APPENDIX J

Geotechnical Report No. 11-20

Pretty Rocks Landslide
2018-2019 Geotechnical Investigation and Conceptual Design Alternatives Report

AK NPS DENA 10(45)
Denali National Park, Alaska
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U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

WESTERN FEDERAL LANDS HIGHWAY DIVISION
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Geotechnical
Services

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1 INTRODUCTION

This geotechnical report has been developed by Western Federal Lands Highway Division (WFL) to document the 2018 and 2019 investigation results and conceptual design through May of 2019 and moved forward for the Pretty Rocks Landslide near MP 45.4 on the Denali National Park Road (Figure 1). Additional geotechnical work performed after this time-period is contained under separate cover in several stand-alone geotechnical documents listed in Section 1.2 of this report.

The technical assistance request for this project originated in winter of 2017-2018. The resulting scope of work included the following milestone activities, outcomes, and additional requests during the course of the project:

- July 2018: Conduct geotechnical investigation to characterize the landslide, install test borings, instrumentation to monitor movement, groundwater, and subsurface ground temperatures, and to collect soil and rock samples for laboratory testing for stability analyses.

- February 2019: Lead and facilitate a workshop based on the results of the 2018 geotechnical investigation and landslide stability analyses with members of Denali National Park (DENA), the Alaska Region of the National Park Service (AKR)(NPS), and WFL to brainstorm conceptual alternatives and select the most apparently viable alternatives to move forward for a preliminary evaluation. Six are selected to move forward by workshop team.

- May 2019: Present preliminary evaluation of six conceptual design alternatives selected by NPS in February 2019 to move forward for proof-in-concept validation. WFL evaluates the six alternatives and recommends eliminating three of the options from further assessment. WFL provides the following concepts for NPS consideration:

    - remove the landslide (earthwork) option,
    - bridge the landslide with minor realignments at the ends of the bridge, and
    - determining if a roadway realignment to the north or south of the existing Polychrome Pass is feasible and desirable (Polychrome Pass realignment alternatives).

  NPS selects to move forward with all three conceptual alternatives.

- August 2019: Conduct geotechnical investigation for design and construction considerations for the remove the landslide (earthwork) option and the bridge the landslide with minor realignments option. Investigation includes test borings, instrumentation to monitor movement, groundwater, and subsurface ground temperatures, and to collect soil and rock samples for laboratory testing at the locations of the proposed bridge footings and in the lower landslide area where no subsequent investigation has been performed previously to refine the landslide model for the earthwork stability analyses. NPS asks for the Polychrome Pass potential realignments to the north or south of the existing alignment to move forward. WFL and NPS decide to split that work out as a separate project. The remove landslide (earthwork) option and the bridging options are moved forward as part of this continued Pretty Rocks Landslide work. The information for the Polychrome Pass realignment alternatives are contained under separate cover as a Project Delivery Plan that will be submitted to NPS in August 2020.

- January 2020: Request to evaluate safety for DENA maintenance personnel ramping into the Pretty Rocks Landslide after dramatic subsidence over the winter months. Additional requests as part of our discussions were to include evaluation of a cut slope terrace concept to stabilize the Park Road, conduct a rockfall analyses for rebuilding and reopening the Park Road, and preparing an emergency contract to bring the road across Pretty Rocks Landslide back up to grade for the tourist season. Detailed information for the geotechnical portion of all these requests are cited in Section 1.2 below.

- February 2020: Co-lead and facilitate a workshop based on the results of the 2019 geotechnical investigation for the remove the landslide (earthwork) option and bridging the landslide options. Evaluations are presented with constructability issues. Supplemental information and analyses is requested by NPS prior to finalizing these two options in geotechnical memorandums cited in Section 1.2 below.

The content of this report covers the time span from beginning of project until May 2019, when preliminary conceptual design alternatives where presented to DENA for consideration and selection. Additional geotechnical information, analyses, and recommendations for the selected preliminary conceptual designs from May 2019 to August 2020 are contained under separate cover as referenced in Section 1.2.

1.1 Background Information

The area known as the Pretty Rocks Landslide moves through a section of the Denali Park Road near mile post 45.4. The section of road was completed in the early 1930s. Roadway movement documentation in this area suggests the road section crossing the landslide was moving before the 1980s. The history and rate of the landslide movement and attempted interim repairs are listed in the following timeline presented below. See Figures 2-11 in Appendix A for timeline related photos.

Pre-1980's: Maintenance had to sweeten up once every two to three years across the slump. (no photos)

1987: Vertical "drop" movement requires heavy maintenance each year; day-labor type project installs geosynthetic reinforcement layers and subsurface groundwater cutoff trench in upper ditch line. (See Figures 2-3)

2004: Vertical movement measured between 1 and 3 inches per month. (See Figure 4)

2014: Vertical movement increases.

2016-2017: Pretty Rocks Landslide: 300-foot section subsided up to 6 inches per month.

2018 April-March: Measurements were between 6 and 9 inches per month; day-labor type project installs deep patch across the landslide and brings road grade back up with 12% grade in and out of the body of the landslide; used rock in the landslide headscarp with limited aggregate surfacing from Tek Pit. (See Figures 5-6)

2018/2019 Sept.-March: Road surface measurements were 0.4 inches per day, or 12 inches per month; dug down east edge as far as possible and reconstructed across landslide similar to 2017 landslide repairs. (See Figures 7-9)

2019/2020 August-January: Landslide surface measurements are 2 inches per day or 5 feet per month. (See Figure 10)

May 2020: Road temporarily repaired in time for spring road opening activities. (See Figure 11)

Historic mitigation methods have had minimal impact on decreasing the landslide movement and current maintenance methods are only temporary solutions for maintaining the road through the landslide area. Deep cutoff trenches in the uphill ditch and attempts to reinforce the landslide edges across the roadway with alternating geotextile fabric layers and aggregate in a deep patch has helped improve the condition of the roadway, but not slowed the slide. Since 2017, greater efforts by Maintenance have been required to maintain the road while dealing with the increased movement of the landslide. This includes using colluvial material within the slide as road fill to maintain the road at a 12% maximum grade. The movement has required Maintenance to perform grading operations as frequently as every other day to maintain a drivable road across the slide.

1.2 Previous and Other Geotechnical Work

Information related to previous and other associated geotechnical work within the Pretty Rocks Landslide is included in the following reports and memoranda prepared by (or for) WFL:

- **Geotechnical Memorandum 14-20**: Pretty Rocks Landslide Earthwork Feasibility and Constructability, Pretty Rocks Landslide Repair AK NPS DENA 10(50), WFL Geotechnical Section, April 20, 2020.
- **Geotechnical Memorandum 03-20, Revised**: Pretty Rocks Landslide Bridge Feasibility and Constructability, Pretty Rocks Landslide Repair AK NPS DENA 10(50), WFL Geotechnical Section, March 23, 2020.
- **Geotechnical Memorandum 10-20**: Pretty Rocks Landslide Rockfall Analyses, Pretty Rocks Landslide Repair AK NPS DENA 10(50), WFL Geotechnical Section, March 10, 2020.
- **Geotechnical Memorandum 07-20**: WFLHD Response to NPS Questions, Pretty Rocks Landslide Geotechnical Investigation AK NPS DENA 10(45), WFL Geotechnical Section, February 26, 2020.

- **Geotechnical Memorandum 04-20**: Pretty Rocks Landslide Maintenance Ramps Recommendations, Pretty Rocks Landslide Repair AK NPS DENA 10(50), WFL Geotechnical Section, February 21, 2020.
- **Geotechnical Report 03-17:** Denali Park Road- Geophysical Investigations: Subsurface Features for the Park Entrance, Dog Kennels Loop, Igloo Forest, Polychrome Pass, and Stony Point Areas, prepared by USACE-CRREL, May 2017

2 GEOTECHNICAL INVESTIGATION

The geotechnical investigation consisted of reviewing the previous geotechnical investigations and work within the Pretty Rocks Landslide area from 2003 and 2016, published geologic maps, and other relevant geotechnical related documents.

In addition to the literature review, a total of eight field reconnaissance visits were conducted in 2018 and 2019. They included observation and mapping of the geologic features and materials within the landslide area and the measuring of key rock discontinuities along the edges of the landslide. The work also included taking site photographs, and gathering information from DENA personnel.

To augment field observations and to fill geotechnical subsurface data gaps from previous investigations within the landslide area, five vertical test borings, PR18-01 through PR18-05, were drilled in July and August 2018. Instrumentation was installed in the test borings for subsurface monitoring. Two borings contained slope inclinometers, three borings contained shape array accelerometers, and all the borings had vibrating wire piezometers and thermistor strings installed. Downhole geophysical surveys within the test borings in the rock materials were also completed. Two base stations (one on the road and the other approximately 325 feet below the roadway, and adjacent to PR18-05) with air temperature and automated rain gauge equipped were installed, with satellite communications at the lower base station at PR18-05.

In 2019 five additional test borings were drilled and downhole geophysical surveys were completed. Instrumentation was also installed in the 2019 test borings for subsurface monitoring. Three slope inclinometers, four vibrating wire piezometers, and three thermistor strings were installed.

2.1 Field Reconnaissance Visits

Field reconnaissance of the Pretty Rocks Landslide has occurred annually, around the first week of May, as part of the Spring Road Opening (SRO) site visits since 2014. In addition to the SRO annual reviews, geologic landslide mapping was done in 2016 by Anna Stancyzk. (See Appendix A, Figure 12 and 13, for the 2016 geologic mapping that includes subsurface geologic materials depicted from the 2003 test borings installed on the road, and Appendix G for the 2016 geologic mapping report presented in Anna Stanczyk thesis work). In 2018 and 2019, during the test boring operations, an additional eight site visits were conducted for geologic mapping by WFL. The 2018 geologic mapping is included in Appendix A, Figure 14.

2.2 Subsurface Investigation

The subsurface investigations for the Pretty Rocks Landslide site include surficial-based geophysical surveys conducted as part of a larger Park Road study in 2016, the 2018 landslide characterization test boring and instrumentation investigation with downhole geophysical surveys, and the 2019 feasibility of preferred conceptual design alternatives subsurface investigation that included test borings, instrumentation, and downhole geophysical surveys also.

The 2019 test borings are included as part of this geotechnical report to formally publish the boring logs. Previously, they were only available in draft form during the accelerated delivery schedule to provide final recommendations for the preferred conceptual alternative evaluations in the first half of 2020.

2.2.1 2016 Geophysical Surveys

WFL contracted with the Army Corp of Engineers - Cold Regions Research and Engineering Laboratory (USACE-CRREL) in 2016 to perform geophysical surveys along the Park Road, including at Pretty Rocks Landslide. They used Capacitive-Coupled Resistivity Methods (CCR), Earth Resistivity Tomography (ERT), and Ground Penetrating Radar Methods (GPR) in conjunction to gather subsurface information along the existing roadway alignment. Combining the results of these methods produced a more accurate estimation of the subsurface conditions. The geophysical surveys, in combination, identified organic and moisture content of the subsurface material, frozen water, and changes in the material types. These surveys were used at the Pretty Rocks Landslide to identify the presence and potential distribution of massive ice and ice rich soils within the subsurface landslide materials. These ice rich subsurface conditions were identified in the 2003 roadway boring logs, but no geotechnical reports were found in this time-period containing these test borings. They completed the field work in late-August 2016, and the conclusions from the survey results for the Polychrome Pass and Pretty Rocks Landslide sections are discussed further in the May 2017 final USACE-CREEL Report presented in Appendix H.

2.2.2 Test Borings

2018 Test Borings

A total of five test borings, PR18-01 through PR18-05, were advanced to collect subsurface samples for characterizing soil, rock, and groundwater conditions for development of the landslide slope stability analysis. See Appendix A, Figure 14 for the location of borings. All 2018 geotechnical test boring logs are presented in Appendix C with corresponding rock core photography in Appendix D.

2019 Test Borings

Six test borings were planned but only five test borings were advanced due to winter conditions arriving in Fall 2019. Four of the five test borings, PR19-06 through PR19-09, were drilled to gather site specific information for bridge foundations and to inform the bridge design and constructability feasibility analysis. PR19-06 and PR19-09 were drilled at an angle between 45 and 60 degrees from horizontal to determine the thickness of the resistant rock ridges the bridge foundations may sit upon. PR19-07 and PR19-08 were drilled vertically in the proximity of the potential bridge foundations to characterize the foundation conditions for a potential bridge foundation design. See Appendix A, Figure 15 for location of borings. Two vertical test borings, PR19-10 and PR19-11, were planned near the base of the landslide, but only one, PR19-11, test boring was installed before wintery conditions shut down the drilling operations in late-September 2019. The purpose of these lower slope test borings was to evaluate the feasibility of the earthwork option. All 2019 geotechnical test boring logs are presented in Appendix C with corresponding rock core photography in Appendix D.

Appendix B, Table 1 includes the drilled depth of the previous 2003 and recent 2018 and 2019 test borings, the purpose of the test boring, and the type of instrumentation installed.

Drill Equipment, Test Boring Descriptions, and Hole Logging

All geotechnical test borings advanced in 2018 were completed by Geotek Alaska Inc. of Anchorage, AK with a truck-mounted CME-75 and Geoprobe 6620 DT drill equipped with a calibrated auto hammer for Standard Penetration Test (SPT). Hollow-stem augers and air rotary casing advancer were used to advance the borings in soil/overburden conditions. When permafrost and rock was encountered, compressed air-rotary methods were used to drill HQ3-sized core.

SPT's were completed at 2.5-foot and 5-foot intervals when in soil to obtain disturbed samples. The SPT consists of using hammer with a 30 inch drop to drive a two-inch OD split-barrel sampler between 18 and 24 inches below the bottom of the borehole and recording the number of blows for each six-inch increment of penetration. The bottom two blow counts for an 18-inch sampler and the middle two blow counts for the 24-inch sampler are added together to determine the blows per foot (bpf), which is known as the field N-value.

In late July of 2018, downhole geophysical surveys were performed in three test borings, PR18-01, PR18-02, and PR18-03, by Enviroprobe Service Inc. Once drilled to depth at each borehole location, the drill hole was cased with steel drill pipe down to bedrock, where a probe could be lowered to take optical televiewer video and measurements of the rock discontinuities (fractures) in the rock formations. See Appendix I for the downhole geophysical survey reports. The surveys used a Mount Sopris 2PCA-1000 caliper probe and ALT QL40-OBI-2G optical televiewer to gather subsurface information on lithology, fracture location, and orientation. An ALT QL40-2G acoustic televiewer was not used due to the lack of water in the boreholes. Significant caliper enlargements were detected in all three borings at different elevations. The optical televiewer survey was poor due to the boring walls being coated with clay and/or rock dust from drilling with air. As a result, in 2019 the drilling operation switched to using water when rock coring to improve the ability to wash the borehole walls and view the rock structure with the acoustic and optical televiewer.

The 2019 test borings were also drilled by Geotek Alaska Inc. with a truck-mounted (Geoprobe 8040DT and CME-75) drill. Casing advancer with an 8-inch diameter was used when in soil. Both drills were equipped with a calibrated auto hammer (140 lbs.) for SPT's. Standard SPT's were collected between 2.5-foot and 5-foot intervals in soils. When permafrost and rock was encountered, wet rotary methods were used to drill HQ3-sized core.

In early September of 2019, downhole geophysical surveys were performed in four test borings, PR19-06, PR19-07, PR19-08, and PR19-09, by Enviroprobe Service Inc. See Appendix I for the geophysical survey report. Again, these surveys used a Mount Sopris 2PCA-1000 caliper probe, ALT QL40-2G acoustic televiewer, and ALT QL40-OBI-2G optical televiewer to gather subsurface information on lithology, fracture location, and orientation. Significant caliper enlargements were detected in all four borings at various elevations. Parts of PR19-08 and PR19-09 boring walls were coated in mud and did not allow for more accurate data in those covered areas.

Test borings drilled during the 2018 geotechnical investigation were logged in the field by WFLHD Geotechnical staff. Test borings drilled during the 2019 geotechnical investigation were logged in the field by an engineering geologist or geotechnical engineer from Shannon and Wilson, Inc.

Disturbed samples and rock core were collected and shipped to WFL in Vancouver, Washington, where the samples and draft test boring logs were reviewed by the WFL Engineering Geologist assigned to the project. The ice rich cores were stored at DENA in a chest freezer and are still stored for possible testing. Following review, selected samples of soil and rock were submitted to the WFL Materials Laboratory for testing. The final test boring logs were modified as necessary to reflect additional information from laboratory testing, instrumentation monitoring, and/or refinements to geologic interpretation of subsurface conditions. Six samples, one from six different boreholes, PR18-01 through PR18-05 and PR19-11, were sent to the Washington State Department of Transportation Materials Laboratory in Tumwater, Washington for specialized, torsional ring shear testing.

The Federal Lands Highway Soil Description and Identification Guidelines and Federal Lands Highway Rock Characterization Guidelines are used to characterize the soil units encountered during the drilling operations. The USCS, as outlined in ASTM 2487 and ASTM 2488, is utilized in the test boring logs and is based on the distribution and behavior of the fine-grained and coarse-grained soil constituents. Description of Frozen Soils (ASTM D4083) was used when in frozen soil conditions. Temperatures were taken of frozen soils below the active layer and interpreted to be in permafrost. For soil and rock descriptive terms and the USCS chart is defined in the Descriptive Terminology for Boring Logs provided at the beginning of Appendix C.

When advancing test borings through bedrock or boulders, continuous rock core was recovered, when possible. Recovered rock core samples were described by the Field Drill

Inspector, placed into core boxes, photographed, and transported to the WFL Materials Laboratory for further evaluation. Rock core photography is presented in Appendix D.

A modified International Society of Rock Mechanics (ISRM) set of rock descriptions were utilized to describe the rock unit materials during the drilling operations. Using the ISRM, rock classification consists of two basic assessments; one based on the *intact* properties of the rock, and the other based on the *in-situ* properties of the rock mass. Rock descriptive terms are defined and provided prior to the boring logs in the Descriptive Terminology for Boring Logs at the beginning of Appendix C.

2.3 Laboratory Testing

Laboratory test results were completed for selected soil and rock samples for the 2018 and 2019 geotechnical test borings. Laboratory testing consisted of soil testing and rock testing to characterize the subsurface materials and to characterize engineering properties of soil and rock that may be encountered during construction. A summary table compiling all 2018 and 2019 laboratory test results can be found in Table 2 in Appendix B. The laboratory test results for the individual 2018 and 2019 geotechnical test boring samples are presented in Appendix E.

All laboratory testing, except the specialized torsional ring shear testing by WSDOT, was conducted at the WFL Materials Laboratory in accordance with appropriate American Association of State Highway and Transportation Officials (AASHTO) and American Society of Testing and Materials (ASTM) test methods. Table 3 in Appendix B lists the test description and methods used for samples selected from the geotechnical test borings.

2.4 Test Boring Instrumentation and Equipment

2.4.1 2018 and 2019 Test Borings

In 2018, with the help of FHWA Turner-Fairbank Highway Research Center, two base stations with air temperature and automated rain gauge were installed, and four types of test boring instrumentation were installed. One base station was installed along the roadway and the other was installed lower down on the landslide near test boring PR18-05. The lower base station was installed with telemetry and satellite communications for transmitting the periodically measured data from automated dataloggers connected to all the 2018 instrumentation. This provided near real time monitoring of the landslide.

In 2019 three types of test boring instrumentation were installed. The lower base station used for transmitting the data via satellite was no longer operable due to the additional landslide movement. All the instrumentation in 2019 required periodic site visits and manual measurements at each boring. For groundwater and ground temperatures, dataloggers housed in the locked well monument were accessed and connected on-site with a laptop computer to download the instrumentation data.

Below is a list of the instrumentation installed in each boring followed by a description of each instrument. See Table 1 in Appendix B and Figure 15 in Appendix A for the location of borings. Appendix F provides the instrumentation data for the test borings.

- Shape Array Accelerometer (SAA)-PR18-01, 02, 03
- Slope Inclinometer (SI)-PR18-04, 05, PR19-07, 08, and 11
- Vibrating Wire Piezometer (VWP)-PR18-01 through PR18-05, and PR19-07, 08, 11
- Thermistor String-PR18-01 through PR18-05, and PR19-07, 08, and 11

Shape Array Accelerometer (SAA) measures ground movement along the depth of the borehole using MEMS gravity sensors, which are contained in an array of rigid segments that can be moved in any direction, but cannot be twisted. It can also be described as an advanced slope inclinometer that is capable of measuring total movements of 20 to 30 inches with a sharp deflection; much greater than traditional slope inclinometer installations. The SAA are attached to a communication cable and grouted into the excavated annulus of the borehole that is protected by a monitoring well monument at the ground surface. Once the grout has cured an automated and satellite transmitting datalogger was wired to the SAA cable to take automated, periodic measurements. An advantage of the SAA system is that a probe does not have to be lowered down a fluid filled casing (see slope inclinometer discussion below) to obtain landslide movement data. Plus, in winter and arctic conditions, the fluid in the casing may freeze, making slope inclinometer readings impossible to obtain.

The slope inclinometer casing diameter (2.75-inch or 70 mm), which is also used to measure ground movement, is a closed end, hollow pipe casing, grouted within the excavated annulus of the test boring from the bottom of the hole to the ground surface where a locking monitoring well monument is installed to protect the borehole instruments. The pipe casing has four machined groves that run the length of the casing on the inside of the pipe wall at 90 degrees to one another. When the pipe casing is grouted one pair of groves is typically oriented down the slope, in line with the direction of slide movement, and the other is parallel to the contour of the slope. In 2018 and 2019 manual measurements were taken using a slope inclinometer probe (with wheel tracks), which is periodically placed in the machined groves and measurements are collected every two feet from the bottom of the casing up to the surface. After each site visit, the slope inclinometer readings can be compared to the initial baseline reading to determine relative movement and depth of movement below the surface. This provides a rate of movement since the baseline (first) reading was collected. The changes in the two slope inclinometer measurements for the 2018 test borings (PR18-04 and 05) over time and the changes in the three slope inclinometer measurements for the 2019 test borings (PR19-07, 08, and 11) over time are shown in Appendix F.

Vibrating wire piezometers were installed at strategic locations below the ground surface following the drilling of the test boring. They are used to monitor groundwater levels using pore-water pressure changes below the ground surface. They are ideal in a cold region since they are attached to a communication cable and grouted into the excavated annulus of the borehole, alleviating the threat of freezing over the winter in an open-standpipe. Once the grout was cured, an automated datalogger was wired to the vibrating wire piezometer cable to take automated, periodic measurements. In 2018, these were hooked up to the near real-time communication and were part of the remote instrumentation monitoring package. In 2019, these measurements were taken periodically during site visits.

Thermistor Strings use multiple sensors, contained within cable housing, to monitor ground temperatures along the desired depths of the test boring. Thermistor strings are attached to communications cable, and like the other instrumentation are grouted into the excavated annulus of the borehole that is protected by a monitoring well monument at the ground surface. Once the grout had cured an automated datalogger was wired to the thermistor string cable to take automated, periodic measurements. In 2018, these dataloggers were hooked up to the near real-time communication and were part of the remote instrumentation monitoring package. In 2019, these measurements were taken periodically during site visits.

3 SITE CONDITIONS

3.1 General

The Pretty Rocks Landslide is located within Polychrome Pass, which is in the Central Alaska Range. The landslide is on a south facing slope above a primary tributary of the East Fork Toklat River. The Denali Park Road climbs along the mid slope of the mountains as it passes through the landslide at an elevation of around 3,620 feet. The slope length of the landslide is approximately 1535 feet, and has a width that ranges from approximately 275 feet at the Park Road, approximately 245 feet at the mid slope, and approximately 635 feet at the toe area. The landslide elevation ranges from about 3700 to 3240 feet. The area is typically covered intermittently by snow for most of the winter in this windy location.

3.2 Climate and Vegetation

Denali National Park has experienced warming temperatures over the last 14 years. An unpublished air temperature analysis was conducted by the National Park Service (2020) to best characterize the changing conditions within the Park. Figure 16 illustrates the increase in 12-month running mean temperatures at the Eielson Visitor Center (EVC), Denali HQ, and at the Toklat Road Camp. The climatic conditions at the location of the Pretty Rocks Landslide is most closely aligned with EVC, so the temperature variations observed at EVC have been used for likely conditions at Pretty Rocks Landslide. Observations of landslide movement at Pretty Rocks appears to correlate to temperature trends shown in Figure 16.

There is some sparse scrub brush and woody shrubs on the lower slopes of the landslide, but the surface is mostly composed of two different types of exposed bedrock. Most of the bedrock at the surface is broken up into loose cobbles and gravels forming a scree slope.

3.3 Geology

The Pretty Rocks landslide is failing in the Tertiary volcanic materials of the Teklanika Formation (Tcv unit), which is composed of deformed sequences of andesite, altered basalt, rhyolite and interlayered dacite flows, felsic pyroclastic rocks, and minor sandstone and mudstone. Some calcareous rocks present locally (Figure 17). These rock formations formed during the Paleocene-epoch, 55 to 60 million years ago. The Pretty Rocks landslide is more specifically covered in a colluvium slope primarily composed of rhyolitic lava rock and mafic intrusive basaltic rock, from the bounding, stronger rock units of the Teklanika Formation (Figure 18 and Appendix G). The rock in this area is weak because after the rhyolitic rock was laid down, hot magma, the now mafic intrusive basalt, intruded into the rhyolitic rock formation and weakened it.

Due to the tectonic activity, this area has undergone after a majority of the Teklanika Formation materials were formed and deposited on the surface, the units have been moved onto their side like a stack of books leaning to the west forming a dipping surface to the east at approximately 60 degrees (see geotechnical report cover photo and Figure 27). Very weak rhyolitic ash tuffs, obsidian weathered and altered to very weak perlite, and other hydrothermally altered Teklanika Formation materials from the injection of the mafic (basalt) intrusion are bound by the more resistant bedrock outcrops of rhyolitic lava flow to the east and the mafic intrusive (basalt) rock to the west. Stated more simply, the softer/weaker landslide material is sandwiched between two layers or more resistant rock, forming a “double stuff Oreo” or a “melting ice cream sandwich” of sorts sitting on edge, dipping 60 degrees to the east.

3.4 Permafrost

Referring to the 1965 Permafrost Map of Alaska by Ferrains, the Pretty Rocks Landslide lies in the areas within the permafrost region and is mapped as *mountainous areas/generally underlain by discontinuous permafrost*. During the 2003 subsurface geotechnical investigation both test borings, PLY03-1 and PLY03-02, encountered massive ice. Ice was recorded in PLY03-1 at a depth of around 20.4 feet to 36.0 feet below ground surface (bgs), and ice was first recorded in PLY03-2 at a depth of around 40.5 feet bgs (See Table 4 below). The 2016 geophysical surveys along the inside ditch of the Park Road, and across the Pretty Rocks Landslide showed that frozen conditions were at a depth of 6.6-ft to 9.8-ft bgs and extends down to 14.8-ft bgs near the road cut on the east end of the landslide (Appendix H). During the 2018 and 2019 subsurface geotechnical investigations, ice was encountered at varying depths in all the 2018 test borings and in most of the 2019 test borings. Installed instrumentation and thermistors showed soil temperatures below freezing (Table 4). Test boring PR19-08 and PR19-09 did not have any visible ice crystals in the SPT samples.

3.5 Subsurface

The 2003 and 2018 test borings and 2016 geophysical surveys within the Pretty Rocks Landslide section of the Park Road indicate very similar subsurface geologic materials and conditions. This report includes the final 2019 test borings, but excludes the 2019 test boring findings and resulting recommendations that are presented under separate cover, as listed in Section 1.2. These 2018 subsurface geotechnical investigations suggest that the subsurface materials can be grouped into three general subsurface materials that were encountered and observed in all five 2018 test borings. They are as follows:

Table 4. Frozen soil depths recorded in the 2003/2018/2019 test borings during drilling and confirmed thermistor data depths for temperatures below freezing.

Year	Boring	Ice Observed During Drilling	Thermistor Measurements Below Freezing (ºF)
		Depth Range (ft. bgs)	Depth Range (ft. bgs)
2003	PLY03-1*	20.4-36.0	NA
	PLY03-2**	40.5-40.9 51.0-54.0 59.0-64.0	Ground not frozen below 11 feet bgs
2018	PR18-01	30.4-40.5	15.0-53.0
	PR18-02	67.8-70.0 72.5-88.4	36.0-88.4
	PR18-03	10.0-19.5 30.0-30.25 30.75-52.0	13.0-57.0
	PR18-04	10.0-15.0 25.0-49.0	10.0-49.0
	PR18-05	58.0-65	30.0-45.0
2019	PR19-06	43.0-48.0	NA
	PR19-07	97.0-98.0	13.0-33.0
	PR19-11	0.0-55.0	0.0-80.0

Note: Table does not include temperatures below freezing in rock
* PLY03-1 measured only during drilling
** PLY03-2 measured during drilling and 2 months later

3.5.1 Road Fill Material and Landslide Debris

We have included the road fill material in this subsurface layer because it is difficult to distinguish from the upper landslide material. Road surfacing material has been imported over the years to relevel the roadway. However, during the more active and substantial landslide movement since 2014, Maintenance crews have been moving upper landslide material above the road to relevel the roadway. We estimate there is at least 20 feet of road fill that has been placed over the years within the limits of the landslide, but it is difficult to distinguish from the landslide debris during the drilling in 2018.

This unit consists of a thin veneer of medium dense to very dense Gravel, Cobbles, and Boulders overlying loose to medium dense Clayey Gravel and Sands (GC, SP with gravel, SC, SM, SW) with layers of cobbles and boulders throughout. A phreatic groundwater table was measured in this subsurface material unit in test boring PR18-02 in the upper landslide deposit. In PR19-02, the upper groundwater table appears to be closely related to air temperature (snow melt runoff) and precipitation events (Figure 19). This material is subject to annual freezing, known as the active layer, to depths in excess of 12 to 16 feet; otherwise the instrumentation data and drilling observations suggest this material is not part of the permafrost layer described below. Based on the 2018 test borings and thermistor string data, this unit ranges from 12.5 to 36 feet bgs.

3.5.2 Ice Rich Landslide Debris

Very dense (hard), cloudy, gray, Massive to Ice Rich Soils, as described in Description of Frozen Soils (ASTM D4083), is located between the overlying, landslide debris and the underlying extremely weak to moderately weak rock that typically breaks down to a Clayey Sand (SC) to a Fat Clay (CH). The ice content is estimated at 10 to 70% in volume within the cored samples (Figure 20). When the core and SPT's were melted, the remaining mineral soil (inclusions) composition ranged from Clayey Sand with gravel (SC) to a Poorly Graded Gravel with clay and sand (GP). Based on the 2018 test borings and thermistor string data, this unit ranges from about 10 to 50 feet thick.

The thermistor string instrumentation data suggests that the drilling action warmed the subsurface materials and massive to ice-rich permafrost soils are likely to be more extensive than encountered and observed during the drilling operations. For example, in Figure 21, the observed ice rich soils during drilling was between 72.5 and 88.4 feet bgs. The thermistor data suggests that once the ground recovered and stabilized from the drilling operations, the ice rich soils are likely from 36 to 88.4 feet bgs. This is a significant change and can be seen in the 2018 test boring instrumentation data provided in Appendix F.

Groundwater was not measured by instruments in the Ice Rich Landslide Debris, but the voids and moist to wet nature of the geologic contact materials between the Ice Rich Landslide Debris and the underlying rock materials suggests that a separate, possibly confined, groundwater table may be present and should be determined in the 2019 geotechnical investigation.

3.5.3 Extremely Weak to Moderately Strong Rock Formations

When rock was encountered in the 2018 test borings within the landslide, it ranged from an extremely weak rhyolitic volcanic ash tuff, to extremely weak to medium strong rhyolite lava flow rock, to a weak to medium strong mafic (basalt) intrusion rock. The weathering of the rock types varied widely from slightly weathered in the lava flow rock and mafic intrusion rocks to highly weathered to completely weathered to a soil in the volcanic ash tuffs to a medium dense to very dense Elastic Silt (very stiff-MH), Clayey Sand with gravel (SC) to a Sandy Fat Clay / Fat Clay with sand (CH) (Figure 22). Discontinuities were very closely to closely spaced and in fair to poor condition. Estimated thickness of the mafic (basalt) intrusion rock is about 32 feet in PR18-04; the rhyolitic lava flow rock is about 25 to 31.5 feet in PR18-01, 03, and 04; and the rhyolitic volcanic ash tuff is approximately 4.5 to greater than 50 feet in PR18-02, 03, 04, and 05.

In the rhyolite lava flow rock, clay infilling in the discontinuity fractures was observed and the driller noted continuous chatter while drilling in this rock unit, indicating highly variable layers of material strength, or in this case, clay infilling in rock discontinuities. In PR18-04, where the mafic (basalt) intrusion rock was encountered, some lean clay infilling was noted but drilling was more consistent and indicates a generally stronger material.

The SAA instruments in PR18-01, 02, 03 and the slope inclinometer measurements in PR18-04 and 05 indicate landslide movement is occurring along the Ice Rich Landslide Debris geologic contact with the underlying, very weak to medium strong rock units. Figure 23 provides a capture of the SAA reading for PR18-01, illustrating the abrupt failure plan at the geologic contact and shows a picture of the core recovered through this sharp failure zone at approximately 40.5 feet bgs. In Figure 24, the slope inclinometer measurements only occurred over 10 days before shearing in PR18-05, similar to PR18-04. The photograph of the core recovered through the failure zone confirms that the landslide is failing along the top of the very weak to medium strong rock units. Note that the total landslide deflection movement in the slope inclinometers is about 3.5 to 4 inches before shearing in PR18-05, while in Figure 23 the SAA reading shows over 25 inches of total landslide deflection movement over the course of several months before shearing. The late-summer/Fall 2018 rate of landslide movement ranged from 0.3 inches/day in PR18-05 over 10 days and shearing on August 30, 2018 to 0.5 inches per day in PR18-03 over 77 days and shearing on October 19, 2018.

No groundwater was encountered or measured within the rock formations.

Thermistor strings that penetrated the rock formations, indicate that the rhyolitic volcanic ash tuff may be frozen but the rhyolitic lava flow rock and mafic (basalt) intrusion rock do not appear to be below freezing. Even though the rhyolitic volcanic ash tuff may show temperatures just below freezing in Appendix F data, it is important to note that we did not observe frozen conditions in this rock formation and the presence of appreciable "fat" clay in this rock type can suppress the temperatures for freezing.

4 LANDSLIDE MODEL, ANALYSIS, AND DISCUSSION

The slope stability model was developed utilizing all available data, but heavily relying on the five 2018 test borings, groundwater, ground temperature, and slope movement data. As shown in Figure 25, two strategic, interpreted geologic cross-sections were developed to analyze the slope stability of the landslide. Interpreted geologic cross-section A to A', as shown in Figure 26, was developed to interpret and visualize the geometry and subsurface conditions of the landslide in the middle of the landslide, aligned with the movement, from the valley floor to the top of the ridge. Interpreted geologic cross-section B to B', as shown in Figure 27, parallels the Park Road from west to east, crossing the landslide. It should be noted that these schematics are illustrative and the term "bedrock" was used to define the approximate depth of the extremely weak to medium strong rock units and should not be construed to imply hard or strong rock conditions were encountered during the 2003 or 2018 geotechnical investigations.

Based on interpreted geologic cross-section A to A', a limit-equilibrium slope stability model was developed using Slide 2018, Version 8.008 Rocscience software. Strength parameters for each of the units were selected based on a combination of relative densities, index test to shear strength correlations, and direct torsional ring shear test measurements of recovered failure plane material during the drilling operations. The laboratory test results are located in Appendix E and the torsional ring shear test results and the plasticity index (residual) shear strength correlations (NAVFAC, 1983) are included in Table 5 below. The strength parameters used for the preliminary 2018 slope stability analyses are presented in Table 6.

Table 5. Torsional ring shear test results compared to plasticity index (residual) shear strength correlations.

Test Boring ID	**Sample Depth (feet)**	**Torsional Ring Shear Test (degrees)**	**Plasticity Index Correlation (degrees)**
PR18-01	40	17	18
PR18-02	53	14	16
PR18-03	56	14	18
PR18-04	50	22	18
PR18-05	66	23	18

Table 6. Preliminary 2018 slope stability strength parameters.

Subsurface Material	**Approximate Unit Weight (moist)(pcf)**	**Approximate Unit Weight (wet)(pcf)**	**Cohesion (psf)**	**Shear Strength (degrees)**
Road Fill and Landslide Debris	130	135	0	20
Ice Rich Landslide Debris	115	115	0	20
Failure Plane	130	135	0	16
Rock Formation Units	145	155	250	35

The groundwater encountered during drilling and measured in the instrumentation confirmed that an unconfined, phreatic groundwater surface was present, perching on the Ice Rich Landslide Debris at depth. However, as mentioned earlier in the description of subsurface materials in Section 3.5.3 above, the wet to saturated nature of the recovered failure plane material and presence of some voids is suspicious and warrants further focus during subsequent drilling investigations for the preferred conceptual design alternatives selected by NPS. In addition to the conditions encountered during drilling, the slope stability modeling indicates that a lower, possibly confined, groundwater table located along the top of the rock formation units is likely present.

Figure 28 provides the preliminary slope stability back-analysis based on a circular and composite failure mechanism. This model, and the other runs in this suite of slope stability analyses, included all the geotechnical investigation information from 2003, 2016, and 2018. The steepness (in degrees) of the upper failure plane exceeds the residual soil material strength tested along the failure plane (Table 5), and therefore has a preliminary factor of safety of 0.884. The groundwater condition used for this analysis is the upper, unconfined groundwater table, perched atop the ice rich landslide debris, and analyses did not select a potential failure occurring from just above the road to the valley floor, as observed in the field. We believed this was problematic and required us to do the following moving forward:

- Confirm the presence, or lack of, groundwater and its confinement in the area of the failure plane.

- Determine the lower landslide subsurface geometry down slope of PR18-05 to properly replicate the “real world” conditions for the slope stability software to provide reasonable results that match field observations.
- Better understand and determine shear strength parameters for the permafrost materials that make up the Ice Rich Landslide Debris, and how will degrading permafrost conditions impact a long-term landslide risk reduction or mitigation.

Although these are issues with the slope stability analyses, there is adequate information from the 2018 geotechnical investigation to move forward with initial conceptual design alternative analyses. However, additional geotechnical investigation would be recommended should an alternative be selected to reinforce portions of the landslide, or redistribute loads (earthwork) within it.

5 CONCEPTUAL DESIGN ALTERNATIVES

The site of the Pretty Rocks Landslide has been the location of most geologic and geotechnical studies since 2016 in the Park, where several options were considered for risk reduction and mitigation of the accelerating landslide movement. The current practice, which required filling in the subsiding roadway to bring it back to grade required an emergency contract to place approximately 5,000 cubic yards of fill and aggregate in April 2020 as the movement of the landslide has significantly increased since 2014. As detailed above, the landslide movement was around 0.5 inches/day in late-2018 but ramped up to about 2 inches per day following historic precipitation events in August 2019. This uncertainty of the magnitude of movement and consistent increase in movement from year to year made us dismiss filling in the subsiding roadway across the landslide from further consideration as a long-term solution since maintenance forces are beginning to struggle to keep up with the releveling of the roadway.

Following the summer 2018 geotechnical investigation program and early winter 2018-2019 preliminary slope stability analyses, WFL met with DENA and AKR personnel to brainstorm all conceptual design alternatives for the Pretty Rocks Landslide. Of that list of alternatives presented below, six of them were moved forward for proof-in-concept validation, and for further analyses and discussion in May 2019. In May 2019, WFL presented their analyses, findings, and conclusions to DENA and AKR while visiting for their annual SRO trip to provide technical assistance to Park Maintenance prior to opening the road to the public. The discussions, ideas brainstormed, and evaluation of the conceptual alternatives are presented in the following sections.

5.1 Brainstorming and Alternatives Moved Forward (February 2019)

In February 2019, WFL, DENA, and AKR met to brainstorm the conceptual design alternatives for the Pretty Rocks Landslide. The following landslide geology and site constraints were discussed at the beginning of the workshop to set the stage for brainstorming potential Pretty Rocks Landslide solutions:

- East Fork of the Toklat River will likely continue to erode the toe of the landslide if not mitigated.
- Landslide is moving along a steep interface based on interpreted geologic cross-section and subsequent preliminary slope stability analyses.
- Significant rockfall and debris flows occur above the Park Road at this location
- Underlying bedrock orientation is striking to the north-north east is dipping 60 degrees from horizontal to the east
- A majority of the bedrock within the limits of the landslide are extremely weak
- Apparent climate change could degrade permafrost further, increasing movement and driving forces
- Evidence of landslides west and east of the Pretty Rocks Landslide (Figure 29)

The workshop attendees conceptualized and considered several risk reduction efforts for the Pretty Rocks Landslide since the 2018 geotechnical drilling investigation, instrumentation, and laboratory testing provided adequate information to characterize the landslide and begin analyzing and understanding what was driving its stability. Four broader categories with conceptual design alternative considerations were brainstormed by the group. They were:

Avoidance

- Realignment away from the landslide (South across the Plains of Murie on the valley floor or to the north in the next drainage)
- Remove the upper landslide – earthwork option
- Bridge over the landslide
- Construct a short or long tunnel behind the landslide, underground

Reduce Driving Forces of the Landslide

- Minor shift in roadway alignment upslope with slope terracing to address rockfall and debris flows
- Reduce weight in upper portion of the landslide (redistribute loads, lightweight fill options) – combine with earthwork option where appropriate
- Improve drainage (surface and subsurface) – combine with all alternatives, where feasible

Increase Resisting Forces (external loads)

- Shear key buttress and/or counter berm at the landslide toe
- Rock-filled shafts installed down-through the failure plane in the lower portion of the landslide to increase shear resistance
- Structural wall with tie-back anchor systems – combine with minor roadway shift and upslope terracing concept
- Large, pre-cast or cast-in-place anchor pads on the surface of the landslide to resist movement

Increase Resisting Forces (internally)

- Large area of rock-filled shafts with drainage improvements in the lower

landslide – combine with earthwork option
    - Ground freezing technology (keep permafrost frozen)

Out of this list of conceptual design alternatives, the avoidance alternatives, light weight fill replacement of the roadway embankment with minor earthwork, and using large pre-cast or cast-in-place anchor pads on the surface of the landslide to resist movement were moved forward for further evaluation and proof-in-concept (Figure 30).

5.2 Selected Conceptual Design Alternatives Proof in Concept (May 2019)

The relative risk was added to Figure 30 during our February to May 2019 evaluation period. We discuss each of the selected conceptual design alternatives in this section and whether we would recommend further consideration for additional geotechnical investigation to confirm the site conditions, analyses, and constructability of them for possible final selection by DENA, AKR, and NPS.

5.2.1 Realignment

Among the avoidance options, the realignment to the north or south of the existing alignment was broken out into its own study and project.

5.2.2 Tunneling

Two tunnel options were considered (Figure 31) as avoidance options as well. The short tunnel would be approximately 1500 feet long on a curvilinear path, entering the slope near Hidden Springs to the west of the landslide and exiting the slope one switch back beyond Pretty Rocks Landslide to the east. The longer tunnel would be approximately 2700 feet long on a straight path, entering the slope near the Bear Cave Landslide area and exiting at the same location as the short tunnel to the east. The following considerations were developed to evaluate this conceptual design alternative:

Pros

- Minimizes closures to existing road
- Avoids the landslide, rockfall, and debris flow issues at the site

Cons

- Portal locations would be very challenging to stabilize for beginning tunneling operations and to mitigate rockfall and debris slides
- Ground squeezing of the very weak rock materials should be anticipated
- Groundwater conditions may be very challenging during construction and thereafter
- Underground construction is always difficult and often requires expensive change modifications to deal with unknowns during construction

Based on this evaluation and its moderate to high risk for design and construction issues, we recommend that this alternative be eliminated from further consideration based on the very difficult issues described above, the inherently high cost, and considering that two other lower risk alternatives exist.

5.2.3 Reducing Driving Forces of Landslide (Upslope)

To reduce the driving forces of the landslide, we analyzed replacement of 20 feet of the heavy, gravel and cobble-rich roadway embankment fill and replaced it with lightweight fill options in our preliminary stability model. The stability analyses suggest only a 2 to 5% improvement in stability for either utilizing wood chip material or expanded polystyrene (EPS) geofoam block products.

Based on our analyses and observing that we may end up debuttressing the upper portion of the landslide above the road without careful analyses and construction considerations, we recommend this conceptual design alternative be eliminated from further consideration.

5.2.4 Increasing Resisting Forces in the Landslide (External Loads)

To evaluate increasing the resisting forces in the landslide, we analyzed the installation of large pre-cast, or cast-in-place anchor pads on the surface of the landslide. In Figure 32, a typical construction method and type of equipment used is shown. The analysis of this method suggests that approximately 2 million pounds per square foot of reinforcement would be needed to achieve a near-standard design factor of safety of 1.25. When the load per square foot to increase the resisting forces is distributed across the area of the landslide, approximately 600,000 kips of anchors would be required. This equates to about 1200 anchor pads with 500 kip anchors installed on the surface of the landslide (Figure 33).

To evaluate this conceptual design alternative, the following considerations were developed:

Pros

- Minimizes closures to existing road; road stays in similar location

Cons

- Does not eliminate the rockfall and debris flow hazard upslope of roadway
- Anchor loads may need to be reduced for very weak nature of underlying rock materials and high clay content
- Pressure exerted on permafrost with high loads will melt it
- Need to consistently retighten anchors to maintain loads and stability
- Aesthetics would be challenging
- The number of anchors required is prohibitive

Based on this evaluation and the high-risk issues associated with it, we recommend that this alternative be eliminated from further consideration based on permafrost and potential anchor installation and long-term performance issues, not to mention the long-term specialty contractor maintenance needs to retighten the anchors consistently until the permafrost melts.

5.2.5 Bridging the Landslide

A promising landslide avoidance measure may be to bridge the landslide, but would require between a 400 to 450 feet long span, limiting the types of steel bridges that could be used. The potential bridge alignment and a photo of a simple span bridge is provided in Figure 34. The roadway alignment would need to be adjusted to accommodate the bridge at the west abutment. It would require rock excavation of approximately 500 feet of the mafic (basalt) intrusive rock to allow an adequate turning radius for trucks and loaded trailers. On the east, the perlite landslide would likely require a robust cut side retaining wall to protect the bridge approach, as shown and identified in Figure 29. To evaluate this conceptual design alternative, the following considerations were developed:

Pros

- Avoids landslide movement area and permafrost issues
- Asymmetrical Bridge may not be needed (high foundation and anchor loads)
- Segments of steel span could be delivered and then assembled on-site

Cons

- Significant road closure periods may be required
- East foundation on thin section of weak to medium strong rhyolitic bedrock
- Road configuration into bridge ends would need modification
- Will need to remove existing road bed to pass upslope rockfall and debris flows beneath the bridge span
- Need to drill foundation locations; confirm available loading in rock units

Based on this evaluation and the comparatively low to moderate risk for design and construction issues associated with it, we recommend that this alternative be considered for further geotechnical investigation, design evaluation, and constructability moving forward.

5.2.6 Remove the Upper Landslide (Earthwork Option)

This appears to be another promising avoidance measure by removing the upper landslide and placing it on the lower portion of the slope at a stable configuration. Figure 35 provides a near-design standard factor of safety of 1.25. We have assumed based on the width of the upper landslide and a cut slope of 1V:1.5H that a rough approximation of the excavated materials with a 20% swell factor once placed at the base of the slope will be about 1.1 million cubic yards. To evaluate this conceptual design alternative, the following considerations were developed:

Pros

- Removes upslope rockfall and debris flow hazard
- Removes upper landslide material; road is placed on rock; although very weak and possibly erodible at roughly the same elevation

Cons

- Permafrost excavation and controlling melt in excavation area
- Excavated material may exceed area available for placement so an alternate waste site will likely be required
- Need to drill lower landslide toe; confirm loading won't destabilize toe of slope

Based on this evaluation and the low risk for design and construction issues associated with it, we recommend that this alternative be considered for further geotechnical investigation, design evaluation, and constructability moving forward.

6 CONCLUSIONS

After presenting this short list of conceptual alternatives with a list of pros and cons under the proof in concept stage, the NPS selected moving forward with the realignment away from the Landslide, remove the upper landslide earthwork option, and bridging over the landslide option in June 2019.

Additional test boring, instrumentation, laboratory testing, and analyses were initiated in September 2019 to conduct focused design viability and constructability evaluations for the earthwork and bridging options at the Pretty Rocks Landslide. The data for this 2019 late-summer geotechnical investigation, fall 2019 laboratory testing, and subsequent analyses are provided under separate covers, as listed in Section 1.2 of this geotechnical report. The major realignment study and options will be concluded and presented under separate cover in 2020.

7 REFERENCES

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8 LIMITATIONS

This report has been prepared to assist WFL, Denali National Park, and the Alaska Region of the National Park Service with evaluating, and narrowing down viable, preliminary conceptual design alternatives for selection to be moved forward by the National Park Service for possible risk reduction or mitigation of the Pretty Rocks Landslide. The information presented in this report should not be used, in part or in whole for other purposes without contacting the WFL Geotechnical Section for a review of the applicability of such reuse. These data are not to be used for other purposes.

The conclusions and recommendations contained in this report are based on WFL's Geotechnical Section's understanding of the project at the time that the report was written and on-site conditions that existed at time of the field observations and subsurface exploration. If significant changes to the nature, configuration, or scope of the project occur, the Geotechnical Section should be consulted to determine the impact of such changes on the data, conceptual alternatives considered, and preliminary findings presented in this geotechnical report.

Subsurface exploration, instrumentation, and associated laboratory testing describes subsurface conditions only at the sites of subsurface exploration and at the intervals where samples are collected. These data are interpreted by members of the WFL Geotechnical Section, who then render a professional geotechnical opinion regarding the general subsurface conditions. The distribution, continuity, thickness, and characteristics of identified (and unidentified) subsurface materials may vary considerably from that indicated by the subsurface data. In addition, the observed water levels and/or conditions indicated on the test boring logs are recorded at the time of the exploration. The water levels and/or conditions may vary considerably, with time, according to the climate, rainfall, and other factors and are otherwise dependent on the duration of, and methods used in, and interpretations made from the subsurface exploration program.

This report should be made available to prospective bidders for their information, or as factual data only, and not as a warranty of ground conditions.

Questions regarding this geotechnical report should be addressed to Douglas A. Anderson, WFLHD Geotechnical Team Lead, at (360) 619-7958, or electronically sent to douglas.a.anderson@dot.gov.

GEOTECHNICAL REPORT No. 11-20

2018-2019 Geotechnical Investigation and Conceptual Design Alternatives Report

Denali National Park – Pretty Rocks Landslide Geotechnical Investigation
AK NPS DENA 10(45)
Denali Borough, Alaska

August 2020

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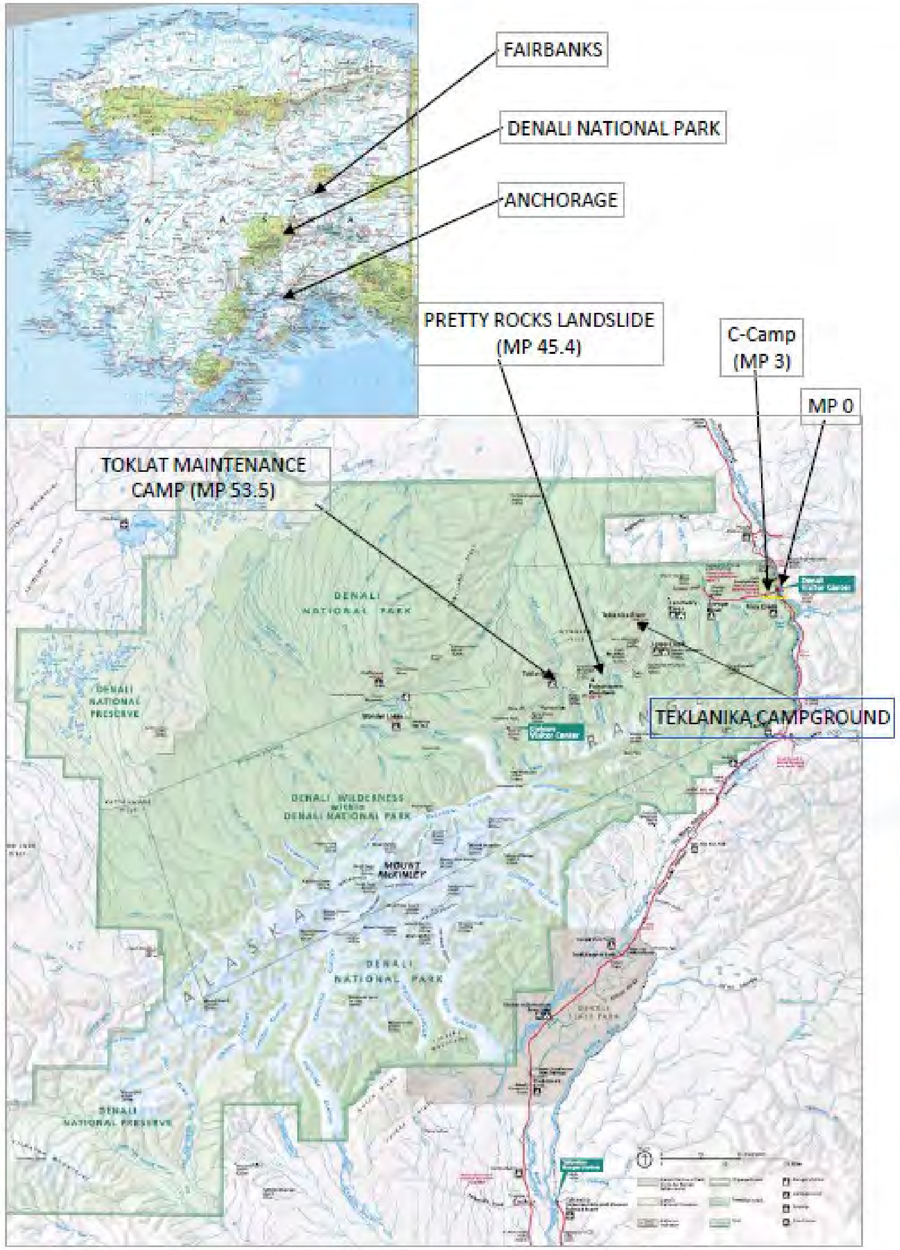
Douglas A. Anderson, WFL Geotechnical Team Lead

APPENDIX A

Figures



U.S. DOT Federal Highway Administration
Office of Federal Lands Highway

Western Federal Lands Highway Division
610 East Fifth Street
Vancouver, WA 98661

Project No.	AK NPS DENA 10(45)
Scale:	N.T.S
File Name:	-
Date:	06JULY2019

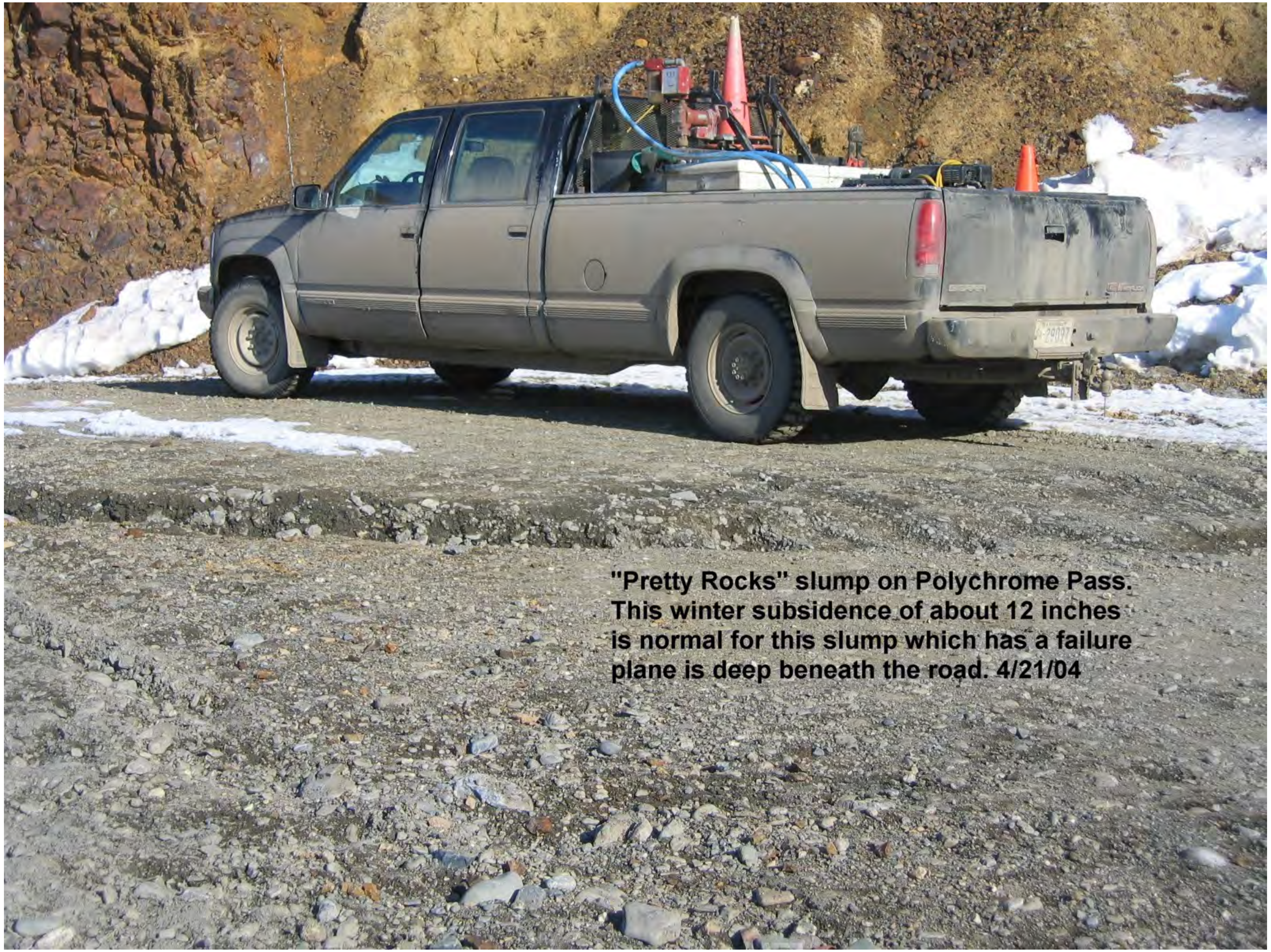
PROJECT LOCATION MAP

PRETTY ROCKS LANDSLIDE
DENALI NATIONAL PARK, ALASKA

FIG
1

Figure 2. 1987 Installing geosynthetic layer reinforcement

Figure 3. 1987 Installing Subsurface Drainage



"Pretty Rocks" slump on Polychrome Pass. This winter subsidence of about 12 inches is normal for this slump which has a failure plane is deep beneath the road. 4/21/04

Figure 4. 2004 subsidence. 12 inches is normal for this slump.

Figure 5. May 2018 Landslide headscarp and lateral scarp limits at road before Maintenance day labor project.

Figure 6. May 2018: After deep patch construction and conduit installation for drilling and instrumentation program

Figure 7. Site Photo from September 29, 2018. As reported by Denali Maintenance, last road level grading operations were on September 24th.

Photos courtesy of Denny Capps

Figure 8. Site Photos from February 6, 2019

Figure 9. Site Photo from March 21, 2019. Rate of Movement from Surface Measurements: ~0.4 inches/day or ~12 inches/month

Figure 10. Site Photo from January 2020

Figure 11. Site photo at the rebuilding of the road grade as it is brought to grade on April 29, 2020.

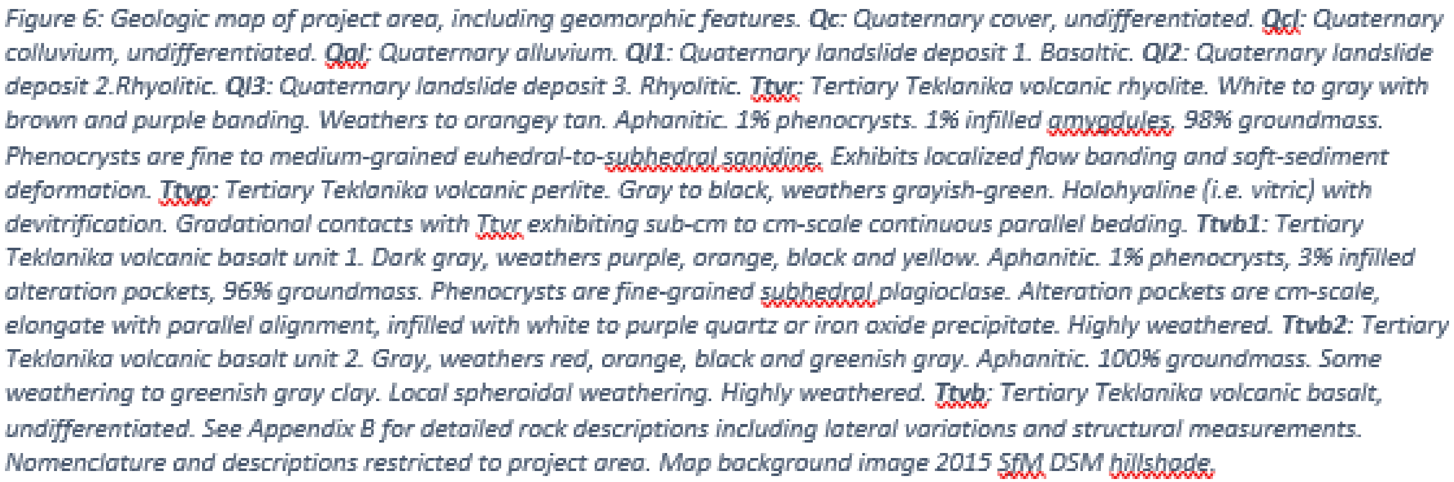


*Figure 6: Geologic map of project area, including geomorphic features. **Qc**: Quaternary cover, undifferentiated. **Qcl**: Quaternary colluvium, undifferentiated. **Qal**: Quaternary alluvium. **Ql1**: Quaternary landslide deposit 1. Basaltic. **Ql2**: Quaternary landslide deposit 2.Rhyolitic. **Ql3**: Quaternary landslide deposit 3. Rhyolitic. **Ttvr**: Tertiary Teklanika volcanic rhyolite. White to gray with brown and purple banding. Weathers to orangey tan. Aphanitic. 1% phenocrysts. 1% infilled amygdules, 98% groundmass. Phenocrysts are fine to medium-grained euhedral-to-subhedral sanidine. Exhibits localized flow banding and soft-sediment deformation. **Ttvp**: Tertiary Teklanika volcanic perlite. Gray to black, weathers grayish-green. Holohyaline (i.e. vitric) with devitrification. Gradational contacts with Ttvr exhibiting sub-cm to cm-scale continuous parallel bedding. **Ttvb1**: Tertiary Teklanika volcanic basalt unit 1. Dark gray, weathers purple, orange, black and yellow. Aphanitic. 1% phenocrysts, 3% infilled alteration pockets, 96% groundmass. Phenocrysts are fine-grained subhedral plagioclase. Alteration pockets are cm-scale, elongate with parallel alignment, infilled with white to purple quartz or iron oxide precipitate. Highly weathered. **Ttvb2**: Tertiary Teklanika volcanic basalt unit 2. Gray, weathers red, orange, black and greenish gray. Aphanitic. 100% groundmass. Some weathering to greenish gray clay. Local spheroidal weathering. Highly weathered. **Ttvb**: Tertiary Teklanika volcanic basalt, undifferentiated. See Appendix B for detailed rock descriptions including lateral variations and structural measurements. Nomenclature and descriptions restricted to project area. Map background image 2015 SfM DSM hillshade.*

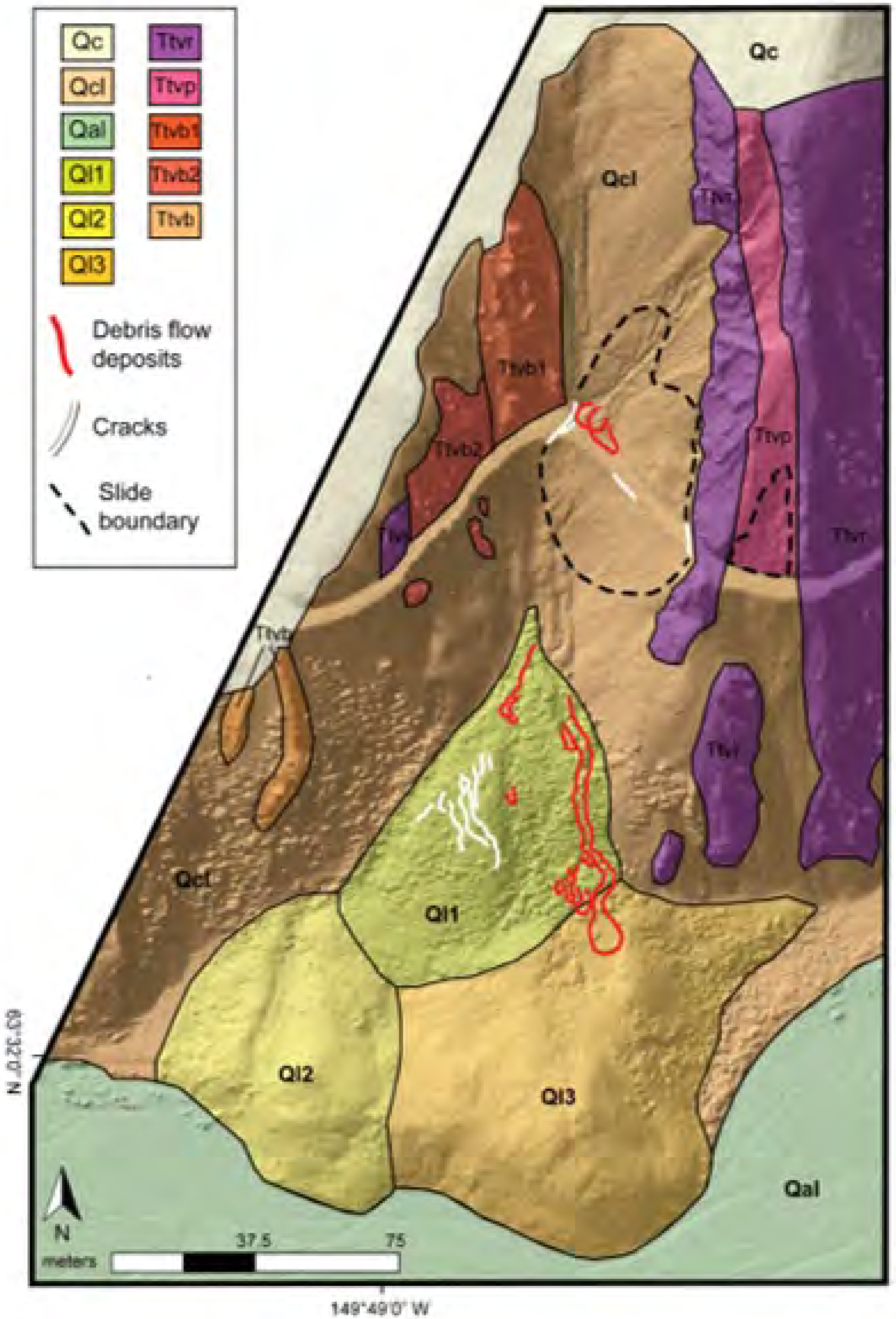


Figure 12. Geologic and Landslide Mapping 2016
Unpublished Figure from Anna Stanczyk, UAA

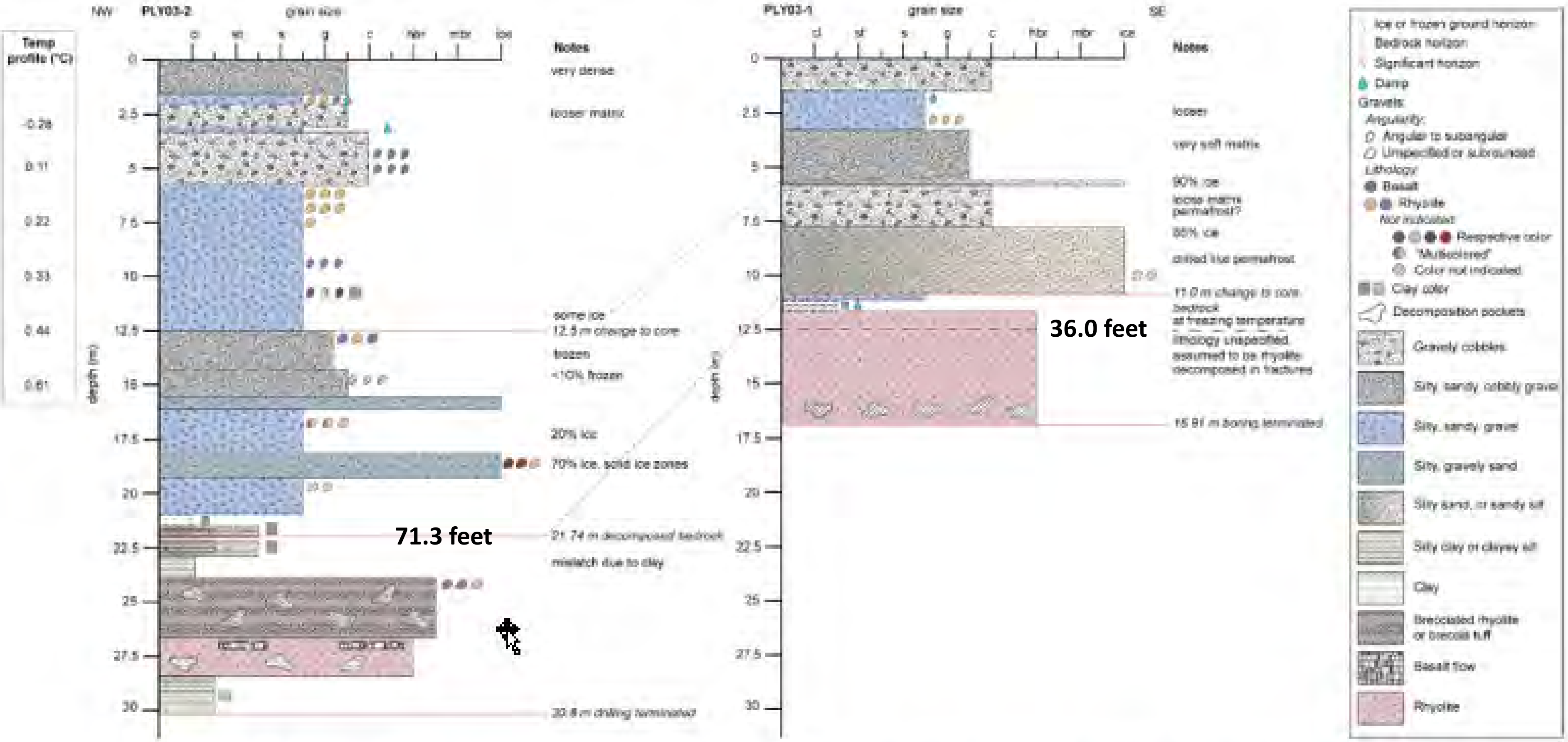


Figure 17: Stratigraphic columns constructed from PLY03-1 and PLY03-2 boring logs. Grain sizes: cl = clay; st = silt; s = sand (undifferentiated); g = gravel; c = cobble; hbr = highly weathered bedrock; mbr = moderately weathered bedrock; ice = ≥70% ice. Drilling took place in June 2003. Temperature log was recorded in PLY03-2 in September 2003. Note the close proximity to the freezing temperature. The blue dashed lines correlates the first mentions of ground ice in each profile, while the red dashed line correlates the first mentions of bedrock.

Figure 13. Unpublished Figure, Geotechnical Investigation-2003, from Anna Stanczyk, UAA

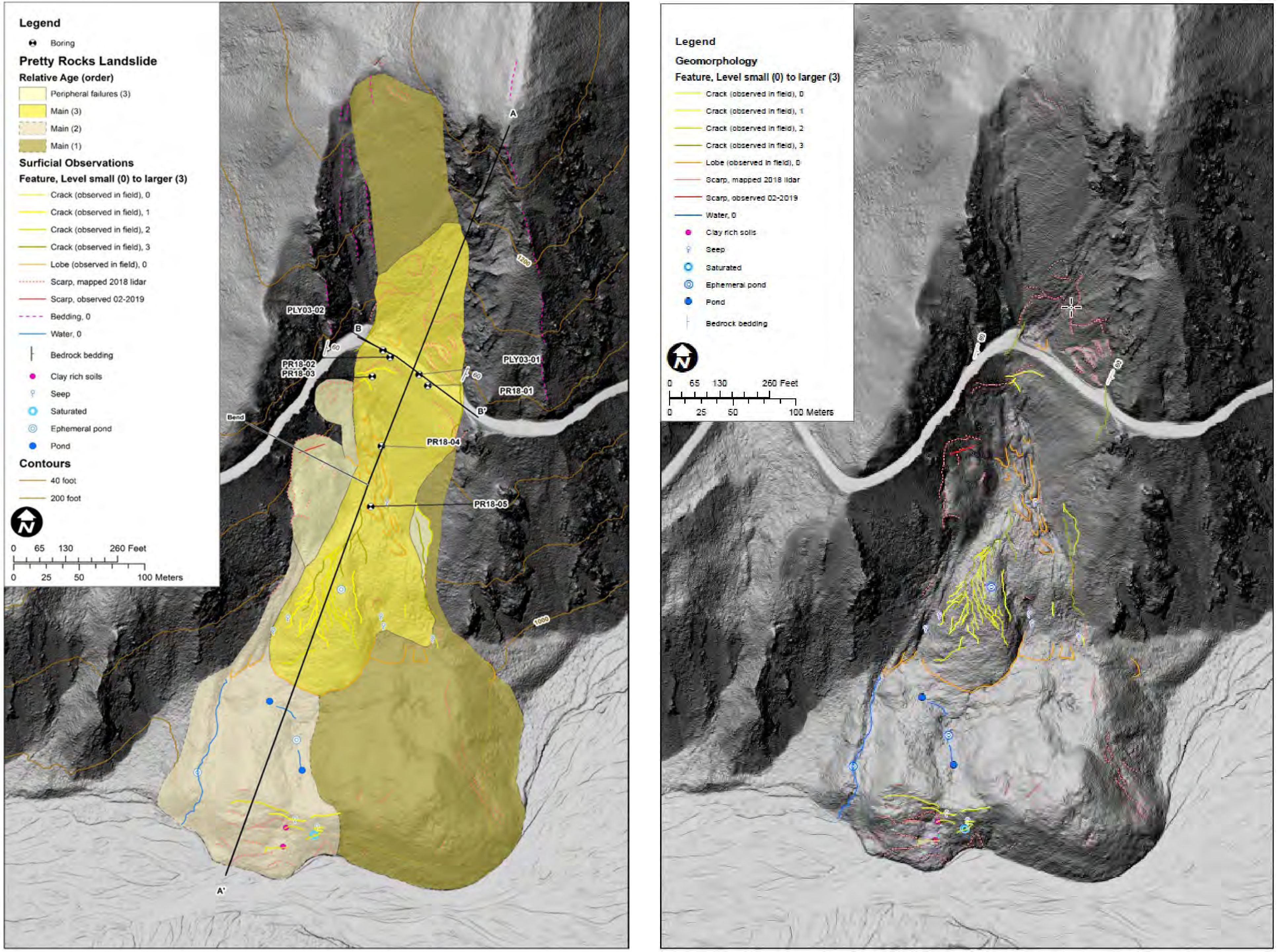


Figure 14. Supplemental Landslide Mapping 2018

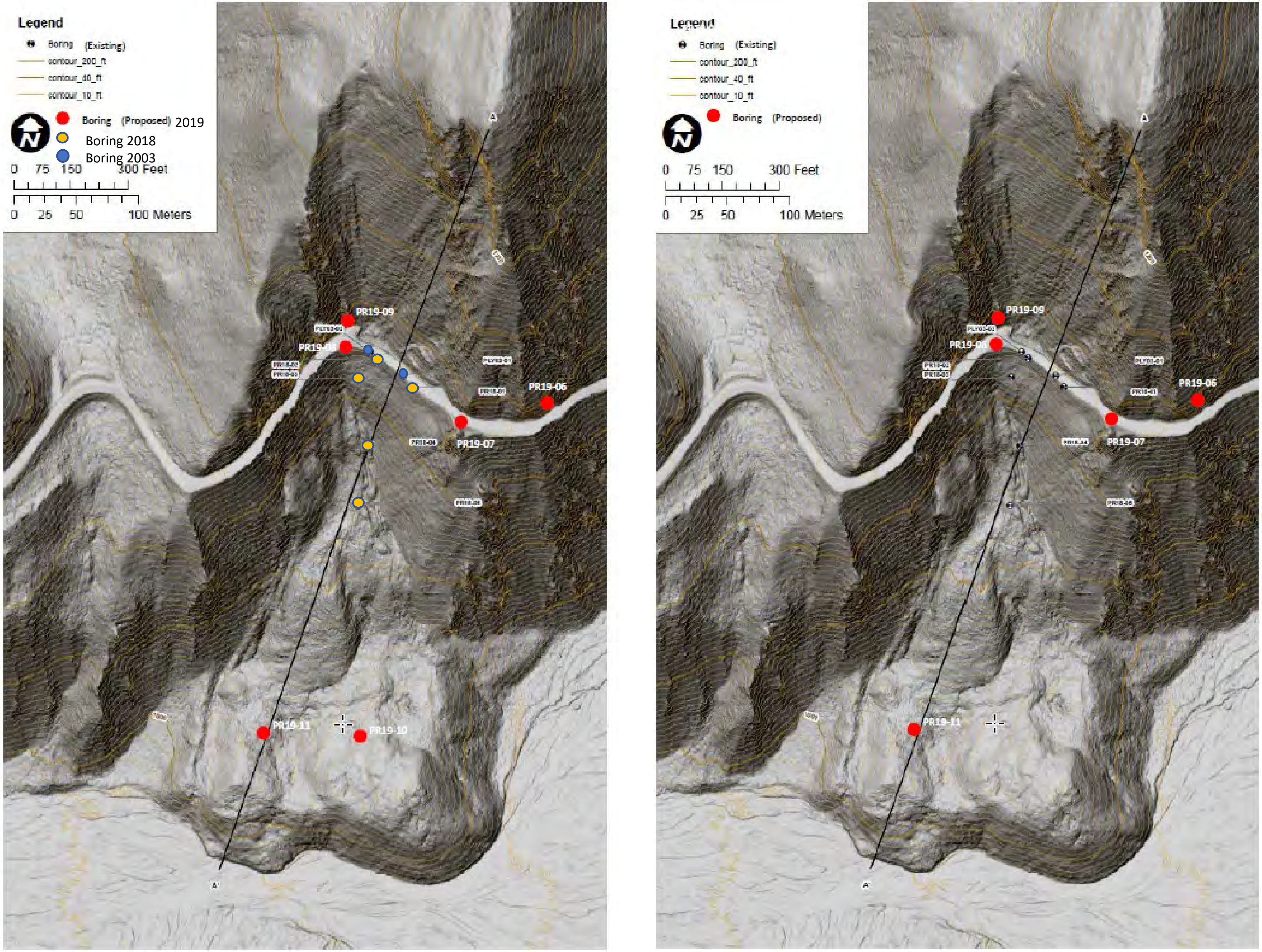


Figure 15. The 2003 and 2018 test boring locations and proposed 2019 test boring locations on the left. On the right, the locations of the 2019 drilled test borings are shown.

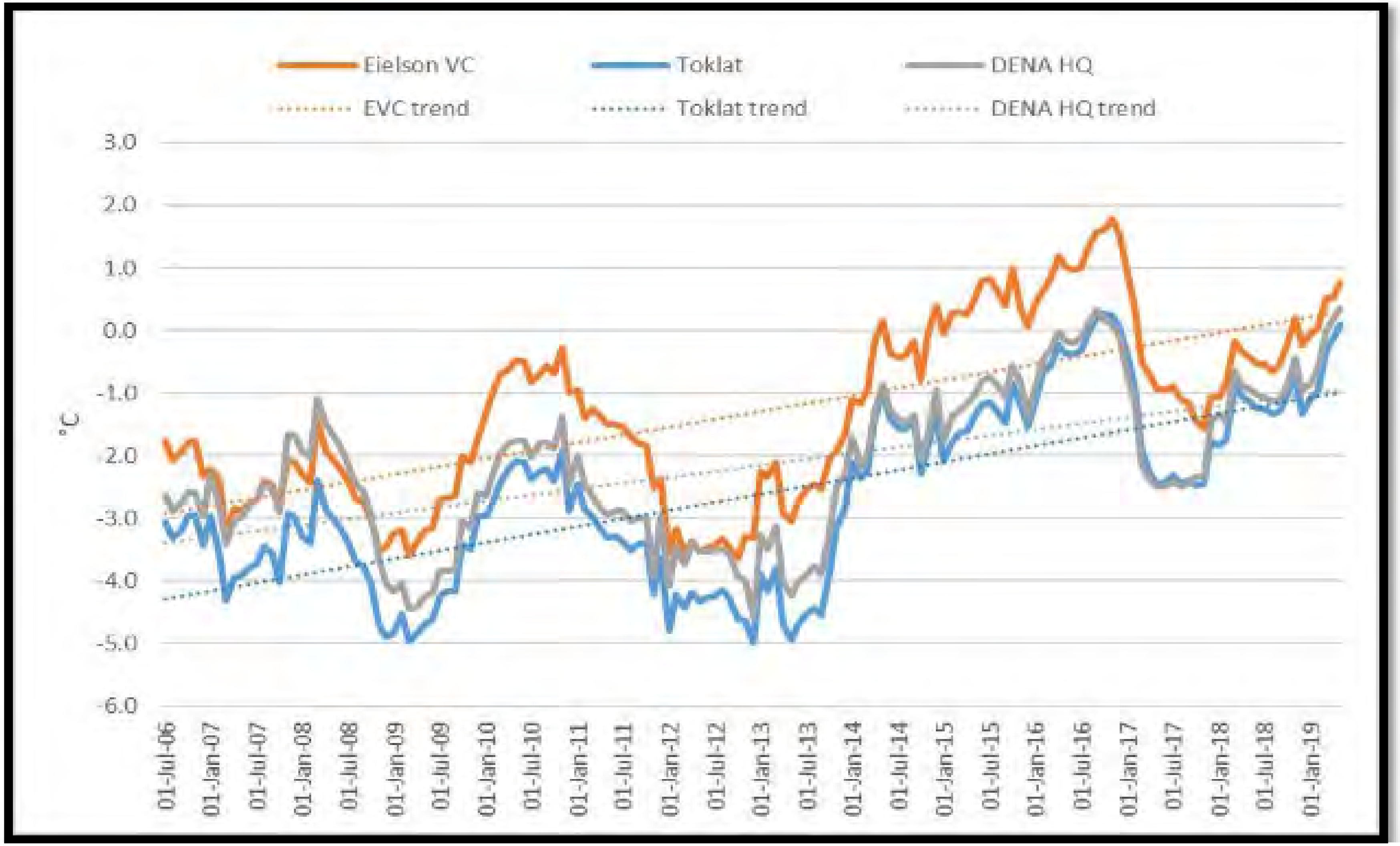


Figure 16. Twelve month running mean temperatures at EVC (orange), Toklat Road Camp (blue), and Denali Park HQ (grey) with 14-year linear trend (dashed lines) (National Park Service 2020).

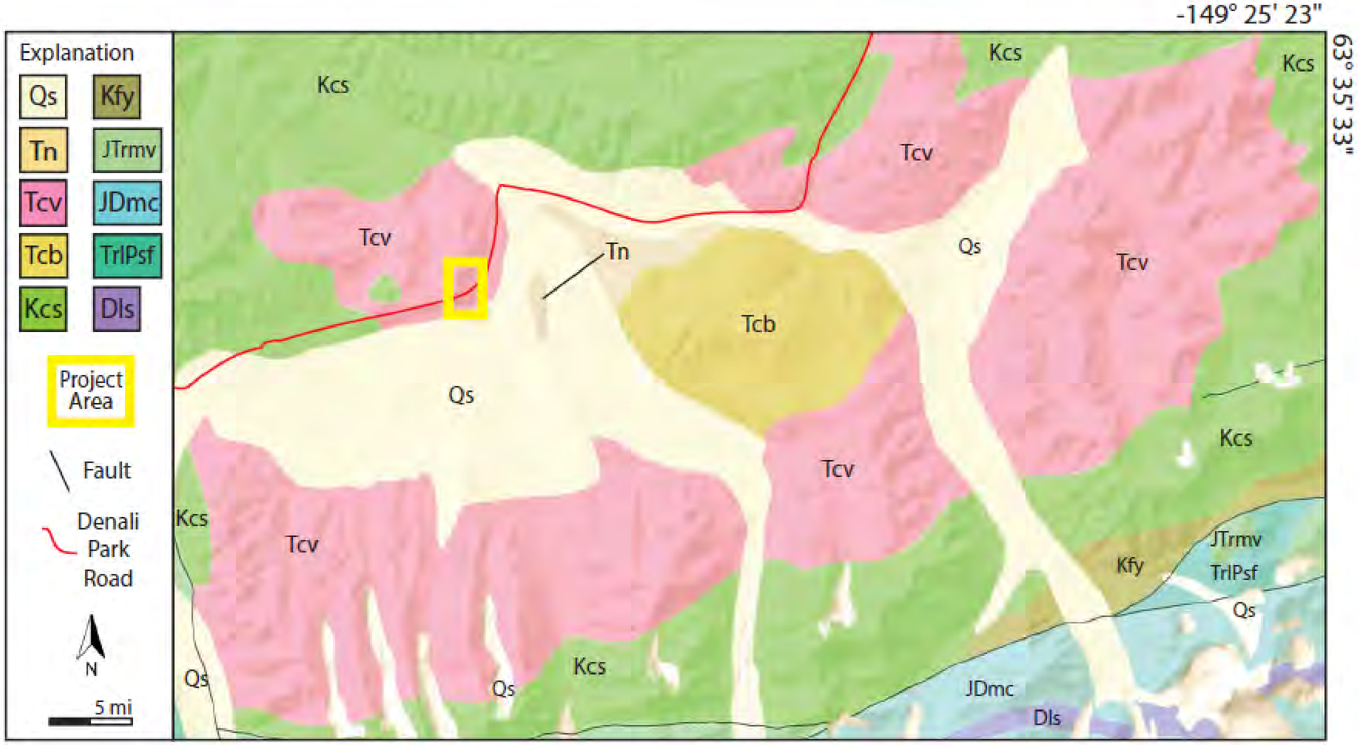


Figure 3: Geologic map of Polychrome Pass modified from USGS Scientific Investigations Map 3340 (2015).
Qs: Quaternary surficial deposits, undifferentiated.
Tn: Tertiary Nenana Gravel; over 4,200 ft thick, containing conglomerate and sandstone with mudstone, claystone, and lignite interbeds. Well-sorted but poorly consolidated. Appears yellowish to brownish in outcrop.
Tcv: Tertiary Volcanic Rocks of the Teklanika Formation; deformed sequences of andesite, altered basalt, rhyolite and interlayered dacite flows, felsic pyroclastic rocks, and minor sandstone and mudstone. Some calcareous rocks present locally.
Tcb: Tertiary coal-bearing rocks; contains cyclic sequences of siltstone, claystone, mudstone, shale, sandstone, subbituminous coal and lignite, quartz, and pebble conglomerates.
Kcs: Cretaceous Cantwell Formation, Sedimentary Rocks Subunit; 13,100-ft-thick interlayered sequence of polymictic conglomerate, sandstone, arkosic sandstone, siltstone, argillite, and shale, and a few thin coal beds.
Kfy: Upper and Lower (?) Cretaceous Sedimentary Flysch
JTrmv: Jurassic and Triassic Tatina River mafic volcanics
JDmc: Jurassic to Devonian sedimentary Mystic structural complex, undivided
TrIPsf: Triassic to Pennsylvanian flysch-like sedimentary rocks
Dls: Devonian limestone of the Mystic structural complex

Figure 17. Geological map of polychrome Pass modified from USGS Scientific Investigations Map 3340 (2015),
from Anna Stanczyk, UAA

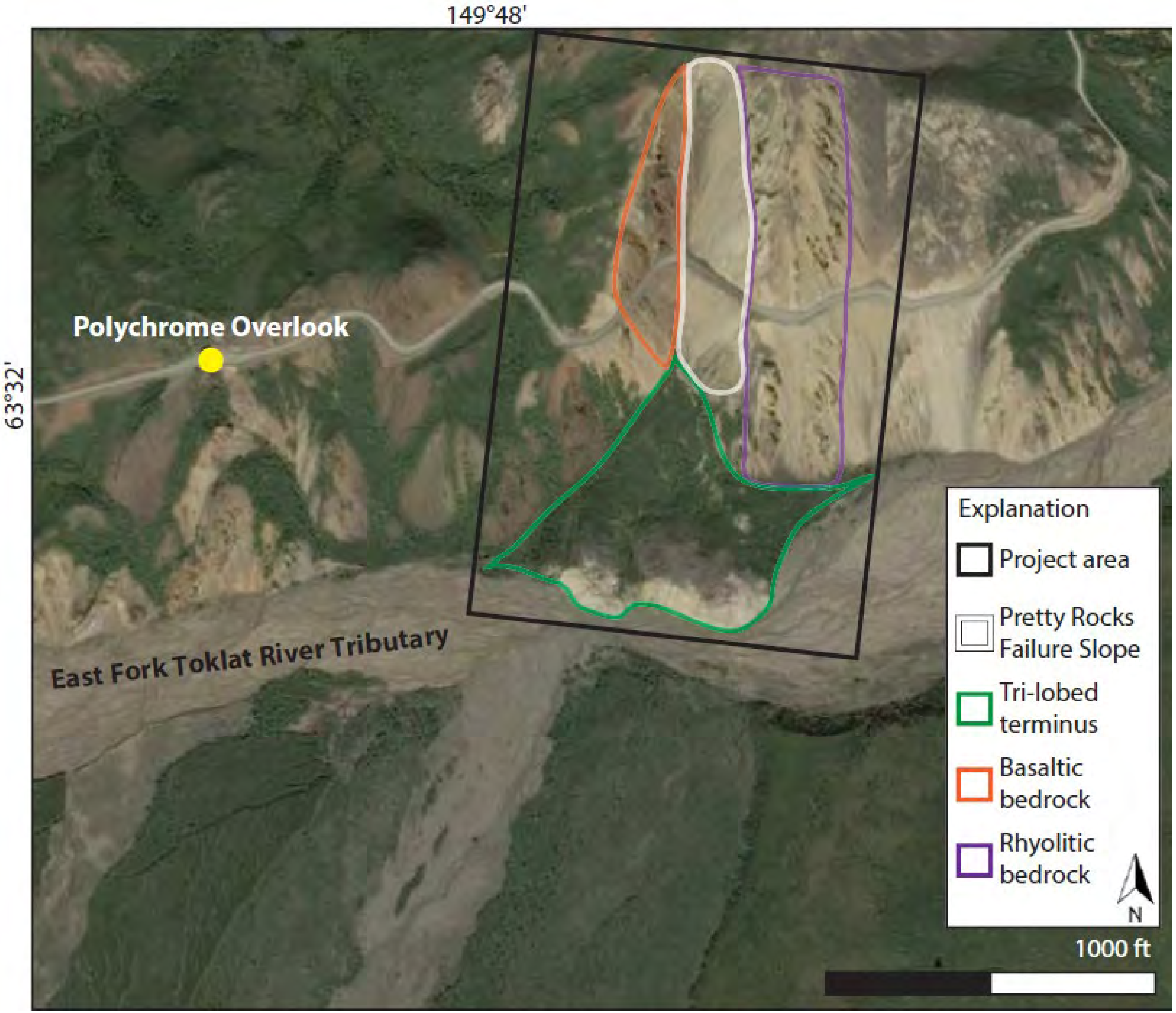


Figure 18. General geologic map of project area, unpublished figure form Ana Stanczyk, UAA.

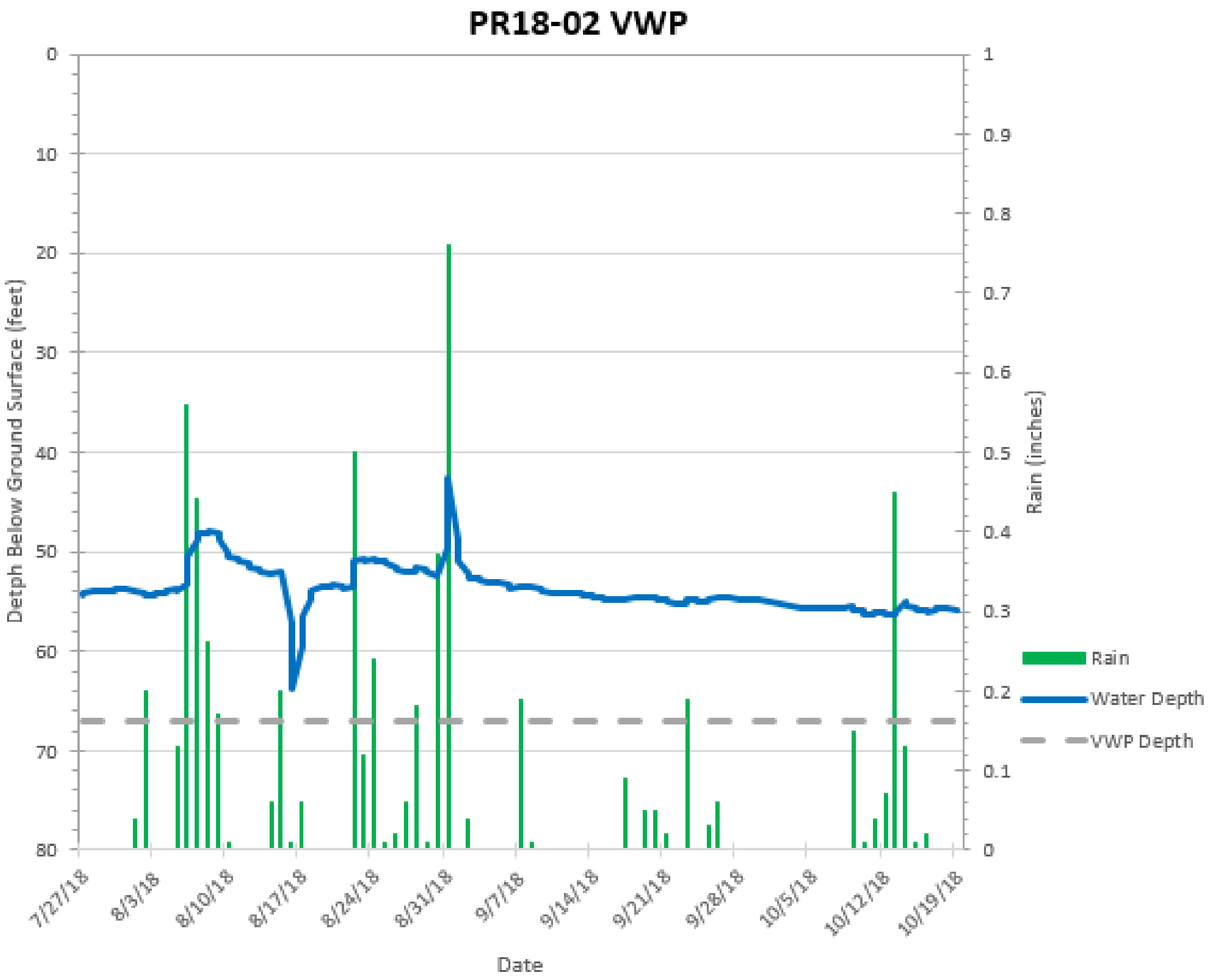


Figure 19. When measured, groundwater appears very responsive to precipitation and snow-melt in the upper landslide deposit.

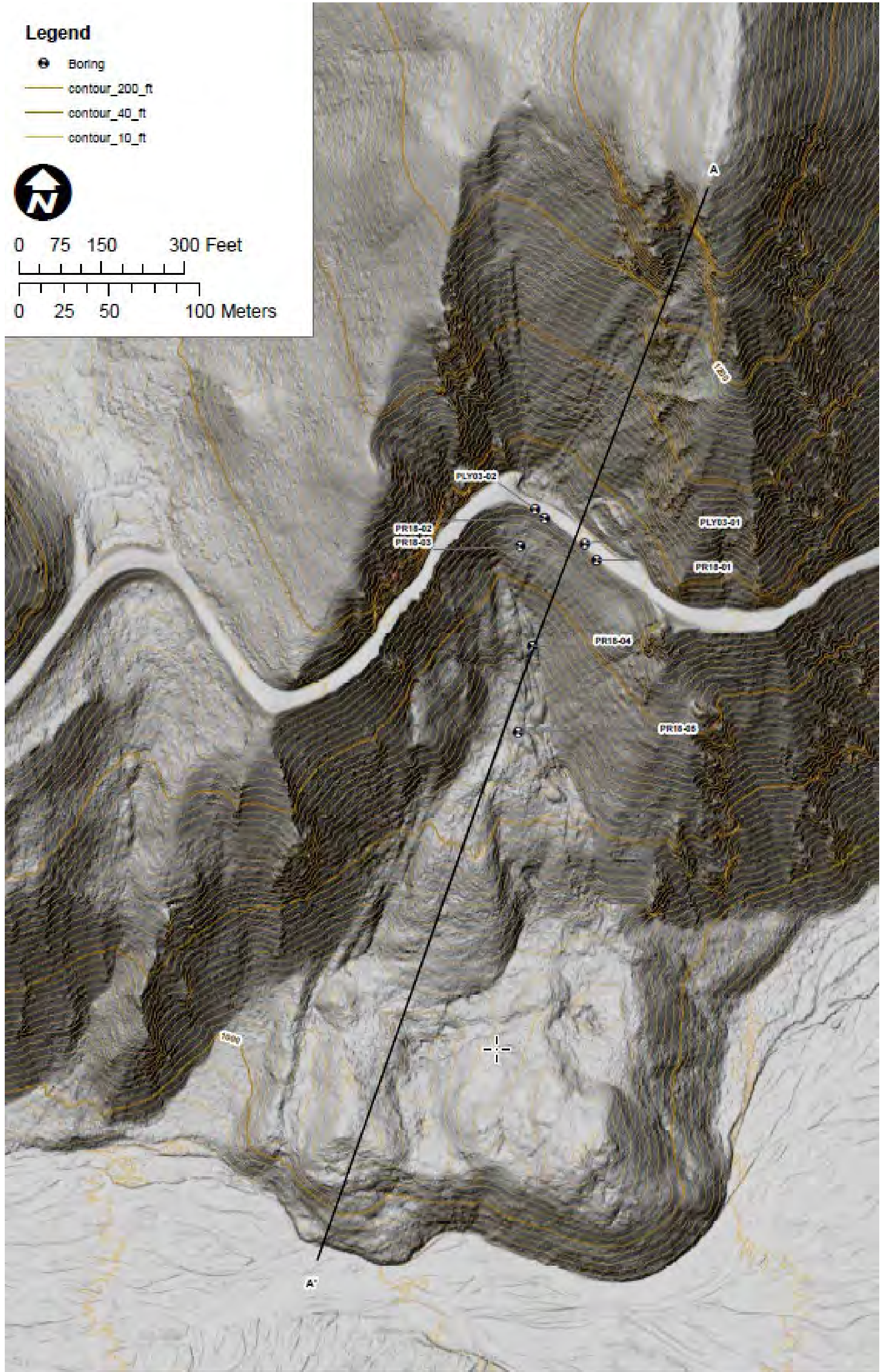


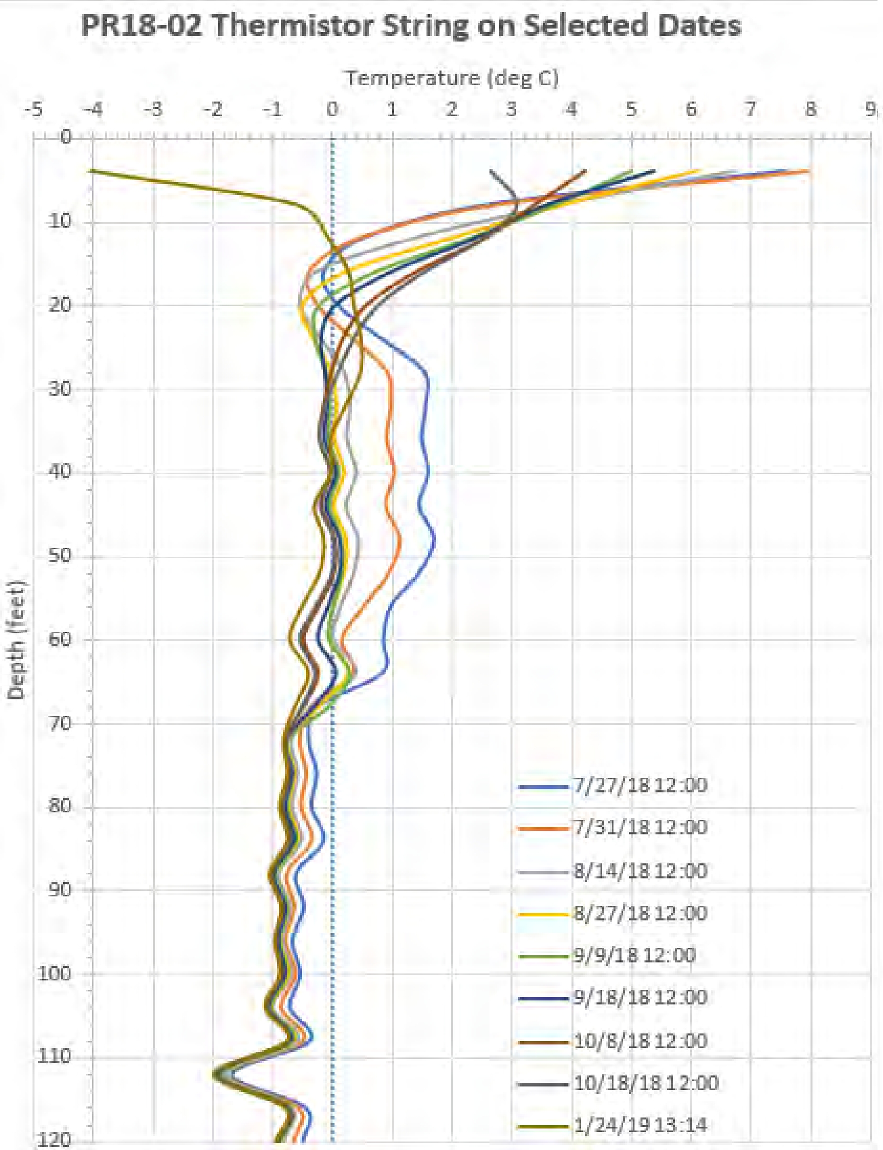
Figure 20. Photographs of ice rich core from 2018 geotechnical investigation.

Figure 21. The drilling actions warmed up the "warm" permafrost, as can be seen in this thermistor string plot of PR19-02. Note that in the test boring, observations of massive to ice-rich soils was confined to 72.5 to 88.4 feet below the ground surface (BGS), but the thermistor readings indicate a restabilizing of the subsurface conditions following drilling, measuring freezing temperatures and potential ice rich soils between 36 and 88.4 feet bgs.

Presence of Permafrost Likely Below Freezing at 35'

PR18-02
0-72.5' Clayey Gravel and Sands
72.5-88.4' Ice-Rich Soils (36-88.4')
88.4-140.3' Volcanic Ash (Tek Clays (CH))

Thermistor Readings Discontinued after shearing on 1/24/2019



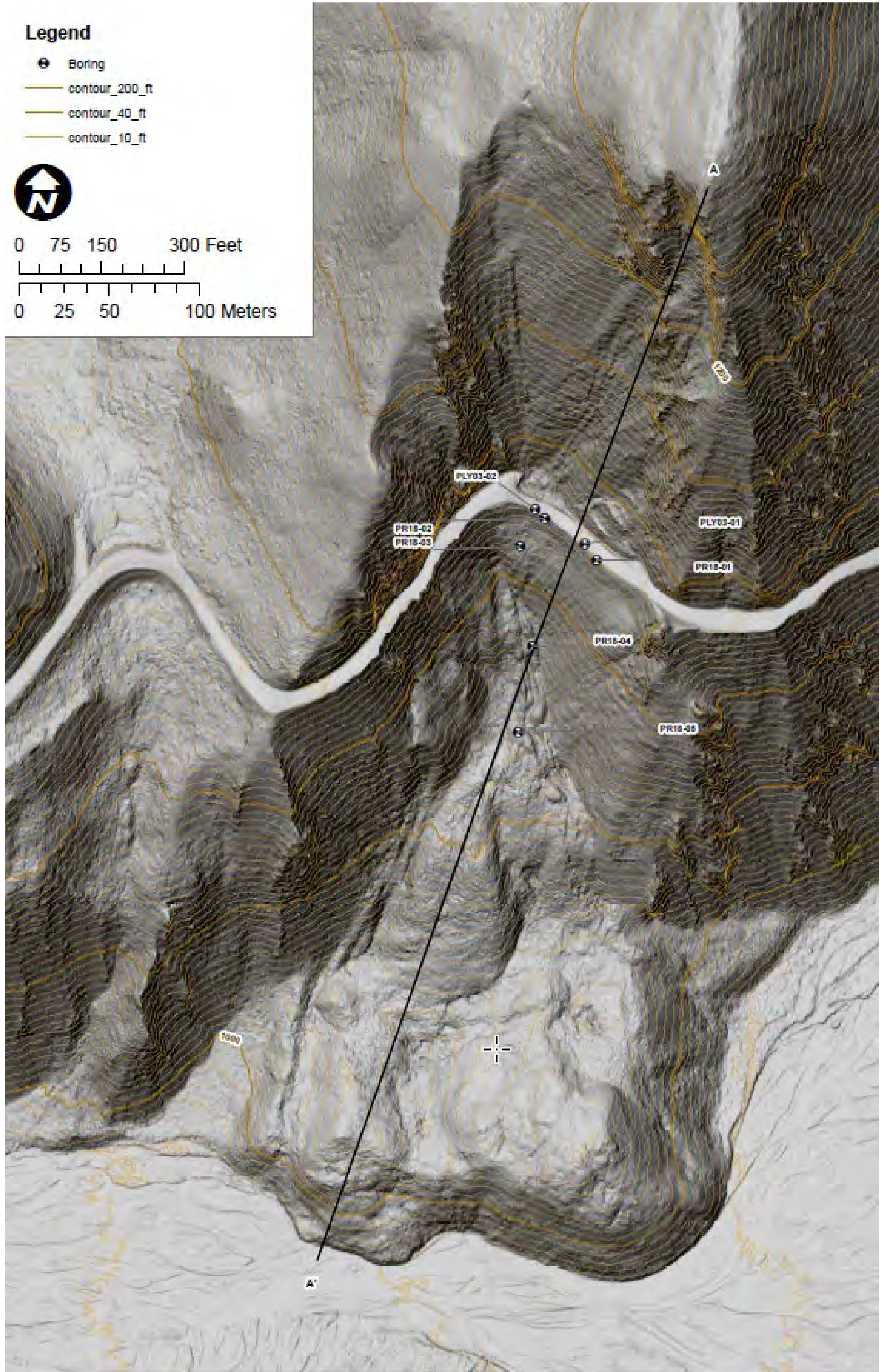
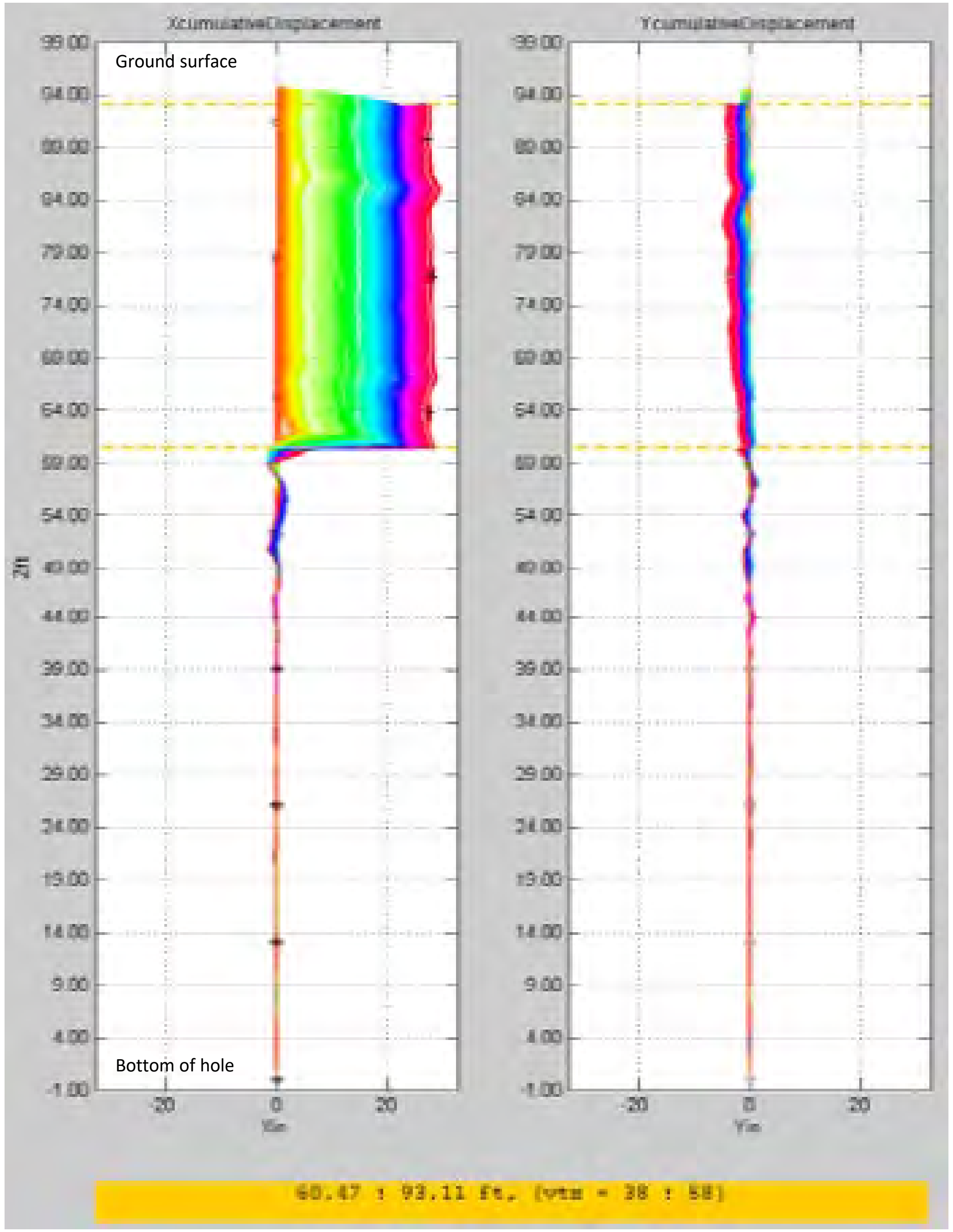


Figure 22. Photographs of the cored materials during the drilling operations. The lower left is primarily mafic (basalt) intrusion rock and the right is very weak rhyolite grading to rhyolitic volcanic ash tuff from top to bottom.

Figure 23. Test boring PR18-01 SAA reading and a photograph of the core recovered thorough the sharp failure plane at approximately 40.5 feet during drilling.



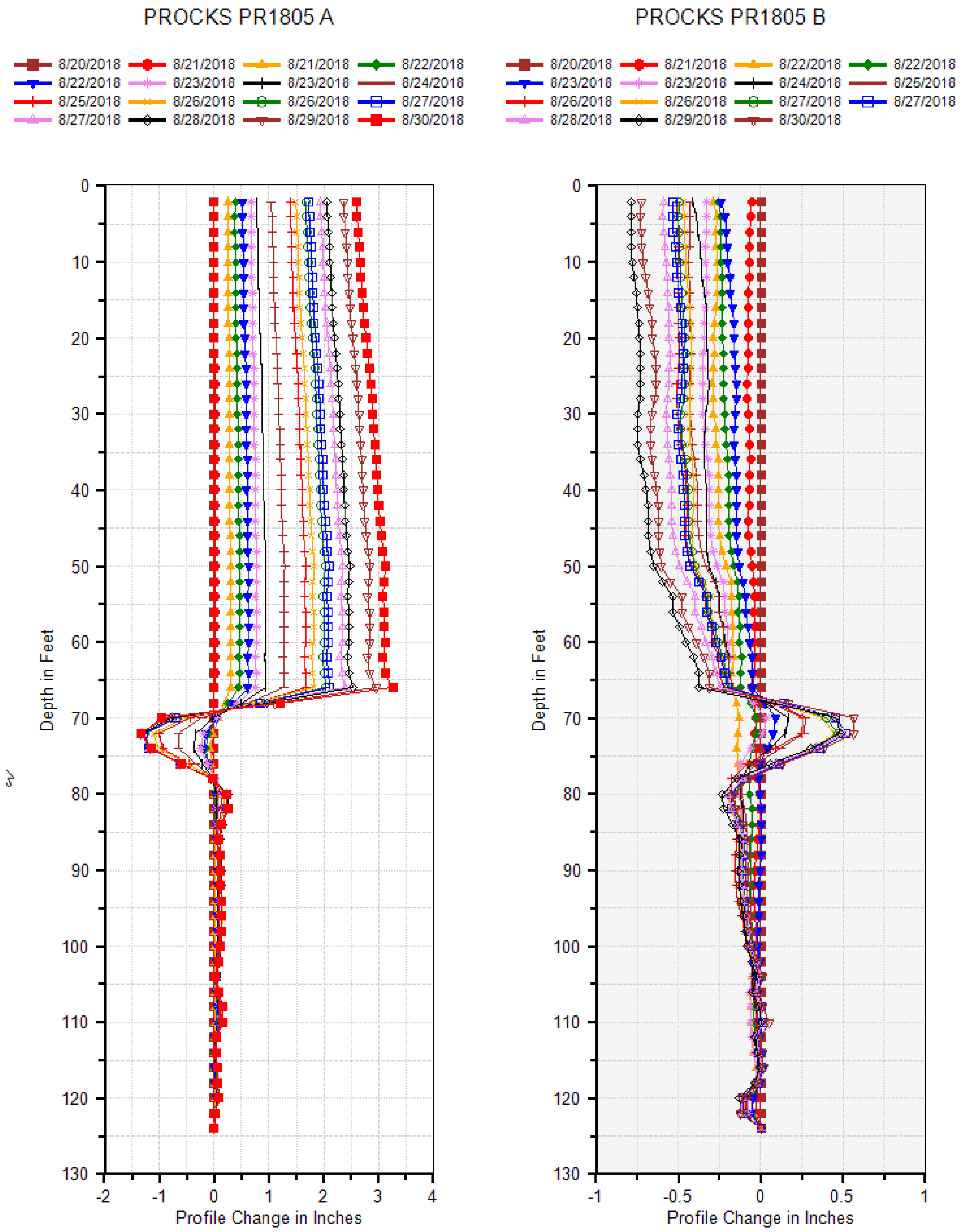
<u>PR18-01 (Saa 221178)</u>

-Azimuth adjusted by 0 deg. in SAA_View

Depth to bottom of SAAV from ground surface = 100.97’

Depth of movement from the ground surface = 40.5’ with 25 to 29 inches of total deflection movement over several months.

Figure 24. Slope inclinometer measurements in PR18-05 and a photograph of the core recovered that contains the abrupt failure plane and change in materials.



-Sharp failure zone at 66 to 68 feet along the very weak rock surface/geologic contact; downward compression of the casing below the failure plane.

-10 days of readings before shearing at 3.5 to 4 inches of total landslide deflection movement.

Figure 25. Map showing the approximate location of the two interpreted geologic cross sections for the Pretty Rocks Landslide.

Interpreted Geologic Cross Section A to A'
(Aligned with Landslide Movement)

Interpreted Geologic Cross Section B to B'
(Profile along Roadway)

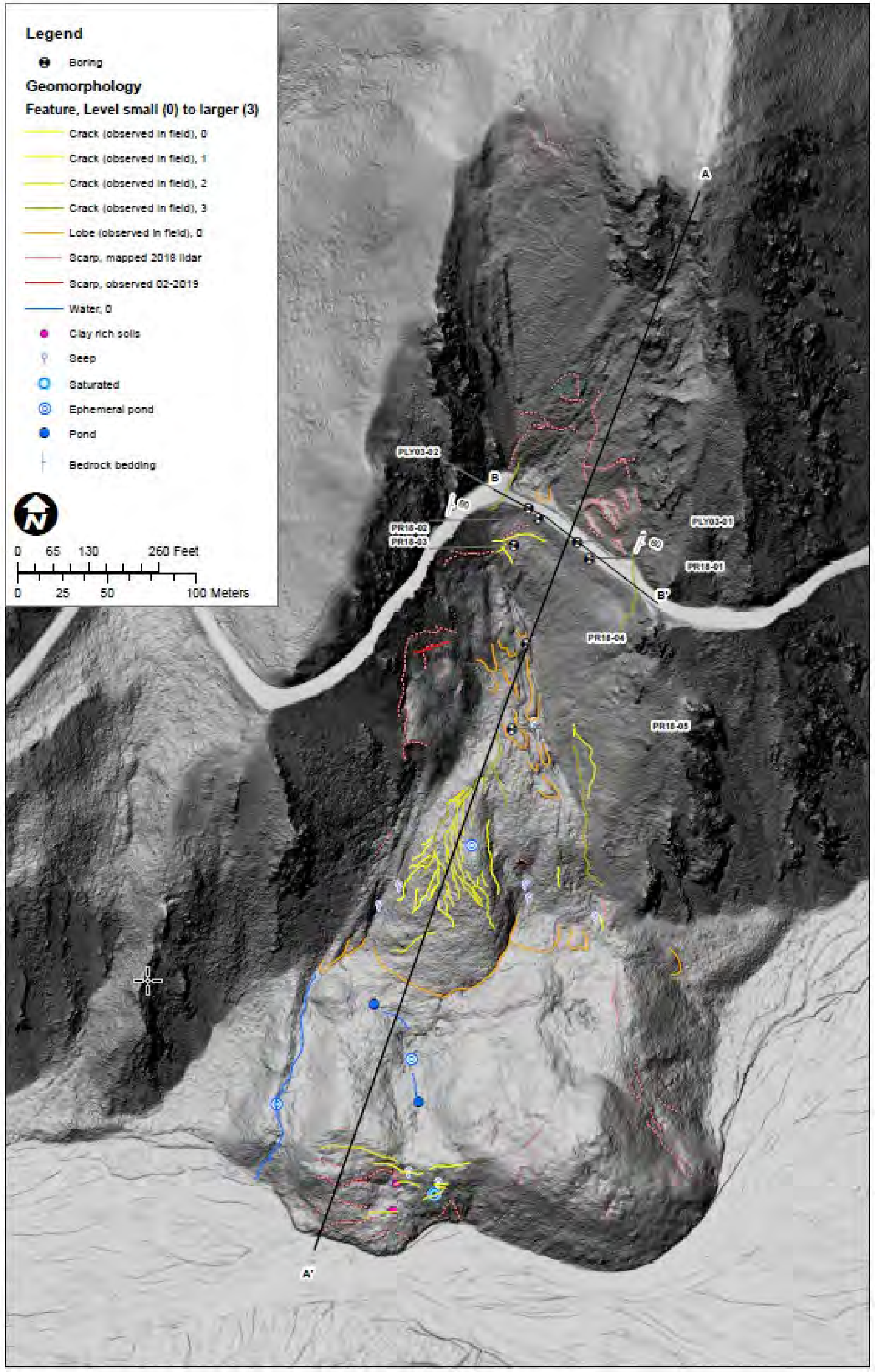


Figure 26. Schematic illustration of interpreted Geologic Cross-Section A to A'. The brown shaded area is road fill that has been used over the years (imported and upper landslide material). The yellow shaded area is unfrozen and ice rich landslide debris. The blue columns adjacent to the test boring locations provide the approximate depths where frozen landslide debris was encountered and subsequently measured in instruments. The pink shaded area is the extremely weak to medium strong rock formation unit at the base of the landsliding material. The upside down blue triangles show where apparent groundwater was encountered during drilling and/or measured in instrumentation. The red circles along the rock unit contact are the depths were landslide movement was detected in the instrumentation.

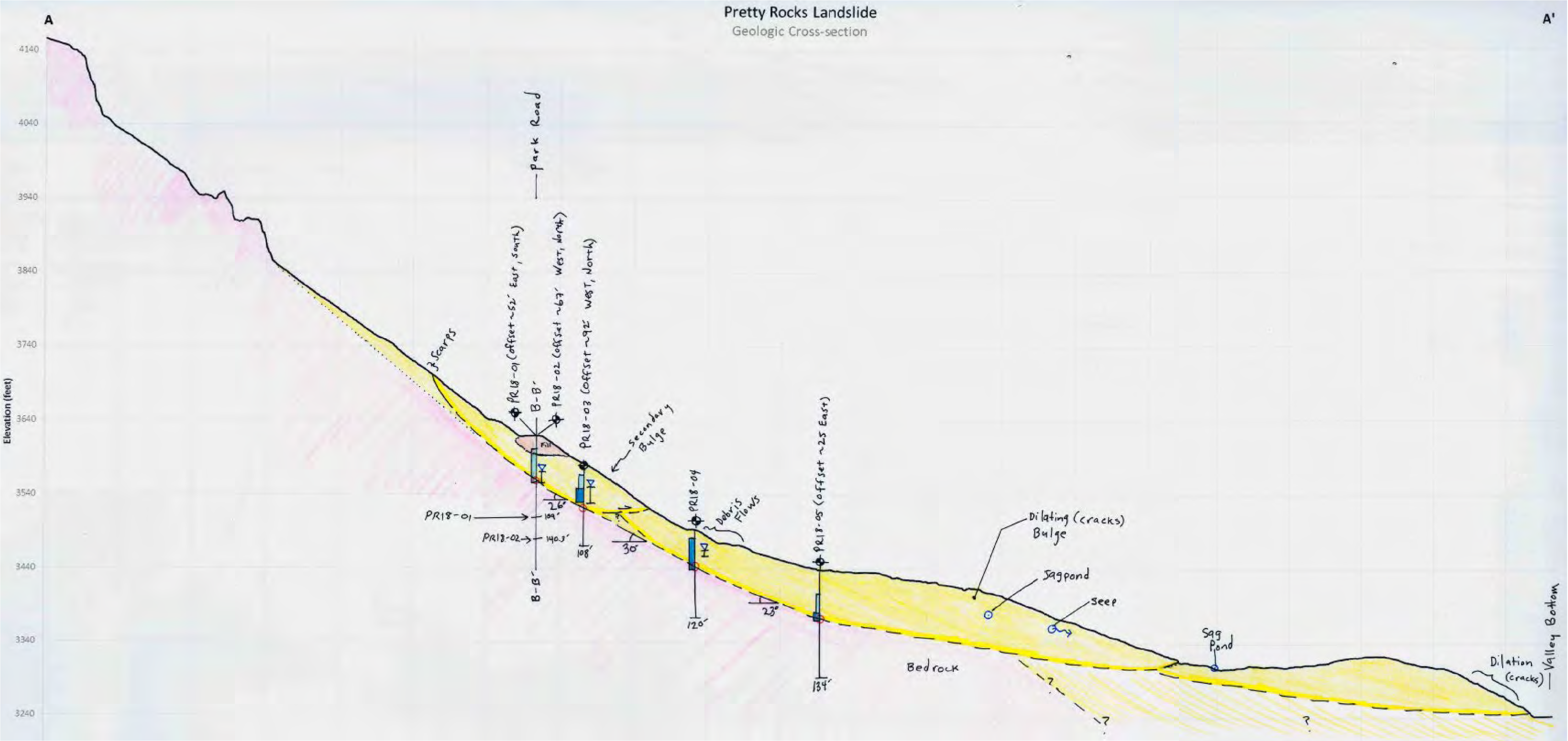


Figure 27. Schematic illustration of interpreted Geologic Cross-Section B to B'. The brown shaded area is road fill that has been used over the years (imported and upper landslide material). The yellow shaded area is unfrozen and ice rich landslide debris. The blue columns adjacent to the test boring locations provide the approximate depths where frozen landslide debris was encountered during drilling and subsequently measured in instruments. The pink and purple shaded areas are the extremely weak to medium strong rock formation unit at the base and along the sides of the landsliding material. The upside down blue triangles show where apparent groundwater was encountered during drilling and/or measured in instrumentation. Note the orientation of the geologic formations, as drawn in near the base of PR18-01, which are dipping to the north-northeast at approximately 60 degrees east.

