Alaska Railroad Corporation

Snow River Stabilization

Malamute Consulting Firm

Alternatives Analysis

Technical Report | April 2020

CED 2020.03

Abstract

The Alaska Railroad Corporation (ARRC) is a full-service freight and passenger railroad that experiences flooding due to glacial outbursts called jökulhlaups in the Snow River area (15 miles north of Seward, AK). This phenomenon creates catastrophic draining of glacial lakes that scour and damage structures, resulting in temporary closures of tracks and financial losses. Alternatives analyzed addressed river hydraulics, existing structures, and railroad requirements; then, combined the best solutions into a Chosen Alternative. With a flow of 7,102 cfs and an average velocity of 14.6 ft/s, three box culverts (65% of total flow) with a permeable subbase (35% of total flow) and track raises were determined to be the most effective, economic, and maintenance-free choices, estimated at $2.1 million.

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List of Acronyms

AS&G	Anchorage Sand & Gravel
ADF&G	Alaska Department of Fish and Game
ARRC	Alaska Railroad Corporation
FoS	Factor of Safety
MHWL	Mean High Water Line
MP	milepost
NOAA	National Oceanic and Atmospheric Administration
ROW	right-of-way
TG	Through Girder
UAA	University of Alaska Anchorage
USGS	United States Geological Survey
USACE	U.S. Army Corps of Engineers

1.0 Introduction

Malamute Consulting Firm (**MCF**) worked cooperatively with the Alaska Railroad Corporation (ARRC) to repair and improve the track structure along the Snow River from ARRC MP 14.3-18.37, located approximately 15 miles north of Seward, Alaska. In this area, Jökulhlaups, which is catastrophic glacial lake draining scours and floods structures, resulting in temporary track closure and financial loss. This report considers alternatives to mitigate the flooding issues and includes 5% designs of viable alternatives and a 15% design of the chosen alternative. Engineering key components like geotechnical, hydraulics and hydrology (H&H), simple structural analysis, and railroad transportation requirements will be addressed.

1.1 Project Background

The Snow River is a 28-mile tributary that is fed by Snow Glacier in the Kenai Mountains and deposits into Kenai Lake, shown in Figure 1 (left). ARRC's Snow River track system consists of a track structure that includes bridges, culverts, and railroad tracks, all of which are owned and operated by ARRC. A major challenge of this area is glacial outbursts called jökulhlaups that occur on a biennial basis (every other year). A jökulhlaups is the catastrophic failure of glacial dam meltwater, resulting from long duration warming events and are increasing in frequency due to climate change. These glacial outbursts flood and scour ARRC structures, resulting in significant structural damage, temporary closure of track, and financial losses, shown in Figure 1 (right).

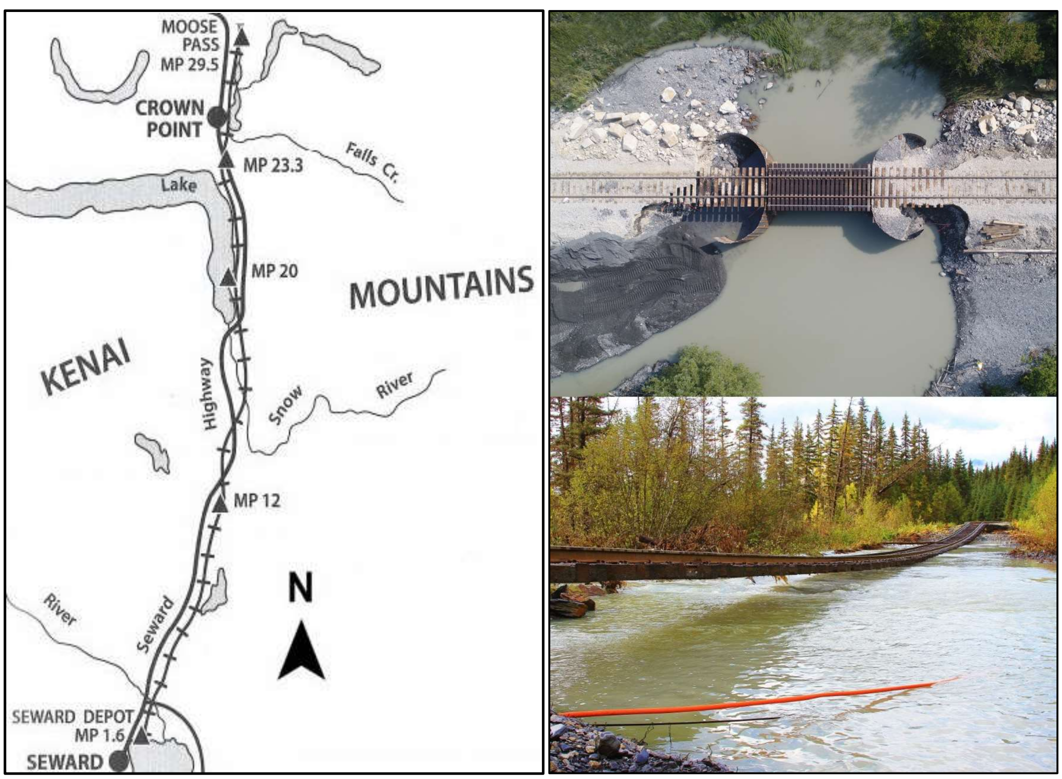

Figure 1: Project Area (left), MP 16.2 Bridge (top right), and Track without Subbase (bottom right)

Imagery Credit: ARRC

1.2 Project Team and Communications

MCF is an Anchorage based, civil engineering firm that provided geotechnical, hydrological, transportation, and environmental expertise for this project. The project team includes Bangnhi Pham, Jon Edillor, Allison Dunbar, Matthew Fischer, Kacy Grundhauser, Christina Hoy, and Andrew Davis. Bangnhi Pham was the Project Manager and utilized her previous experience of working on ARRC projects, especially with bridge and culvert structures. Figure 2 shows the team with their engineering expertise.

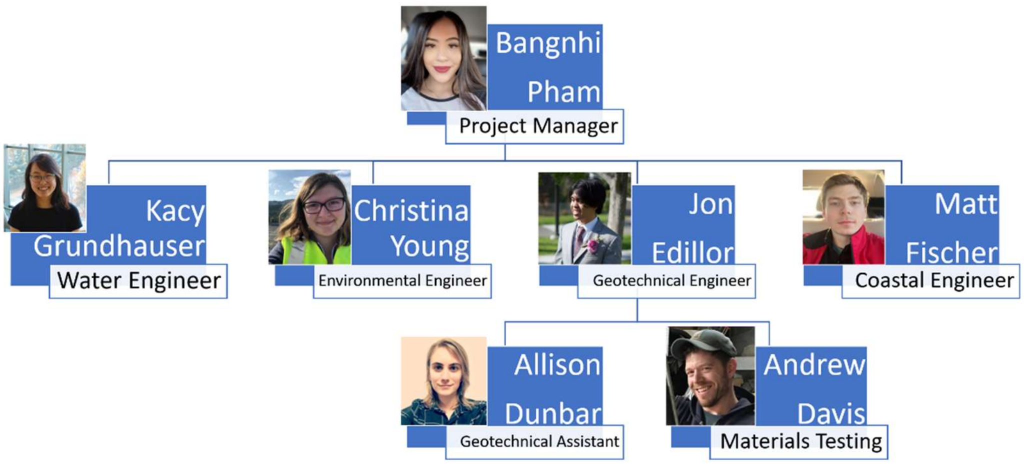

Figure 2: MCF Team Organization Chart

1.3 Client

This report was completed for ARRC, to provide guidance in mitigating damage sustained during jökulhlaups flood events along the Snow River. Gabriel Thomas, EIT, was the main contact from ARRC. The client provided background information, site specific conditions, and documents on previous mitigation efforts.

1.4 Engineering Advisors and Mentors

MCF worked with a series of advisors and mentors from the University of Alaska Anchorage (UAA) Civil Engineering Department and ARRC. From UAA, Dr. Matthew Calhoun (Assistant Professor) and Dr. Joey Yang (Professor and Department Chair) provided technical assistance during research and alternatives design phases. From the ARRC, Brian O'Dowd, PE, served as the Professional Mentor and provided specialized expertise and technical information related to the railroad and other similar, Alaskan projects.

2.0 Scope of Work

Phase I included reviewing existing records and plans of the area. A site visit was conducted to fully understand the existing conditions. This exploration provided information that was critical to Phase II.

Phase II explored all the alternatives, including a feasibility analysis and economic viability exploration. The team also eliminated some alternatives due to various economic and feasibility constraints. An effective combination of feasible alternatives was determined and carried into the next phase for further analysis and design.

Phase III included the design of the chosen alternative and the preparation of the draft deliverables: an analysis report, a 15% design plan set, a presentation, and a poster.

Phase IV revised draft deliverables with comments from the client and other technical experts. The final documents were then shared with the client and the project was closed out.

2.1 Project Description

ARRC faces problematic, biennial flooding caused by jökulhlaups on the Snow River system, near Seward, Alaska. These catastrophic floods are a result of the high head pressure found under glacial lakes when glacial ice and debris block their discharge flow. Inflow to the glacial lake exceeds the lake's outflow which increases headwall pressure until a sudden failure occurs. After failure, the fast-moving water erodes banks, damages forested areas, washes out culverts, upturns ballast, and displaces railroad tracks as it makes its way downstream. The majority of these issues have occurred from MP 14.5 to MP 16.5, shown in red in Figure 3. The main channel is shown in dark blue and the direction of flow is shown with white arrows. As noted in past floods and through hydraulic modeling, there is an area of concern (MP 6.2) where water accumulates along the railroad track structure, shown by a red star.

