METHOW RIVER
PROJECT OPPORTUNITY ASSESSMENT: TWISP RIVER TO LEWISIA ROAD

April 8, 2011

Provided for:
The Confederated Tribes and Bands of the Yakama Nation
P.O. Box 151, Fort Road
Toppenish, WA 98948

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TABLE OF CONTENTS

INTRODUCTION 1

METHOW RIVER PROCESSES 2

GEOLOGIC CONTEXT 2
CHANGES IN NATURAL PROCESSES 2

ENHANCING AND EMULATING NATURAL PROCESS AND HABITAT 3

GENERAL HABITAT PRESCRIPTIONS 4
River Bank Log Jams and Large Wood Enhancement of Existing Riprap 4
Pool Enhancement 5
Side Channels 5
Bar Apex and Mid-Channel Logjams 5
Backwater Channels and Alcoves 5
Enhancing Natural River Migration Processes 6

ENHANCEMENT PROJECT OPPORTUNITIES 7

TWO CHANNELS SUB-REACH (RM 44.0 - 45.5) 7
Analysis and Findings 7
TWO CHANNELS REACH PROJECT OPPORTUNITIES 10
Backwater Channels and Alcoves 10
River Bank Logjams and Large Wood Enhancement of Existing Riprap 12
Bar Apex and other Mid-River Logjams 12
Side Channels 13
EAGLE ROCKS SUB-REACH (RM 42.7 – 44) 13
Analysis and Findings 13
EAGLE ROCKS REACH PROJECT OPPORTUNITIES 17
Backwater Channels and Alcoves 17
River Bank Log Jams and Large Wood Enhancement of Existing Riprap 18
Bar Apex and Mid-River Logjams 18
Enhancing Natural River Migration Processes 19
SUGAR DIKE SUB-REACH (RM 41 – 42.7) 20
Analysis and Findings 20
SUGAR DIKE REACH PROJECT OPPORTUNITIES 25
Backwater Channels and Alcoves 25
River Bank Logjams and Large Wood Enhancement of Existing Riprap 27
Bar Apex and Other Mid-River Logjams 27
Enhancing Natural River Migration Processes 28

REFERENCES 37

APPENDIX A: SITE MAPS AND TYPICAL DRAWINGS 39

APPENDIX B: HYDROLOGY & HYDRAULIC MODELING 41

HYDROLOGY 41
HYDRAULIC MODELING 41
Existing Conditions Hydraulic Model 41
Model Geometry 41
Roughness 42

Boundary Conditions....43
Calibration....43
Limitations....44

APPENDIX C: PROJECT RANKING 45

PROJECT RANKING METHODS 45
Benefit Score....45
Cost Score 46
Benefit-to-Cost Score....46
Feasibility Designation 47
PROJECT RANKING 48

INTRODUCTION

This report summarizes salmon habitat restoration and enhancement concepts developed by Inter-Fluve, Inc. for the Yakama Nation's Department of Fisheries Resource Management. Work conducted for this report is part of the Middle Methow (M2) Habitat Project, which encompasses an eight mile stretch of the Methow River in Okanogan County, WA. The M2 Habitat Project is a publicly funded reach based restoration project being undertaken by the Yakama Nation (YN), the United States Bureau of Reclamation (USBR), and the Methow Salmon Recovery Foundation (MSRF) for the benefit of recovering endangered and threatened salmonids in the Upper Columbia Basin. Upper Columbia River spring Chinook salmon (*Oncorhynchus tshawytscha*) and Upper Columbia River steelhead (*O. mykiss*) are the focal species for habitat restoration in this project. The M2 project area extends from near the southern boundary of the Town of Winthrop at River Mile (RM) 50 to the confluence of the Twisp and Methow Rivers at RM 41.1.

The study reach in this report is known as the Lewisia Road to Twisp (LRT) reach, which encompasses the lower 4.4 miles of the M2 project region (RM 45.5 to RM 41.1). The YN Upper Columbia Habitat Restoration Project (YN UCHRP) is the lead project sponsor implementing salmon habitat restoration projects in this area with funding from the Bonneville Power Administration. The USBR and MSRF are the lead project sponsors implementing projects in the northern half of the M2 project area, known as M2 Reach 1. Project concepts and design alternatives for the M2 Reach 1 are being reported on separately by the USBR, and are not included in this report.

The concepts and data presented in this report build upon recent studies conducted by the USBR in the *Middle Methow Reach Assessment* (USBR 2010) and the *Methow Sub-basin Geomorphic Assessment* (USBR 2008a). These reports, along with the *Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan* (UCSRB 2007), provide the framework for focusing on the LRT reach as a key location in the Methow Subbasin for conducting salmon habitat restoration actions. Specifically, these reports identify the need to improve river geomorphic condition, floodplain function, and salmonid spawning and juvenile rearing habitat in the M2 project area, among other things. However, while these reports provide an adequate overview of general restoration actions that may be needed to enhance salmon habitat at a watershed or reach scale, by their nature these reports are too coarse in scale to be useful in designing and engineering actual habitat restoration projects at the project scale.

The intent of this report is to build upon the coarser level information and restoration suggestions provided in these previous reports and studies, and through our own field investigations and analyses develop salmon habitat restoration and enhancement concepts at the project implementation scale that are physically feasible, biologically beneficial, socially responsible, and cost effective. The project opportunities presented in this report are conceptual alternatives. Projects recommendations are based on limited survey data and preliminary analyses to identify viable projects. This important first stage is required to communicate opportunities to landowners and stakeholders and to seek permission to construct projects before spending further effort and money for permitting and design.

METHOW RIVER PROCESSES

GEOLOGIC CONTEXT

The upper LRT Reach within the Methow River is an alluvial reach that originally formed within a down-faulted graben of soft sedimentary rocks. These rocks are part of a larger, tightly folded, synclinal, sedimentary block that plunges southeast (down valley). The block is composed of varied layers of conglomerate, mudstone, chert, volcanic greywacke and plagioclase arkose (Waitt, 1972). The rock composition of the remaining watershed is much harder crystalline rock that varies from granite plutons to metamorphic gneiss and schist of varied composition (Stoffel et al., 1991). Alpine and regional ice sheet glaciation has since carved through the valley rocks. Glaciation also deposited a deep layer of glacial outwash that is composed of both the same bedrock that underlies the valley, and crystalline rock that forms the valley walls. Following glacial retreat, the Methow River eroded down and formed the floodplain we see today within glacial outwash deposits. In most locations, the river is bounded by a glacial terrace that indicates the degree of the most recent downward erosion.

Today, the LRT reach is vertically controlled by a bedrock contact near the Twisp River confluence at RM 41 and another near RM 44. The river cannot erode downward very rapidly due to the bedrock and is now re-working and transporting alluvial bank material (sand, gravel, cobbles) and the constant supply of watershed tributary sediments that are delivered to the river.

CHANGES IN NATURAL PROCESSES

Changes in river processes occur naturally and on a large scale, modifying the way a river behaves, its physical shape, and the habitats it can provide for plants and animals. The decrease in sediment load and runoff between the glaciated era and the current day is an example of a large-scale change in river processes.

Smaller-scale change has occurred on the Methow River since European settlement. The Methow River works differently today than the way we believe it worked before European settlement. Before settlement, the watershed and riparian forests were relatively undisturbed and the valley bottom was vegetated with large trees much more expansively than we see today. These forest conditions allowed floods, bank erosion, and channel avulsions to incorporate trees into the river channel. They also metered the rate of bank erosion and created a high degree of sinuosity. Habitats were very complex – with backwater channels, gravel sorting, and channel shifts into different parts of the valley. This was good for the plants and animals that evolved to occupy river environments and rely on these physical processes. Once the forests were cleared a key component of the dynamic balance disappeared. Without trees to meter bank erosion and help create much tighter meander geometries while still transporting sediment load, the river lost much of the habitat, stability and resilience it once had.

Although we do not know the exact year that European settlement began to transform the Methow River, it is clear that settlers were the catalysts of river alteration and disruption of the dynamic balance. Many of these alternations continue to occur. Unfortunately, within the LRT reach, human modifications have changed the river to a point where it cannot meander, and provide the habitat it once did. Land clearing was followed by the addition of riprap and levees to protect fields, houses, and roads from flooding – now common features influencing the Methow River. The post-European settlement changes have been gradual and occurred over generations, but the cumulative habitat loss is substantial, and combined with other factors, has been detrimental to the Methow River anadromous fish populations.

ENHANCING AND EMULATING NATURAL PROCESS AND HABITAT

The underlying goal of this habitat restoration effort is to re-create habitat conditions to which spring Chinook salmon and steelhead are evolved for critical phases of their life cycles. To achieve this end, the restoration concepts presented within this report consider two underlying goals: 1) provide immediate habitat for fish utilization, and 2) restore natural riverine ecosystem processes that will continue to create habitat in perpetuity. For the first goal, we design our projects to emulate the physical habitat conditions that would have been produced by the river as it was unconstrained in pre-European settlement conditions. The premise of this approach is that it provides instant benefit to the target species by replacing lost habitat, which is a critical component for recovering endangered species. However, these "installed" habitats, like naturally created habitat, will over time become obliterated, transformed, or adjusted by the river. Therefore their existence as useful habitat in the landscape is potentially finite on a relatively short time scale.

For the second goal of restoring natural processes, our focus is in creating conditions that allow river processes to do the work of sustainably creating habitat over time and under constantly changing conditions. Designing for this goal can more successfully ensure that a long term supply of habitat needs is met; however it may take decades for restored processes to provide adequate levels of habitat. To meet both long-term and short-term habitat needs, we attempt to incorporate both goals into our project designs. While it may not be realistic to return to pre-European vegetative conditions and habitats, our goal is to create optimal habitat that is useful to fish returning to the river now, while also emulating natural processes and encouraging them to occur when possible within the current river's management, ownership, and conditions.

Much of what is proposed in this report is designed to create habitat and processes that emulate what we believe would have been naturally created by the river 200 years ago. Our alternatives and approach accelerate habitat development by adding missing pieces (log jams) in appropriate locations, or using heavy equipment to replicate large floods running through riparian forests. In some cases, the proposed projects can be thought of as moving fast-forward through time, accelerating the river's recovery rate. In others, it is as if we are moving backward through time to create historic types of habitat on the landscape that could not be naturally created today due to human development, riprap, land clearing, vegetation management, and levees.

Proposed project locations and prescriptions attempt to fit the naturally created habitat types and locations. For instance, log jams or large wood enhancements are proposed where they would naturally develop if a forest of large mature cottonwood trees were available to naturally fall in the channel, move downstream in a flood, deposit, become partially buried, and accumulate other woody debris. Our proposed side channels and alcoves are in geomorphically correct locations within floodplains and configured to emulate what could be naturally created, following larger floods, meander migration, and avulsion. In some areas, we have proposed enhancing groundwater flow to take advantage of local conditions and maximize habitat potential or enhance existing banks where cover habitat would benefit salmonids.

Almost all habitat restoration concepts proposed in this report would yield beneficial results for other aquatic and terrestrial wildlife species as well. The simplification of the main channel and loss/alteration of floodplain vegetation cover has had negative habitat impacts to many other species besides Chinook salmon and steelhead. Because our projects focus on re-creating historic habitat features such as wetlands, backwater channels, large wood jams, and native riparian vegetation cover, it is anticipated that all local wildlife adapted to utilize these types of habitat will also benefit from these projects.

The opportunities presented herein are conceptual but have been vetted as technically possible based on our experience and knowledge of contemporary conditions. We have done our best to identify "unknowns" and areas where further study is required to confirm our current analysis and support design-level work. It is expected that these original concepts will be modified following landowner discussions, further design survey, design criteria agreement, and discussions with the others working in the basin.

GENERAL HABITAT PRESCRIPTIONS

Enhancement and restoration projects on the Methow River LRT Reach will emphasize natural stream characteristics created by existing river geomorphology. A stream's geomorphology impacts the manner in which water and sediment interact to create habitat features that fish utilize and depend on. Using enhancement techniques that emulate naturally created habitat features; our goal is to provide Chinook salmon and steelhead habitat features that optimize their sustained survival.

Below we describe general enhancement practices or "tools" that we hope to use along the Methow River. These techniques may be repeated in isolation at several locations, or in varying combinations, depending on the geomorphic condition of each site. Additional scientific studies and engineering will be undertaken before project prescriptions are permitted and constructed.

RIVER BANK LOG JAMS AND LARGE WOOD ENHANCEMENT OF EXISTING RIPRAP

Buried lateral log jams can be applied in areas where bank erosion is prevalent. This treatment is generally recommended to protect valuable property while enhancing habitat characteristics along the channel edge. This solution is a much more fish-friendly way to protect property than riprap since it provides cover and refuge for adult salmonids and rearing habitat for juvenile salmonids. In many instances, existing riprap can be replaced or modified through the construction of buried lateral log jams while maintaining its original design strength.

In non-riprap areas, eroding banks are excavated and rebuilt with a combination of logs, boulders, stream gravels, and soil. The area is then planted with native riparian vegetation, forming a very durable and habitat-friendly riverbank. The engineering of ballast is dependent on reach conditions, and local site characteristics such as hydraulics, native soil and forest, and risk.

In areas where riprap cannot be modified, it is possible to enhance cover habitat adjacent to the riprap using large wood material and boulder ballast.

POOL ENHANCEMENT

Pools are deeper areas of the stream usually associated with changes in channel direction (bends) or constrictions caused by bedrock or large wood. In healthy streams under normal flow conditions, pools provide key habitat for young fish because the currents are slow, the flow patterns are diverse, and the deeper water and logs that project into the water provide cover for fish. Pool enhancement will act to increase the variety of habitat for young fish by establishing areas that have these characteristics. These sheltered areas can be created through selective grading of existing pool features, and installation of logs in side-channel habitats or along segments of river channel. The degree to which pool enhancement is used will depend on specific site conditions and the ability of each installed feature to maintain itself over time. In most cases, pool enhancement will be associated with construction of log jams or cover habitat created by individual trees or logs.

SIDE CHANNELS

Side channels occur where the channel flow is distributed to two or more channels. The reduced current in side channels, in combination with pools and wood in the water, make side channels attractive for juvenile salmon. The fish use these side channels for feeding, velocity refuge, and avoiding predators. On the Methow River, side-channel habitat will most often be constructed in the wider areas of the river. Abandoned channels or side channels active only during flooding may be excavated for more frequent wetting or perennial flow. Construction of new side channels generally entails significant excavation to form the channel and pools, and placement of logs at appropriate locations.

BAR APEX AND MID-CHANNEL LOGJAMS

The interaction between the wood and flowing water can form deep pools that provide excellent fish habitat. Log jams placed on mid-channel bars and areas riverward of the stream bank provide cover habitat, and in certain locations, promote natural river migration processes beneficial to long-term habitat development.

To create a mid-channel log jam, an area is excavated and then trees and logs are stacked and knit together and then buried. This combination of burying logs, using excavated river alluvium, and in some cases using boulders as ballast, stabilizes the log jam during floods. Installed vertical snags allow additional wood to rack against the jam during high water events. Log jams are located, designed, engineered, and constructed to fit each site's geomorphology and hydraulic forces; therefore, they vary in size, shape, and orientation to the river.

BACKWATER CHANNELS AND ALCOVES

Backwater channels and alcoves are old, abandoned channel segments connected to the main river only at their downstream end. In most cases, water from the main river backs into these areas with little, or no, current. During higher flows in the main river, these backwater areas continue to have quiet water. Low water velocity, submerged vegetation, and dense overhead vegetation make alcoves and backwater channels important habitat to young fish.

Backwater channels can also intercept groundwater. In rare instances, the groundwater elevation and valley slope can provide conditions where intercepted groundwater flows through an alcove or backwater channel and into the river during a portion of the year. Where groundwater levels are high and soils are conducive, a backwater channel can be enhanced or created to develop groundwater flow. Existing groundwater upwelling can also be enhanced by constructing a horizontal screen or gallery that collects the water and delivers it to a created or enhanced alcove or backwater channel. Compared to the river, groundwater-fed channels are generally cooler in the summer and warmer in the winter. This is valuable to juvenile fish: it allows them to find refuge from stressful warm water in the summer, and in the winter, juvenile fish grow more quickly in the warmer water.

Like side channels, alcoves and backwater channels are primarily constructed in wider areas of a river. The Methow has several areas along its length that gain groundwater, and provide opportunities for alcoves and backwater. Construction of alcoves and backwater channels involves excavation to form the channel and pools, placement of wood (trees and logs) at appropriate locations, and planting of riparian vegetation.

The Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (2007) and the Upper Columbia Regional Technical Team (UCRTT) Biological Strategy (2008) indicated that the most limiting habitat factor in the Methow River is the lack of low-flow and over-winter habitats for juveniles. Therefore, where the right conditions exist along the river and valley bottom, backwater or groundwater-fed side-channel project sites will be important opportunities for enhancement or restoration of key habitat.

ENHANCING NATURAL RIVER MIGRATION PROCESSES

Promoting river migration processes is one component of restoring long-term habitat development. This type of project seeks to remove levees, dikes, riprap, roads, houses and other human infrastructure to enable the river to naturally migrate and change its form and function throughout the valley bottom. Allowing the river to migrate is beneficial because it creates new spawning areas, new habitat by incorporating mature trees, and allows other floodplain processes, such as beaver activity to occur. An actively migrating river creates side channels, backwater channels, logjams, and gravel bars that become sites for colonizing floodplain cottonwood trees.

Fish seek these newly formed habitats because old decaying backwater channels and log jams become less accessible and usable to the fish over time. A river that can create and maintain habitat features across the valley bottom through time is constantly rotating physical habitats and nutrients at various stages of birth and decay. Because this project is broad in scale, property and infrastructure can be affected directly or indirectly due to future channel shifts and flooding. Therefore, land purchase, agreement, or easements will be required before this type of project can be carried forward.

ENHANCEMENT PROJECT OPPORTUNITIES

We identified three sub-reaches for our Methow River LRT work (see Appendix A for maps of these sub-reaches). These are the Two Channels sub-reach (RM 44.0 – 45.5), the Eagle Rocks sub-reach (RM 42.6 – 44.0) and the Sugar Dike sub-reach (RM 41.1 – 42.6). These sub-reaches frame our following presentation of local site conditions that support conceptual project alternatives.

TWO CHANNELS SUB-REACH (RM 44.0 - 45.5)

ANALYSIS AND FINDINGS

River Constraints

The Two Channels sub-reach is a 1.5-mile east-to-west bend in the river (looking downstream, the bend turns to the right). There are several areas along the reach where the channel is confined by levees and/or riprap. Starting at the upstream end of the reach, a right bank segment is controlled by a riprap-reinforced levee that prevents water from entering a former side channel near the western valley wall. The riprap prevents any lateral bank erosion along its length. Downstream, as the river makes its turn to the right, it encounters a high Pleistocene outwash terrace on the left. Riprap has been added to segments of this terrace to reduce the rate of terrace erosion. Further downstream, the river leaves the outwash terrace behind and runs along a lower middle terrace a short distance before running along an active floodplain bank. Along the left bank of the floodplain bank, another levee has been constructed to prevent flow down the left valley floodplain and into the Eagle Rocks sub-reach downstream. At the downstream end of the reach, the river meets a bedrock outcrop forcing a 90-degree turn in the river and forming a very deep pool. With the exception of upstream right bank riprap, all remaining right banks are composed of floodplain alluvium downstream to the end of the sub-reach.

Historical Air Photo Analysis and Flood Response

The Bureau of Reclamation (Reclamation) completed a substantial 2-dimensional hydraulic modeling and historical air photo analysis to understand how the river between Twisp and Winthrop has eroded and changed over the photo record. This analysis used air photos (1945 through 2006) and historical maps (1894/1900 GLO) that show that existing interior flood channels and alcove channels of the Two Channels sub-reach were formed during the 1948 flood. Since that time, segments of the channel network have been modified, and constructed levees have greatly decreased the amount of flooding into western floodplain segments. Major levee and riprap construction was completed by 1964 (Reclamation, 2010).

Two major channels formed in 1948 within the eastern segment of the floodplain were active during small (2- to 5-yr) floods (Figure 1). However, the riprap-reinforced levee at the upstream end of the Two Channels bend blocks the western side channel from most floods. The levee is overtopped only during rare large floods (>50-yr). The eastern side channel still starts becoming active by between the 2- and 5-yr flood.

The Two Channels Reach has not had substantial changes in planform throughout the photo record. Due to the downstream bedrock control and upstream riprap reinforced levee, substantial changes in river planform are unlikely to occur during floods smaller than the 50-year flood. Several houses have been built behind the existing levee and there are presently no indications that these lands could be purchased and houses removed. Therefore, no effort was made to propose a riprap or levee removal project in the Two Channels Reach.

The Two Channels sub-reach has had substantial vegetation removed since settlement. We estimate that the entire valley bottom was once vegetated with riparian forests. The 1945 air photo shows that 90 percent of the valley bottom was likely a cottonwood forest before settlement, but is now largely pasture. Patches of forests have regenerated on some of the land holdings and it is estimated that 50 percent of the sub-reach is now in a forested condition. The majority of the trees are less than 50 years old (Figure 2).

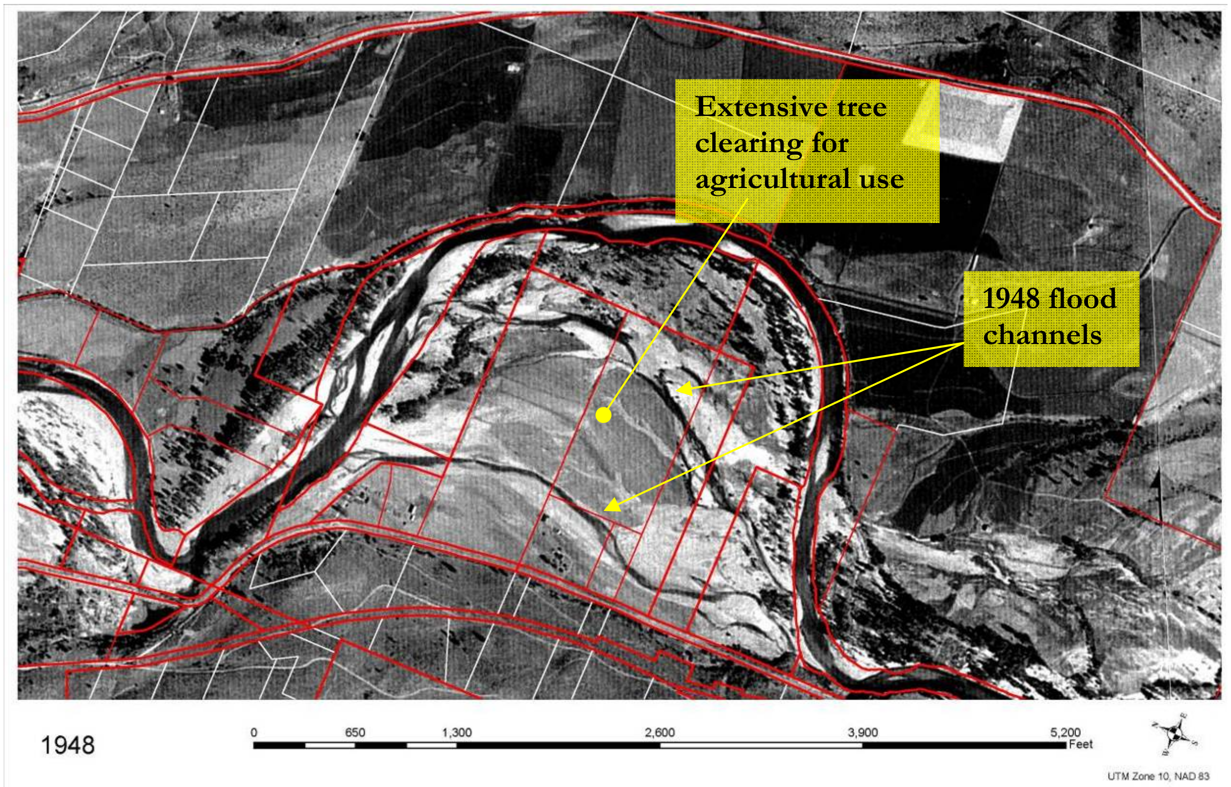

Figure 1. 1948 Air Photo

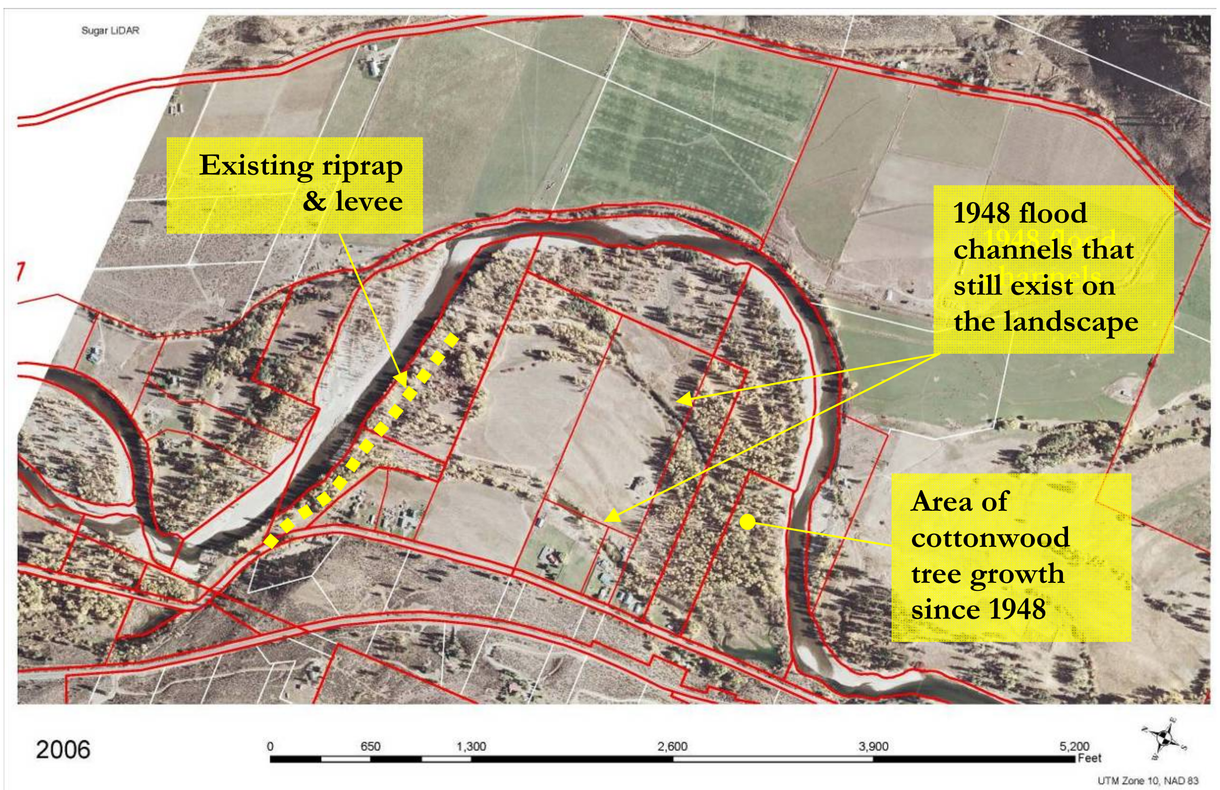

Figure 2. 2006 Air Photo

Pump Testing

Pump testing has been completed in segments of the valley where near-surface groundwater may enable the development of gallery-fed or enhanced-alcove side channels. The pump test is used to measure the equilibrium water surface elevation associated with a water withdrawal rate from a trench of given length. This data is used to characterize the hydraulic conductivity of the local soil profile and predict the available yield for spring development. The side-channel elevations and gradients can be compared with flow rates and associated equilibrium elevations to determine if groundwater-fed alcove channels are feasible, and if so, what flow rates can be expected at particular locations.

For each pump test, a linear trench was excavated and the water was pumped out by a 200-gallon-per-minute trash pump with reducer and valve fitted to the discharge hose. The water was pumped down under maximum throttle and with an open valve, then the throttle was backed off slightly to allow the trench to partially refill with groundwater until the inflow equaled the outflow. When the water surface elevation became relatively constant for 30 minutes, the groundwater inflow to the trench was considered to be equal to the pumped outflow from the trench. At that time, measurements were recorded for the equilibrium water surface elevation, wetted trench length, and pump discharge. Then the sequence was repeated for a lesser discharge. The results form a simple relationship of groundwater flow per unit length at equilibrium water surface elevation. This relationship can then be used for groundwater collection gallery design.

Two Channels Pump Test

At the Two Channels site, one pump test was conducted approximately 100-feet downstream of the inlet to the eastern side channel. The data showed that it would be feasible to establish a groundwater gallery. The groundwater gallery could be established near the pump test location and water from the gallery delivered to a constructed alcove side-channel habitat down valley.

Piezometer Wells

Two piezometer wells and one stage gage were installed within the Two Channels reach to determine how groundwater fluctuates seasonally with river stage. The piezometer wells allow for the measurement of seasonal groundwater elevations – important data for habitat creation – particularly the low levels. Data will be used to design elevations of alcove and side-channel habitat.

TWO CHANNELS REACH PROJECT OPPORTUNITIES

BACKWATER CHANNELS AND ALCOVES

Project T1: Groundwater Gallery and Alcove Channel (Existing East Channel)

Project T1 is a potential alcove side channel that could be developed within the existing East Side Channel. Groundwater pump testing results indicate that a groundwater gallery could be developed to supplement the channel with perennial flow. The proposed alcove channel would generally follow existing flood channel alignments and flow out to a pool on the river to reduce the potential for deposition at the confluence.

Low water surface measurements from the piezometers will be collected in the summer and fall of 2011. To maximize fish access and use throughout the year, this data will be used in conjunction with pump test data to design the alcove channel grade, width, and depth. Bedform diversity will be graded into the channel and large wood habitat will be imported to the site and installed to provide cover habitat.

Design Considerations

Principal design considerations relate to high-flow interaction with the low-flow grading design. By enlarging and deepening a side channel, more water is expected to enter the side channel during flooding. The T1 side channel would be constructed into existing alluvium so stability would be inherited from the river gravels. Constructed log jams and increased floodplain roughness can be implemented to further reduce flow and sediment loading. The geometry of the side channel will be configured to optimize transport of fine sediments that deposit during flooding. Flood interaction with the side channel will be addressed further during the design.

