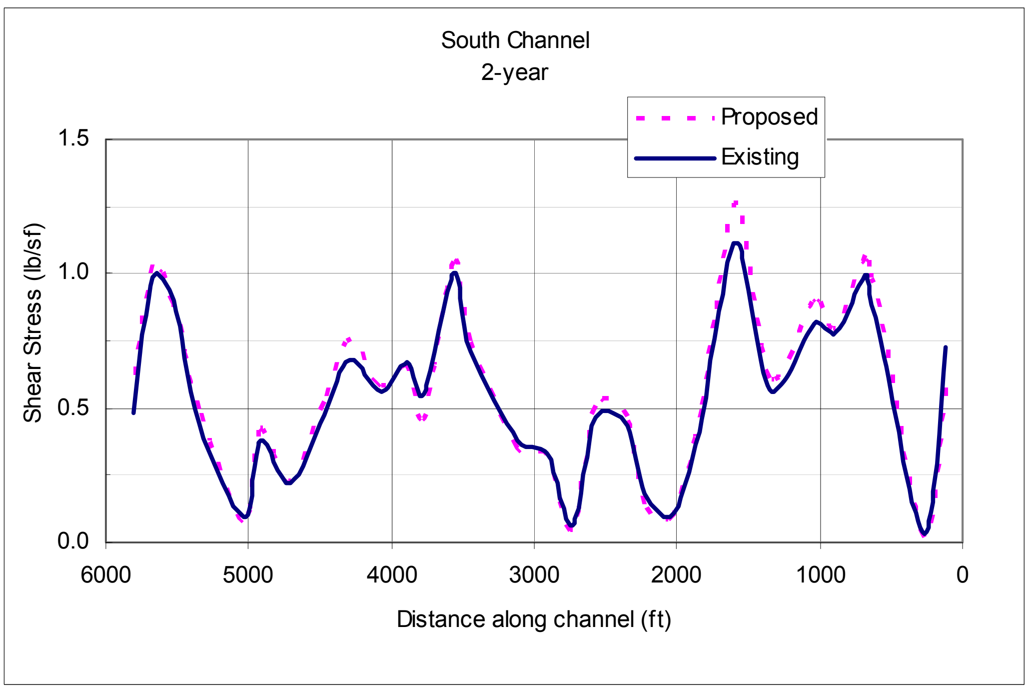

Figure 75 - Comparison of bed shear stress in existing and proposed conditions in the South Channel along the thalweg for the 2-year discharge. Zero feet corresponds to the bifurcation of the North Channel and South Channel.

http://www.usbr.gov/pn/blackcanyon/index.html

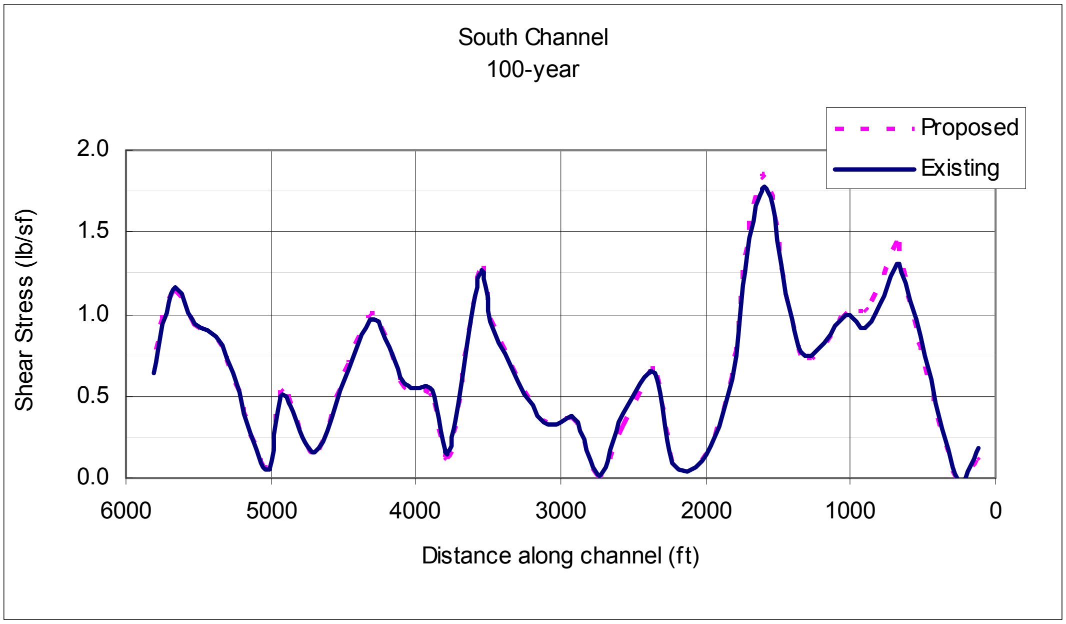

Figure 76 - Comparison of bed shear stress in existing and proposed conditions in the South Channel along the thalweg for the 2-year discharge. Zero feet corresponds to the bifurcation of the North Channel and South Channel.

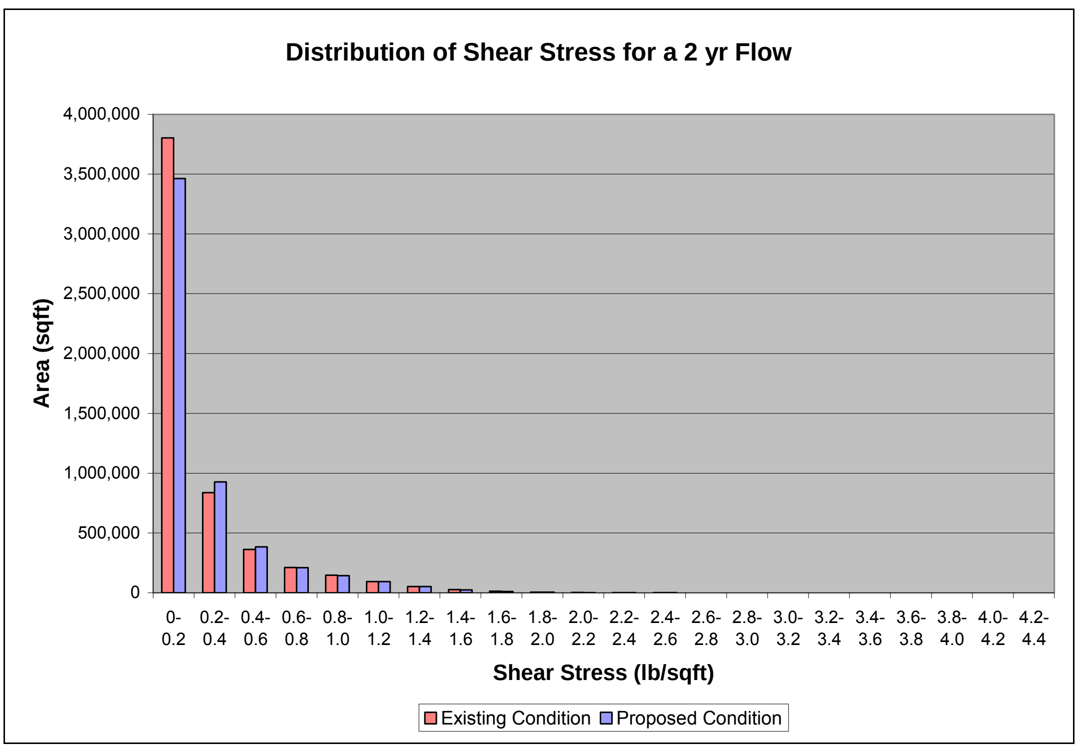

Figure 77 - Distribution of shear stress for a 2-year discharge for the entire reach under existing and proposed conditions.

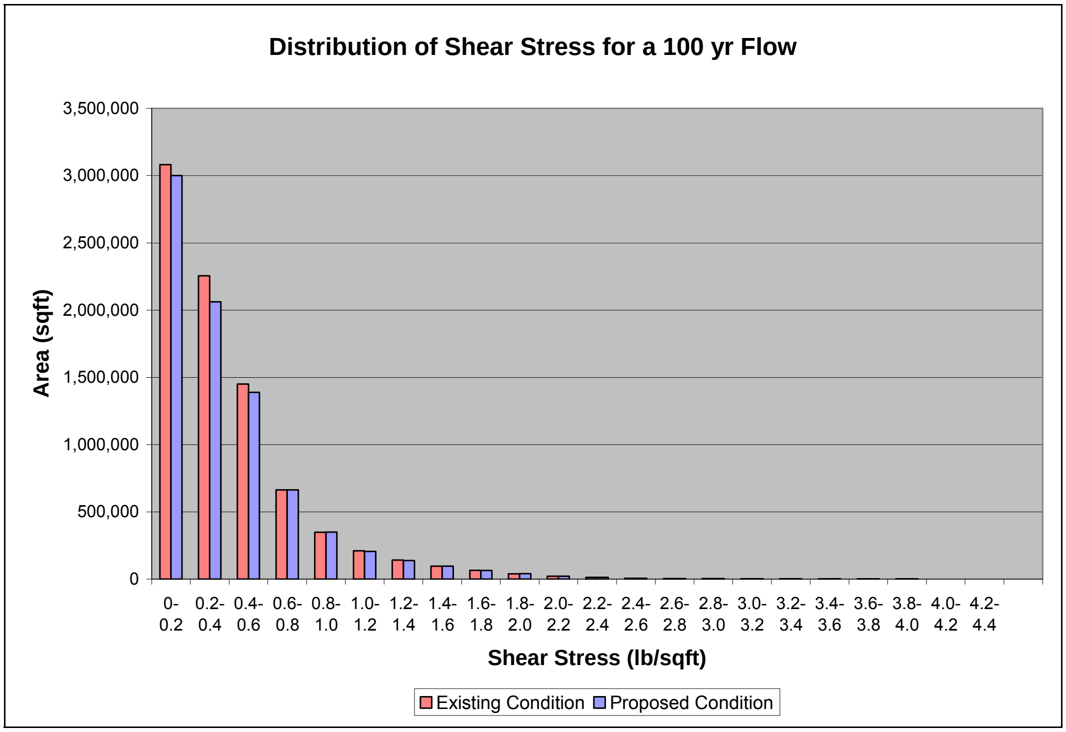

Figure 78 - Distribution of shear stress for a 100-year discharge for the entire reach under existing and proposed conditions.

Table 8 - Magnitude of differences in distribution of bed shear stress from existing to proposed conditions. Negative values indicate a reduction in area when the North Channel is blocked.

Difference in Areal Distribution of Depths from Existing to Proposed Conditions			
Shear Stress Bins (lb/sf)	2-year difference (square feet)	10-year difference (square feet)	100-year difference (square feet)
0-0.2	-341,284	-276,766	-82,421
0.2-0.4	90,480	-69,372	-193,019
0.4-0.6	19,426	48,109	-61,990
0.6-0.8	-1,615	18,154	850
0.8-1.0	-3,139	-4,958	1,377
1.0-1.2	-60	-3,289	-5,248
1.2-1.4	113	1,020	-3,437
1.4-1.6	-2,881	-1,929	-1,082
1.6-1.8	-1,093	835	-508
1.8-2.0	-646	1,486	1,807
2.0-2.2	-309	412	-757
2.2-2.4	-9	18	-118
2.4-2.6	33	17	-77
2.6-2.8	-14	27	114
2.8-3.0	0	2	122
3.0-3.2	0	0	53
3.2-3.4	0	-1	-6
3.4-3.6	0	0	62
3.6-3.8	0	0	-262
3.8-4.0	0	0	-308
4.0-4.2	0	0	-104
4.2-4.4	0	0	0

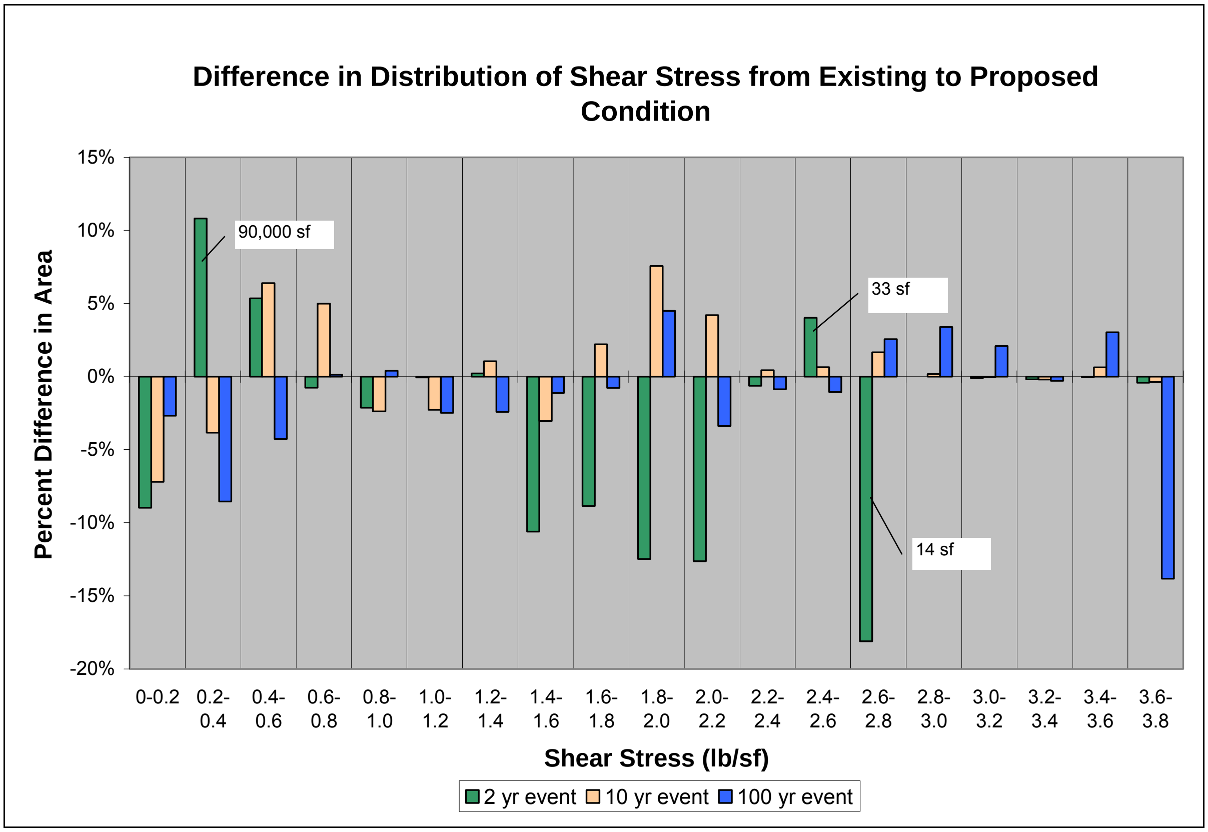

Figure 79 - Difference in distribution of shear stress for bins of 0.5 lb/sf. A negative difference represents a decrease from existing conditions.

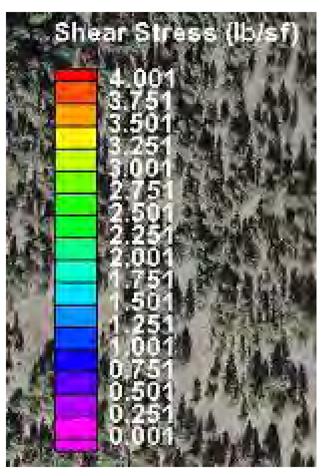

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Figure 80 - Model results for the 2-year discharge shear stresses under existing conditions downstream of bifurcation. Legend is on the left.

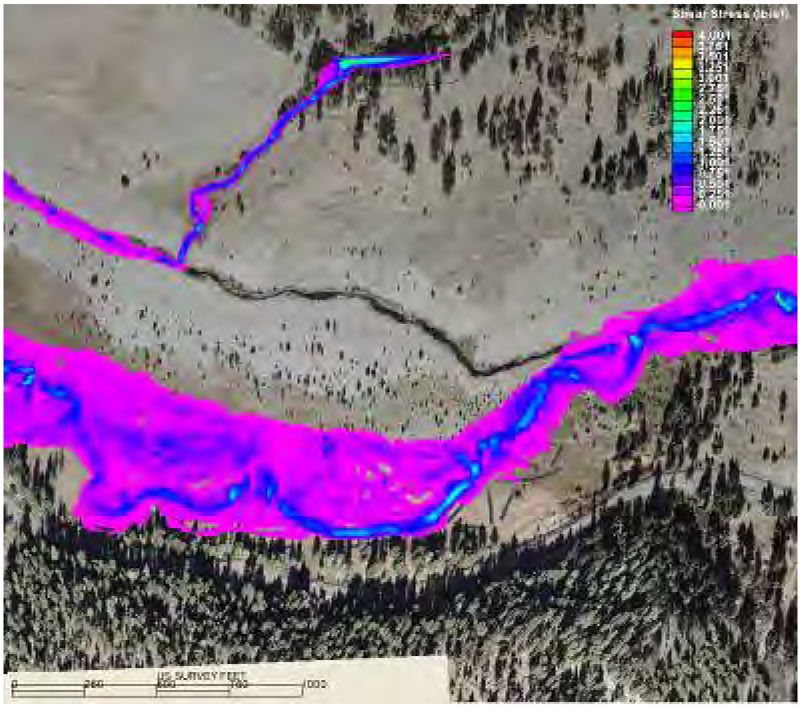

Figure 81 - Model results for the 2-year discharge shear stresses with the North Channel blocked downstream of bifurcation. Legend is left of Figure 68.

4.4 Flow Splits between the North and South Channels

Modeled discharges resulting from the split flow at the bifurcation were determined by placing “monitoring lines” across the channel in the SRH-2D model at seven locations. In SRH-2D, monitoring lines can be a maximum of 20 elements (cells). For this analysis, they were placed at locations where the majority of the flow was expected to be contained within those 20 elements (e.g., in a confined channel section) and where overbank flow was expected to be minimal; however, in most instances, the monitoring lines did not fully capture the flow through an area, missing floodplain flow. For that reason, the results provided here indicate trends only, not exact flow volumes that are conveyed through an area.

The locations of the seven monitoring lines included the inlet (1), the North Channel (2), the South Channel (3), the outlet (4), the North Channel below Ruby Creek (5), the South Slough (6), and the ditch (7) (Figure 102). Values for the South Channel connect (8), the North Channel above the South Slough connection (9), the North Channel below the South Slough (10), and the Ruby Creek connect (14), were generated using formulas from the original seven monitoring lines. Flows from Granite Boulder Creek (11), Ruby Creek (12), and Beaver Creek (13) were used in the existing conditions model (Table 2).

As the flood discharge in the MFJDR system increases, the percentage of flow from the North Channel that contributes to the South Channel flow decreases because:

1. More volume is being conveyed in the floodplain of the South Channel.
2. The North Channel maximum conveyance capacity is approximately 455 cfs, which is a small portion of the total flow volume of the 100-year event in the MFJDR.

Several other key trends were noted as a result of blocking the North Channel flow:

a) A greater percentage of the North Channel blocked flow is conveyed down the South Channel Connect (8) than through the South Slough (6).
b) Minor increases in flow in Ruby Connect (14) and the ditch were predicted.
c) Substantial changes to any of the hydraulic parameters resulting from the North Channel blocked flow ends at or just above Ruby Creek.

4.5 Limitations due to Sensitivity and Variability

4.5.1 Hydraulic Modeling Sensitivity

Section 4.1 demonstrated that the modeled events of 2005 and 2008 were well represented by the model; however, no quantitative calibration information 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.

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 in-channel roughness using the 2-year SRH-2D existing conditions model. These values are typically modified during a model calibration process. As mentioned in Section 4.1, the peak flows for the inlet conditions of the Oxbow Conservation Area on the MFJDR were determined by adjusting gage data from the Ritter Gage. The inlet flow for the three tributaries, Ruby, Granite Boulder, and Beaver Creeks, were developed using standard ungaged subbasin calculations for eastern Oregon (Reclamation 2008). Measured discharges in the tributaries and main channel in combination with surveyed water surface elevations at these discharges could improve estimates for the hydraulic parameters evaluated in this report. The following discussion explores how varying model input parameters, apart from flow, modified model results.

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. A 10-year discharge was selected because it represents a moderate value between a 2- and 100-year discharge (i.e., not a very frequent discharge or extremely rare discharge). Using the 1D model generated in the *Tributary Assessment*, the downstream stage for a 10-year discharge was 3682.35 feet. Varying the downstream boundary condition resulted in changes in water depths for less than 700 feet upstream from the downstream boundary (Figure 82).

The sensitivity of channel roughness was tested by varying Manning's *n* in the 2-year existing conditions model. The results discussed in this report are based on a Manning's n value of 0.039 in the channel and the sensitivity analysis was based on a Manning's *n* of 0.044. This simulation predicted that the maximum change in depth was less than 0.25 feet; however, the average change throughout the reach was less than 0.1 feet, which is not significant.

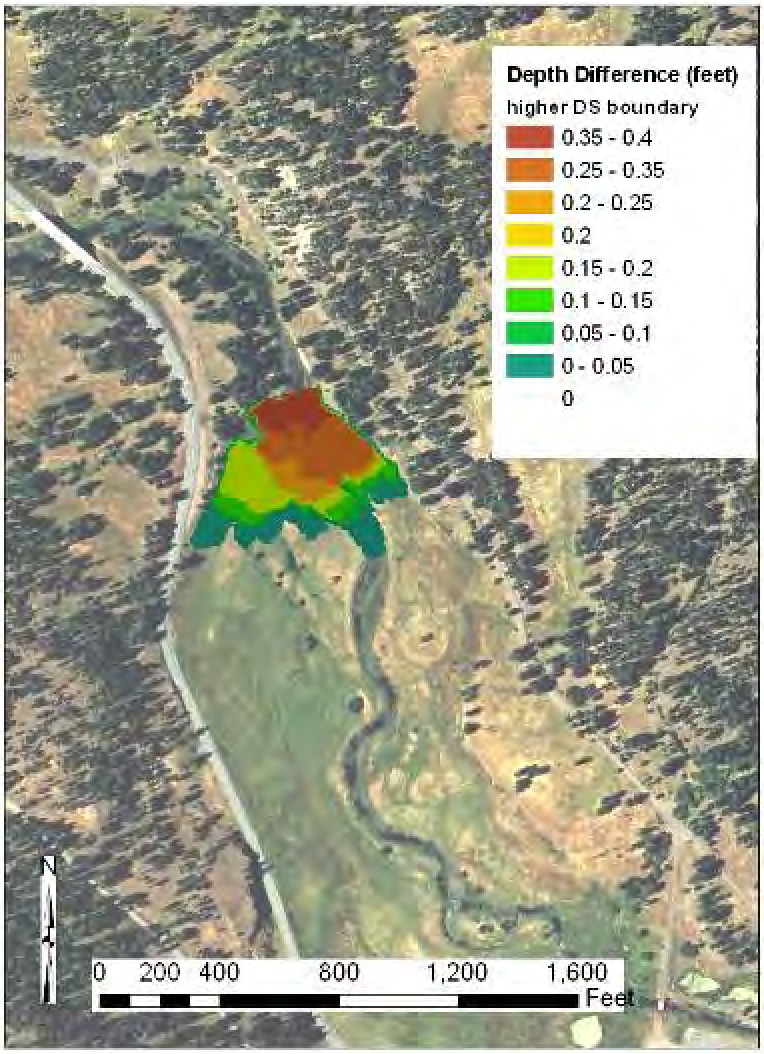

Figure 82 - Difference in depths between the initial downstream boundary (3682.35 feet) and the higher downstream boundary (3682.85 feet).

4.5.2 Limitations of Hydraulic Analysis

The development of this 2D model included a significant amount of survey data from both LiDAR and ground surveys of bathymetry through most of the study area; however, a portion of the North Channel TIN surface (stream segments (SS) 2, 9, and part of 10; Figure 102) was generated using only channel cross-section data. The balance of the bathymetry was collected with sufficient data to generate one-foot contours and anecdotal information was used in areas of deep pools or other locations where data could not be collected. This lack of data in specific areas and less-than-robust bathymetry for habitat analysis made the 2D model unusable for low flow analysis. These survey limitations also complicated digitizing the channel banks. As a result, some channel widths may be over or underestimated, which can affect flow depth during low flow conditions. Although these data are more than sufficient for analyzing out-of-bank discharges, as was done in this study, more detailed analyses of in-channel habitat are not recommended, as data are too sparse.

The location of the plug in the model of the first potential option was selected based on Interdisciplinary Team input at the 2008 meeting in John Day, Oregon in which some members requested the plug be located some distance downstream of the bifurcation. The elevation of the plug needs to prevent any flow from entering the North Channel. To meet this objective, the bed elevation at the location of the plug was raised to an elevation two feet greater than the water surface elevation of the 100-year peak discharge just upstream of the plug. Elevations of surrounding elements (cells) were also evaluated to ensure that no flow could be conveyed around the plug into the North Channel (SS2). During the design of the selected rehabilitation option, the ultimate location of the plug can be adjusted upstream or downstream based on Interdisciplinary Team input.

The upstream boundary condition chosen for in the model may have impacted results in the vicinity of a series of side channels near RM 58. As shown in Figure 83, the inlet flow was conveyed over the entire floodplain rather than just in the channel for all flows evaluated. This approach was taken to ensure that the boundary condition did not impact flow conveyance, but resulted in floodplain flow that may or may not actually occur. In addition, the floodplain flow may have reduced the flow available to the side channels on the left bank of the main channel and, as a result, the model results may not be as accurate in this location as they are in the rest of the model. If these side channels are evaluated in the future, the model boundary should be moved further upstream, inlet flows recalculated if necessary, and TIN surface construction in the newly added area completed.

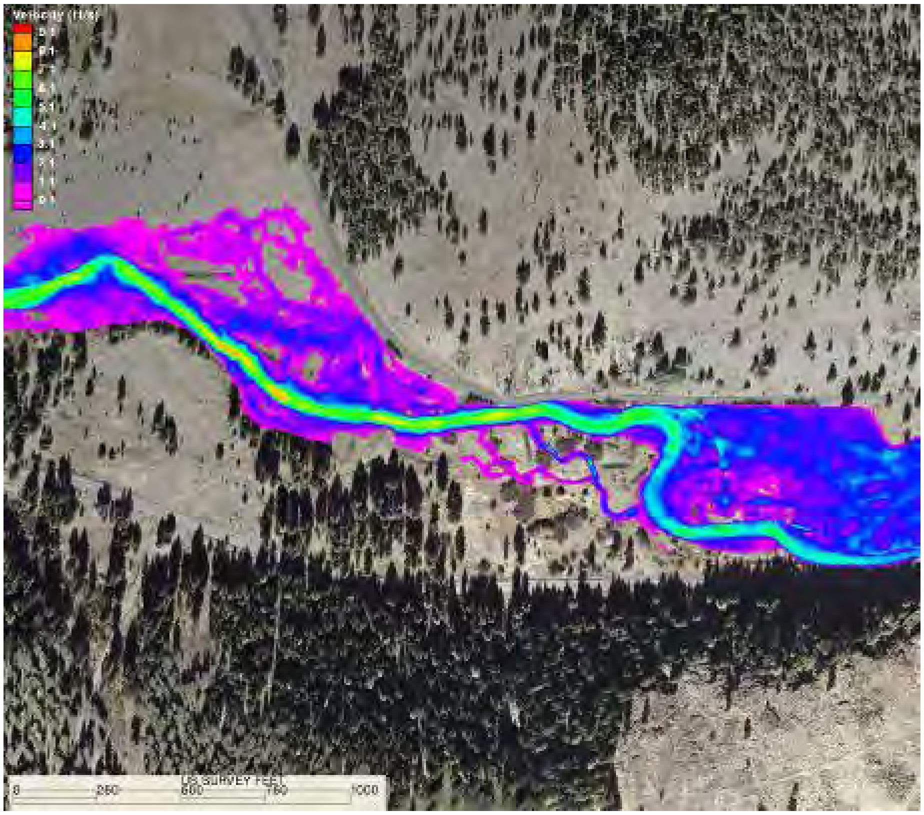

Figure 83 - Modeled velocity near the upstream model boundary for the 2-year peak discharge.

4.6 Geomorphic Variability

Uncertainties associated with this geomorphic assessment relate to the accuracy of mapping, estimates for the age of the surficial geologic units, the characterization of soil properties, the description of the sedimentology and geomorphology for surficial geologic units, and their stratigraphic relationships as determined in the field. Numerical ages are derived from the work of Bandow (2003), which are based on the radiocarbon analyses of charred wood. The type of wood submitted for analysis was not determined; therefore, it is not possible to evaluate possible age inheritance issues related to analyzing an unknown type of material. All reported ages were calibrated using a radiocarbon calibration program (CALIB version 5.0.2). Numerous problems exist with radiocarbon.

Chapter 5 CONCLUSIONS

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 and proposed conditions of blocking off the North Channel based on predicted changes to water surface elevation, depth-averaged velocity, and bed shear stress. These hydraulic parameters were compared along the channel thalweg and across the floodplain.

5.1 Existing and Potential Floodplain Connectivity

To evaluate floodplain connectivity, the entire study area was analyzed on a reach basis. The reaches of this study correspond to those developed during the *Tributary Assessments* (Reclamation 2008), with the addition of the area adjacent to the North Channel. A description of each reach is provided below and shown in Figure 5:

a) Downstream portion of Reach 9: extends from the upstream model boundary to just above the North-South Channel bifurcation.

b) Higher surface of the North Channel: this surface was historically the toe of the alluvial fan from Granite Boulder Creek, but is more frequently inundated by the MFJDR today due to anthropogenic impacts. This small area is adjacent to the floodplain of the South Channel and extends from the flow bifurcation to the confluence with Ruby Creek.

c) Reach 8: extends from just upstream of the North-South Channel bifurcation to just upstream of the Beaver Creek confluence. This reach does not include the higher surface of the North Channel.

d) Reach 7: extends from just above the Beaver Creek confluence to the downstream model boundary.

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, reaches 7, 8, and 9 are fairly well inundated during most flood events with 15 to 30 percent of floodplain connected during a 2-year discharge, 30 to 45 percent of the floodplain connected during a 5-year discharge, and 40 to 55 percent of the floodplain connected during a 10-year discharge (Figure 84). By blocking flow to the North Channel above Granite Boulder Creek, floodplain connectivity along the higher surface of the North Channel is reduced to a maximum of 4 acres and the floodplain connectivity within reach 8 primarily along the South Channel increases to a maximum of 6 acres (Figure 85 and Figure 86).

Under the proposed scenario, as the peak discharge increases, the additional floodplain area connected gained in reach 8 decreases due to the limited capacity of the North Channel; therefore, under a 100 year-event, blocking the North Channel does not result in a substantial increase of discharge in the South Channel, and for this reason, does not considerably modify floodplain connectivity within reach 8.

Although the historical toe of the Granite Boulder Creek alluvial fan-a higher surface of the North Channel-is not part of the natural floodplain, the modeled results predict areas inundated more than 0.5 feet outside of the low flow channel under existing conditions. A large portion of this area is along the channel fringes, but some of the area is located downstream of the Granite Boulder Creek confluence where the North Channel spills over its banks into the South Channel. Blocking flow to the North Channel results in a loss of this connected area that increases in magnitude with larger storm events. This is area was not considered high-quality high-flow habitat based on the analysis presented in Section 5.3.

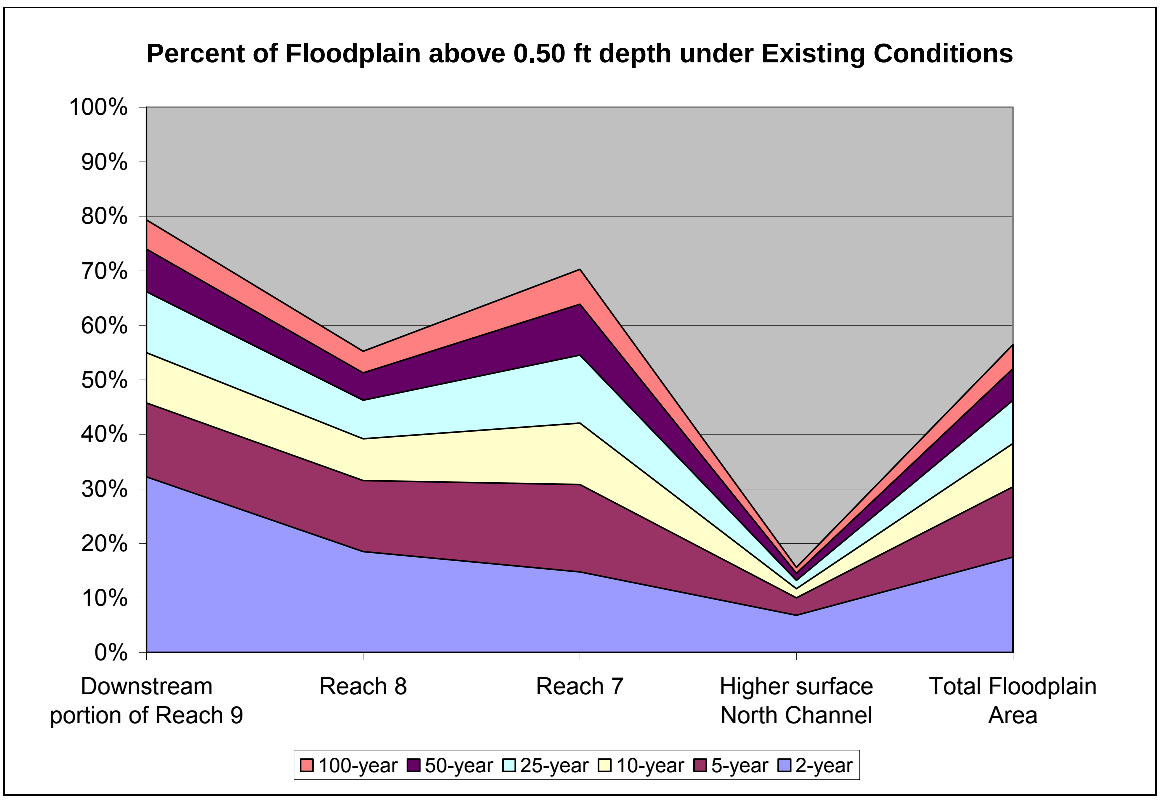

Figure 84 - Percent of floodplain area meeting criteria for connectivity for each reach under existing conditions.

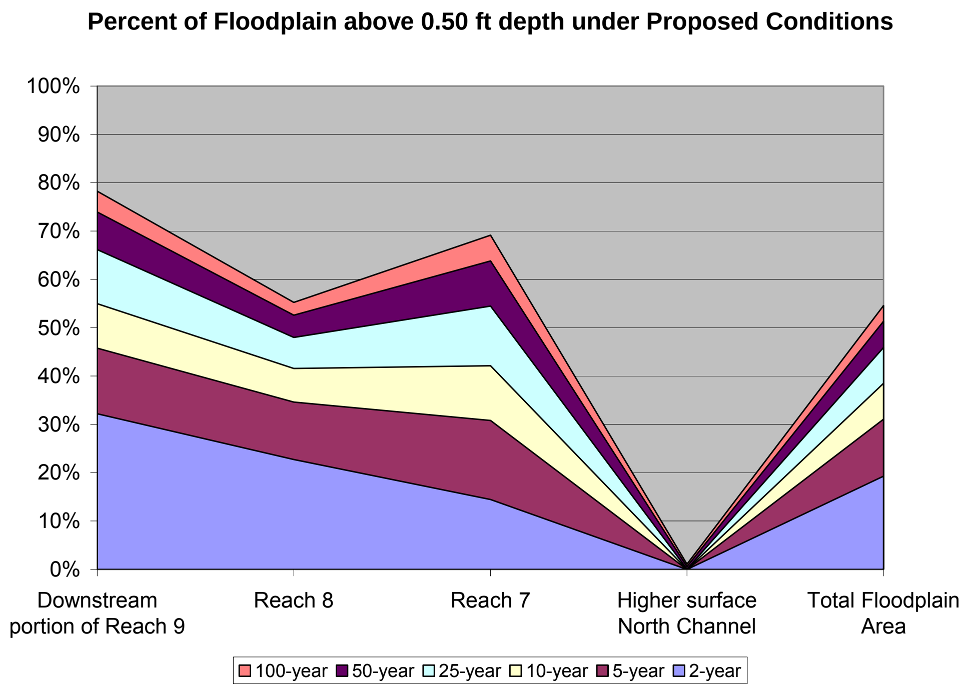

Figure 85 - Percent of floodplain area meeting criteria for connectivity for each reach with the proposed condition.

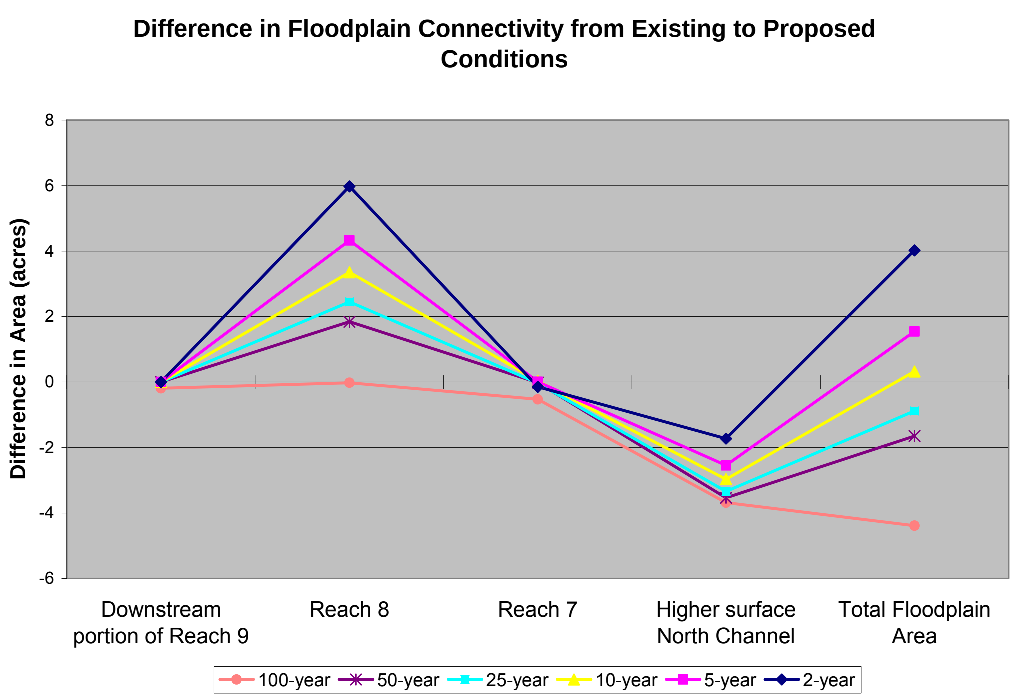

Figure 86 - Difference in the area of connected floodplain from the existing to the proposed scenario. A negative area indicates a loss in floodplain connectivity with the North Channel blocked.

5.2 Side Channel Connectivity

Since the floodplain is inundated in most reaches under the 2-year discharge, most side channels that are present in the study area appear connected under discharges of this magnitude. Several side channels are present in reach 9 where the channel bends sharply to the north upstream from the North-South Channel bifurcation (Figure 87 to Figure 89). While the 2-year peak discharge activates theses side channels, their connectivity under a 10-year peak discharge is much more pronounced. Additional analysis of the side channels would be necessary prior to any efforts to enhance their connectivity using the results of the 2D model because of the proximity of these side channels to the upstream boundary condition.

Several poorly defined side channels are present within reach 8 between the flow bifurcation and the North-South Channel confluence. Most of the overbank flow along the South Channel floodplain is not conveyed through well-defined side channels, but rather as overland flow or through very shallow swales. Side channels in reach 8 downstream of Ruby Creek that were present historically were modified drastically during the dredging operations of the 1940s. One channel that appears to have been the main low flow channel in the 1939 aerial photographs begins to convey flow at the 10-year discharge and is well connected at the 100-year discharge (Figure 90 and Figure 91). In addition, a portion of flow from Ruby Creek is intercepted by an irrigation ditch, which ultimately spills onto the floodplain and is conveyed through an existing shallow swale in the tailings along the left side of the floodplain (Figure 92).

Reach 7 is characterized by multiple secondary flow paths across the floodplain that are not well connected and do not convey substantial flow until a 10-year discharge is experienced. Flow depths in these secondary flow paths are generally less than 1 foot during a 2-year discharge and approach 2 feet during a 10-year discharge (Figure 92 and Figure 93).

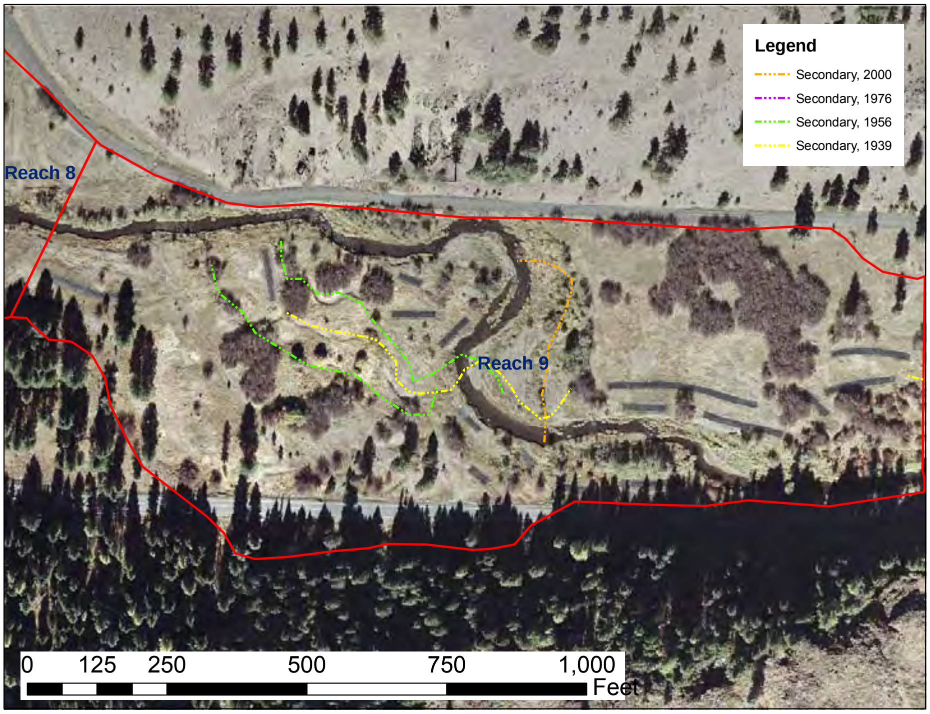

Figure 87 - Side channel mapped in the downstream section of reach 9 from *Tributary Assessment* (Reclamation 2008).

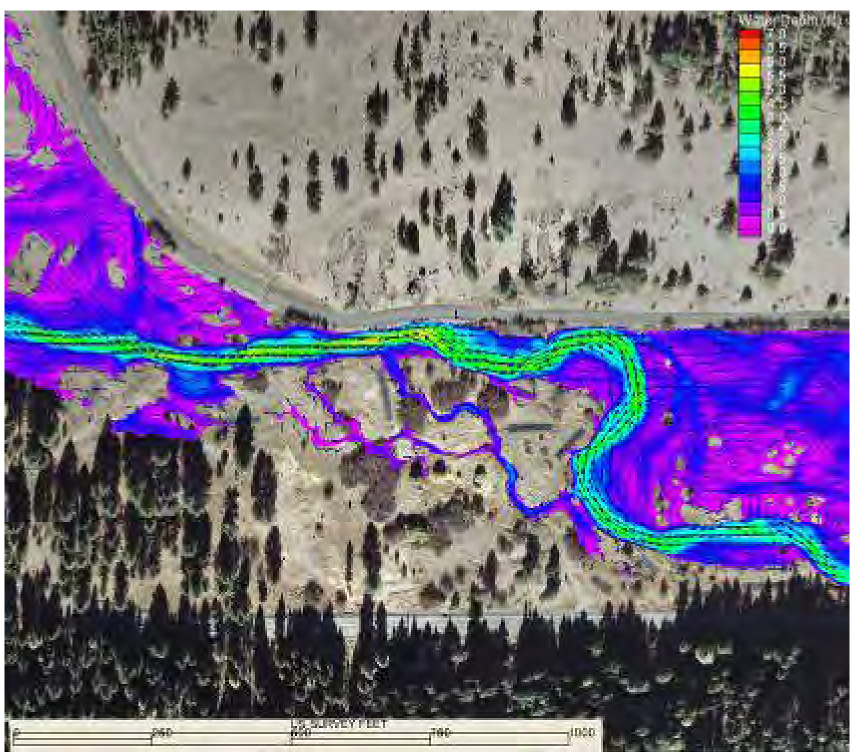

Figure 88 - Model results of side channels activated in reach 9 under a 2-year discharge.

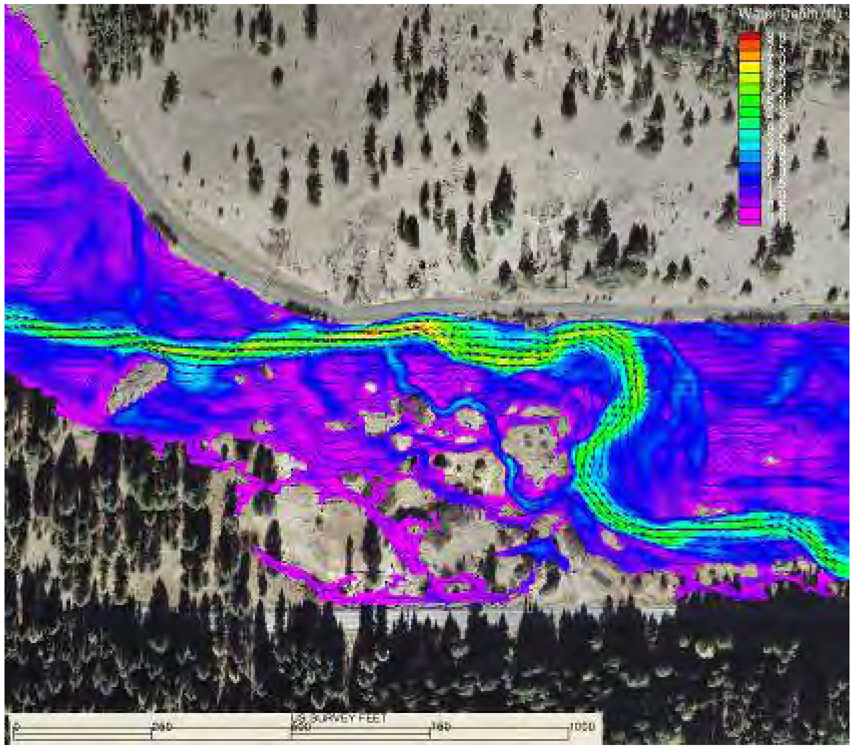

Figure 89 - Model results of side channels activated in reach 9 under a 10-year discharge.

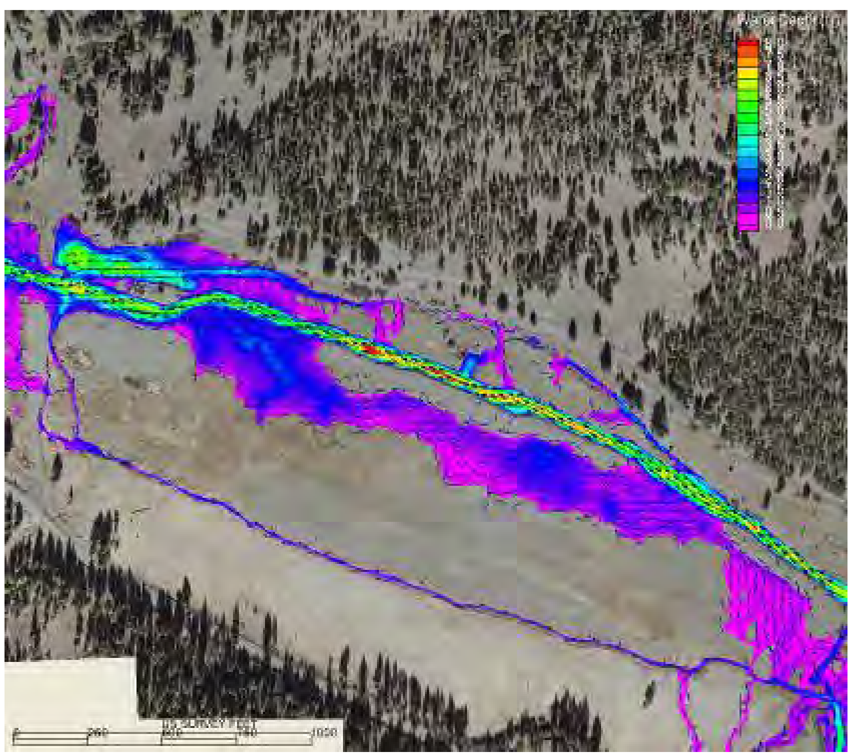

Figure 90 - Model results showing secondary flow paths present in reach 8 downstream of Ruby Creek confluence during a 10-year discharge.

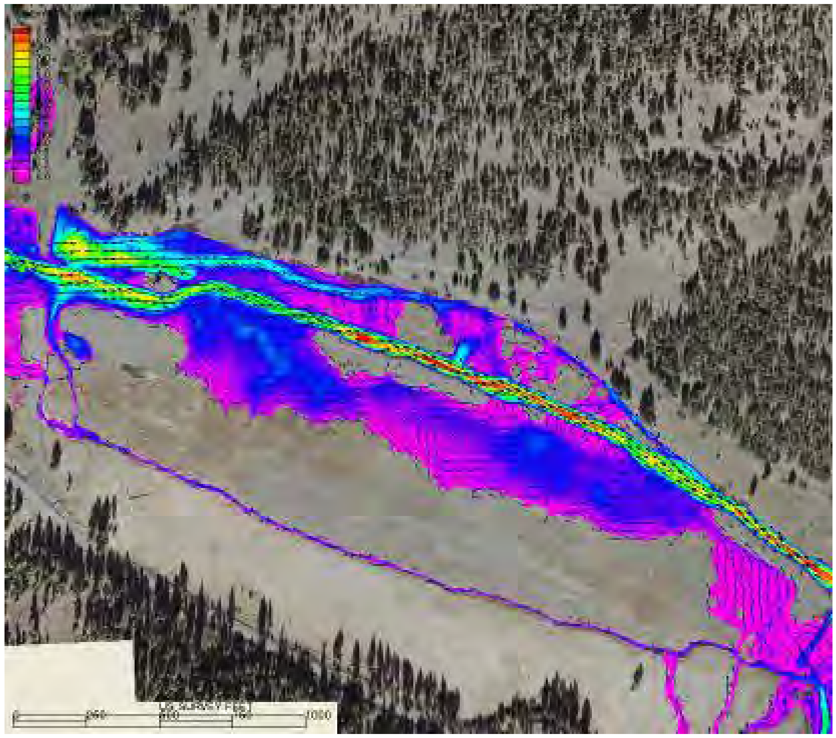

Figure 91 - Model results showing secondary flow paths present in reach 8 downstream of Ruby Creek confluence during a 100-year discharge.