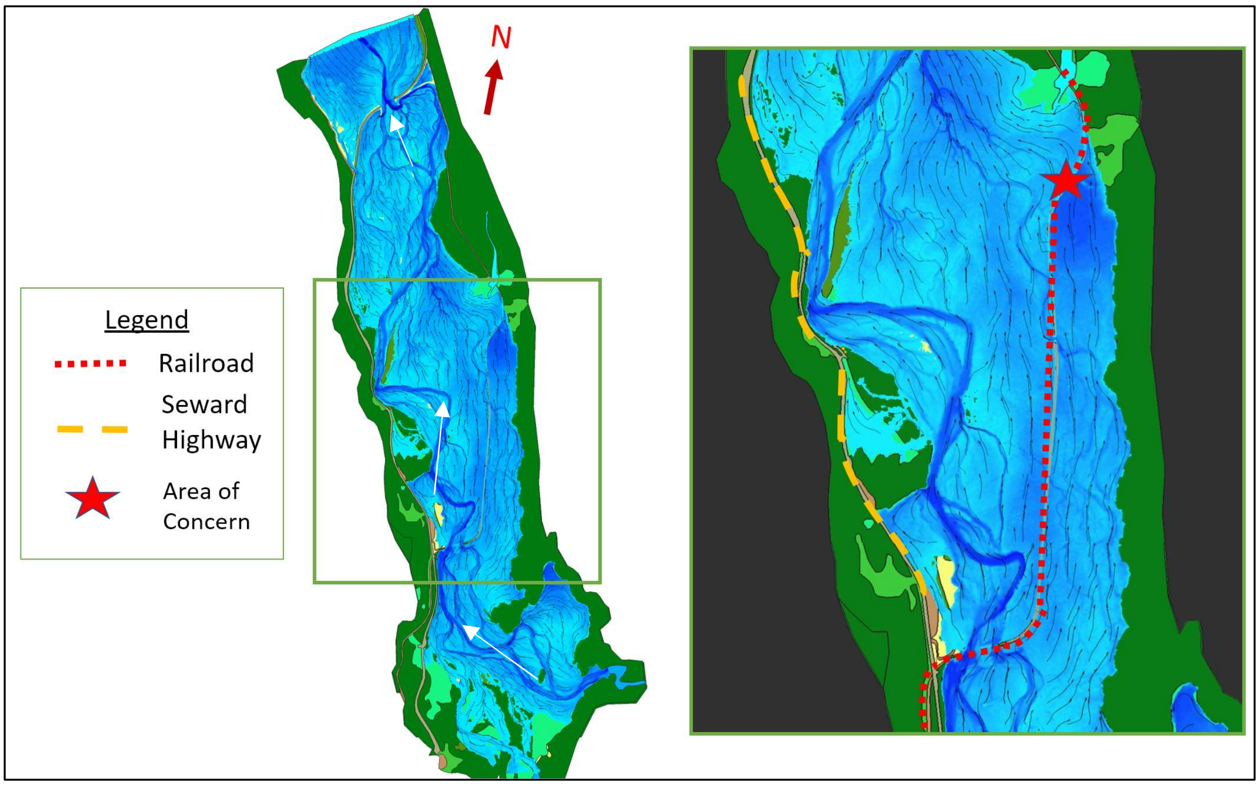

Figure 3: Project Area Hydraulic Model During Flood Event

Imagery Credit: Alaska USGS

In 2019, flooding volumes reached up to 4.5 billion gallons and caused $350,000 of track structure damage and operation delays. **MCF** was tasked with providing ARRC with flood mitigation alternatives for this area in the form of an alternatives analysis report.

2.2 Other Considerations

Environmental: Snow River has been historically known as a habitat for anadromous fish, tracked by the Alaska Department of Fish and Game (ADF&G) through an online reporting system. Map imagery with locations and observations are given in Appendix A-1. Permitting is required to allow development in anadromous bodies of water, per the Anadromous Fish Act (AS 16.05.871-.901). A project plan must be submitted, and determination will be given by ADF&G's Commissioner with further instructions, as necessary. The excerpt from the Anadromous Fish Act with project construction steps are provided in Appendix A-2. These documents can be utilized in further mobilization efforts.

Right-of-Way: ARRC owns a right-of-way (ROW) of 100 ft from the center line of the track, that extents outwards on both sides. Other ROW's to be considered in this area would be the Alaska Department of Transportation & Public Facilities (Alaska DOT&PF) Seward Highway, US Chugach National Forest's owned land and wetlands, various utilities ownership, and private land. Project ROW acquisition is notorious for being costly and time-consuming. The work outlined in this report should stay within ARRC ROW but utility locations and National Forest boundaries should be verified.

Hydraulic Modeling: ARRC has worked collaboratively with Alaska's US Geological Survey (USGS) office and local engineering firms to model the hydraulics of the Snow River, with the use of SMS software. This model uses historic stream gage data from past floods to optimize its accuracy in predicting future flood sizes. It also uses current topography and ARRC track updates to model as close to life as possible. When designing mitigation efforts, the alternative characteristics can be input into the model to better predict how the river system will react to the changes. But like any model, it has its limits and its outputs should still be taken with consideration as models can only be so accurate to real-world systems.

3.0 Alternatives Considered

3.1 Alternatives Development and Screening Process

The process of developing alternatives started with brainstorming options that address the needs of the project. The alternatives were based on past projects dealing with similar issues, innovative concepts to modify existing structures, and suggestions from technical mentors and advisors.

Each alternative was researched and analyzed individually to ensure it would address increasing water capacity or flow through the project area. If the alternative did not address the issue in an effective way, it was not retained for further analysis. Of the alternatives that were retained, further analysis resulted in a final recommendation of a combination of alternatives.

3.2 Alternatives Not Retained for Analysis

Several alternatives were explored but not retained for further analysis. These alternatives could be considered feasible but were less effective than others and therefore not retained.

3.2.1 Dredging

Dredging is the act of removing silt, sediment, and other material from the bottom of a body of water for the purpose of improving existing water features. Dredging the Snow River could improve flow and capacity of water during flood events. However, it is unknown if the accumulation of settlement is the main cause of the flooding issues in the area and how effective dredging would be. A study and hydraulic model would need to be completed and analyzed to provide data on how the river might react to dredging. Additionally, permitting in a US National Forest would not only be time consuming but also costly. Previous ARRC projects in the area have permitting costs of $45,000+ associated with the required work. Maintenance, effects downstream on fish/wildlife, effects on stationary objects (scour), and disposal location of dredged material should also be considered.

With a depth of 18.9 ft in the deepest section of the river, it is estimated that 99,770.3 cubic yard of sediment would need to be removed around the MP 14.5 bridge, seen in Figure 4. Dredging costs from previous projects has been estimated to be $15.00 per cubic yard, giving a subtotal cost of $1.5 million for dredging alone. The potential need for annual or biennial maintenance dredging is unknown and was a key factor in not retaining this alternative for further analysis.

Figure 4: Sediment Upstream of MP 14.5 Bridge

Imagery Credit: ARRC

3.2.2 Bridge Addition

The addition of bridge spans within the Snow River system was considered to provide additional openings for flood water. There are several existing bridge structures, including the most recent addition at MP 16.2 in 2019. Even after the MP 16.2 bridge was upsized after the 2017 flood, the total combined structures still do not allow for sufficient flow and result in flooding. Studying the hydraulic and hydrological behaviors in the region, the structure's openings would be designed to meet flowrate requirements. The design of the bridge is meant as a relief to the existing water conditions, and not meant to act as a solution on its own. A sufficient relief opening does not currently exist where the water is accumulating at MP 16.2; a bridge could be implemented to provide that relief.

An alternative could be to add a hybrid bridge, consisting of a single or series of through-girder (TG) spans with rip-rap substructures on both sides of the spans. A preliminary hybrid bridge span design is shown in Figure 5 and was used for preliminary analysis and consideration. To accommodate the full 45,000 cfs flow rate, the bridge addition would need to be 600 ft in length. However, that long of a bridge for periodic flood events is inefficient and costly. The cost per linear foot of the bridge is $15,000 based on prior ARCC projects, giving a total bridge cost of $9 million. To deal with the full volume of flow during a flood, a bridge alone will not only be costly but ineffective to the whole problem.

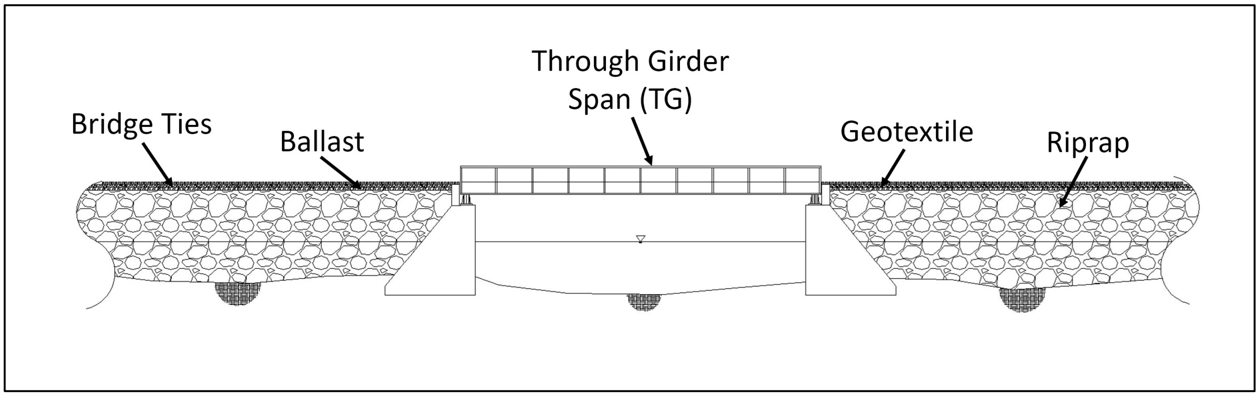

Figure 5: Preliminary Design for Bridge Hybrid

3.3 Alternatives Retained for Analysis

3.3.1 No Build Alternative

The biennial jökulhlaups is forecasted to become more frequent, increase in duration, and grow in years to come. Alaska's USGS and National Oceanic and Atmospheric Administration (NOAA) offices have been working to provide information related to the buildup and release of the Snow River jökulhlaups to help predict and prepare for these floods in the future.

Under a No Build alternative, no new elements would be introduced that would change the existing design of ARRC MP 14-18. These mileposts would still be in danger of flooding, erosion of stationary objects, damage to rail infrastructure, and threat of impact to highway infrastructure and downstream communities. The hydraulic condition of the Snow River track infrastructure would remain unimproved, making the likelihood of another major flood repair very high in future years. The existing condition of the tracks are considered unsatisfactory by ARRC in terms of serviceability and longevity, so this alternative would not meet any of the project objectives.

With the No Build alternative, ARRC could undertake a thorough review of existing issues and repairs to determine how and where best to provide uninterrupted freight and passenger services through this area. However, this alternative would only prolong the issue and not improve this section of track.

Based on repair costs from the 2019 flood event, a No Build Alternative would cost $350,000 biennially. This cost does not include costs accrued due to interrupted freight services.

3.3.2 Track Raising

Railroad track raises involve raising existing track to increase local relief and mitigate track flooding. The railroad grade cannot exceed 2% (2 ft rise or fall over 100 ft length). Small track raises of 6 inches or less can be completed by using a machine to prop up and lift the rails, and then fill in ballast underneath. Track raises have been implemented by ARRC in previous projects that have proven to mitigate overtopping issues.