Project T2: Groundwater Gallery and Alcove Channel (Existing West Channel)

Project T2 is similar to T1 but is located within the footprint of the older West Channel near the valley wall and existing private pond network. The channel outfall would be to the pool at the downstream bedrock control. Permission was not granted in the fall of 2010 to conduct a pump test at the upstream end of the West Channel. Assuming soils and groundwater levels are similar to the T1 side channel, the T2 project shows promise for a groundwater-fed alcove channel because of its alignment along the valley wall and its association with a long bend in the river with several riffles. A new alcove channel alignment would be within the hydraulic shadow of a levee so frequent flooding and deposition is not a major concern. A pump test is recommended prior to design work if a project here is to proceed.

To build this project, and to maximize fish access and use throughout the year, piezometer and pump test data will be used to design a channel grade, width and depth. Bedforms will be graded into the channel and large wood habitat will be imported to the site and installed to provide cover habitat.

Design Considerations

Physically this project is feasible. However, there are several unknowns related to private land use that need to be understood and resolved. Several excavated ponds exist along the proposed alignment. Whether these ponds and a downstream beaver pond complex can be modified and how they would interact with a side channel with flow supplied by a groundwater gallery is currently not fully understood. To increase understanding of the site and have an informed conversation with stakeholders, a pump test and profile survey is recommended. If, for instance, the ponds are too high, they would have to be modified, lowered or eliminated to fit an alcove-type channel as described above.

The advantage of the T2 site is that the West Channel is well protected from flood discharges compared to the East Channel. An alcove channel within the old West Channel alignment would provide inherent protection from the existing levee and riprap, so there would be low risk of instability or deposition.

RIVER BANK LOGJAMS AND LARGE WOOD ENHANCEMENT OF EXISTING RIPRAP

Project T3: Large Wood Habitat Enhancement along Riprap Banks

Project T3 identifies opportunities to enhance habitat along existing riprap banks. This type of project is identified for areas where riprap cannot be modified. Trees or logs with root wads could be ballasted within these zones using riprap or imported boulders. To do this, cable would be tightly wrapped around trees and securely fastened to boulders by epoxying both ends of the cable into holes drilled into the boulders. The ballasted trees would be placed in deeper areas of pools or near the toe of the riprap slope.

Design Considerations

It will be important to insure there will be no impact to the riprap bank following implementation. Whole trees, logs and logs with boulders can be utilized with this work. The habitat work would occur in deep pool areas where the addition of large wood as cover wood would provide the greatest benefit to fish.

Project T4: Bank Logjams within Riprap Banks, Low Terrace and Floodplain Banks

In both riprap banks and native banks, there are opportunities to establish bank logjams that extend out into the channel. The jams would be between 30 and 60 feet in length and extend out into the channel up to 15 feet. They would be formed out of multiple imported tree and log complexes that extend up vertically at least to the 2-year flood stage.

Design Considerations

The exact footprint will depend on local site conditions, riprap condition, bank height and river use. Bank logjams would be focused in pool areas where the addition of wood will benefit overall habitat.

BAR APEX AND OTHER MID-RIVER LOGJAMS

Project T5: Bar Apex Jam to Establish Seasonal Flow into Side Channel (Southeast)

A large logjam is proposed along the inside of the bend near RM 44.75 to encourage flow into a high-flow side channel. The jam would be located at the bifurcation point between the mainstem and the side-channel inlet. The jam would be large and extend out in the river enough to reduce local cross-sectional capacity and push water into the side channel. Currently, flows greater than the 10-year return flow enter the side channel. Pool habitat adjacent to the logjam would be enhanced in the side channel and mainstem.

Design Considerations

Ideally this project would be combined with project T6 (discussed below) to improve seasonal high flows into this segment of floodplain. If project T6 is not constructed, most of the benefits of a logjam at this site will be to enhance the existing edge and pool habitat near the jam.

SIDE CHANNELS

Project T6: Excavated Flow-Through Side Channel (Southeast)

Project T6 would create a seasonal side channel by deepening a side channel created during the 1948 flood. The flow into the side channel would be enhanced by building the bar apex logjam described in Project T5. The outlet of the channel would be at the downstream end of the mainstem riffle. Imported wood would be used to create lateral bank jams within the excavated side channel to provide habitat.

Design Considerations

The channel would be seasonal due to its location on the inside of a relatively immature meander bend. However, the goal will be to create as much use within the channel as possible. This could be achieved by establishing the bar apex logjam described in T5, as well as a sizable left bank logjam downstream of the inlet within the zone as described in T4. The goal in both logjams would be to reduce discharge in the main channel so that more flow would enter the constructed side channel.

EAGLE ROCKS SUB-REACH (RM 42.7 – 44)

ANALYSIS AND FINDINGS

Note: The landowner did not grant permission to examine the left valley segment of the Eagle Rocks Sub-Reach between RM 43.7 and RM 44 hindering our ability to understand the sub-reach and project opportunities.

River Constraints

The Eagle Rocks sub-reach is a relatively straight, 1.4 mile river segment. With the exception of right bank segments adjacent to Highway 20, it is relatively unconstrained by levees and riprap along most of its meander corridor. A left bank levee identified within the Two Channels reach prevents floodwater from entering the Eagle Rocks reach at that location.

Starting at the bedrock pool located at the downstream end of the Two Channels sub-reach, there is a relatively short (1,000 foot) segment of right bank floodplain within 50 feet of higher Holocene terrace abutting valley wall bedrock. Downstream, the right bank is confined by riprap protecting Highway 20 from approximately RM 43.8 to 43.3. The riprap does not substantially impact the natural meander corridor because the highway has been constructed up against valley wall bedrock. The riprap protects the highway road bench and the river could not substantially erode the bedrock behind the road bench if it were removed. The adjacent left bank (RM 44 to 43.3) is composed of unprotected alluvial bank and floodplain. This left bank floodplain surface continues east between 1,000 feet (upstream) and 3,000 feet (downstream) where it encounters late Holocene terrace alluvium buttressing yet higher glacial terrace outwash.

Both right and left banks downstream of RM 43.3 to the end of the sub-reach (RM 42.7) are composed of unconstrained alluvial bank with adjacent floodplain. The left bank width varies from 3,000 feet at the upstream end, narrowing to less than 1,000 feet wide at the downstream end. Floodplain surfaces meet Holocene terraces along the same length which then abut higher and older glacial outwash terraces. The right bank floodplain is between 500 and 900 feet wide and encounters a glacial outwash terrace and Highway 20 west of the river. With the exception of this small right bank floodplain segment behind Highway 20, the Eagle Rocks reach is free to laterally erode throughout the valley bottom.

Historical Air Photo Analysis and Flood Response

Air photographs and 1894/1900 GLO maps indicate the channel has been in a similar low sinuosity planform condition with relatively little change over the last 110 years. Air photos show mature meander bend signatures and cutoffs on the eastern side of the floodplain, but these were active sometime before 1894. The 1894 river alignment was mapped generally along its present alignment (Figure 3)

Currently, the east side of the valley rarely floods. The levee on the right bank of the Two Channels reach reduces the flow that can enter the left side of the valley through the Eagle Rocks sub-reach. If this levee were to be removed, it is estimated that flows between the 25-year and 50-year flow could enter some of the channels within the Eagle Rocks reach. Hydraulic modeling indicates that hydraulic connectivity between the river and the historical channels is disconnected for floods less than the 25-year frequency.

Downstream segments of the channels within the reach are backwatered at the outlets as the Methow river stage raises during high water. Deep historical pools or low areas that have been excavated are also watered depending on the river stage, but none is effectively connected hydraulically with mainstem surface flows.

Based on our modeling efforts, field work, and analysis of existing information, Inter-Fluve agrees with previous 2010 RECLAMATION analyses and does not believe that contemporary surface water disconnection to old channel networks is caused by regional downcutting. Bedrock control near the Twisp River confluence coupled with Twisp River discharge and sediment loads set the base level for the LRT reach. The loss in floodplain connection to Methow River flooding is more likely due to a combination of loss in channel length from historical meander bend cutoff and localized incision, infilling of old channels, modification from past landowners, floodplain grading and upstream levee work. It is even possible that a large logjam created conditions to develop the old meander traces we see in the air photos. Air photo and survey data are post-1894, so we can only speculate on the processes that created or destroyed the historical meander bends on the east side of the Eagle Rocks sub-reach prior to 1894. The flood of record (estimated over 500-year) occurred in 1894. Such a flood event is capable of resetting river planform and local grade for decades, and if this was preceded by valley bottom land clearing, it is conceivable that the relatively straight planform conditions within the Eagle Rocks sub-reach is a symptom of the 1894 flood event.

Currently, there is nothing to prevent the river from laterally eroding east and gradually occupying the eastern half of the valley again. It is one of the few sub-reaches in the Methow where long-term, valley-wide river processes are possible without substantial removal or alteration of human infrastructure.

The Eagle Rocks sub-reach has had substantial vegetation removed since European settlement. Based on air photo records, it appears that much of the land clearing had already taken place by 1945 and since that time little has changed. We have made the assumption that the entire valley bottom was forested prior to European settlement, and we have estimated that 70 percent of the area has been cleared for agricultural use (Figure 4).

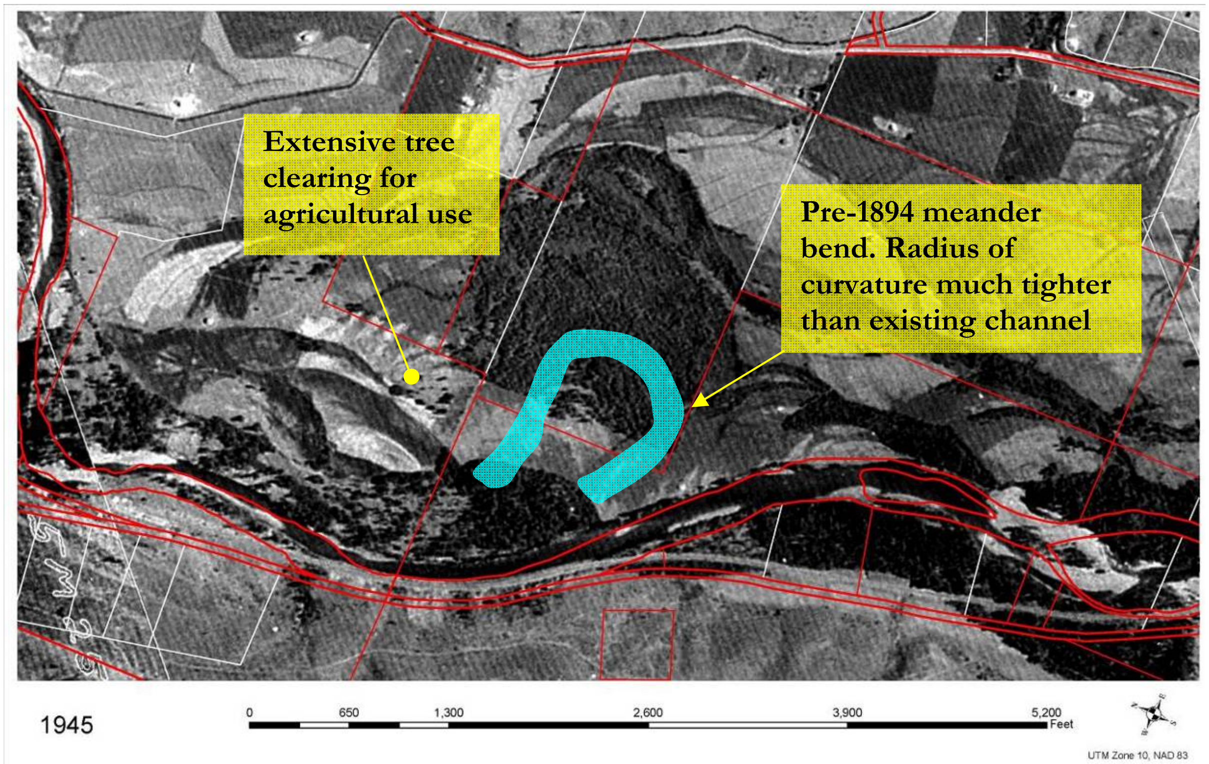

Figure 3. 1945 Air Photo

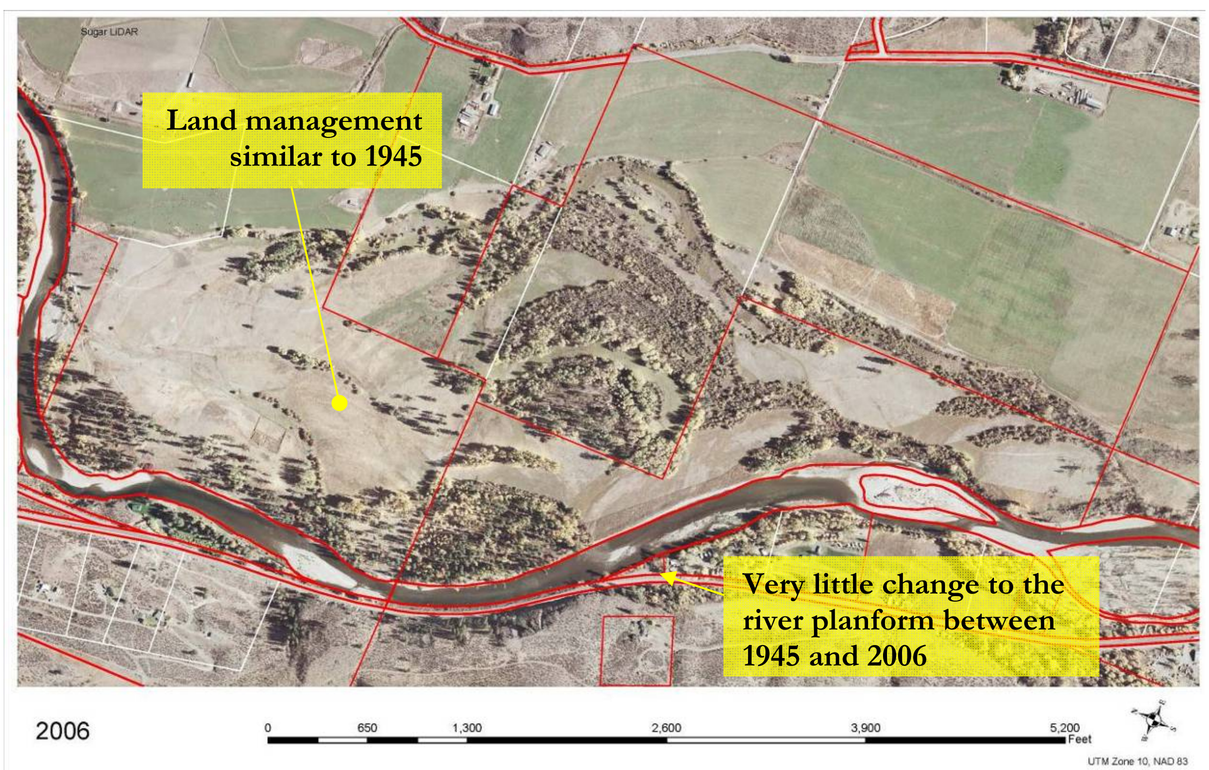

Figure 4. 2006 Air Photo

Piezometer Wells

We installed four piezometer wells within the lower Eagle Rocks sub-reach to determine seasonal fluctuations in groundwater and relationship with river stage. The data collected from the wells will be used to develop side-channel connection with local groundwater elevations during the lowest levels. Side-channel excavation or enhancement work will be based on this data.

EAGLE ROCKS REACH PROJECT OPPORTUNITIES

BACKWATER CHANNELS AND ALCOVES

Project E1: Groundwater Fed Alcove Side Channel

Project E1 creates an alcove side channel approximately 4,900 feet long within former river channels that existed before 1894. Along segments of the new channel, free draining backwater wetland zones would be constructed to enhance floodplain and alcove channel complexity. The location is well suited for an alcove channel and has great potential as a backwater habitat off the Methow River.

The new alcove channel could be enhanced by a groundwater gallery that captures elevated groundwater elevations from infiltration losses from the Barclay Irrigation Ditch. It may be possible to intercept these elevated seasonal groundwater flows and daylight them to the new alcove channel. It is also our understanding that there may be an existing agreement to return approximately 9 cfs of Barclay Ditch surface water to the river. If this is true, it would be an excellent opportunity to install a short lateral diversion to deliver the 9 cfs to the upstream end of the alcove channel.

A channel would be constructed to maximize usable area for juvenile salmonids. Imported trees and salvaged vegetation would be used to create cover habitat throughout the new channel alignment.

Design Considerations

We do not know the potential for groundwater gallery development yet. Four piezometer wells were installed in the fall of 2010. The goal will be to create a new channel that will have the streambed at or below the lowest well readings along the entire channel profile in order to assure perennial flow. The wells will be monitored over the year to determine seasonal water elevations. It is recommended that a pump test be conducted during the irrigation season and again when no water is in the ditch to gain an understanding of the influence of potential infiltration losses from the ditch that could supplement flow to a new excavated channel. It is possible the groundwater gallery could collect Barclay Ditch seepage water flowing west towards the river during the summer.

Agreements regarding surface water returns from the Barclay Ditch could also be designed as part of this project. To do so, landowner permission would be required to create a diversion from the ditch to the new alignment.

RIVER BANK LOG JAMS AND LARGE WOOD ENHANCEMENT OF EXISTING RIPRAP

Project E2: Large Wood Habitat Enhancement along Riprap Banks

This project work is recommended for areas where riprap cannot be modified along Highway 20. The river segment is a long pool and the addition of cover habitat would be beneficial to salmonids there. Trees or logs with root wads could be ballasted using riprap (if large enough) or imported boulders. To do this, cable would be tightly wrapped around trees and securely fastened to boulders by epoxying both ends of the cable into holes drilled into the boulders. The ballasted trees would be placed in deeper areas of pools or near the toe of riprap slope. Work would be conducted from the river via access from the east riverbank to prevent disruption of highway traffic.

Design Considerations

It will be important to insure there will be no impact to the riprap bank following implementation. Whole trees, logs, and logs with boulders can be utilized for this work.

Project E3: Bank Logjams within Riprap Banks, Low Terrace and Floodplain Banks

Downstream of the E2 project work there is an opportunity to create bank logjams at an eroding segment of the left and right bank. The proposed logjams would be between 40 and 60 feet in length and extend out into the channel up to 15 feet. They would be formed out of multiple imported trees and logs to form complexes with bases below the scour depth and with heights to at least the 2-year flood stage. Vertical snags would be incorporated into the design. This work emulates buried lateral logjams and the habitat they create. Large wood key pieces could be emulated by using smaller imported wood to form a stable wood matrix.

Design Considerations

The exact footprint will depend on local site conditions, riprap condition, bank height and river use. The bank zones where these types of logjams are proposed can be viewed in the appendix.

BAR APEX AND MID-RIVER LOGJAMS

Project E4: Bar Apex and Mid-River Bank Logjams

Project E4 would enhance natural river processes such as lateral migration and natural habitat development by constructing large bar apex logjams or extended bank jams at three sites within the Eagle Rocks Reach. Each jam would enhance low- and high-flow habitats near the logjam and encourage split flow side-channel development and/or channel expansion to increase river length and riparian habitats.

These large jams would be excavated deep into existing gravel bars and river banks and work up vertically and outward. The jam structure would be large enough to collect native wood material floating downstream during flooding.

Design Considerations

To be successful, this project would require substantial volumes of large wood. In a river with mature riparian forest, this type of logjam would force water against banks causing erosion. As the large trees fall into the river and accumulate additional debris, the erosion rate decreases while the woody debris along the bank protects the bank and provides excellent habitat. This would not be the case where two of the three proposed logjam sites are located. At these sites, lateral expansion into pastures would cause the development of lower and wetter gravel bar surfaces that could be colonized by cottonwoods. Currently, the high banks are too dry for colonizing riparian trees, and have been/are maintained for pasture. Lateral erosion would begin the process of regenerating new riparian floodplain forests as gravel bars are extended and new floodplain surfaces are created through bank erosion.

ENHANCING NATURAL RIVER MIGRATION PROCESSES

Project E5: Methow River Valley Bottom Re-Grade

Pre-1894 meander traces that exist on the eastern half of the Eagle Rocks reach indicate that the river at one time had much greater channel length and lower local slope. This probably provided a much wetter floodplain than exists today. The E5 project would reset the Methow River planform and valley bottom conditions to levels similar to what may have occurred before human settlement. One could think of this as going back in time hundreds of years to pre-European settlement impacts. Or it could be thought of as going forward in time hundreds of years if current management practices of the valley bottom ceased. In either case, the channel bedforms, floodplain conditions and river planform would emulate what the river could do in an unaltered setting. The river alignment and habitats would not be static and would continue to evolve and change following construction as they do in undisturbed river environments.

To do this, vast quantities of valley bottom alluvial material would be excavated and removed to create a new river alignment, floodplain wetland areas, backwater habitats, and large logjams. Very large volumes of large wood material would have to be imported to emulate the roughness of a mature floodplain forest. The imported wood required to emulate a mature forest would be critical to maintain sediment transport, meter lateral erosion rate and provide overbank resiliency during larger floods.

Design Considerations

Projects such as this have been completed successfully. However, few have been completed on rivers as large as the Methow in the LRT Reach. Valley-wide land ownership agreement would be required. There are a variety of potential alignments and habitat types that could be created, and a more detailed understanding of valley-bottom topography, potential channel slopes, and sediment transport requirements would have to be attained before a preferred alignment is chosen. Sediment continuity through the project reach would be critical for long-term stability.

SUGAR DIKE SUB-REACH (RM 41 – 42.7)

ANALYSIS AND FINDINGS

River Constraints

The Sugar Dike sub-reach extends 1.4 miles from the bottom of the Eagle Rocks sub-reach (RM 42.6) down to the Twisp River confluence (RM 41.2). It is confined by levees and riprap in several areas. The left bank, starting at the upstream end of the reach, is composed of floodplain sediments, some of which are actively eroding just downstream of a static point bar that is maintained by the presence of right bank riprap (Sugar Dike). As the river makes a downstream turn to the right, it encounters a high Pleistocene outwash terrace on the left. Some segments of the left bank are riprapped to reduce the rate of terrace erosion. Further downstream, the river leaves the glacial terrace behind and is bordered again by active floodplain banks that continue downstream to bedrock near the Methow and Twisp River confluence.

The right bank, starting at the upstream end, is controlled by a 1,500-foot long, riprap-reinforced levee (Sugar Dike) that was constructed in 1974. The riprap prevents lateral bank migration and the levee prevents flow from entering the southern interior floodplain and channels. Sometime after the levee construction, many of the low areas landward of the levee were filled in.

As the river turns to the right, it leaves the levee and riprap behind and alluvial bank and floodplain form the banks downstream to river mile 41.5. At RM 41.5, the right bank is composed of higher Holocene terrace for approximately 700 feet before returning back to lower floodplain banks downstream to the Twisp River.

Historical Air Photo Analysis and Flood Response

Historical air photos indicate that substantial river planform changes have occurred due to large floods, road reconstruction, land clearing, and efforts to prevent bank erosion and flooding. The most significant changes to river meander processes followed the construction of the valley bottom road, which led to a series of actions culminating in the Sugar Dike. Between 1894 and 1945, the valley bottom road alignment was changed from a location outside the floodplain to its current alignment. It is not known when the change occurred, but the current bridges along the Sugar Dike sub-reach were designed in 1945, and the design drawings indicate that an existing Timber Bridge was removed as part of the construction. The road alignment later became Highway 20, and it bisects approximately one-third of the most western segment of the valley bottom with two bridges that cross a historical side channel mapped in 1894. Based on historical imagery, we suspect that the upstream bridge opening (side-channel inlet) flowed with more water and more frequently when it was constructed than it does now. Currently, the river flows into this old 1894 side channel during the ~5-yr and greater floods. Downstream meander bend translation (down-valley river bend migration) from 1945-1972 may have been the primary reason for the flow reduction in the 1894 side channel.

Down-valley river bend migration during the same period might have also increased the rate of erosion on the right bank near Highway 20. Between 1964 and 1972, the Sugar Dike was constructed to re-align the channel and eliminate the bank erosion that had been occurring near Highway 20. The Sugar Dike has stopped lateral bank erosion and river migration and this has influenced the location and degree of lateral bank movement downstream of the dike. The dike and supporting riprap is similar to bedrock in that it maintains a relatively static planform condition.

A small segment of river downstream of the Sugar Dike is laterally eroding into floodplain banks and creating side-channel habitat. This is one of the few areas within the Sugar Dike Reach that can actively adjust its boundaries, and it is approximately one-third of the area that was historically available for river migration before Highway 20 and the Sugar Dike were constructed.

In summary, there have been two major incremental losses of the meander migration zone, and both have influenced river/floodplain and river/flood-channel interaction. The first loss was caused by a change in road location from outside the floodplain to inside the floodplain. The second was following the 1974 completion of the Sugar Dike. Side channels created before 1974 are now sealed off from the river by the Highway 20 and the Sugar Dike, isolating them from the flood water interaction, erosion, decay and/or expansion that may have otherwise evolved.

In contrast, channels and meander corridor areas outside the influence of Highway 20 and the Sugar Dike have continued to evolve. East of the dike and downstream to the Twisp River, new channels have been created and old channels have been obliterated as the river continues to migrate where it can, although within a much smaller meander migration zone than historically available (RECLAMATION, 2010) (Figure 5).

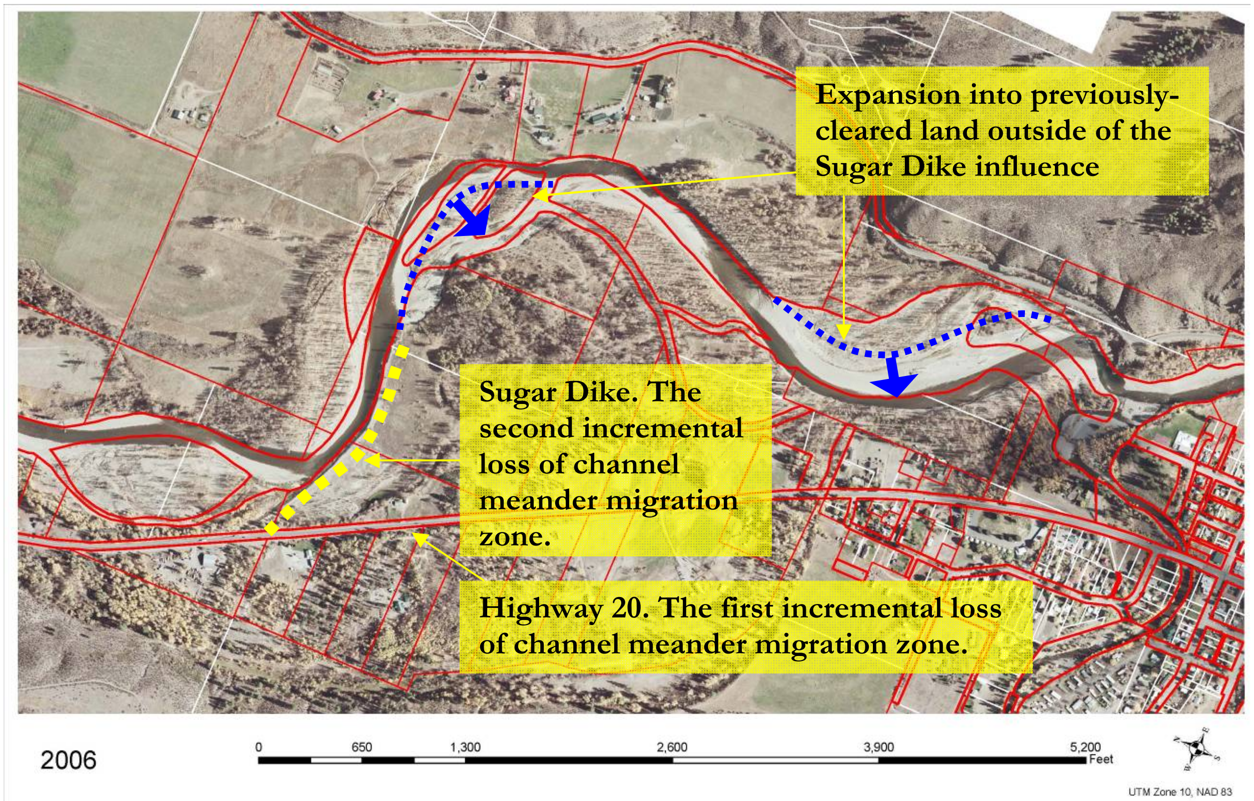

Figure 5. 2006 Air Photo

The Sugar Dike sub-reach vegetation has been heavily modified since settlement, and based on air photo records; it appears to have played a role in channel instability. We assume the entire valley bottom was once vegetated with riparian forests. Based on the 1945 air photo, we estimate that half the valley bottom was converted to pasture; we suspect that it was a cottonwood forest before settlement. There appears to be a strong correlation between tree clearing and rapid changes in channel morphology. In the 1945 photo, several areas that were cleared are the same areas where either more rapid lateral migration or channel avulsions occurred following the 1948 flood (500-year return)(Figures 6 & 7). Additional tree clearing occurred between 1954 and 1964. By 1964, only 10 to 20 percent of the valley bottom had tree densities similar to what may have occurred historically. Again, as in the 1948 flood, areas that were cleared in the 1964 air photo received accelerated lateral bank erosion between 1964 and 1974 photo years. During recent fieldwork, Inter-Fluve noted slow tree regeneration in large segments of the previously-cleared floodplain (Figures 8 & 9).

