Asotin Creek Project Area 06 Fish Habitat Restoration

Asotin Creek, Snake River Basin,
Near Asotin, WA

Basis of Design Report 100% Design

PREPARED FOR:

ASOTIN COUNTY CONSERVATION DISTRICT
Assisting, protecting, and restoring Asotin County's natural resources.

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PREFACE

BACKGROUND

For medium and high-risk projects, a Basis of Design Report (BDR) shall be included as part of any engineering design contract. The BDR requirements serve as the design submittal framework that is needed to assess and evaluate the adequacy of the proposed project. The requirements were developed using the River Restoration Analysis Tool and address the 16 overarching questions proposed within the RiverRAT Framework.

The BDR will be submitted for HIP review to determine if the technical deliverables provided are adequate for functionality (adherence to HIP Conservation Measures) and technical quality (competent execution of design and project plans – contract documents).

PROJECT REVIEW JUNCTURES (typical steps in the RRT review process)

The following project review junctures are proposed as standard project quality assurance protocols for high-risk projects and may be used for medium risk projects based on the scope and complexity of the project. The number of review junctures depends on the adequacy of information provided, incorporation of comments recommendations, and may be modified to align with identified project junctures.

Conceptual Project Review (typically 15%): The project sponsor will notify the Bonneville Power Administration (BPA) at 15% or project concept stage by submitting conceptual drawings and a description of limiting factors, periodicity, and project objectives (or Chapter 1 of the BDR). The project sponsor will help the EC Lead coordinate a site visit (if needed) to review concepts and confirm the direction and planning for subsequent phases of project design. Staff biologists from the NMFS and USFWS shall be invited to the site visit. A typical site visit will include the review of limiting factors and any pertinent studies or reports that document restoration targets for implementation and draft project concepts. Additional data that may be presented and reviewed include other data sources (e.g., high-resolution aerial photography, topographic maps, soil maps, GIS/CAD data layers, or other resource data). After the site visit, BPA will collate and provide comments from BPA engineering and interagency partners. Once comments are resolved, the EC Lead will notify the sponsor to proceed with the next design iteration.

Initial Review of Plans and BDR (typically 30%): Preliminary drawings, specifications, a draft BDR (typically Chapters 1 through 3), and other supporting documentation (profiles, details, cross-sections, quantities, technical analyses/appendixes, etc.) for the preferred project alternative will be submitted for review. The 30% design should demonstrate incorporation of technical comments and recommendations from the previous review.

In addition to BPA technical and functional reviews, NMFS may require a separate Engineering Review. The EC Lead will collate comments from reviewers and interagency partners and submit them to the sponsor. The EC Lead will notify the Sponsor to proceed to the 80% design plans once 30% comments are resolved.

Final Project Review (typically 80%): The 80% project drawings and BDR (all chapters and appendices) will be submitted to the EC Lead. Technical, functional, and interagency reviews will take place. The 80% design should demonstrate complete incorporation of technical comments and recommendations developed at the previous design review. The 80% design materials should include near-final drawings and specifications, including specific site locations, site plans, profiles, cross sections, details, construction quantities, implementation resource plans, and design technical analyses. If HIP requirements are not met, an additional review iteration may be necessary. Once the EC Lead and BPA Engineering have approved the 80% design, the EC Lead will proceed with final agency approval and notifications.

1.0 PROJECT BACKGROUND

The Asotin Creek Project Area 06 (PA-06) Fish Habitat Restoration Project is located approximately 7 miles southwest of Asotin, WA along Asotin Creek Road (see Figure 1). The project begins at River Mile (RM) 7.0 and ends at approximately RM 7.4. Asotin Creek is a tributary to the Snake River and is listed as a major spawning area (MaSA) for the Asotin Population of the Snake River Steelhead Distinct Population Segment and the project is in a Priority Restoration Reach as identified by the Snake River Salmon Recovery Plan for southeast Washington (Snake River Salmon Recovery Board, 2011).

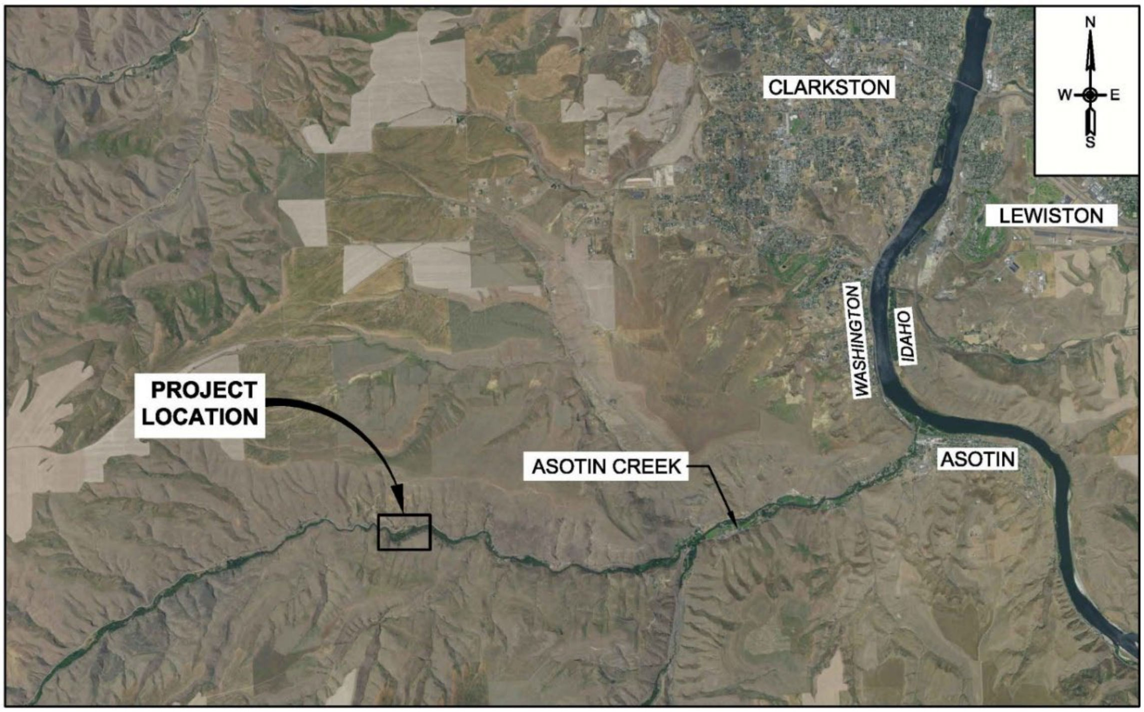

Figure 1. Project Location

The project reach is located downstream of a 1-mile-long bedrock canyon. PA-06 is the first wide spot where sediment transported from the bedrock canyon could deposit before the valley constricts again. Due to incision, most flood channels in the project reach are currently not accessible at the annual flood and PA-06 inappropriately operates as a sediment transfer zone. The channel has low hydraulic and geomorphic complexity, irregular floodplain access, and limited large wood (LW). In addition, the floodplain has several flood channels, which have been modified for landowner access. The project area has been in the Conservation Reserve Enhancement Program (CREP) for 15 years and was re-enrolled for an additional 15 years in October 2017. CREP has allowed the vegetation to recover and start to mature in the project area; however, the site still lacks LW needed to encourage natural stream processes and provide salmonid habitat.

There is a natural side channel in PA-06, but the flow has been restricted by a concrete barricade (Figure 2) and the side channel lacks riparian vegetation and channel complexity. The primary objectives in this reach identified through the Asotin County Conceptual Restoration Plan (Bennett et.al, 2018a) are to restore fish habitat and reconnect floodplains and side channels where possible. Reconnecting the side channel and the addition of LW structures will provide instream channel complexity to improve sediment sorting for steelhead spawning and high flow refugia/cover for steelhead and chinook juveniles.

Figure 2. Concrete barricades blocking existing side channel

1.1 NAME AND TITLES OF SPONSOR, FIRMS, AND INDIVIDUALS RESPONSIBLE FOR DESIGN.

Table 1 below shows the project team for this effort.

Table 1. Project Team

Name	Entity	Role	Title
Megan Stewart	Asotin County Conservation District	Sponsor	District Coordinator
Brad Riehle	Asotin County Conservation District	Sponsor	Project Coordinator
Susan Firor, P.E.	Alta Science & Engineering, Inc.	Engineer	Professional Restoration Engineer
Jessica Dzara, P.E.	Alta Science & Engineering, Inc.	Project Manager & Engineer	Professional Project Engineer
Reid Camp	Cramer Fish Sciences	Fluvial Geomorphologist	Fluvial Geomorphologist

1.2 LIST OF PROJECT ELEMENTS THAT HAVE BEEN DESIGNED BY A LICENSED PROFESSIONAL ENGINEER.

The following list contains the project design elements that have been or will be overseen by a licensed professional engineer:

1. Construction Bid Package
    a. Construction Drawings
    b. Special Provisions
    c. Cost Estimate
2. Side Channel Reconnection
3. Habitat Structures
4. Key Structures
5. Brush Fascines
6. Off-channel Habitat Area
7. Livestock Crossings and Fencing
8. Rock Crossing Replacement
9. Rock/Soil Berm
10. Revegetation Plan
11. Microtopography and Floodplain Roughness

1.3 EXPLANATION AND BACKGROUND ON FISHERIES USE (BY LIFE STAGE - PERIOD) AND LIMITING FACTORS ADDRESSED BY PROJECT.

Chinook and steelhead spawn and rear in this reach and bull trout use this reach during migratory periods (Table 2). There is very little LW and hydraulic diversity, limiting opportunities for suitable rearing habitat and cover. Pools are rare and typically created along the lateral edge of the channel near bedrock walls at the valley margin. Lamprey migrate through this reach and likely rear here as well, but little information on their distribution and abundance is available.

Table 2. Salmonid life histories present in PA-06

Species	Life History Present (egg, juvenile, adult)	Current Population Trend (decline, stable, rising)	Endangered Species Act **(ESA)** Coverage (Y/N)
Snake River Steelhead	Egg, Juvenile, Adult	Unknown	Yes
Snake River Spring Chinook	Juvenile, Adult	Unknown	Yes (extirpated)
Columbia River Bull Trout	Adult	Unknown	Yes
Snake River Fall Chinook	Egg, Juvenile, Adult	Increasing	Yes

Habitat diversity, key habitat quantity, temperature, and sediment load limit freshwater survival and production of juvenile steelhead and Chinook. Adding LW to the channel would improve habitat quality for all ESA-listed species present in the reach. LW interacts with stream flows to provide refuge and feeding lanes for juvenile salmonids. Increased sediment retention and improved sediment sorting will increase suitable spawning areas for all species. Moreover, creating pockets of slow water through LW addition and increasing floodplain connection will increase suitability for juvenile lamprey by creating areas of sand and fine sediment deposition. Promoting overbank flow and increasing access to flood channels will help expedite riparian recovery by increasing fine sediment and nutrient deposition on the floodplain.

1.4 PROJECT DESIGN ALTERNATIVE SELECTION

Alta Science & Engineering, Inc. (Alta) developed three 15% Design Alternatives for the Asotin Creek PA-06 Project that were provided for review at the conceptual design phase (Alta 2021).

All three alternatives begin with the removal of the concrete barricades to reconnect the existing side channel to the main channel. In addition, all three provide livestock access across the side channels at the west end of the property and increased floodplain roughness in the central meadow area.

ALTERNATIVE 1

The focus of Alternative 1 is adding large wood structures in both the main channel and side channels. Doing so provides off-channel rearing habitat for salmonids, in-stream habitat complexity, and floodplain connectivity.

Alternative 1 includes:

- Removal of concrete barricades to allow flows to access the existing side channel. Perennial flows in the side channel will be targeted if possible and verified at 30% Design.
- Installation of large logs in the side channel entrance to allow flows in while keeping the main channel in its current location. Logs will be lodged between existing large, standing trees. Figure 3 shows an example.
- Connection of 1,200 linear feet (LF) of side channel and 1 off-channel habitat area to support salmonid rearing and provide habitat.
- Installation of 16 in-stream habitat structures (non-channel-spanning) and 7 in-stream key structures (channel-spanning) to promote floodplain access and aggradation and provide salmonid habitat.
- Enhancement of floodplain roughness using logs, slash, and vegetation to promote fine sediment accumulation on the floodplain and combat non-native vegetation.
- Construction of a rock and soil berm to protect existing buildings and septic system from flooding up to approximately the 100-year flood event.
- Construction of 2 livestock crossings with fencing and removable cattle panels to aid in cattle operations.
- Installation of a drivable crossing (rock ford) to allow landowner vehicle access over the side channel.
- Bank stabilization in the form of 200 LF of brush fascine treatment along a currently eroding bank that is near the buildings.
- Revegetation of the existing areas that are not well vegetated by planting live willows, alders, and cottonwoods.

Figure 3. Logs at an existing side channel entrance in Asotin Creek

ALTERNATIVE 2

The focus of Alternative 2 also reconnects the existing side channel but plugs off the portion of the channel that is closest to the existing house to reduce flooding concerns. Construction of a rock and soil berm and bank stabilization would likely be eliminated from Alternative 2.

Alternative 2 includes:

- Removal of concrete barricades to allow flows to access the existing side channel. Perennial flows in the side channel will be targeted if possible and verified at 30% Design.
- Installation of large logs in the side channel entrance to allow flows in while keeping the main channel in its current location. Logs will be lodged between existing large, standing trees. Figure 3 shows an example.
- Connection of approximately 600 LF of existing side channel and excavation of an additional 600 LF of new side channel to support salmonid rearing and provide habitat.
- Installation of 4 ditch plugs to eliminate or greatly reduce flow in the existing channel section nearest to critical infrastructure. Sections of channel between plugs will remain as wetland cells. The first ditch plug will divert flows into the new side channel.
- Installation of 14 habitat structures (non-channel-spanning) and 5 key structures (channel-spanning) to promote floodplain access, aggradation, and provide habitat.
- Enhancement of floodplain roughness using logs, slash, and vegetation to promote fine sediment accumulation on the floodplain and combat non-native vegetation.
- Construction of 2 livestock crossings with fencing and removable cattle panels to aid in cattle operations.
- Maintain the existing drivable crossing over the existing side channel (replacement is not necessary for Alternative 2).
- Revegetation of the existing areas that are not well vegetated by planting live willows, alders, and cottonwoods.

ALTERNATIVE 3

Alternative 3 is the same as Alternative 1 with a few distinct differences: 1) rather than logs, use a roughened riffle with boulder additions at the side channel entrance to prevent downcutting, and 2) add an excavated side channel to the design to help encourage flows away from the house and infrastructure.

Alternative 3 includes:

- Removal of concrete barricades to allow flows to access the existing side channel. Perennial flows in the side channel will be targeted if possible and verified at 30% Design.
- Installation of a riffle support area in the main channel at the side channel entrance for stability against downcutting.
- Connection of 1,200 LF of existing side channel and construction of 400 LF of new side channel to support salmonid rearing and provide habitat.
- Excavation of 3 off-channel habitat areas to support salmonid rearing and provide habitat.
- Installation of 16 in-stream habitat structures (non-channel-spanning) and 6 in-stream key structures (channel-spanning) to promote floodplain access, aggradation, and provide salmonid habitat.
- Enhancement of floodplain roughness using logs, slash, and vegetation to promote fine sediment accumulation on the floodplain and combat non-native vegetation.
- Construction of a rock and soil berm to protect existing buildings and septic system from flooding up to approximately the 100-year flood event.
- Construction of 2 livestock crossings with fencing and removable cattle panels to aid in cattle operations.
- Installation of a drivable crossing (rock ford) to allow landowner vehicle access over the side channel.
- Bank stabilization in the form of 200 LF of brush fascine treatment along a currently eroding bank that is near the buildings.
- Revegetation of the existing areas that are not well vegetated by planting live willows, alders, and cottonwoods.

SELECTED ALTERNATIVE

Alternative 1 was selected for the project design by the project team because it achieves the project objectives using the least amount of earthwork, which makes it the least invasive and most cost-effective method. The existing riparian corridor along the main channel is in good condition and minimizing damage to the existing vegetation is desirable. Furthermore, several desired morphological features already exist on the floodplain and Alternative 1 capitalizes on their presence (e.g., flood channels, swales, depressions, etc.).

1.5 LIST OF PRIMARY PROJECT FEATURES INCLUDING CONSTRUCTED OR NATURAL ELEMENTS.

Alta proposes the following design features to address the fisheries limiting factors stated above:

1. Improving connection of approximately 1,200 linear feet of side channel to support juvenile rearing and over-wintering habitat.
2. Over 6 acres of floodplain connectivity with a target of overbank flows at the 2-year flow.
3. 275 linear feet of new livestock fence, 70 linear feet of removable water gates, and 2 cattle crossings installed to restrict cattle access to fenced corridor only and minimize bank erosion and sedimentation to the creek.
4. 16 log habitat structures and 6 log key structures for aquatic organism habitat and channel complexity.
5. 3 additional key structures to provide approximately 100 linear feet of logs installed at side channel entrance to prevent downcutting.
6. 0.1 acres of off-channel habitat to create backwater for juvenile salmonid and aquatic organism habitat.

7. 180 linear feet of brush fascine bank treatment for bank roughness and stability.
8. 165 linear feet of rock/soil berm to protect existing home and septic system from flooding.
9. Remove 1 rock crossing from the side channel, which currently blocks flow, and replace it with a rock ford to allow unrestricted flow in the side channel.
10. Approximately 1 acre of microtopography and floodplain roughness to minimize erosion of disturbed areas and promote revegetation, including a series of 11 post assisted log structures (PALS) to help keep slash in place.
11. Hydroseeding of approximately 1.5 acres of the project area to restore native plant communities, stabilize the banks and floodplain, and enhance the riparian ecosystem.

1.6 DESCRIPTION OF PERFORMANCE / SUSTAINABILITY CRITERIA FOR PROJECT ELEMENTS AND ASSESSMENT OF RISK OF FAILURE TO PERFORM, RISK TO INFRASTRUCTURE, POTENTIAL CONSEQUENCES AND COMPENSATING ANALYSIS TO REDUCE UNCERTAINTY.

Restoring side channel connections, floodplain connectivity, riparian function, and habitat complexity have been identified as priorities in this project area through the Asotin County Conceptual Restoration Plan (Bennett et al., 2018a). This design project aims to develop construction-ready plans that restore fish habitat when implemented and will position Asotin County Conservation District (ACCD) for construction funding. This project is located on private property owned by an active cattle operator. Livestock crossings and access to the project area will need to be incorporated into the design. Protection of the landowner's private residence is also a concern that will need to be addressed.

ACCD has established the following goals for the Asotin Creek PA-06 Project:

- Develop a construction-ready design for PA-06. The design will address the management objectives identified in the Asotin County Conceptual Restoration Plan.
- Safely increase floodplain and side channel connection throughout the project area.
- Promote riparian function by replanting altered sections of floodplain and creating roughness and hydration where fine sediments can once again deposit and grow vegetation.
- Provide instream habitat complexity through the placement of large wood structures.
- Enhance juvenile Snake River steelhead and Snake River spring/fall Chinook rearing habitat (all life stages will benefit).

The goal of the Asotin Creek Fish Habitat Restoration Project is to improve native salmonid habitat by accomplishing a set of process-based design objectives to restore natural channel processes and floodplain interaction. The side channel connection was designed such that the expected side channel flow frequency is on a nearly annual basis to increase regular floodplain inundation, slow in-stream velocities, and reduce bed and bank erosion in the main channel during flood events. Off-channel habitat areas were designed to be sustainable through annual flooding to create juvenile salmonid habitat and limit the potential for stranding. Habitat structures are designed to provide sustainable aquatic habitat and increase habitat complexity and hydraulic diversity. Bank treatments are designed to increase bank stability, reduce sedimentation, and incorporate native streambank vegetation. The revegetation plan's intent is to replenish the site with native vegetation and enhance the current riparian vegetation. The rock/soil berm was designed to protect the home from flooding to the 100-year flood event. Livestock crossings and the rock ford were designed to minimize the impact of cattle and landowner crossings and remain stable at the 25-year flood event.

Risks of these performance criteria failing to perform are mitigated in the short term by stability analyses completed during design and in the long term by establishment of native vegetation on the floodplain, streambanks, and riparian area to increase the LW source. Section 3.6 discusses stability analyses for the primary project elements. Potential consequences of failure include damage to the home on site, downcutting of the side channel entrance, and the side channel capturing the bulk of the flow, making it the new main channel. Hydrologic and hydraulic analyses and placement of LW at the side channel entrance help minimize these risks. Risks associated with the individual project elements are discussed in Section 1.7.

1.7 DESCRIPTION OF DISTURBANCE INCLUDING TIMING AND AREAL EXTENT AND POTENTIAL IMPACTS ASSOCIATED WITH IMPLEMENTATION OF EACH ELEMENT.

The in-water work window for this project is estimated to be July 15th to September 15th. Work on the floodplain can be commenced as soon as the floodplain is adequately dry to support construction activities. The sections below describe construction disturbances including timing, areal extent, and potential impacts for each major project element.

SIDE CHANNEL RECONNECTION

Side channel reconnection increases channel length of Asotin Creek through the project area and activates the floodplain. Reconnection will be accomplished by removing concrete jersey barriers and regrading a portion of the side channel entrance where angular rock was used to stabilize the jersey barriers. The angular rock could be placed in the side channel to lessen the steep slope at the entrance to the side channel. Key structures will be placed in the side channel entrance to reduce the potential for downcutting where a steeper channel slope exists. Side channel reconnection work can be accomplished when water levels in the main channel are below the side channel elevation or within the in-water work window. We expect this work to occur after all log structures have been installed in the side channel. The side channel reconnection areal extent is approximately 8,000 square feet. Concrete barrier and angular rock excavation and hauling in the floodplain could negatively impact native vegetation. The Contractor will be required to preserve and protect native vegetation marked by the Engineer, and haul routes will be adjusted accordingly.

LOG STRUCTURES

Log structures are designed to have a natural appearance and engage at all flows with logs and boulders placed along the channel bottom. Two types of log structures are included in this design: Habitat Structures and Key Structures.
Key structures are made of large woody debris and are built to span the bankfull channel. Their primary objective is to slow and spread flows laterally during flood events. Key structures will be partially buried in the streambed or banks or wedged between live trees or log posts for stability. Smaller wood material will be wedged within the larger logs to decrease porosity of the structure. No hardware will be used to anchor the key structures. Stability analysis results for the key structures are discussed in Section 3.6.

Habitat structures are made of large woody debris but are smaller than key structures and do not span the bankfull channel. Their primary objectives are to trap and sort sediment, deflect flood flows in a desired direction to target bank or floodplain features, and provide quality habitat and refuge for salmonids during all flows. They are usually bank-attached and deflect flow laterally but can also be built in the middle of the bankfull channel to split flows. Root wads shall be placed on channel bed to ensure they are active at a range of flows, including low flows. Backfill over anchor logs buried in the streambank will be placed in lifts and compacted with vibratory compaction equipment. No hardware will be used to anchor the habitat structures. All structures will be partially buried in the banks or wedged between trees or log posts for stability. Stability analysis results are discussed in Section 3.6.

Log structure installation in the mainstem will occur during the in-water work window, although side channel structures may be installed at any time the structure sites are dry. This work’s areal extent is about 200 square feet per structure for habitat structures and 900 square feet for key structures. Potential impacts are minimal, but disturbance to native vegetation along the existing channel is possible. Disturbed areas will be treated with microtopography, floodplain roughness, and new vegetation. Stability analysis were conducted to design habitat and key structures to stay in place during flood events, minimizing risks to the project and downstream infrastructure.

