REPORT

30 PERCENT DESIGN REPORT
UPPER MIDDLE METHOW REACH
WHITEFISH ISLAND

Prepared for

U.S. Bureau of Reclamation

Prepared by

Anchor QEA, LLC

1605 Cornwall Avenue

Bellingham, Washington 98225

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LIST OF ACRONYMS AND ABBREVIATIONS

1-D	one dimensional
AER	Alternatives Evaluation Report
cfs	cubic feet per second
CPAA	Conceptual Project Alternatives Assessment
ELJ	engineered log jams
ESA	Endangered Species Act
GPS	Global Positioning System
HEC-RAS	Hydraulic Engineering Center-River Analysis System
LWD	large woody debris
M2	Middle Methow
RA	Reach Assessment
Reclamation	U.S. Bureau of Reclamation
TA	Tributary Assessment
UCRTT	Upper Columbia Regional Technical Team

1 INTRODUCTION

The purpose of the Whitefish Island Restoration Project (Project) is to increase and improve the presence and quality of overwintering habitat for juveniles and to promote system complexity by restoring natural processes that will benefit the abundance and productivity of salmonid populations in the Middle Methow (M2) reach of the Methow River. The U.S. Bureau of Reclamation (Reclamation) has been involved in improving habitat for Endangered Species Act- (ESA-) listed fish species in the Methow River for the past 8 years. Previous efforts related to the Project include:

- The Tributary Assessment (TA) (Reclamation 2008)
- The Middle Methow Reach Assessment (RA) (Reclamation 2010)
- Conceptual Project Alternatives Assessment (CPAA) (Anchor QEA 2010)
- Alternatives Evaluation Report (AER) (Anchor QEA 2011a)

Complexity in the Project area is limited by poor side channel and floodplain connectivity and low hydraulic and bedform complexity in the main channel. Several factors have led to these conditions, most notably a lack of large woody debris (LWD) accumulation and temporary sediment storage. Without the hydraulic complexity created by key wood pieces that allow stable log jams to develop and retain additional mobile wood, cover and refuge during juvenile-rearing periods is limited. The Project area includes one of the few side channels in the Upper M2 reach and improving the lack of channel complexity through the side channel is a vital component of this Project.

Restoration treatments proposed in this report are necessary to address the current shortfall in habitat conditions in the M2 reach. Channel migration and natural habitat creation is extremely limited and the rehabilitation of natural processes through passive restoration actions is not a prudent option, given the timeline necessary to implement salmon recovery actions in an ecologically responsible manner. Therefore, Project components are designed so that immediate and short-term benefits are achieved while remaining consistent with geomorphic processes. By implementing projects that achieve objectives in both the short and long term, the functionality of natural processes will be increased over time for a healthier and more self-sustaining system.

2 GOALS AND OBJECTIVES

The overall goals and objectives of the Project are to improve instream habitat for ESA-listed fish in the M2 reach. Restoration actions and selected components are based on critical life history stages for target species and identified limiting factors for these species. Specific restoration goals for the Whitefish Island Project area include:

- Increase channel complexity in the existing side channel by installing instream structures largely composed of LWD
- Increase duration and extent of surface water flow in existing side channel through natural processes after the installation of a series of engineered log jams (ELJs)
- Protect and improve existing overwinter rearing habitat in groundwater-fed pools by enhancing the pool depth with an instream structure composed primarily of LWD
- Increase habitat complexity in the main channel with LWD assemblies and structures that will influence hydraulics resulting in high-flow refuge and sediment sorting and temporary storage
- Protect and improve the quantity and function of riparian vegetation by stabilizing unstable banks, promoting bar deposition and the potential for natural establishment of vegetation, and planting appropriate riparian vegetation
- Increase floodplain/channel connectivity through promotion of natural processes associated with adding instream structure to better emulate natural wood loading

2.1 Target Species

The M2 fish habitat Project aims to maximize habitat value in the Methow River between Twisp and Winthrop to support the short- and long-term recovery of ESA-listed fish in the area. The target species of interest in the Upper M2 reach include all three Upper Columbia ESA-listed salmonid species: spring Chinook, steelhead, and bull trout. These species use the Upper M2 reach for all or part of their life cycles. The Upper M2 reach serves as a migratory corridor for adult spring Chinook (May through June), steelhead (October through May), and bull trout (June through July and October through November; Peven 2003) and for spring Chinook smolts (March through May) and steelhead smolts (March to June) migrating into and out of the Methow subbasin. Spring Chinook, steelhead, and bull trout use the Upper M2 reach for adult holding habitat during migration; steelhead are present for a more extended adult holding period. The Upper M2 reach is a rearing and overwintering area for spring Chinook and steelhead juveniles. Juvenile bull trout may rear in the Upper M2 reach to the extent that they may migrate out of natal tributaries because of high flows in the spring, or because they are seeking thermal refuge in the fall (Peven 2003). Steelhead and spring Chinook spawn in the Upper M2 reach; consequently, the reach also supports incubation over winter.

2.2 Limiting Factors

Low-flow/overwintering habitat for juvenile salmonids was identified in the M2 Reach Assessment (Reclamation 2010a) and the Upper Columbia Regional Technical Team (UCRTT) Biological Strategy (UCRTT 2008) as the most limiting condition to the recovery of self-sustaining Methow subbasin spring Chinook salmon and steelhead populations. As flows diminish throughout the summer months and into the fall, rearing habitat is reduced and juvenile salmonids must compete for suitable habitat. Suitable habitat exists along a longitudinal and vertical axis of the water column, with differences in habitat availability, food availability, stream temperature, and predation risk across these axes. Although fall precipitation typically provides a small increase in stream flows, instream flows are low throughout the winter, which leads to a majority of side channel habitat becoming cut off from the main channel. The reduced habitat during the winter months reduces the carrying capacity and survival for overwintering juveniles in the Upper M2 Reach, affecting abundance. Increasing habitat complexity during low-flow periods can increase the carrying capacity of the habitat, contributing to an increase in abundance consistent with available food supply and territorial behaviors.

2.3 Treatment Actions

The habitat restoration actions selected to address limiting factors in the Project area focus on increasing and improving overwintering conditions for juveniles, developing instream complexity, and restoring long-term natural processes that will benefit the abundance and productivity of salmonid populations. Complexity in the Project area is limited by access to side channels, poor floodplain connectivity, and low hydraulic and bedform complexity in the main channel due to the lack of LWD accumulation and sediment deposition. Specific restoration actions for the Project area include:

- Installing two bar apex ELJs, one at the head of the island and one in the side channel
- Installing five ELJs along the side channel left bank
- Installing two LWD assemblies along the side channel left bank
- Installing one live crib along the side channel right bank
- Installing various LWD on gravel bars adjacent to the main channel and side channel

3 PROJECT AREA DESCRIPTION

The Project area is primarily composed of a wide, plane-bed main channel and a large side channel that is connected during spring runoff and fall storm events, but remains disconnected during much of the summer and winter months. The main channel is wide and relatively shallow (other than the large pool at the downstream end of the Project area) with little to no structural or bedform complexity. Habitat conditions are poor for target species during critical life history stages, particularly during summer and winter low flows. The side channel provides valuable habitat for juveniles during the spring, but becomes disconnected and benefits are significantly reduced much or the year. There is a groundwater-fed pool near Witte Road that provides some habitat year round, although survival is not clearly understood from year to year. Additional Project area description, habitat conditions, and background information is available in the AER (Anchor QEA 2011a).

4 DESIGN DEVELOPMENT

For purposes of discussion, the design development is delineated into main channel, side channel, and riparian components. Some restoration elements are designed to provide habitat benefits individually while others are designed to function as a unit.

4.1 Main Channel Components

The **bar apex ELJ** planned for the head of the island is designed to interact with main channel flow throughout the flow regime and will promote scour of large, deep pools adjacent to and directly upstream of the ELJ. Working in conjunction with bank ELJs constructed in the side channel, this ELJ will promote a deepening and narrowing of the primary channel through the side channel opening. Currently, the side channel in this area is very wide and shallow with flow depths of less than 6 inches when it is connected to the river.

The scour pools developed and maintained during high flows will provide valuable holding habitat for adults as well as refuge and cover for juveniles. The ELJ will provide refuge and cover in the main channel during low flow, which is currently non-existent through the reach. By promoting a deepening and narrowing of the side channel opening, the ELJ will in part improve habitat conditions throughout the side channel during summer/overwintering low flows.

Bar roughness LWD placements along the right gravel bars are intended to interact with spring runoff and promote deposition of finer sediment along the bar areas. Deposition of finer sediment will help increase local grades and promote a sorted gradation of surface sediments along the bar area. Deposition of fine grained sediment will promote the natural generation of cottonwoods through the bar areas.

The structural complexity provided by the LWD placement will provide high-flow refuge and cover for juveniles during spring runoff. Regeneration of cottonwoods in the low lying areas will improve refuge and cover and improve riparian conditions leading to greater shading, LWD recruitment, and nutrient loading over time.

4.2 Side Channel Components

Bank ELJs and LWD assemblies along the left bank are intended to function as a unit to promote the deepening and narrowing of the thalweg through the side channel. Currently, the side channel is wide and shallow with an ill-defined thalweg. Hydraulic energy along the ELJs in the side channel will result in increased sediment transport capacity compared to existing conditions and promote the development and maintenance of a pool-riffle sequence through the side channel.

The development of a series of pools will provide refuge and cover for juveniles, thereby significantly increasing the habitat quality and carrying capacity of the side channel. A more pronounced thalweg through the side channel, coupled with the increased low flow in the side channel as a result of the ELJ at the head of the channel, will significantly increase the habitat value provided by the side channel.

The **live crib** constructed along the right bank near Witte Road is intended to protect and improve the existing groundwater-fed pool and increase the local riparian zone. The live crib will be constructed primarily with wood and will be built adjacent to the right bank and placed at the expected scour depth. Because groundwater contributions are coming from the right valley wall (below Witte Road), the base level of the live crib will be backfilled with large angular rock to allow groundwater to flow through the structure and into the adjacent pool. The upper layers of the live crib will be vegetated with live cuttings to promote the development of a diverse riparian zone within the structure.

The structural complexity of the live crib will significantly improve the quality of the local habitat for juveniles. The improved local habitat along with the increased low flow through the side channel will significantly increase the carrying capacity of the existing groundwater-fed pool. Riparian growth within the live crib will improve shading and nutrient inputs to the side channel, further improving habitat value through time.

Bar roughness LWD placements throughout the left and right gravel bars are intended to interact with spring runoff and promote deposition of finer sediment along the bar areas. Deposition of finer sediment will help increase local grades and promote a sorted gradation of surface sediments along the bar area. Deposition of fine grained sediment will promote the natural generation of cottonwoods through the bar areas.

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4.3 Riparian Vegetation Enhancement

The riparian zone provides several habitat and physical process benefits, including increased bank and floodplain roughness, cover, and nutrients for instream species and wildlife. Increased roughness encourages sediment deposition and decreased channel and overbank velocities during floods. Additionally, fully developed, mature riparian areas are a source of LWD to the river over time.

Rehabilitation of riparian habitat has been identified in the Upper M2 Reach Assessment as a recommended management objective (Reclamation 2010). The overall objectives of riparian restoration in the Upper M2 reach are to:

- Encourage regeneration of cottonwood in viable areas
- Protect existing regenerating cottonwood (fencing/caging)
- Develop structural diversity by diversifying riparian tree species, develop multiple canopy layers where they are lacking, and encourage regeneration of different layers
- Increase density of vegetative cover
- Remove non-native species as needed

Although riparian areas in the Whitefish Island reach are generally classified as having moderate to good health (Reclamation 2010), these areas generally lack a diversity and density of plant species that contributes to a highly functional riparian ecosystem. Cottonwood regeneration and invasive species are also important considerations.

