MENDENHALL GLACIAL LAKE OUTBURST FLOODING (GLOF)

CHARRETTE REPORT FOR THE MENDENHALL GLOF TECHNICAL STUDY

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Acronyms and Abbreviations

2D	two-dimensional
3D	three-dimensional
ACRD	Asphalt Core Rockfill Dam
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADOT&PF	Alaska Department of Transportation and Public Facilities
AEP	annual exceedance probability
AK DNR	Alaska Department of Natural Resources
AK DOT	Alaska Department of Transportation
ANCSA	Alaska Native Claims Settlement Act
bgs	below ground surface
Blows/ft	blows per foot
CBJ	City and Borough of Juneau
CFRD	Concrete-Face Rockfill Dam
cfs	cubic feet per second
DBB	Design–Bid–Build
DDR	Design Document Report
EA	Environmental Assessment
ECB	Engineering and Construction Bulletin
ECI	early contractor involvement
ECRD	Earth Core Rockfill Dam
EIS	Environmental Impact Statement
EL.	elevation
EPB	Earth pressure balance
FEMA	Federal Emergency Management Agency
FFRM	Flood Risk Management
FRMS	Flood Risk Management System
GLOF	Glacial Lake Outburst Floods
H&H	hydraulics and hydrology
H:V	horizontal: vertical
HFD	Hardfill Dam
LiDAR	light detection and ranging
MBI	Michael Baker International
MGRA	Mendenhall Glacier Recreation Area

MTBM	Microtunneling Boring Machine
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRHP	National Register of Historic Places
NWS	National Weather Service
O&M	operations and maintenance
PAR	Population at Risk
PDB	Progressive Design–Build
PFM	potential failure modes
ROM	rough order of magnitude
SHPO	State Historic Preservation Officer
SPT	Standard Penetration Test
T&H	Tlingit and Haida Indian Tribes of Alaska
TBM	tunnel boring machine
TRG	tolerable risk guidelines
UAS	University of Alaska Southeast
USACE	United State Army Corps of Engineers – Alaska District
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WSE	water surface elevations

Mendenhall GLOF Charrette Report

Executive Summary

The Mendenhall Valley in Juneau, Alaska, faces recurring Glacial Lake Outburst Floods (GLOFs) from Suicide Basin, a side-basin of the Mendenhall Glacier. Starting in 2011, these events have increased in frequency and severity, with recent floods (2023–2025) exceeding previous records causing significant damage to homes, infrastructure, and public facilities. A 3-day multi-agency charrette, held in December 2025, brought together the United States Army Corps of Engineers, Alaska District (USACE), and key stakeholders to identify and evaluate long-term solutions to mitigate GLOF risks.

The charrette included USACE, City and Borough of Juneau, Central Council of Tlingit and Haida Indian Tribes of Alaska, United States Forest Service, Alaska Department of Transportation, National Weather Service, United States Geological Survey, University of Alaska Southeast, and Alaska Department of Natural Resources. Public and other agency input was solicited through National Environmental Policy Act (NEPA) processes prior to the charrette. During the charrette, the stakeholders prioritized solutions that offered rapid implementation, lower cost [both capital and operations and maintenance (O&M) costs], minimized community disruption, and addressed environmental and cultural concerns.

Five main conceptual alternatives were evaluated prior to the charrette, were summarized into a pre-charrette packet, and distributed to USACE and the stakeholders for review.

1. Lake Tap Tunnel: A gravity-drained tunnel from Suicide Basin to Mendenhall Lake to control and reduce GLOF risk.
2. Dam: Construction of a flood control dam to temporarily store and regulate GLOF discharges.
3. Floodwall: A network of floodwalls and levees to protect developed land.
4. Hybrid Dam/Floodwall: Combination of a dam and floodwalls for integrated protection.
5. Relocation: Buyout and relocation of structures in flood-prone areas.

Preliminary hydraulic modeling was completed for each alternative to evaluate how the design flows translate into inundation extents, flow depths, and velocities. Two modeling approaches were applied. For the Lake Tap Tunnel Alternative, an HY-8 model was used to estimate flow depths and velocities within the tunnel. For all other alternatives, a HEC-RAS 2D model was used to simulate inundation extent, depths, and velocities in the Mendenhall River and its floodplain under the design flow.

Results from the preliminary modeling were used to screen out several channel and floodplain modification alternatives from further consideration at the charrette. These options were found to provide limited benefits and could introduce unacceptable long-term risks. The alternatives screened out are flood storage areas, bypass channels, cutoff channels, and river widening or deepening.

The five main conceptual alternatives were assessed using the following evaluation criteria including:

- Risk reduction (life safety and economic)
- Reliability, adaptability, and resiliency
- Environmental and cultural considerations, permitting and land acquisition requirements, and economic considerations
- Design and construction duration
- Constructability
- Comparative construction capital cost
- Acceptability within the metrics of the USACE Planning Principles and Guidelines
- O&M costs, requirements, and lifecycle costs

During the charrette, the Lake Tap Tunnel was unanimously preferred by the stakeholders due to:

- Highest risk reduction for life safety and economic loss
- Technical feasibility, reliability, and resiliency
- Lower capital and O&M costs compared to other options
- Minimal disruption to the community, tourism, and environment
- Faster implementation timeline

USACE and the stakeholders acknowledged key risks and technical unknowns, especially regarding geotechnical conditions, and emphasized the need for further investigation and design refinement. Risks and technical unknowns include the following:

- Geotechnical and geological uncertainties along the tunnel alignment
- Potential for intake/outfall clogging or freezing
- Impacts during construction to environmental and cultural resources, and to tourism, recreation, and the local economy
- Permitting and stakeholder coordination requirements
- Ongoing need for adaptive management as glacial and hydrologic conditions evolve.

At the conclusion of the charrette, USACE carefully evaluated the stakeholders' comments and reasoning for the preferred engineering solution. As a result, the Lake Tap Tunnel Alternative was identified as the preferred engineering solution by those in attendance of the charrette for mitigating GLOF risk in Mendenhall Valley as it appears to offer the best balance of risk reduction, feasibility, and cost while minimizing community disruption and environmental impact.

Extensive stakeholder engagement prior to and during the charrette, and a structured evaluation process supported this collective preference. USACE and the stakeholders acknowledged that key risks remain, particularly regarding subsurface conditions and permitting, requiring further study, design, and adaptive management.

The design of the Lake Tap Tunnel Alternative will be advanced beyond the conceptual stage that was presented at the charrette. This preliminary design of the Lake Tap Tunnel will be based upon existing information only and will be documented in a Technical Report scheduled to be completed in May 2026.

This Charrette Report documents the evaluation and decision-making process used to select the preferred engineering solution. The structure of the charrette report begins with an overview of the project with a brief description of the GLOFs followed by summaries of the five alternatives that were considered. This is followed in Chapter 3 by overviews of several pertinent topics covered in the charrette aimed at preparing the stakeholders for their individual analyses of the alternatives presented. These include overviews of NEPA, risk evaluation, alternative evaluation criteria, hydrologic inputs, and the hydraulic modeling that was used to assess the alternatives. It also describes the alternatives that were screened out prior to the charrette as a result of the analyses indicating that they were not technically feasible.

Chapter 4 contains detailed technical information regarding each of the five alternatives, followed by an overview of the probable cost of each alternative. Chapter 5 addresses additional topics that were prepared and covered during the charrette as a result of the discussions held during the charrette and the questions from the stakeholders, including a summary of stakeholder responses to the questionnaire that was distributed prior to the charrette. Chapter 6 contains detailed descriptions of the evaluation criteria that were used to assess the alternatives by the stakeholders while Chapter 7 has a description of the USACE risk evaluation framework and methodology.

Chapter 8 is an overview of the assessment of the alternatives by the individual stakeholder breakout groups. Chapter 9 describes the selection of the preferred engineering solution and the summaries of the discussions that occurred within the discipline specific breakout groups that assessed the key questions needed to advance the design of the lake tap tunnel and to identify next steps needed to complete the technical report.

1. Introduction

1.1. Overview

The purpose of this charrette report is to summarize the information and outcomes of the multi-agency charrette held from December 9 through 11, 2025, in Juneau, Alaska to identify an enduring solution to the Glacial Lake Outburst Floods (GLOF) impacting the residents of Mendenhall Valley. AECOM worked with the United State Army Corps of Engineers (USACE) and other key stakeholders to prepare the technical information included in this charrette report. This charrette report selects an alternative that will be developed for preliminary design as defined in task order W911KB26FA002.

1.2. Problem Statement/Project Description

The charrette reviewed a variety of concepts and selected an alternative to address the recurring glacial lake outburst flooding hazard in Juneau, Alaska, associated with Suicide Basin, a side-basin of the Mendenhall Glacier. Since 2011, Suicide Basin has repeatedly filled with meltwater and then released sudden, high-volume outburst floods into Mendenhall Lake and the Mendenhall River. These events occur annually, or more frequently, with increasing severity. In 2023, the flood from the GLOF peaked at 34,200 cubic feet per second (cfs); in 2024, the peak reached 42,700 cfs; and in 2025, the peak rose further to 51,000 cfs (provisional). Each of these events exceeded prior records and caused flooding which impacted homes, public facilities and infrastructure, and utilities in the Mendenhall Valley, which is the largest residential area in Juneau. For context, peak discharges of the 2023, 2024, and 2025 GLOF events surpassed what was previously believed to be the 1 percent annual exceedance probability (AEP) (100-year) flood on the Mendenhall River.

The flooding threat is driven by the complex and evolving dynamics of the Glacier and the Basin. Suicide Basin is dammed by the Mendenhall Glacier, impounding large volumes of meltwater during the summer season. When the water level in Suicide Basin increases to the point where water is forced under the ice dam, a GLOF occurs. The GLOFs start slowly but increase rapidly as the friction from the water flowing under the glacier widens the sub-glacial drainage channel. It typically takes about two days for the water in the Basin to drain out and cause flooding in the Mendenhall Valley downstream. The magnitude of these GLOF releases has grown even as the glacier has thinned and retreated, a pattern observed at other glaciers in Alaska.

The ice-marginal lake in Suicide Basin fills annually and drains rapidly underneath the Mendenhall Glacier, creating a glacier outburst flood that impacts Mendenhall Lake and the Mendenhall River in Juneau. The ice marginal lake in Suicide Basin is expected to persist for up to several decades, creating an ongoing flood hazard for residents and infrastructure in the Mendenhall Valley. Eventually, the Mendenhall Glacier will retreat to the point where it no longer dams Suicide Basin and there will no longer be GLOFs from the Basin.

Preliminary estimates from glaciologists point to a potential end range of the Suicide Basin GLOF lifespan of 30 years and highlights that there is unparalleled uncertainty in the lifespan and evolution of Suicide Basin and its GLOFs. Since study and forecasting of Suicide Basin and its GLOFs began, subject matter experts and peer-reviewed academic journals have struggled and often failed to accurately predict the behavior of Suicide Basin. Observed behavior of Suicide Basin consistently does not match predictions by SMEs and journals. For example, since Kienholz et al. (2020), Suicide Basin and its GLOFs have dramatically changed. A range of 30 years represents one end case for the lifespan of Suicide Basin, based on projections of past trends. On the other hand, the Snow Glacier Dammed Lake (an analog system in coastal Alaska) has been producing GLOFs with no decreasing trend in magnitude for at least 75 years, despite significant thinning and retreat. Projecting the evolution of Suicide Basin and the Mendenhall Glacier based on past trends will likely not accurately predict the lifespan or evolution of Suicide Basin. The rate of recession of the Mendenhall Glacier will change now that the Mendenhall Glacier has retreated out of Mendenhall Lake and the downstream boundary condition of the Mendenhall Glacier has changed. The downstream boundary condition has changed from that of a calving/tidewater glacier to that of a land-terminating glacier. If Mendenhall Glacier dynamics change with the change in the downstream boundary condition, the Mendenhall Glacier may not retreat past Suicide Basin (and could maintain the glacier lake ice dam) for more than 100 years.

This project was initiated to first provide conceptual level alternative designs that would consider life safety and economic risk reduction to the residents of Mendenhall Valley from annual GLOF events that originate from Suicide Basin. Five concept level designs were provided at the initiation of the project. The concepts were formulized into low level designs (2 to 5%) for the purposes of presenting the designs to the stakeholders for review prior to the charrette. The charrette was used to evaluate each alternative based on a set of criteria given to the stakeholders. Stakeholders were provided information regarding the current state of the Basin and an assessment of possible glacial changes that will impact future GLOFs. Stakeholders were asked to provide input for each design alternative and to provide their recommendations to USACE to select a preferred engineering solution based on the evaluation criteria. This report documents the alternative designs and the results of the charrette, including the selection of the preferred engineering solution.

1.3. Acknowledgements

On behalf of the Alaska District USACE, we would like to acknowledge that the charrette took place on the traditional lands of Tlingit and Haida, particularly the Áak'w Kwáan people, and wish to honor the indigenous people of this land. For more than ten thousand years, Alaska Native people have been stewards of the land, including the Mendenhall Glacier, Lake, and River, and continue to be integral to its well-being. We are grateful to have been in this place, a part of this community, and to honor the culture, traditions, and resilience of the Aak'w Kwaan people. We appreciated their guidance in our deliberations. Gunalchéesh!

2. Background

2.1. History of GLOF in Juneau

Suicide Basin is dammed by the Mendenhall Glacier (Figure 2-1). The Basin is currently about 4,000 feet long, 1,400 feet wide, and has a maximum depth of 450 feet (bottom elevation ~900 feet and top of ice dam elevation ~1,360 feet). The Basin fills with water during the summer, and in recent years, has regularly reached the point of overtopping the ice dam and flowing along the margin of the Mendenhall Glacier. Within a few days of the ice dam being overtopped, the water in the Basin forces its way under the ice dam and drains beneath the glacier into Mendenhall Lake. The resulting outburst floods occur quickly through the enlargement of a subglacial drainage channel, peaking within roughly 48 hours of initiation.

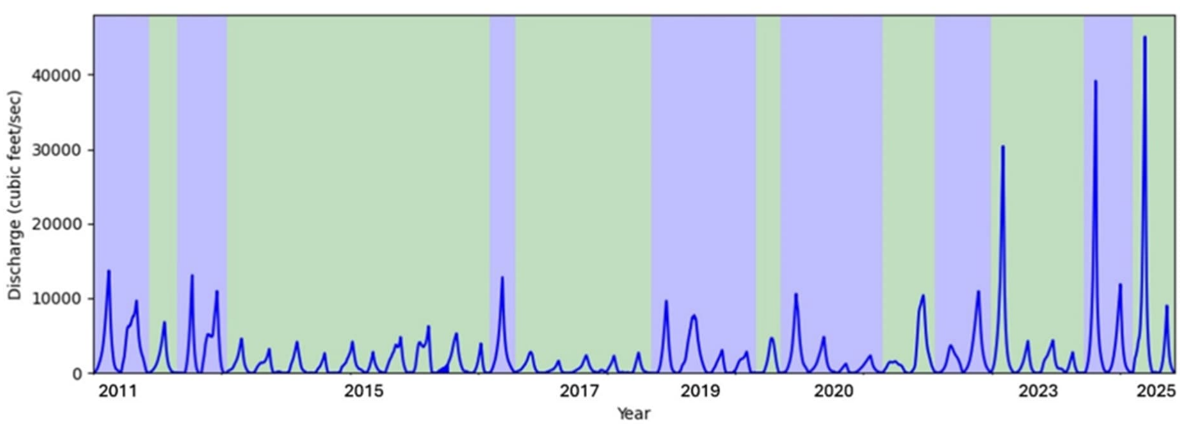
GLOF events from Suicide Basin pose a significant hazard to Juneau's Mendenhall Valley, with recent releases causing widespread impacts to homes, infrastructure, and emergency planning efforts. The 2024 record GLOF peaked with a discharge exceeding 35,000 cfs at the Mendenhall River gauge, flooding neighborhoods and damaging approximately 300 residences as waters overtopped banks and spilled into developed areas of the Valley (HMP 2025, p. 3-117). This discharge far exceeded what is considered a severe event; for context, according to a 2020 Federal Emergency Management Agency (FEMA) flood insurance study, an event with a discharge of 26,000 cfs has a ~0.2 percent chance of occurring. This highlights how extraordinary GLOF flows can be when compared to defined flood risk thresholds in the region.

According to National Weather Service hydrographs, the 2025 GLOF also produced a new peak of record preliminary discharge near ~51,000 cfs and a crest stage of 16.65 feet, with the river remaining above moderate and major flood stage thresholds for many hours during the event. These magnitudes of flow exceed levels at which damage to homes and critical infrastructure can occur. Historically, levels above 14 feet on the Mendenhall River gauge signify major flooding for the Valley.

In response, the City and Borough of Juneau (CBJ) has incorporated GLOF risk into its 2025 Hazard Mitigation Plan, noting that these floods repeatedly impact the most populated residential areas along the Mendenhall River and pose ongoing threats to life and property. CBJ and partner agencies have implemented temporary mitigation measures such as installing extensive temporary HESCO barriers along sections of the river corridor. In 2025, these mitigation efforts prevented the kind of widespread residential flooding seen in the 2024 GLOF event. Nevertheless, nearly 50 homes reported damage.

Figure 2-1 Photograph of Partially Filled Suicide Basin in Summer 2025 and the Lower Reaches of Mendenhall Glacier

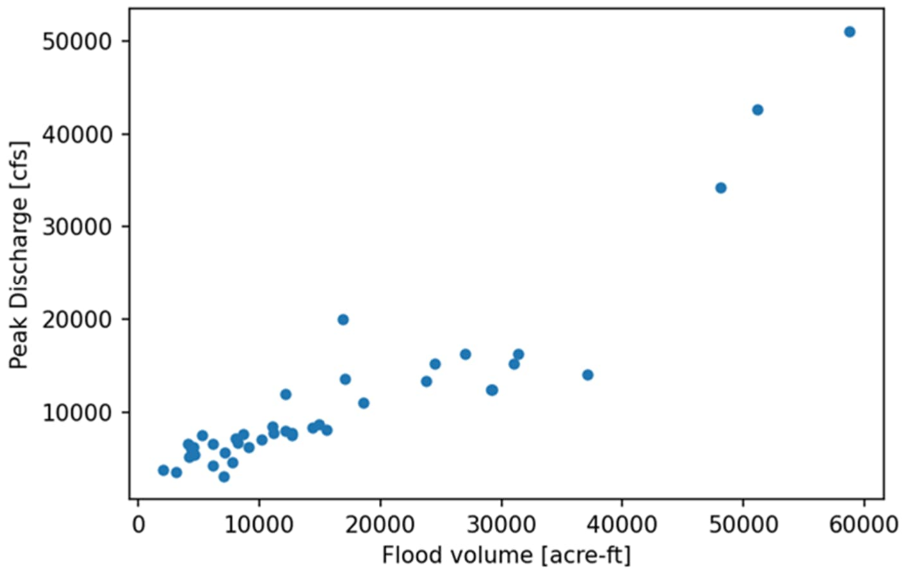
The first known and confirmed GLOF from Suicide Basin occurred in 2011. Since then, outburst floods have occurred almost every year, with typically more than one flood per year (Figure 2-2). In some years the Basin only fills part way before draining, and in others it fills completely, but only drains partially. From 2023-2025, the Basin filled completely and drained almost to the bottom, resulting in much larger flood peaks. Following these large GLOF events, smaller GLOF's occurred as a result of partial filling of the Basin.



Source: UAS and NWS

Figure 2-2 Time Series of Outburst Floods from Suicide Basin

A summary of GLOF discharge events is condensed in this chart. The GLOF discharges are lined up one after another to help visualize the relative size of the floods. In reality, the floods are spaced in time by weeks to months. Alternating color stripes represent individual years. The peak discharge associated with a GLOF is proportional to the total volume of water released from Suicide Basin (Figure 2-3). As a result, the continued evolution of Suicide Basin will control the magnitude of future outburst floods.



Source: UAS

Figure 2-3 Comparison of Peak Discharge during the Flood to the Flood Volume for Each of the Floods Depicted in Figure 2-2

The magnitude of the outburst flood peak is clearly related to the volume of water released from Suicide Basin during a flood. Although not all floods have involved complete drainage of the Basin, the total volume, and therefore water-holding capacity of the Basin places some constraints on the maximum possible floods. The Basin volume changes over time due to thinning of the ice dam (decreases storage), Basin expansion into the Mendenhall Glacier (increases storage), and melt-driven reduction in the amount of icebergs within the Basin (increases storage). The lifecycle of outburst floods from ice-marginal lakes such as Suicide Basin can extend for decades. When an ice-marginal basin first forms, the basin volume will increase over time. Eventually, as the glacier thins and retreats, the basin volume will decrease, implying that flood magnitude should also be expected to undergo a cycle of growth and decay over decadal time scales. In addition, flood magnitude varies due to poorly understood differences in flood initiation and drainage efficiency.

Over the past 15 years, the volume of icebergs in the Basin has dramatically decreased, with overwhelming changes in volume due to ice-dam thinning and Basin expansion. However, the iceberg volume represents about 10 percent of the Basin volume, with very little change in iceberg volume from 2024–2025. Therefore, reductions in iceberg volume are unlikely to have major impacts on Basin volume going forward.

The ice dam has been thinning at a consistent rate of 3 to 4 feet per year. It is anticipated that this will continue into the future. The current thinning rate is nearly offsetting increases in Basin volume due to lateral expansion: over the past 2 years the Basin volume has increased by just a few percent. Basin expansion is the largest source of uncertainty; it is difficult to quantify, and even more difficult to project into the future.

See Section 3.3 for additional information regarding Suicide Basin GLOF evolution and a discussion regarding the possibility of the formation of additional GLOF capable basins further up the glacier in the future.

2.2. Overview of Alternatives

Alternatives were developed to regulate the conveyance of GLOF events to reduce the flooding impact along the Mendenhall River. The following five alternatives were developed in preparation for the December 2025 multi-agency charrette:

1. Lake Tap Tunnel
2. Dam
3. Floodwall
4. Hybrid Dam/Floodwall
5. Relocation

These alternatives are summarized below and described in greater detail in Section 4 of this report. Other alternatives that were screened out prior to the charrette are discussed in Section 3.8.

2.2.1. Lake Tap Tunnel Alternative

The Lake Tap Tunnel Alternative proposes an approximately 2-mile (12,000-foot), 10-foot-inside-diameter gravity tunnel conveying and controlling flows from Suicide Basin to Mendenhall Lake to significantly reduce GLOF risk (Figure 2-4). The system relies on a robust precast concrete–lined tunnel, outfall structure, and screened intake capable of operating in high-velocity, high-flow conditions. An abrasion resistant liner, such as a steel liner, may also be required in addition to the concrete tunnel liner to resist the hydraulic loads and increase the durability of the system.

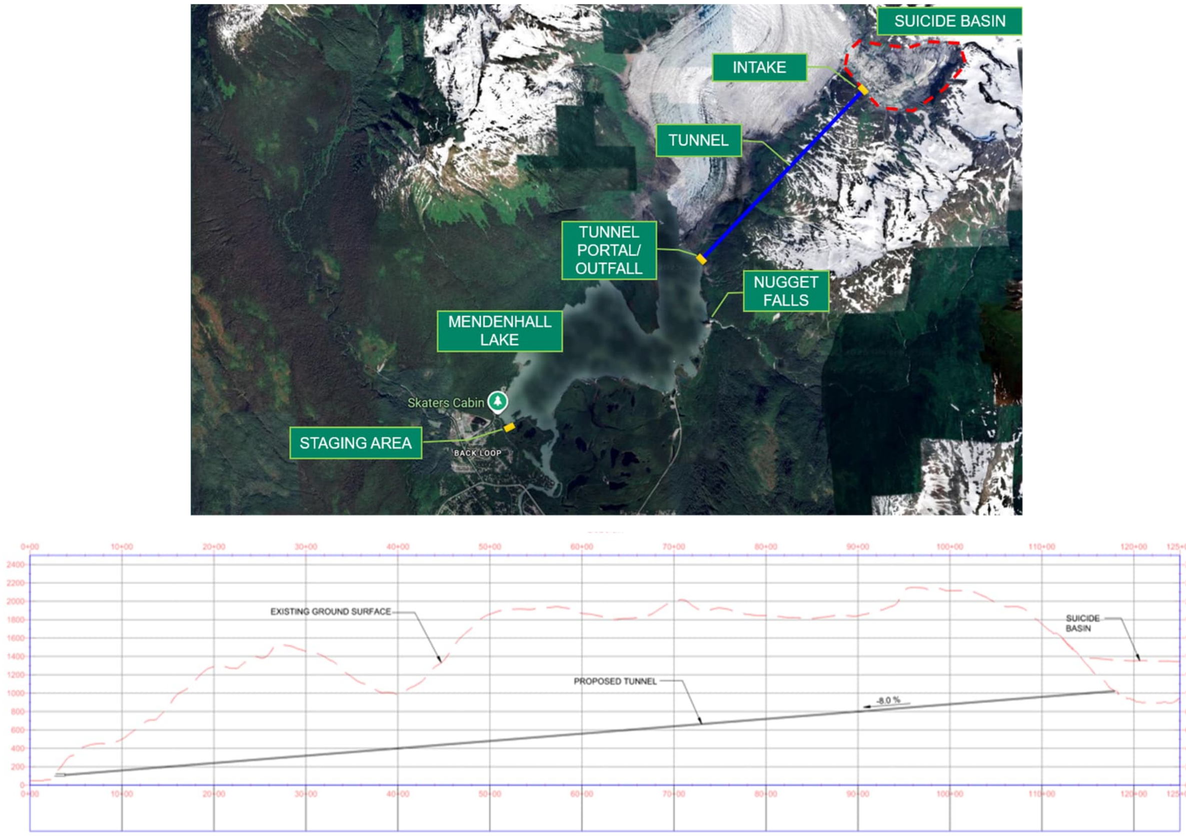


Figure 2-4 Lake Tap Tunnel Alternative Plan and Profile (Tentative)

The system's proposed configuration provides long-term hydraulic resilience, limits disruption to tourism and the community, requires minimal maintenance, and integrates with the environmental setting. The configuration provides GLOF risk reduction under a wide range of future basin conditions and climatic scenarios.

This alternative fundamentally lowers GLOF hazard by maintaining Suicide Basin at controlled water levels. The tunnel is designed to operate continuously in open-channel mode, providing high conveyance capacity (greater than 800-cfs design flow) with minimal rise in water levels in Mendenhall Lake and River. Tunnels historically perform better than other structures during seismic events; with this tunnel primarily in rock, seismic resilience is expected to be high. The passive, gravity-driven system reduces dependency on mechanical components and therefore lowers likelihood of systemic failure, as well as minimizing operations and maintenance (O&M) costs during the life-span of the asset.

The base alternative uses a single intake and is the basis of the cost estimate provided. The possible incorporation of a strategic shaft or cavern near Suicide Basin provides a significant increase in system adaptability and resilience. Such a chamber would allow for:

- Un-clogging from ice blocks and avalanches and maintenance access should the intake become blocked by ice, debris, or sediment.

- Potentially adding future intakes to address evolving basin geometry, changes in glacier dynamics, or new drainage connections as Suicide Basin evolves over time.

- Providing pressure relief and redundancy by adding a parallel intake to balance inflow, minimize clogging risk, and diffuse hydraulic loading. An additional intake helps reduce risk and provides mitigation, in the event that future morphological changes in Suicide Basin render the primary intake sub-optimal.

This configuration mirrors successful resiliency-enhancing designs implemented in complex glacial and reservoir drawdown systems. Although drilling a shaft in wet conditions poses constructability and safety risks, lake access excavated from the main tunnel in controlled ground conditions remains a credible and resilient option (e.g., Anderson Dam in California).

The tunnel system, especially when paired with a cavern/shaft, provides a robust, flexible response framework to accommodate:

- Increased GLOF volumes driven by climate change
- Uncertain future basin enlargement or deepening
- Debris and iceberg accumulation near the intake
- Potential changes in water inflow patterns across the glacier system

Beyond reducing the risk of catastrophic releases, the system enhances community safety by providing predictable, managed hydrologic behavior, reducing emergency response reliance and protecting infrastructure, tourism assets, and residential areas.

Despite the promising resilience and adaptability profile, final alignment, cost, and schedule cannot yet be confirmed with adequate confidence. Subsurface ground conditions remain the dominant technical uncertainty, with key parameters—including quality of bedrock, presence of faults, groundwater pressures, inflow pathways, and rock mass abrasivity—requiring detailed investigation. A comprehensive geotechnical program, including drilling, geophysics, and detailed geological interpretation, is therefore essential before constructability, schedule, and cost can be validated with any accuracy.

In summary, the Lake Tap Tunnel Alternative presents a resilient, long-term, and safety-enhancing solution for mitigating Suicide Basin GLOF events. Incorporation of a shaft or cavern near the Basin significantly increases system adaptability as it allows for future intakes into the Basin, operational functionality, and resilience to clogging or future basin evolution. However, constructability feasibility cannot be assessed until substantial geotechnical data are obtained, because ground conditions are the primary driver of risk, cost, and engineering viability. Pending these investigations, the alternative remains technically sound, future-resilient, and well-aligned with long-term regional resilience objectives. Known environmental constraints are discussed in Section 4.1.13.

2.2.2. Dam Alternative

The Dam Alternative involves constructing a new dam that would temporarily store water during GLOF events but would not create a permanent reservoir. Passive outlet works and fixed-crest spillways would manage flows safely and reduce potential downstream impacts.

Several dam types were considered: Earth Core Rockfill, Asphalt Core Rockfill, Concrete-Face Rockfill, and Hardfill Dam. Each type must address seismic stability, seepage control, and rapid drawdown capability in a dynamic glacial environment. The Earth Core Rockfill dam type with a clay core was selected for cost estimating purposes of the charrette. Foundation conditions present a major challenge: the valley floor consists of thick glacial and alluvial deposits over bedrock, requiring extensive ground treatment to mitigate piping and limit settlement. Southeast Alaska's seismic activity adds complexity, demanding robust design to mitigate foundation liquefaction risks.

Two alignments were evaluated. The upstream alignment, approximately 2.4 miles long with a 60-foot impoundment depth, would require fewer property relocations but impact the Mendenhall Campground. The downstream alignment, about 2.5 miles long with a 40-foot impoundment depth, would offer greater storage area but would require relocation of roughly 35 properties and leave the campground unprotected. To reduce potential environmental impacts, the upstream alignment was selected (Figure 2-5).

Figure 2-5 Dam Alternative Plan and Profile (Approximate)

Although a dam could significantly reduce flood risk and protect lives and property, it introduces environmental and social trade-offs with potential impacts to wetlands, fish habitat and passage, cultural resources, aesthetics, socioeconomics, sediment transport, and recreational access near the Mendenhall Glacier Visitor Center and Skater's Cabin. A fish ladder to provide fish bypass through the dam would be required. Permitting would be complex, involving multiple federal, state, and Alaska Native tribal organizations and native corporations.

Construction of the Dam Alternative would require relocation of 90 structures within the dam footprint or construction zone, or the areas not protected from inundation. The analysis of potential effects associated with relocation for this alternative is discussed under the Section 4.5 Relocation Alternative as partial relocation. Known environmental constraints are discussed in Section 4.2.12.

In summary, the dam alternative offers substantial risk reduction, but faces significant engineering, construction, environmental, and schedule challenges. Success will depend on comprehensive geotechnical investigations, adaptive design to accommodate future glacier changes, and committed stakeholder engagement throughout planning and implementation.

2.2.3. Floodwall Alternative

The Floodwall Alternative develops a viable system of interconnected floodwalls, earthen levees, underground seepage cut-offs, and engineered drainage features for the Mendenhall Valley that would protect most developed land from the design GLOF event. Together, these elements would be designed to limit floodwaters from inundating the Valley's developed areas while maintaining essential stormwater drainage services.

The Floodwall Alternative (a Flood Risk Management system in USACE parlance) is composed of several key elements. Earthen levees, composed of local and imported clay soil are planned for less-developed, wider areas, particularly along the northern and northeastern alignments. In more densely populated or space-constrained areas, such as all developed riverbanks of the Mendenhall River, reinforced-concrete floodwalls are proposed; these include smaller "I-wall" sections and larger "T-wall" sections for higher exposures, each with deep foundations to provide stability. All protection features incorporate seepage cut-offs, such as sheet piles or slurry grout curtains, to limit seepage beneath the barriers. Armoring unstable riverbanks with riprap or concrete paving would be necessary.

Overall required protection length is approximately 8 miles (approximately 60 to 75 percent floodwalls). Floodwalls along the river are anticipated to average 10 to 15 feet above existing ground. Levees along Mendenhall Loop Road and northwestern neighborhoods are anticipated to average 10 to 25 feet in height. Some specific sites would require significantly larger floodwall or levee structures, as well as require engineered openings for roadways and pedestrian access. A general plan of the proposed alignment is provided in Figure 2-6.

Figure 2-6 Proposed Floodwall/Levee Alternative: Floodwall Alternative Alignment and Inundation Extents

A separate critical aspect of the Alternative design is interior drainage. The floodwall system would trap rainfall and local runoff in the protected area, so engineered drainage pathways, backflow preventers, and pump stations are necessary to manage this water and limit interior flooding. Hydraulically, the system must address both riverine flooding and internal stormwater management, especially during coincident rain and GLOF events. Pump stations and reconfigured drainage networks are essential to limit interior flooding when the Mendenhall River is at an elevated stage.

A construction corridor approximately 150 feet wide is assumed to accommodate floodwalls along most riverfront segments; 225 feet is assumed along roadways and northwestern neighborhoods to accommodate levees. In both cases, drainage features, storage yards, haul roads, and space for construction activities are also included in the footprint.

Construction of the Floodwall Alternative would require relocation of 340 structures affected by the construction zone or not protected from inundation. The analysis of potential effects associated with relocation for this alternative is discussed under the Section 4.5 Relocation Alternative as partial relocation.

Key implementation challenges include large-scale land acquisition, relocation of utilities and infrastructure, and coordination with multiple stakeholders. Technical unknowns remain regarding drainage system specifics, groundwater impacts, river mechanics, and seismic stability.

Environmentally, construction would impact wetlands, wildlife habitats, and local air quality, necessitating extensive permitting and environmental review. In addition, the seepage cutoffs of the floodwalls and levees would interrupt subsurface flow between the River and adjacent areas, leading to groundwater impacts. Environmental permitting must comply with the Clean Water Act, Endangered Species Act, and local and federal regulations. The floodwall would be visually prominent, with an average height of 15 feet above grade, and may obstruct river views. Noise, traffic, and community disruption very close to residential dwellings are anticipated during the multi-year construction period. Additionally, historic and cultural sites, as well as legacy contamination, require careful assessment and mitigation. Details on known environmental constraints are discussed in Section 4.3.12.

If implemented as designed, the Floodwall Alternative would significantly reduce life safety and economic risk from GLOF events. However, this benefit is contingent on thorough design, construction, and ongoing maintenance. Key risks include overtopping, internal or external erosion, foundation instability, equipment malfunction, and debris impacts. Routine inspection, maintenance, and replacement of critical components are required for long-term reliability. The question of long-term ownership and operational responsibility—whether by a local district or the USACE—remains to be decided.

In conclusion, the Floodwall Alternative offers a robust, technically feasible solution to mitigate GLOF flood risks in the Mendenhall Valley. However, it presents significant challenges in land acquisition, construction logistics, environmental compliance, and community impact.

2.2.4. Hybrid Dam/Floodwall Alternative

The Hybrid Dam/Floodwall Alternative combines a flood control dam with a system of floodwalls in the Mendenhall Valley to mitigate GLOF risks (Figure 2-7). This approach reduces the required height of both structures compared to stand-alone options, improving constructability while shifting some environmental and community impacts. The analysis assumes a peak flow release of 50,000 cfs during the design event, storing the remaining volume of the hydrograph behind the dam. This discharge is similar to the 2025 GLOF event, which was successfully managed by temporary HESCO barriers, demonstrating that 4- to 8-foot high walls can protect most of the community. Lower wall heights allow for the use of I-Walls instead of T-Walls, thus reducing the footprint. The floodwall alignment would largely follow the Floodwall Alternative alignment, but terminate near the Mendenhall River at Back Loop Road Bridge (subsequently called the “Mendenhall Loop Bridge” for the purpose of this report), with further hydraulic modeling needed to confirm protection on the river’s western side. It should be noted that the hybrid alternative includes a floodwall alignment that differs slightly from the alignment evaluated under the standalone floodwall alternative.

The dam design mirrors the Dam Alternative alignment, but with reduced height, smaller footprint, and larger outlet works to accommodate the higher release. Both components must operate as an integrated system to increase resilience and reliability. The main benefit of this alternative offers smaller structures (dams and floodwalls) and narrower project footprint widths per segment while seeking to minimize community impacts and visual obstructions. Challenges remain in optimizing floodwall segments, managing interior drainage, and addressing unknowns such as utility conflicts and foundation quality. Armoring unstable riverbanks near the floodwalls with riprap or concrete paving would be necessary. The negative is a large project footprint that spans the length of the floodwall and the length of the dam across the Valley.

The environmental impacts of the hybrid system would likely be a combination of those described in the Dam and Floodwall Alternatives. Construction of the dam/floodwall hybrid alternative would require relocation of 270 structures within the dam footprint or construction zone, or the areas not protected from inundation. The analysis of potential effects associated with relocation for this alternative is discussed under the Section 4.5 Relocation Alternative as partial relocation.

Figure 2-7 Floodwalls and Dam Shown with a Dam Release of 50,000 cfs

2.2.5. Relocation Alternative

Under the Relocation Alternative, Mendenhall Glacier Lake outburst flooding (GLOF) would likely require buyout and relocation of structures and construction of replacement infrastructure affected by inundation with no flood protection measures constructed, including the areas protected by the temporary HESCO barriers. In addition, the dam, floodwall, and dam/floodwall hybrid alternatives would require partial relocation due to the 1) physical and construction zone footprint of those alternatives, and 2) inundation of parcels that are not protected by those alternatives. The analysis of potential effects of complete relocation is discussed in Section 4.5, along with the potential effects of partial relocation associated with the dam, floodwall, and dam/ floodwall hybrid alternatives. The description of this alternative represents a simplified, singular concept for relocation. Further study and analysis of relocation concepts would be needed if this alternative were to be developed beyond the conceptual level.

The Relocation Alternative would involve six procedural steps:

1. **Identify affected parcels and types of structures under the projected flood stage for alternatives**. Complete relocation would require relocating approximately 2,500 structures inundated under the flood scenario with the peak flow of 118,000 cfs presented in the hydrologic input and modelling analysis. Partial relocation is associated with structures not protected from inundation, and structures within the physical and construction footprints of specific alternatives. Hydraulic modelling results and input from the hydrologic analysis resulted in estimates of structures and parcels potentially affected by inundation and subject to relocation. The Dam Alternative would require relocation of approximately 90 structures; the Floodwall Alternative would require relocating approximately 340 structures; and the Dam/Floodwall Hybrid Alternative would require relocating approximately 270 structures. These numbers do not include public facilities affected by flood inundation that may need to be relocated, of which 20 are in the area affected by inundation under complete relocation.

2. **Buyout, compensation, and demolition of affected parcels and structures.** USACE Relocation Real Estate Guidance 405-1-16 outlines procedures for determining the buyout, compensation, and demolition. An overview of this process was summarized at the design charrette.

3. **Identification and acquisition of undeveloped, suitable, and available land for relocation.** Depending on the GLOF response alternative selected, relocation would require large parcels of undeveloped, suitable, and available land, or relocation could be accommodated through infill development along the road system. Topography, natural hazards, wetlands and land ownership influence the suitability and availability of land for development. As a point of reference, under complete relocation, the total acreage of parcels with structures affected by inundation would be roughly 2,000 acres. This step would need to occur if the Relocation Alternative were to be selected.

4. **Master Planning for site development.** Parcels of land associated with relocation of larger numbers of structures, as compared to infill development, would require site master planning for location of roads, utilities, and public facilities.

5. **Construction of road and utility access.** Relocation of large numbers of structures may require development of land that is not currently connected to existing road and utility systems. Extension of road and utility access may be needed under those circumstances. In addition, should large-scale relocation take place on Douglas Island, a second crossing of Gastineau Channel may be necessary. These challenges would likely require a timeline of several years.

6. **Site preparation and construction of relocated structures.** Finally, relocation of large numbers of structures would require significant site preparation and involve a construction workforce beyond what is available in Juneau. This would also require temporary housing for the non-resident workforce.

In summary, relocation would remove structures from areas of inundation and provide compensation to property owners. The amount of relocation required varies by alternative. The Relocation Alternative would involve relocating the largest number of structures, followed by partial relocation for the Floodwall, Hybrid Dam/Floodwall, and Dam Alternatives. All would require analysis to determine if there is adequate, undeveloped, and suitable land for relocation. In addition, complete relocation would potentially result in significant adverse social and economic impacts to Juneau in terms of outmigration, disruption of commercial and industrial activities, and loss of municipal revenue. Environmental impacts would also occur as a result of developing previously open lands. Details on other known environmental constraints are discussed in Section 4.5.12.

Even if there is adequate, undeveloped, and suitable land for relocation, it is uncertain if property owners would make those lands available for relocation. Relocation of commercial structures has a unique set of challenges, including land requirements and if a business case can be made for potential locations. Finally, the construction workforce for demolition and relocation would likely require some outside workers, and the need for temporary housing would need to be addressed.

Temporary Relocation

Flood protection for residents and properties will continue to be required through the construction period of the Lake Tap Tunnel, Dam, Floodwall, and Dam/Floodwall Hybrid Alternatives, and through completion of buyout and compensation associated with permanent relocation. This would likely involve maintaining and potentially extending the HESCO barriers until completion of design and construction, which will vary from 3 to 10 years, depending on the alternative. Doing so could result in the need for some temporary relocation of residents and businesses until construction is completed and permanent flood protection is operating. The extent and duration of temporary relocation would depend on the nature of individual GLOF events, the condition and extension of the existing HESCO barriers, and the ability to phase extension of HESCO barriers to minimize the need for temporary relocation. However, this relocation would not be permanent and would likely entail a smaller number of structures than permanent relocation scenarios associated with the Dam, Floodwall, and Dam/Floodwall Hybrid, and Relocation Alternatives.

3. Charrette Meeting Overview

3.1. Overview

The USACE and key stakeholders participated in a 3-day Multi-Agency Charrette to assess the five alternatives to address GLOF events from Suicide Basin impacting the Mendenhall Valley in Juneau. The charrette took place from December 9 to 11, 2025, in Juneau, Alaska. The charrette was not open to the public. It was a meeting of invited stakeholders, including in-person and online participants (total of 122 participants [Appendix A]).

The charrette covered the following high-level topics. It should be noted that the agenda of Days 2 and 3 were adjusted when a preferred engineering solution was unanimously selected on Day 2.

Day 1

- Overview
- Stakeholders and Project Roles
- Technical Briefing/Problem Statement/History of GLOF in Juneau
- Public Input and National Environmental Policy Act (NEPA)
- Risk Evaluation Overview
- Evaluation Criteria Overview
- Hydrologic Inputs and Hydraulic Modeling Approach
- Screened-Out Alternatives
- Presentation on Alternatives: Lake Tap Tunnel, Dam, Floodwall, Hybrid Dam/Floodwall, and Relocation
- Cost Discussion
- Close-Out

Day 2

- Stakeholder Questionnaire
- Environmental Baseline
- Future GLOF Flood Risk (from another basin)
- Evaluation Criteria, Risk Evaluation, and Instructions for Breakout Groups
- Stakeholder Breakout Groups and Share-Out
- Stakeholder Leadership Breakout Group and Share-Out
- Close-Out

Day 3

- Project Briefing for USACE
- Discussion of Preferred Engineering Solution
- Technical Breakout Groups and Share-Out
- USACE Breakout Group
- Close-Out

The following Rules of Engagement were agreed on to provide a collaborative and constructive meeting environment.

1. Stay focused on the charrette's purpose and objectives.
2. Respect diverse perspectives and value all contributions.
3. Speak respectfully and listen without interrupting.
4. Assume positive intent and ask clarifying questions.
5. Honor time limits and stay on schedule.
6. Be concise and allow time for everyone to contribute.
7. Hold one conversation at a time.
8. Approach disagreements respectfully and seek consensual solutions.
9. Hold your questions until the end of each presentation.
10. Capture areas of disagreement and off-topic items in a "parking lot" for later resolution.
11. Understand that the facilitators may move the charrette along to keep on schedule and mean no disrespect.
12. Use the facilitators by bringing concerns and feedback to them during breaks.

3.1.1. Stakeholders and Project Roles

Representative stakeholders from the following organizations participated in the charrette:

- United States Army Corps of Engineers, Alaska District (USACE)
- City and Borough of Juneau (CBJ)
- Central Council of the Tlingit and Haida Indian Tribes of Alaska (Tlingit and Haida)
- United States Forest Service (USFS)
- Alaska Department of Transportation (AK DOT)
- National Weather Service (NWS)
- University of Alaska Southeast (UAS)
- Alaska Department of Natural Resources (AK DNR)

The participants discussed that USACE is the final decision-maker on recommending a preferred engineering solution.

The City and Borough of Juneau was identified as the Project Sponsor and a primary decisionmaker.

Central Council of the Tlingit and Haida Indian Tribes of Alaska was identified as a primary decisionmaker as representative of the Traditional Lands of Tlingit and Haida impacted by the GLOF events and any resulting selected solution.

USFS was identified as a primary decisionmaker as a representative for the lands impacted by GLOF events and any resulting selected solution.

The United States Geological Survey (USGS) was invited to the charrette but did not attend in person or virtually.

The remaining stakeholders provided technical input in the decision-making process. The complete list of charrette attendees is provided in Appendix A.

3.2. Public Input and National Environmental Policy Act

NEPA is a procedural law establishing a national environmental policy that requires federal agencies to consider the environmental impacts of their actions before making decisions through an Environmental Assessment (EA) or Environmental Impact Statement (EIS). Public participation is sought during the scoping period, and again to review draft documents.

The USACE conducted public scoping from October 31 to November 30, 2025, and an agency Scoping Meeting was held on November 19, 2025. Comments received from agencies and the public are included in Appendix H.

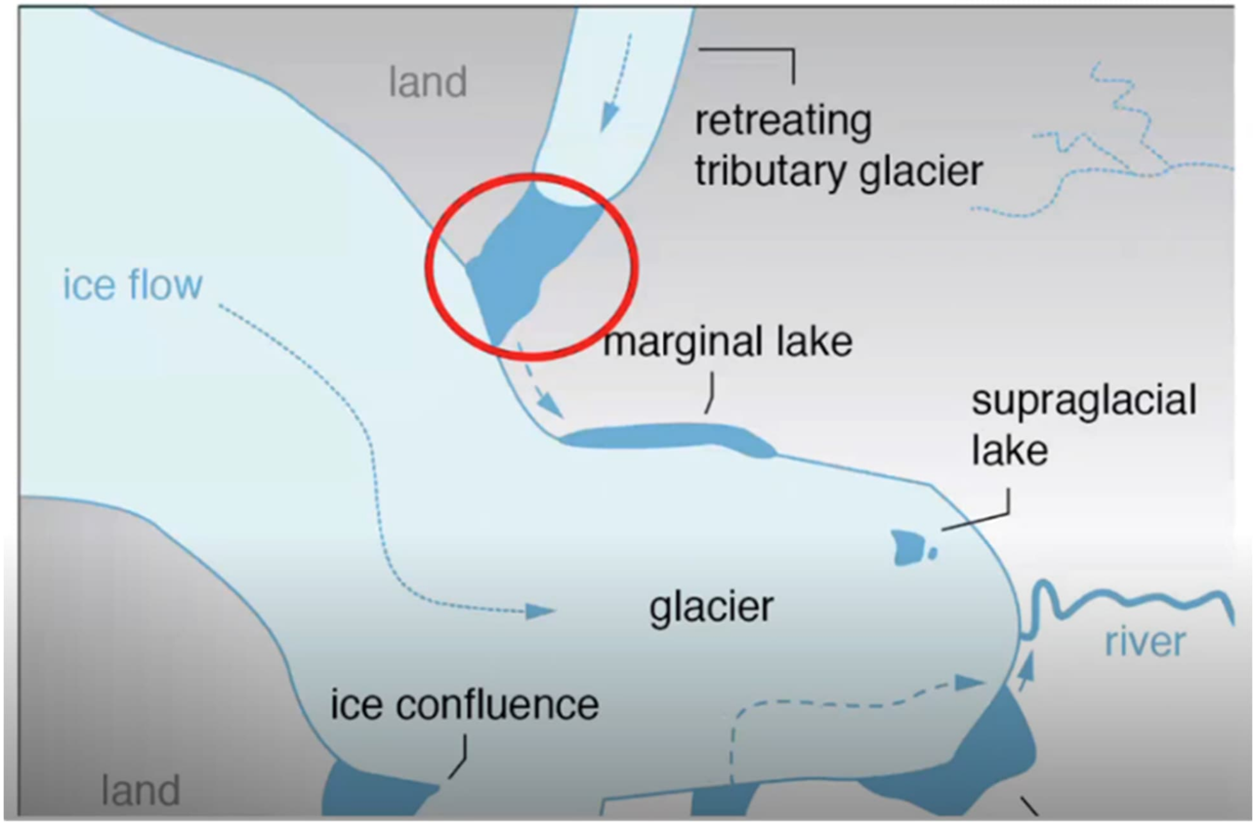
During the scoping period, the USACE provided a list of five potential alternatives and the public and agencies were asked to provide initial feedback. It should be noted that the alternatives were further refined between the initiation of scoping and the charrette, and one was eliminated during that time (bypass channel – see Section 3.8). Thirty-four public submissions were received. Support among the public was varied for individual alternatives, with the relocation alternative viewed most unfavorably. In general, the public sought a long-term solution that could be implemented rapidly. Top environmental concerns brought up by members of the public include impacts to fish (particularly salmon), tourism (both adverse and beneficial), the viewshed, and riverine erosion.

Agencies expressed a desire to continue and to strengthen agency coordination through the process, especially for permitting considerations and consultation. Top environmental concerns brought up by agencies include impacts to fish and fish habitat (particularly salmon), cultural resources, recreation and tourism, hydrology, and wildlife, as well as a need for climate resiliency.

3.3. Technical Briefing/Problem Statement

UAS and other agencies, including USGS and NWS, have been researching the glaciological and hydrological aspects of the GLOF for many years.

GLOFs can form in a multitude of ways. In the case of Suicide Basin, there is a receding tributary glacier that has pulled back from the main Mendenhall Glacier, leaving an over-deepened basin. This basin gets dammed or sealed off by the main glacier. Refer to Figure 3-1 below.



Source: antarcticglaciers.org

Figure 3-1 Ice-Dammed Lakes Form Where Glaciers Block the Flow of Water in Either a Trunk or Tributary Valley

Historically, Suicide Glacier was adding ice to the Mendenhall Glacier. Figure 3-2 shows this condition in 1893. Suicide Glacier has since receded and pulled away from the Mendenhall Glacier, leaving an over-deepened basin. This basin is sealed off by the Mendenhall Glacier (Figure 3-2). The Mendenhall Glacier therefore acts as a dam, impounding water in Suicide Basin. When the Basin is full, it can currently hold approximately 50,000 acre-feet of water. It is estimated the elevation of the drainage conduit for the past 3 years (2023-2025) has been close to an elevation of 900 feet. The elevation at the top of the ice dam (representing a "full basin") is about 1,360 feet.

The volume of water in Suicide Basin is approximately 60 percent of the volume of Mendenhall Lake itself. The Lake has an average elevation of 61 feet and an elevation of 56 feet during low-water conditions. During a GLOF event, the lake level increases substantially (greater than an elevation of 70 feet) and causes high flows in the Mendenhall River. These flooding events have caused extensive erosion along the river corridor.

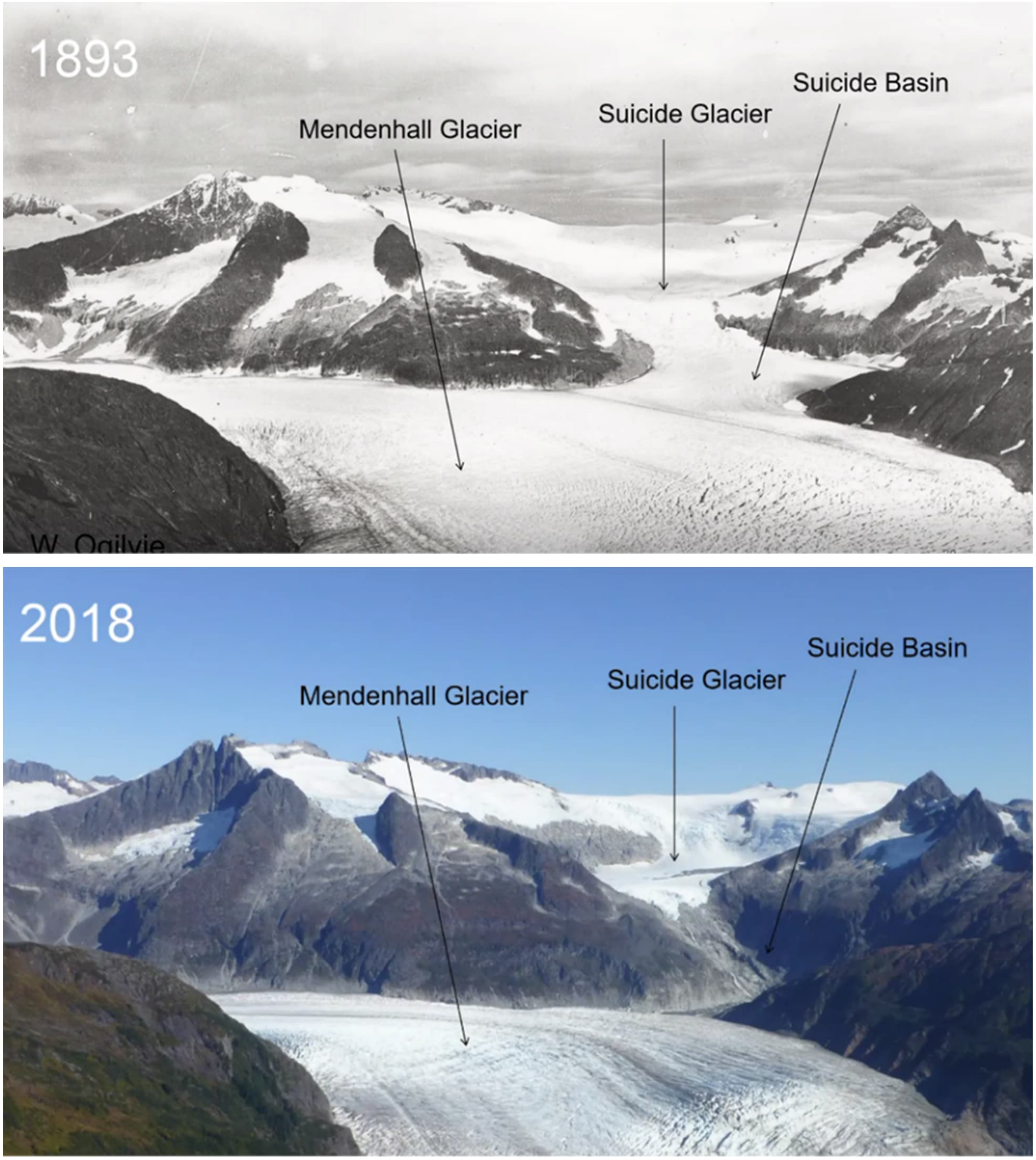


Figure 3-2 Mendenhall and Suicide Glaciers in 1893 and 2018, UAS

The first GLOF was documented in 2011, although there may have been smaller events before that. Relatively minor flooding was experienced from 2011 to 2023. In recent years, the dynamics in Suicide Basin have changed—since 2023, the Basin has drained entirely to the bottom. This development led to larger flooding events in 2023, 2024, and 2025.

It is challenging to predict the future trajectory of the GLOF. Eventually, this phenomenon will end when the Mendenhall Glacier recedes to the point where it can no longer impound water in Suicide Basin. This is on a life-cycle of decades. Until then, there is uncertainty around the worst-case scenario flood—both in terms of when it may occur and how much water will be released from the Basin.

There are a number of useful tools that are being used by university researchers and agency scientists to better understand the GLOF and inform forecasting. Drone mapping of the Basin began in 2018 and helps track changes in the Basin itself. Elevation-volume curves developed by the NWS are a useful forecasting tool. In 2025, an ice-penetrating radar mission was flown to identify the floor of the Basin. This data were not yet available, but will provide a bed map for modeling, as well as information about where other GLOFs may form in the future.

3.4. Risk Evaluation Overview

A brief overview of the risk evaluation performed for the charrette is provided in this section and covered in more detail in Section 7.

The overall project objective is to reduce GLOF-related risk in Mendenall Valley and identify the alternative that provides the greatest risk reduction. To achieve this objective, the project incorporates a risk-informed design approach.

Risk is a measure of both the likelihood of failure occurring, and the severity of adverse consequences should failure occur. Given the current conceptual design level for the alternatives and limited supporting data, a high-level, qualitative risk evaluation was considered appropriate for the charrette. Risk of each alternative was qualitatively discussed and evaluated using three criteria:

- The level of risk reduction the alternative provides, in terms of life loss.
- The level of risk reduction the alternative provides, in terms of economic loss.
- The ability of responsible parties to meet USACE tolerable risk guidelines (TRG) (Figure 3-3).