OFF-CHANNEL HABITAT AREA

The off-channel habitat area is inundated at the 2-year flow. It captures hyporheic flows and provides rearing habitat and resting places for native fish. The 15% design showed two off-channel habitat areas where there are existing flood channels that are inundated during the 2-year event. The western off channel habitat area was removed from the design as no excavation is required in this area. The design plans show one off channel habitat area, which will be excavated and will be planted heavily to increase water retention. Key structures will be placed downstream of the off-channel habitat area to increase inundation. Excavation will be required for the off-channel habitat area shown on the design drawings to create a low area that is inundated at the 2-year flow event. This area will be sloped to drain to the main channel to minimize fish stranding at low flows. We expect off-channel habitat area planting to occur when other revegetation work is taking place. This work's areal extent is approximately 2,500 square feet. Potential impacts are minimal, but disturbance to native vegetation along the existing channel is possible. Disturbed areas will be treated with microtopography, floodplain roughness, and hydroseeding.

BRUSH FASCINE

Bioengineered bank treatments decrease sedimentation and boost native vegetation along the streambanks. In this design, brush fascines are to be located along approximately 180 LF of the side channel streambanks. We expect brush fascine installation to occur during the same time period as log structure construction in the side channel. This treatment's areal extent is approximately 2,000 square feet. Potential impacts are minimal, but disturbance to native vegetation along the side channel is possible. Disturbed areas around the treatment will be planted, seeded, and treated with microtopography and floodplain roughness.

ROCK/SOIL BERM

We positioned and sized the berm so no flood water reaches the home up to the 100-year flow event, as shown in the HEC-RAS 2D modelling results. The design incorporates an impermeable rock and clay core that restricts flow and discourages piping failure. Rock armoring is included to minimize erosion potential. The rock and clay material will be compacted using vibratory compaction equipment to provide a cohesive connection between the surfaces. The top width and side slopes are designed to be gentle enough for horse traffic in the areas where the berm is located within pasture.

Berm construction may be completed at any time when the area is dry enough for access and construction to take place. This work's areal extent is approximately 1,300 square feet. Potential impacts could include damage to existing native vegetation and floodplain next to the structure. The finished berm structure will be covered with slash and seeded. Disturbed areas around the structure will be planted, seeded, and treated with microtopography and floodplain roughness.

LIVESTOCK CROSSINGS & ROCK FORD

Livestock crossings provide a pathway to move cattle through the project area between grazing areas, and the rock ford provides an access point for the landowner. Construction of Livestock Crossing 2 must be done within the in-water work window, while the rock ford and Livestock Crossing 1 may be constructed at any time when the area is dry. This work's areal extent is approximately 1,000 square feet. Hauling of materials in the floodplain could negatively impact native vegetation. The Contractor will be required to preserve and protect native vegetation marked by the Engineer, and locations will be adjusted if needed to avoid significant impacts.

MICROTOPOGRAPHY & FLOODPLAIN ROUGHNESS

The microtopography and floodplain roughness treatment breaks up flow paths, helps reestablish native vegetation by providing microsites, and promotes sediment accumulation on the floodplain. Floodplain roughness will include a series of 11 post assisted log structures (PALS) to help accumulate fine sediment. Microtopography and floodplain roughness will be located on floodplain areas disturbed by construction including temporary construction access and haul routes and small disturbed areas next to log structures, brush fascine, and livestock crossings. This work's areal extent is approximately 1.0 acre. There are no potential impacts as a result of this work because it will occur in previously disturbed areas. These areas will also be seeded and planted per the revegetation plan.

REVEGETATED AREA

Revegetation of the project site provides native plant species to help reestablish native vegetation, outcompete weeds, and reduce erosion potential. Hydroseeding helps prevent reoccupation by unwanted plant species. We expect revegetation will be the final project component. Additional revegetation in the form of planting will occur post construction as part of a separate contract. This work's areal extent is approximately 1.5 acres. There are no potential impacts from revegetation because it occurs in areas that were previously disturbed by construction or lacking native vegetation cover.

2.0 RESOURCE INVENTORY AND EVALUATION.

2.1 DESCRIPTION OF PAST AND PRESENT IMPACTS ON CHANNEL, RIPARIAN AND FLOODPLAIN CONDITIONS.

Prior to the 1990s, intensive agriculture on loess soils with a high erosion potential led to an over-supply of fine sediment that severely degraded spawning habitat in Asotin Creek. Logging in the headwaters, grazing throughout the watershed, removal of mature riparian forests, and numerous diversion dams for irrigation also led to degradation of fish habitat. Several large floods that happened every 10-20 years in the last century exacerbated the impact on channel, riparian, and floodplain conditions. In 1995, a community-led Model Watershed Plan was developed and in the subsequent 20 years, restoration projects were implemented to improve upland and stream conditions. Prior to 1995, channel stability, sediment supply, stream flow, habitat diversity, temperature, and key habitat quantity were considered the most significant limiting factors on fish productivity. The Asotin County Watershed Assessment (Bennett et al. 2018b) found no evidence of over-supply of fine sediment, which is likely due to the extensive investment in erosion control measures on the loess uplands in the past 20 years.

While efforts discussed above greatly improved the condition of PA-06, there are still significant human-induced changes from land management, particularly the blocking of the side channel that runs the length of the project. In addition, the floodplain has several flood channels which have been modified for land use and the side channel is completely blocked in a second location by a drivable rock crossing. A large section of the natural floodplain is devoid of riparian vegetation due to cobble sheet deposits during past large floods and a lack of fine sediment. Portions of the existing Asotin Creek stream channel in PA-06 are incised and lack of large woody debris in the main channel and off-channel areas limits habitat complexity for salmonids.

The project area has been in the Conservation Reserve Enhancement Program (CREP) for 15 years and was re-enrolled for an additional 15 years in October 2017. CREP has allowed the vegetation to recover and start to mature in the project area; however, the site still lacks LW needed to encourage natural stream processes and provide salmonid habitat.

2.2 INSTREAM FLOW MANAGEMENT AND CONSTRAINTS IN THE PROJECT REACH.

The list below contains the project constraints for Asotin Creek:

- Flow is not listed as a limiting factor in the Asotin County Conceptual Restoration Plan (Bennett et al. 2018a).
- The side channel inlet is at a lower elevation than the main channel which needs to be addressed in the design to minimize downcutting.
- The Asotin Creek floodplain is naturally confined between steep hillslopes.
- The project is located on private land with a private residence on site.
- There are residences upstream and downstream of PA-06.
- Livestock fences exist in the project area.
- Infrastructure downstream of the project area includes the community of Asotin.
- Spawning periods for adult anadromous species affect this project’s timing and limit in-stream construction to select times of the year.
- Hydrologic changes are underway due to changing climatic conditions.

2.3 DESCRIPTION OF EXISTING GEOMORPHIC CONDITIONS AND CONSTRAINTS ON PHYSICAL PROCESSES.

The geomorphic function in PA-06 is moderate, primarily due to low hydraulic and geomorphic complexity, intermittent floodplain access, and limited LW. The stream channel is incised, making the reach a sediment transport zone rather than a sediment sink in most years. Sediment in the floodplain is dominated by alluvial deposits of cobble from floods; fine sediment is limited on the floodplain in some areas, likely due to a lack of roughness and access at lower flows. Heightened stream power in the upstream adjacent bedrock canyon reach delivers substantial amounts of sediment to PA-06. The existing side channel in PA-06 has been unnaturally blocked and is likely causing further channel incision due to increased stream power and decreased floodplain access.

Figure 4. Eroding Bank in Asotin Creek PA-06

2.4 DESCRIPTION OF EXISTING RIPARIAN CONDITION AND HISTORICAL RIPARIAN IMPACTS.

Riparian function near the channel is high and dominated by young white alder. Cottonwood and willow are also present in the riparian area. Open spaces in the riparian zone are a result of cobble sheet deposits during past large floods. These open areas are slowly recovering, but invasive vegetation and a lack of fine sediment may be delaying recovery. Fine sediments needed for supporting healthy riparian areas are limited on the floodplain, likely due to a lack of roughness and regular inundation (Bennett et al. 2018a). Where vegetation is present on the floodplains it is a mix of native woody vegetation, pasture grass, and reed canary grass (see Figure 5).

Clearing of vegetation, cattle grazing, and lack of floodplain connection have negatively impacted the historically present species that likely featured cottonwood, hawthorn, willow, and alder in the overstory. In addition, beavers were more abundant in Asotin Creek historically, impacting vegetative cover, riparian buffer width, and water retention. Desirable vegetation in Asotin Creek's riparian zone has been negatively affected by the stream's proximity to pastures and the spread of invasive species.

Figure 5. Typical Asotin Creek PA-06 Riparian Vegetation

2.5 DESCRIPTION OF LATERAL CONNECTIVITY TO FLOODPLAIN AND HISTORICAL FLOODPLAIN IMPACTS.

Channel entrenchment due to agricultural and human impacts on geomorphic processes discussed above limits Asotin Creek's floodplain access and its ability to function naturally. Flows into this side channel are unnaturally blocked by concrete barricades and borrowed fill (see Figure 2). Access to floodplain areas only occurs during larger flood events due to high stream banks and channel incision. Most off-channel areas are inaccessible during more commonly reoccurring (1- to 2-year) floods and do not retain water year-round like the main channel. While small inset floodplains have developed in some locations, they do not provide adequate area to prevent sediment from being flushed through the system.

Lack of accessible floodplain area is resulting in little energy dissipation or sediment and nutrient delivery to the floodplain. Increasing the floodplain area accessed through side channel reconnection and log structure placement will help store sediment on the floodplain.

2.6 TIDAL INFLUENCE IN PROJECT REACH AND INFLUENCE OF STRUCTURAL CONTROLS (DIKES OR GATES).

N/A

3.0 TECHNICAL DATA.

3.1 INCORPORATION OF HIPIII SPECIFIC ACTIVITY CONSERVATION MEASURES FOR ALL INCLUDED PROJECT ELEMENTS.

The Design Drawings include HIP conservation measures (Sheet G2 – G4). HIP conservation measures were incorporated into the design. HIP conservation measures considered for this design, along with the correlating project elements, are:

1. Category 1h) Installation of Fords
    - Livestock crossings
    - Rock crossing replacement
2. Category 2a) Improve Secondary Channel and Wetland Habitats
    - Off-channel Habitat Areas
    - Reconnecting Side Channel
3. Category 2c) Protect Streambanks Using Bioengineering Methods
    - Brush Fascine
4. Category 2d) Install Habitat-Forming Natural Material Instream Structures (LW, Boulders, and Gravel)
    - Habitat Structures
    - Key Structures
5. Category 2e) Riparian Vegetation Planting
    - Revegetation Plan
    - Microtopography & Floodplain Roughness
6. Category 9d) Fencing Construction for Grazing Control

Berm construction is not a HIP-specific activity but is included to ensure the private residence on site is protected from flooding. Berm construction is not funded by BPA.

3.2 SUMMARY OF SITE INFORMATION AND MEASUREMENTS (SURVEY, BED MATERIAL, ETC.) USED TO SUPPORT ASSESSMENT AND DESIGN.

Site information and measurements used to support the design of this project are listed below:

- Asotin County Watershed Assessment (Bennett et al., 2018b) and Conceptual Restoration Plan (Bennett et al., 2018a).
- Topographic and cross-section survey using survey-grade GPS completed in summer 2021.
- Salmonid Assessments in Asotin Creek (Crawford and Herr 2014 and Mayer et al. 2008).
- Aerial imagery and LiDAR data of Asotin Creek collected in fall 2011 (Eco Logical Research, 2012).
- Hydrologic data from U.S. Geological Survey (USGS) StreamStats and USGS gage analysis.
- Survey data and hydrologic data incorporated into a HEC-RAS 2-D hydraulic model.
- Multiple site visits for habitat assessment and survey.

3.3 SUMMARY OF HYDROLOGIC ANALYSES CONDUCTED, INCLUDING DATA SOURCES AND PERIOD OF RECORD INCLUDING A LIST OF DESIGN DISCHARGE (Q) AND RETURN INTERVAL (RI) FOR EACH DESIGN ELEMENT.

Hydrology data used for this design includes USGS stream gage data and USGS regional regression analyses. Several hydrologic analyses were compared to choose design flows. The sections below describe the data and analysis methods used.

USGS STREAM GAGE DATA

The USGS stream gage currently in operation on Asotin Creek (13335050) is located near Asotin, WA just upstream of the confluence with the Snake River and approximately 7 river miles downstream from the project site. This gage station has been in operation since 1991. There were two additional gages on the mainstem of Asotin Creek that are no longer active. Table 3 provides the period of record and location of the stream gages on Asotin Creek.

Table 3. Discharge records available for Asotin Creek that are applicable to the project site.

Gage #	Period of Record	Gage Location	Distance from PA 06
USGS 13334500	1928-1959	Headgate Dam	2 miles upstream
USGS 13334700	1960-1996	Kearney Gulch	1 mile downstream
USGS 13335050	1990-present	Highway 129 Bridge	7 miles downstream

Figure 6 shows the hydrograph for the Highway 129 Bridge gage station. Discharge fluctuates between less than 20 cfs and over 3000 cfs during the period of record.

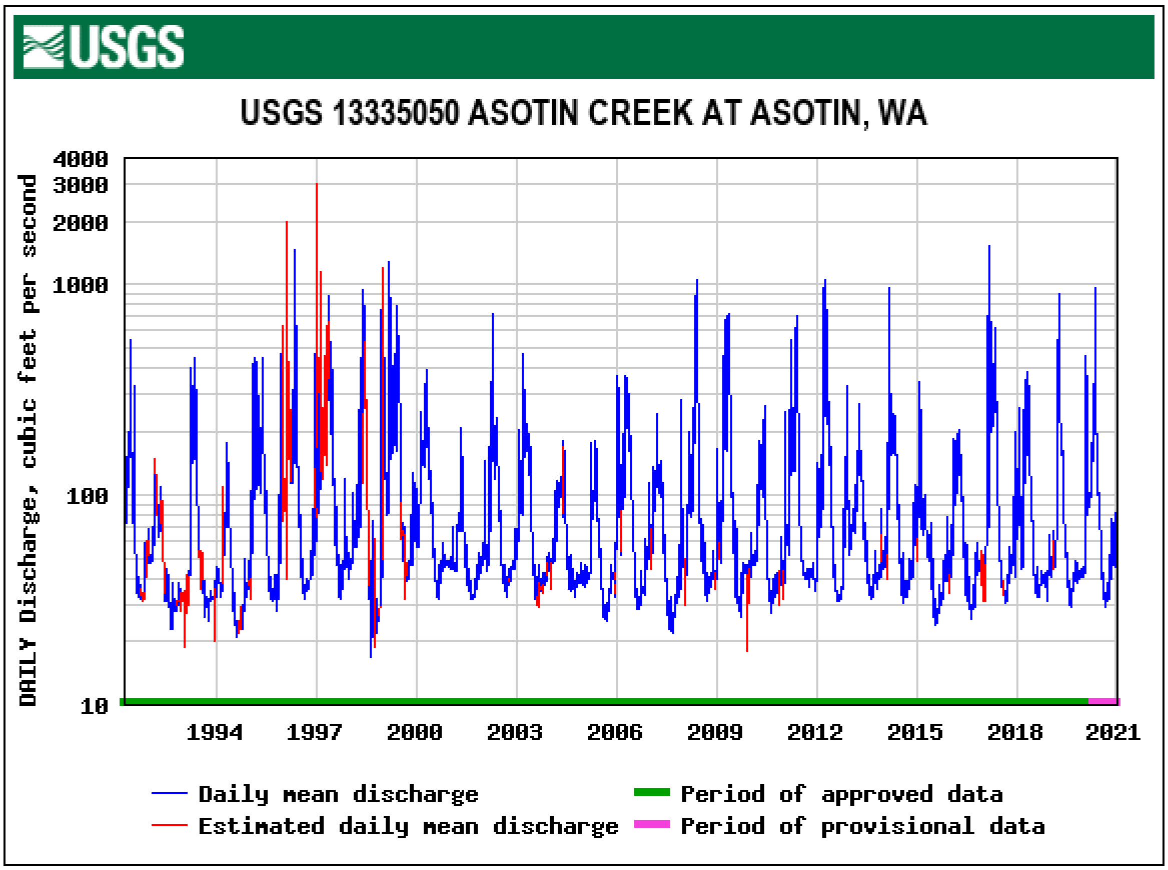

Figure 6. Asotin Creek Hydrograph for Asotin, WA (13335050) Gage

HYDROLOGIC ANALYSIS METHODS

The following methods were used for analyzing hydrology at the project site and then compared to select the design flows.

LINEAR REGRESSION AND LOG PEARSON III

Because the Highway 129 Bridge gage and Kearney Gulch gage are in different locations in the watershed, a linear regression relationship was developed between them to make use of the longer period of record of gage data. The Highway 129 Bridge peak flow data vs. the Kearney Gulch peak flow data was plotted for the 6 years of overlap between the two gages. The resulting linear regression equation (R^2 = 0.981) was used to scale the Highway 129 Bridge gage data to the Kearney Gulch gage location and add these data to the Kearney Gulch record. The gage data from Headgate Dam were excluded because of the difference in watershed size between the Headgate Dam and Kearney Gulch locations, and there is no overlap period between gages available to create a regression equation.

The USGS PeakFQ Flood Frequency Analysis version 7.3 program was used to develop recurrence interval statistics from the peak gage data based on USGS Bulletin 17B (Interagency Advisory Committee on Water Data, 1982) Log Pearson III method. The period of record from 1960 to 2021 was used in the PeakFQ analyses. Years with only a partial year of data, such as 2021, are excluded by the program. Years with provisional data, such as 2020, are also excluded from the recurrence interval calculation performed by PeakFQ.

SIMILAR WATERSHEDS

The USGS method for estimating flood magnitudes at ungaged sites near a gage (Mastin, et. al 2016), referred to here as the similar watersheds method, was applied to all three gages on the mainstem of Asotin Creek. This method uses flood frequency information from the long-term stream gage (10 years or more of record), watershed drainage area, percent canopy cover, and mean annual precipitation to estimate the flood quantiles at the ungagged site. The drainage area, percent canopy cover, and mean annual precipitation of the project site are 166 square miles, 30%, and 23 inches, respectively. The USGS Flood Q Ratio Tool available with Mastin, et al. 2016 was used to perform these calculations. Because each gage has an individual set of flood frequency information, the data from the three gages must remain separate in this method.

USGS STREAMSTATS

The USGS regional regression equations for Washington (Mastin, et. al 2016) were accessed via the StreamStats website (USGS, 2021). The StreamStats results were identical to the results from the Highway 129 Bridge similar watersheds method above. This indicates that StreamStats is using the Highway 129 gage data and scaling it to the ungagged project site using the method described by Mastin, et al. (2016) in place of the usual regional regression equations because of the available gage data on Asotin Creek.

DAILY FLOW DURATION CURVE

A mean daily flow duration curve was calculated to estimate the 95% exceedance flow. Mean daily flow data from March 1991 to July 2021 at the Highway 129 gage (USGS 13335050) was used. The 95% exceedance flow, the flow that is met or exceeded 95% of the time, is 30 cfs (Figure 7).

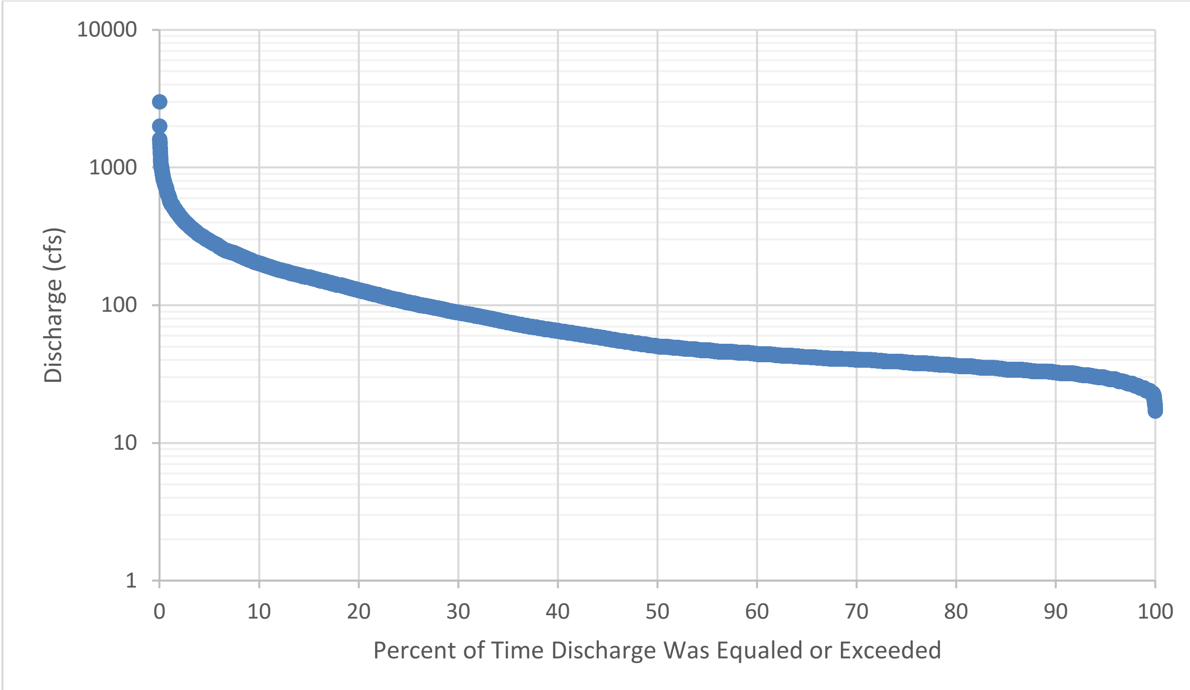

Figure 7. Daily Flow Duration Curve for Asotin Creek March 1991 – July 2021, USGS 13335050

HYDROLOGIC ANALYSIS COMPARISON AND DESIGN FLOWS

Table 4 shows hydrology comparisons for the methods described above.

Table 4. Asotin Creek Hydrologic Analysis Comparisons

	Peak Flow Estimation Method				
Return Interval (Yrs)	**Similar Watersheds - Highway 129 (CFS)**	**Similar Watersheds - Kearney Gulch (CFS)**	**Similar Watersheds - Headgate Dam (CFS)**	**USGS StreamStats (CFS)**	**Linear Regression and Log Pearson III - Kearney Gulch**
Years of Record	n = 25	n = 30	n = 32		n = 53
Q2	540	424	367	540	383
Q5	1010	942	610	1010	862
Q10	1420	1460	804	1420	1347
Q25	2050	2360	1090	2050	2201
Q50	2620	3190	1320	2620	3049
Q100	3240	4230	1590	3240	4113
Q200	3880	5470	1870	3880	5436
Q500	4900	7460	2280	4900	7671

Design flows for project elements are based on the hydrology comparisons above. The similar watersheds method (Mastin, et. al 2016) for the currently active Highway 129 Bridge gage was selected for the project element design flows, which are shown in Table 5. These flows are also the same magnitude as the flows estimated by StreamStats. It appears that StreamStats uses the USGS similar watersheds method (Mastin, et al. 2016) in place of regional regression equations in creeks where gage data is present. Design flows for project elements (Table 5) were determined based on the hydrology from Similar Watersheds equations (Table 4).

Table 5. Asotin Creek PA-06 Design Flows

Project Element	Peak Flow Return Interval (year)	Design Flow (cfs)
Side Channel, Floodplain Features	2	540
Log Structures Stability	25	2050
Habitat Structure Performance	95% Exceedance	30
Berm	100	3240
Livestock Crossings & Ford	25	2050

Synthetic hydrographs for hydraulic modeling were developed by obtaining a representative peak flow event from the gage record and scaling it such that the peak of the hydrograph was equal to the design flow.

