2021 Healy Canyon

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Final Report

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EXECUTIVE SUMMARY

The Alaska Railroad Corporation operates eleven miles of track between the Denali Park Entrance (MP348) and Healy, Alaska (MP361) in a corridor called the Healy Canyon. The route follows the Nenana River through a narrow canyon where ARRC has faced a long history of slope stability problems associated with the complex geology and the downcutting of the Nenana River. Slope movement is largely influenced and exacerbated by the infiltration of surface water. Drainage features including culverts, ditches, and flumes have historically been used to limit infiltration in areas experiencing slope failures. Retaining walls are widespread in the canyon, stabilizing local sections of track embankment.

Studies were performed in 2021 to evaluate conditions and make mitigation recommendations at two slope failure areas (MP357.1 and MP353.2) and a rockfall area (MP352.9). In addition, a retaining wall inventory was performed to generally assess the conditions of retaining walls. Recommendations were made on the order in which to repair retaining walls in poor condition (Phase 1-4). A similar inventory was performed to assess the conditions of culverts. A LiDAR collection was completed in 2021 to support the landslide studies and future engineering. This report presents the results from these studies and assessments, identifies and prioritizes projects, and proposes a timetable for project funding and implementation.

The identified projects were separated into three classes to differentiate projects that can be readily implemented (Class 1), those requiring more study and engineering (Class 2), and those that are considered less urgent or have a long-term objective (Class 3). Class 2 projects underwent further prioritization based on their relative urgency, impact, and complexity. The identified projects in their respective classes are presented in the table below.

Class 1 Projects	Class 2 Projects (prioritized)	Class 3 Projects
• MP352.9 Rockfall Mitigation • Phase 1 Retaining Wall Repairs • Install Monitoring Equipment	1. MP357.1 Slope Stability Improvements 2. Phase 2 Retaining Wall Repairs 3. Phase 3 Retaining Wall Repairs 4. MP353.2 (Moody Slide) Drainage Improvements	• Phase 4 Retaining Wall Repairs • Marginal Retaining Wall Repairs • Change Detection LiDAR survey

A programmatic approach to executing projects in Healy Canyon will be required to obtain grant funding, meet permit compliance, and perform engineering design and construction. A timetable of approximately 10 years should be considered for full implementation of the recommended projects.

Revision History

Rev #	Originator	Reviewed By	Approved By	Date	Description
A	Brooks, Bill Kubic, Andrew	Yager, Garrett	Yager, Garrett	12/09/2021	Draft – Issued for Review
0	Brooks, Bill Kubic, Andrew	Yager, Garrett	Yager, Garrett	04/06/2022	Final – Issued for Use
1	Brooks, Bill Kubic, Andrew	Yager, Garrett	Yager, Garrett	05/09/2022	Final – Issued for Use

TABLE OF CONTENTS

TABLES

FIGURES

ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Definition
AEP	Annual Exceedance Probability
ARRC	Alaska Railroad Corporation
CMP	Corrugated Metal Pipe
GCL	Geosynthetic Clay Liner
LiDAR	Light Detection and Ranging
Michael Baker	Michael Baker International
MP	Milepost
NEPA	National Environmental Policy Act

1. Introduction

The Alaska Railroad Corporation (ARRC) operates between the ports of Seward and Whittier, both year-round ice-free seaports, and Fairbanks, in Interior Alaska, crossing through two major mountain ranges with approximately 468 miles of mainline track and an additional 56 miles of track along spur lines. The route passes through the Alaska Range in what is called the Healy Canyon, a transportation corridor approximately 11 miles long between the Denali Park Entrance (MP348) and Healy, Alaska (MP361). Due to the topography, the rail route is confined to the canyon with no alternative route available.

This area has a long history of slope stability problems in the form of deep-seated landslides, rapid slope movement, washouts, and rockfall issues, which all affect operations and safety in the Healy Canyon. Much of the slope instability is related to the complex geological history in the Healy Canyon. The slumps and earthflows encountered by ARRC track are located primarily in the lakebed clay deposited by glacial Lake Moody. Additionally, the Birch Creek schist is highly susceptible to weathering, forming large talus slopes in the steep canyon. The talus slopes become unstable due to lateral erosion and downcutting of the Nenana River, saturation by surface water infiltration, and melting permafrost. The railroad, which cuts along the top or middle of these talus slopes, is subject to constant movement, often associated with precipitation events. The constant movement has led to failure of retaining walls and drainage structures, and it causes settling or downward movement of the track.

ARRC tasked Michael Baker International (Michael Baker) to evaluate conditions throughout Healy Canyon in 2021. As part of these efforts, LiDAR was used to collect topographic survey data from MP344 to MP361. A retaining wall and culvert inventory were performed to document ARRC's existing infrastructure assets in Healy Canyon. These inventories include assessments of the overall condition of each retaining wall and culvert. In addition, three specific problem areas were evaluated in separate reports:

- ARRC MP357.1 Slope Failure
- ARRC MP353.2 (Moody Slide) Slope Failure
- MP352.9 Rockfall

Conceptual designs of mitigation alternatives and options were developed for each of these areas to develop viable solutions and inform engineering design. An overview figure of the extents of the 2021 assessments is presented in Figure 1-1.

This final report is a culmination of the 2021 assessments and incorporates the results of these surveys and reports to identify and prioritize projects throughout the Healy Canyon. Section 2 presents findings from the three slope failure evaluations and summarizes the retaining walls and culverts determined to be in poor condition. Section 3 provides a 2022 Action Plan that prioritizes projects and presents a timetable to help guide funding and implementation.

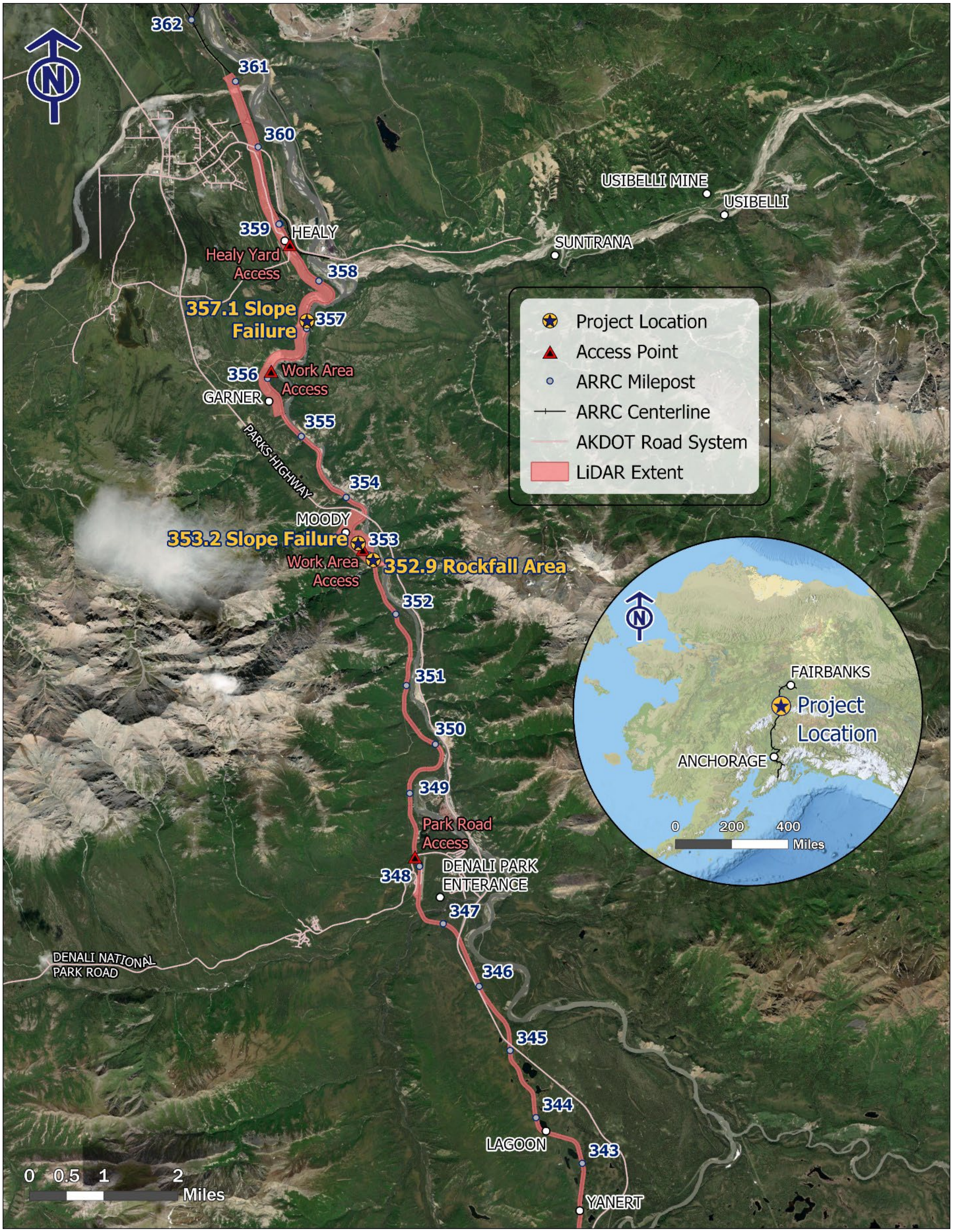


Figure 1-1: Project Location Map

2. 2021 Healy Canyon Study Results

Since the completion of the railroad linking southcentral Alaska and Fairbanks in 1923, ARRC has fought to maintain the tracks in the Healy Canyon. Historical documentation of the slope failures, fixes, and engineering applied to the railroad through this corridor is recorded in historical reports that are still applicable to the problems faced in 2021.The surveys and analyses conducted in 2021 by Michael Baker build on this historical data.

The slope stability studies at MP357.1 and MP353.2 recognize drainage as the most effective mitigation tool in stabilizing landslides, and generally the most cost-effective given the high cost of other solutions, such as large retaining walls or massive movement of earth to unload the top of a slope or to buttress the toe. As such, many of the alternatives include an aspect of drainage as part of the solution.

The retaining wall inventory was conducted by trained, rope-access professionals who stopped at each retaining wall in the canyon to document conditions with photos and notes. They provided an assessment of each structure. Forty-five walls were inspected over two separate trips in 2021, with a total of four days in the field working from a hi-rail truck operating on the tracks.

The culvert inventory was conducted by surveyors, who accessed the tracks via hi-rail to photo-document culvert condition and survey the position, including invert elevations of the inlet and outlet, for each culvert along the tracks.

The following sections present each of the studies conducted in the Healy Canyon in 2021 including the recommended mitigation strategies. Additional detail for each study is available in the appendices. The studies were supported by the LiDAR collected from MP344 to MP361 in summer 2021. Appendix A contains the LiDAR data accuracy report.

2.1 MP357.1 Slope Failure

Background

Slope movement at MP357.1 has been a long, ongoing problem requiring track realignments and frequent surfacing to maintain service through this dynamic area, with slope movement observed dating back to 1936. The tracks at the MP357.1 slope failure site are located on a bench cut into the side slopes of the west bank of the Nenana River. Re-alignment of the track to the west was performed as long ago as 1950 and most recently in 2010. The 2010 realignment provided horizontal offset from the edge of the canyon at MP356. 9 at two aging retaining structures that suffered storm-related damage during disaster DR-1796. This 2008 mid-summer storm event with heavy rain resulted in downward movement of the slope. The 2010 realignment is thought to have inadvertently re-activated the historic landslide at MP357.1, requiring resurfacing with increasing frequency from 2013 to 2016, and continued maintenance efforts into 2021. Between 2010 and 2016, it was estimated that 5 to 7 feet of displacement downward toward the river had occurred. The MP357.1 Slope Failure report is included as Appendix B.

Geotechnical investigations suggest the regular slope movement is attributed to a translational slide, exacerbated by precipitation events. Observations during a site visit in May 2021 further support characterizing the slide as a translational slide. The active slide area is shown in Figure 2-1.

Drainage structures in the vicinity include a drop inlet on the inside ditch and a culvert just north of the slide area. The culvert was conveying flow during the May 18, 2021 site visit. The drop inlet has no apparent connection to an outlet on the downhill side of the track, though a relic culvert outlet is present. Slide movement has likely broken any connection between the inlet and outlet. Proper drainage is further impeded as little-to-no gradient is present in the ditch to direct flow to the drainage structures.

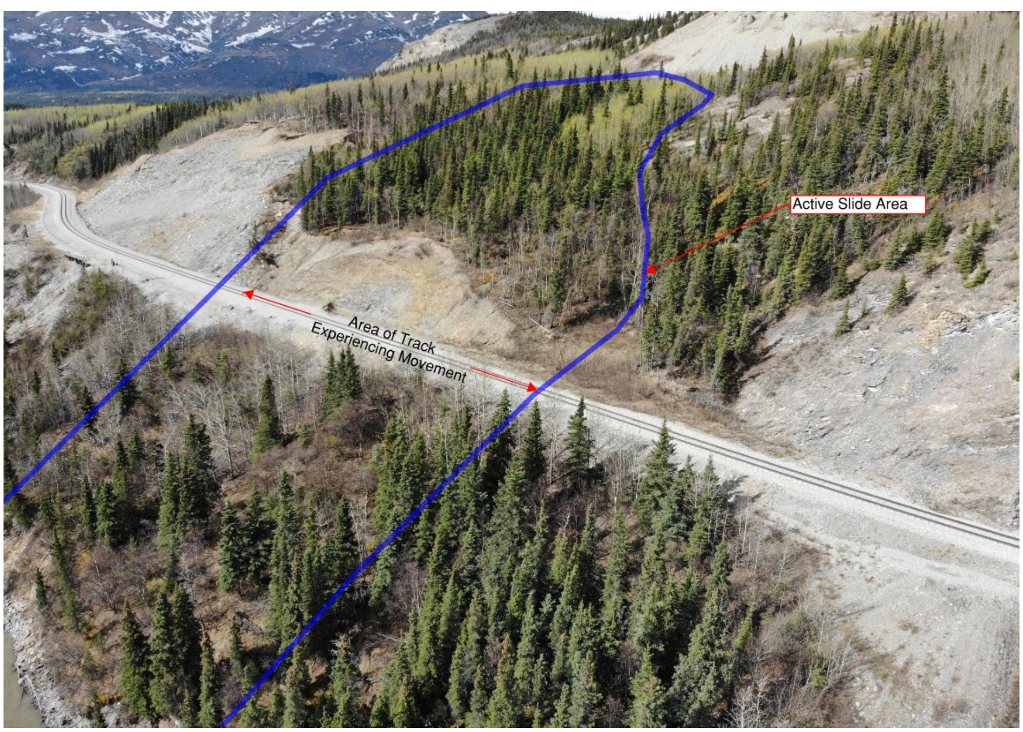


Figure 2-1: MP357.1 slope failure site layout and features

Alternatives Evaluated

Drainage is recognized as the main contributor to the slope movement at MP357.1. Any slope stability solutions at this location should incorporate drainage improvements to intercept water before it enters the slide mass. Facilitating runoff conveyance to the other side of the track structure and ultimately down to the Nenana River reduces pore-water pressures and limits infiltration to the failure plane, where water can facilitate movement.

Three alternatives, in addition to drainage improvements, were evaluated to improve slope stability at MP357.1:

- Track re-alignment
- Retaining structures
- Flattening uphill slope

Recommended Mitigation

DRAINAGE IMPROVEMENTS

A combination of improved ditches, trench subdrains, culverts, and site earthwork are recommended. These improvements would be designed to capture and convey the surface runoff downslope and across the embankment.

At a minimum, drainage improvements at the site include:

- Installing three 36-inch diameter, steel pipe pile culverts to convey flow across the track embankment. A riser pipe and trash rack preventing material from impeding drainage through the culvert should be installed. Culverts should be placed where drainage improvements reach the track structure and are integrated with the inside ditch.

- Grading the inside ditch to direct flow to newly-installed culverts and remove the existing “ditch plug” currently present. An impervious geosynthetic clay liner (GCL) is recommended in the base of the ditches to prevent infiltration through the ditch bottom.

- Constructing a brow ditch to intercept water prior to entering the slide area. An existing access road above the slide can be ditched on one side to provide an interception trench and carry water past the slide area and down to the tracks.

- Removing, grouting, or repairing the existing drop inlet.

Additional drainage improvements to consider at the site include:

- Two additional trench drains, lower in the slope, are proposed to intercept surface water and drain the center of the slide mass. The regraded inside ditch should be lined with GCL to reduce infiltration into the subsurface.

- Horizontal drains installed in an array below the track some distance into the slope and sloped appropriately. These should be installed below the track to limit icing at the track in the winter. Horizontal drains should consist of hollow pipe with perforations wrapped in a geotextile.

The proposed drainage improvements at MP357.1 are presented in Figure 2-2.

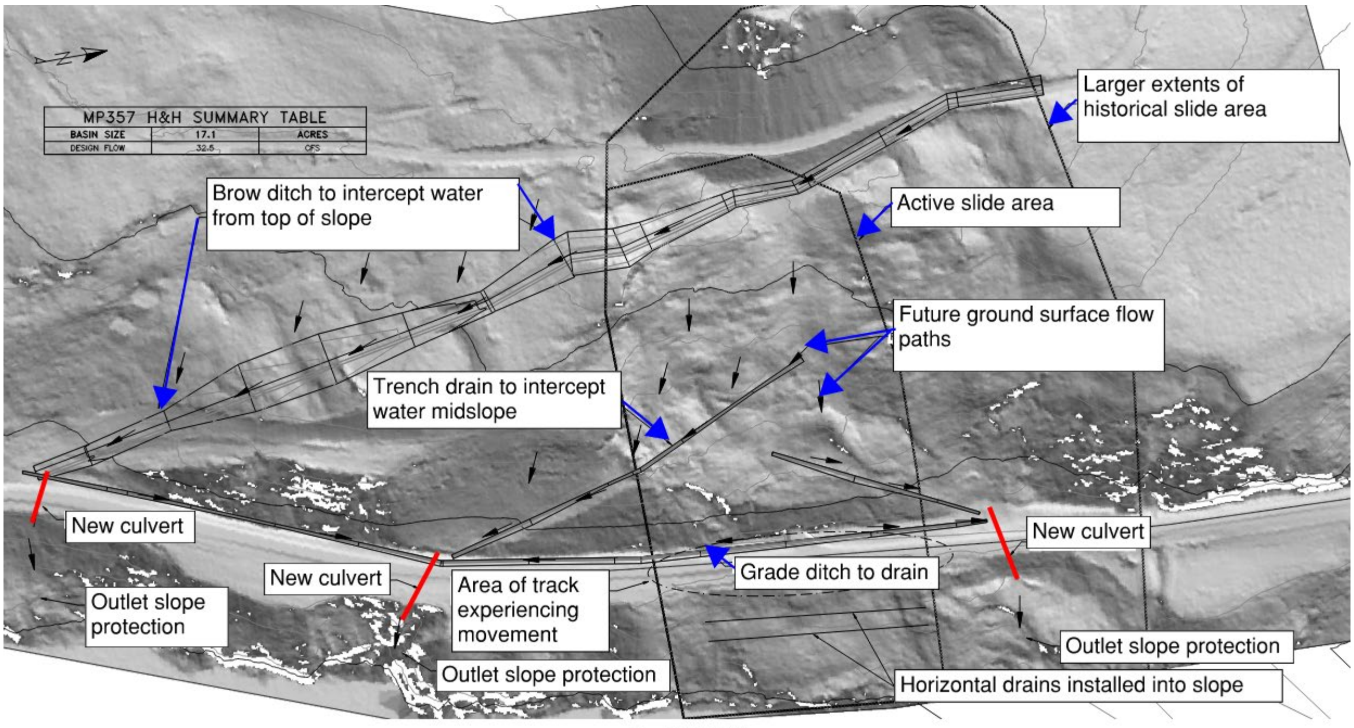


Figure 2-2: MP357.1 proposed drainage improvements

<u>Slope Flattening</u>

In addition to drainage improvements at MP357.1, slope flattening will help reduce infiltration uphill of the tracks by clearing, grubbing, and grading the slope. Old tension cracks or grabens, allowing surface water infiltration near the head of the slide, would be addressed by removing the existing vegetation and re-grading the slope to fill in tension cracks. Surface runoff on the graded slope would then be directed to the improved ditch line and across the embankment using the new culverts included as part of the proposed drainage improvements.

Grading also helps reduce the driving force by flattening the slope and removing approximately 62,000 cubic yards of material from upslope.

When paired with the drainage solutions, this combination reduces the driving force and reduces pore water pressures. Ideally, this solution could be assisted in the future with a structural option, if ongoing monitoring indicates continued movement.

2.2 MP353.2 (Moody Slide) Drainage Improvement Options

Background

Another area of slope movement, MP353.2 (Moody Slide), has been an ongoing problem since the 1920s, requiring multiple track realignments resulting in a sharp curve in the alignment. Early efforts to control slope movement involved constructing drainage ditches and flumes to intercept and direct runoff downhill across the tracks, reducing infiltration in the active slide area. Slope movement over time has displaced sections of these ditches and flumes from their original positions. Though historical slope movement has been severe at times, the slope along the curve at MP353.2 has been relatively stable recently. Minimizing infiltration by improving drainage is considered the most cost-effective option to mitigating future slide activity. The curve and existing drainage features at MP353.2 are shown in Figure 2-3. The MP353.2 Slope Failure report is included as Appendix C.

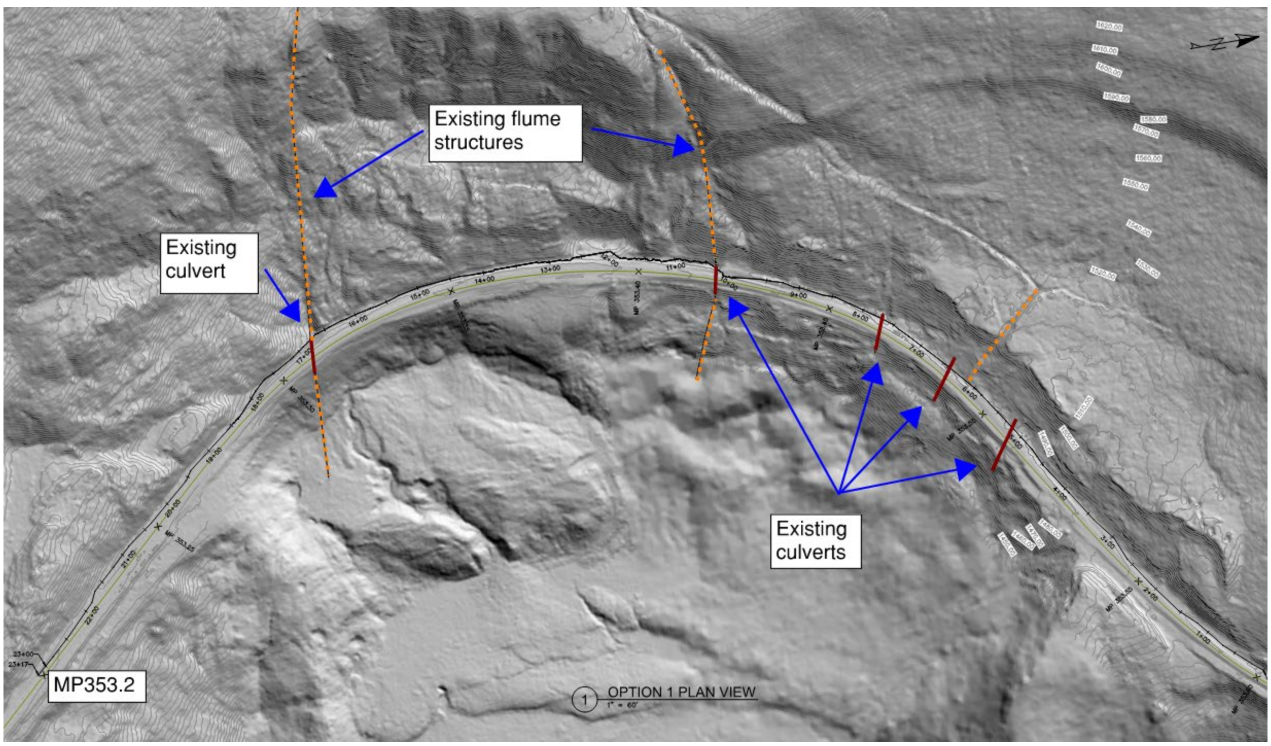


Figure 2-3: MP353.2 "Moody Slide" area and existing drainage structures

Alternatives Evaluated

The alternatives for MP353.2 were presented as "tiers" focused on improving drainage and moving water down the slope and across the tracks. The tiers address drainage in different locations and advance in difficulty, mainly due to site access. The proposed drainage improvement tiers start with improving drainage around the track structure (Tier 1), followed by improving drainage upslope of the tracks at MP353.5 (Tier 2), and finally addressing runoff from the mountain slopes by extending drainage ditches to intercept water prior to reaching the slide area at the top of the slope (Tier 3).

Recommended Mitigation

Implementation of Tier 1 and Tier 2 improvements is recommended, which would place several new culverts, re-grade the existing ditches to drain directly to the culvert locations, armor the outfall areas below the culvert outlets, and improve intercept ditches upslope of the tracks at MP353.5. Improvements are shown on the site plan in Figure 2-4. A follow-up monitoring plan is recommended to evaluate the effectiveness of the improvements and inform further mitigation.

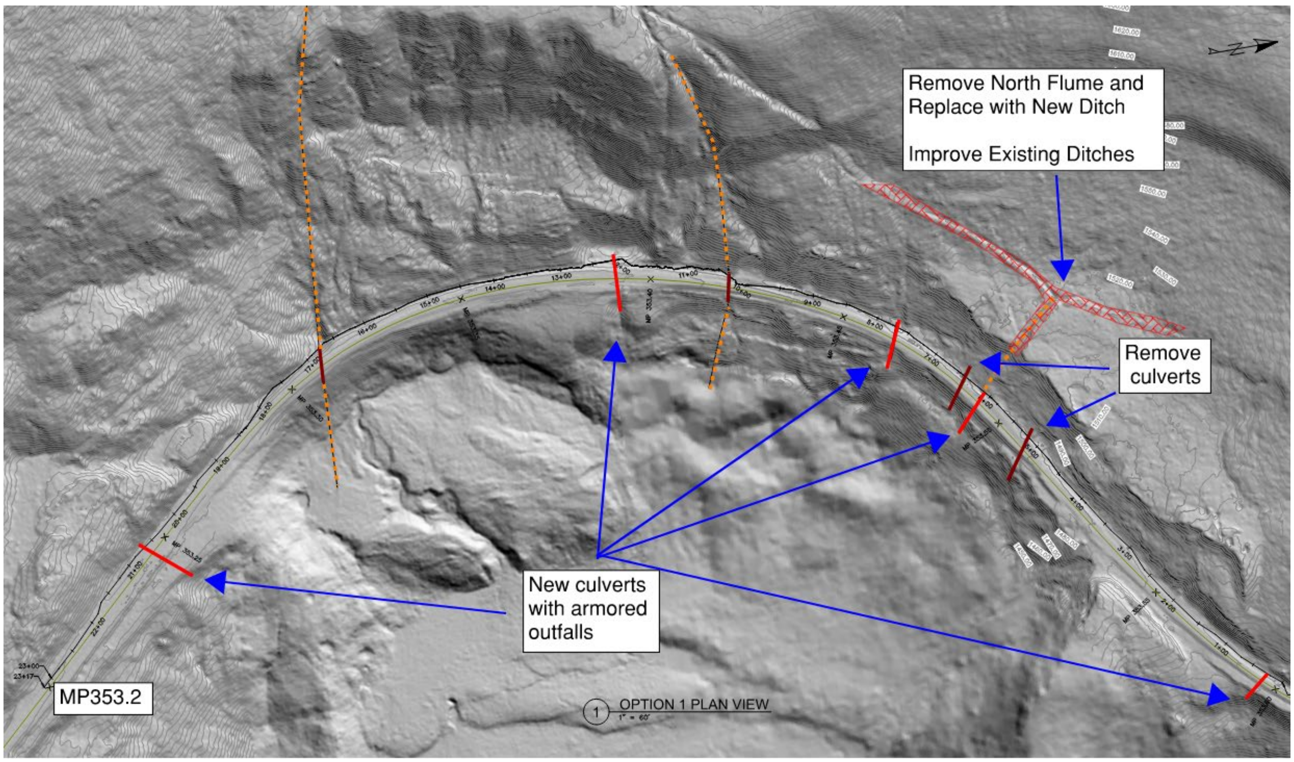


Figure 2-4: Recommended drainage improvements at MP353.2

2.3 MP352.9 Rockfall Mitigation

Background

The rockslide area at MP352.9 has been a source of delays and safety concerns to ARRC traffic. Erosion of fine particles by environmental factors like precipitation, freeze-thaw cycles, and wind destabilizes larger cobbles and occasional boulders trapped in a layer of silts and sands, leading to a near constant sloughing of material toward the tracks. The alluvial, rounded shape makes them susceptible to rolling at high speeds and landing on the tracks. More discussion of the MP352.9 Rockfall Mitigation is included in Appendix C.

Recommended Mitigation

Protecting the tracks from rockfall is the best value engineering solution. Given the size of the rockfall, typically cobble-sized with the occasional boulder, installing a series of Jersey barriers along the tracks, enhanced with a fencing barricade on top, will prevent most rockfall from impacting the track. The approximate extent of Jersey barrier is shown in Figure 2-5 and an example of a Jersey barrier with enhanced fencing is shown in Figure 2-6. The use of anchor rods driven into the ground between Jersey barriers and/or tie back cables will help stabilize the barrier from tipping over onto the tracks during rockfall impacts or high wind events.

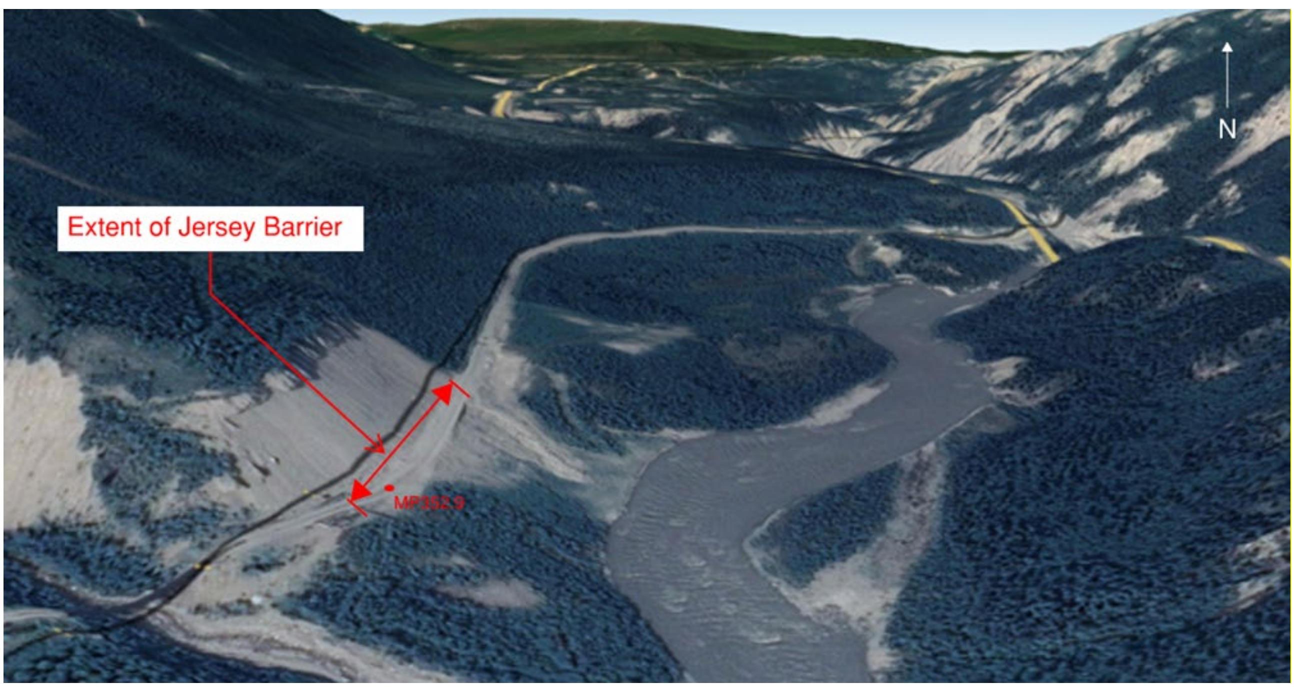


Figure 2-5: Approximate Jersey barrier location

Figure 2-6: Jersey barrier enhanced with fencing

2.4 Retaining Wall Inventory and Condition Rating

Background

Over the course of two trips in 2021, 41 retaining walls were identified and inspected in Healy Canyon between MP348 and MP361. An Inventory and Condition Assessment was performed that assigned a 1 (poor) through 5 (excellent) value to the associated wall based on a list of pre-defined items included in the Alaska Railroad Retaining Wall Inspection Form. These forms are attached to this report as Appendix D. Roughly 50% of the walls in this section of track received a score of 1 (poor) or 2 (marginal), requiring immediate attention within the next year. Table 2.1 describes the rating system.

Table 2.1: Alaska Railroad Retaining Wall Inspection Form Condition Assessment Qualifier

Rating	Condition	Description
5	Excellent	No visible defects, new or near new condition, may still be under warranty if applicable
4	Good	Good condition, but no longer new, may be slightly defective or deteriorated, but is overall functional
3	Adequate	Moderately deteriorated or defective, but has not exceeded useful life: repair within 3 - 5 years
2	Marginal	Defective or deteriorated, in need of replacement, exceeded useful life: repair within 1 year
1	Poor	Critically damaged or in need of immediate repair; well past useful life

A poor/marginal rating was selected based on a combination of the consequences associated with wall proximity to track and the overall wall condition. The following items were taken into consideration when classifying a wall:

- whether the area surrounding the wall appears to be sliding with indications of loose/failing structural components, causing the wall to rotate or slide;
- whether the up-station/down-station interaction of the layout of the track with the surrounding geography indicate opportunity for continued deterioration;
- whether the track is in close proximity to the wall and could be in jeopardy if the slope failure continues; and
- whether the structural material components of the wall are critically damaged or in need of immediate repair.

An example of a wall in poor condition is provided in Figure 2-7.

Figure 2-7: Wall # 41 - condition rating: poor

Additional data was analyzed in order to filter the walls by criticality, region, recommended repair cost, and the ability to combine additional wall projects in the immediate vicinity. Four moderately proportional regions were created based on ease of accessibility between MP348 and MP361. Region 1 is adjacent to the Denali Park road access point and Region 4 is adjacent to the Healy Yard access point and were considered the most convenient in terms of access to the main entries. A potential third construction point of entry at MP355.88 was also considered in Region 3. The following section utilized these regions to finalize and prioritize repair recommendations into phases for the seven walls that received a 1 (poor) condition rating. Table 2.2 provides the spread of wall condition states across the regions and Figure 2-8 represents the retaining walls rated marginal and poor throughout the canyon.

Table 2.2: Table of separated retaining wall regions and their mileposts

Region	Mile Post Range	Breakdown of Wall Condition State				
		1-Poor	2-Marginal	3-Adequate	4-Good	5-Excellent
1	MP348 – MP352	2	1	0	1	0
2	MP352 – MP354	1	3	4	2	0
3	MP354 – MP356	4	9	8	2	2
4	MP356 – MP359	0	0	2	0	0

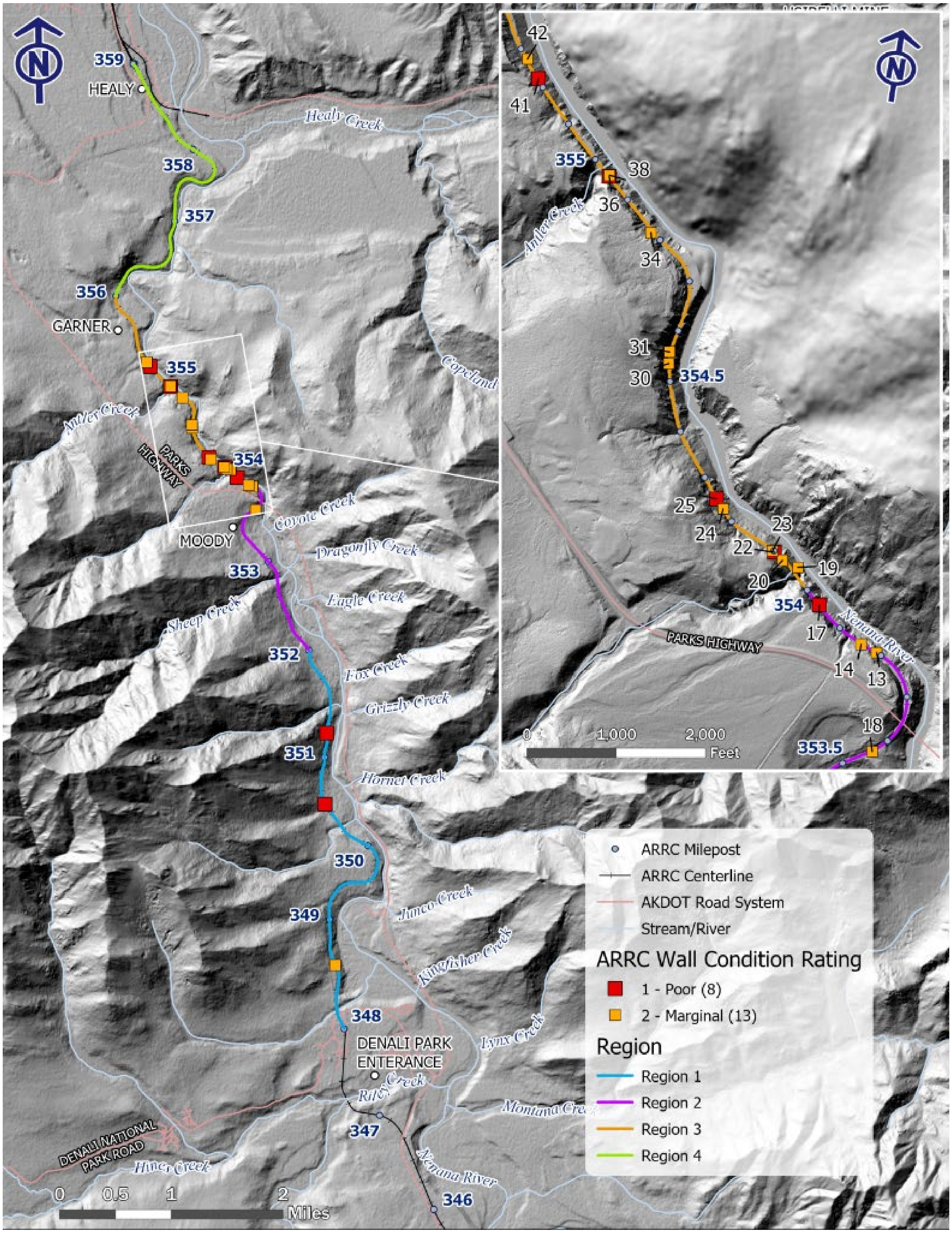


Figure 2-8: Marginal and poor rated retaining walls in Healy Canyon

Recommended Mitigation

ARRC has seven retaining walls with a poor condition rating between Denali National Park and Healy Yard; these poor walls are critically damaged or in need of immediate repair and are well past their useful life. Below, the walls have been divided into phases.

Criticality is determined by multiple factors: the distance of the wall to the tracks, slope of ground below wall, geometric interaction with area up-station and down-station of wall, and the effect of wall failure on the safe passage of trains. The criticality range is from 1-3 with 1 representing a dangerous effect on railroad if wall fails, 2 representing a moderate effect on railroad if wall fails, and 3 representing little effect on railroad if wall fails.

The cost is a range of $-$$$, which is relative to these specific walls and includes the general cost of labor, materials, and design of the replacement/repair. Of the 41 walls, seven have a poor rating and 13 have a marginal rating. The marginal rated walls are defective or deteriorated and in need of replacement or repair within a year. Some of these walls are shown below in the tables as combination projects with the designated poor walls. Additional descriptions of these phases are provided in Table 2.3 to Table 2.6 below.

PHASE 1 (IN PROGRESS & SIMPLICITY)

Table 2.3: Phase 1

Wall Number	Region Number	Criticality (1-3)	Cost ($-$$$)	Combination Project
Wall 3	1	1	$$	None
Wall 25	3	2	$	Yes - Wall 24

PHASE 2 (HIGH CRITICALITY OF WALL FAILURE)

Table 2.4: Phase 2

Wall Number	Region Number	Criticality (1-3)	Cost ($-$$$)	Combination Project
Wall 36	3	1	$$	Yes – Wall 38
Wall 41	4	1	$$	Yes – Wall 42

PHASE 3 (HIGHER COST & ADDITIONAL ENGINEERING DESIGN)

Table 2.5: Phase 3

Wall Number	Region Number	Criticality (1-3)	Cost ($-$$$)	Combination Project
Wall 17A	2	3	$$	Yes – Wall 16 & 17B
Wall 22	3	1	$$$	None

PHASE 4 (LEAST CRITICAL)

Table 2.6: Phase 4

Wall Number	Region Number	Criticality (1-3)	Cost ($-$$$)	Combination Project
Wall 4	1	3	$$	None

Phase 1 (In Progress and Simplicity)

Wall 3 and Wall 25 have been set in Phase 1 due to the simplicity of repair/replacement. The existing Wall 3 main structural section is comprised of a timber pile wall system with cable tiebacks. The north end of the wall is already in the process of being replaced with a soldier pile wall. On the right side of tracks there is potential to have a work area that can be used as staging storage outside the foul zone, where workers and equipment can clear during construction. Since there is new construction going on, it is assumed no engineering work or additional design would need to be done to complete the wall.

The existing Wall 25 main structural section is comprised of a soldier pile wall with timber lagging and cable tiebacks. The top timber lagging is missing and the remainder is failing. Wall 25 is in Phase 1 for the simplicity of the fix and lack of major equipment. The main structure components that require engineering, large equipment, and major track shutdowns (the steel piles and cable tiebacks) appear to be in solid condition and can be reused. Only the timber lagging will need to be replaced.

Optional (2-Marginal Wall) Combined Project

Wall 24 is a timber retaining wall with steel solider piles. The lateral timber members are deteriorated and buried. Considering the proximity to Wall 25, the steep slope beneath the wall, and the rating of 2 (marginal), it would be useful to repair Wall 24 at the same time as Wall 25. The recommendation for Wall 24 is to repair the existing 30 feet of deteriorating timber lagging and install an additional 45 feet of timber lagging.

Phase 2 (High Criticality of Wall Failure)

Wall 36 and Wall 41 are set in Phase 2 due to the high criticality of imminent wall failure. The main sections of both Wall 36 and Wall 41 are comprised of timber pile with cable tiebacks. Due to the steep nature of this location, workers and equipment can clear during construction both down-station (MP354.72) and up-station at the Road Access Area (MP356.13) that can be used as staging storage outside the foul zone. It is recommended to replace the damaged and decaying timbers on Wall 36. It is recommended to replace Wall 41 with soldier pile and lagging or steel sheet pile in front of the existing wall.

Optional (2-Marginal Wall) combined project

Wall 38 is a small timber wall with about 10 feet of exposed timber lagging. The wall's purpose is to retain the ballast material, not to maintain slope stability. With the proximity to Wall 36, Wall 38 would be a useful wall to repair.

Wall 42 is a small timber wall with about 45 feet of exposed area. The timber piles are crushed and deteriorated at the exposed locations and the retaining wall is buried. With the proximity to Wall 41, Wall 42 would be a useful wall to repair.

Phase 3 (Higher Costs and Additional Engineering Design)

Wall 17 and Wall 22 have been set in Phase 3 due location and the predicted associated design and construction costs. These walls are located in a 0.5 mile stretch of track (MP353.80 to MP354.30), narrowly confined on either side by a rock face uphill and a sliding slope on the exposed downhill. This section of track is designated as critical when considering the role of an associated wall failure based on the proximity of the track alignment and the consequences associated with the exposed downhill portion of the wall. Wall 17 is a timber pile wall with cable tiebacks and Wall 22 is a timber crib wall. Both walls are recommended to be replaced with a soldier pile wall, but this will require engineering design due to the complexity of the area and required wall heights to retain soil.

<u>Optional (2-Marginal Wall) combined project</u>

Wall 16 is a middle-sized timber crib retaining wall with about 25 feet of exposed timbers. The wall is decaying and missing timbers due to rockfall. With the proximity to Wall 17, Wall 16 would be a useful wall to repair.

Wall 17B is a middle-sized timber crib retaining wall, almost identical to Wall 16, with about 27 feet of exposed timbers. The wall has sections of 30-50% decay and parts of the wall are not bearing on the ground below. With the proximity to Wall 17 and Wall 16, Wall 17B would be a useful wall to repair.

Phase 4 (Least Critical)

Wall 4 has been set in Phase 4 due to being the least critical among all other poor walls. The main structural section of the wall is comprised of a timber pile wall system with cable tiebacks. This wall would likely fail due to its rotation/displaced position and could result in severe impact to the track due to the approaching 1:1 exposed slope and the associated intersecting failure plane of the soil. Wall 4 is in the last phase of the poor wall repairs due to its location, wall height, and downhill slope conditions.

2.5 Culvert Inventory and Condition Rating

Background

A complete inventory of culverts along the 468 miles of ARRC mainline and 56 miles of spur lines was performed in 2021. A total of 1,447 culverts were located and surveyed from April 21 to July 30. Culverts in Healy Canyon were inventoried on May 12, July 16, and July 17. A total of 46 culverts were located between MP348 and MP361.

Data for culvert type, diameter, and condition were collected along with a series of photos showing the condition of the culvert inlet, culvert outlet, inside of the culvert, and upstream and downstream drainage. Photos were used to evaluate if a culvert was embedded or perched, and to document other issues such as debris, rust, or collapse. Survey data was collected and post-processed to provide highly accurate location and invert elevations for the inlet and outlet of each culvert. From this survey data, the length and flow direction of each culvert was calculated.

Culverts in Poor Condition

Culvert condition was accessed using the same condition rating system used for the retaining walls. Table 2.7 defines condition and the rating of culverts within Healy Canyon.

Table 2.7: Culvert Condition Rating

Rating	Condition	Description	Number of Culverts
5	Excellent	No visible defects, new or near-new condition, may still be under warranty if applicable	0
4	Good	Good condition, but no longer new; may be slightly defective or deteriorated, but is overall functional	33
3	Adequate	Moderately deteriorated or defective, but has not exceeded useful life: repair within 3 - 5 years	8
2	Marginal	Defective or deteriorated, in need of replacement, exceeded useful life: repair within 1 year	0
1	Poor	Critically damaged or in need of immediate repair, well past useful life	5

Table 2-3: Culvert Condition Rating in Healy Canyon

Most of the culverts (72%) inventoried between MP348 and MP361 were rated in good condition, eight culverts (17%) were rated in adequate condition, and five culverts (11%) were rated in poor condition.

Table 2.8 lists the most common types of culverts used under and adjacent to ARRC track; it also provides a summary of the type of culverts identified within Healy Canyon. Corrugated metal pipe (CMP) is the most common type of culvert that was inventoried, accounting for 85% of the culverts within Healy Canyon.

Table 2.8: Culvert Type and Count Summary

Culvert Type	Total Count
CMP - Round Corrugated Metal Pipe	39
O - Other	2
SMP - Round Solid Metal Pipe	2
RCP - Reinforced Concrete Pipe	3
Total Culverts Located	**46**

The remainder of this section focuses on the five culverts rated in poor condition and in need of immediate repair. The condition rating of poor was assigned to culverts within Healy Canyon due to either the inlet or outlet being completely buried or filled with debris. All culverts found to be in poor condition are round CMP material. Two vertical CMP rated in poor condition, inventoried near MP353.5, are within the MP353.2 slope failure project area. Ground movement within this area has pushed the perforated inlets of both culverts above grade 1.5 to 2.5 feet. The CMP at MP353.48 is shown in Figure 2-9. Figure 2-10 shows the location of the five culverts rated in poor condition within the project extent.