Risk reduction (life loss and economic loss) is considered to be the primary evaluation criteria. Additionally, TRGs provide risk-informed decision goals for life safety. There are four TRGs, which together encompass all phases of alternative implementation—planning, design, construction, and operation:

- TRG 1 – Understanding the risk
- TRG 2 – Continuing risk awareness
- TRG 3 – Monitoring and managing risk
- TRG 4 – Taking action to reduce risk

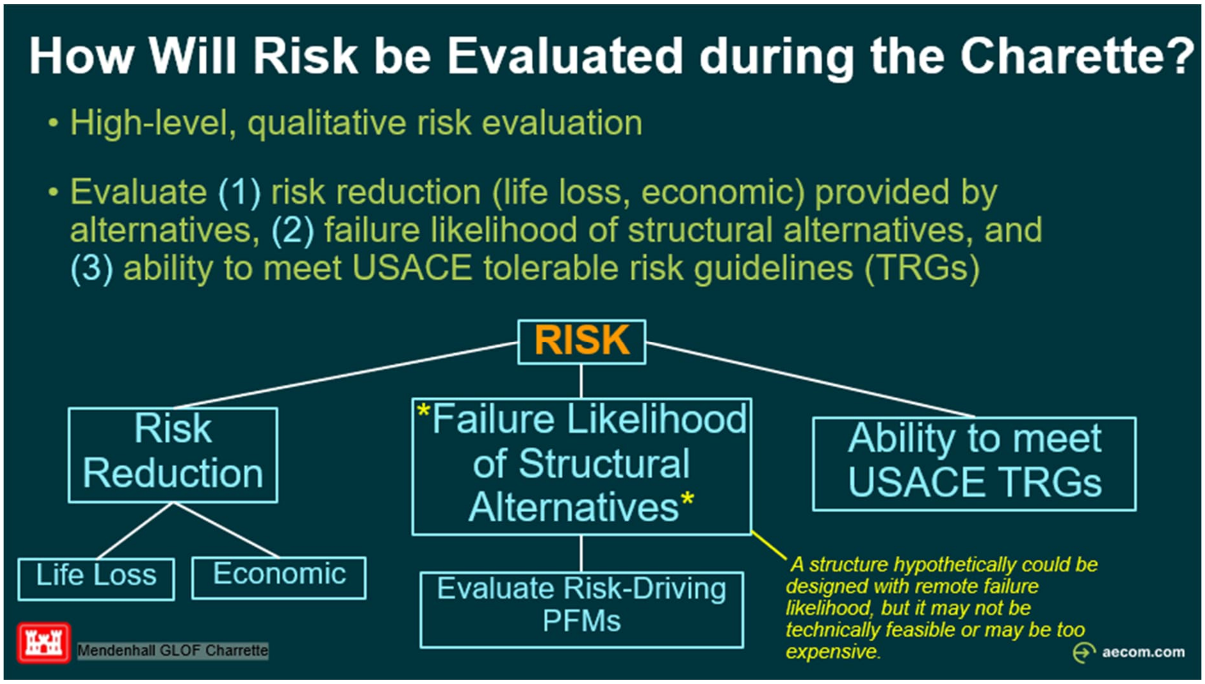


Figure 3-3 Risk Evaluation During the Charrette

Key questions designed to aid charrette participants in evaluating whether the TRGs would be met are provided in Section 7 and cover considerations such as risk communication, risk reduction actions, responsibilities for monitoring and managing risk, and funding availability for any necessary future risk reduction measures. During the charrette, participants rated each alternative, taking into consideration the three criteria described above, and described in greater detail in Section 7.

Baseline (current) risk was also evaluated, considering the following:

- Estimated GLOF loading (prior to constructed alternative).
- Vulnerabilities with current HESCO flood protection.
- Population at Risk (PAR).
- Estimated loss of life during future GLOF loading, before alternative implementation.

Qualitative baseline vulnerability and consequences were estimated to be as follows:

- Likelihood of HESCO failure during future major GLOF event = HIGH.

- Estimated economic consequences of HESCO failure during a future major GLOF event = LOW to HIGH, depending on severity of inundation and emergency response and mitigation efforts.

- Estimated life loss consequences of HESCO failure = LOW to HIGH, depending on severity of inundation and effectiveness of emergency response and evacuation efforts.

3.5. Evaluation Criteria Overview

The following criteria in Table 3-1 were used to evaluate the alternatives.

Table 3-1 Evaluation Criteria Overview

Criterion	Definition	Considerations
1. Risk Reduction	Ability of alternative to reduce risk (life safety, economic) and ability to meet USACE TRGs.	• USACE will consider risk to life safety as priority. TRGs "will be used as the risk-informed decision goal for life safety." Paragraph 8, Paragraph 9 and Appendix C of the ECB (Rev. 1 – 8/8/25) defines the application of TRGs for risk-informed decision making. • Risk reduction is also to be evaluated in terms of economic risk reduction. • Failure likelihood of constructed alternatives will be considered. • Consider performance, community impact, or likeliness to protect people/property within this criterion. • Uncertainties: o What are the potential issues that could stand in the way of accomplishing risk reduction goal? o Scoring will consider how much relative uncertainty there would be for each alternative, including the following: ▪ Geotechnical – variability of soils and rock in foundations and construction materials; liquefaction potential; stability ▪ Hydrogeological – level of groundwater ▪ Hydrological – water surface levels in Mendenhall Lake and along Mendenhall River ▪ Seismic performance ▪ Seepage control ▪ Erosion potential ▪ Relocation – Availability of suitable land for partial or complete relocation.
2. Reliability, Adaptability, Resiliency	Certainty of adequate long-term (50-year design life) performance (to satisfy project goal)	• Adaptability to changing hydrologic, glacial, and climate conditions. • Can alternative be modified to account for changing conditions, such as increased GLOF outflows? Water level increases in Mendenhall Lake or along the Mendenhall River? • Consider the certainty of the alternative to perform as intended. • Consider whether the alternative would increase or decrease reliability of the system. The alternative that presented a greater risk of failure or less redundancy in the system is deemed less reliable. • Consider the alternative's capacity to withstand damage, to recover from loading events, and to adapt accordingly.

Criterion	Definition	Considerations
3. Environmental/ Cultural Considerations, Permitting Requirements, Required Land Acquisition, Economic Considerations	Potential environmental impacts; required permits and associated agencies; footprint of the alternative, including construction access; impact on tourism/local economy	• Environmental/Cultural Considerations: o Tlingit and Haida, CBJ, USFS, State of Alaska, and other agency input. o Environmental impacts (threatened and endangered species; wetlands; floodplain; historical and cultural resources; contaminated sites), including those during construction (air quality, noise, traffic, water quality, recreation, visual impacts, vegetation). o Will implementation of the alternative create negative environmental and cultural resources impacts that require extensive mitigative actions and associated costs? o Community disruption from either construction or relocation; consider material shipping and hauling. o Vegetation clearing, dredging, stream crossings considerations. • Permitting: o Permitting agencies: USACE, USFS, CBJ, State of Alaska, ANCSA Native Corporation land holders, tribal stakeholders, SHPO, others. o Relative level of difficulty or any fatal flaws in obtaining environmental/regulatory clearances and/or permits. • Land acquisition: o Consider temporary and permanent roads to construction site, laydown areas, storage and stockpile areas. o Permanent land and easements required. o Land acquisition and suitable areas needed for relocation. • Economic: o Effects on local economy (industry and tourism)
4. Design and Construction Duration	Length of time required for design process to be able to start construction, and total construction duration from mobilization to substantial completion	• Consider preliminary, final design, outreach, and bidding/ contractor procurement phases. • Consider seasonality and other no-construction periods (e.g., tourism constraints). • Consider real estate acquisition duration prior to construction.
5. Constructability	Provide competent plans and specs and minimize exposure to claims	• Access for equipment, materials, labor; need to ship materials. • Seasonality. • Type of contract delivery method; opportunities for ECI. • Simplicity of construction, number of contractor trades and vendors required, complexity of the equipment, potential for claims.

Criterion	Definition	Considerations
		• Can the alternative be constructed in a timely, efficient, and conventional manner without specialized equipment or excessive hand labor? • Can on-site materials be used to the maximum extent possible without importing large quantities of material? • Limitations on construction access and hours of operation required by permitting.
6. Comparative Construction Capital Cost (ROM) for Charrette	Conceptual comparative relative construction cost	• The evaluation will be done on the conceptual 2 to 5 percent designs that are presented at the Charrette. ROM for the Charrette cost will consider the main cost drivers plus a reasonable contingency. • Capital costs, including cost of construction, engineering, and administration, with appropriate contingencies. Cost of operations and maintenance is not considered in this evaluation factor. • Alaska prices are higher due to remoteness. • Consider real estate acquisition cost.
7. Acceptability	The Principles and Requirements for Federal Investments in Water Resources	The viability and appropriateness of an alternative from the perspective of the nation's general public and consistency with existing federal laws, authorities, and public policies. It does not include local or regional preferences for particular solutions or political expediency.
8. Operations and Maintenance Cost and Requirements/ Lifecycle Costs	Operation and maintenance/repair of alternative	• Including estimate of operations, maintenance, and major replacement costs. • Frequency, access, and type of expected maintenance and inspections. • Access for maintenance and repair work. • ROM maintenance cost (in today's dollars). • Consider access and operability of the project in remote/ extreme conditions. • Operation and maintenance complexity: • Regular inspections and instrumentation data (water levels, piezometric pressures, seepage, movement, etc.) evaluations needed. • Structural inspections and valves/gates will require regular inspections, exercising and periodic maintenance. • Monitoring and repair of erosion.

Notes:
ANCSA = Alaska Native Claims Settlement Act
CBJ = City and Borough of Juneau
DDR = Design Document Report
ECB = Engineering and Construction Bulletin
ECI = early contractor involvement
ROM = rough order of magnitude
SHPO = State Historic Preservation Officer
TRG = tolerable risk guideline
USACE = United States Army Corps of Engineers
USFS = United States Forest Service

3.6. Hydrologic Inputs

USACE provided estimated peak discharges and associated AEPs for both GLOF and non-GLOF events. A non-GLOF event can be thought of as an extreme precipitation event driven by atmospheric rivers likely combined with extreme snow and ice melt runoff. The USACE GLOF event estimates are based on glaciology-informed assumptions for the maximum potential release from Suicide Basin (approximately 63,000 acre-feet based on potential basin expansion) and recurrence intervals for how quickly that volume could be discharged (e.g., a peak release of 98,000 cfs corresponding to a 0.2 percent AEP, 500-year event).

These values were used during the charette to provide uniform loading conditions for technical solutions to be conceptualized and presented to the meeting attendees for discussion and evaluation. Due to the expedited nature of the project, coincident events were used as an approximation of an expected Probable Maximum Flood value because a dam concept was to be evaluated, and a hydrograph with sufficient volume was needed to estimate storage requirements. A loading event was needed to scope solutions to estimate Rough Order of Magnitude costs. The team plans to refine the joint probability analysis of the events and revise the peak inflow value for design refinement following the charrette.

USACE also noted that the annual maximum 10-day inflow rate for Suicide Basin is approximately 800 cfs, which was used to size the tunnel for the Lake Tap Tunnel Alternative. There are only 2 years of data (2024 and 2025) about the Suicide Basin filling rate, so the lake tap capacity was based on an analysis of the filling record for Suicide Basin compared to the Mendenhall River streamflow period of record; they exhibit the same regime of maximum filling rate during the summer months. Given the similarity in cumulative flow regimes between the Mendenhall River and Suicide Basin, the Mendenhall River streamflow record was used to quantify the variability in the annual maximum 10-day fill rate. The Mendenhall River annual maximum 10-day streamflow was then scaled by a factor to be representative of Suicide Basin. A Log-Pearson Type III AEP analysis was then performed on this scaled record to develop the AEP events for the annual maximum 10-day inflow rate for Suicide Basin. The methodology and assumptions used by USACE to develop these values are presented in Appendix F. These will be further refined by USACE for future design.

Figure 3-4 summarizes the GLOF volume, AEP values for various peak flow rates, and provides a graphical comparison of peak flows between GLOF and non-GLOF scenarios.

GLOF Event

AEP	Discharge
(%)	(cfs)
0.20%	98,000
0.50%	88,000
1%	79,000
2%	72,000
4%	65,000
10%	56,000
20%	49,000
50%	40,000
80%	34,000
95%	30,000

GLOF Volume =
63,000 acre-ft

Non-GLOF Event

AEP	Discharge
(%)	(cfs)
0.20%	20,000
0.50%	18,000
1%	17,000
2%	15,000
4%	14,000
10%	12,000
20%	11,000
50%	8,600
80%	6,900
95%	5,600

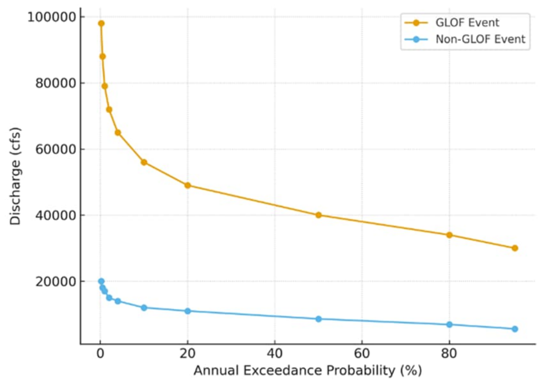


Figure 3-4 Comparison of Peak Flow Rates and Annual Exceedance Probabilities for GLOF and Non-GLOF Events

For development of a design flow to be used in alternatives analyses, a conservative assumption was adopted based on discussions with USACE. The peak of the 0.2 percent AEP GLOF (98,000 cfs) was assumed to occur at the same time as the peak of a 0.2 percent non-GLOF event (20,000 cfs). In practical terms, this means the analysis assumes that a GLOF occurs during a period of intense rainfall and snow/ice melt in the Mendenhall River watershed, resulting in a combined peak flow. The August 2025 Mendenhall GLOF occurred during an atmospheric river event, demonstrating that GLOFs can coincide with periods of intense rainfall. A Probable Maximum Precipitation/Probable Maximum Flood analysis was not completed at this stage, although such an analysis would likely be required for any dam design, if selected. Using this approach, the resulting design hydrograph had a peak flow of 118,000 cfs (98,000 cfs from the GLOF plus 20,000 cfs from the non-GLOF event). This peak flow is assumed to be the design flow and is used as the basis for evaluating the Relocation, Floodwall, Dam, and Hybrid Dam–Floodwall alternatives. Other AEP flow events were not evaluated for this charrette.

In coordination with USACE, AECOM further developed these peak flow values into hydrographs (i.e., flow rates over time) and applied them as inflow boundary conditions for the hydraulic model. Figure 3-5 illustrates the process used to generate the design hydrograph. For the GLOF event, the hydrograph shape from the Michael Baker International model (MBI 2025) was adjusted to match the specified peak flow rate and volume (Figure 3-5, graph a). For the non-GLOF event, the August 14, 2021, high-flow hydrograph recorded at the Mendenhall River gage (USGS 15052500) was scaled to the design peak of 20,000 cfs (Figure 3-5, graph b). This hydrograph was configured to begin with a flow assumption of 3,000 cfs, corresponding to “normal” conditions prior to the combined GLOF and non-GLOF event. Lastly, the design hydrograph was created by combining these two adjusted hydrographs so that their peaks align in time (Figure 3-5, graph c). It is also worth noting that the Montana Creek inflow was modeled as a constant 1,820 cfs throughout the entire simulation period, consistent with the higher flow scenarios used in the MBI model. See Appendix I, Mendenhall River Preliminary 2D Surface Water Model Report, for further discussion on assumptions and setup of the MBI model.

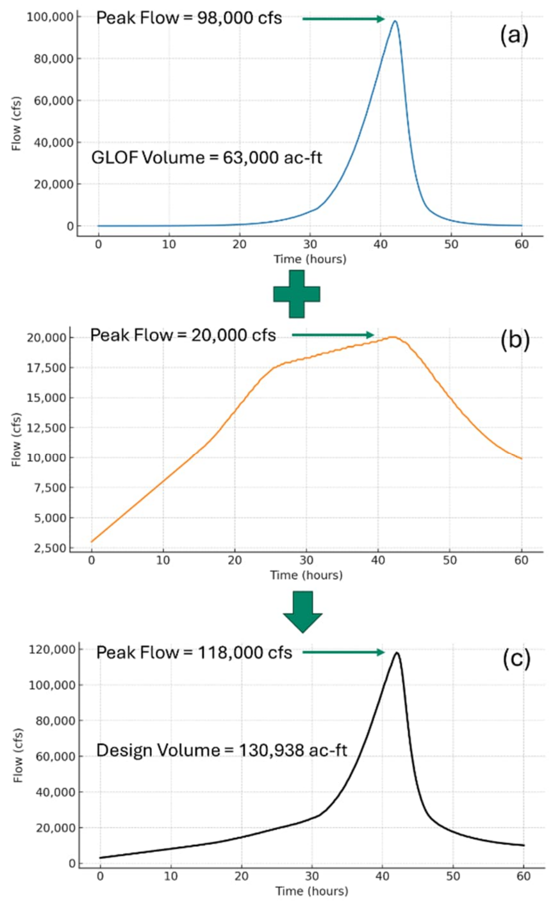


Figure 3-5 Process for Developing Design Hydrograph

(a) Adjusted GLOF hydrograph to match 0.2 percent AEP (500-year) peak flow and volume, (b) scaled non-GLOF hydrograph based on August 14, 2021 event, and (c) combined hydrograph aligning both peaks for model input.

3.7. Hydraulic Modeling Approach and Assumptions

Preliminary hydraulic modeling was completed for each alternative to evaluate how the design flows translate into inundation extents, depths, and velocities. Two modeling approaches were applied. For the Lake Tap Tunnel alternative, an HY-8 model was used to estimate flow depths and velocities within the tunnel. For all other alternatives, a HEC-RAS 2D model was used to simulate inundation extent, depths, and velocities in the Mendenhall River and its floodplain under the design flow.

Results from the preliminary modeling were used to screen out several channel and floodplain modification alternatives from further consideration. These options were found to provide limited benefits and could introduce unacceptable long-term risks. The alternatives screened out are flood storage areas, bypass channels, cutoff channels, and river widening or deepening.

MBI developed a two-dimensional (2D) surface water model (HECRAS 2D v6.6) for the Mendenhall River Valley in Juneau, Alaska (MBI 2025). This model was not developed for this project but rather was developed in 2025 to design the HESCO barriers. Results from this model are available on the Juneau Glacial Flood Dashboard (available online at: https://juneauflood.org/#/flood-map). AECOM leveraged this existing model, and modified it only as needed to provide additional insight and analysis for the different alternatives discussed in this document. The model was calibrated by MBI using high-water marks and survey data. Key simulations in the original model included existing conditions and scenarios with proposed HESCO barriers along the eastern bank of the river. These barriers were tested for their ability to protect vulnerable areas while assessing potential impacts on adjacent properties.

Although the model offers valuable insights for planning and mitigation, it is preliminary and subject to uncertainties, particularly regarding future flood events and changes in riverbed geometry. For instance, because detailed bathymetric data at the outlet of Mendenhall Lake and along the Mendenhall River were unavailable, MBI assumed a typical riverbed geometry shown in Figure 3-6. The elevation and shape of this assumed geometry control the rate of water released from Mendenhall Lake, introducing additional uncertainty into the evaluation of alternative flood protection strategies. Despite aleatory uncertainties (due to natural variability) and epistemic uncertainties (due to limited data or knowledge), the model, as is, serves as a practical tool to visualize potential risks and evaluate flood protection strategies.

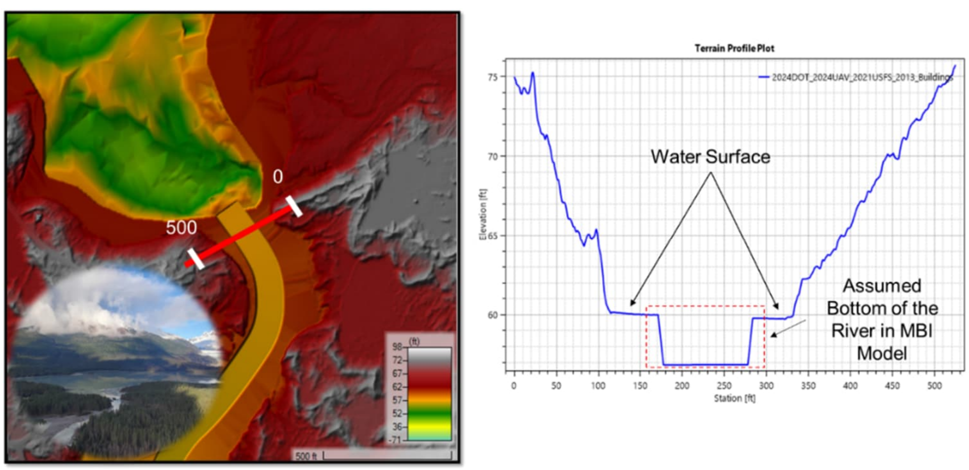


Figure 3-6 Assumed Riverbed Geometry at the Outlet of Mendenhall Lake and along the Mendenhall River Used in the MBI Hydraulic Model

Another source of uncertainty in the analysis is the vertical datum, which can affect the reported water surface elevations (WSEs). For this preliminary stage, it was assumed that the datum used in the MBI's hydraulic model is appropriate. As the work progresses, the vertical datums for all terrain datasets and digital elevation models used for hydraulic modeling will be verified for consistency, and any needed corrections will be applied for the detailed analysis.

Similar to MBI, AECOM applied the Diffusion Wave equation set in HEC-RAS 2D to accelerate simulations for multiple alternatives within a compressed schedule. Although full-momentum equations can provide higher accuracy, they significantly increase computation time. For this preliminary analysis, the Diffusion Wave approach was considered an appropriate balance of accuracy and efficiency. AECOM will evaluate the use of full-momentum equations for the preferred engineering solution during a future project development phase. See Appendix I, Mendenhall River Preliminary 2D Surface Water Model Report, for further discussion on assumptions and setup of the MBI model.

To better understand how the 118,000 cfs design flow compared with previously modeled conditions, it is useful to reference the 20-foot event (i.e., 20-foot flood stage as modeled by MBI on the Juneau Flood Dashboard), which had a peak flow of 89,002 cfs. Figure 3-7 compares the inundation extents for two peak flow scenarios: the highest flow modeled in the MBI analysis (89,002 cfs without HESCO barriers), and the design flow of 118,000 cfs. As expected, the higher peak discharge results in larger flood extents. It also produces a consistently higher WSE throughout the Valley.

The graph in Figure 3-7 presents the WSE profiles for the MBI 20-foot event and the 118,000 cfs event at Cross Section A, which is at the upstream end of the developed portion of the city, and depicted as the red dashed line in Figure 3-7. The 118,000 cfs scenario is roughly 1 foot higher than the 89,002 cfs scenario at this cross section, which indicates deeper flooding and higher velocities.

The hydraulic modeling approach for the lake tap tunnel alternative was different than the other alternatives. The lake tap tunnel alternative controls and reduces GLOF risk, thus the peak GLOF flow of 98,000 cfs is no longer a relevant design constraint for this alternative. As stated in the Hydrologic Inputs section of this report, USACE estimated the annual maximum 10-day inflow rate for Suicide Basin to be approximately 800 cfs. This maximum flow rate was used to estimate velocity and depth in the lake tap tunnel. HY-8 Software, developed by the Federal Highway Administration (FHWA) was applied to calculate tunnel flow depths and velocities. Tailwater conditions were defined based on a representative cross-section of the lake, with the outlet assumed to discharge under freefall conditions. The tunnel was assumed to be straight, constructed of smooth concrete, and have a diameter of 10 feet. No inlet depression was assumed. The tunnel invert elevation was set at 1,100 feet, and the outlet elevation was selected to result in an overall tunnel slope of approximately 8 percent. If the lake tap tunnel alternative is advanced, three-dimensional computational fluid dynamics modeling of the intake and trash rack, the main tunnel, and the outlet energy dissipation structure should be conducted for final design.

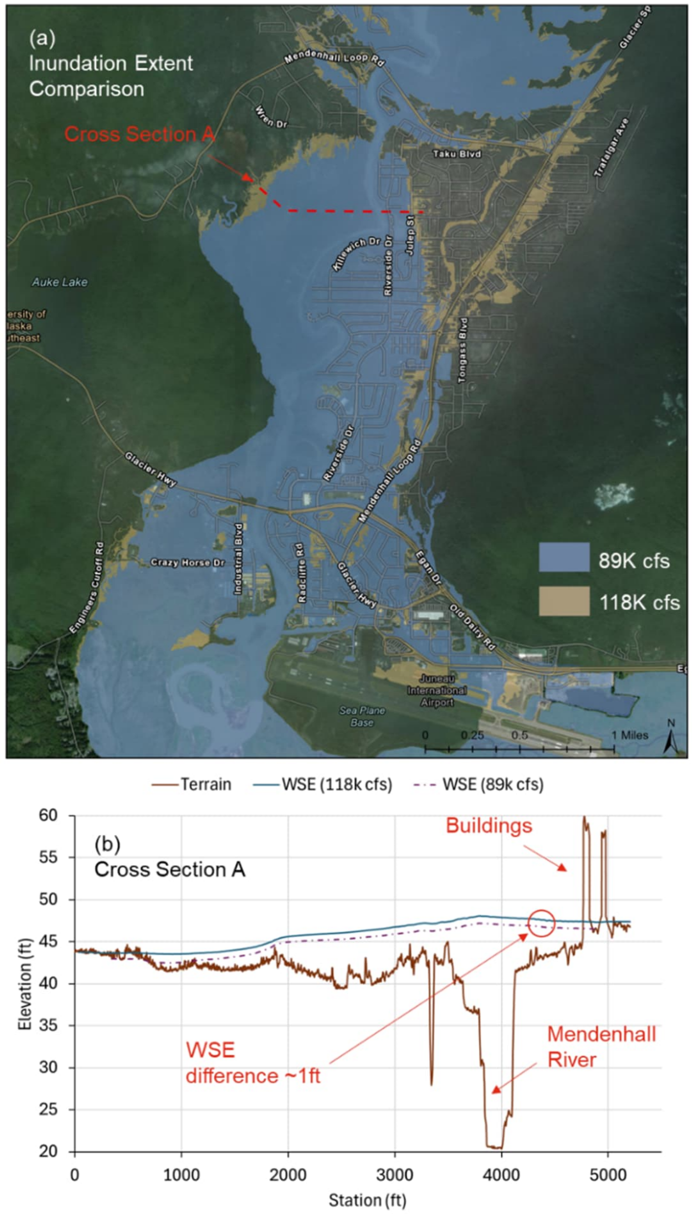


Figure 3-7 Comparison of Inundation Extents for 89,002 cfs (MBI Model) and 118,000 cfs Design Peak Flow

Overall, hydraulic modeling informs the analysis and recommendations presented in this report, providing input to all five alternatives (Lake Tap Tunnel, Dam, Floodwalls and Levees, Hybrid Dam/Floodwalls, and Relocation) along with the Screened Out Alternatives (Channel and Floodplain Modifications). For each alternative, the model was updated and re-run multiple times to test various alignments, terrain adjustments, and other design considerations. The HY-8 and HEC-RAS hydraulic models were applied using different modeling inputs and evaluation bases for the various alternatives, resulting in different hydraulic outputs. A summary of the modeling approach and key results for each alternative is provided in Table 3-2.

Table 3-2 Hydraulic Modeling Approach and Results Used to Screen and Evaluate Alternatives

Alternative	Hydraulic Modeling Basis	Hydraulic Modeling Results
Lake Tap Tunnel	Peak inflow to HY-8 model of 800 cfs, based on the maximum 10-day filling rate of Suicide Basin	Flow depth and velocities within the tunnel (see Section 4.1.1)
Dam	Peak inflow to HEC-RAS Model: 118,000 cfs (volume = 130,938 ac-ft) Dam peak release: ~30,000 cfs	Water surface elevations used to approximate dam height (see Section 4.2.1)
Floodwalls	Peak inflow to HEC-RAS Model: 118,000 cfs	Water surface elevations in Mendenhall River used to approximate height of floodwalls (see Section 4.3.3)
Hybrid Dam-and-Floodwall	Peak inflow to HEC-RAS Model: 118,000 cfs (volume = 130,938 ac-ft) Dam peak release: ~50,000 cfs	Water surface elevations used to approximate dam height Water surface elevations in Mendenhall River used to approximate height of floodwalls (see Section 4.4.1)
Relocation	Peak inflow to HEC-RAS Model: 118,000 cfs	Extent of inundation and number of at-risk structures (see Section 4.5.1 and Section 4.5.4)
Screened Out Alternatives	Peak inflow to HEC-RAS Model: 118,000 cfs	Mendenhall River conveyance capacity, depths, and velocities (see Section 3.8)

3.7.1. Assumptions and Considerations

For the Lake Tap Tunnel Alternative, the previously described 2D hydraulic model was not used because this option releases the GLOF volume gradually over time. As a result, an outburst-type flood wave does not occur and does not need to be represented in the HEC-RAS model. This alternative involves tunneling, which requires a pipe-flow–based hydraulic evaluation. To assess the hydraulic performance of the proposed tunnel conveying a peak flow of 800 cfs, HY-8 Software was used. The tunnel effectively functions as a long, large-diameter culvert, making HY-8 an appropriate tool for preliminary hydraulic assessment. The additional 800 cfs, which is released from Suicide Basin to Mendenhall Lake, are considered to have only a minimal impact on the capacity of the Mendenhall River since this additional peak flow would be dampened by the time it passes through the lake. Hydraulic analysis demonstrates that the river can convey approximately 20,000 cfs without widespread flooding. Adding 800 cfs to this flow is not expected to meaningfully alter inundation extents.

Regarding the assumptions behind modeling the Dam-related alternatives, it should be noted that the dam height evaluated in this study is directly influenced by how water is released through the outlet of the dam. For modeling efficiency purposes and for this preliminary analysis, outflows were modeled as a function of available head, allowing a discharge hydrograph to passively develop based on upstream water levels rather than controlling a fixed release rate. This approach is referred to as a passive outlet configuration, where the outlet capacity increases with head and does not rely on active operational controls. Investigating alternative outlet designs that release higher or more constant flows would have required more complex modeling but could reduce the required dam height. Therefore, the selection of passive outlet control led to higher dams in order to model multiple scenarios more quickly in preparation for the charrette.

Actively controlled outlet structures, such as Tainter gates designed to maintain a constant high discharge, would introduce additional mechanical complexity, cost, impact to construction schedule, and long-term O&M requirements. These systems rely on moving, custom-fabricated parts, which require time-dependent adjustment to respond to changing head conditions. Although an active outlet could reduce the dam height, it would not significantly reduce the overall length of the dam for this project. As a result, a lower dam with active mechanical systems may not be more cost-effective than a higher dam with a passive outlet configuration. For this reason, a conservative, passive outlet assumption was used for the preliminary analysis.

3.8. Screened Out Alternatives

Note: *These alternatives were determined to be not viable and were, therefore, not carried forward into further analysis. The following section describes the rationale for screening them out from further consideration.*

The following four alternatives (Figure 3-8), collectively known as the Channel and Floodplain Modification Alternatives, focus on modifying how the Mendenhall River conveys and stores floodwater from the GLOF by altering the river corridor and its adjacent floodplain.

1. Flood Storage Area Alternative
2. Bypass Channel Alternative
3. Cut-off Channels Alternative
4. Widening and Deepening the Mendenhall River Alternative

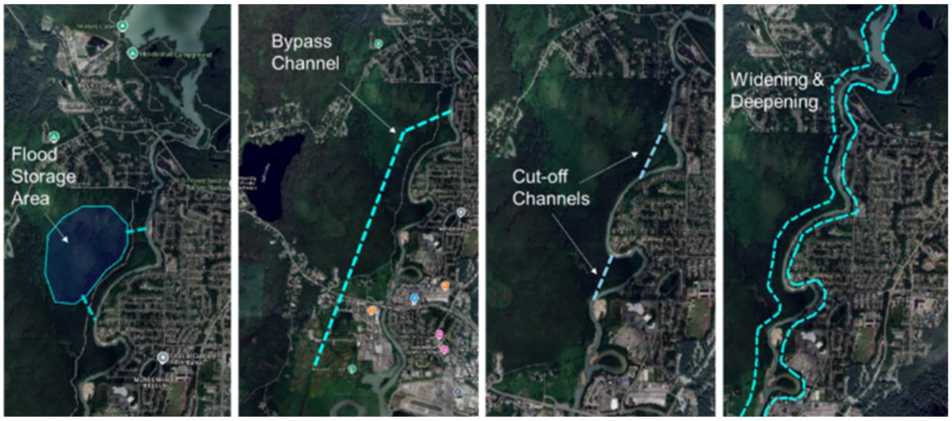


Figure 3-8 Conceptual Alignment of Channel and Floodplain Modification Alternatives

After preliminary hydraulic modeling and analysis, channel and floodplain modification alternatives were screened out from further consideration. Although some of these alternatives may lower safety and economic risks initially, the protection they would provide is limited, temporary, and could lead to other unacceptable long-term risks. Some of the key challenges and limitations associated with these alternatives are:

- Minimal overall benefit in reducing inundation extents or flood damages.
- Potential for increased downstream water levels.
- A high groundwater table in the wetland area, which limits effective storage capacity.
- Ongoing needs for sediment management, bank stabilization, and long-term maintenance.
- Potential for post-project river instability, including increased risk of bank erosion, channel degradation, and aggradation.
- Environmental impacts on fish habitat and complex permitting considerations (Eaton et al. 2011).
- Potential need for tunnel construction through Pederson Hill to convey flows southward.
- Increased flow velocities and scour potential in new cut-off channels, with associated downstream impacts.
- Substantial excavation and disposal volumes and associated cost and impacts.

3.8.1. Screened Out Alternative 1 – Flood Storage Area

The Flood Storage Area Alternative considered the creation of a storage area, either on-channel or off-channel, in the wetland area west of the Mendenhall River to temporarily retain a portion of the flood peak. On-channel storage refers to a storage area that is directly connected to the main river channel and fills naturally as river stages rise. Off-channel storage is separated from the main channel and fills through a controlled inlet, allowing water to be diverted into the storage area only when flows reach designated thresholds.

By capturing water during the highest flows and releasing it gradually as conditions recede, the storage area reduces flows and associated peak water levels in the main channel. The storage can make use of existing wetland features or rely on constructed storage areas to provide the necessary temporary detention/retention capacity. Figure 3-9 illustrates this concept by showing how flood storage areas temporarily retain water, delay the peak, and attenuate (i.e., lower) the peak of the hydrograph.

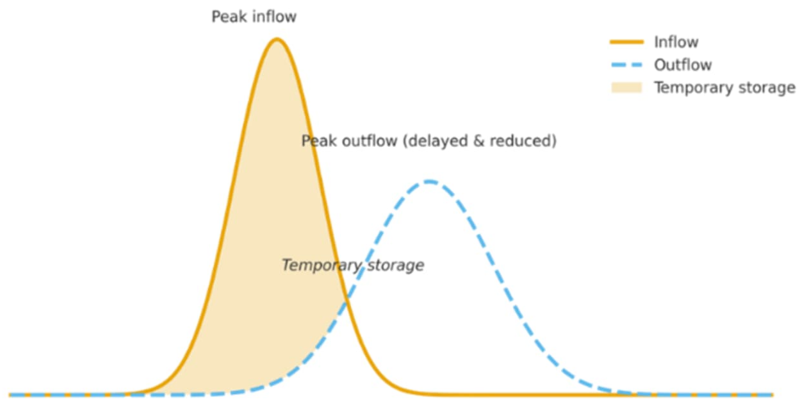


Figure 3-9 Conceptual Illustration of How a Flood Storage Area Delays and Reduces the Peak of the Hydrograph

According to the United States Geological Survey report on channel incision and water-table decline along the Mendenhall River (Neal 2009), groundwater levels adjacent to the river (Well 29) dropped by approximately 2 feet over a 17-year period (1984–2001). This trend is aligned with the documented rate of channel incision, which averaged about 0.10 foot per year. Despite this long-term reduction of the water table, the report notes that groundwater elevations at the time of the study were still typically 4.9 to 10.5 feet (1.5 to 3.2 meters) below the land surface across much of the area.

These conditions introduce a constraint on any flood-storage alternative. To meaningfully delay and reduce the GLOF hydrograph, a storage basin must retain flow volume above the existing groundwater table. The relatively shallow depth to groundwater in parts of the wetland area limits the feasible storage volume and complicates excavation, seepage control, and long-term performance of this type of temporary storage system.

Even if a concrete-lined flood storage area were considered, the required storage volume for a GLOF event remains prohibitively large. The volume of 63,000 acre-feet required to retain the GLOF event would necessitate a basin of sufficient size and depth based on the limited footprint available. For context, the stage–volume relationship for Mendenhall Lake shows that at a lake elevation of 60 feet, the lake holds approximately 76,000 acre-feet of water. In other words, the GLOF volume for detention is only about 17 percent less than the entire volume of Mendenhall Lake at a typical level. Although the full 63,000 acre-feet do not need to be stored because an outlet structure would release some flow during the event, a substantial portion of the GLOF volume must still be detained temporarily to achieve any meaningful reduction in peak discharge.

In summary, even when using an intentionally high assumed outflow and ignoring the impact of groundwater flow, the temporary detention volume would still be on the order of 44,000 acre-feet. If this volume were placed in a storage area of roughly 200 acres (Figure 3-10) which itself is a conservative to aggressive estimation of area of available space, the resulting average storage depth is about 220 feet. A flood storage area of that depth is not practical given site constraints, and it underscores the scale mismatch between the required GLOF storage and what the landscape can support. In addition, the flood storage area would not reduce inundation extents for locations upstream of the feature, such as areas along View Drive.

Figure 3-10 Approximate Footprint of the Potential Flood Storage Area West of the Mendenhall River

3.8.2. Screened Out Alternative 2 – Bypass Channel

The Bypass Channel Alternative considered the construction of a bypass channel to improve conveyance and divert excess flows away from the Mendenhall River. The general goal for this approach was to reduce flood risk by creating an alternative flow path capable of conveying higher channel capacity during extreme events, such as GLOFs. Although conceptually straightforward, it does not meaningfully reduce the extent of flooding, based on the design flow event considered for the purposes of the charrette.

Constructing a channel capable of passing peak flows would require extensive excavation, resulting in an unusually deep and wide structure. Shallow groundwater levels of approximately 5 to 10 feet below ground surface (Neal 2009) in adjacent wetlands would additionally reduce hydraulic capacity. In addition, routing a large artificial channel through sensitive habitats introduces significant environmental and permitting obstacles. To move water south, approximately 4,400 feet of tunneling through Pederson Hill would be required, adding technical risk and expense. Even if constructed, the channel would have limited long-term usefulness, because it is designed for a GLOF event with an approximate 20- to 30-year lifecycle, after which it would be oversized and obsolete. Ongoing maintenance, including sediment removal and bank stabilization, would also impose an operational cost, and diverting large flows could result in unintended geomorphic impacts such as altered groundwater levels, wetland hydrology, and downstream channel instability.

To understand the dimensional requirements of such a bypass channel and its effect on flood extents, a preliminary model was developed to evaluate this option for the design peak flow of 118,000 cfs. The bypass channel was modeled as a trapezoidal, approximately 430-foot-top-width channel and 2:1 horizontal-to-vertical side slopes. Although not fully realistic, groundwater inflows were excluded from the analysis to illustrate the channel dimensions required for conveyance. As depicted on Figure 3-11a, the channel would pass through a wetland area and cross Montana Creek west of the Mendenhall River, ultimately requiring a tunnel through Pederson Hill. To better illustrate the scale of the bypass channel, Figure 3-11b presents a cross section comparing its dimensions to those of the Mendenhall River at Cross Section A. Figure 3-11c shows the inundation extent resulting from adding a bypass channel to the terrain, sized to convey a peak flow of 50,000 cfs with a maximum depth of 31 feet. The modeling results indicate that, even at this scale, and without accounting for groundwater inflow, the channel is still unable to convey the required discharge with resulting flooding in the city.

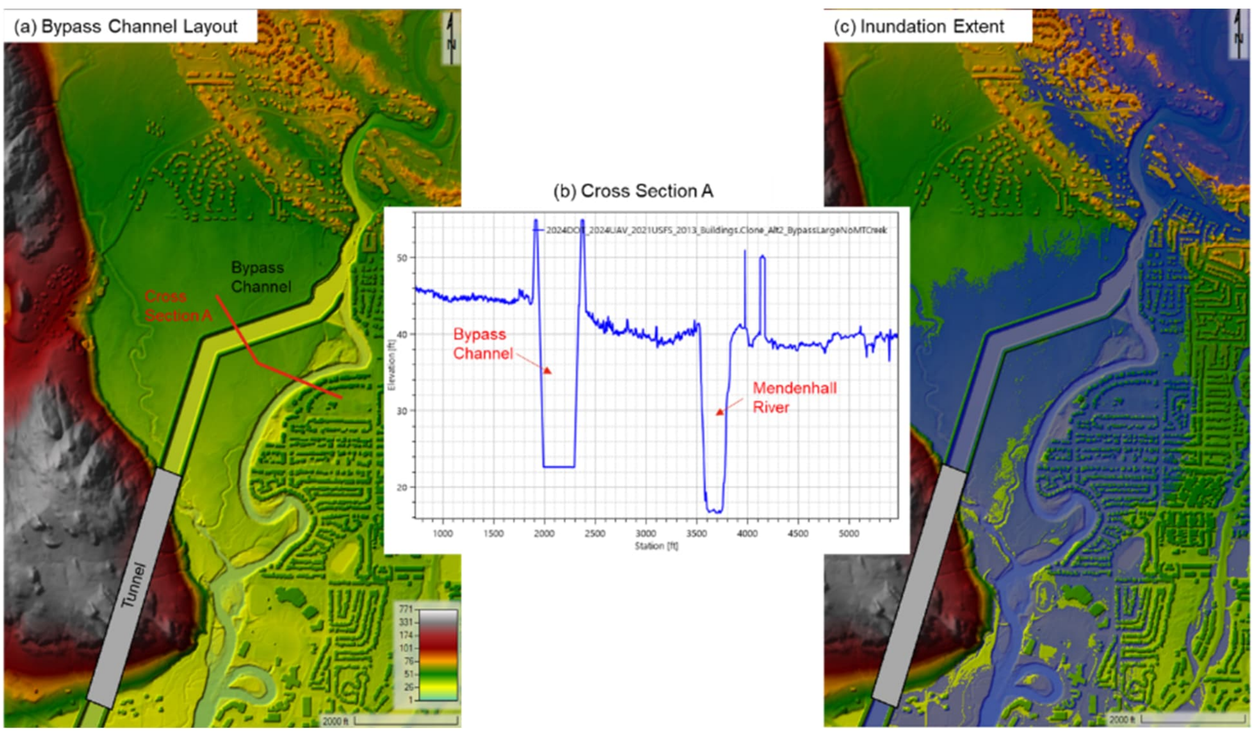
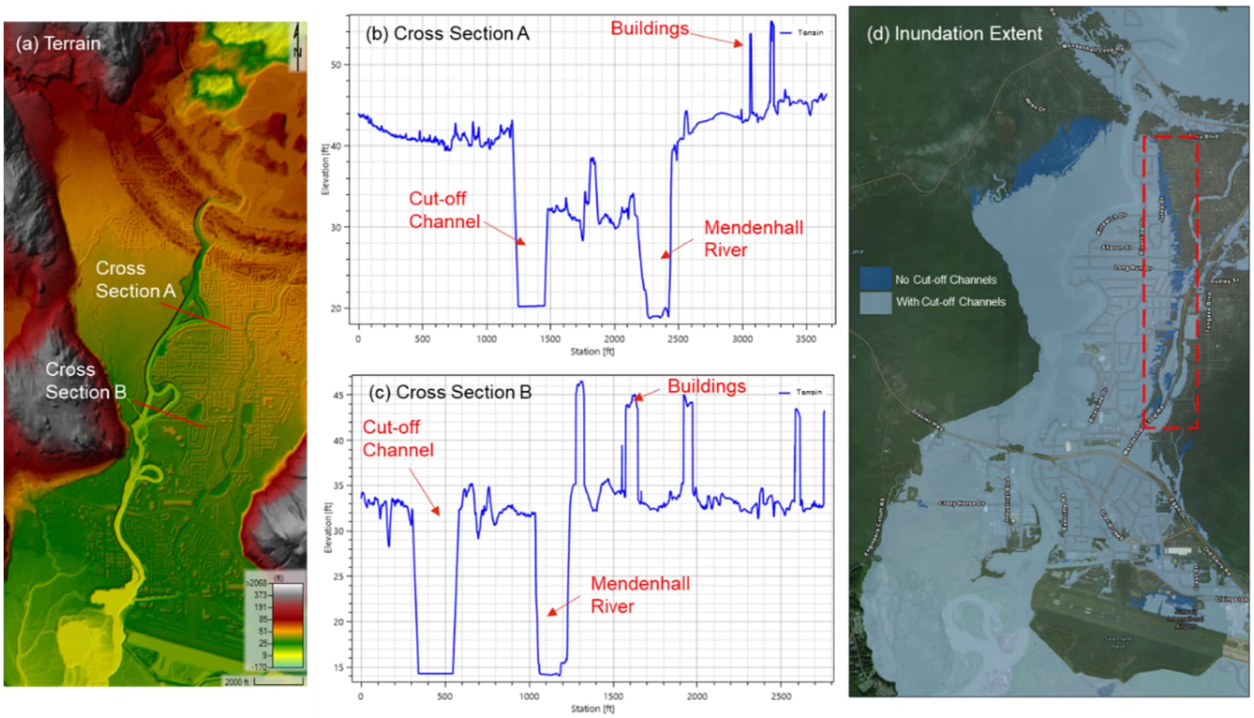


Figure 3-11 Conceptual Bypass Channel Alignment and Scale Comparison

(a) Proposed alignment crossing Montana Creek and Pederson Hill; (b) Cross-section showing channel dimensions versus Mendenhall River; (c) Modeled inundation extent for a 50,000 cfs bypass channel showing persistent flooding despite added conveyance.

3.8.3. Screened Out Alternative 3 – Cut-Off Channels Alternative

The Cut-Off channels Alternative included creating two new straightened flow paths through the major meanders along the Mendenhall River. Each cut-off channel was modeled with a top width of approximately 280 feet and side slopes of 2:1 (H:V). Figure 3-12a-c, depict the dimensions of these channels and show how they compare to the existing river geometry. Two scenarios were evaluated in the hydraulic model: one with the cut-off channels in place and one without them, both using the 118,000 cfs peak design flow.



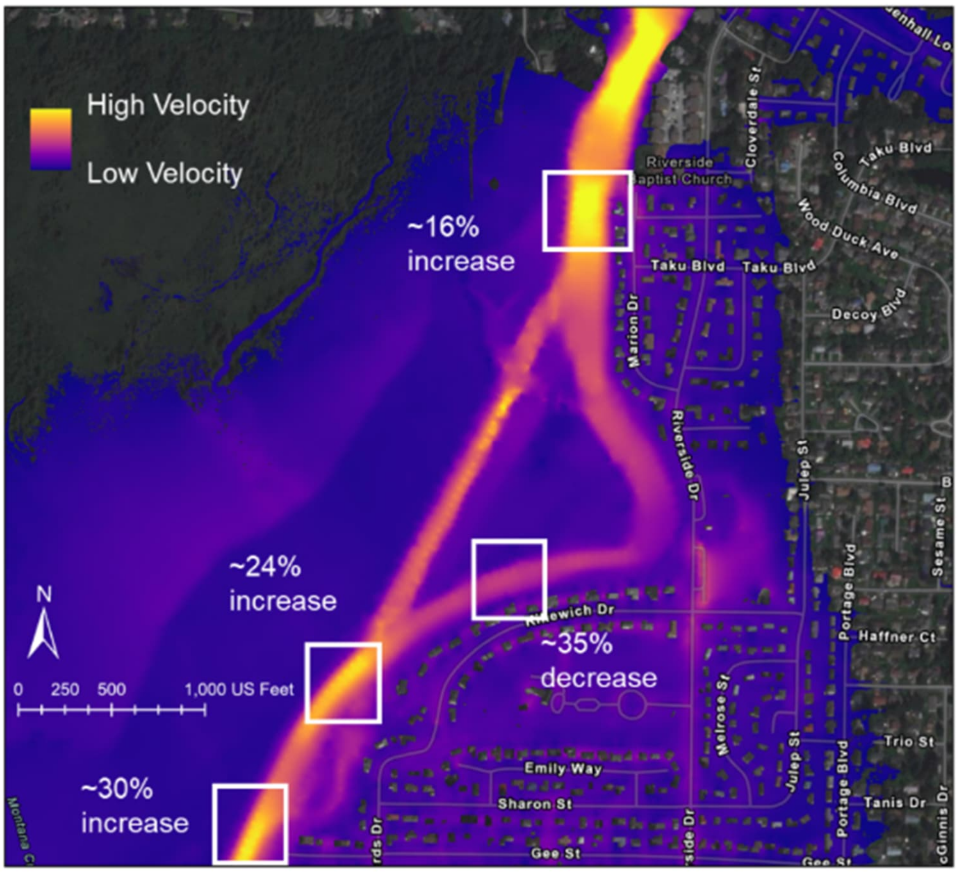
(a) Cut-off channel layout (modified terrain); (b–c) channel dimensions and comparison to existing river geometry; (d) hydraulic model results for the 118,000 cfs design flow with and without the cut-off channels.

Figure 3-12 Cut-Off Channel Layouts, Comparison to Existing River Geometry, and Hydraulic Model Results

The inundation extents for both scenarios are depicted in Figure 3-12d. The results indicate that adding the cut-off channels leads to only a small reduction in inundation, primarily along the northwestern side of the Mendenhall River (south of Wren Drive) and in a few narrow areas along the eastern edge of the floodplain. These localized reductions occur because the cut-off channels improve conveyance through the meander bends. The change in inundation extent is minimal north of Mendenhall Loop Bridge along View Drive and south of Glacier Highway.

It is important to note that introducing cut-off channels increases flow velocities, which leads to greater conveyance, and in turn, deeper flooding in areas south of the cut-off channels. This effect limits the practicality of enlarging the cut-off channels to eliminate flooding on the eastern side of the river. As the channel size increases, so does downstream conveyance, resulting in higher water depths and a larger inundation extent. In the modeled scenario, which used a top width of approximately 280 feet and 2:1 side slopes, the peak flow immediately downstream of the southern cut-off channel increased by about 7,000 cfs. This increase becomes more pronounced as the cut-off channels are enlarged.

In addition to the hydraulic considerations noted above Figure 3-13 presents the velocity patterns in and around the northern cut-off channel. As expected, the cut-off channels increase flow velocities immediately upstream and downstream because of the added conveyance. Model results show that velocities downstream of the cut-off channel can increase by up to 30 percent compared to the scenario without cut-off channels. On the other hand, velocities in the bypassed meander decrease by roughly 35 percent because less flow is routed through that section. These changes influence sediment transport dynamics of the Mendenhall River, which is already affected by channel incision (Neal 2009).



(a) Cut-off channel layout (modified terrain); (b–c) channel dimensions and comparison to existing river geometry; (d) hydraulic model results for the 118,000 cfs design flow with and without the cut-off channels.

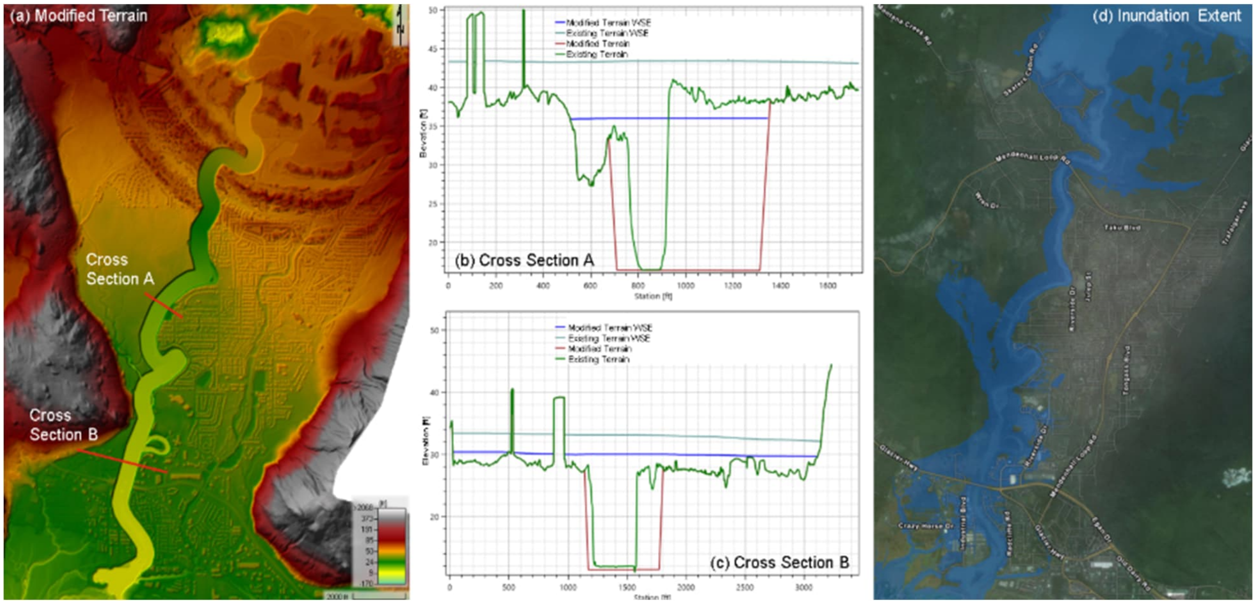
Figure 3-13 Velocity Distribution Around the Northern Cut-Off Channel, Showing Increased Velocities Upstream and Downstream and Reduced Velocities in the Bypassed Meander

3.8.4. Screened Out Alternative 4 – Widening and Deepening the Mendenhall River

The Widening and Deepening the Mendenhall River Alternative considered increasing the width and depth of the Mendenhall River to improve the river's ability to pass GLOFs. A larger channel cross section would allow the river to convey higher discharges with lower water-surface elevations, which in turn could reduce the extent of overbank flooding during peak events. This alternative was modeled by adjusting the existing terrain to create a top width of roughly 700 feet from the Mendenhall Lake outlet to the river mouth. As a point of comparison, the river width immediately downstream of the Mendenhall Loop Road is approximately 145 feet. This layout maintains the existing alignment along the eastern side through the developed portion of the Valley, with most of the additional width added on the western side of the river.

Approximately 7,000 feet of the Mendenhall River upstream towards the lake was deepened by 2 to 5 feet in the model. Deepening this upstream reach of the Mendenhall River, through the glacial moraines at a consistent slope, allows more water to be conveyed through the channel in this location. This eliminates flooding that, in the existing condition, overtops the moraines in multiple locations and floods the northern end of town near the southernmost moraine. The terrain used in this preliminary modeling did not include surveyed bathymetry, so the "deepening" applied in this alternative is measured relative to the water surface at the time of the light detection and ranging (LiDAR) collection. According to the Mendenhall River Preliminary 2D Surface Water Model Report (MBI 2025), the LiDAR used for the hydraulic model was collected on October 21, 2024, during a declining river discharge of 4,500 to 2,800 cfs.

Figure 3-14a illustrates the extent of terrain modification needed to incorporate the widened and deepened channel. Figure 3-14b and Figure 3-14c highlight how the existing Mendenhall River compares to the proposed geometry, indicating that in some sections, the widened channel would be more than three times the current width. Figure 3-14d shows the inundation map for the 118,000 cfs design peak flow. As expected, given the large footprint of the proposed channel, the modeling results indicate a meaningful reduction in flooding for structures and buildings in the northern part of the Mendenhall Valley. Some improvement is also found farther downstream, although certain infrastructure would still experience flooding. The modeling results demonstrate that even with this exaggerated, expanded channel configuration, some structures would still remain vulnerable during a GLOF event.



(a) Modified terrain; (b–c) Cross-sections of modeled water surface elevations (WSEs) for existing and modified terrain; (d) Modeled inundation extent for channel with top width of approximately 700 feet.

Figure 3-14 Conceptual Channel Widening with Top Width of Approximately 700 Feet

In theory, expanding the channel footprint even further would continue to increase conveyance capacity without redirecting flow elsewhere in the Valley. In practice, several factors limit the feasibility of this approach. The hydraulic challenges of constructing and maintaining such a large channel are significant, and high groundwater levels in the adjacent wetlands would introduce additional complications, similar to what was described for the bypass channel alternative. Groundwater inflow would continually enter the widened and deepened channel, reducing its effective hydraulic capacity and making it difficult to rely on the channel to convey extreme GLOF discharges. Additionally, there is uncertainty around the long-term stability of enlarging a river that is already experiencing natural incision. Further deepening or widening may not be sustainable over time and could introduce geomorphic risks that reduce the practicality of this alternative. Finally, property acquisition and relocation of residents would be required south of the Mendenhall Loop Bridge and south of Brotherhood Bridge.

3.8.5. Conclusions

The channel and floodplain modification alternatives described above (i.e., creating flood storage, adding a bypass channel, cutting off meanders, or widening and deepening the river) were screened out before proceeding into detailed evaluation and comparative cost estimation. Preliminary analyses concluded that these alternatives do not offer an enduring solution for reducing GLOF flooding in the Mendenhall Valley. Their benefits are limited, and in some cases, could increase downstream water levels or exacerbate channel instability.

The alternatives face major physical and environmental constraints. The groundwater levels in the Valley are too shallow to allow meaningful storage or deep excavation. The scale of earthwork and tunneling needed would be difficult and costly to construct and maintain. In addition, the impacts to wetlands and salmon habitat, along with complex permitting requirements, further limit their feasibility.

Given the limited hydraulic effectiveness, potential to create new flooding and/or erosion issues, and short useful life relative to the remaining Suicide Basin GLOF lifecycle, these alternatives were not advanced as viable solutions for the Mendenhall Valley.

4. Description of Alternatives

4.1. Lake Tap Tunnel Alternative

4.1.1. Technical Discussion

The Lake Tap Tunnel Alternative involves constructing an approximately 2-mile-long, 10-foot-internal-diameter finished tunnel from Suicide Basin to Mendenhall Lake to continuously drain the flows up to 800 cfs from Suicide Basin to significantly reduce GLOF risk. Refer to Figure 4-1 for an overview of the Lake Tap Tunnel Alternative. The outfall is anticipated to be a reinforced-concrete structure, the tunnel would be lined with reinforced concrete (precast or cast-in-place) and/or steel, and the intake structure would feature a robust steel intake screen. The 10-foot-internal diameter was initially selected since it is a standard tunnel size which may increase the availability of excavation equipment. The excavated diameter of the tunnel will be approximately 13 feet, assuming a 16-inch-thick concrete liner. A larger starter tunnel will be used for the first 100 feet. Additionally, this diameter meets the hydraulic requirements which is discussed below. Figure 4-2 provides the profile for this alternative, Figure 4-3 shows the preliminary location of the outfall, and Figure 4-4 shows the preliminary intake location.