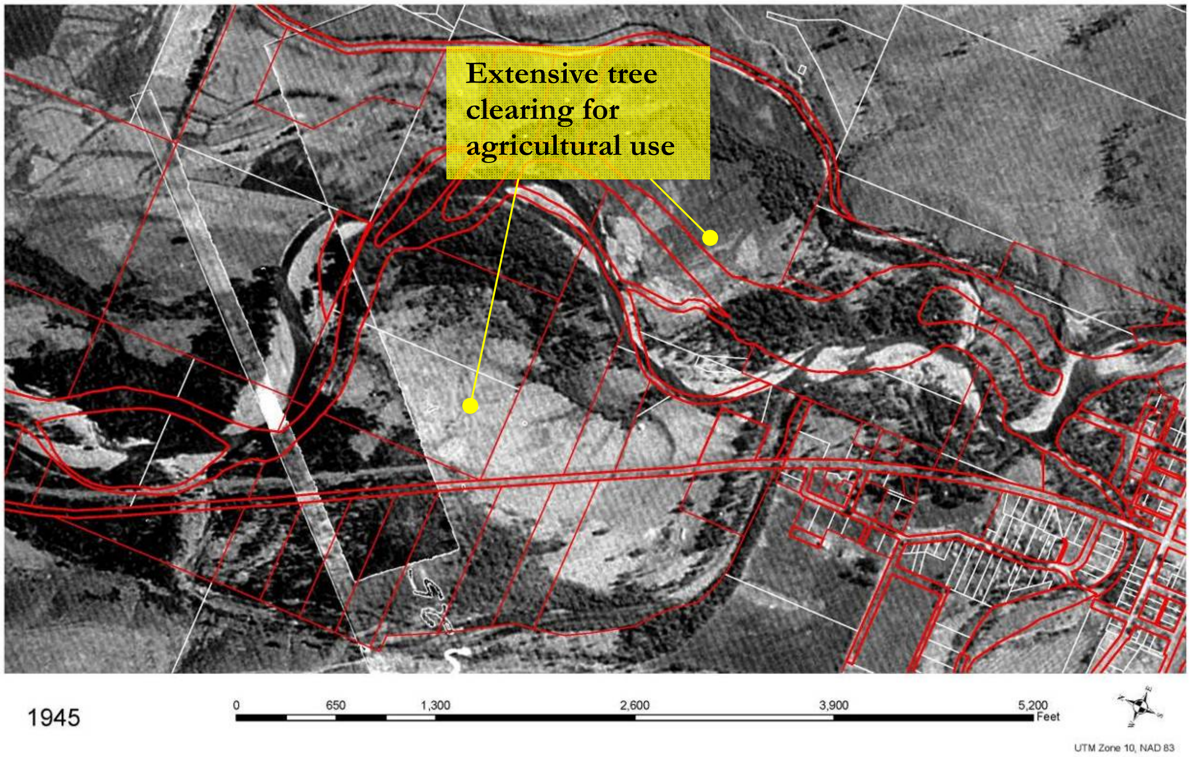

Figure 6. 1945 Air Photo

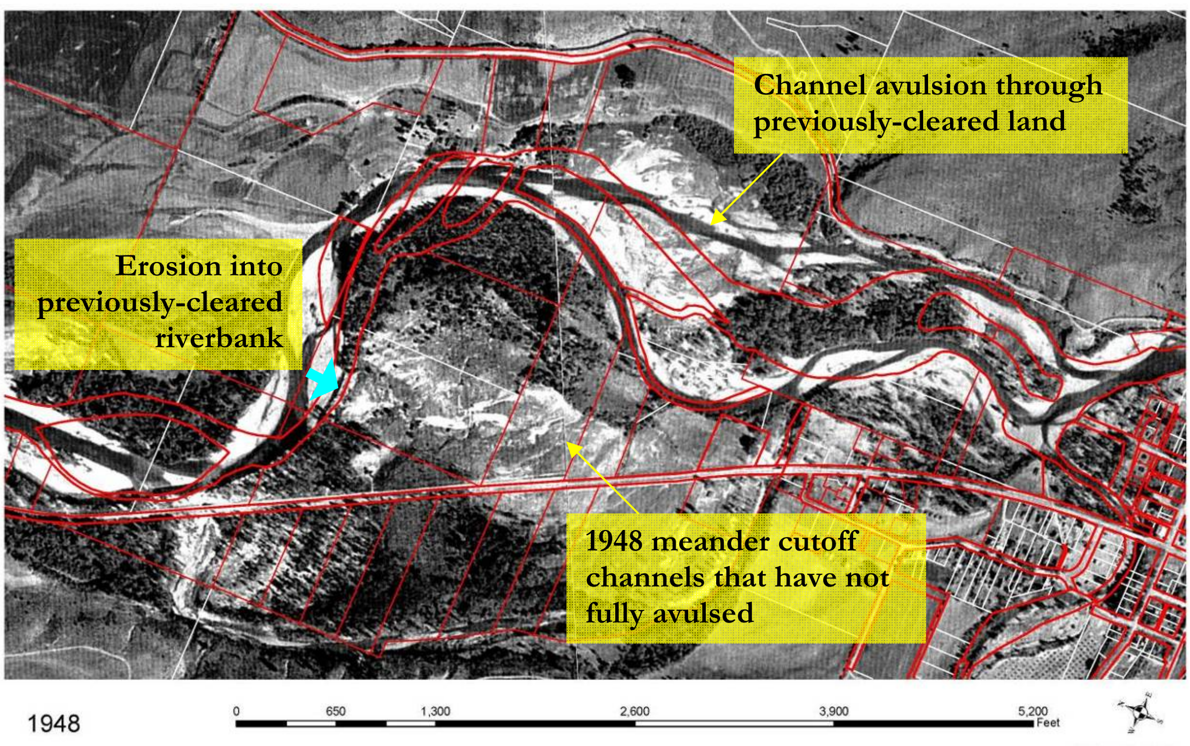

Figure 7. 1948 Air Photo

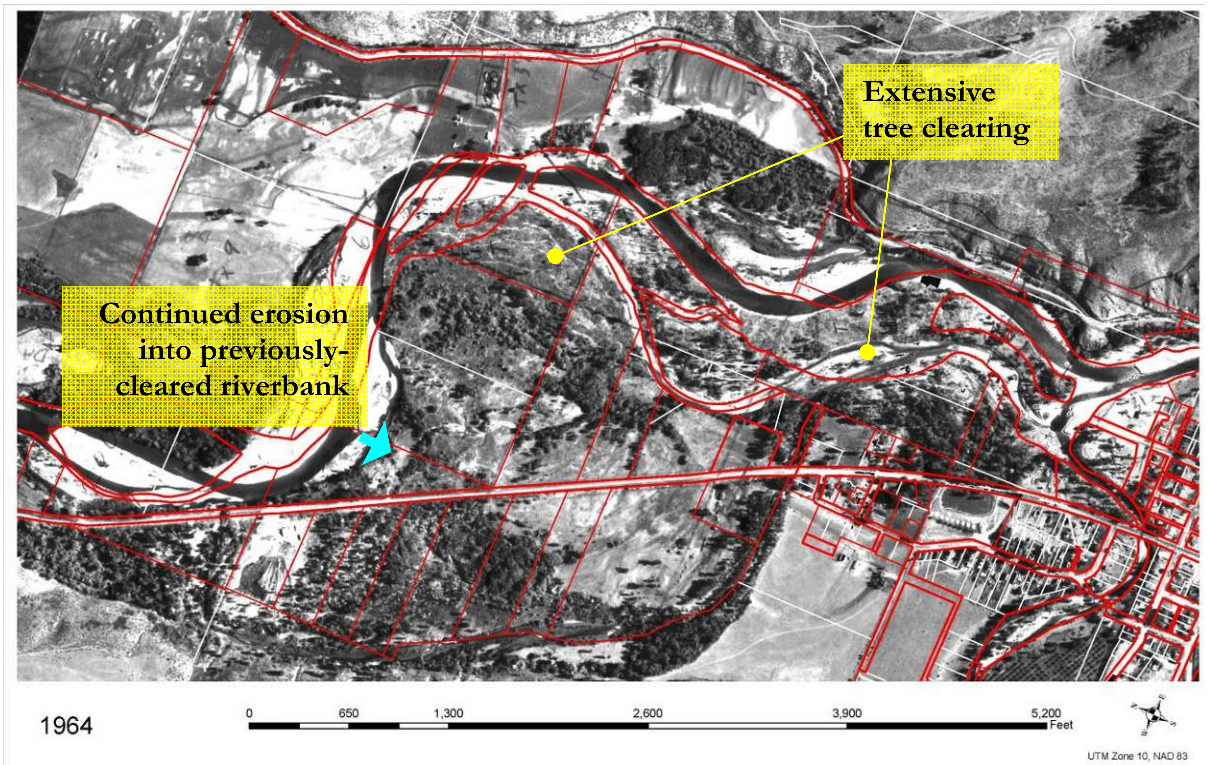

Figure 8. 1964 Air Photo

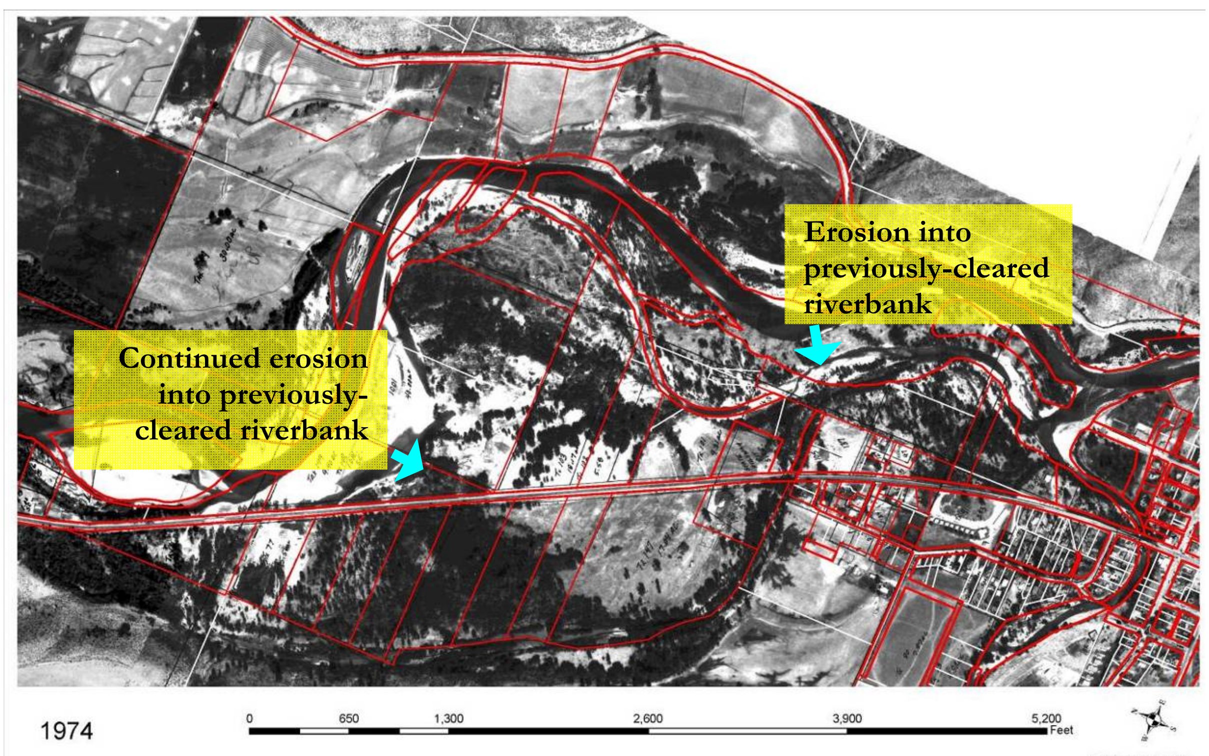

Figure 9. 1974 Air Photo

Pump Testing

We completed three pump tests within the Sugar Dike sub-reach. Pump testing objectives and methods were as described in the Two Channels sub-reach analysis section. Two pump tests were east of Highway 20 and one was west of Highway 20.

Pump Test 1 Result

The pump test that was approximately 1,400-feet east of Highway 20 could support a gallery but with less flow.

Pump Test 2 Result

The pump test that was approximately 50-feet east of Highway 20 produced the most flow and could easily support a ground water gallery.

Pump Test 3 Result

The pump test that was approximately 800-feet west of Highway 20 could not support a ground water gallery.

Piezometer Wells

Five piezometer wells were installed within the Sugar Dike sub-reach to determine seasonal fluctuations in groundwater with river stage. The data collected using the wells will be used to create as much low-flow, alcove, side-channel habitat as possible via side-channel excavation or enhancement.

SUGAR DIKE REACH PROJECT OPPORTUNITIES

BACKWATER CHANNELS AND ALCOVES

Project S1: Groundwater Gallery-Fed Alcove Side Channel behind the Sugar Dike

Project S1 would construct a backwater alcove channel or channels fed by an upstream groundwater gallery. Like the Two Channels alcove opportunities, this type of habitat would utilize inter-gravel water that is colder in the summer and warmer in the winter. Benefits to juvenile salmonids during low and high flows would be gained. To create this habitat, a new alcove side channel would be excavated into the valley bottom. Constructed groundwater galleries would then collect subsurface water and convey it to the new channels.

Design Considerations

It would be possible to construct two groundwater galleries and two gallery-fed side channels that outfall to the Methow. Alternatively, creating one or more galleries to feed one or two separate side channels are possible. We recommend that each side-channel outlet be located at the downstream half of a pool located at a bend in the river. By placing the outlet in the downstream half of the bend pool, future meander migration and down-valley riffle migration will remain upstream of the side channel for as long as possible. The goal is to reduce deposition of coarse sediments that could limit fish utilization of a new alcove channel. The total length of alcove channel can vary and depends mostly on landowner partners and funding limitations. We have provided a concept location for one alcove side-channel alignment.

Side-channel alignments and groundwater galleries constructed closer to Highway 20 will have less risk of alteration from the river during a large flood than those constructed closer to the existing river channel.

Project S2: Backwater Wall-Based Seasonal Groundwater-Fed Alcove Side Channel

The project identified as S2 provides an opportunity to create alcove side-channel habitat along the western valley edge. Historical surveys indicate this segment was watered approximately 100 years ago. The project proposes to take advantage of existing wall-based groundwater resources and express them as flowing water through excavation. The project would create the enhanced side channel by deepening the existing historical 1894 channel starting at its outlet to the river and extending upstream, through the Highway 20 Bridge and along the valley wall.

Design Considerations

A pump test was conducted near the upstream end of the historic side channel. Although groundwater was encountered at shallow excavated depth, the pump quickly de-watered the pit because the rate of groundwater inflow was very low. This low infill rate was attributed to tightly cemented subsurface gravel and sand, and poor connectivity to Methow River water.

Downstream of the pump test, water from tributary watersheds is expressed as surface water on top of relic Methow River alluvium. Based on preliminary interpretation of field observations, test pits, and well data, the flow in the existing side channel appears to be ephemeral and with discontinuous surface flow as it transitions from open water in the relic pools to subsurface flow through the relic riffles. Existing monitoring wells established in October 2010 will be monitored through the summer of 2011 to increase understanding of seasonal groundwater levels.

The depth of a new channel that runs underneath the most downstream Highway 20 Bridge is limited by the elevation of the bridge footings. The 1945 as-built drawings were compared with recent survey data to evaluate potential side-channel elevations compared to the bridge footings. Based on the drawings and our survey, a lower elevation side channel is viable.

The poor inflow rate at the pump tests suggests that a groundwater gallery is not possible west of Highway 20. However, it might be possible to establish a groundwater gallery on the east side of Highway 20. This could collect greater quantities of groundwater near the river and convey flow via pipe under the upstream Highway 20 Bridge and to the head of the alcove side channel. To see if this is possible, a pump test for potential groundwater should be explored during the summer of 2011. A suitable groundwater gallery site is near RM 42.

We do not believe a sustainable surface water connection to this side channel is possible. This is due to a change in the river planform that causes a depositional condition near the side-channel inlet just upstream of the Sugar Dike. Since 1945, the meander bend has translated downstream and the river was later straightened by the Sugar Dike. It appears these changes caused a lowering of local water surface near the side-channel inlet making it relatively inactive. The depositional nature of this location makes it a poor candidate for re-activation by excavation since it could soon fill in.

RIVER BANK LOGJAMS AND LARGE WOOD ENHANCEMENT OF EXISTING RIPRAP

Project S3: General Large Wood Enhancements within Existing Riprap

Project S3 identifies opportunities to enhance habitat along existing riprap banks. This type of project is identified for areas where riprap cannot be modified. Trees or logs with root wads could be ballasted within these zones using riprap or imported boulders. To do this, cable would be tightly wrapped around trees and securely fastened to boulders by epoxying both ends of the cable into holes drilled into the boulders. The ballasted trees would be placed in deeper areas of pools or near the toe of the riprap slope.

Design Considerations

The project is feasible and site configurations would vary depending on specific site characteristics, land owner approval, and site access.

Project S4: Bank Logjams within Riprap, Low Terrace, and Floodplain Banks

There are opportunities to create bank logjams within riprap banks and eroding segments of floodplain or terrace bank. The proposed logjams would be between 40 and 60 feet in length and extend out into the channel up to 15 feet. They would be formed out of multiple imported trees and logs that extend up vertically to at least the 2-year flood stage. This work would emulate buried lateral logjams and the habitat they create.

Design Considerations

The exact footprint will depend on local site conditions, bank height, and river use.

BAR APEX AND OTHER MID-RIVER LOGJAMS

Project S5: Log Jam Habitat Bar Apex near RM 42.2

Project S5 would enhance natural river processes such as lateral migration and habitat development by constructing large bar apex jams near RM 42.2. The site is at a location where log jams of this type would naturally develop if the large trees were still a part of the natural wood recruitment and transport system. The bar apex jam would enhance low- and high-flow habitats near the jam and encourage split flow side-channel development during larger discharges.

A project here would start with deep excavation into the existing bar surface and then install large wood working upward and outward. The jam structure would function during high flows and collect native wood, trees, and slash floating downstream during bankfull and greater discharges. The jam would create and maintain pool habitats along the upstream edges of the jam for adult and juvenile salmonids.

Design Considerations

This project is feasible but would require a substantial volume of large wood due to its location and the variation in river stage. The amount of split flow to the south of the jam would be increased so lateral migration of the right bank is likely to occur. Ideally bar apex jams are installed at sites that cause flow to run into areas with rough vegetative conditions so that large riparian trees become incorporated as riverine habitats. However, this will not be the case at the S5 location. The area subject to lateral migration lacks a mature cottonwood forest so erosion may occur at a rapid pace without incorporating substantial volumes of large trees and associated habitat. New gravel bars created during lateral migration would be colonized by new cottonwood trees, enhancing development of new riparian cottonwood forests for future recruitment.

This project would be optimized by also removing the Sugar Dike as described below in project S6. However, if the Sugar Dike stays in place, it does not appear to provide as much cost/benefit in the short term. The longer-term benefits would include the possible natural growth of this jam and its presence on the landscape over decades.

ENHANCING NATURAL RIVER MIGRATION PROCESSES

Project S6: Sugar Dike Removal

Project S6 would re-establish natural meander migration processes by removing the Sugar Dike. This project would allow the river to laterally erode into its right flank and in doing so extend the left bank gravel bar, which will provide floodplain and riparian area for establishing cottonwoods that would eventually replenish large wood to the system.

This project is feasible. However, there are several outcomes and risks relating to dike and riprap removal that are difficult to accurately predict. Most notable risks are to downstream property owners and public infrastructure such as Highway 20. To better understand relative migration rates and possible outcomes following Sugar Dike removal, a meander migration analysis was conducted.

Sugar Dike Removal Meander Migration Analysis

Analysis of meander stability on the Methow River at the Sugar Dike location was performed according to the NCHRP Report 533 Handbook for Predicting Stream Meander Migration. The Map and Aerial photo comparison technique was followed with adaptation to GIS using ArcGIS (ArcMap 3.2). The meander bend upstream of the Sugar Dike (Bend A) and downstream of the Sugar Dike (Bend B) were examined (Figure 10). To help estimate avulsion risk following Sugar Dike removal, a nearby bend within the available photo record was examined between RM 45 and 46.

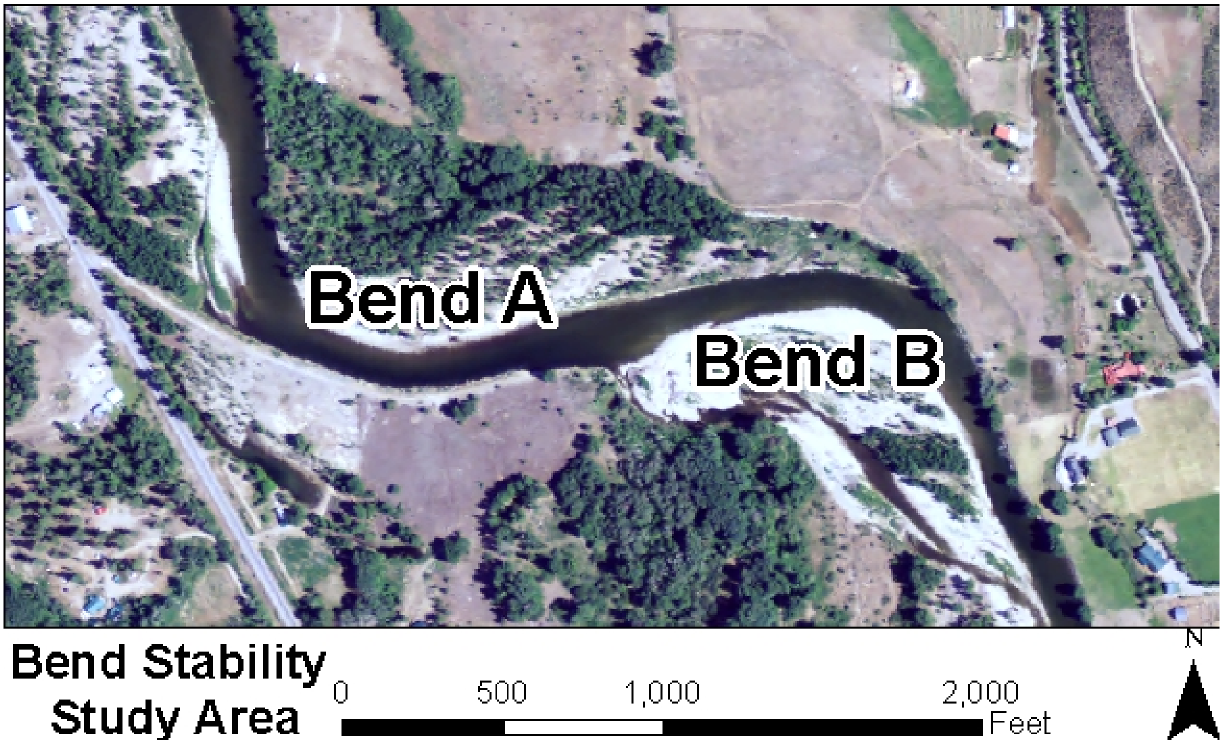

Figure 10. Sugar Dike Meander Bend A and B

Meander Bend Stability Analysis Steps

1. Aerial photography was obtained from the Yakama Nation Fisheries Program including years 1945, 1948, 1954, 1964, 1972, and 2006. Recent NAIP aerial photography was obtained via the USDA Geospatial data gateway found at ***http://datagateway.nrcs.usda.gov***. These data sets were obtained in a geo-referenced state and no subsequent geo-referencing was required.
2. Left and right active channel-bank alignments were digitized for each photo year. The active channel was determined to be the extent of visible water plus bare alluvial sediment out to the point of persistent vegetation as visible in each photo record.
3. The bend centroid location was estimated and associated radius of curvature was measured. The digitized bank alignments were used to determine the centroid and radius of curvature at two bends within the Sugar Dike sub-reach. In GIS, a circle was fit to the outside bank at the apex of each bend. Two perpendicular lines were drawn across the circle, and a centroid located at the intersection of the lines. The radius of curvature was determined to be half the length of one of the perpendicular lines. This procedure was followed for each photo year used.
4. Bank erosion rates were determined by measuring the bank position on the outside of the bend between successive photo years and dividing the total distance by the number of years between photos.
5. To measure bend translation, the centroid migration rate was determined. To do this, the distance between centroid locations for successive photo years was determined geometrically using the Cartesian coordinates of the centroid point. The azimuth of the direction was

determined trigonometrically. The rate of migration was calculated by dividing the total distance migrated by the number of years between photos.

6. Next, the length of the radius of curvature was measured for each year and calculated as either a positive (increased radius) or negative (decreased radius) number. The annual rate of change was calculated by dividing the total change in radius length by the number of years between photos.
7. To estimate future location of meander bends following removal of the Sugar Dike, the long-term annual rates and directions calculated from 1948 to 1974 were used to forecast the position of Bend A and Bend B for several future time periods. This forecasting was done under the assumption that historic rates and direction apply to future conditions. However, substantial shifts in hydrologic, geomorphic, or climatic variables could change future rates.

Analysis of Historic Bend Migration

The results of historic analysis of bend migration are summarized in Table 1. The historic analysis highlights several characteristics about the interaction between the two bends that carry implications for potential future conditions. Over the historic photo record prior to dike construction (1948-1974), the two bends each changed substantially, but in distinct ways (Figure 10). Bend A migrated at a higher rate and over a greater overall magnitude than Bend B. Both bends underwent long-term reduction in radius of curvature, but Bend B had about twice the rate of change in radius reduction. Thus while Bend A migrated laterally in a generally southerly direction, Bend B “tightened” as the radius of curvature grew smaller through the apex of the bend while bank position maintained a relatively constant position (Figure 11). This could be explained by the fact that Bend B is slowly eroding against higher Holocene terrace material compared to lower floodplain alluvium in Bend A. Therefore, the amount of material that has to be eroded per unit distance of lateral migration is much less in Bend A than in Bend B. There is also observed field evidence of riprap at Bend B. The timing and placement of that riprap may also have influenced the bend tightening in the air photo record.

Migration Prediction

In 1974, the Sugar Dike was completed and the position of the river was moved to the north. The river currently occupies a similar but slightly down-valley position to that of the river in 1948 near the beginning of the historic photo period. Assuming that the river would resume its historic rate and direction of bend migration after the removal of the Sugar Dike, its position can be forecast for a given time period. Far-reaching predictions are less certain considering changes in climate and hydrologic patterns that influence the river. A forecast out to 2025 estimates that the bend will migrate south approximately 416 feet, and the radius of curvature will reduce by approximately 114 feet (Figure 12).

We know that during the construction of the dike, a portion of the river was filled. Our estimates of migration rates are based on the action of the river working on alluvial sorted and deposited sediments. The fill material behind the levee may have different characteristics than the native valley bottom alluvium. It is possible that the fill material could erode rapidly if it is finer than natural alluvial bank sediments; or the rate could be slower if the fill is coarser. Future large magnitude floods or even small floods with long duration play a major role in bank erosion rates that can differ from estimates based historical floods shown between each photo record.

Table 1. Summary of results for bend migration analysis.

Bend Centroid Migration

Bend A						Bend B					
Year	N	E	Distance Moved (ft)	Annual Migration Rate (ft/yr)	Bearing of Movement (°)	Year	N	E	Distance Moved (ft)	Annual Migration Rate (ft/yr)	Bearing of Movement (°)
1948	505518.106	1811950.744				1948	503961.857	1812801			
1954	505317.996	1811949.166	200	33	180.5	1954	504164.323	1812922	236	39	30.9
1964	505127.457	1812003.179	198	20	164.2	1964	504307.519	1813147	267	27	57.5
1974	504858.755	1811995.772	269	27	181.6	1974	504246.813	1813119	66	7	24.0
Long-Term Rates				**26**	**176.1**					**22**	**48.2**
Median Values				**27**	**180**					**27**	**31**
Average Values				**27**	**175**					**24**	**37**

Radius of Curvature Change Rates

Bend A				Bend B			
Year	Radius Length	Change in Length	Annual Rate of Change	Year	Radius Length	Change in Length	Annual Rate of Change
1948	1021.58			1948	961.23		
1954	1001.01	-20.6	-3.4	1954	723.17	-238.1	-39.7
1964	935.06	-66.0	-6.6	1964	558.44	-164.7	-16.5
1974	835.81	-99.2	-9.9	1974	643.32	84.9	8.5
Long-Term Rates			**-7.1**				**-12.2**
Median Values		**-66**	**-7**			**-165**	**-16**
Average Values		**-62**	**-7**			**-106**	**-16**

Bank Retreat Rates

Bend A			Bend B		
Year	Distance (max ft)	Annual Retreat Rate (ft/yr)	Year	Distance (max ft)	Annual Retreat Rate
1948			1948		
1954	199	33.17	1954	34	5.7
1964	211	21.1	1964	98	9.8
1974	370	37	1974	65	6.5
Long-Term Rates		**30**			**8**
Median Values		**33**			**7**
Average Values		**30**			**7**

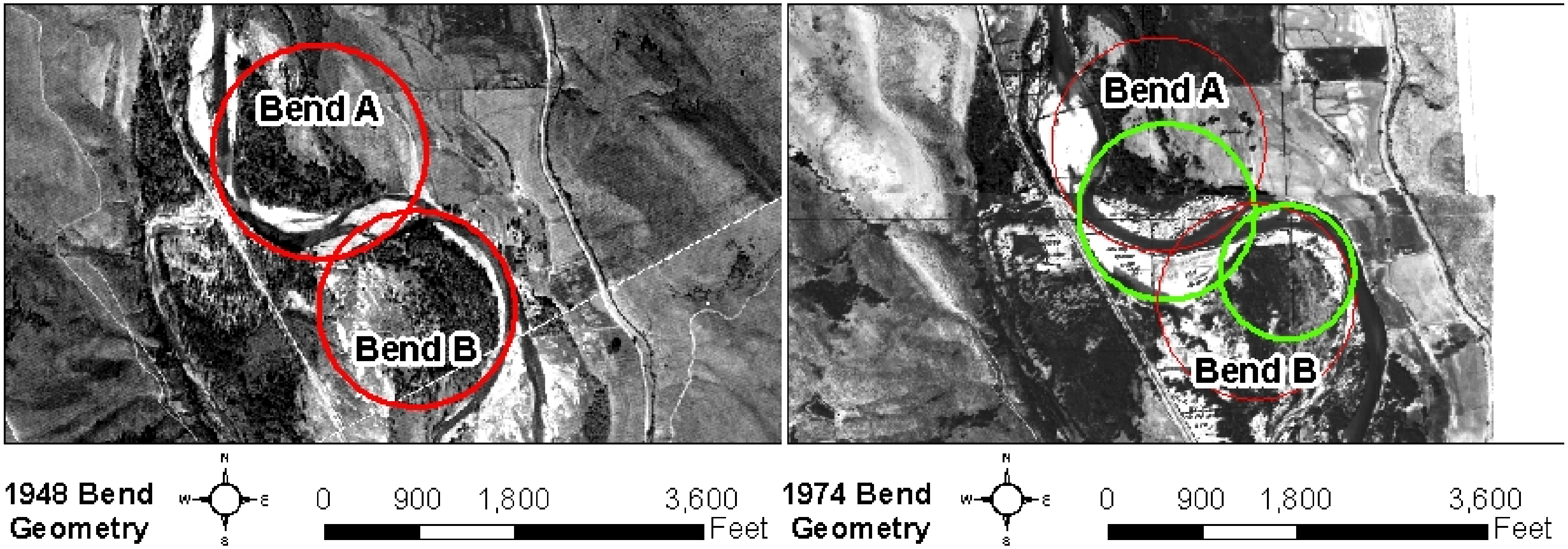

Figure 11. Comparison of photographs and best fit circles to Bend A and Bend B for the first photo year of 1948 and the last photo year of 1974 prior to the construction of the dike. Radius of curvature is reduced in both bends, though to a much greater degree at Bend B. Bend A migrates to the south while Bend B maintains an essentially constant outside bank position.