Figure 2-9: Vertical 12-inch CMP rated in poor condition at MP353.48

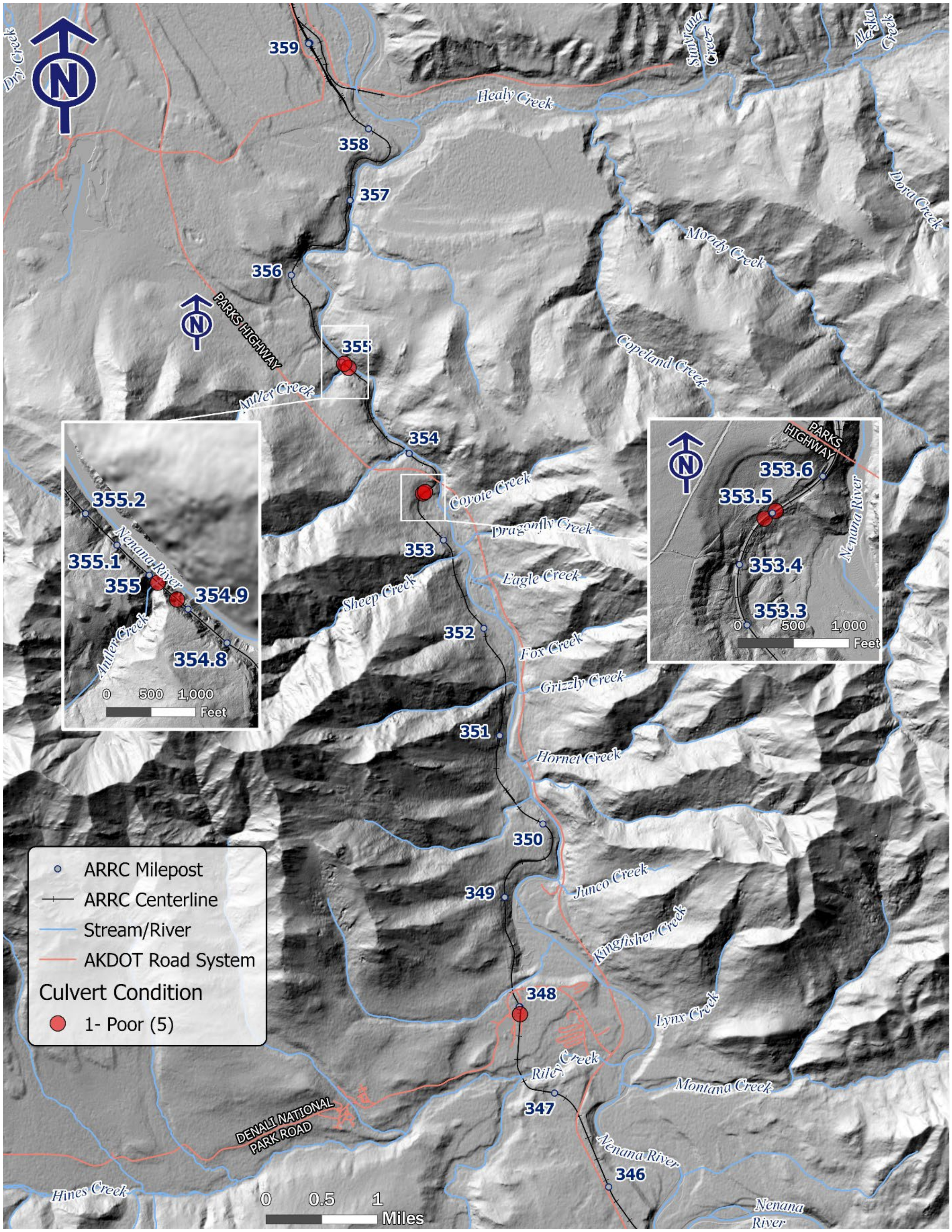


Figure 2-10: Culverts rated in poor condition in Healy Canyon

Recommended Mitigation

All culverts in poor condition are recommended for replacement. Some of the culverts are incorporated in the improvements recommended for MP353.2. Other culverts are in the near vicinity of Phase 2 wall repair and should be replaced as part of those projects. Structural steel pipe should be installed for new culverts rather than CMP culverts, which tend to fail at the seams when subjected to land movement forces common in the canyon. During culvert replacements, track-side ditches should be evaluated and regraded as necessary to properly drain to the culverts. Perforated vertical riser pipes should be considered at culvert inlets, subject to infilling from sloughing material.

2.6 Healy Canyon Long-Term Monitoring

Continued monitoring to observe changes to the track structure, ground surface, and climate can help maintain safe operations and influence future design. Continued monitoring on a project-by-project basis is recommended to provide advance notice of instability, allow correlation of issues to weather events, and provide additional data to help better understand underlying issues. Long-term monitoring may also provide a means to gauge the effectiveness of project improvements. Recommended monitoring includes:

Weather Station - A weather station, with a precipitation gauge, installed in the Healy area: This data is useful to correlate precipitation events with observed slope movement. Currently no public weather station data is available measuring precipitation in Healy.

Change Detection Surveys - Regular change detection surveys to measure movement against the baseline data provided by the June 2021 LiDAR data: A follow-up LiDAR survey of Healy Canyon several years from now may be used to help determine the effectiveness of drainage improvements and identify areas of excessive movement indicative of geohazard areas in the canyon.

Slope Monitoring – Long-term slope-monitoring program at MP357.1 and MP353.2 and similar: This could involve documenting maintenance, installing instrumentation during geotechnical efforts, installing game cameras, or more complex solutions as needed. Slope monitoring could also be accomplished through change detection surveys.

3. Healy Canyon Action Plan

Projects were identified from the recommended mitigation strategies to address slope failure at MP357.1 and MP353.2, address rockfall at MP352.9, and repair retaining walls and culverts in poor and marginal condition. These projects are deemed critical to the ongoing operational safety of the railroad through the canyon and have been incorporated into the Healy Canyon Action Plan. Recognizing that these projects have just been identified, the action plan considers the need for the projects to obtain funding through federal grant opportunities, which requires compliance with the National Environmental Policy Act (NEPA).

The Healy Canyon Action Plan takes the identified alternatives and classifies them into three general classes of projects. In general, Class 1 projects are expected to be possible to construct in 2022 with minimal upfront effort; Class 2 and 3 projects are expected to be constructed in 2023 and beyond following the appropriate funding request, NEPA documentation, and project engineering and design. As such, they should be programmed into ARRC's long-term priorities and budget.

3.1 Class 1 Projects

Class 1 projects represent small projects that are relatively simple to fully execute and provide immediate improvements. These projects require minimal engineering design and permitting, and full construction/implementation is feasible in 2022. These projects are highly recommended due to their low risk and relatively low cost to complete. Class 1 projects identified include:

1. MP352.9 Rockfall Mitigation – This project includes installing 700 linear feet of enhanced jersey barrier along the track at MP352.9.
2. Phase 1 Retaining Wall Repairs – This project includes finishing repairs at Wall 3 and making the recommended improvements to bring Wall 25 to a fully functional status. The added option of combining nearby Wall 24 would likely elevate this to a Class 2 project.
3. Install monitoring equipment in Healy Canyon – This project includes installing a weather station with precipitation sensors at the Healy Station and the installation of slope inclinometers at MP353.2 and MP357.1 to correlate any slope movement with precipitation events.

3.2 Class 2 Projects

Class 2 projects represent projects that require full engineering design, potential service disruptions, and may be associated with a higher risk in their effectiveness to mitigate problems. The required engineering design and construction process will likely span a couple years with engineering design commencing in 2022. Class 2 projects identified include:

1. MP357.1 Slope Stability Improvements – This project includes the drainage improvements and slope flattening recommendations described in Section 2.1.
2. MP353.2 (Moody Slide) Drainage Improvements – This project includes the Tier 1 and Tier 2 drainage improvement recommendations described in Section 2.2. These drainage improvements include replacing the poor condition culverts in the Moody Slide area.

3. Phase 2 Retaining Wall Repairs – This project includes repairing Walls 36 and 41, with the option of combining Wall 38 and Wall 41 respectively. In addition, the two culverts in poor condition between MP354.9 and MP355 should be replaced while working in this area.
4. Phase 3 Retaining Wall Repairs – This project includes repairing Walls 17A and 22 with the option of combining Walls 16 and 17B when repairing Wall 17A.

3.3 Class 3 Projects

Class 3 projects are considered long-term projects that should be included in any long-term programmatic planning for Healy Canyon. More projects are likely to arise through monitoring and continued operations in Healy Canyon. Class 3 projects identified include:

1. Phase 4 Retaining Wall Repairs - Includes repairing Wall 4. Wall 4 is the final retaining wall with a poor rating and is not considered to be in critical condition.
2. Repair retaining walls in marginal condition – The remining retaining walls in marginal condition should undergo repairs as they are anticipated to become defective in the short-term.
3. Follow-up change detection LiDAR survey – A follow up LiDAR survey of Healy Canyon with similar survey extents as the 2021 LiDAR collection should be performed.

3.4 Priority Evaluation

Class 1 projects represent small projects that are relatively simple to fully execute and likely completed internally by ARRC. Class 3 projects are long-term projects with lower urgency. As such, the Class 1 and Class 3 projects were not recommended in any particular order and the priority evaluation was focused on Class 2 projects. Priorities were evaluated for Class 2 projects based on urgency, impact, and complexity criteria. The priority evaluation criteria definitions and scoring justification are presented below.

URGENCY

Urgency is the measure of whether active failure or high consequences exist if the project is not expedited. Urgency was weighted high if it is directly related to the criticality of the project and should be highly considered when prioritizing projects. A higher score indicates a more urgent project.

The large and frequent track displacements corresponding with precipitation events that required excessive maintenance elevated the MP357.1 slope stability improvements to the highest score. The Phase 2 and Phase 3 retaining wall repairs received the next highest scores respectively since they have walls that are in critical condition. Track movement, however, has not been an ongoing problem at these locations. The MP353.2 Drainage Improvements project received the lowest score because the slow progression of slope failure in this area does not currently require frequent and excessive maintenance and is not in a critical state of failure.

IMPACT

This rating defines the impact the project will have on improving railroad operations at the project location. Impact received a medium weight since it is largely attributed to the scale of the improvements and not necessarily the criticality. Higher numbers mean a larger impact.

Reducing the ongoing maintenance associated with track realignments and frequent surfacing to maintain service elevated the MP357.1 Slope Stability Improvements project to the highest score. The MP353.2 Drainage Improvements project received the next-highest score because of the long section of track that would benefit from these improvements. Phase 3 and Phase 2 retaining wall repairs received the lowest scores since their repairs are very localized, stabilizing the embankment in the near vicinity of the walls.

COMPLEXITY

This rating is a measure of the complexity of the project and the certainty of the project to mitigate the problem for which it was designed to improve. Complexity was weighted low since it is a measure of the likelihood a project will meet its objective but should not be a deterrent for implementing critical projects.

There is higher certainty that the Phase 2 and Phase 3 retaining wall repairs will improve the local embankment stability than the outcomes of the slope failure improvements. Retaining wall repairs were therefore assigned the highest scores. The Phase 2 walls have easier site access and were elevated to the top. The MP357.1 Slope Failure Improvements project received the next-highest score due to the rapid failure associated with precipitation events and the higher confidence that drainage improvements and slope flattening will slow the movement associated with the translational slide. MP353.2 drainage improvements received the lowest score because of the inherent uncertainties associated with the deep-seated slide.

The Class 2 priority matrix with final scores based on the criteria weights and scoring justification is presented in Table 3.1. A visual depiction of the Class 2 project priority evaluation is presented in the radar plot in Figure 3-1.

Table 3.1: Priority Matrix for Class 2 projects

Criteria	Weight	MP357.1 Slope Stability Improvements	MP353.2 Drainage Improvements	Phase 2 Retaining Wall Repairs	Phase 3 Retaining Wall Repairs
Urgency	0.6	4	1	3	2
Impact	0.3	4	3	1	2
Complexity	0.1	2	1	4	3
Score:		3.8	1.6	2.5	2.1
Rank:		**1**	**4**	**2**	**3**

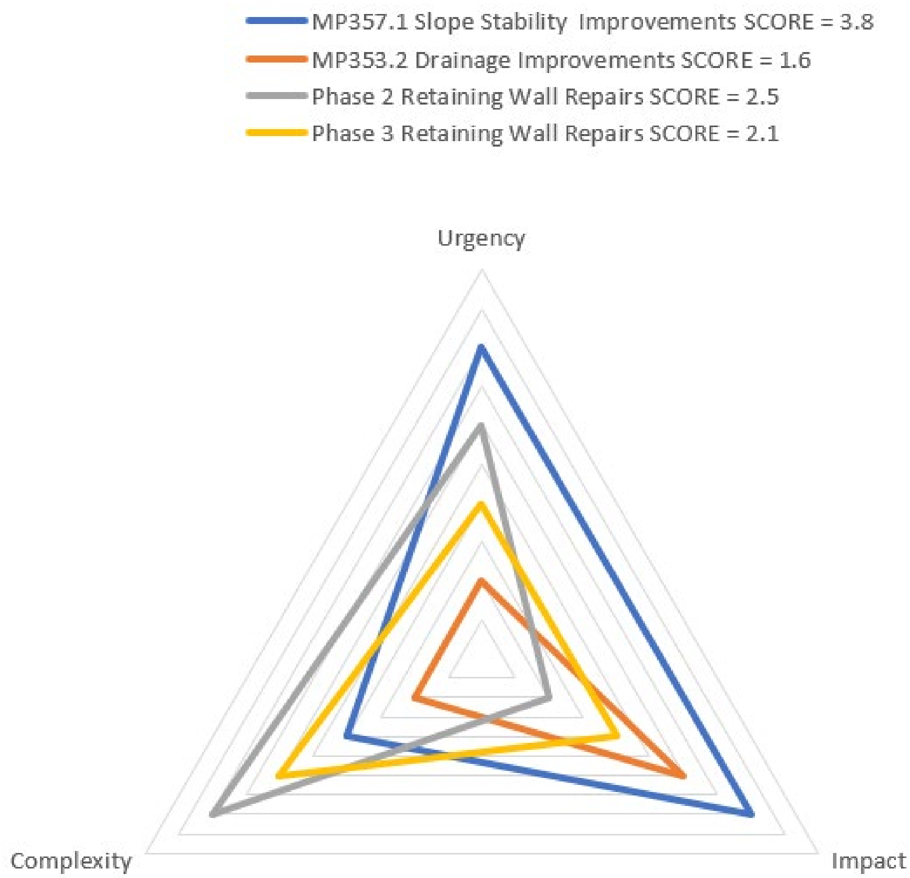


Figure 3-1: Class 2 project radar plot

4. Conclusion

The Healy Canyon Study results present an evaluation of current conditions and provide a list of potential projects between MP348 and MP361 that are important to continued railroad operations and safety. The project execution process generally spans several years of engineering design, permitting, and construction, however some projects may be expedited based on the simplicity of the project. A Healy Canyon Action Plan has been proposed to provide a timetable for funding and executing the projects.

The Healy Canyon Action Plan has been developed based on three classes of projects. Class 1 projects are those that are relatively easy to execute, require minimal engineering design to complete, and can be implemented the first year. Class 2 projects require full engineering design, have more complex construction, and have longer timetables. Class 3 projects are forward-looking projects. A summary of the identified projects in the Healy Canyon Action Plan is presented in Table 4.1.

Table 4.1: Healy Canyon Action Plan project summary

Class 1 Projects	Class 2 Projects (prioritized)	Class 3 Projects
• MP352.9 Rockfall Mitigation • Phase 1 Retaining Wall Repairs • Install Monitoring Equipment	1. MP357.1 Slope Stability Improvements 2. Phase 2 Retaining Wall Repairs 3. Phase 3 Retaining Wall Repairs 4. MP353.2 (Moody Slide) Drainage Improvements	• Phase 4 Retaining Wall Repairs • Marginal Retaining Wall Repairs • Change Detection LiDAR survey

A conceptual timeline and approximate location of the projects identified in this report are shown in Figure 4-1.

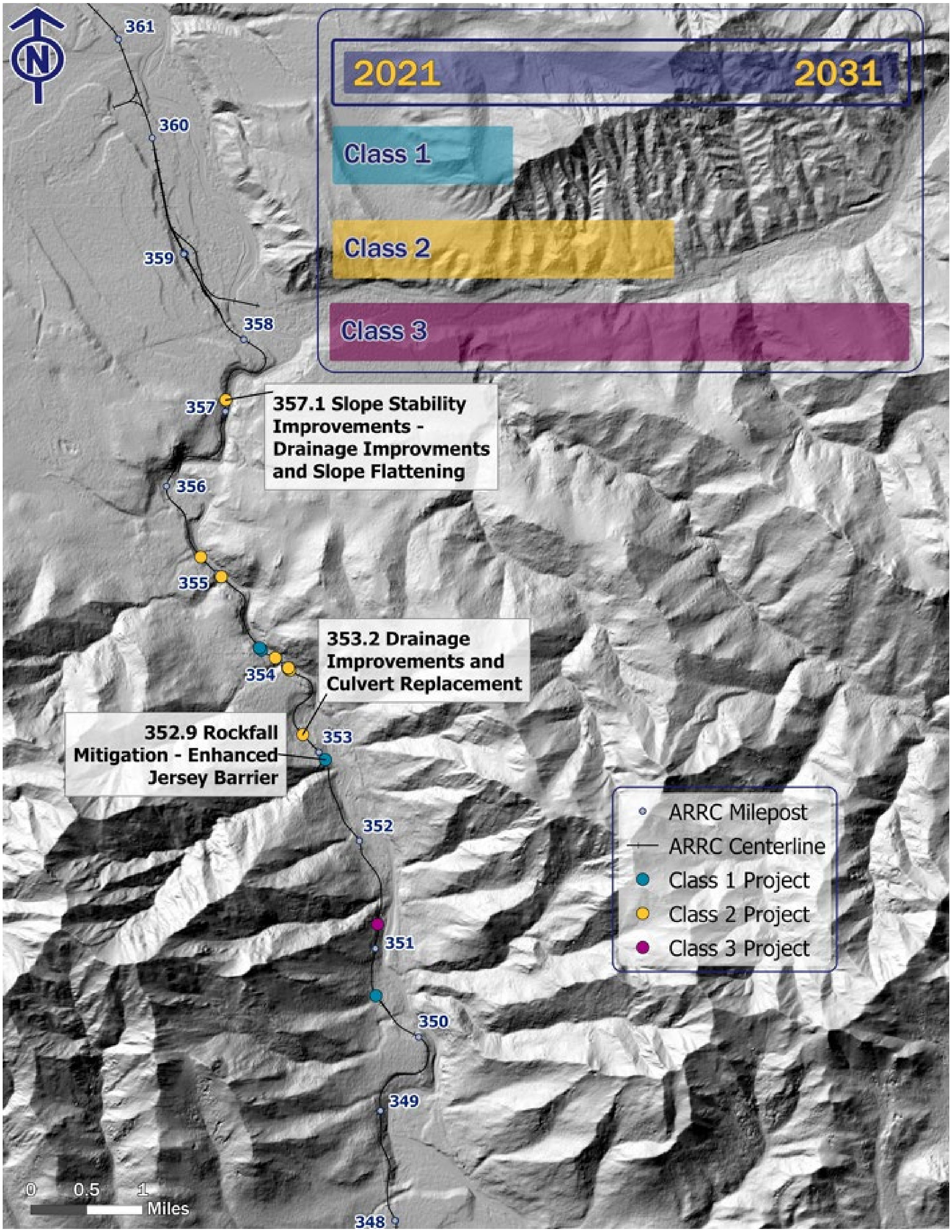


Figure 4-1: Healy Canyon Action Plan

Appendix A. LiDAR Data Accuracy Report

ALASKA RAILROAD COORPORATION

Healy MP 357.1 Slope Failure Project

2021 LIDAR SURVEY CONTROL QA/QC REPORT

Provided to:

Caitlin Vernlund, Project Manager - Alaska
NV5 Geospatial, powered by Quantum Spatial
2014 Merrill Field Drive | Anchorage, AK 99501 | P: 907-771-5230

Provided By:

Max Schillinger, PLS PE, Manager
All Points North LLC
PO BOX 4207 | 17600 E Rambling Road,
Palmer, AK 99645 | P: 907-746-4185

Dated: 7-14-2021

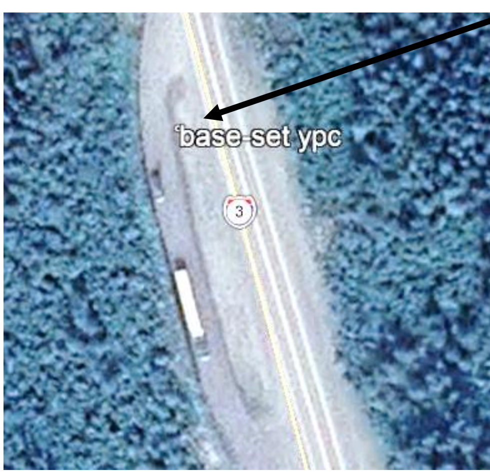
BACKGROUND

All Points North LLC provided LIDAR and Orthoimagery ground control and quality control for the 2021 Alaska Railroad Corporation Healy MP 357.1 Slope Failure project. This project was to survey between Railroad Milepost 344 and Railroad Milepost 361, near Healy Alaska. The survey area is shown below:

SURVEY COORDINATE SYSTEM AND DATUM

Survey was performed in May 2021 with by field crew R. Johnson and T. Gaffey. ALTUS APS3g Survey Grade GPS receivers were used, and Carlson Surv-Ce data collection software and geoid12b file. Survey datum and projection was NAD83 (2011) State Plane Coordinates, in US Feet, with vertical datum NAVD88 (Geoid12b). Basis of coordinates was based on National Geodetic Survey OPUS processing of the GPS base station at control point #100, which is a 5/8" Rebar and Plastic Cap marked "SCHILLINGER LS12039" located at turnout of the Parks Highway, south of Healy approximately 6.5 miles, and south of the Nenana River Gorge Bridge approximately 0.6 miles. The location of this base station follows:

<u>APN #100, See Appendix A OPUS Report</u>
Latitude N 63◦ 47' 42.20610",
Longitude W 148 55 20.29642,
NAVD88 (Geoid12b) 485.852(m),
Northing: 3,580,803.21 US Feet
Easting: 1,814,668.90 US Feet
Geoid12B Ortho: 1594.00 US Feet



Google photo of Base Location

Project Location Map

LIDAR and ORTHOIMAGERY CONTROL

APN set six areal target points to be used by Quantum Spatial. These points were painted marks with nails that were easily identifiable from the air, such as that shown in the photo. The marks were occupied with minimum 3 minute RTK GPS observations. Photos of the aerial targets are in Appendix C.

Point	Northing	Easting	Geoid12b	Description
11	3545547.71	1823742.08	1830.53	AT001 - SET PK INSIDE OF X
12	3546841.96	1822372.34	1843.38	AT002 - SET PK INSIDE OF X
13	3559537.44	1816459.45	1720.37	AT003 - SET PK STOP BAR CORNER
14	3559405.42	1816162.03	1731.99	AT004 - SET PK STOP BAR CORNER
15	3583908.10	1812403.36	1576.03	AT005 - SET PK - B&W HARLEQUIN
16	3611633.16	1804093.30	1283.72	AT006 - SET SPK - VINYL PHOTO P

In addition to the above, APN provided over 250 ground control shots listed in Appendix B. These shots were asphalt surface and gravel surface shots taken with RTK GPS.

QUALITY ASSURANCE AND CONTROL

Along the track alignment, evenly distributed throughout the survey area, over 50 points were established for QC checks. These were typically 5/8" rebar control points. Other points included pk nails set at the center of track ties. They were all stored with RTK methods and included redundant shots. If the rebar/cap was not set flush with the existing ground, the height above the ground was noted such as to compare with the final LIDAR DEM.

After Quantum Spatial processed their LIDAR they provided APN with the orthometric heights at the control positions. The DEM values are consistent with the ground elevation values, with most differences under 0.1 feet. See Appendix D for a complete list of the QA/QC Control Points and their differences with the provided DEM.

Areal Target Photo AT005. See Appendix C for others

APPENDIX A OPUS REPORT, BASE STATION at #100

Subject	**OPUS solution : healy100hi6p31ft.obs OP1621877657599**
From	opus <opus@ngs.noaa.gov>
To	<ryan@allpointsnorth.us>
Reply-To	<ngs.opus@noaa.gov>
Date	2021-05-24 09:38 AM

```
 FILE: healy100hi6p31ft.obs OP1621877657599

                              NGS OPUS SOLUTION REPORT
                              ========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: https://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

       USER: ryan@allpointsnorth.us                  DATE: May 24, 2021
RINEX FILE: heal123x.21o                            TIME: 17:38:32 UTC


   SOFTWARE: page5  2008.25 master53.pl 160321      START: 2021/05/03  23:28:00
  EPHEMERIS: igs21561.eph [precise]                  STOP: 2021/05/04  04:54:00
   NAV FILE: brdc1230.21n                        OBS USED: 15038 / 15370   :  98%
   ANT NAME: APSAPS-3L       NONE              # FIXED AMB:    66 /    69   :  96%
ARP HEIGHT: 1.923                            OVERALL RMS: 0.013(m)


  REF FRAME: NAD_83(2011)(EPOCH:2010.0000)              ITRF2014 (EPOCH:2021.3372)

          X:     -2418938.920(m)   0.005(m)          -2418940.109(m)   0.005(m)
          Y:     -1457913.216(m)   0.003(m)          -1457912.205(m)   0.003(m)
          Z:      5700111.038(m)   0.006(m)           5700111.278(m)   0.006(m)

        LAT:   63 47 42.20610      0.006(m)        63 47 42.19516      0.006(m)
      E LON:  211  4 39.70358      0.005(m)       211  4 39.59551      0.005(m)
      W LON:  148 55 20.29642      0.005(m)       148 55 20.40449      0.005(m)
     EL HGT:          499.205(m)   0.004(m)               499.640(m)   0.004(m)
  ORTHO HGT:          485.852(m)   0.087(m) [NAVD88 (Computed using GEOID12B)]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 06)         SPC (5004 AK 4)
Northing (Y)  [meters]    7075602.699           1091431.001
Easting (X)   [meters]     405298.702            553112.186
Convergence   [degrees]   -1.72485833            0.96695278
Point Scale                0.99970982            0.99993453
Combined Factor            0.99963174            0.99985643

US NATIONAL GRID DESIGNATOR: 6VVR0529875602(NAD 83)


                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
DL6471 GRNX GRNX_AKDA_AK2004 CORS ARP      N635007.799 W1485841.394     5282.9
DP3841 AC70 BROKEBITS_AK2003 CORS ARP      N631816.961 W1481117.857    65727.9
DP3847 AC74 CANTWELLO_AK2002 CORS ARP      N632751.685 W1484826.034    37306.2

                NEAREST NGS PUBLISHED CONTROL POINT
TT2398      Y 115                          N634728.000 W1485547.000      572.0

This position and the above vector components were computed without any
knowledge by the National Geodetic Survey regarding the equipment or
field operating procedures used.
```

APPENDIX B POINTS USED FOR LIDAR CONTROL				
Point	Northing	Easting	Elevation	Description
11	3545547.715	1823742.076	1830.527	AT001 - SET PK INSIDE OF X
12	3546841.965	1822372.335	1843.383	AT002 - SET PK INSIDE OF X
13	3559537.44	1816459.445	1720.37	AT003 - SET PK STOP BAR CORNER
14	3559405.42	1816162.033	1731.988	AT004 - SET PK STOP BAR CORNER
15	3583908.104	1812403.357	1576.031	AT005 - SET PK - B&W PAINT HARLEQUIN
16	3611633.162	1804093.297	1283.721	AT006 - SET SPK - VINYL PHOTO PANEL
126	3546193.478	1822930.411	1831.758	asph
127	3546197.828	1822925.383	1832.027	asph
128	3546204.217	1822917.461	1832.273	asph
129	3546209.709	1822910.852	1832.5	asph
130	3546216.441	1822902.388	1832.761	asph
131	3546222.877	1822894.82	1832.944	asph
132	3546230.064	1822900.481	1832.482	asph
133	3546223.795	1822908.509	1832.297	asph
134	3546216.536	1822916.8	1832.092	asph
135	3546209.302	1822924.884	1831.844	asph
136	3546202.953	1822932.464	1831.59	asph
137	3546203.364	1822940.973	1831.396	asph
138	3546211.085	1822932.177	1831.563	asph
139	3546217.171	1822924.763	1831.685	asph
140	3546223.917	1822916.048	1831.887	asph
141	3546230.593	1822908.02	1832.041	asph
142	3546238.164	1822899.373	1832.25	asph
143	3546246.823	1822905.32	1831.559	asph
144	3546239.455	1822914.022	1831.354	asph
145	3546233.146	1822921.967	1831.198	asph
146	3546225.836	1822930.63	1831.11	asph
147	3546219.624	1822938.49	1831.071	asph
148	3546213.544	1822945.69	1831.003	asph
149	3546206.99	1822953.874	1830.974	asph
150	3546255.469	1822896.007	1831.979	asph
151	3546261.415	1822888.681	1832.201	asph
152	3546268.349	1822880.05	1832.422	asph
153	3546271.697	1822874.621	1832.631	asph
154	3546279.091	1822866.677	1832.797	asph
155	3546272.066	1822859.992	1833.366	asph
156	3546266.12	1822866.784	1833.127	asph
157	3546259.548	1822874.684	1832.854	asph
158	3546253.619	1822882.866	1832.574	asph
159	3546245.872	1822891.755	1832.354	asph
160	3546235.888	1822892.779	1832.699	asph
161	3546242.125	1822885.084	1832.81	asph
162	3546248.447	1822877.412	1833.02	asph
163	3546255.83	1822868.809	1833.279	asph
164	3546264.103	1822858.52	1833.61	asph

APPENDIX B

165	3546270.939	1822849.459	1834.001	asph				
166	3546264.945	1822843.689	1834.577	asph				
167	3546258.494	1822852.033	1834.244	asph				
168	3546252.355	1822859.506	1833.978	asph				
169	3546244.993	1822868.232	1833.712	asph				
170	3546237.866	1822877.197	1833.445	asph				
171	3546229.703	1822886.444	1833.202	asph				
172	3546271.234	1822836.256	1834.887	asph				
173	3546276.465	1822829.639	1835.097	asph				
174	3546282.624	1822822.282	1835.257	asph				
175	3546289.071	1822814.425	1835.403	asph				
176	3546295.364	1822806.874	1835.611	asph				
177	3546303.078	1822812.586	1835.014	asph				
178	3546296.21	1822819.62	1834.858	asph				
179	3546290.248	1822827.135	1834.691	asph				
180	3546284.851	1822835.024	1834.472	asph				
181	3546278.717	1822842.696	1834.214	asph				
182	3546284.96	1822848.974	1833.611	asph				
183	3546292.186	1822840.853	1833.835	asph				
184	3546298.561	1822832.397	1834.04	asph				
185	3546305.905	1822823.013	1834.267	asph				
186	3546312.814	1822814.149	1834.561	asph				
187	3546319.217	1822819.407	1834.067	asph				
188	3546312.061	1822827.098	1833.885	asph				
189	3546304.721	1822836.202	1833.681	asph				
190	3546298.762	1822843.673	1833.469	asph				
191	3546292.563	1822850.546	1833.332	asph				
192	3546285.899	1822858.315	1833.092	asph				
193	3546280.335	1822854.012	1833.474	asph				
194	3559397.35	1816150.298	1732.308	asph				
195	3559391.901	1816157.027	1732.482	asph				
196	3559386.246	1816164.351	1732.257	asph				
197	3559380.478	1816171.149	1731.976	asph				
198	3559375.571	1816177.73	1731.608	asph				
199	3559382.337	1816183.326	1731.294	asph				
200	3559388.237	1816176.713	1731.653	asph				
201	3559394.933	1816169.151	1731.969	asph				
202	3559400.598	1816162.014	1732.122	asph				
203	3559414.078	1816156.681	1731.665	asph				
204	3559409.873	1816163.92	1731.779	asph				
205	3559405.074	1816170.767	1731.814	asph				
206	3559399.771	1816177.511	1731.556	asph				
207	3559394.782	1816183.837	1731.27	asph				
208	3559390.237	1816189.46	1730.955	asph				
209	3559396.824	1816195.019	1730.669	asph				
210	3559403.087	1816188.336	1730.961	asph				
211	3559408.692	1816181.814	1731.294	asph				

APPENDIX B

212	3559414.267	1816174.971	1731.497	asph			
213	3559419.945	1816167.952	1731.363	asph			
214	3559425.513	1816160.882	1731.193	asph			
215	3559433.452	1816165.344	1730.906	asph			
216	3559427.488	1816172.411	1731.07	asph			
217	3559421.562	1816178.37	1731.22	asph			
218	3559415.941	1816184.845	1731.058	asph			
219	3559411.482	1816191.642	1730.742	asph			
220	3559406.96	1816197.708	1730.472	asph			
221	3559404.056	1816201.115	1730.316	asph			
222	3559409.977	1816206.632	1730.01	asph			
223	3559415.077	1816200.585	1730.296	asph			
224	3559420.22	1816194.673	1730.544	asph			
225	3559425.922	1816188.585	1730.804	asph			
226	3559430.421	1816183.318	1730.808	asph			
227	3559436.085	1816177.581	1730.712	asph			
228	3559441.699	1816170.957	1730.62	asph			
229	3559446.817	1816164.842	1730.489	asph			
230	3559454.325	1816169.625	1730.247	asph			
231	3559449.248	1816175.362	1730.386	asph			
232	3559444.362	1816181.12	1730.42	asph			
233	3559438.721	1816186.464	1730.508	asph			
234	3559432.744	1816193.118	1730.532	asph			
235	3559427.356	1816199.117	1730.299	asph			
236	3559422.282	1816204.55	1730.105	asph			
237	3559418.004	1816209.846	1729.879	asph			
238	3559415.858	1816212.134	1729.821	asph			
239	3559422.172	1816218.659	1729.42	asph			
240	3559427.169	1816212.861	1729.661	asph			
241	3559432.338	1816206.865	1729.903	asph			
242	3559437.598	1816201.633	1730.09	asph			
243	3559443.222	1816195.552	1730.229	asph			
244	3559448.993	1816190.159	1730.212	asph			
245	3559454.745	1816184.043	1730.146	asph			
246	3559459.821	1816177.798	1730.068	asph			
247	3559466.759	1816183.825	1729.795	asph			
248	3559461.19	1816189.727	1729.862	asph			
249	3559455.8	1816195.437	1729.903	asph			
250	3559450.281	1816200.994	1729.91	asph			
251	3559444.242	1816206.83	1729.828	asph			
252	3559438.965	1816212.872	1729.554	asph			
253	3559433.742	1816218.559	1729.302	asph			
254	3559428.651	1816224.209	1729.118	asph			
255	3559435.05	1816230.54	1728.722	asph			
256	3559440.124	1816224.399	1728.992	asph			
257	3559445.847	1816218.948	1729.265	asph			
258	3559450.637	1816213.471	1729.452	asph			

APPENDIX B

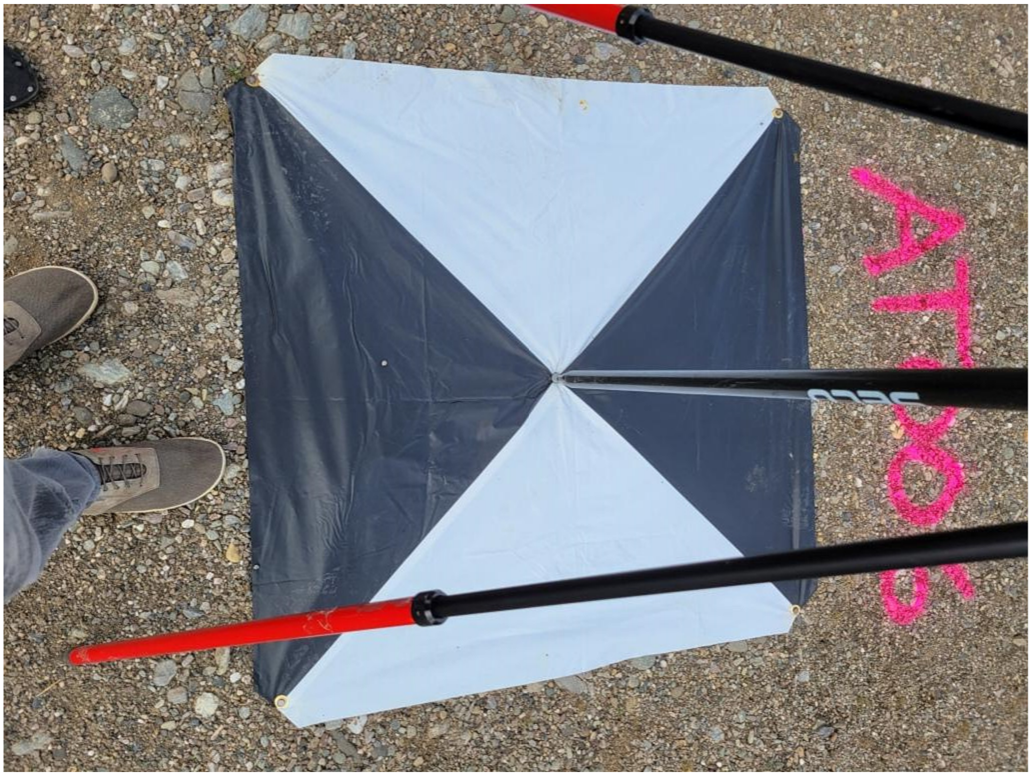
259	3559455.084	1816209.57	1729.521	asph			
260	3559460.632	1816204.397	1729.577	asph			
261	3559466.412	1816198.994	1729.531	asph			
262	3559472.429	1816205.839	1729.179	asph			
263	3559466.256	1816210.985	1729.216	asph			
264	3559460.661	1816215.926	1729.157	asph			
265	3559455.385	1816220.743	1729.028	asph			
266	3559449.679	1816225.642	1728.907	asph			
267	3559445.146	1816230.848	1728.658	asph			
268	3559440.439	1816235.627	1728.445	asph			
270	3604157.739	1806581.377	1326.94	gravel			
271	3604149.608	1806585.598	1327.025	gravel			
272	3604141.048	1806590.165	1327.143	gravel			
273	3604131.892	1806595.542	1327.308	gravel			
274	3604123.451	1806600.022	1327.479	gravel			
275	3604114.882	1806604.764	1327.61	gravel			
276	3604107.073	1806609.781	1327.724	gravel			
277	3604098.466	1806614.47	1328.016	gravel			
278	3604090.203	1806618.718	1328.292	gravel			
279	3604082.447	1806622.882	1328.558	gravel			
280	3604073.723	1806627.147	1328.703	gravel			
281	3604065.896	1806631.407	1328.791	gravel			
282	3604057.18	1806635.64	1328.954	gravel			
283	3604053.06	1806627.703	1328.952	gravel			
284	3604060.816	1806623.939	1328.839	gravel			
285	3604068.786	1806620.368	1328.664	gravel			
286	3604077.168	1806616.209	1328.565	gravel			
287	3604085.983	1806611.958	1328.414	gravel			
288	3604094.754	1806607.404	1328.171	gravel			
289	3604103.554	1806602.977	1327.987	gravel			
290	3604112.233	1806598.752	1327.831	gravel			
291	3604121.042	1806594.388	1327.654	gravel			
292	3604129.488	1806589.338	1327.384	gravel			
293	3604137.991	1806584.663	1327.227	gravel			
294	3604134.549	1806575.55	1327.331	gravel			
295	3604126.507	1806580.944	1327.397	gravel			
296	3604117.992	1806585.928	1327.64	gravel			
297	3604109.536	1806590.962	1327.898	gravel			
298	3604100.441	1806595.551	1327.998	gravel			
299	3604092.224	1806600.525	1328.197	gravel			
300	3604083.041	1806604.6	1328.477	gravel			
301	3604074.034	1806608.769	1328.529	gravel			
302	3604064.93	1806613.028	1328.744	gravel			
303	3604056.493	1806617.674	1328.892	gravel			
304	3604047.366	1806621.136	1329.001	gravel			
305	3604041.847	1806613.048	1329.068	gravel			
306	3604050.308	1806608.525	1329.096	gravel			

307	3604058.77	1806603.932	1329.025	gravel			
308	3604067.42	1806599.48	1328.828	gravel			
309	3604076.193	1806595.92	1328.51	gravel			
310	3604084.991	1806592.796	1328.269	gravel			
311	3604095.482	1806588.605	1327.991	gravel			
312	3604104.527	1806584.456	1327.88	gravel			
313	3604113.266	1806580.279	1327.7	gravel			
314	3604109.367	1806571.567	1327.866	gravel			
315	3604100.669	1806575.81	1327.917	gravel			
316	3604092.017	1806580.258	1327.962	gravel			
317	3604082.588	1806584.609	1328.214	gravel			
318	3604073.118	1806589.018	1328.51	gravel			
319	3604063.611	1806592.199	1328.844	gravel			
320	3604055.392	1806596.789	1328.9	gravel			
321	3604047.291	1806600.545	1329.107	gravel			
322	3604040.125	1806604.46	1329.179	gravel			
323	3604032.349	1806608.19	1329.226	gravel			
324	3604028.308	1806598.895	1329.289	gravel			
325	3604037.154	1806594.856	1329.135	gravel			
326	3604045.845	1806592.27	1329.124	gravel			
327	3604053.337	1806588.935	1329.009	gravel			
328	3604061.665	1806585.489	1328.758	gravel			
329	3604070.726	1806581.777	1328.453	gravel			
330	3604079.248	1806578.741	1328.243	gravel			
331	3604088.549	1806575.244	1328.018	gravel			
332	3604097.806	1806571.215	1328.026	gravel			
333	3604106.152	1806567.168	1328.027	gravel			
334	3604114.014	1806562.961	1327.872	gravel			
335	3604118.562	1806569.054	1327.686	gravel			
336	3604123.095	1806576.125	1327.475	gravel			
337	3604130.384	1806571.622	1327.382	gravel			
338	3604127.144	1806563.968	1327.475	gravel			
339	3604122.358	1806557.702	1327.67	gravel			
340	3604146.078	1806579.218	1327.104	gravel			
341	3604142.379	1806571.412	1327.198	gravel			
342	3604137.407	1806563.776	1327.295	gravel			
343	3604132.255	1806556.798	1327.382	gravel			
344	3604128.107	1806549.472	1327.487	gravel			
346	3611654.019	1804084.736	1284.298	cl trcks - tie			
347	3611649.171	1804077.884	1284.528	cl trcks - tie			
348	3611643.856	1804069.129	1284.695	cl trcks - tie			
349	3611638.625	1804061.032	1284.917	cl trcks - tie			
350	3611633.491	1804052.914	1285.082	cl trcks - tie			
351	3611628.104	1804043.934	1285.21	cl trcks - tie			
352	3611622.985	1804035.266	1285.417	cl trcks - tie			
353	3611618.106	1804026.967	1285.553	cl trcks - tie			
354	3611612.986	1804017.48	1285.812	cl trcks - tie			

355	3611607.847	1804008.058	1286.006	cl trcks - tie			
356	3611602.889	1803998.229	1286.228	cl trcks - tie			
357	3611597.558	1803987.847	1286.48	cl trcks - tie			
358	3611593.48	1803979.92	1286.699	cl trcks - tie			
359	3611589.766	1803972.442	1286.833	cl trcks - tie			
360	3611585.968	1803965.375	1286.86	cl trcks - tie			
361	3611582.117	1803957.526	1286.876	cl trcks - tie			
362	3611578.384	1803948.815	1286.988	cl trcks - tie			
363	3611586.27	1803945.068	1286.022	gravel rd			
364	3611590.759	1803954.156	1286.058	gravel rd			
365	3611594.984	1803962.537	1285.992	gravel rd			
366	3611599.022	1803970.3	1285.898	gravel rd			
367	3611602.97	1803977.811	1285.724	gravel rd			
368	3611606.819	1803985.187	1285.487	gravel rd			
369	3611611.519	1803994.594	1285.537	gravel rd			
370	3611615.685	1804002.559	1285.421	gravel rd			
371	3611619.947	1804009.891	1285.315	gravel rd			
372	3611624.476	1804018.348	1285.159	gravel rd			
373	3611628.796	1804025.981	1285.012	gravel rd			
374	3611633.482	1804033.92	1284.858	gravel rd			
375	3611638.551	1804042.692	1284.711	gravel rd			
376	3611644.057	1804051.415	1284.607	gravel rd			
377	3611649.981	1804060.933	1284.431	gravel rd			
378	3611655.68	1804069.887	1284.278	gravel rd			
379	3611659.835	1804077.451	1284.128	gravel rd			
380	3611665.524	1804085.553	1283.979	gravel rd			
381	3611673.498	1804079.061	1283.787	dirt			
382	3611668.213	1804071.172	1284.132	dirt			
383	3611663.034	1804063.184	1284.368	dirt			
384	3611657.776	1804055.8	1284.504	dirt			
385	3611653.164	1804048.605	1284.777	dirt			
386	3611648.581	1804039.279	1284.88	dirt			
387	3611644.23	1804029.674	1284.979	dirt			
388	3611639.616	1804021.248	1285.002	dirt			
389	3611635.309	1804012.926	1285.114	dirt			
390	3611630.861	1804004.874	1285.168	dirt			
391	3611625.819	1803996.574	1285.267	dirt			
392	3611621.298	1803987.693	1285.174	dirt			
393	3611616.764	1803979.212	1285.4	dirt			
394	3611612.279	1803970.828	1285.534	dirt			
395	3611607.562	1803962.132	1285.613	dirt			
396	3611602.973	1803953.737	1285.767	dirt			
397	3611599.019	1803944.793	1285.861	dirt			
398	3611594.696	1803936.513	1285.853	dirt			

APPENDIX C

AREAL TARGET POINT PHOTOS



APPENDIX C

APPENDIX C

APPENDIX D : QAQC and CONTROL

APN	APN	APN	APN	APN	APN	QUANTUM	
Point	Northing	Easting	Geoid 12b	Description	Geoid 12b-Ground	laser_z	*Difference*
401	3546056.45	1822957.08	1830.16	set 58in rbar 2in agl	1830.00	1829.91	***0.09***
403	3546044.99	1823006.11	1831.50	pk cl trx	1831.50	1831.38	***0.12***
409	3543258.38	1824043.47	1857.36	set 58in rbar flush	1857.36	1857.25	***0.11***
411	3543267.47	1824053.91	1858.40	sharipe x on tie	1858.40	1858.12	***0.28***
413	3548400.73	1822047.98	1806.27	set 58in rbar 2in agl	1806.11	1806.06	***0.05***
415	3548371.38	1822043.59	1808.81	pk cl trx	1808.81	1808.71	***0.10***
419	3550241.56	1820828.68	1787.42	pk cl trx	1787.42	1787.37	***0.05***
421	3553620.77	1819439.22	1757.20	58in rbar 2in agl	1757.04	1757.02	***0.02***
425	3554661.93	1818278.27	1742.55	set 58in rbar 2in agl	1742.39	1742.32	***0.07***
427	3554683.64	1818280.50	1743.72	pk cl trx	1743.72	1743.62	***0.10***
429	3555779.00	1816576.95	1729.90	58in rbar flush	1729.90	1729.80	***0.10***
433	3558798.43	1816622.63	1729.84	58in rbar 1in agl	1729.76	1729.59	***0.17***
435	3558755.92	1816590.56	1733.05	pk cltrx	1733.05	1732.85	***0.20***
437	3559405.44	1816162.00	1732.00	stkpk	1732.00	1731.90	***0.10***
438	3562087.14	1816095.32	1700.07	58in rbar 1in agl	1699.99	1699.85	***0.14***
440	3562078.03	1816077.31	1703.08	x in cxt on conc tie	1703.08	1702.98	***0.10***
442	3563969.21	1815915.85	1681.77	58in rbar 2in agl	1681.61	1681.60	***0.01***
444	3563962.28	1815895.88	1683.21	x in cxt conc tie	1683.21	1683.19	***0.02***
446	3565723.31	1817699.44	1660.47	58in rbar 2in agl	1660.31	1660.24	***0.07***
448	3565742.05	1817691.36	1660.97	x in cxt conc tie	1660.97	1660.85	***0.12***
450	3567454.69	1817740.29	1634.46	set 58in rbar 2in agl	1634.30	1634.29	***0.01***
452	3567432.84	1817735.58	1638.16	x in cxt conc block	1638.16	1638.11	***0.05***
454	3569280.59	1815744.46	1612.39	58in rbar 2in agl	1612.23	1612.18	***0.05***
456	3569294.45	1815763.22	1616.33	x in cxt conc tie	1616.33	1616.20	***0.13***
458	3571644.83	1815671.48	1595.02	58in rbar 1in agl	1594.94	1594.88	***0.06***
460	3571641.10	1815655.14	1595.45	x in cxt conc tie	1595.45	1595.29	***0.16***
462	3574263.37	1815961.27	1571.36	58in rbar flush	1571.36	1571.32	***0.04***
464	3574250.22	1815941.57	1573.06	pk cl trx	1573.06	1573.05	***0.01***
466	3576697.06	1814941.02	1548.25	58in rbar 3in agl	1548.25	1548.10	***0.15***
468	3576690.98	1814915.25	1550.72	x in cxt conc tie	1550.72	1550.63	***0.09***
469	3579934.12	1813503.74	1515.80	58in rbar 2in agl	1515.64	1515.67	***-0.03***
471	3579930.11	1813442.75	1515.25	pk cl trx	1515.25	1515.18	***0.07***
473	3580903.99	1813013.54	1507.54	58in rbar 2in agl	1507.38	1507.39	***-0.01***
475	3580888.69	1813003.56	1510.10	x in cxt conc block	1510.10	1510.15	***-0.05***
477	3583164.40	1812084.57	1486.02	58in rbar 1in agl	1485.94	1486.01	***-0.07***
479	3583146.59	1812094.87	1486.37	x cxt conc tie	1486.37	1486.33	***0.04***
481	3585014.46	1811389.43	1463.20	58in rbar flush	1463.20	1463.11	***0.09***
483	3585004.27	1811354.71	1461.11	pk cl trx	1461.11	1460.91	***0.20***
485	3586697.86	1809609.56	1434.71	58in rbar 1in agl	1434.63	1434.67	***-0.04***
487	3586672.64	1809580.59	1439.79	x on cxt conc	1439.79	1439.67	***0.12***
488	3588400.38	1809536.15	1435.42	fnd shillinger ypc flush	1435.42	1435.53	***-0.11***
489	3589457.06	1808119.02	1411.49	fnd 58in rbar flush	1411.49	1411.48	***0.01***
491	3589414.68	1808098.42	1416.25	fnd x cxt conc panel	1416.25	1416.14	***0.11***
492	3589844.11	1807660.14	1418.00	fnd 3.25in bc in conc abut	1418.00	1417.94	***0.06***
494	3590037.10	1807487.71	1420.66	fnd shillinger ypc flush	1420.66	1420.82	***-0.16***
496	3591084.13	1806869.14	1431.29	58in rbar 1in agl	1431.21	1431.16	***0.05***
498	3591075.61	1806845.33	1432.63	x cxt conc tie	1432.63	1432.61	***0.02***
500	3593461.43	1805766.80	1421.62	58in rebar flush	1421.62	1421.73	***-0.11***
502	3593440.16	1805790.93	1424.18	x cxt conc tie	1424.18	1424.14	***0.04***
503	3594832.55	1807925.83	1396.84	58in rbar flush	1396.84	1396.80	***0.04***
505	3594858.26	1807898.13	1400.80	x in cxt conc tie	1400.80	1400.77	***0.03***
506	3596984.90	1808583.55	1382.87	58in rbar flush	1382.87	1382.91	***-0.04***
508	3596988.98	1808557.79	1384.13	x on conc tie	1384.13	1384.15	***-0.02***
511	3598846.05	1809692.75	1362.82	x cxt conc tie	1362.82	1362.71	***0.11***
						AVERAGE	***0.06***

Appendix B. 357.1 Slope Failure Report

ARRC MP357.1 Slope Failure

184595-MBI-RPT-001

Slope Stability Alternatives Analysis

Prepared for:

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907-273-1600

April 6, 2022

EXECUTIVE SUMMARY

Slope movement at MP357.1 in Healy Canyon has been a long, ongoing problem requiring track realignments and frequent surfacing to maintain service through this dynamic area. Although there is no “Silver Bullet” solution for landslide mitigation and the failure mechanisms are often complex and multifaceted, slope movement can often be reduced through a combination of drainage and slope stability improvements. This report presents a review of site conditions, including geotechnical and hydrologic investigations followed by an evaluation of alternatives for increasing slope stability at the site. An evaluation matrix was developed for scoring the alternatives based on their performance, cost, and constructability.