Figure 4-1 Lake Tap Tunnel Alternative Overview

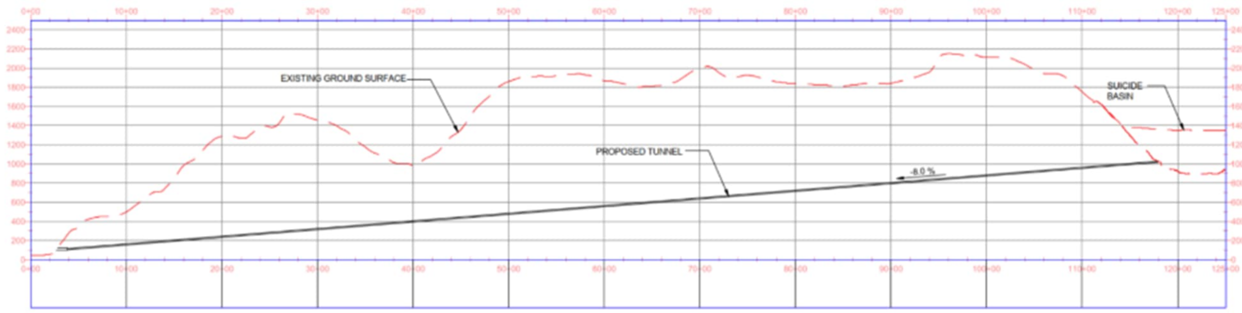


Figure 4-2 Lake Tap Tunnel Alternative Profile (Intake and Outfall Elevation Subject to Change)

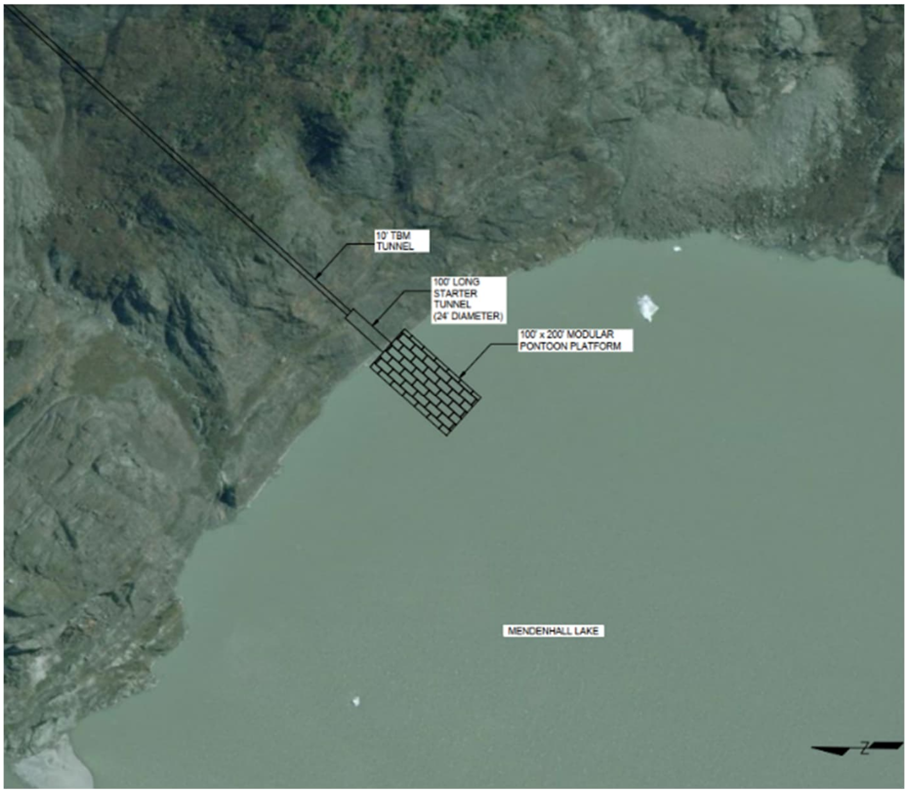


Figure 4-3 Tunnel Portal/Outfall Preliminary Location

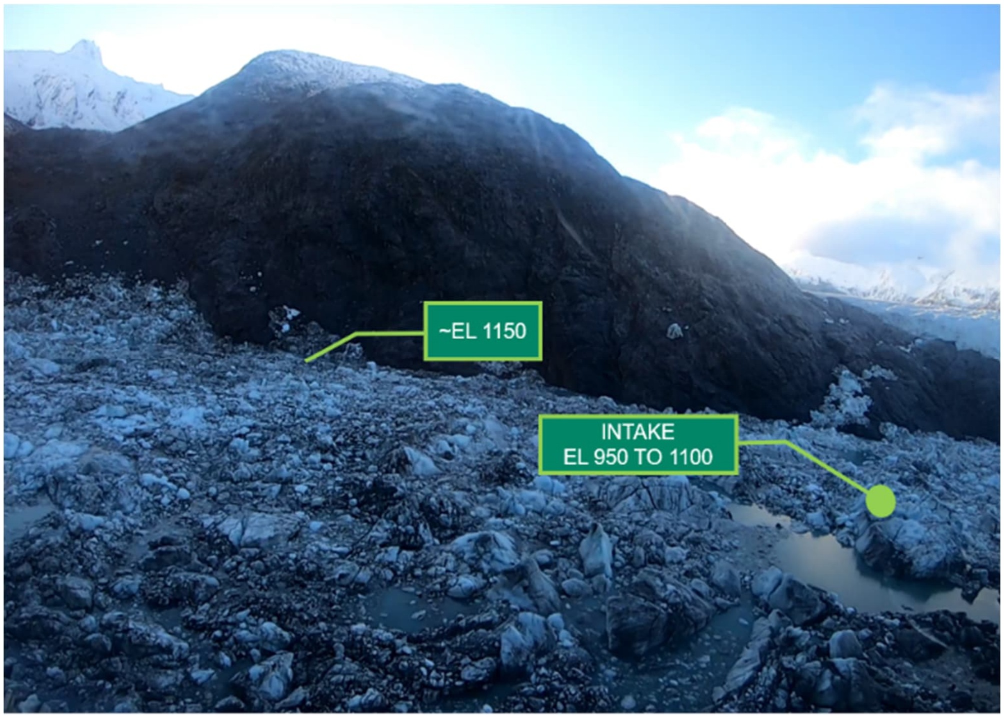


Figure 4-4 Preliminary Intake Location in Suicide Basin

Hydraulic and Hydrologic

The Lake Tap Tunnel Alternative is expected to significantly reduce the risk of a GLOF event by passively draining Suicide Basin into Mendenhall Lake. The hydraulic and hydrologic analysis are conceptual level, but it indicates that the 10-foot tunnel has enough capacity to past the design flow of 800 cfs without pressurizing the system (i.e., operate in an open channel manner). However, the velocity of the flow would be high and the flow would be supercritical. The hydraulic and hydrologic parameters are also at a conceptual level and would need to be confirmed in the next design phase to reflect any updates. As part of the updates, a parametric analysis would be performed on the entrance loss coefficient to understand its effects on the depth (i.e., increasing the roughness). The parameters assumed for this analysis are summarized below:

- Design discharge = 800 cubic feet per second. This is based on the maximum 10-day filling rate of Suicide Basin.
- Tunnel length = approximately 12,000 feet
- Tunnel slope = approximately 8.0 percent.
- Material = smooth concrete or similar
- Manning's roughness = approximately 0.013
- Maximum depth at inlet = less than approximately 7 feet.
- Minimum depth = less than approximately 3 feet. Flow would be open channel, not pressurized.
- Maximum velocity = greater than 40 feet per second. Flow would be supercritical, i.e., high velocity.

With a design flow of 800 cfs, flooding impact is not anticipated. At 30,000 cfs, flows can be conveyed by the existing river channel, with the exception of some flooding in the northern part of the Valley, including View Drive. The peak flow of the lake tap tunnel is approximately 800 cfs, and this inflow into Mendenhall Lake would be partially attenuated (i.e., reduced and spread out) by the lake's natural storage. Even if no attenuation is assumed, and even if the lake tap tunnel peak flow coincided with the 20,000 cfs peak of the non-GLOF event, the combined flow would be approximately 20,800 cfs, a 4 percent increase. This increase is below the level associated with flooding and is not expected to cause significant downstream impacts or require additional flood-mitigation measures. Additionally, the 800 cfs flow into Mendenhall River at its "normal" water surface elevation would convey it without overtopping its banks.

It is estimated the elevation of the drainage conduit for the past 3 years (2023-2025) has been close to an elevation of 900 feet. The maximum possible elevation of the inlet would be 1,100 feet. The volume of water that can be held in the Basin between 900 and 1,100 feet elevation is not large enough to create an outburst flood that would have any impact in Mendenhall Valley. Moreover, it is unlikely that there would even be enough water pressure at an elevation of 1,100 feet to initiate any sort of outburst flood. The elevation at the top of the ice dam (representing a "full basin") is about 1,360 feet, so much of the effective basin volume (i.e. between 1,100 and 1,360 feet) would be eliminated when the tunnel came online.

Geological Conditions

Geologic maps indicate that the tunnel would traverse bedrock consisting of metasedimentary and metavolcanic rock and tonalite. The metasedimentary rocks consist of graywacke and mudstone but may also contain interbedded carbonates (marble).

The bedrock is steeply dipping to the northeast and is cut by several thrust faults (of similar dip) creating shear zones up to several hundreds of feet wide. Secondary fracturing is also present. Both fault types are considered inactive. Pyrite mineralization associated with faults and quartz veins is likely along shear zones and metamorphic rocks and may cause acid generation and metal leaching of tunnel waste over time.

Rockfalls, talus deposition, avalanches, and local snow slumps could occur at or near intake and outfall.

4.1.2. Technical Unknowns

The design presented for the Lake Tap Tunnel Alternative is conceptual, and a detailed study and analysis would be needed to characterize the following:

- Geotechnical and geological hazards
- Geotechnical and geological conditions
- Seismic Loading
- Groundwater levels and flow dynamics
- Suicide Basin inflow over the design life

- Size, shape, and volume of Suicide Basin over the design life
- Bottom elevation of Suicide Basin over the design life
- Environmental and climatic influences
- Hydraulic and structural considerations
- Construction risks
- O&M requirements

4.1.3. Assumptions

Key assumptions associated with the conceptual design alternatives presented herein are presented below:

General

- Tunnel Break-out at Elevation 950 feet to 1,100 feet would create an intake capable of reducing future GLOF events caused by Suicide Basin filling. Alternative solutions such as shaft and cavern from which to tunnel future additional smaller intakes to the Suicide Basin offer some mitigation should the configuration of the Basin change in the coming years or should the tunnel intake clog.

- O&M activities could occur during the winter seasons when there is minimal flow into the tunnel. An intake gate is not assumed at this time but will be considered in the next design phase for inspection and maintenance purposes.

Geological and Geotechnical Conditions

- Geotechnical conditions along the alignment consist of rock that are poor to good quality with potential shear and fault zones to be identified in a later stage.

- The tunnel would most probably encounter faults that would result in poor ground conditions along parts of the tunnel alignment.

- The local faults are inactive as per the information currently collected.

- The intake and outfall portals would require minimal rock slope stabilization such as rock bolts and shotcrete.

- Avalanche remediation would occur as needed during construction and during long-term operations at the intake and outfall portals.

- The groundwater is near the surface along the alignment.

- The maximum depth of the tunnel below ground level is approximately 1,730 feet along the preliminary alignment.

Construction

- Drill-and-blast methods for a starter tunnel are acceptable, but jack hammer and road header options would be kept open pending equipment availability.
- The tunnel boring machine (TBM) would break into Suicide Basin soon after a GLOF Event when the water level would be lower than the break-out location: it is acknowledged this is a limiting factor in the construction schedule and may be the cause for significant schedule variance, but the presence of icebergs and uncertainties related to the depth of the Basin based on early inspections confirmed the limited feasibility of cofferdams and wet well type of intakes: contingency plans would still be prepared for a smaller diameter microtunneling method (i.e., remotely operated) to possibly enter Suicide Basin if still filled with water.
- Tunnel spoils would be able to be transported on Mendenhall Lake.
- Construction of the staging area can continue through winter. This is based upon local knowledge of the area and feedback from the stakeholders.
- The staging area and tunnel portal would need to be protected from flooding risk, including readiness plans for temporary relocation of personnel and equipment and remobilization after the GLOF events during construction.
- Dredging would be allowed in Mendenhall Lake.
- The existing roads, bridges, and ports can accommodate the construction of the Lake Tap Tunnel Alternative; therefore, at this stage, it is excluded from any design and construction schedule and cost impact of any improvement of existing facilities to support the project, pending a future logistic assessment on their existing capacity.

4.1.4. Geographic Footprint

The Lake Tap Tunnel Alternative would require a construction staging area and pier near the southern side of Mendenhall Lake to launch barges that would move construction equipment and spoils over Mendenhall Lake. The construction staging area development may require locally clearing land and campgrounds on National Forest Service land as well as dredging in Mendenhall Lake. The required staging area depicted in Figure 4-5 below is approximately 1 acre. If additional land is needed, a potential staging area is also identified in Figure 4-5, and is approximately 2 acres.

Figure 4-5 Staging Area and Pier

Alternatively, there is an opportunity to consider a staging area north of the Westside Trailhead (north of Skaters Cabin near the boat launch), that requires less dredging but would require a temporary access road.

4.1.5. Design Feasibility

The Lake Tap Tunnel Alternative is feasible and would require further consideration of the following factors:

- Ground and groundwater loads, including seepage flows into the tunnel
- Seismic loads
- Icebergs and freezing conditions at the intake and outfall structure
- Freezing conditions in the tunnels
- Potential for debris clogging the intake
- Access for O&M
- Hydraulic conditions, including high-discharge velocities and potential cavitation

At high-flow conditions, portions of the tunnel may operate under full or near-full conduit hydraulics, which could require reinforced concrete lining or localized steel lining to withstand increased internal pressures, abrasion, and transient hydraulic loads. In addition, seasonal lake ice presents operational risks at the intake: surface ice sheets and calved blocks may obstruct the intake screen or impose impact loads. Accordingly, the intake structure may require a larger opening screen geometry, structural ice-loading design, and mechanical or passive features to control the size and trajectory of ice blocks approaching the portal. Final determination of these requirements would depend on refined hydraulic modeling, structural analysis, and lake ice characterization during Preliminary Design. Similarly, impact of additional ice blocks in the Mendenhall Lake would be confirmed both for lake users and environment, but it is not expected to be a dramatic change with respect to conditions already experienced.

4.1.6. Constructability

Construction Sequence

The construction of the Lake Tap Tunnel Alternative is anticipated to be performed with the following general sequence:

1. Develop the construction staging area
2. Perform Mendenhall Lake dredging if necessary depending on final pier location
3. Install pier on the southern side of Mendenhall Lake
4. Launch boats and barges to create temporary platforms and tunnel launch pad at the outfall
5. Transport tunnel equipment on barges and create tunnel spoil barges
6. Construct the starter tunnel using drill-and-blast methods at the outlet end (tunnel entry portal)
7. Set up working area in the starter tunnel/portal, including power generators
8. Launch the TBM and construct the mainline tunnel from the outlet end
9. Recover the TBM
10. Install the intake screen and reinforced-concrete outfall structure. Install steel liner in the mainline tunnel as necessary.
11. Demobilize the outfall temporary platform
12. Restore the staging at the southern side of Mendenhall Lake per discussion with stakeholders.

The following work restrictions would also need to be considered:

- Annual GLOF events
- Freezing of Mendenhall Lake that prevents boat access
- Tourism and recreation, which may prevent or limit barge transport or tunnel excavations
- Availability of suitable aggregate and batching plant for concrete production.
- Transportation and handling constraints, including limitations on load size and weight due to local roads, bridges, and site access.

Staging Area

The Lake Tap Tunnel Alternative would require clearing and preparation of land to serve as the construction staging area. This would involve clearing and grubbing followed by placement of a gravel base. These activities appear feasible year-round and do not appear to be constrained by seasonal conditions. The work can be performed using locally sourced equipment and materials. The staging area would also accommodate stockpiling of excavated tunnel material for characterization, testing, and subsequent disposal or reuse in accordance with regulatory requirements. A one-acre staging area, not including piers, would accommodate a single truck turn around, crane, staging of pipe sections and stockpiling of several days of tunnel material. In addition, there exist several stockpile locations owned by the City of Bureau of Juneau as well as local contractors. It is feasible that additional material could be stockpiled or disposed of offsite.

Dredging

This alternative would require Mendenhall Lake to be dredged near the staging area to allow pier development and barging of construction equipment, material and spoils. It is anticipated that a minimum lake depth of 20 feet is needed to provide adequate draft (vertical distance between waterline and lowest point of the boat). Dredging equipment may be available locally but may require importing. Maintenance dredging could be required.

Dredged material would need to be evaluated and managed in accordance with regionally appropriate guidance, and contingent upon concurrence from relevant state and federal agencies. Testing may not be required if the material can be evaluated at tier 1, and the agency can determine there is no reason to believe contamination exceeding the screening criteria is present in the dredged material. It is assumed that the spoils may be disposed of locally. If spoils are identified to be hazardous, they would need to be hauled to and disposed of to the continental United States.

Piers and Platforms

Temporary piers and platforms would need to be constructed to allow barges to berth near shore and at the tunnel portal. Pile driving would likely be required to construct the temporary pier and platform. The temporary pier and platform may be constructed using modular pontoons, which may be available to be sourced locally, or may need to be imported.

Barging

Barging would be required to move construction equipment and spoils across the lake. Barges may be created using modular pontoons and then pushed using boats (Figure 4-6 and Figure 4-7).

Figure 4-6 8-Foot-Diameter Micro-Tunnel Boring Machine Being Recovered

Figure 4-7 Long-Reach Excavator and Spoils Barge Performing Dredging on Lake

Tunneling

Tunneling is specialty work, and this tunnel would require two types of tunneling methods: drill -and-blast tunneling method and mechanized tunneling method (TBM). The drill-and-blast tunneling method is required to create the initial 100 feet to 200 feet of starter tunnel, and involves drilling several small-diameter holes, filling them with explosives, and then detonating the holes in a controlled manner. The resulting rock muck would need to be hauled off using an excavator. The drilling would require specialized tunneling drilling machines (Figure 4-8) that would need to be brought in from outside Alaska, and the excavators may be sourced locally. Blast mats would be placed near the tunnel face to mitigate materials projecting fly-rock from the portal. The starter tunnel would also need to be supported using rock bolts and shotcrete.

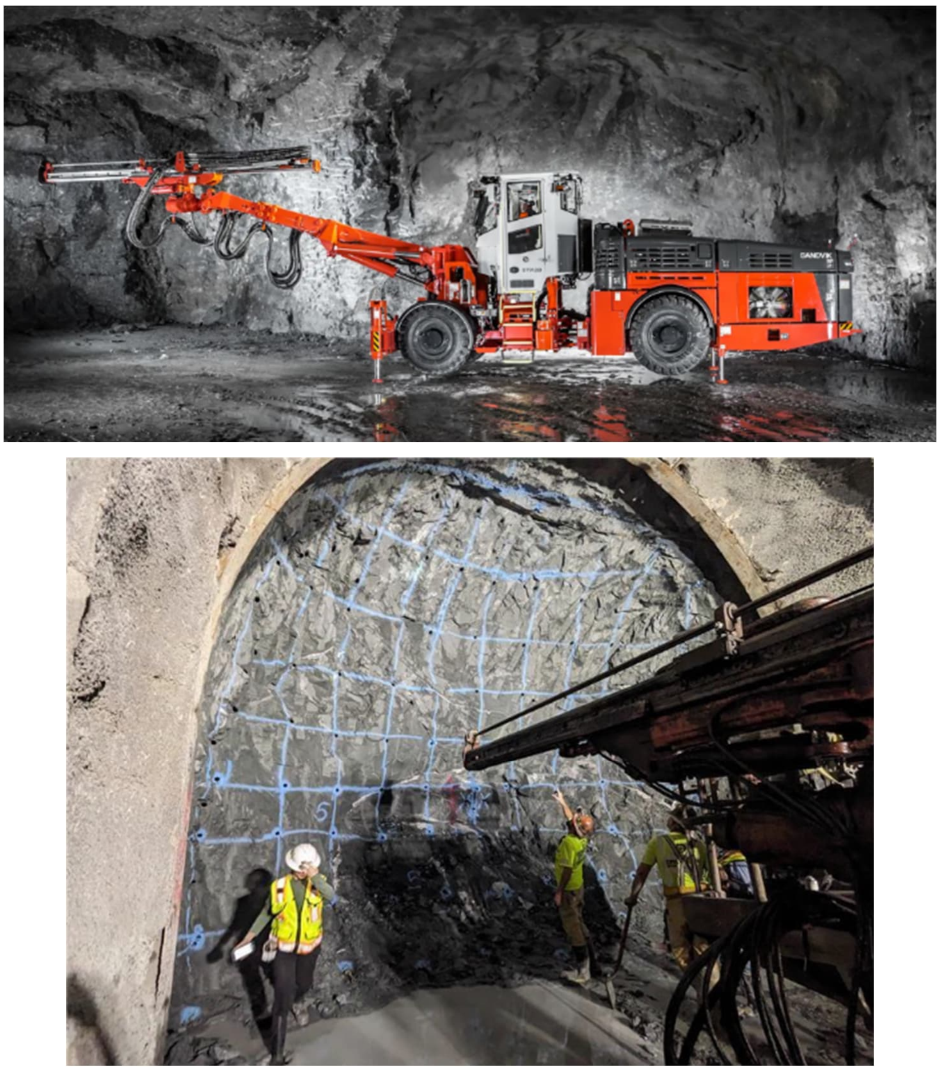


Figure 4-8 (Top) Tunneling Jumbo for Drilling Blast Holes (Bottom) Example of Blast Hole Pattern

Thereafter, the majority of the tunnel would need to be excavated using a TBM (Figure 4-9), which is specialized machinery that excavates and supports the ground concurrently.

Depending on the geology encountered, the use of closed-face EPB or slurry TBM may be preferred to an open-gripper or doubleshield TBM (Figure 4-10). The TBMs would require probe drilling and grouting capabilities, especially for the open TBMs, which have substantial schedule advantages. The choice of tunnel excavation method requires geotechnical and risk evaluation to determine the use of open or closed, shielded or unshielded TBMs. This evaluation would include geotechnical analysis, schedule requirements, risk and safety issues, and cost.

Single, double, open or closed TBMs may have ground support installed behind them, which would consist of reinforced-concrete bolted segmental rings (Figure 4-11). This specialty tunneling equipment, along with precast molds, would need to be imported, but the concrete segmental rings may be locally sourced.

Tunnel Waste

The tunneling process generates waste materials (i.e., tunnel muck) that consist of excavated rock and groundwater. For the drill-and-blast tunneling method, the first 10 to 30 feet of excavation would be near surface. Measures would be implemented to capture outflowing ground water at the tunnel's starting point: a water tank and a sump trap would be created to collect both infiltration water from the rock and construction water to control potential environmental contamination. Beyond this initial phase, construction water would be systematically contained and pumped into containers for treatment. In contrast, the closed TBM method seals the ground and groundwater at the machine's face, along with the installation and grouting of segmental lining. Tunnel muck, composed of rock, water, and tunneling conditioners, is transported out of the machine in a controlled manner through pipes; in the case of a slurry shield or variable-density TBM, the muck would be fluidized in the circulating slurry fluid, consisting of a suspension of additives and bentonite, pumped via pipes from the slurry mixing and treatment plant set up on the lakeshore, where the treatment plant separates the excavated spoil from the slurry fluid, which is recirculated back to the TBM. The separated spoil would be tested for contamination before disposal. For an EPB TBM, the spoil is removed either by muck haul cars running on rail track or by a continuous conveyor belt system. In this case a separation plant is not required, and the spoil can be tested for contamination and disposed directly. For all of these TBMs, a tunnel haulage train is required to deliver segments and or other support material to the TBM.

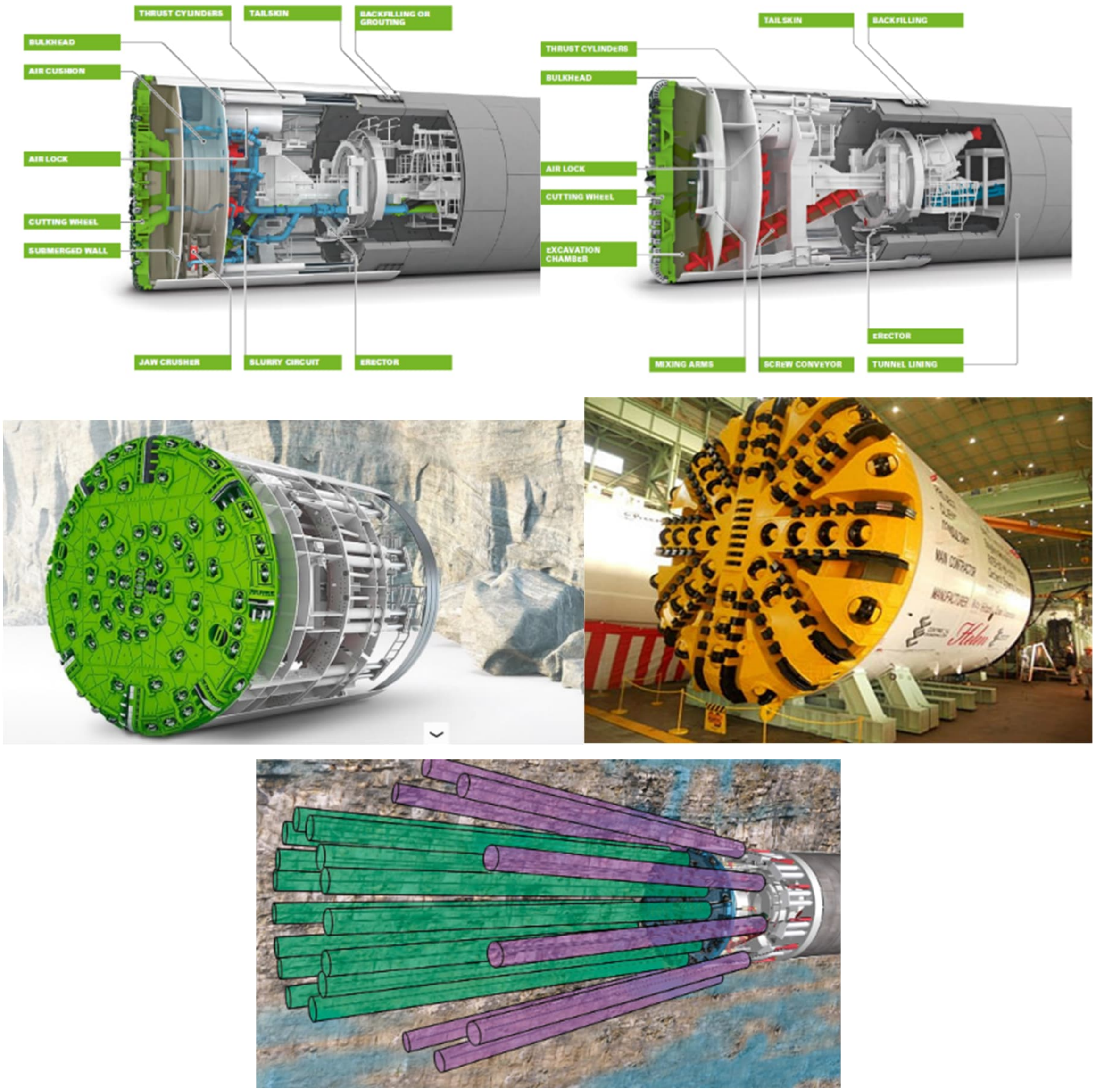


Figure 4-9 (Top Left) Slurry Tunnel Boring Machine; (Top Right) Earth Pressure Balance Tunnel-Boring Machine; (Center) Single-Shield Tunnel-Boring Machines; (Bottom) Probing and Grouting Capability

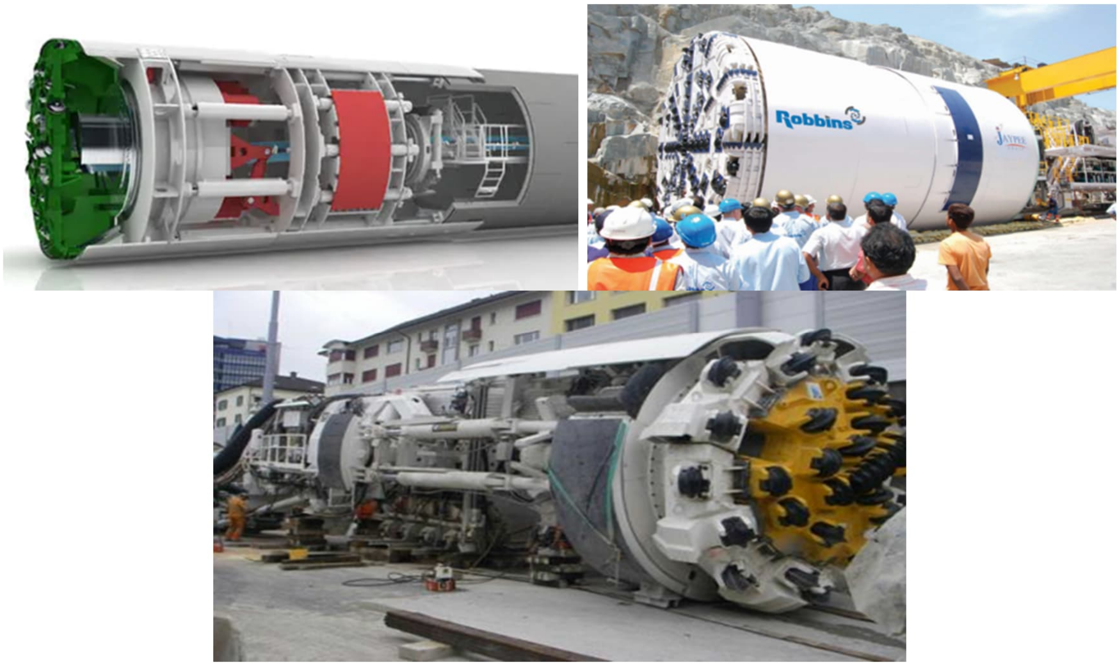


Figure 4-10 (Top) Open Double Shield for Rock; (Bottom) Open-Gripper TBM

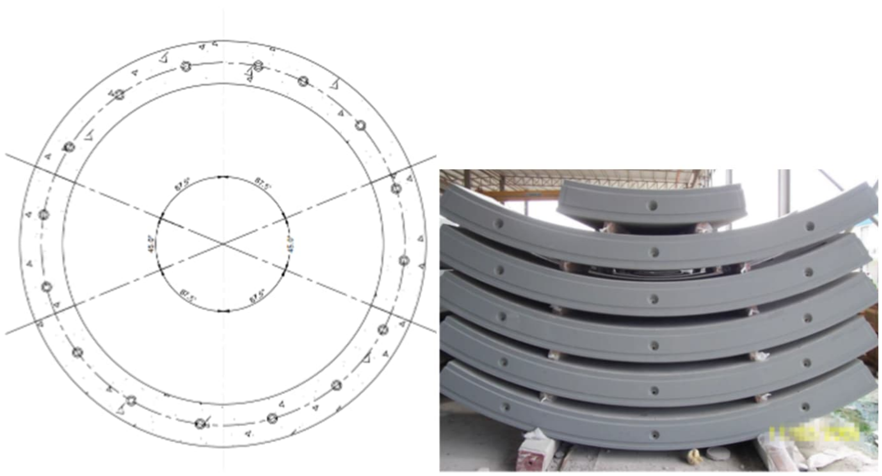


Figure 4-11 Tunnel Lining Section

Tunneling Risks during Construction

There are multiple risks associated with tunneling during the construction period; the Table 4-1 presents a preliminary list and mitigation measures.

Table 4-1 Potential Tunneling Risks and Mitigation Measures

Potential Risk	Potential Mitigation Measures
TBM equipment breaks down and there is a long lead time for replacement parts	Require contractor to have replacement parts on site prior to TBM work.
TBM is stuck due to ground loads, which would prevent further excavation	Perform geotechnical investigation to better understand the ground conditions and where areas of poor ground may be. Mining stoppage for extended periods shall only be limited in good rock conditions. Use an unshielded gripper TBM.
Shortage of segmental lining that would prevent TBM from continuously operating	Mandate that the contractor maintains a minimum stockpile of segmental lining throughout the construction process to mitigate interruptions to TBM operations.
Differing site conditions leading to TBM failure	Perform detailed geotechnical investigations to identify ground conditions, including potential high groundwater inflows. Develop grouting protocols to address these conditions directly from the tunnel heading. TBM must have probing and grouting capability and must be used for the full tunnel length.
Labor shortage leading to decreased production	Conduct early outreach to contractors, labor unions, and training centers to secure workforce availability. Require contractors to submit workforce development plans.
High ground and groundwater loads	Operate TBM to manage face pressure and groundwater inflows. Use a Hybrid TBM open and closed mode.
Longer-than-expected delivery of specialty tunneling equipment	Engage TBM suppliers early in the project to secure manufacturing slots and delivery schedule.
Working permit is revoked due to general public complaints or noise complaints	Conduct proactive public outreach, including community meetings and construction schedules. Implement noise-reduction measures.
Chimney (ground loss) develops above the TBM due to unexpected ground conditions	Monitor muck volume and pressure differentials to detect ground loss. Apply rapid grouting or foam injection and adjust TBM advance rates to stabilize conditions.
Ground conditions lead to excessive wear on the TBM equipment, decreasing production rate	Perform abrasivity tests during geotechnical investigations. TBM must have face access and back-loading tooling.
Working area is significantly damaged by a GLOF event	Include work restriction windows and site improvement in the design. Develop contingency recovery plans in advance of construction.
A GLOF event does not drain Suicide Basin sufficiently to allow for a dry lake tap tunnel by the TBM	Design for wet-tap capability using pre-installed bulkhead gates or water-tight chambers. Coordinate with hydrologic authorities for lake-level monitoring and provide redundant dewatering capacity.

4.1.7. Potential Intake Sub-Alternative

A sub-alternative for the Lake Tap Tunnel Alternative intake involves constructing a shaft adjacent to Suicide Basin that would be the termination point for the TBM tunnel discussed above (Figure 4-12). From this shaft, multiple intakes could be driven into Suicide Basins using a Microtunneling Boring Machine (MTBM), which would allow breaking into Suicide Basin in a wet condition. This subalternative is not included in the provided cost estimate.

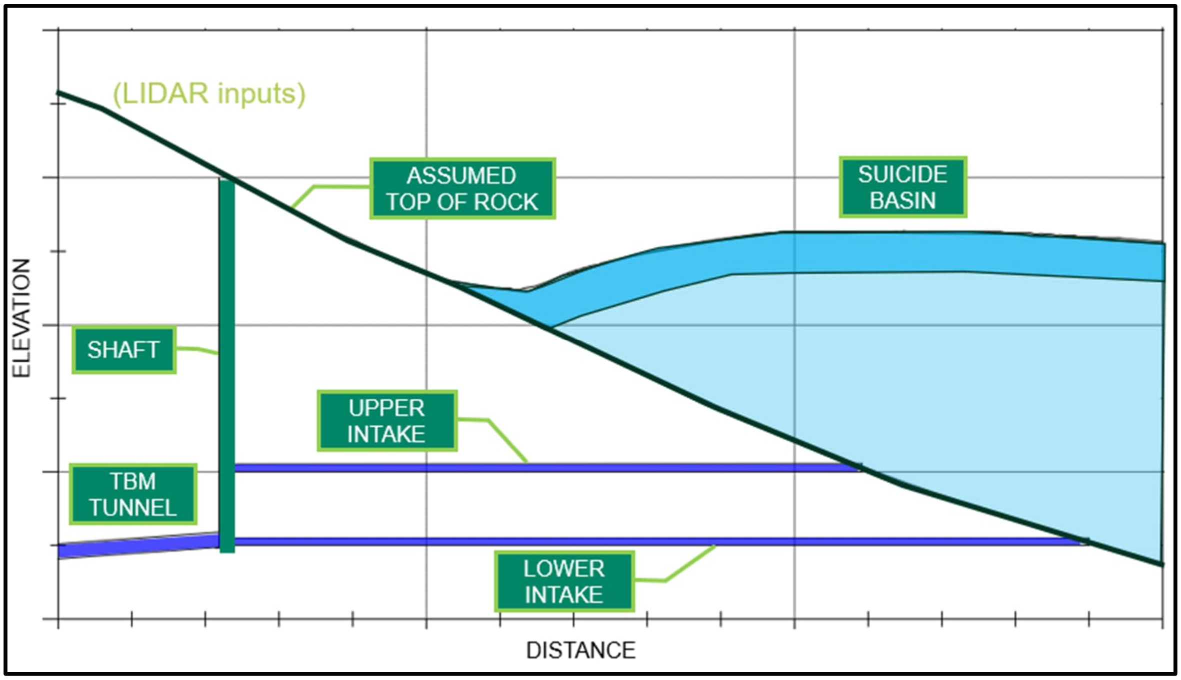


Figure 4-12 Multi-Level Intake Sub-Alternative

For this sub-alternative, the TBM tunnel would be required to be a larger diameter to accommodate the shaft and the potential higher flows from multiple intakes. The shaft would be approximately 30 feet in diameter to allow room for the multiple intakes and to launch the MTBM. The MTBM intakes would be approximately 6 to 8 feet in diameter. This would be similar to the Anderson Dam project in California. An air vent reinforced concrete lining, and vortex structure would then be installed in the shaft.

The option of an intake shaft drilled in the wet would create high risks for safety and constructability even if bringing the rigs and barges and other equipment would be possible with heavy-lift helicopters.

4.1.8. Design and Construction Duration

The design of the Lake Tap Tunnel Alternative would require a phased approach that includes preliminary design, final design, outreach, contractor procurement, and construction. The preliminary design phase would involve further desktop studies on geotechnical and geological conditions, structural analysis, hydraulic modeling, environmental conditions, and conceptual layouts to identify data gaps that would be used to inform the data collection during the final design. The completion of the preliminary design could then allow the RFQ for onboarding a contractor team if Progressive Design–Build (PDB) delivery was chosen. Either way, the final design would include data collection either by the PDB team or the owner if Design–Bid–Build (DBB), such as geotechnical investigation information to refine the preliminary design and develop the guaranteed maximum price (GMP) and contract documents for PDB or for contractor procurement in DBB. Stakeholder outreach would be conducted concurrently with design phases to address community concerns and environmental compliance, and foster collaboration with regulatory agencies.

For a DBB process, the bidding/contractor procurement phase would begin after the final design phase, but early advertisement and contractor outreach is anticipated to occur prior to completion of final design. Construction is anticipated to take 3 to 4 years, and is influenced by equipment procurement, staging area development, weather restrictions, and GLOF events. Table 4-2 presents a schedule for a DBB procurement.

Table 4-2 Design and Construction Schedule

Item	Schedule*
Reference Preliminary Design	January 2026 to May 2026
Final Design	June 2026 to November 2027
Stakeholder Outreach	June 2026 to November 2027
Request for Qualifications	March 2027 to November 2027
Bidding/Contractor Procurement Phases	November 2027 to March 2028
Construction Duration	March 2028 to October 2031

*Schedule presented is approximate. Start dates are subject to approvals.

As part of this phase, the project team completed a preliminary review of construction logistics associated with the Lake Tap Tunnel Alternative, including high-level assessments of access road conditions, potential road-widening needs, site land re-arrangement, and requirements for construction staging and laydown areas.

This review relied on available public information on local traffic patterns, roadway constraints, utilities, and community infrastructure within the Mendenhall Valley transportation network. These investigations were undertaken solely to confirm feasibility at a screening level, and no detailed engineering, modeling, or permitting evaluations were performed at this stage.

Final access design, construction traffic planning, site optimization, and confirmation of required improvements would be completed only during the subsequent Preliminary Design stage, following additional survey, geotechnical, environmental, and coordination inputs from CBJ, USACE, and Alaska Department of Transportation and Public Facilities (ADOT&PF). All these new data and analyses would inform a more certain design and construction schedule that can be transmitted at a later stage.

4.1.9. Reliability/Adaptability/Resiliency

Reliability

The Lake Tap Tunnel Alternative is a reliable solution, providing continuous dewatering to mitigate future GLOF events from Suicide Basin. Hydraulic modeling has indicated that the tunnel can pass the design flows in an open channel configuration, making sure that the tunnel remains unfilled. Additionally, Mendenhall Lake is capable of accommodating these inflows without causing a significant rise in water elevation, further demonstrating the reliability of this alternative.

Adaptability

Although effective in addressing GLOF risks specifically from Suicide Basin, this alternative does not mitigate potential GLOF events from other basins in the Mendenhall Glacier system. Furthermore, it may not adapt to changes in the shape or dynamics of Suicide Basin over time, limiting its broader applicability to evolving glacial conditions.

Resiliency

The Lake Tap Tunnel Alternative is designed with resilience in mind, capable of withstanding critical loading conditions such as earthquakes and risks associated with freezing or clogging. Historically, tunnels—particularly those constructed in rock—have demonstrated strong performance during seismic events and have remained functional and reliable under extreme conditions.

4.1.10. Operations and Maintenance

The Lake Tap Tunnel Alternative is designed as a gravity drainage system, eliminating the need for a control structure to regulate inflow and outflow. However, regular inspections and maintenance are critical to maintaining the long-term functionality and safety of the system.

Inspections should include both unmanned (drone) and manned evaluations of the intake and outfall structure and tunnel on a regular basis. Additional inspections will be necessary following any major outflow events to identify potential distress or damage to the system. Regular monitoring of the intake screen and iceberg control structure is essential to check for blockages or freezing conditions, particularly during colder months and when these risks are heightened.

A primary long-term operational challenge for the tunnel is managing the significant potential for abrasion damage to the concrete liner from high-velocity, sediment-laden flows. A proactive inspection and maintenance program will be critical. The design may need to incorporate a hardened or sacrificial liner (e.g., steel, high-strength concrete, or granite blocks) in high-velocity zones to ensure the tunnel's 50-year design life and prevent costly, long-duration shutdowns for repairs.

Hydraulic analyses will evaluate the potential for freezing of water in the tunnel, particularly during low flow time periods, with potential for cross section reduction: currently this is a low risk even if with potentially high mitigation costs for either more frequent inspection and fix or permanent heating solutions; it will be further studied in the design development stages.

Maintenance and repairs would be required throughout the system's design life. The screen intake is expected to need periodic maintenance, repair, and potential replacement due to environmental exposure. Maintenance-level repairs of the tunnel's concrete lining and the outfall structure are also anticipated, especially due to high-flow velocities and freezing conditions. These repairs should be scheduled during winter months, when inflows from Suicide Basin are minimal to no flow, such that the tunnel maintenance can be performed without an intake gate. This intake gate will be further considered during the preliminary design phase. Additionally, annual avalanche mitigation measures should be implemented at both the outfall and intake to mitigate clogging or structural damage.

Lifecycle costs would primarily consist of expenses related to inspections, monitoring, and routine maintenance of the intake screen, tunnel lining, and outfall structure. Repair and replacement of the intake screen, along with periodic repairs to the tunnel lining and outfall, would contribute to overall lifecycle costs. Budgeting for annual avalanche mitigation would also be necessary to maintain the safety and functionality of the system.

4.1.11. Risk Reduction/Life Safety

Risk evaluation for the Lake Tap Tunnel Alternative summarized in the paragraphs below is qualitative and includes three criteria:

- Risk reduction (life loss and economics)
- Failure likelihood of the lake tap tunnel
- Ability to meet USACE TRGs

Refer to the risk section for descriptions of the meanings of these three aspects of risk.

Risk Reduction

A tunnel that continuously drains Suicide Basin into Mendenhall Lake and maintains low water elevations in the Basin is expected to significantly reduce downstream flood risk. This reduction in flood risk would, in turn, lower life safety hazards for residents and visitors in the Juneau area while also minimizing the potential for economic damages. This alternative is aimed at protecting vulnerable assets such as homes, utilities, and tourism facilities from the impacts of GLOF events, and it would help preserve community infrastructure by reducing both the frequency and severity of flooding.

Failure Likelihood of the Lake Tap Tunnel

Estimating the failure likelihood of a tunnel not yet designed or constructed with a reasonable degree of confidence is a risk itself, given the significant number of unknowns at the present time. However, based on preliminary evaluation of available hydrologic, hydraulic, geological, and geotechnical information, several potential failure modes (PFM) appear to be credible and further evaluation as additional data become available is recommended. These PFMs, along with potential risk mitigation measures, are listed in Table 4-3.

Table 4-3 Potential Failure Modes and Mitigation Measures

Credible PFM	Potential Risk Mitigation Measure
Clogging or freezing of the intake screen resulting in reduced conveyance through tunnel and downstream flood impacts.	• Design the screen with larger spacing to minimize freezing conditions. • Shape the screen, use size grading control ahead of the main screen to mitigate clogging caused by large icebergs or debris. • Implement regular monitoring of the screen to identify and address clogging or freezing occurrences promptly.
Water freezing the tunnel resulting in reduced conveyance through tunnel and downstream flood impacts.	• Consider installing heating units or some other method at regular intervals in the tunnel to reduce ice formation. Further analysis on temperature and velocity/flow would be performed to confirm the need.
Tunnel concrete lining is damaged from high velocity flows resulting in progressive erosion/degradation of tunnel interior, leading to tunnel failure and downstream flood impacts.	• Design the tunnel lining (reinforced concrete or steel) to withstand high flows and abrasion. • Perform regular inspections and monitoring of the concrete lining to detect early signs of wear or damage.
Outfall is clogged by freezing conditions or other obstructions, resulting in reduced conveyance through tunnel and downstream flood impacts.	• Conduct regular monitoring of the outfall to identify and address obstructions. • Install flow monitoring instrumentation to detect anomalies.
Ground and groundwater loads exceed the lining capacity, resulting in progressive erosion/degradation of tunnel interior, leading to tunnel failure and downstream flood impacts.	• Conduct detailed geologic and geotechnical investigations to assess ground and groundwater loads. • Design the tunnel lining to accommodate the anticipated loads and implement reinforcement where necessary. • Additionally, consider installing seepage ports in the tunnel lining to facilitate controlled drainage and reduce hydrostatic pressure buildup.
Slope instability at the intake or outfall resulting in sloughed rock/soil obstructing tunnel flow and reduced tunnel conveyance and downstream flood impacts.	• Conduct geologic and geotechnical investigations, including stability analyses, to identify potential slope instability risks. • Monitor intake and outfall structures regularly to detect and address slope movement or obstructions.
Abrasion of the liner to failure.	• Regular and extraordinary maintenance, or installation of an abrasion resistant liner such as a steel liner.

Ability to Meet USACE Tolerable Risk Guideline

The third criterion is the ability or willingness of the responsible or affected parties (USACE, Sponsor, Stakeholders, Public) to meet the four USACE TRGs:

- TRG 1 – Understanding the risk.
- TRG 2 – Continuing risk awareness.
- TRG 3 – Monitoring and managing risk.
- TRG 4 – Taking action to reduce risk.

Together, the four TRGs encompass all phases of alternative implementation: planning, design, construction, and operation. Any project that would be constructed would include all necessary project features to ensure that the project meets USACE's four TRGs. The four TRGs can be better understood in terms of key questions provided in the risk section, which were discussed during the charrette and helped charrette participants collaboratively identify whether the TRGs can be met.

Several key questions are provided below as examples:

- **Is the risk associated with the Lake Tap Tunnel Alternative reasonably understood by all responsible/affected parties (TRG-1)?**

- **Will risk be properly monitored and managed throughout the operational period of the Lake Tap Tunnel Alternative (TRG-3)?** For example, would regular tunnel inspections be performed to monitor tunnel integrity and make necessary repairs?

- **Is it likely there would be cost-effective, socially acceptable, or environmentally acceptable ways to reduce any credible risks identified during the charrette or new risks that may be identified after construction (TRG-4)?** For example, if updated future GLOF estimates indicate increased water volume in Suicide Basin that exceed tunnel design assumptions, how would any increased risk be mitigated?

4.1.12. Operational Impacts

During construction, there may be impacts to roads due to construction hauling (e.g., tunneling equipment, or waste debris), and, where roads are narrow, lane closures may be required to transport large construction equipment. However, it is anticipated that most operations during construction would take place from barges or with the support of helicopters due to the remote area, where temporary platforms in front of Suicide Basin or on the mountain can be created to support portal construction, final breakthroughs, and even borehole drilling (Figure 4-13). Construction operations such as barging equipment and drill-and-blast activities may impact local vendors.

Once construction is completed and the system is installed, minimal operational impacts are anticipated to existing structures since the Lake Tap Tunnel is isolated. Boats and/or maintenance equipment may periodically be transported on Mendenhall Lake to the Tunnel, but large equipment that would impact existing structures such as bridges is also not expected.

Figure 4-13 An Example of "Crux" Platform Installed on a Mountain Side

4.1.13. Environmental/Cultural Considerations

Staging and construction of the tunnel would have environmental and cultural impacts that need to be assessed during the design phase. Staging areas, even if limited in dimension, would require vegetation clearing and lake dredging, which would impact wildlife habitat, fish spawning, and recreational areas. Cultural resources and historic properties in the Valley, including areas of significance to Indigenous communities, may also be impacted, requiring consultation and compliance with the National Historic Preservation Act (NHPA).

From a regulatory standpoint, the project would require local, state, and federal permits and coordination between multiple agencies, including fulfilling requirements of Section 404 of the Clean Water Act, Alaska Department of Environmental Conservation (ADEC) water quality certifications, and consultations under the National Environmental Policy Act.

Environmental Impacts

- Threatened, Endangered, Sensitive, and Special-Status Wildlife Species: Queen Charlotte Goshawk (USFS Region 10 Sensitive Species), Bald Eagle (protected by the Bald and Golden Eagle Protection Act), harbor seals (protected by the Marine Mammal Protection Act). The shore of Mendenhall Lake is also an important area for breeding seabirds, including Arctic Terns, Mew Gulls, Herring Gulls, and Glaucous-winged Gulls, all protected by the Migratory Bird Treaty Act. Some seabird nesting occurs on Bullard Mountain. Consultation would be required with USFS and United States Fish and Wildlife Service (USFWS) for construction activities that could result in take. Seabird nesting and nearby Goshawk nests should be taken into consideration when determining construction schedule.

- Fish Habitat: Mendenhall Lake and Mendenhall River and its tributaries are home to spawning populations of coho salmon, sockeye salmon, Dolly Varden char, coastal cutthroat trout, and rainbow trout/steelhead trout. Fish spawning should be taken into consideration when determining construction schedule. Consultation would be required with the National Marine Fisheries Service (NMFS) for Essential Fish Habitat.

- Other Wildlife: Bullard Mountain is mountain goat habitat. Tunnel construction would be organized to minimize causing displacement.

- Vegetation: Sensitive plant species jointed rush (Juncus articulates) is found in the area. Coordination with USFS would be considered, but limited surface occupancy is expected.

- Cultural Resources: Archaeological sites and traditional use areas require NHPA Section 106 review with the State Historic Preservation Officer (SHPO), NEPA review and tribal consultation to determine impacts, assess potential mitigation, and consider possible inclusion in the National Register of Historic Places (NRHP).

- Historic Properties: Sites of particular concern include Skater's Cabin (JUN-00242), Mendenhall Campground (JUN-01303), and Mendenhall Glacier Visitor Center (JUN-00579), and others in the vicinity of the lakeshore. In addition, the entirety of the Mendenhall Glacier Recreation Area (MGRA) is designated as a Historic Property. Historic Properties require NHPA Section 106 review with the SHPO, NEPA review, and tribal consultation.

- Air Quality: Juneau is a maintenance area for particulate matter 10 microns in diameter or smaller; dust from haul roads and material stockpiles must meet State Implementation Plan requirements.

- Noise and Traffic: Heavy equipment and material hauling would increase noise and congestion primarily along Glacier Highway and Egan Drive, particularly during tourism season, which would coincide with the available ice-free construction window.

- Water Quality: Sediment and turbidity from stream crossings require best management practices. Dredged material management would include characterization of the material and specific environmental controls prior to determining disposal procedures. Tunnel muck and water generated during tunneling require appropriate collection and disposal.

- Vegetation Clearing: Clearing for staging areas and access roads would remove vegetation.

- Recreation and Visual: MGRA is a major tourist destination with more than 1 million visitors annually; construction would likely not disrupt access to most visitor activities and would have limited impact to scenic views, most of which would be temporary. The tunnel outlet would not be visible from Nugget Falls or Mendenhall Campground once construction is complete. Tourism activities on Mendenhall Lake, such as personal watercraft, would be disrupted by barge activity.

- Socioeconomics: Juneau's economy depends heavily on cruise tourism; prolonged construction could reduce visitor satisfaction and revenue.

4.1.14. Permitting Concerns

State, federal, and local permits that may be required under this alternative include the following:

- USACE requirements under Section 404 (Clean Water Act) – Dredging and/or discharge in Mendenhall Lake or Waters of the U.S. The Clean Water Act is enforced by the ADEC.

- USACE requirements under Section 401 (Clean Water Act) – Certificate of Reasonable Assurance for potential discharge into Mendenhall Lake. The Clean Water Act is enforced by the ADEC.

- NEPA is required for major federal actions unless otherwise exempted (USACE and USFS).

- Magnuson-Stevens Fishery Conservation Management Act – Essential Fish Habitat consultation with National Oceanic and Atmospheric Administration (NOAA) Fisheries.

- NHPA Section 106 – SHPO and tribal consultation.

- USFS Special Use Authorization – Required for construction activities, such as motorized vessels on Mendenhall Lake.

- USFS consistency with the 2016 Tongass Forest Plan

- Fish Habitat Consultation – NOAA Fisheries for Essential Fish Habitat.

- Anadromous Fish Act (AS 16.05.871-.901) – Fish Habitat Permit – Alaska Department of Fish and Game (ADF&G) for anadromous streams.

- Coordination with Tlingit and Haida and Alaska Native Claims Settlement Act Regional and Village corporations for cultural and land interests.

4.1.15. Key Takeaways

- Primary Benefit: The Lake Tap Tunnel Alternative significantly reduces the risk of a Suicide Basin GLOF event by passively draining the Basin, and significantly reduces the risk of downstream floods.
- Major Challenges: Access to the project site, steep tunnel slope and high flow velocities.
- Although the tunnel avoids the risks of a water-retaining structure, its long-term viability is critically dependent on managing liner abrasion, which represents a potential operational risk and possibly a key driver of lifecycle costs.
- Critical Unknowns: Surface and subsurface geological and geotechnical conditions. Hydrologic loading on the system and the analyses required. Extensive geotechnical investigation and design will be required.
- Schedule: 5 to 6 years from design to commissioning, with seasonal construction constraints.

4.1.16. Discussion

Following the presentation of the Lake Tap Tunnel Alternative during the charrette, a number of questions were posed by participants. These talking points are summarized below. Please refer to Appendix B: Charrette Meeting Minutes for additional information.

Geotechnical and Subsurface Data:

- A question was posed about the timing of subsurface investigation for the Lake Tap Tunnel Alternative. Subsurface investigations would be conducted during the next design phase.
- There were concerns regarding the lack of geotechnical data and how that would impact cost and the participants' ability to evaluate this alternative based on its cost. It was noted that the current cost evaluation includes a robust TBM, which can drive through hard rock and poor ground conditions such as faults and shear zones.
- There were additional concerns about the lack of geotechnical data at this stage. The next steps for design include more in-depth geotechnical investigation and analyses. It is not uncommon for a tunnel project in mountainous terrain to do geotechnical studies during the preliminary design phase. No geotechnical desktop analysis had been done as of the charrette. A geological desktop analysis was begun prior to the charrette that indicated the proposed alignment area would encounter hard rock and shear zones. It is not likely that there is homogeneous hard rock across the length of the alignment.

Operations and Maintenance:

- In terms of lining maintenance, the lining would be made of concrete, but steel could be used if necessary.

- There was discussion about how to mitigate potential large debris or landslides in Suicide Basin impacting the intakes and tunnel. There are no large trees in the area, but clogging risk from ice was considered. It was suggested to install a steel screen to reduce large debris from entering the intake. Slope stability would be considered in the next design phase.

- There were questions about the assumptions used to estimate the number of individuals needed for maintenance each year. Tunnel maintenance is usually done by drones and real-time monitoring equipment. Specialized crews would be used on occasion, but not frequently.

- There was discussion about the cost and complexity of O&M, including the potential need for specialized crews and their costs. It was reiterated that the capital cost estimates presented at the charrette are orders of magnitude for the purposes of comparison between the alternatives. O&M costs will be further studied once an alternative is selected.

Environmental and Cultural Impacts:

- A participant commented that additional studies on environmental impacts, and the impacts of the byproducts of drilling machines, should be completed. There were concerns about increasing water alkalinity, impacting water clarity, and negatively impacting wildlife. Mitigation strategies were then discussed, including transporting out tunneling byproducts in a controlled manner and capturing water and performing water treatment. It was noted that tunneling additives are used often in environmentally sensitive areas.

- There were concerns about tourism and cultural impacts, especially at the staging site. Multiple staging areas were discussed. At the current proposed staging area there would likely be more traffic near the boat ramp, with barges moving across the lake during the construction period. These impacts would be looked at further.

- A question was asked about the environmental impact of water inflow into Mendenhall Lake. Water inflow is estimated to be less than one-tenth of the volume of the lake. There is not an anticipated significant impact on water temperature, but this would be considered in the next design phase.

- There was a question about whether TBM runs the risk of shaking loose rock and ice, causing unforeseen issues, and whether the TBM would affect mountain wildlife. The proposed drilling methods are not expected to have significant impacts. These methods are used near sensitive sites, such as near the Colosseum in Rome and near a symphony hall, without any reported impacts. Additionally, after the initial blasting to start the tunnel, the drilling will occur a couple of hundred feet underground. There are mitigation measures that can be taken during that initial blast phase such as scaling loose rock above the tunnel prior to the initial blast.

- There was discussion about acid drainage and why the cost proposal included HAZMAT disposal. It was explained that there are three kinds of rock expected based on existing literature and what is visible: tonalite, shear zones, and metamorphosed volcanics and sedimentary rocks. In shear zones, iron sulfides such as pyrite could form that could cause acid rock drainage. Part of the geotechnical program would include geochemical analysis to understand this potential. For the purposes of cost, a conservative estimate was made that this material would need to be shipped offshore as hazardous material.

Tunnel Design:

- There was a question about the exterior diameter of the tunnel. The conceptual design has an excavated diameter of 13 feet with a 16-inch-thick lining.
- Other portal alignments were considered, and the one presented was the base case.
- A question was asked about ice freezing on the trash racks. The design would consider temporary blockage events.
- The tunneling methods proposed for the alternative have precedent in other places, including in Alaska. It is the first time these methods would be used to mitigate a GLOF.

Construction Timeline:

- Concerns were raised about the estimated timeline for construction, because Mendenhall Lake can freeze over and limit the construction window (due to barge transport across the lake when frozen). Weather restrictions were noted and factored into the construction timeline.
- There was discussion about the proposed construction period and how work crews would be transported across the lake during the winter months, approximately October through April. The time when ice covers the lake needs to be confirmed and incorporated into the construction schedule. It is possible there could be other strategies to consider that could prolong the construction period during the winter.