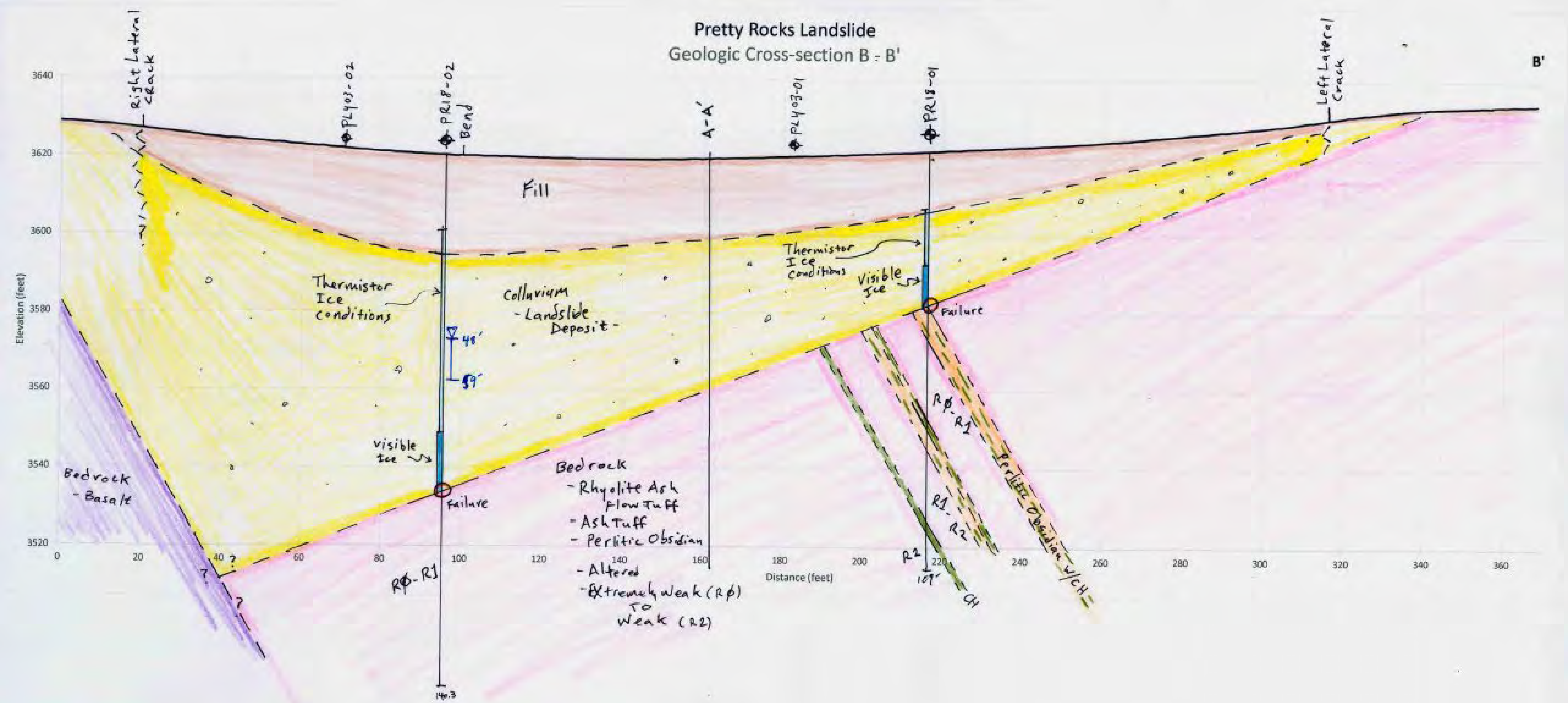
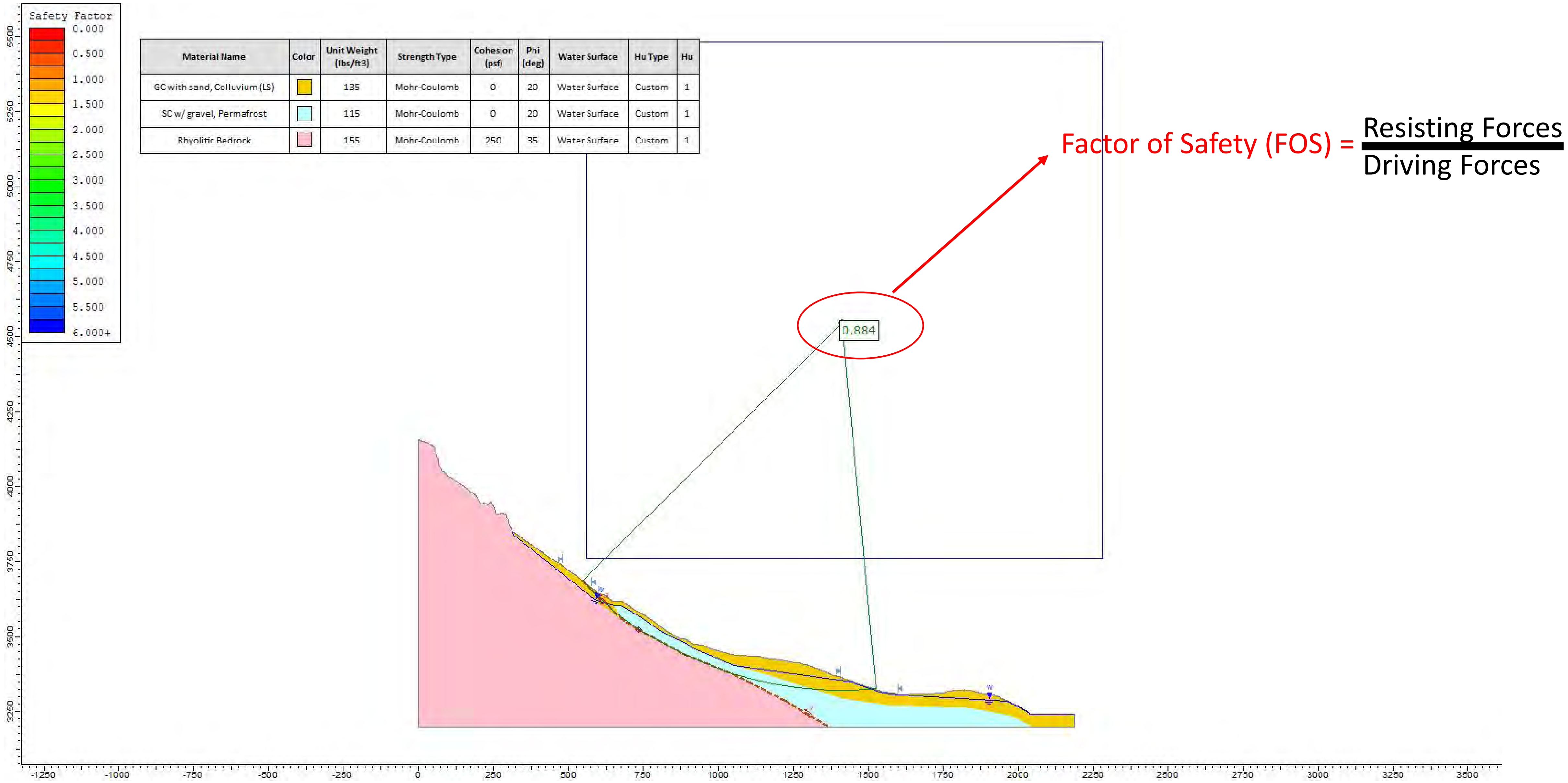


Figure 28. Preliminary slope stability model for geologic cross-section A to A’ for the Pretty Rocks Landslide. A polyline was used to add the thin and sharp failure plane shear strength properties along the geologic contact between the underlying rhyolitic rock formation unit and the overlying ice rich landslide debris. Note that the preliminary landslide analysis does not select a possible failure down to the valley floor, as observed in the field.

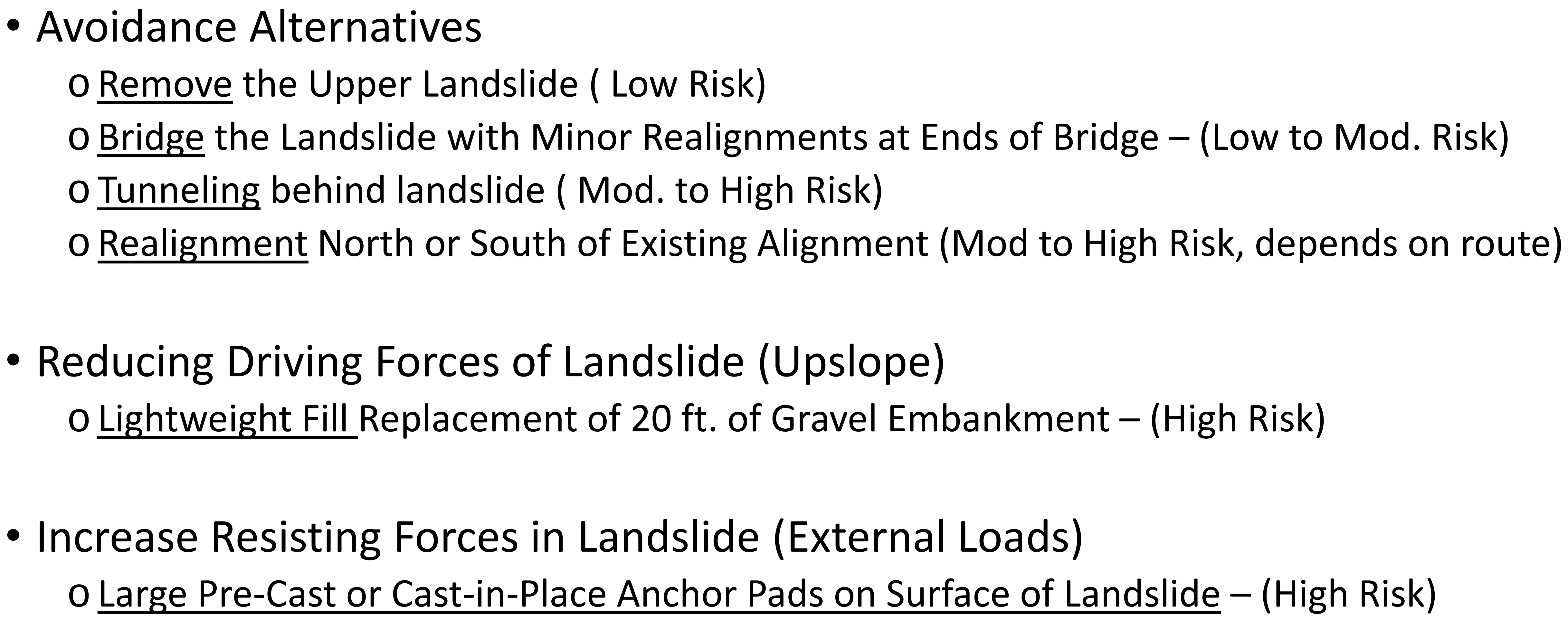


Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
GC with sand, Colluvium (LS)	🟨	135	Mohr-Coulomb	0	20	Water Surface	Custom	1
SC w/ gravel, Permafrost	🟦	115	Mohr-Coulomb	0	20	Water Surface	Custom	1
Rhyolitic Bedrock	🟥	155	Mohr-Coulomb	250	35	Water Surface	Custom	1

$$\text{Factor of Safety (FOS)} = \frac{\text{Resisting Forces}}{\text{Driving Forces}}$$

Figure 29. A LiDAR image of significant landslides within Polychrome Pass, and suspect topography just east of Pretty Rocks Landslide. Note the proximity of the Perlite Landslide to the eastern margin of the Pretty Rocks Landslide and the photo below from August 16, 2015 precipitation event.

Figure 30. Alternatives selected for proof in concept evaluation in February 2019



- Avoidance Alternatives
    - Remove the Upper Landslide (Low Risk)
    - Bridge the Landslide with Minor Realignments at Ends of Bridge – (Low to Mod. Risk)
    - Tunneling behind landslide (Mod. to High Risk)
    - Realignment North or South of Existing Alignment (Mod to High Risk, depends on route)

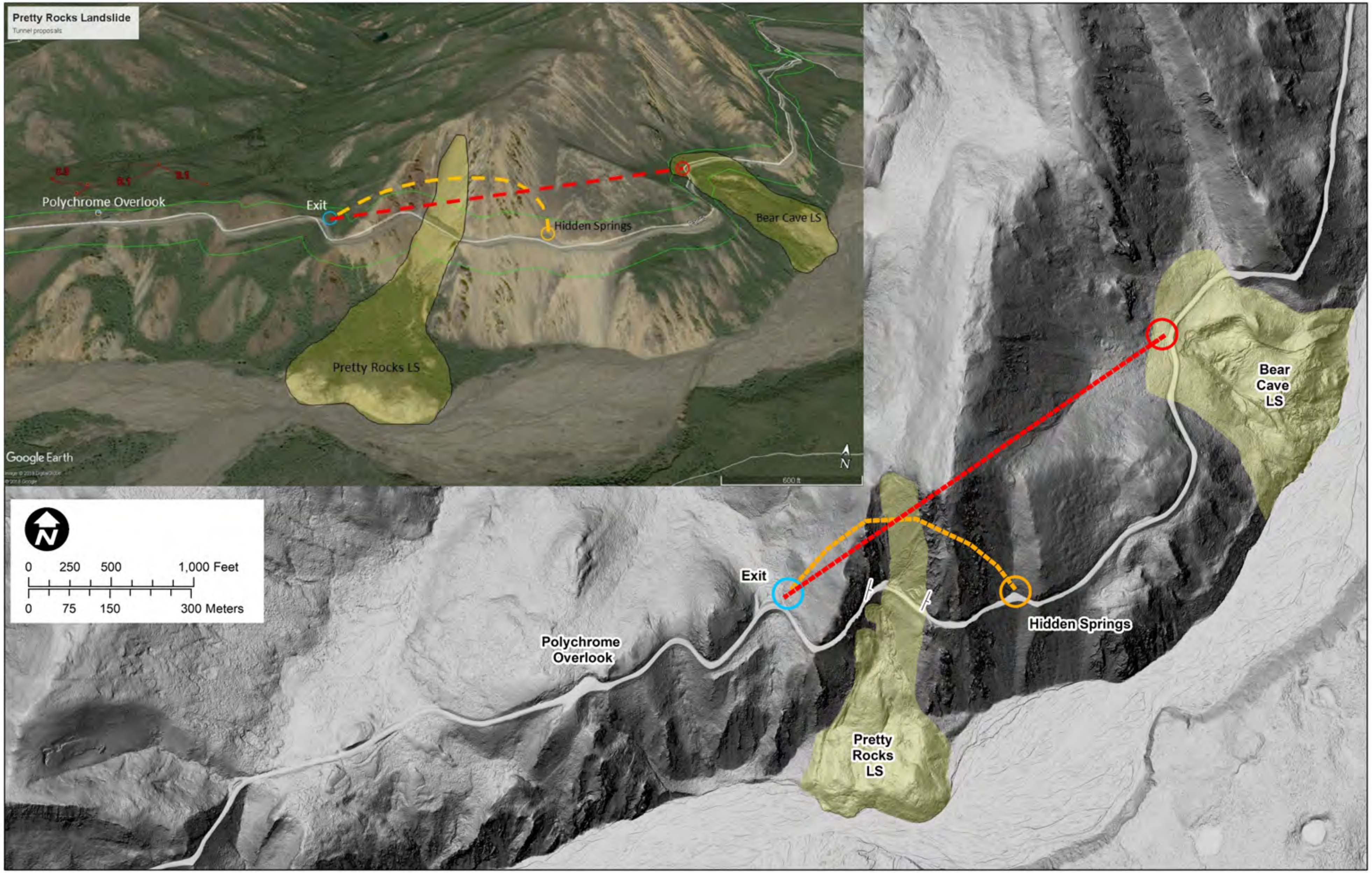
- Reducing Driving Forces of Landslide (Upslope)
    - Lightweight Fill Replacement of 20 ft. of Gravel Embankment – (High Risk)

- Increase Resisting Forces in Landslide (External Loads)
    - Large Pre-Cast or Cast-in-Place Anchor Pads on Surface of Landslide – (High Risk)

Figure 31. Short or Long Tunnel Concept behind the landslide

- Short Tunnel is ~1500 ft. long

- Long Tunnel is ~2700 ft. long



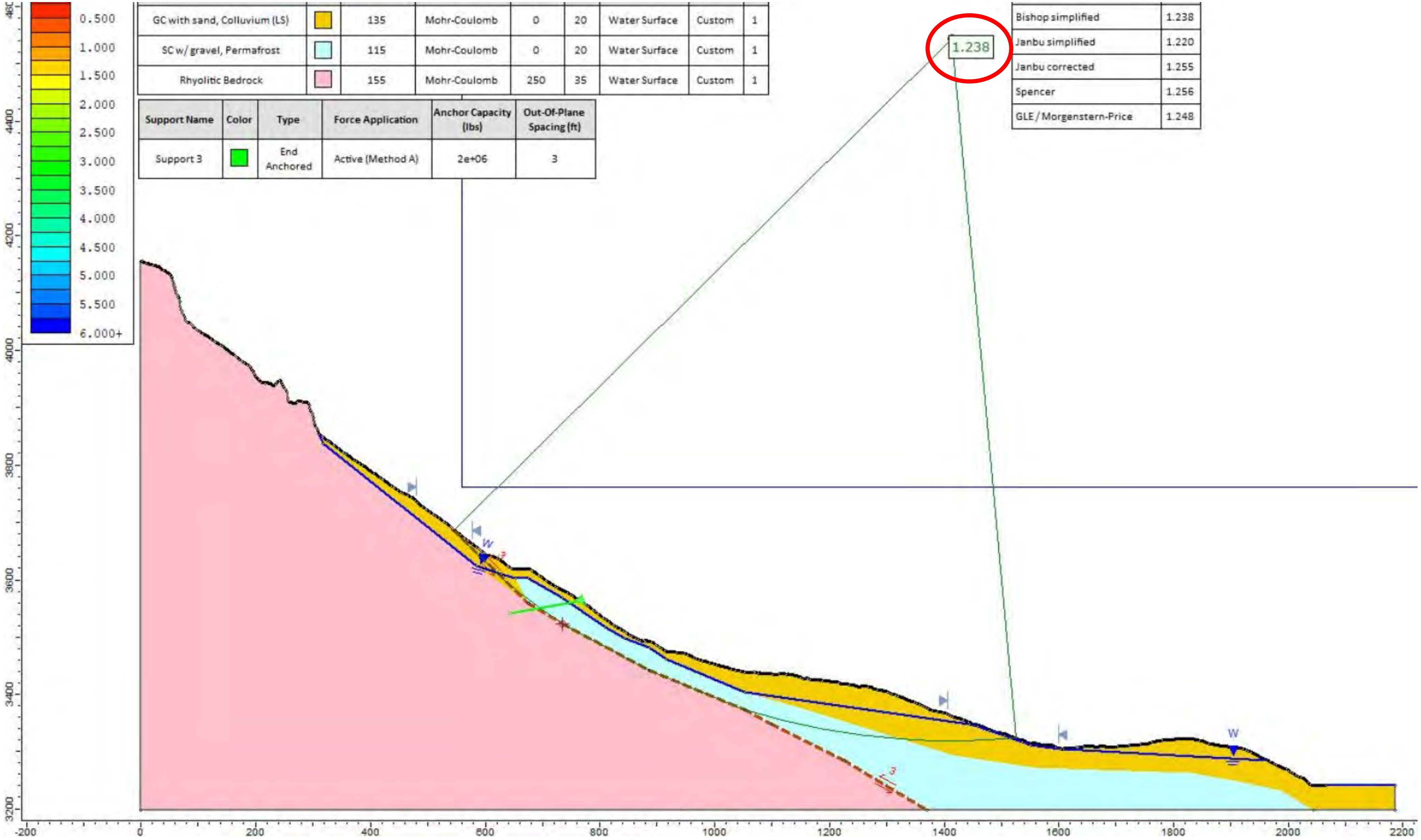

Courtesy of D'Appolonia Consultants

Figure 32. An example of high capacity anchors with bearing pads on the surface of landslide

Figure 33. A Rocscience SLIDE software graphical output for the loads required to significantly improve the stability of the landslide.

- 2,000,000 lbs/ft * 300 ft long = ~600,000 kips of anchors required

- ~1,200 anchor blocks @ ~500 kips/anchor



GC with sand, Colluvium (LS)	🟧	135	Mohr-Coulomb	0	20	Water Surface	Custom	1
SC w/ gravel, Permafrost	▢	115	Mohr-Coulomb	0	20	Water Surface	Custom	1
Rhyolitic Bedrock	▢	155	Mohr-Coulomb	250	35	Water Surface	Custom	1

Support Name	Color	Type	Force Application	Anchor Capacity (lbs)	Out-Of-Plane Spacing (ft)
Support 3	🟩	End Anchored	Active (Method A)	2e+06	3

Bishop simplified	1.238
Janbu simplified	1.220
Janbu corrected	1.255
Spencer	1.256
GLE / Morgenstern-Price	1.248

Figure 34. Rough concept of a modular steel truss constructed at Pretty Rocks Landslide, and the purple line on the LiDAR image to the right indicates the approximate bridge alignment and earthwork that would be required to accommodate the bridge option.

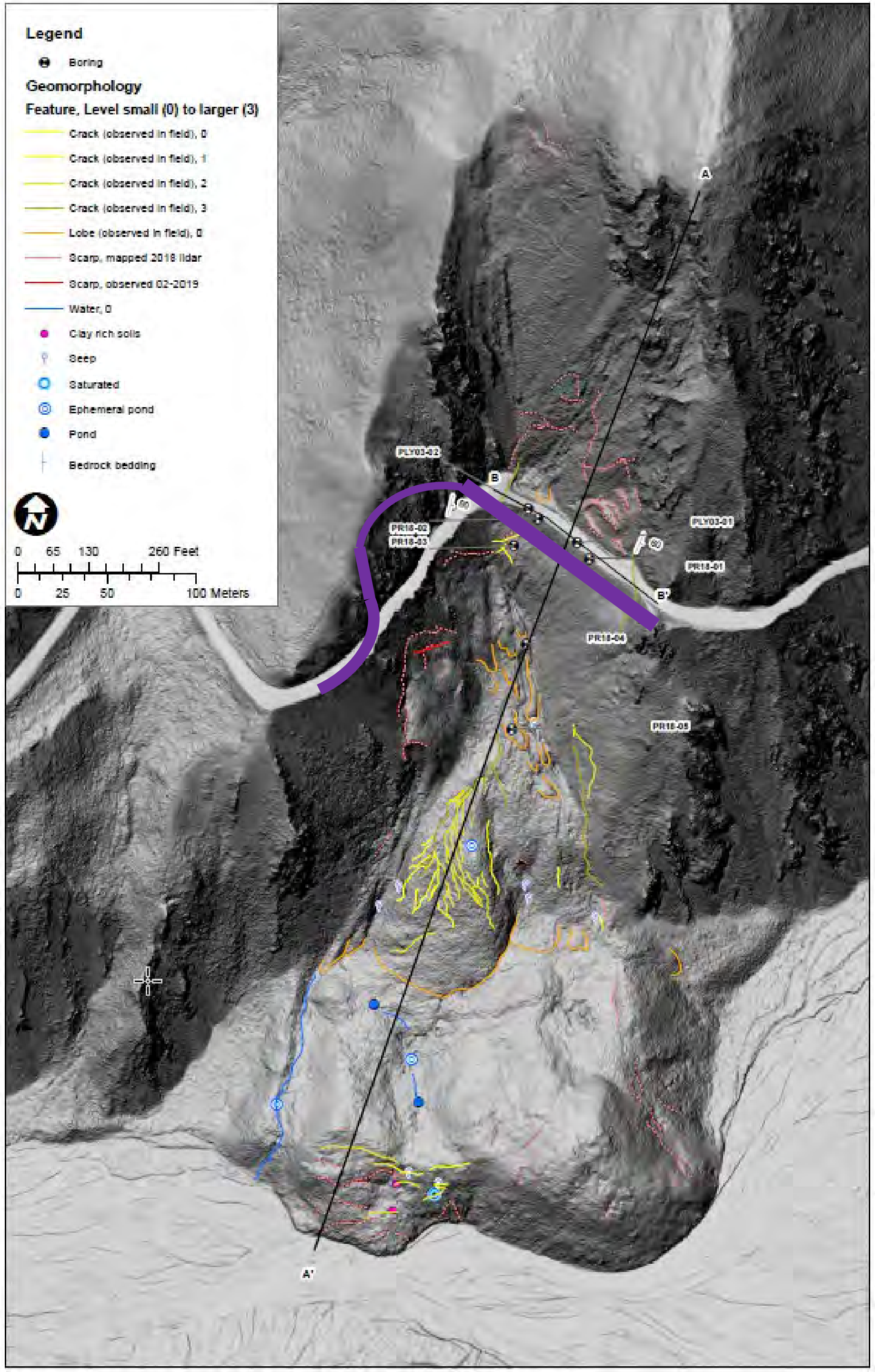
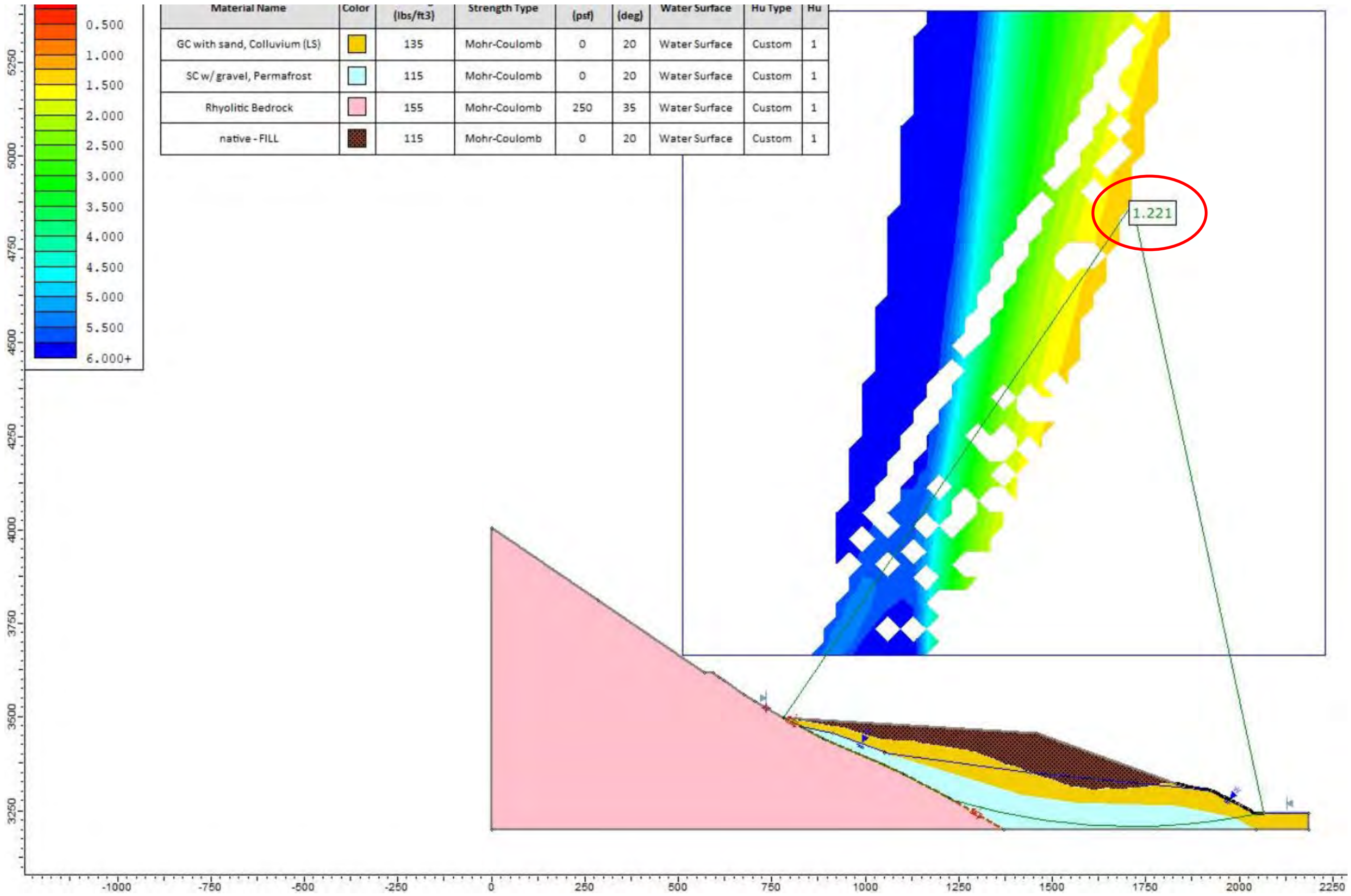


Figure 35. A Rocscience SLIDE software graphical output for the preliminary analyses of the removal of the upper, unconsolidated landslide material and placing it on the lower portion of the landslide



Material Name	Color	(lbs/ft3)	Strength Type	(psf)	(deg)	Water Surface	Hu Type	Hu
GC with sand, Colluvium (LS)	🟧	135	Mohr-Coulomb	0	20	Water Surface	Custom	1
SC w/ gravel, Permafrost	🟦	115	Mohr-Coulomb	0	20	Water Surface	Custom	1
Rhyolitic Bedrock	🟥	155	Mohr-Coulomb	250	35	Water Surface	Custom	1
native - FILL	▨	115	Mohr-Coulomb	0	20	Water Surface	Custom	1

APPENDIX B

Tables

B-1: Table 1. Test Boring Locations
B-2: Table 2. Summary of All Laboratory Test Results
B-3: Table 3. Geotechnical Test Boring Laboratory Tests

APPENDIX B-1

Table 1. Test Boring Locations

Table 1. Pretty Rocks Landslide Test Boring Locations

Bore Hole Name/Number	Longitude (Deg W)	Latitude (Deg N)	Elevation (ft)	Location	Drilled Depth (ft)	Purpose for Test Boring	Instrumentation
PLY03-1	-	-	-	West side of landslide/LT roadway shoulder	55.5	Landslide/subsurface characterization	SI
PLY03-2	-	-	-	East side of landslide/ LT roadway shoulder	101.2	Landslide/subsurface characterization	SI, Thermistor String
PR18-01	149.816461°	63.536629°	3620	West side of landslide/LT roadway shoulder	109	Landslide/subsurface characterization	VWP, Thermistor String, SAAV
PR18-02	149.817116°	63.536863°	3620	East side of landslide/ LT roadway shoulder	140.3	Landslide/subsurface characterization	VWP, Thermistor String, SAAV
PR18-03	149.817283°	63.536354°	3581	East side of landslide/below roadway	108	Landslide/subsurface characterization	VWP, Thermistor String, SAAV
PR18-04	149.817268°	63.536078°	3493	Middle of landslide/below roadway	120	Landslide/subsurface characterization	VWP, Thermistor String, SI, SAAV
PR18-05	149.817441°	63.535525°	3448	Middle of landslide/below roadway	134	Landslide/subsurface characterization	VWP, Thermistor String, SI, SAAV
PR19-06	149.814394°	63.536236°	-	East of landslide/RT roadway shoulder	150	Bridge Foundation	NA
PR19-07	149.81569°	63.536276°	-	East edge of landslide/LT roadway shoulder	100.3	Bridge Foundation	VWP, SI, Thermistor
PR19-08	149.817512°	63.536892°	-	West edge of landslide/LT roadway shoulder	103	Bridge Foundation	VWP, SI, Thermistor
PR19-09	149.817329°	63.537014°	-	West edge of landslide/RT roadway shoulder	142.5	Bridge Foundation	NA
PR19-11	149.819308°	63.534009°	-	West side of Landslide/near toe of landslide	157.1	Earthwork	VWP, SI, Thermistor

APPENDIX B-2

Table 2. Summary of All Laboratory Test Results

Table 2. Pretty Rocks Landslide Summary of All Test Results

Sample								Test Results						
Type	Boring	Sample Number	Depth		Longitude (Deg W)	Latitude (Deg N)	Elevation (ft)	Soil Classification (DL145)		Apparent Specific Gravity (T100)	Natural Moisture (T265), %	Atterberg Limits (T89)		UCS (DL22), psi
			From	To				AASHTO	USCS			Liquid Limit	Plasticity Index	
SPT	PR18-01	S13	32.5	34.2	149.816461°	63.536629°	3620	-	-	-	18.7	-	-	-
SPT	PR18-01	S15	37.5	39.5'	149.816461	63.536629°	3620	A-7-6(7)	SC; Clayey sand	2.504	30.9	55	30	-
SPT	PR18-01	S17	42.5	44'	149.816461	63.536629°	3620	A-2-7(1)	SM; Silty sand with gravel	2.555	22.1	48	17	-
SPT	PR18-01	S21	65	67'	149.816461	63.536629°	3620	A-4(0)	SM; Silty sand	2.665	35.8	NP	NP	-
SPT	PR18-02	S08	20	22'	149.817116°	63.536863°	3620	-	-	-	3.7	-	-	-
SPT	PR18-02	S18	45	47	149.817116°	63.536863°	3620	-	-	-	15.6	-	-	-
SPT	PR18-02	S24	60	62	149.817116°	63.536863°	3620	-	-	-	20.4	-	-	-
SPT	PR18-02	S27	70	70.3	149.817116°	63.536863°	3620	-	-	-	17.1	-	-	-
SPT	PR18-02	S31	77.5	78.9	149.817116°	63.536863°	3620	A-2-6(0)	SC; Clayey sand with gravel	2.526	19.4	37	17	-
SPT	PR18-02	S32	80.2	81.7	149.817116°	63.536863°	3620	A-2-6(0)	GC; Clayey gravel with sand	2.602	22.3	36	18	-
SPT	PR18-02	S34	85	87	149.817116°	63.536863°	3620	A-2-6(0)	SC; Clayey sand with gravel	2.608	29.2	39	20	-
SPT	PR18-02	S35	87.5	88.4	149.817116°	63.536863°	3620	-	-		26.2	47	28	-
SPT	PR18-02	S36	90	92	149.817116°	63.536863°	3620	A-7-6(10)	SC; Clayey sand	2.617	30.2	74	47	-
SPT	PR18-03	S03	10	12	149.817283°	63.536354°	3581	A-2-6(0)	SC; Clayey sand with gravel	2.547	20.7	34	12	-
SPT	PR18-03	S06	17	19	149.817283°	63.536354°	3581	A-2-7(1)	SC; Clayey sand with gravel	2.506	31.8	49	26	-
SPT	PR18-03	S15	40	41.4	149.817283°	63.536354°	3581	A-2-7(1)	SC; Clayey sand with gravel	2.761	23.5	42	19	-
SPT	PR18-03	S18	47	48	149.817283°	63.536354°	3581	-	-		36.1	-	-	-
SPT	PR18-03	S21A	55	56	149.817283°	63.536354°	3581	A-2-7(2)	GC; Clayey gravel with sand	2.74	37.6	57	33	-
SPT	PR18-03	S22	57	59	149.817283°	63.536354°	3581	A-7-6(6)	SC; Clayey sand	2.785	46.4	51	27	-
SPT	PR18-05	S10	25	27	149.817441°	63.535525°	3448	A-2-7(0)	GC; Clayey gravel with sand	2.749	24.7	44	22	-

Table 2. Pretty Rocks Landslide Summary of All Test Results

Sample								Test Results						
Type	Boring	Sample Number	Depth		Latitude	Longitude	Elevation (ft)	Soil Classification (DL145)		Apparent Specific Gravity (T100)	Natural Moisture (T265), %	Atterberg Limits (T89)		UCS (DL22), psi
			From	To				AASHTO	USCS			Liquid Limit	Plasticity Index	
SPT	PR18-05	S17	42.5	44	149.817441°	63.535525°	3448	A-2-7(2)	SC; Clayey sand with gravel	2.789	30	55	32	-
SPT	PR18-05	S21	52.5	54.5	149.817441°	63.535525°	3448	A-2-7(0)	GC; Clayey gravel with sand	2.722	25	49	27	-
SPT	PR18-05	S26	65	66.3	149.817441°	63.535525°	3448	-	-	-	26.2	NP	NP	-
RC	PR19-06	R2: Box 1	28.3	28.7	149.814394	63.536236	-	-	-	-	-	-	-	4280
RC	PR19-06	R2: Box 2	32.2	32.6	149.814394	63.536236	-	-	-	-	-	-	-	5430
RC	PR19-06	R4: Box 3	42.5	42.9	149.814394	63.536236	-	-	-	-	-	-	-	7870
RC	PR19-06	R3: Box 4	35.2	35.6	149.814394	63.536236	-	-	-	-	-	-	-	14600
RC	PR19-06	R7: Box 5	57.4	57.8	149.814394	63.536236	-	-	-	-	-	-	-	11620
RC	PR19-06	R10: Box 6	71.7	72.1	149.814394	63.536236	-	-	-	-	-	-	-	3990
RC	PR19-06	R11: Box 7	73.8	74.2	149.814394	63.536236	-	-	-	-	-	-	-	9230
RC	PR19-06	R11: Box 7	76.8	77.2	149.814394	63.536236	-	-	-	-	-	-	-	3070
RC	PR19-06	R12: Box 8	82.7	83.1	149.814394	63.536236	-	-	-	-	-	-	-	2500
RC	PR19-06	R14: Box 8	89.4	89.8	149.814394	63.536236	-	-	-	-	-	-	-	7170
RC	PR19-06	R16: Box 9	98.8	99.2	149.814394	63.536236	-	-	-	-	-	-	-	4930
RC	PR19-06	R20: Box 12	118.2	118.6	149.814394	63.536236	-	-	-	-	-	-	-	9430
RC	PR19-06	R25: Box 15	143.5	143.9	149.814394	63.536236	-	-	-	-	-	-	-	4740
RC	PR19-07	R8: Box 4	41	41.4	149.81569	63.536276	-	-	-	-	-	-	-	7260
RC	PR19-07	R15: Box 8	73.5	73.9	149.81569	63.536276	-	-	-	-	-	-	-	4960
RC	PR19-07	R18: Box 9	89	89.4	149.81569	63.536276	-	-	-	-	-	-	-	1260
RC	PR19-07	R18: Box 10	90.4	90.8	149.81569	63.536276	-	-	-	-	-	-	-	4410

Table 2. Pretty Rocks Landslide Summary of All Test Results

Sample								Test Results						
Type	Boring	Sample Number	Depth		Latitude	Longitude	Elevation (ft)	Soil Classification (DL145)		Apparent Specific Gravity (T100)	Natural Moisture (T265), %	Atterberg Limits (T89)		UCS (DL22), psi
			From	To				AASHTO	USCS			Liquid Limit	Plasticity Index	
SPT	PR19-08	S-6	15	17.5	149.817512	63.536892	-	A-7-6(44)	CH; Sandy fat clay	2.75	-	105	81	-
RC	PR19-08	R1: Box 1	41.4	41.9	149.817512	63.536892	-	-	-	-	-	-	-	8210
RC	PR19-08	R8: Box 4	72.2	72.6	149.817512	63.536892	-	-	-	-	-	-	-	22070
RC	PR19-08	R9: Box 5	74.2	74.6	149.817512	63.536892	-	-	-	-	-	-	-	26500
RC	PR19-08	R11: Box 6	82.6	83	149.817512	63.536892	-	-	-	-	-	-	-	10510
RC	PR19-08	R14: Box 7	91.1	91.5	149.817512	63.536892	-	-	-	-	-	-	-	14020
RC	PR19-08	R15: Box 7	95.5	95.9	149.817512	63.536892	-	-	-	-	-	-	-	31020
RC	PR19-08	R16: Box 8	100	100.4	149.817512	63.536892	-	-	-	-	-	-	-	21170
RC	PR19-09	R3	11.8	12.4	149.817329	63.537014	-	A-7-6(42)	CH; Fat clay with sand	2.791	27	74	50	-
RC	PR19-09	R4	16.5	17.1	149.817329	63.537014	-	A-7-6(34)	CH; Fat clay with sand	2.847	22.2	70	47	-
RC	PR19-09	R17: Box 9	76	76.4	149.817329	63.537014	-	-	-	-	-	-	-	8220
RC	PR19-09	R17: Box 9	78.1	78.5	149.817329	63.537014	-	-	-	-	-	-	-	19840
RC	PR19-09	R17: Box 9	79.2	79.6	149.817329	63.537014	-	-	-	-	-	-	-	16040
RC	PR19-09	R19: Box 10	88.1	88.5	149.817329	63.537014	-	-	-	-	-	-	-	26510
RC	PR19-09	R20: Box 11	92.7	93.1	149.817329	63.537014	-	-	-	-	-	-	-	27120
RC	PR19-09	R21: Box 11	96	96.4	149.817329	63.537014	-	-	-	-	-	-	-	14420
RC	PR19-09	R22: Box 12	100.2	100.6	149.817329	63.537014	-	-	-	-	-	-	-	11980
RC	PR19-09	R22: Box 12	103.1	103.5	149.817329	63.537014	-	-	-	-	-	-	-	23990
RC	PR19-09	R23: Box 13	108.5	108.9	149.817329	63.537014	-	-	-	-	-	-	-	6700
RC	PR19-09	R24: Box 14	112.9	113.3	149.817329	63.537014	-	-	-	-	-	-	-	7070
RC	PR19-09	R25: Box 14	118.6	119	149.817329	63.537014	-	-	-	-	-	-	-	16210
RC	PR19-09	R26: Box 15	121.2	121.6	149.817329	63.537014	-	-	-	-	-	-	-	8070

Table 2. Pretty Rocks Landslide Summary of All Test Results

Sample								Test Results						
Type	Boring	Sample Number	Depth		Latitude	Longitude	Elevation (ft)	Soil Classification (DL145)		Apparent Specific Gravity (T100)	Natural Moisture (T265), %	Atterberg Limits (T89)		UCS (DL22), psi
			From	To				AASHTO	USCS			Liquid Limit	Plasticity Index	
RC	PR19-09	R27: Box 15	126.9	127.3	149.817329	63.537014	-	-	-	-	-	-	-	16260
RC	PR19-09	R28: Box 16	132.5	132.9	149.817329	63.537014	-	-	-	-	-	-	-	34940
RC	PR19-09	R30: Box 17	142.1	142.5	149.817329	63.537014	-	-	-	-	-	-	-	29790
SPT	PR19-11	S-1, S-2	7	13.5	149.819308	63.534009	-	A-2-7(5)	SC; Clayey sand	2.462	-	63	37	-
SPT	PR19-11	S-4	22	23.5	149.819308	63.534009	-	A-7-5(59)	CH; Fat clay with sand	2.629	-	100	69	-
SPT	PR19-11	S-9	47	47.7	149.819308	63.534009	-	A-2-6(0)	SC; Clayey sand with gravel	2.635	-	33	15	-
SPT	PR19-11	S-11, S-12A	57	62.3	149.819308	63.534009	-	A-7-5(47)	CH; Fat clay with sand	2.66	-	88	55	-
SPT	PR19-11	S-12B	62.3	63.4	149.819308	63.534009	-	A-2-7(2)	SC; Clayey sand	2.749	-	47	30	-
SPT	PR19-11	S-13	67	68.5	149.819308	63.534009	-	A-2-6(0)	SC; Clayey sand with gravel	2.745	-	37	19	-
SPT	PR19-11	S-17, S-18	87	93.5	149.819308	63.534009	-	A-2-6(0)	SC; Clayey sand with gravel	2.718	-	29	11	-
SPT	PR19-11	S-19	97	98.5	149.819308	63.534009	-	A-2-6(0)	SC; Clayey sand with gravel	2.668	-	30	13	-
SPT	PR19-11	S-22, S-23	112	118.5	149.819308	63.534009	-	A-7-6(34)	CH; Fat clay with sand	2.71	-	59	38	-
SPT	PR19-11	S-25, S-26	127	132.2	149.819308	63.534009	-	A-2-7(2)	SC; Clayey sand with gravel	2.707	-	46	25	-
SPT	PR19-11	S-28	142	143	149.819308	63.534009	-	A-7-6(32)	CH; Fat clay	2.709	-	52	36	-
SPT	PR19-11	S-6	15	17.5	149.819308	63.534009	-	A-7-6(44)	CH; Sandy fat clay	2.75	-	105	81	-

APPENDIX B-3

Table 3. Geotechnical Test Boring Laboratory Tests

Table 3. Geotechnical Test Boring Laboratory Tests

Type of Sample	**Test Description**	**Testing Method(s)**
Geotechnical Boring	Sieve Analyses	AASHTO T11/T27
Geotechnical Boring	Atterberg	AASHTO T89/T90
Geotechnical Boring	Apparent Specific Gravity	ASSHTO T 100
Geotechnical Boring	Natural Moisture Content	ASSHTO T 265
Geotechnical Boring	Uniaxial Compressive Strength	AASHTO T 22
Geotechnical Boring	Soil Classification	AASHTO DL145
Geotechnical Boring	Ring Shear	ASTM D6467-13

APPENDIX C

Geotechnical Test Boring Logs

Descriptive Terminology for Boring Logs

U.S. Department of Transportation
Federal Highway Administration

Field descriptions of borings are based on the FLH Soil and Rock Description and Identification Guidelines that generally follow the Visual-Manual Procedure (ASTM D 2488). The soil classifications shown on the boring logs are based on laboratory tests (ASTM D 2487) when the two-letter group symbol follows the group name in parenthesis.

SOIL CLASSIFICATION CHART

Criteria for Assigning Group Symbols and Group Name Using Laboratory Tests[A]				Group Symbol	Group Name[B]
COARSE-GRAINED SOILS More than 50% retained on No. 200 Sieve	**GRAVELS** More than 50% of coarse fraction retained on No. 4 Sieve	**Clean GRAVELS** Less than 5% fines [E]	Cu ≥ 4 and 1 ≤ Cc ≤ 3[C]	GW	Well-graded GRAVEL [D]
			Cu < 4 and/or 1 > Cc > 3 [C]	GP	Poorly-graded GRAVEL [D]
		GRAVELS with fines More than 12% fines [E]	Fines classify as ML or MH	GM	Silty GRAVEL [D,F]
			Fines classify as CL or CH	GC	Clayey GRAVEL [D,F]
	SANDS Less than 50% retained on No. 4 Sieve	**Clean SANDS** Less than 5% fines [I]	Cu ≥ 6 and 1 ≤ Cc ≤ 3 [C]	SW	Well-graded SAND [H]
			Cu < 6 and/or 1 > Cc > 3 [C]	SP	Poorly-graded SAND [H]
		SANDS with fines More than 12% fines [I]	Fines classify as ML or MH	SM	Silty SAND [F,H]
			Fines classify as CL or CH	SC	Clayey SAND [F,H]
FINE-GRAINED SOILS 50% or more passes the No. 200 Sieve	**SILTS and CLAYS** Liquid limit less than 50	Inorganic	PI > 7 and plots on or above the "A" line [J]	CL	Lean CLAY [K,L,M]
			PI < 4 or plots below "A" line [J]	ML	SILT [K,L,M]
		Organic	$\frac{\text{Liquid limit – oven dried}}{\text{Liquid limit – not dried}} < 0.75$	OL	Organic CLAY [K,L,M,N] Organic SILT [K,L,M,O]
	SILTY and CLAYS Liquid limit 50 or more	Inorganic	PI plots on or above "A" line	CH	Fat CLAY [K,L,M]
			PI plots below "A" line	MH	Elastic SILT [K,L,M]
		Organic	$\frac{\text{Liquid limit – oven dried}}{\text{Liquid limit – not dried}} < 0.75$	OH	Organic CLAY [K,L,M,P] Organic SILT [K,L,M,Q]
HIGHLY ORGANIC SOILS	Primarily organic matter, dark in color, and organic odor			PT	PEAT

[A] Based on material passing the 3-inch sieve.

[B] If field sample contains cobbles or boulders, add "with cobbles" or "boulders" or both, to group name.

[C] Cu = D_{60}/D_{10} Cc = $(D_{30})^2 / (D_{10} \times D_{60})$

[D] If soil contains ≥15% sand, add "with sand" to group name.

[E] Gravels with 5 to 12% fines require dual symbols:
GW-GM well-graded GRAVEL with silt
GW-GC well-graded GRAVEL with clay
GP-GM poorly-graded GRAVEL with silt
GP-GC poorly-graded GRAVEL with clay

[F] If fines classify as CL-ML, use dual symbol GC-GM or SC-SM

[G] If fines are organic, add "with organic fines" to group name.

[H] If soil contains ≥15% gravel, add "with gravel" to group name.

[I] Sand with 5 to 12% fines require dual symbols:
SW-SM well-graded SAND with silt
SW-SC well-graded SAND with clay
SP-SM poorly-graded SAND with silt
SP-SC poorly-graded SAND with clay

[J] If Atterberg limits plot in hatched area, soil is a CL-ML, silty CLAY.

[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel", whichever is predominant.

[L] If soil contains ≥ 30% plus No. 200, predominantly sand, add "sandy" to beginning of group name.

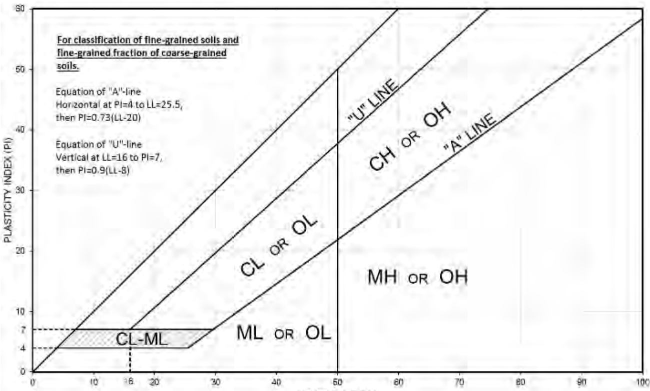
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to beginning of group name.

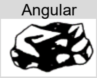
[N] PI ≥ 4 and plots on or above "A" line.

[O] PI < 4 or plots below "A" line.

[P] PI plots on or above "A" line.

[Q] PI plots below "A" line.



ANGULARITY OF COARSE-GRAINED SOILS	
Angular 	Sharp edges and relatively plane sides with unpolished surfaces
Subangular 	Similar to angular description, but with rounded edges
Subrounded 	Nearly plane sides, but will have well-rounded corners and edges.
Rounded 	Smoothly curved sides and no edges

PARTICLE SIZE OF COARSE-GRAINED SOILS	
Component	**Grain Size Limits**
Boulders	> 12" (> 300 mm)
Cobbles	3 – 12" (75 – 300 mm)
Coarse Gravel	3/4 - 3" (19 - 75 mm)
Fine Gravel	#4 Sieve - 3/4" (4.75 - 19 mm)
Coarse Sand	#10 - #4 Sieve (2.00 - 4.75 mm)
Medium Sand	#40 - #10 Sieve (0.425 - 2.00 mm)
Fine Sand	#200 - #40 Sieve (0.075 - 0.425 mm)

Standard Penetration Test (SPT): the SPT consists of driving a 2 in (50 mm) O.D. split barrel sampler a depth of 18 in (450 mm) or 24 in (600 mm) using a 140 lb (63.6 kg) hammer with a 30 in (750 mm) drop. The blow count is the number of blows recorded for each 6 inch (50 mm) increment. The N-value is the total number of blows for the second and third increments. Note that the N-values shown on the boring logs do not include any corrections for non-standard sampler size, hammers, drill rods, etc.

SOIL STRUCTURE TERMS	
Stratified	Alternating layers of varying material or color with layers > 1/4 inch (6 mm), note thickness and inclination.
Laminated(1)	Alternating layers of varying material or color with layers < 1/4 inch (6 mm), note thickness and inclination.
Fissured(1)	Breaks along definite planes of fracture with little resistance to fracturing.
Slickensided(1)	Fracture planes appear polished or glossy, sometimes striated.
Blocky(1)	Cohesive soil that can be broken down into smaller angular lumps which resists further breakdown.
Disrupted	Soil structure is broken and mixed. Infers that material has moved substantially - landslide debris.
Homogeneous	Same color and appearance throughout.
Lensed	Inclusion of small pockets of different soil, such as small lenses of sand scattered through a mass of clay; < 1/4 inch (6 mm) note thickness.

(1) Do not use laminated, fissured, slickensided, or blocky for coarse-grained soils.

APPARENT DENSITY OF COARSE-GRAINED SOIL	
SPT N-value (blows per foot)	**Apparent Density**
0 to 4	Very Loose
5 to 10	Loose
11 to 30	Medium Dense
31 to 50	Dense
> 50	Very Dense

CONSISTENCY OF FINE-GRAINED SOIL	
SPT N-value (blows per foot)	**Consistency**
0 to 1	Very Soft
2 to 4	Soft
5 to 8	Firm
9 to 15	Stiff
16 to 30	Very Stiff
> 30	Hard

10/04/2018

GRAIN/CRYSTAL SIZE FOR ROCKS (MODIFIED AFTER WENTWORTH, 1972)

Grain Size	Description	Criteria
Less than 0.003 inches (<0.075 mm)	Very fine grained	Cannot be distinguished by unaided eye. Few to no mineral grains are visible with a hand lens.
0.003 to 0.02 inches (0.075 to 0.425 mm)	Fine grained	Few grain/crystal boundaries are visible; grains can be distinguished with difficulty by the unaided eye but can be somewhat distinguished by hand lens.
0.02 to 0.08 inches (0.425 to 2 mm)	Medium grained	Most grain/crystal boundaries are visible; grains distinguishable by eye and with the aid of a hand lens.
0.08 to 0.2 inches (2 to 4.75 mm)	Coarse grained	Grain/crystal boundaries are visible; grains distinguishable with the naked eye and hand lens.
Greater than 0.2 inches (>4.75 mm)	Very coarse grained	Grain/crystal boundaries are Clearly visible; grains are distinguishable with the naked eye.

DEGREE OF WEATHERING

Term	Description	Grade
Fresh	No visible sign of rock material weathering; slight discoloration on major discontinuity surface is possible.	I
Slightly Weathered	Discoloration indicates weathering of rock material and discontinuity surfaces. All rock material may be discolored by weathering and the external surface may be somewhat weaker than in its fresh condition.	II
Moderately Weathered	Less than half the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a discontinuous framework or as corestones. A minimum 2-inch (50 mm) diameter sample *cannot* be broken readily by hand across the rock fabric.	III
Highly Weathered	More than half of the rock is decomposed and/or disintegrated to soil. Fresh or discolored rock is present either as a discontinuous framework or as corestones. A minimum 2-inch (50 mm) diameter sample *can* be broken readily by hand across the rock fabric.	IV
Completely Weathered	All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact. Material can be granulated by hand. ***If rock is considered to be completely weathered, use FLH Soil Description and Identification Guidelines to describe the residual soil material.***	V
Residual Soil	All rock material is converted to soil. The mass structure and material fabric are destroyed but the apparent structure remains intact. There may be a large change in volume, but the soil has not been significantly transported. Material can be easily broken-down by hand. ***If rock is considered to be completely weathered, use FLH Soil Description and Identification Guidelines to describe the residual soil material.***	VI

RELATIVE STRENGTH OF INTACT ROCK SPECIMENS (ISRM, 1978 &1981)

Grade	Description	Field Indentificaiton	Approximate Uniaxial Compressive Strength
R0	Extremely Weak Rock	Specimen can be indented by thumbnail	35 - 150 psi (250 - 1,000 kPa)
R1	Very Weak Rock	Specimen crumbles under sharp blow with point of geological hammer, and can be peeled with a pocket knife.	150 - 725 psi (1,000 - 5,000 kPa)
R2	Weak Rock	Shallow cuts or scrapes can be made in a specimen with a pocket knife. A firm blow with a geological hammer point creates shallow indents.	725 - 3,500 psi (5,000 - 25,000 kPa)
R3	Medium Strong Rock	Specimen cannot be scraped or cut with a pocket knife. Specimen can be fractured with a single firm blow with a geologic hammer point.	3,500 - 7,250 psi (25,000 - 50,000 kPa)
R4	Strong Rock	Specimen requires more than one firm blow of the geologic hammer point to fracture.	7,250 - 14,500 psi (50,000 - 100,000 kPa)
R5	Very Strong Rock	Specimen requires many firm blows from the hammer end of the geologic hammer to fracture.	14,500 - 36,250 psi (100,000 - 250,000 kPa)
R6	Extremely Strong Rock	Specimen can only be chipped with firm blows from the hammer end of the geologic hammer.	>36,250 psi (>250,000 kPa)

DISCONTINUITY CONDITION (ISRM, 1978, 1981)

Condition	Description
Excellent Condition	Very rough surfaces, no separation, hard discontinuity wall (>R2).
Good Condition	Slightly rough surfaces, separation less than ~0.04 inches (1 mm), hard discontinuity wall (>R2).
Fair Condition	Slightly rough surface, separation greater than ~0.04 inches (1 mm), soft discontinuity wall (<R3).
Poor Condition	Slickensided surfaces, or soft gouge less than ~0.2 inches (5 mm) thick, or open discontinuities between ~0.4 and 0.2 inches (1 to 5 mm).
Very Poor Condition	Soft gouge greater than ~0.2 inches (5 mm), or open discontinuities greater than ~0.2 inches (5 mm).

DISCONTINUITY SPACING (INCLUDES JOINTS/FRACTURES, BEDDING, AND FAULTS

Description	Spacing of Discontinuity
Extremely Widely Spaced	>20 feet (>6 m)
Very Widely Spaced	~6 to 20 feet (2 to 6 m)
Widely Spaced	~2 to 6 feet (600 mm to 2 m)
Moderately Spaced	~8 inches to 2 feet (200 to 600 mm)
Closely Spaced	~2 to 8 inches (60 to 200 mm)
Very Closely Spaced	~3/4 to 2 inches (20 to 60 mm)
Extremely Closely Spaced	<3/4 inches (<20 mm)

$$CR\ (\%) = \left(\frac{Total\ Length\ of\ Core\ Recovered}{Total\ Length\ of\ Core\ Run\ Drilled}\right) * 100$$

$$RQD\ (\%) = \frac{Length\ of\ Sound\ Core\ in\ pieces > 4\ inches\ (100\ mm)}{Total\ Length\ of\ Core\ Run} x\ 100$$

$$FF = \frac{Number\ of\ natural\ fractures}{Total\ length\ of\ core\ recovered\ (feet)}$$

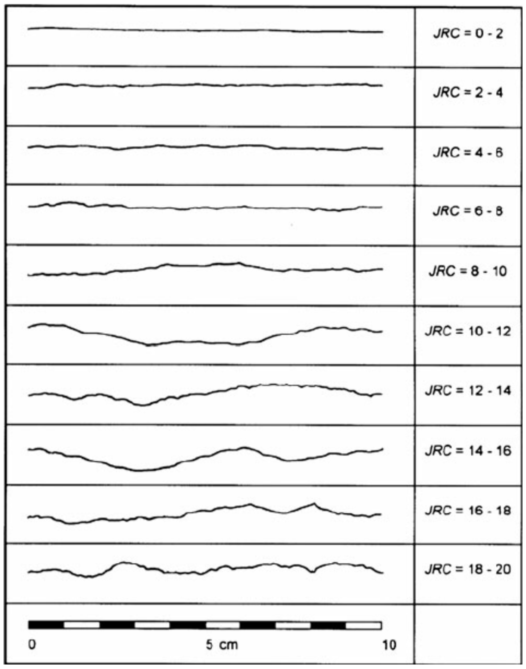
GRAIN SHAPE (FOR SEDIMENTARY ROCKS)

Description	Characteristic
Angular	Showing very little evidence of wear. Grain edges and corners are sharp. Secondary corners are numerous and sharp.
Subangular	Showing definite effects of wear. Grain edges and corners are slightly rounded off. Secondary corners are slightly less numerous and slightly less sharp than in angular grains.
Subrounded	Showing considerable wear. Grain edges and corners are rounded to smooth curves. Secondary corners are reduced greatly in number and highly rounded.
Rounded	Showing extreme wear. Grain edges and corners are smoothed off the broad curves. Secondary corner are few in number and rounded.
Well-rounded	Completely worn. Grain edges or corners are not present. No secondary edges or corners are present.

RELATIVE STRENGTH OF SOIL INFILLING (ISRM, 1978 & 1981)

Grade	Description	Field Identification	Approximate Uniaxial Compressive Strength
S1	Very Soft	Easily penetrated several inches by fist	<3.5 psi (<25 kPa)
S2	Soft	Easily penetrated severl inches by thumb	3.5 - 7 psi (25 - 50 kPa)
S3	Firm	Can be penetrated several inches by thumb with moderate effort	7 - 14.5 psi (50 - 100 kPa)
S4	Stiff	Readily indented by thumb but penetrated only with great effort	14.5 - 36 psi (100 - 250 kPa)
S5	Very Stiff	Readily indented by thumbnail	36 - 72.5 psi (250 - 500 kPa)
S6	Hard	Indented with difficulty by thumbnail	>72 psi (>500 kPa)

JRC RANGES (ISRM, 1978 &1981)



FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 6/25/2003
DATE FINISHED: 6/26/2003
DRILLER: Chris Peterson
COMPANY:
LOGGER: "Orion George"
WEATHER:

BORING PLY03-1

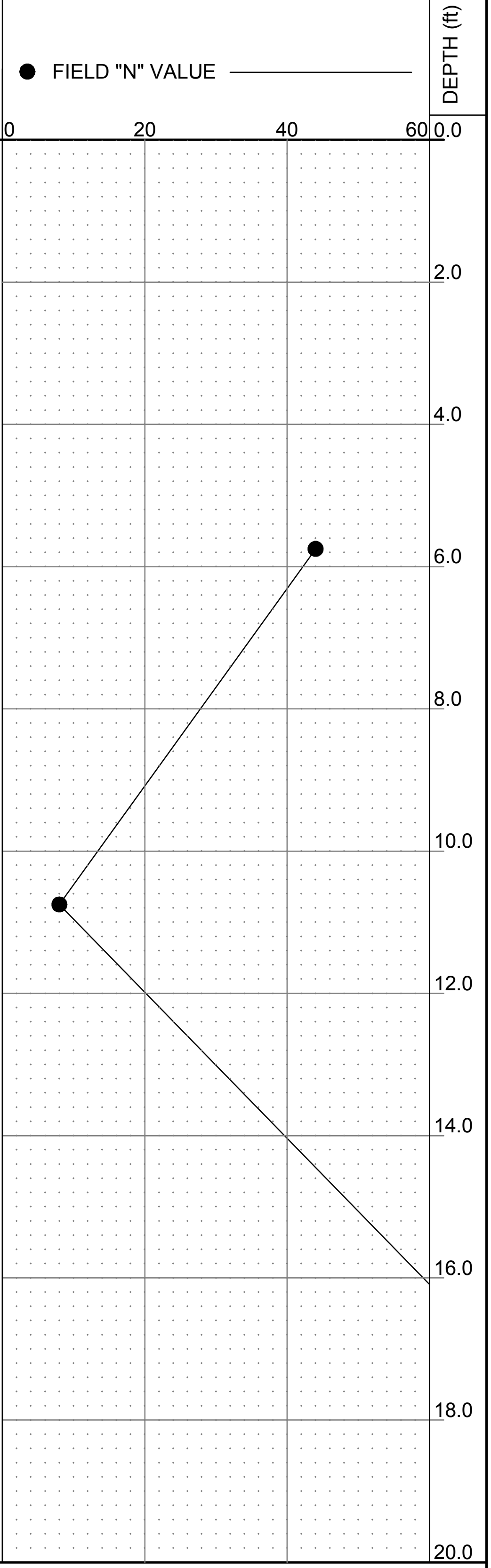
DRILL: CS1000
HAMMER:
DRILLING METHODS:

PROJECT: Denali National Park
STATION, OFFSET:

NOTES: Thermister string readings were collected on 09/02/2003. Geologist Orion George added logging observations to core on 03/08/2017 with observations in "quotes".

TOTAL DEPTH: 55.5'

DEPTH (ft)	DESCRIPTION	GRAPHIC LOG	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)
0.0	Gravelly to 3.5 ft. 3.5 ft to 5.0 ft cobbles, gravel, possible boulder. Return water changed gray to brown.		R-1		
5.0	Tan-rust and multicolored silty, sandy gravel or gravely sand (damp).		SPT-1		16-17-27
6.5	Looser, soft 7.0 ft to 10.0 ft. Lost return water at 9.5 ft.		R-2		
10.0	Light tan sandy gravel, trace of silt. Angular to subangular rhyolite gravels.		SPT-2		8-4-4
11.5	Very soft between cobbles, it will jack the drill up, so voids unlikely. Granular, loose, smoother at 18.2 ft, less soft zones.		R-3		
20.0					



WATER LEVELS
- WHILE DRILLING
- AT COMPLETION
- AFTER DRILLING

- Solid Stem Auger
- Rock / Soil Core
- 2" OD Split Spoon (SPT)

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 6/25/2003
DATE FINISHED: 6/26/2003
DRILLER: Chris Peterson
COMPANY:
LOGGER: "Orion George"
WEATHER:

BORING PLY03-1

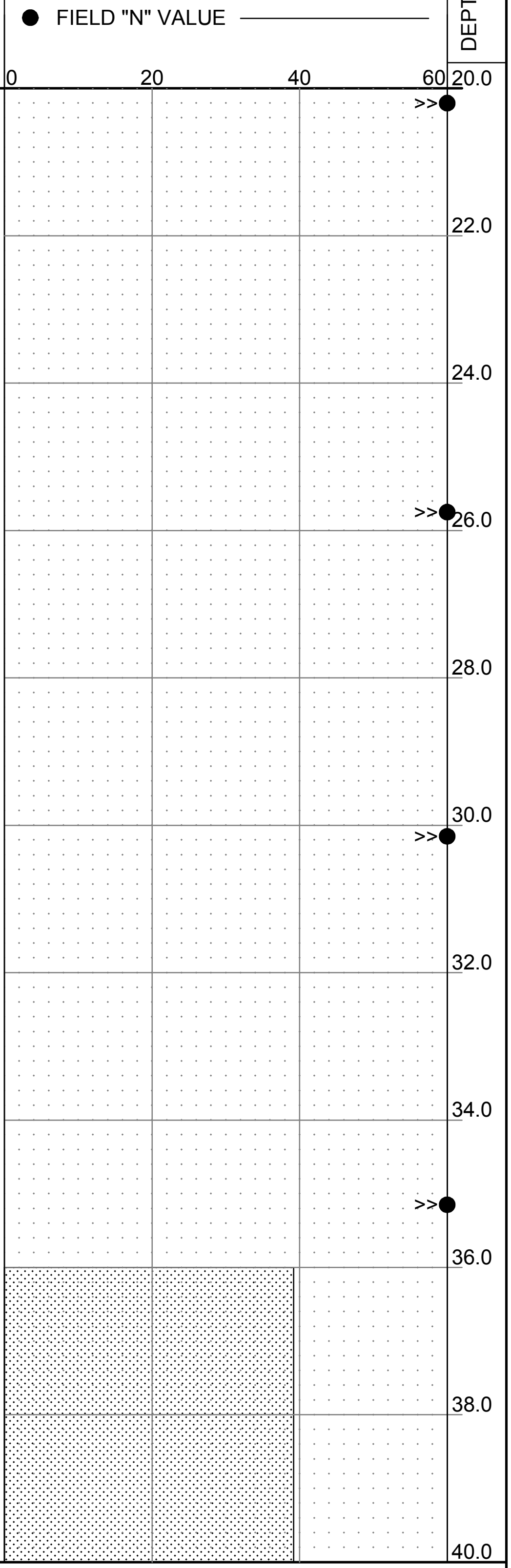
DRILL: CS1000
HAMMER:
DRILLING METHODS:

PROJECT: Denali National Park
STATION, OFFSET:

NOTES: Thermister string readings were collected on 09/02/2003.
Geologist Orion George added logging observations to core on 03/08/2017 with observations in "quotes".

TOTAL DEPTH: 55.5'

DEPTH (ft)	DESCRIPTION	SAMPLE #	FIELD BLOW COUNT (Recovery)
20.4	Tan sandy, small gravely, silt, frozen, pieces of ice visible to 0.5 inch. Approximately 90% ice. Cobbly, loose matrix, permafrost?	SPT-3	50/0.4 ft
		R-4	
25.0	85% ice, tan silty sand with a few small gravels.	SPT-4	41-25-37
26.5	Same.	R-5	
30.0 30.3	Silty sand, approximately 85% ice. Drilled like permafrost.	SPT-5	50/0.3 ft
		R-6	
35.0 35.3	0.2 ft silty sandy ice, few gravels. 0.1 ft silty sand (frozen). Same.	SPT-6 R-7	50/0.3 ft
36.0	**change to core** 0.2 ft gravel angled 0.25 ft x 0.4 ft. Green fine sandy, silty clay, few small rock fragments (damp). 4.5 ft highly weathered, very close to closely fractured, very soft rhyolite, decomposed in horizontal and vertical fractures. Rock is at freezing temperature. 0.5 ft below rock surface is a 0.25 ft decomposed zone. Bedrock.	R-8	



WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Solid Stem Auger
Rock / Soil Core
2" OD Split Spoon (SPT)

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 6/25/2003
DATE FINISHED: 6/26/2003
DRILLER: Chris Peterson
COMPANY:
LOGGER: "Orion George"
WEATHER:

BORING PLY03-1

DRILL: CS1000
HAMMER:
DRILLING METHODS:

PROJECT: Denali National Park

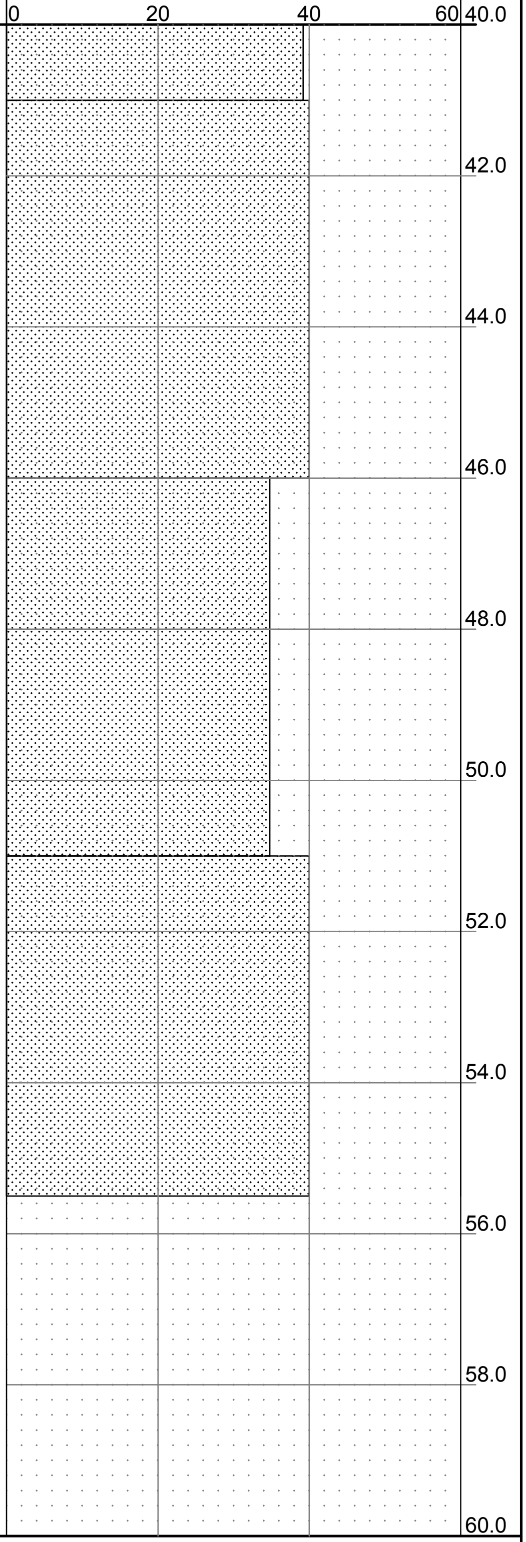
STATION, OFFSET:

NOTES: Thermister string readings were collected on 09/02/2003. Geologist Orion George added logging observations to core on 03/08/2017 with observations in "quotes".

TOTAL DEPTH: 55.5'

DEPTH (ft)	DESCRIPTION	GRAPHIC LOG	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)
41.0	Light, tan gray moderately weathered soft rock, extremely close to very close, vertical and horizontal fracturing decomposed in fractures to 0.5 inch. Added 03-08-2017: "Highly to moderately weathered very fine to fine grain prophyritic RHYOLITE flow with white clay prevalent. Alternating gray, cream flow banding observed ~30 degrees off horizontal. very close to close fractures varied from near horizaontal to vertical core axis; some with brown oxidation infilling; some oxidized fractures with evidence of movement with brecciation and generally 50 to 60 degrees off horizontal."		R-9		
46.0	Light tan-white highly weathered decomposed in fractures. Pockets of decomposition through, small voids. Last 0.5 ft is 40 to 50% of full diameter. Picked up 0.7 ft core on R-11 "Flowbanding observed"		R-10		
51.0	Highly weathered close fracturing. Decomposition in horizontal and vertical fractures. Photograph mislabeled Total Depth to 56.5 ft. Actual TD = 55.5 ft.		R-11		
55.5	**BORING TERMINATED AT A DEPTH OF 55.5 feet**				

● FIELD "N" VALUE



WATER LEVELS	
▽ WHILE DRILLING	Solid Stem Auger
▼ AT COMPLETION	Rock / Soil Core
▼ AFTER DRILLING	2" OD Split Spoon (SPT)

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 6/27/2003
DATE FINISHED: 7/1/2003
DRILLER: Chris Peterson
COMPANY:
LOGGER: "Orion George"
WEATHER:

BORING PLY03-2

DRILL: CS1000
HAMMER:
DRILLING METHODS:

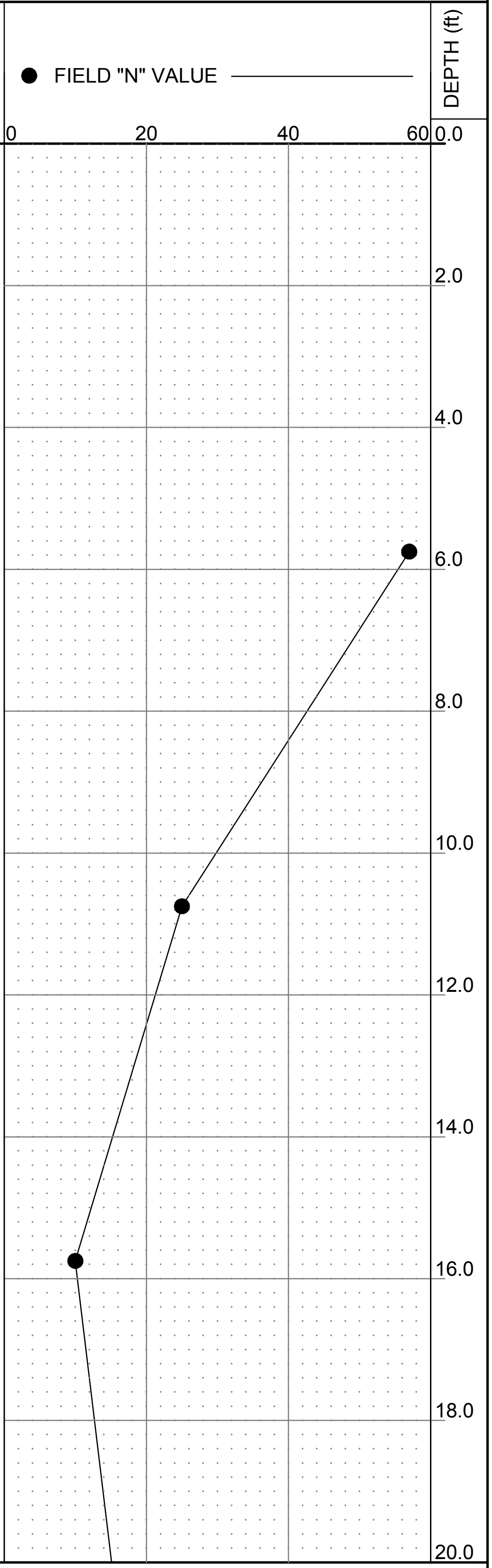
PROJECT: Denali National Park

STATION, OFFSET:

NOTES: Geologist Orion George added logging observations to core on 03-08-2017 with observations in "parentheses".

TOTAL DEPTH: 101.2'

DEPTH (ft)	DESCRIPTION	GRAPHIC LOG	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)
0.0	Gravely soils, some cobble and possible boulder, very dense.		R-1		
5.0	Brown sand, silty, gravel. Gravel is tan-cream rhyolite. Few pieces gray basalt, angular to subangular (damp). Last 0.2 ft changes to silty, sandy gravel.		SPT-1		12-25-32
6.5	More cobbles, looser matrix. Thermistor reading 31.5 degrees F at 9 ft.		R-2		
10.0	Brown and multicolored silty, sandy, gravel (damp).		SPT-2		6-13-12
11.5	Gravely cobbles in loose soil matrix. Thermistor reading 32.2 degrees F at 12 ft.		R-3		
15.0	Same, except gravel is mostly angular basalt. Thermistor reading 32.2 degrees F at 15 ft.		SPT-3		7-5-5
16.5	Same. Thermistor reading 32.2 degrees F at 18 ft.		R-4		
20.0					



WATER LEVELS	
⊻ WHILE DRILLING	Solid Stem Auger
⊻ AT COMPLETION	Rock / Soil Core
⊻ AFTER DRILLING	2" OD Split Spoon (SPT)

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 6/27/2003
DATE FINISHED: 6/1/2903
DRILLER: Chris Peterson
COMPANY:
LOGGER: "Orion George"
WEATHER:

BORING PLY03-2

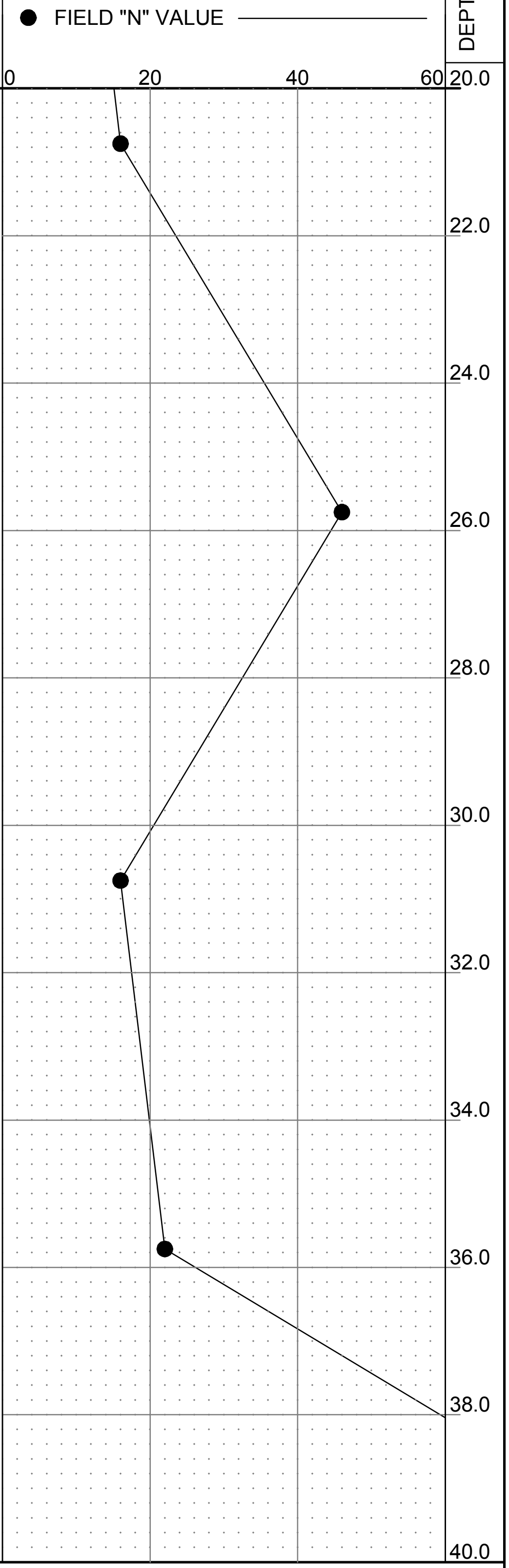
DRILL: CS1000
HAMMER:
DRILLING METHODS:

PROJECT: Denali National Park
STATION, OFFSET:

NOTES: Geologist Orion George added logging observations to core on 03-08-2017 with observations in "parentheses".

TOTAL DEPTH: 101.2'

DEPTH (ft)	DESCRIPTION	SAMPLE #	FIELD BLOW COUNT (Recovery)
20.0	Sandy, gravel, trace of silt. Gravel mostly light cream colored rhyolite. Thermistor reading 32.3 degrees F at 21 ft.	SPT-4	8-8-8
21.5	Same. Thermistor reading 32.4 degrees F at 24 ft.	R-5	
25.0	Tan silty, sandy, gravel, less gravel than last 2 SPT's.	SPT-5	13-38-8
26.5	Loose gravely soils. Thermistor reading 32.5 degrees F at 27 ft.	R-6	
30.0	Tan silty, sandy, gravel. Gravel is angular purple rhyolite. Thermistor reading 32.5 degrees F at 30 ft.	SPT-6	15-8-8
31.5	Same. Thermistor reading 32.6 degrees F at 33 ft.	R-7	
35.0	Tan-cream and multicolored silty, sandy, gravel with a trace of clay. Gravels vary purple-tan-dark gray angular to subangular. Thermistor reading 32.6 degrees F at 36 ft.	SPT-7	14-11-11
36.5	Slightly denser. Thermistor reading 32.7 degrees F at 39 ft.	R-8	
40.0			



WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Solid Stem Auger
Rock / Soil Core
2" OD Split Spoon (SPT)

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 6/27/2003
DATE FINISHED: 6/1/2903
DRILLER: Chris Peterson
COMPANY:
LOGGER: "Orion George"
WEATHER:

BORING PLY03-2

DRILL: CS1000
HAMMER:
DRILLING METHODS:

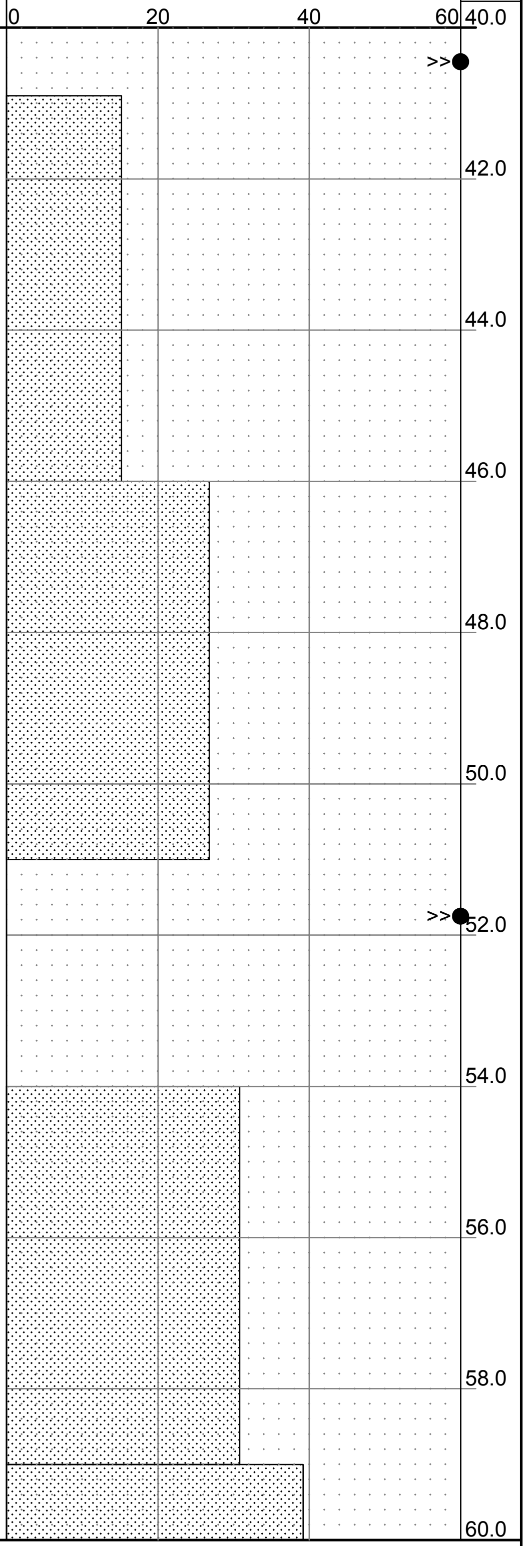
PROJECT: Denali National Park

STATION, OFFSET:

NOTES: Geologist Orion George added logging observations to core on 03-08-2017 with observations in "parentheses".

TOTAL DEPTH: 101.2'

DEPTH (ft)	DESCRIPTION	SAMPLE #	FIELD BLOW COUNT (Recovery)
	Tan silty sandy, gravel and ice. **change to core**	SPT-8	18-50/5.0 in
40.9	Tan silty, sandy gravels and a small cobble, gravels mostly. Light tan and a few purple rhyolite and a coupl small basalt gravels (frozen). Didn't recover much ice. Added 03-08-2017: "tumbled rozk at top of run. majority of material lt grayish to cream fine grain porphyritic RHYOLITE flow" Thermistor reading 32.8 degrees F at 42 ft. Thermistor reading 33.0 degrees F at 45 ft.	R-9	
46.0	Tan and multicolored silty, sandy, cobbly, gravel. Multirock type angular to subangular (frozen <10%). "As above; fractures with clay infiliing and some with brown oxidation generally oriented ~50 to 60 degrees off horizontal. At 50 ft - 51 ft vug (indeterminate size) with amber to lt green, but mostly black obsidian" Thermistor reading 33.0 degrees F at 48 ft.	R-10	
51.0	Tan silty, gravely sandy ice, core runs are minus melted ice. Thermistor reading 33.1 degrees F at 51 ft.	SPT-9	23-36-30
52.5	Tan and multicolored silty, sandy, gravel, approximately 20% ice. "54 ft - 59 ft: highly fractured with fine SAND and some coarse gravel apparently within the fractures. Majority of material fractured lt gray, fine grain porphyritic RHYOLITE flow. Interpretted as disturbed bedrock, could be boulders of rhyolite." Thermistor reading 33.1 degrees F at 54 ft. Thermistor reading 33.0 degrees F at 57 ft.	R-11 R-12	
59.0	0.6 ft sandy, silty, gravel red-tan. 4.3 ft silty, sandy, cobbly, gravel with solid ice zones to 0.6 ft. Approximately 70% ice (chipped ice out and tossed).		



WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Solid Stem Auger
Rock / Soil Core
2" OD Split Spoon (SPT)

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FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 6/27/2003
DATE FINISHED: 6/1/2903
DRILLER: Chris Peterson
COMPANY:
LOGGER: "Orion George"
WEATHER:

BORING PLY03-2

DRILL: CS1000
HAMMER:
DRILLING METHODS:

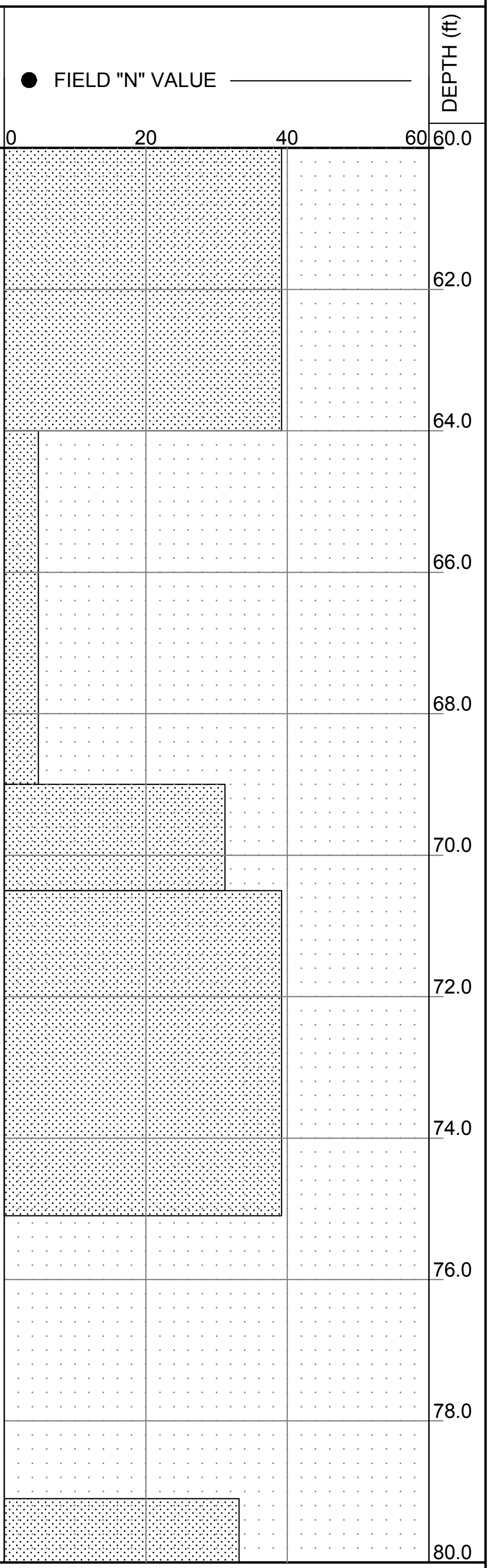
PROJECT: Denali National Park

STATION, OFFSET:

NOTES: Geologist Orion George added logging observations to core on 03-08-2017 with observations in "parentheses".

TOTAL DEPTH: 101.2'

DEPTH (ft)	DESCRIPTION	GRAPHIC LOG	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)
	"Clasts mostly lt gray flow banded RHYOLITE, some clasts are dk gray." Thermistor reading 34.1 degrees F at 60 ft. Thermistor reading 35.2 degrees F at 63 ft.		R-13		
64.0	Few gravels subrounded with trace of sandy silt on some surfaces. "color change of RHYOLITE flow to tan - lt gray" Thermistor reading 38.6 degrees F at 66 ft.		R-14		
69.0	Tan rhyolitic cobble to 0.9 ft and 0.2 ft gray-green sandy, very small gravely, silty clay. High percent clay. "Clayey SAND with dark obsidian clasts incorporated. Interpretted approximate contact of upper rhyolite flow and lower rhyolite ash flow tuff"		R-15		
70.5	0.6 ft silty, gravely, sand. 2.5 ft gray-green silty clay. 3.3 ft alternating layers of tan sandy silt and gray silty, clayey sand layers are 0.2 ft to 0.8 ft decomposed. Last 0.5 ft gray silty coarse sand, tan-rust soils, gray gravels. "Clayey, fine gravelly, coarse sand; interpretted decomposed RHYOLITE ash flow tuff" Decomposed bedrock at 71.3 ft.		R-16		
75.1	Clayey silt plugging bit and getting between inner and outer barrels, causing mislatch. "Material change to lt brown - medium dark brownish cream"		R-17		
79.1	Decomposed orange-brown, gray and multicolored breccia tuff. Decomposed to a silty sandy gravel or silty gravely sand. Gravels or harder fragments are rhyolite.				



WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Solid Stem Auger
Rock / Soil Core
2" OD Split Spoon (SPT)

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 6/27/2003
DATE FINISHED: 6/1/2903
DRILLER: Chris Peterson
COMPANY:
LOGGER: "Orion George"
WEATHER:

BORING PLY03-2

DRILL: CS1000
HAMMER:
DRILLING METHODS:

PROJECT: Denali National Park

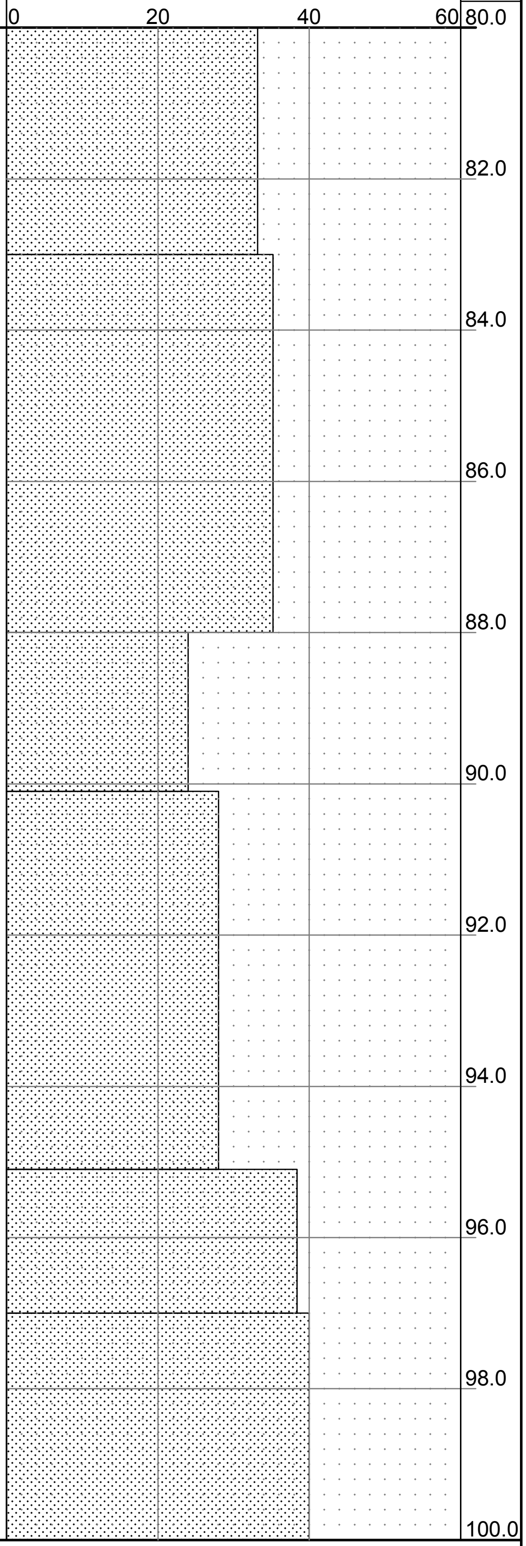
STATION, OFFSET:

NOTES: Geologist Orion George added logging observations to core on 03-08-2017 with observations in "parentheses".

TOTAL DEPTH: 101.2'

DEPTH (ft)	DESCRIPTION	GRAPHIC LOG	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)
			R-18		
83.0	Decomposed rhyolite or breccia (silty, sandy gravel). 1.7 ft highly weathered rhyolite or rhyolitic tuff. Sandy gravel. "Clear mica observed at 83 ft. High clay content with clay filled vugs"		R-19		
88.0	Highly weathered rhyolite washed away decomposed material x 0.8 ft. Some gray basalt rock flows in the rhyolite. "vugs infilled with silica and some with clay; most material appears tumbled"		R-20		
90.1	Highly weathered rhyolite or decomposed with harder fragments. Decomposed areas are tan, sandy, silty clay.		R-21		
95.1	0.6 ft decomposed tan rhyolite. 1.2 ft blue gray silty clay or clayey silt. Decomposed siltstone or mudstone. "weathered ASH (rhyolitic?) with undulating slickensided surfaces separating ~25 - 30 degrees off horizontal"		R-22		
97.0	Blue-gray decomposed mudstone. Silty clay or clayey silt. Core was pulled 0.2 ft out of end of inner barrel, weight of rods pushed string 0.3 ft into the mudstone before run started. "Last ~ 4 ft core weathered porphytic RHYOLITE ash flow tuff"		R-23		

● FIELD "N" VALUE ———



WATER LEVELS	
▽ WHILE DRILLING	Solid Stem Auger
▼ AT COMPLETION	Rock / Soil Core
▼ AFTER DRILLING	2" OD Split Spoon (SPT)

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FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 6/27/2003
DATE FINISHED: 6/1/2903
DRILLER: Chris Peterson
COMPANY:
LOGGER: "Orion George"
WEATHER:

BORING PLY03-2

DRILL: CS1000
HAMMER:
DRILLING METHODS:

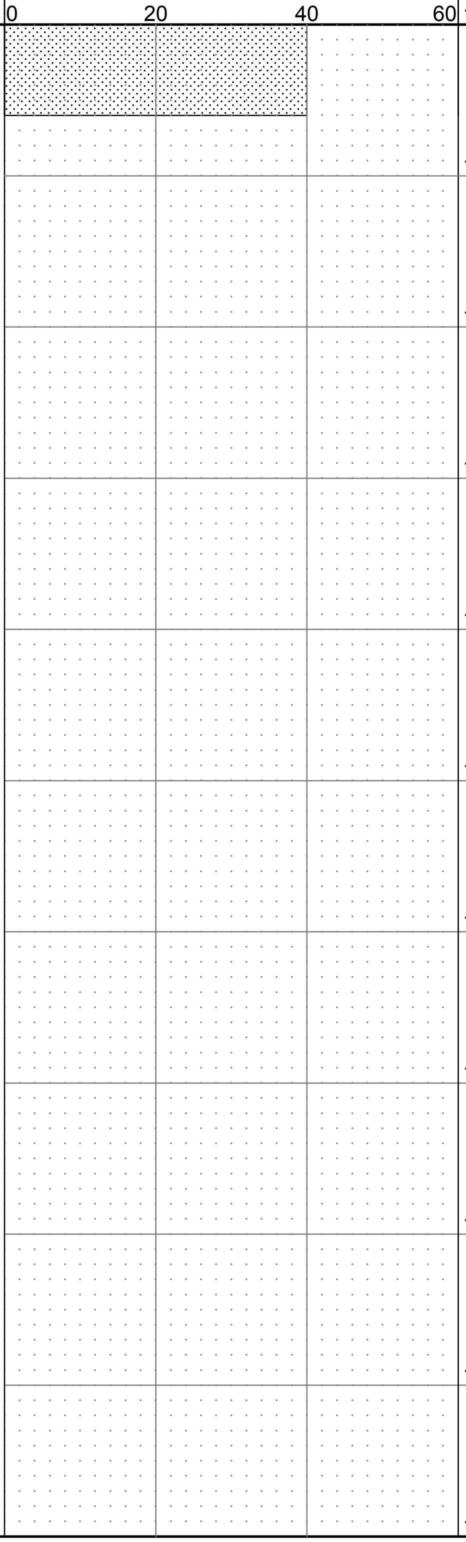
PROJECT: Denali National Park

STATION, OFFSET:

NOTES: Geologist Orion George added logging observations to core on 03-08-2017 with observations in "parentheses".

TOTAL DEPTH: 101.2'

DEPTH (ft)	DESCRIPTION	GRAPHIC LOG	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)	● FIELD "N" VALUE	DEPTH (ft)
				⌸			100.0
101.2	**BORING TERMINATED AT A DEPTH OF 101.2 ft**						
							102.0
							104.0
							106.0
							108.0
							110.0
							112.0
							114.0
							116.0
							118.0
							120.0



WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

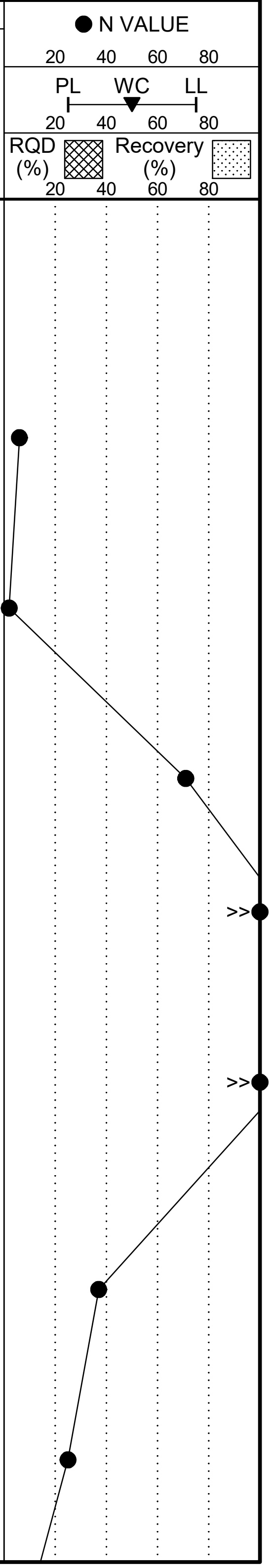
- Solid Stem Auger
- ⌸ Rock / Soil Core
- 2" OD Split Spoon (SPT)

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-01

Project Name: Pretty Rocks
Sheet: 1 of 6
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3620 ft
Datum: MSL
Groundwater Depth:
Date Started: 7/19/18
Date Completed: 7/23/18
While Drilling: ---
Driller/Company: Tim Beckner/Geotek Alaska
Drill CME-75
At Completion: ---
Hammer Type: 340 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Orion George
Notes:
Weather: Overcast
VWP (S/N: 1814517); SAAV installed in 3.34" SI casing to 95'; thermistor to 100'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	SAMPLE Test Results
		Well graded SAND with gravel, loose, light brown to tan, moist, medium sand, angular, rhyolite clasts predominant, gravel ~ 45% with some silt, geotextile at 2.9'. 52.5° F measured	6.25" ID	☒	S01	4-3-3-2 (9" = 38%)	
3615	5	Very loose, rounded, cobble up to 4".		☒	S02	3-1-1-2 (0" = 0%)	
		7.5 ft / El. 3612.5 ft Well graded SAND with silt and gravel, very dense, brown gray, moist, medium sand, rounded. 50.5° F measured		☒	S03	15-26-45-43 (25" = 104%)	
3610	10	Dry. 44.2° F measured		☒	S04	30-50/5" (12" = 109%)	
		12.5 ft / El. 3607.5 ft Well graded SAND with gravel, very dense, brown gray, dry, coarse gravel, rounded. 44.5° F measured		☒	S05	40-50/5" (12" = 109%)	
3605	15	Dense, cobbles likely. 43.4° F measured		☒	S06	12-19-18-11 (15" = 63%)	
		Medium dense, boulders likely.		☒	S07	7-10-15-12 (14" = 58%)	
		20 ft / El. 3600 ft					

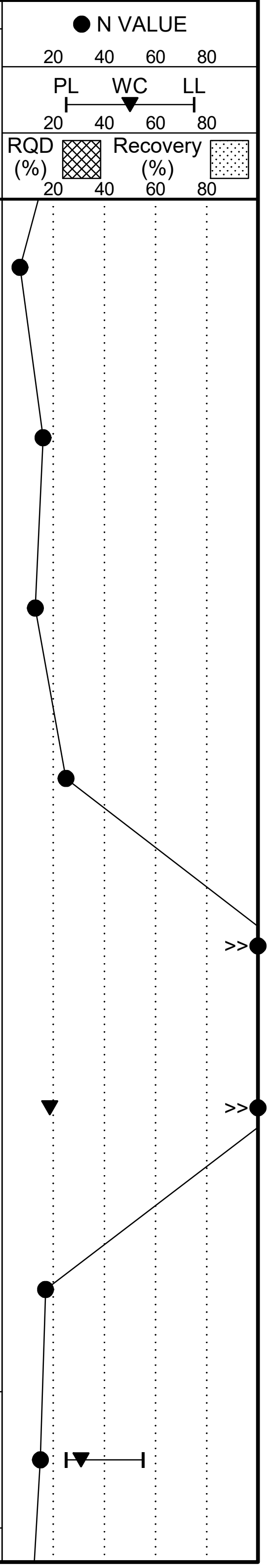


U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-01

Project Name: Pretty Rocks
Sheet: 2 of 6
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3620 ft
Datum: MSL
Groundwater Depth:
Date Started: 7/19/18
Date Completed: 7/23/18
While Drilling: ---
Driller/Company: Tim Beckner/Geotek Alaska
Drill CME-75
At Completion: ---
Hammer Type: 340 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Orion George
Notes:
Weather: Overcast
VWP (S/N: 1814517); SAAV installed in 3.34" SI casing to 95'; thermistor to 100'

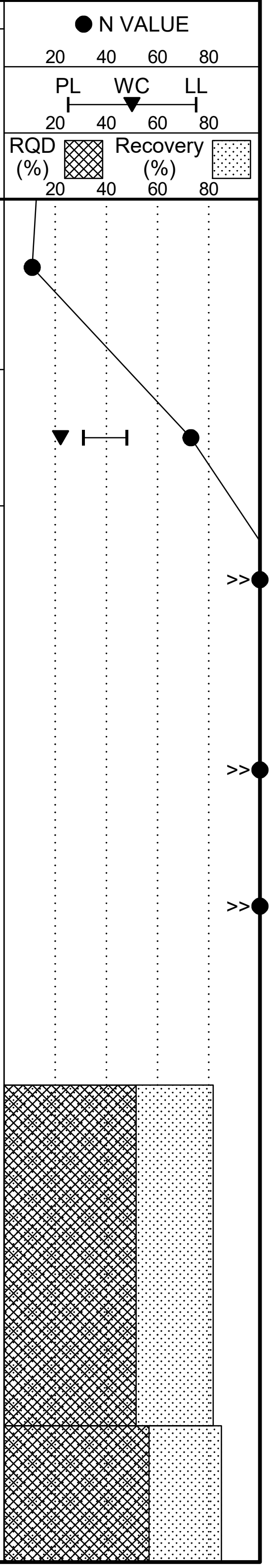
Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
		Poorly graded GRAVEL with sand, loose, orange tan, dry, fine gravel, angular, cobbles and boulders likely. 47.1° F measured	6.25" ID		S08	5-3-4-4 (18" = 75%)	
		22.8 ft / El. 3597.2 ft					
		Poorly graded SAND with gravel, medium dense, light tan, dry, medium sand, angular, cobbles and boulders likely. 48.5° F measured			S09	6-8-8-8 (11" = 46%)	
3595	25						
		46.4° F measured			S10	7-7-6-8 (9" = 38%)	
		50.5° F measured			S11	41-17-8-6 (12" = 50%)	
		30 ft / El. 3590 ft					
3590	30	Clayey SAND with gravel, very dense, dark brown to light gray, moist, fine sand, angular, no dilatancy, high toughness, high plasticity. 30.4 ft / El. 3589.6 ft			S12	4-17-49-50/5" (24" = 104%)	
		Poorly graded GRAVEL with sand, very dense, beginning at 30.4', massive interstitial irregularly oriented ice inclusions observed, ~ 60% visible ice, hard, and clear to colorless.. 31.1° F measured Clay likely, ~ 40% visible ice, hard, clear to cloudy.			S13	3-26-35-50/2" (23" = 115%)	
		30.6° F measured					
3585	35	Medium dense. 35.5 ft / El. 3584.5 ft					
		Poorly graded SAND with clay, medium dense, light gray to black, medium sand, angular, perlitic obsidian, frozen, well bonded with some excessive visible ice (< 5%). 35.5' - 36.6' preserved in freezer ¿BDRX? perlite obsidian 30.4° F measured 37.5 ft / El. 3582.5 ft			S14	4-6-11-8 (24" = 100%)	
		Clayey SAND (SC), medium dense, light gray to black, medium sand, angular, massive irregular oriented ice, ~ 40% visible, hard, clear to cloudy. 30.8° F measured 38.6' - 39.5' preserved in freezer			S15	2-6-9-10 (22" = 92%)	Fines = 41% SG = 2.50



BORING LOG PR18-01

Project Name: Pretty Rocks
Sheet: 3 of 6
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3620 ft
Datum: MSL
Groundwater Depth:
Date Started: 7/19/18
Date Completed: 7/23/18
While Drilling: ---
Driller/Company: Tim Beckner/Geotek Alaska
Drill CME-75
At Completion: ---
Hammer Type: 340 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Orion George
Notes:
Weather: Overcast
VWP (S/N: 1814517); SAAV installed in 3.34" SI casing to 95'; thermistor to 100'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
		40.5 ft / El. 3579.5 ft Poorly graded SAND with clay and gravel, medium dense, black to light tan with light olive, moist, medium sand, angular, no dilatancy, high toughness, high plasticity, residual RHYOLITE lapilli tuff and volcanic ash is highly to completely weathered extremely to very weak rock (R0 - R1) below 41.2'. 30.6° F measured	6.25" ID		S16	8-5-6-18 (24" = 100%)	40.5' - 41.2' perlite obsidian
		42.5 ft / El. 3577.5 ft Silty SAND with gravel (SM), very dense, light olive gray with black, interbedded with brittle and highly fractured perlite obsidian, very weak rock (R1). 34.3° F measured			S17	7-23-50 (18" = 75%)	Fines = 25% SG = 2.56
3575	45	45 ft / El. 3575 ft Poorly graded SAND, very dense, dark gray to black with light tan, dry, primarily perlite obsdian interbedded with fine beds of rhyolite ash completely weathered to fat clay, very weak rock (R1).			S18	28-44-50/2" (16" = 114%)	
					S19	24-25-33-50/3" (23" = 110%)	
3570	50				S20	2-50/3" (4" = 44%)	
		53 ft / El. 3567 ft Silty SAND (SM), dense, olive tan to light gray, dry, fine sand, no dilatancy, high toughness, high plasticity, residual RHYOLITE volcanic ash is highly to completely weathered, extremely to very weak rock (R0 - R1). Fine grained grained, bedded. Discontinuities are moderately spaced and in fair condition, bedding range from 45 - 75 degrees from assumed horizontal, Teklanika Volcanics.	HQ, compressed air		R-1	Rec = 82% RQD = 52%	
3565	55						
		Bluish greenish grey. joint/fractures range from 55 - 60 degrees from assumed horizontal.					

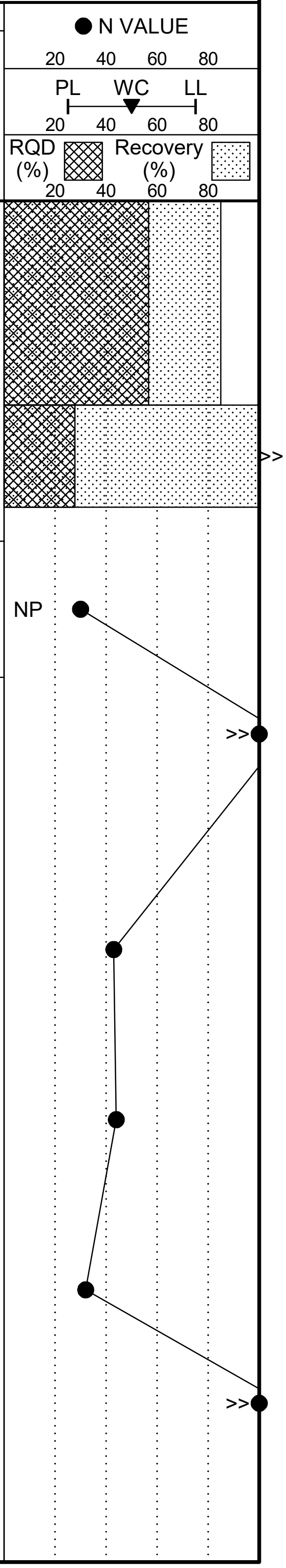


U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-01

Project Name: Pretty Rocks
Sheet: 4 of 6
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3620 ft
Datum: MSL
Groundwater Depth:
Date Started: 7/19/18
Date Completed: 7/23/18
While Drilling: ---
Driller/Company: Tim Beckner/Geotek Alaska
Drill CME-75
At Completion: ---
Hammer Type: 340 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Orion George
Notes:
Weather: Overcast
VWP (S/N: 1814517); SAAV installed in 3.34" SI casing to 95'; thermistor to 100'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
		Silty SAND (SM), dense, olive tan to light gray, dry, fine sand, no dilatancy, high toughness, high plasticity, residual RHYOLITE volcanic ash is highly to completely weathered, extremely to very weak rock (R0 - R1). Fine grained grained, bedded. Discontinuities are moderately spaced and in fair condition, bedding range from 45 - 75 degrees from assumed horizontal, Teklanika Volcanics. *(continued)* Bedding.	HQ, compressed air	R-2	Rec = 85% RQD = 57%	
				R-3	Rec = 139% RQD = 28%	
		"bit getting clogged and rods getting stuck"		R-4	Rec = 0% RQD = 0%	
3555	65	With perlitic obsidian. switch to tri-cone with air	tri-cone, compressed air	S21	8-11-19-35 (24" = 100%)	Fines = 38% SG = 2.67
				S22	13-50/2" (12" = 150%)	
3550	70			S23	18-18-25-46 (25" = 104%)	
		Flow banded. bedding.		S24	9-18-26-43 (25" = 104%)	
3545	75	Light olive.		S25	12-14-18-35 (25" = 104%)	
		77.5 ft / El. 3542.5 ft RHYOLITE, light brown with black, fine grained grained, highly weathered, flow banded. similar to outcrop above road.		S26	50/4" (4" = 100%)	



BORING LOG PR18-01

Project Name: Pretty Rocks
Sheet: 5 of 6
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3620 ft
Datum: MSL
Groundwater Depth:
Date Started: 7/19/18
Date Completed: 7/23/18
While Drilling: ---
Driller/Company: Tim Beckner/Geotek Alaska
Drill CME-75
At Completion: ---
Hammer Type: 340 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Orion George
Notes:
Weather: Overcast
VWP (S/N: 1814517); SAAV installed in 3.34" SI casing to 95'; thermistor to 100'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	SAMPLE Test Results	● N VALUE
		RHYOLITE, light brown with black, fine grained grained, highly weathered, flow banded. similar to outcrop above road. *(continued)*		☒	S27	50/3" (2" = 67%)		>>●
		White and grey, moderately weathered, very weak rock (R1) to weak rock (R2). Discontinuities are very closely spaced to closely spaced.	HQ, compressed air		R-5	Rec = 75% RQD = 0%		
3535	85				R-6	Rec = 30% RQD = 0%	seams up to 0.5" of clayey sand, moist, brown, high plasticity	
			tri-cone					
3530	90	With orange.			S28	50/0"		>>●
			HQ, compressed air		R-7	Rec = 52% RQD = 0%		
3525	95	95.5 ft / El. 3524.5 ft						
		Fat CLAY, very stiff, blue gray, dry, high plasticity. 96 ft / El. 3524 ft			R-8	Rec = 73% RQD = 0%		
		Slightly weathered to moderately weathered, weak rock (R2). Discontinuities are in poor condition, disconinuities filled with clayey sand < 0.25" thick.			R-9	Rec = 100% RQD = 0%		

PL WC LL 20 40 60 80
RQD (%) ▩ Recovery (%) ░ 20 40 60 80

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FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-01

Project Name: Pretty Rocks
Sheet: 6 of 6
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3620 ft
Datum: MSL
Groundwater Depth:
Date Started: 7/19/18
Date Completed: 7/23/18
While Drilling: ---
Driller/Company: Tim Beckner/Geotek Alaska
Drill CME-75
At Completion: ---
Hammer Type: 340 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Orion George
Notes:
Weather: Overcast
VWP (S/N: 1814517); SAAV installed in 3.34" SI casing to 95'; thermistor to 100'

Elevation (ft)	Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	SAMPLE Test Results	● N VALUE 20 40 60 80 PL WC LL 20 40 60 80 RQD (%) ▨ Recovery (%) ░ 20 40 60 80
				HQ, compressed air					
						R-10	Rec = 100% RQD = 0%		
3515	105								
						R-11	Rec = 78% RQD = 0%		
			109 ft / El. 3511 ft						

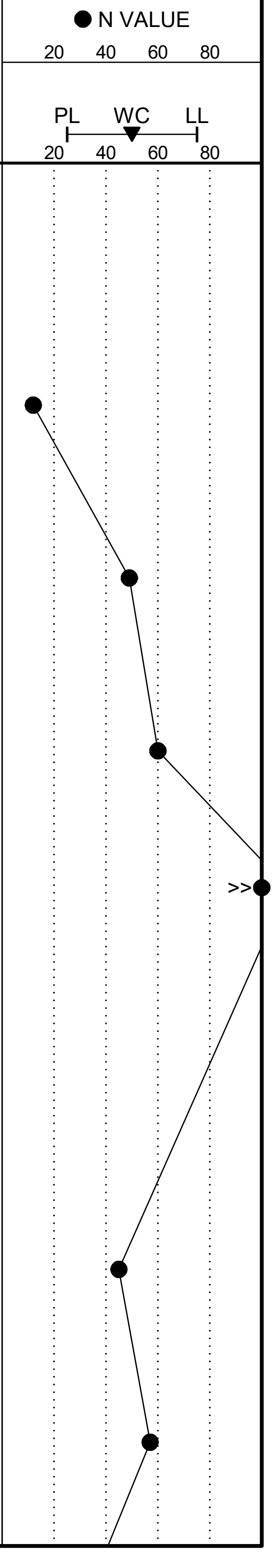
Bottom of borehole at 109 ft.

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-02

Project Name: Pretty Rocks
Sheet: 1 of 8
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3620 ft
Datum: MSL
Groundwater Depth:
While Drilling: ---
At Completion: ---
After Drilling: --- No groundwater encountered
Date Started: 7/11/18
Date Completed: 7/17/18
Driller/Company: Tim Beckner/Geotek Alaska
Drill CME-75
Hammer Type: 340 lbs Automatic
Logger/Company: Orion George
Weather: Rain
Notes:
VWP (S/N: 1816098); SAAV installed in 3.34" SI casing to 114'; thermistor string to 120'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery)	SAMPLE Test Results
		2.5 ft / El. 3617.5 ft					
		Well graded SAND with gravel, medium dense, gray, dry, fine sand, angular, trace silt, cobble likely. Colluvium.		☒	S01	4-7-5-4 (1" = 4%)	
3615	5	Very dense, some silt.		☒	S02	5-21-28-15 (24" = 100%)	
				☒	S03	25-30-30-23 (24" = 100%)	
3610	10	Increasing silt.	6.25" ID	☒	S04	17-50/6" (16" = 139%)	
				☒	S05	50 (5" = 45%)	
3605	15	Dense, increasing gravel.		☒	S06	20-22-23-26 (24" = 100%)	
		Very dense.		☒	S07	17-31-26-25 (24" = 100%)	



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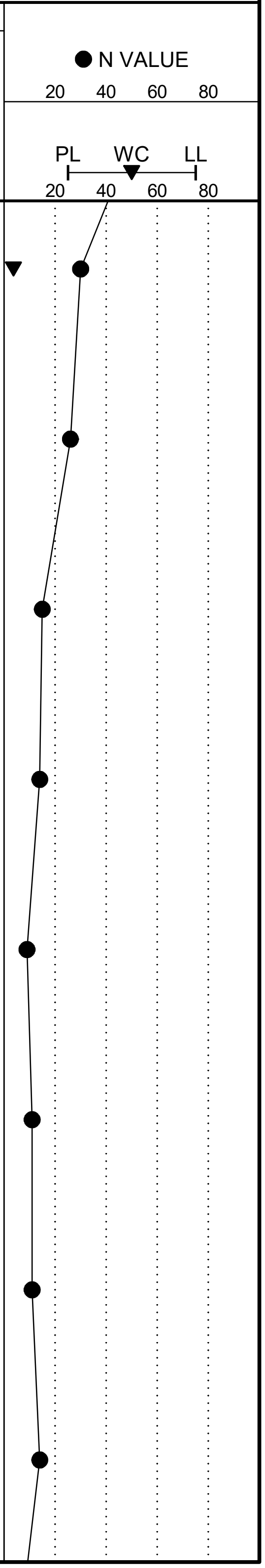
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-02

Project Name: Pretty Rocks
Sheet: 2 of 8
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3620 ft
Datum: MSL
Groundwater Depth:
Date Started: 7/11/18
Date Completed: 7/17/18
While Drilling: ---
Driller/Company: Tim Beckner/Geotek Alaska
Drill CME-75
At Completion: ---
Hammer Type: 340 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Orion George
Notes:
Weather: Rain
VWP (S/N: 1816098); SAAV installed in 3.34" SI casing to 114'; thermistor string to 120'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery)	SAMPLE Test Results
		Well graded SAND with gravel, medium dense, gray, dry, fine sand, angular, trace silt, cobble likely. Colluvium. *(continued)* Medium dense, tan, moist, becoming angular, mostly rhyolite with some basalt incorporated.	6.25" ID		S08	7-17-13-11 (22" = 92%)	
		Out of rhyolite.			S09	7-15-11-11 (20" = 83%)	
3595	25	No recovery.			S10	4-9-6-6 (0" = 0%)	
		Rhyolite cobbles up to 0.7'. 28.6 ft / El. 3591.4 ft Poorly graded GRAVEL with clay and sand, medium dense, brown with tan, moist, fine sand, angular, slow dilatancy, high toughness, high plasticity, cobbles likely. Landslide debris.			S11	3-7-7-4 (17" = 71%)	
3590	30	Loose. 40.8° F measured			S12	3-4-5-5 (14" = 58%)	
		Medium dense, with few obsidian clasts. 39.8° F measured			S13	6-6-5-6 (16" = 67%)	
3585	35	Rhyolite boulders and cobbles likely. 46.5° F measured			S14	3-6-5-8 (17" = 71%)	
		Purple and red clasts incorporated. 43.5° F measured 40 ft / El. 3580 ft			S15	7-8-6-6 (16" = 67%)	



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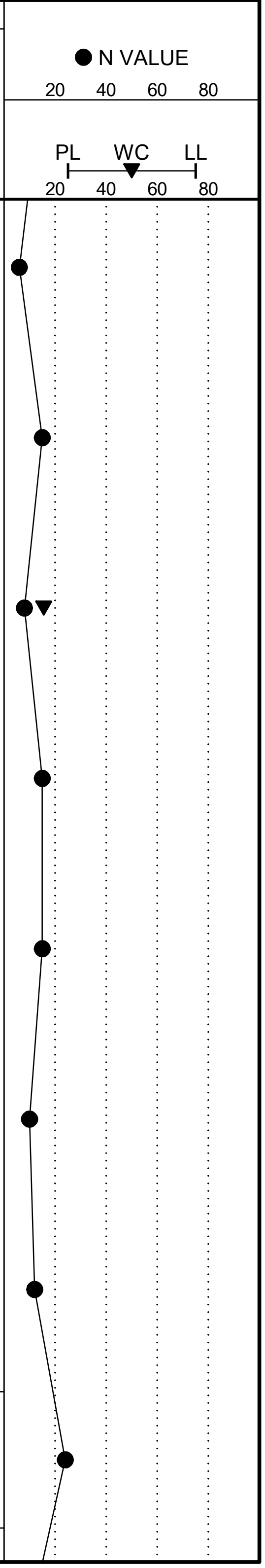
BORING LOG PR18-02

Project Name: Pretty Rocks
Sheet: 3 of 8
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3620 ft
Datum: MSL
Groundwater Depth:
Date Started: 7/11/18
Date Completed: 7/17/18
While Drilling: ---
Driller/Company: Tim Beckner/Geotek Alaska
Drill CME-75
At Completion: ---
Hammer Type: 340 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Orion George
Notes:
Weather: Rain
VWP (S/N: 1816098); SAAV installed in 3.34" SI casing to 114'; thermistor string to 120'

Elevation (ft)	Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery)	SAMPLE Test Results
			Clayey SAND with gravel, loose, brown with gray and tan, wet, coarse gravel, angular, no dilatancy, high toughness, high plasticity, with obsidian clasts, cobble likely. Landslide debris. 49.5° F measured	6.25" ID	☒	S16	2-2-4-7 (14" = 58%)	
			Medium dense, moist, boulders likley. 42.9° F measured		☒	S17	4-8-7-5 (20" = 83%)	
3575	45		38.5° F measured		☒	S18	2-4-4-4 (17" = 71%)	
			39.3° F measured		☒	S19	9-7-8-7 (18" = 75%)	
3570	50		37.9° F measured		☒	S20	2-5-10-7 (18" = 75%)	
			Loose. 42.5° F measured		☒	S21	1-5-5-5 (16" = 67%)	
3565	55		Medium dense. 38.0° F measured		☒	S22	3-4-8-8 (22" = 92%)	
			41.8° F measured		☒	S23	6-8-16-10 (21" = 88%)	sample split in S23a and S23b for gradation



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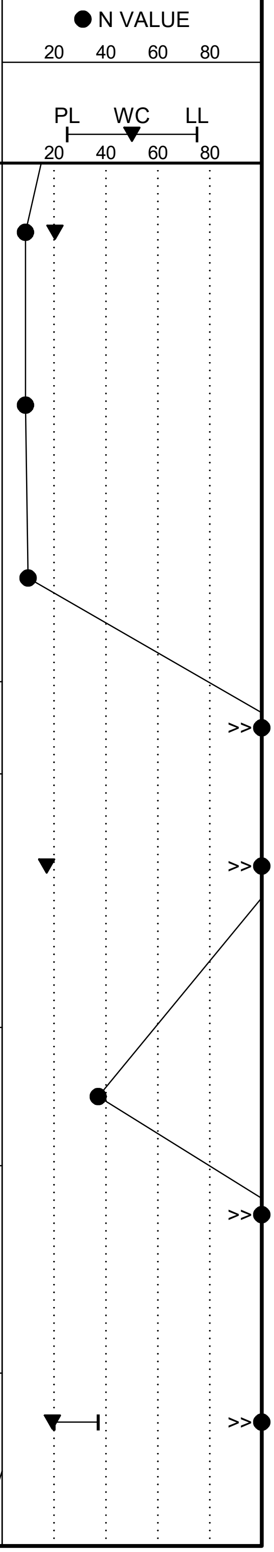
BORING LOG PR18-02

Project Name: Pretty Rocks
Sheet: 4 of 8
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3620 ft
Datum: MSL
Groundwater Depth:
Date Started: 7/11/18
Date Completed: 7/17/18
While Drilling: ---
Driller/Company: Tim Beckner/Geotek Alaska
Drill CME-75
At Completion: ---
Hammer Type: 340 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Orion George
Notes:
Weather: Rain
VWP (S/N: 1816098); SAAV installed in 3.34" SI casing to 114'; thermistor string to 120'

Elevation (ft)	Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	No.	Field Blow Count (Recovery)	Test Results
			Clayey SAND with gravel, loose, brown with gray and tan, wet, coarse gravel, angular, no dilatancy, high toughness, high plasticity, with obsidian clasts, cobble likely. Landslide debris. *(continued)* Loose.	6.25" ID	☒	S24	3-4-5-6 (20" = 83%)	
			41.0° F measured		☒	S25	4-5-4-5 (14" = 58%)	
3555	65		65 ft / El. 3555 ft Poorly graded GRAVEL with clay and sand, loose, light brown, coarse gravel, angular, no dilatancy, high toughness, high plasticity. 39.7° F measured		☒	S26	2-5-5-4 (12" = 50%)	
			Very dense. Beginning at 67.8', massive interstitial irregularly oriented ice inclusions observed, ~70% visible ice, hard, and clear to colorless. 31.5° F measured		☒	S27	12-19-50/4" (21" = 131%)	68.0' to 69.1' separated & frozen
3550	70		At 70' no ice observed		☒	S28	50/4" (4" = 100%)	
			72.5 ft / El. 3547.5 ft Clayey SAND with gravel (SC), dense, brown, coarse sand, angular, no dilatancy, high toughness, high plasticity, ~60% visible ice.. 29.7° F measured		☒	S29	7-13-24-30 (18" = 75%)	73.7' to 74.0' separated & frozen
3545	75		~40% visible ice.. 30.5° F measured		☒	S30	50/5" (5" = 100%)	
			30.1° F measured		☒	S31	16-22-50/5" (21" = 124%)	Fines = 15% SG = 2.53 77.5' to 78.7' separated & frozen



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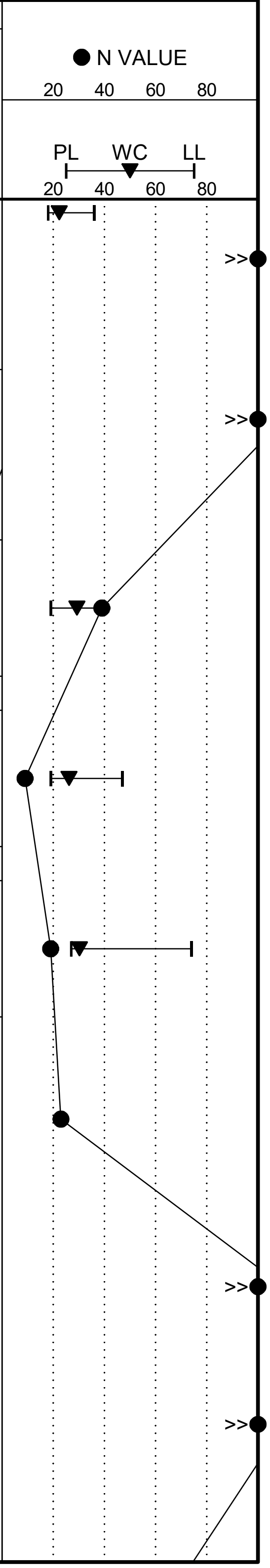
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-02

Project Name: Pretty Rocks
Sheet: 5 of 8
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3620 ft
Datum: MSL
Groundwater Depth:
While Drilling: ---
At Completion: ---
After Drilling: --- No groundwater encountered
Date Started: 7/11/18
Date Completed: 7/17/18
Driller/Company: Tim Beckner/Geotek Alaska
Drill CME-75
Hammer Type: 340 lbs Automatic
Logger/Company: Orion George
Weather: Rain
Notes:
VWP (S/N: 1816098); SAAV installed in 3.34" SI casing to 114'; thermistor string to 120'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	No.	Field Blow Count (Recovery)	Test Results
		80.2 ft / El. 3539.8 ft Clayey GRAVEL with sand (GC), very dense, brown, fine gravel, angular, massive interstitial irregularly and stratified oriented ice inclusions, ~70% visible ice. 29.9° F measured	6.25" ID	☒	S32	28-26-36-50/3" (22" = 105%)	Fines = 17% SG = 2.60
		~45% visible ice, 83.5' to 84.0' of sample melted: ~30% supernatant water. 30.4° F measured		☒	S33	22-48-50/6" (19" = 109%)	83.5' to 84.0' melted with ~30% supernatant water
3535	85	85 ft / El. 3535 ft Clayey SAND with gravel (SC), dense, brown, coarse sand, angular, ~35% visible ice. 29.9° F measured		☒	S34	12-21-18-11 (24" = 100%)	Fines = 15% SG = 2.61 85.9' to 87.0' separated & frozen
		88.4 ft / El. 3531.6 ft Fat CLAY with sand, stiff, gray to light olive gray, fine sand, no dilatancy, high toughness, high plasticity, frozen with no visible ice, well bonded, no excess ice. VOLCANIC ASH. 29.9° F measured		☒	S35	3-3-6-6 (18" = 75%)	88.4' to 89.5' separated & frozen
3530	90	90 ft / El. 3530 ft Clayey SAND (SC), medium dense, blue gray, dry, fine sand, not frozen. 35.9° F measured		☒	S36	5-7-12-23 (24" = 100%)	Fines = 38% SG = 2.62
		Small white specs < 1 mm appear to be relict bedrock texture altered to clay. 39.4° F measured	tri-cone, compressed air	☒	S37	5-10-13-25 (26" = 108%)	
3525	95	Steeply dipping relict structure observed, zones of less clayey alteration. 37.8° F measured		☒	S38	6-11-18-50/5" (24" = 104%)	
		96.8 ft / El. 3523.2 ft Clayey SAND with gravel, very dense, light gray, dry, medium sand, angular, no dilatancy, high toughness, high plasticity, VOLCANIC ASH. 38.1° F measured		☒	S39	23-50/6" (10" = 87%)	

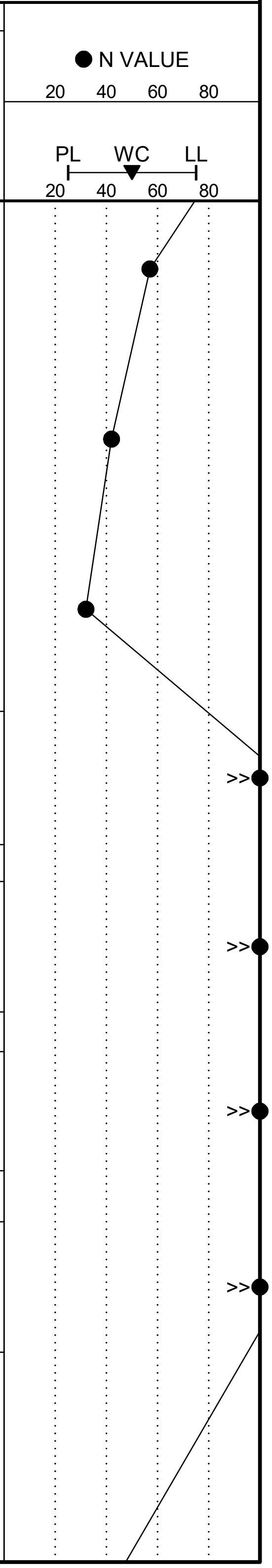


U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-02

Project Name: Pretty Rocks
Sheet: 6 of 8
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3620 ft
Datum: MSL
Groundwater Depth:
While Drilling: ---
At Completion: ---
After Drilling: --- No groundwater encountered
Date Started: 7/11/18
Date Completed: 7/17/18
Driller/Company: Tim Beckner/Geotek Alaska
Drill CME-75
Hammer Type: 340 lbs Automatic
Logger/Company: Orion George
Weather: Rain
Notes:
VWP (S/N: 1816098); SAAV installed in 3.34" SI casing to 114'; thermistor string to 120'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery)	SAMPLE Test Results
		Clayey SAND with gravel, very dense, light gray, dry, medium sand, angular, no dilatancy, high toughness, high plasticity, VOLCANIC ASH. *(continued)* 39.3° F measured	tri-cone, compressed air		S40	13-20-37-44 (24" = 100%)	
		103.1 ft / El. 3516.9 ft Sandy fat CLAY with gravel, very stiff, gray, dry, fine gravel, angular, no dilatancy, high toughness, high plasticity, gravel clasts are vesicular basalt. VOLCANIC ASH. 40.1° F measured			S41	15-18-24-28 (24" = 100%)	
3515	105	105 ft / El. 3515 ft Fat CLAY with sand, very stiff, gray to olive gray, dry, medium sand, no dilatancy, high toughness, high plasticity, stratified, bedding observable. VOLCANIC ASH.			S42	6-10-22-31 (26" = 108%)	
		Moist.			S43	9-18-21-50/6" (25" = 106%)	stored in core box
3510	110				S44	(6" = 100%)	
					S45	13-21-32-50/5" (25" = 109%)	stored in core box
		112.5 ft / El. 3507.5 ft Sandy fat CLAY with gravel, very stiff, gray, dry, fine gravel, no dilatancy, high toughness, high plasticity, VOLCANIC ASH.			S46	16-23-40-50/3" (25" = 119%)	stored in core box
3505	115				S47	11-21-31-50/5" (25" = 109%)	stored in core box

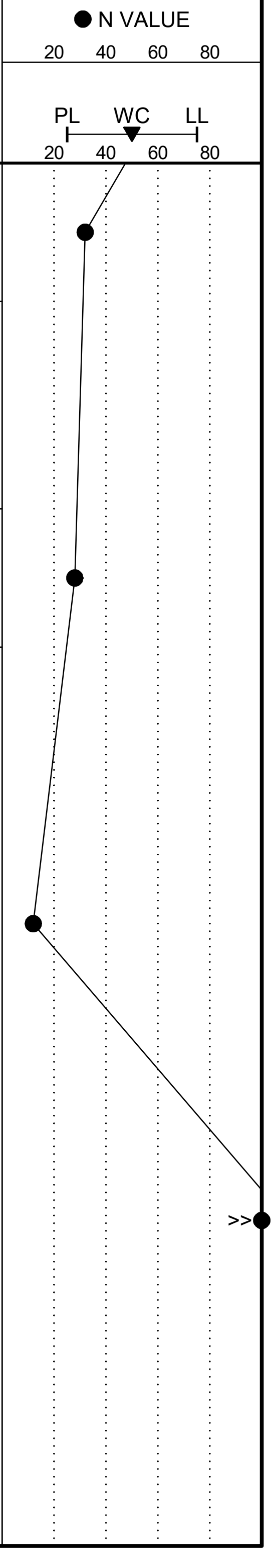


U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-02

Project Name: Pretty Rocks
Sheet: 7 of 8
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3620 ft
Datum: MSL
Groundwater Depth:
Date Started: 7/11/18
Date Completed: 7/17/18
While Drilling: ---
Driller/Company: Tim Beckner/Geotek Alaska
Drill CME-75
At Completion: ---
Hammer Type: 340 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Orion George
Notes:
Weather: Rain
VWP (S/N: 1816098); SAAV installed in 3.34" SI casing to 114'; thermistor string to 120'

Elevation (ft)	Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery)	SAMPLE Test Results
			Sandy fat CLAY with gravel, very stiff, gray, dry, fine gravel, no dilatancy, high toughness, high plasticity, VOLCANIC ASH. *(continued)* Dark gray, stratified, bedding observed at 75° from horizontal.	tri-cone, compressed air	☒	S48	7-13-19-44 (25" = 104%)	stored in core box
3495	125				☒	S49	5-8-20-35 (25" = 104%)	stored in core box
3490	130		Stiff, moist.		☒	S50	3-5-7-14 (25" = 104%)	
3485	135		Very stiff, dry.		☒	S51	12-50/1" (15" = 214%)	



U. S. DEPARTMENT OF TRANSPORTATION
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FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-02

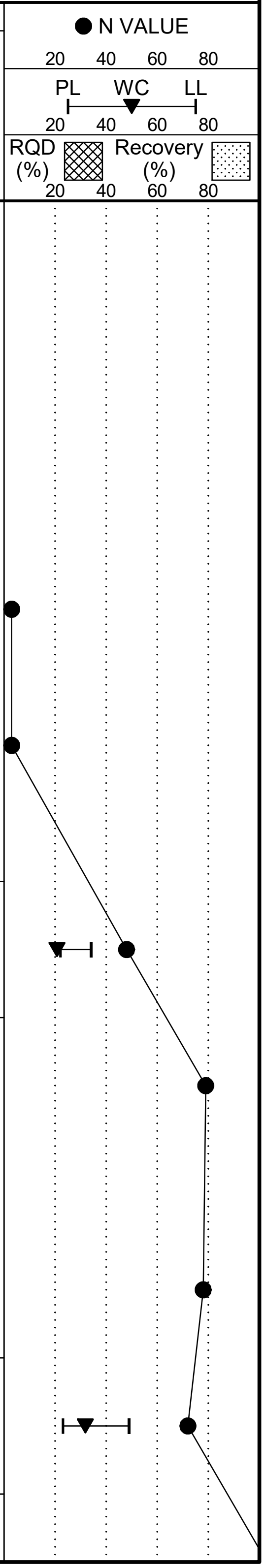
Project Name: Pretty Rocks
Sheet: 8 of 8
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3620 ft
Datum: MSL
Groundwater Depth:
Date Started: 7/11/18
Date Completed: 7/17/18
While Drilling: ---
Driller/Company: Tim Beckner/Geotek Alaska
Drill CME-75
At Completion: ---
Hammer Type: 340 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Orion George
Notes:
Weather: Rain
VWP (S/N: 1816098); SAAV installed in 3.34" SI casing to 114'; thermistor string to 120'

Elevation (ft)	Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery)	SAMPLE Test Results	● N VALUE 20 40 60 80 PL WC LL 20 40 60 80
			140.3 ft / El. 3479.7 ft		☒	S52	50/4" (4" = 100%)		>>●
			Bottom of borehole at 140.3 ft.						

