Little Tonsina Tributary ATV Trail
Hydraulic and Hydrology Report
ADF&G no. 20103687

Outlet photo of Little Tonsina Tributary ATV Trail

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APPENDICES

1 INTRODUCTION

The United States Fish and Wildlife Service (USFWS) has developed this concept assessment to evaluate the crossing of a tributary to Little Tonsina on an All-Terrain Vehicle (ATV) trail in Tonsina, Alaska. The current crossing is a barrier at all flows, obstructing migration of Chinook and Coho Salmon. The tributary to Little Tonsina watershed is small, with valuable upstream habitat comprised of smaller channels. This report provides concept level recommendations to improve fish passage, ecological function, and flood resiliency at the project site.

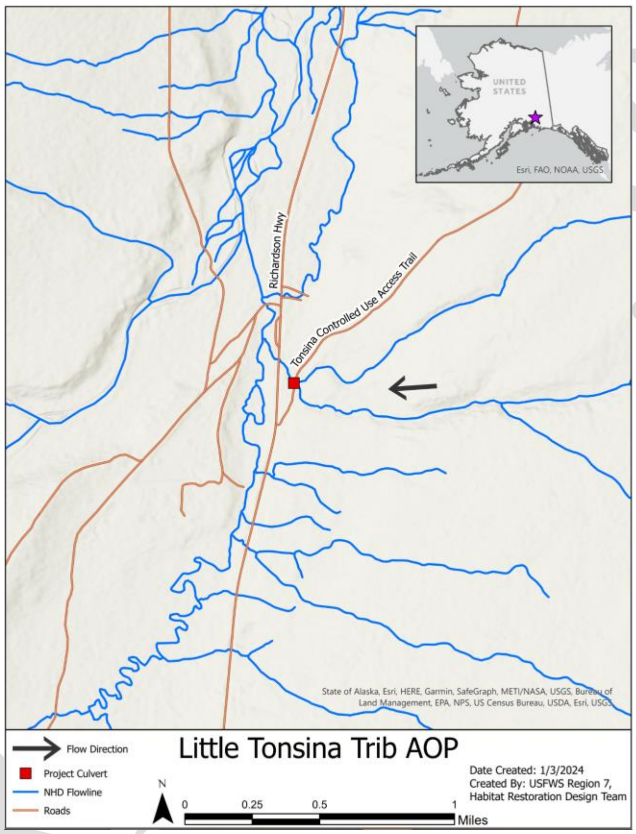

Figure 1. Vicinity map.

This report includes hydrologic and hydraulic analyses of the existing culvert and a preliminary design recommendation for a replacement structure. The proposed project consists of removing the existing fish passage barrier and installing a new crossing designed based on a geomorphic approach. The existing undersized and deformed culvert will be removed and replaced with channel-spanning structure. The channel will be reconstructed through the crossing, and the gravel road reconstructed to maintain ATV access.

2 PROBLEM DESCRIPTION

The tributary to Little Tonsina supports Chinook salmon, Coho salmon and Dolly Varden. The main stem of Little Tonsina is cataloged for anadromy with Anadromous Waters Catalog (AWC) entry 212-20-10080-2331-3081. In the upper watershed, this crossing splits into smaller steeper tributaries.

The existing crossing is a severely damaged culvert, 5ft round CMP, that acts as a total barrier to juvenile and adult salmon. The undersized culvert has a slope of 6.5%, a hydraulic jump at the inlet, a perched outlet with a detached/deformed outlet apron and is in poor condition. The site is experiencing a head cut, causing channel incision directly upstream of the crossing. Directly downstream of the crossing is a large scour pool and an over-widened channel.

The crossing is rated red in Alaska Department of Fish and Game's (ADF&G) fish passage database (ADFG # 20103687) from a survey completed in 2017. Ranking criteria produced a red rating due to outfall height and constriction ratio, identified fish barriers. The trail has washed out immediately adjacent to the crossing (potentially numerous times) and been minimally repaired. The washout damage impacts usability of the trail. The trail is primarily used by pedestrians, ATVs, and snowmachines. The trail is expected to qualify as a very low volume road (less than 400 vehicles per day).

Project stakeholders would like to restore the ATV trail for pedestrian, subsistence, and ATV/Utility Task Vehicle(UTV) use. The ATV trail accesses public lands that are otherwise inaccessible. An emphasis is placed on providing more than adequate flood conveyance due to the washout history of this crossing and a highway crossing downstream. The proposed design incorporates an ATV bridge to address these requirements.

3 PROJECT GOALS AND OBJECTIVES

The USFWS is working collaboratively with Copper River Watershed Program (CRWP), Bureau of Land Management (BLM), and ADF&G to develop a design alternative to address the total barrier to juvenile and adult fish on Little Tonsina Tributary (**Table 1**).

The objectives of the project are to:

- Remove existing failing culvert
- Restore ecological function of impacted riparian area
- Restore fish passage during typical flow conditions
- ~~Provide a crossing designed to withstand at least a 1% Annual Exceedance Probability (AEP) event~~
- Reroute ATV trail

4 PROJECT CONSTRAINTS AND DESIGN CRITERIA

The project is located on an unnamed ATV trail that accesses Tonsina Controlled Use Access Trail. The trail is gravel and is used by both public and private entities.

4.1 Utilities

No utility locates were completed for this design. Utility locates should be completed by contractors prior to construction.

4.2 Ownership

BLM owns and maintains the ATV trail. Accessible parcels are owned and managed by Copper Valley Telephone Company and DNR. Private and public parcels are located and accessed through the ATV trail.

4.3 Local Design Guidelines or Requirements

The USFWS Culvert Design Guidelines for Ecological Function were used for guidance in this design. Available here:
https://www.fws.gov/alaska-culvert-design-guidelines

Alaska Department of Fish and Game has a streambank revegetation and protection guide that was consulted for this design. Available here:
https://www.adfg.alaska.gov/index.cfm?adfg=streambankprotection.main

4.4 Flood Hazards or Floodplain Management Requirements

The existing crossings are in unmapped flood hazard area (FEMA, 2023).

4.5 Geotechnical

No geotechnical investigations were completed for concept design development. A geotechnical investigation may be necessary for some potential crossing alternatives.

4.6 Salvage

It is likely that some viable salvageable streambed material will be available for construction of the new channel. Additional streambed materials will likely need to be brought in from offsite. Trees, soil, and vegetative material usable for revegetation may be salvaged during demolition.

4.7 Fish Passage

This project seeks to replicate natural conditions found elsewhere within this system outside the influence of the existing crossing, thereby providing a range of depths and velocities appropriate for various aquatic species and life-stages found in the system.

4.8 Traffic, Loading and Design Vehicle

~~The replacement crossing should be designed for ATV/UTV, snowmachine, and pedestrian use as the primary traffic; and be able to accommodate an occasional light duty pickup truck~~.

5 SITE ASSESSMENT AND EXISTING CONDITIONS

The USFWS and CRWP representatives completed preliminary assessments of the barrier during a 2022 site visit.

The USFWS conducted a site assessment in October 2022 and August 2023, to observe existing site conditions and collect measurements for hydrology estimates (Section 6). USFWS collected approximately 703 linear feet of stream survey data and approximately 235 linear feet of trail survey data.

5.1 Existing Site Condition

Table 1. Existing culvert on Little Tonsina Tributary

Crossing	Lat, Long	Diameter (ft)	Length (ft)	Slope	Material	Condition
20103687	61.59001°, -145.22047°	5	61	6.5% *End of outlet apron	CMP	Hydraulic Jump, Perched, Undersized, Rusted, Significant inlet and outlet damage, Damaged outlet apron

*Culvert information from ADF&G Fish Resource Monitor Website & 08/23 Survey

5.1.1 Geomorphic Conditions and Longitudinal Profile

Upstream of the ATV crossing, the tributary splits into smaller streams. Downstream of the ATV crossing, the creek joins the mainstem of the Little Tonsina River. The tributary is a moderately entrenched stream with a head cut working its way upstream, and a channel slope ranging from 3.4%-4.4% (.034-.044 ft/ft). This system is consistent with a B4 stream type. Upstream of the crossing is consistent with B4a and downstream of the crossing is consistent with B4c.

A longitudinal profile was collected of the channel through the crossing as part of the survey at the site assessment. The longitudinal profile provided a crossing slope of 4.5-5.0% (.045-.05 ft/ft).

5.2 Reference Reach Selection and Data Collection

Two reference reaches (one upstream and one downstream) were collected as a part of this study. The upstream reference reach was chosen as a less impacted and more representative reach. Due to this reach being above the confluence of another tributary, cross section data was scaled up using percent difference in watershed areas.

The reference reach was collected under the methodology outlined in the USFWS Culvert Design Guidelines for Ecological Function (USFWS, 2022). The reference reach was approximately 170 feet upstream of the crossing, on the main channel of Little Tonsina Tributary.

5.2.1 Bankfull Width

Cross section information was collected during the survey at the identified reference reach. Bankfull indicators were noted in the survey and corroborated back at the office. Scaled bankfull width tolerance is 9.0-10.5 ft.

5.2.2 Existing Sediment Gradation

The field investigation included a pebble count taken in each of the reference reaches as well as noting key piece dimensions. Data indicates most of the material near the project crossings consisted of cobbles and medium gravels with some small gravels and fines. Proposed sediment gradation is based on pebble count information (Section 9).

6 HYDROLOGIC ANALYSIS

6.1 Watershed Information

The watershed was delineated with ArcGIS Pro Hydrology toolbox using the National Hydrography Dataset (NHD) Plus 5m x 5m flow direction raster available for the 19020102 Hydrologic Unit Code(HUC).

The Little Tonsina River Tributary watershed is 78% forested with an average slope of 20%, with 3 very small lakes in the upper watershed that amount to less than 0.2% of the watershed. The total area of the watershed upstream of the crossing is 3.7mi^2 and receives 17in of mean annual precipitation based on the PRISM 1971 – 2000 dataset.

