Basis of Design Report

Cougar Creek Fish Passage Barrier Removal
Asotin County, Washington

for
Asotin County Conservation District

January 21, 2022

GeoEngineers

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File No. 22281-004-00

January 21, 2022

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LIST OF ACRONYMS

BPA – Bonneville Power Administration

cfs – cubic feet per second

ESA – Endangered Species Act

HIP – Habitat Improvement Program

NMFS – National Marine Fisheries Service

ACCD – Asotin County Conservation District

WDFW – Washington Department of Fish and Wildlife

RRT – Restoration Review Team

RCO – Recreation and Conservation Office

USACE – United States Army Corps of Engineers

USGS – Unites States Geological Society

1.0 INTRODUCTION

GeoEngineers, Inc. (GeoEngineers) has prepared this Basis of Design report (report) for the Asotin County Conservation District (ACCD). The ACCD is proposing to remove a fish passage barrier at the crossing of Cougar Creek and Grande Ronde Road. The fish passage barrier limits access to spawning and rearing habitat for anadromous salmonids including Endangered Species Act-listed (ESA) Steelhead within Cougar Creek. To restore fish passage, this project proposes to replace the currently undersized culvert with a fish passable crossing structure and restoring the roadway. This report provides a summary of our findings pertaining to the existing conditions of the Cougar Creek project site in Asotin County, Washington, and an explanation of the design process, analyses, and preliminary outcomes for the proposed enhancement design.

GeoEngineers organized the following sections of this report to describe the General Project and Data Summary Requirements required by the Bonneville Power Administration (BPA) for regulatory compliance coverage under the Habitat Improvement Program (HIP). This report is submitted to satisfy the final design step as part of the BPA Restoration Review Team (RRT) review process. BPA developed the requirements to effectively communicate that appropriate planning, analysis, design, and resulting construction documentation are met. The conditions of the project reach are described in terms of processes that shaped the stream and associated ecosystem within the context of various ecological disciplines. This includes discussions on hydrology, hydraulics, habitat, and geomorphology. The evaluation and consideration of the site conditions provide the basis for the project design.