BORING LOG PR18-03

Project Name: Pretty Rocks
Sheet: 1 of 6
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3581 ft
Datum: MSL
Groundwater Depth:
Date Started: 7/27/18
Date Completed: 7/30/18
While Drilling: ---
Driller/Company: Travis Drewery/Geotek Alaska
Drill Geoprobe 6620 DT
At Completion: ---
Hammer Type: 140 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Brian Collins
Notes:
VWP (S/N: 1814519); SAAV installed in 3.34" SI casing to 95';
thermistor string to 96'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
3580		2.5 ft / El. 3578.5 ft	6.25" ID				
		COBBLES, Clayey SAND, brown and white, moist, angular, mostly cobbles with boulders up to 3', mostly rhyolite clasts. Colluvium.					
	5	Very loose.					
3575				⧗	S1	2-1-2-3 (9" = 38%)	
				⧗	S2	2-3-0-0 (2" = 8%)	
		9 ft / El. 3572 ft					
	10	Clayey SAND with gravel (SC), dense, brown, moist, medium sand, angular, soil unfrozen, but 1" layers of ice and individual ice inclusions, 32.5° measured.					
3570				⧗	S3	9-23-25-42 (24" = 100%)	Fines = 13% SG = 2.55
		Very dense, 37° F measured.		⧗	S4	27-45-34-37 (24" = 100%)	
	15	35° F measured.					
3565				⧗	S5	35-42-36-50 (24" = 100%)	
		Clayey SAND with gravel (SC), dense, brown, moist, medium sand, angular, occasional cobbles and boulders, soils frozen, poorly bonded with individual ice inclusions, ~5% visible ice, 31° F measured.		⧗	S6	36-50-22-15 (24" = 100%)	Fines = 22% SG = 2.51
		19.5 ft / El. 3561.5 ft					

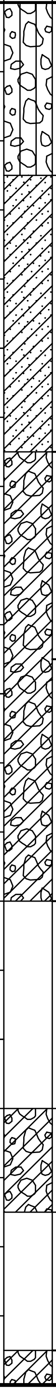


U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-03

Project Name: Pretty Rocks
Sheet: 2 of 6
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3581 ft
Datum: MSL
Groundwater Depth:
Date Started: 7/27/18
Date Completed: 7/30/18
While Drilling: ---
Driller/Company: Travis Drewery/Geotek Alaska
Drill Geoprobe 6620 DT
At Completion: ---
Hammer Type: 140 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Brian Collins
Notes:
VWP (S/N: 1814519); SAAV installed in 3.34" SI casing to 95';
thermistor string to 96'

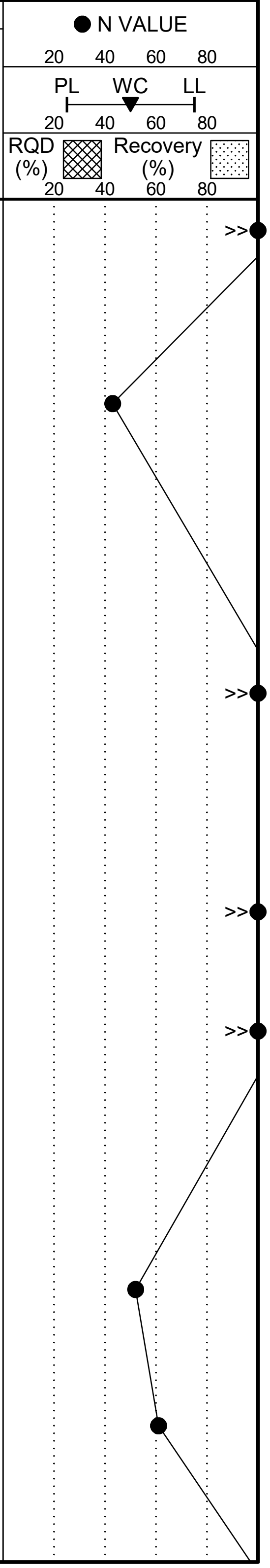
Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION
		Silty GRAVEL with sand, very dense, brown, wet, medium sand, angular, occasional cobbles and boulders, soil unfrozen, 37° F measured.
3560		
		22.5 ft / El. 3558.5 ft
		Clayey SAND with gravel, dense, brown, moist, medium sand, angular, occasional cobbles and boulders, soil unfrozen, 32.5° F measured.
	25	Very dense, soils with poorly bonded frozen layers, 32.5° F measured.
3555		26.5 ft / El. 3554.5 ft
		Clayey GRAVEL with sand, very dense, brown, moist, medium sand, angular, occasional cobbles and boulders, 38° F measured.
		driller comments boulder 27.5' - 29.5'
		29.5 ft / El. 3551.5 ft
	30	Clayey GRAVEL, very dense, brown, moist, medium sand, angular, soft, colorless, cloudy ICE 30.0' - 30.25', soils unfrozen 30.25' to 30.75', soils frozen with individual ice inclusions below 30.75', ~ 20% visible ice, 32° F to 38° F measured.
3550		37° F measured, driller remarks softer 32.0' - 35.0'.
		33 ft / El. 3548 ft
	35	Very dense, ICE without soil inclusions, soft, colorless, cloudy, horizontal layers, 31° F measured.
3545		36 ft / El. 3545 ft
		Clayey GRAVEL with sand, very dense, brown, medium sand, angular, occasional cobbles and boulders, soils frozen with ice inclusions ~30% visible ice, 31° F measured.
		37.5 ft / El. 3543.5 ft
		Very dense, ICE without soil inclusions, soft, white, 31° F measured. ICE
		39.5 ft / El. 3541.5 ft

Graphic Log


Drilling Method: 6.25" ID

SAMPLE

No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
S7	18-50/5" (11" = 100%)	
S8	17-21-22-30 (24" = 100%)	
S9	50/6" (6" = 100%)	
S10	45-50/6" (6" = 100%)	
S11	28-50/5" (11" = 100%)	
S12	50/5" (3" = 60%)	
S13	27-27-25-24 (24" = 100%)	
S14	19-38-23-40 (24" = 100%)	



U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

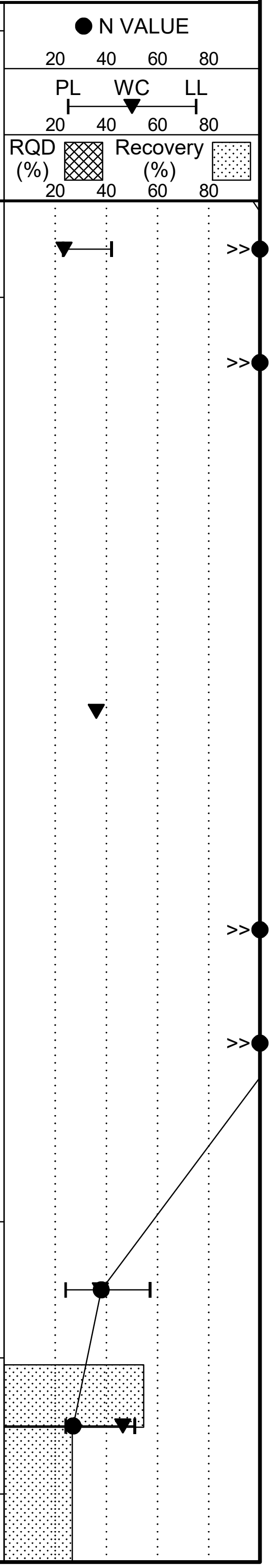
BORING LOG PR18-03

Project Name: Pretty Rocks
Sheet: 3 of 6
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3581 ft
Datum: MSL
Groundwater Depth:
Date Started: 7/27/18
Date Completed: 7/30/18
While Drilling: ---
Driller/Company: Travis Drewery/Geotek Alaska
Drill: Geoprobe 6620 DT
At Completion: ---
Hammer Type: 140 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Brian Collins
Notes:
VWP (S/N: 1814519); SAAV installed in 3.34" SI casing to 95';
thermistor string to 96'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION
		Clayey SAND with gravel (SC), very dense, brown, occasional cobbles and boulders, frozen with occasional ice inclusions ~10% ice visible, 30.5° F measured.
3540		
		Frozen soils with ice inclusions, ~50% visible ice, 30° F measured.
	45	31° F measured.
3535		
		Layers of unfrozen and frozen soils with ~30% visible ice inclusions, 32° - 36° F measured.
	50	ICE, soft, clear to cloudy 50.0' - 50.5', 31° F measured.
3530		
		Frozen soils with ice inclusions, ~30% visible ice, 31.5° F measured, driller comments very soft drilling 52.0' - 55.0'.
	55	Clayey SAND with gravel (SC), dense, 37° F measured.
3525		56 ft / El. 3525 ft
		Elastic SILT, very stiff, light blue gray, moist, medium to high plasticity, disrupted, 0.2' of wet angular gravel clasts at 56.0'.
		57 ft / El. 3524 ft
		Clayey SAND (SC), blue green, 38° F measured. TUFF, blue green, completely weathered. RCT 2 min. RCT 30 min.

Drilling Method: 6.25" ID; HQ, compressed air

SAMPLE No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
S15	45-44-50/5" (17" = 100%)	Fines = 24% SG = 2.76
S16	39-50/3" (9" = 100%)	
S17	50/6" (6" = 100%)	
S18	31-50/6" (12" = 100%)	
S19	49-29-50/5" (17" = 100%)	
S20	34-50/3" (8" = 89%)	
S21	6-14-24-12 (24" = 100%)	Fines = 24% SG = 2.74
R1	Rec = 55% RQD = 0%	
S22	8-13-14-21 (24" = 100%)	Fines = 40% SG = 2.79



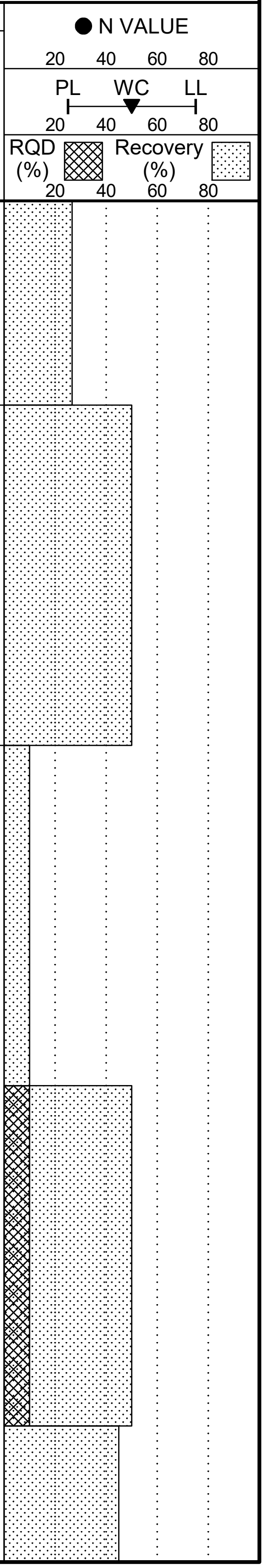
FHWA LOG - FHWA_DATATEMPLATE.GDT - 5/20/20 08:43 - C:\PW-WORK\D0350231\PRETTY ROCKS 2018.GPJ

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-03

Project Name: Pretty Rocks
Sheet: 4 of 6
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3581 ft
Datum: MSL
Groundwater Depth:
Date Started: 7/27/18
Date Completed: 7/30/18
While Drilling: ---
Driller/Company: Travis Drewery/Geotek Alaska
Drill Geoprobe 6620 DT
At Completion: ---
Hammer Type: 140 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Brian Collins
Notes:
VWP (S/N: 1814519); SAAV installed in 3.34" SI casing to 95';
thermistor string to 96'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	SAMPLE Test Results
3520		Clayey SAND (SC), blue green, 38° F measured. TUFF, blue green, completely weathered. RCT 2 min. *(continued)*	HQ, compressed air		R2	Rec = 27% RQD = 0%	
		63 ft / El. 3518 ft					
3515	65	RHYOLITE, bluish grey, fine grained grained, moderately weathered, strong rock (R4). Discontinuities are very closely spaced to extremely closely spaced and in poor condition, range from JRC 4-6 degrees from assumed horizontal, continuous chatter while drilling, RCT 50 min.			R3	Rec = 50% RQD = 0%	RCT 50 min
3510	70	Driller remarks "like drilling on marbles with soft layers", RCT 21 min.			R4	Rec = 10% RQD = 0%	
		73 ft / El. 3508 ft					
3505	75	RHYOLITE, grey, medium grained grained, moderately weathered to completely weathered, weak rock (R2). Discontinuities are in very poor condition, range from 40° - 50°, JRC 0-4 degrees from assumed horizontal, clay infill, continuous chatter while drilling, RCT 25 min.			R5	Rec = 50% RQD = 10%	
		RCT 19 min.					



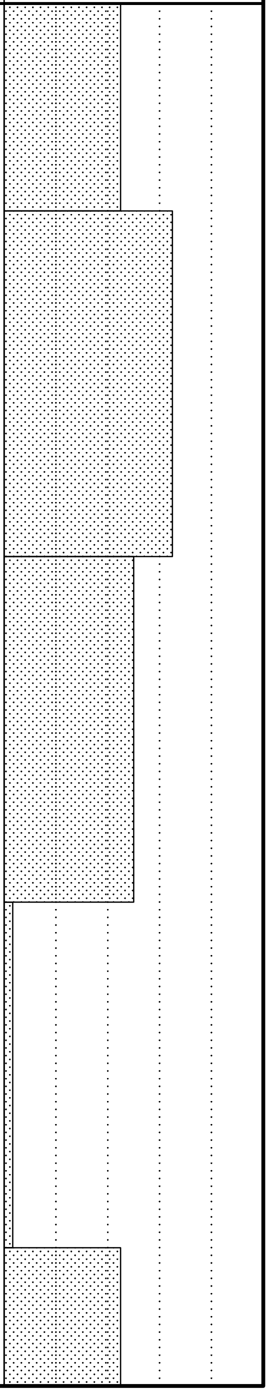
U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-03

Project Name: Pretty Rocks
Sheet: 5 of 6
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3581 ft
Datum: MSL
Groundwater Depth:
Date Started: 7/27/18
Date Completed: 7/30/18
While Drilling: ---
Driller/Company: Travis Drewery/Geotek Alaska
Drill Geoprobe 6620 DT
At Completion: ---
Hammer Type: 140 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Brian Collins
Notes:
VWP (S/N: 1814519); SAAV installed in 3.34" SI casing to 95';
thermistor string to 96'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
3500		RHYOLITE, grey, medium grained grained, moderately weathered to completely weathered, weak rock (R2). Discontinuities are in very poor condition, range from 40° - 50°, JRC 0-4 degrees from assumed horizontal, clay infill, continuous chatter while drilling, RCT 25 min. *(continued)*	HQ, compressed air	R6	Rec = 45% RQD = 0%	
	85	RCT 19 min.		R7	Rec = 65% RQD = 0%	
3495						
	90	RCT 27 min.		R8	Rec = 50% RQD = 0%	
3490		93 ft / El. 3488 ft				
	95	TUFF. RCT 25 min.		R9	Rec = 3% RQD = 0%	
3485		Grey, fine grained grained, highly weathered, very weak rock (R1). Discontinuities are very closely spaced, RCT 13 min.				

● N VALUE 20 40 60 80
PL WC LL 20 40 60 80
RQD (%) ▩ Recovery (%) ▨ 20 40 60 80



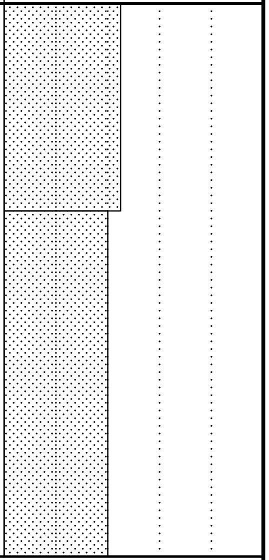
U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-03

Project Name: Pretty Rocks
Sheet: 6 of 6
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3581 ft
Datum: MSL
Groundwater Depth:
While Drilling: ---
At Completion: ---
After Drilling: --- No groundwater encountered
Date Started: 7/27/18
Date Completed: 7/30/18
Driller/Company: Travis Drewery/Geotek Alaska
Drill Geoprobe 6620 DT
Hammer Type: 140 lbs Automatic
Logger/Company: Brian Collins
Notes:
VWP (S/N: 1814519); SAAV installed in 3.34" SI casing to 95';
thermistor string to 96'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results	● N VALUE 20 40 60 80 PL WC LL 20 40 60 80 RQD (%) ▩ Recovery (%) ░ 20 40 60 80
		TUFF. RCT 25 min. *(continued)*	HQ, compressed air		R10	Rec = 45% RQD = 0%		
3480								
		RCT 20 min.			R11	Rec = 40% RQD = 0%		
	105							
3475								
		108 ft / El. 3473 ft						

Bottom of borehole at 108 ft.

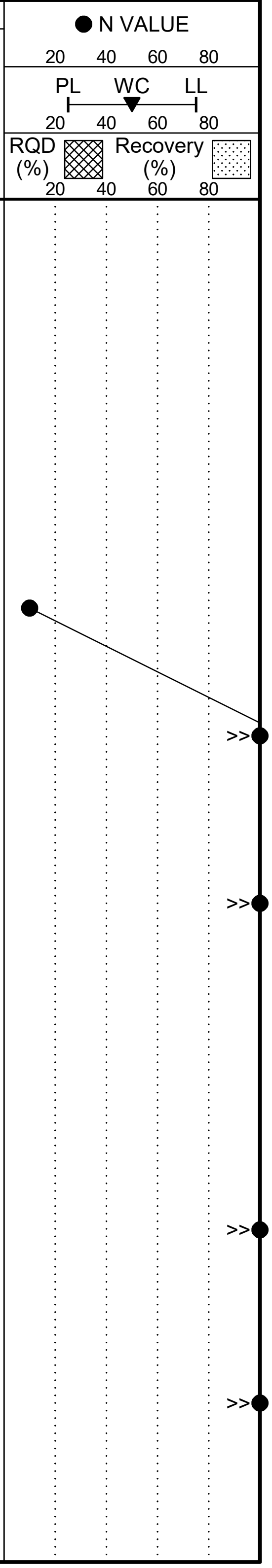


U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-04

Project Name: Pretty Rocks
Sheet: 1 of 6
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3493 ft
Datum: MSL
Groundwater Depth:
Date Started: 8/21/18
Date Completed: 8/25/18
∇ While Drilling: 14.5 ft / Elev 3478.5 ft
Driller/Company: Glen Rawson/Geotek Alaska
Drill: Geoprobe 6620 DT
At Completion: ---
Hammer Type: 140 lbs Automatic
After Drilling: ---
Logger/Company: Nick Farny
Notes:
Weather: Partly cloudy
VWP (SN: 1814519); thermistor string to 48'

Elevation (ft)	Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	SAMPLE Test Results
			COBBLES AND BOULDERS, angular, rhyolite and basalt fragments. Fill created by drillers to construct drilling pad. 2.5 ft / El. 3490.5 ft	6.25" ID				
3490			COBBLES AND BOULDERS in a Poorly graded GRAVEL with clay and sand matrix, matrix is loose, brown, moist, coarse gravel, loose, medium sand, subangular to angular, clasts up to 1', 54° F measured. 7.5 ft / El. 3485.5 ft					
	5					S1	9-9-1-1 (8" = 33%)	
3485			COBBLES AND BOULDERS in a Clayey GRAVEL with sand matrix, matrix is very dense, brown, wet, angular to subangular, fine to coarse gravel, medium to coarse sand, 33° F measured. 10 ft / El. 3483 ft			S2	12-50/3" (6" = 67%)	
	10		COBBLES AND BOULDERS in a Silty GRAVEL with sand matrix, matrix is very dense, wet to moist, white to brown, subangular to angular, medium to coarse sand, fine to coarse gravel. Frozen, Vs, ice crystals visible, lenses horizontal up to 1/8" thick, low ice saturation, spaced 1/4", milky, 32° F measured. 12.5 ft / El. 3480.5 ft			S3	12-50/2" (6" = 75%)	
3480			ICE, hard, gray, cloudy, inclusions of silty GRAVEL with cobbles, soil is very dense, brown, wet, angular, coarse to fine gravel, medium to coarse sand, 31.5° F measured. ∇ 15 ft / El. 3478 ft			S4	50/6" (6" = 100%)	
	15		Silty GRAVEL with sand, brown, wet, cobbles, and boulders, angular to subangular, medium sand, fine to coarse gravel, very dense, 35° F measured. 16.5 ft / El. 3476.5 ft			S5	50/3" (3" = 100%)	
3475			Poorly graded GRAVEL with silt and sand, brown, wet, angular to subangular, coarse to fine gravel, medium sand, very dense. Frozen, Nf, low saturation, 32° F measured.			S6	50/4" (4" = 100%)	



BORING LOG PR18-04

Project Name: Pretty Rocks
Sheet: 2 of 6
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3493 ft
Datum: MSL
Groundwater Depth:
Date Started: 8/21/18
Date Completed: 8/25/18
∇ While Drilling: 14.5 ft / Elev 3478.5 ft
Driller/Company: Glen Rawson/Geotek Alaska
Drill: Geoprobe 6620 DT
At Completion: ---
Hammer Type: 140 lbs Automatic
After Drilling: ---
Logger/Company: Nick Farny
Notes:
Weather: Partly cloudy
VWP (SN: 1814519); thermistor string to 48'

● N VALUE: 20 40 60 80
PL WC LL: 20 40 60 80
RQD (%) ▩ Recovery (%) ▦: 20 40 60 80

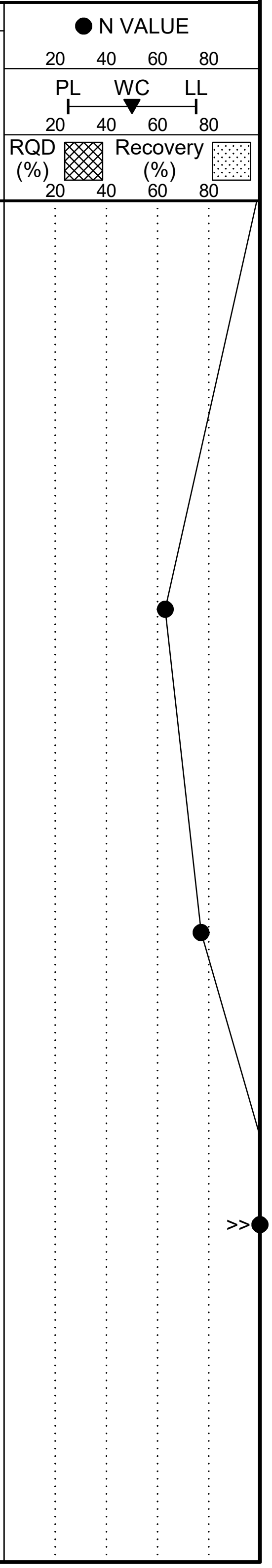
Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results	N VALUE
		Poorly graded GRAVEL with silt and sand, brown, wet, angular to subangular, coarse to fine gravel, medium sand, very dense. Frozen, Nf, low saturation, 32° F measured. *(continued)* 31.5° F measured at 20' 22.5 ft / El. 3470.5 ft			S7	50/3" (3" = 100%)		>>
3470		Poorly graded GRAVEL with silt and sand, brown, wet, cobbles, subangular to angular, coarse to fine gravel, medium sand, very dense, 38° F measured. 25 ft / El. 3468 ft			S8	50/5" (5" = 100%)		>>
3465	25	ICE, hard, gray, cloudy, inclusions of silty GRAVEL with sand, wet, very dense, brown, fine to coarse gravel, medium sand, subangular to angular, 31.5° F measured.			S9	40-50/3" (6" = 67%)		>>
	30		6.25" ID		S10	50/3" (3" = 100%)		>>
3460		31.5 ° measured.			S11	40-50/4" (6" = 60%)		>>
	35	37.5 ft / El. 3455.5 ft			S12	50/6" (6" = 100%)		>>
3455		ICE, hard, cloudy, gray, inclusions of silty SAND with gravel, brown, very dense, wet, fine gravel, medium to fine sand, angular to subangular, 31.5 ° measured.			S13	20-33-50/3" (15" = 100%)		>>

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-04

Project Name: Pretty Rocks
Sheet: 3 of 6
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3493 ft
Datum: MSL
Groundwater Depth:
Date Started: 8/21/18
Date Completed: 8/25/18
⊻ While Drilling: 14.5 ft / Elev 3478.5 ft
Driller/Company: Glen Rawson/Geotek Alaska
Drill Geoprobe 6620 DT
At Completion: ---
Hammer Type: 140 lbs Automatic
After Drilling: ---
Logger/Company: Nick Farny
Notes:
Weather: Partly cloudy
VWP (SN: 1814519); thermistor string to 48'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Sample No.	Field Blow Count (Recovery) / Core Rec., RQD, and Frac. Freq.	Test Results
		ICE, hard, cloudy, gray, inclusions of silty SAND with gravel, brown, very dense, wet, fine gravel, medium to fine sand, angular to subangular, 31.5 ° measured. *(continued)*	6.25" ID	S14	50/6" (6" = 100%)	
3450	45			S15	17-30-33-47 (18" = 75%)	
3445				S16	25-50/6" (12" = 100%)	
		49 ft / El. 3444 ft				
		VOID from 49' to 50'. 50 ft / El. 3443 ft				
	50	RHYOLITE, highly weathered to completely weathered, extremely weak rock (R0). gray to brown, fine grained, residual soil is lean CLAY with gravel and sand, hard, moist to wet, low plasticity to medium plasticity, fine to coarse gravel.		S17	17-27-50/6" (18" = 100%)	
3440						
	55	White, moderately weathered, weak rock (R2) to medium strong rock (R3).		S18	50/1" (1" = 100%)	
3435						

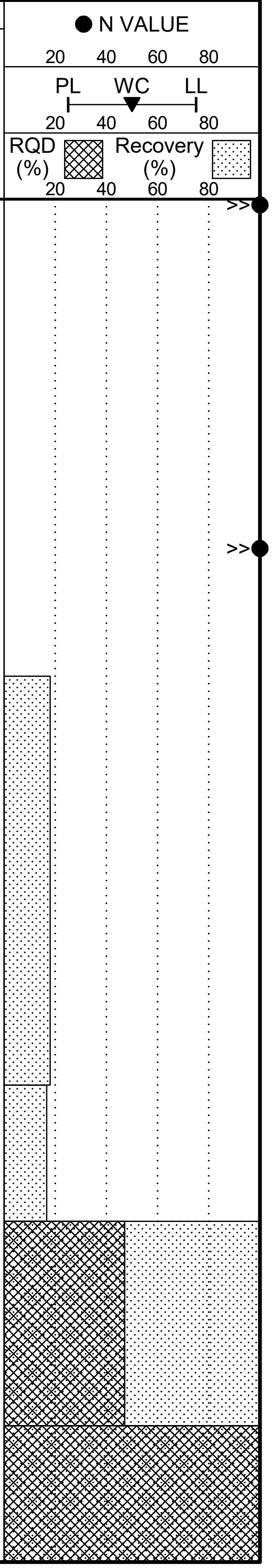


U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-04

Project Name: Pretty Rocks
Sheet: 4 of 6
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3493 ft
Datum: MSL
Groundwater Depth:
Date Started: 8/21/18
Date Completed: 8/25/18
⊻ While Drilling: 14.5 ft / Elev 3478.5 ft
Driller/Company: Glen Rawson/Geotek Alaska
Drill Geoprobe 6620 DT
At Completion: ---
Hammer Type: 140 lbs Automatic
After Drilling: ---
Logger/Company: Nick Farny
Notes:
Weather: Partly cloudy
VWP (SN: 1814519); thermistor string to 48'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
		RHYOLITE, highly weathered to completely weathered, extremely weak rock (R0). gray to brown, fine grained, residual soil is lean CLAY with gravel and sand, hard, moist to wet, low plasticity to medium plasticity, fine to coarse gravel. *(continued)*	6.25" ID	⧗	S19	50/2" (3" = 150%)	
3430							
	65			⧗	S20	50/3" (2" = 67%)	
		Extremely weak rock (R0) to medium strong rock (R3). brown to gray to white, highly weathered, residual soil is clayey GRAVEL with cobbles, moist, subrounded to subangular, coarse gravel, RCT=13 min. 54 sec., discontinuities are extremely closely spaced to very closely spaced and in poor condition, clay infilling, orientation unknown, structure lost, 54° F measured.	HQ, compressed air				
3425							
	70				R1	Rec = 18% RQD = 0% FF = 10	
3420							
					R2	Rec = 17% RQD = 0% FF = 10	
		75 ft / El. 3418 ft					
	75	ASH TUFF, gray, highly weathered to moderately weathered. RCT= 29 min. 46 sec. Discontinuities are very closely spaced to closely spaced and are in very poor condition, Discontinuities are oriented at 0 to 45° from assumed horizontal, residual soil is fat CLAY, hard, high plasticity to medium plasticity.			R3	Rec = 100% RQD = 47% FF = 3	
3415		RCT= 30 min. 36 sec.					

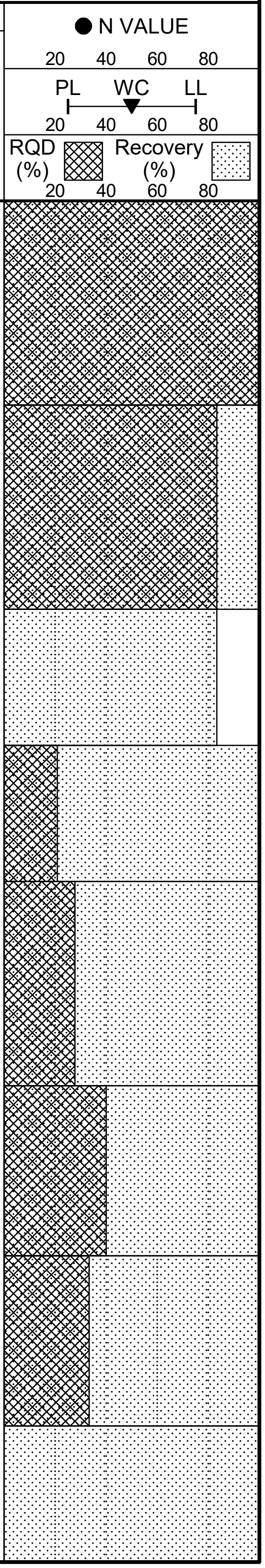


U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-04

Project Name: Pretty Rocks
Sheet: 5 of 6
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3493 ft
Datum: MSL
Groundwater Depth:
Date Started: 8/21/18
Date Completed: 8/25/18
⊻ While Drilling: 14.5 ft / Elev 3478.5 ft
Driller/Company: Glen Rawson/Geotek Alaska
Drill Geoprobe 6620 DT
At Completion: ---
Hammer Type: 140 lbs Automatic
After Drilling: ---
Logger/Company: Nick Farny
Notes:
Weather: Partly cloudy
VWP (SN: 1814519); thermistor string to 48'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
		ASH TUFF, gray, highly weathered to moderately weathered. RCT= 29 min. 46 sec. Discontinuities are very closely spaced to closely spaced and are in very poor condition, Discontinuities are oriented at 0 to 45° from assumed horizontal, residual soil is fat CLAY, hard, high plasticity to medium plasticity. *(continued)* Weak rock (R2) to medium strong rock (R3). no discontinuities.	HQ, compressed air		R4	Rec = 100% RQD = 100% FF = 0	
3410		83 ft / El. 3410 ft BASALT, brown, fine grained grained, highly weathered, very weak rock (R1) to weak rock (R2). Residual soil is fat CLAY with gravel, moist, high plasicity to low plasticity. RCT= 24 min. 56 sec.			R5	Rec = 100% RQD = 83% FF = 1.3	
	85	85 ft / El. 3408 ft Moderately weathered. dark gray, fine to medium grained, medium strong rock (R3). RCT=21 min. 40 sec. Discontinuities are oriented at 0 to 45° from assumed horizontal, in poor to fair condition, very closely spaced to closely spaced, iron oxide staining.			R6	Rec = 83% RQD = 0% FF = 10	
3405		Dark gray brown, highly weathered to moderately weathered, medium strong rock (R3) to weak rock (R2). Discontinuities are very closely spaced to closely spaced, fair to poor condition, oriented at 0 to 45° from assumed horizontal, iron oxide stains, residual soil is clayey SAND and broken rock infill in discontinuities.			R7	Rec = 100% RQD = 21% FF = 3	
	90	RCT=32 min. 15 sec. Lean CLAY with sand infilling discontinuities, discontinuities are in poor to very poor condition. RCT=27 min. 18 sec.			R8	Rec = 100% RQD = 28% FF = 3.3	
3400		Structure lost from 93' to 94', extremely closely spaced discontinuities. RCT=31 min. 29 sec. Below 94', very closely spaced to closely spaced discontinuities.			R9	Rec = 100% RQD = 40% FF = 10	
	95	RCT= 21 min. 8 sec.			R10	Rec = 100% RQD = 33% FF = 4	
3395		Completely weathered to highly weathered. discontinuities are very closely spaced and in very poor to poor condition, residual soil is Clayey GRAVEL with sand, brown, moist, fine to coarse gravel, medium sand. RCT= 33 min. 2 sec..			R11	Rec = 100% RQD = 0% FF = 10	



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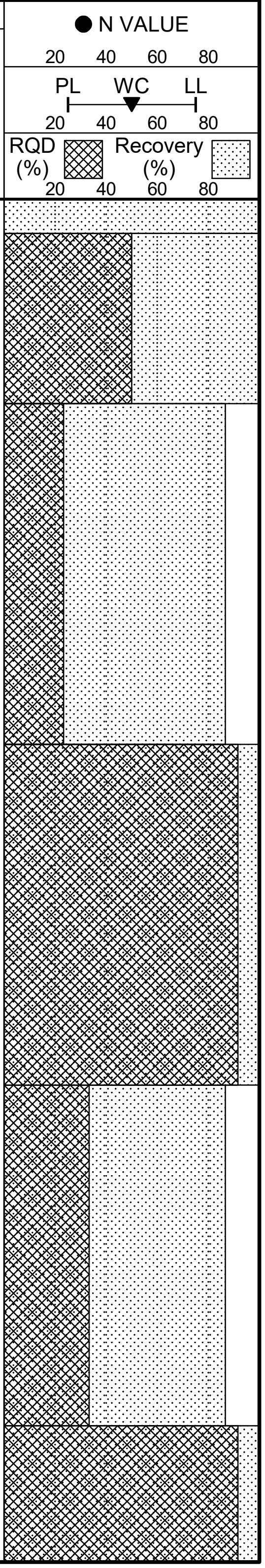
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR18-04

Project Name: Pretty Rocks
Sheet: 6 of 6
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3493 ft
Datum: MSL
Groundwater Depth:
Date Started: 8/21/18
Date Completed: 8/25/18
∇ While Drilling: 14.5 ft / Elev 3478.5 ft
Driller/Company: Glen Rawson/Geotek Alaska
Drill: Geoprobe 6620 DT
At Completion: ---
Hammer Type: 140 lbs Automatic
After Drilling: ---
Logger/Company: Nick Farny
Notes:
Weather: Partly cloudy
VWP (SN: 1814519); thermistor string to 48'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
3390		Moderately weathered. dark gray, fine to medium grained, medium strong rock (R3). RCT=21 min. 40 sec. Discontinuities are oriented at 0 to 45° from assumed horizontal, in poor to fair condition, very closely spaced to closely spaced, iron oxide staining. *(continued)* Moderately weathered, medium strong rock (R3). Discontinuities are very closely spaced to closely spaced and are in fine to good condition, oriented at 0 to 80° from assumed horizontal, iron oxide staining. RCT= 16 min. 23 sec.	HQ, compressed air	R12	Rec = 100% RQD = 50% FF = 1.75	
	105	Discontinuities are extremely closely spaced, discontinuities from 105.3-106.7', some discontinuities infilled with quartz, structure lost. RCT= 48 min. 43 sec.		R13	Rec = 87% RQD = 23% FF = 2	
3385	110	Gray dark gray, moderately weathered to slightly weathered, medium strong rock (R3). Discontinuities are moderately spaced to very closely spaced, oriented at 20-45° from assumed horizontal, and in good to fair condition, medium to fine grained. RCT= 48 min. 10 sec.		R14	Rec = 100% RQD = 92% FF = 0.8	
3380	115	115.3 ft / El. 3377.7 ft ASH TUFF with BASALT interbeds, bluish gray, highly weathered to completely weathered, very weak rock (R1) to weak rock (R2). Discontinuities are closely to very closely spaced, are in poor condition, and are oriented at 45 to 70° from assumed horizontal, RCT= 43 min. 52 sec.		R15	Rec = 87% RQD = 33% FF = 2	
3375		RCT= 18 min. 44 sec. 120 ft / El. 3373 ft		R16	Rec = 100% RQD = 92% FF = 1	

Bottom of borehole at 120 ft.



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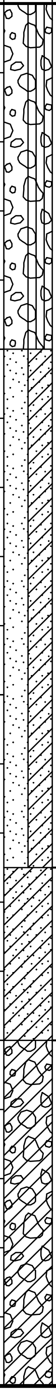
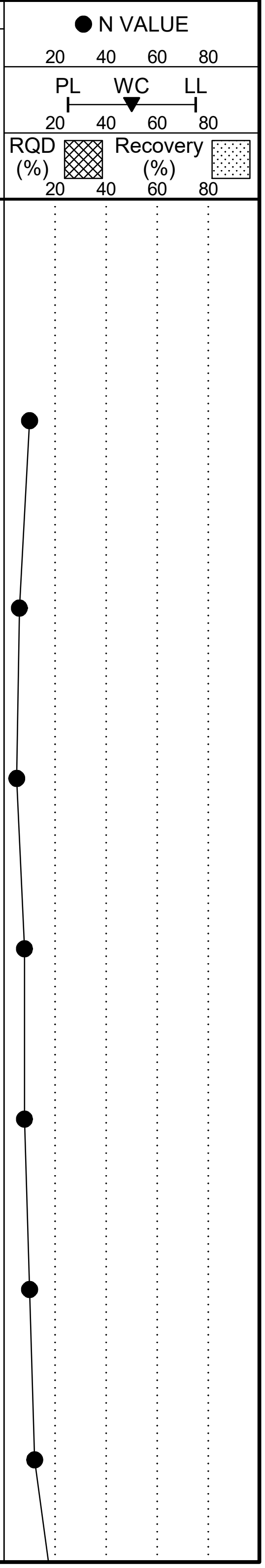
BORING LOG PR18-05

Project Name: Pretty Rocks
Sheet: 1 of 7
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3448 ft
Datum: MSL
Groundwater Depth:
Date Started: 8/3/18
Date Completed: 8/12/18
While Drilling: ---
Driller/Company: Glen Rawson/Geotek Alaska
Drill Geoprobe 6620 DT
At Completion: ---
Hammer Type: 140 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Orion George
Notes:
Weather: Overcast
VWP (S/N: 1816099); thermistor string to 48'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
3445		Poorly graded GRAVEL with silt and sand, loose, light tan and brown with purple, moist, medium sand, angular, some clay, boulders and cobbles.	6.25" ID		S01	5-6-4 (9" = 50%)	
	5	Poorly graded SAND with clay and gravel, loose, light tan brown, moist, medium sand, angular, low toughness, medium plasticity, boulders and cobbles likely. Dark brown. 49.4° F measured			S02	5-4-2-2 (11" = 46%)	
3440		Very loose, some perlitic obsidian and basalt, less clay.			S03	1-2-3-4 (14" = 58%)	
	10	Loose, increased gravel (~40%). 41.9° F measured			S04	1-4-4-6 (9" = 38%)	
		12.5 ft / El. 3435.5 ft					
3435		Clayey SAND with gravel, loose, brown, moist, medium sand, angular, no dilatancy, medium toughness, medium plasticity, basalt and rhyolite clasts, cobbles likely.			S05	2-4-4-7 (11" = 46%)	
	15	15 ft / El. 3433 ft					
		Clayey GRAVEL with sand, loose, brown, moist, fine gravel, angular, no dilatancy, medium toughness, medium plasticity, with cobbles, ~30% sand. 40.4° F measured			S06	6-4-6-7 (11" = 46%)	
3430		Medium dense, wet, ~60% gravel and ~15% sand. 43.8° F measured			S07	1-5-7-10 (9" = 38%)	





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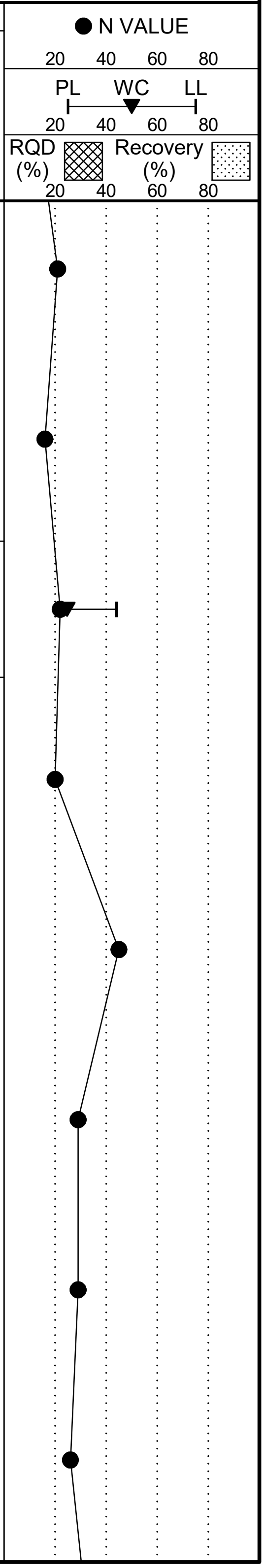
BORING LOG PR18-05

Project Name: Pretty Rocks
Sheet: 2 of 7
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3448 ft
Datum: MSL
Groundwater Depth:
Date Started: 8/3/18
Date Completed: 8/12/18
While Drilling: ---
Driller/Company: Glen Rawson/Geotek Alaska
Drill: Geoprobe 6620 DT
At Completion: ---
Hammer Type: 140 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Orion George
Notes:
Weather: Overcast
VWP (S/N: 1816099); thermistor string to 48'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	Field Blow Count (Recovery) / Core Rec., RQD, and Frac. Freq.	Test Results
		Clayey GRAVEL with sand, loose, brown, moist, fine gravel, angular, no dilatancy, medium toughness, medium plasticity, with cobbles, ~30% sand. *(continued)* Moist, ~70% gravel and ~10% sand. 42.9° F measured	6.25" ID		S08	5-8-13-10 (18" = 75%)	
3425		Slow dilatancy, ~60% gravel and ~20% sand. 42.8° F measured			S09	10-7-9-10 (13" = 54%)	
	25	41.3° F measured			S10	8-10-12-11 (21" = 88%)	Fines = 18% SG = 2.75
3420		27.5 ft / El. 3420.5 ft Clayey SAND with gravel, medium dense, brown, moist, medium sand, angular, ~40% sand and ~30% gravel, cobbles likely. 42.6° F measured			S11	8-4-16-20 (14" = 58%)	
	30	30 ft / El. 3418 ft Clayey GRAVEL with sand, dense, brown, moist, fine gravel, angular, no dilatancy, medium toughness, medium plasticity, ~45% gravel and ~30% sand. 41.3° F measured			S12	15-30-15-17 (19" = 79%)	
3415		Medium dense. 41.9° F measured			S13	9-10-19-16 (20" = 83%)	switch to casing advancer
	35	~40% gravel and ~35% sand. 43.5° F measured			S14	9-15-14-14 (17" = 71%)	
3410		37.5 ft / El. 3410.5 ft Clayey SAND with gravel, medium dense, brown, moist, medium sand, angular, no dilatancy, medium toughness, medium plasticity, cobbles likely. 41.5° F measured			S15	14-11-15-23 (18" = 75%)	"bit gumming up"



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BORING LOG PR18-05

Project Name: Pretty Rocks
Sheet: 3 of 7
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3448 ft
Datum: MSL
Groundwater Depth:
Date Started: 8/3/18
Date Completed: 8/12/18
While Drilling: ---
Driller/Company: Glen Rawson/Geotek Alaska
Drill Geoprobe 6620 DT
At Completion: ---
Hammer Type: 140 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Orion George
Notes:
Weather: Overcast
VWP (S/N: 1816099); thermistor string to 48'

Elevation (ft) / Depth (ft) markers: 3405; 45; 3400; 50; 3395; 55; 3390

Drilling Method: tri-cone, compressed air

MATERIAL DESCRIPTION

Clayey SAND with gravel, medium dense, brown, moist, medium sand, angular, no dilatancy, medium toughness, medium plasticity, cobbles likely. *(continued)*
~40% sand and ~30% gravel.

Medium to high toughness, medium to high plasticity, ~40% sand and ~25% gravel.

~45% sand and ~40% gravel, less clay, boulders likely.

47.8° F measured

47.5 ft / El. 3400.5 ft

Clayey GRAVEL with sand, very dense, tan to brown, moist, fine gravel, angular, ~50% gravel and ~30% sand.

~45% gravel and ~35% sand.

42.4° F measured

~60% gravel and ~25% sand.

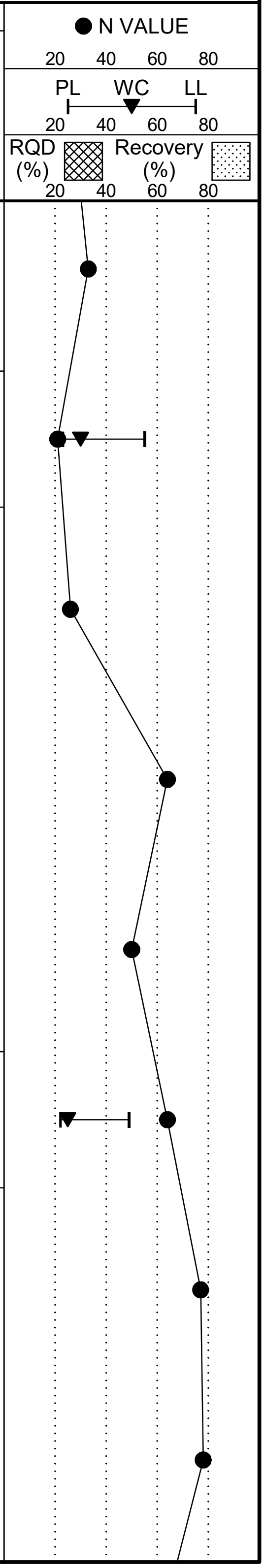
44.2° F measured

55 ft / El. 3393 ft

Poorly graded GRAVEL with clay and sand, very dense, brown, moist, fine gravel, angular, ~45% gravel and ~40% sand, cobbles likely.
41.9° F measured

At 58.0' irregularly oriented ice and ice coating particles, ~20% visible ice, soft, cloudy and colorless to clear.
33.0° F measured

SAMPLE No.	Field Blow Count (Recovery) / Core Rec., RQD, and Frac. Freq.	Test Results
S16	11-16-17-15 (18" = 75%)	
S17	6-12-9-18 (17" = 71%)	Fines = 26% SG = 2.79
S18	12-13-13-18 (23" = 96%)	
S19	13-18-46-39 (24" = 100%)	
S20	14-25-25-26 (23" = 96%)	
S21	13-30-34-24 (22" = 92%)	Fines = 15% SG = 2.72
S22	13-30-47-29 (24" = 100%)	
S23	23-29-49-43 (24" = 100%)	



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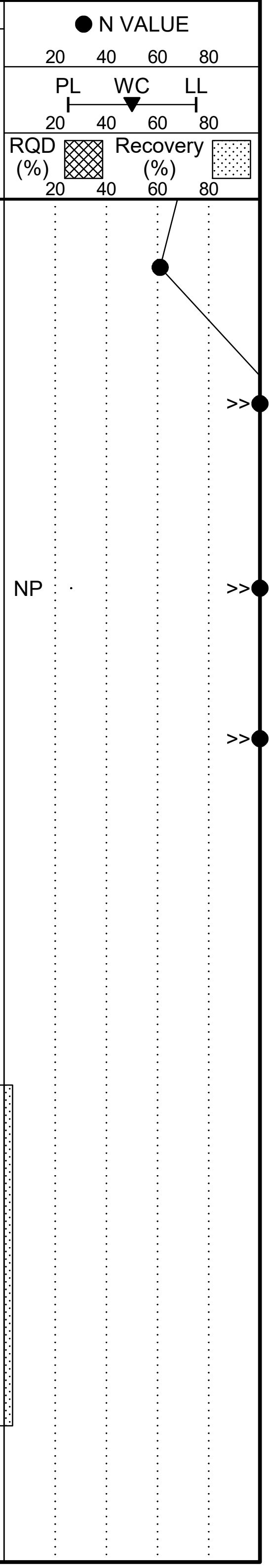
BORING LOG PR18-05

Project Name: Pretty Rocks
Sheet: 4 of 7
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3448 ft
Datum: MSL
Groundwater Depth:
Date Started: 8/3/18
Date Completed: 8/12/18
While Drilling: ---
Driller/Company: Glen Rawson/Geotek Alaska
Drill: Geoprobe 6620 DT
At Completion: ---
Hammer Type: 140 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Orion George
Notes:
Weather: Overcast
VWP (S/N: 1816099); thermistor string to 48'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
		Poorly graded GRAVEL with clay and sand, very dense, brown, moist, fine gravel, angular, ~45% gravel and ~40% sand, cobbles likely. *(continued)* ~60% visible ice, irregularly oriented with soil inclusions, clear to cloudy, hard, 60.5' to 62.0' preserved in freezer. 36.5° F measured	tri-cone, compressed air		S24	33-32-29-42 (25" = 104%)	
3385		~40% visible ice, irregularly oriented, 62.8' to 63.4' preserved in freezer.			S25	38-28-50/6" (14" = 117%)	
	65	No ice observed.			S26	8-14-50/5" (7" = 41%)	NP
		67.5 ft / El. 3380.5 ft					
3380		Clayey SAND with gravel, very dense, brown to light tan, moist, medium sand, angular, no dilatancy, medium toughness, medium plasticity, unfrozen, cobbles likely.			S27	38-50/4" (9" = 90%)	
		68.2 ft / El. 3379.8 ft					
	70	Poorly graded SAND with gravel, very dense, light tan, dry, medium sand, angular.			S28	50/6" (5" = 83%)	
3375		73 ft / El. 3375 ft					
	75	Fat CLAY with sand, medium sand, angular, no dilatancy, high toughness, high plasticity. Light purplish buff, fine grained grained, highly weathered to completely weathered, extremely weak rock (R0). low recovery, no discontinuities observed.	HQ, compressed air		R1	Rec = 3% RQD = 0%	switch to core
3370		No recovery.					



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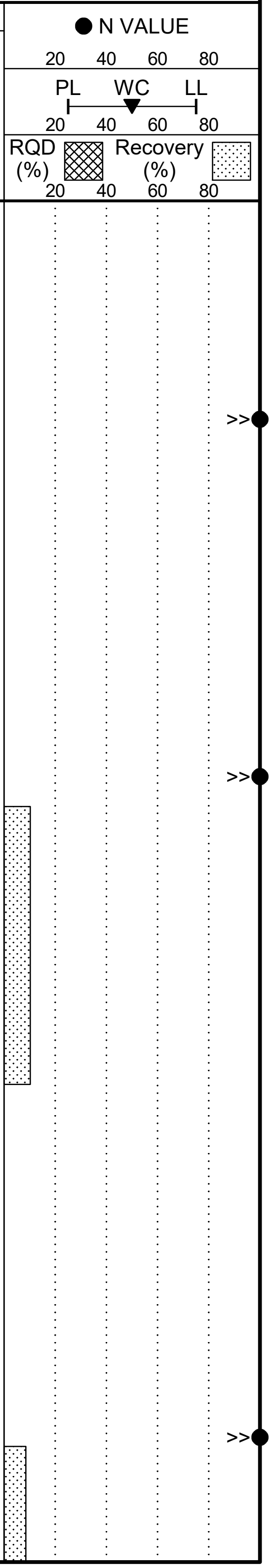
BORING LOG PR18-05

Project Name: Pretty Rocks
Sheet: 5 of 7
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3448 ft
Datum: MSL
Groundwater Depth:
While Drilling: ---
At Completion: ---
After Drilling: --- No groundwater encountered
Date Started: 8/3/18
Date Completed: 8/12/18
Driller/Company: Glen Rawson/Geotek Alaska
Drill Geoprobe 6620 DT
Hammer Type: 140 lbs Automatic
Logger/Company: Orion George
Weather: Overcast
Notes:
VWP (S/N: 1816099); thermistor string to 48'

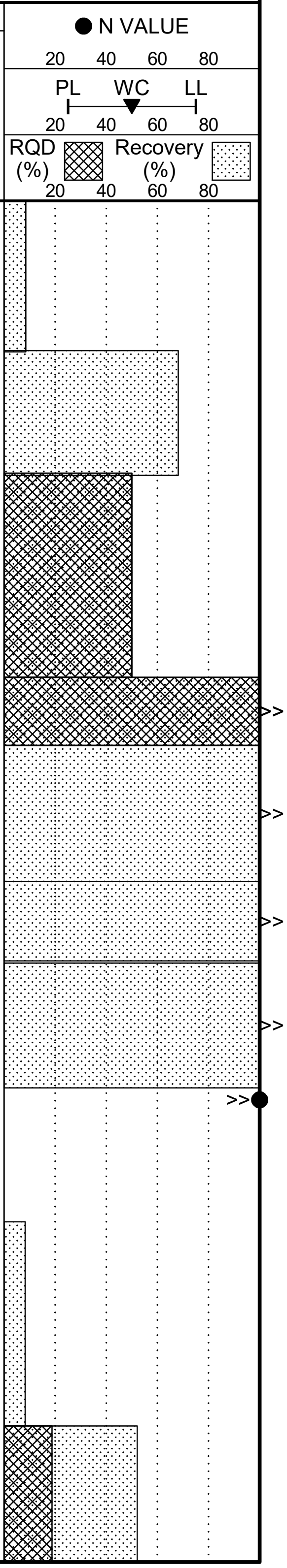
Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
		Fat CLAY with sand, medium sand, angular, no dilatancy, high toughness, high plasticity. Light purplish buff, fine grained grained, highly weathered to completely weathered, extremely weak rock (R0). low recovery, no discontinuities observed. *(continued)*	HQ, compressed air		R2	Rec = 0% RQD = 0%	
3365		83 ft / El. 3365 ft			S29	50/5" (5" = 100%)	
	85				R3	Rec = 0% RQD = 0%	
3360					S30	27-50/5" (9" = 82%)	
	90				R4	Rec = 10% RQD = 0%	
3355							
	95				R5	Rec = 0% RQD = 0%	
3350		98 ft / El. 3350 ft			S31	50/4" (2" = 50%)	



BORING LOG PR18-05

Project Name: Pretty Rocks
Sheet: 6 of 7
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3448 ft
Datum: MSL
Groundwater Depth:
Date Started: 8/3/18
Date Completed: 8/12/18
While Drilling: ---
Driller/Company: Glen Rawson/Geotek Alaska
Drill Geoprobe 6620 DT
At Completion: ---
Hammer Type: 140 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Orion George
Notes:
Weather: Overcast
VWP (S/N: 1816099); thermistor string to 48'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
			HQ, compressed air	R6	Rec = 9% RQD = 0%	
3345				R7	Rec = 68% RQD = 0%	
	105			R8	Rec = 50% RQD = 50%	
		107 ft / El. 3341 ft		R9	Rec = 300% RQD = 300%	
3340				R10	Rec = 142% RQD = 0%	
	110			R11	Rec = 236% RQD = 0%	
				R12	Rec = 105% RQD = 0%	
3335				S32	50/5" (18" = 360%)	
				R13	Rec = 0% RQD = 0%	
	115	115 ft / El. 3333 ft		R14	Rec = 8% RQD = 0%	
3330		118.9 ft / El. 3329.1 ft perlite obsidian			Rec = 52%	



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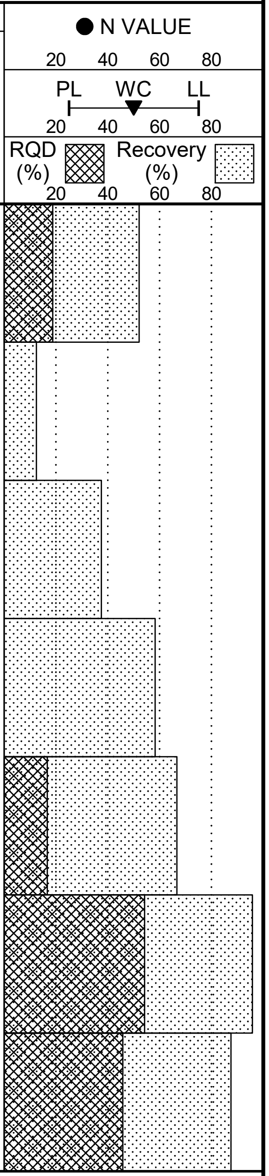
BORING LOG PR18-05

Project Name: Pretty Rocks
Sheet: 7 of 7
Project Location: Denali National Park and Preserve, Alaska
Surface Elevation: 3448 ft
Datum: MSL
Groundwater Depth:
Date Started: 8/3/18
Date Completed: 8/12/18
While Drilling: ---
Driller/Company: Glen Rawson/Geotek Alaska
Drill Geoprobe 6620 DT
At Completion: ---
Hammer Type: 140 lbs Automatic
After Drilling: --- No groundwater encountered
Logger/Company: Orion George
Notes:
Weather: Overcast
VWP (S/N: 1816099); thermistor string to 48'

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
		perlite obsidian *(continued)*	HQ, compressed air		R15	RQD = 19%	
3325					R16	Rec = 13% RQD = 0%	
	125				R17	Rec = 38% RQD = 0%	
					R18	Rec = 58% RQD = 0%	
3320					R19	Rec = 67% RQD = 17%	
	130				R20	Rec = 96% RQD = 54%	
3315		134 ft / El. 3314 ft			R21	Rec = 88% RQD = 46%	

Bottom of borehole at 134 ft.



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BORING LOG PR19-06

Project Name: Pretty Rocks Landslide
Sheet: 1 of 7
Project Location: Denali National Park, Alaska
Latitude: 63.537014° Longitude: -149.817329°
Groundwater Depth:
While Drilling: --- No Groundwater
At Completion: ---
After Drilling: ---
Date Started: 9/9/19 Date Completed: 9/12/19
Driller/Company: Ryan/GEOTEK AK Drill: Geoprobe 8040DT
Hammer Type: 140 lbs Automatic
Logger/Company: JLD/S&W
Weather: 30-40's, night, windy
Notes:
Azmuth: 290 Dip: 60 Downhole geophysical survey conducted.
No other instrumentation installed.

Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	SAMPLE Test Results	● N VALUE 20 40 60 80 PL WC LL 20 40 60 80 RQD (%) ▩ Recovery (%) ░ 20 40 60 80
		NO CORE, residual soil. Advanced HWT casing with casing shoe through unconsolidated material to 23.0 feet. Loose overburden (landslide debris) washed out as casing advanced to somewhat competent depth. Intent was to capture material by coring through conductor casing once seated into bedrock. Material captured was washed away while coring. Based on drill action, visual observations, and knowledge of the area, material assumed to be silty, sandy, GRAVEL with cobbles and boulders. (Colluvium)	CONDUCTOR CASING					
5								
10								
15								

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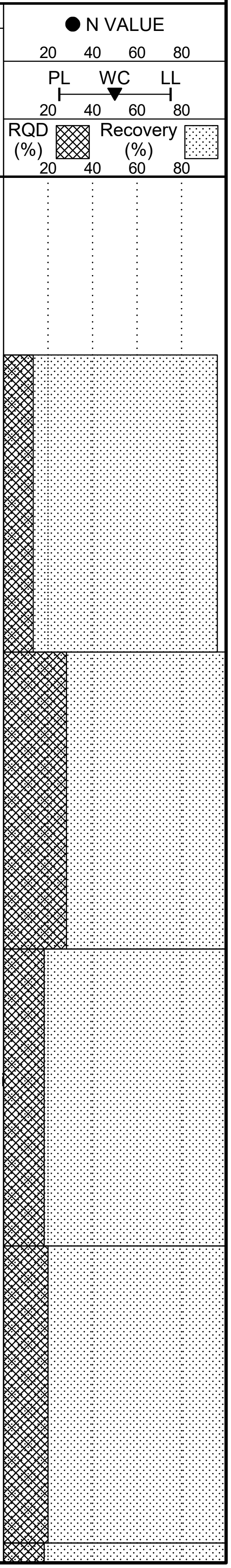
BORING LOG PR19-06

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Sheet: 2 of 7

Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
	23 ft					
	BASALT, fine grained, slightly weathered, medium strong rock (R3) to strong rock (R4). Discontinuities are very closely spaced and in good condition, with core loss from 23.0 to 23.2 feet. R1: Joint/fractures range from 30-70 degrees from relative to angle of boring, with iron oxide staining, RCT = 9 min.					
25	24 ft			R1	Rec = 96% RQD = 13% FF = 10	
	RHYOLITE, slightly vesicular, light yellowish brown to light grey, fine grained, perlite inclusions, slightly weathered, medium strong rock (R3). Discontinuities are very closely spaced to closely spaced and in good condition, highly fractured 24.0 to 24.3 feet and 26.0 to 26.3 feet.					
	R2: Joint/fractures range from 40-65 degrees from relative to angle of boring, with iron oxide staining, RCT = 16 min.					UC = 4280 psi
	Weak rock (R2) 29.1 to 30.5 feet.					
30	Medium strong rock (R3) 30.5 to 33.0 feet.			R2	Rec = 100% RQD = 28% FF = 10	UC = 5430 psi
	No perlite inclusions 33.0 to 95.7 feet. Weak rock (R2) from 33.0 to 61.0 feet and highly fractured 35.0 to 36.0 feet.	HQ3				
35	R3: Joint/fractures range from 20-75 degrees from relative to angle of boring, with iron oxide staining, RCT = 11 min.			R3	Rec = 100% RQD = 18% FF = 7	UC = 14600 psi
	R4: Joint/fractures range from 5-30 degrees from relative to angle of boring, with iron oxide staining, RCT = 23 min.					
40				R4	Rec = 100% RQD = 20% FF = 3	UC = 7870 psi
	R5: Joint/fractures range from 25-90 degrees from					



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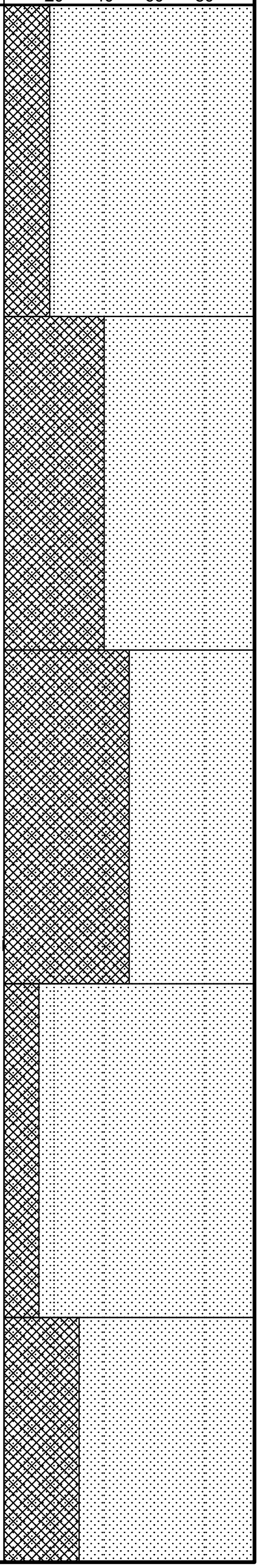
BORING LOG PR19-06

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Sheet: 3 of 7

Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
45		relative to angle of boring, with iron oxide staining, RCT = 16 min. Highly to slightly weathered, ice visible (Vr), hard, clear, colorless, approximately 0.5 inch or less diameter. Highly fractured 44.4 to 45.5 feet.	HQ3		R5	Rec = 100% RQD = 18% FF = 6	
50		R6: Joint/fractures range from 10-88 degrees from relative to angle of boring, with iron oxide staining, RCT = 23 min. Dark reddish purple to bluish grey 52.0 to 53.6 feet.			R6	Rec = 100% RQD = 40% FF = 3	
55		R7: Joint/fractures range from 25-50 degrees from relative to angle of boring, with iron oxide staining, RCT = 15 min. Light yellowish brown to light grey 53.6 to 95.7 feet.			R7	Rec = 100% RQD = 50% FF = 3	UC = 11620 ps
60		R8: Joint/fractures range from 25-60 degrees from relative to angle of boring, with iron oxide staining, RCT = 16 min. Moderately weathered to highly weathered, extremely weak rock (R0) from 61.0 to 62.0 feet. Slightly weathered 62.0 to 95.7 feet. Medium strong rock (R3) 62.0 to 65.1 feet.			R8	Rec = 100% RQD = 14% FF = 5	
65		R9: Joint/fractures range from 10-60 degrees from relative to angle of boring, with iron oxide staining, RCT = 15 min. Weak rock (R2), highly fractured 65.1 to 65.6 feet. Medium strong rock (R3) 65.6 to 95.7 feet.			R9	Rec = 100% RQD = 30% FF = 4	

● N VALUE
20 40 60 80
PL WC LL
20 40 60 80
RQD (%) ▨ Recovery (%) ░
20 40 60 80



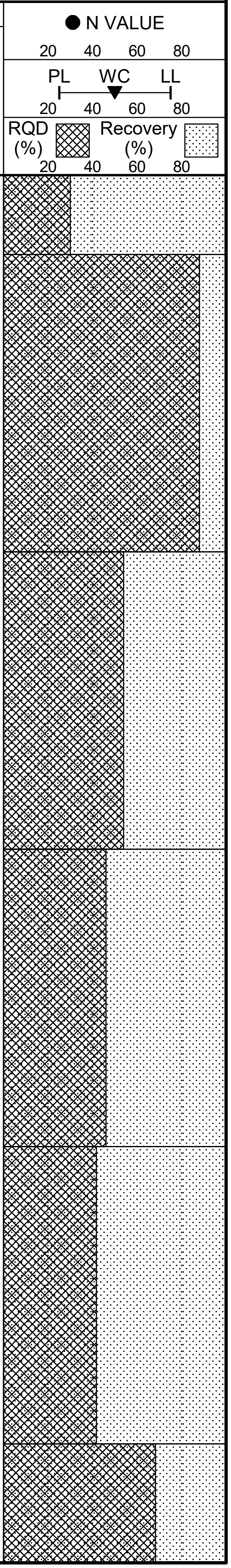
U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR19-06

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Sheet: 4 of 7

Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	SAMPLE Test Results
			HQ3				
70		R10: Joint/fractures range from 35-60 degrees from relative to angle of boring, with iron oxide staining, RCT = 17 min. Broken core from 68.0 to 68.2 feet.			R10	Rec = 100% RQD = 88% FF = 3	UC = 3990 psi
75		R11: Joint/fractures range from 0-85 degrees from relative to angle of boring, with iron oxide staining, RCT = 10 min. Discontinuities are very closely spaced to moderately spaced and in good condition from 73.2 to 98.5 feet.			R11	Rec = 100% RQD = 54% FF = 2	UC = 9230 psi UC = 3070 psi
80		R12: Joint/fractures range from 5-70 degrees from relative to angle of boring, with iron oxide staining, RCT = 16 min.			R12	Rec = 100% RQD = 46% FF = 3	UC = 2500 psi
85		R13: Joint/fractures range from 30-85 degrees from relative to angle of boring, with iron oxide staining, RCT = 27 min.			R13	Rec = 100% RQD = 42% FF = 3	
		R14: Joint/fractures range from 35-55 degrees from relative to angle of boring, with iron oxide staining, RCT = 17 min.					UC = 7170 psi



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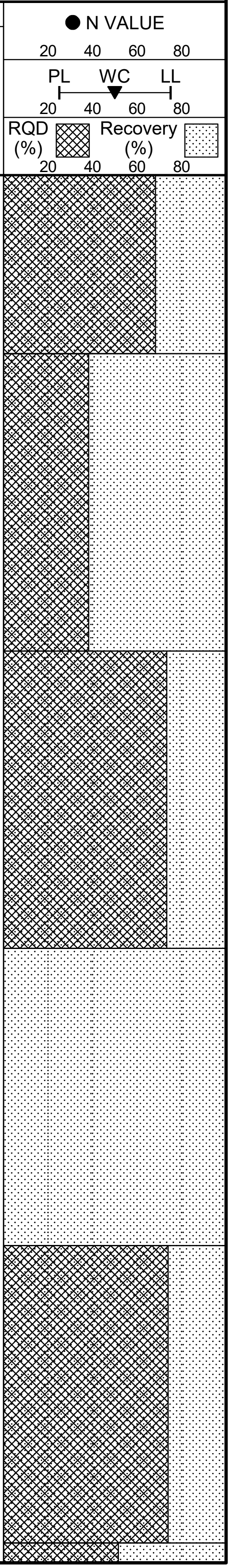
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR19-06

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska
Sheet: 5 of 7

Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
		HQ3		R14	Rec = 100% RQD = 68% FF = 1.5	
95	R15: Joint/fractures range from 5-75 degrees from relative to angle of boring, with iron oxide staining, RCT = 14 min. Light grey to buff 95.7 to 113.5 feet. Perlite inclusions 95.7 to 98.5 feet. Slightly weathered to moderately weathered, very weak rock (R1) to weak rock (R2) 95.7 to 98.0 feet			R15	Rec = 100% RQD = 38% FF = 4	
100	R16: Joint/fractures range from 25-40 degrees from relative to angle of boring, with iron oxide staining, RCT = 15 min. No perlite inclusions, fresh to slightly weathered below 98.5 feet. Medium strong rock (R3) 98.5 to 118.7 feet. Discontinuities are closely spaced to moderately spaced and in good condition from 98.5 to 103.7 feet.			R16	Rec = 100% RQD = 73% FF = 1.5	UC = 4930 psi
105	R17: Discontinuities are very closely to closely spaced. Joint/fractures range from 30-40 degrees from relative to angle of boring, with iron oxide staining, RCT = 20 min. Highly fractured 103.3 to 107.7 feet.			R17	Rec = 100% RQD = 0% FF = 10	
110	R18: Joint/fractures range from 20-70 degrees from relative to angle of boring, with iron oxide staining, RCT = 16 min.			R18	Rec = 100% RQD = 74% FF = 2	
	R19: Joint/fractures range from 5-70 degrees from					



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FEDERAL LANDS HIGHWAY DIVISION

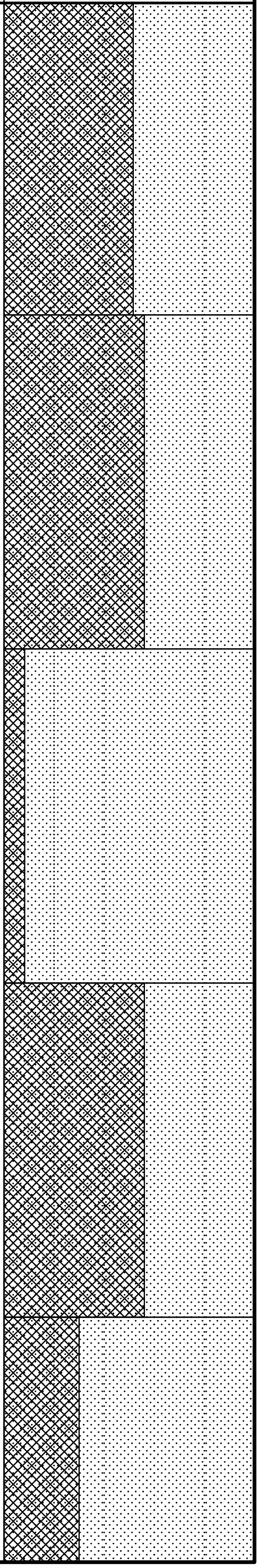
BORING LOG PR19-06

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Sheet: 6 of 7

Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
115	relative to angle of boring, with iron oxide staining, RCT = 15 min. Light reddish brown to buff below 113.0 feet.	HQ3		R19	Rec = 100% RQD = 52% FF = 2.5	
120	R20: Joint/fractures are 40 degrees from relative to angle of boring, with iron oxide staining, RCT = 18 min. Highly fractured 119.8 to 120.7 feet. Very weak rock (R1) to weak rock (R2). Discontinuities are very closely spaced.			R20	Rec = 100% RQD = 56% FF = 2	UC = 9430 psi
125	R21: Weak rock (R2) to medium strong rock (R3). Joint/fractures range from 10-40 degrees from relative to angle of boring, with iron oxide staining. Highly fractured 124.5 to 128.0 feet.			R21	Rec = 100% RQD = 8% FF = 10	
130	R22: Joint/fractures range from 10-40 degrees from relative to angle of boring, with iron oxide staining, RCT = 14 min. Medium strong rock (R3) 129.0 to 130.7 feet. Weak rock (R2) 130.7 to 133.2 feet .			R22	Rec = 100% RQD = 56% FF = 3.5	
135	R23: Joint/fractures range from 25-65 degrees from relative to angle of boring, with iron oxide staining, RCT = 7 min. Highly fractured 132.7 to 132.9 feet. Medium strong rock (R3) 133.2 to 134.6 feet. Weak rock (R2) 134.6 to 136.1 feet. Weak rock (R2) to medium strong rock (R3) 136.1 to			R23	Rec = 100% RQD = 30% FF = 8	

● N VALUE
20 40 60 80
PL WC LL
20 40 60 80
RQD (%) ▩ Recovery (%) ░
20 40 60 80



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FEDERAL LANDS HIGHWAY DIVISION

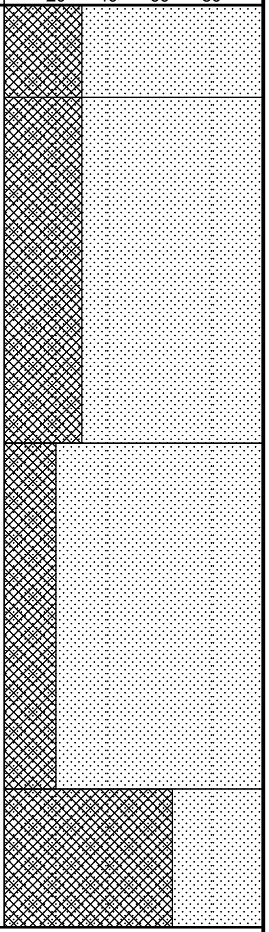
BORING LOG PR19-06

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Sheet: 7 of 7

Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
	146.3 feet. Highly fractured 136.6 to 138.0 feet.	HQ3				
140	R24: Joint/fractures range from 20-90 degrees from relative to angle of boring, with iron oxide staining, RCT = 12 min. Highly fractured 140.3 to 141.2 feet			R24	Rec = 100% RQD = 30% FF = 8	
145	R25: Joint/fractures range from 25-60 degrees from relative to angle of boring, with iron oxide staining, RCT = 16 min. Very weak rock (R1) to weak rock (R2). Highly fractured 146.3 to 148.0 feet.			R25	Rec = 100% RQD = 20% FF = 10	UC = 4740 psi
150	Weak rock (R2) to medium strong rock (R3) below 148.0 feet. R26: Joint/fractures range from 20-90 degrees from relative to angle of boring, with iron oxide staining, RCT = 7 min. 150 ft			R26	Rec = 100% RQD = 65% FF = 4	

● N VALUE



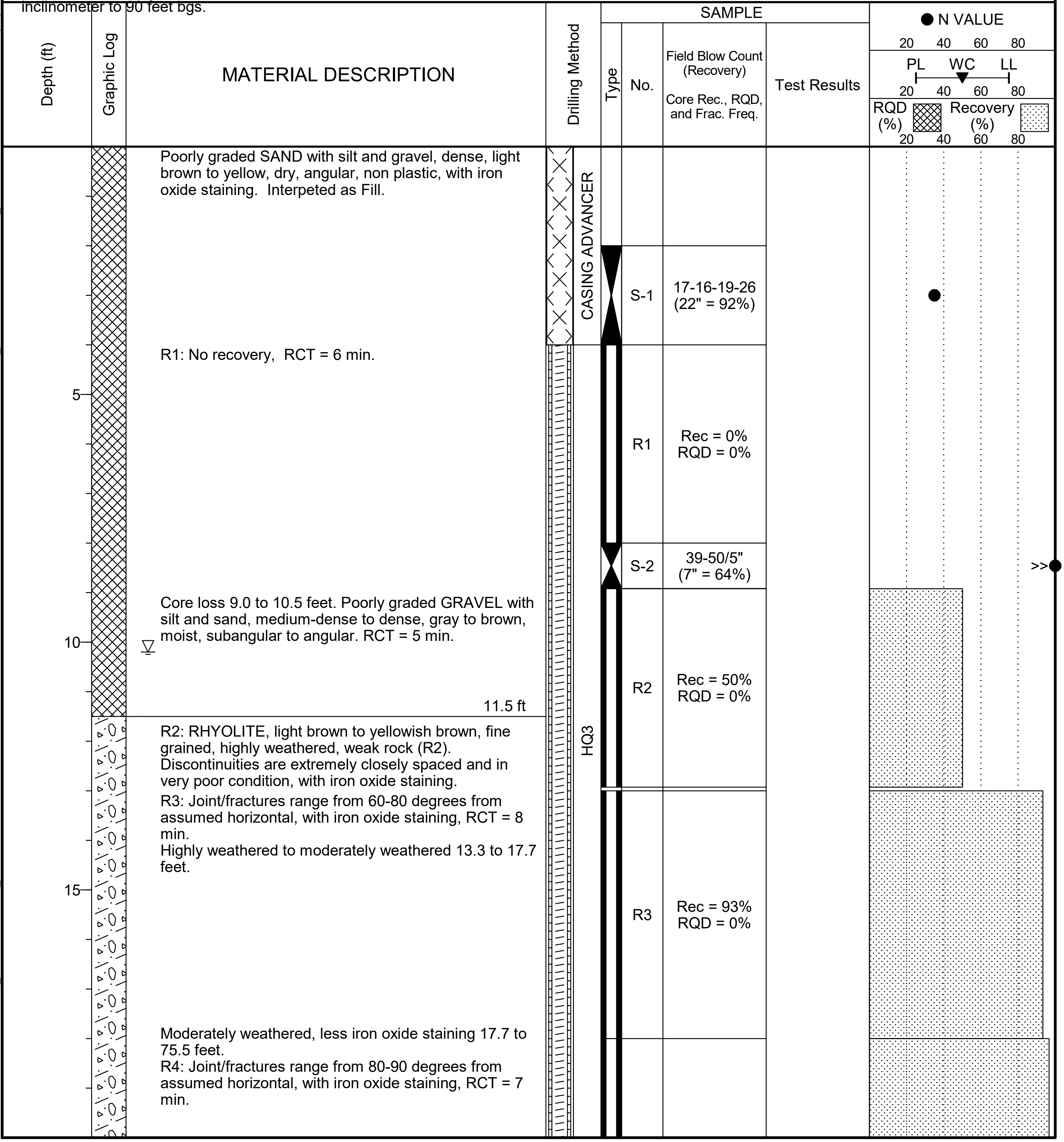
No instumentation installed. Backfilled with grout.
Bottom of borehole at 150 ft.

FHWA BORING LOG - FHWA_DATATEMPLATE_20171103.GDT - 7/2/20 09:19 - \\FL17VFILE.HFL17DO1.WFL.FLD.FHWA.DOT.GOV\COMMON\TECH_SERVICES\GEOTECH\01_PROJECTS\AK\AK NPS DENA 10(45) PRETTY ROCKS INVESTIGATION\GEOTECHNICAL INVESTIGA

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR19-07

Project Name: Pretty Rocks Landslide
Sheet: 1 of 5
Project Location: Denali National Park, Alaska
Latitude: 63.536276° Longitude: -149.81569°
Groundwater Depth:
Date Started: 9/7/19 Date Completed: 9/12/19
▽ While Drilling: 10.2 ft
Driller/Company: Glen/GEOTEK AK Drill: CME-75
At Completion: ---
Hammer Type: 140 lbs Automatic
▼ After Drilling: 70.2 ft 10.2 to 70.2 ft.
Logger/Company: RDD/S&W
Weather: 40's, night, windy
Notes:
VWPs (▮) installed at 90 ft depth.
Geophysical borehole survey conducted. Thermistor string installed 3 - 33 feet bgs (sensor every 2'). 3.34-inch slope inclinometer to 90 feet bgs.



Poorly graded SAND with silt and gravel, dense, light brown to yellow, dry, angular, non plastic, with iron oxide staining. Interpeted as Fill.

R1: No recovery, RCT = 6 min.

Core loss 9.0 to 10.5 feet. Poorly graded GRAVEL with silt and sand, medium-dense to dense, gray to brown, moist, subangular to angular. RCT = 5 min.

11.5 ft

R2: RHYOLITE, light brown to yellowish brown, fine grained, highly weathered, weak rock (R2). Discontinuities are extremely closely spaced and in very poor condition, with iron oxide staining.

R3: Joint/fractures range from 60-80 degrees from assumed horizontal, with iron oxide staining, RCT = 8 min.

Highly weathered to moderately weathered 13.3 to 17.7 feet.

Moderately weathered, less iron oxide staining 17.7 to 75.5 feet.

R4: Joint/fractures range from 80-90 degrees from assumed horizontal, with iron oxide staining, RCT = 7 min.

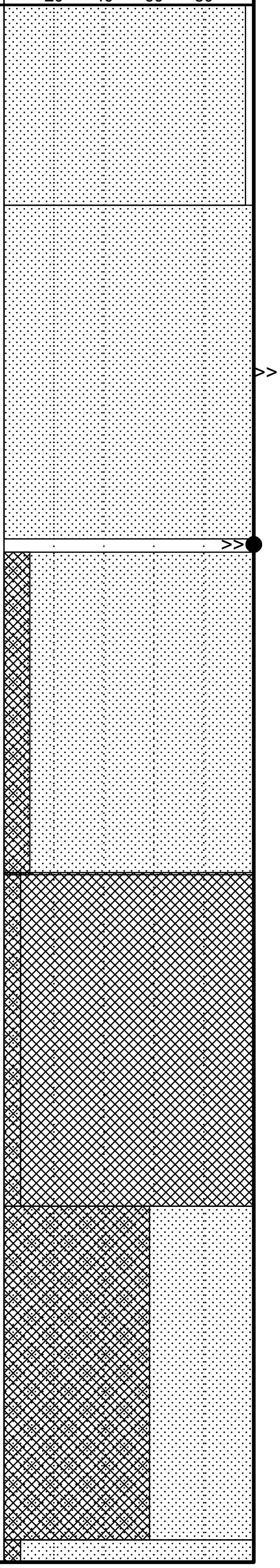
No.	Field Blow Count (Recovery) / Core Rec., RQD, and Frac. Freq.	Test Results
S-1	17-16-19-26 (22" = 92%)	
R1	Rec = 0% RQD = 0%	
S-2	39-50/5" (7" = 64%)	
R2	Rec = 50% RQD = 0%	
R3	Rec = 93% RQD = 0%	

BORING LOG PR19-07

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
		HQ3		R4	Rec = 97% RQD = 0%	
25	R5: Joint/fractures 70 degrees from assumed horizontal, with iron oxide staining, RCT = 9 min.			R5	Rec = 103% RQD = 0%	
	R6: Joint/fractures 80 degrees from assumed horizontal, with iron oxide staining, RCT = 8 min.			S-3	50/2" (1" = 50%)	
30				R6	Rec = 100% RQD = 10%	
35	R7: Joint/fractures 90 degrees from assumed horizontal, with clay infill, with iron oxide staining, RCT = 9 min.			R7	Rec = 7% RQD = 100%	
40	R8: Discountinuities are in good condition, joint/fractures range from 0-80 degrees from assumed horizontal, with iron oxide staining, RCT = 11 min.			R8	Rec = 100% RQD = 58% FF = 10	UC = 7260 psi
	R9: Joint/fractures range from 0-90 degrees from					

● N VALUE
20 40 60 80
PL WC LL
20 40 60 80
RQD (%) ▨ Recovery (%) ░
20 40 60 80



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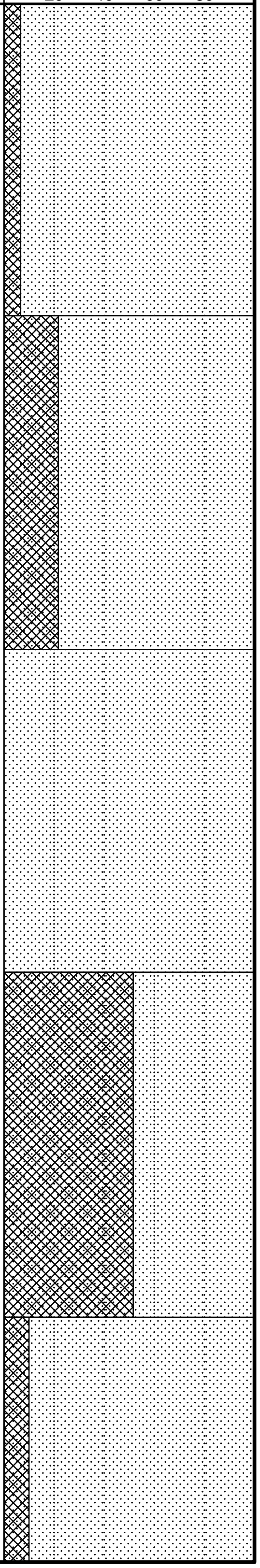
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR19-07

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Sheet: 3 of 5

Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results	● N VALUE 20 40 60 80 PL WC LL 20 40 60 80 RQD (%) ▨ Recovery (%) ░ 20 40 60 80
45		assumed horizontal, with iron oxide staining, RCT = 8 min.	HQ3		R9	Rec = 100% RQD = 7% FF = 10		
50		R10: Joint/fractures range from 0-80 degrees from assumed horizontal, with iron oxide staining, RCT = 11 min.			R10	Rec = 100% RQD = 22% FF = 4		
55		R11: Joint/fractures range from 30-90 degrees from assumed horizontal, with iron oxide staining, RCT = 11 min.			R11	Rec = 100% RQD = 0% FF = 10		
60		R12: Joint/fractures range from 30-90 degrees from assumed horizontal, with iron oxide staining, RCT = 8 min. Weak rock (R2) to medium strong rock (R3) 58.1 to 93.8 feet. Discontinuities are in very poor condition, with clay infill at 59.3 feet.			R12	Rec = 100% RQD = 52% FF = 3		
65		R13: Joint/fractures range from 30-90 degrees from assumed horizontal, with iron oxide staining, RCT = 9 min.			R13	Rec = 100% RQD = 10% FF = 10		



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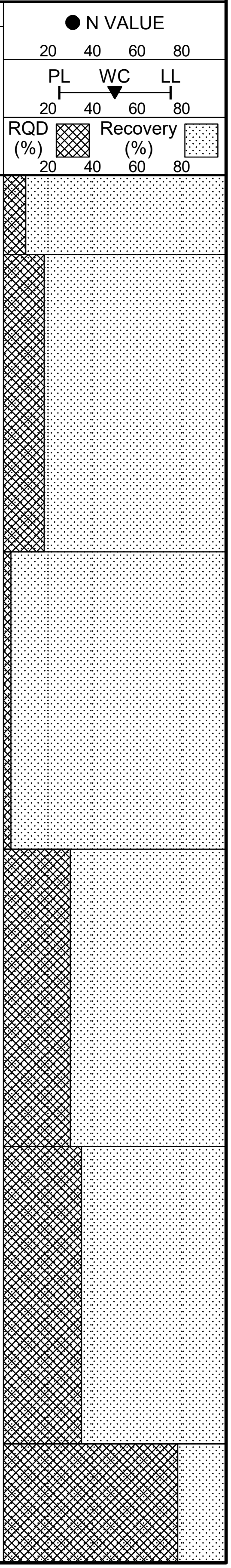
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR19-07

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Sheet: 4 of 5

Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
	R14: Joint/fractures range from 0-90 degrees from assumed horizontal, with iron oxide staining, RCT = 11 min. Vescular void at 68.7 feet.				
70			R14	Rec = 100% RQD = 18% FF = 10	
	R15: Joint/fractures range from 0-70 degrees from assumed horizontal, with iron oxide staining, RCT = 7 min. Discontinuities are in very poor condition, with clay infill at at 73.9 feet.				UC = 4960 psi
75			R15	Rec = 100% RQD = 3% FF = 10	
	Highly weathered, higher fractures from 75.5 to 76.0 feet. Moderately weathered 76.0 to 93.8 feet.				
	R16: Discountinuities are in good condition, joint/fractures range from 10-90 degrees from assumed horizontal, with iron oxide staining, RCT = 10 min.	HQ3			
80			R16	Rec = 100% RQD = 30% FF = 10	
	Yellowish black to reddish brown 81.0 to 93.8 feet.				
	R17: Joint/fractures range from 40-90 degrees from assumed horizontal, with iron oxide staining, RCT = 11 min.				
85	Discountinuities are in very poor condition, with greenish grey infill clay and quartz at 85.1 feet		R17	Rec = 100% RQD = 35%	
	Flow banding at 87.0 feet.				
	R18: Discountinuities are in good condition, joint/fractures range from 0-90 degrees from assumed horizontal, with iron oxide staining, RCT = 14 min. Perlite inclusions at 88.2 feet.				UC = 1260 psi

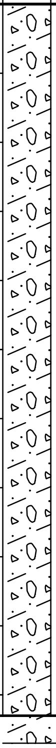


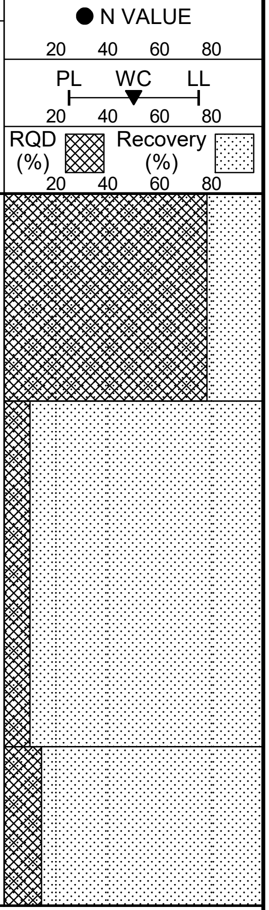
BORING LOG PR19-07

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Sheet: 5 of 5

Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
		HQ3		R18	Rec = 100% RQD = 78%	UC = 4410 psi
95	R19: Joint/fractures range from 70-90 degrees from assumed horizontal, with iron oxide staining, RCT = 16 min. Bluish grey to yellowish brown, extremely weak rock (R0) to weak rock (R2) 93.8 to 97.3 feet. Highly weathered to completely weathered below 93.8 feet. Occasional pockets of gravel below 96.0 feet Ice inclusions, Vx, hard, clear, colorless, approximately 0.5 inch diameter at 97.0 feet			R19	Rec = 100% RQD = 10%	
100	Light grey to yellowish brown, medium strong rock (R3) below 97.3 feet. R20: Joint/fractures range from 0-70 degrees from assumed horizontal, with iron oxide staining, RCT = 10 min.			R20	Rec = 100% RQD = 14%	





100.7 ft

Water levels obtained day after bailing excavation; due to subsurface conditions may not indicate accurate groundwater levels.
VWP S/N 1901649 installed to 90.0 feet bgs.
Thermistor string installed 3 - 33 feet bgs (sensor every 2'). 3.34-inch slope inclinometer installed to 90 feet bgs.

Bottom of borehole at 100.3 ft.

U. S. DEPARTMENT OF TRANSPORTATION
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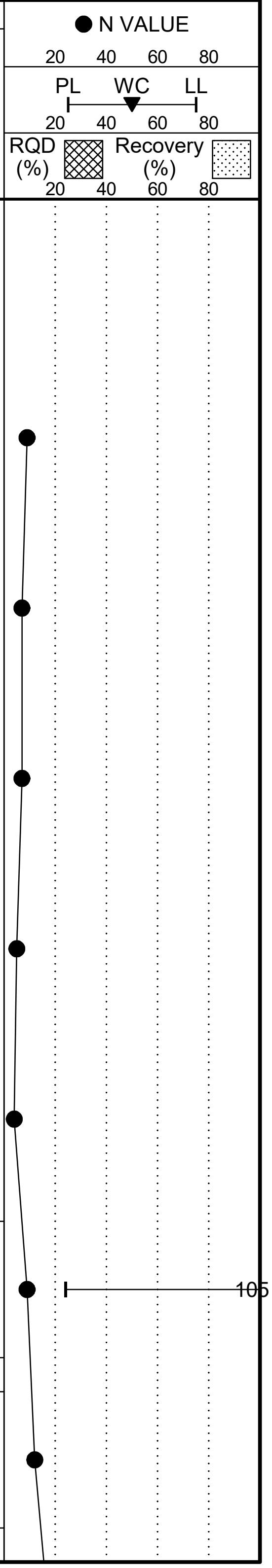
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR19-08

Project Name: Pretty Rocks Landslide
Sheet: 1 of 5
Project Location: Denali National Park, Alaska
Latitude: 63.536892° Longitude: -149.817512°
Groundwater Depth:
Date Started: 8/31/19 Date Completed: 9/4/19
∇ While Drilling: 89.8 ft
Driller/Company: Glen/GEOTEK AK Drill: CME-75
At Completion: ---
Hammer Type: 140 lbs Automatic
After Drilling: ---
Logger/Company: RDD/JLD/S&W
Notes:
Weather: 40's, night, windy

VWPs (▮) installed at 93 ft depth.
Geophysical survey performed following drilling. Thermistor string installed 0 - 32 feet bgs (sensor every 2 feet). 3.34-inch slope inclinometer installed to 100 feet bgs.

Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
0	Clayey GRAVEL with sand, loose, brown to dark brown, moist, angular, disrupted. Interpeted as Fill.	CASING ADVANCER				
			⧗	S-1	2-5-4-3 (18" = 75%)	
4.75 ft	Poorly graded GRAVEL with silt and sand, loose, dark brown to light yellow, moist, angular, disrupted.					
5			⧗	S-2	3-4-3-1 (13" = 54%)	
			⧗	S-3	2-4-3-1 (10" = 42%)	
10			⧗	S-4	3-4-1-1 (12" = 50%)	
11.5 ft	Clayey SAND, very loose, yellow to brown, moist, angular.					
11.9 ft	Fat CLAY, soft, yellow to brown, moist, high plasticity, blocky. Residual Rhyolite and Ash Tuff completely weathered, extremely weak rock.		⧗	S-5	2-2-2-2 (11" = 46%)	
15			⧗	S-6	3-4-5-7 (17" = 71%)	Fines = 59% SG = 2.75 Temp. = 41.2°F
			⧗	S-7	3-5-7-7 (24" = 100%)	Temp. = 55.1°F
19.8 ft						



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FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR19-08

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Sheet: 2 of 5

MATERIAL DESCRIPTION

RHYOLITE, loose, yellowish brown to light grey, moist, fine grained, completely weathered to highly weathered, extremely weak rock (R0) to very weak rock (R1). weathered to fat clay with sand. *(continued)*

23.6 ft

BASALT, dark grey, fine grained, olivine inclusions, slightly weathered to fresh, weak rock (R2) to medium strong rock (R3).

24 ft

RHYOLITE, yellowish brown to dark grey, fine grained, basalt and perlite linclusions, completely weathered to highly weathered, extremely weak rock (R0) to very weak rock (R1), residual soil is clayey GRAVEL with sand, moist, fine to coarse gravel. Occasional quartz infill in joints.

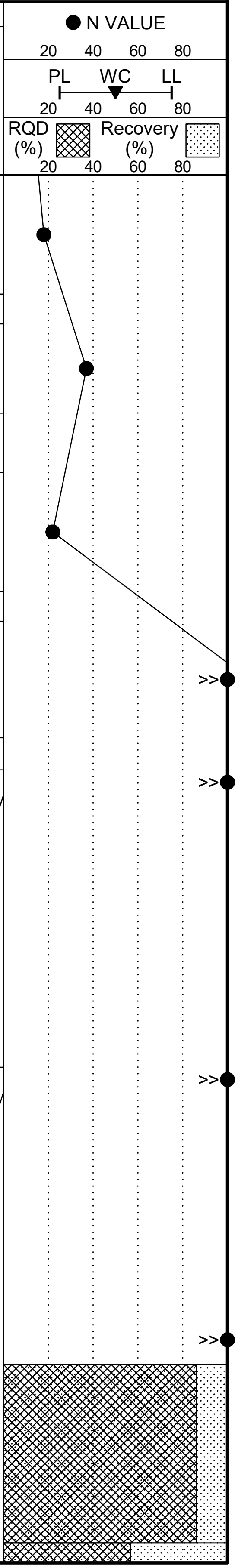
40 ft

BASALT, slightly vesicular, grey to reddish brown, fine grained, slightly weathered to fresh, strong rock (R4) to very strong rock (R5).
R1: Discontinuities are closely spaced to very closely spaced and in good condition. Joint/fractures range from 30-60 degrees from assumed horizontal, with iron oxide staining, RCT = 8 min.

R2: Joint/fractures range from 20-90 degrees from

Depth (ft): 25, 30, 35, 40

Drilling Method	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
CASING ADVANCER	S-8	5-8-10-9 (24" = 100%)	Temp. = 40.2°F
CASING ADVANCER	S-9	8-11-26 (18" = 100%)	Temp. = 42.3°F
CASING ADVANCER	S-10	5-11-11-16 (24" = 100%)	Temp. = 41.0°F
CASING ADVANCER	S-11	9-30-35-50/6" (22" = 94%)	Temp. = 42.3°F
CASING ADVANCER	S-12	50/5" (5" = 100%)	Temp. = 43.7°F
CASING ADVANCER	S-13	50/5" (4" = 80%)	Temp. = 43.0°F
CASING ADVANCER	S-14	9-9-50/2" (0" = 0%)	
HQ3	R1	Rec = 100% RQD = 86% FF = 2	UC = 8210 psi



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FEDERAL LANDS HIGHWAY DIVISION

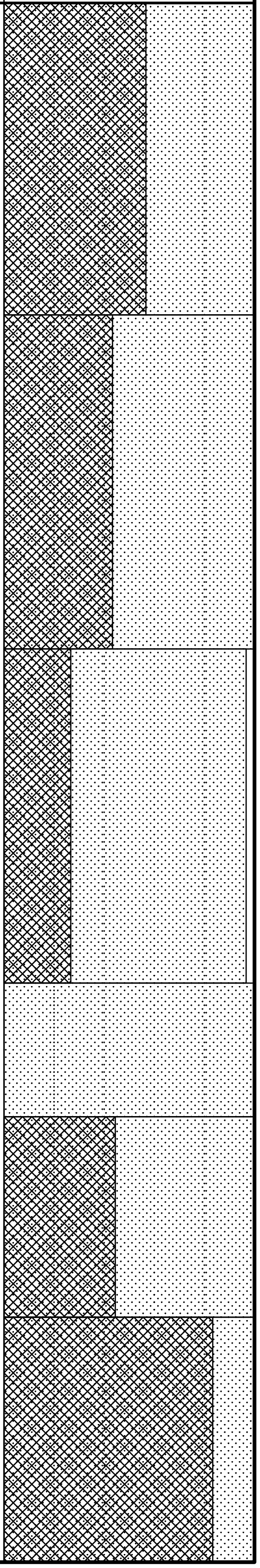
BORING LOG PR19-08

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Sheet: 3 of 5

Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
45		assumed horizontal, with iron oxide staining, RCT = 11 min. BASALT, slightly vesicular, grey to reddish brown, fine grained, slightly weathered to fresh, strong rock (R4) to very strong rock (R5). R1: Discontinuities are closely spaced to very closely spaced and in good condition. Joint/fractures range from 30-60 degrees from assumed horizontal, with iron oxide staining, RCT = 8 min. *(continued)* Slightly weathered to moderately weathered 47.3 to 47.8 feet.	HQ3		R2	Rec = 100% RQD = 57% FF = 6	
50		Slightly weathered to fresh 47.8 to 75.0 feet. R3: Joint/fractures range from 70-90 degrees from assumed horizontal, with iron oxide staining, RCT = 8 min.			R3	Rec = 100% RQD = 43% FF = 10	
55		R4: Joint/fractures range from 10-90 degrees from assumed horizontal, with iron oxide staining, RCT = 9 min.			R4	Rec = 97% RQD = 27% FF = 10	
		Core loss 58.0 to 58.2 feet R5: Joint/fractures range from 70-90 degrees from assumed horizontal, with iron oxide staining, RCT = 7 min.			R5	Rec = 100% RQD = 0% FF = 10	
60		R6: Joint/fractures range from 10-90 degrees from assumed horizontal, with iron oxide staining, RCT = 20 min.			R6	Rec = 100% RQD = 44% FF = 5	
65		R7: Joint/fractures range from 60-70 degrees from assumed horizontal, with iron oxide staining, RCT = 23 min.			R7	Rec = 100% RQD = 83% FF = 3	

● N VALUE
20 40 60 80
PL WC LL
20 40 60 80
RQD (%) ▨ Recovery (%) ░
20 40 60 80



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FEDERAL LANDS HIGHWAY DIVISION

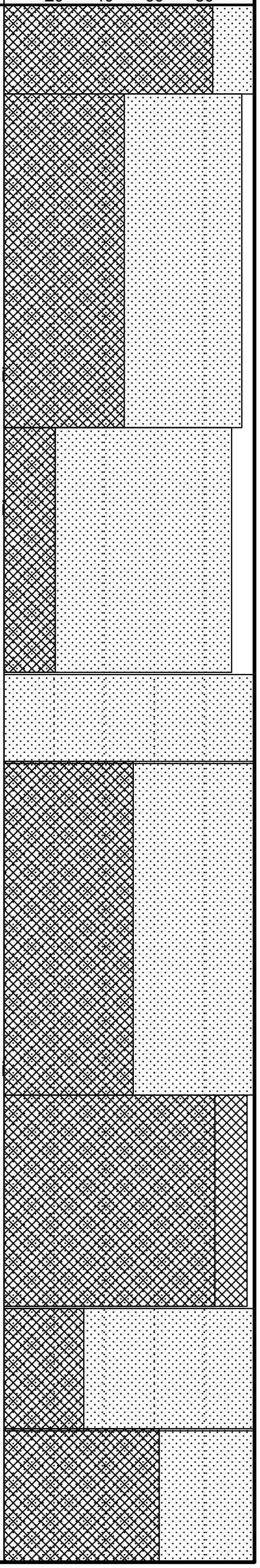
BORING LOG PR19-08

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Sheet: 4 of 5

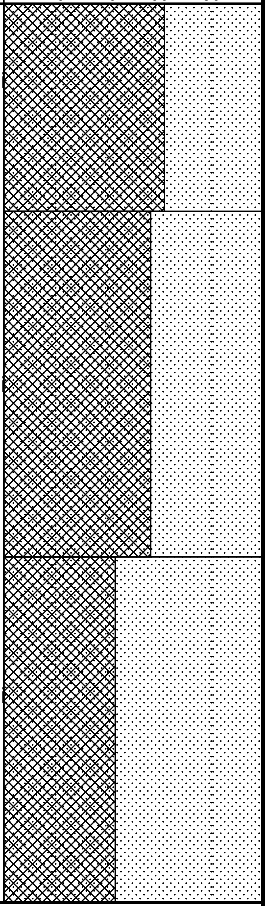
Depth (ft)	Material Description	Drilling Method	Sample Type	Sample No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
	Quartz veinlets at 67.7 feet.	HQ3				
70	R8: Joint/fractures range from 0-70 degrees from assumed horizontal, with iron oxide staining, RCT = 10 min. 69 ft Void 69.0 to 69.3 feet. 69.3 ft			R8	Rec = 95% RQD = 48% FF = 10	UC = 22070 ps
75	R9: Joint/fractures range from 0-90 degrees from assumed horizontal, with iron oxide staining, RCT = 12 min. Core loss 73.0 to 73.3 feet. 75 ft Highly weathered, with clay infill 75.0 to 75.25 feet. 75.25 ft Slightly weathered to fresh below 75.25 feet.			R9	Rec = 91% RQD = 20% FF = 10	UC = 26500 ps
	R10: Joint/fractures range from 10-90 degrees from assumed horizontal, with iron oxide staining, RCT = 6 min.			R10	Rec = 100% RQD = 0% FF = 10	
80	R11: Joint/fractures range from 0-90 degrees from assumed horizontal, with iron oxide staining, RCT = 23 min.			R11	Rec = 100% RQD = 52% FF = 10	UC = 10510 ps
85	R12: Joint/fractures range from 10-90 degrees from assumed horizontal, with iron oxide staining, RCT = 12 min.			R12	Rec = 84% RQD = 97% FF = 10	
	R13: Joint/fractures range from 0-70 degrees from assumed horizontal, with iron oxide staining, RCT = 7 min.			R13	Rec = 100% RQD = 32%	
	R14: Joint/fractures range from 10-75 degrees from assumed horizontal, with iron oxide staining, RCT = 17 min.					

● N VALUE 20 40 60 80
PL WC LL 20 40 60 80
RQD (%) ▨ Recovery (%) ░ 20 40 60 80



BORING LOG PR19-08

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	SAMPLE Test Results	● N VALUE 20 40 60 80 PL WC LL 20 40 60 80 RQD (%) ▩ Recovery (%) ▒ 20 40 60 80
		Slightly weathered to fresh below 75.25 feet. *(continued)*	HQ3		R14	Rec = 100% RQD = 62% FF = 7	UC = 14020 ps	
95		R15: Joint/fractures range from 30-90 degrees from assumed horizontal, with iron oxide staining, RCT = 15 min.			R15	Rec = 100% RQD = 57% FF = 4	UC = 31020 ps	
100		R16: Joint/fractures range from 20-75 degrees from assumed horizontal, with iron oxide staining, RCT = 14 min. Occasional quartz mineralization in vescules at 98.5 feet. 103 ft			R16	Rec = 100% RQD = 43% FF = 10	UC = 21170 ps	

Water levels obtained day after bailing excavation before drilling started. Due to subsurface conditions indicated groundwater levels may not be accurate. VWP S/N 1901650 installed to 93.0 feet. Thermistor string installed 0 - 32 feet bgs (sensor every 2 feet). 3.34-inch slope inclinometer installed to 100 feet bgs.

Bottom of borehole at 103 ft.

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FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR19-09

Project Name: Pretty Rocks Landslide
Sheet: 1 of 7
Project Location: Denali National Park, Alaska
Latitude: 63.536236° Longitude: -149.814394°
Groundwater Depth:
While Drilling: --- No Groundwater
At Completion: ---
After Drilling: ---
Date Started: 9/2/19 Date Completed: 9/6/19
Driller/Company: Travis/GEOTEK AK Drill: Geoprobe 8040DT
Hammer Type: 140 lbs Automatic
Logger/Company: JLD/S&W
Weather: 30-40's, night, windy
Notes:
Azmuth: 290 Dip: 45 Downhole geophysical conducted.

Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results	● N VALUE 20 40 60 80 PL WC LL 20 40 60 80 RQD (%) ▩ Recovery (%) ░ 20 40 60 80
		Poorly graded GRAVEL, Colluvium	HQ3					
3.5 ft		BASALT, light grey to reddish brown, fine grained, highly weathered to slightly weathered, medium strong rock (R3) to strong rock (R4). Discontinuities are extremely closely spaced to closely spaced and in good condition, with iron oxide staining. R1: Joint/fractures range from 25-80 degrees from relative to angle of boring, with iron oxide staining, RCT = 6 min. Highly fractured, broken core 3.5 to 5.0 feet.			R1	Rec = 100% RQD = 0% FF = 10		
5		R2: Highly fractured, slightly weathered to fresh, discontinuities are closely spaced and in good condition. Joint/fractures range from 60-80 degrees from relative to angle of boring, with iron oxide staining, RCT = 12 min. Discontinuities are very closely spaced and in good condition below 9.0 feet.			R2	Rec = 92% RQD = 0% FF = 10		
10 / 10.4 ft		R3: RCT = 20 min. Stiff, yellow to yellow-brown, Fat Clay, moist, blocky, medium to high plasticity. Completely weathered, redisual soil is Rhyolite Ash Tuff, hard, moist.					Fines = 79% SG = 2.79	
12.4 ft		RHYOLITE TUFF, light gray to blue gray, fine grained, highly weathered, extremely weak rock (R0). Discontinuities are closely spaced and in good condition, with iron oxide staining.			R3	Rec = 72% FF = 1		
15		R4: RCT = 13 min.			R4	Rec = 100%	Fines = 72% SG = 2.85	

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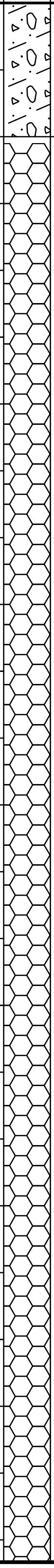
FEDERAL LANDS HIGHWAY DIVISION

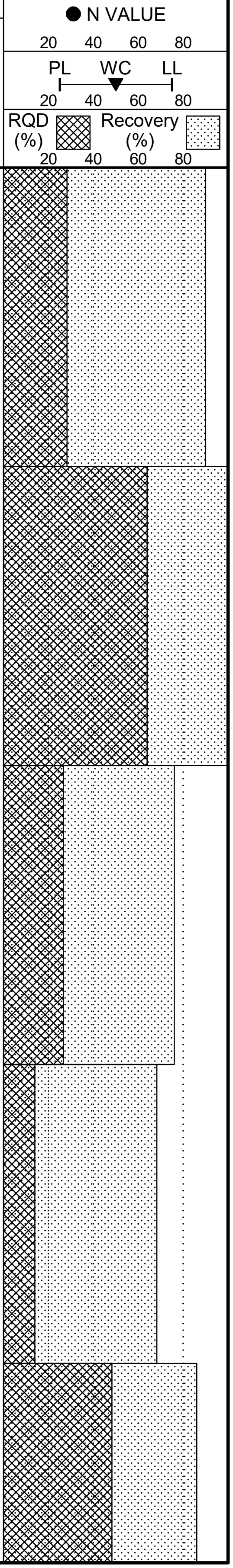
BORING LOG PR19-09

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Sheet: 2 of 7



Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
	R5: Joint/fractures range from 40-90 degrees from relative to angle of boring, with iron oxide staining, RCT = 23 min. Core loss 20.0 to 20.5 feet. Broken core 22.0 to 23.5 feet. 22 ft BASALT, grey to reddish brown, fine grained, slightly weathered to fresh, medium strong rock (R3) to strong rock (R4). Discontinuities are very closely spaced to closely spaced and in good condition, with iron oxide staining.	HQ3		R5	Rec = 90% RQD = 28% FF = 8	
25	R6: Joint/fractures range from 0-85 degrees from relative to angle of boring, with iron oxide staining, RCT = 12 min.			R6	Rec = 100% RQD = 64% FF = 6	
30	R7: Joint/fractures range from 30-80 degrees from relative to angle of boring, with iron oxide staining, RCT = 15 min. Core loss 30.8 to 31.4 feet.			R7	Rec = 76% RQD = 27% FF = 10	
35	R8: Joint/fractures 80 degrees from relative to angle of boring, with iron oxide staining. RCT = 27 min.			R8	Rec = 68% RQD = 14% FF = 7	
40	R9: Joint/fractures range from 80-85 degrees from relative to angle of boring, with iron oxide staining, RCT = 18 min. Light reddish grey below 40.0 feet.			R9	Rec = 86% RQD = 48% FF = 6	



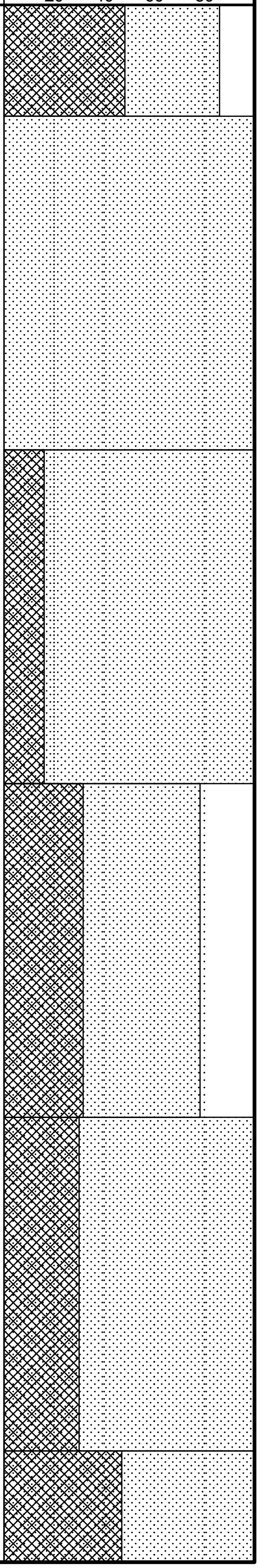
BORING LOG PR19-09

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Sheet: 3 of 7

Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
45	R10: Joint/fractures range from 15-85 degrees from relative to angle of boring, with iron oxide staining, RCT = 12 min.	HQ3		R10	Rec = 100% RQD = 0% FF = 8	
50	R11: Joint/fractures range from 30-88 degrees from relative to angle of boring, with iron oxide staining, RCT = 35 min.			R11	Rec = 100% RQD = 16% FF = 7	
55	R12: Joint/fractures range from 70-75 degrees from relative to angle of boring, with iron oxide staining, RCT = 32 min. Core loss 55.0 to 56.1 feet.			R12	Rec = 78% RQD = 32% FF = 10	
60	R13: Joint/fractures range from 30-88 degrees from relative to angle of boring, with iron oxide staining, RCT = 11 min.			R13	Rec = 100% RQD = 30% FF = 6	
65	R14: Joint/fractures range from 65-80 degrees from relative to angle of boring, with iron oxide staining, RCT = 24 min.				Rec = 100%	

● N VALUE
20 40 60 80
PL WC LL
20 40 60 80
RQD (%) ▨ Recovery (%) ░
20 40 60 80



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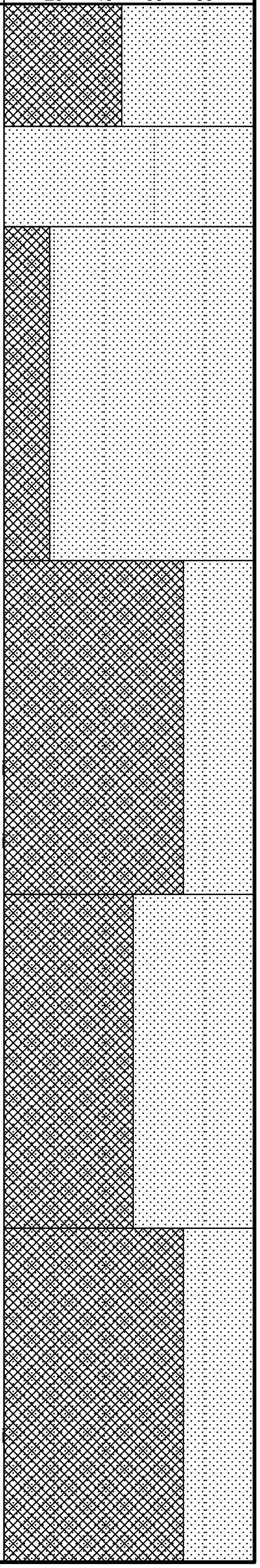
BORING LOG PR19-09

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska
Sheet: 4 of 7

Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	SAMPLE Test Results
		HQ3		R14	RQD = 47% FF = 5	
	R15: Joint/fractures range from 65-80 degrees from relative to angle of boring, with iron oxide staining, RCT = 8 min.			R15	Rec = 100% RQD = 0% FF = 10	
70	R16: Joint/fractures range from 55-85 degrees from relative to angle of boring, with iron oxide staining, RCT = 11 min.			R16	Rec = 100% RQD = 18% FF = 10	
75	R17: Joint/fractures range from 5-90 degrees from relative to angle of boring, with iron oxide staining, RCT = 16 min. Discontinuities are moderately spaced and in good condition 77.7 to 96.9 feet.			R17	Rec = 100% RQD = 72% FF = 2	UC = 8220 psi UC = 19840 ps UC = 16040 ps
80	R18: Joint/fractures range from 60-90 degrees from relative to angle of boring, with iron oxide staining, RCT = 20 min.			R18	Rec = 100% RQD = 52% FF = 2	
85	R19: Joint/fractures range from 20-80 degrees from relative to angle of boring, with iron oxide staining, RCT = 12 min. 1 to 2 mm Quartz veins at 85.8 feet. 1 to 2 mm Quartz veins at 89.0 feet.			R19	Rec = 100% RQD = 72% FF = 2	UC = 26510 ps

● N VALUE
20 40 60 80
PL WC LL
20 40 60 80
RQD (%) ▨ Recovery (%) ░
20 40 60 80



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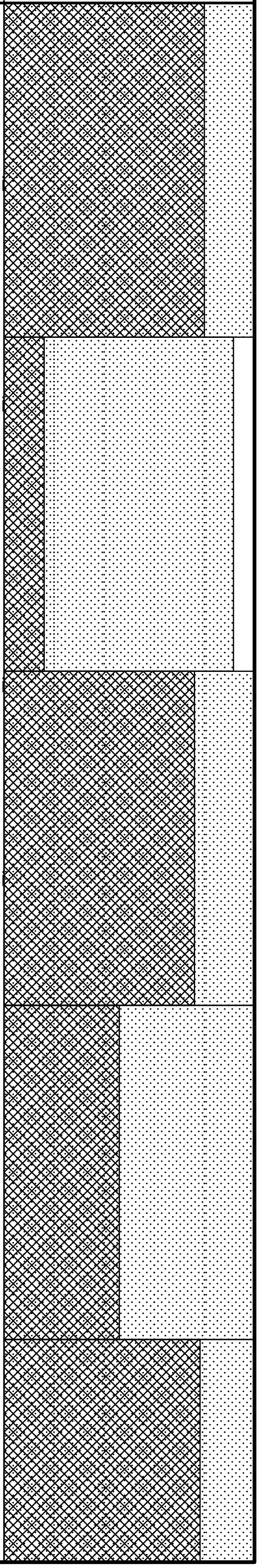
BORING LOG PR19-09

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Sheet: 5 of 7

Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
	R20: Joint/fractures range from 0-70 degrees from relative to angle of boring, with iron oxide staining, RCT = 16 min.	HQ3		R20	Rec = 100% RQD = 80% FF = 2	UC = 27120 ps
95	R21: Joint/fractures range from 5-50 degrees from relative to angle of boring, with iron oxide staining, RCT = 16 min. Discontinuities are very closely spaced to closely spaced and in good condition 96.9 to 100.0 feet.			R21	Rec = 92% RQD = 16% FF = 10	UC = 14420 ps
100	Discontinuities are closely spaced to moderately spaced and in good condition below 100.0 feet. R22: Joint/fractures range from 15-60 degrees from relative to angle of boring, with iron oxide staining, RCT = 18 min.			R22	Rec = 100% RQD = 76% FF = 3	UC = 11980 psi UC = 23990 psi
105	R23: Joint/fractures range from 60-90 degrees from relative to angle of boring, with iron oxide staining, RCT = 20 min.			R23	Rec = 100% RQD = 46% FF = 5	UC = 6700 psi
110	R24: Joint/fractures range from 10-80 degrees from relative to angle of boring, with iron oxide staining, RCT = 15 min.			R24	Rec = 100% RQD = 78% FF = 2	UC = 7070 psi

● N VALUE
20 40 60 80
PL WC LL
20 40 60 80
RQD (%) ▨ Recovery (%) ░
20 40 60 80



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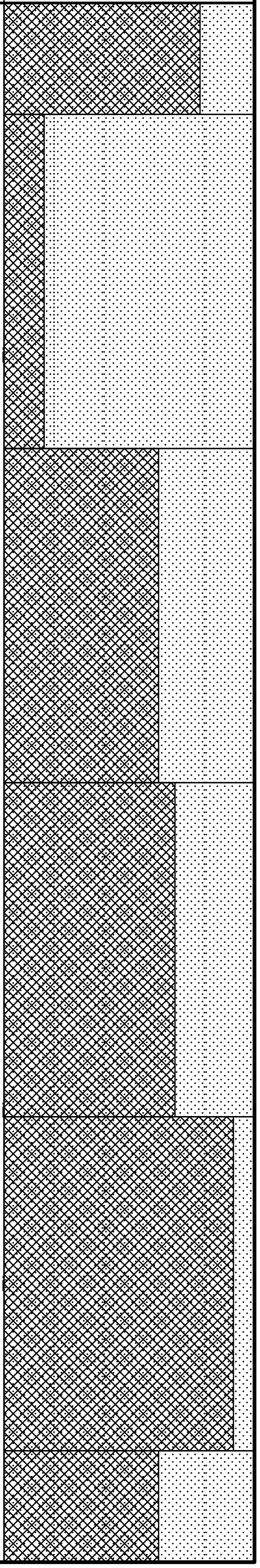
BORING LOG PR19-09

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska
Sheet: 6 of 7

Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	Test Results
115	R25: Joint/fractures range from 20-90 degrees from relative to angle of boring, with iron oxide staining, RCT = 22 min.			R25	Rec = 100% RQD = 16% FF = 6	UC = 16210 psi
120	R26: Joint/fractures range from 5-85 degrees from relative to angle of boring, with iron oxide staining, RCT = 19 min.			R26	Rec = 100% RQD = 62% FF = 1	UC = 8070 psi
125	R27: Joint/fractures range from 10-90 degrees from relative to angle of boring, with iron oxide staining, RCT = 27 min.	HQ3		R27	Rec = 100% RQD = 68% FF = 1	
130	R28: Joint/fractures range from 10-70 degrees from relative to angle of boring, with iron oxide staining, RCT = 13 min.			R28	Rec = 100% RQD = 92% FF = 1	UC = 16260 psi UC = 34940 psi
135	R29: Joint/fractures range from 5-50 degrees from relative to angle of boring, with iron oxide staining, RCT = 26 min.					