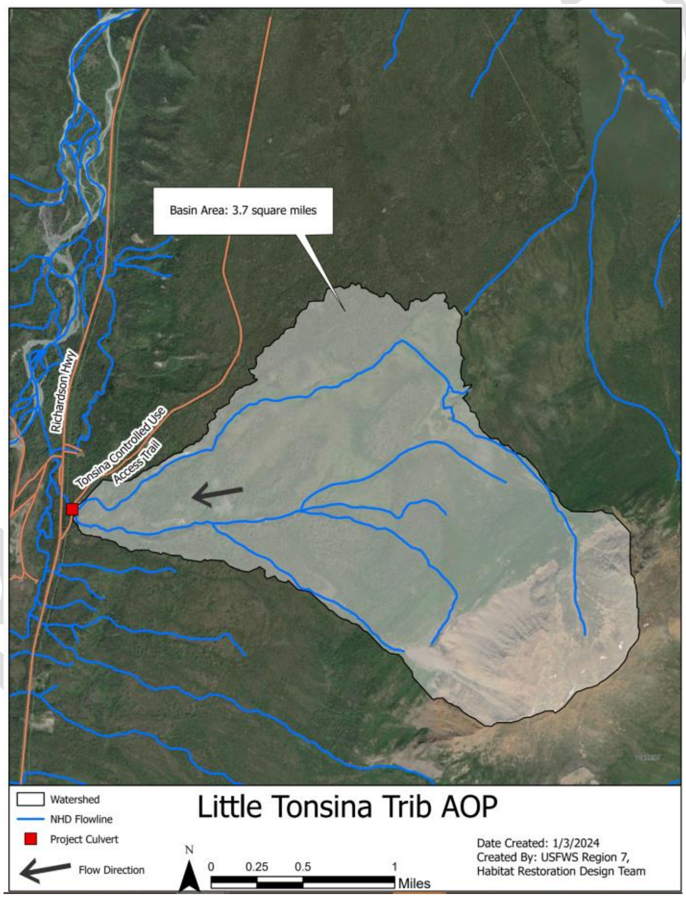

Figure 2. Watershed for the culvert crossing location on tributary to Little Tonsina River.

6.2 Discharge Estimates

Little Tonsina Tributary is ungaged, so several hydrology estimation methods were used to arrive at the design discharge. Nearby gaged streams differ widely in watershed area and precipitation compared to the design watershed. Basin transfer method estimates were completed for nearby gages, but they were not preferred for design. The basin transfer results were much smaller either the 2003 or 2016 regression equation and poor agreement with the geomorphic hydrology method (Appendix B for basin transfer results).

The design watershed is in the acceptable precipitation and area range to apply either the 2003 or 2016 regional regression equations (Curran et al. 2003, 2016). The 2016 regional regression equation result was selected for the design discharge over the 2003 because the 2-year flood estimate derived from the 2016 equation was in agreement with the bankfull discharge determined by the geomorphic hydrology approach. The geomorphic hydrology method used reference reach cross section, profile and pebble count data in Rivermorph software to develop bankfull discharge estimates between 44-52cfs. Results and discussion for all methods considered can be found in Appendix B.

Flow measurements were not analyzed or utilized to calibrate current project design. Flow measurements, collected by Kirsti Jurica of CRWP, can be found in Appendix B. Subsequent design stages shall analyze and consult collected flow data.

Table 2. Regression Equation Results for Main watershed flows at Little Tonsina Tributary (design flows bolded)

RI	Main Watershed 2003 Regression Method	Main Watershed 2016 Regression Method
yr	cfs	cfs
2	38	**51**
5	72	94
10	101	128
25	143	177
50	178	217
100	216	**259**
200	257	304
500	316	367

Table 3. Sub-watershed South (upstream reference reach) and Main watershed flows at Little Tonsina Tributary.

RI	Sub-Watershed South 2016 Regression Method	Main Watershed 2016 Regression Method	Percent Difference: Sub-Watershed 2 and Main Watershed
yr	cfs	cfs	%
2	29	51	56.86
5	52	94	55.32
10	69	128	53.90
25	94	177	53.11
50	114	217	52.53
100	135	259	52.12
200	157	304	51.64
500	187	367	50.95

Table 4. Design discharge estimates

Return Interval	Discharge (cfs)	Notes
2	51	2-year event
100	259	100-year flow

7 PROPOSED STREAM CHANNEL AND STRUCTURE DESIGN

The proposed design removes the existing culvert on an ATV Trail crossing of the tributary to Little Tonsina River and ~~replaces it with a structure capable of conveying predicted floods;~~ spanning the full width of the channel; and allowing for natural processes such as debris conveyance, aggradation, degradation, and animal movement.

7.1 Proposed Channel Planform and Geometry

7.1.1 Channel Horizontal Alignment

The proposed channel alignment could be reconstructed to match existing channel alignment. This alignment could achieve the goals and objectives of this project. Further consideration on alignments is discussed in section 11.2.

7.1.2 Channel Profile

The bed planform of this system contains a step-pool/riffle-pool system. Further design development should consider use of grade control structures or a step pool system approach. Step-pool systems occur naturally between 3 and 8 percent slopes.

Proposed channel profile will consist of 178 feet of regrade with a continuous channel slope of approximately 4.1% (Appendix E). The design slope is within 1.25% of the channel slope (USFS 2008). Upstream and downstream tie in locations occur at stable grade controls. Recommended downstream tie in is 38 feet downstream of the current crossing. A potential upstream tie in is approximately 80 feet upstream of the current crossing at a stable grade control. Due to the intended movement of the upstream sediment wedge, alternative upstream tie in locations may meet project needs and agree with the channels design slope.

7.1.3 Channel Cross Section

The proposed channel cross section is discussed in Table 5.
Proposed bankfull area is 9.3 square feet. Proposed low flow channel area is 2.8 square feet, 30% of the bankfull area. The low flow channel shall be maintained through the entirety of the reconstructed channel. See proposed channel geometry design in Figure 4.

The 4-foot floodplain benches are proposed on either side of the bankfull channel through the road prism and are at a 5% to direct flow back towards the main channel during flood events while still facilitating overbank inundation.

Due to the large variance in upstream and downstream channel geometry at the tie in locations for the reconstructed channel, reconstructed channel bankfull and low flow channel widths and depths shall be tapered to tie into existing channel geometry upstream and downstream.

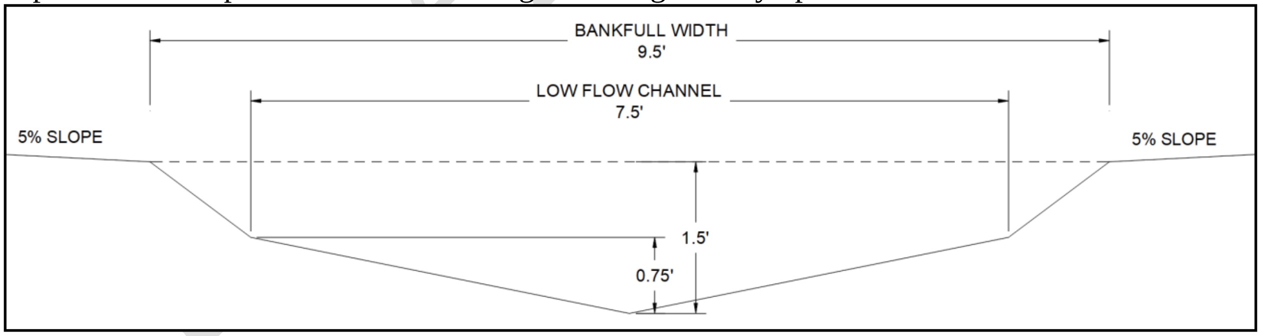

Figure 3. Proposed cross section for channel geometry.

Table 5. Proposed cross section dimensions and justification

Component	Dimension	Slope	Justification
Bankfull Width And	Width: 9.5’ Depth: 1.5’	1.33H:1V	Hydraulic analysis indicates flow will overtop onto benches ~2-year event.

Depth			Area and bankfull width are within tolerance or consistent with reference reach cross section.
Low Flow Channel Width and Depth	Width: 7.5’ Depth: .75’	5H:1V	30% of the bankfull event. 29.4% of the 2-year event. Guidance ~15-30% of the 2-year event area (USFWS, 2022) 4 inches = minimum low flow channel depth for fish passage (USFWS, 2022)
Bench Width	Width: 4’	20H:1V	Total width (benches + bankfull width) of 17.5 feet

~~7.2 Proposed Structure~~

~~A 48-foot span single span bridge was chosen as an economical structure to accommodate the 100-year flow event and maximize fish passage, based on HY-8 and FHWA Hydraulic toolbox analysis. Parameters for the recommended bridge are listed in Table 6 and the ATV bridge is shown in Figure 5. Freeboard for this crossing will be more than 8’, more than 2 times the guidance. The Alaska Department of Transportation recommends 3 feet of freeboard at the 100-year flood event for highway bridges (ADOT&PF, 2017).~~

~~The recommended bridge span will pass the 100-year flood flows. Substrate calculations, the hydraulic analysis using HY-8, and other supporting information are attached in Appendix B. The recommended structure will accommodate Q100 flow of 259 cfs predicted by the 2016 regression equation. The overtopping flow for the recommended new crossing design is 746 cfs, which is higher the 500-year flood flow estimate.~~

~~Table 6. Proposed bridge dimensions *based off Rolling Barge 8’ Vehicle Bridge (12,000-pound live load)~~

~~Span (ft)~~	~~Width (ft)~~	~~Girder Depth (ft)~~
~~48~~	~~8~~	~~1~~

8 HYDRAULIC ANALYSIS

8.1 Existing Conditions Hydraulic Results

Existing conditions hydraulic analysis was completed for the current Little Tonsina Tributary crossing. The existing structure is failing, perched at the inlet and outlet, steeper than channel grade, and has identifiable conveyance capacity issues. Hydraulic results were modeled through HY-8 hydraulic analysis.

8.2 Proposed Design Hydraulic Results

Hydraulic analysis at the proposed fish passage crossing was completed using the HY-8, FHWA program Hydraulic Toolbox Version 5.2, and RiverMorph Version 5.2. The proposed design is anticipated to pass adult coho salmon at all flows. The 2-year flood flow design velocity was designed with an average velocity of less than 5.5 feet per second (fps).