If a track raise were to be completed on the track in the project area, it could mitigate overtopping issues that erode the track structure and halt services through the area, as shown in Figure 6. It is advised for the whole project area to undergo a track raise but the tunnels (at MP 14.3 and 18.37) and MP 14.5 bridge limit this. Therefore, the suggested raise would not increase hydraulic storage capacity because it is not continuous over the whole area.

Figure 6: Tracks Submerged during a Flood Event

Imagery Credit: ARRC

Smaller portions of the track historically known for flooding should be prioritized and added to ongoing improvements. This will increase capacity and minimize glacial flow overtopping the track during peak flooding events. The proposed design would consider 0” to 18” track raises from MP 15 – MP 18, following the standard maximum 2% grade change and considering existing structures, as seen in Figure 7. Track raises between 0” – 6” were assumed to be minimal and easily done with the addition of ballast. Track raises of greater than 6” were considered major and would require reconstruction of the track structural trapezoid.

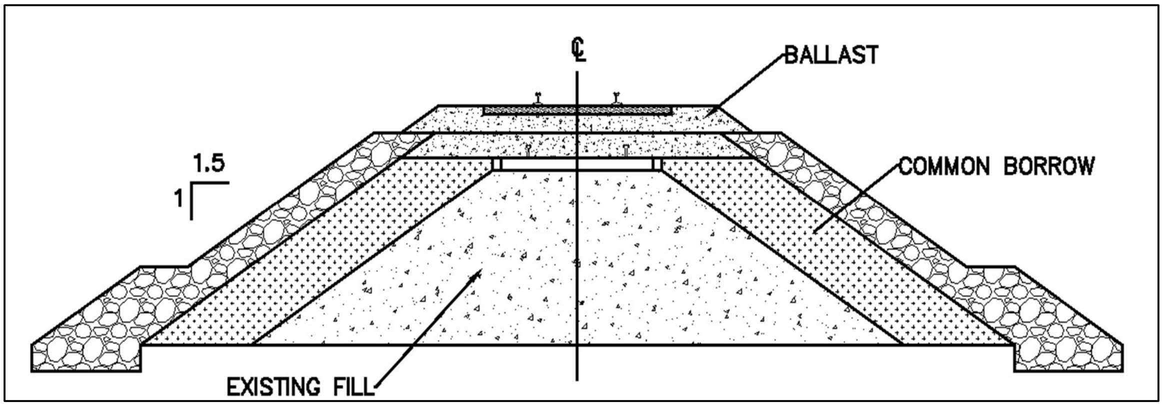

Figure 7: Track Raise Alternative

The cost of a track raise is largely dependent on the quantity and type of aggregate required to complete the raise. The track raise was estimated to be a 0”-18” track raise, throughout MP 15.9 – 16.4 section. To accomplish this, 10,302 tons of riprap would be needed. If this alternative was done in conjunction with permeable riprap, the existing cut riprap could be used to complete the track raise.

This alternative adds increased retention time and capacity when used in conjunction with alternatives that promotive transmissivity through the track structural section. If other structures provide flow through this area, the tracks will be stable at a safe elevation above the flood water level for uninterrupted operation of services during jökulhlaups events.

3.3.3 Permeable Riprap Substructure

During previous flood events, water built up along both sides of the railroad track structure and began to flow back and forth through culverts and openings in the track’s structure. Eventually, this caused scour to occur around bridges and culverts to blow out due to the previous design not being able to withstand the amount of water flowing back and forth.

A solution to this water equalization problem is to create a porous subbase structure of riprap. Figure 8 shows a typical cross-section with a combination of riprap, geotextile, borrow and ballast layers to provide porosity and integrity for the track structure. From top to bottom, the top layer directly below the tracks consists of 1.5 ft of ballast to support the tracks, the layer below that is 1.5 ft of borrow, the 1.0 ft layer below is filter rock consisting of Class I riprap. The next layer down is geotextile, below the geotextile layer is another 1 ft layer of filter rock consisting of Class I riprap. The filter rock is used to transition between the borrow and the riprap layer to prevent the borrow layer above from falling into the riprap layer. This layer of filter rock will require a gradation of rock sizes 10” and greater. This is needed as a transition between the two different rock sizes to prevent material from following through the voids of the Class IV riprap. Riprap Class III and Class IV dimensions are calculated in Table 1 and Table 2, respectively. The layer below the filter rock is the permeable riprap section made of large, angular stones. This section consists of 10 ft of Class IV riprap with an additional 2 ft of Class IV riprap keyed in to prevent washout. The bottom of the total track will be 0.25 ft of shot rock. The shot rock will be clean with no fines.

The overall height of a typical cross section of the track will be approximately 15 ft with a slope of 1.5:1 for the embankment. With additional track raises, the common borrow layer will be adjusted to accommodate for the new track heights no other material heights will change. In addition to the structural riprap, the toe of the slope would be extended to prevent scour and add stability. This design would allow increased flow in this area during flooding events.

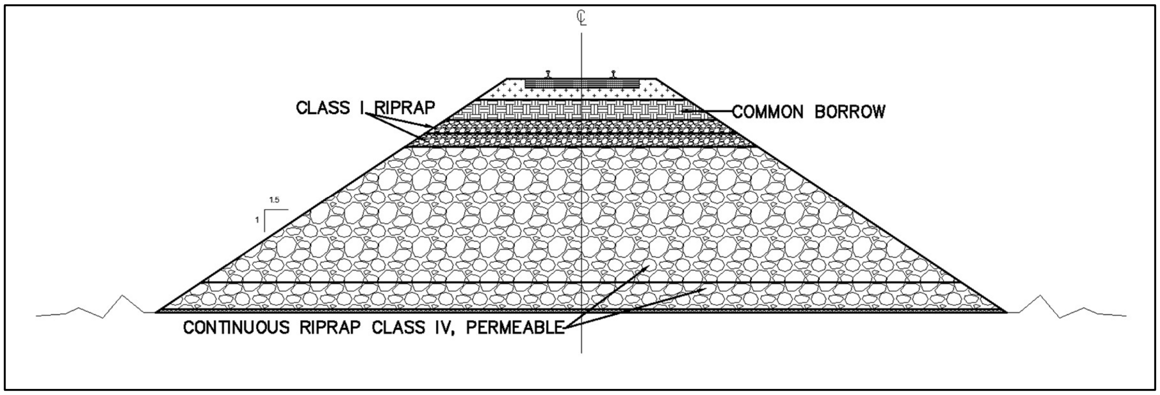

Figure 8: Rip Rap Design Cross-Section

The riprap chosen will have to survive a flood event and able to drain a large amount of water in highly flooded areas. From calculations, Class III and Class IV riprap would survive a flood event, making them desirable for this alternative. Class IV riprap was chosen for the permeable subbase to allow for maximum voids and minimize the total length of the alternative needed. Class III calculations are included for comparison purposes only to justify the use of Class IV.

Table 1: Riprap calculations for Class III

CLASS III			
Parameter	**Value**	**Unit**	**Assumption**
Safety Factor	1.10		Largest Applicable
Stability Coefficient	0.30		USACE Riprap Design Report - Angular Rock
Vertical Velocity Distribution Contribution	1.25		USACE Riprap Design Report - Turbulent Flow
Black Thickness Coeffect	1.00		USACE Riprap Design Report - Largest Applicable
Side-Slope Correction	0.89		USACE Riprap Design Report - Slopes
Gravity	32.2	ft/s^2	
Local Depth of Flow	15.00	ft	Height of Tracks
Unit Weight of Sample	2602.50	kg/m^3	USACE Riprap Design Report and sample average
Unit Weight of Water	998.00	kg/m^3	
Average Velocity	14.214	ft/s	Average Velocity based off D_{50} Riprap
Riprap Size (D_{50})	1.33	ft	Riprap D_{50} in feet
Riprap Size (D_{50})	15.96	in	Riprap D_{50} in inches

Table 2: Riprap Calculations for Class IV

Class IV			
Parameter	**Value**	**Unit**	**Assumption**
Safety Factor	1.10		Largest Applicable
Stability Coefficient	0.30		USACE Riprap Design Report - Angular Rock
Vertical Velocity Distribution Coefficient	1.25		USACE Riprap Design Report - Turbulent Flow
Blanket Thickness Coefficient	1.00		USACE Riprap Design Report - Largest Applicable
Side-Slope Correction	0.89		USACE Riprap Design Report - Slopes
Gravity	32.3	ft/s²	
Local Depth of Flow	15.00	ft	Height of Tracks
Unit Weight of Sample	2602.50	kg/m³	USACE Riprap Design Report and sample average
Unit Weight of Water	998.00	kg/m³	
Average Velocity	16.160	ft/s	Average Velocity based off D_{50} Riprap
Riprap Size (D_{50})	1.83	ft	Riprap D_{50} in feet
Riprap Size (D_{50})	22.00	in	Riprap D_{50} in inches

Calculations to determine which riprap would be suitable during a flood event can be seen below using the U.S. Army Corps of Engineers (USACE) Maynord Equation, Equation 1. Assumptions for a factor of safety, stability coefficient (Cs), vertical velocity distribution (Cv), blanket thickness (Ct), side-slope correction (K1), unit weight of rock sample, and specific gravity were all obtained from the USACE Riprap Design for Flood Channels Report (USACE, 1993). Other values used were 32.2 ft/s² for the acceleration of gravity, and 15 ft for the local depth of flow, which is estimated as the average height of the tracks.

Equation 1: USACE Maynord Equation

$$D_{30} = S_f C_s C_v C_T d \left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right)^{1/2} \frac{V}{\sqrt{K_1 g d}} \right]^{2.5}$$

From these calculations for stone size, the average velocities were used to determine which riprap class should be chosen for the porous subbase structure. The riprap determined would also need to have a high porosity to drain water in areas that are highly flooded. Near MP 16.2, lies the area of greatest flooding, shown in Figure 9, due to the hydrologic limiting factor in that section. The approximate amount of water that needs to be drained from this area is about 26 million cubic feet (25,568,025 ft³). In order to drain this water in 24 hours, a flowrate of ~7200 ft³/s (7102.23 ft³/s) is needed.