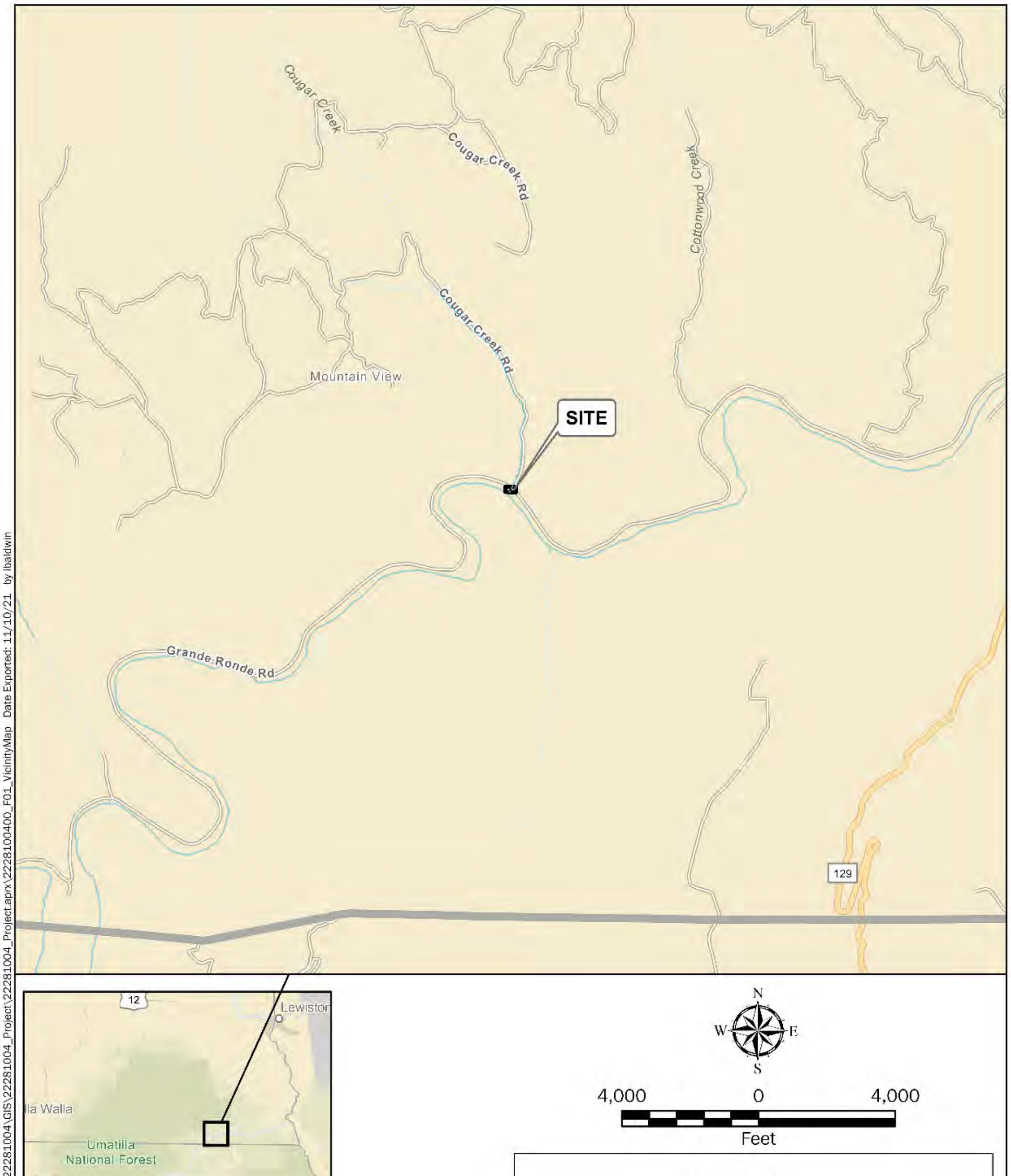
- Appendix A—Final Design Drawings
- Appendix B—Site Photographs
- Appendix C—Hydrologic and Hydraulic Analyses
- Appendix D—Construction Quantities and Estimate of Anticipated Costs
- Appendix E—Bonneville Power Comment Response
- Appendix F—Monitoring and Adaptive Management Plan
- Appendix G—Report Limitations and Guidelines for Use

1.1. Project Responsible Parties

- The project sponsor is the ACCD, and the project manager is Megan Stewart 509.552.8100.
- The prime design consultant is GeoEngineers, Inc. and the engineer of record is Ryan S. Carnie, PE, 208.258.8326.

1.2. Site Location

The project site is located in southern Asotin County on Grande Ronde Road. The roadway is owned and maintained by Asotin County and the land adjacent to the crossing is owned by the Washington Department of Fish and Wildlife (WDFW). Cougar Creek is a tributary to the Grande Ronde River and crosses Grande Ronde Road approximately 120 feet upstream of the confluence. The approximate site location is shown on the Vicinity Map, Figure 1.



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Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: ESRI, World Topographic Map.

Projection: NAD 1983 UTM Zone 11N

Vicinity Map

Cougar Creek Barrier Fish Passage Design
Asotin County, Washington

GeoEngineers

Figure 1

2.0 PROJECT BACKGROUND

2.1. Project Goals, Objectives and Constraints

GeoEngineers worked collaboratively with ACCD to develop and evaluate alternatives for providing fish passage at the Cougar Creek crossing. We published the conceptual alternatives analysis and described the alternatives in a document dated May 3, 2021 (GeoEngineers 2021).

2.1.1. Vision

Restore accessibility to approximately 2.25 miles of available habitat for Snake River Steelhead within the Cougar Creek watershed in compliance with the Snake River Recovery Plan (NOAA 2017).

2.1.2. Goal

Restore fish passage under Grande Ronde Road with the modification or replacement of the existing fish passage barrier culvert.

2.1.3. Objectives

1. Identify feasible alternatives for the modification or replacement of the identified fish passage barrier culvert that conveys Cougar Creek flow under Grande Ronde Road.
2. Provide a set of construction-ready design drawings and special provisions adequately detailing a restoration action for replacing the culvert on Cougar Creek. The design drawings and special provisions shall restore natural channel morphology upstream and downstream of the crossing to the greatest extent practical while allowing for proper bed load transport. The design drawings and special provisions shall consider and accommodate passage of all life stages of steelhead and resident trout.
3. Implement the crossing replacement as designed.