Discrete riparian restoration areas were delineated using the following sources:

- Vegetation assessment for M2 reach conducted in 2009 (Appendix E, Reclamation 2010)
- Plant communities and species lists for Upper M2 subreaches of interest conducted in 2010 to 2011 (MSRF 2011)
- Wetland delineation and additional field reconnaissance completed in August 2011 (Anchor QEA 2011b)

Within each restoration area, a variety of appropriate species are recommended for restoration actions based on proximity to the channel and water table, frequency of flood inundation, and existing plant communities. Each area corresponds to a series of planting tables; each table lists four to five species for restoration of willow, shrub, and other tree species within these general vegetation categories:

- Riparian sun
- Riparian shade
- Wetland

In areas of existing good health, vegetated areas will be supplemented with proposed species to achieve the approximate spacing and density recommended within the species table. Areas of moderate health or local sparsely vegetated areas will be treated with a greater quantity of plants to achieve adequate density and species diversity. In all areas, invasive species eradication is recommended. Fencing and caging is recommended to prevent damage to new plants by deer and beaver.

Planting in the lee areas of LWD placements will also be part of the planting plan. These areas will be planted using live stakes from the riparian sun vegetation category. The live stakes will be installed into native material placed in the lee of the LWD during construction. As additional fine sediment is deposited, the live stakes will continue to grow through the deposit.

Monitoring and maintenance will likely be required for at least the first few years after planting and will greatly contribute to the success of the restoration effort. Eradication of invasive species such as reed canary grass (*phalaris arundinacea*) will likely require a longer and more involved maintenance and monitoring effort.

5 HYDRAULIC ANALYSIS

A reach-based, one-dimensional (1-D) Hydraulic Engineering Center-River Analysis System (HEC-RAS) hydraulic model (Brunner 2010a, 2010b) was developed for the Project area to provide estimates of hydraulic conditions for existing and proposed conditions alternatives. The model was run for the design hydrology shown in Table 1 (see Appendix A for development details). The design hydrology provided a thorough understanding of hydraulic conditions over a wide range of discharges.

Table 1
Design Hydrology, Upper Middle Methow River

Discharge (cfs)	Significance
250	Year-round average minimum
700	Seasonal, exceeded on average 120 days per year
3,020	1-year return period
9,450	2-year return period
14,280	5-year return period
17,720	10-year return period
22,310	25-year return period
25,890	50-year return period
29,600	100-year return period

Note:
1. Hydrology was developed by Anchor QEA in conjunction with Reclamation and other Upper M2 Project partners (Cuhaciyan 2010).
2. The statistical analysis used to estimate return period discharges calculates a discharge value for the 1-year return period that is slightly less than the mean discharge in the months of May and June. This result is not uncommon for snowmelt dominated systems.

Detailed descriptions of the existing and proposed conditions models are presented in Appendix A. In addition, results of our sediment transport and sensitivity analyses are displayed in Appendix A along with the justification for selecting or omitting critical design features or configurations.

6 PUBLIC SAFETY EVALUATION AND CONSIDERATIONS

The Methow River is used by a variety of boaters, including rafters, kayakers, and tubers. Public safety was a prime consideration in the design of the LWD and ELJs and included consideration of feature location, arrangement of logs, potential anchoring techniques, size of assemblies/structures, and inundation timing. Each LWD and ELJ feature is designed to minimize risks to public safety while meeting the goals and objectives of the Project. ELJs are specifically designed to deflect flow and river users away from the structure. An analysis of boater approach time was completed to further assess the potential risk posed by the largest ELJ structures in or adjacent to the main channel.

Two factors were considered in the calculation of boater approach time—sight distance and average channel velocity. For this analysis, line of sight distances were measured using geographical (GIS) methods. Average monthly flows during the boating season were simulated in the proposed conditions HEC-RAS model. In order to be conservative in terms of the boater approach rate, the highest channel velocity upstream of the structure within the sight distance was selected for the approach time calculation. A summary of boater approach time for each modeled discharge is shown in Table 2.

Within the Project area, the ELJ that could potentially be hazardous to boaters is located at the upstream end of Whitefish Island, near river station 415+00. The sight distance for this structure is approximately 1,410 feet. Using the highest channel velocity upstream of the structure from the HEC-RAS model, the shortest boater approach time is approximately 4.2 minutes for the months of May and June, which have similar average monthly flows. For the 2-year return period flow the approach time is 3.3 minutes. With these approach times, boaters or other river users are likely to have sufficient time to position themselves to avoid the ELJ.

Table 2
Boater Approach Time to Structure

Approximate Station	Sight Distance (feet)	Month	Average Flow (cfs)	Channel Velocity (feet per second)	Approximate Approach Time (minutes)
415+00	1,410	2-year RP	9,450	7.16	3.3
		May	4,410	5.45	4.3
		June	4,590	5.53	4.2
		July	1,460	3.33	7.1
		August	470	1.95	12.1
		September	270	1.45	16.2
		Seasonal	700	2.34	10.0

Notes:
RP = return period
cfs = cubic feet per second

7 CONSTRUCTION ACTIVITIES

7.1 Mobilization and Project Area Preparation

Mobilization and Project area preparation includes transporting equipment to the area, clearing for construction access and staging, and installing silt fencing and other Project-specific best management practices. Any trees and brush cleared for access and staging will be side cast and used during decommissioning of the Project area or integrated into other Project components. Construction fencing will be placed along the perimeter of the staging areas and access roads to protect adjacent areas from disturbance.

7.1.1 Temporary Access

Temporary access roads may be constructed to access the Project area from both sides of the river. In addition, temporary side channel crossings may be installed to access island components of the Project. This may require some clearing of immature deciduous trees and shrubs. Any trees and brush cleared during this process will be stockpiled in the Project area and used in decommissioning of the access routes or integrated into other Project components. Unvegetated gravel bars that are exposed during the construction window will be used as access routes between Project area locations to minimize riparian impacts. For this reason, these areas may also be used as staging areas.

7.1.2 Weed Control/Prevention

To minimize the establishment and colonization of weeds and invasive plant species in the Project area several preventative measures can be implemented:

Pre-construction

- A survey for invasive/weed species should be conducted in the entire Project area and upstream of all contributing waters prior to construction, planting, or soil-disturbing activities
- Invasive/weed species that are found should be documented on a map or noted by global positioning system (GPS) coordinates for annual inspection
- Invasive/weed species should be removed during or before flowering to prevent the spreading of target species seeds

- In removal areas, soil disturbance should be minimized by cutting the invasive/weed at the stem
- Removed invasive/weed species should be collected and taken away from the Project area

During Construction

- The root systems of woody invasive/weed species should be removed if they are in the footprint of the designed soil-disturbance area
- Disturbed soils should be stabilized and covered with a seed-free mulch or anti-erosion material once final grade is established
- Established corridors of travel by construction and support vehicles should be minimized to prevent disturbance of soil and carrying invasives/weeds into the Project area
- All staged or delivered materials (rock, soil, mulch, plants, and LWD) should be inspected upon arrival to minimize the introduction of invasive seed sources and plant material

Post-construction

- All disturbed soils, including soil at planting areas, should be protected with seed-free mulch or compost to suppress invasives/weeds and to retain moisture
- Revisit pre-construction invasive/weed survey areas to look for regeneration and or suppression (document findings)
- If plantings require irrigation, use a localized drip system instead of a broadcast system to minimize benefit to invasive/weed seed sources
- Establish an annual or biannual monitoring plan to identify and address the problem invasive/weed species

7.2 General Earthwork

Earthwork involves excavation, hauling, and backfilling of native materials. Earthwork associated with a majority of the LWD and ELJ placements will likely be in coarse gravel/cobble material with a variable sand and organic fraction. Earthwork associated with the live crib in the side channel will likely be in coarse gravel/cobble material with a significant number of riprap boulders and the potential to encounter localized bedrock outcrops. Boulders excavated as part of the Project will be stockpiled for reuse in other components of this Project or other Projects in the Upper M2 Reach.

Generally, a majority of the excavation may be efficiently accomplished using a tracked excavator with an appropriately sized bucket. A bucket with a clamp would be advantageous for working with larger sized material, including boulders. Hauling of material within the Project area may be accomplished with a dump truck (standard or articulating depending on the condition of the haul route). Generally, a majority of backfill could be efficiently accomplished using a tracked excavator.

7.3 Large Woody Debris

This activity involves placing LWD of various types throughout the Project area. Once the placement locations have been surveyed and, if required, field adjusted by the engineer, placement would begin at the location farthest from the staging area and progressively work toward the staging area. Installation of LWD could be accomplished by using an excavator with a bucket equipped with a clamp (or a grapple) for log placement and a skidder (or similar machine) to ferry materials to the placement site. Before construction begins, all necessary material would be staged in an area on the floodplain or gravel bar adjacent to each LWD location so that the materials are within reach of the excavator once it is in a position to build the LWD. Some LWD types will require excavation for installation. If excavation extends below the water table, turbid water will be generated. Any dewatering required for installation of the LWD will be carried out in accordance with the best management practices for water control (Section 7.7.2.1). Each LWD placement will be completed before the start of construction of another unless enough equipment is present to work concurrently.

7.4 Engineered Log Jams

All necessary material will be staged in an area on the floodplain or gravel bar adjacent to each ELJ location before construction of each structure such that the materials are in reach of the excavator once it is in a position to build the ELJ. ELJs will be founded at the specified elevation to minimize undermining from scour after completion. Construction will involve excavation of the footprint of the structure and subsequently backfilling the structure with the material excavated for the footprint. Construction of ELJs could be accomplished by using an excavator with a bucket equipped with a clamp (or a grapple) for the log placement and a skidder (or similar machine) to ferry materials to the placement site. Because the ELJs will be constructed below the water table, turbid water will be generated. Any dewatering required for installation of the ELJs will be carried out in accordance with the best management practices for water control (Section 7.7.2.1). Once the initial logs are placed at the necessary elevation, the structure can be constructed rapidly. Each ELJ will be completed before the start of construction of another unless enough equipment is present to work concurrently. The construction activities for the live cribs are similar to those for ELJs.

7.5 Riparian Vegetation Enhancement

Riparian restoration will occur following implementation of other restoration actions and Project area demobilization. Planting areas should be prepared so that existing native vegetation is not disturbed. Live stakes and cottonwood poles should be planted during the dormant period (approximately October to April) when the ground is not frozen. The proposed restoration areas on Sheet 22 correspond to the table codes shown on Sheet 23. Each area is to be planted with appropriate species from each table indicated for that area, considering availability of water and existing plant communities. Areas disturbed by construction are to be restored using the proposed restoration areas (Sheet 22). Wire fencing should be used to protect the plantings from deer and beaver. The planting areas should be monitored and maintained for at least 3 years following restoration. Maintenance includes maintaining fencing and irrigation and removing invasive species.