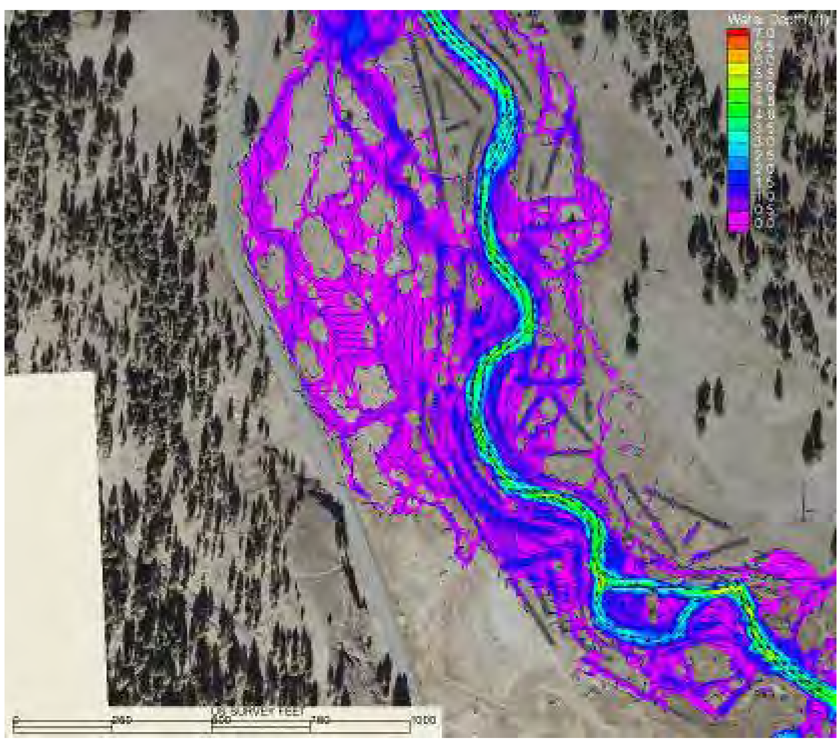

Figure 92 - Model results showing secondary flow paths present in reach 7 during a 2-year discharge.

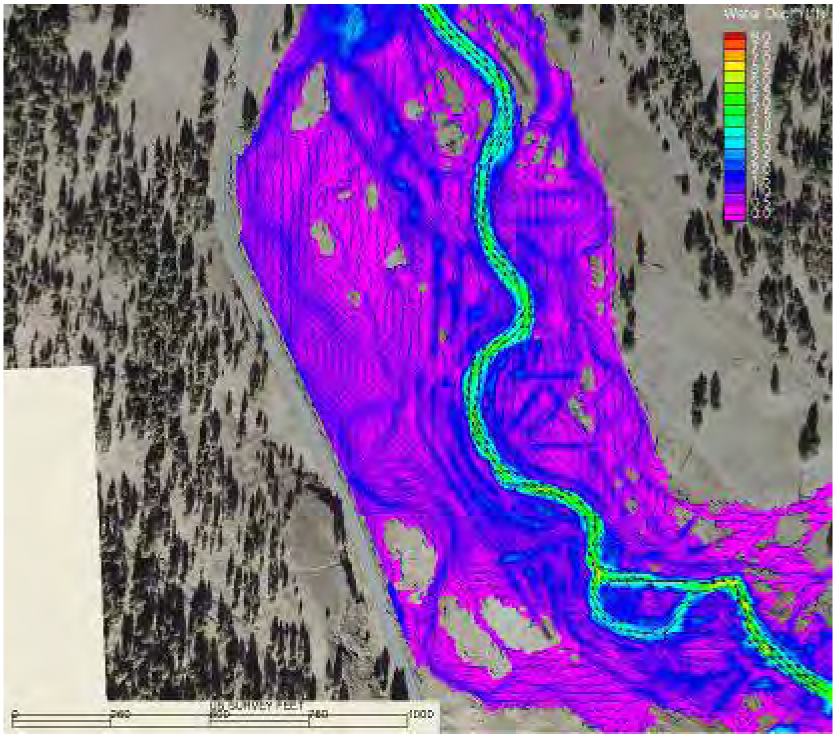

Figure 93 - Model results showing secondary flow paths present in reach 7 during a 10-year discharge.

5.3 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 feet per second. Areas meeting these criteria accounted for 10 to 17 percent of the total floodplain area under existing and proposed conditions depending on the discharge simulated. In comparing the floodplain area meeting the criteria in the existing and proposed conditions, changes were only noted between the flow bifurcation of the North Channel and South Channel and the confluence of Ruby Creek and the MFJDR. Figure 94 illustrates how the total floodplain area (in acres) meeting the criteria differs between the existing and proposed conditions. Figure 95 through Figure 97 demonstrate differences in the locations of high-flow habitat between existing and proposed conditions for the 2-, 10-, and 100-year peak discharges.

In general, by removing flow from the North Channel and adding it to the South Channel under proposed conditions, the high-quality high-flow habitat of the North Channel was reduced while the high-quality high-flow habitat of the South Channel increased. During the 2-year discharge, more high-quality high-flow habitat was predicted to occur in the proposed conditions simulation than in the existing conditions simulation. In other words, more high-flow habitat was gained on the South Channel floodplain than was lost in the North Channel. For flows exceeding the 2-year discharge, slightly more high-quality high-flow habitat was predicted under existing conditions than under proposed conditions (a maximum of 2.3 acres more in existing conditions during a 10-year discharge). These results of slightly more high-quality high-flow habitat were primarily due to the loss of habitat along the fringes of the North Channel under the proposed conditions simulation (when the North Channel is blocked in the proposed conditions simulation). In the development and design of potential options for habitat rehabilitation through the Oxbow Conservation Area, the potential for gains in high-quality high-flow habitat along the South Channel floodplain far outweighs the potential to develop this habitat in the North Channel for high flows of any magnitude. Locations of high-quality habitat under existing and proposed conditions throughout the study area are shown in Appendix E.

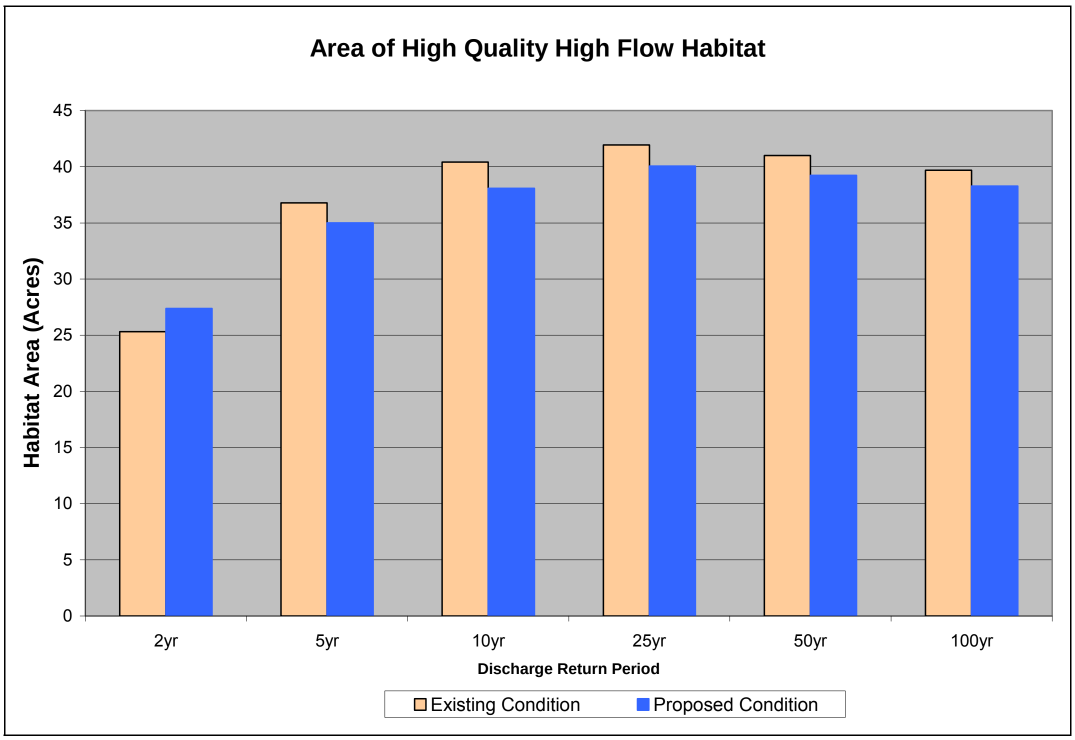

Figure 94 - Changes in the area (acres) of high-quality high-flow habitat for all flows evaluated.

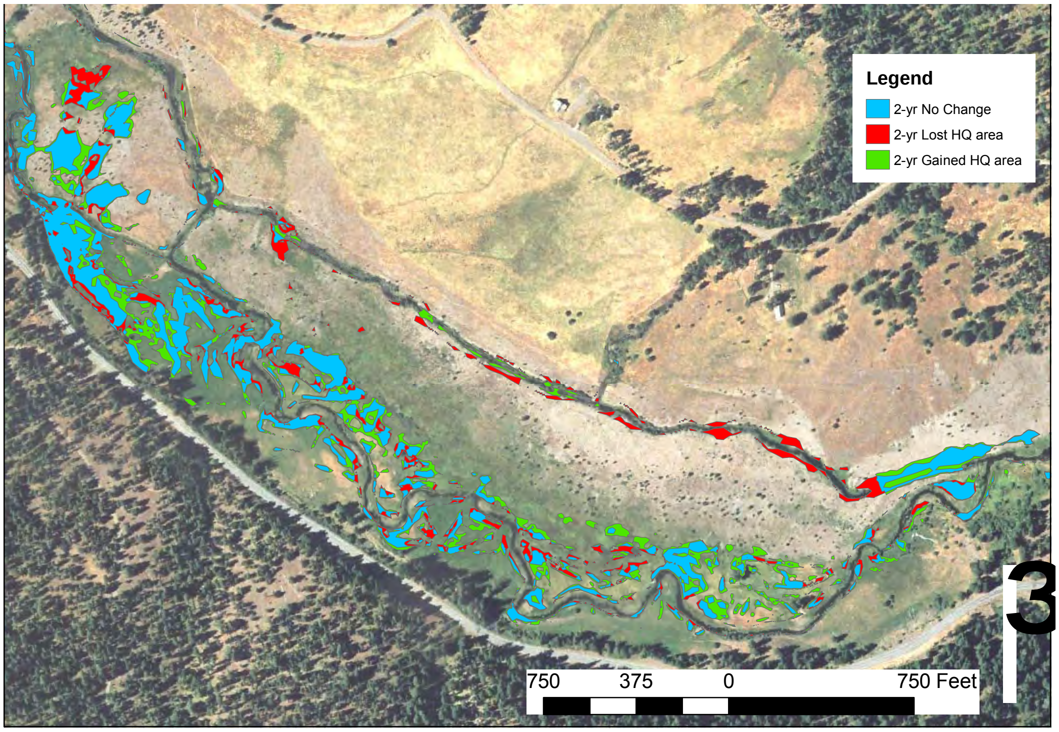

Figure 95 - Difference in high-quality high-flow habitat between existing and proposed conditions for a 2-year discharge.

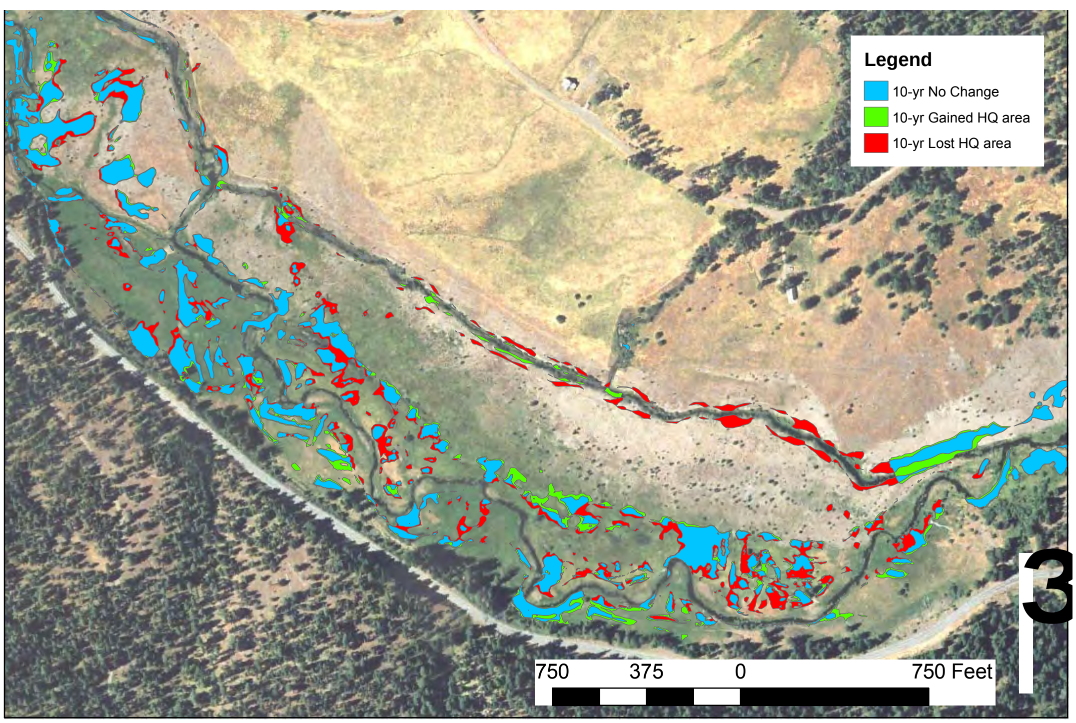

Figure 96 - Difference in high-quality high-flow habitat between existing and proposed conditions for a 10-year discharge.

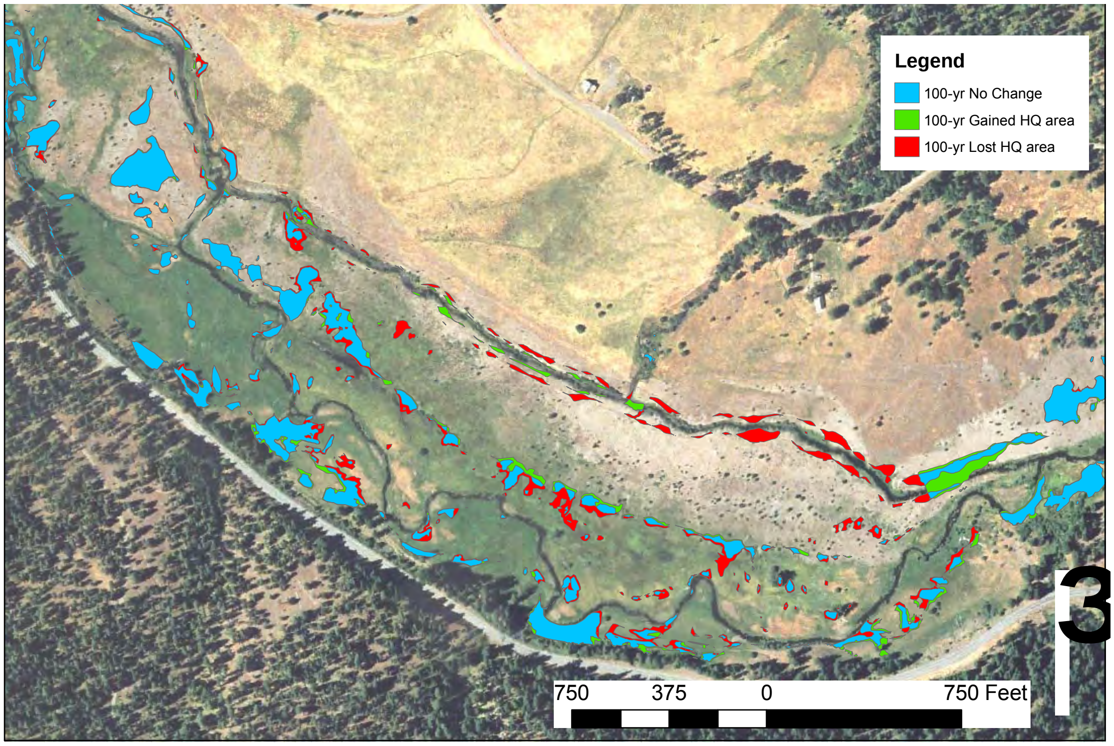

Figure 97 - Difference in high-quality high-flow habitat between existing and proposed conditions for a 100-year discharge.

5.4 Low Flow Habitat

Low-flow habitat is a primary concern in the Oxbow Conservation Area 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 Oxbow 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 and by investigating potential changes in South Channel depths through a 1D model.

5.4.1 Deep Pool Locations

Measured flow rates on the day of the survey (July 30, 2008) ranged between 22 cfs at the upstream end of the property to 31 cfs at the downstream end of the property. 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 Oxbow Conservation Area, 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 (Figure 98 to Figure 101).

Figure 100 illustrates that if the North Channel is blocked between the flow bifurcation and the mouth of Granite Boulder Creek, approximately 5 deep pools would be lost. By reducing flows through the North Channel, pool depths in the channel downstream from Granite Boulder Creek would likely be negatively influenced. Changes to the channel capacity of the North Channel downstream of the Granite Boulder Creek or modifications to the alignment of Granite Boulder Creek would mediate the negative impacts. This area has a high density of redds, which are related in part to the coarse gravel and cold water inputs from Granite Boulder Creek. Input from biologists is necessary to determine how changes to the alignment of Granite Boulder Creek would ultimately affect habitat quality. The sediment and flow inputs from Granite Boulder Creek, which substantially influence habitat quality, are not anticipated to change if the current channel alignment is modified or if complexity features are added to the current channel alignment. If Granite Boulder Creek is connected to the South Channel, it is anticipated that fish would preferentially spawn downstream of the new confluence similar to current spawning behavior at the current confluence with the North Channel. The design of the reconnection would need to ensure that the configuration of the South Channel supports the deposition of coarser sediment to form potential redd sites and that channel morphology and riparian development support thermal preservation and refugia.

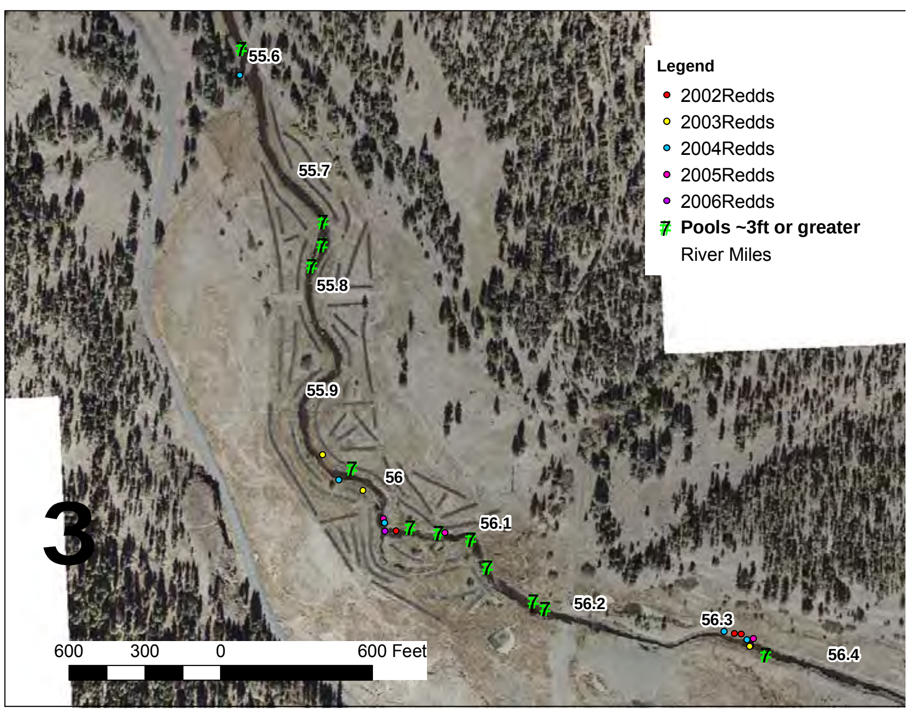

Figure 98 - Pools downstream from Beaver Creek identified by USFS as approximately 3 feet deep or deeper on July 30, 2008.

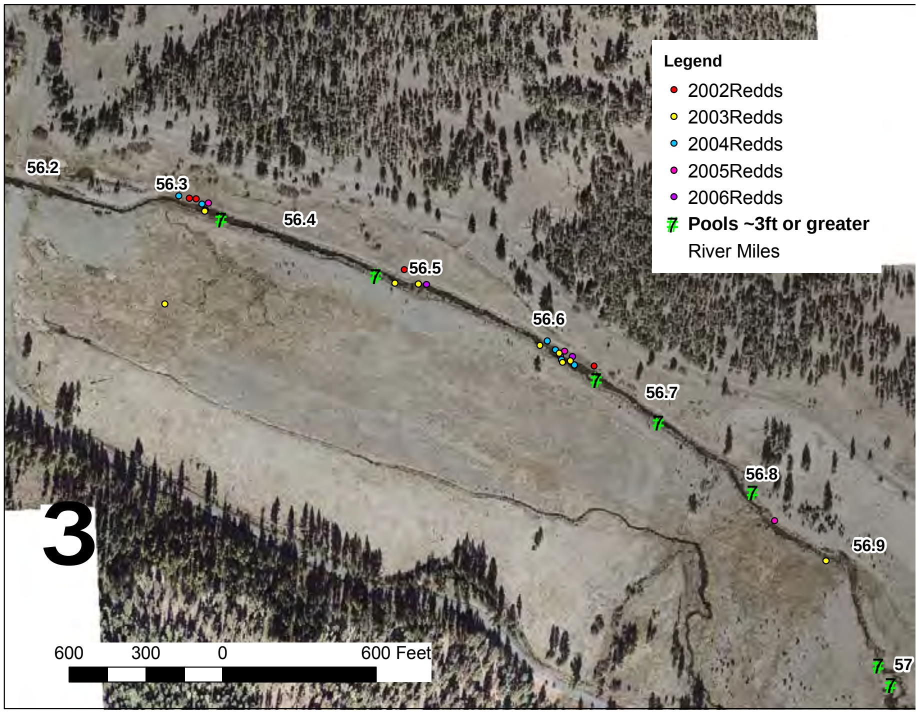

Figure 99 - Pools downstream from Ruby Creek identified by USFS as approximately 3 feet deep or deeper on July 30, 2008.

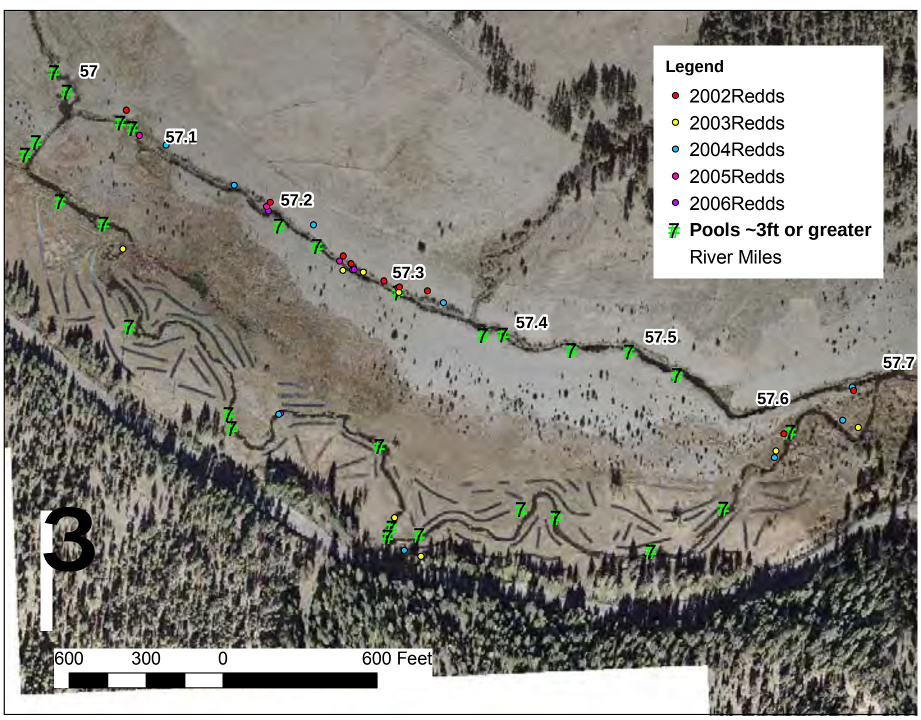

Figure 100 - Pools downstream from bifurcation of flow between North Channel and South Channel identified by USFS as approximately 3 feet deep or deeper on July 30, 2008.

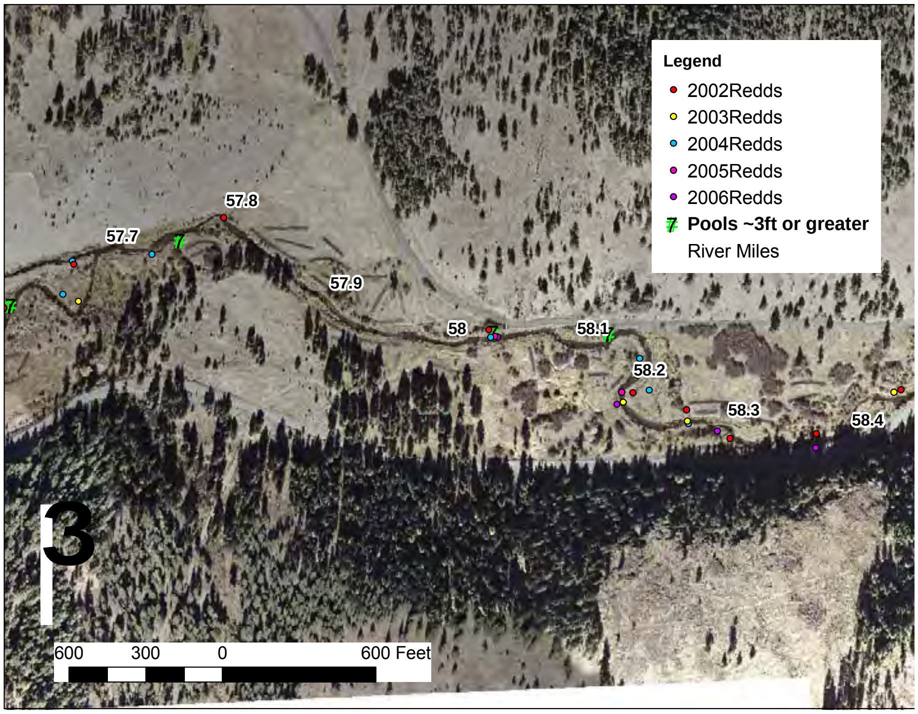

Figure 101 - Pools near upstream end of study area identified by USFS as approximately 3 feet deep or deeper on July 30, 2008.

5.4.2 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. Oregon Department of Fish and Wildlife spring Chinook redd data from 2002 to 2006 were plotted to evaluate the spatial distribution of redds identified in the study area. In the area of North Channel above the confluence of Granite Boulder Creek that conveys no flow under the proposed conditions, minimal redds were established between 2002 and 2006. Blocking the North Channel above Granite Boulder Creek would, however, lead to reduced flow in the North Channel downstream of Granite Boulder Creek if the tributary is not redirected to the South Channel. This area of the North Channel has a high density of redds which are related in part to the coarse gravel and cold water inputs from Granite Boulder Creek.

Input from biologists is necessary to determine how changes to the alignment of Granite Boulder Creek would ultimately affect habitat quality. The sediment and flow inputs from Granite Boulder Creek, which substantially influence habitat quality, are not anticipated to change if the current channel alignment is modified or if complexity features are added to the current channel alignment. If Granite Boulder Creek is connected to the South Channel, it is anticipated that fish would preferentially spawn downstream of the new confluence similar to the current spawning behavior at the current confluence with the North Channel.

5.4.3 1D Model

The 2D model used for this analysis was developed for high-flow analysis. Attempts were made to use the 2D model for base flows, but the in-channel topography proved to be insufficient to capture measured flow splits at the North-South Channel bifurcation for flows less than 30 cfs (Section 5.1). The 1D model developed for the *Tributary Assessment* was utilized to capture potential changes in channel depth within the South Channel. Although the 1D model was developed for evaluating high flows with most cross sections being located at hydraulic controls (e.g., riffles), the model provides a relative comparison of low flows and provides some indication of the expected changes in depths if all flows are routed through the South Channel. Results are based on 20 cross sections spaced between 200 to 300 feet apart. This analysis did not account for tributary flows from Granite Boulder or Butte Creeks. Attempts were made to use the 2D model for base flows, but because the 2D model used for this analysis was developed for high-flow analysis, the in-channel topography proved to be insufficient to capture measured flow splits at the North-South Channels bifurcation for flows less than 30 cfs (Section 5.1).

All results were calculated assuming subcritical flow. If no subcritical water surface elevation existed at a particular cross section, the model defaulted to the critical water surface elevation. Low flows were determined assuming 59 percent of flow is currently conveyed down the North Channel and the remaining 41 percent is conveyed through South Channel. These estimates were based on the average measured flow split for flows between 15 and 36 cfs. Simulations were run assuming incoming flows of 30 cfs and 60 cfs upstream of the flow bifurcation. In the first scenario, the 1D model was evaluated with South Channel flows at 17.7 cfs (41 percent of flow under existing conditions) and then at 30 cfs (100 percent of flow with North Channel blocked). The second scenario of 60 cfs incoming upstream of the bifurcation was simulated with South Channel flows at 35 cfs (41 percent of flow under existing conditions) and 60 cfs (100 percent of flow with North Channel blocked) to evaluate gains at a slightly higher than low flow conditions. Flows in the North Channel were not modeled.

When flows in the South Channel are increased from 17.7 cfs to 30 cfs, 1D model results indicated that the average hydraulic depth (flow area divided by top width) through the South Channel increases by 0.1 feet, a 25 percent increase from existing conditions, and maximum depth increased by 0.3 feet on average, a 26 percent increase from existing conditions. When flows in the South Channel were increased from 35 cfs to 60 cfs, model results indicated that the average hydraulic depth through the South Channel increased by 0.2 feet, a 25 percent increase from existing conditions, and maximum depth increased by 0.3 feet on average, a 24 percent increase from existing conditions. These increases in depths would typically occur during late summer to early fall and would benefit juvenile rearing and possibly adult holding of steelhead and holding, spawning, rearing, and egg incubation of spring Chinook (USDI 2000).

5.5 Linking Results of the Assessments to Rehabilitation Options

Currently, several rehabilitation options may be considered on the Oxbow Conservation Area. The first, as addressed in this report, is focused on blocking the North Channel and returning all of the stream flow into the South Channel. Due to conditions resulting from dredge mining in the area of the bifurcation, concerns have been raised as to potential impacts of increased depths, velocities, and shear stresses in the South Channel and along the channel bed, banks, and floodplain. Hydraulic modeling results suggest that these parameters will not substantially change from current conditions. Based on geomorphic characteristics of the river that are visible in the 1939 aerial photographs, it is evident that the proposal to block the North Channel would essentially return the river to a position in the valley that it occupied historically. While the current channel form appears to be quite similar to that of the river in 1939, data does not exist to allow comparison of the current channel geometry (i.e., channel widths and depths) relative to the geometry of the river in 1939.

For returning flows to the South Channel, the model shows increases in velocity, shear stress, and depth, but these increases are considered relatively minor as only sediment in the range of fine sand to coarse gravel can be mobilized. This condition does not support widespread floodplain scour or channel erosion as sediment will only be mobilized in local areas. Field observations made during high flows in 2008 suggest that the scour of the floodplain produced narrow shallow channels that should provide areas of shallower depth and slower velocity than in the main channel. Additionally, widespread deposition of sand on the floodplain adjacent to areas of scour was also observed. A dramatic change in the channel morphology of the South Channel is not expected as a result of blocking the North Channel given the character of the Granite Boulder Creek alluvium and current processes, which further alleviates recognized concerns. Due to the limited capacity of the North Channel during larger floods (about 400 cfs), the vast majority of flow is conveyed by the South Channel. In the more than 50 years since the dredge mining activities altered the floodplain, the MFJDR has experienced the flood of record (December 1964) and there has been no discernible adverse scouring of the floodplain or erosion of the channel.

An additional rehabilitation option under consideration is the reconnection of Granite Boulder Creek to the South Channel as a result of a channel reconfiguration. If reconnected, Granite Boulder Creek would serve as an important source of colder water inflow to the MFJDR, which could help mitigate high water temperatures not conducive to salmonids. Concerns with this reconnection are the potential loss of a surface flow connection due to the disruptions by mining activity in the grain size of the Granite Boulder Creek alluvium because much of the fine-grained sediment may have been winnowed out of the alluvium in the area between the confluence of Granite Boulder Creek with the North Channel and the South Channel floodplain. Geomorphic evidence suggests that loss of the surface connection would not be expected due to these three factors:

4) The current course of Granite Boulder Creek flows across tailings for a distance of almost 400 feet and through the North Channel for a distance of more than 2,800 feet with no recognizable loss in surface flow.

5) Sediment data collected from four test pits excavated in tailings downstream of Ruby Creek do not appear to be dramatically different from material in the area between the North and South Channels.

6) Ponding of water on the floodplain in the area between the North and South Channels and cooler water temperatures in both the North and South Channels determined by the TIR survey strongly suggest that there is a groundwater link with Granite Boulder Creek and that groundwater is relatively high year-round.

In additional to rehabilitation options discussed previously, several more potential rehabilitation actions have been listed for consideration in Section 6 based on the results of the hydraulic modeling and geomorphic conditions. Results from the geomorphic analysis would continue to be evaluated in conjunction with the 2D model and used as tools to investigate additional rehabilitation actions and subsequent results on habitat.

Chapter 6 POTENTIAL OPTIONS

Based on this hydraulic and geomorphic analysis, several general design concepts can be discussed to address habitat complexity for fish species. The following potential options are presented for discussion during the selection process of one or more options for consideration in the Alternatives Evaluation Report (AER). References to stream segments (SS) in the following potential options conceptual descriptions are found on Figure 102.

All potential options assume some level of installed large woody debris or other habitat complexity structures and varying degrees of revegetation. For discussion purposes, funding is described as minimal, average, or extensive. Minimal construction costs would likely be less than $100,000; average costs are estimated between $100,000 and $200,000; and extensive costs are greater than $200,000. Once a potential option is selected for further analysis, these values would be updated through a more rigorous cost estimation procedure.

To construct a project in 2010, it is assumed the option is selected by February 2009 and the final design is completed by the end of calendar year 2010. In addition to plans and specifications, it is assumed that any permitting or environmental documents required for the construction of the effort could be completed in time for 2010 construction. It is also assumed that funding is secured and contractors are available for mobilization.

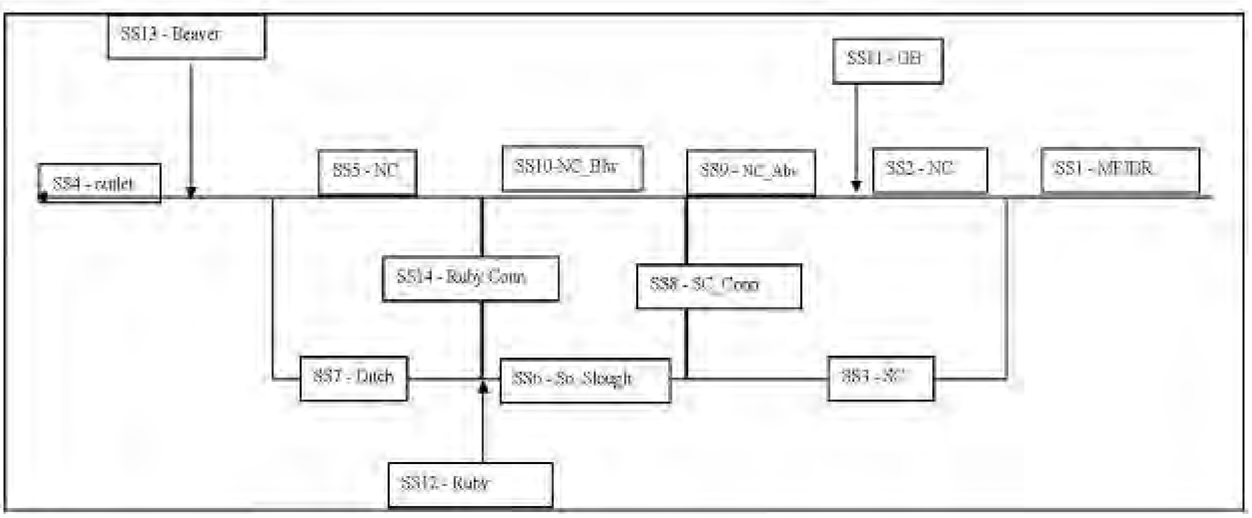

Figure 102 – Numerical schematic of Oxbow reach channel segments.

6.1 Potential Option 1

No action	
Description:	This option requires no action
Potential Issues:	None
Additional data required:	None
Hydraulic Modeling:	None
Geomorphic Analysis:	None
Biological Benefits:	None.
Considerations:	None
Funding:	None
Construct in 2010?	Not applicable

6.2 Potential Option 2

Block the North-South Channel bifurcation upstream of the confluence of the North Channel and Granite Boulder	
Description:	Potential Option 2 represents the proposed conditions in this hydraulic and geomorphic analysis. It includes blocking the North Channel with a plug or similar structure just downstream of the North-South Channels bifurcation and upstream of the confluence of Granite Boulder Creek and the North Channel (SS2). The connection between Granite Boulder Creek and the North Channel (SS9) is maintained. All other flow patterns are maintained.
Potential Issues:	Removing main channel flow that is currently conveyed through SS2 will reduce sediment transport capacity of SS9. This will have to be addressed.

Block the North-South Channel bifurcation upstream of the confluence of the North Channel and Granite Boulder	
Additional data required:	May need to update bathymetric survey in North Channel (SS9) depending on the level of design required.
Hydraulic Modeling:	Conduct 1D modeling to evaluate SS9 capacity requirements.
Geomorphic Analysis:	Evaluate impact to channel geomorphology, sediment load from Granite Boulder Creek.
Biological Benefits:	1) Increased flow to the South Channel during low flow conditions would help reduce instream temperatures, increase in-channel depths; 2) SS9 channel capacity reduction could incorporate woody debris and other in-channel complexity required for improved salmonid habitat.
Considerations:	1) Design the location and type of plug (large woody debris, clay, riprap, or a combination; 2) Determine if all or part of the SS2 is filled; 3) Reduce the channel capacity of SS9 to maintain sediment transport.
Funding:	Average to extensive.
Construct in 2010?	Yes.

6.3 Potential Option 3

Block the North Channel downstream of the North-South Channel bifurcation to upstream of the North-South Channel confluence and reconnect Granite Boulder Creek with the South Channel	
Description:	Reconnect Granite Boulder Creek with the South Channel at or near its original location in the 1939 photo. This option most closely corresponds to the pre-disturbed geomorphic conditions as evidence of this connection existed in the 1939 photos. This proposal would also involve blocking SS2 and SS9.
Potential Issues:	Ensuring groundwater connection between the North Channel and the South Channel is maintained; 2) Ensure sediment transport processes considered at the new confluence of Granite Boulder Creek and the South Channel and throughout the downstream segment of the South Channel (SS3).
Additional data required:	1) Piezometer data to evaluate the groundwater patterns (potentially could install new piezometers following reconnection to monitor changes in groundwater table post-construction); 2) Potentially updated survey depending on level of design.
Hydraulic Modeling:	Update the 2D model or construct 1D model to remove all the flow from the North Channel and add Granite Boulder Flow to the South Channel. Evaluate hydraulic parameters and potential impacts to channel stability.
Geomorphic Analysis:	Evaluate impact to channel geomorphology, sediment load from Granite Boulder Creek.
Biological Benefits:	Increased flow to the South Channel during low flow conditions would help reduce in-stream temperatures, increase in-channel depths.
Considerations:	1) Design the location and type of plug (large woody debris, clay, riprap, or a combination of materials; 2) Determine if all or part of the SS2 and SS9 are filled; 3) Design new Granite Boulder Creek stream segment between existing mouth and reconnection point.

Block the North Channel downstream of the North-South Channel bifurcation to upstream of the North-South Channel confluence and reconnect Granite Boulder Creek with the South Channel	
Funding:	Average to extensive depending on the level of design required and the results of the technical analyses.
Construct in 2010?	Yes.

6.4 Potential Option 4

Potential Option 2 with new channel construction between SS5 and SS7	
Description:	This potential option maintains Granite Boulder Creek's connection with the North Channel, partially or entirely fills SS2, and constructs a new main channel through the floodplain between SS7 and SS5. Remainder of flow patterns generally maintained.
Potential Issues:	Ensuring groundwater connection between the North Channel and the South Channel is maintained.
Additional data required:	1) Piezometer data to evaluate the groundwater patterns; 2) Updated survey data in critical areas (e.g., where old and new channel connections may occur).
Hydraulic Modeling:	Evaluate hydraulic parameters and potential impacts to channel stability. Construct a 1D model to evaluate the new channel SS5 or consider constructing a 2D model of typical desired habitat feature conditions (e.g., construct a typical pool-riffle sequence in 2D model and infer results to balance of project area and determine if pool-riffle sequence is sustainable).
Geomorphic Analysis:	Evaluate impact to channel geomorphology, sediment load from Granite Boulder Creek, sediment load through new channel.
Biological Benefits:	Increased flow to the South Channel during low flow conditions would help reduce in-stream temperatures, increase in-channel depths.

Potential Option 2 with new channel construction between SS5 and SS7	
Considerations:	1) Design the location and type of plug (large woody debris, clay, riprap or a combination; 2) Determine if all or part of the SS2 is filled; evaluate morphology, habitat features, and design new channel segment 5; 3) likely establish a multi-disciplined design subcommittee to review and comment on design options for the Interdisciplinary Team to discuss.
Funding:	Extensive
Construct in 2010?	This potential option would likely be phased due to funding considerations. If funding is available, it is possible to construct entire project in 2010.

6.5 Potential Option 5

Potential Option 3 with new channel construction between SS5 and SS7	
Description:	This potential option reconnects Granite Boulder Creek with the South Channel at its original location in the 1939 photo, partially or entirely fills SS2 and SS9, and constructs a new channel through the floodplain between SS7 and SS5. Remainder of flow patterns generally maintained.
Potential Issues:	Ensuring groundwater connection is maintained or enhanced.
Additional data required:	Piezometer data in this area to evaluate the groundwater patterns.
Hydraulic Modeling:	Update the 2D model to remove all the flow from the North Channel and add Granite Boulder Flow to the South Channel. Evaluate hydraulic parameters and potential impacts to channel stability. Possibly construct a 1D model to evaluate the new channel SS5 or consider constructing a 2D model of typical desired habitat feature conditions.

Potential Option 3 with new channel construction between SS5 and SS7	
Geomorphic Analysis:	Evaluate impact to channel geomorphology, sediment load from Granite Boulder Creek, sediment load through new channel.
Biological Benefits:	Increased flow to the South Channel during low flow conditions would help reduce in-stream temperatures, increase in-channel depths.
Considerations:	1) Design the location and type of plug (large woody debris, clay, riprap, or a combination; 2) Determine if all or part of the SS2 and 9 are filled; 3) Likely establish a multidisciplinary design subcommittee to review and comment on design options for the full committee to discuss.
Funding:	Extensive
Construct in 2010?	This potential option would likely be phased due to funding considerations. If funding is available, it is possible to construct entire project in 2010.

6.6 Potential Option 6

Potential Option 3 with SS8 blocked and flow to SS3 to SS6 to SS14 and reconstructed SS5	
Description:	This potential option reconnects Granite Boulder Creek with the South Channel at its original location in the 1939 photo and partially or entirely fills SS2, SS9, and SS8. Flow is conveyed through the South Channel, the South Slough, and through a newly constructed channel on the floodplain between SS7 and SS5.
Potential Issues:	Ensuring groundwater connection is maintained or enhanced.
Additional data required:	Piezometer data to evaluate the groundwater patterns; 2) Possibly bathymetric survey at new channel connections.

Potential Option 3 with SS8 blocked and flow to SS3 to SS6 to SS14 and reconstructed SS5	
Hydraulic Modeling:	1) Update the 2D model and/or construct a 1D model to remove all the flow from the North Channel and add Granite Boulder Flow to the South Channel; evaluate conveyance capacities of all channels and identify necessary modifications; evaluate new channel design, 2) Evaluate hydraulic parameters and potential impacts to channel stability.
Geomorphic Analysis:	Evaluate impact to channel geomorphology, sediment load from Granite Boulder Creek, and sediment load through new or modified channel(s).
Biological Benefits:	Increased flow to the South Channel during low flow conditions would help reduce in-stream temperatures; increase in-channel depths.
Considerations:	1) Design the location and type of plug (large woody debris, clay, riprap or a combination; 2) Determine if all or part of the SS2 and 9 are filled; 3) design new Granite Boulder stream segment between existing mouth and reconnection point; 4) new channel capacity of south slough (SS6) would need to be determined; 5) connection of new flow through SS7 or SS14 would need to be considered; 6) likely establish a multidisciplinary design subcommittee to review and comment on design options for the full committee to discuss.
Funding:	Extensive
Construct in 2010?	This potential option would likely be phased due to funding considerations. If funding is available and decision to pursue option made early in AER process, it may possible to construct entire project in 2010.

6.7 Potential Option 7

Lower tailings piles	
Description:	This potential option lowers the adjacent floodplain of SS9, SS10, and SS5.
Potential Issues:	1) Determine where to temporarily store the dredge material until it can be used on site or trucked to an off-site location; 2) If trucked to an off-site location, this could be expensive.
Additional data required:	None
Hydraulic Modeling:	Conduct 1D modeling to evaluate hydraulic parameters and determine overbank elevation and impacts to channel stability.
Geomorphic Analysis:	Evaluate impact to channel geomorphology, sediment load from Granite Boulder Creek.
Biological Benefits:	Increased floodplain connectivity.
Considerations:	Determine extent of overbank area and elevation to be constructed.
Funding:	Average to extensive
Construct in 2010?	Yes

6.8 Potential Option 8

Lower inlet elevations of side channels	
Description:	This potential option evaluates side channels throughout the extent of the study area in the existing condition.
Potential Issues:	1) Design should evaluate self-sustaining connections; 2) Removing flow from the main channel during base flows and adding to the side channel may exacerbate existing high channel temperature issues; under high flows, potential stranding issues may need to be addressed; 3) Because the upstream boundary condition of the existing 2D model affects the hydraulics of the most upstream side channel, the model boundary would need to moved upstream prior to consideration of any modifications to this area.
Additional data required:	Side channel entrance survey update.
Hydraulic Modeling:	Update the 2D model to evaluate hydraulic parameters and potential impacts of selected side channel connections.
Geomorphic Analysis:	Evaluate impact to channel geomorphology
Biological Benefits:	1) Creation of high flow refugia; 2) Increased channel complexity.
Considerations:	1) Determine design flow that each side channel is to be accessed; 2) Likely establish a multidisciplinary design subcommittee to review and comment on design options for the full committee to discuss.
Funding:	Average to extensive depending on number of side channels considered.
Construct in 2010?	Yes

LIST OF PREPARERS

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Rob Hilldale, M.S., P.E.	Bureau of Reclamation Technical Service Center Denver, Colorado	Hydraulic Peer Review
Lucy Piety	Bureau of Reclamation Technical Service Center Denver, Colorado	Geomorphology Peer Review

Chapter 7 LITERATURE CITED

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Parenthetical Reference	Bibliographic Citation
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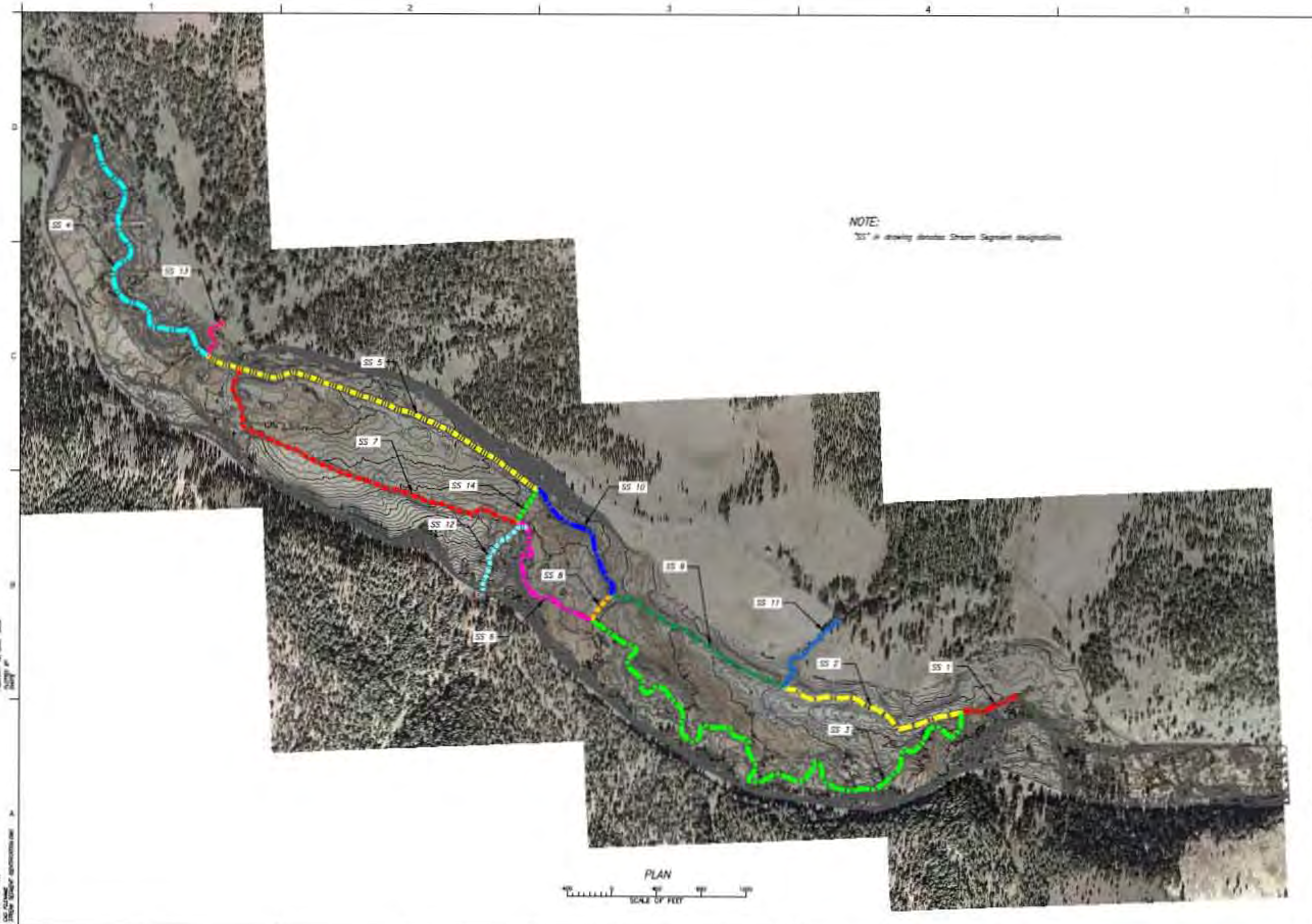
Chapter 8 APPENDICES

APPENDIX A - SURFICIAL GEOLOGIC MAPPING



RECLAMATION

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MIDDLE FORK

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STREAM SEGMENT IDENTIFICATION PLAN

1678-100-XXXX

RECLAMATION
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DESCRIPTION:

Potential Option 2 was the proposed conditions in this hydraulic and geomorphic analysis. It includes blocking the North Channel (NC) with a plug or similar just downstream of the North–South Channel bifurcation and upstream of the confluence of Granite Boulder Creek and the NC (SS2). The connection between Granite Boulder Creek and the NC (SS9) is maintained. All other flow patterns are maintained.