3.0 EXISTING CONDITIONS

3.1. Hydrology

Cougar Creek generally flows from north to south through the project reach and crosses Grande Ronde Road through an existing 64-inch-diameter corrugated metal culvert, approximately 120 feet upstream of the confluence with the Grande Ronde River. Figure 2, Watershed Map, shows the Cougar Creek watershed.

Legend

- ● Project Site
- ▭ Watershed

N W E S

4,000 0 4,000

Feet

Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: ESRI

Projection: NAD 1983 HARN StatePlane Washington South FIPS 4602 Feet

Watershed Map

Cougar Creek Barrier Fish Passage Design
Asotin County, Washington

GeoEngineers

Figure 2

\\geoengineers.com\WAN\Projects\22\22281004\GIS\22281004_Project\22281004_Project.aprx\Watershed Map Date Exported: 11/10/21 by lbaldwin

3.1.1. Peak Recurrence Interval Flows

GeoEngineers evaluated discharge at the culvert crossing of Grande Ronde Road and Cougar Creek using the United States Geologic Survey (USGS) StreamStats Program, version 4.5.1 (USGS 2019). The StreamStats discharge estimation program calculates discharges based on regional regression equations, as stream gage data is not available at or near the project site. Table 1 lists the design discharges. StreamStats does not provide the 1.5-year discharge. Therefore, we extrapolated the peak recurrence discharge values provided by StreamStats, using a curve fit to that data. Site observations of the outlet of the culvert during August of 2020 indicate seasonal low flows are limited in Cougar Creek (Appendix B, Site Photographs).

The WDFW Culverts and Climate Change web application was used to evaluate the effects climate change may have on flows in Cougar Creek. The projected 2040 100-year flow was estimated using methods described in a paper published in 2017 (Wilhere, et al. 2017). The tool predicts a 48 percent increase from the current predicted 100-year flow to the 2040 predicted 100-year flow. The 2040 predicted 100-year flow is reported in Table 1.

TABLE 1. DISCHARGE SUMMARY TABLE

Recurrence Interval	Discharge (cfs)
1.5-Year	20
2-Year	36
5-Year	81
10-Year	125
25-Year	199
50-Year	270
100-Year	355
500-Year	603
2040 100-Year	525

3.2. Geomorphology

GeoEngineers conducted a field-based site assessment on March 9, 2021. We collected bankfull width measurements, a Wolman pebble count, documentation of riparian vegetation, documentation of channel morphologic conditions, and general site observations. The assessment included the reach from the confluence with the Grande Ronde River, upstream through the crossing and to a location approximately 200 feet upstream of the crossing.

3.2.1. Channel Geometry

GeoEngineers conducted bankfull width measurements at three locations upstream of the crossing structure. Two bankfull width measurements were made within the reference reach (Figures B-5 and B-6, Appendix B). We used substrate material size variation and vegetation changes as indicators of bankfull width for the two measurements within the reference reach. The location of the bankfull width measurements relative to the existing culvert are included in Table 2. We used an average bankfull width of 13.9 feet for design. Bank heights within the reference reach exceeded 2 feet. Upland embankment heights exceeded 6 vertical feet, and the channel was confined within the reference reach due to the low flood utilization ratio.

TABLE 2. BANKFULL WIDTH MEASUREMENTS

Measurement Location (ft upstream of inlet)	Width (ft)	Distance from Culvert Inlet (ft)
110–120	14.0	110–120
130–140	13.8	130–140
Design Average	13.9	—

3.2.2. Bed Material

GeoEngineers observed the bed material within the reach upstream of the existing culvert as predominantly gravels, cobbles and boulders with apparent immobile boulders composing steps and providing grade control (Appendix B). We conducted a Wolman pebble count within the reference reach, including grade-controlling boulders and material within the pools. The results of the material sampling are included in Table 3. The maximum material size identified was approximately 36 inches in diameter and represented grade-controlling, immobile boulders that comprised the steps within the reach.