7.5.1 Irrigation and Watering

To minimize stressors, decrease mortality, minimize irrigation, and prevent competition from invasives/weeds, all planting and live staking should be conducted between October 15 and March 15. Newly planted tree and shrub species in exposed and more xeric areas should be watered in the mid- to late spring once the native soils begin to dry out and watering should continue every week or every other week based on daily temperatures and precipitation monitoring. Ideally, a watering plan should extend through the first three growing seasons post-planting. Broadcast irrigation should be avoided to minimize colonization and competition from invasives/weeds. If on-site water resources (well, stream, or river) are available, a series of semi-permanent irrigation lines/hoses could be established and connected to a portable pump during irrigation visits. Each planting should receive targeted watering until the surrounding soil is saturated. During irrigation visits, the plantings should be monitored for mortality, stress, and invasives/weeds and mulch around the planting should be replaced if missing to help retain moisture. If mortality and evidence of stress (yellow leaves, wilting, or leaf loss) becomes evident, then irrigation frequency should be increased and the stressed plants should be documented and monitored. Live staking areas should be monitored for mortality and stress, but should not require irrigation if placed within saturated soils. If live staking areas are implemented in more xeric areas, then these areas should be irrigated on the same schedule. Irrigation water should not contain additives such as fertilizer but can contain natural sediments from adjacent water sources. The use of reclaimed water should be assessed prior to use to minimize nutrient sinks and, if used, should be avoided in the spring and fall to minimize mixing with adjacent water sources during flood or storm events.

7.6 Project Area Decommissioning

The contractor will break down any equipment and clean any remaining areas that need decommissioning. Water and sediment control structures will be left in place until all construction activities within the river have been completed and any temporary surface erosion control measures are in place. Once construction is complete, these components will be broken down and removed by hand and the rest of the Project area will be decommissioned before leaving the Project area. Any temporary access routes will be regraded to blend into the adjacent topography and revegetated per the planting plan to minimize erosion of materials disturbed during construction.

7.7 Best Management Practices

7.7.1 Surface Erosion Control

Surface erosion control during construction is an important turbidity control measure for the Project. Removal of undesirable vegetation may leave areas exposed and vulnerable to erosion before establishment of vegetation per the planting plan. Silt fencing around the perimeter of areas where vegetation is removed is recommended to capture sediment and delineate the construction disturbance limits. During Project area decommissioning, straw mulch should be placed to minimize erosion of materials as vegetation is established. Silt fencing should be removed by hand once temporary surface erosion control measures are in place or vegetation is established in the disturbed areas.

7.7.2 Water Control

Water control during construction is the most critical turbidity control measure for the Project. Installation of many Project components may require excavation below the water table, and turbid water will be generated. The following sections provide a brief description of the recommended water control procedures for each Project feature. A recommended Project area water control plan is shown on Sheet 4. The contractor will be responsible for dewatering the excavations as required for constructability and pumping water to a location suitable for natural infiltration as approved by the engineer. The contractor will provide sufficient equipment to accommodate changes to the water control plan required by Project area conditions during construction as directed by the engineer.

7.7.2.1 Large Woody Debris and Engineered Log Jam Construction

Many LWD assemblies and ELJs may be placed outside of the active channel to avoid direct contact with river flow. In that case, water entering the excavation area will be groundwater, but likely will be of a significant volume. We recommend pumps (of sufficient size and quantity) to partially dewater the excavation. Water would be pumped from the excavation area into an infiltration area. The infiltration area should be located on the floodplain to minimize the potential for overland flow back into the river and to prevent damage to sensitive habitat (wetlands and alcoves). Infiltration rates into the floodplain will be significant, and we expect that only a minimum amount of turbid water pumped onto the floodplain will not be infiltrated. If the infiltration capacity is exceeded, overland flow will be routed over existing vegetation to encourage suspended sediment deposition before flowing back to the river.

For LWD assemblies and ELJs placed in areas with a surface water connection to the active channel during construction, any required excavation will be conducted within silt curtains (or other temporary flow separation method) to minimize the dispersion of turbid water into the active channel. Dewatering of these locations is likely impractical and cost prohibitive. Therefore, assemblies and structures placed in the active channel are specifically designed to be constructible without dewatering of the excavation.

7.7.3 Refueling Practices and Spill Prevention and Countermeasures

The following best management practices will be implemented for spill prevention during refueling:

- Each piece of machinery will be checked daily for leaks and any repairs will be done before work in or near water
- All vehicle staging, cleaning, maintenance, refueling, and fuel storage will take place above the ordinary high water line in an approved staging area that is 150 feet or more from any waterbody in accordance with local, state, and federal regulations and permit conditions
- A driver/operator must be present and maintain constant observation/monitoring of the fuel transfer at all times
- A driver/operator must be trained in spill prevention, cleanup measures, and emergency procedures
- All employees must be made aware of the significant liability associated with fuel spills
- Spill containment and countermeasures must be maintained at all locations where refueling occurs, materials include non-water absorbents capable of absorbing 15 gallons of diesel fuel and drip pans
- All machinery and equipment working in or near waterbodies will maintain non-water absorbents capable of absorbing 15 gallons of diesel fuel and drip pans
- If a power generator is used during construction, the generator should be placed out of the river channel within a spill containment unit

8 LIMITATIONS

We have prepared this report for use by Reclamation for use in securing permits for the Project. Further development of the designs described in this document will require additional analysis and evaluation. The Drawings that accompany this report were not developed for use in construction or contract bidding. Conditions within the Project area may change both spatially and with time as additional scientific data may become available. Significant changes in Project area conditions or the available information may require re-evaluation. Within the limitations of scope, schedule, and budget, our services have been executed in accordance with generally accepted scientific and engineering practices in this area at the time this report was prepared.

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APPENDIX A
HYDROLOGY AND SEDIMENT

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LIST OF ACRONYMS AND ABBREVIATIONS

1-D	one dimensional
3-D	three dimensional
cfs	cubic feet per second
Chl.	Channel
D_{50} or d50	median sediment grain size by mass
ESRI ArcGIS®	Environmental Systems Research Institute Arc Geographic Information System
HEC-GeoRAS	Hydraulic Engineering Center – Geographic River Analysis System
HEC-SSP	Hydraulic Engineering Center – Statistical Software Package
HEC-RAS	Hydraulic Engineering Center – River Analysis System
LiDAR	Light Detection and Ranging
LPIII	Log Pearson Type III
LWD	large woody debris
M2	Middle Methow
mm	millimeters
Reclamation	U.S. Bureau of Reclamation
RP	return period
USGS	U.S. Geological Survey
WY	water year

A.1 HYDRAULIC MODEL DEVELOPMENT

A reach-based, one-dimensional (1-D) Hydraulic Engineering Center-River Analysis System (HEC-RAS) hydraulic model (Brunner 2010a, 2010b) was developed for the Upper Middle Methow (M2) Reach to provide estimates of hydraulic conditions for existing and proposed conditions. The model was run for the hydrology presented in Section 1.1, to provide a thorough understanding of hydraulic conditions over a wide range of discharges.

A.1.1 Model Hydrology

Hydrology for the Upper M2 Reach was developed for both the range of annual flows and for peak flow events (floods). The Upper M2 Reach is located just downstream of the U.S. Geological Survey (USGS) Methow River gage in Winthrop, Washington (#12448500). For the purposes of this Project, discharge contributions or withdrawals between the gage and the project location were assumed to be insignificant.

A.1.1.1 Annual Flow Hydrology

A wide range of flows occur over the typical annual hydrograph of the Methow River. Low flows occur in the late summer/early fall, when the quantity of water to the river drops to an average of approximately 270 cubic feet per second (cfs) in September and 300 cfs in October (Table A-1 and Figure A-1). Late summer and fall discharge is also influenced by the diversion of water into irrigation ditches. Similar discharges occur when the upper watershed is frozen during the winter months, which extends the low flow period through February. As the snow pack begins to melt in March, the river discharge rises significantly, to an average of over 4,000 cfs in May and June.

Table A-1
Annual Flow Hydrology, Methow River at Winthrop, WA

Exceedance Probability (%)	Discharge (cfs)												
	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Avg. (WY)
5	533	865	598	450	420	873	2,774	8,804	8,268	2,840	784	413	2,302
10	372	659	482	396	381	790	2,536	7,308	7,208	2,379	669	364	1,962
20	315	509	407	328	312	620	2,055	5,943	6,109	1,929	588	333	1,621
30	301	433	364	287	278	480	1,748	5,101	5,457	1,642	485	289	1,406
40	291	350	316	262	257	389	1,494	4,318	4,732	1,423	446	261	1,212
50	278	326	290	252	249	356	1,306	3,712	4,184	1,252	415	242	1,072
60	251	301	267	237	232	310	1,112	3,267	3,676	1,112	377	232	948
70	238	256	242	223	218	270	970	2,956	3,189	969	358	223	843
80	222	225	206	197	201	242	804	2,424	2,653	816	322	206	710
90	196	198	192	184	179	209	642	1,972	1,993	662	235	171	569
95	188	188	186	179	173	190	494	1,727	1,301	579	219	165	466
Minimum	143	162	153	160	144	144	166	373	897	291	160	138	138
Average	315	417	338	282	269	443	1,444	4,406	4,593	1,459	465	266	1,225
Maximum	5,930	3,910	2,750	1,170	766	2,200	4,850	21,000	21,400	5,800	1,970	699	21,400

Notes:
Statistics calculated from mean daily discharges at the USGS gage #12448500 for the approved period of record (1912 to 2009). Twenty-one water years, including partial record water years, are included in the analysis.
A normal distribution was assumed for exceedance calculations. The minimum, average, and maximum values are from daily values for the indicated period, and are not statistics of the exceedance probabilities. In this report, a water year (WY) is from October 1 through September 30, and is identified by the calendar year it ends in.

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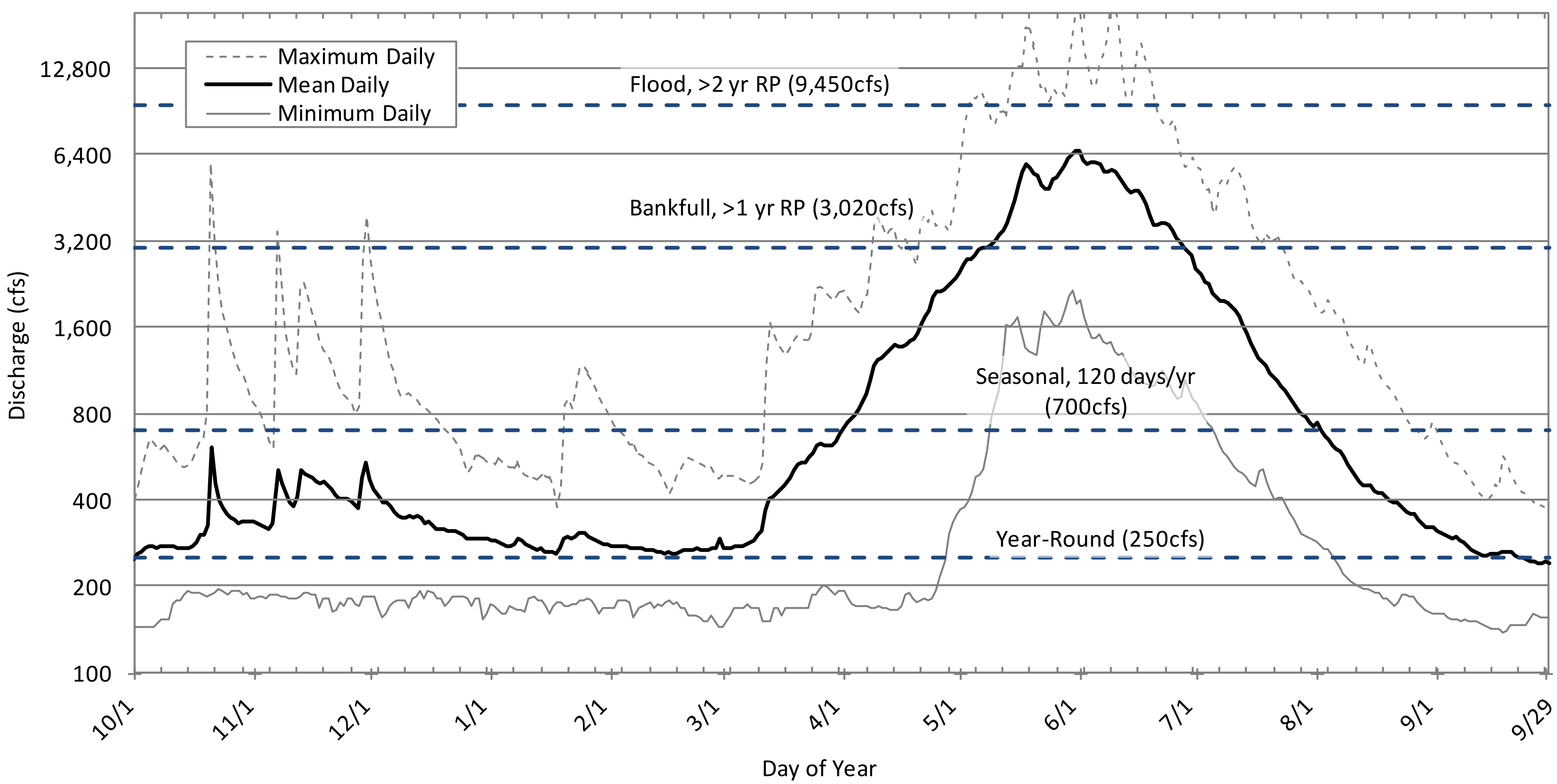
Figure A-1

