Denali Park Realignment (MP 344-348) Feasibility Study

FTA Grant AK-55-X003

ARRC Project No. 10437

Alaska Railroad Corporation

Riley Creek, AK

November 30, 2018

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Contents

Tables

Figures

Appendices

Acronyms and Abbreviations

AADT	Average Annual Daily Traffic
ARRC	Alaska Railroad Corporation
DNP	Denali National Park and Preserve
DOT&PF	Alaska Department of Transportation and Public Facilities
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
MP	Milepost
mph	miles per hour
NEPA	National Environmental Policy Act
NPS	National Park Service
USACE	US Army Corps of Engineers

Executive Summary

This study assesses the feasibility of realigning the Alaska Railroad Corporation (ARRC) track near the entrance to Denali National Park (DNP) to reduce maintenance costs, provide operational efficiency, and improve safety by removing two highway-rail crossings on the Parks Highway: an at-grade crossing at ARRC Milepost (MP) 345.09 and a grade-separation at ARRC MP 346.7.

The purpose of the proposed project is to improve railroad safety, reduce rail transportation times, reduce roadway transportation delays, and reduce operation and maintenance costs.

This study accomplishes the following:

- Identifies background documentation supporting the purpose and need for the project;
- Includes a preliminary environmental overview (opportunities and constraints);
- Develops a range of preliminary realignment alternatives (and explores a grade-separation as an alternative to realignment);
- Provides a comparison of feasible alternatives against the No Build Alternative; and
- Identifies a feasible realignment alternative and provides refined engineering and evaluation of that alternative, including mapping, geotechnical and environmental reviews, and conceptual cost estimates.

Alternative 1 Rail Realignment (Preferred): This study identifies a rail realignment west of the existing track alignment through DNP as recommended for future development. The realignment would reduce lifecycle maintenance costs, eliminate the potential for vehicle-train conflicts by removing the at-grade crossing, and eliminate traffic delay on the Parks Highway. The realignment would not only solve the at-grade safety and maintenance issues at ARRC MP 345.09, it also would eliminate future bridge maintenance and replacement at the grade-separation at MP 346.7. Bypassing the existing section of track would also result in straighter track and reduced curves, and would remove the constriction that the MP 346.7 bridge poses for future double tracking. The shorter track would slightly reduce train travel times, and the reduction in curvature would reduce wear and tear on rail equipment and track. By not crossing the highway and by having greater separation, the potential for public trespass would also be reduced.

Other Alternatives: Alternative 2, a separate realignment alternative, was also explored, but was eliminated as not feasible due to earthwork requirements and wetland and park impacts. Alternative 3 – Grade Separate ARRC MP 345.09 is a feasible alternative, but is not preferred as it would not provide as significant maintenance cost savings or travel benefits, and would not provide the same level of improvement in public safety. A No Build Alternative that would make no improvements would not eliminate the safety or maintenance issues of the at-grade crossing at ARRC MP 345.09 and is not recommended.

1. Introduction

This study assesses the feasibility of realigning the ARRC track near the entrance to DNP in order to improve railroad safety, reduce rail transportation times, reduce roadway transportation delays, and reduce operation and maintenance costs. This feasibility study was developed through a Federal Transit Administration (FTA) grant to evaluate the feasibility of a rail realignment. The study:

- Identifies background documentation supporting the purpose and need for the project;
- Includes a preliminary environmental overview (opportunities and constraints);
- Develops a range of preliminary realignment alternatives (and explores a grade-separation as an alternative to realignment);
- Provides a comparison of feasible alternatives against the No Build Alternative; and
- Identifies a feasible realignment alternative and provides refined engineering and evaluation of that alternative, including mapping, geotechnical and environmental reviews, and conceptual cost estimates.

The planning-level analysis includes conceptual engineering, consideration of potential environmental and geotechnical constraints, and conceptual cost estimates. Detailed appendices provide additional information on these topics, and include the Alaska Policy on Railroad/Highway Crossings (Appendix A), the plan set and cost estimate (Appendix B), the geotechnical analysis (Appendix C), the wetlands analysis (Appendix D), and the Railroad Track Quantities and Trail Design Report (Appendix E).

This feasibility study will be shared with project stakeholders to solicit input and develop consensus on which alternative to move forward into permitting, design, and construction. Key stakeholders include the ARRC, Alaska Department of Transportation and Public Facilities (DOT&PF), National Park Service (NPS), and Denali Borough. The general public and environmental organizations with an interest in DNP are also stakeholders, and additional outreach and coordination may be needed as the project advances.

1.1. Study Area and Setting

The study area is located between ARRC MP 344.8 and 347.3 (approximately Parks Highway MP 235.0 and 237.0; see Figure 1-1) and is in the Denali Borough. The study area falls entirely within the DNP boundaries. The DOT&PF has an easement for the Parks Highway through the DNP, and its width varies from 100 to 200 feet wide.[1] The ARRC has a 200-foot right-of-way (100 feet to either side of the track centerline) through the DNP for the existing track.[2]

The Parks Highway generally runs parallel and to the east of the ARRC track through DNP, except for the segment between ARRC MP 345.09 and 346.7, where the Parks Highway crosses the ARRC tracks and

[1] Riley Creek Bridge Replacement Project plan set, DOT&PF Project Number 63763.

[2] Deed for Exclusive Use Easement and Railroad Related Improvements, recorded on January 9, 1985, in Book 33, Page 985, Nenana Recording District, Fourth Judicial District, State of Alaska.

parallels the tracks to the west. The Parks Highway in this section is managed by DOT&PF's Northern Region.

The Parks Highway crosses the ARRC track twice in the study area: at an at-grade crossing at ARRC MP 345.09 and at a grade-separation at ARRC MP 346.7. The grade-separation at ARRC MP 346.7 is a steel through-plate girder-bridge approximately 240 feet long that crosses two lanes of the Parks Highway. The current track speed is 30 miles per hour (mph) and the current highway speed is 55 mph. The bridge allows for approximately 0.8 percent track grade and is situated at a 47-degree skew from perpendicular with the roadway.

The Alaska Policy on Railroad/Highway Crossings encourages considering "…the feasibility of eliminating crossings if this can be accomplished with safety benefits which outweigh the increased operational costs and inconvenience to users…" (see Appendix A). Over time, ARRC and DOT&PF have been able to reduce the number of at-grade crossings on the Parks Highway to two: the at-grade crossings at Parks Highway MP 169/ARRC MP 279 (Hurricane) and Parks Highway MP 235.0/ARRC MP 345.09 (Denali). DOT&PF has identified grade-separating MP 169/ARRC MP 279 (Hurricane) as part of the Parks Highway Mile Point 127–148 (Milepost 163–183) Rehabilitation Project.[3] Once that project is implemented, the only remaining at-grade crossing on the Parks Highway would be at Parks Highway MP 235.0/ARRC MP 345.09.

Immediately north of the study area is the Denali Visitor Center and Entrance, which is the main and most heavily visited entrance to DNP. Transportation modes to the park entrance include car, bus, public transportation, and train. The entrance area contains most of the park infrastructure, including the park headquarters, visitor center, railroad depot, and Wilderness Access Center. Riley Creek Campground, located nearby, is the largest camping area within the park and the only campground open year-round. The ARRC passenger depot is located 100 yards from the Denali Visitor Center.[4]

[3] According to the 2018-2021 State Transportation Improvement Program, this project is scheduled for funding after Federal Fiscal Year 2021. http://dot.alaska.gov/stwdplng/cip/stip/assets/STIP.pdf (page 208)
[4] DNP website: https://www.nps.gov/dena/planyourvisit/campgrounds.htm#6/63.421/-148.491

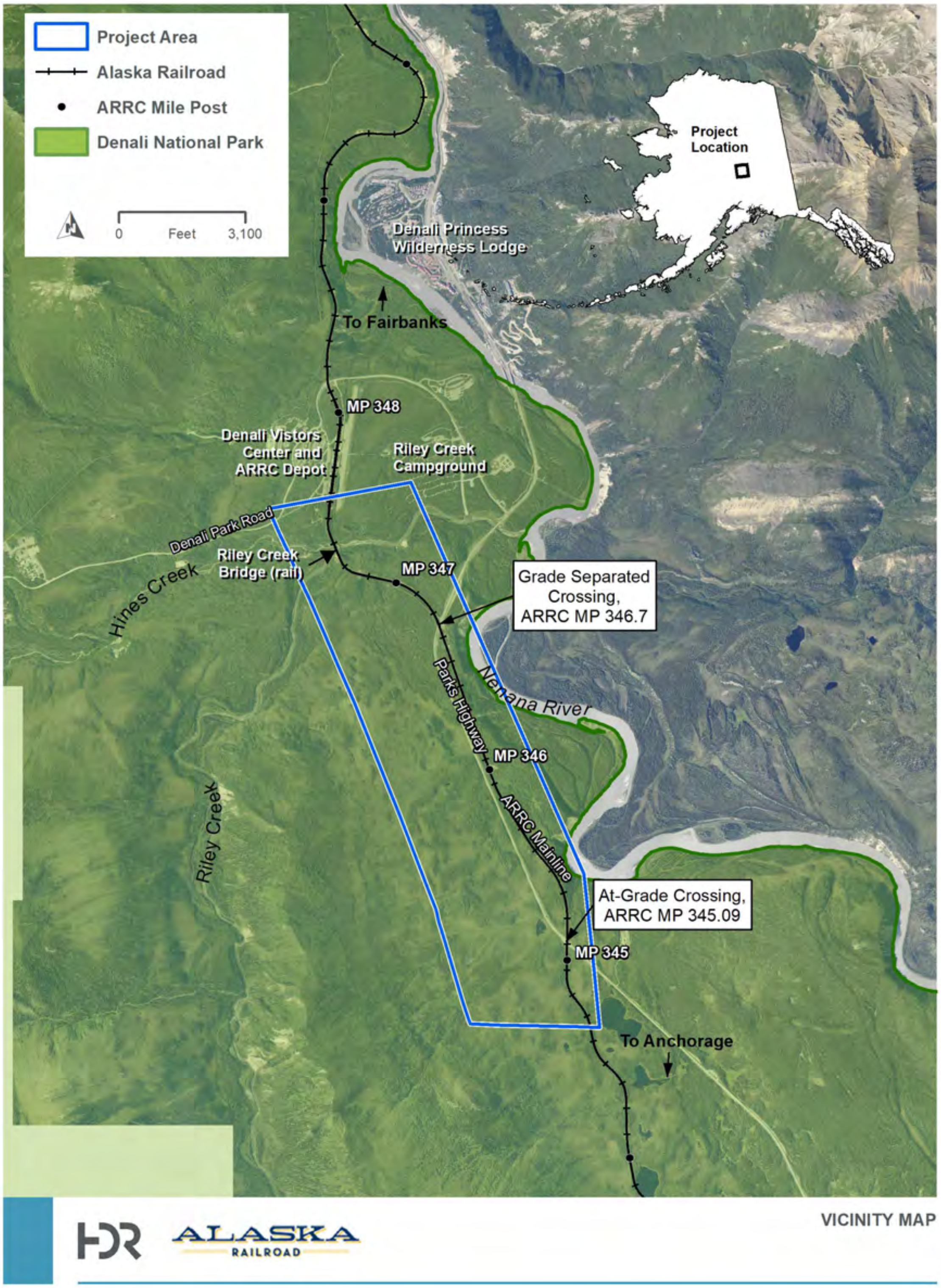

Figure 1-1. Vicinity Map

Each year, DNP has approximately 600,000 visitors (642,809 in 2017[5]). A 2011 visitor study identified that 91 percent of DNP visitors came through the main entrance.[6] Numerous tour companies offer a variety of road/rail packages for their passengers to access DNP, which means that tour buses regularly travel the Parks Highway throughout the summer. This is in addition to independent travelers who access the park using rental cars or passenger cars. According to the Denali National Park Long Range Transportation Plan,[7] in 2008 285,000 visitors arrived at the park via road and 150,000 visitors arrived via train. The park is popular enough that congestion is experienced during the peak tourism months at DNP.

A few miles farther north is a developed area that is a tourist destination with many hotels, restaurants, and tourism businesses.

1.2. Methodology

Based on a review of the study area, ARRC commissioned a number of special studies to provide baseline information to support the feasibility study. The review determined the most critical factors that would help determine feasibility, including topographic mapping, a geotechnical report that provides a geotechnical data review and limited geotechnical borings (Appendix C), a wetland delineation of the project area (Appendix D), a Railroad Track Quantities and Trail Design Report (Appendix E), and a preliminary review of potential cultural resources.

Engineers at ARRC laid out preliminary alignments, taking into consideration topography; potential tie-in points; and geotechnical, wetland, and cultural resource constraints. Two realignment options were explored, and a grade-separation was evaluated for comparison. A No Build Alternative was also evaluated for comparison. The four alternatives are denoted as:

- Alternative 1 – Railroad Realignment (parallel to the Parks Highway)
- Alternative 2 – Westerly Railroad Realignment (minimize curvature)
- Alternative 3 – Grade Separate ARRC MP 345.09 (highway over rail) on the existing alignment
- No Build Alternative

ARRC first conducted a fatal flaw screening analysis of these alternatives and identified Alternatives 1 and 3 to move forward for more refined engineering and feasibility analysis. Realignment Alternative 2 was eliminated due to substantial earthwork and park and wetland impacts, and is not considered feasible. See Section 4 for more details regarding alternatives.

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[5] DNP website: https://www.nps.gov/dena/planyourvisit/campgrounds.htm#6/63.421/-148.491

[6] Fix, P. J., A. Ackerman, and G. Fay. 2012. Estimating visits to Denali National Park and Preserve: Spring/Summer 2011. Natural Resource Technical Report NPS/AKR/NRTR—2012/641. National Park Service, Fort Collins, Colorado. Available online at https://irma.nps.gov/DataStore/DownloadFile/460185

[7] NPS. 2012. National Park Service Alaska Region Long Range Transportation Plan: A Drop-Down Plan to the Alaska Federal Lands Long Range Transportation Plan. Available online at https://flh.fhwa.dot.gov/programs/flpp/lrtp/documents/nps-ak-lrtp.pdf

2. Purpose and Need

This section provides background information regarding project need. It includes a discussion of the importance of the Alaska Railroad and the level of train traffic to be planned for; the importance of the Parks Highway and the level of traffic that contributes to the potential for conflicts; the safety concerns at at-grade crossings, including potential train-vehicle conflicts; and the operational and maintenance reasons for realigning the railroad.

2.1. Alaska Railroad Traffic

The ARRC provides a critical freight and passenger surface transportation connection between the tidewater ports of Anchorage, Whittier, and Seward as well as between DNP, Fairbanks, Fort Wainwright, and several Railbelt communities. The railroad and the Parks Highway support resource development in Interior Alaska and on the North Slope. The railroad provides tourists with a rare look at back-country Alaska as it takes passengers from Anchorage to DNP and Fairbanks, or south to Seward and Kenai Fjords National Park.

The construction of the railroad was completed in 1923, making it one of the oldest transportation systems in the state. The ARRC's ability to provide both regularly scheduled passenger and freight service makes it unique in the United States. In 2017, the ARRC transported approximately 506,000 passengers and 4.77 million tons of freight, including gravel, coal, petroleum products, lumber, and general cargo.[8] The ARRC supports many of Alaska's industries, including resource development and tourism, making it an essential part of the state's economy.

Within the study area, the ARRC track is a heavily used mainline corridor that serves substantial traffic. Train traffic in the project corridor varies by season. Regularly scheduled winter train traffic (mid-September–mid-May) generally consists of two freight trains per day (one northbound and one southbound) and four passenger trains per week (two northbound and two southbound), totaling approximately 68 regularly scheduled trains per month (see Table 2-1). In addition, work trains and coal trains travel through the area (approximately 15–20 trains per month; the number varies depending on project and client needs).

Table 2-1. Regularly Scheduled ARRC Train Traffic in Project Corridor, Winter

Winter Season (September 22–May 5, 2018)			
Time	**Direction**	**Train**	**Frequency**
0400	North	Freight	Sunday, Monday, Tuesday, Wednesday, Friday*
1200	South	Aurora	Sunday with varying Wednesday and Friday service
1600	North	Aurora	Saturday with varying Tuesday and Thursday service
2315	South	Freight	Sunday, Monday, Tuesday, Wednesday, Friday*

* A sixth freight train is operated on an as-needed basis.
Total: Approximately 68 regularly scheduled trains per month.
Source: ARRC website https://www.alaskarailroad.com/

[8] Alaska Railroad 2017 Annual Report, available online at https://www.alaskarailroad.com/sites/default/files/Communications/ARRC_Annual_Report_2017_forWeb.pdf

Summer train traffic (mid-May–mid-September) consists of two freight trains per day (one northbound and one southbound) and four passenger trains per day, with two additional passenger trains (one northbound and one southbound) on Saturdays and every other Wednesday. This totals approximately 192 regularly scheduled trains per month (see Table 2-2). In addition, work trains and coal trains travel through the project area (approximately 15–20 trains per month, depending on project and client needs).

Table 2-2. Regularly Scheduled ARRC Train Traffic in Project Corridor, Summer

Summer Season (May 6–September 21, 2018)			
Time	**Direction**	**Train**	**Frequency**
0400	N	Freight	Sunday, Monday, Tuesday, Wednesday, Friday*
0815	S	Denali Express	Saturday, every other Wednesday
0915	S	Healy Express	Daily
1200	S	Denali Star	Daily
1600	N	Denali Star	Daily
1640	N	Healy Express	Daily
1745	N	Denali Express	Saturday, every other Wednesday
2315	S	Freight	Sunday, Monday, Tuesday, Wednesday, Friday*

* A sixth freight train is operated on an as-needed basis.
Total: Approximately 192 regularly scheduled trains per month.
Source: ARRC website https://www.alaskarailroad.com/

2.2. Parks Highway Traffic

The rail realignment is proposed, in part, due to potential conflicts with traffic at the at-grade intersection with the Parks Highway. This section provides supporting background information on the highway.

Completed in 1971, the Parks Highway is an important surface transportation connection, essential for commerce, resource development, and recreation. The highway is part of the National Highway System, linking Alaska's largest cities, Anchorage and Fairbanks. It provides support to the North Slope oil development via its connection to the Dalton Highway, while also providing access to unmatched recreation opportunities. The Parks Highway generally parallels the ARRC's tracks. When it was built, the Parks Highway had numerous at-grade crossings of the ARRC track throughout its length. By 2021, the only remaining at-grade crossing on the Parks Highway will be at Parks Highway MP 235.0/ARRC MP 345.09.

The most recent traffic data in the area provided by DOT&PF are for Parks Highway MP 237 at Riley Creek. This location is approximately 0.25 mile north of the grade-separation (ARRC MP 346.7) and provides the best available data for capturing current traffic flow at both crossings. DOT&PF historical Average Annual Daily Traffic (AADT) data for this location shows an average AADT count of 2,947 between 2000 and 2016.[9] The lowest traffic count was 1,869 in 2000, and the peak year was 2008. Over the past 16 years, the rate of traffic flow has been generally steady.

2.3. Safety Considerations

The at-grade crossing at ARRC MP 345.09/Parks Highway MP 235 represents a safety issue. While there are statistically few crashes at at-grade crossings in Alaska, they represent a substantial safety concern because of the potential for highway vehicle-rail crashes. Studies of crash severity document that, compared to highway traffic crashes, highway vehicle-rail crashes lead to a higher rate of fatality and injury to vehicle users: "For example, data [from 2005-2012] indicate that 8.55% of vehicle-rail crashes were fatal and 26.68% resulted in injury (FRA 2012). However, in the case of highway traffic crashes, the percentage of fatal crashes is no more than 2% (NHTSA 2012)."[10]

At the existing at-grade crossing, a signalized advance warning system is in place. Even when signalized advance warning devices are installed, there is not 100 percent compliance. Unlike a roadway vehicle, a train cannot safely stop within the same distance as an automobile once a perceived hazard is identified. There is always the potential for a collision and/or train derailment at any at-grade crossing. This places the train crews, train passengers, and vehicle occupants at risk. Additionally, traffic delays resulting from highway vehicle-rail crashes have the potential to cause additional accidents along the affected corridor.

ARRC and DOT&PF have been working together to eliminate all remaining at-grade crossings on the Parks Highway to address safety concerns and improve travel times for users. Eliminating the MP 345.09 at-grade crossing would reduce safety concerns associated with that crossing, including the potential for train and vehicle/pedestrian traffic crashes. The Alaska Policy on Railroad/Highway Crossings (see Appendix A) outlines the formation and tasks of a diagnostic team to evaluate crossings. Section 4.3.4 of the policy states:

> The diagnostic team should always consider the feasibility of eliminating crossings if this can be accomplished with safety benefits which outweigh the increased operational costs and inconvenience to users, and if it would not shift the safety problem to another area, or increase the area-wide hazard potential.

There have been few incidents recorded at the grade crossing in the project area. The only incident in recent years involved the railroad bridge at ARRC MP 346.7 being struck by equipment on a moving semi-truck on the highway.

Commercial motor vehicles transporting passengers or hazardous materials must stop at all at-grade crossings, with few exceptions. These stops can increase the risk of rear-end collisions on the highway. Just such a collision happened in 2014 between a semi-truck and a Princess tour bus at Parks Highway MP 169/ARRC MP 279 (Hurricane). The bus was heading north from the McKinley Wilderness Lodge to

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[9] Vockeroth, S. 2018. Personal communication from Scott Vockeroth, Highway Data Manager, Fairbanks Field Office, DOT&PF, January 17, 2018. On file at HDR.

[10] Fan, Wei (David), Martin R. Kane, and Elias Haile. 2015. Analyzing Severity of Vehicle Crashes at Highway-Rail Grade Crossings: Multinomial Logit Modeling. *Journal of Transportation Research Forum*, Volume 54, Number 2, Summer 2015.

DNP and was stopped at an at-grade crossing when it was rear-ended by a semi-truck. Twelve to 14 of the 44 bus passengers reported minor injuries and were transported from the scene by ambulance, the highway was closed for several hours, and 200 to 300 gallons of diesel fuel was spilled.[11] The ARRC MP 345.09/Parks Highway MP 235 at-grade crossing does not have an auxiliary slow-vehicle turn-out lane for use by commercial traffic. As a result, all traffic is delayed while a commercial vehicle is stopped at the at-grade crossing.

Considering the growing numbers of visitors to DNP, the steady traffic on the ARRC mainline track and Parks Highway, and the severity of potential highway vehicle-rail crashes, it is clear that eliminating the MP 345.09 at-grade crossing would improve safety for the traveling public both now and in the future.

2.4. Maintenance Costs

2.4.1. At-Grade Crossing at ARRC MP 345.09

The ARRC MP 345.09/Parks Highway MP 235 at-grade crossing has unusually high maintenance costs due to its remote location, challenging subsurface geotechnical conditions, and underlying permafrost. Additionally, power must be generated at the crossing site in order to operate the active warning devices, as it is off the Alaska Railbelt power grid.[12] Power is generated at the site using a combination of both renewable (battery banks, solar, wind) and non-renewable (fossil fuels) sources, all of which require maintenance on a regular basis. The ARRC must maintain these active warning devices to Federal Railroad Administration (FRA) 49 Code of Federal Regulations Part 234 Standards. If the power runs out, the gates close over the Parks Highway, preventing traffic from using the highway until the gates are opened again. The ARRC is currently installing remote monitoring equipment to monitor the various power generation systems to reduce the likelihood of the at-grade crossing being closed due to power loss.

Considerable public funds are expended by DOT&PF to maintain the at-grade crossing (ARRC MP 345.09/Parks Highway MP 235). The total signal maintenance and general repair costs at the at-grade crossing over the last 5 years are approximately $620,000 ($124,000 annually). Maintenance includes replacing the signals every 15–20 years (approximately $800,000), batteries within the signal hut every 10–15 years (approximately $13,000), and the generator every 7–10 years (approximately $80,000–$100,000). In addition, the crossing pads are damaged almost annually and cost approximately $8,500 per repair.

The subsurface geotechnical conditions of the site heavily influence the differential settlement that occurs at both the at-grade crossing and the adjacent highway. The settlement in this general area requires repairs to both the highway and the at-grade crossing at a more frequent rate than other adjoining sections of the highway. According to DOT&PF, "the segment of the Parks Highway between MP 230.5 and 236 has been one of the most problematic for maintenance along the highway" (see the geotechnical report in Appendix C). According to the ARRC, settlement issues result in the at-grade

[11] Available online at https://ktna.org/2014/08/semi-tour-bus-crash-near-mile-169-of-the-parks-highway/
[12] Active warning devices installed include advanced warning (W-10), cantilever signals, gates, and flashing lights.

crossing track having to undergo regular surfacing (every 3–5 years).[13] Each surfacing costs approximately $30,000.[14]

DOT&PF indicates that between Parks Highway MP 235.0 and 236.0, numerous sections of the roadway have been frost jacked to an extent that requires annual pavement patching between the worst sections. Over the years, ongoing settlement repairs have resulted in sections of the Parks Highway amassing up to an 8-foot-thick layer of asphaltic-concrete pavement in areas near the at-grade crossing (see the geotechnical report in Appendix C). These settlement issues have resulted in a 10-year expected lifespan of the at-grade crossing, which is much shorter than the 20-year lifespan of a typical concrete panel at-grade crossing. The most recent upgrade to the ARRC MP 345.09/Parks Highway MP 235 at-grade crossing was completed in 2010, and it is expected that the at-grade crossing will need to be replaced no later than 2020. Table 2-3 summarizes the key maintenance expenses associated with this at-grade crossing.

In addition, the DOT&PF is likely to incur other costs that are not captured here. For example, the DOT&PF is required to process Lane Closure Permits and provide temporary traffic control measures, in addition to FRA-mandated railroad flagging operations, for the duration that work is being performed on the at-grade crossing.

Table 2-3. Key Maintenance Expenses Associated with At-grade Crossing at ARRC MP 345.09

Item	Occurrence Interval	Cost per Occurrence
Crossing Resurfacing	3–5 years	$30,000
Signalization System Replacement	15–20 years	$800,000
Signal Hut Batteries Replacement	10–15 years	$13,000
Generator Replacement	7–10 years	Between $80,000 and $100,000
Crossing Rebuild	10 years	$300,000
Crossing Pad Repair	Annual	$8,500

Source: Information provided by ARRC.

2.5. Draft Purpose and Need Statement

Based on the analysis above, the following draft project purpose and need statement has been developed to reflect the problems the project should aim to solve and the goals that should be achieved by the preferred alternative.

> **Draft Purpose and Need Statement:** The purpose of the project is to improve public safety, improve travel times for rail and road vehicles, and reduce maintenance costs.

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[13] Information provided by ARRC.

[14] Information provided by ARRC.

3. Constraints

The following sections describe the constraints that focused the potential realignment analysis within the study area, including railroad design criteria and geographic, geotechnical, wetlands, and cultural resources constraints.

3.1. Railroad Design Criteria

Railroad design criteria are identified as a constraint; horizontal and vertical curvature limit the ability to change direction and grade. In order to maintain train speed and efficiency, the ARRC has established design constraints when designing track. Consistent with ARRC mainline design practice, realignment alternatives are designed for 60-mph rail operations.[15] Though not all trains may operate at this speed, time-sensitive traffic, including intermodal and potentially passenger traffic, would likely require transit time that should not be limited by track geometry.

According to ARRC technical standards,[16] desirable grades should generally be kept below 1.0 percent (either positive or negative), and horizontal curvature below 3.0 degrees. The ruling grade (maximum encountered) between Anchorage and Fairbanks is 1.90 percent at ARRC MP 293 near Honolulu Creek.[17] There are horizontal curves near MP 293 greater than 4.0 degrees. Concept design for the realignment has a maximum grade of 1.61 percent and maximum degree of curvature of 4.0 degrees; both values are below the ruling grades and curves for the segment of track between Anchorage and Fairbanks. The existing track in the area near the realignment has maximum grades of approximately 1.0 percent. The realignment is shorter than the current alignment and, thus, grades increase. The area of the proposed realignment has a negative grade (i.e., downgrade) for northbound traffic. As design progresses, an operations modeling effort must be undertaken to verify that the proposed alignment and profile work with ARRC's train operations.

The proposed right-of-way would be 200 feet wide, providing adequate space for signals, utility lines, sidings, and other facilities. This width would also provide a reasonable safety buffer along the proposed route and is consistent with ARRC standards. The railroad typical cross section would provide for a 40-foot embankment section to accommodate the railroad track and a potential future track-level access road. The access road would facilitate construction of modern railroad track incorporating welded rail and concrete ties. Further, the access roadway would provide access for railroad maintenance crews during operations.

3.2. Geographic

Physical geographic constraints such as steep slope, erosion, and floodplains limit the engineering options in the study area. These constraints include the Nenana River (flooding, steep bluffs, and

[15] Note: The track in the study area is bracketed by 25 mph and 30 mph track speeds to the north and south. While the design speed would allow for higher speeds in this section, in actuality, train operating speeds would remain at 30 mph.
[16] ARRC. January 2014. Technical Standards for Roadway, Trail, and Utility Facilities.
[17] ARRC. April 2015. Track Chart.

erosion), Riley Creek Bridge (existing water crossing), and the Riley Creek valley (steep slopes and wetland/riparian terrain).

In the study area, the Nenana River flows south to north immediately east of the highway and railroad. The west side of the river valley has moderately tall, steep bluffs. The railroad is built parallel to and near the top of these bluffs. In two places, river bends are actively eroding the western valley edge bluffs. At both bends, the railroad alignment sits at the top of the bluff with no room to construct another transportation corridor between the railroad and the top of the bluff. In addition, the northern river bend erosion is causing active slides into the river, which could destabilize the bluff top. Because of the river position in the valley and active bluff erosion, there is no available area to site a relocated railroad or road to the east of the existing railroad without the infrastructure being placed in the valley bottom with the Nenana River, where there is high flooding potential. Furthermore, any transportation corridor relocated into the valley bottom would require at least two bridges over the river itself as well as flood protection measures. Finally, relocating the railroad into the valley bottom would not be possible because of the steep rail grades needed to lower the railroad from the top of the river bluff to the valley bottom and then return it back to the northbound rail line at the north end of the project area. For these reasons, no realignment options are available to the east.

Halfway between ARRC MP 347 and 348, the tracks cross over Riley Creek via a bridge at MP 347.4. The Riley Creek Bridge is a 570-foot-span deck plate girder bridge, put into service in 1922.[18] As a substantial and costly bridge, any realignment options must be back on alignment before reaching this bridge to maintain its continued use.

Riley Creek Bridge (photo courtesy of ARRC)

Similar to the Nenana River, but to a lesser extent, Riley Creek valley limits realignment options. To the west, the topography drops off to the Riley Creek streambed, then quickly rises again into low hills. Routing to the west would require substantial earthwork (cuts and fills) to provide acceptable grades because the terrain sloping down to Riley Creek is too steep to easily traverse.

3.3. Geotechnical

The study area is known to have challenging geotechnical conditions. In 2017, ARRC performed geotechnical analysis in support of the proposed realignment. The full geotechnical report can be found in Appendix C. The analysis included sub-surface and field investigation, laboratory testing, and site mapping for areas within the DNP and within the DOT&PF right-of-way along the Parks Highway. ARRC found that the general area contains discontinuous permafrost, with some test holes showing

[18] ARRC Bridge Inventory, Chief Engineer's Files.

permafrost as shallow as 17 feet, while others were drilled as deep as 42 feet without encountering permafrost. The geotechnical characteristics tend to improve moving from south to north.

The findings for each segment by ARRC Milepost along the proposed alignment are summarized below.

MP 344.85–346.3

Glacial deposits with meadow or forested terrain. Most of this segment contains permafrost, except the area close to the existing roadway embankment. It also contains patches of organic soils, especially at the southern and northern ends of the segment.

MP 346.3–347.1

This segment was found to contain mostly sandy gravel with small amounts of fines. Moisture content was found to be relatively low (5 percent or less) and, in general, this segment would be recommended for re-use of embankment materials.

MP 347.1–347.4

Boreholes in this area identified a mixture of sandy-silty gravel, slightly silty gravel, and cobbles and boulders. This segment would entail cutting into a 70- to 90-foot-high hill comprised of glacial end moraine.

MP 347.4–Riley Creek

This final segment of the alignment traverses the Birch Creek Schist and the south approach fill of the Riley Creek Bridge.

The geotechnical investigation corroborates the ARRC's discussions with DOT&PF regarding the maintenance history of this area. The design of any project in the project corridor needs to consider geotechnical and permafrost-related issues, including thaw-unstable permafrost with excess ground ice, thick cover of peat and organic-rich materials, potentially unstable (and difficult) cuts through permafrost, significant cross-flow of subsurface and near-surface drainage, associated icing in the cut slopes, and areas that have already thawed (due to proximity to existing development) but have not yet consolidated and would be expected to do so under the weight of the new embankment.

3.4. Wetlands

Wetlands are also a constraint, and realignment options attempted to avoid or minimize impacts to wetlands. Wetlands refer to "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (33 Code of Federal Regulations Part 28.3(b)). Wetlands are a subset of "waters of the U.S." Note that the "wetlands" definition does not include unvegetated areas such as streams and ponds.

An office-based wetland and water body assessment identified wetlands and water bodies in the project area. These wetlands and water bodies were then given a preliminary U.S. Army Corps of Engineers (USACE) management category (see Figure 4-4). Those categories are:

Category I: These are wetlands that: 1) provide habitat for threatened or endangered species that has been documented; 2) represent a high quality example of a rare wetland type; 3) are rare within a given region; 4) provide habitat for very sensitive or important wildlife or plants; and/or 5) are undisturbed and contain ecological attributes that are impossible or difficult to replace within a human lifetime, if at all. Examples of the latter are mature, very productive forested wetlands unique to an ecoregion that may take a century to develop, and certain bogs and fens with their special plant populations that have taken centuries to develop. The position and function of the wetland in the landscape plays an integral role in overall watershed health.

Category II: These wetlands can be important for a variety of wildlife species and can be critical for the watershed depending on where they are located. In contrast to Category I wetlands, Category II wetlands do not provide critical habitat for any threatened and endangered species or species of concern. Generally these wetlands are pristine, not fragmented; they are common but more productive and sustain higher biodiversity compared to Category III wetlands.

Category III: These wetlands are usually plentiful in the watershed, and often include the least biodiversity. Category III wetlands are not rare or unique, and overall productivity and species diversity in Category III wetlands are relatively low. These wetlands may be impacted by humans (or by fire or other natural events) and are not considered to be “pristine” examples. As a result, in some cases these wetlands require less than 1:1 compensation.

The project vicinity is mostly Category III wetlands, with a small amount of Category II wetlands. No Category I wetlands were identified in the area. Wetlands were considered in the routing and evaluation of alternatives but were not deemed to be a fatal flaw. Alignments explored ways to minimize wetland impacts.

3.5. Cultural Resources

Avoiding or minimizing impacts to cultural resources is required by the National Historic Preservation Act. Avoiding cultural resources was taken into consideration during development of the realignments, but was not considered a fatal flaw in the screening analysis.

Cultural resources generally refer to “physical evidence or place of past human activity: site, object, landscape, structure; or a site, structure, landscape, object or natural feature of significance to a group of people traditionally associated with it.” [19] Examples of cultural resources include historic resources, archaeological resources, cultural landscapes, and ethnographic resources. A preliminary cultural resource evaluation of the study area, based on a review of existing literature and archival research, indicated that there are multiple previously identified cultural resources in the vicinity, and there is the potential for additional cultural resource sites in the unsurveyed areas. Additional research and site investigation will be needed if the ARRC pursues a build alternative.

[19] NPS website, Cultural Resources. Available online at https://www.nps.gov/acad/learn/management/rm_culturalresources.htm

3.6. Constraints Summary

Figure 3-1 depicts the general locations of the constraints that were identified and considered to be most significant in determining the technical feasibility based on a preliminary environmental review. The blue project area boundary represents the area that was determined to be most feasible for a potential realignment. Other environmental considerations discussed in Section 4 were too prevalent to avoid. DNP and wetland terrain essentially cover the study area. While the impacts to these resources are reported in Section 4, they were not determinants in identifying feasible realignment alternatives. The locations of cultural resources are protected by law, and thus are not depicted.

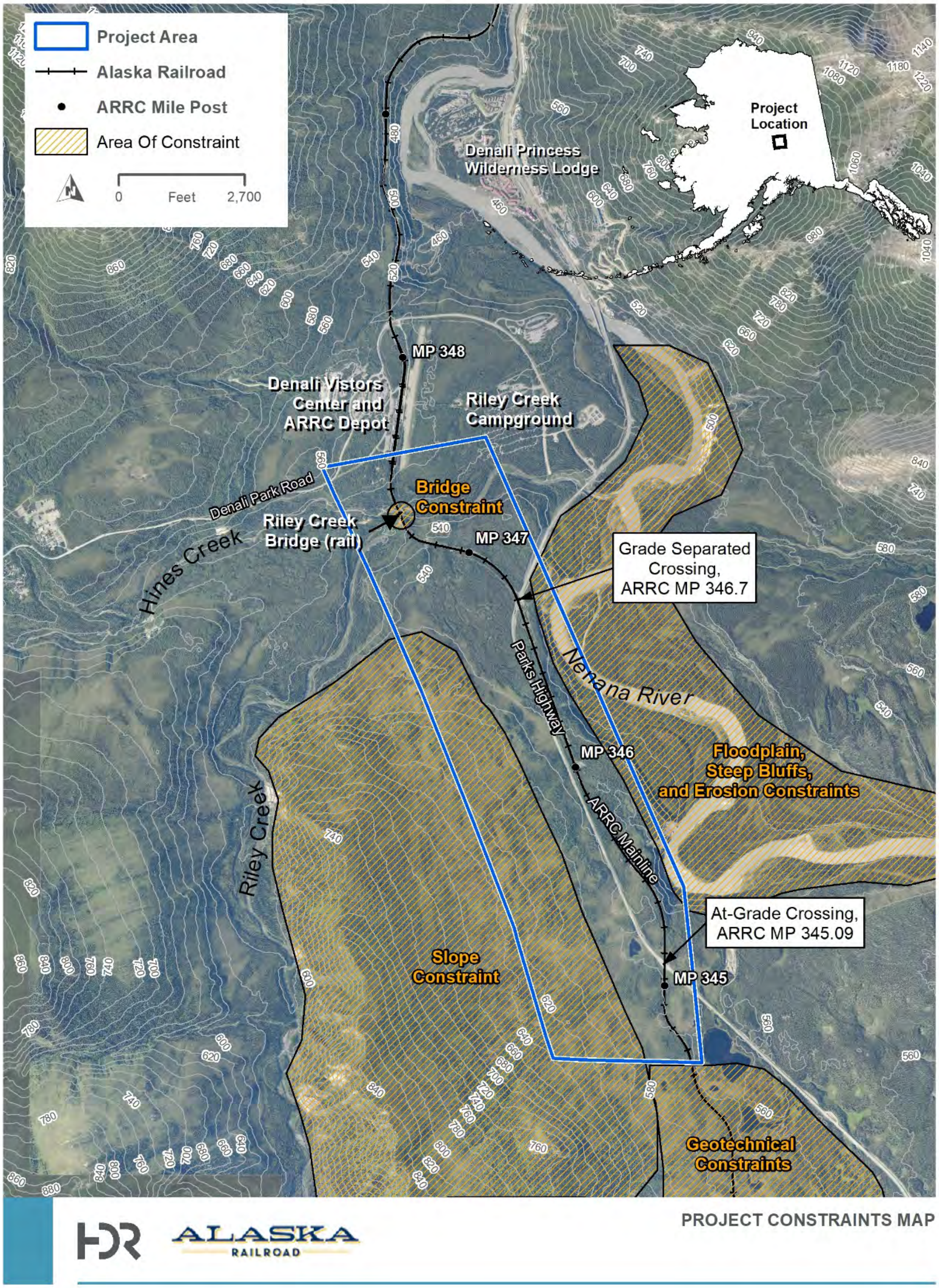

Figure 3-1. Project Constraints Map

4. Alternatives

This section describes the realignment alternatives that were identified and evaluated for feasibility in a fatal flaw analysis (and includes a grade-separation alternative at MP 345.09). Alternatives that were not feasible were removed from further study. Alternatives that were found to be feasible were advanced for additional analysis to determine the benefits and impacts of each alternative. The analysis identifies the realignment in Alternative 1 as the preferred alternative, as it best meets the purpose and need, and balances impacts and costs. Alternative 2 (the westernmost realignment) was found not to be feasible.

4.1. Fatal Flaw and Constraints Analysis

Preliminary engineering was conducted to identify distinct alternatives within the study area. The beginning and end points for the rail realignment were identified as south of the existing at-grade crossing (south of ARRC MP 345.09) and the Riley Creek Bridge to the north. Figure 4-1 depicts the three alternatives identified. Alternative 1 would realign the railroad to the west of the Parks Highway and follow the existing Parks Highway alignment more closely, creating a parallel corridor, but without crossing the Parks Highway. Alternative 2 would realign the railroad farther west, away from the Parks Highway. Alternative 3 would replace the current at-grade crossing with a grade-separation at ARRC MP 345.09.

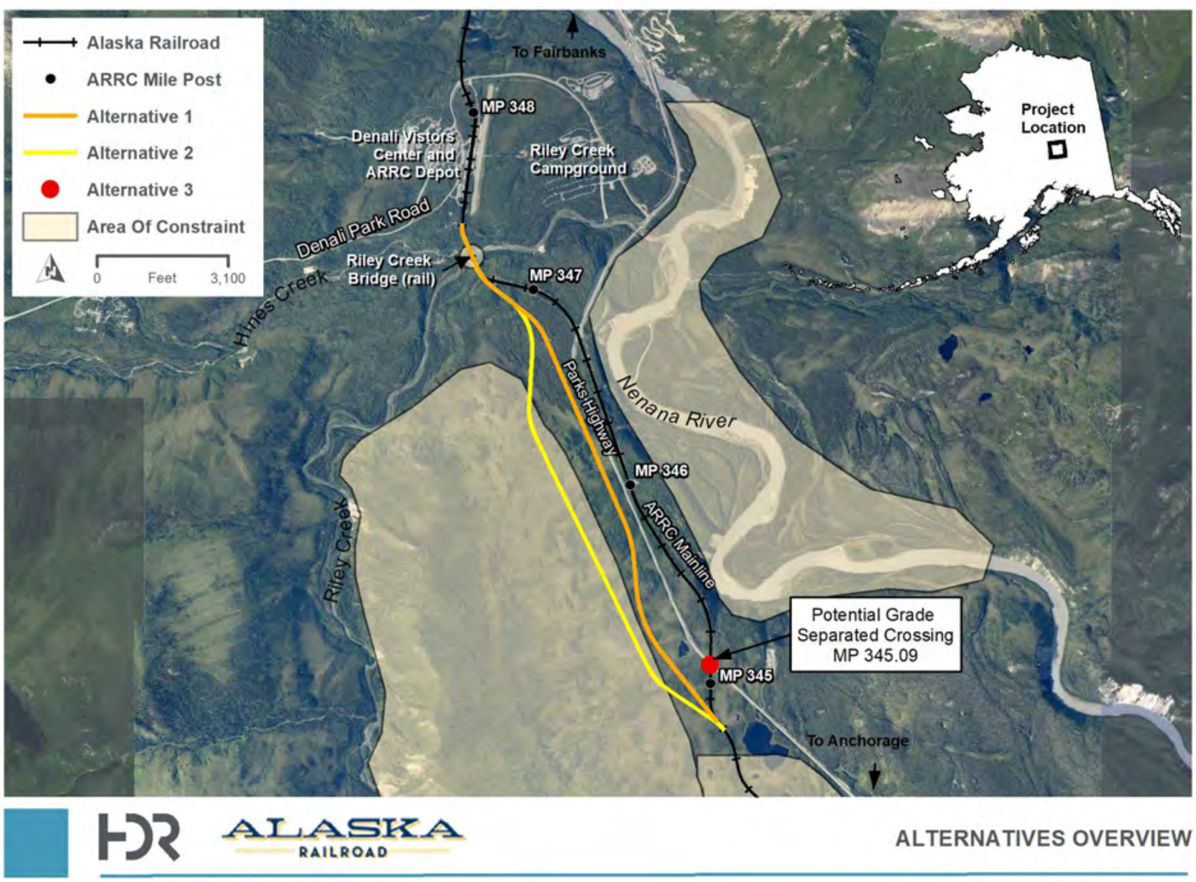

Figure 4-1. Alternatives Overview

Alternative 1 is less desirable from an engineering standpoint because it has additional curvature. However, it would avoid more wetlands, and would not create a “no man’s land” between the rail and highway rights-of-way. Alternative 1 would reduce impacts to the DNP, as it would keep the rail and highway alignments closer together in a transportation corridor so that impacts would be consolidated more directly with the existing road. Alternative 1 would be easier to construct because the alignment follows the existing topography more closely, and therefore would require much less fill.

Alternative 2 is the most efficient alternative from an engineering perspective, as it would provide the straightest alignment and least curvature. This would result in less wear on the infrastructure and lower maintenance costs. This alternative would provide the greatest separation in between the railroad and existing highway, which would provide a more natural viewing experience for passengers. However, this alignment would move the railroad into an area that slopes downward toward Riley Creek, and would require considerable cuts and fills to meet grade requirements and design standards. The alignment would extend farther into DNP land and would have higher wetland impacts.

Realignment options under Alternatives 1 and 2 would both avoid the open water wetland (pond) at the southern end of the study area and the more peaty soils to the south of the study area. Both Alternatives 1 and 2 would require land acquisition or exchange between the ARRC and NPS.

Alternative 3 is considered feasible, as it would be constructible and would have a smaller footprint than the realignment alternatives. DOT&PF has recent comparable experience replacing at-grade crossings with grade-separations also on the Parks Highway (e.g., HSIP Parks Highway Grade Separations at Montana Creek [MP 92] and Sunshine [MP 100]). Alternative 3 was advanced for further analysis (see Section 4.2.2 for detail).

The fatal flaw analysis determined that it would be feasible to realign the railroad within the identified constraints. Of the two realignment alternatives evaluated, Alternative 1 was deemed preferable due to its lesser impacts on DNP and wetlands and better constructability, and Alternative 1 was advanced as a feasible alternative for further refinement. Alternative 2 was eliminated from further consideration due to the excessive earthwork that would be required to maintain acceptable grades, and greater wetland and park impacts.

4.2. Feasible Alternatives

Three alternatives were analyzed in greater detail:

- Alternative 1 – Railroad Realignment
- Alternative 3 – Grade Separate ARRC MP 345.09 (highway over rail)
- No Build Alternative

Appendix B contains a plan set showing each alternative.

4.2.1. Alternative 1 – Railroad Realignment

Alternative 1 would bypass both Parks Highway crossings by constructing a new rail alignment through DNP to the west side of the Parks Highway (see Figure 4-2). The new track would consist of two 2-degree and two 4-degree horizontal curves, and maximum 1.61 percent grades. The realignment would eliminate both existing crossings: the grade-separation at ARRC MP 346.71 and the at-grade crossing at ARRC MP 345.09. The track length would be reduced by 0.1 mile, and the operating speed would remain the same (30 mph).

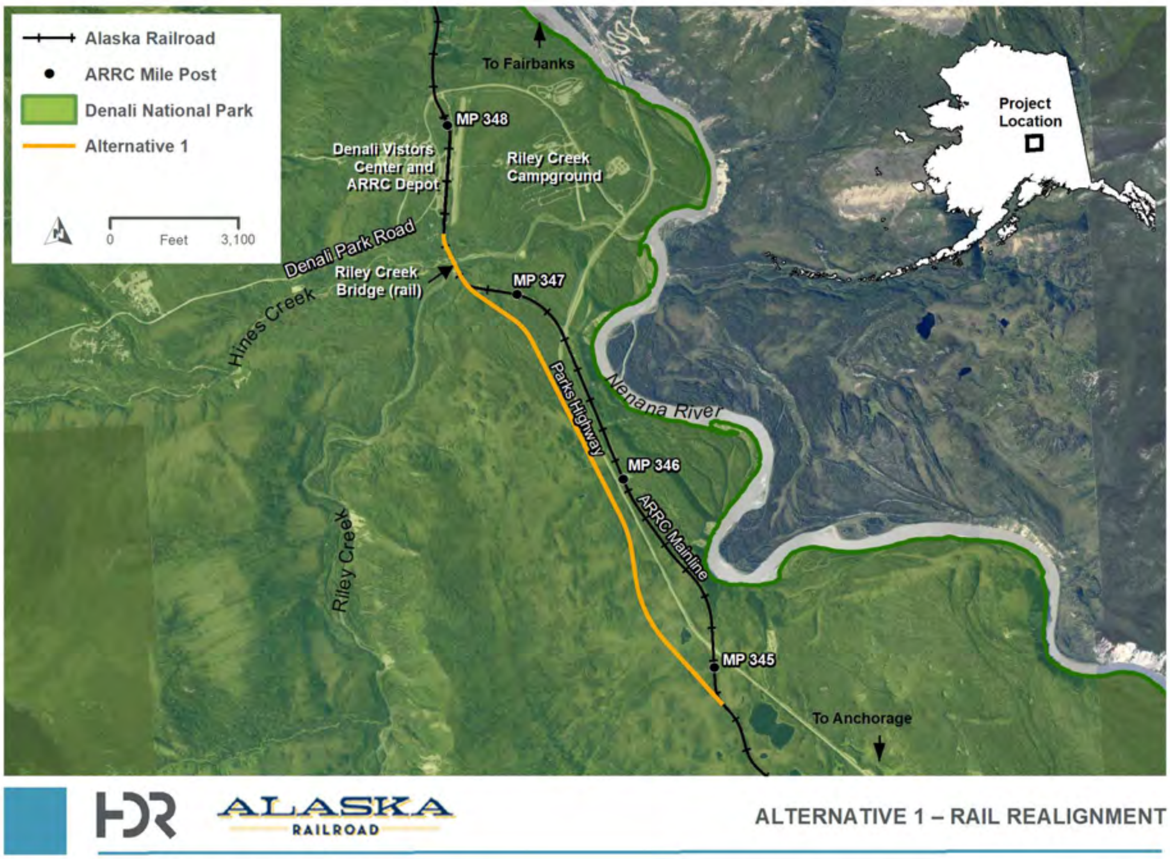

Figure 4-2. Alternative 1 – Rail Realignment

The track, ties, and other rail infrastructure would be removed from the existing alignment. There is interest by stakeholders in converting this corridor to a trail or other beneficial use; however, those uses and associated costs are not considered in this analysis and would need to be developed as part of additional studies.

4.2.2. Alternative 3 – Grade Separate ARRC MP 345.09

Alternative 3 would replace the at-grade crossing with a grade-separation with the highway over the ARRC tracks on the existing highway alignment (see Figure 4-3). The grade-separation's highway overpass would have sufficient width to allow the double-tracking of this section under the proposed highway bridge, should the ARRC chose to do so in the future, with 16-foot spacing between the tracks with 25-foot clear spacing on each side. The proposed bridge spans would be 80-140-80-foot spans with a minimum clear vertical distance of 24 feet, 6 inches over the existing and future tracks. The bridges were assumed to use standard Pre-stressed Concrete Bulb-Tee girders that are 5 feet, 5 inches in height. The railroad overpass bridge at the grade-separation at ARRC MP 346.7/Parks Highway MP 236.7 would be assumed to be replaced at the end of its lifespan (approximately year 2048). It is anticipated that the replacement bridge would have the same characteristics as the existing bridge, with substructure strengthening/repair if needed. No other substantial capital improvements would occur.

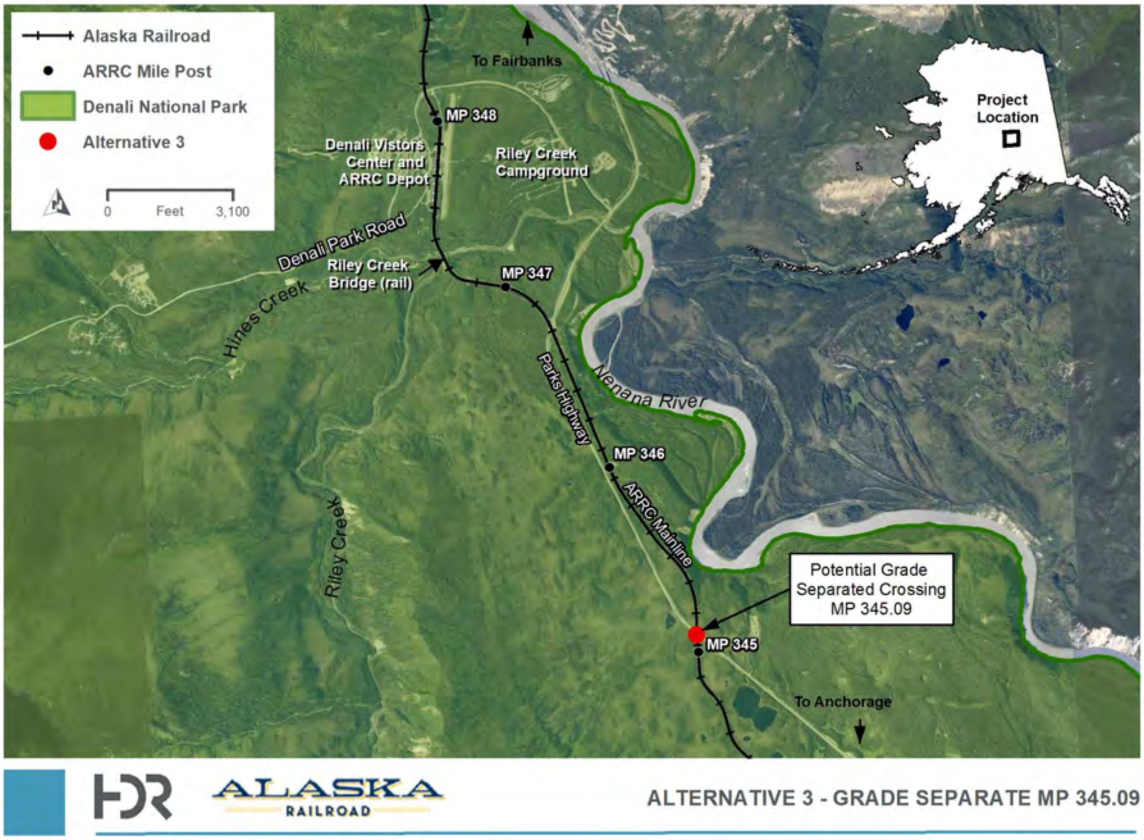

Figure 4-3. Alternative 3 – Grade Separate ARRC MP 345.09

4.2.3. No Build Alternative

The No Build Alternative would make no physical changes to the existing ARRC track alignment between MP 344 and 348 and the Parks Highway, and would maintain the existing at-grade crossing. The No Build Alternative is included as a baseline for comparison of the benefits and impacts of the other alternatives.

Under the No Build Alternative, only regular maintenance activities would be performed by the ARRC and DOT&PF. The grade-separation at ARRC MP 346.7/Parks Highway MP 236.7 would be replaced at the end of its lifespan (approximately year 2048). It is anticipated that the replacement bridge would have the same characteristics as the existing bridge, with substructure strengthening/repair if needed. The at-grade crossing at ARRC MP 345.09 would also be rebuilt as necessary. No other substantial capital improvements would occur under the No Build Alternative.

4.3. Alternatives Evaluation

This section contains a planning-level analysis of the realignment alternative that compares it to both the No Build and Grade-Separation alternatives. The analysis includes geotechnical and environmental reviews.

4.3.1. Evaluation Criteria

To compare the relative benefits and impacts of the feasible alternatives, the following criteria were assessed:

- Traffic impacts
- Safety
- Rail operations
- Consistency with existing policy/guidance
- Preliminary construction cost
- Preliminary maintenance cost
- Environmental considerations
- Construction impacts
- Other considerations

4.3.2. Traffic Impacts

Under the No Build Alternative, traffic would continue to be delayed by commercial vehicles that are required to stop at the at-grade crossing at levels similar to today's levels. Under Alternatives 1 and 3, commercial vehicles would no longer need to stop at the at-grade crossing, thereby eliminating vehicle delay.

As a safety feature, if the equipment at ARRC MP 345.09 runs out of power, the gates close and block traffic on the Parks Highway. Under the No Build Alternative, this condition would continue. Both Alternatives 1 and 3 would remove the at-grade crossing and eliminate the possibility of the Parks Highway being closed due to a lack of power at this location.

For safety reasons, lane closures may occur while at-grade crossing maintenance is being performed. Lane closures are more likely to occur, and be of longer duration, at the at-grade crossing under the No Build Alternative. The realignment of the rail and separation from the road under Alternative 1 would result in lane closures being less likely than under Alternative 3, which would still require bridge inspections and maintenance.

4.3.3. Safety

Alternatives 1 and 3 would improve safety over the No Build Alternative because they would eliminate the at-grade crossing and the potential for train-vehicle crashes. Because grade-separations still provide a railroad access point for the public, they are less desirable than eliminating the crossing altogether. Alternative 1 would provide the additional safety benefit of completely removing any crossings of the highway and railroad, and the separation from the road achieved through the realignment would slightly reduce the potential for trespassing.

4.3.4. Rail Operations

Track speed would remain the same for all alternatives. Rail operations would remain largely unchanged under the No Build Alternative and Alterative 3 – Grade Separate ARRC MP 345.09. Alternative 1 reduces the track by 0.1 mile, resulting in a reduced travel time through the corridor by 12 seconds. This time savings is not substantial enough to change rail operations.

Alternative 1 – Rail Realignment would reduce the curvature of the rail alignment, thereby improving overall operations. Curved track can be more than ten times as expensive to maintain as straight track.[20] As trains travel around curves, lateral forces develop. These lateral forces require a stronger track structure and a higher standard of maintenance. Curved tracks also accelerate wear in railcar wheels, the rail, and the ties, and cause breakdown of the track ballast.[21]

A rail bridge is a major capital investment that has a typical lifespan of 80 to 100 years. Due to the cost of replacement, bridges are often not replaced until the end of their useful life. Both the No Build Alternative and Alternative 3 would leave the existing grade-separation in place (ARRC MP 346.7), which would constrain any potential future expansion of the ARRC. Alternative 1 would eliminate/bypass this grade-separation, and therefore the potential for future double tracking through this corridor would not be as constrained.

4.3.5. Consistency with Existing Policy/Guidance

The Alaska Policy on Railroad/Highway Crossings (see Appendix A) documents the ARRC's procedure for administering the review, construction, and maintenance of all railroad/highway crossings on the ARRC's right-of-way and property. This policy acknowledges the challenge when trying to move people and goods in a safe, efficient, and economical manner with the constraints on available financial resources. This policy does not require the replacement of at-grade crossings with grade-separations. Rather, it provides a process to evaluate existing and proposed crossings to determine what type of crossing recommendations, such as warning devices or construction of a grade-separation, should be made.

Nonetheless, the policy encourages evaluating the feasibility of "eliminating crossings if this can be accomplished with safety benefits which outweigh the increased operational costs and inconvenience to users." Both Alternatives 1 and 3, which eliminate the at-grade crossing, have safety benefits that warrant consideration for this project to move forward into design and construction.

4.3.6. Preliminary Construction Cost Estimate

Planning-level, preliminary opinion of construction cost estimates were developed for each alternative. Major elements included railroad and highway construction estimates based on conceptual engineering design, including earthwork, drainage, and structures. A Railroad Track Quantities and Trail Design Report study was completed that estimated earthwork and track construction quantities and calculated

[20] ARRC and FTA. 2002. Track Realignment Project: Eagle River to Knik River Segment, Mile 127.5 to Mile 164.4 Environmental Assessment.
[21] ARRC and FTA. 2005. South Wasilla Track Realignment Environmental Assessment.

conceptual earthwork costs (see Appendix E). The estimates also include preliminary and final design engineering, construction administration, and contingency costs.

Assumptions used to prepare this estimate include:

- Organic soils will be excavated from under proposed rail and roadway bed, and backfilled with Borrow C.
- Removal of existing railroad infrastructure is not included, as that depends on the future use of the existing alignment (as a siding or trail).
- Board insulation may be needed in permafrost areas to prevent settling.
- Project development costs were estimated as follows:
    - Engineering – 6 percent
    - Administration – 4.65 percent and Construction Oversight – 7.5 percent
    - Permitting – 1 percent
    - Contingency – 20 percent
- No right-of-way acquisition costs are included; it is assumed that the right-of-way would be obtained through a land swap with the NPS under Alternative 1 at no cost to the ARRC, and Alternative 3 is anticipated to fit within the existing ARRC/DOT&PF right-of-way. See USC 45 Ch. 21 Alaska Railroad Transfer Act for more detail.

Table 4-1 summarizes the preliminary construction cost estimate for each alternative in 2018 dollars. Appendix B contains additional information regarding the cost estimate.

Table 4-1. Preliminary Construction Cost (2018 dollars), by Alternative

Elements	**Alternative 1 – Rail Realignment**	**Alternative 3– Grade Separate ARRC MP 345.09**	**No Build Alternative**
Track, Ties, & Ballast	$2,460,000	$30,000	$0
Sub-ballast	$559,000	$0	$0
Structural Fill/Embankment	$3,482,000	$5,336,000	$0
Excavation	$6,637,000	$247,100	$0
Culverts	$200,000	$0	$0
Superstructure & Substructure	$0	$3,900,800	$0
Roadway	$50,000	$807,500	$0
Temporary Crossing/Flagging	$0	$500,000	$0
Extras (15%)	$2,059,000	$1,736,500	$0
Wetland Mitigation	$690,000	$150,000	$0
Engineering (6%)	$924,000	$750,000	$0
Administration (4.65%) and Construction Oversight (7.5%)	$2,015,000	$1,617,100	$0
Permitting (1%)	$154,000	$125,000	$0
Contingency (20%)	$3,670,000	$2,900,000	$0
Total	**$22,900,000**	**$18,100,000**	**$0**

4.3.7. Preliminary Maintenance Cost Estimate

A planning-level preliminary opinion of maintenance cost estimates were developed for each alternative for an 80-year lifecycle. The 80-year lifecycle was selected because bridges typically have an 80- to 100-year life. Thus, under Alternative 1, the highway bridge over the railroad would be expected to last at least 80 years. Other maintenance costs were calculated out to the same lifespan to allow an “apples to apples” comparison. Major maintenance activities estimated included annual bridge inspections, crossing replacements, signal replacement, generators, crossing pads, and road surfacing.

According to the 2017 Bridge Inventory Report, the existing railroad overpass bridge at the grade-separation at ARRC MP 346.7 (DOT&PF Bridge 0696 at Parks Highway MP 236.7) was built in 1968. It is currently undergoing an engineering analysis to determine its remaining lifespan. Based on an 80-year design life, the existing railroad overpass bridge will need to be replaced in year 2048. Replacing the superstructure with substructure strengthening and repair is anticipated to cost approximately $3 million in 2018 dollars. The DOT&PF owns the existing railroad overpass bridge and is responsible for funding its maintenance. ARRC performs annual inspections to ensure that it meets FRA standards to carry train loads. Each annual inspection costs approximately $10,000–15,000.[22]

Both the No Build Alternative and Alternative 3 include a replacement railroad overpass bridge at the existing grade-separation at ARRC MP 346.7 in 2048. The replacement railroad overpass bridge is assumed to have the same characteristics as the existing bridge.

Table 4-2 summarizes preliminary estimate for the 80-year maintenance cost (in 2018 dollars) of each alternative. This estimate does not include track-related maintenance; it is assumed to be performed regardless of the alternative, as there are no significant changes in track mileage.

Table 4-2. Preliminary Maintenance Cost for 80-year Lifecycle (2018 dollars), by Alternative

Elements	Alternative 1 – Rail Realignment	Alternative 3– Grade Separate ARRC MP 345.09	No Build Alternative
FRA At-Grade Inspection	$0	$0	$20,000
Annual Inspections	$0	$1,600,000	$800,000
Crossing Replacement	$0	$0	$2,400,000
Signal Replacement	$0	$0	$3,200,000
Generator	$0	$0	$800,000
Signal Hut Batteries	$0	$0	$70,000
Crossing Pads	$0	$0	$680,000
Surfacing	$0	$0	$480,000
Railroad Overpass Bridge Replacement	$0	$3,000,000	$3,000,000
Total Maintenance Costs (80-year lifecycle)	**N/A**	**$4,600,000**	**$11,450,000**
Annual Maintenance Cost	**N/A**	**$57,517**	**$143,125**
Annual Maintenance Savings	**$134,312**	**$76,795**	**$0**

[22] Information provided by ARRC.

By constructing Alternative 3, annual maintenance costs would be reduced by an estimated $76,795. Over 80 years, Alternative 3 would save approximately $6.8 million in maintenance costs compared to the No Build Alternative.

With Alternative 1, maintenance costs would be reduced by an estimated $143,125 per year in 2018 dollars. Over 80 years, Alternative 1 would save approximately $11.5 million in maintenance costs (2018 dollars).

4.3.8. Geotechnical

Alternative 1: There are a number of geotechnical and permafrost related issues that should be considered in design of the realignment, including (1) thaw-unstable permafrost with excess ground ice, (2) thick cover of peat and organic-rich materials, (3) potentially unstable (and difficult) cuts through permafrost, (4) significant cross flow of subsurface and near-surface drainage, (5) associated icing in the cut slopes, and (6) areas that have already thawed (due to proximity to existing development) but have not yet consolidated and would be expected to do so under the weight of the new embankment. A full discussion of the inferred conditions along the proposed realignment is contained in the geotechnical report (Appendix C, pages 22-24).

The southern portion of the realignment (between ARRC MP 344.0 and 346.3) is expected to largely consist of ice-rich material and would likely require multiple and lengthy cuts. However, between ARRC MP 346.3 and 347.4, conditions improve and are largely considered ice-poor and thaw-stable, which is better for construction.

Alternative 3: The grade-separation would be located in an area of organic deposits (Qo Terrain Unit). This terrain unit contains organic-rich material, likely underlain by silty sand. Borehole TH-3 (Appendix C) best characterizes this terrain unit. That borehole indicates near-surface organics, including a vegetative tundra mat underlain by a mixture of peat, organic silt, vegetative matter, and silt. The material was seasonally frozen down to 4 feet and contained 10 to 20 percent visible ice. Moisture content ranging from 76 to 216 percent made it oversaturated and soupy. The underlying mineral soils had up to 14 percent moisture and were loose in the upper 30 feet, but became denser at greater depth. The inferred conditions, based on this boring, suggest a covering of organic rich materials ranging from 3 to 12 feet thick, with underlying materials underlain by sandy silt and silty sand, and gravel with moisture content of 20 percent or less. Construction of a bridge and approaches in these soils would be challenging and would likely require excavating the upper layers of organic rich materials and silty sand, and replacing the materials with non-frost-susceptible materials. Embankment and foundation construction would likely require engineering features to minimize permafrost degradation within the soil profile and to deal with soil compression and settling.

No Build Alternative: Based on the soils profile at the at-grade crossing (see description below under Alternative 1), it is likely that the settlement associated with melting permafrost and the consolidation of loose materials at the at-grade crossing (ARRC MP 345.09) would continue to create maintenance issues.

4.3.9. Environmental Considerations

This section describes the environmental considerations that could affect the alternatives' feasibility. They were assessed at a planning level using available information. Should the project advance, the magnitude of impact to these, and other, environmental resources would be quantitatively and qualitatively evaluated using acceptable methods and procedures.

Wetlands

Figure 4-4 shows the wetland management categories within the study area and in relationship to the alternatives.

Alternative 1 would result in approximately 46 acres of newly disturbed ground, approximately 25 acres of which would be in wetlands. A wetlands permit would be needed, and there is the potential for compensatory mitigation for loss of aquatic resources.

Alternative 3 would result in approximately 10 acres of newly disturbed ground. No wetland impacts have been identified in this planning-level analysis.

The **No Build Alternative** would result in no fill in wetlands.

If the ARRC pursues an alternative impacting wetlands, a wetland field survey would be recommended to collect additional information in support of the USACE Section 404 permit application. As part of the design process, the ARRC could potentially identify ways to further avoid and minimize unavoidable losses of aquatic resources.

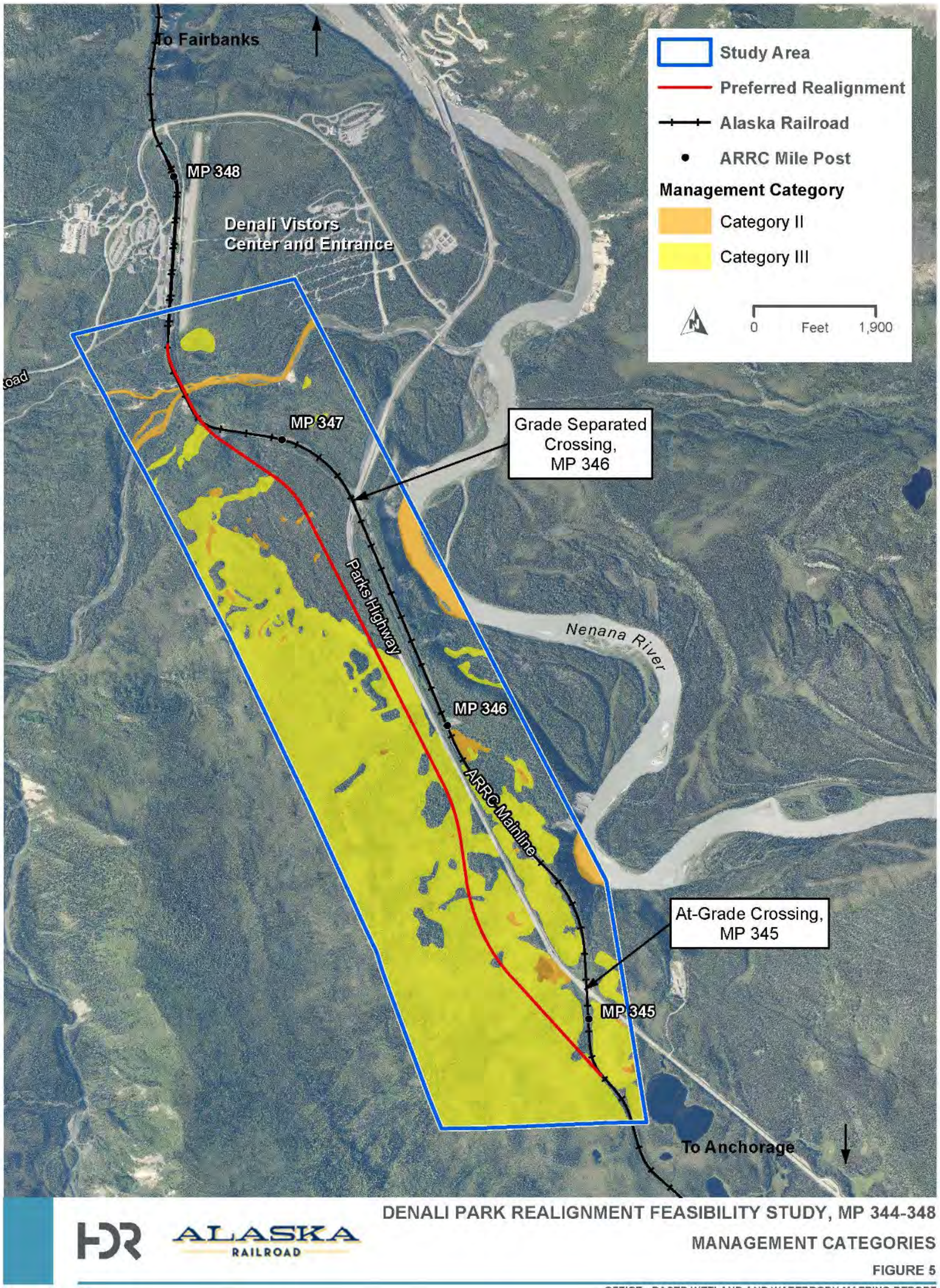

Figure 4-4. Wetland Management Categories

Source: Office-Based Wetland and Waterbody Mapping Report, 2017

Cultural Resources

Alternative 1 would have the potential to impact two known cultural resources. Additional study may identify additional cultural resources in the study area.

Alternative 3 would have no anticipated impacts to known cultural resources.

The **No Build Alternative** would result in no impacts to cultural resources.

4.3.10. Environmental Clearance

Alternative 1: This alternative would require fill in up to 25 acres of wetlands and would affect 62 acres of DNP land. It would likely require using the National Environmental Policy Act (NEPA) process, with an Environmental Assessment to determine if there are significant impacts.

Alternative 3: Based on the level of environmental impacts, it may be possible to obtain environmental approval for Alternative 3 under a Categorical Exclusion. DOT&PF has authority over NEPA for projects funded with Federal Highway Administration dollars. Additional consultation would be required to determine the class of action (i.e., type of NEPA documentation that would be required). Wetland acreage is anticipated to be minor, if any.

The **No Build Alternative** would not require any environmental clearance or permits.

4.3.11. Land Ownership – Denali National Park

This section presents information on how much DNP land would be needed under each of the feasible alternatives.

Alternative 1: This alternative would require approximately 62 acres of DNP lands. The NPS "will preserve and protect the natural resources, processes, systems, and values of units of the national park system in an unimpaired condition to perpetuate their inherent integrity and to provide present and future generations with the opportunity to enjoy them."[23] According to the NPS Director's Order-12 2006 Management Policies (Section 1.4.5), an impairment of park land "is an impact, in the professional judgment of the responsible NPS manager, would harm the integrity of park resources or values, including the opportunities that otherwise would be present for the enjoyment of those resources or values."

The NPS would have to make a determination of whether Alternative 1 would impair the DNP's resources and values. The NPS is required to complete this non-impairment determination for any action prior to signing a Finding of No Significant Impact or a Record of Decision associated with the appropriate environmental document. In addition, a National Park boundary can be modified only as authorized by law. To modify a boundary, it is anticipated that an act of Congress would be needed, or the project may fall under the requirements of the Alaska National Interest Lands Conservation Act or Alaska Railroad Transfer Act.

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[23] National Park Service Management Policy 2006, Chapter 4. Available online at https://www.nps.gov/policy/mp/chapter4.htm

However, under Alternative 1, the ARRC could vacate the existing alignment and could swap that land with the DNP for the right-of-way needed on the west side of the Parks Highway. Several similar land swaps have occurred in Alaska, as well as in other states, so this is not considered a fatal flaw for Alternative 1. Given its proximity to the Parks Highway and the existing railbed, the NPS may wish to repurpose this land, possibly as a trail or other beneficial use, thereby improving access for pedestrians and bicyclists.

A Section 4(f) evaluation may also be required as part of the environmental review process if federal transportation dollars were to be used. Section 4(f) regulation requires that a proposed transportation use of any land from significantly publically owned public park, recreation area, wildlife and waterfowl refuge, or public or private historic site that is on or eligible for the National Register of Historic Places be avoided, if avoidance if feasible and prudent, before any U.S. Department of Transportation funding or approvals can be obtained.

Alternative 3: Because Alternative 3 is anticipated to stay within the DOT&PF/ARRC right-of-way, it is not anticipated to affect DNP lands.

The **No Build Alternative** would not result in any change to DNP land.

4.3.12. Construction Impacts

Alternative 1: This alternative would reduce the amount of traffic disruptions that would occur compared to Alternative 3 because most of the construction activities would occur off both the rail and highway alignments. Construction disruption on the Parks Highway would be limited to the removal of both crossings (the at-grade crossing at ARRC MP 345.09 and the grade-separation at ARRC MP 346.7), and, for the railroad, it would occur only at the cutovers at the north and south ends of the realignment.

Alternative 3: This alternative would require replacing the at-grade crossing at ARRC MP 345.09 with a grade-separation at the same location and would keep the Parks Highway on the existing alignment, and would result in some traffic disruption during construction. Traffic would have to be detoured around the project area to allow construction activities to occur. The temporary road is expected to have a 45-mph speed limit and would not substantially increase travel time in the project corridor. A temporary at-grade crossing would be needed as part of the detour route. Active warning devices would be needed at the at-grade crossing, as well as site control measures to ensure safety during construction. It is believed that the active warning devices could be powered using the power generation equipment currently at the at-grade crossing.

Based on the existing information, it is believed that the detour route and construction activity would occur within the existing DOT&PF right-of-way. However, until the final design is developed, the exact right-of-way and construction needs cannot be identified. If construction activity were to go outside the existing DOT&PF right-of-way, the DOT&PF may need a temporary construction easement from the NPS. It can take 6 months or longer to obtain a temporary construction permit on NPS land, which would need to be considered as part of the project development process.

The **No Build Alternative** would involve replacing the spans and substructure modification for the bridge at ARRC MP 346.7.

4.4. Alternatives Analysis Summary

Table 4-3 summarizes how each alternative would perform relative to the evaluation criteria.

Table 4-3. Alternatives Analysis Matrix

Evaluation Criteria	**Alternative 1 – Rail Realignment**	**Alternative 3 – Grade Separate ARRC MP 345.09**	**No Build**
Traffic	• Eliminates vehicle delay eliminated • Eliminates need for commercial vehicles to stop • Eliminates delay due to at-grade crossing closure during power failures	• Eliminates vehicle delay • Eliminates need for commercial vehicles to stop • Eliminates delay due to at-grade crossing closure during power failures	• No change
Safety	• Eliminates potential for train and vehicle/ pedestrian conflict	• Eliminates potential for train and vehicle/ pedestrian conflict	• No change (potential for train and vehicle/pedestrian conflict remains)
Rail Operations	• Reduces travel time by 12 seconds • Reduces track curvature	• No change	• No change
Consistency with Existing Policy/ Guidance	• Consistent with Alaska Policy on Railroad/ Highway Crossings	• Consistent with Alaska Policy on Railroad/ Highway Crossings	• Makes no improvement toward implementing Alaska Policy on Railroad/Highway Crossings
Preliminary Construction Cost	• **$22.9 million**	• **$18.1 million**	• N/A

Evaluation Criteria	Alternative 1 – Rail Realignment	Alternative 3 – Grade Separate ARRC MP 345.09	No Build
Preliminary Lifecycle Maintenance Cost of the Highway/Rail Crossings (note that track maintenance is not included as it is effectively identical for all three alternatives)	• Eliminates annual bridge inspections and other maintenance costs • Eliminates signal (and related) costs	• Approximately **$4.6 million** over 80 years (estimated at $57,517 annually) • Eliminates signal (and related) costs • Adds one additional annual bridge inspection	• Approximately **$11.5 million** over 80 years (estimated at $143,125 annually) • Requires annual bridge inspection and other maintenance (e.g., crossing replacement, signal replacement, signal hut batteries, crossing pads, road surfacing) on a periodic basis
Geotechnical	• Southern portion - requires cuts and fills in ice-rich material; as the alignment progresses north, conditions improve and are ice-poor and thaw-stable, which is better for construction	• Construction in study area soils is challenging and requires excavation of materials and replacement with non-frost susceptible materials	• No change (challenging geotechnical conditions would continue to result in higher than normal maintenance)
Wetlands	• 46 acres of newly disturbed ground, 25 acres of which is in wetlands	• 10 acres of newly disturbed ground; no wetland impact anticipated	• No change
Cultural Resources	• Potential impact to two cultural resources	• No anticipated impact to cultural resources	• No change
Environmental Clearance	• Likely to require an Environmental Assessment	• Minimal impact (most impacts are associated with construction activity) • Likely to require a Categorical Exclusion	• No change

Evaluation Criteria	Alternative 1 – Rail Realignment	Alternative 3 – Grade Separate ARRC MP 345.09	No Build
Land Ownership – DNP	• 62 acres of DNP land needed • Requires NPS to determine whether or not the alternative would impair the park • May require a boundary change from Congress • May require a transfer of land between ARRC and DNP	• No DNP land anticipated to be needed • Not likely to be considered an “impairment”	• No change
Construction Impacts	• Off-alignment construction • Traffic disruption occurs only during removal of both rail crossings and rail cutover	• Traffic detours are needed • Likely able to construct within the existing right-of-way	• No change
Other Considerations	• Eliminates potential for power failure resulting in a gate closure on the Parks Highway • Does not preclude expansion of Parks Highway or ARRC tracks • Existing rail corridor could be reused as a trail • Reduces at-grade crossing maintenance-related lane closures	• Eliminates potential for power failure resulting in a gate closure on the Parks Highway • Limits ability to expand Parks Highway or ARRC tracks due to bridges • Reduces at-grade crossing maintenance-related lane closures	• Potential for power failure resulting in gate closure that blocks the Parks Highway • Limits ability to expand Parks Highway or ARRC tracks due to restriction at bridge • More at-grade crossing maintenance-related lane closures

5. Conclusion

In accordance with the FTA Grant application, this report provides a feasibility study, conceptual level cost estimates, and preliminary engineering to realign ARRC's mainline track south of the DNP main entrance and remove two highway-rail crossings on the Parks Highway: an at-grade crossing at ARRC MP 345.09 and at a grade-separation at ARRC MP 346.7. The study identifies a feasible realignment alternative that would improve railroad safety, reduce rail transportation times, reduce roadway transportation delays, and reduce operation and maintenance costs.

5.1. Preferred Alternative

Alternative 1 – Rail Realignment: This alternative was identified as the preferred, feasible realignment alternative. It would reduce lifecycle maintenance costs, eliminate the potential for train-vehicle conflicts, and eliminate traffic delay on the Parks Highway. The realignment would not only solve the at-grade safety and maintenance issues at ARRC MP 345.09, it also would also eliminate future railroad overpass bridge maintenance and replacement at the grade-separation at MP 346.7. Bypassing the existing section of track would also result in straighter track and reduced curves, and would remove the constriction that the MP 346.7 bridge poses for future double tracking. The shorter track would slightly reduce train travel times, and the reduction in curvature would reduce wear and tear on rail equipment and track. By not crossing the highway, and by having greater separation, the potential for public trespass would also be reduced.

5.2. Other Alternatives

Alternative 3 – Grade Separation: Alternative 3 is a feasible alternative, but is not preferred as it would not provide sufficient maintenance cost savings, travel benefits, or safety improvements as compared to Alternative 1. It would not provide the same level of improvement in public safety, reduced lifecycle costs, and travel benefits. If a land swap or environmental clearance (wetland permits and NPS approval) were to prove unachievable, this option would remain a feasible, fallback alternative.

No Build Alternative: This alternative would not eliminate the safety or maintenance issues of the at-grade crossing at ARRC MP 345.09 and is not recommended.

5.3. Next Steps

As a next step, the ARRC should coordinate with stakeholders, including the NPS, DOT&PF, and others, for their consideration and feedback. Further analysis would be required to advance the project, including a preliminary engineering report that further refines the alignment and cost estimate. This information would be needed to support the environmental review and permitting process.

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Appendix A – Alaska Policy on Railroad/Highway Crossings (revised September 1988)

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I. ~ ALASKA RAILROAD CORPORATION

BOARD RULE NO. 13

Adopted March 16, 1987
Amended September 15, 1988

Subject: Railroad/Highway Crossing Policy

Purpose: Adopts a uniform policy for maintenance and construction of all railroad/highway crossings on the Corporation's property and rights-of-way.

ALASKA RAILROAD CORPORATION

Adopted March 16, 1987

RULE NO. 13 RAILROAD/HIGHWAY CROSSING POLICY

This Rule relates to the Alaska Railroad's requirement to provide for the safe, efficient and economical movement of people, goods, and services and, therefore, the need to adopt a uniform policy for administering the review, construction and maintenance of ail railroad/highway crossings on the Alaska Railroad Corporation's rights-of-way and property.

ALASKA POLICY ON RAILROAD/HIGHWAY CROSSINGS
Revised September 1988

1.0 INTRODUCTION

The goal of any transportation agency is to provide for the safe, efficient, and economical movement of people, goods and services. It is a continuing challenge to seek the proper balance between safety, efficiency and economy to bring the greatest good to the most people within the constraints of available resources.

With the acquisition of the Alaska Railroad by the State, continued population growth. and decreasing financial resources, the need for a more uniform statewide program to provide safe railroad/highway grade crossings became apparent.

Responding to this need, the Commissioner of the Department of Transportation and Public Facilities (DOT&PF), and the President and Chief Executive Officer of the Alaska Railroad Corporation (ARRC), established a Task Force on Rail/Highway Crossings composed of representatives of their agencies and the Federal Highway Administration (FHWA).

At the Task Force's first meeting on October 29, 1985, the Commissioner outlined his concept of the three subtasks required to carry out his charge to the Task Force:

1. After referring to available technology and standards, determine the reasonable type of protection for each "class" of crossings.

2. Inventory all crossings in the State to determine the appropriate protection "classes".

3. Develop a reasonable structured priority system to implement improvements through a rational and systematic allocation of available resources.

Within these subtasks, the Task Force set out to accomplish this change and make the Alaska highway system and Alaska Railroad safer for the traveling public.

1.1 1988 Policy Revision

Early in 1988 it became apparent that this policy needed to be revised to include more information on sight triangles and how diagnostic teams function. A total of four work sessions were held (2 in Anchorage and 2 in Fairbanks). The procedures in new Section 5.1 were used in developing the revised policy.

2.0 DISCUSSION

Most crossings of the Alaska Railroad Corporation (ARRC) are under permit to the agency (State or local) which has the road authority. The terms of the permit make the road agency responsible for construction and maintenance costs associated with the permitted road crossing, and for claims resulting from the construction, maintenance and use of the road crossing.

The Task Force, with the assistance of the FHWA and the Federal Railroad Administration (FRA), reviewed the latest safety resource allocation techniques, including an accident prediction model developed through FHWA research. FHWA's research was aimed at establishing a national standard for planning crossing improvements.

The computed "DOT Accident Prediction Value" (APV) of a crossing is the product of a series of factors representing the various characteristics of the crossing, and is equivalent to the expected number of accidents per year at that crossing.

The State Inventory was completed and the APV's of all crossings were computed. A graph was made of the number of crossings exceeding the various values of APV, and this was compared to a similar graph developed by the FHWA/FRA for all crossings in the nation. On a percentage basis, the two graphs were very similar. The Task Force found that the crossings with the highest APV's are generally those that are already known to be in need of improvement, many of which are already programmed or in progress.

The FHWA resource allocation model develops threshold values of the APV to determine the optimum cost-effective safety improvement decisions at each crossing.

With the exception of grade separations, the biggest decision is whether or not to install active warning devices (train activated flashing lights or flashing lights and gates). The allocation model arrives at an APV of 0.1 as the cost-effective threshold value for considering going from passive devices only (signs, markings) to active protection. Rapidly decreasing safety benefits along with rapidly rising costs are associated with an APV less than a value near 0.1, both for the national inventory and the state distribution. When this criterion is applied to the State's crossings, the Task Force found that it resulted in a program that can be accomplished in a reasonable time within the available State and federal resources.

In addition, this technique meets the federal requirement of a rational prioritization scheme for using federal crossing safety improvement funds.

The Task Force noted that this prioritization system is only an indicator of the probable treatment required at a given crossing in order to concentrate efforts where they are most urgently needed. In other words, the final decision as to what major treatment is required at a crossing would be based on an on-site evaluation by a professional diagnostic team, and the APV criterion would not normally be blindly followed, especially for borderline cases. There will be instances in which an evaluation reveals that relatively low-cost improvements such as increased sight-distance in conjunction with better signing might change the accident potential to a level that would not require active devices which are expensive to install and maintain, thereby freeing funds to be applied where they would do more good.

It is also imperative that local jurisdictions be brought into the diagnostic process when they are affected by the engineering decision. Likewise, local jurisdictions, developers, and other State agencies that have the potential to create a rail/highway safety conflict must take this into account in their planning functions, and should be responsible for their fair share of any costs created by their actions.

Provision should be made to maintain the program through regular updating of the inventory and priority list, and periodic evaluation of the effectiveness of the improvements made.

The following subsections summarize the results of the Task Force investigations and deliberations.

3.0 DEFINITIONS

3.1 The U.S. Department of Transportation (DOT)/Association of American Railroads (AAR) National Railroad-Highway Crossing Inventory Procedures Manual ("Procedures Manual") defines public and private crossings as follows:

> "Public Crossing: A public crossing is a location where the tracks cross a road which is under the jurisdiction of and maintained by a public authority and which is open to public travel."
>
> "Private Crossing: A private crossing is a location where a physical crossing is present but the road does not meet the conditions indicated above for a public crossing. Private crossings usually restrict public use by an agreement which the railroad has with the property owner, or by gates or similar barriers."

3.2 When the Task Force looked at the inventory of crossings on the Alaska Railroad, it became apparent that there are numerous crossings that are open to public travel but not "under the jurisdiction of and maintained by a public authority." The Procedures Manual also states "In some instances changes in land use have resulted in an expansion of crossing use to the extent that it has become a public crossing in fact, whether or not any public agency has accepted responsibility for maintenance or control of the use of the traveled way over the crossing. The railroad company and highway agency should make every effort to mutually resolve and agree on the appropriate classification (either public or private) of questionable crossings."

3.3 The Task Force recognized the problem of crossings that are open to public travel but are not under the jurisdiction of and maintained by a public authority. To be able to move forward and identify the magnitude of the problem, the Task Force developed and assigned the designation of "PUB-4" to this type of crossing.

3.4 The Task Force's definition is: "PUB-4. A crossing that is open to the public but the road is not maintained by a public authority." Open to the public means that (1) there is no restriction placed upon the use of the crossing; (2) if there is a gate, the gate is not being closed to restrict the use of the crossing; (3) there is more than one user regularly using the crossing; or (4) the roadway serves more than one piece of property on the opposite side of the tracks. One or more of these conditions may exist today on a truly "private" crossing. With the exception of serving more than one piece of property. most existing private crossings could be made to fit this definition.

3.4.1 While the problems are the most acute in the Fairbanks North Star Borough, other boroughs, cities and municipalities have PUB-4 crossings. These include the Matanuska-Susitna Borough, Kenai Peninsula Borough, Municipality of Anchorage, City of Houston, City of Nenana, City of North Pole, and City of Seward. To be eligible for federal funding, the road authority must be responsible for the maintenance and meet the standards for public crossings as defined by the DOT/AAR Railroad-Highway Crossing Inventory Procedures Manual.

3.5 The roadway crossing at a PUB-4 crossing may have a designated street name, may be recognized as a public roadway and may be platted as such on either side of the railroad right-of-way.

3.6 The only known PUB-4 crossings outside of the boundaries of local government are the crossings at Cantwell (ARRC MP 319.6), at Ferry (ARRC MP 371.1), and North Nenana (ARRC MP 415.5). The first two crossings are at the end of State-maintained roads.

3.7 For the area outside of the organized boroughs (Broad Pass to Dunbar), the Task Force recognized the problem of no planning agency. To be able to properly plan the development in this area, all state and federal agencies having land in this area must work together.