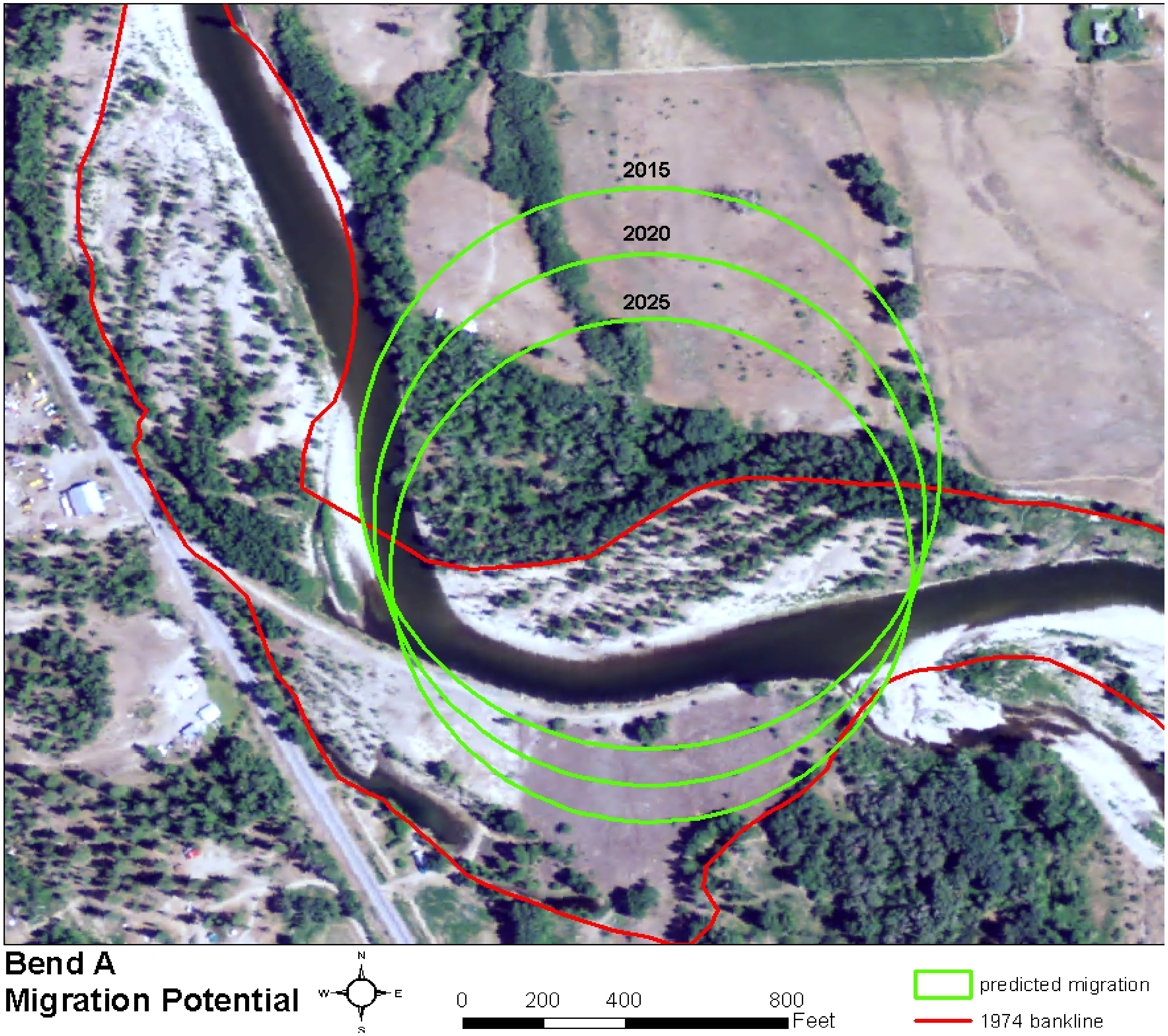

Figure 12. Predicted bend migration pattern for Bend A from years 2015 to 2025. The bend is estimated to migrate south approximately 416 feet with a radius of curvature reduction of about 114 feet.

Avulsion Risk

Multiple factors can influence the tendency of a channel to avulse. One factor is bend geometry and its effect on hydraulic competency of a particular meander sequence. Avulsion risk increases as hydraulic competency of a meander bend decreases. In other words, as the channel becomes less able to transport water, sediment, and wood through a bend, deposition in the bend begins to occur, causing increased flow across the interior floodplain of the bend, leading to concentrated flow and head-ward erosion of the floodplain, eventually causing a new avulsion channel. The literature suggests that a meander's hydraulic competency is optimized at an Rc/W ratio of between 2 and 4, where Rc is the radius of curvature and W is the active channel width. If the ratio is smaller than 2, the bend is tight and the energy loss is so great at the bend that deposition begins to occur, driving the process to a meander cut-off and avulsion. A local example of this can be found about six miles upstream of the Sugar Dike site (Figure 13). At this location, the downstream bend in a pair of bends similar to those at Sugar Dike reached an Rc/W value of 1.2 in the 1945 aerial photo while the upstream meander in the pair reached an Rc/W value of 2.3. In the following photo year of 1954, a meander cut-off had occurred at the upstream bend. However, a full avulsion did not occur at this site. Instead, the cut-off functions as a high-flow side channel. The site isn't purely alluvial due to the downstream bedrock control and adjacent Holocene terrace but it provides an example of local avulsion processes close to the Sugar Dike within the contemporary photo record.

The historic record suggests that a similar situation could occur at the Sugar Dike site. Currently a point bar cut-off chute has formed on the inside of Bend B. The historic record shows that Bend B is more likely to contract to an Rc/W value of less than 2 before Bend A does. If the Rc/W ratio at Bend B falls much below 2 then the risk of avulsion through the existing cut-off chute increases. Projections using the historic trends suggest that the Rc/W ratio at Bend B will fall below 2 by year 2040 if historic rates of change of radius of curvature and the current active channel width are maintained.

Valley bottom roughness, development of in-channel logjams, and flood magnitude are some of the many influencing factors of avulsion risk and location. The likelihood of avulsion is greater near the existing and developing chute cut-off during smaller floods. During larger floods, due to backwater created by the Twisp River, avulsion risk across smoother floodplain surfaces can occur in a similar fashion to the 1948 flood from RM 42 to RM 41.5 (Figure 7). This would equate to an avulsion behind the Sugar Dike nearer to Highway 20. This type of avulsion risk can be reduced by establishing floodplain roughness in areas where avulsions would not be desired.

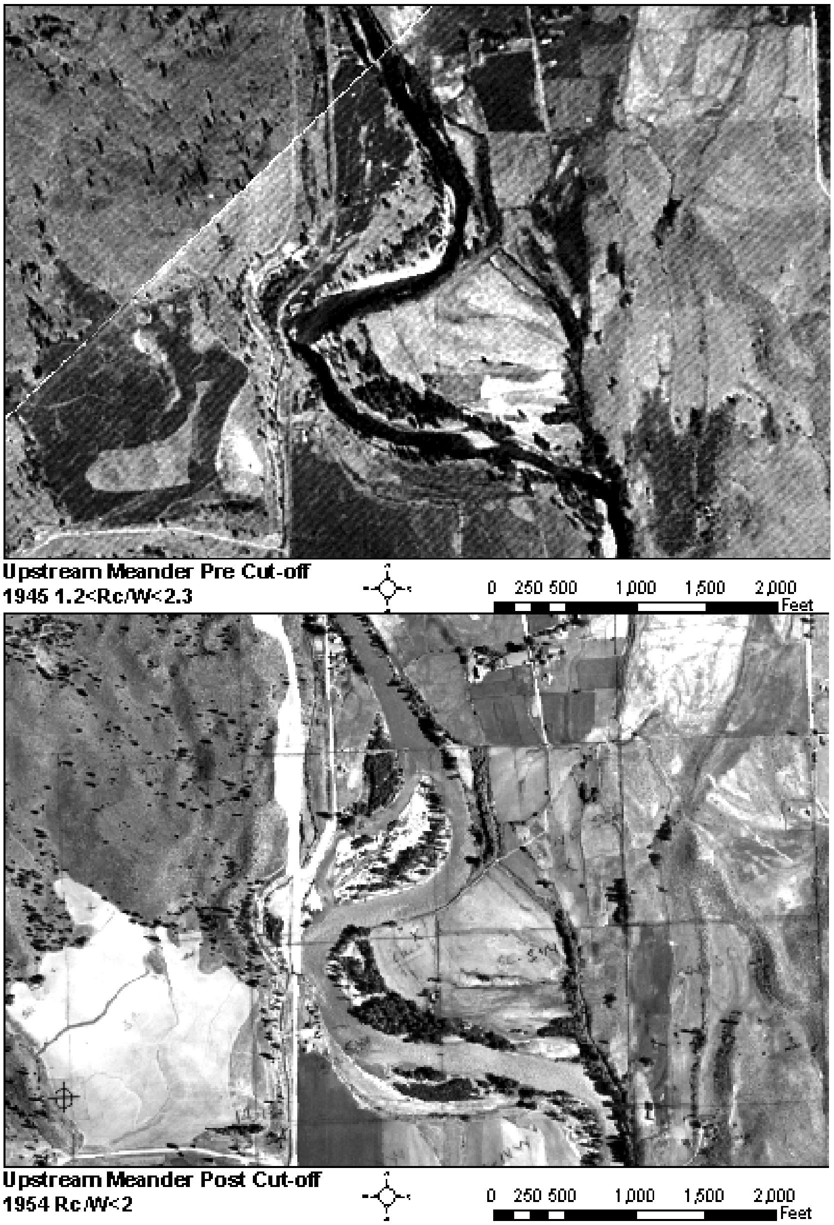

Figure 13. Comparison of 1945 an 1954 aerial photos at a location approximately 6 miles upstream of the Sugar Dike site where bend geometry reached an unstable configuration and a meander cut-off chute formed.

Design Considerations

This analysis leads to a question regarding the timing of migration process restoration for the Sugar Dike. Currently, there are very few large, mature trees in the sub-reach that could form the foundation of a natural jam. Although there are mature trees in the area, they are in small patches. If the goal is to establish habitats created by large diameter wood using natural migration processes and floodplain trees, the trees necessary to create large wood riverine habitats must exist in the meander migration zone. Currently they do not.

Enhancing lateral migration processes into unforested areas or into stands of smaller trees opens a debate about the benefits of near-term recruitment of small wood vs. delaying the channel migration until the forest matures enough to provide restored migration and habitat processes.

Alternatively, if the goal is to establish new gravel bars that result from channel migration, then we feel success is likely and is especially true in the case of a large flood following dike removal.

If large wood habitat is a goal following the removal of the Sugar Dike, we feel it is unlikely to happen without large volumes of imported trees to emulate the roughness and wood associated with mature stands of Cottonwood trees. It would be possible to set up the valley bottom downstream of the Sugar Dike to receive the Methow River by burying and creating log jams within the valley segments that the river is likely to erode through. Channel avulsion risk to downstream properties could be mitigated by establishing buried riprap, log jams and possibly flood levees to protect specific property. The scale of this effort would be very large.

Project S7: Re-Grading and Intensive Planting behind the Sugar Dike and Delayed Dike Removal

Another option regarding the Sugar Dike would be to delay its removal by several decades. Before the removal, the land behind the dike would be re-graded so that it would be inundated at channel-forming flows and better connected to groundwater. This surface would be replanted along with all of the area that was previously cleared of trees. These trees would be allowed to mature for 70 to 100 years before the Sugar Dike is removed. Greater floodplain resiliency and natural rates of bank erosion coupled with natural large wood recruitment would emulate pre-European migration processes.

Design Considerations

We have made the assumption that a mature cottonwood tree could be grown in 90 years. This is not based on an analysis of mature cottonwood trees that currently exist in the valley bottom. We would recommend a tree ring analysis of the biggest cottonwood trees to refine our estimate of the years required to grow them in the Methow Valley. Our estimate of the timing of the Sugar Dike removal would be adjusted based on this information.

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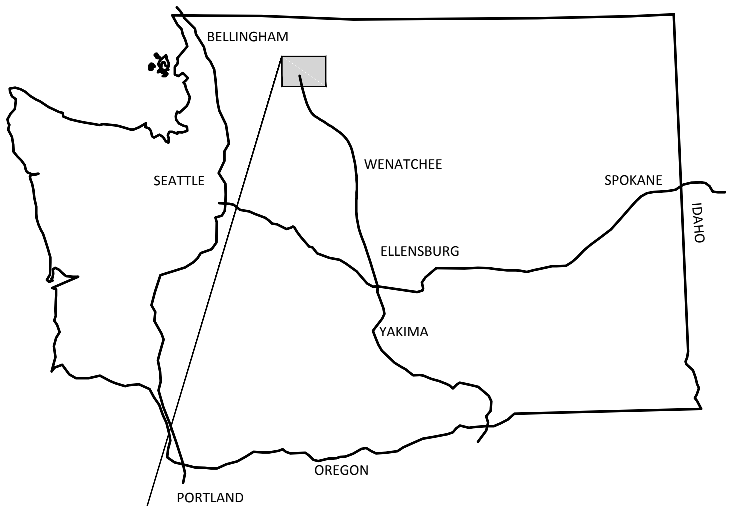
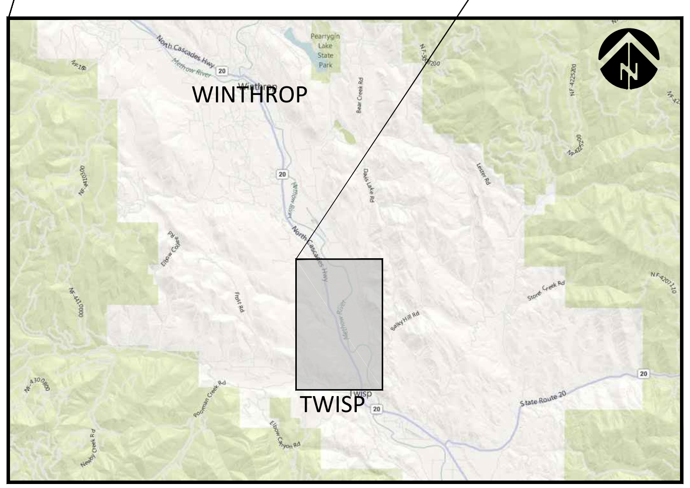
APPENDIX A: SITE MAPS AND TYPICAL DRAWINGS

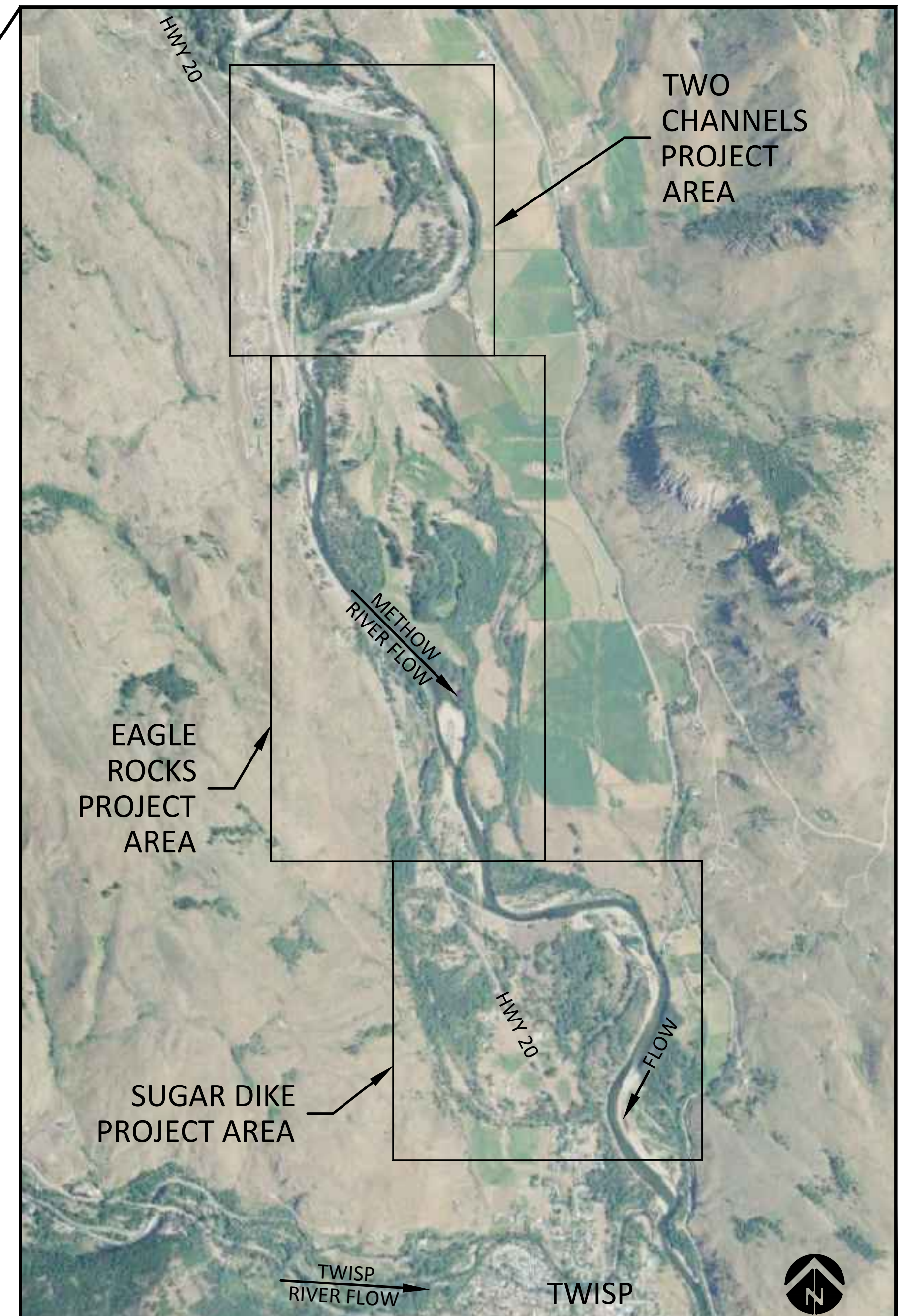
Methow River Conceptual Fish Habitat Project Opportunities
Lewisia Road to Twisp River
Okanogan County, Washington
March 28, 2011



STATE OF WASHINGTON



VICINITY MAP



SITE MAP

SHEET INDEX

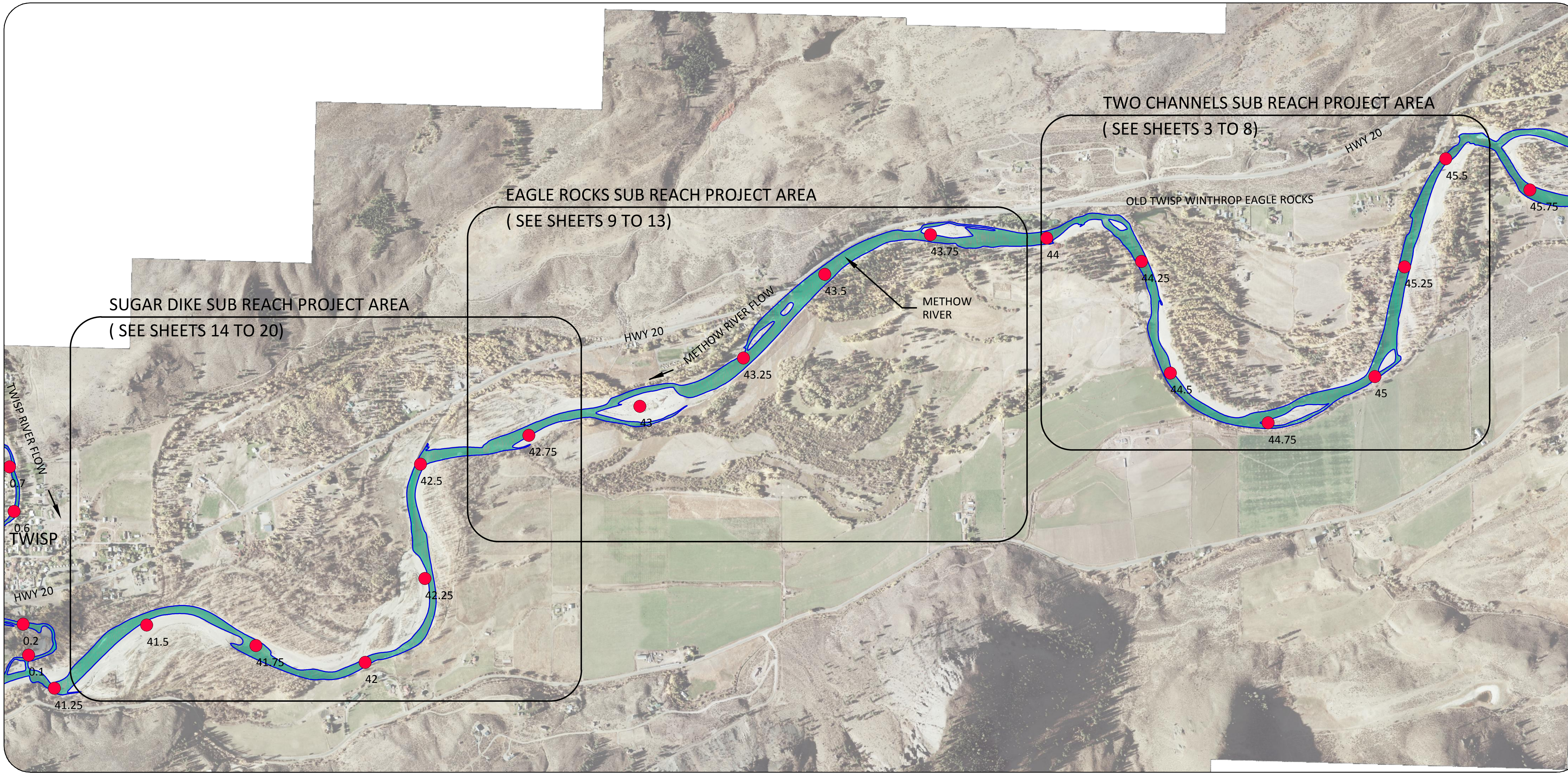
1 COVER AND SHEET INDEX
2 SITE PLAN SHOWING PROJECT AREA LOCATIONS
3 TWO CHANNELS SUBREACH - T1 PROJECT GROUNDWATER GALLERY AND ALCOVE CHANNEL
4 TWO CHANNELS SUBREACH - T2 PROJECT GROUNDWATER GALLERY AND ALCOVE CHANNEL
5 TWO CHANNELS SUBREACH - T3 PROJECT LARGE WOOD ENHANCEMENT ALONG RIPRAP BANKS
6 TWO CHANNELS SUBREACH - T4 PROJECT BANK LOGJAMS WITHIN RIPRAP BANKS, LOW TERRACE AND FLOODPLAIN BANKS
7 TWO CHANNELS SUBREACH - T5 PROJECT BAR APEX LOGJAMS TO ESTABLISH FLOW INTO SIDE CHANNEL (SOUTHEAST)
8 TWO CHANNELS SUBREACH - T6 PROJECT EXCAVATED FLOW THROUGH SIDE CHANNEL
9 (SOUTHEAST)
10 EAGLE ROCKS SUBREACH - E1 PROJECT GROUNDWATER GALLERY AND ALCOVE CHANNEL
11 EAGLE ROCKS SUBREACH - E2 PROJECT LARGE WOOD ENHANCEMENT ALONG RIPRAP BANK
EAGLE ROCKS SUBREACH - E3 PROJECT BANK LOGJAMS WITHIN RIPRAP BANKS, LOW TERRACE
12 AND FLOODPLAIN BANKS
13 EAGLE ROCKS SUBREACH - E4 PROJECT BAR APEX AND MID RIVER LOGJAMS
EAGLE ROCKS SUBREACH - E5 PROJECT ENHANCING NATURAL RIVER MIGRATION PROCESSES BY
14 REGRADING AND REALIGNING RIVER
15 SUGAR DIKE SUBREACH - S1 PROJECT GROUNDWATER GALLERY AND ALCOVE CHANNEL
16 SUGAR DIKE SUBREACH - S2 PROJECT GROUNDWATER GALLERY AND ALCOVE CHANNEL
17 SUGAR DIKE SUBREACH - S3 PROJECT LARGE WOOD ENHANCEMENT OF EXISTING RIPRAP
SUGAR DIKE SUBREACH - S4 PROJECT BANK JAMS WITHIN RIPRAP BANKS, LOW TERRACE, AND
18 FLOODPLAIN BANKS
19 SUGAR DIKE SUBREACH - S5 PROJECT BAR APEX LOGJAM HABITAT NEAR RM 42.2
20 SUGAR DIKE SUBREACH - S6 PROJECT SUGAR DIKE REMOVAL
SUGAR DIKE SUBREACH - S7 PROJECT RE-GRADE AND INTENSIVE COTTONWOOD PLANTING BEHIND SUGAR DIKE FOLLOWED BY 2090 REMOVAL

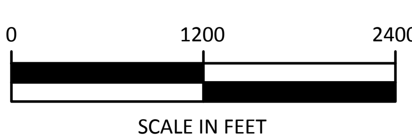
SITE LOCATION:

LATITUDE: 48°22'25" NORTH
LONGITUDE: 120°07'15" WEST
OKANOGAN COUNTY, WASHINGTON

inter·fluve

Cover and Sheet Index



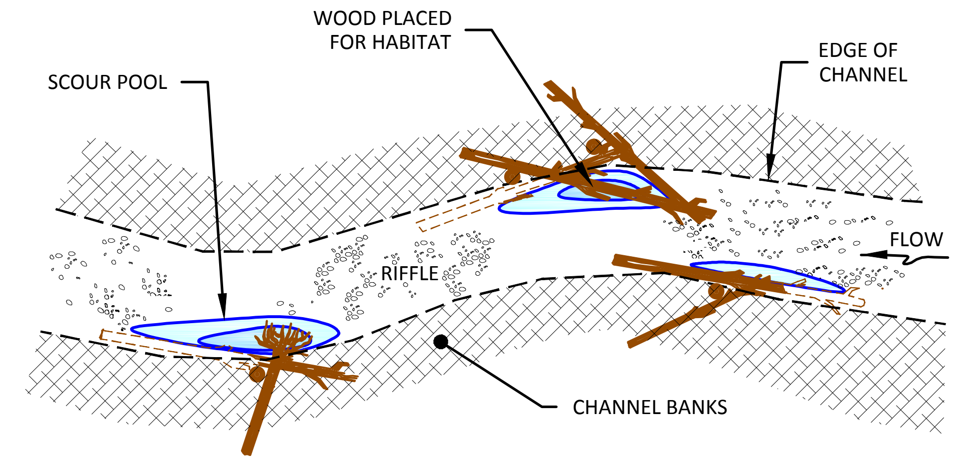


LEGEND:

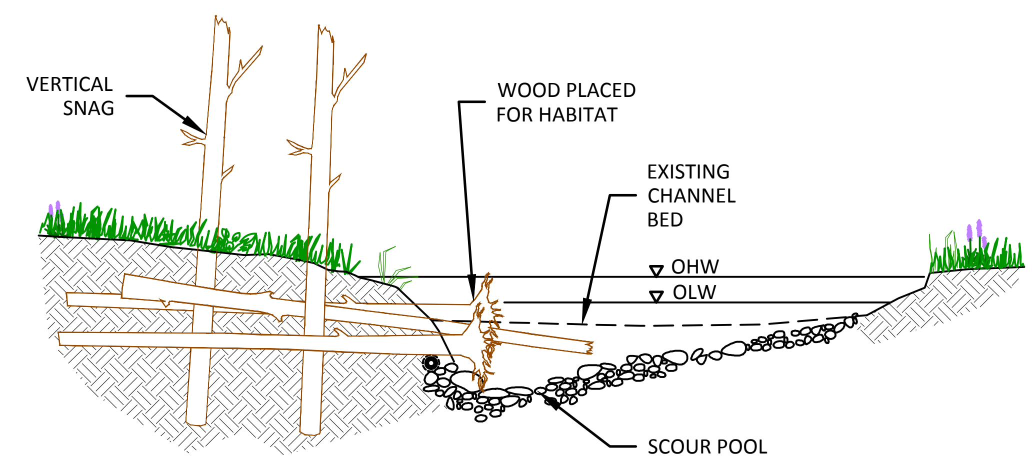
45.25 METHOW RIVER MILES

METHOW RIVER

Site Plan Showing Project Area Locations



TYPICAL PLAN VIEW
BACKWATER CHANNEL AND ALCOVES
NOT TO SCALE



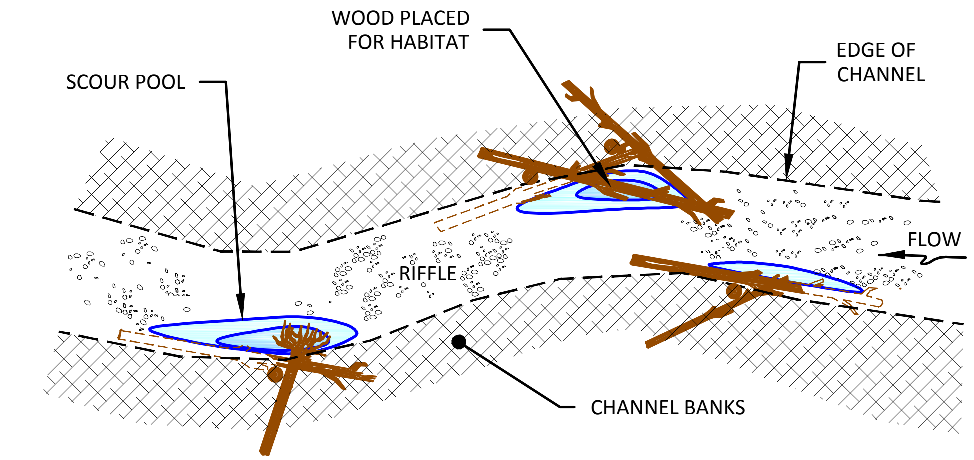
TYPICAL CROSS-SECTION
BACKWATER CHANNEL AND ALCOVES
NOT TO SCALE

0 500 1000
SCALE IN FEET

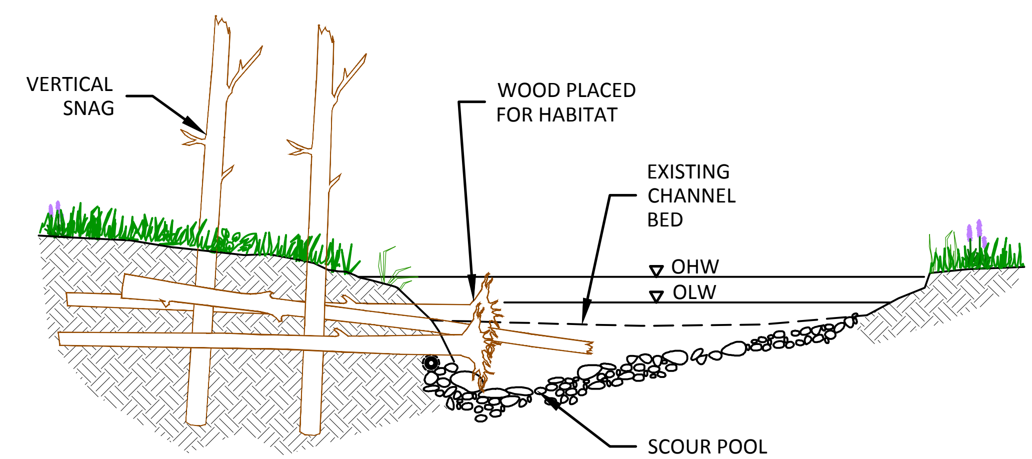
LEGEND:

45.25	METHOW RIVER MILES
	METHOW RIVER
	T1 - GROUNDWATER GALLERY
	T1 - GROUNDWATER GALLERY PIPE
	T1 - ALCOVE CHANNEL
	T1 - LOGJAM FOOTPRINT

Two Channels Sub Reach - T1 Project
Groundwater Gallery and Alcove Channel



TYPICAL PLAN VIEW
BACKWATER CHANNEL AND ALCOVES
NOT TO SCALE



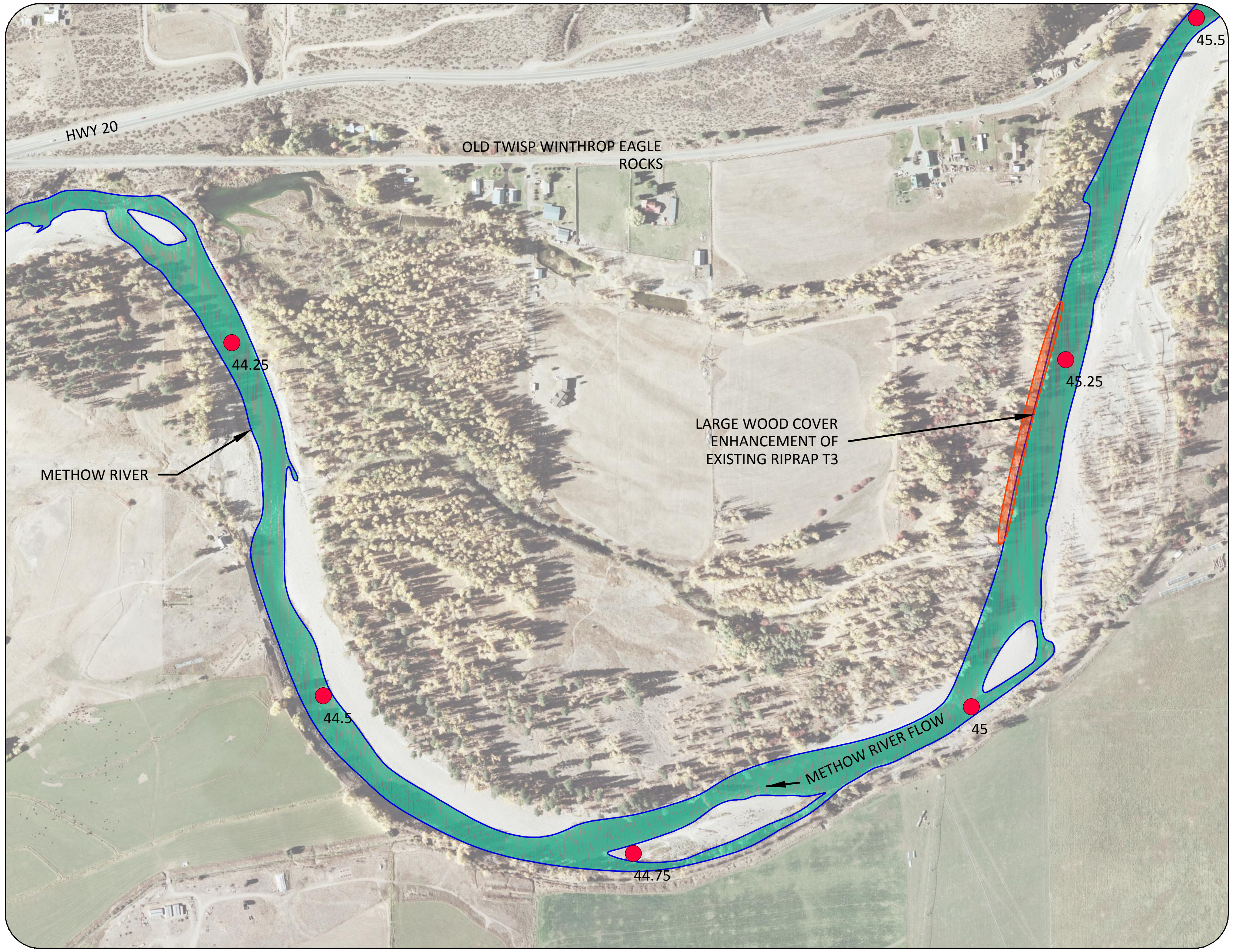
TYPICAL CROSS-SECTION
BACKWATER CHANNEL AND ALCOVES
NOT TO SCALE

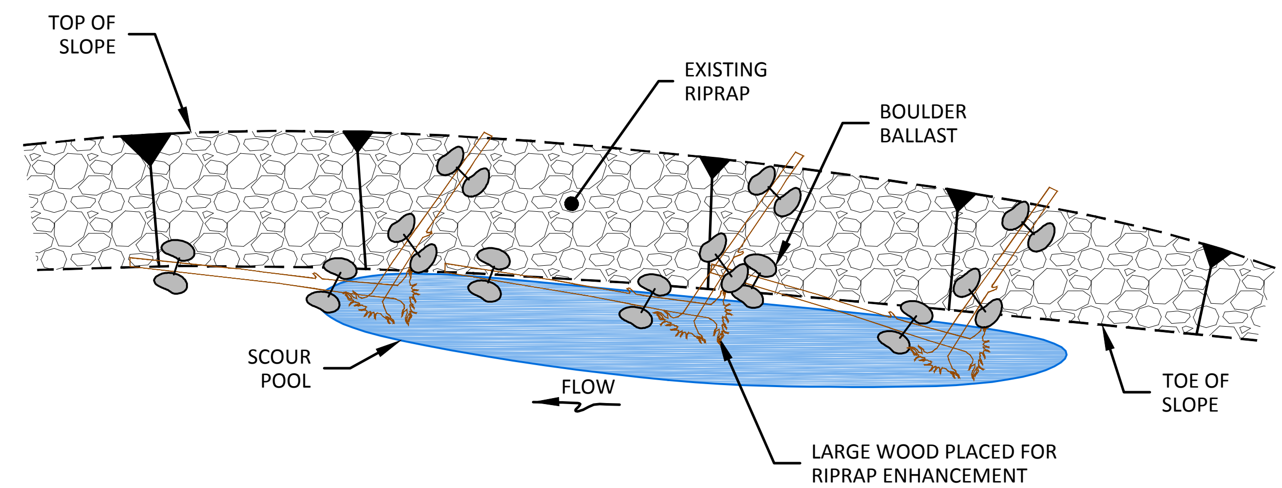
0 500 1000
SCALE IN FEET

LEGEND:

- 45.25 METHOW RIVER MILES
- METHOW RIVER
- T2 - GROUNDWATER GALLERY
- T2 - GROUNDWATER GALLERY PIPE
- T2 - ALCOVE CHANNEL
- T2 - LOGJAM FOOTPRINT

Two Channels Sub Reach - T2 Project
Groundwater Gallery and Alcove Channel

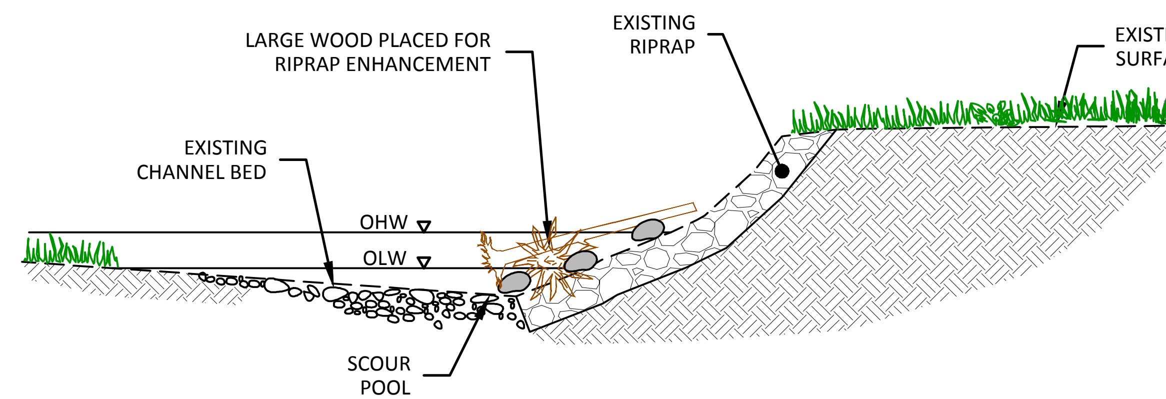




TYPICAL PLAN VIEW

LARGE WOOD ENHANCEMENT OF RIPRAP

NOT TO SCALE



TYPICAL CROSS-SECTION

LARGE WOOD ENHANCEMENT OF RIPRAP

NOT TO SCALE

0 500 1000

SCALE IN FEET

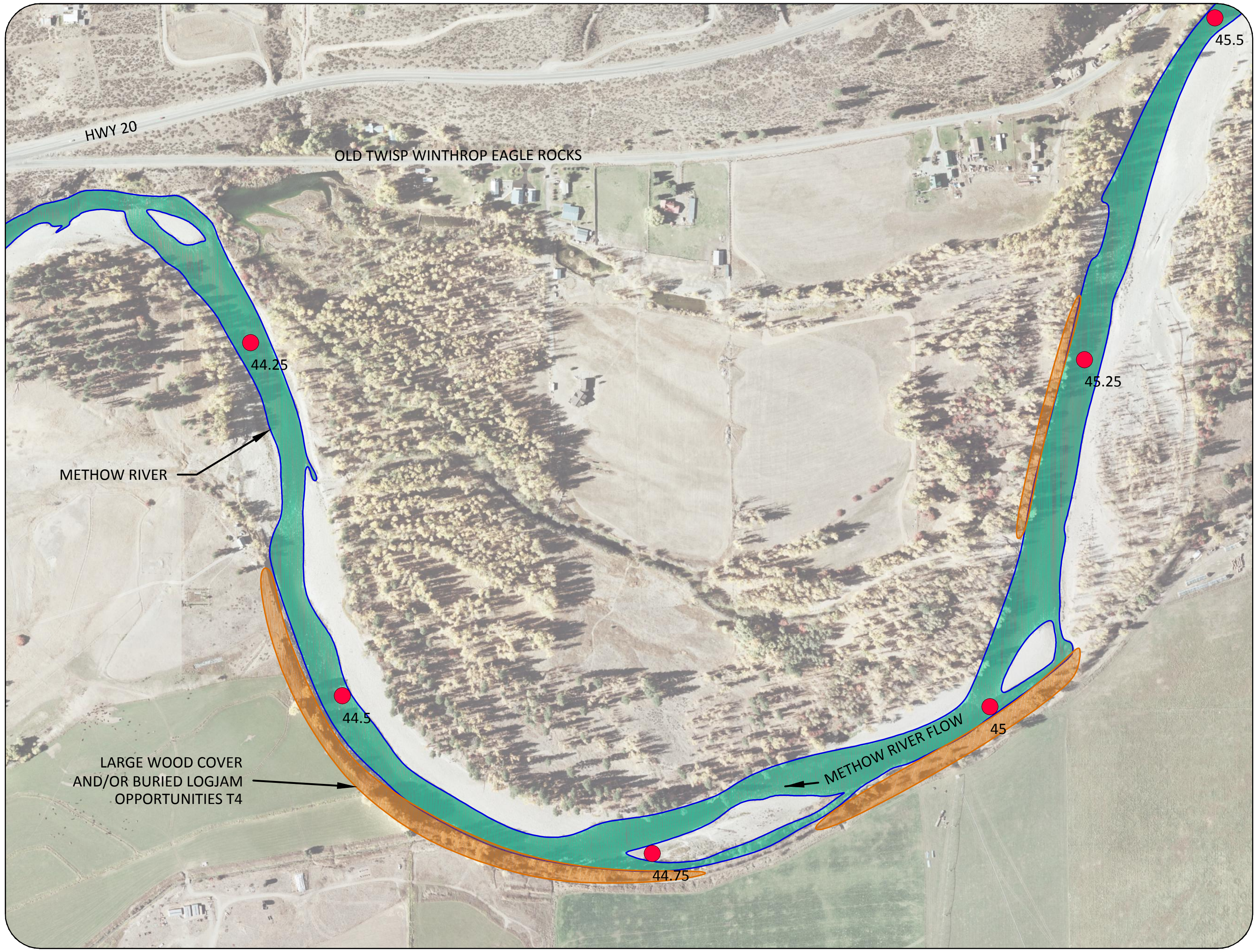
LEGEND:

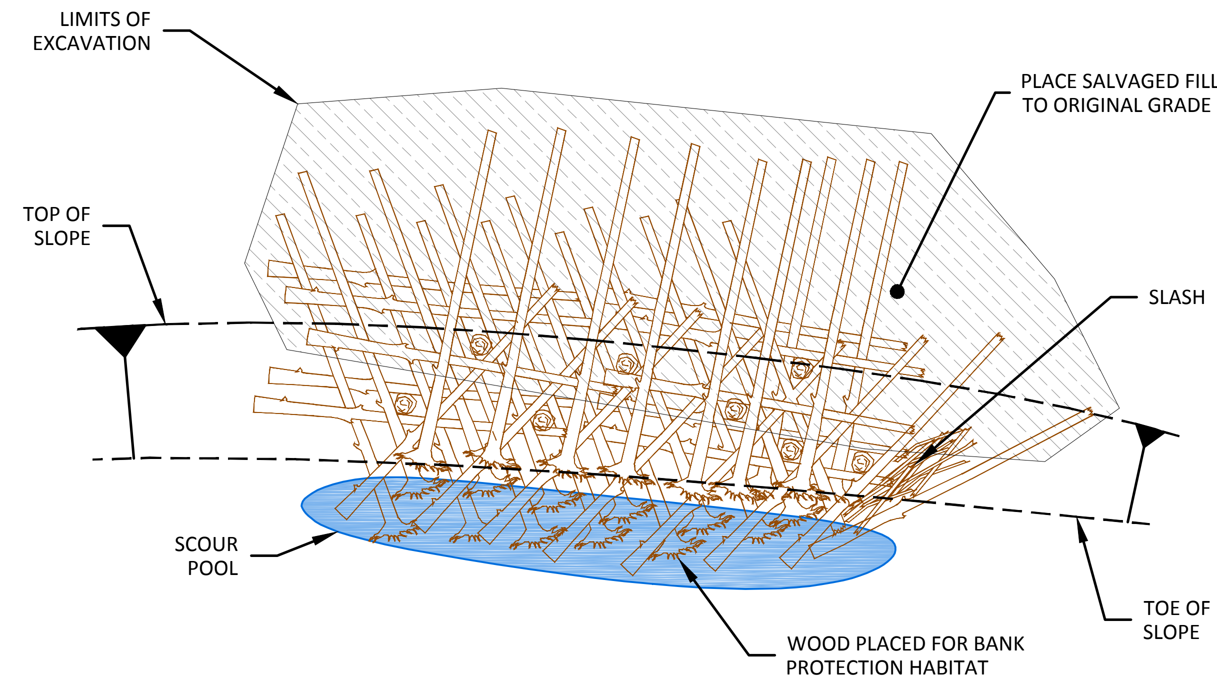
45.25 METHOW RIVER MILES

METHOW RIVER

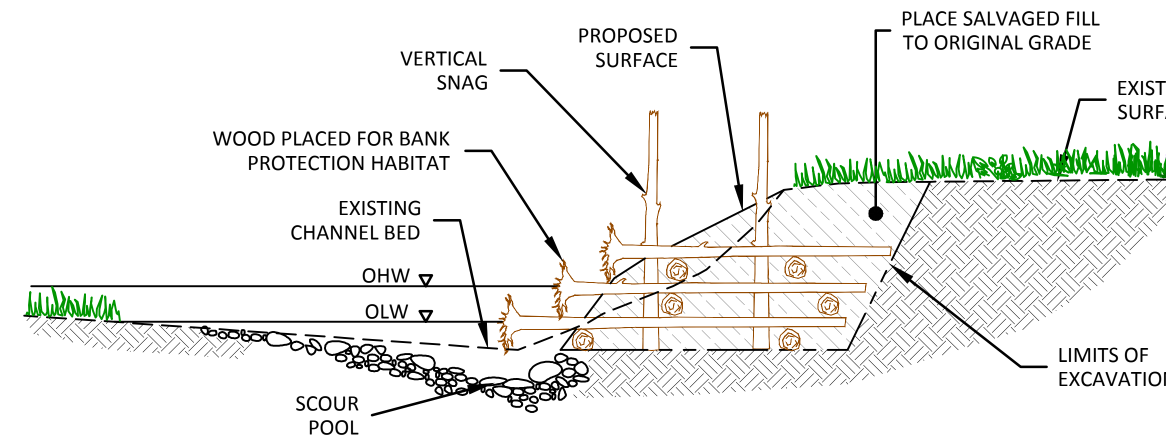
T3 - LARGE WOOD ENHANCEMENT OF EXISTING RIPRAP

Two Channels Sub Reach - T3 Project
Large Wood Enhancement Along Riprap Banks





TYPICAL PLAN VIEW
BURIED LOGJAMS
NOT TO SCALE



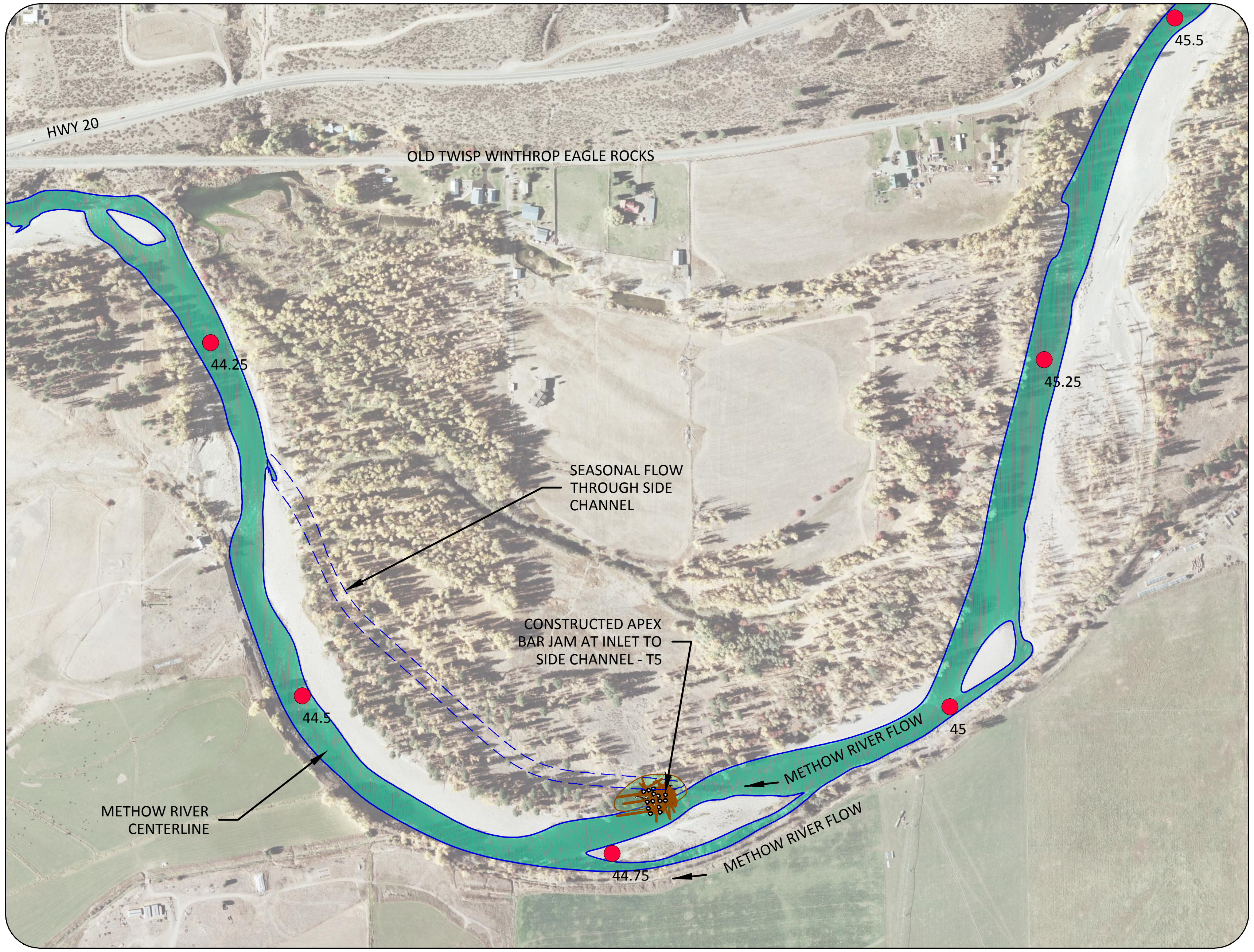
TYPICAL CROSS-SECTION
BURIED LOGJAMS
NOT TO SCALE

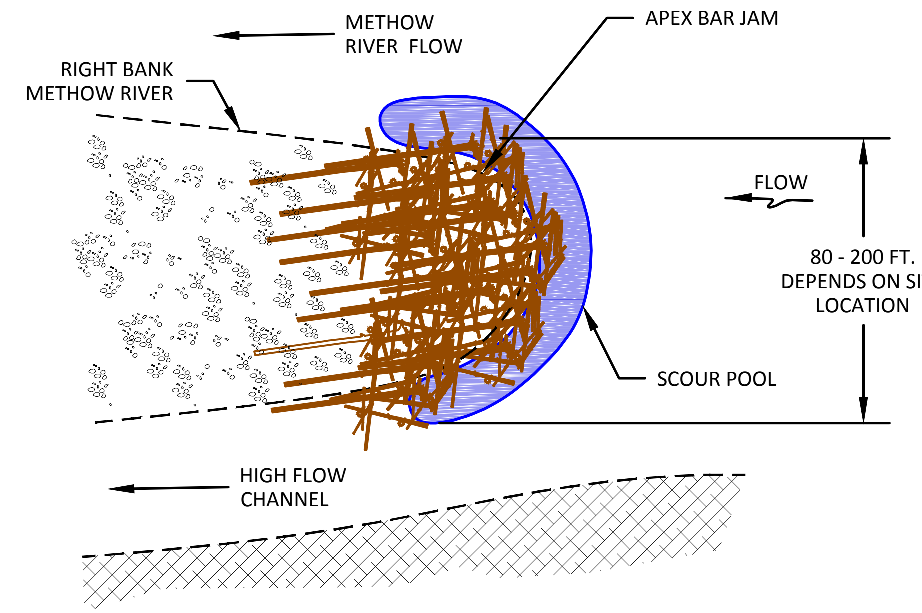
0 500 1000
SCALE IN FEET

LEGEND:

45.25	METHOW RIVER MILES
	METHOW RIVER
	T4 - BURIED LATERAL LOGJAMS

Two Channels Sub Reach - T4 Project Bank Logjams Within Riprap Banks, Low Terrace and Floodplain Banks

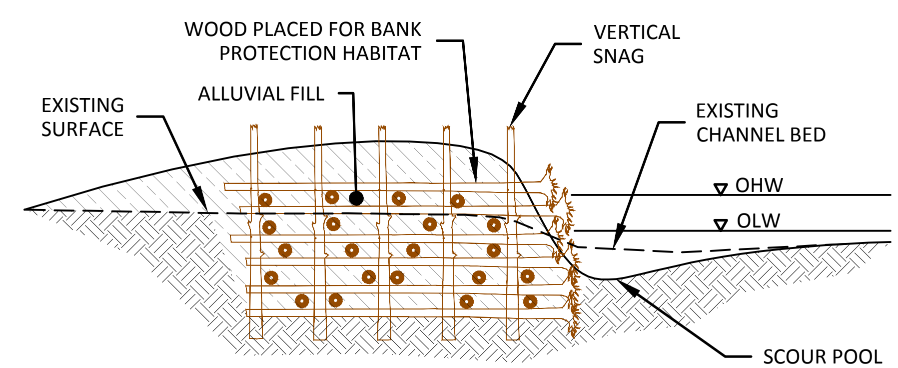




TYPICAL PLAN VIEW

APEX BAR JAM

NOT TO SCALE



TYPICAL CROSS-SECTION

APEX BAR JAM

NOT TO SCALE

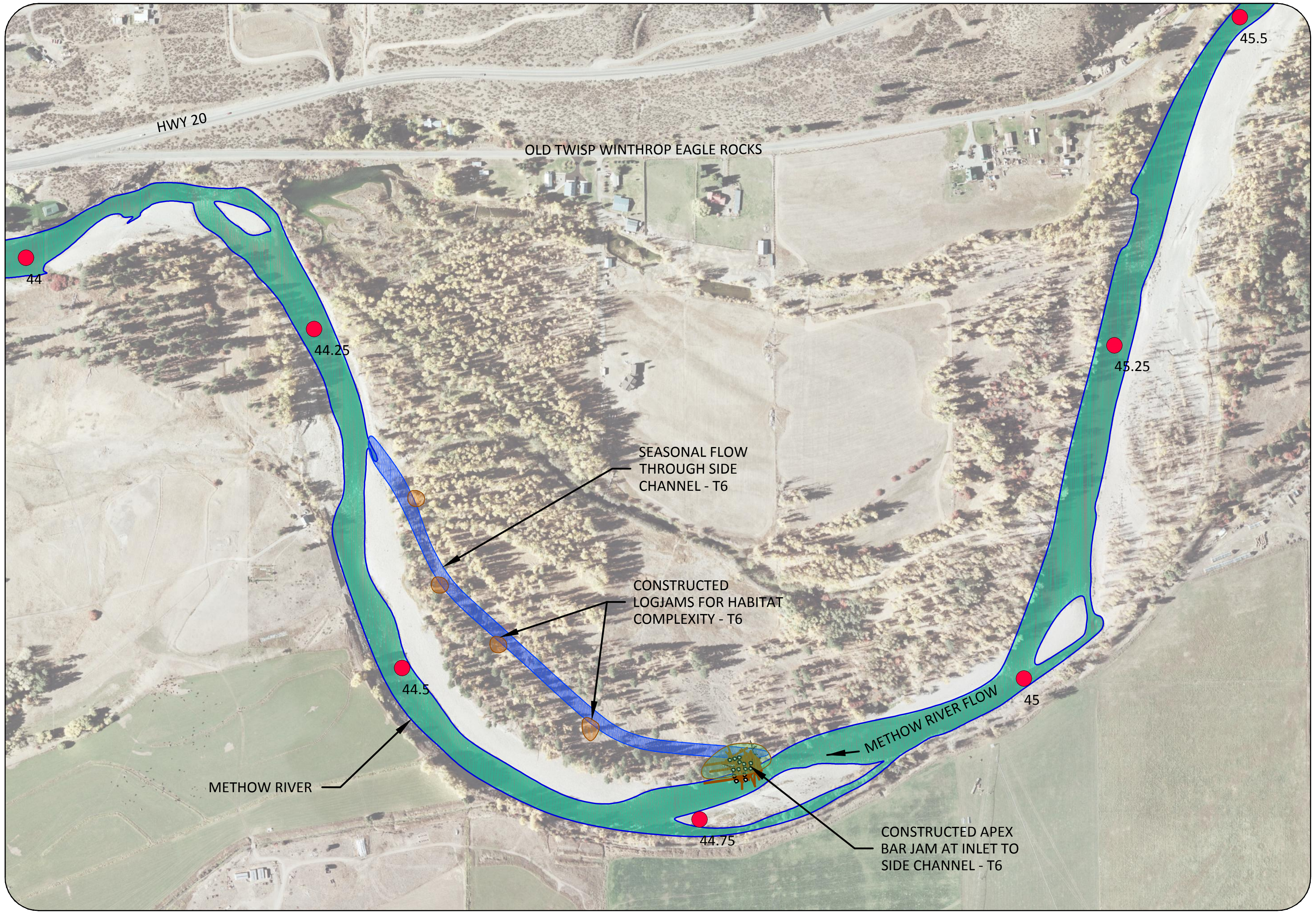
0 500 1000

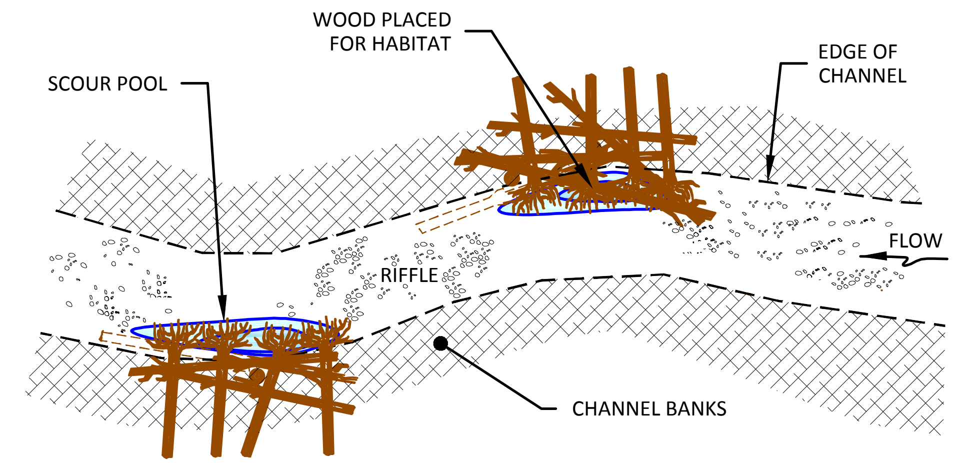
SCALE IN FEET

LEGEND:

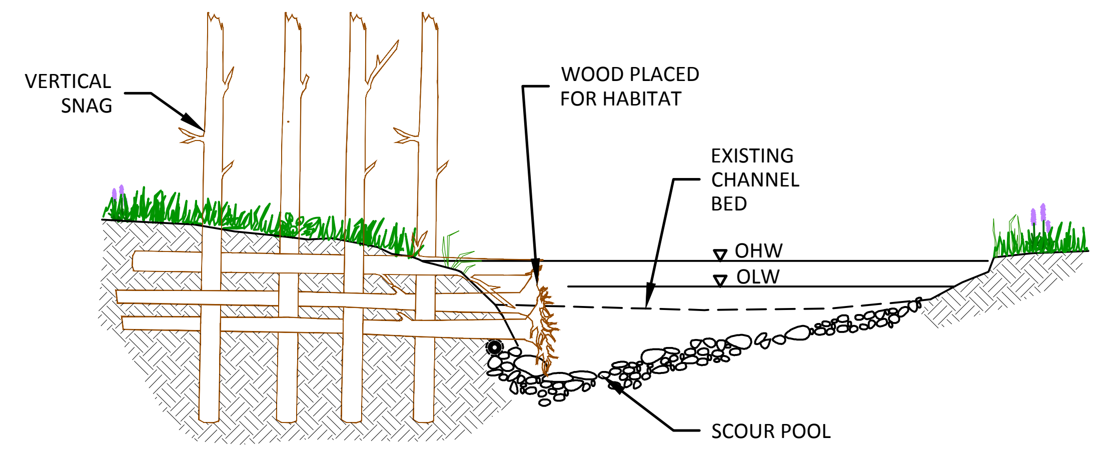
45.25	METHOW RIVER MILES
	METHOW RIVER
	T5 - SIDE CHANNEL APEX BAR JAM FOOTPRINT
	HIGH FLOW SIDE CHANNEL

Two Channels Sub Reach - T5 Project Bar Apex Logjams to Establish Flow Into Side Channel (Southeast)





TYPICAL PLAN VIEW
SIDE CHANNEL EXCAVATION WITH LOGJAMS
NOT TO SCALE



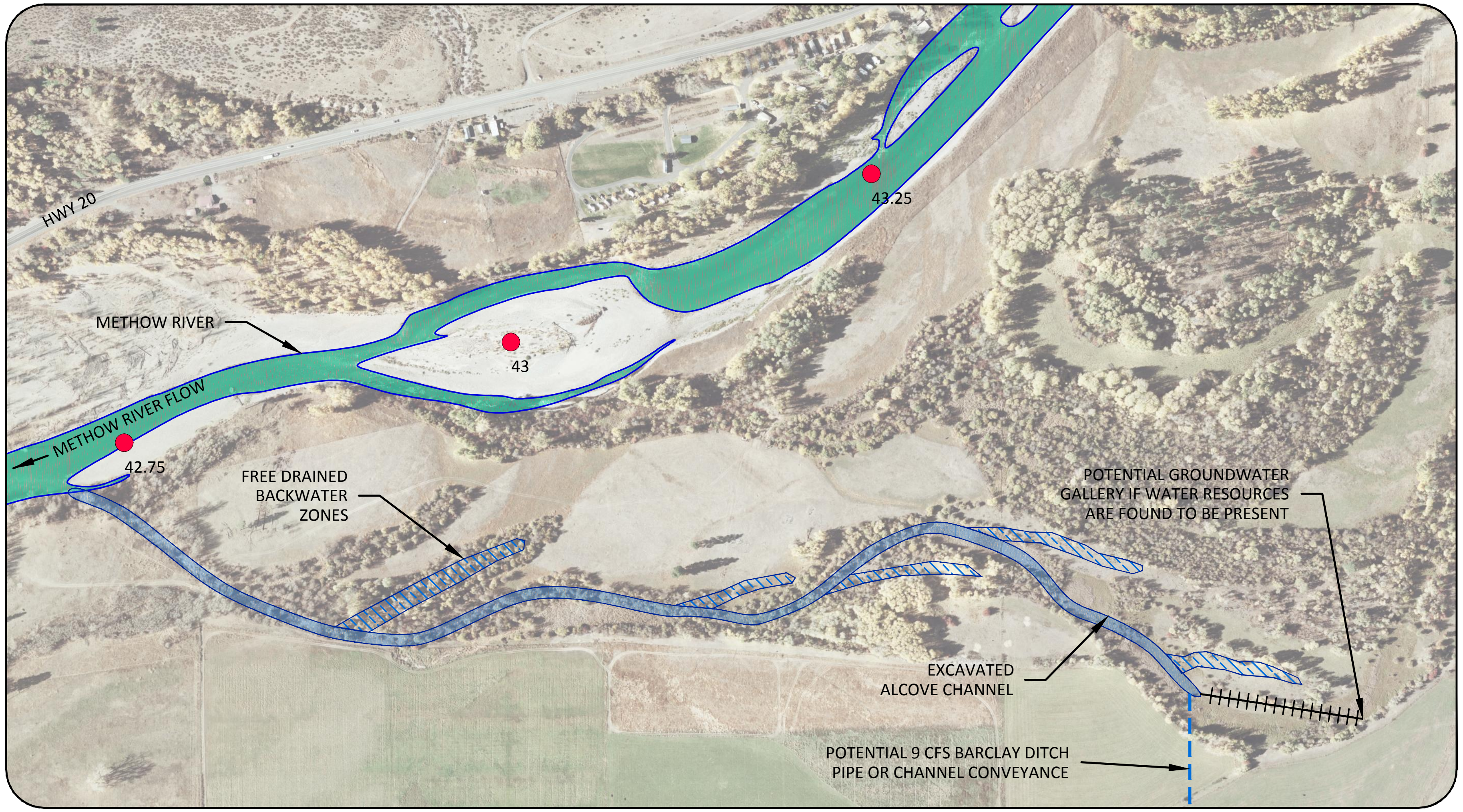
TYPICAL CROSS-SECTION
SIDE CHANNEL EXCAVATION WITH LOGJAMS
NOT TO SCALE

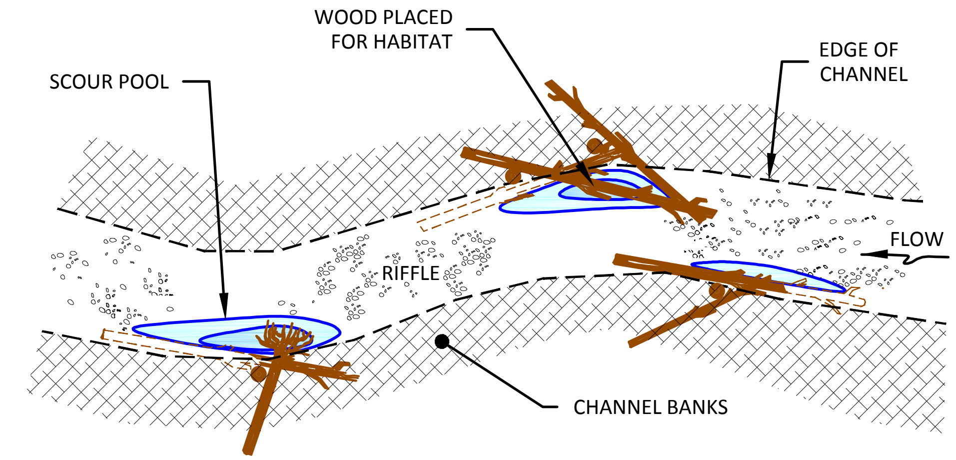
LEGEND:

45.25	METHOW RIVER MILES		T6 - SIDE CHANNEL EXCAVATION
	METHOW RIVER		T6 - LOGJAM FOOTPRINT
			T6 - SIDE CHANNEL APEX BAR JAM FOOTPRINT

0 500 1000
SCALE IN FEET

Two Channels Sub Reach - T6 Project
Excavated Flow Through Side Channel (Southeast)

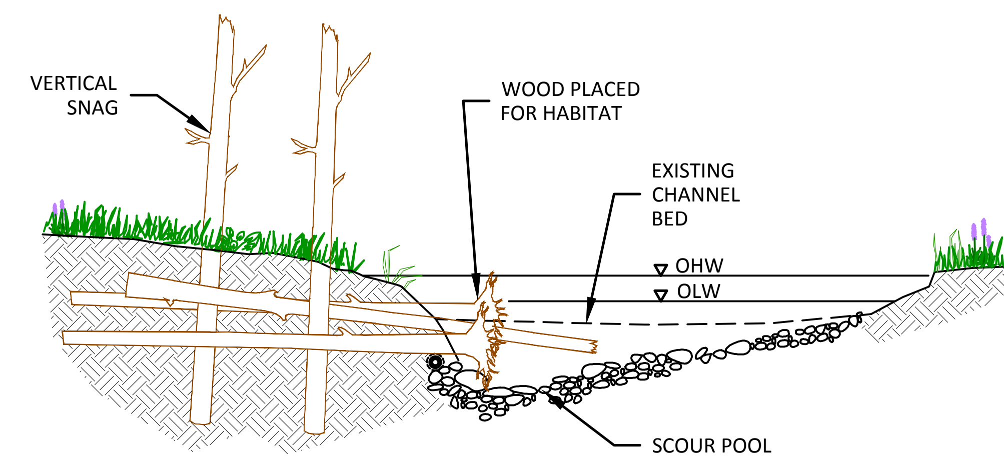




TYPICAL PLAN VIEW

BACKWATER CHANNEL AND ALCOVES

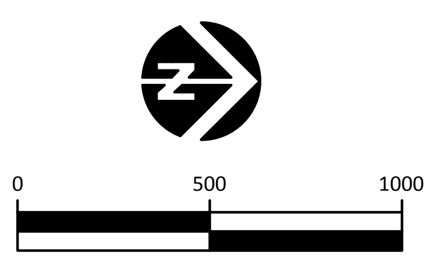
NOT TO SCALE



TYPICAL CROSS-SECTION

BACKWATER CHANNEL AND ALCOVES

NOT TO SCALE

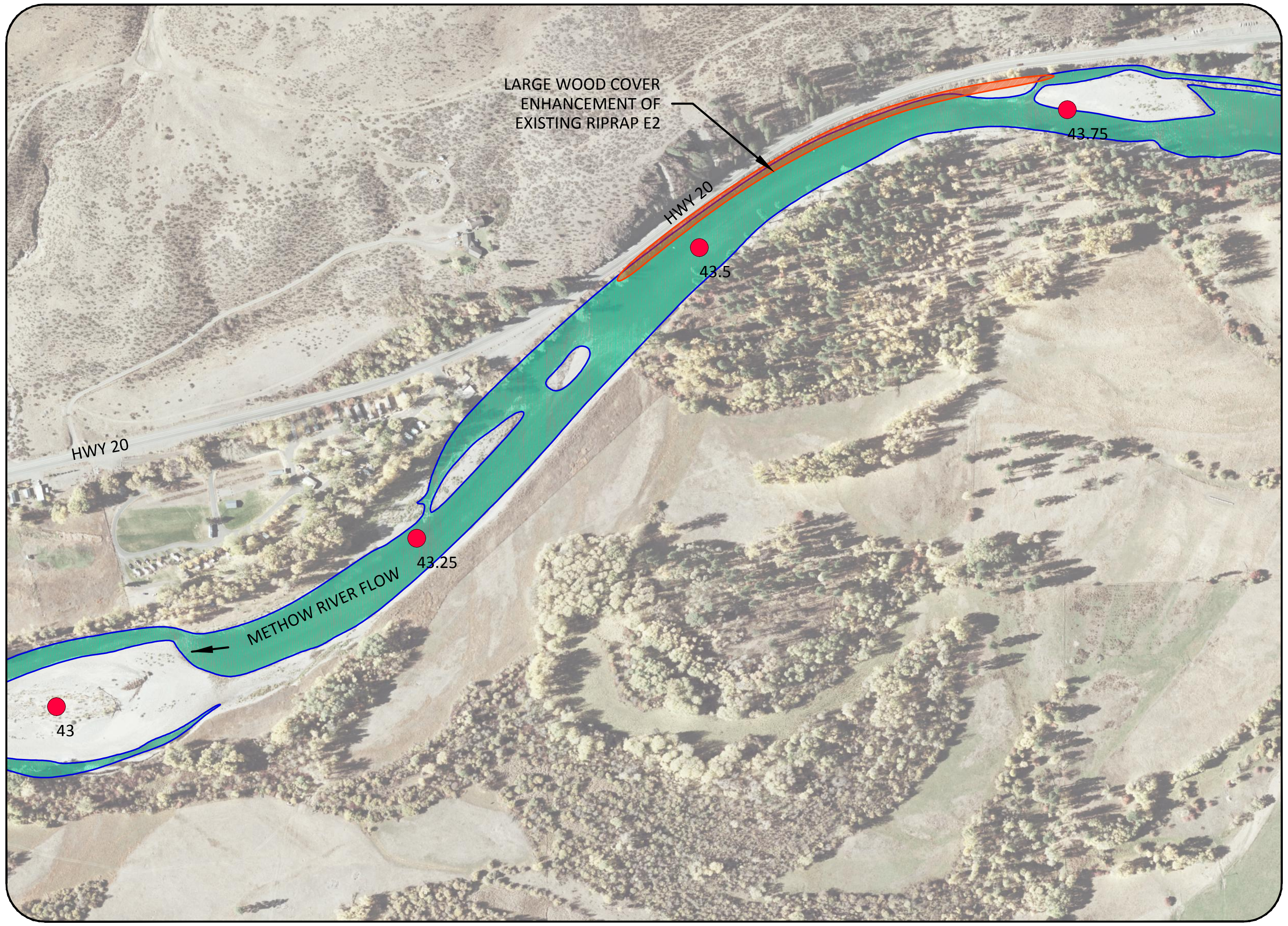


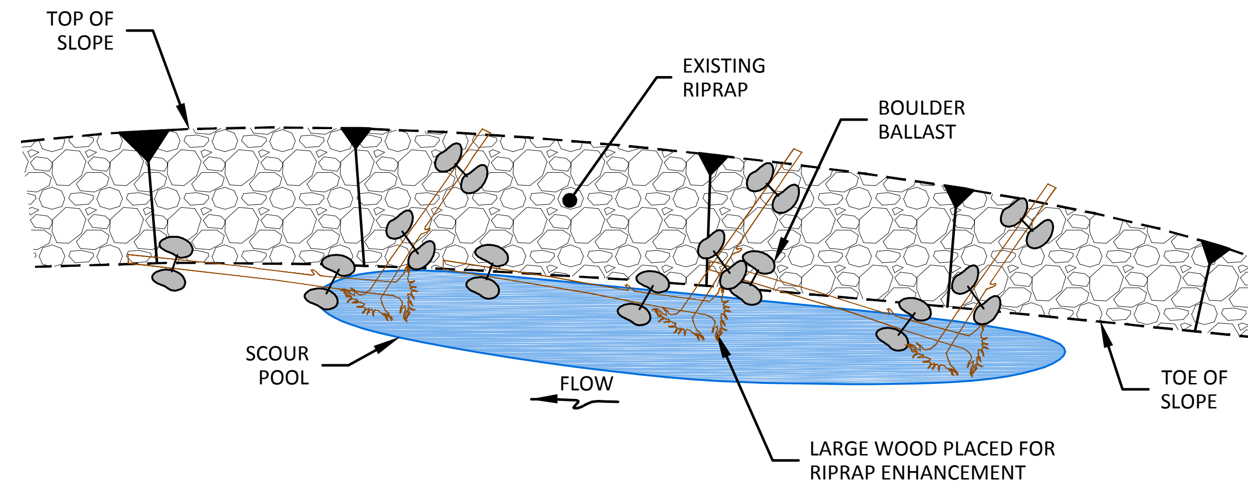
SCALE IN FEET

LEGEND:

45.25	METHOW RIVER MILES
	METHOW RIVER
	E1 - POTENTIAL GROUNDWATER GALLERY TO BE DETERMINED
	E1 - POTENTIAL PIPE OR CHANNEL CONVEYANCE TO BE DETERMINED
	E1 - ALCOVE SIDE CHANNEL
	E1 - FREE DRAINED BACKWATER CHANNEL

Eagle Rocks Sub Reach - E1 Project
Groundwater Gallery and Alcove Channel

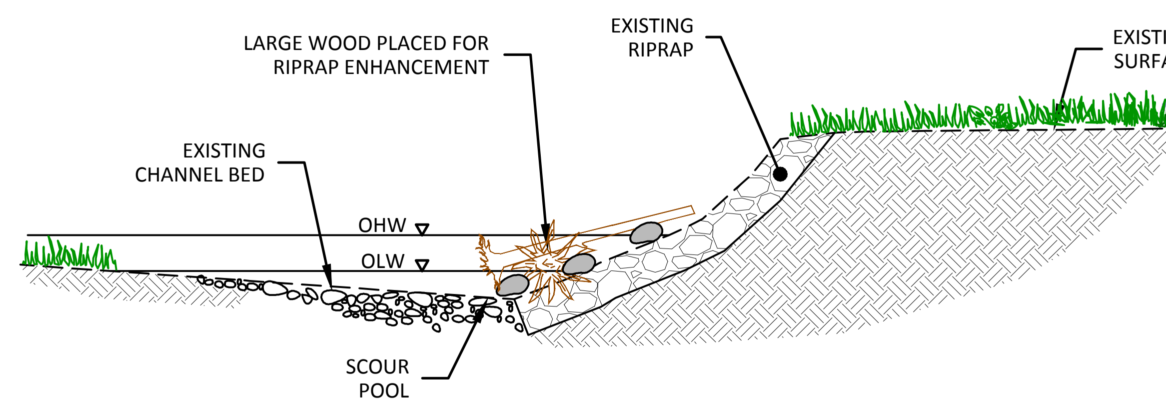




TYPICAL PLAN VIEW

LARGE WOOD ENHANCEMENT OF RIPRAP

NOT TO SCALE



TYPICAL CROSS-SECTION

LARGE WOOD ENHANCEMENT OF RIPRAP

NOT TO SCALE

0 500 1000

SCALE IN FEET

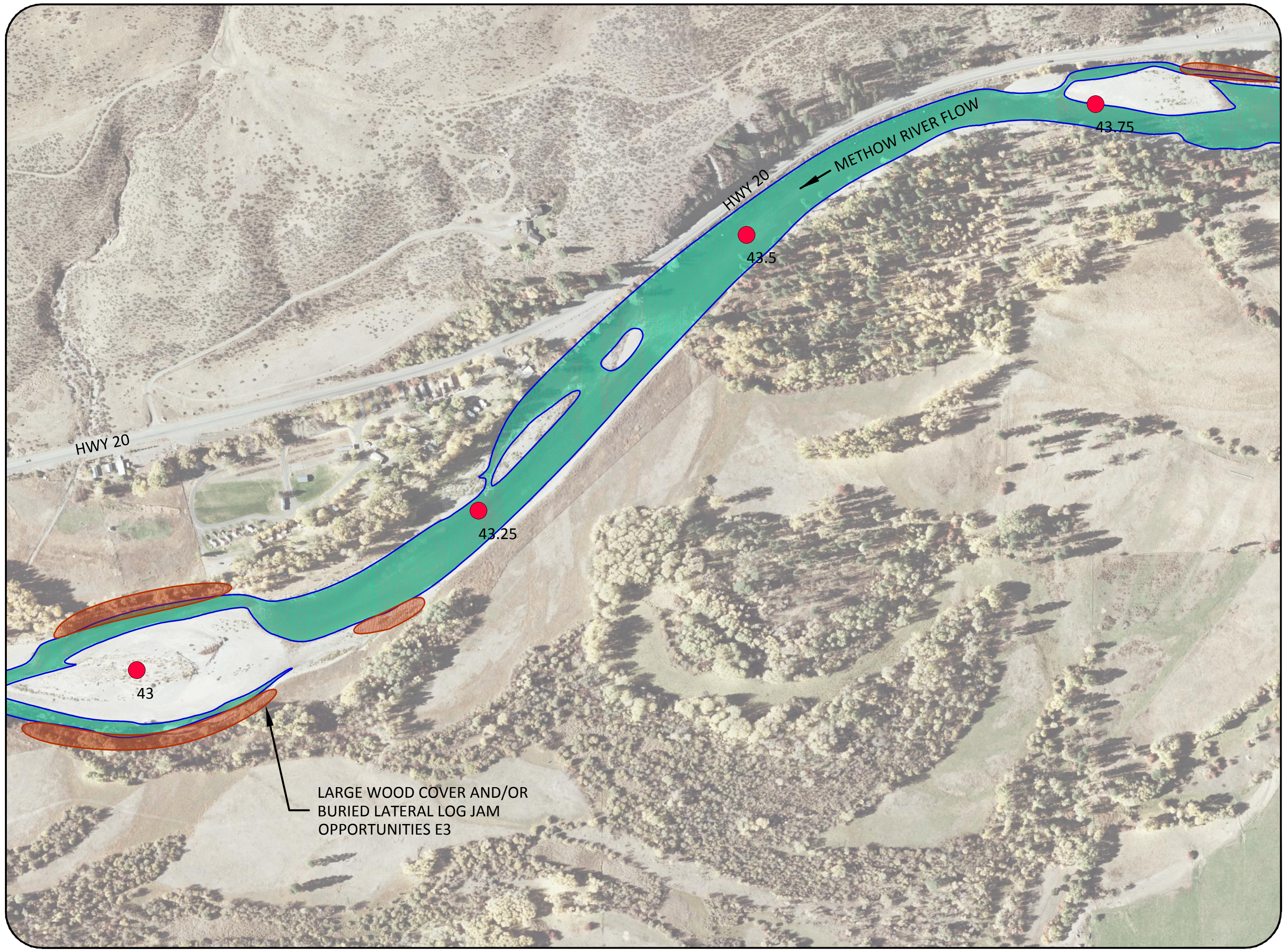
LEGEND:

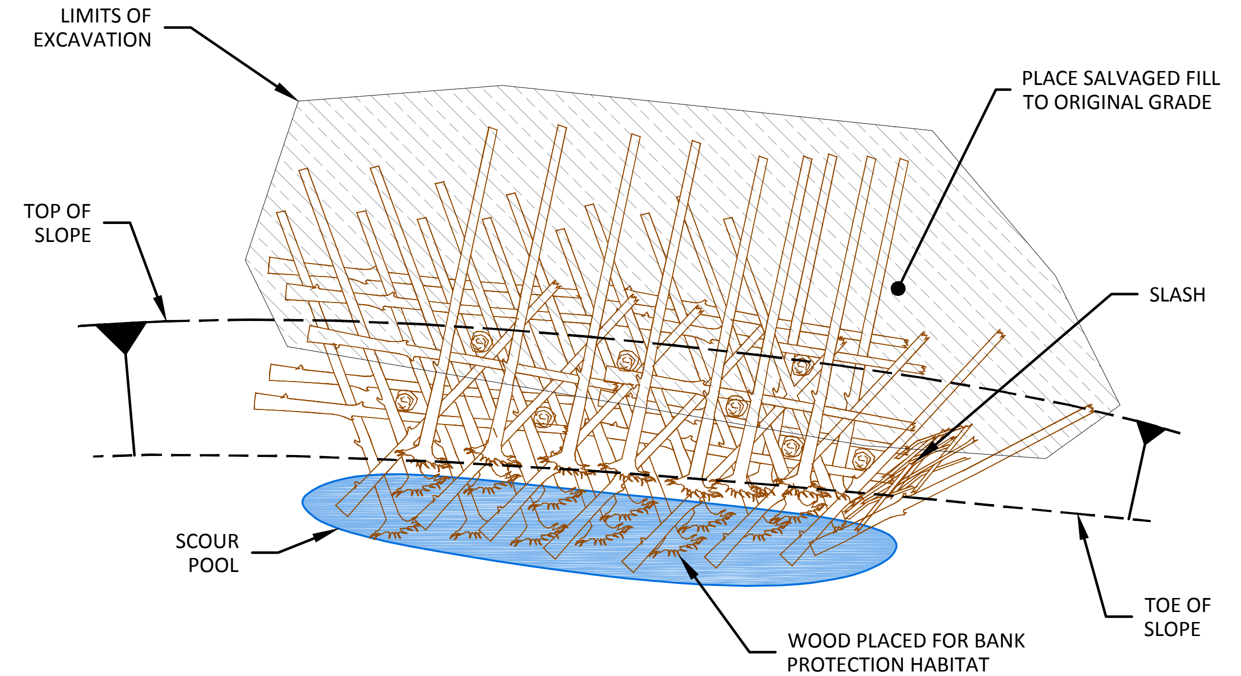
45.25 METHOW RIVER MILES

METHOW RIVER

E2 - LARGE WOOD ENHANCEMENT OF EXISTING RIPRAP

Eagle Rocks Sub Reach - E2 Project Large Wood Enhancement Along Riprap Banks

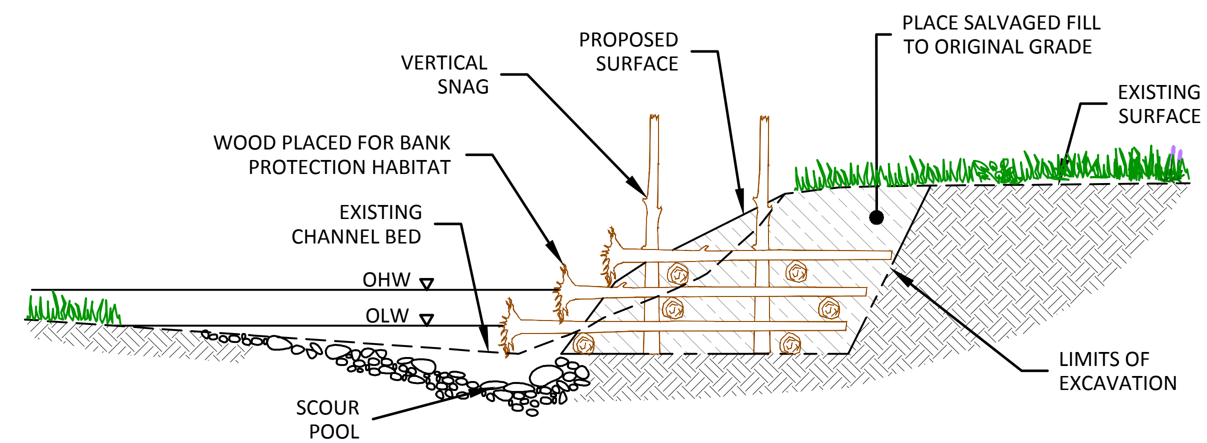




TYPICAL PLAN VIEW

BURIED LOGJAMS

NOT TO SCALE



TYPICAL CROSS-SECTION

BURIED LOGJAMS

NOT TO SCALE

0 500 1000

SCALE IN FEET

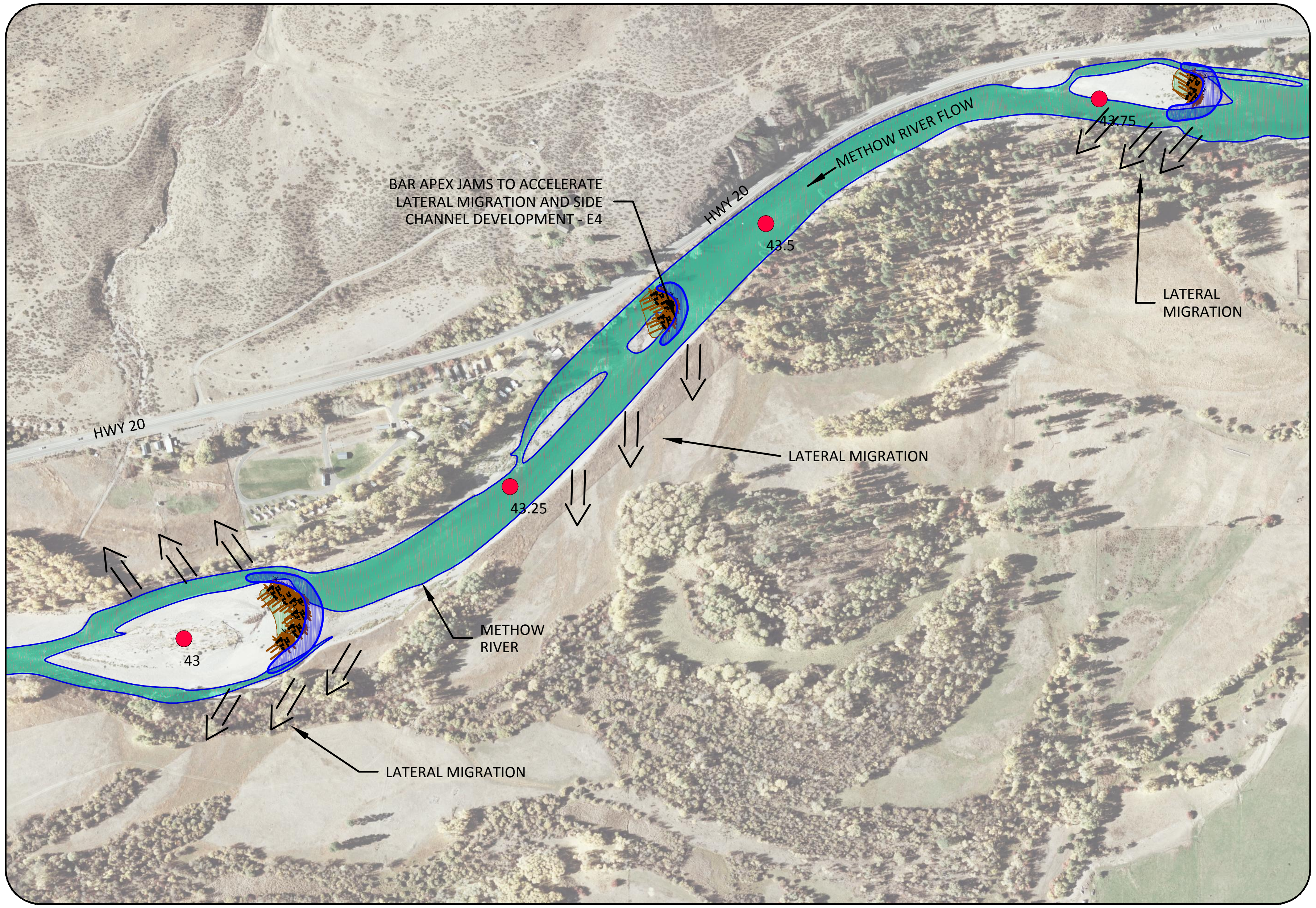
LEGEND:

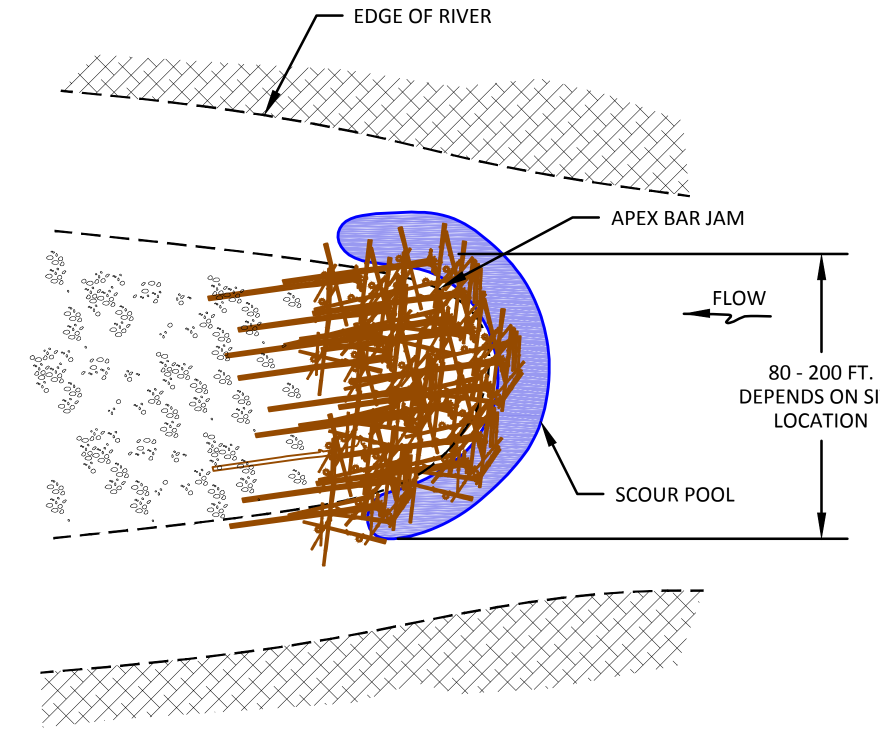
45.25 METHOW RIVER MILES

METHOW RIVER

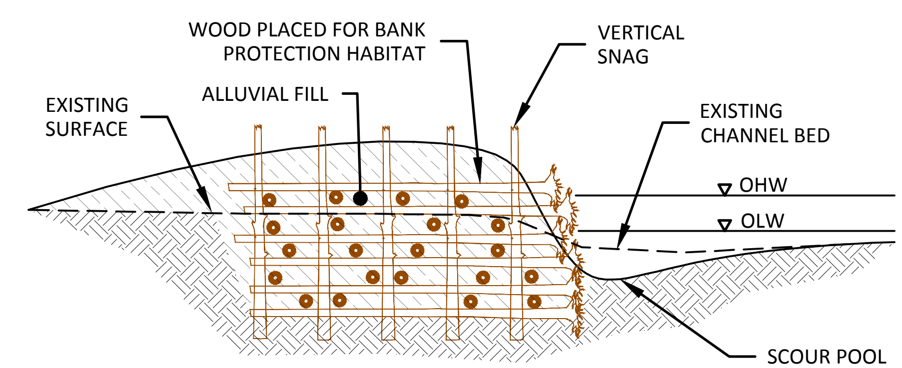
E3 - LATERAL LOG JAMS

Eagle Rocks Sub Reach - E3 Project
Bank Logjams Within Riprap Banks, Low Terrace and Floodplain Banks





TYPICAL PLAN VIEW
APEX BAR JAM
NOT TO SCALE



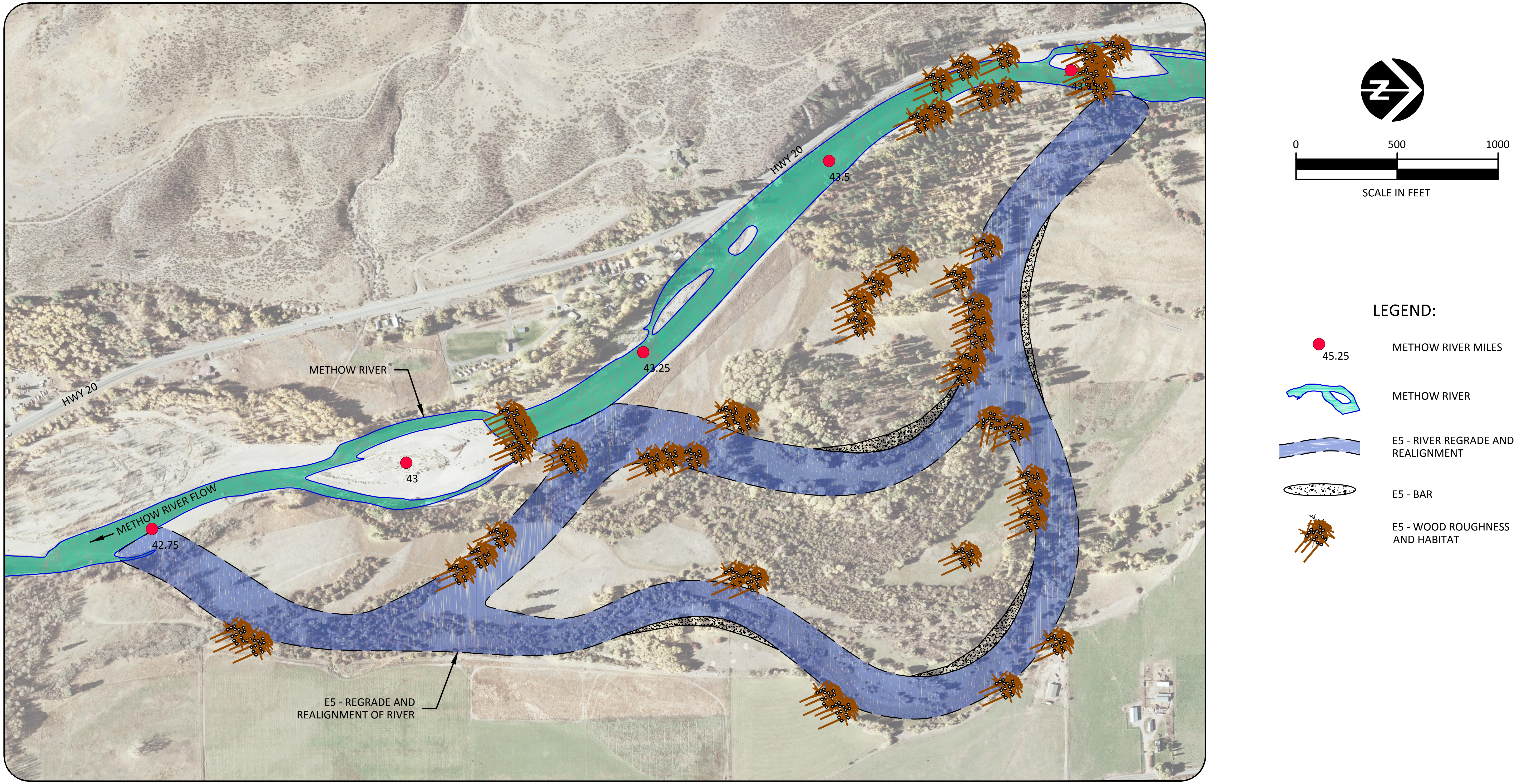
TYPICAL CROSS-SECTION
APEX BAR JAM
NOT TO SCALE

0 500 1000
SCALE IN FEET

LEGEND:

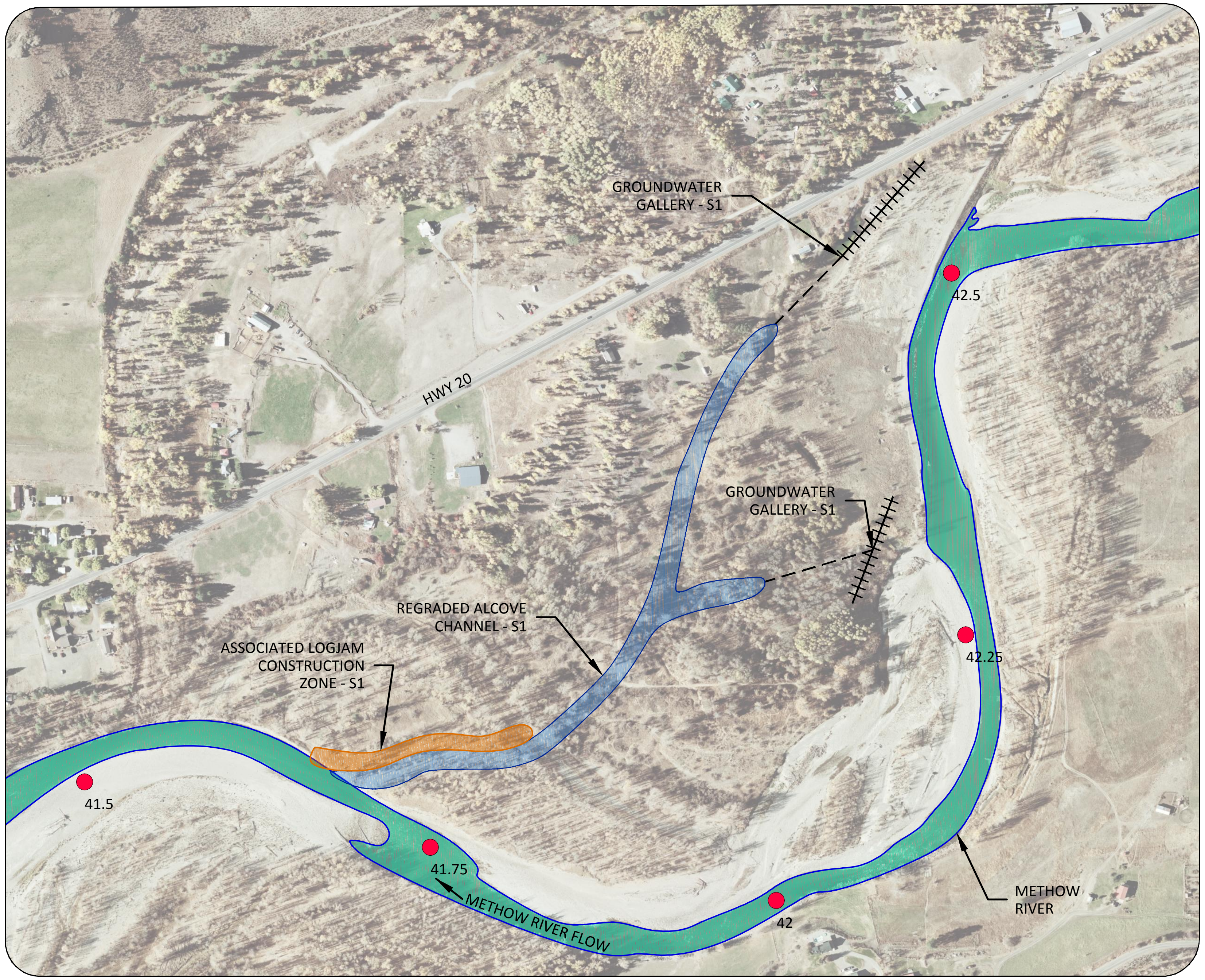
45.25	METHOW RIVER MILES		E4 - BAR APEX AND MID RIVER LOGJAMS
	METHOW RIVER		E4 - POOL
	POTENTIAL EROSION TREND		

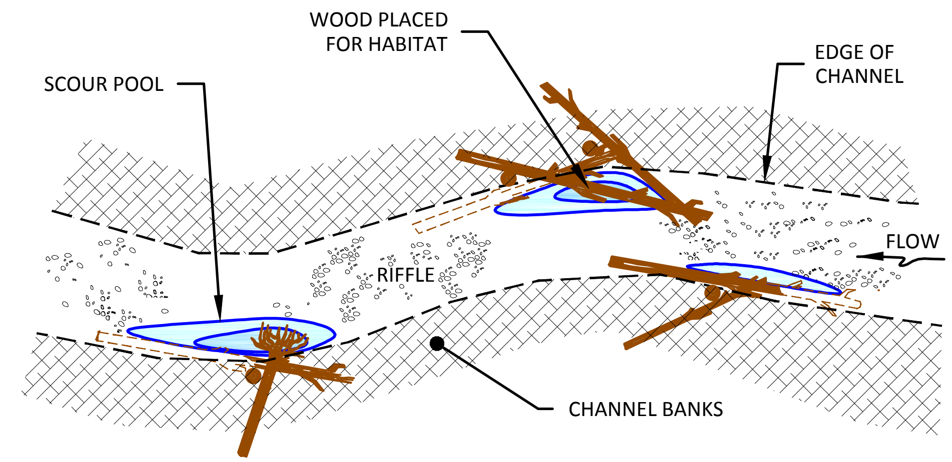
Eagle Rocks Sub Reach - E4 Project
Bar Apex and Mid River Logjams



Eagle Rocks Sub Reach - E5 Project

Enhancing Natural River Migration Processes by Regrading and Realigning River

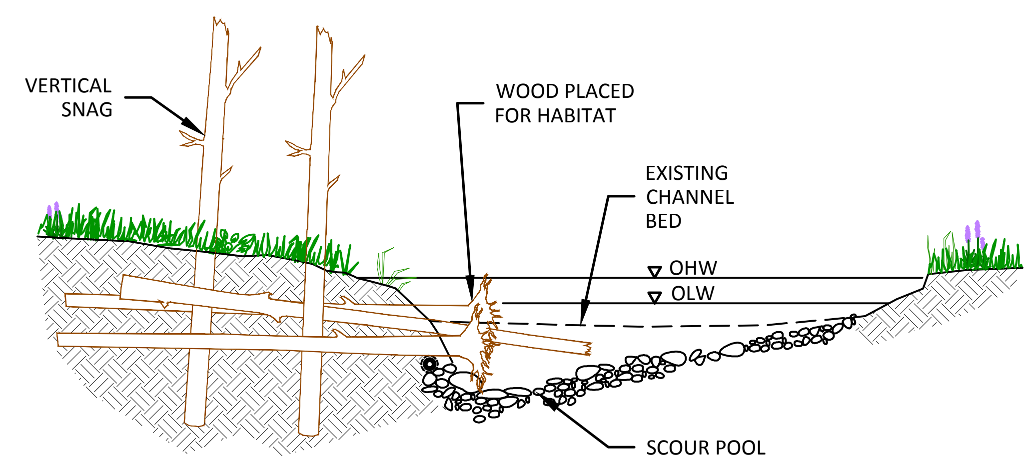




TYPICAL PLAN VIEW

BACKWATER CHANNEL AND ALCOVES

NOT TO SCALE



TYPICAL CROSS-SECTION

BACKWATER CHANNEL AND ALCOVES

NOT TO SCALE

0 500 1000

SCALE IN FEET

LEGEND:

45.25 METHOW RIVER MILES

METHOW RIVER

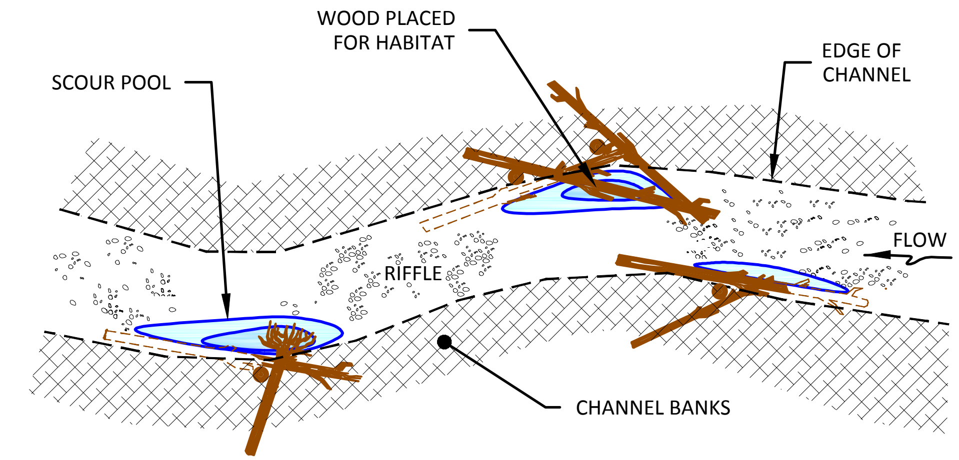
S1 - GROUNDWATER GALLERY

S1 - GROUNDWATER GALLERY PIPE

S1 - ALCOVE CHANNEL

S1 - LOGJAM FOOTPRINT

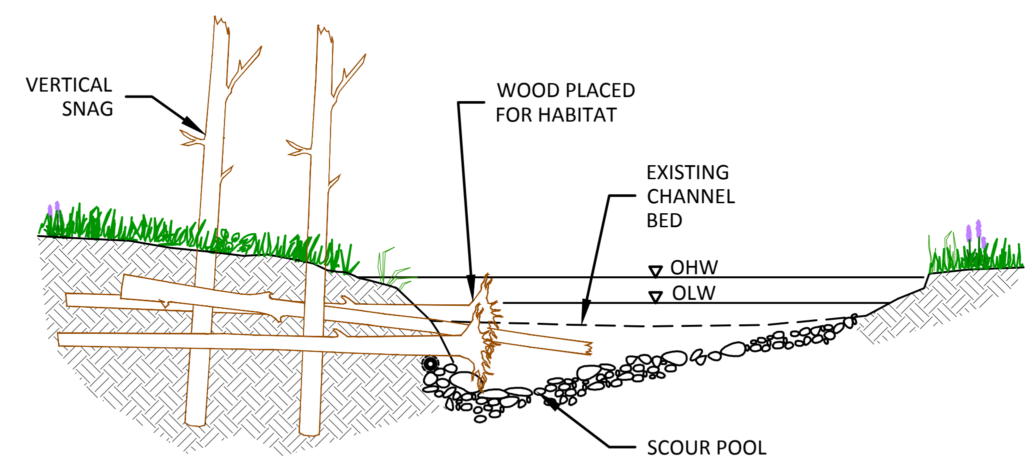
Sugar Dike Sub Reach - S1 Project
Groundwater Gallery and Alcove Channel



TYPICAL PLAN VIEW

BACKWATER CHANNEL AND ALCOVES

NOT TO SCALE



TYPICAL CROSS-SECTION

BACKWATER CHANNEL AND ALCOVES

NOT TO SCALE

LEGEND:

45.25 METHOW RIVER MILES

METHOW RIVER

S2 - GROUNDWATER GALLERY TO BE DETERMINED

S2 - GROUNDWATER GALLERY PIPE

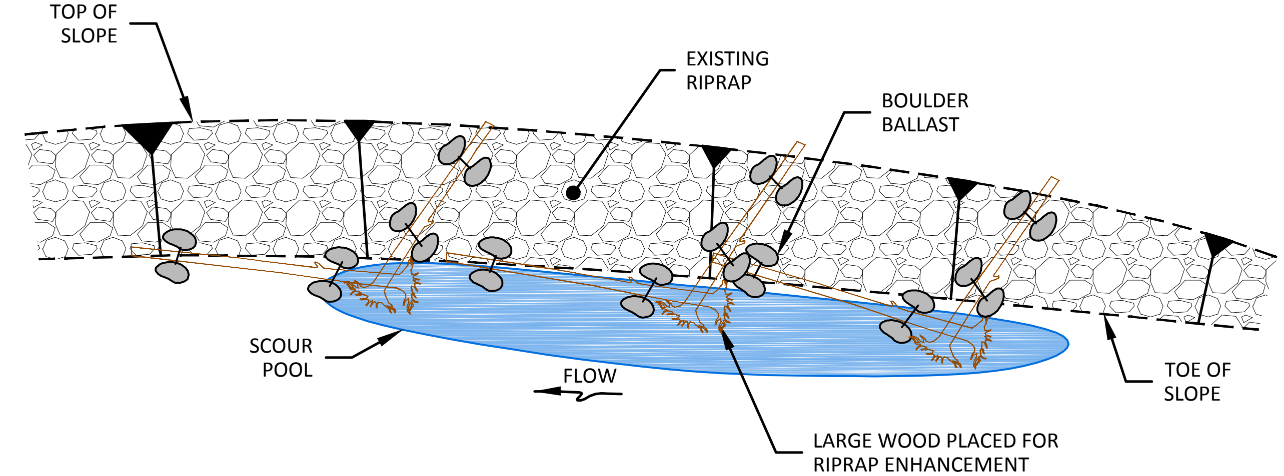
S2 - ALCOVE CHANNEL

S2 - LOGJAM FOOTPRINT

0 500 1000

SCALE IN FEET

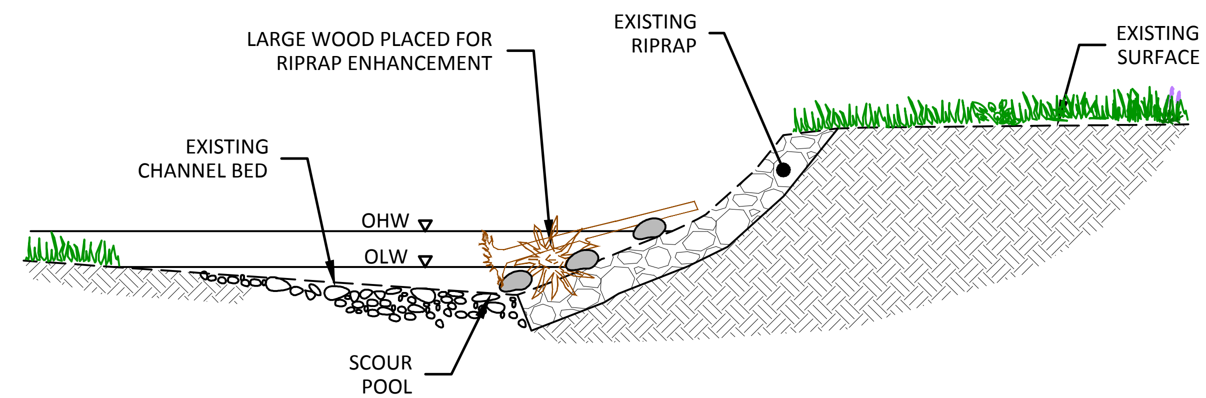
Sugar Dike Sub Reach - S2 Project
Groundwater Gallery and Alcove Channel



TYPICAL PLAN VIEW

LARGE WOOD ENHANCEMENT OF RIPRAP

NOT TO SCALE



TYPICAL CROSS-SECTION

LARGE WOOD ENHANCEMENT OF RIPRAP

NOT TO SCALE

0 500 1000

SCALE IN FEET

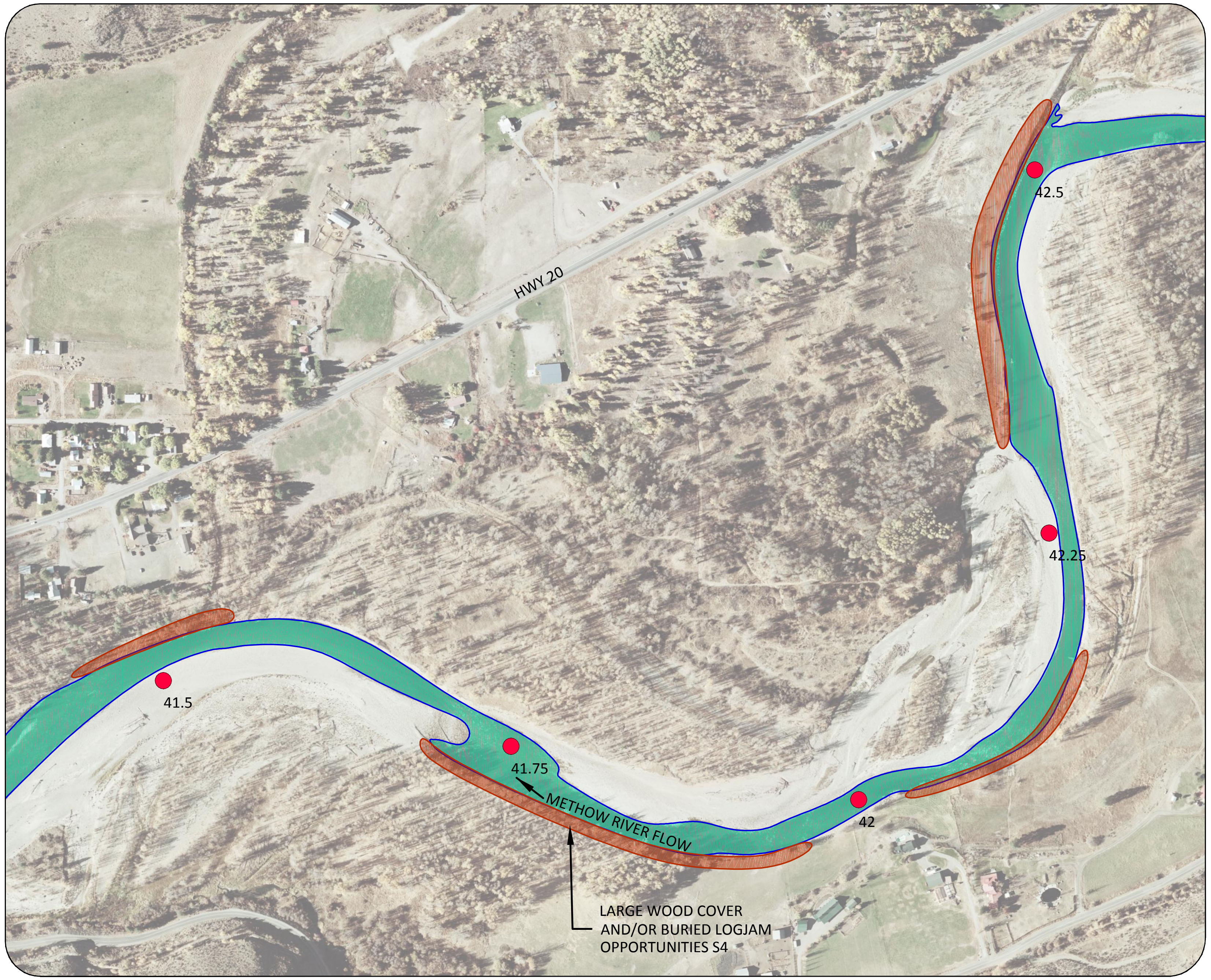
LEGEND:

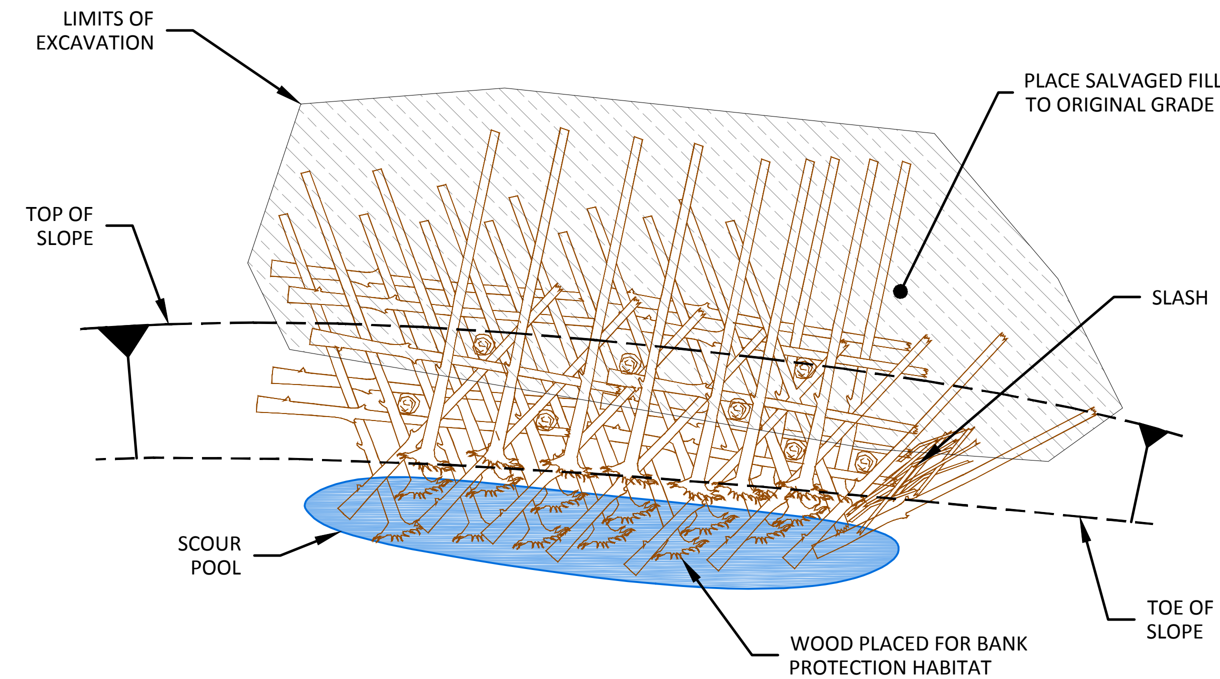
45.25 METHOW RIVER MILES

METHOW RIVER

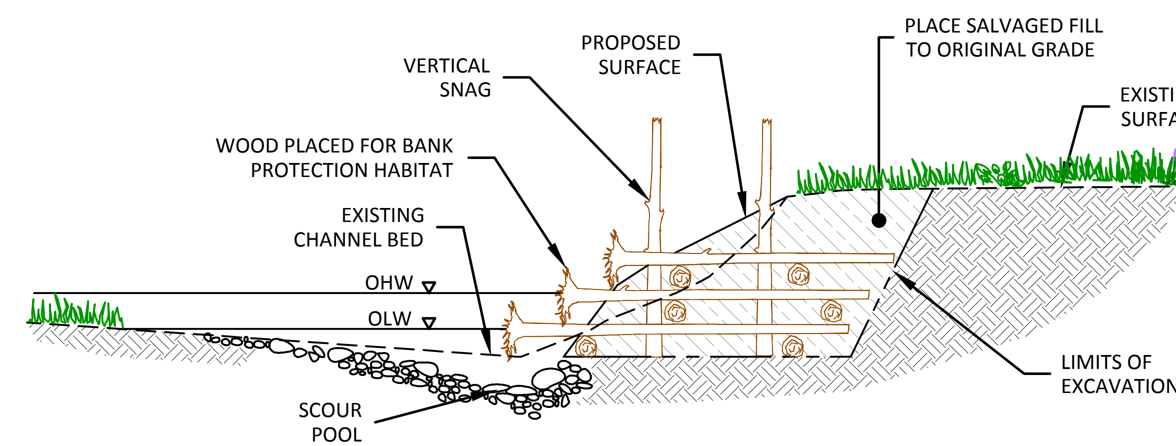
S3 - LARGE WOOD ENHANCEMENT OF EXISTING RIPRAP