Annual Flow Hydrology, Methow River at Winthrop, Washington



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Notes:
RP = return period, yr = year
Statistics calculated from mean daily discharges at the USGS gage #12448500 for the approved period of record (1912 to 2009). Twenty-one water years, including partial record water years, are included in the analysis.
A normal distribution was assumed for exceedance calculations.
In this report, a water year (WY) is from October 1 through September 30.
See Section A.1.1.2 for an explanation of bankfull and flood discharges and corresponding return periods.

A.1.1.2 Peak Flow Hydrology

Flooding in the Methow River typically corresponds to years with heavy snowpack or rapid melting in late spring and early summer months (typically May and June). Although some smaller peaks may occur in the fall and late-winter months associated with heavy precipitation or short warm-weather events that cause some snowmelt, these typically do not exceed the average flows during May and June. The largest floods on the Methow River occurred in water years 1894, 1948, and 1972.

Data from the USGS #12448500 gage at Winthrop was used to calculate peak flow hydrology for the Methow River in the Upper M2 Reach for the approved period of record through the 2009 water year (WY). The peak flow hydrology calculations used the Log Pearson Type III (LPIII) method as prescribed in publications from the USGS (2001) and the Water Resources Council (1981). The calculations were carried out using the U.S. Army Corp of Engineers' HEC-SSP software (Brunner 2010c). This analysis updated the values reported in the U.S. Bureau of Reclamation's Geomorphic Assessment (Reclamation 2008) to reflect more recent gage data since the 2004 water year, including peak flow events of 20,100 cfs in 2006 and 18,800 cfs in 2008. In general, the updated discharge values are slightly higher than those presented in the Geomorphic Assessment, especially for the more frequent return periods. The results of the updated analysis, as well as the analysis reported in the 2008 Geomorphic Assessment, are provided in Table A-2 and shown on Figure A-2. The updated peak flow hydrology analysis presented herein has been reviewed by Reclamation (Cuhaciyan 2010) and was approved for distribution for use in design and analysis for the M2 Reach (Richardson 2010). It should be noted that the nature of the statistical analysis calculates a discharge value for the 1-year return period that is slightly less than the mean discharge in the months of May and June. This result is not uncommon for snowmelt dominated systems.

Table A-2
Peak Flow Hydrology, Methow River at Winthrop, WA

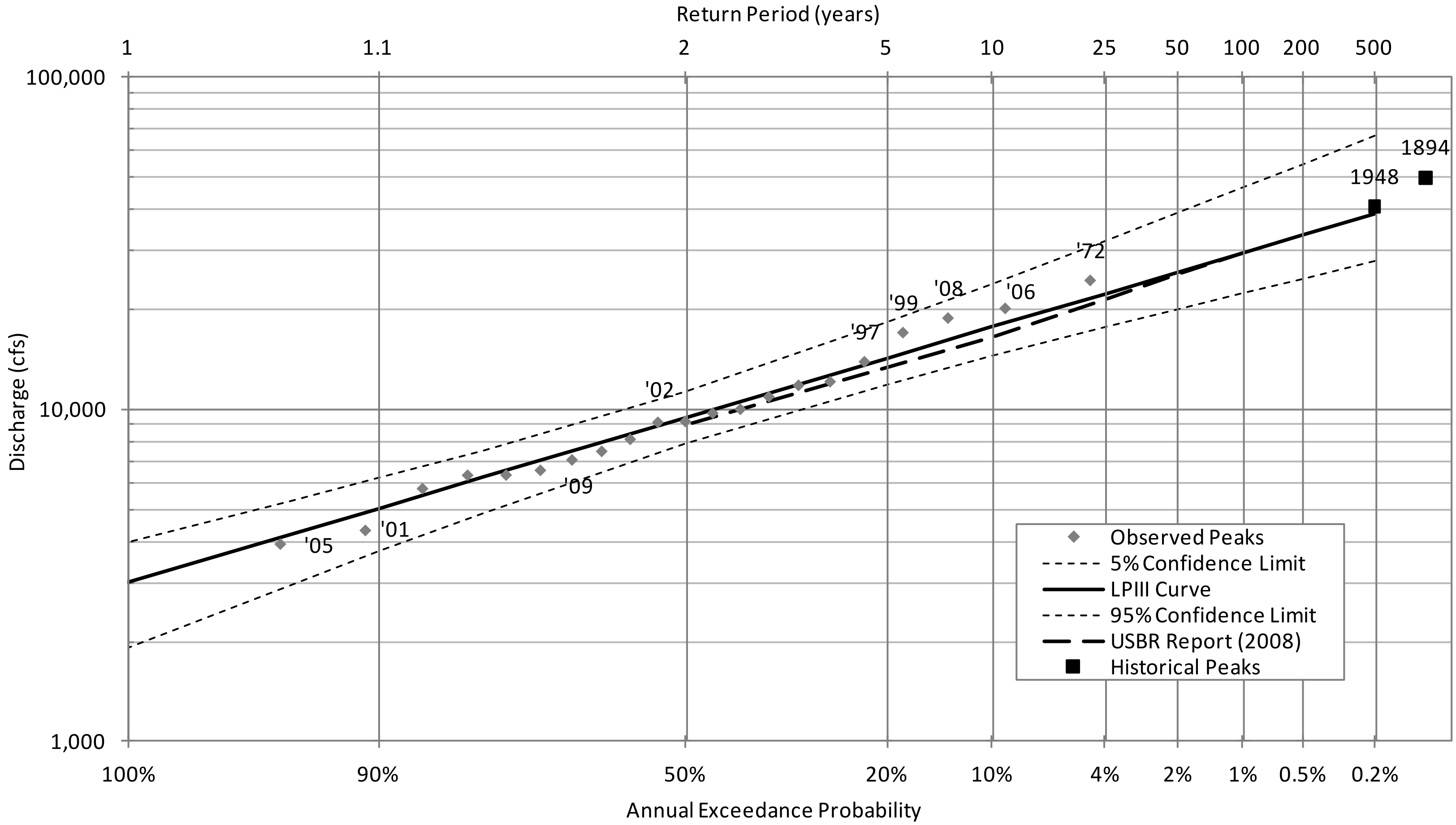
Return Period (years)	Reclamation Report Discharge Value[2] (cfs)	Updated Discharge Value[1] (cfs)	Most Recent Similar Event of Record
1	NA	**3,020**	Typically occurs multiple days annually
2	9,020	**9,450**	May 2010 (9,850 cfs)
5	13,300	**14,280**	June 2011 (14,700 cfs)
10	16,600	**17,720**	May 2008 (18,800 cfs)
25	21,400	**22,310**	May 2006 (20,100 cfs)
50	25,400	**25,890**	May 1972 (24,400 cfs)
100	29,700	**29,600**	1948 (~31,360 cfs)[3]
500	NA	**38,800**	1894 (no gage record)[4]

Notes for Table A-2 and Figure A-2:

1. The computed return period discharge values are for a Log Pearson Type III (LPIII) analysis of the indicated period of record using HEC-SSP software. A regional skew value of zero was used to be consistent with previously published analysis results (Reclamation 2008). Observed events used for the analysis are peak annual discharges from USGS gage #12448500 for the approved period of record (1912 to 2009).
2. The Reclamation report analysis curve is from the 2008 Methow Basin Subbasin Geomorphic Report, Okanogan County, Washington. The report used data through WY 2003.
3. No record at the Winthrop gage is available for the 1948 event. This value is the difference between the discharge at the Pateros, Washington, gage (USGS #12449950) and the Twisp River gage (#12448998).
4. 1894 flood peak estimated at Pateros, Washington

Figure A-2

Flood Frequency Analysis, Methow River at Winthrop, Washington



Notes:

1. See notes on previous page.

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A.2 HYDRAULIC MODEL GEOMETRY

A.2.1 Existing Conditions

Hydraulic model geometry was developed for the existing conditions to simulate the existing hydraulic conditions within the Project site. The model provided estimates of hydraulic conditions, including water surface elevations, flow velocities, and channel bed shear stress, to develop a baseline for comparison to proposed conditions.

The HEC-RAS cross-section station elevation data was taken from a 3-dimensional (3-D) existing conditions surface developed by Reclamation for the Upper M2 Reach Project (Bountry 2011). The 3-D surface used the bare earth data from 2010 aerial Light Detection and Ranging (LiDAR) survey merged with ground survey data (cross-sections and thalweg) collected in 2010 by Reclamation. Local modifications were also made to the surface using 2008 bathymetry data where known pools or other bedforms were not captured by the 2010 data. Cross-sections and other model geometries were drawn in ESRI ArcGIS® and exported using HEC-GeoRAS (Ackerman 2011) and imported into the 1-D HEC-RAS model. Cross-sections in the model were located to capture significant changes in channel and floodplain planform, as well as changes in channel gradient, with the spacing of cross-sections varying in proportion to planform complexity of the channel and floodplain. Channel and floodplain roughness values were estimated using typical values for the land use and channel condition reported in the 2008 Geomorphic Assessment (Reclamation 2008) as identified from 2009 aerial photography and field surveys. In select locations, the roughness values were adjusted slightly so model output would better match measured or observed water surface elevations for known discharges at the USGS Winthrop gage.

Model junctions were used to calculate split flows for the various side channels located in the Methow River. Junction lengths were measured from aerial photos using the cross section locations previously determined. The HEC-RAS modeling software allows the user to select different methods for modeling junctions; the energy-based method was chosen. The energy-based method solves for water surface elevations across the junction by performing standard step calculations with the 1-D energy equation. This method was found to be computationally stable and representative of typical junction conditions.

Cross-sections in the Whitefish Island side channel were placed so that they coincided with the end of the cross-section in the main channel. This cross-section alignment allowed for direct comparison of water surface elevations downstream of the junction to verify junction computations.