3.4 SUMMARY OF SEDIMENT SUPPLY AND TRANSPORT ANALYSES CONDUCTED, INCLUDING DATA SOURCES AND SEDIMENT SIZE GRADATION USED IN STREAMBED DESIGN.

The geomorphic function in PA-06 is moderate, primarily due to low hydraulic and geomorphic complexity, irregular floodplain access, and limited LW. The stream channel is incised, making the reach act more like a sediment transport zone rather than a sediment sink in most years. The floodplain has several flood channels which have been modified for land use. Sediment in the floodplain is dominated by alluvial deposits of cobble from floods; fine sediment is limited on the floodplain in some areas, likely due to a lack of roughness. Heightened stream power in the upstream adjacent bedrock canyon reach delivers substantial amounts of sediment to PA-06. Therefore, it is assumed that there is adequate sediment supply from upstream and that the project area lacks floodplain connection to enable fine sediment storage and energy dissipation.

The proposed side channel reconnection has been an active channel in the past, and a majority of the side channel contains native substrate. Therefore, minimal modification of the streambed is planned at the inlet only, and no streambed sediment will be imported.

3.5 SUMMARY OF HYDRAULIC MODELING OR ANALYSES CONDUCTED AND OUTCOMES – IMPLICATIONS RELATIVE TO PROPOSED DESIGN.

EXISTING CONDITION & MODEL SET UP

U.S. Army Corps of Engineers HEC-RAS v6.0 software was used to create a two-dimensional, unsteady state hydraulic model of the project site. LiDAR topographic data, GPS surveyed topographic data, and hydrologic data (See Section 3.2 and 3.3) were input into the model to formulate an existing conditions model.

As described in Section 3.3, flow inputs for the model included the steady-state peak flows shown in Tables 4 and 5 and their corresponding scaled synthetic hydrographs for unsteady-state computations. The synthetic hydrograph extended from approximately January 28th to January 31st, resulting in an unsteady flow simulation period of approximately 4 days. Modelling time step was set to ten seconds in order to produce a stable model. Cell size, where individual hydraulic computations are performed, was set to 20ft by 20ft on the floodplains and 10ft by 10ft in the stream channels (Figure 8).

Downstream boundary conditions were set to normal depth, approximated by the bed slope of 0.02 ft/ft, or 2 percent.

Manning's n values used for roughness were varied spatially depending on landcover type. Landcover type and extent were determined from aerial imagery and site survey. The manning's n value for each landcover type (Table 6) was selected based on the references presented in Chow (1959).

Table 6. Manning's n Roughness Values Used in the 2D Hydraulic Model

Landcover Type	Manning's n Value
Main Channel	0.04
Side Channel, Grassy	0.045
Side Channel, Forested	0.1
Floodplain, Treed	0.1
Floodplain, Grassy	0.035
Floodplain, Bare Ground	0.02
Wetland	0.045
Habitat Structure	0.15
Key Structure	0.15
Brush Fascine	0.15

No stage and flow data could were available to calibrate the existing model. Hydraulic indicators observed on site were used to check that the model was producing reasonable inundation results for the 2-year flow event.