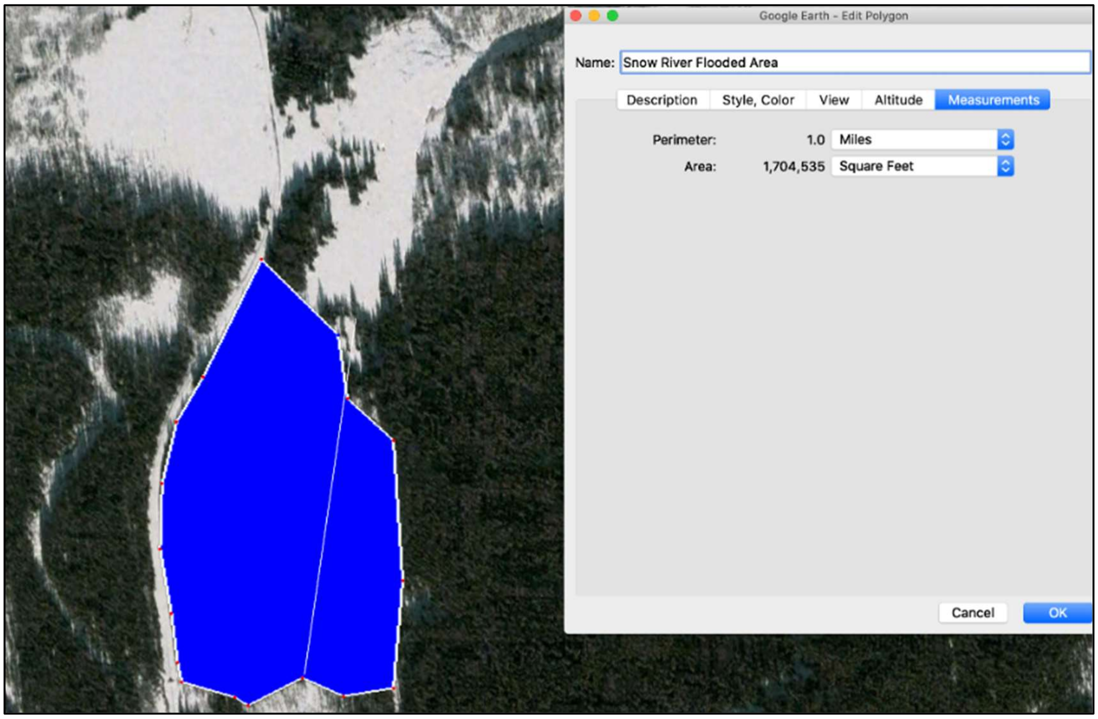

Figure 9: Area of Greatest Flooding

Imagery Credit: Google Earth Image

The values obtained for flowrate were then used to determined how much riprap would be needed to support the track structure. This was determined by calculating the seepage velocity per foot of riprap. The calculations are given in Table 3 and Table 4 with the following assumptions: a percentage of voids of 0.15 and 0.30 for Class III and IV, respectively.

Table 3: Seepage Velocity per foot of Class III Riprap

Class III Riprap				
		Values	Units	Notes
Seepage Velocity	v	14.20	ft/s	Max Velocity D50 Riprap Can Withstand
Seepage Velocity / FoS	FoS	12.91	ft/s	Average Velocity Riprap Can Withstand / FoS
Factor of Safety		1.10		Highest FoS for Class IV Riprap
Percentage of Voids	ne	0.15		Percentage of Voids Needed
Specific Discharge	q	2.13	ft/s	
Bulk Cross-Sectional Area	A	3331.10	ft/s^2	Cross-Area of water flowing through riprap
Width of Riprap	b	333.11	ft	Length of Riprap Needed
Height of Riprap	y	10.00	ft	Height of Riprap
Flowrate	Q	7102.23	ft^3/s	Flow Needed to Drain Flooded Area
Seepage per Foot of Riprap				
		Values	Units	Notes

Seepage Velocity	**v**	**14.21**	ft/s	Average Velocity Riprap Can Withstand
Width of Riprap	**b**	**555.18**	ft	Length of Riprap Needed
Seepage per Foot of Riprap	**v**	**0.03**	ft/s	Seepage per Foot of Riprap

Table 4: Seepage Velocity per Foot of Class IV Riprap

Class IV Riprap				
		Values	Units	Notes
Seepage Velocity	v	16.16	ft/s	Average Velocity Riprap Can Withstand
Seepage Velocity /Factor of Safety	FoS	14.69	ft/s	Average Velocity Riprap Can Withstand / FoS
Factor of Safety		1.10		Highest FoS for Class IV Riprap
Percentage of Voids	n_e	0.30		Percentage of Voids Needed
Specific Discharge	q	2.42	ft/s	
Bulk Cross-Sectional Area	A	2929.96	ft/s²	Cross-Area of Water Flowing Through Riprap
Width of Riprap	b	293.00	ft	Total Length of Riprap if Sole Alternative
Height of Riprap	y	10.00	ft	Height of Riprap
Flowrate	Q	7102.23	ft³/s	Flow Needed to Drain Flooded Area
Seepage per Foot of Riprap				
		Values	Units	Notes
Seepage Velocity	**v**	**14.69**	ft/s	Average Velocity Riprap Can Withstand
Width of Riprap	**b**	**293.00**	ft	Length of Riprap Needed
Seepage per Foot of Riprap	**v**	**0.05**	ft/s	Seepage per Foot of Riprap

Equation 2: Darcy's Law

Variation 1 Variation 2

$$q = \frac{Q}{A} \qquad v = \frac{q}{n_e} = -\frac{K}{n_e} J$$

Equation 2 variations were used to determine the area needed to drain the water. With these equations and previously calculated values, the seepage velocity per foot of riprap is 0.03 ft/s and 0.05 ft/s for Class III and IV riprap, respectively.

In order to construct a permeable subbase, the riprap needs to be sized to prevent scour during a flood event but also have a gradation that provides a large percentage of voids. Class III and IV riprap fits these requirements and range in stone size from about 8" to 27" in diameter. Based on previous projects, Class III riprap was used on an Alaska DOT&PF project in Hyder, AK and survived a flood event in 2019. To create a permeable subbase, a riprap classes with an ideal percentage of voids in the gradation will allow the maximum amount of water to flow through the track structure. This will be achieved by the removal of the smaller diameter stones in the gradation, D_{10} sizes and smaller, given in Table 5.

Table 5: Rip Rap Gradation Class

Rip Rap Gradation Class			
Rip Rap Class	Rock Size (ft)	Rock Size (lb)	% Rip Rap Smaller Than
IV	2.5	1904.30	100
	1.83	746.91	50
	0.83	69.69	10
I			
	1	50	100
	0.83	25	50
	0	0	10

Class IV riprap is prioritized to use for a permeable subbase due to its flow capacity and small footprint. The length of riprap needed to drain the water is 555.18 ft for Class III and 293 ft for Class IV. Since class III riprap was chosen on a previous project, stability and scour should not be an issue for either class. However, class IV will be chosen for this project it will also provide a larger percentage of voids and allow for a short length of permeable riprap.

Unit weight estimates from ARRC's 59.7 Railbed Section project provided avenues to cost estimate based on the weight of riprap and was further calculated out in Table 6. Additional information about layers of riprap can be found in Appendix B.

Table 6: Volumes of Riprap per Foot for the Permeable Subbase

Riprap Layer		Values	Units	Values	Units	Notes
Length	L	1.0	ft			Length of Riprap Needed
Height of the riprap layer	H	10.0	ft			Height of Riprap Layer
Base Width	P	56.0	ft			Base Width of Riprap Layer
Top Width	Q	26.0	ft			Top Width of Riprap Layer
Volume	V	410.0	ft³	15.19	yd³	Volume per Foot
Keyed Riprap Layer		Values	Units	Values	Units	Notes
Length	L	1.0	ft			Length of Riprap Needed
Height of the riprap layer	H	2.0	ft			Height of Riprap Layer
Base Width	P	62.0	ft			Base Width of Riprap Layer
Top Width	Q	56.0	ft			Top Width of Riprap Layer
Volume	V	118.0	ft³	4.37	yd³	Volume per Foot

The volumes of the riprap layers were then added together and multiplied by the unit weight of the sample to determine the total weight of the riprap needed. With this calculation the 30% voids needed is also used to determine the weight. Sample calculation for how much riprap needed for a 1-foot section can be seen below:

$$[410\ Ft^3 + 118\ Ft^3] \times 162.5\ [lb/\ Ft^3] \times 0.70 = 60060\ [lb] = 30.03\ [tons]$$

From previous ARRC project cost estimates, the cost of riprap averaged to $41/ton. The cost for a 1-foot section of the track for just the riprap portion would weigh about 30 tons and cost about $1242. If the permeable riprap structure was designed with Class IV riprap, it would need to be 293 ft long, with a total riprap weight of about 8,800 tons.

A key component of this alternative proving effective in the field will be the rate at which the over-sized riprap substructure will fill its voids with fine glacial sediment and other river debris. The highest suspended sediment transport rates will coincide exactly with the time period in which the riprap substructure transports the most water, and therefore moves the suspended sediment out of the voids in the riprap. If hydraulic forces on the sediment particles exceed the threshold conditions for stability, the particles become suspended. The flow conditions for incipient motion of submerged soils is governed by a dimensionless shear stress ratio called the Shields parameter, solved for in Equation 3. Detailed below is the ratio of active horizontal force that is a function of fluid mixture density and median grain size, to a passive vertical force that is dominated by the specific weight of fluid mixture. Equation 3 governs sediment transport on the assumptions that lift force is negligible, bed slope is horizontal, and buoyant force acts exactly opposite to particle weight.

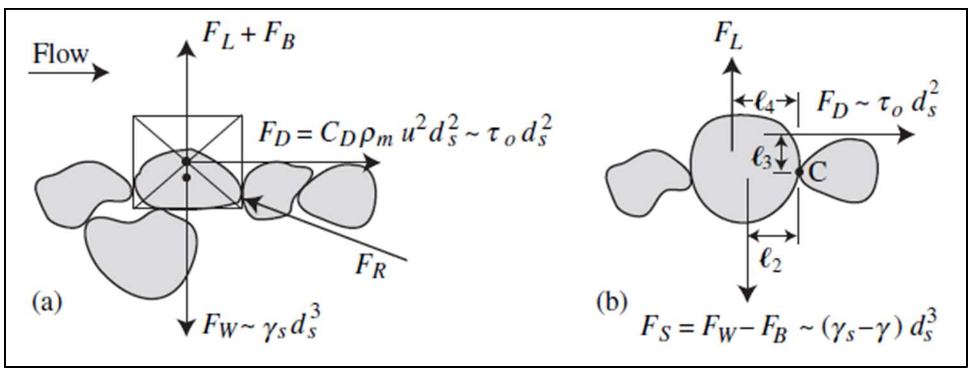

Figure 10: Non-Hydrostatic Force Diagram of Submerged Particles

Equation 3: Submerged Incipient Motion

$$\tau_* = \frac{\tau_0}{(\gamma_s - \gamma_m) * d_s} = \frac{\rho_{m*} U_*^2}{(\gamma_s - \gamma_m) * d_s}$$

Where:

F_l = lift force

F_b = buoyant Force

F_w = weight force

F_s = submerged weight of particle

F_d = drag force

τ_* = Shields parameter

τ_0 = boundary shear stress

ρ_m = fluid mixture density

u_* = shear velocity

γ_s = specific weight of a sediment particle

γ_m = specific weight of the fluid mixture

d_s = significant particle size

Factors to consider for this alternative include a build-up of glacial silt in the voids of the porous subbase that may decrease capacity and possible problems that arise with frost/ice in the voids. A balance between structural integrity and void capacity must be found to make this alternative successful. Scour, erosion, and downstream effects must also be considered. More testing and analysis of this alternative is recommended before implementation.