PLAN
POTENTIAL OPTION 2

400 0 400 800 1200
SCALE OF FEET

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MIDDLE FORK
POTENTIAL OPTION 2

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TECH. APPR.
APPROVED

BOISE, ID 2008-01-28

POTENTIAL OPTION 2 PLAN

1678–100–XXXX

SHEET 2 OF 15

RECLAMATION
Managing Water in the West

DESCRIPTION:

Reconnect Granite Boulder Creek with the South Channel (SC) at or near its original location in the 1939 photo. This option is the preferred geomorphic alternative as evidence of this connection existed in the 1939 photos. This proposal would also involve blocking Stream Segment 2 (SS2) and SS9.

PLAN
POTENTIAL OPTION 3

SCALE OF FEET: 400 0 400 800 1200

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OXBOW
POTENTIAL OPTION 3
PLAN

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TECH. APPR. ________ NAME – TITLE
APPROVED ________ ADMINISTRATIVE APPROVAL – NAME – TITLE
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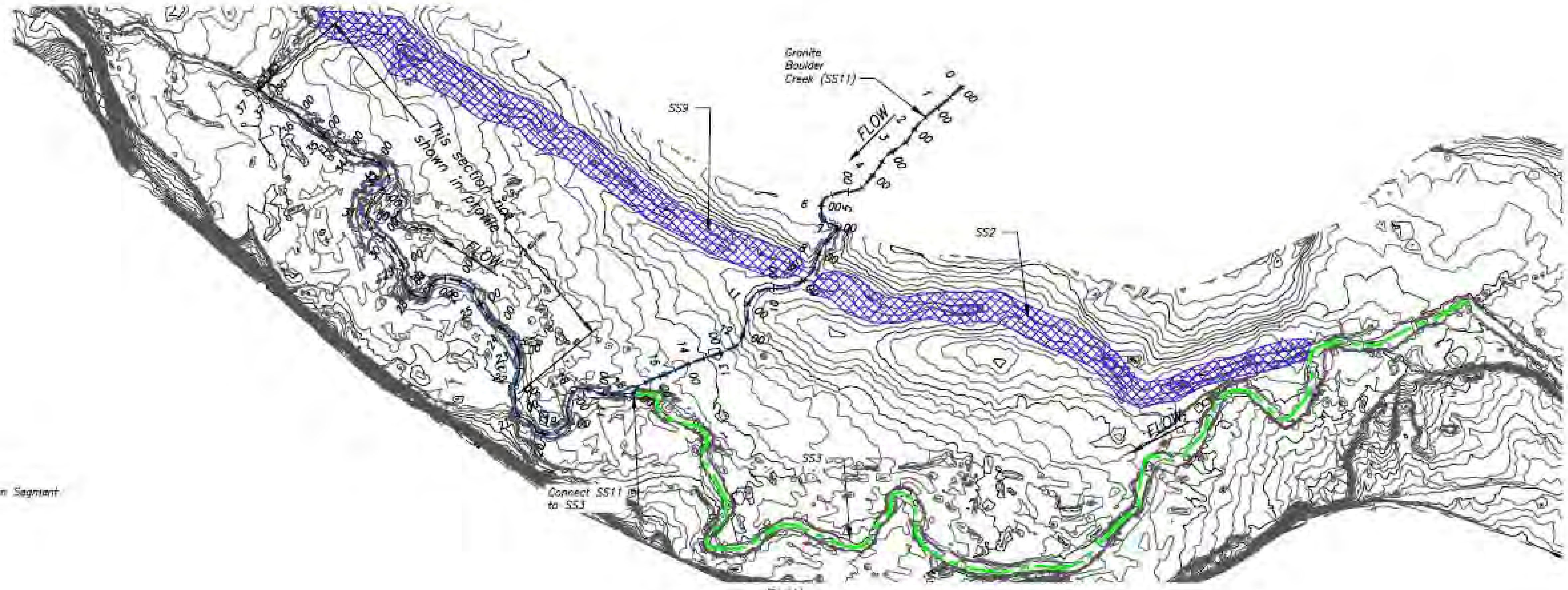
POTENTIAL OPTION 3 PLAN

1678-100-XXXX

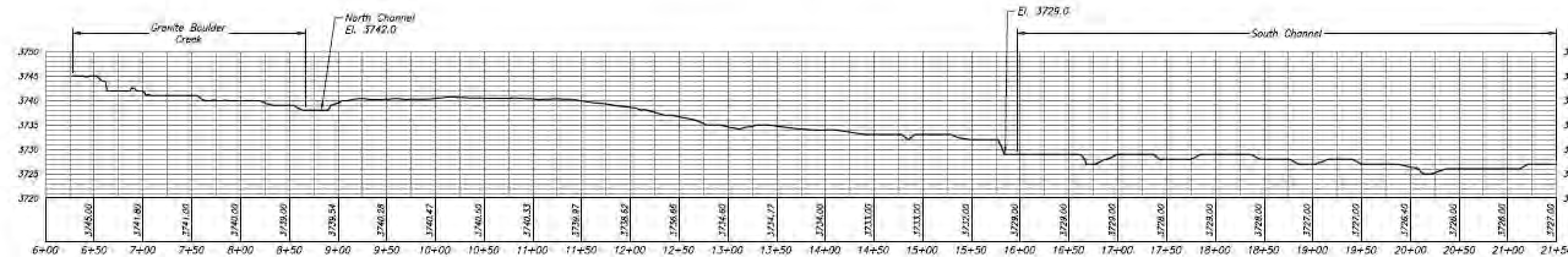
SHEET 3 OF 15



NOTE:
SS = Stream Segment

PLAN

SCALE OF FEET



PROFILE

SCALE OF FEET
5:1 Vertical Exaggeration

POTENTIAL OPTION 3

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POTENTIAL OPTION 3
PLAN AND PROFILE

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POTENTIAL
OPTION 3
PLAN AND PROFILE

1678-100-XXXX

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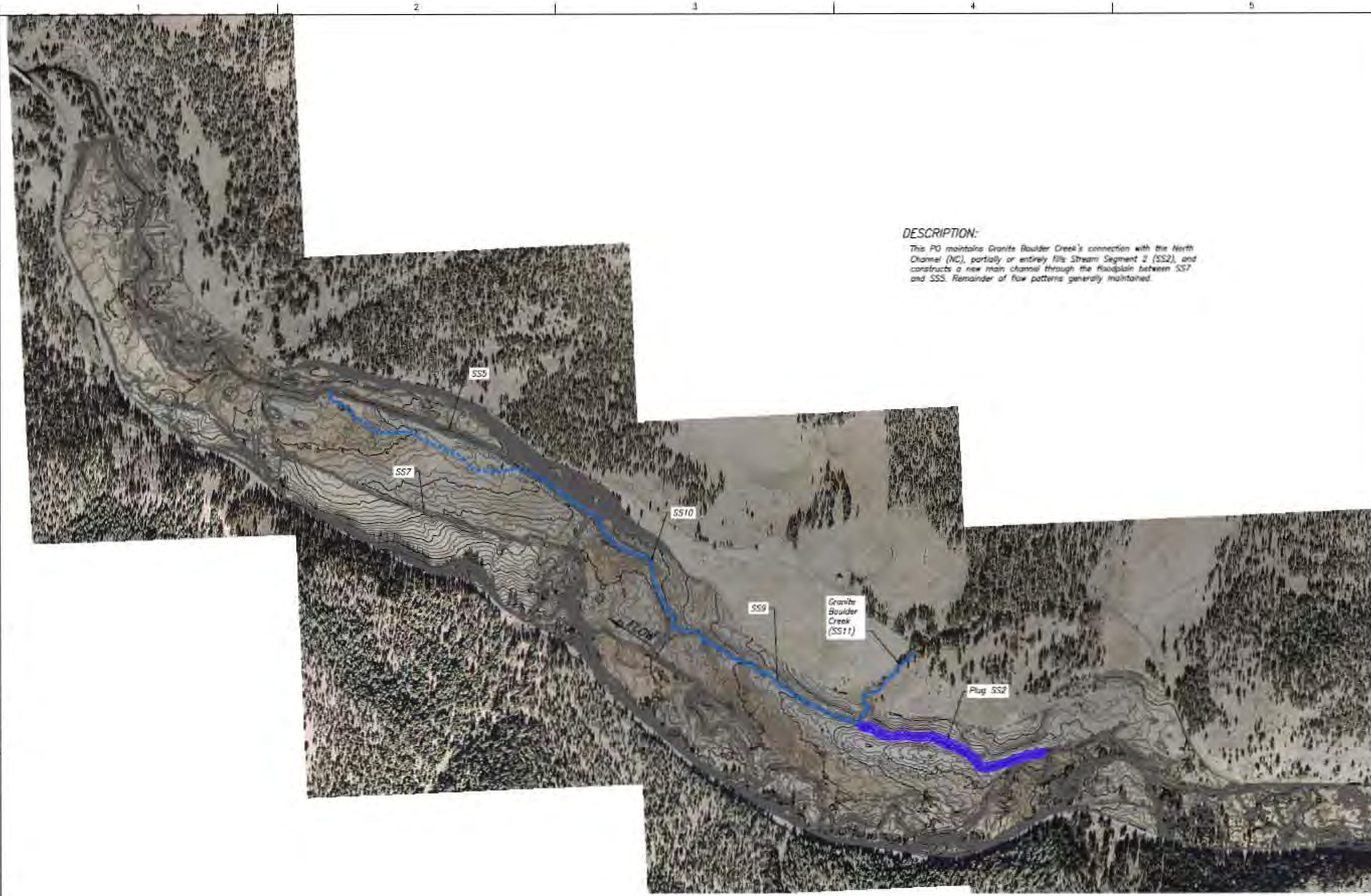

DESCRIPTION:

This PO maintains Granite Boulder Creek's connection with the North Channel (NC), partially or entirely fills Stream Segment 2 (SS2), and constructs a new main channel through the floodplain between SS7 and SS5. Remainder of flow patterns generally maintained.

PLAN
POTENTIAL OPTION 4

SCALE OF FEET

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POTENTIAL OPTION 4

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POTENTIAL OPTION 4 PLAN

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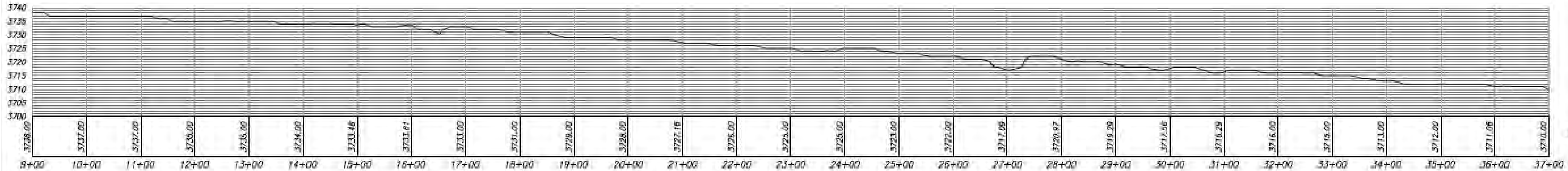
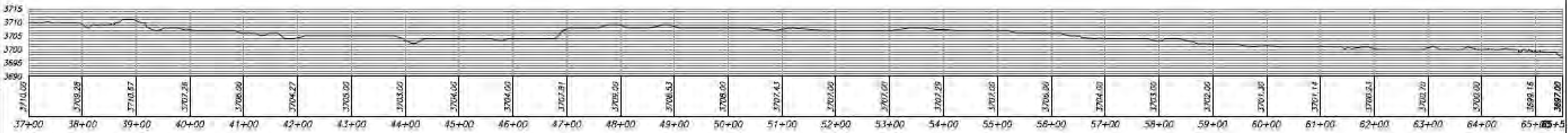
RECLAMATION
Managing Water in the West

PLAN

200 0 200 400 600
SCALE OF FEET





PROFILE

100 0 100 200 300
SCALE OF FEET

POTENTIAL OPTION 4

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POTENTIAL OPTION 4
PLAN AND PROFILE

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POTENTIAL
OPTION 4
PLAN AND PROFILE

1678–100–XXXX

RECLAMATION
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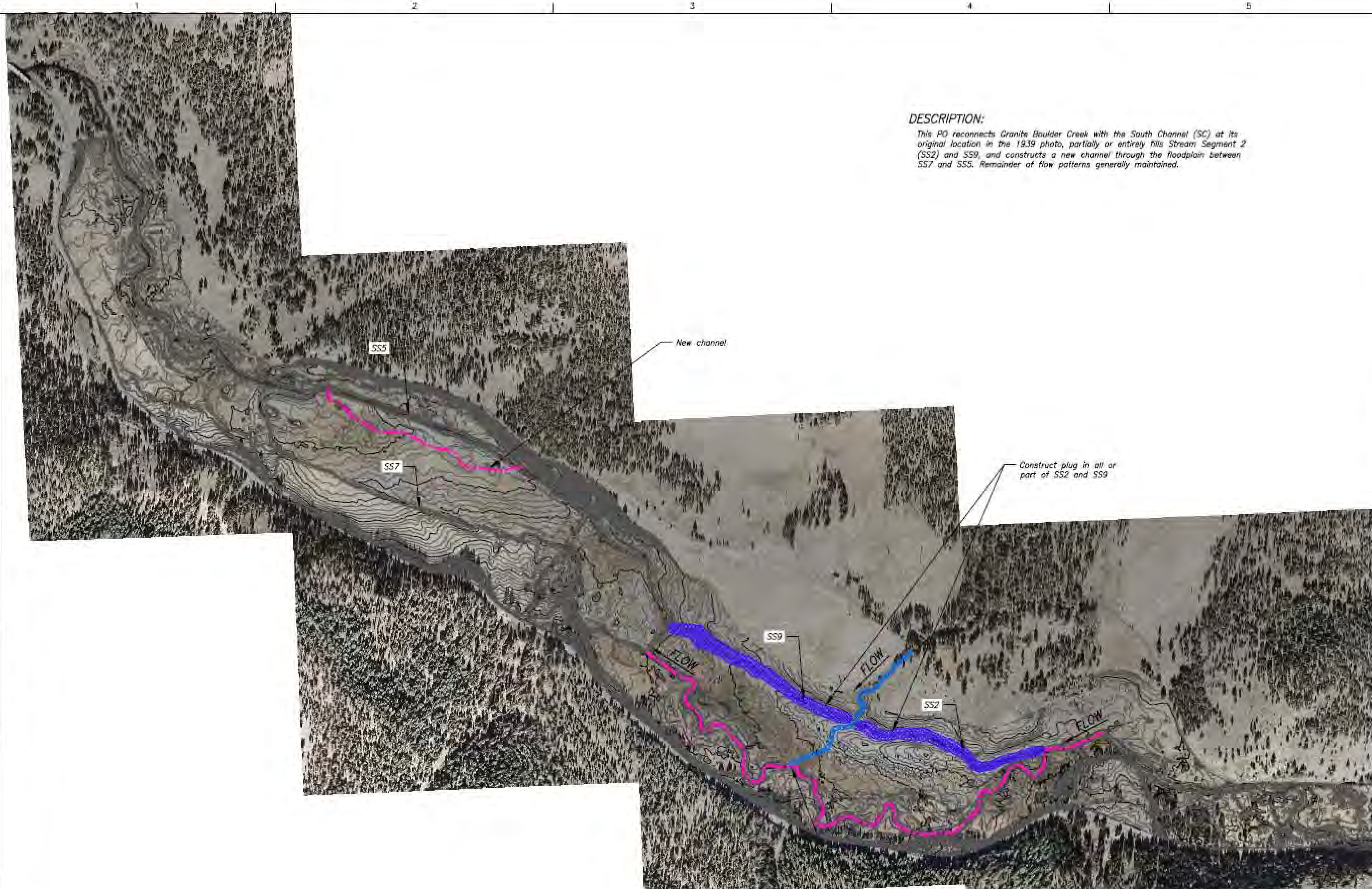
DESCRIPTION:

This PO reconnects Granite Boulder Creek with the South Channel (SC) at its original location in the 1939 photo, partially or entirely fills Stream Segment 2 (SS2) and SS9, and constructs a new channel through the floodplain between SS7 and SS5. Remainder of flow patterns generally maintained.



PLAN
POTENTIAL OPTION 5

400 0 400 800 1200
SCALE OF FEET

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POTENTIAL OPTION 5

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POTENTIAL OPTION 5 PLAN

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SHEET 7 OF 15

RECLAMATION
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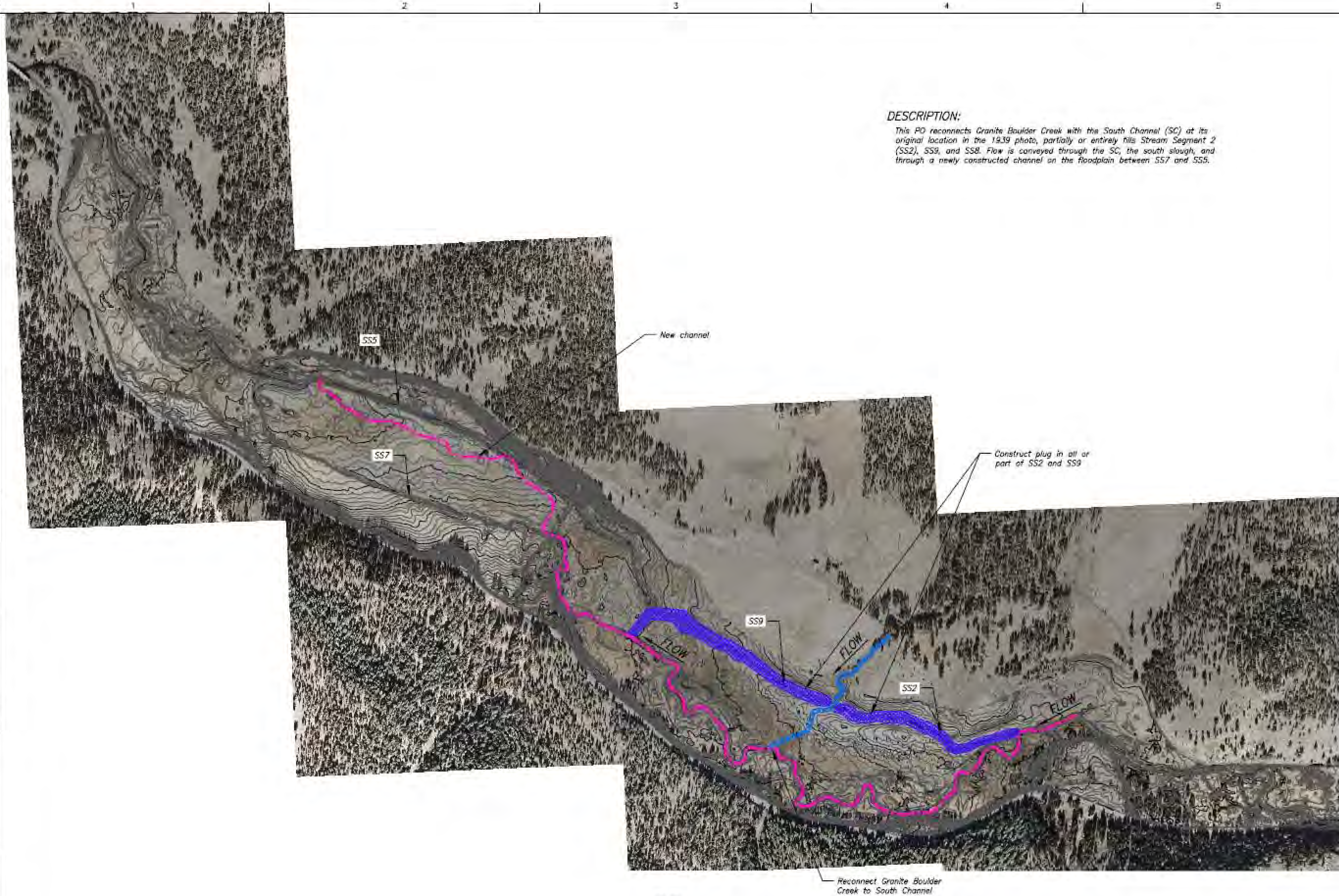
DESCRIPTION:

This PO reconnects Granite Boulder Creek with the South Channel (SC) at its original location in the 1939 photo, partially or entirely fills Stream Segment 2 (SS2), SS9, and SS8. Flow is conveyed through the SC, the south slough, and through a newly constructed channel on the floodplain between SS7 and SS5.



PLAN
POTENTIAL OPTION 6

400 0 400 800 1200
SCALE OF FEET

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JOHN DAY SUBBASIN
MIDDLE FORK
OREGON
POTENTIAL OPTION 6

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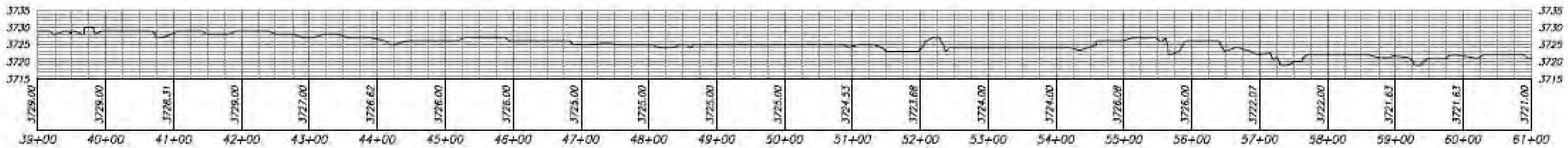
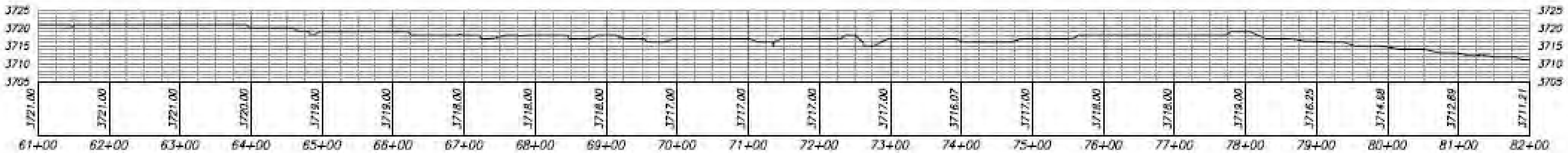
POTENTIAL
OPTION 6
PLAN

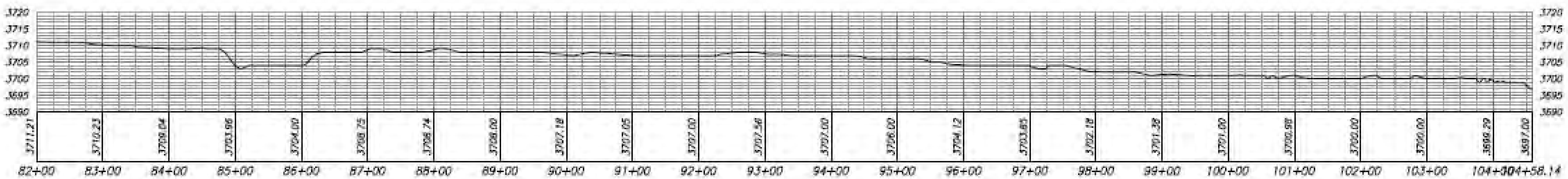
1678-100-XXXX

PLAN

300 0 300 600 900
SCALE OF FEET







PROFILE 1 – (CHANNEL SOUTH OF BERM)

100 0 100 200 300
SCALE OF FEET

POTENTIAL OPTION 6

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MIDDLE FORK
OXBOW
POTENTIAL OPTION 6
PLAN AND PROFILE 1

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POTENTIAL
OPTION 6
PLAN AND PROFILE 1

1678–100–XXXX
SHEET 9 OF 15

DATE AND TIME PLOTTED
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PLOTTED BY
LBROOKES

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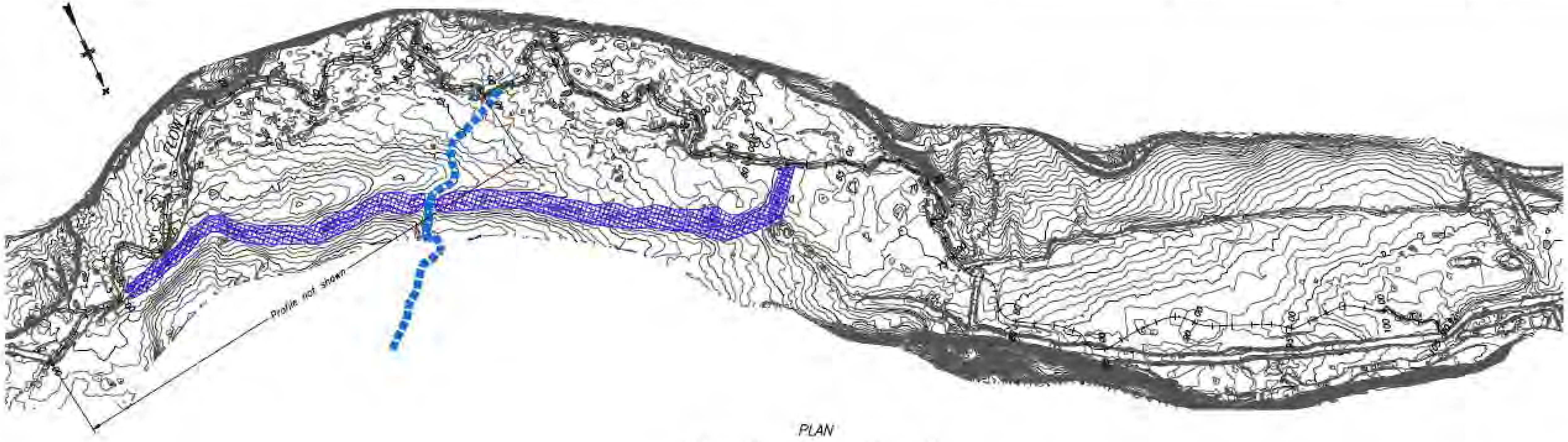
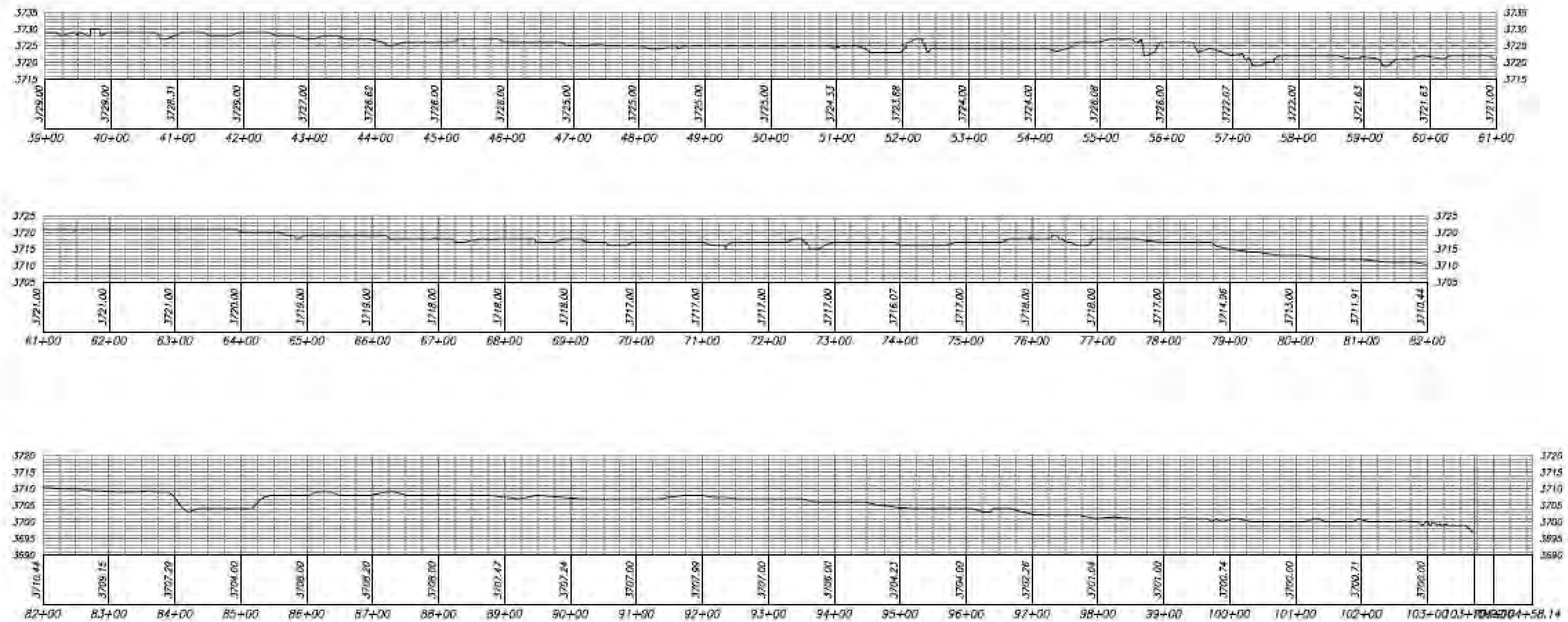
RECLAMATION
Managing Water in the West



PLAN

SCALE OF FEET



PROFILE 2 – (CHANNEL NORTH OF BERM)

SCALE OF FEET

POTENTIAL OPTION 6

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POTENTIAL OPTION 6
PLAN AND PROFILE 2

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POTENTIAL
OPTION 6
PLAN AND PROFILE 2

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SHEET 10 OF 15

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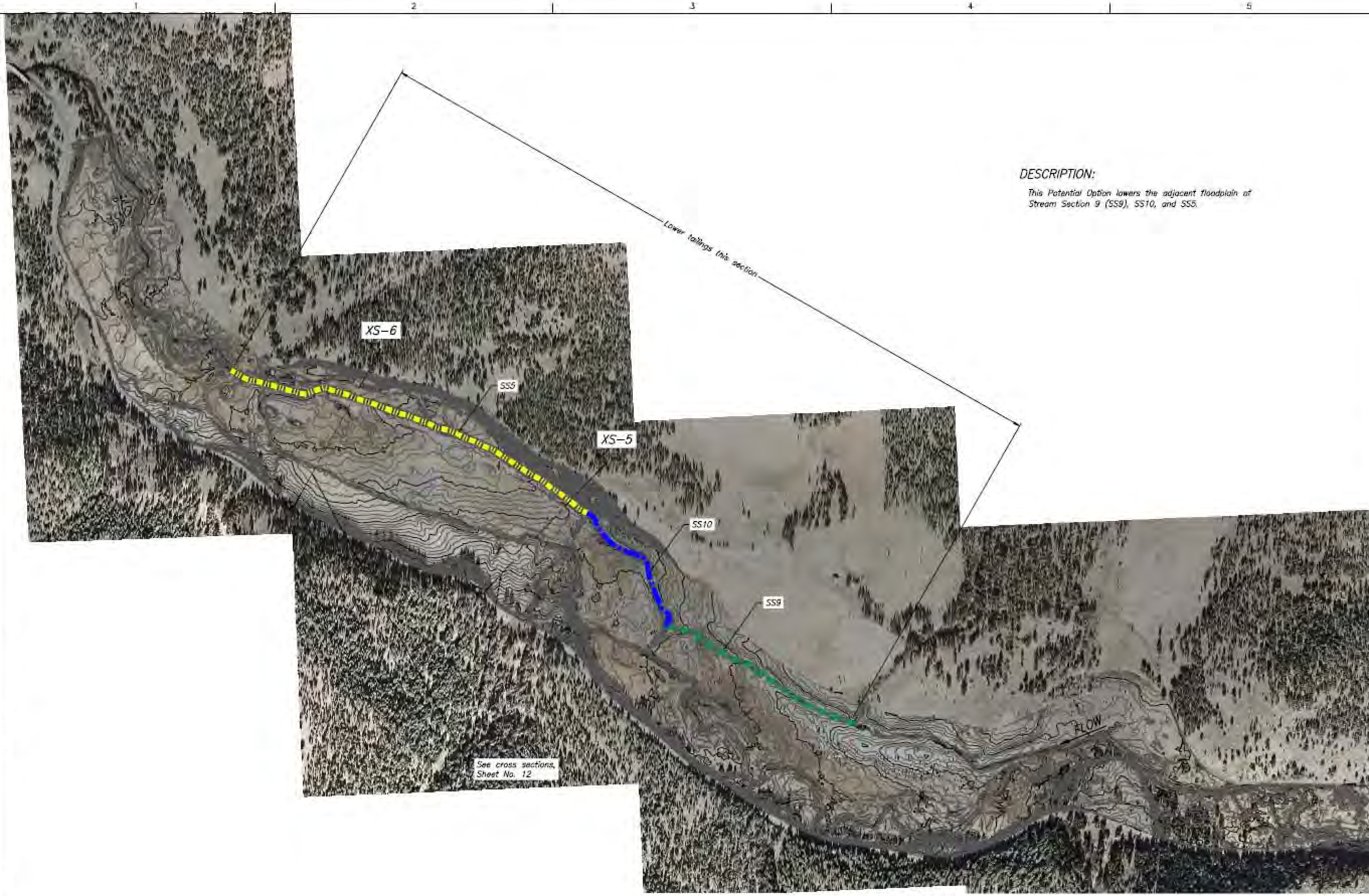

DESCRIPTION:

This Potential Option lowers the adjacent floodplain of Stream Section 9 (SS9), SS10, and SS5.

PLAN
POTENTIAL OPTION 7

400 0 400 800 1200
SCALE OF FEET

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OREGON
POTENTIAL OPTION 7

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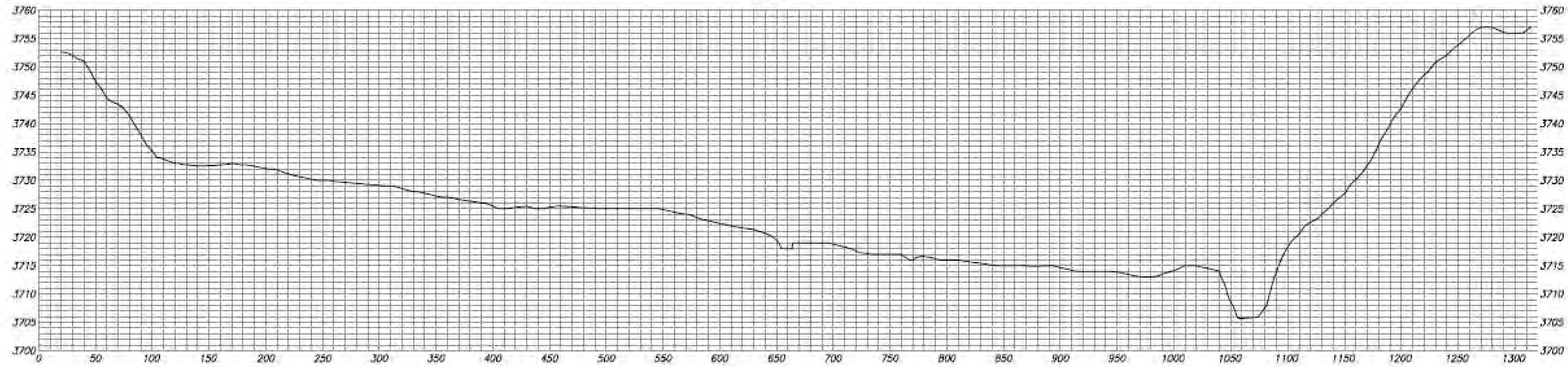
POTENTIAL
OPTION 7
PLAN

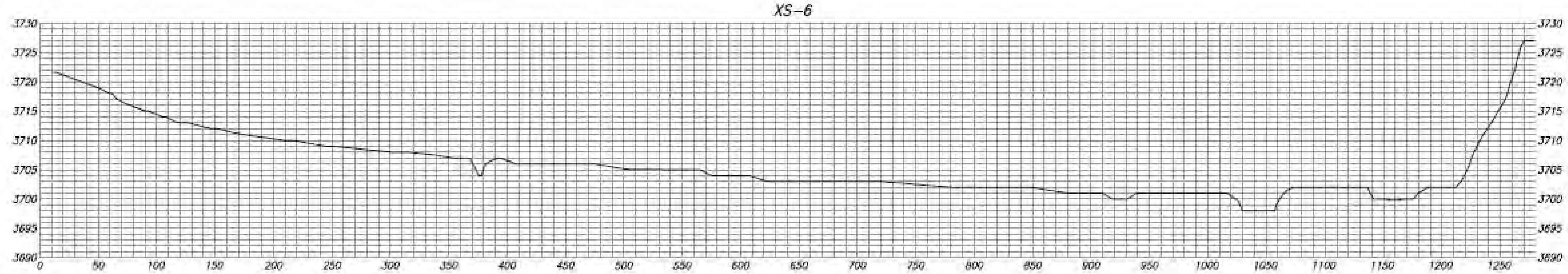
1678-100-XXXX

SHEET 11 OF 15

XS-5



XS-6



CROSS SECTIONS

HORIZ. 50 0 50 100 150
SCALE OF FEET
VERT. SCALE AT 5:1 EXAGGERATION

RECLAMATION
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MIDDLE FORK
OREGON
CROSS SECTIONS XS-5 AND XS-6

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DRAWN
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APPROVED

BOISE, ID [illegible]

CROSS SECTIONS
XS-5 AND XS-6

1678-100-XXXX

SHEET 12 OF 15

RECLAMATION
Managing Water in the West

DESCRIPTION:

This Potential Option evaluates side channels throughout the extent of the study area in the existing condition.

PLAN
POTENTIAL OPTION 8

400 0 400 800 1200
SCALE OF FEET

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JOHN DAY SUBBASIN
MIDDLE FORK
POTENTIAL OPTION 8

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DRAWN ____
CHECKED ____
TECH. APPR. ____
NAME - TITLE
APPROVED ____
ADMINISTRATIVE APPROVAL - NAME - TITLE

BOISE, ID 2009-01-26

POTENTIAL
OPTION 8
PLAN

1678-100-XXXX

PLAN
CROSS SECTION LOCATIONS

400 0 400 800 1200
SCALE OF FEET

RECLAMATION
Managing Water in the West

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COLUMBIA/SNAKE RIVER/SALMON RECOVERY PROGRAM
HABITAT IMPROVEMENT PROGRAM - OREGON
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MIDDLE FORK
OREGON
CROSS SECTION LOCATION

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APPROVED

CROSS SECTION LOCATIONS PLAN VIEW

1678-100-XXXX

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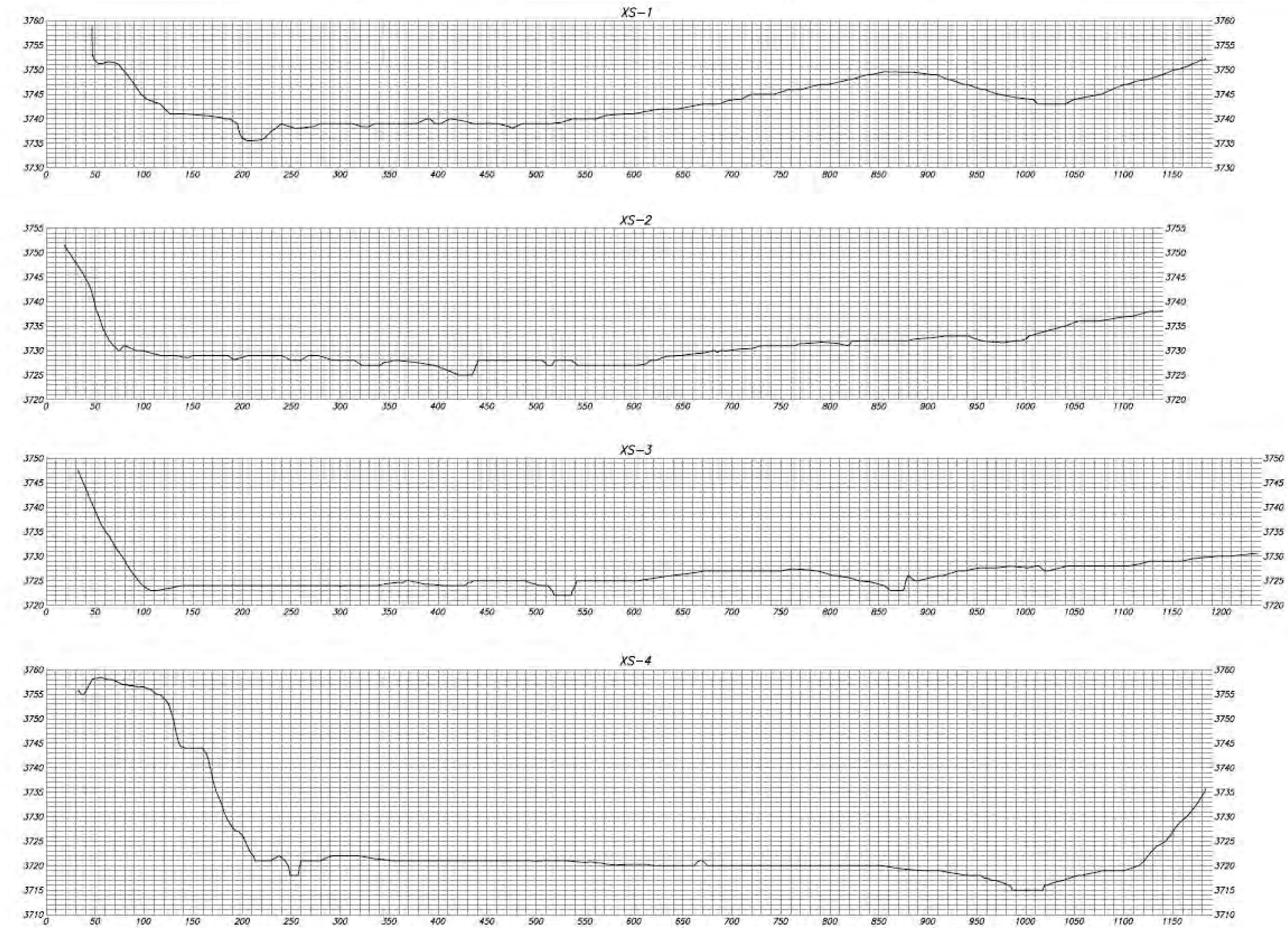

CROSS SECTIONS

HORIZ. 50 0 50 100 150 SCALE OF FEET

VERT. SCALE AT 5:1 EXAGGERATION

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FCRPS HABITAT IMPROVEMENT PROGRAM – OREGON

JOHN DAY SUBBASIN
MIDDLE FORK
OREGON

CROSS SECTIONS XS-1 TO XS-4
SECTIONS

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APPROVED

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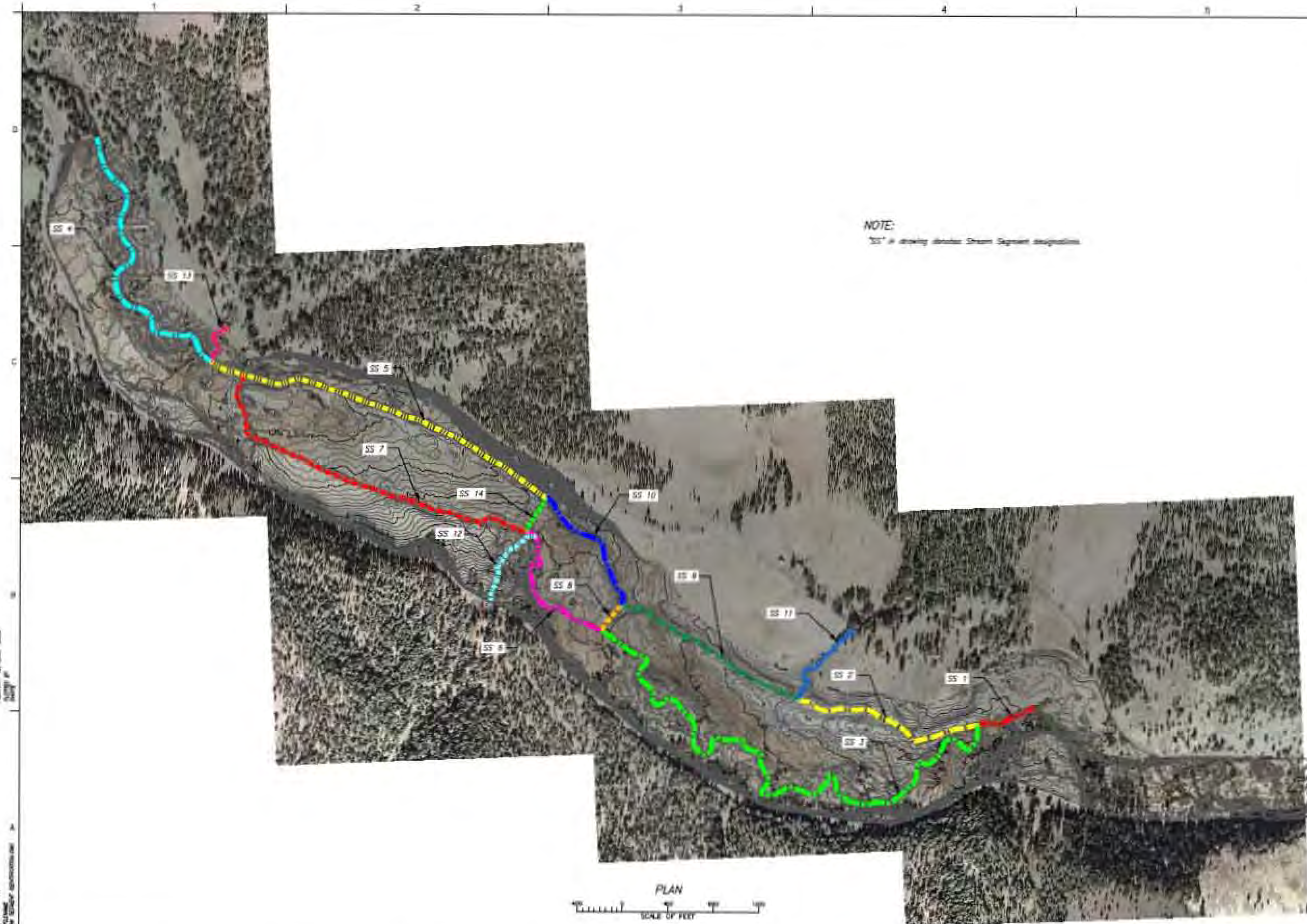
CROSS SECTIONS
XS-1 TO XS-4

1678-100-XXXX



NOTE:
"SS" in drawing denotes Stream Segment designations.

PLAN

SCALE OF FEET

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STREAM SEGMENT IDENTIFICATION

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STREAM SEGMENT
IDENTIFICATION
PLAN

1678-100-XXXX

DESCRIPTION:

Potential Option 2 was the proposed conditions in this hydraulic and geomorphic analysis. It includes blocking the North Channel (NC) with a plug or similar just downstream of the North—South Channel bifurcation and upstream of the confluence of Granite Boulder Creek and the NC (SS2). The connection between Granite Boulder Creek and the NC (SS9) is maintained. All other flow patterns are maintained.

PLAN
POTENTIAL OPTION 2

400 0 400 800 1200
SCALE OF FEET

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MIDDLE FORK
POTENTIAL OPTION 2

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POTENTIAL
OPTION 2
PLAN

1678–100–XXXX

SHEET 2 OF 15

RECLAMATION
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DESCRIPTION:

Reconnect Granite Boulder Creek with the South Channel (SC) at or near its original location in the 1939 photo. This option is the preferred geomorphic alternative as evidence of this connection existed in the 1939 photos. This proposal would also involve blocking Stream Segment 2 (SS2) and SS9.