Geotechnical investigations suggest the regular slope movement is attributed to a translational slide, exacerbated by precipitation events. Under these conditions, addressing drainage has been determined to be a cost-effective solution and should be the first course of action. Installing a precipitation gauge and implementing a slope movement monitoring program will help assess the effectiveness of the drainage improvements and the need to implement further action. Evaluation of the slope stability alternatives suggests that flattening the uphill slope through clearing, grubbing, and grading will reduce the driving forces and can be designed to work in conjunction with the drainage solutions further reducing pore water pressures. Flattening the slope also has constructability and cost advantages. For these reasons, we have selected this option as our preferred alternative in addition to improving site drainage.

The intent of this report is to provide the Alaska Railroad Corporation (ARRC) the background information and a flexible tool for further evaluation of these alternatives. Follow up discussions may alter the scoring and other alternatives may be incorporated into the evaluation. We look forward to working with ARRC through this process to move forward with the best viable alternative.

Revision History

Rev #	Originator	Reviewed By	Approved By	Date	Description
A	Brooks, Bill	Burgess, Bill	Yager, Garrett	07/22/2021	Draft – Issued for Review
0	Brooks, Bill	Yager, Garrett	Yager, Garrett	04/06/2022	Final – Issued for Use

Table of Contents

TABLES

FIGURES

ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Definition
AEP	Annual Exceedance Probability
AREMA	American Railway Engineering and Maintenance-of-Way Association
ARRC	Alaska Railroad Corporation
Cfs	Cubic feet per second
DEM	Digital Elevation Model
LiDAR	Light Detection and Ranging
Michael Baker	Michael Baker International
MP	Milepost
NRCS	Natural Resources Conservation Service
Psf	Pounds per square foot

1. Introduction

The Alaska Railroad Corporation (ARRC) has tasked Michael Baker International (Michael Baker) to investigate possible solutions for a segment of ARRC track experiencing slope movement near MP357.1, just south of Healy, Alaska. This report presents design alternatives to mitigate slope movement, mainly in the form of drainage improvements, along with three alternatives to further increase slope stability. An order of magnitude cost estimate, site plans at the 10-15% design level, and a list of disadvantages accompanies each of the alternatives.

The necessary level of slope improvement often requires a combination of several mitigation systems to adequately increase the stability of a landslide or a marginally stable slope. Typical solutions address surface water and groundwater flow, and look to retaining structures, soil reinforcement, or grading to improve slope stability.

Site plans for each alternative include the area of the slope and track affected by the improvements, identifies changes to surface water flow paths, and outlines the limits of the disturbed area. A location map is presented in Figure 1-1.

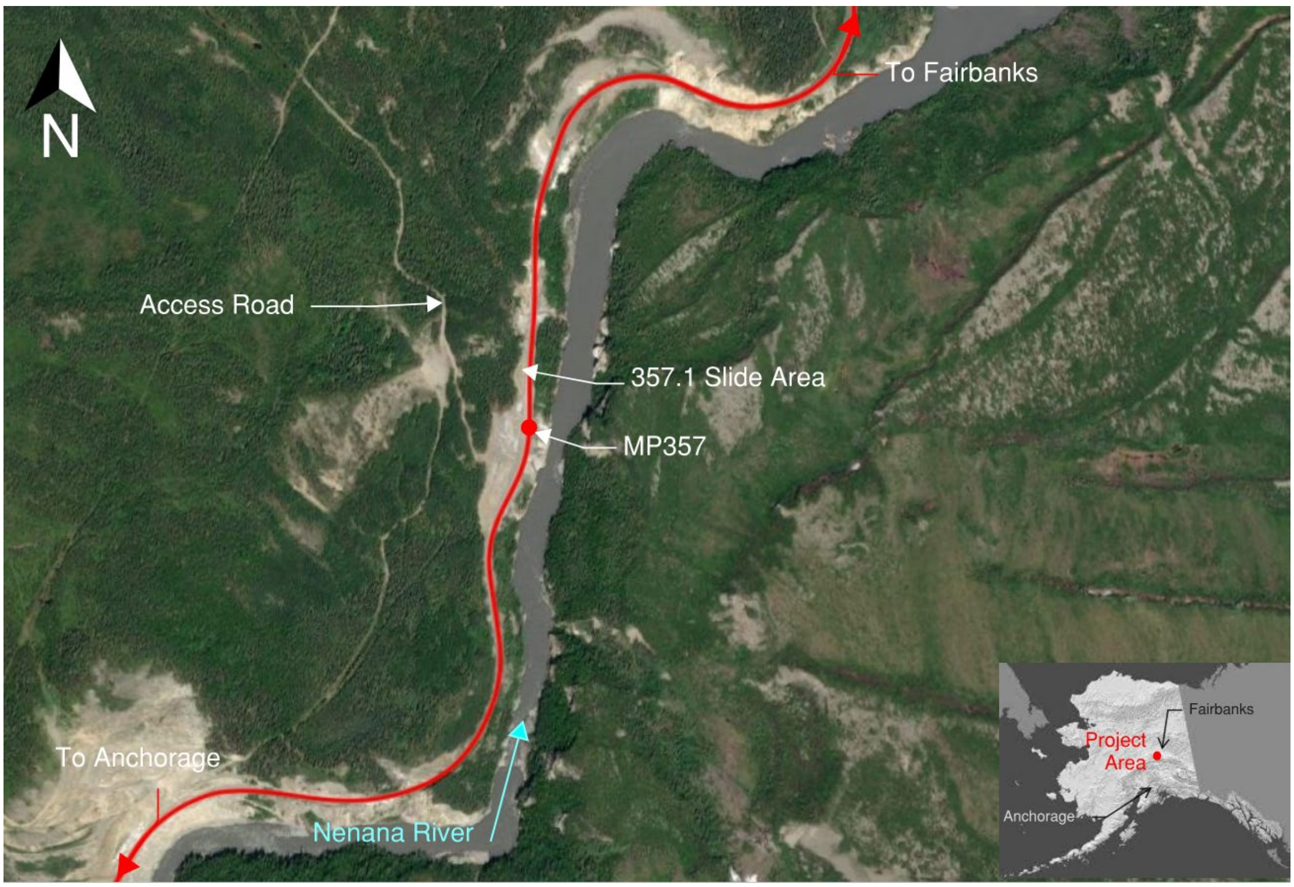


Figure 1-1: Project Location Map

2. Site Conditions

The project site is located within Healy Canyon at MP357.1 where the track is located on a bench cut into the side slopes of the west bank of the Nenana River. Slope movement has been observed dating back to 1936. Re-alignment of the track to the west was performed as long ago as 1950 and most recently in 2010. The 2010 realignment re-activated the historic landslide at MP357.1, requiring resurfacing with increasing frequency from 2013 to 2016, and continued maintenance efforts into 2021. Between 2010 and 2016, it was estimated 5-7 feet of displacement downward towards the river had occurred.

A geotechnical investigation conducted in August 2016 characterized the subsurface conditions and a draft report detailing soil and rock properties, engineering analyses, and a discussion of the possible modes of failure was produced (Golder Associates, 2017).

The downslope movement of rock and soil at MP357.1 is characterized by:

- A probable planar slip surface (translational slide). The slip surface is estimated to be 25 to 33 feet deep under the embankment, inside and outside of the tracks, respectively. Triggering mechanisms for translational landslides are primarily intense rainfall or changes in groundwater levels due to snowmelt or other infiltration of water.

- The slip surface is within a zone of completely weathered bedrock degraded to soil-like material. Engineering properties back-calculated from slope stability modelling estimate an internal friction angle of 17 to 25 degrees and cohesion of 250 to 550 pounds per square foot (psf) when modelled as a saturated slope (Golder, 2017). Weathered, weak rock/soil contains fine grained sediment that is slick, clayey, and micaceous; likely originating from lacustrine deposits of glacial lake Moody. These same deposits are known to be present nearby and have caused issues at the Moody slide area, 4 miles south (approx. ARRC MP 353).

- Anecdotal evidence indicates movement is triggered by precipitation events, in which moisture is introduced to the subgrade, thereby increasing pore pressures, reducing shear strength and frictional resistance in the shear zone. ARRC M&O has reported that noticeable slope movement occurs after 3-4 days of persistent rain.

Two site visits were performed by Michael Baker in the spring of 2021 in support of this alternative analysis. The first site visit on April 15, was timed to observe peak runoff associated with spring melt. Most of the north facing slopes in the immediate vicinity of the track were snow free. Further up the hillside, snow remained in the forested area and in low points of terrain features. Minimal runoff was observed at the site.

During a second site visit on May 18, Michael Baker confirmed the depth of the slip surface, inspected the slide area for potential areas contributing to water infiltration, and generally assessed the slide area. Rebar was lowered into the casing at BH-3, where it encountered soil approximately 30-33 feet below grade where the casing installed in 2016 had sheared. Throughout the slide area and near the head of the slide area, tension cracks or depressions (grabens) running transverse to the slope were noted as a possible avenue of infiltration. The grabens observed were masked by surface debris and vegetation, suggesting the slide movement is both old and slow. No rotation was noted in the trees on the hillside that would otherwise suggest rotational movement or circular slip surface. These observations further support characterizing the slide as a translational slide. Slide features are called out in Figure 2-1. Tension crack features are shown in Figure 2-2.

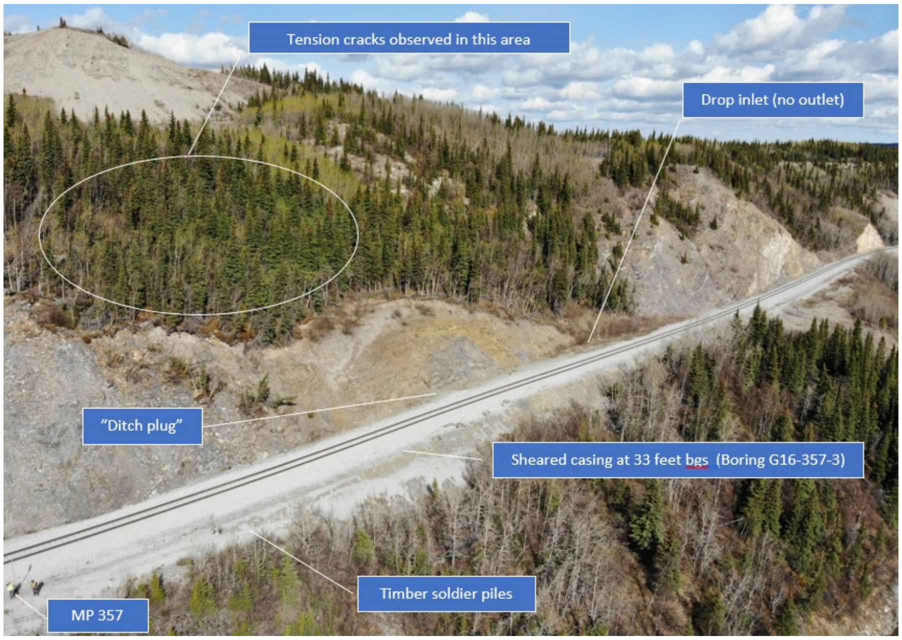


Figure 2-1: MP357.1 slope features, May 18, 2021

Figure 2-2: Tension cracks or grabens buried in debris, May 18, 2021

A LiDAR survey was performed through Healy Canyon from MP340 to MP361 during June 2021 in conjunction with this project. Topographic data obtained from the LiDAR survey was used to develop a bare earth digital elevation model (DEM).

2.1 Existing Drainage

Drainage structures in the vicinity include a drop inlet on the inside ditch and a culvert just north of the slide area. The culvert was conveying flow during the May 18, 2021 site visit. The drop inlet has no apparent connection to an outlet on the downhill side of the track, though a relic culvert outlet is present. Slide movement has likely broken any connection here. Little to no gradient is present in the ditch to direct flow to the drainage structures.

An analysis of the surface water flow paths, based on the LiDAR DEM surface, indicate surface water flow paths are concentrated-in and align-with the areas of observed slope movement. Slide features, topography and active slide extents identified from the LiDAR are shown in Figure 2-3.

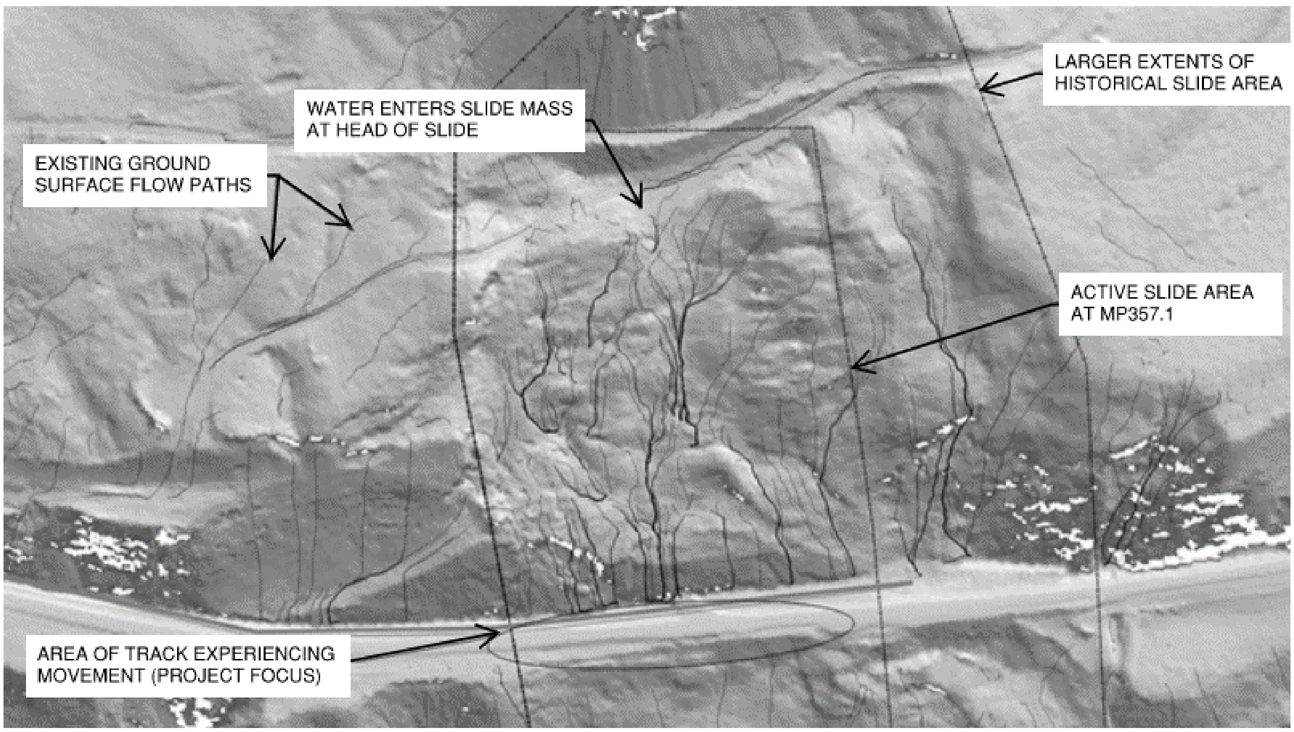


Figure 2-3: Drainage flowpaths derived from the LiDAR DEM at MP357.1

The orientation of flowpaths suggest the access road at the head of the slide area promotes drainage of surface water into the slide mass. The darker lines in Figure 2-3 indicate areas where flow paths tend to converge; these paths coincide with the center of the active slide area.

3. Hydrology and Hydraulics

3.1 Climate Summary

Healy Canyon is located within the subarctic continental climate zone and experiences extremely cold winters and warm summers. Peak flows at the MP357.1 slide area most likely result from rainfall runoff events. The average annual precipitation is 15 inches, more than half of which falls as rain between June and August. Climate projections created by the National Climate Assessment (NCA 2014) predict a 15-30% increase in annual precipitation across the state of Alaska by the end of the 21st century. A 2019 rainfall event resulted in approximately 3 inches of rain in the Healy Canyon and brought rock slides down near MP350. Large rainfall events also coincided with high stage on the Nenana River, including on August 20th, 2006, where the Nenana River stage was 13.64 feet and on September 21st, 2012, where the Nenana River gauge saw a record peak stage of 14.80 feet.

3.2 Drainage Basin Delineation

A drainage basin was delineated for determining the peak discharge during the design storm for culvert hydraulics. The drainage basin was delineated using the LiDAR DEM. A prominent ridge uphill of the head of the slide divides surface runoff that flows north, away from the slide. The drainage basin area was equal to approximately 17.1 acres and is shown in Figure 3-1.

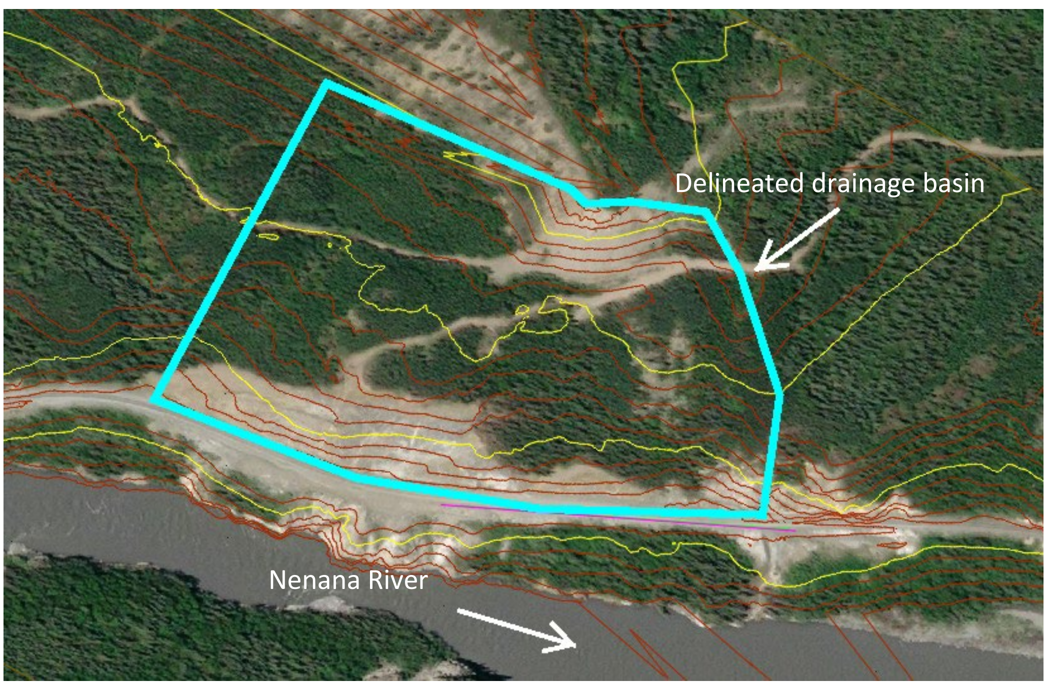


Figure 3-1: Drainage basin delineation

Precipitation for annual exceedance probability (AEP) storms in Healy, Alaska were found from NOAA Atlas 14 precipitation data (NOAA 2018). The design storm for sizing culverts was a 24-hour, 50-year event. The 100-yr storm was used for checking against overtopping of the track. NOAA Atlas 14 was used to estimate rainfall amounts. Precipitation estimates, and the selected design storm precipitation, are shown in Figure 3-2. An estimated 3.1 inches of precipitation occurs during the design storm.

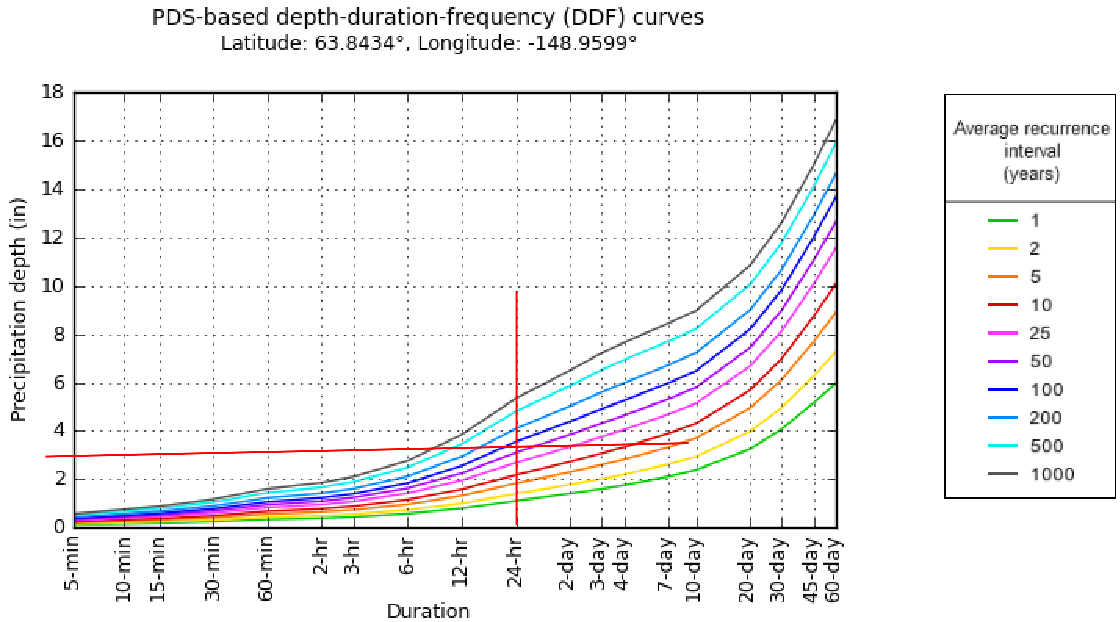


Figure 3-2: NOAA Atlas 14 precipitation estimates for Healy, AK

3.3 Design Hydrograph

The approximate runoff volume was calculated using Natural Resources Conservation Service (NRCS) TR-55 methods, which are suitable for small watersheds similar to MP357.1. Rainfall distribution selection was Type 1 which is recommended for interior regions of Alaska (DOT&PF, 2006). NRCS TR-55 method uses drainage basin area, rainfall, a runoff factor, and time of concentration for inputs and considers the time distribution of rainfall and a decreasing infiltration rate based on soil permeability and ground cover. SCS curve numbers represent the runoff factors with infiltration rates for different soil types. This analysis was developed for agricultural and urban uses with different flow regimes than the steep drainage within this project. It should also be noted that the SCS curve numbers were calibrated in the conterminous United States. Nevertheless, lacking better hydrologic tools, the NRCS TR-55 method is generally accepted for determining design discharge from precipitation events for small drainages in Alaska.

Drainage basin size, longest flow path, and slope were determined for the time of concentration using the LiDAR DEM. Sheet flow was assumed to occur in the first 50 feet of the longest flow path and shallow concentrated flow was assumed to occur the remaining length of the longest flow path. Manning's roughness and ground cover was estimated using aerial imagery. Hydrologic soil group areas were determined for each drainage and the TR-55 computer program was used to calculate time of concentration, weighted curve number, and design discharges from these inputs.

Table 3.1 includes the input parameters used to create the rainfall runoff hydrograph show in Figure 3-3. Curve numbers were calculated based on the slope features. No outflow was assumed through the existing features at the site. Peak runoff discharge is approximately 22.1 cubic feet per second (cfs) for the 50-yr event and 32.5 cfs for the 100-yr event.

Table 3.1: NRCS TR-55 Hydrologic Inputs to develop Hydrograph

Hyd Type	Area	Curve No.	Tc Method	Tc	Distribution	Duration	Shape Factor	Frequency
SCS	17 acres	55	TR-55	7 minutes	Type 1	24-hour	484	50 years

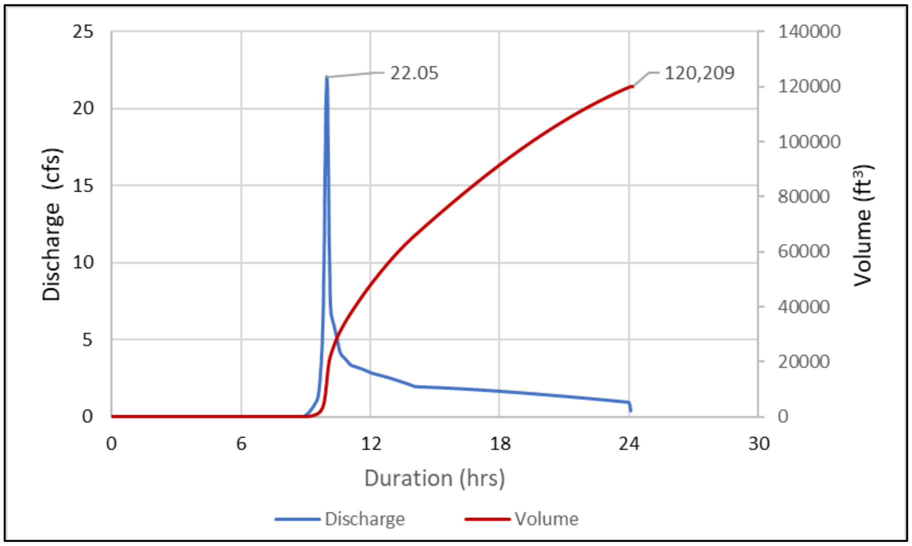


Figure 3-3: MP357 50- year design hydrograph

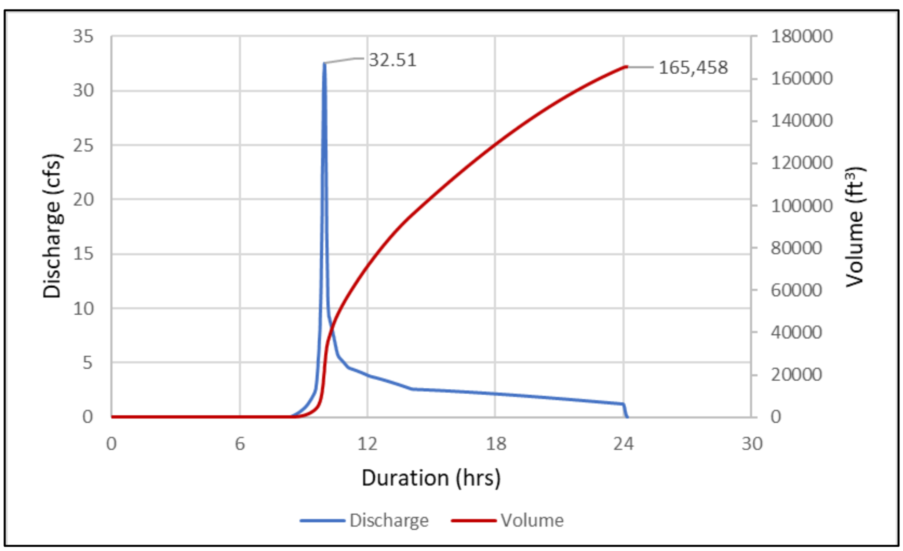


Figure 3-4: MP357 100-year design hydrograph

3.4 Groundwater

A source of groundwater described as "an unusually high flow of clear water" was encountered 35 feet below the ground surface while drilling Borehole G16-357-3. It was noted the depth groundwater was encountered and the outlet of the relic 4-foot diameter culvert were at similar elevations, suggesting the culvert may have been placed to address this source of water (Golder, 2017).

An investigation at MP356.9 identified a shear zone associated with a possible fault striking to the northwest approximately 6 feet wide. The shear zone does not display evidence of surface rupture during the Holocene but is characterized as an area of broken rock which shows considerable buildup of ice in early winter, indicative of groundwater seeping along the fault. In 2008, damage to the wall and track was attributed to weak materials washing out of the fault zone. (Golder, 2017).

3.5 Culvert Sizing

Culverts were sized using CulvertMaster with the design hydrograph results. In accordance with AREMA requirements, the allowable headwater was restricted to less than 1.5 times the culvert diameter (AREMA, 2013).

Results indicate a 36-inch smooth wall steel pipe culvert is sufficient to handle the 100-year design flow. However, three culverts are planned. If the flow is split between three, the design indicates 18-inch culverts are sufficient; however, due to winter icing and ease of maintenance, a 36-inch diameter culvert is recommended for each of the three culvert installations with a minimum wall thickness of 1/2 to 5/8 inches. Additionally, riser pipes with trash racks installed at the inlet will mitigate debris clogging and increase culvert effectiveness.

The culvert design should incorporate a slope drain at the outfall to convey outflow down the steep embankment without causing erosion. Flume chutes made of half-round corrugated metal pipe are common in the Healy Canyon. Rock or concrete lined chutes may also be an option. Any slope drain should be designed to handle the 50-yr design flow.

4. Alternatives Analysis

Landslide mitigation is often difficult with many contributing factors to the slope instability and insufficient data to fully understand the complex geology and environmental forces. The alternatives presented seek to improve drainage, reduce the driving forces, and increase the resistive forces.

Drainage is recognized as a main contributor to the slope movement at MP357.1. Translational failure of thin geologic sections is found to be more sensitive to water level increases in the upper slope compared to groundwater seepage in the lower slope (WSDOT, 2013). As such, improving drainage is considered a necessity and several drainage improvements common to all alternatives are presented separately. Stabilization of creeping landslides is typically attempted by constructing a drainage system in the landslide body with success of such a system largely dependent on how long the drainage system can remain open and intact. Drainage improvements can then be paired with a structural solution to increase the forces resisting the movement, further reducing slope movement.

The three non-drainage alternatives (A-C) look at distinct options to address and mitigate slope movement: re-alignment, a retaining structure, and flattening slopes.

4.1 Drainage Improvements

Drainage improvements are targeted to intercept water before it enters the slide mass, provide a means to lower the groundwater table and reduce pore-water pressures, and facilitate runoff conveyance to the other side of the track structure and ultimately down to the Nenana River.

A combination of improved ditches, trench subdrains, culverts, and site earthwork are presented in the drainage improvements site plan in Appendix A. These improvements have been designed to capture and convey the precipitation from the design storm downslope and across the embankment.

At a minimum, drainage improvements at the site should include:

- Three 36-inch diameter, steel pipe pile culverts installed to convey flow across the track embankment. A riser pipe and trash rack preventing material from impeding drainage through the culvert should be installed. Culverts were placed where drainage improvements reach the track structure and are integrated with the inside ditch.

- Grading of the inside ditch to direct flow to newly installed culverts and remove the existing "ditch plug" currently present. We recommend incorporating an impervious geosynthetic clay liner (GCL) in the base of the ditches to prevent infiltration through the ditch bottom.

- A brow ditch to intercept water prior to entering the slide area. An existing access road above the slide can be ditched on one side to provide an interception trench and carry water past the slide area and down to the tracks.

- Removal, grouting, or repair of the existing drop inlet

Additional drainage improvements to consider at the site should include:

- Two additional trench drains, lower in the slope, are proposed to intercept surface water and drain the center of the slide mass. As above, the regraded inside ditch should be lined with GCL to reduce infiltration into the subsurface.

- Horizontal drains installed in an array below the track some distance into the slope and sloped appropriately. These should be installed below the track to limit icing at the track in the winter. Horizontal drains should consist of hollow pipe with perforations wrapped in a geotextile

The proposed solutions make use of existing slopes to facilitate trench construction and site access. Total earthwork is approximately 12,000 cubic yards, as the brow ditch is essentially a 12-foot-wide access road with a trench drain along the outer ditch that extends at a 15 to 20% grade down to the track, where it intersects the new ditch along the inside of the tracks. This track ditch drains to the north, picking up inflow from the two lower trench drains and discharging through the newly installed culverts.

Disadvantages

- Horizontal drains may not be effective due to soil type, differences in the soil's horizontal and vertical permeability, and uncertainty in the groundwater flow characteristics. Additionally, they may be a source of water that allows for significant icing in the winter.

4.2 Alternative A – Realignment

Alternative A addresses the ongoing slope movement through a re-alignment shifting the track centerline into the hillside to remove mass and driving force from the slide. This alternative also reduces the number of curves in this section of track and increases setback from the river, possibly allowing for higher track speeds. A proposed centerline, drainage solution, and site earthwork are presented in the site plan for Alternative A in Appendix B.

Movement observed in the inclinometer casings installed in 2016 are the best indicator of the depth at which movement is occurring in the slide area. Based on this data, an assumed failure plane was extended up and downslope. The realignment into the hillside, a distance of approximately 50 feet, may not move the track centerline behind the slip surface, based on the limited geotechnical investigation results.

Constructing this option requires removal of approximately 134,000 cubic yards of material. However, the railroad centerline would be offset further from the river, and the driving force upslope of the track would be greatly reduced.

A geotechnical program characterizing the cut section would be required to support design of the newly aligned track.

Disadvantages

- Past re-alignments have resulted in improved conditions and more unstable conditions. This earthwork effort could activate historical slide areas and cause additional problems at this location which are difficult to quantify and predict.

- The large quantities of earthwork require locating disposal areas nearby and assessing the excavated material for possible uses or sale.

- Uncertain if the new realignment will be behind the existing failure surface, which may lead to continued problems.

4.3 Alternative B - Retaining Structure

Alternative B considers the use of a retaining structure to limit the downslope movement of the slide mass and is paired with drainage improvements. An earth retaining structure at MP357.1 will require structural members with lateral resistance sufficient to resist the earth forces with resistance developed using tie-backs, vertical embedment extending through the failure surface, or a combination thereof.

For cost estimating, the failure surface is assumed 30 feet below grade and structural members are positioned on the outside of the track. Required embedment below the failure plane was conservatively estimated with 60 feet total embedment. The cost estimate provided for the alternative evaluation is based on a traditional earth retaining structure.

Geostabilization Inc. presented a reticulating grade beam concept installed on the outside of the existing track. This grade beam would house vertical, grouted micropiles closely spaced, along with “Supernails” acting as tension members extending through the slide mass to competent soils/rock. Such a system can be installed with minimal earth moving and site access. The grouted micropiles are interesting, as the installation involves pressure grouting that could serve to improve the ground conditions, especially given the tight (1 to 2 ft) spacing. One concern is that the grouted micropiles could act as a hydraulic barrier to groundwater, increasing pore-pressures. Nevertheless, this option would be considerably less expensive than the traditional earth retaining structure.

Additional geotechnical data upslope and downslope of the tracks would be beneficial for design of the retaining structure. When paired with the drainage solutions, this combination reduces porewater pressures and increases resistance in the shear zone.

Disadvantages

- The deep seated failure surface requires deep embedment of structural elements; poor rock quality and variable subsurface characteristics may require additional geotechnical investigations.
- Closely spaced micropiles may limit water flow through the track structure, increasing pore water pressure and driving forces.

4.4 Alternative C – Flatten Slopes

Alternative C seeks to reduce infiltration uphill of the tracks by clearing, grubbing, and grading the slope. Old tension cracks or grabens, allowing surface water infiltration near the head of the slide, would be addressed by removing the existing vegetation and re-grading the slope to fill in tension cracks. Surface runoff on the graded slope would then be directed to the improved ditch line and across the embankment using the new culverts included as part of the proposed drainage improvements.

Grading is designed to reduce the driving force by flattening the slope. Approximately 62,000 cubic yards of material is removed upslope.

When paired with the drainage solutions, this combination reduces the driving force and porewater pressures. Ideally, this solution could be assisted in the future with a structural option if ongoing monitoring indicates continued movement.

Disadvantages

- Vegetation removal could disturb the slope and cause additional instability.
- Construction occurs above the track structure on the slide mass, a potential safety issue.
- Will require a significant amount of earthwork and requires a disposal area for earth removed during grading. However, several possible sites, located relatively close, may be suitable.
- Steepening the upper slope may adversely affect the ridge further up the hill.

4.5 Additional Data Required

For each alternative, additional data may be required to further the design. There is some uncertainty in the landslide geometry that could be improved with further geotechnical investigations. This data could then be used to estimate the effects of large earthwork projects such as Alternative A – Realignment which could reactivate other, older failure planes. We recommend ARRC consider:

- Long term slope monitoring program to evaluate the effectiveness of any improvement
- A weather station, with a precipitation gauge, installed in the Healy area to correlate precipitation events with observed slope movement. This data is useful for arctic engineering and determining climate effects on infrastructure.
- A geotechnical/geophysical survey to identify zones of preferential drainage for horizontal drain locations, either geophysical or using a direct imaging tool, such as the hydraulic profiling tool from GeoProbe, to profile the subsurface permeability to support horizontal drain design. Additionally, monitoring wells, slope extensometers, and other monitoring equipment could be installed.
- Regular change detection surveys to measure movement against the baseline data provided by the June 2021 LiDAR data
- Slope stability modelling evaluating mass removal upslope to determine the actual earthwork required to reach a satisfactory slope factor of safety.

4.6 Other Considered Alternatives

The alternatives listed below were considered during this exercise and generally ruled out due to site access issues and/or cost.

- **Realignment out of the Nenana River Canyon**

  We understand the railroad has explored this option and deemed it very expensive and not feasible due to the required changes in grade and corresponding earthwork.

- **Structural Span**

  Spanning the slide mass with a bridge founded on either side of the active slide is a possibility, though the cost is much greater than the alternatives considered. Further site investigation and slide characterization would also be required to ensure such an expensive option was a constructible, stable, and long-term solution.

- **Toe Buttress**

  A toe buttress is a typical solution to rotational slides that provide a resisting force to the downslope movement and rotation. In this case, there is limited evidence to suggest a rotational failure and the steep slope down to Nenana River leaves little area to provide a suitable toe buttress. Additionally, the high energy of the Nenana River is actively cutting the toe of the slope.

- **Soldier Pile Array**

  Soldier pile, micropile, or other long member driven throughout the slope to add resistance against soil movement in the shear zone. This array of soldier piles could be spaced throughout the slope with each soldier pile contributing additional shear resistance as the mass of the slide tries to move downhill. The depth of the assumed failure plane would require relatively deep embedment making this option more expensive and less effective as a solution.

5. Slope Mitigation Criteria

5.1 Criteria

Criteria is presented to evaluate the landslide mitigation alternatives, all of which incorporate the proposed drainage solution. An evaluation matrix was created to identify the preferred solution based on the selected criteria.

The slope movement is a function of the slide geometry, soil and rock characteristics, and drainage through the area. Alternatives have been developed to reduce the driving forces, reduce pore-water pressures, increase resistance to sliding, and provide an efficient, cost-effective solution.

Alternatives were ranked for each criteria relative to the other alternatives, with 4 being the best alternative and 1 the worst alternative considered. The evaluation criteria include:

- Reduce driving force – generally removing mass from the slide.
- Reduce pore-water pressures– generally accomplished by drainage improvements
- Increased resistance to sliding – applicable to the retaining structures only.
- Cost – Alternatives ranked by estimated cost.
- Constructability – if the tracks need to be occupied for 30 days to move material, that is less constructible than a week to install a retaining structure.

5.2 Weights

Reducing the driving force is weighted highly as this is considered a potential long-term fix to the issue, and ARRC is capable of moving large quantities of earth efficiently.

A reduction in pore pressures was weighted less as this is a by-product of the drainage solutions common to all other alternatives; weighting it higher would skew results.

Increased resistance to sliding is largely associated with a retaining structure. Since the criteria favors one alternative, its weight was reduced. Additionally, the slope has shown it is sensitive to rainfall events and has done little to gain any strength or improve over time. We consider this solution “less durable” than one that moves a significant amount of earth, hence the lower weighting.

Cost and constructability were assumed to be important factors in choosing alternatives and were weighted accordingly.

5.3 Evaluation Matrix

The presented alternatives were ranked according to the slope mitigation criteria. The best alternative for each criteria received a 4; the next best a 3; and so on. High scores indicate the best alternative. Criteria were weighted to identify the solution that is most beneficial in terms of cost, schedule, and performance. Table 5.1 shows the criteria weighting and ranking for each alternative. A comparison chart is shown in Figure 5-1 and provides a visual representation of the strengths and weaknesses of each alternative.

Table 5.1: Evaluation matrix and alternatives scoring

Criteria	Weight	Alternative A - Realignment	Alternative B - Retaining Structure	Alternative C - Flatten Slope	Drainage Improvements
Reduce driving force	0.3	4	2	3	1
Reduce pore-water pressures	0.1	3	1	2	4
Increase resistance to sliding	0.1	3	4	2	1
Cost	0.3	1	3	2	4
Constructibility	0.2	1	2	3	4
Score:		2.3	2.4	2.5	2.8

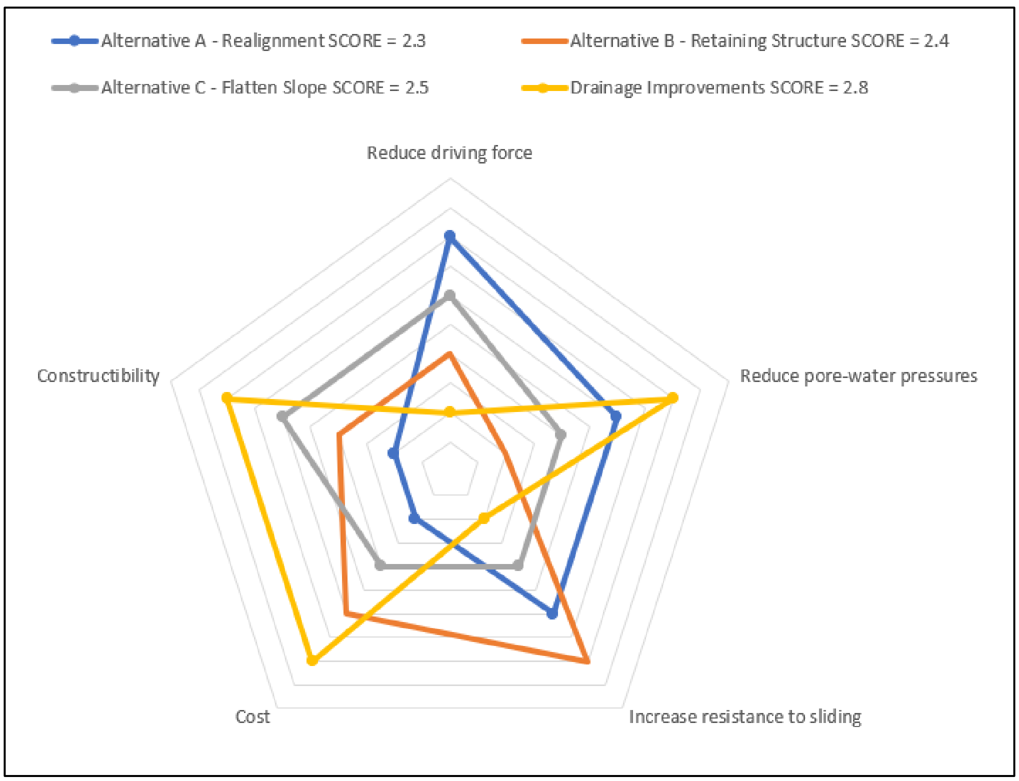


Figure 5-1: Alternatives comparison chart

6. Cost Estimate

The estimated cost for each alternative and the drainage improvements are presented in Table 6.1.

This technical report and associated site plans were used to create a civil estimate using unit rates modified based upon current large work scopes and the unique activity, remoteness, constructability issues at the MP357.1. Additionally, a consensus of internet technical sources was evaluated, considered credible, and used for this high-level (Class 5 +) estimate exercise. The total expected costs are presented in Table 6.1.