3.3.4 Box Culvert

Box culverts are generally pre-cast and made of concrete. They can replace small bridge spans acting as drainage systems and circular pipes that cannot provide adequate flow capacity. Bridges are usually more expensive to build and require major maintenance. As opposed to box culverts, which are already pre-cast, require less labor, and take significantly less time to implement. Since the box culverts are made of concrete, water takes longer to corrode them than other materials, such as steel bridge piles. Box culverts are somewhat new to railroad use but are gaining popularity.

Multi-plate culverts are composed of multiple steel plates bolted together. They are easier to transport and assemble but are flimsier than box culverts and require more skill to construction. Due to their steel nature, multi-plate culverts require more frequent maintenance due to corrosion.

The nature of flooding in the Snow River is large-scale, so box culverts are a superior alternative to reduce maintenance costs and increase strength. Since the ARRC limits culvert dimensions to 10 ft X 10 ft, the size of the designed culvert will be 9 ft X 9 ft box culvert, 55 ft long, with wing walls, to ensure a small size and easy fabrication. Using Equation 4 and previous calculations of a peak flow rate of 7,102 cfs requires a design with five culverts to accommodate that capacity. The culverts were designed in such a manner to provide a 1.5 ft headspace to allow a factor of safety for debris and clogging. Wing walls were included to support the surrounding track structure and redirect flow into the culverts. The culvert length would need to be equivalent to the width of the track structure, averaged 55 ft. Design also requires E80 class loading and spacing to adhere to railroad standards.

Equation 4: Manning's Equation

$$Q = \frac{K}{n} A R^{2/3} \sqrt{S_0}$$

Where:

Q = flow rate

A = cross-sectional area of flow

R = hydraulic radius (cross-section area divided by wetting perimeter)

S = slope of the channel at the point of measurement

n = Manning's surface roughness coefficient: 0.012 for concrete

K = constant: 1.486 for US units and 1 for SI units

Procurement, installation, and maintenance will need to be factored into the total costs over the lifespan of the culvert. Additionally, geotechnical considerations like soil compaction between adjacent culverts should be investigated and implemented in further designs.

3.3.5 Groin Revetment

Armoring is the implementation of protective structures along coastlines or riverbanks to protect from erosion. Groin revetments are a specific type of armoring that act to absorb flowing waters energy, and trap existing soils. They are sloped, passive mounds that protect the underlying earth from the shear forces that initiate incipient motion, an example given in Figure 11. The groin field pictured protects the beachfront properties by entrapping sediment that otherwise would be transported longshore by wave action.

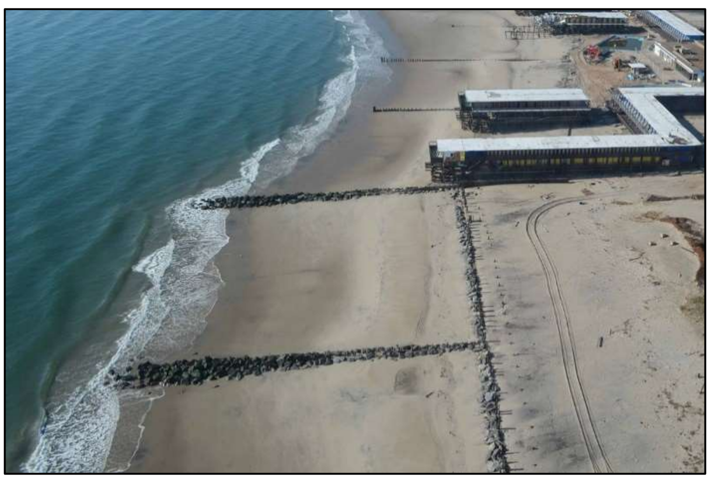

Figure 11: Example of a Groin Revetment

Imagery Credit: National Park Service

If used on the Snow River, a groin field would trap a percentage of the longshore sediment transport. Groin revetments can be constructed of numerous materials; selection is based on budget and location. A conventional revetment consists of a geotextile sheet separating native soils, then layered aggregate with large armor rocks on the outer walls and toes. A more modern revetment can consist of concrete mats. Successful use of a revetment will significantly delay the rate of bank erosion that would otherwise change the river's course over time.

Most of the flow transmitted on the Snow River, during normal conditions, involves the sharp left-hand bend, shown circled in Figure 12. This final twisting spline before emptying into Kenai Lake is a location of heavy erosion because of the fast-moving flow transporting sediment from the outside of the bend.

This channel is growing eastward toward the ARRC tracks and could be mitigated with the addition of a groin field, shown with blue lines. The blue arrows indicate the direction of flow of Snow River.

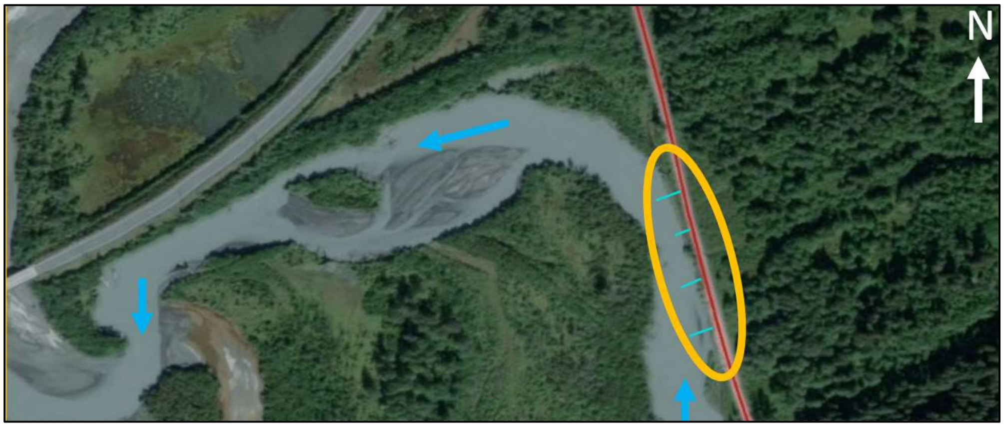

Figure 12: Snow River Area Subject to Groin Design

Imagery Credit: ArcGIS

The direct method for determining stable riprap size as a function of shear stress is a more pedagogically attractive computation than the iterative method outlined by Anderson et al. (1970). Circumventing the use of a solver, this direct method coupled with a factor of safety returns an appropriate stable riprap size. Method adapted from Yongliang Jin and Brian Barkdoll (2009), given in Equation 5 and Equation 6.

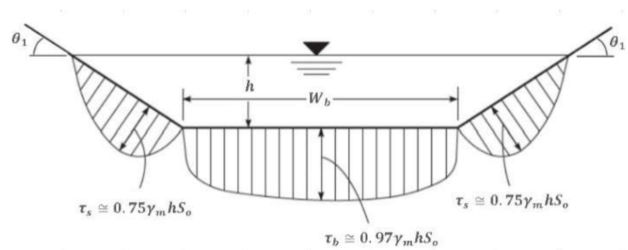

Figure 13: Applied Shear Stress Distribution in Trapezoidal Channels

Equation 5: Trapezoidal Channel Side Shear Stress

$$\tau_s = 0.75\gamma_m h S_0$$

Equation 6: Trapezoidal Channel Bottom Shear Stress

$$\tau_b = 0.95\gamma_m h S_0$$

Where:

b = bottom width in ft

d_{50} = median riprap diameter in ft

K_r = tractive force ratio

n = Manning's roughness coefficient

Q = discharge in ft^3/s

R = hydraulic radius in ft

S = longitudinal channel bed slope

y = normal flow depth in ft

ϕ = angle of repose in degrees

θ = side slope angle in degrees

$(\tau_o)_c$ = critical shear stress required for initiation of motion in lb/ft^2

$(\tau_o)_{max}$ = maximum bed shear stress in lb/ft^2

$(\tau_o w)_{max}$ = maximum wall shear stress in lb/ft^2

γ = specific weight of water

Based on USGS stream gage data, whole channel flow rates for normal conditions and jökulhlaups flow conditions were calculated.

Table 7: Calculations Under Normal Flow Conditions

Variable	Unit	Measured	Included Factor of Safety (1.25)
Q	ft^3/s	20,000	25,000
S	ft/ft	.0001	.00018
b	ft	45	56.25
γ	lb/ft^3	62.43	78.0375

Table 8: Calculations under Jökulhlaups Flow Conditions

Variable	Unit	Measured	Included Factor of Safety (1.25)
Q	ft^3/s	45,000	56,250
S	ft/ft	.0001	.00018
b	ft	45	56.25
γ	lb/ft^3	62.43	78.0375

Equation 7: Direct Method for Determining Riprap Size for Erosion Protection in Rivers

$$d_{50} = \frac{2.41 * Q^{0.60355} * S^{0.79358} * b^{-0.51341}}{1 + 1.65e^{\frac{-0.5b}{\gamma}}}$$

$$d_{50(Stable)} = 1.85"$$

$$d_{50(Flood\ Conditions)} = 3.0"$$

The rock groins extending out into the Snow River could be composed of Anchorage Sand & Gravel (AS&G) riprap Class I and Class II. The groins are layered in construction with a riprap Class II bedding followed by riprap Class I to fill voids. This process repeats until groin extends 3 ft above the Mean High Water Line (MHWL) measured at each groin location.

Table 9: Rip Rap Size and Weight

Item	Size (Diameter) ft.	Weight (Per Piece) lbs.
Rip Rap Class I	1/12' – 1'	1-75
Rip Rap Class II	1.25' - 1.75'	200-800

Mitigating this erosion problem with a groin armoring would unfortunately be expensive because of this relatively inaccessible location. Ultimately, this alternative is not considered for our final design because of its predicted effectiveness and ecological impact. The difference in the proposed groin field compared to a strip beach nourishment is not great. By simply armoring the beach with large riprap, the negative effect on fish and other aquatic organisms can be circumvented. In addition, the placement of the groins would require specific equipment.