4.2. Dam Alternative

4.2.1. Technical Discussion

Overview

The Dam Alternative would provide for flood control to detain or regulate flows into the Mendenhall River to reduce downstream peak discharges from GLOF events. Dam types to consider include Earth Core Rockfill Dam (ECRD), Concrete-Face Rockfill Dam (CFRD), Hardfill Dam (HFD), or Asphalt Core Rockfill Dam (ACRD). Design must address seismic loading, rapid drawdown, seepage control, foundation treatment, and constructability in a subarctic-maritime, glacier-influenced environment.

Construction of the dam alternative would require relocation of 90 structures affected by the dam footprint, construction zone, or from inundation if unprotected. The analysis of potential effects associated with relocation for this alternative is discussed under the Section 4.5 Relocation Alternative, as partial relocation.

Objectives and Performance Criteria

- Reduce peak discharge to meet life-safety and economic risk reduction goals.
- Provide reliable performance under seismic events and rapid reservoir fluctuations.
- Minimize uncontrolled seepage, piping, and slope instability.
- Deliver maintainable features and emergency action planning consistent with USACE Dam Safety practices and ER 1110-2-1150 guidance.
- Achieve constructability and schedule alignment with intent to begin construction soon after November 2027.
- According to the MBI hydraulic model, a 30,000 cfs peak-flow scenario can be conveyed by the existing river channel, although some flooding is still expected in the northern part of the Valley, including areas such as View Drive. Design storage capacity is based on this assumption.
- Primary and emergency spillways are assumed to be concrete chutes with energy dissipation structures.
- Material sources are assumed to be locally available with suitable gradation.

Geologic Conditions

The bedrock in the area consists of the Coast Plutonic Complex tonalite that forms steep valley walls and local outcrops; this is generally strong but foliated and can fracture along foliation planes. Much of the Valley floor and near-lake margins are covered by glacial and fluvial sediments—tills, outwash, and fine “glacial flour” (silt and clay)—that vary laterally and commonly have low permeability where fine sediments dominate. The area is actively evolving because of glacier retreat, changing ice-dam geometry in Suicide Basin and of the Mendenhall Glacier, and repeated GLOFs that alter sediment distributions and channel form the soil conditions surrounding Mendenhall Lake, characterized by permeable alluvial deposits and glacial sediments, make seepage a critical consideration for a proposed dam structure. Excessive seepage can lead to internal erosion (piping), instability, and ultimately, structural failure. To mitigate this risk, the dam would be designed as a “dry dam,” meaning it would primarily function as a flood-control structure rather than a permanent reservoir. By limiting the volume and duration of water impounded behind the dam, a dry dam significantly reduces seepage potential through the foundation and abutments.

Hydraulic Loading

Figure 4-14 presents the inundation extent corresponding to the proposed dam peak release of approximately 30,000 cfs. Under this condition, the majority of the flow is conveyed within the Mendenhall River, with only limited downstream flooding. Residual flooding is primarily observed along View Drive and in a few other downstream areas, which would require additional mitigation measures. The inflow hydrograph used in the hydraulic model is based on the peak design flow of 118,000 cfs, as described in Section 3.6 (Hydrologic Inputs). The inflow hydrograph is shown in Figure 3-5.

For this preliminary analysis, dam outflow was modeled as a function of available head, allowing the discharge hydrograph to develop in response to upstream water levels rather than imposing a release rate. This approach represents a passive outlet configuration, in which outlet capacity increases with head and does not rely on active operational controls.

Figure 4-14 Inundation Extent for the Peak Release Scenario ~30,000 cfs

Figure 4-15 presents water surface elevations for the dam alternative along the profile line shown in Figure 4-15a. Figure 4-15b compares reservoir water surface elevations for two peak release scenarios: approximately 30,000 cfs (S1) and approximately 50,000 cfs (S2). This comparison illustrates how dam outflow affects maximum water surface elevation within the reservoir. As dam releases increase, less water is stored in the reservoir, which reduces the maximum water surface elevation and, in turn, the required dam height. This indicates that alternative outlet configurations that allow higher or more sustained releases could potentially reduce dam height by releasing water more rapidly. However, higher or more constant releases would also increase downstream flows and could introduce additional flood risk, requiring channel armoring, relocation and/or other downstream mitigation measures. Additional discussion of alternative outlet works from a hydraulic perspective is provided in Section 3.7.1 (Assumptions and Considerations).

It should also be noted that, if this alternative is selected as the preferred engineering solution, the next phase of design would require more detailed inflow-outflow hydraulic analysis and a fully developed outlet structure capable of releasing flows based on a defined hydrograph.

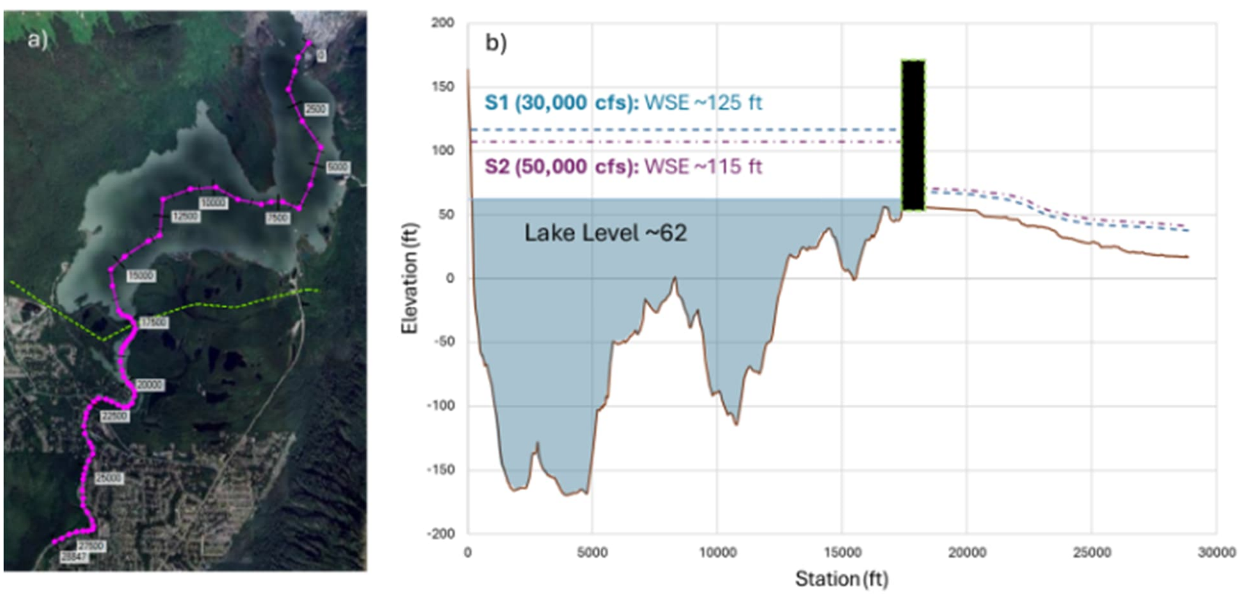


Figure 4-15 Approximate Maximum Water Surface Elevation for Peak Release Scenarios of S1 = ~30,000 cfs and S2 = ~50,000 cfs

Dam Alignments

Two dam alignments were chosen for consideration for this alternative: upstream (Figure 4-16) and downstream (Figure 4-17). Each alignment spans the Valley from west to east. A minimum crest width of 10 feet was assumed for conceptual volume and cost calculations. If the dam alternative had been selected as the base option, the crest width would need to be adjusted based on the specific dam type. Additionally, the crest may need to be wider to accommodate riprap, embankment zoning and constructability.

- The upstream alignment (Figure 4-16) follows high ground to the maximum extent practical and crosses the outlet of Mendenhall Lake where the river channel is narrowest. This alignment is approximately 2.4 miles in length and has an estimated design height of 60 feet based on storing a design event with a peak flow release of 30,000 cfs. This alignment would extend through the Mendenhall Campground and require relocation of approximately five private properties. Two roads would need to be reconstructed to go up and over the new dam alignment. The upstream alignment is the recommended alignment for the Dam Alternative.

- The downstream alignment (Figure 4-17) follows a higher ridge further south, crossing the Mendenhall River before a tight bend. This alignment provides more storage capacity for Mendenhall Lake and therefore requires a lower dam height at about 40 feet, based on the same hydraulic considerations. The alignment is approximately 2.5 miles in length. The downstream alignment extends closer to residential areas, specifically along View Drive, and would require relocation of at least 35 private properties. This option would also leave Mendenhall Campground unprotected from future GLOF events. Similarly, two roads would need to be reconstructed to go up and over the dam.

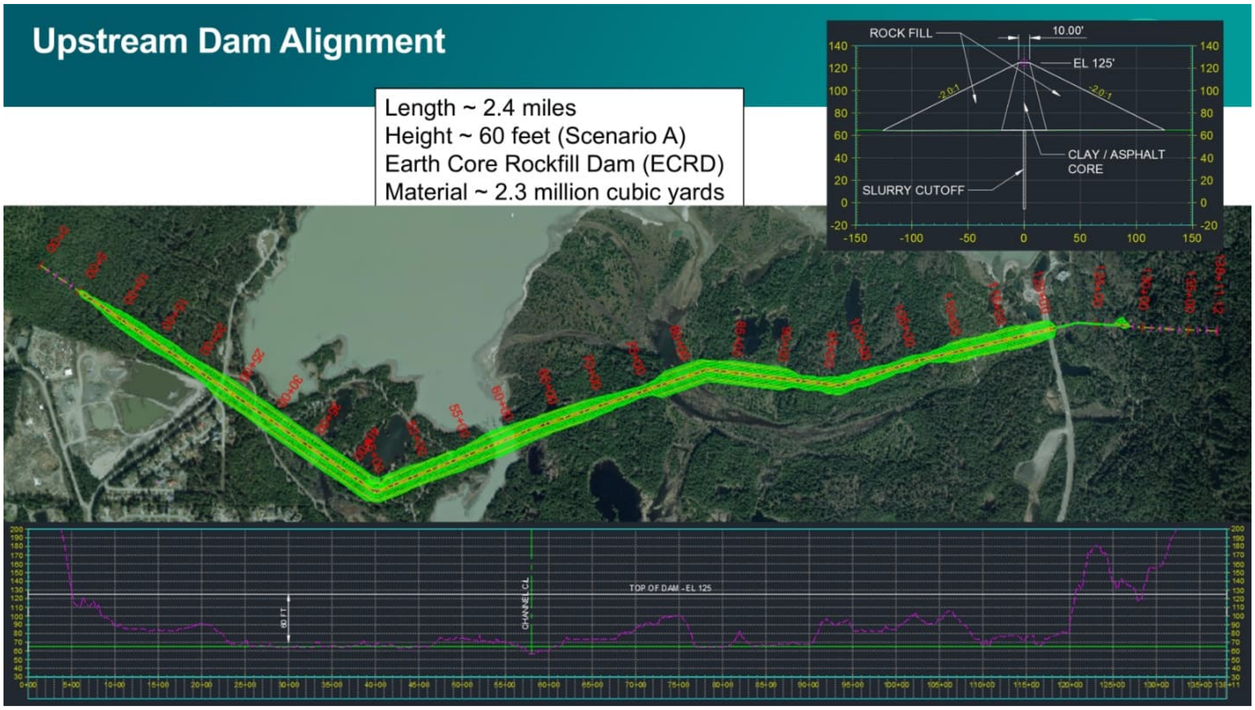


Figure 4-16 Upstream Alignment

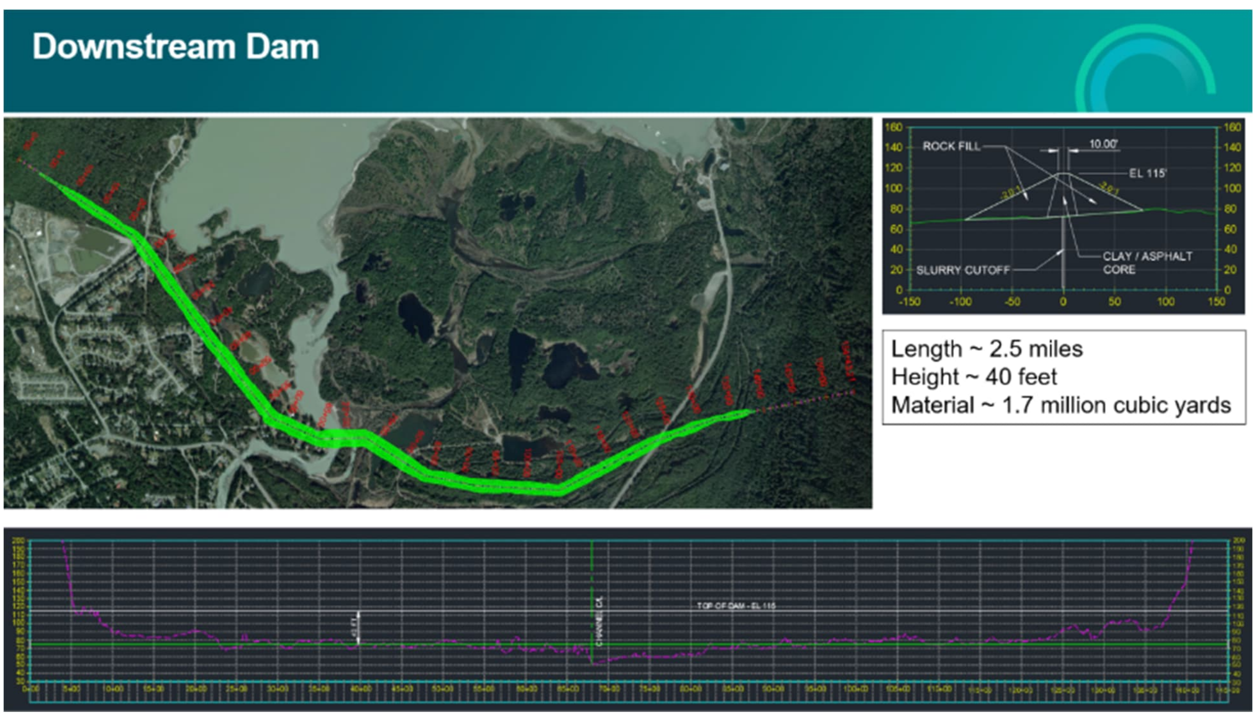


Figure 4-17 Downstream Alignment

Dam Types

To evaluate this alternative, four dam types were considered:

- Concrete-Face Rockfill Dam (CFRD)
- Hardfill Dam (HFD)
- Earth Core Rockfill Dam (ECRD)
- Asphalt Core Rockfill Dam (ACRD)

Hydraulic Components

The following hydraulic components were not modeled as part of this preliminary analysis, but are identified here to inform and guide future design considerations, if this alternative is selected:

- Spillway: Adequate capacity for design floods, consideration of gated versus ungated spillways, energy dissipation, and protection. Spillway design will consider both a "Service" spillway and an "Emergency" spillway for conveying the project flood (GLOF event) and for dam safety based on the inflow design flood and the hazard potential classification of the dam.

- Outlet works: Investigate alternative outlets that include intake structure, trash racks, control gates, conduit size to manage outflow and minimize blockage risk from ice/debris (refer to Figure 4-18 for example outlet works, and Figure 4-19 for potential outlet works location.)

- Cofferdams and temporary dewatering: Need to be planned to address GLOF season, including design temporary works for construction phases considering access, ice, and flood events.

Figure 4-18 Outlet Works from Moose Creek Dam

Figure 4-19 Potential Location of Future Outlet Works at Mendenhall Lake

4.2.2. Technical Unknowns

The lack of geotechnical information and detailed hydrological data for the Mendenhall Valley introduces significant uncertainty into the design process for a potential dam. Subsurface conditions are poorly characterized; existing information is general and limited to a few shallow borings near the visitor center and at a bridge; these are unlikely to represent the Valley's unique foundation conditions. Critical unknowns include the depth and variability of glacial and alluvial deposits, presence of weak or organic layers, groundwater conditions, and the location and quality of bedrock for potential keying of the dam structure. Without these data, accurately assessing geotechnical properties, settlement potential, or seepage risks, all of which are fundamental to dam design, becomes highly uncertain and may lead to design decisions that are inadequate to meet the project objectives and require further design features and modification as actual conditions become known.

Additional gaps include hydrologic and hydraulic parameters necessary for sizing the dam, reservoir, outlet and spillway systems. Peak inflow rates during a GLOF event, sediment load, and long-term changes in glacier meltwater contribution remain uncertain. Seismic hazard characterization and potential liquefaction susceptibility of valley soils also require detailed investigation. To complete the design, extensive field programs would be needed, including borings, geophysical surveys, groundwater monitoring, and laboratory testing of soil and rock properties. During construction, adaptive measures may be required if actual conditions differ from assumptions. These unknowns represent major risks to both design reliability and constructability.

Future design analysis and investigations include, but are not limited to:

- Geotechnical Investigations Visual site reconnaissance
- Drilling to bedrock
- Geophysics to assess variability of soil types and depths beneath the dam footprint and abutment bedrock
- Soil sampling and lab testing (e.g., soil characterization, hydraulic conductivity, strength testing)

Geotechnical Analysis and Modeling Stability:

- Assess static and seismic stability of dam materials
  - Liquefaction: assess whether deep soils are liquifiable, and effects on dam stability
  - Erodibility: assess scour potential at control structures
  - Seismic: assess site-specific deterministic and probabilistic hazard analyses
  - Seepage: assess foundations and underseepage requirements
  - Hydrogeological: assess the level of groundwater at the dam site
  - Assess rate and effects of isostatic rebound
- Hydrologic and Hydraulic Analysis and Modeling
  - Hydrological: assess water surface levels in Mendenhall Lake and along Mendenhall River
  - Hydraulic: routing flows through the dam site and for the design of the outlet works.

4.2.3. Assumptions

Key assumptions associated with the conceptual design alternatives presented herein are bulleted in the subsections below:

General Requirements

- Robust seepage control (grout curtain, cutoff wall) systems are needed to avoid piping.
- Designs must account for transient loads from GLOFs and for changing glacier conditions; conservative spillway sizing and rapid drawdown capability are essential.
- Access, construction seasonality, and environmental permitting in a sensitive glacial landscape add cost and schedule risk.
- Subsurface conditions listed under Basis of Design estimated based on limited regional information in literature: Alaska Department of Transportation and Public Facilities (ADOT&PF) test holes at Mendenhall Loop Bridge, circa 1984, extrapolation from deeper Brotherhood Bridge borings (ADOT&PF 2010), Alaska Department of Natural Resources (ADNR 2025) Well Log Tracking System water well drillers logs in upper

Valley neighborhoods, and Miller (1975) surface mapping and fence diagram interpretation based on USGS geophysics and well data.

- Relative density of sand and gravel deposits up to 100 feet below ground surface (bgs) at Mendenhall Loop bridge mid-Valley: medium-dense to very dense with Standard Penetration Test (SPT) blow counts in the range of 15 to 73; mechanical penetrometer tests in range of 5 to 20 blows per foot (blows/ft) in the top 20 to 25 feet, general increase from 20 to 200+ blows/ft to 25 to 110 feet bgs, with occasional dense peaks throughout from boulders or logs.

Geology/Subsurface Conditions

- Subsurface conditions listed under Basis of Design were estimated based on limited regional information in literature: ADOT&PF (1984) test holes at Mendenhall Loop Bridge, extrapolation from deeper Brotherhood Bridge borings (ADOT&PF 2010), Golder Associates 2010), Alaska Department of Natural Resources (ADNR 2025) Well Log Tracking System water well drillers logs in upper Valley neighborhoods, and Miller (1975) surface mapping and fence diagram interpretation based on USGS geophysics and well data.

- Surficial deposits consist of terminal moraine deposits in semi-circular ridge landforms, and intervening outwash deposits in topographic lows.

- Ridges may provide some source material for dam construction.

- Glacial deposits extend to about 200 to 250 feet below ground surface (bgs) mid-Valley and consist of dominantly sand and gravel with silt and boulders. Sandy silt layers with organics (wood, peat) and clay/sand “hardpan” reported in upper glacial deposits to about 75 feet bgs; deeper outwash deposits appear to be cleaner sand and gravels with less silt.

- Relative density of sand and gravel deposits up to 100 feet bgs at Mendenhall Loop Bridge mid-Valley: medium-dense to very dense with SPT blow counts in the range of 15 to 73; mechanical penetrometer tests in range of 5 to 20 blows/ft in the top 20 to 25 feet, general increase from 20 to 200+ blows/ft to 25 to 110 feet bgs, with occasional peaks throughout from boulders or logs. Glacial deposits are underlain by roughly 150 feet of glaciomarine deposits (mid-Valley thickness), consisting of interbedded mix of coarse outwash and fine-grained marine silt and clay, and extending to bedrock.

- Bedrock is interpreted to be roughly 350 to 400 feet bgs mid-Valley, rising to near ground surface at the western and eastern abutments. It consists of steeply northeast-dipping metasedimentary and metavolcanic rocks: graywacke, mudstone, and andesitic and basaltic volcanics with greenschist facies metamorphism.

- Bedrock at abutments could contain shear zones from local thrust faults and regional Coastal Shear Zone.

- Permafrost is not present.

Geotechnical Investigations

- Initial phase borings varying from a 200- to 2,000-foot spacing (final phase spacing may be reduced to optimize design parameters and requirements).
- In general, the locations would follow existing guidance to include EM 1110-1-1804:
  - Along the centerline and toe: borings every ~500 feet, alternating between undisturbed (for strength/permeability testing) and general/cone-penetration or SPT borings
  - At high-risk or critical zones (river-side toe, transitions, structures, uncertain geology): tighten spacing — e.g., every 200 to 300 feet, or more borings per reach
- Visual site reconnaissance
- Drilling to bedrock or competent layers to design pile depths and properties
- Potentially, geophysics to assess variability of soil types and depths beneath the alignment(s)
- Soil sampling and lab testing (e.g., soil characterization, hydraulic conductivity, strength testing)

Groundwater

- Generally shallow (less than 5 feet bgs), deeper along moraine ridges, shallower in between.
- Groundwater is hydraulically connected to lake.
- Silt layers in upper glacial deposits are likely discontinuous and not expected to create confining conditions for deeper groundwater.

Faults/Seismicity

- Local faults are considered inactive.
- Closest active faults to site: Queen Charlotte-Fairweather fault (85 miles west) and Denali-Chatham Strait fault (15 miles west to questionably active segment, 50 miles north to known active segment).
- Eight earthquakes greater than Magnitude (M) 6.0 have occurred since the late 1800s within 120 miles of site. The largest was M 7.8 on Queen Charlotte-Fairweather fault in 1958.
- Preliminary peak ground acceleration is approximately 0.3g (2 percent probability of exceedance in 50 years) (Petersen et al. 2023, 2024).
- Liquefaction risk is considered low-moderate. Coarse glacial deposits are generally not expected to liquefy, but there could be liquefiable saturated fine sands at depth.

Other Hazards

- Landslides and avalanche risk are considered low-moderate at abutments; local snow slides or talus deposition is a potential. Seiches from landslides also are a potential.
- Tsunami inundation from offshore earthquakes and landslides is not expected to reach dam alignments.
- Isostatic rebound could cause a 2- to 4-foot rise in ground level over the project life if the rate continues at the current 0.6 inch per year. A similar amount of sea level rise is expected due to climate change trends.

4.2.4. Geographic Footprint

The geographic footprint for the dam varies significantly between the upstream and downstream alignments. The upstream option would require approximately 54 acres, including acquisition of about four private properties within a 100-foot buffer zone and the Mendenhall Campground, which is a key recreational asset. In contrast, the downstream option would occupy a slightly smaller footprint of 49 acres, but would require acquisition of 30 private properties within the same buffer zone. Notably, with the downstream alignment, the Mendenhall Campground would be subject to flooding from GLOF events, which may raise concerns regarding public access and recreational impacts. Both alignment alternatives involve substantial coordination with property owners and stakeholders, as well as environmental and cultural resource evaluations, which could influence project timelines and costs.

For either alternative, reconstruction of at least two major roads—Glacier Spur Road and Skaters Cabin Road—would be necessary to maintain access and accommodate construction activities. These road modifications would require careful planning to minimize disruption to local traffic and tourism, particularly during peak visitor seasons. Utility relocations associated with these roads could further complicate sequencing and increase schedule risk, especially if multiple utility owners are involved. Although the upstream option consolidates impacts into fewer properties, the downstream alternative introduces greater complexity in land acquisition and stakeholder coordination, which may negatively affect constructability and schedule certainty, while reducing the height of the dam required for this alternative and the resulting visual impact and dam break potential impacts.

4.2.5. Design Feasibility

Constructing a dam across Mendenhall Valley to temporarily impound water from GLOFs presents significant engineering and environmental challenges. The Valley is a broad, relatively flat area underlain by complex glacial and alluvial deposits, which may include loose sands, silts, and organic layers over bedrock. These conditions raise concerns about foundation stability, seepage control, and settlement. Achieving seepage control would likely require ground improvement (deep soil mixing) or seepage cutoff, such as slurry walls. Additionally, the dam would need to accommodate high inflow rates during a GLOF event while maintaining safe spillway discharge capacity to limit the risk of overtopping.

The dam's footprint would significantly alter the Valley's natural drainage and ecosystem. The storage volume required to contain a GLOF event could potentially inundate recreational areas and infrastructure near the visitor center. Designing spillways and outlet works to safely convey both normal flows and extreme flood events would be critical to minimize downstream impacts.

Geologic conditions that affect dam design include the following:

- Foundation bearing
    - Where the proposed footprint overlies glacial tills or thick silt/clay deposits, compressible, heterogeneous materials increase settlement risk and require deeper foundation treatment (ground improvement).
- Seepage and drainage
    - Fine glacial deposits with low permeability can reduce seepage through the foundation but can also create perched water and unpredictable flow paths. Where coarse outwash exists, high permeability zones/channels will require cutoff works, ground modification, grout curtains, or sheet piles to control seepage and the potential for piping.
- Stability and structural orientation
    - Foliation and fracture sets in tonalite can cause rock slope instability; rock slopes and abutments may fail along planar weaknesses. Such a condition would require treatment such as with anchors, rock bolts, and/or shotcrete.
- Sediment load and reservoir longevity
    - Active glacial erosion supplies large volumes of sediment (including fine glacial flour) that can rapidly reduce storage capacity and clog outlets; sediment management (sluicing, sediment bypass, dredging) must be integral to design.
- Dynamic hazard environment
    - The catchment is subject to GLOFs and rapidly changing glacier behavior; the dam must be designed for extreme, rapid inflow events, potential ice impacts, and evolving upstream geometry—increasing spillway capacity and emergency drawdown capability needs.

- Seismic considerations
    - Southeast Alaska is seismically active; both seismic loading on dam structures and earthquake-induced liquefaction potential in loose sediments must be evaluated and mitigated (strong-motion design, foundation improvement).

Implementing the dam alternative would require creating and maintaining a safe, dry, and controllable work environment during dam construction, throughout multiple GLOF seasons. A diversion, cofferdam, and/or means of controlling GLOF inflow into Mendenhall Lake would be necessary to achieve this objective.

The proposed Dam Alternative would be developed in compliance with both federal and state regulations to provide safe, reliability, and regulatory adherence. Design and construction would follow the USACE's risk-informed dam safety policies, as outlined in ER 1110-2-1156, incorporating best practices for structural integrity, hydrologic performance, and emergency preparedness. In addition, the project would adhere to the ADNR Dam Safety Program requirements, including the Alaska Dam Safety Guidelines and applicable provisions of 11 Alaska Administrative Code 93. These standards govern design review, permitting, operation, and maintenance, ensuring that the dam meets jurisdictional criteria and includes robust measures for hazard mitigation and long-term stewardship.

4.2.6. Constructability

Constructability and Design Considerations

Constructing a 50(+/-) foot-tall, 2.5-mile (+/-) long dam in the Mendenhall Valley can generally be achieved using conventional heavy civil construction equipment and methods. The design would need to define material requirements, compaction criteria, and drainage details. The inclusion of mechanical features such as spillway and/or gates could require coordination among multiple contractor trades and vendors. Clear sequencing and well-defined tolerances will be essential to mitigate schedule delays and claims.

Diversion during Dam Construction

Implementing the dam alternative would require creating and maintaining a safe, dry, and controllable work environment during dam construction, throughout multiple GLOF seasons. A diversion, cofferdam, and/or means of controlling GLOF inflow into Mendenhall Lake would be necessary to achieve this objective.

Designing and constructing a diversion (in combination with a cofferdam) may pose constructability challenges and some downstream risk, particularly if a large GLOF event exceeds the combined conveyance capacity of the diversion and outlet. Implementing a cofferdam would entail: (a) initially constructing a small cofferdam to facilitate construction of the dam outlet structure and maintaining flow through the existing Mendenhall River Channel; (b) once outlet construction is complete, removing the outlet cofferdam, rerouting flow from the river channel to the outlet structure; (c) small cofferdams would be construction for the embankment section outside of the main river channel, (d) constructing a large cofferdam to facilitate dam construction in the Mendenhall River channel; and (e) removal of the cofferdams as sections of the dam are complete (if the cofferdam is not included as part of the main dam).

Material Availability and Equipment Needs

One of the key constructability advantages of an embankment/rockfill dam is the use of on-site materials, which can significantly reduce hauling costs and logistical challenges. However, the suitability of local soils for embankment construction must be confirmed through geotechnical investigations.

Site Access and Infrastructure Constraints

Access to the Mendenhall Valley site poses notable constructability challenges. Seasonal weather conditions, limited road infrastructure, and potential environmental restrictions will affect the efficiency of material delivery and equipment mobilization. If existing utilities require relocation, coordination among multiple owners could introduce significant schedule risk. Similarly, if construction staging areas are constrained by terrain or environmental buffer zones, additional planning will be needed to reduce delays.

Constructability and Logistics

- Access and mobilization: heavy equipment mobilization via road, barge, or helicopter depending on site access; identify and secure staging, laydown, and equipment assembly areas.

- Large cranes would entail procurement, operator certification, and mobilization challenges.

- Material sourcing and haul distances: identify and test local borrow sources; quantify haul routes and seasonal constraints; if local sources are insufficient, plan import routes.

- Seasonal work windows: plan major earthworks in suitable seasons to minimize frost implications, and high-flow risks; incorporate winter construction techniques if necessary.

- Temporary works sequencing: cofferdams, diversion channels, and staged impoundment must be designed for safety and constructability under GLOF conditions.

- Quality Control and Quality Assurance: specify compaction, moisture control, material acceptance tests, and monitoring during construction.

Construction Season and GLOF Risk Mitigation Strategy for Multi-Year Dam Construction

- The Dam Alternative presents challenges for a multi-year construction project due to the short construction season and recurring GLOF events. The primary construction window typically spans from May through September, when weather conditions are most favorable and freeze-thaw cycles are minimal. To maximize productivity during this limited period, major earthwork and concrete placement would likely be scheduled for summer months. Construction of a rockfill embankment is conducive to a longer construction season than typical. Rockfill placement in the shoulder period at the beginning and end of the primary construction season would extend each construction season by several weeks to a couple of months. During the off-season, work can continue through modular construction strategies, such as fabricating spillway gates and mechanical components off site for later installation. Winterization measures, including frost blankets, heated enclosures, and protective cofferdams, will be essential to safeguard partially completed structures and maintain progress during colder months.

- Annual GLOF events pose a significant risk to construction activities. To mitigate this hazard, temporary flood protection measures such as cofferdams, sheet pile walls, and diversion channels would need to be implemented to isolate work areas from potential floodwaters. Continuous real-time lake level monitoring will provide early warning of GLOF triggers, enabling rapid response and evacuation if necessary. Construction sequencing should prioritize the early completion of outlet works or diversion structures to reduce lake levels and minimize flood risk before the main dam structure is in place. Critical activities, such as foundation excavation and concrete placement, should be scheduled outside peak GLOF risk periods, as practical. Redundant access routes and emergency egress plans will further enhance resilience against unexpected flooding.

- Risk management strategies would include contingency budgeting for emergency repairs and protective measures, as well as contractual provisions to address potential delays caused by GLOF events. Coordination with stakeholders and emergency services would provide for an integrated response plan to be in place. In the long term, early implementation of the permanent outlet works would provide controlled lake discharge and significantly reduce GLOF hazards during subsequent construction phases.

4.2.7. Design and Construction Duration

The implementation of a Dam in the Mendenhall Valley would require a multi-phase approach encompassing preliminary design, final design, stakeholder outreach, and contractor procurement, followed by construction, see Table 4-4. The preliminary design phase (approximately 12 to 18 months) would focus on geotechnical investigations, hydrologic and hydraulic modeling, environmental assessments, and conceptual layouts. This phase also includes early coordination with regulatory agencies and public outreach to address community concerns and environmental compliance. The final design phase (12 to 15 months) would refine dam design, spillway and outlet works, seepage control measures, and seismic design, confirming compliance with USACE TRGs. Concurrently, real estate acquisition for the dam footprint, staging areas, and potential relocation zones would proceed, which could require 12 to 24 months depending on land ownership complexity and environmental permitting.

Table 4-4 Design and Construction Schedule

Item	Schedule*
Reference Preliminary Design	January 2026 to May 2026
Final Design	May 2026 to November 2027
Real Estate Acquisition (overlapping)	September 2026 to April 2028
Bidding/Contractor Procurement Phases	November 2027 to April 2028
Construction Duration	April 2028 to October 2035

*Schedule presented is approximate. Start dates are subject to approvals.

Construction duration is expected to span 5 to 7 years, influenced by seasonal constraints and tourism-related restrictions. ECRD/ACRD dams require extensive materials, which is typically limited to the frost-free season (April/May–October) in Southeast Alaska. Mid-winter months would be largely unsuitable for embankment construction due to freezing conditions/snow, high precipitation, and potential flood risks. Additionally, construction activities near the Mendenhall Glacier Visitor Center may need to be curtailed during peak tourism periods to minimize disruption, requiring careful scheduling of high-impact operations such as blasting or major earthwork. The overall timeline must also account for procurement and bidding processes (6 months), which include contractor selection and mobilization.

In total, from initial design through commissioning, the project could require 7 to 10 years, with the critical path driven by real estate acquisition, environmental permitting, and seasonal construction windows.

4.2.8. Reliability/Adaptability/Resiliency

Reliability

Reliability refers to the dam's ability to consistently perform its intended function—impounding GLOF flows—under expected and extreme conditions. The Dam option offers a high degree of reliability when properly designed and maintained. Its primary function—impounding GLOF flows and regulating releases—can significantly reduce flood hazards downstream. Dams have long service lives, but reliability depends on addressing key failure modes such as overtopping, internal erosion, and seismic instability. In the Mendenhall Valley, foundation conditions include glacial outwash and alluvial deposits, which would require robust seepage control measures such as cutoff walls and filter zones. Continuous monitoring through piezometers and automated systems will be essential to detect seepage and deformation early. Although the dam provides strong performance under normal and extreme conditions, it introduces a single point of failure; therefore, redundancy through auxiliary spillways and emergency planning is critical to maintain system reliability.

Adaptability

The dam structures could be modified over time to accommodate changing hydrologic and climate conditions, including glacier retreat and increased GLOF magnitudes. Future upgrades such as raising the dam crest, enlarging spillways, or adding gated outlets can be implemented without replacing the entire structure. Operational adaptability—through controlled outlet works—allows dynamic management of lake levels and flood routing. However, adaptability is constrained by valley geometry, environmental regulations, and cost escalation for major modifications. Incorporating adaptive design principles during initial planning, such as reserving space for future spillway expansion so that the dam could remain effective under evolving conditions.

Resiliency

Resiliency reflects the dam's ability to withstand damage, recover from loading events, and continue functioning. Embankment dams are flexible and can tolerate some deformation, making them well-suited for seismic regions. Proper zoning and filter/drain design would provide for resistance to piping/internal erosion. Recovery after extreme events—such as earthquakes or overtopping—may require significant repairs. System-level resiliency depends on integrating redundancy measures like diversion channels and emergency drawdown capabilities, as well as maintaining a robust Emergency Action Plan. Climate resilience will require designing for probable maximum flood scenarios and monitoring glacier retreat trends to anticipate future hydrologic changes.

4.2.9. Operations and Maintenance Cost and Requirements

The long-term O&M of a 50(+)-foot-tall, 2.5-mile-long earth-fill dam in the Mendenhall Valley would primarily involve routine inspections, vegetation control, seepage monitoring, and periodic repair of erosion protection features such as riprap and drainage systems. Given the dam's size and sub-arctic environment, monitoring for frost heave and seasonal hydrologic changes would be needed. Maintenance of spillways, infrastructure, and closure gates would require scheduled servicing and potential replacement of mechanical components over time. The remote location and harsh climate would increase labor and logistics costs, because access for heavy equipment and skilled personnel may be limited during winter months. These factors contribute to higher baseline O&M costs compared to similar dams in temperate regions.

Lifecycle costs would include not only routine maintenance but also major rehabilitation events, such as resurfacing the crest road, replacing gate actuators, and upgrading instrumentation for dam safety compliance. If the design incorporates large closure gates, procurement of specialty equipment—such as a high-capacity crane for lifting gate assemblies—may be necessary. This represents a significant capital investment, because cranes suitable for this application can be costly and require operator certification and ongoing training. Additionally, licensing and insurance for operating such equipment in Alaska would add to recurring costs. These specialty requirements, combined with the need for cold-weather adaptations and potential reliance on barges or helicopters for transport, make the lifecycle cost profile substantially higher than for smaller or more accessible dams.

4.2.10. Risk Reduction/Life Safety

Risk evaluation for the Dam Alternative summarized in the paragraphs below is qualitative and includes three aspects:

- Risk reduction (life loss and economic).
- Failure likelihood of the dam.
- Ability to meet USACE TRGs.

Refer to the risk section for descriptions of the meanings of these three aspects of risk.

Risk Reduction

A dam across Mendenhall Valley designed to impound and attenuate GLOF flows could substantially reduce downstream flood risk, thereby reducing life safety risk for residents and visitors in the Juneau area, and reducing risk for economic damages in the Juneau area. By temporarily storing and/or regulating the rapid increase of GLOF flows, the dam would decrease peak discharge into the Mendenhall River, reducing the likelihood of catastrophic flooding in residential neighborhoods and critical infrastructure corridors. This mitigation would directly protect lives by decreasing the probability of rapid-onset flooding that currently offers little warning time.

The alternative could mitigate millions of dollars in damage to homes, roads, utilities, and tourism facilities that are vulnerable to GLOF events. Community impacts would also be significant: reducing flood frequency and severity would preserve infrastructure. However, the effectiveness of this alternative would depend on proper sizing and operational protocols so that the dam could handle extreme inflow scenarios without introducing new hazards, such as dam overtopping. Although the potential for risk reduction is high, the scale of investment and environmental trade-offs must be weighed against other alternatives or early warning systems.

Although the dam alternative reduces GLOF risk, it would introduce a new, permanent public safety risk associated with potential dam failure. The consequences of a catastrophic dam breach could equal or exceed those of the GLOF events the structure is intended to mitigate. Meeting the USACE TRGs throughout the life of the dam would be essential to mitigate this new risk.

Failure Likelihood of the Dam

Estimating the failure likelihood of a dam not yet designed or constructed with a reasonable degree of confidence is not feasible, given the significant number of unknowns at the present time. However, based on preliminary evaluation of available hydrologic, hydraulic, geologic, and geotechnical information, several PFMs appear to be credible and would need further evaluation as additional data become available. These PFMs, along with possible risk mitigation measures, are listed in Table 4-5.

Table 4-5 Dam Alternative Potential Failure Modes and Potential Mitigation Measures

Credible PFM	Potential Risk Mitigation Measure
Overtopping leading to rapid erosion and breach	Adequate spillway capacity, freeboard, and erosion-resistant downstream protection
Internal erosion/piping through foundation or embankment	Keyed cutoffs, grout curtain, properly designed filters and drains, and quality-controlled compaction
Slope instability under static, seismic, or rapid-drawdown loading	Flatter embankment slopes and/or berms
Seismic-induced liquefaction of foundation	Avoidance or over-excavation of liquefiable layers, densification, or deep stabilization
Construction-phase flooding or ice impacts	Develop robust temporary works including cofferdam, contingency plans, and seasonal work sequencing
Overtopping due to settlement	Provide appropriate dam crest camber

Ability to Meet USACE TRGs

The third criterion is the ability or willingness of the responsible or affected parties (USACE, Sponsor, Stakeholders, Public) to meet the four USACE TRGs:

- TRG 1 – Understanding the risk.
- TRG 2 – Continuing risk awareness.
- TRG 3 – Monitoring and managing risk.
- TRG 4 – Taking action to reduce risk.

Together, the four TRGs encompass all phases of alternative implementation: planning, design, construction, and operation. Any project that would be constructed would include all necessary project features to ensure that the project meets USACE's four TRGs. The four TRGs can be better understood in terms of key questions provided in the risk section that were asked during the charrette and helped charrette participants collaboratively identify whether the TRGs can be met.

Some key questions are provided below as examples:

- **Is the risk associated with the Dam Alternative reasonably understood by all responsible/affected parties (TRG-1)?** For example, if further evaluation reveals the overtopping PFM to be risk-driving, is there a clear understanding what the estimated overtopping frequency is, and is that likelihood of overtopping considered to be tolerable?

- **Will risk be properly monitored and managed throughout the operational period of the dam (TRG-3)?** For example, would the Sponsor develop a dam safety program, perform periodic dam safety inspections, and perform instrumentation monitoring and analysis?

- **Is it likely there would be cost-effective, socially acceptable, or environmentally acceptable ways to reduce any credible risks identified during the charrette or new risks that may be identified after construction (TRG-4)?** For example, what actions would be taken to reduce risk if/when updated GLOF projections indicate a substantially higher expected flood volume? If/when Mendenhall Lake becomes substantially infilled with silt, reducing flood storage capacity, who would be responsible for dredging, what would be the funding source for dredging, and how would dredging affect the local tourism industry?

Such questions, among others, were asked during the charrette and input of charrette participants was requested. If one or more questions could not be confidently answered or there were significant uncertainties with the answers, a lower risk score was considered. Conversely, if the questions could be reasonably answered in the positive, a higher risk scoring was considered.

4.2.11. Operational Impacts

- Develop robust Emergency Action Plans with community notification, consistent with best practices and guidance.
- Early stakeholder engagement and environmental baseline studies are essential, given the protected and recreational nature of Mendenhall Lake and downstream Valley to assist in regulatory and environmental permitting requirements.

4.2.12. Environmental/Cultural Considerations

Constructing a dam across Mendenhall Valley would have substantial potential environmental and cultural implications that would need to be fully evaluated. The footprint of the structure and its associated reservoir would inundate wetlands, wildlife habitats, and recreational areas near the Mendenhall Glacier Visitor Center, potentially altering ecosystems and reducing biodiversity. Cultural resources and Historic Properties within the Valley, including areas of significance to Indigenous communities, would also be impacted, requiring consultation and compliance with the NHPA. Sediment deposition and changes in river morphology downstream could affect fish habitats and water quality, introducing long-term ecological risks. A NEPA review would be completed if the action was determined to have substantial environmental impacts.

From a regulatory standpoint, the project would require multiple permits, agency coordination, and procedural requirements, including USACE Section 404 (Clean Water Act) requirements, ADEC water quality certifications, NEPA and consultation under the Endangered Species Act. Construction access would likely involve building temporary roads and staging areas in sensitive environments, increasing disturbance and requiring mitigation measures. Economically, although the dam could reduce flood-related damages, the initial capital cost and ongoing maintenance would be significant, and potential impacts on tourism and recreation could offset some benefits. These factors underscore the need for a comprehensive environmental review and stakeholder engagement before advancing design.

Environmental Impacts

- Land management: The Valley is ancestral Áak'w Ḵwáan land. The Central Council of the Tlingit and Haida have co-stewardship agreements with the USFS (Tongass National Forest) to govern management of the MGRA. The City and Borough of Juneau (CBJ): Local government responsible for land use and floodplain management.

- Oversight of dam safety, fish habitat, and water rights is the jurisdiction of the State of Alaska. Other Stakeholders include Alaska Native Claims Settlement Act (ANCSA) Native Corporations (Sealaska, Goldbelt, Inc.), tourism operators, conservation groups.

- Threatened, Endangered, Sensitive, and Special-Status Wildlife Species: Steller sea lion, humpback whale (protected by the Endangered Species Act) from downstream releases as modeled, Queen Charlotte Goshawk (USFS Region 10 Sensitive Species), Bald Eagles (protected by the Bald and Golden Eagle Protection Act), harbor seals (protected by the Marine Mammal Protection Act). The shore of Mendenhall Lake is an important area for breeding seabirds, including Arctic Terns, Mew Gulls, Herring Gulls, and Glaucous-winged Gulls, all protected by the Migratory Bird Treaty Act. Consultation would be required with USFS, USFWS, and NMFS for Essential Fish Habitat and potentially marine species. Nearby Goshawk nests and bald eagle nests should be taken into consideration when determining construction schedule.

- Wetlands and Floodplains: Mendenhall Wetlands State Game Refuge (3,786 acres) is a globally significant bird habitat; dam-induced hydrologic changes could degrade wetland function.

- Fish Habitat: Mendenhall Lake and Mendenhall River and its tributaries are home to spawning populations of coho salmon, sockeye salmon, Dolly Varden char, coastal cutthroat trout, and rainbow trout/steelhead trout. Reservoir inundation and altered flows may impair spawning.

- Vegetation: Sensitive plant species jointed rush (*Juncus articulatus*) found in the area.

- Cultural Resources: Archaeological sites and traditional use areas require NHPA Section 106 review with the SHPO, NEPA review, and tribal consultation. to determine impacts, assess potential mitigation, and consider possible inclusion in the NRHP

- Historic Properties of particular concern include Skater's Cabin (JUN-00242), Mendenhall Campground (JUN-01303), and Mendenhall Glacier Visitor Center (JUN-00579), and others in the vicinity of the lakeshore. In addition, the entirety of the MGRA is designated as a Historic Property. Historic Properties require NHPA Section 106 review with the SHPO, NEPA review, and tribal consultation.

- Additional requirements for cultural resources compliance could include the development of a historic properties management plan that identifies cultural resources; defines mitigations and protections for these resources; and sets goals for the ongoing management of facilities, archaeological resources, and cultural landscapes.

- Potential legacy contamination near former industrial or maintenance areas; Phase I Environmental Site Assessment recommended. Disposal of hazardous material may require shipment for treatment and disposal outside of Juneau.

- Air Quality: Juneau is a maintenance area for particulate matter 10 microns in diameter or less; dust from haul roads and material stockpiles must meet State Implementation Plan requirements.

- Noise and Traffic: Heavy equipment and material hauling would increase noise and congestion along Glacier Highway and Egan Drive, particularly during tourism season.

- Water Quality: Sediment and turbidity from stream crossings require best management practices. Dredged material management would include characterization of the material and specific environmental controls prior to determining disposal procedure.

- Vegetation Clearing: Clearing for dam footprint, staging areas, and access roads would remove vegetation.

- Recreation and Visual: MGRA is a major tourist destination with more than 1 million visitors annually; construction would disrupt access and degrade scenic views.

- Tourism and Economy: Juneau’s economy depends heavily on cruise tourism; prolonged construction could reduce visitor satisfaction and revenue.

- Implementation would require extensive mitigation for wetlands, fish passage, cultural resources, and recreational impacts, adding significant cost and schedule risk.

- Disruption to Visitor Access: Construction near the Mendenhall Glacier Visitor Center (a major tourist destination with more than 1 million visitors annually) would restrict access and degrade scenic views during multi-year construction.

- Visual and Recreational Impacts: The dam footprint and reservoir could inundate recreational areas, including campgrounds, trails, and a boat launch, reducing opportunities for hiking, boating, wildlife viewing, winter lake recreation, and photography.

- Socioeconomics: Juneau’s economy heavily depends on cruise tourism. Prolonged construction noise, traffic, and visual impacts could lower visitor satisfaction and reduce revenue for local businesses.

Economic Community Impacts

- A dam could significantly reduce GLOF-related flood hazards, protecting homes, roads, and utilities—potentially saving millions in damages and improving long-term economic stability and safety.

- Hauling large volumes of embankment material would strain local roads, increase congestion, and raise safety concerns, impacting businesses and residents.

- Private parcels may need to be acquired, and some homes relocated, creating social and economic stress.

- Reduced visitor access during peak seasons could hurt local operators (guides, shops, restaurants), especially if construction overlaps with cruise season.

Land Acquisition Requirements

- Permanent:
  - Dam site and reservoir inundation zone (mostly USFS and State lands, but some private parcels would also be affected).
  - Easements across state and CBJ lands.
  - Possible acquisition of conservation lands in MGRA.

- Temporary:
  - Access Roads: From Glacier Highway/Egan Drive to dam site.
  - Laydown Areas: For equipment and material stockpiles.
  - Borrow Sites: May require separate permits and land agreements.

- Relocation:
  - Residential properties in inundation zone; relocation assistance per Uniform Relocation Act.

4.2.13. Permitting Concerns

State, federal, and local permits that may be required under this alternative include the following:

- USACE requirements for Section 404 (Clean Water Act) – Fill in waters/wetlands.

- USACE requirements under Section 401 (Clean Water Act) – Certificate of Reasonable Assurance for potential discharge into Mendenhall Lake. The Clean Water Act is enforced by the ADEC.

- USACE requirements for Section 9 and 10 (Rivers and Harbors Act) (potentially) – Construction of structure in or over any navigable water of the United States.

- NEPA – Required for major federal actions unless otherwise exempted (USACE and USFS).

- Endangered Species Act Section 7 Consultation – USFWS and NOAA Fisheries.

- Magnuson-Stevens Fishery Conservation Management Act – Essential Fish Habitat consultation with NOAA Fisheries.

- NHPA Section 106 – SHPO and tribal consultation.

- USFS Special Use Authorization – Potentially required for construction activities.
- USFS Consistency with 2016 Tongass Forest Plan.
- Alaska Dam Safety Program – Design review and approval (ADNR Division of Mining, Land and Water).
- Anadromous Fish Act (AS 16.05.871-.901) – Fish Habitat Permit – Alaska Department of Fish and Game (ADF&G) for anadromous streams.
- Fish Passage Act (AS 16.05.841) – ADF&G for fish passage
- ADEC Water Quality Standards – Enforcement of Clean Water Act water quality measures
- Water Rights Authorization – For reservoir storage.
- Floodplain Development Permit, and other zoning and conditional use authorizations (CBJ)
- Coordination with Tlingit and Haida and ANCSA Regional and Village corporations for cultural and land interests.

4.2.14. Key Takeaways

- Primary Benefit: Significant reduction in flood risk and protection of downstream communities.
- Major Challenges: Complex foundations, seismic risk, environmental impacts, and lengthy construction duration.
- Critical Unknowns: Subsurface conditions and hydrologic analyses require extensive investigation and design.
- Schedule: 7 to 10 years from design to commissioning, with seasonal construction constraints.
- Success Factors: Adaptive design, robust seepage control, stakeholder coordination, and emergency planning.

4.2.15. Discussion

Below is a summary of talking points that followed the presentation of the Dam alternative. Please refer to Appendix B: Charrette Meeting Minutes, for additional information.

Timeline:

- The timeline for this alternative is estimated to be 7 to 10 years – a drawback of this alternative.

- There was a question about the possibility of expediting the 7-to-10-year timeline if more contractors are brought on board; hypothetically yes, that could help expedite the timeline.

Design and Construction:

- The number and location of properties that would need to be acquired for this solution needs to be further studied.
- It was clarified that the dam would sit dry for the majority of the year. It would only be loaded during the short duration of a GLOF event.
- There were questions about how much vegetation clearing would need to be done along the floodway; it's likely this would be similar to the 1,000-foot clearing done in the Moose Creek floodway.
- The Visitor Center itself would be above the flood level, but the elevator shafts and utilities would not be protected.
- There was a recommendation to look at alignments further east.
- Material availability – such as the possibility of using local material – needs to be further studied.
- The design objective of the dam alternative is to handle the design flow with a release of 30,000 cfs to limit downstream impacts. Detailed outlet structure design is needed to determine how much water is stored behind the dam and how much is released, both of which directly influence the required dam height.
- There was discussion about the potential need to reinforce the riverbanks downstream of the dam so that the river can handle outflows from the dam. Those reinforcement provisions are not included in the cost estimate for this alternative.

4.3. Floodwall Alternative

4.3.1. Technical Discussion

Overview

The Floodwall Alternative is a conceptual plan for a USACE Flood Risk Management (FRM) system that would protect as much developed land within the Mendenhall Valley as is technically feasible while meeting the project design objectives. A Flood Risk Management System (FRMS) is defined herein as a network of levees and/or floodwalls, underground seepage cutoffs, interior drainage collection systems, and drainage structures that manages and mitigates the risk of water inundation within protected areas.

Proposed FRM features would be placed along the full eastern bank of the Mendenhall River and along developed portions of the western bank to mitigate flooding from the river; along Mendenhall Loop and Glacier Spur Roads to restrict flood flows from the north (through Dredge Lake area); and between northwestern residential areas and Mendenhall Campground to restrict flood flow from where the lake intersects the river. Overall required protection length is approximately 8 miles (approximately 60 to 75 percent floodwalls). Floodwalls along the river would average 10 to 15 feet tall above the prevailing grade. Levees in the north would average 15 to 25 feet tall; some could be incorporated into existing roadway embankments.

Objectives and Performance Criteria

A "floodwall solution" to a GLOF river event is not simply a hardened version of the current temporary HESCO barriers; it is a complex network of engineered systems that reduce the risk of GLOF inundation damage to the community while accommodating existing levels of stormwater drainage service and may be designed and constructed to facilitate future enlargements and improvements to the FRM structures. The proposed Mendenhall Valley FRMS provides a system of floodwalls and embankments to protect most of the Valley's developed land from inundation due to a 118,000 cfs GLOF river discharge event (see Section 3.7 for details of H&H assumptions and design).

At this conceptual stage, the primary design criterion for this system is the "Top of Wall Elevation (EL.)," which is the elevation the protection structures must be constructed. This criterion is the primary determining factor for levee/wall structures to resist the design GLOF event that are feasible in the Mendenhall Valley. Top of Wall EL. is determined by hydraulics and hydrology (H&H) analysis and is not affected by the choice of floodwall, levee, etc. structure type. Another key feature is the "alignment" of the FRMS, or the linear route the wall and/or levee segments would take through the Valley. For this phase of development, the presented alignment should not be evaluated on a granular, block-by-block level; it is a suggestion that is improved throughout design as H&H, geotechnical, utility, and other factors are identified and located.

Introduction to Flood Protection Features: Earthen Embankment Levees

A levee is a human-made earthen embankment that is designed to hold back periodic flood waters and reduce risks associated with flood events (refer to Figure 4-20). The levee provides an impervious barrier to seepage of water over or underground from the flood side to the protected side of the levee (refer to Figure 4-21). Impervious soil types (clay) are the best materials to use in levees; however, if availability of code-required clay material is limited, the use of geotextiles, berms, soil improvement methods (e.g., deep soil mixing), or others can improve imperviousness and stability while using a larger quantity of local materials. Levees in areas of strong current would typically be armored with riprap (large-scale stone gravel/boulders placed on the slope), riprap that is grouted together with a concrete slurry, or concrete slope paving. Levees in a USACE system have limits on vegetation growth on or around them to reduce failure risks and aid in routine inspections (refer to Figure 4-22).

Figure 4-20 Levees Protecting Suburban Neighborhood with Over-Top Roadway Crossing

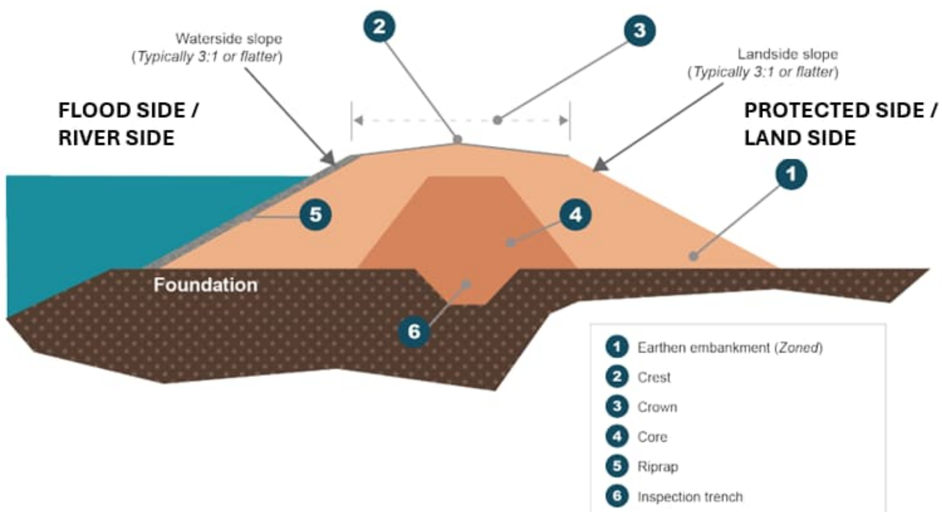


Figure 4-21 Typical Earthen Levee Cross-Section (Image from Draft National Levee Safety Guidelines 2: Understanding Levee Fundamentals)

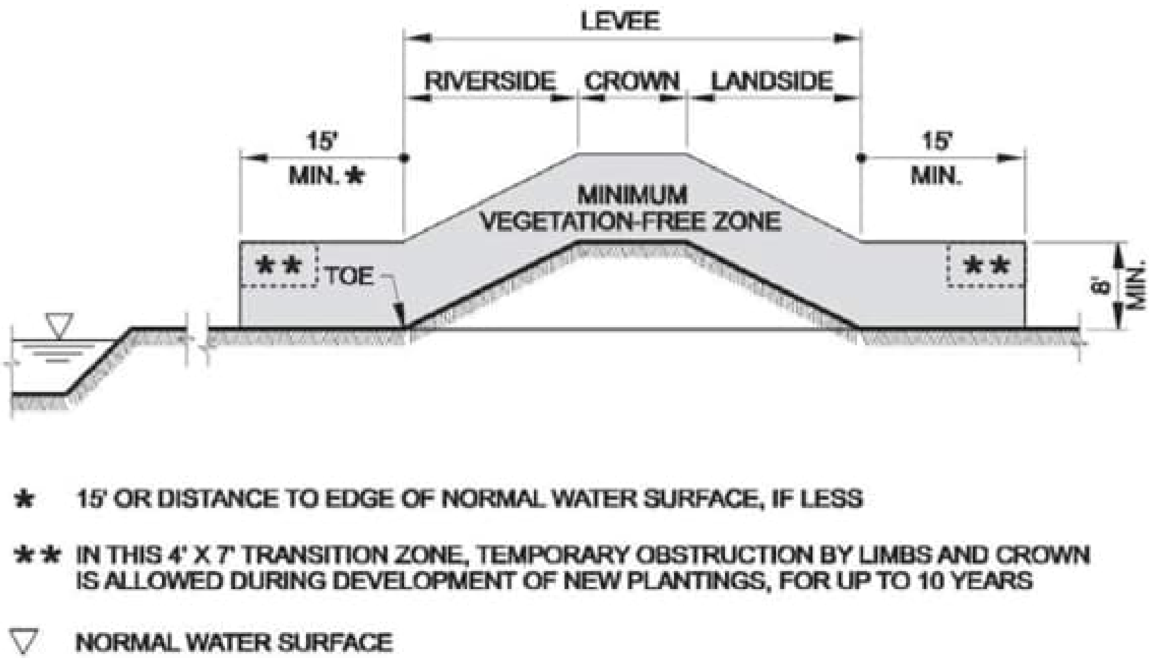


Figure 4-22 Vegetation Restrictions – No Trees or Large Woody Vegetation Allowed in Grey Zone

Introduction to Flood Protection Features: Floodwalls

The most common flood walls are “I-wall” and “T-Wall” types, which are shaped as their names describe. Other walls, such as “L-walls” are similar in function and nomenclature.