Results for the proposed cross section at a 4.1% slope for the fish passage low flow, 2-year, and 100-year events are presented in **Table 7**.

Table 7. Hydraulic results for proposed cross section geometry.

Event	Discharge At Each Crossing (cfs)	Depth (ft)	Average Velocity (ft/s)	Average Shear Stress (lb/ft^2)
Low Flow	8.35	0.75	2.97	0.94
2-Year	51	1.5	5.26	2.05
100-Year	259	2.7	8.20	3.50

9 STREAMBED MOBILITY AND SUBSTRATE DESIGN

9.1 Streambed Sediment

The proposed streambed sediment gradation was calculated using the pebble count data collected during the survey, and the substrate design methodology outlined in the USFWS Culvert Design Guidelines for Ecological Function (USFWS, 2022). The proposed design gradation includes a minimum of 10% sand size #10.

The D100 and D30 coarse sediment design targets were estimated using the Corps of Engineers Equations for rip rap design outlined in the FHWA River Engineering for Highway Encroachments (Richardson, Simons, & Lagasse, 2001). The final material gradation was designed using the Fuller Thompson equation to develop a well graded mixture with the FHWA D100 set as the maximum material size. The proposed material D30 from the Fuller Thompson equation is equal to the FHWA stable D30. Rounded or angular materials will be used for the proposed streambed substrate. The proposed sediment gradation is shown Table 9, additional calculation information is available in Appendix D.

Table 8. Proposed coarse sediment gradation for channel

Sieve	% Passing
20 in	1.00
16 in	0.8 to 0.9
12 in	0.6 to 0.7
9 in	0.3 to 0.4

6 in	0.2 to 0.3
4 in	0.1 to 0.2

Table 10. Proposed fine sediment gradation for channel

Sieve	% Passing
9 in	1.00
6 in	0.85 to 1
2 in	0.7 to 0.9
0.75 in	0.4 to 0.6
#4	0.15 to 0.35
#10 Sand	0.15 min

*Includes 5% tolerance
** D_{100} and D_{30} calculated with factor of safety of 1.5 due to uncertainty in hydrology.

9.2 Channel Complexity Elements

Cross section complexity will occur when tying into the existing upstream and downstream channel. To tie in structurally, geomorphically, and aesthetically with upstream and downstream, transitional/tapering cross sections will be need. The cross section shall become narrower and more entrenched when transitioning upstream into existing channel banks, while cross sections shall become wider and less entrenched when transitioning downstream into existing channel banks.

Use of bio-engineering and large woody debris to increase complexity and enhance stream functions/processes should be considered in subsequent design phases.

10 REVEGETATION RECOMENDATIONS

Revegetation of the tributary to Little Tonsina River and the ATV trail embankment shall be completed as a part of this project. Recommended revegetation after the structure installation is to transplant vegetative mat along the streambanks, to a minimum width of 4 feet. This technique is to re-establish appropriate riparian species as quickly as possible before non-native species can outcompete, and to increase bank stability. The vegetative mat can be salvaged during grubbing or harvested after the channel is constructed and transplanted within 24 hours to increase the chances of survival.

All riparian areas disturbed by construction beyond the 4 feet of vegetative mat on the banks, will receive either alder plugs or willow livestakes. Disturbed and exposed soil surfaces outside of the riparian area should be seeded as shown in future design drawings with a native seed mix, free of noxious weed materials. Embankments will be seeded after placing soil in the voids and topsoil to a depth of 9 inches above the upper surfaces of placed rock. Slash, consisting of native plant materials free of noxious weeds may be salvaged during construction, and placed on the roadway embankments to supplement reseeding efforts and establishment of riparian area habitat.

11 ALTERNATIVES CONSIDERED

In order to be considered, a structure had to provide a span of at least 9.5 feet at bankfull elevation, as well as a high vertical clearance. The vertical clearance is critical at this site to provide ample depth for the broad range of vertical adjustment potential, provide adequate hydraulic capacity for the peak discharges of this flashy system, and embed the large key pieces necessary for stability within the substrate mix.

Structures considered for this evaluation included:

Aluminum box culvert(s)
- 15’6” x 7’3”

Pipe arch:
- 167” x 101”

Bottomless pipe arch
- 16’0” x 8’3”

Modular bridges:
- 42’ long x 8’ wide
- 48’ long x 8’ wide

11.1 Structure

Due to the head cut potential and the depth required to embed large stable material below the lower vertical adjustment potential (VAP), structures with full inverts (including round, pipe-arch, and box culverts) would require deep excavations, deep infill, and create large footprints of disturbance. Given that material costs are comparable between a modular ATV bridge and full-invert structures of the appropriate dimensions for this crossing; the increased excavation, earthwork, and disturbance is expected to make a full-invert structure more expensive to construct than a modular bridge.

A low-water ford crossing was considered, as it would be a less expensive way to span the entire floodplain and reduce maintenance cost. However, it was not evaluated as a viable crossing because fords are not compatible with incised, entrenched systems and are difficult to design for sustained long term fish passage. This approach would not be optimal due to the entrenchment of the channel and the headcut moving through the crossing location. There is the potential risk that the channel adjustment creates the ford to be a grade control unaligned with channel slopes upstream and downstream of the crossing.

A bottomless pipe arch was also evaluated, as it could reduce the excavation and infill required, especially if the bottom of footers and riprap don’t extend below the VAP. However, this approach would introduce significant scour risk and is likely only feasible if the bottom of footers could be placed above the 100-year flood elevation. A geotechnical investigation would also need to be completed to confirm the suitability for the site and inform the footer design. ~~A modular ATV bridge was considered and selected as the preferred option for the site. A modular ATV bridge has the following advantages:~~

- ~~Abutments can be placed outside of and above 100-year floodplain, due to naturally entrenched nature of the channel~~
- ~~Comparable material cost to buried structures; lower total construction cost expected~~
- ~~Reduced need for heavy construction equipment; can be assembled by hand tools and lifted by a team of persons or picked and swung into place with a small excavator~~
- ~~Shorter construction and stream diversion duration compared to buried structures~~
- ~~Moderate to minimal excavation required, depending on selected channel alignment~~
- ~~Moderate to minimal footprint of disturbance, depending on selected channel alignment~~
- ~~Greater hydraulic capacity and freeboard compared to other structures~~
- ~~Increased clearance for constructives~~

~~A modular ATV has the following disadvantages compared to a buried structure:~~

- ~~Reduced vehicle weight limit; inadequate for use as access route to material site~~
- ~~Increased maintenance required in the form of occasional bridge deck replacement~~

11.2 Alignment

The site topography has developed an overflow channel just north of the existing pipe and alignment. Numerous trail washouts have occurred at this overflow channel. While the preliminary design depicts maintenance of the current channel alignment, diverting the stream to the overflow route is considered a viable option and should be evaluated during further design development.

Advantages and disadvantages of maintaining current stream alignment:

+ Smaller construction footprint constrained area impacted by ATV trail
+ Shorter channel construction length
+ Maintains straight channel alignment through crossing
– Channel slope on the high end of acceptable
– Requires more in-water work

Advantages and disadvantages of diverting to overflow route:

+ Reduced excavation volume
+ Most work completed dry
+ One diversion
+ Increased channel length & decreased slope (to middle of target range)
– Introduces new curvature & potential for scour and channel migration

Whichever alignment is selected, the designer should consider lowering the profile at the alternate alignment to below the bottom chord of the bridge, such that in the event of an extreme event beyond the design discharge, the trail will wash out instead of the bridge in the event of an extreme event above the design discharge.

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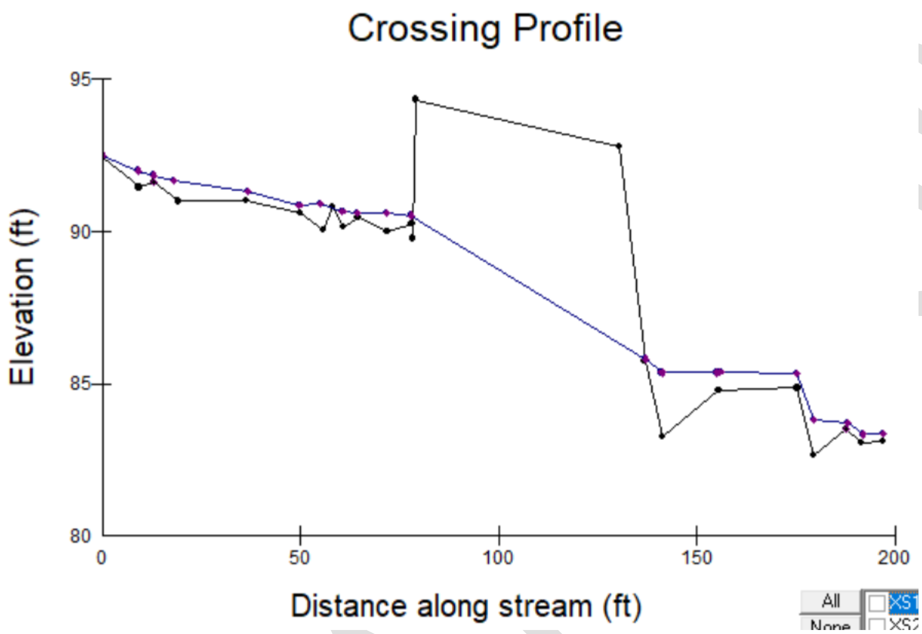
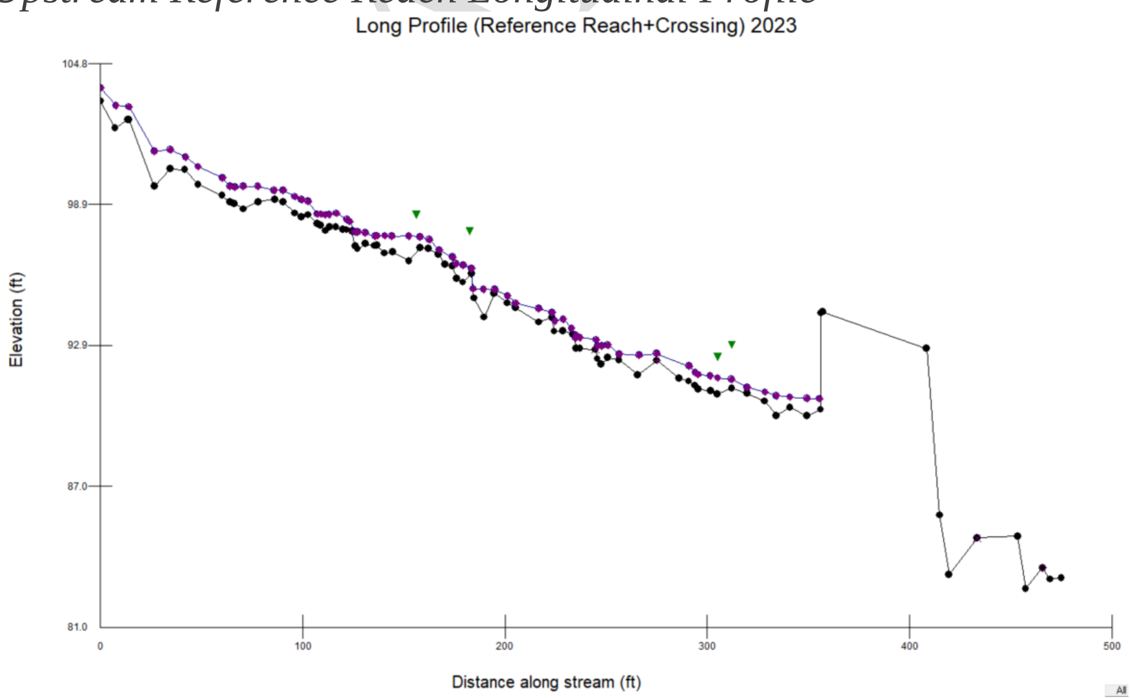
Appendix A:
Existing Site Conditions