3.8 Sight Triangles

3.8.1 A sight triangle for at-grade crossings is an area free of obstructions, which allows a motor vehicle operator approaching an at-grade crossing to safely observe a train approaching the crossing. The size of the sight triangle is based upon maximum train speeds and the posted highway speed. A table of sight triangle distances is shown in Appendix "A". There are two scenarios with regard to sight triangles:

a. Case I involves a moving vehicle approaching the crossing at the posted speed limit and the train traveling at the maximum speed approved for that location.

b. Case II involves a stopped vehicle departing from the crossing and the train traveling at the maximum speed approved for that location.

3.8.2 The table in Appendix "A" is based on the latest sight triangle calculations available and has been agreed to by the ARRC and DOT&PF. It will not be changed without concurrence of both parties.

3.9 New Crossing

3.9.1 A new crossing is a crossing that is being proposed where there is currently no crossing in existence.

3.9.2 Construction of a crossing at a new location that is replacing an existing crossing in the same vicinity will be seen as a major improvement project and not considered a new crossing.

3.10 Highway

For the purposes of this policy, the words "highway", "road", and "roadway" are synonymous.

4.0 RECOMMENDATIONS

4.1 General Recommendations

4.1.1 All crossings should be brought up to the basic safety standards in the Alaska Traffic Manual.

4.1.2 New construction will adhere to the standards in the Alaska Traffic Manual, Association of American Railroads (AAR) Rail/Highway Grade Crossing Handbook, and other State standards for the installation of passive and active warning devices.

4.1.2.1 Sight distances, track profile, drainage and train operation will all be factors considered in the design and improvement of crossings. The Railroad-Highway Grade Crossing Handbook, Federal Highway Administration Publication TS-86-215 (or revision) and current State of Alaska design standards thereof will be consulted in the design of crossings.

4.1.3 12-inch rounders for flashing lights, and RR crossbucks with high intensity reflective sheeting on both sides should be adopted as a standard in the State of Alaska.

4.1.4 DOT&PF and the ARRC will update the FRA National Rail/Highway Crossing Inventory annually or more frequently if significant changes are discovered, and use this data base to compute the crossing Accident Prediction Values.

4.1.5 "Operation Lifesaver" should be actively supported and participated in by the ARRC, DOT&PF, local governments and law enforcement agencies.

4.1.6 The ARRC and DOT&PF should arrange meetings with all local governmental planning and road agencies in the railbelt. These meetings would be used to discuss the results of the Task Force and set up procedures for implementing these recommendations.

4.2 Planning Recommendations

4.2.1 Local jurisdictions, state and federal agencies, and private enterprise should incorporate planning processes (a) aimed at minimizing the need for at-grade crossings and traffic at existing at-grade crossings; and (b) which will evaluate the effect on a crossing by changes in zoning, approval of new subdivisions and other elements of the planning process. Estimated future Accident Prevention Values based on the proposed activity and future highway and railroad traffic densities will be used in the evaluation of the crossings. New at-grade crossings are discouraged and no new crossings will be permitted without concurrence of the appropriate diagnostic team.

4.2.2 Agencies, authorities, jurisdictions, and/or private enterprise whose actions have an impact on the crossings should be required to participate in the funding of the construction and maintenance costs precipitated by those actions. For construction, this could include the matching funds (10%) if federal funding is available.

4.2.3 The ARRC and DOT&PF should arrange a meeting with the Bureau of Land Management (BLM), Department of Natural Resources (DNR), National Park Service (NPS), Community and Regional Affairs Department, and Division of Parks and Outdoor Recreation to review the planning processes for the area in the unorganized boroughs.

4.3 Diagnostic Team Recommendations

4.3.1 A professional diagnostic team should perform an on-site evaluation before any major improvement is planned for an existing crossing or a new crossing is approved.

4.3.2 Diagnostic teams should include as a minimum:

a. Alaska Railroad Corporation
b. DOT&PF Region
c. Borough (Kenai Peninsula, Municipality of Anchorage, Matanuska-Susitna, or Fairbanks North Star as appropriate)
d. The city when within incorporated city limits
e. Proposed permittee of the crossing if not one of the above entities

Where appropriate, representatives of the following should be informed and invited to assist the diagnostic team:

a. The FHWA;
b. DOT&PF Headquarters;
c. School District;
d. Municipality or other local agency; and
e. Law enforcement agency(ies);

4.3.3 The recommendation of the diagnostic team will be forwarded to the appropriate parties involved for action. The action at the crossing shall be in accordance with the permit and construction agreement with the ARRC.

4.3.4 The diagnostic teams should always consider the feasibility of eliminating crossings if this can be accomplished with safety benefits which outweigh the increased operational costs and inconvenience to users, and if it would not shift the safety problem to another area, or increase the area-wide hazard potential.

4.3.5 Diagnostic teams may be initiated by request of any interested party. The request is to be forwarded to the ARRC Chief Engineer. The Chief Engineer will arrange for the notification of the team members and establish the location and time for the meeting.

4.3.6 Where there are majority and minority Policies from the Diagnostic Team, it will be referred to a resolution committee. The committee will consist of the ARRC President and CEO, the DOT&PF Commissioner, and the chief administrator of the local jurisdiction. For crossings outside of a local jurisdiction, the Commissioner of Community and Regional Affairs will be the third person.

4.4 Existing Crossing Recommendations

4.4.1 The DOT Accident Prevention Value (APV) should be used as one factor in classifying and prioritizing crossings for improvements.

4.4.2 Diagnostic teams should consider an APV of 0.1 (one accident every 10 years) as an indicator of probable need to go from passive to active warning devices.

4.4.3 Diagnostic teams should evaluate crossings which have an APV greater than 0.1 to determine the feasibility of providing grade separations (overpass/underpass) or increasing the level of protection of the warning devices. Table VIII-I Quantitative Procedures in the Alaska Traffic Manual will be used as part of the process for determining possible upgrades of the existing crossing. The current table is shown in Appendix "B." If the Alaska Traffic Manual is revised, Appendix B will automatically become the revised Table VIII-1.

4.4.4 Where possible, upgrades and improvements should be accomplished when there is another project affecting the roadway or railway in the area of the crossing.

4.4.5 Sight triangles for at-grade road crossings shall be maintained to the minimum required by Appendix A. As a minimum, all crossings shall have Case II sight triangles except for certain industrial tracks.

In industrial areas, where local roads cross industrial tracks, there are crossings where the Case II requirements cannot be met due to building construction next to the track and road. In these cases, the ARRC will issue instructions that the crossing must be flagged by ARRC personnel prior to entering the crossing.

Case I sight triangles are desirable at all crossings, however, they are difficult and often impractical to achieve, except possibly in flat, open terrain.

4.4.5.1 When Case I sight triangles cannot be provided at a public crossing, a diagnostic team shall review the crossing. The team could, in addition to closing the crossing, propose one of the following requirements:

a. Active warning devices installed.

b. A crossing with low highway volume and low highway speed may have an advisory speed posted that is consistent with the sight triangles that can be provided. In no case should the difference in the posted speed and the advisory speed be greater than 10 miles per hour.

   Low highway speeds generally mean 40 mph or less. Low highway volume is generally in the range of less than 500 vehicles per day.

c. Stop signs installed if the Alaska Traffic Manual requirements for stop signs can be met.

4.4.5.2 If the maximum authorized train speed or posted highway speed are increased, the sight triangle requirements will be recalculated. If the new sight triangles are impractical to achieve, the provisions of Section 4.4.5.1 will apply.

4.5 <u>New Crossing Recommendations</u>

4.5.1 New crossings must be part of a comprehensive community plan. For the area between Broad Pass and Dunbar (unorganized borough), DOT&PF or Community and Regional Affairs Department (or the appropriate State agency) will be required to develop the plan. The comprehensive community plan must address factors such as future growth in the area, existing local governmental agencies, land ownership, geographical restrictions, availability and/or restrictions of natural grade separation locations.

4.5.2 New at-grade crossings should not be allowed if ' there is another crossing within two miles of the proposed new location, nor if there is a reasonable alternative to a crossing such as a feeder road. Exception may possibly be made after the diagnostic team review. Factors to be considered would include terrain conditions which make alternative access impossible or economically unfeasible.

4.5.3 It will be the responsibility of the government authority having road jurisdiction in the area of the proposed crossing to hold the necessary public hearings to insure that the road will be located so as to efficiently connect into future road networks. It will also be that governmental authority's responsibility to handle all protests concerning crossing location.

4.5.4 A professional diagnostic team will perform an on-site evaluation before any new crossing is approved. Factors to be considered by the diagnostic team include:

4.5.4.1 Any new crossing will likely become a permanent crossing and possibly become a major roadway.

4.5.4.2 The proximity of the proposed new crossing to existing crossing and/or other planned crossings.

4.5.4.3 The effect the construction of the new crossing will have on the elimination of one or more existing crossings, making the transportation network safer and better able to serve the road needs of the area.

4.5.4.4 The grade of approaches to all crossings should be level with top of rail (+/- 1") for at least 100' to prevent long low trailers from hitting the crossing.

4.5.4.5 Roadway approaches to the crossing should be at or nearly 90°. Short radius curves or skew angle approaches below 75° will not be permitted.

4.5.4.6 For public crossings, the road must have a dedicated right-of-way on both sides of the Alaska Railroad track right-of-way. The dedicated road right-of-way must include dedicated clear sight triangles for maximum design highway and train speeds.

4.5.4.7 For private crossings, the owner must own or secure road right-of-way and sight triangles for maximum design speeds. The private owner will be restricted from developing within the sight triangles.

4.5.4.8 The dedicated sight triangles referenced in 4.5.4.6 and 4.5.4.7 are for Case I and Case II scenarios. If the Case I sight distances cannot be achieved, automatic crossing signals will be required.

4.5.4.9 Sight triangles for at-grade road crossings shall be maintained to provide the sight distances required for both Case I and Case II scenarios.

4.5.5 The DOT Accident Prediction Values will be used as a factor in determining protection at new crossings. The new crossing will also be compared to existing crossings of similar geometric characteristics and rail and highway traffic densities. The comparison will also consider accident history and the effect of accidents on the DOT Accident Prediction Value.

4.5.6 The crossing permit issued by the ARRC for private crossings will be recorded as an encumbrance against the real property benefited by the crossing including the restriction on sight triangles, with the obligations of the permit to remain appurtenant to the real property.

4.5.7 For public crossings, the ARRC will only issue the permit to the DOT&PF or government authority having road construction and maintenance jurisdiction at the location of the crossing.

4.6 Private Crossings Recommendations

4.6.1 Existing truly "private" crossings and new private crossings will be deemed public when any of the following occur:

4.6.1.1 The crossing serves two or more parcels of property, unless all parcels are owned or leased by the same permittee;

4.6.1.2 The use of the crossing cannot be or is not controlled by the permittee of the crossing;

4.6.1.3 The roadway is designated by plat as a public roadway by the governmental authority responsible for planning and/or zoning; or

4.6.1.4 If school buses or mass transit vehicles use the crossing unless the school district notifies the ARRC in writing that it will operate across the private crossing and has permission of the permittee.

4.6.2 Some existing private crossings currently serve more than one parcel of property. The crossing may remain as a private crossing as long as there is not further subdivision of the property.

4.6.2.1 Private crossings may serve property owned or leased by more than one person or entity provided the following conditions are met:

a. The roadway is not open to public travel, and

b. The permit for the crossing has been executed by all owners/lessees of all property which can gain access from the crossing or a legally formed association of property owners.

4.6.3 If the permittee no longer complies with the conditions of the "Private Crossing Permit" and the crossing has not become a public crossing, the ARRC will notify the permittee of the deficiencies. If the permittee fails to correct the deficiencies, the crossing will be removed at the permittee's expense.

4.6.4 If the crossing's use has become public, the ARRC will work with the appropriate public authority to permit the crossing as a public crossing. A diagnostic team shall review the crossing prior to the issuance of the public crossing permit. The diagnostic team will recommend improvements to the crossing required to bring it into conformance with current design standards.

4.6.5 If the public authority refuses to accept the responsibility for the public crossing, the permittee of the crossing shall take appropriate action (if possible) to make the crossing "private". If the permittee fails to correct the deficiencies, the ARRC will remove the crossing at the permittee's expense.

4.6.6 Where Case I sight triangles are impractical to achieve at a private crossing, stop signs shall be posted at the crossing and Case II sight triangles will be maintained.

4.7 <u>PUB-4 Crossings Recommendations</u>

4.7.1 ARRC and DOT&PF should involve the local governments and use diagnostic teams to address the problems of these crossings. The local public authority with road powers must make decisions on the continuing need for the crossing balanced with the cost and liability of maintaining the crossings.

4.7.1.1 Diagnostic teams should be formed as soon as possible with each governmental agency which has PUB-4 crossings within its boundaries.

4.7.2 The use of ARRC right-of-way to eliminate a crossing will be reviewed on a case by case basis. When development has occurred and natural physical obstructions such as lakes and rivers prevent alternate access, the ARRC may permit to the public authority a road on ARRC right-of-way to facilitate the removal of one or more crossings. The use of ARRC right-of-way should only be permitted after a diagnostic team review and coordination with the local planning and zoning agency.

4.7.3 Roadway signing at the PUB-4 crossing should be in accordance with the Alaska Traffic Manual and include as a minimum:

4.7.3.1 Stop sign on both sides of the track unless a diagnostic team determines that stop signs are not required;

4.7.3.2 Crossbuck on both sides of the track;

4.7.3.3 Railroad advance warning signs (W10 Series) according to the Alaska Traffic Manual; and

4.7.3.4 An "ARRC Property-Proceed at Your Own Risk" sign at the right-of-way line on both sides of the track.

5.0 CHANGES AND ADOPTION OF POLICY

5.1 Changes to Policy

5.1.1 This policy was developed by a process that included input from the local governmental bodies. Changes to the policy will be developed in accordance with the following subsections.

5.1.2 The proposed changes will be coordinated by the ARRC Engineering Department and DOT&PF Headquarters Engineering and Operations Standards Section. DOT&PF will coordinate with the Federal Highway Administration.

5.1.3 Work sessions on the proposed changes will be held in Anchorage and Fairbanks. All government agencies concerned with crossings will be notified of the meeting and encouraged to attend.

5.1.4 After the work sessions, the changes will be reviewed by the ARRC and DOT&PF and all parties in attendance at the work sessions before being finalized.

5.2 Adoption and Implementation of Policy

5.2.1 Section 42.40.180 of the Alaska Railroad Corporation Act mandates that policies which affect the general public require adoption by the ARRC Board as a board rule once public notification has been made and a public hearing has been held on the Rule. In accordance with this procedure the proposed changes (see 5.1.4) will be submitted to the ARRC Board of Directors for approval in accordance with Board rules.

5.2.2 After adoption of the changes by the ARRC Board of Directors and concurrence by DOT&PF, the ARRC Policies and Procedures Manual relating to the Railroad Crossing Policy will be updated to incorporate the changes.

Appendix B – Plan Set and Cost Estimate

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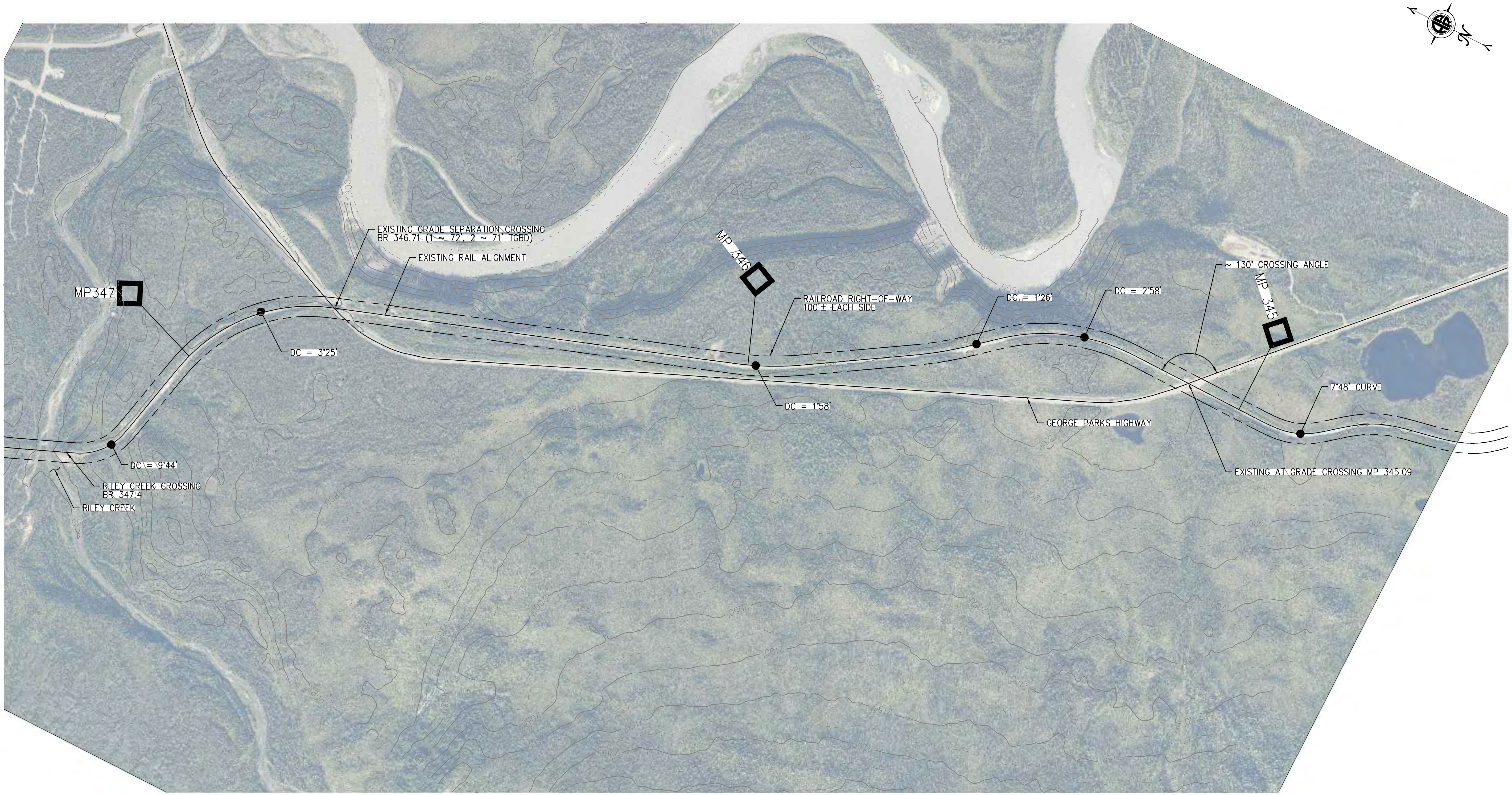


PLAN

SCALE

0 500 1000 1500 2000 3000

(IN FEET)
1 INCH = 1000 FEET

NOTE:

TRACK SPEED 30 MPH FREIGHT AND PASSENGER.

HDR

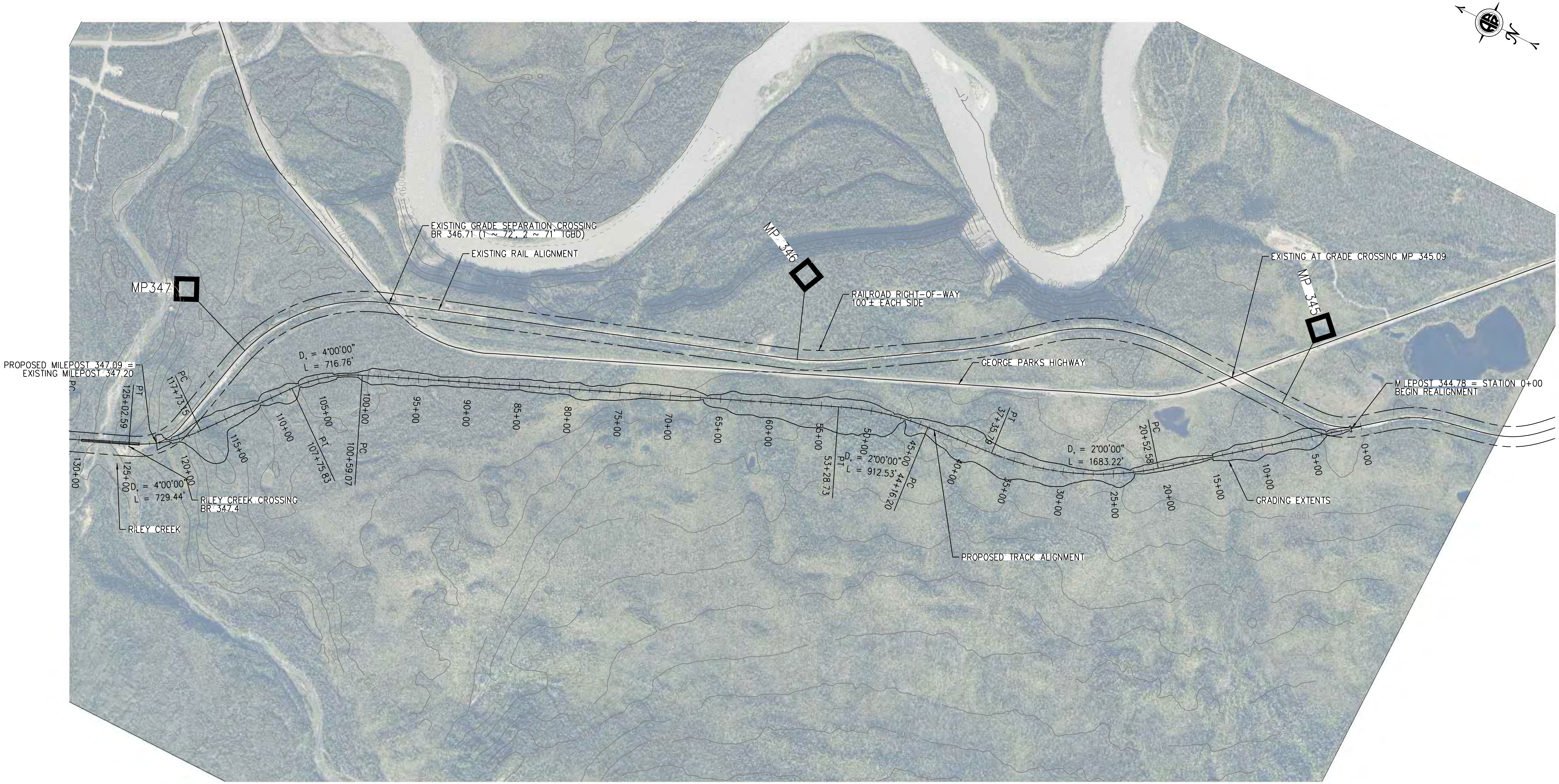
REV.	DATE	BY	REVISION

ALASKA RAILROAD

PROJECT:
DENALI PARK REALIGNMENT FEASIBILITY STUDY MP 344-348

TITLE:
NO BUILD

DESIGNED BY: CPH	SCALE: AS NOTED		AFE NO.:
DRAWN BY: AEP			ACAD FILE:
CHECKED BY: CPH	DATE: 07/13/2018		DWG NO.
APPROVED BY:			1 OF 7



PLAN

SCALE

0 500 1000 1500 2000 3000

(IN FEET)
1 INCH = 1000 FEET

NOTES:

DRAINAGE IMPROVEMENTS WILL BE REQUIRED, BUT HAVE NOT BEEN ADVANCED.

TRACK SPEED 30 MPH FREIGHT AND PASSENGER.

ALASKA RAILROAD

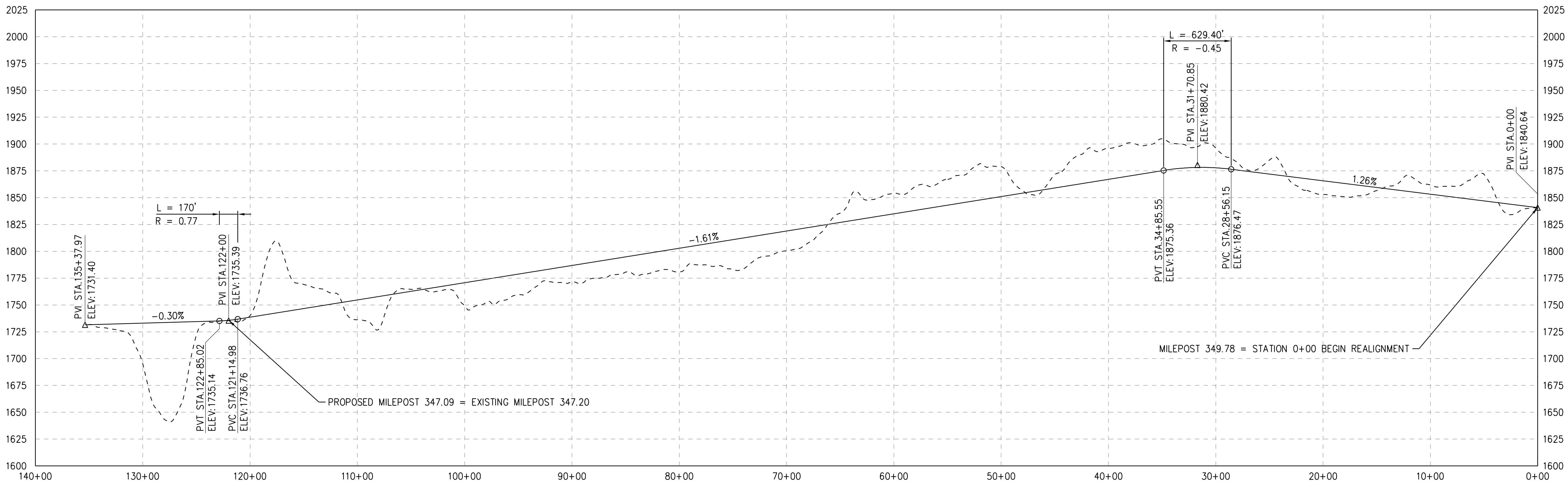
PROJECT:
DENALI PARK REALIGNMENT FEASIBILITY STUDY MP 344-348

TITLE:
ALTERNATIVE 1 - REALIGN TRACK THROUGH THE PARK PLAN VIEW

HDR

REV.	DATE	BY	REVISION

DESIGNED BY: CPH	SCALE: AS NOTED		AFE NO.:
DRAWN BY: AEP			ACAD FILE:
CHECKED BY: CPH	DATE: 07/13/2018		DWG NO. 2 OF 7
APPROVED BY:			



LOW RAIL PROFILE

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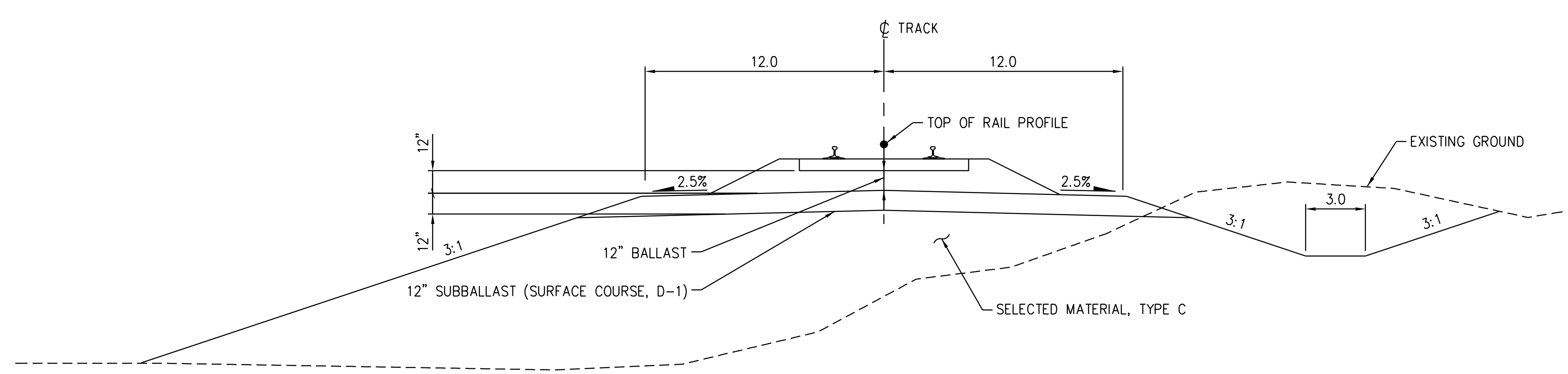
V = 1" = 1000'-0"



TYPICAL TRACK SECTION

SCALE: ⅛" = 1'-0"

REV.	DATE	BY	REVISION

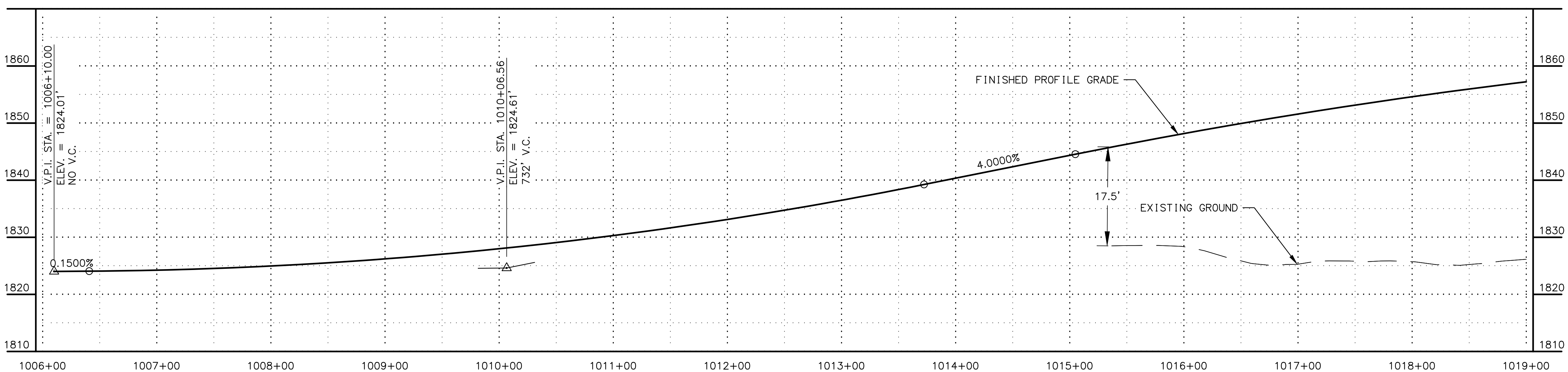
HDR

ALASKA RAILROAD

PROJECT:
DENALI PARK REALIGNMENT FEASIBILITY STUDY MP 344-348

TITLE:
ALTERNATIVE 1 - REALIGN TRACK THROUGH THE PARK LOW RAIL PROFILE AND TYPICAL TRACK SECTION

DESIGNED BY: CPH	SCALE: AS NOTED		AFE NO.:
DRAWN BY: AEP			ACAD FILE:
CHECKED BY: CPH	DATE: 07/13/2018		DWG NO. 3 OF 7
APPROVED BY:			



HIGHWAY PROFILE
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V:1"=20'-0"

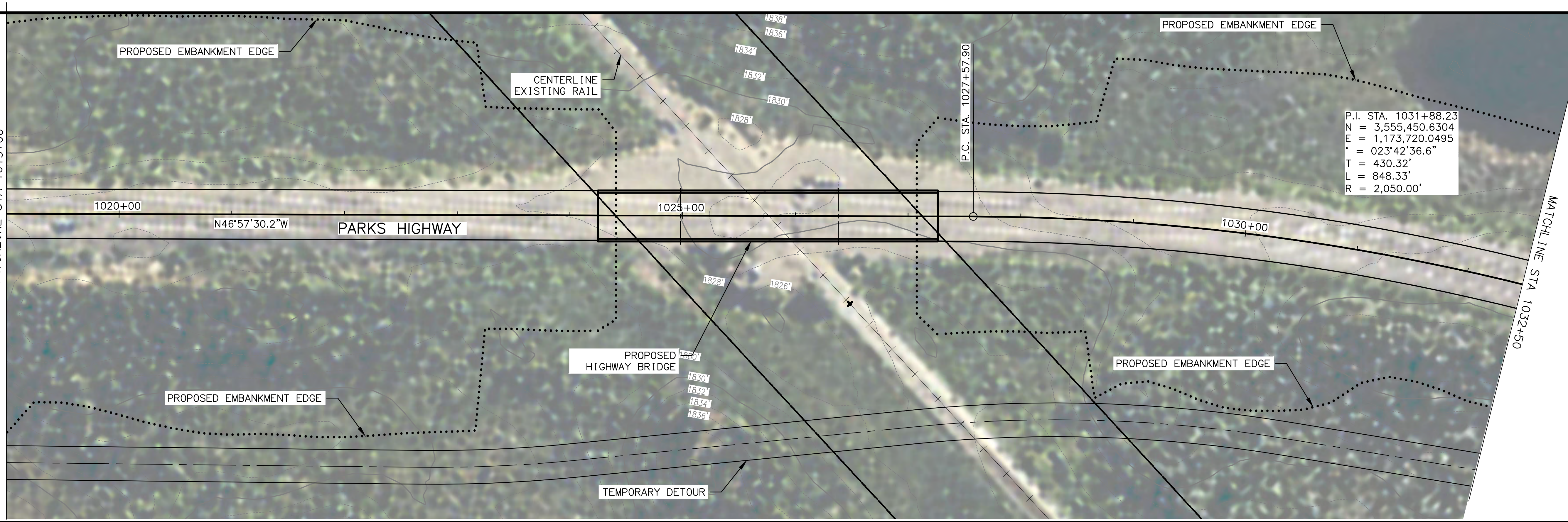
REV.	DATE	BY	REVISION

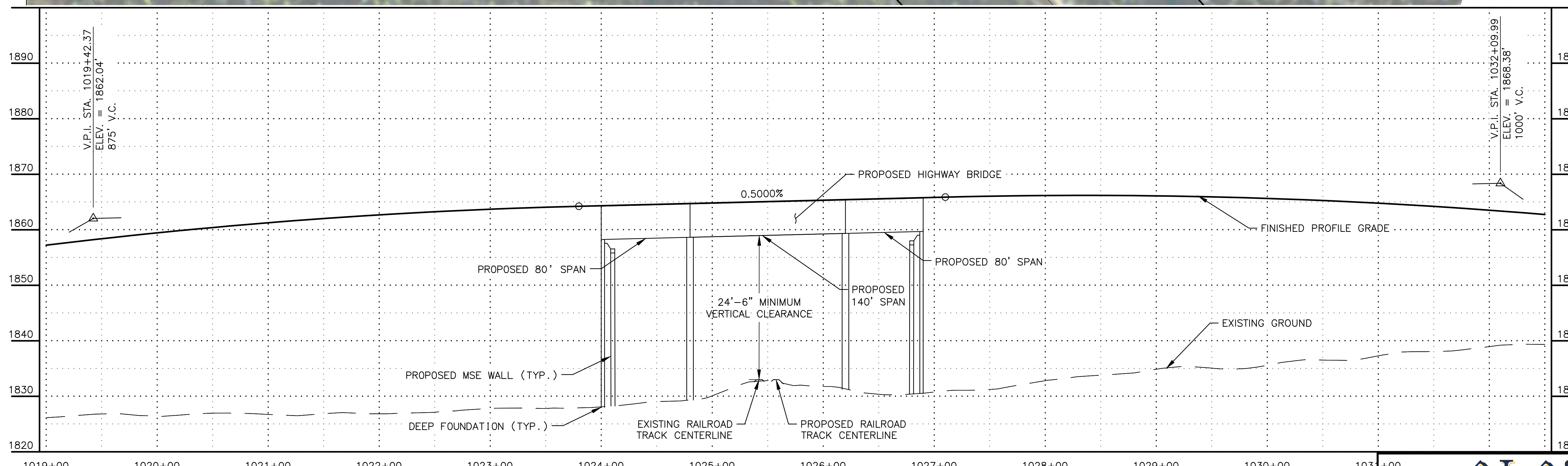
ALASKA RAILROAD

PROJECT:
DENALI PARK REALIGNMENT FEASIBILITY STUDY
MP 344-348

TITLE:
ALTERNATIVE 3
GRADE SEPARATE MP 345.09

DESIGNED BY: TCP
DRAWN BY: TCP
CHECKED BY: CPH
APPROVED BY:
SCALE:
DATE:
AFE NO.:
ACAD FILE:
DWG NO. 4 OF 7





HIGHWAY PROFILE
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ALASKA RAILROAD

PROJECT:
DENALI PARK REALIGNMENT FEASIBILITY STUDY MP 344-348

TITLE:
ALTERNATIVE 3
GRADE SEPARATE MP 345.09

HDR

REV.	DATE	BY	REVISION

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APPROVED BY:
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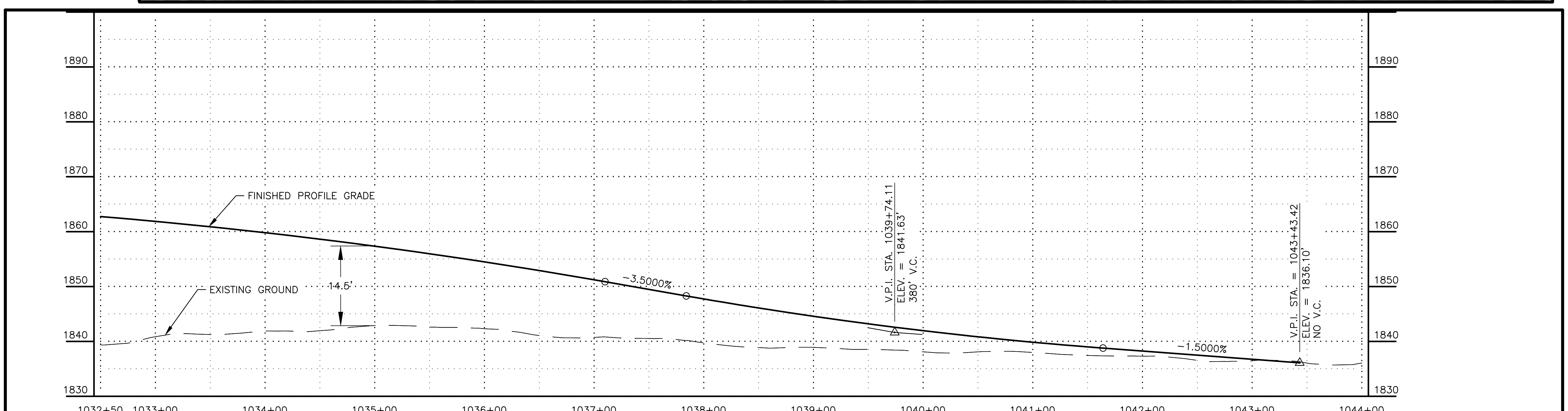

HIGHWAY PROFILE
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V:1"=20'-0"

HDR

REV.	DATE	BY	REVISION

ALASKA RAILROAD

PROJECT:
DENALI PARK REALIGNMENT FEASIBILITY STUDY MP 344-348

TITLE:
ALTERNATIVE 3
GRADE SEPARATE MP 345.09

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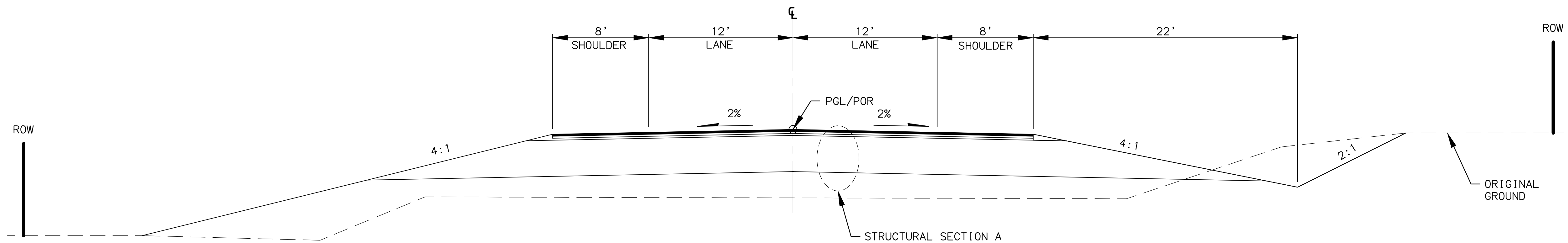
DRAWN BY: TCP
CHECKED BY: CPH
APPROVED BY:
SCALE:
DATE:
AFE NO.:
ACAD FILE:
DWG NO. 6 OF 7



PARKS HIGHWAY

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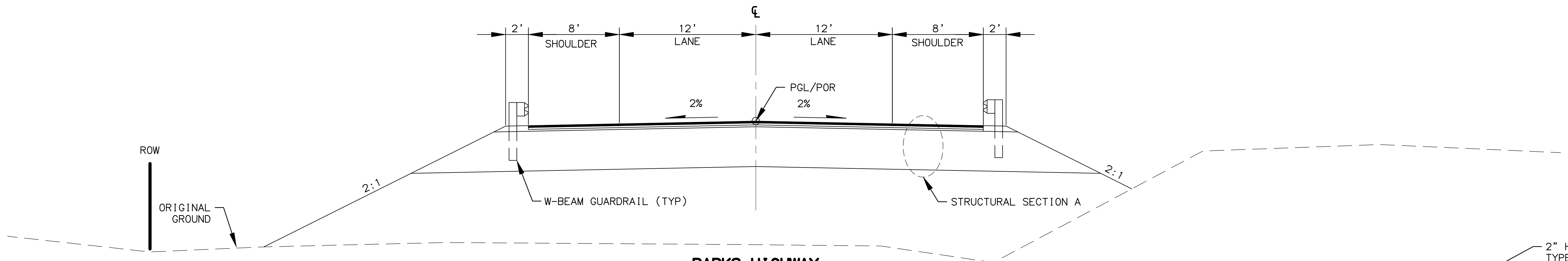
"SC" STA 1028+60.0 TO STA 1043+40.0



PARKS HIGHWAY

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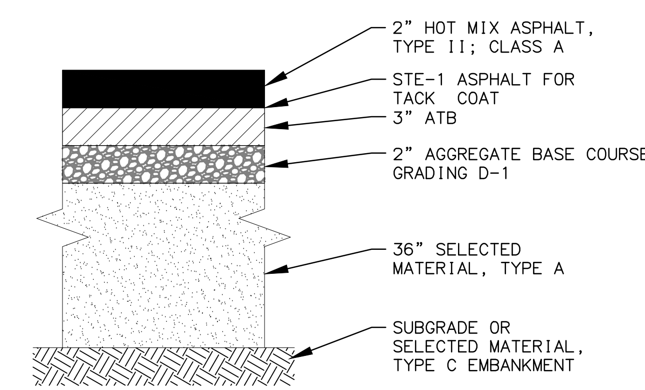
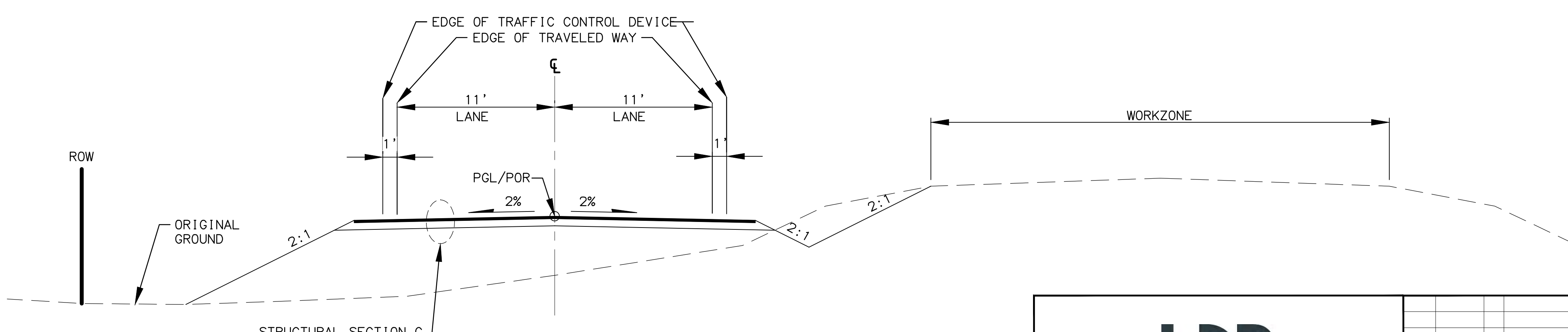


STRUCTURAL SECTION A



DETOUR

ALASKA RAILROAD

HDR

REV.	DATE	BY	REVISION

PROJECT:
DENALI PARK REALIGNMENT FEASIBILITY STUDY MP 344-348

TITLE:
ALTERNATIVE 3
GRADE SEPARATE MP 345.09

DESIGNED BY: TCP	SCALE:		AFE NO.:
DRAWN BY: TCP			ACAD FILE:
CHECKED BY: CPH	DATE:		DWG NO. 7 OF 7
APPROVED BY:			

Alternative 1 - Realignment Through The DNP

DENALI REALIGNMENT

Opinion of Probable Railroad Structure Construction Cost

DESCRIPTION	ITEM No	Pay Unit	Unit Price	Quantity	Amount	Price Source	Quantity Source
UNCLASSIFIED EXCAVATION	203(3)	CY	$7.00	948,200	$6,637,000	2007-2014 Alaska DOT&PF CR Bid Tabulation Summaries	Microstation
TRACK SECTION							
-RAIL/BALLAST/TIES		FT	$200.00	12,300	$2,460,000	ARRC	Microstation
- SUBBALLAST		TON	$23.00	24,300	$559,000	Engineering Estimate HDR	Microstation
- BORROW C	203(5B)	TON	$7.00	497,400	$3,482,000	2007-2014 Alaska DOT&PF CR Bid Tabulation Summaries	Microstation
EXTRAS							
-CROSSING REMOVAL		LS	$50,000.00	1	$50,000		
-CULVERTS		LS	$200,000.00	1	$200,000	Estimated Lump Sum due to unknown number and size	
SUBTOTAL					**$13,388,000**		
Other ITEMS NOT QUANTIFIED	15%				**$2,008,000**		
CONSTRUCTION SUBTOTAL					**$15,396,000**		
CONSTRUCTION OVERSIGHT	7.50%				**$1,154,700**		
ENVIRONMENTAL and PERMITTING	1.00%				**$154,000**		
WETLAND MITIGATION		Acre	$15,000.00	46	**$690,000**		
DESIGN	6.00%				**$924,000**		
PROJECT SUBTOTAL					**$18,318,700**		
ADMINISTRATION	4.65%				**$860,000**		
CONTINGENCY	20.00%				**$3,670,000**		
GRAND TOTAL					**$22,900,000**		

Alternative 3 - Grade Separated Crossing at MP 345.09

DENALI REALIGNMENT

Opinion of Probable Railroad Structure Construction Cost

DESCRIPTION	ITEM No	Pay Unit	Unit Price	Quantity	Amount	Price Source	Quantity Source
UNCLASSIFIED EXCAVATION	203(3)	CY	$7.00	35,300	$247,100	2007-2014 Alaska DOT&PF CR Bid Tabulation Summaries	Auto CAD
EMBANKMENT							
- BORROW A	203(5A)	TON	$18.00	46,000	$828,000	2007-2014 Alaska DOT&PF CR Bid Tabulation Summaries	Auto CAD
- BORROW C	203(5B)	TON	$7.00	644,000	$4,508,000	2007-2014 Alaska DOT&PF CR Bid Tabulation Summaries	Auto CAD
ROAD SECTION							
-CRUSHED AGGREGATE BASE COURSE (D-1)	301(1)	TON	$11.00	6,500	$71,500	2007-2014 Alaska DOT&PF CR Bid Tabulation Summaries	Auto CAD
-ASPHALT CEMENT, Grade 52-40	306(2)	TON	$1,000.00	150	$150,000	2007-2014 Alaska DOT&PF CR Bid Tabulation Summaries	
-ATB	306(1)	TON	$95.00	2,800	$266,000	2007-2014 Alaska DOT&PF CR Bid Tabulation Summaries	Auto CAD
-STE-1 TACK COAT	402(1)	TON	$850.00	5	$4,000	2007-2014 Alaska DOT&PF CR Bid Tabulation Summaries	
-ASPHALT BINDER, GRADE PG 52-40	401(2)	TON	$1,000.00	100	$100,000	2007-2014 Alaska DOT&PF CR Bid Tabulation Summaries	Auto CAD
-HOT MIX ASPHALT, Type II, Class A	401(1A)	TON	$120.00	1,800	$216,000	2007-2014 Alaska DOT&PF CR Bid Tabulation Summaries	Auto CAD
STRUCTURES							
-LUMP SUM		FT	$10,918.09	300	$3,276,000	Parks Grade Separation Schedule of Values 30% Design	
-CLASS A CONCRETE	501 (1)	CY	Lump Sum per foot estimate				Due to poor conditions at the site along with permafrost a per foot basis was used due to the face that goby was 2 bridges with 4 total abutments and the proposed is 2 abutments and 2 piers
-CLASS A-A CONCRETE	501 (2)	CY					
-PRECAST CONCRETE MEMBERS (GIRDERS)	501 (7)	EA					
-REINFORCING STEEL	503 (1)	LBS					
-EPOXY-COATED REINFORCING STEEL	503 (2)	LBS					
-FURNISH STRUCTURAL STEEL PILES	505 (5)	LF					
-STEEL BRIDGE RAILING	507 (1)	LF					
-WATERPROOF MEMBRANE	508 (1)	SY					
-MECHANICALLY STABILIZED EARTH WALL	511 (1A)	LS	$624,800.00	1	$624,800		
TEMPORARY CROSSING/ FLAGGING		LS	$500,000.00	1	$500,000	Engineering Estimate HDR	
GUARDRAIL	606(1)	FT	$35.00	1,665	$58,275	2007-2014 Alaska DOT&PF CR Bid Tabulation Summaries	Auto CAD
END-SECTIONS (ET-2000)	606(11)	EACH	$3,500.00	4	$14,000	2007-2014 Alaska DOT&PF CR Bid Tabulation Summaries	Standard
TRACK SECTION							
-RAIL/BALLAST/TIES		FT	$200.00	150	$30,000	ARRC	
SUBTOTAL					**$10,863,675**		
Other ITEMS NOT QUANTIFIED	15%				**$1,630,000**		
CONSTRUCTION SUBTOTAL					**$12,494,000**		
CONSTRUCTION OVERSIGHT	7.50%				**$937,100**		
ENVIRONMENTAL and PERMITTING	1.00%				**$125,000**		
WETLAND MITIGATION		Acre	$15,000.00	10	**$150,000**		
DESIGN	6.00%				**$750,000**		
PROJECT SUBTOTAL					**$14,456,100**		
ADMINISTRATION	4.65%				**$680,000**		
CONTINGENCY	20.00%				**$2,900,000**		
GRAND TOTAL					**$18,100,000**		

Appendix C – Geotechnical Analysis

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REPORT

GEOTECHNICAL REPORT FOR FEASIBILITY STUDY OF ARRC MP 345 TO 347.5 RAIL REALIGNMENT NEAR DENALI NATIONAL PARK

Submitted To: Alaska Railroad Corporation (ARCC)
327 W. Ship Creek Avenue
Anchorage, AK 99501

Submitted By: Golder Associates Inc.
2121 Abbott Road, Suite 100
Anchorage, AK 99507 USA

Distribution: Jesse Moose and Peter Blake

December 1, 2017 **Project No. 1771891**

Table of Contents

List of Tables

List of Figures

List of Appendices

1.0 INTRODUCTION AND PROJECT UNDERSTANDING

The Alaska Railroad Corporation (ARRC) is completing a feasibility study for realigning approximately two and a half miles of railroad between MP 345 and 347.5. The project is located just south of the entrance to the headquarters and visitor center of Denali National Park and Preserve (DENA) at Riley Creek, as shown in Figure 1. The purpose of the realignment is to eliminate two crossings of the Parks Highway, one at-grade crossing at MP 345.1 and bridge overpass at MP 346.8, and thereby increase traffic safety. The proposed realignment would require new right-of-way acquisition into designated Wilderness land within DENA.

In support of the feasibility study, Golder assembled historical geotechnical data, mapped surficial geologic units, performed a reconnaissance of the proposed alignment, and conducted a limited number of geotechnical boreholes. Based on the limited data, general subsurface soil and permafrost conditions along the alignment are extrapolated according to expectations within the various geologic terrain units. This served as basis for developing preliminary geotechnical engineering considerations for the project.

2.0 PROJECT SETTING, GEOLOGY, CLIMATE, AND PERMAFROST

2.1 Regional Geology

The realignment of Milepost 345-347 of the Alaska Railroad is located approximately 10 miles south of Healy, Alaska along the border of the Alaska Range (Central Part) and the Northern Foothills of the Alaska Range physiographic provinces (Wahrhaftig, 1965). The highest point in the Alaska Range, Denali, is approximately 20,300 feet high and is the tallest mountain in North America. Moving north towards the foothills, mountains are typically flat topped east-trending ridges ranging from 2,000 to 4,500 feet in altitude. Ridges in the foothills are separated by rolling lowlands and are largely unglaciated. Glaciers in the Alaska Range will typically terminate in the foothills and are the source for many rivers and braided streams in the area.

2.2 Project Setting and Site Geology

The proposed realignment of Milepost 345-347 of the Alaska Railroad runs parallel to the west of the Parks Highway just south of the Denali National Park entrance. The area generally consists of glacial deposits from the Riley Creek Glaciation, including glacial moraine and outwash deposits. The Nenana River is a north-flowing river that lies to the east of the alignment, approximately 200 feet elevation below the Parks Highway. The river is currently undercutting the glacial deposits. This undercutting appears to result in slope instability along portions of the banks along the Nenana River in the past.

2.2.1 Terrain Units – Based on Interpretation of Aerial Imagery

The following surficial geologic units were developed based on interpretation of aerial imagery and review of surficial geologic mapping completed by Wahrhaftig and Black (1958a). Surficial engineering geologic maps are presented in Figures 2 through 6 for the proposed realignment. The generalized descriptions for the surficial mapping units include:

- **Alluvium (Qal):** Sedimentary deposits in present river and stream channels. Alluvial deposits may include fine-grained sediment, sand, gravel, and cobbles and boulders.
- **Colluvium (Qc):** Unconsolidated sediments left on slopes due to gravity, rainwash, downslope creep, or a combination of the processes. Typically found on slopes along active stream channels, mountain slopes, and other steep terrain.
- **Fill (Qhf):** Present day road, rail, and embankment fill. Generally consists of gravel with silt and sand.
- **Glacial Outwash (Qgo):** Glacial sediments including sand and gravel transported and deposited by the Nenana River and other glacial melt waters. Glacial outwash deposits can be identified here as abandoned river terraces with old braided streams, and river channels that are at a higher elevation than the present-day Nenana River.
- **Landslide (Qls):** Landslides, slope instabilities, and associated debris that appear to have failed in the past.
  - A significantly-sized (2,000 foot width) historic landslide is located near ARRC MP 346.3, located between the tracks (reaching the embankment) and downslope to the

Nenana River. The aerial extent is shown on Figure 1. The suspected cause was undercutting the high face of the glacial moraine at its toe by the Nenana River.

- **Glacial Moraine (Qm):** Moraine, till, and associated deposits laid down by glaciers. Terminal, lateral, and ground moraine deposits. Mainly glacial till, but included till-mantled hills of outwash gravel, lake clay, and some closely pitted outwash deposits. Till is a heterogeneous, poorly-sorted mixture of boulders, cobbles, gravel, sand, silt, and clay. Moraine deposits in this area can be identified by hummocky surface texture.
  - **Glacial Deposits, Forested (Qmf):** Glacial deposits that are heavily vegetated or forested. Mineral deposits consist of silt, sand, gravel, and cobbles, with possible boulders and clay component.
  - **Glacial Deposits, Meadow (Qmm):** Glacial deposits that are not forested and consist of thin tree cover and low lying grassy meadows. Mineral deposits consist of silt, sand, gravel, and cobbles, with possible boulders and clay component.
- **Organics (Qo):** Organic deposits.
- **Birch Creek Schist (BCS):** Precambrian schist bedrock, predominantly quartz-sericite, but locally contains layers of quartzite and black carbonaceous schist. Here, it appears as highly weathered and very to extremely weak.

2.3 Permafrost

Perennially frozen ground, or permafrost, is soil or rock that remains below 0°C (32°F) continuously for at least two consecutive years. The definition is based entirely on temperature and is independent of type and content of ice and moisture, and may also contain a small portion of unfrozen water content. Above the permafrost is a layer that seasonally-thaws in the summer called the active layer. In many cases, the seasonally-thawed active layer will completely refreeze, but in other cases the thawed layer advances deeper than the ensuing freeze, and thus creates a thawed talik zone above the top of permafrost.

2.3.1 Regional / Statewide Permafrost Mapping

Regional permafrost mapping for the project site is characterized as “mountainous area underlain by discontinuous permafrost”, according to Ferrians (1965). In 2008, the Institute of Northern Engineering (INE / UAF, 2008) made updates to permafrost mapping for Alaska using a terrain-unit approach to distribution. The 2008 INE data classifies the project area as having permafrost that is “discontinuous with 50- to 90-percent distribution.” This generally characterizes the upper 10 meter ground profile.

2.3.2 High-Resolution Permafrost Modeling by NPS & UAF

In 2014, NPS, in cooperation with the UAF Geophysical Institute, conducted high-resolution modeling of near-surface permafrost in DENA (Panda, S.K., and others, NPS, 2014). The primary objective and accomplishment of this report is modeling the presence or absence of near-surface permafrost by modeling ground temperatures at the bottom of the seasonal freeze-thaw active layer and thickness of the active layer. This ground temperature modeling was completed for past decadal period (1950-1959), conditions over first decade of this century (2000–2009), and endeavors, as a planning tool, to predict future conditions (2050s and 2090s).

The model shows in 2000 – 2009 that 49-percent of DENA total area is underlain by near-surface permafrost, predominantly on the north side and north of the Alaska Range. Near-surface permafrost is predicted to decline to 6-percent by the 2050s and 1-percent by the 2090s. Near-surface permafrost here is defined as ground temperature at the base of the active layer. Despite how profound and useful these predictions may be, it is important to keep in mind their limitation; whereby they strictly relate to near-surface permafrost conditions and temperature at the bottom of the active layer. The fate and temperature of permafrost at greater depth is unknown, as is the full vertical reach of these effects or how deeply the top of permafrost may degrade.

A brief summary of the findings from this report, as it relates to this project, is as follows:

Table 1: Near-Surface Permafrost Modeling Results by NPS & UAF

	1950 - 1959	**2000 - 2009**	**2051 - 2060**	**2091 - 2100**
Mean Decadal Ground Temperature [MDGT, °C and (°F)]	-2 to -1°C (28 to 30°F)	Southern Portion: -1 to 0°C (30 to 32°F) Northern Portion: 0 to +0.5°C (32 to 33°F)	+0.5 to +2°C (33 to 36°F)	+2 to >3°C (36 to >37°F)
Seasonally Thawed Active Layer Thickness (ALT) [m and (ft.)] [3]	Southern Portion: 0.5 to 1.5 m (1.5 to 5 ft.) Northern Portion: 1.5 to 2.0 m (5 to 6.5 ft.)	Southern Portion: 0.5 to 1.5 m (1.5 to 5 ft.) Northern Portion: n/a	n/a (absent of near-surface permafrost)	n/a (absent of near-surface permafrost)
Seasonally Frozen Layer Thickness (SFLT) [m and (ft.)] [3]	n/a	Southern Portion: n/a Northern Portion: 1 to 1.5 m (3 to 6 ft.)	1 to 1.5 m (3 to 5 ft.)	0.5 to 2 m (1.5 to 6 ft.)

Notes: 1) For this purpose, the boundary between southern and northern portions of this project is near MP 346.3, at the boundary between glacial deposits and glacial outwash materials.
2) In general, thaw depths and ground temperatures are predicted greater in the northern portion compared to the southern.
2) m = meters. ft. = feet.
3) Presence of Seasonally Thawed Active Layer Thickness (ALT) infers that there is underlying near-surface permafrost. Presentation of Seasonally Frozen Layer Thickness (SFLT), without ALT, infers absence of near-surface permafrost.

2.4 Climate

2.4.1 Western Regional Climate Center (WRCC)

The project area lies within the sub-arctic continental climate zone. This continental climate zone encompasses most of the Interior portion of the state, which experiences extremely cold, long winters and short, warm summers. Over the three-decade period 1981 – 2010, the mean annual air temperature measured was about 27.7°F, and average annual air freezing index was 4090°F-days for McKinley Park station (WRCC, 2017). Annual precipitation averages about 15 inches, with over half of that falling as rain June through August, and about 79 inches of snowfall (WRCC, 2017). Snow depth, over the freezing months, averages over 16 inches.

2.4.2 Scenarios Network for Alaska Planning (SNAP)

Historical climate data, including average air temperature and average thawing and freezing indices, are presented in Table 2 for the McKinley Park area from 1948 to 2009. The indices are calculated from the data available through Scenarios Network for Alaska Planning (SNAP, 2017), developed by the International Arctic Research Center (IARC) at the University of Alaska Fairbanks (UAF). Design thawing and freezing indices presented are based on the three coldest winters or three warmest summers, respectively, observed during the analysis period, which is typically three decades.

Table 2: Engineering Climate Indices for McKinley Park, AK

	1948 - 1978	1979 - 2009	2020 - 2050	2050 - 2080
Average Air Temperature	26.5°F	29°F	30.4°F	32.8°F
Average Freezing Index	4740°F-days	4070°F-days	3560°F-days	2940°F-days
Average Thawing Index	2770°F-days	2990°F-days	2970°F-days	3270°F-days
Design Freezing Index	5760°F-days	5100°F-days	4320°F-days	3530°F-days
Design Thawing Index	3090°F-days	3380°F-days	3210°F-days	3550°F-days

Notes: 1) Monthly temperature data and climate indices are derived from SNAP dataset for coordinates N 63.7185°, W 148.9127° (Dillon, 2015, http://akindices.akdillon.net/).
2) Future forecast is based on a 5 climate model average, assuming carbon Scenario A1B.

SNAP also provides forecast climate data based on select global climate models and three carbon emission scenarios. For purposes of this study, the future forecast predicted by SNAP is based on composite average of five global climate models (5-GCM), assuming carbon emission Scenario A1B (moderate, of three possible scenarios between low and high). Impacts to the current climate design indices are expected to occur within the next three decades (2020 to 2050), and may be more profound beyond that period.

Based on a review of the projected climate conditions, SNAP data projects the average annual air temperature to increase by about 1.4°F over the next three decades, compared to the 1979 – 2009 period. The average air thawing index appears steady over that same period, and therefore increase in annual air temperature appears to amounts to sharp decrease (roughly 12-percent) in average air freezing index. Simply put, summer temperatures are expected to remain similar, with noticeable increase in winter.

Precipitation, both winter and summer, is predicted to increase by 5- to 10-percent. However, effects from snow distribution and wind, which can have significant effects on ground temperatures, are not predicted here or in the SNAP model.

3.0 BACKGROUND DATA

Historical geotechnical background data from various sources is presented in the following sections.

3.1 Historic Railroad Site Information

There is continued and long-term settlement reported at the highway crossing at MP 345.1. It is inferred settlement is associated with the Qo organic terrain unit and related to initial thaw strain due to melting of permafrost and now continued consolidation of those materials. The section of track north of the crossing up to MP 346 has also had minor settlement and drainage issues related to degrading permafrost. This includes the Qo organic unit near the end of that segment MP 346, but not to the degree as experienced at the highway crossing.

At MP 346.4, the head scarp of a landslide almost reaches the rail embankment (as shown on Figures 1 and 6). Stability of this slope should be evaluated further, but was not part of the scope of this document. Aside from the toe of the slope being undercut by the Nenana River, cross drainage that is concentrated near MP 346.25 may also contribute to slope instability. This drainage path is most evident on the LiDAR based hillshade image shown in Figure 2.

The ensuring rail cuts north between MP 346.8 and 347.25 appear to be performing well. There are reports of pumping fines under the railbed at MP 347.2, near the saddle of the railroad through-cut. We suspect that this is related to fine-grained mineralogy of the underlying Birch Creek Schist, which may be particularly weathered due to the faulting, and also likely aggravated by drainage that flows from the side slopes of the cut and perched along the bedrock interface (as noted in Borehole TH-10-ROW).

Performance of the bridge foundations and canyon side slopes was not evaluated as part of this task.

3.2 Alaska Department of Transportation & Public Facilities (ADOT&PF)

3.2.1 Historic Boreholes

Between the years 2012 to 2014, ADOT&PF conducted several geotechnical explorations for the Riley Creek Bridge replacement project along the Parks Highway. This also included associated highway approaches. In addition to the nine test holes and five penetrometers completed at the bridge, twenty one test holes were drilled along its north and south approaches, including at two locations three-quarters of a mile south of the crossing (near this subject project), and at the intersection with Denali Park Road. In 1966, the Department of Highways completed five borings for the Parks Highway underpass of the Alaska Railroad (at current Parks Hwy. MP 236.7, ARRC MP 346.7). This was presumably done before the road cut happened. Copies of the respective reports are included in Appendix E, including: logs for the Riley Creek Bridge in Appendix E-1, the Geotechnical Report for the bridge approaches in E-2, and the Foundation Report for the underpass in E-3.

- <u>2013 Highway Boreholes – Parks Hwy. MP 236.5</u>
  - Two boreholes (13-5106 and 13-5107, as shown on Figure 5) were drilled within the road embankment of the Parks Highway, about three-quarters of a mile south of Riley Creek Bridge, and are located within the project area.
  - Conditions found included approximately 2 feet of poorly-graded gravel fill with sand and silt, underlain by mostly gravels with sand and minor amounts of silt and numerous cobbles and boulders. These borings are located within the glacial outwash terrain unit.
  - No shallow permafrost remained within these boreholes, as would be expected within the road embankment, coupled with relatively shallow explorations (17 to 21 foot depths).
- <u>1966 Highway Underpass – Parks Hwy. MP 236.7 (ARRC MP 346.7)</u>
  - Boreholes drilled for the highway underpass show a thin surficial layer of silty sand underlain mostly by poorly-graded sands and gravels to approximately 70 feet below ground surface. These sediments had trace amounts of silt, an abundance of cobbles and boulders, and occasional lenses of silt and sand.
  - Silty gravels were observed in one boring from 70 to 90 feet below ground surface.
  - Shallow permafrost was not encountered during this investigation. Two boreholes found 10 to 17 foot thick zones of permafrost in deeper soils below 75 and 22 foot depths, respectively.

3.2.2 Highway Road Cut – Parks Hwy. MP 236.5 to 237

Visual inspection of the road cuts fore and aft of the highway underpass suggest mostly gravels with sand and minor amounts of silt and numerous cobbles and boulders. With that said, silt and fine sands are readily susceptible to erosion and may no longer be visible in the cut. The angle of the cuts range from 1.8H:1V to 2H:1V (Horizontal : Vertical, H:V), and appear stable, with the exception of minor unravelling or erosion of the surface. These soils conditions visible in the cut are similar as found in the two historical boreholes mentioned above, and agree with sediments expected within glacial outwash terrain unit (Qgo).

3.2.3 Highway Settlement and Continual Maintenance

Golder conducted telephonic conversations with key ADOT&PF geology and road maintenance personnel (ADOT&PF, 2017) related to the section of the Parks Highway that parallels this project. A paraphrased summary of the information conveyed from ADOT&PF is listed below:

- The segment of the Parks Highway between MP 230.5 and 236 has been one of the most problematic along the highway. This is related to settlement associated with permafrost, ice lenses, kettle lakes, melt ponds, and drainage.
- In the highway segment MP 235 to 236, there are a number of roadway dips (see Figure 1), some of which require annual pavement patching. Some patches may contain up to 8 feet of cumulative repairs.
- The at-grade crossing at Parks MP 235 (ARRC MP 345.1) has long experienced settlement, and requires costly annual maintenance. There was reported a boring completed there last year that did not reveal ice or frozen materials, and had wicking water through the sediments. Details and depth of the boring are unknown. From this, it is

suspected that settlement was once related to thaw strain, but is now happening as a result of consolidation of those thawed and loose soils. It is unknown if organic materials remain under the embankment, which may be contributing as well to settlement.

- Between Parks Highway MP 236 and 237, performance of the road appears significantly improved. Road cuts there appear stable, although they are susceptible to shallow surface unravelling and erosion.

3.3 United States Department of Agriculture (USDA) - Soil Survey

In 2006, USDA, in cooperation with UAF and NPS, published a Soil Survey of Denali National Park Area (Clark and Duffy, USDA, 2006). The soil represented by the survey includes shallow, near surface profile from the ground down into unconsolidated mineral materials, typically logged in the top 59 inches or less. This includes the upper mantle of material that contains organic matter and other living organisms and that has been changed by biological activity. USDA soil survey is commonly used for agronomic purposes, but here, surface organics are also an indicator of geologic terrain unit, permafrost, and subsurface drainage.

USDA soil survey data is made available through the *USDA – Web Soil Survey* website (USDA, 2017), where a custom *Soil Resource Report* and associated map was generated for this project. This information is included for reference in Appendix F, including more detailed descriptions of units. Findings relevant to this project are summarized below:

- <u>BOP to Future ARRC MP 346.3</u>: Inspection of the custom USDA map shows:
  - A majority of the proposed alignment from beginning of project (BOP) to future MP 346.3 is mapped as *Unit 7P4 - Boreal Glaciated Plains and Hills with Discontinuous Permafrost*.
  - Map unit composition includes: 35-percent boreal-forested gravelly till, 30-percent boreal-taiga loamy drift, 20-percent boreal-forested gravelly till, and 15-percent other.
  - This segment of rail coincides with the mapped *Glacial Deposits, forested (Qmf)* and *Glacial Deposits, meadow (Qmm)* geologic terrain units (see Figure 1).
- <u>Future ARRC MP 346.3 to 347.3</u>: North of future MP 346.3, surficial geology changes to glacial outwash, and wherein the USDA soil survey mapping changes. Inspection of the custom USDA map shows:
  - The segment between future MP 346.3 and 347.3 is mapped as *Unit 7P2 - Boreal Glaciated Plains and Hills*.
  - Map unit composition includes primarily 75-percent boreal-forested gravelly outwash.
- <u>Future ARRC MP 347.3 to Riley Creek</u>: The final quarter-mile segment of this project to Riley Creek is mapped per the custom USDA data as:
  - Unit *7FP1 – Boreal Flood Plains and Terraces*.

4.0 SEISMIC

4.1 Seismicity and Park Fault

The rail alignment crosses the Park Road fault at the northern end of the project, prior to crossing Riley Creek, as shown on Figure 1. This Quaternary fault is an east-northeast to northeast trending thrust fault with fault dip to the north (Koehler, 2013). The fault is part of the Northern Foothills fold and thrust belt, a zone of deformation located in a belt south of the Nenana Basin and north of the Denali fault. The fault is categorized as having most recent surface deformation in the last 15,000 years, with a slip rate estimated at 0.2 to 1 mm/yr. (Koehler, 2013). For comparison, the slip rate estimated for the Denali fault, located 18 miles to the south, is an order-of-magnitude greater at approximately 5 to 13 mm/yr. (Matmon, A. et al., 2006 and 2017). Denali fault slip rate is noted highest along central portion and lower to the west (closest to this project) and east.

A recent paleoseismic investigation was completed by Federschmidt (2014) at three paleoseismic trenches located northeast of the alignment. The paleoseismic trenches were completed on a fault named the Hines Creek fault. The fault traces of the Park Road fault (Koehler, 2013) and Hines Creek fault (Federschmidt, 2014) are similar. The differences in the two faults are related to the interpretation of fault geometry and movement. In Koehler (2013), the Park Road fault is a reverse-slip fault that dips to the north. In Federschmidt (2014), the vertical Hines Creek fault (block motion north side up) intersects a splay fault, the north-dipping Park Road fault, at depth; fault slip on the Park Road reverse-slip fault transfers to the vertically-dipping Hines Creek fault. The results of the paleoseismic investigation by Federschmidt (2014) suggest the possibility of at least four prehistoric earthquakes to have occurred in approximately the last 2,000 years at locations along the Hines Creek fault.

4.2 Seismic Design Parameters

Probabilistically-derived seismic hazard mapping for Alaska has been completed by the U.S. Geological Survey as part of the National Seismic Hazards Mapping Program (USGS, 1998), and subsequently updated in 2008 (USGS, 2008). The 2008 updates are based on revisions to the hazard mapping made by Wesson and others (2007), which incorporates revised understanding of the hazard based on the 2002 Denali Fault earthquake. The USGS seismic dataset is packaged into a computer application titled *U.S. Seismic Design Maps* (USGS, 2008) and made available through the USGS website. The USGS on-line application incorporates various design standards, including: International Building Code (2012), AASHTO (2009), and American Society of Civil Engineers (2010). Supporting Seismic design parameters are included in Appendix F.

4.2.1 Seismic Design Parameters and Performance Criteria

The American Railway Engineering and Maintenance-of-Way Manual for Railway Engineering (AREMA, 2013) provides a framework for seismic design of railroad structures, based on three levels of performance criteria, including Serviceability, Ultimate, and Survivability. The three performance criteria levels reflect incrementally increasing seismic hazards with a decreasing probability of exceedance. Corresponding seismic design parameters, including peak ground accelerations (PGAs) on firm bedrock, are shown in Table 3 below. PGA values represent mean accelerations in rock (or "base acceleration" per AREMA) at the "B/C Boundary" of Firm Bedrock (Site Class B) and Very Dense Soil and Soft Rock (Site Class C), per ASCE 7-10, and have not been adjusted for site soils.

Table 3: Seismic Design Parameters

AREMA Seismic Performance Criteria Limit State	Return Period (years)	Probability of Exceedance	Peak Ground Acceleration, in rock (PGA, g)
Serviceability	100	50% in 50 years	0.15g [1]
Ultimate	475	10% in 50 years	0.28g [2]
Survivability	2,475	2% in 50 years	0.47g [2, 3]

Notes: 1) USGS (2007) Unified Hazard Tool.
2) Wesson et al. (2007) seismic hazard, incorporated into USGS 2008 dataset.
3) ASCE 7-10 (2010), Risk-Targeted Maximum Considered Earthquake (MCE_R) is 2 percent probability of exceedance in 50-years. Probabilistic hazard is based on USGS 2008 dataset.
4) See Appendix D-1 through D-3 for USGS seismic design parameters.

The current 2008 USGS dataset does not produce seismic ground motions specifically for AREMA's Serviceability (100-year return) criteria, nor is this recurrence period listed in the Wesson et al. (2007) report. Instead, PGA listed for Serviceability Limit State is based on interpolation of the Hazard Curves from the USGS Unified Hazard Tool (2007).

4.2.2 Site Classification

This site classifies as "Soil Type 2" per AREMA (2013). AREMA defines "Soil Type 2" as:

> "Deep cohesionless or stiff clay conditions where the soil depth exceeds 200 feet and the soil types overlying rock are stable deposits of sands, gravel, or stiff clays."

The corresponding seismic "Site Coefficient (S)" for "Soil Type 2" is 1.2, but does not apply to the Survivability Limit State, where S coefficient of 1.0 is suggested. For the purpose of this project, AREMA "Soil Type 2" is considered roughly equivalent to "Site Class C - Very Dense Soil and Soft Rock" per ASCE 7-10 (2010). ASCE classifies "Site Class C" as having average shear wave velocity (in the upper 100 foot depth) ranging from 1,200 to 2,500 feet per second.

Only relatively shallow boreholes were advanced for this project, and no direct measurements of shear wave velocity were taken; and thus conditions in the upper 100 and 200 feet are unknown. Therefore, soil site class is inferred based on geologic conditions. Site soil class will change over the life and length of the project. Shallow bedrock near the Riley Creek Bridge crossing will be more characteristic of Soil Type 1 - Rock (or Site Class B, per ASCE). And the same can be said about most of the remainder of the project where permafrost exists and average shear wave velocities likely exceed 2,500 feet per second. However, Soil Type 2 is recommended, both for simplicity over the project and conservatism, given the uncertainty of the future thermal state.

5.0 SUBSURFACE AND FIELD INVESTIGATION

The subsurface investigation included advancing a total of twelve boreholes, including four within the Park boundary, four within ADOT&PF right-of-way, and four within ARRC right-of-way. A bulk sample was also collected within the existing railroad through-cut in the approach to the Riley Creek crossing. Methods of drilling, sampling, and borehole completion are detailed in the following sections. Ground temperature measurements were also taken at select borehole locations.

A reconnaissance of the proposed alignment was also performed, in order to view terrain features, delineate changes in vegetative ground cover, and to advance hand-held push probes.

5.1 Borehole Drilling and Sampling

Twelve boreholes were drilled and sampled to depths ranging from 15.1 to 46.5 feet depths below the ground surface. Boreholes TH-1-Park, TH-2-Park, TH-4-Park, and TH-5-Park were completed inside Denali National Park and Preserve (DENA) Boundary. Access to the boreholes inside the Park was via designated routes that were covered with packed snow and had frozen ground conditions to minimize disturbance. Borehole TH-3-ROW was completed inside the Alaska Railroad Right-of-Way (ROW) on the south end of the project, but very near to the DENA borderline. Boreholes TH-6-ROW, TH-7-ROW, TH-11-ROW, and TH-12-ROW were completed off from the Parks Highway embankment within the ADOT&PF ROW. Lastly, Boreholes TH-8-ROW, TH-9-ROW, and TH-10-ROW were completed inside the Alaska Railroad Right-of-Way (ROW) on the north end of the project. Each of the borehole locations are shown on the Borehole Location Maps included as Figures 3 thru 7.

Drilling was conducted by Discovery Drilling Inc., based in Anchorage, Alaska, between the dates of April 10th to 14th, 2017. Drilling equipment utilized was a hydraulically-powered Geoprobe 7822DT drill rig, mounted on a self-contained rubber-tracked carrier. The Geoprobe drill rig was equipped with 3.25-inch inside diameter (I.D.) hollow-stem augers.

Representative samples of the soils encountered in the boreholes were obtained by driving a split-spoon sampler ahead of the augers. Drive samples were collected generally at 2.5 foot intervals in the top 10 feet and at 5 foot intervals thereafter to the depth of boring. A 3 inch outside diameter (O.D.) split-spoon sampler was driven by a 340 pound (lb.) automatic drop hammer allowing for 30 inch free fall. The inside diameter (I.D.) of the sampler was 2.5 inches, and no liners were used inside the barrel. These samples are identified as “HD” type on the record of borehole logs. The number of blows required to drive the sampler each 6-inch interval of the sampling attempt is recorded on the borehole logs. In addition, the total number of blows required to advance the sampler through the 6 inch to 18 inch sampling interval is presented as blows per foot “N” on the borehole logs. Please note that these blow counts are field values that have not been corrected for hammer efficiency, rod length, overburden pressure, or other factors. In many cases, gravel or oversized material was stuck or broken in the shoe of the sampler, as noted on the logs; and therefore the blow counts may be inflated, and thus not representative. Also, samples were often frozen, and therefore blow counts are not representative and do not necessarily correlate to relative density. Grab samples were also gathered directly from the augers within the upper soils above 2.5 feet.

The field investigation was supervised by a Golder Associates Geotechnical Engineer Travis Ross, who logged the recovered soils and directed the drilling operation. Soils encountered were visually classified in the field according to the Unified Soils Classification System (USCS) that is summarized in Figure A-1 in Appendix A. Frozen soils were characterized according to ASTM D4083, abbreviated in Figure A-2 attached. Weathered bedrock was encountered in two boreholes, located on the north end of the project near the southern bridge approach in Boreholes TH-8-ROW and TH-10-ROW, which was classified according to the rock logging legend found in Figure A-3. Records of Borehole logs are presented in Appendix A as Figures A-4 thru A-15. Photos of the samples and drill sites are included in Appendix D.

Soil samples (and weathered rock where encountered) were sealed in double plastic bags for shipment to our Anchorage laboratory for further examination, classification, and testing. Select samples of permafrost, primarily from Boreholes TH-1 thru TH-5, were maintained frozen through the field investigation and during transport back our Anchorage laboratory.

The location of the boreholes were recorded in the field by recording geographical coordinates, referenced to the WGS84 datum, using a hand-held GPS instrument for navigational accuracy. GPS coordinates are listed on the Record of Borehole logs.

5.2 Borehole Completion and Post Monitoring

Prior to drilling boreholes inside DENA, the surface vegetation was cut out from around the boreholes. After completing the boreholes, and backfilling with drill cuttings, the surface vegetation was replaced. No permanent installation was added to the boreholes inside DENA.

At the completion of the remaining boreholes outside of the Park boundary, with the exception of TH-6-ROW, either a single or double 1 inch PVC pipe(s) was installed to final boring depths. PVC pipes were either sealed to allow for future ground temperature measurements, with the exception of those boreholes with double pipes, wherein the second standpipe was field slotted to allow for measurement of groundwater levels. The annulus space around the thermistor casings and standpipes were backfilled with drill cuttings. A flush-mounted metal monitoring well cap was placed at the surface to protect the pipes.

5.2.1 Ground Temperature Measurements

Ground temperatures were not measured during the initial subsurface investigation, due to unrepresentative heat that was introduced into the ground from drilling. Follow-up ground temperature measurements were collected within the following boreholes on the noted dates:

- Boreholes TH-7-ROW, TH-11-ROW, and TH-12-ROW on August 12, 2017.
- Boreholes TH-7-ROW and TH-9-ROW on November 15, 2017

Plots of temperatures versus depth are shown in Figure C-1 included in Appendix C. Future monitoring is recommended.

5.2.2 Groundwater Level Measurements

Groundwater was only encountered while drilling in Borehole TH-10-ROW. However, boreholes were drilled in April during the full extent of the seasonally frozen active layer, which influenced the presence of free water.

The occurrence and availability of groundwater will change with seasons, precipitation, and other factors; and future monitoring is recommended.

5.3 Bulk Sample Collection

A single bulk sample was collected from the exposed railroad cut on the south side of the rail that precedes the final approach to the Riley Creek Bridge. The sampling location is shown in Figure 7 and in site photos in Appendix D. The material classifies as poorly-graded Sandy Gravel with trace fines (GP) and numerous cobbles and boulders.

5.4 Reconnaissance of Proposed Alignment

Reconnaissance of the proposed alignment were conducted on February 9 and again on November 14 and 15, 2017, which entailed walking/snow-shoeing or cross-country skiing the proposed alignment, either near centerline or offset. Portions not covered during these field trips are small portions of the northern part of the glacial outwash (Qgo) unit and southern portion of the ensuing glacial moraine (Qm) unit. The purpose of the trips were to first plan the borehole locations, and then to refine unit boundaries and evaluate surface conditions along the proposed alignment.

5.5 Hand Push Probes

A total of five probes were advanced along the alignment targeting respective terrain units (see locations on Figures 3 through 6). Probes were either metal or fiberglass rods, each less than 1 inch diameter, that were pushed by hand into the upper soil surface then removed. Resistance from the probes was used as a gauge of thickness of near surface organic materials. No soil samples were retained from the holes. A summary of the probes holes is found in Table 4 below.

Table 4: Summary of Push Probes

Probe ID	Refusal Depth (feet, bgs)	Terrain Unit	Lithology / Comments
Qo Probe 1	2.5	Qo – Organic Deposits	Organic rich top 2.5+ feet [1]
Qmf Probe 2	1.8	Qmf – Glacial Deposits, Forested	Organic rich top 1.8 feet
Qmm Probe 3	3	Qmm – Glacial Deposits, Meadow	Organic rich top 3+ feet [1]
Qo Probe 4	3	Qo – Organic Deposits	0 – 0.4 feet: surface vegetation 0.4 – 3+ feet: Peat and Organic Silt [1]
Qgo Probe 5	1.3	Qgo – Glacial Outwash	0 – 0.3 feet: surface vegetation 0.3 – 1.2 feet: Silt, brown, dry 1.2 – 1.3 feet: Gravel, sand, cobbles

Notes: 1) Probes 1, 3, and 4 met refusal on gravel or cobbles at noted depths, and thus could not confirm bottom extent of organics.

6.0 LABORATORY TESTING

Laboratory tests were performed to measure selected index properties of the samples. Moisture content tests were run on a large majority of samples and generally conducted according to procedures described in ASTM D-2216. In addition, eleven samples were tested for percent passing No. 200 sieve (ASTM D422), and two samples were tested for grain size distribution (ASTM D422). One sample was also tested for grain size distribution by hydrometer analysis (ASTM D7928). Two samples were tested for organic content using ignition methods (per ASTM D2974).

The results of the laboratory testing are summarized in Table B-1. Results of the moisture content testing, and percent of gravel, sand, and fines, where applicable, are also presented on the borehole logs adjacent to the samples tested. Plots of grain size distribution are included in Appendix B, Figure B-1. Plots of moisture content versus depth are shown in Figures B-2 through B-7, for all boreholes and for collective boreholes within respective terrain units.

7.0 SUBSURFACE CONDITIONS – ENCOUNTERED IN BOREHOLES

Subsurface conditions encountered in the boreholes are described below. Discussion of each is categorized and combined here according to their location within a respective terrain unit.

7.1 Borehole TH-3-ROW (within southern Qo Organic unit)

Borehole TH-3-ROW is located within the ARRC ROW, about 90 feet west of rail centerline, near the initial tangent of this project and close to the Park boundary. This borehole is located within the Qo – Organic Deposits unit, in a greater meadow area and near the fringe of forested (Qmf) terrain to the north. Its location is on a south-facing slope residing above a lower-lying meadow area that has standing water partially impounded by the rail embankment.

Subsurface conditions include 7.5 feet of organic-rich material underlain by Silty Sand with gravel and little clay (SMg) and Sandy Gravelly Silt (MLg). Near surface organics included a vegetative (tundra) mat underlain by a mixture of Peat (Pt), Organic Silt (OL), vegetative matter, and Silt (ML). This material was seasonally frozen to 4 feet bgs and contained 10 to 20-percent visible ice. Moisture content ranged from 76 to 216-percent, which made it over-saturated and soupy. The underlying mineral soils (below 7.5 feet) had up to 14-percent moisture, and was loose in the upper 30 feet, but became medium dense at greater depth. A plot of moisture content versus depth for Borehole TH-3-ROW is included in Figure B-3.

Borehole TH-3-ROW was found to be absent of shallow permafrost within the 46.5 feet drilled. Our interpretation is that proximity to the rail embankment, impounded water, and south-facing slope all contribute to the degraded permafrost. It is suspected that where the proposed rail moves further north into the Park and into the Qmf unit, that permafrost will be more preserved.

7.2 Boreholes TH-2-Park, TH-12-ROW, and TH-6-ROW (within Qmf unit)

Each of these boreholes were completed within terrain unit Qmf – Glacial Deposits, Forested (as shown in Figures 2, 3, and 4).

Subsurface conditions in these three boreholes contained organic-rich Peat and Organic Silt (Pt + OL) in the upper 2.5 to 2.8 feet bgs. Borehole TH-2-Park is unique amongst these three borings, where Silt with little organics (ML w/ org.) extended from 2.8 to 5.9 feet bgs. The underlying mineral soils were predominantly a mixture of varying layers of Sandy Silty Gravel (GMs), Silty Sand (SM), and Sandy Gravelly Silt (MLg). Sediments contained numerous cobbles and occasional to frequent boulders. A plot of moisture content versus depth for these three boreholes is included in Figure B-4, showing excess moisture in the upper 7 to 10 feet, but generally less than 10 percent at greater depth.

Boreholes TH-2-Park and TH-6-ROW were completely frozen from the ground surface down to bottom of exploration, containing both seasonal frost and permafrost, the top of which was not discernible. Borehole

TH-2-Park had higher visible ice content in the upper 6 to 12 feet bgs (5 to 25-percent visible ice by volume), but with less ice (5-percent or less visible) deeper in TH-2-Park and throughout TH-6-ROW.

Borehole TH-12-ROW was found to be absent of shallow permafrost. This borehole is located within the ADOT&PF ROW, about 90 feet west of the highway centerline. Its location is on a south-facing slope residing above a lower-lying meadow area that has standing water partially impounded by the road embankment. Our interpretation is that these factors all contribute to the degraded permafrost, and will not necessarily apply to the proposed rail alignment.

7.3 Boreholes TH-1-Park, TH-11-ROW, TH-7-ROW (within Qmm unit)

Each of these five boreholes were completed within the terrain unit Qmm – Glacial Deposits, Meadow. Borehole locations are shown in Figures 2, 3, and 4, and as you can see in Figure 4, Boreholes TH-4-Park and TH-5-Park are located near the boundary with Qo unit. Of these five boreholes, TH-1-Park and TH-11-ROW are each unique, and thus described individually. Boreholes TH-7-ROW, TH-4-Park, and TH-5-Park are each similar to each other and characterized in a group.

Borehole TH-1-Park is located within an extensive network of meadow. Here, the thickest organic-rich layer of all the boreholes completed for this project was found. This is likely influenced by its proximity to a natural kettle lake and organic deposits that are located immediately down-gradient. The upper 2.5 feet contained vegetative tundra mat with Peat (Pt) and Organic Silt (OL), and is underlain by Organic Silt (OL) and ice down to 12 feet bgs. In the upper 12 feet, visible ice content ranged from 20 to 40-percent by volume. This excess ice is reflected on the plot of moisture content versus depth in Figure B-5, with a wide range of moisture content from 5 to well over 100 percent. Below 12 feet depth, mineral soils varied between Sandy Silt (MLs), and Silty Sand and Gravel (SMg to GMs). Visible ice content was higher between 12 and 20 feet bgs, ranging from 15 to 30-percent by volume, and decreased slightly to 5 to 25-percent below 20 feet bgs. Moisture contents below 12 feet are 20 percent or less, with a couple outlier exceptions (see Figure B-5).

Borehole TH-11-ROW is also within an extensive network of meadow and is adjacent to a thaw pond created by the highway embankment. This portion of road experiences some of the worst and most severe settlement along this stretch of highway. The top of permafrost within Borehole TH-11-ROW was found down at a depth of 17 feet bgs, which is inferred to be degraded due to its proximity to the thaw pond. The other unique feature of this borehole is a layer of Organic Silt (OL) mixed with Silt (ML) between 11.5 and 19 foot depths. Although unproven, perhaps consolidation of this OL layer is contributing to the highway settlement, in addition to alleviation of ice upon thaw. Otherwise, mineral soils here were Sandy Silty Gravel (GMs), which is common class amongst the Glacial Deposits (Qmm and Qmf).

Subsurface conditions in Borehole TH-7-ROW is given here, and is also found similar to Boreholes TH-4-Park and TH-5-Park. Subsurface conditions in these three boreholes contained organic-rich Peat and Organic Silt (Pt + OL) in the upper 2.5 to 3.1 feet bgs. Below the organic layer is Silt (ML) down to 5.7 to 8.5 feet bgs. This Silt (ML) unit within TH-4-Park and TH-5-Park had ground ice up to 2 inches thick. Deeper mineral soils below 5.7 to 8.5 feet bgs were predominantly a mixture of varying layers of Sandy Silty to Slightly Silty Gravel (GMs to GP-GMs), Silty Sand (SM), and Sandy Gravelly Silt (MLg). Sediments contained abundant cobbles and frequent boulders.