A.2.2 Proposed Conditions

Hydraulic model geometry was developed for the proposed conditions to simulate the impact on hydraulic conditions of engineered log jams and other Project components within the Project site. The model provided estimates of hydraulic conditions relevant to Project component design and performance, including water surface elevations, flow velocities, and channel bed shear stress. This information was used to evaluate structure suitability and the top and bottom elevation of each structure. The information was also used to evaluate changes to sediment transport conditions from existing to proposed conditions.

The existing conditions model was modified to reflect the proposed conditions for the purposes of evaluating hydraulic conditions and sediment transport competency changes due to modified channel configurations through the side channels. The geometry of the model cross-sections were manually modified in the HEC-RAS interface as follows:

30 Percent Design

- Added cross-sections and blocked obstructions at the head of the side channels to simulate large woody debris (LWD) placement and the associated pools
- Modified cross-section geometry at the head of the side channel to provide year-round activation
- Added blocked obstructions and modified cross-sections to represent the live crib near the downstream end of the side channel
- Modified Manning's n at live crib to simulate increased roughness

A.3 SEDIMENT DATA COLLECTION AND ANALYSIS

The sediment mobility and transport competency within the Project area was calculated using the results of the HEC-RAS 1-D hydraulic model and applicable sediment mobility formulas. These results were then compared to sediment grain size distributions from samples to evaluate changes in erosional and depositional trends within the site as a result of the Project components.

A.3.1 Sediment Grain Size Sampling

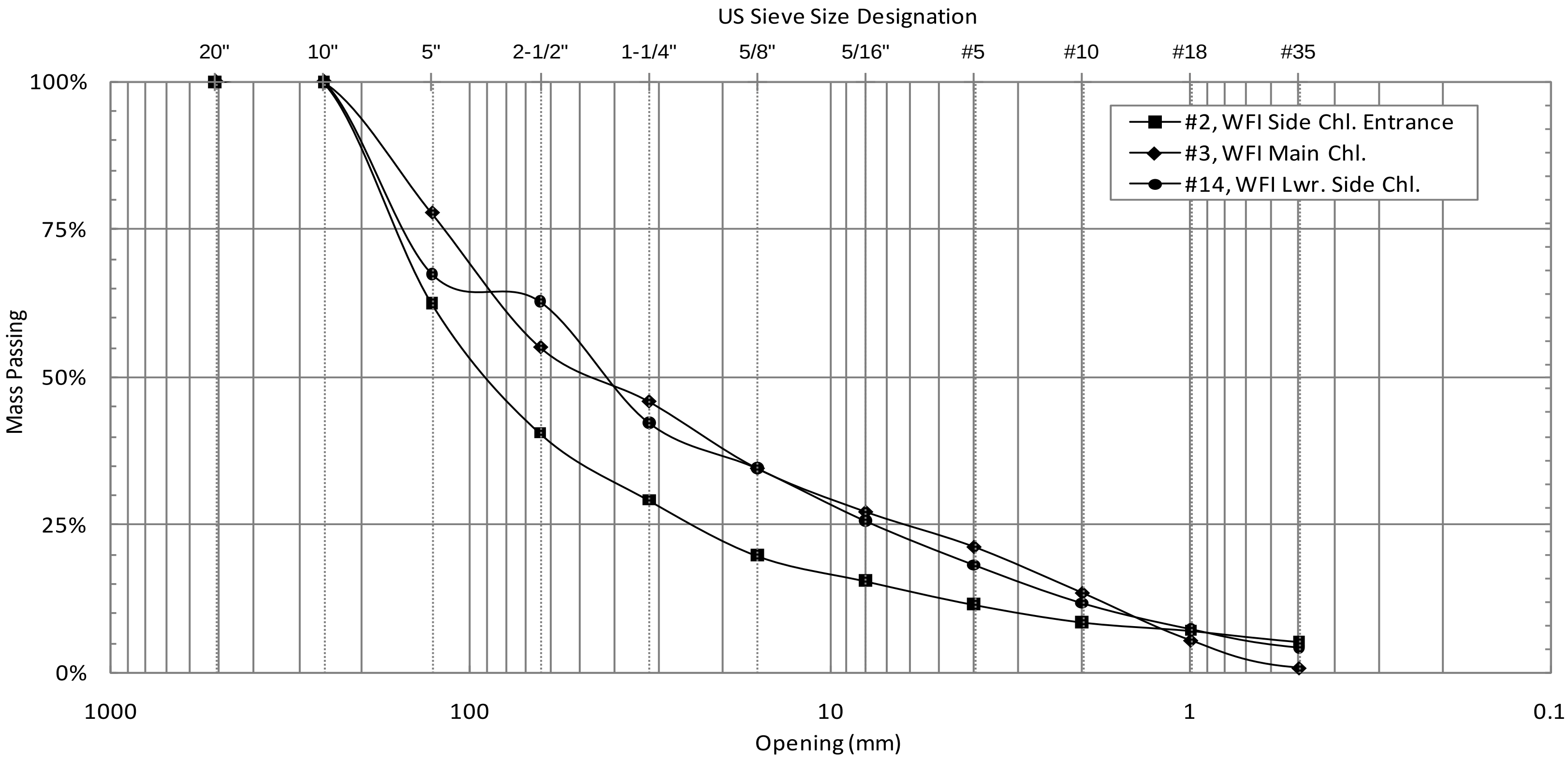
The bedload channel sediment sampling was conducted on gravel bars during November 2010. The average discharge at the Winthrop gage during sampling was 412 cfs. This low-flow condition exposed sediment deposits composed of material transported by recent sediment mobilizing discharges; this material is assumed to be representative of the bedload. Bulk sediment samples and Wolman pebble counts (Wolman 1954) were taken at 14 locations distributed along 21 miles of river to capture potential changes in sediment grain size distribution. The pebble counts were used to define the surface armor grain size distribution, while bulk sediment samples were used to define the subsurface grain size distribution. Samples located in the side channels were used to evaluate the ability of the side channels to mobilize and transport sediment over a wide range of discharges. Grain size distributions have been characterized by their median sediment grain size (D_{50} or d50).

Sample locations relevant to the project area include:

- Sample #2, high point in entrance to the of the WFI side channel, D_{50} = 90 millimeters (mm)
- Sample #3, main channel adjacent to WFI, D_{50} = 45 mm
- Sample #14, lower portion of the WFI side channel, D_{50} = 42 mm

The subsurface grain size distributions for sediment sample locations relevant to the Project area are shown in Figure A-3. The median grain sizes for the distributions are calculated from subsurface samples.

Figure A-3
Sediment Grain Size Distributions, Subsurface



Notes:
Sediment samples collected by Anchor QEA staff on 11/10/2010 and 10/11/2010
Sediment grains larger than 32 mm were typically removed from the bulk sample and weighed in the field. Total weight of bulk sample (including grains larger than 32 mm) was typically 50 to 100 pounds. No more than 1 kilogram of the sediment with a grain size smaller than 4 mm was sieved.
Chl. = Channel, Lwr. = Lower

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A.3.2 Sediment Transport Methodology

To evaluate sediment transport competency in the side channel for existing and proposed conditions the threshold sediment grain size was compared to the sediment sample grain size distributions. The results of the transport calculations assisted in the development and evaluation of the project design.

A.3.2.1 Threshold Sediment Grain Size

The threshold (or critical) sediment grain size is the grain size that is just mobile under given hydraulic forces. This analysis used the dimensionless critical shear stress concept (Shields 1936) to define the mobility threshold for sediment grains exposed to the force of flowing water. The approach uses the following relationship between critical grain size (D_c) and critical dimensionless shear stress (τ^*_c):

(A-1)

where:

τ^*_c	=	critical dimensionless shear stress
τ	=	bed shear stress
ρ_s	=	sediment grain density
ρ	=	water density
g	=	gravitational acceleration
D_c	=	critical grain size

For this evaluation, a critical dimensionless shear stress (τ^*_c) of 0.050 was used. This value is valid for critical grain sizes in the cobble size range (Fischenich 2001).

The results of the threshold sediment grain size calculations were used to evaluate the existing conditions and proposed alternatives' ability to transport sediment. Results from calculations were compared with the bedload samples for evaluation.

A.3.2.2 Sediment Transport Regime Indicators

For the purposes of this report, two basic sediment transport regimes, depositional and erosional, are used to describe the sediment transport conditions for the existing conditions and the proposed alternative conditions.

Depositional Area Indicators

Areas that are likely to be depositional at a particular discharge may show any combination of the following:

- A critical grain size smaller than a nearby sediment sample grain size
- A critical grain size smaller than the anticipated upstream sediment supply grain size
- A rapid decrease in the critical grain size from upstream to downstream

Erosional Area Indicators

Areas that are likely to be erosional at a particular discharge may show any combination of the following:

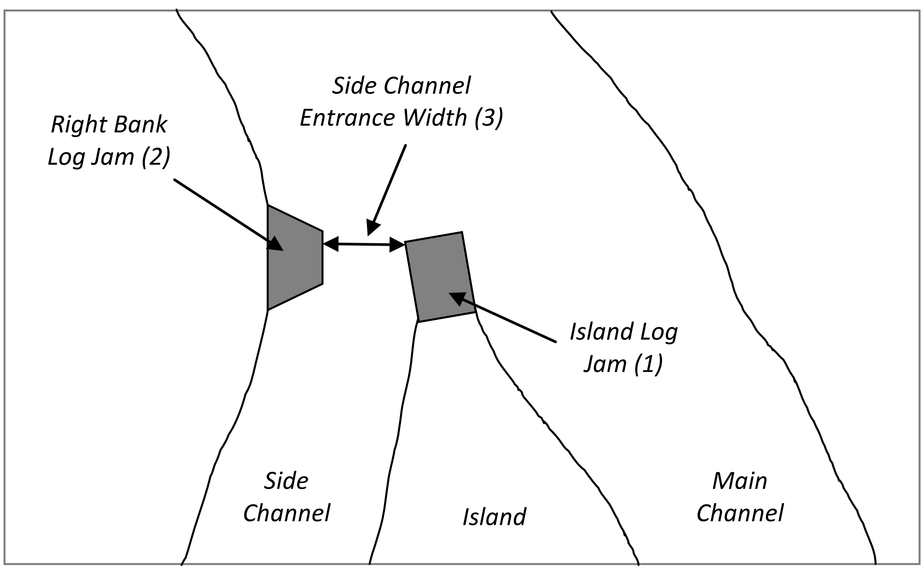
- A critical grain size larger than a nearby sediment sample grain size
- A critical grain size larger than the anticipated upstream sediment supply grain size
- A rapid increase in the critical grain size from upstream to downstream

A.4 SIDE CHANNEL ENTRANCE SENSITIVITY ANALYSIS

To help refine the project design, three alternatives for the side channel entrance configuration were modeled and analyzed for their influence on flow splits and sediment transport characteristics.

- **Alternative 1**: Reflects the Preferred Alternative from the AER Report (Anchor QEA 2011). The side channel entrance is 50 feet and includes both log jams 1 and 2 shown in Figure A-4.
- **Alternative 2**: The side channel entrance was widened to 75 feet (3) by reducing the protrusion of the right bank log jam (2) into the side channel (Figure A-4).
- **Alternative 3**: The side channel entrance width was widened to 112 feet (3) by removing the right bank log jam (2) at the side channel entrance (Figure A-4).

Figure A-4
Side Channel Entrance Variations



Notes:
Figure not to scale. For illustration purposes only.