Table 6.1: Estimated cost of each alternative

Alternative	Material Cost	Equipment Cost	Freight Cost	Crew Manhours	Crew Cost	Total Cost (No contingency)
Drainage Improvements	$150,109	$411,108	$32,930	3,347	$296,875	**$891,021**
Alternative A - Realignment	$12,090	$5,251,070	$1,451	13,804	$1,797,794	**$7,062,405**
Alternative B - Retaining Structure	$25,512	$235,762	$3,479	1,386	$1,980,838	**$2,245,591**
Alternative C - Flatten Slopes	$2,500	$2,521,840	$300	8,131	$721,238	**$3,245,878**

These cost estimates could be further refined to consider the ARRC's internal capabilities, such as using air side dumps to move material to a waste/stockpile location as opposed to large end dump trucks.

7. Permitting

Common to all alternatives: there are no wetlands, waterways, threatened or endangered species or critical habitat in the project area. The Nenana River is further downslope from the track; this is a regulatory feature, with US Army Corps of Engineers, US Coast Guard, AK Department of Fish & Game and AK Department of Natural Resources all having regulatory permitting requirements associated with impacts to the waterway. Each alternative's footprint stays outside of the bed and banks of the Nenana River.

There are no communities in the project vicinity, including minority or economically disadvantaged communities. All earthwork and disturbance is expected to fall within the ARRC's right-of-way. Noise is unlikely to be an issue, given the lack of nearby residences. Disruptions to life or traffic patterns are unlikely except to the ARRC itself, which is proposing the improvements. Air quality is unlikely to be an issue given the generally good air quality in the area.

Cultural resources, including prehistoric and historic resources and traditional cultural properties, are unlikely to be an issue given the project area's nature as a steeply-sloped area prone to instability and rockslide/movement. However, a **qualified cultural professional** should be relied upon to provide a more reliable evaluation of the area's potential for cultural or historic resources.

A brief description of each alternative's environmental impact:

A. This alternative has the most substantial alteration to the physical landscape, as it requires moving a lot of material (134,000 c.y.) from areas adjacent to and uphill of the track. This material is from areas consisting of loose substrate such as shale, and the 5.3-acre area of disturbance consists almost entirely of non-vegetated, disturbed slope.
B. This alternative has the least physical alteration to the physical landscape. It involves placing a retaining wall 330 feet long, consisting of a 60-foot deep embedment into the substrate with a 110-foot tieback length, also subsurface.
C. This alternative has a moderate amount of alteration to the physical landscape, as it involves smoothing out and flattening the unstable slope uphill of the track. This would require removal of 62,000 c.y. of material from upslope, which would work in tandem with the proposed drainage improvements to stabilize the slope.

All alternatives also feature a revised drainage system for the slide area. The proposed drainage involves:

- Extending an old access road and using it to capture drainage form the uppermost part of the slide zone;
- Adding a trench drain midway down the slope to capture water and funnel it to the south;
- Adding a trench drain below the aforementioned drain, capturing water and funneling it to the north;
- Adding a ditch between the slide area and the track, graded to drain, and;
- Adding three new culverts to provide drainage from the new ditch, conveying water under the track to outfalls with slope protection.

These features will have a modest effect on hydrology, however they are not anticipated to result in new permanent flows. Rather these replace overland sheet flow and a single culvert that has eroded the slope below its outfall. No permitting is anticipated with the proposed drainage improvements.

8. Recommendations

The newly acquired LiDAR imagery illustrates the complex geology present in the vicinity of MP357, and how ongoing movement has shaped the slope. Currently, the active slide area appears to be clearly bounded by slope features on either side, resulting in a slide area approximately 330 feet across, located within a larger slide complex. The topography also indicates access roads at the head of the slide guide runoff into the slide mass, likely exacerbating movement. The slide mass appears to be in quasi-equilibrium, with precipitation tipping the scales and causing movement.

It is recommended that drainage improvements are constructed, and a monitoring program implemented. The monitoring program, at its most basic level, would correlate rainfall events to maintenance events necessitated by slope movement. This would require installation of a weather station and documentation of maintenance events. The resulting data would help determine the amount of precipitation it takes to initiate slide movement and provide local climate data to assist engineering analyses throughout Healy Canyon.

Following the drainage improvements, we recommend unloading the slope as presented in Alternative C – Flatten Slopes. ARRC has the means to efficiently haul large amounts of material and there are potential areas to stockpile or waste the material nearby. Unloading the slope reduces the driving forces on the slide by removing an estimated 83,000 tons of mass from the slope.

The cost of the recommended improvements at MP357.1 is approximately $4,137,000.

9. Limitations

This report was prepared for use in the evaluation of the slope movement at MP357.1 along the ARRC alignment. The natural variability of earth materials across the project site may include variations in the subsurface conditions different than those characterized in this report. Unexpected conditions found during construction should be communicated to a qualified geotechnical engineer who is able to provide corrective recommendations.

This work was conducted following the standard of care expected of professionals undertaking similar work in the State of Alaska under similar conditions. No warranty, expressed or implied, is made.

10. References

Alaska Department of Transportation and Public Facilities. 2006. “Highway Drainage Manual”.

American Railway Engineering and Maintenance-of-Way Association. 2013. “Part 4, Culverts”.

Golder Associates. May 2017. “ARRC MP357 Slope Movement - Geotechnical Investigation Report – Draft”.

National Oceanic and Atmospheric Administration, University of Alaska Fairbanks. 2018. “NOAA Atlas 14, Precipitation-Frequency Atlas of the United States”.

U.S. Global Change Research Program. 2014. “The Third National Climate Assessment, Climate Change Impacts in the United States, Ch. 22: Alaska”.

Washington State Department of Transportation. March 2013. “Design Guidelines for Horizontal Drains used for Slope Stabilization”.

Appendix A. Drainage Improvements

1 PLAN VIEW
1" = 100'

NO.	DATE	REVISION	BY	CHK	APPD

PRELIMINARY NOT FOR CONSTRUCTION

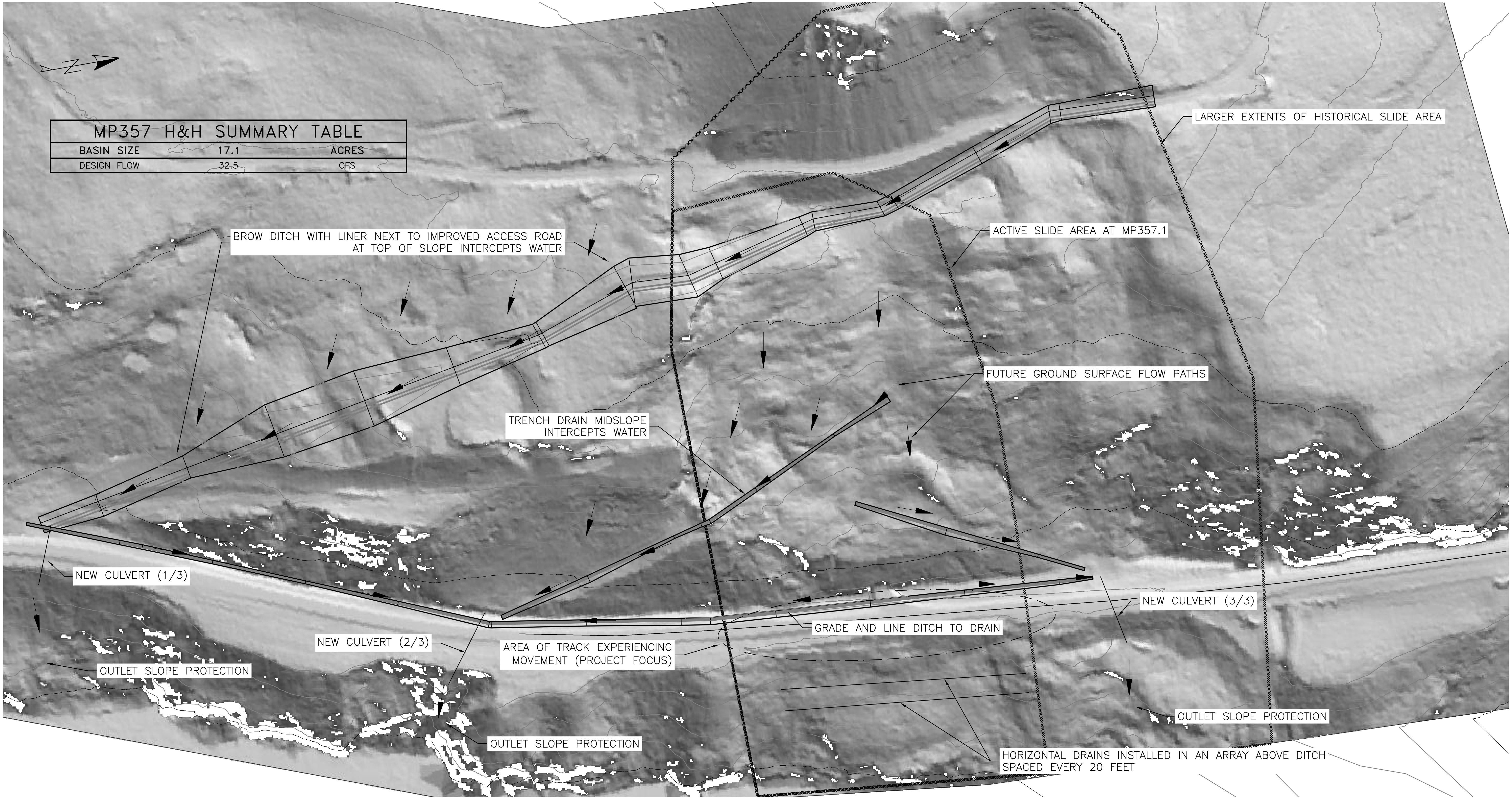
ENGINEERING RECORD		DATE
DRN:	WAB	6/13/2021
DSGN:	WAB	6/13/2021
CHK:	GCY	6/28/2021
APP:		
APP:		
SCALE:	VARIES	

Michael Baker INTERNATIONAL

ARRC MP 357.1
SLOPE FEATURES
PLAN & CROSS SECTION

TASK ORDER	DOCUMENT NUMBER	SHEET	REVISION
ITEM 3		01	A
DELIVERABLE NUMBER 184595			

MP357 H&H SUMMARY TABLE		
BASIN SIZE	17.1	ACRES
DESIGN FLOW	32.5	CFS



1 PLAN VIEW
1" = 100'

NO.	DATE	REVISION	BY	CHK	APPD

PRELIMINARY NOT FOR CONSTRUCTION

ENGINEERING RECORD		DATE
DRN:	WAB	6/28/2021
DSGN:	WAB	6/28/2021
CHK:	GCY	7/20/21
APP:		
APP:		
SCALE:	VARIES	

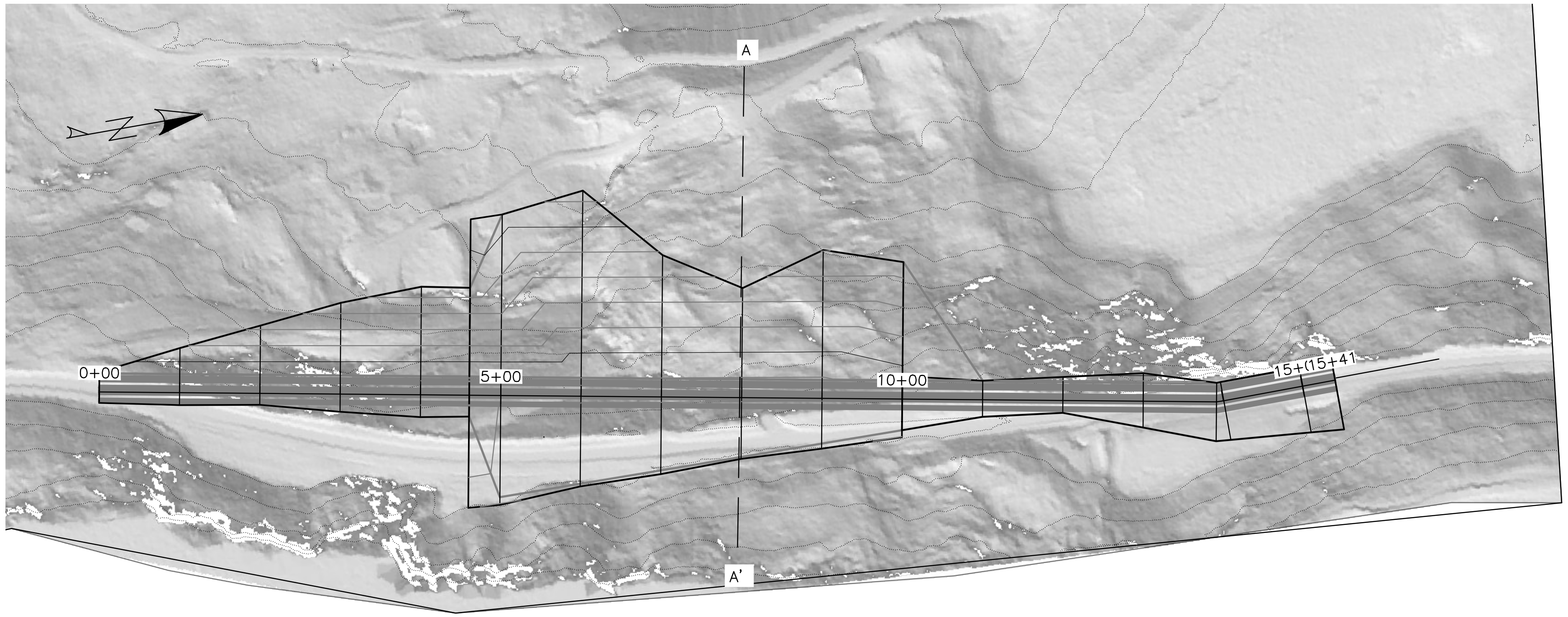
THE ALASKA RAILROAD ESTABLISHED 1914

Michael Baker INTERNATIONAL

ARRC MP 357.1
SLOPE FEATURES FUTURE GROUND
PLAN VIEW

TASK ORDER	DOCUMENT NUMBER	SHEET	REVISION
ITEM 3		01	A
DELIVERABLE NUMBER			
184595			

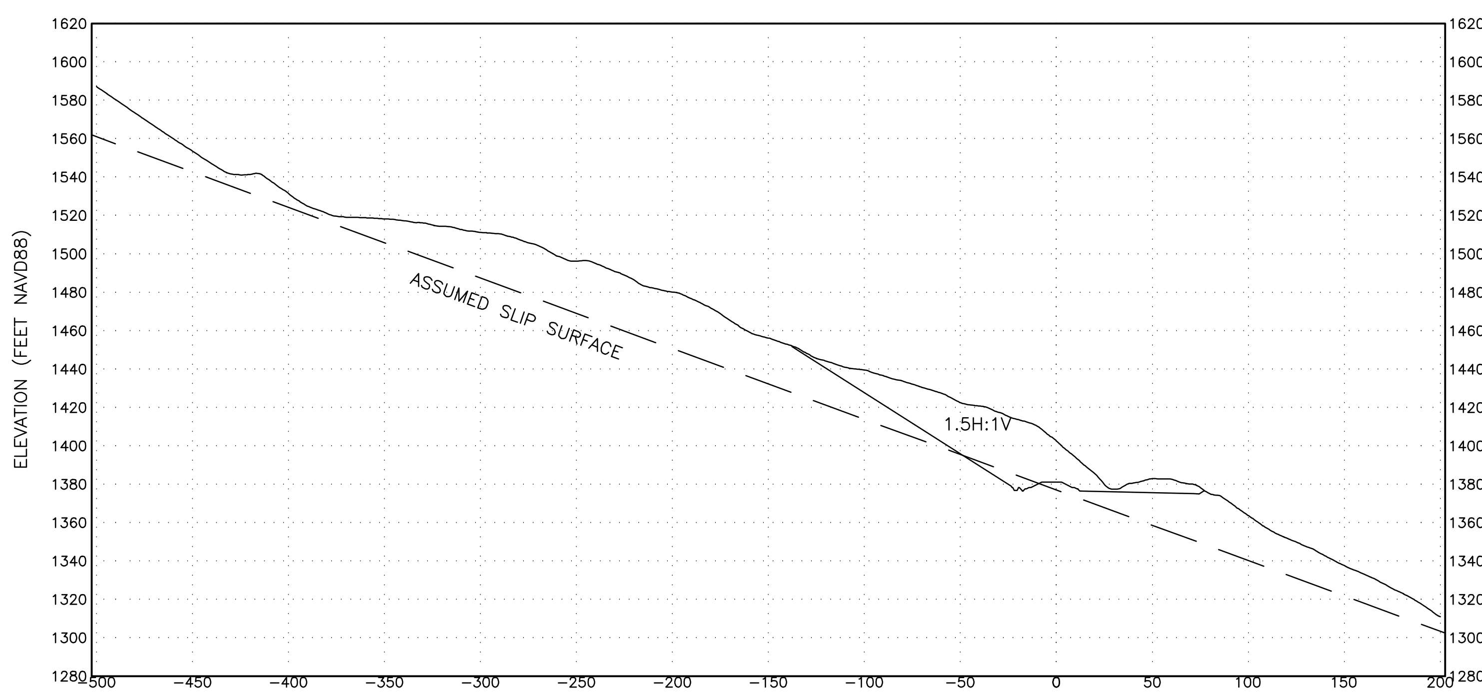
Appendix B. Alternative A – Realignment



1 PLAN VIEW
1" = 100'

MATERIAL QUANTITIES		
MATERIAL TYPE	QUANTITY	UNIT
CUT	134,158	CU. YD

CONSTRUCTION FOOTPRINT		
	QUANTITY	UNIT
IMPACTED AREA	232,257	SQ. FEET



2 CROSS SECTION A-A'
1" = 50'

NO.	DATE	REVISION	BY	CHK	APPD

PRELIMINARY NOT FOR CONSTRUCTION

ENGINEERING RECORD		DATE
DRN:	WAB	6/28/2021
DSGN:	WAB	6/28/2021
CHK:	GCY	7/20/2021
APP:		
APP:		
SCALE:	VARIES	

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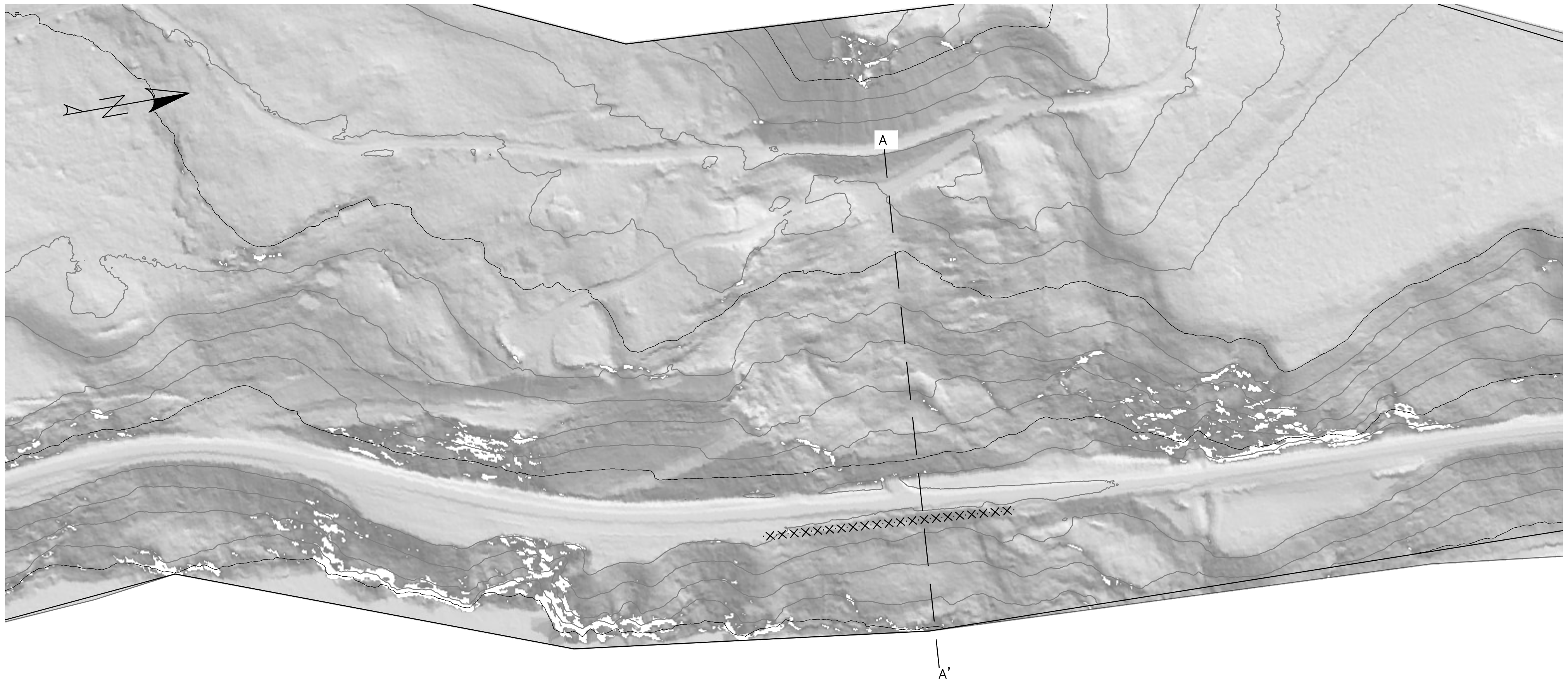
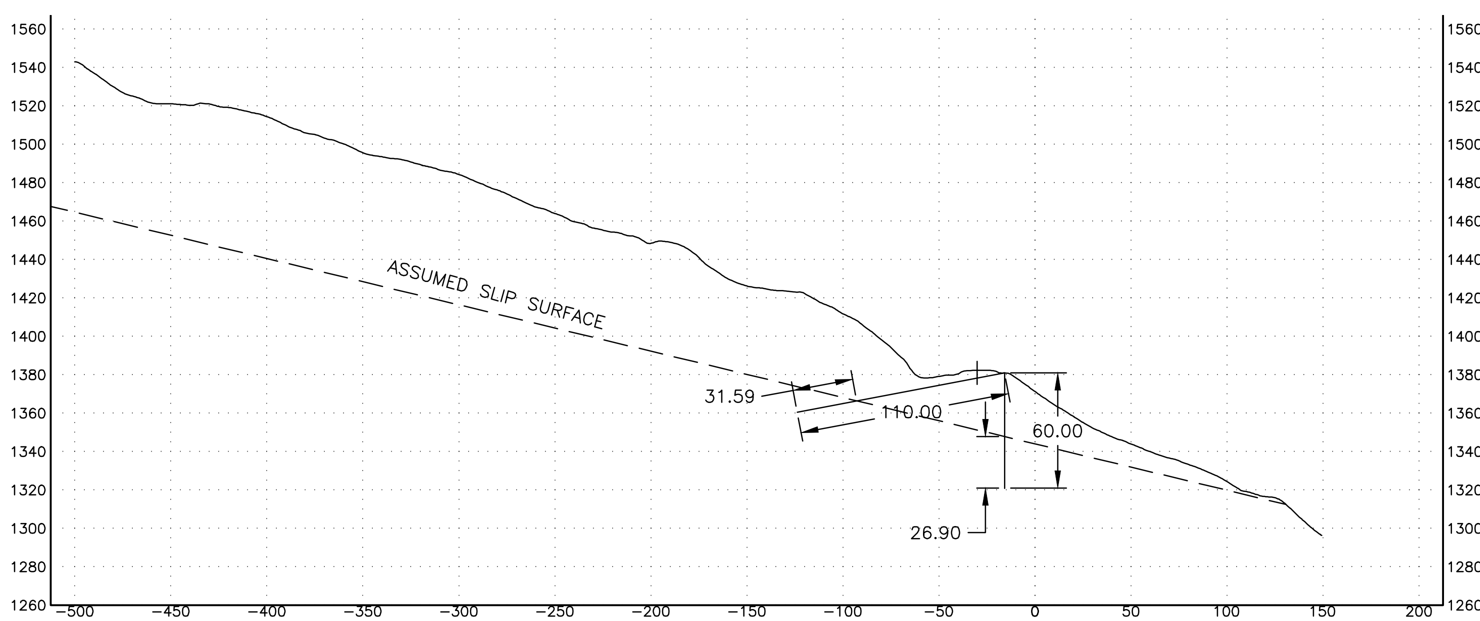
ARRC MP 357.1 ALTERNATIVE A
REALIGNMENT
PLAN & CROSS SECTION

TASK ORDER	DOCUMENT NUMBER	SHEET	REVISION
ITEM 3		01	A
DELIVERABLE NUMBER			
184595			

Appendix C. Alternative B – Retaining Structure



1 PLAN VIEW
1" = 100'



CROSS SECTION A-A'
1" = 50'

NOTES:

1. WALL LENGTH = 330 FEET
2. APPROXIMATE VERTICAL STRUCTURE EMBEDMENT = 60 FEET
3. TIEBACK LENGTH =110 FEET (30 FEET UNBONDED)

NO.	DATE	REVISION	BY	CHK	APPD

PRELIMINARY NOT FOR CONSTRUCTION

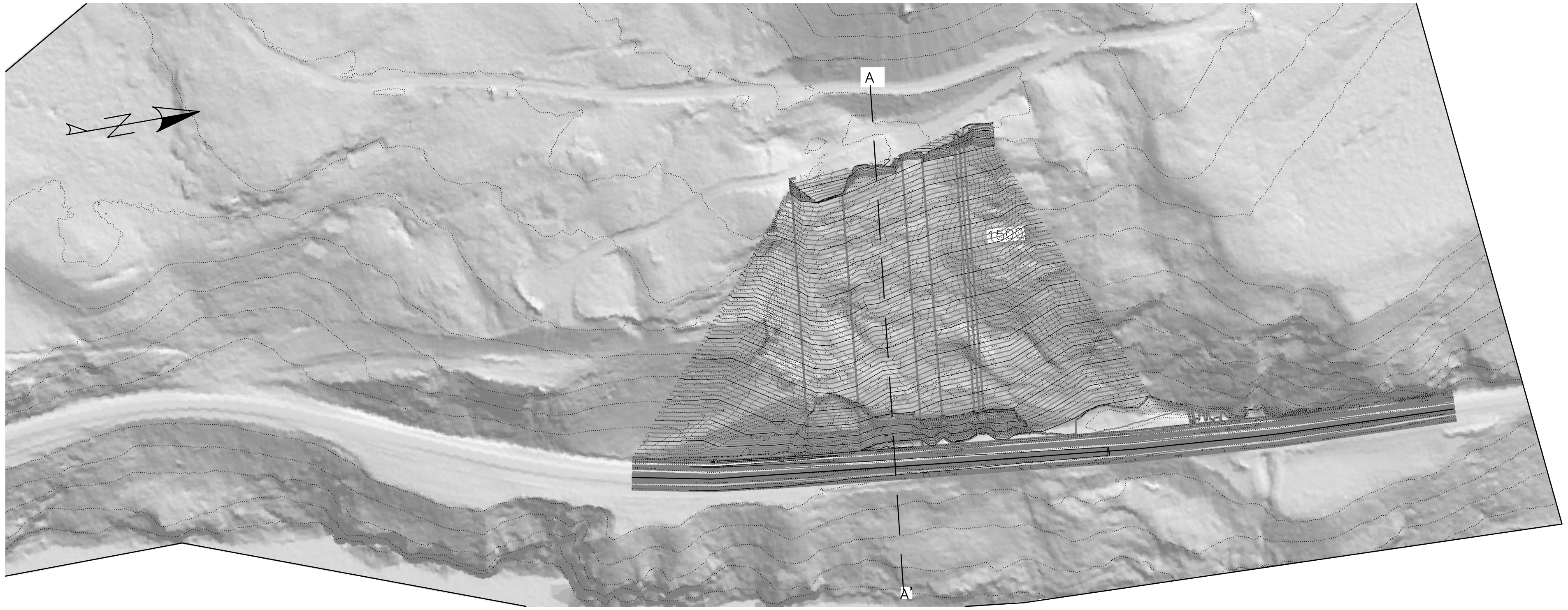
ENGINEERING RECORD		DATE
DRN:	WAB	6/13/2021
DSGN:	WAB	6/13/2021
CHK:	GCY	6/28/2021
APP:		
APP:		
SCALE: VARIES		

Michael Baker INTERNATIONAL

ARRC MP 357.1 ALTERNATIVE B
RETAINING STRUCTURE
PLAN & CROSS SECTION

TASK ORDER	DOCUMENT NUMBER	SHEET	REVISION
ITEM 3		01	A
DELIVERABLE NUMBER 184595			

Appendix D. Alternative C – Flatten Slopes



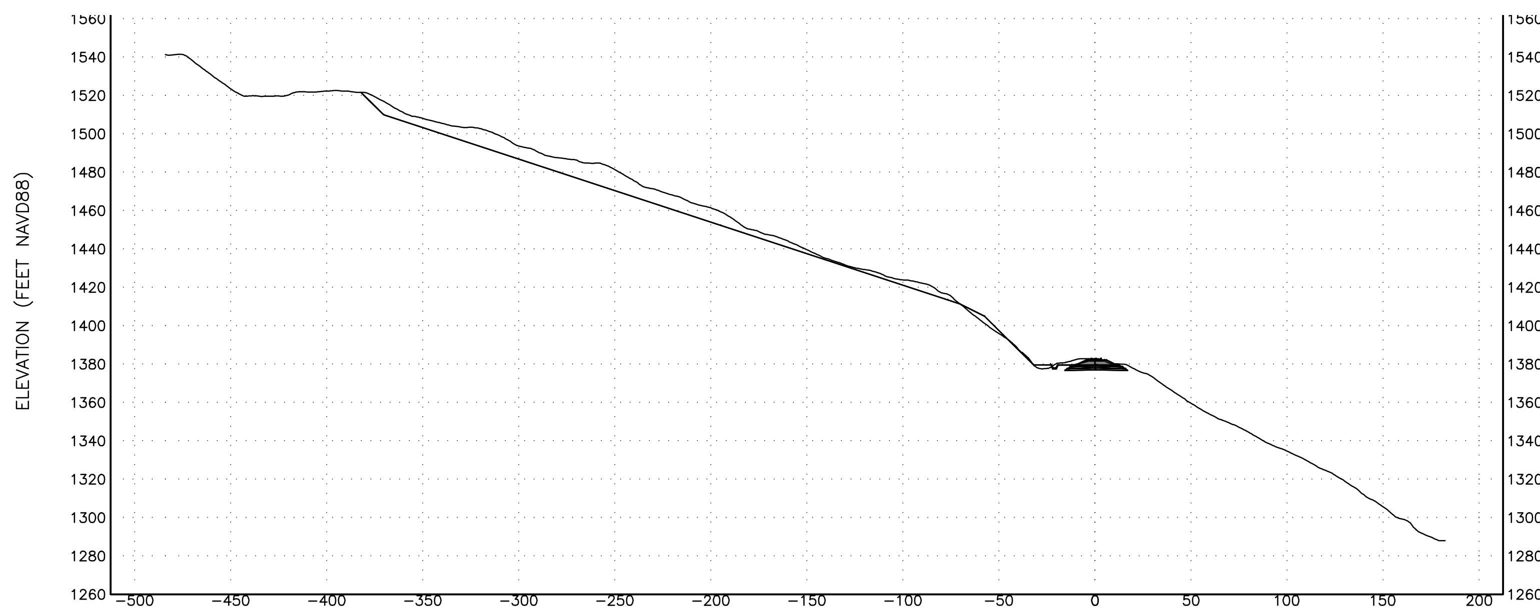
1 PLAN VIEW
1" = 100'

MATERIAL QUANTITIES		
MATERIAL TYPE	QUANTITY	UNIT
CUT	62,040	CU. YD

NOTES:
1. GRADE SLOPE TO REDUCE DRIVING FORCE
2. SEAL SURFACE CRACKS TO REDUCE INFILTRATION
3. INCORPORATE DRAINAGE IMPROVEMENTS IN FINAL DESIGN

CONSTRUCTION NOTES:

1. AIRDUMPS TO MOVE MATERIAL
2. SIZE EQUIPMENT TO SUPPORT AIRDUMPS



2 CROSS SECTION A-A'
1" = 10'

NO.	DATE	REVISION	BY	CHK	APPD

PRELIMINARY NOT FOR CONSTRUCTION

ENGINEERING RECORD		DATE
DRN:	WAB	6/13/2021
DSGN:	WAB	6/13/2021
CHK:	GCY	6/28/2021
APP:		
APP:		
SCALE:	VARIES	

Michael Baker INTERNATIONAL

ARRC MP 357.1 ALTERNATIVE C
FLATTEN SLOPES
PLAN & CROSS SECTION

TASK ORDER	DOCUMENT NUMBER	SHEET	REVISION
ITEM 3		01	A
DELIVERABLE NUMBER 184595			

Appendix C. 353.2 and 352.9 Alternative Analysis Report

ARRC MP353.2 Slope Failure

186593-MBI-RPT-001

MP353.2 Drainage Improvement Options and MP352.9 Rock Fall Mitigation

Prepared for:

Alaska Railroad Corporation
327 West Ship Creek Ave
Anchorage, Alaska 99510

Prepared by:

Michael Baker International
3900 C Street Suite 900
Anchorage, AK 99503
907-273-1600

April 6, 2022

EXECUTIVE SUMMARY

Slope movement at MP353.2 in Healy Canyon has been an ongoing problem since the 1920s, requiring multiple track realignments and slope stabilization attempts. Early efforts to control slope movement involved constructing drainage ditches and flumes to intercept and direct runoff downhill across the tracks, reducing infiltration in the active slide area. Slope movement over time has displaced sections of these ditches and flumes from their original positions. Minimizing infiltration by improving drainage is still considered the most cost-effective option to mitigating slide activity. This report presents a review of site conditions, including geotechnical and hydrologic investigations, followed by a detailed evaluation of the options for increasing track stability by improving drainage at the site.

Three tiers of drainage improvements are proposed which largely involve repairing and enhancing existing drainage features. The Tiers address drainage in different locations and progress in difficulty mainly due to site access. Implementation of the first two tiers is recommended which improves drainage at locations easily accessible from the track. A follow-up monitoring plan is recommended to evaluate the effectiveness of the improvements and inform further mitigation.

Mitigation options were also evaluated to address rockslide activity at MP352.9. Avoidance, stabilization, monitoring, and protection options were evaluated. Protecting the track using an enhanced barrier system was determined to be the most viable option.

The intent of this report is to provide the Alaska Railroad Corporation (ARRC) the background information and a flexible tool for further evaluation of drainage improvements at Moody Slide. Follow up discussions may alter the preliminary conceptual designs, and other alternatives may be incorporated into the evaluation. We look forward to working with ARRC through this process, to move forward with the best viable option.

Revision History

Rev #	Originator	Reviewed By	Approved By	Date	Description
A	Braun, Kieran	Brooks, Bill	Yager, Garrett	11/24/2021	Draft – Issued for Review
0	Braun, Kieran	Yager, Garrett	Yager, Garrett	04/06/2022	Final – Issued for Use

Table of Contents

TABLES

FIGURES

ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Definition
AEP	Annual Exceedance Probability
AREMA	American Railway Engineering and Maintenance-of-Way Association
ARRC	Alaska Railroad Corporation
Cfs	Cubic feet per second
DEM	Digital Elevation Model
LiDAR	Light Detection and Ranging
Michael Baker	Michael Baker International
MP	Milepost
NRCS	Natural Resources Conservation Service
Psf	Pounds per square foot

1. Introduction

The Alaska Railroad Corporation (ARRC) has tasked Michael Baker International (Michael Baker) to provide design assistance in developing conceptual alternatives to improve slope stability in the Healy Canyon between ARRC MP353.2 northward to the Parks Highway overpass, an area known as the Moody Slide. Landslide mitigation options typically include drainage improvements, reducing the driving forces, and increasing the resistive forces.

Slope movement at the Moody Slide is likely attributed to a deep-seated, rotational slide, though shallow, surficial slides may also occur. Groundwater, surface runoff infiltration, decaying permafrost, and the underlying lacustrine deposits of clay all contribute to slope movement. The depth of the clay deposits and possibility of multiple failure surfaces limit the effectiveness of retaining structures and internal slope reinforcements such as soil nails and piles. Also, massive modifications to slope geometry would be required to reduce the driving forces or general slope angle. Instead controlling surface water drainage and minimizing infiltration has long been an integral remedy in this area.

This report presents mitigation options to stabilize this section of track by improving existing drainage features to minimize surface infiltration within the active slide zone. An order of magnitude cost estimate and general site plans at the 10-15% design level accompanies each option.

In addition, this report presents mitigation options to address ongoing issues caused by the rockslide area at MP352.9.

A location map is presented in Figure 1.1.

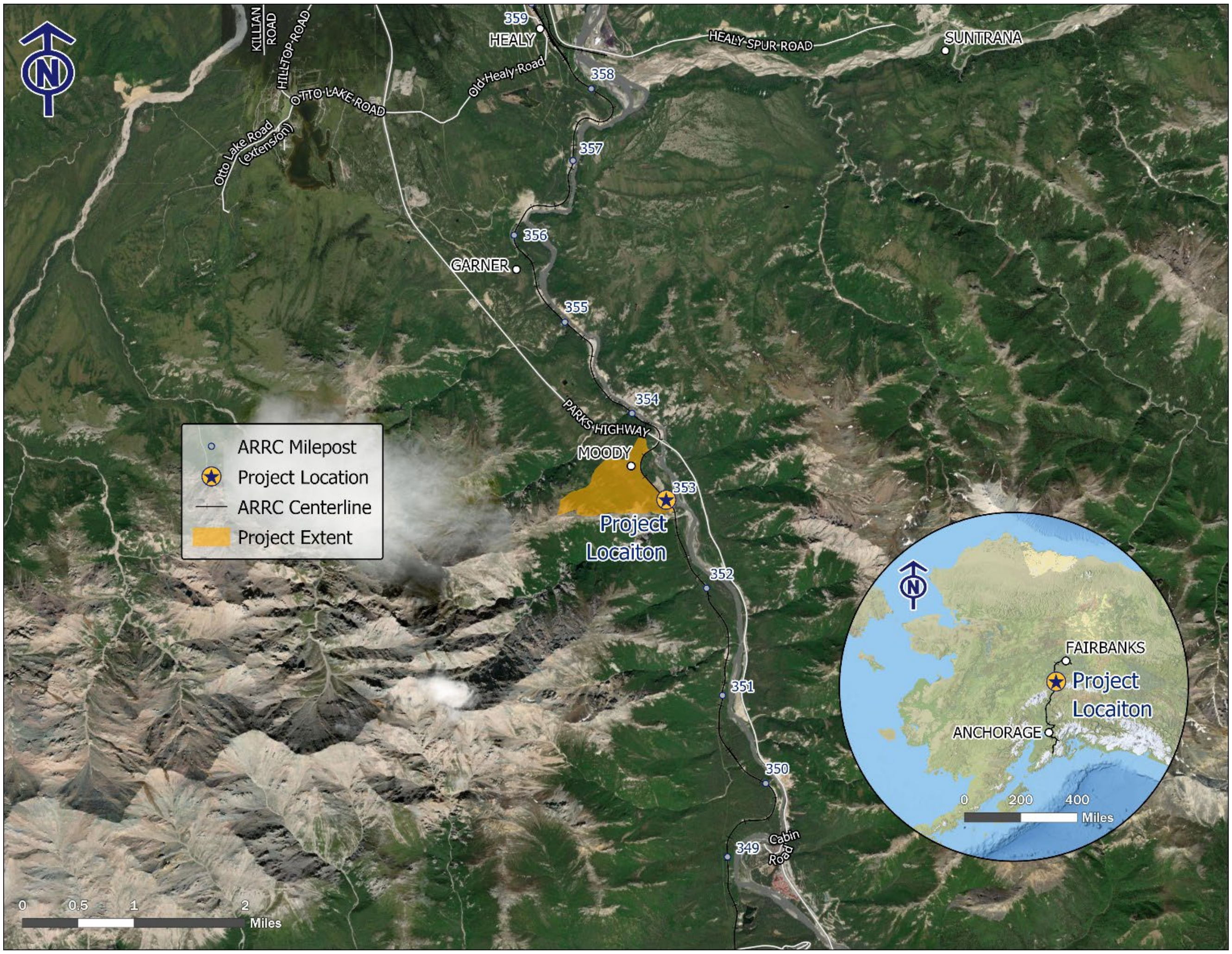


Figure 1.1: Project Location Map

2. Site Conditions

2.1 Geology

The project site is located within the Healy Canyon beginning at MP353.2 and extending northward to the Parks Highway overpass at approximately MP353.5. The track near MP353.2 is in an ancient glacial gorge (Nenana gorge) at the base of the mountains forming the west wall of the Nenana gorge. Continuing northbound from the highway overpass, the track alignment arcs eastward and leaves the west wall of the Nenana gorge, entering a narrow steep-walled river gorge superposed in the east wall of the Nenana gorge. The Parks Highway overpass and northern extent of the study area is located where the track enters the narrow river gorge. The slide area can be loosely defined along the portion of track traversing the Nenana gorge from the west wall to the east wall (hereafter referred to as “Moody”).

Slope movement at Moody has been observed dating back to 1923. Numerous westward track realignments were performed as the landslide progressed. Evidence of prior track alignments are still visible east of the current track alignment. Slope movement is the result of complex hydrologic, geologic, and glacial forces. An ancient lake once filled the Nenana gorge at Moody and produced lacustrine deposits of varved clay extending up to 150-ft above the current Nenana riverbed. This clay was then overlain with outwash gravel and alluvium from the Nenana River and other nearby tributaries to the west. Based on this information the landslide may be classified as a deep-seated rotational slide, likely exacerbated by the erosional effects of the Nenana River.

2.2 Past Geotechnical Investigations

Though many geotechnical efforts have focused on slope stability issues near MP353.3, an extensive drilling effort conducted in 1967 and 1970 drilled 12 boreholes from 20 feet to approximately 150 feet below the ground surface along the curve at MP353. These borings are identified on the historic site plan from 1968, which also identifies scarps and several site features from that time, as shown in Figure 2.1.

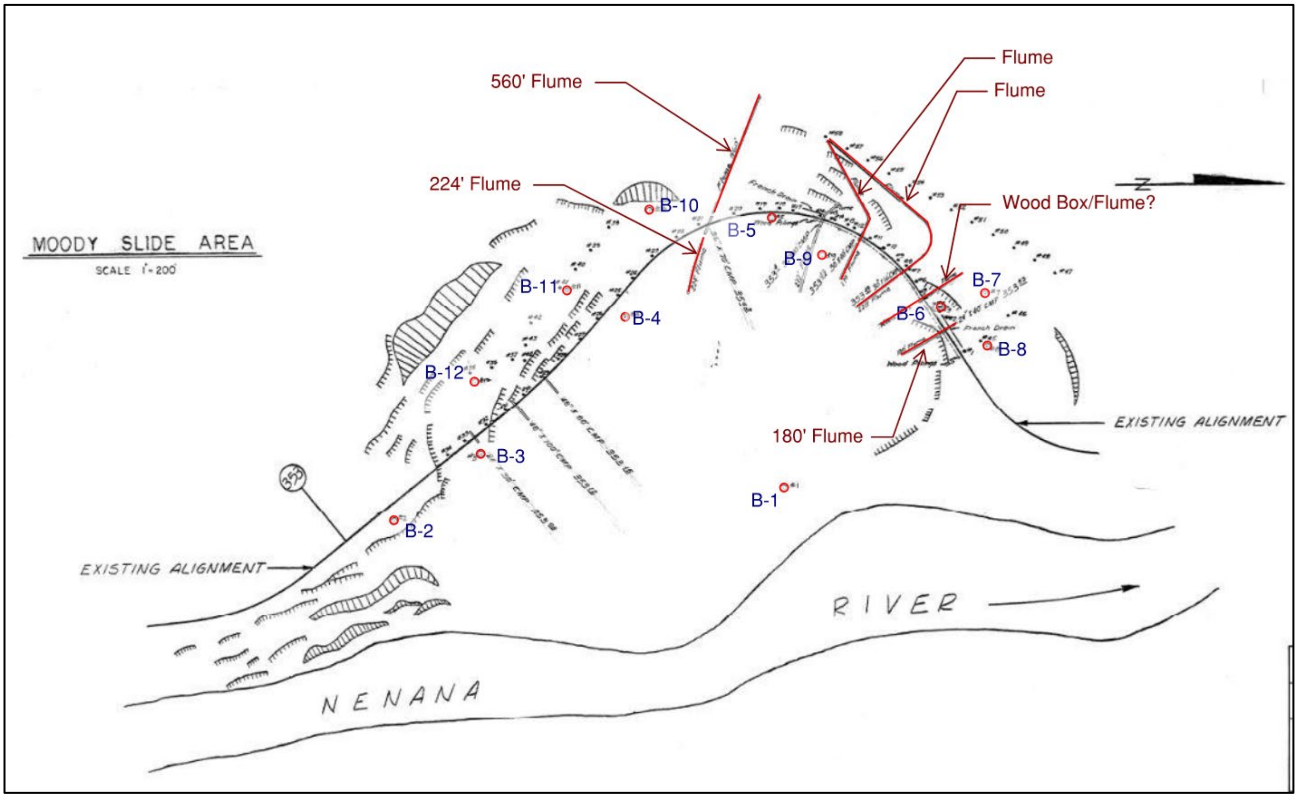


Figure 2.1: 1968 Site Plan and "Deep" Boring Locations

In general, the subsurface results are consistent with our geologic understanding of the area; alluvial, granular deposits (slide debris) overlie fine-grained silts and clays. Perhaps due to the former glacial lake, most of the drilling encountered non-frozen soil. Frozen soil on the logs was typically encountered 30 feet below ground and was relatively thin.

Groundwater was encountered between 4 and 22-ft below ground surface near the track during the 1967 geotechnical exploration (Fuglestad 1983).

Appendix A presents the boring logs from the 1967 and 1970 drilling programs.

2.3 Site Visit

A site visit was performed by Michael Baker on October 14, 2021 in support of this alternative analysis. Field crews hiked to the Upper Bench at the uphill section of the slide zone to evaluate potential areas of water infiltration, document evidence of landslide activity, and to inspect existing drainage ditches and flumes. The crew then inspected this section of track and lower slide area from the tracks via hi-rail equipped trucks.

During the site visit, field crews noted signs of prior slide activity, however evidence of recent movement was largely absent. Minimal rotation of trees was noted on the hillside that would otherwise suggest recent rotational movement. Scarps, formed as steps or offsets in the ground surface as a result of ground movement, were visible throughout the slide area. Vegetation cover is medium-dense with many areas of sparser coverage. Trees, shrubs, and mosses provide the majority of ground cover. Ground coverage within the slide area is highly variable due to past construction efforts and landslide activity.

2.4 LiDAR Review

A LiDAR survey was performed through the Healy Canyon from MP340 to MP361 during June 2021 to support this and other ARRC projects in Healy Canyon. Topographic data obtained from the LiDAR survey was used to develop a bare earth digital elevation model (DEM). The newly acquired LiDAR imagery reveals in better detail the historic and active slide surfaces and the conditions of the existing drainage structures. Observations suggest the most active section of the Moody slide area currently is between MP353.2 and MP353.5, however historical records note movement both in this area and in section MP353.0 to MP353.2 (Fugelstad 1983). The topography indicates that existing ditches and flumes have displaced from their original position. In some cases, these drainage features now collect and store runoff, which increases surface infiltration into the slide area.

2.5 Existing Drainage Features

The terrain in the active slide area is characterized by a series of relatively flat land benches and steep-walled crescent-shaped headwall scarps (Fugelstad 1983). Drainage structures in the vicinity include culverts through the railroad embankment and CMP flumes and ditches which facilitate runoff downhill and minimize surface infiltration. The drainage ditches were initially graded to direct runoff into the nearest flume or culvert, but ground movement has since shifted their grade and positioning such that improvements are necessary to restore their function. The condition of the CMP flumes varied from poor to moderate, but no flumes in their current state are fully functional. Perforated vertical near MP353.5 are no longer serviceable due to ground movement.