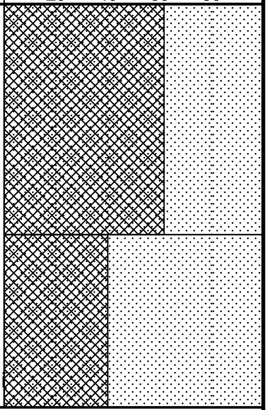
● N VALUE
20 40 60 80
PL WC LL
20 40 60 80
RQD (%) ▩ Recovery (%) ░
20 40 60 80



BORING LOG PR19-09

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska
Sheet: 7 of 7

Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery) Core Rec., RQD, and Frac. Freq.	SAMPLE Test Results	● N VALUE 20 40 60 80 PL WC LL 20 40 60 80 RQD (%) ▨ Recovery (%) ░ 20 40 60 80
			HQ3		R29	Rec = 100% RQD = 62% FF = 3		
140		R30: Joint/fractures range from 10-90 degrees from relative to angle of boring, with iron oxide staining, RCT = 15 min. 142.5 ft			R30	Rec = 100% RQD = 40% FF = 2	UC = 29790 ps	



No instumentation installed. Backfilled with grout.
Bottom of borehole at 142.5 ft.

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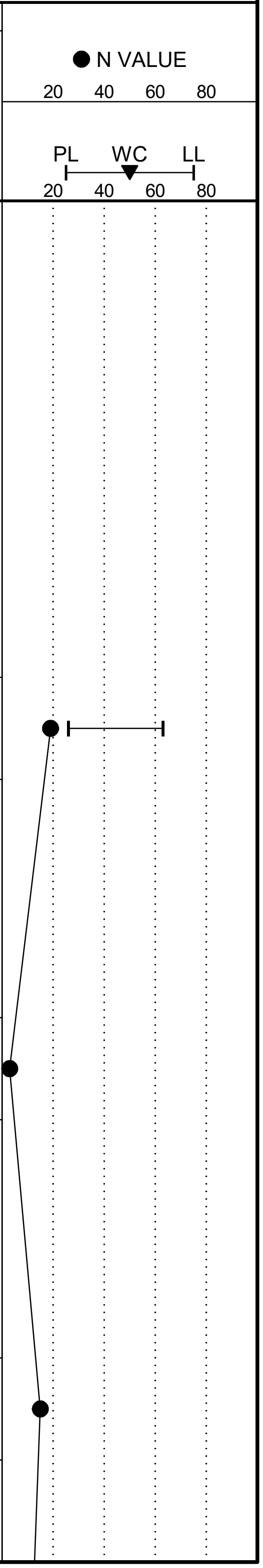
BORING LOG PR19-11

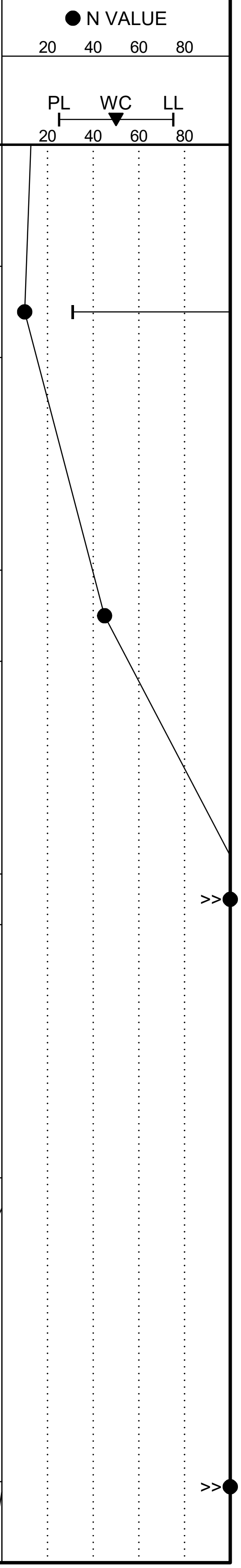
Project Name: Pretty Rocks Landslide
Sheet: 1 of 7
Project Location: Denali National Park, Alaska
Latitude: 63.534009° Longitude: -149.819308°
Groundwater Depth:
Date Started: 9/12/19 Date Completed: 9/22/19
∇ While Drilling: 23.4 ft
Driller/Company: Travis/GEOTEK AK Drill: Geoprobe 8040DT
At Completion: ---
Hammer Type: 140 lbs Automatic
▼ After Drilling: 64 ft
Logger/Company: RDD/S&W
Notes:
Weather: 40-50's, partly cloudy, windy

VWPs (▮) installed at 55, 98 ft depth.
Thermistor string installed 0 - 105 feet bgs (sensors: 0 - 50 ft every 2 ft & 50 - 105 ft every 5 feet). 3.34-inch slope inclinometer installed to 157 feet bgs.

Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery)	SAMPLE Test Results
0		Elastic SILT with sand, stiff, yellow and brown to dark gray, moist. Frozen (Vr), random ice inclusions up to 1/2 inch in diameter and up to 1 inch in length; cloudy ; disrupted; perlite inclusions.	CASING ADVANCER				
5							
				⧗	S-1	5-8-11 (18" = 100%)	Fines = 33% SG = 2.46 Temp. = 32.0°F
10							
10.3 ft		Silty SAND, very loose, yellow and brown to black, moist, trace gravel. Frozen (Vx) visible ice crystals 1mm to 3mm in size; cloudy; disrupted; perlite inclusions.					
				⧗	S-2	3-2-1 (18" = 100%)	Temp. = 32.7°F
15							
15.5 ft		Elastic SILT, stiff, yellow and brown to light gray, moist, trace gravel. Frozen (Vx) visible ice crystals 1mm to 3mm in size; cloudy; homogeneous.					
				⧗	S-3	4-6-9 (18" = 100%)	Temp. = 31.9°F
19.5 ft		*(description on next page)*					



Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Sample Type	No.	Field Blow Count (Recovery)	Test Results
	Fat CLAY, stiff, yellow and brown to light gray, moist. Frozen (Vr), random ice inclusions up to 1/2 inch in diameter and up to 1 inch in length; cloudy; homogeneous. *(continued)*	CASING ADVANCER				
	⊻		⧗	S-4	4-4-6 (18" = 100%)	Fines = 78% SG = 2.63 Temp. = 32.3°F
25	25.5 ft					
	COBBLES, very dense, light brown.					
	Sandy GRAVEL, light gray to light brown. Frozen (Vr), random ice inclusions up to 1/4 inch in dimaeter; cloudy; homogeneous. Sample 5A was frozen and is stored in NPS freezer at Denali National Park.		⧗	S-5	12-9-36 (17" = 94%)	Temp. = 32.1°F
30						
			⧗	S-6	29-50/4" (10" = 100%)	Temp. = 32.4°F
	34 ft					
35	Ice, hard, (Vs), ice lenses up to 1 inch thick and 2 1/2 inches long oriented approximately 60 degrees from horizontal; cloudy; rhyolite inclusions and gravel with cobbles in ice.					
	Sample 7 was frozen and is stored in NPS freezer at Denali National Park.		⧗	S-7	50 (6" = 100%)	Temp. = 31.6°F
40						
	Sample 8 was frozen and is stored in NPS freezer at Denali National Park.		⧗	S-8	50/2" (2" = 100%)	Temp. = 38.5°F

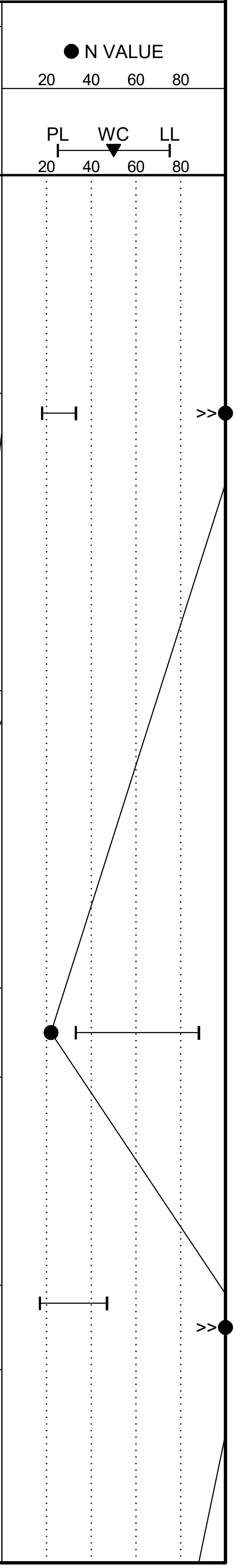


BORING LOG PR19-11

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Sheet: 3 of 7

Depth (ft)	Material Description	Drilling Method	Sample No.	Field Blow Count (Recovery)	Test Results
44.5 ft	Silty SAND with gravel, very dense, light brown, moist. Frozen (Vr), visible ice inclusions up to 1 inch wide and 1 inch long; cloudy; disrupted; 1-inch hard cobbles inferred from drilling action at 47.5 feet.	CASING ADVANCER			
			S-9	26-50/2" (8" = 100%)	Fines = 17% SG = 2.64 Temp. = 32.6°F
	Sample 10 was frozen and is stored in NPS freezer at Denali National Park.		S-10	50 (6" = 100%)	Temp. = 33.1°F
55 ft	Fat CLAY, very stiff, gray, moist, trace fine sand; homogeneous. Occcasional weathered rhyolite gravel.				
			S-11	3-10-12 (18" = 100%)	Fines = 78% SG = 2.66 Temp. = 40.1°F
62.3 ft	Silty SAND with gravel, very dense, yellow and brown to gray, moist, iron oxide staining, angular gravel.		S-12	11-21-50/5" (17" = 100%)	Fines = 26% SG = 2.75 Temp. = 44.1/45.9°F
66 ft	Sandy GRAVEL with clay; with basalt cobbles below 66.0 feet.				



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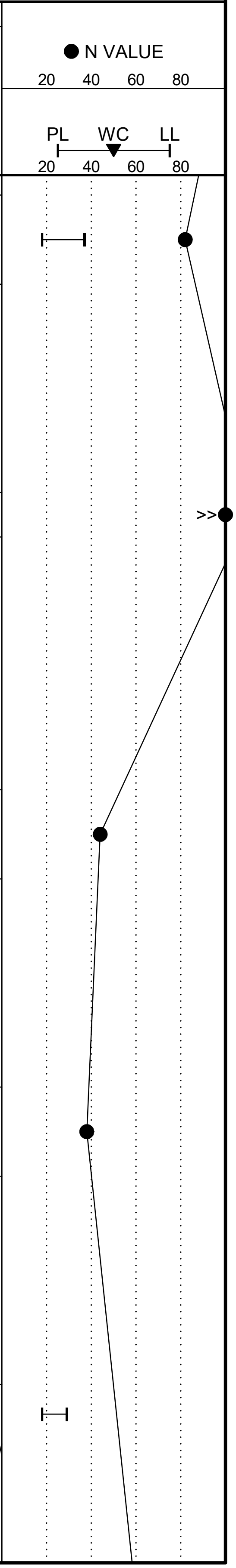
BORING LOG PR19-11

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Sheet: 4 of 7

Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Sample No.	Field Blow Count (Recovery)	Test Results
	Sandy GRAVEL with clay; with basalt cobbles below 66.0 feet. *(continued)*	CASING ADVANCER	S-13	38-40-42 (14" = 78%)	Fines = 12% SG = 2.75 Temp. = 43.9°F
70	70 ft Silty GRAVEL with sand, very dense, yellow and brown to gray, moist, iron oxide staining; disrupted, Angular cobbles inferred from drilling with basalt inclusions. Sample 14 was frozen and is stored in NPS freezer at Denali National Park.		S-14	20-50/3" (9" = 100%)	Temp. = 42.3°F
75	75 ft Silty SAND, dense, brown to gray, moist, trace gravel; disrupted. Angular to subangular gravel.		S-15	11-21-23 (5" = 28%)	Temp. = 43.9°F
80	80 ft Fat CLAY, very stiff, yellow and brown to light gray, trace sand, trace gravel, iron oxide staining, Coarse sand; homogeneous; basalt nodule in shoe; rounded gravel.		S-16	6-10-28 (18" = 100%)	Temp. = 43.4°F
85	85 ft Silty SAND with gravel, very dense, brown to dark gray, moist, subrounded to rounded sand and gravel, disrupted, mostly rhyolite.		S-17	20-50 (10" = 83%)	Fines = 14% SG = 2.72 Temp. = 43.7°F



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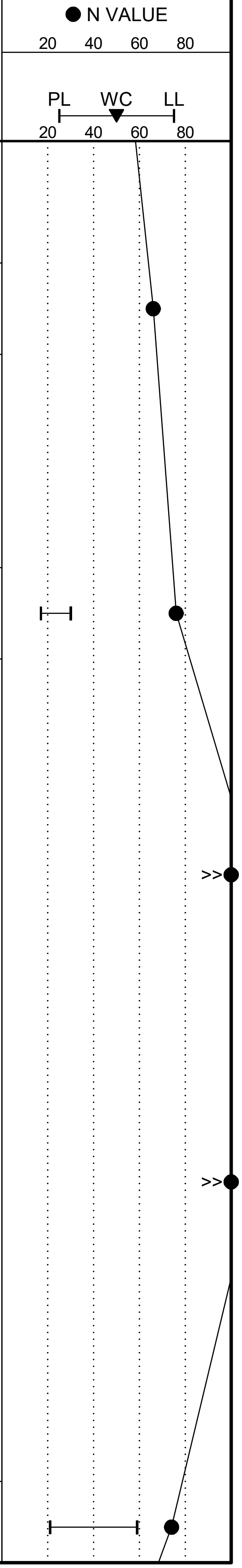
BORING LOG PR19-11

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska

Sheet: 5 of 7

Depth (ft)	Material Description	Drilling Method	SAMPLE Type	No.	Field Blow Count (Recovery)	Test Results
	Gravel more angular and basaltic below 90.0 feet.	CASING ADVANCER				
			⧗	S-18	30-32-34 (15" = 83%)	Temp. = 48.6°F
95	95 ft Silty GRAVEL with sand, very dense, brown, moist, subrounded to angular gravel, disrupted.					
			⧗	S-19	20-41-35 (13" = 72%)	Fines = 17% SG = 2.67 Temp. = 48.0/47.7°F
100	100 ft No recovery from samples taken at 102.0 and 107.0 feet, rhyolite inferred based on drilling action and residue on split spoon.					
			⧗	S-20	50/1" (0" = 0%)	
105						
			⧗	S-21	50/2" (0" = 0%)	
110	110 ft RHYOLITE TUFF, bluish grey, moist, fine grained, residual soil, extremely weak rock (R0). Completely weathered to fat clay.					
			⧗	S-22	20-32-42 (18" = 100%)	Fines = 84% SG = 2.71 Temp. =



U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

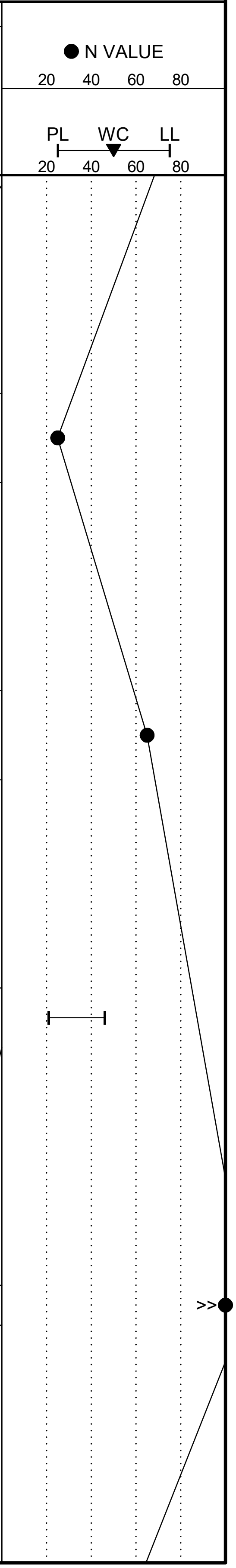
BORING LOG PR19-11

Project Name: Pretty Rocks Landslide

Project Location: Denali National Park, Alaska

Sheet: 6 of 7

Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	No.	Field Blow Count (Recovery)	Test Results
		CASING ADVANCER			43.7°F
115					
			S-23	15-15-10 (18" = 100%)	Temp. = 41.9°F
120					
			S-24	20-26-39 (18" = 100%)	Temp. = 40.7°F
125	125 ft Fat CLAY with sand and gravel, very stiff, blue to gray, moist, angular gravel, disrupted.				
			S-25	29-50 (12" = 100%)	Fines = 27% SG = 2.71 Temp. = 39.8°F
130					
			S-26	29-50/2" (8" = 100%)	Temp. = 35.8°F
135	135 ft RHYOLITE, bluish grey, moist, fine grained, residual soil, extremely weak rock (R0). Completely weathered to fat clay.				



FHWA BORING LOG - FHWA_DATATEMPLATE_20171103.GDT - 7/2/20 09:19 - \\FL17VFILE.HFL17DO1.WFL.FLD.FHWA.DOT.GOV\COMMON\TECH_SERVICES\GEOTECH\01_PROJECTS\AK\AK NPS DENA 10(45) PRETTY ROCKS INVESTIGATION\GEOTECHNICAL INVESTIGA

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG PR19-11

Project Name: Pretty Rocks Landslide
Project Location: Denali National Park, Alaska
Sheet: 7 of 7

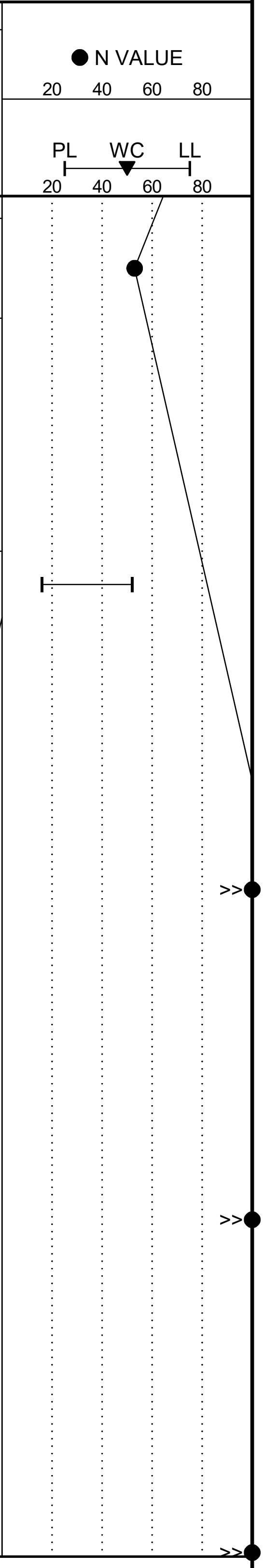
Depth (ft)	Sample Type	No.	Field Blow Count (Recovery)	Test Results
		S-27	18-23-30 (18" = 100%)	Temp. = 39.0°F
140				
		S-28	29-50 (12" = 100%)	Fines = 87% SG = 2.71 Temp. = 38.1°F
145				
		S-29	50/2" (0" = 0%)	
150				
		S-30	50/1" (0" = 0%)	
155				
		S-31	50/1" (0" = 0%)	

MATERIAL DESCRIPTION

No recovery from samples taken at 147.0, 152.0, and 157.0 feet, rhyolite inferred based on drilling action and residue on split spoon.

157.1 ft

Drilling Method: CASING ADVANCER



Water levels obtained after bailing borehole, and before drilling. Due to subsurface conditions groundwater levels may not be accurate.
VWP S/N 1902185 installed to 55.0 feet and VWP S/N 1932186 installed to 98.0 feet.
Bottom of borehole at 157.1 ft.

FHWA BORING LOG - FHWA_DATATEMPLATE_20171103.GDT - 7/2/20 09:19 - \\FL17VFILE.HFL17DO1.WFL.FLD.FHWA.DOT.GOV\COMMON\TECH_SERVICES\GEOTECH\01_PROJECTS\AK\AK NPS DENA 10(45) PRETTY ROCKS INVESTIGATION\GEOTECHNICAL INVESTIGA

APPENDIX D

Rock Core Photography

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

PHOTOGRAPH LOG

BORING PLY03-1

PROJECT: Denali National Park

STATION, OFFSET: ,

SURFACE ELEVATION: ft

Figure PLY03-1.1 Depth: 36ft to 46ft

Figure PLY03-1.2 Depth: 46ft to 55.5ft
Note: Final depth mislabeled at 56.5 ft. Actual final depth is 55.5 ft.

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

PHOTOGRAPH LOG

BORING PLY03-2

PROJECT: Denali National Park

STATION, OFFSET: ,

SURFACE ELEVATION: ft

Project No.: AK PRA AKRO ES(3)
Project Name: Denali 2016 Geotechnical Investigation
Laboratory sample ID: W-17-0354-MI
Boring ID: PLY 03-2
Box No.: 1 of 4
Depth (ft): 40.9 to 58.7

Figure PLY03-2.1 Depth: 40.9ft to 58.7ft

Project No.: AK PRA AKRO ES(3)
Project Name: Denali 2016 Geotechnical Investigation
Laboratory sample ID:W-17-0354-MI
Boring ID: PLY 03-2
Box No.: 2 of 4
Depth (ft): 58.7 to 74.8

Figure PLY03-2.2 Depth: 58.7ft to 74.8ft

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

PHOTOGRAPH LOG

BORING PLY03-2

PROJECT: Denali National Park

STATION, OFFSET: ,

SURFACE ELEVATION: ft

Figure PLY03-2.3 Depth: 74.8ft to 90.1ft

Figure PLY03-2.4 Depth: 90.1ft to 101.2ft

Test Boring
PR18-01

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide Investigation

Laboratory sample ID: W-18-1808-MI

Boring ID: PR18-01

Box No.: 1 of 4

Depth (ft): 53 to 63

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide Investigation

Laboratory sample ID: W-18-1810-MI

Boring ID: PR18-01

Box No.: 3 of 4

Depth (ft): 93.9 to 103

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide Investigation

Laboratory sample ID: W-18-1811-MI

Boring ID: PR18-01

Box No.: 4 of 4

Depth (ft): 103 to 109

Test Boring
PR18-03

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide Investigation

Laboratory sample ID: W-18-1812-MI

Boring ID: PR18-03

Box No.: 1 of 3

Depth (ft): 57 to 78

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide Investigation

Laboratory sample ID: W-18-1813-MI

Boring ID: PR18-03

Box No.: 2 of 3

Depth (ft): 78 to 93

Project No.: AK NPS DENA 10(45)	
Project Name: Pretty Rocks Landslide Investigation	
Laboratory sample ID: W-18-1814-MI	
Boring ID: PR18-03	Box No.: 3 of 3
Depth (ft): 93 to 108	

Test Boring
PR18-04

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide Investigation

Laboratory sample ID: W-18-1815-MI

Boring ID: PR18-04

Box No.: 1 of 5

Depth (ft): 67 to 83

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide Investigation

Laboratory sample ID: W-18-1816-MI

Boring ID: PR18-04 | Box No.: 2 of 5

Depth (ft): 83 to 91.5


Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide Investigation

Laboratory sample ID: W-18-1817-MI

Boring ID: PR18-04

Box No.: 3 of 5

Depth (ft): 91.5 to 100.5

Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide Investigation
Laboratory sample ID: W-18-1818-MI
Boring ID: PR18-04
Box No.: 4 of 5
Depth (ft): 100.5 to 109.75

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide Investigation

Laboratory sample ID: W-18-1819-MI

Boring ID: PR18-04

Box No.: 5 of 5

Depth (ft): 109.75 to 120

Test Boring
PR18-05

Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide Investigation
Laboratory sample ID: W-18-1820-MI
Boring ID: PR18-05
Box No.: 1 of 4
Depth (ft): 73 to 107.5

Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide Investigation
Laboratory sample ID: W-18-1821-MI
Boring ID: PR18-05
Box No.: 2 of 4
Depth (ft): 105.5 to 112.3

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide Investigation

Laboratory sample ID: W-18-1822-MI

Boring ID: PR18-05 | Box No.: 3 of 4

Depth (ft): 112.3 to 131.2


Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide Investigation
Laboratory sample ID: W-18-1823-MI
Boring ID: PR18-05
Box No.: 4 of 4
Depth (ft): 131.2 to 134.0
134.0'
132.0'

Test Boring
PR19-06

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1773-RC

Boring ID: PR19-06

Box No.: Box 1

Depth (ft): 23.0 - 31.0

Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide
Laboratory sample ID: W-19-1773-RC
Boring ID: PR19-06
Box No.: Box 2
Depth (ft): 31.0 - 40.0

Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide
Laboratory sample ID: W-19-1773-RC
Boring ID: PR19-06
Box No.: Box 3
Depth (ft): 40.0 - 48.6

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1773-RC

Boring ID: PR19-06

Box No.: Box 4

Depth (ft): 48.6 - 55.9

Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide
Laboratory sample ID: W-19-1773-RC
Boring ID: PR19-06
Box No.: Box 5
Depth (ft): 55.9 - 64.4

Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide
Laboratory sample ID: W-19-1773-RC
Boring ID: PR19-06
Box No.: Box 6
Depth (ft): 64.4 - 73.0

Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide
Laboratory sample ID: W-19-1773-RC
Boring ID: PR19-06
Box No.: Box 7
Depth (ft): 73.0 - 81.7

Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide
Laboratory sample ID: W-19-1773-RC
Boring ID: PR19-06
Box No.: Box 8
Depth (ft): 81.7 - 90.3


Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide
Laboratory sample ID: W-19-1773-RC
Boring ID: PR19-06
Box No.: Box 9
Depth (ft): 90.3 - 99.7


Project No.: AK NPS DENA 10(45)

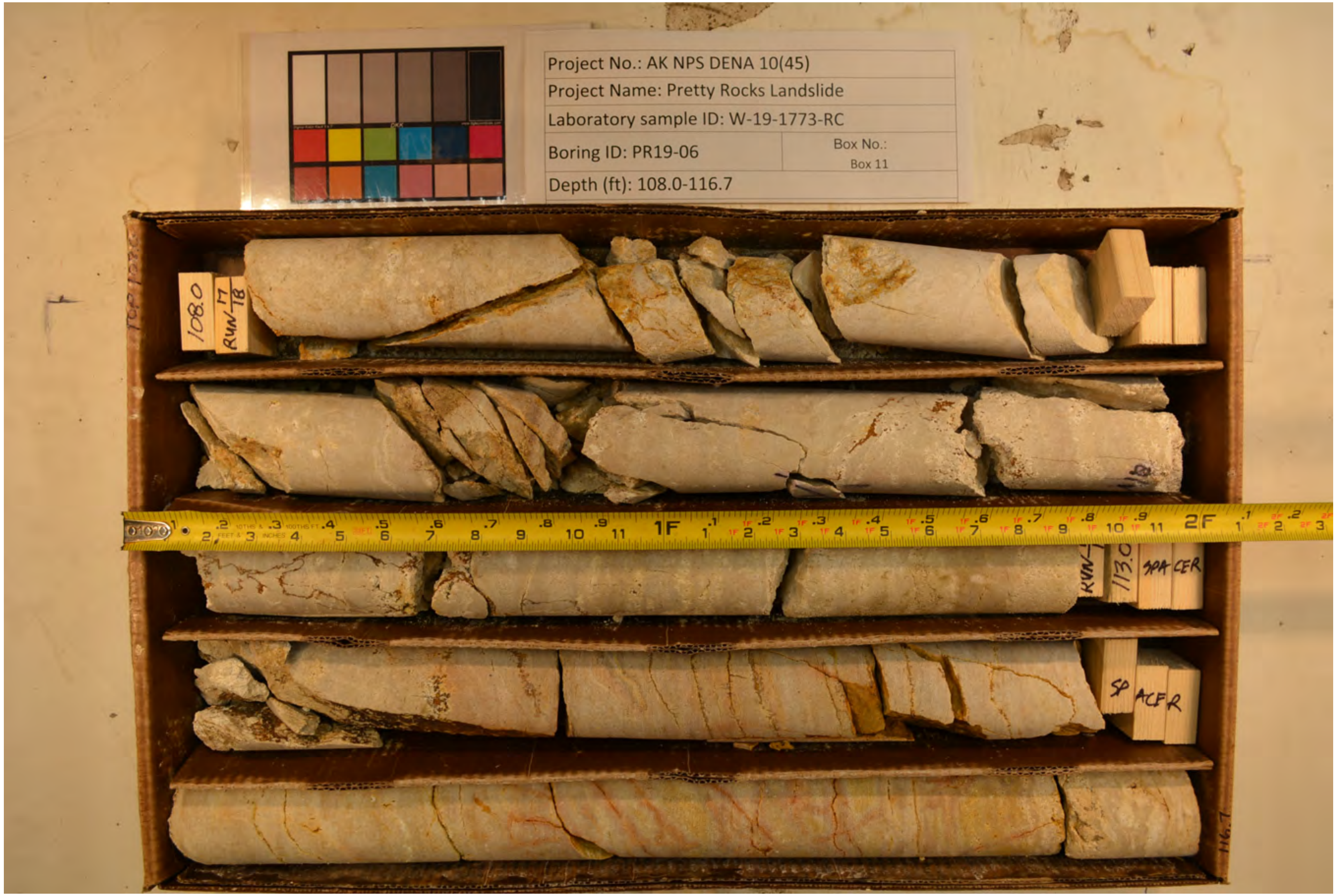
Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1773-RC

Boring ID: PR19-06

Box No.:
Box 10

Depth (ft): 99.7 - 108.0



Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1773-RC

Boring ID: PR19-06

Box No.: Box 11

Depth (ft): 108.0-116.7

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1773-RC

Boring ID: PR19-06

Box No.: Box 12

Depth (ft): 116.7-125.0

Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide
Laboratory sample ID: W-19-1773-RC
Boring ID: PR19-06
Box No.: Box 13
Depth (ft): 125.0-133.0

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1773-RC

Boring ID: PR19-06

Box No.: Box 14

Depth (ft): 133.0-140.4

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1773-RC

Boring ID: PR19-06

Box No.: Box 15

Depth (ft): 140.4-149.0

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1773-RC

Boring ID: PR19-06

Box No.: Box 16

Depth (ft): 149.0-150.0

Test Boring
PR19-07

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1782-RC

Boring ID: PR19-07

Box No.: Box 1

Depth (ft): 8.0 - 20.1

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1782-RC

Boring ID: PR19-07

Box No.: Box 2

Depth (ft): 20.1 - 28.6

Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide
Laboratory sample ID: W-19-1782-RC
Boring ID: PR19-07
Box No.: Box 3
Depth (ft): 28.6 - 37.0

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1782-RC

Boring ID: PR19-07

Box No.: Box 4

Depth (ft): 37.0 - 46.0

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1782-RC

Boring ID: PR19-07

Box No.: Box 6

Depth (ft): 55.0 - 64.0

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1782-RC

Boring ID: PR19-07

Box No.: Box 7

Depth (ft): 64.0 - 73.0

Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide
Laboratory sample ID: W-19-1782-RC
Boring ID: PR19-07
Box No.: Box 8
Depth (ft): 73.0 - 81.8

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1782-RC

Boring ID: PR19-07

Box No.: Box 9

Depth (ft): 81.8 - 90.3

Project No.: AK NPS DENA 10(45)	
Project Name: Pretty Rocks Landslide	
Laboratory sample ID: W-19-1782-RC	
Boring ID: PR19-07	Box No.: Box 10
Depth (ft): 90.3 - 98.9	

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1782-RC

Boring ID: PR19-07

Box No.: Box 11

Depth (ft): 98.9 - 100.3

Test Boring
PR19-08


Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide
Laboratory sample ID: W-19-1774-RC
Boring ID: PR19-08
Box No.: Box 1
Depth (ft): 40.0 - 48.8

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1774-RC

Boring ID: PR19-08

Box No.: Box 2

Depth (ft): 48.8 - 58.3

Project No.: AK NPS DENA 10(45)	
Project Name: Pretty Rocks Landslide	
Laboratory sample ID: W-19-1774-RC	
Boring ID: PR19-08	Box No.: Box 3
Depth (ft): 58.3 - 66.0	

Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide
Laboratory sample ID: W-19-1774-RC
Boring ID: PR19-08
Box No.: Box 4
Depth (ft): 66.0 - 73.8

Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide
Laboratory sample ID: W-19-1774-RC
Boring ID: PR19-08
Box No.: Box 5
Depth (ft): 73.8 - 81.9

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1774-RC

Boring ID: PR19-08

Box No.: Box 6

Depth (ft): 81.9 - 89.9

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1774-RC

Boring ID: PR19-08

Box No.: Box 7

Depth (ft): 89.9 - 96.2

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1774-RC

Boring ID: PR19-08

Box No.: Box 8

Depth (ft): 96.7 - 103.0

Test Boring
PR19-09

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1787-RC

Boring ID: PR19-09 | Box No.: Box 1

Depth (ft): 3.5 - 10.0

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1787-RC

Boring ID: PR19-09

Box No.: Box 2

Depth (ft): 10.0 - 20.0


Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide
Laboratory sample ID: W-19-1787-RC
Boring ID: PR19-09
Box No.: Box 3
Depth (ft): 20.0 - 30.0

Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide
Laboratory sample ID: W-19-1787-RC
Boring ID: PR19-09
Box No.: Box 4
Depth (ft): 30.0 - 40.0

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1787-RC

Boring ID: PR19-09

Box No.: Box 5

Depth (ft): 40.0 - 50.0

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1787-RC

Boring ID: PR19-09

Box No.: Box 6

Depth (ft): 50.0 - 60.0

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1787-RC

Boring ID: PR19-09

Box No.: Box 7

Depth (ft): 60.0 - 67.4

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1787-RC

Boring ID: PR19-09

Box No.: Box 8

Depth (ft): 67.4 - 75.9

Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide
Laboratory sample ID: W-19-1787-RC
Boring ID: PR19-09
Box No.: Box 9
Depth (ft): 75.9 - 82.1

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1787-RC

Boring ID: PR19-09

Box No.: Box 10

Depth (ft): 82.1 - 90.0

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1787-RC

Boring ID: PR19-09

Box No.: Box 11

Depth (ft): 90.0 - 98.5

Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide
Laboratory sample ID: W-19-1787-RC
Boring ID: PR19-09
Box No.: Box 12
Depth (ft): 98.5 - 105.7

Project No.: AK NPS DENA 10(45)
Project Name: Pretty Rocks Landslide
Laboratory sample ID: W-19-1787-RC
Boring ID: PR19-09
Box No.: Box 13
Depth (ft): 105.7-112.6

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1787-RC

Boring ID: PR19-09

Box No.: Box 14

Depth (ft): 112.6-120.0

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1787-RC

Boring ID: PR19-09

Box No.: Box 15

Depth (ft): 120.0-127.4

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1787-RC

Boring ID: PR19-09

Box No.: Box 16

Depth (ft): 127.4-136.3

Project No.: AK NPS DENA 10(45)

Project Name: Pretty Rocks Landslide

Laboratory sample ID: W-19-1787-RC

Boring ID: PR19-09

Box No.: Box 17

Depth (ft): 136.3-142.5

APPENDIX E

Laboratory Testing Results

E-1: 2018 Geotechnical Boring Laboratory Reports
E-2: 2019 Geotechnical Boring Laboratory Reports
E-3: 2018 Ring Shear Test Reports
E-4: 2019 Ring Shear Test Reports
E-5: 2019 Unconfined Compressive Strength (UCS)

APPENDIX E-1

2018 Geotechnical Boring Laboratory Reports

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1768-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL **Sample No:** S15
Project Number: AK NPS DENA 10(45) **Sampled By:** Orion George
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:** 7/19/2018

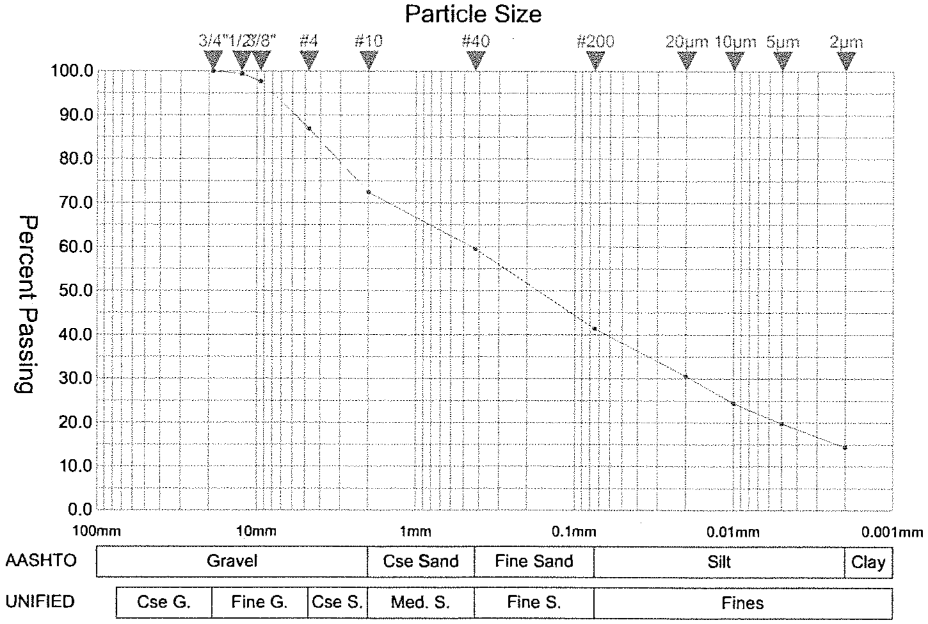
Submitted By: Orion George/Brian Colli **Address:**
Phone: 619-7657

Sample of: **Date Received:** 10/09/2018
Quantity Rep: **No. & Containers:** ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18

Owner: **County:** **State:** AK
Boring No./Test Pit: PR18-01 **Depth:** 37.5-39.5'

Sieve Analysis

Sieve Size	As Received % Passing
3/4"	100.0
1/2"	99.4
3/8"	97.7
#4	86.9
#10	72.4
#40	59.5
#200	41.4
20μm	30.6
10μm	24.4
5μm	19.8
2μm	14.4



Soil Classification (DL145)

AASHTO	A-7-6(7)	GR-SA-CLAY
Unified	SC; Clayey sand	

Apparent Specific Gravity (T100)	2.504
Natural Moisture (T265) (Sample dried at 140 °F), %	30.9
Atterberg Limits (T89)	
Liquid Limit	55
Plasticity Index	30

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2018.11.16 10:17:39 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

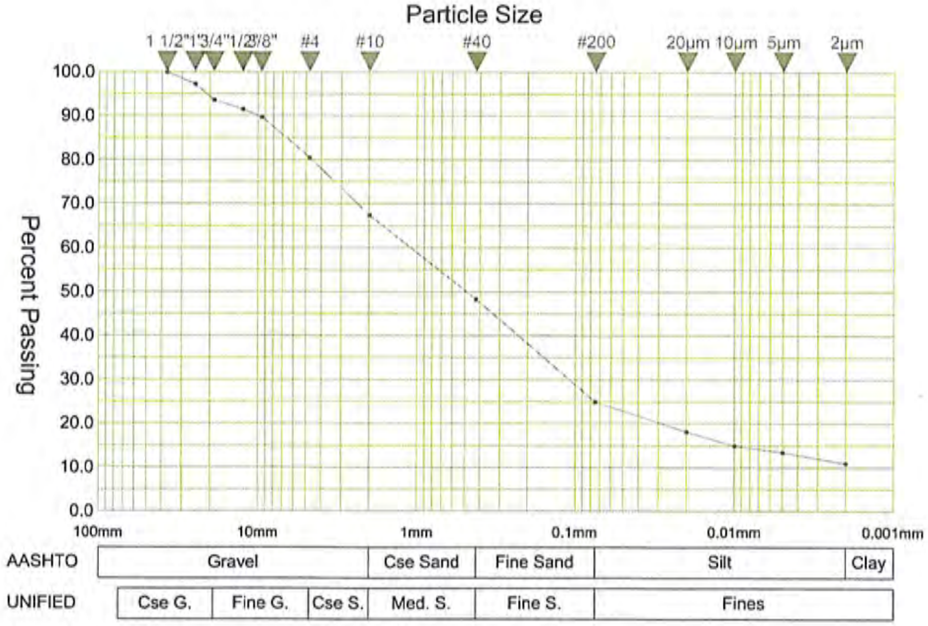
Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1769-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL
Sample No: S17
Project Number: AK NPS DENA 10(45)
Sampled By: Orion George
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled: 7/19/2018
Submitted By: Orion George/Brian Colli
Address:
Phone: 619-7657
Sample of:
Date Received: 10/09/2018
Quantity Rep:
No. & Containers: ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18
Owner:
County:
State: AK
Boring No./Test Pit: PR18-01
Depth: 42.5-44'

Sieve Analysis

Sieve Size	As Received % Passing
1 1/2"	100.0
1"	97.2
3/4"	93.6
1/2"	91.5
3/8"	89.7
#4	80.5
#10	67.4
#40	48.3
#200	24.9
20μm	18.1
10μm	14.9
5μm	13.4
2μm	10.9



Soil Classification (DL145)		
AASHTO	A-2-7(1)	CL-GR-SAND
Unified	SM; Silty sand with gravel	
Apparent Specific Gravity (T100)		2.555
Natural Moisture (T265) (Sample dried at 140 °F), %		22.1
Atterberg Limits (T89)		
Liquid Limit		48
Plasticity Index		17

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2018.11.16 10:04:41 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1770-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL **Sample No:** S21
Project Number: AK NPS DENA 10(45) **Sampled By:** Orion George
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:** 7/19/2018

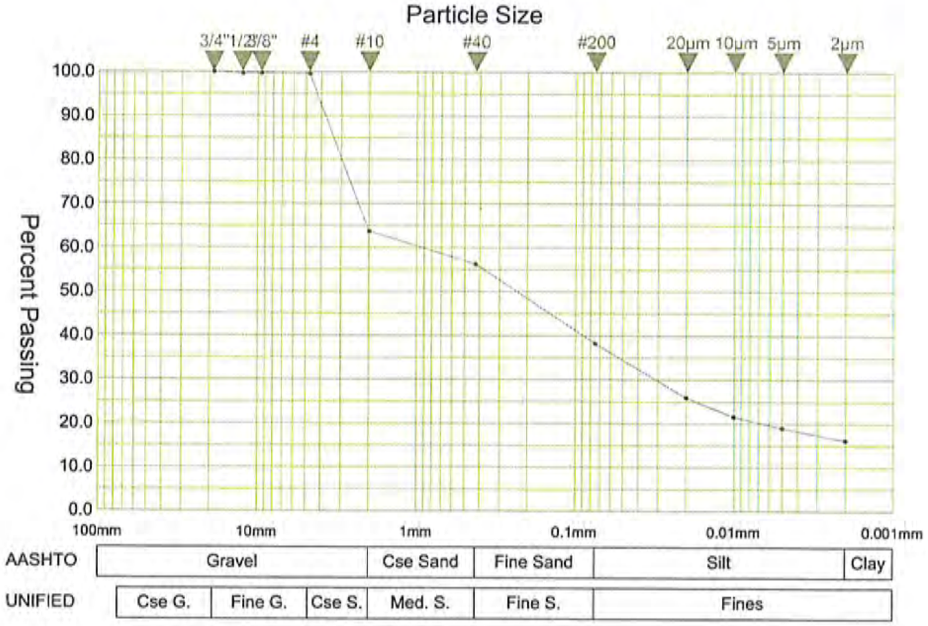
Submitted By: Orion George/Brian Colli **Address:**
Phone: 619-7657

Sample of: **Date Received:** 10/09/2018
Quantity Rep: **No. & Containers:** ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18

Owner: **County:** **State:** AK
Boring No./Test Pit: PR18-01 **Depth:** 65-67'

Sieve Analysis

	As Received
Sieve Size	% Passing
3/4"	100.0
1/2"	99.7
3/8"	99.7
#4	99.6
#10	63.7
#40	56.2
#200	38.2
20µm	25.9
10µm	21.5
5µm	19.0
2µm	16.2



Soil Classification (DL145)

AASHTO	A-4(0)	SA-GR-SILT
Unified	SM; Silty sand	

Apparent Specific Gravity (T100)	2.665
Natural Moisture (T265) (Sample dried at 140 °F), %	35.8
Atterberg Limits (T89)	
Liquid Limit	NP
Plasticity Index	NP

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Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1771-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL
Sample No: S08
Project Number: AK NPS DENA 10(45)
Sampled By: Orion George
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled: 7/19/2018

Submitted By: Orion George/Brian Colli
Address:
Phone: 619-7657

Sample of:
Date Received: 10/09/2018
Quantity Rep:
No. & Containers: ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18

Owner:
County:
State: AK
Boring No./Test Pit: PR18-02
Depth: 20-22'

Natural Moisture (T265) (Sample dried at 230 °F), %	3.7

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Date: 2018.11.16 10:03:58 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

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Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1772-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL
Sample No: S18
Project Number: AK NPS DENA 10(45)
Sampled By: Orion George
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled: 7/19/2018
Submitted By: Orion George/Brian Colli
Address:
Phone: 619-7657
Sample of:
Date Received: 10/09/2018
Quantity Rep:
No. & Containers: ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18
Owner:
County:
State: AK
Boring No./Test Pit: PR18-02
Depth: 45-47'

Natural Moisture (T265) (Sample dried at 230 °F), %	15.6

WALTER F STONG Digitally signed by WALTER F STONG Date: 2018.11.16 10:03:39 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1773-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL
Sample No: S24
Project Number: AK NPS DENA 10(45)
Sampled By: Orion George
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled: 7/19/2018
Submitted By: Orion George/Brian Colli
Address:
Phone: 619-7657
Sample of:
Date Received: 10/09/2018
Quantity Rep:
No. & Containers: ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18
Owner:
County:
State: AK
Boring No./Test Pit: PR18-02
Depth: 60-62'

Natural Moisture (T265) (Sample dried at 230 °F), % 20.4

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Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1774-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL **Sample No:** S27
Project Number: AK NPS DENA 10(45) **Sampled By:** Orion George
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:** 7/19/2018

Submitted By: Orion George/Brian Colli **Address:**
Phone: 619-7657

Sample of: **Date Received:** 10/09/2018
Quantity Rep: **No. & Containers:** ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18

Owner: **County:** **State:** AK
Boring No./Test Pit: PR18-02 **Depth:** 70-70.3'

Natural Moisture (T265) (Sample dried at 230 °F), %	17.1

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Date: 2018.11.16 10:18:14 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1775-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL **Sample No:** S31
Project Number: AK NPS DENA 10(45) **Sampled By:** Orion George
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:** 7/19/2018

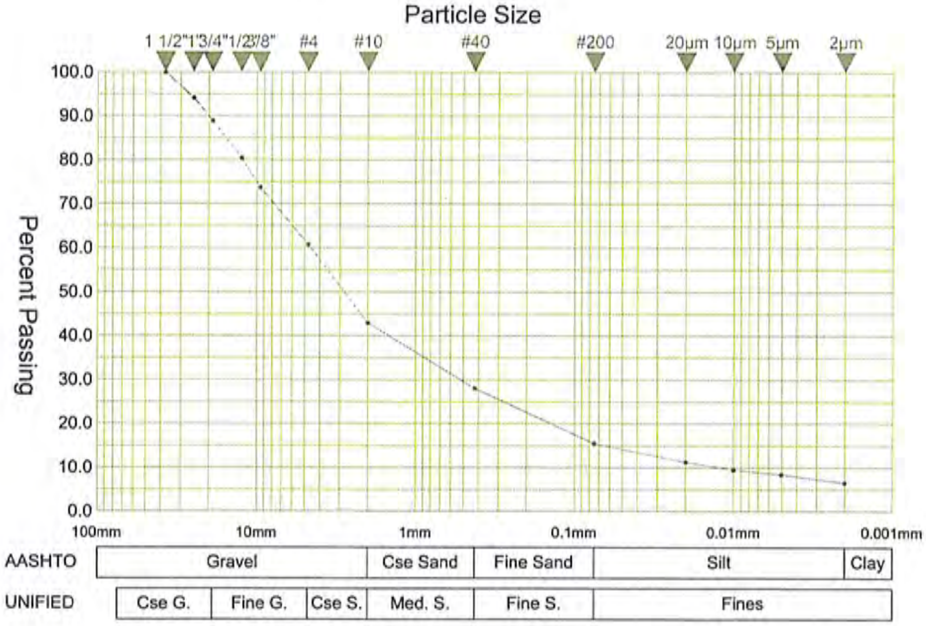
Submitted By: Orion George/Brian Colli **Address:**
Phone: 619-7657

Sample of: **Date Received:** 10/09/2018
Quantity Rep: **No. & Containers:** ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18

Owner: **County:** **State:** AK
Boring No./Test Pit: PR18-02 **Depth:** 77.5-78.9'

Sieve Analysis

Sieve Size	As Received % Passing
1 1/2"	100.0
1"	94.1
3/4"	88.9
1/2"	80.4
3/8"	73.7
#4	60.7
#10	42.9
#40	28.0
#200	15.4
20μm	11.2
10μm	9.5
5μm	8.4
2μm	6.5



Soil Classification (DL145)		
AASHTO	A-2-6(0)	CL-SA-GRAVEL
Unified	SC; Clayey sand with gravel	
Apparent Specific Gravity (T100)	2.526	
Natural Moisture (T265) (Sample dried at 140 °F), %	19.4	
Atterberg Limits (T89)		
Liquid Limit	37	
Plasticity Index	17	

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Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

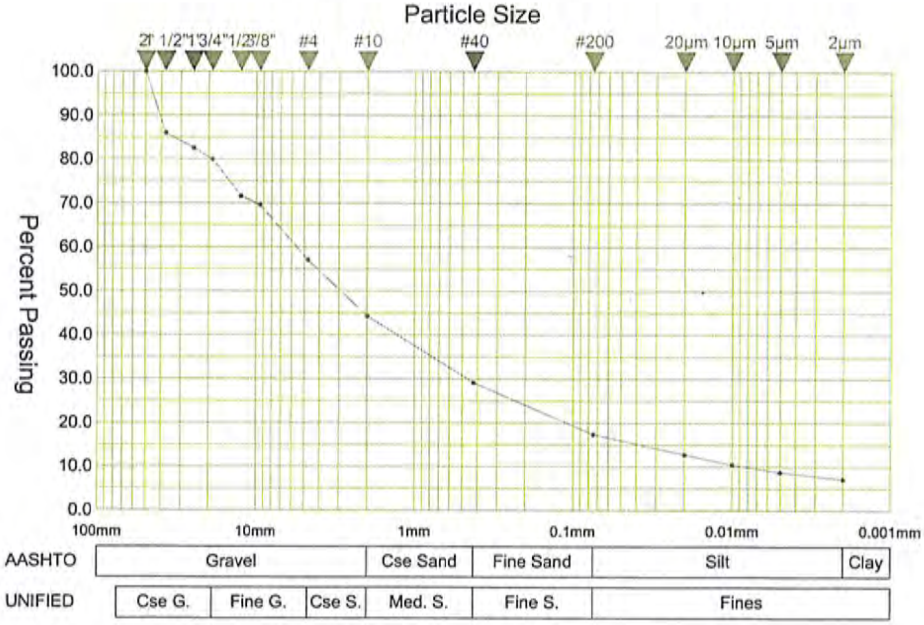
Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1776-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL
Sample No: S32
Project Number: AK NPS DENA 10(45)
Sampled By: Orion George
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled: 7/19/2018
Submitted By: Orion George/Brian Colli
Address:
Phone: 619-7657
Sample of:
Date Received: 10/09/2018
Quantity Rep:
No. & Containers: ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18
Owner:
County:
State: AK
Boring No./Test Pit: PR18-02
Depth: 80.2-81.7'

Sieve Analysis

Sieve Size	As Received % Passing
2"	100.0
1 1/2"	85.9
1"	82.5
3/4"	79.9
1/2"	71.6
3/8"	69.6
#4	57.1
#10	44.3
#40	29.1
#200	17.3
20µm	12.7
10µm	10.4
5µm	8.7
2µm	7.1



Soil Classification (DL145)

AASHTO	A-2-6(0)	CL-SA-GRAVEL
Unified	GC; Clayey gravel with sand	

Apparent Specific Gravity (T100)	2.602
Natural Moisture (T265) (Sample dried at 140 °F), %	22.3

Atterberg Limits (T89)

Liquid Limit	36
Plasticity Index	18

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Walt Strong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

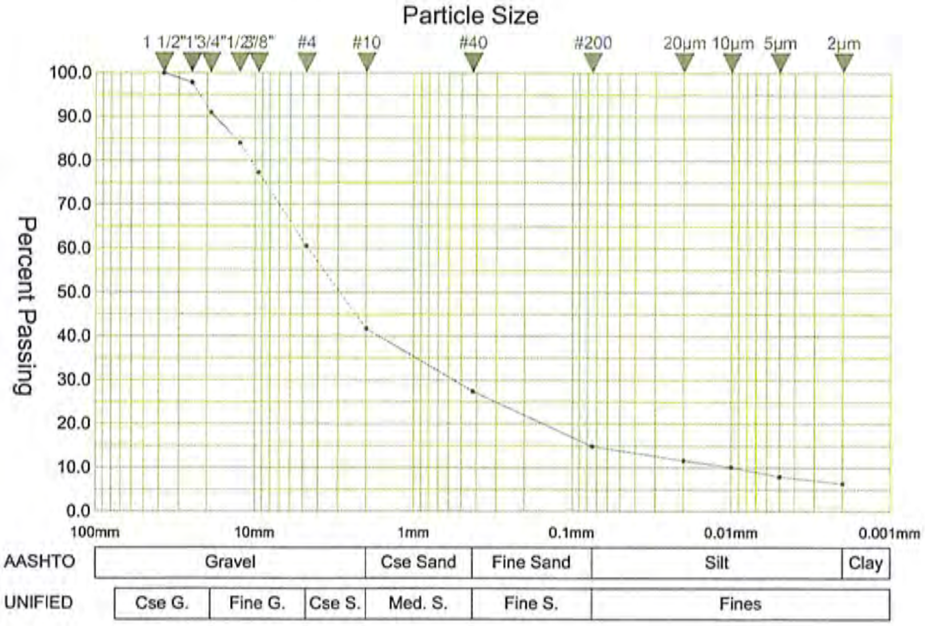
Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1777-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL
Sample No: S34
Project Number: AK NPS DENA 10(45)
Sampled By: Orion George
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled: 7/19/2018
Submitted By: Orion George/Brian Colli
Address:
Phone: 619-7657
Sample of:
Date Received: 10/09/2018
Quantity Rep:
No. & Containers: ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18
Owner:
County:
State: AK
Boring No./Test Pit: PR18-02
Depth: 85-87'

Sieve Analysis

Sieve Size	**As Received** % Passing
1 1/2"	100.0
1"	97.8
3/4"	90.9
1/2"	84.0
3/8"	77.3
#4	60.5
#10	41.7
#40	27.4
#200	14.8
20µm	11.6
10µm	10.1
5µm	8.0
2µm	6.3



Soil Classification (DL145)

AASHTO	A-2-6(0)	CL-SA-GRAVEL
Unified	SC; Clayey sand with gravel	

Apparent Specific Gravity (T100)	2.608
Natural Moisture (T265) (Sample dried at 140 °F), %	29.2

Atterberg Limits (T89)

Liquid Limit	39
Plasticity Index	20

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Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

DEPARTMENT OF TRANSPORTATION UNITED STATES OF AMERICA

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1778-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL
Sample No: S35
Project Number: AK NPS DENA 10(45)
Sampled By: Orion George
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled: 7/20/2018

Submitted By: Orion George/Brian Colli
Address:
Phone: 619-7657

Sample of:
Date Received: 10/09/2018
Quantity Rep:
No. & Containers: ZIP-LOK (2)
Dates Tested: 10-09-18 to 11-09-18

Owner:
County:
State: AK
Boring No./Test Pit: PR18-02
Depth: 87.5-88.4'

Insufficient quantity of material for T88 Hydrometer and T100 SG, unable to classify..

Natural Moisture (T265) (Sample dried at 140 °F), %	26.2
Atterberg Limits (T89)	
Liquid Limit	47
Plasticity Index	28

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Date: 2018.11.16 10:01:09 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1779-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL
Sample No: S36
Project Number: AK NPS DENA 10(45)
Sampled By: Orion George
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled: 7/19/2018

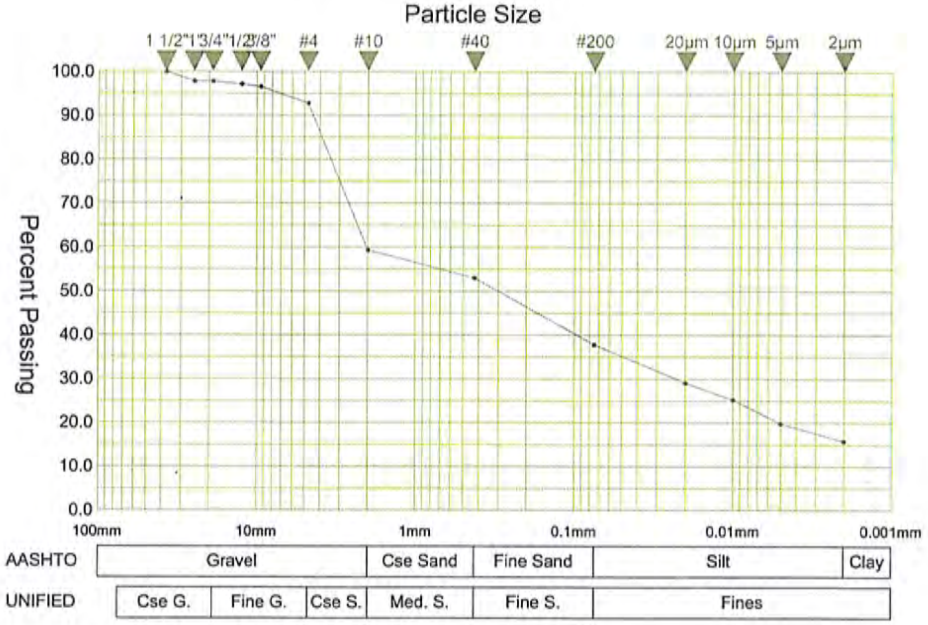
Submitted By: Orion George/Brian Colli
Address:
Phone: 619-7657

Sample of:
Date Received: 10/09/2018
Quantity Rep:
No. & Containers: ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18

Owner:
County:
State: AK
Boring No./Test Pit: PR18-02
Depth: 90-92'

Sieve Analysis

Sieve Size	As Received % Passing
1 1/2"	100.0
1"	97.8
3/4"	97.8
1/2"	97.1
3/8"	96.5
#4	92.8
#10	59.3
#40	53.0
#200	37.8
20µm	29.1
10µm	25.2
5µm	19.8
2µm	15.8



Soil Classification (DL145)

AASHTO	A-7-6(10)	SA-CL-GRAVEL
Unified	SC; Clayey sand	

Apparent Specific Gravity (T100)	2.617
Natural Moisture (T265) (Sample dried at 140 °F), %	30.2

Atterberg Limits (T89)

Liquid Limit	74
Plasticity Index	47

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Walt Strong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

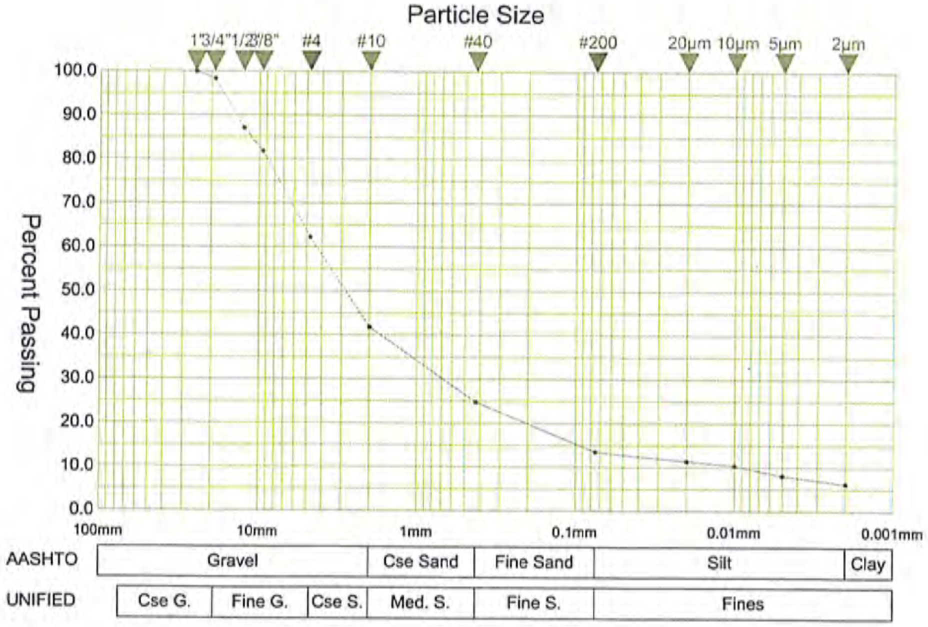
Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1780-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL **Sample No:** S03
Project Number: AK NPS DENA 10(45) **Sampled By:** Orion George
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:** 7/27/2018
Submitted By: Orion George/Brian Colli **Address:**
Phone: 619-7657
Sample of: **Date Received:** 10/09/2018
Quantity Rep: **No. & Containers:** ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18
Owner: **County:** **State:** AK
Boring No./Test Pit: PR18-03 **Depth:** 10-12'

T-89 Method B.

Sieve Analysis

Sieve Size	**As Received** % Passing
1"	100.0
3/4"	98.3
1/2"	87.1
3/8"	81.8
#4	62.2
#10	41.8
#40	24.7
#200	13.4
20µm	11.3
10µm	10.3
5µm	8.1
2µm	6.2



Soil Classification (DL145)

AASHTO	A-2-6(0)	CL-SA-GRAVEL
Unified	SC; Clayey sand with gravel	

Apparent Specific Gravity (T100)	2.547
Natural Moisture (T265) (Sample dried at 140 °F), %	20.7

Atterberg Limits (T89)

Liquid Limit	34
Plasticity Index	12

WALTER F STONG Digitally signed by WALTER F STONG Date: 2018.11.16 10:00:28 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1781-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL
Sample No: S06
Project Number: AK NPS DENA 10(45)
Sampled By: Orion George
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled: 7/27/2018

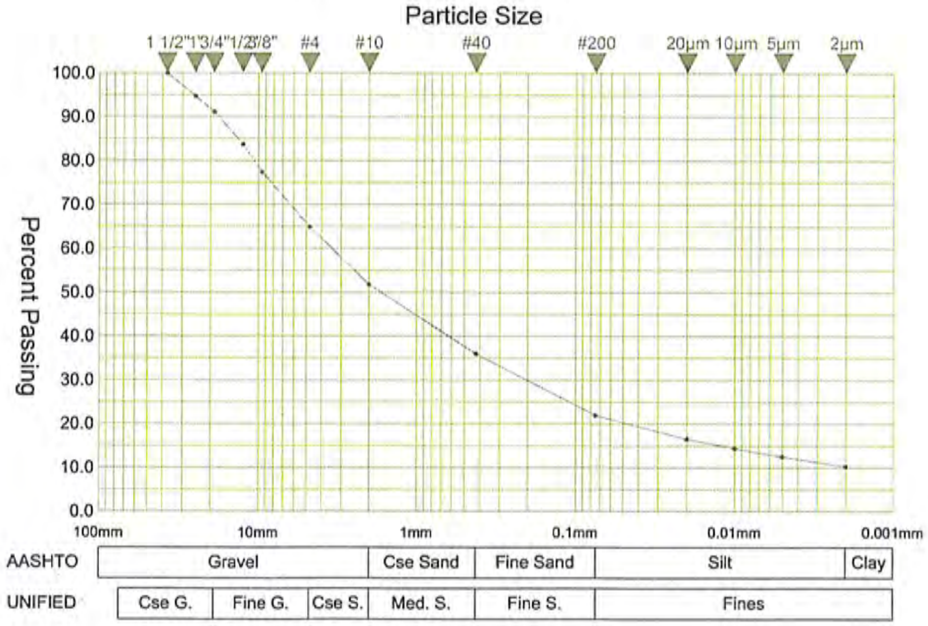
Submitted By: Orion George/Brian Colli
Address:
Phone: 619-7657

Sample of:
Date Received: 10/09/2018
Quantity Rep:
No. & Containers: ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18

Owner:
County:
State: AK
Boring No./Test Pit: PR18-03
Depth: 17-19'

Sieve Analysis

	As Received
Sieve Size	% Passing
1 1/2"	100.0
1"	94.7
3/4"	91.1
1/2"	83.7
3/8"	77.4
#4	64.9
#10	51.8
#40	36.0
#200	21.9
20µm	16.5
10µm	14.4
5µm	12.5
2µm	10.2



Soil Classification (DL145)

AASHTO	A-2-7(1)	CL-SA-GRAVEL
Unified	SC; Clayey sand with gravel	

Apparent Specific Gravity (T100)	2.506
Natural Moisture (T265) (Sample dried at 140 °F), %	31.8

Atterberg Limits (T89)

Liquid Limit	49
Plasticity Index	26

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Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

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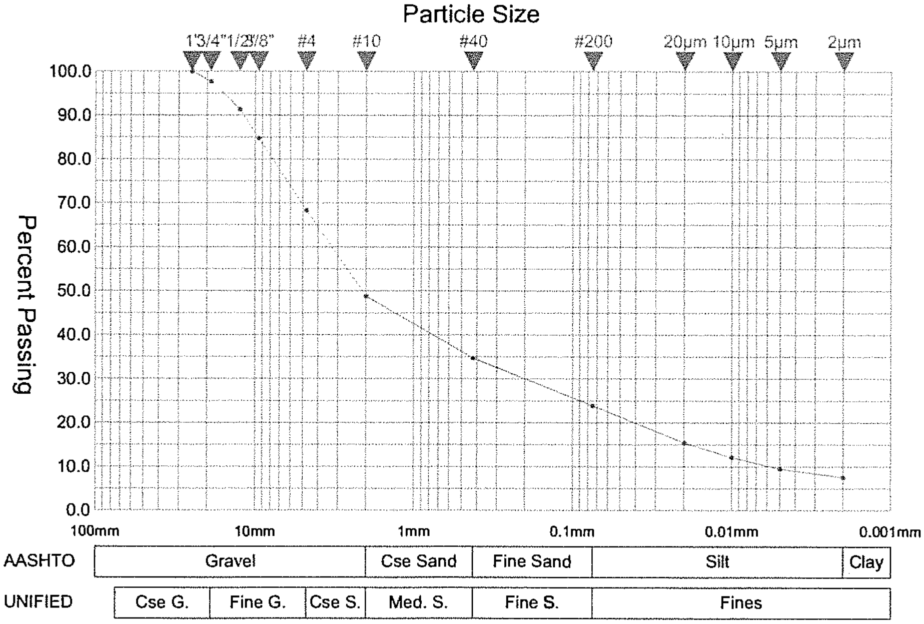
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1782-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL
Sample No: S15
Project Number: AK NPS DENA 10(45)
Sampled By: Orion George
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled: 7/27/2018
Submitted By: Orion George/Brian Colli
Address:
Phone: 619-7657
Sample of:
Date Received: 10/09/2018
Quantity Rep:
No. & Containers: ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18
Owner:
County:
State: AK
Boring No./Test Pit: PR18-03
Depth: 40-41.4'

Sieve Analysis

Sieve Size	**As Received** % Passing
1"	100.0
3/4"	97.7
1/2"	91.3
3/8"	84.7
#4	68.3
#10	48.8
#40	34.7
#200	23.9
20μm	15.4
10μm	12.1
5μm	9.4
2μm	7.6



Soil Classification (DL145)

AASHTO	A-2-7(1)	CL-SA-GRAVEL
Unified	SC; Clayey sand with gravel	

Apparent Specific Gravity (T100)	2.761

Natural Moisture (T265) (Sample dried at 140 °F), %	23.5

Atterberg Limits (T89)

Liquid Limit	42
Plasticity Index	19

WALTER F STONG

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Date: 2018.11.16 09:59:26 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1783-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL
Project Number: AK NPS DENA 10(45)
Acct. No.: 1517020701045 510.PE.K700.02
Sample No: S18
Sampled By: Orion George
Date Sampled: 7/27/2018

Submitted By: Orion George/Brian Colli
Phone: 619-7657
Address:

Sample of:
Quantity Rep:
Date Received: 10/09/2018
No. & Containers: ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18

Owner:
Boring No./Test Pit: PR18-03
County:
Depth: 47-48'
State: AK

Natural Moisture (T265) (Sample dried at 230 °F), %	36.1

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Date: 2018.11.16
09:31:32 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

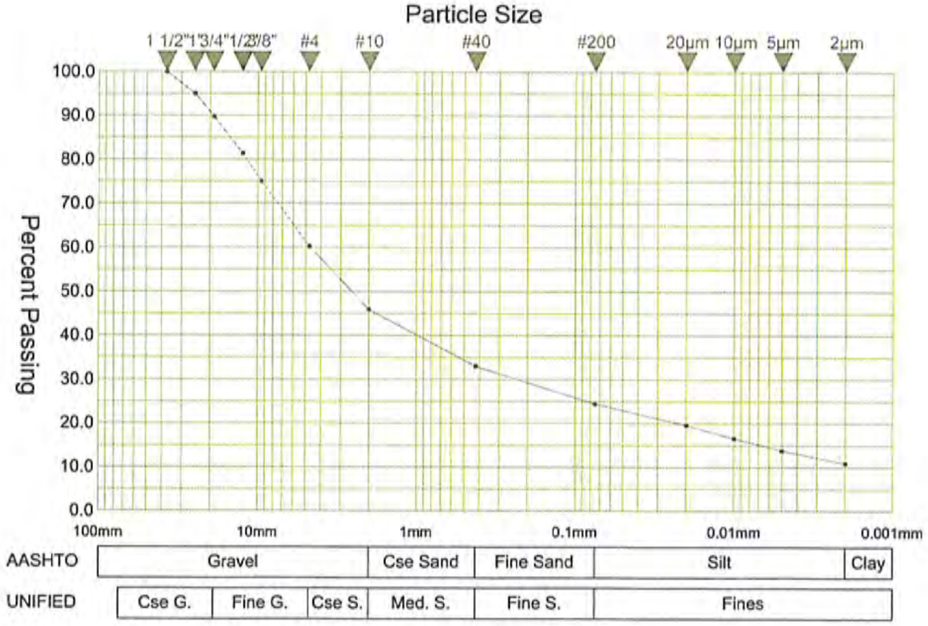
Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1784-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL
Sample No: S21A
Project Number: AK NPS DENA 10(45)
Sampled By: Orion George
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled: 7/27/2018
Submitted By: Orion George/Brian Colli
Address:
Phone: 619-7657
Sample of:
Date Received: 10/09/2018
Quantity Rep:
No. & Containers: ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18
Owner:
County:
State: AK
Boring No./Test Pit: PR18-03
Depth: 55-56'

Sieve Analysis

Sieve Size	**As Received** % Passing
1 1/2"	100.0
1"	95.0
3/4"	89.7
1/2"	81.4
3/8"	75.1
#4	60.3
#10	45.9
#40	33.0
#200	24.4
20μm	19.6
10μm	16.6
5μm	13.8
2μm	10.9



Soil Classification (DL145)

AASHTO	A-2-7(2)	SA-CL-GRAVEL
Unified	GC; Clayey gravel with sand	

Apparent Specific Gravity (T100)	2.740
Natural Moisture (T265) (Sample dried at 140 °F), %	37.6

Atterberg Limits (T89)

Liquid Limit	57
Plasticity Index	33

WALTER F STONG
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Date: 2018.11.16 09:31:11 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1785-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL
Sample No: S22
Project Number: AK NPS DENA 10(45)
Sampled By: Orion George
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled: 7/27/2018

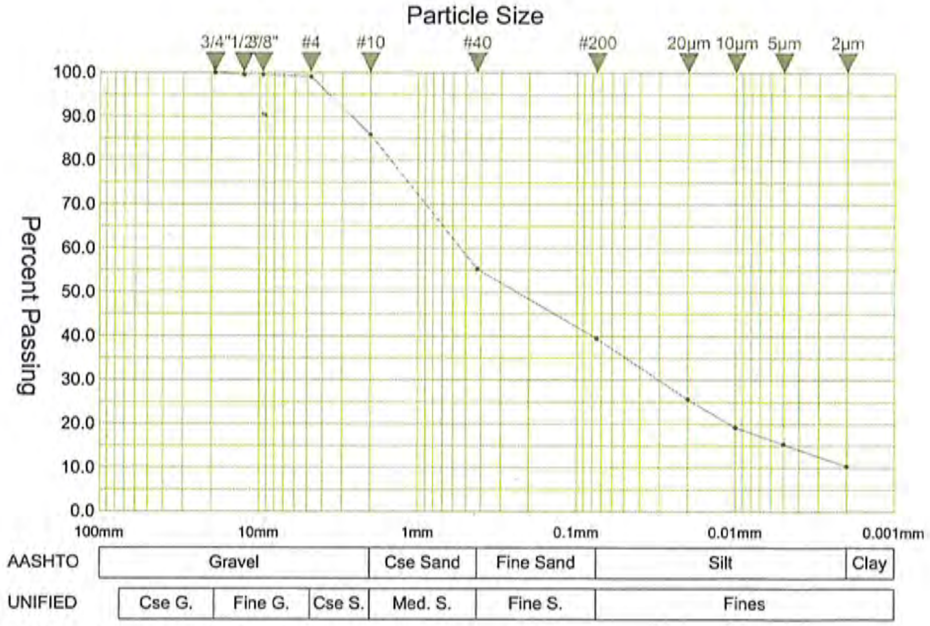
Submitted By: Orion George/Brian Colli
Address:
Phone: 619-7657

Sample of:
Date Received: 10/09/2018
Quantity Rep:
No. & Containers: ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18

Owner:
County:
State: AK
Boring No./Test Pit: PR18-03
Depth: 57-59'

Sieve Analysis

	As Received
Sieve Size	% Passing
3/4"	100.0
1/2"	99.6
3/8"	99.6
#4	99.1
#10	85.9
#40	55.3
#200	39.5
20µm	25.6
10µm	19.2
5µm	15.4
2µm	10.3



Soil Classification (DL145)

AASHTO	A-7-6(6)	GR-CL-SAND
Unified	SC; Clayey sand	

Apparent Specific Gravity (T100)	2.785
Natural Moisture (T265) (Sample dried at 140 °F), %	46.4
Atterberg Limits (T89)	
Liquid Limit	51
Plasticity Index	27

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2018.11.16 09:30:45 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

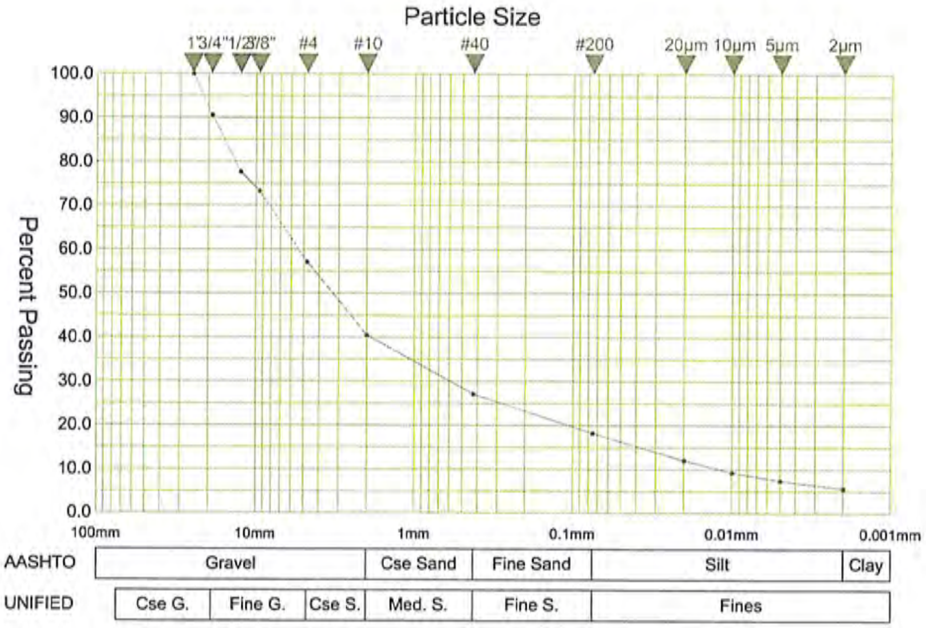
Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1786-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL
Sample No: S10
Project Number: AK NPS DENA 10(45)
Sampled By: Orion George
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled: 8/03/2018
Submitted By: Orion George/Brian Colli
Address:
Phone: 619-7657
Sample of:
Date Received: 10/09/2018
Quantity Rep:
No. & Containers: ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18
Owner:
County:
State: AK
Boring No./Test Pit: PR18-05
Depth: 25-27'

Sieve Analysis

Sieve Size	As Received % Passing
1"	100.0
3/4"	90.5
1/2"	77.6
3/8"	73.2
#4	57.1
#10	40.5
#40	27.1
#200	18.2
20µm	12.0
10µm	9.2
5µm	7.4
2µm	5.6



Soil Classification (DL145)

AASHTO	A-2-7(0)	CL-SA-GRAVEL
Unified	GC; Clayey gravel with sand	

Apparent Specific Gravity (T100)	2.749
Natural Moisture (T265) (Sample dried at 140 °F), %	24.7

Atterberg Limits (T89)

Liquid Limit	44
Plasticity Index	22

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2018.11.16 09:30:07 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

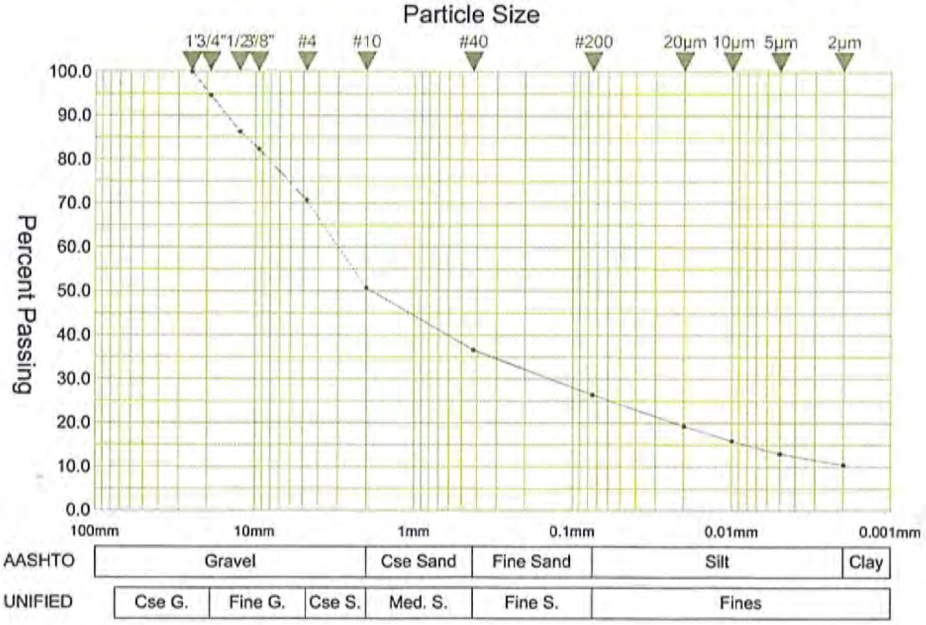
Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1787-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL
Sample No: S17
Project Number: AK NPS DENA 10(45)
Sampled By: Orion George
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled: 8/03/2018
Submitted By: Orion George/Brian Colli
Address:
Phone: 619-7657
Sample of:
Date Received: 10/09/2018
Quantity Rep:
No. & Containers: ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18
Owner:
County:
State: AK
Boring No./Test Pit: PR18-05
Depth: 42.5-44'

Sieve Analysis

Sieve Size	As Received % Passing
1"	100.0
3/4"	94.6
1/2"	86.3
3/8"	82.3
#4	70.7
#10	50.7
#40	36.6
#200	26.4
20μm	19.3
10μm	15.9
5μm	13.0
2μm	10.4



Soil Classification (DL145)		
AASHTO	A-2-7(2)	SA-CL-GRAVEL
Unified	SC; Clayey sand with gravel	
Apparent Specific Gravity (T100)	2.789	
Natural Moisture (T265) (Sample dried at 140 °F), %	30.0	
Atterberg Limits (T89)		
Liquid Limit	55	
Plasticity Index	32	

WALTER F STONG Digitally signed by WALTER F STONG Date: 2018.11.16 09:29:43 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1788-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL **Sample No:** S21
Project Number: AK NPS DENA 10(45) **Sampled By:** Orion George
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:** 8/03/2018

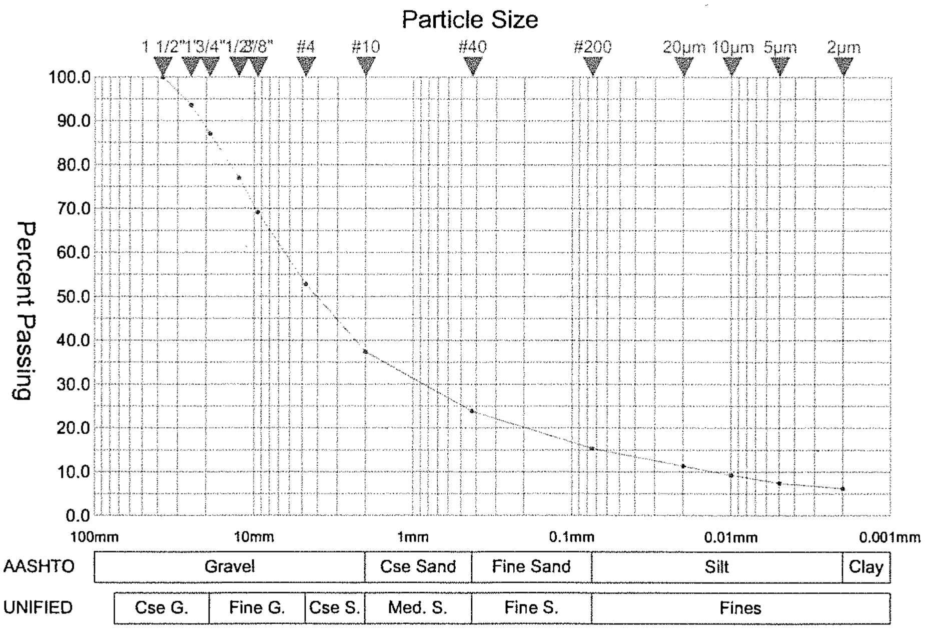
Submitted By: Orion George/Brian Colli **Address:**
Phone: 619-7657

Sample of: **Date Received:** 10/09/2018
Quantity Rep: **No. & Containers:** ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18

Owner: **County:** **State:** AK
Boring No./Test Pit: PR18-05 **Depth:** 52.5-54.5'

Sieve Analysis

Sieve Size	As Received % Passing
1 1/2"	100.0
1"	93.6
3/4"	87.1
1/2"	77.0
3/8"	69.2
#4	52.8
#10	37.4
#40	23.8
#200	15.3
20μm	11.3
10μm	9.3
5μm	7.5
2μm	6.2



Soil Classification (DL145)

AASHTO	A-2-7(0)	CL-SA-GRAVEL
Unified	GC; Clayey gravel with sand	

Apparent Specific Gravity (T100)	2.722
Natural Moisture (T265) (Sample dried at 140 °F), %	25.0

Atterberg Limits (T89)

Liquid Limit	49
Plasticity Index	27

WALTER F STONG Digitally signed by WALTER F STONG Date: 2018.11.16 09:28:26 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **16 Nov 2018**
Lab Control Number: **W-18-1789-SO**

Project Name: (PE) PRETTY ROCKS LANDSLIDE GEOTECHNICAL
Sample No: S26
Project Number: AK NPS DENA 10(45)
Sampled By: Orion George
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled: 8/03/2018
Submitted By: Orion George/Brian Colli
Address:
Phone: 619-7657
Sample of:
Date Received: 10/09/2018
Quantity Rep:
No. & Containers: ZIP-LOK
Dates Tested: 10-09-18 to 11-09-18
Owner:
County:
State: AK
Boring No./Test Pit: PR18-05
Depth: 65-66.3'

Insufficient material to perform T100 and T88, unable to classify.

Natural Moisture (T265) (Sample dried at 140 °F), %	26.2

Atterberg Limits (T89)

Liquid Limit	NP
Plasticity Index	NP

WALTER F STONG Digitally signed by WALTER F STONG Date: 2018.11.16 09:27:46 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

APPENDIX E-2

2019 Geotechnical Boring Laboratory Reports

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **11 Dec 2019**
Lab Control Number: **W-19-2006-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG
Sample No: Box 1
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

Sample of: ROCK CORE
Date Received: 12/06/2019
Quantity Rep:
No. & Containers: WAXED CARDBOARD
Dates Tested: 12/6/2019-12/10/2019

Owner:
County: DENALI
State: AK
Boring No./Test Pit: PR19-06
Depth: 28.3-28.7

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-06
Depth	28.3
Test Date	12/10/2019
Height, in	4.90
Diameter, in	2.35
Cross section, in	4.34
Weight of Core, g	751.3
Unit Weight, pcf	134.67
Maximum Load, lbf	18574
Compressive Strength, psi	4280

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.11 09:13:46 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **11 Dec 2019**
Lab Control Number: **W-19-2007-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** Box 2
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORE **Date Received:** 12/06/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 12/6/2019-12/10/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-06 **Depth:** 32.2-32.6

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-06
Depth	28.3
Test Date	12/10/2019
Height, in	4.91
Diameter, in	2.36
Cross section, in	4.37
Weight of Core, g	807.1
Unit Weight, pcf	143.16
Maximum Load, lbf	23732
Compressive Strength, psi	5430

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.11 09:10:52 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **11 Dec 2019**
Lab Control Number: **W-19-2008-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG
Sample No: Box 3
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

Sample of: ROCK CORE
Date Received: 12/06/2019
Quantity Rep:
No. & Containers: WAXED CARDBOARD
Dates Tested: 12/6/2019-12/10/2019

Owner:
County: DENALI
State: AK
Boring No./Test Pit: PR19-06
Depth: 42.5-42.9

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-06
Depth	42.5
Test Date	12/10/2019
Height, in	4.91
Diameter, in	2.38
Cross section, in	4.45
Weight of Core, g	854.5
Unit Weight, pcf	149.03
Maximum Load, lbf	34996
Compressive Strength, psi	7870

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.11 09:11:27 -08'00'

Walt Strong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **11 Dec 2019**
Lab Control Number: **W-19-2009-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** Box 4
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORE **Date Received:** 12/06/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 12/6/2019-12/10/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-06 **Depth:** 35.2-35.6

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-06
Depth	53.2
Test Date	12/10/2019
Height, in	5.40
Diameter, in	2.39
Cross section, in	4.49
Weight of Core, g	956.3
Unit Weight, pcf	150.38
Maximum Load, lbf	65501
Compressive Strength, psi	14600

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.11 09:09:29 -08'00'

Walt Strong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **11 Dec 2019**
Lab Control Number: **W-19-2010-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** Box 5
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORE **Date Received:** 12/06/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 12/6/2019-12/10/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-06 **Depth:** 57.4-57.8

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-06
Depth	57.4
Test Date	12/10/2019
Height, in	5.41
Diameter, in	2.39
Cross section, in	4.49
Weight of Core, g	912.2
Unit Weight, pcf	143.18
Maximum Load, lbf	52133
Compressive Strength, psi	11620

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.11 09:11:14 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **11 Dec 2019**
Lab Control Number: **W-19-2011-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG
Sample No: Box 6
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

Sample of: ROCK CORE
Date Received: 12/06/2019
Quantity Rep:
No. & Containers: WAXED CARDBOARD
Dates Tested: 12/6/2019-12/10/2019

Owner:
County: DENALI
State: AK
Boring No./Test Pit: PR19-06
Depth: 71.7-72.1

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-06
Depth	71.7
Test Date	12/10/2019
Height, in	4.83
Diameter, in	2.39
Cross section, in	4.49
Weight of Core, g	796.1
Unit Weight, pcf	139.96
Maximum Load, lbf	17882
Compressive Strength, psi	3990

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.11 09:13:28 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **11 Dec 2019**
Lab Control Number: **W-19-2012-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** Box 7
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORE **Date Received:** 12/06/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 12/6/2019-12/10/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-06 **Depth:** 73.8-74.2

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-06
Depth	73.8
Test Date	12/10/2019
Height, in	5.22
Diameter, in	2.39
Cross section, in	4.49
Weight of Core, g	899.4
Unit Weight, pcf	146.31
Maximum Load, lbf	41418
Compressive Strength, psi	9230

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.11 09:12:56 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **11 Dec 2019**
Lab Control Number: **W-19-2013-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** Box 7
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORE **Date Received:** 12/06/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 12/6/2019-12/10/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-06 **Depth:** 76.8-77.2

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-06
Depth	76.8
Test Date	12/10/2019
Height, in	5.19
Diameter, in	2.39
Cross section, in	4.49
Weight of Core, g	882.9
Unit Weight, pcf	144.46
Maximum Load, lbf	13788
Compressive Strength, psi	3070

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.11 09:12:42 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **11 Dec 2019**
Lab Control Number: **W-19-2014-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIGA
Sample No: Box 8
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

Sample of: ROCK CORE
Date Received: 12/06/2019
Quantity Rep:
No. & Containers: WAXED CARDBOARD
Dates Tested: 12/6/2019-12/10/2019

Owner:
County: DENALI
State: AK
Boring No./Test Pit: PR19-06
Depth: 82.7-83.1

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-06
Depth	82.7
Test Date	12/10/2019
Height, in	4.92
Diameter, in	2.39
Cross section, in	4.49
Weight of Core, g	813.6
Unit Weight, pcf	140.42
Maximum Load, lbf	11236
Compressive Strength, psi	2500

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.11 09:12:28 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **11 Dec 2019**
Lab Control Number: **W-19-2015-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG
Sample No: Box 8
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

Sample of: ROCK CORE
Date Received: 12/06/2019
Quantity Rep:
No. & Containers: WAXED CARDBOARD
Dates Tested: 12/6/2019-12/10/2019

Owner:
County: DENALI
State: AK
Boring No./Test Pit: PR19-06
Depth: 89.4-89.8

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-06
Depth	89.4
Test Date	12/10/2019
Height, in	5.31
Diameter, in	2.40
Cross section, in	4.52
Weight of Core, g	924.8
Unit Weight, pcf	146.66
Maximum Load, lbf	32414
Compressive Strength, psi	7170

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.11 09:12:12 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **11 Dec 2019**
Lab Control Number: **W-19-2016-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG
Sample No: Box 9
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

Sample of: ROCK CORE
Date Received: 12/06/2019
Quantity Rep:
No. & Containers: WAXED CARDBOARD
Dates Tested: 12/6/2019-12/10/2019

Owner:
County: DENALI
State: AK
Boring No./Test Pit: PR19-06
Depth: 98.8-99.2

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-06
Depth	98.8
Test Date	12/10/2019
Height, in	4.69
Diameter, in	2.39
Cross section, in	4.49
Weight of Core, g	813.7
Unit Weight, pcf	147.33
Maximum Load, lbf	22117
Compressive Strength, psi	4930

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.11 09:11:57 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **11 Dec 2019**
Lab Control Number: **W-19-2017-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** Box 12
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORE **Date Received:** 12/06/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-06 **Depth:** 118.2-118.6

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-06
Depth	118.2
Test Date	12/10/2019
Height, in	4.98
Diameter, in	2.40
Cross section, in	4.51
Weight of Core, g	884.8
Unit Weight, pcf	150.24
Maximum Load, lbf	42480
Compressive Strength, psi	9430

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.11 09:11:42 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **11 Dec 2019**
Lab Control Number: **W-19-2018-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIGA
Sample No: Box 15
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

Sample of: ROCK CORE
Date Received: 12/06/2019
Quantity Rep:
No. & Containers: WAXED CARDBOARD
Dates Tested: 12/6/2019-12/10/2019

Owner:
County: DENALI
State: AK
Boring No./Test Pit: PR19-06
Depth: 143.5-143.9

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-06
Depth	143.5
Test Date	12/10/2019
Height, in	5.38
Diameter, in	2.39
Cross section, in	4.49
Weight of Core, g	915.8
Unit Weight, pcf	144.55
Maximum Load, lbf	21247
Compressive Strength, psi	4740

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.11 09:13:10 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1783-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** BOX 4
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORES **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 11/1/2019-11/20/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-07 **Depth:** 41.0-41.4

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-07
Depth	41.0
Test Date	11/19/2019
Height, in	4.40
Diameter, in	2.35
Cross section, in	4.34
Weight of Core, lb	747.5
Unit Weight, pcf	149.10
Maximum Load, lbf	31498
Compressive Strength, psi	7260

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:17:40 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1784-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** BOX 8
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORES **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 11/1/2019-11/20/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-07 **Depth:** 73.5-73.9

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-07
Depth	73.5
Test Date	11/19/2019
Height, in	4.78
Diameter, in	2.37
Cross section, in	4.41
Weight of Core, lb	815.3
Unit Weight, pcf	147.19
Maximum Load, lbf	21894
Compressive Strength, psi	4960

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:17:26 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1785-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIGA **Sample No:** BOX 9
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORES **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 11/1/2019-11/20/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-07 **Depth:** 89.0-89.4

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-07
Depth	89.0
Test Date	11/19/2019
Height, in	5.45
Diameter, in	2.37
Cross section, in	4.41
Weight of Core, lb	916.2
Unit Weight, pcf	145.17
Maximum Load, lbf	5574
Compressive Strength, psi	1260

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:17:10 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1786-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** BOX 10
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORES **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 11/1/2019-11/20/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-07 **Depth:** 90.4-90.8

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-07
Depth	90.4
Test Date	11/19/2019
Height, in	3.73
Diameter, in	2.37
Cross section, in	4.41
Weight of Core, lb	600.7
Unit Weight, pcf	139.07
Maximum Load, lbf	19460
Compressive Strength, psi	4410

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:26:53 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1814-SO**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** S-6
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

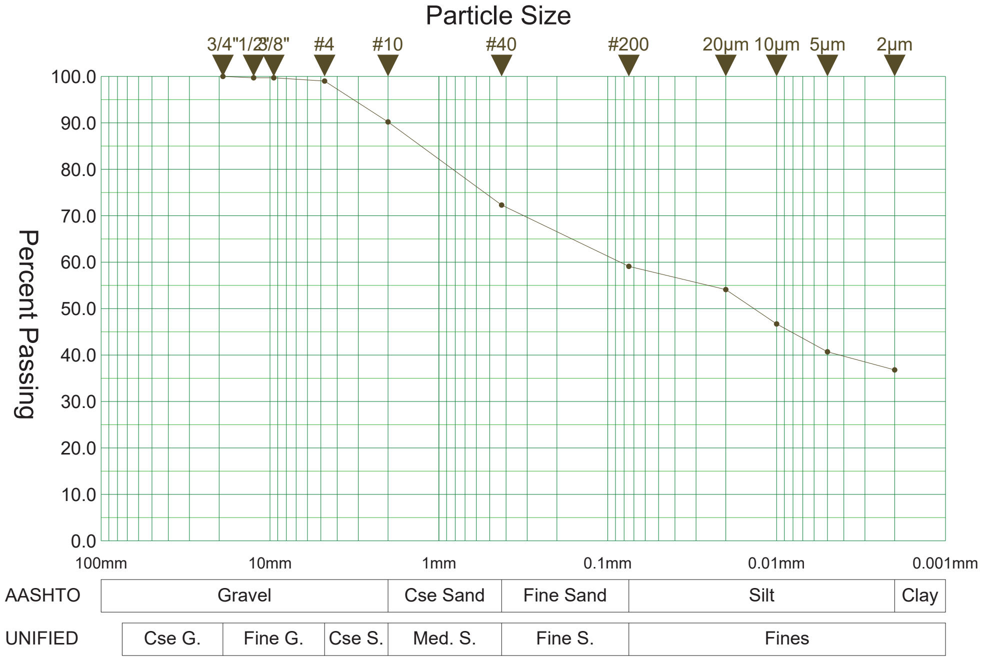
Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** ZIP LOC
Dates Tested: 11-01-19 to 11-22-19

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-08 **Depth:** 15.0-17.5

Sieve Analysis

	As Received
Sieve Size	% Passing
3/4"	100.0
1/2"	99.7
3/8"	99.7
#4	99.0
#10	90.2
#40	72.3
#200	59.1
20µm	54.1
10µm	46.7
5µm	40.7
2µm	36.8



Soil Classification (DL145)

AASHTO	A-7-6(44)	GR-SA-CLAY
Unified	CH; Sandy fat clay	

Apparent Specific Gravity (T100)	2.750

Atterberg Limits (T89)

Liquid Limit	105
Plasticity Index	81

Reported results apply to the sample as received

WALTER F STONG

Digitally signed by WALTER F STONG
Date: 2019.12.06 13:33:13 -08'00'

Walt Strong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1775-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** BOX 1
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORES **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 11/1/2019-11/20/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-08 **Depth:** 41.4-41.9

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-08
Depth	41.4
Test Date	11/19/2019
Height, in	4.69
Diameter, in	2.39
Cross section, in	4.49
Weight of Core, lb	856.5
Unit Weight, pcf	155.08
Maximum Load, lbf	36812
Compressive Strength, psi	8210

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:16:26 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1776-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** BOX 4
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORES **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 11/1/2019-11/20/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-08 **Depth:** 72.2-72.6

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-08
Depth	72.2
Test Date	11/19/2019
Height, in	4.71
Diameter, in	2.40
Cross section, in	4.52
Weight of Core, lb	933.9
Unit Weight, pcf	167.09
Maximum Load, lbf	99834
Compressive Strength, psi	22070

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:16:40 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1777-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** BOX 5
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORES **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 11/1/2019-11/20/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-08 **Depth:** 74.2-74.6

NOTE: This specimen partially fractured in the SATEC machine, but the test was aborted due to 'over-limit switch activated' on the SATEC. Machine made a 'hard stop'.

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-08
Depth	74.2
Test Date	11/19/2019
Height, in	4.72
Diameter, in	2.40
Cross section, in	4.52
Weight of Core, lb	937.1
Unit Weight, pcf	75835.98
Maximum Load, lbf	119895
Compressive Strength, psi	26500

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:16:04 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1778-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** BOX 6
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORES **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 11/1/2019-11/20/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-08 **Depth:** 82.6-83.0

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-08
Depth	82.6
Test Date	11/20/2019
Height, in	4.96
Diameter, in	2.40
Cross section, in	4.52
Weight of Core, lb	974.0
Unit Weight, pcf	75008.18
Maximum Load, lbf	47534
Compressive Strength, psi	10510

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:18:52 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1779-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** BOX 7
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORES **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 11/1/2019-11/20/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-08 **Depth:** 91.1-91.5

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-08
Depth	91.1
Test Date	11/20/2019
Height, in	5.61
Diameter, in	2.40
Cross section, in	4.52
Weight of Core, lb	1116.0
Unit Weight, pcf	167.52
Maximum Load, lbf	63426
Compressive Strength, psi	14020

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:18:37 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1780-RC**

Project Name:	PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG	**Sample No:**	BOX 7
Project Number:	AK NPS DENA 10(45)	**Sampled By:**	ROBBIE & JAMES (S&W)
Acct. No.:	1517020701045 510.PE.K700.02	**Date Sampled:**	
Submitted By:	ORION GEORGE/DOUG ANDERS	**Address:**	
Phone:	X7824		
Sample of:	ROCK CORES	**Date Received:**	11/01/2019
Quantity Rep:		**No. & Containers:**	WAXED CARDBOARD
		Dates Tested:	11/1/2019-11/20/2019
Owner:		**County:**	DENALI **State:** AK
Boring No./Test Pit:	PR19-08	**Depth:**	95.5-95.9

NOTE: This specimen was tested in the SATEC machine, but the test was aborted due to 'over-limit switch activated' on the SATEC, prior to failure. Machine made a 'hard stop'. Subsequent testing in the Concrete Break machine yielded even higher strength.

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-08
Depth	95.5
Test Date	11/20/2019
Height, in	4.82
Diameter, in	2.40
Cross section, in	4.52
Weight of Core, lb	957.1
Unit Weight, pcf	167.22
Maximum Load, lbf	140326
Compressive Strength, psi	31020

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:18:24 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1781-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** BOX 8
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORES **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 11/1/2019-11/20/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-08 **Depth:** 100.0-100.4

Sample tested in the Concrete Break machine, due to high anticipated strength based on results of adjacent samples. No Young's Modulus is available for this sample.

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-08
Depth	100.0
Test Date	11/20/2019
Height, in	5.61
Diameter, in	2.40
Cross section, in	4.52
Weight of Core, lb	1105.3
Unit Weight, pcf	165.91
Maximum Load, lbf	95756
Compressive Strength, psi	21170

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:18:09 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1788-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG
Sample No: BOX 9
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

Sample of: ROCK CORES
Date Received: 11/01/2019
Quantity Rep:
No. & Containers: WAXED CARDBOARD
Dates Tested: 11/1/2019-11/22/2019

Owner:
County: DENALI
State: AK
Boring No./Test Pit: PR19-09
Depth: 76.0-76.4

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-09
Depth	76.0
Test Date	11/21/2019
Height, in	4.92
Diameter, in	2.39
Cross section, in	4.49
Weight of Core, g	966.8
Unit Weight, pcf	166.86
Maximum Load, lbf	36897
Compressive Strength, psi	8220

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:23:59 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1789-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG
Sample No: BOX 9
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

Sample of: ROCK CORES
Date Received: 11/01/2019
Quantity Rep:
No. & Containers: WAXED CARDBOARD
Dates Tested: 11/1/2019-11/22/2019

Owner:
County: DENALI
State: AK
Boring No./Test Pit: PR19-09
Depth: 78.1-78.5

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-09
Depth	78.1
Test Date	11/21/2019
Height, in	5.05
Diameter, in	2.39
Cross section, in	4.49
Weight of Core, g	992.1
Unit Weight, pcf	166.82
Maximum Load, lbf	89013
Compressive Strength, psi	19840

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:24:19 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1790-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** BOX 9
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORES **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 11/1/2019-11/22/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-09 **Depth:** 79.2-79.6

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-09
Depth	79.2
Test Date	11/21/2019
Height, in	5.44
Diameter, in	2.40
Cross section, in	4.52
Weight of Core, g	1062.6
Unit Weight, pcf	164.49
Maximum Load, lbf	72547
Compressive Strength, psi	16040

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:26:37 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1791-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG
Sample No: BOX 10
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

Sample of: ROCK CORES
Date Received: 11/01/2019
Quantity Rep:
No. & Containers: WAXED CARDBOARD
Dates Tested: 11/1/2019-11/22/2019

Owner:
County: DENALI
State: AK
Boring No./Test Pit: PR19-09
Depth: 88.1-88.5

NOTE: This specimen partially fractured in the SATEC machine, but the test was aborted due to 'over-limit switch activated' on the SATEC. Machine made a 'hard stop'.

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-09
Depth	88.1
Test Date	11/21/2019
Height, in	5.03
Diameter, in	2.40
Cross section, in	4.52
Weight of Core, g	1022.9
Unit Weight, pcf	171.25
Maximum Load, lbf	119909
Compressive Strength, psi	26510

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:26:24 -08'00'

Walt Strong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1792-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG
Sample No: BOX 11
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

Sample of: ROCK CORES
Date Received: 11/01/2019
Quantity Rep:
No. & Containers: WAXED CARDBOARD
Dates Tested: 11/1/2019-11/22/2019

Owner:
County: DENALI
State: AK
Boring No./Test Pit: PR19-09
Depth: 92.7-93.1

Tested in Concrete Break Machine, no Young's Modulus data collected.

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-09
Depth	92.7
Test Date	11/21/2019
Height, in	5.55
Diameter, in	2.40
Cross section, in	4.52
Weight of Core, g	1123.9
Unit Weight, pcf	170.53
Maximum Load, lbf	122685
Compressive Strength, psi	27120

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:24:47 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1793-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG
Sample No: BOX 11
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

Sample of: ROCK CORES
Date Received: 11/01/2019
Quantity Rep:
No. & Containers: WAXED CARDBOARD
Dates Tested: 11/1/2019-11/22/2019

Owner:
County: DENALI
State: AK
Boring No./Test Pit: PR19-09
Depth: 96.0-96.4

Tested in Concrete Break Machine, no Young's Modulus data collected.

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-09
Depth	96.0
Test Date	11/21/2019
Height, in	5.45
Diameter, in	2.39
Cross section, in	4.49
Weight of Core, g	1072.6
Unit Weight, pcf	167.12
Maximum Load, lbf	64680
Compressive Strength, psi	14420

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:25:00 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1794-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIGA **Sample No:** BOX 12
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORES **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 11/1/2019-11/22/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-09 **Depth:** 100.2-100.6

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-09
Depth	100.2
Test Date	11/21/2019
Height, in	4.92
Diameter, in	2.40
Cross section, in	4.52
Weight of Core, g	959.3
Unit Weight, pcf	164.19
Maximum Load, lbf	54188
Compressive Strength, psi	11980

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:26:10 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1795-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIGA
Sample No: BOX 12
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

Sample of: ROCK CORES
Date Received: 11/01/2019
Quantity Rep:
No. & Containers: WAXED CARDBOARD
Dates Tested: 11/1/2019-11/22/2019

Owner:
County: DENALI **State:** AK
Boring No./Test Pit: PR19-09
Depth: 103.1-103.5

Tested in Concrete Break Machine, no Young's Modulus data collected.

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-09
Depth	103.1
Test Date	11/21/2019
Height, in	5.49
Diameter, in	2.39
Cross section, in	4.49
Weight of Core, g	1114.1
Unit Weight, pcf	172.32
Maximum Load, lbf	107620
Compressive Strength, psi	23990

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:25:56 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1796-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** BOX 13
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORES **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 11/1/2019-11/22/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-09 **Depth:** 108.5-108.9

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-09
Depth	108.5
Test Date	11/22/2019
Height, in	5.46
Diameter, in	2.40
Cross section, in	4.52
Weight of Core, g	1083.9
Unit Weight, pcf	167.17
Maximum Load, lbf	30312
Compressive Strength, psi	6700

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:25:44 -08'00'

Walt Strong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1797-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG
Sample No: BOX 14
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

Sample of: ROCK CORES
Date Received: 11/01/2019
Quantity Rep:
No. & Containers: WAXED CARDBOARD
Dates Tested: 11/1/2019-11/22/2019

Owner:
County: DENALI
State: AK
Boring No./Test Pit: PR19-09
Depth: 112.9-113.3

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-09
Depth	112.9
Test Date	11/22/2019
Height, in	5.56
Diameter, in	2.39
Cross section, in	4.49
Weight of Core, g	1122.9
Unit Weight, pcf	171.50
Maximum Load, lbf	31716
Compressive Strength, psi	7070

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:25:31 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1798-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** BOX 14
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORES **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 11/1/2019-11/22/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-09 **Depth:** 118.6-119.0

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-09
Depth	118.6
Test Date	11/22/2019
Height, in	4.89
Diameter, in	2.40
Cross section, in	4.52
Weight of Core, g	974.9
Unit Weight, pcf	167.89
Maximum Load, lbf	73337
Compressive Strength, psi	16210

Reported results apply to the sample as received

WALTER F STONG Digitally signed by WALTER F STONG Date: 2019.12.06 14:25:13 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1799-RC**

Project Name:	PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG	**Sample No:**	BOX 15
Project Number:	AK NPS DENA 10(45)	**Sampled By:**	ROBBIE & JAMES (S&W)
Acct. No.:	1517020701045 510.PE.K700.02	**Date Sampled:**	
Submitted By:	ORION GEORGE/DOUG ANDERS	**Address:**	
Phone:	X7824		
Sample of:	ROCK CORES	**Date Received:**	11/01/2019
Quantity Rep:		**No. & Containers:**	WAXED CARDBOARD
		Dates Tested:	11/1/2019-11/22/2019
Owner:		**County:**	DENALI **State:** AK
Boring No./Test Pit:	PR19-09	**Depth:**	121.2-121.6

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-09
Depth	121.2
Test Date	11/22/2019
Height, in	5.51
Diameter, in	2.40
Cross section, in	4.52
Weight of Core, g	1083.8
Unit Weight, pcf	165.64
Maximum Load, lbf	36503
Compressive Strength, psi	8070

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:28:29 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1800-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** BOX 15
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORES **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 11/1/2019-11/22/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-09 **Depth:** 126.9-127.3

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-09
Depth	126.9
Test Date	11/22/2019
Height, in	5.52
Diameter, in	2.39
Cross section, in	4.49
Weight of Core, g	1094.7
Unit Weight, pcf	168.40
Maximum Load, lbf	72969
Compressive Strength, psi	16260

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:27:50 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1801-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIGA **Sample No:** BOX 16
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORES **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 11/1/2019-11/22/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-09 **Depth:** 132.5-132.9

NOTE: This specimen maxed out in the SATEC machine, WITHOUT fracturing, but the test was aborted due to 'over-limit switch activated' on the SATEC. Machine made a 'hard stop'. Taken to failure point in the concrete break machine to determine ultimate strength.

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-09
Depth	132.5
Test Date	11/22/2019
Height, in	5.72
Diameter, in	2.40
Cross section, in	4.52
Weight of Core, g	1162.4
Unit Weight, pcf	171.13
Maximum Load, lbf	158051
Compressive Strength, psi	34940

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:27:28 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1802-RC**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** BOX 17
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: ROCK CORES **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** WAXED CARDBOARD
Dates Tested: 11/1/2019-11/22/2019

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-09 **Depth:** 142.1-142.5

No Young's Modulus data collected, sample tested to failure in the concrete break machine.