3.3 Alternative Summary

Table 10 provides a summary for all alternatives discussed.

Table 10: Alternatives Summary Table

Alternative	Pros	Cons	Bottom Line
Dredging	• Improved capacity during flooding	• Unknown if sediment is the main issue • Need hydraulic model to determine river changes • Permitting constraints • Requires annual maintenance • Large amount of material to be dredged	Dredging has unknown benefits that require maintenance and permitting.
Bridge Addition	• Significant conveyance capacity at a specific location	• Long length required for needed capacity • Expensive to construct and maintain	The total bridge length and associated cost were unfeasible.
No Build	• No environmental impact • No upfront costs	• Leaves track in threat of continued damage • Would not improve hydraulic condition • Historic $350,000 emergency repairs required biennially	No build alternative would result in continued repair costs and disruption to ARRC services.
Track Raise	• Increases elevation and mitigate track flooding • If completed with permeable riprap alternative, existing	• Unfeasible for whole project area to undergo a track raise due to tunnels and MP 14.5 bridge	Set elevations of existing structures limit track raises. However, raises should be done in flood prone regions in

	riprap and material could be utilized for track raise	• Grade not to exceed railroad standard of 2% (2 ft rise or fall over 100 ft length)	conjunction with ARRC projects.
Permeable Riprap	• Riprap allows water to flow freely from one side of the track to the other • Able to withstand velocities up to 14.64 ft/s • Consists of class IV riprap to provide maximum voids (30%), with a seepage velocity of 0.05 ft/s	• Riprap stability and clogging testing needed before implementation • Large amount of specific riprap required	Permeable subbase will allow water to flow through the track structure to prevent flooding, while also adding protection for scour and erosion.
Box Culvert	• Significant conveyance capacity at a specific location • Multiple can be implemented • Withstand velocities up to 14.64 ft/s • Include wingwalls to support riprap • Concrete body is strong against water erosion • "Tried and true"	• Needed capacity with box culverts alone would require 5 structures • Requires E80 loading • Design must account for adequate spacing and soil compaction	Culverts provide increased capacity key locations.
Groins	• Decreases erosion at implementation site	• Could cause downstream erosion • Potential to impact wildlife	Could reduce erosion but has potential for effects on wildlife.

4.0 Preferred Alternative Combination

4.1 Assumptions

Since various factors are difficult to estimate accurately, general assumptions are used throughout the design process. These assumptions include a flow rate of 7102.23 cfs, an existing track height of 15 ft, and knowledge of existing structures such as the MP 14.5 bridge and tunnels. Calculated assumptions include a flow velocity of 14.64 ft/s through the culverts, and a permeable riprap seepage velocity of 2.42 ft/s (0.05 ft/s per foot of permeable riprap), both adjusted with a 1.1 factor of safety. Considering these velocities, Class IV riprap was determined to provide the most flow and be structurally efficient for permeable subbase usage. Track raises were assumed to be minor if under 6" and major if greater than 6", which would require the track structure trapezoid to be rebuilt.

4.2 Final Design

Combined Alternatives

The Chosen Alternative consists of a combination of the permeable riprap and box culverts with additional track raises. A total of 125 ft of permeable riprap will be used along MP 16.2 and 16.3. The three, concrete box culverts will be centered at MP 16.15. This combination will have 75 ft of permeable riprap placed on the southern side of the box culverts, and 50 ft of the riprap placed north of MP 16.2 bridge. This track region was chosen due to previous damage and water overtopping during flood events. The concrete box culverts and permeable riprap alone are designed to relieve over 100% of the calculated flow required to eliminate damage and overtopping. Track raises act as an additional safety measure to guard against any unforeseeable factors and are easily implemented with the additional cut material.

Considering the theoretical nature of the permeable riprap, the box culverts will be taking the majority (65%) of the total flow during a flood event. The permeable riprap will alleviate the remaining 35%. Table 11 provides the calculated flows and percentages of total flow each alternative can accommodate.

Table 11: Flow Comparison by Hydraulic Structure

	Box Culvert Flow	**Permeable Riprap Flow**
Flow Rate (cfs)	4606.46	2495.77
Total Flow (%)	64.86	35.14

4.2 Cost Estimate

Class IV riprap and ballast needed for the permeable riprap alternative would be sourced from the quarry in Curry, Alaska. Work trains can take 50 train cars of material, with 15 tons per train car. ARRC owns 30 side-dump train cars that can be utilized to transport and dump material. Work trains will take two days to complete a round-trip from Anchorage, to Curry, down to Seward, and back to Anchorage. The material will be staged at MP 11.6 and MP 18.4. Moving material from Curry is estimated to take 18 days, assuming nine work train trips. The other materials and equipment will be utilized from Seward or brought down from Anchorage, as needed.

Work crews will start a few days later and be based out of Seward. Workers will be on the site for up to 25 days, prepping the site, removing the existing track structure, and placing the layers for the permeable riprap. Cut, existing material will be stored onsite and utilized in the track raise alternative throughout the construction area. While on-going construction occurs, work trains will transport the culverts and corresponding materials and equipment to the worksite. Crews will then put in the culverts, ensuring to compact the soil between the culverts to prevent blow outs. Workers will then finish erosion prevention riprap placement and reconnection of tracks. Equipment will then be sent back to its corresponding yard and workers will leave the site. It is advised to complete work during off-season operations to prevent delays and effects to daily operation.

To construct 125 ft of permeable riprap, the equipment, labor, and materials totals $1.18 million. The proposed box culverts are estimated to cost $69,192 for materials, for a total of $113,000 with equipment and labor. The track raise was estimated to be a 0”-18” track raise, throughout MP 15.9 – 16.4 section. The track raise will reuse the cut material from the permeable riprap, which cuts costs and time for procurement.

A grand total of $2.1 million is estimated to complete the chosen alternative, broken out by each alternative in Table 12. A detailed cost estimate can be found in Appendix C.

Table 12: Cost Estimate Summary

Description	**Total**
Construction	
Permeable Riprap Retrofit	
Equipment	$198,009
Labor	$664,715
Materials	$317,134
Contracts	$3,125
Subtotal	**$1,183,000**
Track Raise & Reconstruction	
Equipment	$161,338
Labor	$199,129
Materials	$69,192
Subtotal	**$429,700**
Culvert Construction	
Equipment	$15,879
Labor	$23,632
Materials	$73,500
Subtotal	**$113,000**
Design & Support	
Engineering and Design	$166,000
Management	$191,100
GRAND TOTAL -	$2,102,300

4.2 Other Factors

The permeable riprap is still a theoretical design without guarantee of its performance. Therefore, laboratory tests and various analysis procedures are recommended in further design and implementation. Tests for general stability, scour, erosion, void blockage, seismic slope stability, and downstream effects are recommended. For concrete box culverts, soil compaction and an E80 load rating should be considered. It is also recommended all further designs should be run through the USGS SMS hydraulic model to better predict the Snow River's reaction to the changes. Like any major construction, permitting and ROW will need to be considered.

5.0 References

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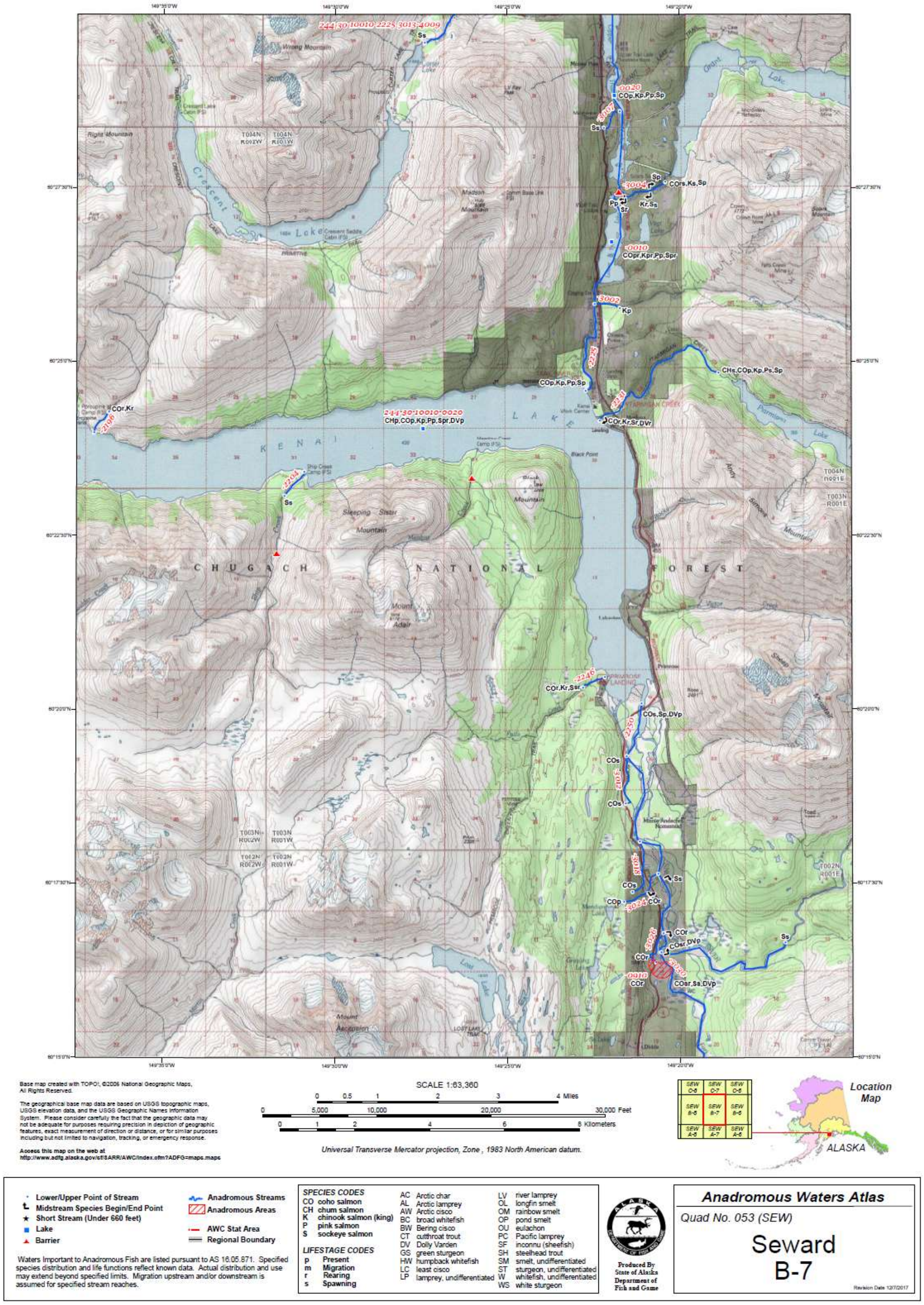
6.0 Appendixes

Appendix A-1: ADF&G – Snow River and Kenai Lake Anadromous Water Atlas



Anadromous Water Atlas

Imagery Credit: Alaska Department of Fish and Game

Publicly available at: https://www.adfg.alaska.gov/anadromouspdfs/regulatory_web/scn/SEWB7.pdf

Appendix A-2: Anadromous Fish Act (AS 16.05.871-.901) Construction Excerpt

Anadromous Fish Act (AS 16.05.871- .901)

Sec. 16.05.871. Protection of fish and game.