Locations and descriptions of all land and existing drainage features pertinent to the proposed drainage improvements are outlined below and shown in Figure 2.2.

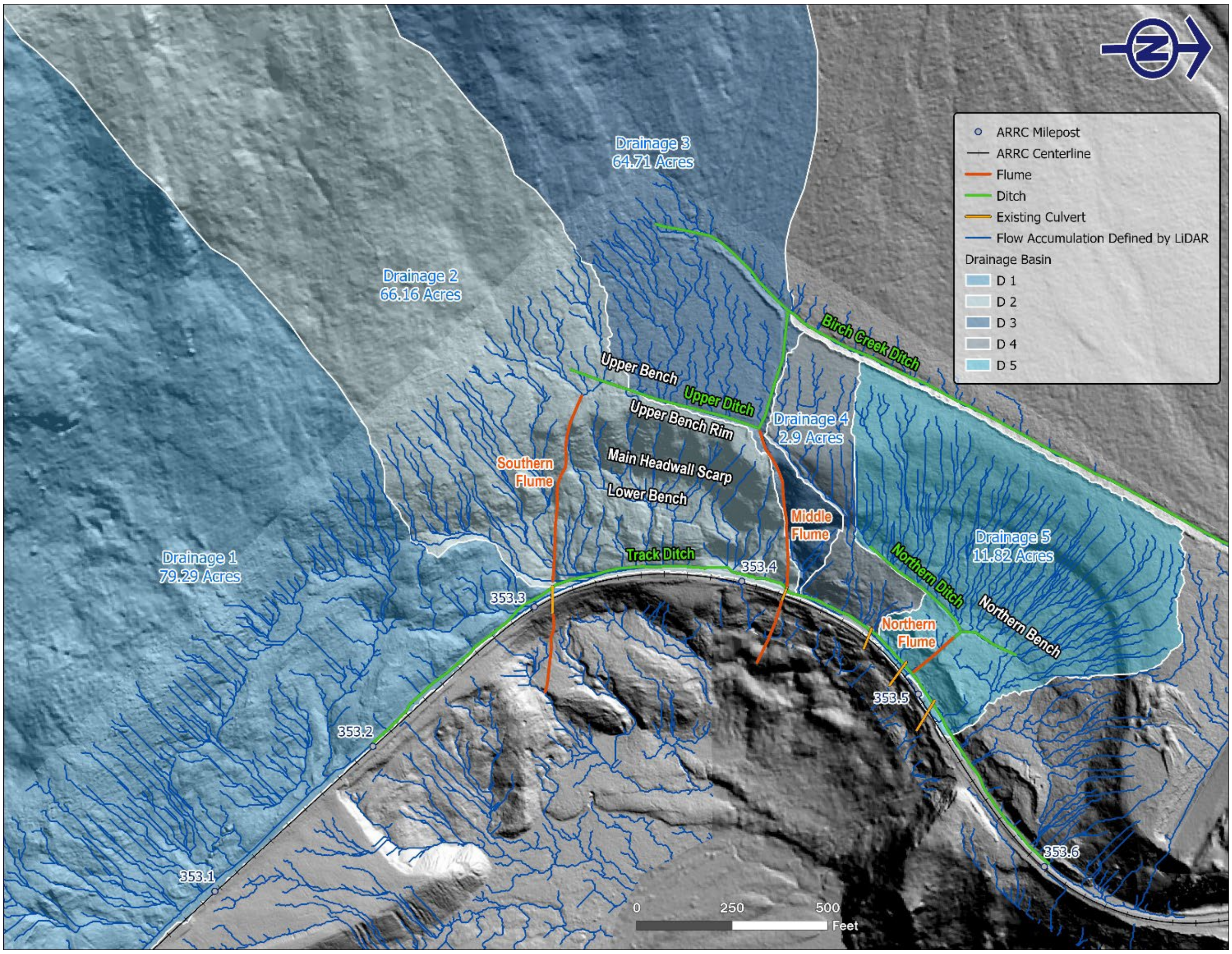


Figure 2.2: Drainage flow paths and existing ditches derived from the project LiDAR DEM at MP353.2

<u>FLUMES</u>

- Three flumes within the study area are referred to as the **Southern Flume, the Middle Flume, and the Northern Flume** in accordance with their relative positions (Photo 2.1). All flumes in their current state are considered non-functional (Photo 2.2). The Southern and Middle Flumes lead directly to culverts and the Northern Flume has two nearby culverts with perforated risers.

Photo 2.1: Existing flume west of the tracks, looking south

Photo 2.2: Section of disconnected pipe in the Middle Flume, looking north

LAND FEATURES

- **The Main Headwall Scarp** is defined as the steep-walled area between the Southern and Middle Flume, separating the Upper and Lower Land Benches. The top of this scarp is referred to as the **Upper Bench Rim**.
- The **Lower Bench** is directly below the Main Headwall Scarp and uphill from the track between approximately MP353.3 and MP353.4.
- The **Upper Bench** is directly above the Main Headwall Scarp between the Southern and Middle Flumes. A low-lying area starting 50-ft uphill from the Southern Flume is considered part of this bench feature. Improvements in this area are recommended as part of Option 3.
- The **Northern Bench** is directly uphill from the track near MP353.5. This feature includes the Northern Ditch and Northern Flume and is referenced as part of Option 2.

DITCHES

- The **Track Ditch** refers to the ditch on the uphill side of the track between MP353.2 and MP353.5. Improvements to this ditch are recommended as part of Option 1.
- The **Northern Ditch** system refers to the brow ditches near MP353.5 which direct runoff from the Northern Bench across the tracks. Two transverse ditches run adjacent and uphill from the tracks and converge at the top of the Northern Flume. The Northern Flume is positioned to direct runoff to two culverts with risers carrying runoff across the tracks. Improvements to this ditch system are recommended as part of Option 2.
- The **Upper Ditch** system refers to two ditches on the Upper Bench running adjacent and perpendicular to the Upper Bench Rim which converge above the Middle Flume (Photo 2.4). Improvements to this ditch are recommended as part of Option 3.
- The **Birch Creek Ditch** refers to the large north-south orientated ditch west of the track between MP353.4 and MP353.6 (Photo 2.3). This ditch is adjacent to the track about 800-ft

uphill and passes under the Parks Highway through a large diameter culvert. This ditch carries runoff from the northwestern mountains above Moody and separates some of the northern sub-basins in the slide area.

Photo 2.3: Birch Creek Ditch near MP353.6, looking south

Photo 2.4: The Upper Ditch and Rim, looking west

3. Hydrology and Hydraulics

3.1 Climate Summary

Healy Canyon is located within the subarctic continental climate zone and experiences extremely cold winters and warm summers. Peak flows at the MP353.2 slide area most likely result from rainfall runoff events. The average annual precipitation is 15 inches, more than half of which falls as rain between June and August. Climate projections created by the National Climate Assessment (NCA 2014) predict a 15-30% increase in annual precipitation across the state of Alaska by the end of the 21st century. A 2019 rainfall event resulted in approximately 3 inches of rain in the Healy Canyon and brought rockslides down near MP350. Large rainfall events also coincided with high stage on the Nenana River, including on August 20, 2006, where the Nenana River stage was 13.64 feet and on September 21, 2012, where the Nenana River gage saw a record peak stage of 14.80 feet.

3.2 Drainage Basin Delineation

Five drainage basins were delineated for determining the peak runoff during the design storm for culvert hydraulics. The drainage basins were delineated using a combination of bare earth DEM data sources including project LiDAR collected in 2021 with a resolution of 1.5 feet, Infrastructure Corridor LiDAR collected in 2011 with a resolution of 1 meter, and USGS IFSAR data collected in 2010 with a resolution of 5 meters. Delineations of the five drainage basins and their longest flow path are displayed in Figure 3.1

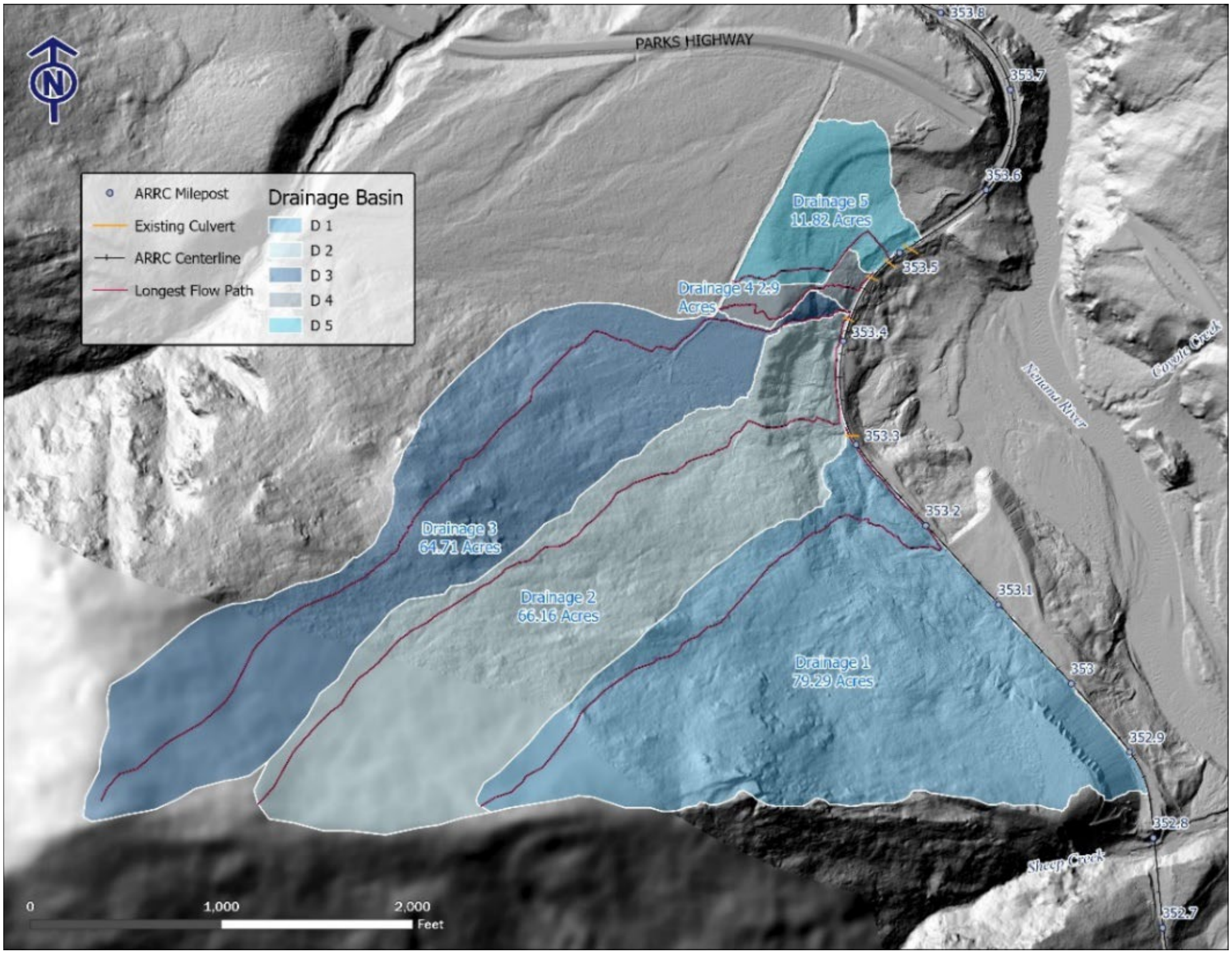


Figure 3.1: Drainage Basin Delineation

Precipitation estimation for annual exceedance probability (AEP) storms in Healy, Alaska was found from NOAA Atlas 14 precipitation data (NOAA 2018). The design storm for sizing culverts was a 24-hour, 50-year event. The 100-yr storm was used for checking against overtopping of the track. NOAA Atlas 14 was used to estimate rainfall amounts. Precipitation estimates, and the selected design storm precipitation, are shown in Figure 3.2. An estimated 3.1 inches of precipitation occurs during the design storm.

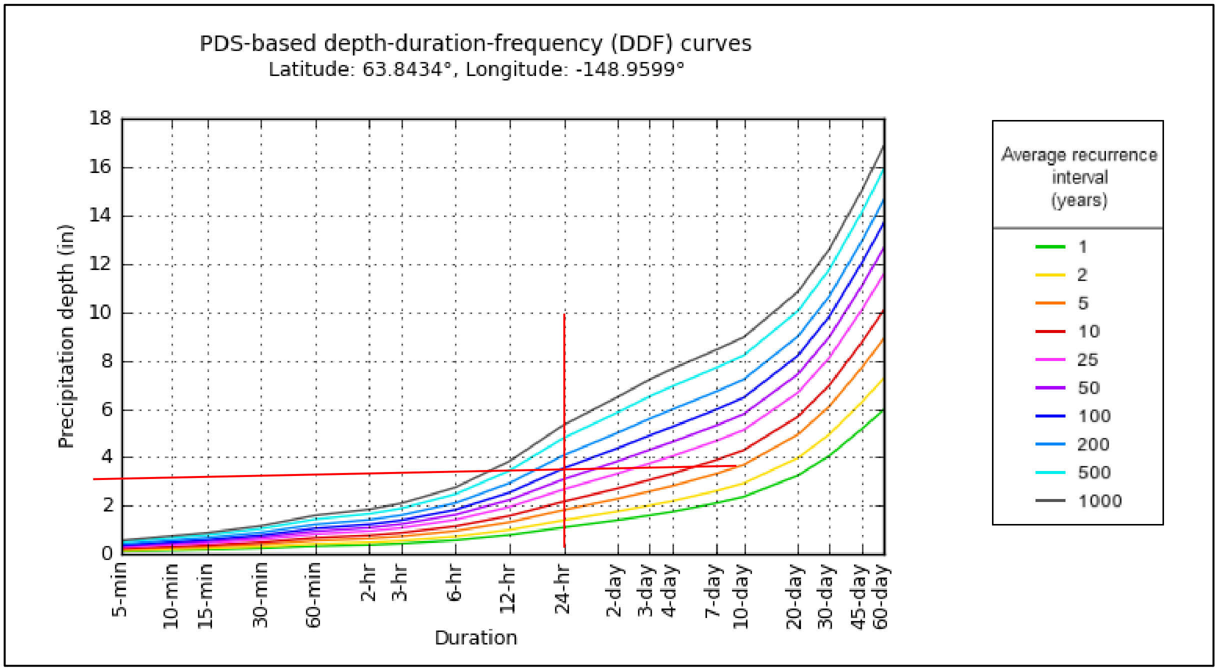


Figure 3.2: NOAA Atlas 14 Precipitation Estimates for Healy, AK

3.3 Design Hydrograph

The approximate runoff volume was calculated using Natural Resources Conservation Service (NRCS) TR-55 methods, which are suitable for small watersheds similar to MP353.2. Rainfall distribution selection was Type 1 which is recommended for interior regions of Alaska (DOT&PF, 2006). NRCS TR-55 method uses drainage basin area, rainfall, a runoff factor, and time of concentration for inputs and considers the time distribution of rainfall and a decreasing infiltration rate based on soil permeability and ground cover. SCS curve numbers represent the runoff factors with infiltration rates for different soil types. This analysis was developed for agricultural and urban uses with different flow regimes than the steep drainage within this project. It should also be noted that the SCS curve numbers were calibrated in the conterminous United States. Nevertheless, lacking better hydrologic tools, the NRCS TR-55 method is generally accepted for determining design discharge from precipitation events for small drainages in Alaska.

Drainage basin size, longest flow path, and slope were determined for the time of concentration using a combination public IFSAR and project LiDAR digital terrain models. Sheet flow was assumed to occur in the first 100 feet of the longest flow path. Shallow concentrated flow was assumed to occur the next 1,000 feet and the remaining length of the longest flow path was considered channel flow. Manning's roughness and ground cover was estimated using aerial imagery. Hydrologic soil group areas were determined for each drainage and the TR-55 computer program was used to calculate time of concentration, weighted curve number, and design discharges from these inputs.

Table 3.1 includes the input parameters used to create the rainfall runoff hydrographs shown in Figure 3.3 and Figure 3.4. Curve numbers were calculated based on the slope features.

Table 3.1: NRCS TR-55 Hydrologic Inputs to develop Hydrograph

Drainage Basin	Hydrologic Type	Area (acres)	Curve No.	Tc Method	Tc (mins)	Distribution	Duration (hours)	Occurrence Frequency
D1	SCS	79.3	70	TR-55	6	Type 1	24	50-year
D2	SCS	66.2	69	TR-55	6	Type 1	24	50-year
D3	SCS	64.7	67	TR-55	6	Type 1	24	50-year
D4	SCS	2.9	68	TR-55	9.84	Type 1	24	50-year
D5	SCS	11.8	67	TR-55	10.14	Type 1	24	50-year

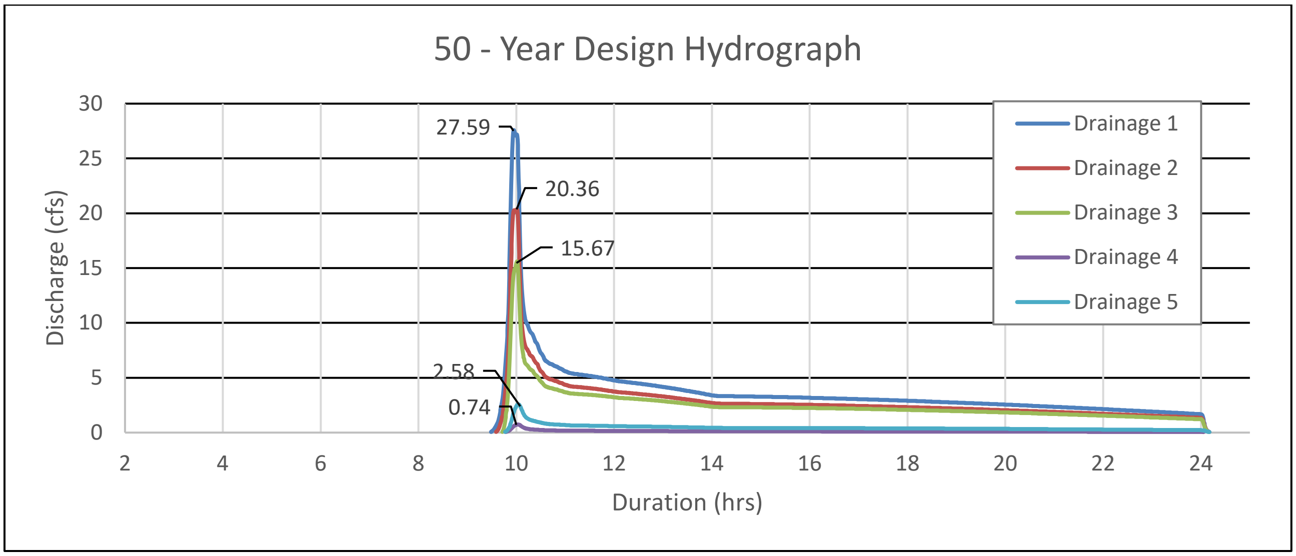


Figure 3.3: MP353.2 50-year Design Hydrograph

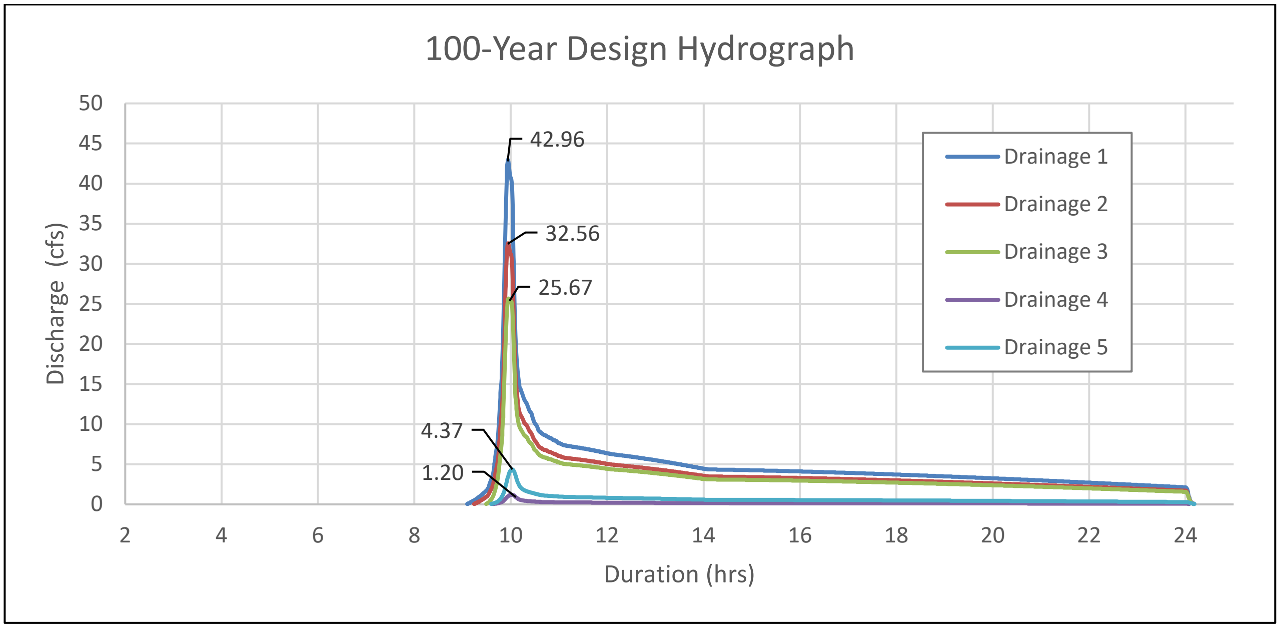


Figure 3.4: MP353.2 100-year Design Hydrograph

4. MP353.2 Drainage Improvements

Landslide mitigation is often difficult with many contributing factors to the slope instability and insufficient data to fully understand the complex geology and environmental forces. The mitigation options presented seek to improve existing drainage features by extending and/or re-grading ditches, lining ditches, rehabilitating existing flume structures, and adding or realigning culverts. Rather than being evaluated against each other, the options are presented as "tiers" because they offer different extents of drainage improvements with increasing difficulty largely due to site access. They are not directly comparable against one another in terms of functionality. A general overview of the proposed improvements are shown in Figure 4.1. Detailed plan and profiles for each tier are presented in the appendix.

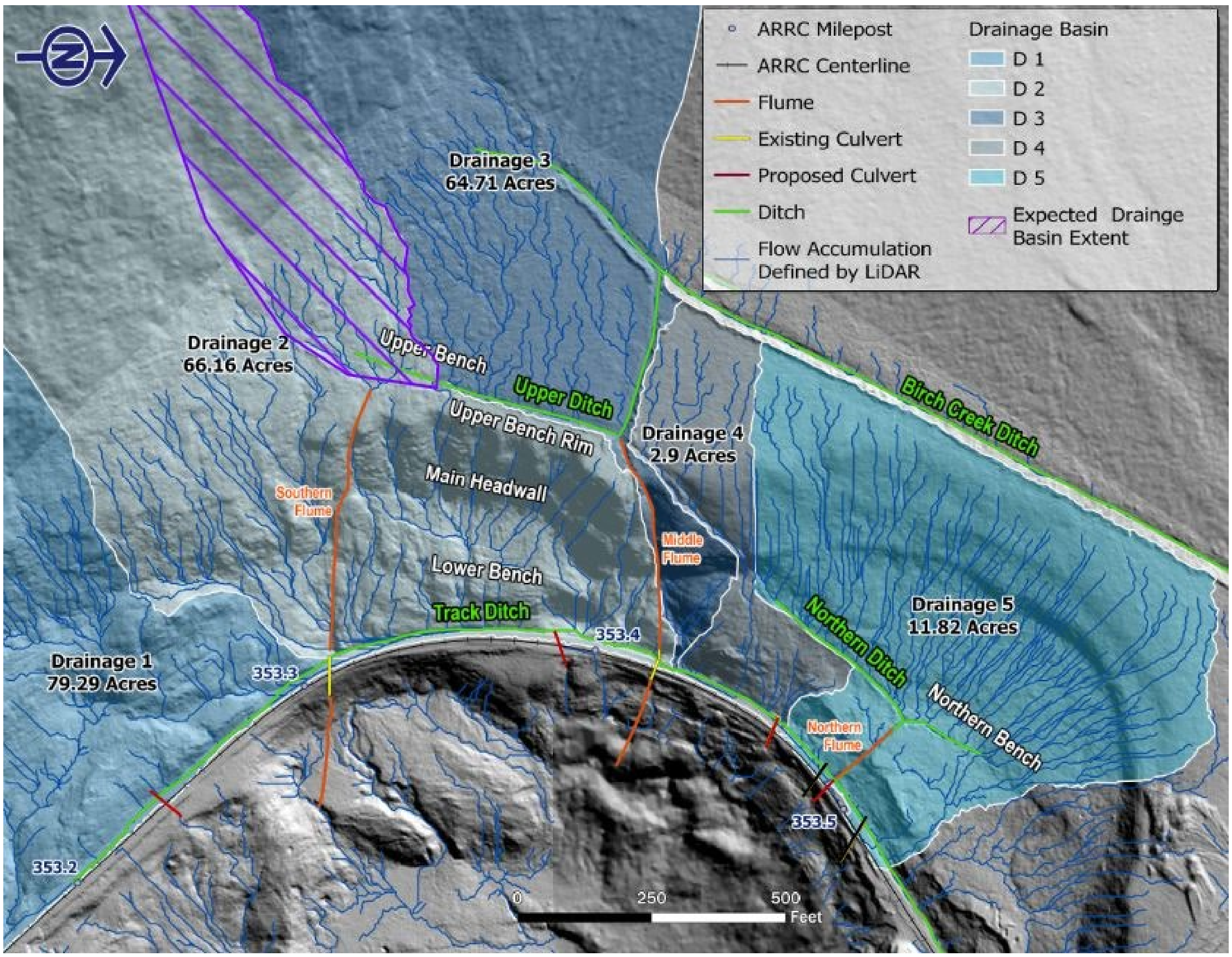


Figure 4.1: Detail of Drainage Improvements

4.1 Tier 1 – Track Ditch Improvements

Tier 1 involves re-grading the Track Ditch between MP353.3 and MP353.6, replacing existing culverts at MP353.47 and MP353.49, and adding three new culverts at MP353.24, MP353.39 and MP353.59 to facilitate drainage through the slide area and past the track structure. The new culvert at MP353.49 should align with the outlet of the Northern Flume to assist in conveying flow. Additionally, Tier 1 proposes removal of the three existing proximal culverts at MP353.47, MP353.49 and MP353.51 which are damaged.

Tier 1 also proposes to address the historic, deteriorated box culverts (4 feet by 4 feet) known to be present along the study area approximately 20-30-ft below the track alignment. They are no longer serviceable and pose a slumping or settling hazard. Tier 1 improvements propose to identify and fill these culverts with grout or injectable foam to prevent their collapse.

TIER 1 CULVERT SIZING

New culverts were sized using CulvertMaster with the design hydrograph results. In accordance with AREMA requirements, the allowable headwater was restricted to less than 1.5 times the culvert diameter (AREMA 2013). The allowable outfall velocity was restricted to less than 12-fps for the 50-year design flow to protect against embankment head cutting at the outlets. Smooth wall steel pipe should be installed for new culverts rather than CMP culverts which tend to fail at the seams when subjected to land movement forces.

Hydraulic results indicate 36-inch smooth wall steel pipe culverts are sufficient to handle the 50- and 100-year design flows. Hydraulic results indicate 18-inch culverts are sufficient in some locations, however due to winter icing and ease of maintenance, 36-inch diameter culverts are recommended for all culvert installations with a minimum wall thickness of 1/2 to 5/8 inches. Additionally, perforated riser pipes with trash racks installed at the inlet will mitigate debris clogging and increase culvert effectiveness.

The culvert design should incorporate a rock-lined slope drain at the outfall to convey outflow down the embankment protecting the subgrade from head cutting or erosion. Slope drains should be designed to handle the 50-yr design flow and lined with geosynthetic fabric and Class I-II riprap. The slope drains will align with existing natural drainage paths and will direct runoff from the culvert outlet downhill past the active slide area. Localized areas of steeper terrain, and the area directly below the culvert outlet (outlet apron), will likely require Class II Riprap.

A summary of flow distribution through each culvert by drainage is shown in Figure 4.1. Plan and Profile drawings of Tier 1 are included in Appendix B.

Table 4.1: Culvert Summary

Culvert MP	Pre / Post Construction	50-yr Runoff (cfs)	% Drainage(s) Captured	HW Depth (ft)	Outfall Velocity (fps)	Notes
353.24	Post	21	75% D1	2.2	11.6	New Culvert
353.31	Pre	35	100% D1 50% D3	3.5	11.6	Existing Culvert in Good Condition as of April 2021
	Post	12	25% D1 25% D2	1.8	8.6	
353.39	Post	15	75% D2	1.8	11.2	New Culvert
353.42	Pre	32	Approx. 100% D2-D5	3.3	12.2	Existing Culvert in Good Condition as of April 2021
	Post	16	100% D3 25 % D4	1.8	10.2	
353.47	Post	1	75% D4 25% D5	0.4	6.3	Remove and replace damaged culvert
353.49	Post	2	75% D5	0.6	7.7	Remove and replace damaged culvert
353.51	Pre	-	-	-	-	Remove damage culvert
353.59	Post	1	Minimal D5	0.4	6.3	New Culvert

4.2 Tier 2 – Northern Bench

Tier 2 extends and enhances the Northern Ditch to improve drainage from the Northern Bench to the Northern Flume. Evaluation of surface runoff flow paths from the LiDAR data indicate the position of the existing brow ditches are effective at capturing runoff, however extending the ditches further in each direction would intercept additional runoff from the upper hillside of Drainage Area 5, increasing their functionality. Ditch improvements include clearing and grubbing, grading to drain, and installing a geosynthetic fabric to improve ditch conveyance and reduce infiltration. Geosynthetic fabric will be overlain with clean Class I-II Riprap to provide surface protection and the flexibility needed for use on unstable ground. The existing Northern flume would be removed and replaced with a rock-lined ditch which conveys runoff to the new culvert at MP353.49 proposed in Tier 1.

Improvements on the Northern Bench can be easily accessed from the tracks.

Plan and Profile drawings of Tier 2 are included in Appendix C.

4.3 Tier 3 – Upper Bench and Middle Flume

Tier 3 extends and the Upper Ditch further south along the Upper Bench Rim and improves the Upper Ditch which conveys drainage to the Middle Flume. Tier 3 would rehabilitate the existing Middle Flume structure through repairs to the flume and by enhancing the inlet conditions where water conveyed by the ditch enters the flume.

Tier 3 intercepts additional runoff from Drainage Area 2 that was formerly captured by the damaged Southern Flume by extending the Upper Ditch to the south. Extending this ditch southward also intersects a low-lying sag area above the Southern Flume that may require placement of fill to create grade to drain conditions in the ditch. Ditch improvements include clearing and grubbing, grading to drain, and installing a geosynthetic fabric to improve ditch conveyance and reduce infiltration. Geosynthetic fabric will be overlain with clean Class I-II Riprap to provide surface protection and the flexibility needed for use on unstable ground. Extending the Upper Ditch further south than described above would intercept additional runoff from Drainage 2 and should be considered in future analysis.

The northern extent of the Upper Ditch ends at the top of the Middle Flume. Tier 3 improvements bring the Middle Flume back to serviceable status by clearing debris from the full extent of the flume and replacing or reconstructing sections of disconnected pipe (approximately 100ft) near the middle of the structure. The outlet to this flume aligns with an existing culvert that will convey flow across the track structure.

The Upper Bench is believed to be accessible from the powerline alignment above the Upper Bench.

Plan and Profile drawings of Tier 3 are included in Appendix D.

5. MP 352.9 Rockfall Mitigation

The rockslide area at MP352.9 has been a source of delays and safety concerns to ARRC traffic. Erosion of fine particles by environmental factors like precipitation, freeze-thaw cycles, and wind destabilizes larger cobbles and occasional boulders trapped in a layer of silts and sands, leading to a near constant sloughing of material towards the tracks. The alluvial, rounded shape makes them susceptible to rolling at high speeds and landing on the tracks.

The rock debris deposited on and near the railroad tracks requires maintenance and extra labor hours to maintain the rail corridor and allow trains to pass safely. Four main mitigation strategies are typically utilized to address rockfall:

- Avoidance – moving the track structure away from the hazard.
- Stabilization – addressing the sloughing at the source, through mitigative efforts such as rock scaling, cable netting, or shotcrete.
- Management – continual monitoring of the slide area to ensure traffic can safely traverse the area and be able to respond to new rockfall.
- Protection – placement of a barrier that arrest falling rocks and prevent them from reaching the track or passing train.

At MP352.9, avoidance is difficult to achieve due to the location of the tracks through Healy Canyon and lack of any other possible alignment. Stabilization is also difficult, as the height of the slope eliminates grading as an option. Stabilizing the slope with dowels, shotcrete, or cable lashing is possible but likely is not cost effective and would be challenging due to the large amount of unconsolidated material.

Protecting the tracks from rock fall is the best value engineering solution. Given the size of the rockfall, typically cobble sized, with the occasional boulder, installing a series of Jersey Barriers, enhanced with a fencing barricade on top, along the tracks will prevent most rockfall from impacting the track. An example is shown below in Figure 5.2. The use of anchor rods driven into the ground between Jersey Barriers and/or tie back cables will help stabilized the barrier from tipping over onto the tracks during rockfall impacts or high wind events.

In addition to a protection solution, ongoing monitoring will assist in managing the hazard posed by rockfall at MP352.9. Ongoing monitoring could consist of a remotely monitored camera and maintenance records. This data could be combined with weather station data at a nearby location to help monitor the local conditions. This data could be used to identify weather patterns that may trigger increased occurrences of rockfall and give advance warning to ARRC of future rockfall events. The general project extent is shown in Figure 5.1.

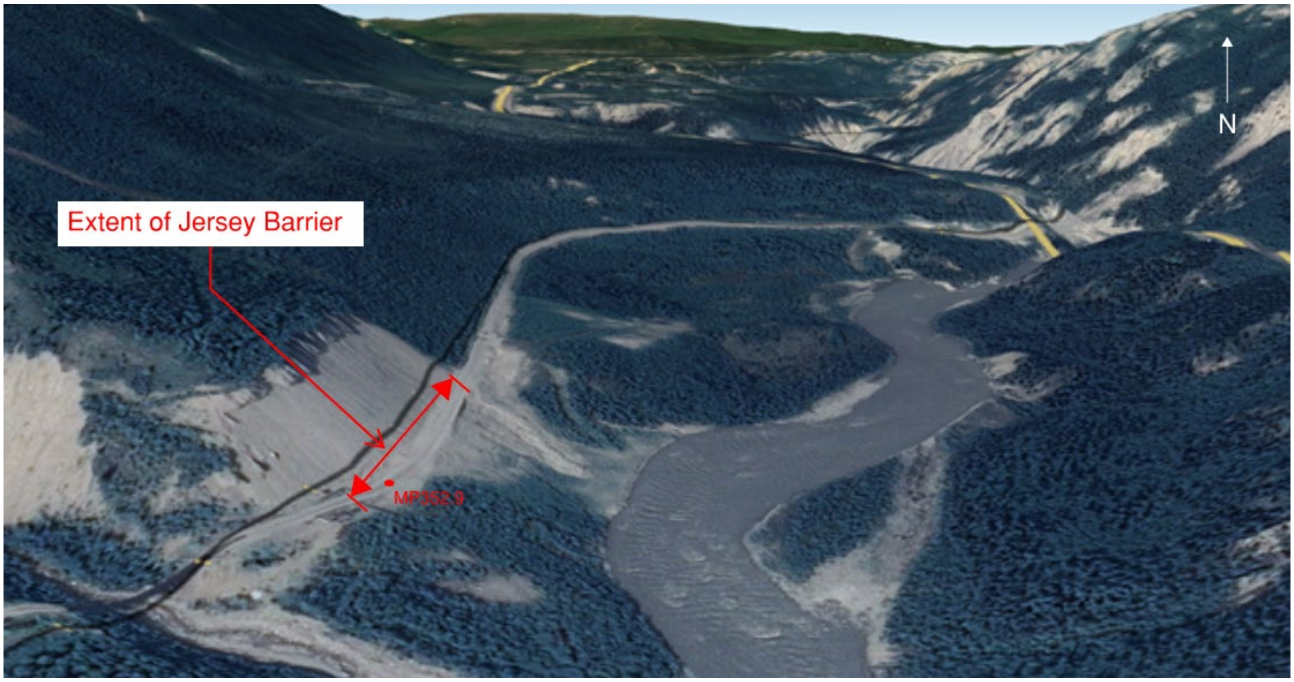


Figure 5.1: Proposed Jersey Barrier Location

Figure 5.2: Jersey Barrier with Fencing

6. Cost Estimate

The estimated cost for the drainage improvement tiers is presented in Table 6.1. These cost estimates (+/- 50%) were developed based on the proposed Tiers and rockfall mitigation options in this report.

Table 6.1: Cost Estimate – MP353.2 Drainage Improvements

Alternative	Labor Cost	Material Cost	Equipment Cost	Total Cost
Tier 1	$73,000	$90,000	$97,000	$260,000
Tier 2	$35,000	$52,000	$138,000	$225,000
Tier 3	$65,000	$59,000	$95,000	$219,000

These cost estimates could be further refined to consider the ARRC's internal capabilities. Details are listed in Appendix E.

Costs to mitigate rockfall are presented in Table 6.2.

Table 6.2: Cost Estimate - MP352.9 Rockfall Mitigation

Option	Labor Cost	Material Cost	Total Cost
Jersey Barrier Protection	$25,000	$25,000	$50,000
Monitoring Equipment	$10,000	$20,000	$30,000

7. Land Ownership and Permitting

7.1 Land ownership

Land ownership in the project location is presented in Figure 7.1 based on publicly available data. Proposed improvements are on ARRC property, AK DNR Property and an area of unknown land situated between the Denali National Park and the AK DNR boundaries. An online property viewer listed this unknown area as municipal/other.

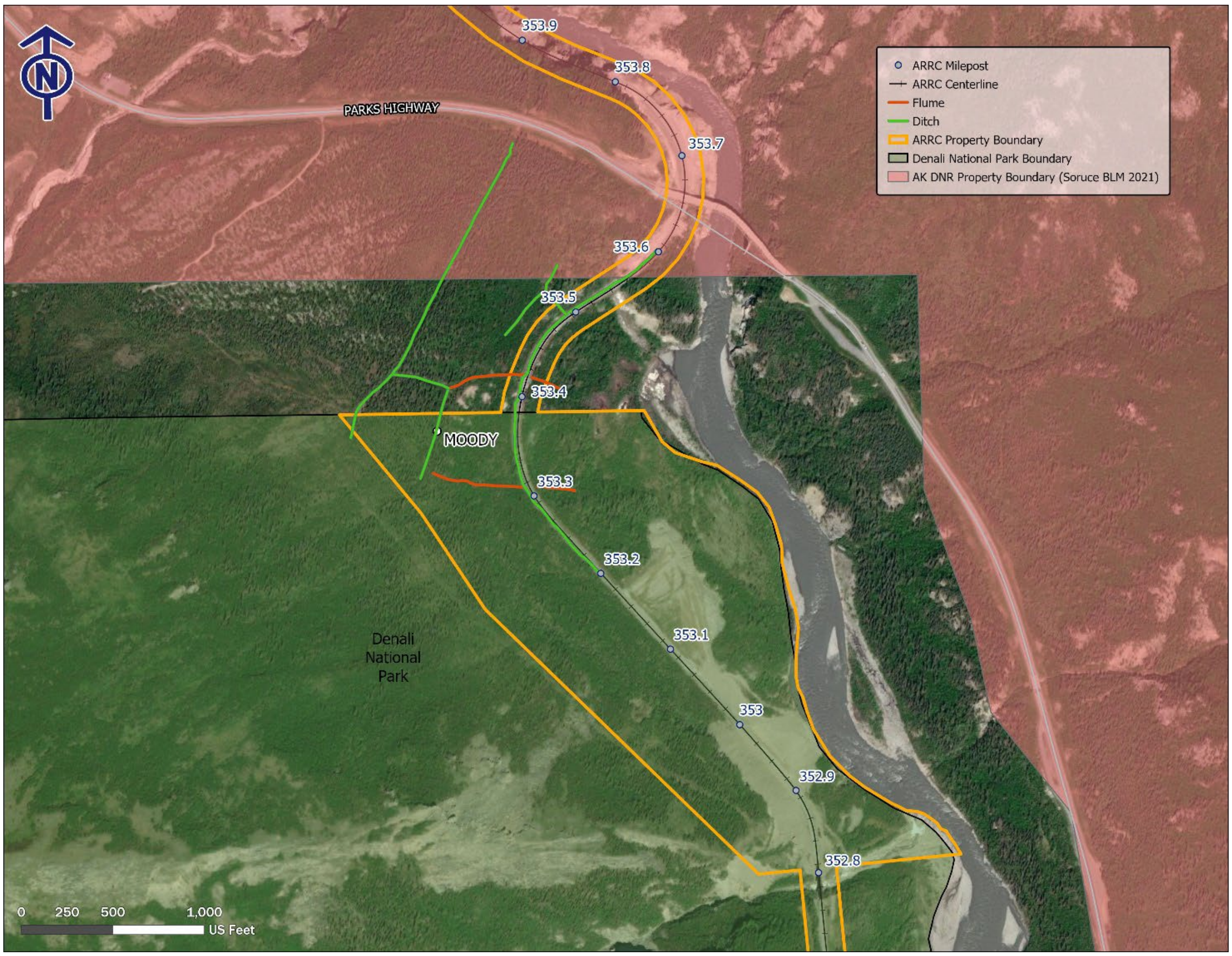


Figure 7.1: Land ownership in the project area

7.2 Permitting

Common to all alternatives: There are no wetlands, waterways, threatened or endangered species or critical habitat in the project area. The Nenana River is further downslope from the track; this is a regulatory feature, with US Army Corps of Engineers, US Coast Guard, AK Department of Fish & Game and AK Department of Natural Resources all having regulatory permitting requirements associated with impacts to the waterway. Each alternative's footprint stays outside of the bed and banks of the Nenana River. This area is unmapped for FEMA floodplains and we are confident all work will occur above any 100-yr flood extent.

There are no communities in the project vicinity, including minority or economically disadvantaged communities. Noise is unlikely to be an issue, given the lack of nearby residences. Disruptions to life or traffic patterns are unlikely except to the ARRC itself, which is proposing the improvements. Air quality is unlikely to be an issue given the generally good air quality in the area.

Cultural resource concerns, including prehistoric and historic resources and traditional cultural properties, are unlikely to be an issue given the project area's nature as a steeply sloped area prone to instability and landslide/movement. However, a **qualified cultural professional** should be relied upon to provide a more reliable evaluation of the area's potential for cultural or historic resources.

The proposed features will have a modest effect on hydrology; however, they are not anticipated to result in new permanent flows, instead they will enhance and improve existing drainage systems. The National Wetland Inventory indicates there are minimal wetlands in the project area and the extent of improvements under all tiers is minimal enough that the project can advance under a USACE Nationwide Permit (No. 14 Linear Transportation or No. 3 Maintenance of Existing Facilities).

Each of the Tiers is less than one acre of disturbance, so a SWPPP plan will not be required under the Construction General Permit.

A brief description of each Tier's environmental impacts and anticipated permits are:

Tier 1 - The improvements under this Tier include installing 5 culverts under the track and constructing rock-lined slope drains at the outlet of each culvert. Approximately 0.9 acres of land disturbance is expected in the form of clearing and grubbing ditches and slope drains. Approximately 533 cubic yards of riprap will be placed in slope drain. All work under this tier is within the ARRC ROW. No additional permits are anticipated.

Tier 2 - The improvements under this Tier include replacing the Northern Flume with a rock lined ditch and improving and extending the Northern Ditch on the Northern Bench. Ditch improvements largely involve lining the ditches with Class I riprap. Approximately 0.25 acres of land disturbance is expected in the form of clearing and grubbing ditches. Approximately 813 cubic yards of riprap will be placed in ditches. Some work will occur on DNR land and the unknown land between the Denali National Park and the AK DNR boundaries and will likely require a temporary land use permit.

Tier 3 - The improvements under this Tier include repairing a short section of the Middle Flume and improving and extending the Upper Ditch. Ditch improvements largely involve lining the ditches with Class I riprap. Approximately 0.17 acres of land disturbance is expected in the form of clearing and grubbing ditches. Approximately 533 cubic yards of riprap will be placed in ditches. Some work will occur on the unknown land between the Denali National Park and the AK DNR boundaries and will likely require a temporary land use permit.

352.9 Rockfall Mitigation – The improvements involve erecting Jersey Barriers and fencing along the toe of the hillside. All proposed work is within the ARRC ROW. No additional permits are anticipated.

8. Conclusions

The curve at MP353, known as the Moody slide area, has been subject to slope movement since the grade at MP353 was constructed. At one point, a 420-foot timber trestle was required to bridge the slide area until the depression was filled in 1943. Efforts to stabilize the slope can be observed in the existing drainage and retaining structures present along the curve. Recently, the slide area has seen less movement than in the past.

This report presents mitigation options to stabilize this section of track by improving existing drainage features to minimize surface infiltration within the active slide zone. Landslide areas may also be stabilized through large earthwork efforts or by installing retaining wall systems, however, drainage improvements are typically the most effective and lowest cost.

The recommendations below follow a review of existing geotechnical subsurface information, historical documents, and hydrology of the area. A site visit was conducted to assess conditions on the ground and take stock of the existing drainage features, including flumes, culverts, and ditches. This information was incorporated in the conceptual design Tiers. The drainage improvement Tiers address existing drainage issues and increase long term stability of the curve at MP353.

In addition, this report touches on the rockfall impacting the tracks at MP352.9 and recommends a conceptual solution to mitigate further impacts to operations and improve safety.

8.1 Moody Slide Drainage Recommendations

It is recommended that the drainage improvements detailed in this report are constructed, beginning with Tier 1 and Tier 2, and a monitoring program implemented. The monitoring program, at its most basic level, would help correlate weather events to maintenance and track movement for the rockfall and landslide and help inform future mitigation options. This data could be used in support of multiple ARRC engineering studies within Healy Canyon. ARRC may consider:

- Long term slope monitoring program to evaluate the effectiveness of any improvement.
- Clearly define land ownership boundary extents, specifically defining Federal land extents.
- A weather station, with a precipitation gage, installed in the Healy area to correlate precipitation events with observed slope movement. This data is useful for arctic engineering and determining climate effects on infrastructure.
- Regular change detection surveys to measure movement against the baseline data provided by the June 2021 LiDAR data. Slope inclinometers are one tool recommended to measure movement.

8.2 MP352.9 Rockfall Mitigation

It is recommended that a system of Jersey Barriers with a fencing barricade on top be constructed along the tracks, as outlined in Section 5. This area would benefit from the implementation of a monitoring system described for the Moody Slide area

9. Limitations

This report was prepared for use in the evaluation of the slope movement at MP353.2 along the ARRC alignment for conceptual design and planning purposes. The natural variability of earth materials across the project site may include variations in the subsurface conditions different than those characterized in this report. The conceptual design alternatives and improvements recommended in this report are conceptual and should be finalized during design.

This work was conducted following the standard of care expected of professionals undertaking similar work in the State of Alaska under similar conditions. No warranty, expressed or implied, is made.

10. References

Alaska Department of Transportation and Public Facilities. 2006. "*Highway Drainage Manual*".