With the exception of Borehole TH-11-ROW, the other remaining boreholes were completely frozen from the ground surface down to bottom of exploration, containing both seasonal frost and permafrost, the top of which was not discernible.

7.4 Boreholes TH-4-Park and TH-5-Park (within northern Qo Organic unit)

Subsurface conditions in Boreholes TH-7-ROW, TH-4-Park, and TH-5-Park are consistent with each other, and are summarized here collectively. Subsurface conditions in these three boreholes contained organic-rich Peat and Organic Silt (Pt + OL) in the upper 2.5 to 3.1 feet bgs. Below the organic layer is Silt (ML) down to 5.7 to 8.5 feet bgs. This Silt (ML) unit within TH-4-Park and TH-5-Park had ground ice up to 2 inches thick. Deeper mineral soils below 5.7 to 8.5 feet bgs were predominantly a mixture of varying layers of Sandy Silty to Slightly Silty Gravel (GMs to GP-GMs), Silty Sand (SM), and Sandy Gravelly Silt (MLg). Sediments contained abundant cobbles and frequent boulders.

7.5 Borehole TH-9-ROW (within Qgo Outwash unit)

Borehole TH-9-ROW was completed within ARRC ROW offset from the rails and located within a minor 10 foot high through-cut about 300 feet track south of existing MP 357 (as shown in Figure 6). This is the only borehole, besides historic data, drilled within the Qgo – Glacial Outwash unit.

Subsurface conditions found in Borehole TH-9-ROW were predominantly comprised of Sandy Gravel with trace to little amounts of fines (GPs to GP-GMs) with numerous cobbles. The gravel was generally dense to very dense, based on drilling and sampler blow counts. A sample collected within one-and-a-half feet from the surface contained 10.4-percent passing the No. 200 US sieve. Moisture content was 5-percent or less here, which is lowest compared to all other locations. A plot of moisture content versus depth for this borehole is presented in Figure B-6.

The natural ground surface had been disturbed here by the railroad cut, and therefore there was not a surficial organic and/or silt layer at this location. Seasonal frost had penetrated about 6 foot depth in mid-April, with no visible ice. No shallow permafrost was encountered at this location, however this may be influenced by the historic ground disturbance. Groundwater was not encountered within this borehole.

7.6 Boreholes TH-8-ROW and TH-10-ROW (within Qm over BCS unit)

Boreholes TH-8-ROW and TH-10-ROW were completed on the south side of the tracks near the toe of the nearly 50 foot high railroad through-cut (near MP 347.3) into Qm – Glacial Moraine unit. This moraine is underlain by a ridge of Birch Creek Schist (BCS), which was found at 10 to 22.5 foot depths bgs, and is exposed north of the through-cut near MP 347.4. We suspect that BCS is shallower than 10 feet at the apex of the through-cut (about midway between TH-8-ROW and TH-10-ROW) due to the occurrence of fine-grained clayey materials (parent constituents of BCS) that pump up underneath the rail bed at that location.

Subsurface conditions consisted mostly of Sandy Silty Gravel (GMs) and slightly Silty Gravel (GP-GMs) with numerous cobbles and boulders, underlain by BCS below 10 to 22.5 foot depths bgs, respectively. The gravel was generally dense to very dense, based on drilling and sampler blow counts. Within Borehole TH-8-ROW, there was also a notable Silty Sand (SM) layer at 8.5 to 10 feet bgs overlying the BCS. Moisture content was 10-percent or less within soil sediments. A plot of moisture content versus depth for these two boreholes is presented in Figure B-7.

Schist bedrock, within its top 3 to 6 feet where it was drilled, was logged as being completely weathered (CW), with only small resemblance of the rock structure remaining, and extremely weak (R0), where pieces could be broken by hand.

The natural ground surface had been disturbed here by the railroad cut, and therefore there was not a surficial organic and/or silt layer at these locations. Seasonal frost had penetrated about 6 foot depth in mid-April. No shallow permafrost was encountered at this location, however this may be influenced by the historic ground disturbance. Groundwater was only encountered within Borehole TH-10-ROW at 20.7 feet bgs, and appeared to be subsurface drainage from the mound of moraine that was perched atop the BCS unit.

7.7 Bulk Sample 1 (within Qm Moraine unit)

Bulk Sample 1 was collected about two-thirds of the way up the MP 347.3 through-cut, on the southern cut face. The sample classifies as Sandy Gravel (GPs) with trace amount of fines and numerous cobbles. Boulders are also prevalent in the cut-face, but were not included in our collected sample. Despite collecting the sample from a foot behind the cut face, it may have been influenced by the surface where wind and rain erode fine sand and silt. Based on the geology of the glacial moraine unit (Qm), it is expected that silt content will vary across the mound, and the overall average will be greater than the trace amounts found in this sample.

8.0 INFERRED CONDITIONS – BASED ON TERRAIN UNIT AND LIMITED DATA

Subsurface conditions that are inferred based on association with geologic terrain unit and extrapolated from the limited number of borehole data is presented here.

8.1 BOP MP 344.85 to MP 346.3 (Glacial Deposits: Qmm and Qmf with Qo)

From the beginning of project (BOP, MP 344.85) to approximately MP 346.3, the proposed alignment traverses glacial deposits, which are distinguished as having meadow or forested terrain. Most of this segment is expected to have permafrost, with the exception of the initial portion that is influenced by the existing embankment. Even though the underlying mineral soils are of similar origin and composition, the meadow areas, in general, will have thicker near-surface organics and greater ice content, and given their topography, receive higher concentration of lateral drainage.

This segment of rail will also encompass patches of organic deposits, most notably at the southern and northern ends of this segment, and at other pockets in between.

A summary of inferred conditions along this segment are included in the following sub-sections.

8.1.1 BOP MP 344.85 to 344.9: Thawed Drainage Impoundment (Qmm & Qo Terrain Unit)

The initial few hundred feet of the proposed alignment is within a lower-lying meadow that also contains organic deposits, with cross drainage that is impounded by the existing embankment. It is inferred that development has altered the thermal regime, and thus shallow permafrost is absent along this segment (within the 46.5 foot depth investigated). The south-facing slope has also influenced the thermal regime.

Subsurface conditions include 7.5 feet of organic-rich and moisture-laden (soupy when thawed) material near the surface, underlain by loose Silty Sand (SMg) and Sandy Gravelly Silt (MLg). The mineral soils are believed to have once been perennially frozen, and their loose condition suggests the material has not fully consolidated post-alleviation of ice.

8.1.2 Glacial Deposits – Forested (Qmf Terrain Unit)

Inferred subsurface conditions in forested glacial terrain includes up to 3 feet of Peat and Organic Silt (Pt + OL), underlain by predominantly Sandy Silty Gravel (GMs), Silty Sand (SM), and Sandy Gravelly Silt (MLg) with numerous cobbles and occasional to frequent boulders. Shallow permafrost soils are expected within this unit, and visible ice content ranged 0 to 25-percent. Plot of moisture content versus depth (see Figure B-4 in Appendix B) shows excess moisture in the upper 11 feet, but generally less than 10 percent moisture (considered at or below saturation) at greater depth.

8.1.3 Glacial Deposits – Meadow (Qmm Terrain Unit)

8.1.3.1 Qmm – MP 344.9 to South of MP 345.4

This segment crosses a more extensive network of meadow, albeit intermixed with forested terrain. Based on two boreholes (TH-1-Park and TH-11-ROW), it is expected that meadow terrain in this southern segment contains greater thickness of organics and ice content compared to meadow terrain north of MP 345.4. Conditions found within Borehole TH-1-Park (as stated in Section 7.3) can be applied as representative of Qmm units MP 344.9 to 345.4. Refer to a plot of moisture content versus depth (see Figure B-5 in Appendix B) that shows excess moisture (as ice) in the upper 16 to 22 feet.

8.1.3.2 Qmm – North of MP 345.4 to 346.3

North of MP 345.4 up to 346.3, subsurface conditions expected within Qmm units can be represented by Borehole TH-7-ROW, and similar to Boreholes TH-4-Park and TH-5-Park; which are described in Section 7.3 of this report. Laboratory data shows excess moisture (as ice) in the upper 4 to 11 feet in these three boreholes.

8.1.4 Organic Deposits (Qo Terrain Unit)

As mentioned, between MP 344.85 to MP 346.3 the rail also crosses patches of organic deposits that are encompassed within the segment, as shown in Figures 1 through 6. There appears to be distinction between subsurface conditions and thickness of organic cover between the Qo units in the southern portion (shown in Figure 3) and Qo unit found in the northern portion (shown in Figures 5 and 6), as described below.

8.1.4.1 Southern Qo Units

Data suggests a covering of organic-rich materials ranging from 3 to 7.5 to 12 feet thick associated with this terrain unit in the southern portion. Underlying mineral soils are expected similar to the nearby Qmm meadows.

8.1.4.2 Northern Qo Units

Data suggests a covering of organic-rich materials up to 3 feet thick associated with this terrain unit in the northern portion. Underlying mineral soils are expected similar to the nearby Qmm meadows. Laboratory data shows excess moisture (as ice) in the upper 6 to 11 feet in these two boreholes.

8.1.5 Lateral Flow of Shallow Groundwater

This segment of proposed rail (BOP to MP 346.3) is situated along the base side hill of a parallel-running ridge that is nearly 2,700 foot elevation and 1,000 feet above grade. The new alignment transects across numerous lateral drainage ways that follow from the ridge to the river. Many of the drainage ways are nondiscernible, in subtle swales, and not concentrated along the surface. The existing highway and rail embankments tend to impound or impede this cross drainage.

This segment of parallel highway is reported to have unusually large amounts of lateral flow of water, both running on the surface, but more prominently as shallow subsurface flow. It is inferred that much of this subsurface drainage and meltwater is perched above permafrost which causes it to flow across the site. Road and rail embankments also impede cross drainage, creating up-gradient ponding, which in turn increases thawing.

8.2 MP 346.3 to MP 347.1: Glacial Outwash (Qgo Terrain Unit)

This segment of rail between MP 346.3 to MP 347.1 is mapped as Qgo Glacial Outwash. These sediments are expected to be predominantly comprised of Sandy Gravel with trace to little amounts of fines (GPs to GP-GMs), with some sandier zones and occasional lenses of silt, and contain numerous cobbles and occasional boulders. Refer to a plot of moisture content versus depth (see Figure B-6 in Appendix B) that shows moisture content 5 percent or less throughout the exploration. These deposits are considered favorable for re-use as embankment materials.

The organic cover is not likely to be thick and expected less than a foot. There may also be a near-surface layer of silt and/or fine sand, with little vegetative material, in the upper 1.5 to 3 feet.

Thermal state and presence of permafrost is unknown within this terrain unit. The lone borehole (TH-9-ROW) completed here did not have shallow permafrost, however it was advanced within disturbed ground as part of the railroad cut, and therefore not reflective of conditions where natural ground cover remains. The historic 1966 borings at the railroad overpass (MP 346.7) of the highway showed only limited extents and deeper permafrost. Background data suggests permafrost is far less prevalent, and where it does remain, its top is deeper and does not commonly have excess ice.

If and where permafrost is encountered within this terrain unit, it is likely to be non-ice-rich and thaw-stable, and therefore is expected to have only very minor detriment to the proposed construction. Soils of this type with low ice content will undergo little if any measurable consolidation upon thawing.

8.3 MP 347.1 to MP 347.4 – Glacial Moraine (Qm Terrain Unit)

Between MP 347.1 and MP 347.4 (of the existing rail alignment), the railroad passes a through-cut into a glacial end moraine that was deposited behind an irregular ridge of Birch Creek Schist during the Riley Creek Glaciation (Fuglestad, 1986). Realignment of the rail is likely to entail further cutting into this 70 to 90 foot high hill of moraine.

The moraine is a mixture of glacially deposited materials, but predominantly till, which is a heterogeneous, poorly-sorted mixture of boulders, cobbles, gravel, sand, silt, and clay. The two Boreholes (TH-8-ROW and

TH-12-ROW) revealed soil conditions characterized mostly as Sandy Silty Gravel (GMs) and slightly Silty Gravel (GP-GMs) with numerous cobbles and boulders. And the lone bulk sample collected in the through-cut face classified as Sandy Gravel (GPs) with traces fines (3-percent) and abundant cobbles and frequent boulders. These deposits are considered suitable for re-use as embankment materials. Two sieve analysis tests from the GMs measured 17 to 24-percent fines content. This amount of fines is considered slightly above what is preferred for use as rail bed fill, but is acceptable for use within lower portions of the proposed embankment (below 5 feet under rails).

8.4 MP 347.4 to Southern Bank of Riley Creek Crossing – Birch Creek Schist

Near MP 347.4, north of the morainal hill through-cut, the railroad emerges onto a ridge of Birch Creek Schist (BCS) and the south approach fill of the Riley Creek Bridge (Fuglestad, 1986).

North of the BCS ridge, the bridge would span the alluvial valley/floodplain and then onto terrace of glacial outwash. The current bridge terminates onto a high fill embankment.

8.5 Active Layer

Seasonal active layer (freeze and thaw) ranges from 5.5 to 8.5 feet depths.

8.6 Degraded Permafrost in ROW

Evidence from the current boreholes located in the existing ROW’s show that top of permafrost has degraded down to the following depths:

- More than 46.5 feet (depth of exploration) in Borehole TH-3-ROW,
- 17 feet in Borehole TH-11-ROW,
- More than 26.3 feet (depth of exploration) in Borehole TH-12-ROW,
- More than 21.5 feet (or non-existent) in Borehole TH-9-ROW,
- More than 16 feet (depth of exploration) in Borehole TH-8-ROW, and
- More than 25 feet (depth of exploration) in Borehole TH-10-ROW
- The deepest thaw in the two boreholes is enhanced by south-facing slopes and ponding.
- None of these were drilled directly through the embankment, which could equate to deeper thaw under centerline.

On the contrary, Boreholes TH-6-ROW and TH-7-ROW, which were completed in undisturbed ground along north-facing, shaded slopes, still had shallow permafrost, within 6 feet depth.

9.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

There are a number of geotechnical and permafrost related issues that should be considered in design of the realignment, including: 1) thaw-unstable permafrost with excess ground ice, 2) thick cover of peat and organic-rich materials, 3) potentially unstable (and difficult) cuts through permafrost, 4) significant cross flow of subsurface and near surface drainage, 5) associated icing in the cut slopes, and 6) areas that have already thawed (due to proximity to existing development) but have not yet consolidated and would be expected to do so under the weight of the new embankment.

A conceptual proposed alignment, provided by ARRC, is shown in the figures. Profile grade of the proposed rail, and associated areas of cut or fill, are still being developed by ARRC and thus are not available at this stage. In general, the first 1.4 miles (MP 344.9 to 346.3) will necessitate multiple and lengthy cuts, based on the terrain and rail grades. Some may be side hill cuts and some through-cuts. North of that, both cut and fill sections are expected between MP 346.3 and 347.1, until reaching a major through-cut into the morainal hill that approaches the Riley Creek crossing.

Preliminary geotechnical engineering for the purpose of this feasibility study are provided in the following sections.

9.1 Future State of Permafrost

Site development will alter the insulating properties of the natural ground surface, and the new embankment will increase heat into the ground; thus changing the thermal regime that will lead to degrading permafrost over the life of the project. Aside from altering the ground surface, predictions for warming climate could also play a secondary role in degrading permafrost.

Predicting the amount and rate of degradation over time and life of the project is complex, and will depend upon many variables. Evidence from the current boreholes located in the existing ROW's show that top of permafrost has degraded down to depths ranging from 17 to more than 46.5 feet. For the purpose of this feasibility study, predicted long-term thaw depths under the embankment could be 30 to 50 feet, or more. Continued thaw beyond those depths, if it occurs, will have diminished impact on the embankment.

9.2 BOP MP 344.85 to 344.9: Surcharge and Pre-Consolidation

The loose and thawed soils in this initial segment are expected to consolidate under the weight of the new embankment and during dynamic loadings from train traffic. Therefore, it is recommended that a surcharge be placed in order to pre-consolidate the soils. First, the upper organic-rich layer should be removed before placing fill, which is estimated as 7.5 feet thick based on Borehole TH-3-ROW. The surcharge should be 4 feet higher than the future grade, and remain in place at least 6 months.

Any cross culverts placed here should be installed after the surcharge is removed or be able to accommodate strain of the embankment.

9.3 Permafrost and Ground Ice

9.3.1 Southern Portion: MP 344.9 and MP 346.3

Estimated thaw strain rates for these types of mineral soils (Nelson, et. al, 1983) are as follows, based on moisture content:

- Moisture Content: less than 10% Thaw Strain: estimated 2 to 3%
- Moisture Content: 15% Thaw Strain: estimated 4 to 5%
- Moisture Content: 20% Thaw Strain: estimated 6 to 7%
- Moisture Content: 25% Thaw Strain: estimated 9 to 12%

Additional consolidation will also occur in fine-grained soil, depending upon the new embankment load.

9.3.2 Northern Portion: MP 346.3 and MP 347.4

Glacial Outwash (Qo) deposits along this segment are largely considered ice-poor and thaw-stable. There is potential for low to moderate amounts of ice within the Glacial Moraine (Qm) deposits which are being through-cut at the north end of the project. The cut here could be up to 70 feet or more deep, and less ice is expected beyond 15 feet below current ground surface.

9.4 Passive Cooling with Thermosyphons

In segments of the alignment where it is impractical to remove the upper zone of ice-rich materials, or the amounts of thaw settlements are not tolerable for long-term maintenance, permafrost would need to be maintained frozen. The most effective means for long-term preservation of permafrost is integration of passive cooling using thermosyphons, coupled with board insulation. Although this option would result in the best performance and least amount of settlement within ice-rich / thaw-unstable terrain, it may prove cost-prohibitive. Another design consideration with this option is to incorporate sub-drainage to facilitate water that may be impeded by the frozen embankment. Preliminary configurations for this option are provided below.

Thermosyphons are heat transfer devices that operate by convection (through vaporization and condensation) and consists of a sealed vessel with an upper part working as a condenser (usually with radiator fins) and a buried part in the ground functioning as an evaporator (Forsström and others, INE, 2003). The units are pressurized with two-phase working fluid (gas and liquid), most commonly carbon dioxide (CO_2).

In this scenario, we would suggest configuring thermosyphons in flat-loop systems, where the evaporator pipe is installed in a horizontal grid pattern across the width of the embankment. Each flat-loop would be about 30 to 40 feet wide transversely and 8 feet dimension in the longitudinal direction. The flat-loops would be installed nominally 4 to 5 feet below rail grade, buried in the middle of a 4 to 6 inch thick layer of bedding sand, and covered with 4 inches of extruded polystyrene (XPS) board insulation. NFS structural fill should cover above the insulation. We understand that the above-grade vertical radiators will need to be placed outside the clear zone of the train, which is offset right and left of centerline between about 15 to 20 feet. Radiators should also be installed outside of potential conflicts with maintenance operations, and well above snow drifting levels. A preliminary estimation of spacing is placing flat-loop thermosyphons every 8 feet along the length of tracks that are to be kept frozen.

Thermosyphons should be fabricated by Arctic Foundations Inc. (AFI) of Anchorage, Alaska; and have vertical radiator condensers of 170 sf nominal fin area above-grade. AFI's typical flat-loop evaporators (installed below grade) are 3/4 inch diameter sealed metal pipes.

Side slopes should be covered with topsoil, seed, and revegetated to provide insulation and reduce summer heat gain.

9.5 Air Convection Embankment (ACE)

Another option for the thaw-unstable southern portion (MP 344.9 and MP 346.3) is incorporating an Air Convection Embankment (ACE) to help reduce and slow the rate of thaw. ACE embankment fill consists of narrowly-graded large aggregate (typically 6 to 10 inch size range and angular) that forms a highly-permeable open matrix that allows convective air flow. The convective air flow enhances wintertime cooling of the ground, and the relatively lower thermal conductivity within the open matrix also serves to reduce summer heat gain. Another benefit of the open matrix fill is facilitating lateral drainage.

As a concept here, ACE material would consist of 5 to 7 feet thick horizontal layer across the width of the embankment and equally thick layers covering the side slopes. A recent successful example of ACE placed in a road section to preserve permafrost is Thompson Drive leading to University of Alaska Fairbanks (Goering/ADOT&PF, 2009) which crosses the railroad.

9.6 Cut Slopes and Through-Cuts

Proposed cut slope angles should be tailored according to conditions found in respective terrain units. Assuming that cuts are being made into permafrost, the stability of cut slopes is largely dictated by ice content. For the southern portion between BOP MP 344.85 and MP 346.3, where higher ice content is anticipated, recommended cut slopes are 3 Horizontal :1 Vertical (3H:1V). As an alternative, cuts could be steepened to 2H:1V while employing surface stabilization and erosion protection measures. Such methods may include placing a blanket layer of small-to-medium coarse rip rap.

For the northern portion between MP 346.3 and MP 347.4, where mostly thaw-stable materials are anticipated, standard cut slopes of 2H:1V should apply.

Through-cuts are expected to be particularly susceptible to snow drifting, and may need special accommodation in the design.

9.7 Fill Slopes

Fill slopes should generally be placed no steeper than 2H:1V.

9.8 Peaty / Organic Ground Cover

Organic-rich materials should be removed from underneath the rail embankment. Thickness are estimated in the previous section. Excavated organics can be placed on the embankment side slopes for disposal and to help insulate.

9.9 Icing and Subdrains

Cross flow drainage, which is commonly sub-surface, is expected to cause significant icing within the cut slopes, and should be accommodated for in the design. Springhead drains should also be planned for areas with particularly concentrated or steady flow, but many of those locations will not be fully known until construction or thereafter.

Subdrains should be installed running along the ditchline throughout cut sections. Conceptual subdrain sections would include small perforated pipe encapsulated in porous drain rock and surrounded by separation geotextile fabric, and the remainder of the trench above also backfilled with drain rock. Trench width of the subdrains would nominally be at least 2.5 to 3.5 feet wide. Subdrains should be installed deep enough to capture cross flow that appears to be perched atop permafrost. Special consideration needs to be given to the outlets of the subdrains given the severe icing that can occur.

9.10 Fill Materials

9.10.1 General Embankment Fill

General embankment fill shall be comprised of a mix of granular sand and gravel and cobble materials with 12 inch max size and preferably with 20 percent maximum passing No. 200 sieve. In some areas, in order to make re-use of on-site materials, the maximum allowable fines content may have to be heightened to 30 percent. However, it is cautioned that these materials with greater fines content would be more sensitive to excess moisture during placement and compaction. General embankment fill should be placed in 12-inch maximum lift thickness and compacted to at least 90-percent of the maximum dry density as determined by modified proctor testing.

9.10.2 Non-Frost Susceptible (NFS) Structural Fill

The upper 5 feet of the embankment should be constructed with non-frost susceptible (NFS) Structural Fill, including ballast and subballast layers. NFS Structural Fill should be comprised of a mix of granular sand and gravel materials with 6 percent maximum passing No. 200 sieve, such as ADOT&PF Standard Specifications, Select Type A (ADOT&PF, 2015) or similar. Structural Fill should be placed in 12-inch maximum lift thickness and compacted to at least 95-percent of the maximum dry density as determined by modified proctor testing.

9.10.3 Reuse of Cut Materials

Most of the mineral glacial deposits (Qmm and Qmf) and moraine deposits (Qm), below the organic layer, are considered suitable for re-use as general embankment fill. And it is anticipated that much of the glacial outwash materials (Qgo) will qualify as NFS Structural Fill, or have slightly higher fines content, up to 10 percent, to meet ADOT&PF Select Type B.

There are large quantities of boulders amongst the glacial deposits and moraine which will either require on-site processing or disposal.

9.11 Riley Creek Bridge Replacement

Proximity of the bridge crossing to the Park Road Fault merits careful design consideration, beyond the scope of this document. It is imperative that the bridge be cited entirely north of the Park Road Fault.

Preliminary information suggests conditions are conducive to supporting the bridge using driven pile foundations. The upper zone of Birch Creek Schist is commonly conducive to driving piles, but deeper installations into it may need to be augmented with drilling during install. Stability of the side slopes in relation to the bridge would need to be evaluated during design and haven't been analyzed here.

10.0 USE OF REPORT

This report was prepared for use by ARRC in the feasibility study of the rail realignment in the Denali Park area. If there are significant changes in the nature, design, or location of the facilities, we should be notified so that we may review our conclusions and recommendations in light of the proposed changes and provide a written modification or verification of the changes. We request the opportunity to review design plans for construction, to verify they meet the intent of our recommendations.

Given the nature of the uncontrolled historic fill, there are possible variations in subsurface conditions between explorations and also with time. Therefore, inspection and testing by a qualified geotechnical engineer should be included during construction to provide corrective recommendations adapted to the conditions revealed during the work.

Unanticipated soil conditions are commonly encountered and cannot fully be determined by a limited number of explorations or soil samples. Such unexpected conditions frequently result in additional project costs in order to build the project as designed. Therefore, a contingency for unanticipated conditions should be included in the construction budget and schedule.

The work program followed the standard of care expected of professionals undertaking similar work in Alaska under similar conditions. No warranty expressed or implied is made.

11.0 CLOSING

Thank you for allowing us to assist with this interesting project, we look forward to continued involvement. Please let us know if you have any questions or comments, or require further information at this time.

Sincerely,

GOLDER ASSOCIATES INC.

Travis E. Ross, PE	Thomas G. Krzewinski, P.E., D.GE, F.ASCE
Senior Engineer	Principal and Senior Geotechnical Engineering Consultant

TER/JK/ECC/TGK

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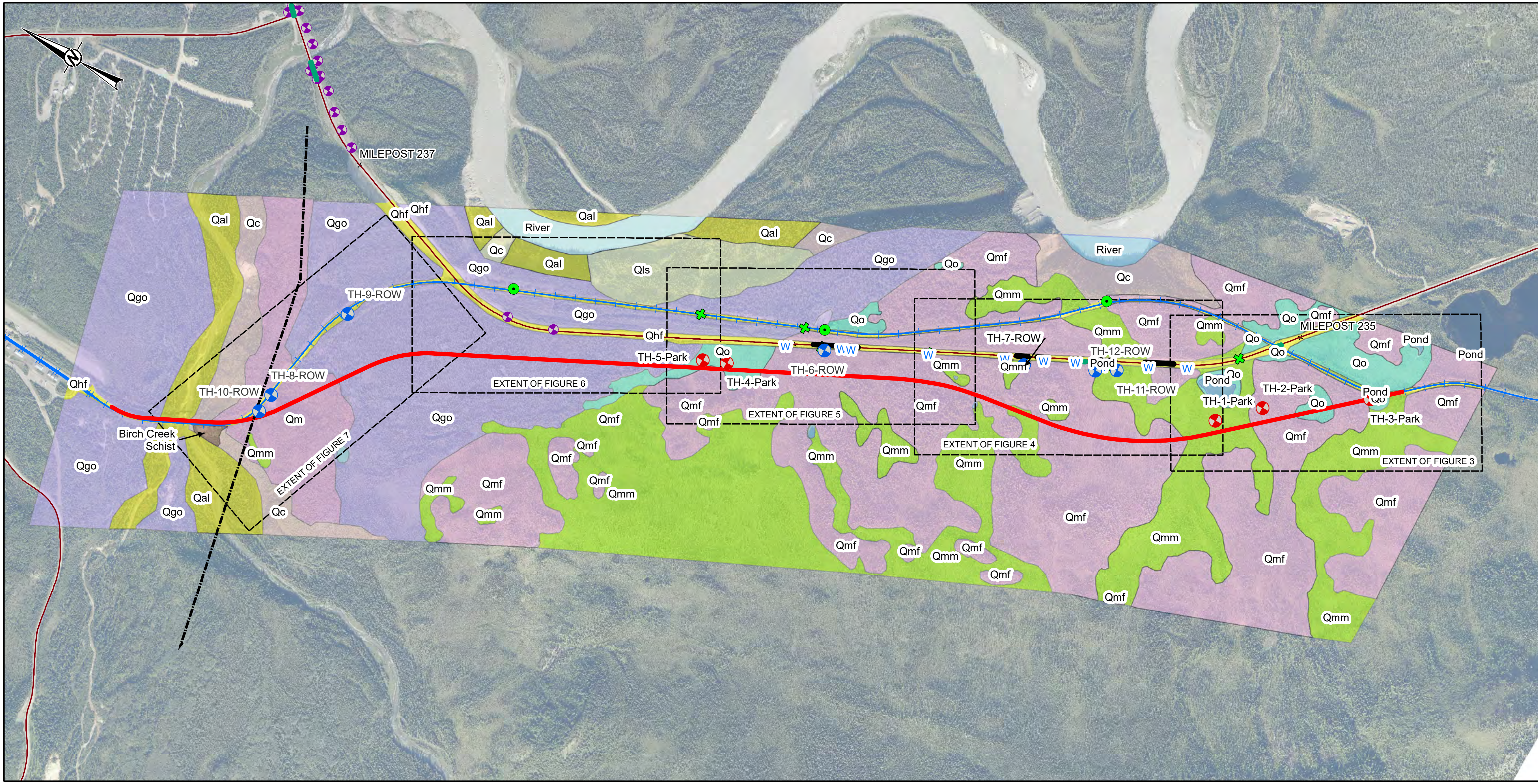
FIGURES



LEGEND

- Borehole within DOT or ARRC ROW
- Borehole Inside Denali National Park (DNP)
- Historic Highway Boreholes
- Settlement Area
- W Standing Water
- Alaska Railroad
- Parks Highway
- Park Road Fault
- Highway Settlement Areas
- Highway Patches
- ADOT&PF or ARRC Culverts

Terrain Units

- Qm - Glacial Moraine
- Qal - alluvium
- Qc - Colluvium
- Qls - Landslide Debris
- Qgo - glacial outwash deposits
- Qhf - Fill
- Qmf - glacial deposits, forested
- Qmm - glacial deposits, meadow
- Qo - organic deposits
- Pond
- River
- Birch Creek Schist Bedrock

0 500 1,000 2,000
Feet

REFERENCE(S)
1. ORTHOIMAGERY ACQUIRED IN 2012 AND 2013 WAS PROVIDED BY FAIRBANKS NORTHWEST BOROUGH AND DISTRIBUTED VIA ARCGIS ONLINE.

CLIENT
ALASKA RAILROAD CORPORATION

PROJECT
MP 345-347 REALIGNMENT

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-11-30
DESIGNED	-
PREPARED	APG
REVIEWED	TER
APPROVED	TGK

TITLE
GENERALIZED SURFICIAL GEOLOGIC MAP

PROJECT NO.	CONTROL	REV.	FIGURE
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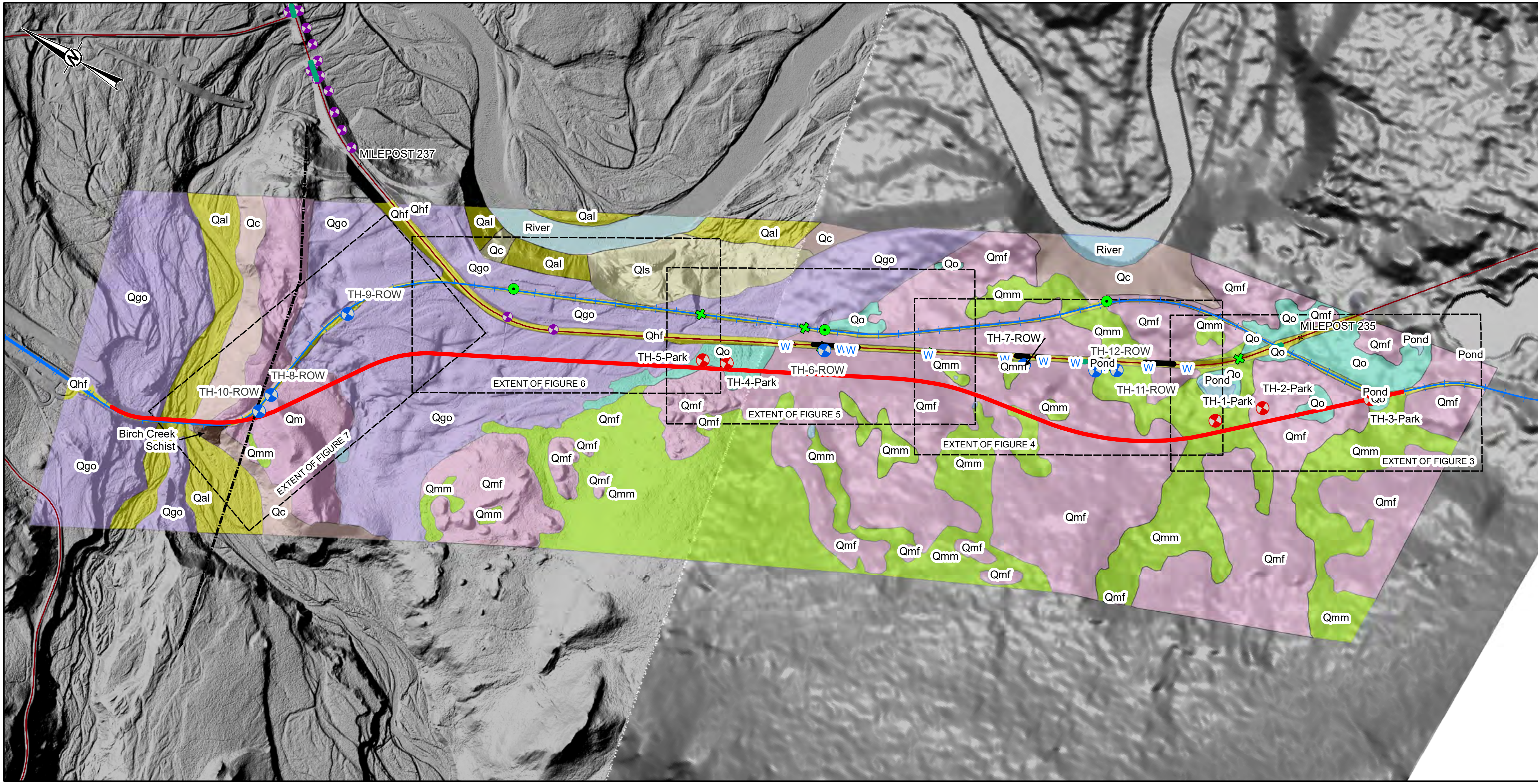


LEGEND

- Borehole within DOT or ARRC ROW
- Borehole Inside Denali National Park (DNP)
- Historic Highway Boreholes
- Settlement Area
- W Standing Water
- Alaska Railroad
- Parks Highway
- Park Road Fault
- Highway Settlement Areas
- Highway Patches
- ADOT&PF or ARRC Culverts

Terrain Units

- Qm - Glacial Moraine
- Qal - alluvium
- Qc - Colluvium
- Qls - Landslide Debris
- Qgo - glacial outwash deposits
- Qhf - Fill
- Qmf - glacial deposits, forested
- Qmm - glacial deposits, meadow
- Qo - organic deposits
- Pond
- River
- Birch Creek Schist Bedrock

0 500 1,000 2,000
Feet

REFERENCE(S)

1. HILLSHADE IMAGES GENERATED FROM TWO DATA SOURCES. NORTHERN HILLSHADE CREATED FROM LIDAR ACQUIRED AND DISTRIBUTED BY ALASKA DIVISION OF GEOLOGICAL AND GEOPHYSICAL SURVEYS, RDF 2011-3, HIGH-RESOLUTION LIDAR DATA FOR ALASKA INFRASTRUCTURE CORRIDORS. SOUTHERN HILLSHADE CREATED FROM IFSAR DATA ACQUIRED FOR USGS AND DISTRIBUTED BY ALASKA DIVISION OF GEOLOGICAL AND GEOPHYSICAL SURVEYS.

CLIENT
ALASKA RAILROAD CORPORATION

PROJECT
MP 345-347 REALIGNMENT

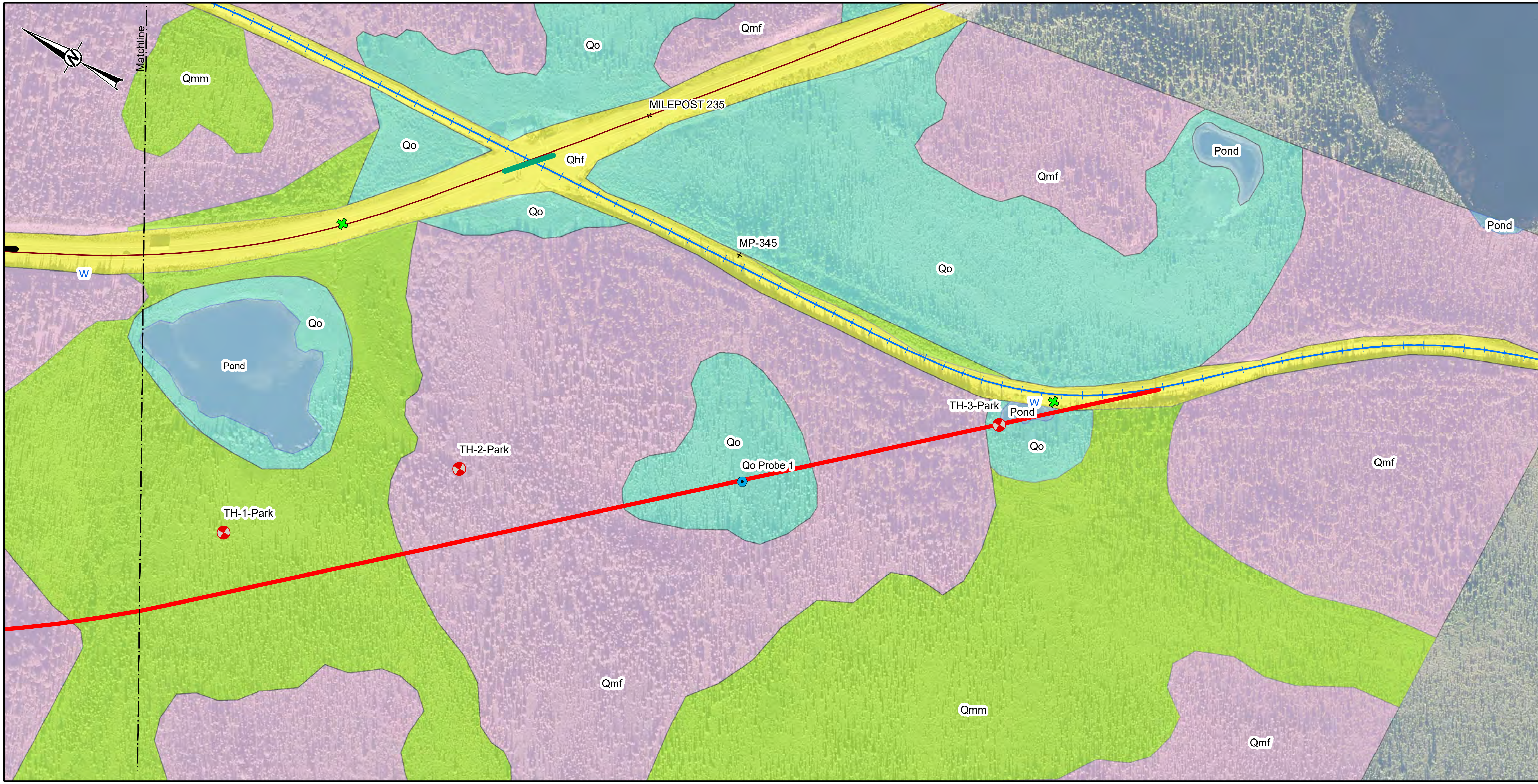
CONSULTANT
Golder Associates

YYYY-MM-DD	2017-11-30
DESIGNED	-
PREPARED	APG
REVIEWED	TER
APPROVED	TGK

TITLE
GENERALIZED SURFICIAL GEOLOGIC MAP-HILLSHADE

PROJECT NO.	CONTROL	REV.	FIGURE
1771891	-	0	2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B



LEGEND

- Borehole Inside Denali National Park (DNP)
- Proposed Rail Realignment
- ADOT or ARRC Culverts
- Standing Water
- Push Probes
- Highway Settlement Areas
- Highway Patch Area
- ADOT&PF or ARRC Culverts
- Parks Highway
- ARRC_Mainline_Mileposts_AK83-4F
- Alaska Railroad

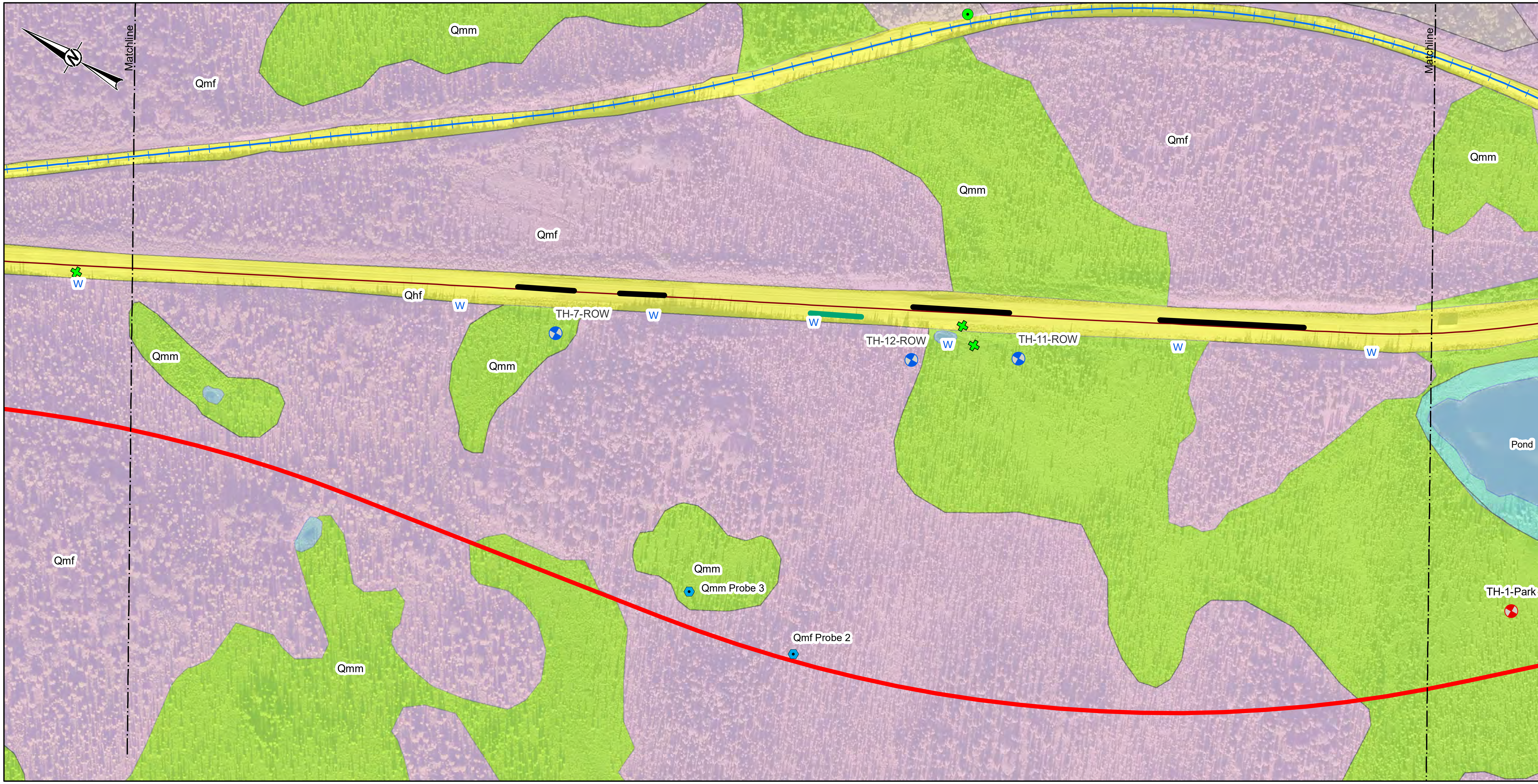
Terrain Units

- Qhf - Fill
- Qmf - glacial deposits, forested
- Qmm - glacial deposits, meadow
- Qo - organic deposits
- Pond

0 100 200 400
Feet

REFERENCE(S)
1. ORTHOIMAGERY ACQUIRED IN 2012 AND 2013 WAS PROVIDED BY FAIRBANKS NORTHWEST BOROUGH AND DISTRIBUTED VIA ARCGIS ONLINE.

CLIENT ALASKA RAILROAD CORPORATION		PROJECT MP 345-347 REALIGNMENT	
CONSULTANT Golder Associates	YYYY-MM-DD: 2017-11-30 DESIGNED: - PREPARED: APG REVIEWED: TER APPROVED: TGK	TITLE BOREHOLE LOCATION MAP - 1 OF 5	
		PROJECT NO. 1771891 · CONTROL - · REV. 0	FIGURE 3



LEGEND

- Borehole within DOT or ARRC ROW
- Borehole Inside Denali National Park (DNP)
- Proposed Rail Realignment
- ADOT or ARRC Culverts
- Settlement Area
- Standing Water
- Push Probes
- Highway Settlement Areas
- Highway Patch Area
- ADOT&PF or ARRC Culverts
- Parks Highway
- Alaska Railroad

Terrain Units

- Qc - Colluvium
- Qhf - Fill
- Qmf - glacial deposits, forested
- Qmm - glacial deposits, meadow
- Qo - organic deposits
- Pond

REFERENCE(S)
1. ORTHOIMAGERY ACQUIRED IN 2012 AND 2013 WAS PROVIDED BY FAIRBANKS NORTHWEST BOROUGH AND DISTRIBUTED VIA ARCGIS ONLINE.

CLIENT
ALASKA RAILROAD CORPORATION

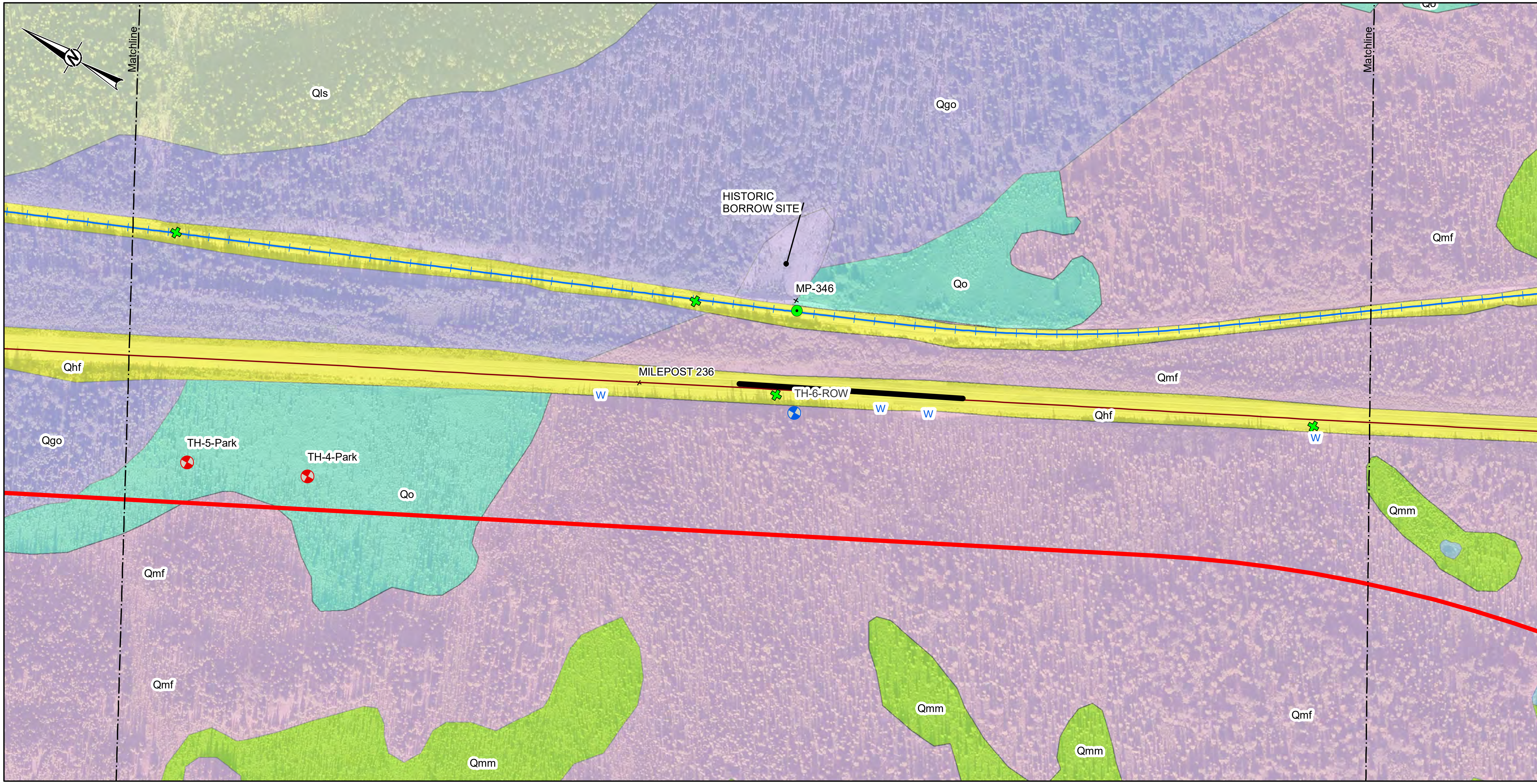
PROJECT
MP 345-347 REALIGNMENT

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-11-30
DESIGNED	-
PREPARED	APG
REVIEWED	TER
APPROVED	TGK

TITLE
BOREHOLE LOCATION MAP - 2 OF 5

PROJECT NO.	CONTROL	REV.	FIGURE
1771891	-	0	4



LEGEND

- Borehole within DOT or ARRC ROW
- Borehole Inside Denali National Park (DNP)
- Proposed Rail Realignment
- ADOT or ARRC Culverts
- Settlement Area
- Standing Water
- Highway Patch Area
- ADOT&PF or ARRC Culverts
- Parks Highway
- ARRC_Mainline_Mileposts_AK83-4F
- Alaska Railroad

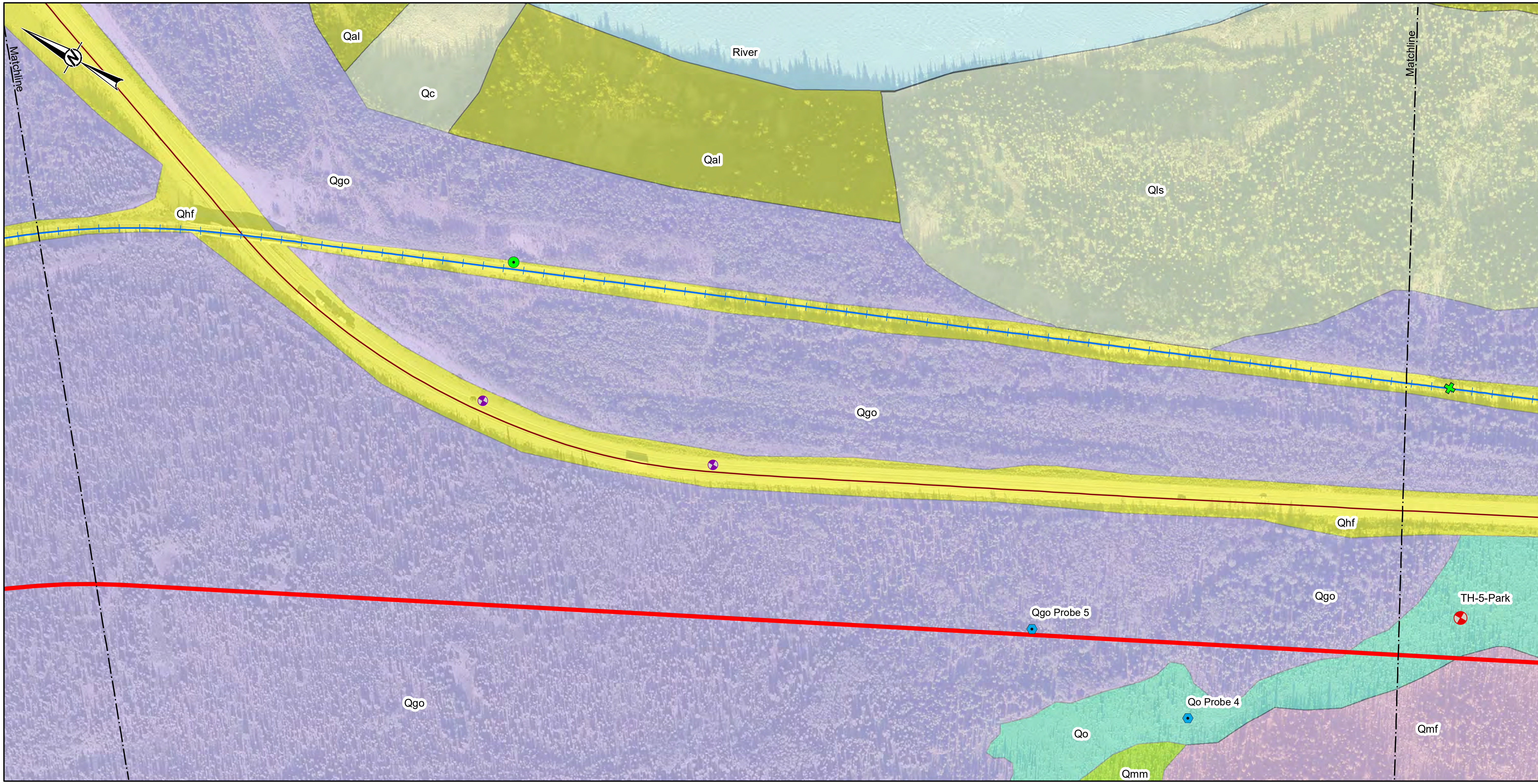
Terrain Units

- Qls - Landslide Debris
- Qgo - glacial outwash deposits
- Qhf - Fill
- Qmf - glacial deposits, forested
- Qmm - glacial deposits, meadow
- Qo - organic deposits
- Pond

0 100 200 400
Feet

REFERENCE(S)
1. ORTHOIMAGERY ACQUIRED IN 2012 AND 2013 WAS PROVIDED BY FAIRBANKS NORTHWEST BOROUGH AND DISTRIBUTED VIA ARCGIS ONLINE.

CLIENT ALASKA RAILROAD CORPORATION		PROJECT MP 345-347 REALIGNMENT	
CONSULTANT Golder Associates	YYYY-MM-DD: 2017-11-30 DESIGNED: - PREPARED: APG REVIEWED: TER APPROVED: TGK	TITLE BOREHOLE LOCATION MAP - 3 OF 5	
		PROJECT NO. 1771891 · CONTROL - · REV. 0	FIGURE 5



LEGEND

- Borehole Inside Denali National Park (DNP)
- Proposed Rail Realignment
- ADOT or ARRC Culverts
- Settlement Area
- Push Probes
- Historic Highway Boreholes
- Parks Highway
- Alaska Railroad

Terrain Units

- Qal - alluvium
- Qls - Landslide Debris
- Qgo - glacial outwash deposits
- Qhf - Fill
- Qmf - glacial deposits, forested
- Qmm - glacial deposits, meadow
- Qo - organic deposits
- River

0 100 200 400
Feet

REFERENCE(S)
1. ORTHOIMAGERY ACQUIRED IN 2012 AND 2013 WAS PROVIDED BY FAIRBANKS NORTHWEST BOROUGH AND DISTRIBUTED VIA ARCGIS ONLINE.

CLIENT
ALASKA RAILROAD CORPORATION

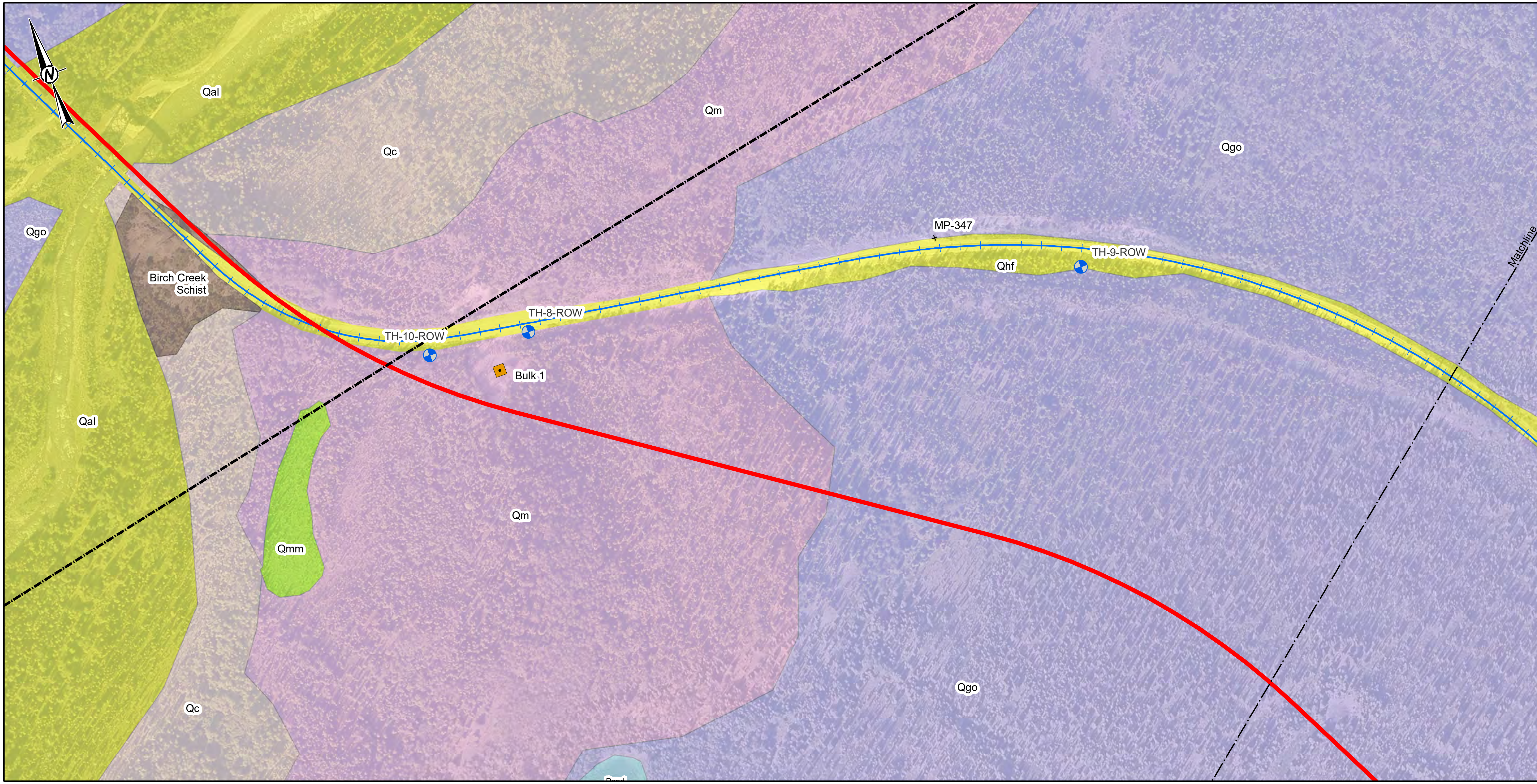
PROJECT
MP 345-347 REALIGNMENT

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-11-30
DESIGNED	-
PREPARED	APG
REVIEWED	TER
APPROVED	TGK

TITLE
BOREHOLE LOCATION MAP - 4 OF 5

PROJECT NO.	CONTROL	REV.	FIGURE
1771891	-	0	6



LEGEND

- Borehole within DOT or ARRC ROW
- Proposed Rail Realignment
- Bulk Sample
- Park Road Fault
- ARRC_Mainline_Mileposts_AK83-4F
- Alaska Railroad

Terrain Units

- Qm - Glacial Moraine
- Qal - alluvium
- Qc - Colluvium
- Qgo - glacial outwash deposits
- Qhf - Fill
- Qmm - glacial deposits, meadow
- Pond
- Birch Creek Schist Bedrock

0 100 200 400
Feet

REFERENCE(S)
1. ORTHOIMAGERY ACQUIRED IN 2012 AND 2013 WAS PROVIDED BY FAIRBANKS NORTHWEST BOROUGH AND DISTRIBUTED VIA ARCGIS ONLINE.

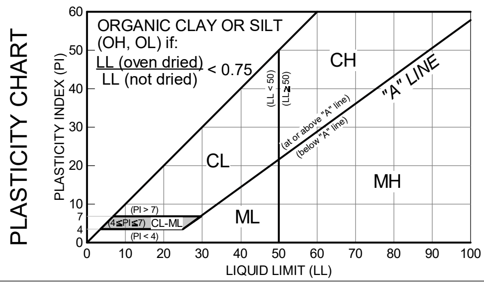
CLIENT ALASKA RAILROAD CORPORATION		PROJECT MP 345-347 REALIGNMENT	
CONSULTANT Golder Associates	YYYY-MM-DD: 2017-11-30 DESIGNED: - PREPARED: APG REVIEWED: TER APPROVED: TGK	TITLE BOREHOLE LOCATION MAP - 5 OF 5	
		PROJECT NO. 1771891	CONTROL - / REV. 0 / FIGURE 7

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
25mm

APPENDIX A
RECORD OF BOREHOLE LOGS

UNIFIED SOIL CLASSIFICATION (adapted from ASTM D2487)

MATERIAL TYPES	CRITERIA FOR ASSIGNING SOIL GROUP NAMES AND GROUP SYMBOLS USING LABORATORY TESTS			GROUP SYMBOL	SOIL GROUP NAMES & LEGEND	
COARSE-GRAINED SOILS >50% RETAINED ON NO. 200 SIEVE	GRAVELS >50% OF COARSE FRACTION RETAINED ON NO 4. SIEVE	CLEAN GRAVELS <5% FINES	$C_U \geq 4$ AND $1 \leq C_C \leq 3$	GW	WELL-GRADED GRAVEL	If soil contains ≥15% sand, add "with sand"
			$C_U < 4$ AND/OR [$C_C < 1$ OR $C_C > 3$]	GP	POORLY GRADED GRAVEL	
		GRAVELS WITH FINES >12% FINES	FINES CLASSIFY AS ML OR MH	GM	SILTY GRAVEL	
			FINES CLASSIFY AS CL OR CH	GC	CLAYEY GRAVEL	
	SANDS ≥50% OF COARSE FRACTION PASSES ON NO 4. SIEVE	CLEAN SANDS <5% FINES	$C_U \geq 6$ AND $1 \leq C_C \leq 3$	SW	WELL-GRADED SAND	If soil contains ≥15% gravel, add "with gravel"
			$C_U < 6$ AND/OR [$C_C < 1$ OR $C_C > 3$]	SP	POORLY GRADED SAND	
		SANDS AND FINES >12% FINES	FINES CLASSIFY AS ML OR MH	SM	SILTY SAND	
			FINES CLASSIFY AS CL OR CH	SC	CLAYEY SAND	
FINE-GRAINED SOILS >50% PASSES NO. 200 SIEVE	SILTS AND CLAYS LIQUID LIMIT <50	PLASTICITY CHART		CL	LEAN CLAY	If soil contains coarse-grained soil from 15% to 29%, add "with sand" or "with gravel" for whichever type is prominent, or for ≥ 30%, add "sandy" or "gravelly"
				ML	SILT	
				OL	ORGANIC CLAY OR SILT	
	SILTS AND CLAYS LIQUID LIMIT ≥50			CH	FAT CLAY	
				MH	ELASTIC SILT	
				OH	ORGANIC CLAY OR SILT	
HIGHLY ORGANIC SOILS		PRIMARILY ORGANIC MATTER, DARK IN COLOR, AND ORGANIC ODOR		PT	PEAT	



NOTES: $C_U = \frac{D_{60}}{D_{10}}$ $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

Gravels or sands with 5% to 12% fines require dual symbols (GW-GM, GW-GC, GP-GM, GP-GC, SW-SM, SW-SC, SP-SM, SP-SC) and add "with clay" or "with silt" to group name. If fines classify as CL-ML for GM or SM, use dual symbol GC-GM or SC-SM. The coefficient of uniformity, C_U, and coefficient of curvature, C_C equations are given above where $D_{(X\%)}$ is soil particle diameter where X% is % finer. *Optional Abbeviations:* Lower case "s" after USCS group symbol denotes either "sandy" or "with sand" while "g" denotes either "gravelly" or "with gravel"

CRITERIA FOR DESCRIBING MOISTURE CONDITION (adapted from ASTM D2488)

DRY	ABSENCE OF MOISTURE, DUSTY, DRY TO THE TOUCH
MOIST	DAMP BUT NO VISIBLE WATER
WET	VISIBLE FREE WATER, USUALLY SOIL IS BELOW WATER TABLE

COMPONENT DEFINITIONS BY GRADATION

COMPONENT	SIZE RANGE
BOULDERS	GREATER THAN 12 in.
COBBLES	12 in. to 3 in.
GRAVEL	3 in. to #4 Sieve (4.76 mm)
COARSE GRAVEL	3 in. to 3/4 in.
FINE GRAVEL	3/4 in. to #4 (4.76 mm)
SAND	#4 (4.76 mm) to #200 (0.074 mm)
COARSE SAND	#4 (4.76 mm) to #10 (2.0 mm)
MEDIUM SAND	#10 (2.0 mm) to #40 (0.42 mm)
FINE SAND	#40 (0.42 mm) to #200 (0.074 mm)
SILT & CLAY (FINES)	SMALLER THAN #200 (0.074 mm)

RELATIVE DENSITY / CONSISTENCY ESTIMATE USING STANDARD PENETRATION TEST (SPT) VALUES

(adapted from Terzaghi and Peck 1967 and NAVFAC DM 7.1)

COHESIONLESS SOILS [a]		COHESIVE SOILS[b]		
RELATIVE DENSITY	$(N_1)_{60}$ (blows/ft)[c]	CONSISTENCY	$(N_1)_{60}$ (blows/ft)[c]	UNCONFINED COMPRESSIVE STRENGTH (TSF)[d]
VERY LOOSE	0 - 4	VERY SOFT	0 - 2	0 - 0.25
LOOSE	4 - 10	SOFT	2 - 4	0.25 - 0.50
COMPACT (MEDIUM DENSE)	10 - 30	FIRM	4 - 8	0.50 - 1.0
		STIFF	8 - 15	1.0 - 2.0
DENSE	30 - 50	VERY STIFF	15 - 30	2.0 - 4.0
VERY DENSE	OVER 50	HARD	OVER 30	OVER 4.0

(a) Soils consisting of gravel, sand, and silt, either separately or in combination possessing no characteristics of plasticity, and exhibiting drained behavior.
(b) Soils possessing the characteristics of plasticity, and exhibiting undrained behavior.
(c) Refer to ASTM D1586 for a definition of N value. $(N_1)_{60}$ is the N value corrected for hammer energy and overburden pressure, and is detailed in ASTM D6066. N values may be affected by a number of factors including: material size, sampler size, hammer weight and type, depth, drilling method, and borehole disturbance. N values are only an approximate guide for cohesive soil and do not apply to frozen soil.
(d) Undrained shear strength, s_u= 1/2 unconfined compression strength, U_c. Note that Torvane (TV) measures s_u and pocket penetrometer (PP) measures U_c

SAMPLER ABBREVIATIONS

SS	SPT Sampler (2 in. OD, 140 lb hammer)	**C**	Core (Diamond Bit)
HD	Large Split Spoon (3 in. OD, 300/340 lb hammer)	**TW**	Thin Wall (Shelby Tube)
-BL	Brass Liners used in Split Spoon	**TP**	Thin Wall Piston Sampler
R	Refusal when driving Split Spoon	**MS**	Modified Shelby
CA	Continous Core (Soil in Hollow-Stem Auger)	**MC**	Geoprobe Macro-Core
GS	Grab Sample from Surface / Test Pit	**RC**	Air Rotary Cuttings
AC	Auger Charge; **AW** Auger Wash	**AG**	Auger Cuttings

DESCRIPTIVE TERMINOLOGY FOR PERCENTAGES (ASTM D2488)

DESCRIPTIVE TERMS	RANGE OF PROPORTION
TRACE	0 - 5%
FEW	5 - 10%
LITTLE	10 - 25%
SOME	30 - 45%
MOSTLY	50 - 100%

LABORATORY TEST AND NOTES ABBREVIATIONS / SYMBOLS

Con	Consolidation	**PID**	Photoionization Detector	**TXCD**	Triaxial, Consolidated Drained
Dd	Dry Density	**PM**	Modified Proctor (D1557)	**TXCU**	Triaxial, Consolidated Undrained
K	Thermal Conductivity	**PP**	Pocket Penetrometer (Field)	**TXUU**	Triaxial, Unconsolidated Undrained
MA	Sieve and Hydrometer	**PTLD**	Point Load	W_L	Liquid Limit (LL)
NP	Non-plastic	**SA**	Sieve Analysis	W_P	Plastic Limit (PL)
OLI	Organic Loss	**SpG**	Specific Gravity	▼	Water Level
P200	Passing #200 Sieve (D1140)	**SR**	Soil Resistivity	▽	Water Level While Drilling
pH	Soil pH	**TC**	Thaw Consolidation/Strain		
PI	Plasticity Index (D4318)	**TV**	Torvane (Field)		

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SOIL CLASSIFICATION / LEGEND

Figure A-1

FROZEN SOIL CLASSIFICATION (ASTM D4083)

1. DESCRIBE SOIL INDEPENDENT OF FROZEN STATE	CLASSIFY SOIL BY THE UNIFIED SOIL CLASSIFICATION SYSTEM			
	MAJOR GROUP		SUBGROUP	
	DESCRIPTION	DESIGNATION	DESCRIPTION	DESIGNATION
2. MODIFY SOIL DESCRIPTION BY DESCRIPTION OF FROZEN SOIL	Segregated ice not visible by eye	N	Poorly bonded of friable	Nf
			Well bonded: No excess ice	Nbn
			Well bonded: Excess ice	Nbe
	Segregated ice visible by eye (ice less than 25 mm thick)	V	Individual ice crystals or inclusions	Vx
			Ice coatings on particles	Vc
			Random or irregularly oriented ice formations	Vr
			Stratified or distinctly oriented ice formations	Vs
			Uniformly distributed ice	Vu
3. MODIFY SOIL DESCRIPTION BY DESCRIPTION OF SUBSTANTIAL ICE STRATA	Ice greater than 25 mm thick	ICE	Ice with soil inclusions	ICE+soil type
			Ice without soil inclusions	ICE

FROST DESIGN SOIL CLASSIFICATION (1)

FROST GROUP	GENERAL SOIL TYPE	% FINER THAN 0.02 mm BY WEIGHT	TYPICAL USCS SOIL CLASS
NFS (non-frost suceptable)	(a) Gravels Crushed stone Crushed rock	0 to 1.5	GW, GP
	(b) Sands	0 to 3	SW, SP
NFS [PFS(3)](2)	(a) Gravels Crushed stone Crushed rock	1.5 to 3	GW, GP
F1 [S1](2)	Gravelly soils	3 to 6	GW, GP, GW-GM, GP-GM, GW-GC, GP-GC
F1	Gravelly soils	6 to 10	GM, GC, GM-GC, GW-GM, GP-GM, GW-GC, GP-GC
F2 [PFS(3)/S2](2)	Sandy soils	3 to 6	SW, SP, SW-SM, SP-SM, SW-SC, SP-SC
F2	(a) Gravelly soils	10 to 20	GW, GP, GW-GM, GP-GM, GW-GC, GP-GC
	(b) Sands	6 to 15	SM, SW-SM, SP-SM, SC, SW-SC, SP-SC, SM-SC
F3	(a) Gravelly soils	Over 20	GM, GC, GM-GC
	(b) Sands, except very fine silty sands	Over 15	SM, SC, SM-SC
	(c) Clays, PI>12	--	CL, CH
F4	(a) Silts	--	ML, MH, ML-CL
	(b) Very fine silty sands	Over 15	SM, SC, SM-SC
	(c) Clays, PI<12	--	CL, ML-CL
	(d) Varved clays or other fine-grained banded sediments	--	CL or CH layered with ML, MH, ML-CL, SM, SC, or SM-SC

(1) From Municipality of Anchorage (MOA) Design Criteria Manual (DCM), 2007 and 2014; Federal Aviation Administration (FAA) Advisory Circular (AC) 150/5320-6E; U.S. Army Corps of Engineers (USACE) "Arctic and Subarctic Construction, Runway and Road Design," Technical Manual TM 5-852-3, 1965; and USACE "Military Soils Engineering" Field Manual FM 5-410, 1997
(2) PFS, S1, and S2 frost groups from USACE, EM 1110-3-138, "Pavement Criteria for Seasonal Frost Conditions," April 1984
(3) Possibly frost susceptible, requires lab test for void ratio to determine frost design soil classification. Gravel with void ratio > 0.25 would be NFS; Gravel with void ratio < 0.25 would be S1; Sands with void ratio > 0.30 would be NFS; Sands with void ratio < 0.30 would be S2 or F2

ICE BONDING SYMBOLS

No ice-bonded soil observed

Poorly bonded or friable

Well bonded

DEFINITIONS

Candled Ice is ice which has rotted or otherwise formed into long columnar crystals, very loosely bonded together.

Clear Ice is transparent and contains only a moderate number of air bubbles.

Cloudy Ice is translucent, but essentially sound and non-pervious

Friable denotes a condition in which material is easily broken up under light to moderate pressure.

Granular Ice is composed of coarse, more or less equidimensional, ice crystals weakly bonded together.

Ice Coatings on particles are discernible layers of ice found on or below the larger soil particles in a frozen soil mass. They are sometimes associated with hoarfrost crystals, which have grown into voids produced by the freezing action.

Ice Crystal is a very small individual ice particle visible in the face of a soil mass. Crystals may be present alone or in a combination with other ice formations.

Ice Inclusions are individual ice masses visible in the face of a soil mass. Inclusions may be present alone or in a combination with other ice formations.

Ice Lenses are lenticular ice formations in soil occurring essentially parallel to each other, generally normal to the direction of heat loss and commonly in repeated layers.

Ice Segregation is the growth of ice as distinct lenses, layers, veins and masses in soils, commonly but not always oriented normal to direction of heat loss.

Massive Ice is a large mass of ice, typically nearly pure and relatively homogeneous.

Poorly-bonded signifies that the soil particles are weakly held together by the ice and that the frozen soil consequently has poor resistance to chipping or breaking.

Porous Ice contains numerous voids, usually interconnected and usually resulting from melting at air bubbles or along crystal interfaces from presence of salt or other materials in the water, or from the freezing of saturated snow. Though porous, the mass retains its structural unity.

Thaw-Stable frozen soils do not, on thawing, show loss of strength below normal, long-time thawed values nor produce detrimental settlement.

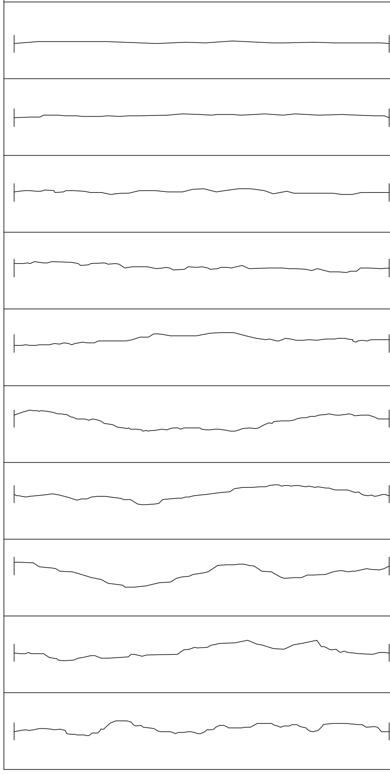
Thaw-Unstable frozen soils show on thawing, significant loss of strength below normal, long-time thawed values and/or significant settlement, as a direct result of the melting of the excess ice in the soil.

Well-Bonded signifies that the soil particles are strongly held together by the ice and that the frozen soil possesses relatively high resistance to chipping or breaking.

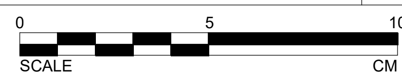
WEATHERING CLASSIFICATION*

TERM	DESCRIPTION	GROUP	SYMBOL
Fresh (FR)	No visible sign of rock material weathering: perhaps slight discoloration on major discontinuity surfaces	I	W1
Slightly Weathered (SW)	Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker externally than in its fresh condition.	II	W2
Moderately Weathered (MW)	Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as discontinuous framework or as corestones.	III	W3
Highly Weathered (HW)	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as discontinuous framework or as corestones.	IV	W4
Completely Weathered (CW)	All rock material is decomposed and/or disintegrated to a soil. The original mass structure is largely intact.	V	W5
Residual Soil (RS)	All rock material is convertged to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.	VI	

TYPICAL ROUGHNESS PROFILES FOR JRC*

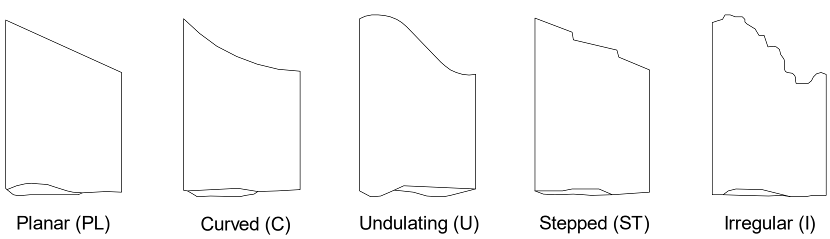


RANGE	ROUGHNESS CODE
0-2	Polished (P) Slickensided (K)
2-4	Smooth (SM)
4-6	Smooth (SM)
6-8	Smooth (SM)
8-10	Rough (R)
10-12	Rough (R)
12-14	Rough (R)
14-16	Very Rough (VR)
16-18	Very Rough (VR)
18-20	Very Rough (VR)

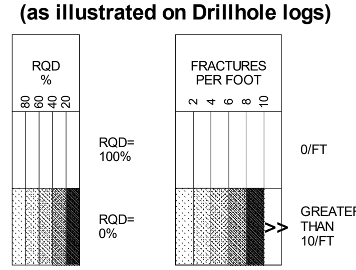


FRACTURE ORIENTATION
with respect to (wrt) core axis

SHAPE



RQD & FRACTURES / FOOT
(as illustrated on Drillhole logs)



INTACT ROCK STRENGTH CLASSIFICATION*

GRADE	DESCRIPTION	FIELD IDENTIFICATION	APPROX. RANGE OF UNIAXIAL COMPRESSIVE STRENGTH MPa	(psi)
R0	Extremely weak rock	Indented by thumbnail	0.25 - 1.0	(35 - 150)
R1	Very weak rock	Crumbles under firm blows with point of geological hammer, can be peeled by a pocket knife	1.0 - 5.0	(150 - 725)
R2	Weak rock	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blows with point of geological hammer	5.0 - 25	(725 - 3500)
R3	Medium strong rock	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with a single firm blow from geological hammer	25 - 50	(3500 - 7000)
R4	Strong rock	Specimen requires more than one blow geological hammer to fracture it	50 - 100	(7000 - 15000)
R5	Very strong rock	Specimen requires many blows from a geological hammer to fracture it	100 - 250	(15000 - 36000)
R6	Extremely strong rock	Specimen can only be chipped with a geological hammer	>250	(>36000)

*From Brown, 1981, *"Suggested Methods for Rock Characterization Testing and Monitoring,"* International Society for Rock Mechanics (ISRM)

MODIFIED CORE RECOVERY AS AN INDEX OF ROCK QUALITY

RQD	DESCRIPTION OF ROCK QUALITY
0 - 25	Very poor
25 - 50	Poor
50 - 75	Fair
75 - 90	Good
90 - 100	Excellent

NOTE: Rock Quality Designation (RQD) is measured as the summation of all the core pieces that are greater than 4 inches in length, divided by the total core run length.

Golder Associates

ROCK CORE LOGGING LEGEND

Figure A-3

RECORD OF BOREHOLE TH-1-Park

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/10/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

BORING METHOD: 3.5 inch I.D. Hollow Stem Auger

VEGETATION: tundra, short grass and brush, and sporadic stunted spruce

DEPTH (ft)	DESCRIPTION	ICE BOND	USCS	ELEV. / DEPTH (ft)
0	0.0 - 0.5 Frozen, wet (over-saturated/soupy) when thawed, dark brown, Vegetative (Tundra) Mat; well bonded (Org.)		Org.	
	0.5 - 2.5 Frozen, wet (over-saturated/soupy) when thawed, dark brown, Organic Vegetation + PEAT; mixed with some Organic Silt, nonplastic, organic odor, well bonded (Org.+Pt)		Org.+ Pt	0.5
	2.5 - 7.0 Frozen, wet (over-saturated/soupy) when thawed, dark brown, ORGANIC SILT + ICE; with organics as roots, peat, and vegetation, trace fine-grained sand, low plasticity, well bonded with approximately 35%-40% visible ice by volume up to 1.5 inch thick (OL + ICE, Vs-Vr/ICE) +Distinct change in drilling at 7 ft, inferred as change in ice and organic content.		OL + ICE	2.5
5				
	7.0 - 12.0 Frozen, wet (over-saturated/soupy) when thawed, brown w/ gray, ORGANIC SILT; mixed w/ little to some Silt, nonplastic, well bonded with approximately 20%-30% visible ice by volume (OL w/ ML, Vx) +Distinct change in drilling at 12 ft.		OL w/ ML	7.0
10				
	12.0 - 15.7 Frozen, wet (over-saturated/soupy) when thawed, gray, SILT with Sand; little to some fine to medium-grained sand, low to medium plasticity, well bonded with approximately 25%-30% visible ice by volume (MLs, Vr-Vs)		MLs	12.0
15				
	15.7 - 20.0 Frozen, wet when thawed, gray, Silty Gravelly SAND; some fines, fine to medium-grained rounded sand and gravel, low plasticity, contains layers (1 to 2 ft thick) of only trace gravel, and layers of higher fines, well bonded with approximately 15%-30% visible ice by volume (SMg, Vx-Vr)		SMg	15.7
20				

Log continued on next page

SAMPLES

NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC / ATT (inch)	WATER CONTENT (PERCENT)
1	AG				689
2	AG				436
3	HD	13-14-19	33	18/18	
4	HD	7-16-13	29	18/18	94
5	HD	10-12-17	29	18/18	57
6	HD	12-16-19	35	18/18	71
7A	HD	8-24-9/3"	R	8/8	
7B	HD	--		7/7	

UNCORRECTED BLOWS / FT ■ (10, 20, 30, 40)
SALINITY (ppt) △
WATER CONTENT (PERCENT) W_P —○ W — W_L (10, 20, 30, 40)

>>

NOTES / TESTS / WATER LEVELS / GRAPHIC

Backfilled with drill cuttings

OLI = 4%

Gravel = 0%, Sand = 67%, Fines = 32.5%

DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Golder Associates

Figure A-4

RECORD OF BOREHOLE TH-1-Park

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/10/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

DEPTH (ft)	BORING METHOD	DESCRIPTION (VEGETATION: tundra, short grass and brush, and sporadic stunted spruce)	ICE BOND	USCS	ELEV. / DEPTH (ft)	NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC / ATT (inch)	NOTES, TESTS, WATER LEVELS, GRAPHIC
20	3.5 inch I.D. Hollow Stem Auger	20.0 - 31.5 Frozen, wet when thawed, gray, Gravelly SILT to Silty GRAVEL; little to some fine to medium-grained sand, rounded to sub-rounded, low to medium plasticity, contains layers (1 to 2 ft thick) of only trace gravel, well bonded with approximately 5%-25% visible ice by volume, multiple ice lenses up to 1 inch (MLg to GMs, Vs-Vr)		MLg to GMs	20.0	8A	HD	18-14-22	36	13/13	
						8B	HD	--		5/5	
						+Sample 8: sampler bouncing; blows n/r.					
25						9	HD	37-32		12/12	Backfilled with drill cuttings
						+Sample 9: sampler bouncing on oversized particle(s); blows n/r.					
30						10	HD	13-19-12	31	18/18	
		Borehole completed at 31.5 ft.									
35											
40											

UNCORRECTED BLOWS / FT ■ (10, 20, 30, 40); SALINITY (ppt) △; WATER CONTENT (PERCENT) W_P — W — W_L (10, 20, 30, 40)

NOTES:
1) No groundwater encountered while drilling; ground was frozen throughout borehole.

2) Prior to drilling, surface vegetation was cut out from around the borehole and replaced after backfilling.

3) Ice content is estimated visually, based on volume.

4) Sampler blow counts in frozen and/or oversized materials are not representative (n/r) and do not necessarily correlate to density. Where noted "R" indicates sampler refusal, defined as greater than 50 blows per 6 inches.

Golder Associates

DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Figure A-4

RECORD OF BOREHOLE TH-2-Park

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/10/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

BORING METHOD: 3.5 inch I.D. Hollow Stem Auger

VEGETATION: tundra, low brush, and heavily forested with spruce

SOIL PROFILE

DESCRIPTION	USCS	ELEV. / DEPTH (ft)
0.0 - 0.5 Frozen, wet (over-saturated/soupy) when thawed, dark brown, Vegetative (Tundra) Mat; well bonded (Org., Vx)	Org.	0.5
0.5 - 2.8 Frozen, wet (over-saturated/soupy) when thawed, dark brown w/ gray, Organic Vegetation + PEAT + ORGANIC SILT mixed with SILT; organic rooty / fibrous vegetation, nonplastic, organic odor, well bonded with approximately 10%-20% visible ice by volume (Org.+Pt+OL+ML, Vs-Vr)	Org.+ Pt+ OL+ ML	2.8
2.8 - 5.9 Frozen, wet (over-saturated/soupy) when thawed, gray w/ dark brown, SILT; with little organics as roots, fibrous vegetation, log, and organic silt, nonplastic, well bonded with approximately 5%-20% visible ice by volume (ML w/ Org., Vs-Vr) +Sample 3A: recovered wood log. +Significant increase in drilling resistance at 5.9 ft, indicative of (frozen) gravel and cobbles.	ML w/ Org.	5.9
5.9 - 12.0 Frozen, wet (over-saturated) when thawed, gray, Sandy Silty GRAVEL; contains 0.5-1 ft thick zones of Silty Sand, fine and coarse-grained rounded to sub-angular, nonplastic, well bonded with approximately 5%-25% visible ice by volume (GMs w/ SM, Vr-Vx-Vs)	GMs w/ SM	12.0
12.0 - 17.5 Frozen, moist when thawed, gray, Sandy Silty GRAVEL; little fines, fine and coarse-grained rounded to sub-angular, nonplastic, well bonded (GMs, Nbe-Nbn) +Hard and chunky drilling 12-17.5 ft, indicative of (frozen) gravel and cobbles.	GMs	17.5
17.5 - 18.5 Frozen, Silty SAND with ICE; ice greater than 1 inch thick , inferred based on drilling, well bonded (SM+ICE)	SM+ ICE	18.5
18.5 - 20.3 Frozen, Silty SAND; inferred based on drilling, well bonded, unknown ice content (SM)	SM	

Log continued on next page

SAMPLES

NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC / ATT (inch)	WATER CONTENT (PERCENT)	NOTES
1	AG				168	
2A	HD	11-19-20/4"	R	4/4	138	
2B	HD	--		12/12	57	
+Sample 2: sampler over-full; blows n/r.						
3A	HD	8-20-20/5"	R	11/11	95	
3B	HD			1/6		
+Sample 3: sampler bouncing on oversized particle(s); blows n/r.						
4	HD	17-22-20/3"	R	18/14		Gravel = 30%, Sand = 42%, Fines = 27.5%
5A	HD	12-18-20	38	7/7		
5B	HD	--		11/11		
6	HD	33-50/4"	R	10/10		
+Sample 6: sampler bouncing on oversized particle(s); blows n/r.						

UNCORRECTED BLOWS / FT ■ (10, 20, 30, 40)
SALINITY (ppt) △
WATER CONTENT (PERCENT) W_P — W — W_L (10, 20, 30, 40)

NOTES / TESTS / WATER LEVELS / GRAPHIC: Backfilled with drill cuttings

DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell
LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Golder Associates

Figure A-5

RECORD OF BOREHOLE TH-2-Park

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/10/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

VEGETATION: tundra, low brush, and heavily forested with spruce

BORING METHOD: 3.5 inch I.D. Hollow Stem Auger

DEPTH (ft)	DESCRIPTION	ICE BOND	USCS	ELEV. / DEPTH (ft)	NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC / ATT (inch)	NOTES / TESTS / WATER LEVELS / GRAPHIC
20			SM							
	20.3 - 30.7 Frozen, moist when thawed, gray, Silty Sandy GRAVEL with Cobbles; little to some fines, fine and coarse-grained rounded to sub-angular, possible boulders, low plasticity, well bonded with approximately 0%-5% visible ice by volume (GMs, Nbn/Nbe to Vx-Vr)		GMs	20.3	7	HD	26-30	R	12/12	
	+Sample 7: Nbn.									
	+Increased cobbles below 22 ft; hard drilling.									
25	+Sample 8: Vx-Vr.				8	HD	26-22-27/4"	R	16/16	Backfilled with drill cuttings
	+Oversized cobbles or possible boulder at 27.5 ft. Hard drilling broke drill bit & lower auger flights.									
30	+Sample 9: Nbn.				9	HD	24-24/2"	R	8/8	
	Borehole completed at 30.7 ft.									

UNCORRECTED BLOWS / FT ■ (10, 20, 30, 40); SALINITY (ppt) △; WATER CONTENT (PERCENT) W_P — W — W_L (10, 20, 30, 40)

NOTES:
1) No groundwater encountered while drilling; ground was frozen throughout borehole.

2) Prior to drilling, surface vegetation was cut out from around the borehole and replaced after backfilling.

3) Ice content is estimated visually, based on volume.

4) Sampler blow counts in frozen and/or oversized materials are not representative (n/r) and do not necessarily correlate to density. Where noted "R" indicates sampler refusal, defined as greater than 50 blows per 6 inches.