A.4.1 Flow Split Results and Analysis

The discharge proportion in the side channel and main channel was evaluated at a variety of discharges to gain an understanding of the resultant changes in flow splits and likely habitat benefits realized. The results of this evaluation are reported in Table A-3.

The design alternatives show a significant increase in side channel flow compared to the existing conditions for the year round flow up to the 1-year return period. This increase in side channel flow compared to existing is consistent for all alternatives, with a 12 percent increase for the year round, 19 percent increase for the seasonal, and 7 percent increase for the 1-year return period.

The flow split for the 2-year through 100-year return periods show a decrease in side channel flow compared to the existing conditions for all design alternatives. A difference in flow split proportions between the design alternatives can be seen for these return periods, and ranges from 1 percent to 4 percent.

In summary, the presence, size, or location of log jam 2 does not significantly alter flow splits when the expected channel changes associated with log jam 1 are incorporated.

Table A-3
Discharge Proportioning, Side Channel Configurations

Configuration	Design Discharge / Event								
	Year Round	Seasonal	1-year RP	2-year RP	5-year RP	10-year RP	25-year RP	50-year RP	100-year RP
Existing Conditions	0%	1%	21%	34%	37%	38%	40%	42%	43%
Alternative 1	12%	20%	28%	30%	30%	32%	34%	36%	38%
Alternative 2	12%	20%	28%	31%	34%	35%	37%	38%	40%
Alternative 3	12%	20%	28%	31%	34%	35%	38%	39%	41%

Notes:
Discharge proportions at each junction were computed using the energy based junction method available in HEC-RAS. The discharge proportions were iterated several times until the user input values and the HEC-RAS output values converged.
RP = return period

A.4.2 Sediment Transport Results and Analysis

In order to analyze the effect of the design alternatives on sediment transport the critical grain sizes were calculated for all alternatives. The results of these analyses are shown in Figures A-5 to A-11. Sediment transport analysis was not completed for the year round or seasonal flow. At these discharges the modeled hydraulic forces are generally insufficient to produce observable sediment transport.

As seen in Figures A-5 and A-6, the data points closely align for all design alternatives downstream of the entrance log jam structures for the 1-year and 2-year return periods. As seen in Figures A-6 and A-7, the 5-year return period shows a slight increase in transport competency at the downstream end for Alternative 3, while the 10-year return period shows a slight increase for Alternative 2 through the side channel when compared with the other design alternatives. Slight differences in transport competency between the design alternatives for the 25-year through 100-year can also be seen in Figures A-8, A-9, and A-10. These slight differences in transport competency can be considered negligible.

For all design alternatives the sediment transport competency at the log jam structure will likely be higher than shown due to some local hydro-dynamic forces that are outside of the model capabilities.

The results of the sediment transport sensitivity analysis indicate that transport competency for the side channel is not significantly affected by the presence of log jam 2.

Figure A-5

Side Channel Entrance Sensitivity Analysis—Critical Grain Size for a 1-Year Return Period

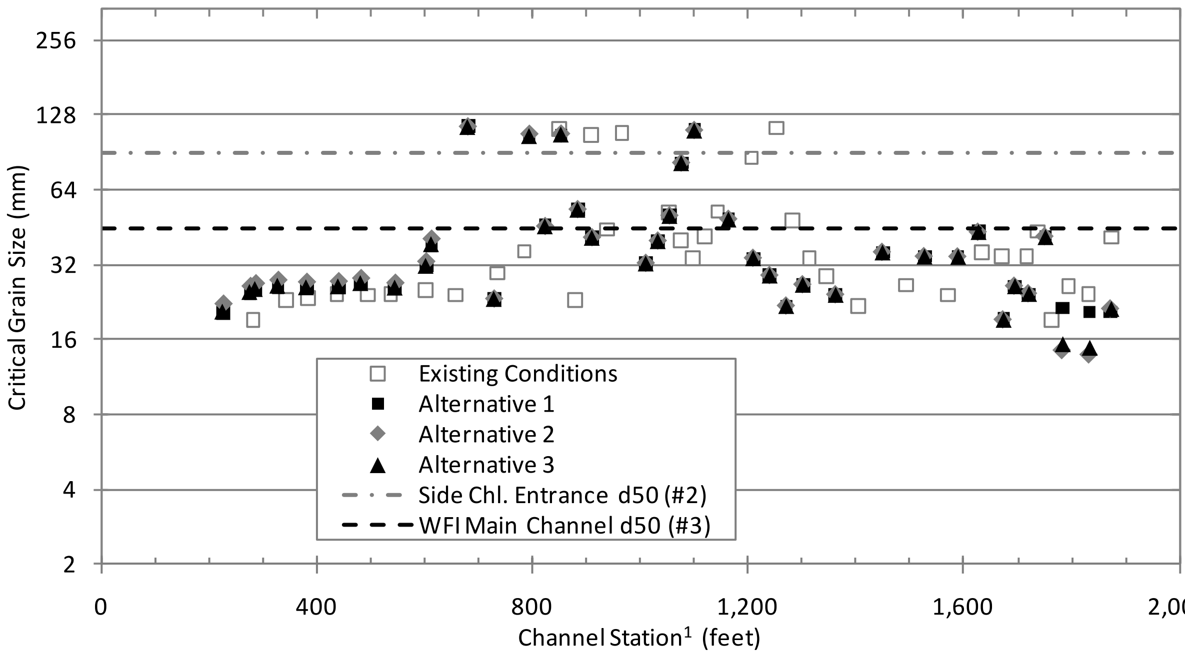


Figure A-6

Side Channel Entrance Sensitivity Analysis—Critical Grain Size for a 2-Year Return Period

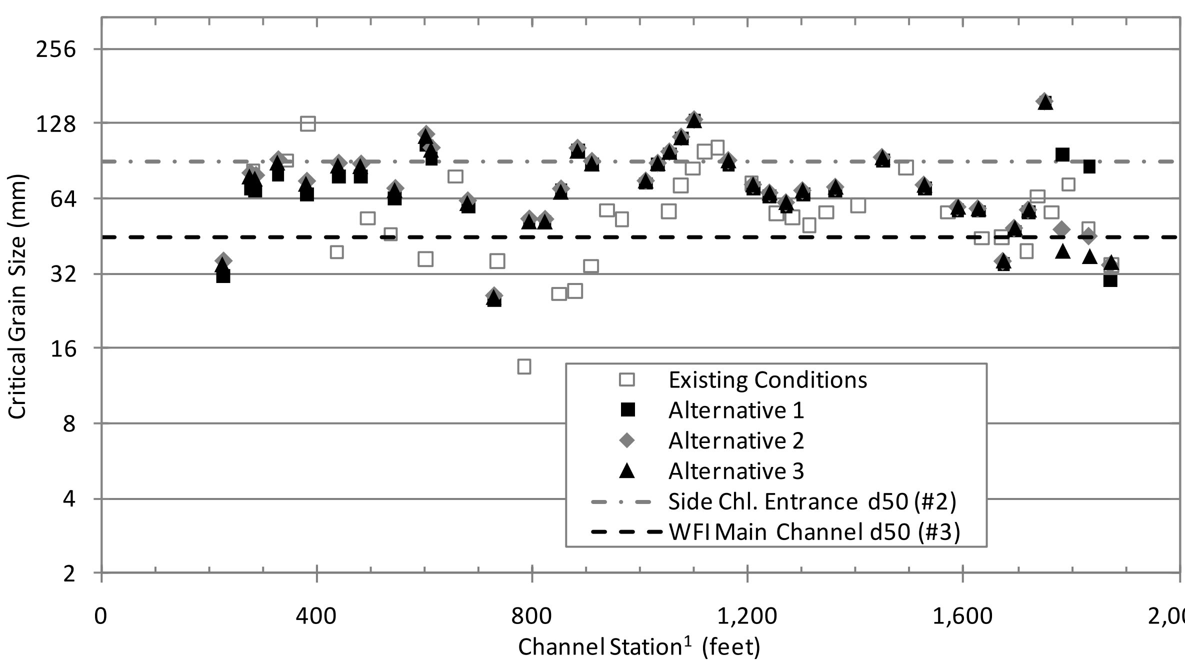


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Figure A-7

Side Channel Entrance Sensitivity Analysis—Critical Grain Size for a 5-Year Return Period

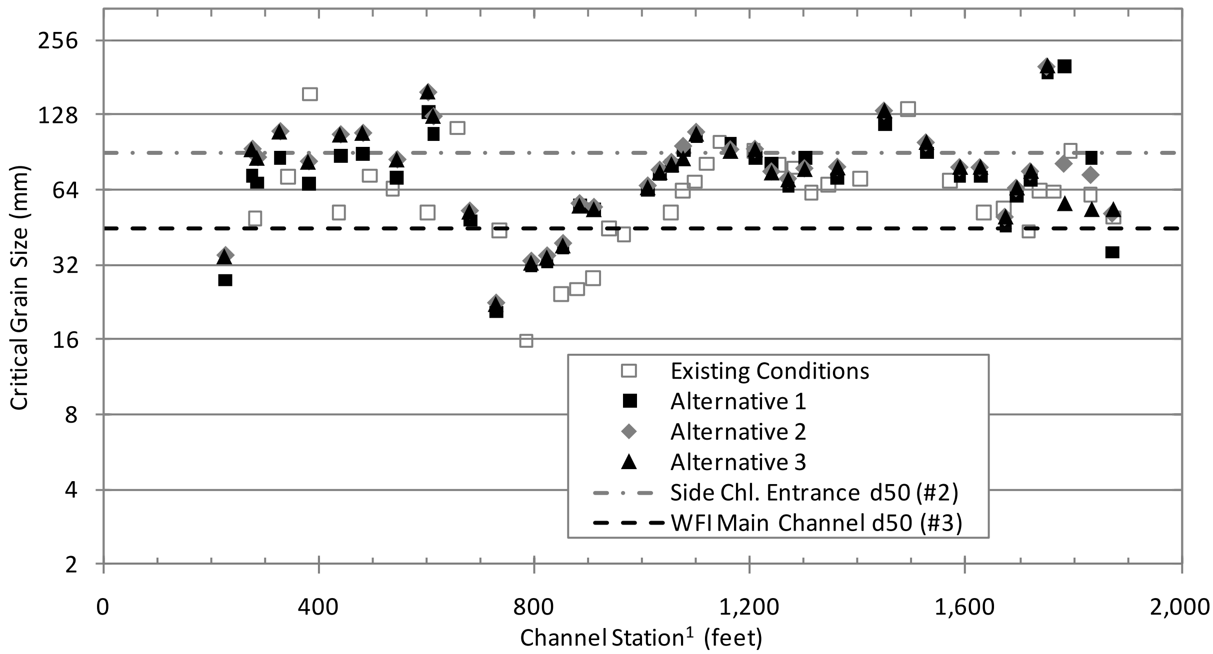

Figure A-8

Side Channel Entrance Sensitivity Analysis—Critical Grain Size for a 10-Year Return Period