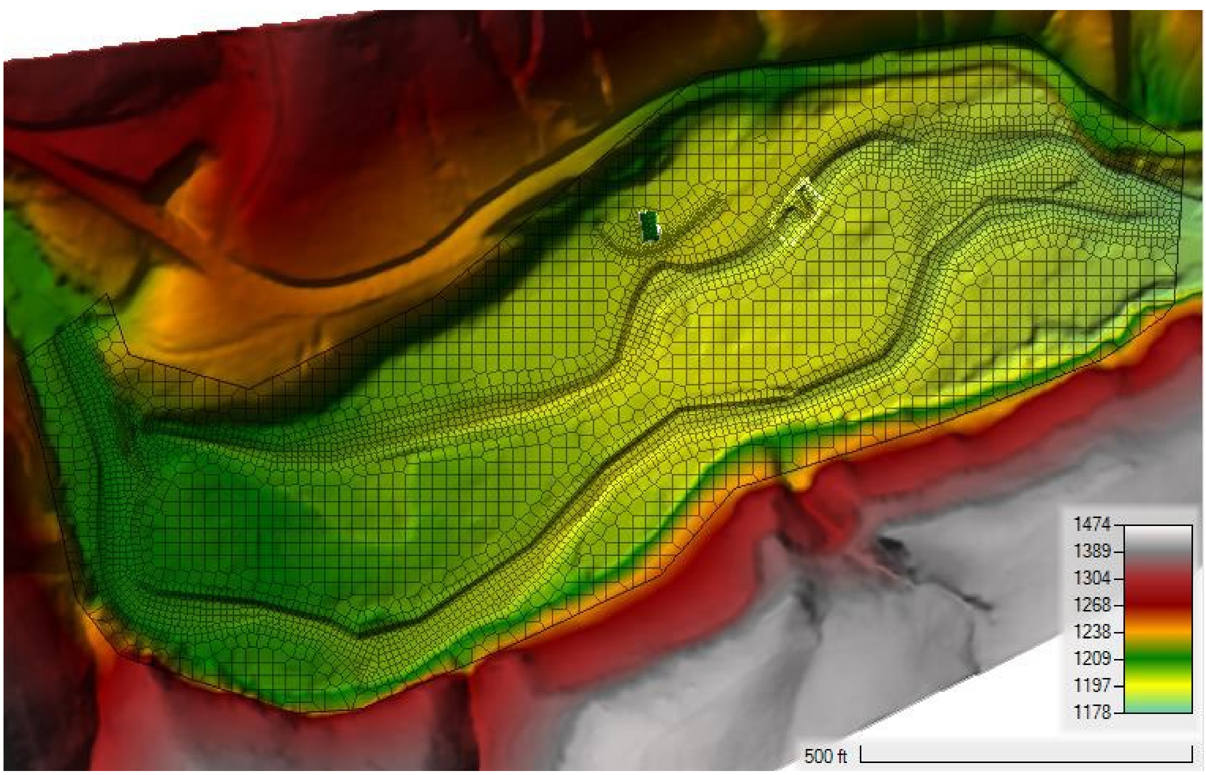

Figure 8. Computational Mesh and Existing Condition Terrain

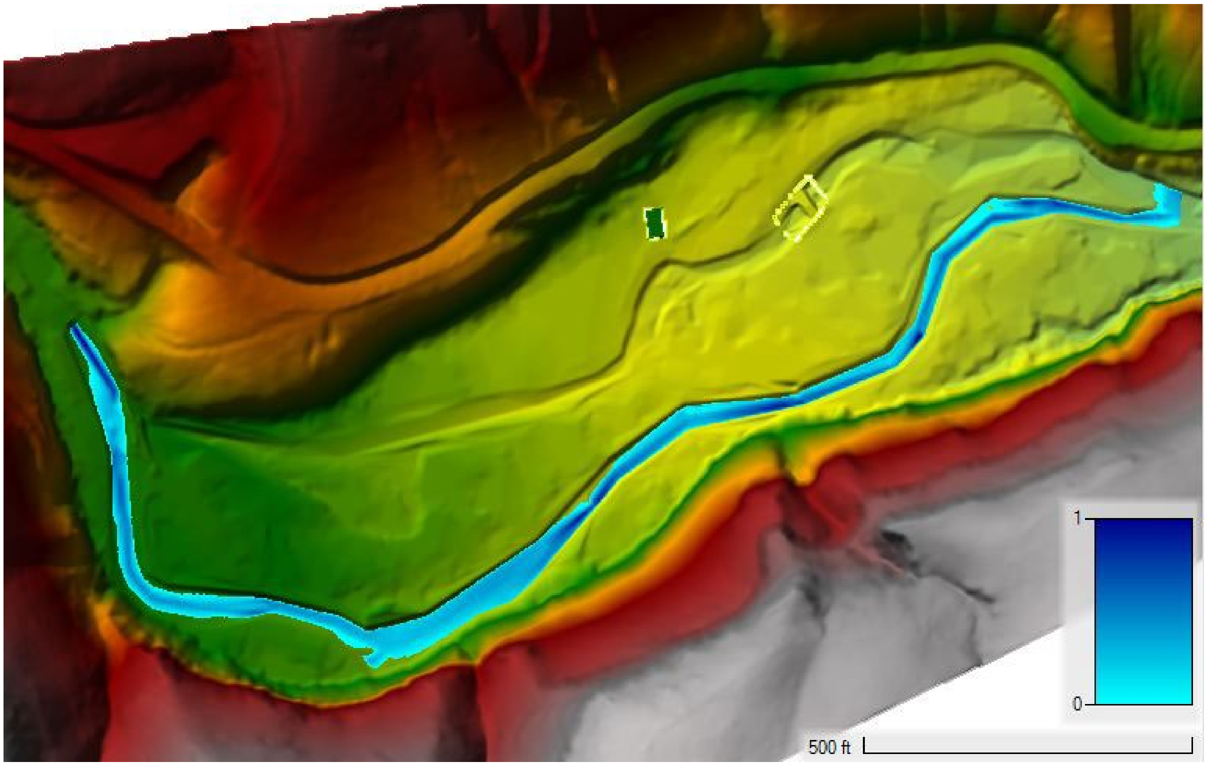

Figure 9. Existing Condition Maximum Depth at the 95% Exceedance Flow

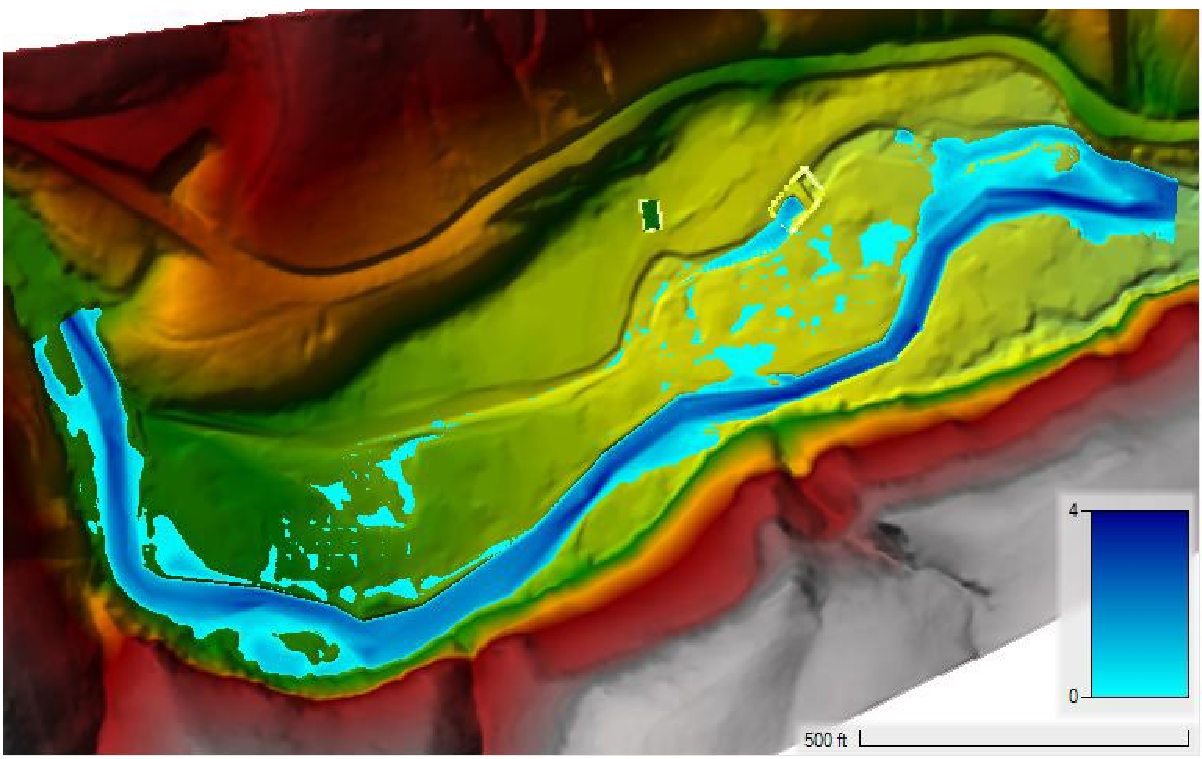

Figure 10. Existing Condition Maximum Depth at the 2-Year Flow Event

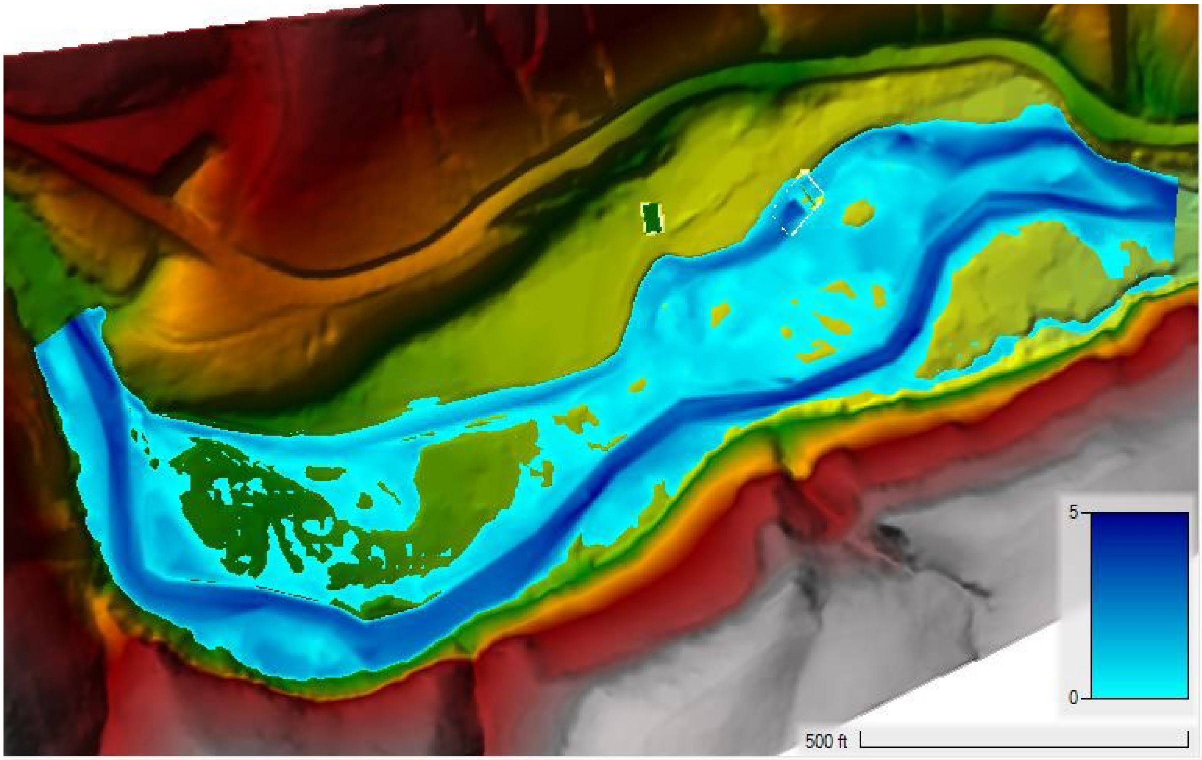

Figure 11. Existing Condition Maximum Depth at the 10-Year Flow Event

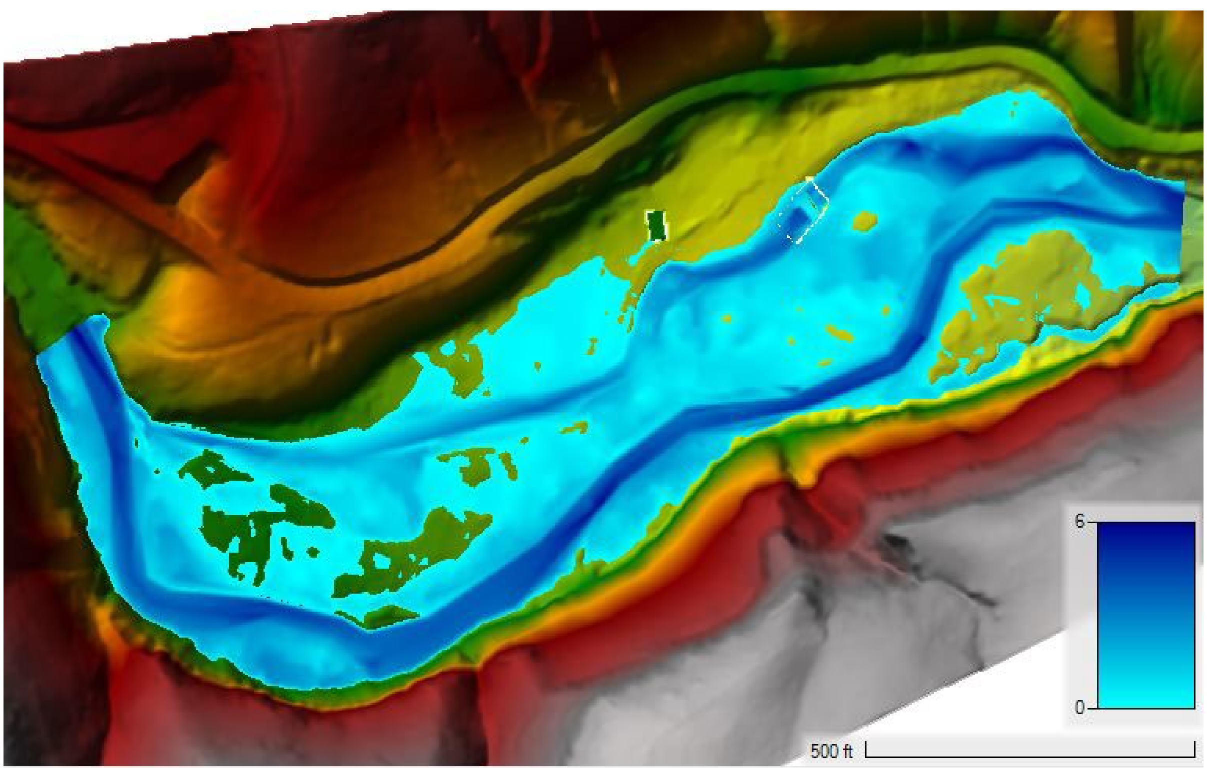

Figure 12. Existing Condition Maximum Depth at the 25-Year Flow Event

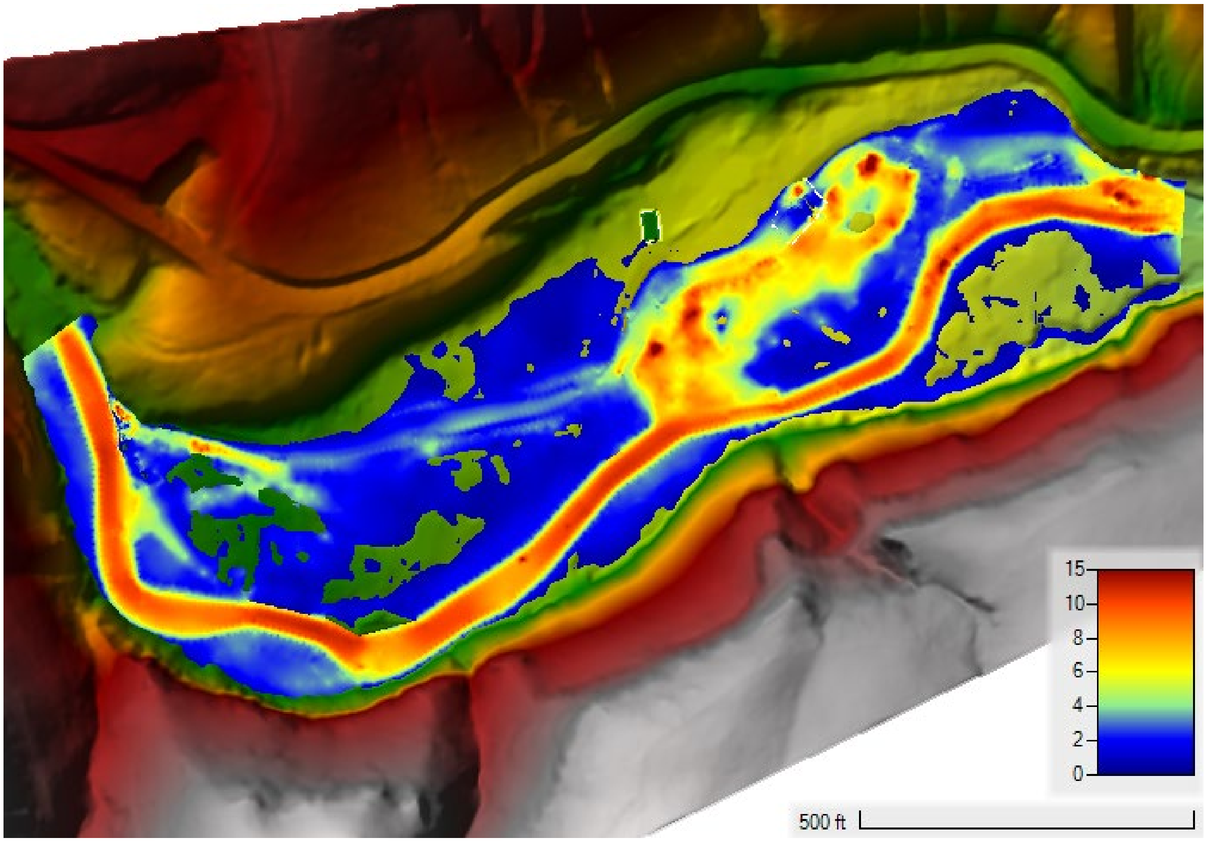

Figure 13. Existing Condition Maximum Velocity at the 25-Year Flow Event

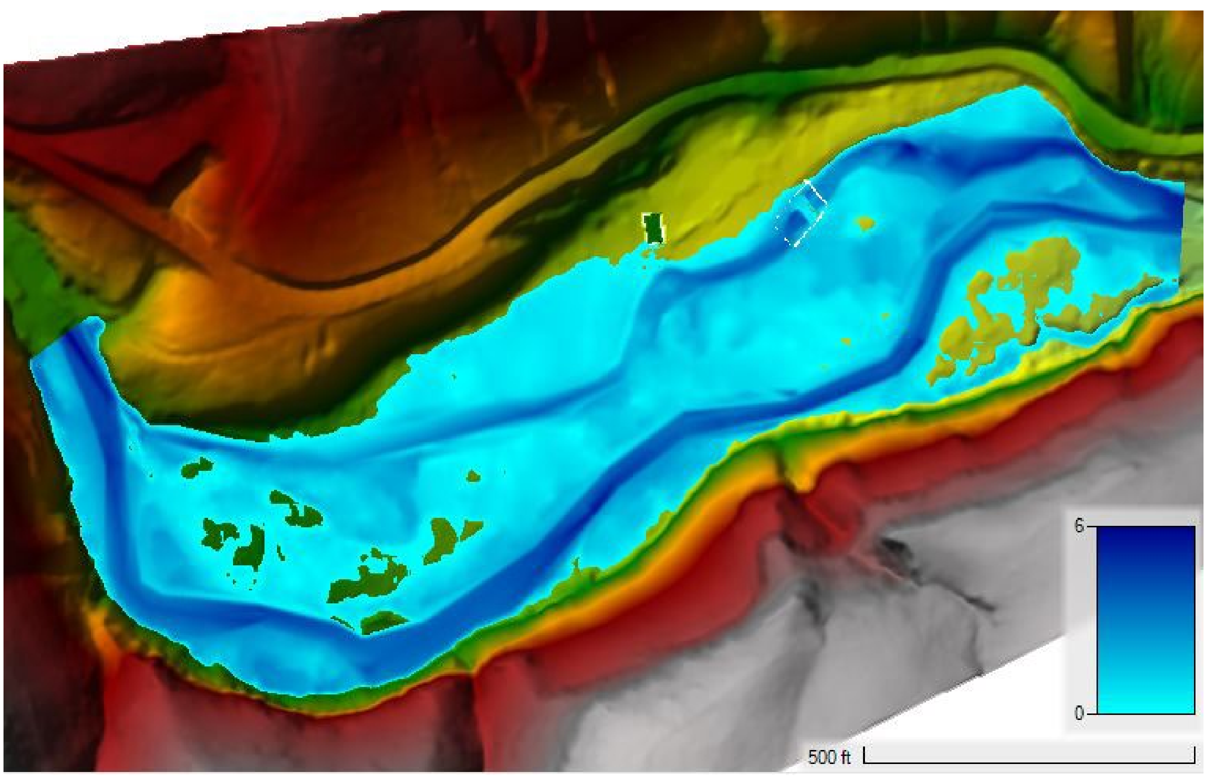

Figure 14. Existing Condition Maximum Depth at the 50-Year Flow Event

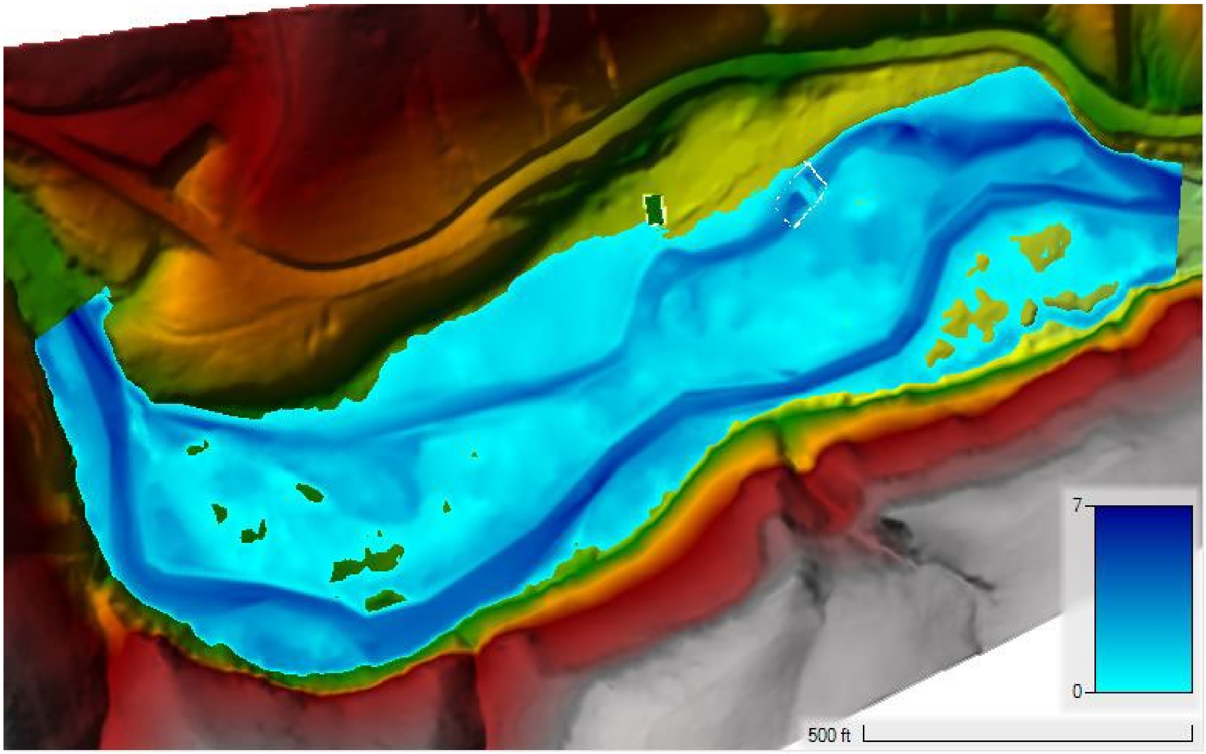

Figure 15. Existing Condition Maximum Depth at the 100-Year Flow Event

DESIGN CONDITION MODEL

A design condition model was also developed by modifying the existing condition terrain (topography) and manning's roughness according to the proposed design features.

A key component of the design condition model is simulating the large wood structures and their impact on water surface elevations within the project area. Large wood structures may be simulated in hydraulic models by modifying cross sections, adding blocked obstructions, or increasing roughness coefficients (Valverde 2014). Habitat and key structures were included in the design condition model by increasing the manning's n roughness coefficient for the approximate footprint of the structures.

The manning's n value for design condition habitat and key structures was estimated based on the work of Addy and Wilkinson (2019), which compiled empirical roughness data from available studies and graphed Manning's n values of naturally occurring large wood features versus channel reach slope normalized by drainage area. The Asotin Creek slope of 0.02 and a drainage area of 420 square kilometer resulted in an estimated manning's n value of 0.15 for naturally occurring large wood features (Table 6).

In addition, the rock crossing and jersey barriers were removed from the terrain. Running the model with just the removal of the jersey barriers didn't result in a significant inundation of the side channel at the 2-year flow event. The model was adjusted by removing a portion of the angular rock pile behind the jersey barriers until side channel inundation occurred at the 95% exceedance flow. The angular rock could be placed in the side channel to lessen the steep slope at the entrance to the side channel. While it is possible to increase the flow in the side channel at the 2-year flow event, the existing slope of the side channel entrance downstream of the rock plug is naturally steep and has the potential to develop a headcut. The elevation at the side channel inlet was chosen to as a balance to maximize side channel inundation while limiting risk of erosion. The model results showed that the increase in mannning's n roughness obtained from the addition of large wood at the side channel entrance is needed to reduce velocity and shear stress in this area. The Design Drawings show the design side channel profile and cross-sections.

The two-dimensional model results, topography, and field survey were used to determine the locations of large wood features. The large wood features were located to increase the floodplain inundation based on the hydraulic modeling results. In particular, Key Structure 1 was moved upstream, closer to the side channel entrance to increase flow directed into the side channel and Key Structure 5 was relocated to increase inundation in the existing high flow path on the southern side of the floodplain. In addition, log structures were removed from the downstream end of the project area where access is difficult, velocities were very high, and stability was difficult to achieve. The design condition model was also run with an increased number of large wood features and it was determined that the proposed design would need to include a significantly greater number of large wood features to increase the floodplain inundation at the 2-year event beyond what is the current design achieves. Figure 17 shows the maximum depth from HEC-RAS two-dimensional (2D) modeling at the 2-year flow for the project area.

As shown in Figures 12-15, the house in the project area receives some water in the existing condition starting at the 25-year flow event. A berm was added to the terrain and modified until model results showed no water reaching the home at the 100-year flow event (Figures 19-22). The Design Drawings show the dimensions of the berm.