35

40

DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Golder Associates

Figure A-5

RECORD OF BOREHOLE TH-3-ROW

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/11/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

VEGETATION: tundra, short grass and brush, and stunted spruce

BORING METHOD: 3.5 inch I.D. Hollow Stem Auger

SOIL PROFILE

DEPTH (ft)	DESCRIPTION	ICE BOND	USCS	ELEV. / DEPTH (ft)
0.0 - 0.5	Frozen, wet (over-saturated/soupy) when thawed, dark brown, Vegetative (Tundra) Mat; well bonded (Org.)	■	Org.	0.5
0.5 - 3.7	Frozen, wet (over-saturated/soupy) when thawed, dark brown w/ gray, Organic Vegetation + PEAT + ORGANIC SILT mixed with SILT; organic rooty / fibrous vegetation, nonplastic, organic odor, well bonded with approximately 10%-20% visible ice by volume (Org.+Pt+OL+ML, Vx)	■	Org.+ Pt+ OL+ ML	3.7
3.7 - 4.0	Frozen, wet when thawed, ORGANIC SILT mixed with Gravel inclusion and Peat; well bonded (OLg)	■	OLg	4.0
4.0 - 7.5	Thawed, soft, wet, dark brown, fibrous PEAT + ORGANIC SILT; organic odor			7.5
7.5 - 16.0	Thawed, loose, moist, gray, Silty SAND with gravel and clay; little to some gravel, few to little clay, fine to coarse-grained rounded to sub-rounded, low to medium plasticity (SMg)		SMg	16.0
16.0 - 46.5	Thawed, loose becoming medium dense below about 30 ft, moist, gray, Sandy Gravelly SILT; pockets of silty gravel, fine to coarse-grained rounded to sub-rounded, contains cobbles (increasing below 37.5 ft), low to medium plasticity (MLg) +Increased drilling resistance and auger torque at 17 ft, inferred to be from plastic silt.		MLg	

SAMPLES

NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC / ATT (inch)	WATER CONTENT (PERCENT)
1	AG				76
2A	HD	6-5-8	13	14/14	216
2B	HD	--		4/4	
3	HD	2-2-5	7	12/18	118
4	HD	2-4-4	8	12/18	
5	HD	3-5-4	9	8/18	
6	HD	5-5-9	14	18/18	

UNCORRECTED BLOWS / FT ■ (10, 20, 30, 40)
SALINITY (ppt) △
WATER CONTENT (PERCENT) W_P — W — W_L (10, 20, 30, 40)

NOTES / TESTS / WATER LEVELS / GRAPHIC

flush-mounted monitoring well cap

Two (2) 1-inch sch.40 PVC pipes, backfilled with drill cuttings

Gravel = 24%, Sand = 45%, Fines = 31.6%, MA

Two (2) 1-inch sch.40 PVC pipes; (1) field slotted, (1) sealed

Log continued on next page

RECORD OF BOREHOLE TH-3-ROW

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/11/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

VEGETATION: tundra, short grass and brush, and stunted spruce

DEPTH (ft)	BORING METHOD	DESCRIPTION	ICE BOND	USCS	ELEV. / DEPTH (ft)	NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC/ATT (inch)	NOTES / TESTS / WATER LEVELS / GRAPHIC
20	3.5 inch I.D. Hollow Stem Auger	16.0 - 46.5 Thawed, loose becoming medium dense below about 30 ft, moist, gray, Sandy Gravelly SILT; pockets of silty gravel, fine to coarse-grained rounded to sub-rounded, contains cobbles (increasing below 37.5 ft), low to medium plasticity (MLg) *(Continued)*				7	HD	4-3-5	8	12/18	
25						8	HD	1-4-4	8	12/18	
30		+Becoming medium dense below about 30 ft.		MLg		9	HD	6-10-9	19	14/18	Two (2) 1-inch sch.40 PVC pipes
35						10	HD	7-5-6	11	18/18	
		+Several cobbles below 37.5 ft.									
40											

UNCORRECTED BLOWS / FT ■ (10, 20, 30, 40)
SALINITY (ppt) △
WATER CONTENT (PERCENT) W_P — W — W_L (10, 20, 30, 40)

Log continued on next page

RECORD OF BOREHOLE TH-3-ROW

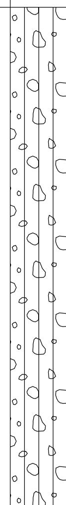
PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

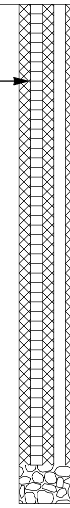
CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/11/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

VEGETATION: tundra, short grass and brush, and stunted spruce

DEPTH (ft)	BORING METHOD	DESCRIPTION	ICE BOND	USCS	ELEV. / DEPTH (ft)	NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC / ATT (inch)	UNCORRECTED BLOWS / FT ■ ; SALINITY (ppt) △ ; WATER CONTENT (PERCENT) W	NOTES TESTS WATER LEVELS GRAPHIC
40	3.5 inch I.D. Hollow Stem Auger	16.0 - 46.5 Thawed, loose becoming medium dense below about 30 ft, moist, gray, Sandy Gravelly SILT; pockets of silty gravel, fine to coarse-grained rounded to sub-rounded, contains cobbles (increasing below 37.5 ft), low to medium plasticity (MLg) *(Continued)*		MLg		11	HD	15-8-15	23	18/18		Two (2) 1-inch sch.40 PVC pipes; (1) field slotted, (1) sealed
45						12	HD	9-21-13	34	18/18		
		Borehole completed at 46.5 ft.										
50												
55												
60												





NOTES:
1) No groundwater encountered while drilling.

2) Prior to drilling, surface vegetation was cut out from around the borehole and replaced after backfilling.

3) Ice content is estimated visually, based on volume.

4) Sampler blow counts in frozen and/or oversized materials are not representative (n/r) and do not necessarily correlate to density. Where noted "R" indicates sampler refusal, defined as greater than 50 blows per 6 inches.

Golder Associates

DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Figure A-6

RECORD OF BOREHOLE TH-4-Park

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/12/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

BORING METHOD: 3.5 inch I.D. Hollow Stem Auger

VEGETATION: tundra, tussocks, short grass and brush, and stunted spruce

SOIL PROFILE

DESCRIPTION	ICE BOND	USCS	ELEV. / DEPTH (ft)
0.0 - 1.0 Frozen, wet (over-saturated/soupy) when thawed, dark brown, Vegetative (Tundra) Mat & Tussocks; well bonded (Org.)	Well bonded	Org.	
1.0 - 3.1 Frozen, wet (over-saturated/soupy) when thawed, dark brown, Organic Vegetation + PEAT + ORGANIC SILT mixed with SILT; organic rooty / fibrous vegetation, nonplastic, well bonded with approximately 45% visible ice by volume up to 2 inch thick (Org.+Pt+OL+ML, Vx-ICE)	Well bonded	Org.+ Pt+ OL+ ML	1.0
3.1 - 7.5 Frozen, wet (over-saturated/soupy) when thawed, gray w/ brown, SILT + ICE; little grading to trace organics and organic silt, nonplastic, well bonded with approximately 60% grading to 20% visible ice by volume up to 2 inch thick, becoming Vx (ML+ICE)	Well bonded	ML+ ICE	3.1
7.5 - 12.5 Frozen, wet when thawed, gray, Sandy SILT grading to Silty SAND; low plasticity, well bonded with approximately 5%-10% visible ice by volume (ML to SM, Vx-Vr)	Well bonded	ML to SM	7.5
12.5 - 15.5 Frozen, BOULDER; and/or numerous cobbles, well bonded +No sample attempt at 15 ft due to boulder.	Well bonded		12.5
15.5 - 22.0 Frozen, wet when thawed, brownish gray, poorly-graded Sandy GRAVEL with Silt; several to numerous cobbles, little fines, fine to coarse-grained rounded to sub-angular,, well bonded, excess visible ice (GP-GMs, Vx)	Well bonded	GP-GMs	15.5

Log continued on next page

SAMPLES

BLOWS per 6 in: 340 lb Hammer (Automatic), 30 in. Drop

NUMBER	TYPE	BLOWS per 6 in	BLOWS PER FT	REC / ATT (inch)	WATER CONTENT (PERCENT)
1	AG				503
2A	HD	9-15-16	31	7/7	136
2B	HD	--		11/11	
3	HD	11-18-15	33	18/18	64
4	HD	14-20-17	37	18/18	
5	HD	9-22-10/2"	R	14/14	

+Sample 5: sampler bouncing on oversized particle(s); blows n/r.

UNCORRECTED BLOWS / FT ■ (10, 20, 30, 40)
SALINITY (ppt) △
WATER CONTENT (PERCENT) W_P — W — W_L (10, 20, 30, 40)

>>

NOTES / TESTS / WATER LEVELS / GRAPHIC

Backfilled with drill cuttings

DEPTH (ft): 0, 5, 10, 15, 20

DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Golder Associates

Figure A-7

RECORD OF BOREHOLE TH-4-Park

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK
CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/12/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks
DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

VEGETATION: tundra, tussocks, short grass and brush, and stunted spruce

Boring method: 3.5 inch I.D. Hollow Stem Auger

DEPTH (ft)	DESCRIPTION	USCS	ELEV. / DEPTH (ft)	NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC / ATT (inch)	BLOWS / FT	NOTES, TESTS, WATER LEVELS, GRAPHIC
20	15.5 - 22.0 Frozen, wet when thawed, brownish gray, poorly-graded Sandy GRAVEL with Silt; several to numerous cobbles, little fines, fine to coarse-grained rounded to sub-angular,, well bonded, excess visible ice (GP-GMs, Vx) *(Continued)*	GP-GMs		6	HD	50/3"	R	3 / 3	>>	Gravel = 35%, Sand = 57%, Fines = 8.0%
	+Sample 6: sampler bouncing on oversized particle(s); blows n/r.									
	22.0 - 25.0 Frozen, Numerous COBBLES; and/or possible boulders, well bonded		22.0							
25	25.0 - 33.5 Frozen, wet when thawed, brownish gray, poorly-graded Sandy GRAVEL with Silt and Cobbles; several to numerous cobbles, little becoming few fines, fine to coarse-grained rounded to sub-angular,, well bonded with approximately 10%-17% visible ice by volume up to 0.75 inch thick (GP-GMs to GPs, Vx-Vr)	GP-GMs to GPs	25.0	7	HD	50/4"	R	4 / 4	>>	Backfilled with drill cuttings
	+Sample 7: sampler bouncing on oversized particle(s); blows n/r.									
30				8	HD	50/2"	R	2 / 2	>>	
	+Sample 8: sampler bouncing on oversized particle(s); blows n/r.									
	33.5 - 36.0 Frozen, COBBLES, possible Boulders, amongst Gravelly matrix; well bonded		33.5							
	+Harder, more continuous auger bite below 33.5 ft, indicative of either boulder or increased cobbles.									
35	+Auger refusal on cobbles/boulders at 36 ft.			9	HD	25/1"	R	0 / 1	>>	
	+Sample 9: sampler bouncing on oversized particle(s); blows n/r.									

Borehole completed at 36.0 ft.

NOTES:
1) No groundwater encountered while drilling; ground was frozen throughout borehole.
2) Prior to drilling, surface vegetation was cut out from around the borehole and replaced after backfilling.
3) Ice content is estimated visually, based on volume.
4) Sampler blow counts in frozen and/or oversized materials are not representative (n/r) and do not necessarily correlate to density. R=Refusal.
5) Very hard drilling 12.5 to 15.5 ft, requiring multiple sequence of hitting boulder through center rods using drop hammer and percussion hammer. Drilling from 15.5 to 22 ft and 25 to 33.5 ft met numerous cobbles and possible boulders. Fewer cobbles between 20 and 22 ft.

Golder Associates

DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Figure A-7

RECORD OF BOREHOLE TH-5-Park

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/12/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

BORING METHOD: 3.5 inch I.D. Hollow Stem Auger

VEGETATION: tundra, tussocks, short grass and brush, and stunted spruce

SOIL PROFILE

DEPTH (ft)	DESCRIPTION	USCS	ELEV. / DEPTH (ft)
0	0.0 - 1.0 Frozen, wet (over-saturated/soupy) when thawed, dark brown, Vegetative (Tundra) Mat & Tussocks; well bonded (Org.)	Org.	
	1.0 - 2.8 Frozen, wet (over-saturated/soupy) when thawed, dark brown, Organic Vegetation + PEAT + ORGANIC SILT mixed with SILT; organic rooty / fibrous vegetation, nonplastic, well bonded with approximately 45% visible ice by volume up to 2 inch thick (Org.+Pt+OL+ML, Vx-ICE)	Org.+ Pt+ OL+ ML	1.0
	2.8 - 5.7 Frozen, wet (over-saturated/soupy) when thawed, gray w/ brown, SILT + ICE; little grading to trace organics and organic silt, low plasticity, well bonded with approximately 30% grading to 15% visible ice by volume up to 1.5 inch thick, becoming Vx (ML+ICE)	ML+ ICE	2.8
5	5.7 - 10.0 Frozen, moist when thawed, gray, Silty Sandy GRAVEL with Cobbles; well bonded with approximately 5% visible ice by volume (GMs, Vx-Vr) +Cobble(s). +Cobble(s).	GMs	5.7
10	10.0 - 40.3 Frozen, moist when thawed, brownish gray, poorly-graded Sandy GRAVEL with Cobbles; trace to few fines, possible boulders, fine to coarse-grained rounded to sub-angular, contains stratified layers (typically 1 to 2 feet thick) varying from few to mostly cobbles, well bonded (GPs to GP-GMs, Vx)	GPs to GP-GMs	10.0
15	+Cobble(s) and/or boulder. +Cobble(s) and/or boulder. +Cobble(s) and/or boulder.		
20			

Log continued on next page

SAMPLES

NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC / ATT (inch)	WATER CONTENT (PERCENT)	NOTES / TESTS
1	AG				896	
2A	HD	6-14-14	28	4/4	66	
2B	HD	--		14/14	60	
3A	HD	11-15		8/8		
3B	HD	--		4/4		
4	HD	50/6"	R	4/6		>> Gravel = 52%, Sand = 37%, Fines = 10.8%
5	HD	20/1"	R	1/1		>>

+Sample 4: sampler bouncing & broke on oversized particle(s); blows n/r.

+Sample 5: sampler bouncing on oversized particle(s); blows n/r.

UNCORRECTED BLOWS / FT ■ (10, 20, 30, 40)
SALINITY (ppt) △
WATER CONTENT (PERCENT) W_P —○W— W_L (10, 20, 30, 40)

NOTES / TESTS / WATER LEVELS / GRAPHIC: Backfilled with drill cuttings

DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Golder Associates

Figure A-8

RECORD OF BOREHOLE TH-5-Park

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/12/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

VEGETATION: tundra, tussocks, short grass and brush, and stunted spruce

DEPTH (ft)	DESCRIPTION	USCS	SAMPLE NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC / ATT (inch)	NOTES
20	10.0 - 40.3 Frozen, moist when thawed, brownish gray, poorly-graded Sandy GRAVEL with Cobbles; trace to few fines, possible boulders, fine to coarse-grained rounded to sub-angular, contains stratified layers (typically 1 to 2 feet thick) varying from few to mostly cobbles, well bonded (GPs to GP-GMs, Vx) *(Continued)*		6	HD	25/2"	R	2/2	
			+Sample 6: sampler bouncing on oversized particle(s); blows n/r.					
25			7	HD	30/3"	R	2/4	
			+Sample 7: sampler bouncing on oversized particle(s); blows n/r.					
	+Cobble(s) and/or boulder.							
30		GPs to GP-GMs	8	HD	40/3"	R	3/4	Backfilled with drill cuttings
			+Sample 8: sampler bouncing on oversized particle(s); blows n/r.					
35			9	HD	25/2"	R	2/2	
			+Sample 9: sampler bouncing on oversized particle(s); blows n/r.					
40								

Log continued on next page

DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Golder Associates

RECORD OF BOREHOLE TH-5-Park

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/12/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

DEPTH (ft)	BORING METHOD	SOIL PROFILE: DESCRIPTION — VEGETATION: tundra, tussocks, short grass and brush, and stunted spruce	ICE BOND	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC / ATT (inch)	UNCORRECTED BLOWS / FT ■ 10 20 30 40; SALINITY (ppt) △; WATER CONTENT (PERCENT) Wp —○W— WL 10 20 30 40	NOTES TESTS WATER LEVELS GRAPHIC
40							10	HD	30/3"	R	3/4	>>	
		Borehole completed at 40.3 ft.											

+Sample 10: sampler bouncing on oversized particle(s); blows n/r.

NOTES:
1) No groundwater encountered while drilling; ground was frozen throughout borehole.

2) Prior to drilling, surface vegetation was cut out from around the borehole and replaced after backfilling.

3) Ice content is estimated visually, based on volume.

4) Sampler blow counts in frozen and/or oversized materials are not representative (n/r) and do not necessarily correlate to density. Where noted "R" indicates sampler refusal, defined as greater than 50 blows per 6 inches.

5) Very hard drilling at 18, 20, and 28 ft, requiring multiple sequence of hitting cobble or boulder through center rods using drop hammer and percussion hammer and continuous bite on auger bit. Drilling from 20 to 28 ft encountered fewer cobbles and 2 ft thick zones with only trace cobbles.

45

50

55

60

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DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Figure A-8

RECORD OF BOREHOLE TH-6-ROW

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/11/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

VEGETATION: tundra, short grass and brush, and thickly forested with spruce to 8 inches trunk diameter

BORING METHOD: 3.5 inch I.D. Hollow Stem Auger

SOIL PROFILE

DEPTH (ft)	DESCRIPTION	USCS	ELEV. / DEPTH (ft)
0.0 - 1.0	Frozen, wet (over-saturated/soupy) when thawed, dark brown, Vegetative (Tundra) Mat & Tussocks; well bonded (Org.)	Org.	
1.0 - 2.5	Frozen, wet (over-saturated/soupy) when thawed, dark brown, Organic Vegetation + PEAT + ORGANIC SILT mixed with SILT; organic rooty / fibrous vegetation, nonplastic, well bonded with approximately 0%-10% visible ice by volume (Org.+Pt+OL+ML, Vx)	Org.+ Pt+ OL+ ML	1.0
2.5 - 10.0	Frozen, moist when thawed, light brownish gray, Sandy Silty GRAVEL with Cobbles; some fines, fine to coarse-grained rounded to sub-angular,, well bonded with approximately 0%-5% visible ice by volume (GMs, Nbe-Vx)	GMs	2.5
10.0 - 15.1	Frozen, moist when thawed, brownish gray, Sandy Silty GRAVEL with Cobbles and Boulders; little fines, fine to coarse-grained rounded to sub-angular,, well bonded with approximately 0%-5% visible ice by volume (GMs, Nbe-Vx) +Very hard drilling 10 to 15 ft, particularly below 12.5 ft.	GMs	10.0

Borehole completed at 15.1 ft.

SAMPLES

NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC / ATT (inch)	NOTES / TESTS
1	AG				Water content 234
2	HD	17-46		12/12	
3	HD	21-30-12/2"	R	14/14	Gravel = 30%, Sand = 38%, Fines = 31.6%
4	HD	8-24-30	54	18/18	
5	HD	12-24-20	44	18/18	
6	HD	40/1"	R	1/1	

+Sample 3: sampler bouncing on oversized particle(s); blows n/r.

+Sample 6: sampler bouncing on oversized particle(s); blows n/r.

UNCORRECTED BLOWS / FT ■ (10, 20, 30, 40)
SALINITY (ppt) △
WATER CONTENT (PERCENT) W_P — W — W_L (10, 20, 30, 40)

NOTES, TESTS, WATER LEVELS, GRAPHIC: Backfilled with drill cuttings

NOTES:
1) No groundwater encountered while drilling; ground was frozen throughout borehole.

2) Ice content is estimated visually, based on volume.

3) Sampler blow counts in frozen and/or oversized materials are not representative (n/r) and do not necessarily correlate to density. Where noted "R" indicates sampler refusal, defined as greater than 50 blows per 6 inches.

4) Very hard drilling from 2.5 ft to bottom of hole at 15.1 ft, with increased resistance and more continuous bite on the auger bit below 12.5 ft, indicative of numerous cobbles and boulders. Auger drilling required multiple sequences of hitting center rod with drop hammer and percussion hammer to advance.

DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Golder Associates

Figure A-9

RECORD OF BOREHOLE TH-7-ROW

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/14/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

BORING METHOD: 3.5 inch I.D. Hollow Stem Auger

VEGETATION: tundra, short grass and brush, and thickly forested with spruce to 8 inches trunk diameter

SOIL PROFILE

DEPTH (ft)	DESCRIPTION	USCS	ELEV. / DEPTH (ft)
0.0 - 1.1	Frozen, wet (over-saturated/soupy) when thawed, dark brown, Vegetative (Tundra) Mat & Tussocks; well bonded (Org.)	Org.	
1.1 - 2.5	Frozen, wet (over-saturated/soupy) when thawed, dark brown, Organic Vegetation + PEAT + ORGANIC SILT mixed with SILT; organic rooty / fibrous vegetation, nonplastic, well bonded with approximately 0%-10% visible ice by volume (Org.+Pt+OL+ML, Vx)	Org.+ Pt+ OL+ ML	1.1
2.5 - 8.5	Frozen, moist to wet when thawed, brownish gray, gravelly SILT with Sand; fine to coarse-grained rounded to sub-angular, no to low plasticity, well bonded with approximately 5%-10% visible ice by volume (MLg, Vx-Vr)	MLg	2.5
8.5 - 19.0	Frozen, wet when thawed, brownish gray, Sandy Silty GRAVEL with Cobbles; little fines, possible boulders, low plasticity, well bonded with approximately 5%-15% visible ice by volume (GMs, Vx-Vr) +Harder drilling below 13 to 19 ft, indicative of numerous cobbles and possible boulders.	GMs	8.5
19.0 -		MLg to GMs	19.0

Log continued on next page

SAMPLES

BLOWS per 6 in: 340 lb Hammer (Automatic) 30 in. Drop

NUMBER	TYPE	BLOWS per 6 in	BLOWS PER FT	REC / ATT (inch)	UNCORRECTED BLOWS / FT	WATER CONTENT (PERCENT)	NOTES / TESTS
1	AG					454	
2	HD	11-20-20/3"	R	15/16	>>		
3	HD	17-25-25/5"	R	17/17	>>		
4	HD	18-30/4"	R	10/11	>>		
5	HD	17-25-10/1"	R	13/13	>>		Gravel = 42%, Sand = 33%, Fines = 24.7%
6	HD	18-20/2"	R	8/8	>>		

+Sample 4: sampler bouncing on oversized particle(s); blows n/r.

+Sample 5: sampler bouncing on oversized particle(s); blows n/r.

+Sample 6: sampler bouncing on oversized particle(s); blows n/r.

WATER LEVELS / GRAPHIC: 1-inch sch.40 PVC pipe, backfilled with drill cuttings

DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Golder Associates

Figure A-10

RECORD OF BOREHOLE TH-7-ROW

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/14/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

DEPTH (ft)	BORING METHOD	DESCRIPTION (VEGETATION: tundra, short grass and brush, and thickly forested with spruce to 8 inches trunk diameter)	ICE BOND	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC / ATT (inch)	UNCORRECTED BLOWS / FT ■; SALINITY (ppt) △; WATER CONTENT (PERCENT)	NOTES TESTS WATER LEVELS GRAPHIC
20	3.5 inch I.D. Hollow Stem Auger	19.0 - 25.9 Frozen, wet to moist when thawed, brownish gray, Sandy Silty GRAVEL inter-layered with Sandy Gravelly SILT; cobbles present, low plasticity, contains layers (1 to 2 ft thick) of only few gravel & cobbles, couples with higher fines, well bonded with approximately 5% visible ice by volume (MLg to GMs, Vx) *(Continued)* +Higher silt content and less gravel and cobbles 19 - 20 ft. +Higher silt content and less gravel and cobbles 22 - 25 ft.		MLg to GMs			7	HD	11-25/2"	R	8/8	>>	
							+Sample 7: sampler bouncing on oversized particle(s); blows n/r.						
							8A	HD-slough			12/12		
25							8B	HD	18-30/4"	R	10/11	>>	
		Borehole completed at 25.9 ft.					+Sample 8: sampler bouncing on oversized particle(s); blows n/r.						

NOTES:
1) No groundwater encountered while drilling; ground was frozen throughout borehole.

2) Ice content is estimated visually, based on volume.

3) Sampler blow counts in frozen and/or oversized materials are not representative (n/r) and do not necessarily correlate to density. Where noted "R" indicates sampler refusal, defined as greater than 50 blows per 6 inches.

Depth scale: 20, 25, 30, 35, 40

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DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Figure A-10

RECORD OF BOREHOLE TH-8-ROW

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/13/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

BORING METHOD: 3.5 inch I.D. Hollow Stem Auger

VEGETATION: n/a, located in railroad cut. Young spruce and alder nearby.

Samples: Blows per 6 in — 340 lb Hammer (Automatic), 30 in. Drop

Depth (ft)	Description	Ice Bond	USCS	Elev. / Depth (ft)	Sample Number	Type	Blows per 6 in	Blows per ft	Rec / Att (inch)	Notes / Tests / Water Levels / Graphic
0.0 - 2.0	Frozen, moist when thawed, light brownish gray, Sandy Silty GRAVEL; nonplastic, well bonded with approximately 0%-5% visible ice by volume (GMs, Nbe-Vx)	Frozen	GMs		1	AG				flush-mounted monitoring well cap
2.0 - 3.0	Frozen, Cobbles or possible Boulder; well bonded	Frozen		2.0						
3.0 - 6.0	Frozen, moist when thawed, gray, Sandy Silty GRAVEL; little fines, fine to coarse-grained rounded to sub-angular, nonplastic, well bonded (GMs) +Cobble(s) and/or possible boulder. +No split spoon sample attempts at 2.5 and 5 ft due to cobbles / boulders. +Cobble(s) and/or possible boulder.	Frozen	GMs	3.0	2	AG				Two (2) 1-inch sch.40 PVC pipes, backfilled with drill cuttings Gravel = 46%, Sand = 37%, Fines = 17.1%
6.0 - 8.5	Moist, gray, poorly-graded Sandy GRAVEL with Silt; little fines, fine to coarse-grained rounded to sub-angular, (GP-GMs) +Cobble(s) and/or possible boulder at 7 ft. Sandier cuttings 7 to 8.5 ft.		GP-GMs	6.0	3	HD	30/2"	R	2 / 2	>>
	+Sample 3: sampler bouncing on oversized particle(s); blows n/r.									
8.5 - 10.0	Moist, light brownish gray, Silty SAND; little fine-grained rounded gravel, fine to medium-grained rounded to sub-angular, possible CW-Bx (with no remnant structure) (SM)		SM	8.5	4	AG				
10.0 - 16.0	Dry to moist, greenish gray with zones of beige, Completely Weathered (CW) BEDROCK; extremely weak rock (R0), only trace resemblance of rock structure remains, contains fragments of medium strong rock, but is mostly compressible by hand (CW-Bx) [Birch Creek Schist]		CW-Bx	10.0	5A	HD	27-50/6"	R	7 / 7	>> Two (2) 1-inch sch.40 PVC pipes; (1) field slotted, (1) sealed
					5B	HD	--		5 / 5	
					6	HD	21-50/6"	R	12 / 12	>>

Borehole completed at 16.0 ft.

NOTES:
1) No groundwater encountered while drilling.

2) Ice content is estimated visually, based on volume.

3) Sampler blow counts in frozen and/or oversized materials are not representative (n/r) and do not necessarily correlate to density. Where noted "R" indicates sampler refusal, defined as greater than 50 blows per 6 inches.

4) High drilling resistance within CW-Bx requires high auger torque. This results in very hot center rod bit.

DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Golder Associates

Figure A-11

RECORD OF BOREHOLE TH-9-ROW

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/13/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

BORING METHOD: 3.5 inch I.D. Hollow Stem Auger

VEGETATION: tundra with moderately thick forested with spruce to 8 inches trunk diameter. near railroad cut.

SOIL PROFILE

DEPTH (ft)	DESCRIPTION	ICE BOND	USCS	ELEV. / DEPTH (ft)
0.0 - 6.0	Frozen, moist when thawed, brownish gray, poorly-graded Sandy GRAVEL with Silt and Cobbles; contains boulders, little fines, well bonded (GP-GMs, Nbn) +Cobble(s) and/or possible boulder.	Nbn	GP-GMs	
6.0 - 16.5	Thawed (confirm), dense to very dense, moist, brownish gray, poorly-graded Sandy GRAVEL with Cobbles; contains boulders, little becoming trace fines, fine and coarse-grained mostly rounded to sub-rounded, (GPs) +Cobble(s) and/or possible boulder. +Cobble(s) and/or possible boulder. +Increased sand content and finer/fewer gravel below 15 ft.		GPs	6.0
16.5 - 18.5	Numerous COBBLES; or possible boulders			16.5
18.5 -	+Fewer cobbles observed below 18.5 ft.		GPs	18.5

SAMPLES

NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC / ATT (inch)
1	AG			
2	HD	12-17-12	29	18 / 18
3	HD	20-37-23	60	18 / 18
4	HD	23-23-29	52	18 / 18
5	HD	25-16-13	29	- / 18
6	HD	6-9-9	18	18 / 18

+Sample 3: sampler pounding on oversized particle(s); blows n/r.

+Sample 4: sampler pounding on oversized particle(s); blows n/r.

UNCORRECTED BLOWS / FT ■ (10 20 30 40)
SALINITY (ppt) △
WATER CONTENT (PERCENT) W_P — W — W_L (10 20 30 40)

>> (Sample 3)
>> (Sample 4)

NOTES / TESTS / WATER LEVELS / GRAPHIC

flush-mounted monitoring well cap

Gravel = 51%, Sand = 39%, Fines = 10.4%

Two (2) 1-inch sch.40 PVC pipes, backfilled with drill cuttings

Two (2) 1-inch sch.40 PVC pipes; (1) field slotted, (1) sealed

Log continued on next page

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DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Figure A-12

RECORD OF BOREHOLE TH-9-ROW

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/13/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

DEPTH (ft)	BORING METHOD	SOIL PROFILE: DESCRIPTION (VEGETATION: tundra with moderately thick forested with spruce to 8 inches trunk diameter. near railroad cut.)	ICE BOND	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES: NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC / ATT (inch)	UNCORRECTED BLOWS / FT ■ / SALINITY (ppt) △ / WATER CONTENT (PERCENT) W_P ⊖W W_L (10 20 30 40)	NOTES TESTS WATER LEVELS GRAPHIC
20		18.5 - 21.5 Thawed (confirm), dense to very dense, moist, brownish gray, poorly-graded Sandy GRAVEL with Cobbles; contains boulders, little becoming trace fines, fine and coarse-grained mostly rounded to sub-rounded, (GPs) *(Continued)*		GPs			7	HD	9-10-14	24	18/18		
		Borehole completed at 21.5 ft.											
25													
30													
35													
40													

NOTES:
1) No groundwater encountered while drilling.

2) Ice content is estimated visually, based on volume.

3) Sampler blow counts in frozen and/or oversized materials are not representative (n/r) and do not necessarily correlate to density. Where noted "R" indicates sampler refusal, defined as greater than 50 blows per 6 inches.

1771891 ARRC MP 345-347.GPJ LIBRARY-ANC(10-11-17).GLB [ANC BOREHOLE] TRoss 11/30/17

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DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Figure A-12

RECORD OF BOREHOLE TH-10-ROW

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/13/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

BORING METHOD: 3.5 inch I.D. Hollow Stem Auger

VEGETATION: n/a, located in railroad cut. Young spruce and alder nearby.

SOIL PROFILE

DEPTH (ft)	DESCRIPTION	ICE BOND	USCS	ELEV. / DEPTH (ft)
0.0 - 4.5	Frozen, dry to moist when thawed, brown, poorly-graded Sandy GRAVEL with Silt and Cobbles; few to little fines, possible boulders, well bonded (GP-GMs, Nf) +Cobbles and/or possible boulder.	Frozen	GP-GMs	
4.5 - 6.0	Frozen, dry to moist when thawed, brown, Sandy Silty GRAVEL with Cobbles; little fines, possible boulders, well bonded (GMs, Nf)	Frozen	GMs	4.5
6.0 - 20.7	Thawed (confirm), dense to very dense, dry becoming moist below 15 ft, brownish gray, poorly-graded Sandy GRAVEL with Silt and Cobbles; little fines, possible boulders (GP-GMs) +Cobble(s) and/or possible boulder at 6.5 ft. +Cobble(s) and/or possible boulder at 8 ft. +Increased fines (to little) at 15 ft. +Cobble(s) and/or possible boulder.		GP-GMs	6.0

Log continued on next page

SAMPLES

BLOWS per 6 in: 340 lb Hammer (Automatic), 30 in. Drop

NUMBER	TYPE	BLOWS per 6 in	BLOWS PER FT	REC / ATT (inch)
1	AG			
2	HD	29-23/4"	R	10 / 11
3	HD	15-30		12 / 12
4	AG			
5	HD	10-12-9	21	18 / 18
6	HD	16-30/3"	R	9 / 10

+Sample 2: sampler pounding on oversized particle(s); blows n/r.

+Sample 5: sampler pounding on oversized particle(s); blows n/r.

+Sample 6: sampler pounding on oversized particle(s); blows n/r.

UNCORRECTED BLOWS / FT ■ (10 20 30 40)
SALINITY (ppt) △
WATER CONTENT (PERCENT) W_P — W — W_L (10 20 30 40)

NOTES / TESTS / WATER LEVELS / GRAPHIC

flush-mounted monitoring well cap

Gravel = 33%, Sand = 43%, Fines = 23.9%

Two (2) 1-inch sch.40 PVC pipes, backfilled with drill cuttings

Two (2) 1-inch sch.40 PVC pipes; (1) field slotted, (1) sealed

Golder Associates

DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Figure A-13

RECORD OF BOREHOLE TH-10-ROW

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/13/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

DEPTH (ft)	BORING METHOD	DESCRIPTION (VEGETATION: n/a, located in railroad cut. Young spruce and alder nearby.)	ICE BOND	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC / ATT (inch)	NOTES / TESTS / WATER LEVELS / GRAPHIC
20	3.5 inch I.D. Hollow Stem Auger			GP-GMs			7A	HD	16-18-9	27	8/8	
		20.7 - 22.5 Thawed (confirm), dense to very dense, wet, brownish gray, Sandy Silty GRAVEL with Cobbles; little fines, possible boulders (GP-GMs to GMs) +Becoming wet at 20.7 ft.		GP-GMs to GMs		20.7	7B	HD	--		10/10	20.7 ft WD
		22.5 - 25.0 Thawed (confirm), dry to moist, greenish gray with zones of beige, Completely Weathered (CW) BEDROCK; extremely weak rock (R0), only trace resemblance of rock structure remains, contains fragments of medium strong rock, but is mostly compressible by hand (CW-Bx) [Birch Creek Schist]		CW-Bx		22.5	8	HD	15-26/6"	R	12/12	
25		Borehole completed at 25.0 ft.										

UNCORRECTED BLOWS / FT ■ (10, 20, 30, 40); SALINITY (ppt) △; WATER CONTENT (PERCENT) W_P — W — W_L (10, 20, 30, 40); >>

NOTES:
1) Groundwater encountered at 20.7 ft while drilling (WD). It is suspected that groundwater may be perched and flowing on top of the weathered bedrock.

2) Ice content is estimated visually, based on volume.

3) Sampler blow counts in frozen and/or oversized materials are not representative (n/r) and do not necessarily correlate to density. Where noted "R" indicates sampler refusal, defined as greater than 50 blows per 6 inches.

4) High drilling resistance within CW-Bx requires high auger torque. This results in very hot center rod bit.

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DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Figure A-13

RECORD OF BOREHOLE TH-11-ROW

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/14/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

BORING METHOD: 3.5 inch I.D. Hollow Stem Auger

VEGETATION: tundra, tussocks, short grass and brush, and moderately thick forested with spruce.

SOIL PROFILE

DESCRIPTION	ICE BOND	USCS	ELEV. / DEPTH (ft)
0.0 - 0.7 Frozen, wet (over-saturated/soupy) when thawed, dark brown, Vegetative (Tundra) Mat; well bonded (Org.)	Frozen	Org.	0.7
0.7 - 6.5 Frozen, moist when thawed, brownish gray, Sandy Silty GRAVEL; little to some fines, few grading to trace organics, possible cobbles, fine to coarse-grained mostly round, low plasticity, well bonded with approximately up to 5% visible ice by volume (GMs, Vx-Nbe) +Cobble(s) at 6.5 ft.	Frozen	GMs	6.5
6.5 - 11.5 Thawed, dense to very dense, Sandy Silty GRAVEL with Cobbles; fine to coarse-grained mostly round, low plasticity (GMs)		GMs	11.5
11.5 - 17.0 Thawed, loose, moist to wet, black, gray, and dark brown, ORGANIC SILT mixed with SILT; nonplastic, strong organic odor (OL+ML)		OL+ML	17.0
17.0 - 19.0 Frozen, wet when thawed, black, gray, and dark brown, ORGANIC SILT mixed with SILT; nonplastic, strong organic odor, well bonded (OL+ML)	Frozen	OL+ML	19.0
19.0 - 20.0 Frozen, Cobbles and/or boulder; well bonded	Frozen		

Log continued on next page

SAMPLES

NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC / ATT (inch)
1	HD	14-20-7/1"	R	13/13
2	HD	25-22		12/12
3	HD	27-27		12/12
4	HD	30-30		12/12
5A	HD	31-36		6/6
5B	HD	--		6/6

UNCORRECTED BLOWS / FT ■ (10, 20, 30, 40)
SALINITY (ppt) △
WATER CONTENT (PERCENT) W_P — W — W_L (10, 20, 30, 40)

NOTES / TESTS / WATER LEVELS / GRAPHIC

flush-mounted monitoring well cap

Gravel = 41%, Sand = 31%, Fines = 27.6%

OLI = 4%

1-inch sch.40 PVC pipes, backfilled with drill cuttings

DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Golder Associates

Figure A-14

RECORD OF BOREHOLE TH-11-ROW

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/14/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

DEPTH (ft)	BORING METHOD	SOIL PROFILE — DESCRIPTION (VEGETATION: tundra, tussocks, short grass and brush, and moderately thick forested with spruce.)	ICE BOND	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	SAMPLES NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC / ATT (inch)	UNCORRECTED BLOWS / FT ■ 10 20 30 40; SALINITY (ppt) △; WATER CONTENT (PERCENT) W_P — W — W_L 10 20 30 40	NOTES TESTS WATER LEVELS GRAPHIC
20	3.5 inch I.D. Hollow Stem Auger	20.0 - 31.3 Frozen, moist to wet when thawed, brownish gray, Silty Sandy GRAVEL with Cobbles; possible boulders, fine to coarse-grained mostly rounded, to sub-angular, low plasticity, well bonded with approximately up to 5% visible ice by volume (GMs, Vx-Nbe)		GMs		20.0	6	HD	45-20/2"	R	8/8	>>	
							+Sample 6: sampler pounding on oversized particle(s); blows n/r.						
25							7	HD	34-30/2"	R	8/8	>>	
							+Sample 7: sampler pounding on oversized particle(s); blows n/r.						
30							8	HD	36-36-40/3"	R	15/16	>>	
		Borehole completed at 31.3 ft.					+Sample 8: sampler pounding on oversized particle(s); blows n/r.						

NOTES:
1) No groundwater encountered while drilling.

2) Ice content is estimated visually, based on volume.

3) Sampler blow counts in frozen and/or oversized materials are not representative (n/r) and do not necessarily correlate to density. Where noted "R" indicates sampler refusal, defined as greater than 50 blows per 6 inches.

4) Soil unit and thermal state between 17 and 19 ft if inferred based on drilling action and auger cuttings.

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DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Figure A-14

RECORD OF BOREHOLE TH-12-ROW

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

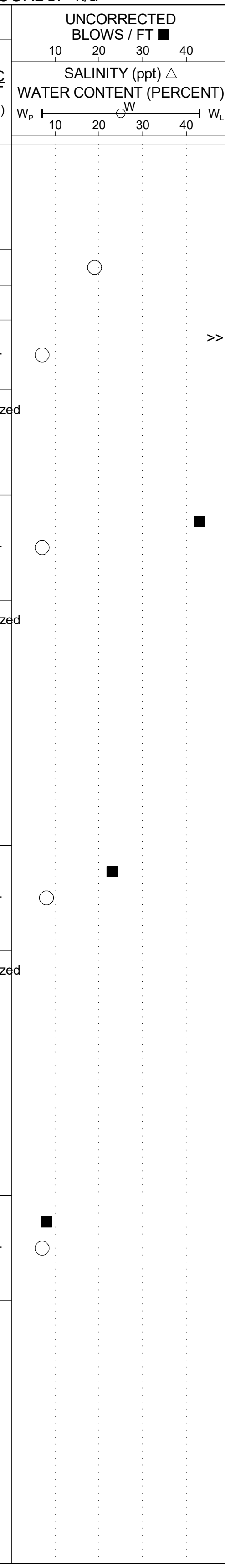
CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/14/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

Boring method: 3.5 inch I.D. Hollow Stem Auger

VEGETATION: tundra, tussocks, short grass and brush, and moderately thick forested with spruce.

Depth (ft)	Description	Ice Bond	USCS	Elev. / Depth (ft)	Sample Number	Type	Blows per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	Blows per ft	REC / ATT (inch)	Notes / Tests / Water Levels / Graphic
0	0.0 - 1.0 Frozen, wet (over-saturated/soupy) when thawed, dark brown, Vegetative (Tundra) Mat; well bonded (Org., Vx)	Frozen	Org.							flush-mounted monitoring well cap
	1.0 - 2.5 Frozen, wet (over-saturated/soupy) when thawed, dark brown w/ gray, Organic Vegetation + PEAT + ORGANIC SILT mixed with SILT; organic rooty / fibrous vegetation, nonplastic, organic odor, well bonded (Org.+Pt+OL+ML, Vx)	Frozen	Org.+ Pt+ OL+ ML	1.0	1	AG				
	2.5 - 7.0 Frozen, moist when thawed, brownish gray, Sandy Silty GRAVEL with Cobbles; fine to coarse-grained mostly rounded to sub-angular, nonplastic, well bonded with approximately 5% visible ice by volume (GMs, Vx)	Frozen	GMs	2.5	2	HD	20-30/6"	R	12/12	
	+Sample 2: sampler pounding on oversized particle(s); blows n/r.									
5					3	HD	17-23-20	43	18/18	
	+Sample 3: sampler pounding on oversized particle(s); blows n/r.									
	7.0 - 12.0 Thawed, dense, moist, gray, Sandy Silty GRAVEL with Cobbles; nonplastic (GMs)		GMs	7.0						
10					4	HD	17-10-13	23	12/18	Gravel = 50%, Sand = 26%, Fines = 24.0%
	+Sample 4: sampler pounding on oversized particle(s); blows n/r.									
	12.0 - 22.0 Thawed, medium dense becoming dense below 17 ft and very dense below 22 ft, moist, gray, Sandy Gravelly SILT; few to little cobbles, low plasticity (MLg)		MLg	12.0						1-inch sch.40 PVC pipes, backfilled with drill cuttings
15					5	HD	6-4-4	8	18/18	
20										



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DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Golder Associates

Figure A-15

RECORD OF BOREHOLE TH-12-ROW

PROJECT: ARRC MP 345-347.5 Realignment
PROJECT NUMBER: 1771891
LOCATION: Denali National Park, Denali, AK

CLIENT: Alaska Railroad Corporation (ARRC)
DRILLING DATE: 4/14/2017
EQUIPMENT: Geoprobe 7822DT, rubber tracks

DATUM: Ground Surface
ELEVATION: n/a
COORDS: n/a

DEPTH (ft)	BORING METHOD	DESCRIPTION (VEGETATION: tundra, tussocks, short grass and brush, and moderately thick forested with spruce.)	ICE BOND	USCS	GRAPHIC LOG	ELEV. / DEPTH (ft)	NUMBER	TYPE	BLOWS per 6 in (340 lb Hammer (Automatic) 30 in. Drop)	BLOWS PER FT	REC ATT (inch)	UNCORRECTED BLOWS / FT ■ / SALINITY (ppt) △ / WATER CONTENT (PERCENT)	NOTES TESTS WATER LEVELS GRAPHIC
20	3.5 inch I.D. Hollow Stem Auger	12.0 - 22.0 Thawed, medium dense becoming dense below 17 ft and very dense below 22 ft, moist, gray, Sandy Gravelly SILT; few to little cobbles, low plasticity (MLg) *(Continued)*		MLg			6	HD	10-15-10	25	18/18		
		22.0 - 26.3 Thawed, dense, moist, gray, Sandy Silty GRAVEL with Cobbles; nonplastic (GMs) +Cobble(s) and/or boulder 23 to 25 ft.		GMs		22.0							
25							7	HD	31-22-9/3"	R	15/16	>>	
		Borehole completed at 26.3 ft.											

+Sample 7: sampler pounding on oversized particle(s); blows n/r.

NOTES:
1) No groundwater encountered while drilling.

2) Ice content is estimated visually, based on volume.

3) Sampler blow counts in frozen and/or oversized materials are not representative (n/r) and do not necessarily correlate to density. Where noted "R" indicates sampler refusal, defined as greater than 50 blows per 6 inches.

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DEPTH SCALE: 1 inch to 2.5 feet
DRILLING CONTRACTOR: Discovery Drilling Inc.
DRILLER: DJ Wardwell

LOGGED: T. Ross
CHECKED: E. Cannon
CHECK DATE: 05/31/2017

Figure A-15

APPENDIX B
LABORATORY TESTING RESULTS

Golder Associates

TABLE B-1: SAMPLE SUMMARY

Client: Alaska Railroad Corporation (ARRC)	**Project No.:** 1771891		
Project: ARRC MP 345-347.5 Realignment			
Location: Denali National Park, Denali, AK	**Reviewed By:** T. Trosper		**Date:** 5/31/2017

SAMPLING DATA							CLASSIFICATION AND INDEX TEST RESULTS									
SAMPLE LOCATION	SAMPLE NUMBER	DEPTH (ft) TOP	DEPTH (ft) BOTTOM	RECOVERY (%)	SAMPLE TYPE	BLOWS PER FOOT	NATURAL MOISTURE CONTENT (%)	LIQUID LIMIT (LL) (%)	PLASTIC LIMIT (PL) (%)	PLASTICITY INDEX (PI) (%)	GRADATION (%) GRAVEL	GRADATION (%) SAND	GRADATION (%) FINES (SILT & CLAY)	ORGANIC CONTENT (%)	DESCRIPTION (USCS)	TESTS / OTHER TESTS
TH-1-Park	1	0.5	1.0		AG		689									
TH-1-Park	2	1.5	2.0		AG		436									
TH-1-Park	3	2.5	4.0	100	HD	33	49									
TH-1-Park	4	5.0	6.5	100	HD	29	94									
TH-1-Park	5	7.5	9.0	100	HD	29	57									
TH-1-Park	6	10.0	11.5	100	HD	35	71							4		
TH-1-Park	7A	15.0	15.7	96	HD	R	20									
TH-1-Park	7B	15.7	16.3	97	HD		15				0	67	32.5		SM	
TH-1-Park	8A	20.0	21.1	98	HD	36	20									
TH-1-Park	8B	21.1	21.5	105	HD		15									
TH-1-Park	9	25.0	26.5	100	HD		11									
TH-1-Park	10	30.0	31.5	100	HD	31	28									
TH-2-Park	1	0.5	1.0		AG		168									
TH-2-Park	2A	2.5	2.8	110	HD	R	138									
TH-2-Park	2B	2.8	3.8	100	HD		57									
TH-2-Park	3A	5.0	5.9	102	HD	R	95									
TH-2-Park	3B	5.9	6.4	10	HD		38									
TH-2-Park	4	7.5	8.7	125	HD	R	17				30	42	27.5		SM	
TH-2-Park	5A	10.0	10.6	97	HD	38	26									
TH-2-Park	5B	10.6	11.5	102	HD		16									
TH-2-Park	6	15.0	15.8	104	HD	R	6									
TH-2-Park	7	20.0	21.0	100	HD	R	8									
TH-2-Park	8	25.0	26.3	102	HD	R	9									
TH-2-Park	9	30.0	30.7	96	HD	R	8									
TH-3-ROW	1	0.5	1.0		AG		76									
TH-3-ROW	2A	2.5	3.7	98	HD	13	216									
TH-3-ROW	2B	3.7	4.0	110	HD		24									
TH-3-ROW	3	5.0	6.5	67	HD	7	118									
TH-3-ROW	4	7.5	9.0	67	HD	8	14									
TH-3-ROW	5	10.0	11.5	45	HD	9	10				24	45	31.6		SM	MA
TH-3-ROW	6	15.0	16.5	100	HD	14	7									
TH-3-ROW	7	20.0	21.5	67	HD	8	8									

1771891 ARRC MP 345-347.GPJ LIBRARY-ANC(10-11-17).GLB [ANC_SAMPLE_SUMMARY] TRoss 11/30/17

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Golder Associates

TABLE B-1: SAMPLE SUMMARY

Client: Alaska Railroad Corporation (ARRC)		**Project No.:** 1771891	
Project: ARRC MP 345-347.5 Realignment			
Location: Denali National Park, Denali, AK		**Reviewed By:** T. Trosper	**Date:** 5/31/2017

SAMPLING DATA							CLASSIFICATION AND INDEX TEST RESULTS										
SAMPLE LOCATION	SAMPLE NUMBER	DEPTH (ft) TOP	DEPTH (ft) BOTTOM	RECOVERY (%)	SAMPLE TYPE	BLOWS PER FOOT	NATURAL MOISTURE CONTENT (%)	LIQUID LIMIT (LL) (%)	PLASTIC LIMIT (PL) (%)	PLASTICITY INDEX (PI) (%)	GRADATION (%) GRAVEL	GRADATION (%) SAND	GRADATION (%) FINES (SILT & CLAY)	ORGANIC CONTENT (%)	DESCRIPTION (USCS)	TESTS / OTHER TESTS
TH-3-ROW	8	25.0	26.5	67	HD	8	8									
TH-3-ROW	9	30.0	31.5	78	HD	19	7									
TH-3-ROW	10	35.0	36.5	100	HD	11	7									
TH-3-ROW	11	40.0	41.5	100	HD	23	9									
TH-3-ROW	12	45.0	46.5	100	HD	34	9									
TH-4-Park	1	1.0	1.5		AG		503									
TH-4-Park	2A	2.5	3.1	97	HD	31	136									
TH-4-Park	2B	3.1	4.0	102	HD		50									
TH-4-Park	3	5.0	6.5	100	HD	33	64									
TH-4-Park	4	7.5	9.0	100	HD	37	44									
TH-4-Park	5	10.0	11.2	98	HD	R	24									
TH-4-Park	6	20.0	20.3	100	HD	R	13				35	57	8.0		SP-SM	
TH-4-Park	7	25.0	25.4	100	HD	R	9									
TH-4-Park	8	30.0	30.2	100	HD	R	12									
TH-4-Park	9	35.0	35.1	0	HD	R										
TH-5-Park	1	1.0	1.5		AG		896									
TH-5-Park	2A	2.5	2.8	110	HD	28	66									
TH-5-Park	2B	2.8	4.0	98	HD		60									
TH-5-Park	3A	5.0	5.7	96	HD		28									
TH-5-Park	3B	5.7	6.0	110	HD		10									
TH-5-Park	4	10.0	10.5	66	HD	R	3				52	37	10.8		GP-GM	
TH-5-Park	5	15.0	15.1	80	HD	R	7									
TH-5-Park	6	20.0	20.2	85	HD	R	8									
TH-5-Park	7	25.0	25.3	57	HD	R	6									
TH-5-Park	8	30.0	30.3	83	HD	R	9									
TH-5-Park	9	35.0	35.2	85	HD	R	6									
TH-5-Park	10	40.0	40.3	83	HD	R	10									
TH-6-ROW	1	1.0	1.5		AG		234									
TH-6-ROW	2	2.5	3.5	100	HD		10									
TH-6-ROW	3	5.0	6.2	98	HD	R	9				30	38	31.6		SM	
TH-6-ROW	4	7.5	9.0	100	HD	54	7									
TH-6-ROW	5	10.0	11.5	100	HD	44	8									

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TABLE B-1: SAMPLE SUMMARY

Client: Alaska Railroad Corporation (ARRC)		**Project No.:** 1771891	
Project: ARRC MP 345-347.5 Realignment			
Location: Denali National Park, Denali, AK		**Reviewed By:** T. Trosper	**Date:** 5/31/2017

SAMPLING DATA							CLASSIFICATION AND INDEX TEST RESULTS									
SAMPLE LOCATION	SAMPLE NUMBER	DEPTH (ft)		RECOVERY (%)	SAMPLE TYPE	BLOWS PER FOOT	NATURAL MOISTURE CONTENT (%)	LIQUID LIMIT (LL) (%)	PLASTIC LIMIT (PL) (%)	PLASTICITY INDEX (PI) (%)	GRADATION (%)			ORGANIC CONTENT (%)	DESCRIPTION (USCS)	TESTS / OTHER TESTS
		TOP	BOTTOM								GRAVEL	SAND	FINES (SILT & CLAY)			
TH-6-ROW	6	15.0	15.1	80	HD	R	9									
TH-7-ROW	1	1.5	2.0		AG		454									
TH-7-ROW	2	2.5	3.8	96	HD	R	15									
TH-7-ROW	3	5.0	6.4	101	HD	R	10									
TH-7-ROW	4	7.0	7.9	92	HD	R	13									
TH-7-ROW	5	10.0	11.1	98	HD	R	12				42	33	24.7		GM	
TH-7-ROW	6	15.0	15.7	96	HD	R	3									
TH-7-ROW	7	20.0	20.7	96	HD	R	5									
TH-7-ROW	8A	22.0	25.0	100	HD-slough		10									
TH-7-ROW	8B	25.0	25.9	92	HD	R	7									
TH-8-ROW	1	1.0	1.5	100	AG		10									
TH-8-ROW	2	5.0	5.5	100	AG		2				46	37	17.1		GM	
TH-8-ROW	3	7.0	7.2	85	HD	R	5									
TH-8-ROW	4	8.5	9.0	100	AG		16									
TH-8-ROW	5A	10.0	10.6	97	HD	R	9									
TH-8-ROW	5B	10.6	21.6	105	HD		9									
TH-8-ROW	6	15.0	16.0	100	HD	R	5									
TH-9-ROW	1	1.0	1.5	100	AG		4				51	39	10.4		GP-GM	
TH-9-ROW	2	3.0	4.5	100	HD	29	2									
TH-9-ROW	3	5.0	6.5	100	HD	60	1									
TH-9-ROW	4	7.5	9.0	100	HD	52	2									
TH-9-ROW	5	10.0	11.5		HD	29	1									
TH-9-ROW	6	15.0	16.5	100	HD	18	2									
TH-9-ROW	7	20.0	21.5	100	HD	24	2									

1771891 ARRC MP 345-347.GPJ LIBRARY-ANC(10-11-17).GLB [ANC_SAMPLE_SUMMARY] TRoss 11/30/17

Golder Associates Inc.
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TABLE B-1: SAMPLE SUMMARY

Client: Alaska Railroad Corporation (ARRC)	**Project No.:** 1771891		
Project: ARRC MP 345-347.5 Realignment			
Location: Denali National Park, Denali, AK	**Reviewed By:** T. Trosper	**Date:** 5/31/2017	

SAMPLING DATA							CLASSIFICATION AND INDEX TEST RESULTS									
SAMPLE LOCATION	SAMPLE NUMBER	DEPTH (ft)		RECOVERY (%)	SAMPLE TYPE	BLOWS PER FOOT	NATURAL MOISTURE CONTENT (%)	LIQUID LIMIT (LL) (%)	PLASTIC LIMIT (PL) (%)	PLASTICITY INDEX (PI) (%)	GRADATION (%)			ORGANIC CONTENT (%)	DESCRIPTION (USCS)	TESTS / OTHER TESTS
		TOP	BOTTOM								GRAVEL	SAND	FINES (SILT & CLAY)			
Bulk 1	BULK	0.0	1.0		GB		0				57	41	2.8		GP	SA
	1															
TH-10-ROW	1	1.0	2.0		AG		4									
TH-10-ROW	2	2.5	3.4	92	HD	R	4									
TH-10-ROW	3	5.0	6.0	100	HD		7				33	43	23.9		SM	
TH-10-ROW	4	7.0	7.5		AG		6									
TH-10-ROW	5	10.0	11.5	100	HD	21	3									
TH-10-ROW	6	15.0	15.9	94	HD	R	7									
TH-10-ROW	7A	20.0	20.7	96	HD	27	4									
TH-10-ROW	7B	20.7	21.5	100	HD		10									
TH-10-ROW	8	24.0	25.0	100	HD	R	8									
TH-11-ROW	1	2.5	4.0	98	HD	R	10				41	31	27.6		GM	
TH-11-ROW	2	5.0	6.0	100	HD		8									
TH-11-ROW	3	7.5	8.5	100	HD		9									
TH-11-ROW	4	10.0	11.0	100	HD		8									
TH-11-ROW	5A	15.0	15.5	100	HD		19							4		
TH-11-ROW	5B	15.5	16.0	100	HD		18									
TH-11-ROW	6	20.0	20.7	96	HD	R	35									
TH-11-ROW	7	25.0	25.7	96	HD	R	8									
TH-11-ROW	8	30.0	31.3	96	HD	R	9									
TH-12-ROW	1	1.5	2.0	100	AG		19									
TH-12-ROW	2	2.5	3.5	100	HD	R	7									
TH-12-ROW	3	5.0	6.5	100	HD	43	7									
TH-12-ROW	4	10.0	11.5	67	HD	23	8				50	26	24.0		GM	
TH-12-ROW	5	15.0	16.5	100	HD	8	7									
TH-12-ROW	6	20.0	21.5	100	HD	25	8									
TH-12-ROW	7	25.0	26.3	96	HD	R	6									

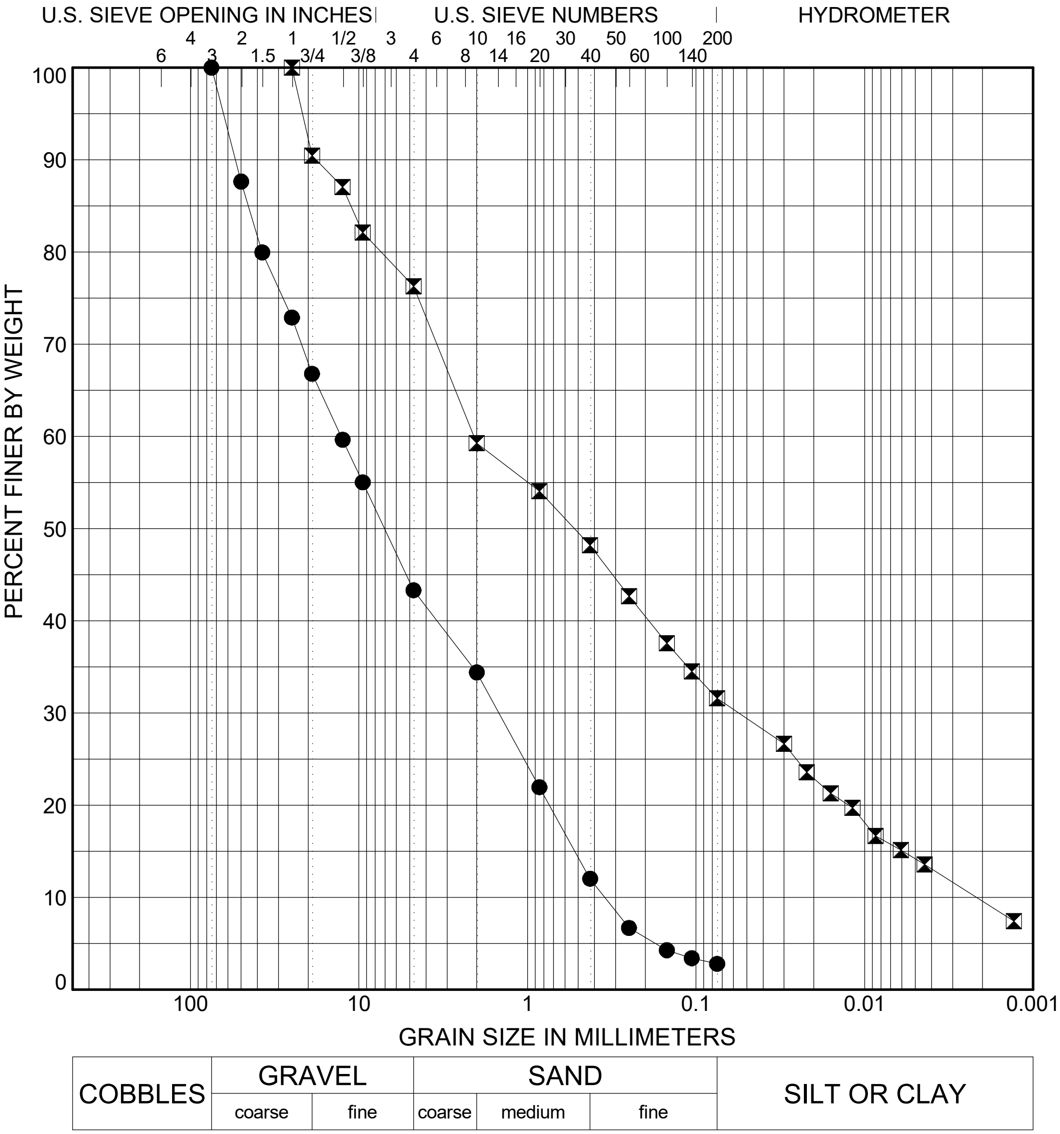
Golder Associates Inc.
2121 Abbott Road, Suite 100, Anchorage, AK
Tel: (907) 344-6001 Fax: (907) 344-6011 www.golder.com

Golder Associates

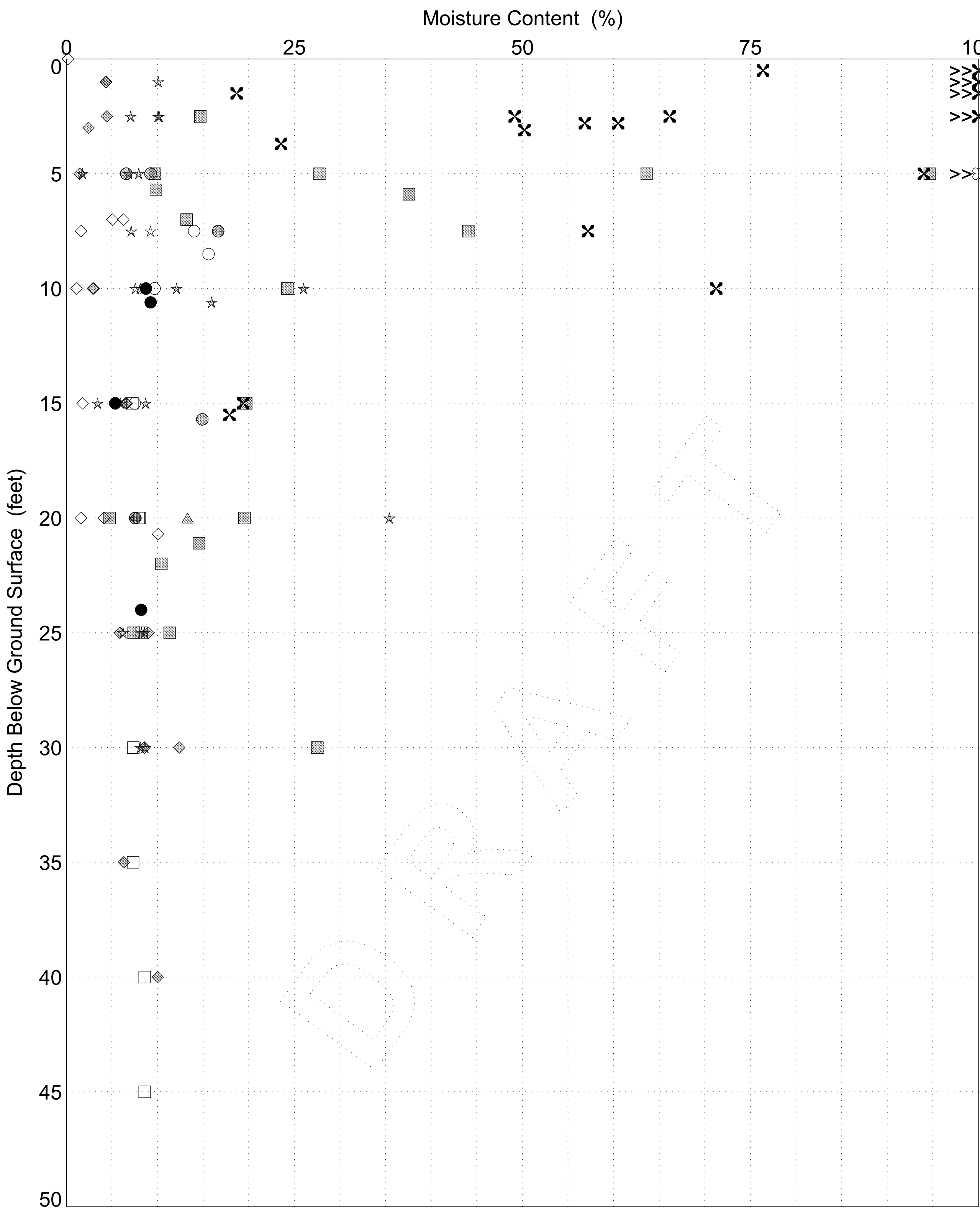
FIGURE B-1: SUMMARY OF PARTICLE SIZE DISTRIBUTION RESULTS

Reference(s)
ASTM D422
ASTM D6913

Client: Alaska Railroad Corporation (ARRC)
Location: Denali National Park, Denali, AK
Project: ARRC MP 345-347.5 Realignment
Project No.: 1771891
Reviewed By: T. Trosper
Date: 5/31/2017



	●	⧗		
Sample Location	Bulk 1	TH-3-ROW		
Sample #	BULK 1	5		
Depth (ft)	0.0	10.0		
Total Sample (g)	14023.9	741.7		
MC (%)	0.2	9.7		
LL				
PI				
% Passing Sieve (interpolated if not measured) 3"	100			
2"	88			
1.5"	80			
1"	73	100		
3/4"	67	90		
1/2"	60	87		
3/8"	55	82		
#4	43	76		
#10	34	59		
#20	22	54		
#40	12	48		
#60	7	43		
#100	4	38		
#140	3	35		
#200	3	32		
% <0.02 mm		23		
% Gravel	57	24		
% Sand	41	45		
% Fines	3	32		
D100	75	25		
D60	12.76	2.08		
D50	7.06	0.53		
D30	1.48	0.06		
D10	0.35	0		
Cc	0.5	0.7		
Cu	36.7	960.4		
USCS Classification	poorly graded sandy gravel with cobbles, trace fines (GP)	silty sand with gravel and clay (SM)		



□ CL,CH,ML,CL-ML ○ SM,SC △ SP,SW,SP-SM ◇ GP,GW,GP-GM ☆ GM,GC ✕ PT,OL,OH ICE,ICE+soil OTHER

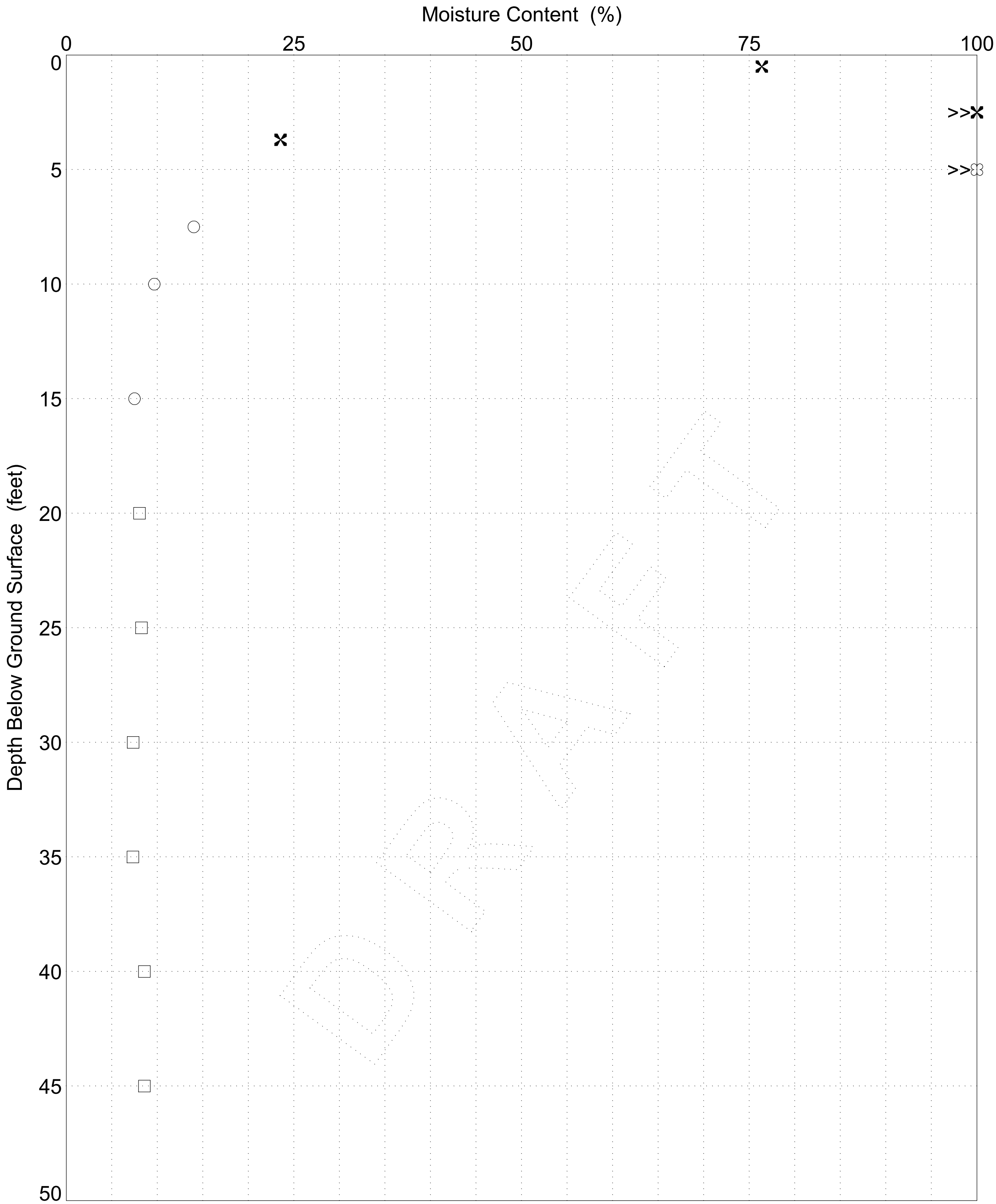
NOTE: FILLED SOIL SYMBOL INDICATES FROZEN AND BONDED CONDITION

CLIENT	PROJECT
ALASKA RAILROAD CORPORATION (ARRC)	ARRC MP 345-347.5 REALIGNMENT DENALI NATIONAL PARK, DENALI, AK

CONSULTANT		
Golder Associates	YYYY-MM-DD	2017-11-07
	PREPARED	TER/TAV
	DESIGN	N/A
	REVIEW	TER
	APPROVED	--

TITLE
MOISTURE CONTENT VS. DEPTH
ALL BOREHOLES

PROJECT No.	CONTROL	Rev.	FIGURE
1771891		----	B-2



□ CL,CH,ML,CL-ML ○ SM,SC △ SP,SW,SP-SM ◇ GP,GW,GP-GM ☆ GM,GC ✕ PT,OL,OH ICE,ICE+soil OTHER

NOTE: FILLED SOIL SYMBOL INDICATES FROZEN AND BONDED CONDITION

CLIENT
ALASKA RAILROAD CORPORATION (ARRC)

PROJECT
ARRC MP 345-347.5 REALIGNMENT

DENALI NATIONAL PARK, DENALI, AK

CONSULTANT

Golder Associates

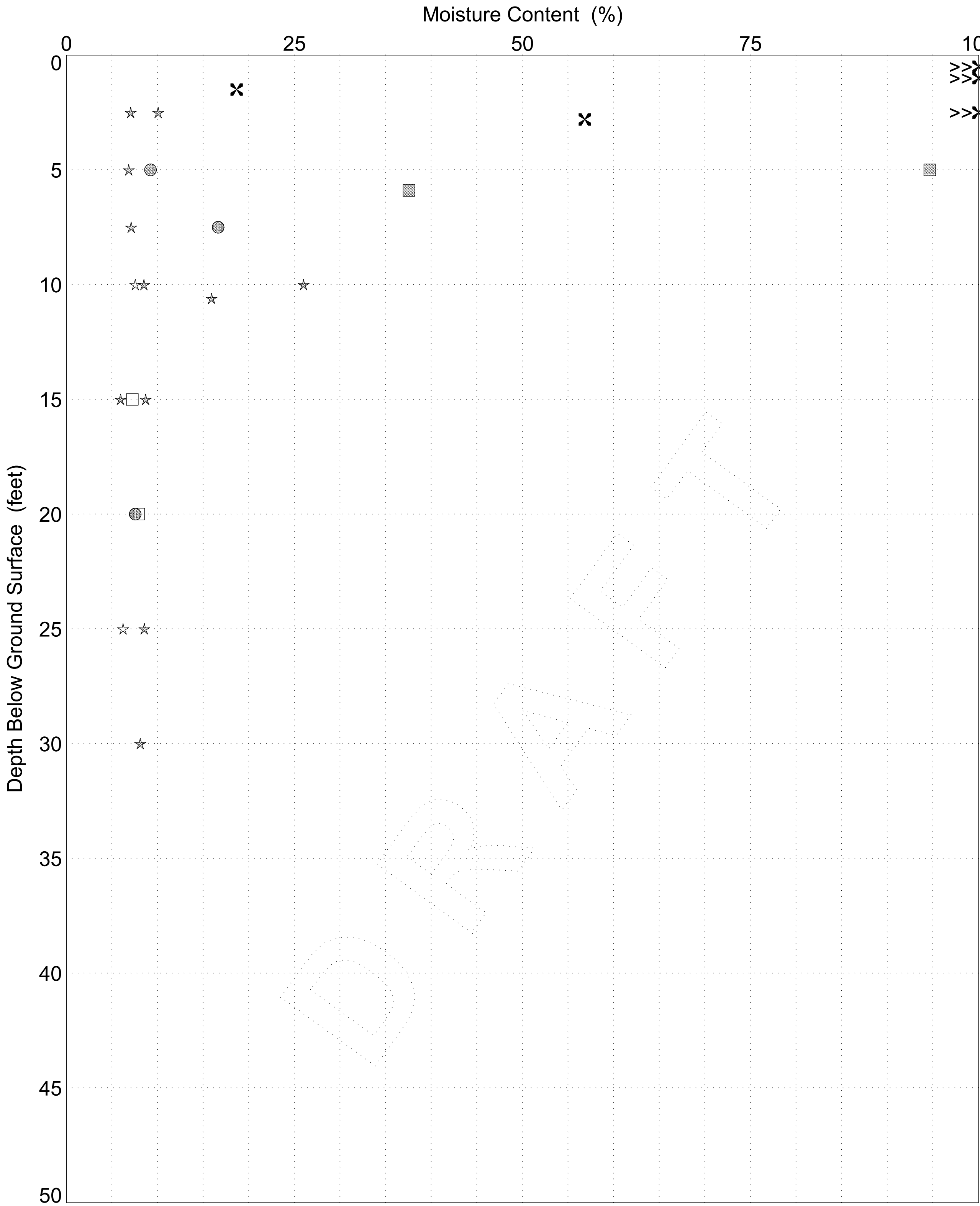
YYYY-MM-DD	2017-11-07
PREPARED	TER/TAV
DESIGN	N/A
REVIEW	TER
APPROVED	

TITLE
MOISTURE CONTENT VS. DEPTH
BOREHOLE TH-ROW-3 (Qo over Qmm)

PROJECT No.	CONTROL	Rev.	FIGURE
1771891		----	B-3

1771891 ARRC MP 345-347.GPJ LIBRARY-ANC(10-11-17).GLB [ANC WATER CONTENT] TRoss 11/7/17

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
1 in.
0



☐ **CL,CH,ML,CL-ML** ○ **SM,SC** △ **SP,SW,SP-SM** ◇ **GP,GW,GP-GM** ☆ **GM,GC** ✕ **PT,OL,OH** **ICE,ICE+soil** **OTHER**

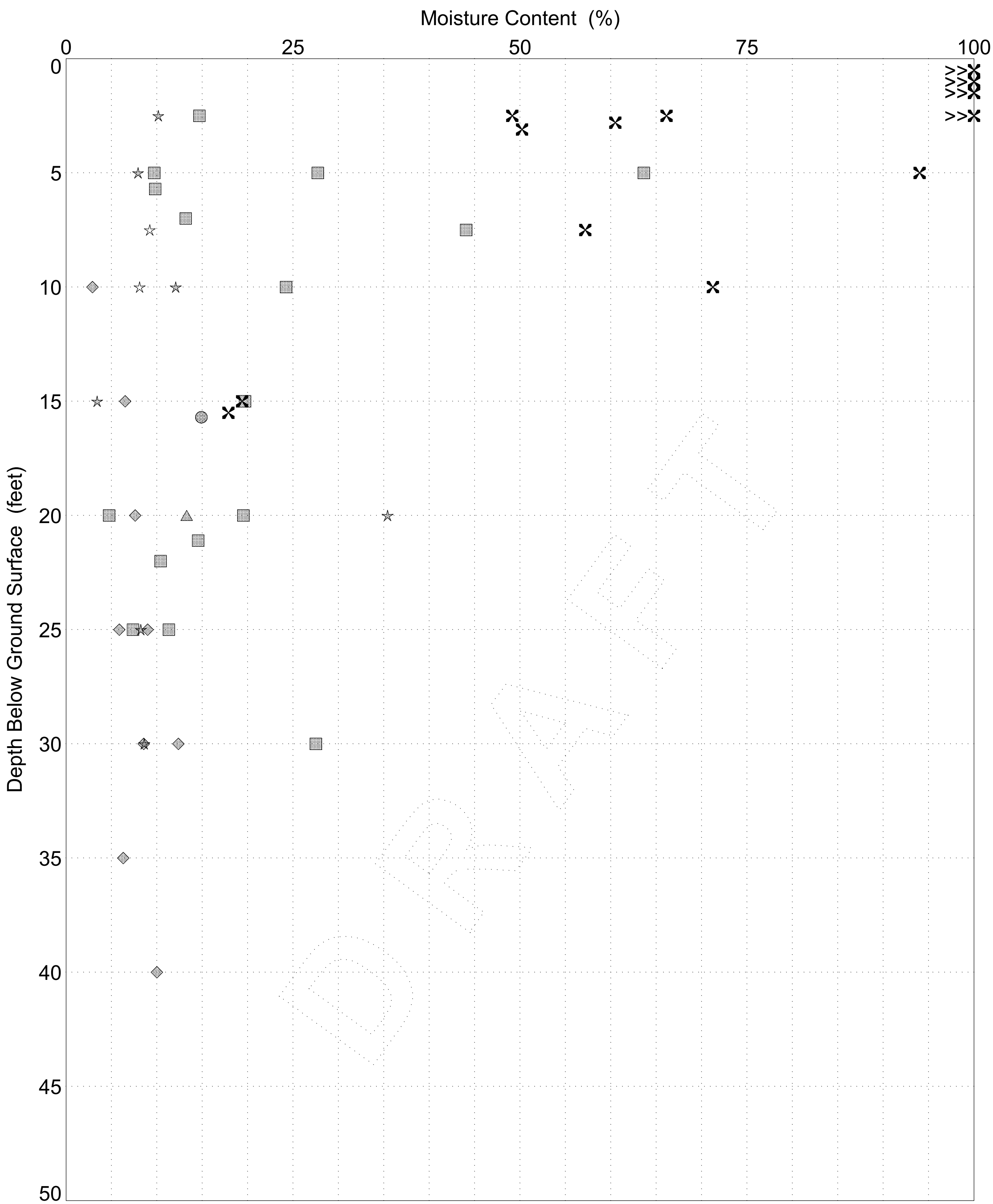
NOTE: FILLED SOIL SYMBOL INDICATES FROZEN AND BONDED CONDITION

CLIENT ALASKA RAILROAD CORPORATION (ARRC)	PROJECT ARRC MP 345-347.5 REALIGNMENT DENALI NATIONAL PARK, DENALI, AK

CONSULTANT		
Golder Associates	YYYY-MM-DD	2017-11-07
	PREPARED	TER/TAV
	DESIGN	N/A
	REVIEW	TER
	APPROVED	

TITLE
MOISTURE CONTENT VS. DEPTH
BOREHOLES TH-2-Park, TH-12-ROW, & TH-6-ROW (Qmf)

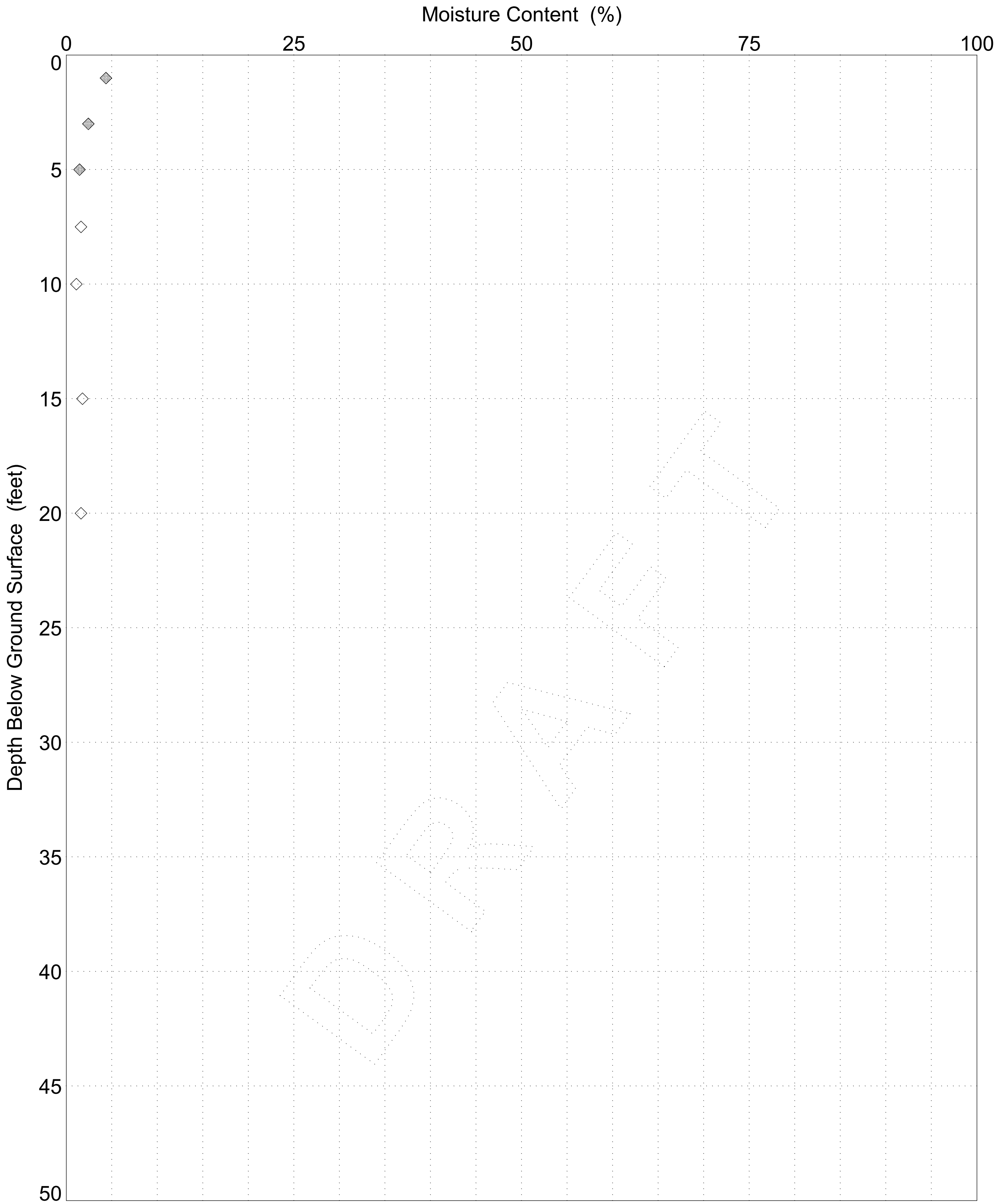
PROJECT No.	CONTROL	Rev.	FIGURE
1771891		----	B-4



☐ **CL,CH,ML,CL-ML** ○ **SM,SC** △ **SP,SW,SP-SM** ◇ **GP,GW,GP-GM** ☆ **GM,GC** ✕ **PT,OL,OH** **ICE,ICE+soil** **OTHER**

NOTE: FILLED SOIL SYMBOL INDICATES FROZEN AND BONDED CONDITION

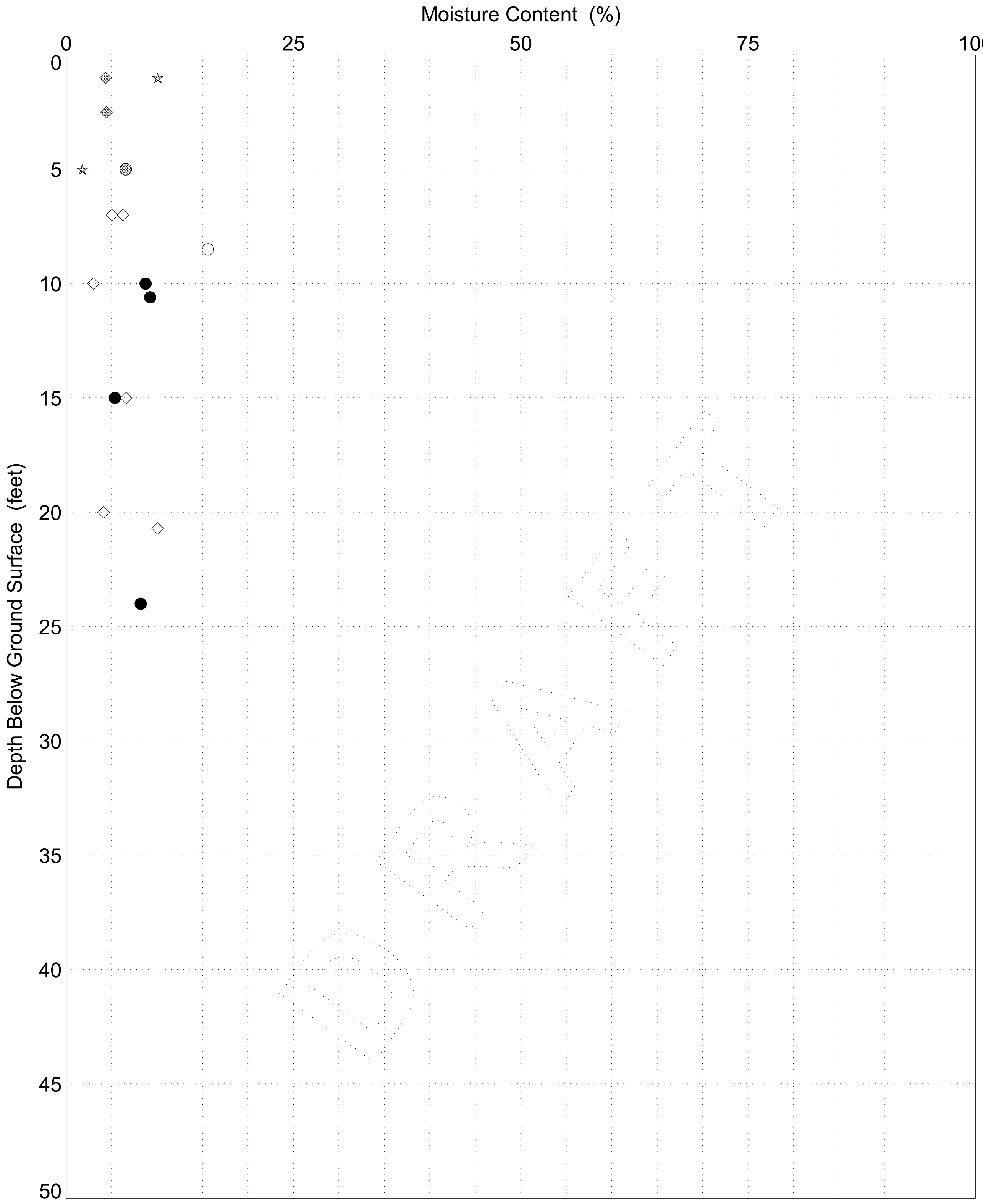
CLIENT ALASKA RAILROAD CORPORATION (ARRC)	PROJECT ARRC MP 345-347.5 REALIGNMENT DENALI NATIONAL PARK, DENALI, AK
CONSULTANT Golder Associates YYYY-MM-DD 2017-11-07 PREPARED TER/TAV DESIGN N/A REVIEW TER APPROVED	TITLE **MOISTURE CONTENT VS. DEPTH** **BOREHOLES TH-1-Park, TH-11-ROW, TH-7-ROW, TH-4-Park, & TH-5-Park (Qmm)** PROJECT No. 1771891 CONTROL Rev. ---- FIGURE B-5



□ **CL,CH,ML,CL-ML** ○ **SM,SC** △ **SP,SW,SP-SM** ◇ **GP,GW,GP-GM** ☆ **GM,GC** ✕ **PT,OL,OH** **ICE,ICE+soil** **OTHER**

NOTE: FILLED SOIL SYMBOL INDICATES FROZEN AND BONDED CONDITION

CLIENT ALASKA RAILROAD CORPORATION (ARRC)	PROJECT ARRC MP 345-347.5 REALIGNMENT DENALI NATIONAL PARK, DENALI, AK
CONSULTANT Golder Associates YYYY-MM-DD 2017-11-07 PREPARED TER/TAV DESIGN N/A REVIEW TER APPROVED	TITLE **MOISTURE CONTENT VS. DEPTH** **BOREHOLE TH-9-ROW (Qgo)**
	PROJECT No. 1771891 CONTROL Rev. ---- FIGURE B-6



□ CL,CH,ML,CL-ML ○ SM,SC △ SP,SW,SP-SM ◇ GP,GW,GP-GM ☆ GM,GC ✕ PT,OL,OH ICE,ICE+soil OTHER

NOTE: FILLED SOIL SYMBOL INDICATES FROZEN AND BONDED CONDITION

CLIENT
ALASKA RAILROAD CORPORATION (ARRC)

PROJECT
ARRC MP 345-347.5 REALIGNMENT

DENALI NATIONAL PARK, DENALI, AK

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-11-07
PREPARED	TER/TAV
DESIGN	N/A
REVIEW	TER
APPROVED	

TITLE
MOISTURE CONTENT VS. DEPTH
BOREHOLES TH-8-ROW & TH-10-ROW (Qm over BCS)

PROJECT No.	CONTROL	Rev.	FIGURE
1771891		----	B-7

1771891 ARRC MP 345-347.GPJ LIBRARY-ANC(10-11-17).GLB [ANC WATER CONTENT] TRoss 11/7/17

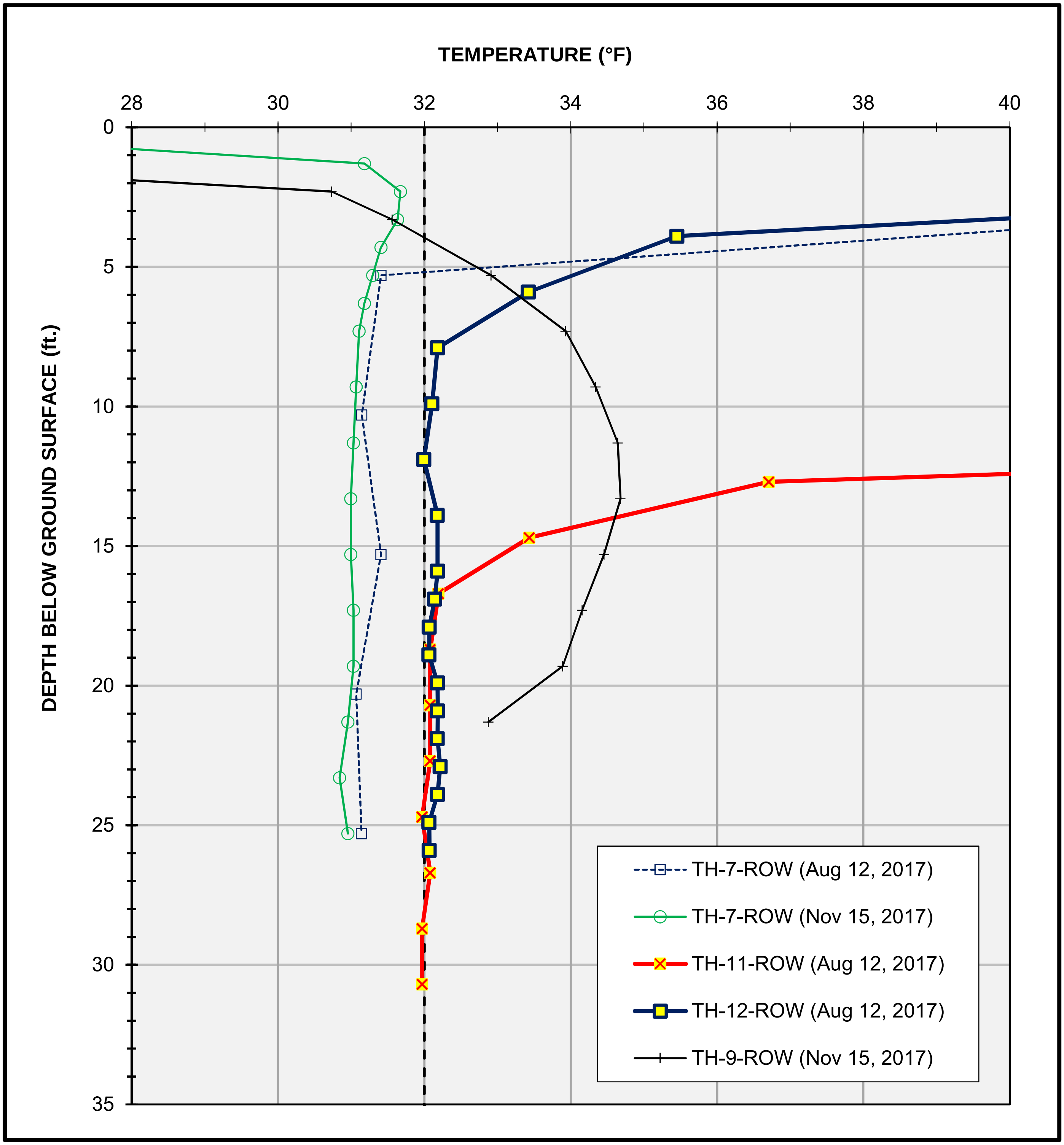
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

1 in.