Sugar Dike Sub Reach - S3 Project
Large Wood Enhancement of Existing Riprap





TYPICAL PLAN VIEW
BURIED LOGJAMS
NOT TO SCALE



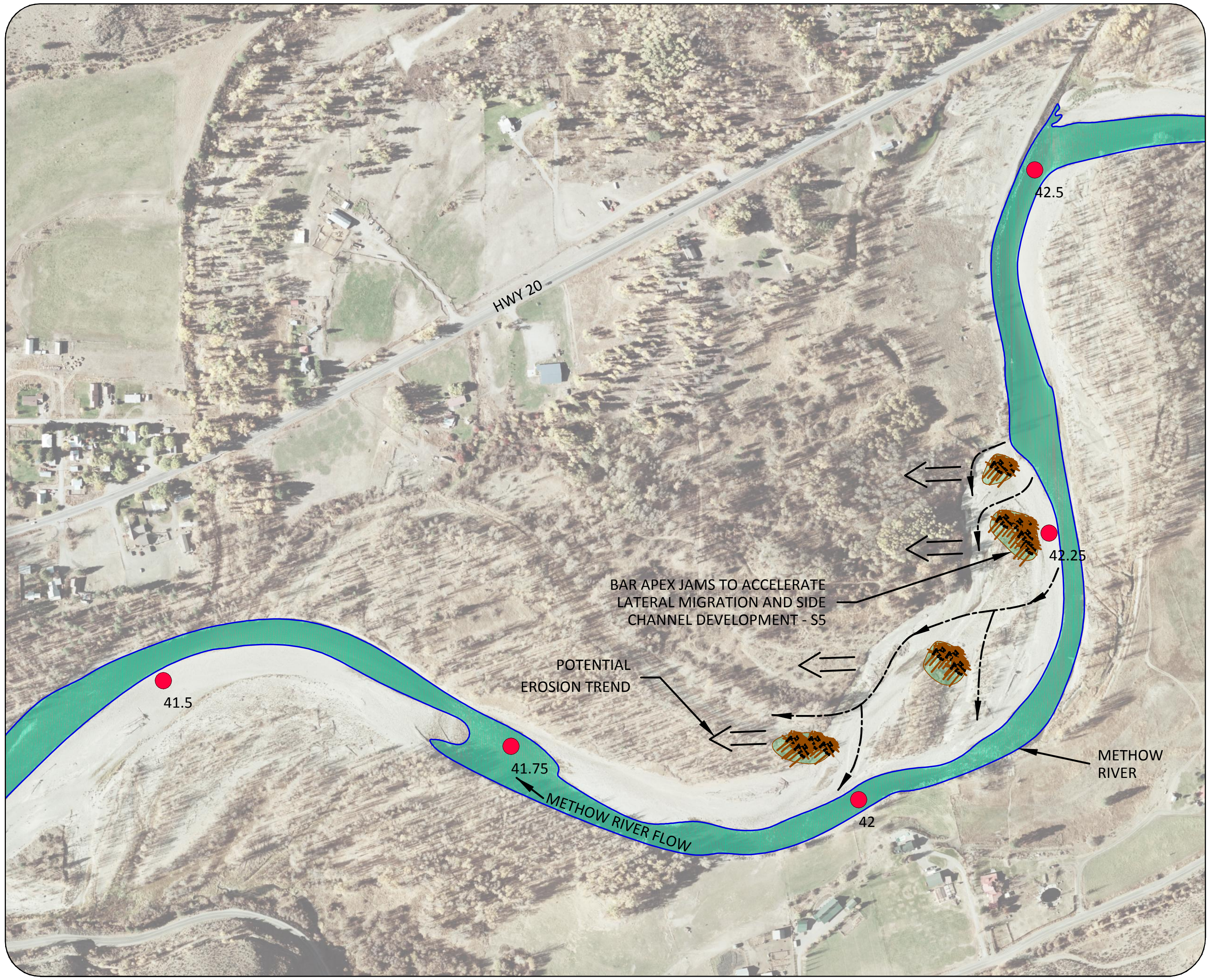
TYPICAL CROSS-SECTION
BURIED LOGJAMS
NOT TO SCALE

0 500 1000
SCALE IN FEET

LEGEND:

45.25	METHOW RIVER MILES
	METHOW RIVER
	S4 - BURIED LOGJAMS

Sugar Dike Sub Reach - S4 Project Bank Jams Within Riprap Banks, Low Terrace, and Floodplain Banks



0 500 1000

SCALE IN FEET

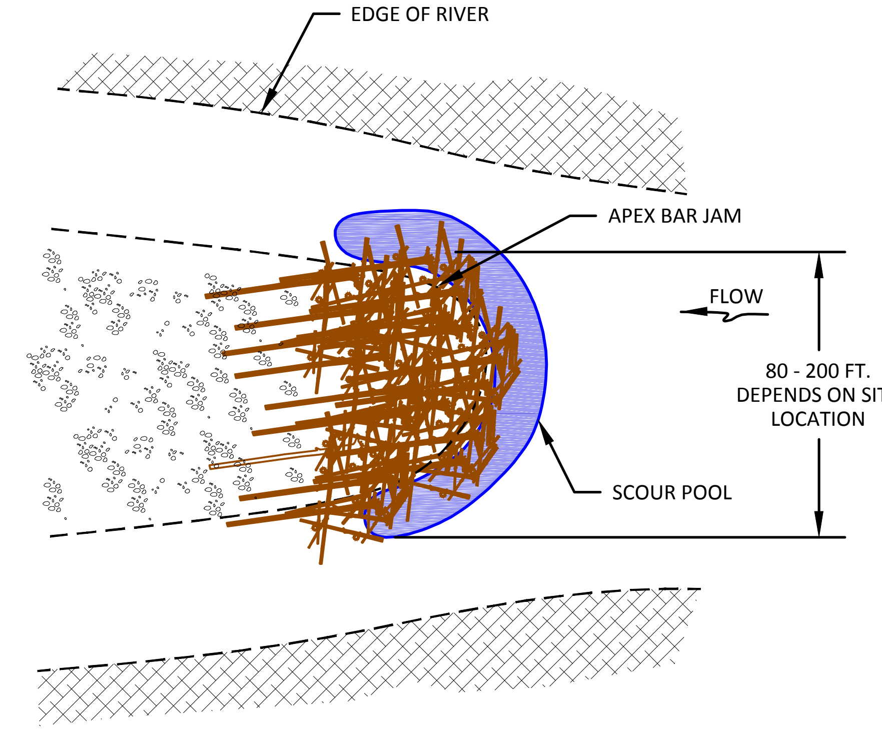
LEGEND:

45.25 METHOW RIVER MILES

METHOW RIVER

S5 - BAR APEX AND BANK LOGJAMS

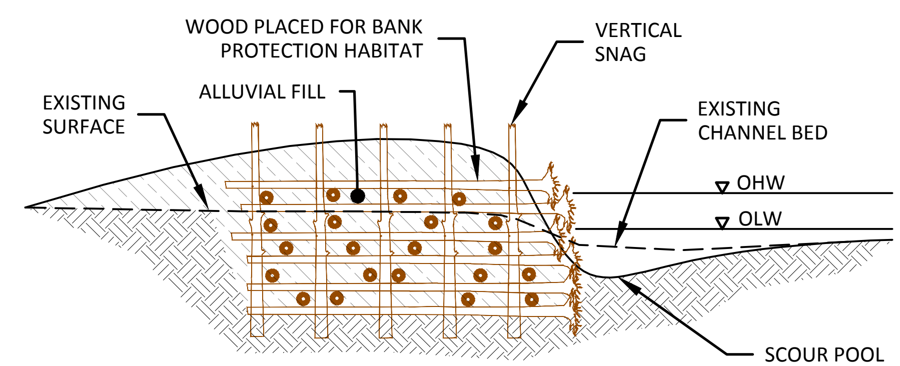
POTENTIAL EROSION TREND



TYPICAL PLAN VIEW

APEX BAR JAM

NOT TO SCALE

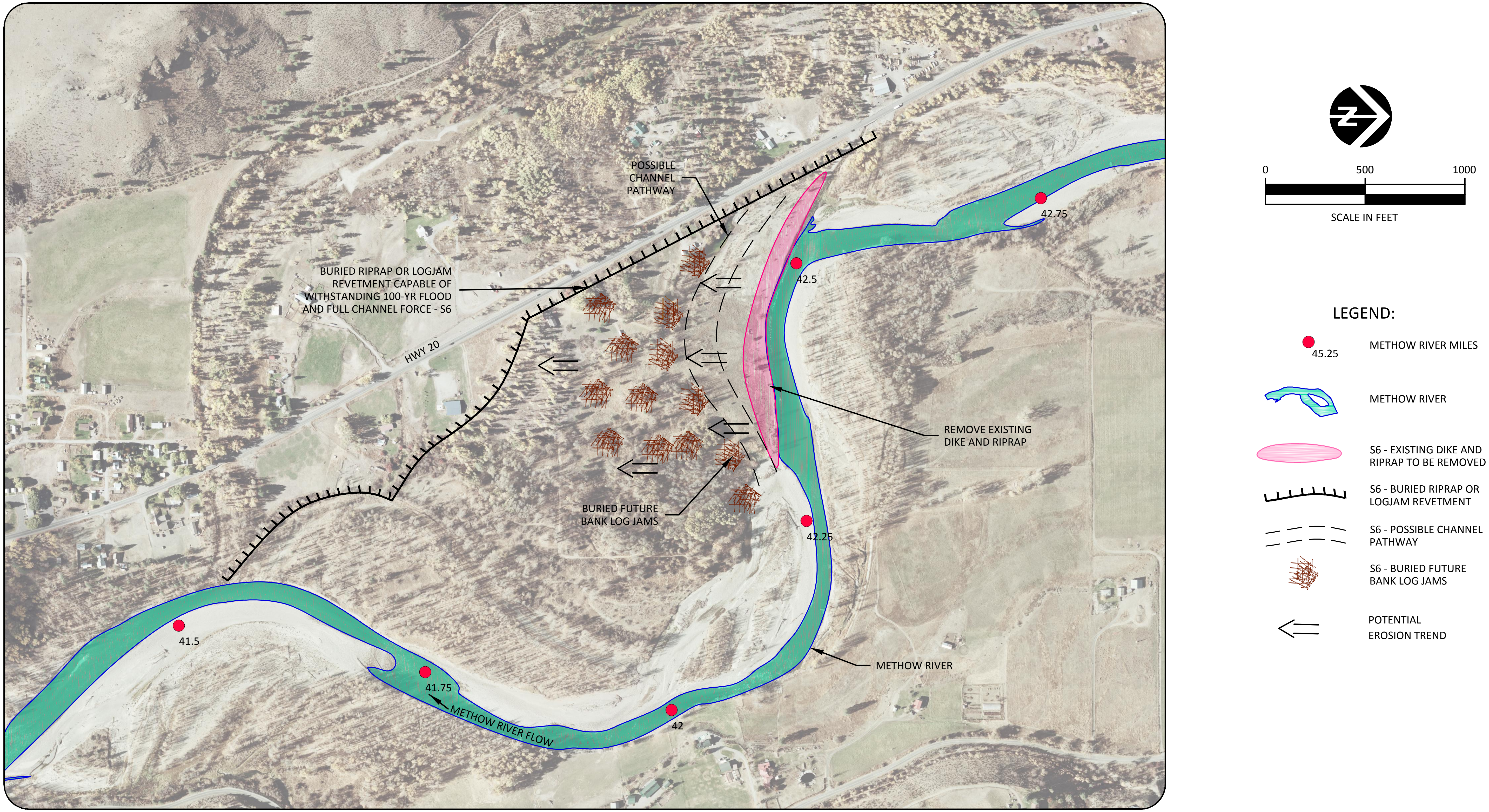


TYPICAL CROSS-SECTION

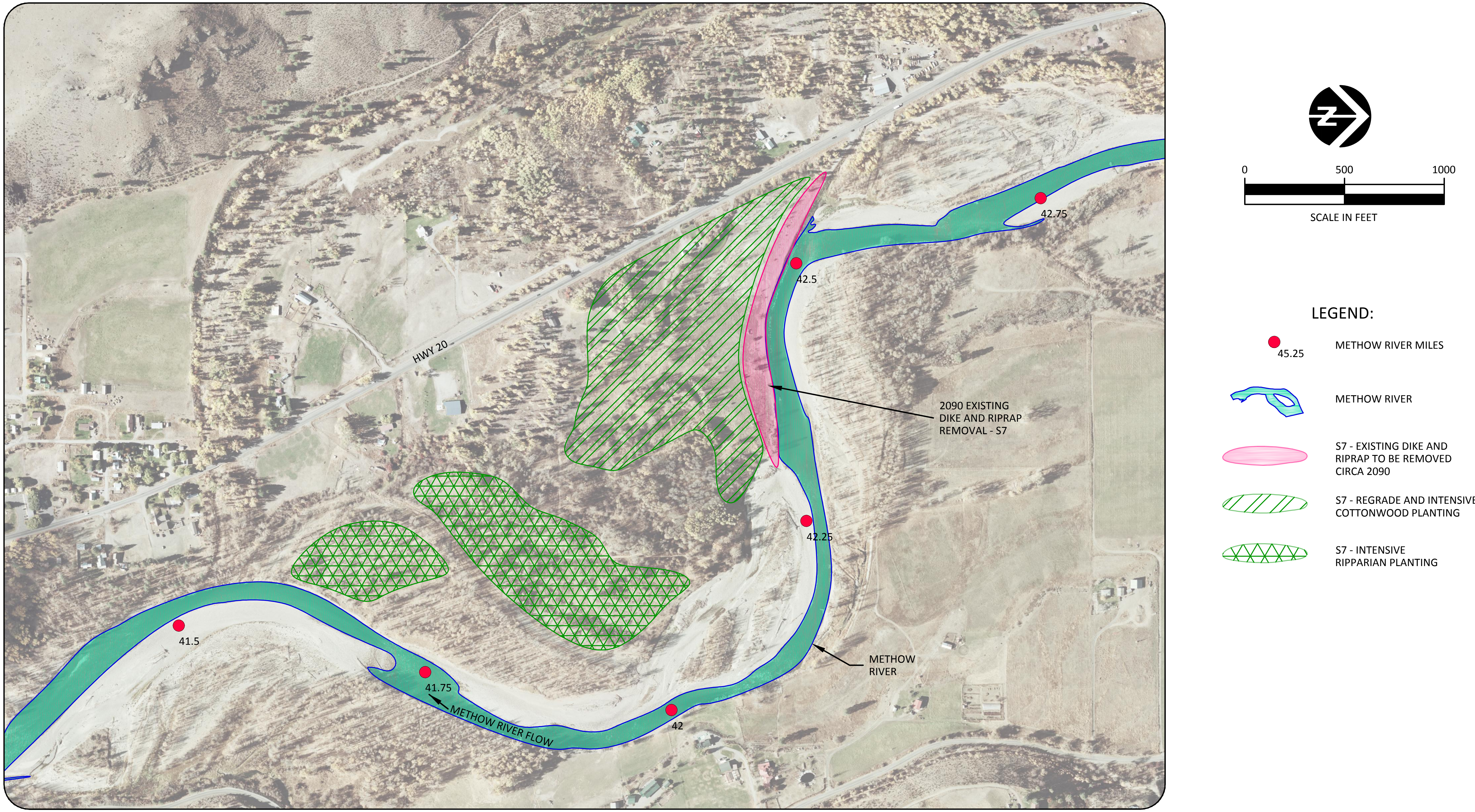
APEX BAR JAM

NOT TO SCALE

Sugar Dike Sub Reach - S5 Project
Bar Apex Logjam Habitat Near RM 42.2



Sugar Dike Sub Reach - S6 Project
Sugar Dike Removal



Sugar Dike Sub Reach - S7 Project
Re-Grade and Intensive Cottonwood Planting Behind Sugar Dike Followed by 2090 Removal

APPENDIX B: HYDROLOGY & HYDRAULIC MODELING

HYDROLOGY

Peak flow return hydrology determines the range of flows that we use for hydraulic modeling and analysis. The LRT reach falls within previous peak flow hydrology efforts completed by Anchor QEA LLC and the Bureau of Reclamation (Reclamation) for the M2 reach from Winthrop to Twisp. The LRT reach is the lower half of the M2 Reach. Peak flow values were computed from a Log Pearson Type-III analysis of the approved period of record (1912-2009). These return period flows will be used for all subsequent hydraulic modeling efforts and will allow consistency between design efforts for all work on the Methow River between Winthrop and Twisp. The modeled discharges include the 1-, 2-, 5-, 10-, 25-, 50- and 100-year recurrence interval floods with discharge magnitudes (Table 1).

Table 1: Peak Discharge Estimates

Flow Event	Discharge (cfs)
1-year	3,017
2-year	9,449
5-year	14,282
10-year	17,723
25-year	22,312
50-year	25,891
100-year	29,597

HYDRAULIC MODELING

EXISTING CONDITIONS HYDRAULIC MODEL

Inter-Fluve completed the existing conditions analysis using the U.S. Army Corps of Engineers Hydraulic Engineering Center River Analysis System (HEC-RAS 4.1.0). HEC-RAS is a computer program that models the hydraulics of water flow through natural rivers and other channels. The program calculates channel and floodplain hydraulic parameters such as water velocity, depth, and shear stress for various input flows.

MODEL GEOMETRY

Model geometry was developed using bathymetric and topographic survey data collected by survey grade GPS and total station, as well as LiDAR. The collected data was referenced to a USGS monument found on the Sugar Dike with elevation 1604.21262 USFT NAVD88. The projection is State Plane Washington North NAD27 USFT. The model includes 30 surveyed cross-sections extending over a 4.2-mile study reach. The upstream extent of the reach is at RM 44.7, and the downstream extent is just upstream of the Twisp River confluence at RM 40.5. We chose locations that characterized the study reach and surveyed cross-sections for hydraulic modeling at those locations (Appendix A). The chosen locations included grade breaks on the river, changes in valley width, or significant changes in roughness. Some areas could not be surveyed because permission to enter the property was not granted.

ROUGHNESS

The hydraulic model uses roughness coefficients (Manning's n values) to calculate flow energy losses, or frictional resistance, caused by channel bed materials, channel irregularity, and type and density of floodplain vegetation. Roughness coefficients represent the various channel surfaces and types and densities of vegetation, and we applied the appropriate coefficient to each model cross-section (Table 2). The roughness delineations and locations were based on survey notes and recent aerial imagery, and roughness values were based on field observations and published methods (Arcement & Schneider, 1989). For low-flow modeling, the Manning's n channel value was increased to 0.046 from 0.035 to better represent the effects of shallow water flowing over cobbles.

Table 2: Roughness coefficients used in the existing conditions model

Description	Manning's n values
Channel, cobble bed and banks	0.035
Gravel bars with willow and discontinuous LWD	0.080
Dense willow	0.150
Mature forest, sparse understory vegetation, scattered LWD	0.120
Tall grass	0.050
Floodplain; road	0.020

BOUNDARY CONDITIONS

HEC-RAS requires boundary conditions before it begins its analysis. Boundary conditions are the starting water surface elevations associated with each discharge at the upstream and downstream ends of the model. For sub-critical flow models, such as this one, computations begin at the downstream end, so only the downstream boundary needs to be defined. The downstream boundary water surface elevations were obtained from *Appendix B: Hydraulic Model Documentation for the Middle Methow (Reclamation, 2010)*, which provided a list of observed water surface elevations for several estimated flow rates at RM 40.3. The surface elevations provided surrogate data to develop a rating curve of corresponding flows for RM 40.5. (Table 3).

Table 3: Downstream Boundary Rating Curve

Water Surface (ft.)	Discharge (cfs)
1561.0	285
1566.0	10,900
1569.0	16,600
1571.0	24,400
1575.0	31,360

A sensitivity analysis was conducted to determine if changes to the downstream boundary water surface elevations caused significant variability in model results. The model results were checked after adjusting the boundary condition by 6-inches in both directions. These adjustments resulted in no significant differences in computed water surface elevations at a short distance upstream. It was found that using water surface data provided by others for RM 40.3 to create a model boundary for RM 40.5 did not significantly alter the results.

CALIBRATION

The Manning's n values for the channel represent friction caused by the channel bed materials and bedforms during bankfull events and larger floods. When the channel is full, a relatively small portion of flow within the channel is in physical contact with the channel boundaries. At low flow, however, a significantly larger fraction of flow is in contact with the channel boundary materials. To account for the increase in channel roughness at low flow, we adjusted the flow roughness factors. In this way, we calibrated the model to maximize agreement between calculated and observed water surface elevations. We recorded the water surface observations used in the calibration on November 5-6, 2010, which was a relatively low flow period. The discharge recorded at the Winthrop gage (12448500) for this date was 400 cfs. The adjusted flow roughness factor for low flow was 1.3, and the channel n value was 0.046.

The computed water surface levels were typically within 0.3-feet of observed levels (Table 4). Sections 6085, 16976, 23125, and 24312, however, initially had errors greater than 0.5-feet. These errors were reduced by adding one interpolated section downstream of each. The uppermost section at station 24312 still has an error of 1.1-feet. The model requires additional sections downstream of that section to better compute the hydraulics, but property access was not granted to collect the ground data in this area during the survey.

Table 4: Low Flow Calibration

River Station	Water Surface		
	Computed	Observed 11-5-10	Error
24312	1647.5	1646.4	1.1
23319	1644.9	1645.2	-0.3
23125	1643.4	1643.9	-0.5
22633	1641.5	1641.6	-0.1
21931	1641.1	1641.0	0.1
20749	1637.1	1637.2	-0.1
19926	1633.9	1633.9	0.0
19358	1632.9	1632.7	0.2
18234	1628.1	1628.0	0.1
17833	1626.3	1626.1	0.2
16976	1625.2	1625.0	0.2
13896	1616.6	1616.6	0.0
13089	1616.1	1616.0	0.1
12988	1615.4	1615.6	-0.2
11843	1612.1	1612.1	0.0
11271	1611.4	1611.2	0.2
10372	1606.7	1607.0	-0.3
10169	1605.6	1605.3	0.3
9836	1604.6	1604.4	0.2
9097	1603.2	1603.5	-0.3
8267	1599.9	1599.5	0.4
7158	1598.0	1598.1	-0.1
7035	1597.7	1597.8	-0.1
6085	1594.3	1594.2	0.0
5083	1589.8	1589.9	-0.1
4007	1587.2	1587.4	-0.2
2887	1583.5	1583.4	0.1
2222	1581.7	1581.6	0.1
1718	1579.9	1580.1	-0.2
1425	1577.0	1577.0	0.0

LIMITATIONS

This model is intended to be an instrument used for designing salmonid habitat. Data collection and model building efforts were biased toward creating a model that provides reliable results for discharges ranging from low flow to small floods in order to predict backwater levels, side-channel activation flows, and seasonal groundwater levels. Large floods are included in the model to support coarse-level stability design and risk assessment but are not meant to be accurate predictors of large flood elevations, extents, or velocities.

APPENDIX C: PROJECT RANKING

PROJECT RANKING METHODS

Step 1: __**Benefit Score.**__ Projects are scored according to 4 benefit categories, which include 2 *biological* categories and 2 *physical process* categories. Scores for each category are summed to obtain the total ***Benefit Score***.

Step 2: __**Cost Score.**__ Projects are given a C***ost Score***, which reflects the overall *relative cost* for the project based on techniques, access, and construction feasibility issues.

Step 3: __**Benefit-to-Cost Score.**__ Total benefit score (sum of all 4 benefit scores) is divided by the cost score to obtain the ***Benefit-to-Cost Score***.

Step 4: __**Feasibility Designation.**__ Project is given a ***Feasibility Designation*** based on the overall likely feasibility of being able to implement the project within a 10-year timeframe.

BENEFIT SCORE

Each of the 5 benefit categories (A through D below) is given a score of 1 to 3, with 3 representing the greatest benefit. The scores for each category are summed to obtain the total benefit score. Application of scores is based on consideration of several factors that are listed under the categories below. These will be further developed in subsequent drafts of the methodology:

Biological Categories

A. Fish use score:

- 3 – High existing or potential productivity area for spawning or rearing for multiple species
- 2 – Moderate existing or potential productivity area for one or more species
- 1 – Low existing or potential productivity area for one or two species

B. Fish life-stage limiting factors score:

- 3 – Addresses key habitat factors at key life-stages for multiple species
- 2 – Addresses either secondary habitat factors, non-key life-stages, or only one or more species
- 1 – Addresses low priority habitat factors at non-key life-stages for a single species

Physical Process Categories

C. Process-based restoration score

- 3 – Full restoration of key physical processes that create and maintain habitat over time
- 2 – Partial restoration of physical processes
- 1 – Primarily a structurally-focused restoration strategy that doesn't significantly address underlying processes

D. Existing physical process condition score

3 – Physical processes are significantly impaired or non-functioning. Habitat quantity and quality are impaired.

2 – Physical processes are moderately impaired with limited availability of quality habitat

1 – Physical processes are functioning well and are supporting high quality habitat conditions

COST SCORE

The cost score reflects the relative cost for the project based on techniques, access, and feasibility issues. This is a relative cost, not an absolute cost, so the scale of the project is NOT factored into this score. The cost score ranges from 1 to 3, with 1 reflecting relatively lower cost projects. The following guidelines/examples can help to determine the cost score.

3 – High relative cost

- Uses high cost techniques (e.g. constructed banks, highly engineered log jams, extensive channel shaping, extensive infiltration galleries)
- Deep excavation or long distance hauling of spoils
- Entails construction of additional new flood control or bank erosion features (e.g. set-back levees or buried rip-rap)
- Extensive planting or invasive weed control
- Limited, difficult, or remote access
- Intensive de-watering requirements

2 – Moderate relative cost

- Uses moderate cost techniques (e.g. typical log jam structures)
- Moderate excavation and hauling distance of spoils
- Typical planting or invasive weed control
- Moderate access conditions
- Standard or no de-watering requirements

1 – Low relative cost

- Uses low cost techniques (e.g. non-ballasted log placements)
- Minimal excavation and hauling distance of spoils
- Little to no planting or weed control
- Easy access conditions
- No de-watering required
- Availability of free materials or volunteer labor

BENEFIT-TO-COST SCORE

The benefit-to-cost score is simply the benefit score divided by the cost score. This is a relative value used to compare project benefits.

FEASIBILITY DESIGNATION

The feasibility designation is the overall likely feasibility of being able to implement the project within a 10-year timeframe. This is based on landownership, as well as economic, regulatory, political, social, permitting, or other considerations that are known to impact the feasibility of conducting projects within a reasonable timeframe. The feasibility designation is not used as part of the project scoring because feasibility issues may change over time and it is desirable to evaluate project benefits independent of feasibility. The designations include the following:

High feasibility

- No known feasibility issues.
- One or two landowners; or landowner(s) has already indicated willingness

Moderate feasibility

- There are potential feasibility constraints that could affect the likelihood of project implementation within a 10-year timeframe
- Three to five landowners; or there is reason to believe landowner(s) would grant permission

Unlikely feasibility

- There are known feasibility constraints that would be expected to limit the ability to implement the project within a 10-year timeframe
- More than five landowners: or there is reason to believe landowner(s) would not grant permission

PROJECT RANKING

LRT Project Ranking 3-22-11

Reach	Project Code	Project Name	Benefit Scores: Fish use	Benefit Scores: Life-stage limiting factors	Benefit Scores: Process-based restoration	Benefit Scores: Existing process condition	Total Benefit Score	Cost Score	Benefit-to-Cost Score	Feasibiilty Designation
TC	TC1	Ground Water Gallery Alcove (East Channel)	3	3	2	2	10	3	3.3	**High**
TC	TC2	Ground Water Gallery Alcove (West Channel)	3	3	2	3	11	3	3.7	**Moderate**
TC	TC3	Large Wood Enhancement along RR Banks	1	2	1	3	7	2	3.5	**High**
TC	TC4	Bank Logjams within RR Banks, LT and FP Banks	2	2	2	3	9	3	3.0	**Moderate**
TC	TC5	Bar Apex Jam to Establish Seasonal SC	2	2	3	2	9	3	3.0	**Moderate**
TC	TC6	Excavated Flow - Through Side Channel	2	2	2	2	8	3	2.7	**Moderate**
							0			
ER	ER1	Groundwater or surface fed Alcove Side Channel	3	3	2	3	11	3	3.7	**High**
ER	ER2	Large Wood Enhancement along RR Banks	1	2	1	3	7	2	3.5	**Moderate**
ER	ER3	Bank Logjams within RR Banks, LT and FP Banks	2	2	2	3	9	3	3.0	**Moderate**
ER	ER4	Bar Apex Jam and Mid River Bankjams	2	2	3	2	9	3	3.0	**Moderate**
ER	ER5	Methow River Valley Bottom Re-Grade	3	3	3	3	12	3	4.0	**Unlikely**
							0			
S	S1	Groundwater Gallery Alcove Behind Sugar Dike	3	3	2	3	11	3	3.7	**Moderate**
S	S2	Backwater Wall-Based Seasonal Alcove Channel	3	3	2	3	11	3	3.7	**High**
S	S3	Large Wood Enhancement along RR Banks	1	2	1	3	7	2	3.5	**High**
S	S4	Bank Logjams within RR Banks, LT and FP Banks	2	2	2	3	9	3	3.0	**Moderate**
S	S5	Log Jam Habitat Bar Apex near RM 42.2	2	2	3	2	9	3	3.0	**Moderate**
S	S6	Sugar Dike Removal	2	2	3	3	10	3	3.3	**Unlikely**
S	S7	Re-Grading, Planting and Delayed Sugar Dike Removal	2	2	3	3	10	3	3.3	**Moderate**
		Projects that would exclude all others in each subreach.								