PLAN
POTENTIAL OPTION 3

400 0 400 800 1200
SCALE OF FEET

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POTENTIAL
OPTION 3
PLAN

1678-100-XXXX

SHEET 3 OF 15

RECLAMATION
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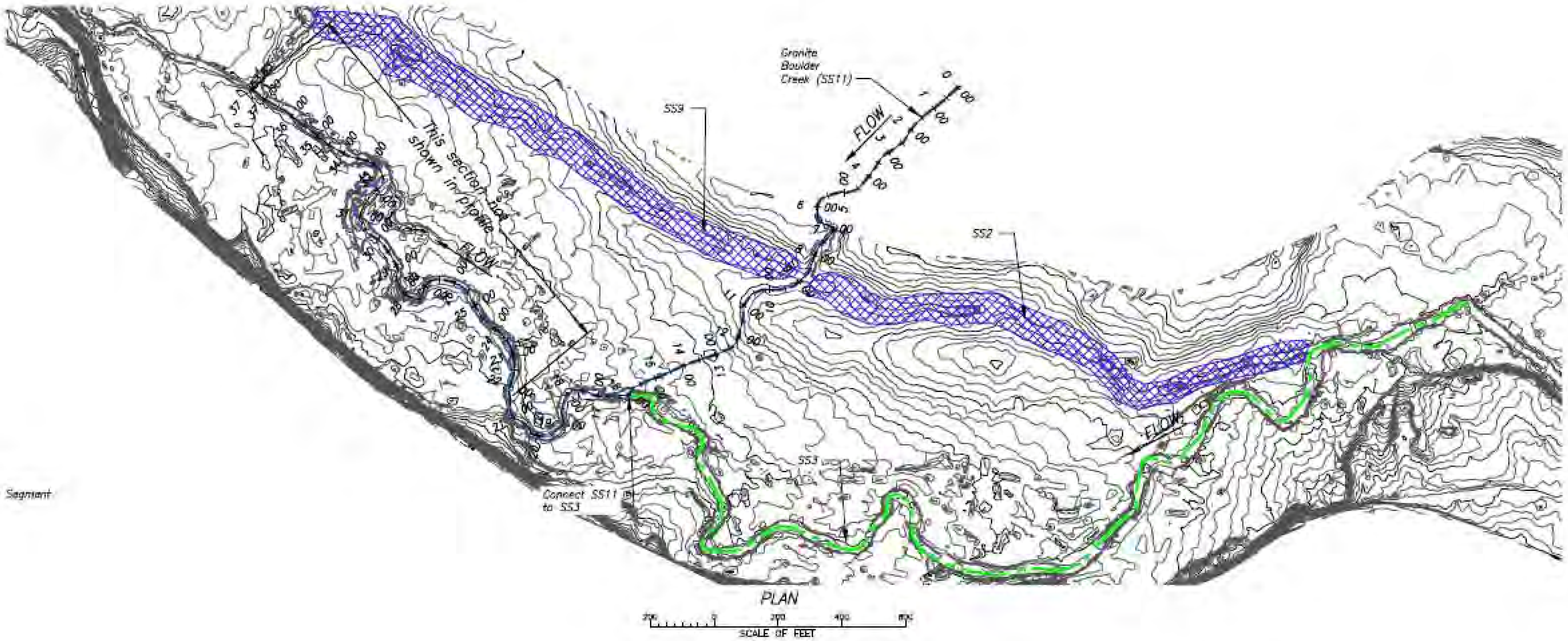
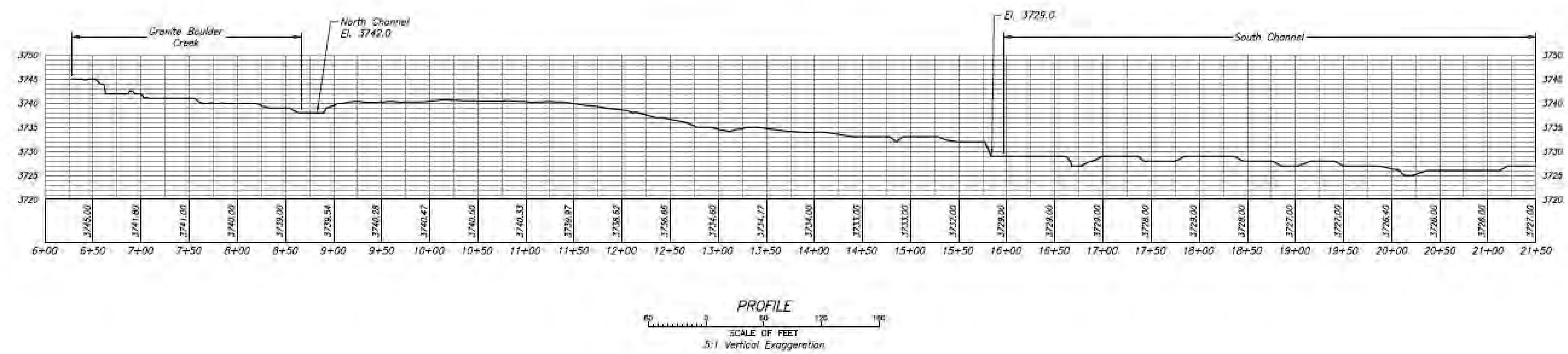


NOTE:
SS = Stream Segment



POTENTIAL OPTION 3

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POTENTIAL OPTION 3
PLAN AND PROFILE

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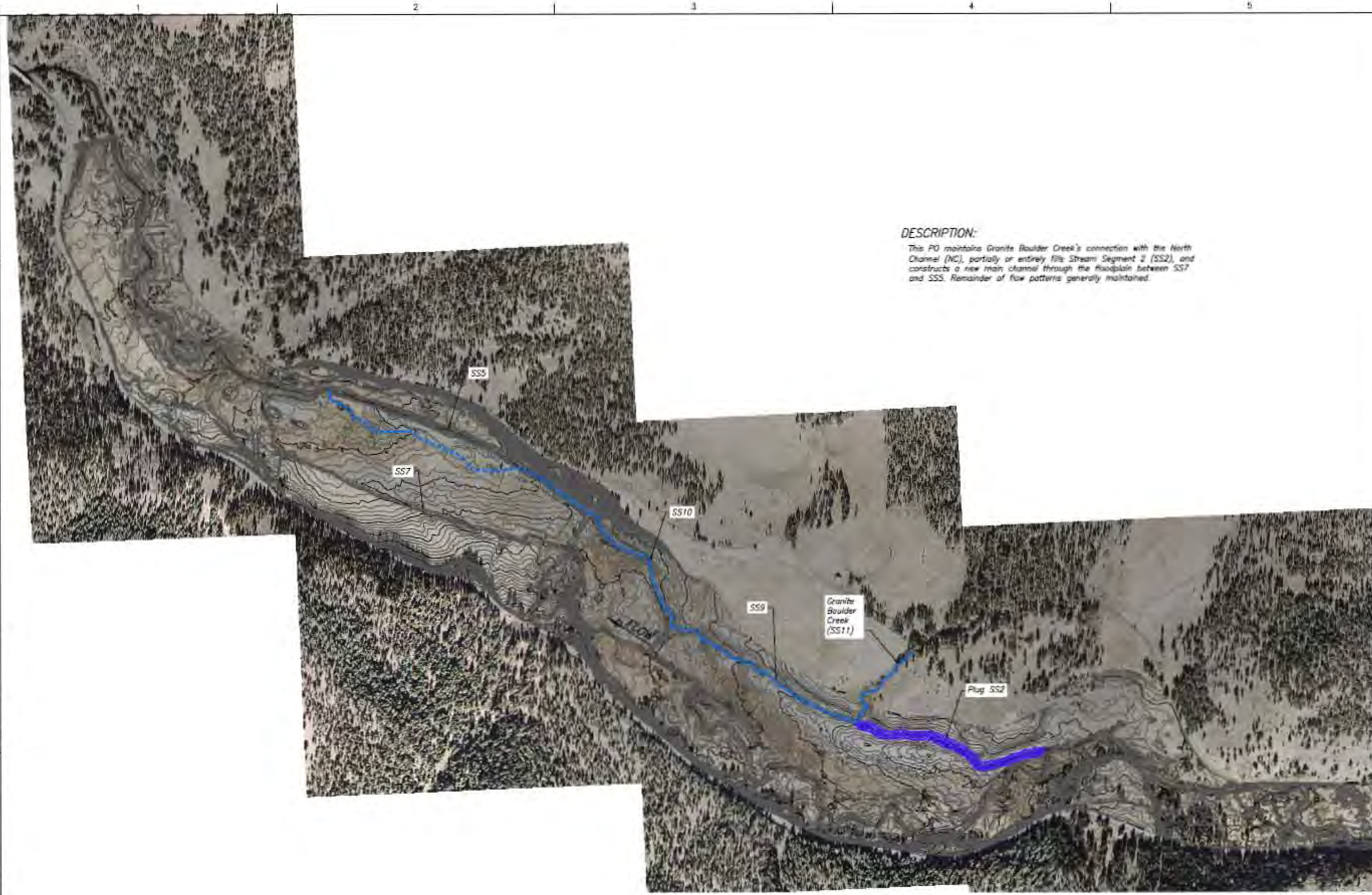
POTENTIAL
OPTION 3
PLAN AND PROFILE

1678-100-XXXX
SHEET 4 OF 19

RECLAMATION
Managing Water in the West



DESCRIPTION:

This PO maintains Granite Boulder Creek's connection with the North Channel (NC), partially or entirely fills Stream Segment 2 (SS2), and constructs a new main channel through the floodplain between SS7 and SS5. Remainder of flow patterns generally maintained.

PLAN
POTENTIAL OPTION 4

SCALE OF FEET (400 0 400 800 1200)

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POTENTIAL OPTION 4

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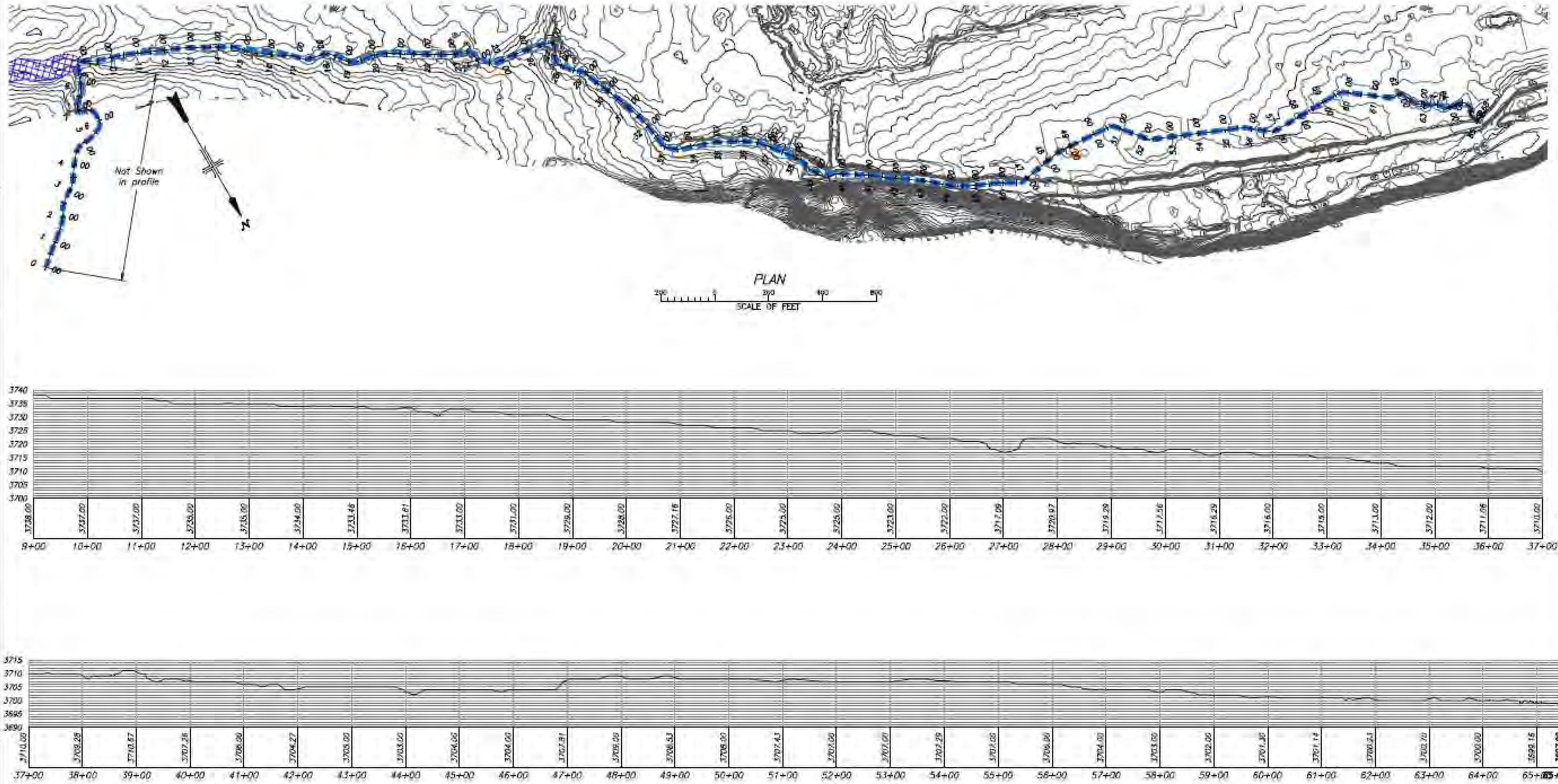
POTENTIAL
OPTION 4
PLAN

1678-100-XXXX



POTENTIAL OPTION 4

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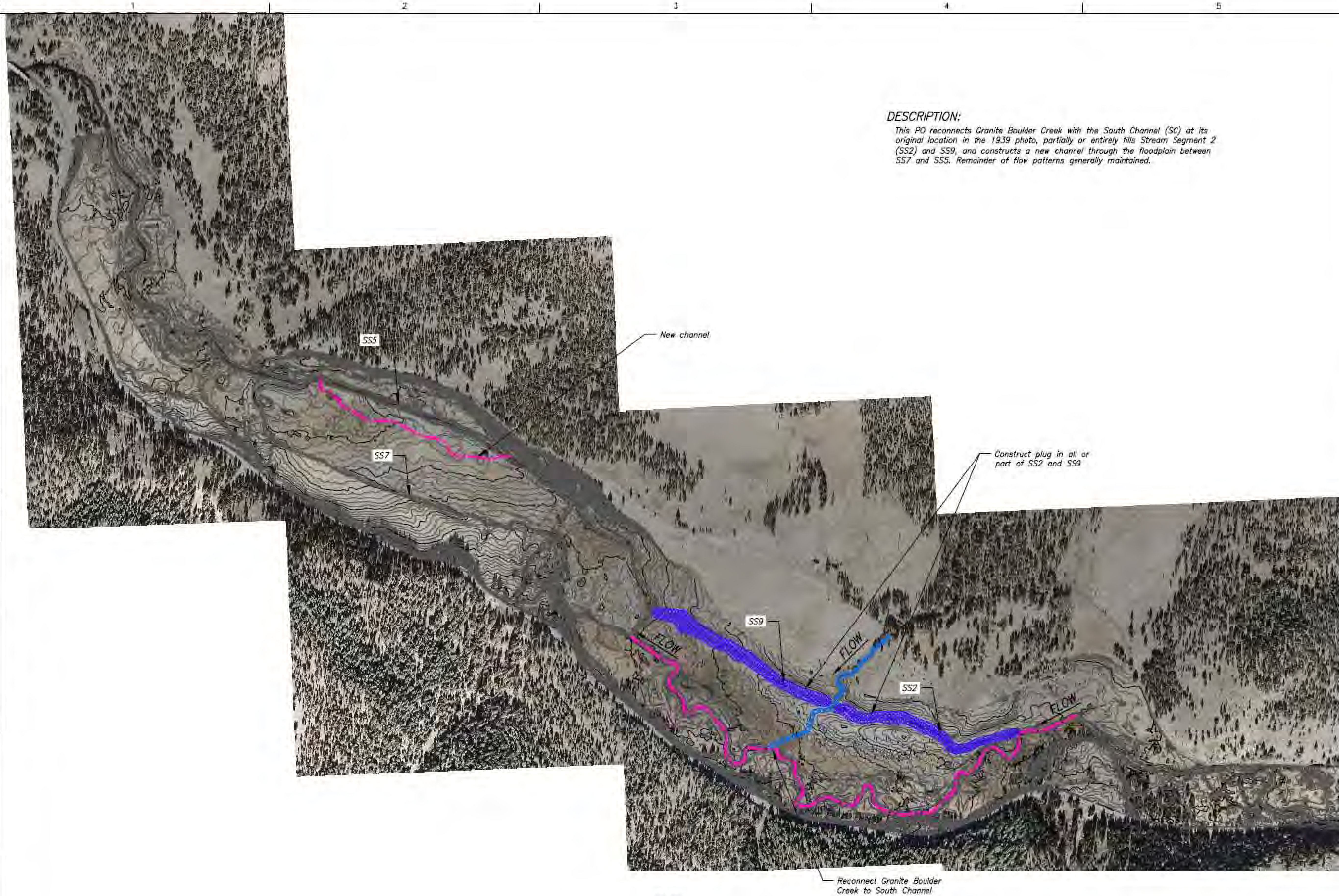
BOISE, ID

POTENTIAL OPTION 4 PLAN AND PROFILE

1678–100–XXXX

DESCRIPTION:

This PO reconnects Granite Boulder Creek with the South Channel (SC) at its original location in the 1939 photo, partially or entirely fills Stream Segment 2 (SS2) and SS9, and constructs a new channel through the floodplain between SS7 and SS5. Remainder of flow patterns generally maintained.



PLAN
POTENTIAL OPTION 5

400 0 400 800 1200
SCALE OF FEET

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POTENTIAL OPTION 5

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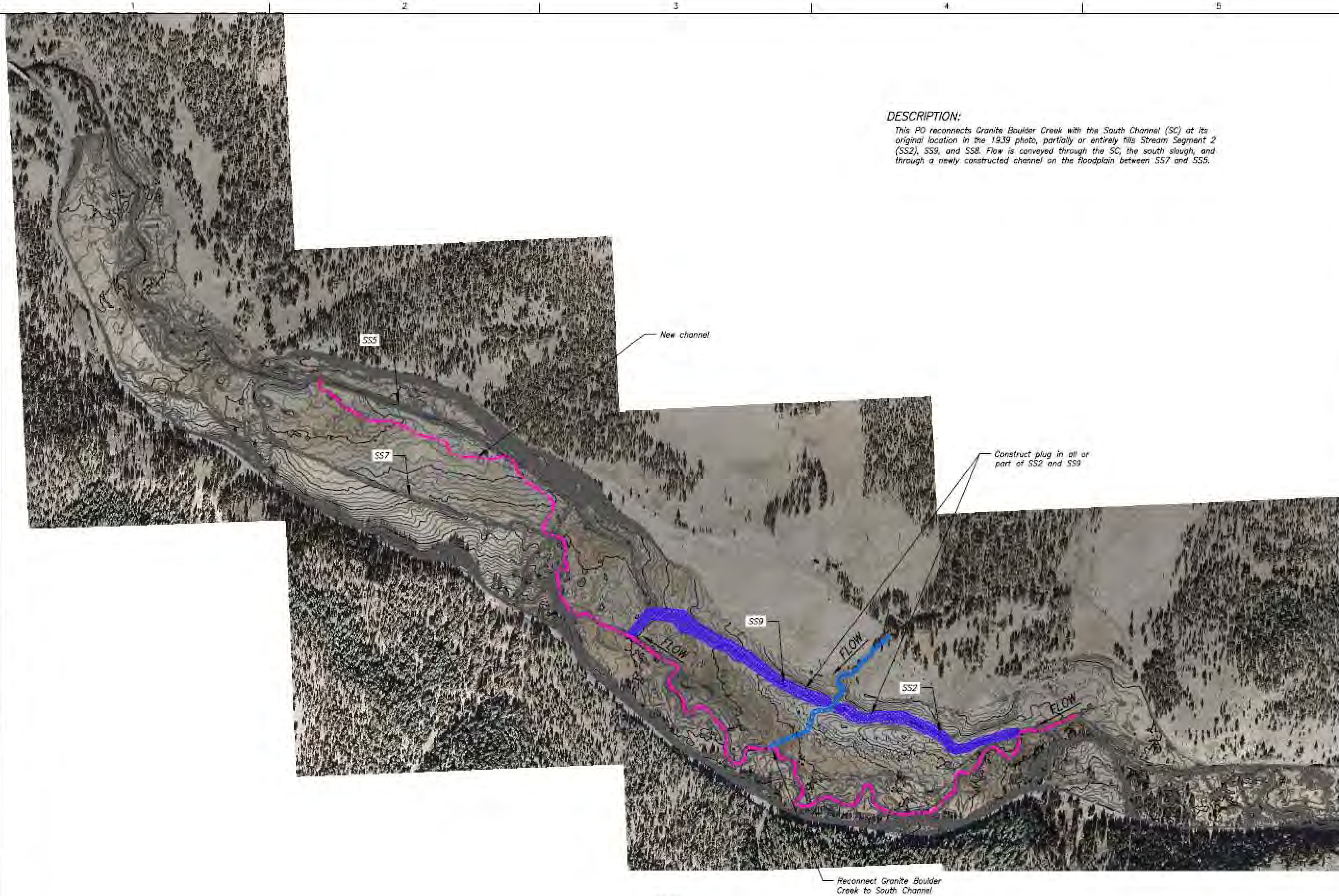
POTENTIAL OPTION 5 PLAN

1678-100-XXXX

SHEET 7 OF 15

DESCRIPTION:

This PO reconnects Granite Boulder Creek with the South Channel (SC) at its original location in the 1939 photo, partially or entirely fills Stream Segment 2 (SS2), SS9, and SS8. Flow is conveyed through the SC, the south slough, and through a newly constructed channel on the floodplain between SS7 and SS5.



PLAN
POTENTIAL OPTION 6

400 0 400 800 1200
SCALE OF FEET

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MIDDLE FORK
POTENTIAL OPTION 6

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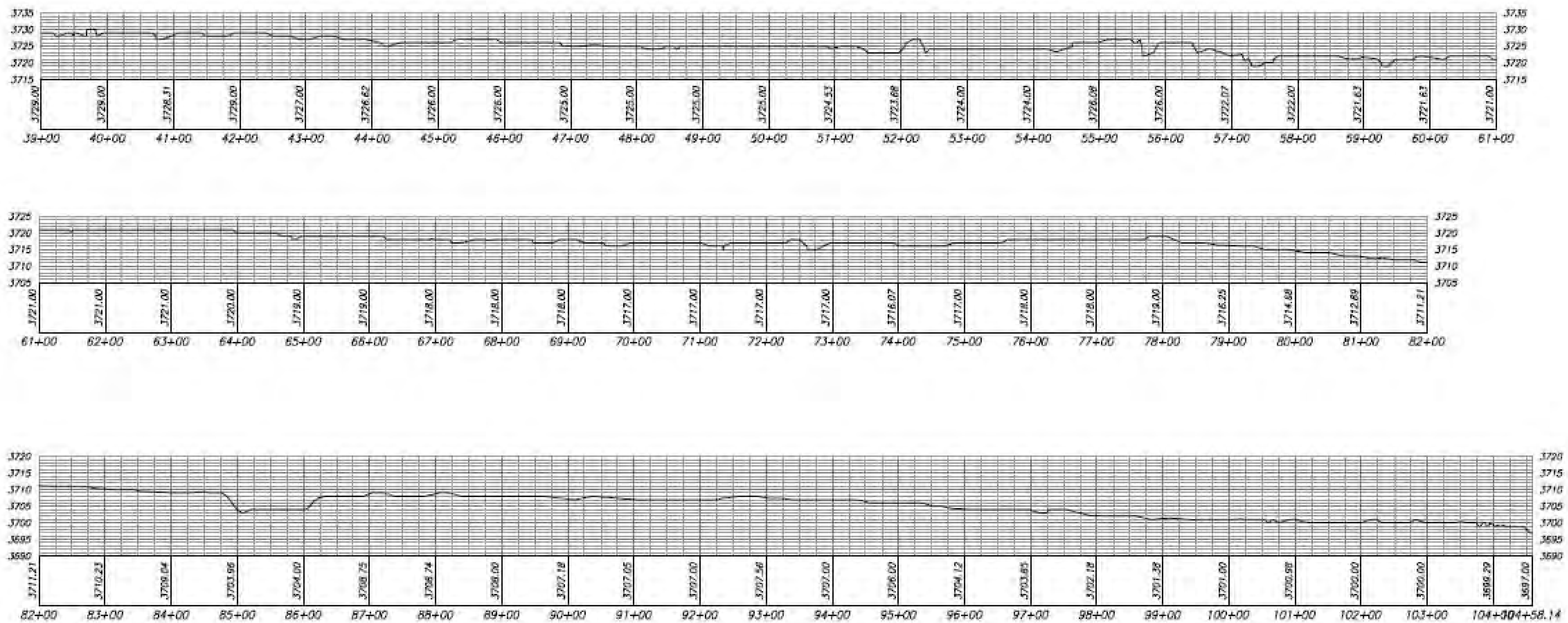
POTENTIAL
OPTION 6
PLAN

1678–100–XXXX

PLAN

300 0 300 600 900
SCALE OF FEET



PROFILE 1 – (CHANNEL SOUTH OF BERM)

100 0 100 200 300
SCALE OF FEET

POTENTIAL OPTION 6

RECLAMATION
Managing Water in the West

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JOHN DAY SUBBASIN
MIDDLE FORK
OXBOW
POTENTIAL OPTION 6
PLAN AND PROFILE 1

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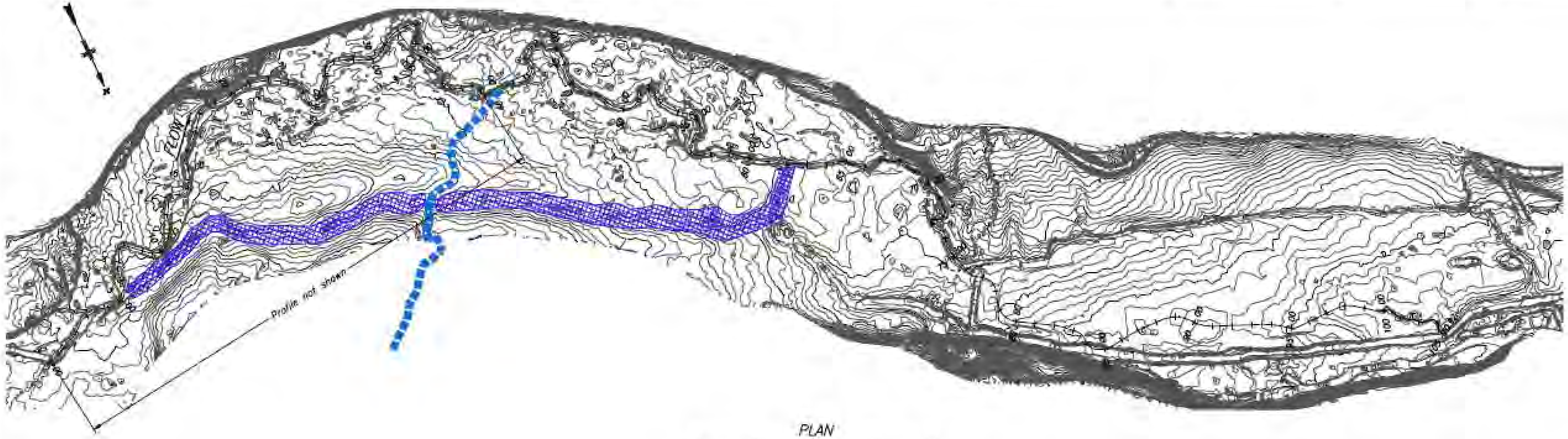
POTENTIAL OPTION 6
PLAN AND PROFILE 1

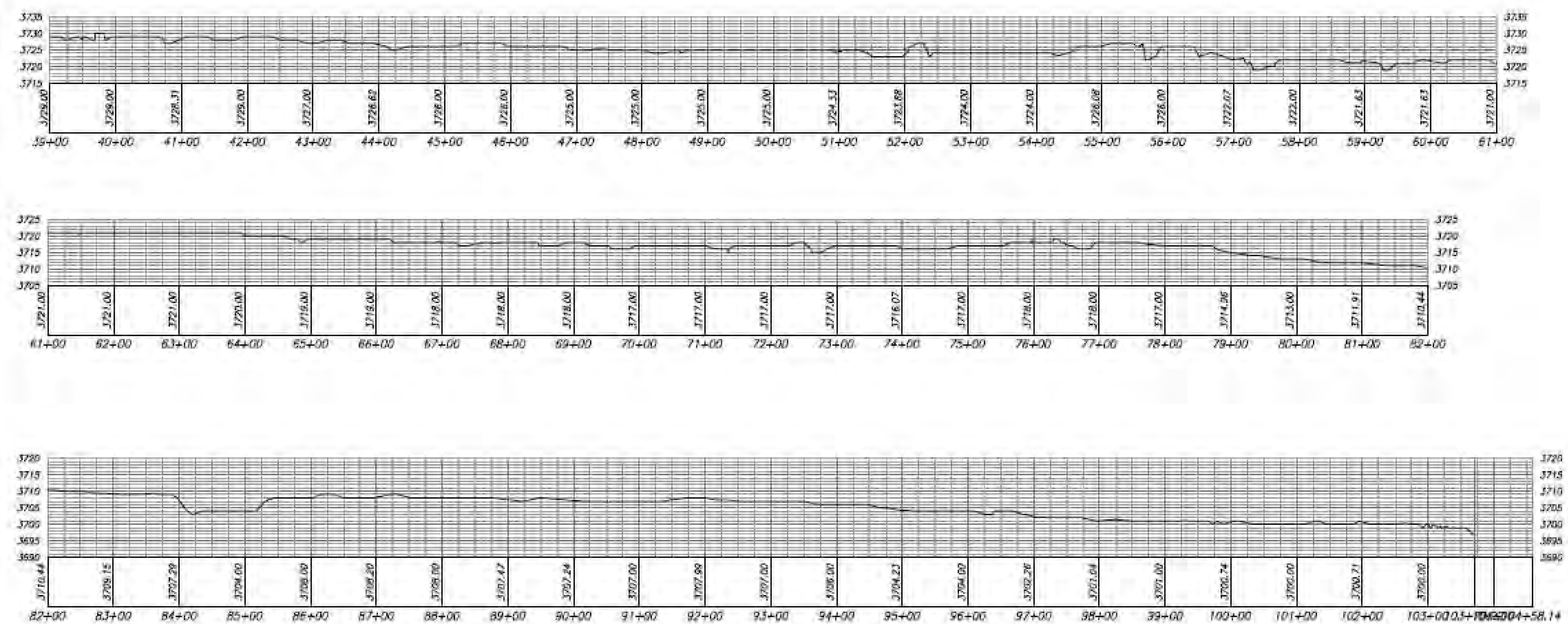
1678–100–XXXX

SHEET 9 OF 15



PLAN

SCALE OF FEET



PROFILE 2 – (CHANNEL NORTH OF BERM)

SCALE OF FEET

POTENTIAL OPTION 6

RECLAMATION
Managing Water in the West

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JOHN DAY SUBBASIN
MIDDLE FORK
OREGON
POTENTIAL OPTION 6
PLAN AND PROFILE 2

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POTENTIAL
OPTION 6
PLAN AND PROFILE 2

1678-100-XXXX

SHEET 10 OF 15

RECLAMATION
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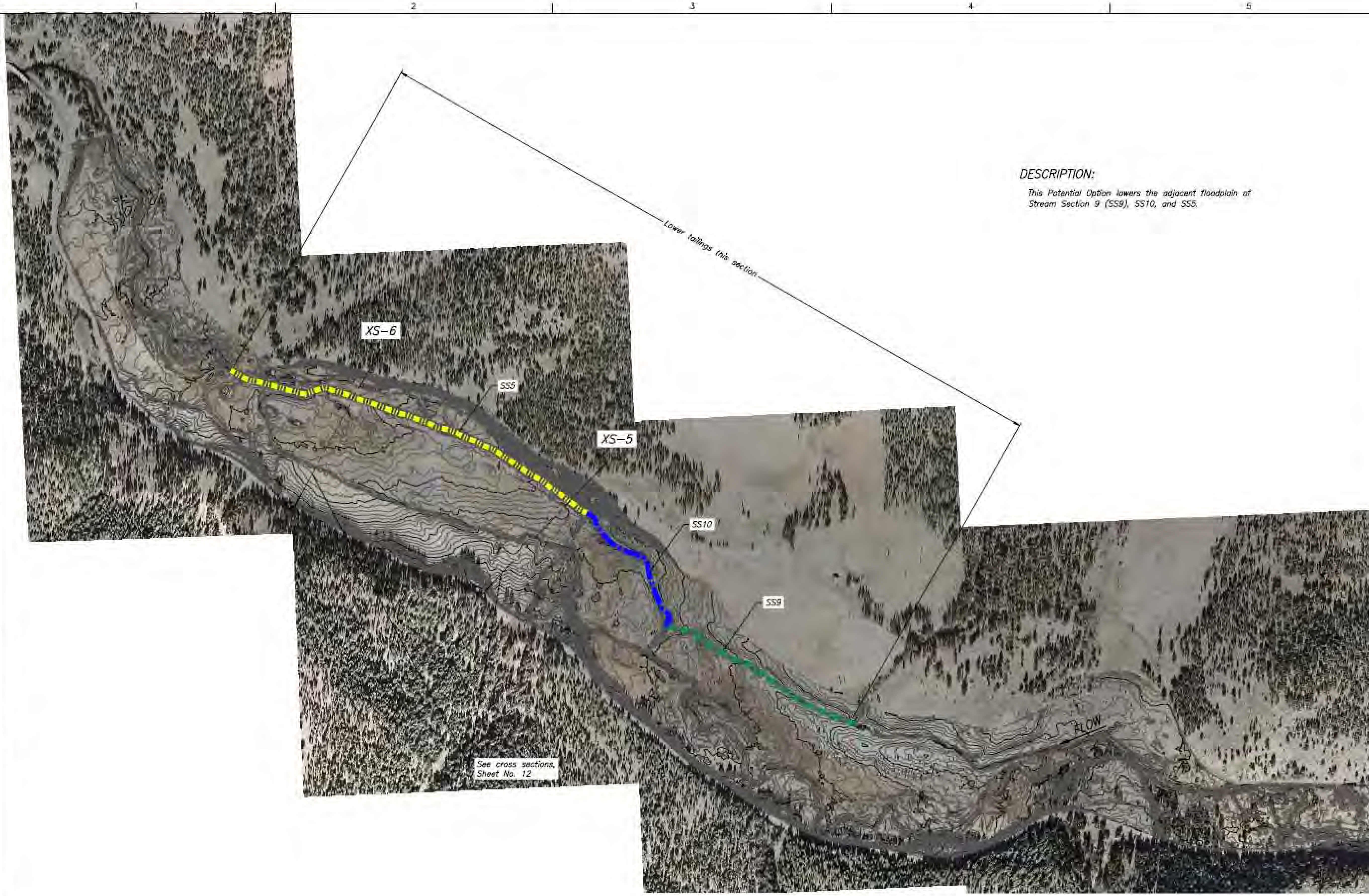
DESCRIPTION:

This Potential Option lowers the adjacent floodplain of Stream Section 9 (SS9), SS10, and SS5.



PLAN
POTENTIAL OPTION 7

400 0 400 800 1200
SCALE OF FEET

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MIDDLE FORK
OXBOW
POTENTIAL OPTION 7

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DRAWN
CHECKED
TECH. APPR. NAME - TITLE
APPROVED ADMINISTRATIVE APPROVAL - NAME - TITLE

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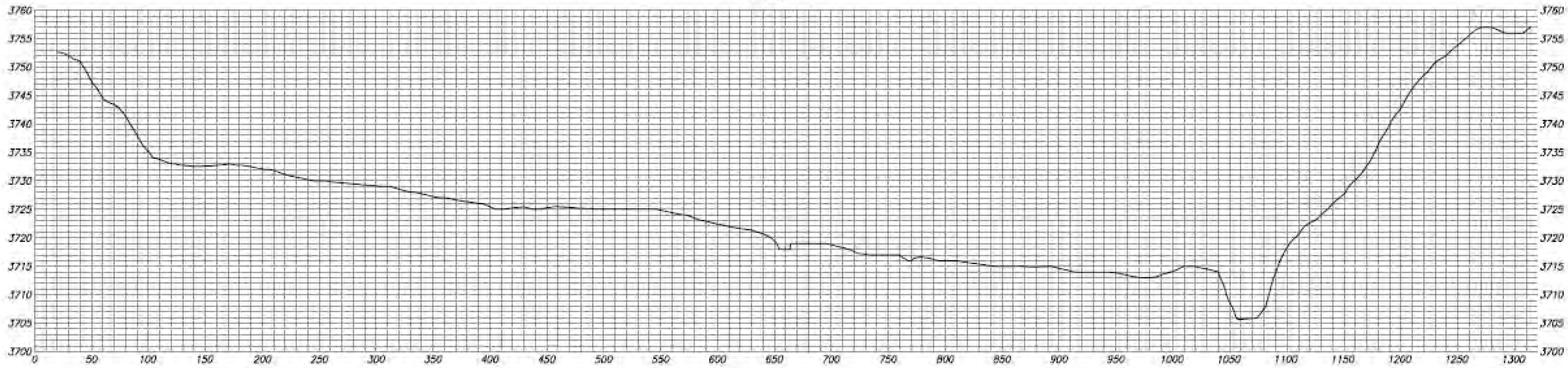
POTENTIAL OPTION 7 PLAN

1678-100-XXXX

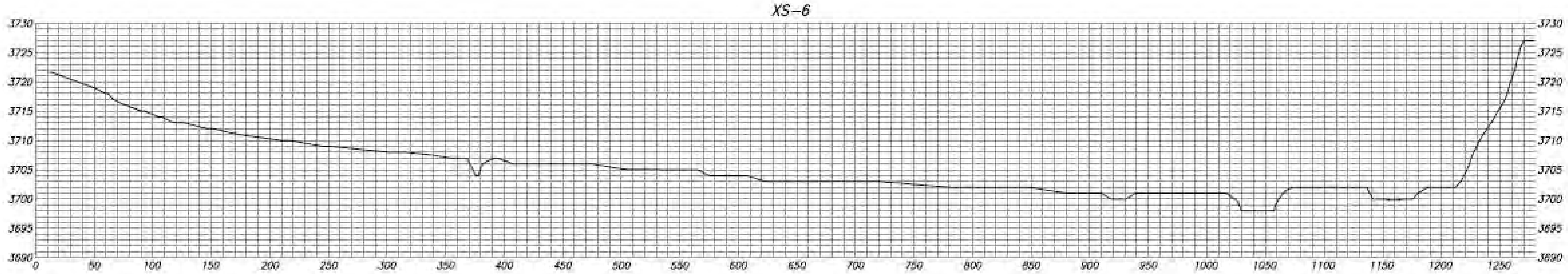
SHEET 11 OF 15

RECLAMATION
Managing Water in the West

XS-5



XS-6



CROSS SECTIONS

HORIZ. 50 0 50 100 150
SCALE OF FEET
VERT. SCALE AT 5:1 EXAGGERATION

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OREGON

CROSS SECTIONS XS-5 AND XS-6

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CROSS SECTIONS
XS-5 AND XS-6

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RECLAMATION
Managing Water in the West

DESCRIPTION:

This Potential Option evaluates side channels throughout the extent of the study area in the existing condition.

PLAN
POTENTIAL OPTION 8

400 0 400 800 1200
SCALE OF FEET

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POTENTIAL OPTION 8

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POTENTIAL
OPTION 8
PLAN

1678-100-XXXX

RECLAMATION
Managing Water in the West

PLAN
CROSS SECTION LOCATIONS

SCALE OF FEET

ALWAYS THINK SAFETY

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CROSS SECTION LOCATION

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CROSS SECTION LOCATIONS PLAN VIEW

1678–100–XXXX

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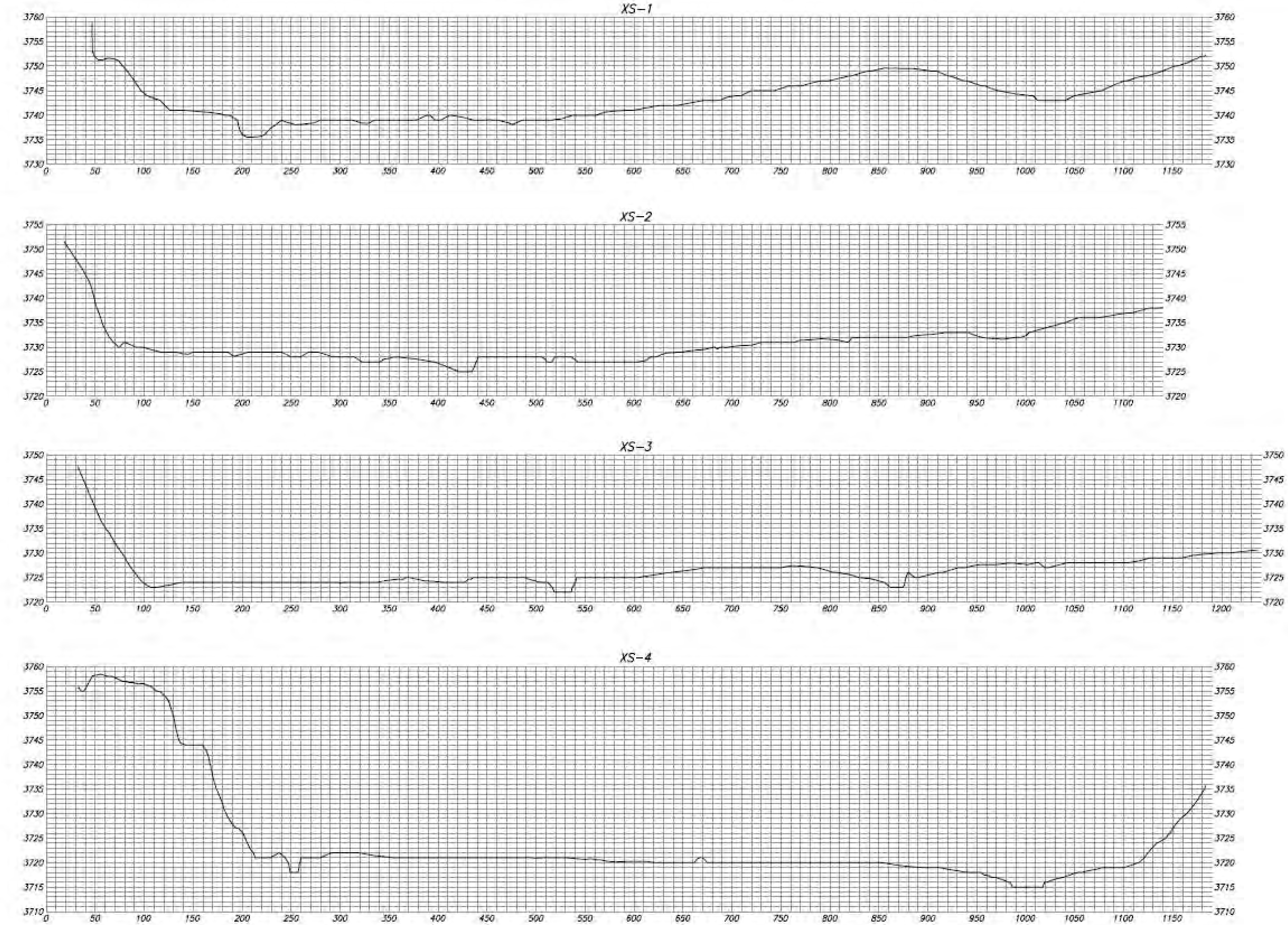

CROSS SECTIONS
HORIZ. 50 0 50 100 150
SCALE OF FEET
VERT. SCALE AT 5:1 EXAGGERATION

ALWAYS THINK SAFETY

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JOHN DAY SUBBASIN
MIDDLE FORK
OREGON
CROSS SECTIONS XS-1 TO XS-4

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CROSS SECTIONS
XS-1 TO XS-4

1678-100-XXXX

SHEET 15 OF 15

APPENDIX B - SOIL FIELD DESCRIPTIONS

FIELD DESCRIPTION OF SOIL PROPERTIES

Site No.: MJD1 **Described by:** Ralph Klinger **Date:** 11/4/2008
Map Unit: Qa2 terrace **Aspect:** SW **Parent Material:** fine- to coarse-grained silty sand
Quadrangle: Boulder Butte, OR (USGS 7.5') **Coordinates:** N44°40'11.4"; W118°43'20.7" (NAD83) **Elevation:** 3590 ft
Location: Downstream margin of alluvial terrace along the right bank on the Nature Conservancy property near Road 45 and downstream of the confluence of Big Boulder Creek.

Horizon	Depth (cm)	Boundaries	Structure	Clay Films	Consistence			Texture	Gravel %	CaCO3 Morphology	Color (moist)
					Stickiness	Plasticity	Dry				
A	0-11	as	sg-1fgr	none			so		0	n/a	
BA	11-20	cs	2fgr-2msbk	none			so		0	n/a	
B1	20-40	as	m-2cgr	none			So		trace	n/a	
B2	40-66	cw	2m-csbk	1fpf			Sh		trace	n/a	
Btb	66-85+	-	3cabk	3ppf			vh		trace	n/a	

Radiocarbon/Pollen Samples:

MJD1-1 detrital charcoal from near the upper boundary of the Btb horizon at 77 cm
MJD1-2 detrital charcoal from the B1 horizon at 26 cm
MJD1-3 detrital charcoal from the B2 horizon at 57 cm
MJD1-4 detrital charcoal from near the boundary of the BA/B1 horizon at 18 cm
MJD1-5 detrital charcoal from the base of the base of the BA horizon at 16 cm
MJD1-6 detrital charcoal from the top of the B1 horizon at 22 cm
MJD1-7 detrital charcoal from the B1 horizon at 38 cm
MJD1-8 detrital charcoal from the B1 horizon at 34 cm
MJD1-9 bulk sediment for pollen from the B2 horizon at 45-60 cm
MJD1-10 bulk sediment for pollen from the B1 horizon at 25-40 cm

Miscellaneous Notes:

The surface of the terrace has been clearly disrupted by logging and agriculture (grazing); many tree stumps present on surface in growth position; irrigation ditch from diversion on Big Boulder Creek flows across the terrace. A/BA horizon may be representative of this disruption (plow horizon). A horizon is very dark; rich in organics; abundant roots. BA horizon appears transitional from overlying A to underlying B1; contains many roots. B1 horizon is mottled; contains many small (<1 mm) pores; trace of rounded gravel (<10 cm diameter). B2 horizon contains trace of rounded gravel (<10 cm) with clean white ash coatings on bottoms of clasts. Btb horizon very coarse rounded to well-rounded sand with trace of sub-rounded pebbles (<1 cm).


A
BA
B1
B2
Btb
Site MJD1

FIELD DESCRIPTION OF SOIL PROPERTIES

Site No.: MJD2A/B **Described by:** Ralph Klinger **Date:** 11/5/2008
Map Unit: Qafs **Aspect:** NW **Parent Material:** poorly-sorted, fine-grained silty sand; moderately-sorted sandy gravel
Quadrangle: Boulder Butte, OR (USGS 7.5') **UTM coordinates:** N44°39'57.8"; W118°43'00.3" (NAD83) **Elevation:** 3600 ft
Location: Natural exposure of alluvial fan deposits along the left bank opposite the mouth of Big Boulder Creek.

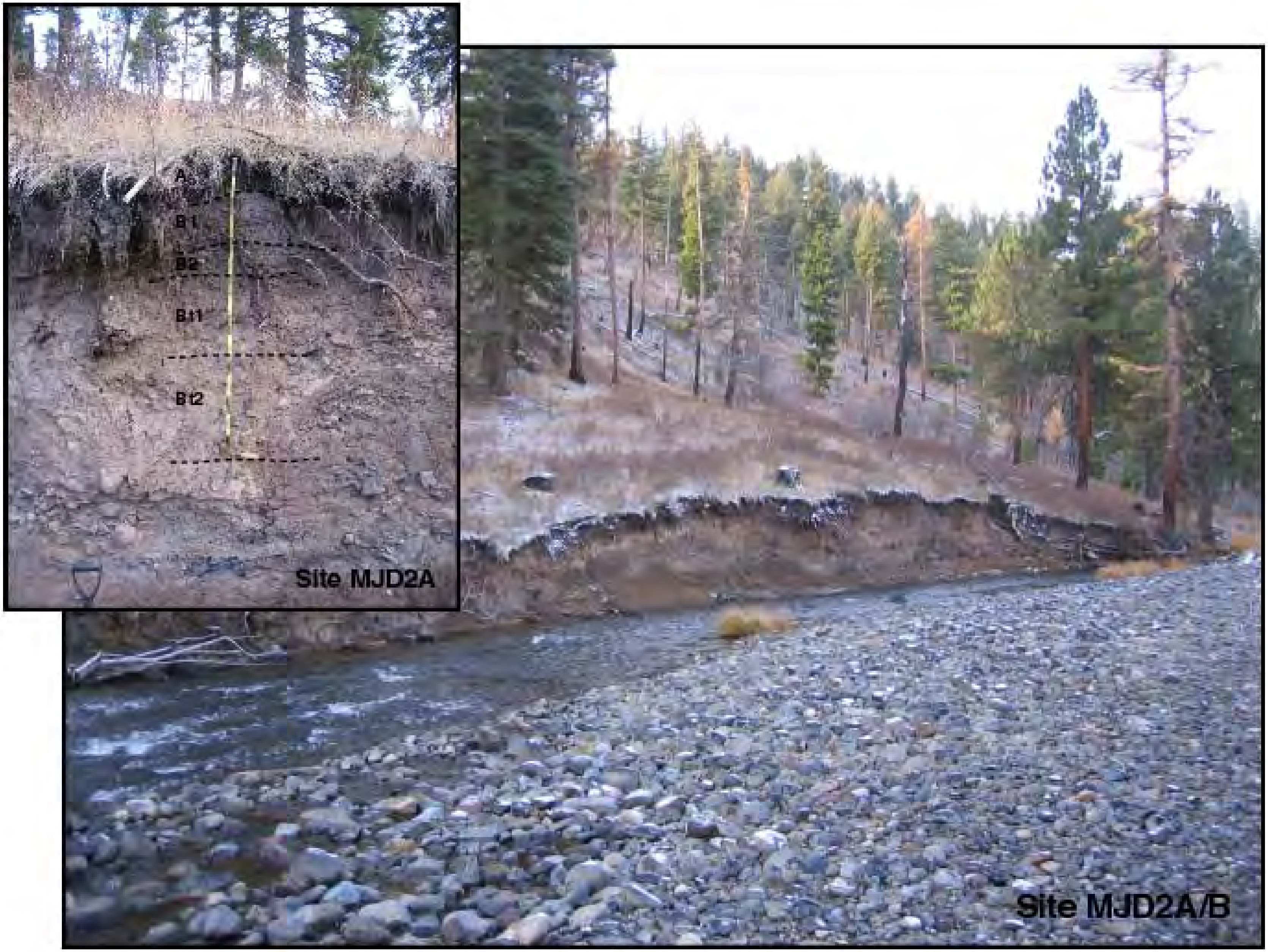
Horizon	Depth (cm)	Boundaries	Structure	Clay Films	Consistence			Texture	Gravel %	CaCO3 Morphology	Color (moist)
					Stickiness	Plasticity	Dry				
A1	0-11	cw	2mgr	none			-		0	n/a	
A2	11-18	aw	3cpl	none			so		0	n/a	
B1	18-42	aw	2cgr-1fsbk	none			so		10	n/a	
B2	42-70	aw	2csbk	none			vh		0	n/a	
Bt1	70-110	cw	2msbk	2fpf			vh		0	n/a	
Bt2	110-150	aw	3vcabk-1cpr	3ppf			eh	vc	0	n/a	

Radiocarbon Samples:

MJD2B-1 detrital charcoal from unit equivalent to Bt2 horizon at 205 cm
MJD2B-2 detrital charcoal from unit equivalent to B2 horizon at 93 cm
MJD2B-3 detrital charcoal from unit equivalent to Bt1 horizon at 135 cm
MJD2B-4 collected from the top of the 3C horizon at 50 cm
MJD2B-5 collected from the 3C horizon at 95 cm

Miscellaneous Notes:

Described composite section of alluvial fan deposits that in part contain reworked volcanic ash; -2A from surface to 150 cm, -2B down to stream-level (175 cm). Upper A horizon contains many roots; wet from recent rain/snow. All horizons below B2 transition laterally; exhibit more sedimentary structure, cross-cut by sand and gravelly sand beds indicating reworking/erosion by stream. Very thin, light-colored ashy silt bed is present between the B2 and Bt1 horizons in section MJD2A at about 70 cm. B2 horizon is composed of mottled coarse sand with is slightly more oxidized than overlying B1 horizon.


A
B1
B2
Bt1
Bt2
Site MJD2A
Site MJD2A/B

FIELD DESCRIPTION OF SOIL PROPERTIES

Site No.: MJD3 **Described by:** Ralph Klinger **Date:** 11/5/2008
Map Unit: Qa3 **Aspect:** SE **Parent Material:** fine silty sand; rounded sandy gravel
Quadrangle: Boulder Butte, OR (USGS 7.5') **UTM coordinates:** N44°40'05.4"; W118°42'44.5" (NAD83) **Elevation:** 3610 ft
Location: Natural exposure at the edge of alluvial terrace along the right bank upstream of Big Boulder Creek.