(a) The commissioner shall, in accordance with AS 44.62 (Administrative Procedure Act), specify the various rivers, lakes, and streams or parts of them that are important for the spawning, rearing, or migration of anadromous fish.

(b) If a person or governmental agency desires to construct a hydraulic project, or use, divert, obstruct, pollute, or change the natural flow or bed of a specified river, lake, or stream, or to use wheeled, tracked, or excavating equipment or log-dragging equipment in the bed of a specified river, lake, or stream, the person or governmental agency shall notify the commissioner of this intention before the beginning of the construction or use.

(c) The commissioner shall acknowledge receiving the notice by return first class mail. If the commissioner determines that the following information is required, the letter of acknowledgement shall require the person or governmental agency to submit to the commissioner:

(1) full plans and specifications of the proposed construction or work;

(2) complete plans and specifications for the proper protection of fish and game in connection with the construction or work, or in connection with the use; and

(3) the approximate date the construction, work, or use will begin.

(d) The commissioner shall approve the proposed construction, work, or use in writing unless the commissioner finds the plans and specifications insufficient for the proper protection of fish and game. Upon a finding that the plans and specifications are insufficient for the proper protection of fish and game, the commissioner shall notify the person or governmental agency that submitted the plans and specifications of that finding by first class mail. The person or governmental agency may, within 90 days of receiving the notice, initiate a hearing under AS 44.62.370. The hearing is subject to AS 44.62.330 - 44.62.630.

Appendix B: Typical Volumes Required for a Cross-Section

Typical Volumes Required for a Cross-Section

Volumes of Layers for Permeable Subbase Cross-Section						
Cross-Section of Track Total Volume per Foot		Values	Units	Values	Units	Notes
Length	L	293.00	ft			Length of Riprap Total
Height of Track	H	15.00	ft			Height of Tracks
Base Width	P	62.75	ft			Base Width of Tracks
Top Width	Q	11.00	ft			Top of Tracks
Volume	V	299954.66	ft^3	11109.43	yd^3	Volume per Foot
Cross-Section of Ballast Layer Column per Foot		Values	Units	Values	Units	Notes
Length	L	1.00	ft			Length of Riprap
Height of Ballast	H	1.50	ft			Height of Ballast
Base Width	P	15.50	ft			Base Width of Ballast
Top Width	Q	11.00	ft			Top Width of Ballast
Volume	V	19.88	ft^3	0.74	yd^3	Volume per Foot
Cross-Section of Borrow Volume per Foot		Values	Units	Values	Units	Notes
Length	L	1.00	ft			Length of Riprap
Height of Borrow	H	1.50	ft			Height of Borrow
Base Width	P	20.00	ft			Base Width of Borrow
Top Width	Q	15.50	ft			Volume per Foot
Volume	V	26.63	ft^3	0.99	yd^3	
Cross-Section of Filter Rock Volume per Foot Above Geotextile		Values	Units	Values	Units	Notes
Length	L	1.00	ft			Length of Filter Rock
Height of Filter Rock	H	1.00	ft			Height of Filter Rock
Base Width	P	23.00	ft			Base Width of Filter Rock
Top Width	Q	20.00	ft			Top Width of Filter Rock
Volume	V	21.50	ft^3	0.80	yd^3	Volume per Foot

Cross-Section of Filter Rock Volume per Foot Below Geotextile		Values	Units	Values	Units	Notes
Length	L	1.00	ft			Length of Filter Rock
Height of Filter Rock	H	1.00	ft			Height of Filter Rock
Base Width	P	26.00	ft			Base Width of Filter Rock
Top Width	Q	23.00	ft			Top Width of Filter Rock
Volume	V	24.50	ft^3	0.91	yd^3	Volume per Foot
Cross-Section of Riprap Layer Volume per Foot		Values	Units	Values	Units	Notes
Length	L	1.00	ft			Length of Riprap
Height of Riprap	H	10.00	ft			Height of Riprap
Base Width	P	56.00	ft			Base Width of Riprap
Top Width	Q	26.00	ft			Top Width of Riprap
Volume	V	410.00	ft^3	15.19	yd^3	Volume per Foot
Cross-Section of Keyed Riprap Volume per Foot		Values	Units	Values	Units	Notes
Length	L	1.00	ft			Length of Riprap
Height of Riprap	H	2.00	ft			Height of Riprap
Base Width	P	62.00	ft			Base Width of Riprap
Top Width	Q	56.00	ft			Top Width of Riprap
Volume	V	118.00	ft^3	4.37	yd^3	Vol per Foot
Cross-Section of Shot rock per Foot		Values	Units	Values	Unites	Notes
Length	L	1.00	ft			Length of Shot Rock
Height of Shot Rock	H	0.25	ft			Height of Shot Rock
Base Width	P	62.75	ft			Base Width of Shot Rock
Top Width	Q	62.00	ft			Top Width of Shot Rock
Volume	V	15.59	ft^3	0.58	yd^3	Volume per Foot

Source Credit: ARRC 59.7 Railbed Section Project

Appendix C. Project Cost Estimate

SNOW RIVER STABILIZTION

General Cost Estimation - Combined Alternatives Analysis

Prepared by: Malamute Consulting Spring 2020

Description	Qty	Unit	Unit Price	Total	Notes / Comments
Construction					
Permeable Riprap Retrofit				$ 1,183,000	
Equipment		**Subtotal**		**$ 198,009**	
Rip Rap, Load					
Loader	18	DY	$ 473	$ 8,520	CAT 988, load work train, Curry, half day to load, one train every two days
Hyrail	18	DY	$ 108	$ 1,948	F-350 hyrail
Work Train	18	DY	$ 3,733	$ 67,201	Work Train, C2ADWD, haul rip rap, one (1) train every two (2) days
Hyrail, Train Crew	18	DY	$ 108	$ 1,948	Hyrail, train crew
Hyrail, Dump Crew	18	DY	$ 108	$ 1,948	Hyrail, dump crew
Rip Rap, Place, ARRC					
Hyrail	18	DY	$ 108	$ 1,948	F-350 hyrail
Hyrail	18	DY	$ 108	$ 1,948	F-350 hyrail
Lube Truck	9	DY	$ 92	$ 825	F-650 lube truck
Loader, 988	18	DY	$ 297	$ 5,346	Loader, CAT 988 or equal
Loader Op $	18	DY	$ 184	$ 3,319	Five (5) hours per day
Deliver & Return	2	EA	$ 1,000	$ 2,000	Delivery and return fees
Dozer, D8	18	DY	$ 921	$ 16,578	Dozer, CAT D8 or equal
Dozer Op $	18	DY	$ 369	$ 6,638	Ten (10) hours per day
Deliver & Return	2	EA	$ 1,000	$ 2,000	Delivery and return fees
Excavator No. 01	18	DY	$ 1,068	$ 19,224	Excavator, CAT 345 or equal
Excavator No. 01 Op $	18	DY	$ 369	$ 6,638	Ten (10) hours per day
Deliver & Return	2	EA	$ 1,000	$ 2,000	Delivery and return fees
Excavator No. 02	18	DY	$ 1,268	$ 22,824	Excavator, CAT 450 or equal
Excavator No. 02 Op $	18	DY	$ 409	$ 7,358	Ten (10) hours per day
Deliver & Return	2	EA	$ 1,000	$ 2,000	Delivery and return fees
Hyrail	18	DY	$ 108	$ 1,948	Hyrail, train crew
Hyrail	18	DY	$ 108	$ 1,948	Hyrail, dump crew
350 Truck	25	DY	$ 90	$ 2,250	F-350 truck
Compactor, Roller	10	DY	$ 647	$ 6,470	Compactor, CAT 583 or equal
Compactor, Roller Op $	10	DY	$ 118	$ 1,183	Five (5) hours per day
Deliver & Return	2	EA	$ 1,000	$ 2,000	Delivery and return fees
Labor		**Subtotal**		**$ 664,715**	
Haul Roads - Equipment Operation					
Labor, ST	18	DY	$ 1,043	$ 18,775	Assume ST, Two HE Operator
Labor, OT	18	DY	$ 782	$ 14,081	Assume OT, Two HE Operator
Per Diem	18	DY	$ 176	$ 3,168	Assume the operator is eligible for per diem
Excavation, Compaction & Fill					
Labor, ST	25	DY	$ 1,565	$ 39,114	Assume ST, one Foreman, three HE Operators
Labor, OT	25	DY	$ 1,173	$ 29,325	Assume OT, one Foreman, three HE Operators
Per Diem	25	DY	$ 352	$ 8,800	Assume the entire group is eligible for per diem
Place, Aggregate Filter Rock					
Labor, ST	0	DY	$ 340	$ -	Assume ST, one HE Operator
Labor, OT	0	DY	$ 190	$ -	Assume OT, one HE Operator
Per Diem	0	DY	$ 88	$ -	Assume the operator is eligible for per diem
Haul, Angular Rock					
Contract Trucking	155	DY	$ 1,920	$ 297,600	Haul Material From Eagle River to Potter Hill - 80 min. rounds. (9 trucks - 18 days)
Labor, Load Trucks	18	DY	$ 1,080	$ 19,440	Assume one Operator + Profit
Equipment, Load Trucks @ ER	18	DY	$ 1,150	$ 20,700	Assume 988K loader and op. cost
Labor & Equipment for Stockpile	18	DY	$ 2,100	$ 37,800	Assume one HE Operator and one Volvo 350 Loader
Labor, OT, Dump Crew	0	DY	$ 458	$ -	Assume OT, one Foreman, one HE Operator
Per Diem, Dump Crew	0	DY	$ 176	$ -	Assume the entire gang is eligible for per diem