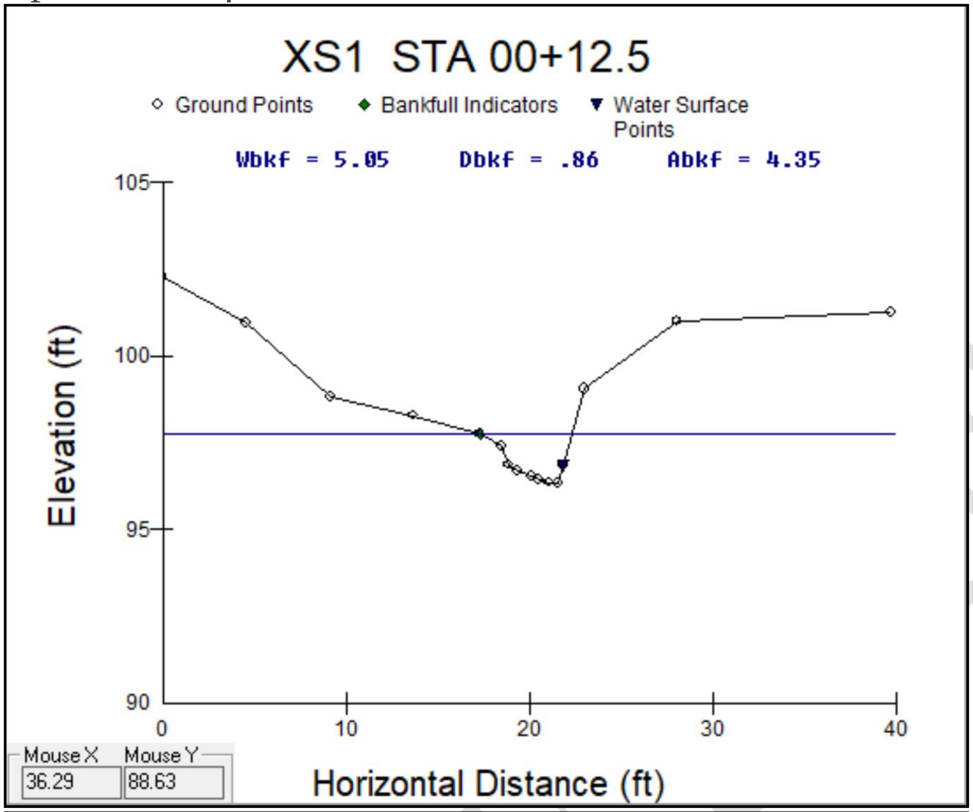
Crossing Profile

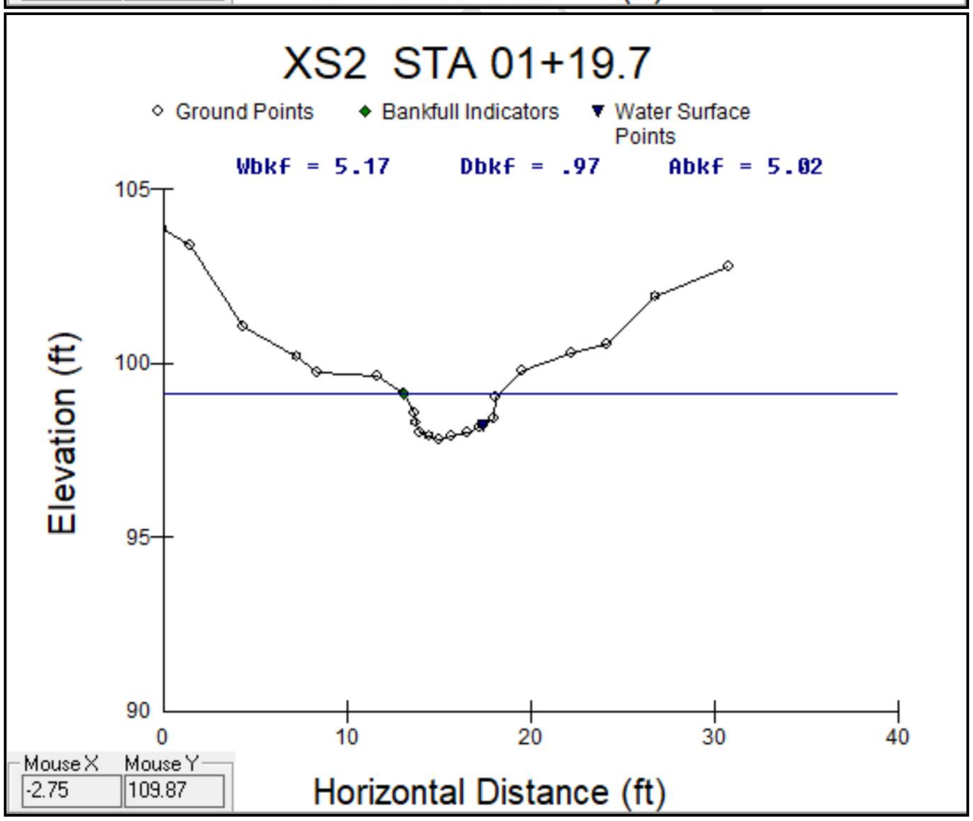


Upstream Reference Reach Longitudinal Profile

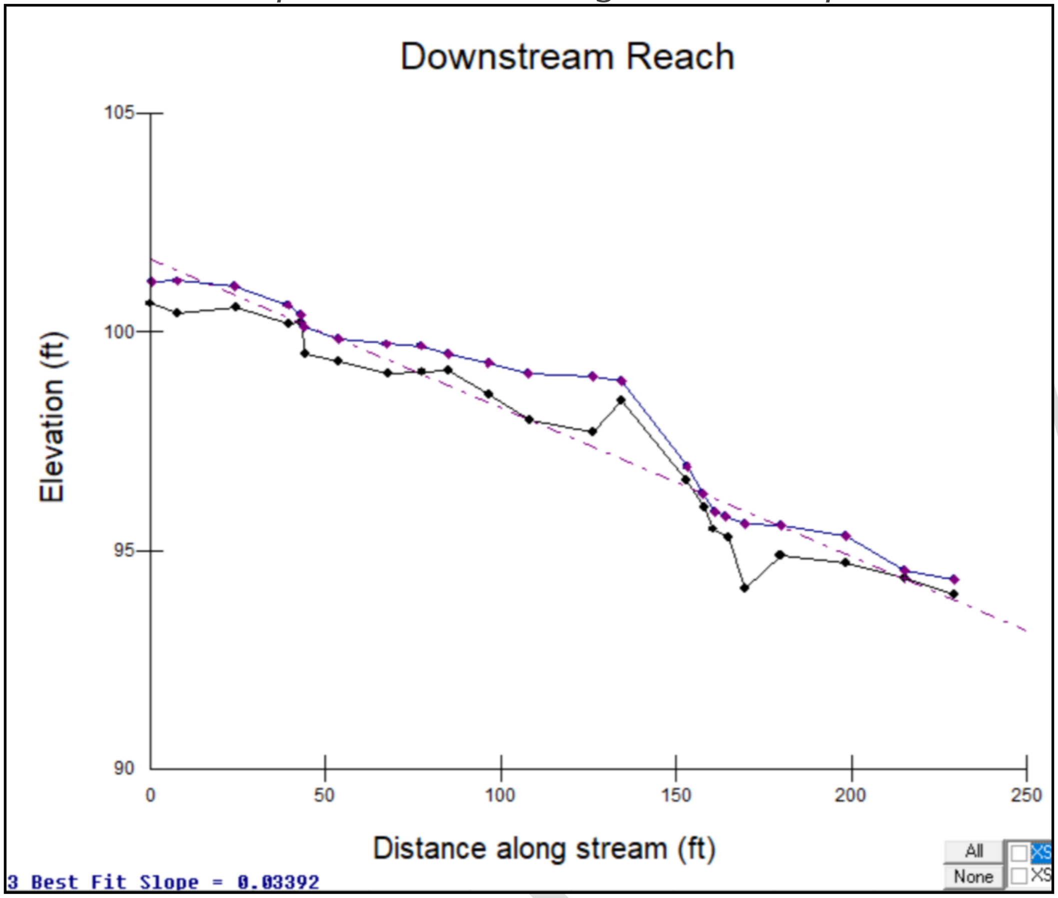


Upstream Reference Reach Cross Sections

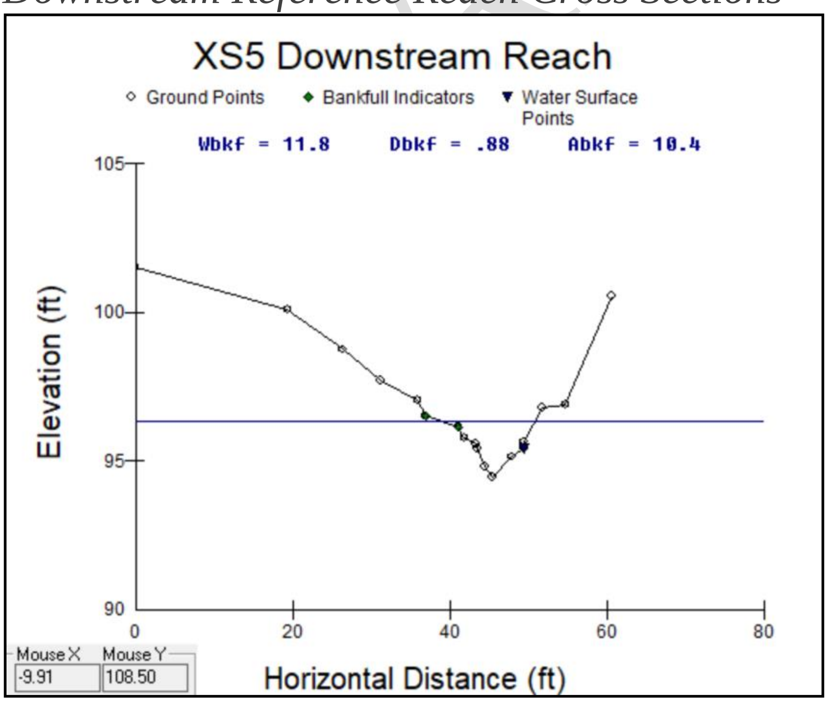


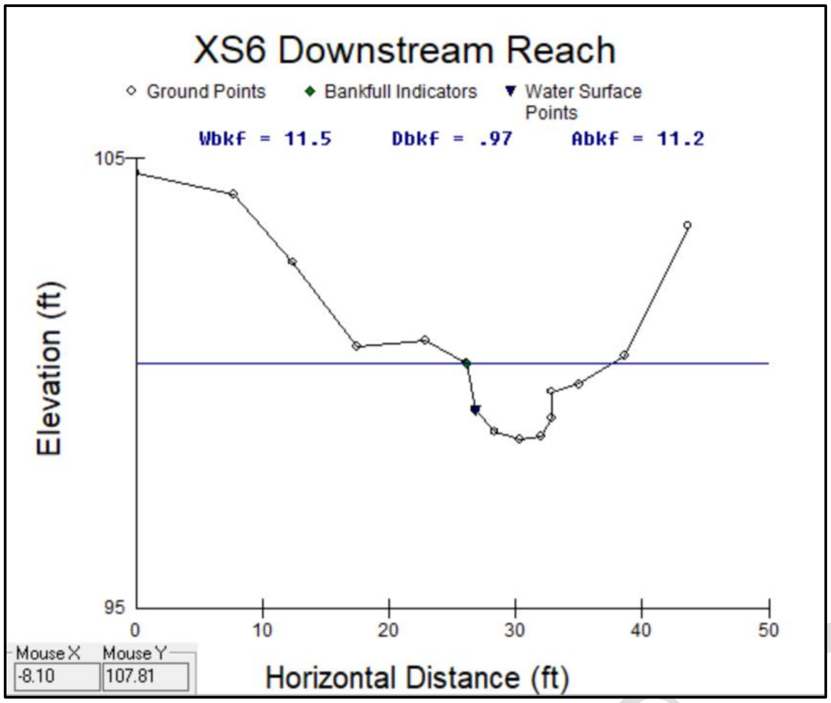


Downstream Reference Reach Longitudinal Profile



Downstream Reference Reach Cross Sections





XS6 Downstream Reach
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 11.5
Dbkf = .97
Abkf = 11.2
105
95
Elevation (ft)
0
10
20
30
40
50
Horizontal Distance (ft)
Mouse X
-8.10
Mouse Y
107.81

Downstream Reference Reach Conditions

Stream:	**Little Tonsina Trib, Reach - ATV Crossing**			
Basin:		Drainage Area: **2368** acres	**3.7**	mi^2
Location:	**Downstream Reference Reach**			
Twp.&Rge: ;		Sec.&Qtr.: ;		
Cross-Section Monuments (Lat./Long.):	**61.59142 Lat / -145.22214 Long**		Date:	**02/02/23**
Observers:	**Jess Straub and Anna Senecal**		Valley Type:	C-CO-U$

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**15.04**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**1.06**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**15.89**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**14.19**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**2.04**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**30.51**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**2.03**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**61.62**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.016**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.03**	