Horizon	Depth (cm)	Boundaries	Structure	Clay Films	Consistence			Texture	Gravel %	CaCO3 Morphology	Color (moist)
					Stickiness	Plasticity	Dry				
A	0-21	cw	1mgr-2csbk	none	ss-s	ps	so	fL	trace	n/a	10YR2/1
B1	21-40	cs	2msbk	none	s	p	sh	fL	trace	n/a	10YR2/2
B2	40-63	aw	2csbk	none	s	p	sh	fL	0	n/a	10YR2/2
Bb	63-87	aw	2vcsbk	none	ss	ps	H	fSL	0	n/a	10YR3/2
2C	87-118+	-	sg	None	so	po	lo	vcS	75	n/a	10YR2/2

Radiocarbon and Pollen Samples:

MJD3-1 detrital charcoal from the B2 horizon at 46 cm
MJD3-2 detrital charcoal from the base of B1 horizon at 40 cm
MJD3-3 detrital charcoal from the B2 horizon at 57 cm
MJD3-4 detrital charcoal from the Bb horizon at 68 cm
MJD3-5 detrital charcoal from the Bb horizon at 77 cm
MJD3-6 detrital charcoal from the base of Bb horizon at 87 cm
MJD3-7 bulk sediment for pollen from the Bb horizon at 65-70 cm

Miscellaneous Notes:

A and B1 horizons contain a few rounded pebbles up to about 2 cm diameter; abundant roots. Pores are common in B2 horizon. Buried B (Bb) horizon is weakly mottled. 2C horizon contains rounded to subrounded basalt pebbles to cobbles; coarse- to very coarse sand; weakly stratified.


A
B1
B2
Bb
2C
Site MJD3

FIELD DESCRIPTION OF SOIL PROPERTIES

Site No.: MJD4 **Described by:** Ralph Klinger **Date:** 11/6/2008
Map Unit: Qa1 **Aspect:** W-SW **Parent Material:** fine silty sand; angular silty gravel; very coarse sandy gravel
Quadrangle: Boulder Butte, OR (USGS 7.5') **UTM coordinates:** N44°39'17.1"; W118°40'43.3" (NAD83) **Elevation:** 3690 ft
Location: At downstream end of high alluvial terrace along right side of valley immediately downstream of confluence of Beaver Creek with Middle Fork John Day River; approximately 25 feet north of stock tank and west of Oxbow Conservation Area access road.

Horizon	Depth (cm)	Boundaries	Structure	Clay Films	Consistence			Texture	Gravel %	CaCO3 Morphology	Color (moist)
					Stickiness	Plasticity	Dry				
A	0-12	cs	2fgr-1msbk	none			so		trace	n/a	
2Bw	12-28	as	2csbk	none			so		25-50	n/a	
2C	28-50	cw	1csbk	none			so		50-75	n/a	
3Btb	50-80+	-	2csbk	1fbr-2dco			sh		>75	n/a	

Radiocarbon Samples:

MJD4-1 detrital charcoal from the 2Bw horizon at 21 cm
MJD4-2 detrital charcoal from the base of the 2Bw horizon at 27 cm
MJD4-3 detrital charcoal from the top of the 2C horizon at 32 cm
MJD4-4 detrital charcoal from the boundary between 2Bw/2C horizons at 28 cm
MJD4-5 detrital charcoal from the boundary between A/2Bw horizons at 13 cm

Miscellaneous Notes:

The most extensive Qa1 terrace on the Oxbow Conservation Area; the slope on the terrace surface is generally in a downstream direction but has some valleyward component. Back edge of the terrace is marked by road, which is cut into landslide deposits. Upper-most part of the profile shows input of hillslope sediment. Texture and color of 2Bw/2C horizons contains large component of volcanic ash; oxidized in 2Bw horizon.


A
2Bw
2C
3Btb
Site MJD4

APPENDIX C - CHARCOAL AND POLLEN ANALYSIS

POLLEN AND MACROFLORAL ANALYSIS OF BULK SOIL SAMPLES AND IDENTIFICATION OF DETRITAL CHARCOAL SAMPLES FROM ALONG THE MIDDLE FORK JOHN DAY RIVER, OREGON

By

Kathryn Puseman
and
Linda Scott Cummings

With Assistance From
R. A. Varney

Paleo Research Institute
Golden, Colorado

Paleo Research Institute Technical Report 08-144

Prepared For

Bureau of Reclamation
Reclamation Service Center
Denver, Colorado

January 2009

INTRODUCTION

Samples from along the Middle Fork of the John Day River in east-central Oregon were collected for a study of fluvial geomorphology. A total of 27 detrital charcoal samples were submitted for identification, and three bulk soil samples were examined for pollen and macrofloral remains. These samples were recovered from soil pit or natural bank exposures along the river. Macrofloral, including charcoal, and pollen identifications will be used to provide information concerning plant taxa that may have been present in this area prehistorically.

METHODS

Pollen

A chemical extraction technique based on flotation is the standard preparation technique used in this laboratory for the removal of the pollen from the large volume of sand, silt, and clay with which they are mixed. This particular process was developed for extraction of pollen from soils where preservation has been less than ideal and pollen density is lower than in peat.

Hydrochloric acid (10%) is used to remove calcium carbonates present in the soil, after which the samples are screened through 150 micron mesh. The material remaining in the pollen screen was saved and examined to recover macrofloral remains. The samples are rinsed until neutral by adding water, letting the samples stand for 2 hours, then pouring off the supernatant. A small quantity of sodium hexametaphosphate is added to each sample once it reaches neutrality, then the samples are allowed to settle according to Stoke's Law in settling columns. This process is repeated with ethylenediaminetetraacetic acid (EDTA). These steps remove clay prior to heavy liquid separation. The samples are then freeze dried. Sodium polytungstate (SPT), with a density 1.8, is used for the flotation process. The samples are mixed with SPT and centrifuged at 1500 rpm for 10 minutes to separate organic from inorganic remains. The supernatant containing pollen and organic remains is decanted. Sodium polytungstate is again added to the inorganic fraction to repeat the separation process. The supernatant is decanted into the same tube as the supernatant from the first separation. This supernatant is then centrifuged at 1500 rpm for 10 minutes to allow any silica remaining to be separated from the organics. Following this, the supernatant is decanted into a 50 ml conical tube and diluted with distilled water. These samples are centrifuged at 3000 rpm to concentrate the organic fraction in the bottom of the tube. After rinsing the pollen-rich organic fraction obtained by this separation, all samples receive a short (20-30 minute) treatment in hot hydrofluoric acid to remove any remaining inorganic particles. The samples are then acetolated for 3-5 minutes to remove any extraneous organic matter.

A light microscope is used to count the pollen to a total of approximately 30 to 100 pollen grains at a magnification of 500x. Pollen preservation in these samples varied from good to poor. Comparative reference material collected at the Intermountain Herbarium at Utah State University and the University of Colorado Herbarium was used to identify the pollen to the family, genus, and species level, where possible.

Pollen aggregates were recorded during identification of the pollen. Aggregates are clumps of a single type of pollen and may be interpreted to represent pollen dispersal over short distances or the introduction of portions of the plant represented into an archaeological setting. Aggregates were included in the pollen counts as single grains, as is customary. The presence of aggregates is noted by an "A" next to the pollen frequency on the pollen diagram. A plus (+) on the pollen diagram indicates that pollen was observed, in spite of the fact that pollen was not present in a sufficient concentration to obtain a full count. Pollen diagrams are produced using Tilia, which was developed by Dr. Eric Grimm of the Illinois State Museum. Total pollen concentrations are calculated in Tilia using the quantity of sample processed in cubic centimeters (cc), the quantity of exotics (spores) added to the sample, the quantity of exotics counted, and the total pollen counted and expressed as pollen per cc of sediment.

Indeterminate pollen includes pollen grains that are folded, mutilated, and otherwise distorted beyond recognition. These grains are included in the total pollen count since they are part of the pollen record. The microscopic charcoal frequency registers the relationship between pollen and charcoal. The total number of microscopic charcoal fragments was divided by the pollen sum, resulting in a charcoal frequency that reflects the quantity of microscopic charcoal fragments observed, normalized per 100 pollen grains.

Macrofloral

The screen contents recovered from the bulk soil samples during pollen extraction were weighed, then passed through a series of graduated screens (US Standard Sieves with 2-mm, 1-mm, 0.5-mm and 0.25-mm openings) to separate charcoal debris and to initially sort the remains. The contents of each screen then were examined. Charcoal pieces were broken to expose a fresh cross section and examined under a binocular microscope at a magnification of 70x. The weights of each charcoal type were recorded. The material that remained in the 2-mm, 1-mm, 0.5-mm, and 0.25-mm sieves was scanned under a binocular stereo microscope at a magnification of 10x, with some identifications requiring magnifications of up to 70x. The material that passed through the 0.25-mm screen was not examined.

The detrital charcoal samples were water-screened through a 250 micron mesh sieve and allowed to dry. The dried samples were scanned under a binocular stereo microscope at a magnification of 10x. Charcoal fragments were separated and examined under a binocular microscope at a magnification of 70x. Macrofloral remains, including charcoal, were identified using manuals (Core, et al. 1976; Martin and Barkley 1961; Panshin and Zeeuw 1980; Petrides and Petrides 1992) and by comparison with modern and archaeological references. The term "seed" is used to represent seeds, achenes, caryopses, and other disseminules.

DISCUSSION

The study sites are located near the town of John Day, Oregon. The morphology of the river terraces and floodplain reflect a long history of snow melt hydrology and landslide activity. Very large landslides appear to have dammed the river for long periods of time, perhaps hundreds of years. Local vegetation in the study area is dominated by conifers and annual grasses.

Samples MJD1-9 from a depth of 45-60 cm, MJD1-10 from a depth of 25-40 cm, and MJD3-7 from a depth of 65-70 cm reflect bulk soil samples examined for pollen and macrofloral remains (Table 1). Small total pollen concentrations were obtained for each of these samples, with sample (MJ1-9) yielding the least pollen. Total pollen concentration probably reflects depositional history, with the largest concentration (MJD1-10) representing the slowest deposition and the smallest concentration (MJD1-9) representing the most rapid deposition.

The pollen record for samples MJD1-10 and MJD3-7 is dominated by *Pinus* pollen (Figure 1, Table 2), reflecting local pines. Other trees represented in this record include *Alnus*, Cupressaceae, *Larix*, and *Tsuga*, representing alder, members of the cypress family, larch, and hemlock. Hemlock does not grow in the area today, although it appears to have been an abundant tree in the local forest in the past. Pollen representing shrubby and herbaceous plants includes *Artemisia*, Low-spine Asteraceae, High-spine Asteraceae, Cheno-am, Corylaceae, Cyperaceae, Onagraceae, Poaceae, and *Symphoricarpos*, indicating local growth of sagebrush, various members of the sunflower family (including the groups that include ragweed, marshelder, cocklebur and most of the rest of the family), Cheno-ams, members of the hazel family, sedges, members of the evening primrose family, grasses, and snowberry. Interpreting the meaning of variation in pollen frequencies lies with a more thorough understanding of the depositional history of these sediments. In addition, algal and fungal spores are present. *Zygnema* spores represent a fungus that grows in the presence of oxidizing conditions. Microscopic charcoal fragments also were recorded and indicate that fires were more abundant or there was more charcoal transport at the time MJD1-10 accumulated than at other times examined.

The macrofloral record for these bulk soil samples yielded small fragments of charcoal. Sample MJD1-9 contained one small fragment of conifer charcoal too small for further identification (Table 3, Table 4). Small fragments of conifer charcoal also were present in sample MJD1-10, including two fragments of incompletely burned conifer charcoal. In addition, three charred bark fragments were noted. Sample MJD3-7 yielded three fragments of *Pinus* charcoal, reflecting local pines. A few uncharred Poaceae leaf/stem fragments and a few uncharred rootlets represent modern grasses.

Charcoal sample MJD1-1 was recovered from the Btb horizon at a depth of 77 cm. This sample contained ten small fragments of conifer charcoal and two pieces of unidentified hardwood too small for identification.

Several fragments of vitrified probable *Larix occidentalis* charcoal were present in sample MJD1-2 from the top of the B1 horizon at a depth of 26 cm. Vitrified charcoal has a shiny, glassy appearance due to fusion by heat. A vitrified appearance might indicate that the wood had burned while "green" and fresh with a higher sap content.

Sample MJD1-3 was taken from a depth of 57 cm at the base of the B2 horizon. This sample consisted of sand and one piece of charred parenchymous tissue. "Parenchyma is the botanical term for relatively undifferentiated tissue, composed of many similar thin-walled cells...which form a ground tissue that surrounds other tissues. Parenchyma occurs in many different plant organs in varying amounts. Large fleshy organs such as ...roots and stems are composed largely of parenchyma. ...The vegetative storage parenchyma in swollen roots and stems stores starch and other carbohydrates and sugars ..." (Hather 2000:1). Recovery of parenchymous tissue reflects either burned root or stem tissue.

Sample MJD1-4 was collected from the base of the BA horizon at a depth of 18 cm. One piece of conifer charcoal was present but was too vitrified for further identification. A few uncharred rootlets represent modern plants.

Sample MJD1-5 reflects the BA horizon at a depth of 16 cm. This sample contained several fragments of *Pinus* charcoal, including three pieces that were incompletely charred. Several small fragments of *Pinus* charcoal also were present in sample MJD1-6 from the top of the B1 horizon at a depth of 22 cm.

Sample MJD1-7 was taken from a depth of 38 cm at the base of the B1 horizon. This sample yielded five fragments of *Larix occidentalis* charcoal, reflecting local western larch wood that burned. Sample MJD1-8 represents the B1 horizon at a depth of 34 cm. Several fragments of conifer charcoal too vitrified for further identification were noted in this sample.

Sample MJD2A-1 was recovered from an outcrop in the channel at a depth of 200 cm. These deposits are believed to be several thousand years old. The sample consisted of sand and one fragment of *Tsuga* charcoal, representing either western hemlock or mountain hemlock. Hemlocks currently are not found in the John Day River basin; however, recovery of *Tsuga* charcoal and pollen in these samples suggests that hemlocks grew in the area prehistorically.

Samples MJD2A-2 and MJD2A-3 were collected from the base of the bank exposure at depths of 172 and 175 cm, respectively. Sample MJD2A-2 yielded only rock/gravel and clay. Three small fragments of *Pinus* charcoal were noted in sample MJD2A-3, representing the presence of pine trees.

Sample MJD2B-1 was recovered from the Bt2 horizon at a depth of 205 cm. This sample contained a piece of *Pinus* charcoal and several fragments of conifer charcoal too small for further identification. Two pieces of charred, vitrified tissue might reflect charcoal or other charred plant tissue too vitrified for identification.

Pieces of vitrified conifer charcoal were present in sample MJD2B-2 from a depth of 93 cm in the B2 horizon. Two other fragments of charcoal were too vitrified for identification. These charcoal fragments may suggest burning of fresh, green wood.

Sample MJD2B-3 was taken from the Bt1 horizon at a depth of 135 cm. This sample yielded several fragments of *Tsuga* charcoal. One uncharred Poaceae floret represents a modern grass in the area. Pieces of *Tsuga* charcoal also were noted in sample MJD2B-4 from the base of the B2 horizon at a depth of 104 cm and in sample MJD2B-5 from a depth of 170 cm in a debris flow. These deposits appear to reflect a time when hemlocks were growing in the area.

Sample MJD3-1 was collected from the top of the B2 horizon at a depth of 46 cm. This sample contained six fragments of charcoal too small for identification. An uncharred *Amaranthus* seed and a few uncharred rootlets represent modern plants.

Sample MJD3-2 from the base of the B1 horizon at a depth of 40 cm contained three small pieces of charred bark. One charred parenchymous tissue fragment reflects burned root or stem tissue. Four pieces of conifer charcoal in sample MJD3-3 from a depth of 57 cm at the base of the B2 horizon were too small and vitrified for further identification.

Sample MJD3-4 was recovered from a depth of 68 cm in the Ab horizon. This sample contained several fragments of *Larix occidentalis* charcoal, reflecting western larch that burned. Two small fragments of charcoal in sample MJD3-5 from a depth of 77 cm in the Bb horizon were too vitrified for identification.

Sample MJD3-6 was taken from the top of the 2C horizon at a depth of 87 cm. This sample yielded seven fragments of *Alnus* charcoal, reflecting alder wood that burned. Alders are shrubs to medium-sized trees, and they are associated with water everywhere they grow. The presence of mountain alder (*A. tenuifolia*) denotes running water (Peattie 1953:396-400; Robinson 1979:17-19).

Sample MJD4-1 was collected from the 2Bw horizon at a depth of 21 cm. This sample contained seven small fragments of *Larix occidentalis* charcoal, reflecting the presence of western larch. Sample MJD4-2 from the base of the 2Bw horizon at a depth of 27 cm yielded a single piece of *Pinus* twig charcoal.

Samples MJD4-3 and MJD4-4 were recovered from the top of the 2C horizon at depths of 32 and 28 cm, respectively. Sample MJD4-3 yielded six small fragments of *Tsuga* charcoal. Several fragments of conifer charcoal too small for further identification were noted in sample MJD4-4.

Sample MJD4-5 represents the top of the 2Bw horizon at a depth of 13 cm. This sample contained eight fragments of unidentified hardwood root charcoal.

SUMMARY AND CONCLUSIONS

Pollen analysis of three bulk soil samples from along the Middle Fork John Day River in east-central Oregon suggests rapid deposition of sediments and provides evidence of local and/or regional fires. The largest quantity of microscopic charcoal corresponds with the largest total pollen concentration, suggesting a slower deposition for sediment represented by sample MJD1-10 than MJD3-7. Sediment represented by sample MJD1-9 appears to have accumulated much faster than either of the other two layers. The pollen record indicates the presence of a wooded or forested area either at the area sampled or within a very short distance of the area sampled.

Macrofloral analysis, including charcoal identification, resulting in recovery of charcoal and other charred material. Conifers appears to have been common in this area, including pine, western larch, and hemlock. Conifer charcoal not further identified to genus was noted in nine of the twenty-seven samples examined, while *Pinus* charcoal was noted in six samples. Four samples contained *Larix occidentalis* charcoal, and five samples yielded *Tsuga* charcoal. Although hemlocks are not noted to grow in the John Day river basin today, recovery of *Tsuga* pollen and charcoal in these samples suggests that hemlocks grew in the area prehistorically. Charcoal representative of riparian plants is rare, represented by *Alnus* charcoal in sample

MJD3-6. Unidentified hardwood charcoal in two other samples might also reflect alder or another type of hardwood such as willow or cottonwood.

TABLE 1
PROVENIENCE DATA FOR SAMPLES FROM MIDDLE FORK JOHN DAY RIVER

Sample No.	Depth (cmbs)	Provenience/ Description	Analysis
MJD1-1	77	Charcoal; Btb horizon	Charcoal ID
MJD1-2	26	Charcoal; Top of B1 horizon	Charcoal ID
MJD1-3	57	Charcoal; Base of B2 horizon	Charcoal ID
MJD1-4	18	Charcoal; Base of BA horizon	Charcoal ID
MJD1-5	16	Charcoal; BA horizon	Charcoal ID
MJD1-6	22	Charcoal; Top of B1 horizon	Charcoal ID
MJD1-7	38	Charcoal; Base of B1 horizon	Charcoal ID
MJD1-8	34	Charcoal; B1 horizon	Charcoal ID
MJD1-9	45-60	Bulk soil sample	Pollen Charcoal ID
MJD1-10	25-40	Bulk soil sample	Pollen Charcoal ID
MJD2A-1	200	Charcoal; Outcrop in channel (sand bed)	Charcoal ID
MJD2A-2	172	Charcoal; Bank of base exposure	Charcoal ID
MJD2A-3	175	Charcoal; Bank of base exposure	Charcoal ID
MJD2B-1	205	Charcoal; Bt2 horizon	Charcoal ID
MJD2B-2	93	Charcoal; B2 horizon	Charcoal ID
MJD2B-3	135	Charcoal; Bt1 horizon	Charcoal ID
MJD2B-4	104	Charcoal; B2 horizon	Charcoal ID
MJD2B-5	170	Charcoal; Debris flow deposit	Charcoal ID
MJD3-1	46	Charcoal; Top of B2 horizon	Charcoal ID
MJD3-2	40	Charcoal; Base of B1 horizon	Charcoal ID
MJD3-3	57	Charcoal; Base of B2 horizon	Charcoal ID
MJD3-4	68	Charcoal; Ab horizon	Charcoal ID
MJD3-5	77	Charcoal; Bb horizon	Charcoal ID
MJD3-6	87	Charcoal; Top of 2C horizon	Charcoal ID
MJD3-7	65-70	Bulk soil sample	Pollen Charcoal ID
MJD4-1	21	Charcoal; 2Bw horizon	Charcoal ID

TABLE 1 (Continued)

Sample No.	Depth (cmbs)	Provenience/ Description	Analysis
MJD4-2	27	Charcoal; Base of 2Bw horizon	Charcoal ID
MJD4-3	32	Charcoal; Top of 2C horizon	Charcoal ID
MJD4-4	28	Charcoal; Top of 2C horizon	Charcoal ID
MJD4-5	13	Charcoal; Top of 2Bw horizon	Charcoal ID

TABLE 2
POLLEN TYPES OBSERVED IN SAMPLES FROM MIDDLE FORK JOHN DAY RIVER, OREGON

Scientific Name	Common Name
ARBOREAL POLLEN:	
Alnus	Alder
Cupressaceae	Cypress family
Pinaceae:	Pine family
Larix	Western Larch
Pinus	Pine
Symphoricarpos	Western snowberry
Tsuga	Hemlock
NON-ARBOREAL POLLEN:	
Asteraceae:	Sunflower family
Artemisia	Sagebrush
Low-spine	Includes ragweed, cocklebur, sumpweed
High-spine	Includes aster, rabbitbrush, snakeweed, sunflower, etc.
Cheno-am	Includes the goosefoot family and amaranth
Corylaceae	Hazel family
Cyperaceae	Sedge family
Onagraceae (Gaura)	Evening primrose family
Poaceae	Grass family
Indeterminate	Too badly deteriorated to identify
ALGAE:	
Algal Spore	Algal spore
Zygnema-type	Algal body
FUNGAL SPORES:	
Fungal Spore	Fungal spore
OTHER:	
Charcoal	Microscopic charcoal
Total pollen concentration	Quantity of pollen per cubic centimeter (cc) of sediment

TABLE 3
MACROFLORAL REMAINS FROM ALONG THE MIDDLE FORK JOHN DAY RIVER, OREGON

Sample No.	Identification	Part	Charred W	Charred F	Uncharred W	Uncharred F	Weights/ Comments
MJD1-9	Pollen Screen Weight						19.65 g
45-60 cm	FLORAL REMAINS:						
Bulk soil	Rootlets					X	Few
	CHARCOAL/WOOD:						
	Conifer	Charcoal		1			<0.001 g
	NON-FLORAL REMAINS:						
	Sand					X	
MJD1-10	Pollen Screen Weight						12.84 g
25-40 cm	FLORAL REMAINS:						
Bulk soil	Rootlets					X	Few
	CHARCOAL/WOOD:						
	Conifer	Charcoal		4			0.003 g
	Conifer	Charcoal		2ic			0.005 g
	Bark	Charcoal		3			0.006 g
	NON-FLORAL REMAINS:						
	Rock/Gravel					X	Few
	Sand					X	
MJD3-7	Pollen Screen Weight						19.13 g
65-70 cm	FLORAL REMAINS:						
Bulk soil	Poaceae	Leaf/Stem				X	Few
	Rootlets					X	Few
	CHARCOAL/WOOD:						
	Pinus	Charcoal		3			0.04 g
	NON-FLORAL REMAINS:						
	Rock/Gravel					X	
	Sand					X	Few
MJD1-1	Water-screened Sample Weight						0.34 g
77 cm	FLORAL REMAINS:						
	Rootlets					X	Few
	CHARCOAL/WOOD:						
	Conifer	Charcoal		10			0.002 g
	Unidentified hardwood - small	Charcoal		2			<0.001 g
	NON-FLORAL REMAINS:						
	Sand					X	

TABLE 3 (Continued)

Sample No.	Identification	Part	Charred W	Charred F	Uncharred W	Uncharred F	Weights/ Comments
MJD1-2	Water-screened Sample Weight						0.82 g
26 cm	FLORAL REMAINS:						
	Rootlets					X	Few
	CHARCOAL/WOOD:						
	cf. *Larix occidentalis* - vitrified	Charcoal		12			0.11 g
	NON-FLORAL REMAINS:						
	Sand					X	
MJD1-3	Water-screened Sample Weight						0.39 g
57 cm	FLORAL REMAINS:						
	Parenchymous tissue			1			0.007 g
	NON-FLORAL REMAINS:						
	Sand					X	
MJD1-4	Water-screened Sample Weight						3.31 g
18 cm	FLORAL REMAINS:						
	Rootlets					X	Few
	CHARCOAL/WOOD:						
	Conifer - vitrified	Charcoal		1			0.87 g
	NON-FLORAL REMAINS:						
	Sand					X	
MJD1-5	Water-screened Sample Weight						2.29 g
16 cm	FLORAL REMAINS:						
	Rootlets					X	Few
	CHARCOAL/WOOD:						
	Pinus	Charcoal		11			0.06 g
	Pinus	Charcoal		1 ic			0.03 g
	NON-FLORAL REMAINS:						
	Clay					X	
MJD1-6	Water-screened Sample Weight						1.47 g
22 cm	CHARCOAL/WOOD:						
	Pinus	Charcoal		9			0.04 g
	NON-FLORAL REMAINS:						
	Sand					X	

TABLE 3 (Continued)

Sample No.	Identification	Part	Charred W	Charred F	Uncharred W	Uncharred F	Weights/ Comments
MJD1-7	Water-screened Sample Weight						0.22 g
38 cm	CHARCOAL/WOOD:						
	Larix occidentalis	Charcoal		5			
	NON-FLORAL REMAINS:						
	Sand					X	
MJD1-8	Water-screened Sample Weight						0.19 g
34 cm	FLORAL REMAINS:						
	Rootlets					X	Few
	CHARCOAL/WOOD:						
	Conifer - vitrified	Charcoal		10			0.02 g
	NON-FLORAL REMAINS:						
	Sand					X	
MJD2A-1	Water-screened Sample Weight						4.78 g
200 cm	FLORAL REMAINS:						
	Rootlets					X	Few
	CHARCOAL/WOOD:						
	Tsuga	Charcoal		1			0.04 g
	NON-FLORAL REMAINS:						
	Sand					X	
MJD2A-2	Water-screened Sample Weight						2.15 g
172 cm	NON-FLORAL REMAINS:						
	Clay					X	
	Rock/Gravel					X	
MJD2A-3	Water-screened Sample Weight						0.85 g
175 cm	CHARCOAL/WOOD:						
	Pinus	Charcoal		3			0.05 g
	NON-FLORAL REMAINS:						
	Sand					X	
MJD2B-1	Water-screened Sample Weight						18.18 g
205 cm	FLORAL REMAINS:						
	Vitrified tissue			2			0.01 g
	Roots					X	Few
	CHARCOAL/WOOD:						
	Conifer	Charcoal		15			0.047 g
	Pinus	Charcoal		1			0.005 g
MJD2B-1	NON-FLORAL REMAINS:						

TABLE 3 (Continued)

Sample No.	Identification	Part	Charred W	Charred F	Uncharred W	Uncharred F	Weights/ Comments
205 cm	Rock/Gravel					X	
MJD2B-2	Water-screened Sample Weight						
93 cm	FLORAL REMAINS:						
	Rootlets					X	Few
	CHARCOAL/WOOD:						
	Conifer - vitrified	Charcoal		6			0.01 g
	Unidentified - vitrified	Charocal		2			0.01 g
	NON-FLORAL REMAINS:						
	Sand					X	
MJD2B-3	Water-screened Sample Weight						2.03 g
135 cm	FLORAL REMAINS:						
	Poaceae	Floret			1		
	Rootlets					X	Few
	CHARCOAL/WOOD:						
	Tsuga	Charcoal		19			0.21 g
	NON-FLORAL REMAINS:						
	Sand					X	
MJD2B-4	Water-screened Sample Weight						3.10 g
104 cm	FLORAL REMAINS:						
	Rootlets					X	Few
	CHARCOAL/WOOD:						
	Tsuga	Charcoal		8			0.09 g
	NON-FLORAL REMAINS:						
	Sand					X	
MJD2B-5	Water-screened Sample Weight						12.59 g
170 cm	CHARCOAL/WOOD:						
	Tsuga	Charcoal		20			
	NON-FLORAL REMAINS:						
	Rock/Gravel					X	
	Sand					X	
MJD3-1	Water-screened Sample Weight						0.71 g
46 cm	FLORAL REMAINS:						
	Amaranthus	Seed			1		
	Rootlets					X	Few
MJD3-1	CHARCOAL/WOOD:						
46 cm	Unidentifiable - small	Charcoal		6			<0.001 g

TABLE 3 (Continued)

Sample No.	Identification	Part	Charred W	Charred F	Uncharred W	Uncharred F	Weights/ Comments
	NON-FLORAL REMAINS:						
	Sand					X	
MJD3-2	Water-screened Sample Weight						2.49 g
40 cm	FLORAL REMAINS:						
	Bark			3			0.008 g
	Parenchymous tissue			1			0.002 g
	Rootlets					X	
	NON-FLORAL REMAINS:						
	Sand					X	
MJD3-3	Water-screened Sample Weight						0.45 g
57 cm	FLORAL REMAINS:						
	Rootlets					X	Few
	CHARCOAL/WOOD:						
	Conifer - vitrified	Charcoal		4			0.05 g
	NON-FLORAL REMAINS:						
	Sand					X	
MJD3-4	Water-screened Sample Weight						0.25 g
08-144	FLORAL REMAINS:						
	Rootlets					X	Few
	CHARCOAL/WOOD:						
	Larix occidentalis	Charcoal		17			0.011 g
	NON-FLORAL REMAINS:						
	Sand					X	
MJD3-5	Water-screened Sample Weight						
77 cm	FLORAL REMAINS:						
	Rootlets					X	Few
	CHARCOAL/WOOD:						
	Unidentified - vitrified	Charcoal		2			0.03 g
	NON-FLORAL REMAINS:						
	Sand					X	

TABLE 3 (Continued)

Sample No.	Identification	Part	Charred W	Charred F	Uncharred W	Uncharred F	Weights/ Comments
MJD3-6	Water-screened Sample Weight						1.10 g
87 cm	CHARCOAL/WOOD:						
	Alnus	Charcoal		7			0.006 g
	NON-FLORAL REMAINS:						
	Sand					X	
MJD4-1	Water-screened Sample Weight						0.26 g
21 cm	FLORAL REMAINS:						
	Rootlets					X	Few
	CHARCOAL/WOOD:						
	Larix occidentalis	Charcoal		7			
	NON-FLORAL REMAINS:						
	Sand					X	
MJD4-2	Water-screened Sample Weight						0.17 g
27 cm	FLORAL REMAINS:						
	Rootlets					X	Few
	CHARCOAL/WOOD:						
	Pinus twig	Charcoal		1			0.05 g
	NON-FLORAL REMAINS:						
	Sand					X	
MJD4-3	Water-screened Sample Weight						2.57 g
32 cm	FLORAL REMAINS:						
	Rootlets					X	Few
	CHARCOAL/WOOD:						
	Tsuga	Charcoal		6			0.01 g
	NON-FLORAL REMAINS:						
	Rock/Gravel					X	Few
	Sand					X	
MJD4-4	Water-screened Sample Weight						0.004 g
28 cm	CHARCOAL/WOOD:						
	Conifer	Charcoal		41			0.0013 g
	NON-FLORAL REMAINS:						
	Sand					X	Few

TABLE 3 (Continued)

Sample No.	Identification	Part	Charred W	Charred F	Uncharred W	Uncharred F	Weights/ Comments
MJD4-5	Water-screened Sample Weight						1.07 g
13 cm	FLORAL REMAINS:						
	Rootlets					X	Few
	CHARCOAL/WOOD:						
	Unidentified hardwood root	Charcoal		8			0.102 g
	NON-FLORAL REMAINS:						
	Rock/Gravel					X	Few
	Sand					X	

W = Whole
F = Fragment
X = Presence noted in sample
g = grams
ic= Incompletely charred

TABLE 4
INDEX OF MACROFLORAL REMAINS RECOVERED FROM
ALONG THE MIDDLE FORK JOHN DAY RIVER, OREGON

Scientific Name	Common Name
FLORAL REMAINS:	
Amaranthus	Pigweed, Amaranth
Poaceae	Grass family
Parenchymous tissue	Relatively undifferentiated plant tissue, composed of many similar thin-walled cells
Vitrified tissue	Represents charred material with a shiny, glassy appearance due to fusion by heat
CHARCOAL/WOOD:	
Alnus	Alder
Conifer	Cone-bearing, gymnospermous trees and shrubs, mostly evergreens, including the pine, spruce, fir, juniper, cedar, yew, and cypress
Pinus	Pine
Larix occidentalis	Western larch
Tsuga	Western or mountain hemlock
Unidentified hardwood - small	Wood from a broad-leaved flowering tree or shrub, fragments too small for further identification
Unidentifiable - vitrified	Charcoal exhibiting a shiny, glassy appearance due to fusion by heat

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APPENDIX D - HYDRAULIC MODELING RESULTS

Flow Depth

Depth-Averaged Velocity

Bed shear Stress

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MODEL RESULTS OF DEPTH

2-Year Conditions

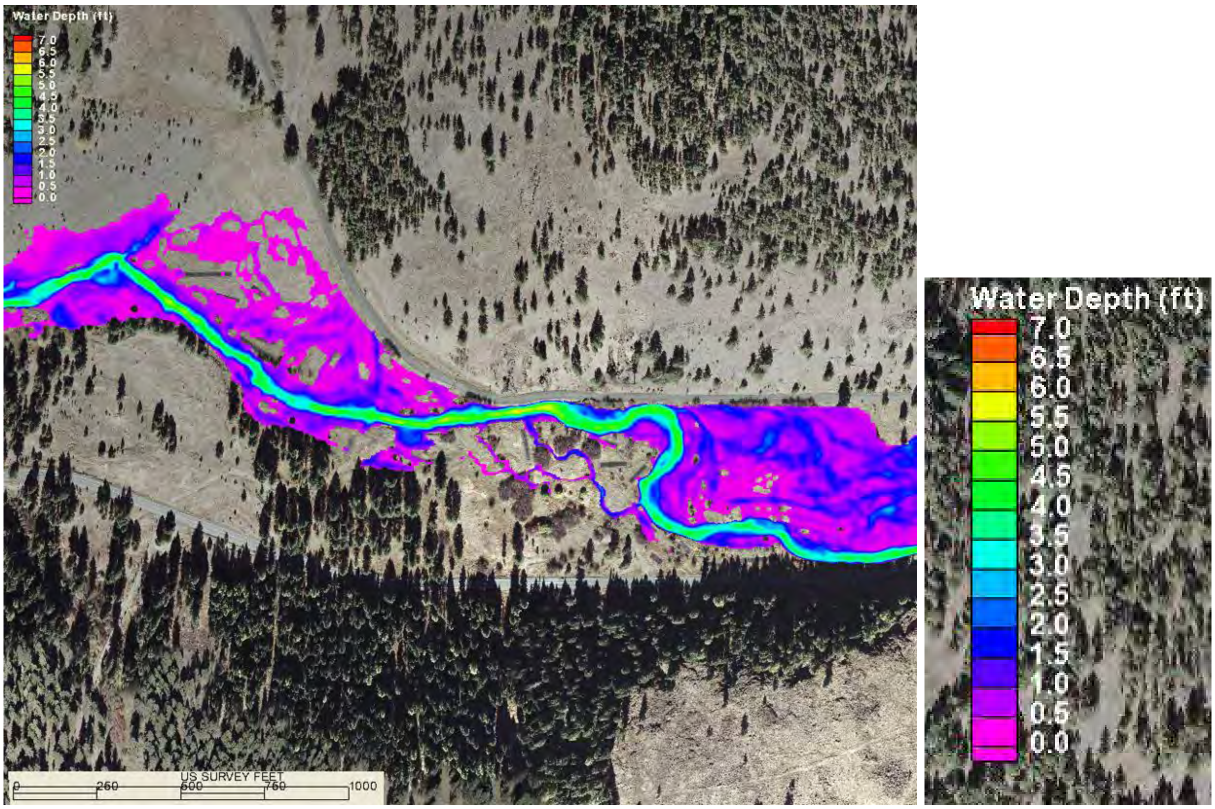


Figure 1 – 2- year water depths under existing conditions upstream of North-South channel bifurcation. Legend is shown at right.

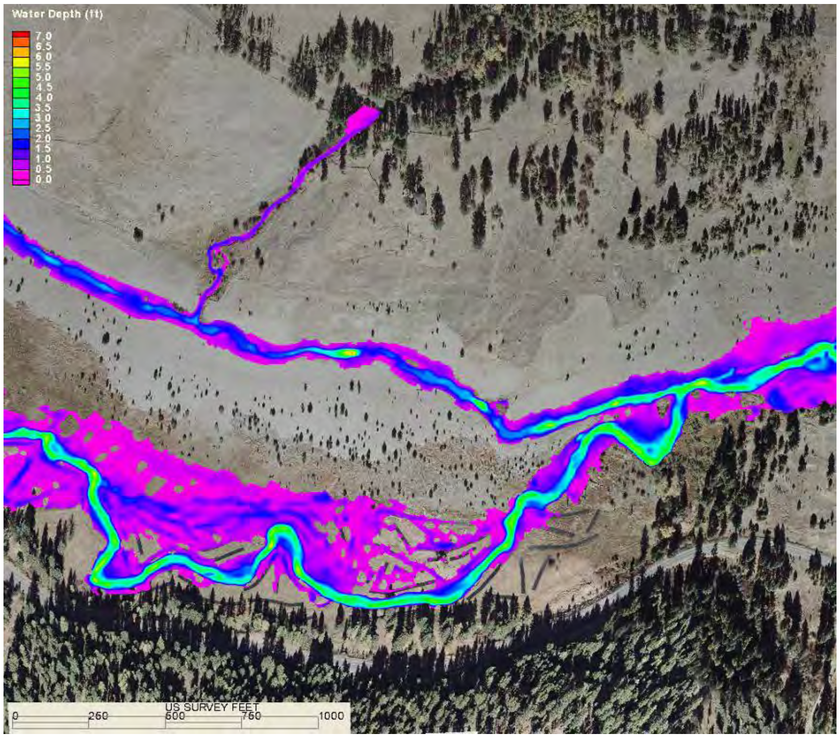


Figure 2 – 2-year water depths under existing conditions downstream of bifurcation.

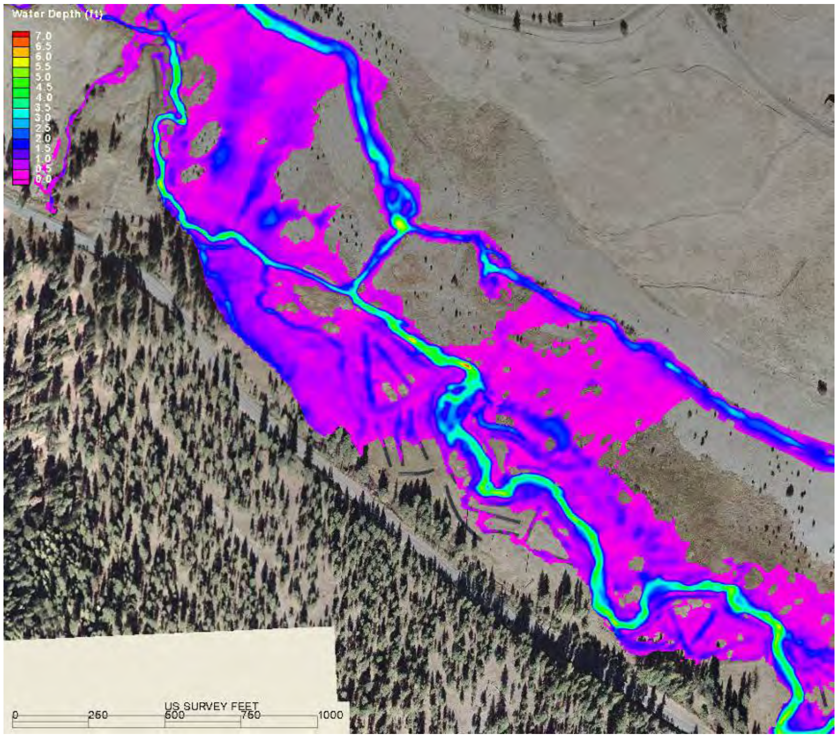


Figure 3 – 2-year water depths under existing conditions near confluence of North and South Channels.

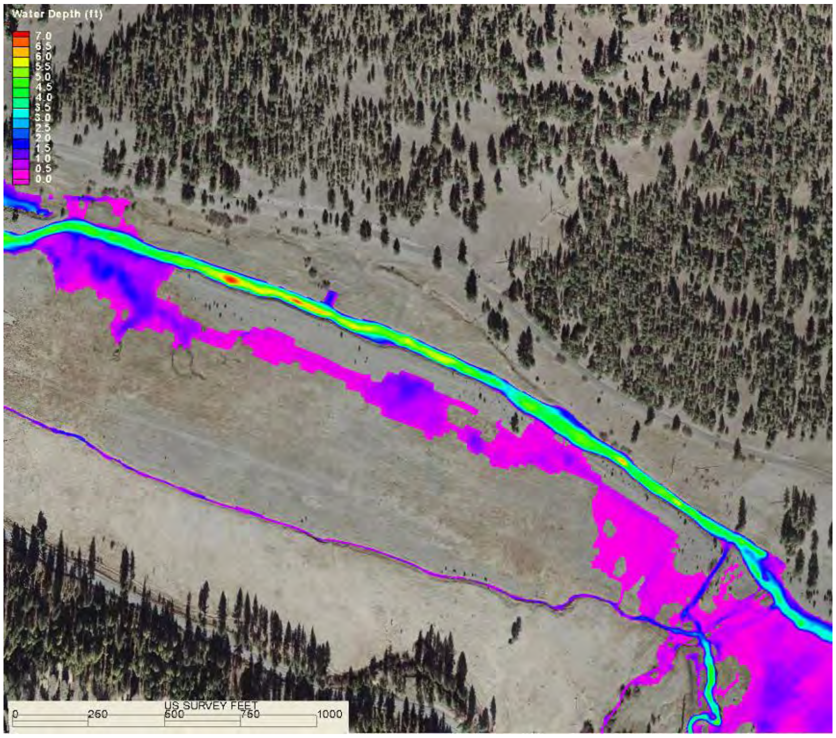


Figure 4 – 2-year water depths under existing conditions downstream from Ruby Creek confluence.

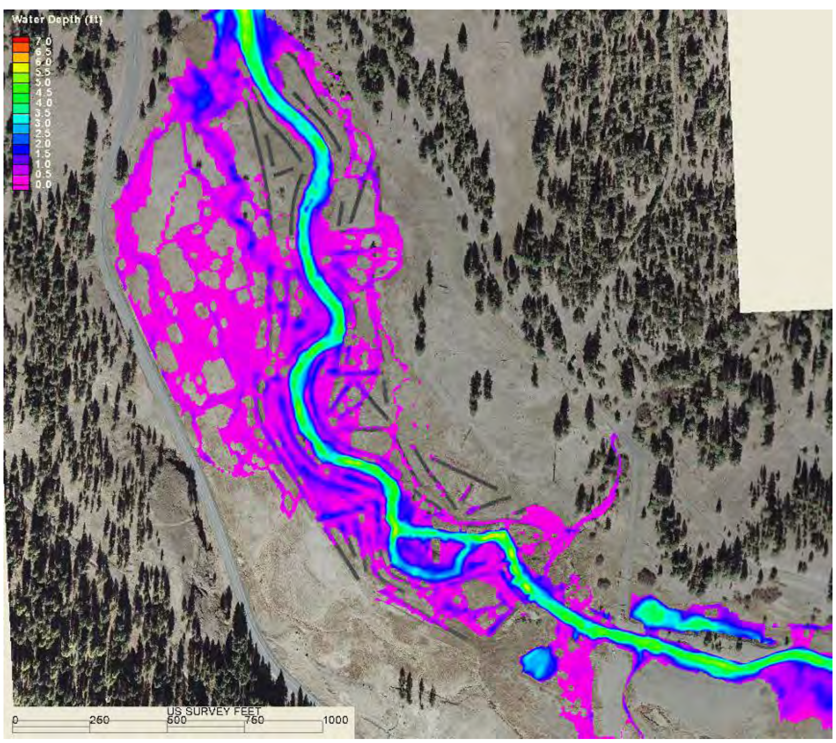


Figure 5 – 2-year water depths under existing conditions downstream from Beaver Creek confluence.

2-Year with North Channel Blocked (only those different than existing)

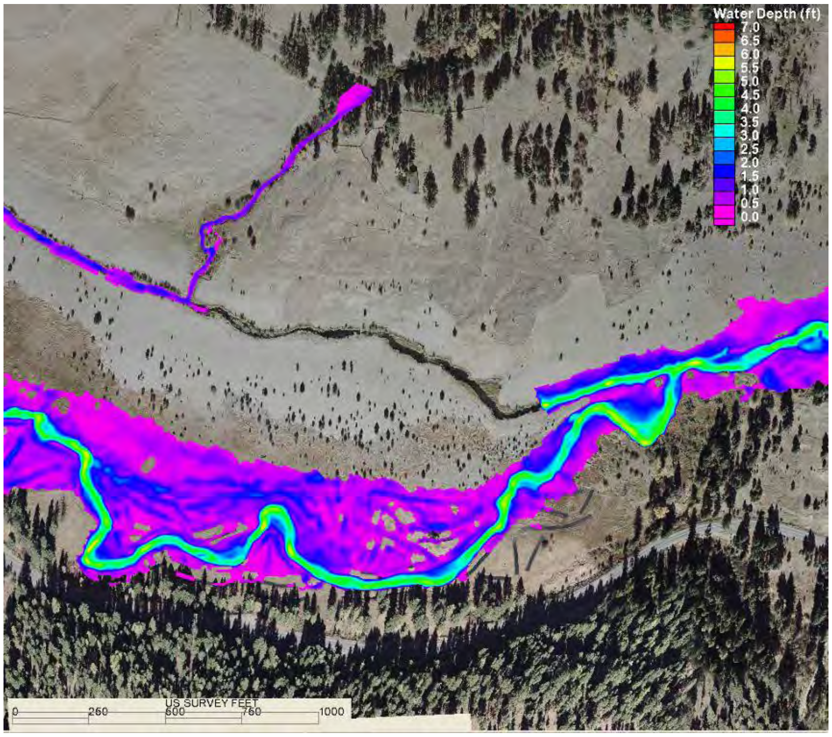


Figure 6 – 2-year water depths with North Channel blocked downstream of bifurcation.

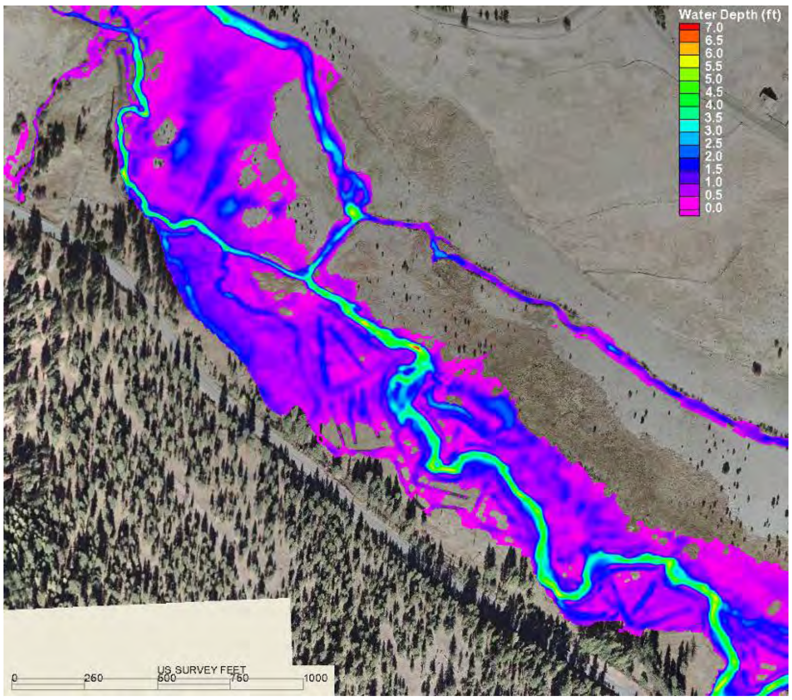


Figure 7 – 2-year water depths with North Channel blocked near confluence of North and South Channels.

10-Year Existing Conditions

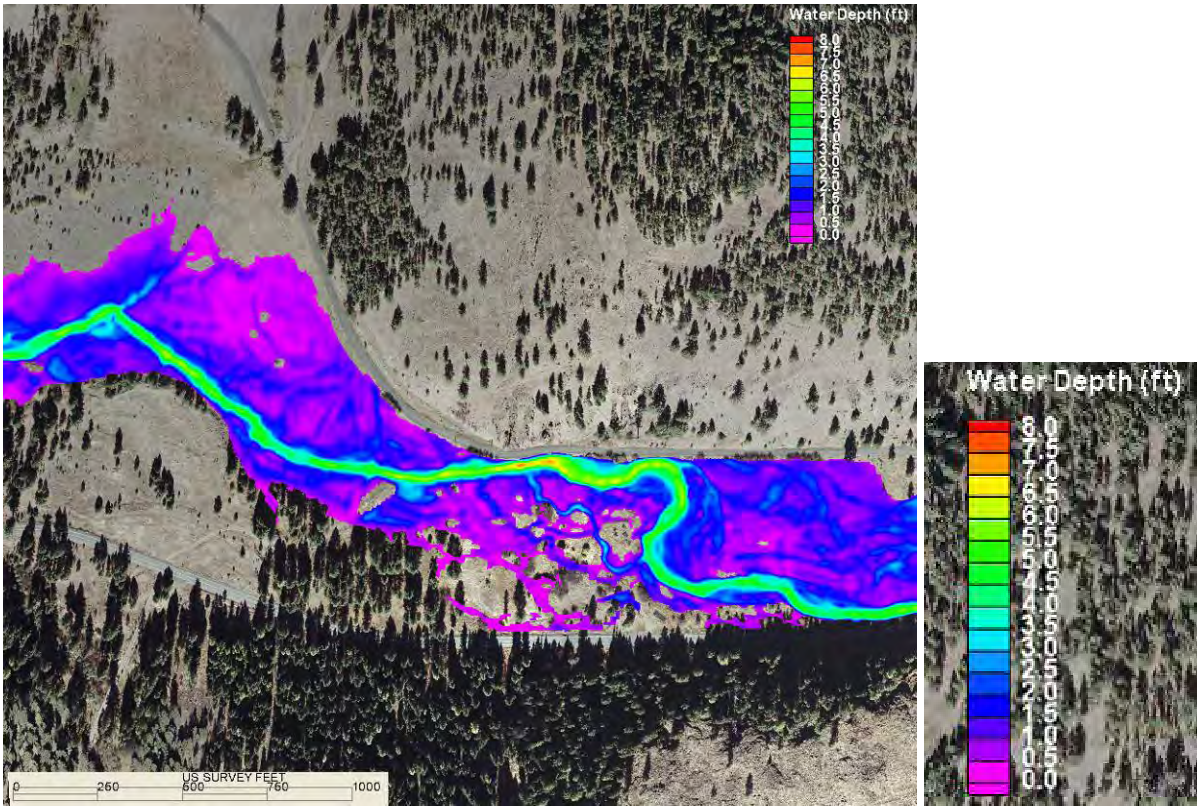


Figure 8 – 10-year water depths under existing conditions upstream of north-south channel bifurcation. Legend is shown at right.