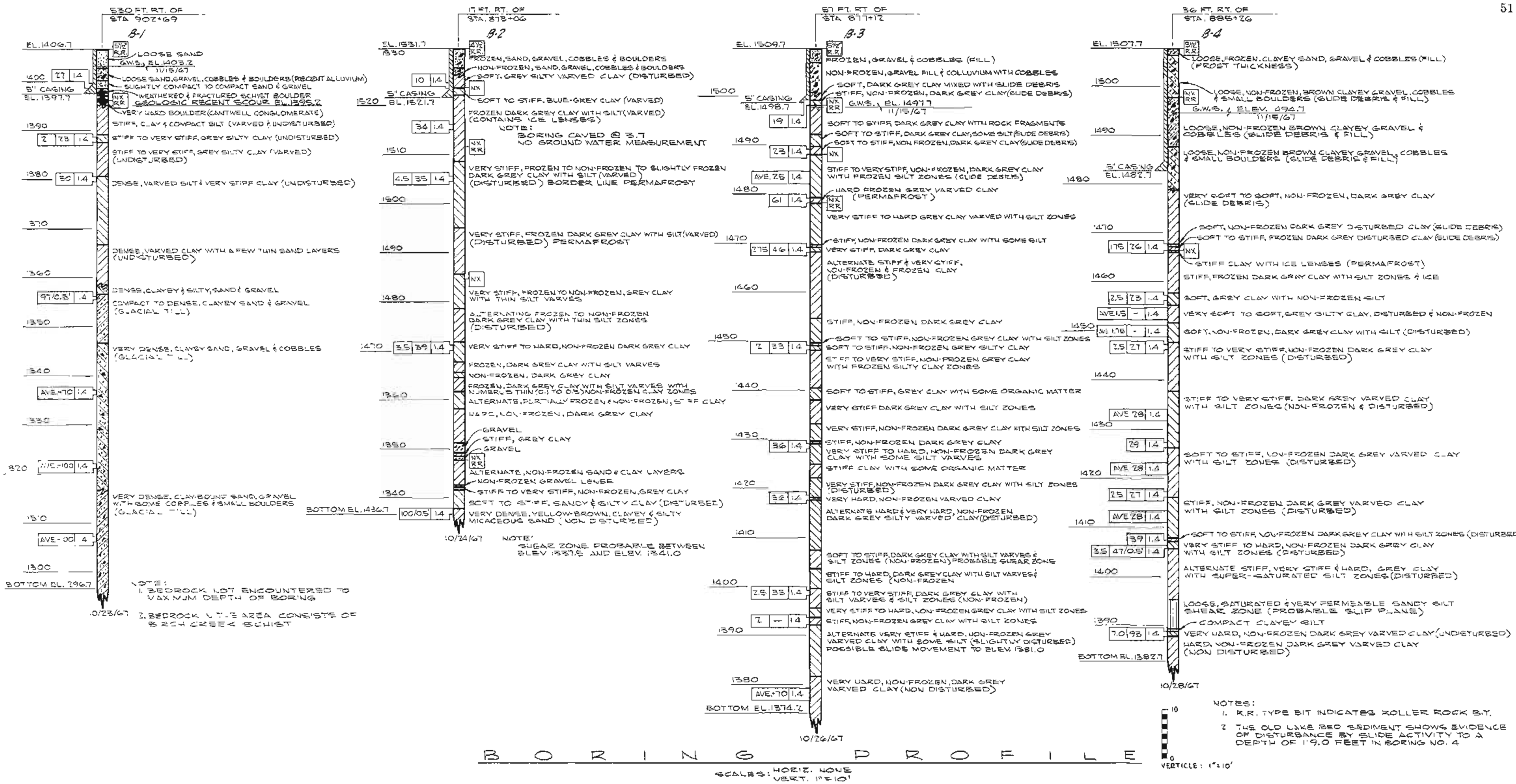
American Railway Engineering and Maintenance-of-Way Association. 2013. "*Part 4, Culverts*".

Fugelstad, T.C. 1983. "*The Alaska Railroad Between Anchorage and Fairbanks – Guidebook to Permafrost and Engineering Problems*". Division of Geological and Geophysical Surveys.

National Oceanic and Atmospheric Administration, University of Alaska Fairbanks. 2018. "*NOAA Atlas 14, Precipitation-Frequency Atlas of the United States*".

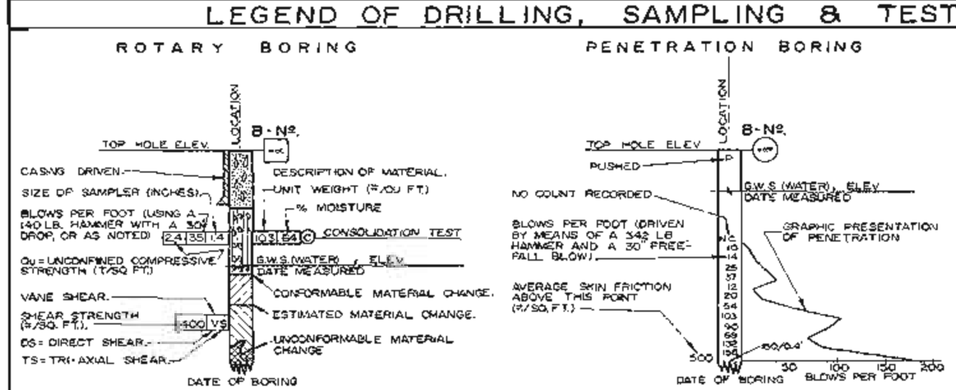
U.S. Global Change Research Program. 2014. "*The Third National Climate Assessment, Climate Change Impacts in the United States, Ch. 22: Alaska*".

Appendix A. 1968 Boring Logs – Moody Slide Near Garner



NOTES:
1. R.R. TYPE BIT INDICATES ROLLER ROCK BIT.
2. THE OLD LAKE BED SEDIMENT SHOWS EVIDENCE OF DISTURBANCE BY SLIDE ACTIVITY TO A DEPTH OF 19.0 FEET IN BORING NO. 4

LEGEND OF DRILLING, SAMPLING & TESTING OPERATIONS



PLAN OF ANY BORING
PENETROMETER (FLUSH-COUPLED)
2 1/4" CONE PENETROMETER
SAMPLER BORING (DRY)
ROTARY BORING (WET)
AUGER BORING (DRY)
JET BORING
DIAMOND CORE BORING
TEST PIT

BIT SIZES; (O.D.) "EX" = 1 15/32", "BX" = 2 3/32", "NX" = 2 29/32".
CASING SIZES, (O.D.) "BX" = 2 7/8", "NX" = 3 1/2".

THE UNIFIED SOIL CLASSIFICATION SYSTEM

MAJ. DIV.		LETTER	SYMBOL	NAME
COARSE GRAINED MATERIAL	GRAVEL AND GRAVELLY SOIL	GW		WELL-GRADED GRAVEL OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
		GP		POORLY-GRADED GRAVEL OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
		GM		SILTY GRAVEL, GRAVEL-SAND-SILT MIXTURES.
		GC		CLAYEY GRAVEL, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOIL	SW		WELL-GRADED SAND OR GRAVELLY SAND, LITTLE OR NO FINES
		SP		POORLY-GRADED SAND OR GRAVELLY SAND, LITTLE OR NO FINES
		SM		SILTY SAND, SAND-SILT MIXTURES
		SC		CLAYEY SAND, SAND-SILT MIXTURES

MAJ. DIV.		LETTER	SYMBOL	NAME
FINE GRAINED SOIL	SILTS AND CLAYS LL<50	ML		INORGANIC SILT AND VERY FINE SAND, ROCK FLOUR, SILTY OR CLAYEY FINE SAND OR CLAYEY SILT WITH SLIGHT PLASTICITY
		CL		INORGANIC CLAY OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAY, SANDY CLAY, SILTY CLAY, LEAN CLAY.
		OL		ORGANIC SILT AND ORGANIC SILT-CLAY OF LOW PLASTICITY.
	SILTS AND CLAYS LL>50	MH		INORGANIC SILT, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILT.
		CH		INORGANIC CLAY OF HIGH PLASTICITY, FAT CLAY
		OH		ORGANIC CLAY OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILT.
HIGHLY ORGANIC SOILS		PT		PEAT AND OTHER HIGHLY ORGANIC SOILS

ROCK CLASSIFICATION

SYMBOL	NAME
	IGNEOUS ROCK
	SEDIMENTARY ROCK
	METAMORPHIC ROCK

NOTE: CLASSIFICATION OF EARTH MATERIAL SHOWN ON THIS SHEET IS BASED UPON FIELD INSPECTION UNLESS NOTED OTHERWISE.

SOIL CONSISTENCY CLASSIFICATION

CONSISTENCY		* BLOWS PER FT.
GRANULAR	COHESIVE	
VERY LOOSE	VERY SOFT	0 TO 5
LOOSE	SOFT	5 TO 10
SLIGHTLY COMPACT	STIFF	10 TO 20
COMPACT	VERY STIFF	20 TO 35
DENSE	HARD	35 TO 70
VERY DENSE	VERY HARD	70

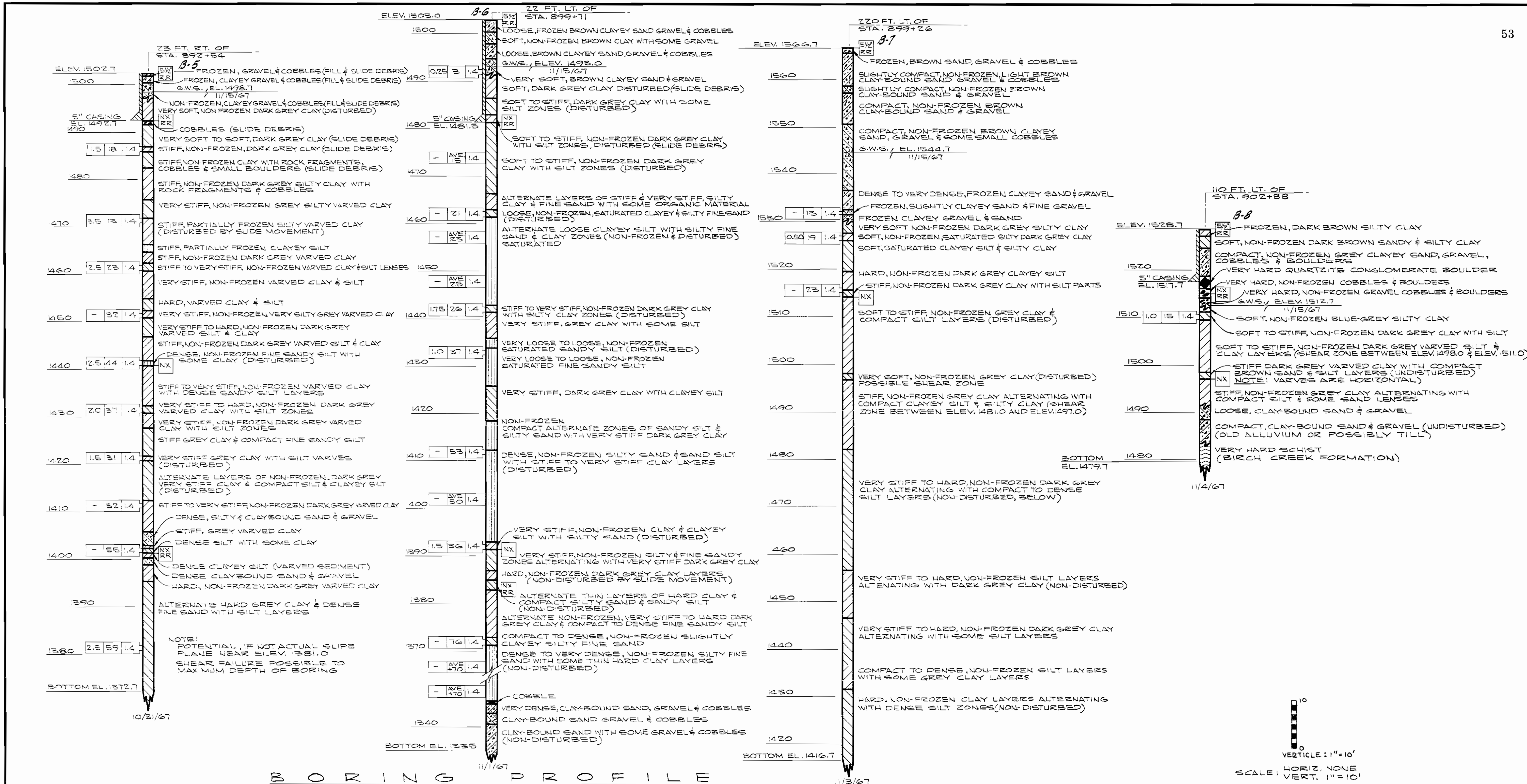
* (STANDARD PENETRATION TEST) BLOWS PER FT (140 LB HAMMER, 30" FREE-FALL BLOW USING A 2" O.D. x 1 3/8" I.D. SAMPLER).

DWN. CHK. OHA DATE JAN., 1968
Clair A. Hill — REG. CIVIL ENG. NO. 5438
ENGINEERING GEOLOGIST

CLAIR A. HILL & ASSOCIATES
FOUNDATION ENGINEERING & TESTING LABORATORY
1526 COURT STREET — REDDING, CALIFORNIA

LOG OF TEST BORINGS
THE ALASKA RAILROAD
MOODY SLIDE NEAR GARNER

DWG. NO. B-2 OF 3
C-1131.01



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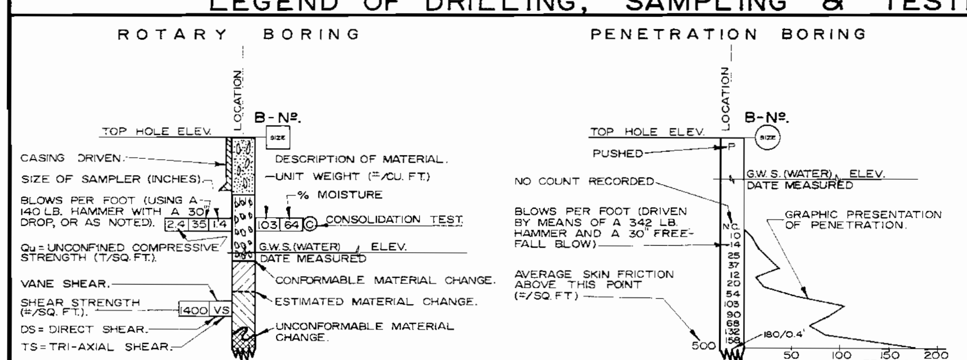

THE UNIFIED SOIL CLASSIFICATION SYSTEM

MAJ. DIV.		LETTER	SYMBOL	NAME
COARSE GRAINED MATERIAL	GRAVEL AND GRAVELLY SOIL	GW		WELL-GRADED GRAVEL OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
		GP		POORLY-GRADED GRAVEL OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES.
		GM		SILTY GRAVEL, GRAVEL-SAND-SILT MIXTURES.
		GC		CLAYEY GRAVEL, GRAVEL-SAND-CLAY MIXTURES.
	SAND AND SANDY SOIL	SW		WELL-GRADED SAND OR GRAVELLY SAND, LITTLE OR NO FINES
		SP		POORLY-GRADED SAND OR GRAVELLY SAND, LITTLE OR NO FINES
		SM		SILTY SAND, SAND-SILT MIXTURES.
		SC		CLAYEY SAND, SAND-SILT MIXTURES.

MAJ. DIV.		LETTER	SYMBOL	NAME
FINE GRAINED SOIL	SILTS AND CLAYS LL<50	ML		INORGANIC SILT AND VERY FINE SAND, ROCK FLOUR, SILTY OR CLAYEY FINE SAND OR CLAYEY SILT WITH SLIGHT PLASTICITY
		CL		INORGANIC CLAY OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAY, SANDY CLAY, SILTY CLAY, LEAN CLAY.
		OL		ORGANIC SILT AND ORGANIC SILT-CLAY OF LOW PLASTICITY.
	SILTS AND CLAYS LL>50	MH		INORGANIC SILT, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILT.
		CH		INORGANIC CLAY OF HIGH PLASTICITY, FAT CLAY.
		OH		ORGANIC CLAY OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILT.
HIGHLY ORGANIC SOILS		PT		PEAT AND OTHER HIGHLY ORGANIC SOILS.

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	SEDIMENTARY ROCK
	METAMORPHIC ROCK

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SOIL CONSISTENCY CLASSIFICATION

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GRANULAR	COHESIVE	
VERY LOOSE	VERY SOFT	0 TO 5
LOOSE	SOFT	5 TO 10
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COMPACT	VERY STIFF	20 TO 35
DENSE	HARD	35 TO 70
VERY DENSE	VERY HARD	70

* (STANDARD PENETRATION TEST) BLOWS PER FT. (140 LB. HAMMER, 30" FREE-FALL BLOW USING A 2" O.D. x 1 3/8" I.D. SAMPLER).

DWN. [signature] CHK. [signature] DATE: JAN., 1968

Clair A. Hill — REG. CIVIL ENG. NO. 5438
[signature] — ENGINEERING GEOLOGIST

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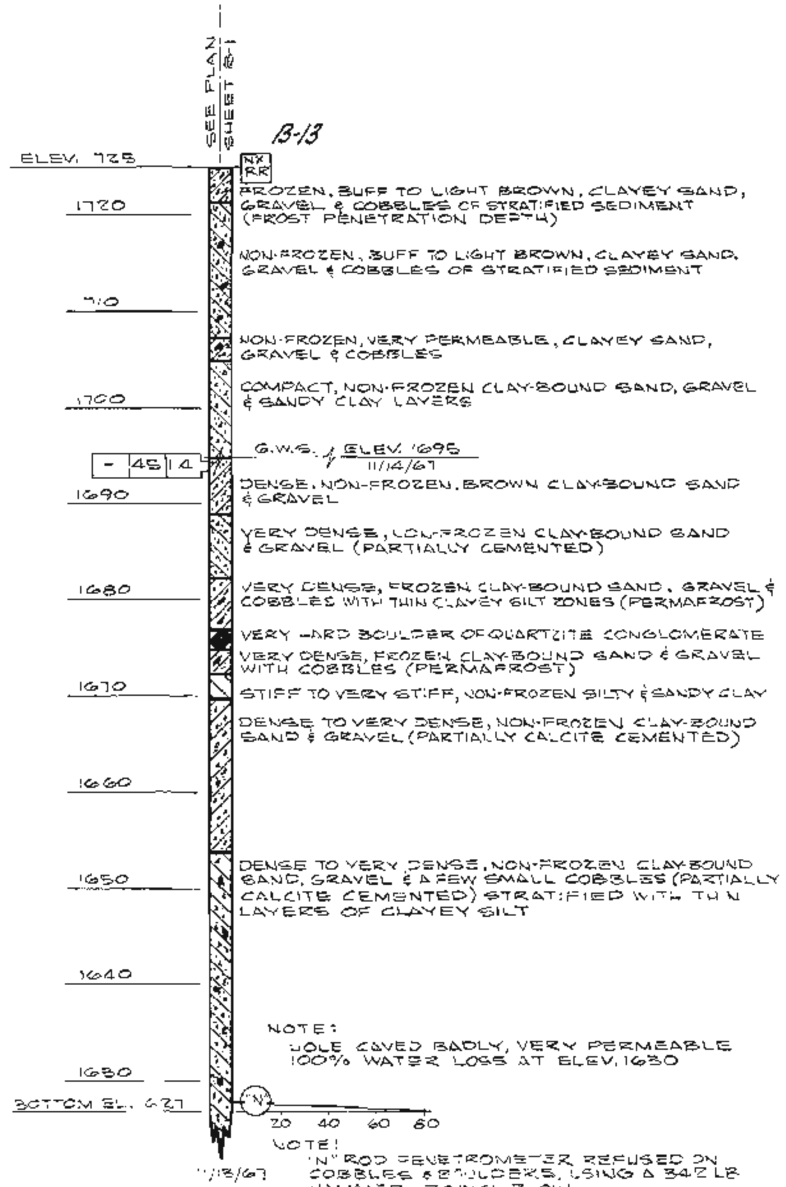
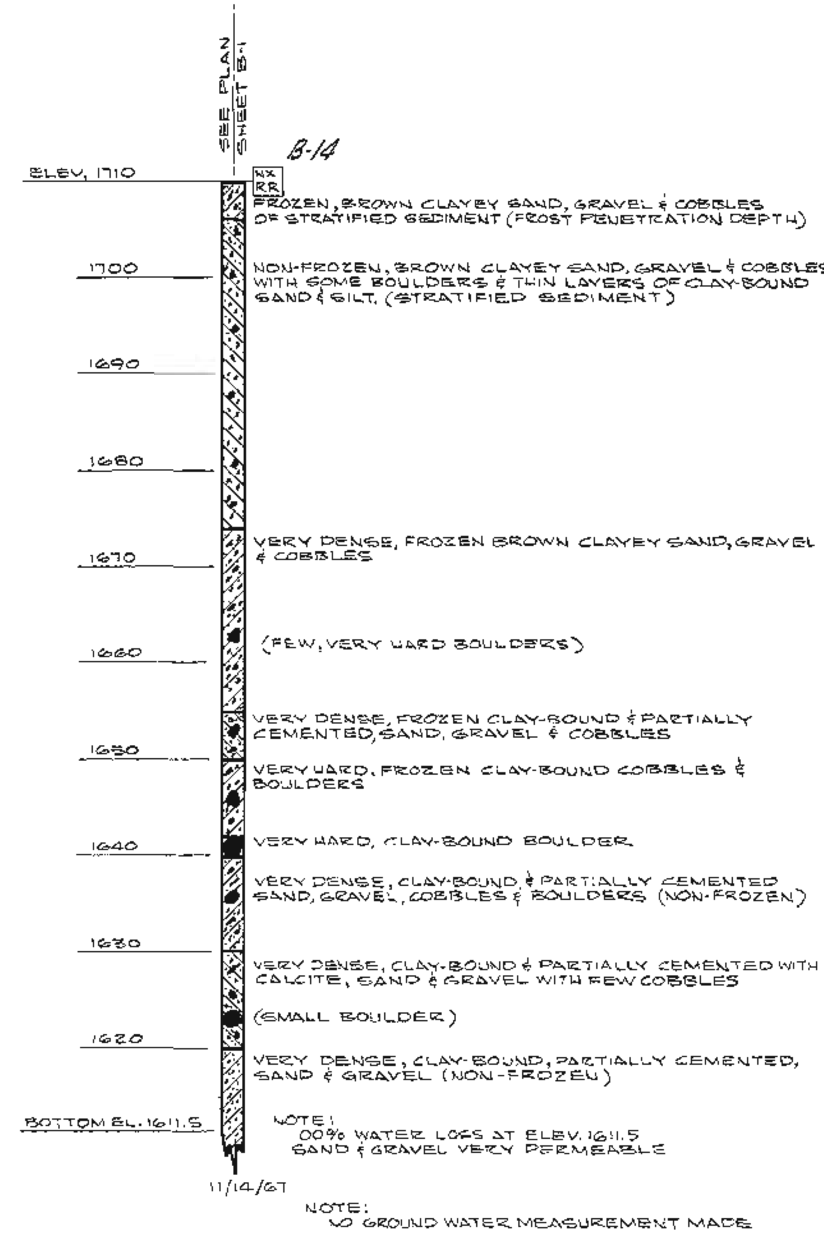
LOG OF TEST BORINGS
THE ALASKA RAILROAD
MOODY SLIDE NEAR GARNER

DWG. NO. B-3 OF 5
C-1131.01



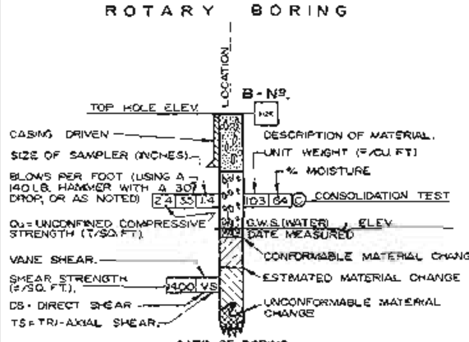


BORING PROFILE

SCALES: HORIZ. NONE
VERT. 1"=10'

LEGEND OF DRILLING, SAMPLING & TESTING OPERATIONS

ROTARY BORING



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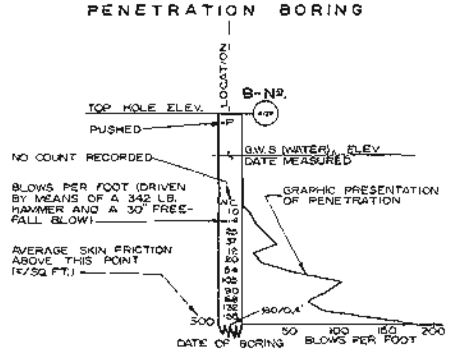

- PLAN OF ANY BORING
- PENETROMETER (FLUSH-COUPLED)
- 2 1/4" CONE PENETROMETER
- SAMPLER BORING (DRY)
- ROTARY BORING (WET)
- AUGER BORING (DRY)
- JET BORING
- DIAMOND CORE BORING
- TEST PIT

BIT SIZES: (O.D.) "AX" = 1 7/8", "BX" = 2 5/32", "NX" = 2 29/32".
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		GM		SILTY GRAVEL, GRAVEL-SAND-SILT MIXTURES.
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MAJ. DIV.		LETTER	SYMBOL	NAME
FINE GRAINED SOIL	SILTS AND CLAYS LL<50	ML		INORGANIC SILT AND VERY FINE SAND, ROCK FLOUR, SILTY OR CLAYEY FINE SAND OR CLAYEY SILT WITH SLIGHT PLASTICITY
		CL		INORGANIC CLAY OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAY, SANDY CLAY, SILTY CLAY, LEAN CLAY.
		OL		ORGANIC SILT AND ORGANIC SILT-CLAY OF LOW PLASTICITY.
	SILTS AND CLAYS LL>50	MH		INORGANIC SILT, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILT
		CH		INORGANIC CLAY OF HIGH PLASTICITY, FAT CLAY
		OH		ORGANIC CLAY OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILT
HIGHLY ORGANIC SOILS		PT		PEAT AND OTHER HIGHLY ORGANIC SOILS.

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	METAMORPHIC ROCK

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CONSISTENCY		* BLOWS PER FT.
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VERY LOOSE	VERY SOFT	0 TO 5
LOOSE	SOFT	5 TO 10
SLIGHTLY COMPACT	STIFF	10 TO 20
COMPACT	VERY STIFF	20 TO 35
DENSE	HARD	35 TO 70
VERY DENSE	VERY HARD	70

* (STANDARD PENETRATION TEST) BLOWS PER FT (140 LB HAMMER, 30" FREE-FALL BLOW USING A 2" O.D. x 1 3/8" I.D. SAMPLER).

DWN.: [signature]
CHKD.: [signature]
DATE: JAN. 1968
[signature] REG. CIVIL ENG. NO. 5438
[signature] ENGINEERING GEOLOGIST

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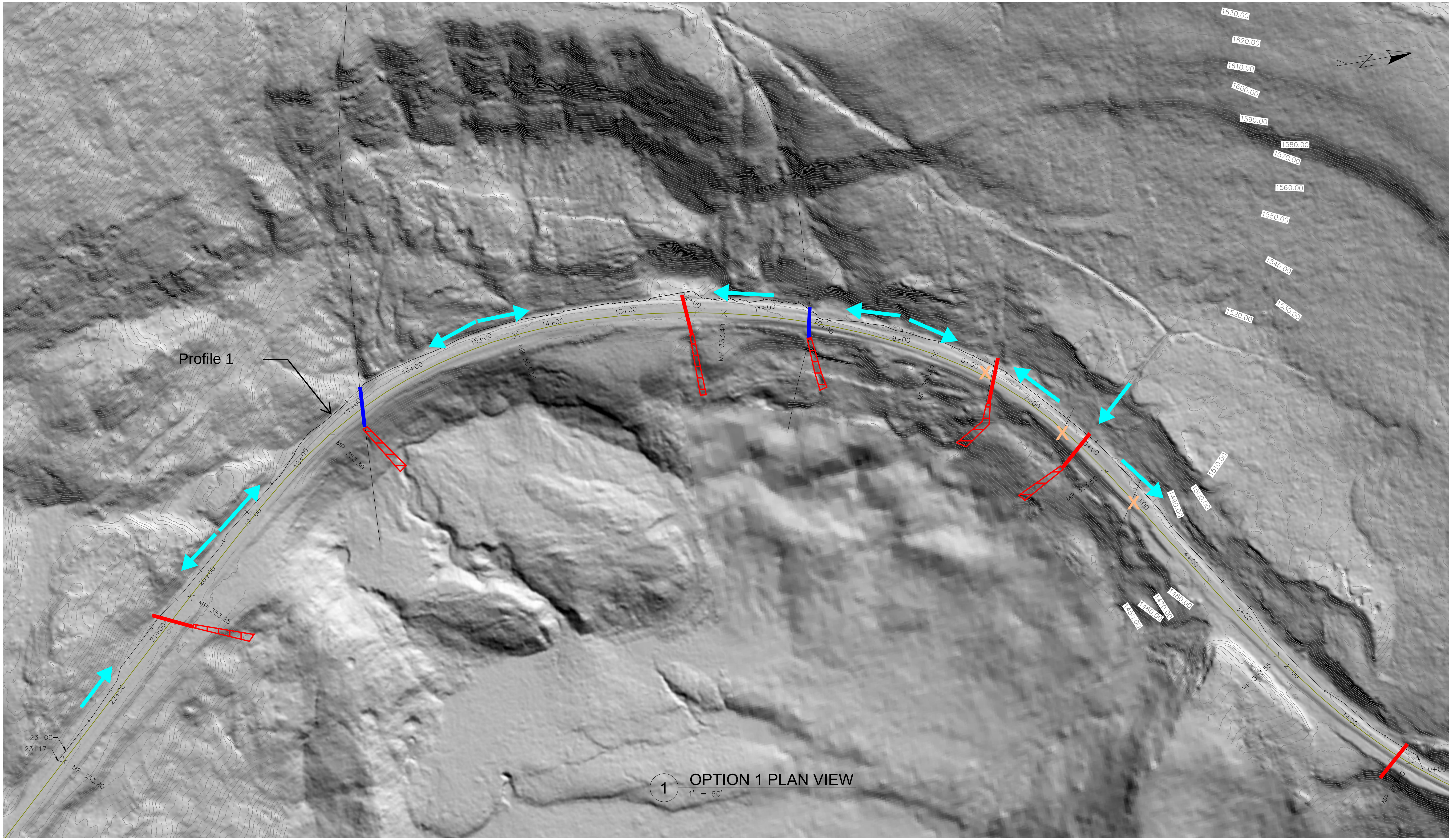
LOG OF TEST BORINGS
THE ALASKA RAILROAD
MOODY SLIDE NEAR GARNER

DWG. NO. B-5 OF 5
C-1131.01

Appendix B. Tier 1



1 OPTION 1 PLAN VIEW
1" = 60'

X Remove Culvert
New Culvert
Existing Culvert (Good Condition)
Rock-Lined Slope Drain
Flow Direction

NO.	DATE	REVISION	BY	CHK	APPD

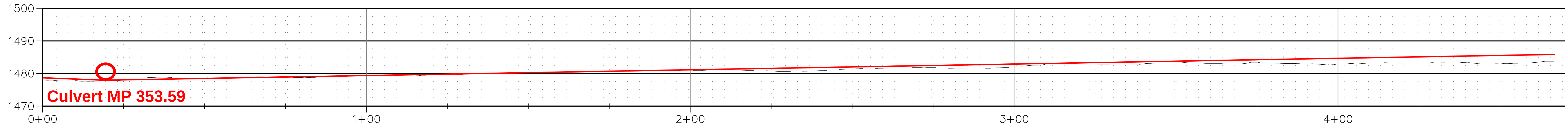
PRELIMINARY NOT FOR CONSTRUCTION

ENGINEERING RECORD		DATE
DRN:	KRH	11/23/2021
DSGN:	XXX	XX/XX/2021
CHK:	XXX	XX/XX/2021
APP:		
APP:		
SCALE:	VARIES	

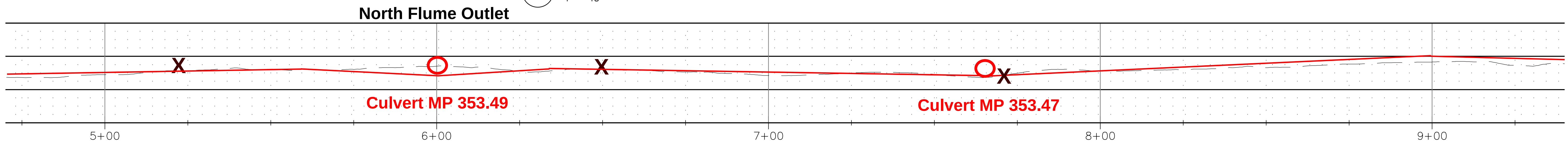
Michael Baker
INTERNATIONAL

ARRC MP 353.2
SLOPE FAILURE IMPROVEMENTS
Tier 1 PLAN

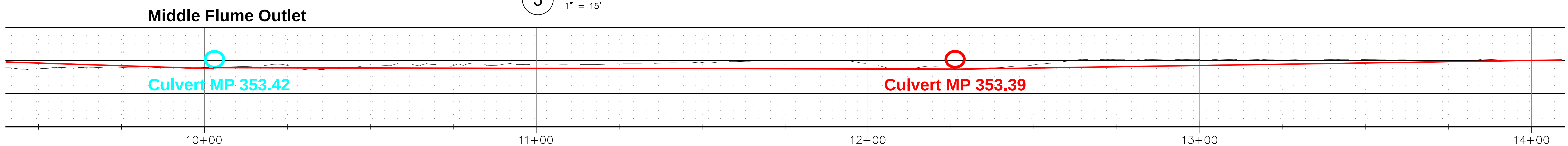
TASK ORDER	DOCUMENT NUMBER	SHEET	REVISION
DELIVERABLE NUMBER 186593		01	#



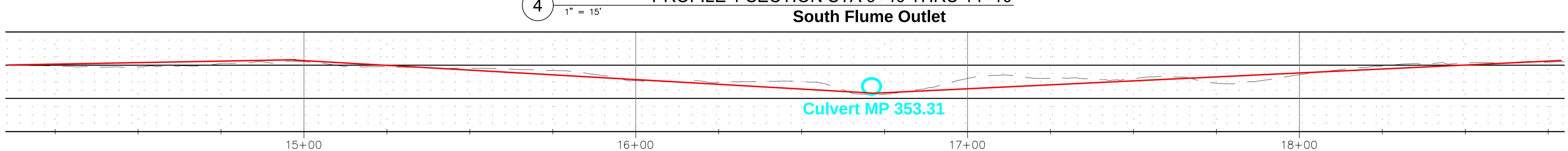
2 PROFILE 1 SECTION STA 0+00 THRU 4+70
1" = 15'



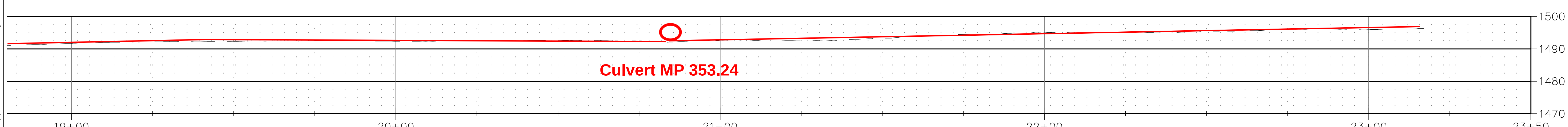
3 PROFILE 1 SECTION STA 4+70 THRU 9+40
1" = 15'



4 PROFILE 1 SECTION STA 9+40 THRU 14+10
1" = 15'



5 PROFILE 1 SECTION STA 14+10 THRU 18+80
1" = 15'



6 PROFILE 1 SECTION STA 18+80 THRU 23+50
1" = 15'

X Remove Existing Culvert
○ New Culvert
— Proposed Ground
○ Existing Culvert (Good Condition)

NO.	DATE	REVISION	BY	CHK	APPD

PRELIMINARY NOT FOR CONSTRUCTION

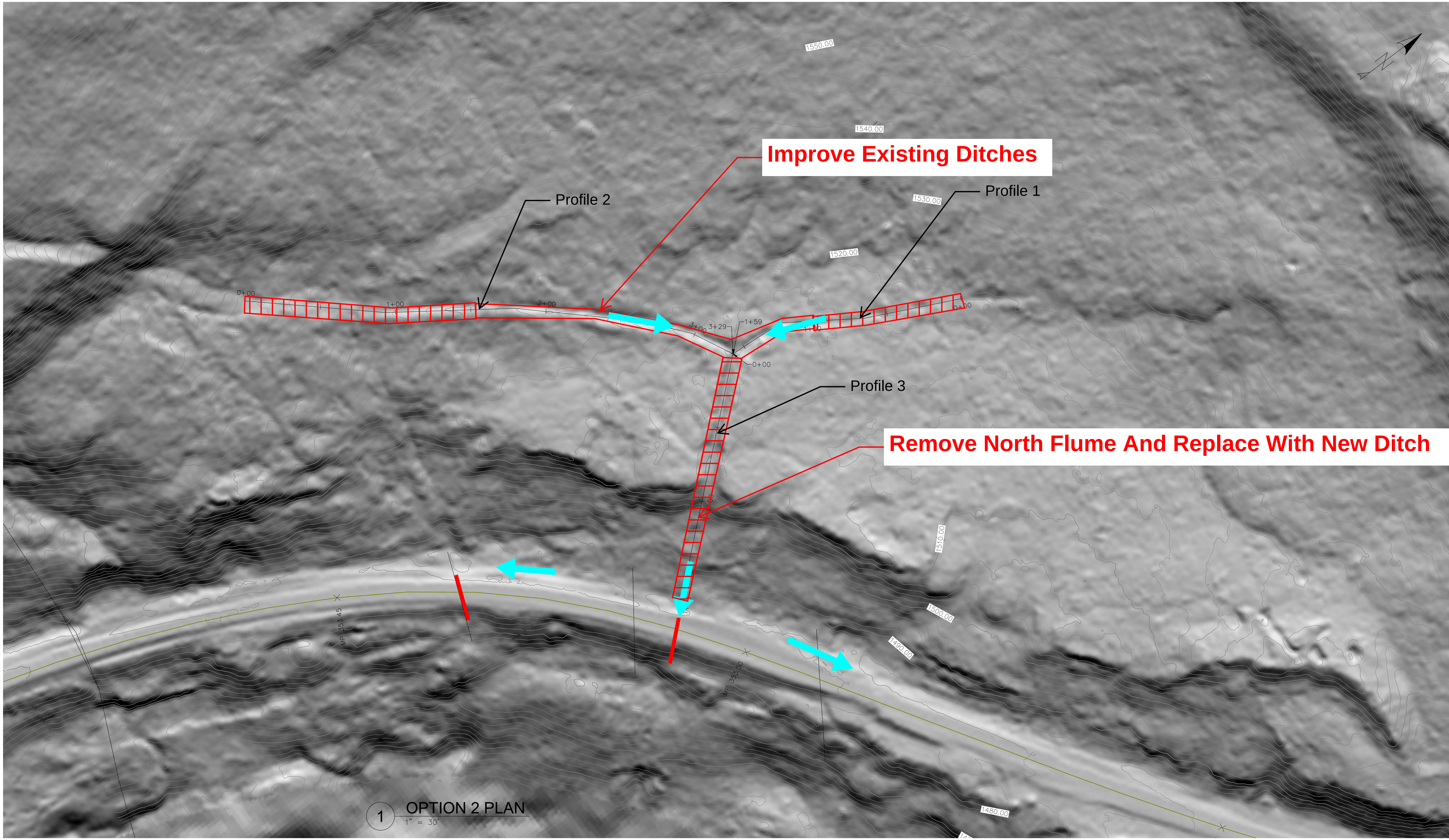
ENGINEERING RECORD		DATE
DRN:	KRH	11/23/2021
DSGN:	XXX	XX/XX/2021
CHK:	XXX	XX/XX/2021
APP:		
APP:		
SCALE: VARIES		

Michael Baker INTERNATIONAL

ARRC MP 353.2
SLOPE FAILURE IMPROVEMENTS
Tier 1 PROFILE SECTION CUTS

TASK ORDER	DOCUMENT NUMBER	SHEET	REVISION
DELIVERABLE NUMBER 186593		02	#

Appendix C. Tier 2



1 OPTION 2 PLAN
1" = 30'

Legend	
New Culverts (Tier 1)	Flow Direction
Existing Ditches	
Proposed Ditch Extension	

NO.	DATE	REVISION	BY	CHK	APPD

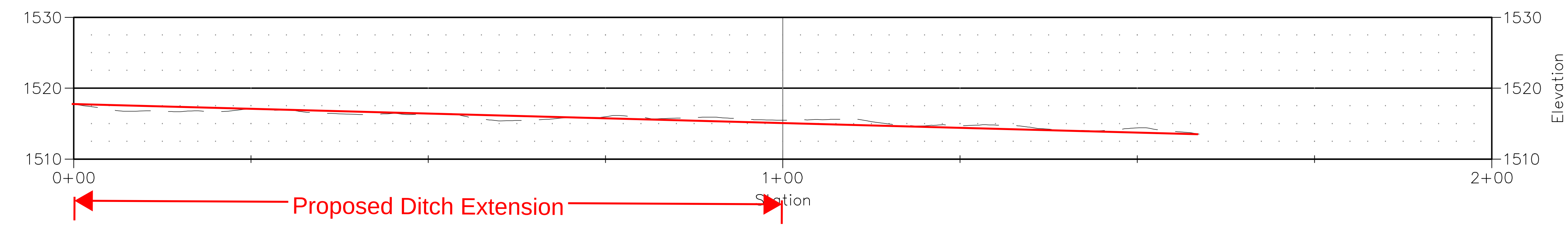
PRELIMINARY NOT FOR CONSTRUCTION

ENGINEERING RECORD		DATE
DRN:	KRH	11/23/2021
DSGN:	XXX	XX/XX/2021
CHK:	XXX	XX/XX/2021
APP:		
APP:		
SCALE:	VARIES	

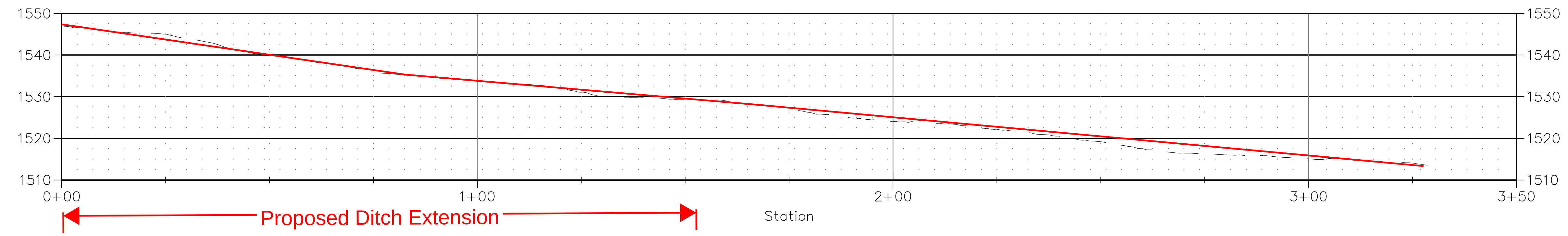
Michael Baker INTERNATIONAL

ARRC MP 353.2
SLOPE FAILURE IMPROVEMENTS
Tier 2 PLAN

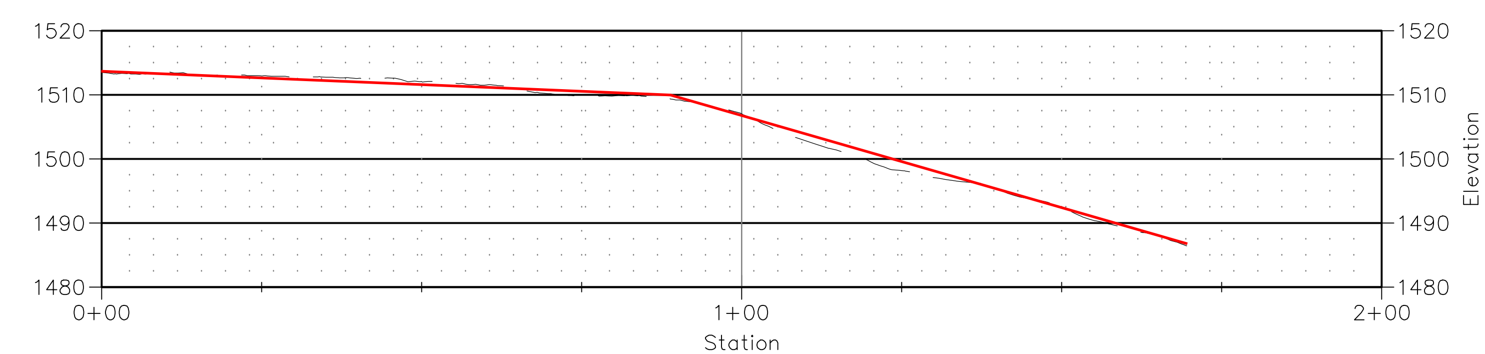
TASK ORDER	DOCUMENT NUMBER	SHEET	REVISION
DELIVERABLE NUMBER 186593		01	#



2 PROFILE 1 SECTION
1" = 10'



3 PROFILE 2 SECTION
1" = 15'



4 PROFILE 3 SECTION
1" = 15'

Proposed Ground

NO.	DATE	REVISION	BY	CHK	APPD

PRELIMINARY NOT FOR CONSTRUCTION

ENGINEERING RECORD		DATE
DRN:	KRH	11/23/2021
DSGN:	XXX	XX/XX/2021
CHK:	XXX	XX/XX/2021
APP:		
APP:		
SCALE:	VARIES	

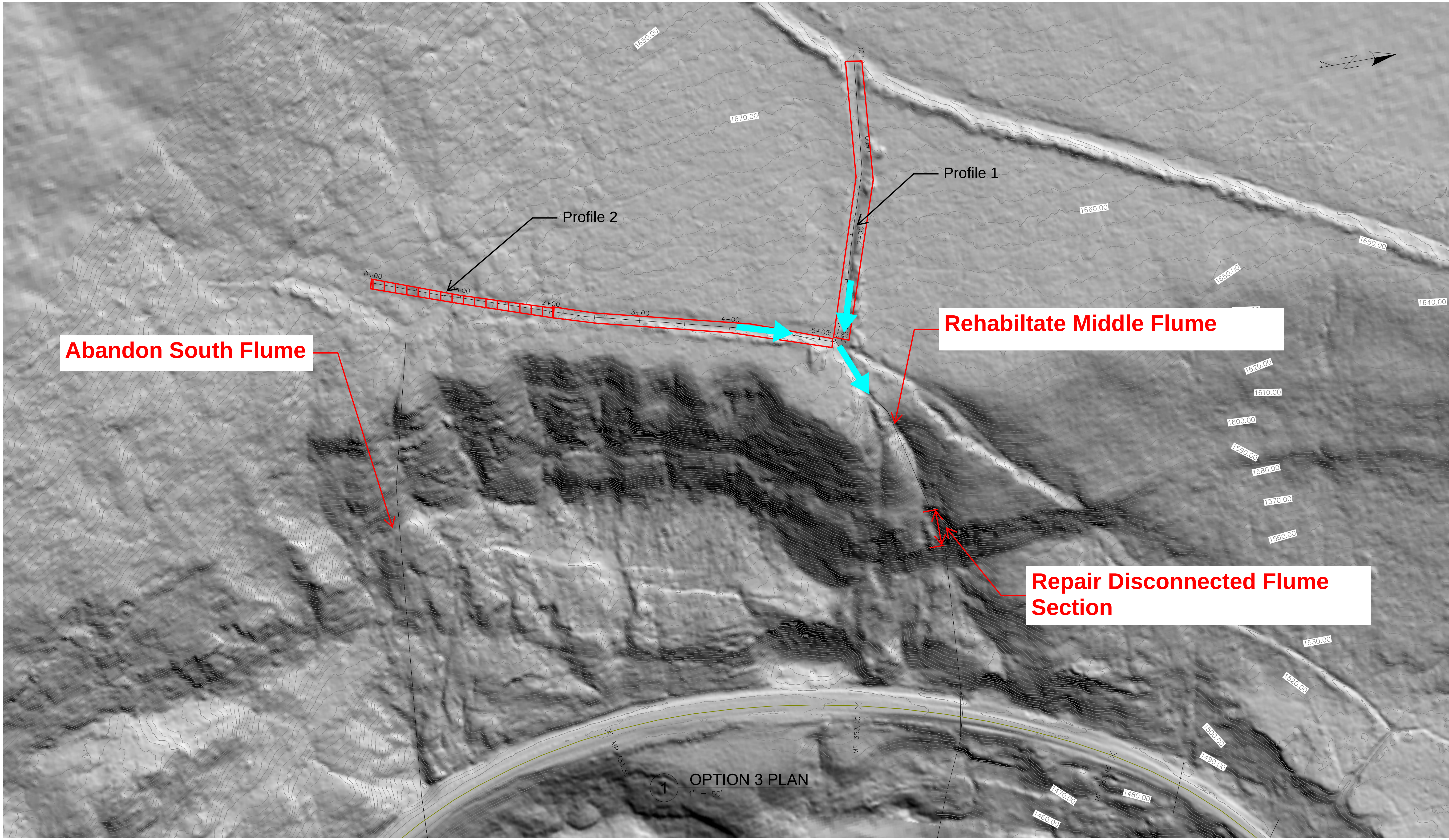
Michael Baker INTERNATIONAL

ARRC MP 353.2
SLOPE FAILURE IMPROVEMENTS
Tier 2 PROFILE SECTION CUTS

TASK ORDER	DOCUMENT NUMBER	SHEET	REVISION
DELIVERABLE NUMBER 186593		02	#

Appendix D. Tier 3

File Path: C:\Users\Kaylin.Hampson\Desktop\ARRC\troubleshoot\Option 3 Plan and Profile.dwg -- Date: Nov 23, 2021 4:45pm -- Kaylin.Hampson