Unconfined Compression of Rock Cores (DL22) - Laboratory Test Results

Core Identification	PR19-09
Depth	142.1
Test Date	11/22/2019
Height, in	4.63
Diameter, in	2.40
Cross section, in	4.52
Weight of Core, g	953.1
Unit Weight, pcf	173.35
Maximum Load, lbf	134775
Compressive Strength, psi	29790

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 14:28:09 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1803-SO**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIGA
Sample No: S-1, S-2
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

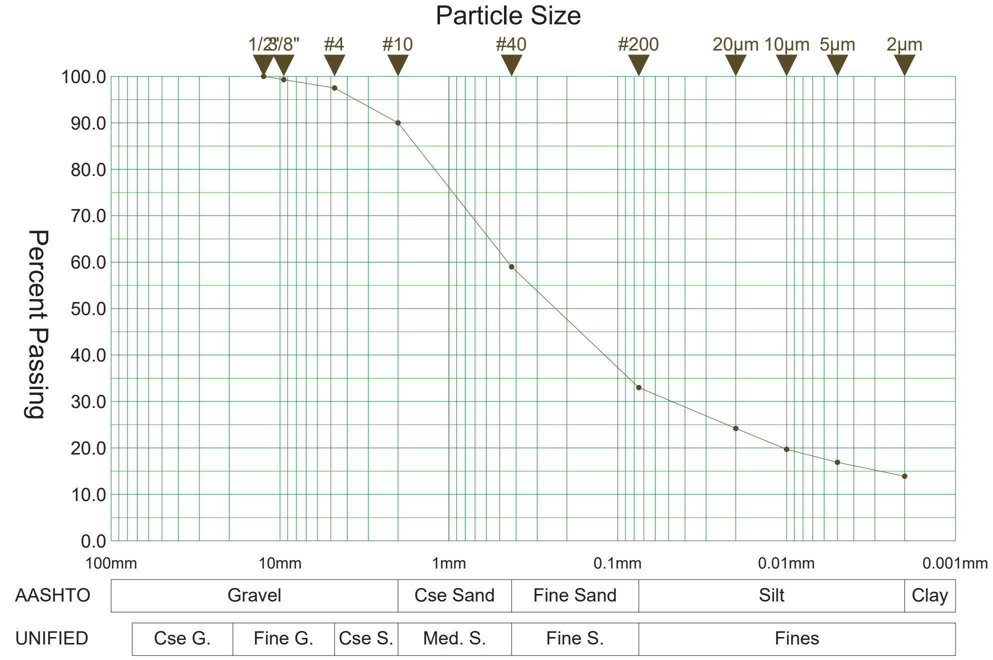
Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

Sample of:
Date Received: 11/01/2019
Quantity Rep:
No. & Containers: ZIP LOC
Dates Tested: 11-01-19 to 11-21-19

Owner:
County: DENALI
State: AK
Boring No./Test Pit: PR19-11
Depth: 7.0-13.5

Sieve Analysis

Sieve Size	As Received % Passing
1/2"	100.0
3/8"	99.3
#4	97.5
#10	90.0
#40	59.0
#200	33.0
20µm	24.2
10µm	19.7
5µm	16.9
2µm	13.9



Soil Classification (DL145)

AASHTO	A-2-7(5)	GR-CL-SAND
Unified	SC; Clayey sand	

Apparent Specific Gravity (T100) 2.462

Atterberg Limits (T89)

Liquid Limit	63
Plasticity Index	37

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 13:34:09 -08'00'

Walt Strong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1804-SO**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** S-4
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

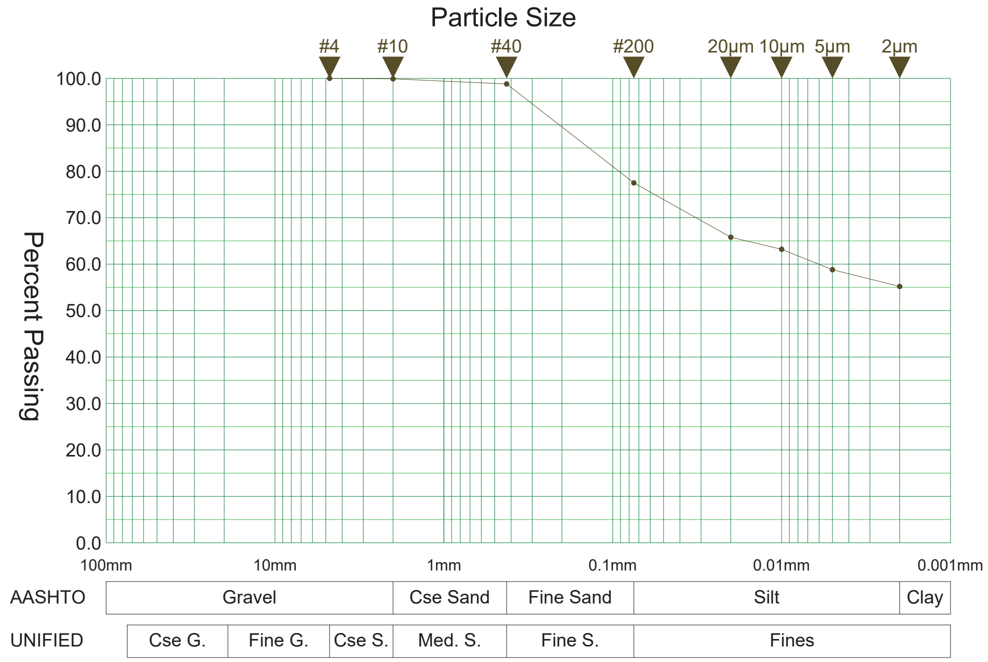
Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** ZIP LOC
Dates Tested: 11-01-19 to 11-21-19

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-11 **Depth:** 22.0-23.5

Sieve Analysis

	As Received
Sieve Size	% Passing
#4	100.0
#10	99.9
#40	98.8
#200	77.5
20µm	65.8
10µm	63.2
5µm	58.8
2µm	55.2



Soil Classification (DL145)

AASHTO	A-7-5(59)	GR-SA-CLAY
Unified	CH; Fat clay with sand	

Apparent Specific Gravity (T100) 2.629

Atterberg Limits (T89)

Liquid Limit	100
Plasticity Index	69

Reported results apply to the sample as received

WALTER F STONG

Digitally signed by WALTER F STONG
Date: 2019.12.06 13:32:25 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1805-SO**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIGA
Sample No: S-9
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

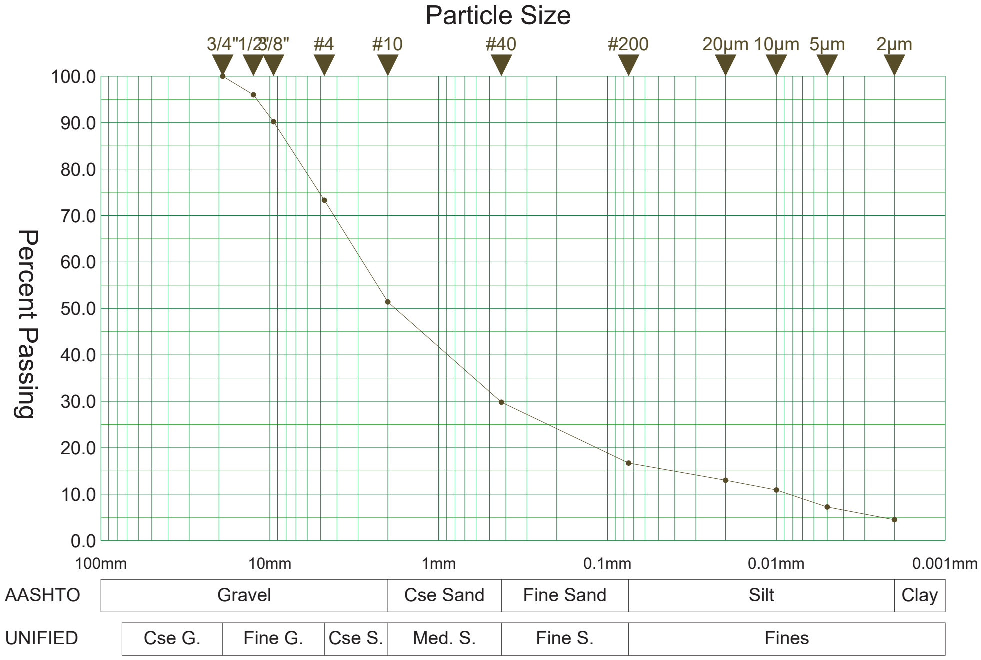
Sample of:
Date Received: 11/01/2019
Quantity Rep:
No. & Containers: ZIP LOC
Dates Tested: 11-01-19 to 11-21-19

Owner:
County: DENALI
State: AK
Boring No./Test Pit: PR19-11
Depth: 47.0-47.7

T-89/90 Method B

Sieve Analysis

Sieve Size	As Received % Passing
3/4"	100.0
1/2"	96.0
3/8"	90.2
#4	73.3
#10	51.4
#40	29.8
#200	16.7
20µm	13.0
10µm	10.9
5µm	7.2
2µm	4.5



Soil Classification (DL145)

AASHTO	A-2-6(0)	CL-SA-GRAVEL
Unified	SC; Clayey sand with gravel	

Apparent Specific Gravity (T100)	2.635

Atterberg Limits (T89)

Liquid Limit	33
Plasticity Index	15

Reported results apply to the sample as received

WALTER
F STONG

Digitally signed by
WALTER F STONG
Date: 2019.12.06
13:31:38 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1806-SO**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIGA
Sample No: S-11, S-12A
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

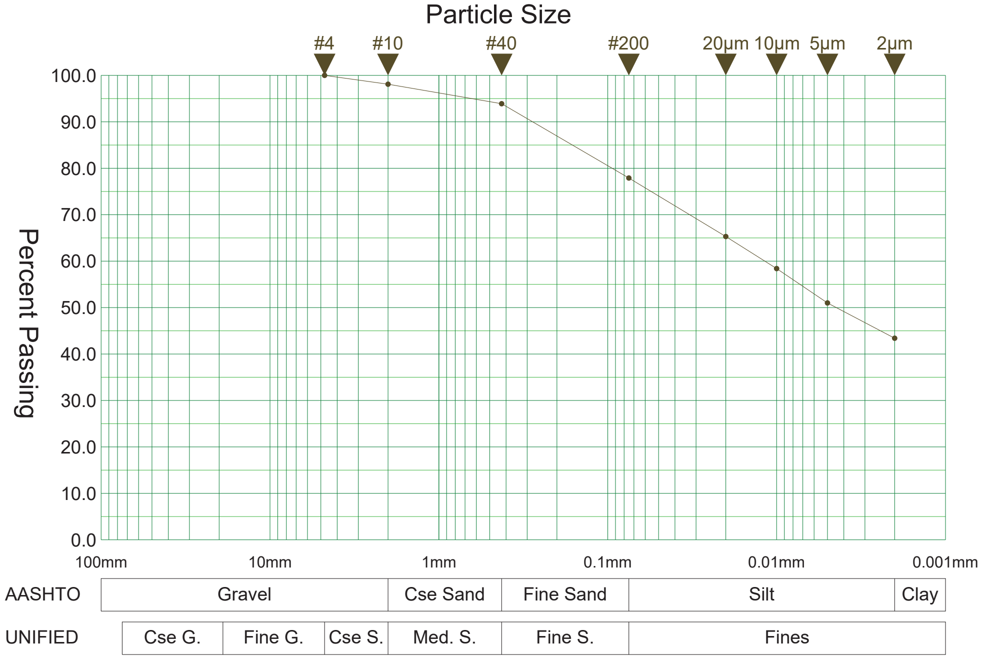
Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

Sample of:
Date Received: 11/01/2019
Quantity Rep:
No. & Containers: ZIP LOC
Dates Tested: 11-01-19 to 11-21-19

Owner:
County: DENALI
State: AK
Boring No./Test Pit: PR19-11
Depth: 57.0-62.3

Sieve Analysis

Sieve Size	As Received % Passing
#4	100.0
#10	98.1
#40	93.9
#200	77.9
20µm	65.3
10µm	58.4
5µm	51.0
2µm	43.4



Soil Classification (DL145)

AASHTO	A-7-5(47)	GR-SA-CLAY
Unified	CH; Fat clay with sand	

Apparent Specific Gravity (T100) 2.660

Atterberg Limits (T89)	
Liquid Limit	88
Plasticity Index	55

Reported results apply to the sample as received

WALTER F STONG Digitally signed by WALTER F STONG Date: 2019.12.06 13:31:55 -08'00'

Walt Strong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1807-SO**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** S-12B
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

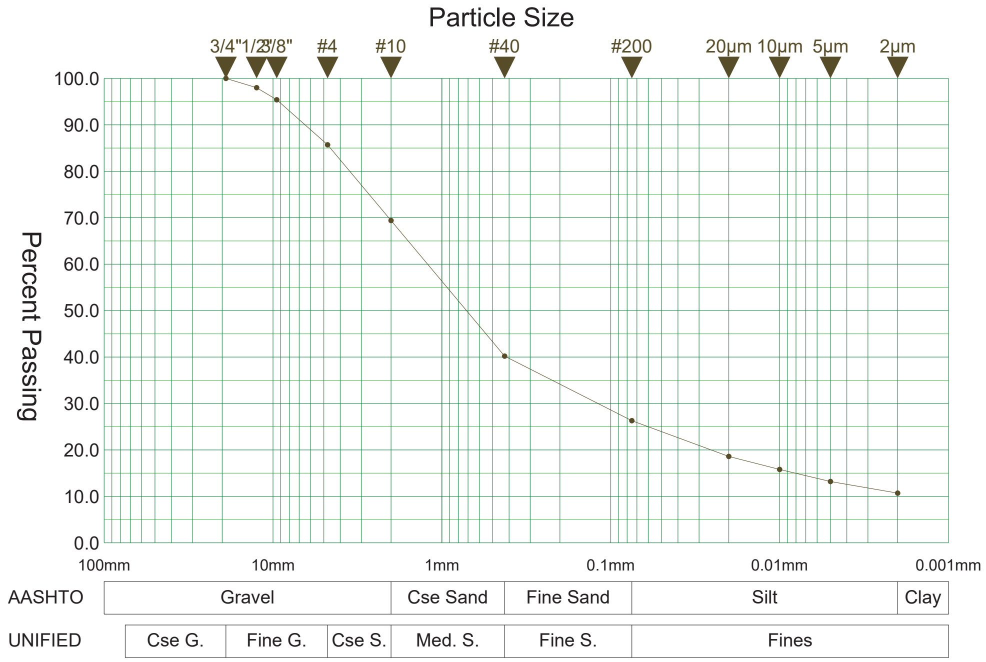
Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** ZIP LOC
Dates Tested: 11-01-19 to 11-21-19

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-11 **Depth:** 62.3-63.4

Sieve Analysis

Sieve Size	As Received % Passing
3/4"	100.0
1/2"	98.0
3/8"	95.4
#4	85.7
#10	69.4
#40	40.2
#200	26.3
20µm	18.6
10µm	15.8
5µm	13.2
2µm	10.7



Soil Classification (DL145)

AASHTO	A-2-7(2)	CL-GR-SAND
Unified	SC; Clayey sand	

Apparent Specific Gravity (T100)	2.749
Atterberg Limits (T89)	
Liquid Limit	47
Plasticity Index	30

Reported results apply to the sample as received

WALTER F STONG

Digitally signed by WALTER F STONG
Date: 2019.12.06 13:32:10 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1808-SO**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** S-13
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

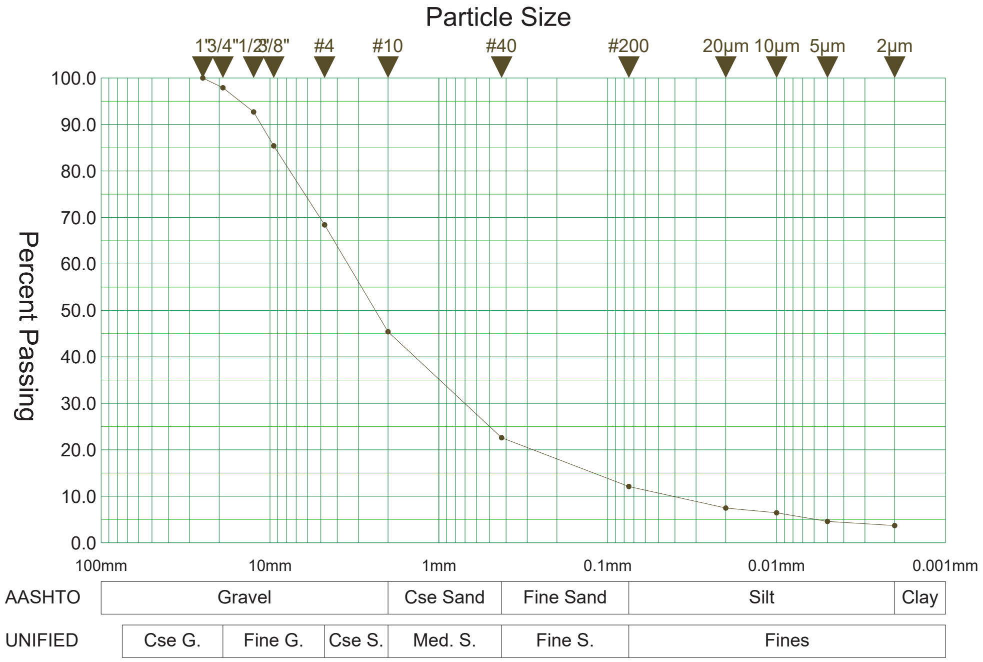
Sample of: **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** ZIP LOC
Dates Tested: 11-01-19 to 11-21-19

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-11 **Depth:** 67.0-68.5

T89/90 Method B

Sieve Analysis

	As Received
Sieve Size	% Passing
1"	100.0
3/4"	97.9
1/2"	92.7
3/8"	85.4
#4	68.4
#10	45.4
#40	22.6
#200	12.1
20µm	7.5
10µm	6.5
5µm	4.6
2µm	3.7



Soil Classification (DL145)

AASHTO	A-2-6(0)	CL-SA-GRAVEL
Unified	SC; Clayey sand with gravel	

Apparent Specific Gravity (T100)	2.745

Atterberg Limits (T89)

Liquid Limit	37
Plasticity Index	19

Reported results apply to the sample as received

WALTER F STONG

Digitally signed by WALTER F STONG
Date: 2019.12.06 13:31:17 -08'00'

Walt Stong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1809-SO**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG
Sample No: S-17, S-18
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

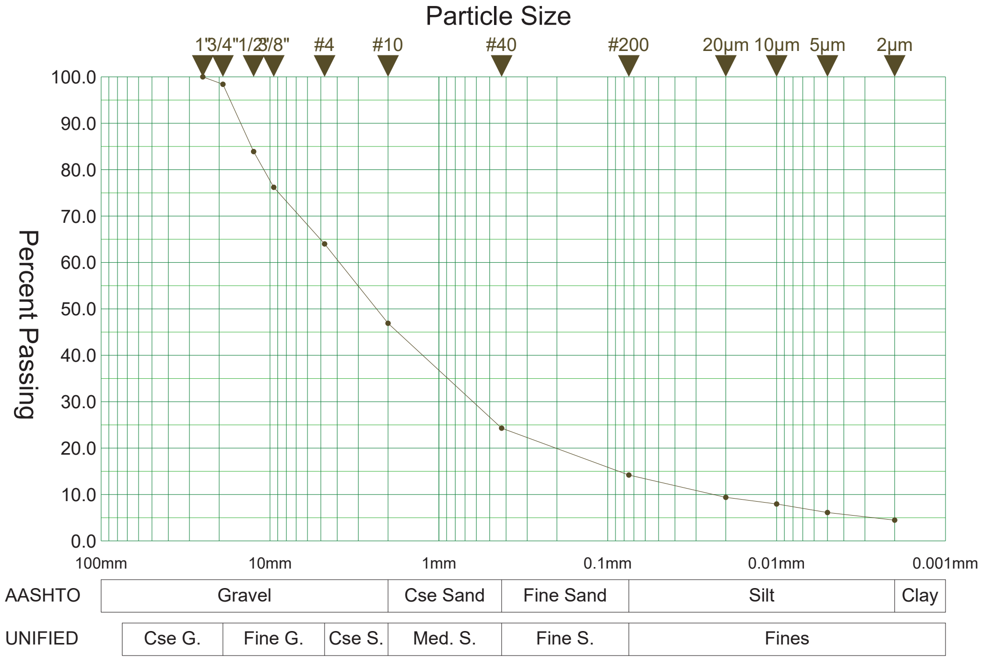
Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

Sample of:
Date Received: 11/01/2019
Quantity Rep:
No. & Containers: ZIP LOC
Dates Tested: 11-01-19 to 11-21-19

Owner:
County: DENALI
State: AK
Boring No./Test Pit: PR19-11
Depth: 87.0-93.5

Sieve Analysis

Sieve Size	As Received % Passing
1"	100.0
3/4"	98.4
1/2"	83.9
3/8"	76.2
#4	64.0
#10	46.9
#40	24.3
#200	14.2
20μm	9.4
10μm	8.0
5μm	6.1
2μm	4.5



Soil Classification (DL145)

AASHTO	A-2-6(0)	CL-SA-GRAVEL
Unified	SC; Clayey sand with gravel	

Apparent Specific Gravity (T100)	2.718

Atterberg Limits (T89)

Liquid Limit	29
Plasticity Index	11

Reported results apply to the sample as received

WALTER F STONG

Digitally signed by WALTER F STONG
Date: 2019.12.06
13:32:59 -08'00'

Walt Strong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1810-SO**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** S-19
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

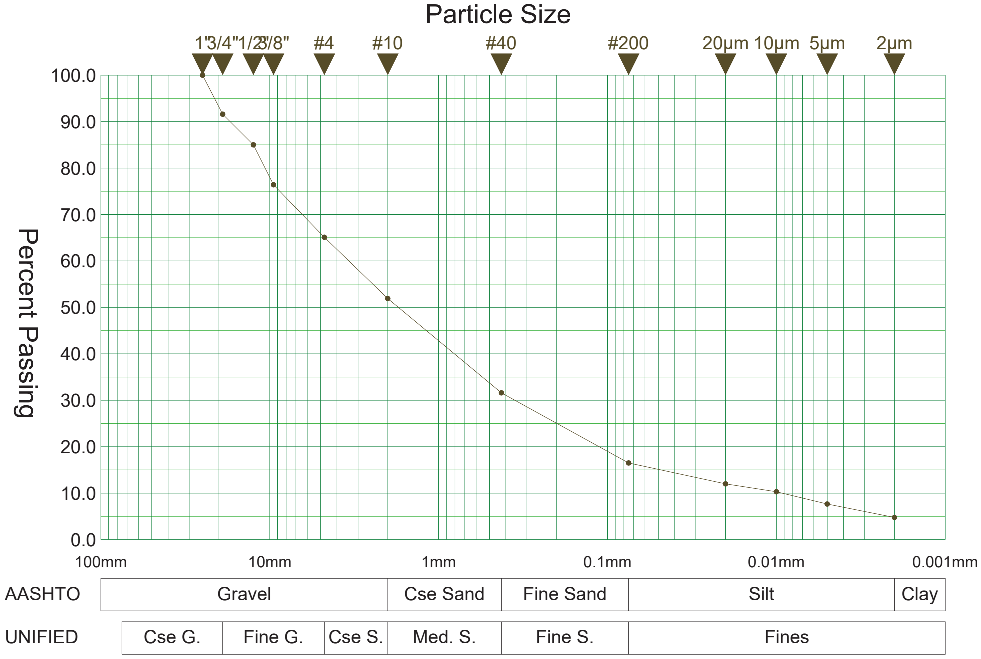
Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** ZIP LOC
Dates Tested: 11-01-19 to 11-22-19

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-11 **Depth:** 97.0-98.5

Sieve Analysis

Sieve Size	As Received % Passing
1"	100.0
3/4"	91.6
1/2"	85.0
3/8"	76.4
#4	65.1
#10	51.9
#40	31.6
#200	16.5
20μm	12.0
10μm	10.3
5μm	7.7
2μm	4.8



Soil Classification (DL145)

AASHTO	A-2-6(0)	CL-SA-GRAVEL
Unified	SC; Clayey sand with gravel	

Apparent Specific Gravity (T100)	2.668

Atterberg Limits (T89)

Liquid Limit	30
Plasticity Index	13

Reported results apply to the sample as received

WALTER F STONG

Digitally signed by WALTER F STONG
Date: 2019.12.06
13:32:39 -08'00'

Walt Strong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1811-SO**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** S-22, S-23
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

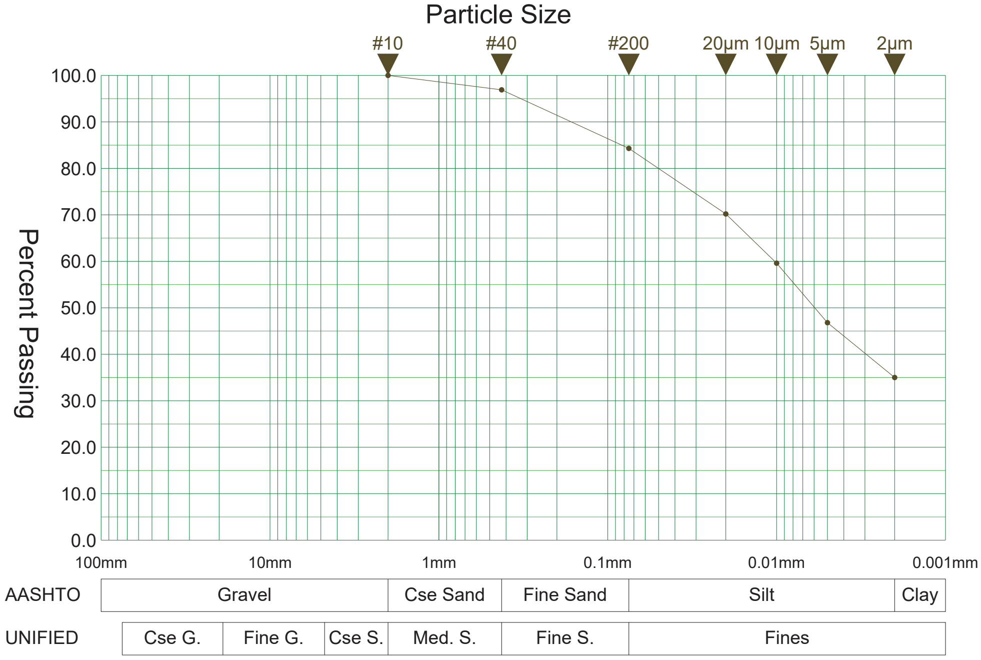
Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** ZIP LOC
Dates Tested: 11-01-19 to 11-22-19

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-11 **Depth:** 112.0-118.5

Sieve Analysis

	As Received
Sieve Size	% Passing
#10	100.0
#40	96.9
#200	84.3
20µm	70.2
10µm	59.6
5µm	46.8
2µm	35.0



Soil Classification (DL145)

AASHTO	A-7-6(34)	SA-CLAY
Unified	CH; Fat clay with sand	

Apparent Specific Gravity (T100) 2.710

Atterberg Limits (T89)

Liquid Limit	59
Plasticity Index	38

Reported results apply to the sample as received

WALTER F STONG
Digitally signed by WALTER F STONG
Date: 2019.12.06 13:33:55 -08'00'

Walt Strong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1812-SO**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG **Sample No:** S-25, S-26
Project Number: AK NPS DENA 10(45) **Sampled By:** ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02 **Date Sampled:**

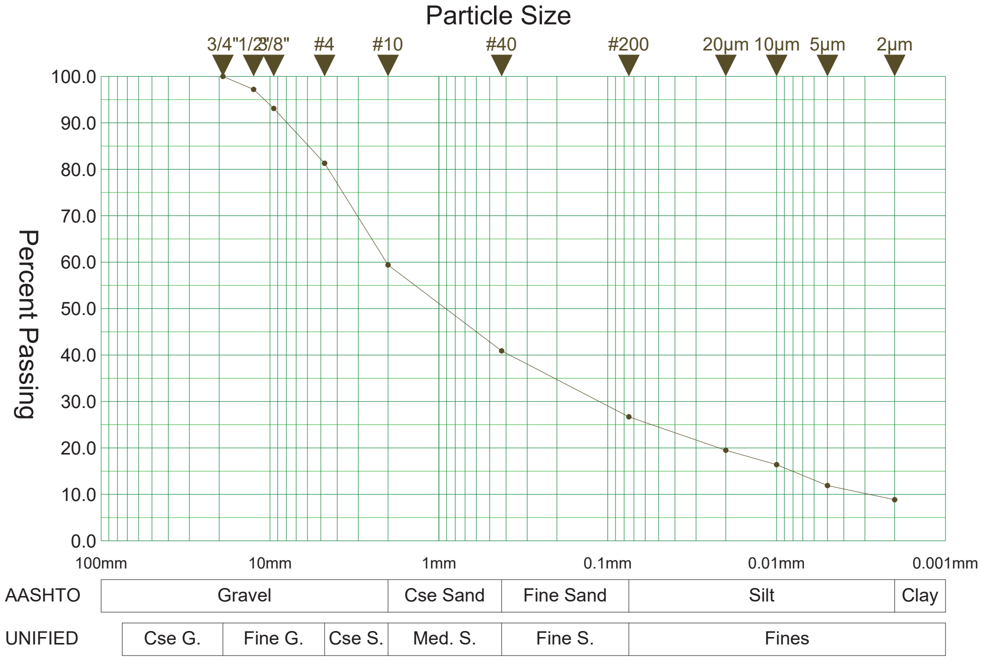
Submitted By: ORION GEORGE/DOUG ANDERS **Address:**
Phone: X7824

Sample of: **Date Received:** 11/01/2019
Quantity Rep: **No. & Containers:** ZIP LOC
Dates Tested: 11-01-19 to 11-22-19

Owner: **County:** DENALI **State:** AK
Boring No./Test Pit: PR19-11 **Depth:** 127.0-132.2

Sieve Analysis

	As Received
Sieve Size	% Passing
3/4"	100.0
1/2"	97.2
3/8"	93.1
#4	81.3
#10	59.4
#40	40.9
#200	26.7
20µm	19.5
10µm	16.4
5µm	11.9
2µm	8.8



Soil Classification (DL145)

AASHTO	A-2-7(2)	CL-SA-GRAVEL
Unified	SC; Clayey sand with gravel	

Apparent Specific Gravity (T100)	2.707
Atterberg Limits (T89)	
Liquid Limit	46
Plasticity Index	25

Reported results applied to the sample as received

WALTER
F STONG

Digitally signed by
WALTER F STONG
Date: 2019.12.06
13:33:41 -08'00'

Walt Strong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

Western Federal Lands Highway Division
Materials Testing Laboratory
610 E. Fifth St, Vancouver, WA 98661

Test Report Issued: **06 Dec 2019**
Lab Control Number: **W-19-1813-SO**

Project Name: PRETTY ROCKS LANDSLIDE GEOTECHNICAL INVESTIG
Sample No: S-28
Project Number: AK NPS DENA 10(45)
Sampled By: ROBBIE & JAMES (S&W)
Acct. No.: 1517020701045 510.PE.K700.02
Date Sampled:

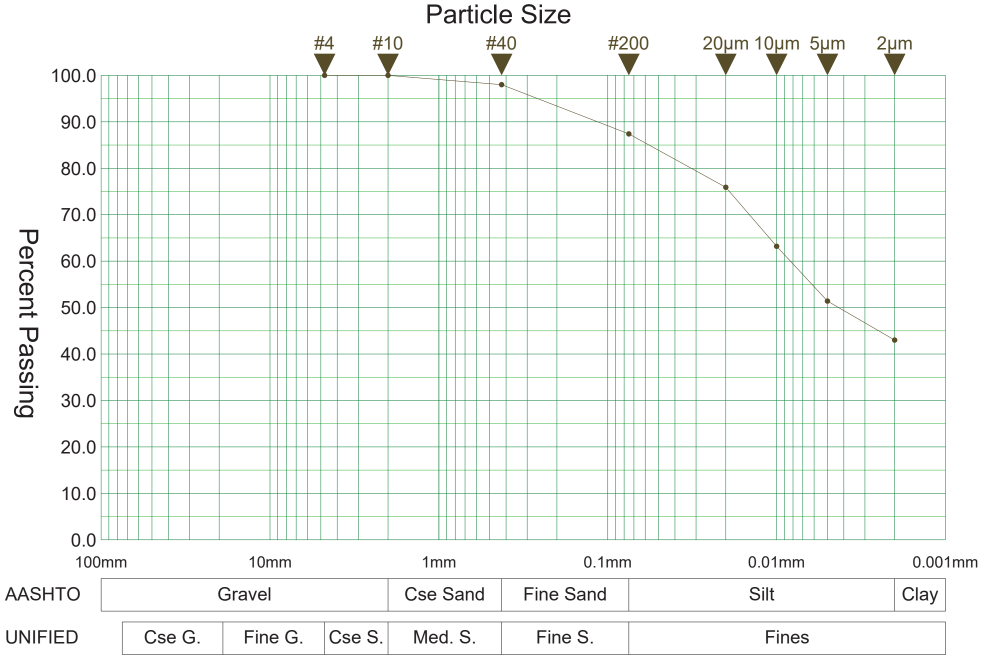
Submitted By: ORION GEORGE/DOUG ANDERS
Address:
Phone: X7824

Sample of:
Date Received: 11/01/2019
Quantity Rep:
No. & Containers: ZIP LOC
Dates Tested: 11-01-19 to 11-22-19

Owner:
County: DENALI
State: AK
Boring No./Test Pit: PR19-11
Depth: 142.0-143.0

Sieve Analysis

	As Received
Sieve Size	% Passing
#4	100.0
#10	100.0
#40	98.0
#200	87.4
20μm	75.9
10μm	63.2
5μm	51.4
2μm	43.0



Soil Classification (DL145)

AASHTO	A-7-6(32)	SA-CLAY
Unified	CH; Fat clay	

Apparent Specific Gravity (T100) 2.709

Atterberg Limits (T89)

Liquid Limit	52
Plasticity Index	36

Reported results apply to the sample as received

WALTER F STONG Digitally signed by WALTER F STONG Date: 2019.12.06 13:33:26 -08'00'

Walt Strong, Materials Laboratory Chief
For: Megan Chatfield, Materials Engineer

APPENDIX E-3

2018 Ring Shear Test Reports

Job No. **RO-2905** Date **January 10, 2019**

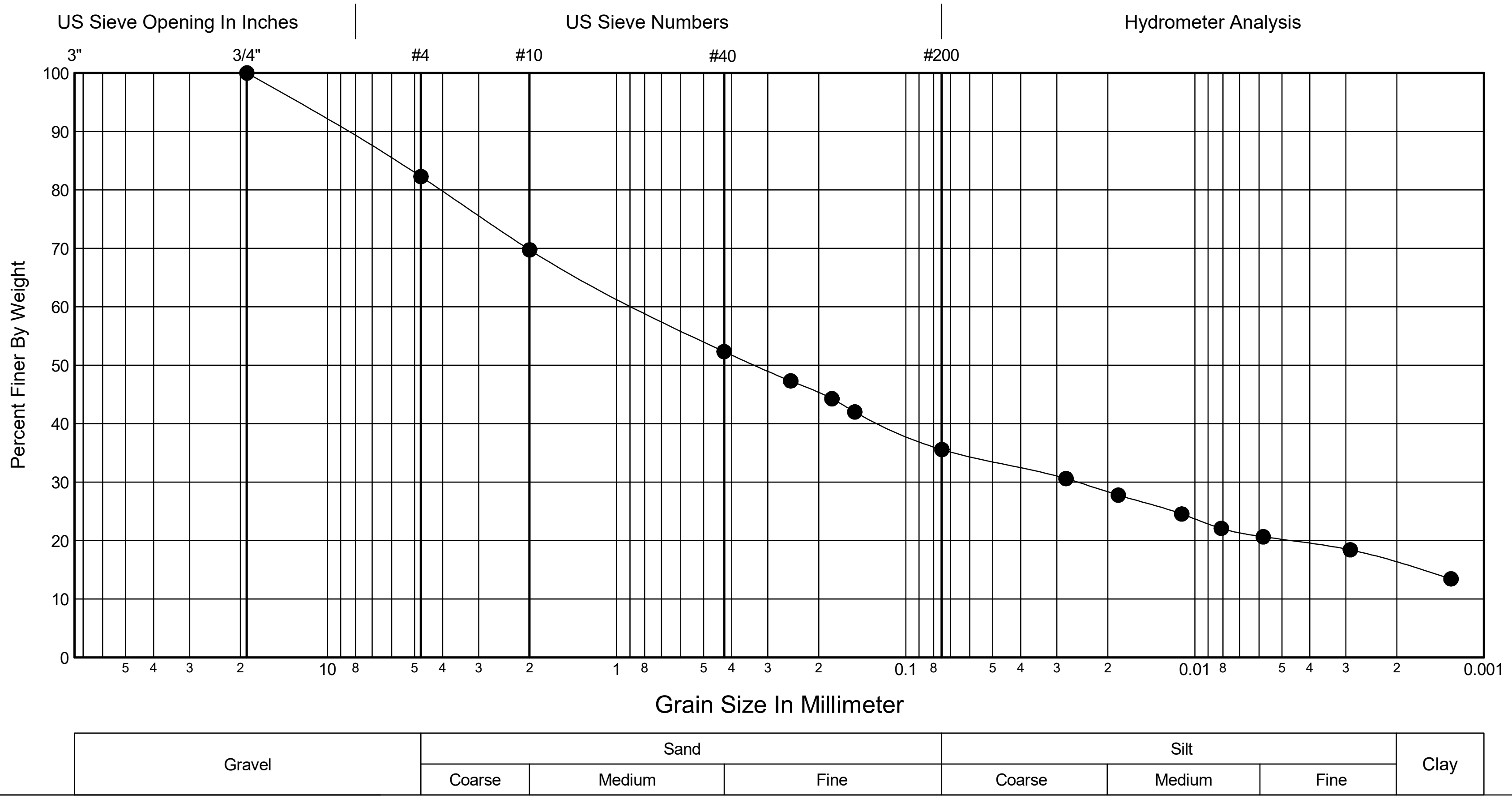
Hole No. **PR18-01** Sheet **1**

Project **AK NPS DENA 10 (45) Pretty Rock Landside Geo Inv**

Laboratory Summary

WSDOT

	Depth (ft)	Sample No.	USCS	Description	MC%	LL	PL	PI	Moist Density (lbs/ft^3)	Specific Gravity	Gravel (%)	Sand (%)	Fines (%)	Cc	Cu	D60	D50	D30	D20	D10
●	**40.0**	**S-16**	**SC**	**CLAYEY SAND with GRAVEL**	**28**	**57**	**25**	**32**		**2.57**	**17.7**	**46.7**	**35.6**			**0.841**	**0.33**	**0.03**	**0.00**	



Ring Shear Test Report (ASTM D6467-13)

Washington State Department of Transportation

PROJECT INFORMATION			
Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S-16
Project Number	RO-2905	Depth	40.0' to 40.5'
Boring Number	PR18-01	Sample Type	Remolded
Description	SC - CLAYEY SAND with GRAVEL		

		Specimen				
INITIAL		**50 KPA**	**100 KPA**	**200 KPA**	**400 KPA**	**700 KPA**
Specimen Thickness (in)		0.200	0.200	0.200	0.200	0.200
Internal Ring Radius(in)		1.375	1.375	1.375	1.375	1.375
External Ring Radius(in)		1.970	1.970	1.970	1.970	1.970
Moisture Content (%)		37.9				
SHEAR		**50 KPA**	**100 KPA**	**200 KPA**	**400 KPA**	**700 KPA**
Rate of Linear Displacement (in/min)		0.0007	0.0007	0.0007	0.0007	0.0007
Rate of Angular Displacement (Deg/min)		0.0240	0.0240	0.0240	0.0240	0.0240
Normal Stress (psi)		7.3	14.5	29.0	58.0	101.0
Residual Shear Stress (psi)		1.542	4.208	8.907	19.089	29.029
Linear Displacement (in)		0.840	0.252	0.840	0.336	0.840
Angular Displacement (Deg)		28.8	8.6	28.8	11.5	28.8
FINAL		**50 KPA**	**100 KPA**	**200 KPA**	**400 KPA**	**700 KPA**
Final Moisture Content (%)						37.8
Assumed Cohesion (psi)		0.0	0.0	0.0	0.0	0.0
Liquid limit		57.0	57.0	57.0	57.0	57.0
Plastic Limit		25.0	25.0	25.0	25.0	25.0
Plasticity Index		32.0	32.0	32.0	32.0	32.0
Specific Gravity		2.57	2.57	2.57	2.57	2.57
Angle of Residual Shear Resistance (Deg)	**16.6**	**11.9**	**16.2**	**17.1**	**18.2**	**16.0**
CF%:	15.4					

COMMENT/REMARKS

Tested By	Donny Henderson	Date	2/5/2019
Checked By	Donny Henderson	Date	2/5/2019

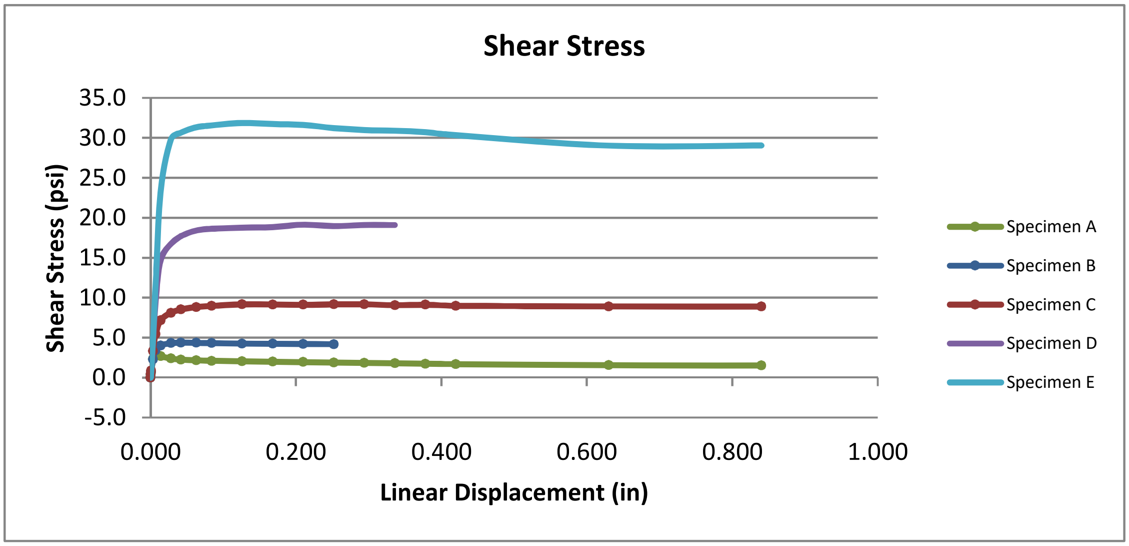
Ring Shear Test Report (ASTM D6467-13)

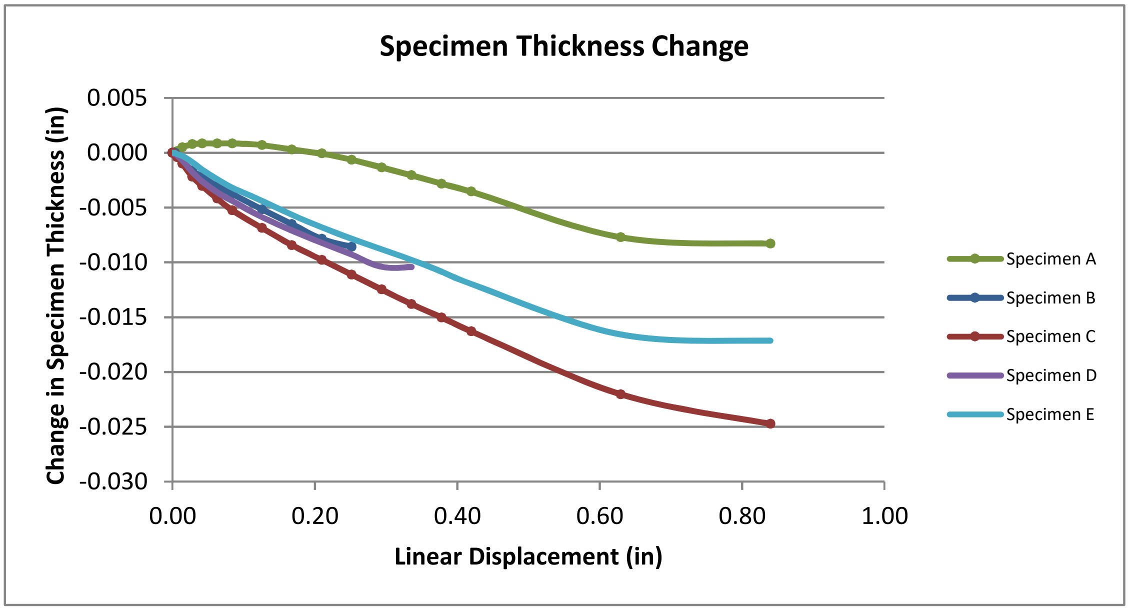
Washington State Department of Transportation Geotechnical Division

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S-16
Project Number	RO-2905	Depth	40.0' to 40.5'
Boring Number	PR18-01	Sample Type	Remolded
Description	SC - CLAYEY SAND with GRAVEL		

FINAL GRAPHS (1 of 3)





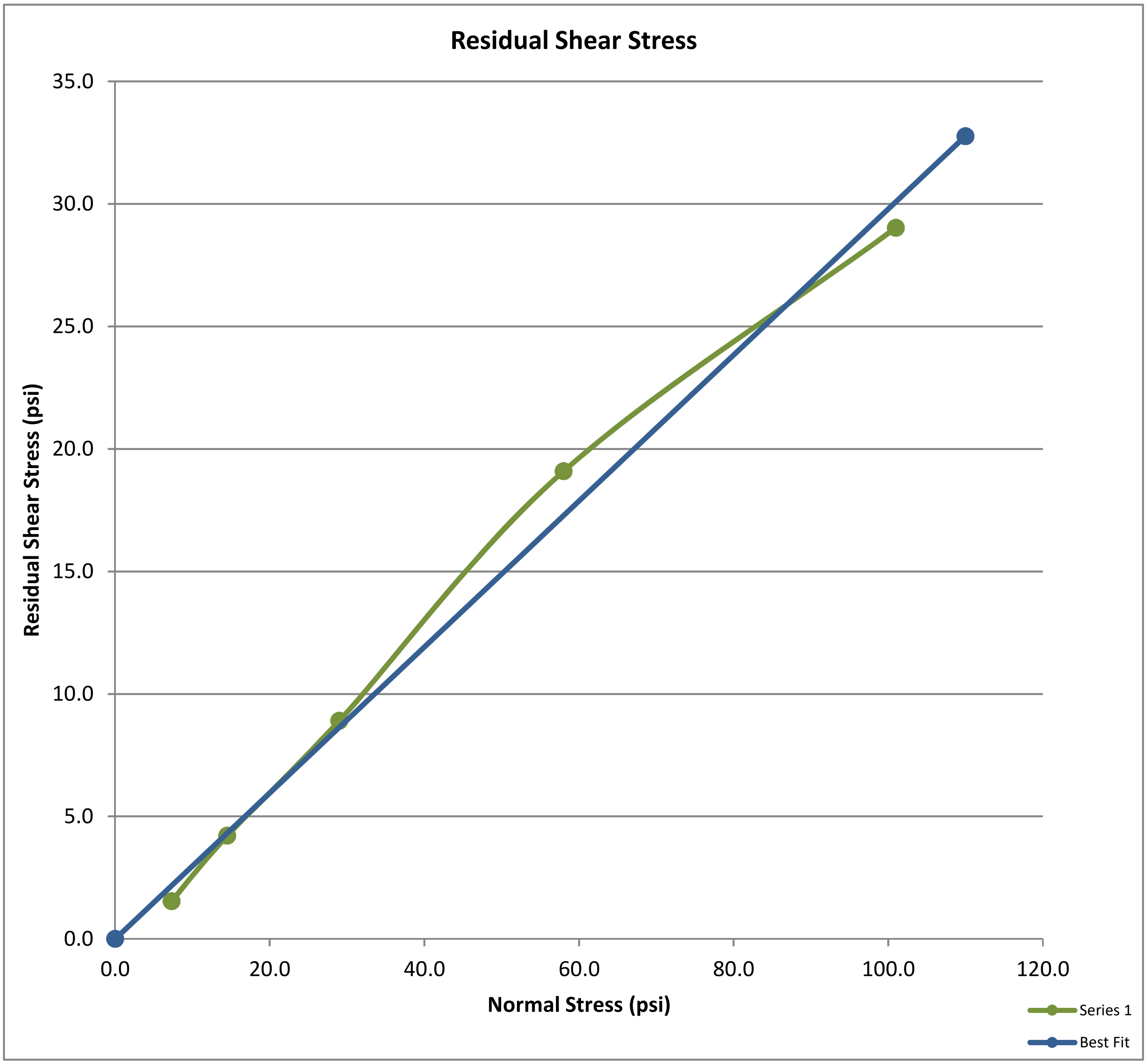
Ring Shear Test Report (ASTM D6467-13)

Washington State Department of Transportation Geotechnical Division

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Numb	S-16
Project Number	RO-2905	Depth	40.0' to 40.5'
Boring Number	PR18-01	Sample Type	Remolded
Description	SC - CLAYEY SAND with GRAVEL		

FINAL GRAPHS (2 of 3)



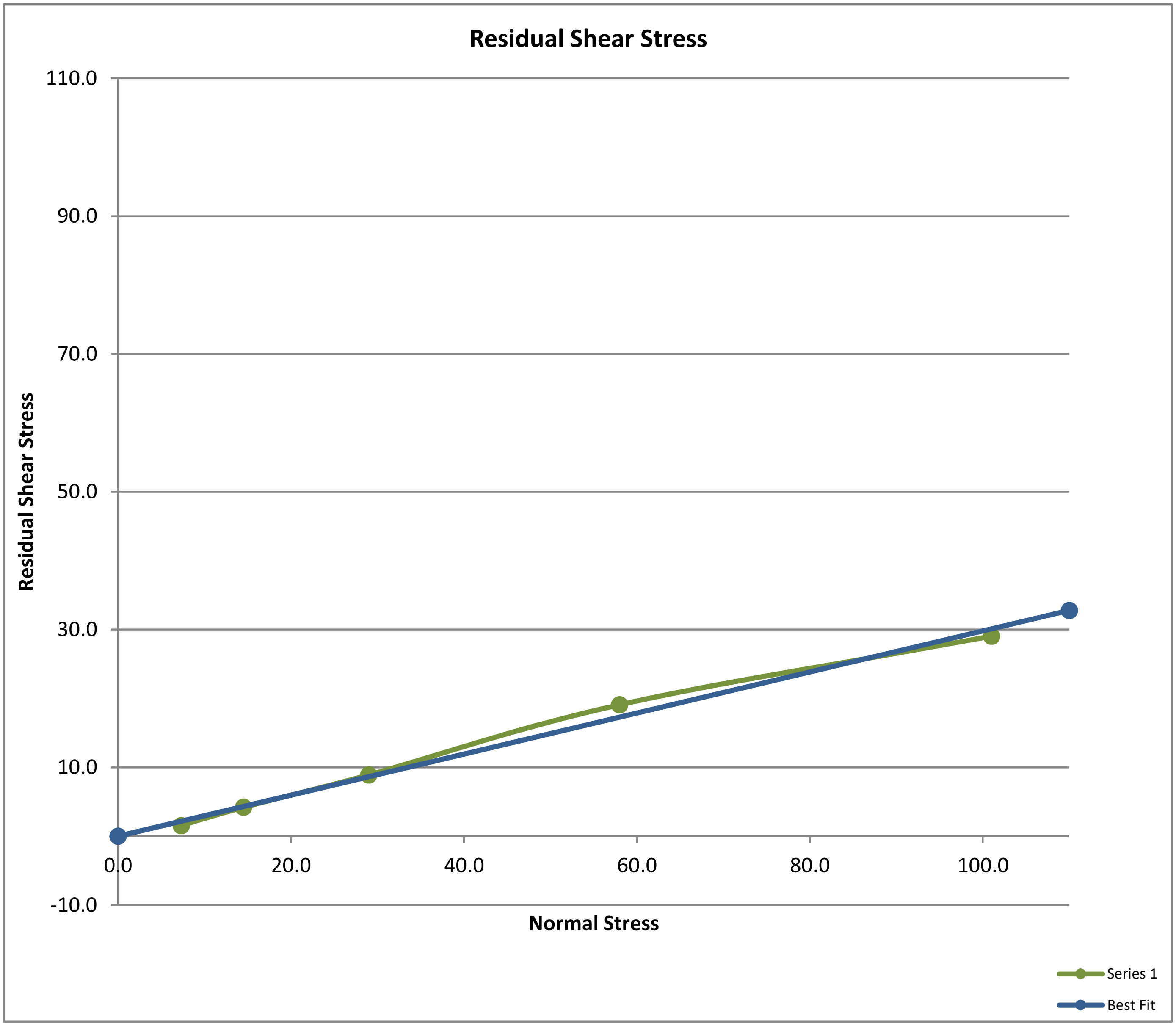
Ring Shear Test Report (ASTM D6467-13)

Washington State Department of Transportation Geotechnical Division

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S-16
Project Number	RO-2905	Depth	40.0' to 40.5'
Boring Number	PR18-01	Sample Type	Remolded
Description	SC - CLAYEY SAND with GRAVEL		

FINAL GRAPHS (3 of 3)

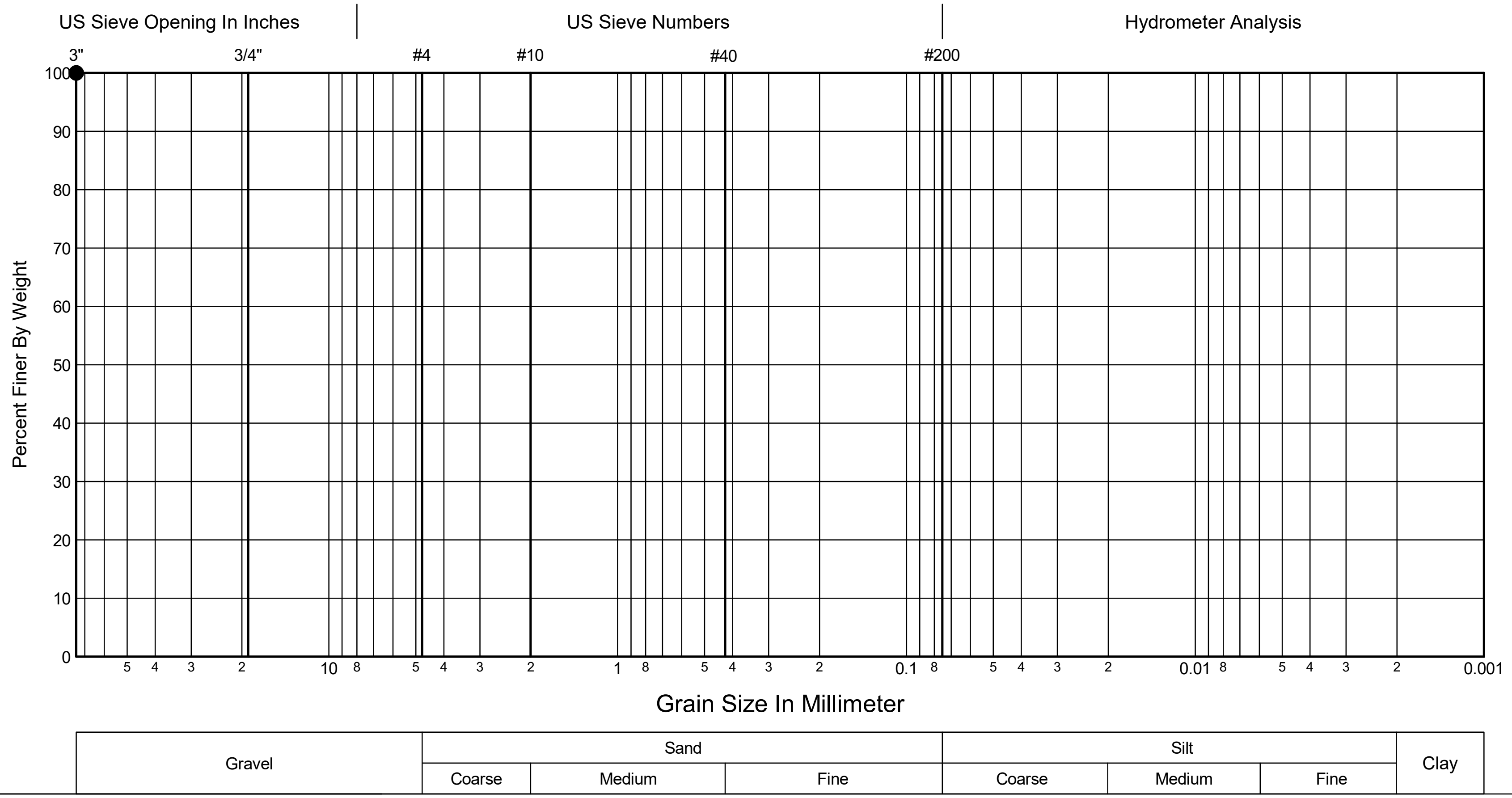


Job No. **RO-2905** Date **January 11, 2019**
Hole No. **PR18-02** Sheet **1**
Project **AK NPS DENA 10 (45) Pretty Rock Landside Geo Inv**

Laboratory Summary

WSDOT

	Depth (ft)	Sample No.	USCS	Description	MC%	LL	PL	PI	Moist Density (lbs/ft^3)	Specific Gravity	Gravel (%)	Sand (%)	Fines (%)	Cc	Cu	D60	D50	D30	D20	D10
●	**88.4**	**S35**		**MC & AL Only**	**30**	**71**	**32**	**39**												



RO-2905 PRETTY ROCK LANDSLIDE.GPJ PUBLIC-COMMON LIBRARY.GLB 1/11/19

Ring Shear Test Report (ASTM D6467-13)

Washington State Department of Transportation

PROJECT INFORMATION			
Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S-35
Project Number	RO-2905	Depth	88.4' to 88.7'
Boring Number	PR18-02	Sample Type	Remolded
Description			

		Specimen				
INITIAL		**50 KPA**	**100 KPA**	**200 KPA**	**400 KPA**	**700 KPA**
Specimen Thickness (in)		0.200	0.200	0.200	0.200	0.200
Internal Ring Radius(in)		1.375	1.375	1.375	1.375	1.375
External Ring Radius(in)		1.970	1.970	1.970	1.970	1.970
Moisture Content (%)		34.0				
SHEAR		**50 KPA**	**100 KPA**	**200 KPA**	**400 KPA**	**700 KPA**
Rate of Linear Displacement (in/min)		0.0007	0.0007	0.0007	0.0007	0.0007
Rate of Angular Displacement (Deg/min)		0.0240	0.0240	0.0240	0.0240	0.0240
Normal Stress (psi)		7.3	14.5	29.0	58.0	101.0
Residual Shear Stress (psi)		1.323	3.356	7.438	15.710	23.855
Linear Displacement (in)		0.630	0.294	0.840	0.336	0.840
Angular Displacement (Deg)		21.6	10.1	28.8	11.5	28.8
FINAL		**50 KPA**	**100 KPA**	**200 KPA**	**400 KPA**	**700 KPA**
Final Moisture Content (%)						33.4
Assumed Cohesion (psi)		0.0	0.0	0.0	0.0	0.0
Liquid limit		71.0	71.0	71.0	71.0	71.0
Plastic Limit		31.0	31.0	31.0	31.0	31.0
Plasticity Index		39.0	39.0	39.0	39.0	39.0
Specific Gravity		2.67	2.67	2.67	2.67	2.67
Angle of Residual Shear Resistance (Deg)	**13.8**	**10.3**	**13.0**	**14.4**	**15.2**	**13.3**
CF%:						

COMMENT/REMARKS

Tester Notes: Only had enough material to run PI only on this sample. Specific Gravity Results are assumed.

Tested By	Donny Henderson	Date	2/5/2019
Checked By	Donny Henderson	Date	2/5/2019

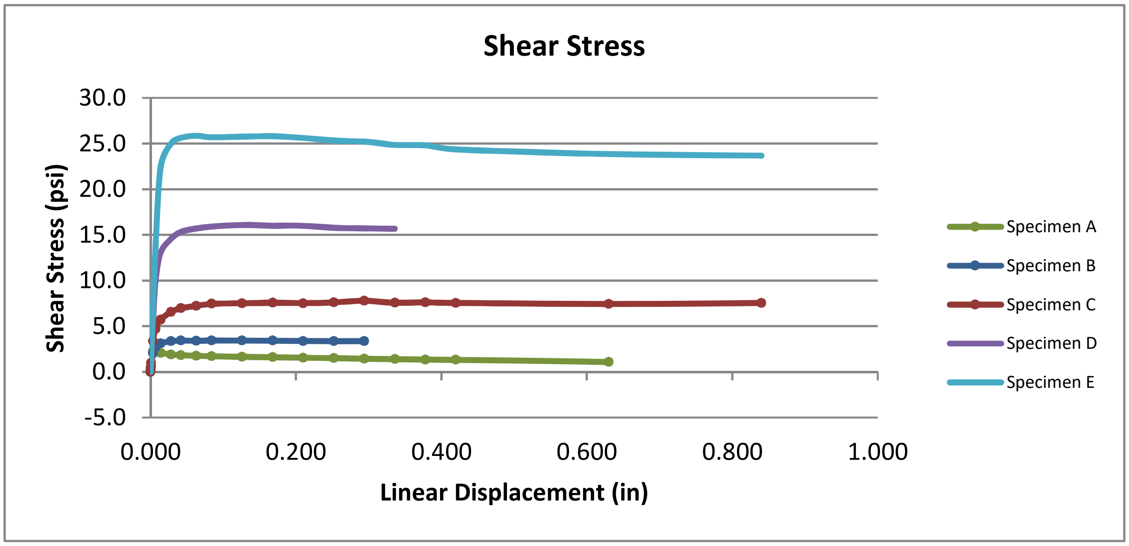
Ring Shear Test Report (ASTM D6467-13)

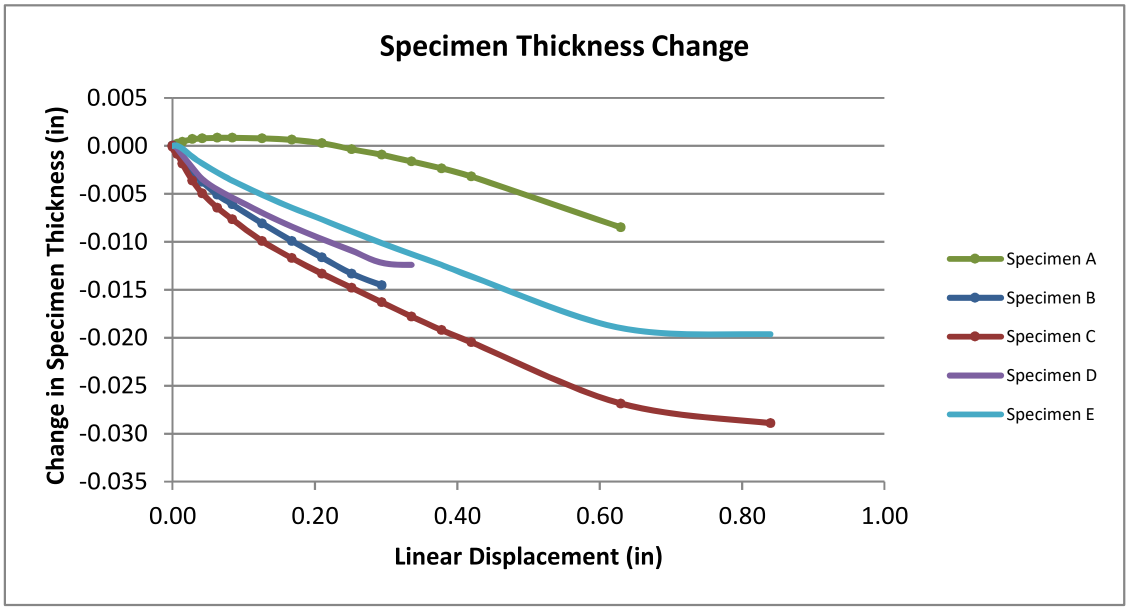
Washington State Department of Transportation Geotechnical Division

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S-35
Project Number	RO-2905	Depth	88.4' to 88.7'
Boring Number	PR18-02	Sample Type	Remolded
Description			

FINAL GRAPHS (1 of 3)





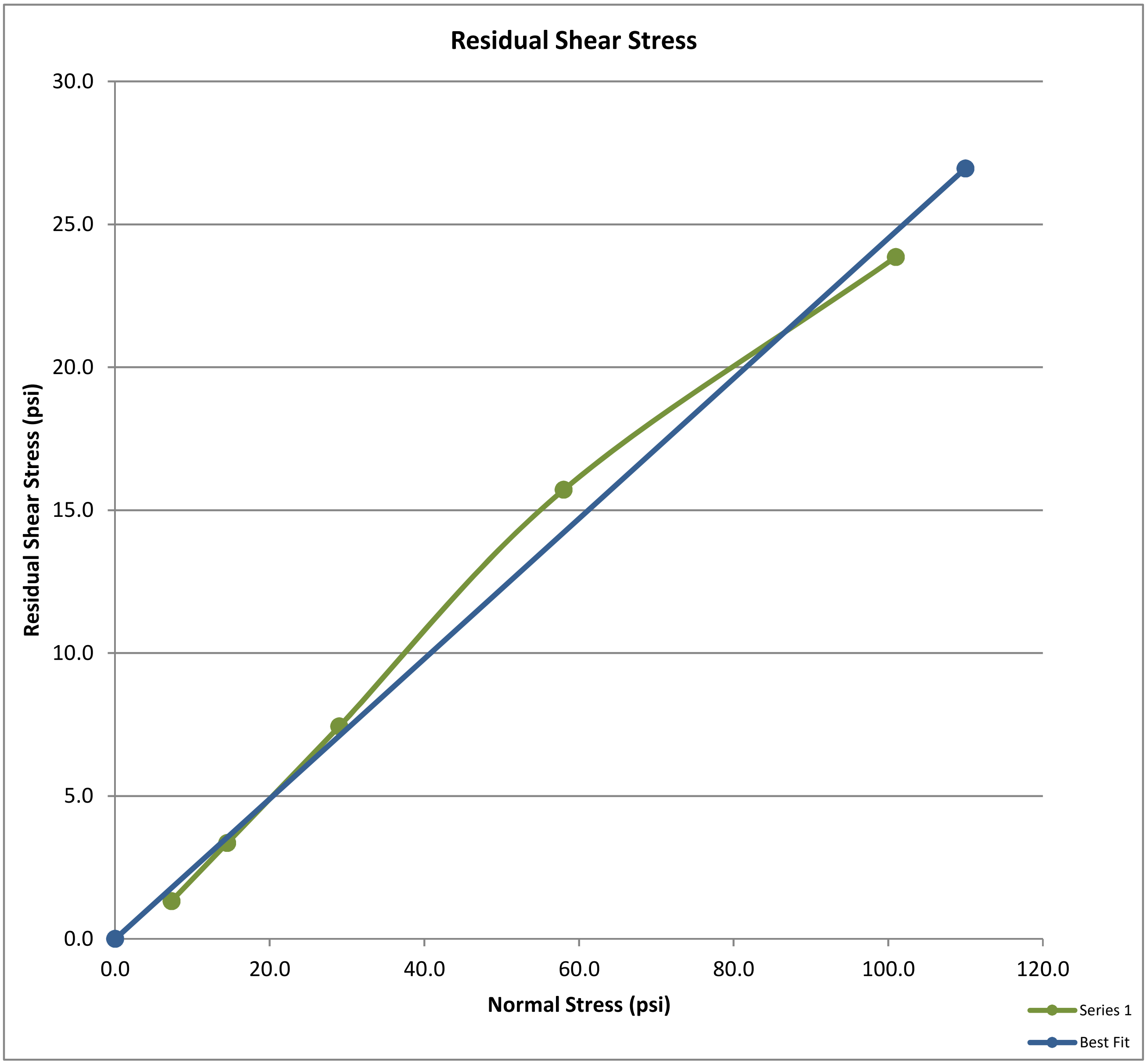
Ring Shear Test Report (ASTM D6467-13)

Washington State Department of Transportation Geotechnical Division

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Numb	S-35
Project Number	RO-2905	Depth	88.4' to 88.7'
Boring Number	PR18-02	Sample Type	Remolded
Description			

FINAL GRAPHS (2 of 3)



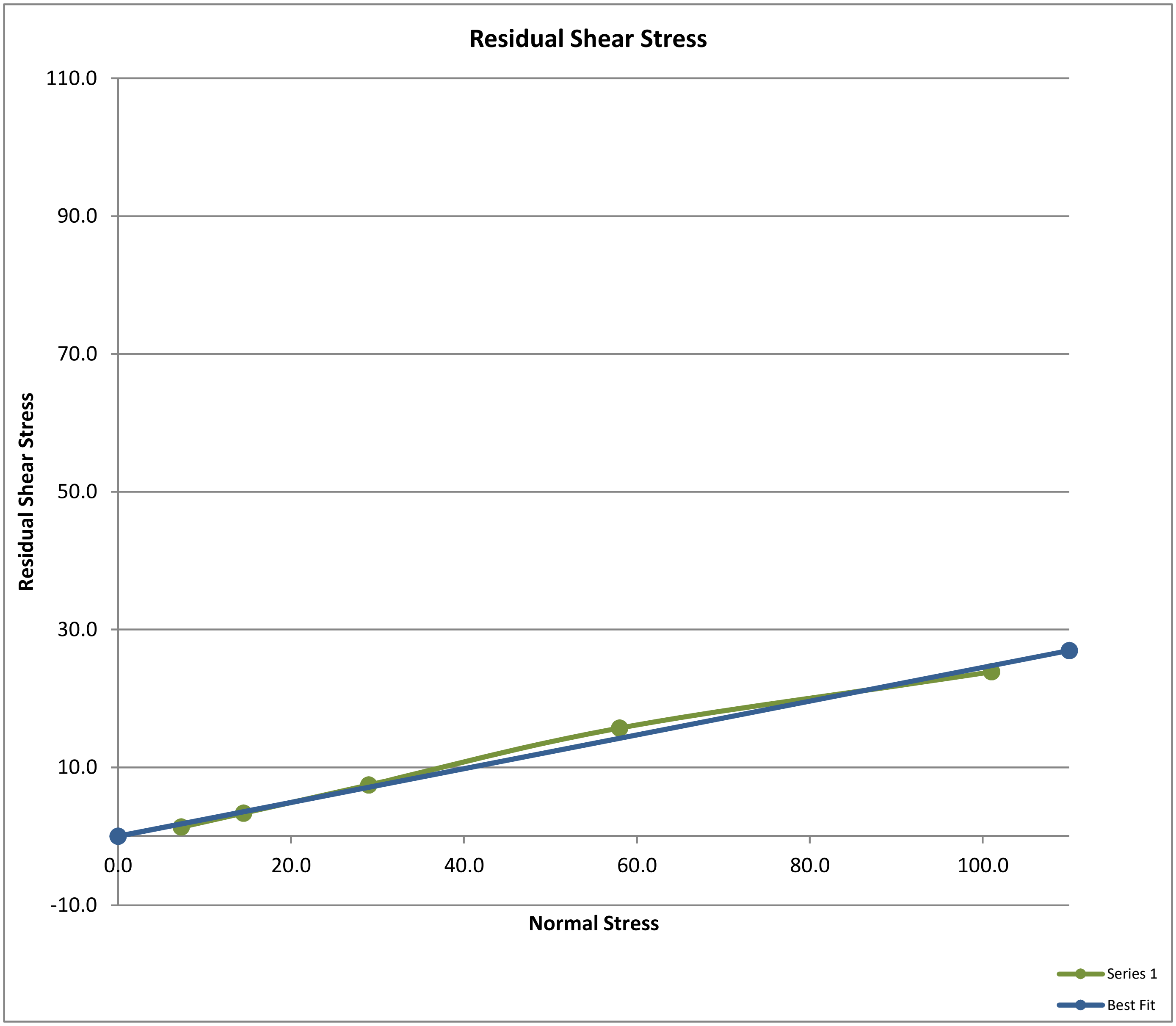
Ring Shear Test Report (ASTM D6467-13)

Washington State Department of Transportation Geotechnical Division

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S-35
Project Number	RO-2905	Depth	88.4' to 88.7'
Boring Number	PR18-02	Sample Type	Remolded
Description			

FINAL GRAPHS (3 of 3)

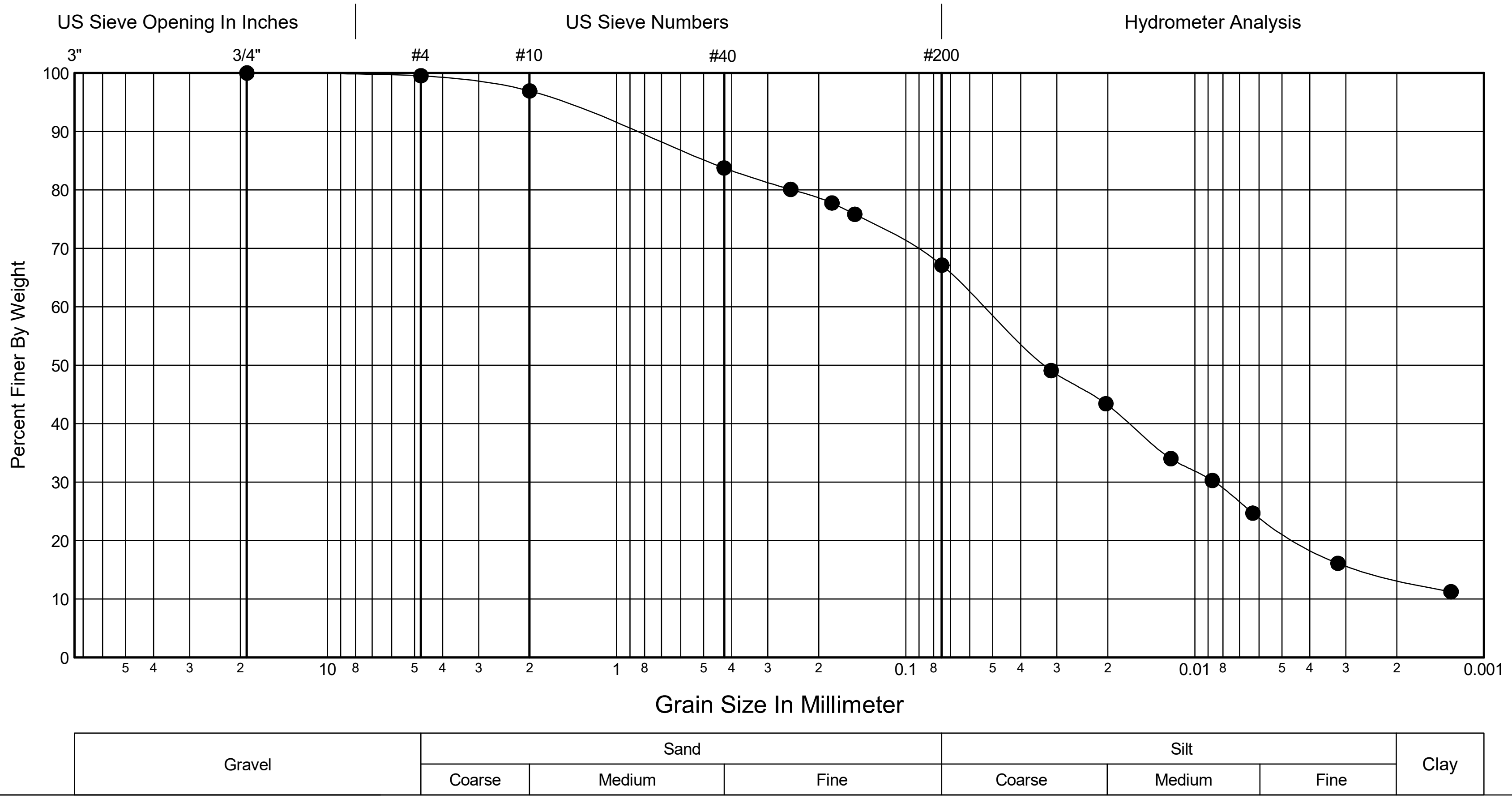


Job No. **RO-2905** Date **January 10, 2019**
Hole No. **PR18-03** Sheet **1**
Project **AK NPS DENA 10 (45) Pretty Rock Landside Geo Inv**

Laboratory Summary

WSDOT

	Depth (ft)	Sample No.	USCS	Description	MC%	LL	PL	PI	Moist Density (lbs/ft³)	Specific Gravity	Gravel (%)	Sand (%)	Fines (%)	Cc	Cu	D60	D50	D30	D20	D10
●	**56.0**	**S-21B**	**CH**	**SANDY FAT CLAY**	**68**	**60**	**30**	**30**		**2.68**	**0.5**	**32.4**	**67.1**			**0.053**	**0.03**	**0.01**	**0.00**	



RO-2905 PRETTY ROCK LANDSLIDE.GPJ PUBLIC-COMMON LIBRARY.GLB 1/10/19

Ring Shear Test Report (ASTM D6467-13)

Washington State Department of Transportation

PROJECT INFORMATION			
Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S-21B
Project Number	RO-2905	Depth	56.0' to 57.0'
Boring Number	PR18-03	Sample Type	Remolded
Description	CH - SANDY FAT CLAY		

		Specimen				
INITIAL		**50 KPA**	**100 KPA**	**200 KPA**	**400 KPA**	**700 KPA**
Specimen Thickness (in)		0.200	0.200	0.200	0.200	0.200
Internal Ring Radius(in)		1.375	1.375	1.375	1.375	1.375
External Ring Radius(in)		1.970	1.970	1.970	1.970	1.970
Moisture Content (%)		29.9				
SHEAR		**50 KPA**	**100 KPA**	**200 KPA**	**400 KPA**	**700 KPA**
Rate of Linear Displacement (in/min)		0.0007	0.0007	0.0007	0.0007	0.0007
Rate of Angular Displacement (Deg/min)		0.0240	0.0240	0.0240	0.0240	0.0240
Normal Stress (psi)		7.3	14.5	29.0	58.0	101.0
Residual Shear Stress (psi)		1.875	4.446	9.993	17.042	23.537
Linear Displacement (in)		0.168	0.630	0.294	0.840	0.882
Angular Displacement (Deg)		5.8	21.6	10.1	28.8	30.2
FINAL		**50 KPA**	**100 KPA**	**200 KPA**	**400 KPA**	**700 KPA**
Final Moisture Content (%)						35.8
Assumed Cohesion (psi)		0.0	0.0	0.0	0.0	0.0
Liquid limit		60.0	60.0	60.0	60.0	60.0
Plastic Limit		30.0	30.0	30.0	30.0	30.0
Plasticity Index		30.0	30.0	30.0	30.0	30.0
Specific Gravity		2.68	2.67	2.67	2.67	2.67
Angle of Residual Shear Resistance (Deg)	**14.3**	**14.4**	**17.0**	**19.0**	**16.4**	**13.1**
CF%:	12.82					

COMMENT/REMARKS

Tested By	Donny Henderson	Date	2/5/2019
Checked By	Donny Henderson	Date	2/5/2019

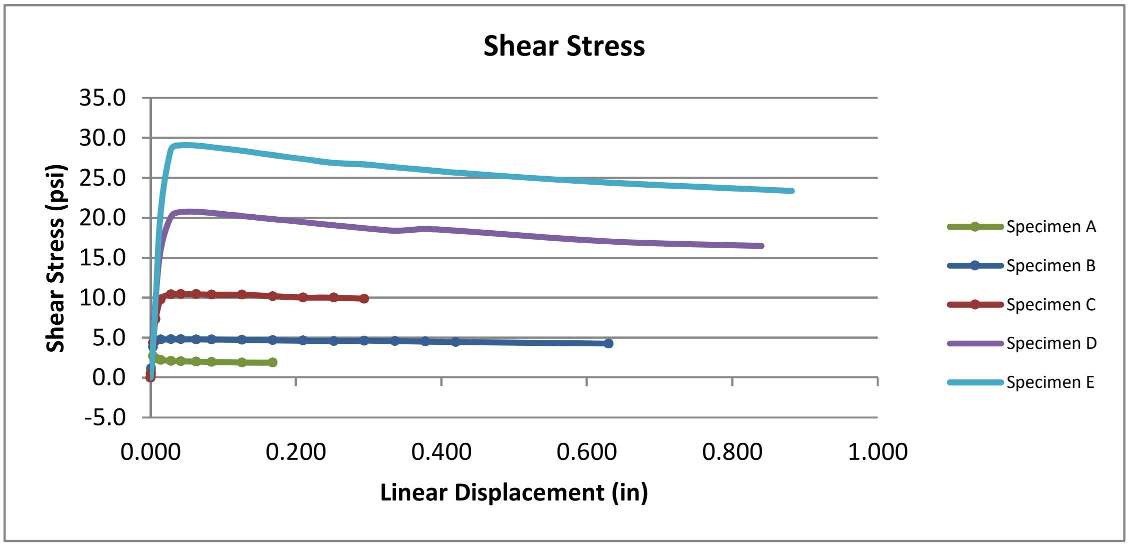
Ring Shear Test Report (ASTM D6467-13)

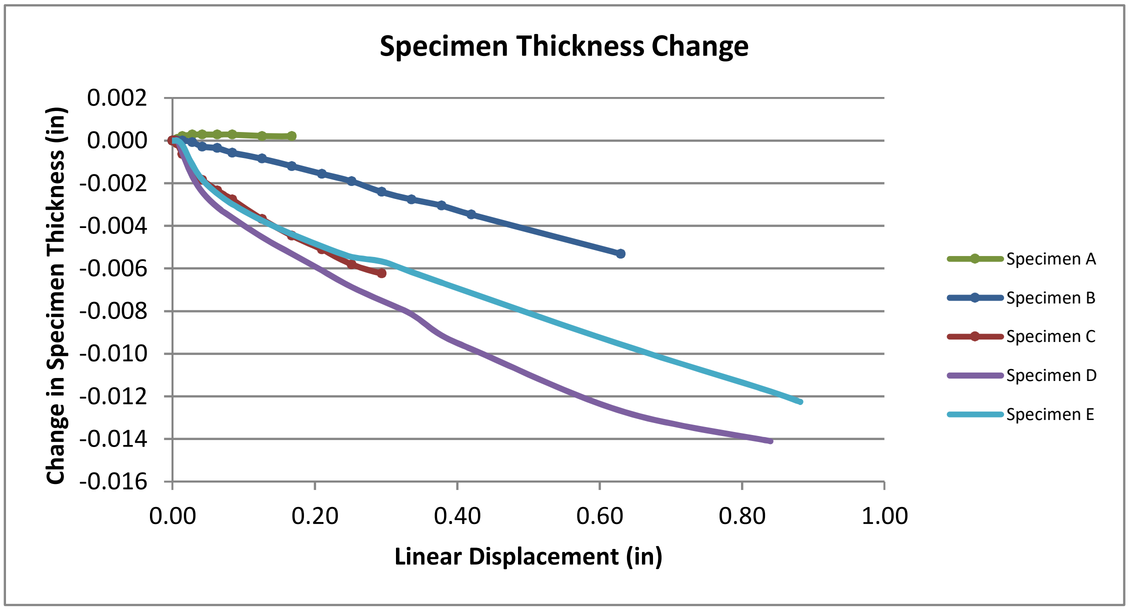
Washington State Department of Transportation Geotechnical Division

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S-21B
Project Number	RO-2905	Depth	56.0' to 57.0'
Boring Number	PR18-03	Sample Type	Remolded
Description	CH - SANDY FAT CLAY		

FINAL GRAPHS (1 of 3)





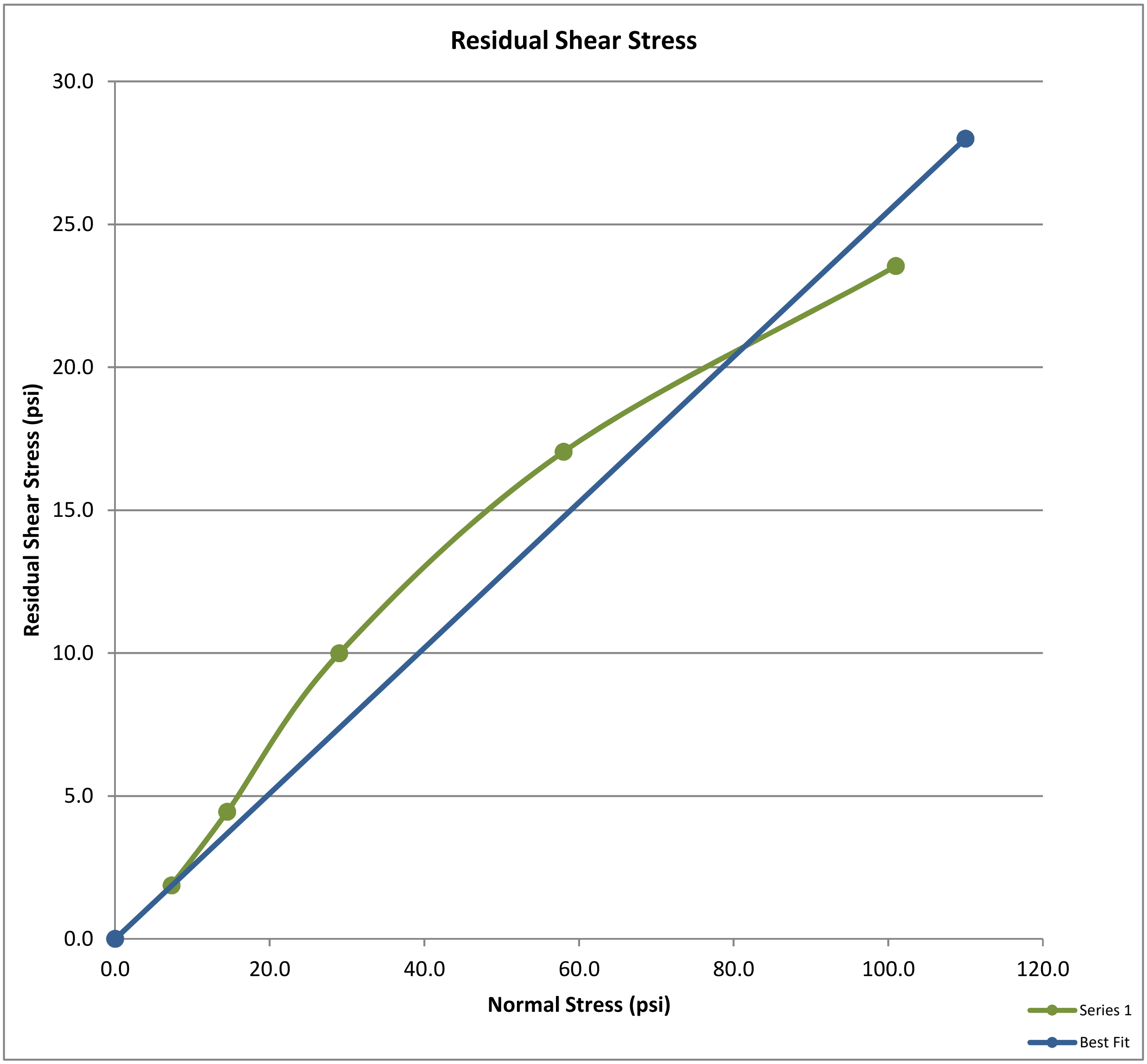
Ring Shear Test Report (ASTM D6467-13)

Washington State Department of Transportation Geotechnical Division

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Numb	S-21B
Project Number	RO-2905	Depth	56.0' to 57.0'
Boring Number	PR18-03	Sample Type	Remolded
Description	CH - SANDY FAT CLAY		

FINAL GRAPHS (2 of 3)



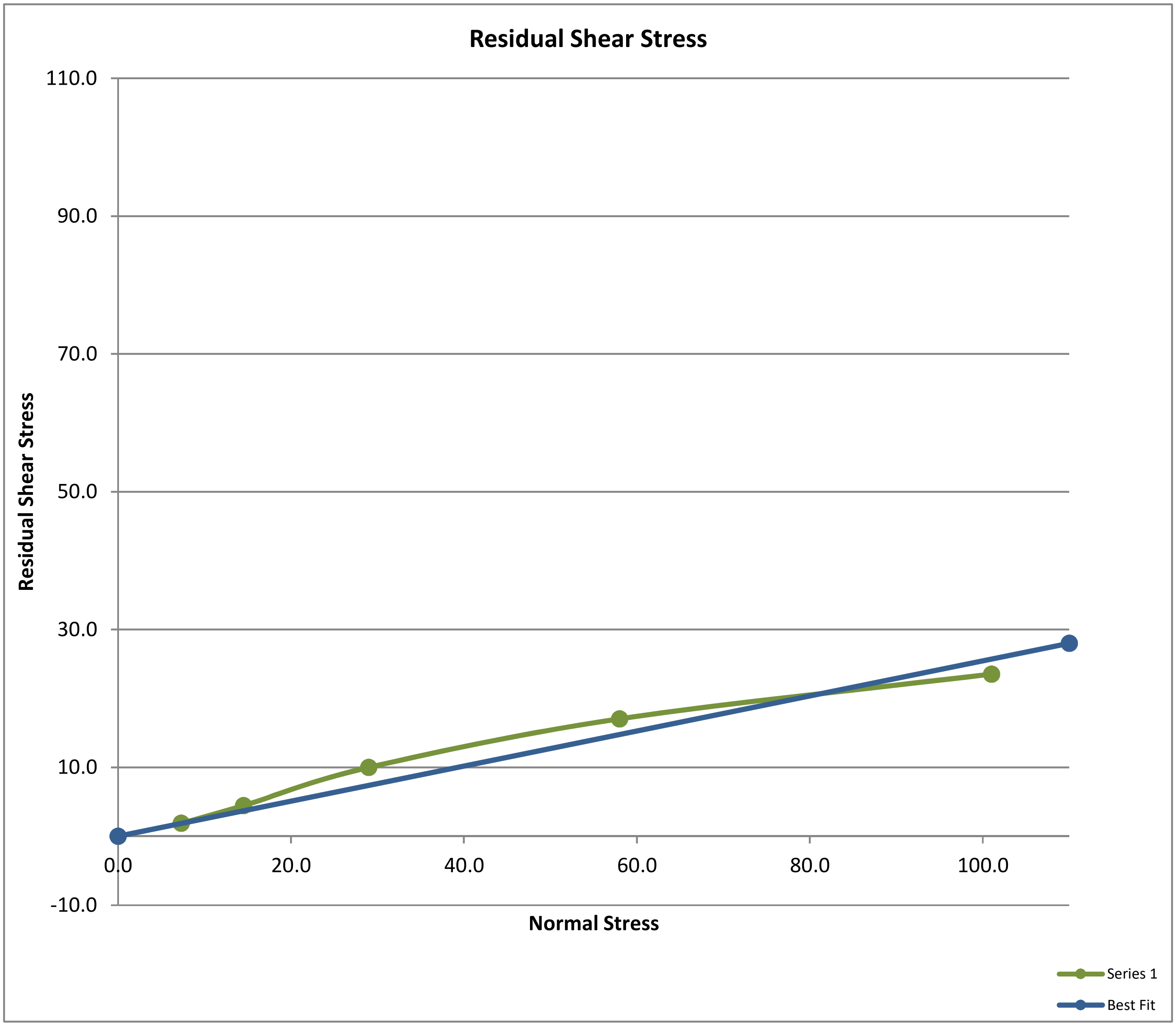
Ring Shear Test Report (ASTM D6467-13)

Washington State Department of Transportation Geotechnical Division

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S-21B
Project Number	RO-2905	Depth	56.0' to 57.0'
Boring Number	PR18-03	Sample Type	Remolded
Description	CH - SANDY FAT CLAY		

FINAL GRAPHS (3 of 3)



Job No. **RO-2905** Date **January 10, 2019**

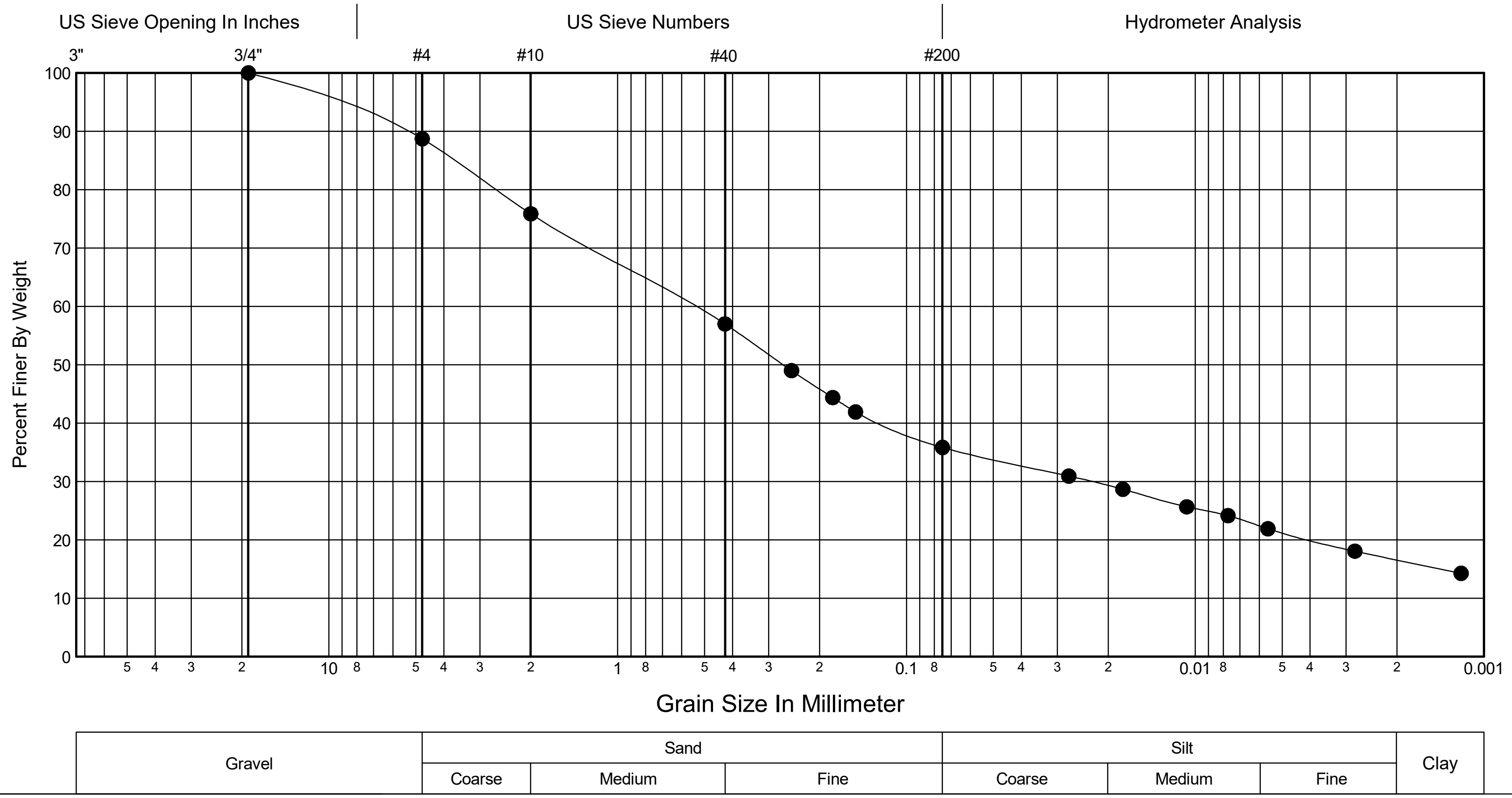
Hole No. **PR18-04** Sheet **1**

Project **AK NPS DENA 10 (45) Pretty Rock Landside Geo Inv**

Laboratory Summary

WSDOT

	Depth (ft)	Sample No.	USCS	Description	MC%	LL	PL	PI	Moist Density (lbs/ft³)	Specific Gravity	Gravel (%)	Sand (%)	Fines (%)	Cc	Cu	D60	D50	D30	D20	D10
●	**50.0**	**S-17**	**SC**	**CLAYEY SAND**	**44**	**48**	**16**	**32**		**2.71**	**11.3**	**52.9**	**35.8**			**0.544**	**0.27**	**0.02**	**0.00**	



Ring Shear Test Report (ASTM D6467-13)

Washington State Department of Transportation

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S-17
Project Number	RO-2905	Depth	50.0' to 51.5'
Boring Number	PR18-04	Sample Type	Remolded
Description	SC - CLAYEY SAND		

		Specimen				
INITIAL		**50 KPA**	**100 KPA**	**200 KPA**	**400 KPA**	**700 KPA**
Specimen Thickness (in)		0.200	0.200	0.200	0.200	0.200
Internal Ring Radius(in)		1.375	1.375	1.375	1.375	1.375
External Ring Radius(in)		1.970	1.970	1.970	1.970	1.970
Moisture Content (%)		24.9				
SHEAR		**50 KPA**	**100 KPA**	**200 KPA**	**400 KPA**	**700 KPA**
Rate of Linear Displacement (in/min)		0.0007	0.0007	0.0007	0.0007	0.0007
Rate of Angular Displacement (Deg/min)		0.0240	0.0240	0.0240	0.0240	0.0240
Normal Stress (psi)		7.3	14.5	29.0	58.0	101.0
Residual Shear Stress (psi)		1.071	4.384	10.803	24.388	42.220
Linear Displacement (in)		0.840	0.252	0.840	0.252	0.840
Angular Displacement (Deg)		28.8	8.6	28.8	8.6	28.8
FINAL		**50 KPA**	**100 KPA**	**200 KPA**	**400 KPA**	**700 KPA**
Final Moisture Content (%)						22.1
Assumed Cohesion (psi)		0.0	0.0	0.0	0.0	0.0
Liquid limit		48.0	48.0	48.0	48.0	48.0
Plastic Limit		16.0	16.0	16.0	16.0	16.0
Plasticity Index		32.0	32.0	32.0	32.0	32.0
Specific Gravity		2.71	2.71	2.71	2.71	2.71
Angle of Residual Shear Resistance (Deg)	**22.5**	**8.3**	**16.8**	**20.4**	**22.8**	**22.7**
CF%:	16.04					

COMMENT/REMARKS

Tested By	Donny Henderson	Date	2/7/2019
Checked By	Donny Henderson	Date	2/7/2019

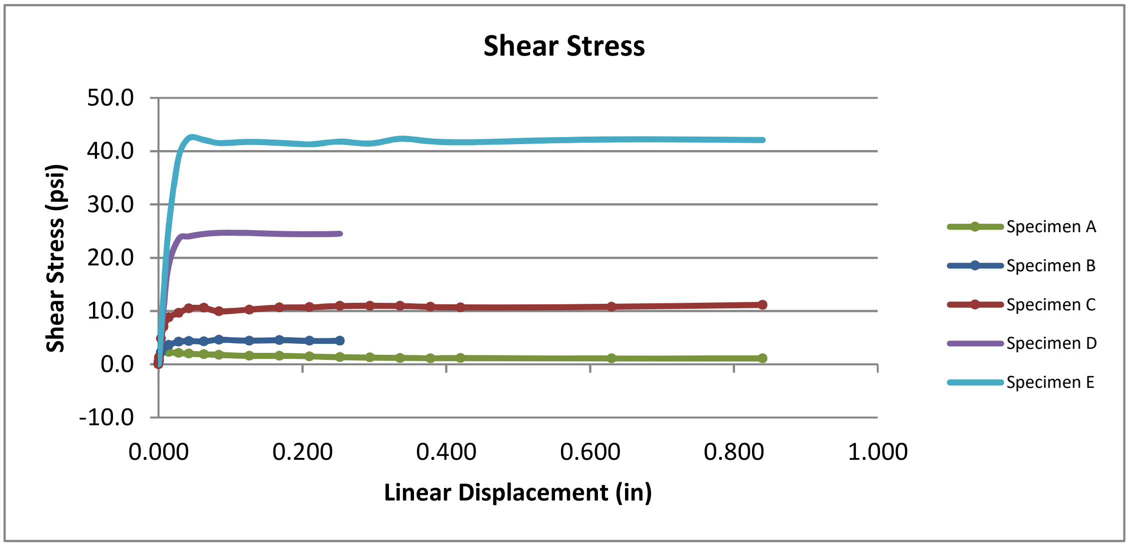
Ring Shear Test Report (ASTM D6467-13)

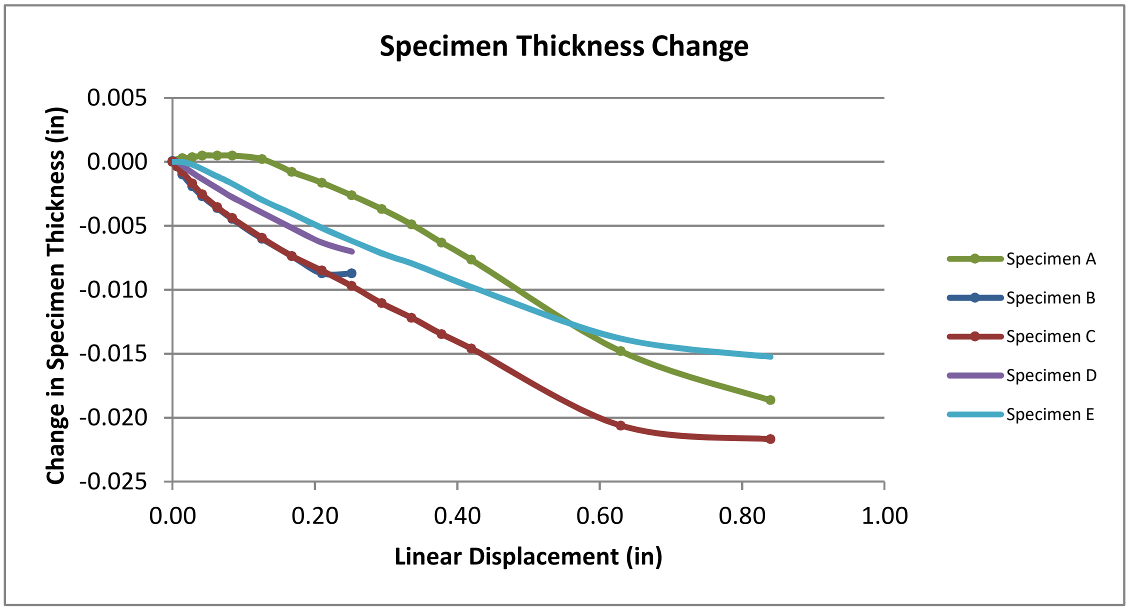
Washington State Department of Transportation Geotechnical Division

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S-17
Project Number	RO-2905	Depth	50.0' to 51.5'
Boring Number	PR18-04	Sample Type	Remolded
Description	SC - CLAYEY SAND		

FINAL GRAPHS (1 of 3)





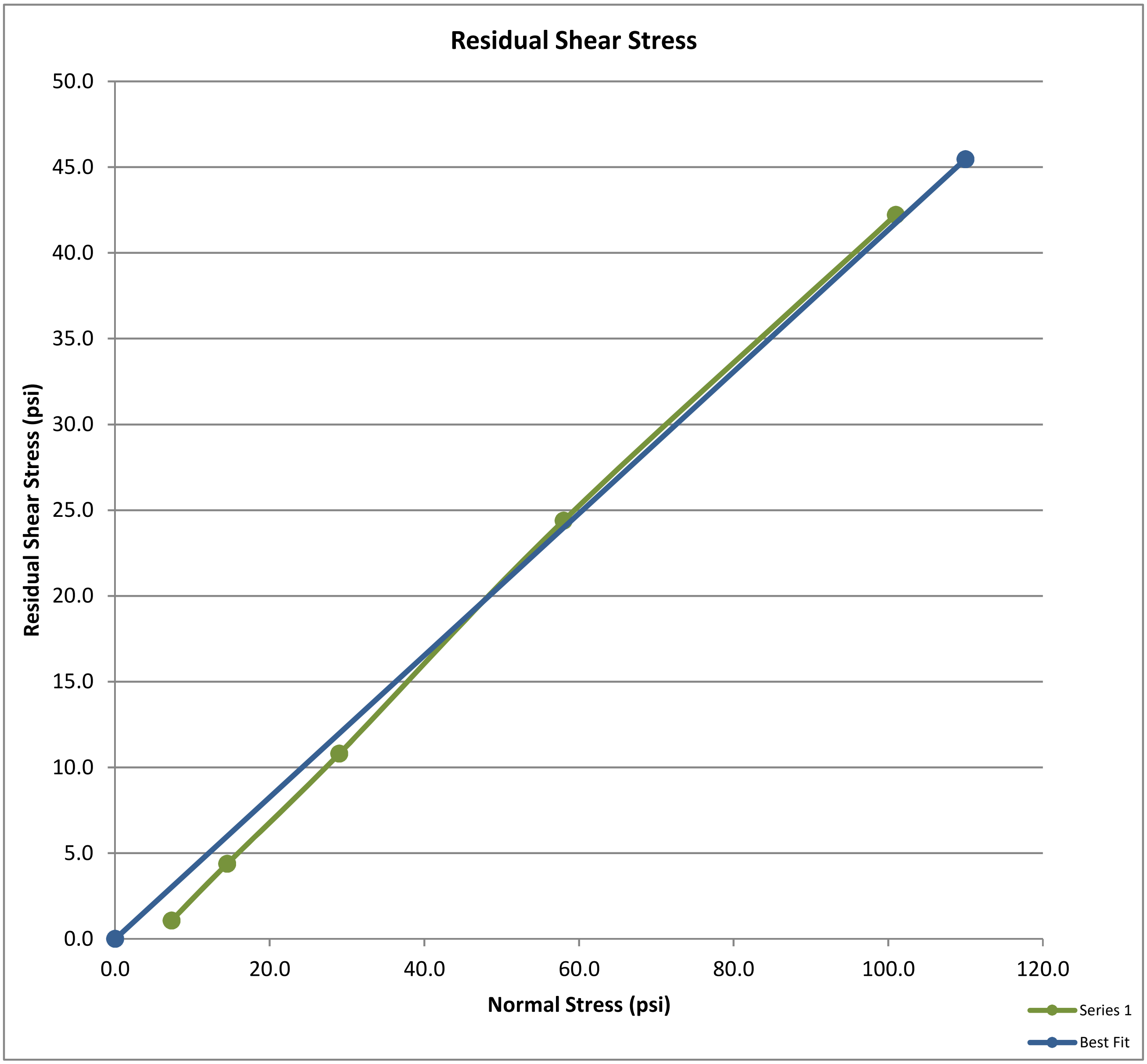
Ring Shear Test Report (ASTM D6467-13)

Washington State Department of Transportation Geotechnical Division

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Numb	S-17
Project Number	RO-2905	Depth	50.0' to 51.5'
Boring Number	PR18-04	Sample Type	Remolded
Description	SC - CLAYEY SAND		

FINAL GRAPHS (2 of 3)



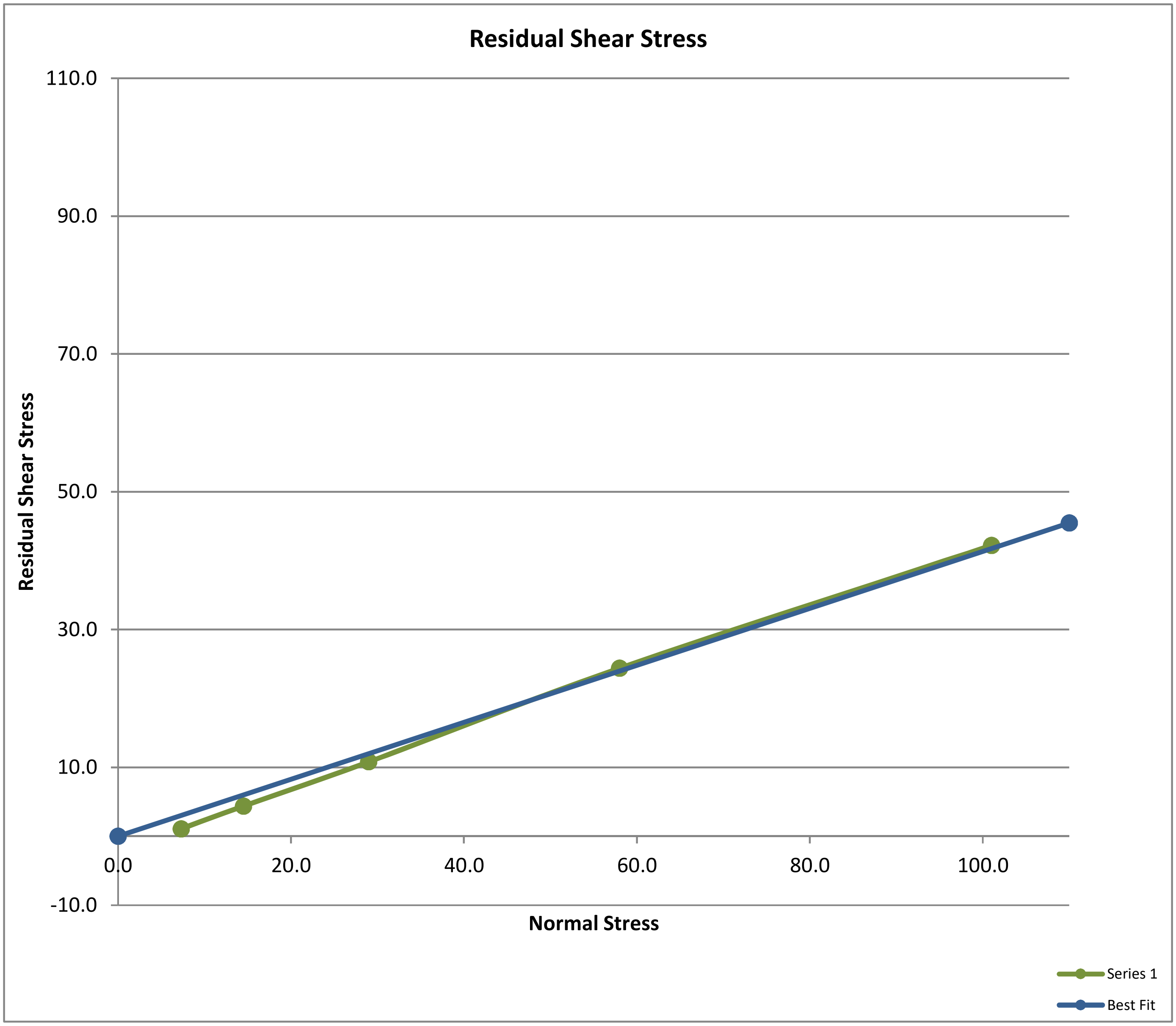
Ring Shear Test Report (ASTM D6467-13)

Washington State Department of Transportation Geotechnical Division

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S-17
Project Number	RO-2905	Depth	50.0' to 51.5'
Boring Number	PR18-04	Sample Type	Remolded
Description	SC - CLAYEY SAND		

FINAL GRAPHS (3 of 3)



Job No. **RO-2905** Date **January 10, 2019**

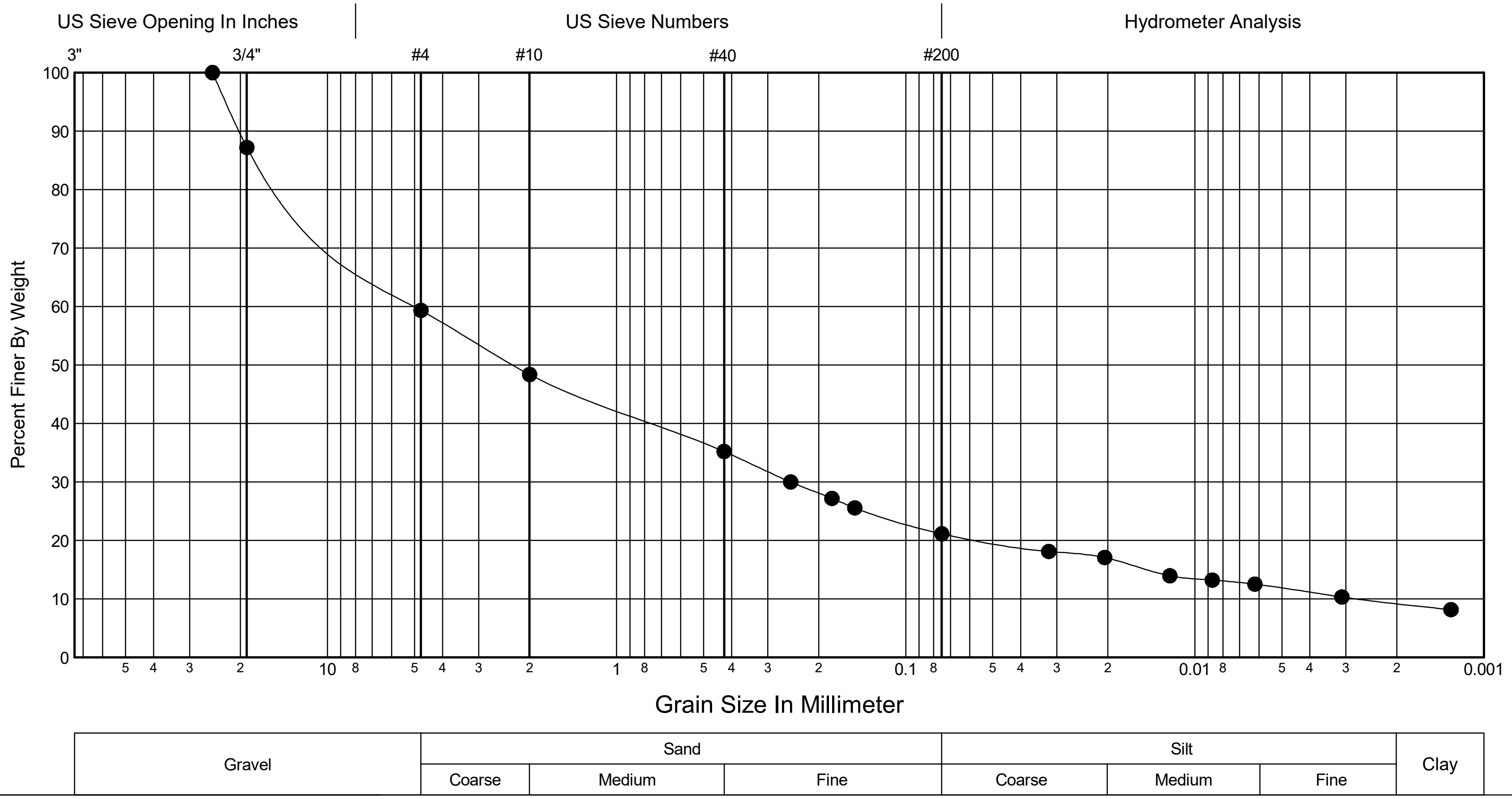
Hole No. **PR18-05** Sheet **1**

Project **AK NPS DENA 10 (45) Pretty Rock Landside Geo Inv**

Laboratory Summary

WSDOT

	Depth (ft)	Sample No.	USCS	Description	MC%	LL	PL	PI	Moist Density (lbs/ft³)	Specific Gravity	Gravel (%)	Sand (%)	Fines (%)	Cc	Cu	D60	D50	D30	D20	D10
●	**65.0**	**S26/27**	**GC**	**CLAYEY GRAVEL with SAND**	**31**	**45**	**18**	**27**		**2.63**	**40.7**	**38.2**	**21.1**	**4.7**	**>1000**	**4.910**	**2.27**	**0.25**	**0.05**	**0.003**



Ring Shear Test Report (ASTM D6467-13)

Washington State Department of Transportation

PROJECT INFORMATION			
Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S26-S27
Project Number	RO-2905	Depth	67.5' to 68.0'
Boring Number	PR18-05	Sample Type	Remolded
Description	GC - CLAYEY GRAVEL with SAND		

		Specimen				
INITIAL		**50 KPA**	**100 KPA**	**200 KPA**	**400 KPA**	**700 KPA**
Specimen Thickness (in)		0.200	0.200	0.200	0.200	0.200
Internal Ring Radius(in)		1.375	1.375	1.375	1.375	1.375
External Ring Radius(in)		1.970	1.970	1.970	1.970	1.970
Moisture Content (%)		20.2				
SHEAR		**50 KPA**	**100 KPA**	**200 KPA**	**400 KPA**	**700 KPA**
Rate of Linear Displacement (in/min)		0.0007	0.0007	0.0007	0.0007	0.0007
Rate of Angular Displacement (Deg/min)		0.0240	0.0240	0.0240	0.0240	0.0240
Normal Stress (psi)		7.3	14.5	29.0	58.0	101.0
Residual Shear Stress (psi)		1.303	5.287	11.579	25.555	42.238
Linear Displacement (in)		0.840	1.008	0.378	0.630	0.336
Angular Displacement (Deg)		28.8	34.6	13.0	21.6	11.5
FINAL		**50 KPA**	**100 KPA**	**200 KPA**	**400 KPA**	**700 KPA**
Final Moisture Content (%)						19.7
Assumed Cohesion (psi)		0.0	0.0	0.0	0.0	0.0
Liquid limit		45.0	45.0	45.0	45.0	45.0
Plastic Limit		18.0	18.0	18.0	18.0	18.0
Plasticity Index		27.0	27.0	27.0	27.0	27.0
Specific Gravity		2.63	2.63	2.63	2.63	2.63
Angle of Residual Shear Resistance (Deg)	**22.8**	**10.1**	**20.0**	**21.8**	**23.8**	**22.7**
CF%:	8.92					

COMMENT/REMARKS

Tested By	Donny Henderson	Date	2/15/2019
Checked By	Donny Henderson	Date	2/15/2019

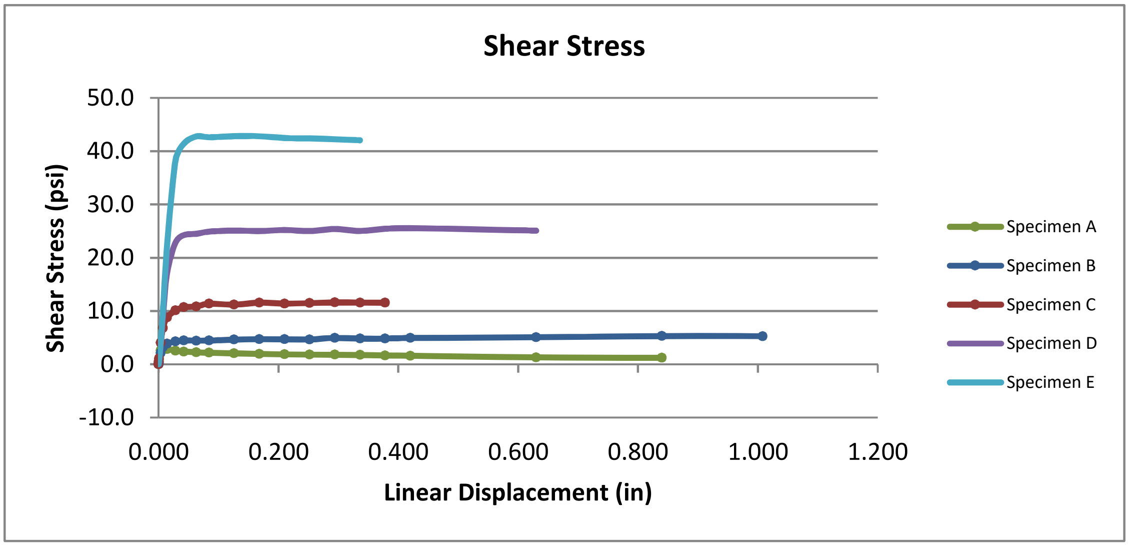
Ring Shear Test Report (ASTM D6467-13)

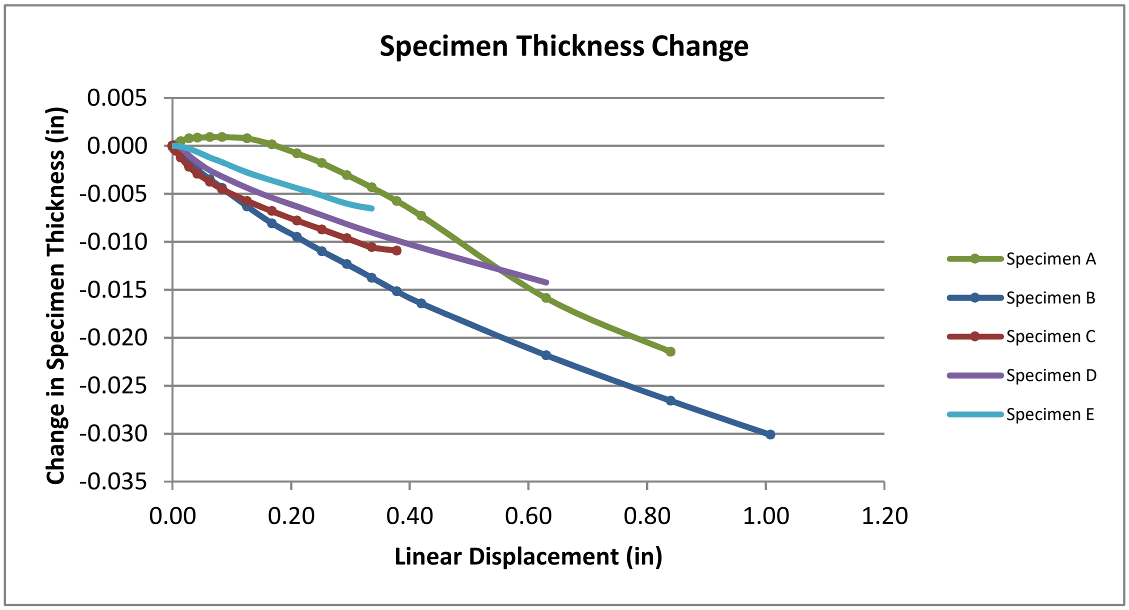
Washington State Department of Transportation Geotechnical Division

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S26-S27
Project Number	RO-2905	Depth	67.5' to 68.0'
Boring Number	PR18-05	Sample Type	Remolded
Description	GC - CLAYEY GRAVEL with SAND		

FINAL GRAPHS (1 of 3)





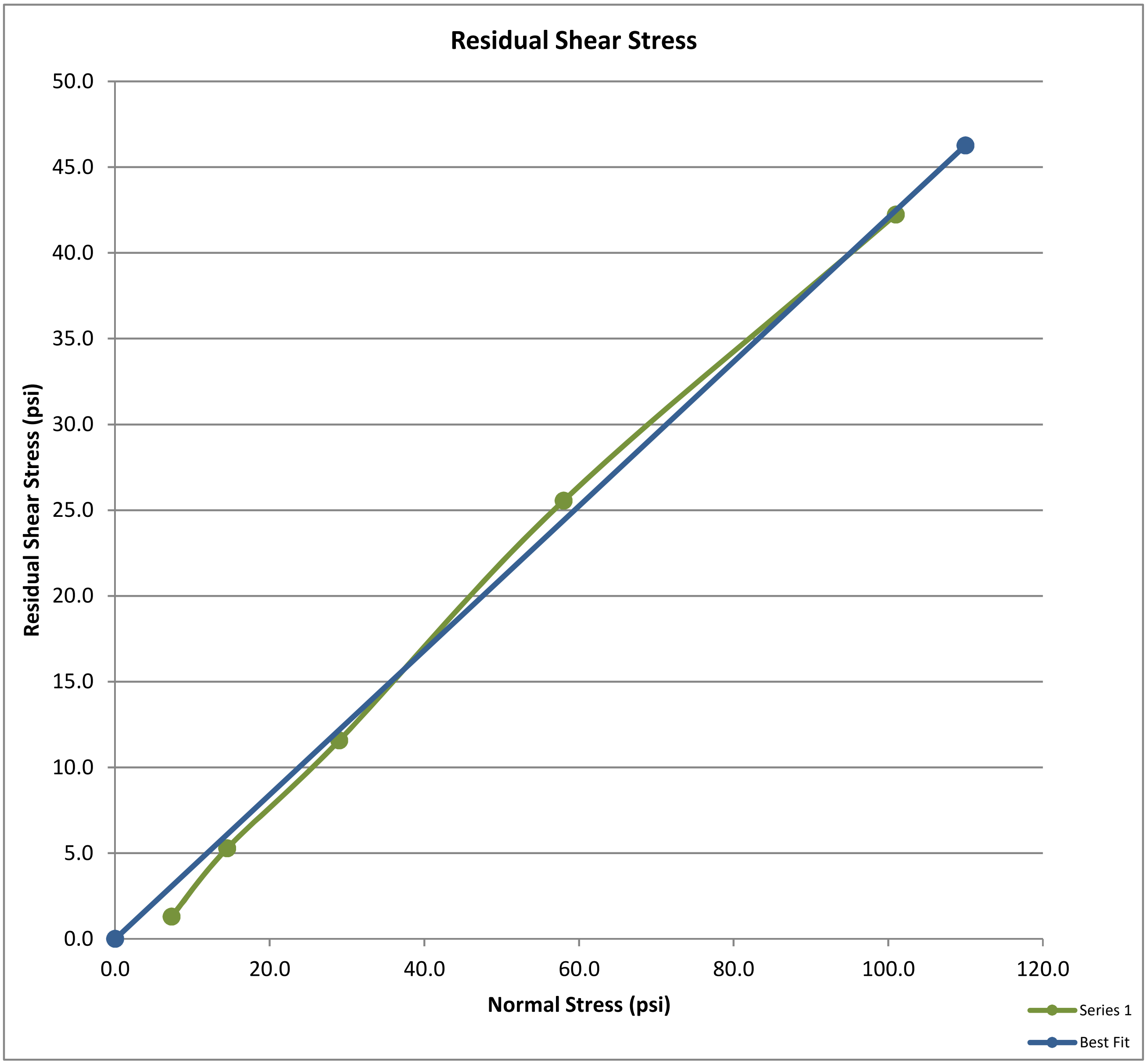
Ring Shear Test Report (ASTM D6467-13)

Washington State Department of Transportation Geotechnical Division

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Numb	S26-S27
Project Number	RO-2905	Depth	67.5' to 68.0'
Boring Number	PR18-05	Sample Type	Remolded
Description	GC - CLAYEY GRAVEL with SAND		

FINAL GRAPHS (2 of 3)



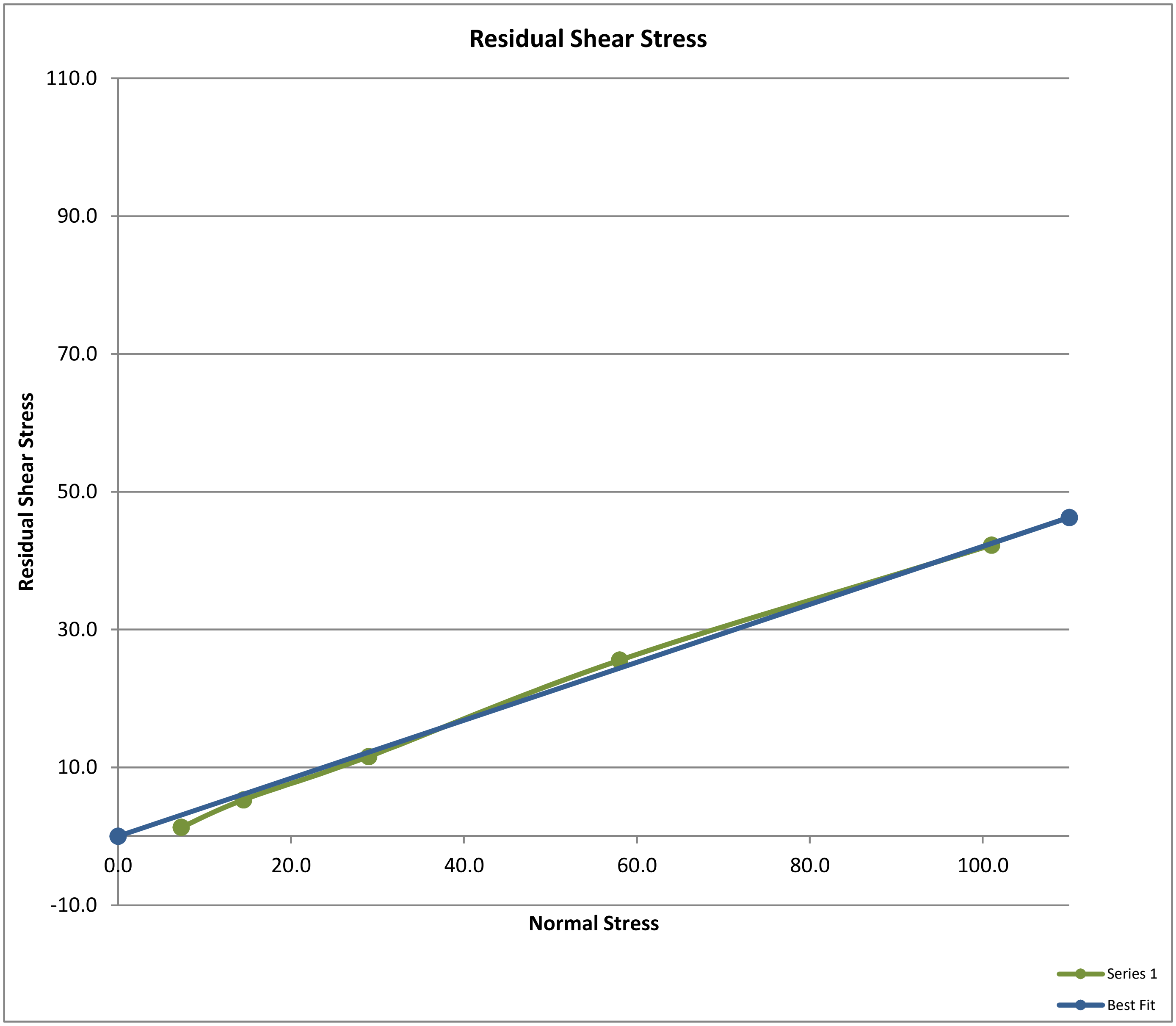
Ring Shear Test Report (ASTM D6467-13)

Washington State Department of Transportation Geotechnical Division

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S26-S27
Project Number	RO-2905	Depth	67.5' to 68.0'
Boring Number	PR18-05	Sample Type	Remolded
Description	GC - CLAYEY GRAVEL with SAND		

FINAL GRAPHS (3 of 3)



APPENDIX E-4

2019 Ring Shear Test Reports

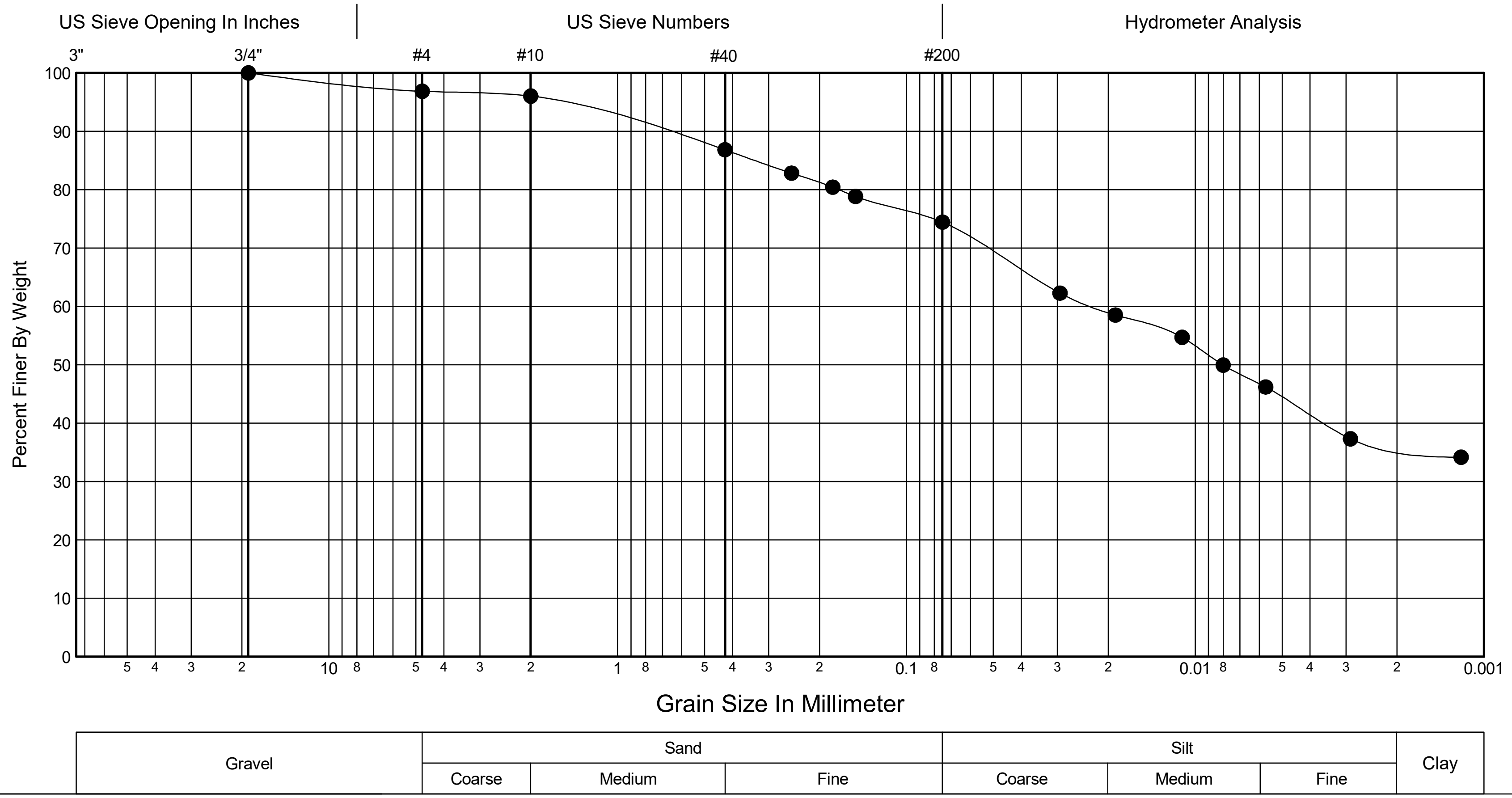
Job No. **RO-2905**
Hole No. **PR19-11**
Project **AK NPS DENA 10 (45) Pretty Rock Landside Geo Inv**

Date **November 25, 2019**
Sheet **1**

Laboratory Summary

WSDOT

	Depth (ft)	Sample No.	USCS	Description	MC%	LL	PL	PI	Moist Density (lbs/ft³)	Specific Gravity	Gravel (%)	Sand (%)	Fines (%)	Cc	Cu	D60	D50	D30	D20	D10
●	**82.0**	**S-16**	**CH**	**FAT CLAY with SAND**	**31**	**62**	**30**	**32**		**2.73**	**3.1**	**22.4**	**74.4**			**0.022**	**0.01**			



RO-2905 PRETTY ROCK LANDSLIDE.GPJ PUBLIC-COMMON LIBRARY.GLB 11/25/19

Ring Shear Test Report (ASTM D6467-13)

Washington State Department of Transportation

PROJECT INFORMATION			
Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S-16
Project Number	RO-2905	Depth	82' to 83.5'
Boring Number	PR19-11	Sample Type	Remolded
Description	CH - FAT CLAY with SAND		

		Specimen			
INITIAL		**4000 psf**	**8000 psf**	**16000 psf**	**25250 psf**
Specimen Thickness (in)		0.200	0.200	0.200	0.200
Internal Ring Radius(in)		1.375	1.375	1.375	1.375
External Ring Radius(in)		1.970	1.970	1.970	1.970
Moisture Content (%)		31.0			
SHEAR		**4000 psf**	**8000 psf**	**16000 psf**	**25250 psf**
Rate of Linear Displacement (in/min)		0.0007	0.0007	0.0007	0.0007
Rate of Angular Displacement (Deg/min)		0.0240	0.0240	0.0240	0.0240
Normal Stress (psi)		27.8	55.6	111.1	175.3
Residual Shear Stress (psi)		6.320	12.678	23.449	36.311
Linear Displacement (in)		0.840	0.252	0.840	0.336
Angular Displacement (Deg)		7.2	5.8	7.2	12.0
FINAL		**4000 psf**	**8000 psf**	**16000 psf**	**25250 psf**
Final Moisture Content (%)					24.8
Assumed Cohesion (psi)		0.0	0.0	0.0	0.0
Liquid limit		62.0	62.0	62.0	62.0
Plastic Limit		30.0	30.0	30.0	30.0
Plasticity Index		32.0	32.0	32.0	32.0
Specific Gravity		2.73	2.73	2.73	2.73
Angle of Residual Shear Resistance (Deg)	**11.9**	**12.8**	**12.8**	**11.9**	**11.7**
CF%:	35.6				

COMMENT/REMARKS

Tested By	Brad Nelson	Date	11/21/2019
Checked By	Samuel Wade	Date	11/25/2019

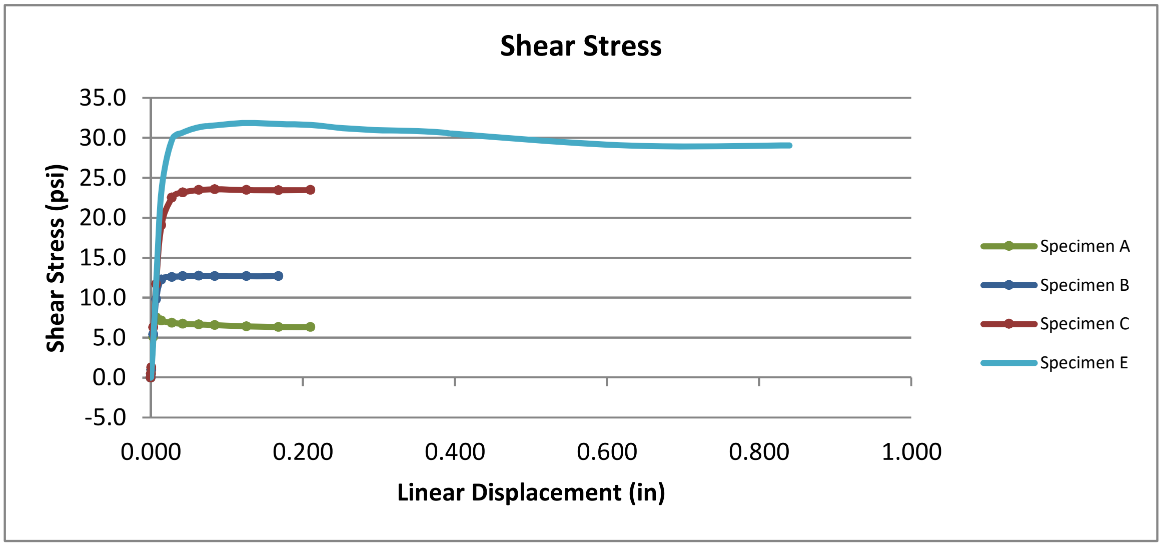
Ring Shear Test Report (ASTM D6467-13)

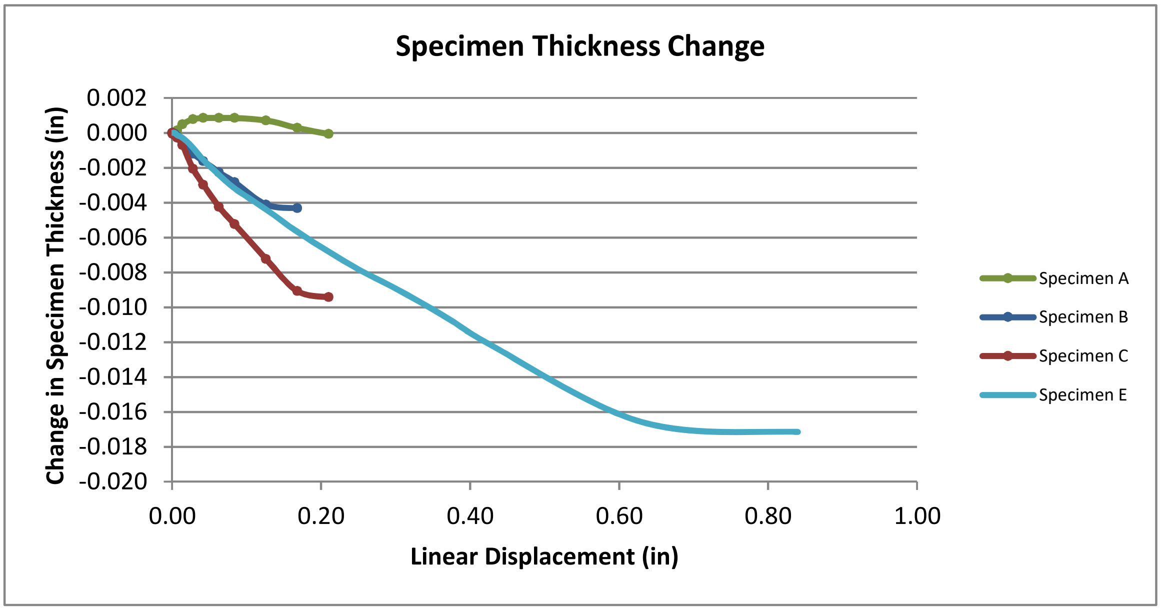
Washington State Department of Transportation Geotechnical Division

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S-16
Project Number	RO-2905	Depth	82' to 83.5'
Boring Number	PR19-11	Sample Type	Remolded
Description	CH - FAT CLAY with SAND		

FINAL GRAPHS (1 of 3)





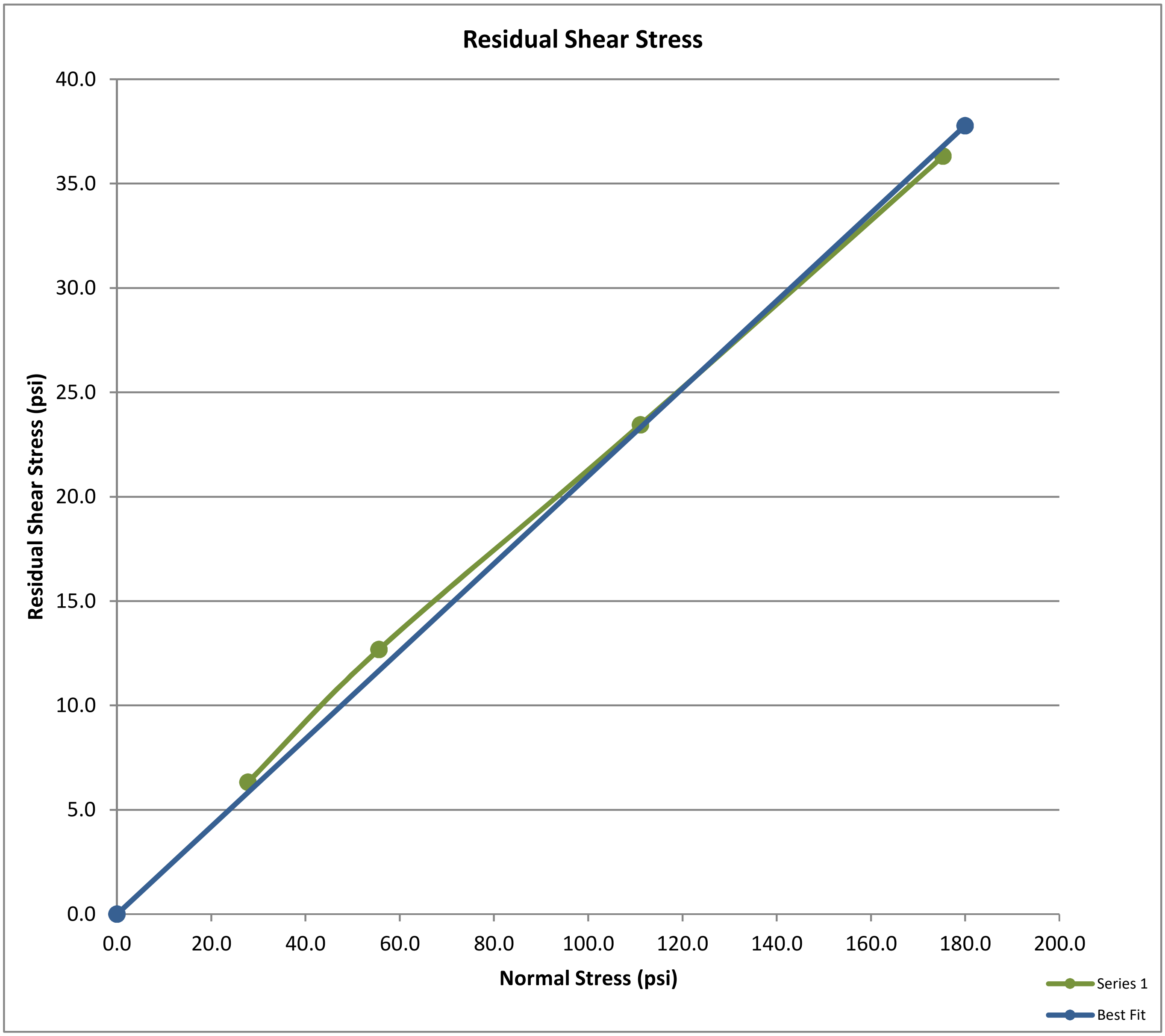
Ring Shear Test Report (ASTM D6467-13)

Washington State Department of Transportation Geotechnical Division

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S-16
Project Number	RO-2905	Depth	82' to 83.5'
Boring Number	PR19-11	Sample Type	Remolded
Description	CH - FAT CLAY with SAND		

FINAL GRAPHS (2 of 3)