Stream Type **B 4c** (See **Figure 2-14**)

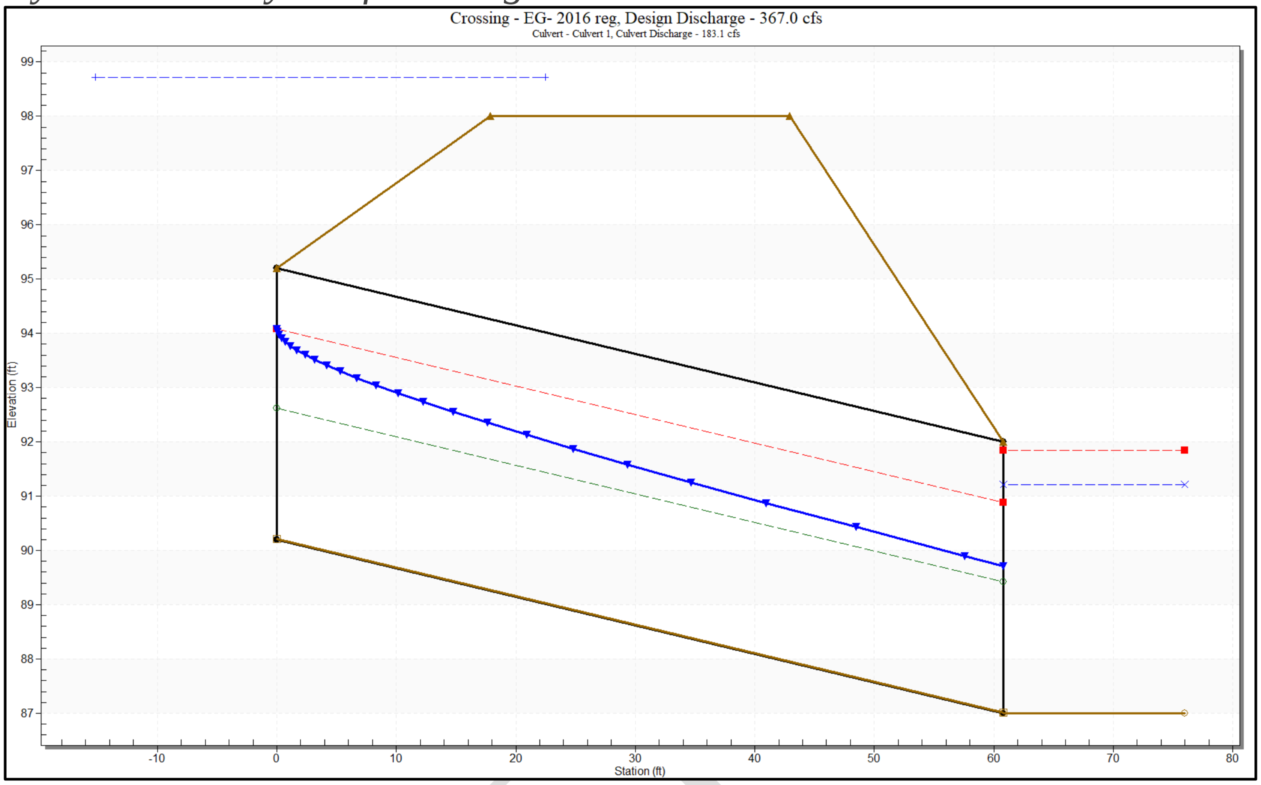
Upstream Reference Reach Conditions

Stream:	**Little Tonsina Trib, Reach - ATV Crossing**		
Basin:		Drainage Area: **838.4** acres	**1.31** mi^2
Location:	**Upstream Reference Reach**		
Twp.&Rge:	**;**	Sec.&Qtr.: **;**	
Cross-Section Monuments (Lat./Long.):	**61.59015 Lat / -145.220648 Long**		Date: **02/02/23**
Observers:	**Jess Straub and Anna Senecal**		Valley Type: **C-CO-U$**

Parameter	Value	Units
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**9.99**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**1.03**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**10.26**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**9.7**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**1.62**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**20.23**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**2.03**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**61.62**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.04**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.1**	

Stream Type **B 4a** (See **Figure 2-14**)

Hydraulic Analysis of Existing Conditions



Crossing Properties

Name: EG- 2016 reg

Parameter	Value	Units
DISCHARGE DATA		
Discharge Method	Recurrence	
Discharge List	Define...	
TAILWATER DATA		
Channel Type	Irregular Channel	
Irregular Channel	Define...	
Rating Curve	View...	
ROADWAY DATA		
Roadway Profile Shape	Constant Roadway Elevation	
First Roadway Station	0.000	ft
Crest Length	100.000	ft
Crest Elevation	98.000	ft
Roadway Surface	Paved	
Top Width	25.000	ft