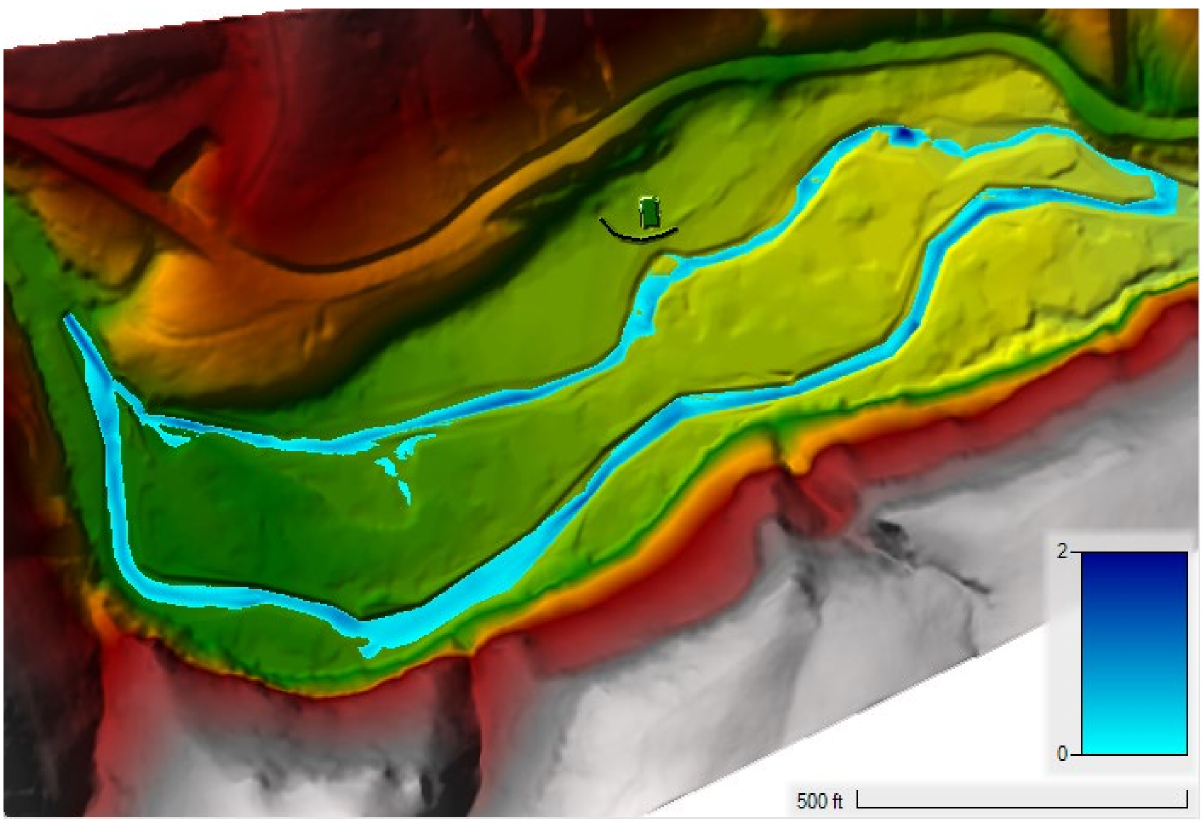

Figure 16. Design Condition Maximum Depth at the 95% Exceedance Flow

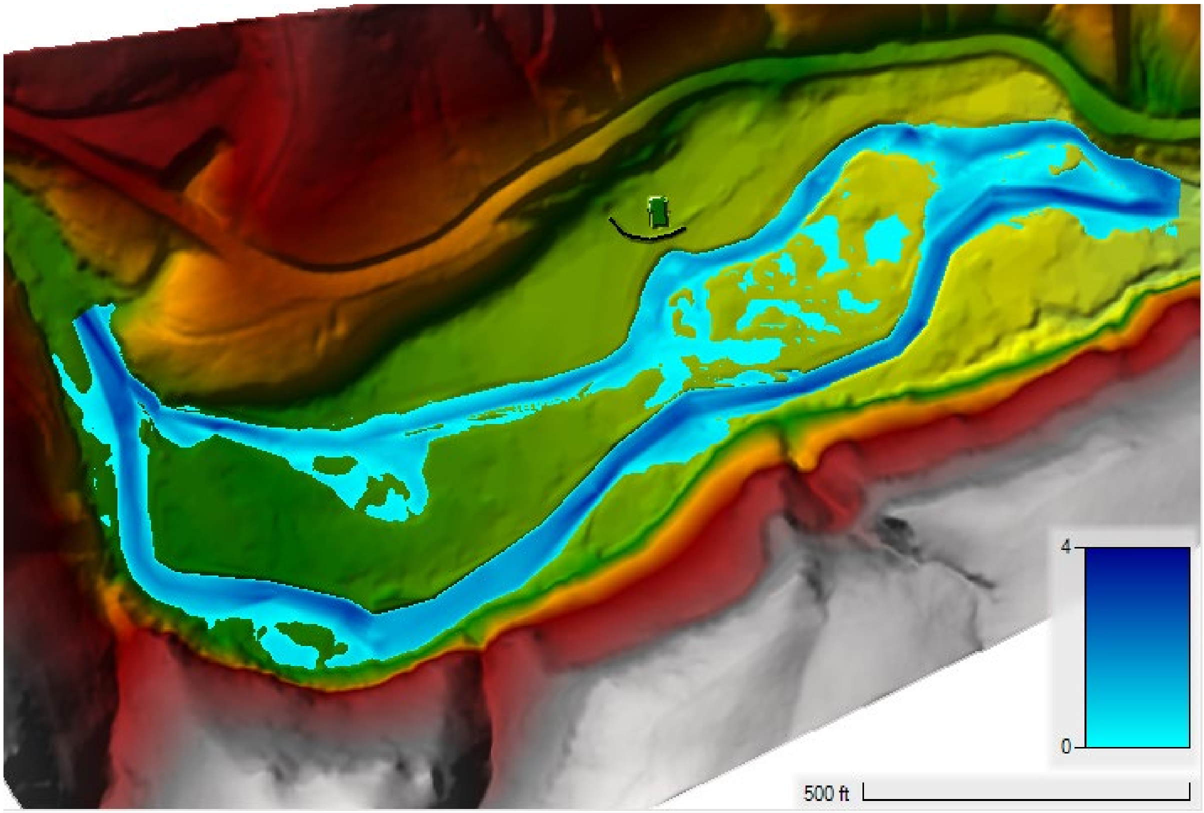

Figure 17. Design Condition Maximum Depth at the 2-Year Flow Event

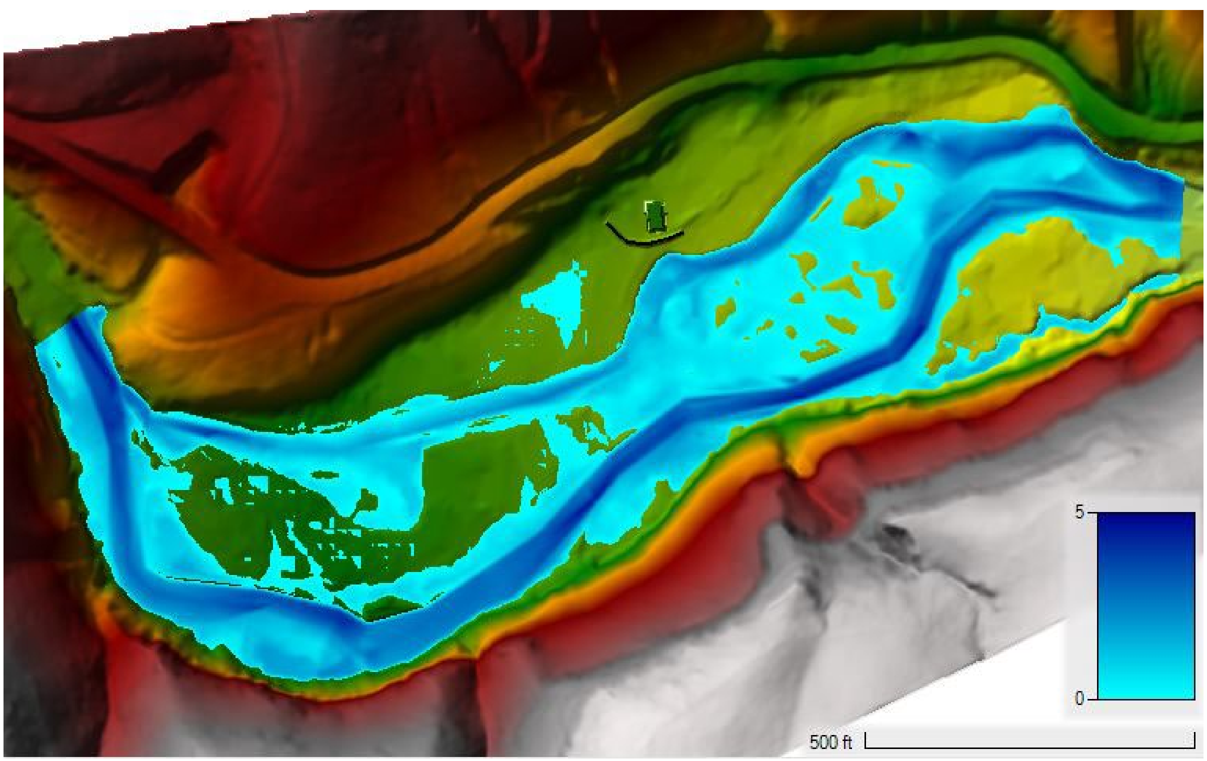

Figure 18. Design Condition Maximum Depth at the 10-Year Flow Event

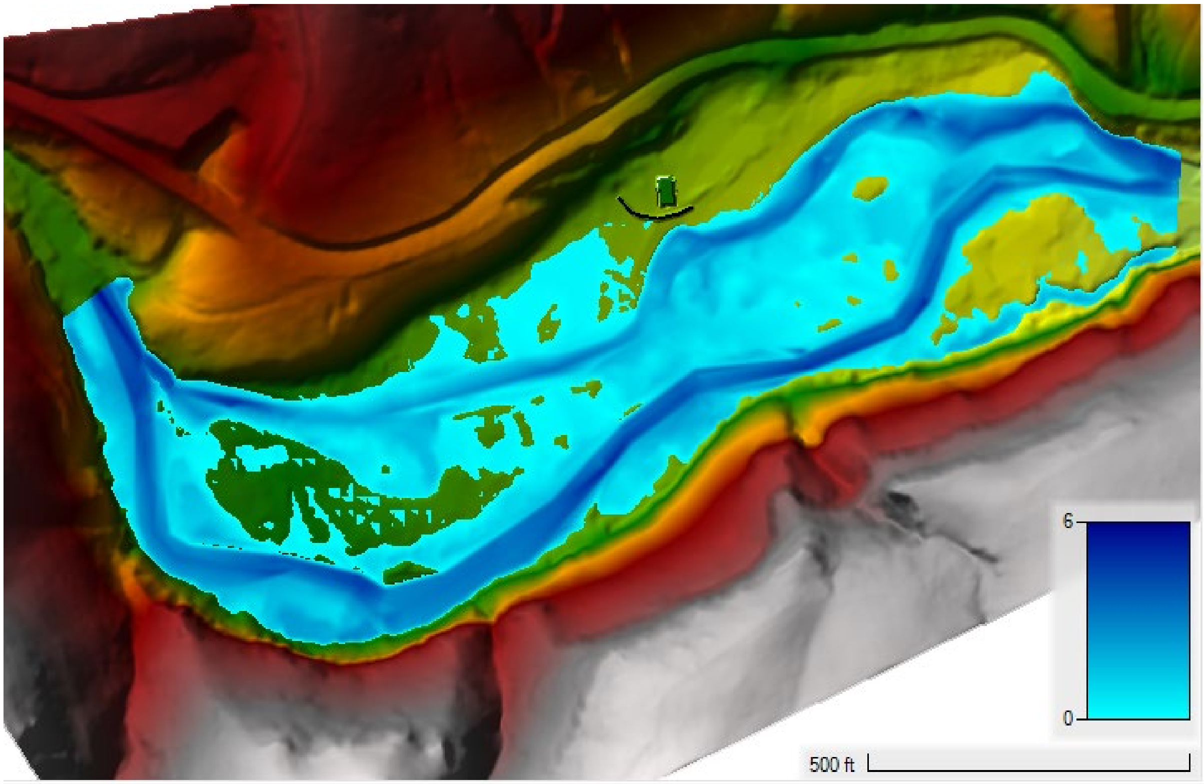

Figure 19. Design Condition Maximum Depth at the 25-Year Flow Event

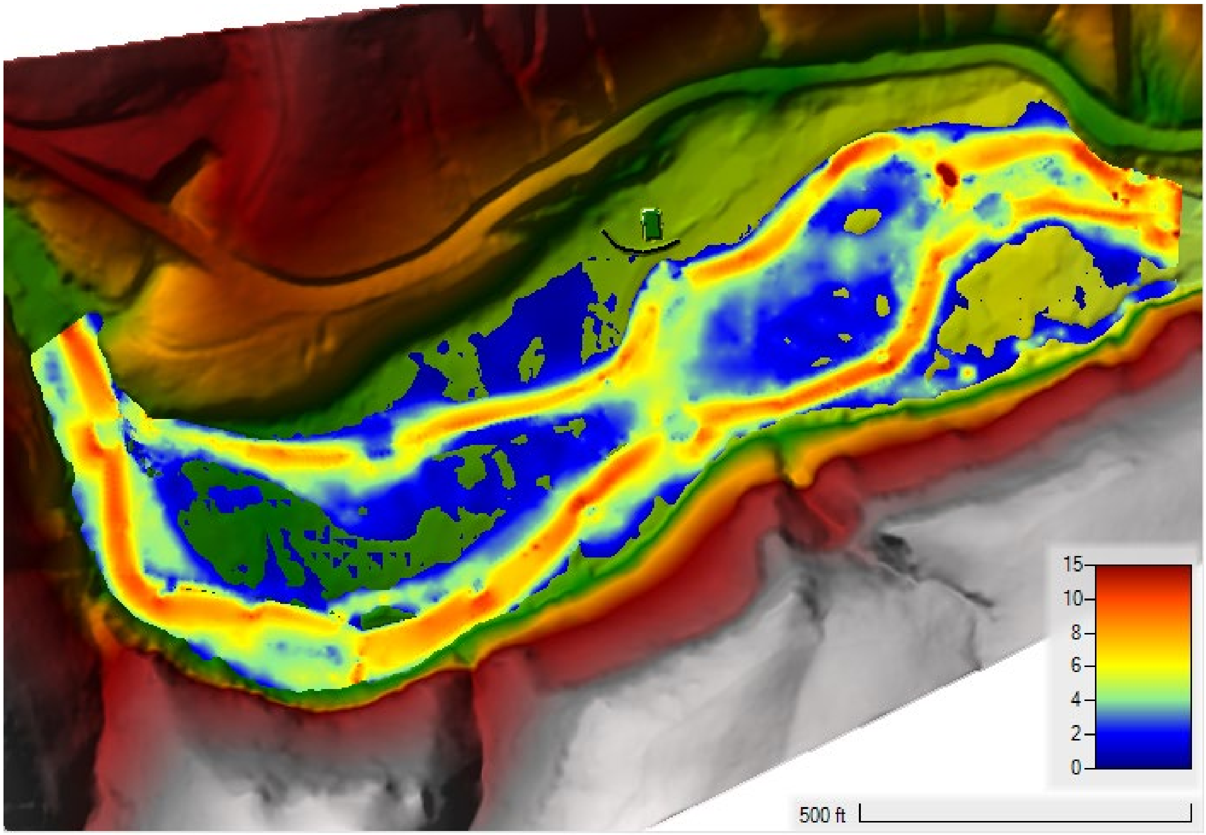

Figure 20. Design Condition Maximum Velocity at the 25-Year Flow Event

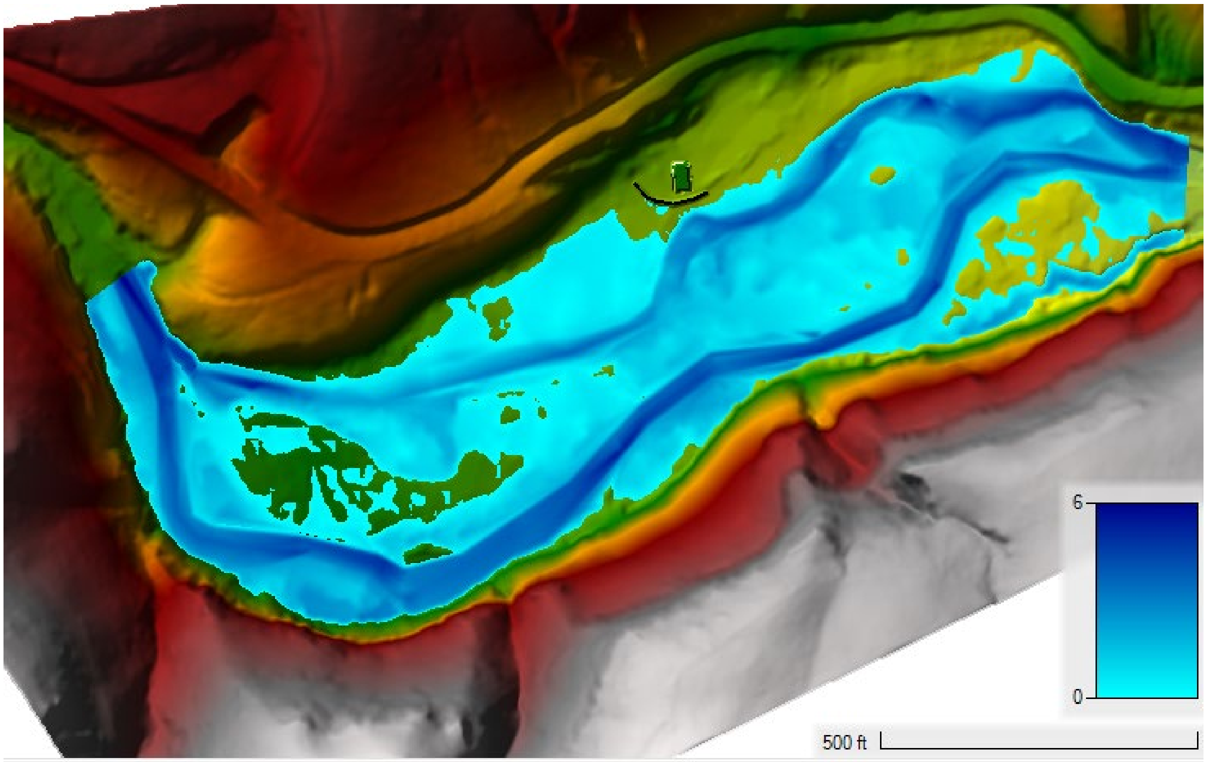

Figure 21. Design Condition Maximum Depth at the 50-Year Flow Event

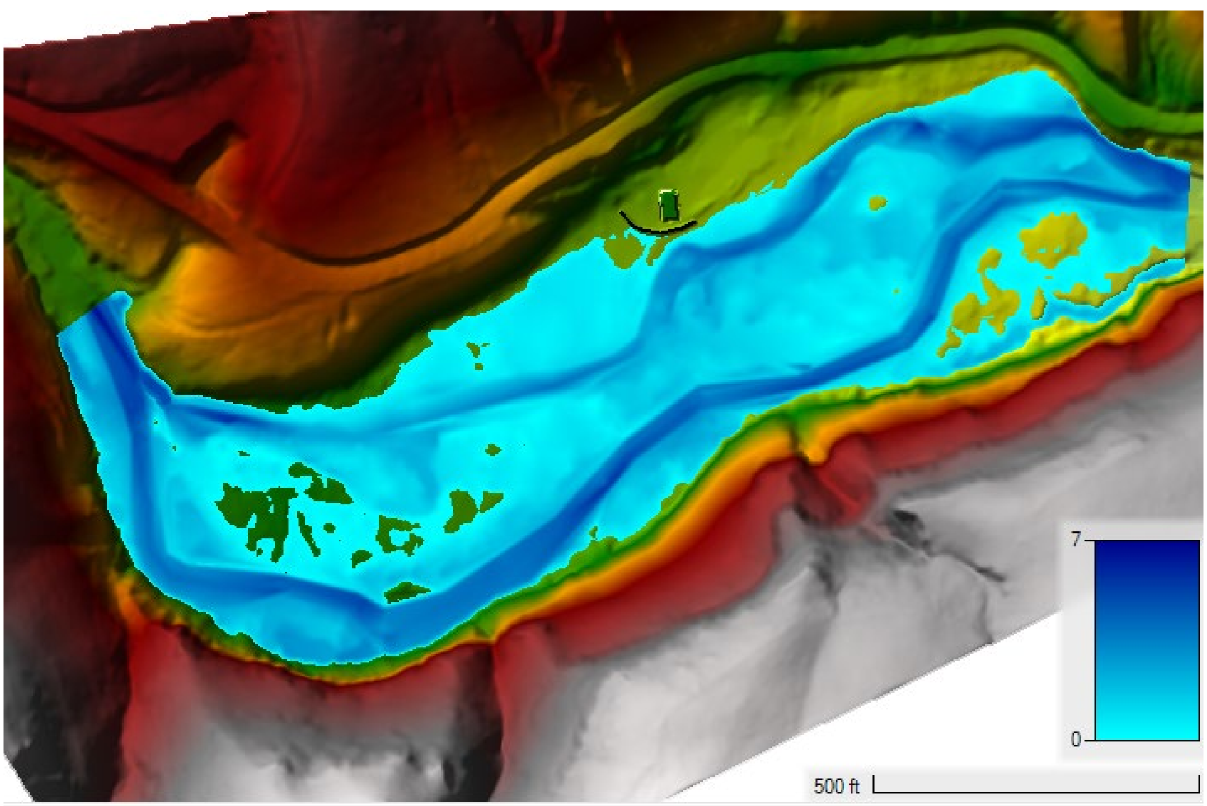

Figure 22. Design Condition Maximum Depth at the 100-Year Flow Event

3.6 STABILITY ANALYSES AND COMPUTATIONS FOR PROJECT ELEMENTS AND COMPREHENSIVE PROJECT PLAN.

Stability analyses and computations were completed for the berm, livestock crossings and ford, side channel reconnection, off-channel habitat area, log structures, and key structures. Design criteria and methods for these project elements are described below. The Drawings show the comprehensive project plan and the Special Provisions will describe the project elements.

SIDE CHANNEL RECONNECTION

The side channel reconnection removes obstructions at the entrance of an existing side channel to allow inundation at the 2-year flow event. This design incorporates reconnection of approximately 1,200 linear feet of side channel.

DESIGN CRITERIA

Design criteria for side channel reconnection are as follows:

1. At a minimum, the side channel is inundated at the 2-year flow event.
2. Erosion and risk of headcutting is limited to the extent possible at the side channel entrance.

DESIGN

Side channel inundation at the design flow was modeled using HEC-RAS 2D to verify side channel entrance elevation. Side channel entrance elevation was chosen so that inundation occurs at flows lower than the 2-year flow event. Jersey barriers and a portion of the angular rock piled behind the barriers will be removed to attain the design channel invert elevation and side channel inundation at the 95% exceedance flow. The angular rock could be placed in the side channel to lessen the steep slope at the entrance to the side channel. The elevation at the side channel inlet was chosen as a balance to maximize side channel inundation while limiting risk of erosion. In addition, HEC-RAS 2D modelling showed that increasing the roughness at the side channel invert was necessary to reduce water velocities and the resulting risk of headcutting. Velocity at the 25-year event is shown in Figures 13 and 20. The Design Drawings show the side channel planform, profile, and cross sections.

LOG STRUCTURES

This design includes 16 log habitat structures and nine log key structures for aquatic organism habitat and channel complexity to benefit adult steelhead and salmon accessing the stream for spawning and to shelter overwintering juvenile steelhead. There are two types of log structures; bank anchored habitat structures and channel spanning habitat structures lodged into both banks, referred to as key structures. The Design Drawings provide details and locations of log structures.

DESIGN CRITERIA

Design criteria for log habitat structures are as follows:

1. The structure withstands the 25-year design flood event without washing out.
2. The structure slows in-stream flows and promotes pool formation and gravel sorting.
3. The structure incorporates large wood and/or boulders to mimic historical natural conditions.
4. The structure meets the criteria under HIP IV category 2d, Install Habitat-Forming Natural Material Instream Structures (LW, Boulders, and Gravel).

DESIGN

Log structures are designed to have a natural appearance and engage at all flows with logs placed along the channel bottom. Backfill over anchor logs in the streambank will be placed in lifts and compacted with vibratory compaction equipment. No hardware will be used to anchor the habitat structures. All structures will be partially buried in the streambank or wedged between trees or log posts for stability.

Habitat structure types are made of LW and do not span the bankfull channel. They are bank-attached and deflect flow laterally. Their primary objectives are to trap and sort sediment, deflect flood flows in a desired direction to target bank or floodplain features, and provide quality habitat and refuge for salmonids during all flows. Root wads shall be placed on channel bed to ensure they are active at a range of flows, including low flows. Backfill over anchor logs buried in the streambank will be placed in lifts and compacted with vibratory compaction equipment. No hardware will be used to anchor the habitat structures. All structures will be partially buried in the banks or wedged between trees or posts for increased stability. Stability analysis results showed the need for partial burial (minimum of 75% of the anchor log length) of the habitat structures.

Key structure types are made of LW and built to span the bankfull channel. Their primary objective is to spread flows laterally during flood events. Key structures will be partially buried in the streambed or banks or wedged between live trees or log posts for stability. Smaller wood material will be wedged within the larger logs to decrease porosity of the structure. No hardware will be used to anchor the key structures. Stability analysis results showed the need for partial burial and ballast with log posts or trees of the key structures.

Design analysis for the wood habitat structures and key structures was completed using the Large Wood Structure Stability Analysis Tool (Rafferty 2013) and hydraulic results from the HEC-RAS 2D design condition at the Q25. Results of these stability analysis are provided in Appendix 7.3 and were used to determine minimum log burial depths and ballast conditions needed for stability. Stability analysis showed that in order for habitat structures to be stable at the Q25, the anchor log must be buried a minimum depth of 3.5 feet. Key structures anchor logs needed to be buried 4.0 feet below the ground surface, with a 2.5-foot diameter boulder ballast placed on top of the log within the trench. These conditions are specified in the design for anchor logs on the north bank. Site access makes crossing Asotin Creek with an excavator difficult in order to achieve these burial conditions of anchor logs on the south bank. To minimize disturbance and stream crossings, habitat structures are all specified as attached to the north bank where they can be buried without the need for stream crossings, and key structures were designed to wedge anchor logs between live trees or log posts where burial cannot be achieved on the south bank without crossing the creek. Stability calculations show that anchor logs would need to be pinned to log posts/ live trees in order achieve stability. Because the use of metal hardware for pinning is not desirable, log posts were specified at a length greater than the modelled height of the water surface elevation at the 25-year flood. It is possible that anchor logs of the key structures will float during the 25-year event without the use of pinning, but they should be held in place horizontally by the log posts/live trees that extend above the water surface elevation of the 25-year event. Key structure locations were selected for areas where live trees exist that can be used as ballast for anchor logs on the south bank.

Note that stability analyses are not conducted for slash or the PALS because they will be composed of wood pieces that have a diameter less than 24 inches and will be cut to lengths less than 75% of the length of the Asotin Creek Road bridge opening to ensure passage if material becomes mobilized.

The Design Drawings show habitat structure and key structure designs and locations. A field engineer is always on site while log structures are constructed.

OFF-CHANNEL HABITAT AREA

Off-channel areas typically have lower water velocities than the main channel and offer rearing habitat for juvenile anadromous species. They are areas that retain spring flows and support native wetland vegetation. This design includes 1 excavated off-channel area.

DESIGN CRITERIA

Design criteria for off-channel habitat areas are as follows:

1. Off-channel habitat areas profile have a concave shape.
2. Off-channel habitat areas are fed from the upstream end and can also backwater from the main channel.
3. Off-channel habitat areas provide low velocities at the 2-year flow event.

DESIGN

The off-channel habitat areas are inundated at the design flow. They capture hyporheic flows and provide rearing habitat and resting places for native fish. They are existing side channels that are inundated during the 2-year event modelled by HEC-RAS and will be planted more heavily to increase water retention. Key structures are placed downstream to increase inundation of these areas. The Design Drawings show the off-channel habitat area location.

BERM

A rock and soil berm protects the existing home located within the project site from flooding. 165 linear feet of rock/soil berm are included in the design. This project element is not funded by BPA.

DESIGN CRITERIA

Berm design criteria are as follows:

1. The structure prevents flooding of the home at the 100-year flow event.
2. The structure will withstand the 100-year design flood without washing out.

DESIGN

We positioned and sized the berm so no flood water reaches the home up to the 100-year flow event. The design incorporates an impermeable rock and clay core that restricts flow and discourages piping failure. The rock and clay material is compacted using vibratory compaction equipment to provide a cohesive connection between the surfaces. The top width and side slopes are designed to be gentle enough for horse traffic in the areas where the berm is located within pasture. The Design Drawings show the berm location and typical detail.

LIVESTOCK CROSSINGS & FORD

Livestock crossings provide a pathway to move cattle through the project area between grazing areas, and the rock ford provides a vehicle access point for the landowner. There are 2 livestock crossings and 1 rock ford as part of this design.

DESIGN CRITERIA

Livestock crossing and ford design criteria are as follows:

1. The crossings will not be constructed in active spawning areas.
3. The crossings will withstand the 25-year design flood without washing out.

DESIGN

The Design Drawings show the crossing substrate gradation, which was calculated using incipient motion calculations, rock sizing calculations, and a factor of safety of 1.2. It is expected that cobble up to 12 inches in diameter will mobilize at an estimated Q25 of 2050 cfs. A smaller rock size can be used to surface the crossing to provide a better surface for cattle and landowner access, but may not be stable at the 25-year design flow.

3.7 DESCRIPTION OF HOW PRECEDING TECHNICAL ANALYSIS HAS BEEN INCORPORATED INTO AND INTEGRATED WITH THE CONSTRUCTION – CONTRACT DOCUMENTATION.

The construction plan set has plan, profile, and section views identifying all design elements. Additional detail sheets have been added for those elements that require extra dimensions and material details. The Special Provisions and accompanying Washington Standard Specifications for Road, Bridge, and Municipal Construction cover each project element in sufficient detail to bid and construct the project. Further, the persons involved with the stream assessment, survey, and design of this project will be overseeing its construction, along with the ACCD. The Bid Schedule includes all items and unit quantities.

3.8 FOR PROJECTS THAT ADDRESS PROFILE DISCONTINUITIES (GRADE STABILIZATION, SMALL DAM AND STRUCTURE REMOVALS): A LONGITUDINAL PROFILE OF THE STREAM CHANNEL THALWEG FOR 20 CHANNEL WIDTHS UPSTREAM AND DOWNSTREAM OF THE STRUCTURE SHALL BE USED TO DETERMINE THE POTENTIAL FOR CHANNEL DEGRADATION.

N/A

3.9 FOR PROJECTS THAT ADDRESS PROFILE DISCONTINUITIES (GRADE STABILIZATION, SMALL DAM AND STRUCTURE REMOVALS): A MINIMUM OF THREE CROSS-SECTIONS – ONE DOWNSTREAM OF THE STRUCTURE, ONE THROUGH THE RESERVOIR AREA UPSTREAM OF THE STRUCTURE, AND ONE UPSTREAM OF THE RESERVOIR AREA OUTSIDE OF THE INFLUENCE OF THE STRUCTURE) TO CHARACTERIZE THE CHANNEL MORPHOLOGY AND QUANTIFY THE STORED SEDIMENT.

N/A

4.0 CONSTRUCTION – CONTRACT DOCUMENTATION.

4.1 INCORPORATION OF HIPIII GENERAL AND CONSTRUCTION CONSERVATION MEASURES

The Asotin Creek PA-06 Fish Habitat Restoration Project incorporates the following HIPIIV general and construction conservation measures:

1. Timing of In-Water Work
2. Erosion Control
3. Dust Abatement
4. Staging, Storage, and Stockpile Areas
5. Spill Prevention, Control, and Counter Measures
6. Turbidity Monitoring
7. Temporary Stream Crossings
8. Temporary Access Roads and Paths
9. Invasive Species Control

4.2 DESIGN – CONSTRUCTION PLAN SET INCLUDING BUT NOT LIMITED TO PLAN, PROFILE, SECTION AND DETAIL SHEETS THAT IDENTIFY ALL PROJECT ELEMENTS AND CONSTRUCTION ACTIVITIES OF SUFFICIENT DETAIL TO GOVERN COMPETENT EXECUTION OF PROJECT BIDDING AND IMPLEMENTATION.

The design/construction plan set accompanies this report.

4.3 LIST OF ALL PROPOSED PROJECT MATERIALS AND QUANTITIES.

This material quantities lists are provided in Sheet S8 of the plans.

4.4 DESCRIPTION OF BEST MANAGEMENT PRACTICES THAT WILL BE IMPLEMENTED AND IMPLEMENTATION RESOURCE PLANS INCLUDING:

1. SITE ACCESS STAGING AND SEQUENCING PLAN.

The Design Drawings show site access and staging and suggested work sequencing. The Mobilization bid item of the Special Provisions will cover site access and staging areas.

2. WORK AREA ISOLATION AND DEWATERING PLAN.

Dewatering will not be needed for this project because the only in water work will be a limited number of creek crossings. The Temporary Construction Access Road and Crossing bid item of the Special Provisions will cover this work. This project does not need a fish salvage plan because ESA-listed species are not anticipated to be near the work area during the construction window and no known spawning habitats are nearby. If fish salvage is needed, the Sponsor will be responsible for coordinating fish salvage according the HIPIV guidelines and the General Conservation Measures.

3. EROSION AND POLLUTION CONTROL PLAN.

The Contractor will be required to follow the HIPIV General Conservation Measures. HIPIV language is included in the design drawings.

4. SITE RECLAMATION AND RESTORATION PLAN.

The Design Drawings show the Site Reclamation and Restoration Plan on the Revegetation Plan sheet and Floodplain Roughness sheet. Additional Hydroseeding detail, including a list of planting species and quantities, is located in Section 5 Bid Item 17 of the Special Provisions.

5. LIST PROPOSED EQUIPMENT AND FUELS MANAGEMENT PLAN.

All proposed equipment will be approved by the Owner prior to entrance on the site. The Contractor will be required to follow the HIPIV General Conservation Measures. HIPIV language is included in the design drawings.

4.5 CALENDAR SCHEDULE FOR CONSTRUCTION/IMPLEMENTATION PROCEDURES.

Construction is tentatively scheduled to begin as soon as floodplain conditions are dry. In-water work window is estimated to begin on July 15th and extend to September 15th. Construction completion will be no later than the end of October.

4.6 SITE OR PROJECT SPECIFIC MONITORING TO SUPPORT POLLUTION PREVENTION AND/OR ABATEMENT.

The Project Sponsor and/or an Sponsor's representative will be onsite during construction to monitor construction activities and equipment. The Contractor will be required to follow HIPIV General Conservation Measures.

5.0 MONITORING AND ADAPTIVE MANAGEMENT PLAN

The Monitoring and Adaptive Management Plan is attached to this report.

6.0 REFERENCES

Addy and Wilkinson. 2019. Representing natural and artificial in-channel large wood in numerical hydraulic and hydrological models. https://wires.onlinelibrary.wiley.com/doi/full/10.1002/wat2.1389.

Alta Science & Engineering, Inc. 2021. 15% Design Alternatives Memorandum. Prepared for Asotin County Conservation District, Clarkston, Washington.

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Bennett, S., Camp, R., Hill, A., Wheaton, J.M., Bouwes, N., O'Brien, G., Floyd, B., and Drury, T. 2018b. Asotin County Watershed Assessment: Technical Document and Appendices. Prepared for Asotin County Conservation District, Clarkston, Washington.

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Mayer, K., Schuck, M., Hathaway, D. 2008. Assess Salmonids in the Asotin Creek Watershed- 2007 annual Report. Prepared for: Bonneville Power Administration.

Rafferty, Michael, 2013. *Development of a Computational Design Tool for Evaluating the Stability of Large Wood Structures Proposed for Stream Enhancement.* Colorado State University.

Snake River Salmon Recovery Board. 2011. Snake River Salmon Recovery Plan for SE Washington.

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Valverde, Rachelle S. 2014. Roughness and Geometry Effects of Engineered Log Jams on 1-D Flow Characteristics. https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/gh93h224f?locale=it.

7.0 APPENDICES

7.1 PROJECT PLAN SHEETS

The project plan sheets accompany this report.

7.2 CONCEPT PLANTING PLAN

The revegetation plan is included in the design drawings.

7.3 OTHER SUPPORTING REPORTS

Large wood structure stability analyses are attached.

7.4 HIP REVIEW COMMENTS AND RESPONSES

See attached for HIP review comments and responses.

Asotin Creek PA-06 Fish Habitat Restoration

Habitat Structure Stability Analysis

TABLE OF CONTENTS

Date of Last Revision: November 3, 2022

Designer:
Jessica Dzara, PE

Reviewed by:
Susan Firor, PE

Reference for Design Method of Large Wood Structures:
NRCS NEH 654 Technical Supplement 14J (2007)

Reference for Companion Paper:
Rafferty, M. (2013). *Development of a Computational Design Tool for Evaluating the Stability of Large Wood Structures Proposed for Stream Enhancement*. Masters of Science Thesis, Colorado State University.

Large Wood Structure Stability Analysis Spreadsheet was developed by Michael Rafferty, P.E.
Version 1.0

Asotin Creek PA-06 Fish Habitat Restoration
Factors of Safety and Design Constants

Spreadsheet developed by
Michael Rafferty, P.E.

Symbol	Description	Value
FS_V	Factor of Safety for Vertical Force Balance	**1.50**
FS_H	Factor of Safety for Horizontal Force Balance	**2.00**
FS_M	Factor of Safety for Moment Force Balance	**2.00**

Symbol	Description	Units	Value
C_{Lrock}	Coefficient of lift for submerged boulder (D'Aoust, 2000)	-	0.17
C_{Drock}	Coefficient of drag for submerged boulder (Schultz, 1954)	-	0.85
g	Gravitational acceleration constant	ft/s^2	32.174
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-	3.00
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-	1.50
SG_{rock}	Specific gravity of quartz particles	-	2.65
γ_{rock}	Dry unit weight of boulders	lb/ft^3	165.0
γ_w	Specific weight of water at 50ºF	lb/ft^3	62.40
η	Rootwad porosity from NRCS Tech Note 15 (2001)	-	0.20
ν	Kinematic viscosity of water at 50ºF	ft/s^2	1.41E-05

Asotin Creek PA-06 Fish Habitat Restoration
Hydrologic and Hydraulic Inputs

Spreadsheet developed by
Michael Rafferty, P.E.

Average Return Interval (ARI) of Design Discharge: 25 yr

Site ID	Proposed Station	Design Discharge, Q_{des} (cfs)	Maximum Depth, d_w (ft)	Average Velocity, u_{avg} (ft/s)	Bankfull Width, W_{BF} (ft)	Wetted Area, A_W (ft^2)	Radius of Curvature, R_c (ft)
PA-06	4+50	2,050	3.50	10.00	35.0	154	75

Asotin Creek PA-06 Fish Habitat Restora
Stream Bed Substrate Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Site ID	Proposed Station	Stream bed D_{50} (mm)	Stream Bed Substrate Grain Size Class	Bed Soil Class	Dry Unit Weight[1], γ_{bed} (lb/ft^3)	Buoyant Unit Weight, γ'_{bed} (lb/ft^3)	Friction Angle, ϕ_{bed} (deg)
PA-06	4+50	**150.00**	Large Cobble	4	140.6	87.6	42

Source: Compiled from Julien (2010) and Shen and Julien (1993); soil classes from NRCS Table TS14E–2 Soil classification

[1] γ_{bed} (kg/m^3) = 1,600 + 300 log D_{50} (mm) (from Julien 2010)

1 kg/m^3 = 0.062 1 lb/ft^3

Asotin Creek PA-06 Fish Habitat Restoration

Spreadsheet developed by
Michael Rafferty, P.E.

Large Wood Properties

Project Location: West Coast

Timber Unit Weights			Air-dried[1] γ_{Td} (lb/ft^3)	Green[2] γ_{Tgr} (lb/ft^3)
Selected Species	**Common Name**	**Scientific Name**		
Tree Type #1:	**Pine, Ponderosa**	Pinus ponderosa	28.0	45.0
Tree Type #2:				
Tree Type #3:				
Tree Type #4:				
Tree Type #5:				
Tree Type #6:				
Tree Type #7:				
Tree Type #8:				
Tree Type #9:				
Tree Type #10:				

[1] **Air-dried unit weight,** γ_{Td} = Average unit weight of wood after exposure to air on a 12% moisture content volume basis. Air-dried unit weight is used in the force balance calculations for the portion of wood that is above the proposed thalweg elevation (assuming unsaturated conditions).