Flow Direction
Improve Existing Ditches
Proposed Ditch Extension

NO.	DATE	REVISION	BY	CHK	APPD

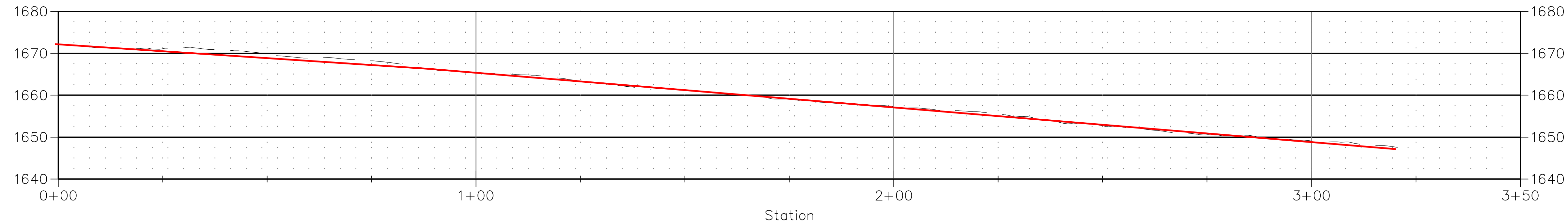
PRELIMINARY NOT FOR CONSTRUCTION

ENGINEERING RECORD		DATE
DRN:	KRH	11/23/2021
DSGN:	XXX	XX/XX/2021
CHK:	XXX	XX/XX/2021
APP:		
APP:		
SCALE:	VARIES	

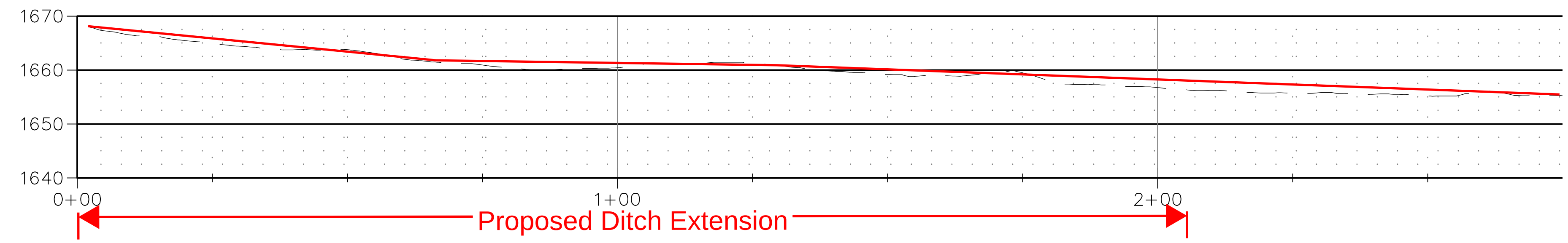
Michael Baker INTERNATIONAL

ARRC MP 353.2
SLOPE FAILURE IMPROVEMENTS
Tier 3 PLAN

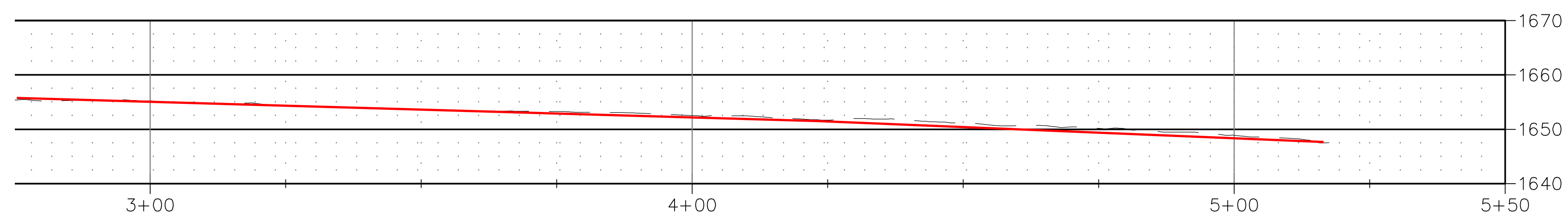
TASK ORDER	DOCUMENT NUMBER	SHEET	REVISION
DELIVERABLE NUMBER 186593		01	#



2 PROFILE 1 SECTION
1" = 15'



3 PROFILE 2 SECTION STA 0+00 THRU 2+75
1" = 15'



4 PROFILE 2 SECTION STA 2+75 THRU 5+50
1" = 15'

— Proposed Ground

NO.	DATE	REVISION	BY	CHK	APPD

PRELIMINARY NOT FOR CONSTRUCTION

ENGINEERING RECORD		DATE
DRN:	KRH	11/23/2021
DSGN:	XXX	XX/XX/2021
CHK:	XXX	XX/XX/2021
APP:		
APP:		
SCALE:	VARIES	

Michael Baker INTERNATIONAL

ARRC MP 353.2
SLOPE FAILURE IMPROVEMENTS
Tier 3 PROFILE SECTION CUTS

TASK ORDER	DOCUMENT NUMBER	SHEET	REVISION
DELIVERABLE NUMBER 186593		02	#

Appendix E. Cost Estimate Details

Tier 1 Cost - $260,000					
Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Notes / Comments**
Additional Culverts					
Culverts	5	EA	$ 30,000	$ 150,000	Culvert installed cost per ARRC Meeting
Ditch Cleaning and Sloping					
Background Information					
Ditch Length	2300	FT			Ditch Along Track
Estimate					
Equipment	5	DAYS	$ 493	$ 2,467	Ditcher, Assumed 500 ft/day
Labor	10	DAYS	$ 1,178	$ 11,782	2 laborers a day, Assumed 500 ft/day
			Total	**$ 14,249**	
Rock Lined Downstream of Culvert Slope Drains					
Background Information					
Existing Culverts	2	EA			Site Visit
Proposed Culverts	4	EA			Per MBI Planning
Distance to end of clay layer	100	FT			Assumed
Riprap Width	12	FT			3 times 4' culvert diameter (assumed)
Riprap Thickness	2	FT			Typical
Estimate					
Riprap	360	TONS	$ 22.00	$ 7,920	2 Feet thick
Woven Geotextile Fabric	2	EA	$ 525	$ 1,050	Contech C300, 15' x 300'
Labor	12	DY	$ 788	$ 9,457	2 laborers a day, (1 culvert per day)
Equipment	6	DY	$6,599.87	$ 39,599	2 loaders, work train, lube truck, excavator
			Total	**$ 58,026**	
Box Culverts to be Filled					
Background Information					
Box Culverts to be Filled	5	EA			Estimated
Culvert Width	4	FT			Site Visit
Culvert Height	4	FT			Site Visit
Culvert Length	40	FT			Assumed
Estimate					
Flow Fill (concrete)	119	YDS	$ 133.00	$ 15,763	Flow Fill Per MP 53.35 Culvert Estimate
Labor	5	DY	$ 788.05	$ 3,940	2 laborers a day, (1 culvert per day)
Equipment	5	DY	$3,669.90	$ 18,350	2 loaders, lube truck, excavator (Per day), work train (1 Total)
			Total	**$ 38,053**	

Tier 2 Cost - $225,000					
Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Notes / Comments**
Ditch Cleaning and Sloping					
Background Information					
Ditch Length	915	FT			Per MBI Planning
Estimate					
Equipment	2	DAYS	$ 493	$ 987	Assumed 500 ft/day
Labor	2	DAYS	$ 1,178	$ 2,356	2 laborer's a day, Assumed 500 ft/day
			Total	**$ 3,343**	
Flume Removal					
Background Information					
Flume Length	300	FT			Per MBI Planning
Estimate					
Equipment	1	DAYS	$ 879	$ 879	Excavator, Lube truck, Assumed 300 ft/day
Labor	2	DAYS	$ 1,178	$ 2,356	2 laborer's a day, Assumed 300 ft/day
			Total	**$ 3,236**	
New Ditch Extension					
Equipment	3	DAYS	$ 1,647	$ 4,942	2 Excavators, 1 Lube truck, Assumed 100 ft/day
Labor	12	DAYS	$ 1,178	$ 14,138	4 laborer's a day, Assumed 100 ft/day
			Total	**$ 19,080**	
Rock Lined Ditch					
Background Information					
Ditch Width Top	15	FT			Assumed
Ditch Width Bottom	3	FT			Assumed
Ditch Height	3	FT			Assumed
Wetted Perimeter	16.4	FT			Trapezoidal Ditch Wetted Perimeter
Riprap Thickness	2	FT			Typical for ditch lining
Estimate					
Riprap	2253	TONS	$ 22.00	$ 49,569	
Woven Geotextile Fabric	4	EA	$ 525	$ 2,100	Contech C300, 15' x 300'
Labor	20	DAYS	$ 788	$ 15,761	2 laborers a day, 100ft/day
Equipment	20	DAYS	$6,599.87	$ 131,997	2 loaders, work train, lube truck, excavator 100ft/day
			Total	**$ 199,428**	

Tier 3 - Cost $219,000					
Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Notes / Comments**
Upper Ditch Cleaning and Sloping					
Background Information					
Total Ditch Length	600	FT			Per MBI Planning
Estimate					
Equipment	2	DAYS	$ 493	$ 987	Assumed 500 ft/day
Labor	4	DAYS	$ 1,178	$ 4,713	2 Laborer's a day, Assumed 100 ft/day
			Total	**$ 5,700**	
Upper Ditch Extension					
Background Information					
Ditch Extension Length	200	FT			Per MBI Planning
Estimate					
Equipment	2	DAYS	$ 1,647	$ 3,295	2 Excavators, 1 Lube truck, Assumed 100 ft/day
Labor	8	DAYS	$ 1,178	$ 9,426	4 Laborer's a day, Assumed 100 ft/day
			Total	**$ 12,720**	
Rock Lined Ditch					
Background Information					
Ditch Width Top	6	FT			Assumed
Ditch Width Bottom	4	FT			Assumed
Ditch Height	4	FT			Assumed
Wetted Perimeter	12.2	FT			Trapezoidal Ditch Wetted Perimeter
Riprap Thickness	2	FT			Typical
Estimate					
Riprap	1102	TONS	$ 22.00	$ 24,247	
Woven Geotextile Fabric	1	EA	$ 525	$ 525	Contech C300, 15' x 300'
Labor	1	DY	$ 788	$ 788	2 laborers a day, 250ft/day
Equipment	1	DY	$6,599.87	$ 6,600	2 loaders, work train, lube truck, excavator 250ft/day
			Total	**$ 7,388**	
Flume Repairs					
Flume Repairs	100	FT	$ 1,125	$ 112,500	Assumed 1/2 of a buried culvert cost installed
Flume Cleaning					
Labor	4	DAYS	$ 1,178	$ 4,713	Assumed 2 workers, 2 days
Site Access Logistics					
Access		30% of total		$ 50,400	

Appendix D. Retaining Wall Assessment Sheets

Michael Baker INTERNATIONAL

Healy Canyon Retaining Wall Assessment Sheets

186863-MBI-CE-RPT-001

Final Report

Prepared for:

ALASKA RAILROAD

Alaska Railroad Corporation
327 West Ship Creek Ave
Anchorage, Alaska 99510

Prepared by:
Michael Baker International
3900 C Street Suite 900
Anchorage, AK 99503
907-273-1600

April 6, 2022

EXECUTIVE SUMMARY

Over the course of two trips in 2021, 41 retaining walls were identified and inspected in Healy Canyon between MP 348 and MP 361. An Inventory and Condition Assessment was performed; assigning a 1 (poor) through 5 (excellent) value to the associated wall based on a list of pre-defined items included in the Alaska Railroad Retaining Wall Inspection Form. Roughly 50% of the walls in this section of track received a score of 1 (poor) or 2 (marginal) requiring immediate attention within the next year. In this report, all 41 walls are organized into described below with the walls in (1-Poor) Condition broken into a detailed three-part assessment.

- Part 1 - Alaska Railroad Retaining Wall Inspection Form
- Part 2 - Alaska Railroad Retaining Wall Inspection Photo Sheets
- Part 3 - Alaska Railroad Retaining In depth Wall Evaluation

PHASE 1 (INPROGRESS & SIMPLICITY)

Wall Number	Combination Project
Wall 3	None
Wall 25	Yes - Wall 24

PHASE 2 (HIGH CRITICALITY OF WALL FAILURE)

Wall Number	Combination Project
Wall 36	Yes – Wall 38
Wall 41	Yes – Wall 42

PHASE 3 (HIGHER COST & ADDITIONAL ENGINEERING DESIGN)

Wall Number	Combination Project
Wall 17A	Yes – Wall 16 & 17B
Wall 22	None

PHASE 4 (LEAST CRITICAL)

Wall Number	Combination Project
Wall 4	None

Prioritized by condition statement and combined into projects based on wall proximity; Phase 4 also includes a summary table for the remaining walls analyzed in the inventory.

Revision History

Rev #	Originator	Reviewed By	Approved By	Date	Description
A	Kubic, Andy	Hokenega, Lisa	Yager, Garrett	12/10/2021	Draft – Issued for Review
0	Kubic, Andy	Hokenega, Lisa	Yager, Garrett	04/06/2022	Final – Issued for Use

TABLE OF CONTENTS

TABLES

FIGURES

1. Introduction

ARRC has 7 retaining walls with a poor condition rating between Denali National Park and Healy yard, these poor walls are critically damaged or in need of immediate repair and are well past their useful life. Below the Walls have been broken up into Phases. Criticality is determined by multiple factors, the distance of the wall to the tracks, slope of ground below wall, geometric interaction with area upstation and downstation of wall, and effect of the wall failure on safe passage of trains. The range is from 1-3 with 1 being dangerous effect on railroad if wall fails, 2 being moderate effect on railroad if wall fails, and 3 little effect on railroad if wall fails. The cost is a range of $-$$$, this range is relative to these specific walls and includes the general cost of labor, materials, and design of the replacement/repair. Of the 41 walls 7 have a poor rating and 13 have a marginal rating. The marginal rated walls are defective or deteriorated and in need of replacement or repair within a year some of these walls have been shown below in the tables as combination projects with the designated poor walls. Additional description of these phases is provided below the following summary.

PHASE 1 (INPROGRESS & SIMPLICITY)

Wall Number	Region Number	Criticality (1-3)	Cost ($-$$$)	Combination Project
Wall 3	1	1	$$	None
Wall 25	3	2	$	Yes - Wall 24

PHASE 2 (HIGH CRITICALITY OF WALL FAILURE)

Wall Number	Region Number	Criticality (1-3)	Cost ($-$$$)	Combination Project
Wall 36	3	1	$$	Yes – Wall 38
Wall 41	4	1	$$	Yes – Wall 42

PHASE 3 (HIGHER COST & ADDITIONAL ENGINEERING DESIGN)

Wall Number	Region Number	Criticality (1-3)	Cost ($-$$$)	Combination Project
Wall 17A	2	3	$$	Yes – Wall 16 & 17B
Wall 22	3	1	$$$	None

PHASE 4 (LEAST CRITICAL)

Wall Number	Region Number	Criticality (1-3)	Cost ($-$$$)	Combination Project
Wall 4	1	3	$$	None

2. Phase 1 (InProgress and Simplicity)

Wall 3 and Wall 25 have been set in Phase 1 due to the simplicity of repair/replacement. Existing Wall 3 main structural section is comprised of a timber pile wall system with cable tiebacks. The north end of the wall is already in the process of being replaced with a soldier pile wall. On the right side of tracks there is potential to have a work area that can be used as staging storage that outside of foul zone, where workers and equipment can clear during construction. Since there is new construction going on it is assumed no engineering work or additional design would need to be done to complete the wall. The existing Wall 25 main structural section is comprised of a soldier pile wall with timber lagging and cable tiebacks. The top timber lagging is missing, and the remainder is failing. Wall 25 is in Phase 1 for the simplicity of the fix and lack of major equipment. The main structure components that require engineering and large equipment and major track shutdowns, the steel piles and cable tiebacks appear to be in solid condition and can be reused and only the timber lagging will need to be replaced.

Optional (2-Marginal Wall) Combined Project

Wall 24 is a timber retaining wall with steel solider piles. The lateral timber members are deteriorated and buried. With the proximity to wall 25, the steep slope beneath the wall, and the rating of 2 (marginal), wall 24 would be a useful wall to repair at the same time as wall 25. The recommendation for wall 24 is to repair the existing 30 feet of deteriorating timber lagging and install an additional 45 feet of timber lagging.

ALASKA RAILROAD RETAINING WALL INSPECTION FORM

Milepost: 350.72 Wall Number: 3			Inspectors: Andy Kubic, Eric Thornley			
Date:	July 29, 2021 3:00 PM		Engineer review required:		Date Forwarded:	
Nearest Hwy Intersection:	Parks Highway at Denali Park				Nearest RR Crossing:	
GPS Coordinates (X,Y)	-148.9172, 63.76382 WGS 1984					
Nearest Siding:	Oliver Siding			Fiber Optic location: East Side of Tracks		
Authorized Track Speed	Passenger: 25		Freight: 25		Overhead Utilities: None	
Track & Slope						
Wall Condition Rating **1-Poor**			Rating scale: 5-Excellent, 4-Good, 3-Adequate, 2-Marginal, 1-Poor (see back for rating description)			
Line & Surface:	CWR/Ballast		Tangent/Curve: Tangent			
Tie condition:	Good					
Tie type:	Concrete					
Distance from end of tie to wall (feet)	South End:	5.25		North End:	6.75	
Distance from end of tie to toe (feet)	South End:	8.25		North End:	7.25	
Culverts:	Yes					
Ditchline:	Ponding					
Water level:						
Downhill Condition & Vegetation:	Scrub Shrub					
Uphill Condition & Vegetation:	Scrub Shrub					
General Retaining Wall Information (include pictures)						
Soldier Pile	Type:	Timber/steel	Qty:	11	Height:	3.5’
Condition:	Poor					
Wall	Type:	Timber/steel	Qty:		Length:	
Condition:						
Wales	Type:		Qty:			
Condition:						
Tie backs	Type:		Qty:		Length:	
Condition:						
Anchor Pile	Type:		Qty:		Height:	
Condition:						
Notes:	Poor wall condition rating justification: material deficiencies, proximity of wall to end of tie, consequences of wall failing. Notes: Part of the wall has been repaired/replaced with steel, but the old remaining timber wall has failure of piles and lattice and tieback piles exposed.					
Supervisor Review:					Date:	
Engineer Review:					Date:	

ALASKA RAILROAD RETAINING WALL INSPECTION FORM

Milepost: 350.72 Wall Number: 3	Date:	July 29, 2021 3:00 PM

Additional Notes/Drawings

Photo of Approach to Wall Start Looking Up Station

Photo of Approach to Wall Start Looking Down Station

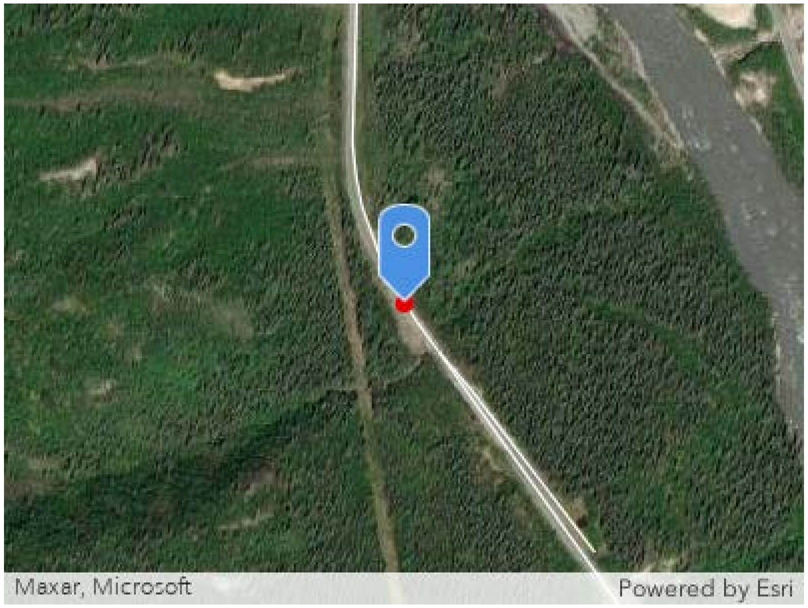
Rating	Condition	Description
5	Excellent	No visible defects, new or near new condition, may still be under warranty if applicable
4	Good	Good condition, but no longer new, may be slightly defective or deteriorated, but is overall functional
3	Adequate	Moderately deteriorated or defective; but has not exceeded useful life: Repair within 3 - 5 years
2	Marginal	Defective or deteriorated in need of replacement; exceeded useful life: Repair within 1 year
1	Poor	Critically damaged or in need of immediate repair; well past useful life

Alaska Railroad Retaining Wall Inspection

Inspection Date:
July 29, 2021 3:00 PM

ARRC Mainline Milepost 350.72
Wall #3
Wall Condition Rating: 1-Poor

Michael Baker International
3900 C St. Suite 900
Anchorage, AK 99503
907.273.1600



Coordinates: -148.9172, 63.76382 WGS 1984

Comments:	Photo of Approach to Wall Start Looking Up Station	Date:	7/29/2021
		photo:	1
Wall # 3 Wall Condition Rating: Poor		MP #:	350.72

Comments:	Photo of Approach to Wall Start Looking Down Station	Date:	7/29/2021
		Photo:	2
Wall # 3 Wall Condition Rating: Poor		MP #:	350.72

Comments:	Center Point of Wall/Track Centerline 360 Photo 1	Date:	7/29/2021	Comments:	Center Point of Wall/Track Centerline 360 Photo 2	Date:	7/29/2021
		photo:	3			Photo:	4
Wall # 3 Wall Condition Rating: Poor		MP #:	350.72	Wall # 3 Wall Condition Rating: Poor		MP #:	350.72

Comments:	Center Point of Wall/Track Centerline 360 Photo 3	Date:	7/29/2021	Comments:	Center Point of Wall/Track Centerline 360 Photo 4	Date:	7/29/2021
		photo:	5			Photo:	6
Wall # 3 Wall Condition Rating: Poor		MP #:	350.72	Wall # 3 Wall Condition Rating: Poor		MP #:	350.72

Comments:	Center Point of Wall/Track Centerline 360 Photo 5	Date:	7/29/2021
		photo:	7
Wall # 3 Wall Condition Rating: Poor		MP #:	350.72

Comments:	Center Point of Wall/Track Centerline 360 Photo 6	Date:	7/29/2021
		Photo:	8
Wall # 3 Wall Condition Rating: Poor		MP #:	350.72

Comments:	Demonstrating the distance between existing wall and new wall	Date:	7/29/2021
		photo:	9
Wall # 3 Wall Condition Rating: Poor		MP #:	350.72

Comments:	Typical failure of piles and lagging	Date:	7/29/2021
		Photo:	10
Wall # 3 Wall Condition Rating: Poor		MP #:	350.72

Comments:	Tieback piles exposed	Date:	7/29/2021
		photo:	11
Wall # 3 Wall Condition Rating: Poor		MP #:	350.72

In depth Wall Evaluation

Milepost: 350.72
Wall Number: 3
Wall Condition Rating 1-Poor
Inspection Date: July 29, 2021 3:00 PM

Existing Wall Description

Wall 3, located at Milepost 350.72 in Healy Canyon, 2.6 miles North of Denali National Park Road and 7.9 miles South of Healy Yard. With no immediate road access, and 5.5 miles between Denali National Park Road and the Parks Highway Crossing the 6 retaining walls in this section are isolated. To the left of the tracks there are anchor piles near the ditch line. The right side of the tracks has potential to have a work area for staging storage outside of the foul zone during construction. The main structural section of the wall is comprised of a timber pile wall system with cable tiebacks. Part of the wall appears to be in the process of repair/update with a solider pile wall.

Wall Component Description

- Timber Pile Walls with Cable Tiebacks
  - Timber piles are typically driven 20-30 feet deep or until refusal and spaced 10-15 feet apart.
  - Timber lagging are the horizontal planks stacked vertically and are the main members to retain soil.
  - Steel cable tiebacks increase lateral carrying capacity to help anchor the wall from overturning/sliding. Tiebacks are anchored into solid rock or use a buried deadman to provide resistance.
- Soldier Pile Wall
  - Steel H piles are typically driven 20-30 feet deep or until refusal and spaced 10 feet apart.
  - Horizontal Lagging are typically made of timber planks or precast concrete panels.

Structure Condition State Justification

Wall 3 is critically damaged or in need of immediate repair, well past useful life. Due to the overall wall condition, the consequences associated are wall proximity to track and wall failure.

Layout/Geometry Considerations

Area surrounding the wall appears to be sliding with indications of loose/failing tiebacks causing the wall to rotate.

Alignment	• Upstation – Slight Right-Hand Curve • Wall Location- Tangent • Downstation- Slight Right-Hand Curve
Left of Track Looking Upstation	• Upslope – Brushy gradual slope, starts approximately 15 feet from centerline of track • Ditch - Defined and clean, vegetated, does not appear to pond due to culvert at North end of wall
Right of Track Looking Upstation	• Existing wall location – Storage area for miscellaneous beams behind wall. • Ditch- N/A • Downslope – Brush and Trees

Material Deficiency

- Piles-Timber piles exhibit section failure and are in need of replacement, steel piles, and sheet piles to remain.
- Lagging-Segments are missing or exhibit section failure and need replacement.
- Tiebacks-Timber tiebacks anchors are exposed, exhibit surface section failure, and need rehabilitation and/or replacement. Further investigation is required to determine if steel cable tiebacks are to remain.

Recommendation

Finalize soldier pile wall installation outside of existing wall.

ALASKA RAILROAD RETAINING WALL INSPECTION FORM

Milepost: 354.26 Wall Number: 25			Inspectors: Andy Kubic, Eric Thornley		
Date:	July 29, 2021 7:45 AM		Engineer review required:	Date Forwarded:	
Nearest Hwy Intersection:	Parks Highway at Denali Park			Nearest RR Crossing:	
GPS Coordinates (X,Y)	-148.94948, 63.80897 WGS 1984				
Nearest Siding:	Healy Siding		Fiber Optic location: East Side of Tracks		
Authorized Track Speed	Passenger: 15	Freight: 15		Overhead Utilities: None	
Track & Slope					
Wall Condition Rating **1-Poor**			Rating scale: 5-Excellent, 4-Good, 3-Adequate, 2-Marginal, 1-Poor (see back for rating description)		
Line & Surface:	CWR/Ballast	Tangent/Curve: Tangent			
Tie condition:	Good				
Tie type:	Concrete				
Distance from end of tie to wall (feet)	South End:	4		North End:	4.5
Distance from end of tie to toe (feet)	South End:			North End:	
Culverts:	No				
Ditchline:	Gravel				
Water level:					
Downhill Condition & Vegetation:	Rock Slope				
Uphill Condition & Vegetation:	Rock Slope				
General Retaining Wall Information (include pictures)					
Soldier Pile	Type:	Steel	Qty: 6	Height:	
Condition:	Marginal				
Wall	Type:	Timber	Qty: 3	Length:	
Condition:	Poor				
Wales	Type:		Qty:		
Condition:					
Tie backs	Type:		Qty:	Length:	
Condition:					
Anchor Pile	Type:		Qty:	Height:	
Condition:					
Notes:	Poor wall condition rating justification: Material deficiencies, consequences of wall failing. Notes: Missing and misaligned timbers with gravel spilling through. Minor corrosion on all the piles. Misaligned timbers with gaps with gravel spill through. Minor corrosion- no measurable section.				
Supervisor Review:				Date:	
Engineer Review:				Date:	

ALASKA RAILROAD RETAINING WALL INSPECTION FORM

Milepost: 354.26 Wall Number: 25	Date:	July 29, 2021 7:45 AM

Additional Notes/Drawings

Photo of Approach to Wall Start Looking Up Station

Photo of Approach to Wall Start Looking Down Station

Rating	Condition	Description
5	Excellent	No visible defects, new or near new condition, may still be under warranty if applicable
4	Good	Good condition, but no longer new, may be slightly defective or deteriorated, but is overall functional
3	Adequate	Moderately deteriorated or defective; but has not exceeded useful life: Repair within 3 - 5 years
2	Marginal	Defective or deteriorated in need of replacement; exceeded useful life: Repair within 1 year
1	Poor	Critically damaged or in need of immediate repair; well past useful life

Alaska Railroad Retaining Wall Inspection

Inspection Date: July 29, 2021 7:45 AM

ARRC Mainline Milepost 354.26
Wall #25
Wall Condition Rating: Poor

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3900 C St. Suite 900
Anchorage, AK 99503
907.273.1600

Coordinates: -148.94948, 63.80897 WGS 1984

Comments:	Photo of Approach to Wall Start Looking Up Station	Date:	7/29/2021
		photo:	1
Wall # 25 Wall Condition Rating: Poor		MP #:	354.26

Comments:	Photo of Approach to Wall Start Looking Down Station	Date:	7/29/2021
		Photo:	2
Wall # 25 Wall Condition Rating: Poor		MP #:	354.26

Comments:	Center Point of Wall/Track Centerline 360 Photo 1	Date:	7/29/2021	Comments:	Center Point of Wall/Track Centerline 360 Photo 2	Date:	7/29/2021
		photo:	3			Photo:	4
Wall # 25 Wall Condition Rating: Poor		MP #:	354.26	Wall # 25 Wall Condition Rating: Poor		MP #:	354.26

Comments:	Center Point of Wall/Track Centerline 360 Photo 3	Date:	7/29/2021	Comments:	Center Point of Wall/Track Centerline 360 Photo 4	Date:	7/29/2021
		photo:	5			Photo:	6
Wall # 25 Wall Condition Rating: Poor		MP #:	354.26	Wall # 25 Wall Condition Rating: Poor		MP #:	354.26

Comments:	Center Point of Wall/Track Centerline 360 Photo 5	Date:	7/29/2021
		photo:	7
Wall # 25 Wall Condition Rating: Poor		MP #:	354.26

Comments:	Center Point of Wall/Track Centerline 360 Photo 6	Date:	7/29/2021
		Photo:	8
Wall # 25 Wall Condition Rating: Poor		MP #:	354.26

Comments:	Missing timber with gravel spilling through	Date:	7/29/2021
		photo:	9
Wall # 25 Wall Condition Rating: Poor		MP #:	354.26

Comments:	Misaligned timbers with gaps with gravel spilling	Date:	7/29/2021
		Photo:	10
Wall # 25 Wall Condition Rating: Poor		MP #:	354.26

Comments:	Minor corrosion no measurable section loss	Date:	7/29/2021
		photo:	11
Wall # 25 Wall Condition Rating: Poor		MP #:	354.26

Comments:	Typical	Date:	7/29/2021
		Photo:	12
Wall # 25 Wall Condition Rating: Poor		MP #:	354.26

Comments:	Typical	Date:	7/29/2021
		photo:	13
Wall # 25 Wall Condition Rating: Poor		MP #:	354.26

Comments:	Typical	Date:	7/29/2021
		Photo:	14
Wall # 25 Wall Condition Rating: Poor		MP #:	354.26

In depth Wall Evaluation

Milepost:	354.26
Wall Number:	25
Wall Condition Rating	1-Poor
Inspection Date:	July 29, 2021 7:45 AM

Existing Wall Description

Wall 25, located at Milepost 354.26 in Healy Canyon, 6.1 miles North of Denali National Park Road, and 4.3 miles South of Healy Yard. With no nearby road access, this wall is 1 of 17 walls located in a 0.5 mile stretch of track (MP 353.80-354.30), narrowly confined on either side by a rock face uphill and a sliding slope on the exposed downhill. This section of track is designated as critical when considering the role of an associated wall failure (based on the proximity of the track alignment and the consequences associated with the exposed downhill portion of the wall). There is a large, mostly flat slope on the right side of the track both up-station (354.72) and down-station (353.14) that can be used as staging storage outside the foul zone, where workers and equipment can clear during construction. Wall 24 is in marginal condition and could be repaired during this project. It is recommended to add 45' of soldier pile wall, and repair 30' of existing wall. The main structural section of Wall 25 is comprised of a soldier pile wall with timber lagging and cable tiebacks.

Wall Component Description

- Steel Soldier Pile Wall with Timber Lagging and Cable Tiebacks
  - Steel piles are driven 20-30 feet deep or until refusal and are spaced approximately 5' feet apart.
  - Timber lagging are the horizontal planks stacked vertically and are the main members to retain soil.
  - Steel cable tiebacks increase lateral carrying capacity to help anchor the wall from overturning/sliding. Tiebacks are anchored into solid rock or use a buried deadman to provide resistance.

Structure Condition State Justification

Wall 25 is critically damaged or in need of immediate repair, well past useful life. This is due to the overall wall condition and consequences with remaining lagging failing.

Layout/Geometry Considerations

Area around wall appears to be sliding with the slope greater than 1:1.

Alignment	• Upstation – Tangent • Wall Location- Tangent • Downstation- Slight Right-Hand Curve
Left of Track Looking Upstation	• Upslope – Rocky vertical wall, starts approximately 8 feet from centerline of track • Ditch – Defined, collecting rock and debris
Right of Track Looking Upstation	• Existing wall location – Immediate steel slope • Ditch – N/A • Downslope – Small flat gravel area, steep cliff slope.

Material Deficiency

- Piles-Steel piles to remain.
- Timber Lagging- missing and misaligned, causing gaps allowing gravel to spill through and failing to provide lateral support. Top lagging may have allowed backfill and slope to erode. Lagging needs to be replaced.
- Tiebacks-Steel cabling to be reused.

Recommendation

Repair and replace missing/broken timbers and lengthen wall on both ends. Long term solution replace wall with a new anchored soldier pile wall and lagging wall in front of existing wall.

3. Phase 2 (High Criticality of Wall Failure)

Wall 36 and Wall 41 are set in Phase 2 due to the high criticality of imminent wall failure. Both Wall 36 and Wall 41 main section of the walls are comprised of a timber pile wall with cable tiebacks. Due to the steep nature of this location workers and equipment can clear during construction both down-station (354.72) and up-station at the Road Access Area (356.13) that can be used as staging storage that outside of foul zone. Wall 36 it is recommended to replace the damaged and decaying timbers. Wall 41 it is recommended to replace with soldier pile wall and lagging wall or steel sheet pile wall in front of the existing wall.

Optional (2-Marginal Wall) combined project

Wall 38 is a small timber wall with about 10 feet in exposed timber lagging. The wall's purpose is to retain the ballast material, not to maintain slope stability. With the proximity to wall 36, wall 38 would be a useful wall to repair.

Wall 42 is a small timber wall with about 45 feet of exposed area. The timber piles crushed and deteriorated at the exposed locations and the retaining wall is buried. With the proximity to wall 41, wall 42 would be a useful wall to repair.

ALASKA RAILROAD RETAINING WALL INSPECTION FORM

Milepost: 354.94 Wall Number: 36		Inspectors: Andy Kubic, Eric Thornley			
Date:	July 29, 2021 10:30 AM	Engineer review required:		Date Forwarded:	
Nearest Hwy Intersection:	Parks Highway at Denali Park			Nearest RR Crossing:	
GPS Coordinates (X,Y)	-148.96035, 63.81821 WGS 1984				
Nearest Siding:	Healy Siding		Fiber Optic location: East Side of Tracks		
Authorized Track Speed	Passenger: 15	Freight: 15		Overhead Utilities: None	
Track & Slope					
Wall Condition Rating **1-Poor**		Rating scale: 5-Excellent, 4-Good, 3-Adequate, 2-Marginal, 1-Poor (see back for rating description)			
Line & Surface:	CWR/Ballast	Tangent/Curve: Tangent			
Tie condition:	Good				
Tie type:	Concrete				
Distance from end of tie to wall (feet)	South End:	6.5		North End:	6.5
Distance from end of tie to toe (feet)	South End:			North End:	
Culverts:	No				
Ditchline:	Gravel				
Water level:					
Downhill Condition & Vegetation:	Rock Slope				
Uphill Condition & Vegetation:	Rock Slope				
General Retaining Wall Information (include pictures)					
Soldier Pile	Type:		Qty:		Height:
Condition:					
Wall	Type: Timber		Qty:		Length:
Condition:	Marginal				
Wales	Type: Timber		Qty:		
Condition:					
Tie backs	Type:		Qty:		Length:
Condition:					
Anchor Pile	Type:		Qty:		Height:
Condition:					
Notes:	Poor wall condition rating justification: Material deficiencies, proximity of wall to end of tie, consequences of wall failing. Notes: The purpose of this wall is to retain the ballast material, not for slope stability. Adequate slab rock exists downhill from wall. Monitor as this location is close to centerline of track. Lateral timber members have 50% section loss.				
Supervisor Review:				Date:	
Engineer Review:				Date:	

ALASKA RAILROAD RETAINING WALL INSPECTION FORM

Milepost: 354.94 Wall Number: 36	Date:	July 29, 2021 10:30 AM

Additional Notes/Drawings

Photo of Approach to Wall Start Looking Up Station

Photo of Approach to Wall Start Looking Down Station

Rating	Condition	Description
5	Excellent	No visible defects, new or near new condition, may still be under warranty if applicable
4	Good	Good condition, but no longer new, may be slightly defective or deteriorated, but is overall functional
3	Adequate	Moderately deteriorated or defective; but has not exceeded useful life: Repair within 3 - 5 years
2	Marginal	Defective or deteriorated in need of replacement; exceeded useful life: Repair within 1 year
1	Poor	Critically damaged or in need of immediate repair; well past useful life

ALASKA RAILROAD

Alaska Railroad Retaining Wall Inspection

Inspection Date: July 29, 2021 10:30 AM

ARRC Mainline Milepost 354.94
Wall #36
Wall Condition Rating: Poor

Michael Baker International
Michael Baker International
3900 C St. Suite 900
Anchorage, AK 99503
907.273.1600

Coordinates: -148.96035, 63.81821 WGS 1984

Comments:	Photo of Approach to Wall Start Looking Up Station	Date:	7/29/2021	Comments:	Photo of Approach to Wall Start Looking Down Station	Date:	7/29/2021
		photo:	1			Photo:	2
Wall # 36 Wall Condition Rating: Poor		MP #:	354.94	Wall # 36 Wall Condition Rating: Poor		MP #:	354.94

Comments:	Center Point of Wall/Track Centerline 360 Photo 1	Date:	7/29/2021
		photo:	3
Wall # 36 Wall Condition Rating: Poor		MP #:	354.94

Comments:	Center Point of Wall/Track Centerline 360 Photo 2	Date:	7/29/2021
		Photo:	4
Wall # 36 Wall Condition Rating: Poor		MP #:	354.94

Comments:	Center Point of Wall/Track Centerline 360 Photo 3	Date:	7/29/2021
		photo:	5
Wall # 36 Wall Condition Rating: Poor		MP #:	354.94

Comments:	Center Point of Wall/Track Centerline 360 Photo 4	Date:	7/29/2021
		Photo:	6
Wall # 36 Wall Condition Rating: Poor		MP #:	354.94

Comments:	Center Point of Wall/Track Centerline 360 Photo 5	Date:	7/29/2021
		photo:	7
Wall # 36 Wall Condition Rating: Poor		MP #:	354.94

Comments:	Center Point of Wall/Track Centerline 360 Photo 6	Date:	7/29/2021
		Photo:	8
Wall # 36 Wall Condition Rating: Poor		MP #:	354.94

Comments:	Lateral timber member with 50% section loss	Date:	7/29/2021
		photo:	9
Wall # 36 Wall Condition Rating: Poor		MP #:	354.94

In depth Wall Evaluation

Milepost:	354.94
Wall Number:	36
Wall Condition Rating	1-Poor
Inspection Date:	July 29, 2021 10:30 AM

Existing Wall Description

Wall 36, located at Milepost 354.94 in Healy Canyon, 6.8 miles North of Denali National Park Road, and 3.7 miles South of Healy Yard. With no nearby road access, this wall is 1 of 14 walls located in a 1 mile stretch of track (MP 354.30-355.30), narrowly confined on either side by a blasted rock face uphill, and a sliding slope on the exposed downhill. There is a large, mostly flat slope on the right side of the track both down-station (354.72) and up-station at the Road Access Area (356.13) that can be used as staging storage outside the foul zone, where workers and equipment can clear during construction. Wall 38 is in marginal condition; it could be repaired with this project by resolving seepage at ground level and replacing damaged/decaying timbers. The main section of the wall is comprised of a timber pile wall with cable tiebacks. Wall purpose appears to be for ballast material retention.

Wall Component Description

- Timber Pile Walls with Cable Tiebacks
  - Timber piles are typically driven 20-30 feet deep or until refusal and spaced 10-15 feet apart.
  - Timber lagging are the horizontal planks stacked vertically and are the main members to retain soil.
  - Steel cable tiebacks increase lateral carrying capacity to help anchor the wall from overturning/sliding. Tiebacks are anchored into solid rock or use a buried deadman to provide resistance.

Structure Condition State Justification

Wall 36 is critically damaged or in need of immediate repair, well past useful life. The consequences associated are the proximity of the wall to track. Lateral timber members exhibit section loss, which could result in failure.

Layout/Geometry Considerations

Exposed slope appears greater than 1:1. The adjacent area appears to be sliding near an exposed portion of the wall, causing the wall to displace laterally away from the track.

Alignment	• Upstation – Tangent • Wall Location- Tangent • Downstation- Tangent
Left of Track Looking Upstation	• Upslope – Rocky vertical wall, starts approximately 8+ feet from centerline of track, trees and brush • Ditch – Well defined, rocky
Right of Track Looking Upstation	• Existing wall location – Immediate steep slope, slab rock at bottom of wall. • Ditch – N/A • Downslope – Steep/rockslide.

Material Deficiency

- Piles-Timber piles sections exhibit up to 100% section failure and need replacement; steel piles and sheet piles to remain.
- Lagging-At-grade segments exhibit section failure, appear to be non-existent in certain areas, and need replacement.
- Tiebacks-Timber tiebacks with cabling will require further investigation to determine if tiebacks are to remain.

Recommendation

Excavate and replace damaged and decaying timbers.

ALASKA RAILROAD RETAINING WALL INSPECTION FORM

Milepost: 355.41 Wall Number: 41			Inspectors: Andy Kubic, Eric Thornley		
Date:	July 29, 2021 11:30 AM		Engineer review required:	Date Forwarded:	
Nearest Hwy Intersection:	Parks Highway at Denali Park			Nearest RR Crossing:	
GPS Coordinates (X,Y)	-148.96624, 63.82082 WGS 1984				
Nearest Siding:	Healy Siding		Fiber Optic location: East Side of Tracks		
Authorized Track Speed	Passenger: 15	Freight: 15		Overhead Utilities: None	

Track & Slope

Wall Condition Rating **1-Poor**		Rating scale: 5-Excellent, 4-Good, 3-Adequate, 2-Marginal, 1-Poor (see back for rating description)		
Line & Surface:	CWR/Ballast	Tangent/Curve: Tangent		
Tie condition:	Good			
Tie type:	Concrete			
Distance from end of tie to wall (feet)	South End:	10	North End:	6
Distance from end of tie to toe (feet)	South End:		North End:	
Culverts:	No			
Ditchline:	Gravel			
Water level:				
Downhill Condition & Vegetation:	Rock Slope			
Uphill Condition & Vegetation:	Rock Slope			

General Retaining Wall Information (include pictures)

Soldier Pile	Type:	Timber	Qty:	12	Height:	
Condition:	Poor					
Wall	Type:	Timber	Qty:		Length:	
Condition:	Marginal					
Wales	Type:		Qty:			
Condition:						
Tie backs	Type:		Qty:		Length:	
Condition:						
Anchor Pile	Type:		Qty:		Height:	
Condition:						
Notes:	Poor wall condition rating justification: Material deficiencies, proximity of wall to end of tie, consequences of wall failing, failure risk due to the wall length and height. Notes: Hollow sounding for entire height of exposed pile with splitting and decay. Up to 100% section loss on top lateral member. First half of wall up to pile seven appears to have been reinforced with new vertical bracing members and are in good condition. The remaining portion of the wall is marginal to adequate.					

Supervisor Review:		Date:	
Engineer Review:		Date:	

ALASKA RAILROAD RETAINING WALL INSPECTION FORM

Milepost: 355.41 Wall Number: 41	Date:	July 29, 2021 11:30 AM

Additional Notes/Drawings

Photo of Approach to Wall Start Looking Up Station

Photo of Approach to Wall Start Looking Down Station

Rating	Condition	Description
5	Excellent	No visible defects, new or near new condition, may still be under warranty if applicable
4	Good	Good condition, but no longer new, may be slightly defective or deteriorated, but is overall functional
3	Adequate	Moderately deteriorated or defective; but has not exceeded useful life: Repair within 3 - 5 years
2	Marginal	Defective or deteriorated in need of replacement; exceeded useful life: Repair within 1 year
1	Poor	Critically damaged or in need of immediate repair; well past useful life

Alaska Railroad Retaining Wall Inspection

Inspection Date: July 29, 2021 11:30 AM

ARRC Mainline Milepost 355.41
Wall #41
Wall Condition Rating: Poor

Michael Baker International
3900 C St. Suite 900
Anchorage, AK 99503
907.273.1600

Coordinates: -148.96624, 63.82082 WGS 1984

Comments:	Photo of Approach to Wall Start Looking Up Station	Date:	7/29/2021	Comments:	Photo of Approach to Wall Start Looking Down Station	Date:	7/29/2021
		photo:	1			Photo:	2
Wall # 41 Wall Condition Rating: Poor		MP #:	355.41	Wall # 41 Wall Condition Rating: Poor		MP #:	355.41

Comments:	Center Point of Wall/Track Centerline 360 Photo 1	Date:	7/29/2021
		photo:	3
Wall # 41 Wall Condition Rating: Poor		MP #:	355.41

Comments:	Center Point of Wall/Track Centerline 360 Photo 2	Date:	7/29/2021
		Photo:	4
Wall # 41 Wall Condition Rating: Poor		MP #:	355.41

Comments:	Center Point of Wall/Track Centerline 360 Photo 3	Date:	7/29/2021
		photo:	5
Wall # 41 Wall Condition Rating: Poor		MP #:	355.41

Comments:	Center Point of Wall/Track Centerline 360 Photo 4	Date:	7/29/2021
		Photo:	6
Wall # 41 Wall Condition Rating: Poor		MP #:	355.41

Comments:	Center Point of Wall/Track Centerline 360 Photo 5	Date:	7/29/2021
		photo:	7
Wall # 41 Wall Condition Rating: Poor		MP #:	355.41

Comments:	Center Point of Wall/Track Centerline 360 Photo 6	Date:	7/29/2021
		Photo:	8
Wall # 41 Wall Condition Rating: Poor		MP #:	355.41

Comments:	Hollow sounding for entire height of exposed pile with splitting and decay	Date:	7/29/2021
		photo:	9
Wall # 41 Wall Condition Rating: Poor		MP #:	355.41

Comments:	Lateral member decay	Date:	7/29/2021
		Photo:	10
Wall # 41 Wall Condition Rating: Poor		MP #:	355.41

Comments:	Up to hundred percent of section loss top horizontal member	Date:	7/29/2021
		photo:	11
Wall # 41 Wall Condition Rating: Poor		MP #:	355.41

In depth Wall Evaluation

Milepost:	355.41
Wall Number:	41
Wall Condition Rating	1-Poor
Inspection Date:	July 29, 2021 11:30 AM

Existing Wall Description

Wall 41, located at Milepost 355.41 in Healy Canyon, 7.3 miles North of Denali National Park Road, and 3.2 miles South of Healy Yard. With no nearby road access, this wall is 1 of 14 walls located in a 1 mile stretch of track (MP 354.30-355.30), narrowly confined on either side by a blasted rock face uphill, and a sliding slope on the exposed downhill. There is a large, mostly flat slope on the right side of the track both down-station (354.72) and up-station at the Road Access Area (356.13) that can be used as staging storage outside the foul zone, where workers and equipment can clear during construction. Wall 42 is in marginal condition; it could be repaired with this project by replacing with steel sheet pile wall to replace rotten timber piling wall. The main section of the wall is comprised of a timber pile wall with cable tiebacks.