Culvert Properties

Culvert 1

Add Culvert

Duplicate Culvert

Delete Culvert

Parameter	Value	Units
CULVERT DATA		
Name	Culvert 1	
Shape	Circular	
Material	Corrugated Aluminum	
Diameter	5.000	ft
Embedment Depth	0.200	in
Manning's n (Top/Sides)	0.031	
Manning's n (Bottom)	0.020	
Culvert Type	Straight	
Inlet Configuration	Thin Edge Projecting (Ke=0.9)	
Inlet Depression?	No	
SITE DATA		
Site Data Input Option	Culvert Invert Data	
Inlet Station	0.000	ft
Inlet Elevation	90.200	ft
Outlet Station	60.800	ft
Outlet Elevation	87.000	ft
Number of Barrels	1	
Computed Culvert Slope	0.052632	ft/ft

Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
2 year	51.00	51.00	93.11	2.89	-0.94	1-S2n	1.21	1.99	1.26	1.67	12.96	6.19
5 year	94.00	94.00	94.63	4.41	0.46	1-S2n	1.67	2.75	1.78	2.37	14.89	7.40
10 year	128.00	128.00	95.91	5.70	1.72	5-S2n	1.97	3.23	2.14	2.84	15.91	7.94
25 year	177.00	172.06	98.06	7.85	4.22	5-S2n	2.32	3.75	2.59	3.35	16.74	8.44
50 year	217.00	175.59	98.27	8.05	4.36	5-S2n	2.35	3.79	2.62	3.66	16.79	8.82
100 year	259.00	178.09	98.42	8.20	3.95	5-S2n	2.37	3.82	2.65	3.90	16.82	9.19
200 year	304.00	180.35	98.55	8.33	4.25	5-S2n	2.39	3.84	2.67	4.12	16.85	9.46
500 year	367.00	183.07	98.72	8.50	4.61	5-S2n	2.41	3.86	2.70	4.37	16.88	9.75

Site Photos

View: Looking upstream from crossing.

View: Looking downstream at culvert inlet.

View: Looking downstream from crossing.


View: Looking upstream at culvert outlet.


View: Looking upstream at washout next to outlet.

View: Looking South from crossing at ATV trail.

4View: Looking North from crossing at ATV trail

Appendix B:
Hydrology Calculations

Watershed Characteristics

The Little Tonsina River Tributary watershed is 78.1% forested with an average slope of 20%, with 3 very small lakes in the upper watershed that amount to less than 0.2% of the watershed. The total area of the watershed upstream of the crossing is 3.7mi^2 and receives 17.0 in of mean annual precipitation based on the PRISM 1971 – 2000 dataset.

Hydrology Methods Applied

Watershed Delineation Method

The watershed was delineated with ArcGIS Pro Hydrology toolbox using the NHD Plus 5m x 5m flow direction raster available for the 19020102 HUC (Figure 1).

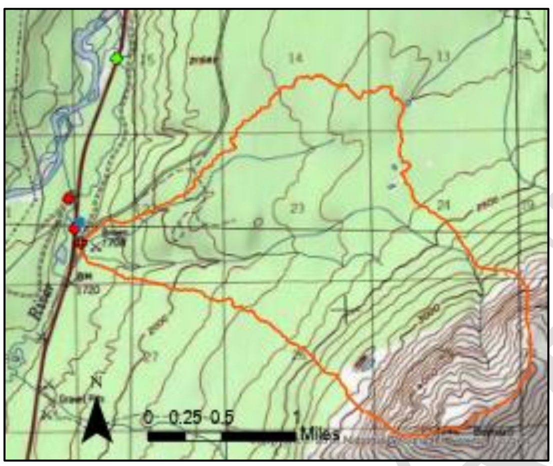


Figure 1. Watershed map

Estimation Methods

1) Gaged Site

The crossing is ungaged.

2) Basin Transfer (Q/A) - Gage in watershed or Nearby

The crossing is located in a watershed with a gage, Little Tonsina River USGS and BLM gages, however the short period of record and the difference in watershed area make it a poor candidate for a gaged site to use for Basin Transfer. The Little Tonsina River gages have a total of 7 peak flows and the watershed is 20 sq. mi (Dekker 2019).

3) Basin Transfer (Q/A) - Gage with Similar Hydrology

Squirrel Creek (USGS gage 15208100) nearby is considerably larger in watershed area (71.9 sq. mi), 19 times larger than the ungaged Little Tonsina River Tributary watershed so likely is not a good candidate for a basin transfer method.

Rock Creek (USGS gage 15208200) nearby is closer in watershed area (16.7 sq. mi), but still 4.5 times larger than the ungaged Little Tonsina River Tributary watershed. It has 28 total peak flows, but all occur prior to 1993. Rock Creek also receives 14in of precipitation per year on average compared to the crossing's 17 in per year. Between the difference in watershed area and precipitation the regional regression equations are likely a better approach than basin transfer methods available for these two nearby gages.

4) Geomorphic Approach

See worksheet 2-2. Bankfull discharge varied from 42-52cfs.

5) USGS Regional Regression Equation

Watershed areas are within the recommended limits of both the 2003 and 2016 regression equation limits. Region 6 was used for the 2003 regression equation, input variable data are above in Watershed Characteristics section.

6) NRCS Method

Not attempted, watershed area and land cover likely not ideal for this method.

7) Rational Method

Watershed area is 2,371 acres which exceeds the ~300 acre recommended upper limit for the Rational Method.

Results

RI	Q/A	Q/A	2003 Regression Method	2016 Regression Method
	Squirrel Creek	Rock Creek		
	15208100	15208200		
yr	cfs	cfs	cfs	cfs
2	16.3	11.7	38	51
5	26.3	20.9	72	94
10	33.7	28.6	101	128
25	44.8	39.9	143	177
50	53.7	49.9	178	217
100	63.7	61.2	216	259
200	74.1	73.7	257	304
500	90.1	92.5	316	367

Design Hydrology Recommendation

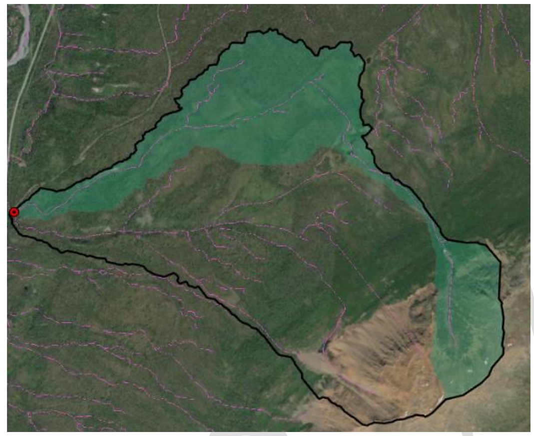
Select the regression equation method that provides the closest agreement to the Geomorphic Approach Q2. The 2016 regional regression equation has close agreement to the geomorphic approach so 259cfs is recommended for the 100 year design discharge. The 2016 is also preferred because it's represents a longer period of record and best possible statistical methods compared to the 2003 equation.

North Sub-Watershed 2016 Hydrology analysis for scaling purposes

Area of north sub-watershed = 1.39mi^2

Mean annual precipitation of north sub-watershed =16.65in

RI	2016 Regression Method – Sub watershed, 1.39mi^2, and 16.65in
yr	cfs
2	22.1
5	42.2
10	59.0
25	83.1
50	103
100	124
200	147
500	180



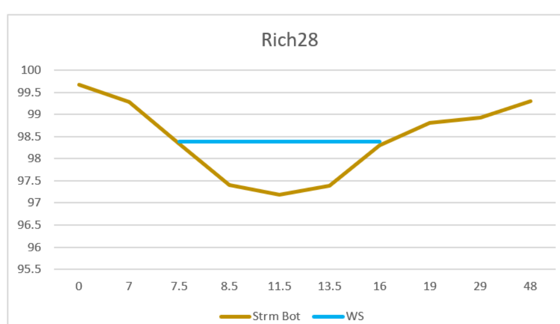
Flow Measurements and Cross Sections collected by Kirsti Jurica, CRWP.

**Measurements were not considered in current design. Data should be analyzed and consulted in subsequent design deliverables.*

	Stream Width (ft)	Q (ft3/s)	Total Area (ft2)	Mean Depth (ft)	
9/11/2023	4.7	4.531	2.655	0.565	DS of Rich28. Ref reach
9/24/2022	6.4	3.792	5.27	0.823	DS of Rich28. Ref reach
6/19/2022	4.7	1.513	1.775	0.378	DS of Rich28. Ref reach
6/19/2022	4.9	1.868	2.545	0.519	US of ATV crossing

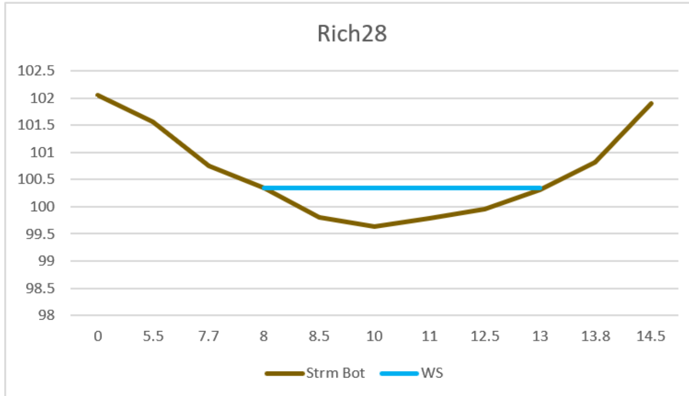
9/11/2023

		Strm Bot	WS
FP Terrace	0	99.68	
BF	7	99.29	
Water edge	7.5	98.34	98.38
Toe of bank	8.5	97.41	98.38
Thalweg	11.5	97.18	98.38
	13.5	97.38	98.38
Water edge	16	98.3	98.38
BF	19	98.81	
	29	98.93	
FP Terrace	48	99.3	