0

APPENDIX C
GROUND TEMPERATURE MEASUREMENTS

ARRC MP 345 to 347.5 Rail Realignment - Denali Area



NOTES:

1) Temperature measurements taken using Digital Temperature Cables by BeadedStream. Temperature accuracy is +/- 0.2°F.

2) °F = degrees Fahrenheit.

Figure C-1

GROUND TEMPERATURE PLOT

ARRC / ARRC MP 345 to 347.5 Rail Realignment / Denali, AK

PROJECT NO.: 1771891 FILE: ARRC MP345-347 GroundTemps DATE: 11/15/17 DRAWN: TER REVIEW: TGK **Golder Associates**

APPENDIX D
SITE, TERRAIN, AND SAMPLE PHOTOS

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-1 Borehole: TH-1-Park View of Drill Site, four days after drilling (post snow melt)	
PHOTO D-2 Borehole: TH-1-Park Sample: 3	
PHOTO D-3 Borehole: TH-1-Park Sample: 4	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali

PHOTO D-4

Borehole: TH-1-Park
Sample: 5

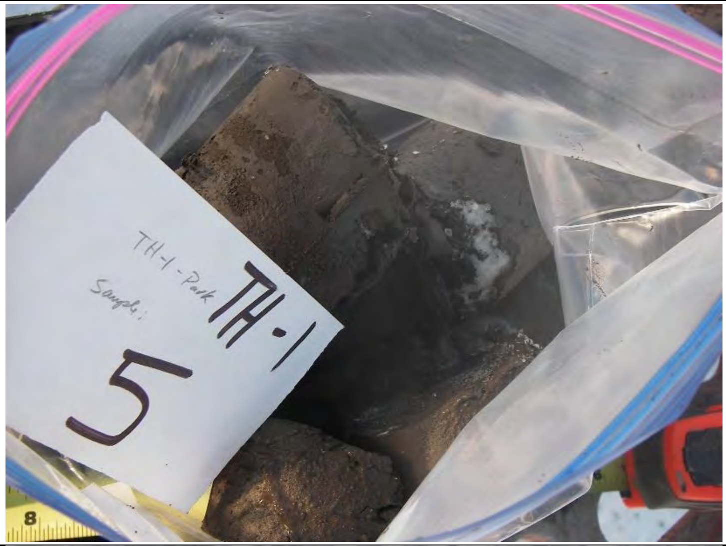


PHOTO D-5

Borehole: TH-1-Park
Sample: 6

PHOTO D-6

Borehole: TH-1-Park
Sample: 7

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-7 Borehole: TH-1-Park Sample: 8	
PHOTO D-8 Borehole: TH-1-Park Sample: 9	
PHOTO D-9 Borehole: TH-1-Park Sample: 10	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-10 Borehole: TH-2-Park View of Drill Site	
PHOTO D-11 Borehole: TH-2-Park Sample: 2A	
PHOTO D-12 Borehole: TH-2-Park Sample: 2B	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-13 Borehole: TH-2-Park Sample: 3A	
PHOTO D-14 Borehole: TH-2-Park Sample: 3B	
PHOTO D-15 Borehole: TH-2-Park Sample: 4	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-16 Borehole: TH-2-Park Sample: 5A	
PHOTO D-17 Borehole: TH-2-Park Sample: 5B	
PHOTO D-18 Borehole: TH-2-Park Sample: 6	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-19 Borehole: TH-2-Park Sample: 7	
PHOTO D-20 Borehole: TH-2-Park Sample: 8	
PHOTO D-21 Borehole: TH-2-Park Sample: 9	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-22 Borehole: TH-3-ROW View of Drill Site and Pond from Railroad Embankment	
PHOTO D-23 Borehole: TH-3-ROW View of Drill Site and Pond from Railroad Embankment	
PHOTO D-24 Borehole: TH-3-ROW View of Pond near Drill Site at toe of Railroad Embankment	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-25 Borehole: TH-3-ROW Drill Site	
PHOTO D-26 Borehole: TH-3-ROW Sample: 2A, 2B	
PHOTO D-27 Borehole: TH-3-ROW Sample: 3	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-28 Borehole: TH-3-ROW Sample: 4	
PHOTO D-29 Borehole: TH-3-ROW Sample: 5	
PHOTO D-30 Borehole: TH-3-ROW Sample: 6	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali

PHOTO D-31

Borehole: TH-3-ROW
Sample: 7

PHOTO D-32

Borehole: TH-3-ROW
Sample: 8

PHOTO D-33

Borehole: TH-3-ROW
Sample: 9

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali

PHOTO D-34

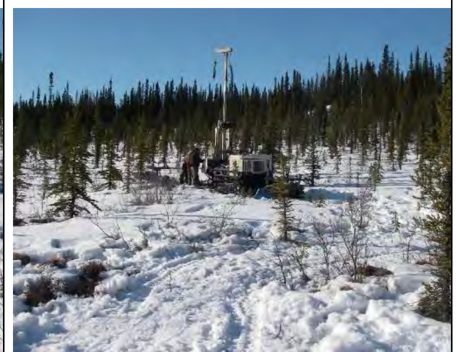
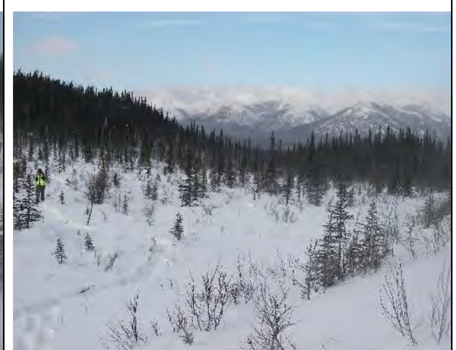
Borehole: TH-3-ROW
Sample: 10

PHOTO D-35

Borehole: TH-3-ROW
Sample: 11

PHOTO D-36

Borehole: TH-3-ROW
Sample: 12

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali		
PHOTO D-37 Borehole: TH-4-Park View of Drill Site		
PHOTO D-38 Boreholes: TH-4-Park and TH-5-Park View of Vegetation and Terrain between Borehole Locations		
PHOTO D-39 Borehole: TH-4-Park Sample: 2A, 2B		

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-40 Borehole: TH-4-Park Sample: 3	
PHOTO D-41 Borehole: TH-4-Park Sample: 4	
PHOTO D-42 Borehole: TH-4-Park Sample: 5	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali		
PHOTO D-43 Borehole: TH-4-Park Sample: 7 and 8	 	
PHOTO D-44 Borehole: TH-5-Park View of Vegetation Near Drill Site		
PHOTO D-45 Borehole: TH-5-Park Sample: 2	 	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-46 Borehole: TH-5-Park Sample: 3	
PHOTO D-47 Borehole: TH-6-ROW View of Drill Site	
PHOTO D-48 Borehole: TH-6-ROW Sample: 2	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-49 Borehole: TH-6-ROW Sample: 3	
PHOTO D-50 Borehole: TH-6-ROW Sample: 4	
PHOTO D-51 Borehole: TH-6-ROW Sample: 6	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-52 Borehole: TH-7-ROW View of Drill Site and Typical Vegetation	
PHOTO D-53 Borehole: TH-7-ROW View of Drill Site	
PHOTO D-54 Borehole: TH-7-ROW View of Drill Site from Highway	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-55 Borehole: TH-7-ROW View of Highway Near Borehole	
PHOTO D-56 Borehole: TH-7-ROW Sample: 2 (top of sample)	
PHOTO D-57 Borehole: TH-7-ROW Sample: 2 (bottom of sample)	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-58 Borehole: TH-7-ROW Sample: 3	
PHOTO D-59 Borehole: TH-7-ROW Sample: 4	
PHOTO D-60 Borehole: TH-7-ROW Sample: 5	

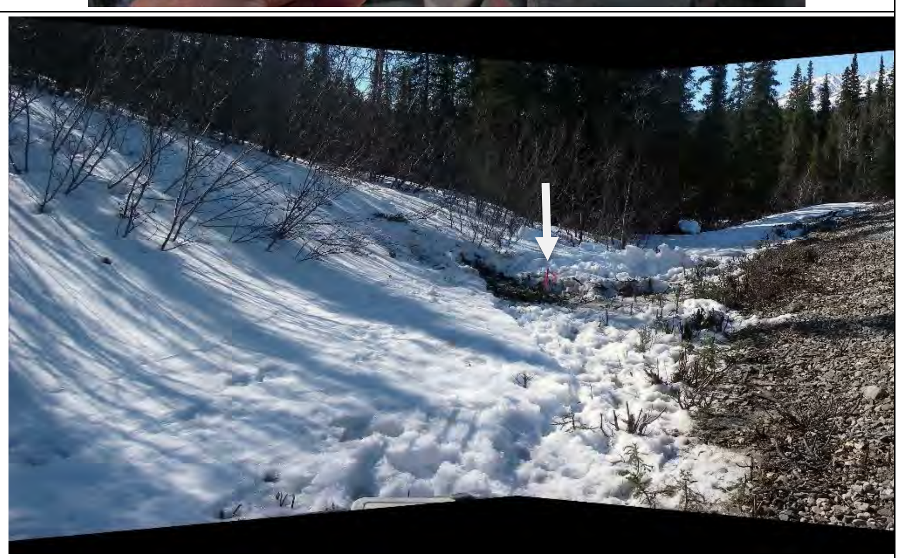
Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-61 Borehole: TH-7-ROW Sample: 6	
PHOTO D-62 Borehole: TH-7-ROW Sample: 7	
PHOTO D-63 Borehole: TH-7-ROW Sample: 8A (top of sample)	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-64 Borehole: TH-7-ROW Sample: 8B (bottom of sample)	
PHOTO D-65 Borehole: TH-8-ROW View of Drill Site	
PHOTO D-66 Borehole: TH-8-ROW View of Drill Site	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-67 Borehole: TH-8-ROW View of Flush Mount Cap	
PHOTO D-68 Borehole: TH-8-ROW Sample: 5	
PHOTO D-69 Borehole: TH-9-ROW Sample: 2	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-70 Borehole: TH-9-ROW Sample: 3	
PHOTO D-71 Borehole: TH-9-ROW Sample: 4	
PHOTO D-72 Borehole: TH-9-ROW Sample: 5	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali

PHOTO D-73 Borehole: TH-9-ROW Sample: 6	
PHOTO D-74 Borehole: TH-9-ROW Sample: 7	
PHOTO D-75 Borehole: TH-10-ROW View of Drill Site	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-76 Borehole: TH-10-ROW View of Borehole From Railroad Cut	
PHOTO D-77 Borehole: TH-10-ROW View From Railroad Cut	
PHOTO D-78 Borehole: TH-10-ROW View of Northside of Railroad Cut from Opposing Southside	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-79 Borehole: TH-10-ROW Sample: 2	
PHOTO D-80 Borehole: TH-10-ROW Sample: 3	
PHOTO D-81 Borehole: TH-10-ROW Sample: 5	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali

PHOTO D-82 Borehole: TH-11-ROW View of Drill Site and Typical Vegetation	
PHOTO D-83 Borehole: TH-11-ROW View of Drill Site from Highway	
PHOTO D-84 Borehole: TH-11-ROW Highway Near Drill Site	

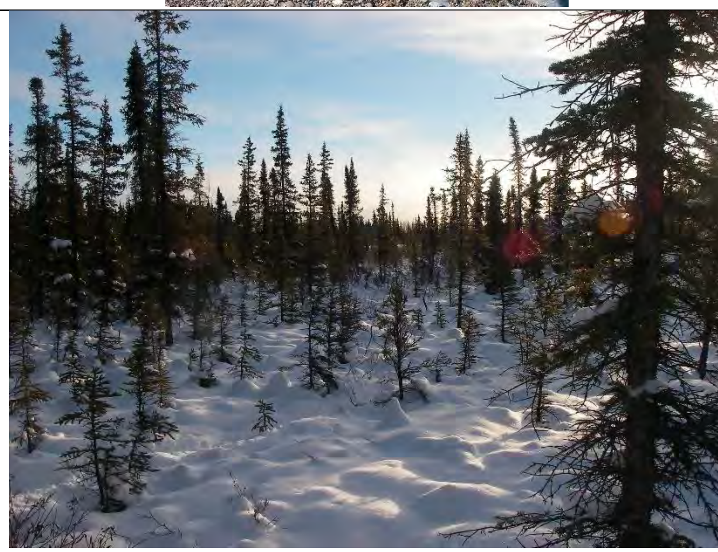
Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-85 Borehole: TH-11-ROW Temperature Readings August 2017	
PHOTO D-86 Borehole: TH-11-ROW Sample: 7	
PHOTO D-87 Borehole: TH-11-ROW Sample: 8	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-88 Borehole: TH-12-ROW View of Drill Site (right) with Nearby Ponding (left)	
PHOTO D-89 Borehole: TH-12-ROW View of Drill Site	
PHOTO D-90 Borehole: TH-12-ROW View of Ponding Near Highway and Borehole Drill Site (left arrow)	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-91 Borehole: TH-12-ROW Sample: 1	
PHOTO D-92 Borehole: TH-12-ROW Sample: 3	
PHOTO D-93 Borehole: TH-12-ROW Sample: 6	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-94 Borehole: TH-12-ROW Sample: 7	
PHOTO D-95 Bulk Sample 1	 
PHOTO D-96 View of Bulk Sample 1 and Borehole TH-8-ROW Locations	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali

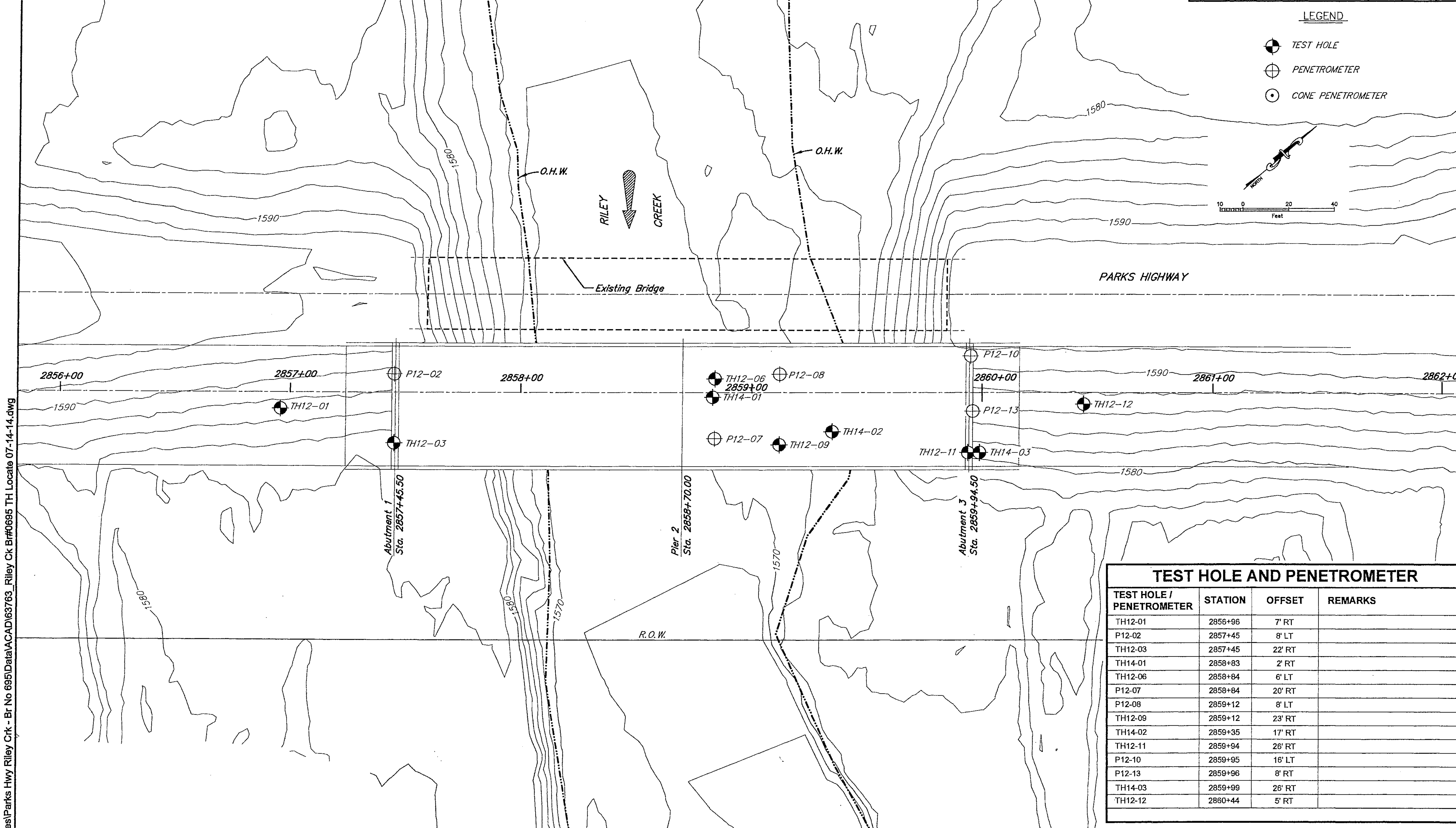
PHOTO D-97 View of Rails from Bulk Sample 1 Location	
PHOTO D-98 Typical Vegetation Qmm Terrain - Small Meadow	
PHOTO D-99 Typical Probe and Vegetation in Qo Organic Terrain	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-100 Typical Probe in Qo Organic Terrain	
PHOTO D-101 Typical Transition from Qmf Forested to Qmm Meadow	
PHOTO D-102 Typical Qmf Forested Terrain	

Project Title: Feasibility Study of ARRC MP 345 to 347.5 Rail Realignment Near Denali	
PHOTO D-103 Typical Probe in Qmf Forest	
PHOTO D-104 View of Snow Covered Kettle Pond	
PHOTO D-105 Typical Birch and Spruce in Qgo Glacial Outwash Terrain	

APPENDIX E
HISTORIC BOREHOLE LOGS FROM ADOT&PF

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	0A44019 / 63763	2014	N15	N63



TEST HOLE AND PENETROMETER			
TEST HOLE / PENETROMETER	STATION	OFFSET	REMARKS
TH12-01	2856+96	7' RT	
P12-02	2857+45	8' LT	
TH12-03	2857+45	22' RT	
TH14-01	2858+83	2' RT	
TH12-06	2858+84	6' LT	
P12-07	2858+84	20' RT	
P12-08	2859+12	8' LT	
TH12-09	2859+12	23' RT	
TH14-02	2859+35	17' RT	
TH12-11	2859+94	26' RT	
P12-10	2859+95	16' LT	
P12-13	2859+96	8' RT	
TH14-03	2859+99	26' RT	
TH12-12	2860+44	5' RT	

N:\Northern\Structures\Parks Hwy Riley Crk - Br No 695\Data\ACAD\63763_Riley Ck Br#0695 TH Locate 07-14-14.dwg

DESIGNED BY:	D.Hemstreet	CHECKED:	Engineer
DRAWN BY:	D.R.Dodge	CHECKED:	Engineer
QUANTITIES BY:	Engineer	CHECKED:	Engineer

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
STATEWIDE MATERIALS

STATE OF ALASKA 49TH David A. Hemstreet No. CE 9600 REGISTERED PROFESSIONAL ENGINEER

David A. Hemstreet 7/14/14

RILEY CREEK BRIDGE

PARKS HIGHWAY

TEST HOLE & PENETROMETER LOCATION

BRIDGE NO. 0695
DWG. NO. 15

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	0A44019 / 63763	2014	N16	N63

TYPICAL TEST HOLE LOG

DATE: Date begun – Date completed
STATION / OFFSET: XX+XX FEET RT or LT

Hole diameter — 3.5 in

Elevation(ft): 100, 95, 90, 85, 80, 75, 70, 65, 60, 55, 50, 45, 40, 35, 30

Depth(ft): 5.0ft, 32.0ft, 48.0ft, 70.0ft

Frozen

Graphic materials description
Stratum contact
Estimated stratum contact

Observed Ground Water Date: xx/xx/xx

Transitional stratum change
Soil graphic and soil type explanation

GRAVEL (GP)
GRAVEL (GW)
SAND (SP)
SAND (SW)
SILT (ML)
SILT (MH)
CLAY (CL)
CLAY (CH)
ORGANICS OR PEAT (PT)
COBBLE OR BOULDER INDICATED BY DRILL REACTION OR CORE
ICE
WEATHERED BEDROCK (Strength Grade, Weathering Grade)
BEDROCK (Strength Grade, Weathering Grade)
COAL

SILTY GRAVEL (GM)
CLAYEY GRAVEL (GC)
SILTY SAND (SM)
CLAYEY SAND (SC)
ORGANIC SILTS (OL)
ORGANIC CLAYS (OH)

Drilling Method

RQD % = Sum of lengths of core pieces > 4" / total length of run
L = Longest length of core in run
S = Shortest lkength of core in run

SAND with Silt — USCS soil name
p200 = 8% — % passing the #200 (0.075mm) sieve
Sa=42% — % sand, retained on #200 (0.075mm) sieve and passing #4 (4.75mm) sieve
Gr=50% — % gravel, retained on #4 (4.75mm) sieve
Moisture=5.0% — moisture content
Org=10% — organic content
PI=8 — plasticity index
LL=18 — liquid limit
SM — USCS classification
PP=2.0 — pocket penetrometer (ton / SF)
TV=2.0 — torvane (ton / SF)
GRAPHICS: (double symbols with split graphics may be used to indicate combinations of soil types)

07-3533 = soil sample number (year – sample number)

Interval sampled with recovery shaded — 10

SPT = blow count / ft. (total blows for second and third 6" increment) with standard penetration test sampler w/ 1.4 ID, 2" O.D. using a CME autohammer with 140 lb. hammer and a 30" freefall latest edition AASHTO T 206 (ASTM D1586).

SPT_{60} = same as SPT except, instead of CME autohamer, the cathead/rope method was used.

SS = blow count with 2" I.D., 2.5" O.D. sampler driven by a 340 lb. CME autohammer with a 30" freefall.

MC = blow count with 2.5" I.D., 3" O.D. sampler driven by a 340 lb. CME autohammer with a 30" freefall.

Indicates no valid SPT
GS — Grab sample from drill cuttings
CS — Continuous sampler
* — Indicates sampler refusal. Refusal defined as 50 or more blows per 6" increment, 100 total blows, or no movement observed with 10 successive blows.
VS — Vane shear test, undrained shear strength, PSF
ST — Thin walled sampler, pushed

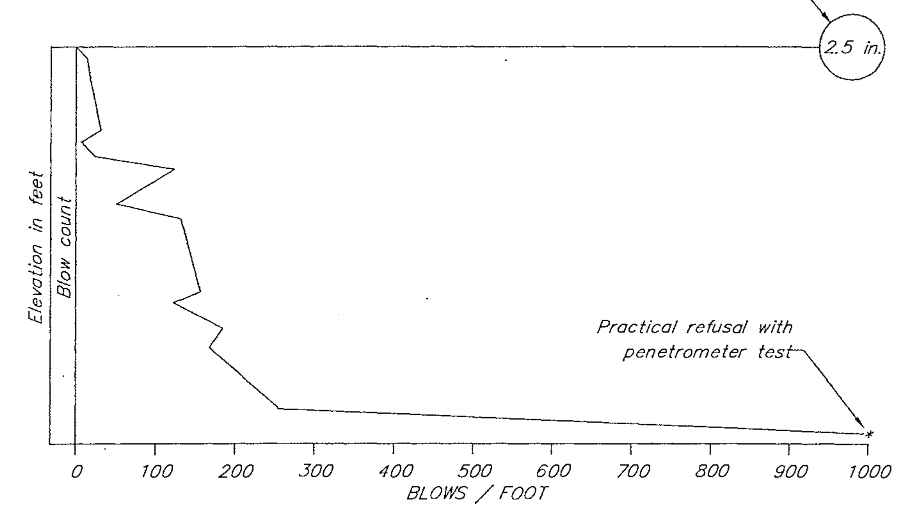
Bottom of hole (BOH) — Total depth

NOTES:

1) The test hole logs depicted graphically in these drawings are distillations of the original field logs, based on post-field investigation review and analysis. These drafted logs include changes made to field descriptions based upon laboratory test data, review and analysis. Detailed field observations of rock and soil sampled during the drilling program are not reproduced in the drafted logs.
2) Description of soils follows Alaska Geotechnical Procedures manual. Classification of soils follows Unified Soil Classification System (ASTM D2487).
3) The test hole logs from these sheets are an integral part of the Foundation Geology Report. See Construction Contract Bid Documents – invitation to bid/notice to bidders. Important information about the test hole logs and the foundation investigation is contained in the report. The test hole logs are not severable from and cannot be completely and correctly interpreted without reference to the Foundation Geology Report.

TYPICAL PENETROMETER TEST LOG

DATE: Date begun – Date completed
ELEVATION: Ground elevation at test hole
STATION / OFFSET: XX+XX FEET RT or LT



Bottom of hole (BOH)

NOTES:
Penetrometer W/2.5" O.D., with a CME AUTOMATIC Hammer using a 340 lb. weight and a 30" freefall

DESIGNED BY: D.Hemstreet	CHECKED: Engineer	
DRAWN BY: D.R.Dodge	CHECKED: Engineer	
QUANTITIES BY: Engineer	CHECKED: Engineer	

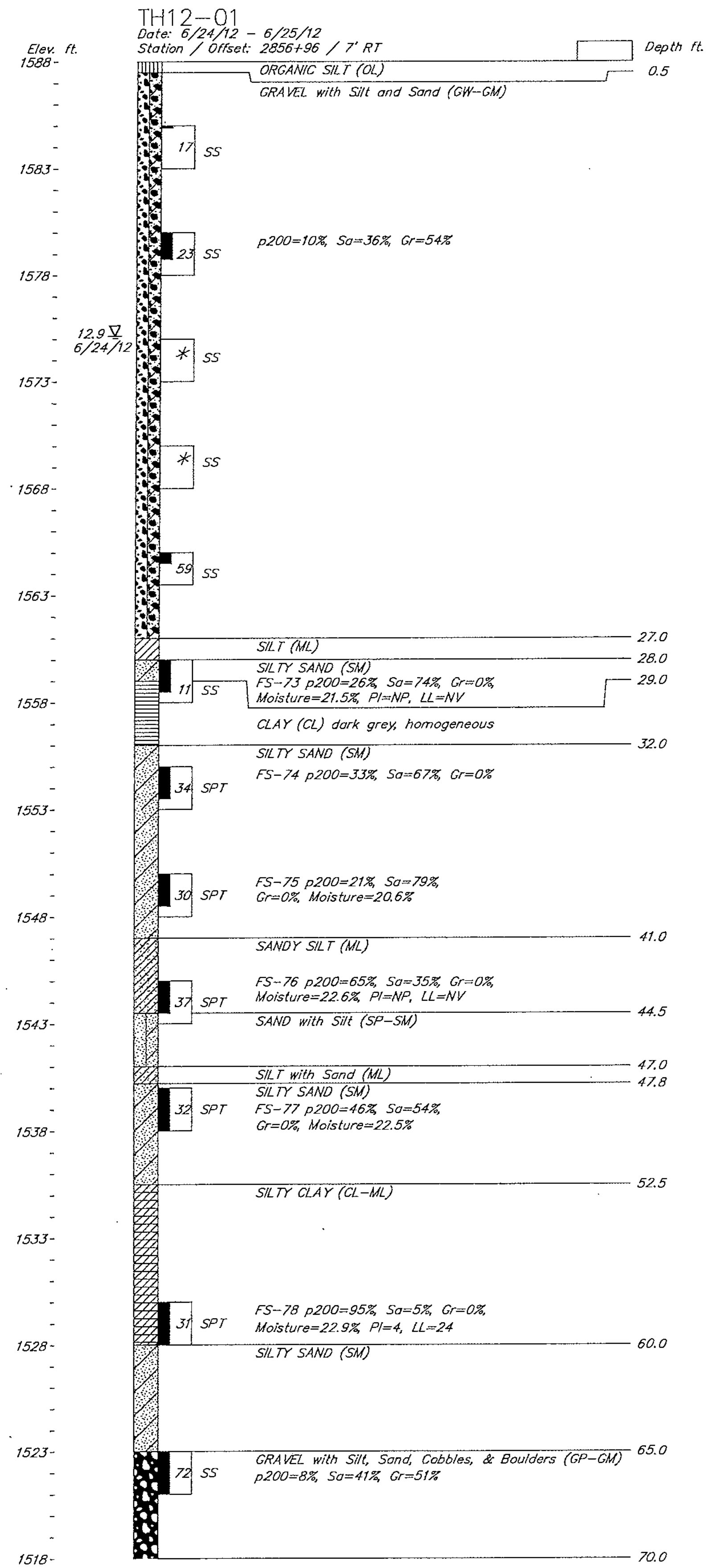
STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
STATEWIDE MATERIALS

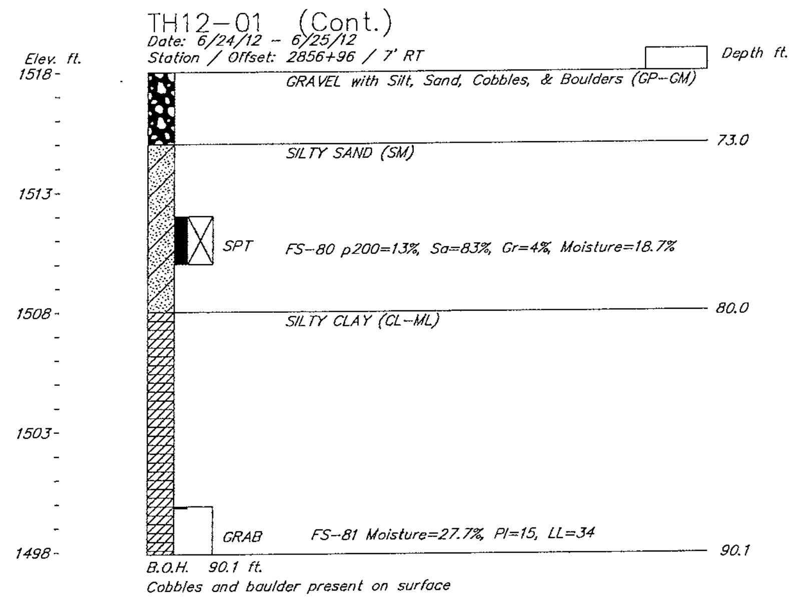
STATE OF ALASKA 49TH David A. Hemstreet No. CE 9800 REGISTERED PROFESSIONAL ENGINEER
4/4/14

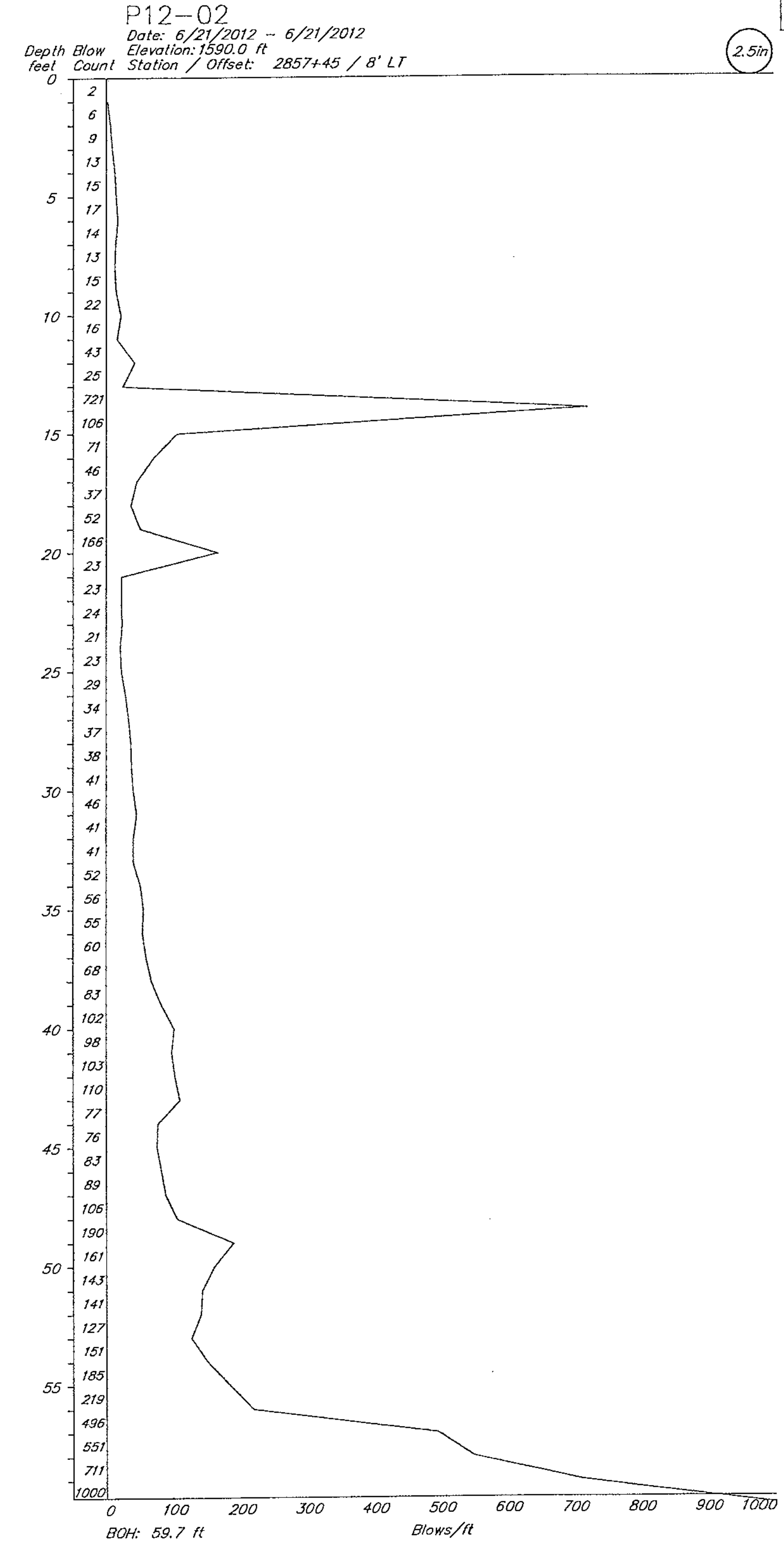
RILEY CREEK BRIDGE
PARKS HIGHWAY
TEST HOLE & PENETROMETER LEGEND

BRIDGE NO. 0695
DWG. NO. 16

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	0A44019 / 63763	2014	N17	N63







DESIGNED BY: D.Hemstreet	CHECKED: Engineer		
DRAWN BY: D.R.Dodge	CHECKED: Engineer		
QUANTITIES BY: Engineer	CHECKED: Engineer		

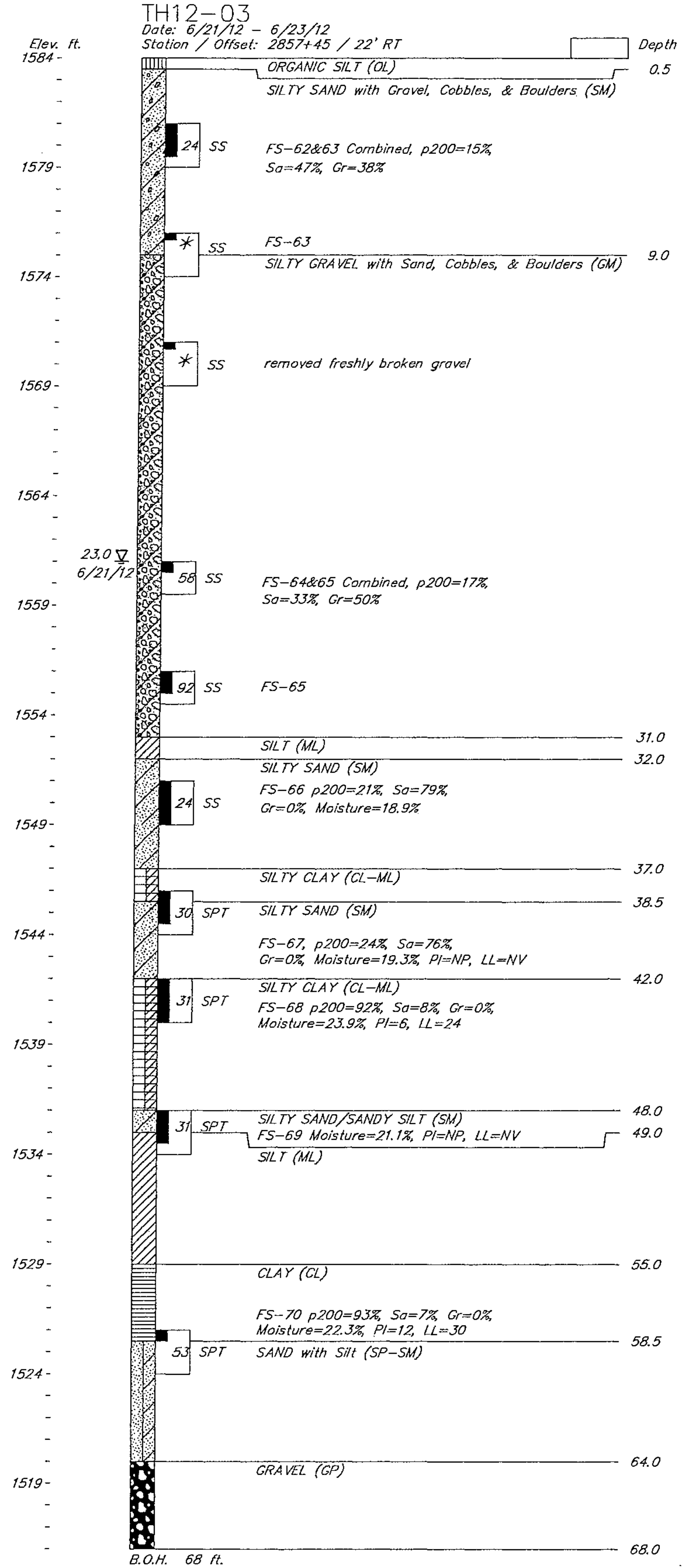
STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
STATEWIDE MATERIALS

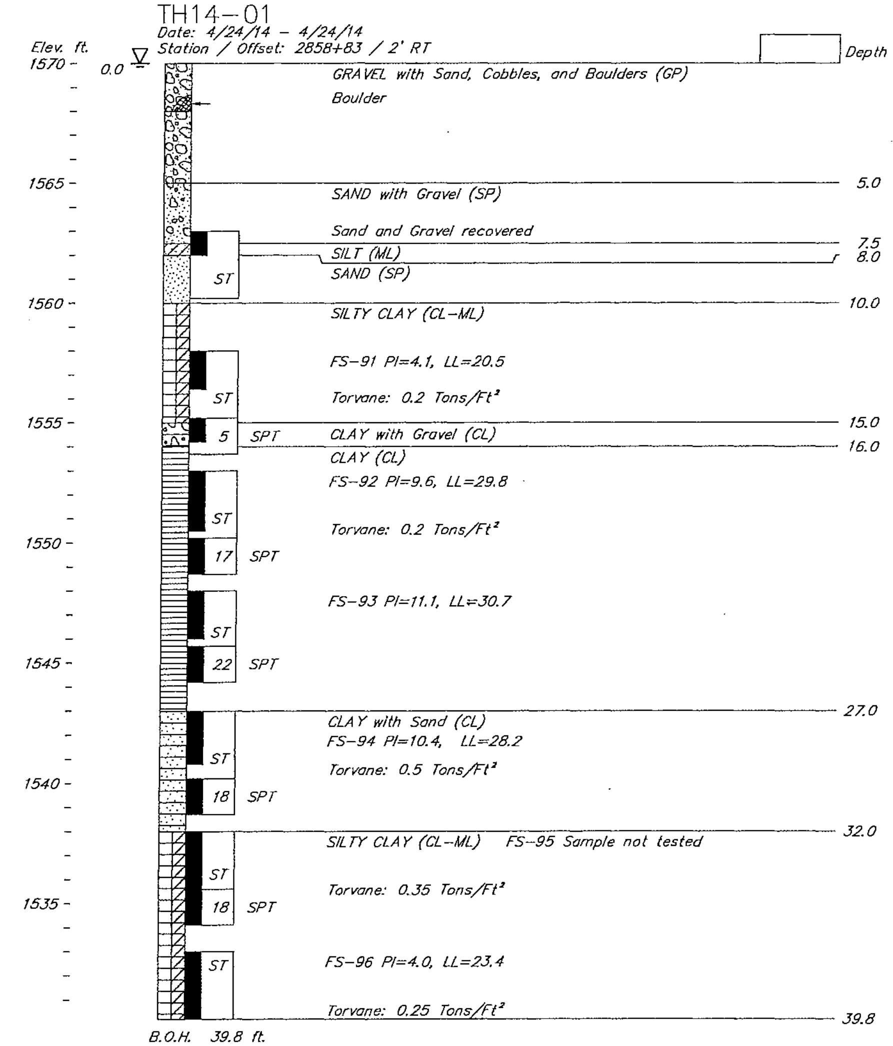
STATE OF ALASKA 49TH David A. Hemstreet No. CE 9800 REGISTERED PROFESSIONAL ENGINEER 7/14/14

RILEY CREEK BRIDGE
PARKS HIGHWAY
TEST HOLE & PENETROMETER LOGS

BRIDGE NO. 0695
DWG. NO. 17

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	0A44019 / 63763	2014	N18	N63





DESIGNED BY: D.Hemstreet	CHECKED: Engineer		
DRAWN BY: D.R.Dodge	CHECKED: Engineer		
QUANTITIES BY: Engineer	CHECKED: Engineer		

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
STATEWIDE MATERIALS

STATE OF ALASKA 49TH David A. Hemstreet No. CE 9800 REGISTERED PROFESSIONAL ENGINEER 7/14/14

RILEY CREEK BRIDGE

PARKS HIGHWAY

TEST HOLE & PENETROMETER LOGS

BRIDGE NO. 0695
DWG. NO. 18

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	0A44019 / 63763	2014	N19	N63

TH12-06

Date: 6/10/12 – 6/12/12
Station / Offset: 2858+84 / 6' LT

Elev. ft.	Depth ft.	Description / Samples
1570	0.2	Thin vegetative mat (water level 0.5 ▽ 6/10/12)
		SILTY GRAVEL with Sand, Cobbles, & Boulders (GM)
1565	5.0	CLAY (CL)
		10 SPT — FS-1 Moisture=21.9%
1560		
		6 SPT — FS-2 Moisture=32.7%
1555		FS-2&3 Combined, p200=99%, Sa=1%, Gr=0%, PI=22, LL=45
		8 SPT — FS-3 Moisture=29.9%
1550		
		10 SPT — FS-4 Moisture=25.8%
1545	27.0	SILT with Sand (ML)
		23 SPT — FS-5 Moisture=22.2%
1540		FS-5&6 Combined, p200=76%, Sa=24%, Gr=0%, PI=NP, LL=NV
		21 SPT — FS-6 Moisture=25.3%
1535	36.5	CLAYEY SILT with Sand (CL-ML)
		21 SPT — FS-7 Moisture=25.4%, PI=3, LL=25
1530	41.5	SILTY SAND (SM)
		22 SPT — FS-8 Moisture=24.1%
	44.0	SILTY CLAY (CL-ML)
1525	47.0	SILT with Sand (ML)
		22 SPT — FS-9 p200=74%, Sa=26%, Gr=0%, Moisture=21.9%
1520		
1515		
		39 SPT — FS-10 p200=85%, Sa=15%, Gr=0%, Moisture=20.6%, PI=NP, LL=NV
1510		
	64.0	CLAY (CL)
1505		
		14 SPT — FS-11 p200=98%, Sa=2%, Gr=0%, Moisture=22.3%, PI=11, LL=30
1500	70.0	

TH12-06 (Cont.)

Date: 6/10/12 – 6/12/12
Station / Offset: 2858+84 / 6' LT

Elev. ft.	Depth ft.	Description / Samples
1500		
1495		
		22 SPT — FS-12 Moisture=23.4%
1490		
		trace fine sand
	84.0	SILT with Sand (ML)
1485		
		19 SPT — FS-13 p200=75%, Sa=25%, Gr=0%, Moisture=23.5%
1480		
1475	95.0	SILTY CLAY (CL-ML)
		25 SPT — FS-14 Moisture=29%
1470		FS-14&15, p200=96%, Sa=4%, Gr=0%, PI=4, LL=24
1465		
		42 SPT — FS-15 Moisture=24.2%
1460		
1455		
		47 SPT — FS-16 Moisture=22.3%, PI=3, LL=21
1450		
1445	125.5	SILTY SAND with Gravel (SM)
		50 SPT — FS-17 p200=28%, Sa=52%, Gr=20%
1440	130.0	GRAVEL with Cobbles & Boulders (GP)
1435	136.0	SILT with Sand (ML)
		31 SPT — FS-18 p200=82%, Sa=18%, Gr=0%, Moisture=17.2%
1430	140.0	

TH12-06 (Cont.)

Date: 6/10/12 – 6/12/12
Station / Offset: 2858+84 / 6' LT

Elev. ft.	Depth ft.	Description / Samples
1430		
	143.0	B.O.H. 143 ft.

DESIGNED BY: D.Hemstreet	CHECKED: Engineer		
DRAWN BY: D.R.Dodge	CHECKED: Engineer		
QUANTITIES BY: Engineer	CHECKED: Engineer		

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
STATEWIDE MATERIALS

STATE OF ALASKA 49TH — David A. Hemstreet — No. CE 9600 — REGISTERED PROFESSIONAL ENGINEER

7/14/14

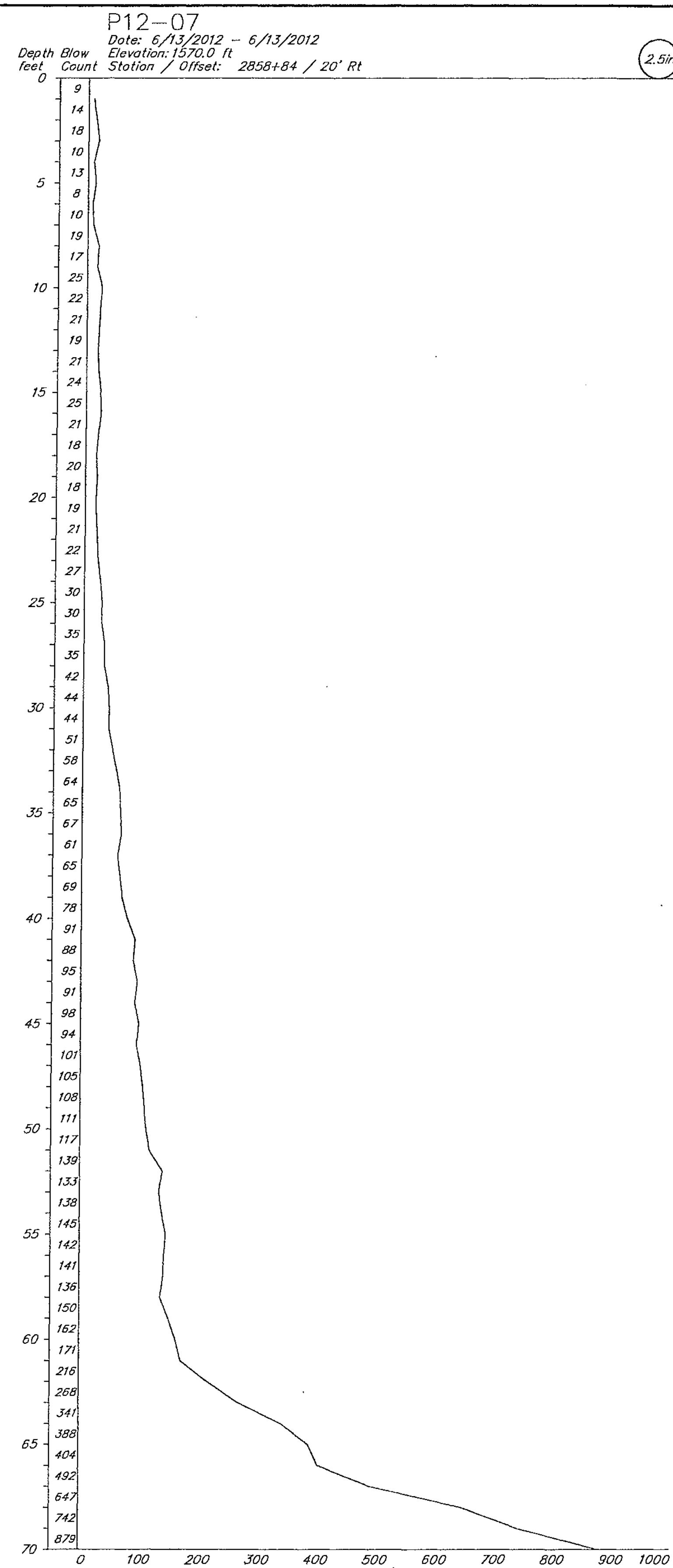
RILEY CREEK BRIDGE

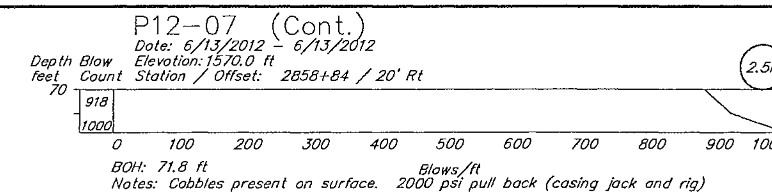
PARKS HIGHWAY

TEST HOLE & PENETROMETER LOGS

BRIDGE NO. 0695
DWG. NO. 19

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	0A44019 / 63763	2014	N20	N63





DESIGNED BY:	D.Hemstreet	CHECKED:	Engineer
DRAWN BY:	D.R.Dodge	CHECKED:	Engineer
QUANTITIES BY:	Engineer	CHECKED:	Engineer

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
STATEWIDE MATERIALS

STATE OF ALASKA 49TH
David A. Hemstreet
No. CE 9600
REGISTERED PROFESSIONAL ENGINEER
7/14/14

RILEY CREEK BRIDGE

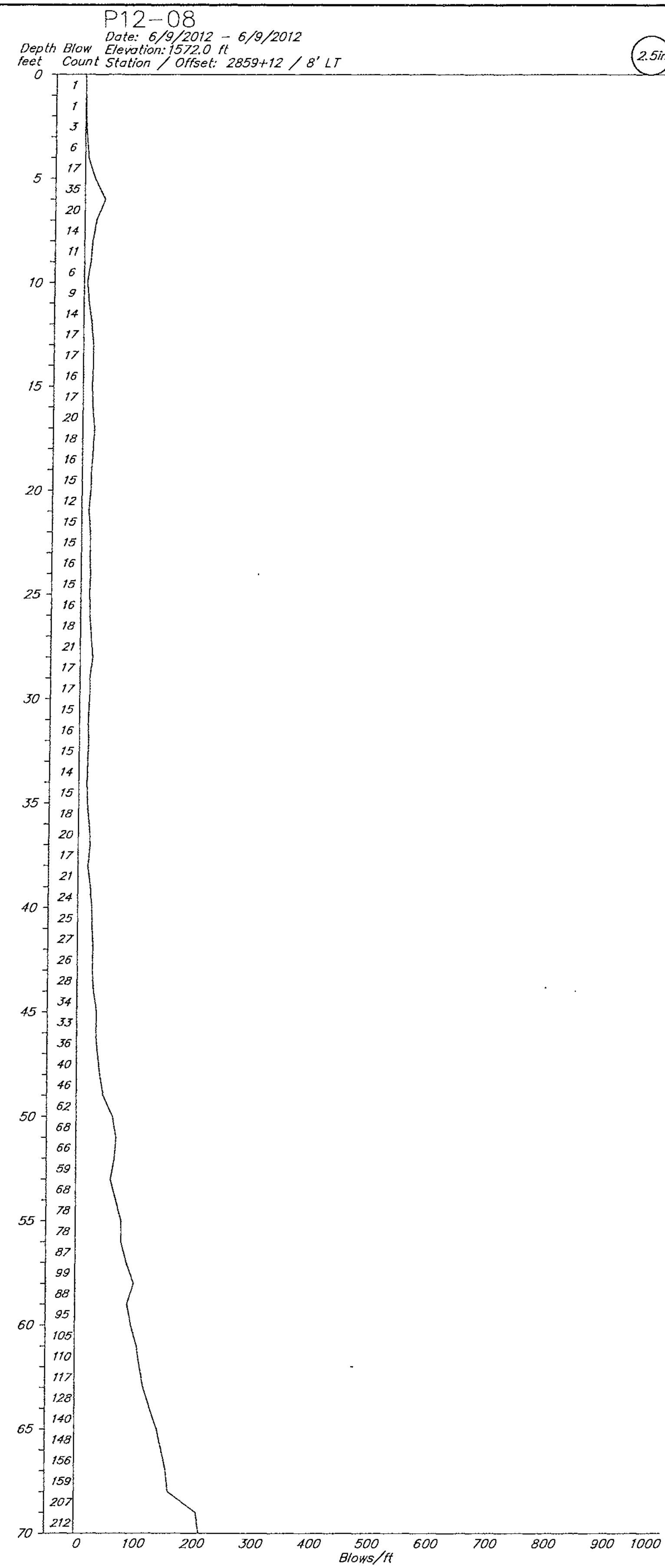
PARKS HIGHWAY

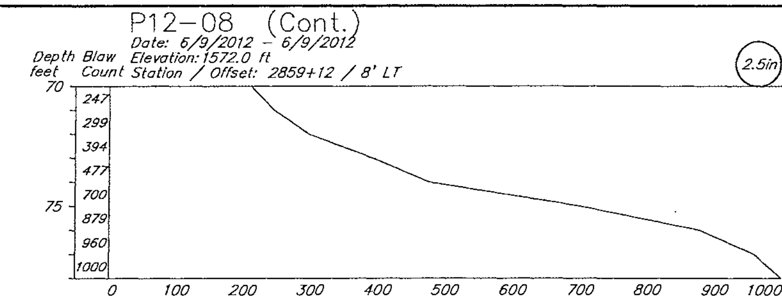
TEST HOLE & PENETROMETER LOGS

BRIDGE NO. 0695

DWG. NO. 20

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	0A44019 / 63763	2014	N21	N63





BOH: 78.0 ft

Notes: Cabbles and boulder present on surface. 2000 psi pull back (casing jack and rig)

DESIGNED BY: D.Hemstreet	CHECKED: Engineer	
DRAWN BY: D.R.Dodge	CHECKED: Engineer	
QUANTITIES BY: Engineer	CHECKED: Engineer	

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
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STATE OF ALASKA 49TH David A. Hemstreet No. CE 9800 REGISTERED PROFESSIONAL ENGINEER

7/14/14

RILEY CREEK BRIDGE

PARKS HIGHWAY

TEST HOLE & PENETROMETER LOGS

BRIDGE NO. 0695

DWG. NO. 21

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	0A44019 / 63763	2014	N22	N63

DESIGNED BY: D.Hemstreet	CHECKED: Engineer	
DRAWN BY: D.R.Dodge	CHECKED: Engineer	
QUANTITIES BY: Engineer	CHECKED: Engineer	

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
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STATE OF ALASKA 49TH David A. Hemstreet No. CE 9800 REGISTERED PROFESSIONAL ENGINEER
7/14/14

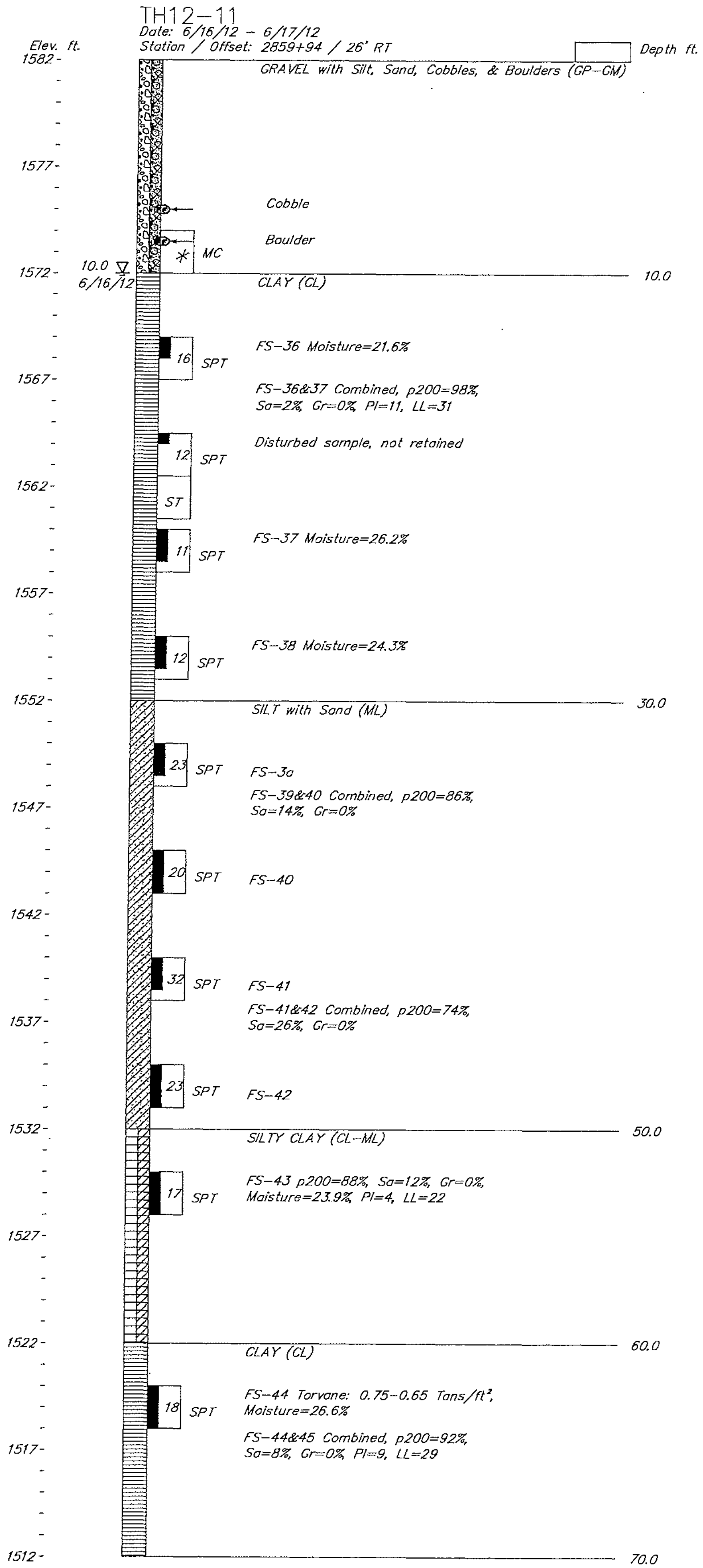
RILEY CREEK BRIDGE

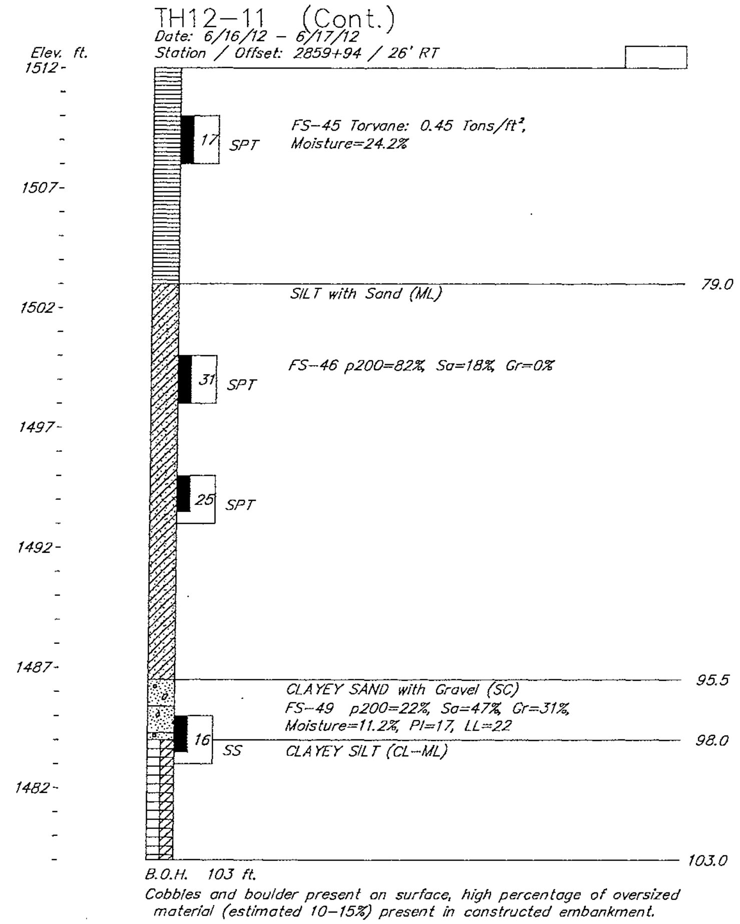
PARKS HIGHWAY

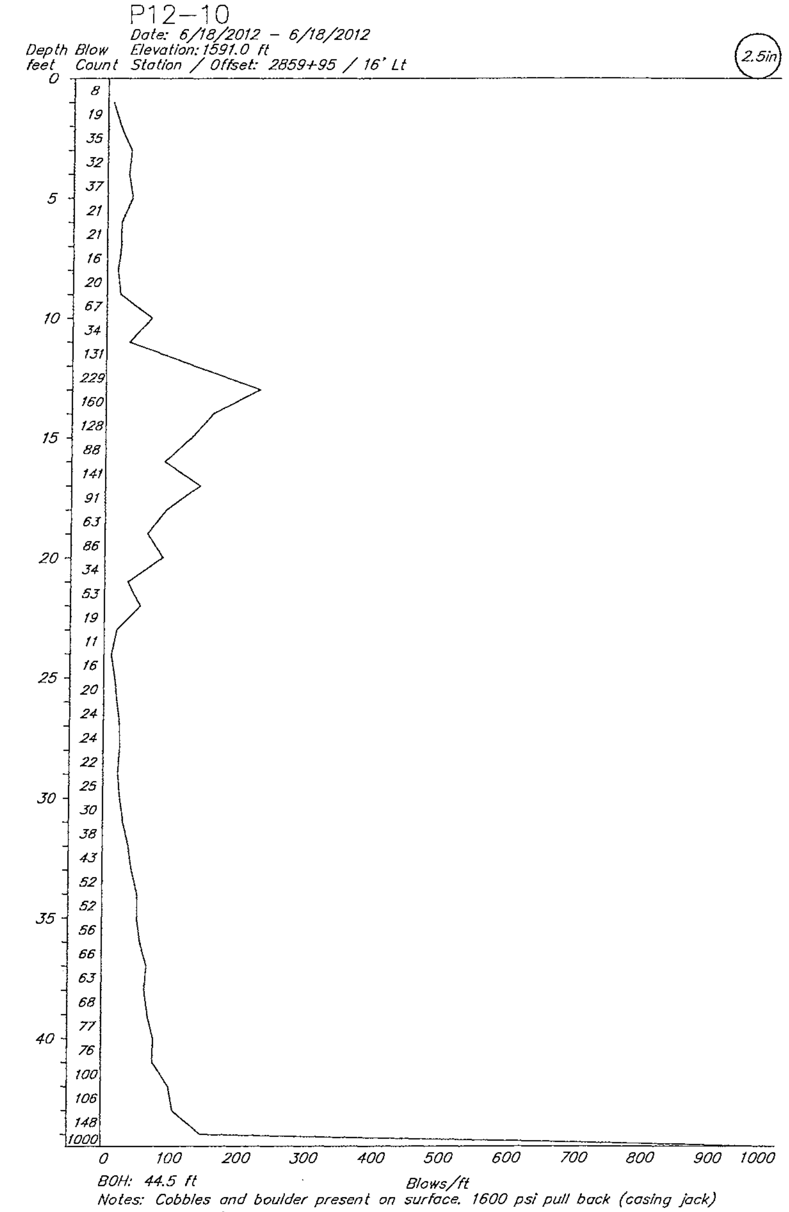
TEST HOLE & PENETROMETER LOGS

BRIDGE NO. 0695
DWG. NO. 22

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	0A44019 / 63763	2014	N23	N63

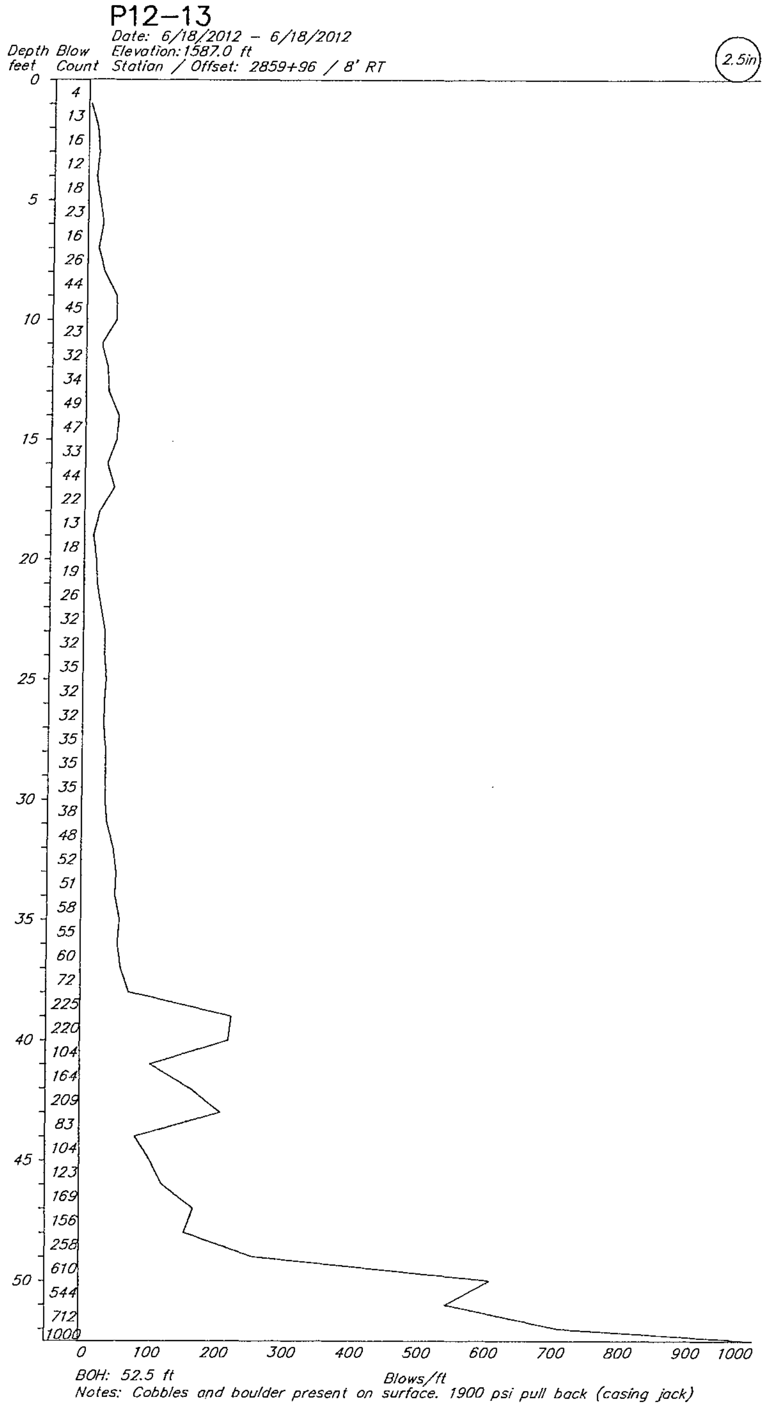


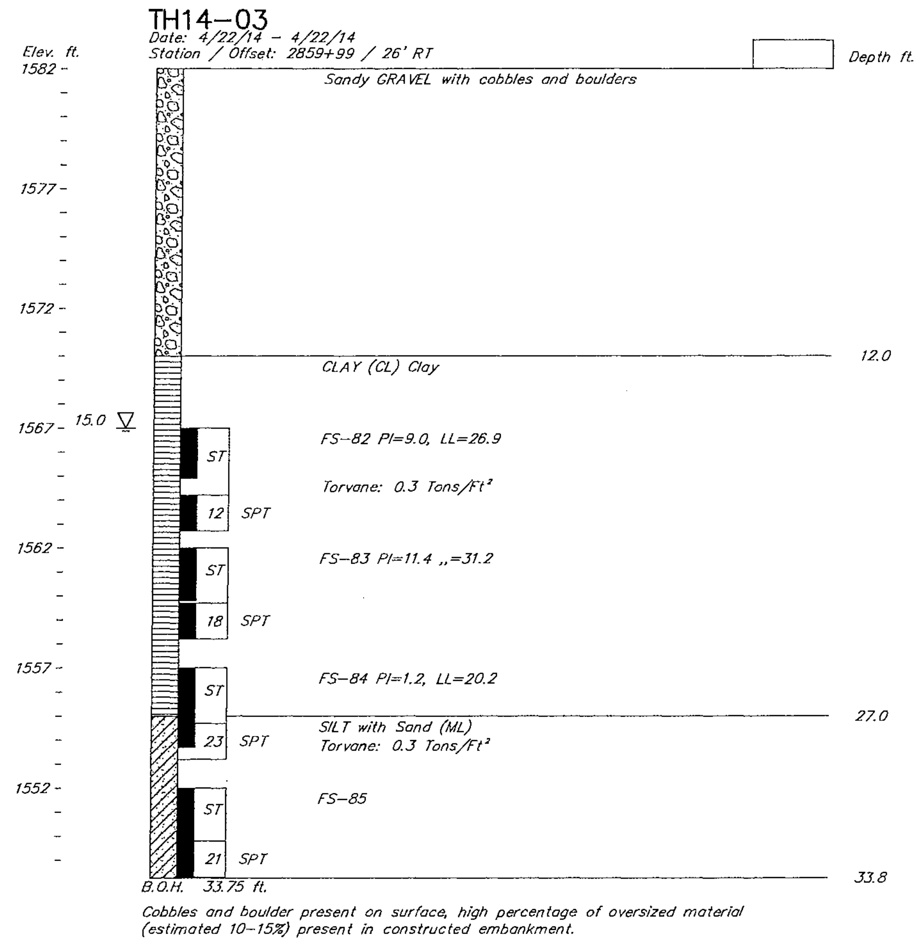


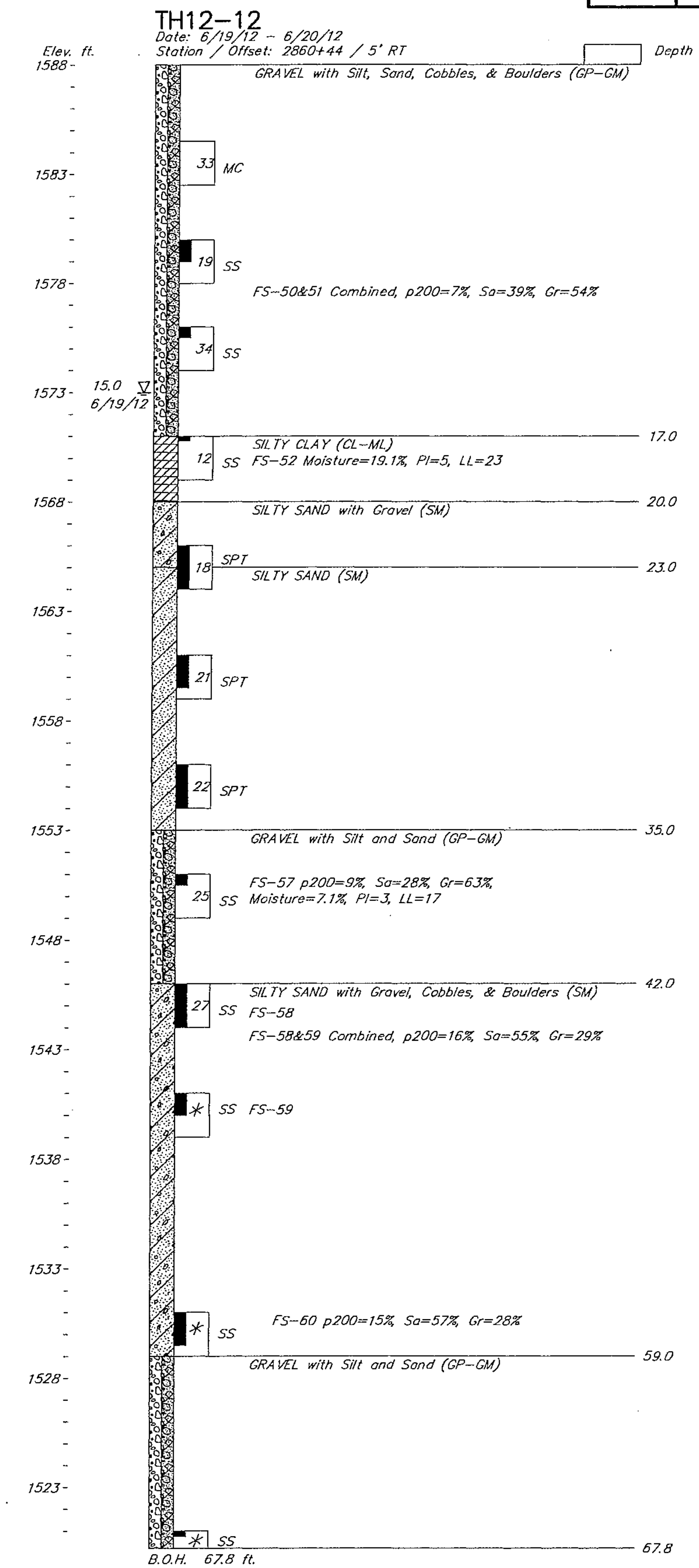


DESIGNED BY: D.Hemstreet	CHECKED: Engineer	STATE OF ALASKA DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES STATEWIDE MATERIALS	STATE OF ALASKA 49TH David A. Hemstreet No. CE 9600 REGISTERED PROFESSIONAL ENGINEER 7/19/14	RILEY CREEK BRIDGE PARKS HIGHWAY TEST HOLE & PENETROMETER LOGS
DRAWN BY: D.R.Dodge	CHECKED: Engineer			BRIDGE NO. 0695
QUANTITIES BY: Engineer	CHECKED: Engineer			DWG. NO. 23

STATE	PROJECT DESIGNATION	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	0A44019 / 63763	2014	N24	N63







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DESIGNED BY: D.Hemstreet	CHECKED: Engineer
DRAWN BY: D.R.Dodge	CHECKED: Engineer
QUANTITIES BY: Engineer	CHECKED: Engineer

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
STATEWIDE MATERIALS

STATE OF ALASKA 49TH David A. Hemstreet No. CE 9600 REGISTERED PROFESSIONAL ENGINEER 7/14/14

RILEY CREEK BRIDGE

PARKS HIGHWAY

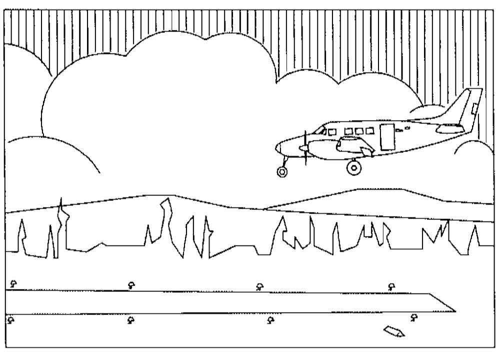
TEST HOLE & PENETROMETER LOGS

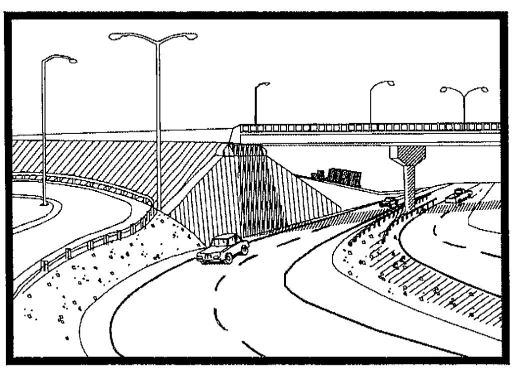
BRIDGE NO. 0695
DWG. NO. 24

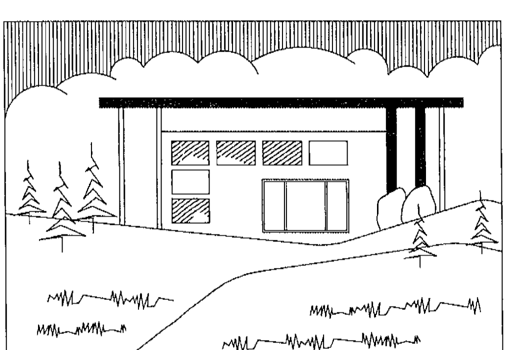
Geotechnical Report

PARKS HIGHWAY MP 237
RILEY CREEK BRIDGE REPLACEMENT

AKSAS: 63763

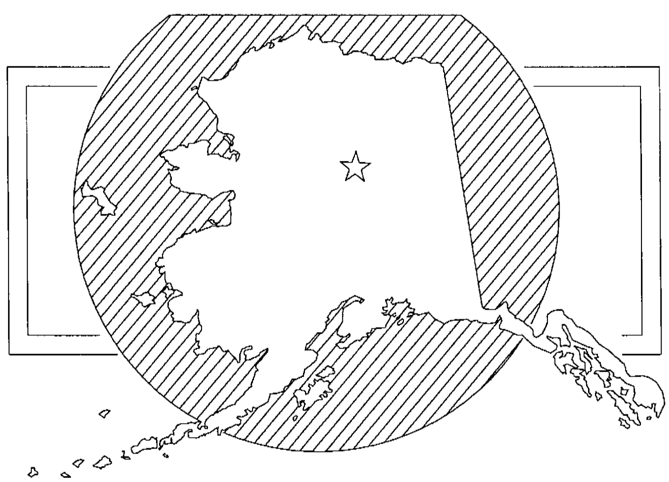






STATE OF ALASKA

Department of Transportation and Public Facilities



NORTHERN REGION

FEBRUARY 2014

GEOTECHNICAL REPORT
PARKS HIGHWAY MP 237
RILEY CREEK BRIDGE REPLACEMENT
PROJECT: 63763
FEDERAL NUMBER IM-BR-0A44(020)
FEBRUARY 2014

PREPARED BY:

GARRETT SPEETER
Engineering Geologist

REVIEWED BY:

KEVIN MAXWELL
Regional Geologist

APPROVED BY:

STATE OF ALASKA
49TH
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JEFFREY L. CURREY
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JEFF CURREY, P.E.
Materials Engineer

Table of Contents

Table of Figures

List of Tables

Introduction

At the request of Project Manager Lauren Little, P.E. NRMS (Northern Region Materials Section) personnel conducted geotechnical exploration of: the new alignment for the Riley Creek Bridge replacement, areas with excessive settlement in the south approach to the existing Riley Creek Bridge and Denali Park Road intersection, and abutments for the Riley Creek Bridge replacement where penetration rod data was requested.

Summary

NRMS Personnel conducted geotechnical exploration drilling in the following areas:

South Approach to Riley Creek Bridge (TH13-5110 to TH13-5112)

The Parks Highway shows significant settlement at its approach to the south Riley Creek Bridge Abutment. Test holes were drilled with hollow-stem augers and SPT tests in 5-foot intervals to collect in-situ soil density information for settlement assessment. Test holes in the settled approach intercepted loose to medium dense gravels in the embankment underlain by loose sandy silt and wet sand with silt.

Test holes drilled in the south approach to the existing Riley Creek Bridge (TH13-5109 through 13-5111) intercepted loose silt and/or soft silty clay at the base of the embankment at depths that ranged from 22.5 to 23-feet below the existing finished grade. Loose, well-graded gravels with sand and silt were also observed in the lower portion of the embankment. Consolidation of subgrade soils and loss of lateral confinement at the base of the existing abutment is likely the cause of excessive settlement in this interval. The embankment has eroded away from the north abutment and possibly the south abutment which could have caused settlement.

Denali Park Road/ Parks Highway Intersection (TH13-5108, TH13-5109, and TH13-5127)

Noticeable settlement has occurred at the intersection of Denali Park Road and the Parks Highway. NRMS drilled three hollow-stem auger test holes with SPT tests in 5-foot intervals to collect in-situ soil density information for settlement assessment. Loose silt with sand, sand with silt, and/or silty sand was encountered by test holes under the embankment in the settled areas.

Test holes in high maintenance sections of the Parks Highway at its intersection with Denali Park Road all showed multiple layers of asphalt (3 layers in TH13-5127) or thin asphalt (1-inch in TH13-5109) and very loose silt in subgrade soils. TH13-5109 intercepted very loose thawed silt beneath the initial 3.6-feet of sand in subgrade. TH13-5127 intercepted loose sandy silt and silty clay in subgrade above frozen, (thaw un-stable) sandy silt with stratified ice (VS) in the bottom of the test hole. Thawing of thaw un-stable frozen soils and/or consolidation of loose subgrade silts is likely the cause for excessive maintenance in this area.

Northern Riley Creek Bridge Alignment (TH13-5114 to TH13-5118) and TH13-5126

The northern Riley Creek Bridge Alignment was drilled predominantly with solid stem augers (with the exception of TH13-5115). Test holes from the northern Riley Creek

Alignment drilling intercepted gravels with sand and silt in the embankment and in the subgrade. These materials were difficult to differentiate from each other. In both cases the material contained a large volume of cobbles and boulders.

Southern Riley Creek Bridge Alignment (TH13-5106, TH13-5107 and TH13-5120 to TH13-5124)

The southern Riley Creek Bridge Alignment was drilled with solid stem augers. Test holes from the southern Riley Creek Bridge Alignment intercepted gravels with silt, sand, and abundant cobbles and boulders in the embankment and subgrade. Embankment material and subgrade material was often difficult to differentiate.

Replacement Riley Creek Bridge Abutments

North (TH13-5113)

- The penetration rod test in the north abutment hit refusal (1,000 blows/minute) abruptly at a depth of 57-feet below the ground surface.

South (TH13-5119)

- The penetration rod test in the south abutment hit refusal (1,000 blows/minute) abruptly at a depth of 66-feet below the ground surface.

Physical Setting

Location

The project area is located on the Parks Highway from milepost 237 to approximately 600-feet north of the Denali Park Road/Parks Highway intersection.

Climate

The project area is in a subarctic climate with long, cold winters and short warm summers. Most annual precipitation falls during the summer months. Winter typically lasts from September to May. Average winter temperatures range from -7.8F to 25F, with extreme cold snaps that can reach -40F and warm periods that can reach 40F. Strong temperature inversions are common along the road alignment with temperatures in topographic highs being 10's of degrees warmer than in topographic lows.

Table 1. Monthly climate summary from Denali Park, Alaska. Period of record: 9/1/1949 to 9/30/2012

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	9.2	16.3	24.8	38.8	53.6	64.2	66.3	61.4	50.7	32.4	17.3	11.2	37.2
Average Min. Temperature (F)	-7.8	-4.1	0.4	15.8	29.9	39.7	43.4	39.9	30.6	14.5	0.9	-5.6	16.5
Average Total Precipitation (in.)	0.68	0.60	0.46	0.37	0.80	2.32	3.14	2.57	1.54	0.92	0.83	0.90	15.12
Average Total SnowFall (in.)	10.3	10.2	7.7	5.1	2.9	0.3	0.0	0.0	4.2	12.3	13.1	13.4	79.5
Average Snow Depth (in.)	17	20	21	17	2	0	0	0	1	3	8	13	8

Percent of possible observations for period of record. Max. Temp.: 94.3% Min. Temp.: 94.4% Precipitation: 95% Snowfall: 95% Snow Depth: 93.2%Source: Western Regional Climate Center, www.wrcc.dri.edu

Laboratory data

Soil samples and test hole conditions were logged in the field using the unified soil classification system. Samples were sealed and transported to the Northern Region Materials Laboratory in Fairbanks. Selected samples were tested in accordance with ASTM/AASHTO methods for a determination of any one or a combination of the following properties:

- Classification (particle size distribution)
- Moisture content
- Atterberg Limits
- Organic content

Table 2. List of tests and standard methods offered by the Northern Region Material Laboratory.

Test Method	AASHTO	ASTM
	Index Tests	
Gradation	T27	C136
Minus #200 Gradation	T11	C117
Hydrometer	T88	D422
Liquid Limit	T89	D4318
Plastic Limit	T90	D4318
Moisture Content – Aggregate Soil	T255 T265	C566 D2216
Organic Content (Burn)	T267	
Proctor	T180	D1557
USCS Classification	D2487	
Fine Specific Gravity	T100	D854
Coarse Specific Gravity	T85	D127
	Quality Tests	
Degradation	T13	
Los Angeles Abrasion	T96	C131
Sodium Soundness	T104	C88
Nordic Abrasion	ATM 312	

Geology/Seismicity

The north end of the project area is located approximately 19 miles north of the main trace of the Denali Fault. The Denali Fault crosses the Parks Highway at MP 238.5.

The Riley Creek Fault runs beneath the north abutment in the existing Riley Creek Bridge. Offset geologic horizons were intercepted by test holes drilled by Alaska Department of Transportation and PF Statewide Foundations personnel, offsets can be seen in draft bore logs but the final report has not been released at this time.

The Denali Fault is a right lateral strike-slip fault that extends from northwestern British Columbia to central Alaska. The Denali Fault was responsible for a magnitude 7.9 earthquake in 2002 that resulted in a 209 mile long surface rupture that crossed several rivers, glaciers, and roads. The Denali Fault is still active with displacement rates that range from 1 to 35mm/year.

Alluvial, fluvial, and glacial deposits above metamorphic, sedimentary, or plutonic bedrock dominate the surficial geology in the project area. The USGS deaggregation calculator indicates that there is a 10 percent probability of the peak horizontal ground acceleration exceeding 27%g in 50 years with a mean return period of 475 years. Currently (as of 2012), this software accesses a 1996 database. As such, it does not factor subsequent events, including the major earthquake on the Denali Fault in 2002.