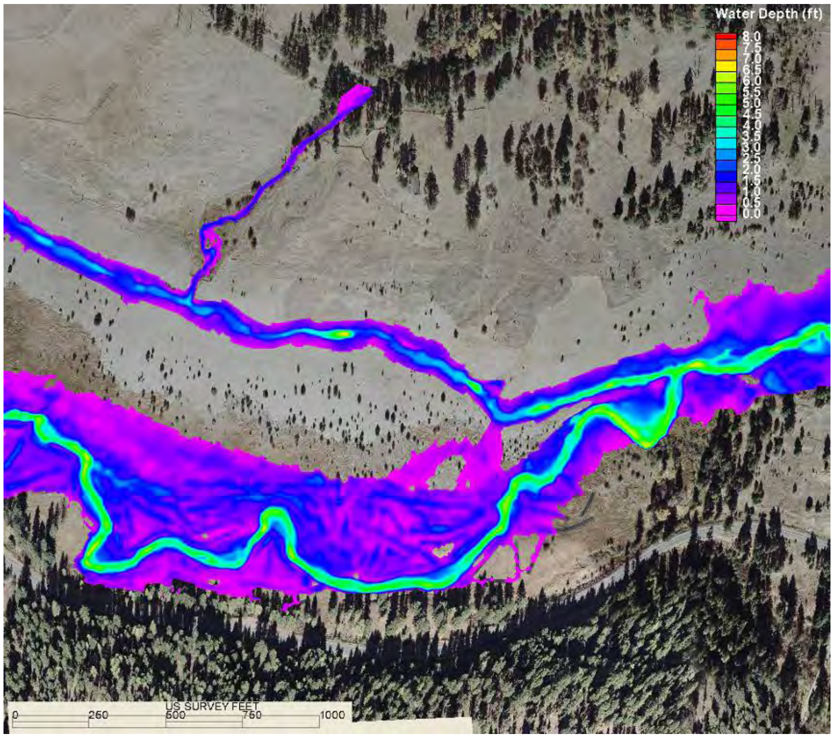


Figure 9 – 10-year water depths under existing conditions downstream from bifurcation.

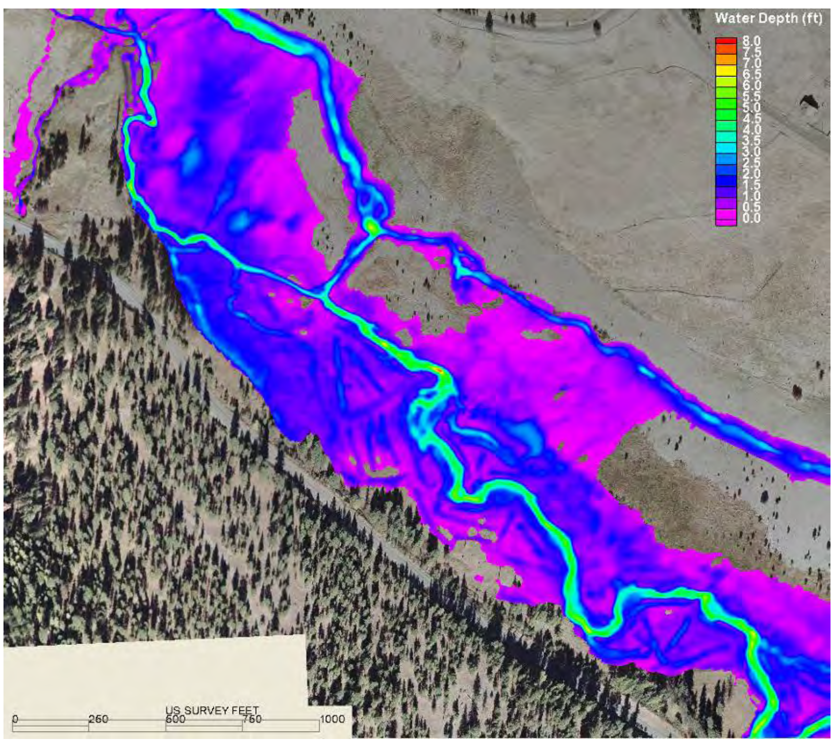


Figure 10 – 10-year water depths under existing conditions near confluence of North and South Channels.

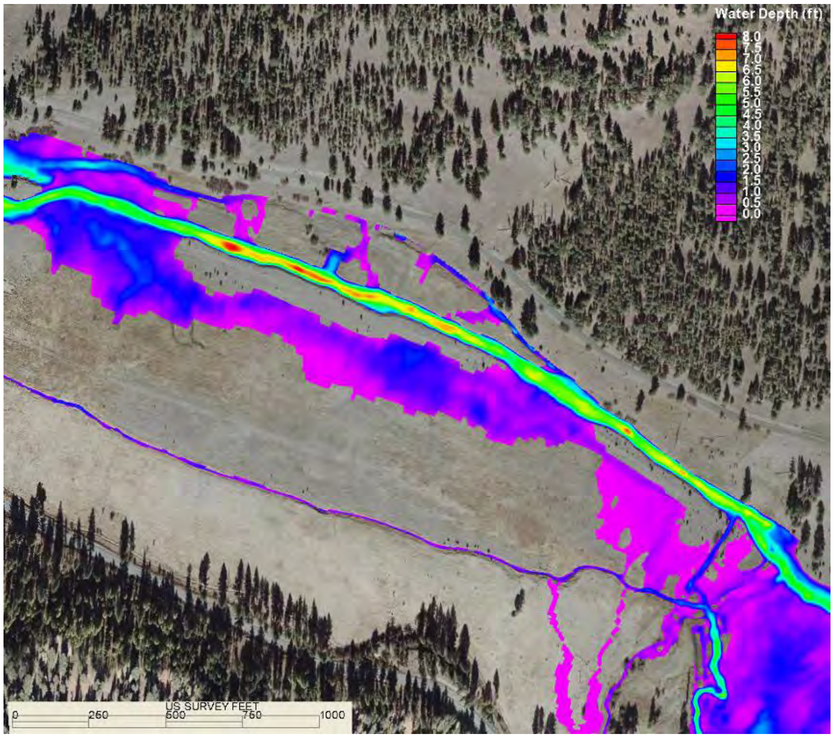


Figure 11 – 10-year water depths under existing conditions downstream from Ruby Creek confluence.

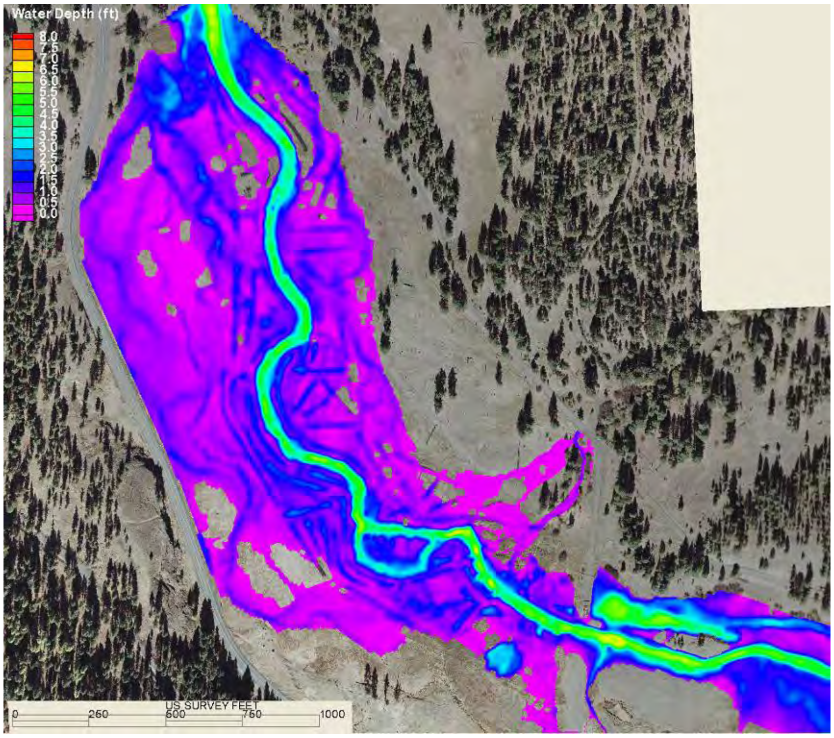


Figure 12 – 10-year water depths under existing conditions downstream from Beaver Creek confluence.

2-Year with North Channel Blocked (only those different than existing)

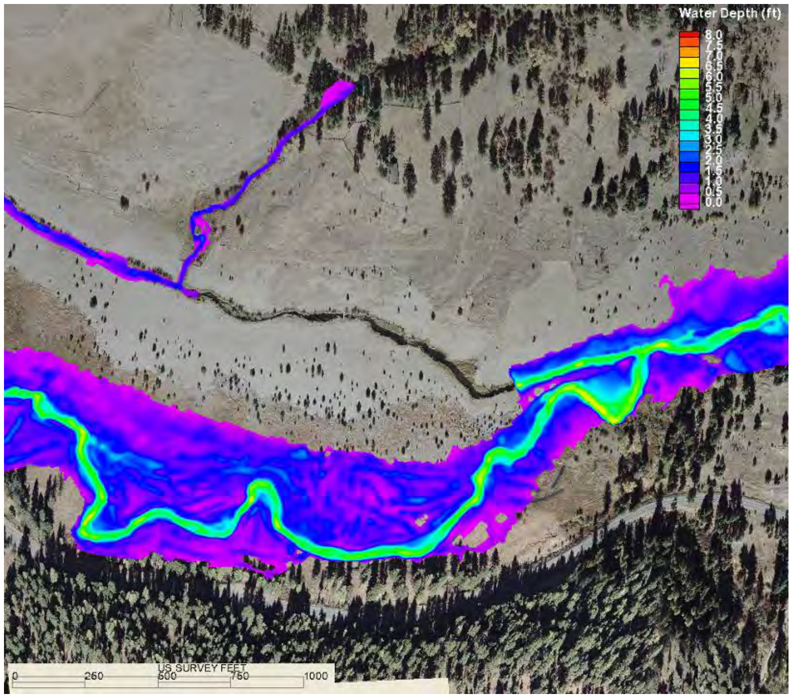


Figure 13 – 10-year water depths with North Channel blocked downstream of bifurcation.

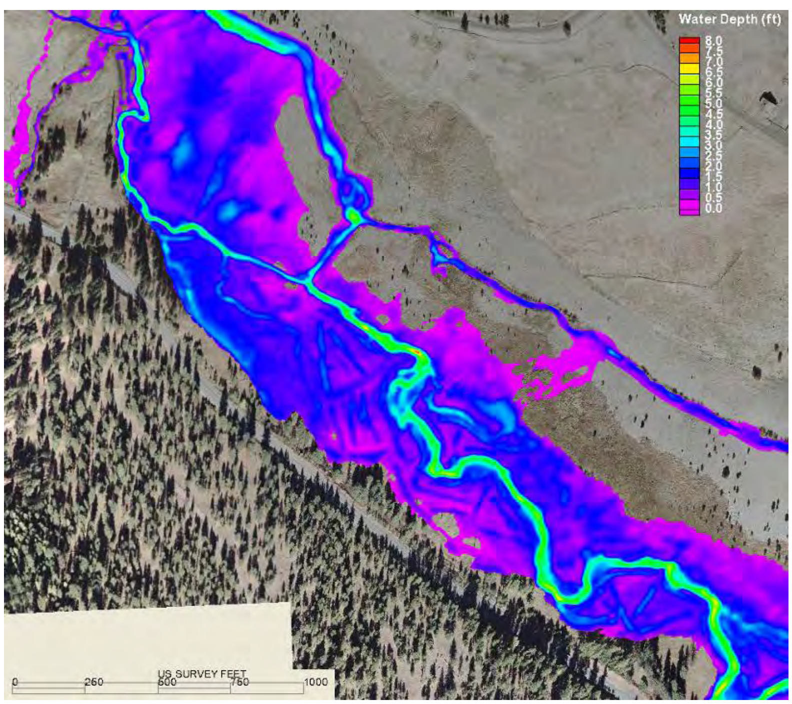


Figure 14 – 10-year water depths with North Channel blocked near confluence of North and South Channels.

100-Year Existing Conditions

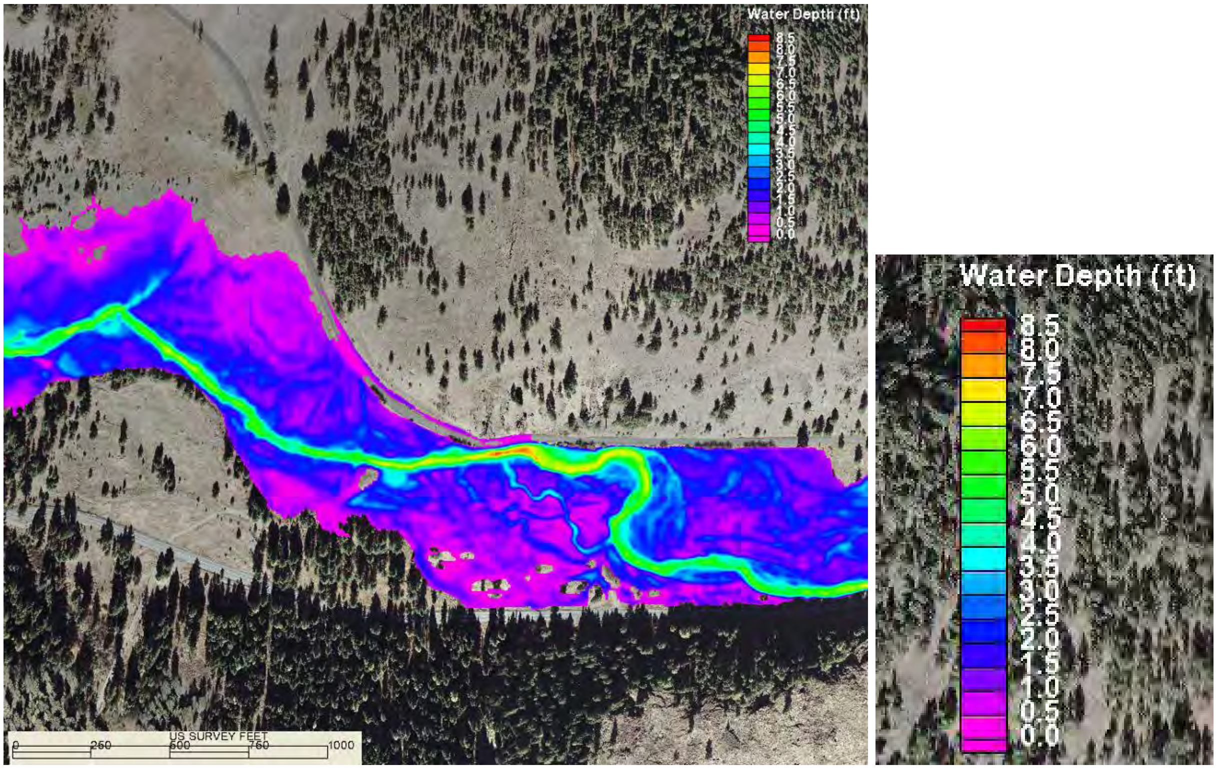


Figure 15 – 100-year water depths under existing conditions upstream of North-South Channel bifurcation. Legend is shown at right.

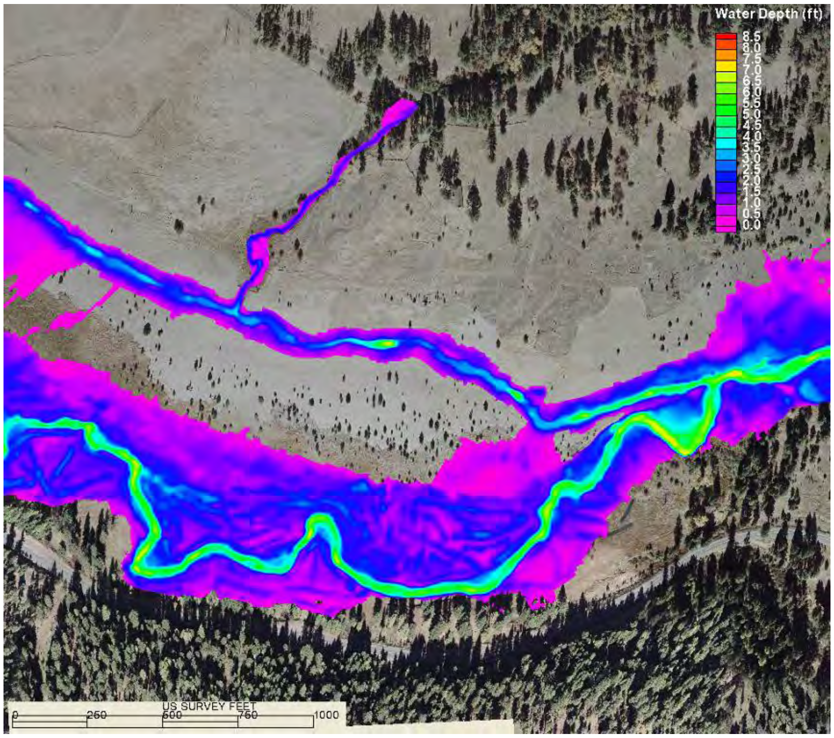


Figure 16 – 100-year water depths under existing conditions downstream from bifurcation.

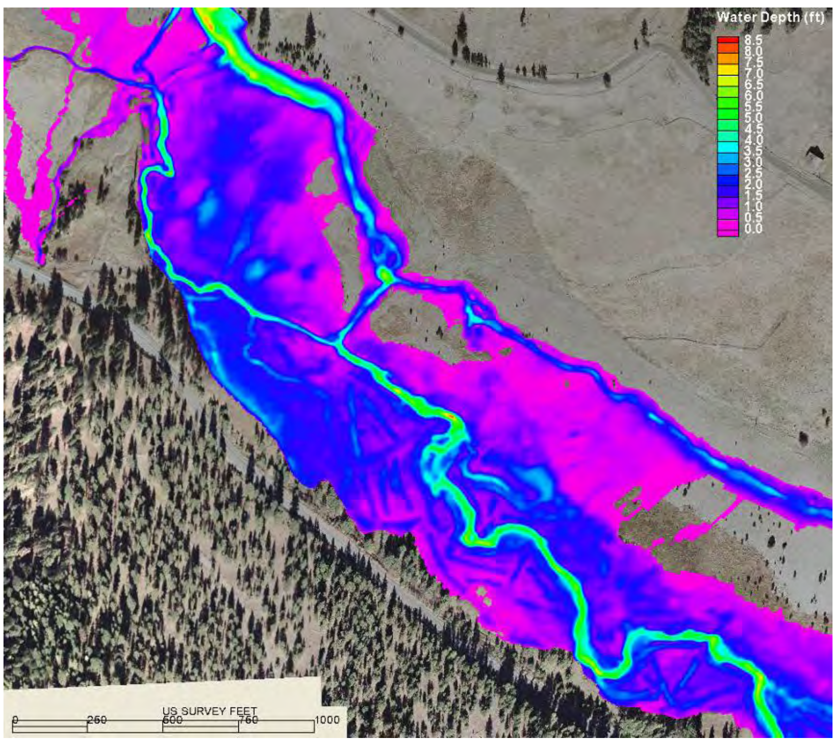


Figure 17 – 100-year water depths under existing conditions near confluence of North and South Channels.

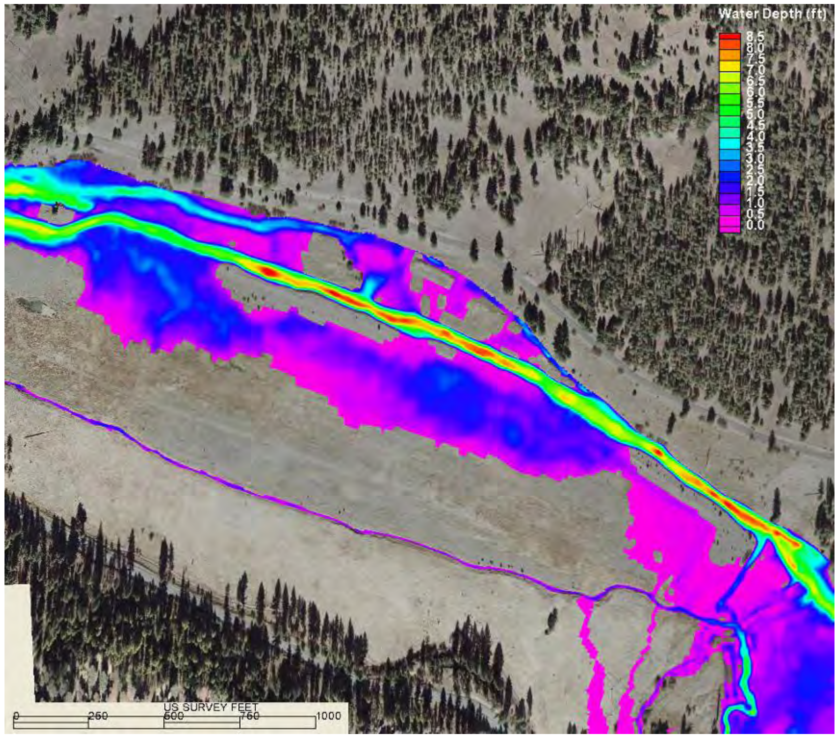


Figure 18 – 100-year water depths under existing conditions downstream from Ruby Creek confluence.

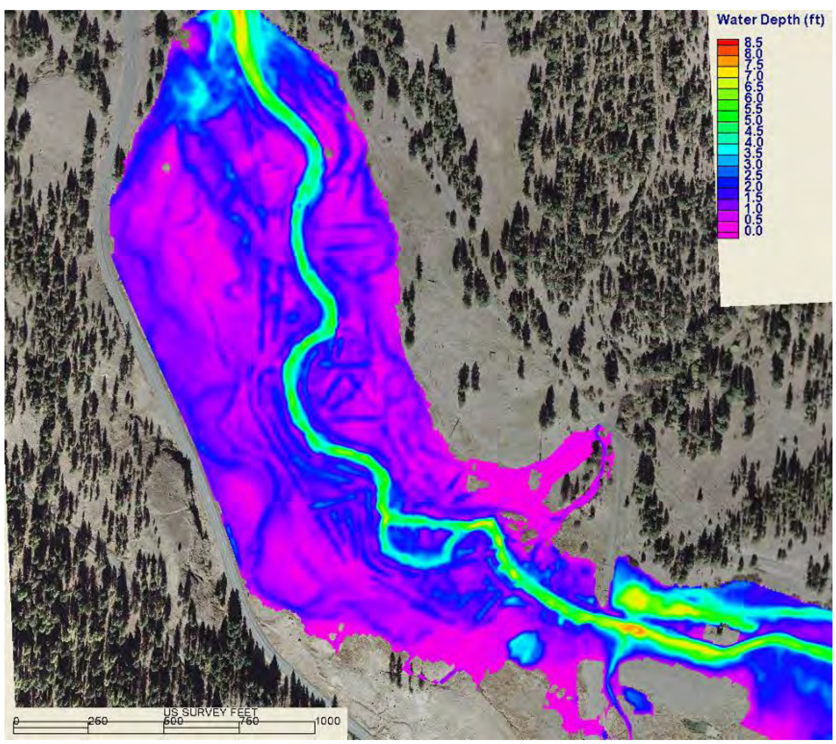


Figure 19 – 100-year water depths under existing conditions downstream from Beaver Creek confluence.

100-Year North Channel Blocked (only those different than existing)

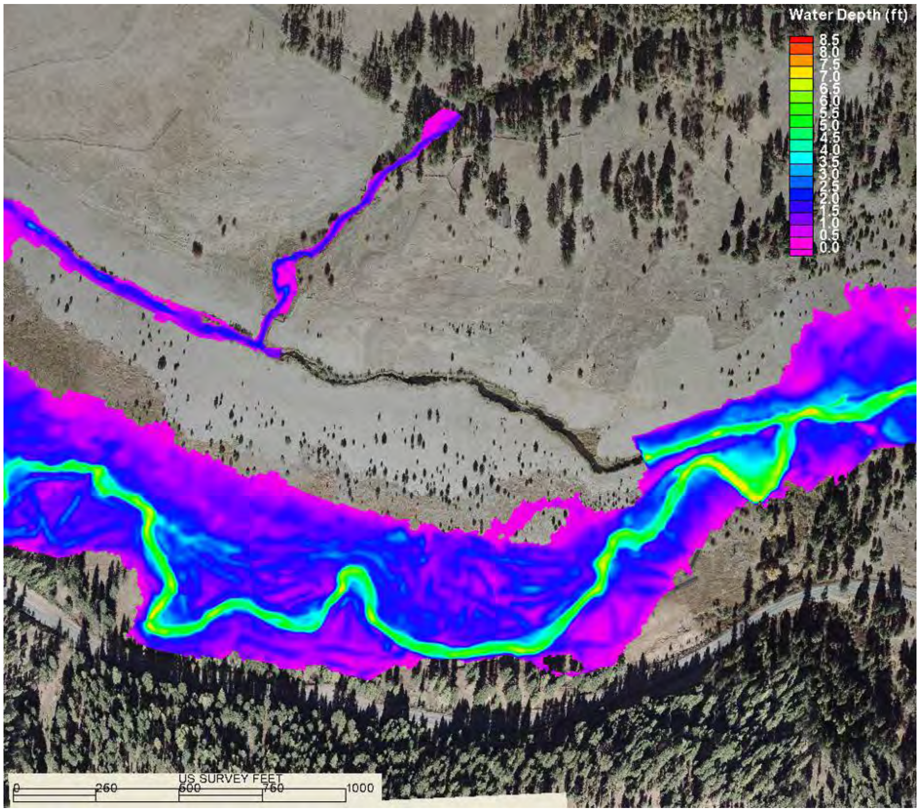


Figure 20 – 100-year water depths with North Channel blocked downstream of bifurcation.

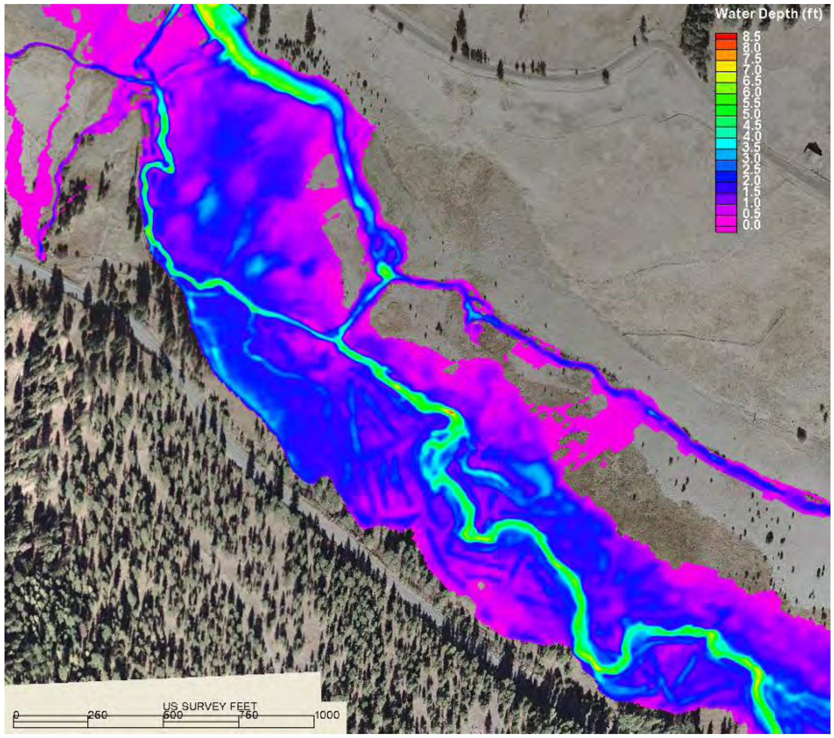


Figure 21 – 100-year water depths with North Channel blocked near confluence of North and South Channels.

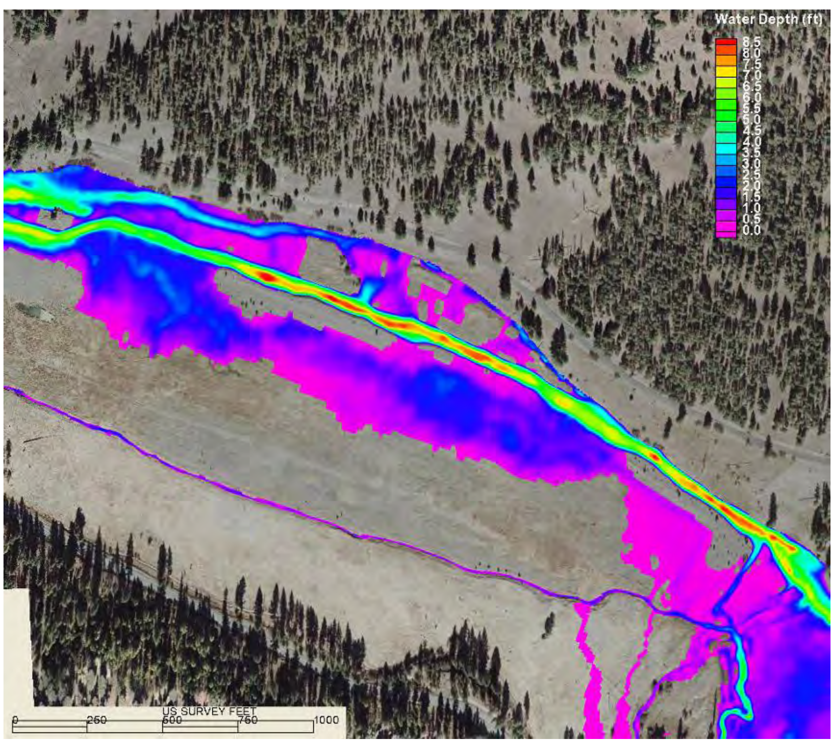


Figure 22 – 100-year water depths with North Channel blocked at Ruby Creek confluence.

MODEL RESULTS OF VELOCITY

2-Year Existing Conditions

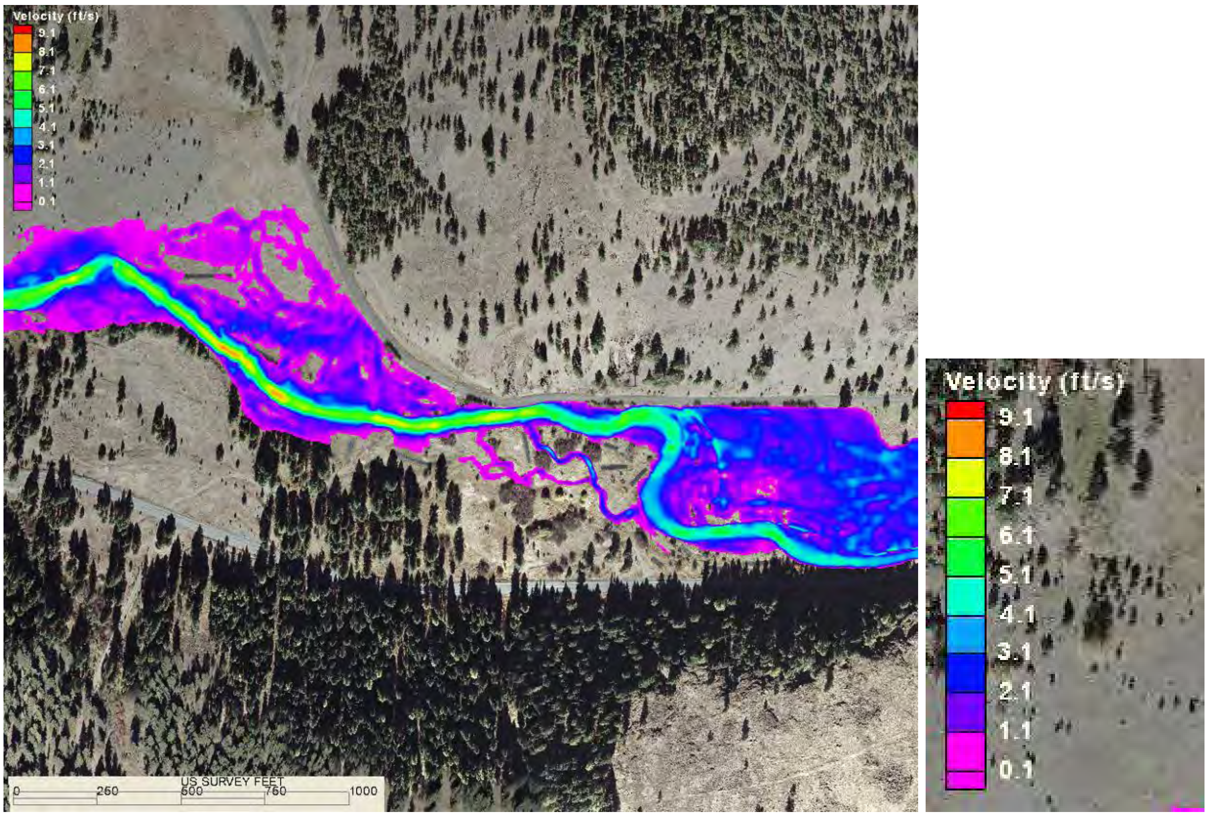


Figure 23 – 2-year velocity under existing conditions upstream of North-South Channel bifurcation. Legend is shown at right.

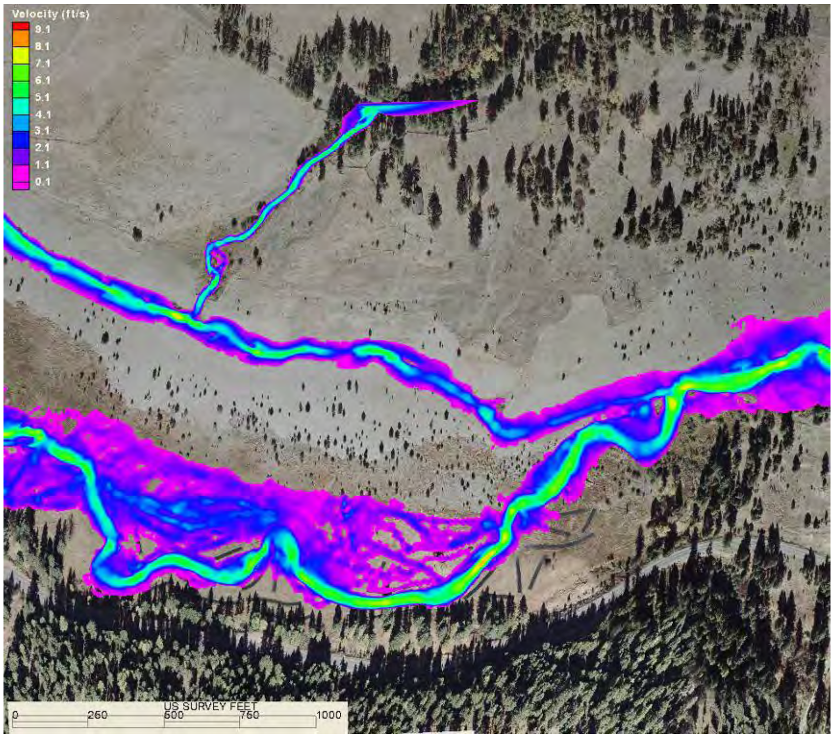


Figure 24 – 2-year velocity under existing conditions downstream of bifurcation.

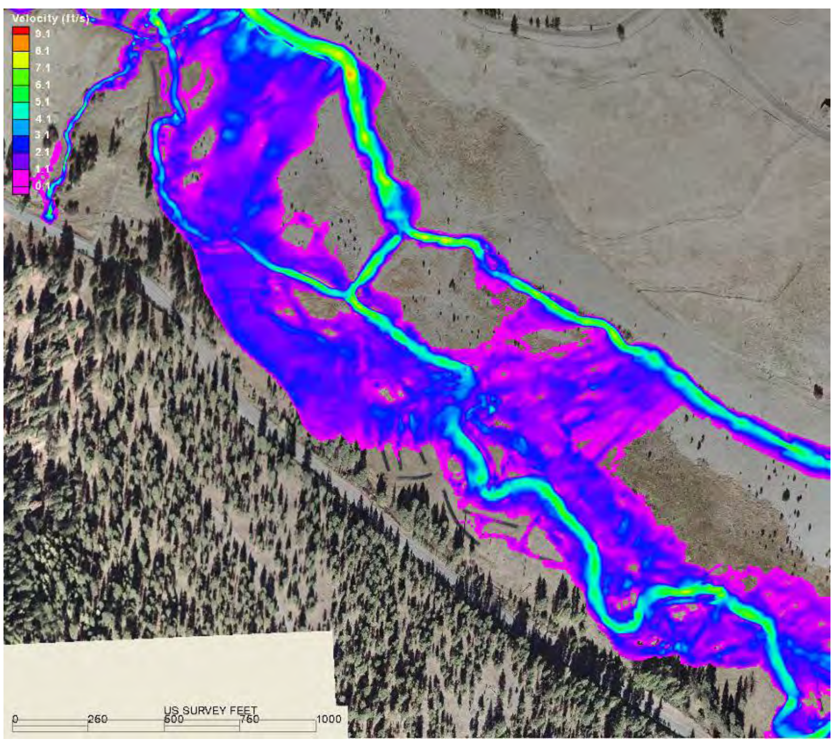


Figure 25 - 2-year velocities under existing conditions near confluence of North and South Channels.

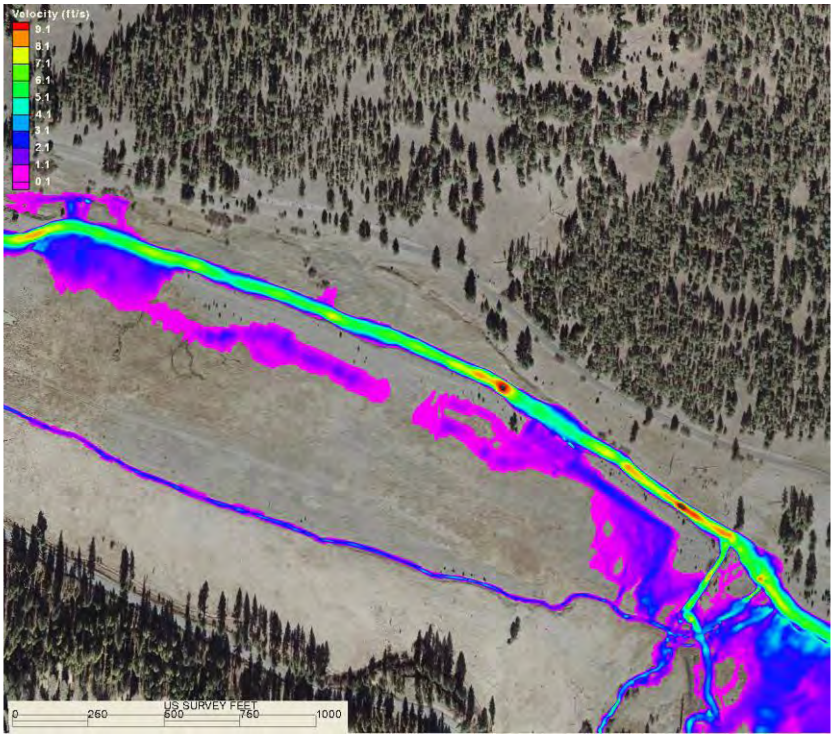


Figure 26 – 2-year velocities under existing conditions downstream from Ruby Creek confluence.

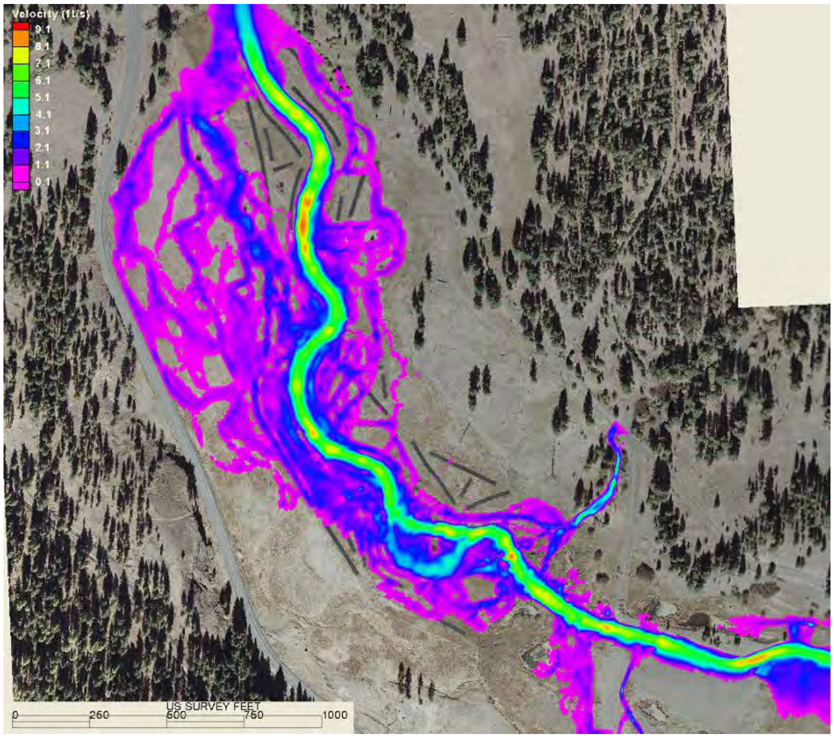


Figure 27 – 2-year velocity under existing conditions downstream from Beaver Creek confluence.

2-Year North Channel Block (only those different than existing)

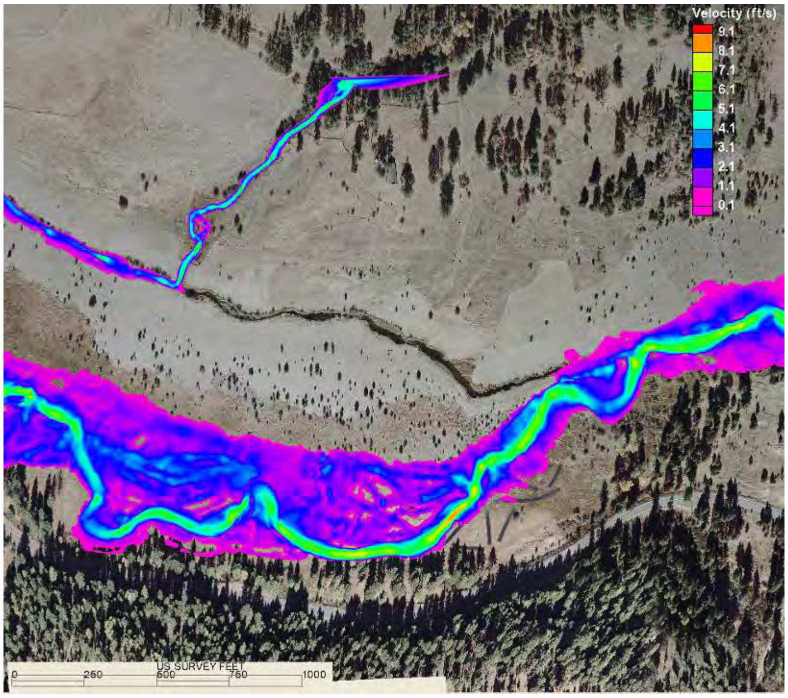


Figure 28 - 2-year velocities with North Channel blocked downstream of bifurcation.

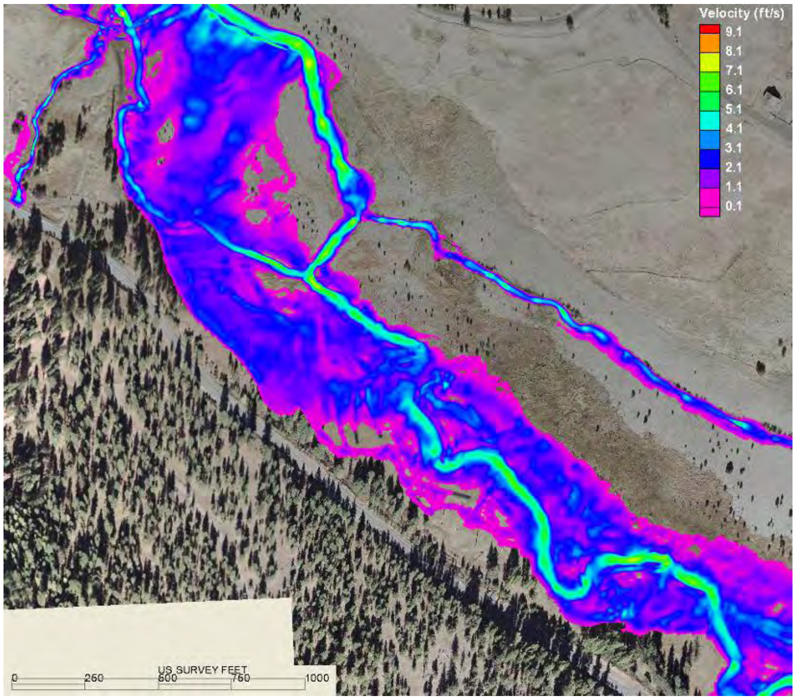


Figure 29 - 2-year velocities with North Channel blocked near confluence of North and South Channels.

10-Year Existing Conditions

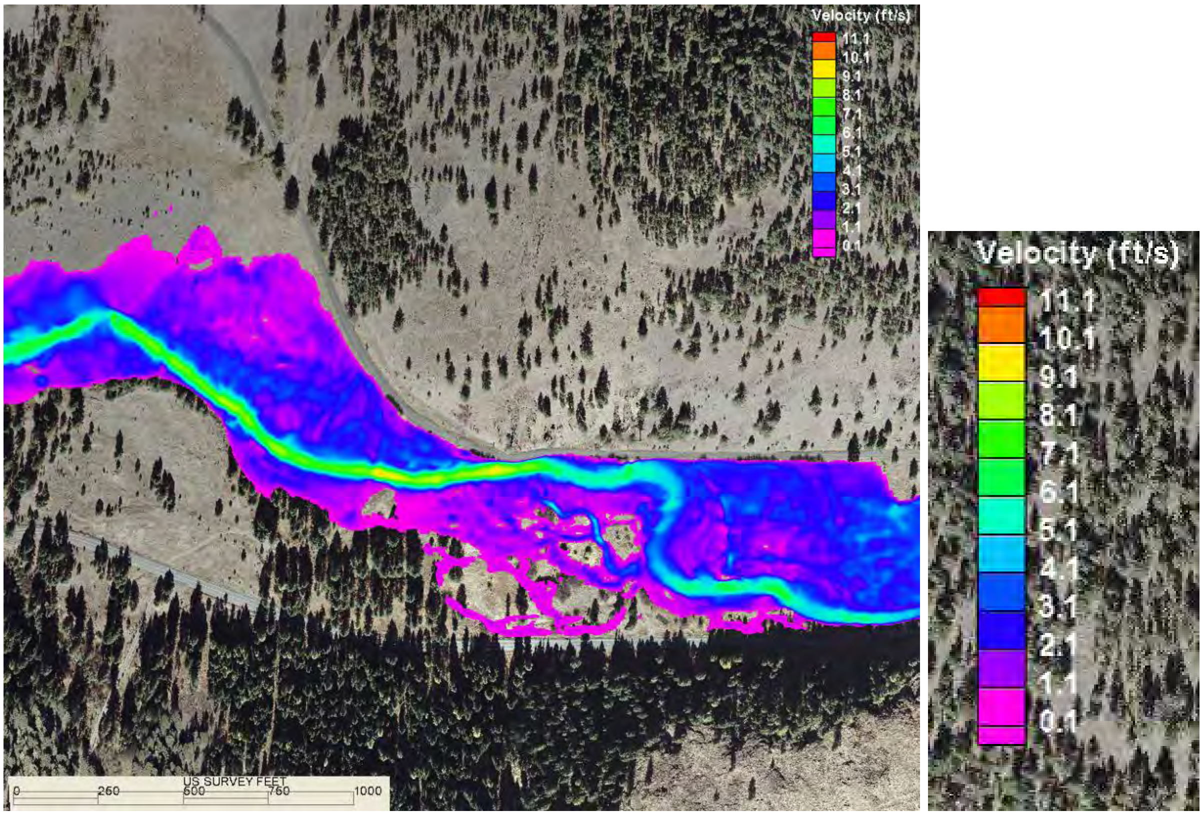


Figure 30 - 10-year velocities under existing conditions upstream of North-South Channel bifurcation. Legend is shown at right.

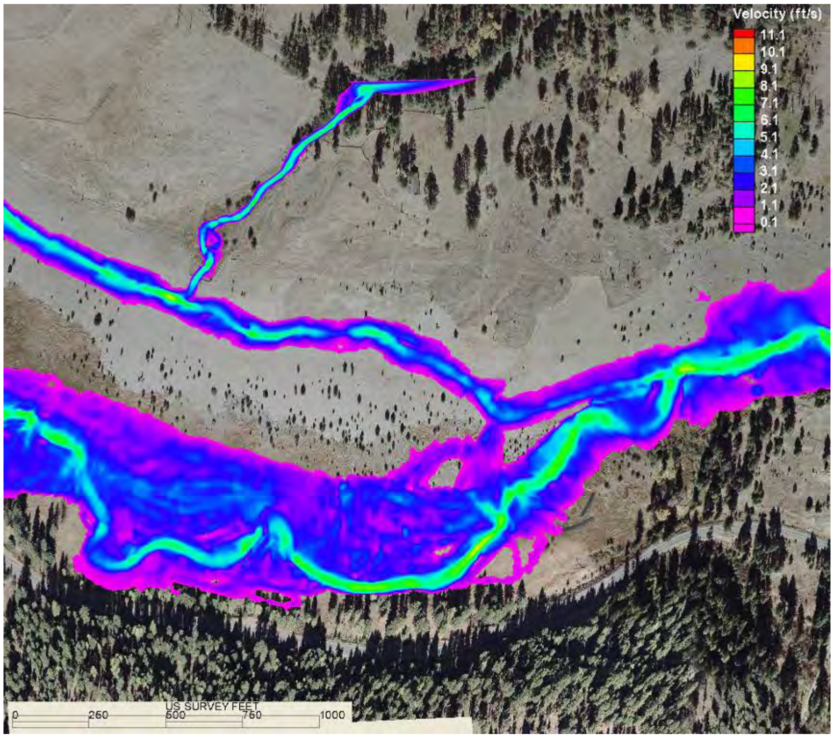


Figure 31 - 10-year velocities under existing conditions downstream from bifurcation.