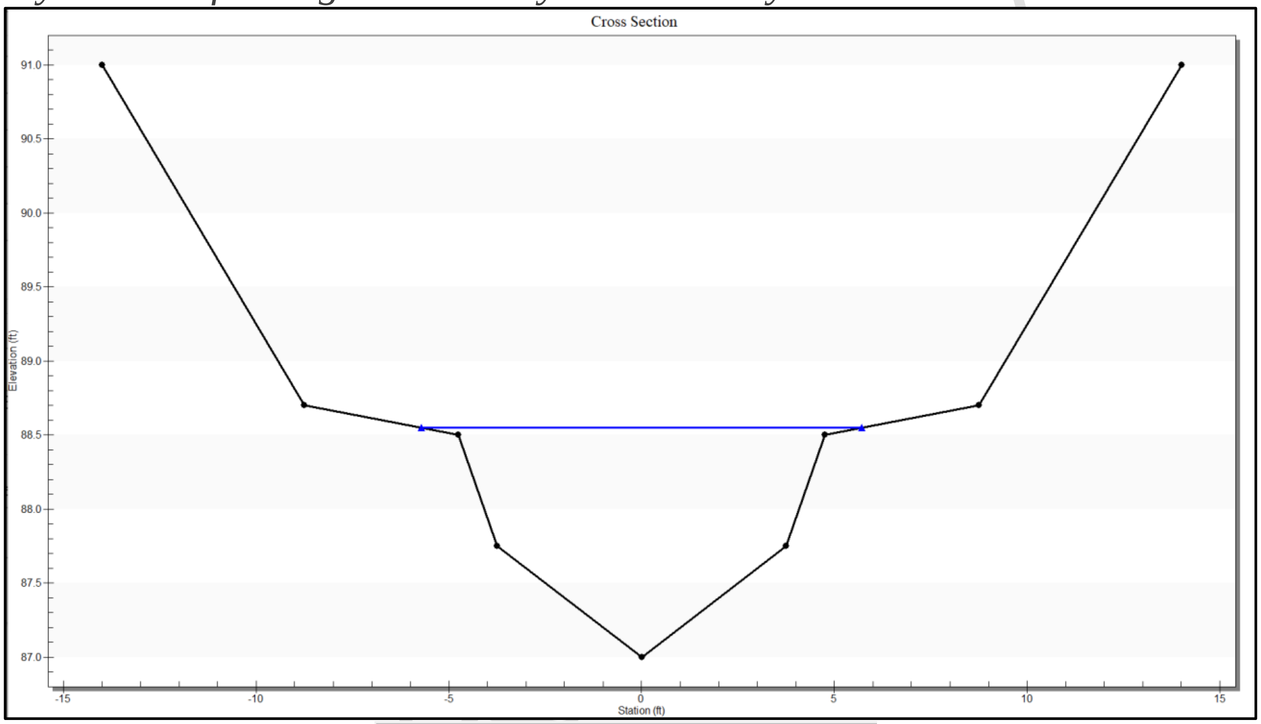
9/11/2023

		Strm Bot	WS
FP	0	102.05	
	5.5	101.56	
BF	7.7	100.76	
Water edge	8	100.35	100.35
	8.5	99.8	100.35
Thalweg	10	99.64	100.35
	11	99.79	100.35
	12.5	99.96	100.35
Water edge	13	100.32	100.35
BF	13.8	100.82	
Top of log	14.5	101.91	



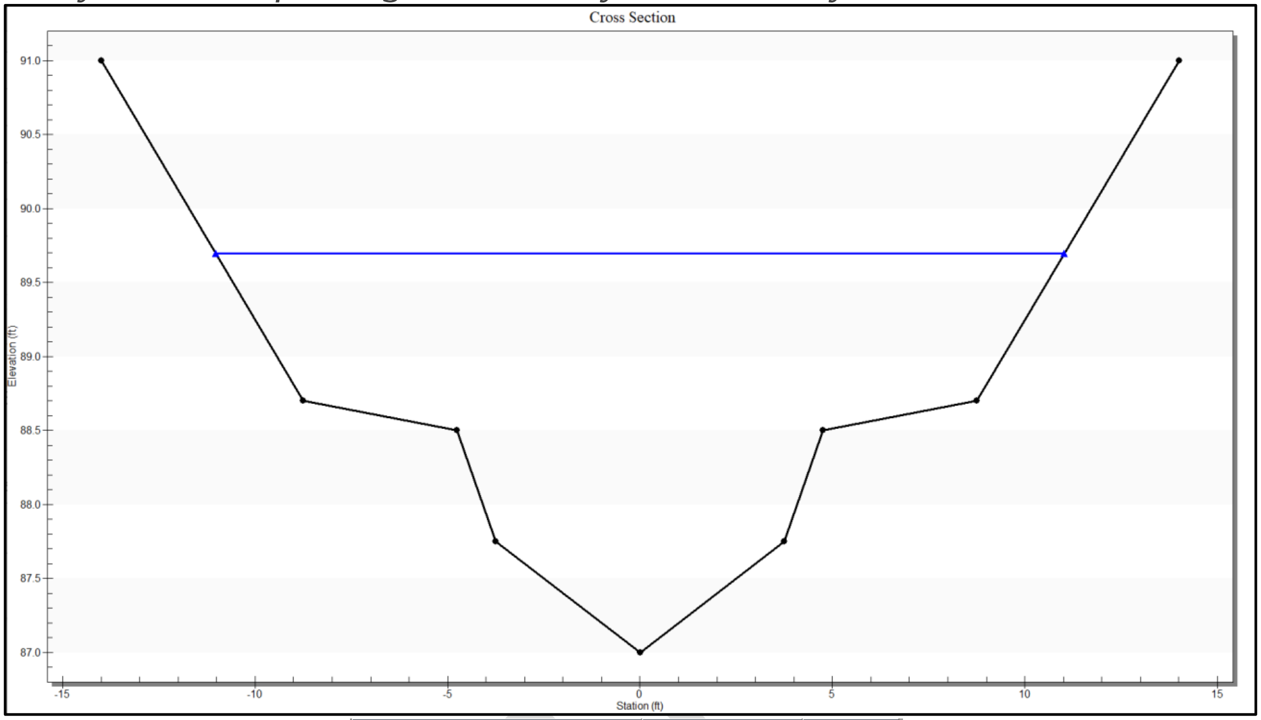
Appendix C:
Hydraulic Analysis

2-year: 51 cfs design channel hydraulic analysis



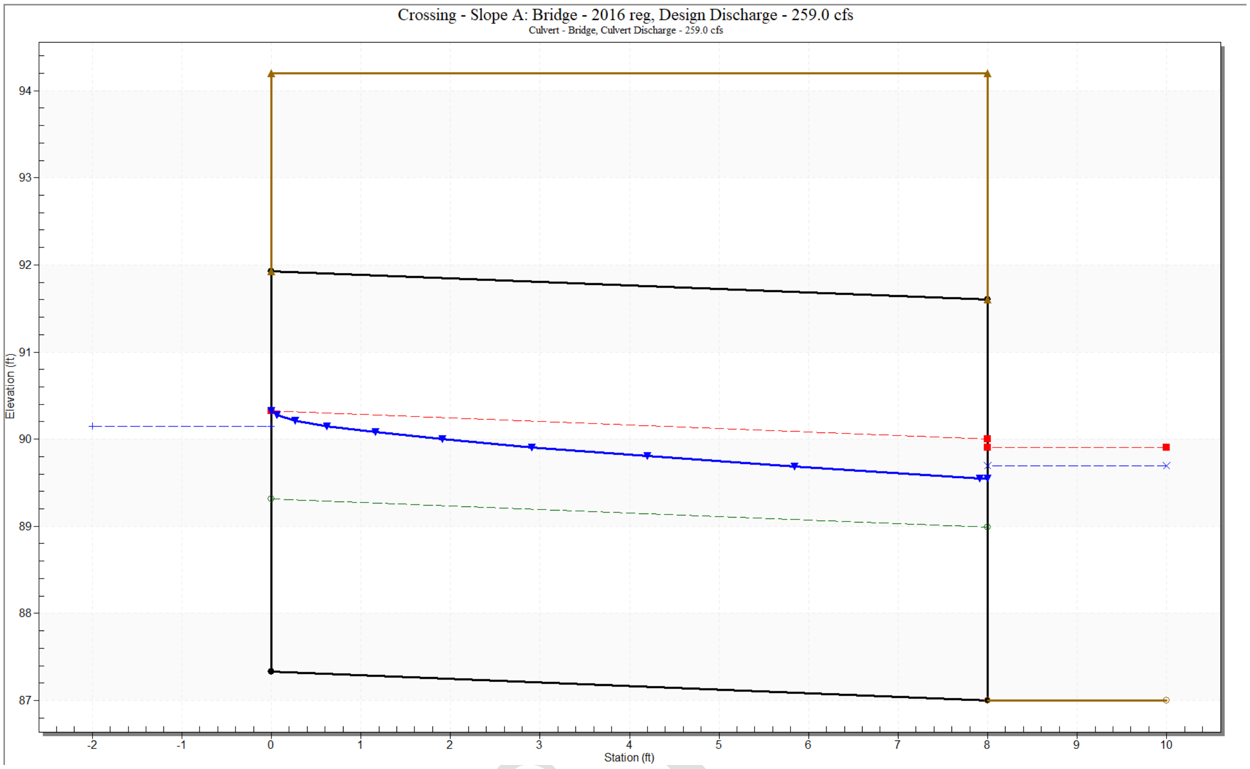
Parameter	Value	Units
Flow	51.000	cfs
Depth	1.548	ft
Area of Flow	9.691	sq ft
Wetted Perimeter	12.077	ft
Hydraulic Radius	0.802	ft
Average Velocity	5.262	fps
Top Width (T)	11.426	ft
Froude Number	1.007	
Critical Depth	1.496	ft
Critical Velocity	5.573	fps
Critical Slope	0.04357	ft/ft
Critical Top Width	9.490	ft
Max Shear Stress	3.961	lb/ft^2
Avg Shear Stress	2.053	lb/ft^2
Composite Manning's n ...	Lotter method	
Manning's Roughness	0.0494	

100-year: 259 cfs design channel hydraulic analysis



Parameter	Value	Units
Flow	259.000	cfs
Depth	2.697	ft
Area of Flow	31.600	sq ft
Wetted Perimeter	23.127	ft
Hydraulic Radius	1.366	ft
Average Velocity	8.196	fps
Top Width (T)	22.051	ft
Froude Number	1.207	
Critical Depth	2.907	ft
Critical Velocity	7.130	fps
Critical Slope	0.02685	ft/ft
Critical Top Width	23.008	ft
Max Shear Stress	6.900	lb/ft^2
Avg Shear Stress	3.496	lb/ft^2
Composite Manning's n ...	Lotter method	
Manning's Roughness	0.0452	