An I-wall is a continuous sheet pile wall driven into the ground and capped with a reinforced concrete wall that extends up above prevailing grade (“stick-up” height). Due to strength, stability, and “lessons-learned” considerations, I-walls are generally limited to use where their stick-up height is limited and/or they are not subject to additional horizontal loads such as flood-borne debris impact (refer to Figure 4-23 and Figure 4-24).

A T-wall is a reinforced concrete structure that forms an inverted “T” shape with its base slab and wall. The base slab provides substantial resistance to overturning and sliding under high water loads, and affords space for inclusion of deep foundation elements (rows of piles, drilled shafts, or other similar items) to transfer flood loads on the wall element into the soils below. T-walls are generally used where required stick-up height is high and/or lateral loads are high, but space limitations do not allow for use of a levee. Figure 4-25 below presents a typical T-wall cross section and introduces its components; Figure 4-26 and Figure 4-27 provide photos of typical T-walls.

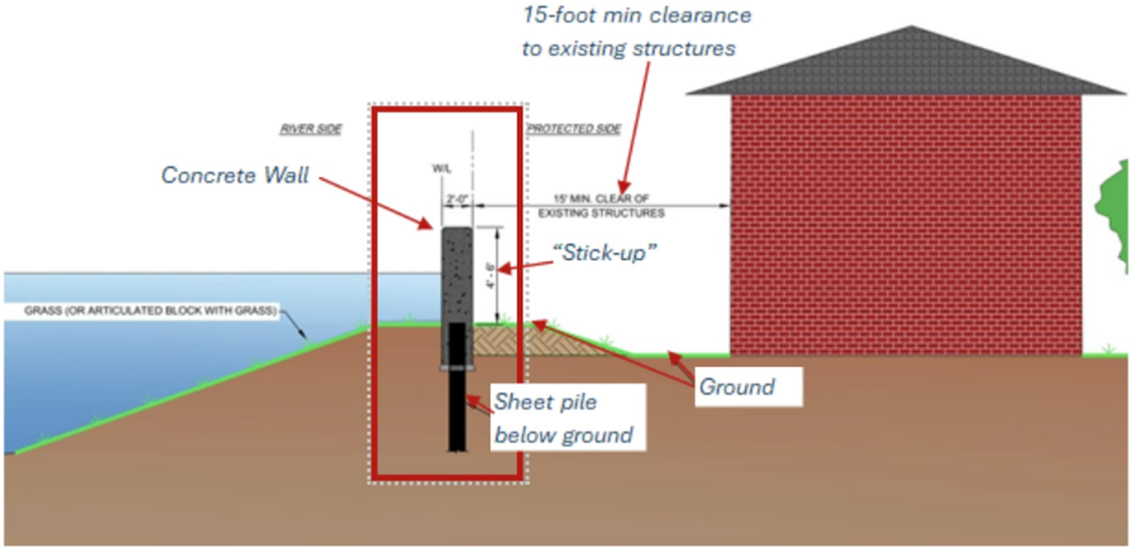


Figure 4-23 Example I-Wall Cross-Section, Shown Close to Existing Structure

Figure 4-24 Photo of I-Wall in Construction

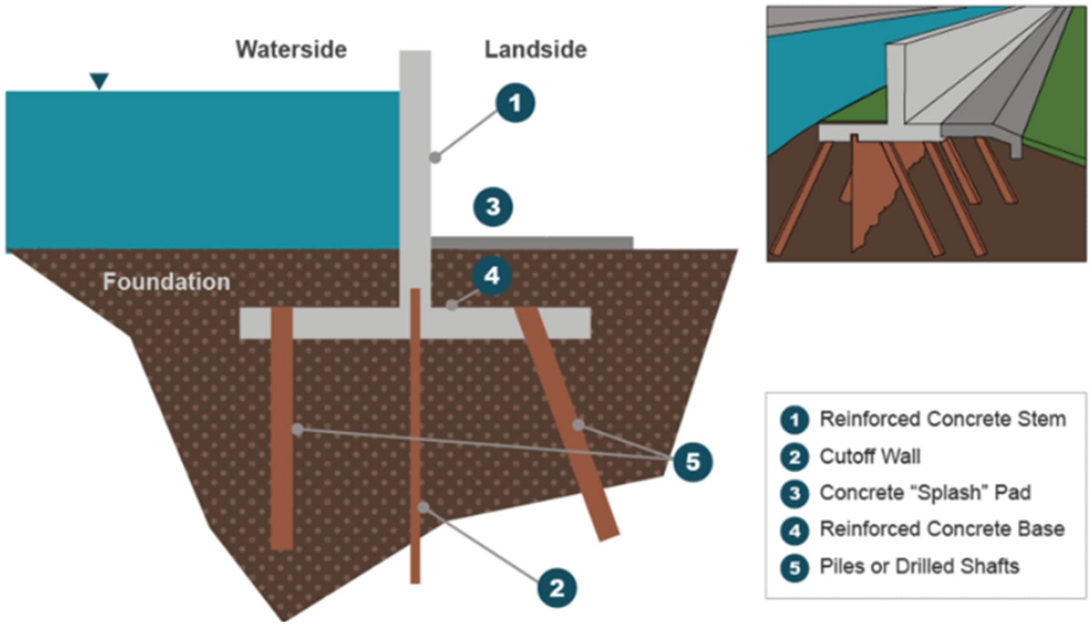


Figure 4-25 Typical T-Wall Cross-Section (Image from Draft National Levee Safety Guidelines 2: Understanding Levee Fundamentals)

Figure 4-26 T-Wall Photograph – Cross-Section During Construction

Figure 4-27 T-Wall Photograph – Interstate Bridge Crossing through a Flood Protection System

Introduction to Flood Protection Features: Seepage Cut-Offs

All the above-discussed structure types require the inclusion of a seepage cutoff that inhibits movement of water underground from the river to the protected side (refer to Figure 4-28 and Figure 4-29). A driven sheet pile wall is the most common type of cutoff. Where sheet piles cannot be driven due to obstructions or soil conditions, slurry wall grout curtains (cement-bentonite mixtures), seepage berms, relief wells or blanket drains, or impervious clay walls may be used. Special attention would be focused on areas where FRM features cross natural tributaries; these areas present unique hydraulic conditions that may increase seepage potential.

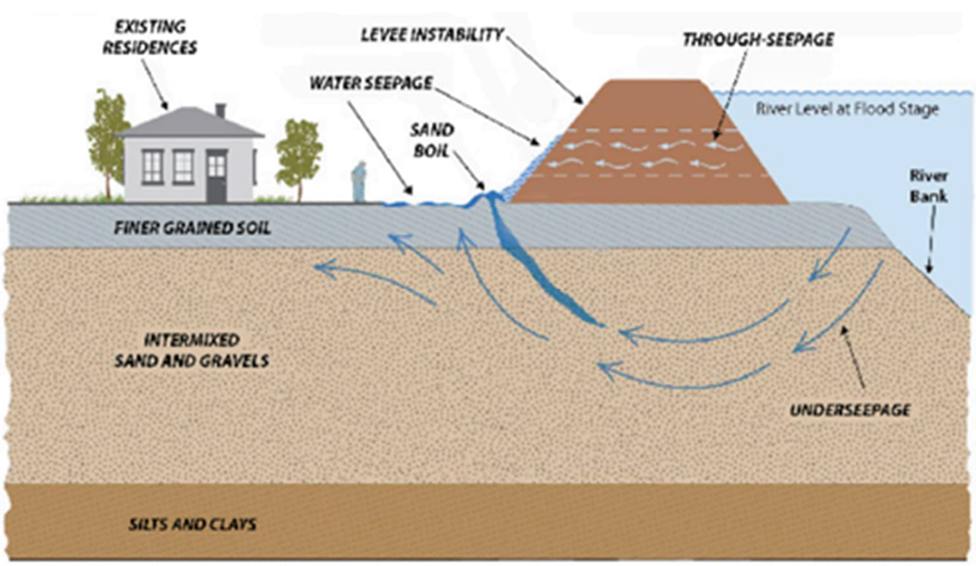


Figure 4-28 Seepage Illustration; Underseepage is Also a Potential Beneath Floodwalls

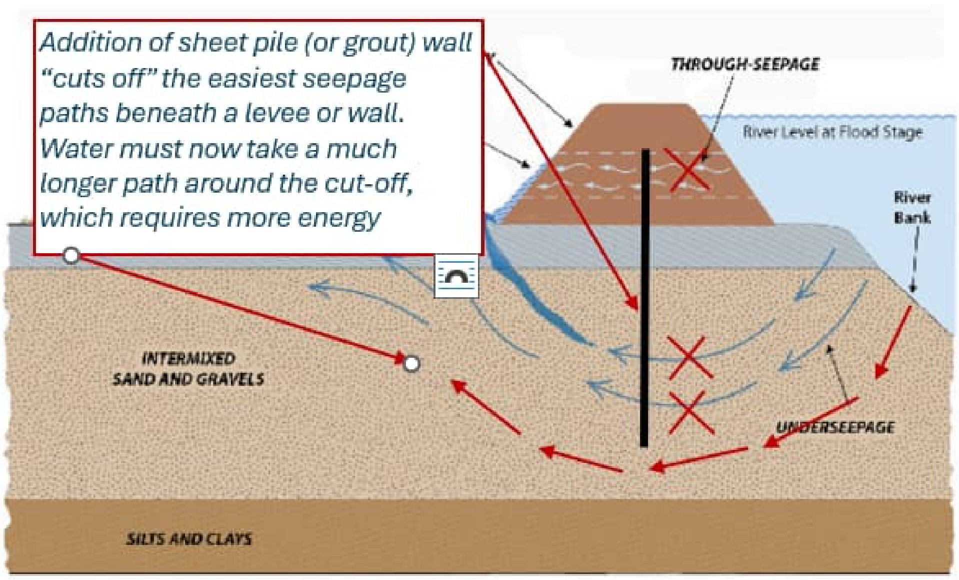


Figure 4-29 Illustration of How a Seepage Cutoff Inhibits Flow-Through Beneath Structures

Introduction to Flood Protection Features: Interior Drainage

Once the system is constructed, rainfall and runoff in the protected area becomes trapped because natural gravity flow to the river is blocked during flood events. Interior water must be collected, conveyed, and removed from the protected area through engineered drainage pathways. Each drainage pathway requires some type of structure to support and harden the utility penetration and provide backflow prevention (stop river water from flowing backwards through the drainage network and into the protected area). Refer to Figure 4-30 for illustrations.

Figure 4-30 Backflow Preventors Currently Installed in Riverbank Drain Pipes (Rubber Gaskets Allow Stormwater from Protected Side Out, But Do Not Allow Water In)

If it is likely that a significant rain event would occur with a high river event, the inclusion of pump stations in the drainage system is often necessary to lift and discharge water over the floodwall and into the elevated river. Figure 4-31 and Figure 4-32 provide illustrations of a pump station's inclusion in a levee system. Regardless of drainage specifics, the system would, at a minimum, require numerous smaller drainage collection and discharge structures (similar to the illustration in Figure 4-33).

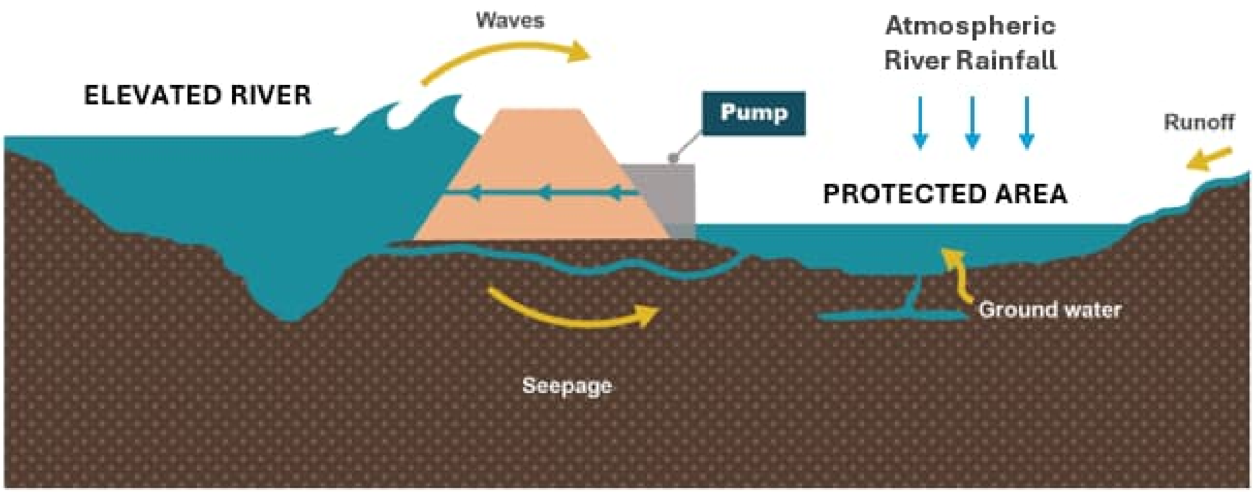


Figure 4-31 (Image from Draft National Levee Safety Guidelines 2: Understanding Levee In Fundamentals)

Figure 4-32 Typical Pump Station and Associated Discharge Piping Arrangement in FRMS (View Is of Protected Side Wall Face)

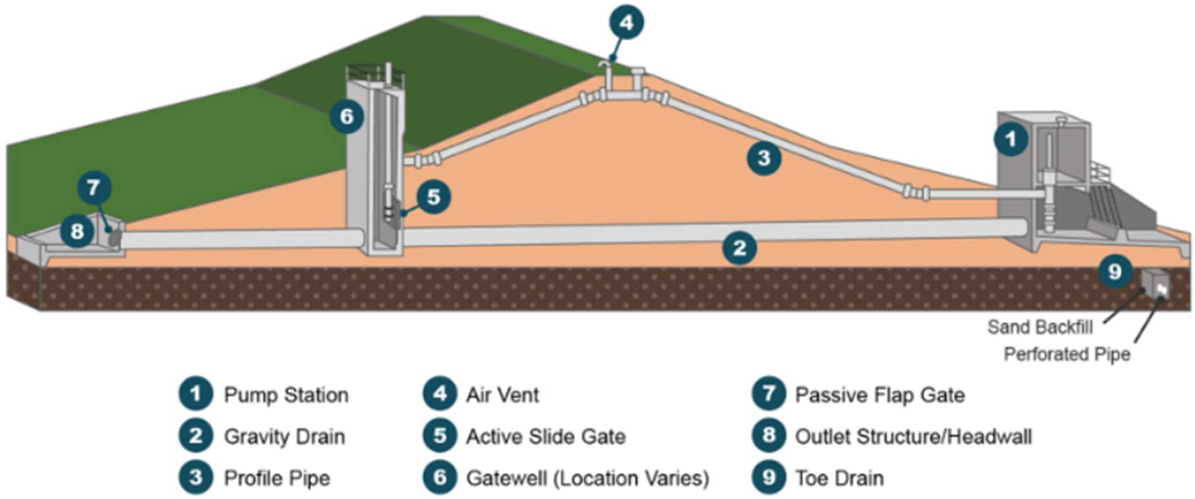


Figure 4-33 From Draft National Levee Safety Guidelines 2: Understanding Levee Fundamentals – Typical Drainage Structure Penetration through Levee Embankment

Hydraulic Components

The floodwall scenario was modeled using an approach similar to MBI's method for HESCO barriers, with floodwalls represented at an exaggerated elevated height to maximize effectiveness. This approach allowed the model to identify the maximum water surface elevations (WSE) behind the floodwall, which can inform the design height for floodwalls along the Mendenhall Valley and the Moraines area. Figure 4-34 depicts the extent of inundation and the alignment of floodwalls protecting structures and buildings on the Mendenhall River and along an east-west corridor that separates the moraines and Mendenhall Lake area from most populated Valley areas.

It is important to note that introducing floodwalls increases WSE in the river channel, which would have upstream and downstream implications in WSE and Top of Protection elevations.

For additional details of the H&H analysis performed as part of this alternative's development, refer to Section 3.7.

Figure 4-34 Floodwall Alternative: Inundation Extent and Alignment

4.3.2. Technical Unknowns

- Specifics of the CBJ drainage system: Understanding is that populated areas are gravity-drained directly to the river via outlets of varying size. Drawings, reports, or other documents about current drainage patterns require analysis. Close coordination with CBJ is required for alternative development.

- H&H design requirements other than the design GLOF event were evaluated during this effort. Protection system requires analysis for a range of water levels, including possibility of reverse load conditions. Also, other features of H&H loading such as potential for of waves, debris collection zones, currents, and other inputs needed for slope protection designs. Impacts of rain and runoff design storms are unknown on interior drainage systems.

- Effects of the proposed structures on the Mendenhall River's mechanics such as velocity, bed scour, sediment transport; changes in normal water levels; etc. are currently unknown. For example, the addition of scour protection features such as slope paving would increase river velocity, although to what degree and how that may affect other parameters is unknown.

- Overall effect on groundwater and other environmental systems is unknown. Once an impervious seepage barrier is installed around segments of the Valley, the groundwater within the protected areas may lower. The amount of decrease in groundwater levels is unknown and will be affected by the internal drainage system design, which is to be determined. Also, the barrier along the river would divert flow and otherwise change the behavior of the river and its tributaries. Water bodies outside the system could potentially change characteristics locally such as water levels and velocities due to the insertion of the FRMS on the landscape.

- Current assessment depends on general regional geotechnical knowledge; no detailed review of geotechnical data for the site has been conducted. A levee/floodwall system along the Mendenhall River would require extensive geotechnical investigations and evaluation to verify stability, seepage control, and long-term performance under static and seismic conditions.

- Seismic conditions would affect FRM designs, especially choice of foundation types and the details of those foundations; possibility of seismic activity suggests need for deep foundations under all main FRM structures.

- Basic seismic data have been collected for the site, but no analysis of seismic forces on structures, liquefaction of soil, etc., has been performed. It was noted that liquefaction was a noted design component of adjacent bridge foundations, pointing to the importance of seismic in design considerations and possibility they would affect details like foundation pile size and depth. Seismic conditions also affect geotechnical stability analysis and other computations.

- Stability of existing land near the river is an unknown and actively changing design parameter. Similar concerns and required additional analysis regarding permeability of soil adjacent to the riverbanks.

- There are numerous locations along both banks of the river that exhibit instability and indicate riverbanks are actively eroding; it must be assumed that these banks would continue to change until the chosen alternative is fully implemented. Numerous stability, settlement, and other geotechnical investigations are required to characterize existing conditions and provide engineering properties for design for a varied and wide-ranging FRMS. Similar concerns and required additional analysis regarding permeability of soil adjacent to the riverbanks.

- Gated openings: Openings in FRM features for roads and pedestrian access would require gates that stay open most of the year and are closed when a GLOF event approaches. The required number, size, and locations of these features is currently unknown.
- Driving deep foundation components may be difficult because of ground conditions (existence of cobbles/boulders/gravel in the soil column) that would impede with piles and sheet pile).
- Utilities: conflicts and penetrations through FRM alignment need to be identified, designed for, the utility owner located, contacted, and coordinated with. Overhead power lines interfere with pile driving, cranes, etc., if crossing or running adjacent to walls.
- Protection of extraneous airport features: Alignment requires adjustment, further analysis around airport depending on level of flood risk tolerance for in-ground items (runway and appurtenances). A choice could be made to protect only the buildings, the whole airport footprint, or a hybrid.
- An important O&M consideration is determining who would have ownership of the FRMS postconstruction. Sometimes "levee districts", or political subdivisions organized with the purpose of constructing and maintaining protection systems, are created and funded through mileage (taxes) allocations. In other local-ownership instances, the local water management authority takes ownership. If local representation is infeasible, the USACE may want to consider maintaining ownership during construction and operation (Note: no ownership decisions have been made at this time).

4.3.3. Assumptions

Key assumptions associated with the conceptual design alternatives presented herein are bulleted in the subsections below:

Hydraulics, River Behavior, Interior Drainage

Initial H&H analyses provide the following WSE for the design event peak flow of 118,000 cfs (Figure 4-35):

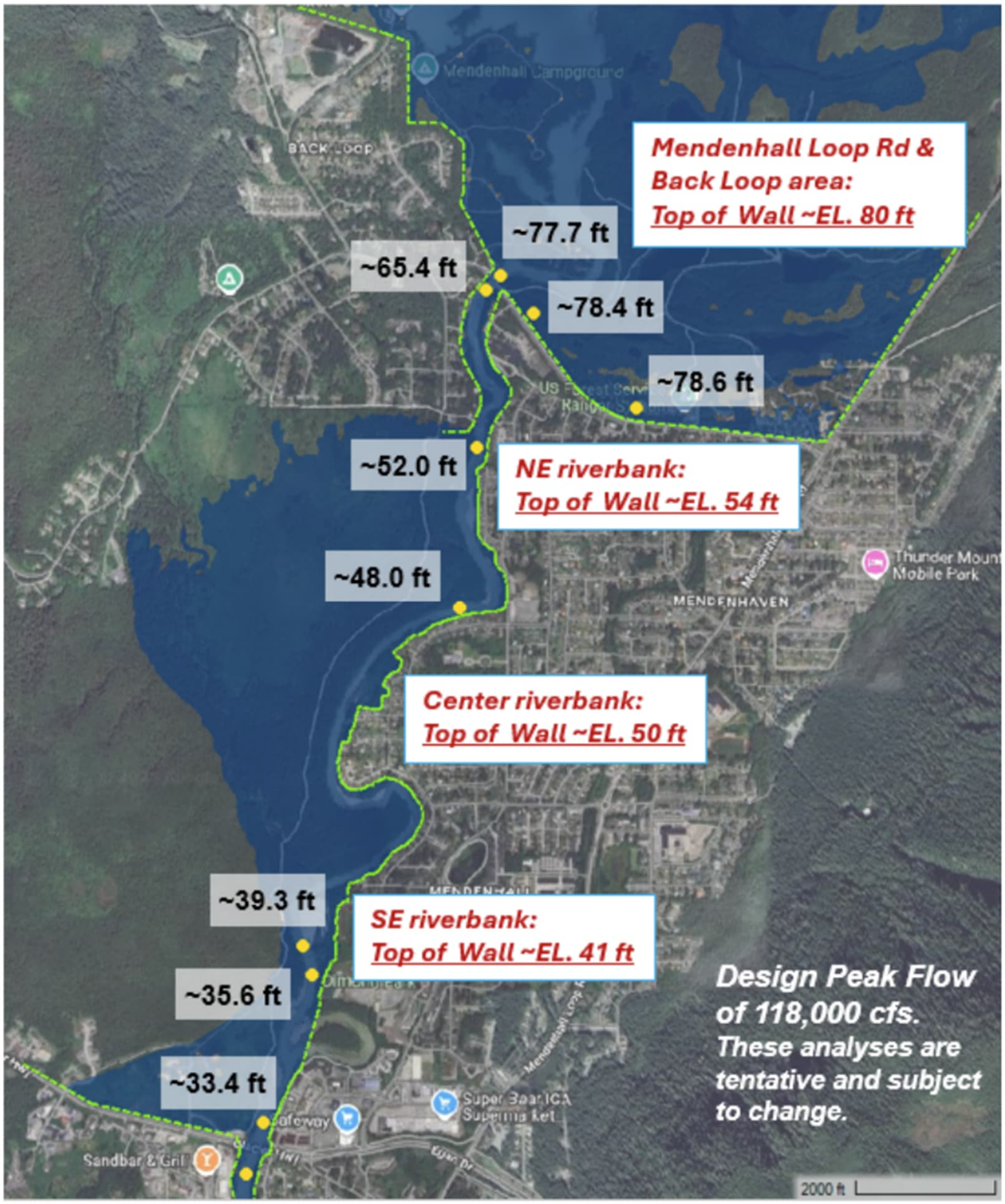


Figure 4-35 Design GLOF Event Water Surface Elevations for Floodwall Alternative

- Preliminary H&H analyses consider the design flow of a combined GLOF and non-GLOF (extreme storm driven by an atmospheric river) event. However, this does not include potential stormwater flooding within the protected area. Because a major rain event could coincide with a high river stage—as seen during the 2025 Suicide Basin GLOF—the design must separately address internal stormwater management. If summer storm runoff within the FRMS is significant enough to cause ponding, the system would require pump stations to lift and discharge water over walls/levees into the elevated river.

- The large oxbow south of Dimond Park may be useful for an interior drainage outlet works. The existing oxbow, which connects to but is mostly separated from the main channel, could be shaped into an outlet channel; nearby land that does not contain residences could be allocated towards a pump station and other drainage structures. Current H&H results consider the oxbow itself to be outside the protected zone, resulting in a longer alignment (conservative assumption for cost purposes).

- Top of Wall Elevation is tentative and subject to change. For the proposed system, Top of Wall has generally been set by rounding up the maximum WSE in the H&H model and adding a 1-foot contingency. It is reasonable to assume any rain or other flood event plus freeboard would result in water levels below the design GLOF event.

- There are abundant drainage outlets for individual properties along the river (refer to Figure 4-36). It would be most advantageous to re-route drainage of properties near the system to a small number of large outlets, which would require the design of a new interior drainage network for many of the settled areas adjacent to riverbanks receiving FRM protection.

- Multiple small waterways network through the Valley and interact with the river. The largest of these is Duck Creek, which traverses the Valley north to south and meets the Mendenhall River near Juneau International Airport (refer to Figure 4-37). Each intersection presents an avenue for backflow into the system similar to what occurs through storm drain networks. Any such waterway crossing would require unique analysis and design to include a control structure and additional seepage cutoff protection. This would necessarily affect the natural environment of the crossing waterways. (Note: Montana Creek is outside the FRMS and would not require a control structure at its outlet.)

Figure 4-36 Photographs of Varied Drainage Outlets throughout the System that Would Require Reconfiguration/New Structures

Figure 4-37 Duck Creek Where it Meets Mendenhall River

Protection Feature Assumptions and Design Details: Floodwalls

In most riverfront areas where FRM features are needed, residences, businesses, and public facilities abut the existing riverbank. Population density along the river suggests the use of primarily T- and I-Walls to minimize the width of frontage that must be acquired (refer to Figure 4-38). A general rule-of-thumb is that levees cost less to design and construct than a concrete floodwall of any type. It would be possible to build a full levee section along both riverbanks to constrict the design GLOF flood; however, the trade-off is a significant increase in the amount of riverfront property that must be acquired and cleared for a wider levee footprint and clear distances.

Figure 4-38 Heavy Population Density Directly Adjacent to Riverbanks

- Length of anticipated riverbank floodwall alignment:
  - 4.5 miles east bank
  - 0.5 mile northwest bank (Back Loop area)
  - 0.75 mile southwest bank (southwest industrial area)

- Heights of anticipated riverbank floodwalls:
  - Northwest and northeast banks south of Mendenhall Loop Bridge:
    - Required Top of Wall ~EL. 60 feet (average of WSEs = 65.4 feet and 52 feet)
    - Existing grade ~EL. 44 feet –Marion Dr. neighborhood topography
    - Required "stick-up" ~16 feet; assume wall structures 18 feet tall.
  - Central eastern banks (from approximately Melvin Park to Riverside Park neighborhoods):
    - Required Top of Wall ~EL. 50 feet
    - Existing grade ~EL. 38 to EL. 40 feet – Killewich Drive neighborhood topography
    - Required "stick-up" ~12 feet; assume wall structures 15 feet tall.
  - Southern eastern banks (from approximately Melvin Park to Riverside Park neighborhoods):
    - Required Top of Wall ~EL. 41 feet
    - Existing grade ~EL. 30 feet – topography south of Foot Bridge
    - Required "stick-up" ~11 feet; land around Husky Stadium highly variable; assume wall structures 15 feet tall.

- Deep foundations will likely be required for bearing capacity, stability, and robustness against GLOF loads. Structural steel pile foundations are assumed herein to develop conceptual footprint, cost and schedule assumptions; however, a thorough evaluation of foundation options and tailoring of chosen solutions to fit project needs would be part of future design phases.

- Assumes sheet pile seepage cutoff walls with slurry wall grout curtains used where utilities, boulders, or other obstructions inhibit driving of sheets. Assumes cast-in-place concrete; however, use of precast concrete units should be investigated in future design phases to speed construction process. Use of precast units may also help with concrete availability concerns.

- Dimensions, pile lengths, etc., assumed based on engineering judgement and similarly sized structures designed for other projects.

Figure 4-39 presents a reasonable representative floodwall for the riverbank alignments. The provided structural section is taken from a previous USACE Flood Risk Reduction Project with similar load conditions (external forces acting on the wall).

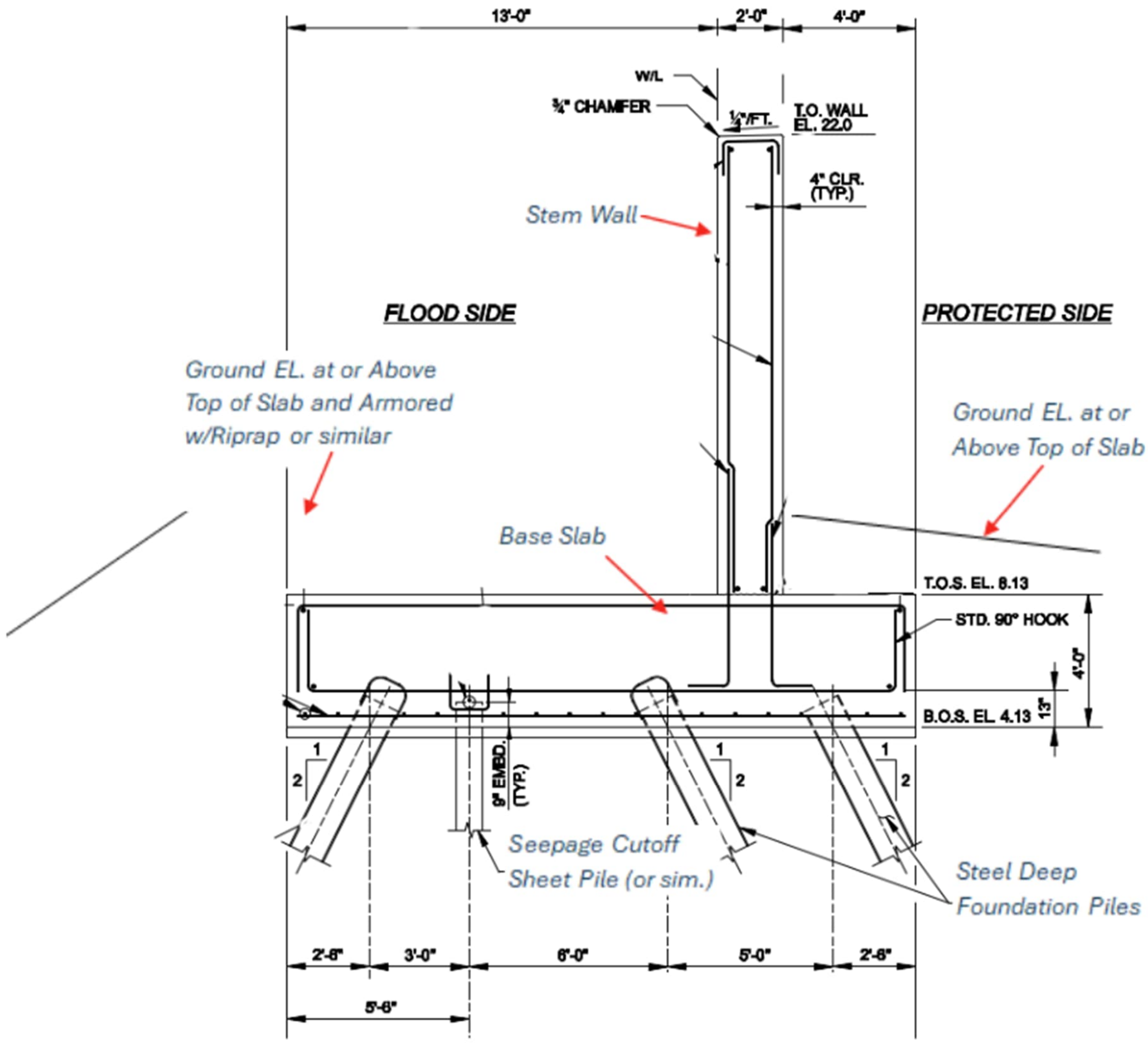


Figure 4-39 Sample Cross-Section of a 14-Foot-Tall T-Wall Floodwall from Previous USACE Project

Protection Feature Assumptions and Design Details: Levees

Unlike the densely populated riverbanks described above, a significant amount of the proposed northern alignment extends through less-developed land. The design team has concluded that levees may be optimal for this stretch because land acquisition and clearing may be less complex, existing roadway right-of-way (ROW) may be used as part of the FRM footprint, and required protection heights are not technically infeasible for levee embankments.

- Levees would be constructed on/adjacent to roadway embankments where roads exist or on undisturbed land adjacent to residences where roads do not.
- Length of anticipated north levee alignment:
  - 0.60 mile Glacier Spur Road
  - 1.0 mile Mendenhall Loop Road
  - 0.8 mile northwestern corner (Back Loop area)
- Heights of anticipated levees:
  - Required Top of Levee ~EL. 80 feet
  - Along Mendenhall Loop Rd, roadway grade varies from ~EL. 70 feet at river to a low point ~EL. 50 feet, then slopes up to ~EL. 64 feet at Glacier Spur Road.
    - Levee would require addition of 10 to 25 feet of embankment to meet Top of Protection requirements along full length of road.
  - Along Back Loop area, existing ground varies from ~EL. 57 feet at its low point to over EL. 80 feet. Practical average for this stretch is a ground surface approximately EL. 70 feet.
    - Levee required averages 15 feet tall, with a maximum ~23 feet tall.
- Slurry wall seepage cutoff.
- Slopes assumed to be 2.5H:1V (slightly steeper than guidelines suggest for riverine levees) on both sides.
- Width of levee at crown:
  - 36-foot-wide crown is anticipated for the Mendenhall Loop Road and Glacier Spur Road levee to accommodate placing the roadways along the levee crest, allowing the current road and shoulder width plus room for guardrails and other safety/utility equipment.
  - 10-foot crown width is assumed a minimum requirement and is anticipated for the northwestern corner (Back Loop).
  - If the levee is constructed along the northern rim of the FRMS, it could incorporate the roadway on top of it or be built adjacent and include a multi-use trail on the crown.

Figure 4-40 presents a reasonable levee cross-section for the riverbank alignments.

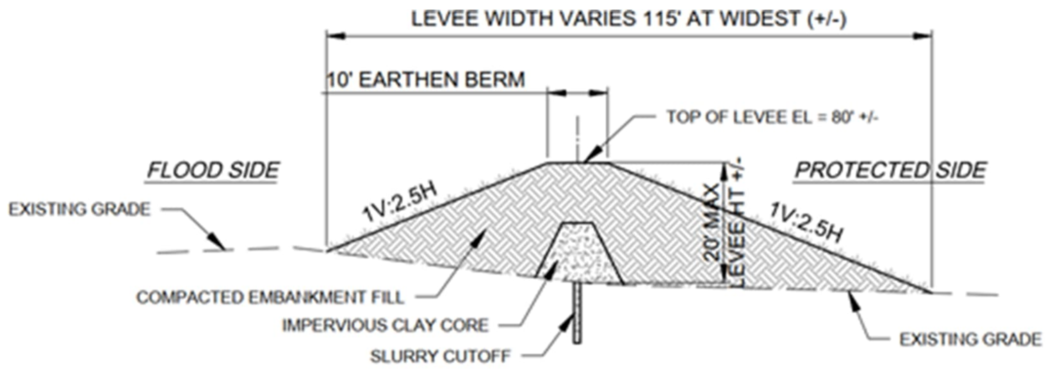


Figure 4-40 Sample Cross-Section of Levee Flood Protection at Back Loop

Geotechnical Assumptions and Details

Current assessment depends on general regional geologic and geotechnical knowledge; no detailed review of geotechnical data for the site has been conducted. A levee/floodwall system along the Mendenhall River would require extensive geotechnical investigations and evaluation to verify stability, seepage control, and long-term performance under static and seismic conditions.

- Subsurface conditions estimated based on limited regional information in literature: ADOT&PF (1984) test holes at Mendenhall Loop Bridge, extrapolation from deeper Brotherhood Bridge borings (ADOT&PF 2010, 2013; Golder 2010), ADNR WELTS water well drillers logs in upper Valley neighborhoods, and Miller (1975) surface mapping and fence diagram interpretation based on USGS geophysics and well data.

- Numerous locations along both riverbanks exhibit instability and indicate banks are actively eroding; it must be assumed that these banks would continue to change until the chosen alternative is fully implemented. Numerous stability, settlement, and other geotechnical investigations will be required to characterize existing conditions and develop engineering properties for design for a varied and wide-ranging FRM. Similar concerns and required additional analysis regarding permeability of soil adjacent to the riverbanks.

- Basic seismic data have been collected for the site but no analysis of seismic forces on structures, liquefaction of soil, etc., has been performed. Liquefaction was a noted design component of adjacent bridge foundations, pointing to the importance of seismic design considerations and possibility they may be design drivers for foundation components. Seismic conditions also affect geotechnical stability analysis and other computations.

- Driving deep foundation components may be difficult because of ground conditions (existence of cobbles/boulders/gravel in the soil column that interfere with piles and sheet pile). Use of soil-mixing technologies to strengthen soils beneath walls and levees and create impermeable barriers in the ground. Deep mixing methods or other such methods to reduce construction footprint and use more existing soils.

- Isostatic rebound could cause a 2- to 4-foot rise in ground level over the project life if the rate continues at the current 0.6 inch per year. A similar amount of sea level rise is expected due to climate change trends.

Future design analysis and investigations include:

- Geotechnical Investigations:
  - Initial phase borings varying from a 200– to 2,000-foot spacing (final phase spacing may be reduced to optimize design parameters and requirements).
  - In general, the locations would follow existing guidance to include EM 1110-2-1913:
    - Along the -centerline and toe: borings every ~500 feet, alternating between undisturbed (for strength/permeability testing) and general/cone-penetration or SPT borings.
    - At high-risk or critical zones (river-side toe, transitions, structures, uncertain geology): tighten spacing — e.g., every 200 to 300 feet, or more borings per reach.
  - Visual site reconnaissance
  - Drilling to bedrock or competent layers to design pile depths and properties
  - Potentially, geophysics to assess variability of soil types and depths beneath the alignment(s)
  - Soil sampling and lab testing (e.g., soil characterization, hydraulic conductivity, strength testing)
- Geotechnical Analysis and Modeling
  - Seepage and Stability: assess static and seismic stability of levee materials along with seepage analyses
  - Liquefaction: assess whether deep soils are liquifiable and how this affects levee and floodwall stability
  - Erodibility: assessing scour potential
  - Seismic: assess site-specific deterministic and probabilistic hazard analyses

Impacts to Existing Infrastructure

- Useful Definitions and H&H Information*:*
    - Low Chord Elevation: The lowest point of a bridge's superstructure.
    - Freeboard: Referencing structures crossing waterways, vertical distance between a bridge structure's low chord and water surface. Referencing flood control structures, additional height of the structure above design water level. Freeboard distances are dictated by codes/guidelines.

Existing structure locations and WSEs along the length of the proposed FRM alignment are presented in Figure 4-41; this figure is used to determine WSE and Top of Wall EL details for structures described in this section.

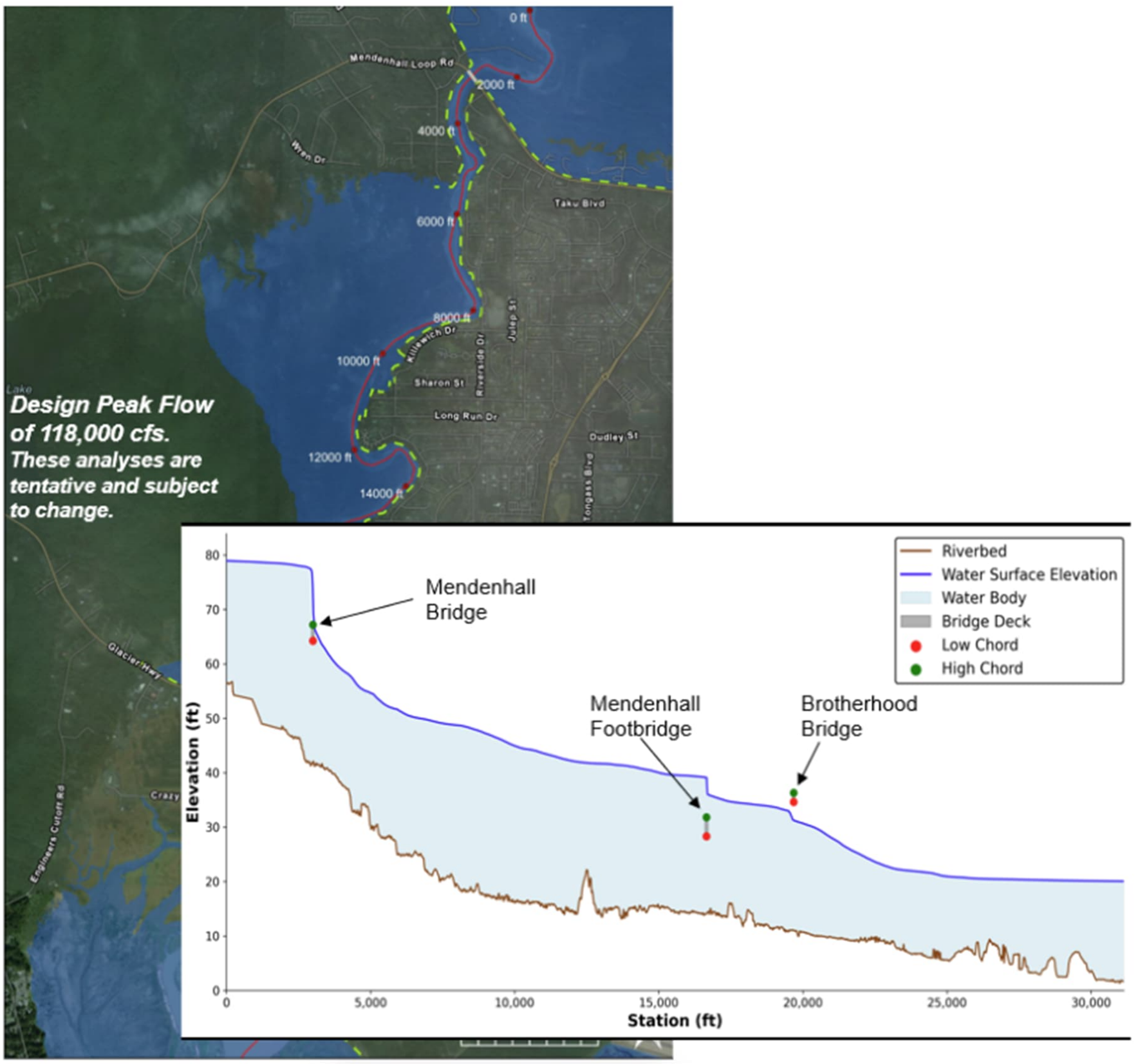


Figure 4-41 Design Water Surface Elevations Along River FRM Alignment

Mendenhall Bridge (on Mendenhall Loop Road)

- Bridge Low Chord = EL. 64.25 feet (west abutment), EL. 67.2 feet (eastern abutment)

- Top of Wall ~EL. 80 feet along Mendenhall Loop Road but drops significantly once channelized into the narrow river cross-section.

- Bridge low chord is below required Top of Wall for the northern levee segment, but above proposed river floodwalls. For the cost and schedule estimates, it should be assumed that this bridge would require significant reconstruction (elevation) or relocation.

- May require the FRMS to extend upstream of current alignment (lengthen length of protection features) to force the WSE drop from the lake flood level (~EL. 80 feet) to the river level (~EL. 56 feet) prior to encountering the bridge. This WSE drop is visible in Figure 4-41 at the Mendenhall Loop Bridge structure.

Mendenhall Foot Bridge (Pedestrian Bridge)

- Bridge Low Chord = EL. 28.25 feet
- Top of Wall ~EL. 41 feet; bridge would be fully submerged in the design GLOF event.
- This bridge would require replacement/relocation above Top of Wall EL. and designed for GLOF flood criteria.

Brotherhood Bridge (on Glacier Hwy)

- Bridge Low Chord = EL. 34.6 feet (western abutment), EL. 35.0 feet (eastern abutment)

- Top of Wall EL. ~EL. 35 feet; bottom of bridge coincides with anticipated WSE.

- Elevating/retrofitting the structure to set all superstructure elements above Top of Wall EL. plus room for floating debris may be economical. This depends on the structure's current condition and design capacities, which are currently unknown.

- Lower-risk option (*Recommended*): raise existing structure, or build new structure, with superstructure elements above design GLOF flood plus freeboard. Design new or retrofit structure for GLOF flood criteria. Raising the structure reduces risk related to flood water and debris flowing over or striking bridge elements. Also, raising the bridge over design flood would maintain a major artery into/out of the system.

- Higher-risk option: install a gated structure across Glacier Highway that would be closed prior to a flood event. A gate of this height and width is technically feasible (roller gate recommended), although its design and construction are significantly more expensive than design of a standard T-Wall. This option also leaves the existing bridge in the floodplain; concerns similar to those of the Foot Bridge higher-risk option above.

Riverside Drive at Melvin Park

- Existing clear space between roadway and top of riverbank is ~25 feet.
- Refer to Figure 4-42. Proposed setback of floodwalls from top of bank is 30 feet. This places the floodwall in the paved area of Riverside Drive at this location. Utility poles run along the western side (water side) of the road, and the watermain is observed along the eastern side (protected side) of the road.
- Special design considerations may be made to shift alignment outside the clear zone of Riverside Drive and avoid reconstruction and relocation of the roadway. This would likely require temporary or permanent relocation of electrical and other utilities running along the utility pole alignment to accommodate construction and move utilities to the protected side of the floodwall. Geotechnical considerations and final wall heights in this segment will determine the feasibility of this design.
- Should floodwall alignment west of the existing Riverside Drive be infeasible, relocation and reconstruction of the roadway may be required. Riverside Drive would be shifted east, and existing parking and structures associated with Melvin Park would need to be removed. Temporary closures, local detour routes, and utility relocations would all be required. The approximate length of reconstruction is 1,000 feet starting at Division Street to the south and ending at Lupine Lane to the north.

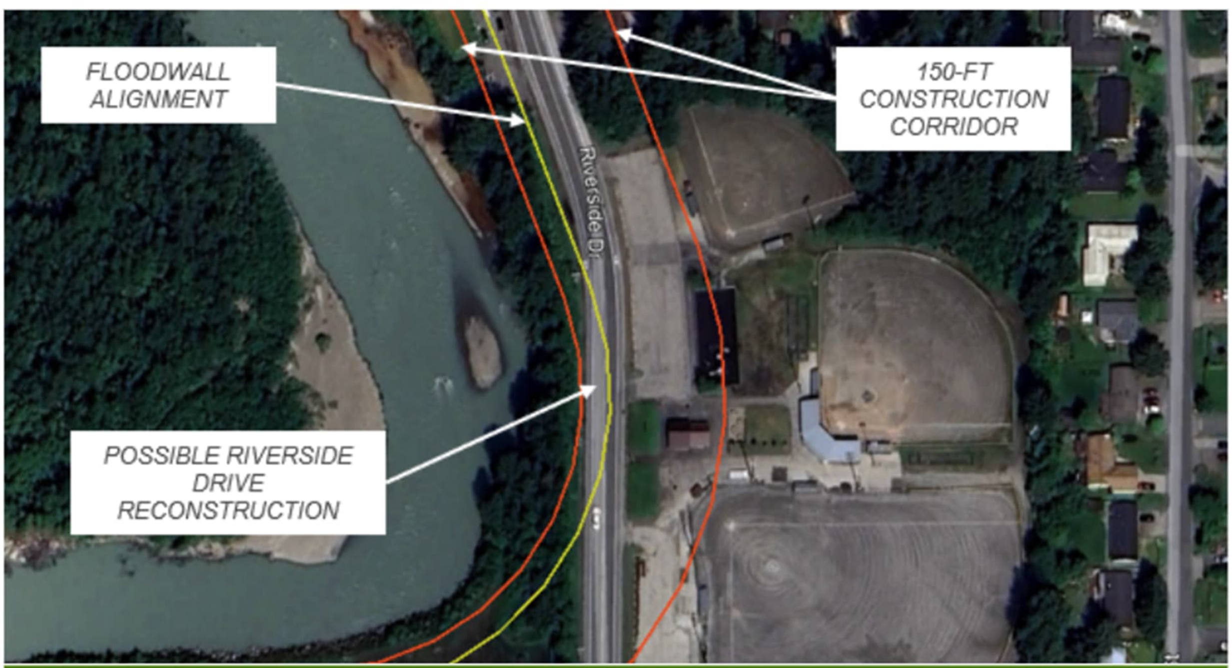


Figure 4-42 Floodwall Conflict at Riverside Drive and Melvin Park

Additional Notes

Through analysis performed as part of other alternatives, the team has determined that solutions that are sometimes combined with FRMS to reduce required Top of Wall EL. are not applicable. Options such as inclusion of a “sacrificial floodplain” or impoundment area are not available due to area topography and large volume of water released due to GLOF events. Also, based on analyses performed on river widening and bypass options, shaping/widening of the river channel to increase flow capacity would not allow for the reduction of Top of Wall EL. to a meaningful degree, while environmental and other impacts could be significant.

4.3.4. Geographic Footprint

The primary aim of the proposed Mendenhall Valley FRMS is to protect as much developed land as practically feasible from the Design GLOF event. Secondary considerations include prioritizing use of readily obtainable easements (i.e., road corridors, public lands), reducing overall impact on the community during and after construction, and reducing impact on the larger environmental systems of the area. The proposed project footprint was developed with these objectives in mind.

An overall map of the proposed Mendenhall Valley FRM alignment and samples of zoomed-in segments are presented below (refer to Figure 4-43 through Figure 4-45). The area bounded by parallel red lines represents an approximate construction limits of work (construction corridor). This construction corridor is a general boundary that encompasses the projected permanent and temporary land needs and should be assumed to be composed of various easements, rights-of-way, fee simple (permanent property ownership), or other land ownership or access agreements. For floodwall alignments, the yellow line is an approximate location of the flood side edges of proposed protection structures; for levee alignments, the yellow line represents the levee structure centerline. A description of the design assumptions and considerations underlying these maps is included in subsequent paragraphs.

The land within the parallel red lines would require acquisition and clearing of the structures and vegetation. There may be a few parcels in the corridor (primarily public buildings or infrastructure) that could be avoided/worked around, provided they only partially intersect the interior (protected side) portion of the corridor and are set back at least 50 feet from the current riverbank. Beyond these work zones, developed parcels indicated on the flood side of the alignment would be outside the flood protection, and would need to be acquired and cleared of structures (but not vegetation) that may become flood-borne debris during a future event.

Construction of the floodwall alternative would require relocation of approximately 340 structures affected by the construction zone or from inundation if unprotected. The analysis of potential effects associated with relocation for this alternative is discussed under the Section 4.5 Relocation Alternative, as partial relocation.

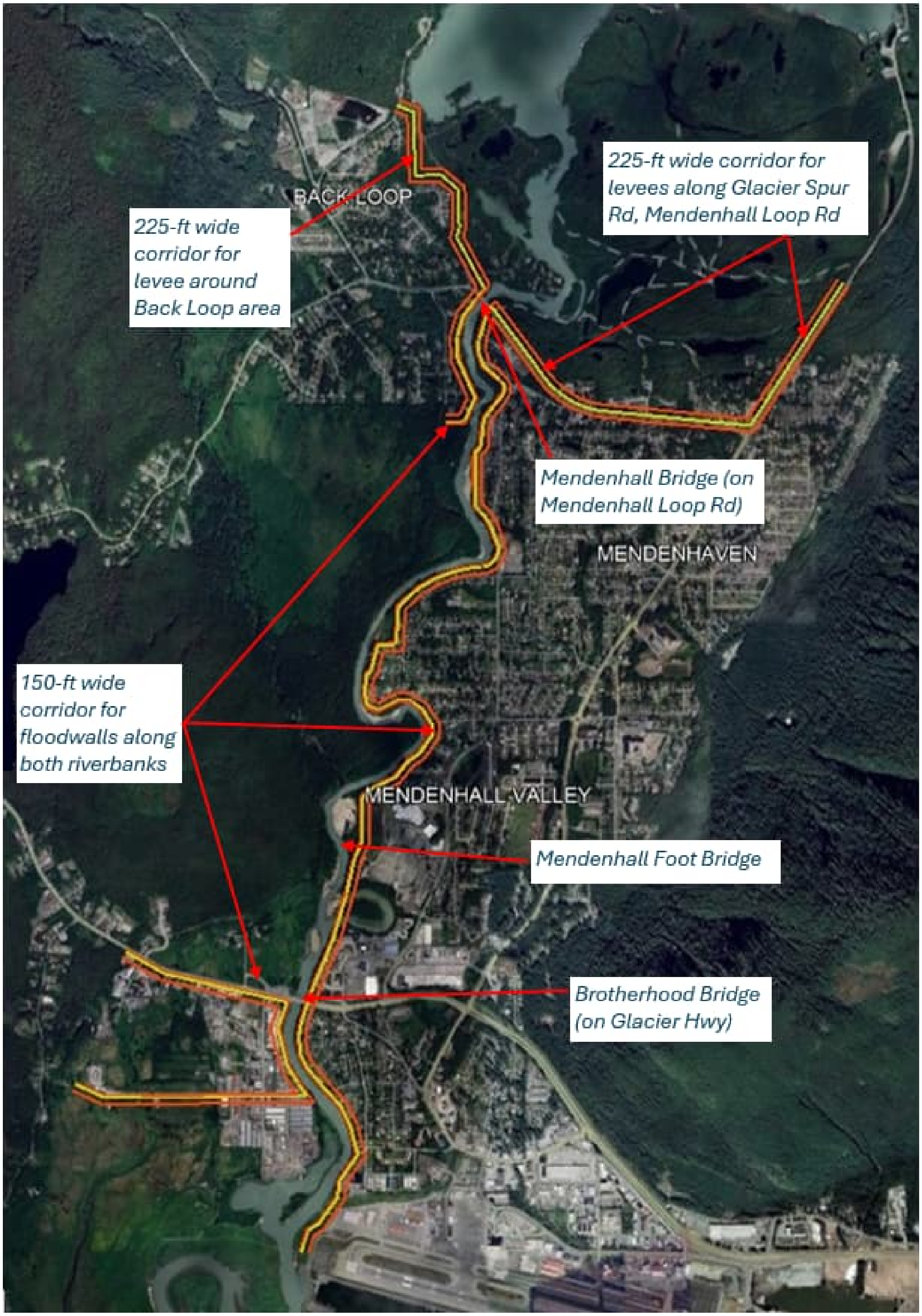


Figure 4-43 Alignment and Construction Corridor for the Proposed Mendenhall Valley FRMS

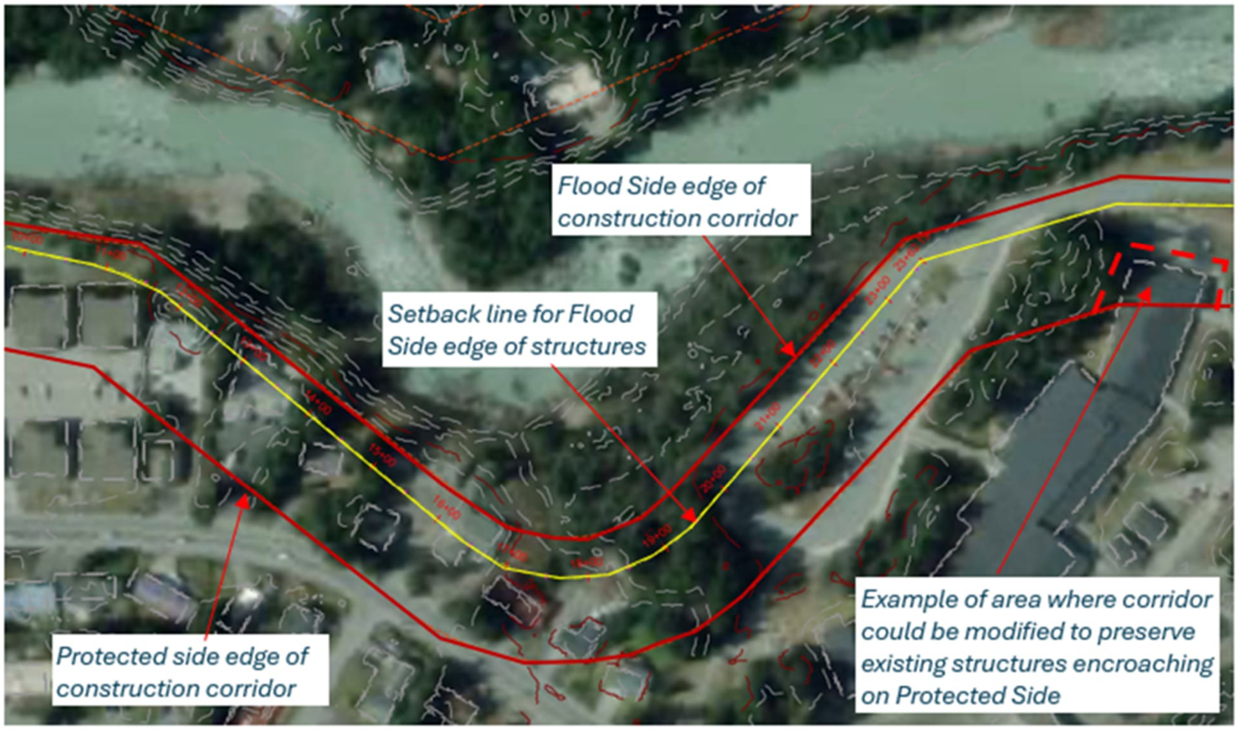


Figure 4-44 Example Floodwall Alignment (Neighborhood South of the Mendenhall Loop Bridge Shown) with 150-Doot Construction Corridor

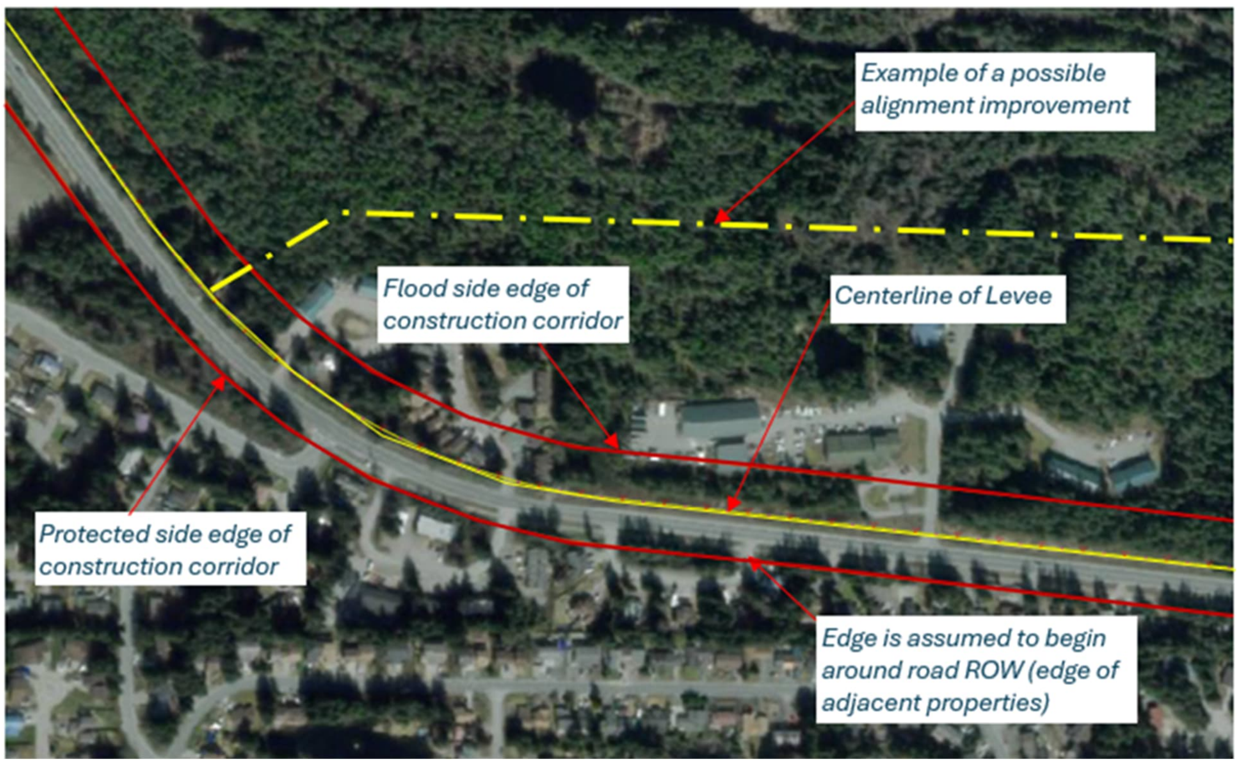


Figure 4-45 Example Levee Alignment (Neighborhood Southeast of Mendenhall Loop Bridge Shown) with 225-Foot Construction Corridor

Proposed Path of Alignment

- Along the river's eastern bank, the alignment generally follows the current temporary HESCO line of protection constructed by the USACE, including second-phase upgrades.
- Along the western bank, alignments follow the riverbank through settled areas between Mendenhall Loop Road and the river's terminus.
- To impede flow from the north, Mendenhall Loop Road and Glacier Spur Road are guides for the alignment from the river to a natural high point to the northeast. Use of road ROW is advantageous because it is public land, generally straight or with gradual curves, and already includes a structural embankment and drainage ditch for the roadway.
- To complete the ring of protection around northwestern residential communities, it is assumed the alignment would extend through the green spaces directly adjacent to neighborhoods; construction corridors are assumed to flank the outermost settled properties and tie into a natural high point to the northwest. Public features like Mendenhall campground and a small number of residences are outside the protected zone.
- To protect the southwestern industrial zone, the alignment is assumed to follow Glacier Highway to the north, follow the riverbank southward, then wrap around the developed land to the south/southwest. Both ends would tie into natural high points.
- Developed areas on the northern edge of the Valley are more challenging to protect because they are lower in elevation and exposed to higher inundation depths.