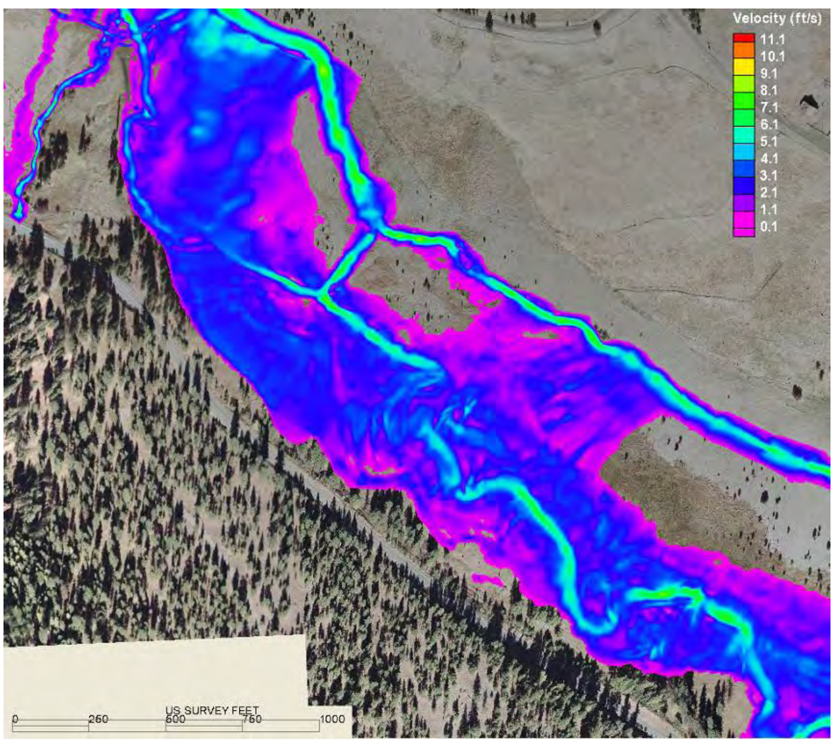


Figure 32 - 10-year velocities under existing conditions near confluence of North and South Channels.

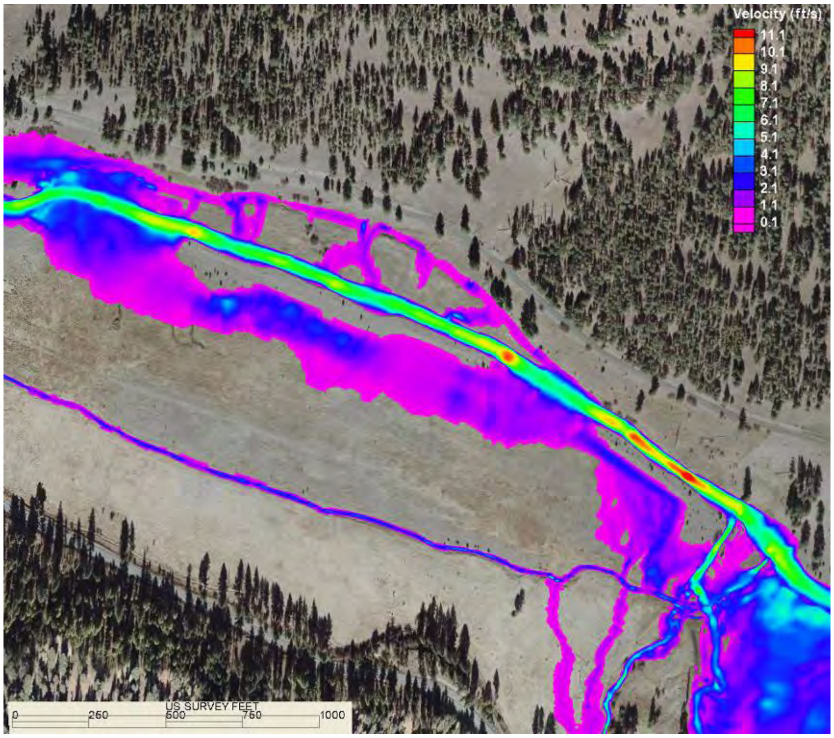


Figure 33 - 10-year velocities under existing conditions downstream from Ruby Creek confluence.

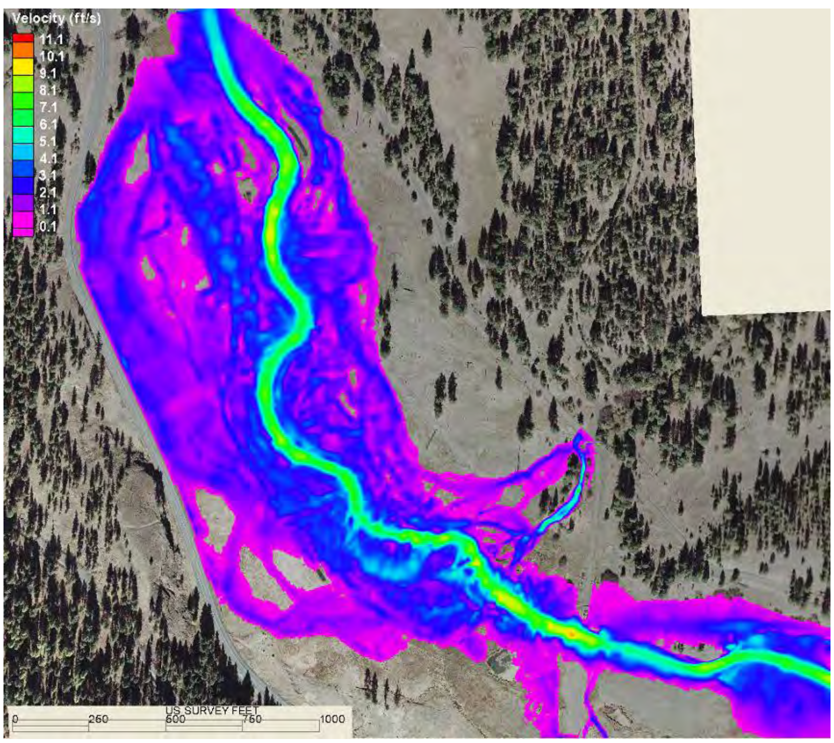


Figure 34 - 10-year velocities under existing conditions downstream from Beaver Creek confluence.

10-Year North Channel Block (only those different than existing)

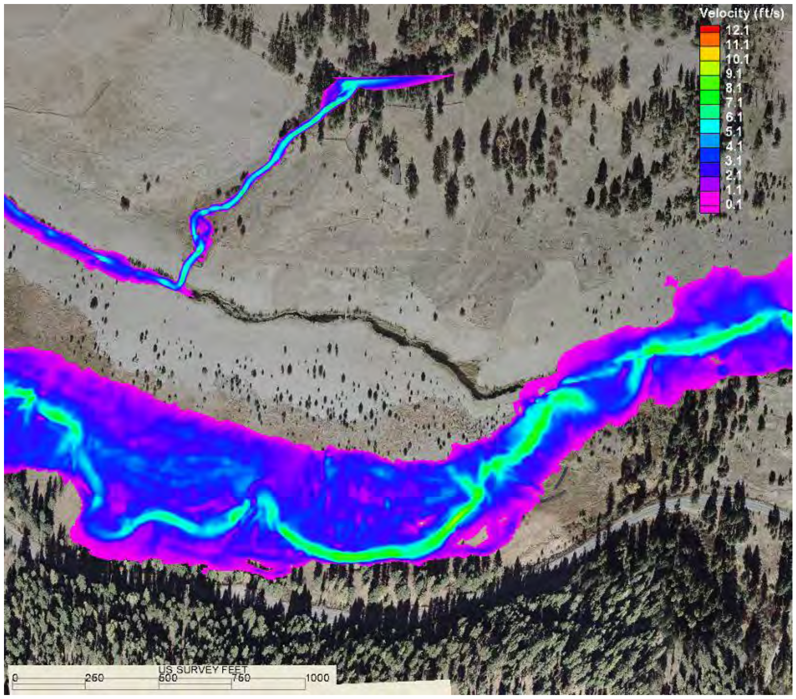


Figure 35 - 10-year velocities with North Channel blocked downstream of bifurcation.

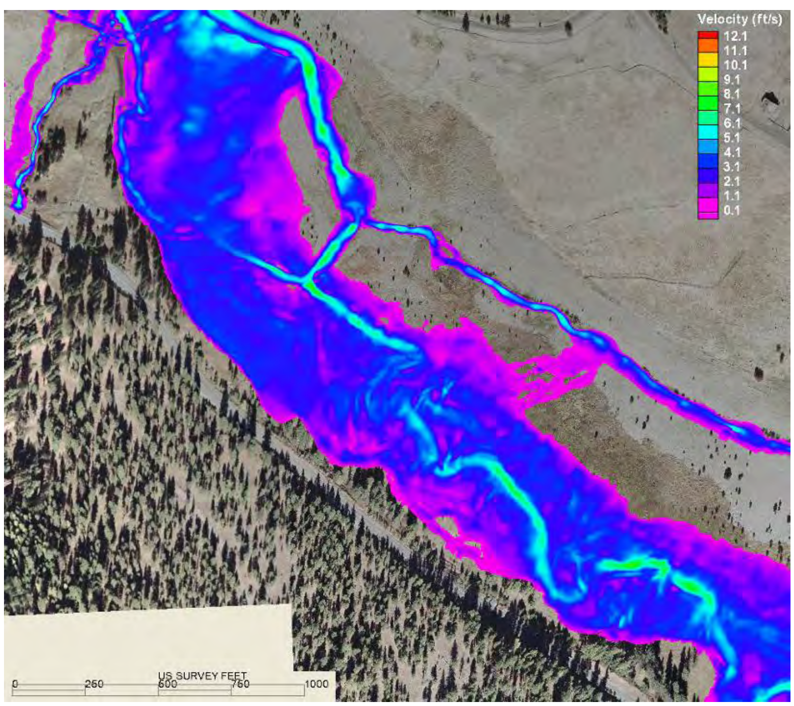


Figure 36 - 10-year velocities with North Channel blocked near confluence of North and South Channels.

100-Year Existing Conditions

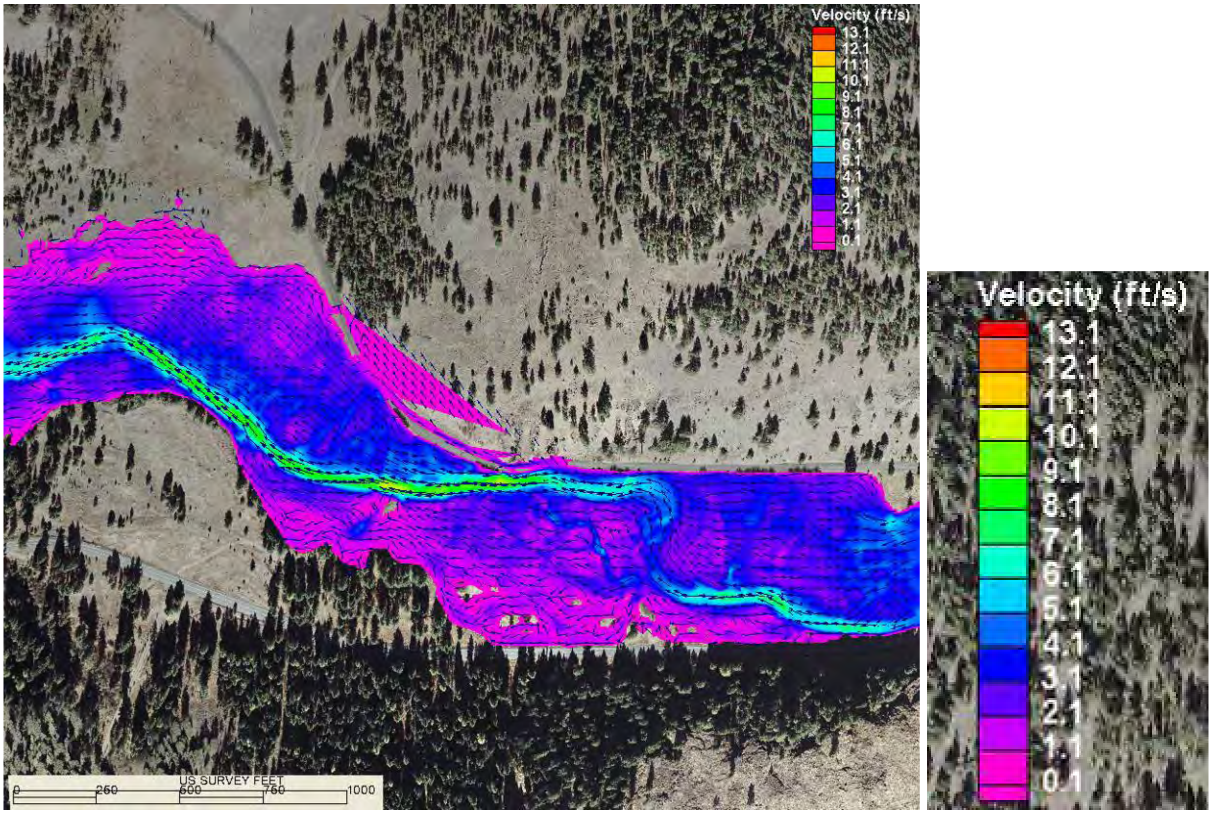


Figure 37 - 100-year velocities under existing conditions upstream of North-South Channel bifurcation. Legend is shown at right.

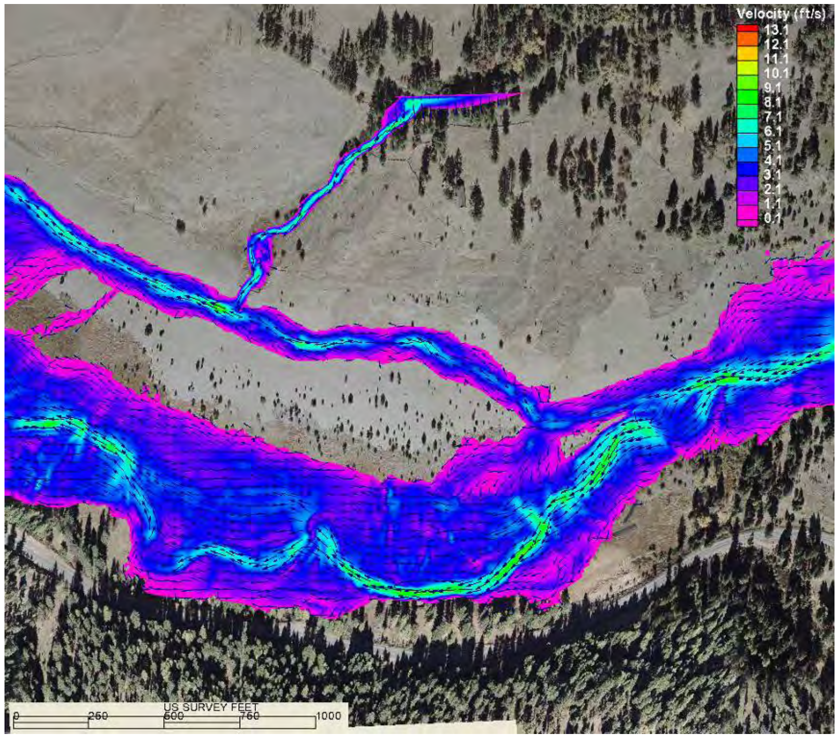


Figure 38 - 100-year velocities under existing conditions downstream from bifurcation.

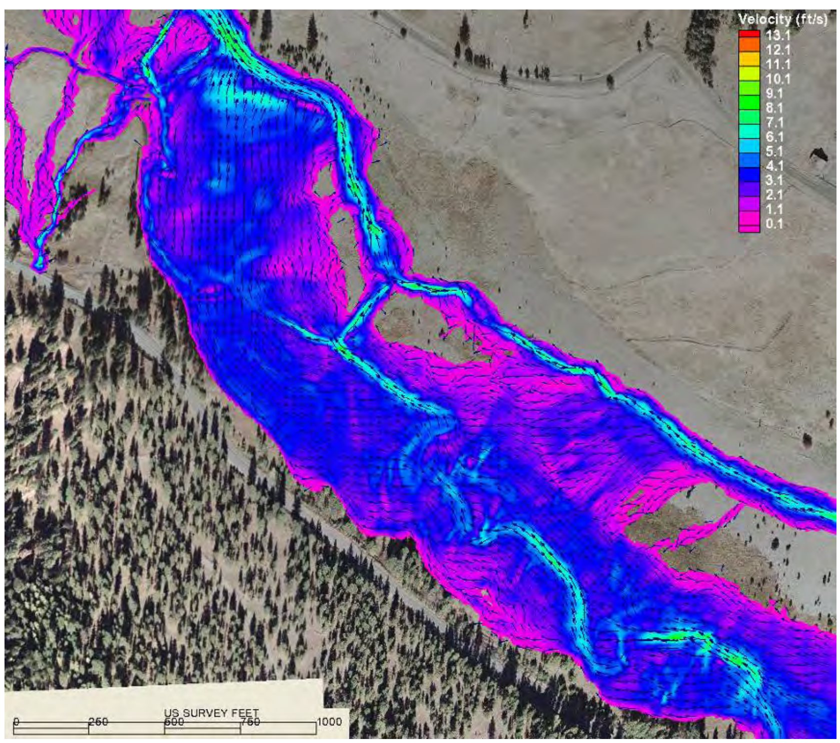


Figure 39 - 100-year velocities under existing conditions near confluence of North and South Channels.

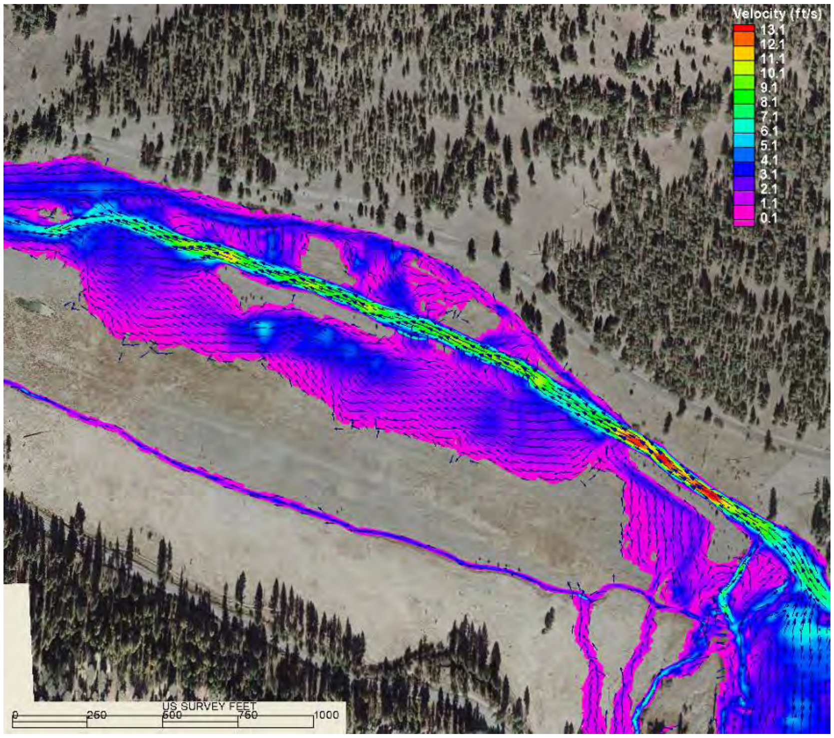


Figure 40 - 100-year velocities under existing conditions downstream from Ruby Creek confluence.

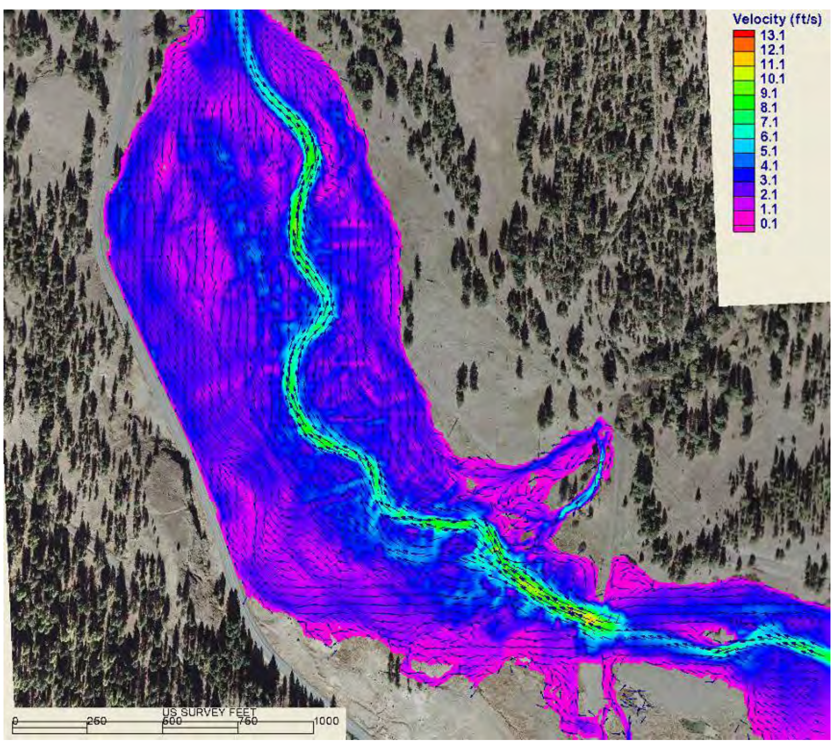


Figure 41 - 100-year velocities under existing conditions downstream from Beaver Creek confluence.

100-Year North Channel Block (only those different than existing)

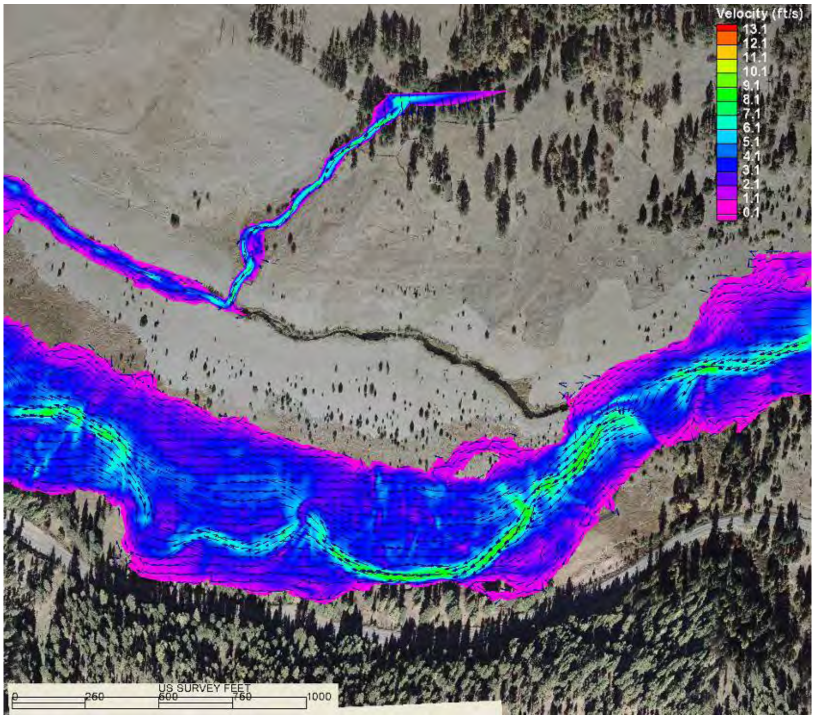


Figure 42 - 100-year velocities with North Channel blocked downstream of bifurcation.

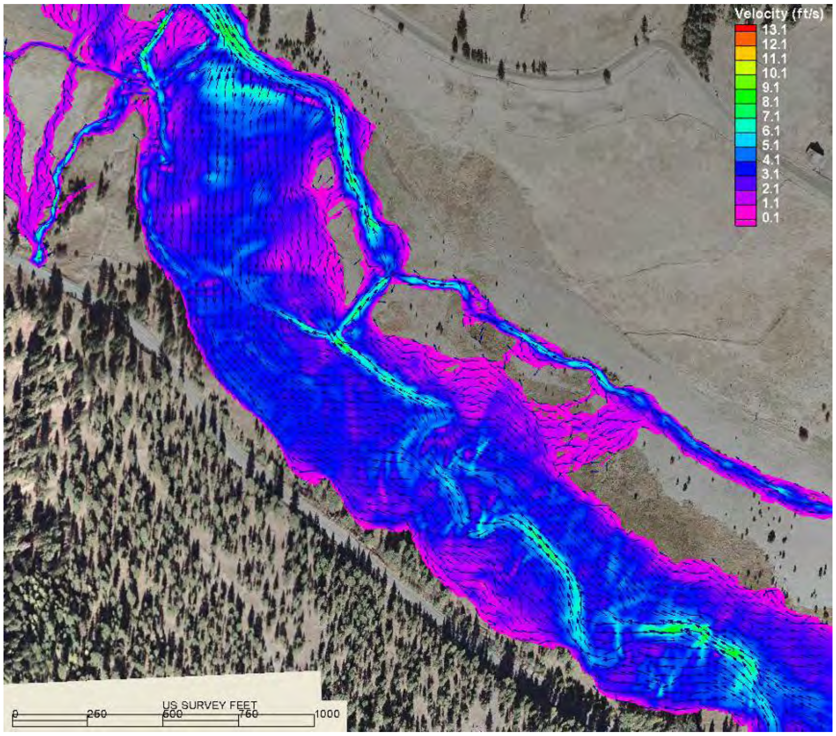


Figure 43 - 100-year velocities with North Channel blocked near confluence of North and South Channels.

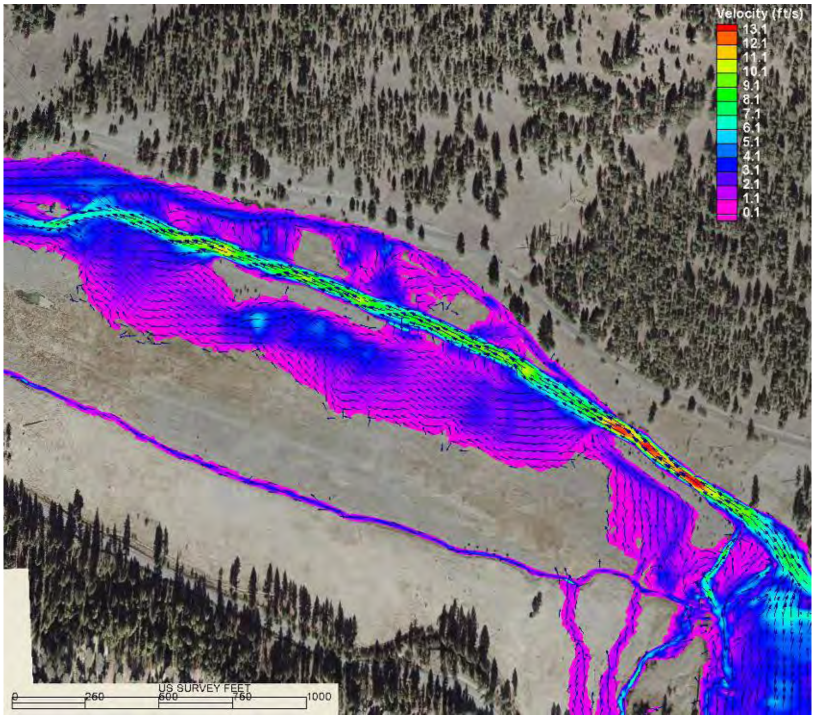


Figure 44 - 100-year velocities with North Channel blocked at Ruby Creek confluence.

MODEL RESULTS OF SHEAR STRESS

2-Year Existing Conditions

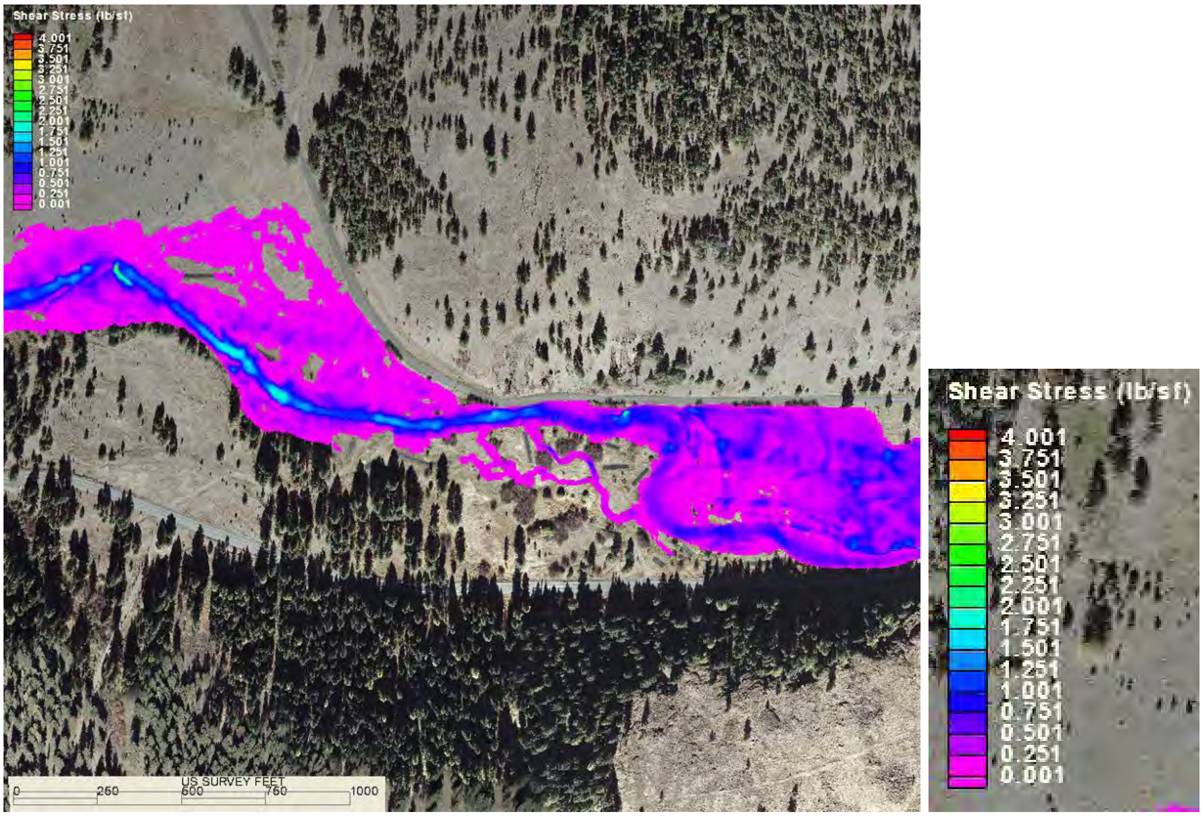


Figure 45 - 2-year shear stress under existing conditions upstream of North-South Channel bifurcation. Legend is shown at right.

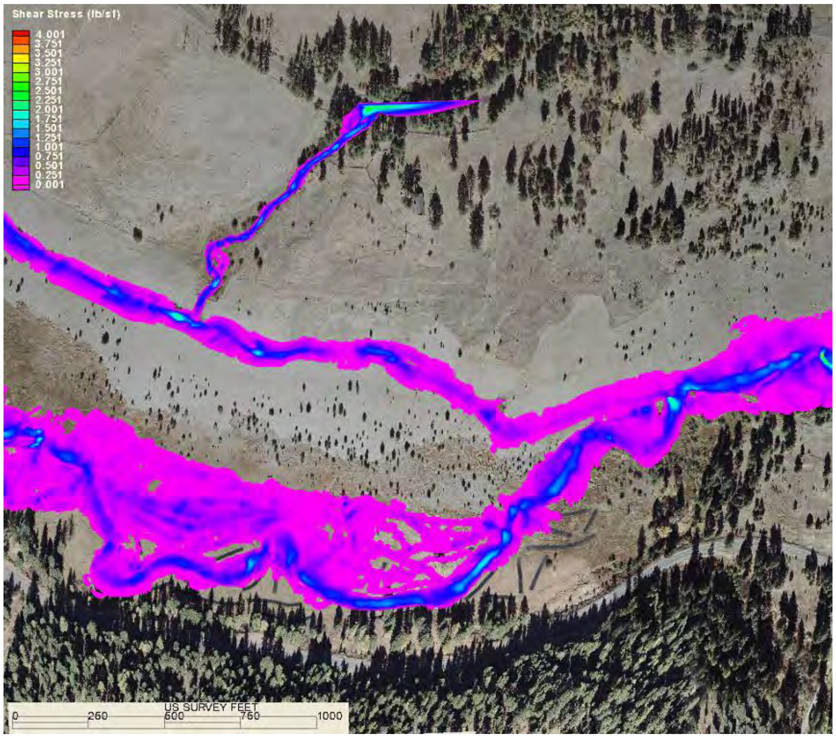


Figure 46 - 2-year shear stress under existing conditions downstream of bifurcation.

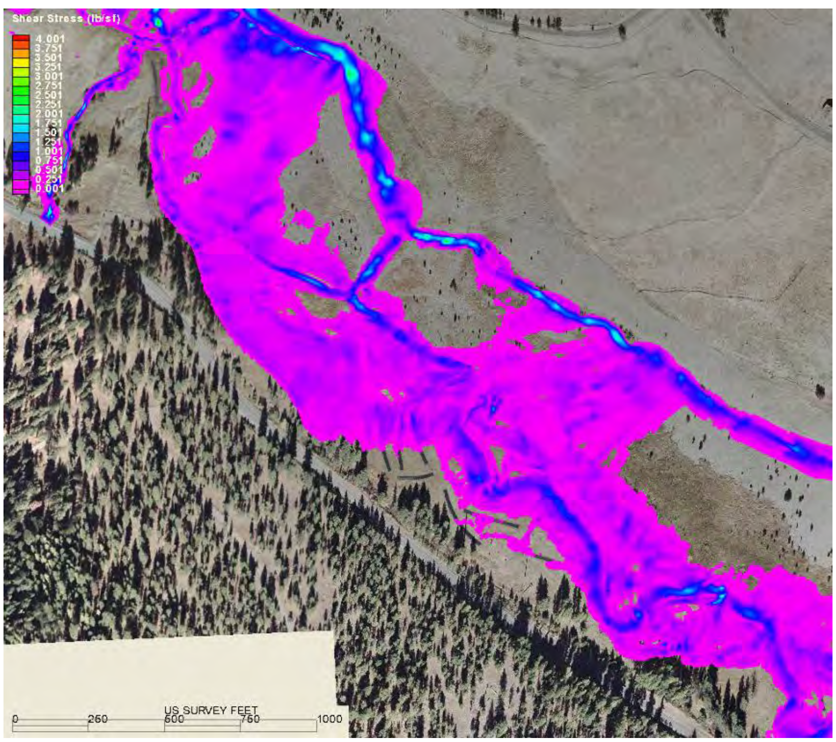


Figure 47 - 2-year shear stress under existing conditions near confluence of North and South Channels.

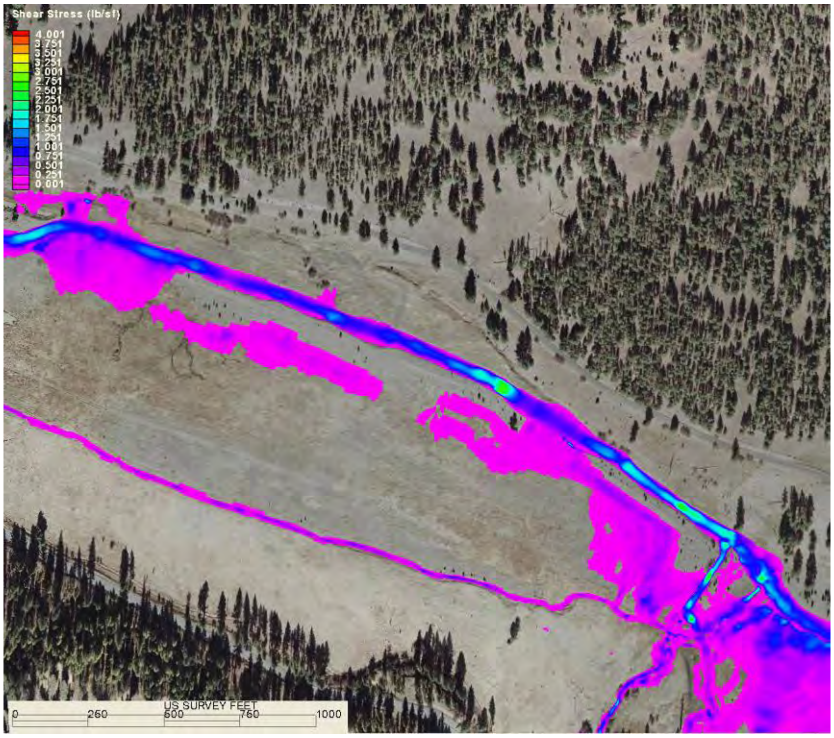


Figure 48 - 2-year shear stress under existing conditions downstream from Ruby Creek confluence.

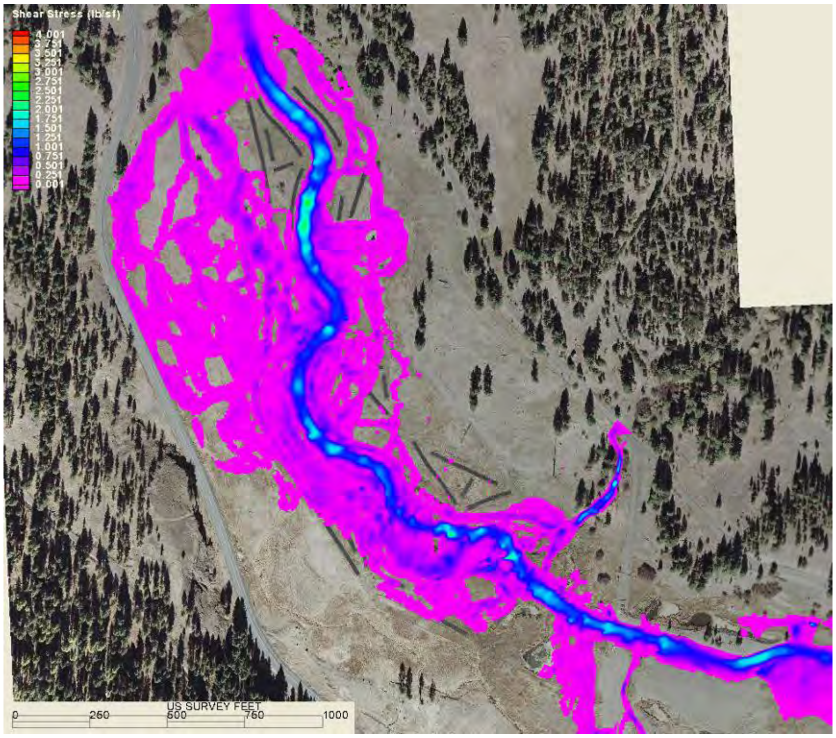


Figure 49 - 2-year shear stress under existing conditions downstream from Beaver Creek confluence.

2-Year North Channel Block (only those different than existing)

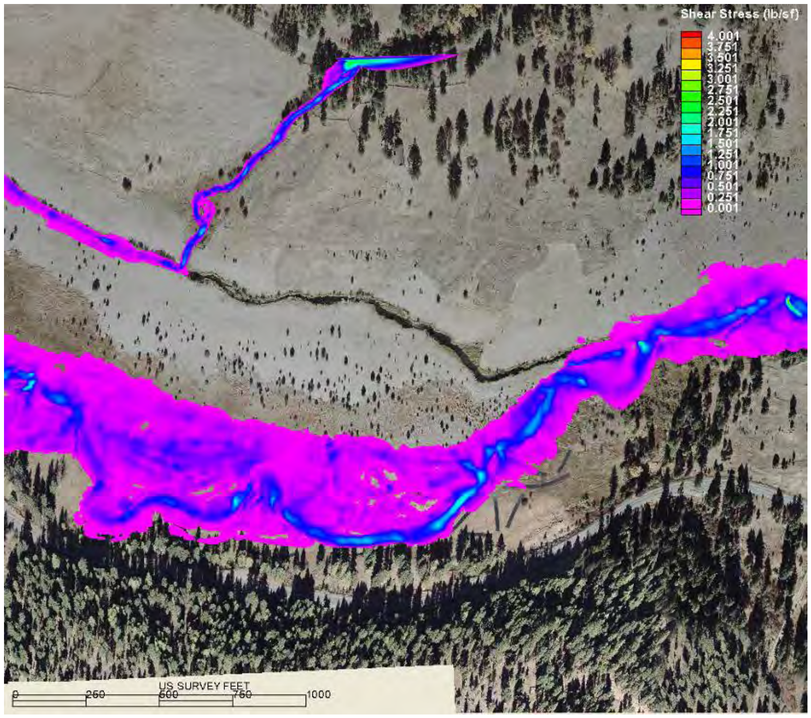


Figure 50 - 2-year shear stress with North Channel blocked downstream of bifurcation.

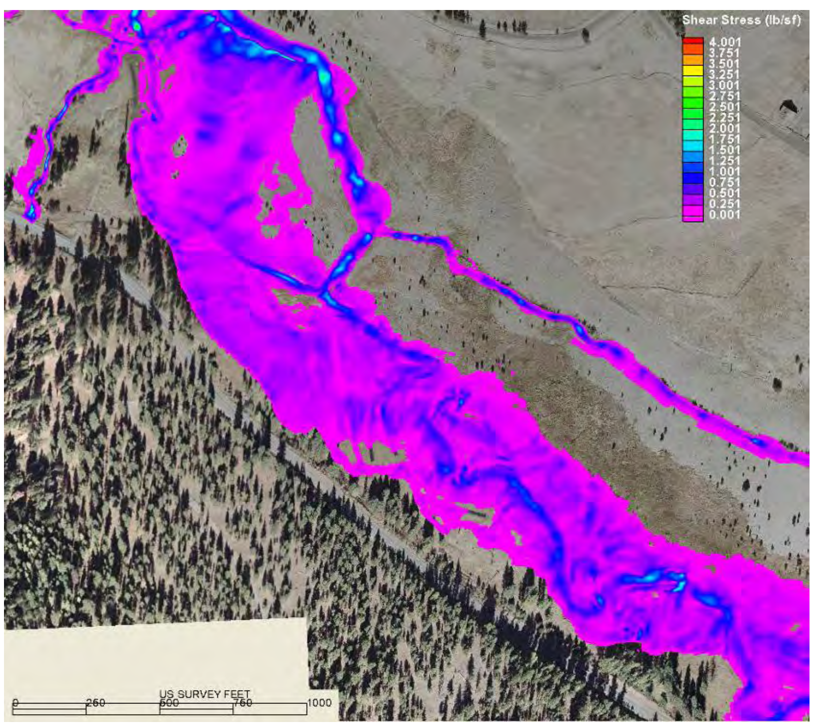


Figure 51 - 2-year shear stress with channel blocked near confluence of North and South Channels.

10-Year Existing Conditions

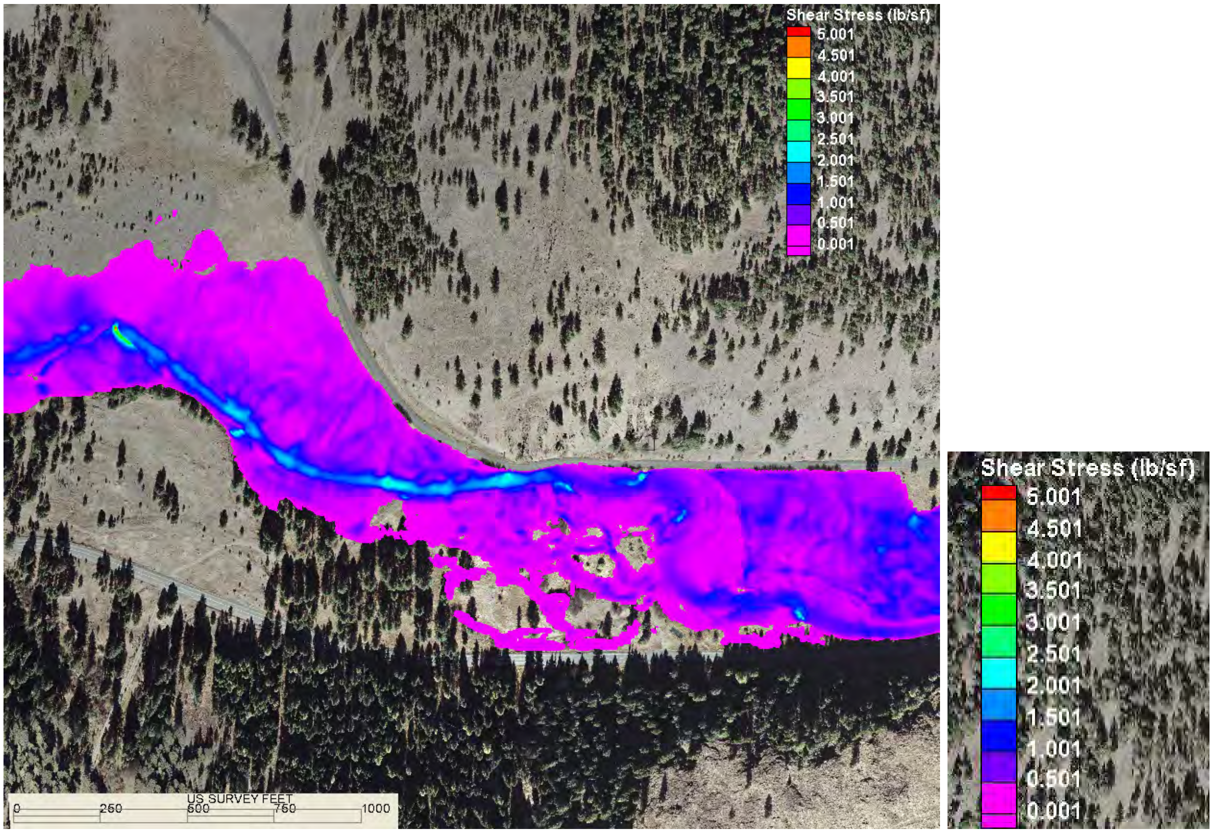


Figure 52 - 10-year shear stress under existing conditions upstream of North-South Channel bifurcation. Legend is shown at right.

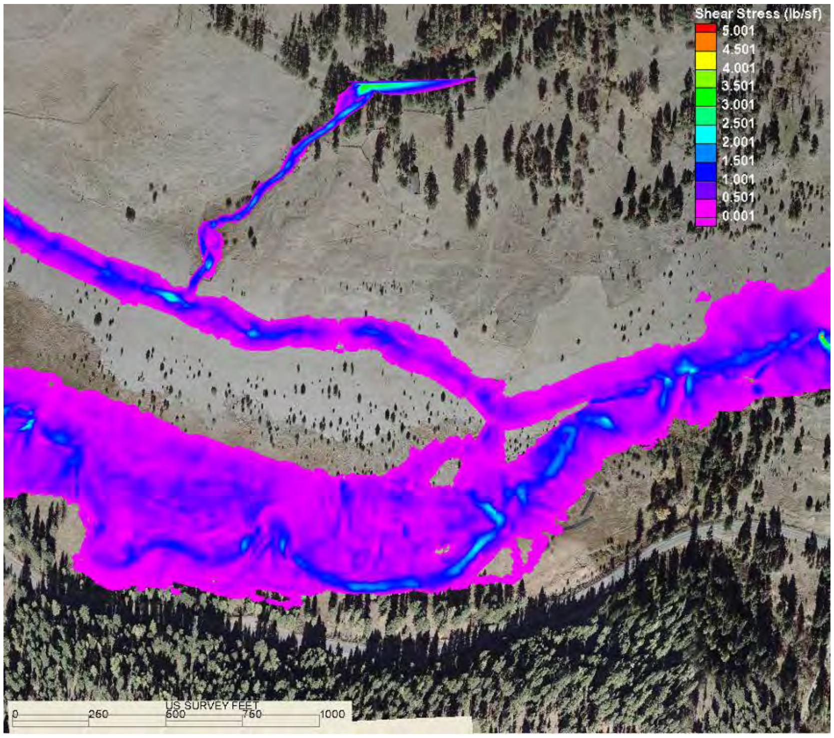


Figure 53 - 10-year shear stress under existing conditions downstream from bifurcation.

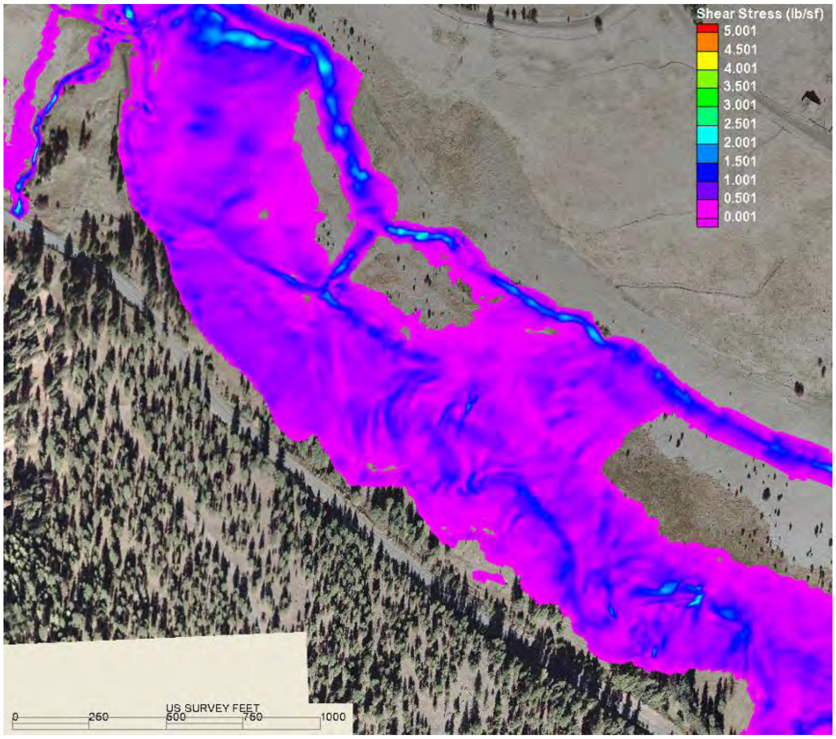


Figure 54 - 10-year shear stress under existing conditions near confluence of North and South Channels.