TABLE 3. STREAMBED MATERIAL GRADATION WITHIN REFERENCE REACH

Particle Size	Distribution (in)
D_{15}	0.6
D_{35}	1.6
D_{50}	2.9
D_{84}	9.6
D_{95}	18.4

3.2.3. Lateral and Vertical Stability

GeoEngineers evaluated the channel downstream of the existing culvert and identified an approximate 2-foot-deep pool and an approximate 6-inch hydraulic drop during the site investigation on March 9, 2021 (Figure B-7, Appendix B). This indicates vertical instability in the system and suggests a more appropriate longitudinal profile would include lowering the channel grade through the crossing and steepening the channel slope through the crossing.

3.3. Fish Use and Habitat Availability

Snake River Steelhead are identified as endangered and subject to compliance with the Endangered Species Act (ESA) in the Snake River system. This section of Cougar Creek is a Steelhead Priority Restoration Reach and provides critical habitat for steelhead. The existing culvert was identified in 2008 as a barrier to Snake River Steelhead by a Walla Walla Community College Road Crossing Barrier Assessment (ACCD 2020). The existing structure has also been identified as a fish barrier by the WDFW, and the crossing is identified as WDFW Site ID 602000 (crossing 602000) (Washington Department of Fish and Wildlife 2016). Upstream of this crossing there is an estimated 11,900 linear feet (LF) of habitat gain (ACCD 2020). Fish passage is identified in the Snake River Salmon Recovery Plan as a primary limiting factor for steelhead in Cougar Creek and several other tributarires in the Lower Grande Ronde River (NOAA 2017).

4.0 DESIGN DEVELOPMENT

4.1. HIP 4 Biological Opinion Considerations

The proposed actions for the Cougar Creek Fish Passage Restoration project include the following categories of action as defined by the BPA HIP Guidelines (Bonneville Power Administration 2021).

- Category of Action: Fish passage restoration
- HIP Category 1f: Bridge and culvert removal or replacement

The following subsections describe the project elements designed under the responsible charge of an engineer licensed in the state of Washington. The conservation measures are included on the design drawings in Appendix A, Final Design Drawings.

4.1.1. Proposed Project Element 1: Culvert replacement

The project proposes to remove the existing CMP crossing structure and replacing it with a concrete open bottom culvert. The proposed culvert is 50 feet in length and has a 24-foot span. The culvert will be supported with spread footings and a prefabricated concrete cap will be placed on the stem wall footings. The culvert includes wingwalls at both the inlet and outlet locations. The proposed span exceeds 1.5 times the bankfull width of 13.9 feet. Therefore, a National Marine Fisheries Services (NMFS) Engineering Review will not be required (Bonneville Power Administration 2021). Preliminary structural drawings illustrating culvert dimensions and features are shown in plan, profile and section views on the design drawings in Appendix A.

4.1.2. Proposed Project Element 2: Reconstructed channel

The proposed reconstructed channel will consist of a step-pool sequence as identified in the reference reach upstream of the crossing. Porous weirs are proposed with a longitudinal spacing of approximately twice the bankfull width to approximately match conditions observed in the reference reach. The streambed material proposed between the porous weirs will generally match the gradation identified in the site reconnaissance (Table 3). Porous weirs will be partially deformable, dissipate energy and direct flow towards the center of the channel to prevent erosion at the structure walls and channel banks (Cramer, et al. 2003). Porous weirs span the channel width and are designed to degrade over time (Cramer, et al. 2003). Fines will be washed into the porous weirs to promote flow over the structure. The proposed reconstructed channel is approximately 75 feet long and has a longitudinal slope of 6.9 percent. The proposed channel cross section includes a low-flow channel thalweg. The reconstructed channel and proposed cross sections are shown in the final design drawings in Appendix A.

4.2. Fish Passage and Channel Design Guidelines

- The February 2018 WDFW/RCO Manual 22 provides implementation guidance for preliminary project design deliverables content and FBRB Grant Program funding. We prepared this Preliminary Basis of Design Report and attached appendices accordingly (WDFW & RCO 2018).