Appendix C. Project Cost Estimate

SNOW RIVER STABILIZTION

General Cost Estimation - Combined Alternatives Analysis

Prepared by: Malamute Consulting Spring 2020

Place & Key In, Angular Rock					
Labor, ST	17	DY	$ 1,043	$ 17,732	Assume ST, Two HE Operator
Labor, OT	17	DY	$ 782	$ 13,299	Assume OT, Two HE Operator
Per Diem	17	DY	$ 176	$ 2,992	Assume the operator is eligible for per diem
Rip Rap, Load					
Labor, ST	18	DY	$ 340	$ 6,126	Assume ST, one HE Operator
Labor, OT	18	DY	$ 190	$ 3,414	Assume OT, one HE Operator
Per Diem	18	DY	$ 88	$ 1,584	Assume the operator is eligible for per diem
Rip Rap, Haul					
Labor, ST, Train Crew	18	DY	$ 2,104	$ 37,872	Assume ST, three man train crew
Labor, OT, Train Crew	18	DY	$ 736	$ 13,248	Assume OT, three man train crew
Per Diem, Train Crew	18	DY	$ 522	$ 9,396	Assume meals & lodging, peak season rates, three man train crew
Labor, ST, Dump Crew	18	DY	$ 679	$ 12,222	Assume ST, one Foreman, one HE Operator
Labor, OT, Dump Crew	18	DY	$ 458	$ 8,244	Assume OT, one Foreman, one HE Operator
Per Diem, Dump Crew	18	DY	$ 176	$ 3,168	Assume the entire gang is eligible for per diem
Rip Rap, Place					
Labor, ST	18	DY	$ 1,437	$ 25,866	Assume ST, one Foreman, three HE Operators
Labor, OT	18	DY	$ 801	$ 14,415	Assume OT, one Foreman, three HE Operators
Per Diem	18	DY	$ 352	$ 6,336	Assume the entire gang is eligible for per diem
Materials		**Subtotal**		**$ 317,134**	
Grade Building, Cut Material	20,000	TN	$ -	$ -	Assume cut material is not suitable for fill, on-site disposal
Grade Building, MP388, Fill Material	0	TN	$ 7	$ -	Assume MP388, valued as Curry fines, suitable for road extension, Stock Code 317873
MP248, Curry Ballast, Siding	0	TN	$ 22	$ -	Assume Curry Ballast, Stock Code 316338
MP248, Curry Ballast, Work Spur	0	TN	$ 22	$ -	Assume Curry Ballast, Stock Code 316338, 8" lift
MP248, Curry Ballast, Turnout, No. 15	0	TN	$ 22	$ -	Assume Curry Ballast, Stock Code 316338, No. 15 Turnout
MP248, Curry Ballast, Turnout, No. 11	1,200	TN	$ 22	$ 26,509	Assume Curry Ballast, Stock Code 316338, No. 11 Turnout
MP248, Curry Ballast, Turnout, No. 09	0	TN	$ 22	$ -	Assume Curry Ballast, Stock Code 316338, No. 09 Turnout
Riprap Class I	0	TN			
Riprap Class II	0	TN			
Riprap Class III	1,000	TN	$ 30	$ 30,000	Imported from Curry (TKA)
Riprap Class IIII	5,500	TN	$ 45	$ 247,500	Imported from Curry (TKA)
Fabric, Woven Geotextile	25	ROLL	$ 525	$ 13,125	Assume woven geotextile fabric, Contech C300, 15' x 300' with 3' overlap
Contracts		**Subtotal**		**$ 3,125**	
Portable Toilet (2)	25	DY	$ 125	$ 3,125	Portable toilet during construction
Track Raise & Reconstruction				$ 429,700	
Equipment		**Subtotal**		**$ 161,338**	
TRACK WORK					
Track Work, Demolition					
ARRC Equipment	18	DY	$ 3,492	$ 62,854	Small Construction gang, track demolition, 1,000 TF / DY
Rental Equipment	18	DY	$ 1,046	$ 18,834	"
Rental Equipment Op $	18	DY	$ 475	$ 8,554	"
Work Train, Ballast, Haul					
Work Train, Ballast	18	DY	$ 3,733	$ 67,201	Work Train, C2ADWD, haul demolition material
Hyrail, Train Crew	18	DY	$ 108	$ 1,948	Hyrail, train crew
Hyrail, Dump Crew	18	DY	$ 108	$ 1,948	Hyrail, dump crew
Labor		**Subtotal**		**$ 199,129**	
TRACK WORK					
Track Work, Demolition					
Labor, ST	18	DY	$ 4,490	$ 80,825	ST, Small Construction gang
Labor, OT	18	DY	$ 2,502	$ 45,044	OT, Small Construction gang
Per Diem	18	DY	$ 660	$ 11,880	Assume one-half the gang is eligible for per diem
Work Train, Demolition					
Labor, ST, Train Crew	18	DY	$ 2,104	$ 37,872	Assume ST, three man train crew
Labor, OT, Train Crew	18	DY	$ 736	$ 13,248	Assume OT, three man train crew
Per Diem, Train Crew	18	DY	$ 570	$ 10,260	Assume meals & lodging, peak season rates, three man train crew

Appendix C. Project Cost Estimate

SNOW RIVER STABILIZTION

General Cost Estimation - Combined Alternatives Analysis

Prepared by: Malamute Consulting Spring 2020

Material		**Subtotal**		**$ 69,192**	
TRACK WORK					
Rail, 115RE	200	LF	$ 22.13	$ 4,426	Assume 115RE rail, JDE issue price
Rail, CWR	200	LF	$ 2.48	$ 496	Assume value added by CWR
Tie, 8.5', Siding	0	EA	$ 83	$ -	Assume ties, 8-1/2 ft., hardwood, Stock Code 001458
Tie, 8.5', Work Spur	616	EA	$ 83	$ 51,173	Assume ties, 8-1/2 ft., hardwood, Stock Code 001458
Tie, No. 11 Turnout, Relocate	0	LS	$ 13,090	$ -	Assume ties, No. 11 tie package, turnout relocation
Plates, 14", Mainline	0	EA	$ 13	$ -	Assume tie plates, 14" recurve
Plates, 13", Relay	1,232	EA	$ 7	$ 8,624	Assume tie plates, 13", Relay
Spikes	0	KEG	$ 30	$ -	Assume spikes, six (6) spikes per tie plate, 61 spikes per keg
Anchors	88	BAG	$ 48	$ 4,241	Assume box anchors, every tie, 28 anchors per bag
Tie Plugs	2	BNDL	$ 23	$ 46	Assume cedar tie plugs, 500 each per bundle
Angle Bars, 115RE	1	PR	$ 102	$ 102	Assume angle bars, temporary during construction, until field welded
Bolts, Track	1	PAIL	$ 84	$ 84	Assume six (6) bolts per angle bar pair, 20 bolts per pail
Culvert Construction				$ 113,000	
Equipment		**Subtotal**		**$ 15,879**	
Culvert Crew					
Equipment	7	DY	$ 108	$ 757	Assume F-350
Equipment Bob Cat	7	DY	$ 410	$ 2,870	Assume Bobcat skid steer
Equipment, Op $	7	DY	$ 35	$ 245	Assume five hours per day
Equipment, EX	7	DY	$ 891	$ 6,236	Assume CAT 320 excavator
Equipment, Op $	7	DY	$ 184	$ 1,291	Assume five hours per day
Rental Equipment Nervous Turtle	7	DY	$ 300	$ 2,100	Assume compactor, nervous turtle, Unit No 1
Rental Equipment, Op $	7	DY	$ 20	$ 140	Assume five hours per day, 1 GPH, $4 per gallon
Rental Equipment Light	7	DY	$ 120	$ 840	Assume light plant, Unit No 1
Rental Equipment, Op $	7	DY	$ 40	$ 280	Assume ten hours per day, 1 GPH, $4 per gallon
Rental Equipment Light	7	DY	$ 120	$ 840	Assume light plant, Unit No 2
Rental Equipment, Op $	7	DY	$ 40	$ 280	Assume ten hours per day, 1 GPH, $4 per gallon
Labor		**Subtotal**		**$ 23,632**	
Culvert Crew					
Labor, ST	7	DY	$ 1,800	$ 12,600	Assume a four (4) man crew, Two HE ops, two laborers
Labor, OT	7	DY	$ 1,400	$ 9,800	Assume 12 hour days
Per Diem	7	DY	$ 176	$ 1,232	Assume one-half the crew is eligible for per diem
Materials		**Subtotal**		**$ 73,500**	
Culvert, PreCast 9x9	3	EA	$ 17,000	$ 51,000	Assume steel culvert, 12" Ø x 1/2" wall x 65 long, spray metalized, inside & out
Culvert, Shipping	3	LS	$ 7,500	$ 22,500	Assume steel culvert, Skyline Steel, or equal, to ANC
Flagging & Inspection				$ 19,500	
Equipment		**Subtotal**		**$ 5,146**	
Flagging					
Rental Equipment	25	DY	$ 74	$ 1,846	Flagging, F-350 hyrail, or equal, during work by others
Rental Equipment, Op $	25	DY	$ 132	$ 3,300	Assume 12 hours per day
Labor		**Subtotal**		**$ 14,346**	
Labor, ST	25	DY	$ 282	$ 7,055	ARW06, average step, 8 hour day
Labor, OT	25	DY	$ 157	$ 3,932	ARW06, average step, 4 hour day
Per Diem	25	DY	$ 88	$ 2,200	Assume the flagman is eligible for per diem
Inspection					
Labor, ST	2	DY	$ 560	$ 1,120	Assume inspection at non-represented rate, 8 hour day
Per Diem	2	EA	$ 20	$ 40	Assume one meal per day
Construction Total				**$ 1,745,100**	
Design & Support					
Engineering and Design				$ 166,000	
NEPA / Permitting	1	LS	$ 25,000	$ 25,000	Assume permit activity required
Environmental	1	LS	$ 30,000	$ 30,000	Assume environmental studies in conjunction with Permit activity
Preliminary Engineering	1	LS	$ 50,000	$ 50,000	
Survey	30	DY	$ 1,700	$ 51,000	
Geotechnical	1	LS	$ 10,000	$ 10,000	Assume geotechnical study
Management				$ 191,100	
Project Management	4.00%			$ 76,444	
Project Management Support	1.00%			$ 19,111	
Construction Management	3.00%			$ 57,333	
Construction Management Support	2.00%			$ 38,222	

Appendix C. Project Cost Estimate

SNOW RIVER STABILIZTION

General Cost Estimation - Combined Alternatives Analysis

Prepared by: Malamute Consulting Spring 2020

Design & Support Total	**$ 357,100**	
Track Structure Credit	**$ -**	
Project Subtotal	$ 2,102,300	
Grand Total (Rounded)	**$ 2,102,300**	

Assumptions and Scope

See Notes / Comments
Assume Angular Rock is Locally Available