General Considerations

- The proposed construction corridors should be considered a general site footprint. Similar to an alignment, the precise limits of work would be tailored to fit project and site specifics if this alternative were chosen for development.
- This is a starting point for design based on a high-level review of the project and engineering judgement. Improvement of the alignment to find the most cost- and benefit-positive solution is a necessary and important part of an FRM design process. It should be anticipated that alignment changes would occur to work around topography, utility, or other local site-specific factors. It is important to consider the proposed alignment on a global, not granular, level; judge the alignment as a general suggestion that would be improved, do not judge on a street-by-street level.
    - Improvement opportunity example: move northeast levee alignment northward through Dredge Lakes area (refer to Figure 4-45 for illustration). This alignment shift could increase number of developed properties in protected area, require fewer acres of rights-of-way to be acquired, and reduce the overall length of the FRM structures needed by incorporating the natural ridge's high ground into the alignment.

- FRM features will need to be installed on stable ground. FRM features should be set back from the embankment, founded on stable ground and with stable, armored land on the flood side of the features to maintain foundation soil in place during the design flood(s).

Sizes of Construction Corridors

- The generalized work zones assumed are intended to encompass needs for construction, operation, and maintenance of the FRMS. Access to these lands would be acquired through varied means such as permanent acquisition or temporary/permanent easements. It is likely that some land needed for construction on the protected side of the system may be returned to public use after completion of construction.

- Regardless of the feature used (T-Wall or levee), temporary and permanent easements are required to shape and re-align some of the riverbanks, construct a floodwall/levee, armor riverbanks, and shape and install drainage features on the protected side.

- A 150-foot construction corridor assumed for riverbank alignments:

    - Assumes riverbanks will require floodwalls due to close proximity to existing structures and infrastructure. Floodwalls require smaller footprints, and would result in less required land acquisition.

    - Assumes the engineered structures would be set back 30 feet from the top edge of bank depicted on topographic maps. Setback provides a buffer for potential changes in condition prior to construction, unstable bank segments, channel reshaping work, or other unknowns. A floodwall or levee structure would be installed behind this 30-foot setback line.

    - The 150-foot corridor is derived from consideration of setback distance, size of required floodwalls, allowances for drainage and other utility needs on the protected side of structures, allowances for maintenance roads or walkways adjacent to structures, a flat (walkable) strip of land on the Flood Side between structures and the channel downslope, and a clear work zone with haul route and small lay-down areas.

    - It is possible to reduce the corridor locally to avoid an existing structure if it protrudes into the work zone but does not obstruct the floodwall structure. However, in locations where banks are unstable or the river turns sharply, a wider strip of land may ultimately be required (refer to Figure 4-44 for illustration).

- A 225-foot construction corridor assumed for levee alignments:

    - Where levees are being constructed on undisturbed land: Protected side limits of work is assumed to abut the outermost properties.

- o The 225-foot ROW is derived from consideration of size of levee, road and shoulder width requirements, allowances for drainage ditches, maintenance/inspection paths and roadways, and utility needs on both sides of the levee.

4.3.5. Design Feasibility

The design of a FRMS for most developed areas of the Mendenhall Valley is achievable. Conventional flood protection and floodplain drainage system means and methods would provide multiple options for most engineering challenges created by the GLOF event.

Levee and wall height requirements in excess of those assumed in this report are feasible to construct. The complications that arise from changes to criteria or site conditions would be more applicable to cost/benefit analyses of the alternative than questions of overall feasibility of a floodwall and levee solution. Major project difficulties are (a) the time required to develop a cost-effective and optimized solution, (b) the high cost of a complex FRMS and interior drainage system for the Valley, (c) community acceptance of a very different landscape, and (d) availability of access to the river, and other metrics discussed herein.

4.3.6. Constructability

Complications regarding constructability relate to the duration that may be required to provide a durable design and constructed product, and the labor, equipment, and land requirements of a complex flood protection and interior drainage system construction project.

- This type of construction requires significant staging areas and storage yards; open areas needed to store building components (piles, soil, riprap, crane(s), equipment), install office trailers and other temporary workspaces, etc. Use of many small areas throughout the project alignment can speed construction and reduce overall footprint.
- Concrete, riprap, and embankment material deliveries would be a consistent need. The scheduling and availability of a consistent supply over a period of years would be imperative for timely completion.
- Construction would require significant movement of earthen materials into and out of the Valley as well as within the project footprint. Material would be removed from riverbanks that is unsuitable for use in new embankments; this material would need to be disposed of according to federal, state and local regulations.
- Prone to seasonal constraints (freezing temperatures, important wildlife seasons).
- Heavy civil works equipment needed (large-tonnage cranes, excavators, dozers, road reconstruction machines, etc.). To speed construction, multiple crews may need these items concurrently.

- Multiple 150- to 250-ton cranes needed for floodwall and drainage structure construction. Their use may dictate the need for additional analysis of riverbank stability to confirm banks can support them during construction, and a possible need for localized widening of the construction corridor along the riverbank to provide a larger clear space for them.

4.3.7. Design and Construction Duration

The following is a list of activities or considerations that would impact overall alternative implementation (from preliminary design through completion of construction).

- Land acquisition, relocation, clearing of structures: large corridors of populated riverbank require purchase and clearing of existing structures and vegetation. Settled neighborhoods to the north also require relocation and structure clearing. At a minimum, the required ROW and easements would be acquired by sponsor(s) before construction on those lands could begin. It is possible that Rights-of-Entry or other temporary agreements may be employed to allow data collection on properties within the alignment prior to signing final agreements.

- Projects of this type are most efficiently performed in a linear fashion. Design work requires data from site investigations; engineering disciplines rely on each other to develop designs and must sometimes wait for another entity to finish an analysis before their work can be completed. A linear work process is most efficient, but it is not requisite, for FRMS design.

- Geotechnical exploration: Exploratory testing and analysis required at routine intervals over the ~8 miles of alignment; geotechnical effort may take 6 to 9 months (or more) and/or require the import of equipment and crews. Field, lab, and analysis work must be complete in early stages of the design process (typically, geotechnical reports are 90 percent complete, including USACE reviews, when the entire project is closer to 35 percent complete). Refer to Section 4.3.3, Geotechnical.

- Large number of unique designs: The variability of this river and adjacent land is not conducive to a few uniform designs that can be repeated in multiple locations. Structures that require individual analysis include each structure with a drainage or utility penetration, wall segments with turns in alignment, walls of varying heights, walls with foundation modifications to avoid obstructions, etc. To speed this process, multiple design teams could be used to design many parts of the system in parallel.

- Projects with a need for expediency and support from local, state, and federal entities, such as this one, have been able to overcome challenges described above to speed their design and construction processes. Reasonable, conservative assumptions can be made during design to reduce iteration and move the disciplines ahead concurrently. A well-coordinated and funded project can allow for multiple investigatory crews, design teams, and construction crews working in parallel to progress many parts of the system at the same time. Contract mechanisms can be chosen that truncate the overall design and construction process by allowing construction of some components to begin while others are still in design phase.

- FRM construction would involve:
  - Clearing and grubbing of land in construction corridors along the river and north levee alignments.
  - Shaping of riverbanks and adjacent land (excavation and building of embankments), creating a stable workbench for walls or other structure construction.
  - Stabilization of riverbanks prior to construction (protect land needed for future FRM features from being eroded prior to system construction).
  - Construction of floodwall and levee technical details may vary from the assumptions made in this conceptual analysis; however, the general types of heavy construction means and methods presented would apply.
  - Construction of drainage features along protected side toe of wall, and construction of drainage structures that collect groundwater and discharge it into the river.
  - Construction of at least one pump station to discharge stormwater that could collect inside the system during a combined rain event and GLOF.
  - Armoring of riverbanks at the end of construction (riprap and concrete slope paving).
- Interior drainage: This would be needed to reroute local storm drains to new, larger drainage outlets. Drainage and roadway reconstruction would affect interiors of neighborhoods adjacent to the river, not just residences on the riverbank.
- Limitations on noise, truck traffic, etc., may restrict number of workdays per week or hours per day near residential neighborhoods. But limitations would extended the construction duration in those areas.
- Scheduling multi-discipline construction activities along a narrow, long corridor: crews must be scheduled and arranged to limit conflicts and rework. However, as long as there are multiple, circular haul routes, the project could be constructed concurrently in segments.
- Limitations on local supplies of labor, materials, and equipment. It is likely that specialty crews from outside the local community would be used; these additional workers would require housing. At least some of the required cranes, backhoes, heavy haul trucks for riprap/soil, bobcats, etc., would require outsourcing.
- Reconstruction of multiple bridges.

- Weather and environmental limitations: Extreme cold weather, frozen ground, and rain/ GLOF events may restrict primary construction activities such as concrete/slurry wall construction, foundation installation, channel embankment stabilization, and levee embankment placement. Also, it would likely be necessary to constrain or sequence work around environmental considerations such as salmon spawning and high-flow seasons.

- The area of the eastern riverbank near Melvin Park has been armored with old cars and other metal waste. This appears to be a long-term condition; embankment and tree roots are intertwined with metal. It is likely environmental remediation would be necessary in this and possibly other locations where waste of unknown composition and origin is uncovered during construction. At a minimum, this riverbank area would require environmental investigation to determine toxicity of the waste before the land can be disturbed.

- Encountering artifacts, sacred sites, or other culturally significant areas/items could delay construction of portions of the alignment, although work on other areas of the system could be progressed. If necessary, the alignment could be altered during construction to avoid previously unknown sensitive area(s).

As shown in Table 4-6, in total, from initial design through commissioning of the FRMS, the project could require 7 to 10 years. The critical path is driven by real estate acquisition, environmental permitting, and seasonal construction windows.

Table 4-6 Floodwall Alternative Design and Construction Schedule

Item	Schedule*
Reference Preliminary Design	January 2026 to May 2026
Final Design	June 2026 to November 2027
Real Estate Acquisition (overlapping)	June 2026 to November 2027
Bidding/Contractor Procurement Phases	December 2028 to June 2028
Construction Duration	June 2028 to December 2034

*Schedule presented is approximate. Start dates are subject to approvals.

4.3.8. Reliability/Adaptability/Resiliency

The following are considerations for reliability, adaptability and resiliency for the Floodwall Alternative:

- Traditional USACE design and construction methods (types of FRM structures and systems proposed, codes/manuals to be used, etc.)

- Similar floodwall, levee, and drainage structures have performed well in flood events and outlasted 50-year design lives, provided routine inspection and maintenance recommendations are followed. Floodwalls are generally robust, designed to withstand impact and other damaging loads.

- Systems of this type are highly dependent on details of the design phase. The more time and data are worked into design, the higher the likelihood of a durable and reliable project. A longer design phase allows for inclusion of additional GLOF and H&H data.

- Complex system with many moving parts; reliability is tied to proper operation.

- Significant unknown: stability of existing slopes; what is required to limit current erosion and provide stable slopes and foundations for FRM features.

- Installation of FRMS may protect the community against floods from other sources: GLOF and non-GLOF.

4.3.9. Operations and Maintenance Cost and Requirements

The following are considerations and drivers of Operation, Maintenance, and Lifecycle costs:

- The need for local personnel to operate the system year-round, and augmented as needed in preparation for GLOF events.

- Routine visual inspection of the full system annually. Include annual exercise of all mechanical features (pumps, gates, valves, etc.).

- Formal inspections, typically at 5-year intervals. These are comprehensive inspections conducted by a USACE multidisciplinary team and include data collection, field assessment, and a report. Inspections also dictate need for detailed/in-depth inspections of components or full system if problems are observed.

- Replacement of backflow prevention valves on the outlets at least twice over the 50-year service life due to product service life; likely more frequently due to turbulent flow and debris impact in flood events.

- Replacement of rubber sealant between wall panels and other similar incidentals.

- Replacement of riprap and other slope armoring features: smaller repairs yearly after each flood, plus larger, whole-system investigation and reconstruction efforts that may include earthwork on slopes below, and larger riprap replacement operations.

- Routine vegetation maintenance: If levees are used, they must be routinely mowed, large vegetation pruned within the clear zone depicted previously and woody vegetation removed. If floodwalls are used, grass and large vegetation must be mowed/pruned within the 15-foot clear zone and woody vegetation removed; however, the overall effort would be smaller.

- The construction of this system may result in the need for maintenance and repair of city infrastructure. Heavy truck traffic would increase on the main roads and many smaller residential streets over a period of years; this may result in the need for new asphalt overlays, curb work, etc.

4.3.10. Risk Reduction/Life Safety

The risk evaluation for the FRM alternative summarized in the paragraphs below is qualitative and includes three aspects:

- Risk reduction (life loss and economic)
- Failure likelihood of the constructed FRM features
- Ability to meet USACE TRGs

Refer to the Risk section for descriptions of the meanings of these three aspects of risk.

Risk Reduction

The installation of an FRMS encompassing the majority of the Mendenhall Valley would significantly reduce overall life safety and economic risk from a GLOF event in the protected area. However, the ability of an FRMS to reduce risk is complicated by a number of factors discussed below.

First, the greatest difficulty in implementing this alternative would be related to the availability of time and resources needed to develop a complex, multi-faceted protection and drainage system. An FRMS has a high likelihood of good performance and risk reduction over a period of 50+ years, but only if: (a) there is sufficient time to thoroughly investigate the site, design tailored flood control solutions, and perform construction in a high-quality manner; and (b) there are sufficient resources (land and funding) to generalize and make conservative assumptions that can speed up the design and construction processes (i.e., simplify and overdesign, skip cost-saving optimization processes). Longer design and construction durations needed for a quality product equate to more years during which reliance is placed on higher-risk temporary protection systems to protect the community during GLOF events.

Subsequently, there is the possibility of identifying adverse environmental conditions during design and construction phases that could require environmental investigation and/or remediation, which would further prolong the design and construction period. For example, one area along the river observed during AECOM's November 2025 site visit will likely require investigation and potential remediation before any work can begin due to metal waste used as armoring, which suggests a higher likelihood of finding other dumped materials that—at a minimum—would require analysis to evaluate potential toxicity.

Finally, a preliminary evaluation of available (limited) geotechnical information indicates subsurface conditions that would require geotechnical investigation, analyses, and design more complex and lengthier:

- High-permeability glacial outflow/alluvial deposits occur throughout the Valley, a high-permeability foundation is undesirable and must be mitigated when developing an under-seepage control system to provide a safe structure that meets the project objectives.
- Soil characteristics are also highly variable, which is common for glacial outwash and alluvial plains, but makes geotechnical and structural designs more complex.
- Stability of land near the river is largely unknown and would be an actively changing design parameter that would likely continue to fluctuate until construction, given the dynamic fluvial geomorphology of the Mendenhall Valley. Examples of issues include:
    - Discovery of slope stability issues during design and construction phases that require additional analysis, unique treatment, and/or additional land acquisition.
    - Land could be lost due to severe erosion during a future GLOF event that was counted on in design, requiring re-alignment and re-analysis.
    - Although it is less likely to occur during GLOF events, seismic loading could significantly affect the design and range of feasible options for river slope and floodwall design. At this time, liquefaction and other seismic effects have been considered on a qualitative, not quantitative, basis.
- Similar concerns exist regarding differential settlement potential. Settlement of new levees or other structures could result in damage to the system if not accounted for in design.
- Site conditions may be challenging for deep foundation and seepage cut-off features; rock, cobbles, and boulders could obstruct installation of piles, requiring re-analysis and rework.

Failure Likelihood

Estimating the failure likelihood of an FRMS not yet designed or constructed with a reasonable degree of confidence is not feasible, given the significant number of current unknowns. However, based on preliminary evaluation of available hydrologic, hydraulic, geologic, and geotechnical information, some key PFMs appear to be credible and warrant further evaluation as additional data become available. These PFMs, along with possible risk mitigation measures, are listed in Table 4-7.

Table 4-7 FRMS Alternative Potential Failure Modes and Potential Mitigation Measures

Potential Failure Mode	Potential Mitigation Measure
Levee/floodwall overtopping leading to breach	Adequate freeboard, erosion-resistant land-side protection
Internal erosion/piping through levee (above existing grade)	Cement-stabilization of levee fill, quality-controlled compaction
Internal erosion through levee or floodwall foundation (below existing grade)	Keyed cutoffs, grout curtain, sheet-pile cutoff (if large rocks/cobbles/boulders are absent), filter zones in the dam foundation
External erosion of levee or FRM foundation during GLOF river flow leading to failure and breach	Cement-stabilization of foundation, robust erosion protection on levee flood side (concrete liner, riprap)
Instability of levee or floodwall due to side slope failures, settlement, etc.	Cement-stabilization of levee fill, quality-controlled compaction, routine inspection
Impact from flood-borne debris causing a breach in floodwall	Inclusion of impact forces in structure design criteria
Debris blocking backflow prevention devices, damage to devices inhibiting their operation, removal of devices during flood from impact damage, etc., allowing floodwater to back up into drainage system and flood interior	Inspection of backflow prevention devices at routine intervals and after flood events. Cleaning, repair, and/or replacement of devices per manufacturer recommendations and at any sign of damage/defect
Malfunctioning of equipment (e.g., pump failure at pump station, gate stuck in open position)	Build redundancy into mechanical systems (e.g., include multiple smaller pumps instead of one large pump and/or build in additional capacity), routine maintenance and inspection, yearly exercising of all movable equipment

Ability to Meet USACE TRGs

The third criterion is the ability or willingness of the responsible or affected parties (USACE, Sponsor, Stakeholders, Public) to meet the four USACE TRGs:

- TRG 1 – Understanding the risk
- TRG 2 – Continuing risk awareness
- TRG 3 – Monitoring and managing risk
- TRG 4 – Taking action to reduce risk

Together, the four TRGs encompass all phases of alternative implementation: planning, design, construction, and operation. Any project that would be constructed would include all necessary project features to ensure that the project meets USACE's four TRGs. The four TRGs can be better understood in terms of key questions provided in the Risk section that were asked during the charrette and helped charrette participants collaboratively identify whether the TRGs can be met.

Some key questions are provided below as examples:

- **Is the risk associated with the FRM alternative reasonably understood by all responsible/affected parties (TRG-1)?** For example, if further evaluation reveals the overtopping PFM to be risk-driving, is there a clear understanding of what the estimated overtopping frequency is, and is that likelihood of overtopping considered to be tolerable? If not, does that disqualify the alternative or are there ways to mitigate the risk?

- **Will risk be properly monitored and managed throughout the operational period of the FRMS (TRG-3)?** For example, would the Sponsor develop a levee/flood wall safety program, perform periodic inspections, and perform instrumentation monitoring and analysis?
- **Is it likely there would be cost-effective, socially acceptable, or environmentally acceptable ways to reduce any credible risks identified during the charrette or new risks that may be identified after construction (TRG-4)?** For example, what actions would be taken to reduce risk if/when updated GLOF projections indicate a substantially higher expected flood volume?

Such questions, among others, were asked during the charrette and input of charrette participants was requested. If one or more questions could not be confidently answered or there were significant uncertainties with the answers, a lower risk score for the FRM alternative was considered. Conversely, if the questions can generally and reasonably be answered in the positive, a higher risk scoring was considered.

4.3.11. Operational Impacts

- Brotherhood Bridge would require closure/detours for a significant period of time (6 months minimum; more likely a 1+ year). This would significantly affect local traffic patterns as well as the haul and access routes for construction of this project.
- A large strip of land along the river and additional outlying areas would require acquisition, relocation, and clearing of existing structures and vegetation.
- Construction would be located adjacent to highly settled areas along the river. Activities such as pile and sheet pile driving, heavy truck traffic, and use of large earth-moving equipment would occur close to existing structures; trucks carrying material and equipment would routinely drive into and out of construction areas through neighborhoods. Assume these activities would occur over multiple years.
- Construction would impact traffic on Mendenhall Loop Road while the adjacent land is cleared, levee/wall segment is built, and the River channel beneath the bridge is shaped. Assume lane closures or bridge and adjacent stretches of road (but likely minimal full bridge closures) intermittently for a multi-year period. This would significantly affect local traffic patterns as well as the haul and access routes for construction of this project.
- Mendenhall Loop Bridge and Brotherhood Bridge comprise the only two vehicle crossings of the Mendenhall River. Construction would need to be staged so that at least one access remains open. During work on either bridge, or during reconstruction of Mendenhall Loop Road for levee construction, detours would route traffic over the open bridge.
- There are fire and ambulatory stations on both sides of the Mendenhall River, with the Auke Bay Fire Station on the west and the Glacier Fire Station on the east. However,

preliminary investigations determined that there are no hospitals, urgent care facilities, or immediate care facilities on the western side of the river. Coordination with emergency response stakeholders, as well as school and bus companies, and advance notification to the public would be needed.

4.3.12. Environmental/Cultural Considerations

Construction of the FRMS would impact wildlife and natural ecosystems in the Mendenhall Valley by creating barriers to migration, and changing natural water systems. There are also cultural concerns, as there is evidence of human use of Mendenhall River going back centuries and it is likely that cultural sites would be discovered during construction. The community would be heavily impacted as well, through construction activities and barriers in residential neighborhoods that create eyesores, take up personal property, and create barriers to access to the Mendenhall River.

Environmental Impacts

- Overall effect on groundwater: There could be an unknown amount of change to existing groundwater table in areas near the FRMS seepage cutoffs. A potential secondary effect of lower water table is settlement. As the water table drops, newly dried soils may consolidate (reduce volume). Settlement of protected areas of the Valley could occur, although the amount is unknown.

- Changes to Mendenhall Lake and River: There could be an unknown level of impact from the proposed structures on mechanics such as velocity, bed scour, sediment transport and deposition, changes in normal water levels, wildlife habitats and behaviors, etc.

- Changes to connecting watershed: Walls along the river would deflect flow and otherwise change behavior of the river and its tributaries year-round. It is likely that even water bodies outside the FRMS would have changes in characteristics such as water levels and velocities due to the insertion of the FRMS on the landscape. For example, it is likely the natural behavior of Montana Creek would change once the system is installed, especially where it nears the Mendenhall River, even though it is external to the FRMS. Montana Creek is known to be an important anadromous stream and may be sensitive to any changes.

- Encroachment into USFS land along northern alignment: ROW is needed adjacent to Mendenhall Loop Road and forested land between the Back Loop neighborhood and park campground.

- Debris removal: An area of the eastern riverbank near Melvin Park has been armored with old cars and other metal waste. This appears to be a long-term condition; embankment and tree roots are intertwined with the metal waste. It is likely environmental remediation would be necessary in this and possibly other locations where waste of unknown composition and origin is uncovered during riverbank shaping and floodwall construction.

- Wetlands: Impacts to wetlands are likely due to construction activities, easements, or other project requirements. FRMS construction would change water levels and potentially other conditions in the wetlands area west of the river. Also, there would likely be significant changes to the existing oxbow area south of Dimond Park (either cutting it off from the river behind the FRMS or leaving it in the river basin but reshaping to use as a large drainage structure outlet). Mendenhall Wetlands State Game Refuge (3,786 acres) is a globally significant bird habitat; FRMS-induced hydrologic changes could degrade wetland function.

- Threatened, Endangered, Sensitive, and Special-Status Wildlife Species: Steller sea lion, humpback whale (protected by the Endangered Species Act), Queen Charlotte Goshawk (USFS Region 10 Sensitive Species), Bald Eagle (protected by the Bald and Golden Eagle Protection Act), harbor seals (protected by the Marine Mammal Protection Act). The shores of Mendenhall Lake and Auke Bay are important areas for breeding seabirds, including Arctic Terns, Mew Gulls, Herring Gulls, and Glaucous-winged Gulls, all protected by the Migratory Bird Treaty Act. Consultation would be required with USFS, USFWS, and NMFS for marine species. Nearby Goshawk nests and Bald Eagle nests should be taken into consideration when determining the construction schedule.

- Fish Habitat: Mendenall River and its tributaries are home to spawning populations of coho salmon, sockeye salmon, Dolly Varden char, coastal cutthroat trout, and rainbow trout/steelhead trout. Instances of rearing Chinook salmon have been reported. Consultation would be needed with NMFS on Essential Fish Habitat.

- Habitat fragmentation: Construction of levees and floodwalls could disrupt terrestrial species' access to Mendenall River and migration pathways.

- Cultural Resources: Archaeological sites and traditional use areas: These areas require NHPA Section 106 review with the SHPO, NEPA review, and tribal consultation. to determine impacts, assess potential mitigation, and consider possible inclusion in the NRHP.

- Historic Properties: Sites of particular concern include Mendenhall Campground (JUN-01303). The MGRA in its entirety is also a designated Historic Property. Historic Properties require NHPA Section 106 review with the SHPO, NEPA review, and tribal consultation.

- Hazardous waste: There could be potential legacy contamination near former industrial or maintenance areas; a Phase I Environmental Site Assessment recommended. Disposal of hazardous material may require shipment for treatment and disposal outside of Juneau.

- Air Quality: Juneau is a maintenance area for particulate matter 10 microns in diameter or less; dust from haul roads and material stockpiles must meet State Implementation Plan requirements.
- Noise and Traffic: Equipment and material hauling would increase noise and congestion, particularly during tourism season.

Impacts on the Community

- As noted previously, a large construction corridor is required for FRMS feature construction along the entire eastern riverbank, portions of the western bank, and the northern alignment along Mendenhall Loop Road, Glacier Spur Road, and the forested area adjacent to the Back Loop and surrounding neighborhoods. Areas that are infeasible for floodwall protection would also require relocation/acquisition.
- The floodwall would be conspicuous and obstruct views of the river from adjacent roads/ properties. It would likely average 15 feet of stick-up above the ground surface. For reference, the current HESCO barrier is a maximum 8 feet tall (Figure 4-46). The wall would be very close to existing properties at multiple locations. It should be anticipated that most banks of the river would be armored for scour protection, at a minimum with large riprap or concrete slope paving.

Figure 4-46 Current 8-Foot-Tall HESCO Barrier Near Melvin Park; Proposed Floodwalls Would Likely Average Approximately Double the Height of These Barriers

- Bridges would require significant retrofit or replacement. Pedestrian and Brotherhood Bridges would require closure and detours for a significant period of time (minimum duration of 6 months, likely extending 1 year or longer).

- Construction would occur adjacent to highly populated riverbanks for multiple years. Construction activities such as pile and sheet pile driving, heavy truck traffic, and use of large earth-moving equipment would occur close to existing structures; trucks carrying material and equipment would routinely drive into and out of construction areas through neighborhoods.

- A large number of varied construction crews (earth moving/channel shaping, pile driving, concrete construction, bridge construction, grass seeding, scour protection installation, interior drainage modifications, roadway construction) would be required. It is likely work crews from outside the Valley would be required to complete work quickly. Similar considerations should be made regarding the equipment and machines needed; it is unlikely that local supplies would be sufficient to support the effort.

4.3.13. Permitting/Programming Concerns

State, federal, and local permits that may be required under this alternative include the following:

- USACE requirements for Section 404 (Clean Water Act) – Fill in waters/wetlands.

- USACE requirements under Section 401 (Clean Water Act) – Certificate of Reasonable Assurance for potential discharge into Mendenhall Lake. The Clean Water Act is enforced by the ADEC.

- USACE requirements for Section 9 and 10 (Rivers and Harbors Act) (potentially) – Construction of structure(s) in or over any navigable water of the United States.

- NEPA – Required for major federal actions unless otherwise exempted (USACE and USFS).

- NHPA Section 106 – SHPO and tribal consultation.

- Section 7 of the Endangered Species Act – USFWS and NOAA Fisheries.

- USFS Consistency with 2016 Tongass Forest Plan.

- Anadromous Fish Act (AS 16.05.871-.901) – Fish Habitat Permit –ADF&G for anadromous streams and NOAA Fisheries for Essential Fish Habitat on anadromous streams.

- Fish Passage Act (AS 16.05.841) – ADF&G for fish passage.

- Floodplain Development Permit, and other zoning and conditional use authorizations (CBJ)

- Coordination with Tlingit and Haida and ANCSA Regional and Village corporations for cultural and land interests.

4.3.14. Key Takeaways

The FRMS is a network of concrete floodwalls and earthen levees, with average wall heights of 10 to 15 feet (floodwalls) and 15 to 25 feet (levees). FRMS protection features include seepage cut-offs (sheet piles, slurry wall curtains) to limit underseepage beneath the wall/levee. The system also includes an engineered interior drainage system with pump stations, backflow preventers, and stormwater outlets

Primary Benefits:

- Reduces life safety and economic risk from GLOF events for most developed land in the Mendenhall Valley.

- Provides robust, long-term flood risk reduction designed to USACE standards and based on similar systems in other locations with proven performance records.

- A comprehensively designed system would also limit flood damage from non-GLOF flood sources (e.g., heavy rainfall, riverine flooding).

Major Challenges:

- Large-scale land acquisition and relocation of existing structures, especially along densely populated riverbanks.

- Complex, multi-year construction with significant impacts on traffic, noise, and community access.

- Extensive H&H, civil and geotechnical investigations would be required to determine GLOF and non-GLOF design criteria, site topography specifics/limitations, potential for variable soils, seismic risks (liquefaction), porosity, and soil strength characteristics.

- Need for major utility relocations, bridge retrofits or replacements, gated openings in system, and coordination with multiple stakeholders.

- High cost and resource requirements for both construction and long-term operation/ maintenance.

- Environmental impacts: wetland disturbance, wildlife habitat disruption, legacy contamination, and air quality concerns.

- A number of critical unknowns at this time, such as specifics of the local drainage system, effects of system on river and tributary mechanics, details of local geology and geotechnical design information, ownership of the FRMS after construction, etc.

4.3.15. Discussion

A summary of talking points from the questions and discussion following the presentation of this alternative are included below. Please refer to Appendix B: Charrette Meeting Minutes, for additional information.

- The amount of setback for this alternative depends on the section of the river. In some places, some frontage could be given back. In others, the setback may need to be moved back even further.

- This alternative attempts to maintain the general shape and composition of the existing riverbed, but it is reasonable to assume most slopes around protection features will require armoring.

- Concern was raised about how CBJ can continue flood fighting while this alternative is under construction. This would require complex coordination, specifically during GLOF season, when the focus would be on filling in gaps in the partially constructed system.

- There was discussion about analogous projects that could be used as precedents—projects were discussed that have similar river characteristics and tight corridors.

4.4. Hybrid Dam/Floodwall Alternative

The Hybrid Dam/Floodwall Alternative combines a flood control dam with a system of floodwalls in the Mendenhall Valley to mitigate the design GLOF risks. This approach reduces the required height of both the Dam and Floodwall structures as stand-alone options, improving constructability and minimizing environmental and community impacts. The analysis assumes a peak dam release of 50,000 cfs during the design event, storing the remaining volume of the flood hydrograph behind the dam. This peak release is similar to the 2025 GLOF event, which was managed by temporary HESCO barriers, demonstrating that 4- to 8-foot high walls can protect most of the community.

Both components (i.e., dam and floodwall) would be designed and operated as an integrated system to increase resilience and reliability. The main benefit of this alternative offers smaller structures (dams and floodwalls) and narrower project footprint widths per segment while seeking to minimize community impacts and visual obstructions. Challenges remain in optimizing floodwall segments, managing interior drainage, and addressing unknowns such as utility conflicts and foundation quality. The negative is a large project footprint that spans the length of the floodwall and the length of the dam across the Valley.

4.4.1. Technical Discussion

The design assumes, and Figure 4-47 depicts, a peak flow release of 50,000 cfs during a GLOF event, storing the remaining inflow higher than the 50,000 cfs release capacity behind the dam for gradual release. This discharge level is comparable to the 2025 GLOF event, which was contained in the river channel by the temporary HESCO barriers (stacked 1 or 2 high, or 4 to 8 feet high), demonstrating that relatively low-height walls can provide substantial reduction in areas of flooding when combined with flood storage with a dam. However, implementation of a levee and floodwall system along the Mendenhall River would offer a permanent mitigation measure to minimize flood impacts from future GLOF events on downstream infrastructure and communities by attenuating peak discharge to a rate that can be safely conveyed through the downstream floodwall system.

Figure 4-48 depicts the hydraulic modeling results of the predicted inundation zones with the implementation of this hybrid alternative. The floodwall alignment would largely follow the Floodwall Alternative, but terminate near Mendenhall Loop Bridge, with further hydraulic modeling needed to confirm protection on the river's western side and the potential impacts likely river stages would have in these areas. Figure 4-48 depicts the floodwall extending east along Mendenhall Loop Road, and north along Glacier Spur Road remains dry, and therefore would not be needed.

The reduced height of floodwalls improves constructability and cost effectiveness. Floodwalls designed at 4 feet or less above grade may use I-Wall configurations, which results in a smaller footprint compared to T-Walls. I-Walls consist of sheet piles driven into the ground and capped with reinforced concrete wall above grade, suitable for low-height applications where stability and seepage control are critical.

Dam design for the Hybrid Dam/Floodwall Alternative would mirror the Dam Alternative, but with reduced height (approximately 10 feet), smaller footprint, and larger outlet works/spillway to convey the same release capacity with a lower flood pool elevation in the reservoir. A minimum crest width of 10 feet was assumed for conceptual volume and cost calculations. If the dam alternative had been selected as the base option, the crest width would need to be adjusted based on the specific dam type. Additionally, the crest may need to be wider to accommodate riprap, embankment zoning and constructability.

The combined Dam/Floodwall alternative would function as a dry dam. By limiting the volume and duration of water impounded, a dry dam configuration significantly reduces seepage potential through the dam foundation. Outlet works would be designed to limit the downstream discharge to 50,000 cfs during GLOF events.

The dam alignment, presented in Figure 4-49, follows the northern alignment presented in the Dam Alternative, extending across the Valley with a smaller base and lower overall height (Figure 4-50).

Figure 4-47 Areas Inundated with a Dam Release of 50,000 cfs without Downstream Floodwalls

Figure 4-48 Floodwalls Shown with a Dam Release of 50,000 cfs

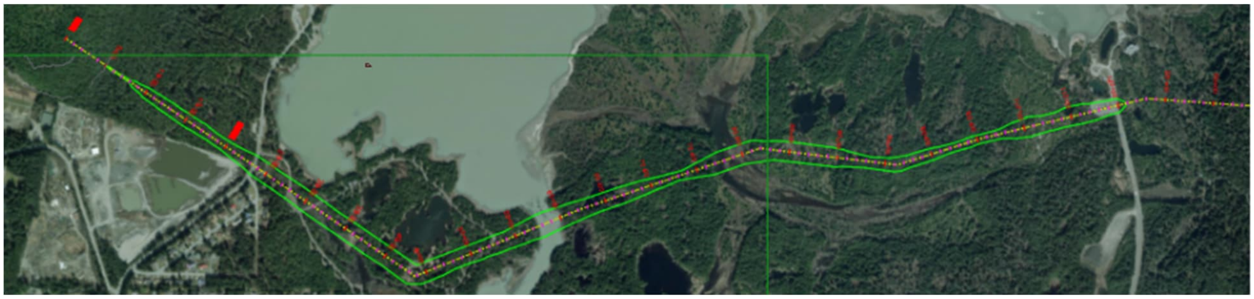


Figure 4-49 Dam Footprint and Alignment

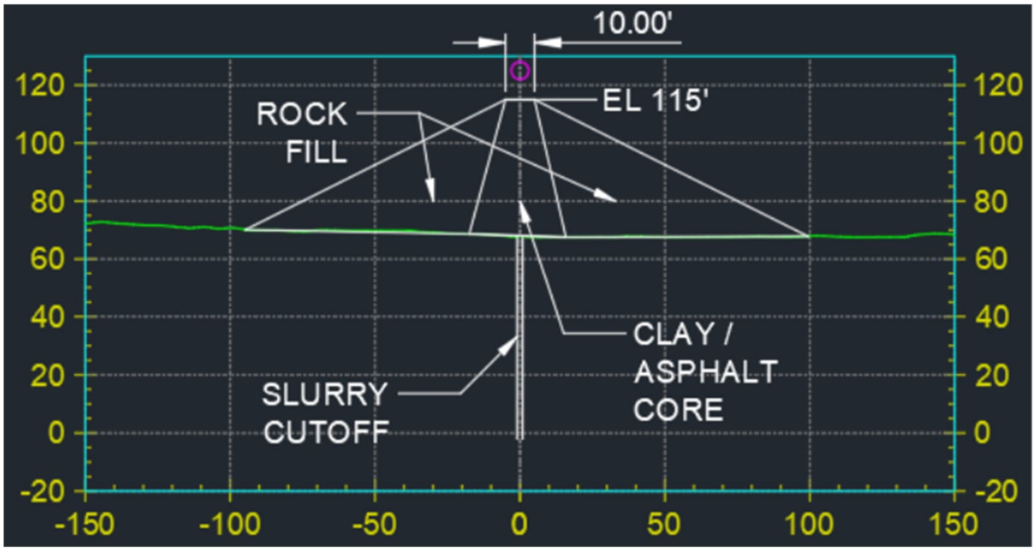


Figure 4-50 Typical Section for the Dam with a Maximum Elevation of 115 Feet

Hydraulic modeling would refine dam height and storage requirements to balance structural efficiency and operational reliability. For further discussion on hydraulic modeling and loading, see Section 4.2.1.

4.4.2. Technical Unknowns

The design presented is conceptual, and a detailed study and analysis would be needed to characterize the following:

- Geotechnical and subsurface conditions, including foundation quality and seepage control
- Seismic performance and structural stability under extreme events
- Utility conflicts and penetrations along floodwall alignment
- Environmental and permitting considerations
- Interior drainage and pump station requirements
- Material availability and construction sequencing
- Long-term O&M costs

For further discussion of the floodwall and levee considerations, assumptions, risks, and unknowns, reference the section for the Floodwall Alternative. In general, this includes:

- Footprint required for wall alignment (less required where I-Walls can be used)
- Construction easement/footprint (less required where I-Walls can be used)
- Offset distance from riverbank for stability
- Interior drainage network, outlet works structures, and pump stations
- Protection of riverbank where erosion and instability exists
- Bridge crossings (less impact with lower stages)
- Seepage cutoff
- Environmental impacts
- Seismic conditions
- Stability of existing land
- Impacts on groundwater
- Utilities – number of conflicts and penetrations through the alignment are unknown

For further discussion of the dam considerations, assumptions, risks, and unknowns, reference the section for the Dam Alternative. In general, this includes:

- Dam type
- Geologic conditions
- Design considerations, assumptions, and technical unknowns
- Design feasibility and construction duration
- Geotechnical and subsurface unknowns
- Foundation considerations
- Seepage and seismic conditions and considerations
- Risks and failure modes
- O&M considerations
- Permitting and environmental considerations
- Impacts on tourism and USFS lands

4.4.3. Assumptions

Refer to Section 4.2.3 (Dam) and Section 4.3.3 (Floodwall) for relevant assumptions associated with the hybrid alternative.

4.4.4. Geographic Footprint

Refer to Section 4.2.4 (Dam) and Section 4.3.4 (Floodwall) for geographic footprint associated with the hybrid alternative.

4.4.5. Design Feasibility

Refer to Section 4.2.5 (Dam) and Section 4.3.5 (Floodwall) for design feasibility discussion associated with the hybrid alternative.

4.4.6. Constructability

Refer to Section 4.2.6 (Dam) and Section 4.3.6 (Floodwall) for constructability discussion associated with the hybrid alternative.

4.4.7. Design and Construction Duration

Refer to Section 4.2.7 (Dam) and Section 4.3.7 (Floodwall) for additional information regarding the design and construction duration discussion associated with the hybrid alternative. The hybrid alternative and construction schedule is shown in Table 4-8.

Table 4-8 Hybrid Alternative Design and Construction Schedule

Item	Schedule*
Reference Preliminary Design	January 2026 to May 2026
Final Design	June 2026 to November 2027
Real Estate Acquisition (overlapping)	June 2026 to November 2027
Bidding/Contractor Procurement Phases	December 2028 to June 2028
Construction Duration	May 2028 to December 2035

*Schedule presented is approximate. Start dates are subject to approvals.

4.4.8. Reliability/Adaptability/Resiliency

Refer to Section 4.2.8 (Dam) and Section 4.3.8 (Floodwall) for reliability/adaptability/resiliency discussion associated with the hybrid alternative.

4.4.9. Operations and Maintenance Cost and Requirements

Refer to Section 4.2.9 (Dam) and Section 4.3.9 (Floodwall) for O&M cost and requirements discussion associated with the hybrid alternative.

One major consideration for this alternative is the added O&M considerations. Operating and maintaining a dual system of a flood control dam and floodwalls introduces significant added complexity and burden compared to a single-structure alternative. The dam requires routine inspection of spillways, embankments, and seepage control measures. Simultaneously, the floodwall system demands ongoing monitoring for settlement, seepage, and structural integrity along multiple segments, plus upkeep of interior drainage networks and pump stations. Coordinating these efforts as an integrated system increases staffing needs, specialized expertise, and long-term costs, while also requiring robust emergency response protocols to manage interdependent components during high-flow events.

4.4.10. Risk Reduction/Life Safety

Refer to Section 4.2.10 (Dam) and Section 4.3.10 (Floodwall) for risk reduction/life safety discussion associated with the hybrid alternative.

4.4.11. Operational Impacts

Refer to Section 4.2.11 (Dam) and Section 4.3.11 (Floodwall) for operational impacts discussion associated with the hybrid alternative.

4.4.12. Environmental/Cultural Considerations

Refer to Section 4.2.12 (Dam) and Section 4.3.12 (Floodwall) for environmental/cultural considerations discussion associated with the hybrid alternative.

4.4.13. Permitting Concerns

Refer to Section 4.2.13 (Dam) and Section 4.3.13 (Floodwall) for permitting concerns discussion associated with the hybrid alternative.

4.4.14. Key Takeaways

Refer to Section 4.2.14 (Dam) and Section 4.3.14 (Floodwall) for key takeaways discussion associated with the hybrid alternative.

This alternative would be designed and operated as a system, with the dam and floodwalls working in tandem to protect the Valley from GLOF events. The reliability and resilience of this system would be a function of the combined components and should not be separated.

The basis of the design of this alternative is largely based on the factors and descriptions contained under the narratives for both the Dam and Floodwall Alternatives. Reference these sections for the technical design parameters for dams, levees, and floodwalls. As with the Floodwall Alternative, it is difficult to optimize efficient floodwall design, due to each segment and drainage structure potentially being different depending on localized conditions; or conversely, the entire system can be overdesigned to the most complex or robust part of the system and replicated to the rest of the area to expedite the design, but with a much higher cost.

4.4.15. Discussion

A summary of talking points from the questions and discussion following the presentation of this alternative are included below. Please refer to Appendix B: Charrette Meeting Minutes, for additional information.

- This alternative would impact the number of structures that are impacted by the dam and levee alternatives, combined, but less the properties needed along the footprint of the eastern flank levee that would not be needed.

- This alternative allows for control of releases to the Mendenhall River.

- It is possible that the floodwalls could impact groundwater levels, like for the Floodwall Alternative.
- From an adaptability perspective, this alternative and the floodwall have the benefit that if the river rises for other reasons—non-GLOF events—would also minimize flooding in the town and community.

4.5. Relocation Alternative

Under the Relocation Alternative, Mendenhall GLOF flooding would likely require buyout and relocation of structures in flood-prone areas and construction of replacement infrastructure affected by inundation with no flood protection measures constructed, including temporary HESCO barriers. In addition, the dam, floodwall, and dam/floodwall hybrid alternatives would require partial relocation due to the 1) physical and construction zone footprint of those alternatives, and 2) inundation of parcels that are not protected by those alternatives. The analysis of potential effects of complete relocation is discussed in Section 4.5, along with the potential effects of partial relocation associated with the dam, floodwall, and dam/floodwall hybrid alternatives.

The Relocation Alternative involves six steps:

1. **Identify affected parcels and types of structures under the projected flood stage for each of the alternatives**. Based on preliminary hydraulic input and modeling that included a design flow with a peak of 118,000 cfs, the Relocation Alternative would require relocating approximately 2,500 structures due to flooding; the Dam Alternative would require relocating approximately 90 structures; the Floodwall Alternative would require relocating approximately 340 structures; and the Dam/Floodwall Hybrid Alternative would require relocating approximately 265 structures. An additional 400 parcels with no structures could be considered for buyout/compensation. The complete Relocation Alternative would also affect approximately 20 critical public facilities, some of which would need to be relocated. Section 8315 allows for federal cost sharing of construction of replacement infrastructure associated with relocation.
2. **Buyout, compensation, and demolition of affected parcels and structures.** USACE has procedures for determining the buyout, compensation, and demolition that are set forth in USACE Relocation Guidance ER 405-1-16. Temporary housing would likely be required between compensation and actual relocation.
3. **Identification and acquisition of undeveloped, suitable, and available land for relocation.** Depending on the GLOF response alternative selected, relocation would require large parcels of undeveloped, suitable, and available land; partial relocation could be accommodated through infill development along the road system. Topography, natural hazards, wetlands, and land ownership influence the suitability and availability of land for development.

4. **Master Planning for Site Development.** Parcels of land associated with the relocation of larger numbers of structures, as compared to infill development, would require site master planning for location of roads, utilities, and public facilities.

5. **Construction of road and utility access.** Relocation of large numbers of structures may require development of land that is not currently connected to existing road and utility systems. Extension of road and utility access may be needed under those circumstances. In addition, should relocation take place on Douglas Island, a second crossing of Gastineau Channel may be necessary.

6. **Site preparation and construction of relocated structures.** Finally, relocation of large numbers of structures would require significant site preparation and involve a construction workforce beyond what is available in Juneau. This would also require temporary housing for the non-resident workforce.

4.5.1. Technical Discussion

Introduction

The Relocation Alternative primarily evaluates the implications of a complete relocation scenario in response to Mendenhall GLOF, while also identifying circumstances in which partial relocation would occur in combination with the dam, floodwall, and hybrid dam/floodwall alternatives (collectively referred to as the "Build Alternatives"). The Build Alternatives would require the buyout and relocation of structures affected by 1) the physical and construction zone footprint of the flood control structures being analyzed, and 2) by flooding of parcels and structures that are not protected by those flood protection structures. The report was specifically structured to discuss all aspects of relocation under this alternative and avoid repetitive analysis, as the steps remain the same and only differ in the scale of structures needing to be relocated.

This analysis has incorporated the results of the H&H analyses conducted by AECOM for the project, which were used to calculate the number of parcels and structures affected by inundation under the Relocation, Dam, Floodwall, and Hybrid Alternatives. For the partial relocation scenarios, this analysis also incorporates the calculations of the physical and construction footprints for the Dam, Floodwall, and Hybrid Dam/Floodwall Alternatives. To be conservative in analyzing potential relocation needs, it is assumed that if a parcel/structure is inundated to any degree, it is a candidate for buyout/compensation/demolition, and relocation is appropriate. Similarly, for the partial relocation scenarios, it is assumed that if the physical and construction footprint touches a structure, it is also a candidate for buyout/compensation and relocation. Parcels with no structures inundated under any of the alternatives would be considered candidates for buyout and compensation.

- **Complete Relocation** – Under this scenario, no new flood protection structures would be constructed, and no physical measures (e.g., HESCO barriers) would be used to reduce exposure to Mendenhall GLOF and non-GLOF events. For terminology purposes, it should be noted that for the purpose of buyout and compensation, USACE makes a distinction of taking no action associated with buyout and relocation, and non-structural measures, which could include buyout and relocation.

- **Partial Relocation –** Several of the action alternatives would result in the buyout/ compensation and relocation of some parcels and structures to accommodate the footprint of these flood structures. The Partial Relocation scenario also includes buyout/ compensation and relocation for parcels that are affected by inundation even with these flood structures in place (e.g., for areas where flood waters are anticipated to overtop or are not protected by the floodwall). Partial relocations are presented in combination with the following action alternatives: Dam, Floodwall, and the Hybrid Dam/Floodwall Alternative. The Lake Tap Tunnel Alternative would not require any property acquisitions and is therefore not included in the Partial Relocation discussion. The Bypass and Lower Dam Alternatives were also considered in the preliminary alternative identification process but have been eliminated from consideration and would not be analyzed for potential relocation.

Because buyout, compensation, and demolition of bought-out structures, and any remediation required are the initial steps in relocation, this process is briefly described later in the analysis.

Objectives

The objectives of the GLOF Relocation Alternative are:

- Address the implications of complete and partial relocation of potentially affected structures associated with Mendenhall GLOF to assist with the comparison and selection of GLOF protection alternatives.
- Describe the steps associated with relocation options (buyout/compensation/demolition, identification of potential sites for relocation, site planning for relocation, transportation, and utility access if necessary, and site preparation/construction).
- Identify the number and classification (residential commercial/industrial, public facilities) of structures potentially affected by GLOF under the complete relocation alternative as well as the partial relocation scenarios being considered for protection from GLOF.
- Describe the USACE process for considering buyout/compensation/demolition.
- Prepare an estimate of the geographic footprint/acreage required for complete and partial relocation.
- Discuss potential locations that are suitable and available for relocation.
- Identify the steps required to implement relocation to suitable and available locations (site acquisition, site planning, developing transportation/utility access, site preparation, construction).

- Identify the potential schedule associated with the steps of complete and partial relocation.
- Identify the cost drivers associated with the steps of complete and partial relocation (a separate cost estimate for complete relocation has been prepared)
- Identify the assumptions and uncertainties associated with steps of complete and partial relocation, including funding required, availability of land for relocation, and constructability.

Methodology

In preparation for the charrette, the project team followed the process documented below in developing a Relocation Alternative:

- Document assumptions for the Relocation Alternative.
- Identify affected parcels and types of structures under the projected flood stage for complete and partial relocation.
- Identify the phases of relocation, from buyout and compensation through construction of replaced structures.
- Identify high-level potential locations for relocation.
- Develop a high-level schedule for relocation.
- Identify cost drivers for relocation (Section 4.6.5, Costs).
- Identify uncertainties and technical unknowns for the Relocation Alternative.
- Identify permitting and environmental considerations associated with relocation.

Data Compilation and Preparation of Spatial Datasets

Data were compiled from AECOM technical alternative teams and information publicly available from CBJ and USACE, and spatial datasets were prepared, including:

- Modeled GLOF flood extents, depths, and frequencies under current and future conditions
- Parcel boundaries and building footprints within modeled flood zones
- Key infrastructure and community facilities throughout CBJ
- Zoning
- Areas potentially suitable and available for relocation of structures from the modeled flood zone

These datasets were translated into large-format maps, map packets, and simplified visual materials (e.g., overlays, figure books, and digital displays) for use during group exercises.

Based on HEC-RAS modeling for a peak flow of 118,000 cfs, the analysis identified the land area and the number and types of parcels affected by inundation. Simplified modeling methods were used in the analysis of relocation alternative for expediency purposes. More robust modeling with a more refined set of hydraulic assumptions and analyses, consistent with USACE/FEMA practices for relocating out of floodplains, would be required if this was chosen as the preferred solution.

Figure 4-51 presents the extent of inundation under the 118,000 cfs scenario.

Figure 4-51 Inundation Extent with No Protection Under the Design Peak Flow of 118,000 cfs

Steps in the Relocation Process

For this analysis, eight distinct steps associated with relocation and consultation considerations have been identified, based on agency and local sponsor jurisdictions, funding considerations, and scheduling:

1. Identify potentially affected parcels for relocation – consultation with USACE.
2. Document the programs and requirements for affected property buyout/compensation, and demolition – consultation with USACE.
3. Estimate the basis of value for property and structures eligible for buyout/compensation and relocation (this was done as part of the cost estimate for relocation).
4. Identify potentially suitable and available sites for relocation – consultation with CBJ.
5. Identify the need for and requirements of site planning for relocation planning – consultation with USACE and CBJ.
6. For sites considered candidates for relocation, identify requirements for additional transportation and utility access if necessary – consultation with CBJ.
7. Identify the steps for land acquisition, site preparation, construction – consultation with CBJ and site property owners.
8. Identify the jurisdictions and potential lead partners for each phase of relocation – consultation with USACE, CBJ, and other potential local sponsors.

4.5.2. Technical Unknowns

There are six general areas of technical unknowns and uncertainties that would affect the scope and schedule of relocation activities; these become more significant as the scope and scale of relocation increases from partial to complete relocation.

1. **Land availability for relocation.** No comprehensive assessment of land available for relocation has been undertaken, including suitability (although data is available to support a suitability analysis).
2. **Jurisdictional responsibility.** Although there are some areas where jurisdictional responsibility is clear, other areas of jurisdictional responsibility are not. For example, USACE would be the jurisdictional lead for the buyout/compensation phase and likely collaborate with CBJ and other stakeholders on demolition and clean-up. CBJ could take the lead with relocation planning, with assistance from USACE. However, assistance with physical relocation, including land acquisition, site preparation, and construction, are beyond the capabilities of a single sponsor. It should be noted that any work conducted by the local sponsor (CBJ) can be considered as in-kind contribution.

3. **Funding availability for structural relocation.** Similar to jurisdictional responsibility, the scale and source of funding for relocating 2,500 structures is beyond the capabilities of a single sponsor. It is unclear where the funding would come from.

4. **Temporary housing availability during relocation.** It is unclear how much time might elapse between buyout/demolition and completion of relocation. In addition, the scale of relocation would require bringing in an outside construction workforce to complete relocation in a timely manner. A significant amount of temporary housing would be required, and given Juneau's current housing shortage, it is unclear where that housing would come from.