- The 2013 WDFW Stream Crossing Design Guidelines (guidelines) provide design guidelines for geomorphic condition documentation, channel design and minimum crossing structure span (Barnard et. al 2013). We designed the proposed structure span using the confined bridge design criteria which requires a complete span of the 100-year width to limit hydraulic influence on the stream
- Federal Highways Administration (FHWA) Hydraulic Engineering Circular 18 (HEC 18) provides guidance on evaluating scour at bridges (FHWA 2012a).
- FHWA Hydraulic Engineering Circular 20 (HEC 20) provides guidance on designing for stream stability at highway structures (FHWA 2012b).

4.3 BPA and RCO Comment

GeoEngineers received comments provided by BPA and RCO following the 15, 30 and 80 percent milestone submittals on October 22 November 3 and December 10, 2021, respectively. The BPA comment matrix is presented in Appendix E, Bonneville Power Comment Response, and includes responses made by GeoEngineers. Comments from BPA and RCO have been incorporated throughout this report and in the design drawings (Appendix A). Additional details and descriptions were added to this report and the design plans as a result of the comments, including the implication of climate change on the design in Section 3.0.

5.0 HYDRAULIC MODELING AND ANALYSIS

5.1. Model Development

GeoEngineers performed the hydraulic analysis of the existing and proposed conditions for the Cougar Creek crossing using the U.S. Bureau of Reclamation's Sedimentation and River Hydraulics Two-Dimensional (SRH-2D) computer program version 3.3. SRH-2D is a two-dimensional finite-volume numerical hydraulic model (US Bureau of Reclamation 2020) that is coupled with the Federal Highway Administration's (FHWA) HY-8 version 7.60 program to model culvert structures (FHWA 2020).

5.1.1. Model Domain

The existing and proposed conditions models encompass an approximate 350-foot reach of Cougar Creek including the project site. Laterally the model spans roughly 520 feet. Appendix C, Hydrologic and Hydraulic Analysis, shows the model domain.

5.1.2. Model Elevation Surface

SRH-2D requires a topographic surface to represent bathymetric and overbank areas in the model. We obtained bathymetric survey from Coffman Engineers that was completed in April 2021. Coffman Engineers used the survey data to develop a two-dimensional surface. We used the two-dimensional surface to prepare the existing conditions model elevation surface. GeoEngineers developed the proposed conditions model elevation surface by modifying the existing two-dimensional model elevation surface to reflect conditions described as the proposed project elements (Sections 4.1.1 and 4.1.2).

5.1.3. Mesh Development

SRH-2D requires development of a mesh, which is a network of triangles and quadrilaterals that make up the computational cells (elements) of the model in which model results are computed. Element size is dictated through definition of node spacing within breaklines. Breaklines are created in the mesh to define important features in the surface (i.e., roads, the river channel, riverbanks, levees, etc.). We created an existing conditions model mesh with breaklines at the top and toe of banks to better model rapid elevation changes. Each point in the mesh (node) has an elevation associated with it, which is defined from the topographic surface input. The existing culvert is represented in the mesh as quadrilateral elements with boundary conditions set at the inlet and outlet. Flow through the existing culvert is calculated using the built in HY-8 modeling routine (FHWA 2020).

5.1.4. Model Roughness

Manning's n is a parameter used in the model to represent roughness of surfaces. Manning's n values are defined within SRH-2D using coverages that define Manning's n regions with polygons. Manning's n regions throughout the existing model domain include the existing channel, brush floodplain, forested area and roads. Manning's n values are defined within SRH-2D using polygon coverages. Manning's n values for the existing culvert crossing are also defined within HY-8 (FHWA 2020). We calculated the existing channel Manning's n values using methods described by Arcement and Schneider (1989), and the existing culvert crossing Manning's n values using engineering judgement. The Manning's n values are listed below in Table 4.