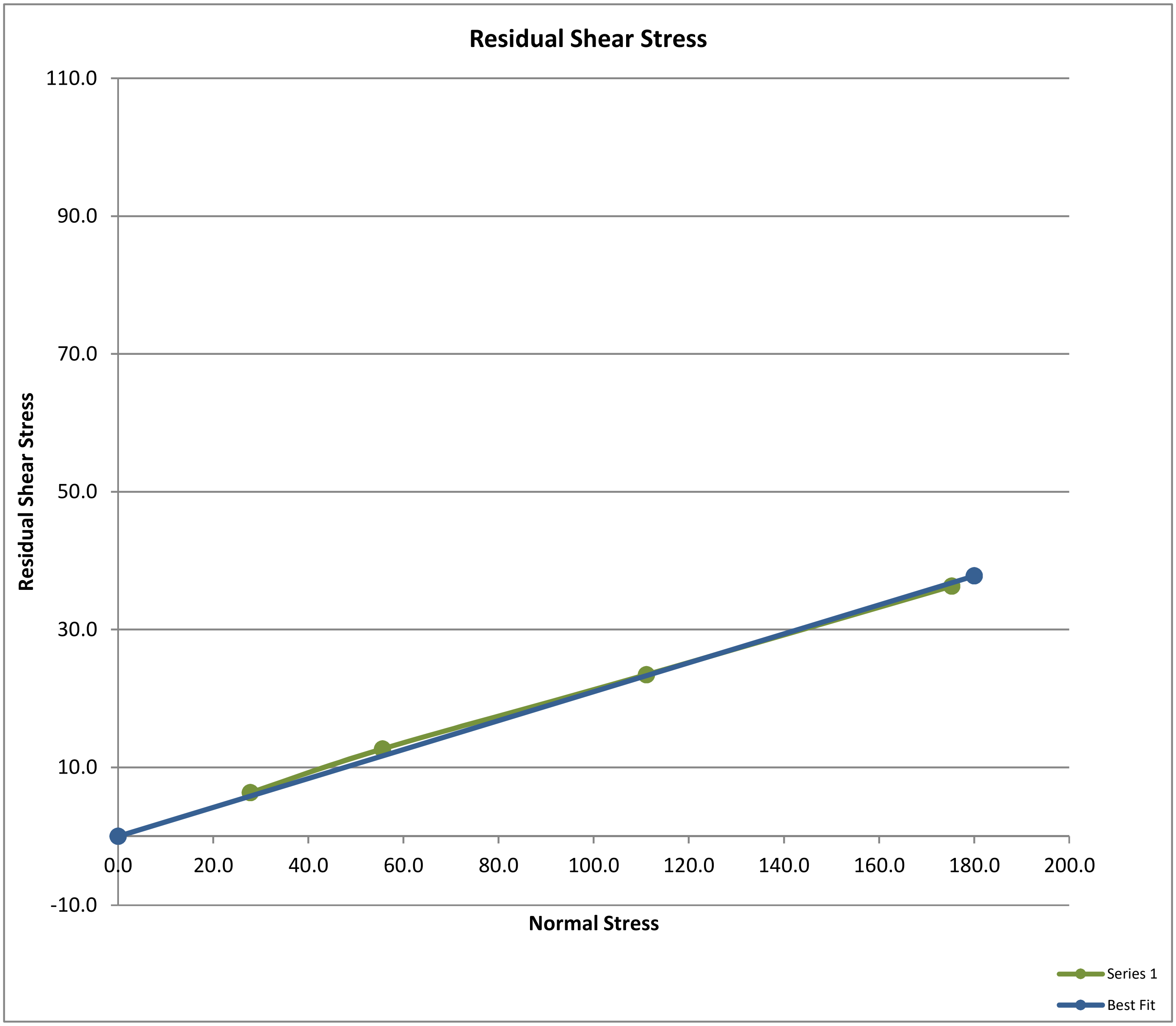
Ring Shear Test Report (ASTM D6467-13)

Washington State Department of Transportation Geotechnical Division

PROJECT INFORMATION

Project	RO-2905		
Location	AK NPS DENA 10(45) Pretty Rock Landslide		
Project Manager	Orion George	Sample Number	S-16
Project Number	RO-2905	Depth	82' to 83.5'
Boring Number	PR19-11	Sample Type	Remolded
Description	CH - FAT CLAY with SAND		

FINAL GRAPHS (3 of 3)



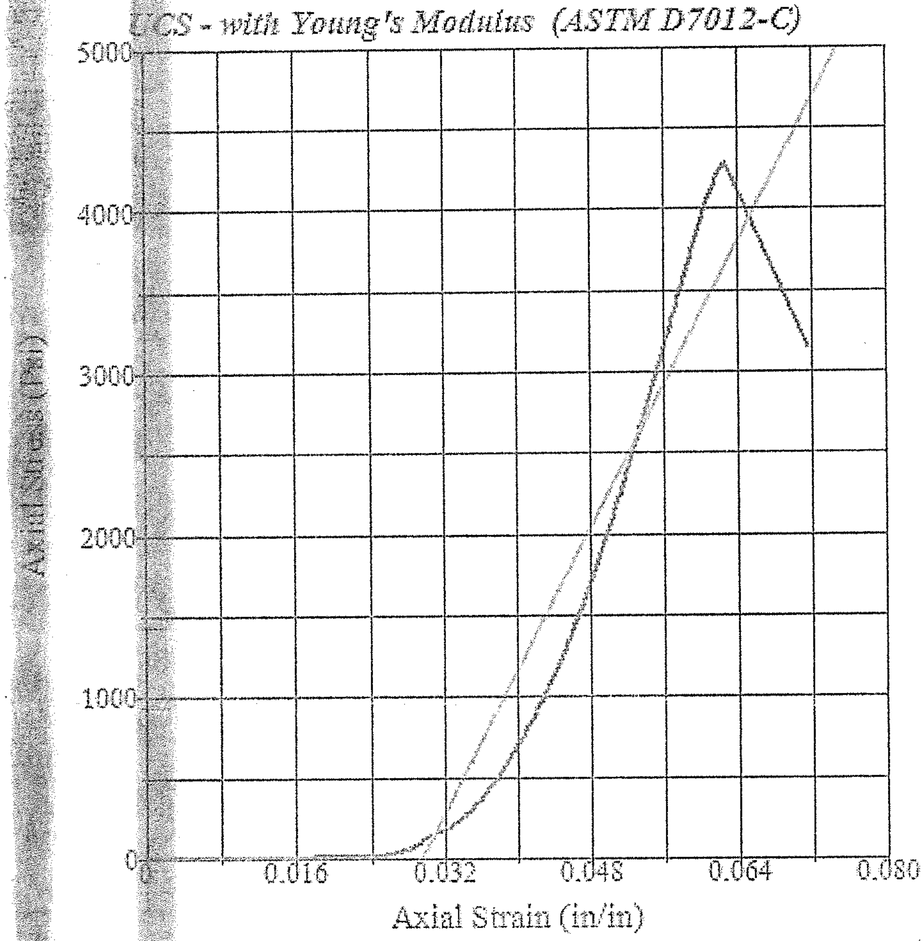
APPENDIX E-5

Unconfined Compressive Strength (UCS)

WFLHD
610 E Fifth St.
Vancouver, Wa
98661

U.S. Department of Transportation
Federal Highway Administration

UCS - with Young's Modulus (ASTM D7012-C)



Test Summary

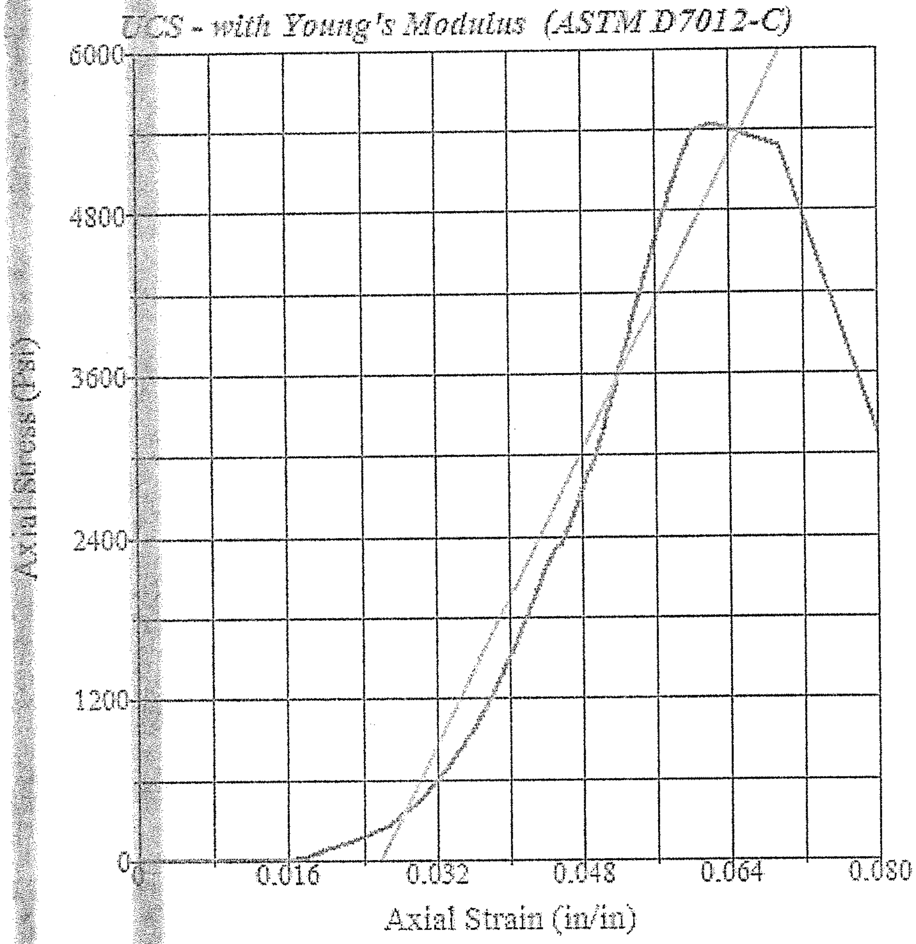
Counter:	1400
Elapsed Time:	00:00:59
Lab Control Number:	W-19-2006-RC
Specimen Identification:	PR19-06 28.3'
Specimen Length:	4.90 in
Start Date:	12/10/2019
Start Time:	7:15:28 AM
End Date:	12/10/2019
End Time:	7:16:27 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	751.3
Dry Density:	pcf

Test Results

Diameter:	2.3500 in
Area:	4.3374 in²
L/D ratio:	2.1
Peak Stress:	4282.2 psi
Peak Load:	18573.80 lbf
Load at Break:	18573.8000 lbf
Young's Modulus:	1.10e+005 psi
Peak Time:	59.40 s
Peak Position:	0.0714 in
Change in Position:	0.0714 in
X Intercept:	0.0295 in/in
Y Intercept:	-3262.3330 psi

WFLHD
610 E Fifth St.
Vancouver, Wa
98661

U.S. Department of Transportation
Federal Highway Administration



Test Summary

Counter:	1401
Elapsed Time:	00:01:15
Lab Control Number:	W-19-2007-RC
Specimen Identification:	PR19-06 32.2'
Specimen Length:	4.91 in
Start Date:	12/10/2019
Start Time:	7:20:38 AM
End Date:	12/10/2019
End Time:	7:21:53 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	807.1
Dry Density:	pcf

Test Results

Diameter:	2.3600 in
Area:	4.3744 in²
L/D ratio:	2.1
Peak Stress:	5425.2 psi
Peak Load:	23732.20 lbf
Load at Break:	23068.2000 lbf
Young's Modulus:	1.37e+005 psi
Peak Time:	75.50 s
Peak Position:	0.0799 in
Change in Position:	0.0799 in
X Intercept:	0.0259 in/in
Y Intercept:	-3546.1160 psi

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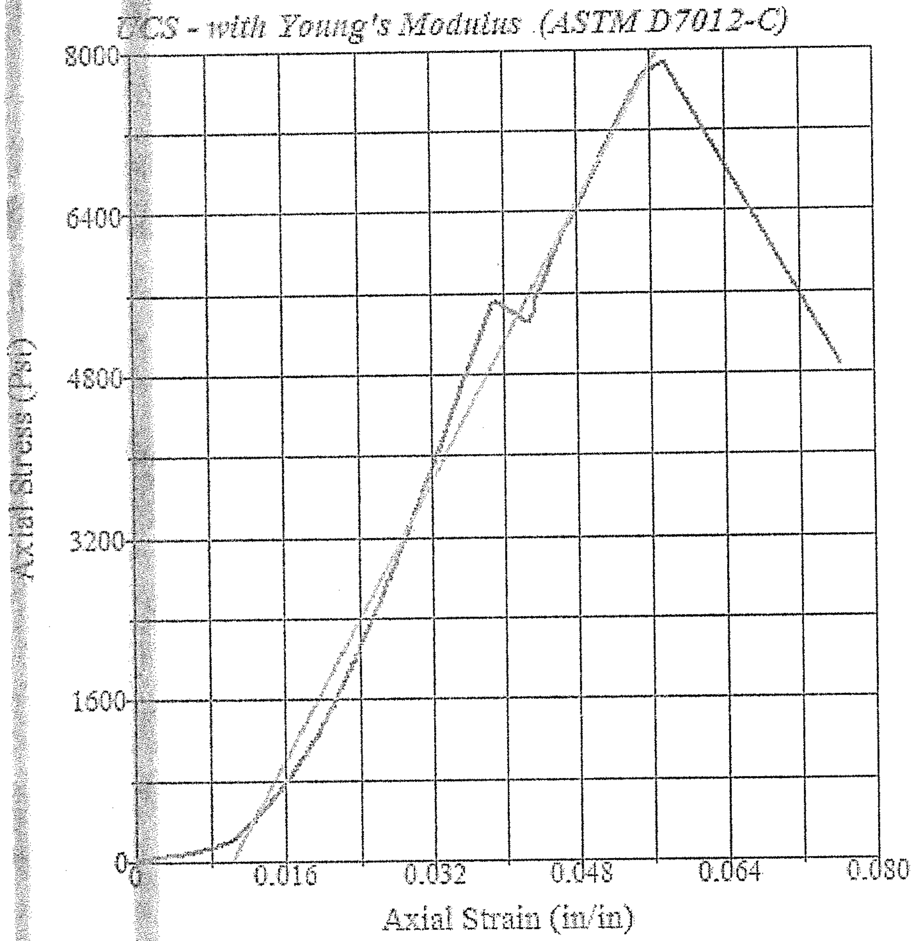

Test Summary

Counter:	1402
Elapsed Time:	00:01:48
Lab Control Number:	W-19-2008-RC
Specimen Identification:	PR19-06 42.5'
Specimen Length:	4.91 in
Start Date:	12/10/2019
Start Time:	7:25:11 AM
End Date:	12/10/2019
End Time:	7:26:59 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	854.5
Dry Density:	pcf

Test Results

Diameter:	2.3800 in
Area:	4.4488 in²
L/D ratio:	2.1
Peak Stress:	7866.4 psi
Peak Load:	34995.90 lbf
Load at Break:	34995.9000 lbf
Young's Modulus:	1.71e+005 psi
Peak Time:	108.70 s
Peak Position:	0.0763 in
Change in Position:	0.0763 in
X Intercept:	0.0101 in/in
Y Intercept:	-1730.8700 psi

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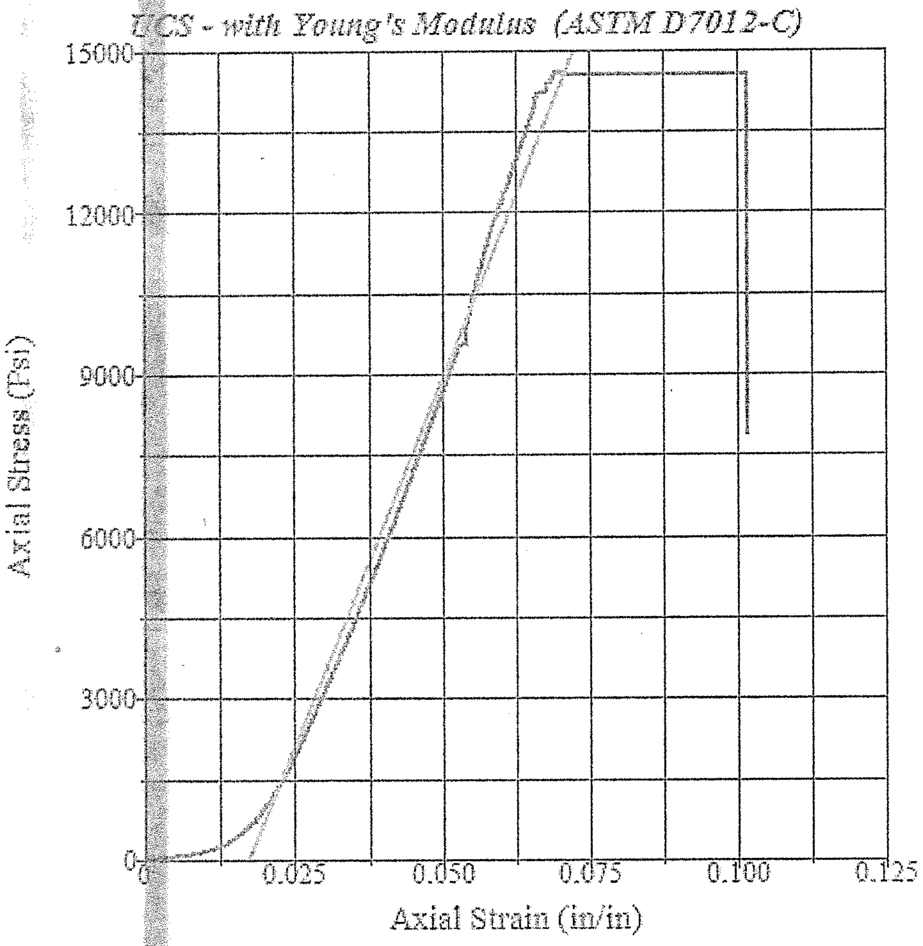

Test Summary

Counter:	1403
Elapsed Time:	00:03:22
Lab Control Number:	W-19-2009-RC
Specimen Identification:	PR19-06 53.2'
Specimen Length:	5.40 in
Start Date:	12/10/2019
Start Time:	7:30:14 AM
End Date:	12/10/2019
End Time:	7:33:36 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	956.3
Dry Density:	pcf

Test Results

Diameter:	2.3900 in
Area:	4.4863 in²
L/D ratio:	2.3
Peak Stress:	14600.2 psi
Peak Load:	65500.80 lbf
Load at Break:	65186.9000 lbf
Young's Modulus:	2.72e+005 psi
Peak Time:	201.90 s
Peak Position:	0.1017 in
Change in Position:	0.1017 in
X Intercept:	0.0171 in/in
Y Intercept:	-4647.8420 psi

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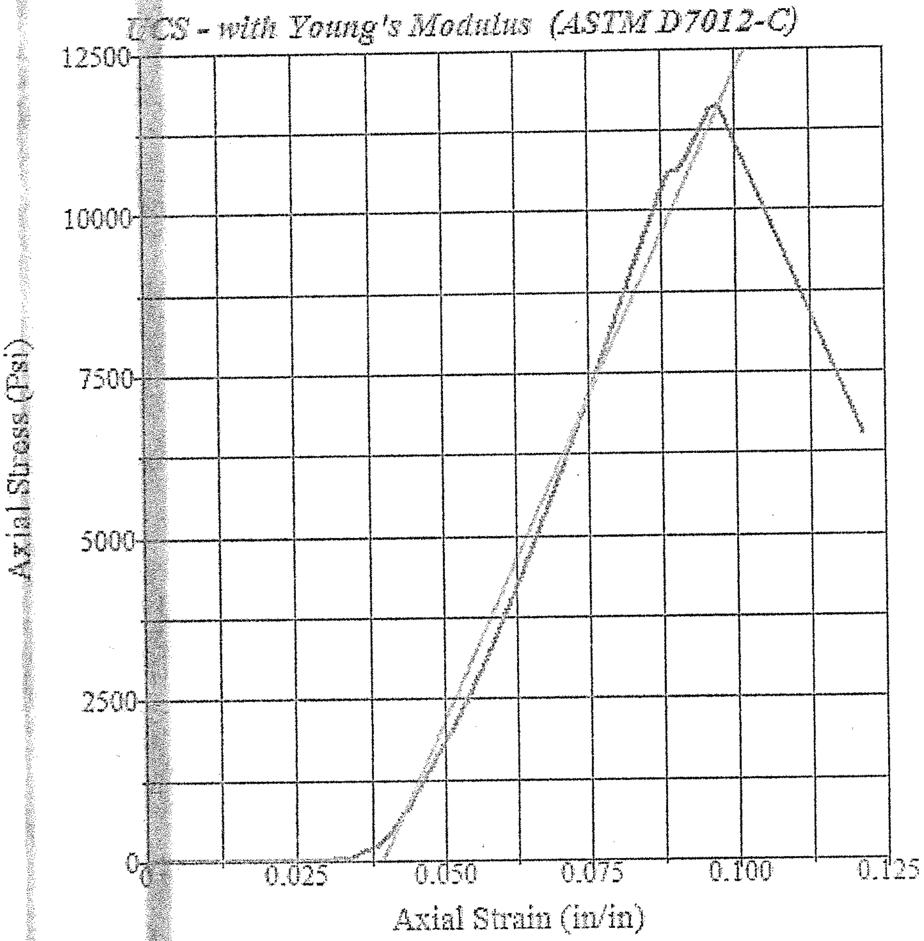

Test Summary	
Counter:	1404
Elapsed Time:	00:02:41
Lab Control Number:	W-19-2010-CO
Specimen Identification:	PR19-06 57.4'
Specimen Length:	5.41 in
Start Date:	12/10/2019
Start Time:	7:37:49 AM
End Date:	12/10/2019
End Time:	7:40:30 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	912.2
Dry Density:	pcf

Test Results	
Diameter:	2.3900 in
Area:	4.4863 in²
L/D ratio:	2.3
Peak Stress:	11620.5 psi
Peak Load:	52132.80 lbf
Load at Break:	52132.8000 lbf
Young's Modulus:	2.01e+005 psi
Peak Time:	160.70 s
Peak Position:	0.1213 in
Change in Position:	0.1213 in
X Intercept:	0.0394 in/in
Y Intercept:	-7933.1050 psi

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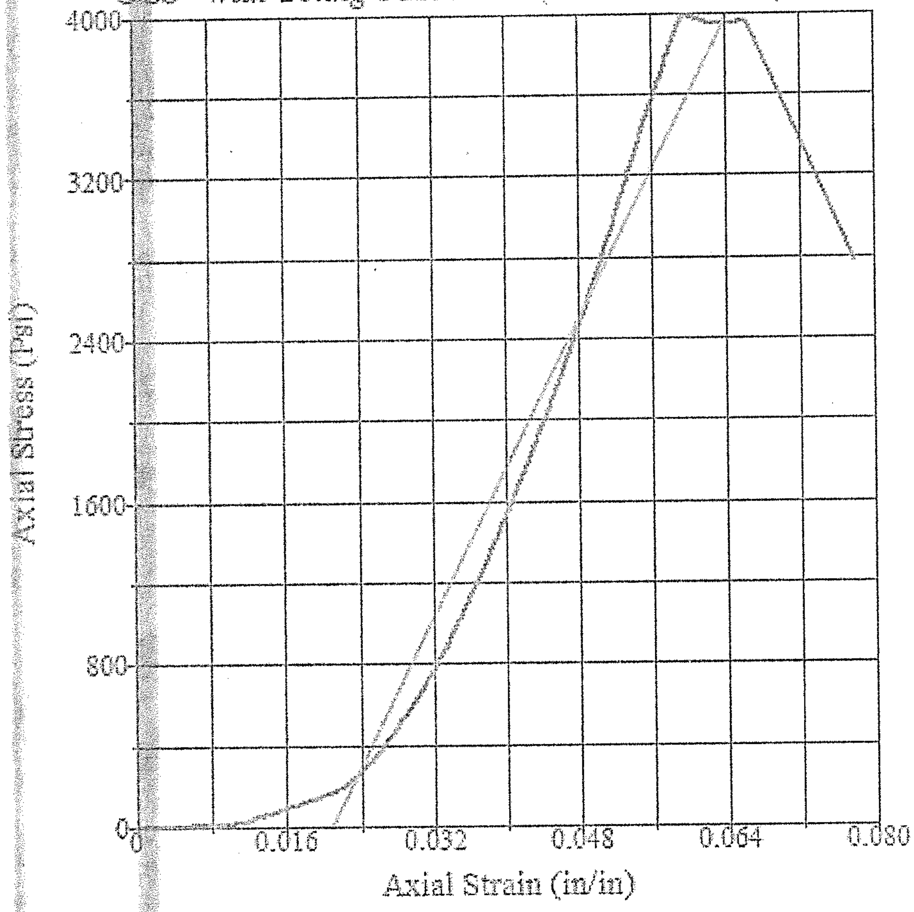

Test Summary

Counter:	1405
Elapsed Time:	00:00:56
Lab Control Number:	W-19-2011-RC
Specimen Identification:	PR19-06 71.7'
Specimen Length:	4.83 in
Start Date:	12/10/2019
Start Time:	7:43:44 AM
End Date:	12/10/2019
End Time:	7:44:40 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	796.1
Dry Density:	pcf

Test Results

Diameter:	2.3900 in
Area:	4.4863 in²
L/D ratio:	2.0
Peak Stress:	3985.9 psi
Peak Load:	17882.00 lbf
Load at Break:	17786.7000 lbf
Young's Modulus:	92491.5700 psi
Peak Time:	55.70 s
Peak Position:	0.0778 in
Change in Position:	0.0778 in
X Intercept:	0.0208 in/in
Y Intercept:	-1926.0090 psi

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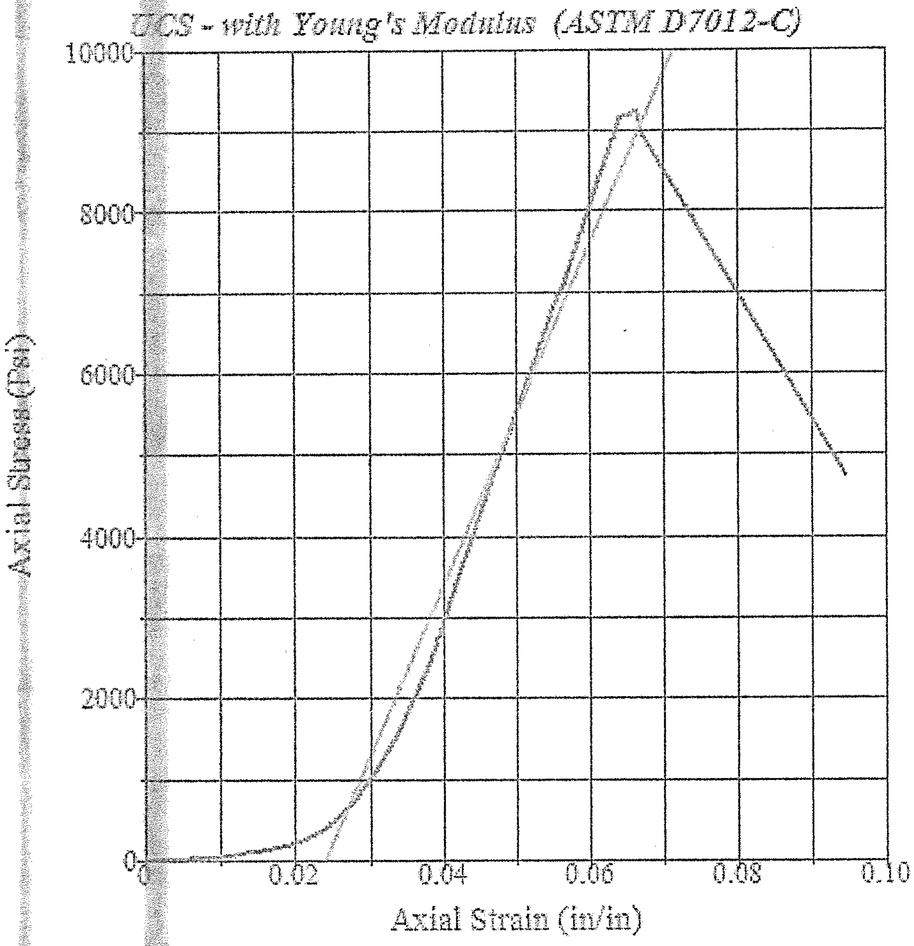

Test Summary

Counter:	1406
Elapsed Time:	00:02:08
Lab Control Number:	W-19-2012-RC
Specimen Identification:	PR19-06 73.8'
Specimen Length:	5.22 in
Start Date:	12/10/2019
Start Time:	7:47:28 AM
End Date:	12/10/2019
End Time:	7:49:36 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	899.4
Dry Density:	pcf

Test Results

Diameter:	2.3900 in
Area:	4.4863 in²
L/D ratio:	2.2
Peak Stress:	9232.1 psi
Peak Load:	41418.00 lbf
Load at Break:	40040.4000 lbf
Young's Modulus:	2.10e+005 psi
Peak Time:	127.80 s
Peak Position:	0.0945 in
Change in Position:	0.0945 in
X Intercept:	0.0238 in/in
Y Intercept:	-5007.2540 psi

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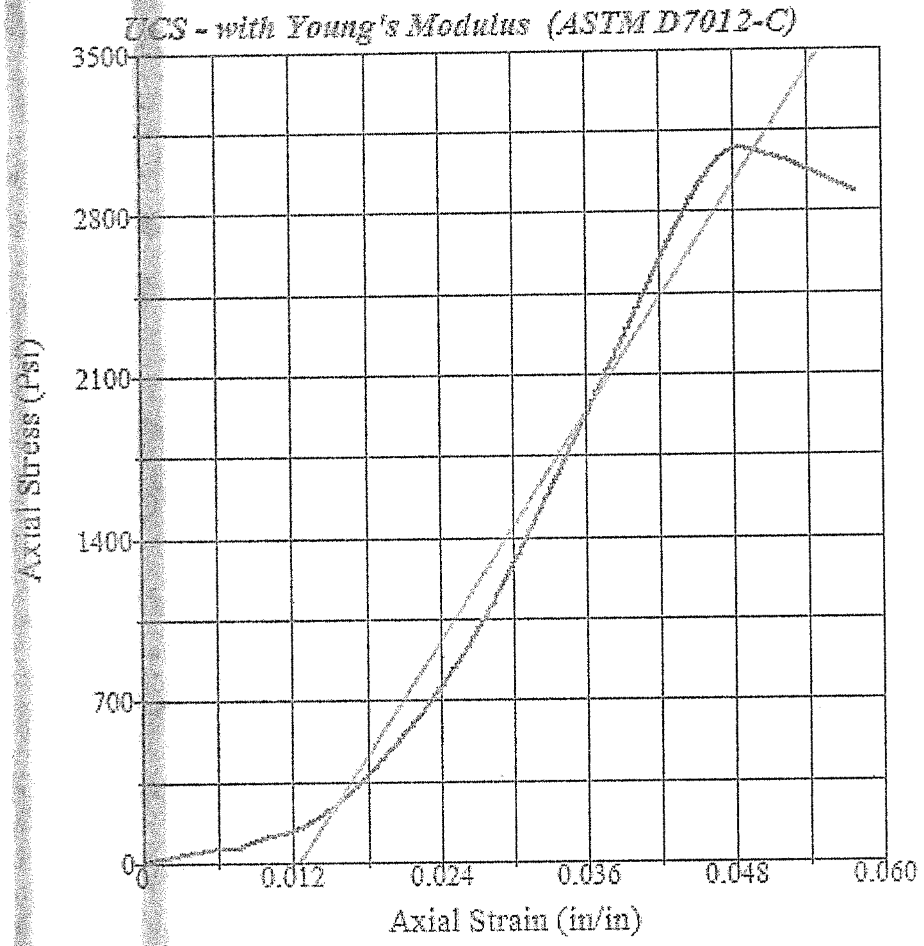
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Test Summary

Counter:	1407
Elapsed Time:	00:00:43
Lab Control Number:	W-19-2013-RC
Specimen Identification:	PR19-06 76.8'
Specimen Length:	5.19 in
Start Date:	12/10/2019
Start Time:	7:52:53 AM
End Date:	12/10/2019
End Time:	7:53:36 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	882.9
Dry Density:	pcf

Test Results

Diameter:	2.3900 in
Area:	4.4863 in²
L/D ratio:	2.2
Peak Stress:	3073.4 psi
Peak Load:	13788.00 lbf
Load at Break:	13547.4000 lbf
Young's Modulus:	82209.8400 psi
Peak Time:	42.70 s
Peak Position:	0.0578 in
Change in Position:	0.0578 in
X Intercept:	0.0124 in/in
Y Intercept:	-1019.8590 psi

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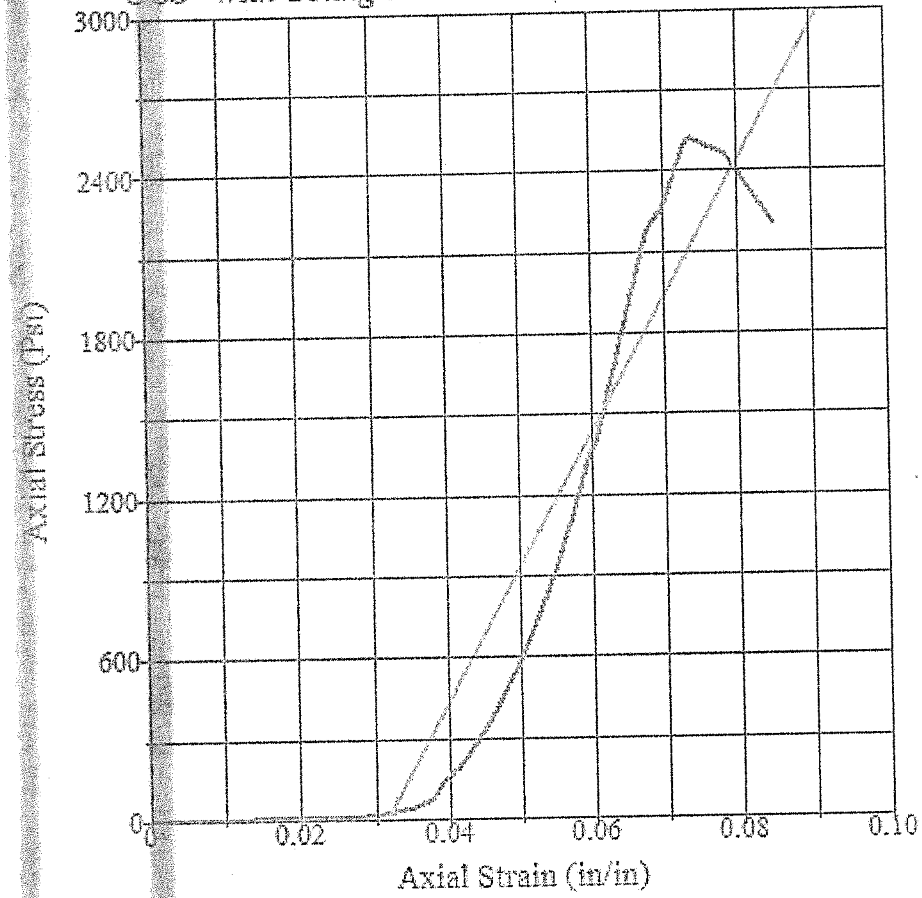

Test Summary

Counter:	1408
Elapsed Time:	00:00:35
Lab Control Number:	W-19-2014-RC
Specimen Identification:	PR19-06 82.7'
Specimen Length:	4.92 in
Start Date:	12/10/2019
Start Time:	7:56:23 AM
End Date:	12/10/2019
End Time:	7:56:58 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	813.6
Dry Density:	pcf

Test Results

Diameter:	2.3900 in
Area:	4.4863 in²
L/D ratio:	2.1
Peak Stress:	2524.5 psi
Peak Load:	11325.80 lbf
Load at Break:	11046.9000 lbf
Young's Modulus:	50370.2000 psi
Peak Time:	35.30 s
Peak Position:	0.0848 in
Change in Position:	0.0848 in
X Intercept:	0.0316 in/in
Y Intercept:	-1589.8640 psi

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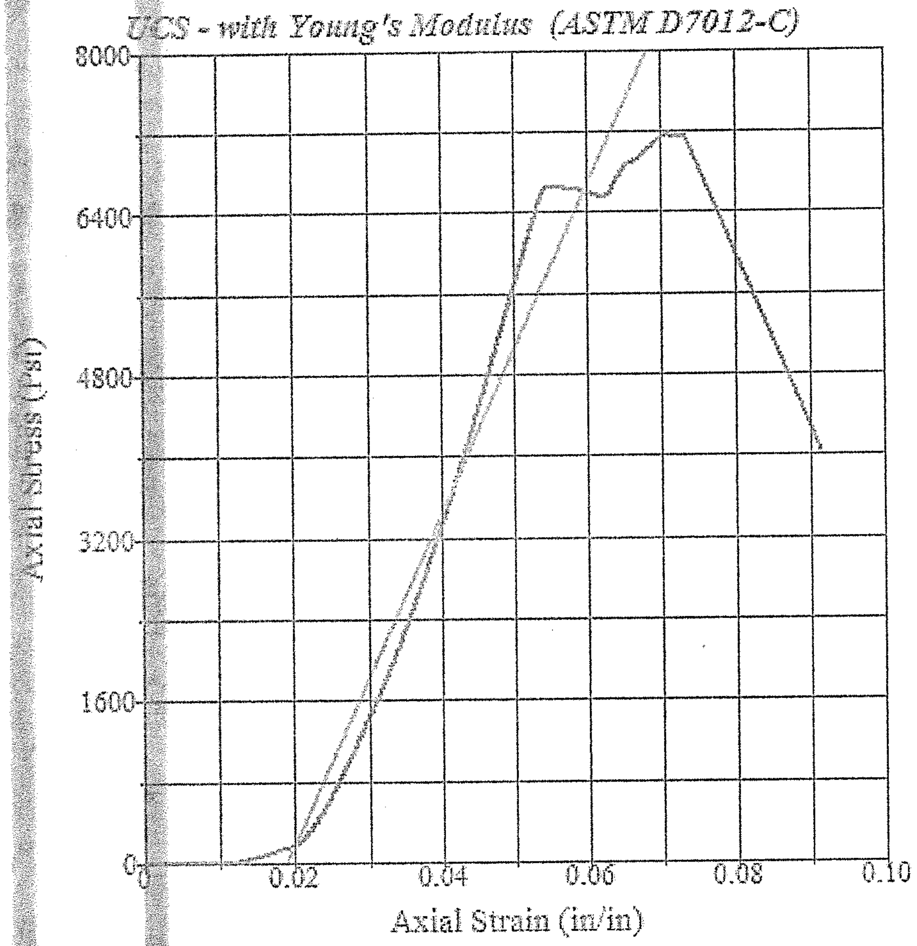
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Test Summary

Counter:	1409
Elapsed Time:	00:01:39
Lab Control Number:	W-19-2015-RC
Specimen Identification:	PR19-06 89.4'
Specimen Length:	5.31 in
Start Date:	12/10/2019
Start Time:	7:59:42 AM
End Date:	12/10/2019
End Time:	8:01:21 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	924.8
Dry Density:	pcf

Test Results

Diameter:	2.4000 in
Area:	4.5239 in²
L/D ratio:	2.2
Peak Stress:	7165.1 psi
Peak Load:	32414.30 lbf
Load at Break:	32342.2000 lbf
Young's Modulus:	1.63e+005 psi
Peak Time:	99.30 s
Peak Position:	0.0913 in
Change in Position:	0.0913 in
X Intercept:	0.0189 in/in
Y Intercept:	-3075.2130 psi

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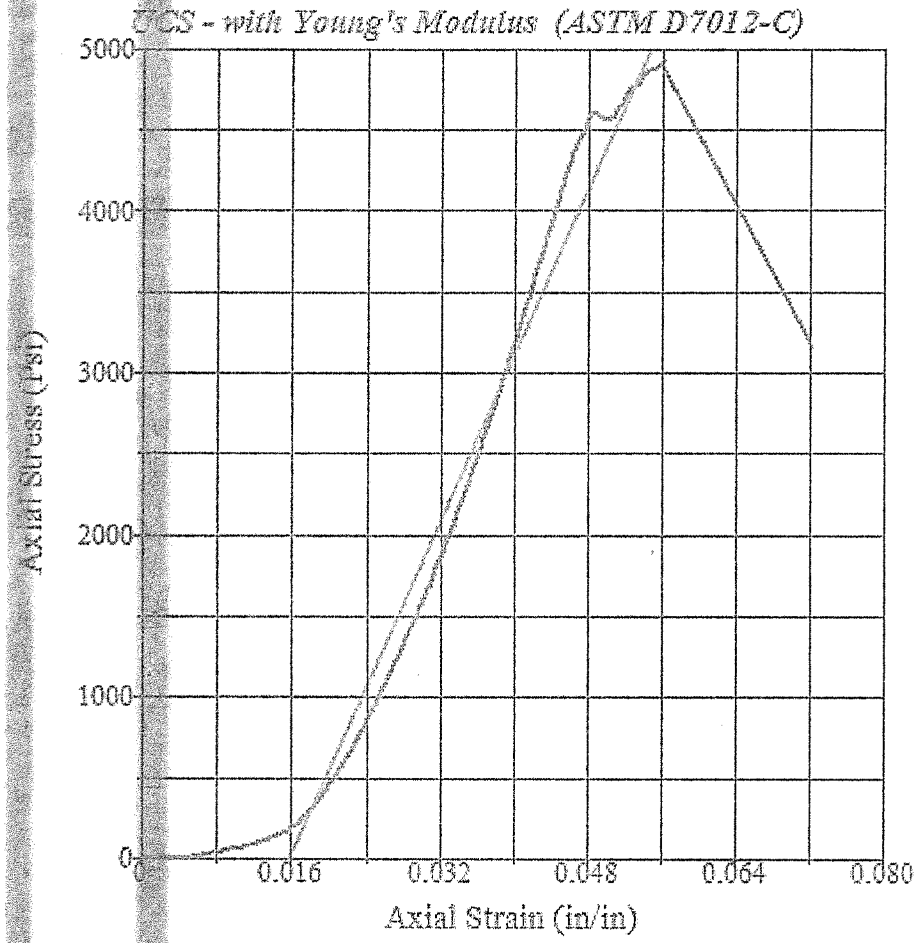

Test Summary		Test Results	
Counter:	1410	Diameter:	2.3900 in
Elapsed Time:	00:01:09	Area:	4.4863 in²
Lab Control Number:	W-19-2016-RC	L/D ratio:	2.0
Specimen Identification:	PR19-06 98.8'	Peak Stress:	4929.8 psi
Specimen Length:	4.69 in	Peak Load:	22116.60 lbf
Start Date:	12/10/2019	Load at Break:	22029.7000 lbf
Start Time:	8:05:59 AM	Young's Modulus:	1.28e+005 psi
End Date:	12/10/2019	Peak Time:	68.40 s
End Time:	8:07:08 AM	Peak Position:	0.0722 in
Tested By:	Walt	Change in Position:	0.0722 in
Specimen Type:	Rock Core	X Intercept:	0.0156 in/in
Sample Weight:	813.7	Y Intercept:	-2002.8690 psi
Dry Density:	pcf		

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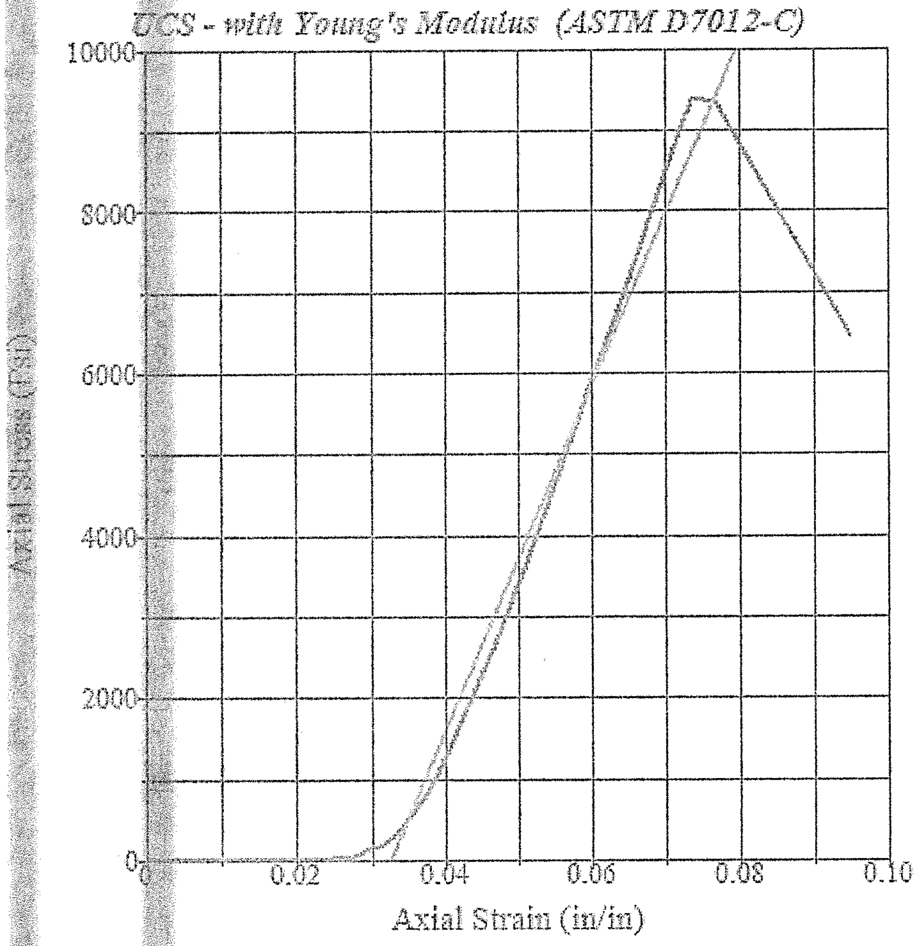

Test Summary

Counter:	1411
Elapsed Time:	00:02:09
Lab Control Number:	W-19-2017-RC
Specimen Identification:	PR19-06 118.2'
Specimen Length:	4.98 in
Start Date:	12/10/2019
Start Time:	8:09:49 AM
End Date:	12/10/2019
End Time:	8:11:58 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	884.8
Dry Density:	pcf

Test Results

Diameter:	2.4000 in
Area:	4.5239 in²
L/D ratio:	2.1
Peak Stress:	9390.1 psi
Peak Load:	42479.70 lbf
Load at Break:	42327.7000 lbf
Young's Modulus:	2.13e+005 psi
Peak Time:	129.90 s
Peak Position:	0.0948 in
Change in Position:	0.0948 in
X Intercept:	0.0324 in/in
Y Intercept:	-6908.2260 psi

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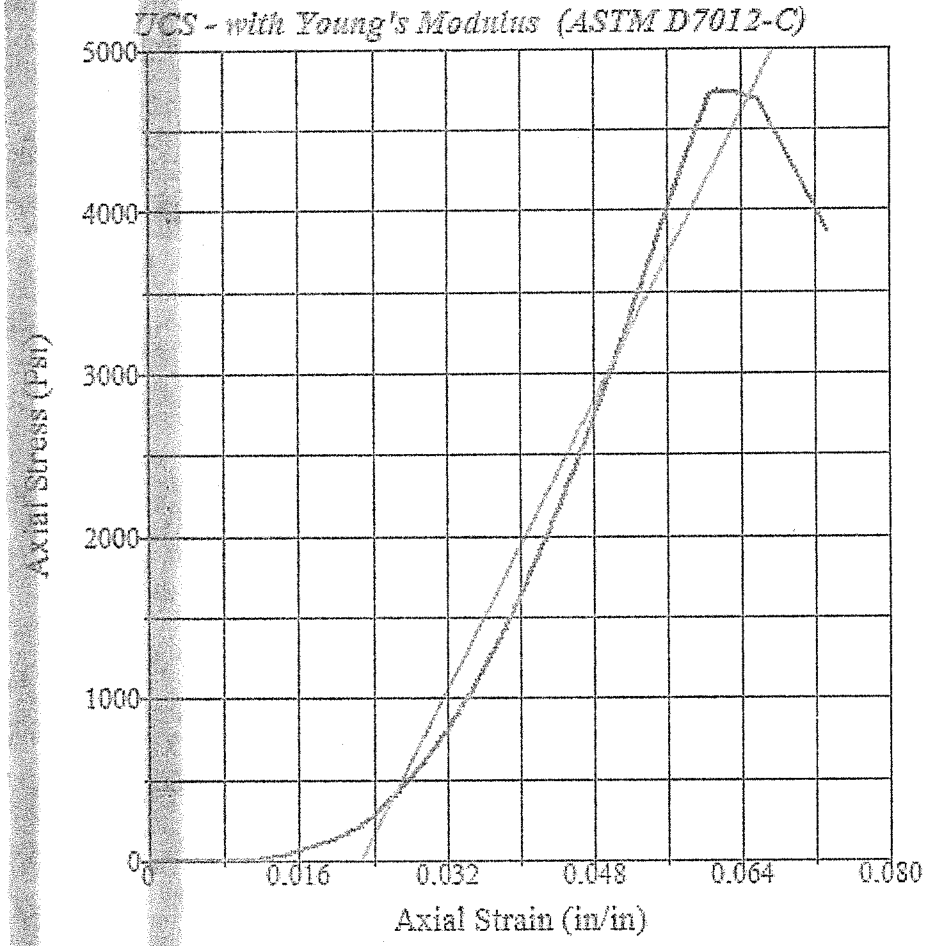

Test Summary

Counter:	1412
Elapsed Time:	00:01:05
Lab Control Number:	W-19-2018-RC
Specimen Identification:	PR19-06 143.5'
Specimen Length:	5.38 in
Start Date:	12/10/2019
Start Time:	8:15:01 AM
End Date:	12/10/2019
End Time:	8:16:06 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	915.8
Dry Density:	pcf

Test Results

Diameter:	2.3900 in
Area:	4.4863 in²
L/D ratio:	2.3
Peak Stress:	4736.0 psi
Peak Load:	21247.30 lbf
Load at Break:	21034.2000 lbf
Young's Modulus:	1.11e+005 psi
Peak Time:	65.90 s
Peak Position:	0.0733 in
Change in Position:	0.0733 in
X Intercept:	0.0225 in/in
Y Intercept:	-2506.6870 psi

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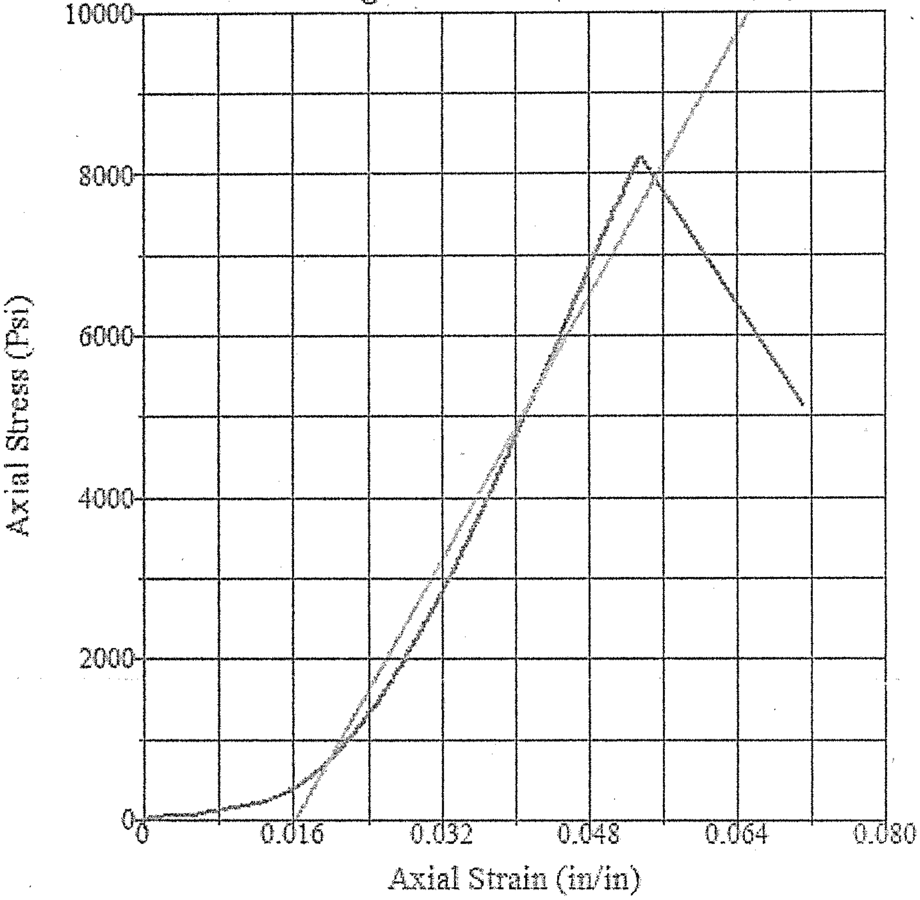

Test Summary		**Test Results**	
Counter:	1283	Diameter:	2.3900 in
Elapsed Time:	00:01:53	Area:	4.4863 in²
Lab Control Number:	W-19-1775-RC	L/D ratio:	2.0
Specimen Identification:	PR19-08	Peak Stress:	8205.5 psi
Specimen Length:	4.69 in	Peak Load:	36812.30 lbf
Start Date:	11/19/2019	Load at Break:	36812.3000 lbf
Start Time:	7:46:33 AM	Young's Modulus:	2.03e+005 psi
End Date:	11/19/2019	Peak Time:	113.20 s
End Time:	7:48:26 AM	Peak Position:	0.0710 in
Tested By:	Walt	Change in Position:	0.0710 in
Specimen Type:	Rock Core	X Intercept:	0.0160 in/in
Sample Weight:	856.5	Y Intercept:	-3257.0350 psi
Dry Density:	pcf		

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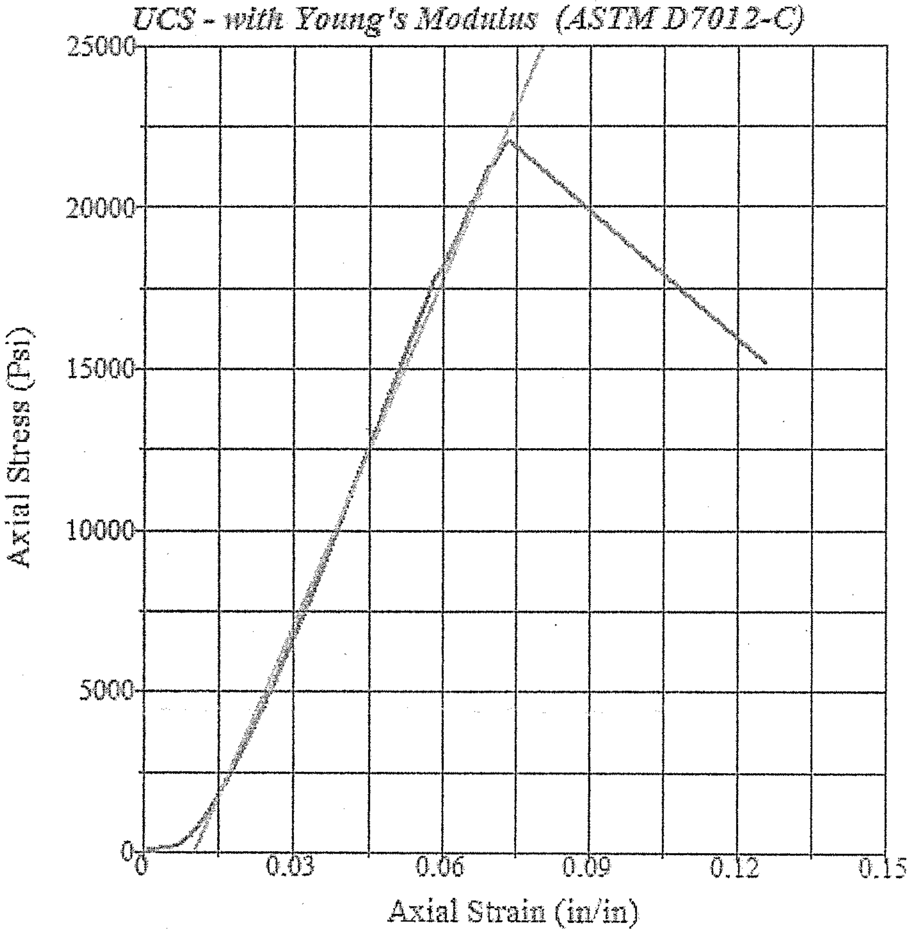

Test Summary

Counter:	1284
Elapsed Time:	00:05:04
Lab Control Number:	W-19-1776-RC
Specimen Identification:	PR19-08
Specimen Length:	4.71 in
Start Date:	11/19/2019
Start Time:	7:53:48 AM
End Date:	11/19/2019
End Time:	7:58:52 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	933.9
Dry Density:	pcf

Test Results

Diameter:	2.4000 in
Area:	4.5239 in²
L/D ratio:	2.0
Peak Stress:	22068.2 psi
Peak Load:	99834.21 lbf
Load at Break:	99834.2100 lbf
Young's Modulus:	3.57e+005 psi
Peak Time:	304.00 s
Peak Position:	0.1254 in
Change in Position:	0.1254 in
X Intercept:	0.0102 in/in
Y Intercept:	-3654.1700 psi

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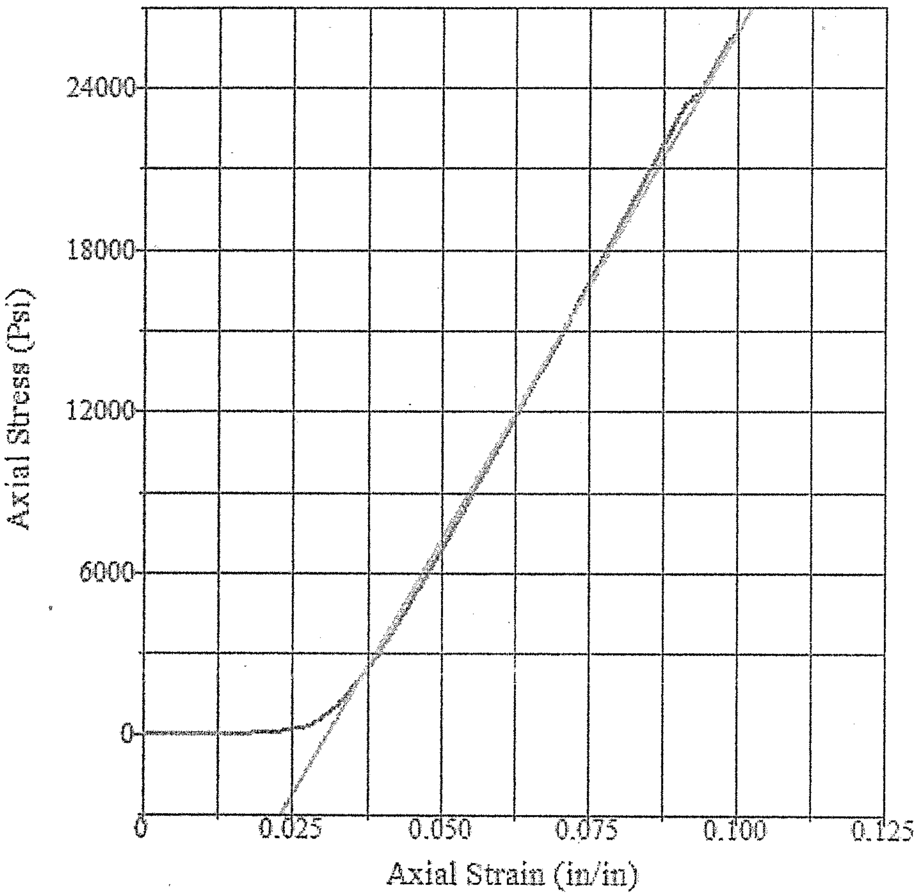

Test Summary

Counter:	1285
Elapsed Time:	00:06:07
Lab Control Number:	W-19-1777-RC
Specimen Identification:	PR19-08
Specimen Length:	4.72 in
Start Date:	11/19/2019
Start Time:	8:16:46 AM
End Date:	11/19/2019
End Time:	8:22:53 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	937.1
Dry Density:	pcf

Test Results

Diameter:	2.4000 in
Area:	4.5239 in²
L/D ratio:	2.0
Peak Stress:	26502.6 psi
Peak Load:	119895.30 lbf
Load at Break:	1.20e+005 lbf
Young's Modulus:	3.79e+005 psi
Peak Time:	365.60 s
Peak Position:	0.1001 in
Change in Position:	0.1001 in
X Intercept:	0.0309 in/in
Y Intercept:	-1.17e+004 psi

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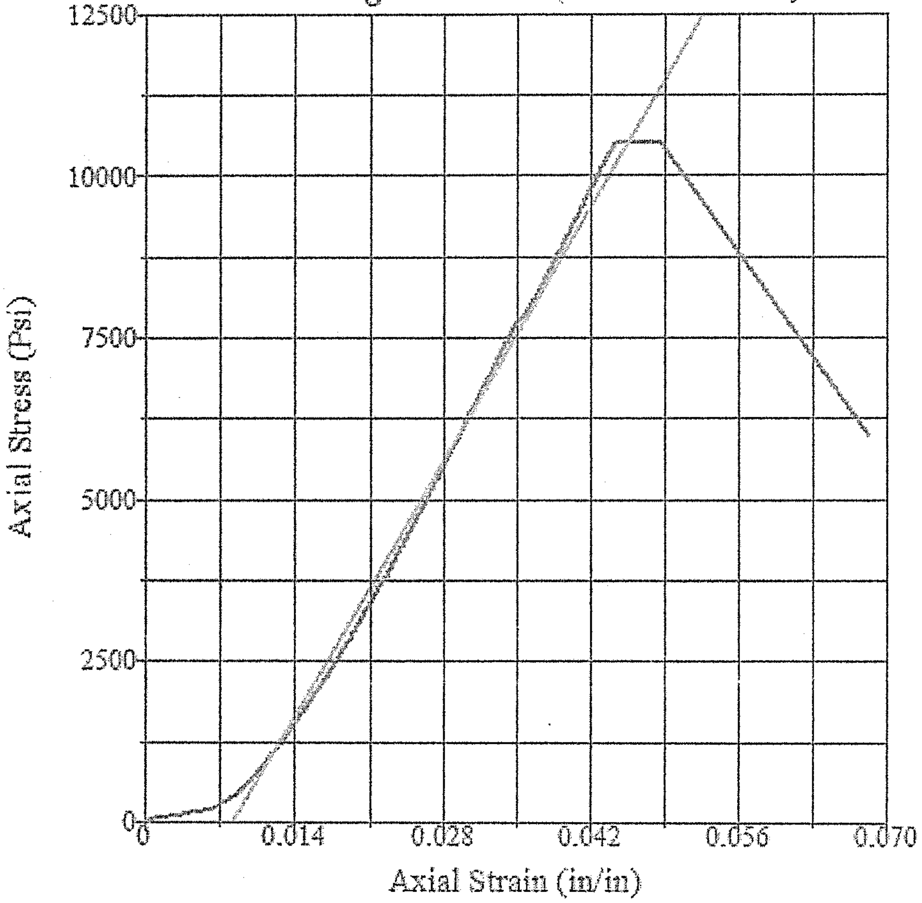

Test Summary

Counter:	1289
Elapsed Time:	00:02:25
Lab Control Number:	W-19-1778-RC
Specimen Identification:	PR19-08
Specimen Length:	4.96 in
Start Date:	11/20/2019
Start Time:	9:15:07 AM
End Date:	11/20/2019
End Time:	9:17:32 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	974.0
Dry Density:	pcf

Test Results

Diameter:	2.4000 in
Area:	4.5239 in²
L/D ratio:	2.1
Peak Stress:	10507.4 psi
Peak Load:	47534.40 lbf
Load at Break:	47471.1000 lbf
Young's Modulus:	2.81e+005 psi
Peak Time:	144.70 s
Peak Position:	0.0683 in
Change in Position:	0.0683 in
X Intercept:	0.0081 in/in
Y Intercept:	-2269.8290 psi

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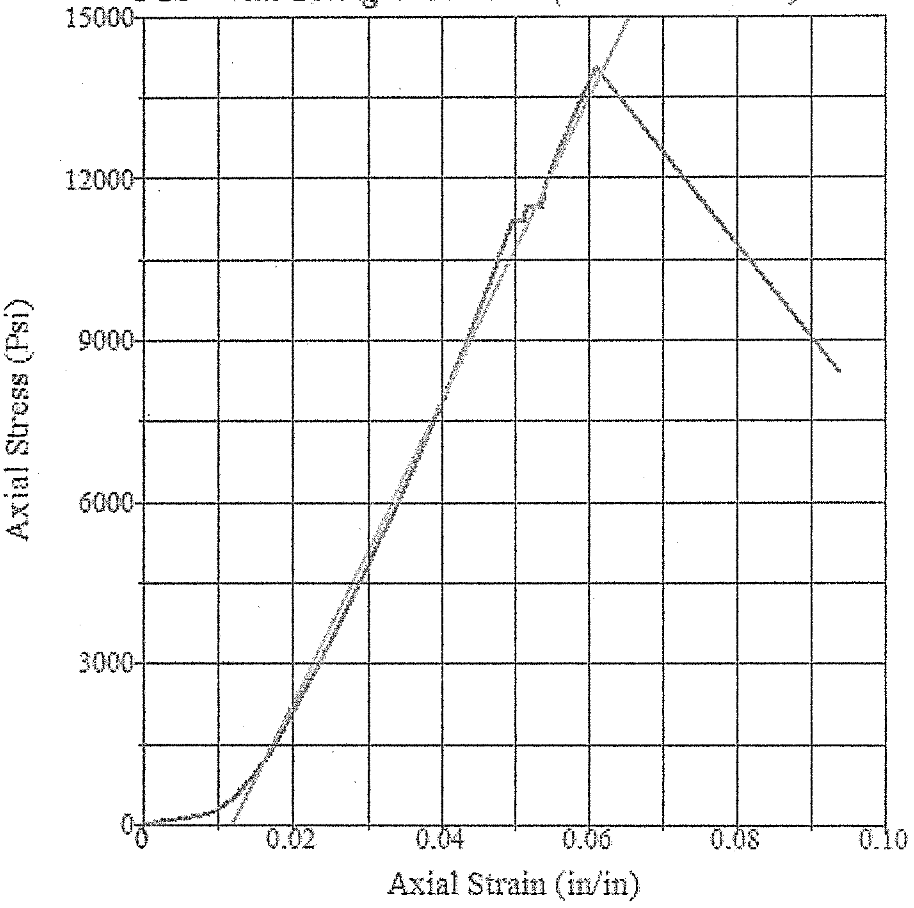

Test Summary

Counter:	1290
Elapsed Time:	00:03:14
Lab Control Number:	W-19-1779-RC
Specimen Identification:	PR19-08
Specimen Length:	5.61 in
Start Date:	11/20/2019
Start Time:	9:22:26 AM
End Date:	11/20/2019
End Time:	9:25:40 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	1116.0
Dry Density:	pcf

Test Results

Diameter:	2.4000 in
Area:	4.5239 in²
L/D ratio:	2.3
Peak Stress:	14020.1 psi
Peak Load:	63425.70 lbf
Load at Break:	63425.7000 lbf
Young's Modulus:	2.79e+005 psi
Peak Time:	193.40 s
Peak Position:	0.0938 in
Change in Position:	0.0938 in
X Intercept:	0.0117 in/in
Y Intercept:	-3279.4120 psi

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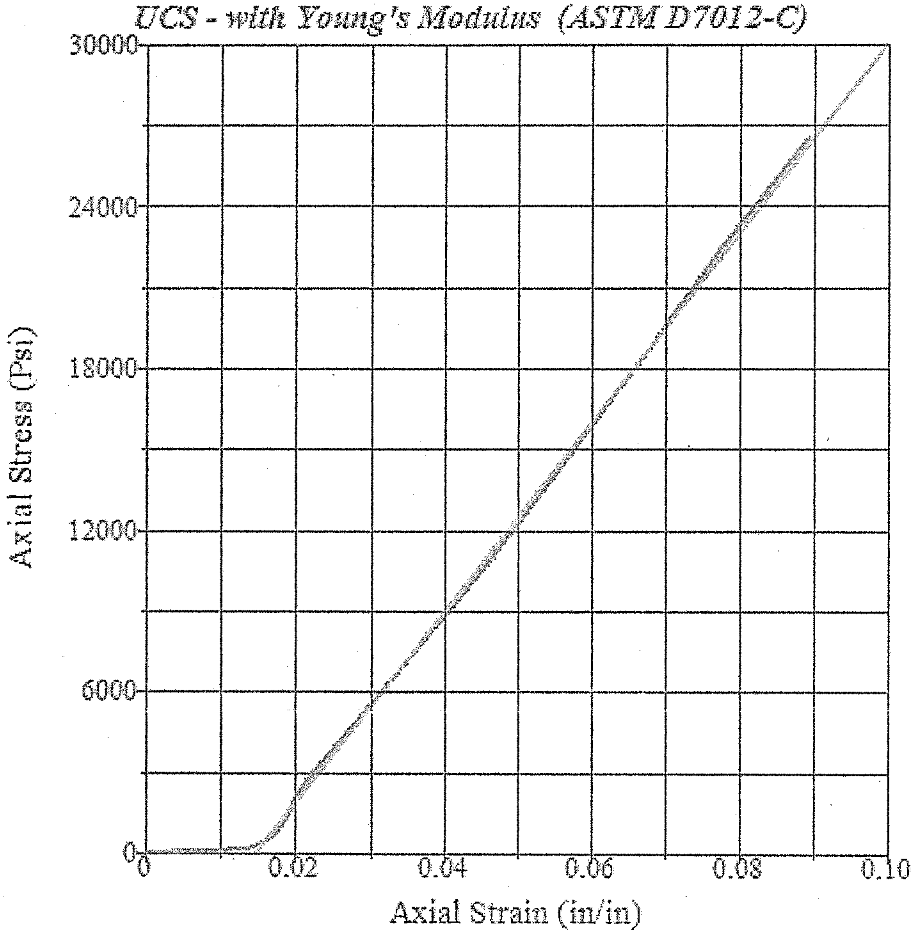

Test Summary

Counter:	1291
Elapsed Time:	00:06:07
Lab Control Number:	W-19-1780-RC
Specimen Identification:	PR19-08
Specimen Length:	4.82 in
Start Date:	11/20/2019
Start Time:	9:30:04 AM
End Date:	11/20/2019
End Time:	9:36:11 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	957.1
Dry Density:	pcf

Test Results

Diameter:	2.4000 in
Area:	4.5239 in²
L/D ratio:	2.0
Peak Stress:	26505.7 psi
Peak Load:	119909.00 lbf
Load at Break:	1.20e+005 lbf
Young's Modulus:	3.53e+005 psi
Peak Time:	365.70 s
Peak Position:	0.0892 in
Change in Position:	0.0892 in
X Intercept:	0.0146 in/in
Y Intercept:	-5164.0040 psi

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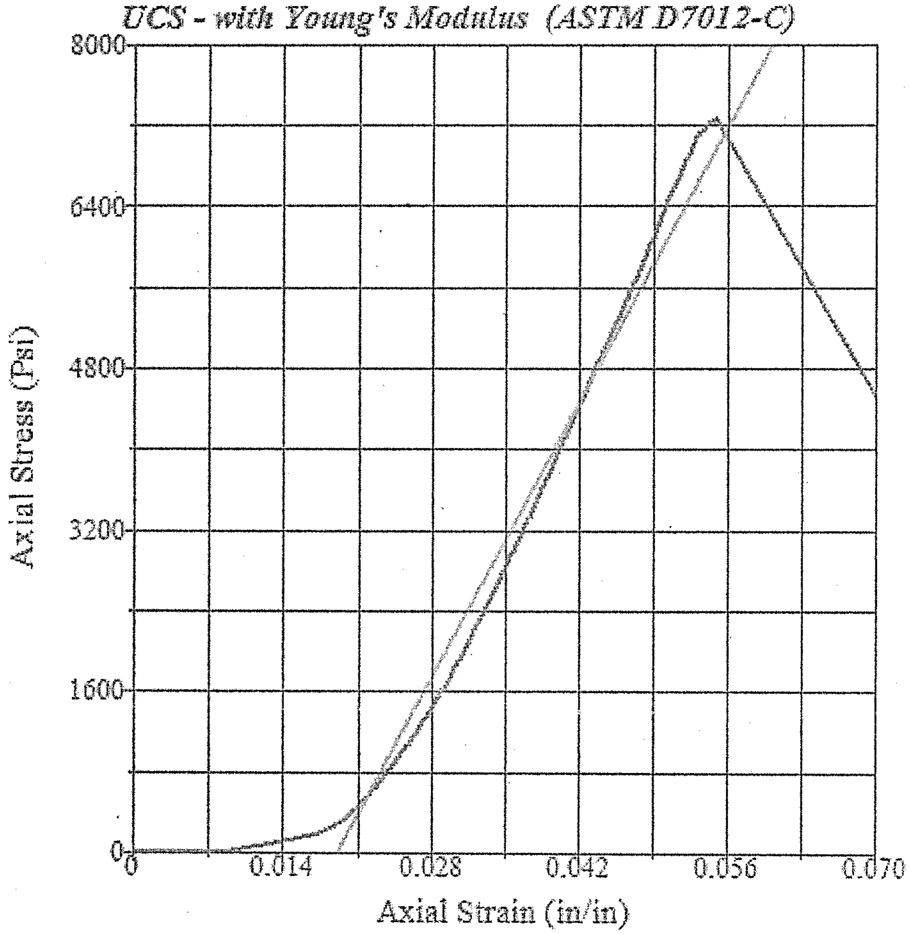
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Test Summary

Counter:	1286
Elapsed Time:	00:01:41
Lab Control Number:	W-19-1783-RC
Specimen Identification:	PR19-07
Specimen Length:	4.40 in
Start Date:	11/19/2019
Start Time:	2:19:02 PM
End Date:	11/19/2019
End Time:	2:20:43 PM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	747.5
Dry Density:	pcf

Test Results

Diameter:	2.3500 in
Area:	4.3374 in²
L/D ratio:	1.9
Peak Stress:	7262.0 psi
Peak Load:	31498.40 lbf
Load at Break:	31498.4000 lbf
Young's Modulus:	1.94e+005 psi
Peak Time:	100.50 s
Peak Position:	0.0699 in
Change in Position:	0.0699 in
X Intercept:	0.0190 in/in
Y Intercept:	-3682.9010 psi

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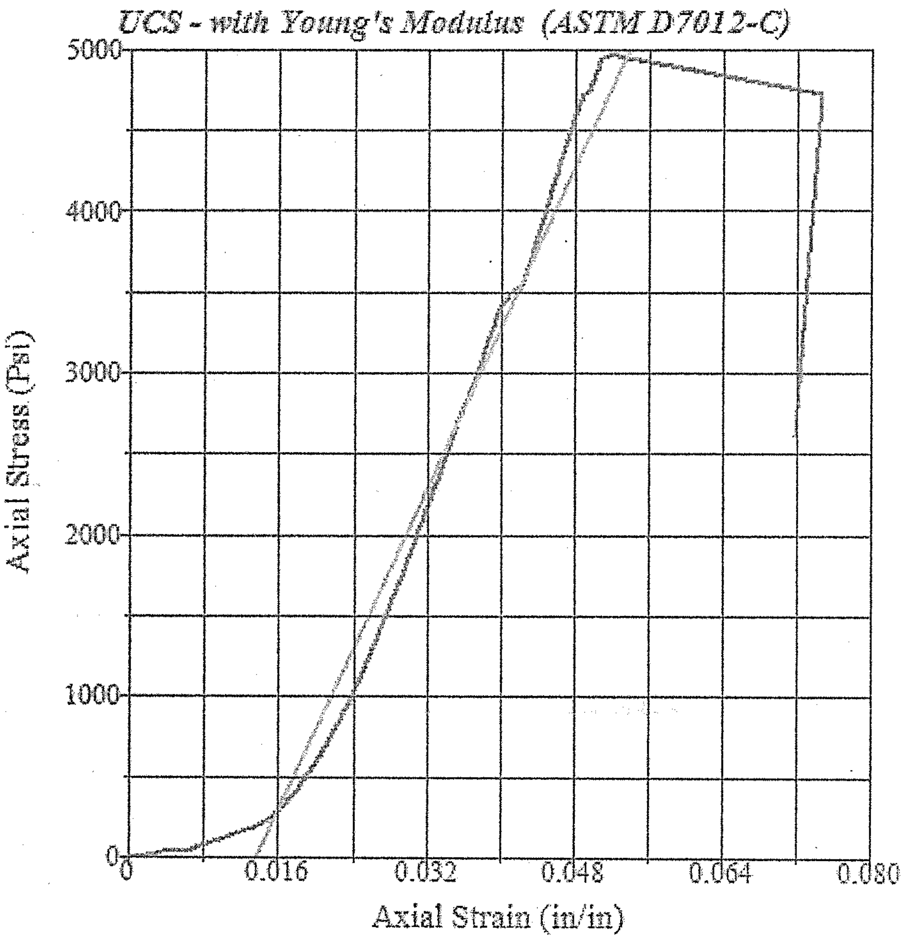

Test Summary

Counter:	1287
Elapsed Time:	00:01:09
Lab Control Number:	W-19-1784-RC
Specimen Identification:	PR19-07
Specimen Length:	4.78 in
Start Date:	11/19/2019
Start Time:	2:24:59 PM
End Date:	11/19/2019
End Time:	2:26:08 PM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	815.3
Dry Density:	pcf

Test Results

Diameter:	2.3700 in
Area:	4.4115 in²
L/D ratio:	2.0
Peak Stress:	4962.9 psi
Peak Load:	21893.80 lbf
Load at Break:	20830.5000 lbf
Young's Modulus:	1.24e+005 psi
Peak Time:	69.00 s
Peak Position:	0.0745 in
Change in Position:	0.0717 in
X Intercept:	0.0136 in/in
Y Intercept:	-1688.8670 psi

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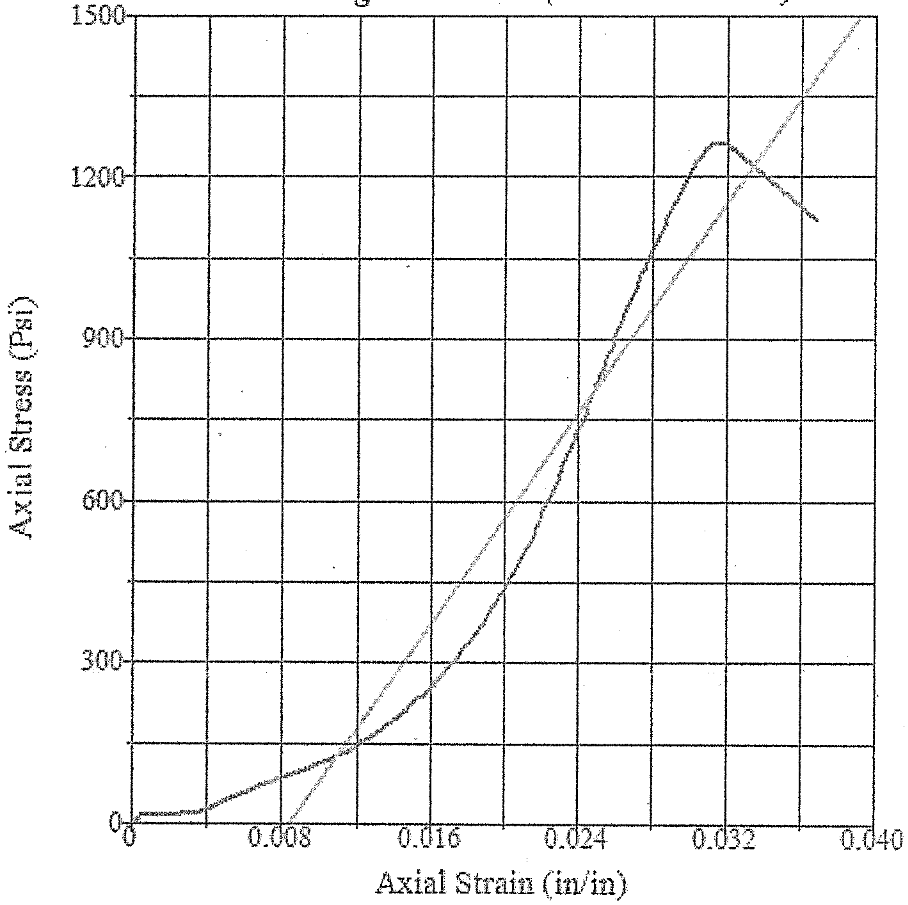
UCS - with Young's Modulus (ASTM D7012-C)



Test Summary

Counter: 1288
Elapsed Time: 00:00:18
Lab Control Number: W-19-1785-RC
Specimen Identification: PR19-07
Specimen Length: 5.45 in
Start Date: 11/19/2019
Start Time: 2:30:43 PM
End Date: 11/19/2019
End Time: 2:31:01 PM
Tested By: Walt
Specimen Type: Rock Core
Sample Weight: 916.2
Dry Density: pcf

Test Results

Diameter: 2.3700 in
Area: 4.4115 in²
L/D ratio: 2.3
Peak Stress: 1263.4 psi
Peak Load: 5573.50 lbf
Load at Break: 5568.2000 lbf
Young's Modulus: 48844.7300 psi
Peak Time: 17.50 s
Peak Position: 0.0368 in
Change in Position: 0.0368 in
X Intercept: 0.0083 in/in
Y Intercept: -407.3547 psi

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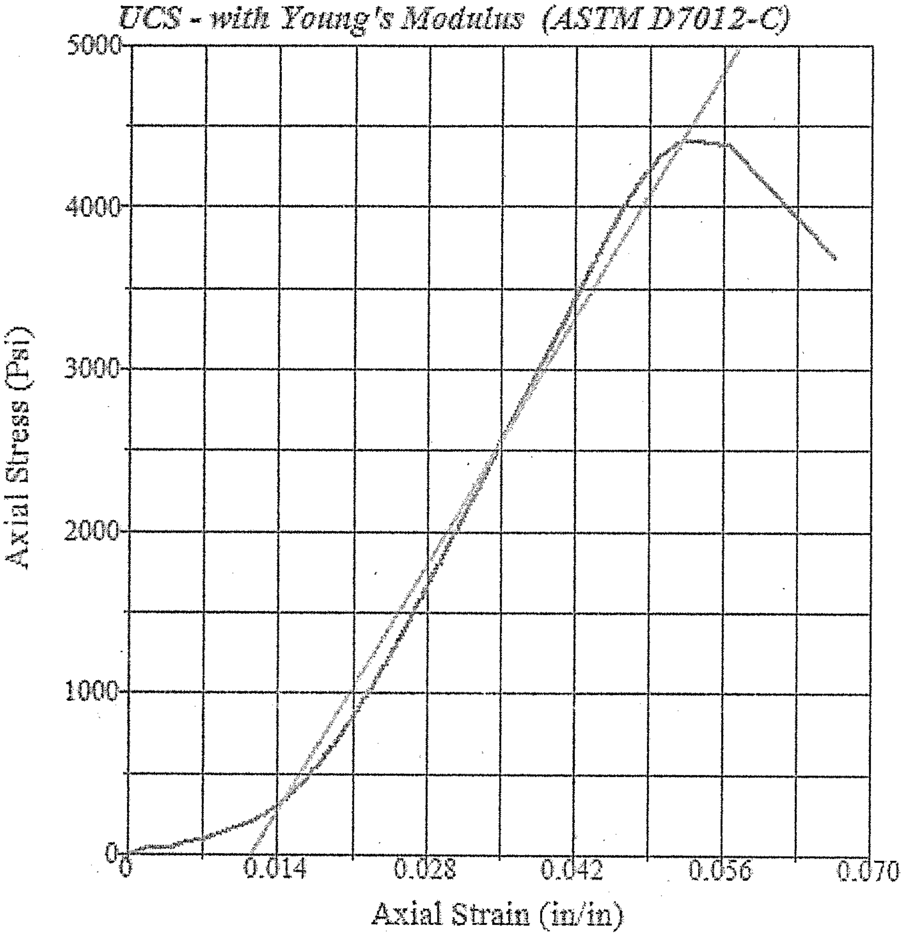

Test Summary

Counter:	1292
Elapsed Time:	00:01:01
Lab Control Number:	W-19-1786-RC
Specimen Identification:	PR19-07
Specimen Length:	3.73 in
Start Date:	11/20/2019
Start Time:	9:48:46 AM
End Date:	11/20/2019
End Time:	9:49:47 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	600.7
Dry Density:	pcf

Test Results

Diameter:	2.3700 in
Area:	4.4115 in²
L/D ratio:	1.6
Peak Stress:	4411.2 psi
Peak Load:	19459.80 lbf
Load at Break:	19295.6000 lbf
Young's Modulus:	1.09e+005 psi
Peak Time:	61.00 s
Peak Position:	0.0666 in
Change in Position:	0.0666 in
X Intercept:	0.0115 in/in
Y Intercept:	-1246.9610 psi

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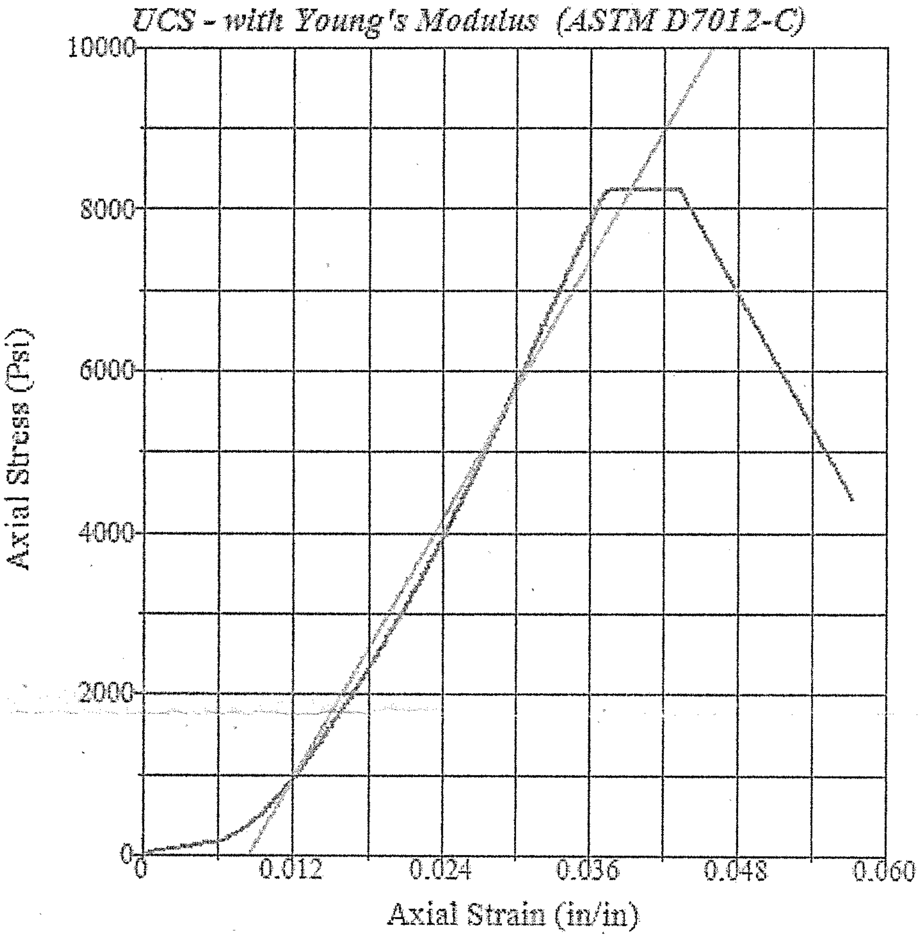

Test Summary

Counter:	1293
Elapsed Time:	00:01:53
Lab Control Number:	W-19-1788-RC
Specimen Identification:	PR19-09
Specimen Length:	4.92 in
Start Date:	11/21/2019
Start Time:	8:32:51 AM
End Date:	11/21/2019
End Time:	8:34:44 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	966.8
Dry Density:	pcf

Test Results

Diameter:	2.3900 in
Area:	4.4863 in²
L/D ratio:	2.1
Peak Stress:	8224.3 psi
Peak Load:	36896.80 lbf
Load at Break:	36890.6000 lbf
Young's Modulus:	2.67e+005 psi
Peak Time:	113.10 s
Peak Position:	0.0572 in
Change in Position:	0.0572 in
X Intercept:	0.0084 in/in
Y Intercept:	-2235.2240 psi

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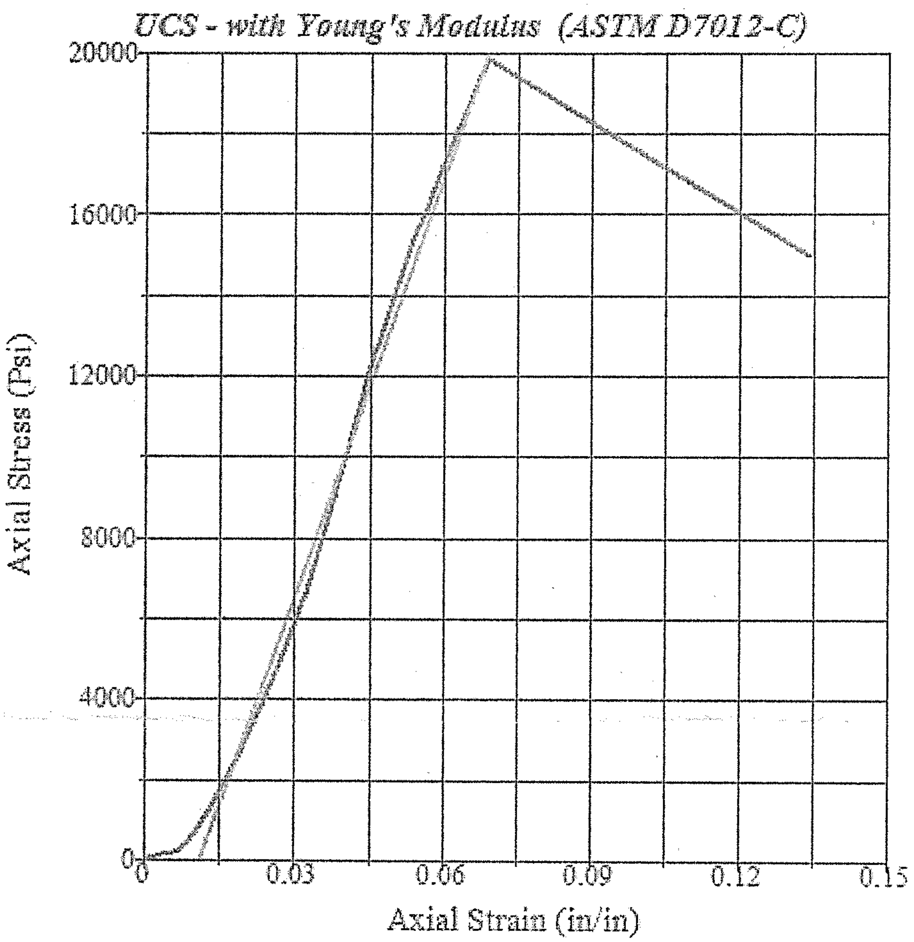

Test Summary

Counter:	1294
Elapsed Time:	00:04:33
Lab Control Number:	W-19-1789-RC
Specimen Identification:	PR19-09
Specimen Length:	5.05 in
Start Date:	11/21/2019
Start Time:	8:39:59 AM
End Date:	11/21/2019
End Time:	8:44:32 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	992.1
Dry Density:	pcf

Test Results

Diameter:	2.3900 in
Area:	4.4863 in²
L/D ratio:	2.1
Peak Stress:	19841.1 psi
Peak Load:	89013.30 lbf
Load at Break:	89013.3000 lbf
Young's Modulus:	3.43e+005 psi
Peak Time:	273.10 s
Peak Position:	0.1341 in
Change in Position:	0.1341 in
X Intercept:	0.0107 in/in
Y Intercept:	-3685.8580 psi

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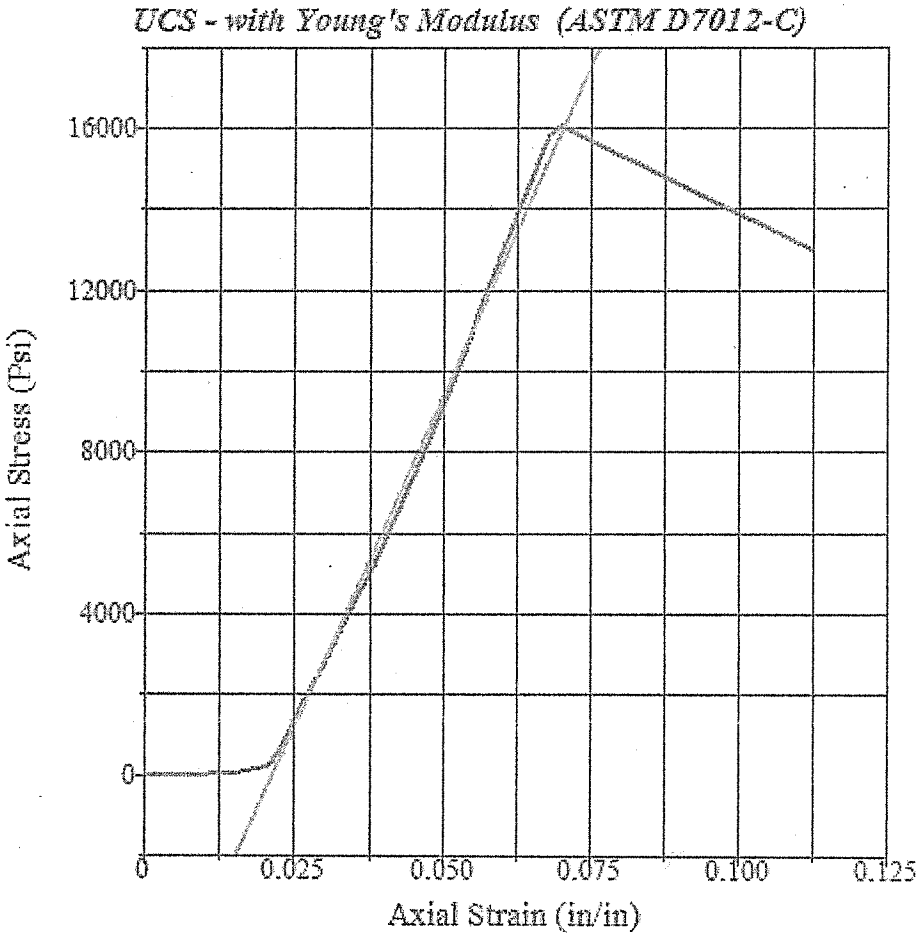

Test Summary

Counter:	1295
Elapsed Time:	00:03:42
Lab Control Number:	W-19-1790-RC
Specimen Identification:	PR19-09
Specimen Length:	5.44 in
Start Date:	11/21/2019
Start Time:	9:24:04 AM
End Date:	11/21/2019
End Time:	9:27:46 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	1062.6
Dry Density:	pcf

Test Results

Diameter:	2.4000 in
Area:	4.5239 in²
L/D ratio:	2.3
Peak Stress:	16036.3 psi
Peak Load:	72546.60 lbf
Load at Break:	72546.6000 lbf
Young's Modulus:	3.26e+005 psi
Peak Time:	221.50 s
Peak Position:	0.1125 in
Change in Position:	0.1125 in
X Intercept:	0.0213 in/in
Y Intercept:	-6937.0050 psi

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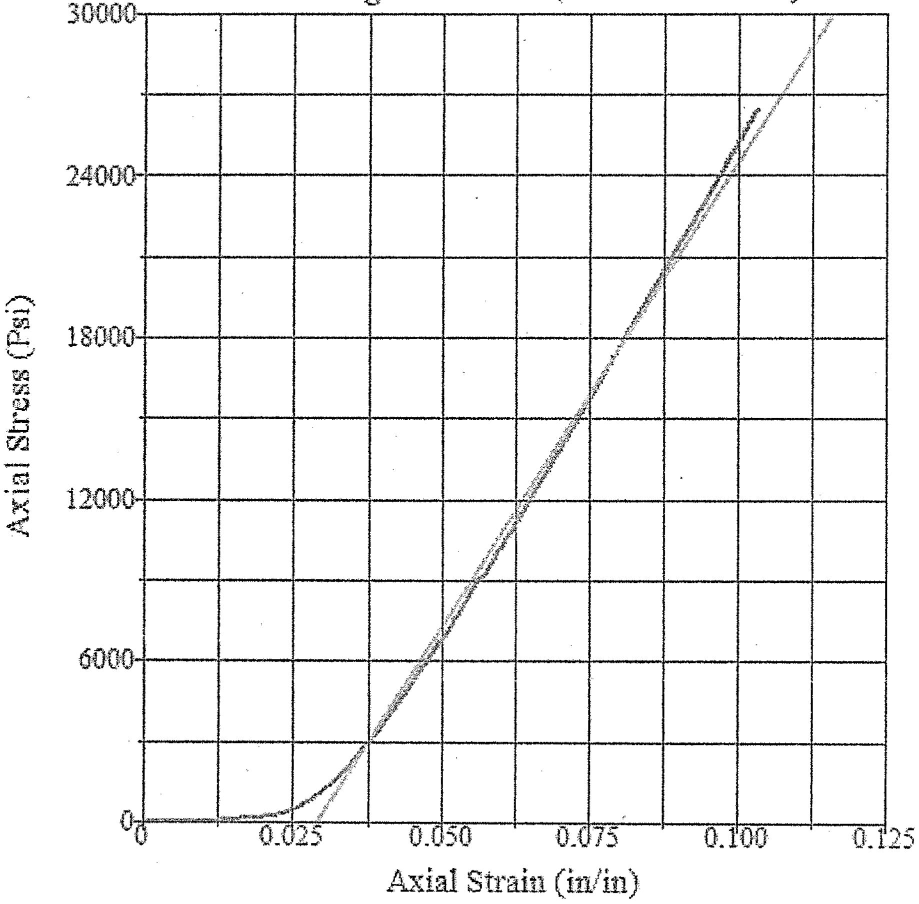

UCS - with Young's Modulus (ASTM D7012-C)

Test Summary

Counter:	1296
Elapsed Time:	00:06:07
Lab Control Number:	W-19-1791-RC
Specimen Identification:	PR19-09
Specimen Length:	5.03 in
Start Date:	11/21/2019
Start Time:	10:10:56 AM
End Date:	11/21/2019
End Time:	10:17:03 AM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	1022.9
Dry Density:	pcf

Test Results

Diameter:	2.4000 in
Area:	4.5239 in²
L/D ratio:	2.1
Peak Stress:	26505.7 psi
Peak Load:	119909.20 lbf
Load at Break:	1.20e+005 lbf
Young's Modulus:	3.45e+005 psi
Peak Time:	365.70 s
Peak Position:	0.1034 in
Change in Position:	0.1034 in
X Intercept:	0.0288 in/in
Y Intercept:	-9948.4250 psi

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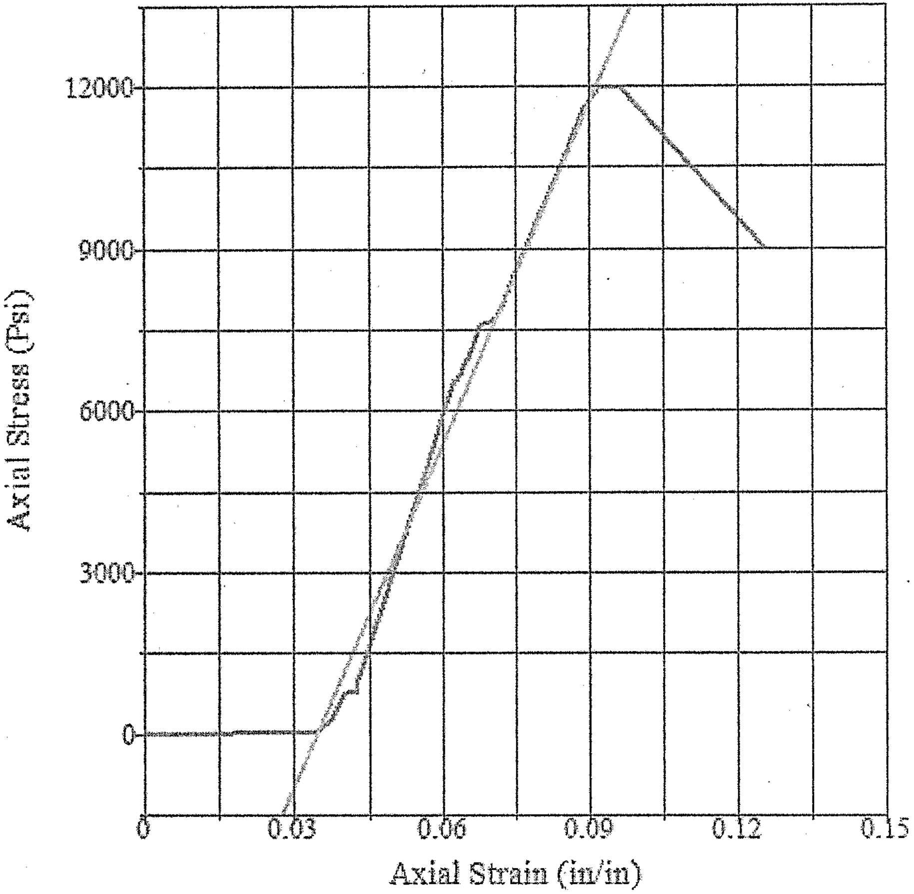

Test Summary

Counter:	1297
Elapsed Time:	00:02:46
Lab Control Number:	W-19-1794-RC
Specimen Identification:	PR19-09
Specimen Length:	4.92 in
Start Date:	11/21/2019
Start Time:	2:01:10 PM
End Date:	11/21/2019
End Time:	2:03:56 PM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	959.3
Dry Density:	pcf

Test Results

Diameter:	2.4000 in
Area:	4.5239 in²
L/D ratio:	2.1
Peak Stress:	11978.2 psi
Peak Load:	54188.00 lbf
Load at Break:	54188.0000 lbf
Young's Modulus:	2.10e+005 psi
Peak Time:	165.80 s
Peak Position:	0.1258 in
Change in Position:	0.1258 in
X Intercept:	0.0344 in/in
Y Intercept:	-7210.0200 psi

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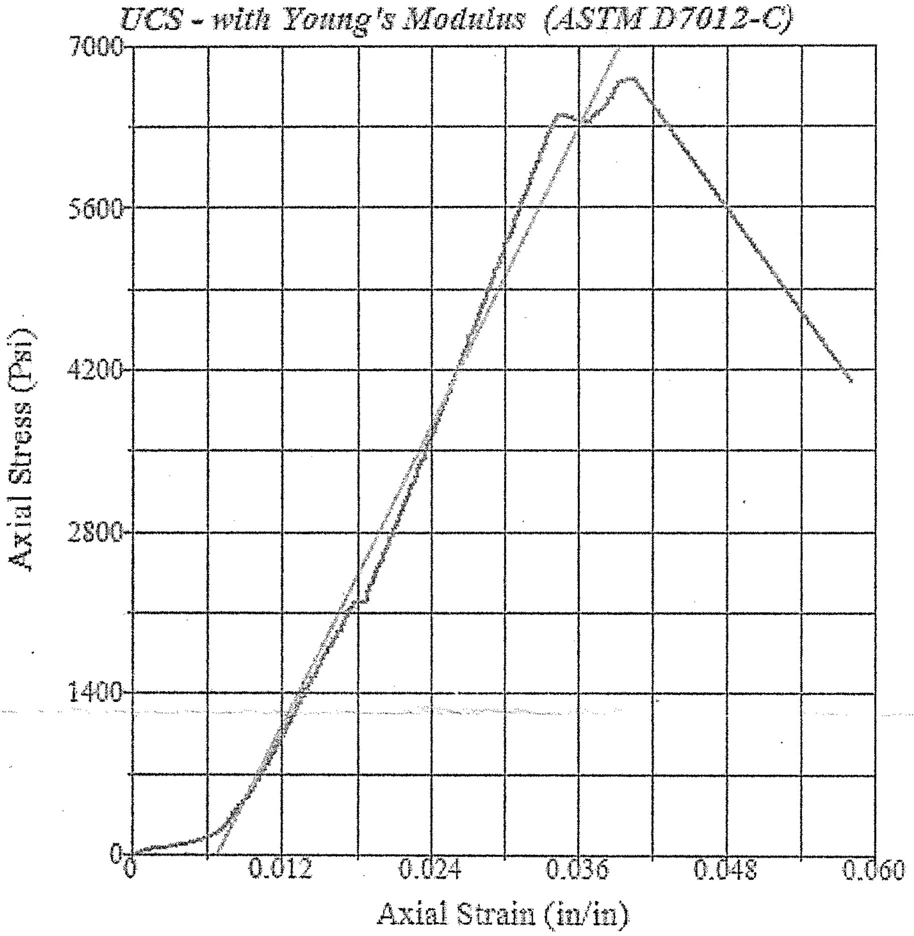

Test Summary

Counter:	1298
Elapsed Time:	00:01:32
Lab Control Number:	W-19-1796-RC
Specimen Identification:	PR19-09
Specimen Length:	5.46 in
Start Date:	11/22/2019
Start Time:	2:23:14 PM
End Date:	11/22/2019
End Time:	2:24:46 PM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	1083.9
Dry Density:	pcf

Test Results

Diameter:	2.4000 in
Area:	4.5239 in²
L/D ratio:	2.3
Peak Stress:	6700.4 psi
Peak Load:	30312.10 lbf
Load at Break:	30278.6000 lbf
Young's Modulus:	2.16e+005 psi
Peak Time:	92.50 s
Peak Position:	0.0580 in
Change in Position:	0.0580 in
X Intercept:	0.0068 in/in
Y Intercept:	-1478.0350 psi

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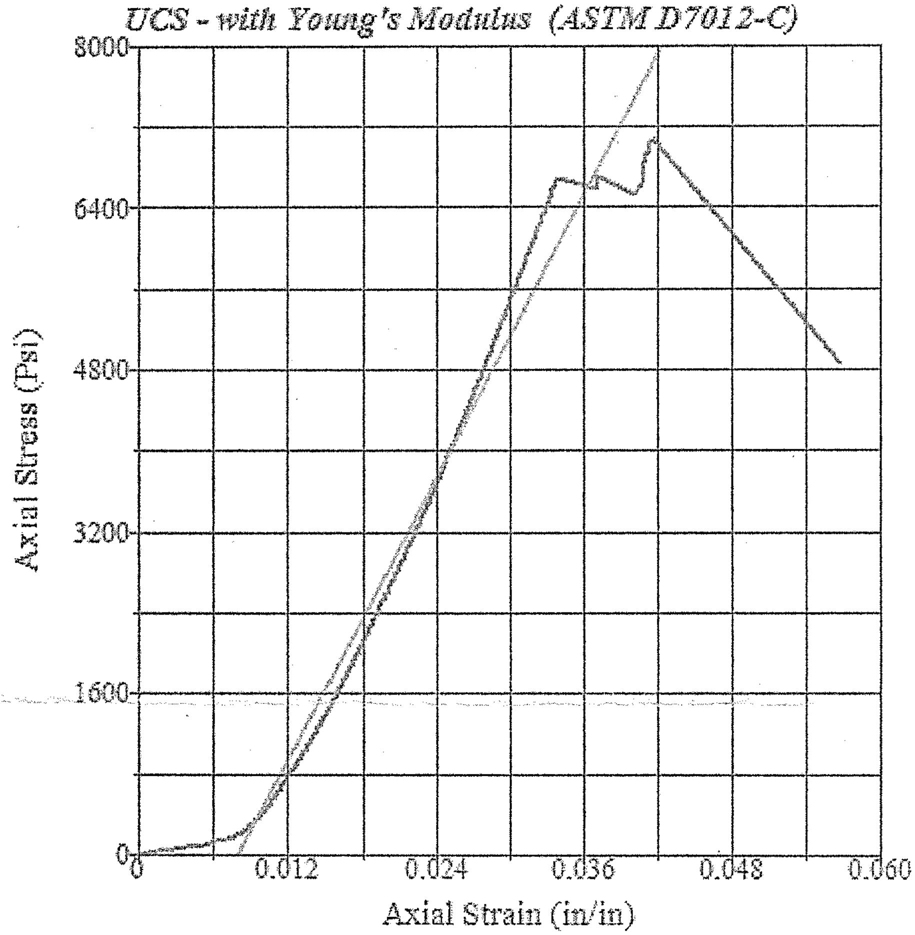

Test Summary	
Counter:	1299
Elapsed Time:	00:01:38
Lab Control Number:	W-19-1797-RC
Specimen Identification:	PR19-09
Specimen Length:	5.56 in
Start Date:	11/22/2019
Start Time:	2:28:51 PM
End Date:	11/22/2019
End Time:	2:30:29 PM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	1122.9
Dry Density:	pcf

Test Results	
Diameter:	2.3900 in
Area:	4.4863 in²
L/D ratio:	2.3
Peak Stress:	7069.6 psi
Peak Load:	31716.20 lbf
Load at Break:	31716.2000 lbf
Young's Modulus:	2.32e+005 psi
Peak Time:	97.60 s
Peak Position:	0.0567 in
Change in Position:	0.0567 in
X Intercept:	0.0079 in/in
Y Intercept:	-1820.5700 psi

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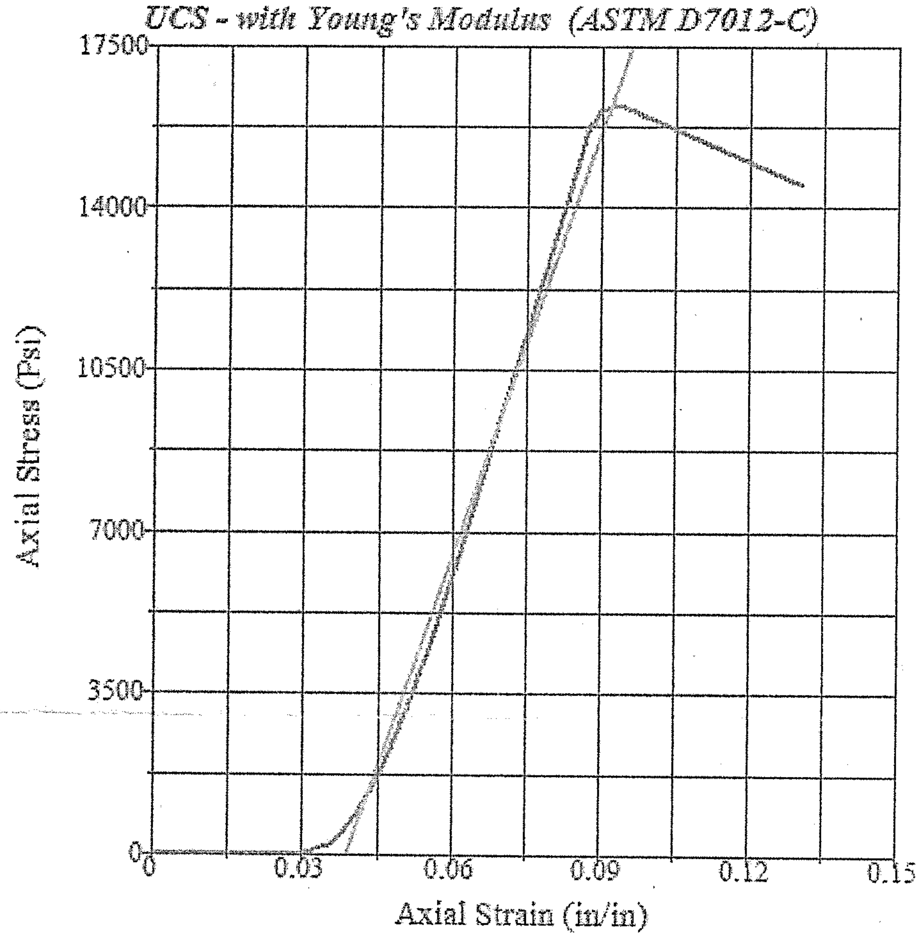

Test Summary

Counter:	1300
Elapsed Time:	00:03:44
Lab Control Number:	W-19-1798-RC
Specimen Identification:	PR19-09
Specimen Length:	4.89 in
Start Date:	11/22/2019
Start Time:	2:35:10 PM
End Date:	11/22/2019
End Time:	2:38:54 PM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	974.9
Dry Density:	pcf

Test Results

Diameter:	2.4000 in
Area:	4.5239 in²
L/D ratio:	2.0
Peak Stress:	16211.1 psi
Peak Load:	73337.30 lbf
Load at Break:	73134.6000 lbf
Young's Modulus:	3.05e+005 psi
Peak Time:	223.90 s
Peak Position:	0.1303 in
Change in Position:	0.1303 in
X Intercept:	0.0387 in/in
Y Intercept:	-1.18e+004 psi

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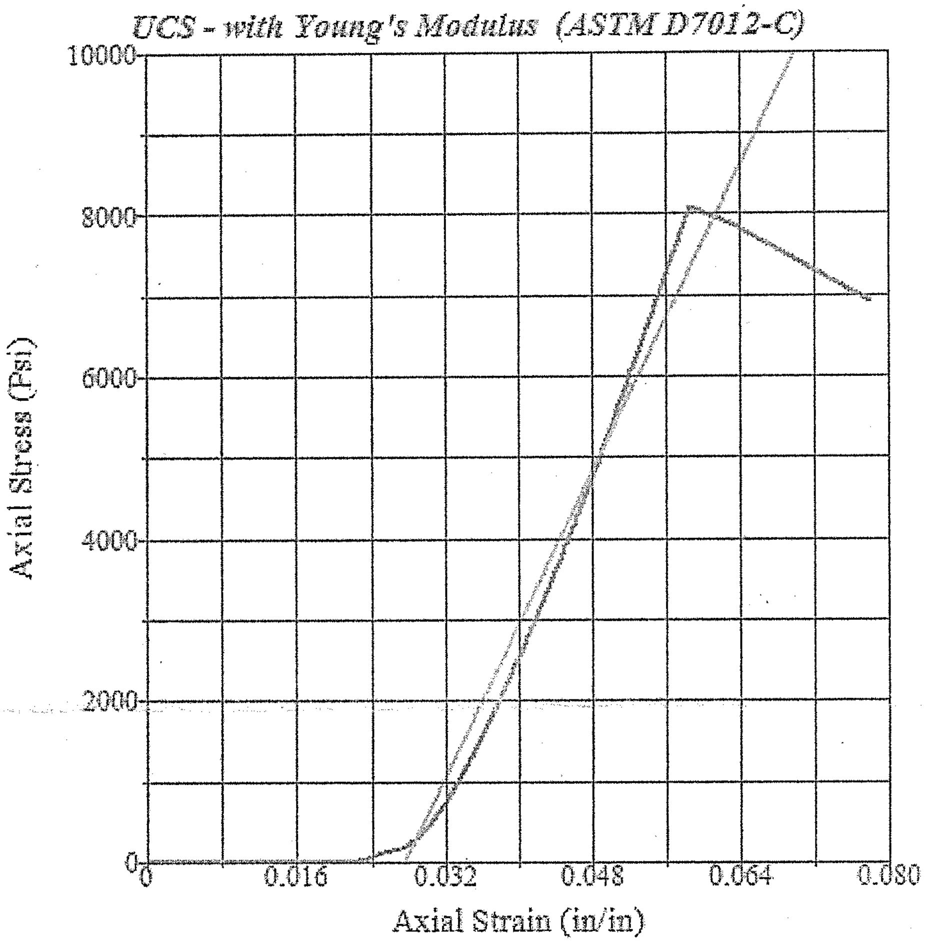

Test Summary

Counter:	1301
Elapsed Time:	00:01:51
Lab Control Number:	W-19-1799-RC
Specimen Identification:	PR19-09
Specimen Length:	5.51 in
Start Date:	11/22/2019
Start Time:	2:43:42 PM
End Date:	11/22/2019
End Time:	2:45:33 PM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	1083.8
Dry Density:	pcf

Test Results

Diameter:	2.4000 in
Area:	4.5239 in^2
L/D ratio:	2.3
Peak Stress:	8068.9 psi
Peak Load:	36502.80 lbf
Load at Break:	35614.1000 lbf
Young's Modulus:	2.37e+005 psi
Peak Time:	111.70 s
Peak Position:	0.0780 in
Change in Position:	0.0780 in
X Intercept:	0.0276 in/in
Y Intercept:	-6562.5090 psi

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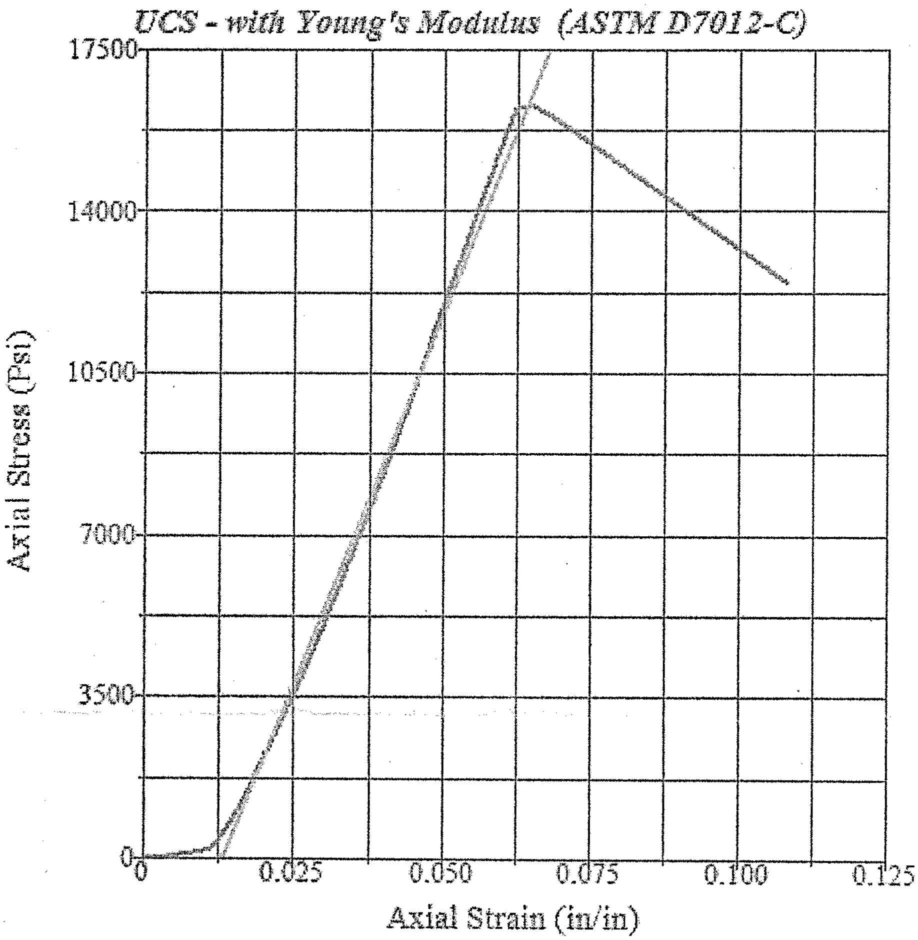

Test Summary

Counter:	1302
Elapsed Time:	00:03:45
Lab Control Number:	W-19-1800-RC
Specimen Identification:	PR19-09
Specimen Length:	5.52 in
Start Date:	11/22/2019
Start Time:	2:52:49 PM
End Date:	11/22/2019
End Time:	2:56:34 PM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	1094.7
Dry Density:	pcf

Test Results

Diameter:	2.3900 in
Area:	4.4863 in²
L/D ratio:	2.3
Peak Stress:	16264.8 psi
Peak Load:	72968.70 lbf
Load at Break:	71665.8000 lbf
Young's Modulus:	3.20e+005 psi
Peak Time:	224.80 s
Peak Position:	0.1079 in
Change in Position:	0.1079 in
X Intercept:	0.0131 in/in
Y Intercept:	-4196.0120 psi

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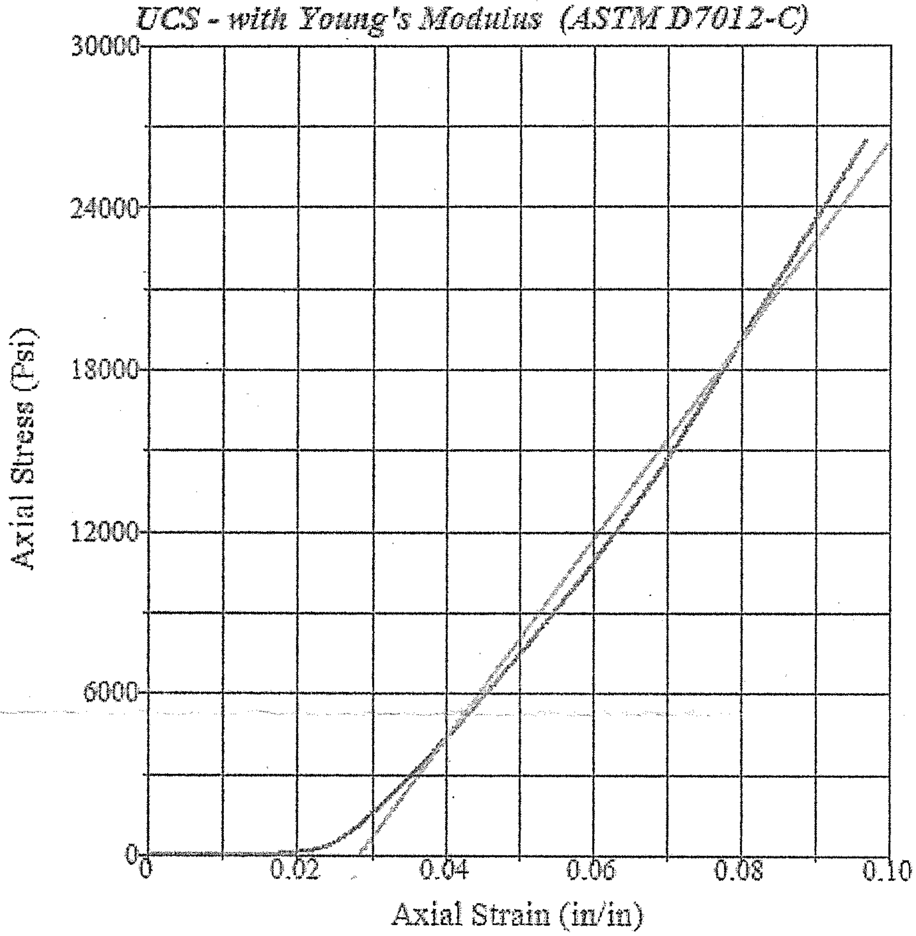


Test Summary

Counter:	1303
Elapsed Time:	00:06:06
Lab Control Number:	W-19-1801-RC
Specimen Identification:	PR19-09
Specimen Length:	5.72 in
Start Date:	11/22/2019
Start Time:	3:02:12 PM
End Date:	11/22/2019
End Time:	3:08:18 PM
Tested By:	Walt
Specimen Type:	Rock Core
Sample Weight:	1162.4
Dry Density:	pcf

Test Results

Diameter:	2.4000 in
Area:	4.5239 in²
L/D ratio:	2.4
Peak Stress:	26505.5 psi
Peak Load:	119908.10 lbf
Load at Break:	1.20e+005 lbf
Young's Modulus:	3.68e+005 psi
Peak Time:	365.70 s
Peak Position:	0.0967 in
Change in Position:	0.0967 in
X Intercept:	0.0282 in/in
Y Intercept:	-1.04e+004 psi

APPENDIX F

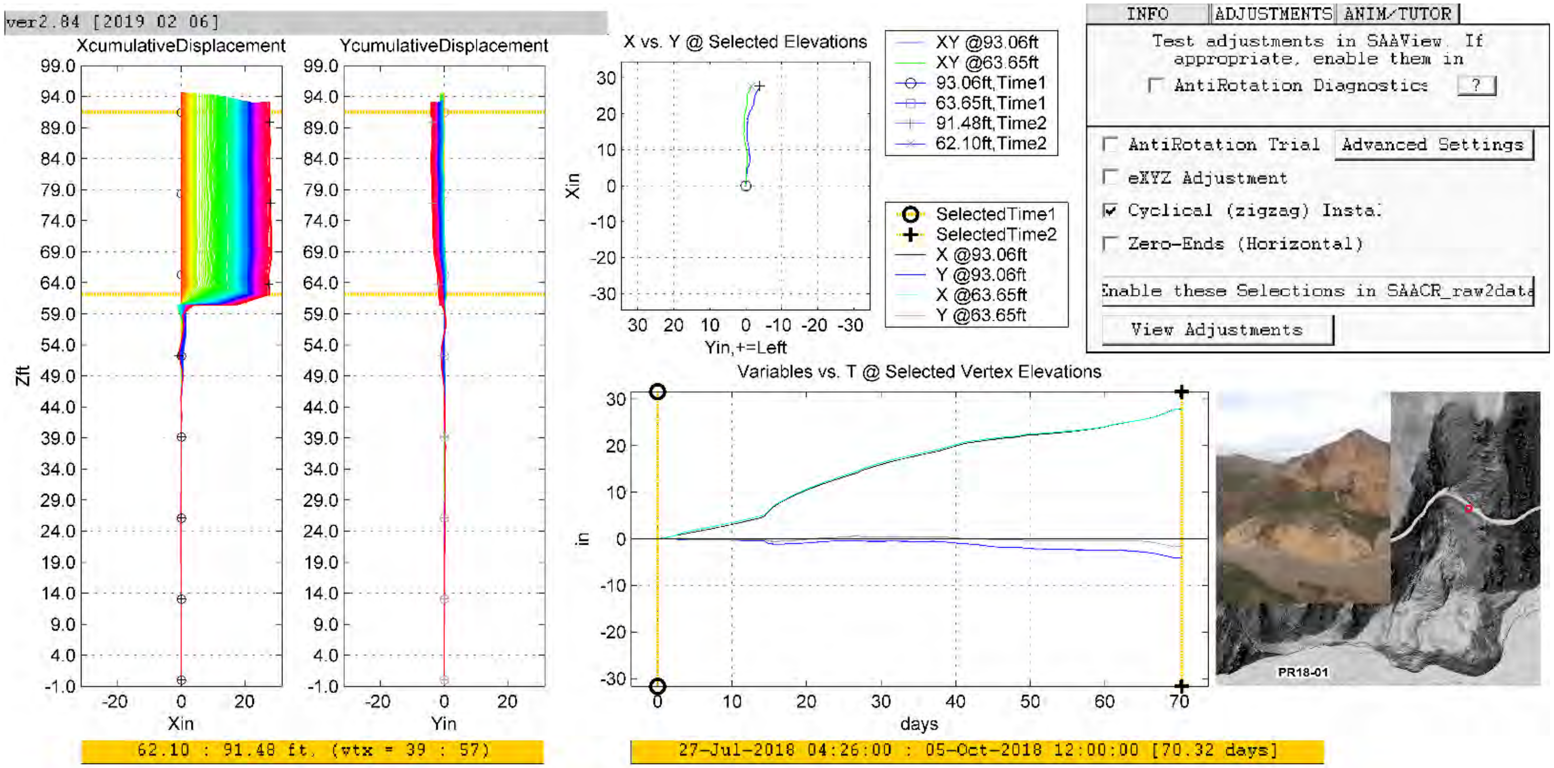
Test Boring Instrumentation

F-1: Shape Array Accelerometer Data
F-2: Slope Inclinometer Data
F-3: Vibrating Wire Piezometer Data
F-4: Thermistor Data

APPENDIX F-1

Shape Array Accelerometer

PR18-01 (Saa 221178) Cumulative Displacement



Test adjustments in SAAView. If appropriate, enable them in

☐ AntiRotation Diagnostics

☐ AntiRotation Trial

☐ eXYZ Adjustment

☑ Cyclical (zigzag) Instal

☐ Zero-Ends (Horizontal)

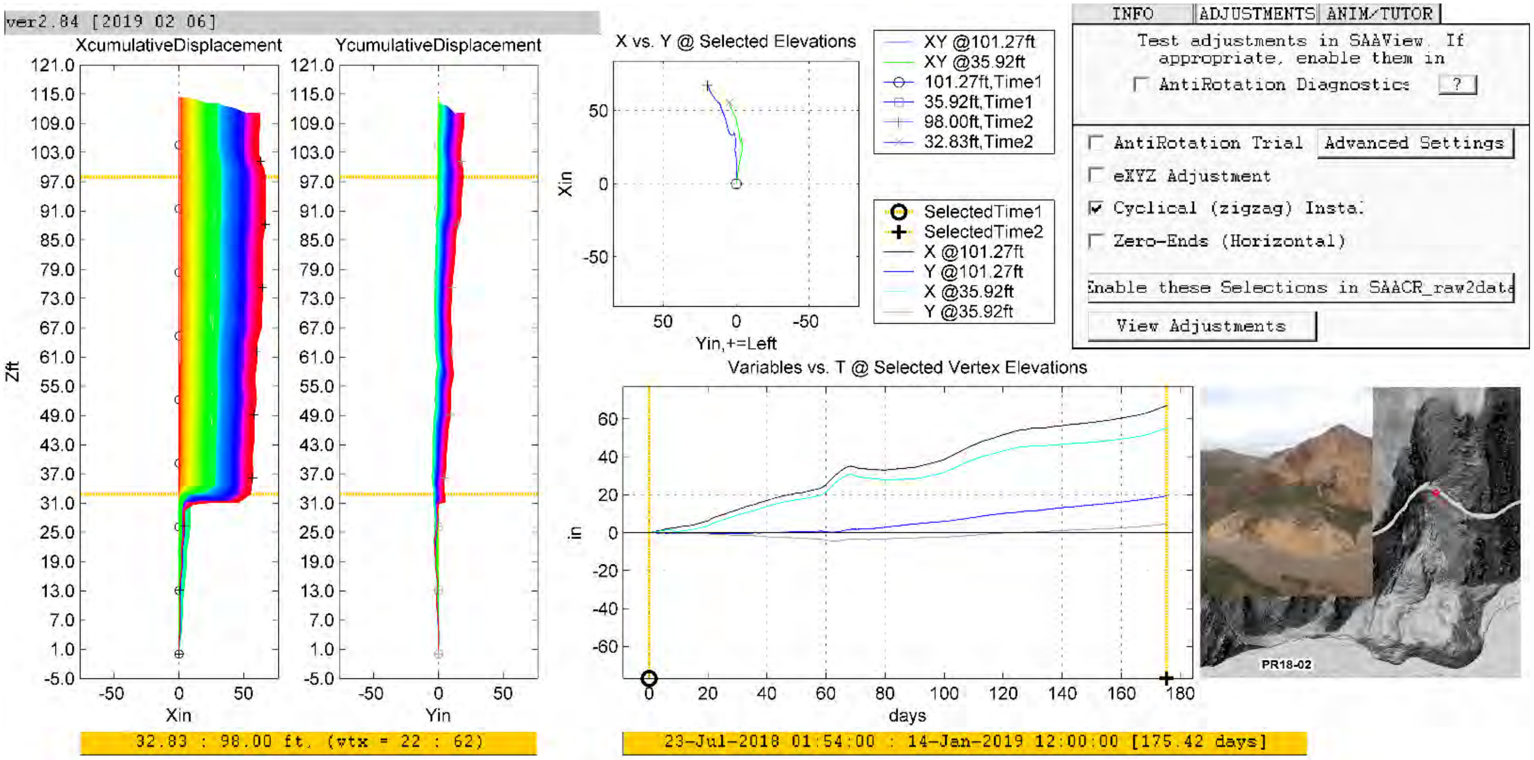
Enable these Selections in SAACR_raw2data

62.10 : 91.48 ft. (vtx = 39 : 57)

27-Jul-2018 04:26:00 : 05-Oct-2018 12:00:00 [70.32 days]

Note: SAA measurements are from the bottom of the hole to the top of the hole. Magnitude of Landslide displacement is measured in inches and represented by the rainbow colors. The left part of the graph show the total movement down slope, and the right part of the graph show the movement left.
The total landslide displacement at 62 feet from the bottom of the hole is around 28 inches in 70 days.