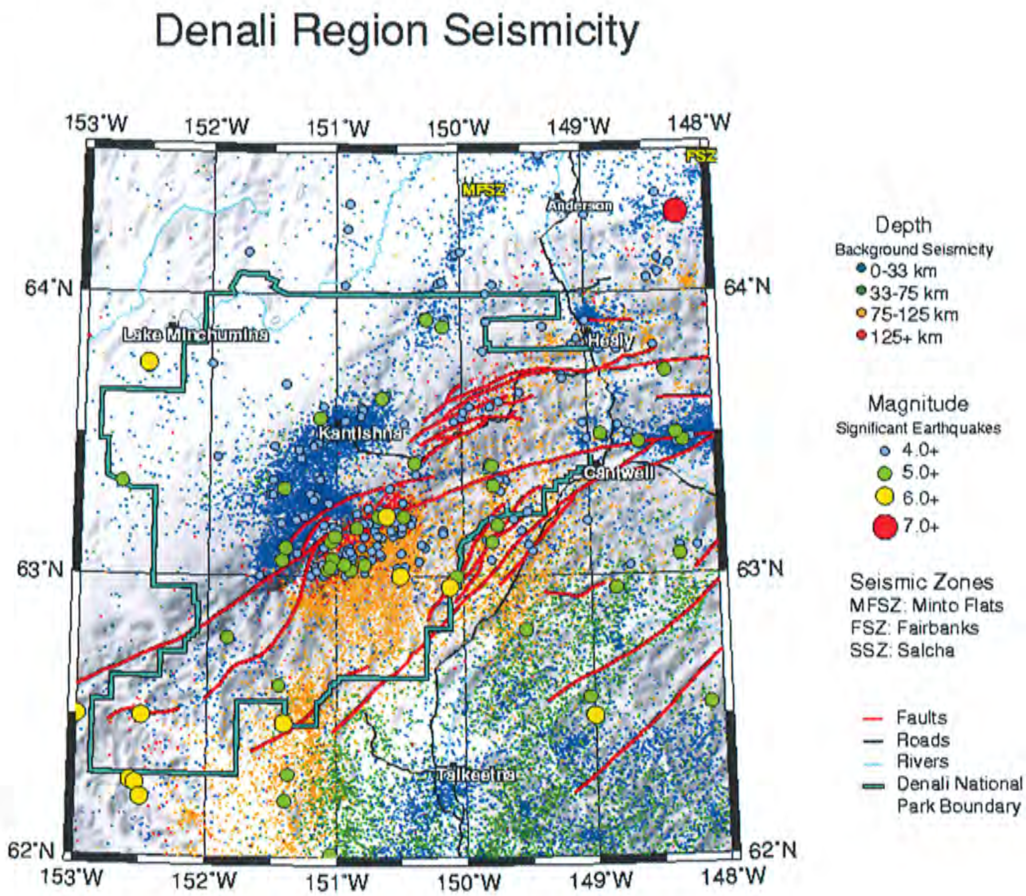


Figure 1. Map of seismicity for interior Alaska. Data displayed is from events that occurred between 1904 and 1-31-2005. Map is available online at http://www.aeic.alaska.edu/maps/interiorseismicitymap.html

Geology

Denali National Park is home to the tallest mountain in North America (Denali or Mount McKinley) which is located in the Alaska Range and has a summit elevation of 20,320 feet. The Denali Fault is located in the Alaska Range approximately 19 miles south of the project area. The Denali fault is North America's largest crustal break with a strike that stretches for 1,300 miles. The Denali Fault is tectonically active with an annual movement of 3/8-inch per year and is responsible for the 2002 earthquake that caused major damage to infrastructure in Alaska including the Parks and Richardson Highways and the Trans-Alaska Pipeline System. Glacial till deposits and alluvial gravels cover the project area and contain little or no permanently frozen soil within the top 30 feet in most places.

Topography

The proposed south alignment and Riley Creek Bridge Replacement runs just east of the existing alignment through a cut in an approximately 50-foot tall (above the alignment) glacial till terrace that tapers out to the north and east as it slopes toward Riley Creek and the Nenana River. Riley Creek marks the topographic low-point in the project area. The northern portion of the proposed alignment runs up a slight hill as the embankment travels up a broad, forested, alluvial terrace.

Permafrost

Generally speaking, permafrost was not encountered while drilling the Riley Creek Bridge abutments, new alignment, or approaches/abutments in the existing Riley Creek Bridge. Test hole TH13-5127 (drilled in the intersection of the Denali Park road and the Parks highway) did intercept frozen soils with 5% visible ice (Vs) at a depth of 12 feet below finished grade in the eastbound turn lane.

Drainage/water table

Riley Creek is a fast moving meandering stream that is typically 50-80 feet wide at the main channel. Riley Creek drains into the Nenana River approximately 600-feet east of the Riley Creek Bridge. Groundwater was only intercepted by the deepest hole in the existing Riley Creek Bridge approach (TH13-5110 intercepted water table 31-feet below finished grade).

Vegetation

Topographic highs are typically thickly covered by a mixture of Black Spruce, Birch, and Alder. Topographic lows are typically covered with thick Black Spruce trees and Alder with tundra. Stream beds are typically lined by Alder Willows and tundra grasses.

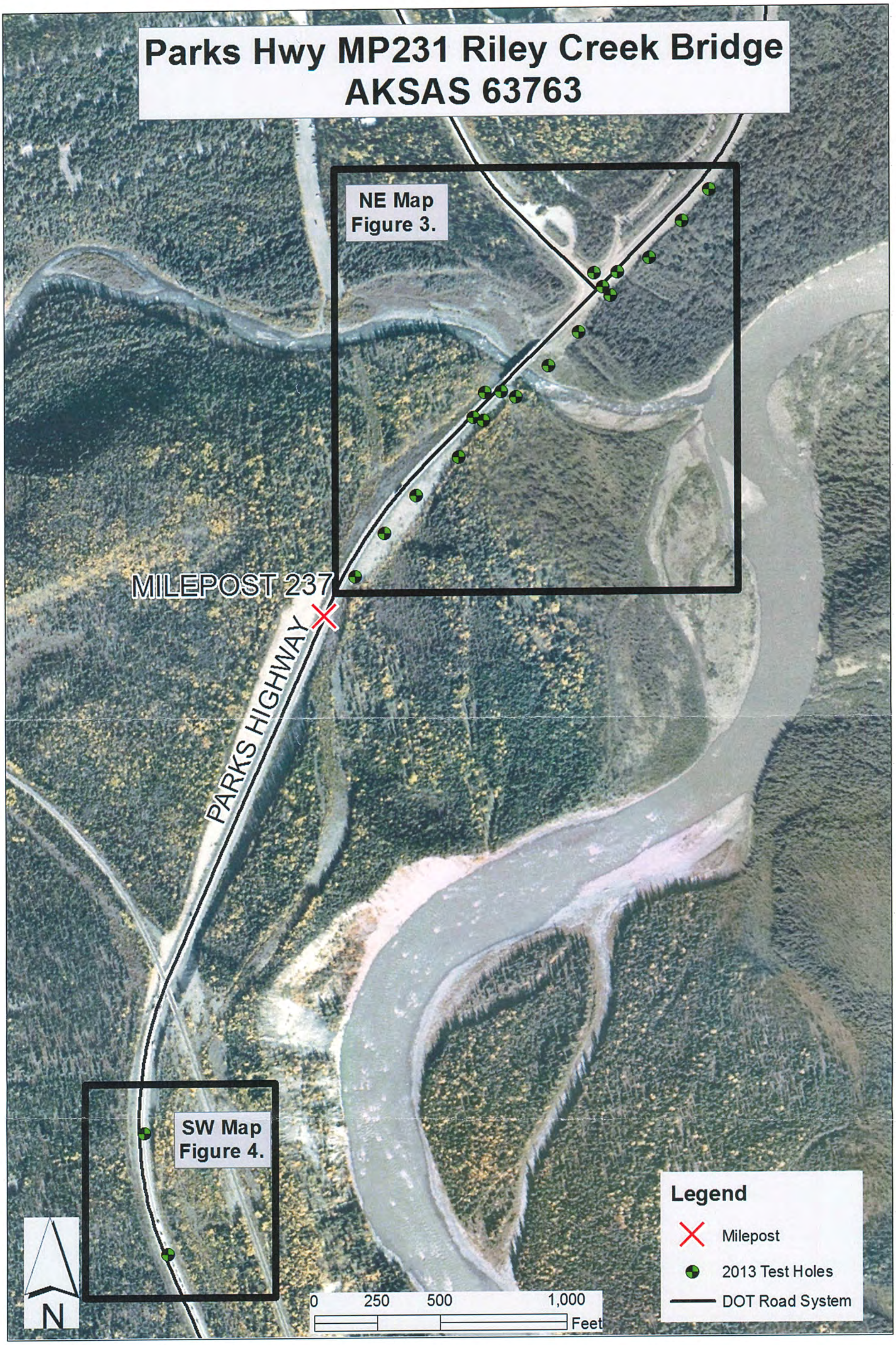


Figure 2. Map of project area.

Figure 3. Detailed map of NE drill pattern.

Figure 4. Map of SW drill pattern.

Field Investigation

NRMS personnel drilled 21 test holes to depths between 14-and 31.5-feet. Drilling was completed between 11-4-13 and 11-22-13. Field personnel included: Engineering Geologist G. Speeter and Drillers S. Parker, G. Nelson, P. Lanigan, and M. Sousa. Test holes were drilled with either a track mounted CME-850 drill rig or truck mounted CME-55 drill rig and 6.5-inch hollow stem or 6-inch solid stem augers. Penetration tests were conducted in 5-foot intervals in all hollow stem auger test holes utilizing 2–inch (ID) 2.5 –inch (OD) California-Modified Style Split-Barrel samplers and a 340-pound auto-hammer. Penetration rod tests were conducted in each abutment for the replacement bridge. Hollow stem augers were used to investigate settling soils in the embankment and subgrade in the approach to the existing Riley Creek Bridge on the south side, settlement near the intersection with the Parks Highway and Denali Park Road, and sporadically through the new alignment. Solid stem augers were used to investigate subsurface conditions along the new alignment. Samples were collected from auger cuttings and split-barrel samplers and submitted to the NRMS Materials Laboratory for gradation analyses, moisture content, and organic content analysis.

Site and Subsurface Conditions

South Approach to Riley Creek Bridge (TH13-5110 to TH13-5112)

The Parks Highway shows significant settlement at its approach to the south Riley Creek Bridge Abutment. Test holes were drilled with hollow-stem augers and SPT tests in 5-foot intervals to collect in-situ soil density information for settlement assessment. Test holes in the settled approach intercepted the following generalized soil profile:

- 1 to 2-feet of asphalt, usually in 2 layers;
- 21 to 27-feet of loose to medium-dense poorly-or well-graded gravel with sand, silt, cobbles, and boulders;
- At least 7 to 7.5-feet of loose sandy silt;
- Underlain by wet, medium dense, poorly-graded sand with silt.

TH13-5110 was the deepest test hole and the only test hole to intercept a water table. TH13-5110 intercepted ground water 31-feet below finished grade.

No frozen soil was encountered while drilling the south approach to the Riley Creek Bridge.

Abundant cobbles and boulders made drilling difficult. Blow counts from SPT tests were likely inflated due to cobble interference with samplers.

Laboratory data

Laboratory analyses of samples collected from drilling in the south approach of the existing Riley Creek Bridge are summarized below:

- One of 4 samples collected for gradation in the embankment met standard highways materials gradation standards for Selected Materials Type A.
- Two of 4 samples collected for gradation in the embankment met standard highways materials gradation standards for Selected Materials Type B.

- One of 4 samples collected for gradation in the embankment met standard highways materials gradation standards for Selected Materials Type C.

Table 3. Laboratory data from drilling in the south approach to the existing Riley Creek Bridge. (Number of determinations is listed in parenthesis)

Site	% Gravel (+#4)	% Sand (-#4, +#200)	% Fines (-#200)	USCS Classification	LA Abrasion	Degradation	%Moisture	Organic	Max density / %Opt. moisture	Liquid Limit / Plastic Index
RCB South Approach	Fill/Glacial Till/Alluvium									
	41-65 (5)	20.8-44.7 (5)	4.8-11.3 (5)	GW, GP-GM (1),(1)	-	-	3.1-5.5 (5)	0.8-3.5 (10)	-	NV/NP (5)
	Deeper silt and sand deposits									
	0-1 (3)	0-12.3 (3)	86.7-94 (3)	-	-	-	19.6-22.5 (3)	1.8-2.3 (3)	-	19-23/NP-5 (3)

Denali Park Road/ Parks Highway Intersection (TH13-5108, TH13-5109, and TH13-5127)

Noticeable settlement has occurred at the intersection of Denali Park Road and the Parks Highway. NRMS drilled three hollow-stem auger test holes with SPT tests in 5-foot intervals to collect in-situ soil density information for settlement assessment. TH13-5108 was drilled where settlement appeared to be at an end to provide basis for comparison. TH13-5109 and TH13-5127 were drilled where settlement was most obvious. These test holes intercepted the following generalized soil profiles:

TH13-5108

- 0.3-foot thick asphalt layer;
- 1.2-feet of crushed poorly-graded gravel with sand and silt (fill)
- 7.5-feet of dense well-graded gravel with sand, silt, cobbles and boulders (fill?)
- 5-feet of loose to medium dense well-graded gravel with sand, silt, cobbles, and boulders.

TH13-5109 and TH13-5127

- 0.1 to 1.5-feet of asphalt (3-layers in TH13-5127);
- 0 to 11.9-feet dense well-graded gravel with sand, silt, and cobbles (fill);
- 8.5 to 11-feet of loose silt with sand, sandy silty, poorly-graded sand with silt, or silty sand;
- 0 to 2-feet of soft to stiff silty clay;
- 0 to 4 feet of sandy silt.

Only TH13-5127 (drilled in the lowest area) intercepted clay and frozen soil.

TH13-5127 intercepted frozen soil with 5% visible Vs (thaw unstable ice) from 12 to 16 feet below finished grade.

Laboratory data
Laboratory analyses of samples collected from drilling in the Denali Park Road Intersection are summarized below:

- Three of 3 samples collected for gradation in the embankment met standard highways materials gradation standards for Selected Materials Type B.

Table 4. Laboratory data from drilling in the Denali Park Road intersection. (Number of determinations is listed in parenthesis)

Site	% Gravel (+#4)	% Sand (-#4, +#200)	% Fines (-#200)	USCS Classification	LA Abrasion	Degradation	%Moisture	Organic	Max density / %Opt. moisture	Liquid Limit / Plastic Index
Denali Park Road Intersection	Fill/Glacial Till/Alluvium									
	34-50 (5)	40.4-51.3 (5)	6.3-14.1 (5)	GW-GM, SM (1), (1)	-	-	1.2-13.1 (5)	1.2-1.7 (5)	-	NV/NP (5)
	Deeper silt and sand deposits									
	0 (3)	4.8-1.8 (3)	95.2-98.2 (3)	-	-	-	19.0-27.2 (3)	1.2-2.0 (3)	-	19-NV/NP (3)

Northern Riley Creek Bridge Alignment (TH13-5114 to TH13-5118 and TH13-5126)

The northern Riley Creek Bridge Alignment was drilled predominantly with solid stem augers (with the exception of TH13-5115 which was drilled with hollow stem because it was located adjacent the Denali Park Road intersection). Test holes from the northern Riley Creek Bridge Alignment intercepted the following generalized soil profile:

- 0 to 1-foot thick lichen/organic mat;
- 3 to 9.5-feet of loose well-or poorly-graded gravels with sand, silt, cobbles, and boulders. Up to 50% cobbles in this interval;
- 1 to 3.5-feet of loose poorly-graded sand with silt;
- Underlain by (in most test holes) cobbles and boulders with silt and gravel or poorly-or well-graded gravel with sand silt, cobbles and boulders.
- Underlain by (only TH13-5114 drilled deep enough to intercept this soil) stiff silty clay with sand.

The deepest test hole, TH13-5114, intercepted silty clay at 17-feet. The majority of other test holes were cut short due to refusal/broken steel complications from hard cobbles and boulders. It is possible that this clay layer is present beneath the other test holes as well.

TH13-5114 intercepted 0.5-feet of seasonal frost (Nbn) just below the surface.

Laboratory data

Laboratory analyses of samples collected from drilling in the northern Riley Creek Bridge Alignment are summarized below:

- One of 10 samples collected for gradation in the embankment met standard highways materials gradation standards for Selected Materials Type A.
- Five of 10 samples collected for gradation in the embankment met standard highways materials gradation standards for Selected Materials Type B.
- Four of 10 samples collected for gradation in the embankment met standard highways materials gradation standards for Selected Materials Type C.

Table 5. Laboratory data from drilling in the northern Riley Creek Bridge Alignment. (Number of determinations is listed in parenthesis)

Site	% Gravel (+#4)	% Sand (-#4, +#200)	% Fines (-#200)	USCS Classification	LA Abrasion	Degradation	%Moisture	Organic	Max density / %Opt. moisture	Liquid Limit / Plastic Index
Northern Alignment	Fill/Glacial Till/Alluvium									
	25-80 (10)	16.4-59.9 (10)	3.6-16.6 (10)	GP-GM, SP-SM, GW, GW-GM (3), (1), (1), (2)	-	-	2.6-3.7 (4)	1.2-2.0 (4)	-	NV/NP (9)
	Deeper silt and sand deposits									
	5 (1)	14.2 (1)	80.8 (1)	-	-	-	23.2 (1)	3.2 (1)	-	19-NV/NP (1)

Southern Riley Creek Bridge Alignment (TH13-5106, TH13-5107 and TH13-5120 to TH13-5124)

The northern Riley Creek Bridge Alignment was drilled with solid stem augers. Test holes from the southern Riley Creek Bridge Alignment intercepted the following generalized soil profile:

- 0 to 0.3-feet of asphalt;
- 0 to 1.75-feet poorly-graded gravel with silt, and sand or silty sand with gravel. Crushed material found only in test holes with asphalt;
- Underlain by poorly-or well-graded gravel with silt, cobbles and boulders. This layer has an intermediate layer of silty sand with gravel in some cases that was never observed to be greater than 2-feet thick.

Seasonal frost was observed in TH13-5120, TH13-5121, TH13-5122, and TH13-5124. The seasonal frost layers observed did not extend to depths greater than 1-foot below the ground surface and were composed of Nbn.

Laboratory data

Laboratory analyses of samples collected from drilling in the southern Riley Creek Bridge Alignment are summarized below:

- Six of 8 samples collected for gradation in the embankment met standard highways materials gradation standards for Selected Materials Type A.
- Two of 8 samples collected for gradation in the embankment met standard highways materials gradation standards for Selected Materials Type B.

Table 6. Laboratory data from drilling in the southern Riley Creek Bridge Alignment. (Number of determinations is listed in parenthesis)

Site	% Gravel (+#4)	% Sand (-#4, +#200)	% Fines (-#200)	USCS Classification	LA Abrasion	Degradation	%Moisture	Organic	Max density / %Opt. moisture	Liquid Limit / Plastic Index
Southern Alignment	Fill/Glacial Till/Alluvium									
	57-87 (9)	10.5-37.5 (9)	2.5-6.5 (9)	GW, GW-GM, GP, GP-GM (3), (2), (2), (2)	-	-	1.7-2.0 (2)	0.8 (2)	-	NV/NP (9)

Replacement Riley Creek Bridge Abutments

North (TH13-5113)

- The penetration rod test in the north abutment hit refusal (1,000 blows/minute) abruptly at a depth of 57-feet below the ground surface.

South (TH13-5119)

- The penetration rod test in the north abutment hit refusal (1,000 blows/minute) abruptly at a depth of 66-feet below the ground surface.

Expected Physical Site Conditions

- Expect to find frozen ground, either seasonal or perennially frozen, anywhere at the site, at any time of the year.
- Boulders and/or cobbles should be anticipated in the glacial and fluvial deposits.
- Expect water table elevations to fluctuate from than those shown in this report. The water table generally fluctuates with changing river levels and precipitation.

Comments and Recommendations

- Test holes in high maintenance section of the Parks Highway at its intersection with Denali Park Road all showed multiple layers of asphalt (3 layers in TH13-5127) or thin asphalt (1-inch in TH13-5109) and very loose silt in subgrade soils. TH13-5109 intercepted very loose thawed silt beneath the initial 3.6-feet of sand in subgrade. TH13-5127 intercepted loose sandy silt and silty clay in subgrade above frozen, thaw un-stable sandy silt in the bottom of the test hole. Thawing of thaw un-stable frozen soils and/or consolidation of loose subgrade silts is likely the cause for excessive maintenance in this area.

- Test holes drilled in the south approach to the existing Riley Creek Bridge (TH13-5110 through 13-5112) intercepted loose silt and/or soft silty clay at the base of the embankment at depths that ranged from 22.5 to 23-feet below the existing finished grade. Loose well-graded gravels with sand and silt were also observed in the lower portion of the embankment. Consolidation of subgrade soils and loss of lateral confinement at the base of the existing abutment is likely the cause of excessive settlement in this interval. The embankment has eroded away from the north abutment and possibly the south abutment which could have caused settlement.
- As noted in the Geology section of this report, Riley Creek Bridge is approximately 19-miles south of the Denali Fault which is an active fault that shows approximately 3/8-ich of slip per year and is the source of the 2002 earthquake that was responsible for major damage to infrastructure throughout Alaska. The Riley Creek Fault also runs through the project area and, based on previous drill logs and surface geomorphology, appears to run directly beneath the north abutment in the existing Riley Creek Bridge. The project's close proximity to the major active Denali Fault and smaller but probably at least Holocene active Riley Creek Fault merits careful design consideration. At minimum, designers should keep the bridge on one side of the Riley Creek Fault if budget and geometric constraints allow.
- Fill material placed in the Parks Highway Embankment is very similar to the native soil the embankment sits on. There appeared to be a slight density contrast between the in-situ density of the embankment fill (higher density) and the native material (looser). In many cases this distinction was evidenced only by drill reaction. It was very difficult to accurately pinpoint the native/fill transition in most of the test holes drilled in this project area.

References

Alaska Department of Transportation and Public Facilities. 2003, Alaska Field Rock Classification and Structural Mapping Guide: State of Alaska, ADOT&PF Geotechnical Procedures Manual, 31 p.

Eberhart-Phillips, Donna, et al. "The 2002 Denali fault earthquake, Alaska: A large magnitude, slip-partitioned event." *Science* 300.5622 (2003): 1113-1118.

Matmon, Ari, et al. "Denali fault slip rates and Holocene–late Pleistocene kinematics of central Alaska." *Geology* 34.8 (2006): 645-648.

Appendix A-Test Hole Logs

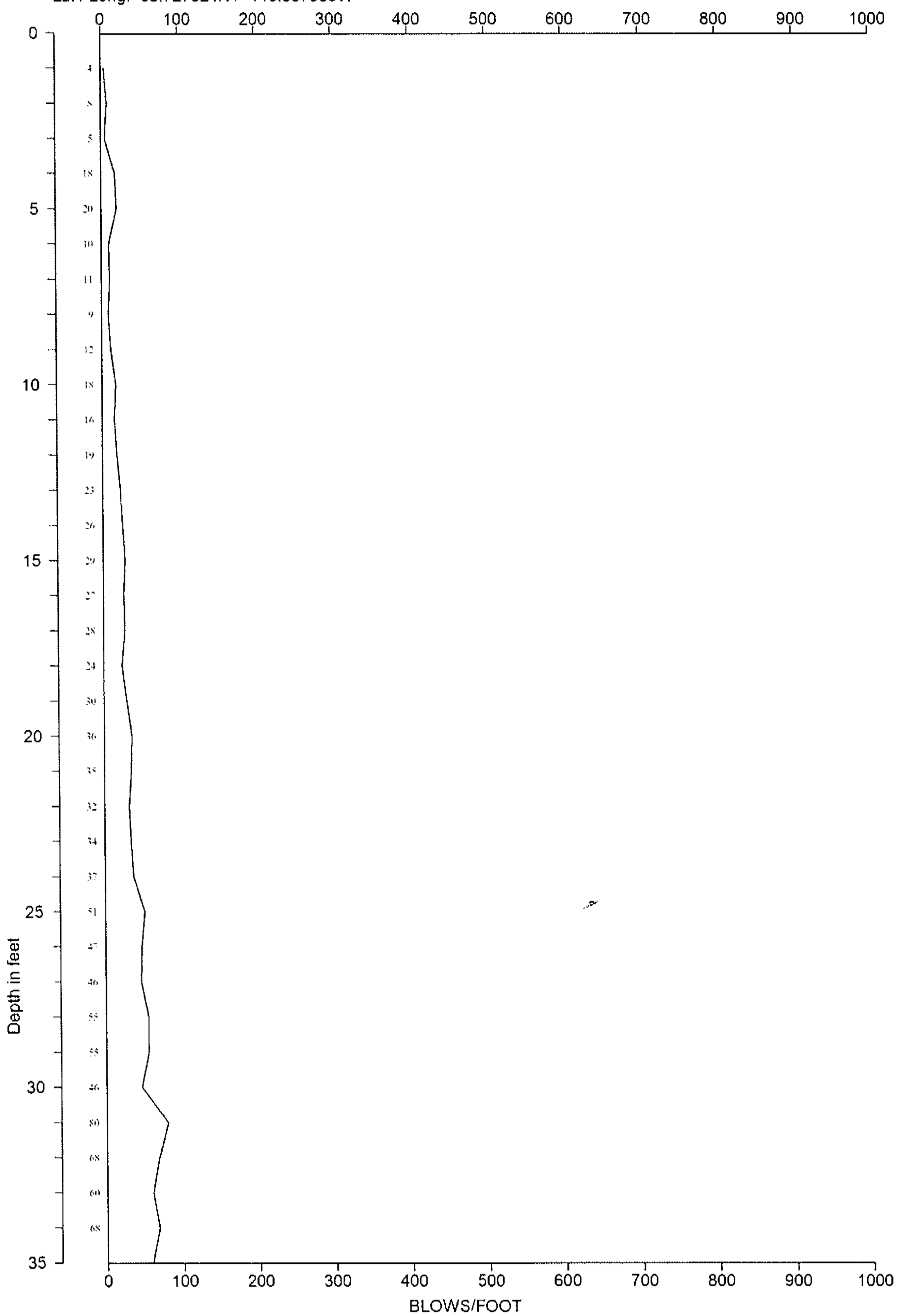
STATE OF ALASKA DEPARTMENT OF TRANSPORTATION
NORTHERN REGION
PENETROMETER REPORT

Sheet 1 of 2

PENETROMETER 13-5113
Elevation:
Date: 11/10/13
Lat / Long: 63.727624N / -148.887385W

PROJECT NAME:
AKSAS NUMBER: 63763
SAMPLED BY: G. SPEETER
STATION / OFFSET: 2859+35 / 25R

BLOWS/FOOT



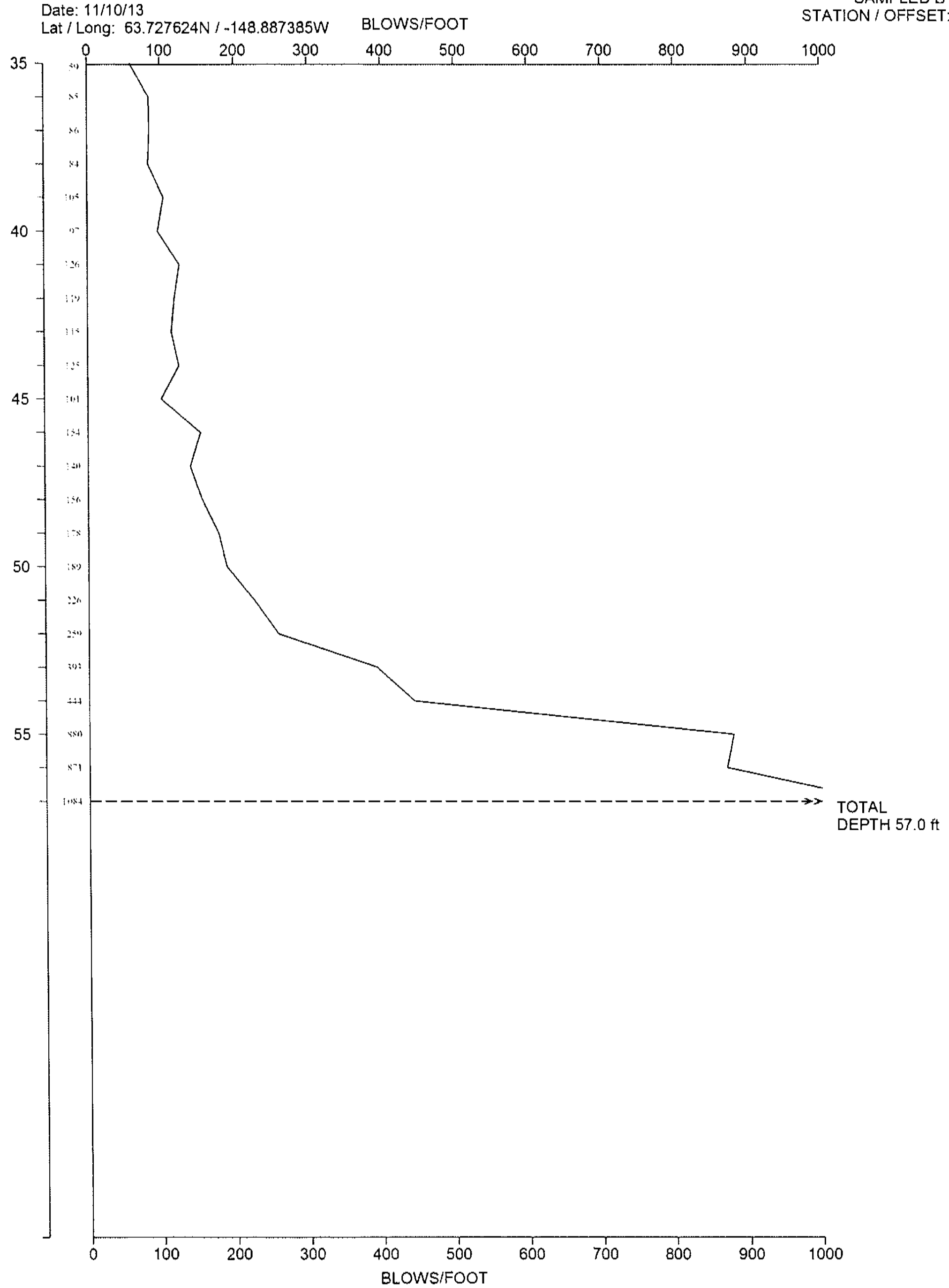
BLOWS/FOOT
(Penetrometer w/ 2.5 in O.D., with a CME automatic hammer using a 340 lb weight and a 30 in freefall)

NOTES:
BODR=Based on drill reaction

STATE OF ALASKA DEPARTMENT OF TRANSPORTATION
NORTHERN REGION
PENETROMETER REPORT

PENETROMETER 13-5113
Elevation:
Date: 11/10/13
Lat / Long: 63.727624N / -148.887385W

PROJECT NAME:
AKSAS NUMBER: 63763
SAMPLED BY: G. SPEETER
STATION / OFFSET: 2859+35 / 25R



(Penetrometer w/ 2.5 in O.D., with a CME automatic hammer using a 340 lb weight and a 30 in freefall)

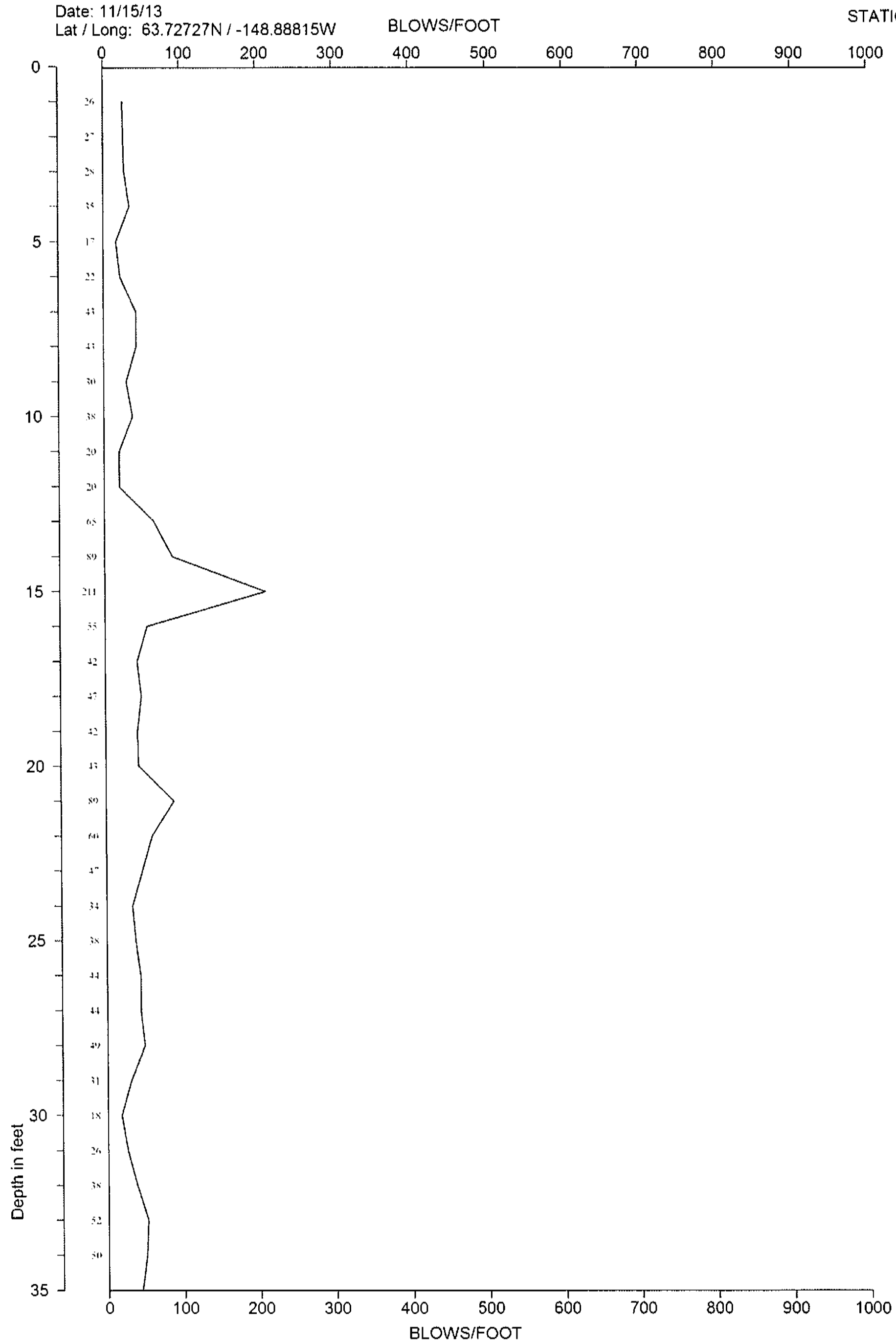
NOTES:
BODR=Based on drill reaction

STATE OF ALASKA DEPARTMENT OF TRANSPORTATION
NORTHERN REGION
PENETROMETER REPORT

Sheet 1 of 2

PENETROMETER 13-5119
Elevation:
Date: 11/15/13
Lat / Long: 63.72727N / -148.88815W

PROJECT NAME:
AKSAS NUMBER: 63763
SAMPLED BY: G. SPEETER
STATION / OFFSET: 2857+72 / 25R



(Penetrometer w/ 2.5 in O.D., with a CME automatic hammer using a 340 lb weight and a 30 in freefall)

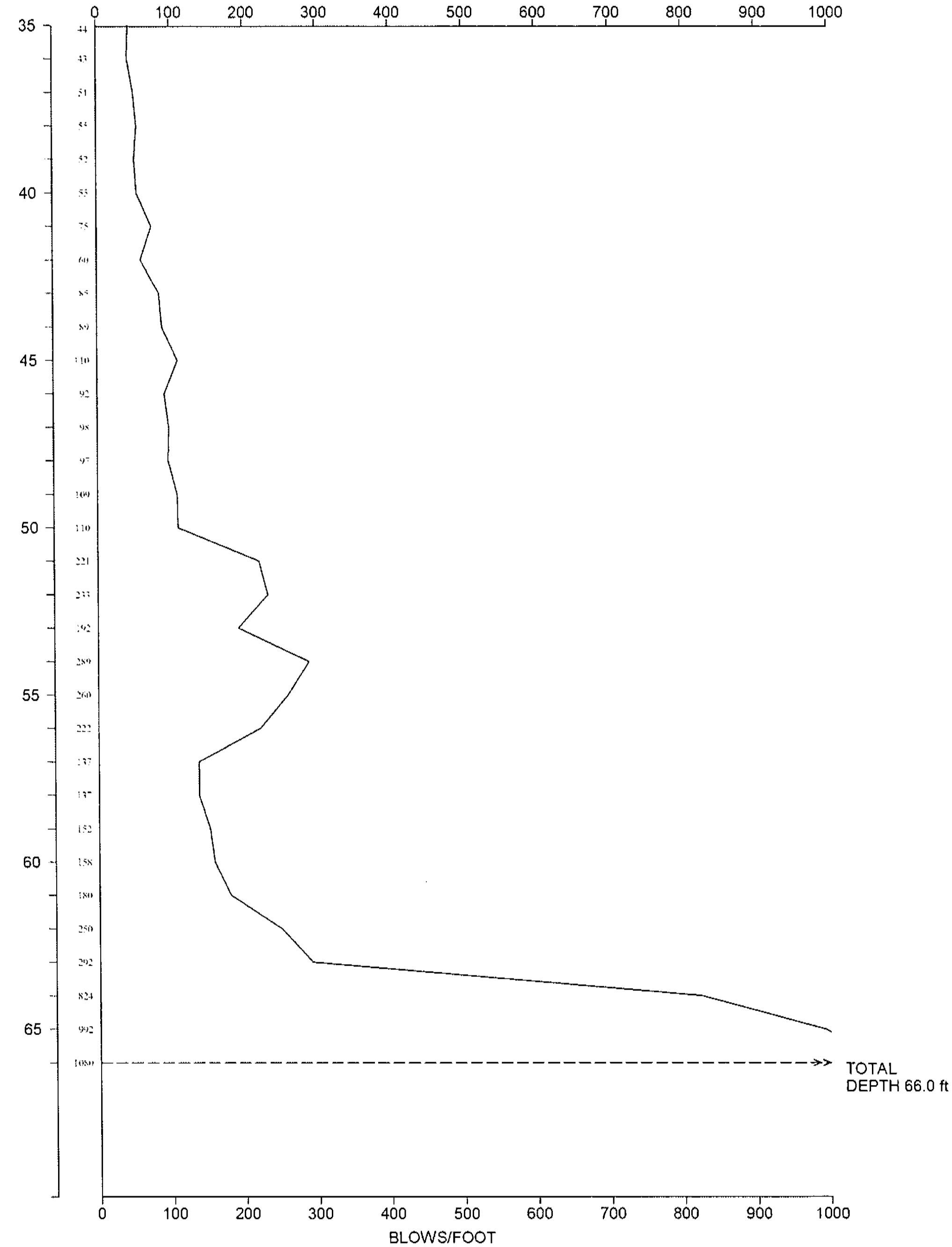
NOTES:
BODR=Based on drill reaction

STATE OF ALASKA DEPARTMENT OF TRANSPORTATION
NORTHERN REGION
PENETROMETER REPORT

PENETROMETER 13-5119
Elevation:
Date: 11/15/13
Lat / Long: 63.72727N / -148.88815W

PROJECT NAME:
AKSAS NUMBER: 63763
SAMPLED BY: G. SPEETER
STATION / OFFSET: 2857+72 / 25R

BLOWS/FOOT



(Penetrometer w/ 2.5 in O.D., with a CME automatic hammer using a 340 lb weight and a 30 in freefall)

NOTES:
BODR=Based on drill reaction

FINAL TEST HOLE LOG

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

Field Geologist	G. SPEETER	Project	Riley Creek Bridge Alignment	Test Hole Number	13-5106
Field Crew	P. Lanigan S. Parker	Project Number	AKSAS 63763	Total Depth	21 feet
TH Finalized By	G. SPEETER	Material Site	S. Riley Creek Alignment	Dates Drilled	11/4/2013 - 11/4/2013
		Equipment Type		Station, Offset	2824+14, 15R
		Weather		Latitude, Longitude	N63.71915°, W148.89648°
		Vegetation		Elevation	

Ground Water Data

	While Drilling	After Drilling
Depth in (ft.)		
Time		
Date		
Symbol		

GENERAL COMMENTS:
S. Riley Creek Alignment

Drilling Method: S-S Auger | Sample Data: Method AUGER, Number 13-5946, sample interval 6.0–9.5 ft

SUBSURFACE MATERIAL

Depth (ft)	Description
0–2	Bk ASPHALT (fill) 2-inch
2–4	Bn Poorly-graded GRAVEL w/ Silt & Sand (fill) dry to moist, crushed
4–6	Bn Well-graded GRAVEL w/ Sand (fill?) w/ Cobbles and Boulders dry to moist, dense BODR
6–10	Bn Well-graded GRAVEL w/ Sand (fill?) w/ Cobbles and Boulders dry to moist, loose BODR SAMPLE 13-5946 (6.0-9.5): GW, 3.8% -200, NM 1.7%, ORG 0.8%, NV, NP
10–11	Bn Poorly-graded SAND w/ Gravel dry to moist
11–21	Bn Well-graded GRAVEL w/ Sand w/ Cobbles and Boulders dry to moist, med-dense BODR
21	BOH

Drilling Notes: BODR=Based on drill reaction

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop. ☐ CME Auto Hammer ☐ Cathead Rope Method

NR AKDOT TEST HOLE LOG - USCS RILEY CREEK BRIDGE.GPJ NR AKDOT PRECON USCS 06 28 07.GDT 4/8/14

FINAL TEST HOLE LOG

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

Field Geologist	G. SPEETER	Project	Riley Creek Bridge Alignment
Field Crew	P. Lanigan S. Parker	Project Number	AKSAS 63763
TH Finalized By	G. SPEETER	Material Site	S. Riley Creek Alignment
		Equipment Type	
		Weather	
		Vegetation	
		Test Hole Number	13-5107
		Total Depth	17 feet
		Dates Drilled	11/4/2013 - 11/4/2013
		Station, Offset	1819-14, 8R
		Latitude, Longitude	N63.71785°, W148.89578°
		Elevation	

Ground Water Data

	While Drilling	After Drilling
Depth in (ft.)		
Time		
Date		
Symbol		

GENERAL COMMENTS:
S. Riley Creek Alignment

Drilling Method	Depth in (Feet)	Casing Blows / ft	Method	Number	Blow Count	Sample Interval	N-Value	Frozen	Graphic Log	SUBSURFACE MATERIAL
S-S Auger	0–0.25									Bk ASPHALT (fill) 3-inch
	0.25–2									Bn Poorly-graded GRAVEL w/ Silt & Sand (fill) dry to moist, crushed
	2–5									Bn Well-graded GRAVEL w/ Silt & Sand (fill?) w/ Cobbles and Boulders dry to moist, dense BODR
	5–17		AUGER	13-5947		5.0–10.0				Bn Well-graded GRAVEL w/ Silt & Sand (fill?) w/ Cobbles and Boulders dry to moist, loose BODR SAMPLE 13-5947 (5.0-10.0): GW-GM, 5.5% -200, NV, NP
	17									BOH

Drilling Notes: BODR=Based on drill reaction

NR AKDOT TEST HOLE LOG - USCS RILEY CREEK BRIDGE.GPJ NR AKDOT PRECON USCS 06 28 07.GDT 4/8/14

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop. ☐ CME Auto Hammer ☐ Cathead Rope Method

FINAL TEST HOLE LOG

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

Project	Riley Creek Bridge Alignment	Test Hole Number	13-5108
Project Number	AKSAS 63763	Total Depth	14.5 feet
Field Geologist: G. SPEETER	Material Site: Denali Park Road Intersection	Dates Drilled	11/4/2013 - 11/5/2013
Field Crew: P. Lanigan S. Parker	Equipment Type:	Station, Offset	2864, 44L
	Weather:	Latitude, Longitude	N63.72867°, W148.8858°
TH Finalized By: G. SPEETER	Vegetation:	Elevation	

Ground Water Data	While Drilling	After Drilling
Depth in (ft.)		
Time		
Date		
Symbol		

GENERAL COMMENTS: Denali Park Road Intersection

Drilling Method	Depth in (Feet)	Casing Blows / ft	Method	Number	Blow Count	N-Value	Frozen	Subsurface Material
H-S Auger	0–0.3							Bk ASPHALT (fill) 4-inch
	0.3–4							Bn Poorly-graded GRAVEL w/ Silt & Sand (fill) dry to moist, crushed
	4–9		AUGER	13-5948	14, 16, 17, 20	33		Bn Well-graded GRAVEL w/ Silt & Sand (fill?) w/ Cobbles and Boulders dry to moist, dense, dense. Sample not representitive. SAMPLE 13-5948 (6.0-7.0): SM, 14.1% -200, NV, NP
	9–14.5		AUGER	13-5949B	7, 7, 7, 12	14		Bn Well-graded GRAVEL w/ Silt & Sand (fill?) w/ Cobbles and Boulders dry to moist, loose, loose. Refusal on boulder ended TH. SAMPLE 13-5949B (10.0-12.0): GW-GM, 6.6% -200, NM 1.7%, ORG 1.2%, NV, NP
	14.5							BOH

Drilling Notes: BODR=Based on drill reaction

NR AKDOT TEST HOLE LOG - USCS RILEY CREEK BRIDGE.GPJ NR AKDOT PRECON USCS 06 28 07.GDT 4/8/14

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop. ☐ CME Auto Hammer ☐ Cathead Rope Method

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

FINAL TEST HOLE LOG

Project	Riley Creek Bridge Alignment	Test Hole Number	13-5109
Project Number	AKSAS 63763	Total Depth	22 feet
Material Site	Denali Park Road Intersection	Dates Drilled	11/7/2013 - 11/7/2013
Equipment Type		Station, Offset	2863+8, 48L
Weather		Latitude, Longitude	N63.72851°, W148.88615°
Vegetation		Elevation	

Field Geologist: G. SPEETER
Field Crew: P. Lanigan S. Parker
TH Finalized By: G. SPEETER

Ground Water Data

	While Drilling	After Drilling
Depth in (ft.)		
Time		
Date		
Symbol		

GENERAL COMMENTS:
Denali Park Road Intersection

Drilling Method: H-S Auger

Sample Data

Depth in (Feet)	Casing Blows / ft	Method	Number	Blow Count	N-Value	Frozen
0.5–3.0		AUGER	13-5949A			
5.0–7.0		SPT	13-5950	5, 11, 11, 13	22	
10.0–12.0				8, 9, 5, 4	14	
15.0–17.0		SPT	13-5982	1, 2, 2, 3	4	
20.0–22.0		SPT	13-5983	1, 2, 3, 2	5	

SUBSURFACE MATERIAL

Depth (ft)	Description
0–0.1	Bk ASPHALT (fill) 1-inch
0.1–11	Bn Well-graded GRAVEL w/ Silt & Sand (fill?) w/ Cobbles and Boulders dry to moist, medium dense, dense BODR SAMPLE 13-5949A (0.5-3.0): GW-GM, 8.6% -200, NM 2.2%, ORG 1.3%, NV, NP SAMPLE 13-5950 (5.0-7.0): GW-GM, 6.3% -200, NM 2.4%, ORG 1.6%, NV, NP
11–14.5	Bn Poorly-graded SAND w/ Silt moist to wet, loose, fine grained.
14.5–19	Gy SILT w/ Sand wet, very loose SAMPLE 13-5982 (15.0-17.0): ML, 98.2% -200, NM 27.2%, ORG 2.0%, NV, NP
19–22	Gy SILT w/ Sand wet, very loose, less sand SAMPLE 13-5983 (20.0-22.0): ML, 95.2% -200, NM 23.2%, ORG 2.1%, LL 24, PI 3
22	BOH

Drilling Notes: BODR=Based on drill reaction

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop. ☐ CME Auto Hammer ☐ Cathead Rope Method

NR AKDOT TEST HOLE LOG - USCS RILEY CREEK BRIDGE.GPJ NR AKDOT PRECON USCS 06 28 07.GDT 4/8/14

FINAL TEST HOLE LOG

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

Project	Riley Creek Bridge Alignment	Test Hole Number	13-5110
Project Number	AKSAS 63763	Total Depth	31.5 feet
Material Site	Riley Creek Bridge Approach	Dates Drilled	11/8/2013 - 11/8/2013
Equipment Type		Station, Offset	2857-37, 40L
Weather		Latitude, Longitude	N63.72733°, W148.88851°
Vegetation		Elevation	

Field Geologist: G. SPEETER
Field Crew: P. Lanigan S. Parker
TH Finalized By: G. SPEETER

Ground Water Data	While Drilling	After Drilling
Depth in (ft.)	31.0	
Time		
Date		
Symbol	▼	

GENERAL COMMENTS:
Riley Creek Bridge Approach

Drilling Method: S-S Auger

Depth (Feet)	Method	Number	Blow Count	N-Value
4–6	SPT		3, 5, 9, 7	14
6.5–11	AUGER	13-5985		
9–11			6, 5, 5, 3	10
14–16	AUGER	13-5986	9, 7, 8, 13	15
19–21	SPT		8, 9, 9, 9	18
24–26	SPT	13-5988	1, 3, 4, 4	7
29–31	SPT	13-5989	1, 6, 7, 8	13

SUBSURFACE MATERIAL

0–1: Bk ASPHALT (fill) 4-inch

1–2: Bk ASPHALT (fill) Old. Softer.

2–22: Bn Well-graded GRAVEL w/ Sand (fill?) w/ Cobbles and Boulders dry to moist, medium dense, dense BODR

SAMPLE 13-5985 (6.5-11.0): GW, 4.8% -200, NM 3.1%, ORG 0.8%, NV, NP

SAMPLE 13-5986 (14.0-16.0): GP-GM, 7.2% -200, NM 3.4%, ORG 1.6%, NV, NP

22–30: Gy Silty CLAY moist, soft, 4.9C

SAMPLE 13-5988 (24.0-26.0): CL-ML, 94.1% -200, NM 21.5%, ORG 2.0%, LL 23, PI 5

SAMPLE 13-5989 (29.0-31.0):

30–31.5: Bn Poorly-graded SAND w/ Silt wet, medium dense

BOH

Drilling Notes: BODR=Based on drill reaction

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop. ☐ CME Auto Hammer ☐ Cathead Rope Method

FINAL TEST HOLE LOG

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

Field Geologist	G. SPEETER	Project	Riley Creek Bridge Alignment
Field Crew	P. Lanigan S. Parker	Project Number	AKSAS 63763
TH Finalized By	G. SPEETER	Material Site	Riley Creek Bridge Approach
		Equipment Type	
		Weather	
		Vegetation	

Test Hole Number	13-5111
Total Depth	30 feet
Dates Drilled	11/8/2013 - 11/9/2013
Station, Offset	2856-94, 80L
Latitude, Longitude	N63.72731°, W148.88891°
Elevation	

Ground Water Data

	While Drilling	After Drilling
Depth in (ft.)		
Time		
Date		
Symbol		

GENERAL COMMENTS:
Riley Creek Bridge Approach

Drilling Method: H-S Auger

Sample Data

Depth in (Feet)	Method	Number	Blow Count	N-Value
4.5–6.5	SPT	13-5990	10, 18, 20, 23	38
9–11	SPT	13-5991	9, 11, 7, 8	18
14–16	SPT	13-5992	14, 17, 15, 14	32
24–26	SPT	13-5993	1, 3, 4, 4	7
28–30	SPT	13-5994	1, 2, 4, 6	6

SUBSURFACE MATERIAL

0–0.5 ft: Bk ASPHALT (fill) 6-inch

2–4 ft: Bk ASPHALT (fill) Old. Softer.

4–23 ft: Bn Well-graded GRAVEL w/ Silt & Sand (fill?) w/ Cobbles and Boulders dry to moist, medium dense, dense BODR

SAMPLE 13-5990 (5.0-6.0): NM 2.8%, ORG 1.0%

SAMPLE 13-5991 (9.0-11.0): NM 1.9%

SAMPLE 13-5992 (14.0-16.0): GW-GM, 8.8% -200, NM 4.2%, ORG 1.6%, NV, NP

23–30 ft: Gy Sandy SILT (fill?) moist, loose, 4.9C

SAMPLE 13-5993 (24.0-26.0): ML, 86.7% -200, NM 22.5%, ORG 2.3%, LL 23, PI 3

SAMPLE 13-5994 (28.0-30.0): ML, 89.2% -200, NM 19.6%, ORG 1.8%, LL 19, NP

BOH (30 ft)

Drilling Notes: BODR=Based on drill reaction

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop. ☐ CME Auto Hammer ☐ Cathead Rope Method

NR AKDOT TEST HOLE LOG - USCS RILEY CREEK BRIDGE.GPJ NR AKDOT PRECON USCS 06 28 07.GDT 4/8/14

FINAL TEST HOLE LOG

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

Field Geologist	G. SPEETER	Project	Riley Creek Bridge Alignment
Field Crew	P. Lanigan S. Parker	Project Number	AKSAS 63763
TH Finalized By	G. SPEETER	Material Site	Riley Creek Bridge Approach
		Equipment Type	
		Weather	
		Vegetation	
Test Hole Number	13-5112	Total Depth	26 feet
Dates Drilled	11/9/2013 - 11/9/2013	Station, Offset	2855+91, 45L
Latitude, Longitude	N63.72704°, W148.88917°	Elevation	

Ground Water Data

	While Drilling	After Drilling
Depth in (ft.)		
Time		
Date		
Symbol		

GENERAL COMMENTS: Riley Creek Bridge Approach

Drilling Method: H-S Auger

Depth in (Feet)	Method	Number	Blow Count	N-Value	SUBSURFACE MATERIAL
0–0.5					Bk ASPHALT (fill) 6-inch
0.5–12.5	AUGER	13-5995, 13-5997	7, X		Bn Poorly-graded GRAVEL w/ Silt & Sand (fill?) w/ Cobbles and Boulders dry to moist, dense BODR. SAMPLE 13-5997 (2.0-9.0): GP-GM, 7.2% -200, NV, NP. SAMPLE 13-5995 (4.0-4.5): NM 3.5%, ORG 1.0%
9–11	SPT	13-5996	6, 9, 10, 4	19	SAMPLE 13-5996 (9.0-11.0): NM 2.3%, ORG 1.1%
12.5–26					Bn Well-graded GRAVEL w/ Silt & Sand (fill?) w/ Cobbles and Boulders dry to moist, loose BODR. 13-5999 gradation not representative.
14–16	SPT	13-5998	6, 13, 13, 14	26	SAMPLE 13-5998 (14.0-16.0): NM 2.3%, ORG 1.5%
19–21	SPT	13-5999	5, 8, 13, 15	21	SAMPLE 13-5999 (19.0-21.0): SP-SM, 11.3% -200, NM 5.5%, ORG 1.7%, NV, NP
26					BOH

Drilling Notes: BODR=Based on drill reaction

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop. ☐ CME Auto Hammer ☐ Cathead Rope Method

NR AKDOT TEST HOLE LOG - USCS RILEY CREEK BRIDGE.GPJ NR AKDOT PRECON USCS 06 28 07.GDT 4/8/14

FINAL TEST HOLE LOG

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

Project	Riley Creek Bridge Alignment	Test Hole Number	13-5114
Project Number	AKSAS 63763	Total Depth	22 feet
Field Geologist: G. SPEETER / Material Site	N. Riley Creek Alignment	Dates Drilled	11/11/2013 - 11/11/2013
Field Crew: P. Lanigan S. Parker / Equipment Type		Station, Offset	2861-13, 13R
Weather		Latitude, Longitude	N63.728°, W148.88668°
TH Finalized By: G. SPEETER / Vegetation		Elevation	

Ground Water Data	While Drilling	After Drilling
Depth in (ft.)		
Time		
Date		
Symbol		

GENERAL COMMENTS: N. Riley Creek Alignment

Columns: Drilling Method | Depth in (Feet) | Casing Blows / ft | Sample Data: Method, Number, Blow Count, Sample Interval, N-Value | Frozen | Graphic Log

Drilling Method: S-S Auger

Samples: AUGER 13-6001 (4.0–10.0 ft); AUGER 13-6002 (17.0–20.0 ft)

SUBSURFACE MATERIAL

Depth (ft)	Description
0 – 9	Bn Well-graded GRAVEL w/ Silt & Sand (fill?) w/ Cobbles and Boulders moist, Dense BODR SAMPLE 13-6001 (4.0-10.0): GW-GM, 6% -200, NV, NP
9 – 11	Bn Poorly-graded SAND w/ Gravel (fill?) w/ Cobbles lose BODR
11 – 17	Bn Well-graded GRAVEL w/ Silt & Sand w/ Cobbles and Boulders moist, lose BODR
17 – 22	Gy SILT w/ Sand wet, Hard BODR. Plastic? SAMPLE 13-6002 (17.0-20.0): ML, 80.8% -200, NM 23.2%, ORG 3.2%, NV, NP
22	BOH

Drilling Notes: BODR=Based on drill reaction

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop. ☐ CME Auto Hammer ☐ Cathead Rope Method

NR AKDOT TEST HOLE LOG - USCS RILEY CREEK BRIDGE.GPJ NR AKDOT PRECON USCS 06 28 07.GDT 4/8/14

FINAL TEST HOLE LOG

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

Project	Riley Creek Bridge Alignment	Test Hole Number	13-5115
Project Number	AKSAS 63763	Total Depth	14 feet
Material Site	N. Riley Creek Alignment	Dates Drilled	11/11/2013 - 11/12/2013
Equipment Type		Station, Offset	2863-4
Weather		Latitude, Longitude	N63.72841°, W148.88595°
Vegetation		Elevation	

Field Geologist: G. SPEETER
Field Crew: P. Lanigan R. Sousa
TH Finalized By: G. SPEETER

Ground Water Data	While Drilling	After Drilling
Depth in (ft.)		
Time		
Date		
Symbol		

GENERAL COMMENTS:
N. Riley Creek Alignment

Drilling Method	Depth in (Feet)	Casing Blows / ft	Method	Number	Blow Count	N-Value	Frozen	Subsurface Material
H-S Auger	0							Gn ORG MAT
	0–9							Bn Poorly-graded GRAVEL w/ Sand w/ Cobbles and Boulders moist, medium dense, 40-50% cobbles and boulders.
	4.0–6.0		SPT	13-6003	7, 5, 7, 9	12		SAMPLE 13-6003 (4.0-6.0): NM 3.7%, ORG 1.7%
	9–13							Bn Poorly-graded SAND w/ Silt loose
	13–14							Bn COBBLES AND BOULDERS w/ Gravel Broken drill bit.

Drilling Notes: BODR=Based on drill reaction

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop. ☐ CME Auto Hammer ☐ Cathead Rope Method

NR AKDOT TEST HOLE LOG - USCS RILEY CREEK BRIDGE.GPJ NR AKDOT PRECON USCS 06 28 07.GDT 4/8/14

FINAL TEST HOLE LOG

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

Field Geologist	G. SPEETER	Project	Riley Creek Bridge Alignment
Field Crew	P. Lanigan R. Sousa	Project Number	AKSAS 63763
TH Finalized By	G. SPEETER	Material Site	N. Riley Creek Alignment
		Equipment Type	
		Weather	
		Vegetation	
		Test Hole Number	13-5116
		Total Depth	14 feet
		Dates Drilled	11/12/2013 - 11/12/2013
		Station, Offset	2865-16, 4R
		Latitude, Longitude	N63.72884°, W148.88504°
		Elevation	

Ground Water Data	While Drilling	After Drilling
Depth in (ft.)		
Time		
Date		
Symbol		

GENERAL COMMENTS: N. Riley Creek Alignment

Drilling Method	Depth in (Feet)	Casing Blows / ft	Method	Number	Blow Count	Sample Interval	N-Value	Frozen	Graphic Log	SUBSURFACE MATERIAL
S-S Auger	0									Gn ORG MAT
	0–3									Bn Poorly-graded GRAVEL w/ Silt & Sand w/ Cobbles and Boulders moist
	3–5		AUGER	13-6005		4.0–5.0				Bn Silty SAND w/ Gravel moist SAMPLE 13-6005 (4.0-5.0): SM, 16.6% -200, NV, NP
	5–14		AUGER	13-6006		5.5–9.5				Bn Poorly-graded GRAVEL w/ Silt & Sand w/ Cobbles and Boulders moist, refusal on boulder @13 feet. SAMPLE 13-6006 (5.5-9.5): GP-GM, 8.9% -200, NM 2.6%, ORG 2.0%, NV, NP
	14									BOH

Drilling Notes: BODR=Based on drill reaction

NR AKDOT TEST HOLE LOG - USCS RILEY CREEK BRIDGE.GPJ NR AKDOT PRECON USCS 06 28 07.GDT 4/8/14

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop.

☐ CME Auto Hammer ☐ Cathead Rope Method

FINAL TEST HOLE LOG

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

Project	Riley Creek Bridge Alignment	Test Hole Number	13-5117
Project Number	AKSAS 63763	Total Depth	15 feet
Field Geologist: G. SPEETER / Material Site	N. Riley Creek Alignment	Dates Drilled	11/12/2013 - 11/12/2013
Field Crew: P. Lanigan R. Sousa / Equipment Type		Station, Offset	2867-11, 4L
Weather		Latitude, Longitude	N63.7296°, W148.88366°
TH Finalized By: G. SPEETER / Vegetation		Elevation	

Ground Water Data	While Drilling	After Drilling
Depth in (ft.)		
Time		
Date		
Symbol		

GENERAL COMMENTS: N. Riley Creek Alignment

Drilling Method: S-S Auger

Sample Data: Method: AUGER; Number: 13-6007; Sample Interval 5.0-8.0

SUBSURFACE MATERIAL

Depth (ft)	Description
0–4	Bn Poorly-graded GRAVEL w/ Silt & Sand w/ Cobbles and Boulders moist
4–5.5	Bn Silty SAND w/ Gravel moist
5.5–15	Bn Well-graded GRAVEL w/ Silt & Sand w/ Cobbles and Boulders moist, refusal on boulder @13 feet. SAMPLE 13-6007 (5.0-8.0): GW-GM, 11.5% -200, NM 2.6%, ORG 1.4%, NV, NP
15	BOH

Drilling Notes: BODR=Based on drill reaction

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop. ☐ CME Auto Hammer ☐ Cathead Rope Method

NR AKDOT TEST HOLE LOG - USCS RILEY CREEK BRIDGE.GPJ NR AKDOT PRECON USCS 06 28 07.GDT 4/8/14

FINAL TEST HOLE LOG

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

Field Geologist	G. SPEETER	Project	Riley Creek Bridge Alignment
Field Crew	P. Lanigan R. Sousa	Project Number	AKSAS 63763
TH Finalized By	G. SPEETER	Material Site	N. Riley Creek Alignment
		Equipment Type	
		Weather	
		Vegetation	
Test Hole Number	13-5118	Total Depth	16 feet
Dates Drilled	11/13/2013 - 11/13/2013	Station, Offset	2868+74, 5R
Latitude, Longitude	N63.72925°, W148.88428°	Elevation	

Ground Water Data	While Drilling	After Drilling
Depth in (ft.)		
Time		
Date		
Symbol		

GENERAL COMMENTS: N. Riley Creek Alignment

Drilling Method	Depth in (Feet)	Casing Blows / ft	Method	Number	Blow Count	Sample Interval	N-Value	Frozen	Graphic Log	SUBSURFACE MATERIAL
S-S Auger	0									Gn ORG MAT
	1–6.5		AUGER	13-6008		1.0–6.5				Bn Poorly-graded GRAVEL w/ Silt & Sand w/ Cobbles and Boulders moist SAMPLE 13-6008 (1.0-6.5): GP-GM, 9.6% -200, NM 2.8%, ORG 1.2%, NV, NP
	7									Bn Silty SAND w/ Gravel moist
	10									Bn Well-graded GRAVEL w/ Silt & Sand w/ Cobbles and Boulders moist
	16									BOH

Drilling Notes: BODR=Based on drill reaction

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop. ☐ CME Auto Hammer ☐ Cathead Rope Method

NR AKDOT TEST HOLE LOG - USCS RILEY CREEK BRIDGE.GPJ NR AKDOT PRECON USCS 06 28 07.GDT 4/8/14

FINAL TEST HOLE LOG

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

Field Geologist	G. SPEETER	Project	Riley Creek Bridge Alignment
Field Crew	P. Lanigan R. Sousa	Project Number	AKSAS 63763
TH Finalized By	G. SPEETER	Material Site	S. Riley Creek Alignment
		Equipment Type	
		Weather	
		Vegetation	
		Test Hole Number	13-5120
		Total Depth	16.5 feet
		Dates Drilled	11/16/2013 - 11/16/2013
		Station, Offset	2856+1, 13L
		Latitude, Longitude	N63.72701°, W148.88891°
		Elevation	

Drilling Method | Depth in (Feet) | Casing Blows / ft | Sample Data: Method, Number, Blow Count, Sample Interval, N-Value | Frozen | Graphic Log

Ground Water Data	While Drilling	After Drilling
Depth in (ft.)		
Time		
Date		
Symbol		

GENERAL COMMENTS:
S. Riley Creek Alignment

SUBSURFACE MATERIAL

Depth (ft)	Description
0–6.5	Bn Well-graded GRAVEL w/ Silt & Sand (fill) w/ Cobbles and Boulders moist, Dense BODR
6.5–16.5	Bn Well-graded GRAVEL w/ Silt & Sand (fill?) w/ Cobbles and Boulders moist, Loose BODR. Broken auger.

BOH

Drilling Notes: BODR=Based on drill reaction

NR AKDOT TEST HOLE LOG - USCS RILEY CREEK BRIDGE.GPJ NR AKDOT PRECON USCS 06 28 07.GDT 4/8/14

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop. ☐ CME Auto Hammer ☐ Cathead Rope Method

FINAL TEST HOLE LOG

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

Field Geologist	G. SPEETER	Project	Riley Creek Bridge Alignment
Field Crew	P. Lanigan R. Sousa	Project Number	AKSAS 63763
TH Finalized By	G. SPEETER	Material Site	S. Riley Creek Alignment
		Equipment Type	
		Weather	
		Vegetation	
		Test Hole Number	13-5121
		Total Depth	15 feet
		Dates Drilled	11/17/2013 - 11/17/2013
		Station, Offset	2854+43, 18R
		Latitude, Longitude	N63.7266°, W148.8895°
		Elevation	

Ground Water Data

	While Drilling	After Drilling
Depth in (ft.)		
Time		
Date		
Symbol		

GENERAL COMMENTS:
S. Riley Creek Alignment

Drilling Method	Depth in (Feet)	Casing Blows / ft	Method	Number	Blow Count	Sample Interval	N-Value	Frozen	Graphic Log	SUBSURFACE MATERIAL
S-S Auger	0–3									Bn Poorly-graded GRAVEL w/ Silt & Sand w/ Cobbles and Boulders moist
S-S Auger	3–5									Bn Silty SAND w/ Gravel moist
S-S Auger	5–15		AUGER	13-6009		5.0–9.0				Bn Poorly-graded GRAVEL w/ Silt & Sand w/ Cobbles and Boulders moist SAMPLE 13-6009 (5.0-9.0): GP-GM, 6.5% -200, NV, NP
	15									BODR

Drilling Notes: BODR=Based on drill reaction

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop. ☐ CME Auto Hammer ☐ Cathead Rope Method

NR AKDOT TEST HOLE LOG - USCS RILEY CREEK BRIDGE.GPJ NR AKDOT PRECON USCS 06 28 07.GDT 4/8/14

FINAL TEST HOLE LOG

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

Field Geologist	G. SPEETER	Project	Riley Creek Bridge Alignment
Field Crew	P. Lanigan R. Sousa	Project Number	AKSAS 63763
TH Finalized By	G. SPEETER	Material Site	S. Riley Creek Alignment
		Equipment Type	
		Weather	
		Vegetation	
Test Hole Number	13-5122	Total Depth	14 feet
Dates Drilled	11/17/2013 - 11/17/2013	Station, Offset	2852~2, 5R
Latitude, Longitude	N63.72617°, W148.89048°	Elevation	

Ground Water Data

	While Drilling	After Drilling
Depth in (ft.)		
Time		
Date		
Symbol		

GENERAL COMMENTS:
S. Riley Creek Alignment

Drilling Method	Depth in (Feet)	Casing Blows / ft	Method	Number	Blow Count	Sample Interval	N-Value	Frozen	Graphic Log
S-S Auger	0–0.5		AUGER	13-6010					
S-S Auger	5.5–10.0		AUGER	13-6011					

SUBSURFACE MATERIAL

0–14 ft: Bn Well-graded GRAVEL
w/ Silt & Sand (fill)
w/ Cobbles
dry to moist, Broken drill bit @ 14.
SAMPLE 13-6010 (0.0-0.5): GW-GM, 6.2% -200, NV, NP

SAMPLE 13-6011 (5.5-10.0): GP, 3.4% -200, NM 2.0%, ORG 0.8%, NV, NP

Drilling Notes: BODR=Based on drill reaction

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop.

☐ CME Auto Hammer ☐ Cathead Rope Method

NR AKDOT TEST HOLE LOG - USCS RILEY CREEK BRIDGE.GPJ NR AKDOT PRECON USCS 06 28 07.GDT 4/8/14

FINAL TEST HOLE LOG

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

Project	Riley Creek Bridge Alignment	Test Hole Number	13-5123
Project Number	AKSAS 63763	Total Depth	20 feet
Material Site	S. Riley Creek Alignment	Dates Drilled	11/17/2013 - 11/17/2013
Equipment Type		Station, Offset	2850+2, 10R
Weather		Latitude, Longitude	N63.72574°, W148.89123°
Vegetation		Elevation	

Field Geologist G. SPEETER
Field Crew P. Lanigan R. Sousa
TH Finalized By G. SPEETER

Ground Water Data	While Drilling	After Drilling
Depth in (ft.)		
Time		
Date		
Symbol		

GENERAL COMMENTS:
S. Riley Creek Alignment

Drilling Method	Depth in (Feet)	Casing Blows / ft	Method	Number	Blow Count	Sample Interval	N-Value	Frozen	Graphic Log	SUBSURFACE MATERIAL
S-S Auger	0									Bn Well-graded GRAVEL w/ Silt & Sand (fill) w/ Cobbles dry to moist, Estimate 30% cobbles. Mixed cuttings starting at 16.
	1.5–5.5		AUGER	13-6012						SAMPLE 13-6012 (1.5-5.5): GP-GM, 5.3% -200, NV, NP
	5.5–10.5		AUGER	13-6013						SAMPLE 13-6013 (5.5-10.5): GW, 4.2% -200, NV, NP
	20									BOH

Drilling Notes: BODR=Based on drill reaction

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop. ☐ CME Auto Hammer ☐ Cathead Rope Method

FINAL TEST HOLE LOG

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

Project	Riley Creek Bridge Alignment	Test Hole Number	13-5124
Project Number	AKSAS 63763	Total Depth	15.5 feet
Material Site	S. Riley Creek Alignment	Dates Drilled	11/18/2013 - 11/18/2013
Equipment Type		Station, Offset	2847-96, 18R
Weather		Latitude, Longitude	N63.72526°, W148.8919°
Vegetation		Elevation	

Field Geologist: G. SPEETER
Field Crew: P. Lanigan R. Sousa
TH Finalized By: G. SPEETER

Ground Water Data	While Drilling	After Drilling
Depth in (ft.)		
Time		
Date		
Symbol		

GENERAL COMMENTS:
S. Riley Creek Alignment

Columns: Drilling Method | Depth in (Feet) | Casing Blows / ft | Sample Data: Method, Number, Blow Count, Sample Interval, N-Value | Frozen | Graphic Log

Drilling Method: S-S Auger

Sample Method	Sample Number	Sample Interval (ft)
AUGER	13-6014	3.0-7.0
AUGER	13-6015	9.0-12.0

SUBSURFACE MATERIAL

0 – 15.5 ft:
Bn Well-graded GRAVEL
w/ Sand (fill)
w/ Cobbles
dry to moist, loose, Broken drill bit Loose BODR 200psi down pressure.

SAMPLE 13-6014 (3.0-7.0): GP, 4.4% -200, NV, NP

SAMPLE 13-6015 (9.0-12.0): GW, 2.5% -200, NV, NP

BOH

Drilling Notes: BODR=Based on drill reaction

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop. ☐ CME Auto Hammer ☐ Cathead Rope Method

NR AKDOT TEST HOLE LOG - USCS RILEY CREEK BRIDGE.GPJ NR AKDOT PRECON USCS 06 28 07.GDT 4/8/14

FINAL TEST HOLE LOG

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

Project	Riley Creek Bridge Alignment	Test Hole Number	13-5126
Project Number	AKSAS 63763	Total Depth	16 feet
Field Geologist: G. SPEETER / Material Site	S. Riley Creek Alignment	Dates Drilled	11/21/2013 - 11/21/2013
Field Crew: P. Lanigan R. Sousa / Equipment Type		Station, Offset	2873+2, 10R
Weather		Latitude, Longitude	N63.73067°, W148.88262°
TH Finalized By: G. SPEETER / Vegetation		Elevation	

Ground Water Data

	While Drilling	After Drilling
Depth in (ft.)		
Time		
Date		
Symbol		

GENERAL COMMENTS:
S. Riley Creek Alignment

Drilling Method: S-S Auger

Sample Data

Method	Number	Sample Interval (ft)
AUGER	13-6022	1.5-5.0
AUGER	13-6023	5.5-9.0
AUGER	13-6024	10.0-12.0
AUGER	13-6025	13.0-16.0

SUBSURFACE MATERIAL

Depth (ft)	Description
0 - 2	Bk ASPHALT (fill) 2-inch
2 - 4	Bn Silty SAND w/ Gravel (fill) moist, Crushed
4 - 10	Bn Poorly-graded GRAVEL w/ Silt & Sand (fill) w/ Cobbles moist SAMPLE 13-6022 (1.5-5.0): SM, 15.1% -200, NV, NP SAMPLE 13-6023 (5.5-9.0): GP-GM, 7.7% -200, NV, NP
10 - 12	Bn Poorly-graded SAND w/ Silt moist SAMPLE 13-6024 (10.0-12.0): SP-SM, 9.4% -200, NV, NP
12 - 16	Bn Well-graded GRAVEL w/ Sand w/ Cobbles moist SAMPLE 13-6025 (13.0-16.0): GW, 3.6% -200, NV, NP
16	BOH

Drilling Notes: BODR=Based on drill reaction

NR AKDOT TEST HOLE LOG - USCS RILEY CREEK BRIDGE.GPJ NR AKDOT PRECON USCS 06 28 07.GDT 4/8/14

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop. ☐ CME Auto Hammer ☐ Cathead Rope Method

FINAL TEST HOLE LOG

STATE OF ALASKA DOT/PF
Northern Region Materials
Geology Section

Project	Riley Creek Bridge Alignment	Test Hole Number	13-5127
Project Number	AKSAS 63763	Total Depth	16 feet
Field Geologist: G. SPEETER	Material Site: Denali Park Road Intersection	Dates Drilled	11/22/2013 - 11/22/2013
Field Crew: P. Lanigan R. Sousa	Equipment Type	Station, Offset	2863+23, 109L
	Weather	Latitude, Longitude	N63.72865°, W148.88637°
TH Finalized By: G. SPEETER	Vegetation	Elevation	

Ground Water Data	While Drilling	After Drilling
Depth in (ft.)		
Time		
Date		
Symbol		

GENERAL COMMENTS:
Denali Park Road Intersection

Drilling Method	Depth in (Feet)	Casing Blows / ft	Method	Number	Blow Count	N-Value	Frozen	Subsurface Material
H-S Auger	0–1.5							Bk ASPHALT (fill) 6-inch
	1.5–3.5		AUGER	13-6026				Bk ASPHALT (fill) older layer 6-inch
								Bk-Bn ASPHALT (fill) chip seal
								Bn Silty SAND w/ Gravel (fill?) dry to moist, medium dense SAMPLE 13-6026 (1.5-3.5): SM, 12.7% -200, NV, NP
	4–6		SPT	13-6027A	2, 13, 5, 8	18		Bn Silty SAND moist, medium dense SAMPLE 13-6027A (5.0-6.0): NM 13.1%, ORG 1.7%
	9–11		SPT	13-6027B	2, 2, 3, 4	5		Bn Sandy SILT moist, loose SAMPLE 13-6027B (9.0-11.0): ML, 95.2% -200, NM 22.0%, ORG 1.9%, LL 19, NP
	12–16						Frozen	Gy Silty CLAY moist, firm
	14–16		SPT	13-6028	4, 9, 8, 5	17		Gy Sandy SILT moist, Vs, 5% visible Vs. SAMPLE 13-6028 (14.0-16.0): ML, 96.7% -200, NM 24.4%, ORG 1.2%, NV, NP
	16							BOH

Drilling Notes: BODR=Based on drill reaction

Note: Unless otherwise noted, all samples are taken with 1-3/8-in. ID Standard Penetration Sampler driven with 140 lb. hammer with 30-in. drop. ☐ CME Auto Hammer ☐ Cathead Rope Method

NR AKDOT TEST HOLE LOG - USCS RILEY CREEK BRIDGE.GPJ NR AKDOT PRECON USCS 06 28 07.GDT 4/8/14

Appendix B- Lab Data

STATE OF ALASKA DEPARTMENT OF TRANSPORTATION
NORTHERN REGION
LABORATORY TESTING REPORT

PROJECT NAME:	Riley Creek Bridge Alignment
PROJECT NUMBER:	
AKSAS NUMBER:	63763
SAMPLED BY:	G. Speeter
MATERIAL SOURCE:	Riley Creek Bridge

TEST HOLE NUMBER		13-5106	13-5107	13-5108	13-5109	13-5108	13-5109	13-5109
DEPTH (feet)		6.0-9.5	5.0-10.0	6.0-7.0	0.5-3.0	10.0-12.0	5.0-7.0	15.0-17.0
LATITUDE		2824+14	1819+14	2864	2863+8	2864	2863+8	2863+8
LONGITUDE		15R	8R	44L	48L	44L	48L	48L
LAB NUMBER		**13-5946**	**13-5947**	**13-5948**	**13-5949A**	**13-5949B**	**13-5950**	**13-5982**
DATE SAMPLED		4-Nov-13	4-Nov-13	4-Nov-13	7-Nov-13	4-Nov-13	7-Nov-13	7-Nov-13
% Passing	**3"**							
	2"	98						
	1.5"	94	99					
Gravel	**1.0"**	78	88	93	91		81	
	0.75"	67	78	87	84		75	
	0.5"	54	64	83	73	65	65	
	0.375"	46	57	71	66	61	60	
	#4	32	43	64	50	47	48	
	#8	21	31		38			
	#10	20	29		36			
	#16	14	23	42	28	27	26	
	#30	10	16		20			
Sand	**#40**	8	13		17			
	#50	7	10		15			
	#60	7	9		14			100
	#80	6	8		12			99
	#100	5	7	19	11	9	9	99
Silt/Clay	**#200**	3.8	5.5	14.1	8.6	6.6	6.3	98.2
	0.02							
Hydro	**0.005**							
	0.002							
	0.001							
LIQUID LIMIT		NV	NV	NV	NV	NV	NV	NV
PLASTIC INDEX		NP	NP	NP	NP	NP	NP	NP
USCS CLASSIFICATION		GW	GW-GM		GW-GM			
USCS SOIL DESCRIPTION		(WGGr w/Sa)	(WGGr w/Si&Sa)	(WGGr w/SiCl&Sa)	(WGGr w/SiCl&Sa)	(WGGr w/SiCl&Sa)	(WGGr w/SiCl&Sa)	(Si w/Sa)
NATURAL MOISTURE		1.7			2.2	1.7	2.4	27.2
ORGANICS		0.8			1.3	1.2	1.6	2.0
SP. GR. (FINE)								
SP. GR. (COARSE)								
MAX. DRY DENSITY								
OPTIMUM MOISTURE								
L.A. ABRASION								
DEGRAD. FACTOR								
SODIUM SULF. (CRSE)								
SODIUM SULF. (FINE)								
NORDIC ABRASION								
REMARKS								

GENERAL COMMENTS

Gradation is based on material passing the 3" sieve, according to Alaska Test Method T-7.
[1] Organic content determination is based on the results of the ATM T-6 test method.
(Soil descriptions shown in parentheses are based on field determinations.)
USCS Soil Description Abbreviations: WG - Well-graded; PG - Poorly-graded; E - Elastic; L - Lean; F - Fat

STATE OF ALASKA DEPARTMENT OF TRANSPORTATION
NORTHERN REGION
LABORATORY TESTING REPORT

PROJECT NAME:	Riley Creek Bridge Alignment
PROJECT NUMBER:	
AKSAS NUMBER:	63763
SAMPLED BY:	G. Speeter
MATERIAL SOURCE:	Riley Creek Bridge

TEST HOLE NUMBER		13-5109	13-5110	13-5110	13-5110	13-5111	13-5111	13-5111
DEPTH (feet)		20.0-22.0	6.5-11.0	14.0-16.0	24.0-26.0	5.0-6.0	9.0-11.0	24.0-26.0
LATITUDE		2863+8	2857+37	2857+37	2857+37	2856+94	2856+94	2856+94
LONGITUDE		48L	40L	40L	40L	80L	80L	80L
LAB NUMBER		**13-5983**	**13-5985**	**13-5986**	**13-5988**	**13-5990**	**13-5991**	**13-5993**
DATE SAMPLED		7-Nov-13	8-Nov-13	8-Nov-13	8-Nov-13	8-Nov-13	8-Nov-13	8-Nov-13
% Passing	**3"**							
	2"							
	1.5"		96	90				
Gravel	**1.0"**		89	73				
	0.75"		78	66				
	0.5"		63	60				99
	0.375"		54	56				99
	#4		35	46				99
	#8		24					99
	#10		22					99
	#16	100	16	32				98
	#30	99	12					98
Sand	**#40**	98	10					98
	#50	98	8					98
	#60	97	8					98
	#80	97	7					98
	#100	97	6	11				98
Silt/Clay	**#200**	95.2	4.8	7.2	94.1			86.7
	0.02							
Hydro	**0.005**							
	0.002							
	0.001							
LIQUID LIMIT		24	NV	NV	23			23
PLASTIC INDEX		3	NP	NP	5			3
USCS CLASSIFICATION			GW					
USCS SOIL DESCRIPTION		(Si w/Sa)	(WGGr w/Sa)	(WGGr w/Sa)	(SiCl)	(WGGr w/Si&Sa)	(WGGr w/Si&Sa)	(Si)
NATURAL MOISTURE		23.2	3.1	3.4	21.5	2.8	1.9	22.5
ORGANICS		2.1	0.8	1.6	2.0	1.0		2.3
SP. GR. (FINE)								
SP. GR. (COARSE)								
MAX. DRY DENSITY								
OPTIMUM MOISTURE								
L.A. ABRASION								
DEGRAD. FACTOR								
SODIUM SULF. (CRSE)								
SODIUM SULF. (FINE)								
NORDIC ABRASION								
REMARKS		sl Org[1]						sl Org[1]

GENERAL COMMENTS

Gradation is based on material passing the 3" sieve, according to Alaska Test Method T-7.

[1] Organic content determination is based on the results of the ATM T-6 test method.

(Soil descriptions shown in parentheses are based on field determinations.)

USCS Soil Description Abbreviations: WG = Well-graded; PG = Poorly-graded; E = Elastic; L = Lean; F = Fat

STATE OF ALASKA DEPARTMENT OF TRANSPORTATION
NORTHERN REGION
LABORATORY TESTING REPORT

PROJECT NAME:	Riley Creek Bridge Alignment
PROJECT NUMBER:	
AKSAS NUMBER:	63763
SAMPLED BY:	G. Speeter
MATERIAL SOURCE:	Riley Creek Bridge

TEST HOLE NUMBER		13-5111	13-5112	13-5112	13-5112	13-5112	13-5114	13-5114
DEPTH (feet)		28.0-30.0	4.0-4.5	9.0-11.0	14.0-16.0	19.0-21.0	4.0-10.0	17.0-20.0
LATITUDE		2856+94	2855+91	2855+91	2855+91	2855+91	2861+13	2861+13
LONGITUDE		80L	45L	45L	45L	45L	13R	13R
LAB NUMBER		**13-5994**	**13-5995**	**13-5996**	**13-5998**	**13-5999**	**13-6001**	**13-6002**
DATE SAMPLED		8-Nov-13	9-Nov-13	9-Nov-13	9-Nov-13	9-Nov-13	11-Nov-13	11-Nov-13
% Passing	**3"**							
	2"						94	
	1.5"						90	
Gravel	**1.0"**					91	79	
	0.75"					89	71	
	0.5"					77	59	
	0.375"					71	50	97
	#4					56	35	95
	#8						27	
	#10						25	
	#16					31	19	90
	#30						13	
Sand	**#40**						11	
	#50						10	
	#60						9	
	#80	100					8	
	#100	99				14	8	83
Silt/Clay	**#200**	89.2				11.3	6.0	80.8
	0.02							
Hydro	**0.005**							
	0.002							
	0.001							
LIQUID LIMIT		19				NV	NV	NV
PLASTIC INDEX		NP				NP	NP	NP
USCS CLASSIFICATION							GW-GM	
USCS SOIL DESCRIPTION		(Si)	(PGGr w/Si&Sa)	(PGGr w/Si&Sa)	(WGGr w/SiCl&Sa)	(WGGr w/SiCl&Sa)	(WGGr w/Si&Sa)	(Si)
NATURAL MOISTURE		19.6	3.5	2.3	2.3	5.5		23.2
ORGANICS		1.8	1.0	1.1	1.5	1.7		3.2
SP. GR. (FINE)								
SP. GR. (COARSE)								
MAX. DRY DENSITY								
OPTIMUM MOISTURE								
L.A. ABRASION								
DEGRAD. FACTOR								
SODIUM SULF. (CRSE)								
SODIUM SULF. (FINE)								
NORDIC ABRASION								
REMARKS								sl Org[1]

GENERAL COMMENTS

Gradation is based on material passing the 3" sieve, according to Alaska Test Method T-7.

[1] Organic content determination is based on the results of the ATM T-6 test method.

(Soil descriptions shown in parentheses are based on field determinations.)

USCS Soil Description Abbreviations: WG Well-graded; PG = Poorly-graded; E = Elastic; L = Lean; F = Fat

STATE OF ALASKA DEPARTMENT OF TRANSPORTATION
NORTHERN REGION
LABORATORY TESTING REPORT

PROJECT NAME:	Riley Creek Bridge Alignment
PROJECT NUMBER:	
AKSAS NUMBER:	63763
SAMPLED BY:	G. Speeter
MATERIAL SOURCE:	Riley Creek Bridge

TEST HOLE NUMBER		13-5115	13-5116	13-5116	13-5117	13-5118	13-5121	13-5122
DEPTH (feet)		4.0-6.0	4.0-5.0	5.5-9.5	5.0-8.0	1.0-6.5	5.0-9.0	0.0-0.5
LATITUDE		2863+4	2865+16	2865+16	2867+11	2868+74	2854+43	2852+2
LONGITUDE		W148.88595°	4R	4R	4L	5R	18R	5R
LAB NUMBER		**13-6003**	**13-6005**	**13-6006**	**13-6007**	**13-6008**	**13-6009**	**13-6010**
DATE SAMPLED		11-Nov-13	12-Nov-13	12-Nov-13	12-Nov-13	13-Nov-13	17-Nov-13	17-Nov-13
% Passing	**3"**							
	2"					95		
	1.5"			97		90		
Gravel	**1.0"**			89	92	84	90	86
	0.75"			84	83	78	79	75
	0.5"		96	73	68	67	54	61
	0.375"		93	64	60	57	41	52
	#4		84	46	46	39	19	37
	#8			33	38	30	14	27
	#10			31	36	28	13	26
	#16		71	26	31	24	12	20
	#30			22	26	19	12	13
Sand	**#40**			19	23	17	11	11
	#50			17	20	15	11	10
	#60			15	19	15	10	9
	#80			13	16	13	10	8
	#100		26	12	15	12	9	8
Silt/Clay	**#200**		16.6	8.9	11.5	9.6	6.5	6.2
	0.02							
Hydro	**0.005**							
	0.002							
	0.001							
LIQUID LIMIT			NV	NV	NV	NV	NV	NV
PLASTIC INDEX			NP	NP	NP	NP	NP	NP
USCS CLASSIFICATION				GP-GM	GW-GM	GP-GM	GP-GM	GW-GM
USCS SOIL DESCRIPTION		(PGGr w/Sa)	(SiSa)	(PGGr w/Si&Sa)		(PGGr w/Si&Sa)	(PGGr w/Si&Sa)	(WGGr w/Si&Sa)
NATURAL MOISTURE		3.7		2.6	2.6	2.8		
ORGANICS		1.7		2.0	1.4	1.2		
SP. GR. (FINE)								
SP. GR. (COARSE)								
MAX. DRY DENSITY								
OPTIMUM MOISTURE								
L.A. ABRASION								
DEGRAD. FACTOR								
SODIUM SULF. (CRSE)								
SODIUM SULF. (FINE)								
NORDIC ABRASION								
REMARKS								

GENERAL COMMENTS

Gradation is based on material passing the 3" sieve, according to Alaska Test Method T-7.

[1] Organic content determination is based on the results of the ATM T-6 test method.

(Soil descriptions shown in parentheses are based on field determinations.)