[2] **Green unit weight,** γ_{Tgr} = Average unit weight of freshly sawn wood when the cell walls are completely saturated with water. Green unit weight is used in the force balance calculations as a conservative estimate of the unit weight for the portion of wood that is below the proposed thalweg elevation (assuming saturated conditions). For comparison, Thevenet, Citterio, & Piegay (1998) determined wood unit weight typically increases by more than 100% after less than 24 hours exposure to water.

Source for timber unit weights:

U.S. Department of Agriculture, U.S. Forest Service. (2009) Specific Gravity and Other Properties of Wood and Bark for 156 Tree Species Found in North America. Research Note NRS-38. Table 1A.

Asotin Creek PA-06 Fish Habitat Restoration

Spreadsheet developed by
Michael Rafferty, P.E.

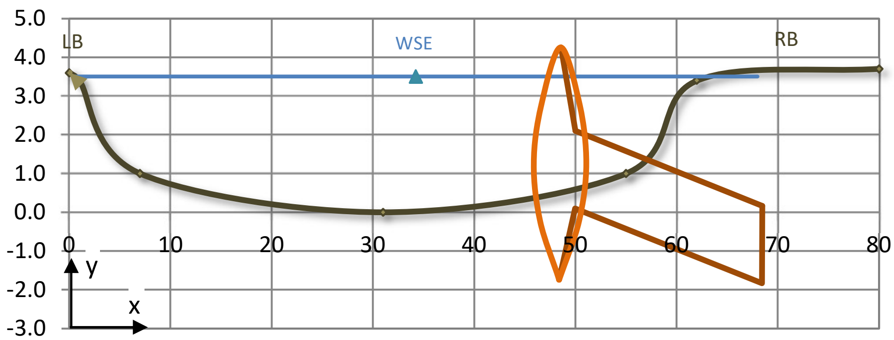
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
PA-06	Rootwad	Left bank	Inside	4+50	3.50	2.14	10.00

Multi-Log Structures	Layer	Log ID
	Key Log	HS1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	0.0	3.60
Top LB	1.0	3.40
Toe LB	7.0	1.00
Thalweg	31.0	0.00
Toe RB	55.0	1.00
Top RB	62.0	3.40
Fldpln RB	80.0	3.70

Proposed Cross-Section and Structure Geometry (Looking D/S)

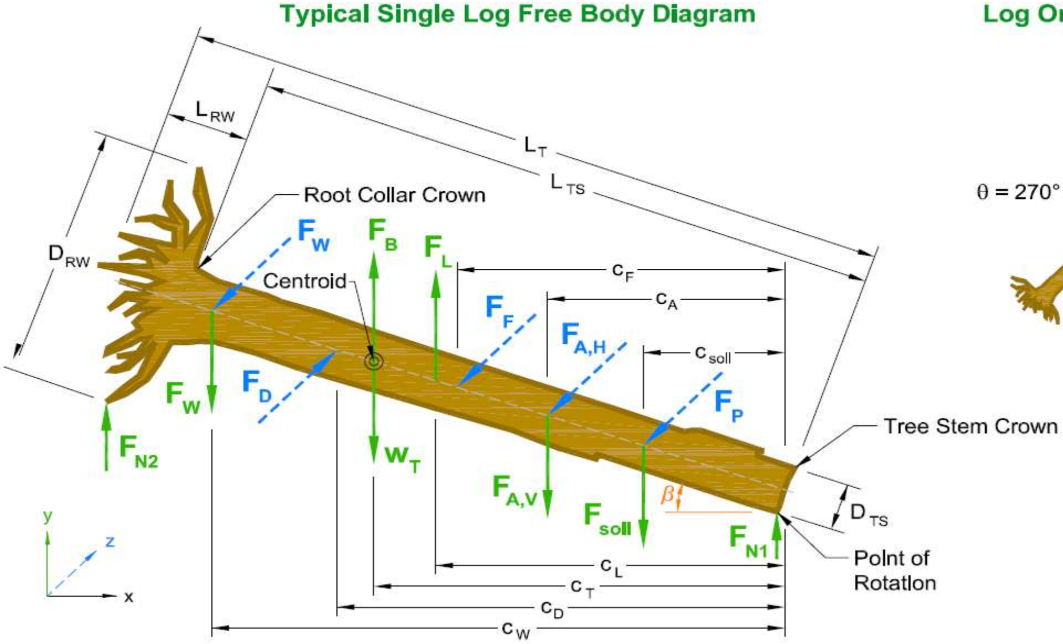


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Pine, Ponderosa	Yes	40.0	2.00	3.00	6.00	28.0	45.0

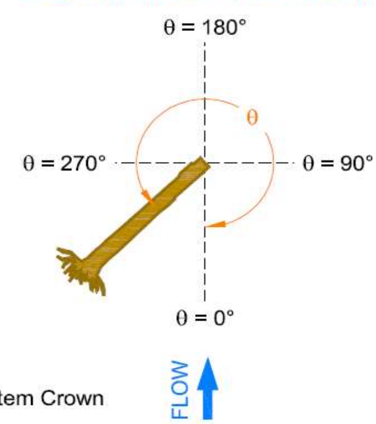
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	330.0	-3.0	Root collar: Crown	50.00	2.10	-1.83	4.25	23.97

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Large Cobble	140.6	87.6	42.0	4	0.00	0.00	0.00
Bank	Gravel/cobble	137.0	85.3	41.0	4	24.41	3.34	2.16

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.7	0.7	19	0
↓WS↑Thw	66.0	26.4	92.3	2,581	5,762
↓Thalweg	50.3	5.6	55.9	2,516	3,488
Total	116.2	32.7	148.9	5,116	9,250

Lift Force

C_{LT}	0.00
F_L (lbf)	0

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	105.8	105.8	9,025
Total	0.0	105.8	105.8	9,025

Vertical Force Balance

F_B (lbf)	9,250	↑
F_L (lbf)	0	
W_T (lbf)	5,116	↓
F_{soil} (lbf)	9,025	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	4,891	↓
FS_V	1.53	✓

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.16	1.25	1.10	0.05	1.63	3,788

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	5.04	0	15.10	0.90	1,583
Bank	4.81	21,728	26.90	0.87	2,723
Total	-	21,728	42.00	-	4,306

Horizontal Force Balance

F_D (lbf)	3,788	→
F_P (lbf)	21,728	←
F_F (lbf)	4,306	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	22,246	←
FS_H	6.87	✓

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
22.5	0.0	32.3	22.5	12.2	20.0	16.3

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	330,382	
M_r (lbf)	761,753	
FS_M	2.31	✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
Above								0	0
Above								0	0
								0	0

Interaction Forces with Adjacent Logs

Applied Forces from other Logs

Log ID	Position	Link	c_{WI} (ft)	$F_{W,V}$ (lbf)	$F_{W,H}$ (lbf)	$F_{W,V}$ (lbf)	$F_{W,H}$ (lbf)
						0	0
						0	0
						0	0
						0	0

Asotin Creek PA-06 Fish Habitat Restoration
Notation, Units, and List of Symbols

Notation

Symbol	Description	Unit
A_W	Wetted area of channel at design discharge	ft^2
A_{Tp}	Projected area of wood in plane perpendicular to flow	ft^2
c_D	Centroid of the drag force along log axis	ft
c_{Am}	Centroid of a mechanical anchor along log axis	ft
c_{Ar}	Centroid of a ballast boulder along log axis	ft
c_{Asoil}	Centroid of the added ballast soil along log axis	ft
$c_{F\&N}$	Centroid of friction and normal forces along log axis	ft
c_L	Centroid of the lift force along log axis	ft
c_P	Centroid of the passive soil force along log axis	ft
c_{soil}	Centroid of the vertical soil forces along log axis	ft
$c_{T,B}$	Centroid of the buoyancy force along log axis	ft
$c_{T,W}$	Centroid of the log volume along log axis	ft
c_{WI}	Centroid of a wood interaction force along log axis	ft
C_{Lrock}	Coefficient of lift for submerged boulder	-
C_{LT}	Effective coefficient of lift for submerged tree	-
C_{Di}	Base coefficient of drag for tree, before adjustments	-
C_D^*	Effective coefficient of drag for submerged tree	-
C_{Di}	Base coefficient of drag for tree, before adjustments	-
C_W	Wave drag coefficient of submerged tree	-
$d_{b,avg}$	Average buried depth of log	ft
$d_{b,max}$	Maximum buried depth of log	ft
d_w	Maximum flow depth at design discharge in reach	ft
D_{50}	Median grain size in millimeters (SI units)	mm
D_r	Equivalent diameter of boulder	ft
D_{RW}	Assumed diameter of rootwad	ft
D_{TS}	Nominal diameter of tree stem (DBH)	ft
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-
e	Void ratio of soils	-
$F_{A,H}$	Total horizontal load capacity of anchor techniques	lbf
$F_{A,HP}$	Passive soil pressure applied to log from soil ballast	lbf
$F_{A,Hr}$	Horizontal resisting force on log from boulder	lbf
F_{Am}	Load capacity of mechanical anchor	lbf
$F_{A,V}$	Total vertical load capacity of anchor techniques	lbf
$F_{A,Vr}$	Vertical resisting force on log from boulder	lbf
$F_{A,Vsoil}$	Vertical soil loading on log from added ballast soil	lbf
F_B	Buoyant force applied to log	lbf
F_D	Drag forces applied to log	lbf
$F_{D,r}$	Drag forces applied to boulder	lbf
F_F	Friction force applied to log	lbf
F_H	Resultant horizontal force applied to log	lbf
F_L	Lift force applied to log	lbf
$F_{L,r}$	Lift force applied to boulder	lbf
F_P	Passive soil pressure force applied to log	lbf
F_{soil}	Vertical soil loading on log	lbf
$F_{W,H}$	Horizontal forces from interactions with other logs	lbf
$F_{W,V}$	Vertical forces from interactions with other logs	lbf

Notation (continued)

Symbol	Description	Unit
F_V	Resultant vertical force applied to log	lbf
Fr_L	Log Froude number	-
FS_V	Factor of Safety for Vertical Force Balance	-
FS_H	Factor of Safety for Horizontal Force Balance	-
FS_M	Factor of Safety for Moment Force Balance	-
g	Gravitational acceleration constant	ft/s^2
K_P	Coefficient of Passive Earth Pressure	-
$L_{T,em}$	Total embedded length of log	ft
L_{RW}	Assumed length of rootwad	ft
L_T	Total length of tree (including rootwad)	ft
L_{Tf}	Length of log in contact with bed or banks	ft
L_{TS}	Length of tree stem (not including rootwad)	ft
$L_{TS,ex}$	Exposed length of tree stem	ft
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-
M_d	Driving moment about embedded tip	lbf
M_r	Driving moment about embedded tip	lbf
N	Blow count of standard penetration test	-
p_o	Porosity of soil volume	-
Q_{des}	Design discharge	cfs
R	Radius	ft
R_c	Radius of curvature at channel centerline	ft
SG_r	Specific gravity of quartz particles	-
SG_T	Specific gravity of tree	-
u_{avg}	Average velocity of cross section in reach	ft/s
u_{des}	Design velocity	ft/s
u_m	Adjusted velocity at outer meander bend	ft/s
V_{dry}	Volume of soils above stage level of design flow	ft^3
V_{sat}	Volume of soils below stage level of design flow	ft^3
V_{soil}	Total volume of soils over log	ft^3
V_{RW}	Volume of rootwad	ft^3
V_S	Volume of solids in soil (void ratio calculation)	ft^3
V_T	Total volume of log	ft^3
V_{TS}	Total volume of tree	ft^3
V_V	Volume of voids in soil	ft^3
V_{Adry}	Volume of ballast above stage of design flow	ft^3
V_{Awet}	Volume of ballast below stage of design flow	ft^3
$V_{r,dry}$	Volume of boulder above stage of design flow	ft^3
$V_{r,wet}$	Volume of boulder below stage of design flow	ft^3
W_{BF}	Bankfull width at structure site	ft
W_r	Effective weight of boulder	lbf
W_T	Total log weight	lbf
x	Horizontal coordinate (distance)	ft
y	Vertical coordinate (elevation)	ft
$y_{T,max}$	Minimum elevation of log	ft
$y_{T,min}$	Maximum elevation of log	ft

Greek Symbols

Symbol	Description	Unit
β	Tilt angle from stem tip to vertical	deg
γ_{bank}	Dry specific weight of bank soils	lb/ft^3
$\gamma_{bank,sat}$	Saturated unit weight of bank soils	lb/ft^3
γ'_{bank}	Effective buoyant unit weight of bank soils	lb/ft^3
γ_{bed}	Dry specific weight of stream bed substrate	lb/ft^3
γ'_{bed}	Effective buoyant unit weight of stream bed substrate	lb/ft^3
γ_{rock}	Dry unit weight of boulders	lb/ft^3
γ_s	Dry specific weight of soil	lb/ft^3
γ'_s	Effective buoyant unit weight of soil	lb/ft^3
γ_{Td}	Air-dried unit weight of tree (12% MC basis)	lb/ft^3
γ_{Tgr}	Green unit weight of tree	lb/ft^3
γ_w	Specific weight of water at 50ºF	lb/ft^3
η	Rootwad porosity	-
θ	Rootwad (or large end of log) orientation to flow	deg
μ	Coefficient of friction	-
ν	Kinematic viscosity of water at 50ºF	ft/s^2
Σ	Sum of forces	-
ϕ_{bank}	Internal friction angle of bank soils	deg
ϕ_{bed}	Internal friction angle of stream bed substrate	deg

Units

Notation	Description
cfs	Cubic feet per second
ft	Feet
lb	Pound
lbf	Pounds force
kg	Kilograms
m	Meters
mm	Millimeters
s	Seconds
yr	Year

Abbreviations

Notation	Description
ARI	Average return interval
Avg	Average
DBH	Diameter at breast height
deg	Degrees
Dia	Diameter
Dist	Distance
D/S	Downstream
ELJ	Engineered log jam
Ex	Example
Fldpln	Floodplain
H&H	Hydrologic and hydraulic
ID	Identification
i.e.	That is
LB	Left bank
LW	Large wood
Max	Maximum
MC	Moisture content
Min	Minimum
ML	Multi-log
SL	Single log
N/A	Not applicable
no	Number
Pt	Point
rad	Radians
RB	Right bank
RW	Rootwad
SL	Single log
Thw	Thalweg (lowest elevation in channel bed)
Typ	Typical
U.S.	United States
WS	Water surface
WSE	Water surface elevation
↑	Above
↓	Below

Asotin Creek PA-06 Fish Habitat Restoration

Key Structure Stability Analysis

TABLE OF CONTENTS

Date of Last Revision: November 18, 2022

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Reviewed by:
Susan Firor, PE

Reference for Design Method of Large Wood Structures:
NRCS NEH 654 Technical Supplement 14J (2007)

Reference for Companion Paper:
Rafferty, M. (2013). ***Development of a Computational Design Tool for Evaluating the Stability of Large Wood Structures Proposed for Stream Enhancement*****. Masters of Science Thesis, Colorado State University.**

Large Wood Structure Stability Analysis Spreadsheet was developed by Michael Rafferty, P.E.
Version 1.0

Asotin Creek PA-06 Fish Habitat Restoration
Factors of Safety and Design Constants

Spreadsheet developed by
Michael Rafferty, P.E.

Symbol	Description	Value
FS_V	Factor of Safety for Vertical Force Balance	**1.50**
FS_H	Factor of Safety for Horizontal Force Balance	**2.00**
FS_M	Factor of Safety for Moment Force Balance	**2.00**

Symbol	Description	Units	Value
C_{Lrock}	Coefficient of lift for submerged boulder (D'Aoust, 2000)	-	0.17
C_{Drock}	Coefficient of drag for submerged boulder (Schultz, 1954)	-	0.85
g	Gravitational acceleration constant	ft/s^2	32.174
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-	3.00
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-	1.50
SG_{rock}	Specific gravity of quartz particles	-	2.65
γ_{rock}	Dry unit weight of boulders	lb/ft^3	165.0
γ_w	Specific weight of water at 50ºF	lb/ft^3	62.40
η	Rootwad porosity from NRCS Tech Note 15 (2001)	-	0.20
ν	Kinematic viscosity of water at 50ºF	ft/s^2	1.41E-05

Asotin Creek PA-06 Fish Habitat Restoration
Hydrologic and Hydraulic Inputs

Spreadsheet developed by
Michael Rafferty, P.E.

Average Return Interval (ARI) of Design Discharge: 25 yr

Site ID	Proposed Station	Design Discharge, Q_{des} (cfs)	Maximum Depth, d_w (ft)	Average Velocity, u_{avg} (ft/s)	Bankfull Width, W_{BF} (ft)	Wetted Area, A_W (ft^2)	Radius of Curvature, R_c (ft)
PA-06	2+00	2,050	4.50	10.00	40.0	154	500

Asotin Creek PA-06 Fish Habitat Restora
Stream Bed Substrate Properties

Spreadsheet developed by
Michael Rafferty, P.E.

Site ID	Proposed Station	Stream bed D_{50} (mm)	Stream Bed Substrate Grain Size Class	Bed Soil Class	Dry Unit Weight[1], γ_{bed} (lb/ft^3)	Buoyant Unit Weight, γ'_{bed} (lb/ft^3)	Friction Angle, ϕ_{bed} (deg)
PA-06	2+00	**150.00**	Large Cobble	4	140.6	87.6	42

Source: Compiled from Julien (2010) and Shen and Julien (1993); soil classes from NRCS Table TS14E–2 Soil classification

[1] γ_{bed} (kg/m^3) = 1,600 + 300 log D_{50} (mm) (from Julien 2010)

Asotin Creek PA-06 Fish Habitat Restoration

Spreadsheet developed by
Michael Rafferty, P.E.

Large Wood Properties

Project Location: West Coast

Timber Unit Weights			Air-dried[1] γ_{Td} (lb/ft^3)	Green[2] γ_{Tgr} (lb/ft^3)
Selected Species	**Common Name**	**Scientific Name**		
Tree Type #1:	Pine, Ponderosa	Pinus ponderosa	28.0	45.0
Tree Type #2:				
Tree Type #3:				
Tree Type #4:				
Tree Type #5:				
Tree Type #6:				
Tree Type #7:				
Tree Type #8:				
Tree Type #9:				
Tree Type #10:				

[1] **Air-dried unit weight,** γ_{Td} = Average unit weight of wood after exposure to air on a 12% moisture content volume basis. Air-dried unit weight is used in the force balance calculations for the portion of wood that is above the proposed thalweg elevation (assuming unsaturated conditions).

[2] **Green unit weight,** γ_{Tgr} = Average unit weight of freshly sawn wood when the cell walls are completely saturated with water. Green unit weight is used in the force balance calculations as a conservative estimate of the unit weight for the portion of wood that is below the proposed thalweg elevation (assuming saturated conditions). For comparison, Thevenet, Citterio, & Piegay (1998) determined wood unit weight typically increases by more than 100% after less than 24 hours exposure to water.

Source for timber unit weights:

U.S. Department of Agriculture, U.S. Forest Service. (2009) Specific Gravity and Other Properties of Wood and Bark for 156 Tree Species Found in North America. Research Note NRS-38. Table 1A.

Asotin Creek PA-06 Fish Habitat Restoration

Spreadsheet developed by Michael Rafferty, P.E.

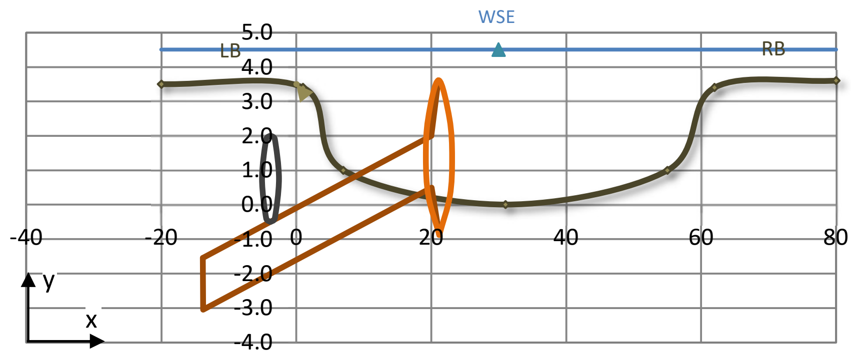
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
PA-06	Full-Span Jam	Full span	Straight	2+00	4.50	12.50	10.00

Multi-Log Structures	Layer	Log ID
	Key Log	1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	-20.0	3.50
Top LB	1.0	3.40
Toe LB	7.0	1.00
Thalweg	31.0	0.00
Toe RB	55.0	1.00
Top RB	62.0	3.40
Fldpln RB	80.0	3.60

Proposed Cross-Section and Structure Geometry (Looking D/S)



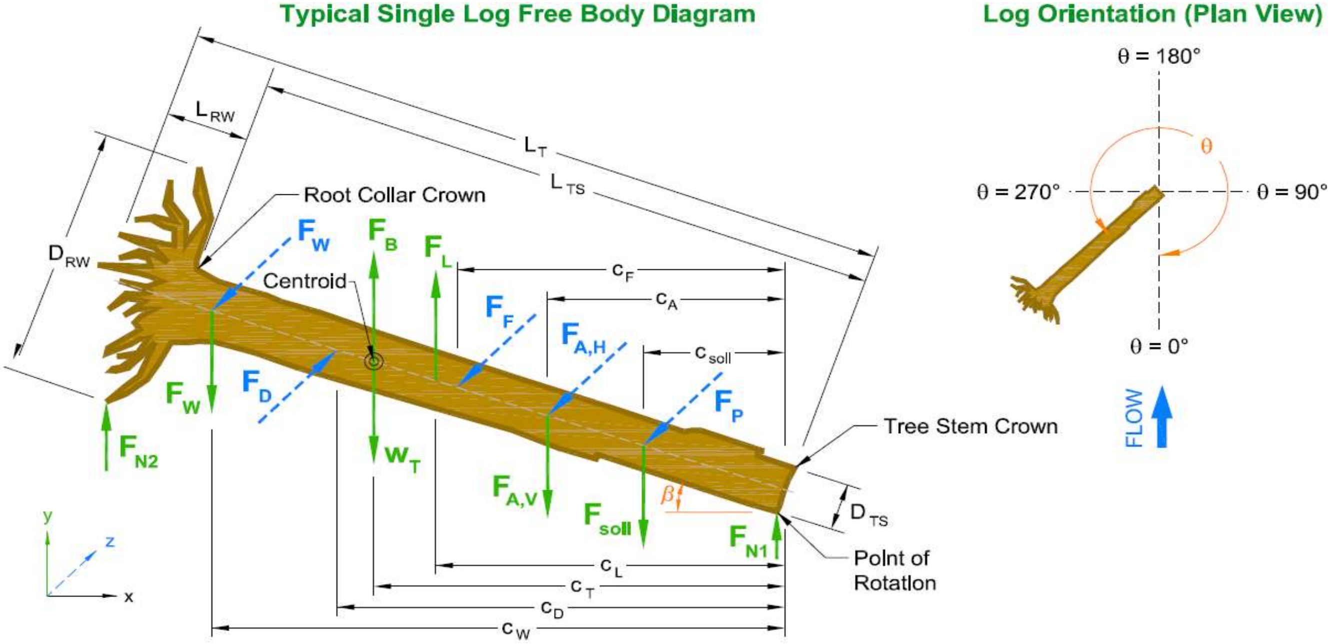
Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Pine, Ponderosa	Yes	70.0	1.50	2.25	4.50	28.0	45.0

-1

Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	30.0	-3.0	Root collar: Crown	20.00	2.00	-3.04	3.62	21.62

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Large Cobble	140.6	87.6	42.0	4	4.96	0.34	0.18
Bank	Gravel/cobble	137.0	85.3	41.0	4	41.71	5.02	3.53

Typical Single Log Free Body Diagram **Log Orientation (Plan View)**



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	42.2	12.8	55.1	1,540	3,437
↓Thalweg	77.5	0.9	78.4	3,529	4,894
Total	119.7	13.8	133.5	5,069	8,331

Lift Force

C_{LT}	0.05
F_L (lbf)	109

Vertical Force Balance

F_B (lbf)	8,331	↑
F_L (lbf)	109	↑
W_T (lbf)	5,069	↓
F_{soil} (lbf)	18,979	↓
$F_{W,V}$ (lbf)	7,934	↑
$F_{A,V}$ (lbf)	839	↓
Σ F_V (lbf)	8,513	↓
FS_V	1.52	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	1.3	1.3	113
Bank	0.0	221.2	221.2	18,866
Total	0.0	222.5	222.5	18,979

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.14	1.44	1.21	0.02	1.67	3,500

Horizontal Force Balance

F_D (lbf)	3,500	→
F_P (lbf)	45,704	←
F_F (lbf)	7,505	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
Σ F_H (lbf)	49,709	←
FS_H	15.20	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	5.04	285	27.20	0.90	3,021
Bank	4.81	45,419	41.83	0.87	4,484
Total	-	45,704	69.03	-	7,505

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
36.7	68.6	58.5	36.7	23.3	33.4	31.0

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	596,077	
M_r (lbf)	2,594,622	
FS_M	4.35	✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
Above	2.50	20.0	0.0	8.2	839	0	0	839	0
								0	0
								0	0

Interaction Forces with Adjacent Logs

						Applied Forces from other Logs		
Log ID	Position	Link	c_{WI} (ft)	$F_{W,V}$ (lbf)	$F_{W,H}$ (lbf)	$F_{W,V}$ (lbf)		$F_{W,H}$ (lbf)
						0		0
4	Below	Gravity	10.0	7,934	256	7,934	↑	0
						0		0
						0		0

Asotin Creek PA-06 Fish Habitat Restoration

Spreadsheet developed by
Michael Rafferty, P.E.