Wall Component Description

- Timber Pile Walls with Cable Tiebacks
    - Timber piles are typically driven 20-30 feet deep or until refusal and spaced 10-15 feet apart.
    - Timber lagging are the horizontal planks stacked vertically and are the main members to retain soil.
    - Steel cable tiebacks increase lateral carrying capacity to help anchor the wall from overturning/sliding. Tiebacks are anchored into solid rock or use a buried deadman to provide resistance.

Structure Condition State Justification

Wall 41 is critically damaged or in need of immediate repair, well past useful life. This is due to overall wall condition and the consequences associated with wall proximity to track and wall failure.

Layout/Geometry Considerations

Area surrounding the wall appears to be sliding with indications of loose/failing tiebacks causing the wall to rotate. The track is in close proximity to the wall, and could be in jeopardy if the slope failure continues.

Alignment	• Upstation – Slight Right-Hand Curve • Wall Location- Tangent • Downstation- Tangent
Left of Track Looking Upstation	• Upslope – Steep sloped rock wall with some debris, trees, and brush • Ditch – Well defined, rocky, minor debris buildup
Right of Track Looking Upstation	• Existing wall location – Immediate steep rock slope with gravel and minor brush • Ditch – N/A • Upslope – Rocky slope wall with minor brush

Material Deficiency

- Piles-Exposed timber piles exhibit up to 100% section failure and are in need replacement.
- Lagging-Above grade segments are missing or exhibit up to 100% section failure and need replacement. Unable to inspect below grade segments due to apparent excavated fill from the opposite side of the track placed on the exterior toe of the wall. Further investigation is required to determine if below grade lagging is structurally sound and adequately retaining the fill supporting the track.
- Tiebacks-Unable to inspect tieback anchors. Further investigation is required to determine if steel cable tiebacks are to remain, but the current state of the wall indicates that these cables are not functioning as designed and could be the cause of the wall rotation.

Recommendation

Replace with soldier pile wall and lagging wall or steel sheet pile wall in front of the existing wall. May need tiebacks.

4. Phase 3 (Higher Costs and Additional Engineering Design)

Wall 17 and Wall 22 have been set in Phase 3 due location and the predicted associated construction costs and design. These walls are located in a 0.5 mile stretch of track (MP 353.80-354.30) narrowly confined on either side by a rock face uphill and a sliding slope on the exposed downhill. This section of track is designated as critical when considering the role of an associated wall failure based on the proximity of the track alignment and the consequences associated with the exposed downhill portion of the wall. Wall 17 is a Timber Pile wall with cable tiebacks and Wall 22 is a timber crib wall. Both walls have a recommendation of being replaced with a soldier pile wall, but this will require engineering design due to the complexity of the area and required wall heights to retain soil.

Optional (2-Marginal Wall) combined project

Wall 16 is a middle-sized timber crib retaining wall with about 25 feet of exposed timbers. The wall is decaying and missing timbers due to rockfall. With the proximity to wall 17, wall 16 would be a useful wall to repair.

Wall 17B is a middle-sized timber crib retaining wall, almost identical to wall 16, with about 27 feet of exposed timbers. The wall has sections of 30%-50% decay and parts of the wall are not bearing on the ground below. With the proximity to wall 17 and wall 16, wall 17B would be a useful wall to repair.

ALASKA RAILROAD RETAINING WALL INSPECTION FORM

Milepost: 353.96 Wall Number: 17			Inspectors: Andy Kubic, Eric Thornley		
Date:	July 28, 2021 1:30 PM		Engineer review required:	Date Forwarded:	
Nearest Hwy Intersection:	Parks Highway at Denali Park			Nearest RR Crossing:	
GPS Coordinates (X,Y)	-148.94128, 63.80626 WGS 1984				
Nearest Siding:	Healy Siding		Fiber Optic location: East Side of Tracks		
Authorized Track Speed	Passenger: 15		Freight: 15	Overhead Utilities: None	
Track & Slope					
Wall Condition Rating **1-Poor**			Rating scale: 5-Excellent, 4-Good, 3-Adequate, 2-Marginal, 1-Poor (see back for rating description)		
Line & Surface:	CWR/Ballast		Tangent/Curve: Tangent		
Tie condition:					
Tie type:	Concrete				
Distance from end of tie to wall (feet)	South End:	3.5		North End:	3
Distance from end of tie to toe (feet)	South End:	4		North End:	3.25
Culverts:	No				
Ditchline:	Gravel				
Water level:					
Downhill Condition & Vegetation:	Gravel				
Uphill Condition & Vegetation:	Gravel				
General Retaining Wall Information (include pictures)					

Soldier Pile	Type:	Timber	Qty:	5	Height:	2’
Condition:	Poor					
Wall	Type:	Timber	Qty:	2	Length:	
Condition:	Adequate					
Wales	Type:		Qty:			
Condition:						
Tie backs	Type:		Qty:		Length:	
Condition:						
Anchor Pile	Type:		Qty:		Height:	
Condition:						
Notes:	Poor wall condition rating justification: Material deficiencies, proximity of wall to end of tie, consequences of wall failing. Notes: Exposed pile deterioration 30% and lateral timber ties with 50% section loss decay. Wall is rotating longitudinally with ballast spilling over top.					
Supervisor Review:					Date:	
Engineer Review:					Date:	

ALASKA RAILROAD RETAINING WALL INSPECTION FORM

Milepost: 353.96 Wall Number: 17	Date:	July 28, 2021 1:30 PM

Additional Notes/Drawings

Photo of Approach to Wall Start Looking Up Station

Photo of Approach to Wall Start Looking Down Station

Rating	Condition	Description
5	Excellent	No visible defects, new or near new condition, may still be under warranty if applicable
4	Good	Good condition, but no longer new, may be slightly defective or deteriorated, but is overall functional
3	Adequate	Moderately deteriorated or defective; but has not exceeded useful life: Repair within 3 - 5 years
2	Marginal	Defective or deteriorated in need of replacement; exceeded useful life: Repair within 1 year
1	Poor	Critically damaged or in need of immediate repair; well past useful life

Alaska Railroad Retaining Wall Inspection

Inspection Date: July 28, 2021 1:30 PM

ARRC Mainline Milepost 353.96
Wall #17
Wall Condition Rating: Poor

Michael Baker International
3900 C St. Suite 900
Anchorage, AK 99503
907.273.1600

Coordinates: -148.94128, 63.80626 WGS 1984

Comments:	Photo of Approach to Wall Start Looking Up Station	Date:	7/28/2021	Comments:	Photo of Approach to Wall Start Looking Down Station	Date:	7/28/2021
		photo:	1			Photo:	2
Wall # 17 Wall Condition Rating: Poor		MP #:	353.96	Wall # 17 Wall Condition Rating: Poor		MP #:	353.96

Comments:	Center Point of Wall/Track Centerline 360 Photo 1	Date:	7/28/2021	Comments:	Center Point of Wall/Track Centerline 360 Photo 2	Date:	7/28/2021
		photo:	3			Photo:	4
Wall # 17 Wall Condition Rating: Poor		MP #:	353.96	Wall # 17 Wall Condition Rating: Poor		MP #:	353.96

Comments:	Center Point of Wall/Track Centerline 360 Photo 3	Date:	7/28/2021	Comments:	Center Point of Wall/Track Centerline 360 Photo 4	Date:	7/28/2021
		photo:	5			Photo:	6
Wall # 17 Wall Condition Rating: Poor		MP #:	353.96	Wall # 17 Wall Condition Rating: Poor		MP #:	353.96

Comments:	Center Point of Wall/Track Centerline 360 Photo 5	Date:	7/28/2021
		photo:	7
Wall # 17 Wall Condition Rating: Poor		MP #:	353.96

Comments:	Center Point of Wall/Track Centerline 360 Photo 6	Date:	7/28/2021
		Photo:	8
Wall # 17 Wall Condition Rating: Poor		MP #:	353.96

Comments:	Rotated longitudinally	Date:	7/28/2021
		photo:	9
Wall # 17 Wall Condition Rating: Poor		MP #:	353.96

In depth Wall Evaluation

Milepost:	353.96
Wall Number:	17
Wall Condition Rating	1-Poor
Inspection Date:	July 28, 2021 1:30 PM

Existing Wall Description

Wall 17, located at Milepost 353.96 in Healy Canyon, 5.8 miles North of Denali National Park Road, and 4.6 miles South of Healy Yard. With no nearby road access, this wall is 1 of 17 walls located in a 0.5 mile stretch of track (MP 353.80-354.30), narrowly confined on either side by a rock face uphill, and a sliding slope on the exposed downhill. This section of track is designated as critical when considering the role of an associated wall failure (based on the proximity of the track alignment, and the consequences associated with the exposed downhill portion of the wall). There is a large, mostly flat slope on the right side of the track both up-station (354.72) and down-station (353.14) that can be used as staging storage outside the foul zone, where workers and equipment can clear during construction. Wall 17B and Wall 16 are adjacent timber crib walls that could be rehabbed by replacing missing and decaying headers and stretchers. The main structural section of the wall is comprised of a timber pile wall system with cable tiebacks.

Wall Component Description

- Timber Pile Walls with Cable Tiebacks
  - Timber piles are typically driven 20-30 feet deep or until refusal and spaced 10-15 feet apart.
  - Timber lagging are the horizontal planks stacked vertically and are the main members to retain soil.
  - Steel cable tiebacks increase lateral carrying capacity to help anchor the wall from overturning/sliding. Tiebacks are anchored into solid rock or use a buried deadman to provide resistance.
- Timber Crib Wall
  - Headers and stretchers are interlocked to form a square or rectangular cell with a slotted opening. Cells are assembled and filled with granular material. The structure of the cells and infill act together as a gravity structure. The safety of a crib wall is determined from proper proportioning of the shape and weight.
  - Headers are longitudinal planks that interlock with transverse stretchers and need to resist the pressure of granular fill and retained earth material.
  - Stretchers are transverse planks that interlock with longitudinal headers and need to resist the pressure of granular fill and retained earth material.

Structure Condition State Justification

Wall 17 is critically damaged or in need of immediate repair, well past useful life. Timber piles are failing, lagging is decaying, wall is rotating /sliding, and ballast is spilling over the top of the wall.

Layout/Geometry Considerations

Area surrounding the wall appears to be sliding and with indications of the wall rotating longitudinally.

Alignment	• Upstation – Tangent • Wall Location- Tangent • Downstation- Slight Right-Hand Curve
Left of Track Looking Upstation	• Upslope – Rocky vertical wall, starts approximately 11 feet from centerline of track • Ditch - well defined, mostly gravel
Right of Track Looking Upstation	• Existing wall location – Immediate rocky, steep slope to riverbed. • Ditch – N/A • Downslope – Steep slope to riverbed, minor brush

Material Deficiency

- Piles-Exposed timber piles sections exhibit section loss and are in need of replacement.
- Lagging-At-grade segments exhibit section failure and are in need replacement. Unable to inspect below grade segments due to ballast overflow on the exterior toe of the wall.
- Tiebacks-Timber tiebacks appear to be failing and might be the cause of the wall rotating. They will need to be replaced.

Recommendation

Install anchored soldier pile or tied back sheet pile wall in front of the existing wall.

ALASKA RAILROAD RETAINING WALL INSPECTION FORM

Milepost: 354.1 Wall Number: 22		Inspectors: Andy Kubic, Eric Thornley		
Date:	July 28, 2021 11:00 AM	Engineer review required:	Date Forwarded:	
Nearest Hwy Intersection:	Parks Highway at Denali Park		Nearest RR Crossing:	
GPS Coordinates (X,Y)	-148.96652, 63.82086 WGS 1984			
Nearest Siding:	Healy Siding		Fiber Optic location: East Side of Tracks	
Authorized Track Speed	Passenger: 15	Freight: 15	Overhead Utilities: None	

Track & Slope					
Wall Condition Rating **1-Poor**			Rating scale: 5-Excellent, 4-Good, 3-Adequate, 2-Marginal, 1-Poor (see back for rating description)		
Line & Surface:	CWR/Ballast		Tangent/Curve: Tangent		
Tie condition:	Good				
Tie type:	Concrete				
Distance from end of tie to wall (feet)	South End:	8.5	North End:	8.5	
Distance from end of tie to toe (feet)	South End:		North End:		
Culverts:	No				
Ditchline:	Gravel				
Water level:					
Downhill Condition & Vegetation:	Rock Slope				
Uphill Condition & Vegetation:	Rock Slope				

General Retaining Wall Information (include pictures)						
Soldier Pile	Type:	Timber	Qty:		Height:	30'
Condition:						
Wall	Type:	Timber Crib	Qty:		Length:	
Condition:	Poor					
Wales	Type:		Qty:			
Condition:						
Tie backs	Type:		Qty:		Length:	
Condition:						
Anchor Pile	Type:		Qty:		Height:	
Condition:						
Notes:	Poor wall condition rating justification: wall is crushing with members dislodged due to associated consequences with wall failure. Notes: Failed members are crushing and dislodged. The under cutting of the slope is causing the cribbing to shift down the hill and rotate. Cribbing has large spacing gaps that do not retain the fill material. Lateral timber wall members are collapsing with gravel spilling through. Gather additional field data in future to assist with engineering recommendations.					
Supervisor Review:					Date:	
Engineer Review:					Date:	

ALASKA RAILROAD RETAINING WALL INSPECTION FORM

Milepost: 354.1 Wall Number: 22	Date:	July 28, 2021 11:00 AM

Additional Notes/Drawings

Photo of Approach to Wall Start Looking Up Station

Photo of Approach to Wall Start Looking Down Station

Rating	Condition	Description
5	Excellent	No visible defects, new or near new condition, may still be under warranty if applicable
4	Good	Good condition, but no longer new, may be slightly defective or deteriorated, but is overall functional
3	Adequate	Moderately deteriorated or defective; but has not exceeded useful life: Repair within 3 - 5 years
2	Marginal	Defective or deteriorated in need of replacement; exceeded useful life: Repair within 1 year
1	Poor	Critically damaged or in need of immediate repair; well past useful life

Alaska Railroad Retaining Wall Inspection

Inspection Date: July 28, 2021 11:00 AM

ARRC Mainline Milepost 354.1
Wall #22
Wall Condition Rating: Poor

Michael Baker International
3900 C St. Suite 900
Anchorage, AK 99503
907.273.1600

Coordinates: -148.96652, 63.82086 WGS 1984

Comments:	Photo of Approach to Wall Start Looking Up Station	Date:	7/28/2021
		photo:	1
Wall # 22 Wall Condition Rating: Poor		MP #:	354.1

Comments:	Photo of Approach to Wall Start Looking Down Station	Date:	7/28/2021
		Photo:	2
Wall # 22 Wall Condition Rating: Poor		MP #:	354.1

Comments:	Center Point of Wall/Track Centerline 360 Photo 1	Date:	7/28/2021
		photo:	3
Wall # 22 Wall Condition Rating: Poor		MP #:	354.1

Comments:	Center Point of Wall/Track Centerline 360 Photo 2	Date:	7/28/2021
		Photo:	4
Wall # 22 Wall Condition Rating: Poor		MP #:	354.1

Comments:	Center Point of Wall/Track Centerline 360 Photo 3	Date:	7/28/2021
		photo:	5
Wall # 22 Wall Condition Rating: Poor		MP #:	354.1

Comments:	Center Point of Wall/Track Centerline 360 Photo 4	Date:	7/28/2021
		Photo:	6
Wall # 22 Wall Condition Rating: Poor		MP #:	354.1

Comments:	Failure of lateral cribbing members typical	Date:	7/28/2021
		photo:	7
Wall # 22 Wall Condition Rating: Poor		MP #:	354.1

Comments:	Failure of lateral cribbing members typical	Date:	7/28/2021
		Photo:	8
Wall # 22 Wall Condition Rating: Poor		MP #:	354.1

Comments:	Dislodged members with rock ball	Date:	7/28/2021
		photo:	9
Wall # 22 Wall Condition Rating: Poor		MP #:	354.1

Comments:	Under cutting slope failure while shifting down	Date:	7/28/2021
		Photo:	10
Wall # 22 Wall Condition Rating: Poor		MP #:	354.1

Comments:	Dislodged members with rockfall	Date:	7/28/2021	Comments:	Typical elevation	Date:	7/28/2021
		photo:	11			Photo:	12
Wall # 22 Wall Condition Rating: Poor		MP #:	354.1	Wall # 22 Wall Condition Rating: Poor		MP #:	354.1

Comments:		Date:	7/28/2021	Comments:		Date:	7/28/2021
		photo:	13			Photo:	14
Wall # 22 Wall Condition Rating: Poor		MP #:	354.1	Wall # 22 Wall Condition Rating: Poor		MP #:	354.1

Michael Baker INTERNATIONAL

We Make a Difference

In depth Wall Evaluation

Milepost: 354.1
Wall Number: 22
Wall Condition Rating 1-Poor
Inspection Date: July 28, 2021 11:00 AM

Existing Wall Description

Wall 22, located at Milepost 354.1 in Healy Canyon, 6 miles North of Denali National Park Road, and 4.5 miles south of Healy Yard. With no nearby road access, this wall is 1 of 17 walls located in a 0.5 mile stretch of track (MP 353.80-354.30) narrowly confined on either side by a rock face uphill and a sliding slope on the exposed downhill. This section of track is designated as critical when considering the role of an associated wall failure (based on the proximity of the track alignment and the consequences associated with the exposed downhill portion of the wall). There is a large, mostly flat slope on the right side of the track both up-station (354.72) and down-station (353.14) that can be used as staging storage outside the foul zone, where workers and equipment can clear during construction. The main structural section of the wall is comprised of a timber crib wall system.

Wall Component Description

- Timber Crib Wall
    - Headers and stretchers are interlocked to form a square or rectangular cell with a slotted opening. Cells are assembled and filled with granular material. The structure of the cells and infill act together as a gravity structure. The safety of a crib wall is determined from proper proportioning of the shape and weight.
    - Headers are longitudinal planks that interlock with transverse stretchers and need to resist the pressure of granular fill and retained earth material.
    - Stretchers are transverse planks that interlock with longitudinal headers and need to resist the pressure of granular fill and retained earth material.

Structure Condition State Justification

Wall 22 is critically damaged or in need of immediate repair, well past useful life. The wall is losing fill, and members are dislodged, which may be the cause of the sliding and rotating in the wall.

Layout/Geometry Considerations

Area surrounding the wall appears to be sliding and undercutting, causing the crib wall to not retain soil and shift down slope.

Alignment	• Upstation – Slight Right-Hand Curve • Wall Location- Slight Left-Hand Curve • Downstation- Slight Left-Hand Curve
Left of Track Looking Upstation	• Upslope – Rocky vertical wall, starts approximately 11 feet from centerline of track • Ditch - Well defined, mostly gravel with light vegetation
Right of Track Looking Upstation	• Existing wall location – Immediate steep slope, cliff area • Ditch – N/A • Downslope – Brush and trees along slope to riverbed

Material Deficiency

- Headers- Exhibit crushing and are dislodged which appears to be the cause of the crib wall not retaining soil.
- Stretchers-Are dislodged and are likely the cause of the wall sliding.

Recommendation

Install a soldier pile wall using top-down construction in front of existing wall and backfill/burry existing wall. May need tiebacks depending on final wall height.

5. Phase 4 (Least Critical)

Wall 4 has been set in Phase 4 due to it being deemed least critical among all of the other poor walls. The main structural section of the wall is comprised of a timber pile wall system with cable tiebacks. This wall will likely fail would likely fail due to the rotation/displaced position of the wall and could result in severe impact to the track due to the approaching 1:1 exposed slope and the associated intersecting failure plane of the soil. Wall 4 is in the last phase of the poor wall repairs due to its location, wall height, and downhill slope conditions.

Prioritized by condition statement and combined into projects based on wall proximity; Phase 4 also includes a summary table for the remaining walls analyzed in the inventory.

ALASKA RAILROAD RETAINING WALL INSPECTION FORM

Milepost: 351.2 Wall Number: 4			Inspectors: Andy Kubic, Eric Thornley			
Date:	July 28, 2021 8:00 AM		Engineer review required:		Date Forwarded:	
Nearest Hwy Intersection:	Parks Highway at Denali Park				Nearest RR Crossing:	
GPS Coordinates (X,Y)	-148.91635, 63.77303 WGS 1984					
Nearest Siding:	Oliver Siding			Fiber Optic location: East Side of Tracks		
Authorized Track Speed	Passenger: 25		Freight: 25		Overhead Utilities: None	
Track & Slope						
Wall Condition Rating **1-Poor**			Rating scale: 5-Excellent, 4-Good, 3-Adequate, 2-Marginal, 1-Poor (see back for rating description)			
Line & Surface:	CWR/Ballast		Tangent/Curve: Tangent			
Tie condition:	Good					
Tie type:	Concrete					
Distance from end of tie to wall (feet)	South End:	8.75			North End:	8
Distance from end of tie to toe (feet)	South End:	9.75			North End:	8.75
Culverts:	Yes					
Ditchline:	Ponding					
Water level:						
Downhill Condition & Vegetation:	Scrub Shrub					
Uphill Condition & Vegetation:	Scrub Shrub					
General Retaining Wall Information (include pictures)						
Soldier Pile	Type:	Timber	Qty:	8	Height:	1’
Condition:						
Wall	Type:	Timber	Qty:		Length:	
Condition:						
Wales	Type:		Qty:			
Condition:						
Tie backs	Type:		Qty:		Length:	
Condition:						
Anchor Pile	Type:		Qty:		Height:	
Condition:						
Notes:	Poor wall condition rating justification: material deficiencies, consequences of wall failing. Note: Piles have a 25%-50% section loss/decay/rot with poor drainage.					
Supervisor Review:					Date:	
Engineer Review:					Date:	

ALASKA RAILROAD RETAINING WALL INSPECTION FORM

Milepost: 351.2 Wall Number: 4	Date:	July 28, 2021 8:00 AM

Additional Notes/Drawings

Photo of Approach to Wall Start Looking Up Station

Photo of Approach to Wall Start Looking Down Station

Rating	Condition	Description
5	Excellent	No visible defects, new or near new condition, may still be under warranty if applicable
4	Good	Good condition, but no longer new, may be slightly defective or deteriorated, but is overall functional
3	Adequate	Moderately deteriorated or defective; but has not exceeded useful life: Repair within 3 - 5 years
2	Marginal	Defective or deteriorated in need of replacement; exceeded useful life: Repair within 1 year
1	Poor	Critically damaged or in need of immediate repair; well past useful life

ALASKA RAILROAD

Alaska Railroad Retaining Wall Inspection

Inspection Date:
July 28, 2021 8:00 AM

ARRC Mainline Milepost 351.2
Wall #4
Wall Condition Rating: Poor

Michael Baker International
3900 C St. Suite 900
Anchorage, AK 99503
907.273.1600

Coordinates: -148.91635, 63.77303 WGS 1984

Comments:	Photo of Approach to Wall Start Looking Up Station	Date:	7/28/2021
		photo:	1
Wall # 4 Wall Condition Rating: Poor		MP #:	351.2

Comments:	Photo of Approach to Wall Start Looking Down Station	Date:	7/28/2021
		Photo:	2
Wall # 4 Wall Condition Rating: Poor		MP #:	351.2

Comments:	Center Point of Wall/Track Centerline 360 Photo 1	Date:	7/28/2021
		photo:	3
Wall # 4 Wall Condition Rating: Poor		MP #:	351.2

Comments:	Center Point of Wall/Track Centerline 360 Photo 2	Date:	7/28/2021
		Photo:	4
Wall # 4 Wall Condition Rating: Poor		MP #:	351.2

Comments:	Center Point of Wall/Track Centerline 360 Photo 3	Date:	7/28/2021
		photo:	5
Wall # 4 Wall Condition Rating: Poor		MP #:	351.2

Comments:	Center Point of Wall/Track Centerline 360 Photo 4	Date:	7/28/2021
		Photo:	6
Wall # 4 Wall Condition Rating: Poor		MP #:	351.2

Comments:	Center Point of Wall/Track Centerline 360 Photo 5	Date:	7/28/2021	Comments:	Center Point of Wall/Track Centerline 360 Photo 6	Date:	7/28/2021
		photo:	7			Photo:	8
Wall # 4 Wall Condition Rating: Poor		MP #:	351.2	Wall # 4 Wall Condition Rating: Poor		MP #:	351.2

Comments:	25%-50% section loss/decay/rot	Date:	7/28/2021	Comments:	Up to 100% section loss/decay/rot	Date:	7/28/2021
		photo:	9			Photo:	10
Wall # 4 Wall Condition Rating: Poor		MP #:	351.2	Wall # 4 Wall Condition Rating: Poor		MP #:	351.2

In depth Wall Evaluation

Milepost:	351.2
Wall Number:	4
Wall Condition Rating	1-Poor
Inspection Date:	July 28, 2021 1:00 PM

Existing Wall Description

Wall 4, located at Milepost 351.2 in Healy Canyon, 3.1 miles North of Denali National Park Road, and 7.4 miles South of Healy Yard. With no nearby road access, and 5.5 miles between Denali National Park Road (348.15) and the Parks Highway Crossing (353.66) the 6 retaining walls in this section are isolated. There is a large, mostly flat slope on the right side of the track both up-station (351.34) and down-station (350.65) that can be used as staging storage outside the foul zone, where workers and equipment can clear during construction. The main structural section of the wall is comprised of a timber pile wall system with cable tiebacks.

Wall Component Description

- Timber Pile Walls with Cable Tiebacks
  - Timber piles are typically driven 20-30 feet deep or until refusal and spaced 10-15 feet apart.
  - Timber lagging are the horizontal planks stacked vertically and are the main members to retain soil.
  - Steel cable tiebacks increase lateral carrying capacity to help anchor the wall from overturning/sliding. Tiebacks are anchored into solid rock or use a buried deadman to provide resistance.

Structure Condition State Justification

Wall 4 is critically damaged or in need of immediate repair, well past useful life. Unable to adequately assess the rotation/displaced position of the wall, but failure would likely result in a severe impact to the track due to the approaching 1:1 exposed slope and the associated intersecting failure plane of the soil.

Layout/Geometry Considerations

Exposed slope appears greater than 1:1. The adjacent area appears to be sliding, and the additional ballast appears to be placing extra active soil pressure on the wall in excess of its original design. This is causing the wall to displace laterally away from the track.

Alignment	• Upstation – Slight Right-Hand Curve • Wall Location- Tangent • Downstation- Tangent
Left of Track Looking Upstation	• Upslope – Rocky vertical wall, starts approximately 11 feet from centerline of track • Ditch – Not well defined, ponding, mostly gravel with light vegetation
Right of Track Looking Upstation	• Existing wall location – Immediate steep slope • Ditch – N/A • Downslope – timber pile wall immediately, brush and trees following wall

Material Deficiency

- Piles-Exposed timber piles sections exhibit up to 100% section failure and need replacement.
- Lagging-At-grade segments exhibit section failure and need replacement. Unable to inspect below grade segments due to ballast overflow on the exterior toe of the wall.
- Tiebacks-Unable to inspect tieback anchors. Further investigation is required to determine if steel cable tiebacks are to remain, but the current state of the wall indicates that these cables are functioning as designed and the wall does not appear to be rotating.

Recommendation

Install anchored steel soldier pile or sheet pile wall in front of existing wall.

6. Overall Recommendation

Table 6-1: Michael Baker International Project Priority Recommendation for All Inspected Retaining Walls

Project Priority	Wall No. & MP	Comments
1	Wall 3 (MP 350.72)	1 wall rated (1-Poor). Requires simple repairs.
2	Wall 24 (MP 354.23) Wall 25 (MP 354.26)	A total of 2 walls: 1 wall rated (1-Poor) and 1 wall rated (2-Marginal). Requires simple repairs.
3	Wall 36 (MP 354.94) Wall 38 (MP 354.95)	A total of 2 walls: 1 wall rated (1-Poor) and 1 wall rated (2 Marginal). High criticality of imminent wall failure.
4	Wall 41 (MP 355.61) Wall 42 (MP 355.50)	A total of 2 walls: 1 wall rated (1-Poor) and 1 wall rated (2-Marginal). High criticality of imminent wall failure.
5	Wall 16 (MP 353.94) Wall 17A (MP 353.96) Wall 17B (MP 353.94)	A total of 3 walls: 1 wall rated (1-Poor) and 2 walls rated (3-Adequate). Requires higher costs and additional engineering design.
6	Wall 22 (MP 354.01)	1 wall rated (1-Poor). Requires higher costs and additional engineering design.
7	Wall 4 (MP 351.20)	1 wall rated (1-Poor). Least critical among all other poor walls.
8	Wall 20 (MP 354.06) Wall 23 (MP 354.10)	2 walls rated (2-Marginal). More criticality of imminent wall failure for marginal walls.
9	Wall 33 (MP 354.80) Wall 34 (MP 354.80)	A total of 2 walls: 1 wall rated (2-Marginal) and 1 wall rated (4-Good). More criticality of imminent wall failure for wall 34 (encompasses culvert). Wall 33 could use repair, but failure of wall should not affect train operation.
10	Wall 18 (MP 353.97)	1 wall rated (2-Marginal). Requires simple repairs.
11	Wall 31 (MP 354.56)	1 wall rated (2-Marginal). Requires intermediate repairs on steep slope. Location will also require improvement in drainage.
12	Wall 14 (MP 353.77)	1 wall rated (2-Marginal). Requires intermediate repairs on steep slope.

13	Wall 1 (MP 348.58)	1 wall rated (2-Marginal). Requires intermediate repairs on gradual slope.
14	Wall 29 (MP 354.51) Wall 30 (MP 354.54) Wall 32 (MP 354.65)	A total of 3 walls: 1 wall rated (2-Marginal) and 2 walls rated (3-Adequate). Requires simple repairs.
15	Wall 26 (MP 354.28) Wall 27 (MP 354.28) Wall 28 (MP 354.40)	3 walls rated (3-Adequate). Requires simple repairs.
16	Wall 10 (MP 353.69) Wall 13 (MP 353.76)	A total of 2 walls: 1 wall rated (2-Marginal) and 1 wall rated (3-Adequate). Timber crib walls, requires higher costs and additional engineering design.
17	Wall 35A (MP 354.90) Wall 35B (MP 354.92)	2 walls rated (3-Adequate). Timber crib walls, requires higher costs and additional engineering design.
18	Wall 43 (MP 356.98)	1 wall rated (3-Adequate). Wall condition is actually poor/marginal, but wall not in proximity of tracks and failure of wall should not affect train operation.
19	Wall 7 (MP 352.93) Wall 8 (MP 353.39)	2 walls rated (3-Adequate). Least critical among adequate walls.
20	Wall 19 (MP 354.01)	1 wall rated (2-Marginal). Concrete wall abutment for bridge, requires intermediate repairs. Recommended to combine this project with the identified bride replacement at this location. Will require additional engineering cost/design and not part of retaining wall scope of work.
21	Wall 44 (MP 356.98)	1 wall rated (4-Good). Requires simple repairs.
22	Wall 15 (MP 353.78)	1 wall rated (4-Good). Timber crib wall, requires higher costs and additional engineering design.
23	Wall 5 (MP 351.23) Wall 6 (MP 352.93)	2 walls rated (4-Good).
24	Wall 39 (MP 355.11) Wall 40 (MP 355.19)	1 wall rated (5-Excellent).
25	Wall 21 (MP 354.08)	1 wall rated (5-Excellent).

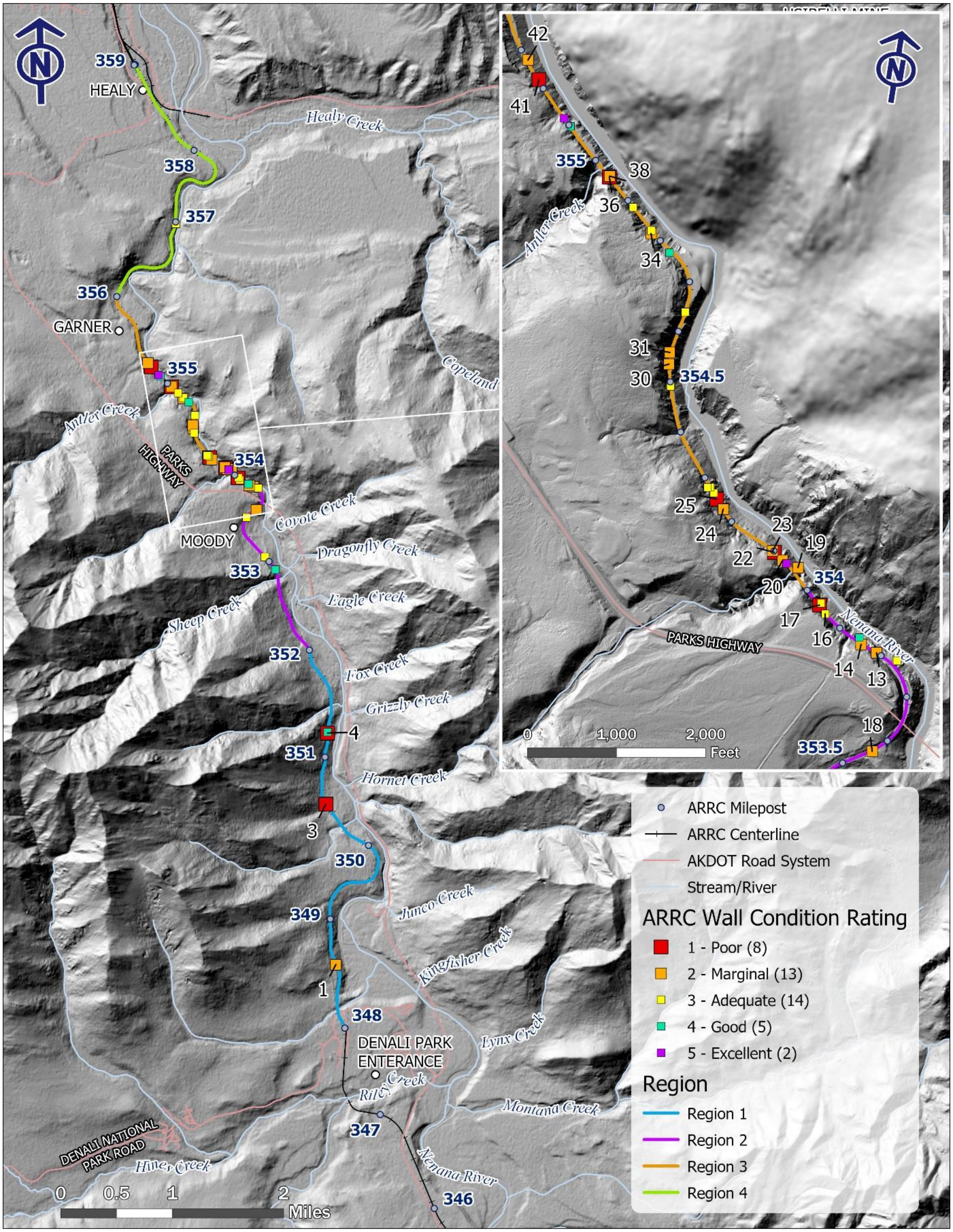

Figure 6-1: All Retaining Walls in Healy Canyon

Project (1-25)	Wall Number (1 -44)	ARRC Wall Condition Rating	Milepost	Nearest Railroad Siding	Fiber Optic Location	Overhead Utilities	Authorized Passenger Track Speed	Authorized Freight Track Speed	Soldier Pile Material	Soldier Pile Quantity	Soldier Pile Exposed Height	Soldier Pile Condition	Wall Material	Wall Quantity	Wall Exposed Length	Wall Condition	Wales Material	Wales Condition
1	3	1	350.72	Oliver Siding	East Side of Tracks	None	25	25	Timber/steel	11	3.5	1	Timber/steel		190			
2	25	1	354.26	Healy Siding	East Side of Tracks	None	15	15	Steel	6		2	Timber	3	25	1		
	24	2	354.23	Healy Siding	East Side of Tracks	None	15	15	Steel	5	2		Timber	1	30	2		
3	36	1	354.94	Healy Siding	East Side of Tracks	None	15	15					Timber		20	2	Timber	
	38	2	354.95	Healy Siding	East Side of Tracks	None	15	15	Timber				Timber		10		Timber	
4	41	1	355.41	Healy Siding	East Side of Tracks	None	15	15	Timber	12		1	Timber		70	2		
	42	2	355.5	Healy Siding	East Side of Tracks	None	15	15	Timber	18		2	Timber		45	2		
5	17A	1	353.96	Healy Siding	East Side of Tracks	None	15	15	Timber	5	2	1	Timber	2	14	3		
	16	3	353.94	Healy Siding	East Side of Tracks	None	15	15	Timber			1	Timber Crib		25	1		
	17B	3	353.94	Healy Siding	East Side of Tracks	None	15	15	Timber			1	Timber Crib		27	1		
6	22	1	354.1	Healy Siding	East Side of Tracks	None	15	15	Timber		30		Timber Crib		60	1		
7	4	1	351.2	Oliver Siding	East Side of Tracks	None	25	25	Timber	8	1		Timber		40			
8	20	2	354.06	Healy Siding	East Side of Tracks	None	15	15	Steel Rail Piles	4	16	2	Timber	10	30	2		
	23	2	354.1	Healy Siding	East Side of Tracks	None	15	15	Timber	9			Timber	2	42	2		
9	33	4	354.8	Healy Siding	East Side of Tracks	None	15	15	Timber	4			Timber		18	2		
	34	2	354.8	Healy Siding	East Side of Tracks	None	15	15	Timber	4	2		Timber	4	9	2		
10	18	2	353.97	Healy Siding	East Side of Tracks	None	15	15	Steel	3	2.5	2	Timber		25	2		
11	31	2	354.56	Healy Siding	East Side of Tracks	None	15	15	Timber and Steel	12			Timber	1	72	2		
12	14	2	353.77	Healy Siding	East Side of Tracks	None	15	15	Timber	3	1	2	Timber	2	18	2		
13	1	2	348.58	Oliver Siding	East Side of Tracks	None	25	25	Timber	8	3	2	Timber	3	60	2		
14	29	3	354.51	Healy Siding	East Side of Tracks	None	15	15	Timber	3	1		Timber		15	2		
	30	2	354.54	Healy Siding	East Side of Tracks	None	15	15	Timber	15			Timber	1	80	2		
	32	3	354.65	Healy Siding	East Side of Tracks	None	15	15	Timber	4			Timber	1	105	2		
15	26	3	354.28	Healy Siding	East Side of Tracks		15	15	Steel			2	Timber					
	27	3	354.28	Healy Siding	East Side of Tracks	None	15	15	Steel	5	1.5		Timber		32	2		
	28	3	354.4	Healy Siding	East Side of Tracks	None	15	15	Timber	5	1	3	Timber		30	1		
16	10	3	353.69	Healy Siding	East Side of Tracks	None	15	15			20		Timber Crib		130	3		
	13	2	353.76	Healy Siding	East Side of Tracks	None	15	15			12		Timber Crib		40	2		
17	35	3	354.9	Healy Siding	East Side of Tracks	None	15	15			15		Timber Crib		36	1		
	35	3	354.92	Healy Siding	East Side of Tracks	None	15	15			15		Timber	2	15	3		
18	43	3	356.98	Healy Siding	West Side of Tracks	None	15	15	Timber	20		3	Timber		120	3		
19	7	3	353.39	Healy Siding	East Side of Tracks	None	15	15	Timber	46	2	3	Timber		300			
19	8	3	353.48	Healy Siding	East Side of Tracks	None	15	15	Timber	32	1	3			45			
20	19	2	354.01	Healy Siding	East Side of Tracks	None	15	15			18		Concrete		55	2		
21	44	3	356.98	Healy Siding	West Side of Tracks	None	15	15	Timber	20		3	Timber		120	3		
22	15	4	353.78	Healy Siding	East Side of Tracks	None	15	15			12		Timber Crib		51	3		
23	5	4	351.23	Oliver Siding	East Side of Tracks	None	25	25	Steel/sheet piles	4	4	5	Timber/steel	4	20	4	Steel	
	6	4	352.93	Healy Siding	East Side of Tracks	None	15	15	Steel Sheet Pile			3			350		Steel	3
24	39	4	355.11	Healy Siding	East Side of Tracks	None	15	15	Timber & Steel	19		4	Timber & Steel		110	4	Steel	4
	40	5	355.19	Healy Siding	East Side of Tracks	None	15	15	Steel	19	10	5	Steel		115	5	Steel	4
25	21	5	354.08	Healy Siding	East Side of Tracks	None	15	15	Steel	14		5	Steel		106	5	Steel	5

Project (1-25)	Wall Number (1 -44)	ARRC Wall Condition Rating	Anchor Pile Material	Anchor Pile Quantity	Anchor Pile Condition	Line and Surface Type	Line Type	Tie Condition	Tie Type	Distance from end of tie to wall (South)	Distance from end of tie to toe (South)	Distance from end of tie to wall (North)	Distance from end of tie to toe (North)	Culverts Present	Type of Material Lining Ditch	Downhill Condition and Vegetation	Uphill Condition and Vegetation
1	3	1				CWR/Ballast	Tangent	4	Concrete	5.25	8.25	6.75	7.25	yes	Ponding	Scrub Shrub	Scrub Shrub
2	25	1				CWR/Ballast	Tangent	4	Concrete	4		4.5		no	Gravel	Rock Slope	Rock Slope
	24	2				CWR/Ballast	Tangent	4	Concrete	4.75	5.5	5	5.5	no	Gravel	Rock Slope	Rock Slope
3	36	1				CWR/Ballast	Tangent	4	Concrete	6.5		6.5		no	Gravel	Rock Slope	Rock Slope
	38	2				CWR/Ballast	Tangent	4	Concrete	7.5				no	Gravel	Scrub Shrub	Scrub Shrub
4	41	1				CWR/Ballast	Tangent	4	Concrete	10		6		no	Gravel	Rock Slope	Rock Slope
	42	2				CWR/Ballast	Curve		Concrete	12.5		12.5		yes	Gravel	Gravel	Gravel
5	17A	1				CWR/Ballast	Tangent		Concrete	3.5	4	3	3.25	no	Gravel	Gravel	Gravel
	16	3	Timber		2	CWR/Ballast	Tangent	4		7.5		7.5		no	Gravel	Rock Slope	Gravel
	17B	3		4		CWR/Ballast	Tangent	4	Concrete	7.5		7.5		no	Gravel	Rock Slope	Gravel
6	22	1				CWR/Ballast	Tangent	4	Concrete	8.5		8.5		no	Gravel	Rock Slope	Rock Slope
7	4	1				CWR/Ballast	Tangent	4	Concrete	8.75	9.75	8	8.75	yes	Ponding	Scrub Shrub	Scrub Shrub
8	20	2				CWR/Ballast	Curve	4	Concrete	17.5				no	Gravel	Rock Slope	Rock Slope
	23	2				CWR/Ballast	Tangent		Concrete	6		4.5		no	Gravel	Rock Slope	Rock Slope
9	33	4				CWR/Ballast	Tangent	4	Concrete	3.75		4.25		yes	Gravel	Rock Slope	Rock Slope
	34	2				CWR/Ballast	Tangent		Concrete	4.75		4.75		yes	Ponding	Rock Slope	Rock Slope
10	18	2				CWR/Ballast	Tangent	4	Concrete	2		4.25		no	Gravel	Rock Slope	Rock Slope
11	31	2				CWR/Ballast	Curve	4	Concrete	5.5		8.75		yes	Gravel	Rock Slope	Rock Slope
12	14	2				CWR/Ballast	Tangent		Concrete	4.25		3		no	Gravel	Rock Slope	Rock Slope
13	1	2				CWR/Ballast	Tangent	4	Concrete	4.5	5.75	5	6	yes	Mesic Herb	Trees	Trees
14	29	3				CWR/Ballast	Curve	4	Concrete	4.25		3.25		no	Gravel	Rock Slope	Rock Slope
	30	2				CWR/Ballast	Tangent	4	Concrete	11.5		11.5		no	Gravel	Rock Slope	Rock Slope
	32	3				CWR/Ballast	Tangent	4	Concrete	12.5		12.5		yes	Gravel	Gravel	Rock Slope
15	26	3				CWR/Ballast	Tangent	4	Concrete					no	Gravel	Rock Slope	Rock Slope
	27	3				CWR/Ballast	Tangent	4	Concrete	4		4		no	Gravel	Rock Slope	Rock Slope
	28	3				CWR/Ballast	Tangent	4	Concrete	7.5				no	Dirt	Gravel	Rock Slope
16	10	3	Timber		3	CWR/Ballast	Curve	4	Concrete	9.5		9.5		no	Gravel	Scrub Shrub	Rock Slope
	13	2				CWR/Ballast	Tangent		Concrete	9.5		9.5		no	Gravel	Rock Slope	Rock Slope
17	35	3	Timber		3	CWR/Ballast	Tangent	4	Concrete	12.5		12.5		no	Gravel	Rock Slope	Rock Slope
	35	3	Timber		3	CWR/Ballast	Tangent	4	Concrete	25		25		no	Gravel	Rock Slope	Rock Slope
18	43	3				CWR/Ballast	Tangent	4	Concrete	30		30		no	Gravel	Gravel	Gravel
19	7	3				CWR/Ballast	Curve	4	Concrete	8.25	9.25	3.75	4.75	yes	Gravel	Scrub Shrub	Trees
19	8	3				CWR/Ballast	Tangent	4	Concrete	8.5				no	Mesic Herb	Scrub Shrub	Trees
20	19	2				CWR/Wood	Tangent		Timber	6.5		7		no	Gravel	Rock Slope	Rock Slope
21	44	3				CWR/Ballast	Tangent	4	Concrete	30		30		no	Gravel	Gravel	Gravel
22	15	4	Timber		3	CWR/Ballast	Tangent		Concrete	10.5		10.5		no	Ponding	Rock Slope	Rock Slope
23	5	4				CWR/Ballast	Tangent	4	Concrete	8.5	9.5	8	8.5	no	Gravel	Rock Slope	Gravel
	6	4				CWR/Ballast	Tangent	4	Concrete	8.25	10.25	7	10.25	no	Gravel	Gravel	Gravel
24	39	4				CWR/Ballast	Tangent	4	Concrete	11.5		5.75		no	Gravel	Rock Slope	Gravel
	40	5				CWR/Ballast	Tangent	4	Timber	5.25		5		no	Gravel	Gravel	Rock Slope
25	21	5				CWR/Ballast	Curve	4	Concrete	11.25		10.5		no	Gravel	Rock Slope	Rock Slope