USCS Soil Description Abbreviations: WG = Well-graded; PG = Poorly-graded; E = Elastic; L = Lean; F = Fat

STATE OF ALASKA DEPARTMENT OF TRANSPORTATION
NORTHERN REGION
LABORATORY TESTING REPORT

PROJECT NAME:	Riley Creek Bridge Alignment
PROJECT NUMBER:	
AKSAS NUMBER:	63763
SAMPLED BY:	G. Speeter
MATERIAL SOURCE:	Riley Creek Bridge

TEST HOLE NUMBER		13-5122	13-5123	13-5123	13-5124	13-5124	13-5126	13-5126
DEPTH (feet)		5.5-10.0	1.5-5.5	5.5-10.5	3.0-7.0	9.0-12.0	1.5-5.0	5.5-9.0
LATITUDE		2852+2	2850+2	2850+2	2847+96	2847+96	2873+2	2873+2
LONGITUDE		5R	10R	10R	18R	18R	10R	10R
LAB NUMBER		**13-6011**	**13-6012**	**13-6013**	**13-6014**	**13-6015**	**13-6022**	**13-6023**
DATE SAMPLED		17-Nov-13	17-Nov-13	17-Nov-13	18-Nov-13	18-Nov-13	21-Nov-13	21-Nov-13
% Passing	**3"**			88				
	2"	88	71	81	96	89		93
	1.5"	82	68	78	89	82		88
Gravel	**1.0"**	70	55	66	77	67	96	83
	0.75"	59	46	59	66	54	95	75
	0.5"	42	36	48	51	34	91	61
	0.375"	33	31	42	42	25	88	53
	#4	21	23	30	25	13	75	37
	#8	14	18	23	18	8	59	28
	#10	13	17	22	16	8	56	27
	#16	10	14	16	13	6	44	22
	#30	7	11	11	10	5	34	17
Sand	**#40**	6	9	9	8	4	29	15
	#50	5	8	7	7	4	25	13
	#60	5	8	7	7	4	23	12
	#80	5	7	6	6	3	20	11
	#100	4	7	6	6	3	19	10
Silt/Clay	**#200**	3.4	5.3	4.2	4.4	2.5	15.1	7.7
	0.02							
Hydro	**0.005**							
	0.002							
	0.001							
LIQUID LIMIT		NV	NV	NV	NV	NV	NV	NV
PLASTIC INDEX		NP	NP	NP	NP	NP	NP	NP
USCS CLASSIFICATION		GP	GP-GM	GW	GP	GW	SM	GP-GM
USCS SOIL DESCRIPTION		(WGGr w/Si&Sa)	(WGGr w/Si&Sa)	(WGGr w/Si&Sa)	(WGGr w/Sa)	(WGGr w/Sa)	(PGGr w/Si&Sa)	(PGGr w/Si&Sa)
NATURAL MOISTURE		2.0						
ORGANICS		0.8						
SP. GR. (FINE)								
SP. GR. (COARSE)								
MAX. DRY DENSITY								
OPTIMUM MOISTURE								
L.A. ABRASION								
DEGRAD. FACTOR								
SODIUM SULF. (CRSE)								
SODIUM SULF. (FINE)								
NORDIC ABRASION								
REMARKS								

GENERAL COMMENTS

Gradation is based on material passing the 3" sieve, according to Alaska Test Method T-7.
[1] Organic content determination is based on the results of the ATM T-6 test method.
(Soil descriptions shown in parentheses are based on field determinations.)
USCS Soil Description Abbreviations: WG = Well-graded; PG = Poorly-graded; E = Elastic; L = Lean; F = Fat

STATE OF ALASKA DEPARTMENT OF TRANSPORTATION
NORTHERN REGION
LABORATORY TESTING REPORT

PROJECT NAME:	Riley Creek Bridge Alignment
PROJECT NUMBER:	
AKSAS NUMBER:	63763
SAMPLED BY:	G. Speeter
MATERIAL SOURCE:	Riley Creek Bridge

TEST HOLE NUMBER		13-5126	13-5126	13-5127	13-5127	13-5127	13-5127	
DEPTH (feet)		10.0-12.0	13.0-16.0	1.5-3.5	5.0-6.0	9.0-11.0	14.0-16.0	
LATITUDE		2873+2	2873+2	2863+23	2863+23	2863+23	2863+23	
LONGITUDE		10R	10R	109L	109L	109L	109L	
LAB NUMBER		**13-6024**	**13-6025**	**13-6026**	**13-6027A**	**13-6027B**	**13-6028**	
DATE SAMPLED		21-Nov-13	21-Nov-13	22-Nov-13	22-Nov-13	22-Nov-13	22-Nov-13	
% Passing	**3"**							
	2"		94					
	1.5"		85					
Gravel	**1.0"**	95	72	99				
	0.75"	92	59	95				
	0.5"	85	42	89				
	0.375"	79	34	82				
	#4	60	20	66				
	#8	42	14	52				
	#10	40	13	50				
	#16	30	10	40				
	#30	21	8	30				
Sand	**#40**	18	7	26				
	#50	16	6	23				
	#60	15	5	21				
	#80	13	5	19				
	#100	12	5	17		100		
Silt/Clay	**#200**	9.4	3.6	12.7		95.2	96.7	
	0.02							
Hydro	**0.005**							
	0.002							
	0.001							
LIQUID LIMIT		NV	NV	NV		19	NV	
PLASTIC INDEX		NP	NP	NP		NP	NP	
USCS CLASSIFICATION		SP-SM	GW	SM				
USCS SOIL DESCRIPTION		(PGSa w/Si)	(WGGr w/Sa)	(SiSa)	(SiSa)	(SaSi)	(SaSi)	
NATURAL MOISTURE					13.1	22.0	24.4	
ORGANICS					1.7	1.9	1.2	
SP. GR. (FINE)								
SP. GR. (COARSE)								
MAX. DRY DENSITY								
OPTIMUM MOISTURE								
L.A. ABRASION								
DEGRAD. FACTOR								
SODIUM SULF. (CRSE)								
SODIUM SULF. (FINE)								
NORDIC ABRASION								
REMARKS								

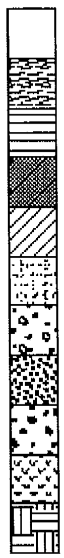
GENERAL COMMENTS

Gradation is based on material passing the 3" sieve, according to Alaska Test Method T-7.
[1] Organic content determination is based on the results of the ATM T-6 test method.
(Soil descriptions shown in parentheses are based on field determinations.)
USCS Soil Description Abbreviations: WG = Well-graded; PG = Poorly-graded; E = Elastic; L = Lean; F = Fat

Appendix C- Symbols and Definitions

SYMBOLS AND DEFINITIONS

BASIC MATERIAL SYMBOLS



- ASPHALT
- PEAT
- CLAY (Cl)
- ICE
- SILT (Si)
- POORLY GRADED SAND (Sa)
- POORLY GRADED GRAVEL (Gr)
- WELL GRADED SAND
- WELL GRADED GRAVEL
- BEDROCK (Bx), soft(Type)
- BEDROCK (Bx), hard(Type)

SOFT OR HARD BEDROCK BASED ON DRILLING RATE

NOTE

MAIN COMPONENT (UPPER CASE ... SOLID LINES)
MINOR COMPONENT (Title Case ... DASHED LINES OR SPARSER PATTERN)

USCS SIZE DEFINITIONS

BOULDERS (Boulders)	12"+
COBBLES (Cobbles)	3" TO 12"
GRAVEL	#4 TO 3"
ANGULAR FRAGMENTS	#10 +
SAND	#200 TO #4
SILT	#200 TO 0.005 mm
CLAY	MINUS 0.005 mm

TEST RESULTS

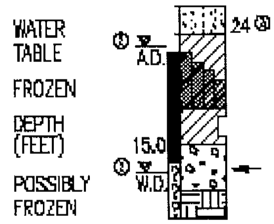
_._%-200	= % PASSING #200 SIEVE
NM _._%	= NATURAL MOISTURE
ORG _._%	= ORGANIC CONTENT
SSc _	= SODIUM SULFATE LOSS(coarse)
SSf _	= SODIUM SULFATE LOSS(fine)
LA _	= LOS ANGELES ABRASION
DEG _	= DEGRADATION
LL _	= LIQUID LIMIT (NV = no value)
PI _	= PLASTIC INDEX (NP = non-plastic)

MISC.

Tr	= TRACE
sl	= SLIGHTLY
hi	= HIGHLY
w/_	= WITH UNSPECIFIED AMOUNT
X'tls	= CRYSTALS
TH	= TEST HOLE
TT	= TEST TRENCH
TP	= TEST PIT

TYPICAL LOG

YEAR-HOLE NUMBER — 05-41
LAT/LONG OR STATION, OFFSET — ① Sta 210+53, Lt 3
ELEVATION (ft) — Elev 375
DATE LOGGED — 18 JUN



① Station value may also be on centerline e.g. Sta 210+53, CL or lat-long format e.g. N64.56789°, W145.67890°
② W.D.= WHILE DRILLING, A.D.= AFTER DRILLING
③ "N VALUE" INDICATES STANDARD PENETRATION TEST (1.4" I.D., 2.0" O.D. SAMPLER DRIVEN WITH 140 LB. HAMMER, 30" FREE FALL) AND IS SUM OF 2nd AND 3rd 6" OF PENETRATION.

PLAN VIEW SYMBOLS

- POWER AUGER TEST HOLE (TH)
- HAND AUGER TEST HOLE (TH)
- EXPOSED MATERIAL
- PROBE
- HAND DUG TEST PIT (TP)
- DOZER/BACKHOE TEST TRENCH (TT)
- BODY OF WATER
- FLOW DIRECTION
- WASTE BERM
- BANK
- SWAMP
- TREELINE

SOIL DENSITY/CONSISTENCY DESCRIPTORS

NON-COHESIVE		COHESIVE	
RELATIVE DENSITY	BLOWS/FOOT (N) VALUE	CONSISTENCY	BLOWS/FOOT (N) VALUE
VERY LOOSE	< 4	VERY SOFT	< 2
LOOSE	5-10	SOFT	2-4
MEDIUM DENSE	11-30	FIRM	5-8
DENSE	31-50	STIFF	9-15
VERY DENSE	> 50	VERY STIFF	16-30
		HARD	> 30

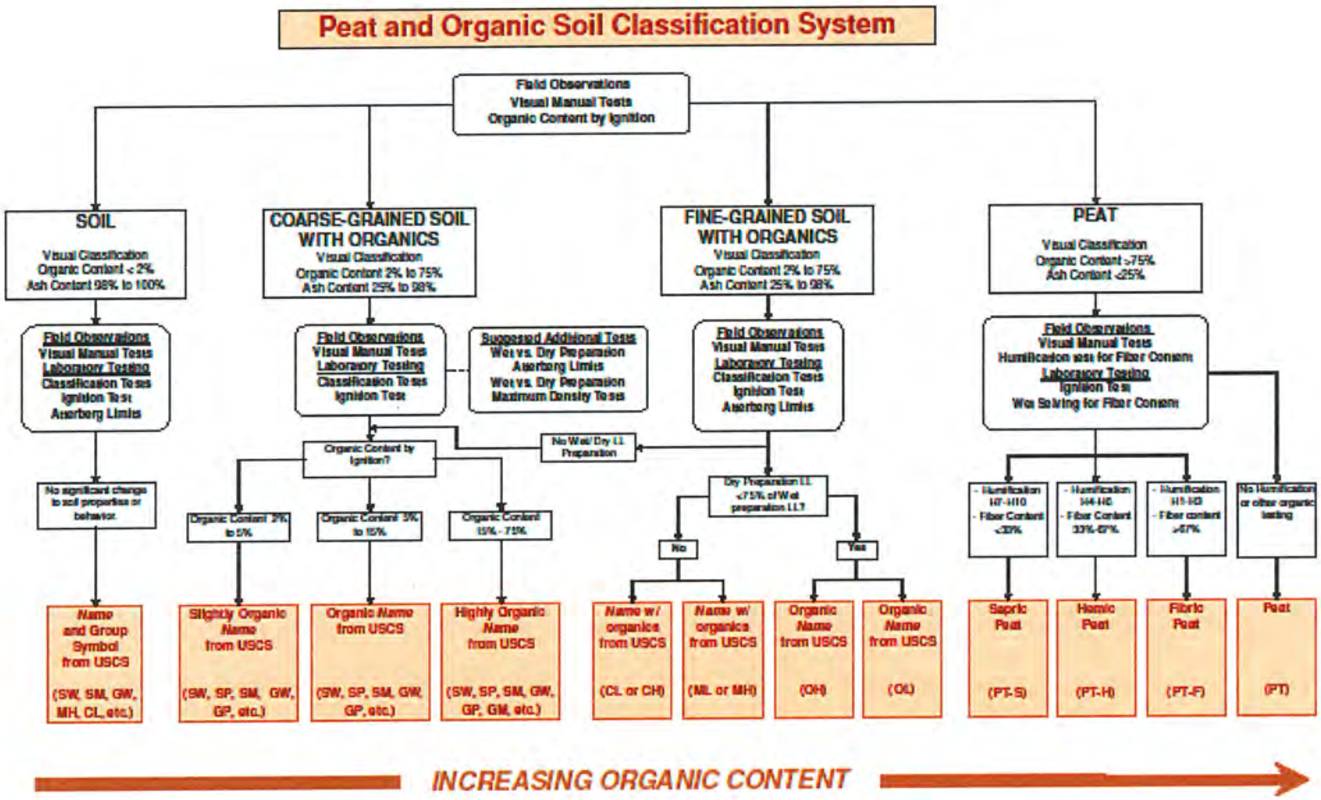
COLOR

Bk = BLACK	Gy = GRAY	Tn = TAN
Bl = BLUE	Or = ORANGE	Wh = WHITE
Bn = BROWN	Rd = RED	Yw = YELLOW
Gn = GREEN		

MOISTURE

dry	= < OPTIMUM*	DUSTY, DRY TO THE TOUCH
moist	~ OPTIMUM*	DAMP, NO VISIBLE WATER
wet	= > OPTIMUM*	VISIBLE FREE WATER

* OPTIMUM MOISTURE FOR MAXIMUM DENSITY



Peat and Organic Soil Classification System
Field Observations
Visual Manual Tests
Organic Content by Ignition
SOIL
Visual Classification
Organic Content < 2%
Ash Content 98% to 100%
COARSE-GRAINED SOIL WITH ORGANICS
Visual Classification
Organic Content 2% to 75%
Ash Content 25% to 98%
FINE-GRAINED SOIL WITH ORGANICS
Visual Classification
Organic Content 2% to 75%
Ash Content 25% to 98%
PEAT
Visual Classification
Organic Content >75%
Ash Content <25%
Field Observations
Visual Manual Tests
Laboratory Testing
Classification Tests
Ignition Test
Atterberg Limits
Field Observations
Visual Manual Tests
Laboratory Testing
Classification Tests
Ignition Test
Suggested Additional Tests
Wet vs. Dry Preparation
Atterberg Limits
Wet vs. Dry Preparation
Maximum Density Tests
Field Observations
Visual Manual Tests
Laboratory Testing
Classification Tests
Ignition Test
Atterberg Limits
Field Observations
Visual Manual Tests
Humification test for Fiber Content
Laboratory Testing
Ignition Test
Wet Sieving for Fiber Content
No significant change to soil properties or behavior
Organic Content by Ignition?
No Wet/Dry LL Preparation
Dry Preparation LL <75% of Wet preparation LL?
No
Yes
Organic Content 2% to 5%
Organic Content 5% to 15%
Organic Content 15% - 75%
- Humification H7-H10
- Fiber Content <33%
- Humification H4-H6
- Fiber Content 33%-67%
- Humification H1-H3
- Fiber content >67%
No Humification or other organic testing
Name and Group Symbol from USCS
(SW, SM, GW, MH, CL, etc.)
Slightly Organic Name from USCS
(SW, SP, SM, GW, GP, etc.)
Organic Name from USCS
(SW, SP, SM, GW, GP, etc.)
Highly Organic Name from USCS
(SW, SP, SM, GW, GP, GM, etc.)
Name w/ organics from USCS
(CL or CH)
Name w/ organics from USCS
(ML or MH)
Organic Name from USCS
(OH)
Organic Name from USCS
(OL)
Sapric Peat
(PT-S)
Hemic Peat
(PT-H)
Fibric Peat
(PT-F)
Peat
(PT)
INCREASING ORGANIC CONTENT

DESCRIPTION AND CLASSIFICATION OF FROZEN SOILS

Part I Description of Soil Phase (a) (Independent of Frozen State)	Major Group: Description (2)	Major Group: Designation (3)	Sub-Group: Description (4)	Sub-Group: Designation (5)	Field Identification (6)	Pertinent Properties of Frozen Materials which may be measured by physical tests to supplement field identification. (7)	Guide for Construction on Soils Subject to Freezing and Thawing: Thaw Characteristics (8)	Guide for Construction on Soils Subject to Freezing and Thawing: Criteria (9)
Part II Description of Frozen Soil	Segregated ice is not visible by eye (b)	N	Poorly Bonded or Friable	Nf	Identify by visual examination. To determine presence of excess ice, use procedure under note (d) below and hand magnifying lens as necessary. For soils not fully saturated, estimate degree of ice saturation: Medium, Low. Note presence of crystals, or of ice coatings around larger particles.	In-Place Temperature Density and Void Ratio a) In Frozen State b) After Thawing in Place Water Content (Total H_2O, including ice) a) Average b) Distribution Strength a) Compressive b) Tensile c) Shear d) Adfreeze Elastic Properties Plastic Properties Thermal Properties Ice Crystal Structure (using optional instruments.) a) Orientation of Axes b) Crystal size c) Crystal shape d) Pattern of Arrangement	Usually Thaw-Stable	The potential intensity of ice segregation in a soil is dependent to a large degree on its void sizes and may be expressed as an empirical function of grain size as follows: Most inorganic soils containing 3 percent or more of grains finer than 0.02 mm in diameter by weight are frost-susceptible. Gravels, well-graded sands and silty sands, especially those approaching the theoretical maximum density curve, which contain 1.5 to 3 percent finer than 0.02 mm by weight without being frost-susceptible. However, their tendency to occur interbedded with other soils usually makes it impractical to consider them separately. Soils classed as frost-susceptible under the above criteria are likely to develop significant ice segregation and frost heave if frozen at normal rates with free water readily available. Soils so frozen will fall into the thaw-unstable category. However, they ma also be classed as thaw-stable if frozen with insufficient water to permit ice segregation. Soils classed as non-frost-susceptible ("NFS) under the above criteria usually occur without significant ice segregation and are not exact and may be inadequate for some structure applications: exceptions may also result from minor soil variations.
			No excess ice	Nb n				
			Well Bonded	Nb				
			Excess ice	Nb e				
	Segregated ice is visible by eye. (ice 1 inch or less in thickness) (b)	V	Individual ice crystals or inclusions	Vx	For ice phase, record the following as applicable: Location — Size Orientation — Shape Thickness Spacing — Pattern of arrangement Length Hardness } Structure } per part III Below Color } Estimate volume of visible segregated ice present as percent of total sample volume.		Usually Thaw-Unstable	
			Ice coatings on particles	Vc				
			Random or irregularly oriented ice formations	Vr				
			Stratified or distinctly oriented ice formations	Vs				
Part III Description of Substantial Ice Strata	Ice (Greater than 1 inch in thickness)	Ice	Ice with soil inclusions	Ice + Soil Type	Designate material as ICE (d) and use descriptive terms as follows, usually one item from each group, as applicable: Hardness: Hard, Soft (mass, not individual crystals) Structure: Clear, Cloudy, Porous, Candled, Granular, Stratified Color: e.g.: Colorless, Gray, Blue Admixtures: e.g.: Contains Thin Silt Inclusions	Same as Part II above, as applicable, with special emphasis on Ice Crystal Structure		In permafrost areas, ice wedges, pockets, veins, or other ice bodies may be found whose mode of origin is different from that described above. Such ice may be the result of long-time surface expansion and contraction phenomena or may be glacial or other ice which has been buried under a protective earth cover.
			Ice without soil inclusions	Ice				

DEFINITIONS:

Ice Coatings on Particles are discernible layers of ice found on or below the larger soil particles in a frozen soil mass. They are sometimes associated with hoarfrost crystals, which have grown into voids produced by the freezing action.

Ice Crystal is a very small individual ice particle visible in the face of a soil mass. Crystals may be present alone or in a combination with other ice formations.

Clear Ice is transparent and contains only a moderate number of air bubbles (e)

Cloudy Ice is translucent, but essentially sound and non-pervious.

Porous Ice contains numerous voids, usually interconnected and usually resulting from melting at air bubbles or along crystal interfaces from presence of salt or other materials in the water, or from the freezing of saturated snow. Though porous, the mass retains its structural unity.

Candled Ice is ice which has rotted or otherwise formed into long columnar crystals, very loosely bonded together.

Granular Ice is composed of coarse, more or less equidimensional, ice crystals weakly bonded together.

Ice Lenses are lenticular ice formations in soil occurring essentially parallel to each other, generally normal to the direction of heat loss and commonly in repeated layers.

Ice Segregation is the growth of ice as distinct lenses, layers, veins and masses in soils, commonly but not always oriented normal to direction of heat loss.

Well-bonded signifies that the soil particles are strongly held together by the ice and that the frozen soil possesses relatively high resistance to chipping or breaking.

Poorly-bonded signifies that the soil particles are weakly held together by the ice and that the frozen soil consequently has poor resistance to chipping or breaking.

Friable denotes a condition in which material is easily broken up under light to moderate pressure.

Thaw-Stable frozen soils do not, on thawing, show loss of strength below normal, long-time thawed values nor produce detrimental settlement.

Thaw-Unstable frozen soils show on thawing, significant loss of strength below normal, long-time thawed values and/or significant settlement, as a direct result of the melting of the excess ice in the soil.

Modified from: Linell, K. A. and Kaplar, C. W., 1966, *Description and Classification of Frozen Soils*, Proc. International Conference on Permafrost (1963), Lafayette, IN, U.S. National Academy of Sciences, Publ. 1287, pp 481-487.

NOTES:

(a) When rock is encountered, standard rock classification terminology should be used.

(b) Frozen soils in the N group may on close examination indicate presence of ice within the voids of the material by crystalline reflections or by a sheen on fractured or trimmed surfaces. However, the impression to the unaided eye is that none of the frozen water occupies space in excess of the original voids in the soil. The opposite is true of frozen soils in the V group.

(c) When visual methods may be inadequate, a simple field test to aid evaluation of volume of excess ice can be made by placing some frozen soil in a small jar, allowing it to melt and observing the quantity of supernatant water as a percent of total volume.

(d) Where special forms of ice, such as hoarfrost, can be distinguished, more explicit description should be given.

(e) Observer should be careful to avoid being misled by surface scratches or frost coating on the ice.

FOUNDATION REPORT
ON THE
RAILROAD UNDERPASS AT MCKINLEY
BRIDGE NO. 696
F-052-3(1)

Prepared by the
Foundation Section
College, Alaska
June 1966

I. INTRODUCTION

The Alaska Department of Highways proposes the construction of a Railroad Overpass near Mile 159 on the Denali Highway in Mt. McKinley National Park. The proposed structure will be utilized to carry the Alaska Railroad over Alaska Route No. 37. The proposed structure will be located at Mile 346.7 of the Alaska Railroad.

Preliminary design plans indicate that the new roadway will be in a depressed section with a minimum vertical clearance of approximately 17 feet. The total depth of cut will therefore approach 20 feet. Cut slopes in the immediate vicinity of the structure are proposed at 1½ horizontal to 1 vertical. The proposed structure will be approximately 221 feet long and will incorporate two piers.

II. FIELD STUDIES

Subsoils at the proposed structure site were investigated by means of five exploratory borings put down to depths ranging from 20 to approximately 100 feet. All borings had an inside diameter of 3.0 in. All borings were put down by truck and tractor mounted Rotary Wash Drills with water as the circulating medium. Standard penetration samples were taken at 5 foot intervals or wherever a change in subsoil indicated a need for sampling. In borings 2, 3 and 4, sampling was continuous in instances where sample recovery was poor. Samples taken in this manner are regarded as disturbed and were used for classification and examination purposes only. All standard penetration tests were made with a standard split spoon, 1.4" I.D., and 2.0" O.D. The sampler was driven with a 140 lb. hammer having a free fall of 30 inches.

Immediately following recovery, all samples were examined by a field geologist, given a visual classification, sealed in glass jars and transmitted to the Laboratory at College, Alaska for detailed testing.

A graphic protrayal of all materials encountered at this site are shown on the 'Log of Test Borings' sheet attached to this report.

III. LABORATORY TESTING

Samples received at the College Laboratory were subjected to tests for determination of the following properties:

1. Particle size distribution

2. Frost susceptibility

3. Natural moisture tests were not run due to the fact that all samples being granular were contaminated by drilling fluid.

The granularity of subsoils at this site prevented the recovery of undisturbed samples and therefore shear and consolidation tests were not run. The results of all tests performed on samples recovered from this site are attached to this report. All tests were run in accordance with procedures approved by the Alaska Department of Highways, A.A.S.H.O., and A.S.T.M.

IV. GENERAL GEOLOGY

A. Surface

The surface in the immediate vicinity of the site is relatively level and is surrounded by a light to thick growth of aspen. The structure site is on an extensive, abandoned river terrace.

Water was not noted on ground surface in the area of the proposed structure.

B. Subsurface

In general, the entire site is underlain by an undetermined thickness of dense to very dense sandy gravel and gravelly sand with cobbles and boulders. Traces and occasional lenses of silt and sand were noted throughout all borings. The only significant departure from the above description is a layer of silty sands with organic material between ground surface and a depth of two to three feet.

Permafrost or permanently frozen ground was encountered in Boring #1 at station 2830+59, eight feet right of the proposed centerline. In this boring permafrost was noted between approximate elevations 1674 and 1664. Numerous test pits dug during centerline studies confirm the fact that permanently frozen soil does not exist in the upper soil layers. One additional deep boring (total depth 76 feet) was put down at station 2842+00. This boring encountered sand and gravel for all but the top two (2) feet. The materials was logged as 'frozen?' between depths of 21.5 feet and 38 feet.

On the basis of all field tests, it is concluded that permanently frozen ground exists at the structure site, but it is neither continuous nor detrimental to the proposed construction, as soils of the type present at the site will undergo little if any consolidation when thawed.

Ground water was not encountered in any boring at this site.

V. ENGINEERING ANALYSES AND RECOMMENDATIONS

Our recommendations for foundation support of the subject structure are based primarily on the following factors:

1. The dense granular nature of subsoils underlying the site

2. The absence of ground water

3. The apparent absence of permafrost in the upper 50 feet of soil underlying the structure site.

4. The depth of cut beneath the proposed structure

A. Structure Foundations

Based on the above listed factors and the results of field and laboratory tests, it is our opinion that both the abutments and piers for this structure may be supported by spread footings placed in the dense to very dense sandy gravels and gravelly sands underlying the structure site. Pile foundations may be used but considerable difficulty should be anticipated in driving the piles into the dense sands, gravels and cobbles underlying the site. In our opinion, the density of subsoils precludes the use of displacement piling. If steel-H piles are used as a means of structural support, bearing values of at least 40 tons per pile should be obtained between the following listed elevations.

Location	Pile Type	Approximate Tip Elevation
Abutment #1	Steel H, 10BP57	1730 - 1720
* Pier #2	Steel H, 10BP57	1713 - 1703
* Pier #3	Steel H, 10BP57	1713 - 1703
Abutment #4	Steel H, 10BP57	1730 - 1720

* Assumes base of the cut at elevation 1728±

(Tip elevation based on Harned formula and 'N' values) Reinforced pile tips are recommended at this site.

Abutment footings should be placed a minimum of five feet below existing ground surface in the dense sandy gravels and gravelly sands underlying the abutment locations. In no case should the footings be founded on the loose silty sands and sandy silts which generally lie within three feet of ground surface. Placement of footings on this material could result in severe deferential settlement at the abutment locations. Since the thickness of this particular layer may be expected to vary from point to point, careful examination of the footing excavation will be necessary in order to ascertain that the footing base is, in fact, placed in the dense sandy gravel and not in the loose sandy silts or silty sands. If, during footing excavations, the loosened soils cannot be adequately removed from the base of said excavation, it is recommended they be moistioned or dried as required and compacted to at least 100 percent of their maximum dry density as obtained through the use of A.A.S.H.O. test method T-180 Method D. Rigid compliance with this recommendation should serve to eliminate all of the settlement due to static loading and some of the settling which could occur due to vibratory or live loading.

Inasmuch as this structure will serve to carry trains over the proposed roadway, consideration of vibratory loading is necessary. It is a known fact that traffic vibrations can cause excessive settlement due to the re-adjustments of the particles in a granular soil mass. This condition is particularly troublesome in loose sands and gravels and can be extremely critical if the subsoils are beneath the water level or saturated. At this site, however, moisture conditions and the relative density of subsoils are such, that settlement due to traffic vibration should be minor and within tolerable limits. The use of a pile foundation to eliminate the effects of traffic vibration would serve one very useful purpose; that is, the vibration and shock due to pile driving would serve to densify the soils and eliminate the probable effects of traffic vibrations. It should be pointed out, however, that it is possible for the pile foundation to vibrate sufficiently to allow foundation settlement even though the piles are driven into dense gravels underlying the site. In all probability the only means in which the traffic vibration and settlement problem could totally be eliminated would be through the use of piling driven to bedrock or a cemented sand and gravel layer. In which case the piles would be totally end bearing. This condition does not exist at this site.

If spread footings are used as a means of supporting the structure it is pointed out that the abutments will be located relatively near the edge of a cutslope, thus necessitating considerations of the possibility of a shear failure with the abutments moving in towards the cut itself. To eliminate this possibility, it is recommended that the abutment footings be placed a distance at least equal to their width away from the edge of the cutslope. In no case, however, should the footing be less than 5 feet from the edge of said slope. Shear failure due to traffic vibrations, etc. is not considered a problem at this site due to moisture conditions in the gravels upon which the footings will be placed. Any settlements, etc. which result from traffic vibration will serve to densify the subsoils and increase their shearing resistance rather than weaken the subsoils and initiate shear failure.

Abutment footings placed as recommended above may be designed on the basis of any safe soil bearing capacity up to and including 3 tons per square foot.

Piers for this structure may be supported by spread footings placed in the dense to very dense sandy gravel, a minimum of 5 feet below ground surface at the base of the cut section. Footings placed at the recommended depth and on the recommended soils may be proportioned on the basis of any safe soil bearing capacity up to 4 tons per square foot.

It should be pointed out that ground water was not encountered at this site and it should therefore present no problems during footing excavation. The subsoils being granular are not expected to stand vertically during excavation and flattened slopes or shoring may be required.

Heave due to seasonal frost is not expected to be a problem at this site. The subsoils are granular and non-frost susceptible and the supply of water necessary for heaving of the foundation is apparently absent over the entire site. In addition, the subsoils being granular and therefore highly permeable, will drain freely and the entrapment of any subsurface moisture is unlikely. Furthermore, surface moisture will be well-drained up station towards 2900+00 at a gradient of 5 percent.

B. Cutting Operations

Subsoils present in the area of the proposed cut should present no serious problem during construction and $1\frac{1}{2}$:1 backslopes should be stable with no major slipouts anticipated. Should permanently frozen soil be encountered, some delay to allow thawing may be necessary.

Respectfully submitted

Ralph R. Migliaccio

Ralph R. Migliaccio
Foundation Geologist

Approved

Wylsie R. Platts

Wylsie R. Platts
Engineer of Tests & Foundations

STATE OF ALASKA
DEPARTMENT OF HIGHWAYS
Road Materials Laboratory

Summary of Test Data-Foundation Soils

Project No. F-052-3(1) Project Name McKinley R.R. Underpass Date 6/28/66 Date Submitted 6/6/66 Submitted By Grahek

Lab No.	Field No.	Depth	Mechanical Analysis- % Passing											LL	PI	Soil Class	FSV	Spec Grav.	Moist %	Dry Density
			1½	1	3/4	1/2	3/8	4	10	40	200	.02	.005							
					STATION		2829	+62		68' Rt.										
66F-812	1-3	6-8		100	90	81	71	57	43	20	9			NV	NP	A-1-a(0)		2.69		
813	2-1	0-2		100	97	89	87	83	74	56	36			31	NP	A-4(1)		2.64		
814	2-2	4-6		100	84	77	72	62	51	23	10	4	2	NV	NP	A-1-b(0)	F-1	2.69		
815	2-4	8-10		100	87	71	64	53	41	20	9	4	2	NV	NP	A-1-a(0)	F-1	2.71		
816	2-5	10-12		100	87	76	68	56	42	17	8	4	2	NV	NP	A-1-a(0)	F-1	2.71		
817	2-6	12-14	100	92	83	72	63	52	37	15	5	3	2	NV	NP	A-1-a(0)	F-1	2.71		
818	2-7	15-17	100	54	37	25	21	18	9	5	1			INSUFFICIENT MATERIAL						
819	2-8	18-20	100	89	82	72	64	54	40	18	6	--		NV	NP	A-1-a(0)		2.71		
							STATION		2829	+57	21'Rt.									
820	5-1	15-17	100	95	84	81	75	65	53	24	6			NV	NP	A-1-b(0)		2.71		
821	5-2	18-19.5		100	94	89	82	61	44	17	5	3	2	NV	NP	A-1-a(0)	NFS	2.73		
822	5-3	20-20.5		100	96	90	85	75	64	28	9	5	3	NV	NP	A-1-b(0)	F-2	2.71		
823	5-4	23-24		100	90	76	65	52	38	16	8	5	3	NV	NP	A-1-a(0)	F-1	2.69		
824	5-5	25-27	100	91	84	76	66	53	38	16	8	-		NV	NP	A-1-a(0)		2.73		
825	5-6	28-30	100	80	64	57	53	43	32	16	7	- INSUFFICIENT MATERIAL					—			
826	5-7	30-31.4	100	87	87	85	83	74	64	33	9		-	NV	NP	A-1-b(0)		2.71		
827	5-8	33-35	100	81	76	66	57	42	27	11	5			NV	NP	A-1-a(0)		2.75		
828	5-9	35-37	100	86	68	60	55	46	33	15	7		INSUFFICIENT MATERIAL							
829	5-10	38-40		100	90	84	75	61	44	19	8			NV	NP	A-1-a(0)		2.73		

Remarks ______________________________

Engr. of Tests & Foundations

STATE OF ALASKA
DEPARTMENT OF HIGHWAYS
Road Materials Laboratory

Summary of Test Data-Foundation Soils

Project No. F-052-3(1) Project Name McKinley R. R. Underpass Date 6/28/66 Date Submitted 6/6/66 Submitted By Utermohle

Lab No.	Field No.	Depth	Mechanical Analysis- % Passing											LL	PI	Soil Class	FSV	Spec Grav.	Moist %	Dry Density
			1½	1	3/4	1/2	3/8	4	10	40	200	.02	.005							
								STATION 2830 + 59 8' Rt.												
66F-830	1-1	5-6	100	81	81	77	73	64	52	24	6			INSUFFICIENT MATERIAL						
831	1-2	10-12	100	94	91	76	66	52	35	16	7			NV	NP	A-1-a(0)		2.71		
832	1-3	15-17	100	93	82	68	59	49	36	12	5			NV	NP	A-1-a(0)		2.70		
833	1-4	20-22	100	94	81	71	65	53	37	14	6	3	2	NV	NP	A-1-a(0)	NFS	2.70		
834	1-5	25-27	100	87	75	62	56	45	30	12	5	3	2	NV	NP	A-1-a(0)	NFS	2.74		
835	1-6	30-32	100	84	75	70	65	54	38	15	5	3	2	NV	NP	A-1-a(0)	NFS	2.70		
836	1-7	35-37	100	95	84	68	62	48	35	18	8	4	2	NV	NP	A-1-a(0)	F-1	2.74		
837	1-8	40-42	100	94	86	70	62	51	41	19	7	--		NV	NP	A-1-a(0)		2.70		
838	1-9	50-52	100	87	81	72	59	38	22	3	1			INSUFFICIENT MATERIAL						
839	1-10	60-62		100	80	65	58	42	22	7	2				"					
840	1-11	70-72	100	92	78	74	69	71	50	28	4			NV	NP	A-1-a(0)		2.74		
841	1-12	75-77	100	85	85	69	58	46	31	13	6			INSUFFICIENT MATERIAL						
842	1-13	80'	100	75	56	44	42	33	22	10	4				"					
843	1-14	85'		100	87	65	55	40	26	16	5				"					

Remarks

Archie C. Platts
Engr. of Tests & Foundations

STATE OF ALASKA
DEPARTMENT OF HIGHWAYS
Road Materials Laboratory

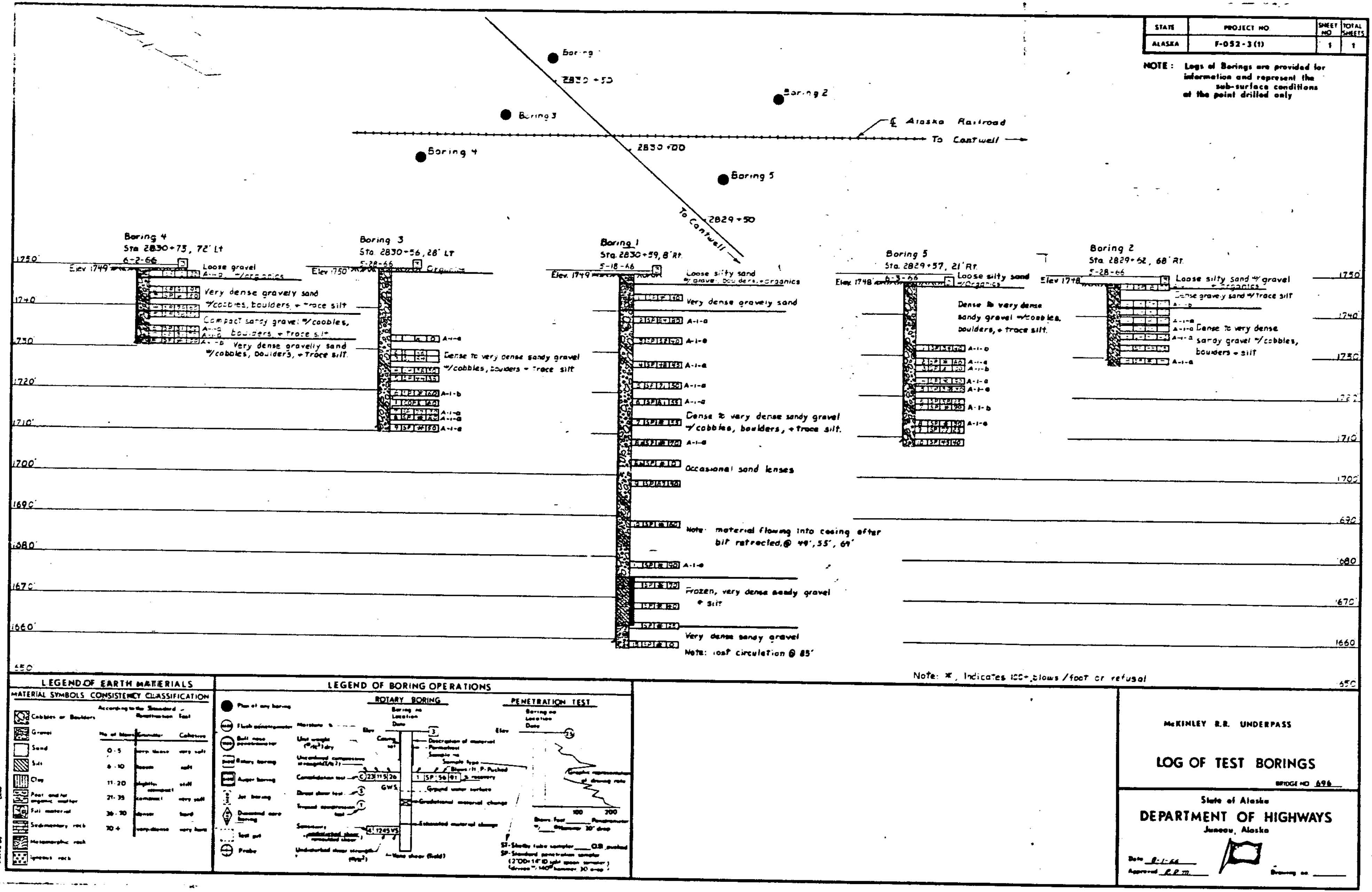
Summary of Test Data-Foundation Soils

Project No. F-052-3(1) Project Name McKinley R. R. Underpass Date 6/28/66 Date Submitted 6/6/66 Submitted By Grahek

Lab No.	Field No.	Depth	Mechanical Analysis- % Passing 1½	1	3/4	1/2	3/8	4	10	40	200	.02	.005	LL	PI	Soil Class	FSV	Spec Grav.	Moist %	Dry Density
							STATION 2830 + 56 28' Lt.													
66F-844	3-2	15-20	100	89	84	74	65	51	37	17	7			NV	NP	A-1-a(0)		2.70		
845	3-3	20-22	100	88	74	68	63	50	35	17	8	5	3	NV	NP	A-1-a(0)	F-1.	2.74		
846	3-4	23-25		100	97	85	75	58	41	17	7	4	2	NV	NP	A-1-a(0)	F-2	2.71		
847	3-5	25-27		100	82	74	65	51	36	16	6	3	1	NV	NP	A-1-a(0)	F-1	2.71		
848	3-6	28-30	100	93	87	82	77	67	54	23	9			NV	NP	A-1-b(0)				
849	3-7	33-35	100	79	72	64	61	48	36	14	6			NV	NP	A-1-a(0)				
850	3-8			100	96	85	77	63	44	17	8			NV	NP	A-1-a(0)				
851	3-9	38-40	100	94	87	75	65	50	38	13	6			NV	NP	A-1-a(0)				
								STATION 2830	+73	72'Lt.										
852	4-1	0-2		100	92	83	69	56	46	18	9			NV	NP	A-1-a(0)				
853	4-2	3-5		100	97	90	84	72	59	31	9	5	2	NV	NP	A-1-b(0)	F-2	2.68		
854	4-3	5-5.5			100	97	95	86	71	31	9		INSUFFICIENT MATERIAL				—			
855	4-4	8-10	100	94	87	82	77	68	53	25	10	5	2	NV	NP	A-1-b(0)	F-2	2.68		
856	4-5	10-12	100	95	87	73	67	53	37	18	8	4	2	NV	NP	A-1-a(0)	F-1	2.73		
857	4-6	13-15		100	88	77	69	59	46	17	7			NV	NP	A-1-a(0)	—			
858	4-7	15-17	100	92	85	74	67	51	38	14	4		-	NV	NP	A-1-a(0)				
859	4-8	18-19		100	97	92	85	75	61	31	13			NV	NP	A-1-b(0)				

Remarks

Kylsie C. Platts
Engr. of Tests & Foundations



STATE | PROJECT NO | SHEET NO | TOTAL SHEETS
ALASKA | F-052-3(1) | 1 | 1
NOTE: Logs of Borings are provided for information and represent the sub-surface conditions at the point drilled only
Boring 1
Boring 2
Boring 3
Boring 4
Boring 5
2830+50
2830+00
2829+50
℄ Alaska Railroad
To Cantwell
Boring 4
Sta 2830+73, 72' Lt
6-2-66
Elev 1749
Loose gravel
A-1-a, w/organics
Very dense gravelly sand w/cobbles, boulders, + trace silt
Compact sandy gravel w/cobbles, boulders, + trace silt
Very dense gravelly sand w/cobbles, boulders, + trace silt.
Boring 3
Sta. 2830+56, 28' Lt
5-28-66
Elev 1750
Organics
Dense to very dense sandy gravel w/cobbles, boulders + trace silt
Boring 1
Sta. 2830+59, 8' Rt.
5-18-66
Elev. 1749
Loose silty sand w/gravel, boulders, + organics
Very dense gravely sand
Dense to very dense sandy gravel w/cobbles, boulders, + trace silt.
Occasional sand lenses
Note: material flowing into casing after bit retracted @ 49', 55', 69'
Frozen, very dense sandy gravel + silt
Very dense sandy gravel
Note: lost circulation @ 85'
Boring 5
Sta. 2829+57, 21' Rt.
6-3-66
Elev 1748
Loose silty sand w/organics
Dense to very dense sandy gravel w/cobbles, boulders, + trace silt.
Boring 2
Sta. 2829+62, 68' Rt.
5-28-66
Elev 1748
Loose silty sand w/gravel + organics
Dense gravely sand w/trace silt
Dense to very dense sandy gravel w/cobbles, boulders + silt
1750'
1740'
1730'
1720'
1710'
1700'
1690'
1680'
1670'
1660'
1650'
Note: *, Indicates 100+ blows/foot or refusal
LEGEND OF EARTH MATERIALS
MATERIAL SYMBOLS
CONSISTENCY CLASSIFICATION
According to the Standard Penetration Test
Cobbles or Boulders
Gravel
Sand
Silt
Clay
Peat and/or organic matter
Fill material
Sedimentary rock
Metamorphic rock
Igneous rock
0-5
6-10
11-20
21-35
36-50
50+
LEGEND OF BORING OPERATIONS
ROTARY BORING
PENETRATION TEST
Plan of any boring
Flush penetrometer
Rotary boring
Auger boring
Jet boring
Diamond core boring
Test pit
Probe
ST-Shelby tube sampler
SP-Standard penetration sampler
MCKINLEY R.R. UNDERPASS
LOG OF TEST BORINGS
BRIDGE NO 696
State of Alaska
DEPARTMENT OF HIGHWAYS
Juneau, Alaska
Date 8-1-66

APPENDIX F
USGS SEISMIC DESIGN PARAMETERS

science for a changing world

Revision of Time-Independent Probabilistic Seismic Hazard Maps for Alaska

Open-File Report 2007–1043

U.S. Department of the Interior
U.S. Geological Survey

Revision of Time-Independent Probabilistic Seismic Hazard Maps for Alaska

By Robert L. Wesson, Oliver S. Boyd, Charles S. Mueller, Charles G. Bufe,
Arthur D. Frankel, and Mark D. Petersen

Open-File Report 2007–1043

U.S. Department of the Interior
U.S. Geological Survey

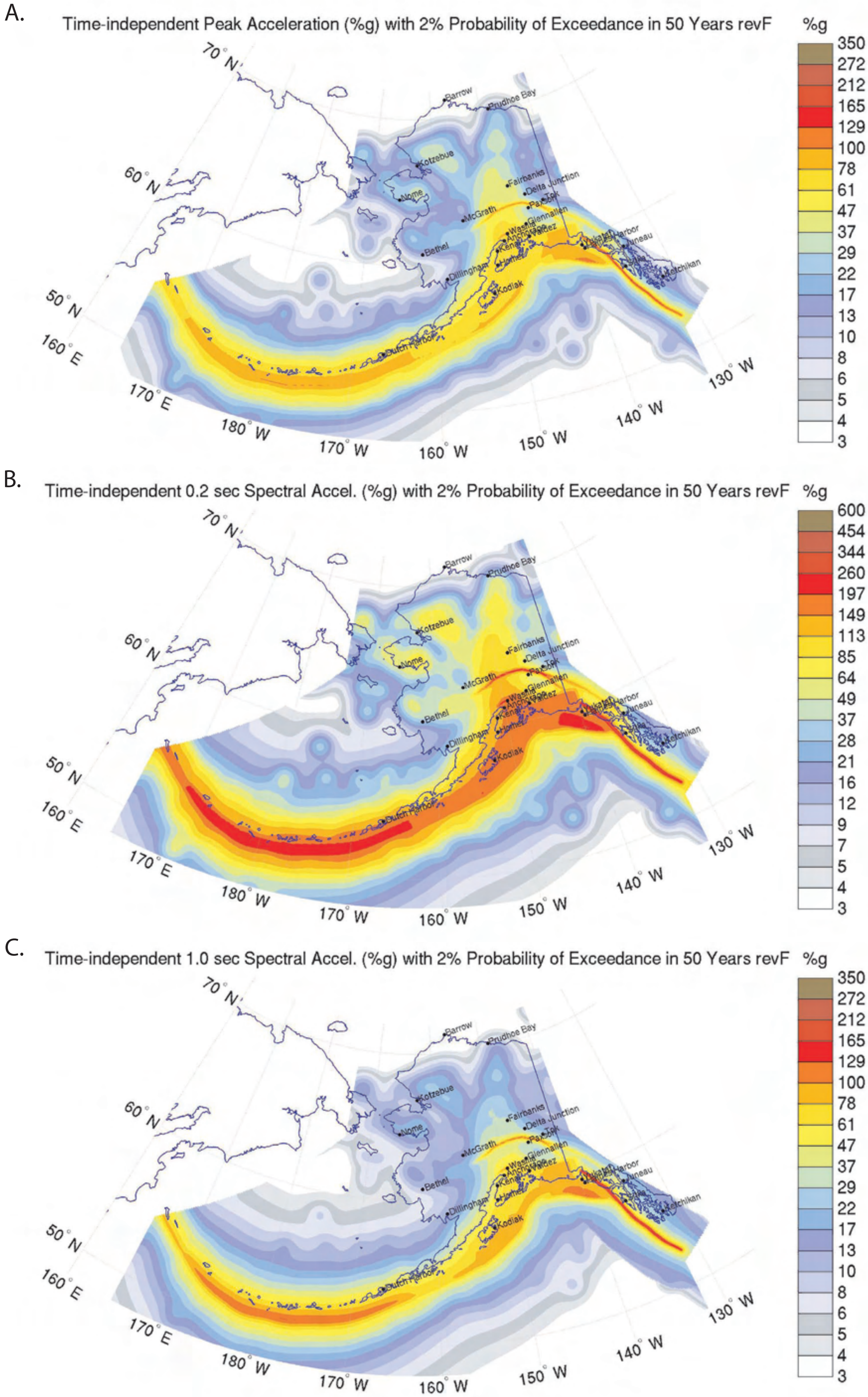


Figure 10. Probabilistic ground motion with a 2-percent probability of exceedance in 50 years for peak ground acceleration (*A*), 0.2 second spectral acceleration (*B*), 1.0 second spectral acceleration (*C*).

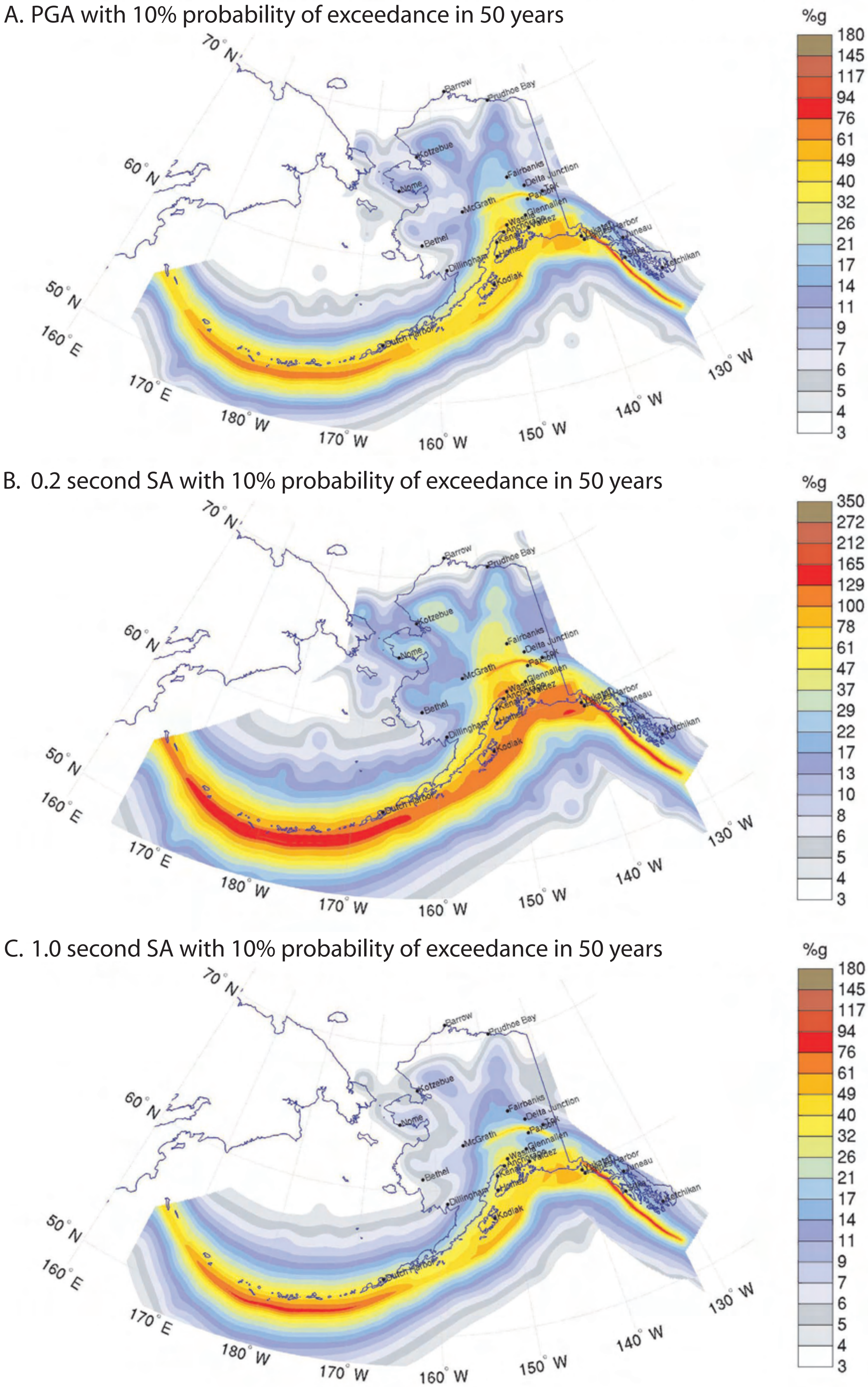


Figure 11. Probabilistic ground motion with a 10-percent probability of exceedance in 50 years for peak ground acceleration (*A*), 0.2 second spectral acceleration (*B*), and 1.0 second spectral acceleration (*C*).

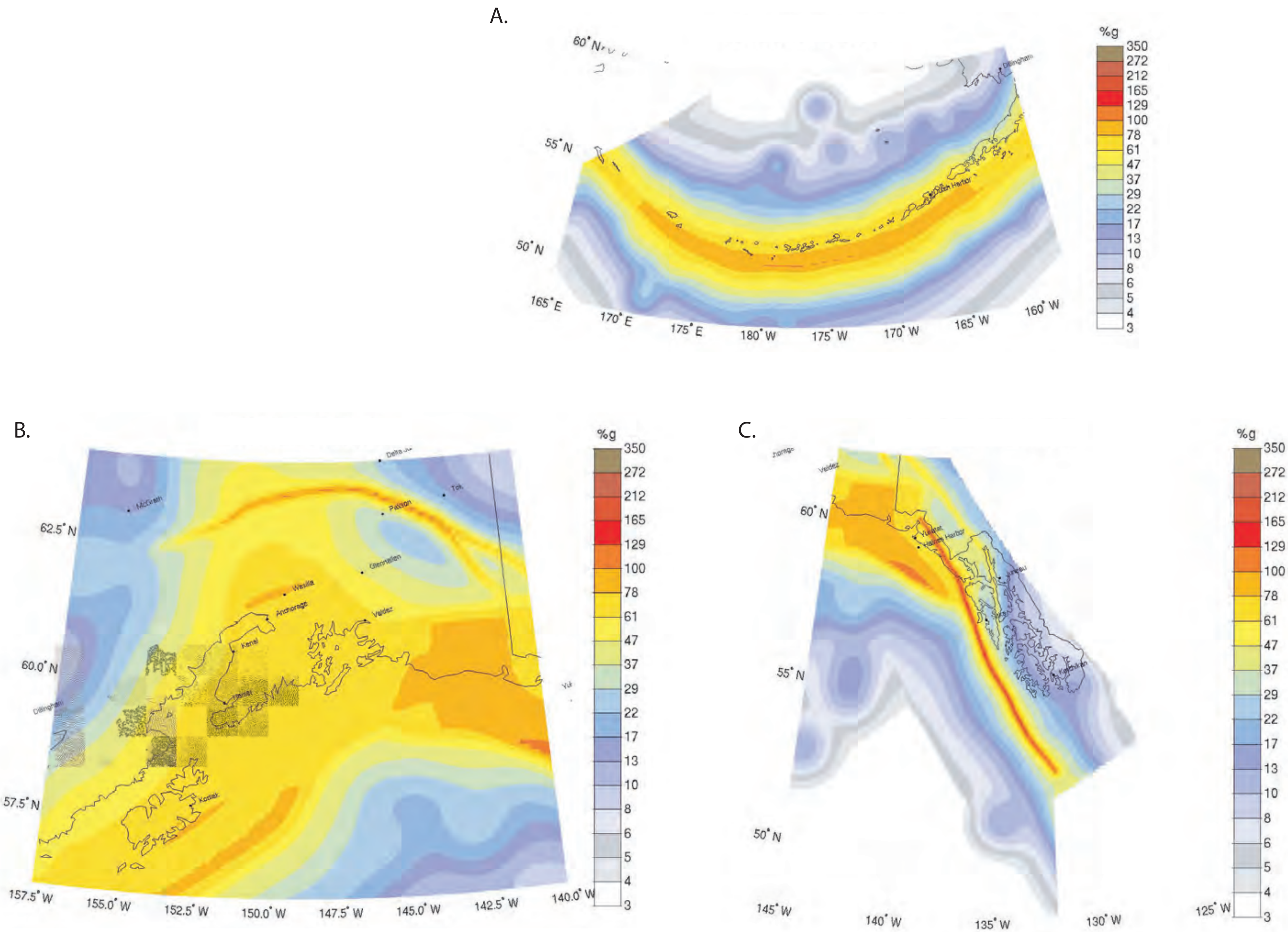


Figure 12. Probabilistic ground motion with a 2-percent probability of exceedance in 50 years for peak ground acceleration at a larger scale in the Aleutians (*A*), south-central Alaska (*B*), and south-east Alaska (*C*).

USGS Design Maps Summary Report

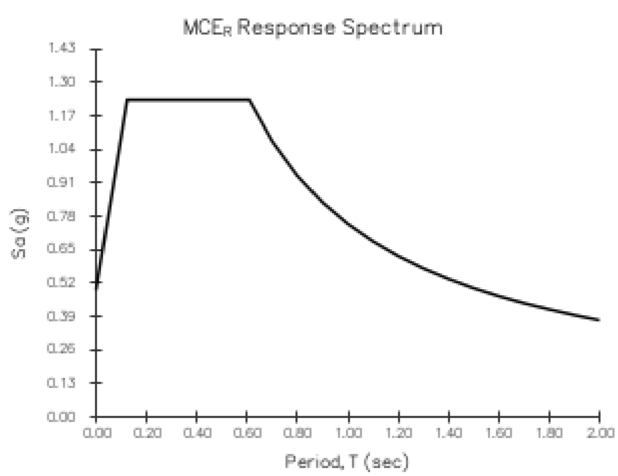
User–Specified Input

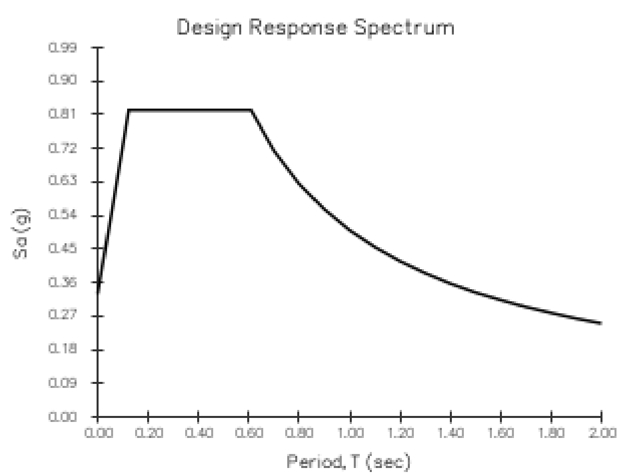
Report Title	ARRC Denali Park Area Wed July 12, 2017 20:24:32 UTC
Building Code Reference Document	ASCE 7-10 Standard (which utilizes USGS hazard data available in 2008)
Site Coordinates	63.71123°N, 148.88737°W
Site Soil Classification	Site Class C – "Very Dense Soil and Soft Rock"
Risk Category	I/II/III

USGS–Provided Output

S_S = 1.232 g	S_{MS} = 1.232 g	S_{DS} = 0.822 g
S_1 = 0.577 g	S_{M1} = 0.750 g	S_{D1} = 0.500 g

For information on how the SS and S1 values above have been calculated from probabilistic (risk-targeted) and deterministic ground motions in the direction of maximum horizontal response, please return to the application and select the "2009 NEHRP" building code reference document.





For PGA_M, T_L, C_{RS}, and C_{R1} values, please [view the detailed report](#).

Design Maps Detailed Report

ASCE 7-10 Standard (63.71123°N, 148.88737°W)

Site Class C – “Very Dense Soil and Soft Rock”, Risk Category I/II/III

Section 11.4.1 — Mapped Acceleration Parameters

Note: Ground motion values provided below are for the direction of maximum horizontal spectral response acceleration. They have been converted from corresponding geometric mean ground motions computed by the USGS by applying factors of 1.1 (to obtain S_S) and 1.3 (to obtain S_1). Maps in the 2010 ASCE-7 Standard are provided for Site Class B. Adjustments for other Site Classes are made, as needed, in Section 11.4.3.

From Figure 22-3 [1]	S_S = 1.232 g
From Figure 22-4 [2]	S_1 = 0.577 g

Section 11.4.2 — Site Class

The authority having jurisdiction (not the USGS), site-specific geotechnical data, and/or the default has classified the site as Site Class C, based on the site soil properties in accordance with Chapter 20.

Table 20.3–1 Site Classification

Site Class	$\bar{v}_S$	$\bar{N}$ or $\bar{N}_{ch}$	$\bar{s}_u$
A. Hard Rock	>5,000 ft/s	N/A	N/A
B. Rock	2,500 to 5,000 ft/s	N/A	N/A
C. Very dense soil and soft rock	1,200 to 2,500 ft/s	>50	>2,000 psf
D. Stiff Soil	600 to 1,200 ft/s	15 to 50	1,000 to 2,000 psf
E. Soft clay soil	<600 ft/s	<15	<1,000 psf
	Any profile with more than 10 ft of soil having the characteristics: • Plasticity index PI > 20, • Moisture content w ≥ 40%, and • Undrained shear strength $\bar{s}_u$ < 500 psf		
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

For SI: 1ft/s = 0.3048 m/s 1lb/ft² = 0.0479 kN/m²

Section 11.4.3 — Site Coefficients and Risk–Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameters

Table 11.4–1: Site Coefficient F_a

Site Class	Mapped MCE_R Spectral Response Acceleration Parameter at Short Period				
	$S_S \le 0.25$	$S_S = 0.50$	$S_S = 0.75$	$S_S = 1.00$	$S_S \ge 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight–line interpolation for intermediate values of S_S

For Site Class = C and S_S = 1.232 g, F_a = 1.000

Table 11.4–2: Site Coefficient F_v

Site Class	Mapped MCE_R Spectral Response Acceleration Parameter at 1–s Period				
	$S_1 \le 0.10$	$S_1 = 0.20$	$S_1 = 0.30$	$S_1 = 0.40$	$S_1 \ge 0.50$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	See Section 11.4.7 of ASCE 7				

Note: Use straight–line interpolation for intermediate values of S_1

For Site Class = C and S_1 = 0.577 g, F_v = 1.300

Equation (11.4–1):	$S_{MS} = F_a S_S = 1.000 \times 1.232 = 1.232$ g
Equation (11.4–2):	$S_{M1} = F_v S_1 = 1.300 \times 0.577 = 0.750$ g

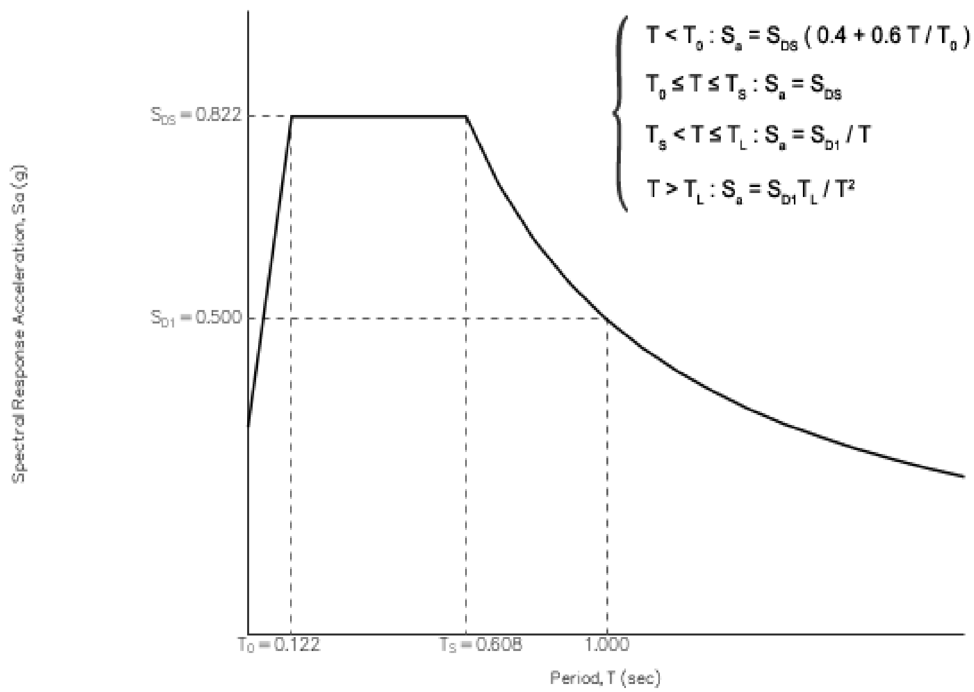
Section 11.4.4 — Design Spectral Acceleration Parameters

Equation (11.4–3):	$S_{DS} = ⅔\, S_{MS} = ⅔ \times 1.232 = 0.822$ g
Equation (11.4–4):	$S_{D1} = ⅔\, S_{M1} = ⅔ \times 0.750 = 0.500$ g

Section 11.4.5 — Design Response Spectrum

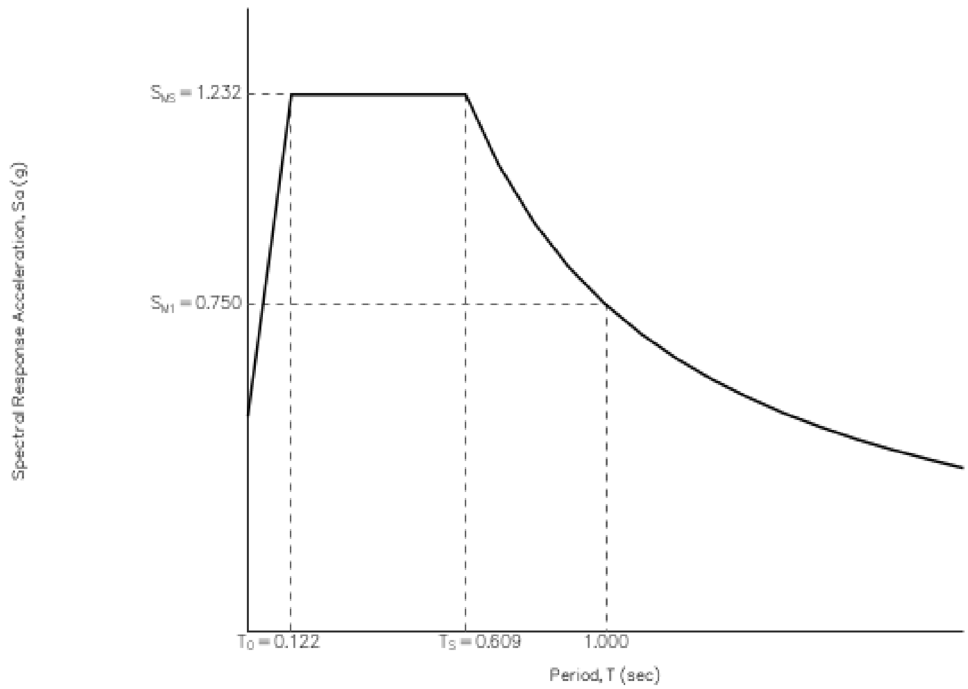
From Figure 22-13 [3]	T_L = 12 seconds

Figure 11.4–1: Design Response Spectrum



Section 11.4.6 — Risk-Targeted Maximum Considered Earthquake (MCE_R) Response Spectrum

The MCE_R Response Spectrum is determined by multiplying the design response spectrum above by 1.5.



Section 11.8.3 — Additional Geotechnical Investigation Report Requirements for Seismic Design Categories D through F

From Figure 22-9 [4]	PGA = 0.475
Equation (11.8–1):	$PGA_M = F_{PGA}PGA = 1.000 \times 0.475 = 0.475$ g

Table 11.8–1: Site Coefficient F_{PGA}

Site Class	Mapped MCE Geometric Mean Peak Ground Acceleration, PGA				
	PGA ≤ 0.10	PGA = 0.20	PGA = 0.30	PGA = 0.40	PGA ≥ 0.50
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight–line interpolation for intermediate values of PGA

For Site Class = C and PGA = 0.475 g, F_{PGA} = 1.000

Section 21.2.1.1 — Method 1 (from Chapter 21 – Site-Specific Ground Motion Procedures for Seismic Design)

From Figure 22-17 [5]	C_{RS} = 1.056
From Figure 22-18 [6]	C_{R1} = 1.002

Section 11.6 — Seismic Design Category

Table 11.6-1 Seismic Design Category Based on Short Period Response Acceleration Parameter

VALUE OF S_{DS}	RISK CATEGORY		
	I or II	III	IV
$S_{DS} < 0.167g$	A	A	A
$0.167g \le S_{DS} < 0.33g$	B	B	C
$0.33g \le S_{DS} < 0.50g$	C	C	D
$0.50g \le S_{DS}$	D	D	D

For Risk Category = I and S_{DS} = 0.822 g, Seismic Design Category = D

Table 11.6-2 Seismic Design Category Based on 1-S Period Response Acceleration Parameter

VALUE OF S_{D1}	RISK CATEGORY		
	I or II	III	IV
$S_{D1} < 0.067g$	A	A	A
$0.067g \le S_{D1} < 0.133g$	B	B	C
$0.133g \le S_{D1} < 0.20g$	C	C	D
$0.20g \le S_{D1}$	D	D	D

For Risk Category = I and S_{D1} = 0.500 g, Seismic Design Category = D

Note: When S_1 is greater than or equal to 0.75g, the Seismic Design Category is E for buildings in Risk Categories I, II, and III, and F for those in Risk Category IV, irrespective of the above.

Seismic Design Category ≡ "the more severe design category in accordance with Table 11.6-1 or 11.6-2" = D

Note: See Section 11.6 for alternative approaches to calculating Seismic Design Category.

References

1. Figure 22-3: https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-3.pdf
2. Figure 22-4: https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-4.pdf
3. Figure 22-13: https://earthquake.usgs.gov/cn1/designmaps/us/2010_ASCE-7_Figures_22-13_and_22-14.pdf
4. Figure 22-9: https://earthquake.usgs.gov/cn1/designmaps/us/2010_ASCE-7_Figures_22-8_and_22-9.pdf
5. Figure 22-17: https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-17.pdf
6. Figure 22-18: https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-18.pdf

Unified Hazard Tool

Please do not use this tool to obtain ground motion parameter values for the design code reference documents covered by the U.S. Seismic Design Maps web tools (e.g., the International Building Code and the ASCE 7 or 41 Standard). The values returned by the two applications are not identical.

Input

Edition

Dynamic: Alaska 2007 (v2.1.0)

Latitude

Decimal degrees

63.711227

Longitude

Decimal degrees, negative values for western longitudes

-148.887371

Site Class

760 m/s (B/C boundary)

Spectral Period

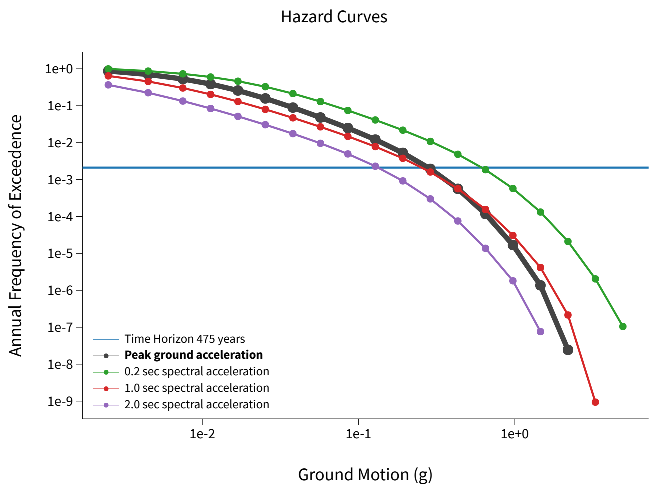
Peak ground acceleration

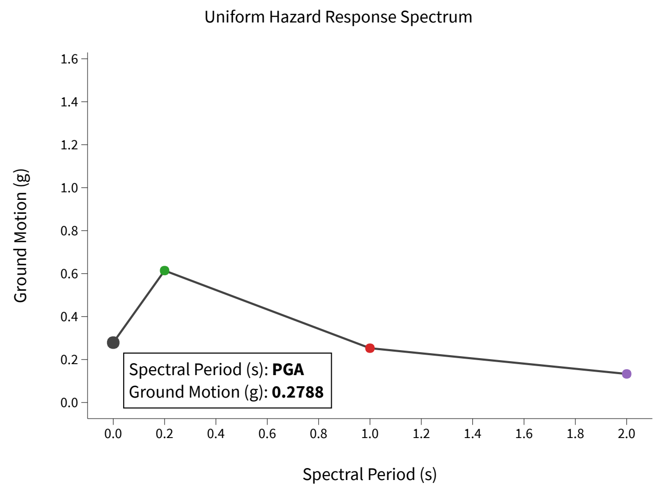
Time Horizon

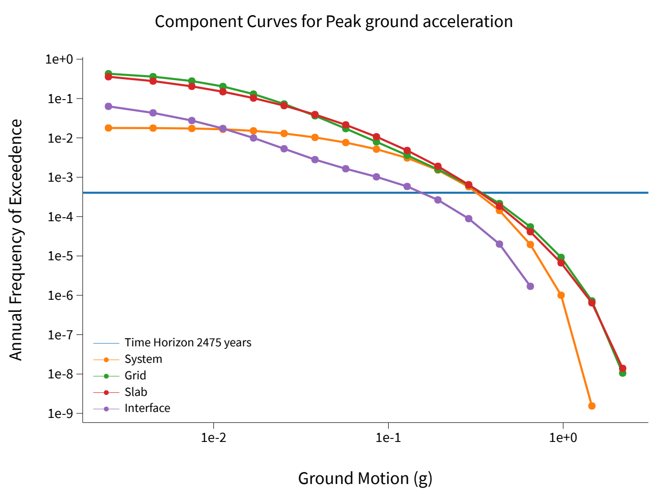
Return period in years

475

Hazard Curve





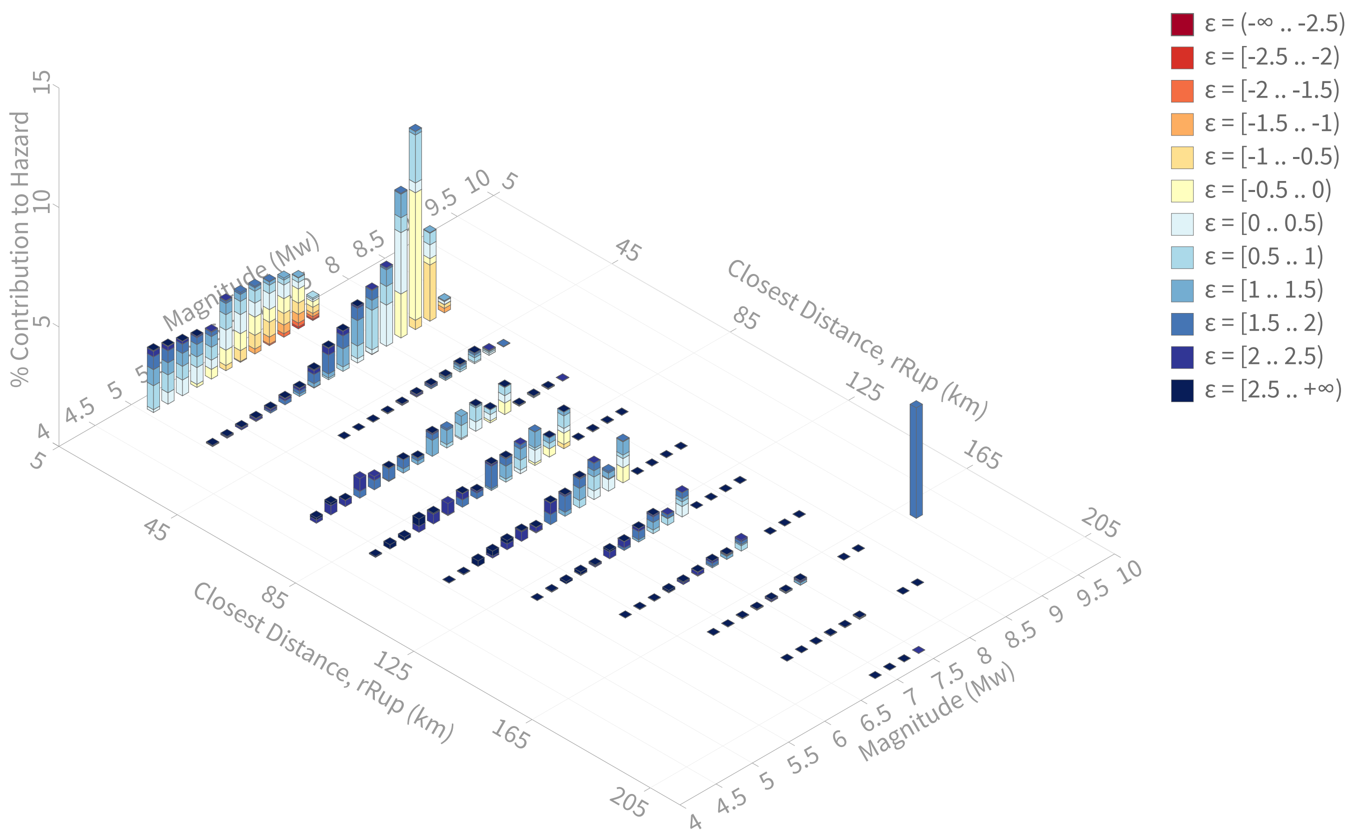


View Raw Data

Deaggregation

Component

Total



Summary statistics for, Deaggregation: Total

Deaggregation targets

Return period: 475 yrs
Exceedance rate: 0.0021052632 yr^{-1}
PGA ground motion: 0.27878183 g

Recovered targets

Return period: 471.25319 yrs
Exceedance rate: 0.0021220016 yr^{-1}

Totals

Binned: 100 %
Residual: 0 %
Trace: 0.33 %

Mean (for all sources)

r: 53.24 km
m: 6.96
ε_0: 0.81 σ

Mode (largest r-m bin)

r: 29.4 km
m: 7.9
ε_0: 0 σ
Contribution: 8.29 %

Mode (largest ε_0 bin)

r: 28.94 km
m: 7.89
ε_0: -0.29 σ
Contribution: 5.33 %

Discretization

r: min = 0.0, max = 1000.0, Δ = 20.0 km
m: min = 4.4, max = 9.4, Δ = 0.2
ε: min = -3.0, max = 3.0, Δ = 0.5 σ

Epsilon keys

ε0: [-∞ .. -2.5)
ε1: [-2.5 .. -2.0)
ε2: [-2.0 .. -1.5)
ε3: [-1.5 .. -1.0)
ε4: [-1.0 .. -0.5)
ε5: [-0.5 .. 0.0)
ε6: [0.0 .. 0.5)
ε7: [0.5 .. 1.0)
ε8: [1.0 .. 1.5)
ε9: [1.5 .. 2.0)
ε10: [2.0 .. 2.5)
ε11: [2.5 .. +∞]

Deaggregation Contributors

Source Set ↳ Source	Type	r	m	ε_0	lon	lat	az	%
Shallow Crust Seismicity (opt)	Grid							32.31
PointSourceFinite: -148.887, 63.725		5.17	5.72	0.04	148.887°W	63.725°N	0.00	3.84
PointSourceFinite: -148.887, 63.797		9.17	6.03	0.36	148.887°W	63.797°N	0.00	2.88
PointSourceFinite: -148.887, 63.752		6.34	5.80	0.17	148.887°W	63.752°N	0.00	2.87
PointSourceFinite: -148.887, 63.761		6.86	5.84	0.22	148.887°W	63.761°N	0.00	2.66
PointSourceFinite: -148.887, 63.806		9.78	6.08	0.40	148.887°W	63.806°N	0.00	2.60
PointSourceFinite: -148.887, 63.833		11.64	6.23	0.48	148.887°W	63.833°N	0.00	2.47
PointSourceFinite: -148.887, 63.842		12.26	6.27	0.51	148.887°W	63.842°N	0.00	1.42
PointSourceFinite: -148.887, 63.851		12.89	6.32	0.53	148.887°W	63.851°N	0.00	1.28
PointSourceFinite: -148.887, 63.815		10.39	6.13	0.42	148.887°W	63.815°N	0.00	1.11
Denali – Totschunda System	System							29.59
Denali Center [83]]		28.77	7.71	0.26	148.778°W	63.457°N	169.08	20.87
Intraslab 80 to 120 km	Slab							16.81
Intraslab 50 to 80 km	Slab							16.67
Eastern Aleutian Region – 1964 Zone	Interface							4.63
Eastern Aleutian Segment		161.84	9.20	1.51	148.182°W	62.282°N	167.05	4.63

APPENDIX G
USDA SOIL RESOURCE REPORT

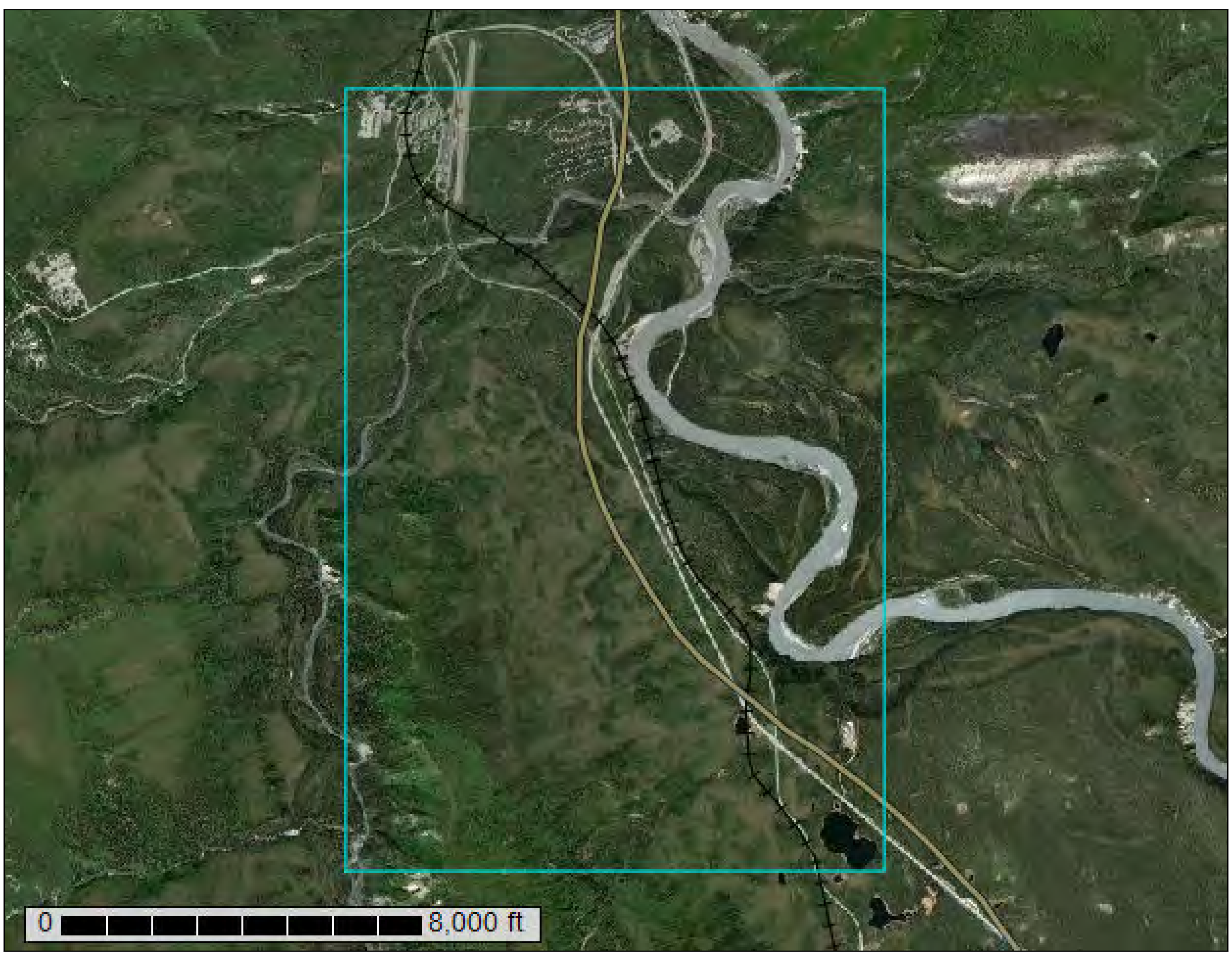
United States Department of Agriculture

NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for
Denali National Park and Preserve Area, Alaska



October 5, 2017

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Custom Soil Resource Report
Soil Map (ARRC MP 345 to 348)

Map Scale: 1:17,200 if printed on B portrait (11" x 17") sheet.