TABLE 4. MANNING'S N VALUES

Material	Existing Manning's Value	Proposed Manning's Value	Source
Existing CMP Culvert	0.024	NA	FHWA 2020
Existing Channel	0.045	0.045	Arcement and Schneider 1989
Proposed Channel	NA	0.045	Arcement and Schneider 1989
Proposed Floodplain	NA	0.06	Arcement and Schneider 1989
Road	0.015	0.015	Brunner 2016
Forested Floodplain	0.15	0.15	Brunner 2016
Brush Floodplain	0.1	0.1	Brunner 2016

5.1.5. Boundary Conditions

The SRH-2D hydraulic model requires upstream and downstream boundary conditions. We developed an upstream boundary condition as an inflow boundary that introduced flow into the model (Table 5). We developed a downstream boundary condition as a normal-depth water surface elevation calculated by SRH-2D using the surface, a composite Manning's n, the downstream channel slope, and the flow.

TABLE 5. MODELED FLOW VALUES

Model Condition	Purpose	Return Interval	Discharge (cfs)
Existing/Proposed	Sediment Mobility / Bankfull Width	2-year	36
Proposed	Long -Term Scour	2-year	36
Proposed	Porous Weir Mobility / Available Freeboard / Floodplain Inundation / Local Scour	100-year	355
Proposed	Scour Check	500-year	603

5.2. Existing Conditions Model Results

Existing hydraulic model results for this report include mapped and tabular results for two peak annual flows including the 2-year and the 100-year flow (Table 5). Plan-view hydraulic results for water depth, velocity, and shear stress are presented in Appendix C. Tables 6 and 7 reflect cross-sectional maximum water surface elevation, water depth, velocity and shear stress values for existing model conditions. Cross-sectional data was extracted upstream and downstream of the existing culvert. Specific data extraction locations can be seen in Appendix C.

TABLE 6. PEAK ANNUAL FLOW EXISTING CONDITIONS MODEL RESULTS 2-YEAR FLOW

Cross Section Location	Avg. Water Surface Elevation (ft, NAVD88)	Max. Depth (ft)	Avg. Velocity (ft/s)	Avg. Shear Stress (lb/sf)	Top Width (ft)
Upstream of Culvert (Section 2)	1345.4	0.9	4.7	3.2	9.1
Downstream of Culvert (Section 5)	1330.6	0.9	4.1	2.8	11.5

TABLE 7. PEAK ANNUAL FLOW EXISTING CONDITION MODEL RESULTS 100-YEAR FLOW

Cross Section Location	Avg. Water Surface Elevation (ft, NAVD88)	Max. Depth (ft)	Avg. Velocity (ft/s)	Avg. Shear Stress (lb/sf)	Top Width (ft)
Upstream of Culvert (Section 2)	1348.1	3.7	6.2	11.3	19.5
Downstream of Culvert (Section 5)	1332.4	2.9	6.8	4.2	21.4

5.3. Proposed Conditions Model Results

Tables 8 and 9 present the proposed model peak annual flow output at the same cross section locations as the existing model conditions, with an additional section within the proposed grading extents. Plan-view hydraulic results for water depth, velocity, and shear stress are presented in Appendix C.

TABLE 8. PEAK ANNUAL FLOW PROPOSED CONDITIONS MODEL RESULTS 2-YEAR FLOW

Cross Section Location	Avg. Water Surface Elevation (ft, NAVD88)	Max. Depth (ft)	Avg. Velocity (ft/s)	Avg. Shear Stress (lb/sf)	Top Width (ft)
Upstream of Culvert (Section 2)	1345.3	0.9	5.0	3.1	10.8
Within Proposed Grading (Road Centerline)	1333.9	0.9	5.6	2.7	8.1
Downstream of Culvert (Section 5)	1330.7	0.9	5.5	2.3	8.7

TABLE 9. PEAK ANNUAL FLOW PROPOSED CONDITIONS MODEL RESULTS 100-YEAR FLOW

Cross Section Location	Avg. Water Surface Elevation (ft, NAVD88)	Max. Depth (ft)	Avg. Velocity (ft/s)	Avg. Shear Stress (lb/sf)	Top Width (ft)
Upstream of Culvert (Section 2)	1348.1	3.6	6.9	11.8	16.7
Within Proposed Grading (Road Centerline)	1335.9	2.9	8.5	4.2	23.2
Downstream of Culvert (Section 5)	1332.8	3.0	8.4	4.6	23.8