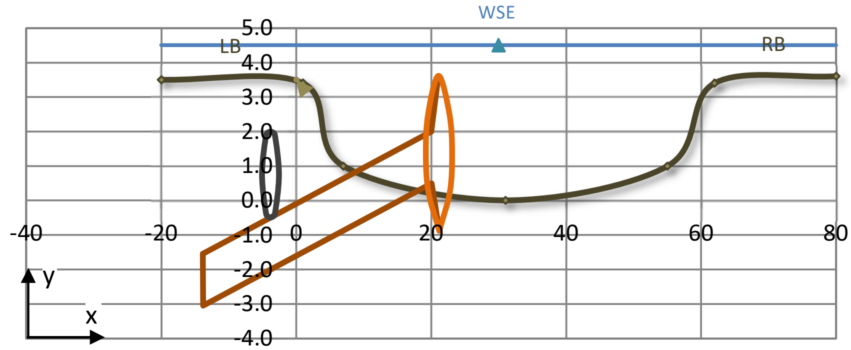
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
PA-06	Full-Span Jam	Full span	Straight	2+00	4.50	12.50	10.00

Multi-Log Structures	Layer	Log ID
	Key Log	2

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	-20.0	3.50
Top LB	1.0	3.40
Toe LB	7.0	1.00
Thalweg	31.0	0.00
Toe RB	55.0	1.00
Top RB	62.0	3.40
Fldpln RB	80.0	3.60

Proposed Cross-Section and Structure Geometry (Looking D/S)



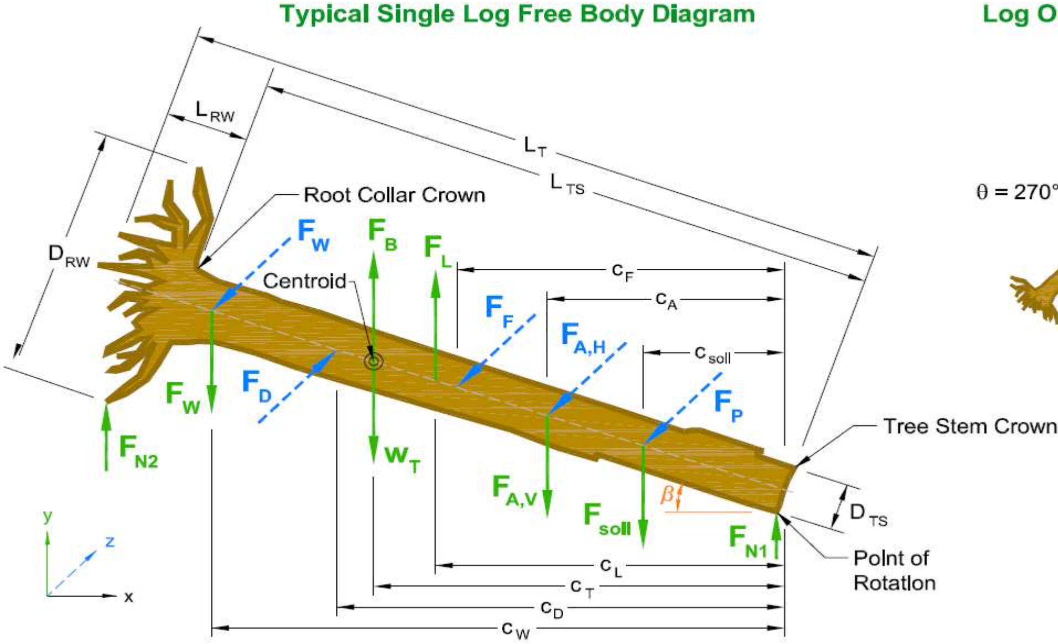
Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Pine, Ponderosa	Yes	70.0	1.50	2.25	4.50	28.0	45.0

-1

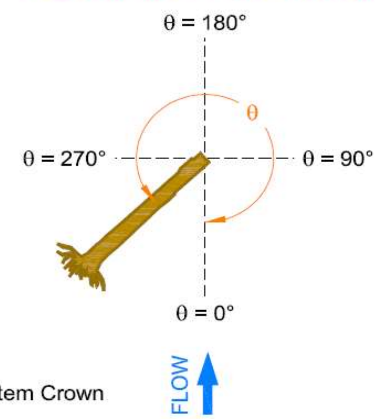
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	30.0	-3.0	Root collar: Crown	20.00	2.00	-3.04	3.62	21.62

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Large Cobble	140.6	87.6	42.0	4	4.96	0.34	0.18
Bank	Gravel/cobble	137.0	85.3	41.0	4	41.71	5.02	3.53

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	42.2	12.8	55.1	1,540	3,437
↓Thalweg	77.5	0.9	78.4	3,529	4,894
Total	119.7	13.8	133.5	5,069	8,331

Lift Force

C_{LT}	0.05
F_L (lbf)	109

Vertical Force Balance

F_B (lbf)	8,331	↑
F_L (lbf)	109	↑
W_T (lbf)	5,069	↓
F_{soil} (lbf)	18,979	↓
$F_{W,V}$ (lbf)	7,746	↑
$F_{A,V}$ (lbf)	839	↓
ΣF_V (lbf)	8,701	↓
FS_V	1.54	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	1.3	1.3	113
Bank	0.0	221.2	221.2	18,866
Total	0.0	222.5	222.5	18,979

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.14	1.44	1.21	0.02	1.67	3,500

Horizontal Force Balance

F_D (lbf)	3,500	→
F_P (lbf)	45,704	←
F_F (lbf)	7,671	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	49,875	←
FS_H	15.25	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	5.04	285	27.20	0.90	3,087
Bank	4.81	45,419	41.83	0.87	4,583
Total	-	45,704	69.03	-	7,671

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
36.7	68.6	58.5	36.7	23.3	33.4	31.0

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	980,969
M_r (lbf)	2,606,429
FS_M	2.66

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
Above	2.50	20.0	0.0	8.2	839	0	0	839	0
								0	0
								0	0

Interaction Forces with Adjacent Logs

Log ID	Position	Link	c_{WI} (ft)	$F_{W,V}$ (lbf)	$F_{W,H}$ (lbf)	Applied Forces from other Logs: $F_{W,V}$ (lbf)	Applied Forces from other Logs: $F_{W,H}$ (lbf)
						0	0
5	Below	Gravity	60.0	7,746	29,353	7,746 ↑	0
						0	0
						0	0

Asotin Creek PA-06 Fish Habitat Restoration

Spreadsheet developed by
Michael Rafferty, P.E.

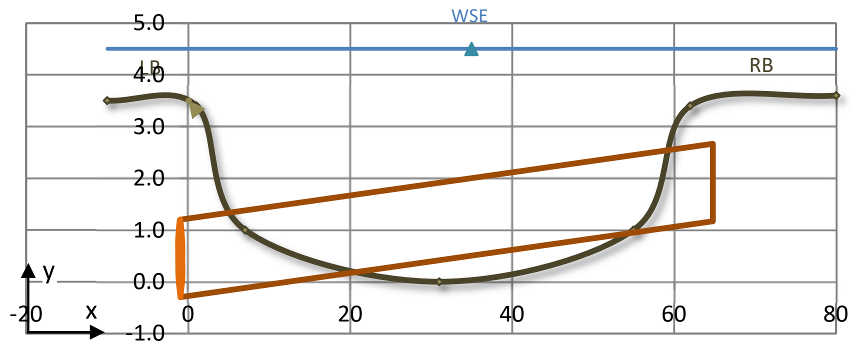
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
PA-06	Full-Span Jam	Left bank	Inside	2+00	4.50	12.50	10.00

Multi-Log Structures	Layer	Log ID
	Middle	4

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	-10.0	3.50
Top LB	1.0	3.40
Toe LB	7.0	1.00
Thalweg	31.0	0.00
Toe RB	55.0	1.00
Top RB	62.0	3.40
Fldpln RB	80.0	3.60

Proposed Cross-Section and Structure Geometry (Looking D/S)

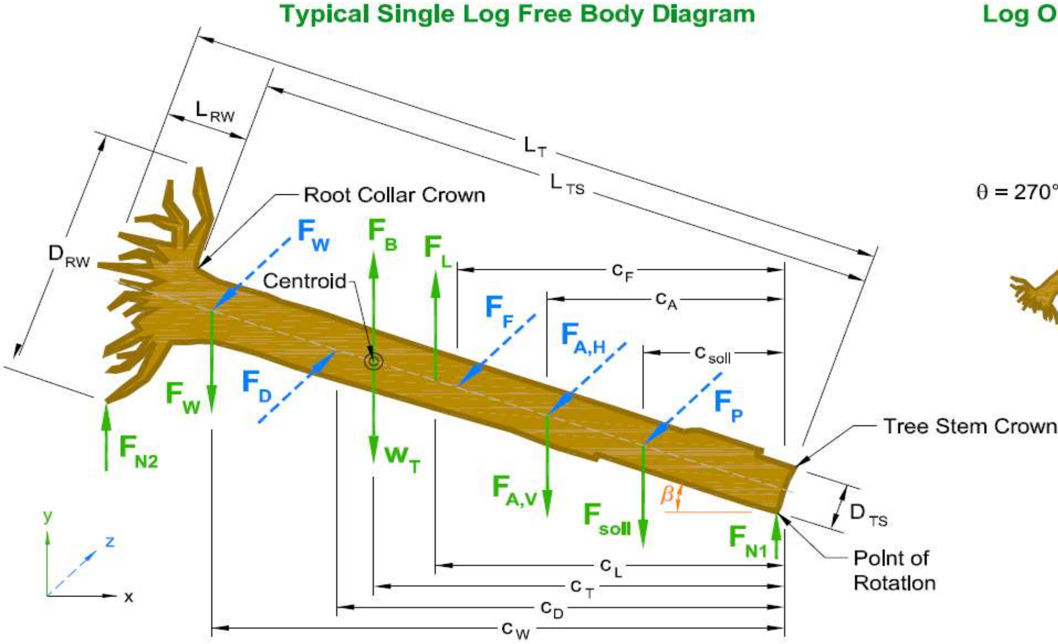


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Pine, Ponderosa	No	70.0	1.50	-	-	28.0	45.0

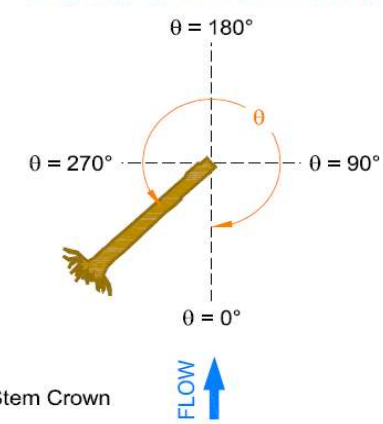
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	290.0	1.2	Root collar: Crown	-1.00	1.20	-0.30	2.67	65.07

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Large Cobble	140.6	87.6	42.0	4	0.00	0.00	0.00
Bank	Gravel/cobble	137.0	85.3	41.0	4	13.15	2.22	1.08

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	122.2	0.0	122.2	3,417	7,627
↓Thalweg	1.5	0.0	1.5	66	91
Total	123.7	0.0	123.7	3,483	7,719

Lift Force

C_{LT}	0.17
F_L (lbf)	1,074

Vertical Force Balance

F_B (lbf)	7,719	↑
F_L (lbf)	1,074	↑
W_T (lbf)	3,483	↓
F_{soil} (lbf)	1,773	↓
$F_{W,V}$ (lbf)	7,934	↓
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	4,397	↓
FS_V	1.50	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	20.8	20.8	1,773
Total	0.0	20.8	20.8	1,773

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.42	1.44	1.12	0.02	3.52	22,232

Horizontal Force Balance

F_D (lbf)	22,232	→
F_P (lbf)	4,269	←
F_F (lbf)	3,898	←
$F_{W,H}$ (lbf)	39,940	←
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	25,874	←
FS_H	2.16	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	5.04	0	23.35	0.90	2,188
Bank	4.81	4,269	18.90	0.87	1,710
Total	-	4,269	42.25	-	3,898

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
35.0	28.0	34.0	35.0	39.5	40.1	35.0

*Distances are from the stem tip

Point of Rotation: Root Collar

Moment Force Balance

M_d (lbf)	1,116,517
M_r (lbf)	2,287,905
FS_M	2.05 ✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Interaction Forces with Adjacent Logs

Log ID	Position	Link	c_{WI} (ft)	$F_{W,V}$ (lbf)	$F_{W,H}$ (lbf)	Applied Forces from other Logs: $F_{W,V}$ (lbf)	Applied Forces from other Logs: $F_{W,H}$ (lbf)
6	Behind	Gravity	10.0	-5,696	-19,970	0	19,970 ←
1	Above	Gravity	30.0	-7,934	-46,209	7,934 ↓	0
6	Behind	Gravity	60.0	-5,696	-19,970	0	19,970 ←
5	Below	Gravity	9.0			0	0

Asotin Creek PA-06 Fish Habitat Restoration

Spreadsheet developed by
Michael Rafferty, P.E.

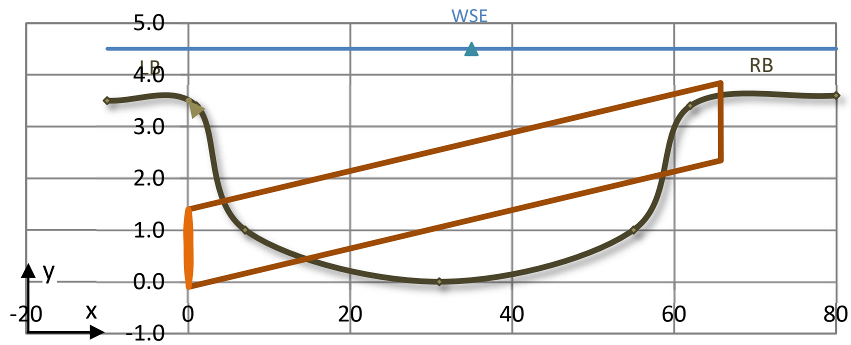
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
PA-06	Full-Span Jam	Left bank	Inside	2+00	4.50	12.50	10.00

Multi-Log Structures	Layer	Log ID
	Top	5

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	-10.0	3.50
Top LB	1.0	3.40
Toe LB	7.0	1.00
Thalweg	31.0	0.00
Toe RB	55.0	1.00
Top RB	62.0	3.40
Fldpln RB	80.0	3.60

Proposed Cross-Section and Structure Geometry (Looking D/S)

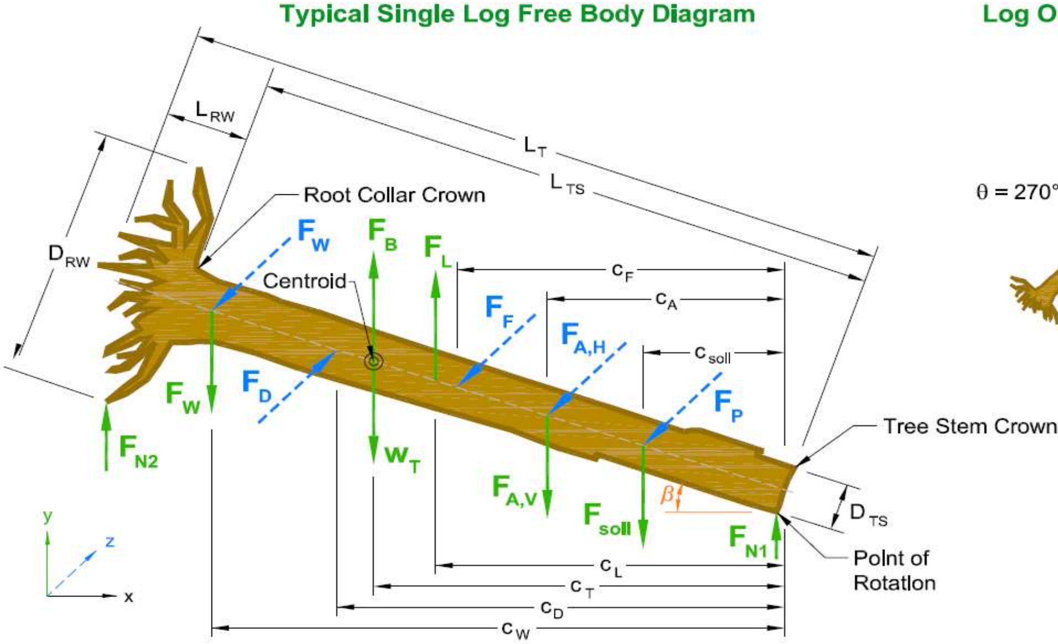


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Pine, Ponderosa	No	70.0	1.50	-	-	28.0	45.0

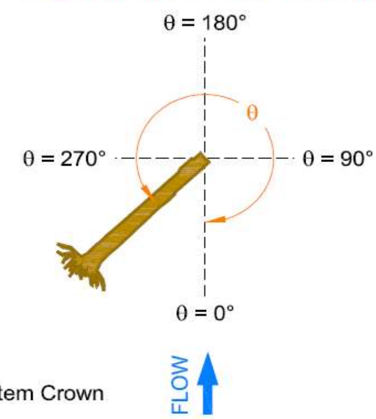
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	250.0	2.0	Root collar: Crown	0.00	1.40	-0.10	3.84	77.15

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Large Cobble	140.6	87.6	42.0	4	0.00	0.00	0.00
Bank	Gravel/cobble	137.0	85.3	41.0	4	5.85	2.01	1.20

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	123.6	0.0	123.6	3,456	7,715
↓Thalweg	0.1	0.0	0.1	3	4
Total	123.7	0.0	123.7	3,459	7,719

Lift Force

C_{LT}	0.04
F_L (lbf)	332

Vertical Force Balance

F_B (lbf)	7,719	↑
F_L (lbf)	332	↑
W_T (lbf)	3,459	↓
F_{soil} (lbf)	872	↓
$F_{W,V}$ (lbf)	7,746	↓
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	4,026	↓
FS_V	1.50	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	10.2	10.2	872
Total	0.0	10.2	10.2	872

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.50	1.44	1.12	0.02	4.77	35,696

Horizontal Force Balance

F_D (lbf)	35,696	→
F_P (lbf)	2,098	←
F_F (lbf)	3,557	←
$F_{W,H}$ (lbf)	39,940	←
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	9,899	←
FS_H	1.28	✗

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	5.04	0	13.20	0.90	1,653
Bank	4.81	2,098	15.75	0.87	1,904
Total	-	2,098	28.95	-	3,557

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
35.0	39.1	32.0	35.0	67.2	43.3	66.3

*Distances are from the stem tip

Point of Rotation:	Root Collar

Moment Force Balance

M_d (lbf)	1,634,981	↷
M_r (lbf)	2,117,852	↶
FS_M	1.30	✗

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

Interaction Forces with Adjacent Logs

Log ID	Position	Link	c_{WI} (ft)	$F_{W,V}$ (lbf)	$F_{W,H}$ (lbf)	Applied Forces from other Logs: $F_{W,V}$ (lbf)		Applied Forces from other Logs: $F_{W,H}$ (lbf)	
6	Behind	Gravity	10.0	-5,696	-19,970	0		19,970	←
4	Above	Gravity	9.0			0		0	
2	Above	Gravity	20.0	-7,746	46,375	7,746	↓	0	
6	Behind	Gravity	60.0	-5,696	-19,970	0		19,970	←

Asotin Creek PA-06 Fish Habitat Restoration

Spreadsheet developed by
Michael Rafferty, P.E.