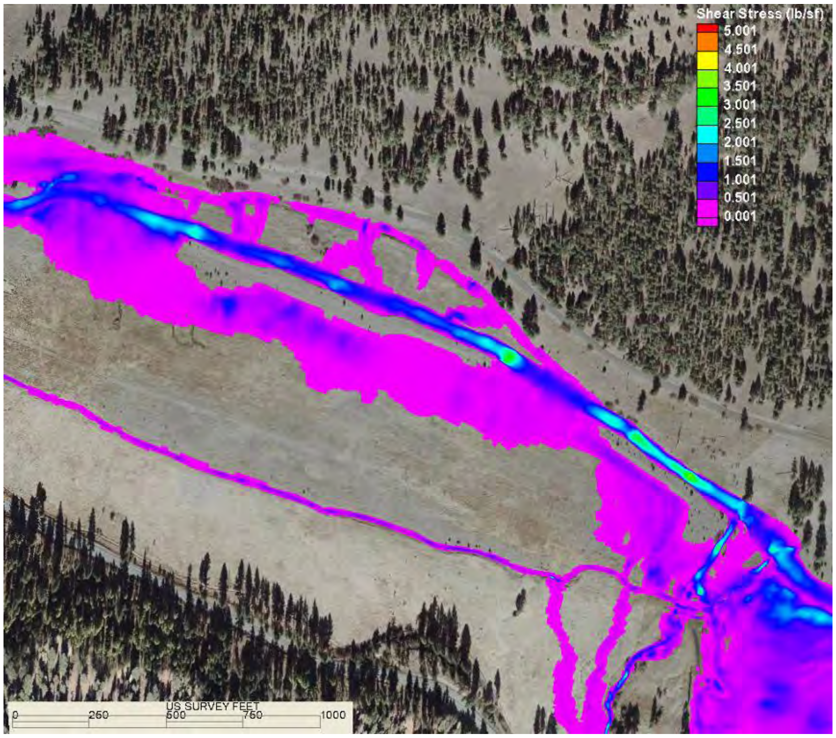


Figure 55 - 10-year shear stress under existing conditions downstream from Ruby Creek confluence.

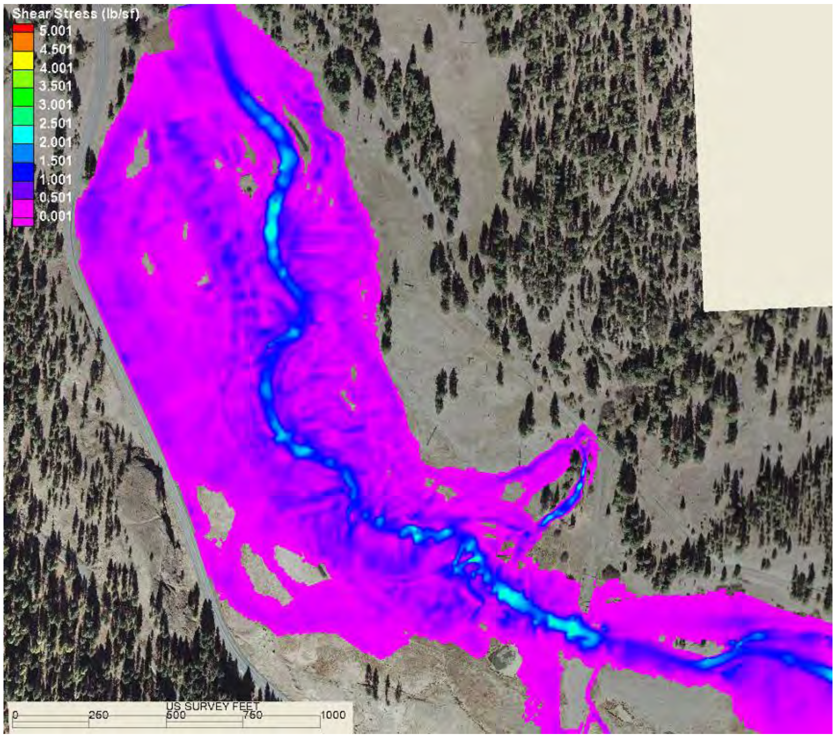


Figure 56 - 10-year shear stress under existing conditions downstream from Beaver Creek confluence.

10-Year North Channel Block (only those different than existing)

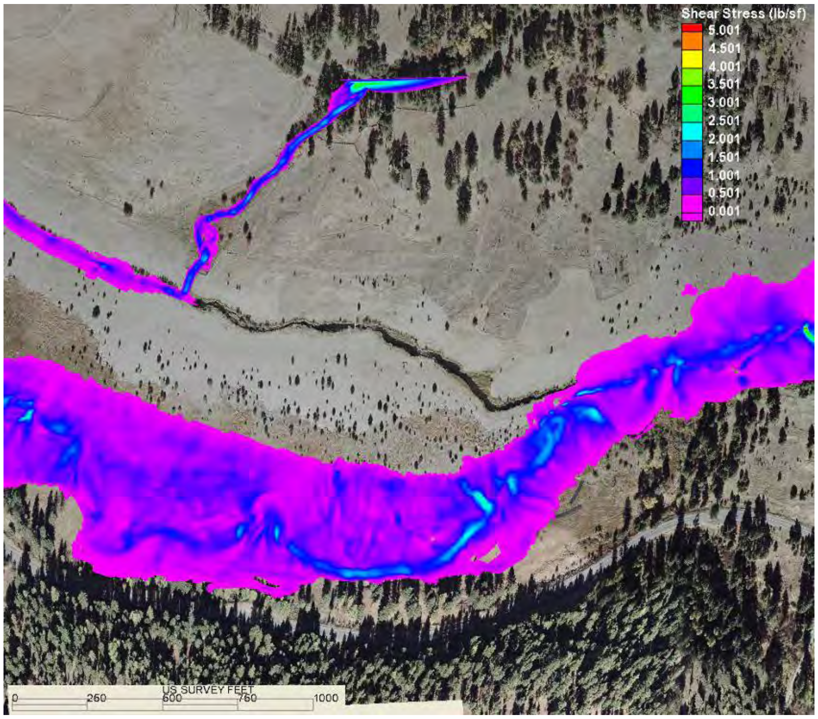


Figure 57 - 10-year shear stress with North Channel blocked downstream of bifurcation.

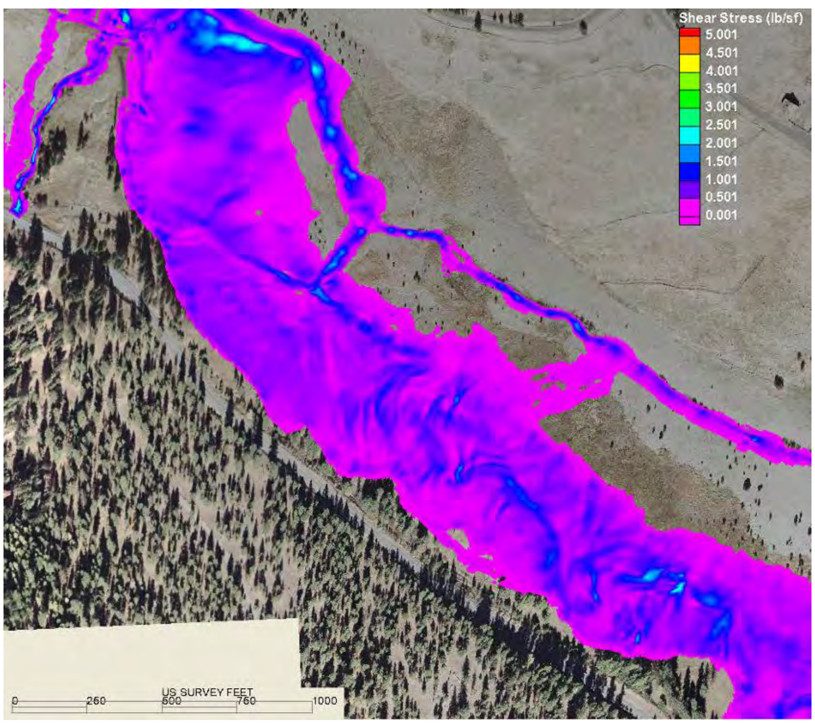


Figure 58 - 10-year shear stress with North Channel blocked near confluence of North and South Channels.

100-Year Existing Conditions

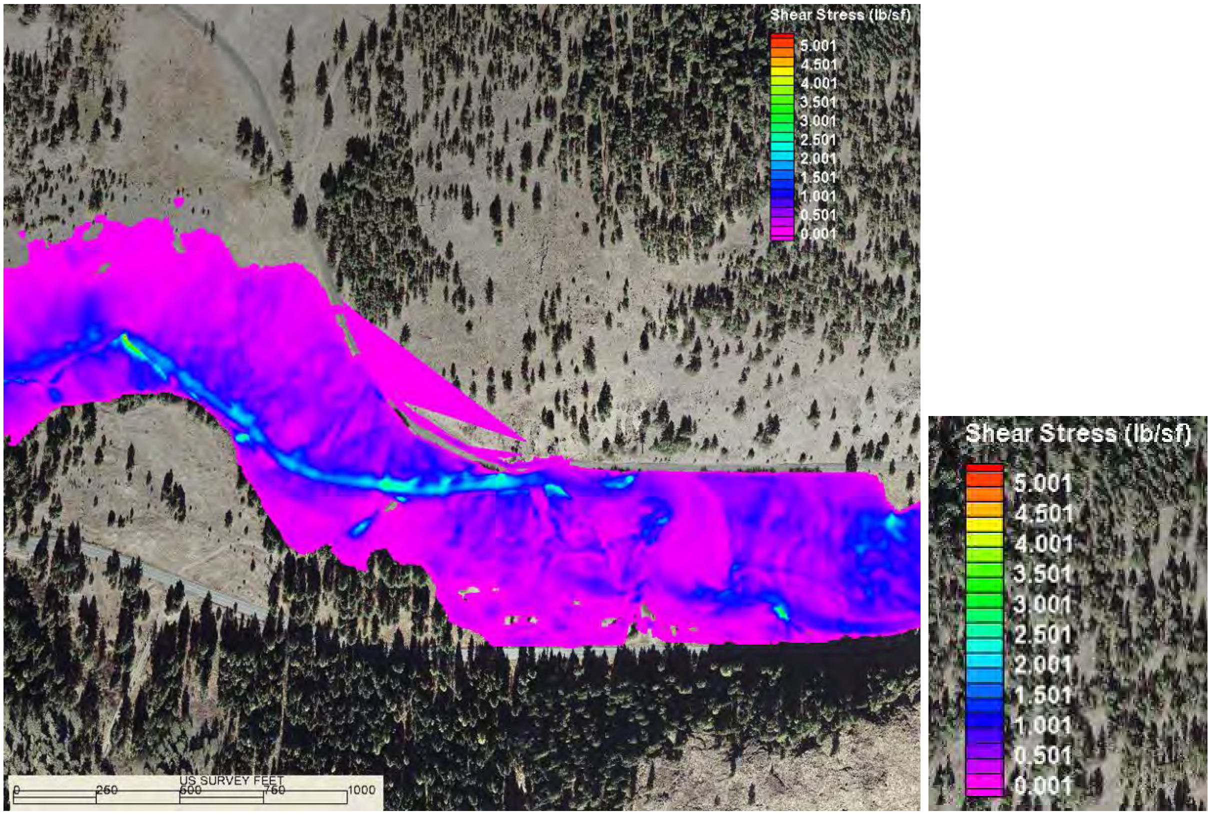


Figure 59 - 100-year shear stress under existing conditions upstream of North-South Channel bifurcation. Legend is shown at right.

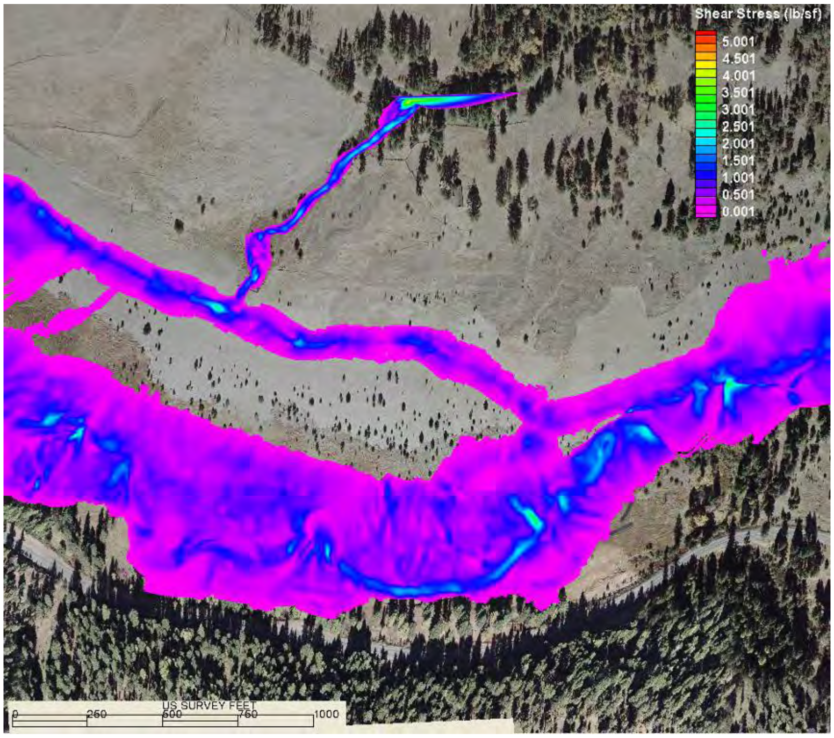


Figure 60 - 100-year shear stress under existing conditions downstream from bifurcation.

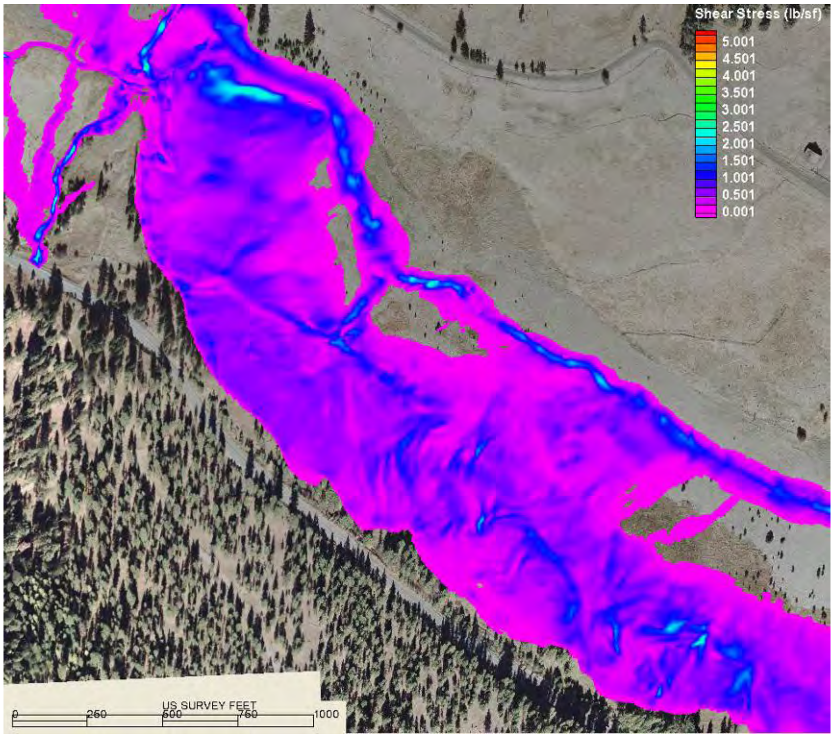


Figure 61 - 100-year shear stress under existing conditions near confluence of North and South Channels.

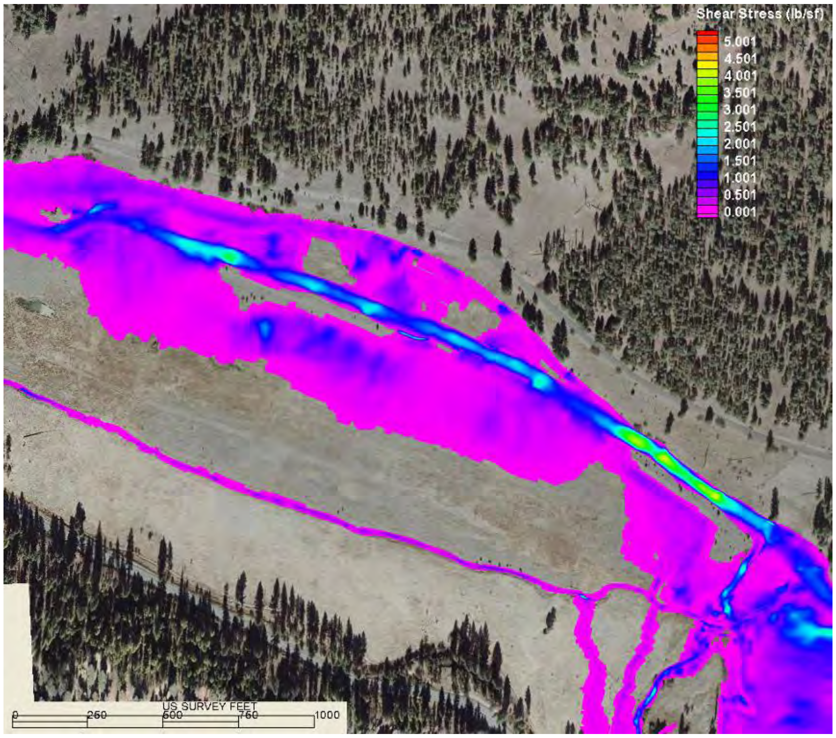


Figure 62 - 100-year shear stress under existing conditions downstream from Ruby Creek confluence.

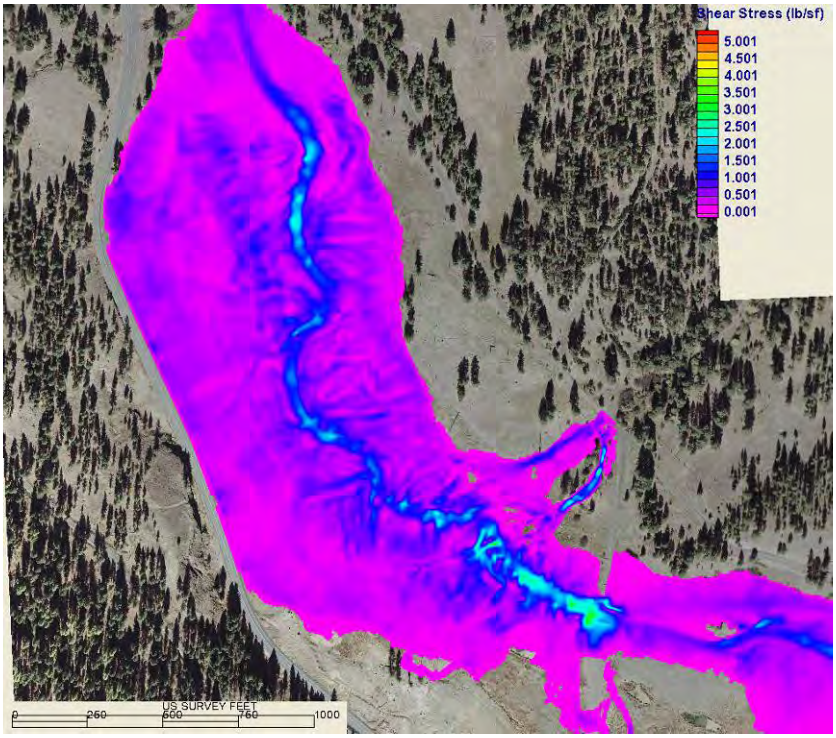
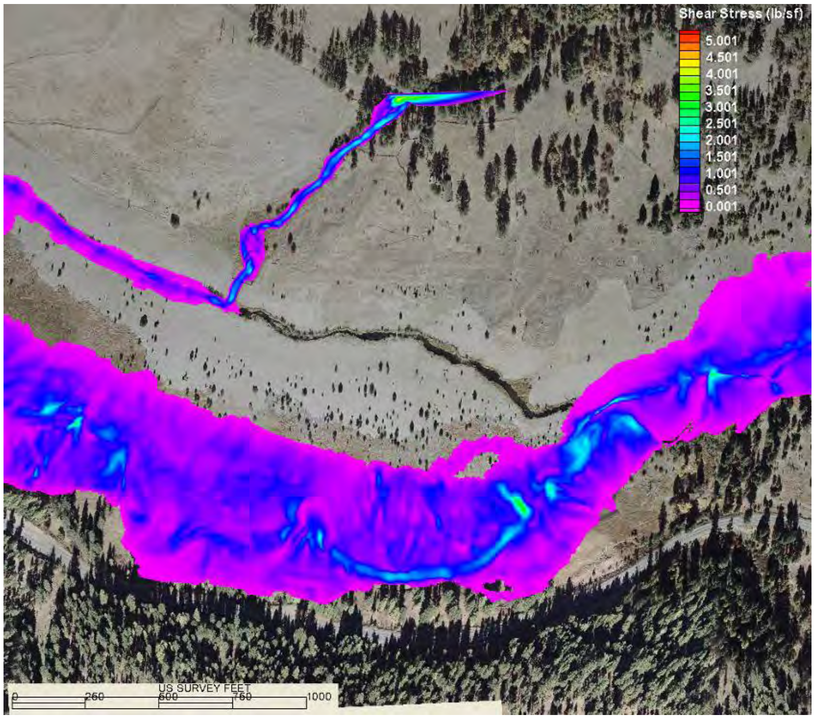


Figure 63 - 100-year shear stress under existing conditions downstream from Beaver Creek confluence.

100-Year North Channel Block (only those different than existing)



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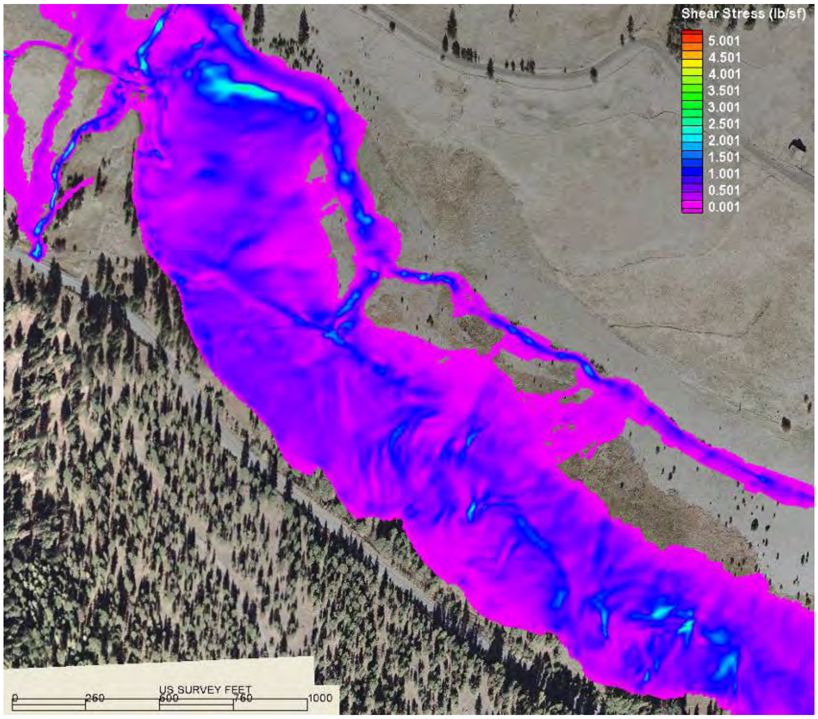

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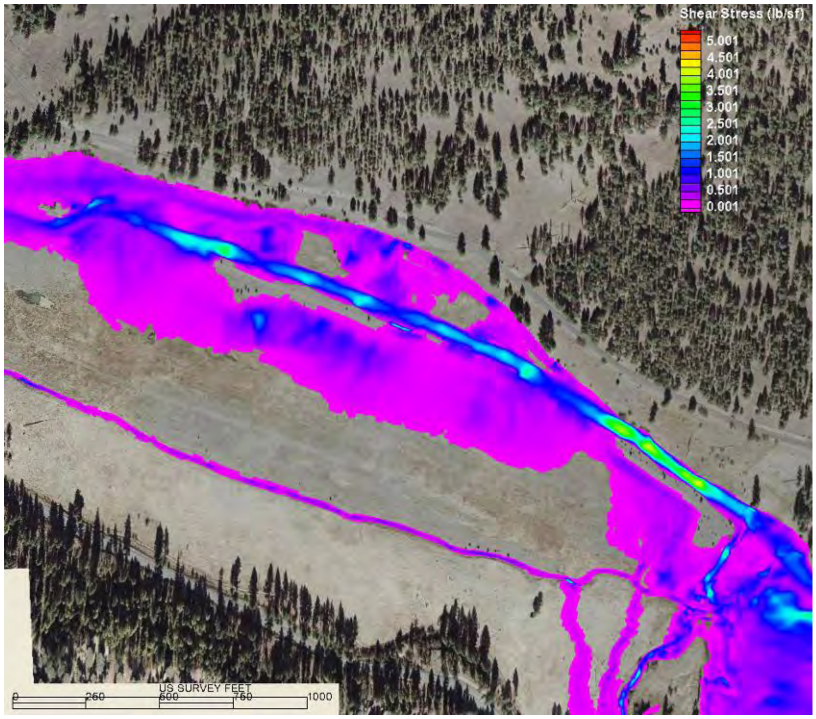

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APPENDIX E – HIGH-FLOW HIGH-QUALITY HABITAT

APPENDIX E: MODEL RESULTS OF HIGH-FLOW HIGH-QUALITY HABITAT

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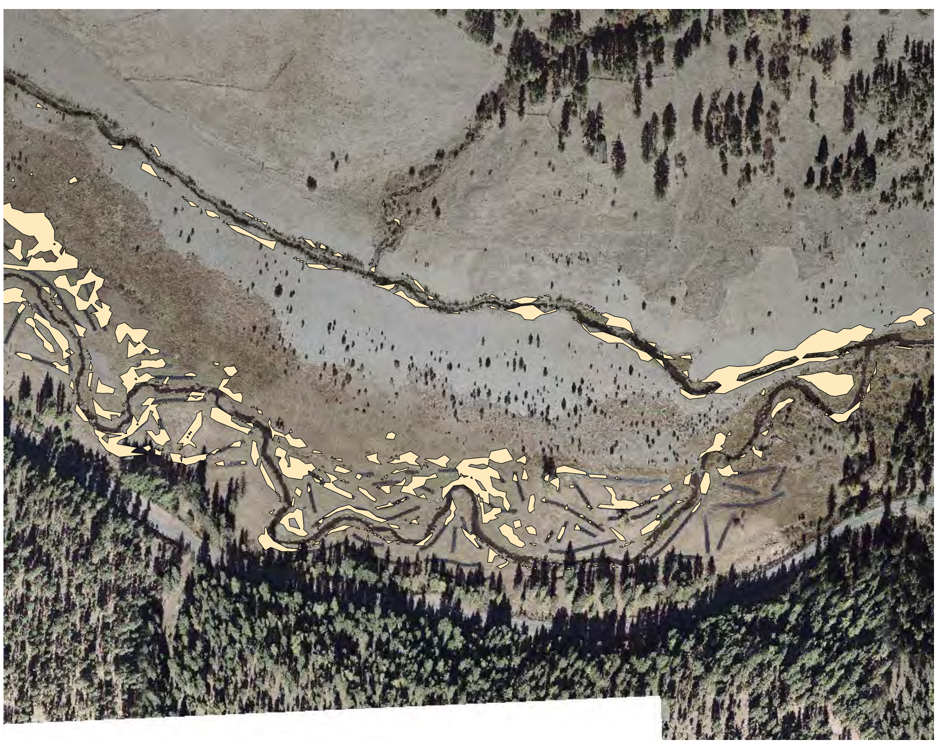

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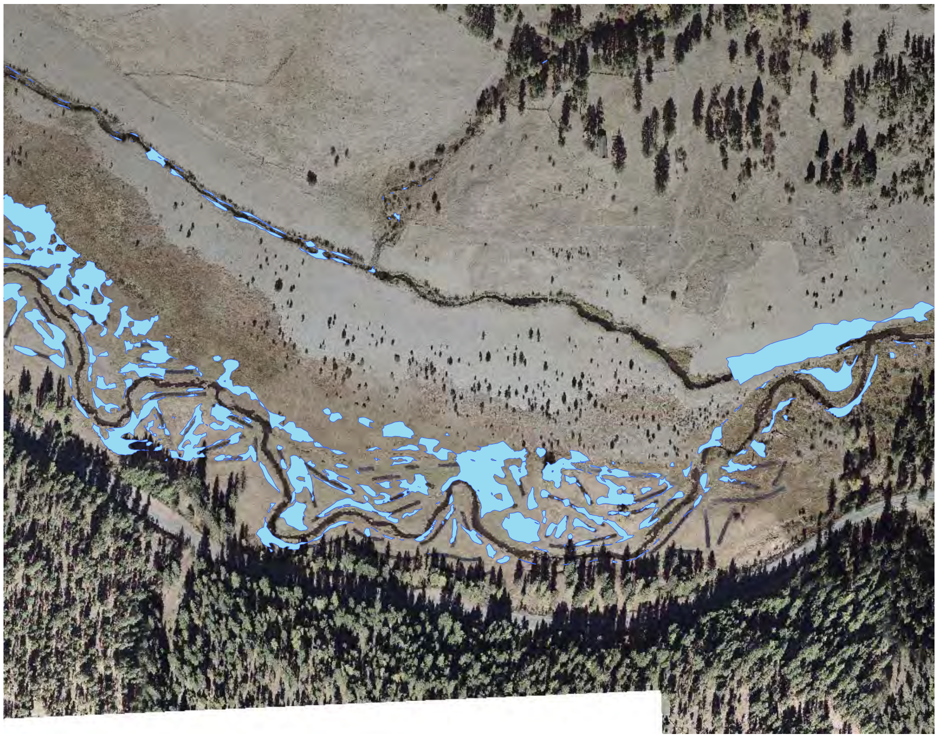

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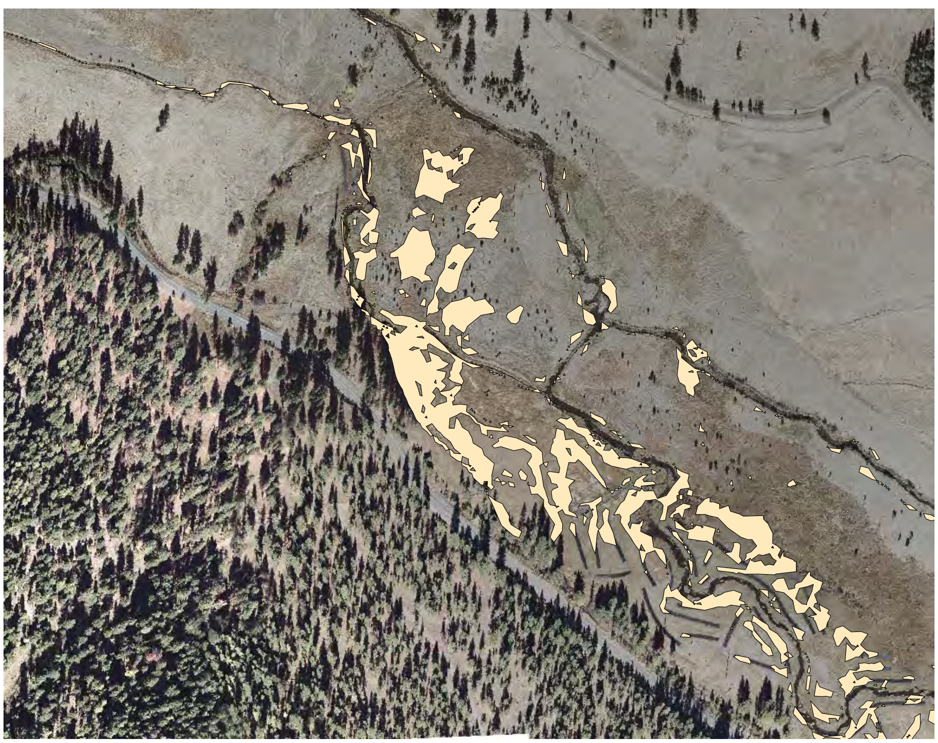

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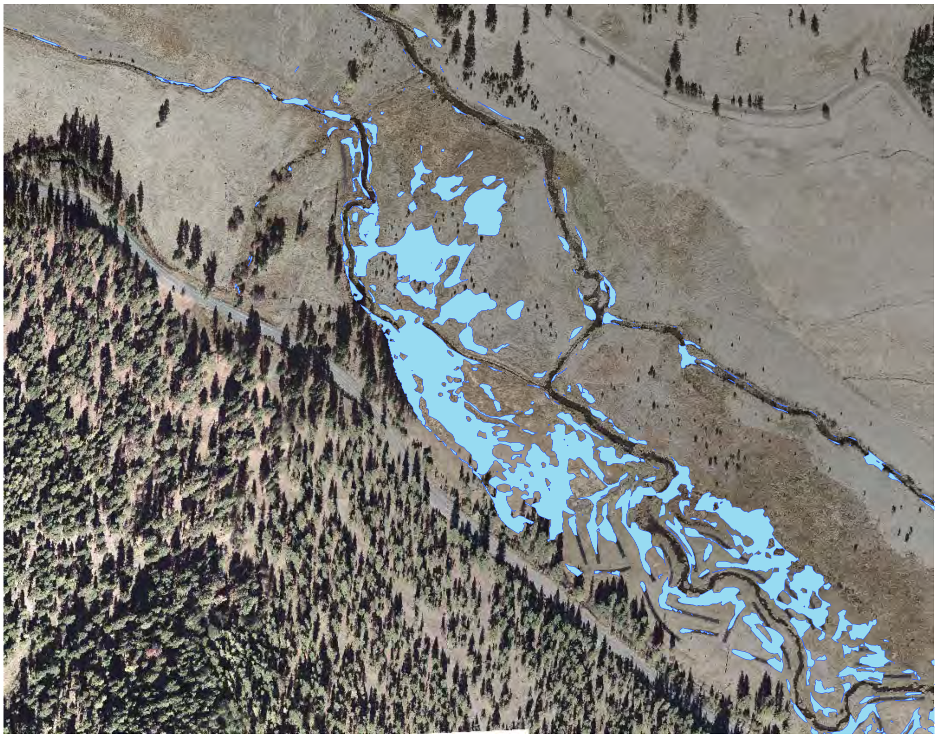

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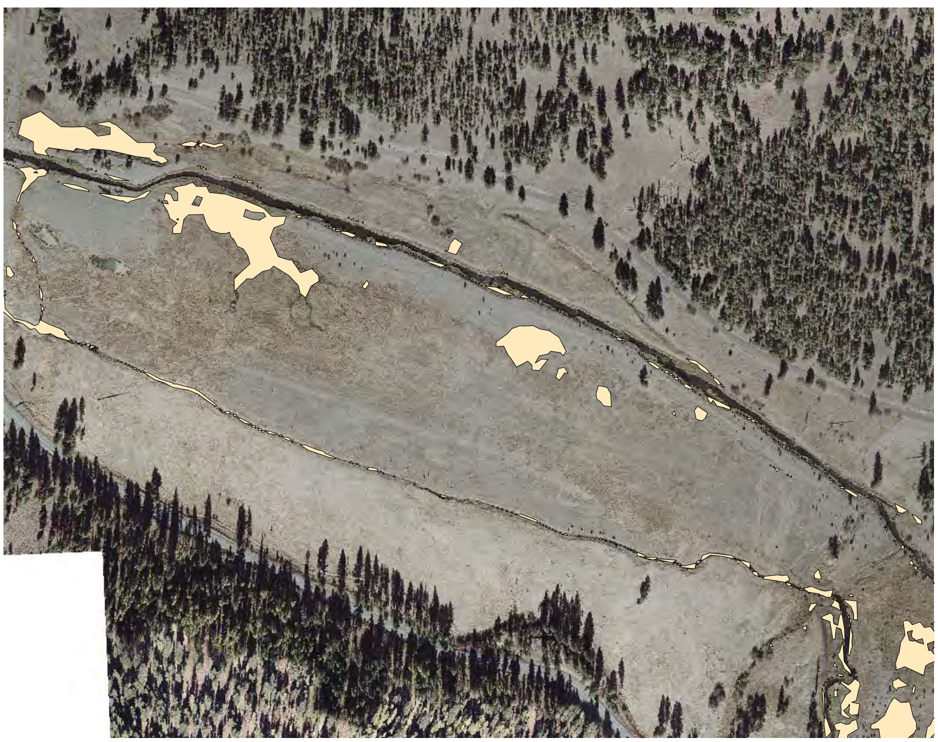

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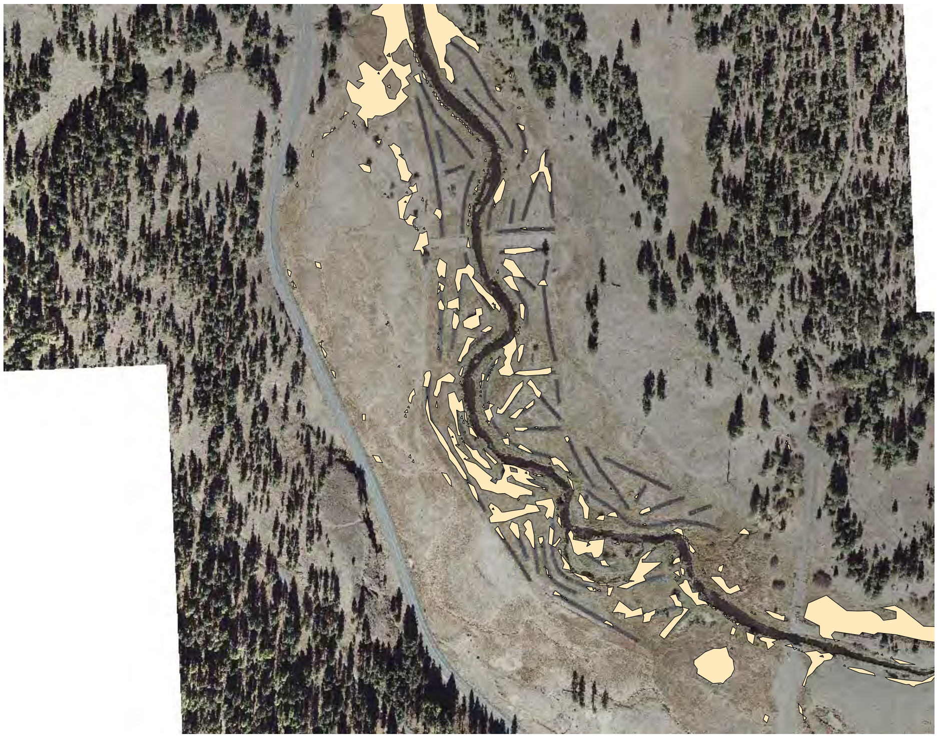

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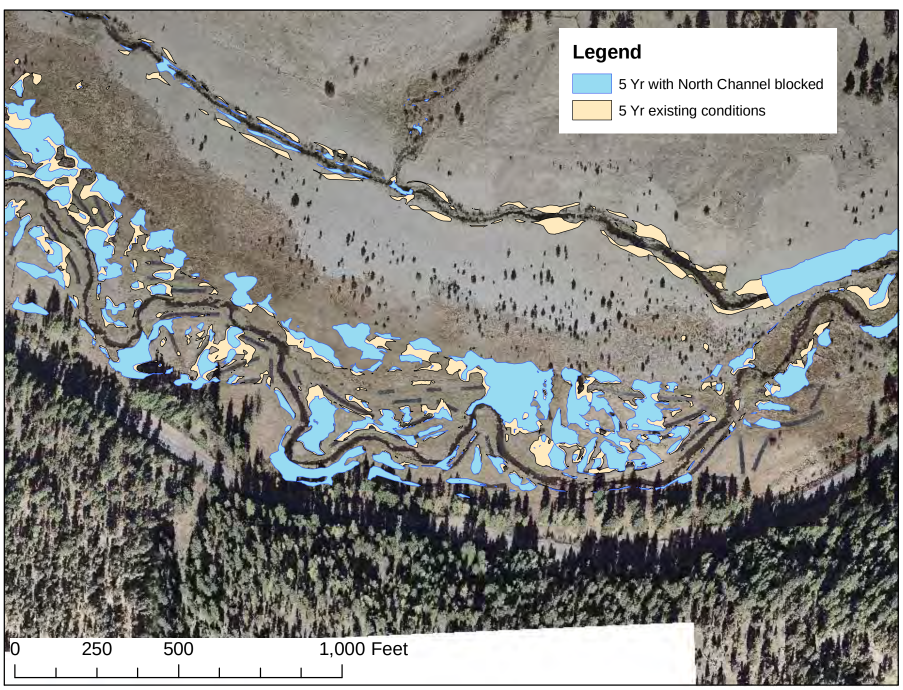

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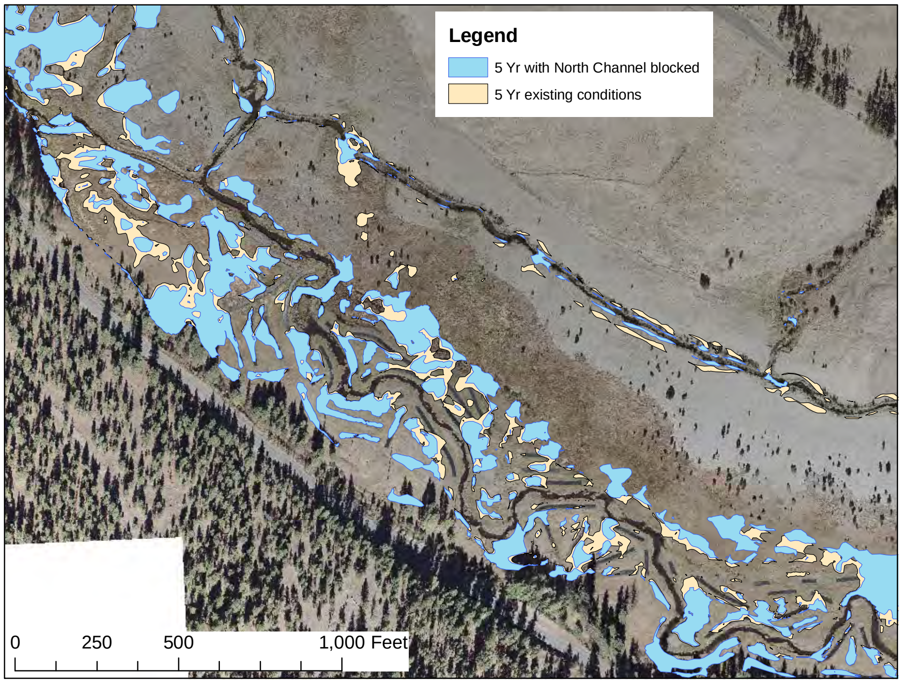

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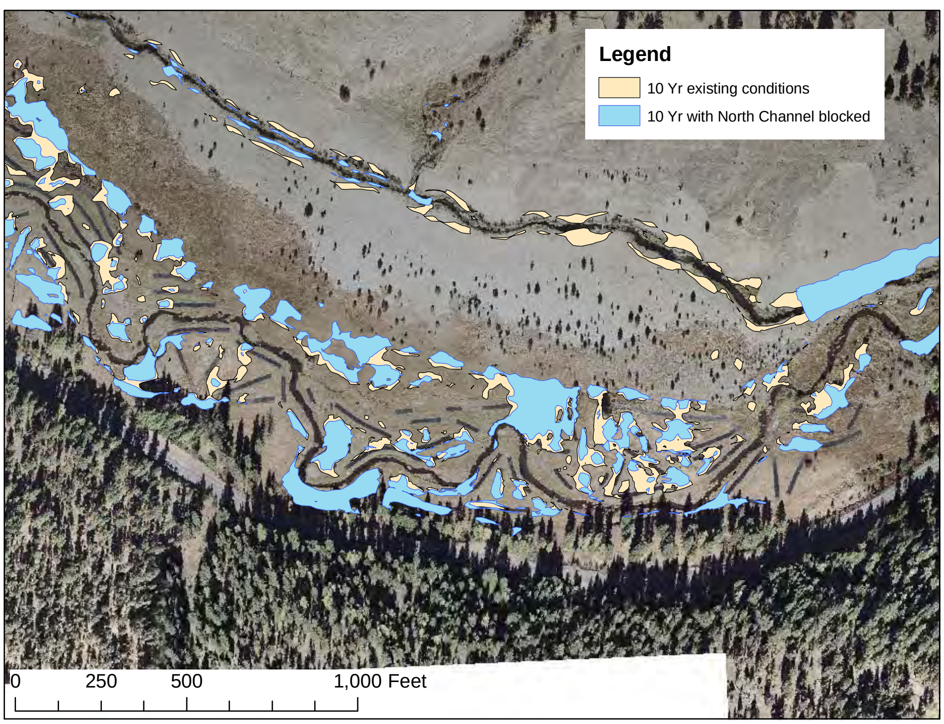

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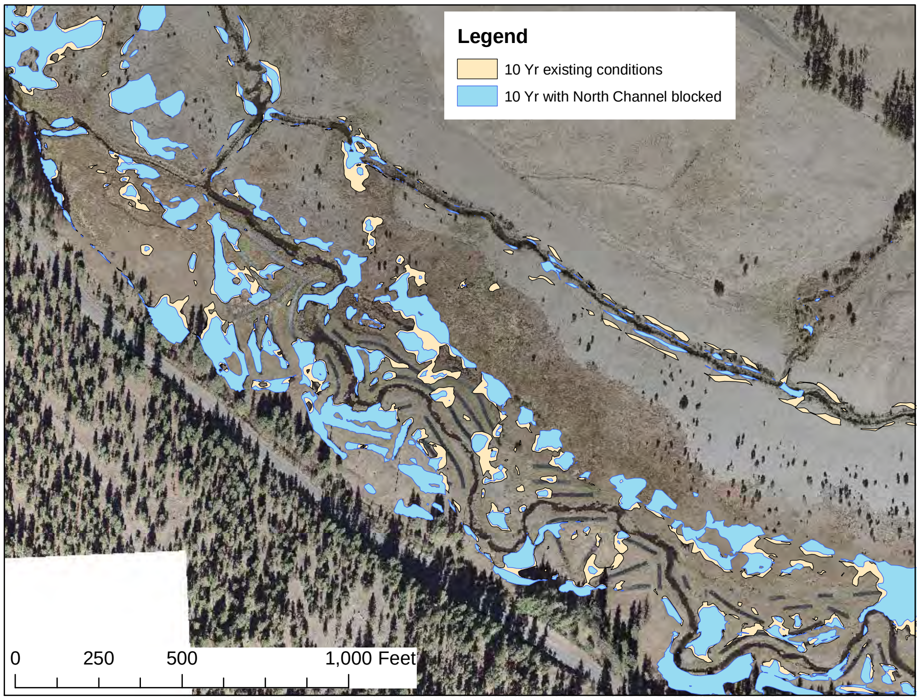

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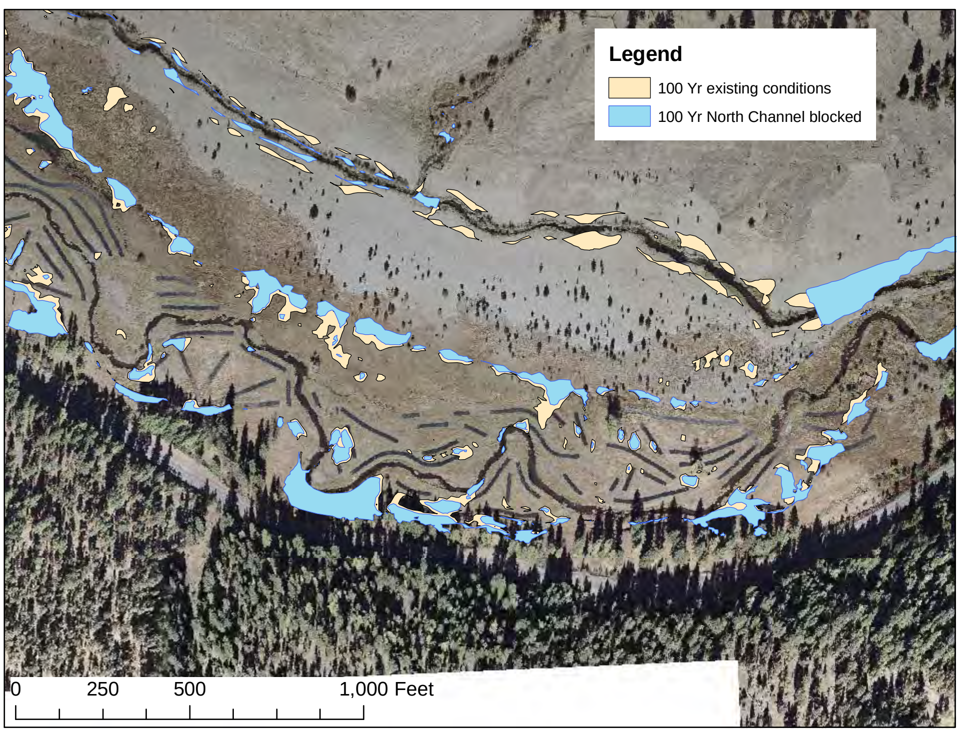

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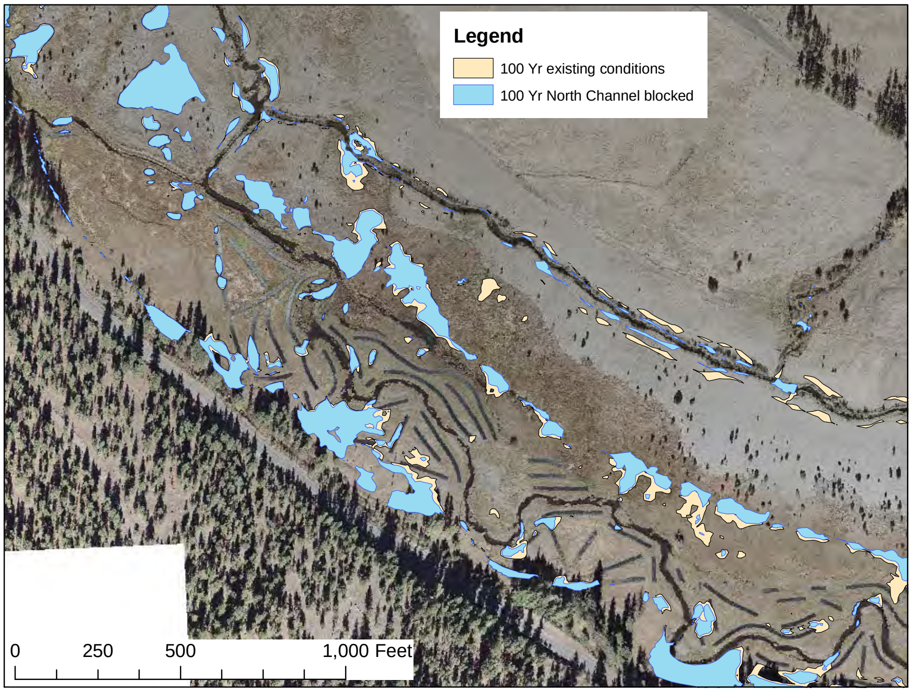

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