Meters: 0, 250, 500, 1000, 1500

Feet: 0, 500, 1000, 2000, 3000

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 6N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:63,400.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Denali National Park and Preserve Area, Alaska
Survey Area Data: Version 14, Sep 27, 2015

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 2, 2010—Jul 11, 2016

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend (ARRC MP 345 to 348)

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
7FP1	Boreal Flood Plains and Terraces	371.0	10.5%
7MS2	Boreal Glaciated Lower Mountain Slopes	283.5	8.0%
7MS3	Alpine Glaciated Mountains with Discontinuous Permafrost	213.6	6.0%
7MS4	Boreal Lower Mountain Slopes with Continuous Permafrost	623.2	17.6%
7P2	Boreal Glaciated Plains and Hills	396.4	11.2%
7P4	Boreal Glaciated Plains and Hills with Discontinuous Permafrost	918.5	25.9%
G	Nonvegetated Alluvium, Alaska Mountains, Boreal	64.5	1.8%
Totals for Area of Interest		**3,545.2**	**100.0%**

Map Unit Descriptions (ARRC MP 345 to 348)

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Denali National Park and Preserve Area, Alaska

7FP1—Boreal Flood Plains and Terraces

Map Unit Setting

National map unit symbol: 1q1y
Elevation: 1,380 to 3,150 feet
Mean annual precipitation: 14 to 36 inches
Mean annual air temperature: 21 to 28 degrees F
Frost-free period: 60 to 80 days
Farmland classification: Not prime farmland

Map Unit Composition

Boreal-riparian forested loamy high flood plains and similar soils: 35 percent
Boreal-riparian scrub gravelly flood plains, moderately wet, and similar soils: 25 percent
Boreal-riparian scrub loamy flood plains and similar soils: 20 percent
Minor components: 20 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Boreal-riparian Forested Loamy High Flood Plains

Setting

Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Sandy and silty alluvium over sandy and gravelly alluvium

Typical profile

Oi - 0 to 3 inches: slightly decomposed plant material
AC - 3 to 7 inches: stratified fine sand to silt
C - 7 to 17 inches: stratified fine sand to silt
2C - 17 to 59 inches: very cobbly sand

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: 13 to 35 inches to strongly contrasting textural stratification
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Rare
Frequency of ponding: None
Calcium carbonate, maximum in profile: 1 percent
Salinity, maximum in profile: Nonsaline (0.1 to 0.5 mmhos/cm)
Available water storage in profile: Low (about 3.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Hydrologic Soil Group: B
Ecological site: Loamy High Flood Plains (F228XY151AK)
Other vegetative classification: White spruce/bog blueberry/feathermoss forest (090), Loamy High Flood Plains (M135A_151)
Hydric soil rating: No

Description of Boreal-riparian Scrub Gravelly Flood Plains, Moderately Wet

Setting

Landform: Channels on flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Sandy and silty alluvium over sandy and gravelly alluvium

Typical profile

AC - 0 to 5 inches: stratified sand to silt
2C - 5 to 59 inches: extremely cobbly coarse sand

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: 3 to 7 inches to strongly contrasting textural stratification
Natural drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Frequent
Frequency of ponding: None
Calcium carbonate, maximum in profile: 5 percent
Salinity, maximum in profile: Nonsaline (0.1 to 0.5 mmhos/cm)
Available water storage in profile: Very low (about 0.8 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Hydrologic Soil Group: C
Ecological site: Gravelly Flood Plains (F228XY204AK)
Other vegetative classification: White spruce-poplar/soapberry forest (098), Gravelly Flood Plains (M135A_204)
Hydric soil rating: Yes

Description of Boreal-riparian Scrub Loamy Flood Plains

Setting

Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy alluvium over sandy and gravelly alluvium

Typical profile

Oi - 0 to 2 inches: slightly decomposed plant material
AC - 2 to 10 inches: stratified fine sand to silt
C - 10 to 36 inches: stratified fine sand to silt
2C - 36 to 59 inches: very cobbly sand

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: 10 to 39 inches to strongly contrasting textural stratification
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Occasional

Frequency of ponding: None
Calcium carbonate, maximum in profile: 1 percent
Salinity, maximum in profile: Nonsaline (0.1 to 0.5 mmhos/cm)
Available water storage in profile: Low (about 5.8 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Hydrologic Soil Group: C
Ecological site: Loamy Flood Plains (F228XY100AK)
Other vegetative classification: Balsam poplar-feltleaf willow scrub (050), Loamy Flood Plains (M135A_100)
Hydric soil rating: No

Minor Components

Boreal-riparian scrub gravelly flood plains, wet

Percent of map unit: 10 percent
Landform: Channels on flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Gravelly Low Flood Plains, Wet (R228XY203AK)
Other vegetative classification: Entire mountain avens/sedge wet dwarf scrub (026), Gravelly Low Flood Plains, Wet (M135A_203)
Hydric soil rating: Yes

Boreal-riparian scrub loamy wet flood plains

Percent of map unit: 5 percent
Landform: Flood plains
Microfeatures of landform position: Channels
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Loamy Wet Flood Plains (R228XY153AK)
Other vegetative classification: Feltleaf willow/shrubby cinquefoil/scouring rush meadow/scrub (028), Loamy Wet Flood Plains (M135A_153)
Hydric soil rating: Yes

Nonvegetated alluvium, riverwash

Percent of map unit: 5 percent
Landform: Flood plains
Other vegetative classification: Sparsely vegetated alluvium (068), Alluvium, Nonvegetated (Riverwash)
Hydric soil rating: Unranked

7MS2—Boreal Glaciated Lower Mountain Slopes

Map Unit Setting

National map unit symbol: 1q21
Elevation: 1,710 to 3,700 feet

Mean annual precipitation: 20 to 31 inches
Mean annual air temperature: 22 to 26 degrees F
Frost-free period: 60 to 80 days
Farmland classification: Not prime farmland

Map Unit Composition

Boreal-forested gravelly till slopes, moderately wet, and similar soils: 55 percent
Boreal-forested gravelly warm till slopes and similar soils: 30 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Boreal-forested Gravelly Till Slopes, Moderately Wet

Setting

Landform: Mountains
Landform position (two-dimensional): Backslope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Silty eolian deposits over gravelly till

Typical profile

Oi - 0 to 1 inches: slightly decomposed plant material
A - 1 to 15 inches: silt loam
2C - 15 to 59 inches: very cobbly loam

Properties and qualities

Slope: 12 to 45 percent
Depth to restrictive feature: 8 to 21 inches to strongly contrasting textural stratification
Natural drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.57 to 1.28 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Low (about 5.9 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Hydrologic Soil Group: C
Ecological site: Loamy Slopes, Wet (F228XY354AK)
Other vegetative classification: White spruce/willow woodland, wet (095), Loamy Slopes, Wet (M135A_354)
Hydric soil rating: No

Description of Boreal-forested Gravelly Warm Till Slopes

Setting

Landform: Mountains
Landform position (two-dimensional): Backslope, footslope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Silty eolian deposits over gravelly till

Typical profile

Oi - 0 to 3 inches: slightly decomposed plant material
A - 3 to 5 inches: silt loam

2Bw - 5 to 8 inches: very gravelly sandy loam
2C - 8 to 59 inches: very gravelly sandy loam

Properties and qualities

Slope: 14 to 45 percent
Percent of area covered with surface fragments: 0.1 percent
Depth to restrictive feature: 2 to 6 inches to strongly contrasting textural stratification
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.57 to 1.28 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very low (about 1.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Hydrologic Soil Group: B
Ecological site: Gravelly Mountains, Warm (F228XY355AK)
Other vegetative classification: White spruce/green alder forest (091), Gravelly Mountains, Warm (M135A_355)
Hydric soil rating: No

Minor Components

Alpine-scrub gravelly till slopes, frozen

Percent of map unit: 10 percent
Landform: Mountains
Landform position (two-dimensional): Backslope, footslope
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Loamy Frozen Slopes, High Elevation (R228XY177AK)
Other vegetative classification: Shrub birch-bog blueberry/moss scrub (060), Loamy Frozen Slopes, High Elevation (M135A_177)
Hydric soil rating: No

Alpine-scrub gravelly till slopes

Percent of map unit: 5 percent
Landform: Mountains
Landform position (two-dimensional): Footslope
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Gravelly Slopes (R228XY358AK)
Other vegetative classification: Shrub birch-bog blueberry scrub (058), Gravelly Slopes (M135A_358)
Hydric soil rating: No

7MS3—Alpine Glaciated Mountains with Discontinuous Permafrost

Map Unit Setting

National map unit symbol: 1q22
Elevation: 1,700 to 4,890 feet
Mean annual precipitation: 22 to 97 inches
Mean annual air temperature: 13 to 28 degrees F
Frost-free period: 50 to 70 days
Farmland classification: Not prime farmland

Map Unit Composition

Alpine-scrub-sedge gravelly till slopes, frozen, and similar soils: 55 percent
Alpine-scrub gravelly till circles, frozen, and similar soils: 25 percent
Subalpine-scrub-meadow mosaic gravelly till swales and similar soils: 15 percent
Minor components: 5 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Alpine-scrub-sedge Gravelly Till Slopes, Frozen

Setting

Landform: Mountains
Landform position (two-dimensional): Backslope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Woody organic material and/or grassy organic material over silty eolian deposits over gravelly till

Typical profile

Oi - 0 to 11 inches: peat
A - 11 to 13 inches: mucky silt loam
2Cgf - 13 to 59 inches: very gravelly loam

Properties and qualities

Slope: 8 to 20 percent
Depth to restrictive feature: 13 to 25 inches to permafrost
Natural drainage class: Poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Very low (0.00 in/hr)
Depth to water table: About 0 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Low (about 4.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Hydrologic Soil Group: D
Ecological site: Gravelly Frozen Slopes (R228XY180AK)
Other vegetative classification: Shrub birch-mixed ericaceous shrub/sedge scrub (063), Gravelly Frozen Slopes (M135A_180)
Hydric soil rating: Yes

Description of Alpine-scrub Gravelly Till Circles, Frozen

Setting

Landform: Mountains
Landform position (two-dimensional): Footslope
Microfeatures of landform position: Nonsorted circles
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex
Parent material: Silty eolian deposits over gravelly cryoturbate

Typical profile

Oe - 0 to 0 inches: moderately decomposed plant material
A - 0 to 2 inches: silt loam
2Bw/Cjj - 2 to 9 inches: gravelly loam
2C/Bwjj - 9 to 47 inches: gravelly loam
2Cf - 47 to 59 inches: gravelly loam

Properties and qualities

Slope: 8 to 22 percent
Depth to restrictive feature: 1 to 13 inches to strongly contrasting textural stratification; 35 to 59 inches to permafrost
Natural drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low (0.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very low (about 0.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Hydrologic Soil Group: D
Ecological site: Gravelly Frozen Slopes, Ruptic (R228XY182AK)
Other vegetative classification: Shrub birch/sedge scrub mosaic (057), Gravelly Frozen Slopes, Ruptic (M135A_182)
Hydric soil rating: No

Description of Subalpine-scrub-meadow Mosaic Gravelly Till Swales

Setting

Landform: Swales on mountains
Landform position (two-dimensional): Backslope
Down-slope shape: Linear
Across-slope shape: Concave
Parent material: Silty eolian deposits over gravelly till

Typical profile

Oi - 0 to 3 inches: slightly decomposed plant material
A - 3 to 15 inches: mucky silt loam
2Bw - 15 to 27 inches: cobbly sandy loam
2C - 27 to 59 inches: gravelly sandy loam

Properties and qualities

Slope: 8 to 25 percent
Percent of area covered with surface fragments: 0.1 percent
Depth to restrictive feature: 8 to 21 inches to strongly contrasting textural stratification
Natural drainage class: Somewhat poorly drained

Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.57 to 1.28 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Low (about 5.8 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Hydrologic Soil Group: C
Ecological site: Swales (R228XY405AK)
Other vegetative classification: Green alder scrub mosaic (034), Swales (M135A_405)
Hydric soil rating: No

Minor Components

Alpine-dwarf scrub gravelly till slopes

Percent of map unit: 5 percent
Landform: Mountains
Landform position (two-dimensional): Backslope
Down-slope shape: Linear
Across-slope shape: Convex
Ecological site: Gravelly Mountains, High Elevations (R228XY310AK)
Other vegetative classification: White mountain avens-mixed ericaceous shrub dwarf alpine scrub (087), Gravelly Mountains, High Elevation (M135A_310)
Hydric soil rating: No

7MS4—Boreal Lower Mountain Slopes with Continuous Permafrost

Map Unit Setting

National map unit symbol: 1q23
Elevation: 1,710 to 2,580 feet
Mean annual precipitation: 20 to 31 inches
Mean annual air temperature: 22 to 26 degrees F
Frost-free period: 60 to 80 days
Farmland classification: Not prime farmland

Map Unit Composition

Boreal-taiga loamy drift slopes, frozen, and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Boreal-taiga Loamy Drift Slopes, Frozen

Setting

Landform: Mountains
Landform position (two-dimensional): Toeslope

Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Mossy organic material and/or woody organic material over silty eolian deposits over loamy drift

Typical profile
Oi - 0 to 8 inches: peat
A - 8 to 11 inches: mucky silt loam
2Cg - 11 to 23 inches: sandy loam
2Cf - 23 to 59 inches: sandy loam

Properties and qualities
Slope: 10 to 22 percent
Depth to restrictive feature: 17 to 27 inches to permafrost
Natural drainage class: Poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Very low (0.00 in/hr)
Depth to water table: About 0 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Low (about 5.6 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Hydrologic Soil Group: D
Ecological site: Loamy Frozen Slopes (R228XY400AK)
Other vegetative classification: Black spruce/bog blueberry-Labrador tea woodland (004), Loamy Frozen Slopes (M135A_400)
Hydric soil rating: Yes

Minor Components

Boreal-forested gravelly till slopes, moderately wet
Percent of map unit: 5 percent
Landform: Mountains
Landform position (two-dimensional): Backslope
Down-slope shape: Linear
Across-slope shape: Convex
Ecological site: Loamy Slopes, Wet (F228XY354AK)
Other vegetative classification: White spruce/willow woodland, wet (095), Loamy Slopes, Wet (M135A_354)
Hydric soil rating: No

Alpine-scrub gravelly till slopes, frozen
Percent of map unit: 5 percent
Landform: Mountains
Landform position (two-dimensional): Footslope
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Loamy Frozen Slopes, High Elevation (R228XY177AK)
Other vegetative classification: Shrub birch-bog blueberry/moss scrub (060), Loamy Frozen Slopes, High Elevation (M135A_177)
Hydric soil rating: No

Alpine-scrub gravelly till slopes
Percent of map unit: 5 percent
Landform: Mountains
Landform position (two-dimensional): Footslope

Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Gravelly Slopes (R228XY358AK)
Other vegetative classification: Shrub birch-bog blueberry scrub (058), Gravelly Slopes (M135A_358)
Hydric soil rating: No

7P2—Boreal Glaciated Plains and Hills

Map Unit Setting

National map unit symbol: 1q27
Elevation: 1,560 to 2,880 feet
Mean annual precipitation: 20 to 29 inches
Mean annual air temperature: 26 to 28 degrees F
Frost-free period: 60 to 80 days
Farmland classification: Not prime farmland

Map Unit Composition

Boreal-forested gravelly outwash slopes and similar soils: 75 percent
Boreal-meadow loamy outwash slope depressions and similar soils: 15 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Boreal-forested Gravelly Outwash Slopes

Setting

Landform: Hills, pitted outwash plains
Landform position (two-dimensional): Backslope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Silty eolian deposits over sandy and gravelly outwash

Typical profile

Oi - 0 to 3 inches: slightly decomposed plant material
A - 3 to 4 inches: silt loam
Bw - 4 to 6 inches: silt loam
2BC - 6 to 8 inches: extremely gravelly loamy coarse sand
2C - 8 to 59 inches: extremely gravelly loamy coarse sand

Properties and qualities

Slope: 0 to 30 percent
Depth to restrictive feature: 6 to 12 inches to strongly contrasting textural stratification
Natural drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.57 to 1.28 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very low (about 1.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Hydrologic Soil Group: A
Ecological site: Gravelly and Sandy Slopes (F228XY350AK)
Other vegetative classification: White spruce/shrub birch woodland (093), Gravelly and Sandy Slopes (M135A_350)
Hydric soil rating: No

Description of Boreal-meadow Loamy Outwash Slope Depressions

Setting

Landform: Kettles on outwash plains, kettles on hills
Down-slope shape: Concave
Across-slope shape: Concave
Parent material: Silty eolian deposits over sandy and gravelly outwash

Typical profile

Oi - 0 to 3 inches: slightly decomposed plant material
A - 3 to 13 inches: silt loam
2C - 13 to 59 inches: extremely cobbly coarse sand

Properties and qualities

Slope: 0 to 30 percent
Depth to restrictive feature: 23 to 48 inches to strongly contrasting textural stratification
Natural drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.57 to 1.28 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Low (about 5.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Hydrologic Soil Group: C
Ecological site: Organic Depressions, Bogs (R228XY530AK)
Other vegetative classification: Graminoid herbaceous meadow (033), Loamy Depressions (M135A_550)
Hydric soil rating: No

Minor Components

Water

Percent of map unit: 5 percent
Landform: Lakes
Other vegetative classification: Water (084), Water, Nonvegetated (Water)

Alpine-wet meadow gravelly pond margins

Percent of map unit: 5 percent
Landform: Kettles
Ecological site: Pond Margins (R228XY500AK)
Other vegetative classification: Sedge wet meadow (052), Pond Margins (M135A_500)
Hydric soil rating: Yes

7P4—Boreal Glaciated Plains and Hills with Discontinuous Permafrost

Map Unit Setting

National map unit symbol: 1q28
Elevation: 1,540 to 3,220 feet
Mean annual precipitation: 20 to 29 inches
Mean annual air temperature: 26 to 28 degrees F
Frost-free period: 60 to 80 days
Farmland classification: Not prime farmland

Map Unit Composition

Boreal-forested gravelly till slopes and similar soils: 35 percent
Boreal-taiga loamy drift slopes, frozen, and similar soils: 30 percent
Boreal-forested gravelly outwash slopes and similar soils: 20 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Boreal-forested Gravelly Till Slopes

Setting

Landform: Hills, till plains
Landform position (two-dimensional): Backslope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Silty eolian deposits over gravelly till

Typical profile

Oi - 0 to 2 inches: slightly decomposed plant material
A - 2 to 4 inches: silt loam
E - 4 to 4 inches: silt loam
2Bs - 4 to 16 inches: very gravelly sandy loam
2C - 16 to 59 inches: very gravelly sandy loam

Properties and qualities

Slope: 0 to 15 percent
Percent of area covered with surface fragments: 0.1 percent
Depth to restrictive feature: 4 to 8 inches to strongly contrasting textural stratification
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.57 to 1.28 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very low (about 1.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Hydrologic Soil Group: B

Ecological site: Gravelly and Sandy Slopes (F228XY350AK)
Other vegetative classification: White spruce/shrub birch woodland (093), Gravelly and Sandy Slopes (M135A_350)
Hydric soil rating: No

Description of Boreal-taiga Loamy Drift Slopes, Frozen

Setting

Landform: Outwash plains
Landform position (two-dimensional): Toeslope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Mossy organic material and/or woody organic material over silty eolian deposits over loamy drift

Typical profile

Oi - 0 to 8 inches: peat
A - 8 to 11 inches: mucky silt loam
2Cg - 11 to 23 inches: sandy loam
2Cf - 23 to 59 inches: sandy loam

Properties and qualities

Slope: 1 to 10 percent
Depth to restrictive feature: 17 to 27 inches to permafrost
Natural drainage class: Poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Very low (0.00 in/hr)
Depth to water table: About 0 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Low (about 5.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Hydrologic Soil Group: D
Ecological site: Loamy Frozen Slopes (R228XY400AK)
Other vegetative classification: Black spruce/bog blueberry-Labrador tea woodland (004), Loamy Frozen Slopes (M135A_400)
Hydric soil rating: Yes

Description of Boreal-forested Gravelly Outwash Slopes

Setting

Landform: Hills, pitted outwash plains
Landform position (two-dimensional): Summit, shoulder, backslope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Silty eolian deposits over sandy and gravelly outwash

Typical profile

Oi - 0 to 3 inches: slightly decomposed plant material
A - 3 to 4 inches: silt loam
Bw - 4 to 6 inches: silt loam
2BC - 6 to 8 inches: extremely gravelly loamy coarse sand
2C - 8 to 59 inches: extremely gravelly loamy coarse sand

Properties and qualities

Slope: 0 to 20 percent

Depth to restrictive feature: 6 to 12 inches to strongly contrasting textural stratification
Natural drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.57 to 1.28 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very low (about 1.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Hydrologic Soil Group: A
Ecological site: Gravelly and Sandy Slopes (F228XY350AK)
Other vegetative classification: White spruce/shrub birch woodland (093), Gravelly and Sandy Slopes (M135A_350)
Hydric soil rating: No

Minor Components

Boreal-taiga/tussock silty frozen loess slopes, alaska mountains

Percent of map unit: 10 percent
Landform: Plateaus
Landform position (two-dimensional): Summit
Microfeatures of landform position: Turf hummocks
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex
Ecological site: Loamy Frozen Terraces, Wet (R228XY105AK)
Other vegetative classification: Black spruce/tussock cottongrass woodland (012), Loamy Frozen Terraces, Wet (M135A_105)
Hydric soil rating: Yes

Water

Percent of map unit: 3 percent
Landform: Lakes
Other vegetative classification: Water (084), Water, Nonvegetated (Water)

Alpine-wet meadow gravelly pond margins

Percent of map unit: 2 percent
Landform: Kettles
Ecological site: Pond Margins (R228XY500AK)
Other vegetative classification: Sedge wet meadow (052), Pond Margins (M135A_500)
Hydric soil rating: Yes

G—Nonvegetated Alluvium, Alaska Mountains, Boreal

Map Unit Setting

National map unit symbol: 1r4j
Elevation: 1,090 to 3,200 feet
Mean annual precipitation: 14 to 36 inches
Mean annual air temperature: 21 to 28 degrees F
Frost-free period: 60 to 80 days
Farmland classification: Not prime farmland

Map Unit Composition

Nonvegetated alluvium, riverwash: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Nonvegetated Alluvium, Riverwash

Setting

Landform: Flood plains
Parent material: Sandy and gravelly alluvium and/or sandy and silty alluvium

Properties and qualities

Slope: 0 to 2 percent
Frequency of flooding: Frequent

Interpretive groups

Land capability classification (irrigated): None specified
Other vegetative classification: Sparsely vegetated alluvium (068), Alluvium, Nonvegetated (Riverwash)
Hydric soil rating: Unranked

Minor Components

Boreal-riparian scrub gravelly diorite flood plains, moderately wet

Percent of map unit: 3 percent
Landform: Channels on flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Gravelly Low Flood Plains, Acid (R228XY250AK)
Other vegetative classification: Feltleaf willow-green alder scrub (030), Gravelly Low Flood Plains, Acid (M135A_250)
Hydric soil rating: Yes

Boreal-riparian forested gravelly high flood plains

Percent of map unit: 3 percent
Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear

Ecological site: Gravelly High Flood Plains, High Elevation (F228XY185AK)
Other vegetative classification: White spruce/willow forest (094), Gravelly High Flood Plains, High Elevation (M135A_185)
Hydric soil rating: No

Alpine-riparian scrub gravelly flood plains, moderately wet

Percent of map unit: 2 percent
Landform: Channels on flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Gravelly Low Flood Plains, High Elevation (R228XY257AK)
Other vegetative classification: Feltleaf willow scrub, cool (027), Gravelly Low Flood Plains, High Elevation (M135A_257)
Hydric soil rating: Yes

Boreal-riparian scrub loamy wet flood plains

Percent of map unit: 2 percent
Landform: Flood plains
Microfeatures of landform position: Channels
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: Loamy Wet Flood Plains (R228XY153AK)
Other vegetative classification: Feltleaf willow/shrubby cinquefoil/scouring rush meadow/scrub (028), Loamy Wet Flood Plains (M135A_153)
Hydric soil rating: Yes

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Appendix D – Office-based Wetland and Waterbody Mapping Report

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Office-Based Wetland and Waterbody Mapping Report

Denali Park Realignment Feasibility Study, Milepost 344-348

Alaska Railroad Corporation

Riley Creek, Alaska

December 15, 2017

Table of Contents

Tables

Figures

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1 Introduction and Purpose

HDR Alaska, Inc. (HDR) is supporting the Alaska Railroad Corporation (ARRC) on the Denali Park Realignment, which is a track realignment project located near Denali National Park and Preserve. The project will eliminate an at-grade crossing of the George Parks Highway (Parks Highway) at ARRC Milepost (MP) 345.09 and a grade-separated crossing of the Parks Highway at ARRC MP 346.71. HDR is providing environmental and engineering assistance to augment ARRC staff by developing a geographic information system (GIS) database; performing feasibility-level wetland and waterbody mapping; conducting cultural resources research; providing conceptual design work to convert the existing ARRC track embankment into a trail; and estimating conceptual construction costs.

Construction of the proposed realignment will involve the discharge of fill into wetlands or other waters of the U.S.; therefore, it would require authorization from the U.S. Army Corps of Engineers (USACE). To evaluate prospective realignment alternatives, ARRC contracted HDR to prepare office-based wetland and waterbody mapping. This report identifies wetlands and waterbodies within the study area that are potentially subject to USACE jurisdiction under authority of Section 404 of the Clean Water Act of 1972 (as amended) or Section 10 of the Rivers and Harbors Act of 1899.

1.1 Study Area Description

The 1,121-acre study area is an approximate 2.7 mile by 0.7 mile corridor covering an area west of the Parks Highway where the potential track realignment would occur (Figure 1). The study area is located within the Denali Borough in Sections 3, 4, 9, 10, 14, 15 of Township 14 South, Range 7 West, Fairbanks Meridian. The study area is located within U.S. Geological Survey (USGS) quadrangle Healy C-4 (USGS 2017). Approximate coordinates of the study area center are 63.7130436° North and 148.8932178° West (NAD83). The study area is within the Denali Lakes-Nenana River, Hines Creek, and Riley Creek watersheds (6th level Hydrologic Unit Code [HUC] 190803080705, 190803080708, and 190803080709 respectively; USGS 2017). It contains portions of Riley Creek and the Nenana River.

1.2 Regulatory Definitions

A consideration for siting project alternatives is the presence of wetlands and other waters of the U.S. By federal law and associated policy, it is necessary to first avoid project impacts to wetlands wherever practicable, minimize impacts that cannot be avoided, and in some cases, compensate for unavoidable impacts. Wetlands, waterbodies, waters of the U.S., and uplands referenced in this report are defined as follows:

Wetlands

"Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (33 Code of Federal Regulations

[CFR] Part 328.3(b)). Wetlands are a subset of “waters of the U.S.” Note that the “wetlands” definition does not include unvegetated areas such as streams and ponds.

As described in the 1987 USACE *Wetlands Delineation Manual* and in the 2007 *Regional Supplement to the Corps of Engineers Wetland Delineation Manual, Alaska Region* (USACE 1987, 2007), wetlands must possess the following three characteristics: (1) a vegetation community dominated by plant species that are typically adapted for life in saturated soils; (2) inundation or saturation of the soil during the growing season; and (3) soils that are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions.

Waterbodies

Waterbodies are defined as open-water areas that do not support an abundance of vegetation that extend above the water surface. These include rivers, lakes, ponds, and streams.

Waters of the U.S.

The term waters of the U.S. refers to wetlands and waterbodies subject to regulation by the USACE (33 CFR 328.3(a)).

Uplands

Non-water and non-wetland areas are called uplands.

2 Mapping Methods

HDR wetland scientists reviewed the following datasets to determine the presence or absence of wetlands and waterbodies in the study area:

- Digital color orthorectified aerial imagery (Microsoft 2017)
- Color aerial imagery provided by ARRC
- U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) mapping (Figure 2; USFWS 2017)
- National Resources Conservation Service (NRCS) Soil Survey of Denali National Park Area, Alaska (Figure 2; NRCS 2004)
- Preliminary Draft Geotechnical Report for Feasibility Study of Rail Realignment near Denali National Park MP 345 to 347.5 (Geotechnical Report; Golder Associates 2017)

No wetland-specific field sampling was undertaken as part of this effort.

According to the existing planning-level NWI mapping, approximately 425.2 acres or 38 percent of the study area was classified as wetlands or waterbodies (Figure 2). NRCS soil mapping identifies five soil units within the study area (Figure 2). Each map unit is classified by the amount of water or hydric soil contained within the soil unit boundary. The ranges of these values for the soil units within the study area are from 10 to 97 percent. Table 1 shows the acreage of each soil unit mapped within the study area.

Table 1. Soil Survey Map Units within the Study Area

Soil Survey Map Unit	Percent of Area Containing Hydric Soil or Water	Acres*
Boreal Flood Plains and Terraces	70	56.2
Boreal Glaciated Plains and Hills	10	284.2
Boreal Glaciated Plains and Hills with Discontinuous Permafrost	45	534.2
Boreal Lower Mountain Slopes with Continuous Permafrost	85	217.7
Nonvegetated Alluvium, Alaska Mountains, Boreal	97	14.5
Unmapped	-	14.3
	Total Study Area	**1,121.1**

*Sum of the individual cells may not add up to total acreage due to rounding. Source: NRCS 2004

Boreholes drilled for the Geotechnical Report within the study area show that much of the central and southern portions of the preferred realignment travel through an area with a surficial organic layer that extends approximately 2.5 feet below the ground surface. This accumulation of peat is consistent with the criteria required to be determined a wetland.

HDR scientists combined these datasets into a GIS database, and analyzed them to prepare a desktop delineation of wetlands and waterbodies. Delineating wetlands from aerial photography includes using the following indicators:

Vegetation Clues

In aerial photography, scientists look for saturation-adapted vegetation communities, low plant height, and the presence of hydrophytic plant species that may indicate the presence of wetlands. A common example includes areas dominated by emergent (herbaceous) plants, which may indicate limitations to the growth of woody species, such as excessively wet soils.

Evidence of Soil Saturation

Scientists seek visible evidence of wetland hydrology, including surface water and darker areas of photos indicating surface saturation. A site's proximity to streams, open water habitat, and marshes can also be indicative of shallow subsurface water.

Topography

Evidence of topographic high points and sloped surfaces that would allow soils to drain is used to support classifying areas as uplands. Topographic lowlands, close proximity to waterbodies, and floodplain topography serve as indicators of potential wetland hydrology.

HDR wetland scientists attributed GIS wetland polygons with NWI mapping codes based on the USFWS' *Classification of Wetlands and Deepwater Habitats of the U.S.* (Cowardin et al. 1979). Figures 3 and 4 show the wetland boundaries overlain on aerial imagery. Descriptions of each mapping code are included in Section 3.0 Mapping Results.

3 Mapping Results

A total of 578.7 acres of wetlands and waterbodies were categorized into 15 NWI types, and mapped within the study area based on aerial photographs (Table 2). Mapped wetlands and wetlands shown in Figures 3 and 4 are either areas where surface saturation is discernable on aerial photographs, or vegetation type and landscape position indicate the likely presence of wetlands or waterbodies.

Table 2. Mapping Summary

Mapping Code	Description	Acres*
Forested Wetlands		
PFO4B	Saturated needle-leaved evergreen forested wetland	17.6
PFO4/SS4B	Saturated needle-leaved evergreen forested wetland with a needle-leaved evergreen scrub shrub understory	52.8
Scrub Shrub Wetlands		
PSS4B	Saturated needle-leaved evergreen scrub shrub wetland	76.6
PSS4/1B	Saturated needle-leaved evergreen and broad-leaved deciduous scrub shrub wetland	175.4
PSS1/4B	Saturated broad-leaved deciduous and needle-leaved evergreen scrub shrub wetland	215.0
PSS1/4C	Seasonally flooded broad-leaved deciduous and needle-leaved evergreen scrub shrub wetland	1.8
PSS1C	Seasonally flooded broad-leaved deciduous scrub shrub wetland	0.4
PSS1/EM1B	Saturated broad-leaved deciduous scrub shrub wetland with an emergent understory	0.5
PSS1/EM1C	Seasonally flooded broad-leaved deciduous wetland with an emergent understory	6.8
Emergent Wetlands		
PEM1/SS1C	Seasonally flooded emergent wetland with a broad-leaved deciduous scrub shrub component	1.5
PEM1C	Seasonally flooded emergent wetland	1.5
PEM1F	Semi-permanently flooded emergent wetland	0.4
	Total Wetlands	***550.4***

Table 2 (continued). Mapping Summary

Mapping Code	Description	Acres*
Other Waterbodies		
PUBH	Permanently flooded pond with an unconsolidated bottom	2.3
R3USC	Seasonally flooded river shoreline	2.1
R3UBH	Permanently flooded river with an unconsolidated bottom	23.9
	Total Other Waterbodies	***28.2***
	Total Wetlands and Other Waterbodies	***578.7***
U	Upland (non-wetland, non-water)	542.5
	Total Mapped Area	**1,121.1**

*Sum of the individual cells may not add up to total acreage due to rounding.

4 Wetland Categorization

All 578.7 acres of wetlands and waterbodies mapped within the study area were evaluated, and given a preliminary USACE management category per current USACE guidance (USACE 2014). Management categories are defined as follows:

> ***Category I**: These are wetlands that: 1) provide habitat for threatened or endangered species that has been documented; 2) represent a high quality example of a rare wetland type; 3) are rare within a given region; 4) provide habitat for very sensitive or important wildlife or plants; and/or 5) are undisturbed and contain ecological attributes that are impossible or difficult to replace within a human lifetime, if at all. Examples of the latter are mature very productive forested wetlands unique to an ecoregion that may take a century to develop, and certain bogs and fens with their special plant populations that have taken centuries to develop. The position and function of the wetland in the landscape plays an integral role in overall watershed health.*
>
> ***Category II**: [These wetlands] can be important for a variety of wildlife species and can be critical for the watershed depending on where they are located. In contrast to Category I wetlands, Category II wetlands do not provide critical habitat for any T&E species or species of concern. Generally these wetlands are pristine, not fragmented; common but more productive and sustain higher biodiversity compared to Category III wetlands.*
>
> ***Category III:** These wetlands are usually plentiful in the watershed often with the least biodiversity. Category III wetlands are not rare or unique and overall productivity and species diversity in Category III wetlands are relatively low. These wetlands may be impacted by man (or by fire or other natural events) and are not considered to be "pristine" examples and as a result in some cases require less than 1:1 [compensation].*

Figure 5 shows the locations of mapped wetlands and waterbodies based on their management category. Professional judgment was used to assign the wetlands into the following categories.

Category I

No wetlands are preliminarily proposed for Category I designation.

Category II

Approximately 40.69 acres are preliminarily proposed for Category II designation. These include:

- All 27.56 acres of perennial streams (Nenena River and Riley Creek) and adjacent riverine wetlands. These streams and wetlands are classified as Category II based on their ability to support resident fish and to export organic material and nutrients to downstream aquatic systems. Approximately 11 miles downstream from the study area, the Nenena River is documented as anadromous fish habitat that supports Chinook, coho, and chum salmon (ADF&G 2017).

- All wetlands and waterbodies with seasonally flooded to permanently flooded hydrologic regime (13.13 acres). These areas typically moderate stream flows, perform groundwater recharge, and provide wildlife habitat.

Category III

All remaining wetlands with a saturated water regime (538.0 acres) are preliminarily proposed for a Category III classification. These wetland types are common throughout the region, and provide limited wildlife habitat.

Summary

A preliminary estimate of the amount of wetlands and waterbodies in each management category within the study area is presented in Table 3.

Table 3. Wetland Management Categories

USACE Management Category	NWI Mapping Code	Acres
Category I	None	0.0
Category II	PSS1/EM1C, PEM1/SS1C, PSS1C, PSS1/4C, PEM1C, PEM1F, PUBH, R3USC, R3UBH	40.7
Category III	PFO4B, PFO4/SS4B, PSS4B, PSS4/1B, PSS1/4B, PSS1/EM1B	538.0
	Total Wetlands	**578.7**

5 Next Steps

This planning-level, office-based wetland and waterbody mapping and categorization effort is adequate for development of project alternatives and an initial comparison of wetland impacts between alternatives. It also allows ARRC to track wetland impact avoidance and minimization measures throughout project development, which is a requirement of the USACE permitting process. However, a wetland field survey is recommended prior to submittal of a USACE Section 404 permit application in order to verify the wetland boundaries presented in this report and collect information on wetland and waterbody functions. In order to assess wetland functions, HDR will use the Alaska Wetland Assessment Method (AKWAM; ADOT&PF 2010) to document the physical characteristics of wetlands and waterbodies in order to place them into the management categories described in Section 4, based on evidence of functions and services performed.

In April 2008 USACE and EPA published the 2008 Mitigation Rule, which addresses compensatory mitigation for unavoidable losses of aquatic resources. The 2008 Mitigation Rule requires documented avoidance and minimization be performed in order to obtain a permit to fill a wetland or waterbody. After USACE evaluates the avoidance and minimization measures, USACE will determine if compensatory mitigation is appropriate and practicable. Since the project is located in predominately undisturbed watersheds where wetlands are common, USACE could determine that compensatory mitigation is not appropriate or practicable.

If USACE determined compensatory mitigation is necessary, the 2008 Mitigation Rule outlines the preference for obtaining compensatory mitigation. The most preferred method is through mitigation banks, followed by in-lieu fee providers, and finally permittee-responsible mitigation. The project is located within the secondary service area of one mitigation bank, the Tanana Watershed Umbrella Stream & Wetland Mitigation Bank-Lower Chena Flats Greenbelt. A secondary service area may be used if the project is not within a primary service area of another bank and documentation can be provided showing that the credits from the mitigation bank will compensate for the lost functions at the project site. The project is not located within a primary service are of any other mitigation bank or in-lieu fee provider.

If necessary, final mitigation ratios based on management category would be negotiated with the USACE during the Section 404 permitting process. In addition, the cost of a compensatory mitigation credit would also be negotiated with the Salcha-Delta Soil & Water Conservation District (the sponsor of the Lower Chena Flats Greenbelt Mitigation Bank).

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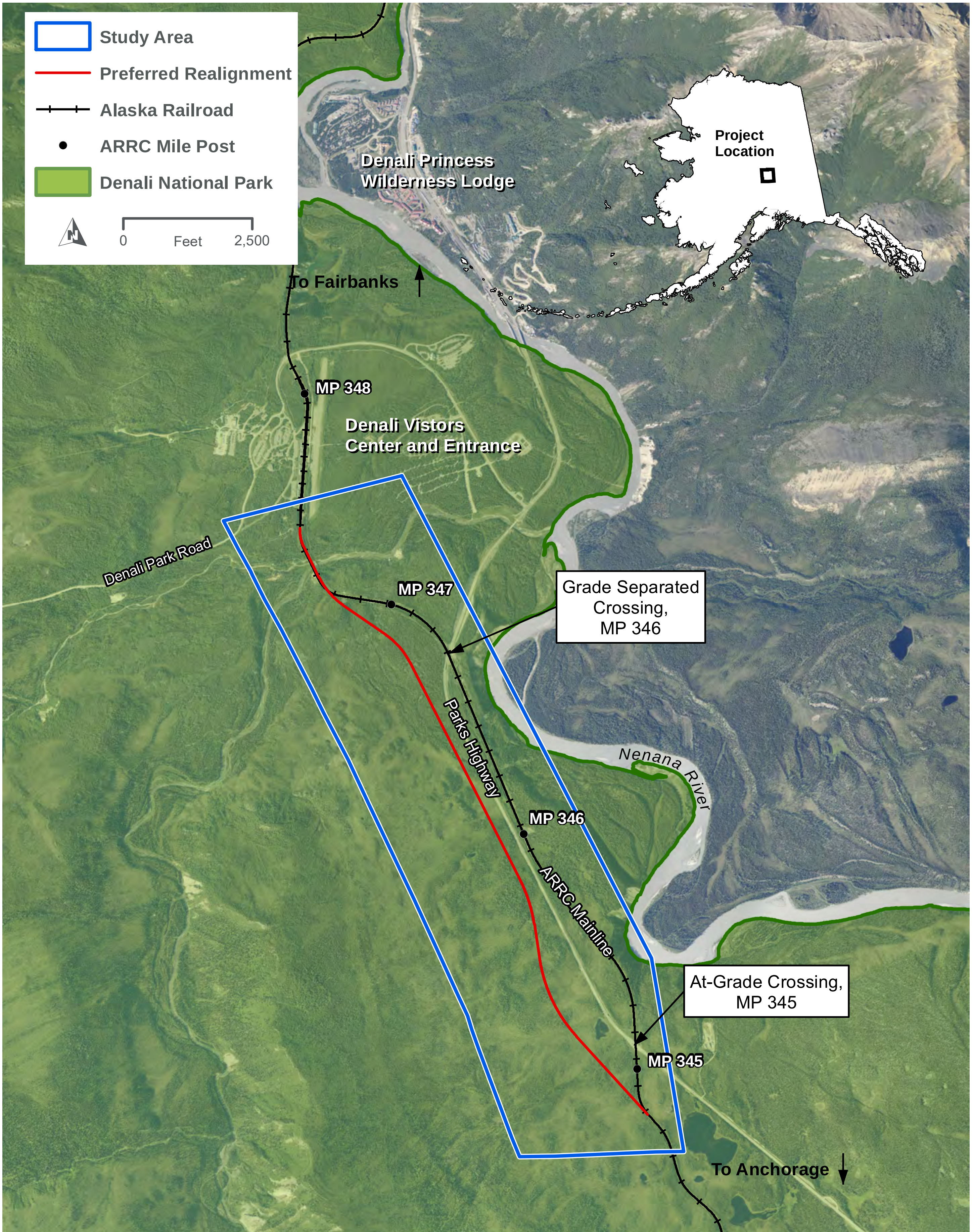
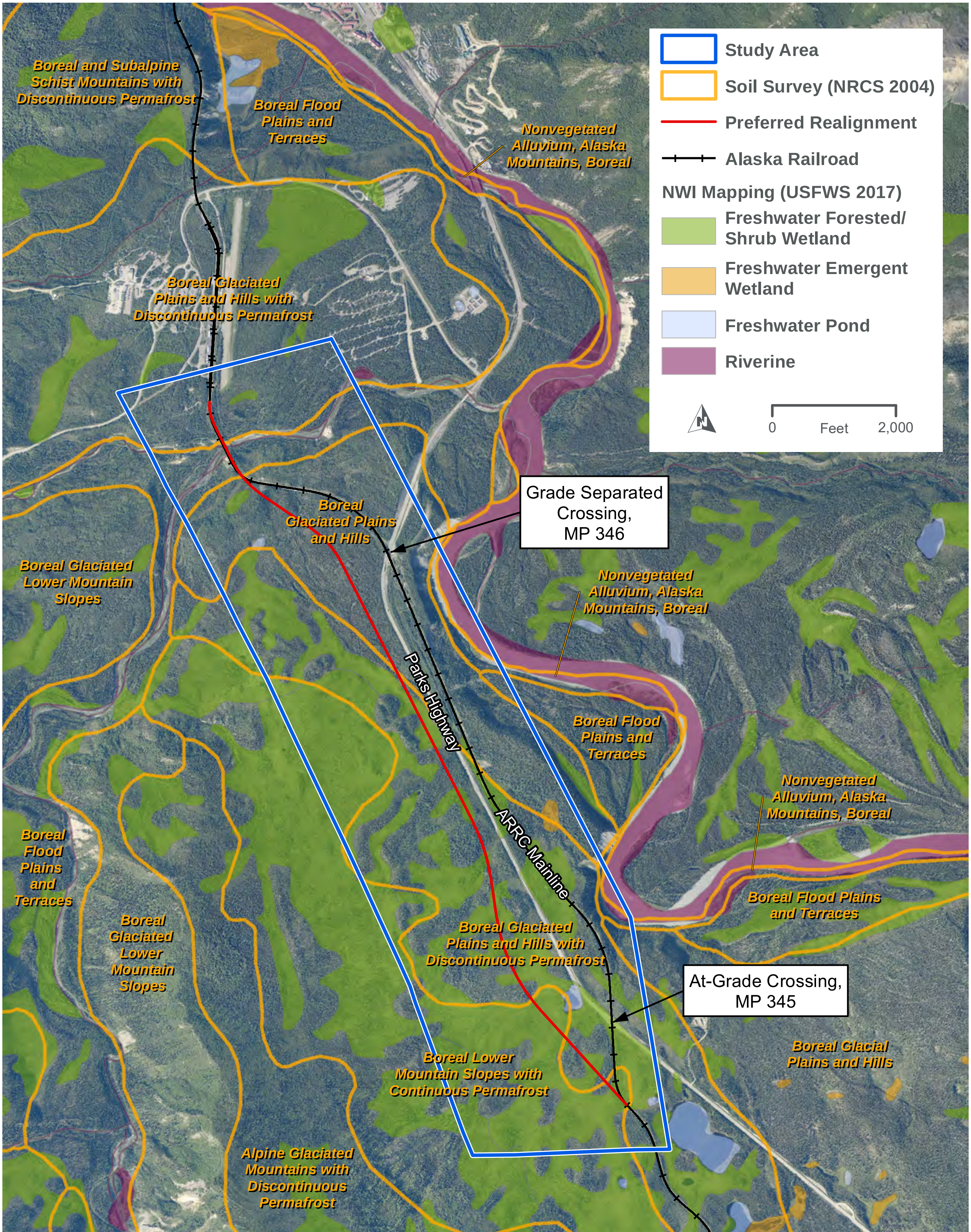
Figures



DENALI PARK REALIGNMENT FEASIBILITY STUDY, MP 344-348

VICINITY MAP

FIGURE 1

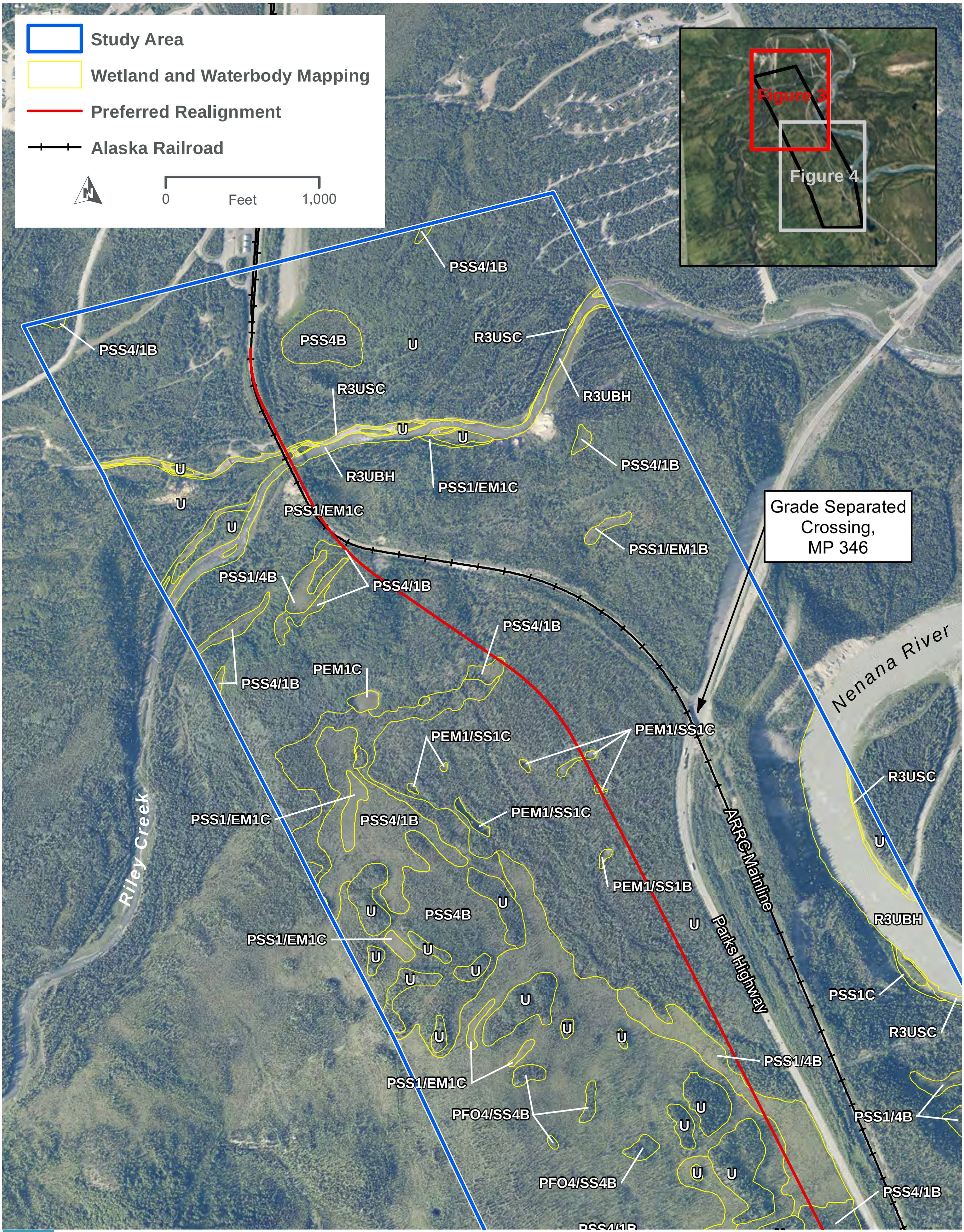


HDR ALASKA RAILROAD

DENALI PARK REALIGNMENT FEASIBILITY STUDY, MP 344-348

EXISTING DATA

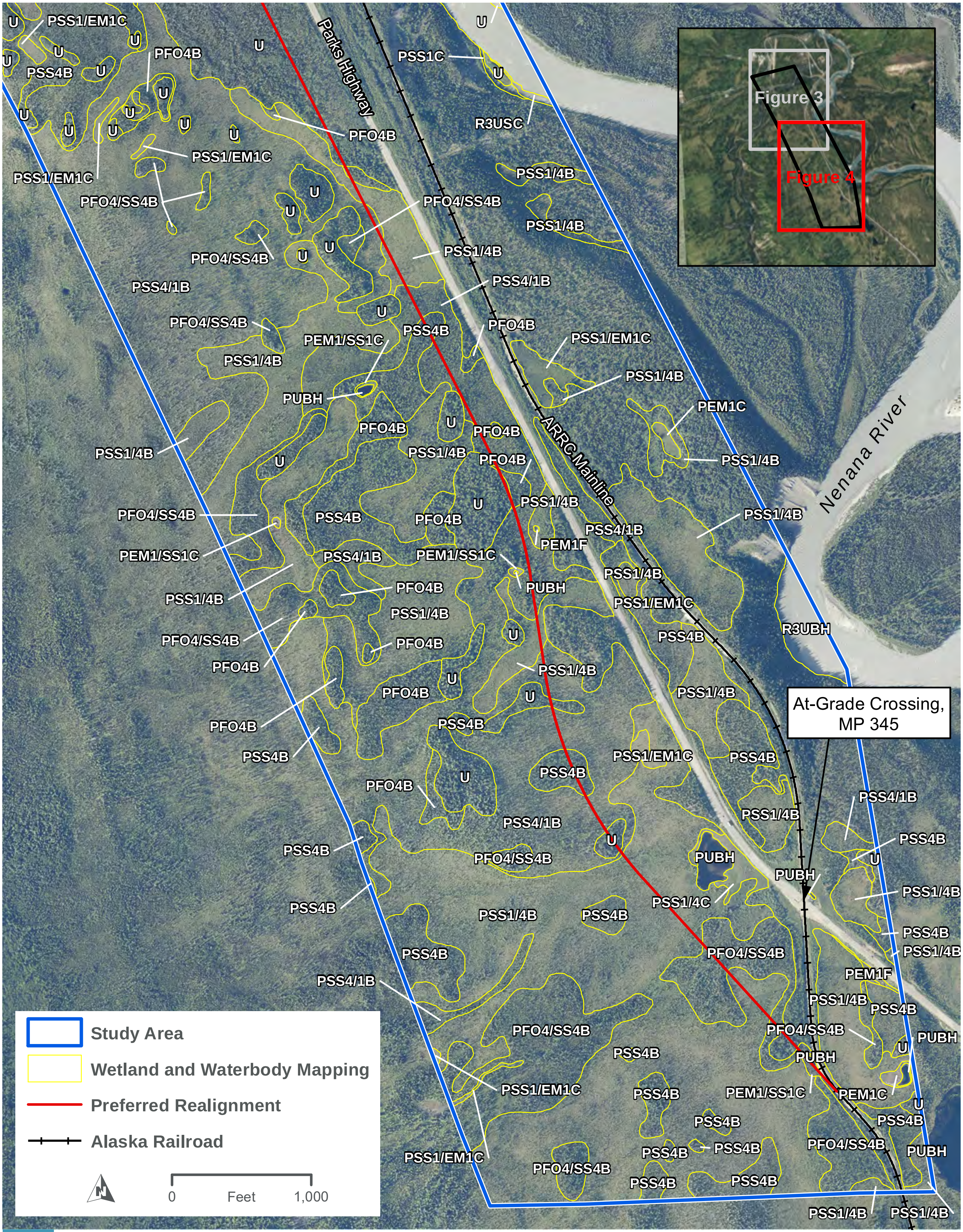
FIGURE 2



DENALI PARK REALIGNMENT FEASIBILITY STUDY, MP 344-348

WETLANDS AND WATERBODY MAPPING

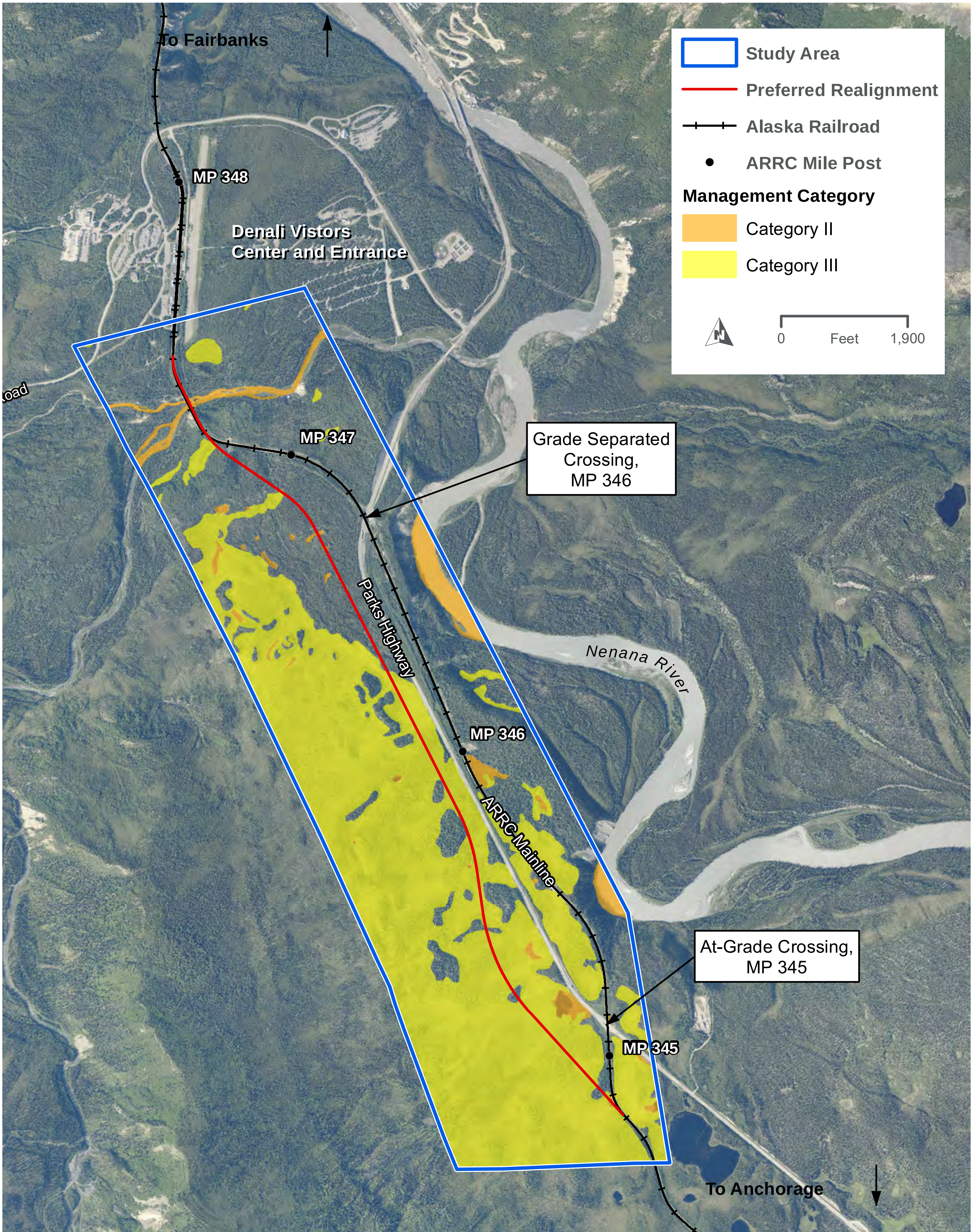
FIGURE 3



DENALI PARK REALIGNMENT FEASIBILITY STUDY, MP 344-348

WETLAND AND WATERBODY MAPPING

FIGURE 4



DENALI PARK REALIGNMENT FEASIBILITY STUDY, MP 344-348

MANAGEMENT CATEGORIES

FIGURE 5

Appendix E – Railroad Track Quantities and Trail Design Report

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Railroad Track Quantities and Trail Design Report

Denali Park Realignment Feasibility Study, Milepost 344-348

Alaska Railroad Corporation

Riley Creek, Alaska
December 15, 2017

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Table of Contents

Tables

Figures

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1 Introduction and Purpose

HDR Alaska, Inc. (HDR) is supporting the Alaska Railroad Corporation (ARRC) on the Denali Park Realignment, which is a track realignment project located near Denali National Park. The project will eliminate an at-grade crossing of the George Parks Highway (Parks Highway) at ARRC Milepost (MP) 345.09 and a grade-separated crossing of the Parks Highway at ARRC MP 346.71. HDR is providing environmental and engineering assistance to augment ARRC staff by developing a geographic information system (GIS) database; performing feasibility-level wetland and waterbody mapping; conducting cultural resources research; providing conceptual design work to convert the existing ARRC track embankment into a trail; and estimating conceptual construction costs.

HDR estimated earthwork and track construction quantities and calculated conceptual earthwork costs. To compute earthwork quantities, the project team developed 3D computer models using Bentley InRoads v8i (Select Series 2). Bid tabulations from the Alaska Department of Transportation and Public Facilities (DOT&PF) provided information regarding earthwork unit costs. Assumptions associated with these tasks appear in Section 2.0.

To evaluate the suitability of the track embankment as a trail embankment, HDR developed a typical trail section and used design criteria from Alaska State Parks and compared it against the ARRC mainline typical section. HDR also developed a 4.2 mile trail alignment to connect the future trail within the project area to Denali Village. Recommendations and assumptions associated with HDR's trail work appear in Section 3.0.

2 Quantity Calculations and Unit Prices

2.1 Track and Earthwork Quantity Calculations

HDR used an existing digital terrain model provided by ARRC. Typically, Light Detection and Ranging (LiDAR) data can reliably generate 2-foot contours. However, the LiDAR data used for this digital terrain model may not have this level of accuracy since it is publicly-available and was not acquired specifically for this project.

ARRC developed the alignment (horizontal and vertical) used in HDR's analysis. The horizontal alignment was named *Proposed 4*, and it only had one vertical alignment. The profile grade point reflects a top-of-rail profile. HDR assumed 115RE rail with typical 7" x 9" x 8'6" hardwood ties. Due to the conceptual nature of this analysis and the level of accuracy obtained from the publicly-available data, curves were not superelevated.

Using Bentley InRoads, HDR created two templates that use three types of material with classifications taken from DOT&PF's Standard Specifications. The material types are Type D-1 Surface Course (subballast), Selected Material: Type A (Type A) for the first two feet of embankment below the subballast (structural fill), and Selected Material: Type C (Type C) below the Type A.

One template mimicked ARRC Standard Drawing 2.3-04 (taken from ARRC's *Standard Plans, Ballast & Track Work*, 2009). See Figure 1. HDR made one minor deviation: instead of a continuous 2 percent slope across the entire embankment, the project team created a 2 percent crown at the embankment's centerline. Any resulting quantity changes from this modification should be negligible.

The second template featured a single-lane, 13-foot access road with a 2-foot shoulder and a 2-foot offset from the toe of the ballast. This is the same typical section that was featured in the construction plans for the ARRC's Northern Rail Extension, Phase 1A. See Figure 2. The access road is on the east side of the track for two reasons: (1) since the track is west of the Parks Highway having the access road on the west side would limit access to the roadway; and (2) the resulting balance of Type C material is 135,000 cubic yards (CY) of excess material for a western access road compared to 32,200 CY of excess material for an eastern access road.

2.2 Earthwork Cost Calculations

HDR developed unit prices based upon DOT&PF bid tabulations. This presents some uncertainty as contractors frequently manipulate unit prices based upon expected project quantity overruns. However, aggregating a sample of unit prices should provide reasonable conceptual unit prices.

For D-1 surface course, nine recent bids in the Denali area had prices that ranged from $17 to $43 per ton with 78 percent of the bids landing between $20 and $25 per ton. HDR used $25 per ton for analysis.

It was difficult to find bids for Type A in the Denali area. Only three recent bids were available, and they ranged from $7.50 to $10 per ton. By expanding the search to include other projects in the Matanuska-Susitna Borough, 19 bids had prices from $8.60 to $16 per ton. The majority (68 percent) were between $9 and $11 per ton. HDR used $10 per ton for analysis.

19 recent bids in the Denali area for Type C material had prices between $5 and $16 per ton with 58 percent of these prices ranging between $7 and $10 per ton. HDR used $9 for its calculation.

2.3 Material Quantities and Costs

Earthwork quantity summaries, a track quantity summary, and conceptual earthwork cost estimates are summarized in the following tables. Note: Ballast is included with earthwork quantities due to slight differences in the ballast portion of both typical sections.

Table 1. Track Quantities

Material	*Quantity*
Total Track Length	***13,538 track feet***
Length of 115RE Rail	***27,076 LF***
7” x 9” x 8’6” Hardwood Ties	***8,123 EA***

Table 2. Earthwork Quantities using ARRC Standard Drawing 2.3-04.

Material	*Cut (CY)*	*Fill (CY)*	*Net Import (CY)*
Ballast	*0*	*14,800*	***14,800***
D-1 Subballast	*0*	*13,600*	***13,600***
Type A	*0*	*36,900*	***36,900***
Type C	*594,800*	*556,500*	***38,300 (Excess)***

Table 3. Earthwork Quantities using ARRC Standard with Access Road.

Material	*Cut (CY)*	*Fill (CY)*	*Net Import (CY)*
Ballast	*0*	*12,900*	***12,900***
D-1 Subballast	*0*	*24,100*	***24,100***
Type A	*0*	*57,900*	***57,900***
Type C	*680,500*	*648,300*	***32,200 (Excess)***

Table 4. Earthwork Tonnage and Costs using ARRC Standard Drawing 2.3-04.

Material	*Cut (Tons)*	*Fill (Tons)*	*Net Import (Tons)*	*Unit Price ($/Ton)*	*Cost*
D-1 Subballast	*0*	*27,200*	*27,200*	*$25.00*	***$680,000.00***
Type A	*0*	*73,800*	*73,800*	*$10.00*	***$738,000.00***
Type C	*1,189,600*	*1,113,000*	*76,600 (Excess)*	*$9.00*	***$(689,400.00)***

Table 5. Earthwork Tonnage and Costs using ARRC Standard with Access Road.

Material	*Cut (Tons)*	*Fill (Tons)*	*Net Import (Tons)*	*Unit Price ($/Ton)*	*Cost*
D-1 Subballast	*0*	*48,200*	*48,200*	*$25.00*	***$1,205,000.00***
Type A	*0*	*115,800*	*115,800*	*$10.00*	***$1,158,000.00***
Type C	*1,361,000*	*1,296,600*	*64,400 (Excess)*	*$9.00*	***$(579,600.00)***

3 Trail Design

HDR developed trail design criteria (Table 3.4) based on the functional classifications of trails listed in the *Alaska State Parks Trail Management Handbook, Section 3: Trail Design Parameters*. HDR assumed that a multi-use, multi-season trail will be desirable for this location. The trail criteria will provide a trail suitable for Class 5 pedestrian and bicycle use, and Class 4 all-terrain vehicle (ATV) and snowmobile use. For pedestrian and bicycle use, a Class 5 trail is considered a fully developed trail. This class of trail is frequently considered to meet federal accessibility requirements and is intended to be accommodating to users with limited trail skills and experience. Class 5 trails are typically not designed for ATV use specifically, though their use of Class 5 trails may be allowed dependent on agency decisions.

3.1 Trail Section

The structural section of the unpaved trail will use the existing alignment and rail embankment to maximize benefits of existing in-situ material. Since the railroad embankment is wider than the specified trail section, minimal earthwork is required. If not already present in the railroad embankment, then the trail embankment section should contain a 6-inch layer of surface course (either D1 or E1) above a 1-foot 6-inch lift of Type A. Type C is acceptable for raising the existing grade to the bottom of the Type A. Confirming the existence of the Type A lift will provide the option of paving the trail in the future without need to reconstruct the subgrade under the unpaved surface course. HDR also suggests adding an additional 6 inches of surface course to smooth out the traveled way after the removal of the track and ballast. Since this is an optional feature, this quantity is not shown in Table 8. The unpaved surface has a 3 percent crowned cross slope to provide improved drainage across the trail, which will mitigate against water infiltration into the structural section. This 3 percent cross slope can be incorporated into the additional 6” layer of surface course (if added) since the track embankment will likely have a 2 percent cross slope. The typical section appears in Figure 3.

3.2 Trail Alignment

The minimum curve radius for a Class 4 trail is 25 feet using arc defined curvature. The ARRC *Track Chart* (April 2015) shows that the sharpest curve on the existing ARRC alignment near the project area is Curve 343A (8 degrees 34 minutes). Using the chord definition for curvature, Curve 343A has a radius of 669.44 feet. This greatly exceeds the minimum for Class 4 trails. Similarly, the maximum target trail grade of 5% is well above the maximum observed track grade.

3.3 Existing Trails

HDR reviewed two existing trail databases to identify existing trails within the project corridor. In addition to reviewing the Alaska Department of Natural Resources (DNR) database, HDR reviewed the RS 2477 database. RS 2477 trails are historic trails that were established prior to 1976 and were recorded in State status plats across federal land. The DNR trails database documents trails captured from digitized USGS quadrangle maps. These sources revealed no existing trails within the corridor between Denali Park Village and Riley Creek.

3.4 Trail Design Criteria

Table 6. Trail Design Criteria.

Criteria	*Value*	*Source & Notes*
Design Width	*10'*	*Alaska State Park Trail Management Handbook 2015 (ASPTMH) Section 3: Trail Design Parameters. Table 3.4- Minimum Design Width Double Lane ATV Trail Class 4*
Design Surface	*E1/D1 Surface Course*	*ASPTMH Appendix A: Standard Trail Structures*
Design Grade		
Target	*5%*	*ASPTMH Appendix A: Standard Trail Structures Section 3: Trail Design Parameters. Table 3.3- Bicycle Terra Trail Design Parameters Trail Class 5*
Short Pitch Maximum	*8%*	*ASPTMH Appendix A: Standard Trail Structures Section 3: Trail Design Parameters. Table 3.3- Bicycle Terra Trail Design Parameters Trail Class 5*
Maximum Pitch Density	*0%-3% of trail*	*ASPTMH Appendix A: Standard Trail Structures Section 3: Trail Design Parameters. Table 3.3- Bicycle Terra Trail Design Parameters Trail Class 5*
Design Cross Slope		
Target	*3%*	*ASPTMH Appendix A: Standard Trail Structures Section 3: Trail Design Parameters. Table 3.3- Bicycle Terra Trail Design Parameters Trail Class 5*
Maximum	*3%*	*ASPTMH Appendix A: Standard Trail Structures Section 3: Trail Design Parameters. Table 3.1- Hiker/Pedestrian Terra Trail Design Parameters Trail Class 5*
Design Clearing		
Height	*12'*	*ASPTMH Appendix A: Standard Trail Structures Section 3: Trail Design Parameters. Table 3.1- Pack and Saddle Terra Trail Design Parameters Trail Class 4*
Width	*10'*	*ASPTMH Appendix A: Standard Trail Structures Section 3: Trail Design Parameters. Table 3.1- Snowmobile Trail Design Parameters Trail Class 4*
Shoulder Clearance	*12"*	*ASPTMH Appendix A: Standard Trail Structures Section 3: Trail Design Parameters. Table 3.1- Snowmobile Trail Design Parameters Trail Class 4*
Design Turn Radius	*25' (Arc-Defined)*	*ASPTMH Appendix A: Standard Trail Structures Section 3: Trail Design Parameters. Table 3.1- Snowmobile Trail Design Parameters Trail Class 4*

3.5 Trail from ARRC MP 345 to Denali Village

HDR developed a conceptual plan for 4.2 miles of multi-use trail to connect Denali Park Village with the existing track alignment that may become a future trail. The trail begins at a tie-in point just east of the at-grade crossing of the Parks Highway and the track. The trail will follow the east side of the Parks Highway with approximately 30 feet of horizontal separation between the trail and the edge of pavement for drainage and clear zone requirements for the roadway to be unaffected by the trail. The initial 0.8 of a mile of trail will follow the corridor of the abandoned Denali Highway. The conceptual alignment for the trail appears in Figure 4.

Quantities for Type C material were not calculated. Topographic information in the form of Interferometric Synthetic Aperture Radar (IFSAR) data downloaded from the Division of Geological and Geophysical Survey's Elevation Portal in November 2017 had incorrect State Plane coordinates and other spatial data incongruities, so this information was not useable. Type C earthwork should be minimal, however, because it was solely intended to be used as a leveling course for the structural section and it would consist of material that was available on site. Calculations for Type A and D-1/E-1 Surfacing were possible since they have a consistent cross-sectional area along the entire length of the new trail alignment.

Table 7. Trail Quantities.

Material	*Quantity*
Total Trail Length	*21,740 LF*
Length of Bridge	*240 LF*

Table 8. Trail Earthwork Quantities.

Material	*Cut (CY)*	*Fill (CY)*	*Net Import (CY)*
D-1 or E-1 Surfacing	*0*	*4,450*	***4,450***
Type A	*0*	*18,500*	***18,500***

Table 9. Trail Earthwork Tonnage and Costs.

Material	*Cut (Tons)*	*Fill (Tons)*	*Net Import (Tons)*	*Unit Price ($/Ton)*	*Cost*
D-1 or E-1 Surfacing	0	8,900	8,900	$25.00	**$222,500**
Type A	0	37,000	37,000	$10.00	**$370,000**

3.6 Trail Bridge Over Nenana River

To fully connect the trail extension to the Denali Park Village, it will be necessary to bridge the Nenana River. HDR looked at a steel truss pedestrian bridge for the purpose of feasibility and cost estimating. Contech Engineered Solutions (Contech) provided a cost for a 240-foot long, 10-foot wide truss bridge suitable for this crossing with adequate capacity for the various user groups identified above in Section 3. Contech suggested a prefabricated 5-segment component truss bridge rated for vehicular live loads of 10,000 lbs. and uniform live loads of 90 PSF. The preliminary bridge cost estimate includes delivery from their facility in Seattle to the site. A copy of the estimate and a drawing of the bridge from Contech appear in Figures 5 and 6.

Abutment and wingwall concrete quantities were estimated using design recommendations taken from Contech's *Pedestrian Truss Bridge Standard Details*. The actual required height will require hydrological studies of the Nenana River, particularly Ordinary High Water elevation at the conceptual crossing location and agency requirements for vertical clearance over the river to allow for transit of vessels using the river. Unit costs for concrete were developed by HDR using DOT&PF bid tabulations.

Table 10. Bridge Estimate.

Item	*Dimension*	*Cost*	*Total*
Pedestrian Truss	*240 ft. (L) x10 ft. (W)*	*$477,200 (EA)*	***$477,200***
Concrete Abutments & Wingwalls	*85 CY*	*$1,500/CY*	***$127,500***

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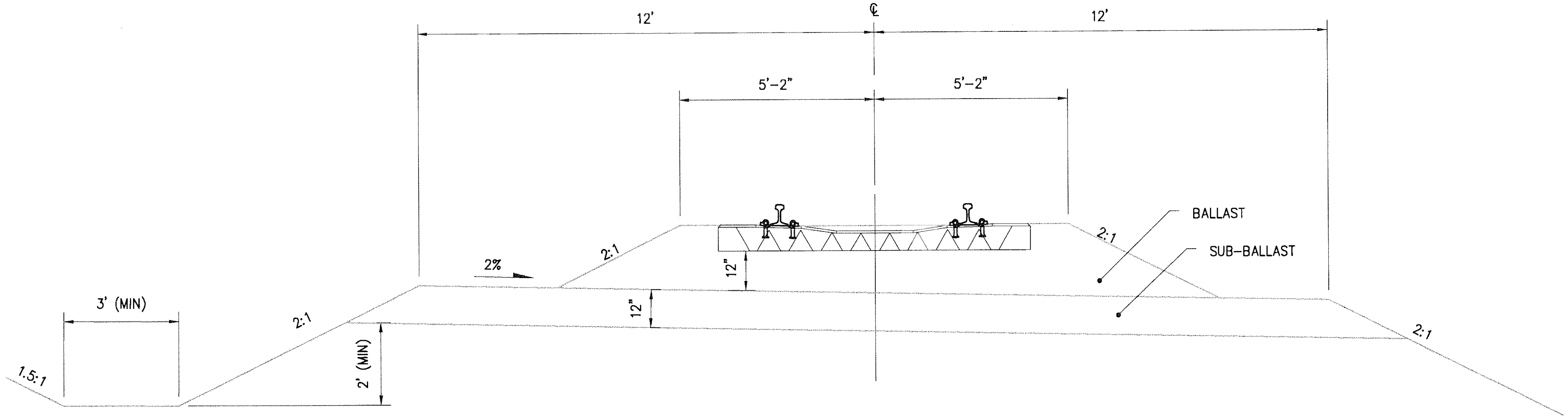
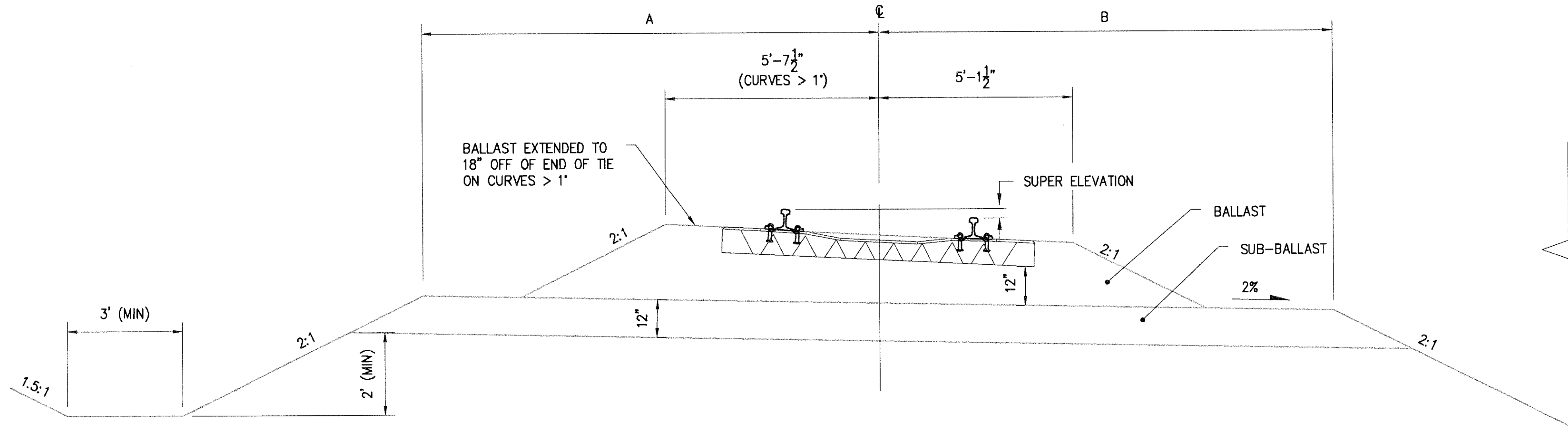


TANGENT SECTION

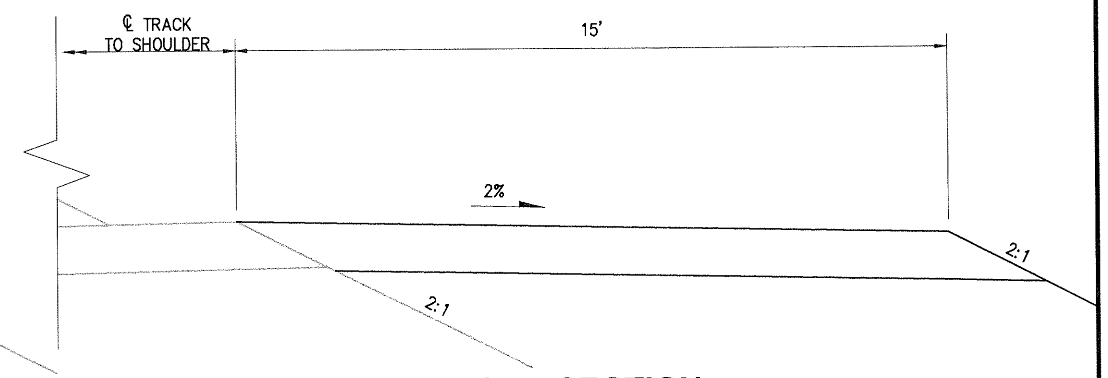
SCALE: 1" = 4'

Note: HDR made two deviations from this typical section -- (1) wooden ties and a 2% embankment crown at the centerline



CURVE SECTION

SCALE: 1" = 4'



ROAD SECTION

SCALE: 1" = 4'

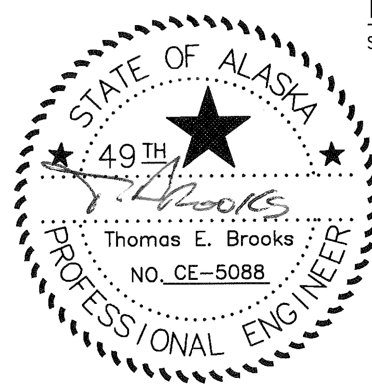
BALLAST REQUIRED FOR 100' OF TRACK		
	SUPER ELEVATION	CUBIC YARDS
CURVED TRACK	1"	80.1
	2"	84.8
	3"	89.6
	4"	94.9
	5"	100.0
TANGENT TRACK		84.3

SUB–BALLAST REQUIRED FOR 100' OF TRACK		
	DEGREE OF CURVE	CUBIC YARDS
CURVED TRACK	0° – 1°	96.3
	1° – 2°	98.2
	2° – 6°	100.0
	+6°	101.9
TANGENT TRACK		96.3

SUB–BALLAST WIDTH FOR DEGREE CURVATURE		
	DIMENSIONS	
	A	B
0° – 1° 00' INCLUSIVE	12'–0"	12'–0"
1° 01' – 2° 00' INCLUSIVE	12'–6"	12'–0"
2° 01' – 6° 00' INCLUSIVE	13'–0"	12'–0"
OVER 6°	13'–6"	12'–0"

NOTES

1. BALLAST DEPTH SHALL BE MINIMUM 12" UNDER TIE, MEASURED AT LOW RAIL.
2. ALL QUANTITIES ESTIMATED, REPRESENT IN–PLACE, COMPACTED MATERIAL, BASED ON 2,640 EACH, 8'–3" CONCRETE TIES PER MILE AND MINIMUM BALLAST AND SUB–BALLAST DIMENSIONS.
3. SUB GRADE SHALL SLOPE TO PREVAILING DRAINAGE SIDE ON TANGENT, OR TO THE INSIDE OF THE CURVE.
4. SUBGRADE SLOPE TRANSITION RATE TO BE 1" IN 10'.
5. DEPTH OF DITCH VARIES TO PROVIDE POSITIVE DRAINAGE.



ALASKA RAILROAD CORPORATION
OFFICE OF THE CHIEF ENGINEER
P.O. BOX 107500, ANCHORAGE, ALASKA 99510–7500 (907) 265–2456

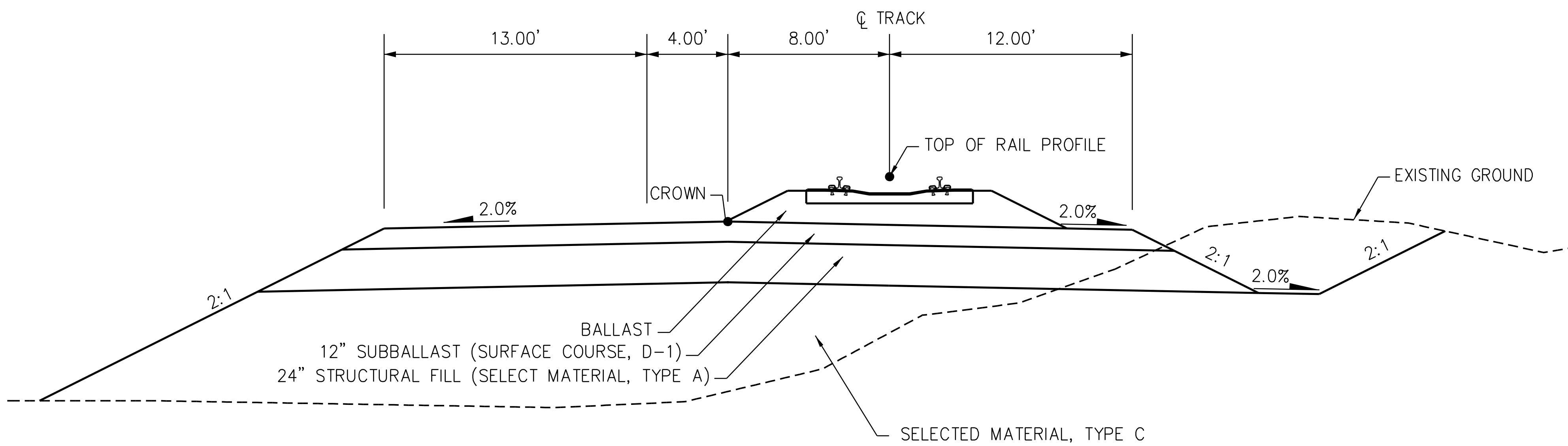
STANDARD
MAIN LINE
BALLAST SECTIONS
CONCRETE TIES

APPROVED: T. E. Brooks DATE: 1/28/04

DESIGNED BY: REH
DRAWN BY: BBF
CHECKED BY: REH
APPROVED BY: TEB

SCALE: 1" = 4'
DATE: 1/28/2004

FILE: s2.3–04.dwg
2.3-04



ALASKA RAILROAD

PROJECT:
DENALI PARK REALIGNMENT FEASIBILITY STUDY
MP 344-348

TITLE:
MAINLINE TYPICAL SECTION
WITH 13-FT ACCESS ROAD

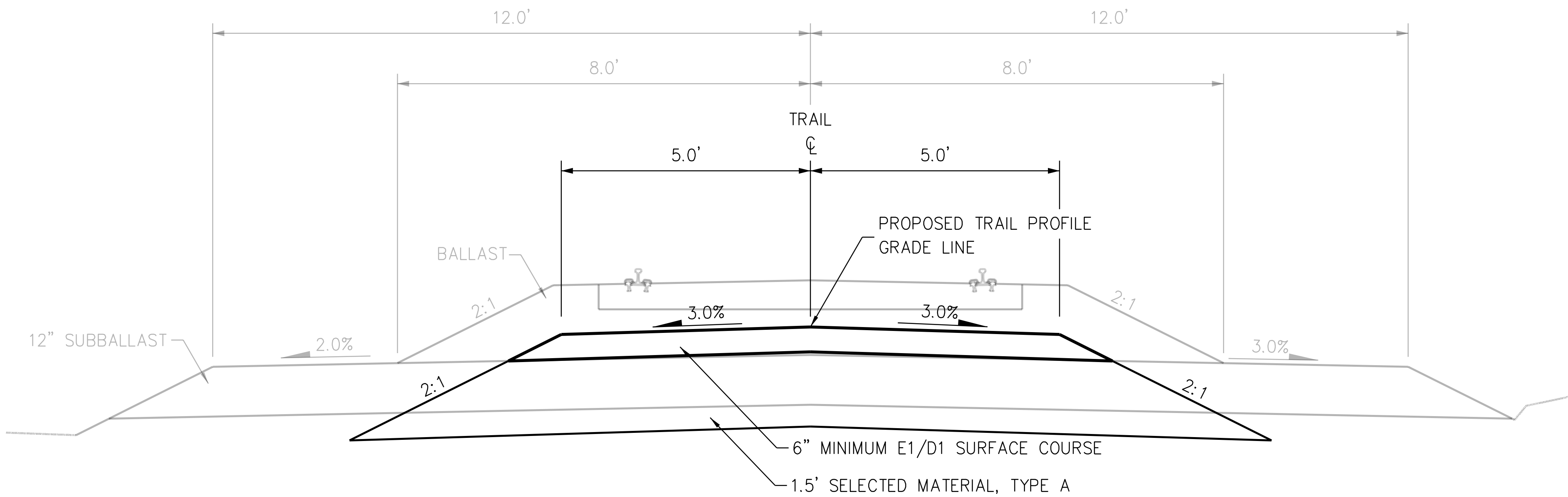
HDR

REV.	DATE	BY	REVISION

DESIGNED BY: DEM
DRAWN BY: DEM
CHECKED BY: JCB
APPROVED BY:

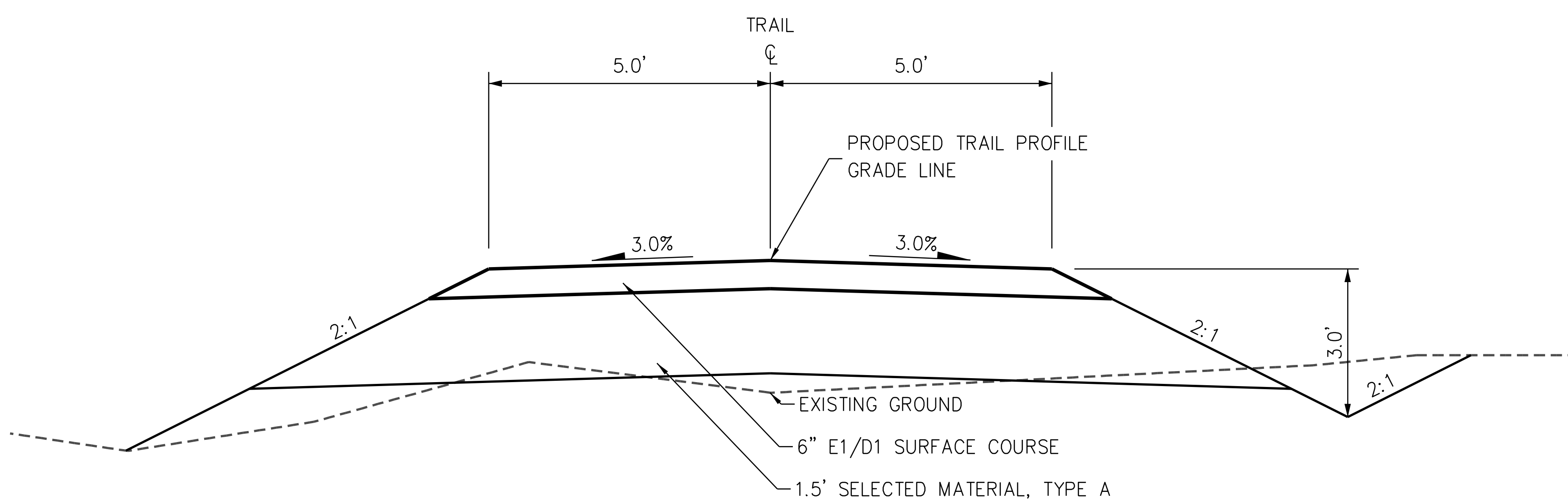
SCALE: NONE
DATE: 12/15/2017

AFE NO.:
ACAD FILE:
DWG NO.
OF



TRAIL SECTION ALONG EXISTING TRACK ALIGNMENT

EXISTING TRACK SECTION PARAMETERS EXCEED TRAIL SECTION DESIGN CRITERIA



TRAIL TYPICAL SECTION

FROM DENALI PARK VILLAGE TO EXISTING TRACK CONNECTION

ALASKA RAILROAD

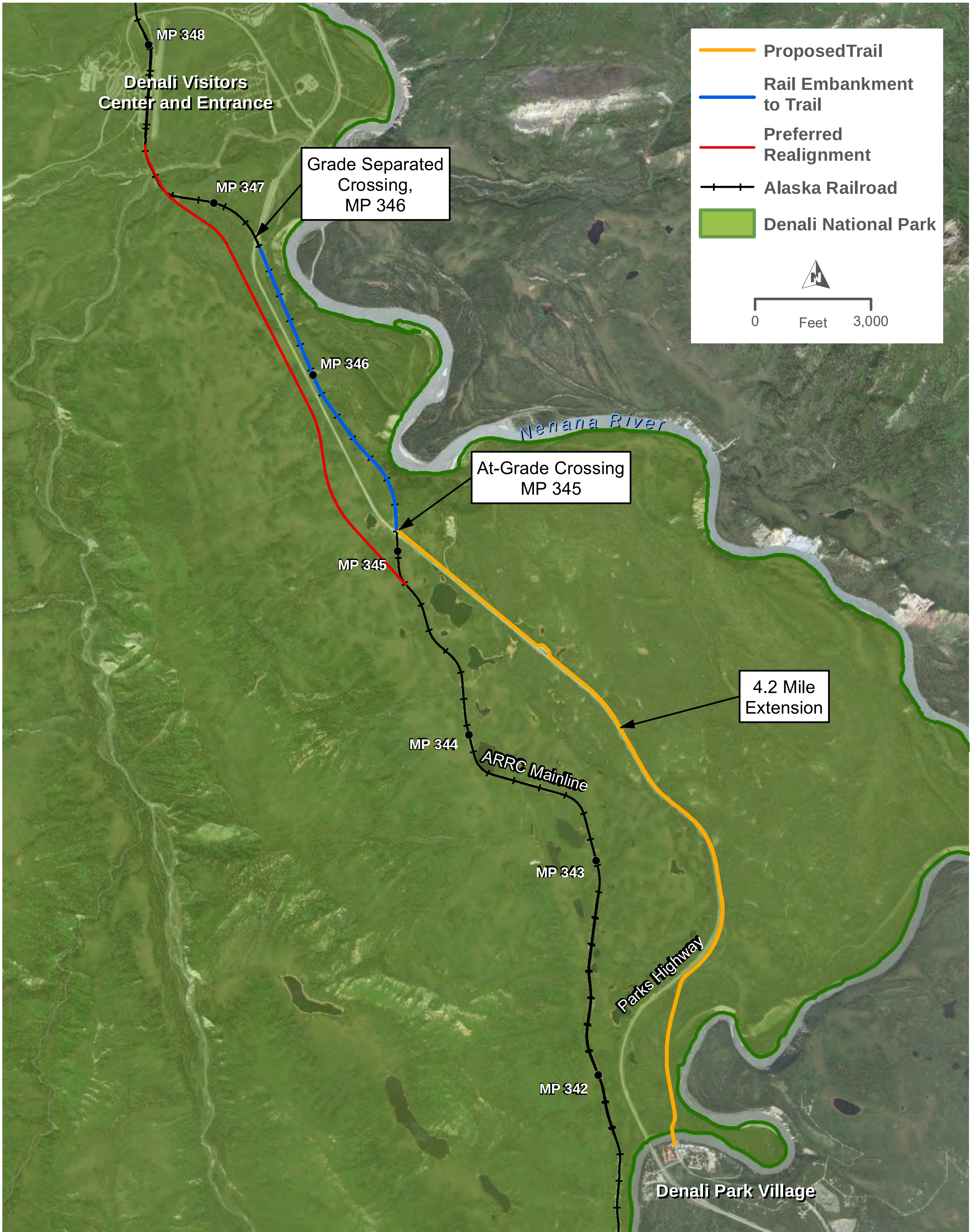
PROJECT:
DENALI PARK REALIGNMENT FEASIBILITY STUDY
MP 344-348

TITLE:
TYPICAL SECTION
MULTI-USE TRAIL

DESIGNED BY: JCB	SCALE: NONE		AFE NO.:
DRAWN BY: JCB			ACAD FILE:
CHECKED BY: DEM	DATE: 12/15/2017		DWG NO.
APPROVED BY:			____ OF ____

HDR

REV.	DATE	BY	REVISION



DENALI PARK REALIGNMENT
FEASIBILITY STUDY, MP 344-348

PROPOSED TRAIL

PATH: Z:\09585 ARRC\10074911_DENALIREALIGNMENT\7.2_WP\MAP_DOCS\OVERVIEW\AREAOFINTEREST_PROPOSEDTRAIL.MXD - USER: SGROSENI - DATE: 12/11/2017

9025 Centre Pointe Drive
Suite 400
West Chester, Ohio 45069
(513) 645-7000
(800) 344-2102
Fax: (513) 645-7689
www.contech-cpi.com

12/8/2017

Subject: WA Pedestrian Bridge, Seattle, WA

The following is a Continental Pedestrian Bridge System ENGINEER'S COST ESTIMATE for the subject project. This ESTIMATE is intended for preliminary estimating purposes only and should **not** be interpreted as a final QUOTATION. The information presented is based on the most current data made available to CONTECH.

CONTECH will fabricate and deliver the following described Continental Pedestrian Bridge components and appurtenances:

DESCRIPTION OF SUPPLIED MATERIALS:

1 - 240 ft span x 10 ft wide Continental Connector Bridge
Unpainted Weathering Steel
3" x 12" (nominal) Douglas Fir Deck
Horizontal Safety Rails at 4" max to height of 54 inches
IPE (rub rail)rail provided
Steel toe plate provided
AASHTO LRFD Pedestrian Guide Specifications
Uniform Live Load of 90 psf (LRFD)
Vehicular Live Load of 10000 lbs
Delivered in 5 sections

ESTIMATE: $477,200 Delivered (F.O.B.)

Estimated Heaviest Crane Pick: 204,100 lbs

These costs do not include the foundation, or installation costs. As part of the construction process, the contractor is to perform the items listed below in accordance with the installation drawings:

- Excavate and/or construction for the structure & foundations
- Provide and install anchor bolts
- Unload and set structure utilizing crane
- Touch-Up paint work
- Third-party testing

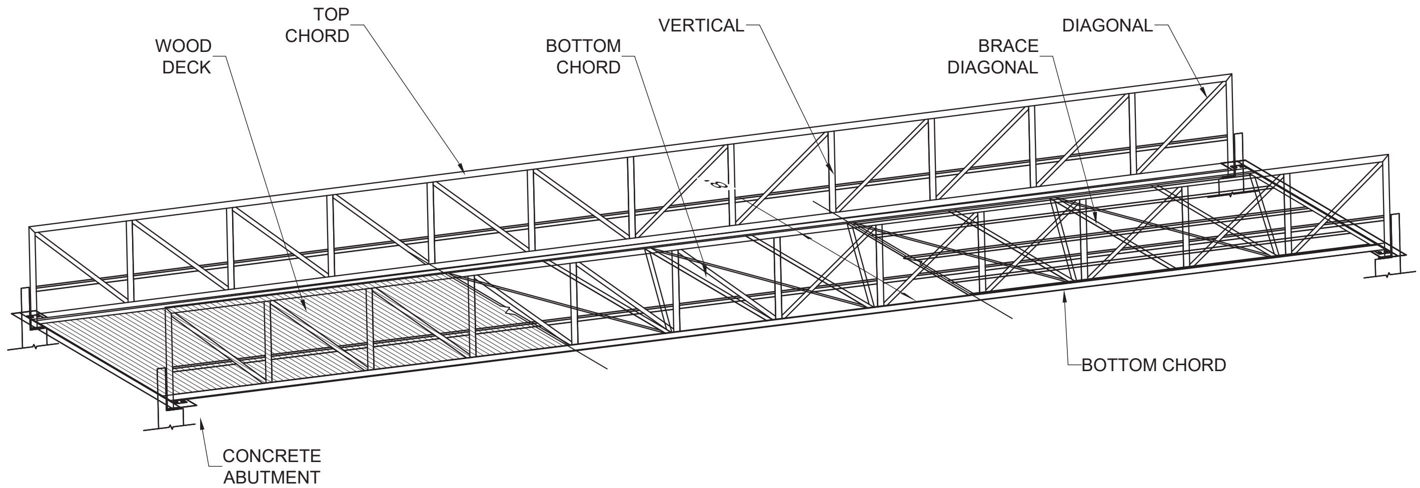
Please contact me should you have any questions or need additional information. Thank you for your interest in the Continental Pedestrian Bridge System.

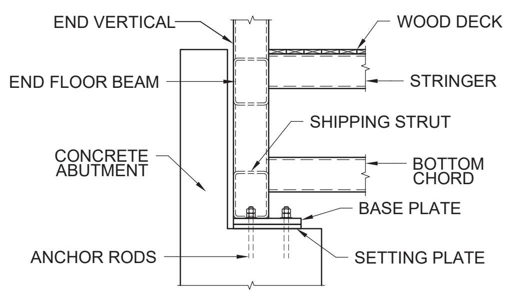
Respectfully,

Michael Blank
(206) 390-3711

CONTECH
ENGINEERED SOLUTIONS

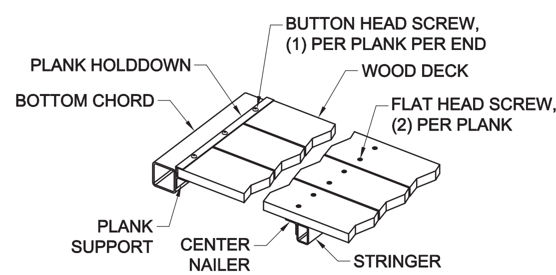
Pedestrian Truss Bridge Details



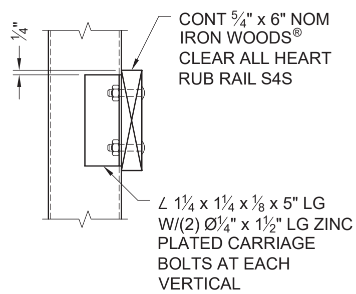


BEARING SIDE VIEW

INFORMATION PROVIDED FOR REPRESENTATION ONLY.
ACTUAL BEARING DIAGRAMS TO BE BASED ON FINAL DESIGN.



WOOD DECK DETAIL



CONTINENTAL BRIDGE