PR18-02 (Saa 221182) Cumulative Displacement



Test adjustments in SAAView. If appropriate, enable them in

☐ AntiRotation Diagnostics

☐ AntiRotation Trial

☐ eXYZ Adjustment

☑ Cyclical (zigzag) Insta

☐ Zero-Ends (Horizontal)

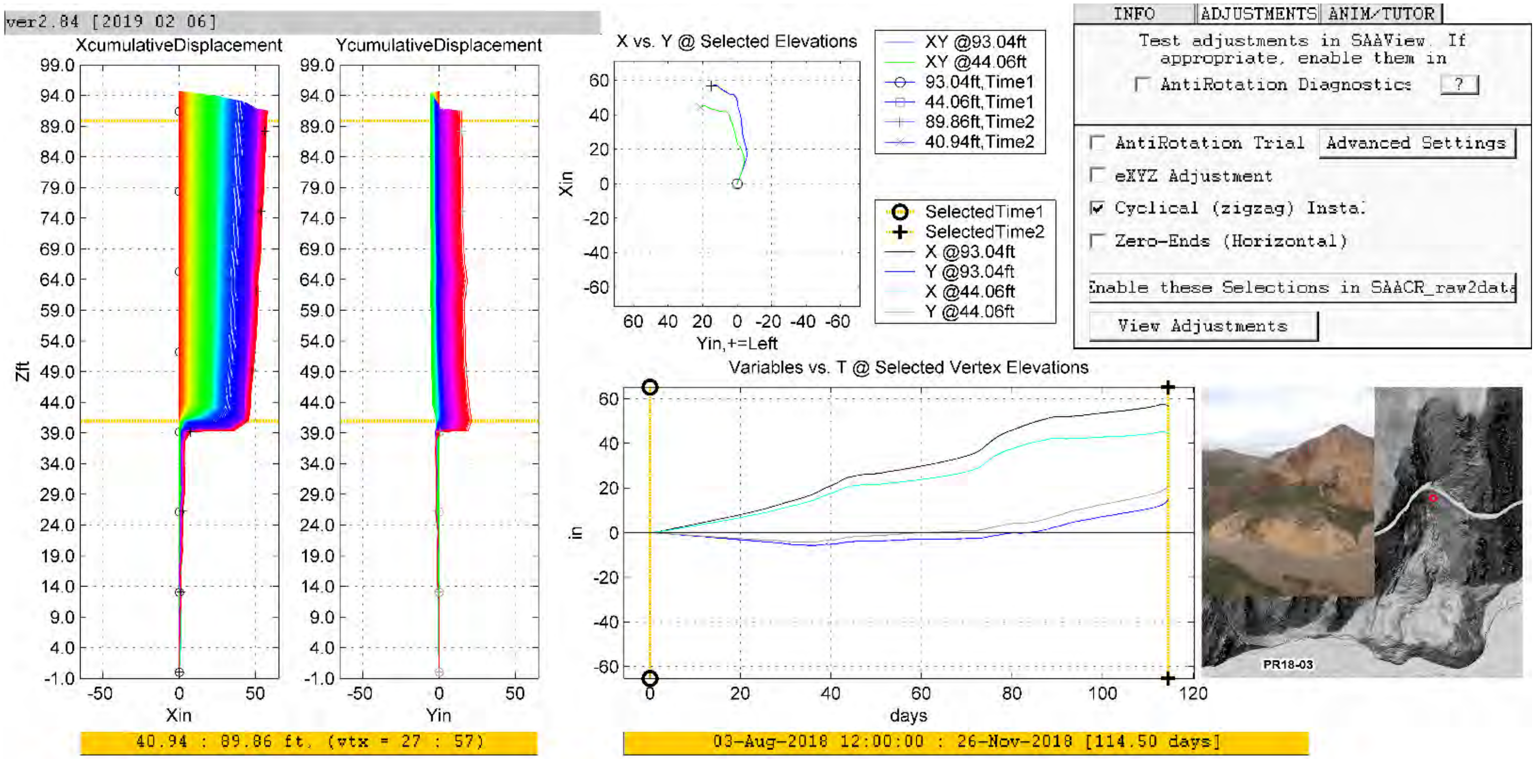
Enable these Selections in SAACR_raw2data

32.83 : 98.00 ft. (vtx = 22 : 62)

23-Jul-2018 01:54:00 : 14-Jan-2019 12:00:00 [175.42 days]

Note: SAA measurements are from the bottom of the hole to the top of the hole. Magnitude of Landslide displacement is measured in inches and represented by the rainbow colors. The left part of the graph show the total movement down slope, and the right part of the graph show the movement right.
The total landslide displacement at 33 feet from the bottom of the hole is around 68 inches in 175 days.

PR18-03 (Saa 221189) Cumulative Displacement



Test adjustments in SAAView. If appropriate, enable them in

☐ AntiRotation Diagnostic

☐ AntiRotation Trial

☐ eXYZ Adjustment

☑ Cyclical (zigzag) Insta

☐ Zero-Ends (Horizontal)

```
40.94 : 89.86 ft. (vtx = 27 : 57)
```

```
03-Aug-2018 12:00:00 : 26-Nov-2018 [114.50 days]
```

Note: SAA measurements are from the bottom of the hole to the top of the hole. Magnitude of Landslide displacement is measured in inches and represented by the rainbow colors. The left part of the graph show the total movement down slope, and the right part of the graph show the movement right.

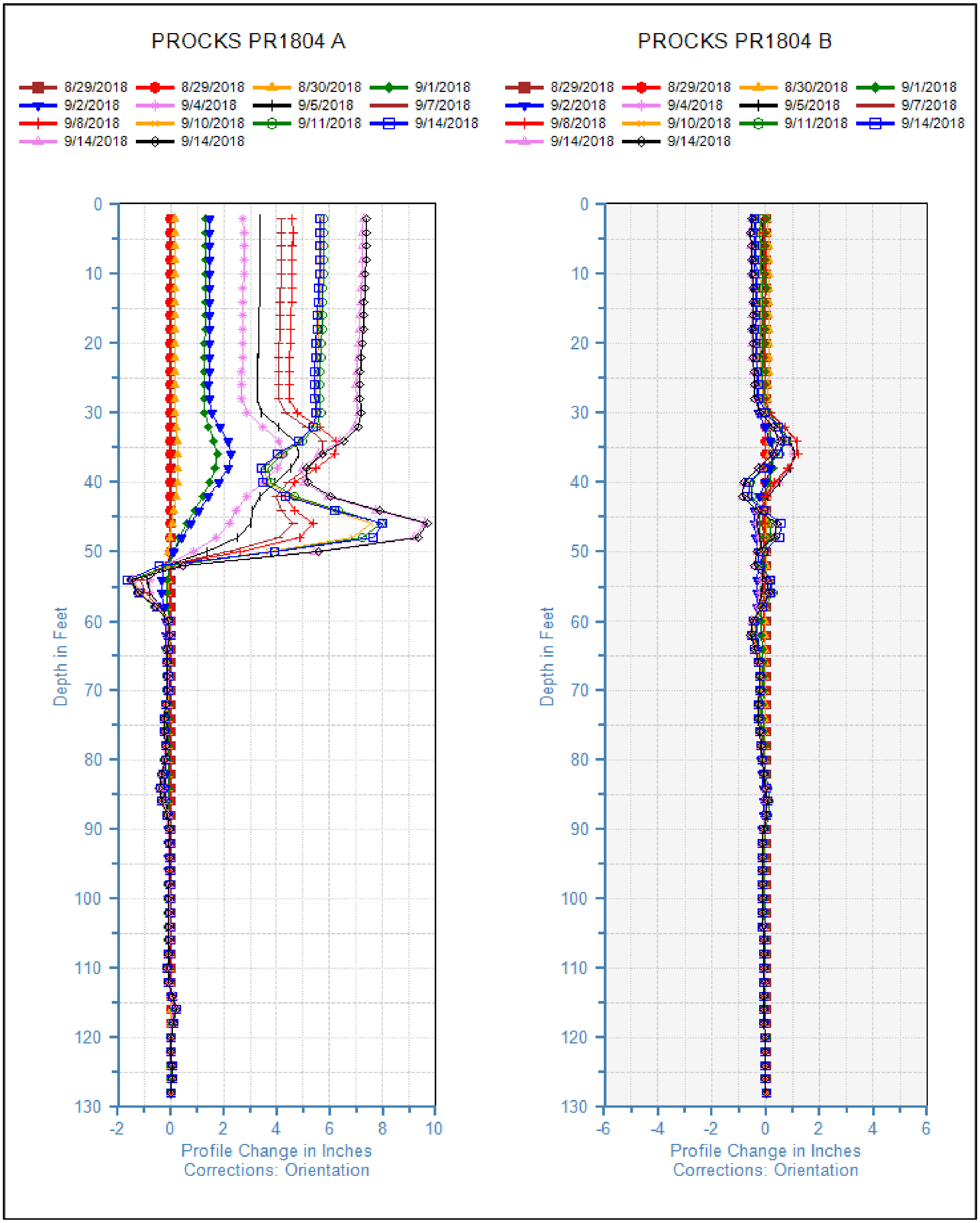
The total landslide displacement at 41 feet from the bottom of the hole is around 60 inches in 115 days.

APPENDIX F-2

Slope Inclinometer Data

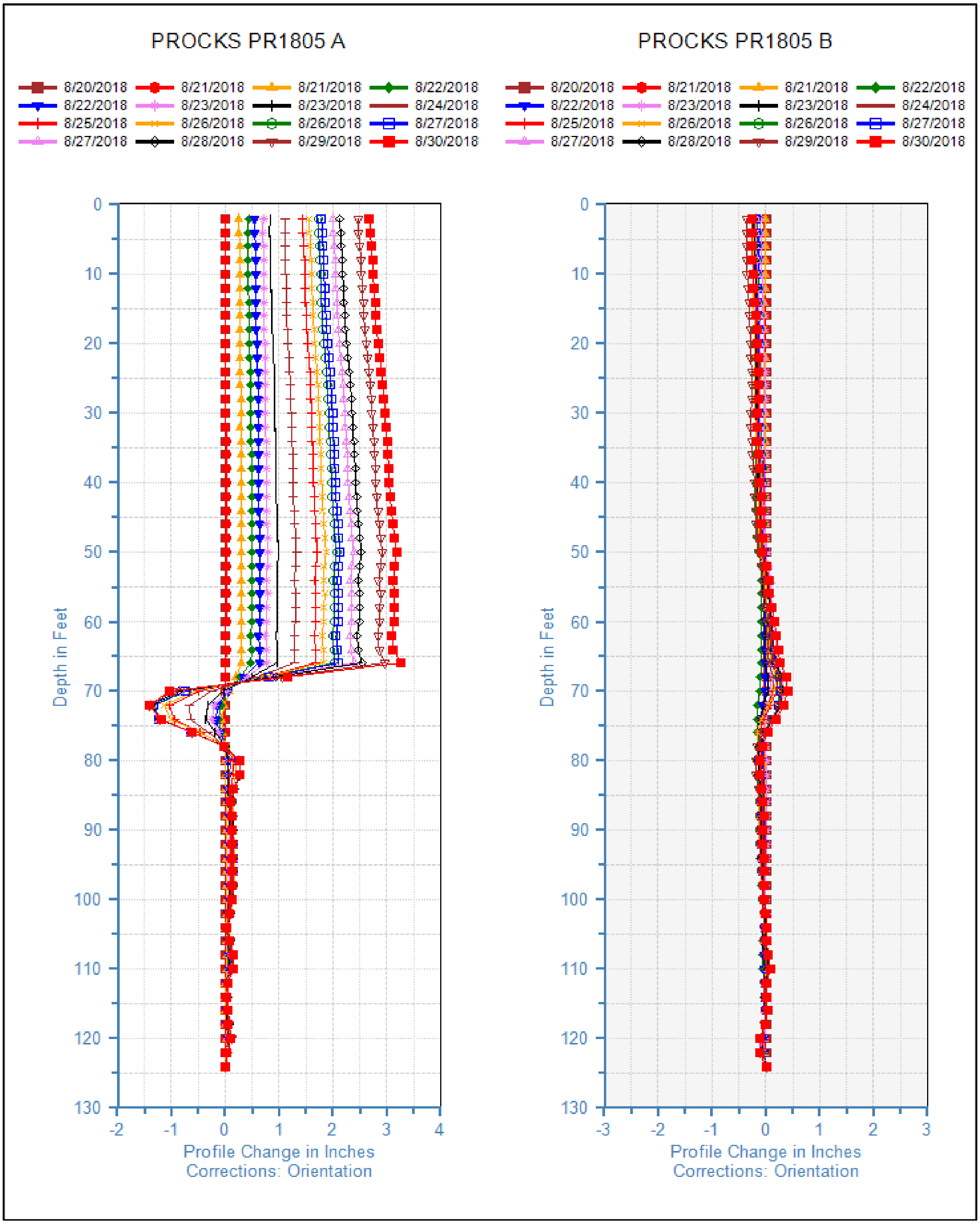
PR18-04 PROFILE CHANGE

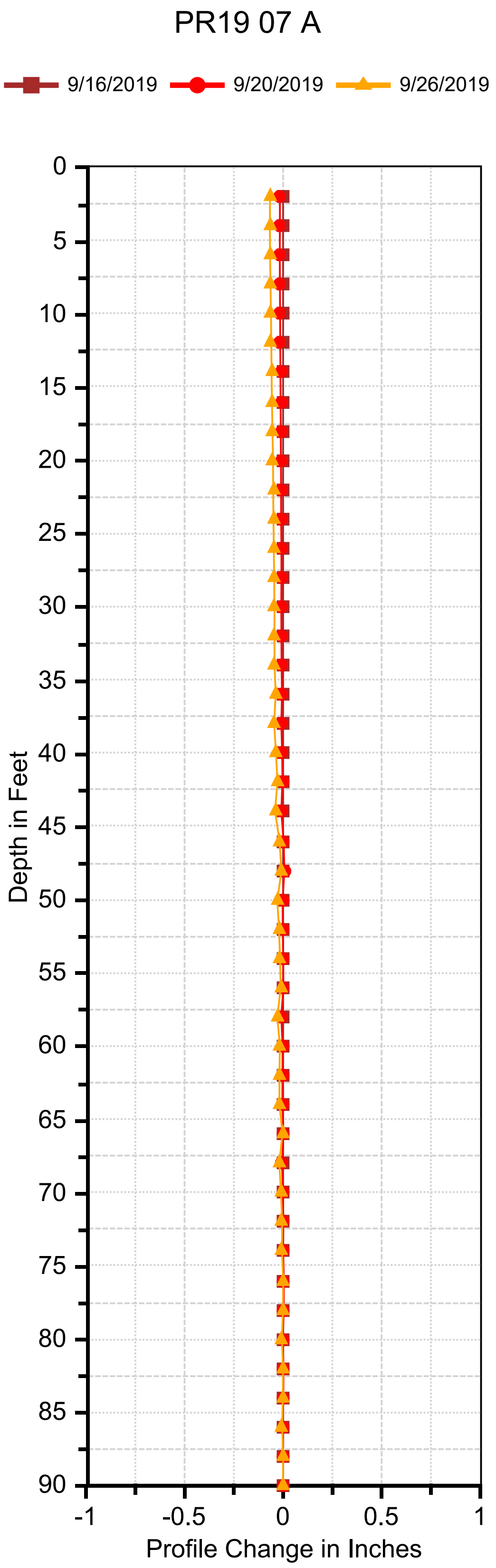
NOTE: Orientation Correction = +30 deg (30 deg clockwise)

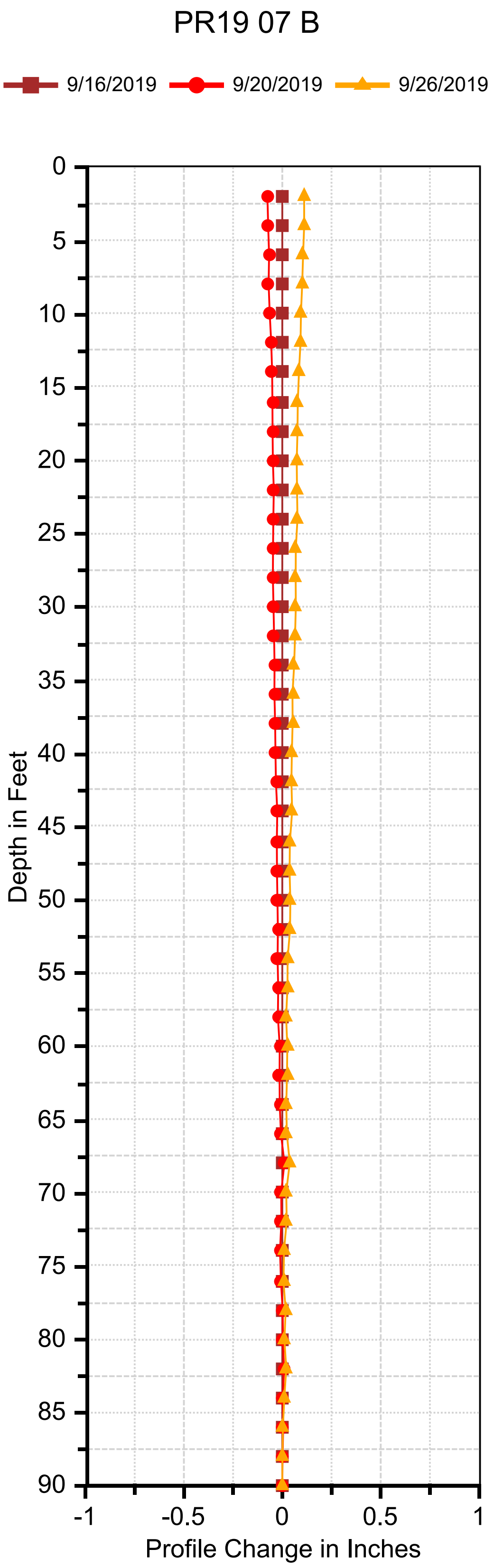


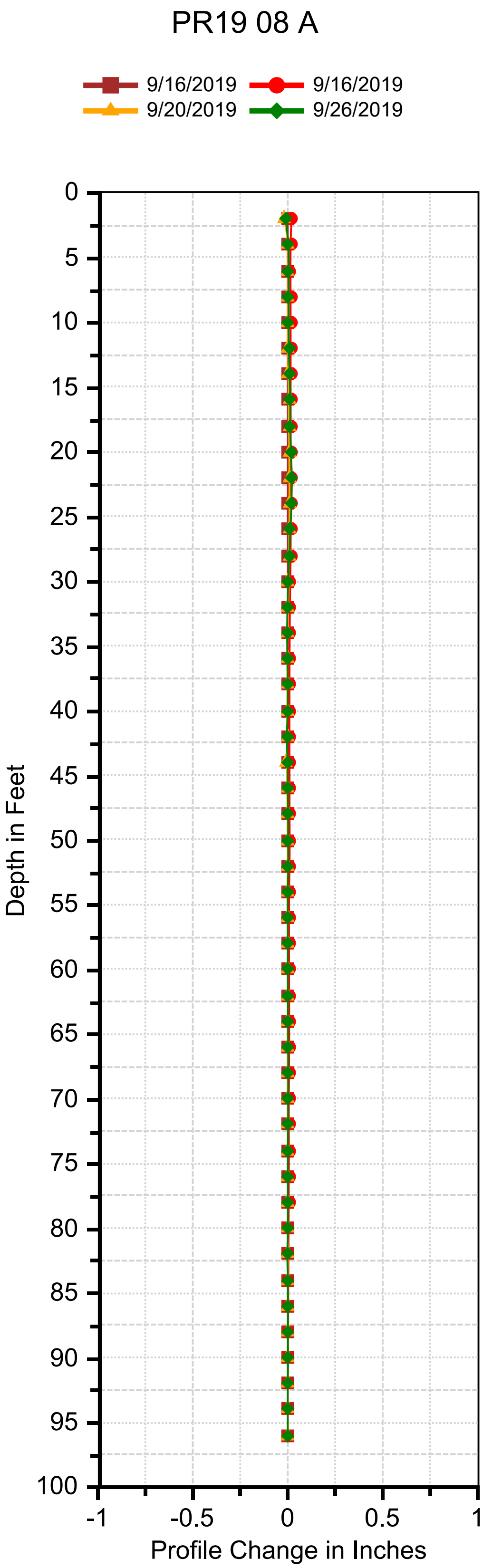
PR18-05 PROFILE CHANGE

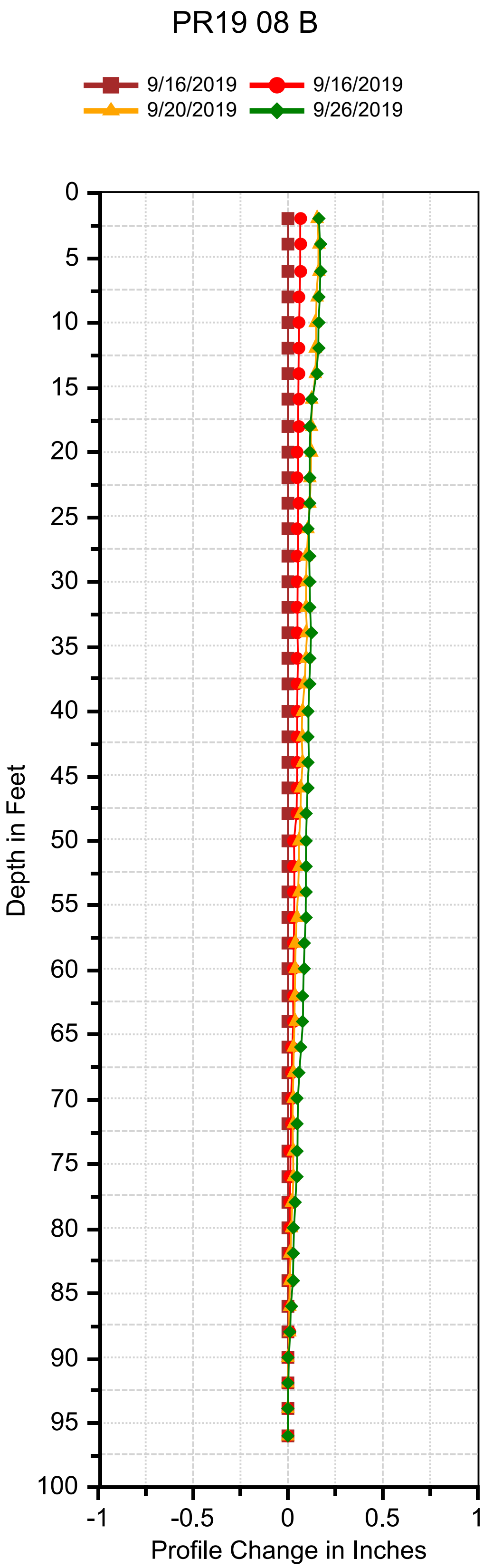
NOTE: Orientation Correction = -10 deg (10 deg counterclockwise)




PR19 07 A
9/16/2019
9/20/2019
9/26/2019
Depth in Feet
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
-1
-0.5
0
0.5
1
Profile Change in Inches

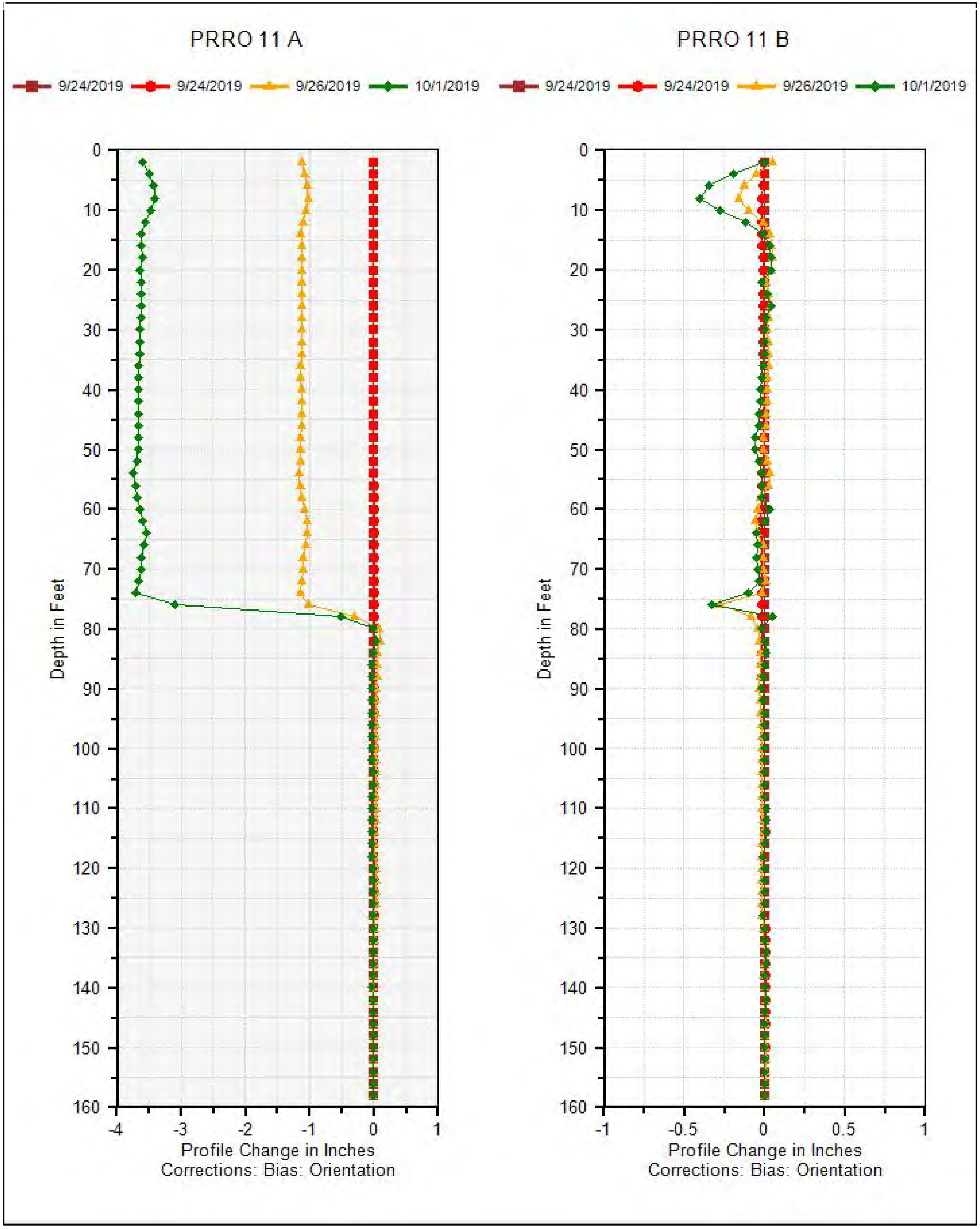

PR19 07 B
9/16/2019
9/20/2019
9/26/2019
Depth in Feet
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
-1
-0.5
0
0.5
1
Profile Change in Inches


PR19 08 A
9/16/2019
9/16/2019
9/20/2019
9/26/2019
Depth in Feet
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
-1
-0.5
0
0.5
1
Profile Change in Inches


PR19 08 B
9/16/2019
9/16/2019
9/20/2019
9/26/2019
Depth in Feet
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
-1
-0.5
0
0.5
1
Profile Change in Inches

PR19-11 PROFILE CHANGE

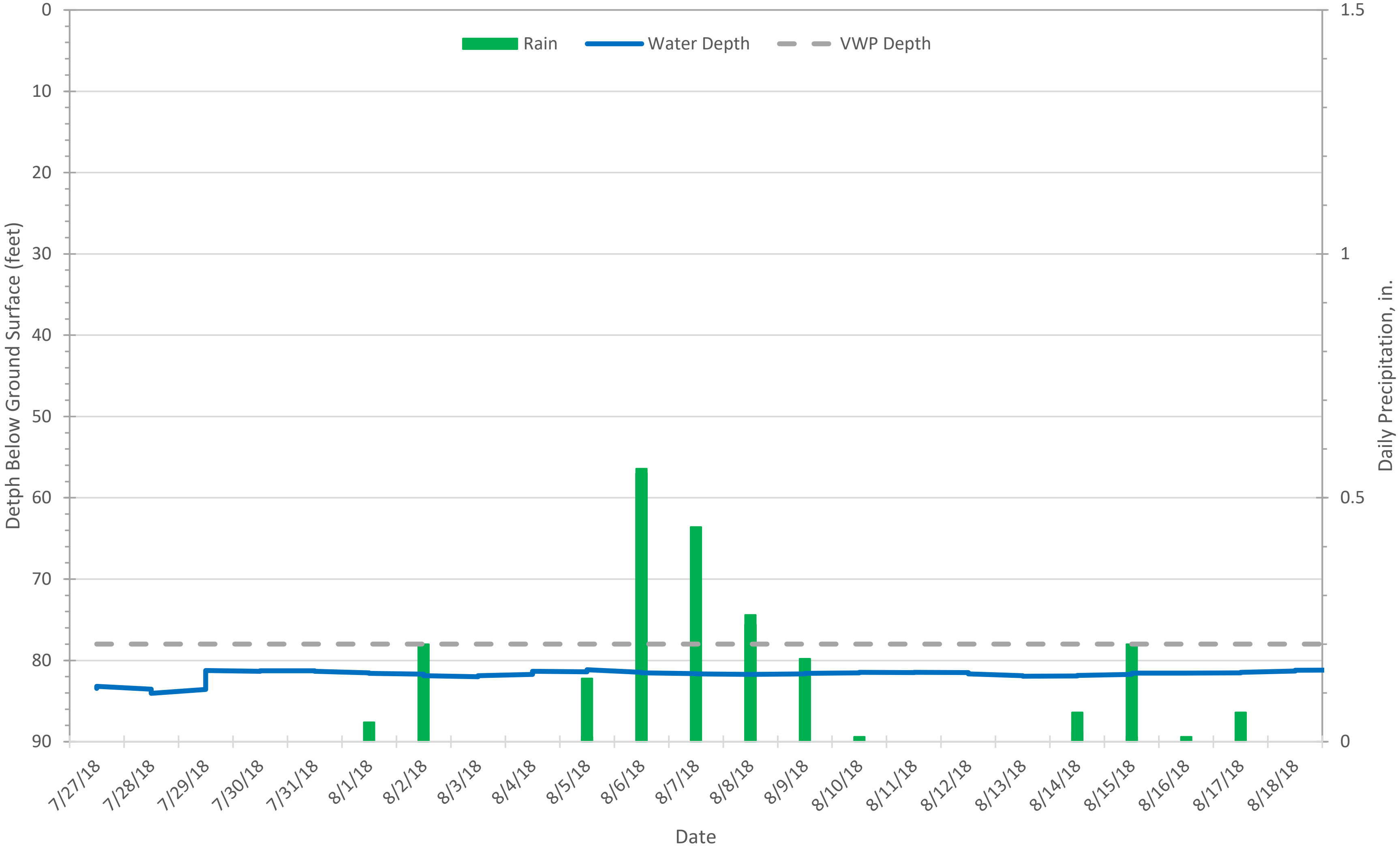
NOTE: Orientation Correction of 128° azimuth; Bias Shift Correction in A and B directions



APPENDIX F-3

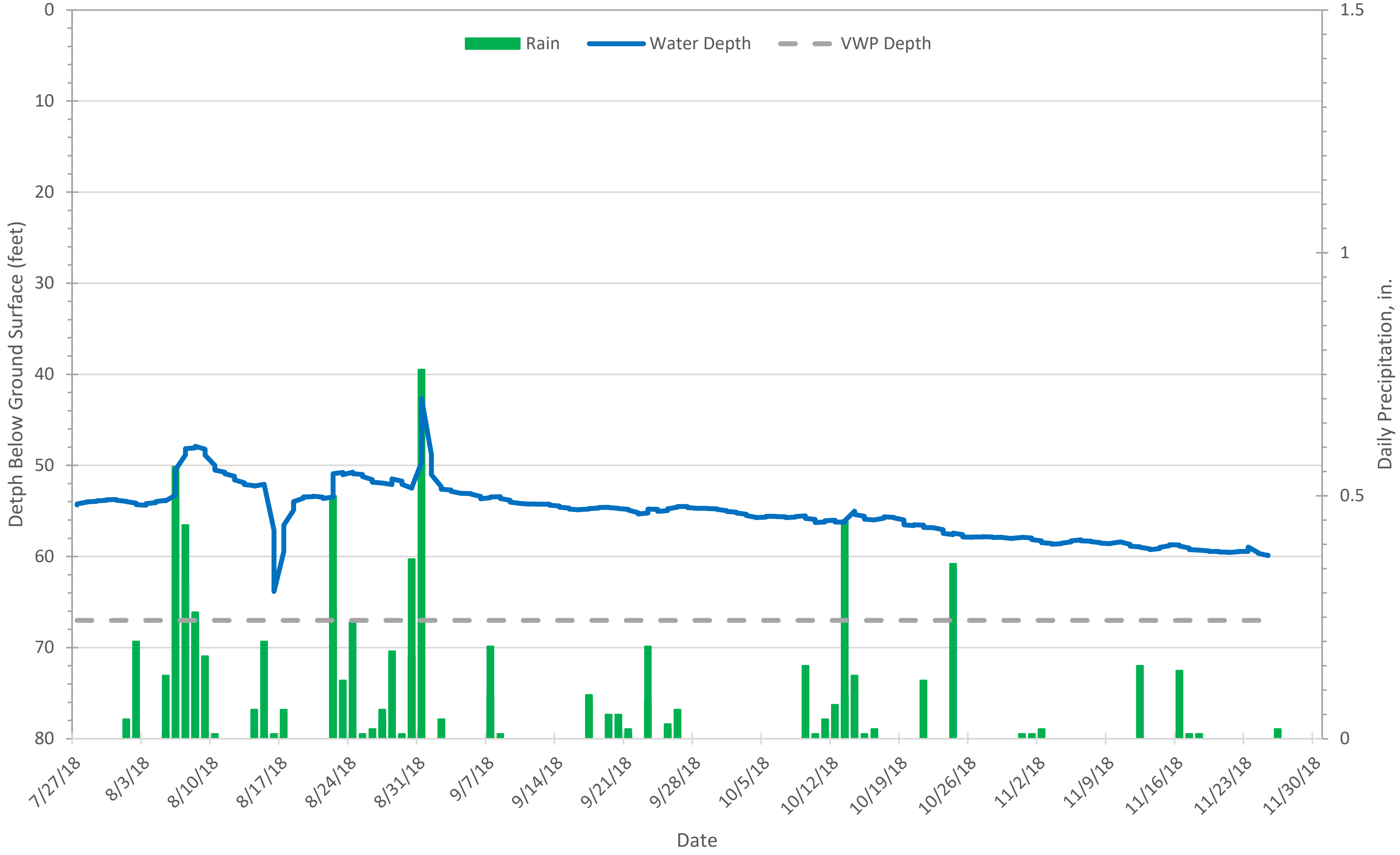
Vibrating Wire Piezometer Data

PR18-01 VWP



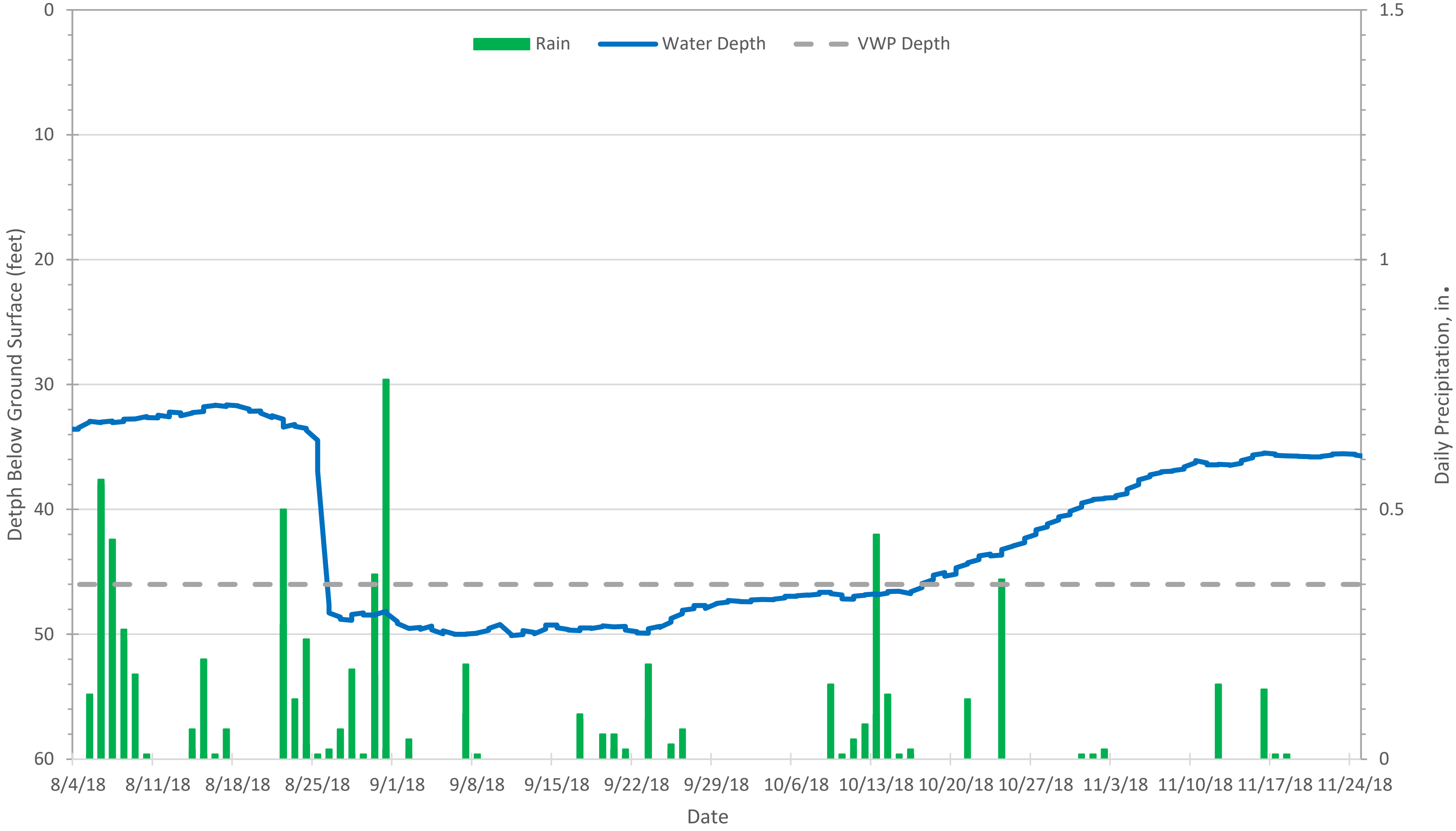
* Measurements below the placement of the VWP sensor indicate no water was measured.

PR18-02 VWP



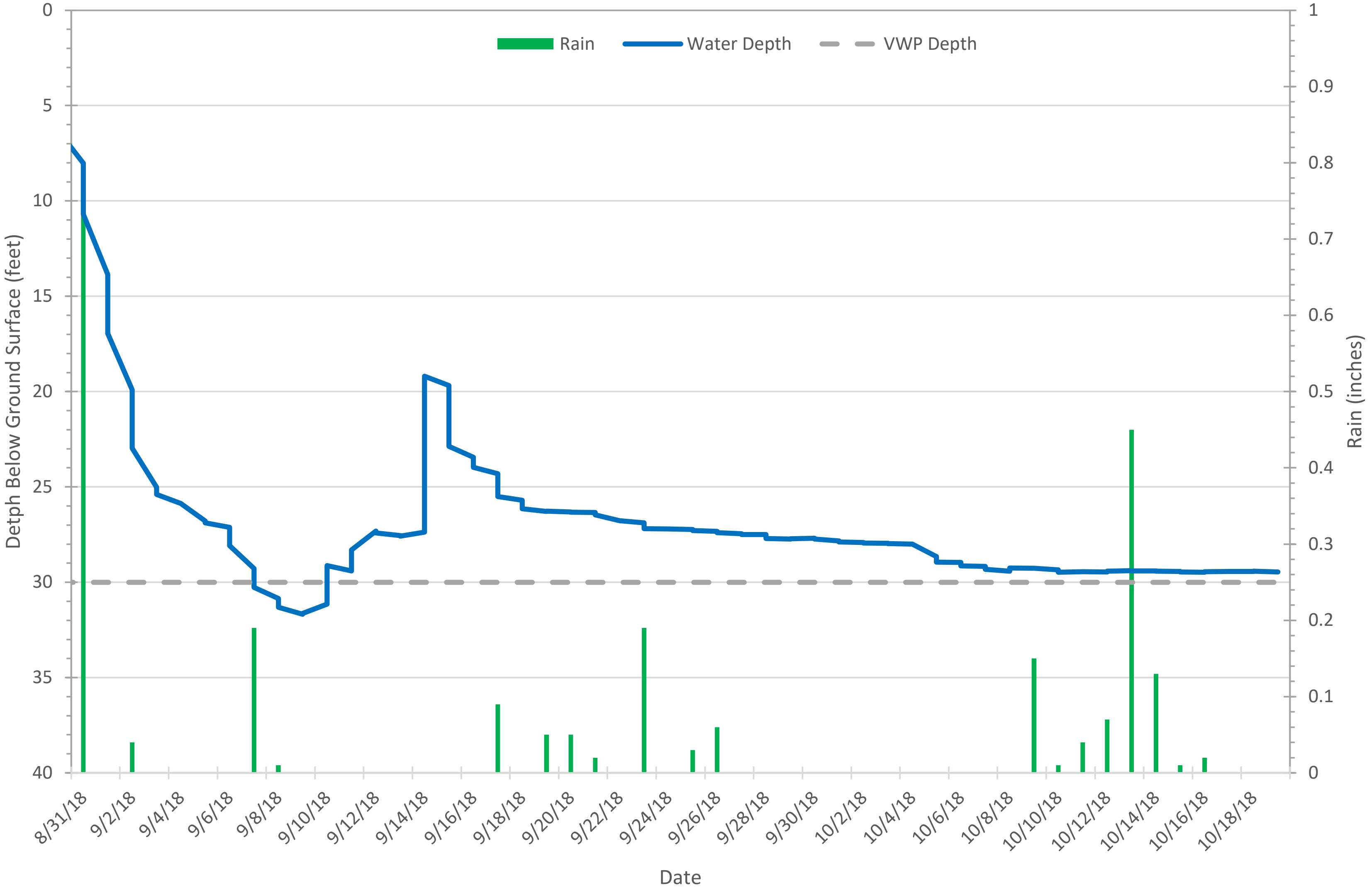
Rain
Water Depth
VWP Depth
Detph Below Ground Surface (feet)
0
10
20
30
40
50
60
70
80
Daily Precipitation, in.
1.5
1
0.5
0
7/27/18
8/3/18
8/10/18
8/17/18
8/24/18
8/31/18
9/7/18
9/14/18
9/21/18
9/28/18
10/5/18
10/12/18
10/19/18
10/26/18
11/2/18
11/9/18
11/16/18
11/23/18
11/30/18
Date

PR18-03 VWP

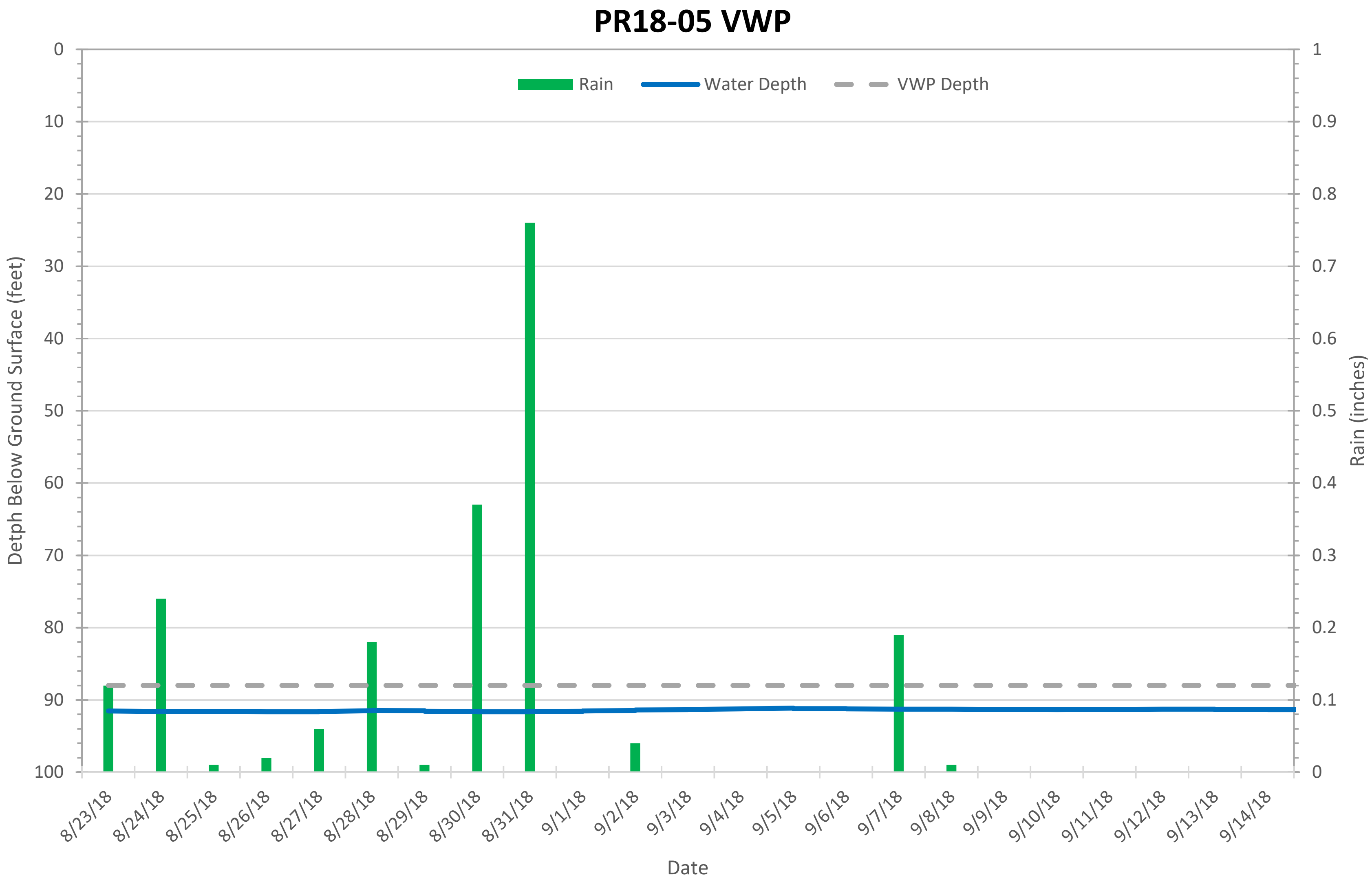


* Measurements below the placement of the VWP sensor indicate no water was measured.

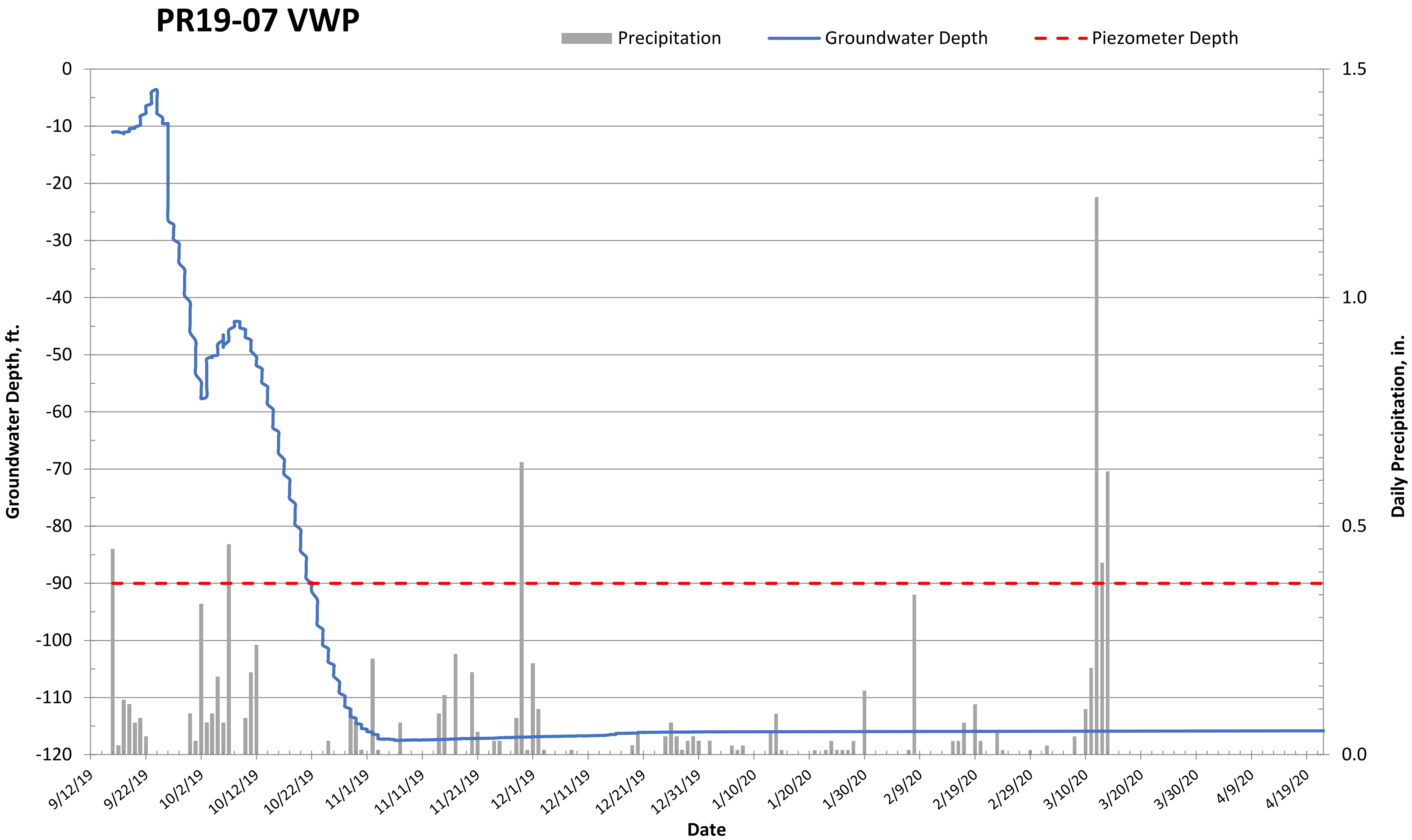
PR18-04 VWP



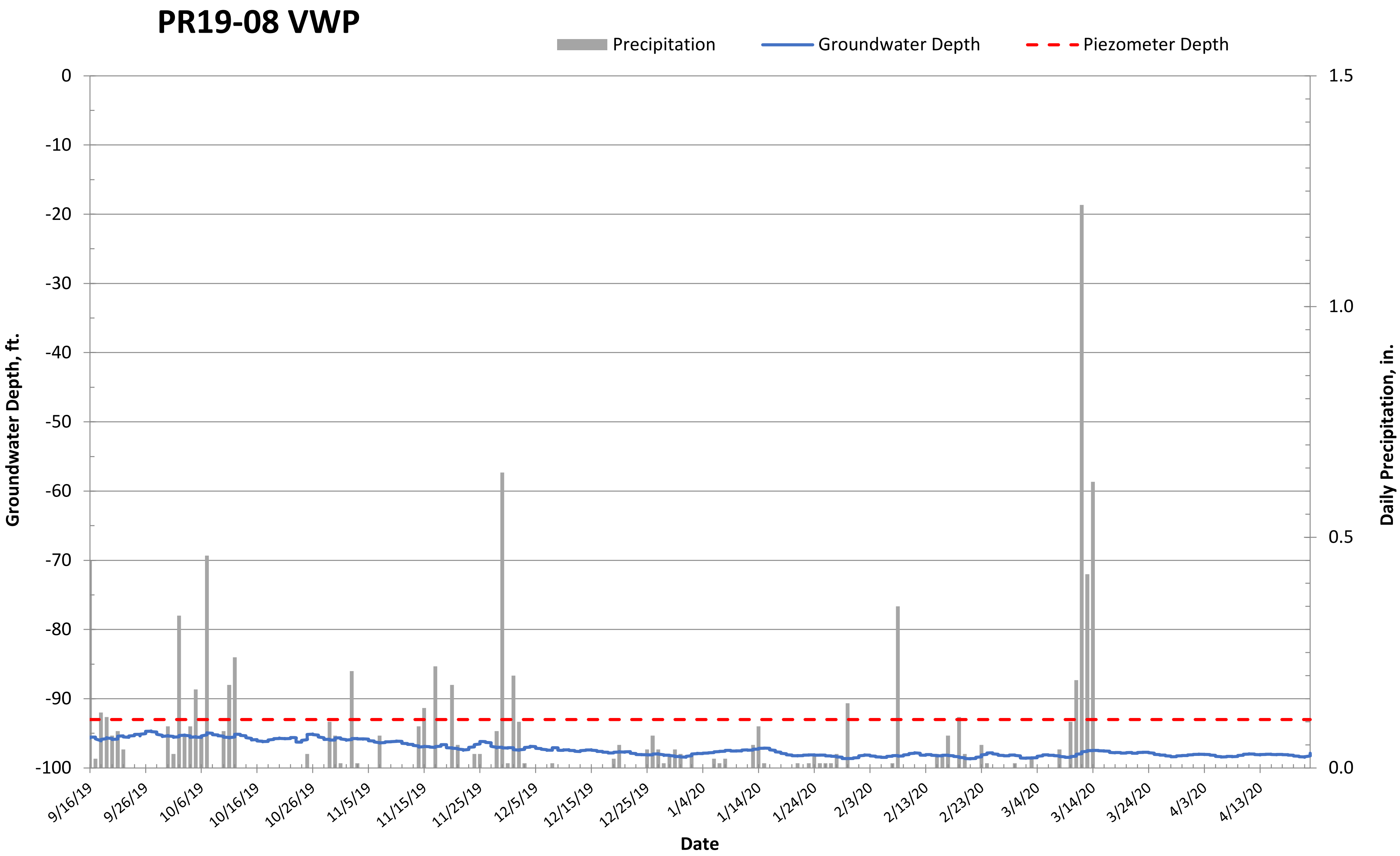
* Measurements below the placement of the VWP sensor indicate no water was measured.



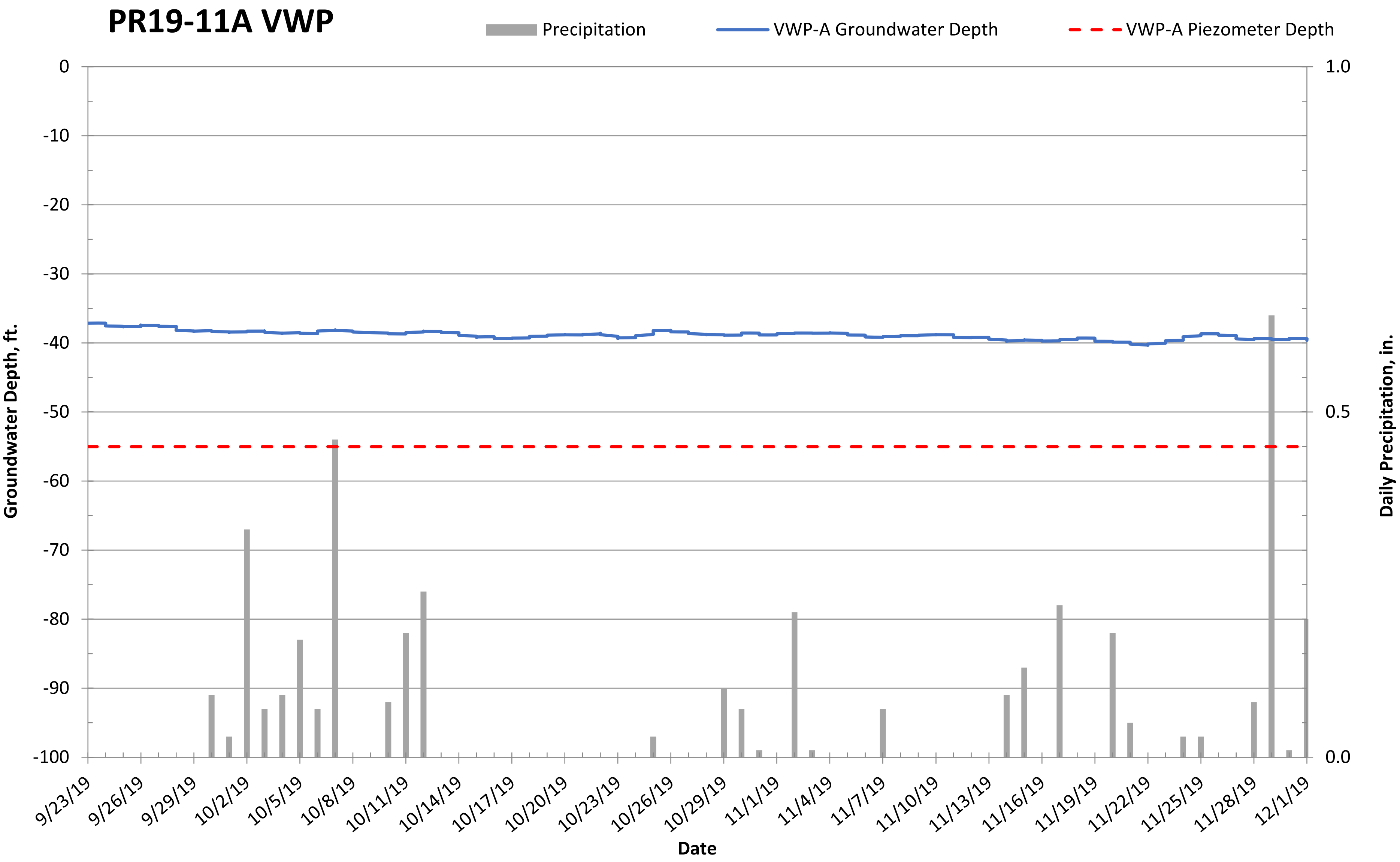
* Measurements below the placement of the VWP sensor indicate no water was measured.



* Measurements below the placement of the VWP sensor indicate no water was measured.



* Measurements below the placement of the VWP sensor indicate no water was measured.


PR19-11A VWP
Precipitation
VWP-A Groundwater Depth
VWP-A Piezometer Depth
Groundwater Depth, ft.
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Daily Precipitation, in.
1.0
0.5
0.0
Date
9/23/19
9/26/19
9/29/19
10/2/19
10/5/19
10/8/19
10/11/19
10/14/19
10/17/19
10/20/19
10/23/19
10/26/19
10/29/19
11/1/19
11/4/19
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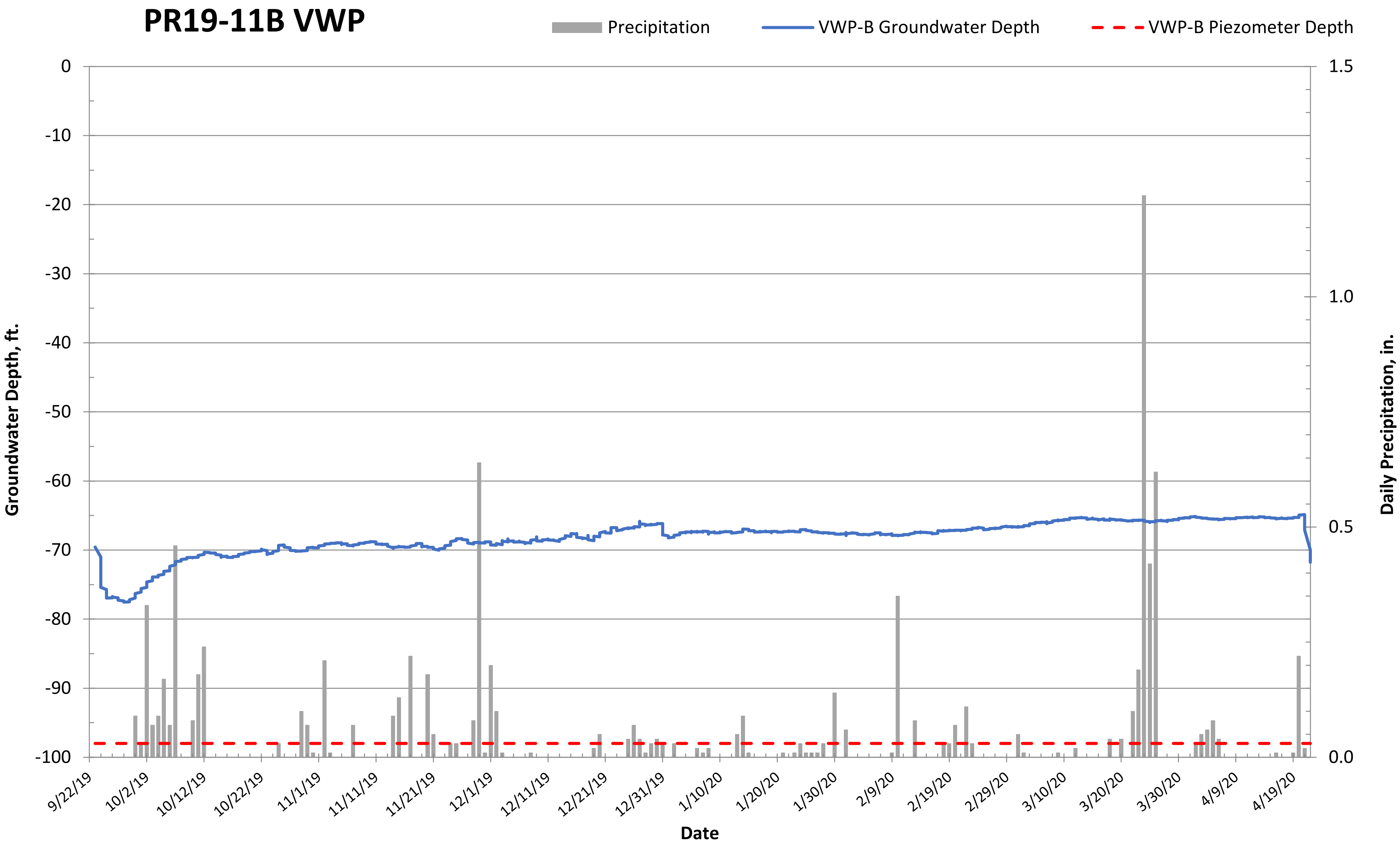
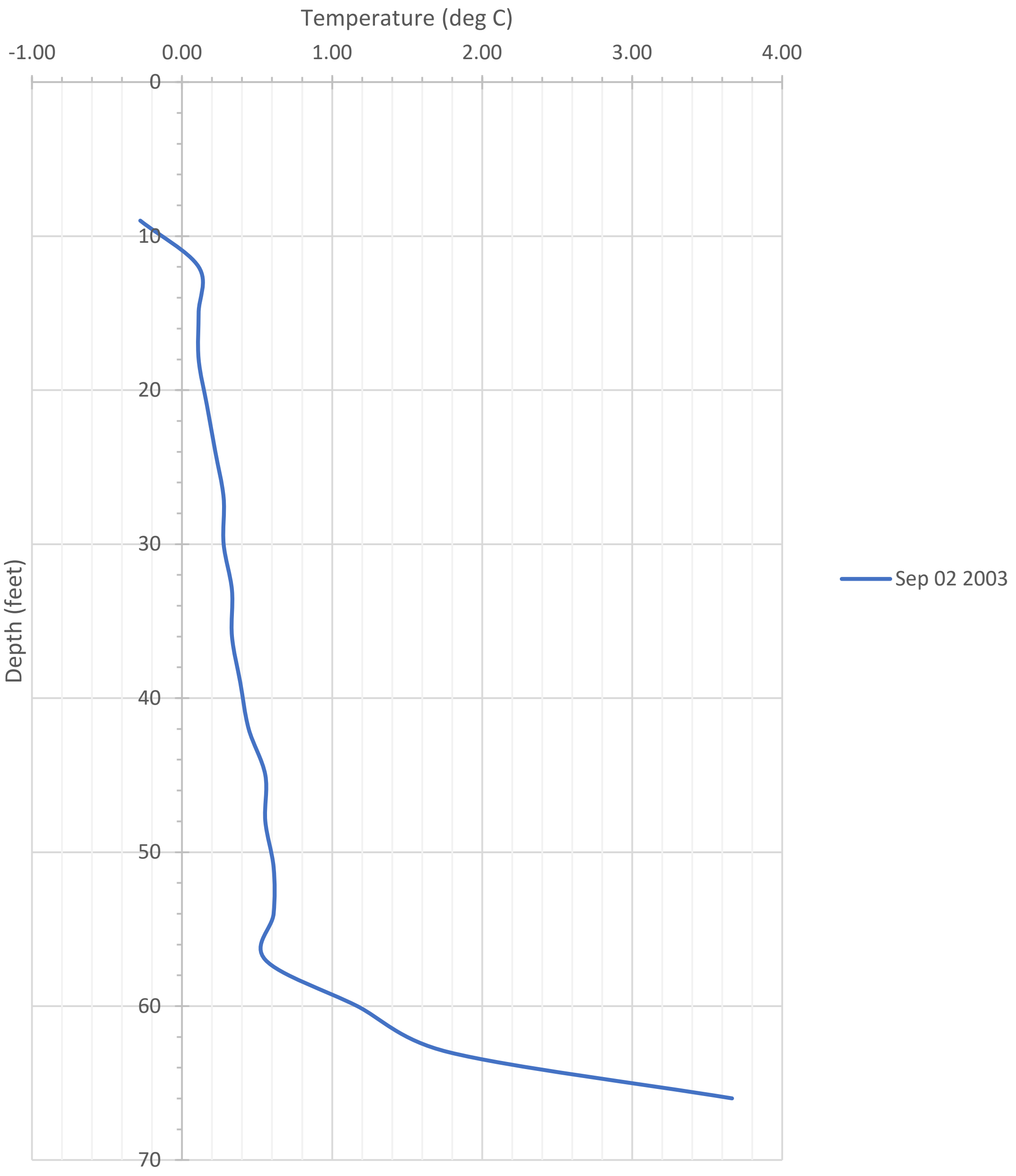
11/25/19
11/28/19
12/1/19


PR19-11B VWP
Precipitation
VWP-B Groundwater Depth
VWP-B Piezometer Depth
Groundwater Depth, ft.
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Daily Precipitation, in.
1.5
1.0
0.5
0.0
9/22/19
10/2/19
10/12/19
10/22/19
11/1/19
11/11/19
11/21/19
12/1/19
12/11/19
12/21/19
12/31/19
1/10/20
1/20/20
1/30/20
2/9/20
2/19/20
2/29/20
3/10/20
3/20/20
3/30/20
4/9/20
4/19/20
Date

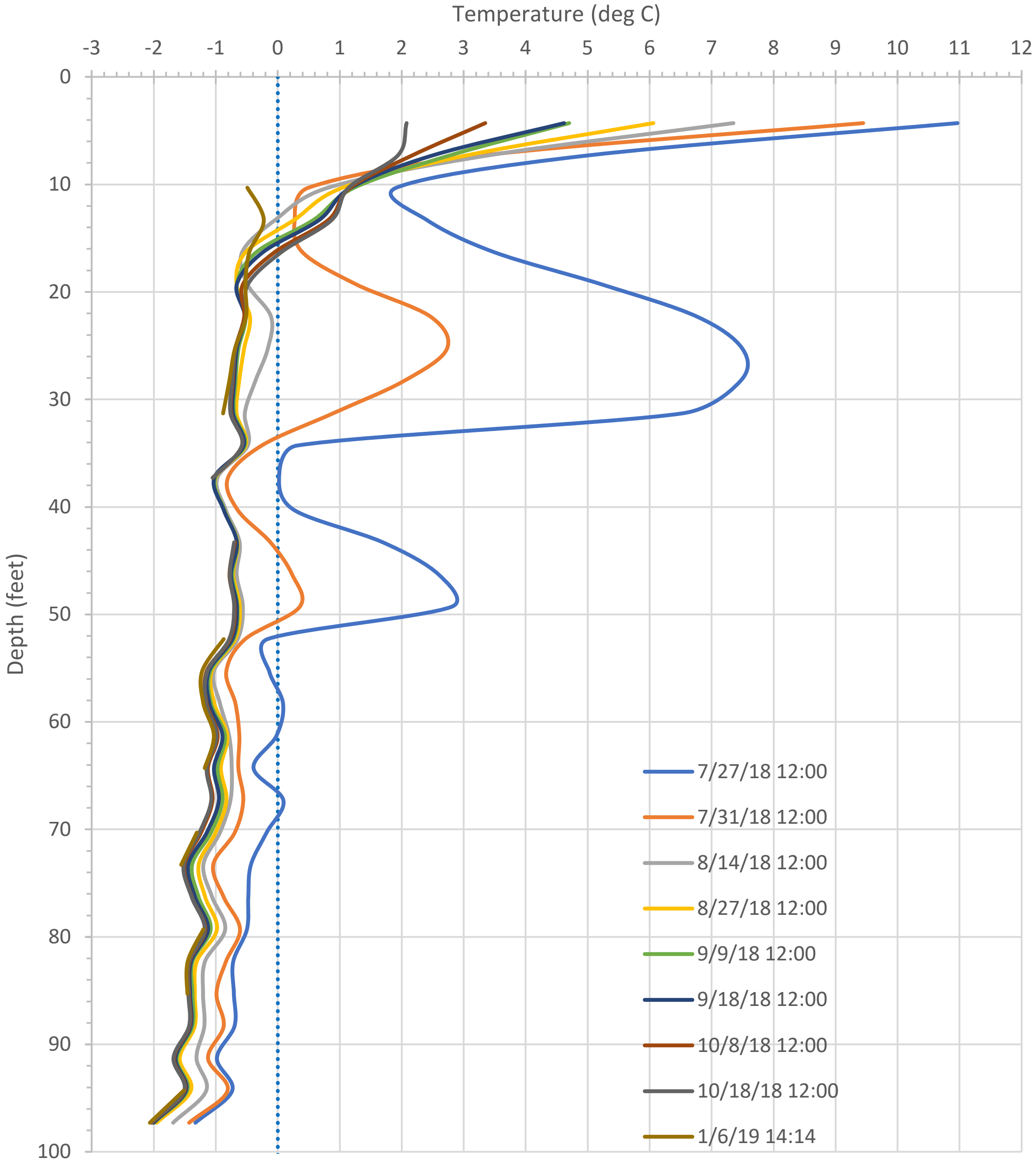
APPENDIX F-4

Thermistor Data

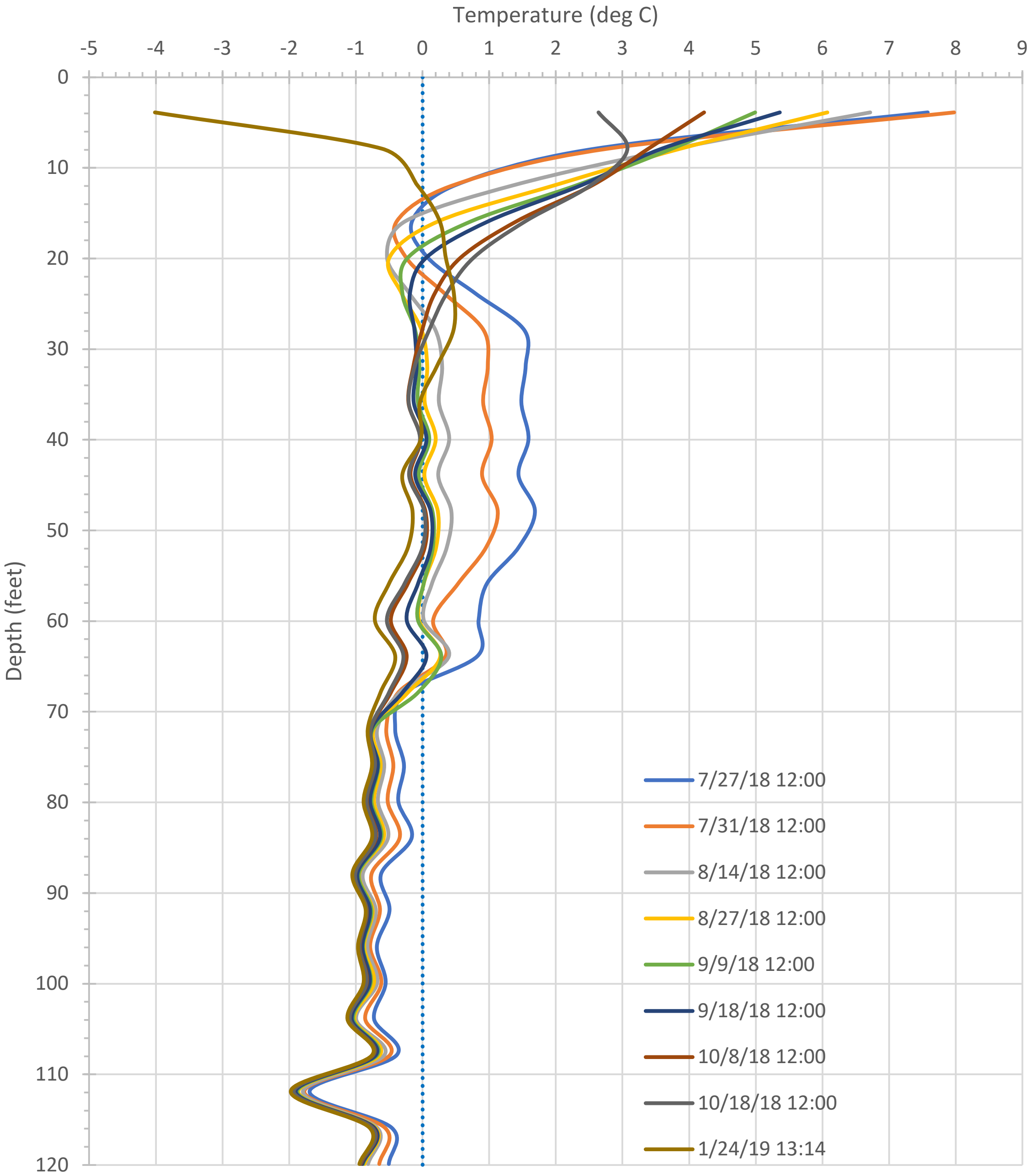
PLY03-2 Thermistor String Readings



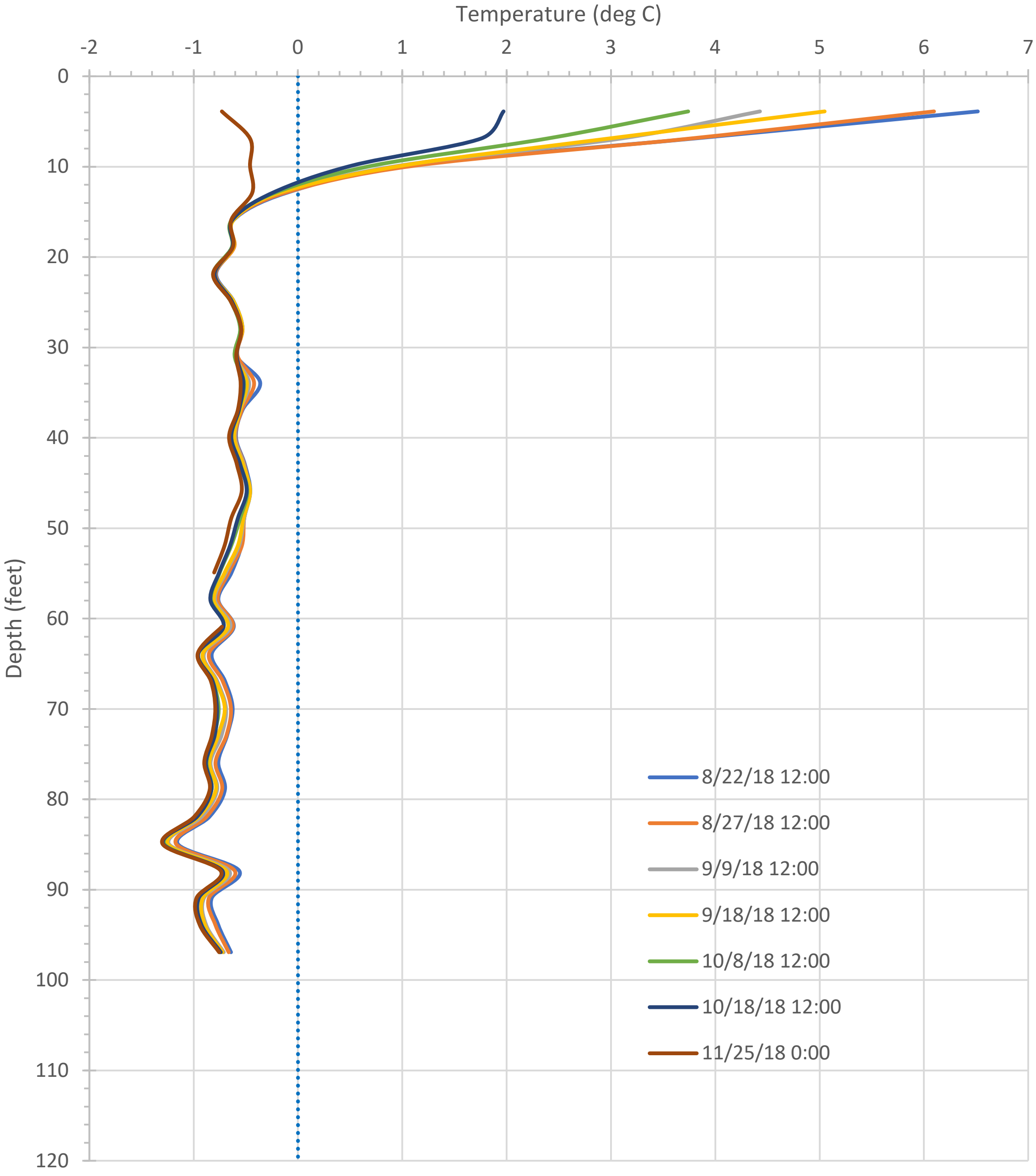
PR18-01 Thermistor String on Selected Dates

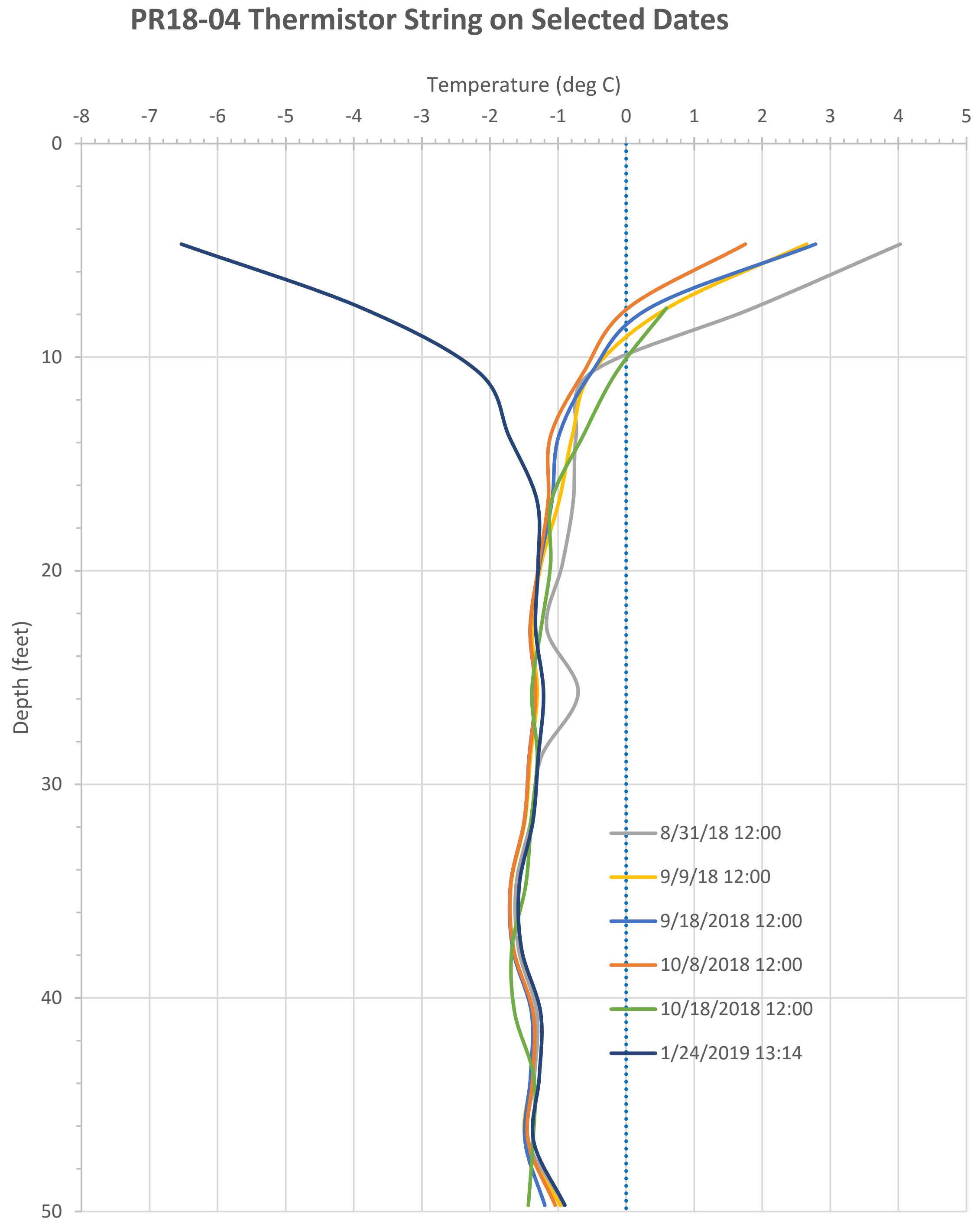


PR18-02 Thermistor String on Selected Dates

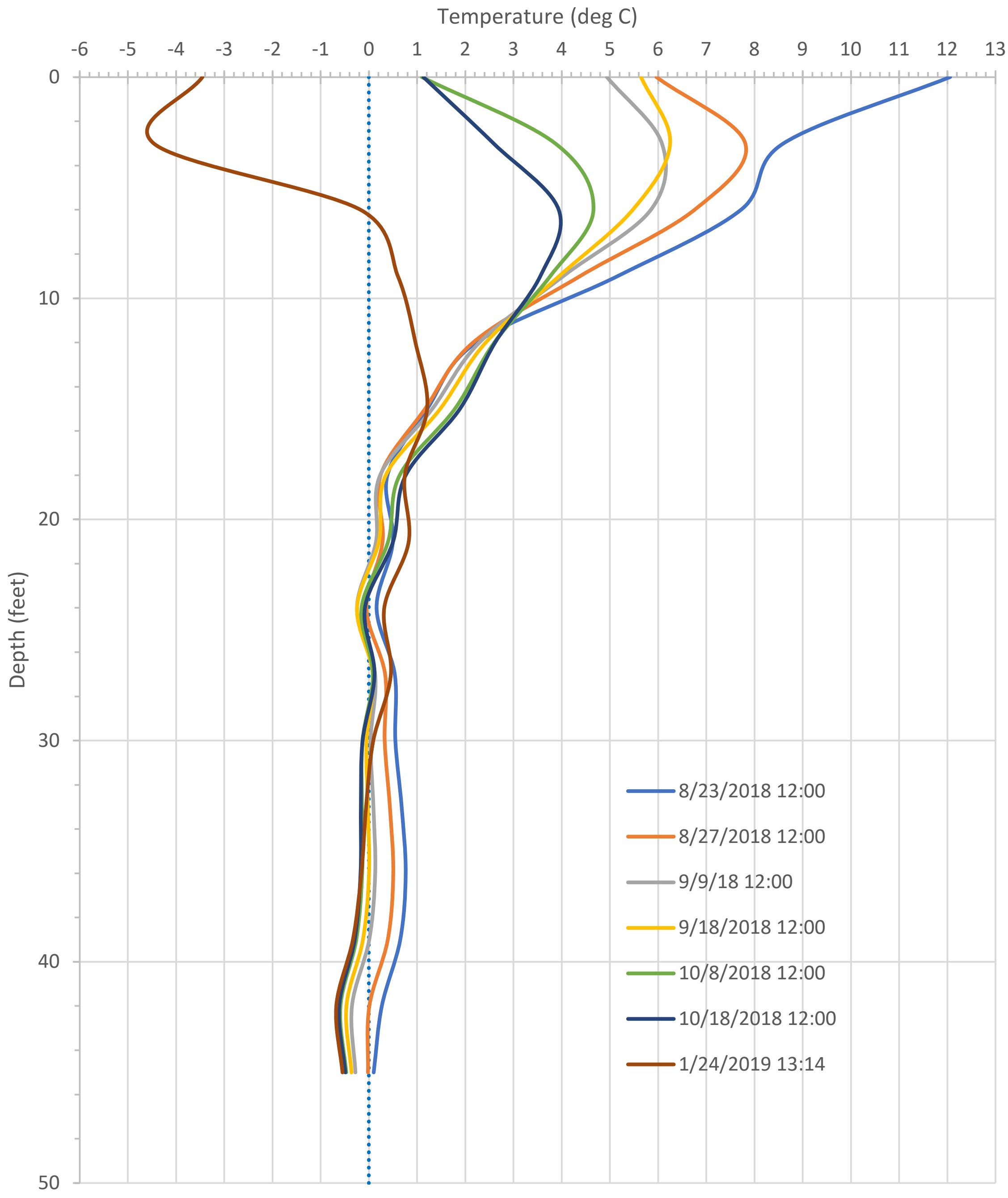


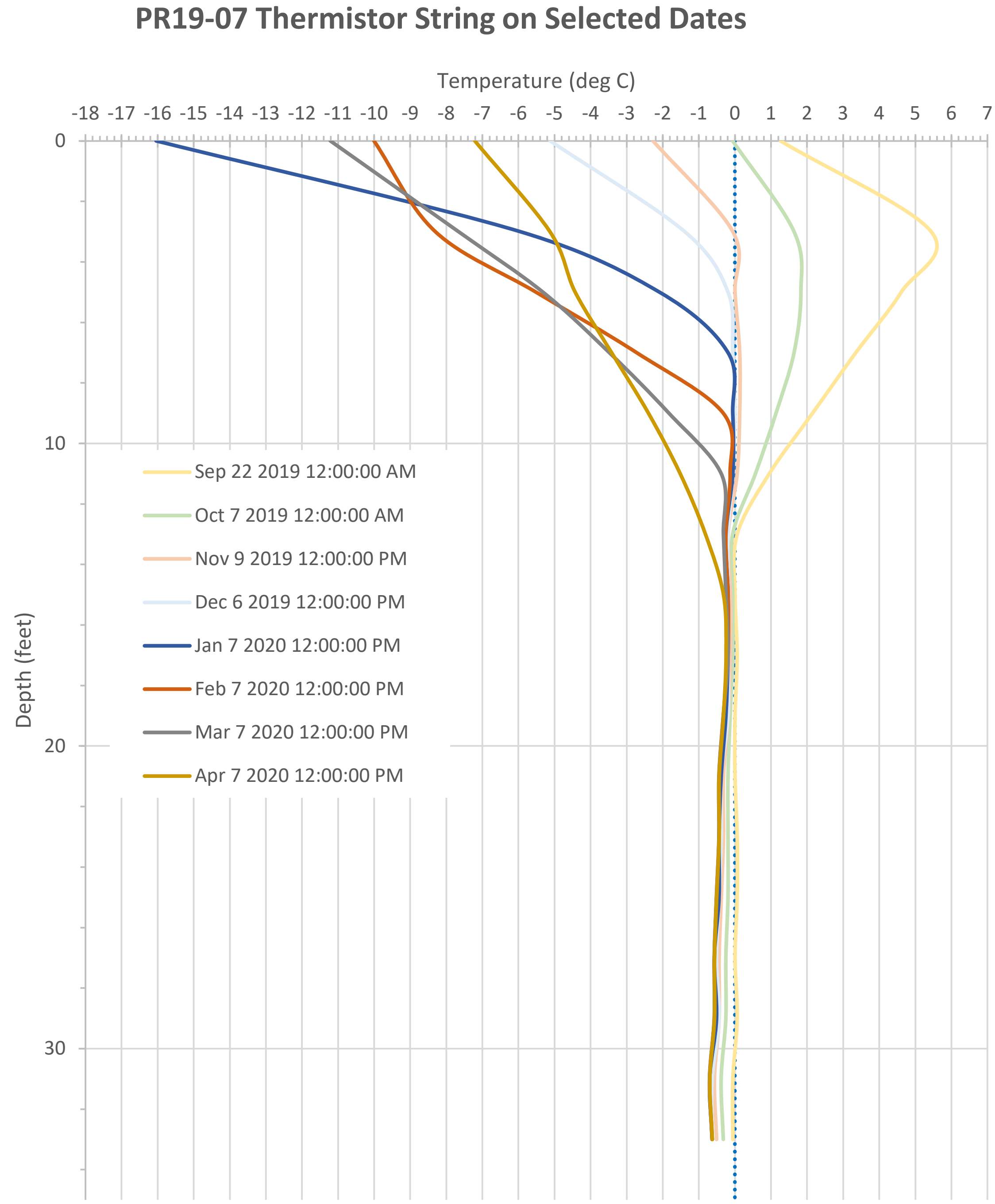
PR18-03 Thermistor String on Selected Dates

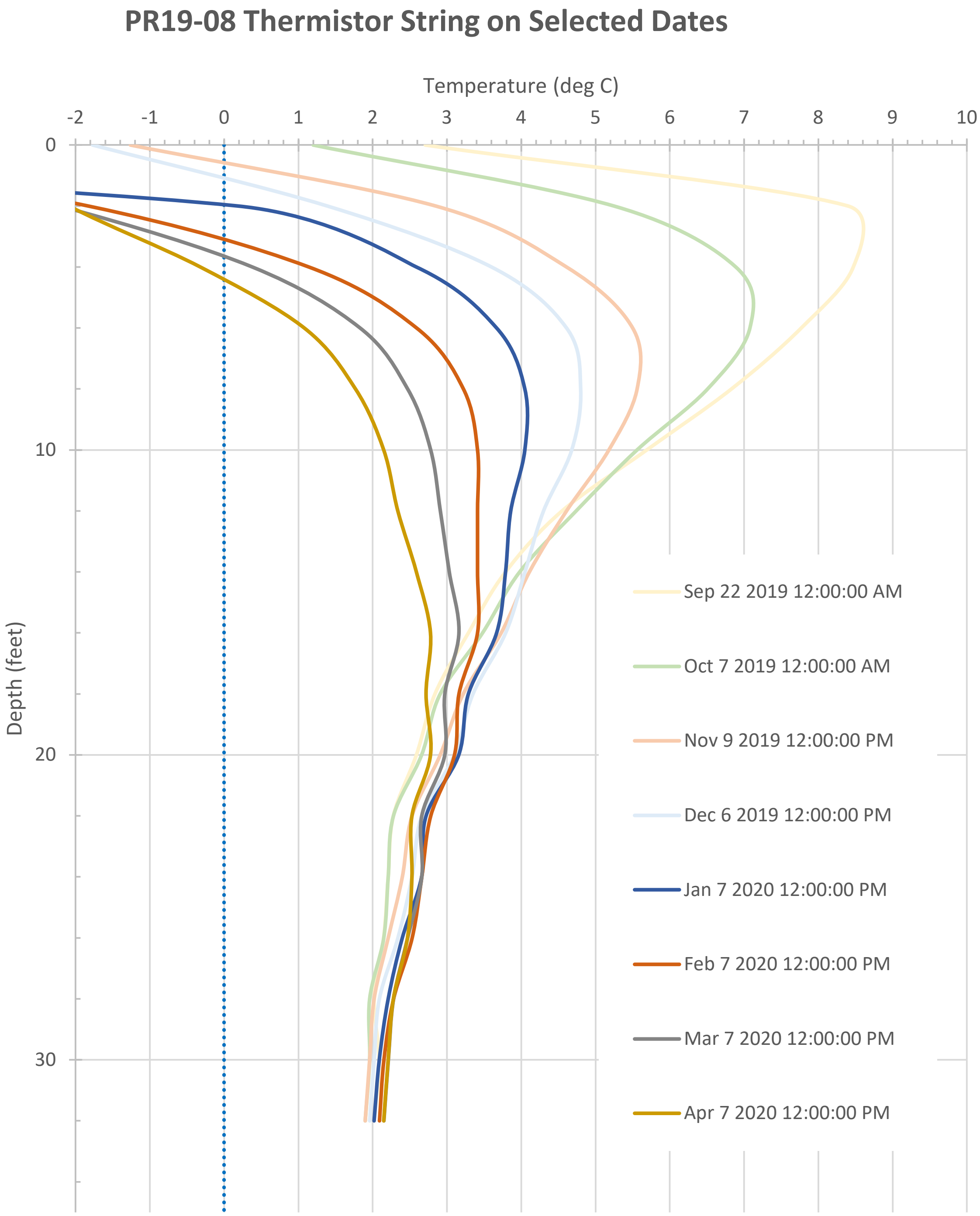



PR18-04 Thermistor String on Selected Dates
Temperature (deg C)
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
Depth (feet)
0
10
20
30
40
50
8/31/18 12:00
9/9/18 12:00
9/18/2018 12:00
10/8/2018 12:00
10/18/2018 12:00
1/24/2019 13:14

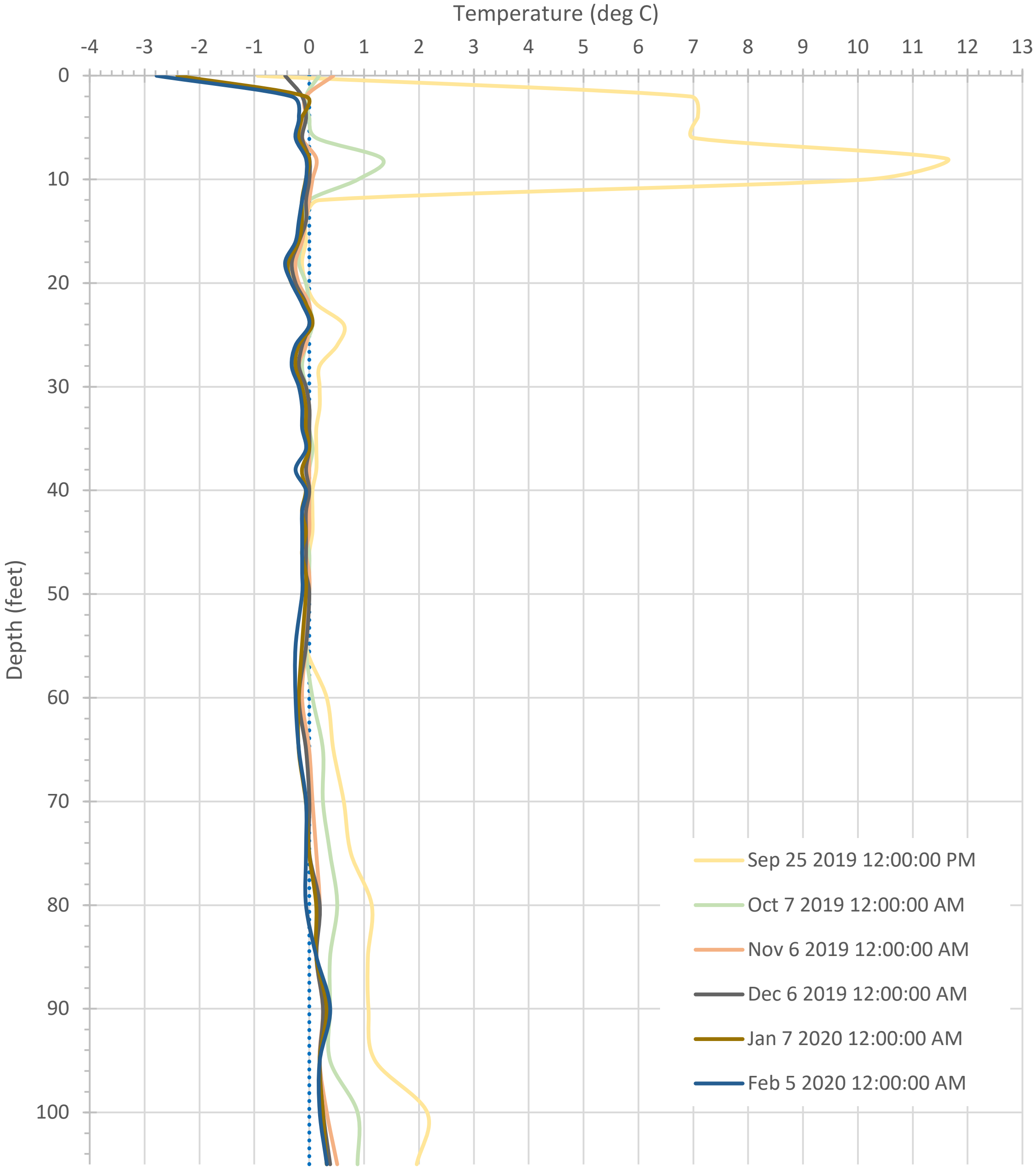
PR18-05 Thermistor String on Selected Dates




PR19-07 Thermistor String on Selected Dates
Temperature (deg C)
-18 -17 -16 -15 -14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7
Depth (feet)
0
10
20
30
Sep 22 2019 12:00:00 AM
Oct 7 2019 12:00:00 AM
Nov 9 2019 12:00:00 PM
Dec 6 2019 12:00:00 PM
Jan 7 2020 12:00:00 PM
Feb 7 2020 12:00:00 PM
Mar 7 2020 12:00:00 PM
Apr 7 2020 12:00:00 PM


PR19-08 Thermistor String on Selected Dates
Temperature (deg C)
-2
-1
0
1
2
3
4
5
6
7
8
9
10
0
10
20
30
Depth (feet)
Sep 22 2019 12:00:00 AM
Oct 7 2019 12:00:00 AM
Nov 9 2019 12:00:00 PM
Dec 6 2019 12:00:00 PM
Jan 7 2020 12:00:00 PM
Feb 7 2020 12:00:00 PM
Mar 7 2020 12:00:00 PM
Apr 7 2020 12:00:00 PM

PR19-11 Thermistor String on Selected Dates



APPENDIX G

Additional Research-Anna Stanczyk Thesis

AN INVESTIGATION OF PRETTY ROCKS DEBRIS SLIDE, MILE 45.4 DENALI PARK ROAD, DENALI NATIONAL PARK, ALASKA

Anna Stanczyk

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ABSTRACT

Pretty Rocks debris slide is currently the top-ranked geohazard in Denali National Park based on its midpoint location in the Denali Park Road and because it exhibits persistent creep-style movement due to historically unstable underlying volcanic ashes within the Teklanika Formation. Aerial imagery and ground investigation indicate multiple deposits from previous failures below the failure slope. Ground-based mapping revealed internal drainage of sediment-laden water into and through the lower slope. Field observation and bore log data confirmed pervasive clays throughout the slope while Atterberg tests indicated swelling and susceptibility to frost in multiple sediment samples. The bore logs indicate that ground ice is present below the road surface. These data indicate a history of failure at Pretty Rocks debris slide and suggest that modern slope movement is occurring due to saturation and lubrication of the slope by surface water drainage, as well as the presence of fat clays and ground ice. This study suggests the classification of Pretty Rocks debris slide as an *active composite very slow moist to wet compound debris slide-very rapid wet debris flow* based on the modified Varnes classification system (1978). Overall, this study provides new insight on failure history and mechanisms to support risk assessment and direct mitigation decisions made by the National Park Service.

INTRODUCTION

Project Area: Pretty Rocks

The informally-named Pretty Rocks Debris Slide (Pretty Rocks) is a large slope failure occurring in Polychrome Pass, 45.4 miles west of the entrance to Denali National Park (the Park) and one-half mile east of Polychrome Overlook. It is located at the midpoint of the Park's single road, which continues to mile 92 in the Kantishna Hills and provides access for park visitors and property owners of the Park's inholdings (Fig. 1). Pretty Rocks has been experiencing gradual creep-style failure for roughly 20 years, though the rate of downhill movement has increased in the last 3-4 years (Capps, pers. comm. 2016). This slope failure poses a major threat to the infrastructure of the Park as the slip surface underlies Denali Park Road on a steep colluvium slope where rerouting would be arduous (Fig. 2). The purpose of this report is to present new data on geomorphological features, surface water drainage, and geologic setting of Pretty Rocks, and to compare these surface observations with existing data including difference elevation models, and drilling bore logs. These data are then used to classify Pretty Rocks, and to make inferences regarding past failures, failure mechanisms, the surficial extent of the failure, and the geometry of the slip plane.

Related Failures

In addition to its direct impact on the road, Pretty Rocks is significant because it is one of four known slope failures that are taking place in the same volcanic Teklanika Formation (the Teklanika) and directly affect the road (Fig. 1). (At least one other location of failure in the Teklanika is also known, although it does not have an impact on infrastructure.) These failures include, from east to west, the Igloo Creek Debris Slide (mile 37.7), Bear Cave Slump (mile 44.9), and the Polychrome Overlook slump (mile 45.8). The Igloo Creek Debris Slide occurred in October 2013 and is attributed to groundwater seepage, frost heaving, and an increase in permafrost thaw (Capps et al 2016). The slip surface was exposed following the slide and found to be a clay layer derived from Teklanika ash deposits. Second, the Bear Cave Slump is composed of unconsolidated materials that has been experiencing slow, downhill movement since the early 1990s. Regular monitoring began in 1993 and groundwater rerouting efforts in 1999 have slowed failure motion according to annual surveys (Capps et al 2016). Last, a slump at Polychrome Overlook took place in 2002 following increased precipitation. The slump originated in Teklanika clay which was removed and infilled with preferable road material. Perforated pipes were also added to divert water away from the area (Capps et al 2016). In all cases, movement is correlated with clay layers produced by alteration of Teklanika volcanic ash. This investigation of Pretty Rocks hopes to contribute additional understanding of failures in the Teklanika Formation – both current and future.

GEOLOGIC BACKGROUND

Polychrome Pass, including the Pretty Rocks failure area, is located in the Central Alaska Range. It is part of the Mesozoic McKinley terrane which is bounded on the south by the Denali Fault and on the north by the Hines Creek Fault, and composed primarily of Mesozoic sedimentary rocks and Pennsylvanian – Triassic volcanic rocks (Trop and Ridgway 1997). Later formations overlie the accreted terrane, including the late Cretaceous sedimentary Cantwell Formation (90 Ma) (Trop and Ridgway 1997), the Tertiary volcanic Teklanika Formation (55 – 60 Ma) (Brease 2004), and the poorly consolidated Tertiary Nenana Gravel (11.62 to 3.6 Ma) (Csejtey et al. 1997) (Fig. 3).

Pretty Rocks is occurring in the volcanic Teklanika Formation within Polychrome Pass. Here, the Teklanika is folded into an approximate east-west trending syncline (Warhaftig et al 1963) and Pretty Rocks is located in a south-facing slope of the syncline's northern flank (Fig. 3). The Paleocene-epoch Teklanika Formation is similar in age (55 – 60 Ma) and mineralogical composition to the McKinley Granite (Capps 2016). Having previously been known as the Upper Cantwell Formation, the Teklanika was redefined by Gilbert et al in 1976. The formation covers 165 square kilometers and is up to 3750-m thick (Gilbert et al 1976: Csejtey et al 1997). It primarily includes moderately deformed andesite and rhyolite with altered basalts and pyroclastic flows (Gilbert 1976). Teklanika dikes and other intrusive features are observed cutting through the underlying Cantwell Formation in several outcrops (Gilbert et al 1976).

In the project area, Gilbert et al (1976) defines a contact between Teklanika rhyolite flows and pyroclastic rocks to the east, and andesite and basalt flows to the west. Pretty Rocks is occurring in a colluvium slope of primarily rhyolitic origin between these bedrock units (Fig. 2). Warhaftig et al (1963) mapped and described a colluvium-covered perlite deposit in the rhyolite bedrock immediately east of the Pretty Rocks slope. They describe it as “rhyolite, obsidian, and perlite, and yellow bentonitic clay derived from decomposition of obsidian and perlite. The local abundance of the clayey material suggests that either perlite or obsidian or both occur beneath parts of the colluvium”. The workers noted the abundance of devitrified glass, and hypothesized that serpentine alteration may be responsible for the green coloration of the perlite. Epidote has also been suggested as an alteration mineral (Shea, pers. comm. 2017).

Aside from geologic mapping of the vicinity, some investigatory work has been performed by the National Park Service on nearby failure areas (Fig. 1), but relatively little work has been conducted on the Pretty Rocks Debris Slide. No known work has been published.

METHODS

Field-Work Methods

The investigation of Pretty Rocks included approximately 3 weeks of field work in July 2016. Field work focused on visual observations of the failure area as well as precise mapping of morphological features using a Trimble Geo7x device running Pathfinder software. Observations were documented by digital photographs. Significant time was also spent on rock descriptions and structural characterization of the surrounding bedrock. In addition to the igneous petrologic descriptions, observations of the bedrock included hardness, weathering, roughness, block size, block shape, seepage, and details regarding structural discontinuities (i.e. joints, fractures and faults). The type of discontinuities present were noted, as well as their aperture, infilling, spacing, and persistence. Structural measurements and observations were based on the Alaska Department of Transportation Alaska Field Rock Classification and Structural Mapping Guide (AKDOT 2003).

Key sediment samples were collected for engineering tests using sample-grade plastic bags that were immediately sealed with zip ties to maintain moisture content. Sediment samples were chosen based on location within the project area, as well as color, plasticity and grain size. Fine grain sediments were specifically collected to test the hypothesis that clays contribute to the failure. Samples should not be considered representative of all sediment at the collection site. These samples were collected with comparison in mind, but mineralogical analyses were not included in this study.

Lab Methods

Prior to field work, historic aerial photography was analyzed with images from the DENA Flight Lines GIS database to identify any changes that occurred. Precipitation and temperature data were plotted from the Toklat Remote Automated Weather Station (RAWS), the nearest weather station to the project area. Additionally, fodar imagery from July 2015 was evaluated, and preliminary slope angle measurements and topographic profiles were created. Fodar is "airborne photogrammetric technique that produces directly georeferenced DEMs and orthoimages" and was produced by Dr. Matt Nolan of University of Alaska Fairbanks (Fairbanks Fodar 2014). This high-resolution structure-from-motion imagery was collected in June 2015 and 2016. Following field work, maps of morphological features were produced with the Pathfinder data using ArcMap, and geologic maps were created using ArcMap and Adobe Illustrator.

Of the sediment samples collected, only ones deemed most important for comparative and characteristic purposes were analyzed. The sediment samples underwent engineering tests at the Alaska Department of Transportation (DOT). Tests included Atterberg limits, sieve analysis by percent passing, moisture content, and organic content (as deduced by the Loss on Ignition method). Not every sample underwent every test. Only coarser samples with a wide variety in grain size were selected for sieve analysis since all others were relatively homogenous and visually determined to be of clay – silt size.

DATA AND OBSERVATIONS

The Pretty Rocks Colluvium Slope

The Pretty Rocks failure occurs in a colluvium slope comprised predominantly of rhyolitic clasts which resemble the rhyolitic bedrock to the east of the slope (Figs. 2 and 13). Material from the perlite deposit is also being introduced to the Pretty Rocks slope by natural drainage, as seen from the ground (Fig. 13) and in aerial photography. This material includes green clays, clasts of obsidian, and devitrified glass. Overall, the slope is covered by a veneer of cobbles and boulders which are underlain by gravel and coarse sand-sized sediment. Profiles produced from the 2015 fodar reveal a slope angle of approximately 35^{0} (Fig. 4).

Mass Movement

Primary Failure

According to the NPS, Pretty Rocks has been experiencing creep-style movement for approximately 20 years with increased rates of downhill motion over the past 4 – 5 years (Capps pers. comm. 2016). The rate of motion had previously been noted but not quantified. The Difference Elevation Model (DEM) produced from the 2015 – 2016 fodar imagery revealed ~31.5 inches of subsidence along the road corridor in one year (Fig. 5). Up to ~130 ft above the road corridor, heterogeneous changes in elevation are observed. Near the center, elevations increased up to >15.75 inches (~1.3 ft), but farther from the center, elevations decreased up to >15.75 inches (~1.3 ft) (Fig. 5). Up to ~260 feet below the road, elevations in the colluvium slope increased up to > 15.75 inches (~1.3 ft). The resulting convex morphology is also observed on the ground (Figs. 4, 5, 14). Directly below the road, there is a band of increased elevation >15.75 inches (~1.3 ft).

Ground truthing and field observations corroborated these data. During field work, cracks in the road were observed at the western and eastern boundaries of the slope (Figs. 7, 18 - 21). To the west, one dominant crack stretches from ~5 – 10 feet above the road to ~3 feet below the road. Measured offset averaged 1.5 - 2 inches (Figs. 18, 19). (Unfortunately, there were poor controls on measurement locations since the road surface was often altered by road maintenance.) Occasionally, other en echelon cracks were observed depending on road maintenance and precipitation (Fig. 18). To the east, cracks in the main road surface were typically comprised of en echelon lineations with little to no offset (Fig. 20). One crack extended several feet below the road, turning easterly to propagate parallel to the road surface (Fig. 21). Offset averaged 1 ft. One crack also extended over 100 feet above the road along the boundary of the rhyolitic bedrock and the colluvium slope (Fig. 16). Offset was ~1 ft. Horizontal lineations were visible in the sediment along the scarp face in this crack (Fig. 17). Lastly, in the solid band of increased elevation observed directly below the road (Fig. 5), a crack developed during field work which paralleled the road (Fig. 22).

According to the NPS, the western and eastern road cracks have been present for multiple years (Capps pers. comm. 2016). Historically, the cracks experience changes in offset and aperture up to several inches during the open summer road season (Capps pers. comm. 2016). The Park Road is closed beyond the first few miles during the winter which prevents regular observation. When the road is cleared in late spring, maintenance crews often find significant vertical road displacement between the bounding cracks (Capps pers. comm. 2016). Although the offset has not been measured or recorded, the NPS estimates annual subsidence between 10's of inches and several feet (Capps pers. comm. 2016).

Secondary Failure

In addition to large-scale downhill motion, the Pretty Rocks colluvium slope experiences smaller debris flows. Two adjacent debris flows occurred on June 30, 2016 just prior to a spike in precipitation on July 1, 2016 (Fig. 6). Both originated in the colluvium slope above the road, in the area affected by the drainage of perlite material (Figs. 23, 24). The larger of the two flows terminated in the ditch on the north (uphill) side of the road, and the smaller flow ended just above it in the colluvium slope. Additionally, 1996 aerial photography reveals a large debris flows which crossed the road and terminated on the eastern portion of the lower eastern lobe (Fig. 7). We mapped numerous older debris flow deposits on the tri-lobed terminus at the base of the slope (Fig. 7). Older deposits are assumed to be masked by vegetation and covered by more recent debris flows.

Failure in the Perlite Deposit

In 2015, the perlite deposit within the rhyolitic bedrock ridge to the east of Pretty Rocks began experiencing mass movement (Capps pers. comm. 2016). On August 25, 2015, a large failure occurred that impacted the road. This failure preceded a spike in precipitation on August 26, 2015 (Fig. 6). During field work in summer 2016, frequent changes in slope morphology within the perlite deposit were noted, and on July 15, 2016 a small debris slide was witnessed. This failure occurred during a spike in precipitation, and closely followed the warmest average daily temperature (62.4^{o}F) recorded for the May 15 – September 15, 2016 period at the Toklat RAWS.

During the field work period, water was observed constantly flowing through this deposit, reaching the road, and continuing eastward (Fig. 8).

The Tri-Lobed Slope Terminus

Fodar and ground investigation revealed three distinct lobes at the base of the slope below the Pretty Rocks failure area. Two lobes overlie the streambed of an East Fork Toklat River tributary, and the third sits atop these two (Fig. 7). The lower two lobes are comprised of cobble- to boulder-sized clasts of rhyolite which are similar to the colluvium slope above. Unlike the colluvium slope, both lobes are covered in lichen with the eastern lobe exhibiting larger and darker lichens than the western (Figs. 26, 28). Surfaces of both lower lobes are unvegetated and hummocky. These lobes are currently eroded by the river, and display signs of failure due to this. (In this location, the lobes are impacted by two flow directions. There is the easterly flow of a larger East Fork Toklat River tributary, and there is northeasterly flow from a smaller tributary stream descending from across the valley. The smaller stream meets the larger channel at the base of Pretty Rocks (Fig. 2).) When viewed from the riverbed, the coloration of the lower lobes differ. The eastern lobe is more yellow and oxidized, while the western lobe is predominantly white (Fig. 25).

Between these lobes, a clay deposit, visually similar to the green clays in the perlite deposit, was noted. Analogous green clays and devitrified glass were also observed at the base of the lobes.

The third upper lobe shows different characteristics than the lower two lobes. It is vegetated and composed of darker, fine-grained material. Numerous surface cracks were observed and mapped (Fig. 7). Most debris flow deposits from the colluvium slope terminate on this upper lobe (Fig. 7).

Surface water: Drainage and Presence

Following several days of heavy precipitation, we were able to map surface water drainage and the interaction between surface water and the Pretty Rocks slope (Fig. 8). Most water above the road followed the topography to the west, arriving at the gulley. At the base of this drainage, the water drained directly into the slope at or near the western road crack. Another prominent drainage existed west of the colluvium slope where the road abuts the basaltic bedrock. We also observed water draining down the channel of the July 2016 debris flows, and heard water draining in this same location on days without precipitation.

Water reappeared at the base of the colluvium slope to the east. It appeared to be controlled by levees and channels of previous debris flows rather than following topographic lows. At one point it was seen elevated between two levees which suggests a perched water table due to a significant percentage of clays in the debris flow deposits. This small stream disappeared into the ground and reappeared several times before pooling on the eastern lobe (Fig. 27). According to historic aerial photography, the water collects in the lobe deposit of a large debris flow that was activated prior to 1996 (it appears fresh in the 1996 aerial photography and is not seen in the 1988 imagery). The ephemeral sediment-laden pond drains and/or evaporates approximately one week after cessation of precipitation (Fig. 27).

In addition to this ephemeral surface water, several permanent surface water features exist in the project area (Fig. 8). First, a small pond is set between two lobes of the terminus in the area underlain by a thick package of green clays. Second, during field work water flowed constantly in the gulley above the road, following the natural topography. This water disappeared into the slope near the western road crack. Third, a near constant flow of water occurred in the perlite deposit and followed the ditch eastward after intersecting the road surface. This water disappeared into the slope at the center of the gulley east of Pretty Rocks (Fig. 8).

Engineering Test Results

Engineering tests were administered to the samples collected during this study (Samples A – N), as well as Federal Highway Administration (FHWA)-collected samples (Sample PR15-01 – PR16-04) (Figs. 9 and 10). FHWA provided analysis of grain sizes, Atterberg limits, moisture content, and organic content.

Tests were performed on only appropriate samples, and the FHWA samples were analyzed using sieves for finer grain size (Fig. 10).

The grain size analyses from this study provide information for the coarser sediments collected, while those from the FHWA provide data on finer sediments. Overall grain sizes range from 1/2” to < 1µm. All FHWA samples passed 21.3% - 40.8% through the 1µm sieve (Fig. 10).

The Atterberg limits define the moisture contents at which a dry sediment sample changes from behaving as a solid, to behaving as a plastic, and finally to behaving as a liquid (USDA NRC 1990). The Plastic limit (PL) is the percent water content at which the sample changes from semi-solid to plastic. The Liquid limit (LL) is the percent water content at which the sample changes from plastic to liquid. The Plastic index (PI) is the range of water content percentages where the sediment exhibits plastic behavior (PI = LL – PL). When plotted on a Plasticity Chart (Fig. 10) they can be used to classify fine sediments (USDA NRC 1990). For the purposes of this study, classification is based on particle size (silt vs. clay) and liquid limit as defined by the Unified Soil Classification System (USCS). High liquid limits clays are called fat clays (symbolized as CH) while high liquid limit silts are known as elastic silts (MH) (USDA NRC 1990). Low liquid limit clays are classified as lean clays (CL), and low liquid limit silts are simply known as silts (ML) (USDA NRC 1990).

The Atterberg limits and associated classifications also reveal physical properties of fine-grained soils such as shear strength, shrinking and swelling, and compressibility. Shear strength is defined by a combination of friction and cohesion. Clays with a high PI (fat clays) tend to have poor shear strength because most of the strength is derived from cohesion. Over time, these soils may exhibit creep (USDA NRC 1990). Silts and lean clays typically have fair shear strength, and elastic silts have fair to poor shear strength (USDA NRC 1990). Swelling potential may also be estimated with PI. Soils with PI greater than 20 typically have moderate to high swelling potential, while a PI exceeding 35 suggests very high swelling potential (USDA NRC 1990). Overall, swelling markedly decreases soil strength. Finally, compressibility is the potential decrease in volume of a soil that is subjected to a load (USDA NRC 1990). Silts and lean clays have medium - high compressibility, elastic silts have high compressibility, and fat clays have very high compressibility (USDA NRC 1990).

The collective data for this study including the FHWA sampling show an LL range from 43 – 116, a PL range from 21 – 43 and a PI range from 19 – 94. Samples K and G are classified as lean clays although Sample G is very close to the 50% liquid limit distinction between lean and fat clays. Samples A and PR16-03 lie at the boundary between elastic silts and fat clays, with Sample PR16-03 directly on the boundary. The remainder of samples that underwent Atterberg testing are classified as fat clays. Moisture content ranged from 27.0% - 86.6% and organic content ranged from 2.1 – 5.1%. (FHWA samples were not tested for organic content.) See Figure 10 for complete results.

Bore Logs

In June 2003, the Federal Highway Administration drilled two bore logs – PLY03-1 and PLY03-2 –through the road surface into the Pretty Rocks slope (Figs. 4, 11). Rock descriptions, field blow counts, and N-values were provided (Appendix B). PLY03-1 was drilled to a depth of 55.5 ft. Ground ice was first mentioned at 20.4 ft. The driller switched from augering to coring at 36.0 ft depth. N values range from 8 to >60. PLY02-3 was drilled to a depth of 101.2 ft. Ground ice was first recorded at ~40.5 ft. The driller switched from augering to coring at a depth of 40.9 ft. N values range from 10 to >60.

In September 2003, thermistor string readings were collected from PLY03-2. Temperatures range from 31.5^{o}F at 9 ft to 38.6^{o}F at 66 ft at the base of the thermistor string.

INTERPRETATIONS

Varnes Classification

The National Park Service has historically referred to Pretty Rocks as a debris slide. According to the modified Varnes Classification System (1978) as found in Cruden and Varnes (1996), Pretty Rocks should be classified specifically as an *active composite very slow moist to wet compound debris slide-very rapid wet debris flow*. This naming system is based on the state, style and rate of the failure as well as the water content, the material involved and the type of movement. *Active* refers to the state of movement and indicates that the slope is currently undergoing failure. *Composite* describes the style of failure by indicating that more than one type of mass movement is taking place, sometimes simultaneously. *Very slow* and *very rapid* point to the rate of failure of their respective types. *Very slow* is classified by Cruden and Varnes (1996) as the velocity range between 1ft/5yr and 5ft/yr. *Very rapid* is the velocity range between 1ft/min and 10ft/sec (Cruden and Varnes 1996). (The velocity of the debris flows are assumed based on characteristic flows and slope steepness. No known eyewitness accounts exist.)

Moist and *wet* refer to water content. *Moist* is defined as: “contain[ing] some water but no free water; the material may behave as a plastic solid but does not flow” (Cruden and Varnes 1996). *Wet* is defined as: “contain[ing] enough water to behave in part as a liquid, has water flowing from it, or supports significant bodies of standing water” (Cruden and Varnes 1996). A range of moisture content is provided for the *debris slide* since it is understood to be in variable states of saturation depending on precipitation and temperature.

Compound slide and *flow* refer to the types of movement occurring. A slide is “downslope movement of [material] occurring dominantly on surfaces of rupture or on relatively thin zones of intense shear strain” (Cruden and Varnes 1996). Cruden and Varnes (1996) describe three main types of slides named for the geometry of their slip surfaces: rotational, translational, and compound. Translational slides occur on a planar or undulatory surface and are typically shallow. Rotational slides occur on a concave surface and are typically deep. Compound slides exhibit a combination of these geometries and depths (Cruden and Varnes 1996). The author interprets Pretty Rocks as a compound debris slide for the following reasons: (1) based on the bore logs, the underlying bedrock is thought to be non-uniform in composition and degree of weathering, which would provide an irregular lower bounding surface (Fig. 11); (2) compound debris slides are associated with the boundary between weathered and unweathered material or the presence of a weak layer (Cruden and Varnes 1996), both were observed in the bore logs (Fig. 11 and Appendix B); (3) the hypothesized slip surface likely exists at a moderate depth (Fig. 11); (4) the generalized geometry of the slip surface (wedge-shaped) is characteristic of translational slides, while the slow rate of movement is characteristic of rotational slides. See *Geometry of the Slip Surface* for further discussion.

Flow is “spatially continuous movement [where…] distribution of velocities in the displacing mass resembles a viscous liquid” (Cruden and Varnes 1996).

Finally, *debris* indicates that slope failures (the main slide and the smaller flows) are occurring in unconsolidated material where of 20 – 80% of clasts are larger than ~0.08 in (2 mm) (Cruden and Varnes 1996).

Surficial Extent of Slide Mass

The proposed surficial extent of the slide mass can be seen in Figure 12. This interpretation is based on several lines of evidence. First, the eastern and western extents along the road corridor are the location of the respective road cracks (Fig. 7). Second, the boundary below the road is based on the convex morphology (Figs. 5, 14). This morphology is interpreted as the surface expression of the lower boundary of the slip surface, where it is extending over the original ground level, as characteristic of translational slides (Cruden and Varnes 1996). Third, the boundary above the road is based on three features. To the west, it is defined by multiple patches in the talus slope which are devoid of the characteristic cobble- to boulder-sized clasts. These patches are in a general alignment which proceeds uphill to the east, and divides the homogenous upper talus from the dissected slope below (Fig. 15). To the east, it is defined by the eastern road crack's continuation along the boundary between talus and bedrock (Fig. 16). Third, these extents correlate with the outline of significant elevation changes observed in the DEM (Fig. 5).

Geometry of the Slip Surface

The author interprets the underlying slip-surface to be wedge shaped, following the dipping (weathered) bedrock whose interpreted upper boundary intersects with the overlapping interval of frozen ground between the two bore logs (Fig. 11). The general wedge-shaped geometry was initially proposed by Denali Park Geologist Dr. Denny Capps (Capps pers. comm. 2016). It is supported by the surficial extent of the slide mass as well as the bore log data which indicates a package of nearly horizontal unconsolidated material overlying dipping bedrock which results in a wedge-shape (Fig. 11).

The increased elevations seen in the central portion of the slide mass above the road (Fig. 5) may coincide with a resistant bedrock irregularity over which the slide mass is flowing. This would also explain the band of increased elevation and associated crack directly below the road, which exist across from the larger area of increased elevations above the road (Fig. 5). The author interprets this as a pressure ridge that has formed as the slope attempts to flow over the bedrock irregularity, but is continually compacted by road graders and buses during the summer months. Any morphologic changes observed prior to spring road grading could test this interpretation. Overall, indications of an irregular slip surface support the classification of Pretty Rocks as a compound slide.

Slides typically include one or more scarps indicating the crown of the slide mass (Cruden and Varnes 1996). This feature is not seen in the Pretty Rocks slope. The author suggests that the scarp may be filled by: the continued addition of colluvium from the incoherent bedrock (small rockfalls were observed in this area), the addition of clayey material from the perlite deposit, or the gravity-induced motion of colluvium from the upper slope. Alternatively, the loose and heterogeneous nature of the overlying slope material and the steep slope angle may have prevented the original formation of a scarp. Grabens, which are characteristic of compound slides (Cruden and Varnes 1996), are also absent, perhaps for these same reasons.