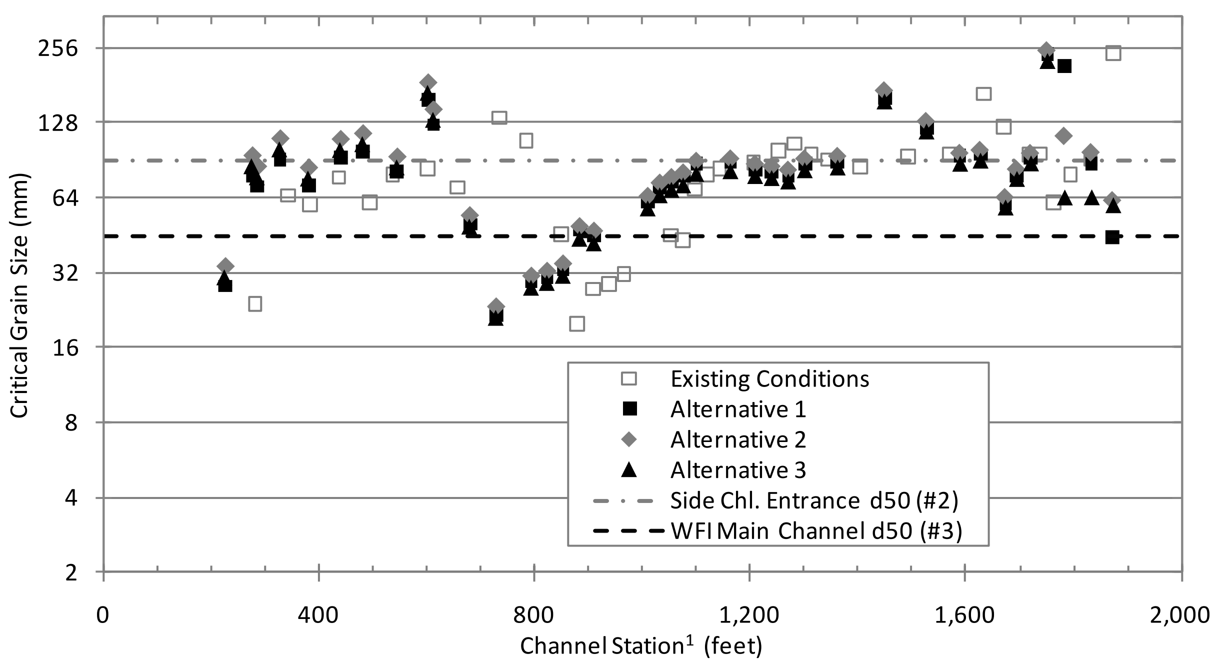

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Figure A-9

Side Channel Entrance Sensitivity Analysis—Critical Grain Size for a 25-Year Return Period

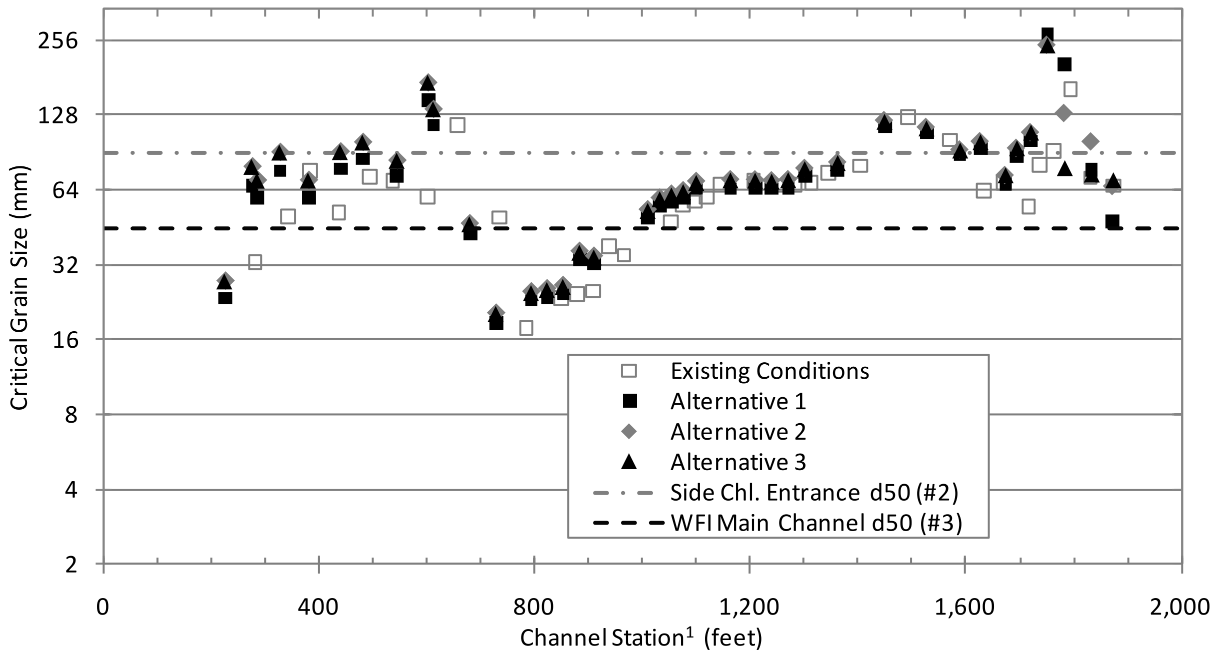

Figure A-10

Side Channel Entrance Sensitivity Analysis—Critical Grain Size for a 50-Year Return Period

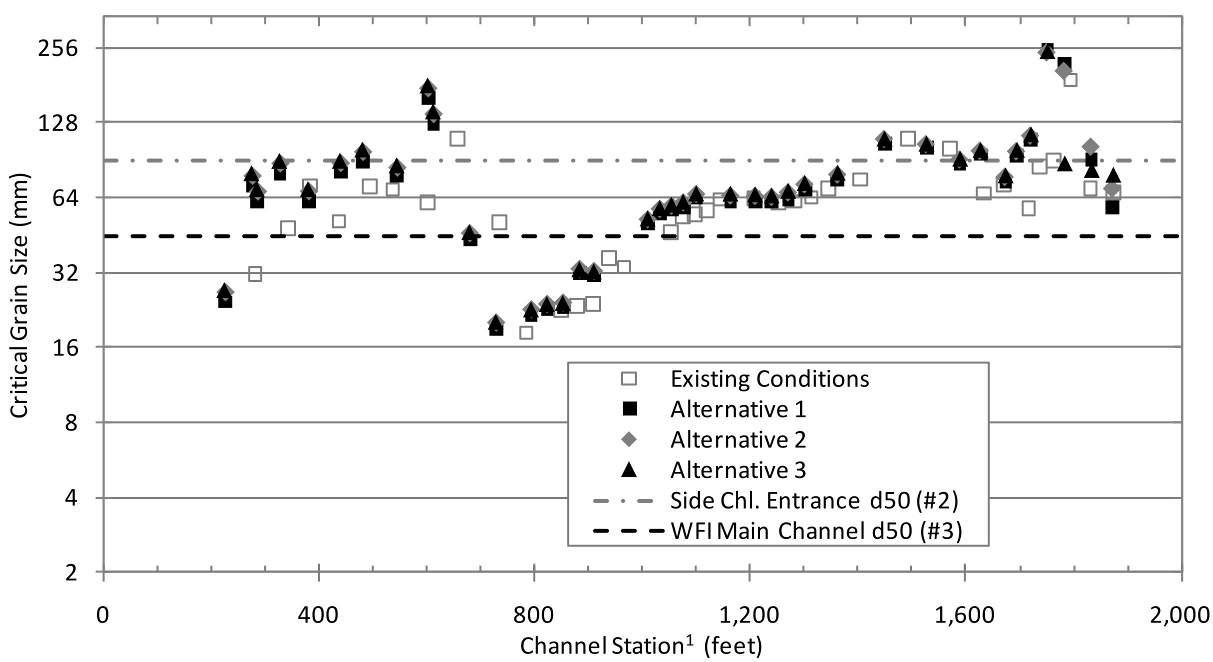

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Figure A-11
Side Channel Entrance Sensitivity Analysis—Critical Grain Size for a 100-Year Return Period

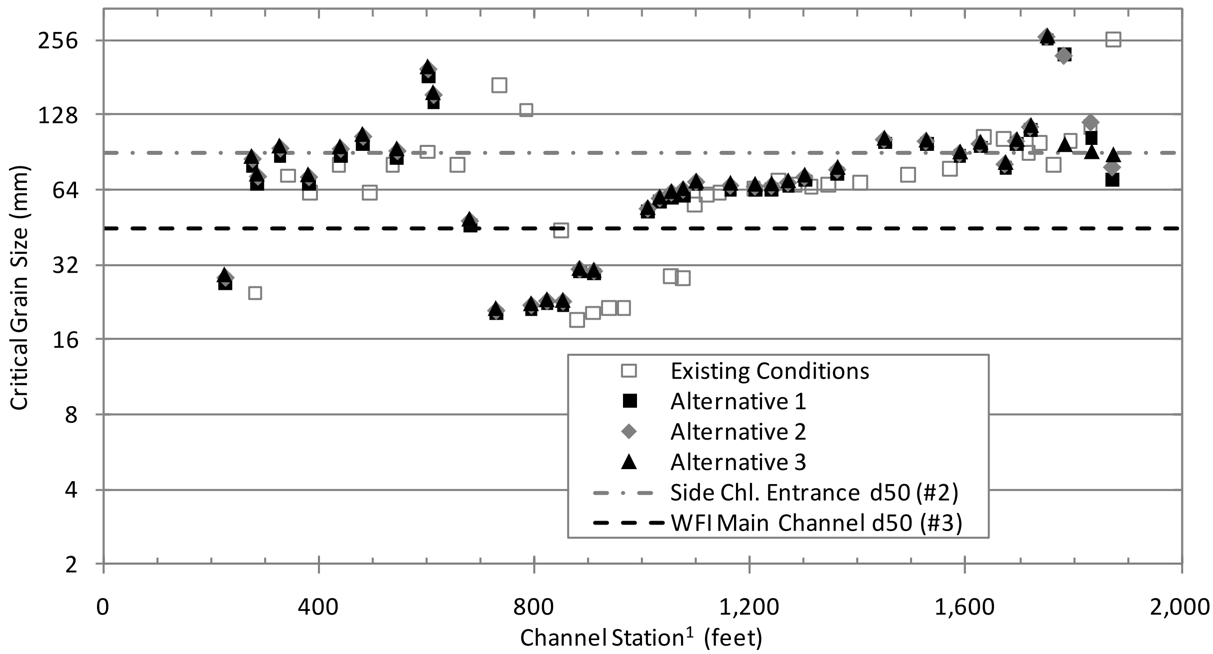

Figure notes:
1. Channel stationing is from downstream to upstream.

A.4.3 Conclusion

Sensitivity analysis indicates that flow splits and sediment transport competency is not significantly affected by the presence, size, or location of log jam 2 as displayed in Figure A-4. Therefore, log jam 2 has been removed from the design and will not be evaluated further.

In general, the Project components show an increase in sediment transport capacity compared to existing conditions throughout the side channel during geomorphically significant discharges (e.g., 2- to 5-year return periods). The configuration of the log jams at the side channel entrance was optimized to provide sufficient entrance sediment transport conditions to maintain the opening while producing desirable flow proportioning between the side channel and the main channel.

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APPENDIX B
WOOD PLACEMENT AND STRUCTURE DESIGNS

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List of Photographs

B.1 LARGE WOODY DEBRIS

B.1.1 Functions and Benefits

Large woody debris (LWD) create instream complexity that will provide cover, hydraulic refuge, and holding areas and will promote retention of additional woody debris, spawning gravels, and fine sediment. Installing LWD is often necessary to supplement existing conditions, recognizing that it will take decades of watershed-scale restoration to begin to provide natural replenishment rates. In the long term, the added channel and bank roughness created by wood structures will help retain additional mobile wood and sediment, thereby further diversifying hydraulic and bedform complexity, and contributing to increased floodplain connectivity and functionality of floodplain processes over time. LWD may be installed to direct flow away from eroding banks or regulate flow into side channels.