5. **How many people would choose to leave Juneau if bought out, rather than relocate.** Given the time that might elapse between buyout/compensation and completion of relocation, the limited availability of available land for relocation, and the cost of new construction, some Mendenhall Valley residents may choose to leave Juneau rather than relocate in the community. A significant outmigration would have adverse economic consequences for Juneau.

6. **Effects on businesses during the relocation period.** Some businesses could be adversely affected by loss of business during the time between buyout/compensation and relocation. Others may have difficulty maintaining their operations in a new location. Both instances would have adverse economic consequences for Juneau.

4.5.3. Assumptions

Complete relocation is only associated with taking no action to protect structures from inundation, including permanent installation of additional HESCO barriers. Partial relocation would be associated with specific action alternatives based on what can be protected from inundation and what must be moved, including structures affected by the footprint of flood protection structures and associated construction zones. These alternatives include the Dam, Floodwall, and Hybrid Dam/Floodwall Alternatives.

No relocation would be required for the Lake Tap Tunnel Alternative.

Structures Considered for Relocation

For the charrette, a combination of zoning and HAZUS data was used as a proxy for current and future use. Once the flood scenarios are finalized, more detailed information (e.g., current use, future/planned use) would be gathered and worked into the analysis. The following are the general categories of structures included in the Relocation Alternative:

- Residential – single family and multifamily (two or more units)
- Commercial/industrial
- Public and critical facilities – defined in collaboration with CBJ

For the charrette discussion, AECOM assumed that large utility and infrastructure sites in the floodplain would be protected and remain in-place. This includes the water treatment plant in the Mendenhall Valley and the Juneau International Airport but may not include schools and infrastructure serving the immediate Mendenhall Valley population.

Consideration of impacts on historic properties and cultural sites would be incorporated into the analysis once final inundation scenarios are identified.

Flood Height Scenarios for Calculating Number of Structures to Be Relocated

The current inundation model is based on a 500-year GLOF event (peak 98,000 cfs) with a 500-year non-GLOF event (high rain event, high flows already in the river, peak 20,000 cfs) for a total peak flow of 118,000 cfs.

Adjustments to the inundation areas, including identification of partial relocation scenarios based on inundation associated with the other alternatives, would be provided by the AECOM H&H team.

Required Footprint/Acreage for Relocation

The acreage of affected parcels affected by inundation would be used as a proxy for this estimate. Smaller lot sizes, particularly for residential relocation, could reduce the required footprint.

Potential Suitable and Available Sites for Relocation

These sites are discussed at a high level but would need to be identified in consultation with CBJ, using publicly available data from CBJ. The availability of sites other than those owned by CBJ would need to be assessed at a future date should this alternative be selected.

Master Site Planning for Relocation

Master site planning would be required for total relocation and for large-scale partial relocation. CBJ would be responsible for master site planning for the relocated structures. The feasibility of the master site planning process would be examined once the alternative is developed further.

Property Buyout, Compensation, and Demolition

USACE Guidelines and Precedents regarding buyouts, compensation, and demolition would be used to describe this phase and estimate associated costs for the purpose of comparing alternatives (USACE Relocation Real Estate Guidance ER 405-1-16).

For the purposes of estimating feasibility, cost, and schedule at this stage, it is assumed that local landfills would have the capacity and ability to accept the debris generated from structure and utility removal in the affected inundation area. However, this would need to be verified and incorporated into the analysis once the Relocation Alternative is further developed. This would be discussed with CBJ.

Additional Transportation and Utility Access Needs for Relocation

For total relocation and for large-scale partial relocation to large-parcel undeveloped sites, developing road and utility access to parcels of land off the road system would be required; a per-mile cost estimate for providing access would be developed in consultation with CBJ. If some of these parcels are on Douglas Island, a second Douglas crossing of the Gastineau Channel may be needed.

Jurisdictional responsibility for planning and implementation would likely include CBJ, the Alaska Department of Transportation and Public Facilities (ADOT&PF), and local utilities.

Land Acquisition, Site Preparation, and Construction for Relocation

Any estimates that can be developed for this phase would be done in consultation with CBJ, including a potential cost-per-acre of land ready for construction.

Temporary Housing during Relocation and Construction

Similar to other Alaska communities, Juneau has a severe housing shortage, which is exacerbated by legislative and tourism-generated seasonal demand. In addition, location of United States Coast Guard icebreaker support to Juneau may create demand for 600 additional housing units.

- Depending on the sequence of temporary protection, buyout, and relocation, some temporary housing may be required for displaced residents.
- For complete relocation, including demolition and construction of relocated residences, businesses, and critical facilities, there is not enough local workforce capacity in Juneau. Temporary housing would be needed for any additional workforce that is brought in.

Jurisdictions and Implementation Responsibilities

For this analysis, the following jurisdictional and implementation responsibilities are assumed:

- USACE – buyout, compensation, demolition, and/or rehabilitation, and possibly providing a relocation planning grant
- CBJ – relocation planning, site and utility access
- ADOT&PF – second Douglas Crossing bridge and access roads as needed
- Landowners – land sales and relocation site preparation

4.5.4. Geographic Footprint

The GLOF inundation area would be based on H&H modeling and whether the alternative is combined with other alternatives (i.e., flood structures, river widening). The physical and construction footprints of Dam, Floodwall, and Dam/Floodwall Alternatives would be based on GIS calculations associated with those alternatives. The maximum geographic footprint/required land acquisition is the total area of affected parcels with structures that are inundated under the current GLOF scenario where no protection measures are taken.

Based on the total acreage of parcels with structures affected by inundation under the complete relocation scenario, roughly equivalent to 2,000 acres would be required for relocation, not including critical public facilities and road and utility rights-of-way required for relocation.

Developing assumptions per acre would be based on the type of structure to be applied for, the demand for land, and how that affects acquisition. A smaller amount of land might be required if residential development could involve smaller lot sizes, or some single-family residences transition to multi-family residences.

Affected Parcels under Complete and Partial Relocation Scenarios

The sections below summarize the following for each of the relocation scenarios: 1) the number of structures that would require relocation and 2) the total number of parcels affected by inundation that would require an acquisition/buyout. The number of structures were estimated based on hydraulic modelling and hydrological input, and gives an estimate of the scale of relocation that may be required under each scenario and the types of structures affected (e.g., single family residence, multi-family residence, commercial building), whereas the total number of parcels helps to establish the scale of the acquisition/buyout that would be required under each scenario and includes parcels with no structures present. These numbers have been updated from those presented in the Charrette Pack and the Charrette Slides.

Please note that a parcel may have multiple structures that would be candidates for relocation; a structure may span multiple parcels, or a parcel may have no structure on it. As alternatives are further refined, additional factors such as existing and planned land uses, the number and type of structures, and other site characteristics would be incorporated into the analysis, and the underlying methodology and assumptions would be updated accordingly. Finally, USACE regulatory guidance on real estate and relocation would likely revise the number of structures to be relocated, should it be required.

Complete relocation is associated with the Relocation Alternative and can serve as a comparison for the build alternatives. For the purposes of this charrette discussion, the analysis is limited to parcel zoning and occupancy type classifications.

Public and critical facilities that would be affected under each relocation scenario, presented in Figure 4-52 below, would be incorporated into the analysis should this alternative be carried forward. It should be noted that USACE guidelines allow for federal cost sharing for construction of replacement infrastructure.

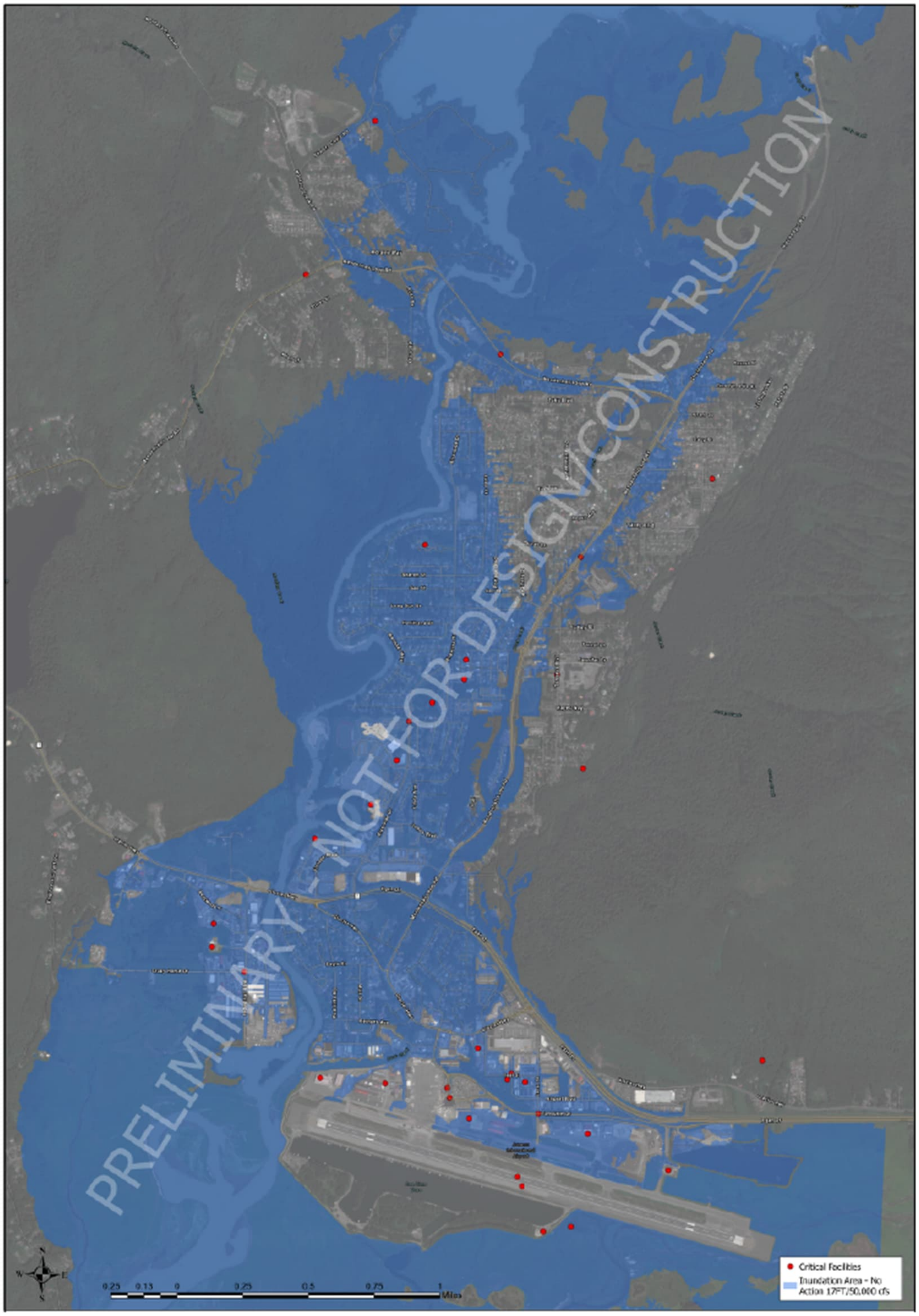


Figure 4-52 Critical Facilities in the Mendenhall Valley Area

Complete Relocation

Complete relocation is based on structure inundation (i.e., flood waters touching the structure) under the following model conditions of a 0.2 percent AEP (500-year) GLOF event (peak 98,000 cfs) with a 0.2 percent AEP (500-year) non-GLOF event (high rain event, high flows already in the river, peak 20,000 cfs) for a total peak flow of 118,000 cfs. Table 4-9 presents the number of structures affected by inundation, as estimated by H&H models (i.e., flood waters inundate or touch the structure on the parcel), emphasizing that these numbers are only estimates. The parcels are organized by occupancy type to give an idea of what kind of structure relocations would be necessary. Table 4-10 presents the total number of parcels that would be affected by inundation, organized by zoning district. Table 4-10 includes empty parcels, which is why the total number is higher than Table 4-9.

Table 4-9 Estimated Structures Affected by Complete Relocation

Occupancy Type	Number of Structures
Agriculture facilities/offices	2
Retail trade (stores)	80
Wholesale trade (warehouses)	44
Personal and repair services (e.g., repair shops)	3
Medical office or clinic	13
Light industrial (less intensive industrial operations)	3
No Type Listed	721
Single-family dwellings	1,544
Manufactured housing/mobile homes	28
Duplex (2 units)	2
3- to 4-unit multifamily dwellings	4
Temporary lodging (e.g., hotels, motels)	43
Grand Total	**2,487**

Source: USACE 2022

Table 4-10 Estimated Parcels Affected by Inundation

Zoning	Number of Parcels Inundated
D1 – Single Family	140
D3 – Single Family	96
D5 – Single Family	1,876
D10 – Single Family	1
D10 – Multi-Family	34
D15 – Multi-Family	209
D18 – Multi-Family	9
MU – Mixed Use	3
LC – Light Commercial	102
GC – General Commercial	77
I – Industrial	289
RR – Rural Reserve	10
Two Zones on Parcel	9
Grand Total	**2,855**

Source: CBJ 2025

Partial Relocations

The following sections list the parcels that would be acquired in the partial relocation scenarios associated with other build alternatives. The relocation numbers include parcels that would be required to build the dam and floodwall structures and parcels that would experience inundation.

Dam Alternative

Table 4-11 describes the number of structures that would need to be relocated under the Dam Alternative assuming a peak inflow of 118,000 cfs with a peak flow release of 30,000 cfs. The inundation area under the Dam Alternative is presented in Figure 4-53. Table 4-11 presents the number of structures affected by inundation (i.e., flood waters inundate or touch the structure on the parcel) and the dam ROW. The parcels are organized by occupancy type to give an idea of what kind of structure relocations would be necessary. Table 4-12 provides the total number of parcels that would be affected by inundation, organized by zoning district. Table 4-12 includes empty parcels, which is why the total number is higher than Table 4-11.

Table 4-11 Estimated Structures Affected by the Inundation and Dam ROW

Occupancy Type	Number of Structures
Agriculture facilities/offices	—
Retail trade (stores)	—
Wholesale trade (warehouses)	—
Personal and repair services (like repair shops)	—
Medical office or clinic	—
Light industrial (less intensive industrial operations)	—
No Type Listed	23
Single-family dwellings	65
Manufactured housing/mobile homes	—
Duplex (2 units)	—
3- to 4-unit multifamily dwellings	—
Temporary lodging (e.g., hotels, motels)	—
Grand Total	**88**

Source: USACE 2022

Table 4-12 Estimated Parcels Affected by Inundation and Dam ROW

Zoning	Number of Parcels Inundated
D1 – Single Family	93
D3 – Single Family	50
D5 – Single Family	240
D10 – Single Family	—
D10 – Multi-Family	—
D15 – Multi-Family	8
D18 – Multi-Family	2
MU – Mixed Use	3
LC – Light Commercial	5
GC – General Commercial	10
I – Industrial	28
RR – Rural Reserve	10
Two Zones on Parcel	1
Grand Total	**450**

Source: CBJ 2025

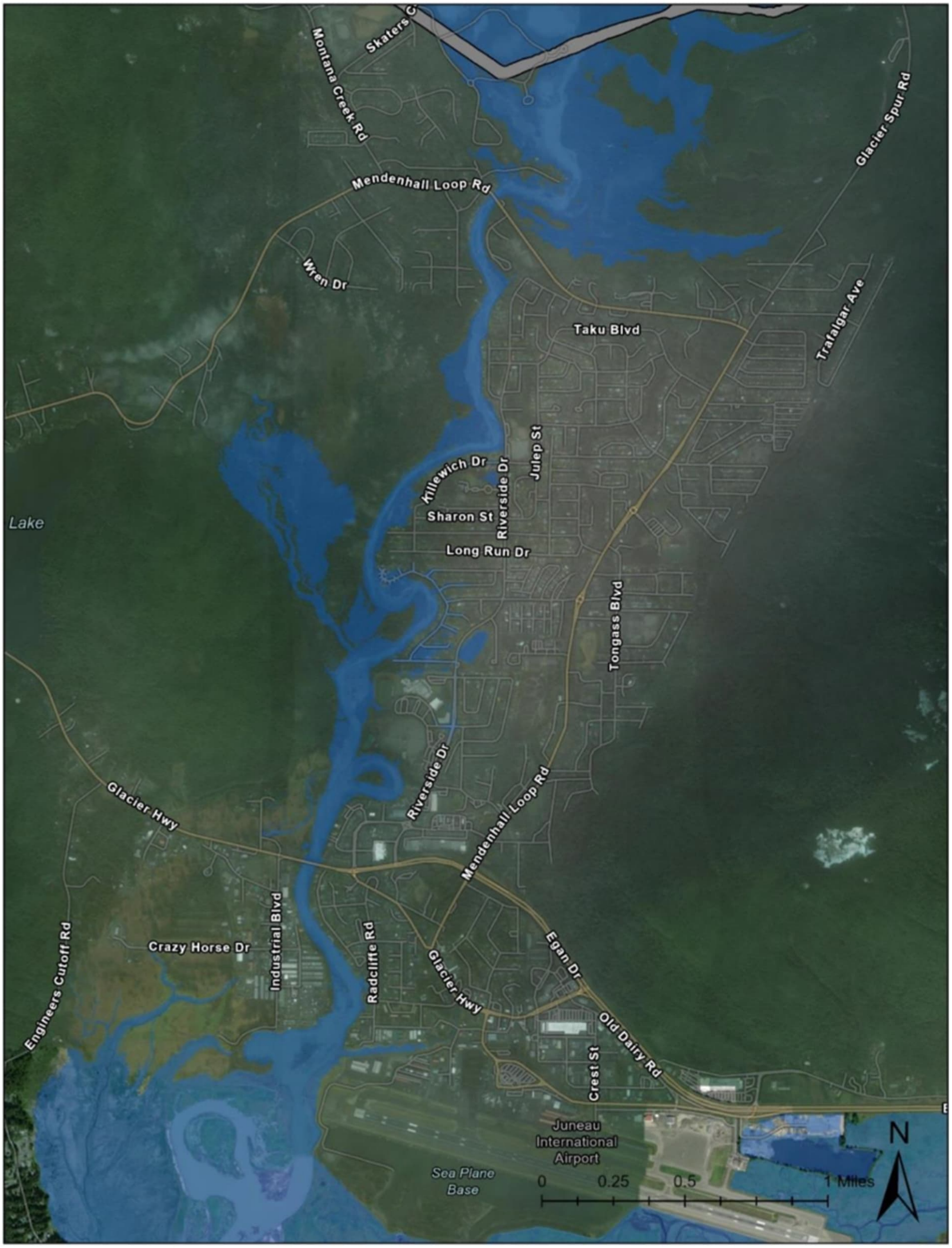


Figure 4-53 Inundation Extent Under the Dam Alternative, with the Peak Release Rate of 30,000 cfs

Floodwall Alternative

Table 4-13 summarizes the number of structures that would need to be acquired under the Floodwall Alternative, based on a peak flow of 118,000 cfs. The inundation area for the Floodwall Alternative is presented in Figure 4-54. Table 4-13 presents the number of structures affected by inundation (i.e., flood waters inundate or touch the structure on the parcel) and the floodwall ROW. The parcels are organized by occupancy type to give an idea of what kind of structure relocations would be necessary. Table 4-14 presents the total number of parcels that would be affected by inundation, organized by zoning district. Table 4-13 includes empty parcels, which is why the total number is higher than Table 4-14. The floodwall alignment was updated between the time the charrette packets were distributed and when the charrette occurred. The tables below reflect the new alignment.

Table 4-13 Estimated Structures Affected by Inundation and Floodwall ROW

Occupancy Type	Number of Structures
Agriculture facilities/offices	—
Retail trade (stores)	9
Wholesale trade (warehouses)	2
Personal and repair services (like repair shops)	—
Medical office or clinic	1
Light industrial (less intensive industrial operations)	—
No Type Listed	90
Single-family dwellings	235
Manufactured housing/mobile homes	—
Duplex (2 units)	—
3- to 4-unit multifamily dwellings	1
Temporary lodging (e.g., hotels, motels)	5
Grand Total	**343**

Source: USACE 2022

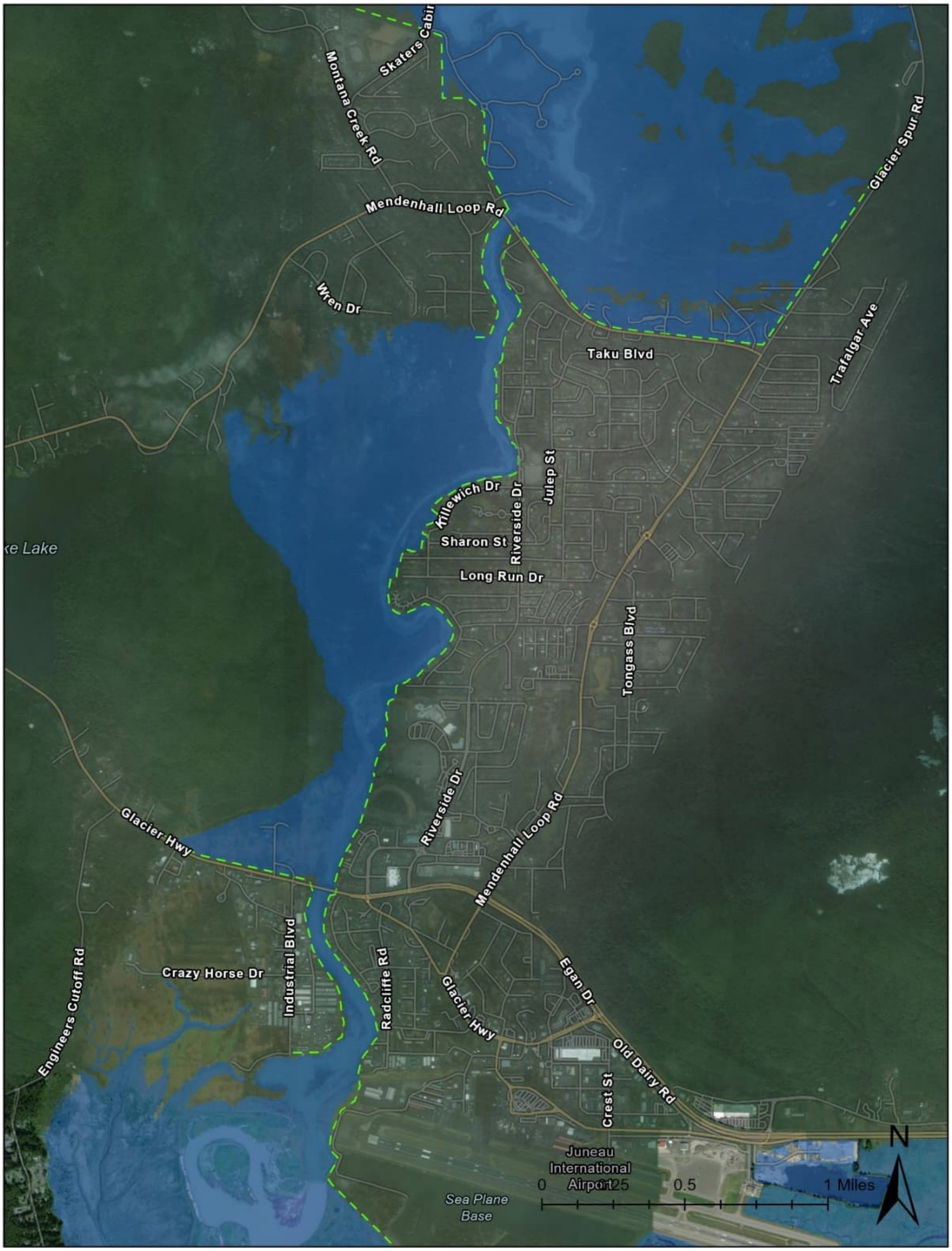


Figure 4-54 Inundation Extent Under the Floodwall Alternative (i.e., Peak Design Flow = 118,000 cfs)

Table 4-14 Estimated Parcels Affected by Inundation and Floodwall ROW

Zoning	Number of Parcels Inundated
D1 – Single Family	107
D3 – Single Family	68
D5 – Single Family	287
D10 – Single Family	1
D10 – Multi-Family	6
D15 – Multi-Family	44
D18 – Multi-Family	2
MU – Mixed Use	3
LC – Light Commercial	13
GC – General Commercial	10
I – Industrial	143
RR – Rural Reserve	10
Two Zones on Parcel	3
Grand Total	**697**

Source: CBJ 2025

Hybrid Dam and Floodwall Alternative

Table 4-15 describes the number of structures by listed category that would need to be acquired for the Hybrid Dam and Floodwall Alternative, assuming a peak flow of 118,000 cfs with a peak release of 50,000 cfs. This alternative would allow for a dam that is a lower height than the stand-alone dam alternative. The inundation area under the Combined Dam and Floodwall Alternative is presented in Figure 4-55. Table 4-16 presents the number of parcels with structures affected by inundation (i.e., flood waters inundate or touch the structure on the parcel) and the dam or floodwall ROW. The parcels are organized by occupancy type to give an idea of what kind of structure relocations would be necessary. Table 4-14 presents the total number of parcels that would be affected by inundation, organized by zoning district. Table 4-15 includes empty parcels, which is why the total number is higher than Table 4-15. Please note that the Hybrid Alternative has a different floodwall alignment than the standalone floodwall alternative.

Table 4-15 Estimated Structures Affected by the Inundation and Dam/Floodwall Hybrid ROW

Occupancy Type	Number of Structures
Agriculture facilities/offices	—
Retail trade (stores)	6
Wholesale trade (warehouses)	—
Personal and repair services (like repair shops)	—
Medical office or clinic	1
Light industrial (less intensive industrial operations)	—
No Type Listed	62
Single-family dwellings	190
Manufactured housing/mobile homes	—
Duplex (2 units)	—
3- to 4-unit multifamily dwellings	1
Temporary lodging (e.g., hotels, motels)	5
Grand Total	**265**

Source: USACE 2022

Table 4-16 Estimated Parcels Affected by Inundation and Dam/Floodwall Hybrid ROW

Zoning	Number of Parcels Inundated
D1 – Single Family	99
D3 – Single Family	60
D5 – Single Family	220
D10 – Single Family	1
D10 – Multi-Family	—
D15 – Multi-Family	32
D18 – Multi-Family	2
MU – Mixed Use	3
LC – Light Commercial	13
GC – General Commercial	10
I – Industrial	51
RR – Rural Reserve	10
Two Zones on Parcel	2
Grand Total	**503**

Source: CBJ 2025

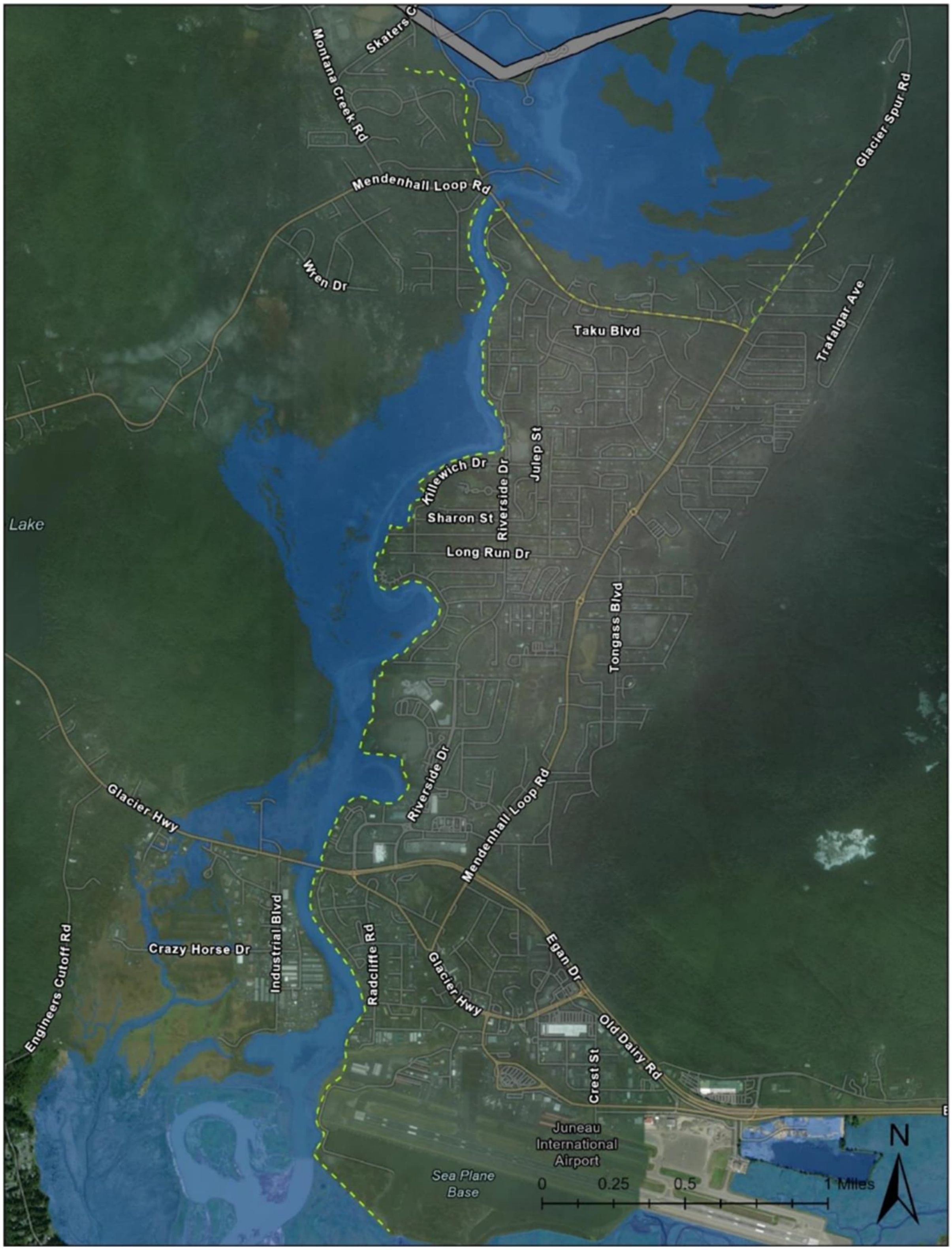


Figure 4-55 Inundation Extent Under the Combined Dam/Floodwall Alternative, with the Peak Release Rate of 50,000 cfs

Buyout, Compensation, and Demolition

Based on jurisdictional and funding considerations, USACE is often the lead federal agency for buyout of properties and structures affected by flooding, determining the eligibility and compensation for buyout, and responsible for demolition and rehabilitation of affected structures. USACE Real Estate Relocation Guidance 405-1-16 provides more detailed information. Appendix J presents an example of the nonstructural process that USACE used for the Amite River and Tributaries East of the Mississippi River, Louisiana. It provides process details on the Application, Screening, and Design/Build Phases of the Project. Other federal, state, and local agencies may be involved in the process. This step should occur after an alternative has been selected and prior to actual land acquisition and construction of relocated structures and uses, although some steps such as relocation site planning might be able to occur simultaneously. Note – at this time, the Relocation Alternative will not be pursued for further analysis.

Relocation Considerations and Options

Actual relocation of structures affected by inundation under the Relocation Alternative, and by inundation and physical/construction footprint under the Dam, Floodwall, and Hybrid Dam/ Floodwall Alternatives, would depend on the following sequential factors:

- Identifying the number and categories of affected structures (residential, commercial/ industrial, and public/critical facilities) that would be subject to relocation (shown in Section 4.5.4).
- Identifying the acreage of affected structures and determining a reasonable acreage that is needed for actual relocation.
- Identifying vacant/undeveloped and suitable land for relocation of affected structures.
- Determining whether such lands are available for acquisition/relocation.
- Determining whether there is adequate road and utility access to areas suitable and available for relocation.
- Identifying the site preparation requirements for construction.
- Construction of relocated structures.

Acreage Needed for Relocation

There are two approaches to estimating the acreage needed for relocation of structures under the alternative:

- Using the total acreage by category of use (residential, commercial/industrial, public facilities) inundated under each of the action alternatives, this can be estimated from total parcels by type under areas of inundation and physical/construction footprint. For complete relocation, this number is roughly over 2,000 acres, not including acreage required for roads and utilities. However, the cost of land and new construction, combined with limitations of available and suitable land, may result in the necessity for smaller lot sizes by certain use categories such as residential. The estimates for total acreage of the partial relocation scenarios are as follows (counting both the ROW required for each and the inundation that would still occur under those alternatives):

- The Dam Alternative would cover 365 acres
- The Floodwall Alternative would cover nearly 550 acres
- The Hybrid Alternative would cover over 460 acres
- Developing an average lot size by category of use—this could result in smaller lot size requirements that might require less land for relocation, making infill development possible. However, this approach would likely result in smaller lot sizes than what some residents currently have.

Relocation Site Screening for Vacant/Undeveloped and Suitable Land

Like many communities in Alaska, Juneau has a shortage of housing. In addition, land ownership patterns, topography, and natural hazards further affect land suitable and available for relocation. There are three factors in determining potential sites for relocation:

- **Is there land that is vacant/undeveloped?** This information is available and mapped for certain areas (CBJ).
- **Is the land suitable for development?** Suitability addresses factors that limit development such as topographical limitations (steep slopes), natural hazards (flood, avalanche, and landslide zones), and wetlands, which may not be available or practical for development.
- **Is the land available for development?** Who owns the land; is the owner able or willing to make it available for development?

Vacant and Underdeveloped Land

The CBJ has mapped areas of vacant and underdeveloped land in certain areas of Juneau, as presented in Figure 4-56. Underdeveloped land is defined as land that is developed below the maximum allowable building units for the parcel, and therefore a potential candidate for infill development. Given the number of structures to be relocated under each scenario, the land required for relocation may require large parcels of vacant land for complete or partial relocation, or small parcels for partial relocation where infill development may be feasible. Vacant and underdeveloped land in the Mendenhall Valley are delineated in Figure 4-56 below.

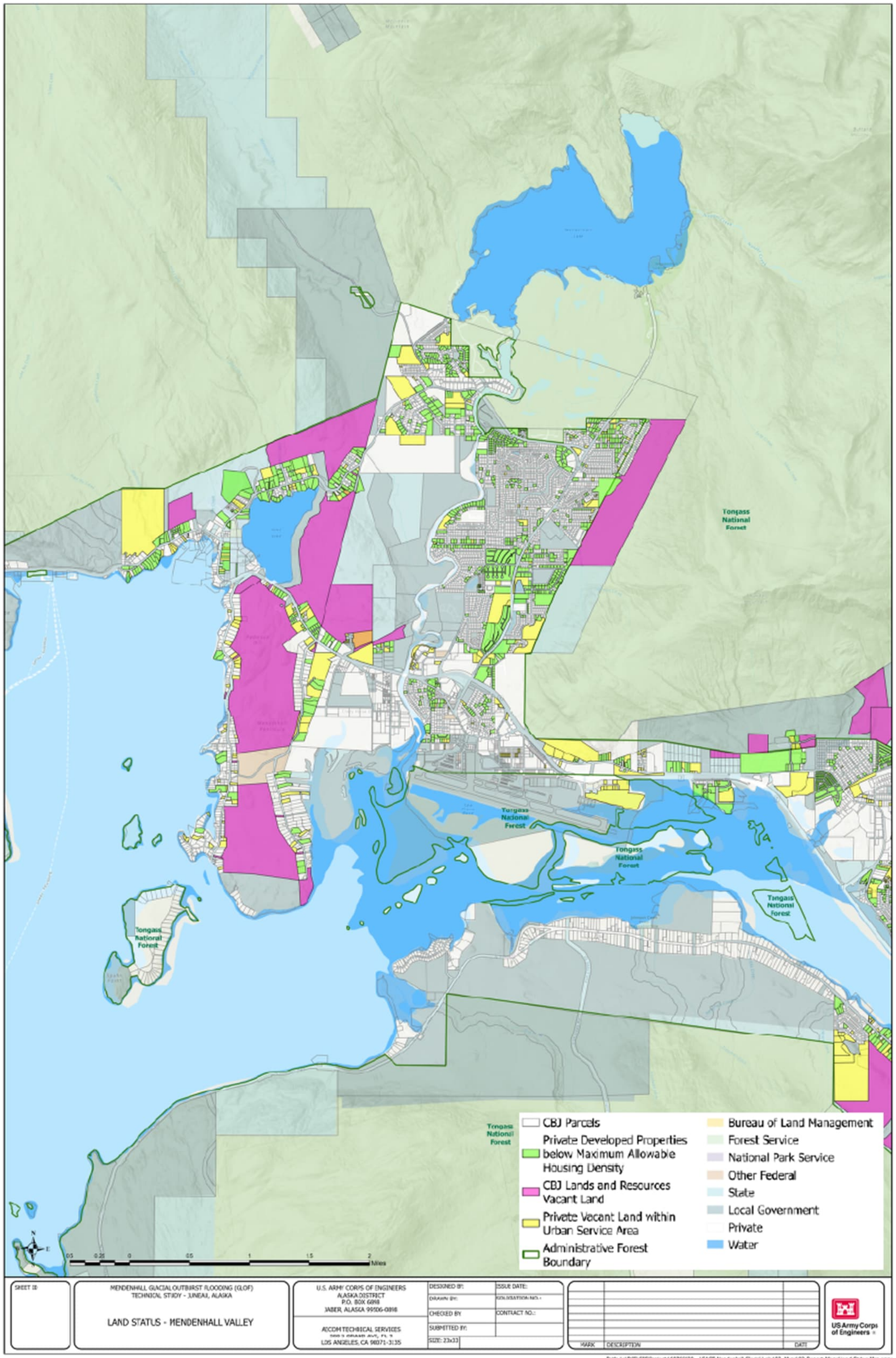


Figure 4-56 Vacant and Underdeveloped Properties in Mendenhall Valley

AECOM

US Army Corps of Engineers
Alaska District

Potential Sites for Relocation

No formal analysis has been conducted for this study; however, informal conversations have provided some guidance. Candidate sites south of Juneau along Thane Road are not suitable due to avalanche risk, which could cut off access for extended periods.

Large sites north of Mendenhall Valley may be suitable and available under CBJ and Alaska Native Corporation ownership. However, north of Echo Point, road maintenance, lack of emergency service access, and distance to critical facilities such as schools and hospitals make this location less viable. No analysis of suitability has been conducted, and no discussions have been held with CBJ and potential landowners regarding this option.

Large sites on Douglas Island may be suitable and available, although not all large tracts of land are accessed by the existing road system and may require development of new road and utility access. Depending on the scale of relocation, consideration of a second Douglas crossing may be necessary. No analysis of suitability has been conducted, and no discussions have been held with CBJ and potential landowners regarding this option.

Infill sites for partial relocation may be available if the scale is small enough. No areas have been specifically identified, and no analysis of suitability or availability has been conducted, and no discussions have been held with CBJ and potential landowners regarding this option.

4.5.5. Design Feasibility

The design feasibility of relocation is affected by the availability and suitability of developable land for relocation, particularly for complete relocation and large-scale partial relocation scenarios. This would be assessed once a preferred engineering solution is chosen, and such lands have been identified.

4.5.6. Constructability

The constructability of relocation is dependent on the availability and suitability of developable land for relocation, particularly for the complete and large-scale partial relocation scenarios, and would be assessed once a preferred engineering solution is chosen and such lands have been identified.

Construction activities associated with demolition of properties that are bought out by USACE would generate waste that needs to be transported to local landfills or shipped to another location, if it exceeds local capacity. This would generate an increase in construction traffic on local roads getting to a landfill or marine shipment location. Some site contamination and hazardous waste may be encountered and need to be disposed of properly as required by regulations.

These construction activities would likely require a workforce that exceeds local availability. Given the limited housing market in Juneau, temporary housing for a non-local workforce would need to be created for this activity.

Similarly, construction associated with the relocation of a large number of residences would also increase vehicle and marine traffic, because a substantial amount of building material would need to be brought into the Juneau area. The existing Juneau Douglas Bridge has a “D” rating for structural condition which could affect use. A “D” structural rating indicates that a bridge has significant structural or maintenance issues that do not pose a risk to safety but may require significant rehabilitation or replacement. This could constrain traffic and the ability to transport heavy loads over this bridge. A second Douglas Island crossing of the Gastineau Channel may be needed between Douglas Island and Juneau.

As with demolition, residential and site preparation construction activities would likely require a workforce that exceeds local availability. Given the limited housing market in Juneau, temporary housing for a non-local workforce would need to be created.

Finally, weather conditions may affect construction schedules for demolition and relocation.

4.5.7. Design and Construction Duration

The schedule (Table 4-17) for complete or partial relocation alternatives depends on available funding, but can be separated into six phases, some of which might overlap depending on available funding and the ability of specific actions to progress concurrently. Depending on several factors, this would likely take 10 years to complete but could take longer. Two rounds of extensive public consultation have been included during key steps in the relocation process, although regular communication and updates are required. The flowchart shown in Figure 4-57 provides a high-level overview of the process of complete or partial relocation. An example of a more detailed USACE-specific flowchart is included in Appendix J; it shows the framework that the USACE could follow for their Application, Screening, and Design/Build Phases of complete or partial relocation. However, it should be noted that the overall process varies from project to project, and potentially from structure to structure depending on numerous factors. If relocation is pursued in any capacity, future studies will be needed to refine opportunities and address requirements and concerns associated with relocation.

Buyout, Compensation, Demolition, and Rehabilitation Phase

This would be determined in consultation with USACE and would be subject to specific requirements for assessment of eligibility. The number of parcels and structures eligible would be based on flood mapping, USACE requirements for and displacement for relocation would not occur until replacement was identified. Given the potential number of structures affected by relocation, a significant amount of demolition would be required. This analysis assumes 2 years for determining eligibility and initiating compensation, and up to 10 years to complete demolition and rehabilitation, depending on available funding, staffing resources, and workforce availability.

Table 4-17 Relocation Alternative Design and Construction Schedule

Item	Schedule*
Develop details on process steps and schedule for complete relocation	January 2026 to May 2026
USACE assessment of flood damage, economic loss, and eligibility for buyout/compensation	June 2026 to June 2027
Assessment and identification of suitable lands for relocation	June 2026 to June 2027
Stakeholder Outreach 1	June 2026 to June 2027
Acquisition and compensation of affected Mendenhall Valley properties	June 2027 to November 2029
Relocation master planning for selected relocation sites	November 2027 to November 2028
Demolition/rehabilitation of Mendenhall Valley properties	June 2028 to March 2036
Stakeholder Outreach 2	June 2028 to November 2028
Land acquisition/sales/subdivision	November 2028 to November 2030
Site preparation for relocation (surveying, lot prep, roads and utilities)	November 2030 to March 2032
Construction of relocated structures	March 2028 to March 2036

*Schedule presented is approximate. Start dates are subject to approvals.

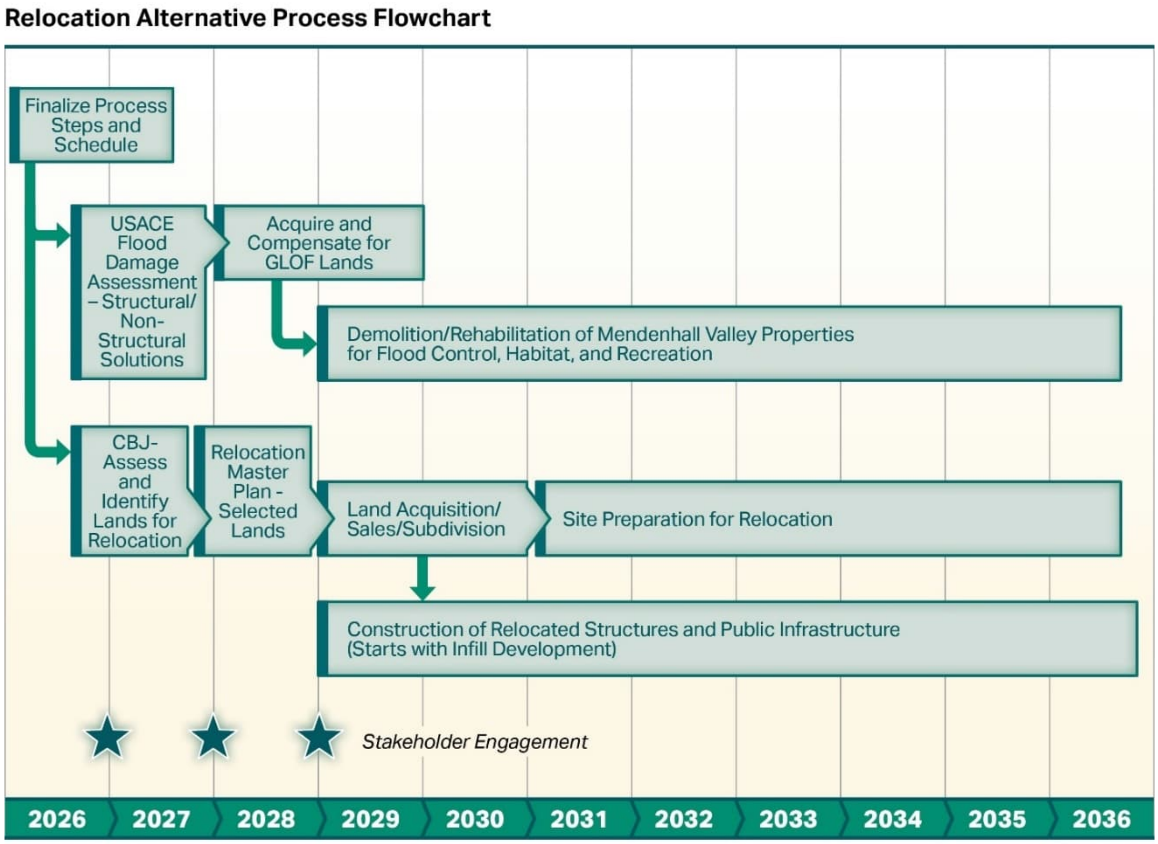


Figure 4-57 Relocation Alternative Process Flowchart

Site Acquisition

- Once the number of structures eligible for buyout and relocation has been determined, an accurate estimate of acreage required for relocation can be prepared**.** This should be used to identify parcels of vacant, suitable, and available lands for relocation. This effort would be the first part of the relocation planning phase described below and could be conducted concurrently with other steps.

- The schedule for acquisition would depend on whether lands are private or public, the availability of funding for acquisition, or whether a private owner might subdivide land and make lots available for purchase.

- Given the number of structures potentially subject to relocation, this step could take 1 to 2 years and depends on available funding and negotiations with landowners.

Relocation Planning Phase

- This would be determined in consultation with USACE and CBJ. This effort should start concurrently with buyout and support site acquisition. The first step would be to assess vacant, suitable, and available lands that meet the acreage requirements for relocation.

- The second step would be to prepare a site plan for the area(s) of relocation. It would identify locations for residential, commercial/industrial, and public facilities uses. It would also identify locations for roads and utilities.

- If funding were available, it would likely take a minimum of 1 year for the site acquisition assessment, and an additional year for preparing a site plan after acquisition of land for relocation.

- The need for new transportation and utility access would be determined during the relocation planning phase in consultation with CBJ and ADOT&PF, depending on need for and location of large undeveloped parcels associated with complete or large-scale partial relocation scenario.

Site Preparation Phase

Site preparation would occur in consultation with CBJ and affected landowners. This would include vegetation clearing, road/utility access construction, earthwork/drainage controls, and any other activities required in advance of structure construction. Depending on the scale of relocation, this could take 2 years to complete.

Construction Phase

Depending on the completion of compensation and parcels available for purchase in areas already developed, some construction could start immediately. However, given the scale of complete relocation, obtaining building materials, and availability of construction workforce, and the need for temporary housing, construction could take more than 10 years for completion of relocation.

4.5.8. Reliability/Adaptability/Resiliency

Reliability

- Complete relocation would serve as a permanent elimination of risk from the Suicide Basin GLOF events to the affected parcels by removing people and relocating structures from the inundation zone; however, it does not account for increase in flows that may occur from other climate-driven events.

- Relocation reduces risk from other hazards in the inundation zones, including non-GLOF flooding.

- Reliance on acceptance from property owners in the inundation area to relocate, or use of eminent domain powers, may be limited.

- Funding sources are unknown at this time. If funding is interrupted or lost in the future, then the functionality of the relocation alternative may be affected.

- Partial relocation depends on the reliability of implemented flood structures.

Adaptability

- Flexible implementation and phasing means that the focus area or phasing of the buyouts/relocations can be adjusted based on changing conditions, funding availability, and agency bandwidth.
- Voluntary options (buyout, structure relocation, land swaps, or acquisition for open space) can be adapted to household circumstances, economic conditions, cultural values, and housing market constraints.
- Relocation allows high-risk areas to be converted to open space, floodwater storage, or habitat, supporting long-term climate adaptation and hazard mitigation planning for CBJ.
- Relocation could also allow high-risk areas to be converted to public recreation or another beneficial use

Resiliency

- By permanently vacating high-risk parcels, local and federal agencies face reduced emergency-response burdens, repetitive-loss claims, and long-term damage costs.
- Relocation can be designed to prioritize the most vulnerable or flood-prone properties and owners.
- Relocation can be combined with engineering alternatives to reduce risk to the community and reduce the design reliance on flood protection structures.
- Vacated parcels can serve as flood management/storage areas that reduce risk to downstream properties.
- Evacuation and emergency response can be improved by removing structures and people in the inundation area, which also helps to protect emergency workers.

4.5.9. Operations and Maintenance Cost and Requirements

There are no operation or maintenance costs associated with relocation that would be comparable to other action alternatives.

4.5.10. Risk Reduction/Life Safety

Complete relocation would eliminate life safety and economic risk from Suicide Basin GLOF in the long term, but depending on temporary protection measures, there would be short-term risk during the time it would take to complete buyout and relocation. However, there may be future economic and life safety risk that could result from climate change-driven events independent of Suicide Basin GLOF. In such cases, dam and floodwall alternatives may perform better for those risks compared to the Lake Tap Tunnel Alternative.

For partial relocation, there would be some short-term risk depending on temporary protection measures during the time it would take to complete buyout.

4.5.11. Operational Impacts

No operational impacts are associated with total or partial relocation alternatives.

4.5.12. Environmental/Cultural Considerations

Repeated flooding of unprotected areas would have long-term impacts on river morphology, fish habitat, wetlands and riparian areas, and cultural resources and historic properties. Additionally, the social and economic impacts of relocation on Juneau could be significant, depending on a number of factors.

Environmental Impacts

- Fish habitat: The Mendenhall River channel would change over time, and with each GLOF event, which could impact fish spawning habitat.

- Wetlands and riparian areas: Repeated GLOF events would inundate wetlands and riparian areas, which are important for habitat areas for aquatic species, shorebirds, and terrestrial wildlife.

- Cultural and archaeological sites and traditional cultural use areas: These areas require NHPA Section 106 review with SHPO, NEPA review and tribal consultation. to determine impacts, assess potential mitigation, and consider possible inclusion in the NRHP.

- Historic Properties: Sites of particular concern include Skater's Cabin (JUN-00242) and Mendenhall Campground (JUN-01303). The entirety of the MGRA is considered a Historic Property, with cultural implications. Historic Properties require NHPA Section 106 review with the SHPO, NEPA review, and tribal consultation. Any areas of new development and existing neighborhoods that could be demolished would require cultural resource surveys and evaluation for potential Historic Properties.

- Hazardous waste: Potential legacy contaminated sites may occur near former industrial or maintenance areas; Phase I Environmental Site Assessments would be recommended at these sites. Disposal of hazardous material may require shipment for treatment and disposal outside of Juneau.

- Air Quality: Juneau is a maintenance area for particulate matter less than 10 microns in diameter; dust from demolition and haul roads must meet State Implementation Plan requirements.

- Noise and Traffic: Heavy equipment and material associated with construction and demolition activities would increase noise and congestion in Mendenhall Valley, particularly during the tourist season. Recreation: The MGRA is a major tourist destination (more than 1 million visitors annually); heavy construction activity would disrupt access and degrade scenic views.

- Socioeconomics: The Juneau area economy depends heavily on cruise tourism; prolonged heavy construction and demolition activities could reduce visitor satisfaction and revenue.

Community Impacts

- People who are bought out may decide to leave Juneau rather than relocate, affecting the tax base and reducing demand for local business and public services, potentially resulting in a significant restructuring of the local community.
- The lag time between buyout and construction of new commercial facilities could affect their economic viability, as could moving to a new location.
- Temporary loss of service from critical facilities would have to be carefully considered and alternative solutions developed.
- Partial relocation associated with build alternatives would affect a smaller number of residences and businesses, and outcomes would vary on scale, location, and phasing of relocation. Higher-density residential replacement structures and the opportunity for infill development in established areas would reduce the severity of impact.

4.5.13. Permitting Concerns

State, federal, and local permits that may be required under this alternative include the following:

- USACE requirements for Section 404 (Clean Water Act) – Development of relocation sites.
- NHPA Section 106 – SHPO and tribal consultation.
- Construction in the floodway is heavily restricted and may require a no-rise certification or a Conditional Letter of Map Revision from the Federal Emergency Management Agency.
- Potential for state permits associated with contaminated sites and hazardous waste associated with demolition and disposal.
- Requirements for construction of additional transportation access may require consultation with the ADOT&PF.
- Floodplain Development Permit, and other zoning and conditional use authorizations (CBJ)
- Coordination with Tlingit and Haida and ANCSA Regional and Village corporations for cultural and land interests.

4.5.14. Key Takeaways

- **Primary Benefits**: Relocation would remove structures from areas of inundation and provide compensation to property owners. The amount of relocation required varies by alternative.

- **Major Challenges**: The complete Relocation Alternative would involve relocating the largest number of structures, followed by Floodwall, Dam, and Hybrid Dam-Flood Alternatives; all would require analysis to determine if there is adequate, undeveloped, and suitable land for relocation. In addition, complete relocation would potentially result in significant adverse social and economic impacts to Juneau in terms of outmigration, disruption of commercial and industrial activities, and loss of municipal revenue.

- **Critical Uncertainties/Unknowns**: Even if there is adequate, undeveloped, and suitable land for relocation, it is uncertain if property owners would make those lands available for relocation. Relocation of commercial structures has a unique set of challenges, including land requirements and whether a business case can be made for potential locations. Finally, the construction workforce for demolition and relocation would likely require some outside workers, and the need for temporary housing would need to be addressed.

- **Relocation Schedule**: the schedule is highly dependent on the scale of relocation, funding availability, and agency jurisdiction/capacity. Under the most optimistic case, large-scale relocation would likely require a minimum of 5 years, and perhaps closer to 10 years, given the experience of relocation of other Alaska communities.

4.5.15. Discussion

A summary of talking points from the questions and discussion following the presentation of this alternative is included below. Please refer to Appendix B: Charrette Meeting Minutes, for additional information.

- Based on comments from CBJ regarding Alaskan experience with the relocation of other communities facing flooding threats, the 10-year estimate for completion of relocation is likely to be a lower bound.

- The time needed for partial relocation included in the dam, Floodwall, and Hybrid Alternatives is not included in the schedule.

- Vertical relocation (elevating structures) was not included in this analysis.

- The implications of inundation of roads, utilities, etc., were not considered at this stage.

- Some of these alternatives – the floodwall/levee, dam – have an induced flooding element. Induced flooding is interpreted as areas that may flood based on flow that might be redirected by flood control structures. The H&H inundation modelling considered redirected flooding but did not specifically identify areas of induced flooding. For the analysis, induced and non-induced flooding were not evaluated separately.

4.6. Cost Overview – Comparative Construction Capital Cost (Rough Order-of-Magnitude) for Charrette

The Rough Order of Magnitude (ROM) cost evaluation for the charrette is based on conceptual designs developed to the 2 to 5 percent level, incorporating the primary cost drivers and a contingency of 50 percent which aligns with AACEI cost guidelines for a Class 4 cost estimate provided in Appendix G. These estimates exclude O&M costs, concentrating solely on capital expenditures required for construction, and administrative activities. These estimates are construction costs only for the major “cost drivers” of each alternative and do not include costs for design, construction management by USACE or engineering services during construction.

Capital costs in Southeast Alaska are inherently higher due to the region’s remoteness, limited construction season, and logistical challenges associated with material sourcing and transport. The ROM cost therefore includes allowances for job office overhead inclusive of mobilization, specialized equipment, and seasonal constraints, as well as real estate acquisition costs for the various alternatives, staging areas, and potential relocation zones. Appropriate contingencies were applied to reflect risks related to geotechnical uncertainty. This approach provides a realistic preliminary cost framework for comparing alternatives and guiding subsequent design development.

The costs were estimated with the following design and construction durations:

- Anticipated Design Start: January 2027
- Anticipated Design Finish: November 2027
- Construction Duration: 5 years starting January 2028 (assumed for all alternatives for the purposes of cost evaluation only)
- Note that some construction durations may vary
- Assumed mid-point of construction: July 1, 2030

The costs presented are an Order of Magnitude or “Conceptual” estimate. These provide a relatively quick method of determining the approximate probable cost of a project without the benefit of a detailed scope definition. These are typically used for:

- Screening estimates for a project or program
- Evaluation of Project Feasibility for a given project
- Screening Project Alternatives

In these estimates, labor is assumed to be imported into the Juneau area. Costs were prepared using the federal cost estimating system, MCACES. R.S. Means was also used, as adjusted for Juneau in addition to Vendor Quotes. Relocations were assumed to be an average cost per parcel based on tax roll information. For the purposes of the cost estimate, if the parcel is in an inundation zone or part of a right-of-way, the entire parcel was taken.

For the cost estimates in the Estimated Contract Cost is based on the "major cost drivers" for each alternative. The estimated cost and that cost after a 50 percent contingency is applied is presented in Table 4-18, Table 4-19, Table 4-20, Table 4-21, Table 4-22, and Table 4-23 presented during the Charrette.