5.4. Crossing Structure Design Criteria

5.4.1. Hydraulic Opening

The flood utilization ratio (FUR) is equal to the flood-prone width (100-year width) divided by the bankfull width within the reference reach upstream of the existing crossing. With a FUR less than 3.0, the WCDG classifies the stream as confined with respect to bridge design criteria. The FUR for the reference reach of Cougar Creek is equal to 1.4 (19.5 feet divided by 13.9 feet). Therefore, Cougar Creek is considered confined. Confined bridge design criteria require that crossings completely span the bankfull width and a factor of safety is recommended (R. J. Barnard, et al. 2013). We specified a minimum hydraulic opening of 24.0 feet to meet the minimum ratio of hydraulic opening width to bankfull width of 1.5 identified in the HIP Guidelines (Bonneville Power Administration 2021). The projected 2040 increase in bankfull width is 6.2 percent yielding a bankfull width of 14.7 feet (Wilhere, et al. 2017). The factor of safety between the minimum hydraulic opening width and the future conditions 2040 bankfull width is equal to 1.6 (24.0 feet divided by 14.7 feet).

5.4.2. Available Freeboard

GeoEngineers calculated the vertical difference between the modeled 100-year water surface elevation at the inlet and out of the proposed structure. We assumed the roadway profile will match the existing roadway elevation and subtracted the designed pavement, subgrade section and the thickness of the concrete structure. The resulting available freeboard is 2.5 feet and 2.8 feet at the inlet and outlet of the structure, respectively.

5.5. Streambed Material Analysis Results

5.5.1. Proposed Conditions Porous Weir Material Sizing

Proposed porous weir gradation sizing was analyzed using the Bathurst Critical Unit Discharge equations (Bathurst 1987). This method evaluates channel slope, channel width, and stream discharge to determine a stable material gradation. We used the resulting D_{84} to inform a range of boulder size between 28 and 36 inches (Appendix C (R. J. Barnard, et al. 2013)). The maximum boulder size was selected for use as the header and footer boulders. The minimum and maximum boulder sizes to be used for porous weirs construction are listed in Table 10 and are consistent with WSDOT Standard Specification 3-man boulders (WSDOT 2020). Porous weirs will be constructed using boulders and native excavated material.

TABLE 10. POROUS WEIR MATERIAL SIZING

Minimum Boulder Size	Maximum Boulder Size
28 inches	36 inches

5.5.2. Proposed Streambed Material Sizing

Streambed material between porous weirs will consist of native stockpiled material and supplemented with imported material. Streambed material should reflect reference material size and have a D50 within 20 percent of the reference reach D_{50} of 2.5 inches (WSDOT 2019). The existing streambed material gradation is shown in Appendix A.

5.6. Scour Analysis

GeoEngineers evaluated various methods of scour based on a design scour flood equal to the 100-year flow and a scour check flood equal to the 500-year flow (FHWA 2012a). For long-term degradation, we used the 2-year channel forming flow (NRCS 2007). We evaluated long-term degradation, contraction scour, abutment scour and local scour at the proposed porous weir channel bed structures.

5.6.1. Long-term Aggradation/Degradation

Long-term scour refers to the vertical response of the streambed, reported as depth of scour in feet. GeoEngineers estimated anticipated long-term vertical channel response at the crossing location following guidance presented in the National Engineering Handbook (NEH) Section 654 Technical Supplement 14B (NRCS 2007). The guidance requires the calculation of a potential armoring layer forming and an equilibrium slope. One of these two depth calculations will control the anticipated long-term degradation, and therefore, the smallest of the two scour depths was considered for this project site. NEH guidance uses the 2-year recurrence interval for long-term degradation calculations. Based on calculations, the formation of an armoring layer is not anticipated. The energy slope required to produce a boundary shear stress equal to the critical shear stress for the streambed material upstream exceeded the existing channel slope downstream of the crossing. Therefore, no degradation is anticipated with the proposed crossing and the calculated long-term scour is 0.0 feet.