Fish species-specific habitat benefits provided by LWD in streams include:

- Improved habitat diversity during low-flow conditions from the small pool and cover created by the rootwad
- Velocity shelters in the lee of the rootwads and boles that act as holding and resting areas for fish
- Natural areas for spawning-sized sediment accumulation in the channel

B.1.2 Types

There are several types of LWD placements that may be installed in the channel bed, bank, or gravel bar to create beneficial fish habitat and desired geomorphic effects. Each type has varying levels of engineering and construction effort and a range in magnitude of physical and biological benefit. Each type is identified by its functional name and the type letter used in the design Drawings.

B.1.2.1 Bar Roughness Log (Type S)

The proposed Type S placements are logs with rootwads, where the bole will be placed roughly perpendicular to flow (Sheet 15). During high flows, the low-velocity area in the lee of the rootwad and within the root mass creates hydraulic refuge. During high flows, the low-velocity area in the lee of the bole will promote fine sediment deposition. The sediment deposit and areas disturbed during placement provide areas for vegetation to be established (i.e., live cuttings and natural cottonwood regeneration), supporting long-term riparian vegetation development and providing a future source of LWD to the river. The rootwad will act as a hard point and produce a small localized scour pool under high-flow conditions. It will also provide refuge in the void spaces under high-flow conditions.

The top height of the proposed rootwads is typically set just below the anticipated water surface elevation at the 2-year return period discharge. The log is secured in place based on site-specific hydraulic and geotechnical conditions. Buried log anchors or vertical pile-logs can be used to hold the rootwad log in place. A limited amount of wire rope or chain, strategically designed to limit visibility, is used to secure the rootwad log to the log anchors and can be used to secure the rootwad log to vertical pile-logs. Although a scour pool may form at the rootwad over time, a pool may also be excavated to provide more immediate benefits if desired.

B.1.2.2 Bar Roughness Assemblies (Type T)

Bar roughness assemblies are constructed of two logs with rootwads that are butted together at an angle facing the channel centerline (Sheet 16). Although these assemblies only require two logs, the triangular shape of the area behind the logs provides a relatively large area within the assembly that promotes fine sediment deposition. The sediment deposit and areas disturbed during placement provide areas for vegetation to be established (i.e., live cuttings and natural cottonwood regeneration), supporting long-term riparian vegetation development and providing a future source of LWD to the river. During high flows, the rootwads will also provide hydraulic refuge areas.

The top height of the proposed assembly is typically set just below the anticipated water surface elevation at the 2-year return period discharge. The assembly is secured in place based on site-specific hydraulic and geotechnical conditions. Buried log anchors or vertical pile-logs (with or without rootwads) can be used to hold the assembly in place. A limited amount of wire rope or chain, strategically designed to limit visibility, is used to secure the assembly to the log anchors and can be used to secure the assembly to vertical pile-logs.

Although a scour pool may form at the rootwads over time, a pool may also be excavated to provide more immediate benefits if desired.

B.1.2.3 Bank Roughness Assemblies (Type W)

The Type W bank roughness assemblies consist of four or more logs with rootwads laid out in a W shape (Sheet 17). Typically, these assemblies are placed atop a gravel bar, with the points of the W (including rootwads) facing toward the channel. These assemblies add roughness and hydraulic complexity to the channel. In some locations, these assemblies are placed in a repeating pattern parallel to the flow direction and have an impact over a large area. Hydraulic refuge for juveniles and adult fish is provided by the complexity of the assembly, which also promotes fine sediment deposition in the lee of the assembly. The sediment deposit and areas disturbed during placement provide areas for vegetation to be established (i.e., live cuttings and natural cottonwood regeneration), supporting long-term riparian vegetation development and providing a future source of LWD to the river. Stability is achieved by placing the logs that make up the assembly against vertical pile-logs (with or without rootwads). A limited amount of wire rope or chain, strategically designed to limit visibility, can also be used to secure the logs to the vertical pile-logs. The logs may also be placed between existing trees for added stability.

B.1.2.4 Bank Roughness Assemblies (Type L)

The Type L bank roughness assemblies consist of multiple logs with rootwads oriented in an L-shape and placed along the channel bank, with two logs parallel to the bank and two or more extending into the channel (Sheet 18). These assemblies help to add hydraulic diversity to the channel. The rootwad that protrudes into the channel provides cover and diversity in the channel during low flows and helps to create a small localized scour pool. The log parallel to the bank is inundated during higher flow events, creating hydraulic refuge areas for fish. Over time, additional woody debris can collect within the assembly to provide added habitat benefits. Over time, sediment deposition may occur in the lee of the perpendicular logs. The sediment deposit and areas disturbed during placement provide areas for vegetation to be established (i.e., live cuttings and natural cottonwood regeneration), supporting long-term riparian vegetation development and providing a future source of LWD to the river. Stability is achieved by placing the logs that make up the assembly against vertical pile-logs (with or without rootwads). A limited amount of wire rope or chain, strategically designed to limit visibility, can also be used to secure the logs to the vertical pile-logs. The logs may also be placed between existing trees for added stability.

B.2 ENGINEERED LOG JAMS

B.2.1 Function

Engineered log jams (ELJs) are large wood structures that can be placed in the main channel of a large river. The primary function of these large log jam structures is to create pools and provide cover and refuge. ELJs also promote woody debris accumulation and gravel retention and maintain pool habitat. ELJs are typically placed along the bank or mid-channel with the bottom of the structure near the anticipated scour depth and the top built to the approximate height of the design water surface elevation (typically the 100-year return period event). A large portion of the structure is backfilled with streambed materials for stability, and a gravel bar deposit may be placed in the lee of the structure to emulate the natural sediment deposit that would occur in the lee of this type of structure.

B.2.2 Benefits

ELJs create diverse hydraulic conditions that provide resting areas in close proximity to complex cover. Fish conserve energy when holding in the flow stagnation areas up-and downstream of the structure. ELJs also contain a substantial amount of void space within the logs and root masses, providing considerable area for fish refuge. During high flows, the rootwads interact with hydraulic forces from the river and scour large, deep pools that provide holding areas for adults, while the void space within the face of the structure is used by juveniles. In addition, these structures are able to retain mobile wood debris, providing greater complexity and refuge habitat (Photograph 1). Because of the hydraulic conditions and hard points created by ELJs, they may also be used as “deflectors” to influence flow direction to promote channel expansion or activation of side channels.

Photograph 1
Natural retention of mobile wood and pool formation at an ELJ on the Stillaguamish River, Washington

On a reach scale, ELJs can influence gravel movement and deposition, creating localized pool-riffle sequences in what are currently straight, confined plane-bed channel segments. Collectively, the addition of ELJs to a channel can result in a significant increase in hydraulic complexity and a more diverse channel profile throughout a reach. Sediment storage and deposition adjacent to the ELJs can create large gravel bars in the active channel, allowing for colonization of riparian vegetation and eventually the development of forested islands. The overall roughening of the active channel and deposition on the riverbed promotes rehabilitation of natural processes by increasing floodplain connectivity and promoting channel migration.

B.2.3 Types

The two types of ELJs proposed for the Project area are:

1. A standard bank (Type B) ELJ constructed along the margins of the active channel (Sheet 19)
2. A bar apex (Type A) ELJ constructed at the head of an island or mid-channel (Sheet 20)

Each structure type provides essentially the same habitat functions but creates different hydraulic conditions and varying levels of benefits.

B.2.3.1 Bank (Type B) Engineered Log Jams

The Type B bank ELJs (Sheet 19) are typically placed along channel banks and may be implemented successfully in high-energy locations such as the outside of meander bends in the main channel. The logs are secured together using wire rope or chain, with rootwads along the exposed sides of the structure. Behind the rootwads, the structure is backfilled with rock materials to provide ballast for stability; the rock backfill does not interact with the river. Key pieces at the base of the structure are typically buried into the bank/channel bed where the rootwads will be exposed as a scour pool develops. The scour pool may be excavated at the time of construction if desired. The protruding rootwads in the low-flow channel provide a holding pool and hydraulic diversity at low flow. The structure is typically constructed to conform to the shape of the bank in a stepped configuration where the upper portion will be inundated only during higher flows. The open spaces between logs on the sides and top of the structure, in addition to the sediment deposit in the lee, provide areas for vegetation to be established (i.e., live cuttings and natural growth), supporting long-term riparian vegetation development. An example of a Type B ELJ is shown in Photograph 2.

Photograph 2
A Type B ELJ constructed in 2009 on the Entiat River, Washington. A scour pool has developed at the structure and mobile wood has been retained.

B.2.3.2 Bar Apex (Type A) Engineered Log Jams

The Type A bar apex ELJs (Sheet 20) are constructed of multiple logs with rootwads configured strategically with rootwads exposed along the front and sides of the structure. The logs are secured together with a limited amount of wire rope or chain at the corners and the structure is backfilled with rock materials to provide ballast for stability; the rock backfill does not interact with the river. Typically, the logs placed parallel to flow are the largest in diameter and rootwad size, providing more exposed rootwad area to the approach flow. The logs perpendicular to flow may be smaller in diameter. When a bar apex ELJ is placed mid-channel, a scour pool is typically maintained around the structure. The scour pool provides a deep holding area at the upstream end that tails out along the sides. The scour pool may be excavated at the time of construction if desired. The hydraulic conditions created by the ELJ create low-velocity stagnation zones upstream and downstream as flow is redirected around the structure. Because the channel adjusts to the structure by forming the scour pool and depositing sediment in the lee, this type of ELJ is often placed in rivers with ample bedload and in areas of the channel where sediment sorting is likely to occur. Bar Apex ELJs may be placed at the head of existing islands to maintain the islands and promote development of riparian forest, or they may be placed mid-channel to promote development of new islands and develop channel complexity. The open spaces between logs on the sides and top of the structure, in addition to the sediment deposit in the lee, provide areas for vegetation to be established (i.e., live stakes and natural growth), supporting long-term riparian vegetation development. An example of a Type A ELJ is shown in Photograph 3.

Photograph 3
A Type A ELJ shortly after construction on the Green River, Washington

B.3 LIVE CRIB STRUCTURE

B.3.1 Function

The live crib structure (Sheet 13) is an interconnected log structure placed along a portion of side channel bank (Sheet 5) to dissipate erosive lateral forces, provide hydraulic diversity and refuge, and promote sediment deposition in the lee of the structure. The logs that make up the crib are secured using a limited amount of wire rope or chain. The upstream end is buried into the bank to reduce the opportunity for flanking the upstream end of the structure. Structure ballast includes native fill and large angular rock fill, as necessary, to properly backfill the structure to roughly match the existing grade upstream and downstream of the structure. The rootwad top elevation is related to a design flood water surface, while the bottom elevation is related to the predicted maximum scour depth.

B.3.2 Benefits

The live crib will replace existing bank armoring with a bioengineered structure that will provide habitat complexity and protect infrastructure at risk of damage via bank erosion. This structure also precludes the future use of riprap and other hard bank armoring. Logs with rootwads protrude into the channel to help provide roughness and hydraulic refuge. Over time, additional woody debris may be retained by the exposed rootwads for added complexity and habitat benefits. In addition to providing bank stability and aquatic habitat, this structure provides an extensive area for incorporating vegetation to support the long-term development of a diverse riparian zone within the structure (Photograph 4).

Photograph 4

An example of a live crib approximately 1 year after construction