Table 4-18 Lake Tap Tunnel Alternative Estimated Cost (U.S. $)

(U.S. $)	Estimated Contract Cost	Contingency +50%
Est. Total Cost	613M	1B
Cost Drivers*		
Tunnel	565M	922M
Material Disposal	48M	78M

* AECOM Tunnel Center of Excellence has reviewed costs
Please note presented numbers may not be additive due to mark-up application

Table 4-19 Dam Alternative Estimated Cost (U.S. $)

(U.S. $)	Estimated Contract Cost	Contingency +50%
Est. Total Cost	1.3B	2.1B
Cost Drivers*		
Rock Fill	269M	438M
Grout Curtain	242M	395M
Clay Core	55M	90M
Relocations**	749M	1.2B

* Vendor quotes were obtained for steel and concrete
** Relocations assumed an average cost per parcel based on tax roll information
Please note presented numbers may not be additive due to mark-up application

Table 4-20 Floodwall Alternative Estimated Cost (U.S. $)

(U.S. $)	Estimated Contract Cost	Contingency +50%
Est. Total Cost	2.4B	3.9B
Cost Drivers*		
T-Walls	1.2B	2.0B
Pump Stations	58M	95M
Levees	84M	137M
Relocations**	991M	1.6B

* Vendor quotes were obtained for steel and concrete
** Relocations assumed an average cost per person based on tax roll information
Please note presented numbers may not be additive due to mark-up application

Table 4-21 Hybrid Dam/Floodwall Alternative Estimated Cost (U.S. $)

(U.S. $)	Estimated Contract Cost	Contingency +50%
Est. Total Cost	2.0B	3.3B
Cost Drivers*		
T-Walls	426M	694M
I-Walls	312M	508M
Dam	438M	714M
Relocations**	850M	1.4B

* Vendor quotes were obtained for steel and concrete
** Relocations assumed an average cost per person based on tax roll information
Please note presented numbers may not be additive due to mark-up application

Table 4-22 Relocation Alternative Estimated Cost (U.S. $)

(U.S. $)	Estimated Contract Cost	Contingency +50%
Est. Total Cost	2.1B	3.4B
Cost Drivers*		
Parcels without Structures**	439M	715M
Parcels with Structures**	1.7B	2.7B

* Vendor quotes were obtained for steel and concrete
** Relocations assumed an average cost per person based on tax roll information
Please note presented numbers may be not additive due to mark-up application

Table 4-23 Alternatives Summary Estimated Cost (U.S. $)

Alternative	Estimated Contract Cost	Contingency +50%
Lake Tap Tunnel	613M	1B
Dam	1.3B	2.1B
Hybrid Flood & Dam	2.0B	3.3B
Relocations	2.1B	3.4B
Floodwalls	2.4B	3.9B

Cost Unknowns:

- Impacts of additional Testing and Studies required for each design alternative – Geotechnical, Formal H&H Modeling, Seismic, and others unique to location
- Incomplete Risk Assessment for each alternative
- Complete understanding of construction constraints: Methodologies, Material acquisition, Location and Labor availability
- Cultural Resource Concerns

A brief discussion about the “cost divers” estimated to establish the numbers presented above is included in Sections 4.6.1, 4.6.2, 4.6.3, 4.6.4 and 4.6.5. A complete estimate report is listed in Appendix F in support of Table 4-18, Table 4-19, Table 4-20, Table 4-21, Table 4-22 and Table 4-23.

4.6.1. Lake Tap Tunnel Alternative

The major estimated cost drivers for the Lake Tap Tunnel Alternative include:

- TBM Tunneling
    - TBM procurement and delivery to site.
    - TBM tunnel excavation
    - Tunnel lining production

- Tunnel excavated material disposal

4.6.2. Dam Alternative

The charrette ROM focused on major components such as embankment construction, spillway and outlet works, seepage control systems, and foundation treatment.

- Volume of earthwork and excavation
- Foundation treatment (grouting, cutoff)
- Spillway and outlet works
- Imported material needs
- Relocation of known structures at the 2 to 5% design phase. Valuation utilized is based on the current City and Borough of Juneau Tax rolls.

4.6.3. Floodwall Alternative

The following is a list of activities or considerations that would drive overall cost of the Floodwall Alternative.

- Miles (square feet) of driven steel sheet piles.

- Driven steel H- or pipe-pile foundations for miles of wall plus drainage structures and pump station(s).

- Reinforced-concrete T-Wall, drainage structure, pump station construction, pump stations are assumed to be two 400 CSF, where pumping would be over the wall alignment from subsurface drainage structures.

- Significant earthwork to shape and stabilize riverbanks; armor most banks with riprap.

- Miles of new levee, which requires clearing of land, excavation and earth shaping, building an engineered embankment (performed in numerous “lifts,” or layers, to restrict how much height is added at one time), likely use of mixing methods, wick drains, or other specialty geotechnical processes to consolidate and stabilize native founding soils and build a large levee on top of them.

- Need to import suitable impervious soils to construct clay plugs or other impervious barriers within new embankments.

- Relocation of known structures at the 2 to 5% design phase. Valuation utilized is based on the current City and Borough of Juneau Tax rolls.

4.6.4. Hybrid Dam/Floodwall Alternative

The cost drivers for the hybrid alternative mirror those of both dam and floodwalls stand-alone alternatives. The differences and exceptions include:

- Lower elevation and footprint of the dam (smaller dam footprint).
- Outlet works for the dam.
- Lower floodwall heights, similar to the height of the HESCO barriers.
- Approximately 50 percent of the floodwalls along the eastern side of the river would convert from T-Walls to I-Walls.
- Levees extending to the east would be eliminated.
- Reconstruction or replacement of bridges would not needed.
- The submitted MII estimate reflects these differences in Appendix G.

4.6.5. Relocation Alternative

Complete or partial relocation scenarios do not generate capital construction costs comparable to other alternatives. However, for the purpose of comparing costs of relocation with the capital costs of other action alternatives, an order-of-magnitude cost was developed using the Relocation of known structures at the 2 to 5% design phase. Valuation utilized is based on the current City and Borough of Juneau Tax rolls given to AECOM in preparation for the Charette. These rolls were classified by property type, then an average value for each property type was established. That established value was multiplied by the number of properties in a given classification. Each classification was divided into residential and commercial. A cost allowance for legal assistance has been included in the estimate.

5. Additional Topics Addressed

5.1. Environmental Baseline

5.1.1. Cultural Resources

- Mendenhall Glacier and the Mendenhall Valley are significant to the Tlingit and Haida, including the Áak'w K̲wáan clan, who were the original stewards of the land around the glacier. Evidence of cultural use in the Valley is present in identified archaeological sites. Unidentified cultural resources may also be present in the Valley.

- The Mendenhall Glacier Recreation Area (MGRA) is a historic property. USFS has determined the recreation area is eligible for inclusion in the NRHP as a historic district. The Mendenhall Glacier Visitor Center, Skater's Cabin, Mendenhall Campground, Registry Booth, East Glacier Loop Trail, West Glacier Trail, Mendenhall Glacier Trail of Time, Tolch Rock, and other features are cultural resources within the district.

- The USFS and Tlingit and Haida manage the MGRA through a co-stewardship agreement that integrates indigenous culture into management. A Programmatic Agreement stipulates requirements under Section 106 of the NHPA for visitor facility improvements. The Programmatic Agreement is specific for projects related to visitor facility improvements.

- Known archaeological resources demonstrate historical mining activity in the MGRA project area.

- Other historic properties in the Mendenhall Valley include residences and barns related to the dairy industry, and infrastructure from former mining operations.

- Many residences in the Valley are older than 50 years in age and have not been evaluated for NRHP eligibility.

5.1.2. Recreation and Tourism

- Mendenhall Glacier Visitor Center is a major tourist destination with more than 1 million visitors annually. This has an economic impact across the City and Borough of Juneau.

- The MGRA includes a network of trails, including the popular Nugget Falls trail. There is a campground, a personal watercraft launch, and outhouse facilities.

- The Mendenhall Valley also has a network of trails along the Mendenhall River, and other recreational infrastructure, such as parks and ball fields (Figure 5-1).

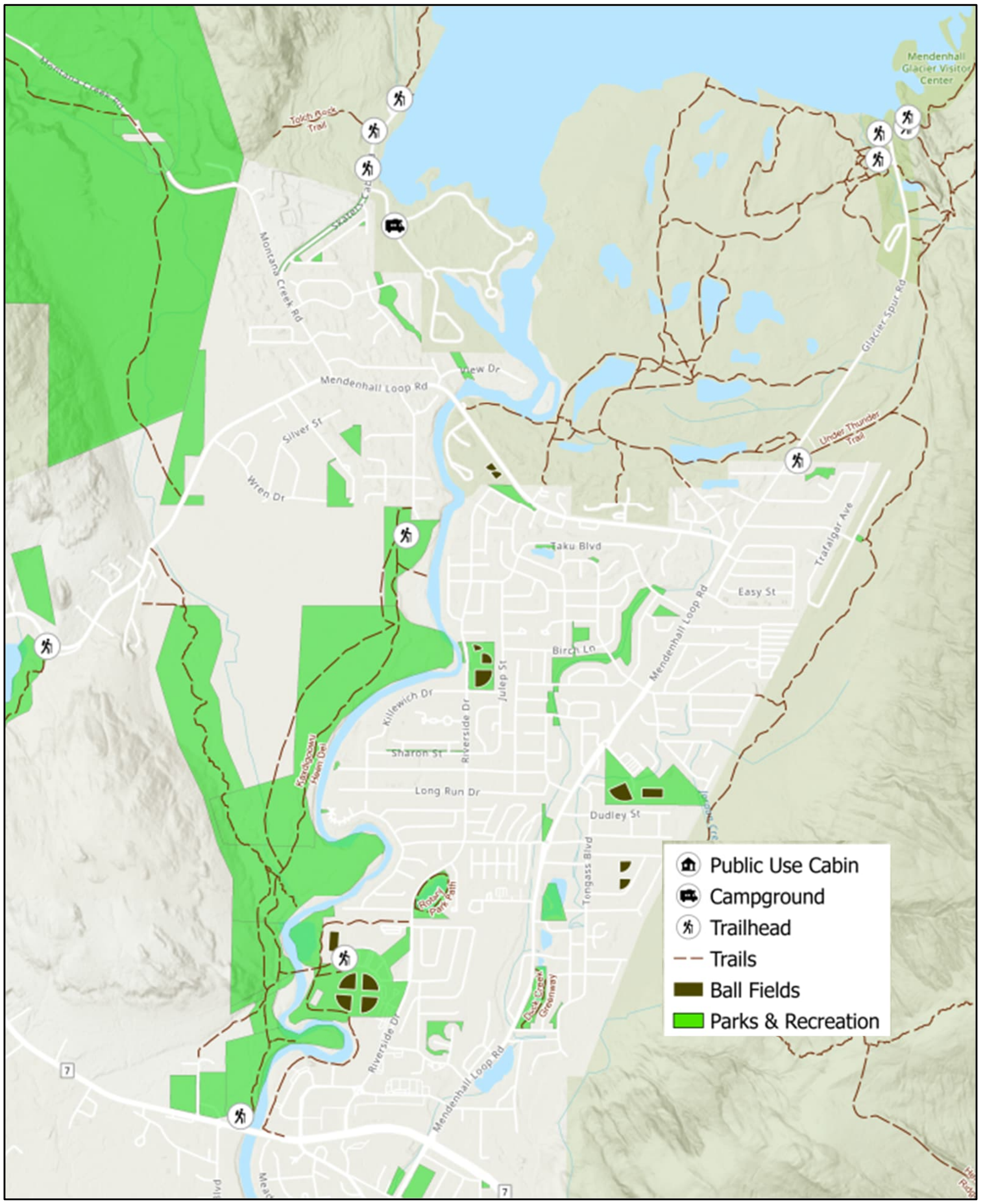


Figure 5-1 Recreation in Mendenhall Valley

5.1.3. Wetlands and Vegetation

- Wetlands: As presented in Figure 5-2, the Mendenhall Valley has wetland areas west of the Mendenhall River, as well as south toward Auk Bay.
- Vegetation: A Bureau of Land Management sensitive plant species of Jointed Rush has been found in Mendenhall Valley, and there are sensitive plant species recognized by USFS' R10 Sensitive Species list that have been found or are suspected to occur (moosewort fern, spatulate moonwort fern, and mountain lady's slipper orchid) in the MGRA.

5.1.4. Fish

- As shown on Figure 5-3, Mendenhall Lake, and Mendenhall River and its tributaries host several anadromous streams.
- Mendenhall River provides habitat for anadromous/resident Dolly Varden char, steelhead/rainbow trout, coastal cutthroat trout, and Pink, Chinook, Coho, and Sockeye salmon. There are significant annual natural runs of Dolly Varden, Coho salmon, and Sockeye salmon.
- The best juvenile salmonid rearing habitat occurs in the upper reaches of the Mendenhall River, but juvenile salmonids have been documented in all reaches of the river. Of the Mendenhall River tributaries, Montana Creek had more salmonids than in any other reach of the river.
- Mendenhall Lake is also an important overwintering area for adult Dolly Varden.

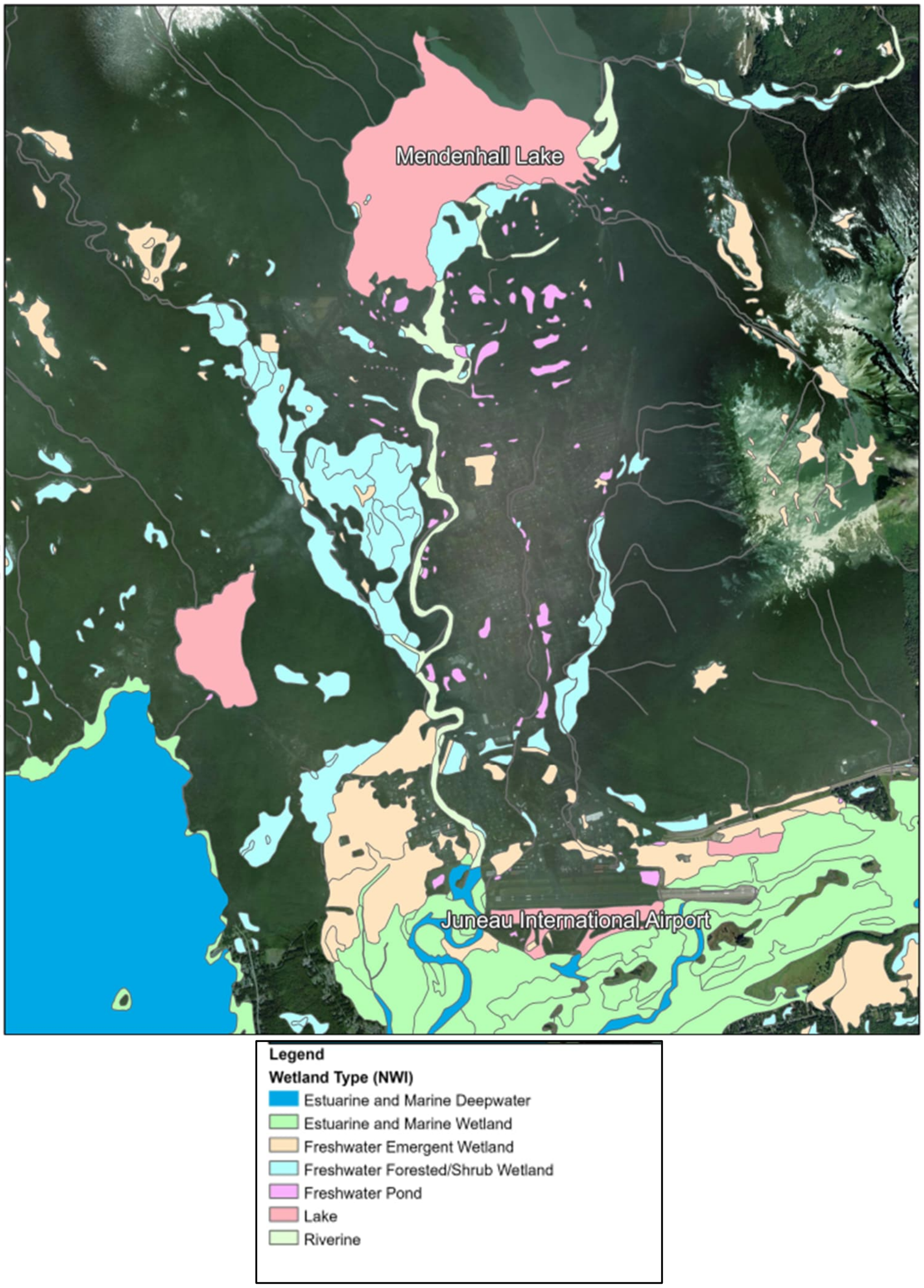


Figure 5-2 Wetlands in Mendenhall Valley

Figure 5-3 Anadromous Streams in Mendenhall Valley

5.1.5. Birds and Terrestrial Mammals:

- Queen Charlotte subspecies of the Northern Goshawk, Bald Eagle, and migratory seabirds are the species of the biggest concern. Bald Eagles are regularly seen in the area. No Bald Eagle nests have been confirmed in the MGRA project area (slightly different from this project), but there is suitable nesting habitat. Bald Eagle nests have been found near Montana Creek.

- Queen Charlotte Goshawk nesting has been observed in the area of Mendenhall Lake/ Visitor Center. Nest locations vary annually. No continuous disturbance is permitted within 600 feet around all known goshawk nest sites during nesting season in the MGRA.

- The north shores of Mendenhall Lake are important areas for breeding migratory birds, including Arctic Terns, Mew Gulls, Herring Gulls, and Glaucous-winged Gulls. All seabirds are protected under MBTA. Red-throated Loons have been documented to breed in the Dredge Lakes Unit of MGRA (near the outflow of the river from the lake).

- Black bears are relatively common, but little is known about their travel corridors. They could be impacted by floodwalls; however, most of the easily accessible fish would be in the upper reaches of the river and the smaller tributaries. Wolves, mountain goats, and beavers also occur in the area, with mountain goats kidding on Bullard Mountain.

5.2. Future GLOF Flood Risk

Dr. Jason Amundson, UAS, presented findings from a recent airborne radar survey of Mendenhall Glacier, discussing the potential for additional basins to form as the glacier retreats, their storage capacity, and implications for future flood risks and project alternatives. Long-wavelength airborne radar was used to map glacier depth and bedrock. The data are preliminary, but provide valuable insights into glacier structure and potential future basins. As the glacier retreats, at least one more lake is expected to form, in a basin on the west side that is currently filled with ice. This basin is larger by area than Suicide Basin but likely less deep, so it may have a lower overall capacity to impound water. The group discussed that new basins could contribute to future outburst floods, but their storage capacity and risk profile differ from Suicide Basin. Further hydrological modeling is needed to assess their impact.

Please refer to Appendix C for slides from this presentation.

5.3. Stakeholder Questionnaire

5.3.1. Summary of Responses

This section summarizes responses from key stakeholders regarding the proposed alternatives for addressing GLOF risks in Juneau. The questionnaire was sent to charrette stakeholders with the Pre-Charrette Packet 1 week prior to the charrette. The questionnaire focused on six core questions, with input from USFS, Central Council of the Tlingit and Haida Indian Tribes of Alaska (T&H), CBJ, and AK DOT.

1. What relevant information does the stakeholder have to share that they have not already shared with USACE or other Stakeholders?

   - USFS: Provided varied resource information references in their scoping response. Offered resource specialists and species-specific timing windows for fish, avian, and mammals and human visitation in any of the project areas under current USFS management. Emphasized the need for consultation with Alaska Native entities for early engagement and contributions. Noted potential adverse effects on historic properties and anticipated that prescribed levels of avoidance and mitigation will be needed commensurate with those impacts. Suggested that environmental/regulatory clearances and/or permits will be more efficient if USFS is a cooperating agency with USACE.

   - CBJ: Indicated the available information has been shared and will continue to be provided.

   - AK DOT: No new information to share.

2. What outcomes and impacts are most important to your organization and/or community?

   - NUSFS: Public safety and preservation of the Mendenhall Glacier Recreation Area's unique character.

   - T&H: Emphasized life safety, tribal sovereignty, cultural identity, community connection to the land, environmental protection, and minimizing displacement of tribal citizens and community members. Emphasized that the preferred engineering solution should be sustainable, maintainable, and realistic.

   - CBJ: Focused on flood risk mitigation and saving the population center of Juneau, with emphasis on how quickly the alternative can be completed, especially in light of the HESCO barrier lifespan. Emphasized maintaining Juneau's cultural/socioeconomic identity. Noted the importance of lifecycle O&M as well as cost.

   - AK DOT: Concerned with infrastructure impacts such as bridge scour, channel migration, road overtopping, and sedimentation.

3. Which of the conceptual alternatives does the stakeholder see as most promising and why?

Lake Tap Tunnel Alternative:

- T&H: Viewed as lower-impact and effective at addressing the source of the problem. This alternative reduces long-term reliance on major structural defenses and avoids widespread property and neighborhood disruption.

- CBJ: Minimal community disruption and infrastructure impact; does not require extensive land acquisition; prevents effects of GLOF closest to source; faster implementation; less consequence of failure.

- AK DOT: Potential for hydroelectric use; suggested syphon system; noted that this alternative would not address risk of a possible future GLOF basin farther up the valley.

Hybrid Alternative:

- T&H: Noted that early review suggests the hybrid balances upstream control with downstream protection while reducing structure size and community intrusion.

- AK DOT: Comparable benefits to levees/floodwalls.

Dam Alternative:

- AK DOT: Strong flood mitigation potential.

Floodwall Alternative:

- AK DOT: Promising, with evacuation and emergency protocols.

4. Which of the conceptual alternatives raises the greatest concern for the stakeholder?

Lake Tap Tunnel Alternative:

- USFS: Staging, operational, and access challenges; viewshed, visitor, commercial user impacts that may be mitigated; power generation, equipment, personnel access challenges; process byproducts need to be managed; preferred location for staging area/barge is north of Skaters Cabin/boat launch/West Glacier trailhead.

- AK DOT: Cost and timeline concerns.

Dam Alternative:

- USFS: Large footprint, USFS resource concerns, USFS does not have resources/ expertise to operate a dam.

- AK DOT: Feasibility, public reception, and safety risks from possible breach, liquefaction, and seepage.

- CBJ: Cultural, socioeconomic, and environmental impacts; timeline; relocation concerns.

Floodwall Alternative:

- T&H: Concerns with extensive footprint, cultural access and long-term operations.

- AK DOT: Cost, public reception.

- CBJ: Cultural, socioeconomic, and environmental impact; public reception, and complexity.

Hybrid Alternative:

- AK DOT: Cost of relocation, public reception, risks with breach, construction on liquifiable soils.

Relocation Alternative:

- CBJ: Uncertainty, feasibility, cost, concerns with relocation of residents for Juneau's community viability.
- AK DOT: Cost, public reception, displaced residents/reduction of housing.
- T&H: Major cultural, economic, and feasibility concerns.

5. Are there access, land use, logistical, cultural, or operational factors that should be considered?
   - USFS: Recommended removal of structures post-use and referenced scoping documents.
   - T&H: Lake Tap Tunnel Alternative, noted need for specialized staff and rapid response capability; impacts to cultural and recreational use of Mendenhall Lake; environmental questions around sediment and water quality. Hybrid Alternative – Presents added complexity; questions around environmental impact. General – Highlighted importance of cultural resources, environmental protections, and community equity. Emphasized cultural/historic site protection, impacts to traditional land and water use, long-term risks associated with maintenance, and environmental impacts.
   - CBJ: Expressed preference for USACE to manage O&M; noted unresolved issues with levees/floodwalls and relocation.
6. Is there anything else you would like us to know (is there something that you want to ensure that we discuss at the charrette)?
   - USFS: Suggested advancing multiple alternatives to pre-engineering due to uncertainties.
   - T&H: Requested clarity on long-term O&M, and identification of primary and backup alternatives.
   - AK DOT: Stressed the importance of understanding time and cost implications of each alternative.

5.3.2. Discussion

A discussion followed presentation of the stakeholder questionnaire. High-level points are summarized below.

- A syphon system with flexible pipes 6 to 8 feet in diameter was proposed in a stakeholder response. The viability of this idea was discussed at the charrette, prompting additional questions about the decision to design a tunnel through the mountain versus a syphon system along the side of the mountain. Ultimately, the syphon system was not moved forward for additional consideration. A few reasons for this include: the upper lake and lower lake are connected by a glacier, meaning that a pipe would be installed over an unstable, moving surface; a pipe would likely be in active avalanche and landslide terrain; if a pipe were routed over the mountain, it would take a lot of energy to pump that water up and over; initially routing the tunnel alongside the glacier was considered, but it was determined that the amount of overhead hazard and steep slope instability made this alignment infeasible. In addition, a siphon has a maximum limit of the height that it can lift water. There are technical limitations for a siphon, without a mechanical pump priming the siphon effect. A pump would have to run continuously to support the siphon.
- One respondent asked about the possibility of using the tunnel for future hydroelectric power. This was briefly discussed at the charrette. There are examples of small turbines in mountainous areas, because even a small flow can offer hydroelectric opportunities. However, at this point in the design, it was agreed that this is not the focus.
- It was clarified that for the levee/floodwall system, pump operations would only be used for the small periods of time when the river is elevated.
- The USFS asked if the USACE could consider advancing more than one alternative into pre-engineering and planning stages. T&H asked a similar question regarding whether a second alternative could be identified if the primary alternative proves to be infeasible. The USACE responded that given the urgency of the situation, the USACE prefers to focus their resources on one alternative. However, they want to investigate all good ideas and there could be opportunities down the road to look at other alternatives. T&H clarified that their intention behind selecting a second alternative is to make sure that this group does not need to meet again if a fatal flaw with the selected alternative is discovered in the next phase of design.
- A question was posed about whether there is a meaningful difference in the lack of geotechnical data between the alternatives that would affect scoring. The answer given was no, it would not affect scoring. It was noted that geotechnical studies are costly. One benefit of the charrette was determining that, because some of these alternatives will not progress forward regardless of the geotechnical components, we do not need to incur the cost to study their geotechnical feasibility.

6. Evaluation Criteria

6.1. Description of the Criteria

The following criteria shown in Table 6-1 were used to help evaluate the alternatives (see also Section 3.5).

Table 6-1 Evaluation Criteria

Criterion	Definition	Considerations
1. Risk Reduction	Ability of alternative to reduce risk (life safety, economic), failure likelihood of structure, ability to meet USACE TRGs	• USACE will consider risk to life safety as priority. TRGs "will be used as the risk-informed decision goal for life safety." Paragraph 8, Paragraph 9 and Appendix C of the ECB (Rev. 1 – 8/8/25) defines the application of TRGs for risk-informed decision making. • Risk reduction is also to be evaluated in terms of economic risk reduction. • Failure likelihood of constructed alternatives will be considered. • Consider performance, community impact, or likeliness to protect people/property within this criterion. • Uncertainties: o What are the potential issues that could stand in the way of accomplishing risk reduction goal? o Scoring will consider how much relative uncertainty there would be for each alternative, including the following: ▪ Geotechnical – variability of soils and rock in foundations and construction materials; liquefaction potential; stability ▪ Hydrogeological – level of groundwater ▪ Hydrological – water surface levels in Mendenhall Lake and along Mendenhall River ▪ Seismic performance ▪ Seepage control ▪ Erosion potential ▪ Relocation – Availability of suitable land for partial or complete relocation.

Criterion	Definition	Considerations
2. Reliability, Adaptability, Resiliency	Certainty of adequate long-term (50-year design life) performance (to satisfy project goal)	• Adaptability to changing hydrologic, glacial, and climate conditions. • Can alternative be modified to account for changing conditions, such as increased GLOF outflows? Water level increases in Mendenhall Lake or along the Mendenhall River? • Consider the certainty of the alternative to perform as intended. • Consider whether the alternative would increase or decrease reliability of the system. The alternative that presented a greater risk of failure or less redundancy in the system is deemed less reliable. • Consider the alternative's capacity to withstand damage, to recover from loading events, and to adapt accordingly.
3. Environmental/ Cultural Considerations, Permitting Requirements, Required Land Acquisition, Economic Considerations	Potential environmental impacts; required permits and associated agencies; footprint of the alternative, including construction access; impact on tourism/local economy	• Environmental/Cultural Considerations: o Tlingit and Haida, CBJ, USFS, State of Alaska, and other agency input. o Environmental impacts (threatened and endangered species; wetlands; floodplain; historical and cultural resources; contaminated sites), including those during construction (air quality, noise, traffic, water quality, recreation, visual impacts, vegetation). o Will implementation of the alternative create negative environmental and cultural resources impacts that require extensive mitigative actions and associated costs? o Community disruption from either construction or relocation; consider material shipping and hauling. o Vegetation clearing, dredging, stream crossings considerations. • Permitting: o Permitting agencies: USACE, USFS, CBJ, State of Alaska, ANCSA Native Corporation land holders, tribal stakeholders, SHPO, others. o Relative level of difficulty or any fatal flaws in obtaining environmental/regulatory clearances and/or permits. • Land acquisition: o Consider temporary and permanent roads to construction site, laydown areas, storage and stockpile areas. o Permanent land and easements required. o Land acquisition and suitable areas needed for relocation. • Economic: o Effects on local economy (industry and tourism).
4. Design and Construction Duration	Length of time required for design process to be able to start construction, and total construction duration from mobilization to substantial completion	• Consider preliminary, final design, outreach, and bidding/ contractor procurement phases. • Consider seasonality and other no-construction periods (e.g., tourism constraints). • Consider real estate acquisition duration prior to construction.

Criterion	Definition	Considerations
5. Constructability	Provide competent plans and specifications and minimize exposure to claims	• Access for equipment, materials, labor; need to ship materials. • Seasonality. • Type of contract delivery method; opportunities for ECI. • Simplicity of construction, number of contractor trades and vendors required, complexity of the equipment, potential for claims. • Can the alternative be constructed in a timely, efficient, and conventional manner without specialized equipment or excessive hand labor? • Can on-site materials be used to the maximum extent possible without importing large quantities of material? • Limitations on construction access and hours of operation required by permitting.
6. Comparative Construction Capital Cost (ROM) for Charrette	Conceptual comparative relative construction cost	• The evaluation will be done on the conceptual 2 to 5 percent designs that are presented at the Charrette. ROM for the Charrette cost will consider the main cost drivers plus a reasonable contingency. • Capital costs, including cost of construction, engineering, and administration, with appropriate contingencies. Cost of operations and maintenance is not considered in this evaluation factor. • Alaska prices are higher due to remoteness. • Consider real estate acquisition cost.
7. Acceptability	The Principles and Requirements for Federal Investments in Water Resources	The viability and appropriateness of an alternative from the perspective of the nation's general public and consistency with existing federal laws, authorities, and public policies. It does not include local or regional preferences for particular solutions or political expediency.
8. Operations and Maintenance Cost and Requirements/ Lifecycle Costs	Operation and maintenance/repair of alternative	• Including estimate of operations, maintenance, and major replacement costs. • Frequency, access, and type of expected maintenance and inspections. • Access for maintenance and repair work. • ROM maintenance cost (in today's dollars). • Consider access and operability of the project in remote/ extreme conditions. • Operation and maintenance complexity: • Regular inspections and instrumentation data (water levels, piezometric pressures, seepage, movement, etc.) evaluations needed. • Structural inspections and valves/gates will require regular inspections, exercising and periodic maintenance. • Monitoring and repair of erosion.

Notes:
ANCSA = Alaska Native Claims Settlement Act
CBJ = City and Borough of Juneau
DDR = Design Document Report
ECB = Engineering and Construction Bulletin
ECI = early contractor involvement
ROM = rough order of magnitude
SHPO = State Historic Preservation Officer

TRG = tolerable risk guidelines

Table 6-2 and Table 6-3 were used to score each alternative in each criterion category. A weighting factor was introduced for each criterion. The weighting factors were decided upon during joint discussions between AECOM and USACE prior to the charrette. Consideration was given to the importance of each criterion to the project purpose and USACE policy. During the charrette, some stakeholders noted that Criteria 3 should have been given a greater weighting factor. However, it was decided a change in that factor would have no impact on the selection of the preferred engineering solution. Furthermore, it was determined during discussions at the charrette that the risk of changing any of the weighting factors was negligible in selection of the preferred engineering solution, due to the overwhelming support for the preferred solution. Each alternative was assigned a score by participants during the charrette, following an explanation and discussion of the criterion and weighting factors. Table 6-4 indicates the scoring definitions.

Table 6-2 Scoring Table

No.	Criterion	Definition	Weighting Factor	Scores (1-5)				
				Laketap	Dam	Floodwalls	Relocation	Hybrid
1	Risk Reduction ***(use Risk Reduction Scoring Table)***	Ability of alternative to reduce risk (life safety, economic), failure likekihiod of structure, ability to meet USACE TRGs	0.25	0.0	0.0	0.0	0.0	0.0
2	Reliability, Adaptability, Resiliency	Certainty of adequate long-term (50-year design life) performance (to satisfy Project goal)	0.20					
3	Environmental/ Cultural Considerations, Permitting Requirements, Required Land Acquisition, Economic Considerations	Potential environmental impacts; required permits and associated agencies; footprint of the alternative, including construction access; impact on tourism/local economy	0.10					
4	Design and Construction Duration	Length of time required for design process to be able to start construction and total construction duration from mobilization to substantial completion	0.15					
5	Constructability	Provide for competent plans and specs and minimize exposure to claims	0.10					
6	Comparative Construction Capital Cost (ROM) for Charrette	Conceptual comparative relative construction cost	0.10					
7	Acceptability	The USACE Planning Principles & Guidelines metric of Acceptability.	0.05					
8	Operations and Maintenance Cost and Requirements/ Life Cycle Costs	Operation and maintenance/repair of alternative	0.05					
	Weighting Total		**1.00**					
	Total Unweighted Score			**0**	**0**	**0**	**0**	**0**
	Total Weighted Score			**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Adjectival Rating							

Table 6-3 Risk Scoring Table

No.	Criterion	Definition	Weighting Factor	Scores (1-5)				
				Laketap	Dam	Floodwalls	Relocation	Hybrid
1a	Risk Reduction - Life loss	Ability of alternative to reduce risk in terms of life loss	0.12					
1b	Risk Reduction - economic	Ability of alternative to reduce risk in terms of economic damage	0.08					
1c	Meeting USACE TRGs	Ability and willingness of responsible and affected parties (USACE, Sponsor, Stakeholders, Public) to meet the four USACE TRG's	0.05					
	Total		**0.25**					
	Total Unweighted Score			**0**	**0**	**0**	**0**	**0**
	Total Weighted Score			**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Adjectival Rating							

Notes:
TRG = tolerable risk guidelines

Table 6-4 Scoring Definitions Table

Definitions: Technical Scores and Ratings (adapted from USACE)		
Adjectival Rating	**Definition**	**Technical Score**
Outstanding (O)	Alternative demonstrates an exceptional approach and understanding of the requirements and contains multiple strengths and/or at least one significant strength, and risk of unsuccessful performance is low.	5
Good (G)	Alternative indicates a thorough approach and understanding of the requirements and contains at least one strength or significant strength, and risk of unsuccessful performance is low to moderate.	4
Acceptable (A)	Alternative meets requirements and indicates an adequate approach and understanding of the requirements, and risk of unsuccessful performance is no worse than moderate.	3
Marginal (M)	Alternative has not demonstrated an adequate approach and understanding of the requirements, and/or risk of unsuccessful performance is high.	2
Unacceptable (U)	Alternative does not meet requirements of the criterion, and therefore contains one or more deficiencies, may not be constructible, and/or risk of performance is unacceptably high.	1

6.2. Discussion and Input on Criteria

On Day 1 of the charrette, participants were given the opportunity to provide feedback on the evaluation criteria. High-level points are included below.

- CBJ noted that there is active discussion on who would be responsible for O&M of the selected alternative. Therefore, complexity was identified as an important factor to include in the evaluation criteria. It was later decided that the assumption would be made that the USACE would be responsible for O&M of the selected alternative for the purposes of evaluating the alternatives. However, under existing authorities, most of the alternatives discussed, including the lake tap alternative, would require O&M from the non-federal sponsor.

- It was noted by T&H that cultural considerations are very important to the Tribe and not something to be overlooked.
- There were questions about the selection of weighting factors for the evaluation exercise. The weighting factors were developed primarily by AECOM and the USACE for the purposes of the evaluation exercise and are not prescribed. They were also briefly discussed with CBJ and T&H prior to the charrette.
- It was noted that in a typical process, an environmental baseline is established within the NEPA process from which to screen alternatives. It was requested that a short presentation on environmental baseline conditions be made during the charrette so that participants are better able to evaluate the alternatives. This presentation on environmental baseline conditions was given on Day 2 of the charrette.

7. Risk Evaluation

7.1. Description of Risk Evaluation Framework/Methodology

7.1.1. Project Objective – Risk Reduction

The overall project objective is to reduce GLOF-related risk in Mendenhall Valley and identify the alternative that provides the greatest risk reduction. To achieve this objective, the project incorporates a risk-informed design approach.

7.1.2. Definition of Risk, Failure, and Consequences

Risk is a measure of both the likelihood of failure occurring, and severity of adverse consequences should failure occur. In the context of GLOF loading for the *current conditions*, failure is defined as breach of the HESCO barrier system that leads to inundation of the community. *After* the selected alternative is constructed and is in operation, failure is defined as damage to or destruction of the structure under loading (GLOF, seismic, landslide, avalanche, or normal loading) that leads to uncontrolled release of flood water and inundation of the community. Post-construction risk may also be associated with non-failure events that exceed the design criteria of the structure. Consequences of HESCO (current conditions) or structure failure (post-construction) could be loss of life and/or economic damages.

7.1.3. Risk Evaluation During the Charrette

There are different types of risk analyses, such as qualitative, semi-quantitative, and quantitative. Given the current conceptual design level for the alternatives and limited supporting data, a high-level, qualitative risk evaluation was considered appropriate for the charrette. Risk of each alternative was qualitatively discussed and evaluated using three criteria:

- The level of risk reduction the alternative provides in terms of life loss.
- The level of risk reduction the alternative provides in terms of economic loss.
- The ability of responsible parties to meet USACE TRGs (USACE 2024).

Risk reduction (life loss and economic loss) is considered to be the primary evaluation criteria. Risk reduction provided by an alternative is measured against the estimated baseline (i.e., current) risk.

Hypothetically, if the risk evaluation had indicated a structural alternative may have a relatively high likelihood of failure during the GLOF lifecycle, that criteria could have governed and disqualified the alternative. Also hypothetically, a structure could be constructed to the standard of practice so that there would be remote likelihood of failure; however, the cost may be prohibitive, or there may be insurmountable constructability issues.

TRGs provide risk-informed decision goals for life safety. The four TRGs together encompass all phases of alternative implementation – planning, design, construction, and operation. Any project that would be constructed would include all necessary project features to ensure that the project meets USACE's four TRGs. The ability or willingness of the responsible or affected parties (USACE, Sponsor, Stakeholders, Public) to meet the four USACE TRGs—can be better understood in terms of key questions, presented below in italics. The goal in the charrette workshop was to solicit input from charrette participants to find out if/how TRGs would be met for each alternative; the degree to which an alternative meets the TRGs should be reflected in the scoring, discussed below.

The four TRGs are summarized as follows.

- TRG 1 – Understanding the risk
  - *Is the risk associated with each alternative reasonably understood by all responsible/ affected parties?*
  - *Are responsible/affected parties willing to live with the risk associated with the alternative to secure the benefits provided by the alternative?*

Potential Failure Modes (PFMs): Identifying and evaluating risk-driving PFMs; i.e., credible PFMs that contribute most to increased risk, is an important way to better understand risk. PFMs should be evaluated for all applicable loading conditions (normal, GLOF, seismic, landslide, avalanche).

Key concept: Designing and constructing structures that are "perfectly safe" in our society is not technically and economically feasible—there remains a certain level of risk that would need to be recognized as tolerable and ***manageable.***

- TRG 2 – Continuing risk awareness
  - *After construction, will there be a continuation of recognition of risk, considering there will be risks that are not broadly acceptable and cannot be ignored?*
  - *In what manner and how effectively will continuing risk be communicated?*
  - *How can the public be encouraged not to grow complacent with any ongoing risks associated with the constructed alternative?*

Possible examples of risk awareness/communication: Develop and keep current an emergency action plan, public outreach, websites.

- TRG 3 – Monitoring and managing risk
  - *Who will be responsible for monitoring and managing risk?*
  - *Will risk be properly monitored and managed throughout the operational period of the alternative?*

> **Examples of monitoring and managing risk**: regulatory oversight, developing and adhering to a dam/levee/tunnel safety program, updates to GLOF loading, periodic inspections, instrumentation monitoring and analysis, periodic comprehensive reviews, maintenance cost considerations.

- TRG – 4 Taking action to reduce risk
  - *Are actions to reduce identified risks associated with the preferred engineering solution warranted, and how effective and economical would those actions be?*
  - *Is it likely there would be cost-effective, socially acceptable, or environmentally acceptable ways to reduce any new risks associated with the constructed alternative that may develop in the future?*
  - *Would funding for any necessary future risk reduction measures be available in a timely manner?*

> For example, what actions would be taken to reduce risk if/when updated GLOF projections indicate a substantially higher expected flood volume, or new GLOF basins develop?

7.1.4. Baseline Risk

Risk reduction was qualitatively measured against the baseline (current conditions) risk. Key considerations associated with baseline risk are:

- Estimated GLOF loading (prior to constructed alternative).
- Vulnerabilities with current HESCO flood protection.
- Population at Risk (PAR).
- Estimated loss of life during future GLOF loading, before alternative implementation.

Currently estimated GLOF and non-GLOF loadings are summarized in Figure 3-4 (in Section 3.6). GLOF loading is conservatively estimated to increase in the future.

A HESCO vulnerability and breach analysis performed by Michael Baker, International (MBI) (MBI 2025) identified seven potential breach locations with increased likelihood of barrier failure at an 18-foot flood stage, summarized in Table 7-1 (Table 2 of the MBI report). Structural vulnerability was based on critical values of water depth, velocity, and shear stress from the model.

Table 7-1 HESCO Breach Locations

Table 2. Phase 1 HESCO Breach Locations

Breach Location #	Phase 1 HESCO Station	Breach Description
01	**2+50**	~200 ft northwest of Fireweed Lane & Marion Drive; historic overtopping waves with high velocity and shear stress
02	28+00	~500 ft west of Killewich Drive & Riverside Drive; historic overtopping waves with moderate directional velocity; super elevation
03	**38+00**	~950 ft northeast of Sharon Street & Killewich Drive; projected corner location exhibiting high depth, velocity and shear
04	56+00	~500 ft west of Betty Court & Richards Drive; projected corner location exhibiting high depth, velocity and shear
05	65+00	~200 ft northwest of Meander Way cul-de-sac; adjacent channel section with high depth, velocity, and shear; armored bank
06	**80+00**	~150 ft west of Turn Street & Meander Way; high velocity and shear; outside bend; current gap in armor protection
07	96+50	~300 ft west of Rivercourt Way & Meander Way; high velocity and shear; near end of barrier

Note: Breach locations in bold are priority breach locations for analysis.

Four locations were identified (Sta. 49+60, 57+50, 66+10, 96+70) where HESCOs could be intentionally breached to release inundation water back into the river.

AECOM observed the following HESCO vulnerabilities during a site visit in November 2025:

- Insufficient footprint in some areas to properly stack HESCO barriers with wider base – representing vulnerability to toppling when loaded with flood-stage river flow.
- Extensive bank erosion and areas of seepage erosion – representing vulnerability to additional bank erosion during future loading, potentially resulting in undermining of HESCOs.
- Breached/damaged HESCO barriers – demonstrating HESCOs are vulnerable to damage/breach during future GLOF loading.
- Surface drainage outfall areas with lower, eroded areas – representing vulnerability to concentrated bank erosion and HESCO undermining.
- Penetrating surface drainage pipes without flaps – could allow reverse flow into protected area if river stage rises high enough.

PAR is defined as the estimated number of people exposed to GLOF floodwaters, and includes residents or workers in structures, transient PAR (motorists), tourists, and recreationists. There was insufficient information to quantitatively estimate PAR for the charrette; however, estimates of structures impacted by inundation were available (see Table 4-9), which were used as a proxy for PAR for the purposes of the charrette.

Current qualitative baseline vulnerability and consequences are estimated as follows, using the descriptors “LOW” and “HIGH,” which do not have a specific definition but are used in a relative sense:

- Likelihood of HESCO failure during future major GLOF event = HIGH.
- Estimated economic consequences of HESCO failure during a future major GLOF event = LOW to HIGH, depending on severity of inundation and emergency response and mitigation efforts.
- Estimated life loss consequences of HESCO failure = LOW to HIGH, depending on severity of inundation and effectiveness of emergency response and evacuation efforts.

7.2. Risk Factors and Relative Weighting

During the charrette, participants rated each alternative, taking into consideration the three criteria described above (life loss risk reduction, economic loss risk reduction, and ability to meet USACE TRGs). Among the eight evaluation criteria for the alternatives *(refer to evaluation criteria and scoring section)*, risk is considered the most important and was assigned a weight of 0.25 out of 1.0, representing 25 percent of the total. Each alternative was assigned a score by charrette participants, with a score of 5 being the highest and 1 being the lowest. The scoring matrix (blank) participants used is provided in Table 7-2.

Table 7-2 Blank Scoring Matrix – Risk

No.	Criterion	Definition	Weighting Factor	Scores (1-5)				
				Alt. A	Alt. B	Alt. C	Alt. D	Alt. E
				Laketap	Dam	Floodwalls	Relocation	Hybrid
1a	Risk Reduction - Life loss	Ability of alternative to reduce risk in terms of life loss	0.12					
1b	Risk Reduction - economic	Ability of alternative to reduce risk in terms of economic damage	0.08					
1c	Meeting USACE TRGs	Ability and willingness of responsible and affected parties (USACE, Sponsor, Stakeholders, Public) to meet the four USACE TRG's	0.05					
	Total		**0.25**					
	Total Unweighted Score			**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Total Weighted Score			**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Table 7-3 was provided to charrette participants to help in comparing risk factors and considerations for the alternatives, as an aid in scoring risk.

Table 7-3 Risk Considerations

Criteria	Alt A – Lake Tap	Alt B – Dam	Alt C – Flood Wall	Alt D – Relocation	Alt E – Hybrid
Standard of Practice/ Tolerable Risk at Design?	Assume	Assume	Assume	NA/Assume	Assume
Tolerable Risk Continues throughout Operation?	Depends – *Meets TRGs?*	Depends – *Meets TRGs?*	Depends – *Meets TRGs?*	NA	Depends – *Meets TRGs?*
Addresses GLOF at Source?	Yes	No	No	No	No
Accommodates increasing GLOF Loading/Suicide Basin Volume (future risk)	Yes – *tunnel conservatively dimensioned for 10 days of peak flow*	Yes – *if dam is raised*	Yes – *possible, but floodwall height increases are complex*	Yes – *but river could still geo-morph beyond relocation*	Yes – *if dam is raised and floodwall height is increased (complex)*
Protects Against Loading from future GLOF Basins?	No – *but there are possible provisions for future tunnelling w/ shaft alternatives*	Yes	Yes	No	No
Protects Lake PAR?	Yes – *only approx. 0.25-foot increase in lake level*	No – *increased lake level results in safety risk near O/W intake*	No	No	No – *increased lake level results in safety risk near O/W intake*
Attenuates GLOF Flow into River?	Yes – *800 cfs (peak) is only a marginal increase in river stage/ velocity.*	Yes – *but 30,000 cfs river flow (peak) poses risk to River PAR*	No	No	Yes – *but 30,000 cfs river flow (peak) poses risk to River PAR*
Reduces future risk assoc. with river geo-morphing?	Yes – *800 cfs (peak) is only a marginal increase in river stage/ velocity and erosive energy.*	Low risk reduction – *30,000 cfs (peak) river flow capable of high erosion*	Yes – *stabilizes/ protects riverbank*	No	Yes – *stabilizes/ protects riverbank*
Non-Failure Exceedance event leading to inundation? (GLOF exceeds design capacity)	Yes – *exceedance of tunnel capacity may lead to sub-glacial discharge*	Yes – *exceedance of O/W capacity may lead to limited overtopping*	Yes – *exceedance of design flood stage may lead to limited overtopping*	NA	Yes – *same considerations as for dam and floodwall*
Risk level associated with catastrophic failure	Low to High– *complete tunnel failure/blockage results in GLOF loading (lower likelihood than pre-project but potentially higher consequences without HESCOs)*	Very High	Medium to High	NA	Medium to Very High – e.g., *FRMS increases risk in event of dam failure*
Life loss w/o economic loss scenarios?	No	Yes – *river and lake PAR risk*	Yes – *river PAR risk*	Yes – *river and lake PAR risk*	Yes – *river and lake PAR risk*
Economic loss w/o life loss scenarios?	Yes – *if tunnel failure (sufficient detection, warning and response time)*	Yes – *slowly developing PFMs (sufficient detection, warning and response time)*	Yes – *slowly developing PFMs (sufficient detection, warning and response time)*	Yes – *if river geo-morphs beyond relocation*	Yes – *same as dam and floodwall*

The Lake Tap Tunnel Alternative scored the highest among the alternatives from a risk perspective. As indicated with the green-shaded cells in the table, the Lake Tap Tunnel Alternative has multiple favorable risk factors compared to the other alternatives.

7.3. Next Step – Risk Assessment

A decision on the preferred engineering solution was determined at the end of the charrette. A 2-day virtual risk assessment will be conducted for the selected alternative, scheduled for the first week in February 2026. Objectives of the risk assessment include:

- Perform a potential failure mode analysis, wherein risk-driving PFMs are developed and evaluated for all applicable loading scenarios.
- Qualitatively evaluate risk in greater detail than performed during the charrette, commensurate with the level of design and supporting information.
- Help refine the project design.
- Provide a reasonable level of assurance that the structure will perform adequately under the full range of loading during the GLOF lifecycle or under other loading types (e.g., seismic, normal, landslide).
- Discuss risk associated with loading events that exceed design criteria to help inform potential modification of the design criteria.

Risk assessment results will be used to develop recommendations for design that improve performance and risk reduction, and may also help inform where the design may be upscaled (e.g., use a factor of safety higher than the minimum) or downscaled (use a factor of safety lower than the minimum), or may help provide justification for any deviations from normal design standards. Methodology and results of the risk assessment will be documented in a risk assessment report, which will be submitted for review and approval by USACE.

8. Alternatives Assessment

After discussing the five alternatives and the evaluation and risk criteria, the following stakeholder groups met in closed breakout sessions to assess the alternatives:

- United States Army Corps of Engineers (USACE)
- City and Borough of Juneau (CBJ)
- Central Council of Tlingit and Haida Indian Tribes of Alaska (T&H)
- United States Forest Service (USFS)
- Alaska Department of Transportation (AK DOT)
- Alaska State Department of Natural Resources (AK DNR)
- University of Alaska Southeast (UAS)

The National Weather Service and United States Geological Survey did not participate in stakeholder breakout groups but later expressed their support for the chosen alternative.

After the breakout sessions, each stakeholder group shared their preferred engineering solution. The Lake Tap Tunnel was selected by each stakeholder group as the preferred engineering solution. Reasons cited for this assessment include:

- Technical feasibility
- Less community and tourism related impacts
- Speed of implementation
- Lower cost and complexity compared to the other alternatives

To some stakeholder groups, the dam alternative was identified as a secondary option. To others, the dam alternative and all other alternatives (floodwall, hybrid, relocation) were deemed largely unacceptable due to their significant impact on community life in the Mendenhall Valley. Concerns cited by stakeholders related to the other alternatives include:

- Technical infeasibility
- Unacceptable scale and impact on cultural and recreational sites
- Impractical timelines for flood protection
- Operational complexity beyond local capacity
- Relocation, in particular, was deemed unrealistic due to the magnitude of effort and time required

Breakout group discussions and scoring were not recorded to maintain privacy and encourage open dialogue.

The alternatives were generally ranked in the following order of preference:

1. Lake Tap Tunnel
2. Dam
3. Floodwall
4. Hybrid
5. Relocation

Although this was the order of preference, the stakeholders were only supportive of the Lake Tap Tunnel Alternative. The stakeholders showed very little support or preference for any of the other alternatives. The stakeholders stated that if a decision is made at some point that the Lake Tap option is not viable, then revisiting the other alternatives and the weighting of the evaluation criteria would be appropriate.

Supplemental information was provided as follow-up to questions generated during the breakout groups associated with environmental baseline information as well as other potential GLOF source locations further up the Mendenhall Glacier.

Although consensus was reached, it was reiterated that this project is still in the conceptual stage. Participants acknowledged the need for more geotechnical information and further studies to refine the Lake Tap Tunnel preferred engineering solution, with USACE providing technical expertise and stakeholders committed to supporting additional research and data collection.

Leadership from each stakeholder group met to discuss the recommended alternative, identify unresolved issues, and formalize the selection of the preferred engineering solution.

9. Selection of Preferred Engineering Solution

9.1. Selected Preferred Engineering Solution(s)

Evaluation and risk criteria were reviewed and discussed as a group. Each stakeholder group had an initial breakout session and came back with a recommended alternative.

Each group selected the Lake Tap Tunnel as their preferred engineering solution.

Leadership from those stakeholder groups went into a separate, private breakout session and came back with a final determination of the Lake Tap Tunnel as the preferred engineering solution.

9.2. Additional Required Information

Each stakeholder group recognized that there are several technical unknowns for the Lake Tap Tunnel Alternative remaining, and that modifications to the alternative may be required once more information was gathered. Geotechnical data were identified as a major technical unknown for this alternative and an emphasis was placed on performing geotechnical investigations.

9.3. Technical Breakout Groups Overview

On the final day of the charrette, participants broke out into the following technical working groups to discuss key questions and identify next steps needed to complete the technical report:

- Civil/Transportation
- Geotechnical
- Cultural/Environmental
- H&H
- Risk
- Cost/Schedule

Below are high-level summaries of these technical breakout groups.

9.3.1. Civil/Transportation

- Discussion of access, staging, traffic, and utilities.
- Discussion of staging area – the location near the campground is not ideal for the USFS. USFS prefers an area that is north of the campground, the existing boat ramp, and the West Glacier Trailhead.
- Waste disposal is an unknown with available data.

9.3.2. Geotechnical

- Discussion about developing a preliminary geotechnical and drilling plan so that as funding becomes available, data can be collected.
- Discussion about boring placements – "Must have" borings and "nice to have" borings were identified.
- The "must haves" in the boring plan will likely not give good confidence on the amount of hazardous material, such as pyrite, along the alignment.
- Discussion about the alignment, the type of rock it likely passes through, and the need to curve the alignment and move it north to get deeper into Suicide Basin and farther from the glacier.
- Discussion about fatal flaws – currently none are identified. The assumptions made in the initial design were conservative.

9.3.3. Cultural/Environmental

- In terms of cultural resources, this project is in a historic property, and design elements will do their best to minimize impacts.
- There is an existing Section 106 agreement for the recreation area that would not apply to this project. USFS will be lead agency on any areas that have not been previously surveyed for cultural resources. There is a general understanding about the area's historic land use; as of now, no cultural resource concerns have been identified as a deal-breaker.
- Discussion of alternative staging locations and impacts on NEPA. USFS prefers to use a staging area that does not impact the campground. It is not a dealbreaker, but the preference is for the campground to be avoided.
- Environmental/cultural concerns include management of dredged material and tunnel muck, barging diesel fuel across the lake for power if needed, tunnel outfall, supplying power, impacts to fish habitat, visitor use impacts. Areas with major concern were identified, such as anadromous streams, culturally significant locations, and areas of terrestrial mammal use.
- Public health concern about people accessing the tunnel – there is a need to reduce access near the tunnel infrastructure.
- USFS has construction timeline limitations that will be shared for consideration.

9.3.4. Hydrology and Hydraulics

- Hydrology: Discussion of 800 cfs and methodology for using this number; it is the number being used moving forward.

- Inlet: Discussion of modeling of the trash rack, sediment passing through the tunnel, potential abrasion and mitigation measures, inlet shape.

- Tunnel design: Discussion of modeling approaches. 2D allows us to figure out flow patterns, 3D is more sophisticated. Discussion of what type of modeling is needed for this level of design, especially given that modeling needs to be done in January so the tunnel team can move forward with design. More discussion is needed on this, if time and scope allow one computational fluid dynamics model without iteration. Discussion about tunnel design specification and minimizing risk of cavitation.

- Outlet: Discussion of location and energy dissipation via a potential stilling basin.

- O&M: Much of this is hydraulics-related.

- Discussion about level of modeling, number of potential shafts needed, thermal dilution in the lake, and energy dissipation.

9.3.5. Risk

- Risk breakout group attendees agreed the main objective of the risk assessment will be to verify the right level of project definition to meet the TRGs. The project is a risk-informed design, and risk portrayal is central to the process for USACE decision making and approval.

- The risk assessment will identify design recommendations that will affect planning, with a need to document design recommendations that will affect cost (construction, O&M).

- The risk assessment will require input from numerous disciplines (H&H, geology, structural, seismic, tunneling, geotechnical, mechanical) to inform the PFMs.

- Each major assumption why or why not a PFM is a risk driver will be tracked and documented.

- Risk workshop (February 3 and 4, 2025) attendees were discussed – 20 to 25 attendees anticipated.

- A preliminary list of PFMs covered in the Lake Tap Tunnel charrette package was discussed.

- The agenda for the risk workshop was discussed.

- It was envisioned that three risk-driving PFMs will be assessed during the workshop, assuming about one-half day per PFM.
- It was envisioned there would be a need to estimate the threshold level of tunnel blockage that would result in critical GLOF loading.
- Detection and intervention associated with a given tunnel PFM were discussed.
- The content of the risk assessment report was discussed.
- There will be a very short review period for the risk assessment report, and likely USACE reviewers were identified.
- It was envisioned that there will be a more detailed (quantitative?) risk assessment at a further design stage.

9.3.6. Cost

- There will be a CSRA exercise – CSRA determines the contingency that will be put on the cost estimate for construction.
- Need to incorporate the impact of additional testing and studies. Waste disposal costs are unknown.
- An alternate alignment was discussed that would nearly double the length of the tunnel. Doing so would facilitate year-round construction, which would shorten the construction window. Estimate that this would have a minimal impact on cost, because once tunneling begins, the incremental cost to go distally is fractional to the act of starting the tunnel.
- There are lingering questions about site location, labor availability, hauling operation.
- Discussion about ways to get creative to expedite the project and keep costs down.

It should be noted that a recommendation to change the alignment of the tunnel and its outtake were discussed on Day 3 of the charrette. This alignment would significantly alter the location and length of the project area.

It was emphasized in the charrette, and in this report, that the original alignment included in the conceptual Lake Tap Tunnel Alternative will be the focus of the technical report, because this is the option that was studied, discussed, and then selected by group consensus as the preferred engineering solution. After the technical report, and depending on available authorities and resources, it may be possible to further investigate alternate alignments.

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Appendices

Appendix A Charrette Participants

Appendix B Charrette Meeting Minutes

Appendix C Charrette Presentation Slides

Appendix D Stakeholder Questionnaire – Blank Copy

Appendix E Charrette Graphics (Wall Maps)

Appendix F Design Flows Determination

Appendix G Opinion of Probable Construction Cost Report

Appendix H Agency and Public Scoping Comments

Appendix I Mendenhall River Preliminary 2D Surface Water Model Report

Appendix J Example Relocation Workflow