5.6.2. Contraction Scour

Contraction scour is caused by overbank flow area blocked by the culvert. We used results from the proposed condition hydraulic model—upstream of the proposed culvert and at the inlet of the culvert—to calculate contraction scour. The hydraulic parameters included the channel width, average depth, average velocity, and discharge. This information was used in a standard contraction scour analysis following HEC-18 methods (FHWA 2012a). We performed a contraction scour analysis using the software Hydraulic Toolbox, version 5.1 (FHWA 2021). Results of the contraction scour analysis indicate that live-bed scour conditions will exist. We calculated a main channel contraction scour depth of 1.0 feet measured from the design thalweg at the inlet of the culvert within the main channel at the 500-year event.

5.6.3. Abutment Scour

GeoEngineers used the HEC-18 NCHRP (FHWA 2012a) abutment scour approach in Hydraulic Toolbox (FHWA 2021), which was developed over a range of abutment types, locations, flow conditions, and sediment transport conditions. The NCHRP uses live-bed and clear-water contraction scour equations to estimate a starting depth for the abutment scour due to contraction. This value is then multiplied by a scour amplification factor to account for additional turbulence and erosive forces due to the abutments. The amplification factor is dependent on the abutment size and configuration. Results from the NCHRP method based on the existing streambed material gradation indicate an abutment scour amplification factor of 2.05 and the calculated abutment scour is 1.6 feet below the proposed grade at the abutment wall. The crossing is located within an historic alluvial fan. Therefore, channel migration is possible over the structure's design life, and the contribution abutment scour depth of 1.6 was applied to the thalweg elevation to calculate the total scour depth.

Total scour at a road crossing is the sum of long-term degradation, contraction scour at the bridge crossing, and local scour at the bridge abutments (FHWA 2012a). Based on the calculated total scour depth, we recommend the top of footing be placed a minimum of 2.5 vertical feet below the proposed channel thalweg elevation through the crossing structure. Table 11 lists the individual scour results and the total scour applicable to the structure footing elevation design.

TABLE 11. SCOUR DEPTHS

Scour Type	Scour Depth (ft) 500-Year Event
Long Term Degradation	0.0
Abutment Scour	1.6
Contraction Scour	1.0
Total Scour	2.5

5.6.1. Porous Weir Scour

We calculated potential scour depth for the porous weirs during the 100-year design discharge using methods identified in the National Engineering Handbook Technical Supplement 14B (NRCS 2007). The resulting potential scour depth was approximately 1.5 feet.

6.0 CONSTRUCTION

6.1. Disturbance Areas and Conservation Measures

Project disturbance areas and conservation measures applicable to all actions are defined and shown on the Final Design Drawings in Appendix A. Turbidity monitoring will be conducted in accordance with HIP protocols (Bonneville Power Administration 2021). Planting is proposed in disturbed areas shown in the Final Design Drawings in Appendix A to restore natural plant communities. The revegetation plan illustrates both a bank zone and a riparian zone and specifies associated cuttings, bare-root plantings and seeding for each zone. The proposed revegetation plan for the bank zone includes willow (*Salix* spp) cuttings, water birch (*Betula occidentalis*) cuttings, black cottonwood (*Populus balsamifera*) cuttings and redosier dogwood (*Cornus sericea*) cuttings.

The riparian zone, which includes the area approximate 3 inches below the top of bank and the adjacent floodplain contains willow cuttings, black cottonwood cuttings and bare root and Oregon ash (*Fraxinus latifolia*) bare root plantings. Both areas propose native grass seeding.

6.2. Construction Quantities and Estimate of Anticipated Construction Costs

GeoEngineers calculated construction quantities and applied unit costs based on recent project experiences, engineering judgment and published documentation (Oman Systems 2020). We included a summary of the anticipated construction costs in Appendix D, Construction Quantities and Estimate of Anticipated Costs.

7.0 LIMITATIONS

We have prepared this report for the Asotin County Conservation District and their authorized agents for the Cougar Creek Fish Passage Barrier Removal project.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in the field of stream and river habitat enhancement, stabilization and fish passage design engineering in this area at the time this report was prepared. The conclusions, recommendations and opinions presented in this report are based on our professional knowledge, judgment, and experience. No warranty, express or implied, applies to our services and this report.

Any electronic form, facsimile or hard copy of the original document (email, text, table and/or figure), if provided, and any attachments should be considered a copy of the original document. The original document is stored by GeoEngineers, Inc. and will serve as the official document of record.

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APPENDICES

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