HY-8 Analysis



Input

Name: Slope A: Bridge - 2016 reg

Parameter	Value	Units
DISCHARGE DATA		
Discharge Method	User-Defined	
Discharge List	Define...	
TAILWATER DATA		
Channel Type	Irregular Channel	
Irregular Channel	Define...	
Rating Curve	View...	
ROADWAY DATA		
Roadway Profile Shape	Constant Roadway Elevation	
First Roadway Station	0.000	ft
Crest Length	200.000	ft
Crest Elevation	94.200	ft
Roadway Surface	Paved	
Top Width	8.000	ft

Bridge

Add Culvert

Duplicate Culvert

Delete Culvert

Parameter	Value	Units
CULVERT DATA		
Name	Bridge	
Shape	User Defined	
Material	Concrete	
Coordinates	Define...	
Span	35.000	ft
Rise	4.600	ft
Embedment Depth	0.000	in
Manning's n (Top/Sides)	0.012	
Manning's n (Bottom)	0.012	
Culvert Type	Straight	
Inlet Configuration	Thin Edge Projecting (Ke=0.9)	
Inlet Depression?	No	
SITE DATA		
Site Data Input Option	Culvert Invert Data	
Inlet Station	0.000	ft
Inlet Elevation	87.328	ft
Outlet Station	8.000	ft
Outlet Elevation	87.000	ft
Number of Barrels	1	
Computed Culvert Slope	0.041000	ft/ft

Output

Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
1	0.00	0.00	87.33	0.00	0.00	0-NF	0.00	0.00	0.00	0.00	0.00	0.00
2	51.00	51.00	88.63	1.30	1.22	1-S2n	0.95	1.64	1.28	1.55	8.53	5.26
5	94.00	94.00	89.23	1.91	1.90	1-S2n	1.18	2.19	1.88	1.94	7.98	5.77
10	128.00	128.00	89.37	2.05	1.81	1-S2n	1.33	2.38	2.04	2.14	8.49	6.42
25	177.00	177.00	89.56	2.23	2.04	1-S2n	1.51	2.63	2.24	2.37	9.07	7.18
50	217.00	217.00	89.79	2.46	2.21	1-S2n	1.64	2.82	2.40	2.54	9.44	7.71
100	259.00	259.00	90.15	2.82	2.37	1-S2n	1.99	3.00	2.55	2.70	9.80	8.20

Appendix D: Proposed Streambed Stability Calculations

New Stream Channel Design (Culvert, Rock Ramp)

MATERIAL PROPORTIONS	
FINE	40%
COARSE	60%

Using Corps of Engineers Equations - FHWA Circular on Development in the River System - Page 6.25.
FHWA NHI 01-004; River Engineering for Highway Encroachments, 2001
http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=8&id=20

YELLOW ARE INPUTS			
Safety Factor	**1.5**		
Stability Coefficient for Incipient Failure	0.3	(0.36 round rock, 0.3 angular rock)	
Vertical Velocity Distribution Coeff	1.00	(1.0 for straight channels)	
Blanket Thickness Coeff	1	(1xD100 or 1.5 or D50 max, whichever is greater)	
Local depth of flow	2.7	ft for 100 year event	
Unit Weight of water	62.4	lb/ft^3	assumed
Unit weight of rock	165	lb/ft^3	assumed
Local depth-average velocity	9.8	ft/s from 100-year event avg. velocity in pipe	
Side Slope correction factor	1		
Gravitational Acceleration	32.2	ft/s^2	
D85/D15	1.7	(1.7-5.2)	
D50/D30	1		

Note: This method is based on the minimum D30 size
Riprap Design Method - Selecting Proper Gradation, Page 131.
Design Hydrology and Sedimentology for Small Catchments, Haan, Barfield and Hayes, 1981.

D15	0.4	ft	5.0	inches
D30	0.7	ft	9.0	inches
D50	0.9	ft	11.0	inches
D85	1.5	ft	18.0	inches
D100	1.8	ft	22.0	inches

Using D50 size, used FHWA circular for Rip Rap design to spec out D100, D85 and D15.
D100 = 2.0D50

Fuller-Thompson Estimating for Maximum Density: D100 (inches) **20.0**

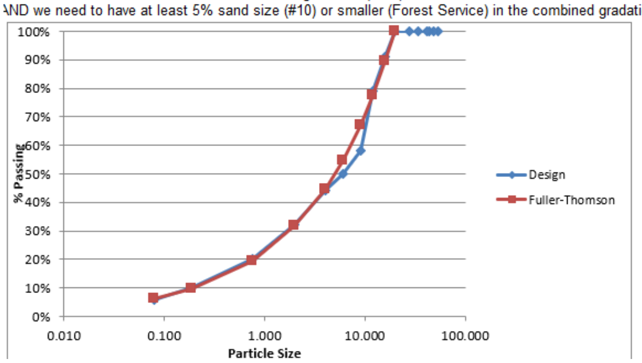
Method Adapted from US Forest Service Stream Simulation Guidelines D30 9.0
D30 Req'd 9.0

Stability (D30): **OK**

YELLOW ARE INPUTS

Size (inches)	Sieve Size	COARSE Custom % Passing	FINES Fine Aggreg. % Passing	Combined % Passing	F-T EQN % Passing	Check Coarse Material Design -D30 Required per FHWA Method: Riprap % Passing	D30 Riprap Req 9.0 / D30 Size = 9.0	
RELATIVE % =		0.60	0.40	1.0000				
54	54 in	1.00	1.00	100%	164%	100%	No	OK
48	48 in	1.00	1.00	100%	155%	100%	No	
44	44 in	1.00	1.00	100%	148%	100%	No	
42	42 in	1.00	1.00	100%	145%	100%	No	
34	34 in	1.00	1.00	100%	130%	100%	No	
28	28 in	1.00	1.00	100%	118%	100%	No	
20	20 in	1.00	1.00	100%	100%	100%	No	
16	16 in	0.85	1.00	91%	89%	85%	No	
12	12 in	0.65	1.00	79%	77%	65%	No	
9	9 in	0.30	1.00	58%	67%	30%	9.00	
6	6 in	0.20	0.95	50%	55%	20%	6.00	
4	4 in	0.10	0.95	44%	45%	10%	4.00	
2	2 in	0.00	0.80	32%	32%	0%	2.00	
0.75	0.75 in	0.00	0.50	20%	19%	0%	0.75	
0.187	#4	0.00	0.25	10%	10%	0%	0.19	
0.0787	#10 Sand	0.00	0.15	6%	6%	0%	0.08	

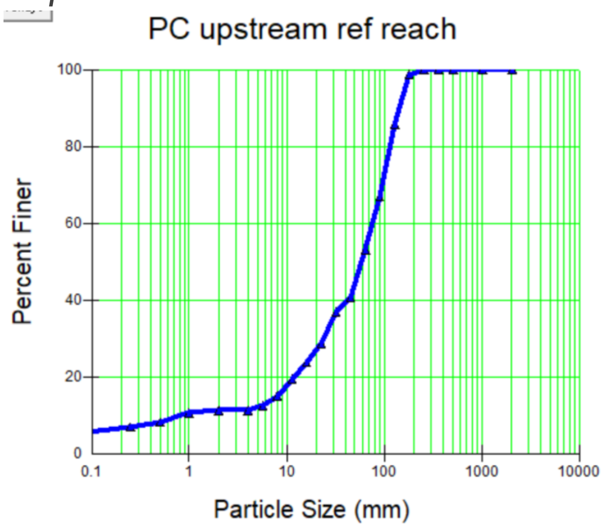
Gradation values should be within +/-5% of this gradation (Rice)
AND we need to have at least 5% sand size (#10) or smaller (Forest Service) in the combined gradation



DATA for Graph & Fuller-Thomson Eqn

Size (in)	Combined % pa	F-T equation
54.000	100%	164%
48.000	100%	155%
44.000	100%	148%
42.000	100%	145%
34.000	100%	130%
28.000	100%	118%
20.000	100%	100%
16.000	91%	89%
12.000	79%	77%
9.000	58%	67%
6.000	50%	55%
4.000	44%	45%
2.000	32%	32%
0.750	20%	19%
0.187	10%	10%
0.079	6%	6%

Ref Reach Pebble Count Distribution



Size (mm)	TOT #	ITEM %	CUM %
0 - 0.062		0.00	0.00
0.062 - 0.125		0.00	0.00
0.125 - 0.25	11	6.88	6.88
0.25 - 0.50	2	1.25	8.13
0.50 - 1.0	4	2.50	10.63
1.0 - 2.0	1	0.63	11.25
2.0 - 4.0	0	0.00	11.25
4.0 - 5.7	2	1.25	12.50
5.7 - 8.0	4	2.50	15.00
8.0 - 11.3	7	4.38	19.38
11.3 - 16.0	7	4.38	23.75
16.0 - 22.6	8	5.00	28.75
22.6 - 32.0	13	8.13	36.88
32 - 45	6	3.75	40.63
45 - 64	20	12.50	53.13
64 - 90	22	13.75	66.88
90 - 128	30	18.75	85.63
128 - 180	21	13.13	98.75
180 - 256	2	1.25	100.00
256 - 362		0.00	100.00
362 - 512		0.00	100.00
512 - 1024	0	0.00	100.00
1024 - 2048	0	0.00	100.00
Bedrock	0	0.00	100.00

Particle Size Analysis

D16 (mm)	8.75
D35 (mm)	29.83
D50 (mm)	59.24
D84 (mm)	124.7
D95 (mm)	165.14
D100 (mm)	255.99
Silt/Clay (%)	0
Sand (%)	11.25
Gravel (%)	41.88
Cobble (%)	46.87
Boulder (%)	0
Bedrock (%)	0

Total Particles = 160

D50 **59.24 mm**