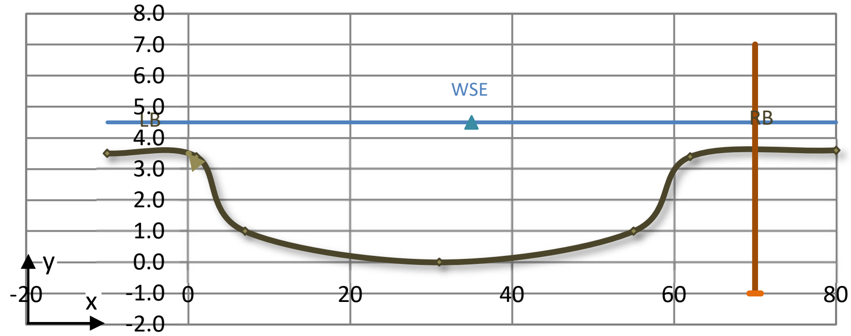
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
PA-06	Full-Span Jam	Left bank	Inside	2+00	4.50	12.50	10.00

Multi-Log Structures	Layer	Log ID
	N/A	6

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	-10.0	3.50
Top LB	1.0	3.40
Toe LB	7.0	1.00
Thalweg	31.0	0.00
Toe RB	55.0	1.00
Top RB	62.0	3.40
Fldpln RB	80.0	3.60

Proposed Cross-Section and Structure Geometry (Looking D/S)

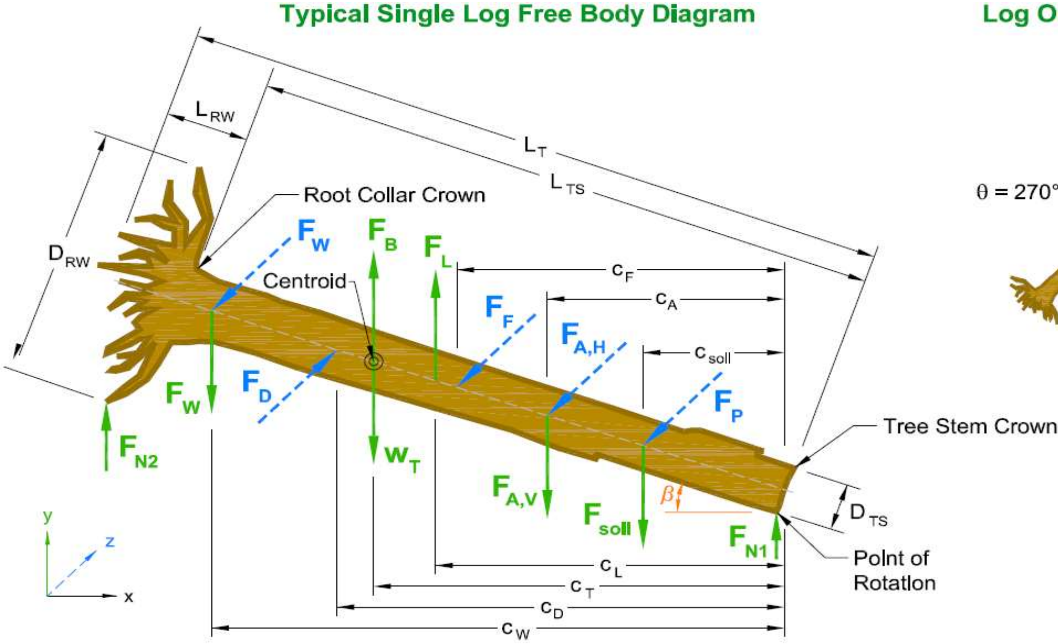


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Pine, Ponderosa	No	8.0	1.00	-	-	28.0	45.0

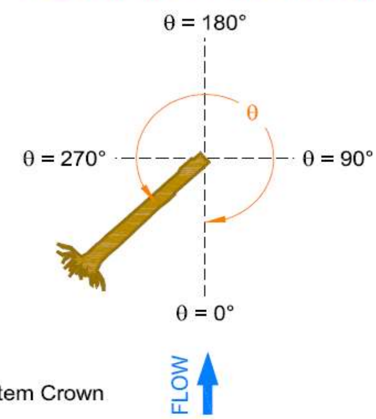
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	0.0	89.9	Root collar: Crown	70.00	-1.00	-1.00	7.00	0.00

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Large Cobble	140.6	87.6	42.0	4	0.00	0.00	0.00
Bank	Gravel/cobble	137.0	85.3	41.0	4	4.49	4.49	4.49

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	2.0	0.0	2.0	55	0
↓WS↑Thw	3.5	0.0	3.5	99	221
↓Thalweg	0.8	0.0	0.8	35	49
Total	6.3	0.0	6.3	189	270

Lift Force

C_{LT}	0.00
F_L (lbf)	0

Vertical Force Balance

F_B (lbf)	270	↑
F_L (lbf)	0	
W_T (lbf)	189	↓
F_{soil} (lbf)	3,063	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	2,983	↓
FS_V	12.06	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	35.9	35.9	3,063
Total	0.0	35.9	35.9	3,063

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.00	1.76	1.12	0.00	1.11	0

Horizontal Force Balance

F_D (lbf)	0	
F_P (lbf)	7,375	←
F_F (lbf)	2,611	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	9,986	←
FS_H	19,976.40	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	5.04	0	2.00	0.90	537
Bank	4.81	7,375	8.00	0.87	2,074
Total	-	7,375	10.00	-	2,611

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
4.0	0.0	0.0	4.0	4.0	4.0	4.0

*Distances are from the stem tip

Point of Rotation:	Root Collar

Moment Force Balance

M_d (lbf)	2
M_r (lbf)	114
FS_M	60.52 ✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
Above								0	0
Above								0	0
								0	0

Asotin Creek PA-06 Fish Habitat Restoration
Notation, Units, and List of Symbols

Notation

Symbol	Description	Unit
A_W	Wetted area of channel at design discharge	ft^2
A_{Tp}	Projected area of wood in plane perpendicular to flow	ft^2
c_D	Centroid of the drag force along log axis	ft
c_{Am}	Centroid of a mechanical anchor along log axis	ft
c_{Ar}	Centroid of a ballast boulder along log axis	ft
c_{Asoil}	Centroid of the added ballast soil along log axis	ft
$c_{F\&N}$	Centroid of friction and normal forces along log axis	ft
c_L	Centroid of the lift force along log axis	ft
c_P	Centroid of the passive soil force along log axis	ft
c_{soil}	Centroid of the vertical soil forces along log axis	ft
$c_{T,B}$	Centroid of the buoyancy force along log axis	ft
$c_{T,W}$	Centroid of the log volume along log axis	ft
c_{WI}	Centroid of a wood interaction force along log axis	ft
C_{Lrock}	Coefficient of lift for submerged boulder	-
C_{LT}	Effective coefficient of lift for submerged tree	-
C_{Di}	Base coefficient of drag for tree, before adjustments	-
C_D*	Effective coefficient of drag for submerged tree	-
C_{Di}	Base coefficient of drag for tree, before adjustments	-
C_W	Wave drag coefficient of submerged tree	-
$d_{b,avg}$	Average buried depth of log	ft
$d_{b,max}$	Maximum buried depth of log	ft
d_w	Maximum flow depth at design discharge in reach	ft
D_{50}	Median grain size in millimeters (SI units)	mm
D_r	Equivalent diameter of boulder	ft
D_{RW}	Assumed diameter of rootwad	ft
D_{TS}	Nominal diameter of tree stem (DBH)	ft
DF_{RW}	Diameter factor for rootwad ($DF_{RW} = D_{RW}/D_{TS}$)	-
e	Void ratio of soils	-
$F_{A,H}$	Total horizontal load capacity of anchor techniques	lbf
$F_{A,HP}$	Passive soil pressure applied to log from soil ballast	lbf
$F_{A,Hr}$	Horizontal resisting force on log from boulder	lbf
F_{Am}	Load capacity of mechanical anchor	lbf
$F_{A,V}$	Total vertical load capacity of anchor techniques	lbf
$F_{A,Vr}$	Vertical resisting force on log from boulder	lbf
$F_{A,Vsoil}$	Vertical soil loading on log from added ballast soil	lbf
F_B	Buoyant force applied to log	lbf
F_D	Drag forces applied to log	lbf
$F_{D,r}$	Drag forces applied to boulder	lbf
F_F	Friction force applied to log	lbf
F_H	Resultant horizontal force applied to log	lbf
F_L	Lift force applied to log	lbf
$F_{L,r}$	Lift force applied to boulder	lbf
F_P	Passive soil pressure force applied to log	lbf
F_{soil}	Vertical soil loading on log	lbf
$F_{W,H}$	Horizontal forces from interactions with other logs	lbf
$F_{W,V}$	Vertical forces from interactions with other logs	lbf

Notation (continued)

Symbol	Description	Unit
F_V	Resultant vertical force applied to log	lbf
Fr_L	Log Froude number	-
FS_V	Factor of Safety for Vertical Force Balance	-
FS_H	Factor of Safety for Horizontal Force Balance	-
FS_M	Factor of Safety for Moment Force Balance	-
g	Gravitational acceleration constant	ft/s^2
K_P	Coefficient of Passive Earth Pressure	-
$L_{T,em}$	Total embedded length of log	ft
L_{RW}	Assumed length of rootwad	ft
L_T	Total length of tree (including rootwad)	ft
L_{Tf}	Length of log in contact with bed or banks	ft
L_{TS}	Length of tree stem (not including rootwad)	ft
$L_{TS,ex}$	Exposed length of tree stem	ft
LF_{RW}	Length factor for rootwad ($LF_{RW} = L_{RW}/D_{TS}$)	-
M_d	Driving moment about embedded tip	lbf
M_r	Driving moment about embedded tip	lbf
N	Blow count of standard penetration test	-
p_o	Porosity of soil volume	-
Q_{des}	Design discharge	cfs
R	Radius	ft
R_c	Radius of curvature at channel centerline	ft
SG_r	Specific gravity of quartz particles	-
SG_T	Specific gravity of tree	-
u_{avg}	Average velocity of cross section in reach	ft/s
u_{des}	Design velocity	ft/s
u_m	Adjusted velocity at outer meander bend	ft/s
V_{dry}	Volume of soils above stage level of design flow	ft^3
V_{sat}	Volume of soils below stage level of design flow	ft^3
V_{soil}	Total volume of soils over log	ft^3
V_{RW}	Volume of rootwad	ft^3
V_S	Volume of solids in soil (void ratio calculation)	ft^3
V_T	Total volume of log	ft^3
V_{TS}	Total volume of tree	ft^3
V_V	Volume of voids in soil	ft^3
V_{Adry}	Volume of ballast above stage of design flow	ft^3
V_{Awet}	Volume of ballast below stage of design flow	ft^3
$V_{r,dry}$	Volume of boulder above stage of design flow	ft^3
$V_{r,wet}$	Volume of boulder below stage of design flow	ft^3
W_{BF}	Bankfull width at structure site	ft
W_r	Effective weight of boulder	lbf
W_T	Total log weight	lbf
x	Horizontal coordinate (distance)	ft
y	Vertical coordinate (elevation)	ft
$y_{T,max}$	Minimum elevation of log	ft
$y_{T,min}$	Maximum elevation of log	ft

Greek Symbols

Symbol	Description	Unit
β	Tilt angle from stem tip to vertical	deg
γ_{bank}	Dry specific weight of bank soils	lb/ft^3
$\gamma_{bank,sat}$	Saturated unit weight of bank soils	lb/ft^3
γ'_{bank}	Effective buoyant unit weight of bank soils	lb/ft^3
γ_{bed}	Dry specific weight of stream bed substrate	lb/ft^3
γ'_{bed}	Effective buoyant unit weight of stream bed substrate	lb/ft^3
γ_{rock}	Dry unit weight of boulders	lb/ft^3
γ_s	Dry specific weight of soil	lb/ft^3
γ'_s	Effective buoyant unit weight of soil	lb/ft^3
γ_{Td}	Air-dried unit weight of tree (12% MC basis)	lb/ft^3
γ_{Tgr}	Green unit weight of tree	lb/ft^3
γ_w	Specific weight of water at 50ºF	lb/ft^3
η	Rootwad porosity	-
θ	Rootwad (or large end of log) orientation to flow	deg
μ	Coefficient of friction	-
ν	Kinematic viscosity of water at 50ºF	ft/s^2
Σ	Sum of forces	-
ϕ_{bank}	Internal friction angle of bank soils	deg
ϕ_{bed}	Internal friction angle of stream bed substrate	deg

Units

Notation	Description
cfs	Cubic feet per second
ft	Feet
lb	Pound
lbf	Pounds force
kg	Kilograms
m	Meters
mm	Millimeters
s	Seconds
yr	Year

Abbreviations

Notation	Description
ARI	Average return interval
Avg	Average
DBH	Diameter at breast height
deg	Degrees
Dia	Diameter
Dist	Distance
D/S	Downstream
ELJ	Engineered log jam
Ex	Example
Fldpln	Floodplain
H&H	Hydrologic and hydraulic
ID	Identification
i.e.	That is
LB	Left bank
LW	Large wood
Max	Maximum
MC	Moisture content
Min	Minimum
ML	Multi-log
SL	Single log
N/A	Not applicable
no	Number
Pt	Point
rad	Radians
RB	Right bank
RW	Rootwad
SL	Single log
Thw	Thalweg (lowest elevation in channel bed)
Typ	Typical
U.S.	United States
WS	Water surface
WSE	Water surface elevation
↑	Above
↓	Below

HIP Project Review
Comment Tracking

Project Information:

Project Name:	Asotin Creek PA-06
BPA Project #:	1994-018-05
Contract #:	85356
Sponsor:	Asotin County Conservation District
Designer:	Alta Science & Engineering, Inc.
Area Lead:	André L'Heureux, EWU, Lower Snake Lead
COR/PM:	Matthew D. Schwartz, EWM
HIP Program Lead:	Daniel A. Gambetta, ECF

HIP Review Team:

BPA EC Lead:	Catherine M. Clark, ECF
BPA Technical Lead:	Douglas D. Knapp, P.E., EWL
NMFS Branch Chief:	Kenneth Troyer, NMFS, Northern Snake Branch Chief
NMFS Biologist:	name
NMFS Engineer:	Dropdown Menu
USFWS Field Office:	Russ MacRae, USFWS (Eastern WA) Spokane Field Office
USFWS Reviewer:	name

Documents Reviewed:

Asotin PA-06 15% Design Memo & Alternatives Drawings; May 5, 2021
Asotin Creek Intensively Monitored Watershed; July 2015
Asotin Creek PA06 – Basis of Design Report; Oct 2021
Asotin Creek 30% Drawings; Oct 2021
Asotin Creek PA06, Basis of Design Report, 80%; May 2022
Asotin Creek PA06, Basis of Design Report Attachments, 80%; May 2022

Activity Categories:	**Risk Level:**
1h - Installation of Fords	Medium
2a - Improve Secondary Channel and Floodplain Connectivity	Medium
2b - Set-back or Removal of Berms, Dikes and Levees	Medium
2c - Protect Streambanks Using Bioengineering Methods	Medium
2d - Install Habitat-Forming Instream Structures	Medium
2e - Riparian and Wetland Vegetation Planting	Low
9b – Fencing Construction for Wildlife Control	Low
Overall Project Risk	**Medium**

Review Timeline:	**Date Completed**
• Conceptual Review (typically 15%)	
○ Site visit, if needed	N/A
○ Sponsor to submit conceptual design to EC Lead and COR	5/26/2021
○ EC Lead to submit concept to HIP Review Team to initiate review	5/28/2021
○ EC Lead to send design package to appropriate HIP Review members	6/1/2021
○ EC Lead to compile comments and forward to Sponsor	6/2/2021
○ Sponsor to provide responses to EC Lead	10/27/2021
○ HIP Review Team and Sponsor to resolve "open" comments	Not Started
○ EC Lead to notify Sponsor to proceed to preliminary design	Not Started
• Preliminary Design or Alternatives Analysis Review (typically 30%)	
○ Sponsor to submit preliminary design to EC Lead and COR	10/27/2021
○ EC Lead to submit design package to HIP Review Team	10/27/2021
~~○ EC Lead to submit design to NMFS Engineer if applicable~~	~~Not Started~~
~~○ NMFS Engineer approves project, if applicable~~	~~Not Started~~
○ EC Lead to compile comments and forward to Sponsor	Not Started
○ Sponsor to provide responses to EC Lead	Not Started
○ HIP Review Team and Sponsor to resolve "open" comments	Not Started
○ EC Lead to notify Sponsor to proceed with design	Not Started
• Permit Level Design Review (typically 60% to 80%)	
○ Sponsor to submit design package to EC lead and COR	5/2/2022
○ EC Lead to submit design package to HIP Review Team	5/2/2022
○ EC Lead to compile comments and forward to Sponsor	5/10/2022
○ Sponsor to provide responses to EC Lead	Not Started
○ HIP Review Team and Sponsor to resolve "open" comments	Not Started
○ EC Lead to notify Sponsor to proceed to final design	Not Started
• Final Design Package (100%)	
○ Sponsor to submit final designs to EC Lead and COR	Not Started
○ EC Lead and BPA Technical Lead to verify no critical changes	Not Started

Comments:

#	Reviewer (Org.)	Date	Document	Page/ Section	Comment		Response by (Org.)	Date	Response to Comment	Status (BPA to Update)
1	BPA	6/2/21	15%		The three proposed alternatives utilize a large suite of HIP Activity Categories. The applicable Categories, associated Conservation Measures and risk determination will be adjusted as plans develop. Please review the Activity Categories listed above in the HIP Handbook and ensure that Conservation Measures are met and appropriate technical data is included in the Basis of Design Report.		Alta	6/8/2021	Thanks for the info, we will review the handbook and make sure to include the technical data needed in the BDR.	For Information Only
2	BPA	6/2/21	BDR		The PA-06 will be medium risk at a minimum for HIP. Medium and higher risk projects required a Basis of Design Report. Please review HIP Handbook section 2.5 for BDR requirements. Please submit a draft BDR with the 30% submittal. **11/2/2021: Closed; BDR Received**		Alta	6/8/2021	We will prepare and submit a BDR with the 30% design. As discussed during our 15% design presentation, the HIP III BDR format will be used and supplemented as needed.	Closed

#	Reviewer (Org.)	Date	Document	Page/ Section	Comment		Response by (Org.)	Date	Response to Comment	Status (BPA to Update)
3	BPA	6/2/21	BDR		BPA concurs with proposed recommendations in the 15% package regarding need for topographic information and hydraulic analysis. Please submit H&H analysis of existing and selected alternative with the 30% design package. Depths, velocities, and water surface profiles in the main and secondary channels for the 50% and 5% duration exceedance and 1.5, 2, 5 and 10 year return interval floods would be appropriate for habitat benefits determination. (Note that there are specific hydraulic analysis requirements associated with passage at grade stabilization and/or structure capacity and stability. Typically this level of hydraulic analysis is provided in the 80% design) **11/2/2021: Closed; provided at 30% BDR**		Alta	6/8/2021	At a minimum, we will provide depths, velocities, and water surface profiles in the main and secondary channels for the 2 and 25-year return interval flows for habitat determination with the 30% design deliverable. We propose the 2-year flood event is sufficient to assess habitat benefits and floodplain connectivity. The 25-year return flow will be used to analyze the stability of habitat structures as well. The available hydrologic data does not yield a high-quality estimate below the Q2. Additionally, the 100 year return interval flow will be modelled to assess risk to the residence on site and for floodplain alteration permitting.	Closed
4	BPA	6/2/21	15%		Recommend that Ordinary High Water be shown on the plan and profile sheets and details to support the USACE 404 permit requirements. **11/2/2021: Closed; Shown on S-1 30% Design**		Alta	6/8/2021	We will include OHW on the plan and profile sheets for the 30% design.	Closed
5	BPA	6/2/21	15%		The final project drawings shall be sealed by the Project Engineer per Revised Code of Washington 18.43.070. **11/2/2021: Changed to FIO, required at final.**		Alta	6/8/2021	The final project drawings will be sealed by the Project Engineer per Revised Code of Washington 18.43.070.	For Information Only

6	BPA	6/2/21	30%		Could livestock crossing #1 be modified to include crossing for vehicles? With the removal of the rock crossing/proposed bridge/culvert closer to the home. If an additional crossing is needed please provide a justification of the need and method (culvert vs. bridge vs. ford). 11/2/2021: Remaining open for clarification. Does landowner need vehicle access to the habitat area? **5/9/22: Closed**		Alta	6/8/2021 12/2/21	See the photo below of the current rock crossing installed by the landowner at the site of the proposed bridge or culvert. This structure extends to the top of banks and completely blocks the side channel. A bridge/culvert is proposed here to allow the landowner to continue vehicle access to the area on the other side of the side channel. A bridge/culvert was proposed to minimize driving through the creek and in general a culvert may be preferred to reduce costs over a bridge. Pending landowner input, this crossing could be a rocked ford to allow maximum floodplain access and economize project costs. The landowner will be consulted to see if crossing #1 would meet his needs for vehicle access, and the 30% design will be updated accordingly.  The landowner does require vehicle access to the area between the side channel and main channel to conduct maintenance for his CREP enrollment. It is anticipated that this crossing will be used just a few times per year with a 4-wheeler. Given the limited use of this	Closed

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									crossing will be a rocked ford, pending approval from permitting agencies.	
7	BPA	6/2/21	15%		BPA does not support ditch plugs at this site. BPA prefers alternatives 1 in this location. **11/2/2021: Closed; went with Alt. 1.**		Alta	6/8/2021	Noted. For clarification, Alternative 1 is also preferred over Alternative 3, correct? We will proceed with Alternative 1 for the 30% design, pending notification to proceed and landowner acceptance of Alternative 1.	Closed

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8	BPA	6/2/21	15%		Please provide sufficient hydrologic and hydraulic analysis to demonstrate if a modification to the existing berm is justified. 11/2/21: Hydraulic modeling shows a decrease in water surface elevation at the proposed berm location. Construction of proposed berm is not justified. **5/9/22: BPA is not authorized to fund flood protection. If a habitat project funded by BPA increases flood inundation, BPA can provide protection equal to the pre-project condition. Since the proposed project decreases flood elevations from the existing condition the berm must be removed from the design. If another funding source is used to fund the berm, please notify the EC Lead as soon as possible as there is not a HIP activity category for new berms (individual ESA consultation would be required).**		Alta	6/8/2021 11/29/21 6/16/22	Alta will provide the H&H analysis to demonstrate whether modification of the existing berm is necessary with the 30% design deliverable. FYI, site survey found that the current berm contains the septic system piping for the residence on site. While there is a decrease in water surface elevation near the house with the design condition, floodwaters would still reach the house at the Q100 design condition without the berm. Figure 20 in the 30% Basis of Design Report shows these floodwaters being stopped by the berm (circled in red in the clip below). Therefore, the berm is needed to protect the home from flooding at the Q100.  Another funding source will be used for the rock/soil berm.	Open (Requirement)

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9	BPA	6/2/21	Plans		Please include the General Conservation Measures detail sheets in the plans at 30%. To be provided by EC Lead. **11/2/2021: Closed; See below comment.**		Alta	6/8/2021	The General Conservation Measures detail sheets will be included with the 30% drawings.	Closed
10	BPA	6/2/21	Plans		Please provide in-water work window at 30%. 11/2/2021: Unable to locate in plans sheet. Reference conservation measure 2E of project design and site preparation, sheet G2 **5/9/22: Closed**		ACCD & Alta	6/2/2021 11/29/21	July 15 – September 15, depending on timing limitations listed on the Hydraulic Project Approval from WDFW. Item 2E on Sheet G2 of the 60% Design Drawings will be updated with the anticipated in-water work window. The final Design Drawings will include timing specified by the Hydraulic Project Approval from WDFW.	Closed
11	BPA	6/2/21	Plans		Please include access roads, any stream crossing, and staging areas at 30%. Note fueling and equipment storage shall take place >150' from streams and wetlands. 11/2/2021: Acknowledge staging area is less than 150ft from wetland – Please provide extra precautions for spills and containment. *Note, EC lead is aware that is currently used for vehicle storage. **5/9/22: Outside 100yr flood. Closed.**		Alta	6/8/2021 11/29/21	Thanks for the reminder, these will be included with the 30% drawings. Item 7a on Sheet G2 will be updated to acknowledge staging area is <150' from floodplain. Item 11 on Sheet G3 will be updated to include extra precautions for spills and containment. Project specifications will also include this information.	Closed

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12	BPA	6/2/21	BDR/Plans	 Sheet S5	EC Lead would like to see a planting plan before 80% design to ensure ESA coverage via HIP. 11/2/2021: EC lead will review planting plan with next design phase. **5/9/22: Revegetation sheet does not call out specific species – Please include species details in either the Designs sheet or Basis of Design Report.**		ACCD	6/2/2021 11/29/21 6/16/22	ACCD will provide the requested planting plan. Noted. Revegetation species lists will be provided in the Specifications and Basis of Design Report as they are too large to include as a table in the drawings.	Open (Requirement)
13	BPA	6/2/21	APE		Please send updated APE files to the EC Lead for the new proposed designs – The original APE (from 2019) does not span the entire footprint of the proposed project. Include staging area, access routes, and vehicle/equipment that will be utilized for implementation. **5/9/22: Cat double check**		ACCD	6/2/2021 11/29/21	ACCD will send updated APE shapefiles and imagery to BPA with fueling and equipment storage labeled. Existing hay shed and parking labeled as well. Noted.	Open (Requirement)
14	BPA	11/2/21	30% BDR	Section 3	Please provide stability calculations for LWD placement and ELJ structures (buoyancy and drag using RAS output) and stability calculations for gradation of livestock crossings (appendix acceptable for placement of calculations). **5/9/22: Closed.**		Alta	11/29/21	Noted, these calculations will be provided as appendices to the60% Basis of Design Report.	Closed