Slope Deformation Behavior

Based on the observed flow of surface water across the colluvium slope, the differing characteristics of the road cracks, and the introduction of fines to the western slope, the author proposes differential deformation behavior across the slide mass. First, the western portion is likely water-saturated due to drainage following the topography and internal drainage of surface water near the western road crack (Fig. 8). In contrast, the eastern portion of the failure area is believed to be undersaturated based on relative topographic elevation, observed movement of surface water, and visual analysis of colluvium in the vicinity. These differences in slope saturation are also apparent in the contrasting nature of the road cracks. The western road crack is visible in the road material but its trace quickly disappears above the road. In contrast, the eastern road crack visibly propagates for an estimated 200 ft above the road. Not only is the crack clearly visible, but the observed lineations in the eastern crack scarp suggest discrete downhill movements (Fig. 17).

Lastly, the western portion of the slope likely receives more fine-grained sediment than the eastern portion because of the drainage patterns. Sediment-laden water was observed flowing directly into the western road crack following heavy precipitation. The sediment load likely includes perlite-derived fines since drainage from the deposit leads directly to the western portion of the slide mass. The perlite deposit is known to include elastic silts and fat clays and is experiencing independent mass movement suggesting it is highly susceptible to failure. Additionally, the 2016 debris flows originated in the perlite drainage path and thus indicate that the material is failure-prone. These materials may be carried directly to the slip surface by the internal drainage and aid in lubrication or destabilization. Thus, the author interprets the saturated western portion as deforming in a ductile manner, while the undersaturated eastern portion of the slide mass deforms in a brittle manner. The western portion may also be the primarily location of failure due to the heavy saturation and lubrication of the slip-surface by sediment-laden water.

Rate of Creep along the Road Corridor

The fodar-derived difference elevation model quantified changes in elevation over a one-year period. The most concentrated, dramatic subsidence (greater than 31.5 inches) occurred along the road corridor (Fig. 5). The author interprets the extreme subsidence of the road corridor as magnification of downhill movement by settlement. Settlement is caused by forces in excess of the bearing capacity, which is defined as the maximum average load per unit area that will not produce failure or extreme settlement (USDA NRC 1990). Settlement issues oftentimes result from the layering of soils with unequal settlement characteristics (USDA NRC 1990), which is likely the case of the road fill being added to the colluvium slope. Though this subsidence is alarming, the road corridor itself may not be an appropriate location for quantifying overall rates of mass movement.

Failure Mechanisms

Present failure is almost certainly related to the Teklanika clays of volcanic origin. This is evidenced by the other failures in the Teklanika Formation (Fig. 1), the engineering test results of the clays within the project area which included abundant fat clays (Fig. 10), the presence of clays in the lobes at the terminus and in the bore logs (Figs. 9, 11 and Appendix B), and the failure of the clay-rich perlite deposit. Fat clays are susceptible to swelling which decreases shear strength, and susceptible to frost which could result in frost heaving. Both properties could be exacerbated by water draining internally through the slope which would help to lubricate the slip surface.

The author also interprets ground ice as contributing to failure based on its presence in the bore logs and on the incidence of failures which sometimes precede spikes in precipitation but follow increases in temperature (Fig. 6). (The ice is thought to be seasonal based on its presence in a south-facing slope and the lack of insulating vegetation or organic matter. Further work should be done to better understand the nature of the ice and the frozen ground.) Not only could in-place ground ice provide a slip-surface and/or exhibit flow (Tart 1996), but annual degradation of the seasonal ice would provide additional water to the slide mass, thereby increasing overall saturation (and associated swelling of fat clays) and lubricating the slide surface.

In addition to the perilous physical properties of the slope, past failures (indicated by the lobes at the base of the deposit (see *Relative Ages and Origins of the Tri-Lobed Terminus*)) may have been triggered by seismic activity, by deglaciation of Polychrome Pass, by increased precipitation or temperature, or by undercutting of the slope by the East Fork Toklat River tributary. The latter is particularly interesting since Pretty Rocks receives two directions of river flow from two East Fork Toklat River tributaries (Fig. 2). The smaller tributary flows northeasterly, colliding with what are now the lobate deposits at the base of Pretty Rocks. Notably, the direction of flow is almost parallel with the strike of the Teklanika beds in this location. Initial failure may have been caused by this intersection of flowing water with incompetent bedrock following deglaciation of Polychrome Pass.

Relatives Ages and Origins of Tri-Lobed Terminus

A characteristic comparison of the three lobate deposits at the base of the slope suggests differences in age and origin.

The two lobes which rest on the riverbed show similar composition (cobble- to boulder-sized clasts of rhyolitic origin which resemble those of the main Pretty Rocks colluvium slope) as well as similar hummocky topography. However, the lobes differ in their lichen coverage and their coloration due to weathering. The eastern lobe is blanketed by larger and darker lichens, and is more yellowed which suggests prolonged exposure and oxidation (Fig. 25). A topographic low also separates the lobes morphologically. The author interprets the lobes as deposits of separate mass wasting events originating in the rhyolitic bedrock and/or colluvium, and interprets the eastern lobe as older than the western lobe (Fig. 7).

The type of mass wasting event responsible for deposition of the lower lobes is difficult to identify. First, the proximity to the slope (i.e. the lack of long distance run-out) suggests deposits from two distinct episodes of creeping failure similar to the Bear Cave Slump. This is challenging to accept with the current emplacement (assuming the eastern lobe is the older deposit), since slow motion, low energy movement is unlikely to have had sufficient energy to overtop the first deposit. In order for this model to work, it could be proposed that the western lobe is actually older and that lesser observed weathering is due to river erosion which preferentially exposes fresh faces on the western lobe. This is logical since the western lobe receives more direct impact from the East Fork Toklat River tributaries. Yet, this would not account for the differences in lichen growth where the eastern lobe has denser, darker lichen coverage than the western lobe. A more sophisticated lichen study could contribute to this understanding.

Second, the hummocky topography of the lobes suggests debris avalanche deposits, yet these typically have a significantly longer run-out distance (Salinas 2010) and there is no evidence of related deposition across the river bed. That being said, the river may have diverted the liquefied portions of the flow to follow the river bed, in which case evidence of the long-run out would be masked by subsequent alluvial depositions.

Additionally, while no stratigraphy is seen within the lobate deposits which could help to determine the mode of mass wasting, the lobes have experienced secondary failures due to river erosion. This exterior dissection of the lobes may be altering or masking original stratigraphy. Similarly, this erosion has almost certainly changed the shape of the deposits by removing the lateral extents. Overall, further work should be done to constrain the specific mass wasting mode responsible for the lower lobe deposits.

The third lobe which sits atop the lower two is interpreted as the youngest based on the principle of superposition (Fig. 7). Unlike the others, this lobe is comprised of dark, very poorly sorted, finer-grained material which resembles the basaltic colluvium to the west of the main Pretty Rocks slope. The author interprets this lobe as an accumulated deposit from multiple debris slides of basaltic colluvium. At present, hillshade imagery and ground-based observations show a large bulge in the basaltic colluvium directly above and to the west of this upper lobe (Fig. 27). Cracks were also seen in the basaltic colluvium slope during field work. This morphology resembles a small rotational slide which may be the next event to contribute material to the upper lobe. In addition to the mass wasting deposits, the author interprets the upper lobe as being shaped by alluvial, colluvial, and debris flow deposits which contribute to its fan-like morphology.

DISCUSSION

Overall, the Pretty Rocks failure slope, the adjacent basaltic colluvium slope, and the basal lobate deposits are understood to be a system of previous and modern failure. Past and current failures are likely linked by physical and compositional properties of the slope including the abundance of Teklanika-derived clays and ground ice. Triggers and modes of failure may differ, although further work will need to be done on the lobate deposits in order to elucidate the timing and type of failure.

In the modern system, previous failure deposits may be aiding present failure. Not only are the lower lobes protecting the slope from river erosion, they could also be serving as an abutment to the Pretty Rocks slope and the adjacent basaltic colluvium slope.

Limitations of this Study

Multiple limitations were encountered in this study and should be noted. First, during most of field work, a Critical Wildlife Habitat Closure of the upper colluvium slope (due to a golden eagle nesting site) prevented field work beyond ~10 feet above the road. This prohibited investigation of the upper colluvium slope and bedrock, effectively reducing the original field project area by 50% and resulting in less detailed mapping above the road. Second, Polychrome Pass is considered one of the more spectacular areas of the park and is an important viewshed to visitors of the Park (Capps pers. comm. 2017). As such, field instrumentation was prohibited due to its visual impact. Temperature and precipitation data was only available from locations outside of Polychrome Pass and may not reflect microclimates within the Pretty Rocks Project Area. Third, the only available bore logs were drilled in 2003. Since then, average annual temperatures have increased from 28.7°F in 2004 to 30.6°F in 2016 – an increase of 6.7%. (These temperature data were calculated from the Wonder Lake RAWS and data were incomplete for 2003. Although the Toklat RAWS is closer to the project area, complete data does not begin until 2006.) Increasing temperatures may have changed the extent and depth of ground ice in the study area. Lastly, the coordinates for the FHWA's bore logs and sediment samples were not collected in the field and thus their locations should be considered approximate.

Further Work

This report presents the first formalized investigation of Pretty Rocks and attempts to incorporate existing data including bore logs and fodar. This report does not include risk mitigation, and final hazard assessment plans should be preceded by additional investigation. Further work should include: drilling additional bore holes to verify bedrock horizon and modern location of ground ice; installing a slope inclinometer, vibrating wire piezometer, and thermistor cable; assessing mineralogy of clays; conducting engineering tests of road material; radiocarbon dating, cosmogenic dating, and/or lichenometry to determine dates of previous failures; installing stakes to reveal shape of deformation and potential variation in the rate of failure across the slope; runout modeling of various failure scenarios, and coordinating with the road maintenance crew to systematize the recording of changes in the slope and failures that occur.

Continuous remote sensing for at least one year is also highly recommended in order to constrain the seasonal timing of maximum downhill movement. If most movement occurs in the spring or fall, frost heave may be a more likely failure mechanism. If movement primarily occurs in the winter, construction of ground ice is likely increasing pore pressures and destabilizing the slope (Tart 1996). Lastly, if maximum movement takes place in the summer, failure is more likely to be related to precipitation and melting of seasonal ground ice.

CONCLUSIONS

- Pretty Rocks should be classified as an *active composite very slow moist to wet compound debris slide-very rapid wet debris flow* based on the modified Varnes Classification System (1978) as found in Cruden and Varnes (1996).
- The surficial extent of the slide mass includes: the western and eastern road cracks, the eastern crack between the bedrock and the colluvium slope, and and the convex morphology below the road. It aligns with the significant elevation changes seen in the DEM.
- The surficial extent of the slide mass and the bore log data suggest that the slip surface of the debris slide is generally wedge-shaped with an irregular lower bounding surface.

- The slide mass is presently deforming in two different manners. The western portion exhibits ductile deformation due to saturation, while the eastern portion exhibits brittle deformation. Drainage patterns and road crack characteristics are evidence of these differences.
- The creep rate along the road corridor is seen on the ground and through the fodar-derived difference elevation model. The road subsidence may being magnified by settlement due to differential settling characteristics of the road material and the colluvium slope, and should not be used as an accurate measure of overall downhill movement of the slope.
- Present-day failure is driven by the abundance of volcanic Teklanika clays, lubrication of the slip surface by internal drainage of sediment-laden surface water into the slope, and melting seasonal ground ice. The addition of clays from the draining perlite deposit is likely exacerbating failure. Diverting surface water flows to prevent internal drainage may help reduce downhill slope movement.
- Past failures may have been triggered by seismic activity, by deglaciation of Polychrome Pass, by increased precipitation or temperature, or by undercutting of the slope by the East Fork Toklat River tributary.
- Below the Pretty Rocks failure slope, the lower eastern lobe is the oldest, the western slope is next in age, and the upper lobe is the youngest. Evidence includes both superposition of the upper lobe and qualitative comparisons of the lower two lobes including lichen coverage and extent of weathering based on coloration.
- The lower two lobes are interpreted as deposits from previous mass wasting events of the rhyolitic bedrock and/or rhyolitic colluvium. The author interprets the third, upper lobe as an accumulated basaltic colluvium deposit from multiple debris slides. It subsequently has been molded by alluvial, colluvial, and debris flow deposits that contribute to its fan shape.

- Further work is recommended for verifying the depth of ground ice and subsurface temperatures, for exacting the ages of the lower lobes, and for constraining the season of maximum creep. A systematized method of recording failures including dates of occurrences is highly suggested. Additionally, road material should be assessed for physical properties in comparison with the properties of the colluvium slope, and care should be taken when adding more fill of differing origin so as not to exacerbate settlement.
- The project area should be understood as a system of past and present failure linked by composition. The lobate deposits of previous failures may now be supporting and protecting the modern day Pretty Rocks slope.

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APPENDIX A – FIGURES

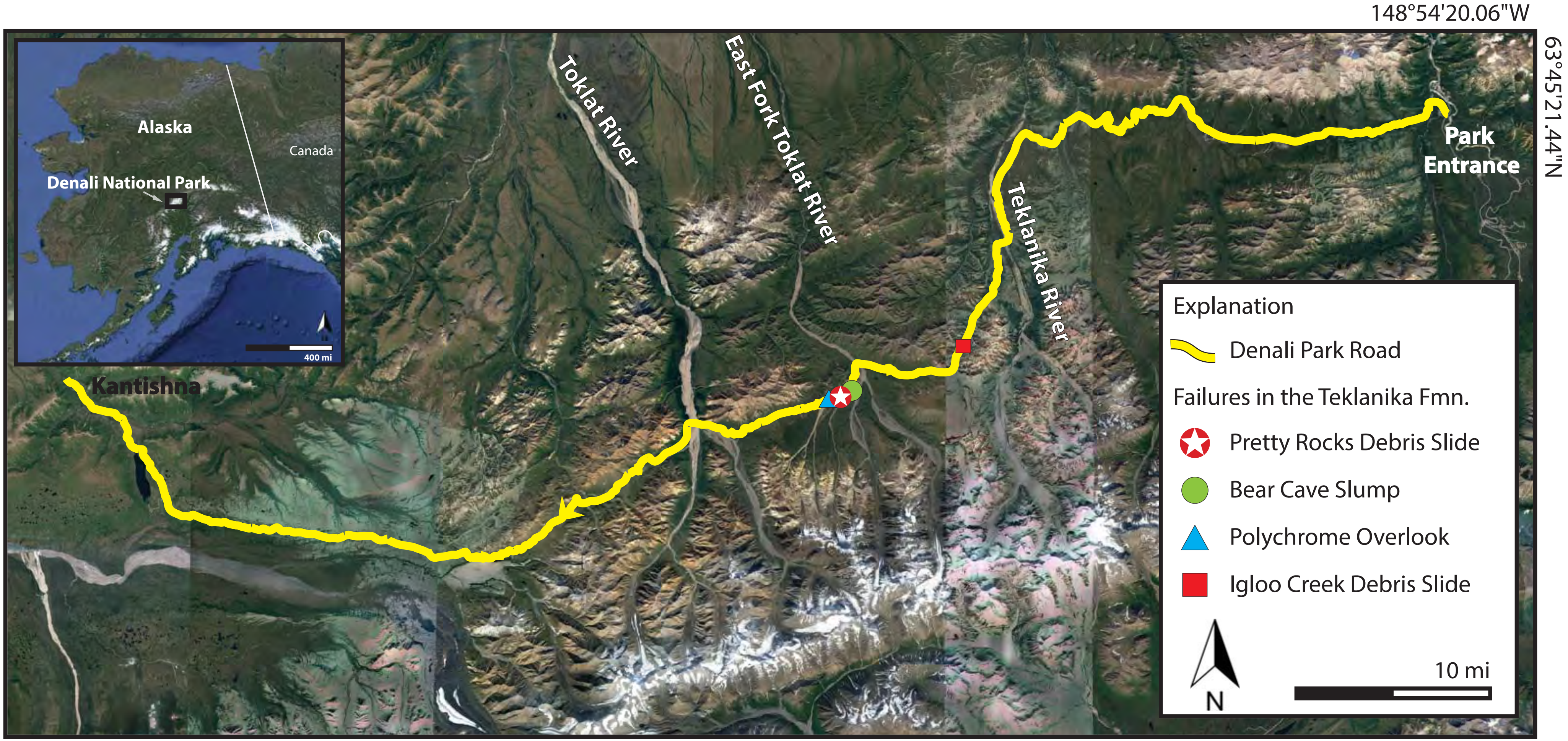


Figure 1: Map of Denali Park Road highlighting failures that have occurred or are occurring within the Teklanika Formation. Note that 3 of the 4 failures are occurring in close proximity to one another within Polychrome Pass. Imagery from Google Earth.

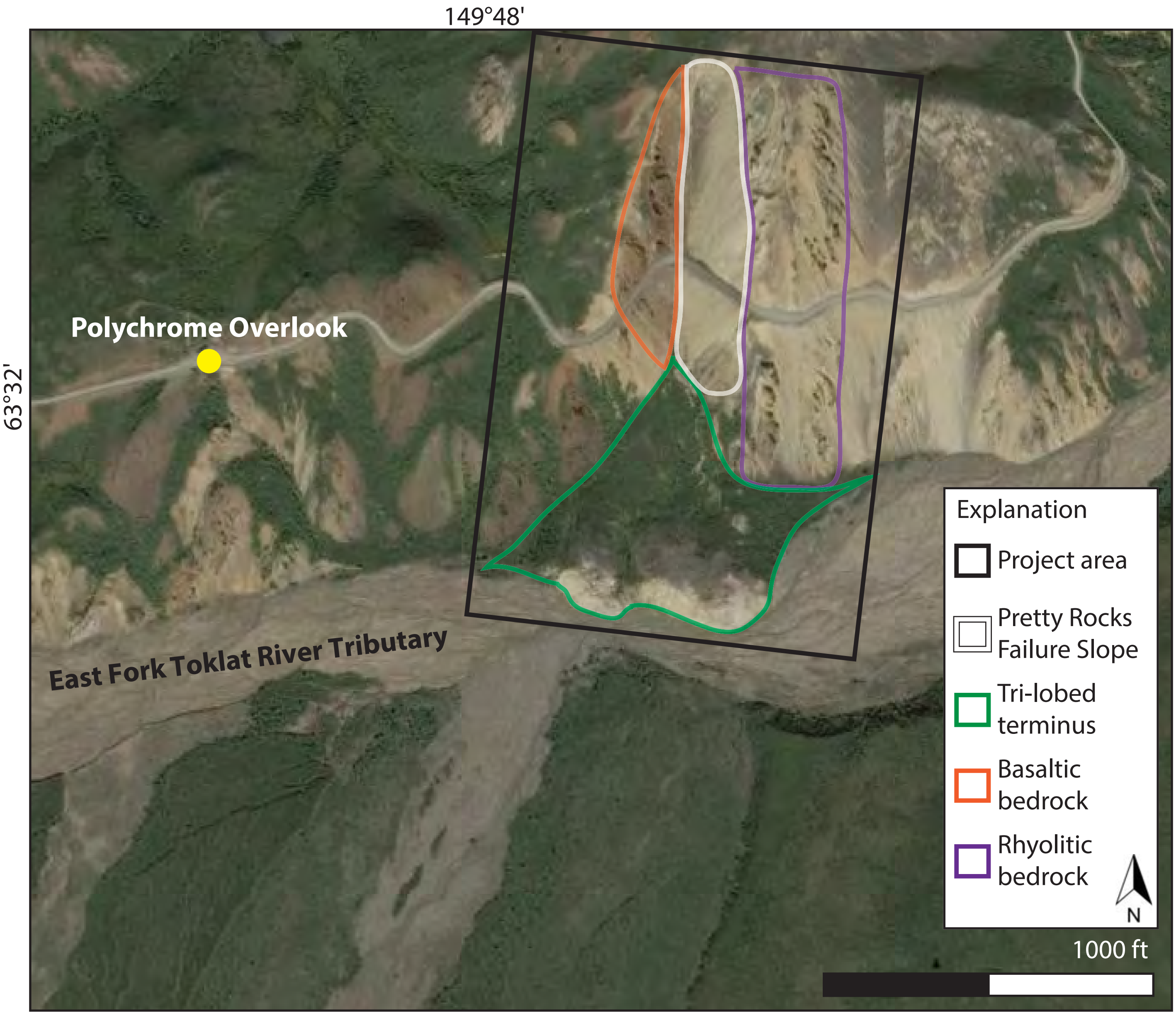


Figure 2: Generalized map of project area.

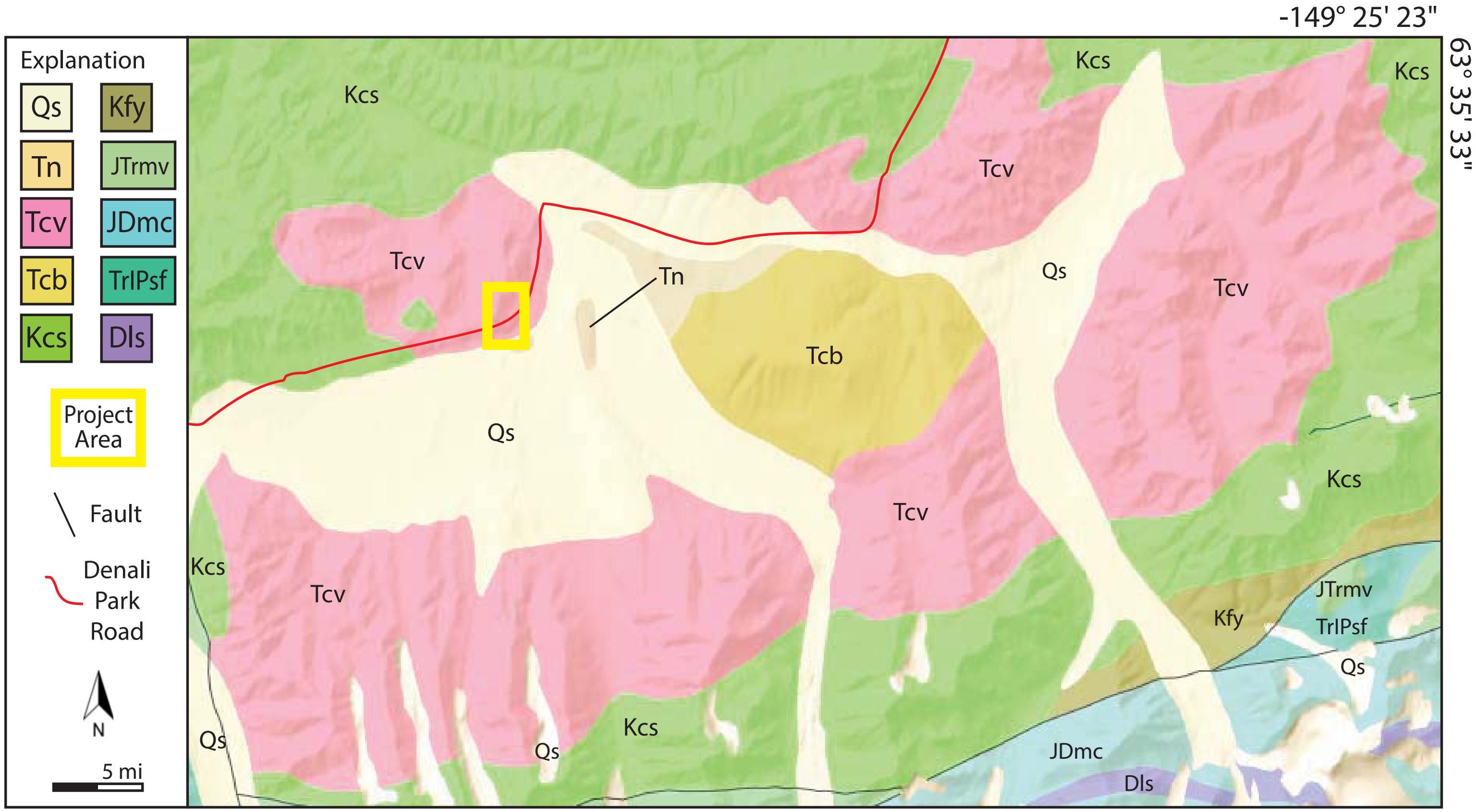


Figure 3: Geologic map of Polychrome Pass modified from USGS Scientific Investigations Map 3340 (2015).
Qs: Quaternary surficial deposits, undifferentiated.
Tn: Tertiary Nenana Gravel; over 4,200 ft thick, containing conglomerate and sandstone with mudstone, claystone, and lignite interbeds. Well-sorted but poorly consolidated. Appears yellowish to brownish in outcrop.
Tcv: Tertiary Volcanic Rocks of the Teklanika Formation; deformed sequences of andesite, altered basalt, rhyolite and interlayered dacite flows, felsic pyroclastic rocks, and minor sandstone and mudstone. Some calcareous rocks present locally.
Tcb: Tertiary coal-bearing rocks; contains cyclic sequences of siltstone, claystone, mudstone, shale, sandstone, subbituminous coal and lignite, quartz, and pebble conglomerates.
Kcs: Cretaceous Cantwell Formation, Sedimentary Rocks Subunit; 13,100-ft-thick interlayered sequence of polymictic conglomerate, sandstone, arkosic sandstone, siltstone, argillite, and shale, and a few thin coal beds.
Kfy: Upper and Lower (?) Cretaceous Sedimentary Flysch
JTrmv: Jurassic and Triassic Tatina River mafic volcanics
JDmc: Jurassic to Devonian sedimentary Mystic structural complex, undivided
TrIPsf: Triassic to Pennsylvanian flysch-like sedimentary rocks
Dls: Devonian limestone of the Mystic structural complex

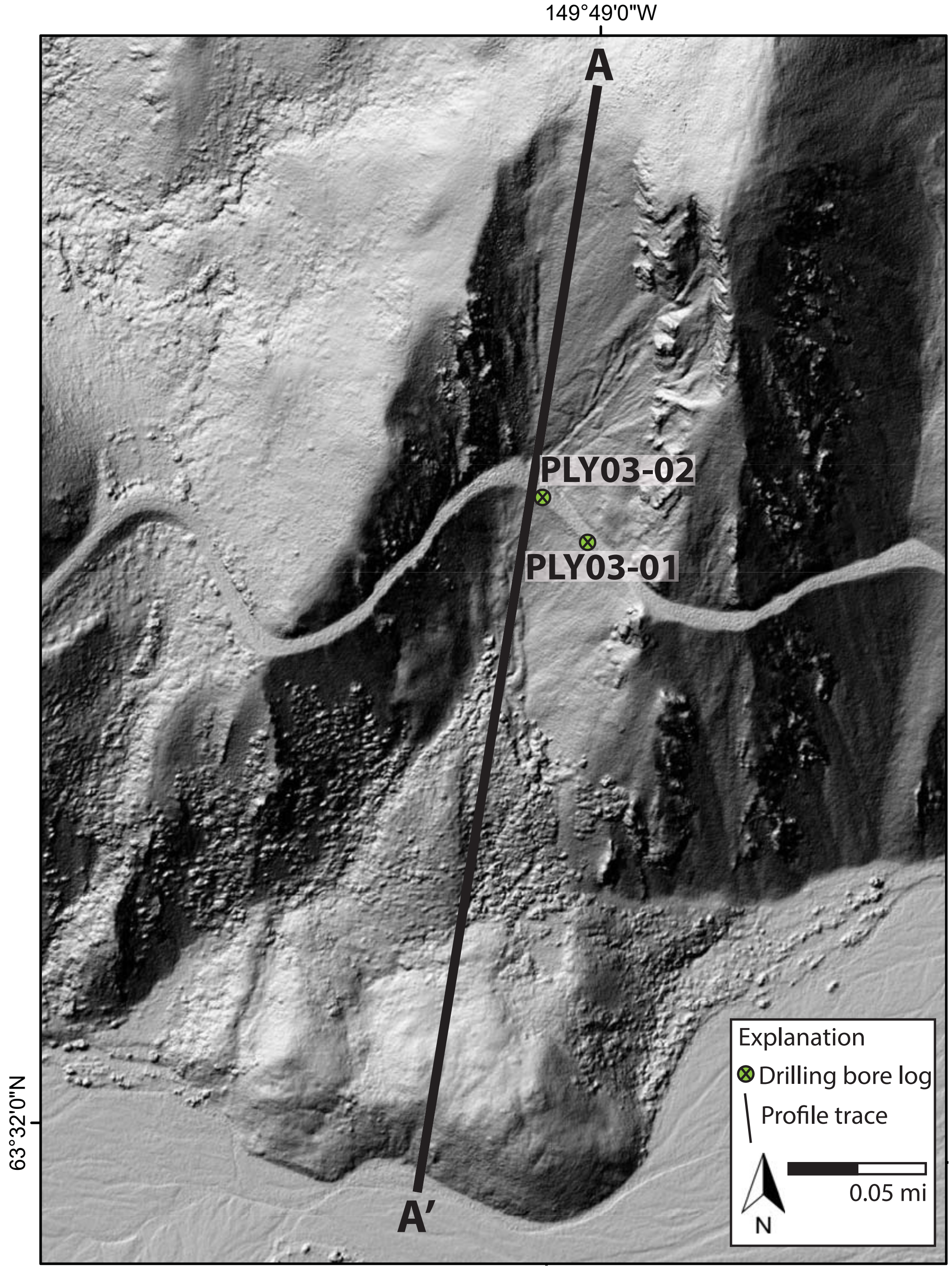
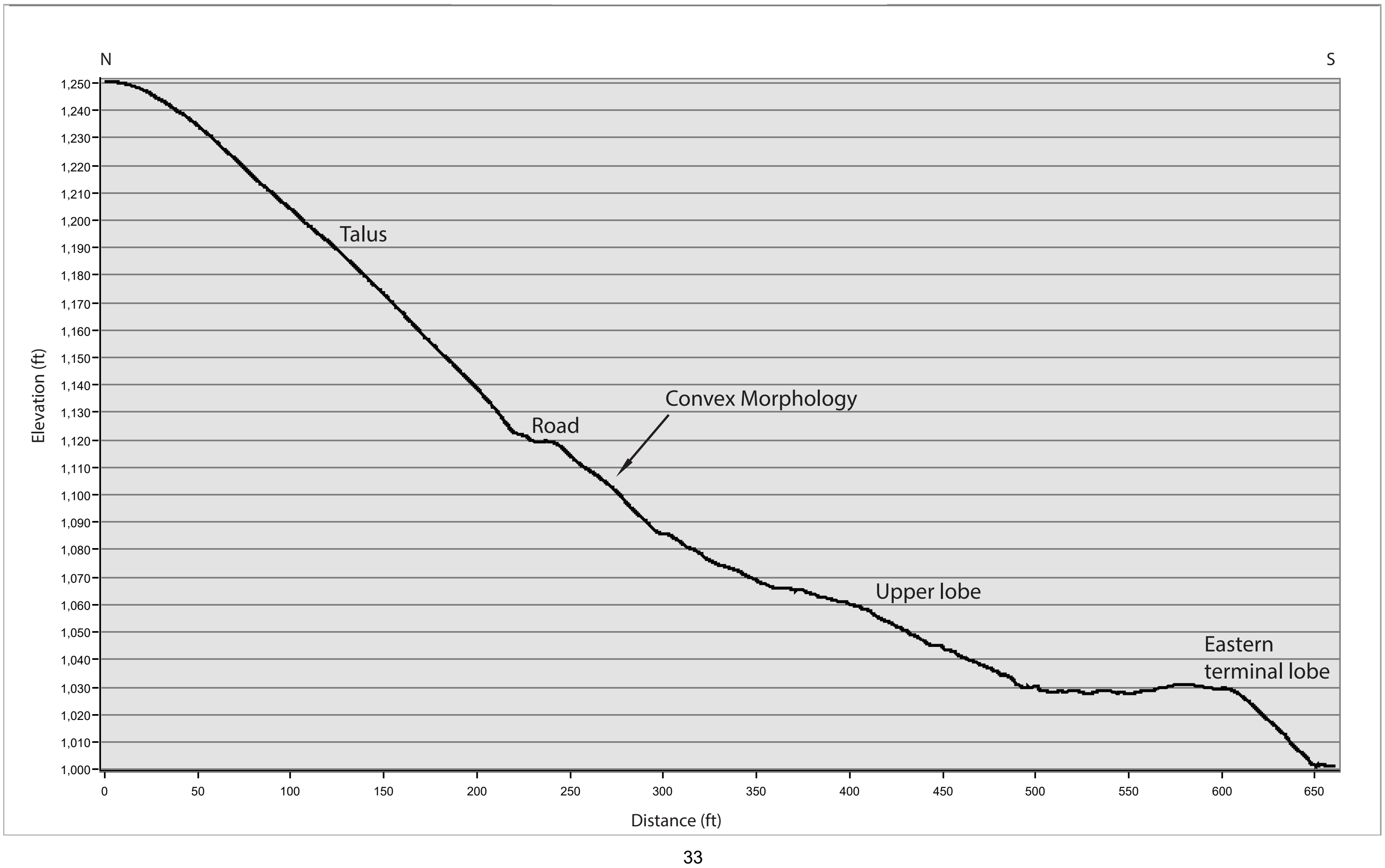


Figure 4: Location of slope profile and drilling bore logs collected by the Federal Highway Administration (FHWA) in June 2003 (left). A – A' profile (below).



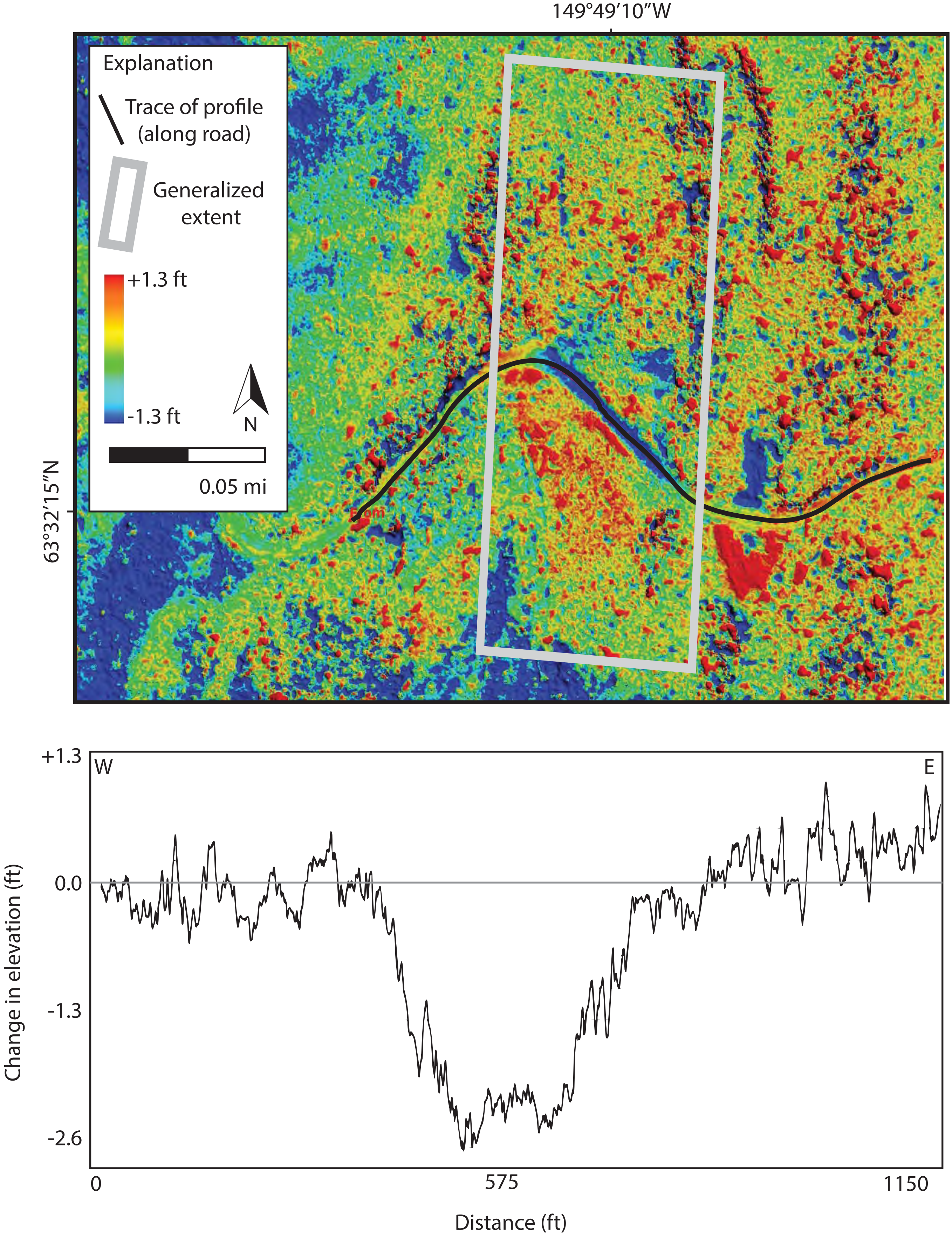
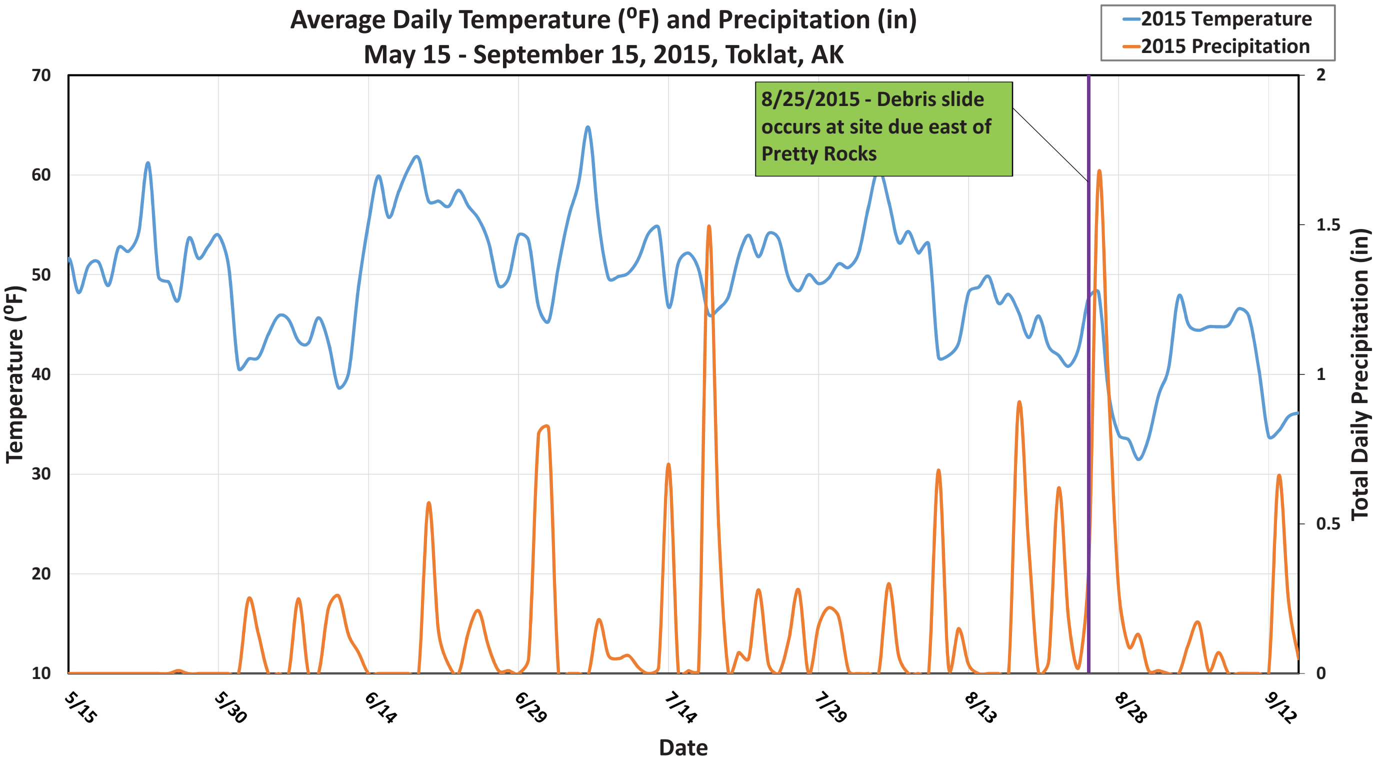


Figure 5: Difference elevation model from June 2015 to June 2016 (top), including road profile from west to east (bottom). Constructed by Dr. Matt Nolan, Fairbanks Fodar, University of Alaska Fairbanks. Note decrease in elevation along and above the road within the generalized extent, and the increased elevation below the road (see also Photo B).



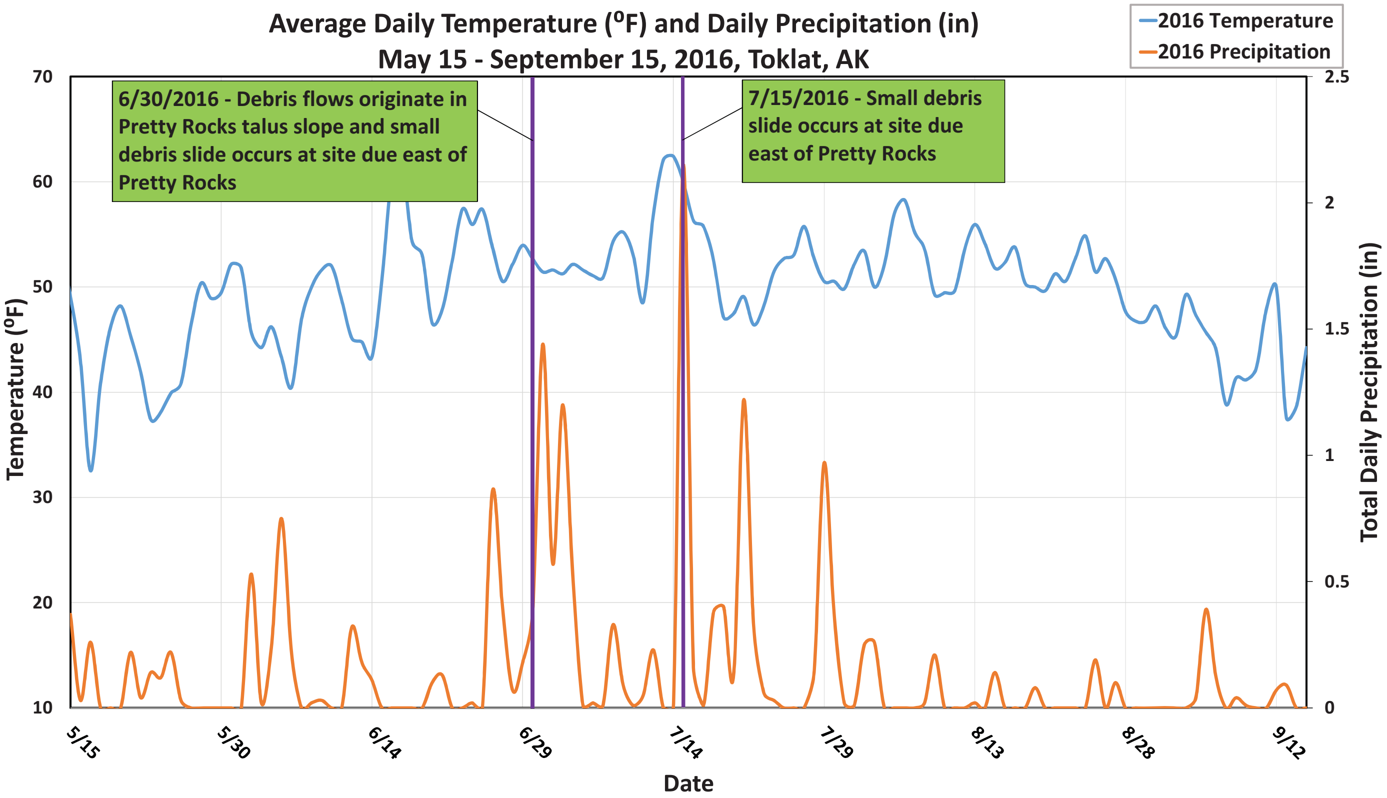


Figure 6: Dates of known failures overlying summer 2015 and 2016 temperature and precipitation data. Other failures may have occurred, but these are the only failures with reliable date constraints based on photographic evidence and eyewitness accounts.

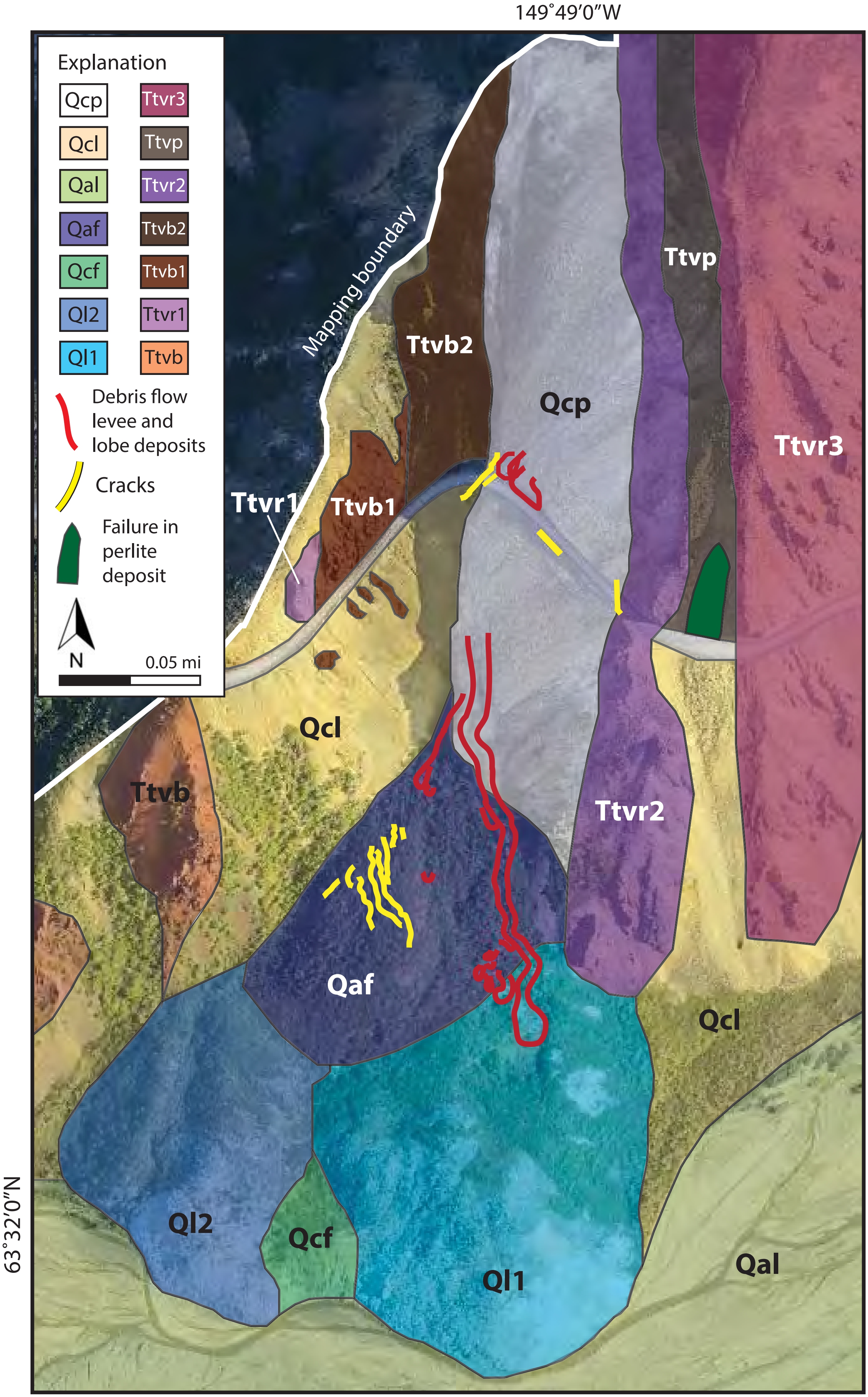


Figure 7: Geologic map of project area including geomorphologic features.
Qcp: Quaternary colluvium primary failure slope
Qcl: Quaternary colluvium, undifferentiated
Qal: Quaternary alluvium, undifferentiated
Qaf: Quaternary alluvial fan
Qcf: Quaternary colluvium, fines
Ql2: Quaternary landslide deposit 2
Ql1: Quaternary landslide deposit 1
Ttvr3: Tertiary Teklanika volcanic rhyolite, unit 3
Ttvp: Tertiary Teklanika perlite
Ttvr2: Tertiary Teklanika volcanic rhyolite, unit 2
Ttvb2: Tertiary Teklanika volcanic basalt, unit 2
Ttvb1: Tertiary Teklanika volcanic basalt, unit 1
Ttvr1: Tertiary Teklanika volcanic rhyolite, unit 1
Ttvb: Tertiary Teklanika volcanic basalt, undifferentiated

See Appendix D for detailed rock descriptions from this study.

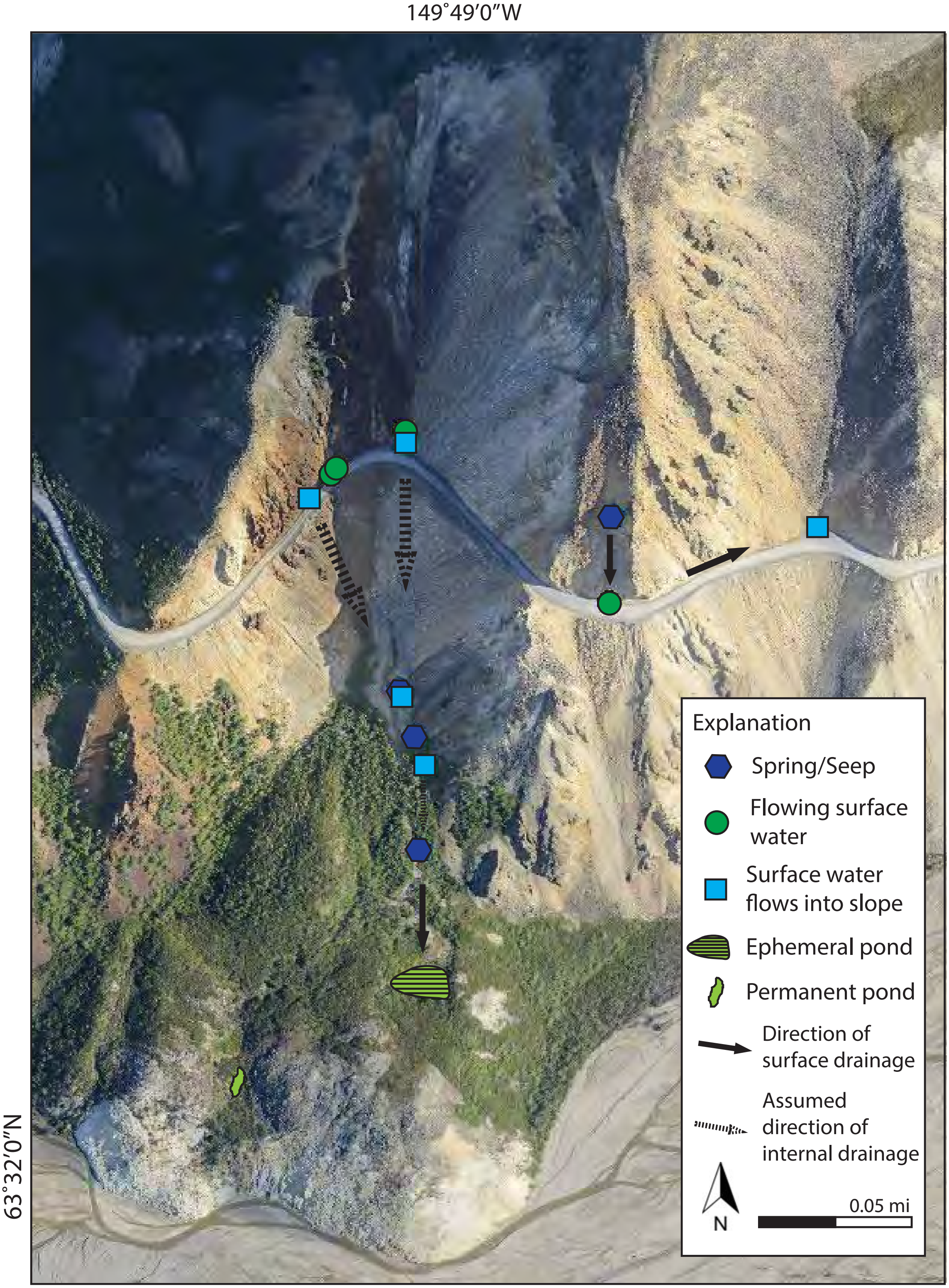


Figure 8: Surface water drainage noted in July 2016. Mapping above the road prevented by Critical Wildlife Habitat Closure. See Discussion Section.

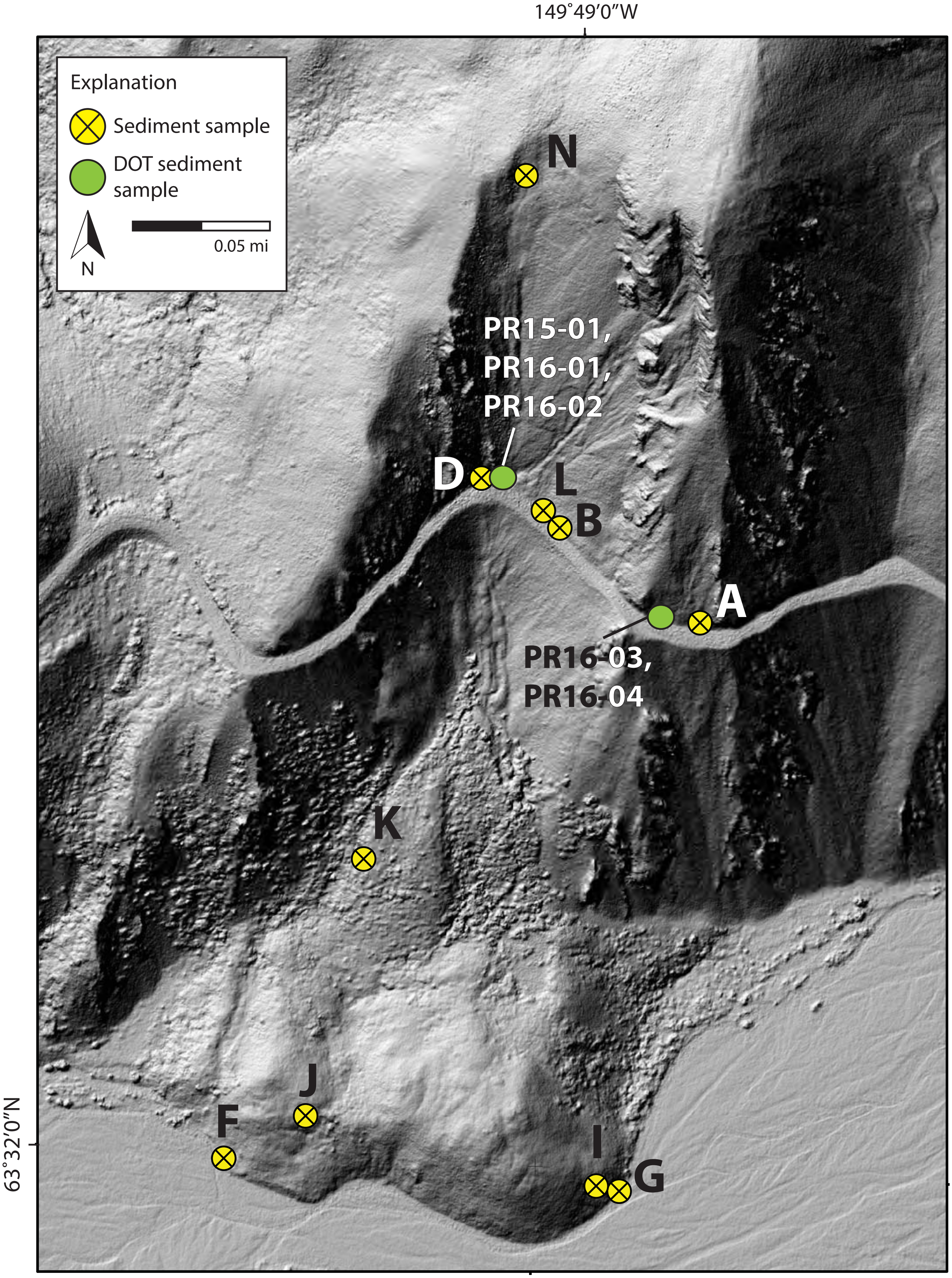


Figure 9: Map of sediment sample locations. Samples A - N were collected during this study, but only those listed on map were analyzed. PR15-01 - PR16-04 were collected and processed by the FHWA in 2015 and 2016, respectively. Baselayer is 2015 Fodar from Dr. Matt Nolan, University of Alaska Fairbanks.

		Sieve analysis, percent passing-													Atterberg Limits					
		Gravel				Sand				Fines										
Origin	Sample	3/4 in.	1/2 in.	3/8 in.	#4	#10	#40	#100	#200	20µm	10µm	5µm	2µm	1µm	LL	PL	PI	Moisture content (%)	Organic (%)	USCS Soil Classification
This study	A	–	–	–	–	–	–	–	–	–	–	–	–	–	97	43	54	86.8	3.0	Silt (MH)
	B	–	–	100	100	94	74	53	37.7	–	–	–	–	–	–	–	–	–	–	Clayey or Silty Sand (SC-SM)
	D	–	–	–	–	–	–	–	–	–	–	–	–	–	66	23	43	27.8	2.1	Fat clay (CH)
	F	–	–	–	–	–	–	–	–	–	–	–	–	–	91	32	59	–	–	Fat clay (CH)
	G	–	–	–	–	–	–	–	–	–	–	–	–	–	50	21	29	–	–	Lean clay (CL)
	I	–	–	–	–	–	–	–	–	–	–	–	–	–	78	26	52	27.0	2.9	Fat clay (CH)
	J	–	–	–	–	–	–	–	–	–	–	–	–	–	81	23	58	39.6	2.1	Fat clay (CH)
	K	100	99	97	89	79	61	47	36	–	–	–	–	–	43	24	19	27.7	3.6	Lean clay (CL)
	L	100	93	87	70	53	27	15	11.1	–	–	–	–	–	–	–	–	–	–	Clayey or Silty Sand (SC-SM)
	N	–	–	–	–	–	–	–	–	–	–	–	–	–	105	27	78	44.6	5.1	Fat clay (CH)
DOT	PR15-01	100	99.8	99.3	98.2	88.4	76.5	–	66.8	46.9	34.7	28.7	23.6	21.3	65	23	42	–	–	Fat clay (CH)
	PR16-01	100	98.6	97.7	95	89.9	75.4	–	65.2	55.3	48.2	40	35.6	32.1	104	23	81	39.6	–	Fat clay (CH)
	PR16-02	100	97.4	95.9	93.5	75.9	63.3	–	56.4	51.1	47.2	41.8	37.1	34.8	116	22	94	67.3	–	Fat clay (CH)
	PR16-03	–	100	99.6	96.7	92.1	85.6	–	79.5	75.1	69.5	63.4	51.9	40.8	91	40	51	25	–	Elastic silt/fat clay (CH/MH)
	PR16-04	–	–	–	100	100	97.3	–	84.9	78.7	72.6	63.4	49.5	39.7	92	38	54	75.4	–	Fat clay (CH)

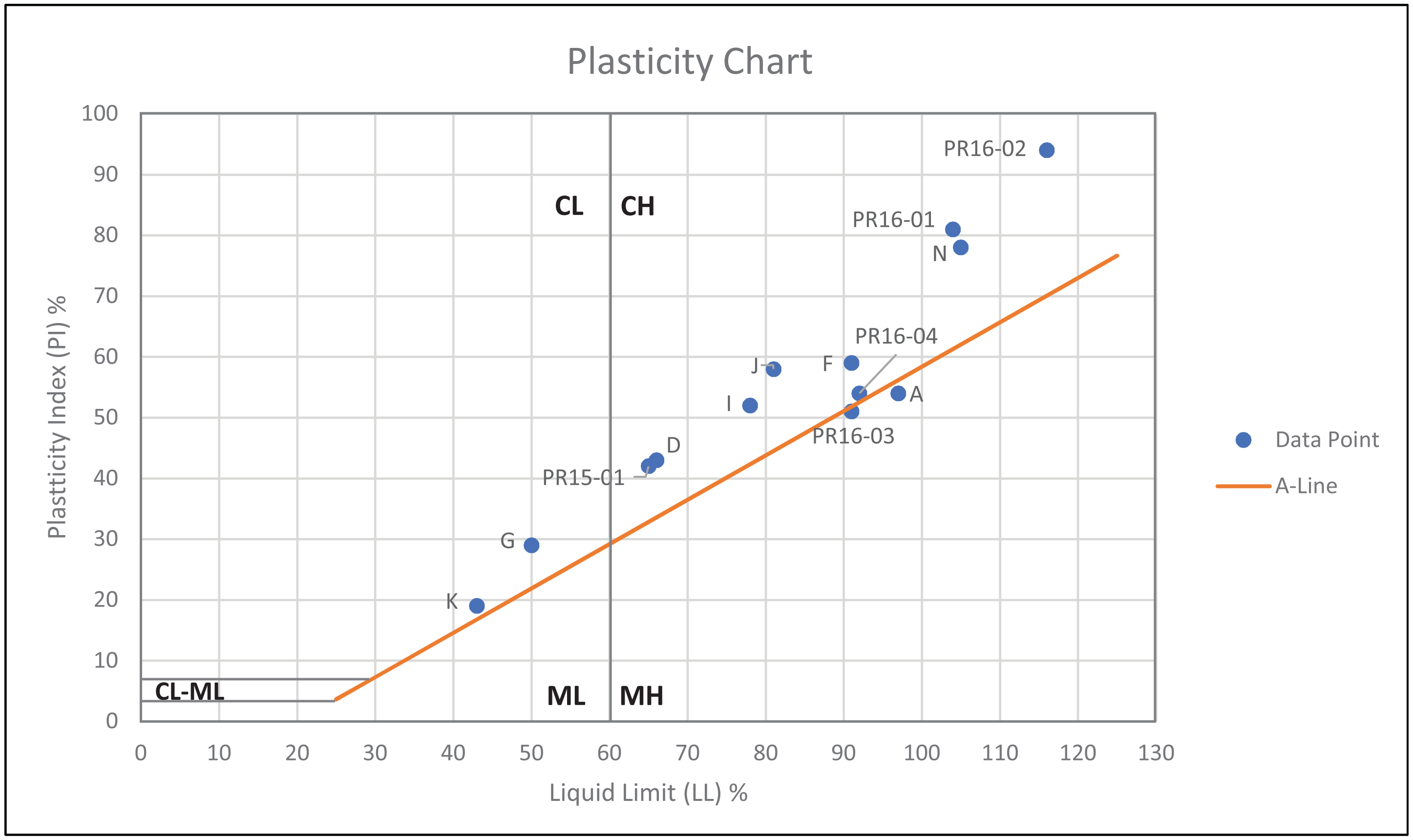


Figure 10: (Above) Sieve analysis results, Atterberg limits, moisture content, organic content, and Unified Soil Classification System (USCS) for sediment samples. Samples A - N from this study. Samples PR15-01 - PR16-04 from FHWA sampling effort. Note that classifications for Samples B and L cannot be further constrained since they were not processed through finer sieve sizes. Sample PRi6-02 lies directly on the division between silts and clays. (Below) Plasticity Chart from the Unified Soil Classification System. Plasticity index is the difference between the Liquid Limit and the Plastic Limit, or the range in which a soil behaves plasticly (see above table for values). The A-Line (PI=0.73(LL-20)) generally separates silts from clays. CH = Fat clays (high liquid limit). CL = Lean clays (low liquid limit). MH = Elastic silts (high liquid limit). ML = Silt (low liquid limit). See Data and Observations section for further details on Atterberg limits.

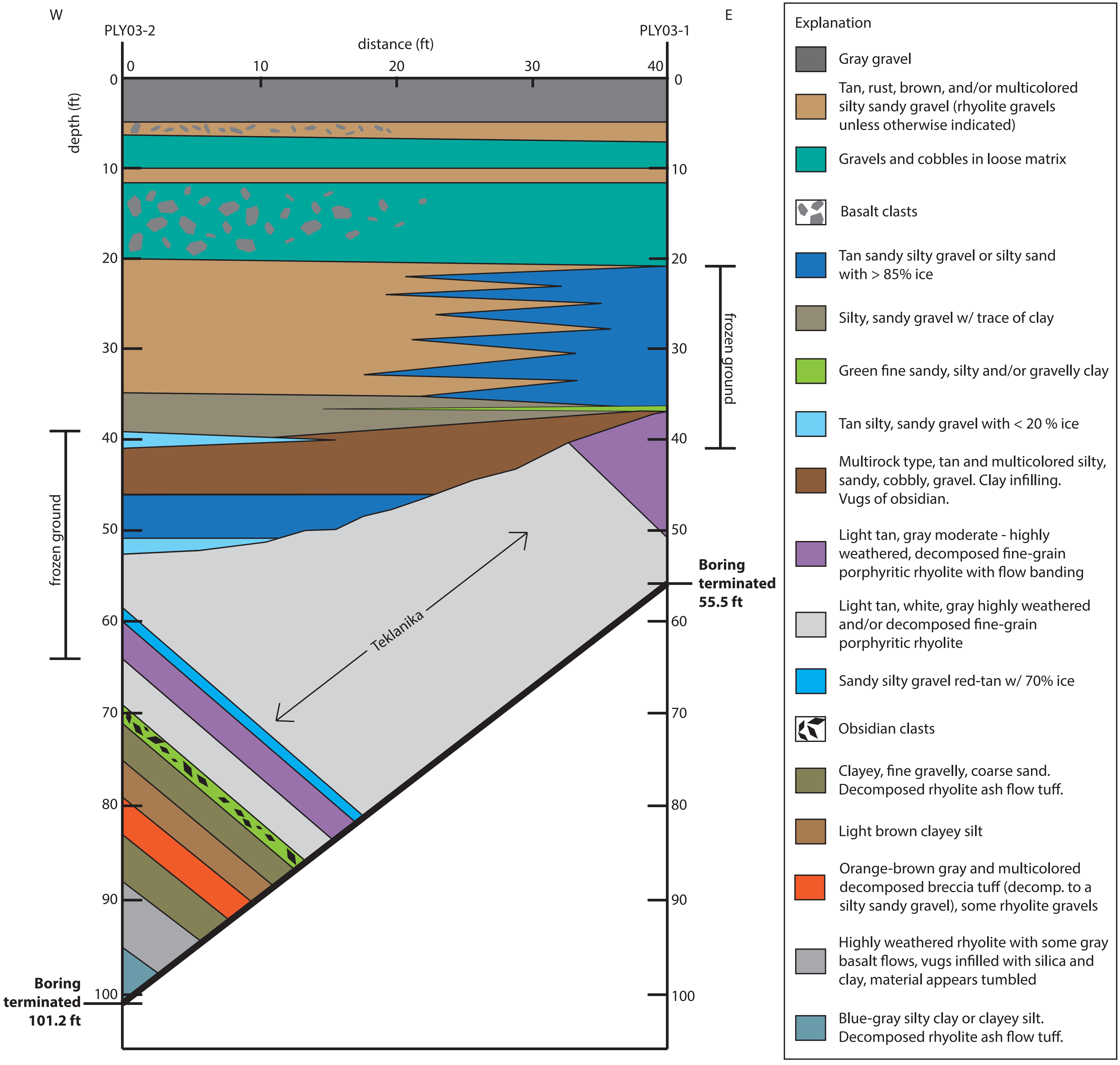


Figure 11: Geologic cross section based on drilling bore logs from the FHWA. See Fig. 4 for locations. Representative descriptions directly from bore logs. Modifiers were considered interchangeable unless deemed inappropriate (ex. “sandy gravels” and “gravelly sands” were grouped together). Boulders, cobbles, and gravels are of rhyolitic origin unless otherwise indicated.

Figure 12: Proposed boundary of slip surface. Extent based on visual observations including cracks in talus slope, mapped locations of road cracks, crack dividing talus from rhyolitic bedrock to the east, and significant elevation changes seen in the Digital Elevation Model (Fig. 5).

Photos

Pretty Rocks Slope

Figure 13: Pretty Rock colluvium slope. Note the drainage of dark perlite-derived material into the main slope, and the homogenous, weathered colluvium on the upper left. Photo taken looking roughly northeast.

Figure 14: Convex morphology seen below the road. Numerous debris flow levees also visible. Person for scale. Photo taken looking northeast.

Figure 15: Outline of western boundary of failure area, and patches of slope devoid of cobble- to boulder-sized clasts. Picture taken roughly above the location of the western road crack.

Figure 16: Outline of eastern boundary of failure area as defined by the crack between bedrock and colluvium. Crack is a continuation of eastern road crack. Highlight added for clarity. Offset averaged 1 foot.

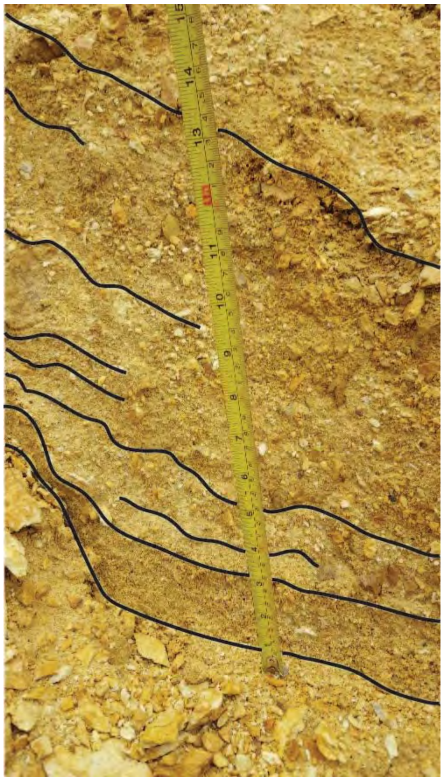


Figure 17: Lineations visible in the scarp of the crack pictured in Photo D. Features highlighted for clarity.

Western Road Crack

Figure 18: Western road cracks. The crack on the right is longer, more prominent, and was visible more often during field work. Highlights added for clarity, but do not represent extent of cracks. Photo taken looking southwest.

Figure 19: Detail of western road crack. Offset varied based on road maintenance and precipitation.

Eastern Road Crack

Figure 20: Eastern, en echelon road cracks. Highlights added for clarity. Photo taken looking east.

Figure 21: Detail of eastern road crack where it continues below the road and turns easterly to propagate parallel to the road surface. Offset averaged 1 ft. Photo taken looking east. Tape measurer for scale.

Figure 22: Crack directly below the road which developed during field work (July 2016). Coincides with band of significantly increased elevation (Fig. 5). Photo taken looking west.

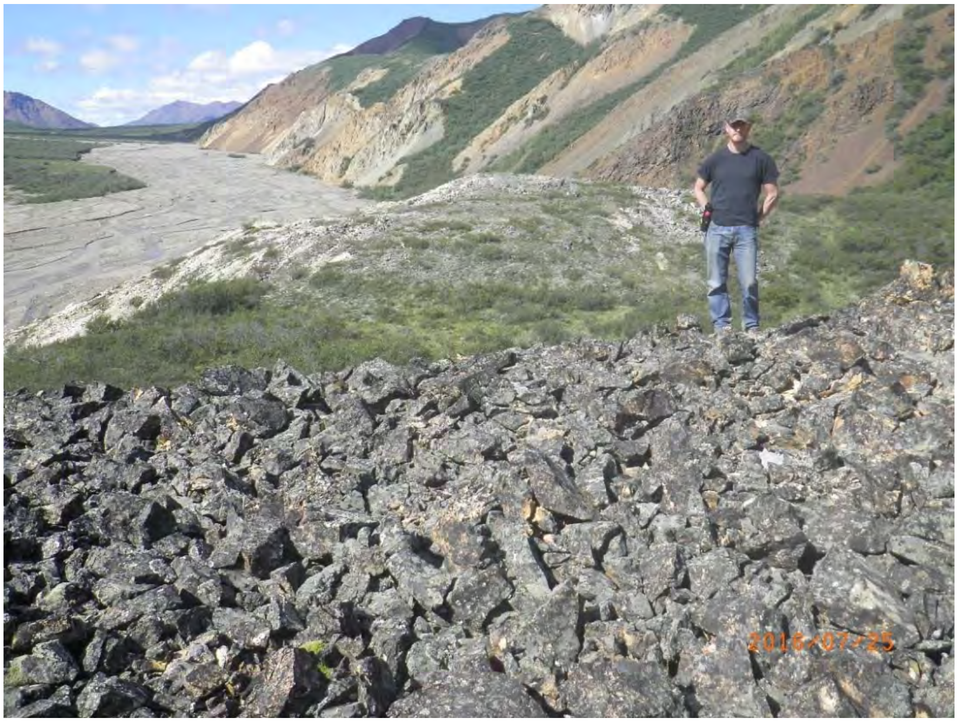
Debris Flows

Figure 23: Two debris flows occurred on June 30, 2016. Partial outline of features highlighted for clarity. Road is one lane wide. Photo taken looking northwest.

Figure 24: Debris flows seen looking northeast. Scarp and lobe deposits highlighted for clarity. Eastern lobe extends beyond the photo frame.

Tri-Lobed Terminus

Figure 25: Pretty Rocks failure slope and lobe deposits seen from the East Fork Toklat River tributary. Photo taken looking north. Road visible in upper slope for scale.



2016/07/25

Figure 26: Lower lobes emplaced on streambed of East Fork Toklat River tributary below Pretty Rocks slope. Eastern lobe in the foreground, western lobe in the background. Note differences in surface coloration due to lichen coverage. Photo taken looking west.

Figure 27: Top arrow indicates sediment-laden ephemeral pond which develops on the lower eastern lobe after heavy precipitation. Bottom arrow indicates large bulge which stretches up and to the right, across the slope of primarily basaltic colluvium. Photo taken from road, looking approximately southeast.

Figure 28: Qualitative comparison of lichen coverage. Highlighted rock is representative rock sample from the western lobe. All other rocks are in place on the eastern lobe.

APPENDIX B – BORE LOGS

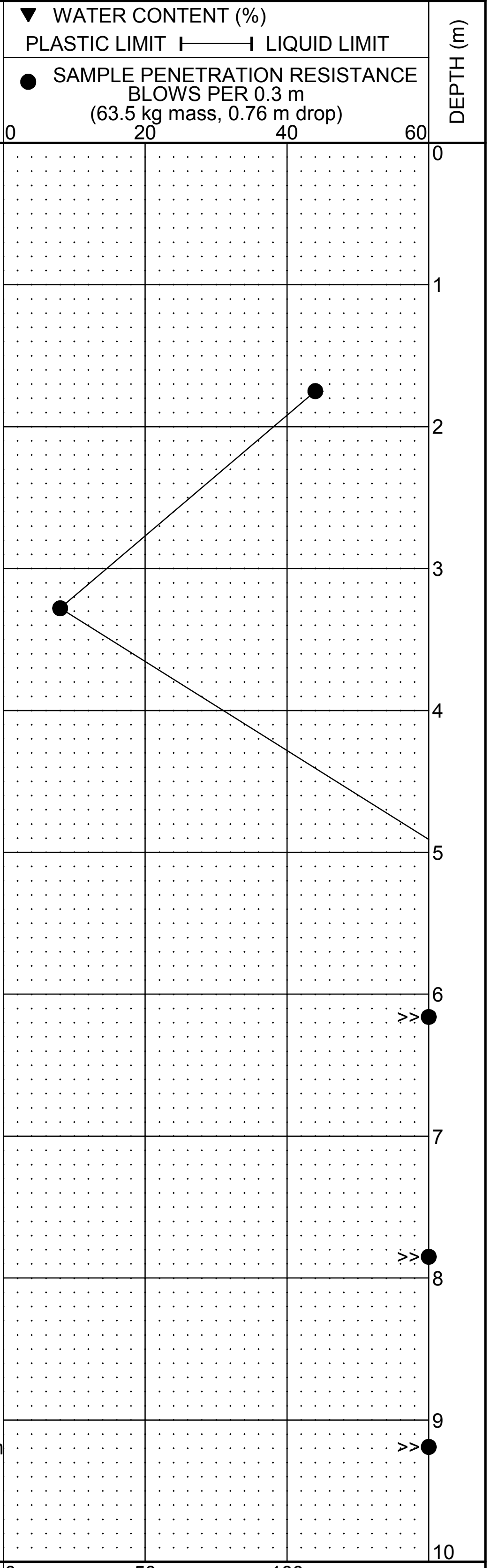
FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (Metric Units)

152 mm H-S AUGER ☐
203 mm H-S AUGER ☐
NQ CORE ☐
HQ CORE ☐
OTHER:

BEGAN: 6/25/03
COMPLETED: 6/26/03
DRILL: CS1000
DRILLER: Chris Peterson
WEATHER:

DEPTH (m)	DESCRIPTION ELEV:	GRAPHIC LOG	SAMPLE #	SAMPLE	BLOW COUNT
0	Gravely to 1.07 m. 1.07 m to 1.52 m cobbles, gravel, possible boulder. Return water changed gray to brown.		R-1		
1.5	Tan-rust and multicolored silty sandy gravel or gravely sand (damp).		SPT-1		16-17-27
2.0	Looser, soft 2.13 m to 3.05 m. Lost return water at 2.9 m.		R-2		
3.1	Light tan sandy gravel, trace of silt. Angular to subangular rhyolite gravels.		SPT-2		8-4-4
3.5	Very soft between cobbles, it will jack the drill up, so voids unlikely. Granular, loose, smoother at 5.56 m, less soft zones.		R-3		
6.1			SPT-3		50/127mm
6.2	Tan sandy, small gravely, silt, frozen, pieces of ice visible to 12.7 mm. Approximately 90% ice. Cobbly, loose matrix, permafrost?		R-4		
7.6	85% ice, tan silty sand with a few small gravels.		SPT-4		41-25-37
8.1	Same.		R-5		
9.1			SPT-5		50/101.6 mm
9.2	Silty sand, approximately 85% ice. Drilled like permafrost.				



1.75 in O.D. SPLIT TUBE SAMPLE
2 in O.D. SPLIT TUBE SAMPLE (SPT)
3.25 in O.D. SPLIT TUBE SAMPLE (D & M)
3 in SHELBY TUBE
AUGER
CORE
WATER LEVEL

0 50 100
▨ RQD (%)
▨ RECOVERY (%)
× FIELD VANE (kPa)
✚ POCKET PEN (kPa)
UNCONFINED COMPR. STRENGTH (MPa)

PROJECT: Denali National Park
STATION, OFFSET:

BORING PLY03-1
Sheet 1 of 2

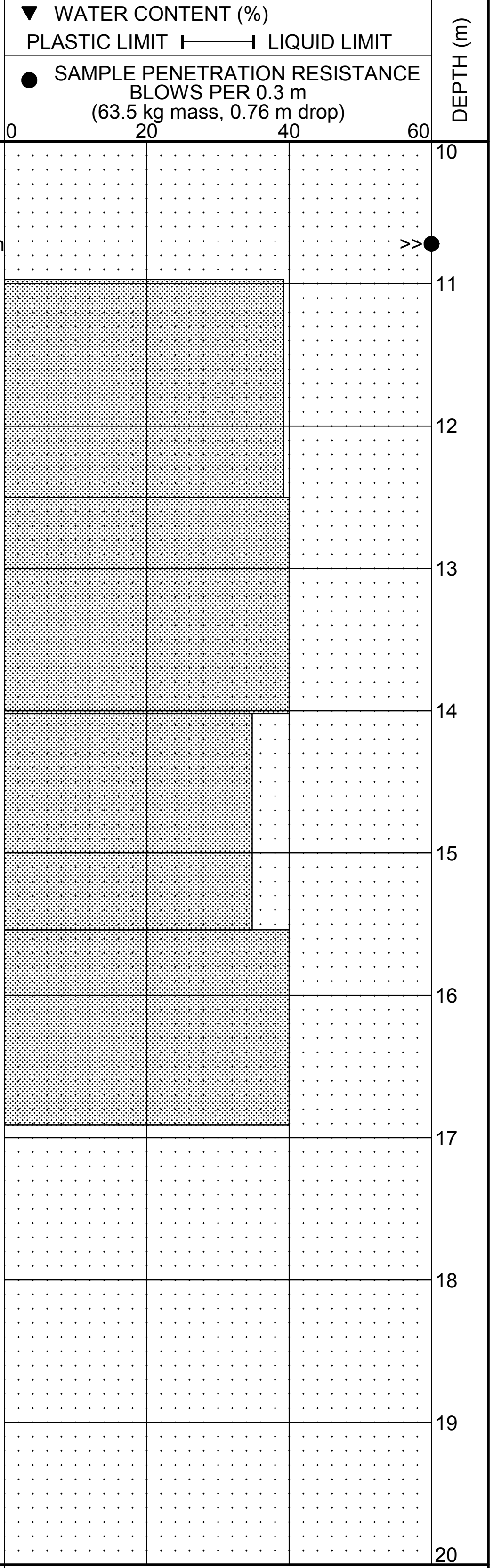
FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (Metric Units)

152 mm H-S AUGER ☐
203 mm H-S AUGER ☐
NQ CORE ☐
HQ CORE ☐
OTHER:

BEGAN: 6/25/03
COMPLETED: 6/26/03
DRILL: CS1000
DRILLER: Chris Peterson
WEATHER:

DEPTH (m)	DESCRIPTION	SAMPLE #	BLOW COUNT
		R-6	
10.7 10.8	76.2 mm silty sandy ice, few gravels. 25.4 mm silty sand (frozen).	SPT-6	50/101.6 mm
11.0	Same. **change to core**	R-7	
	50.8 mm gravel angled 76.2 mm x 127 mm. Green fine sandy, silty clay, few small rock fragments (damp). 1358.9 mm highly weathered, very close to closely fractured, very soft rhyolite, decomposed in horizontal and vertical fractures. Rock is at freezing temperature. 152.4 mm below rock surface is a 76.2 mm decomposed zone. Bedrock.	R-8	
12.5	Light, tan gray moderately weathered soft rock, extremely close to very close, vertical and horizontal fracturing decomposed in fractures to 12.7 mm.	R-9	
14.0	Light tan-white highly weathered decomposed in fractures. Pockets of decomposition through, small voids. Last 152.4 mm is 40 to 50% of full diameter. Picked up 203.2 mm core on R-11	R-10	
15.5	Highly weathered close fracturing. Decomposition in horizontal and vertical fractures.	R-11	
16.9	**BORING TERMINATED AT A DEPTH OF 16.91 M**		



1.75 in O.D. SPLIT TUBE SAMPLE
2 in O.D. SPLIT TUBE SAMPLE (SPT)
3.25 in O.D. SPLIT TUBE SAMPLE (D & M)
3 in SHELBY TUBE
AUGER
CORE
WATER LEVEL

▩ RQD (%)
▨ RECOVERY (%)
× FIELD VANE (kPa)
✚ POCKET PEN (kPa)
UNCONFINED COMPR. STRENGTH (MPa)

PROJECT: Denali National Park
STATION, OFFSET:

BORING PLY03-1

Sheet 2 of 2

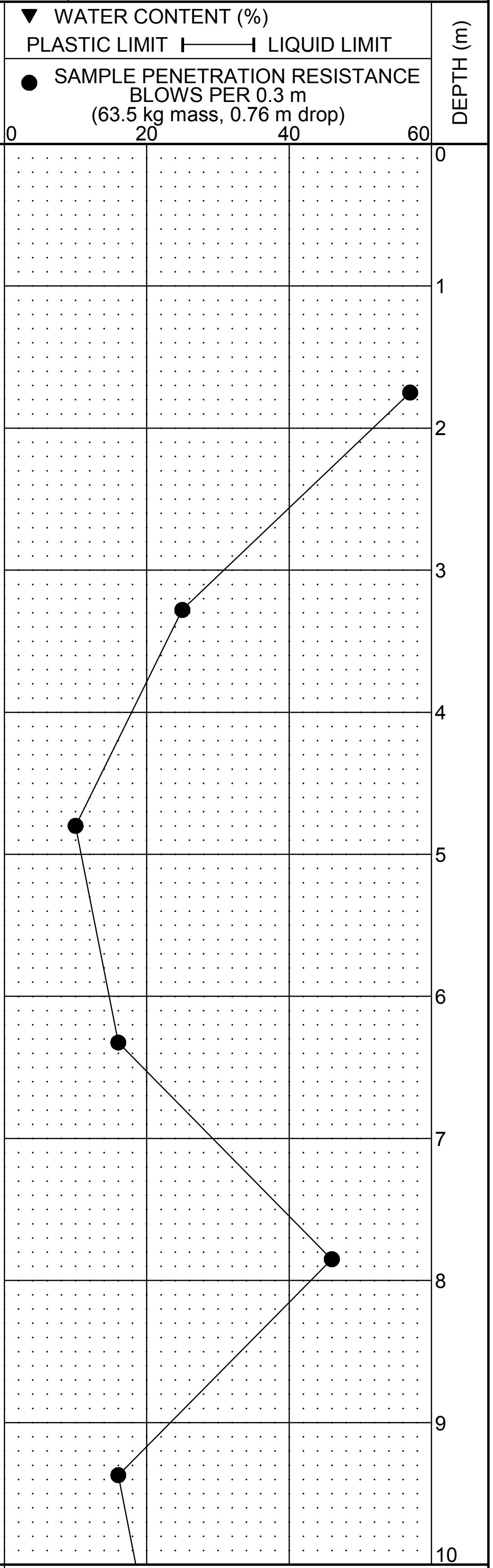
FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (Metric Units)

152 mm H-S AUGER ☐
203 mm H-S AUGER ☐
NQ CORE ☐
HQ CORE ☐
OTHER:

BEGAN: 6/27/03
COMPLETED: 6/1/03
DRILL: CS1000
DRILLER: Chris Peterson
WEATHER:

DEPTH (m)	DESCRIPTION ELEV:	GRAPHIC LOG	SAMPLE #	SAMPLE	BLOW COUNT
0	Gravely soils, some cobble and possible boulder, very dense.		R-1		
1.5	Brown sand, silty, gravel. Gravel is tan-cream rhyolite. Few pieces gray basalt, angular to subangular (damp). Last 63.5 mm changes to silty, sandy gravel.		SPT-1		12-25-32
2.0	More cobbles, looser matrix.		R-2		
3.1	Brown and multicolored silty, sandy, gravel (damp).		SPT-2		6-13-12
3.5	Gravely cobbles in loose soil matrix.		R-3		
4.6	Same, except gravel is mostly angular basalt.		SPT-3		7-5-5
5.0	Same.		R-4		
6.1	Sandy, gravel, trace of silt. Gravel mostly light cream colored rhyolite.		SPT-4		8-8-8
6.6	Same.		R-5		
7.6	Tan silty, sandy, gravel, less gravel than last 2 SPT's.		SPT-5		13-38-8
8.1	Loose gravely soils.		R-6		
9.1	Tan silty, sandy, gravel. Gravel is angular purple rhyolite.		SPT-6		15-8-8
9.6	Same.				



1.75 in O.D. SPLIT TUBE SAMPLE
2 in O.D. SPLIT TUBE SAMPLE (SPT)
3.25 in O.D. SPLIT TUBE SAMPLE (D & M)
3 in SHELBY TUBE
AUGER
CORE
▽ WATER LEVEL

0 50 100
▩ RQD (%)
▨ RECOVERY (%)
× FIELD VANE (kPa)
✚ POCKET PEN (kPa)
⊠ UNCONFINED COMPR. STRENGTH (MPa)

PROJECT: Denali National Park
STATION, OFFSET:

BORING PLY03-2
Sheet 1 of 4

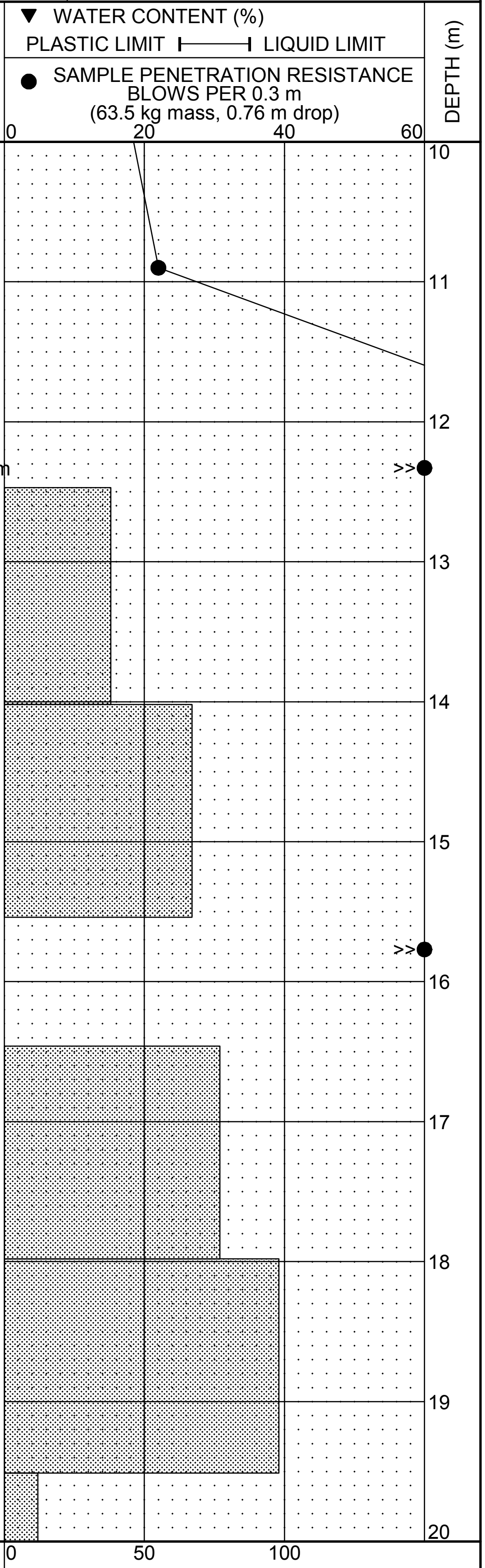
FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (Metric Units)

152 mm H-S AUGER ☐
203 mm H-S AUGER ☐
NQ CORE ☐
HQ CORE ☐
OTHER:

BEGAN: 6/27/03
COMPLETED: 6/1/03
DRILL: CS1000
DRILLER: Chris Peterson
WEATHER:

DEPTH (m)	DESCRIPTION	GRAPHIC LOG	SAMPLE #	SAMPLE	BLOW COUNT
			R-7		
10.7	Tan-cream and multicolored silty, sandy, gravel with a trace of clay. Gravels vary purple-tan-dark gray angular to subangular.		SPT-7		14-11-11
11.1	Slightly denser.		R-8		
12.2	Tan silty sandy, gravel and ice.		SPT-8		18-50/127 mm
12.5	**change to core** Tan silty, sandy gravels and a small cobble, gravels mostly. Light tan and a few purple rhyolite and a coupl small basalt gravels (frozen). Didn't recover much ice.		R-9		
14.0	Tan and multicolored silty, sandy, cobbly, gravel. Multirock type angular to subangular (frozen <10%).		R-10		
15.5	Tan silty, gravely sandy ice, core runs are minus melted ice.		SPT-9		23-36-30
16.0	Tan and multicolored silty, sandy, gravel, approximately 20% ice.		R-11 R-12		
18.0	177.8 mm sandy, silty, gravel red-tan. 1320.8 mm silty, sandy, cobbly, gravel with solid ice zones to 177.8 mm. Approximately 70% ice (chipped ice out and tossed).		R-13		
19.5	Few gravels subrounded with trace of sandy silt on some surfaces.				



1.75 in O.D. SPLIT TUBE SAMPLE
2 in O.D. SPLIT TUBE SAMPLE (SPT)
3.25 in O.D. SPLIT TUBE SAMPLE (D & M)
3 in SHELBY TUBE
AUGER
CORE
WATER LEVEL

▩ RQD (%)
▨ RECOVERY (%)
× FIELD VANE (kPa)
✚ POCKET PEN (kPa)
UNCONFINED COMPR. STRENGTH (MPa)

PROJECT: Denali National Park
STATION, OFFSET:

BORING PLY03-2
Sheet 2 of 4

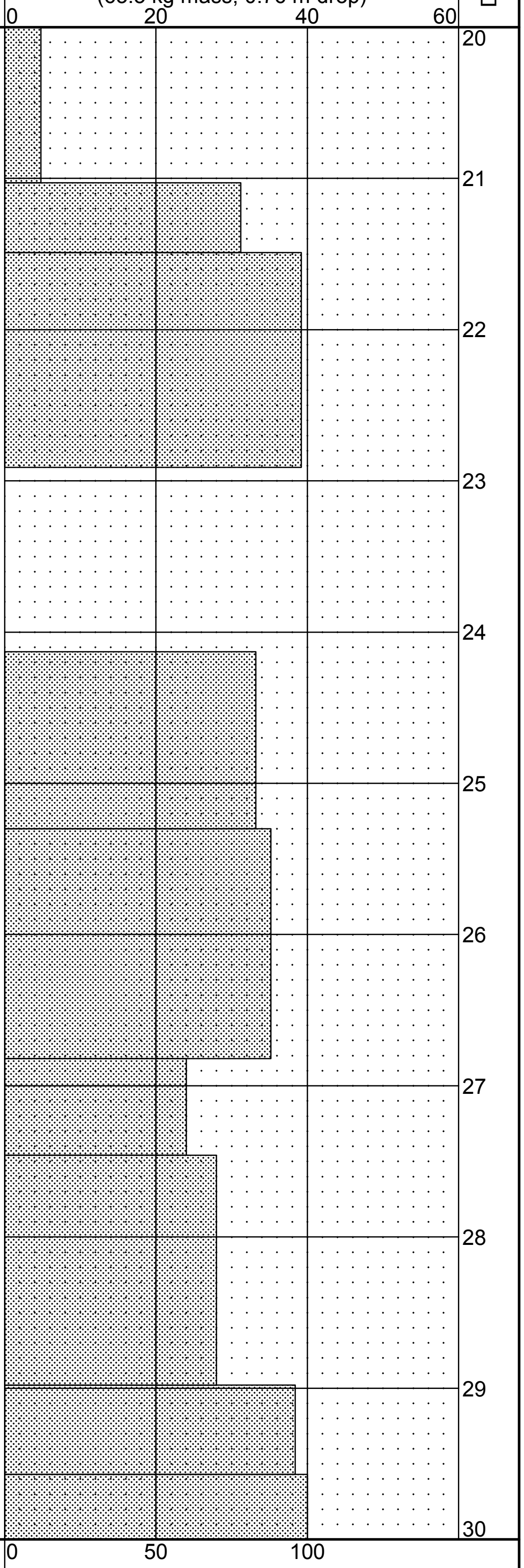
FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (Metric Units)

152 mm H-S AUGER	☐	BEGAN:	6/27/03
203 mm H-S AUGER	☐	COMPLETED:	6/1/03
NQ CORE	☐	DRILL:	CS1000
HQ CORE	☐	DRILLER:	Chris Peterson
OTHER:		WEATHER:	

DEPTH (m)	DESCRIPTION	GRAPHIC LOG	SAMPLE #	SAMPLE	BLOW COUNT
			R-14		
21.0	Tan rhyolitic cobble to 279.4 mm and 76.2 mm gray-green sandy, very small gravely, silty clay. High percent clay.		R-15		
21.5	177.8 mm silty, gravely, sand. 63.5 mm gray-green silty clay. 1016 mm alternating layers of tan sandy silt and gray silty, clayey sand layers are 76.2 mm to 254 mm decomposed. Last 139.7 mm gray silty coarse sand, tan-rust soils, gray gravels. Decomposed bedrock at 21.74 m.		R-16		
22.9	Clayey silt plugging bit and getting between inner and outer barrels, causing mislatch.		R-17		
24.1	Decomposed orange-brown, gray and multicolored breccia tuff. Decomposed to a silty sandy gravel or silty gravely sand. Gravels or harder fragments are rhyolite.		R-18		
25.3	Decomposed rhyolite or breccia (silty, sandy gravel). 508 mm highly weathered rhyolite or rhyolitic tuff. Sandy gravel.		R-19		
26.8	Highly weathered rhyolite washed away decomposed material x 254 mm. Some gray basalt rock flows in the rhyolite.		R-20		
27.5	Highly weathered rhyolite or decomposed with harder fragments. Decomposed areas are tan, sandy, silty clay.		R-21		
29.0	177.8 mm decomposed tan rhyolite. 381 mm blue gray silty clay or clayey silt. Decomposed siltstone or mudstone.		R-22		
29.6	Blue-gray decomposed mudstone. Silty clay or clayey silt. Core was pulled 50.8 mm out of end of inner barrel, weight				

▼ WATER CONTENT (%)
PLASTIC LIMIT ├──┤ LIQUID LIMIT
● SAMPLE PENETRATION RESISTANCE BLOWS PER 0.3 m (63.5 kg mass, 0.76 m drop)



1.75 in O.D. SPLIT TUBE SAMPLE	3 in SHELBY TUBE
2 in O.D. SPLIT TUBE SAMPLE (SPT)	AUGER
3.25 in O.D. SPLIT TUBE SAMPLE (D & M)	CORE

WATER LEVEL

▩ RQD (%)	× FIELD VANE (kPa)
▨ RECOVERY (%)	✚ POCKET PEN (kPa)
UNCONFINED COMPR. STRENGTH (MPa)	

PROJECT: Denali National Park
STATION, OFFSET:

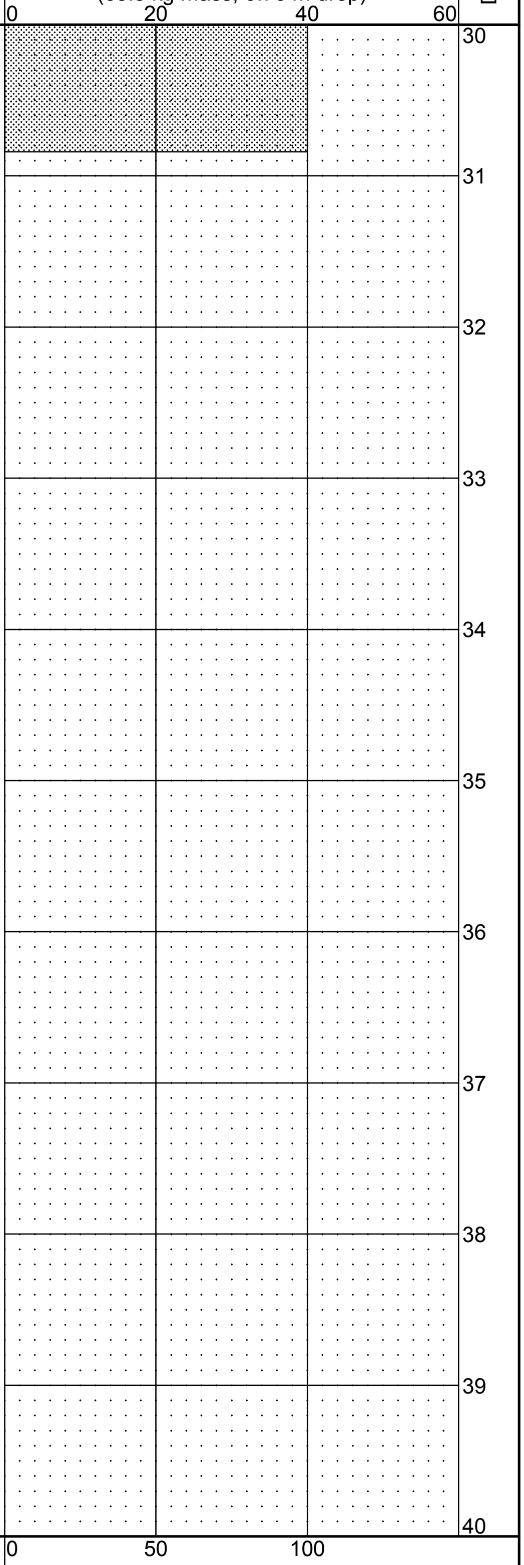
BORING PLY03-2
Sheet 3 of 4

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (Metric Units)

152 mm H-S AUGER	☐	BEGAN:	6/27/03
203 mm H-S AUGER	☐	COMPLETED:	6/1/03
NQ CORE	☐	DRILL:	CS1000
HQ CORE	☐	DRILLER:	Chris Peterson
OTHER:		WEATHER:	

DEPTH (m)	DESCRIPTION	GRAPHIC LOG	SAMPLE #	SAMPLE	BLOW COUNT	▼ WATER CONTENT (%) PLASTIC LIMIT ⊢—⊣ LIQUID LIMIT ● SAMPLE PENETRATION RESISTANCE BLOWS PER 0.3 m (63.5 kg mass, 0.76 m drop)	DEPTH (m)
	of rods pushed string 101.6 mm into the mudstone before run started.		R-23				30
30.8	**BORING TERMINATED AT A DEPTH OF 30.84 M**						



1.75 in O.D. SPLIT TUBE SAMPLE
2 in O.D. SPLIT TUBE SAMPLE (SPT)
3.25 in O.D. SPLIT TUBE SAMPLE (D & M)
3 in SHELBY TUBE
AUGER
CORE
WATER LEVEL

▩ RQD (%)
▨ RECOVERY (%)
× FIELD VANE (kPa)
✚ POCKET PEN (kPa)
UNCONFINED COMPR. STRENGTH (MPa)

PROJECT: Denali National Park
STATION, OFFSET:

BORING PLY03-2
Sheet 4 of 4

APPENDIX C – ROCK DESCRIPTIONS AND STRUCTURAL MEASUREMENTS

Pretty Rocks Rock Descriptions and Structural Data

			Structural features											Structural Measurements (Azimuth)						
Description	Unit	Rock Description	Hardness	Weathering	Discontinuities	Aperture	Infilling	Roughness	Spacing		Persistence	Block Size and Shape	Seepage	Type	Plane	Strike	Dip	Dip Direction	Strike of Road	Notes
1	Ttvr3 Tertiary Teklanika volcanic rhyolite, unit 3	White w/ bands of brown and purple. Weathers to orangey tan. Aphanitic. 1% phenocrysts. 1% amygdules filled with white, chalky material interpreted as devitrification texture. 98% groundmass. Phenocrysts are medium to fine-grained sanidine, subhedral. Exhibits flow banding, soft sediment deformation.	Strong	Slight	Joints	1 - 5 mm, 2 mm typical	Little to none. Some small grains and some weathering material from bedrock.	Smooth	Plane 1:	3 -10 cm	Low	Tabular to columnar	2	Joint	1	025	45	SE	071	
					Fractures				Plane 2:	1 - 25 cm	Low			Joint	2	350	53	260		
									Plane 3:	1 - 20 cm	Low			Joint	3	280	55	190		
2	Ttvr3	Same, except purple coloring and no banding. Soft sediment deformation present. Purple coloration appears in amorphous shapes, interpreted as devitrification product. Rough.	Strong	Slight	Joints	1 - 5 mm, 3 mm typical	Little to none. (Same.)	Rough	Plane 1:	6 - 16 cm	V. low - low	Tabular	2	Joint	1	032	48	122	070	Larger block size than description 1. Plane 1 is visibly undulating. Surface of Plane 1 more irregular. Seems that presence of purple material makes joint planes break more unevenly and become more persistent.
					Fractures				Plane 2:	5 - 40 cm	Medium			Joint	2	330	45	240		
									Plane 3:	4 - 40 cm	Medium			Joint	3	270	50	180		
3	Ttvr3	Same.	Strong	Slight	Joints	1 - 5 mm, 2 mm typical	Same	Rough	Plane 1:	4 - 10 cm	Very low	Tabular	2	Joint	1	038	76	128		Similar to Descr. 2 with exception of persistence of plane 2. Blocks still larger and more irregular than Descr. 1.
					Fractures				Plane 2:	4 - 61 cm	Very low			Joint	2	339	35	249		
									Plane 3:	2 - 66 cm	Medium			Joint	3	283	56	193		
4	Ttvr3	Similar, except with inclusion of soft white, chalky material which are similar in shape to the amorphous occurrences of purple material. Weathers differently than surrounding material - same tan color, but weathered texture is more bumpy and irregular. White interpreted as devitrification product.	Strong	Slight	Joints	1 - 5 mm, 3 mm typical	Same	Rough	Plane 1:	3 - 20 cm	Very low	Irregular, varied, some tabular	2 - 3	Joint	1	006	63	096	055	"Gap" and varying orientation of Plane 2 are unique, as is presence of chalky material. Blocks less regular and decrease in size going up rock face.
					Fractures				Plane 2:	10 - 37 cm	V. low - low			Joint	1	025	48	115		
			(chalky material excepted)		"Gap"				Plane 3:	8 - 40 cm	High			Joint	2	320	58	230		
														Joint	2	325	55	235		
								(Rougher than previous locations where white material located)						Joint	2	315	90	225		
														Joint	3	080	25	350		
														Joint	3	102	28	012		
5	Ttvr3	Similar. Purple, weathering purple/orange. Seemingly more iron oxide. Hardest yet. Minor occurrence of white chalky material.	V. Strong	Slight	Joints	1 - 8 mm, 2 mm typical	Same	Smooth	Plane 1:	19 cm - 2 m	Medium	Blocky/Irregular Shapes become more tabular and decrease in size upsection.	2	Joint	1	025	43	115	055	Change in size and shape of blocks seems to correlate with decrease in hard purple material. Plane 1 is very undulatory. Overall, more purple, harder, bigger blocks, more persistance esp. in Plane 1.
				Large bands of iron oxide in joints.	Fractures				Plane 2:	1 - 2 m	Low			Joint	1	015	66	105		
								(Esp. Plane 1)	Plane 3:	10 cm - 1.5 m	High			Joint	2	325	64	235		
														Joint	2	305	52	215		
														Joint	3	280	86	180		
														Joint	3	320	33	230		
6	Ttvr3	Between description #5 and #6, rock face is irregular without well developed planes. Soft, white material common, forming rough weathered exterior. At description #6 site, returns to rock type seen at #5 with lots of purple and well-developed joint planes.	Strong	Slight	Joints	1 - 20 mm, bimodal many are 1 mm, many are around 20 mm, few in between	Same	Rough	Plane 1:	50 cm - not many locations available for measurement	Low	Blocky to tabular - blocks are large	2	Joint	1	025	50	115	080	
					Fractures				Plane 2:	1.5 m	Medium			Joint	2	335	50	245		
									Plane 3:	55 cm - 2.5 m	Medium			Joint	3	338	26	248		
7	Ttvr3	Western extent of Rhyolite Formation #1 rock classification similar. Minor flow banding seen for the first time since description #1. Still some chalky material. Rock appears irregular, and more fractured possibly due to proximity to contact.	Strong	Moderate	Joints	1 - 4 mm	Same	Rough	Plane 1:	18-24 cm - very difficult to discern in this irregular area	Very low	Irregular - fractured	2	Joint	1	071	45	161	272	Joint plane 1 very irregular
					Fractures									Joint	1	060	45	150		
														Joint	1	059	62	149		
														Joint	2	341	79	251		
														Joint	2	340	64	250		
									Plane 2:	6 - 50 cm	Low			Joint	3	066	46	336		
									Plane 3:	18 - 30 cm: area north fractured and irregular. Difficult to discern plane spacing	Very low			Joint	3	050	62	320		
Overall	Ttvr3	90 yds thick along road												Unit		335	62	245		
														Fault		325	86	055		
1	Ttvr2 Tertiary Teklanika volcanic rhyolite, unit 2	Gray, weathering tan to orange, aphanitic rhyolite, with fine to medium grained sanidine phenocrysts. Texture is dense, hard, seemingly compact. White speckles of devitrification texture throughout. 1% phenocrysts. 99% groundmass. All phenocrysts are euhedral sanidine.	Strong to Very Strong, difficult to break	Slight	Joints	0 - 2 mm	None	Smooth with slickenslides (slickenslides only on plane 1 - appears to be primary failure plane	Plane 1:	2 - 20 cm	Very low	Columnar	1 to 2	Joint	1	095	67	185	290	Slickensides along some planes
					Fractures				Plane 2:	.5 - 10 cm (most 2-3 cm)	Medium			Joint/Bedding Pla	2	359	68	269		
					Possible bedding planes				Plane 3:	14 - 58 cm	Very low			Joint	3	080	40	170		
														Fault?	1	330	87	030		
														Fault?	2	080	78	350		
2	Ttvr2	Same.	Strong	Slight	Joints	0 -1 mm	None	Plane 1: smooth with slickenslides Plane 2: rough but with minor slickenslides	Plane 1:	1 - 34 cm	Medium	Columnar, but lacking a distinct 3rd plane	1 to 2	Joint	1	272	55	182	310	Slickensides along some planes
					Fractures				Plane 2:	14 - 80 cm	Medium			Joint	2	315	060	225		
3	Ttvr2	Similar but with increasing occurence of chalky material and evident flow banding. Evidence of previous toppling failure. As seen previously, chalky material produces more irregular exterior weathering texture.	Strong	Slight	Joints	0 - 8 mm 1 - 2 mm typical	None	Rough	Plane 1:	55 cm	Medium	Tabular/Columnar	1 to 2	Joint	1	032	65	122		
					Fractures				Plane 2:	18 - 60 cm	Medium			Joint	2	315	80	225		
4	Ttvr2	More highly fractured - increased occurence of chalky material, which is much softer and seems	Strong	Slight	Joints	0 - 2 mm	None	Rough	Plane 1:	10 - 20 cm	Very Low	Irregular	1 to 2	Joint	1	085	56	176		
					Fractures			But with		Highly fractured				Joint	2	320	85	230		

		to weaken the bedrock and decrease the persistence of joint planes. Lacking phenocrysts.						occurrences of slickenslides in deposit of iron oxide	Plane 2:	and difficult to establish 6 - 18 cm highly fractured	Very Low									
5	Ttvr2	Gray, weathers orange, aphanitic rhyolite. Localized flow banding. Euhedral very fine grain sanidine phenocrysts. 1% phenocrysts, 99% groundmass	Strong	Slight - Moderate	Joints Faults Fractures	Joints - 2 mm Fractures - up to 40 mm	None	Rough	Plane 1: Plane 2: Plane 3:	Too Fractured 15 - 34 cm Too Fractured	Very Low Very Low Very Low			Joint Joint Joint	1 2 3	030 345 350	55 85 50	120 255 260		
Overall	Ttvr2	Highly fractured. Competency decreases, fracture increases east to west. Planes are curved. Devitrification texture present. 32 yds thick along road.												Unit		005	45	275		No apparent faulting
1	Ttvb2 Tertiary Teklanika volcanic basalt, unit 2	Aphanitic basalt. Dark gray, weathers purple, orange, black and yellow. Fine- grained plagioclase phenocrysts and pockets of alteration filled with secondary minerals. These pockets and elongate with parallel alignment. 1 % phenocrysts, 3% alteration pockets, 96% groundmass. Alteration pockets infilled with white to purple quartz, or iron oxide precipitate.	Strong	Slight - Moderate	Joints Fractures	0 - 2 mm	None	Smooth	Plane 1: Plane 2: Plane 3:	5 - 15 cm 6 - 18 cm 6 - 22 cm	Low Very Low Very Low	Small blocks, cut up appearance, fractured. Plane 1	1 to 2	Joint Joint Joint Joint Joint Joint	1 1 2 2 3 3	035 083 310 310 065 285	46 49 75 85 76 66	125 173 220 220 155 195	295	
2	Ttvb2	Same.	Strong	Slight - Moderate	Joints Fractures Faults	0 - 3 mm	None Some yellow clay	Smooth	Plane 1: Plane 2: Plane 3:	6 - 24 cm 6 - 30 cm 5 - 40 cm	Very Low Low Very Low		1 to 2	Joint Joint Joint	1 2 3	020 335 055	35 68 55	110 245 145	075	
3	Ttvb2	Similar. 100% groundmass. Weathering is extensive, difficult to find fresh rock face.	Strong	Slight	Joints Fractures Faults	0 - 2 mm	None	Smooth	Plane 1: Plane 2: Plane 3:	25 - 42 cm 23 cm - 1.5 m 12 - 33 cm		Blocky	1	Joint Joint Joint	1 2 3	025 305 275	60 50 55	115 215 005	065	
4	Ttvb2	Same.	Strong	Slight - Moderate	Joints Fractures Faults?	0 - 5 mm	None	Smooth - Rough	Plane 1: Plane 2: Plane 3:	8 cm - 1 m 5 cm - 62 cm 15 cm - 1 m	Medium Low Very Low	Columnar to Tabular	2	Joint Joint Joint	1 2 3	025 295 050	50 85 45	115 025 320	065	
5	Ttvb2	Same.	Strong	Slight	Joints Faults Fractures	0 - 3 mm	Joints - none Faults - clay gouge	Smooth - Rough	Plane 1: Plane 2: Plane 3: Plane 4:	4 - 20 cm 7 - 26 cm 5 - 22 cm 5 - 15 cm	Medium Very Low Very Low Very Low	Blocky		Joint Joint Joint Joint	1 2 3 4	040 305 350 320	52 55 57 65	130 035 260 230	055	
6	Ttvb2	Same.	Strong	Slight - Moderate	Joints Fractures Faults	0 - 3 mm 1 mm typical	Only along faults	Rough - increased by	Plane 1: Plane 2: Plane 3:	2 - 8 cm 3 - 30 cm 5 - 23 cm	Very Low Medium Very Low	Blocky	1 to 2	Joint Joint Joint	1 2 3	050 350 105	50 55 50	140 240 015	045	
7	Ttvb2	Overall - small blocks. Definite faulting. Looks "cut up." Fault breccia/gouge present, weathering to yellow. 54 yds thick along road plane.												Unit Fault Fault Fault Fault	 1 2 3 	300 340 295 330 315	46 62 50 75 62	210 250 025 060 045		
1	Ttvb1 Tertiary Teklanika volcanic basalt, unit 1	Aphanitic basalt. Gray, weathers red, orange, black and greenish gray. 100% groundmass. Some weathering to greenish gray clay. Local spheroidal weathering (coincides in greenish gray clay).	Strong	Moderate	Faults Joints Fractures	0 - 4 cm 0 - 3 mm	Some gouge None	Rough	Fault 1: Fault 2: Fault 3: Plane 1:	3 m 1.5 - 2 m Only 1 visible 2 cm - 1.5 m	Med - High Medium Medium Very Low	Irregular	2	Fault Fault Fault Joint	1 2 3 1	085 355 020 025	85 85 * inaccessible - strike estimated 65	355 265 115	040	
2	Ttvb1	Similar, but with vesicles whose previous infilling mineral is weathering in situ to iron oxide.	Strong	Moderate Wthrg. to green gray clay w/ spheroidal wthrg.	Joints Faults Fractures	0 - 2 mm 22 - 35 cm	Fault gouge clay	Rough	Plane 1: Plane 2: Plane 3: Fault 2: Fault 3:	8 - 40 cm 4 - 53 cm 6 - 16 cm 2.5 m 2 - 3 m	Very Low Very Low Very Low Medium Medium	Tabular to Irregular	2	Joint Joint Joint Fault Fault	1 2 3 2 3	035 080 005 340 315	45 55 50 69 85	125 350 275 250 225	040	
3	Ttvb1	Same. Highly weathered to orange, red, brown. Difficult to find a fresh face.	Strong	Moderate Lots of faulting, spheroidal	Joints Faults Fractures	1 - 3 mm	Fault gouge breccia	Rough	Plane 1: Fault 1: Fault 2:	3 - 18 cm 3 m 2 m	Very Low High High	Blocky/Irregular	2	Joint Joint Joint Fault Fault	1 1 1 1 2	050 020 045 350 025	48 48 46 60 68	140 110 135 260 295		
4	Ttvb1	Same, but area between faults has streaks of red within the fresh gray face.	Strong Very easy to break along planes of weakness	Moderate Spheroidal	Joints Faults Fractures	1 - 3 mm	Fault breccia and gouge	Rough	Plane 1: Plane 2: Plane 3:	3 - 20 cm 3 - 10 cm 3 - 8 cm	Very Low Very Low Very Low	Blocky, tabular with spheroidal weathering. Very	2	Joint Joint Joint Fault Fault	1 2 3 1 2	035 085 350 330 345	51 87 55 90 80	125 185 260 060 255	040	
5	Ttvb1	Appears to be the same, but entirely weathered. Could not find a fresh surface.	Strong - Very Strong	Moderate	Joints Faults Fractures	1 - 4 mm	Fault breccia and gouge	Rough	Plane 1: Plane 2: Plane 3:	7 - 20 cm 7 - 20 cm 5 - 20 cm	Very Low Very Low Very Low	Blocky/Irregular	2 to 3	Joint Joint Joint	1 2 3	030 075 340	46 45 85	120 345 250	035	
Overall	Ttvb1	Very cut up near contact with rhyolite unit 3, more breccia and gouge as you approach contact. Very weathered. 70 yds thick along road plane.												Unit Fault Fault Fault		300 065 320 340	46 40 90 70	210 335 230 250	* not measured. Taken from Basalt Unit 2 (parallel)	
1	Ttvr3 Tertiary Teklanika volcanic rhyolite, unit 3	Aphanitic rhyolite. Purple, white, pink, weathers to tan and orange. 3% quartz and sanidine phenocrysts. 97% groundmass. Minor occurrence of white chalky material as seen in the eastern unit, though to a lesser extent.	Strong	Slight	Joints Fractures Faults	1 - 4 mm	None to localized breccia and	Smooth, w/ rough patches	Plane 1: Plane 2: Plane 3:	4 - 40 cm 9 - 53 cm 6 - 54 cm	Low Very Low Medium	Blocky/Irregular	1 to 2	Joint Joint Joint Fault	1 2 3 1	010 050 320 330	42 70 46 65	100 320 230 240	040 *also use for overall strike and dip	
Overall	Ttvr3	V. well defined blocks and jointing planes. Less cut up than basalt. Bigger blocks. 6 yds thick along road.																		

Notes on rock description collection:
Utilized Brunton compass w/ declination set to 17 degrees.
Azimuth recorded.
Measurement taken approximately every 10 meters across a unit. Measured from E to W, from road corridor. (Critical wildlife habitat closure prevented ascent above road.)
If discontinuity planes were well-defined and parallel, one measurement taken for each plane.
If discontinuity planes more irregular, multiple measurements were taken for each plane to establish an average.
Assumption: Characteristics seen at the road are representative of the entire unit.
Followed: Alaska Department of Transportation and Public Facilities (AKDOT). 2003. Alaska field rock classification and structural mapping guide. State of Alaska, Juneau, AK.

APPENDIX H

Geophysical Investigation 2016

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Denali Park Road – Geophysical Investigations

Subsurface Features for the Park Entrance, Dog Kennels Loop, Igloo Forest, Polychrome Pass, and Stony Point Areas

Western Federal Lands Highway Division - WFLHD Geotechnical Report No. 03-17

Kevin Bjella, P.E., Stephanie Saari, Andrew Balser, and Ann Staples

May 2017

Approved for public release; distribution is unlimited.

Engineer Research and Development Center

Denali National Park Roadway – Geophysical Investigations

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CRREL
US Army Engineer Research and Development Center
Cold Regions Research and Engineering Laboratory
9th Street, Building 4070
Fort Wainwright, AK 99703

Final report

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Prepared for US Army Corps of Engineers
Washington, DC 20314-1000

Under Project , “Denali Park Road Resistivity and Ground Penetrating Radar Permafrost Investigation”

Monitored by Cold Regions Research and Engineering Laboratory
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Abstract

Geophysical investigations of four sections of the primary roadway, and one section of a secondary roadway serving Denali National Park were conducted from August 22 through August 26, 2016. These investigations were to ascertain the presence and extent of subsurface features and anomalies impacting roadway infrastructure. A suite of complementary geophysical techniques were utilized to survey the subsurface and included Capacitive-Coupled Resistivity (CCR), Ground-Penetrating RADAR (GPR), and Electrical Resistivity Tomography (ERT). Analytical results of the surveys in image form were overlain on aerial photography and satellite imagery, and were interpreted in context of known areas of ground deformation, and visible surface features.

Investigations occurred between August 22 and August 26, 2016 at: 1) the Park Entrance and Park Headquarters areas (mile 0 to 4) to include the parking area near the Dog Kennels Loop; 2) The Igloo Forest area (mile 31 to mile 34; Teklanika River to the Igloo Creek Campground); 3) Polychrome Pass (mile 44 to 46); and 4) the Stony Overlook area (mile 61 to 63). Initial interpretations include estimating bodies of ground ice within permafrost, material type changes, and subsurface hydrological features. Subsidence appears to be impacting roadway infrastructure within at least three of the four sections surveyed: 1) Mile 0 to 4 from the Park Entrance, 2) Polychrome Pass, and 3) Dog Kennels Loop parking lot, and currently existing or previous existing ground ice appears to be associated with some subsidence features, such as some portions of Mile 0 to 4, and the parking lot to the Dog Kennels. Although the subsurface at Pretty Rocks (Polychrome Pass) contains significant ground ice, this also appears to be an active rock wedge controlled landslide feature. The Igloo Forest section appears to be underlain primarily by alluvial deposits which are generally permafrost free or very low in ice content.

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Preface

This study was conducted for the U.S. Department of Transportation, Federal Highway Administration, Western Federal Lands Highway Division (WFLHD) under Project, "Denali Park Road Resistivity and Ground Penetrating Radar Permafrost Investigation." The technical monitor was Brian Collins, PE, WFLHD Senior Geotechnical Engineer.

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COL Bryan S. Green was the Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

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Unit Conversion Factors

Multiply	By	To Obtain
Feet	0.3048	meters
Inches	0.0254	meters
miles (nautical)	1,852.0	meters
miles (US statute)	1,609.347	meters
Yards	0.9144	meters

1 Introduction

At the request of the U.S. Department of Transportation, Federal Highway Administration, Western Federal Lands Highway Division (DOT), the Alaska Research Office (AKRO) of the Cold Regions Research and Engineering Laboratory (CRREL) performed geophysical investigations along four sections of the Denali National Park primary roadway and a secondary roadway. These investigations included three complementary geophysical techniques performed in the field (Bjella, 2015), and subsequent analysis and interpretation using aerial and satellite imagery in concert with field results and boring logs from drilling investigations. The goal was to link geophysical measurements with observed surface features and institutional knowledge from NPS and DOT personnel.

Investigations occurred between August 22 and August 26, 2016 at: 1) the Park Entrance and Park Headquarters areas (mile 0 to 4) to include the parking area near the Dog Kennels; 2) The Igloo Forest area (mile 31 to mile 34; Teklanika River to the Igloo Creek Campground); 3) Polychrome Pass (mile 44 to 46); and 4) the Stony Overlook area (mile 61 to 63). Capacitive-Coupled Resistivity (CCR) and Ground-Penetrating RADAR (GPR) were used along the length of each road section, while Electrical Resistivity Tomography (ERT) was also employed for the Pretty Rocks segment within the Polychrome Pass section.

DOT performed borehole drilling at ten locations within some of these sections in September 2016. The geophysical results were utilized to inform the drilling plan, and the boreholes will be used for further interpretation and corroboration of the geophysical field results. In combination, these results and analyses will assist DOT in planning for and targeting road maintenance efforts along the Denali National Park road, which is the primary transportation infrastructure serving over 600,000 visitors (2016), resource managers, scientists, and staff annually.

*Note: Geophysical survey units are noted in metric, as this is typical notation for these technologies. Road mile distances and borehole depths are provided in imperial units (miles and feet).

2 Study Area

Geophysical investigations were conducted along four sections of the Denali National Park Road from the Park Entrance on the eastern end, westward to the Stony Overlook area at roughly Mile 63 (Figure 1). The area is primarily Interior Alaska boreal forest, with areas of alpine tundra at higher elevations along toe slopes of the Alaska Range and foothills. These landscapes have a history of repeated glaciations and are characterized by periglacial landforms and surfaces modified by weathering, hydrologic and biologic processes occurring since the last glacial maximum.

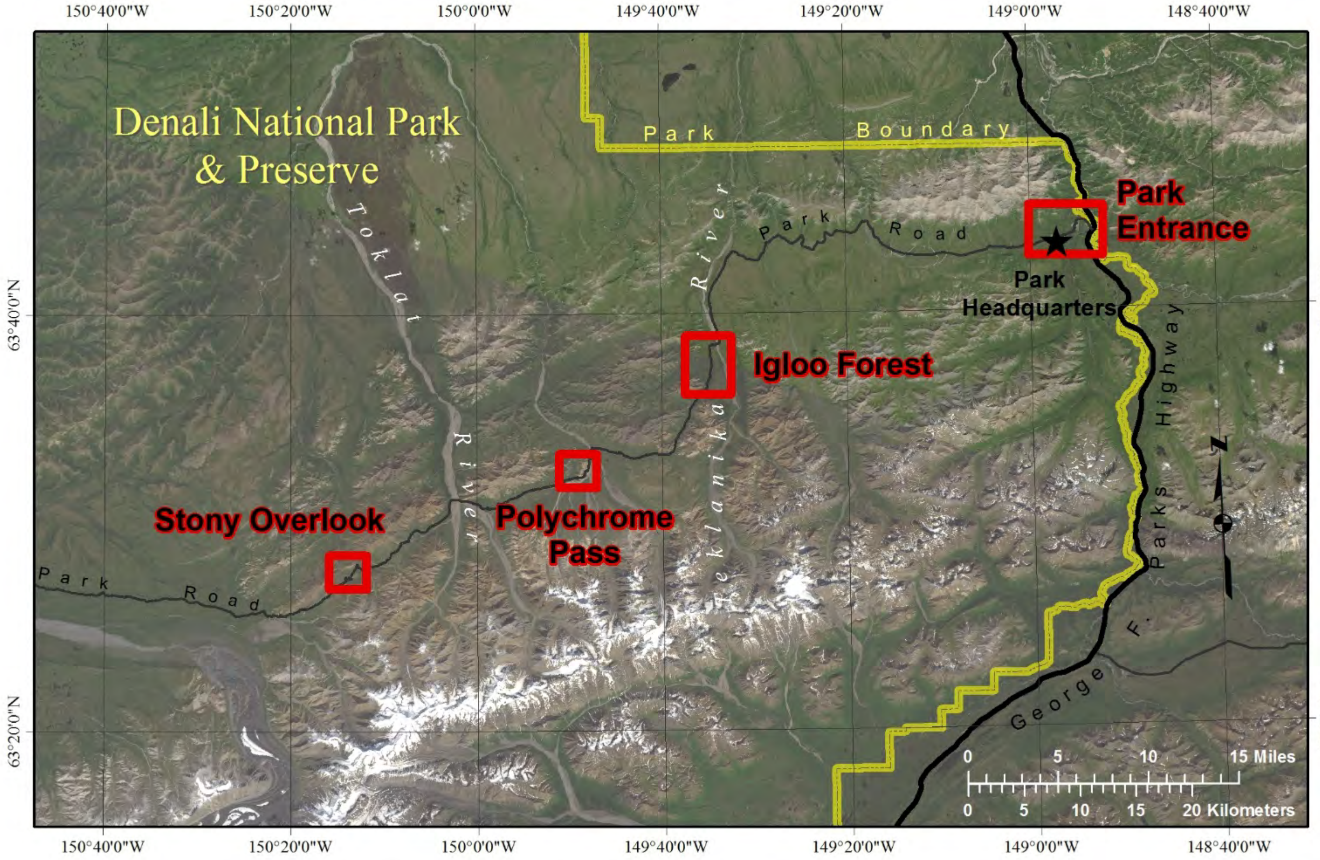

Figure 1. Eastern Portion of Denali Park Road with geophysical study sites in red boxes.

Denali National Park is within the Discontinuous Permafrost Zone (Jorgenson et al 2008), with both climate-driven ecosystem-modified permafrost, and ecosystem-protected permafrost (Shur & Jorgenson 2007). Recent degradation of near-surface permafrost is evident at multiple points along the road corridor as active layer detachment sliding and retrogressive thaw slumping (solifluction lobes), where mass-wasting leaves a break in the ground surface and a debris flow of displaced substrate downhill. Many other areas of in-situ ground subsidence may relate with other modes of permafrost degradation, and are recognizable by depressions in the ground surface without lateral sliding.

Other drivers of subsidence along the roadway in Denali National Park may include fluvial/erosional processes, and settling and compaction from prior work to the roadway and appurtenances.

2.1 Park Entrance and Park Headquarters (mile 0 to 4)

This section begins at the entrance to the park from the George F. Parks Highway and continues through upland boreal forest past various park infrastructure including the visitor center, the train station, several campsites, the park headquarters building, and the dog kennels (Figure 2).

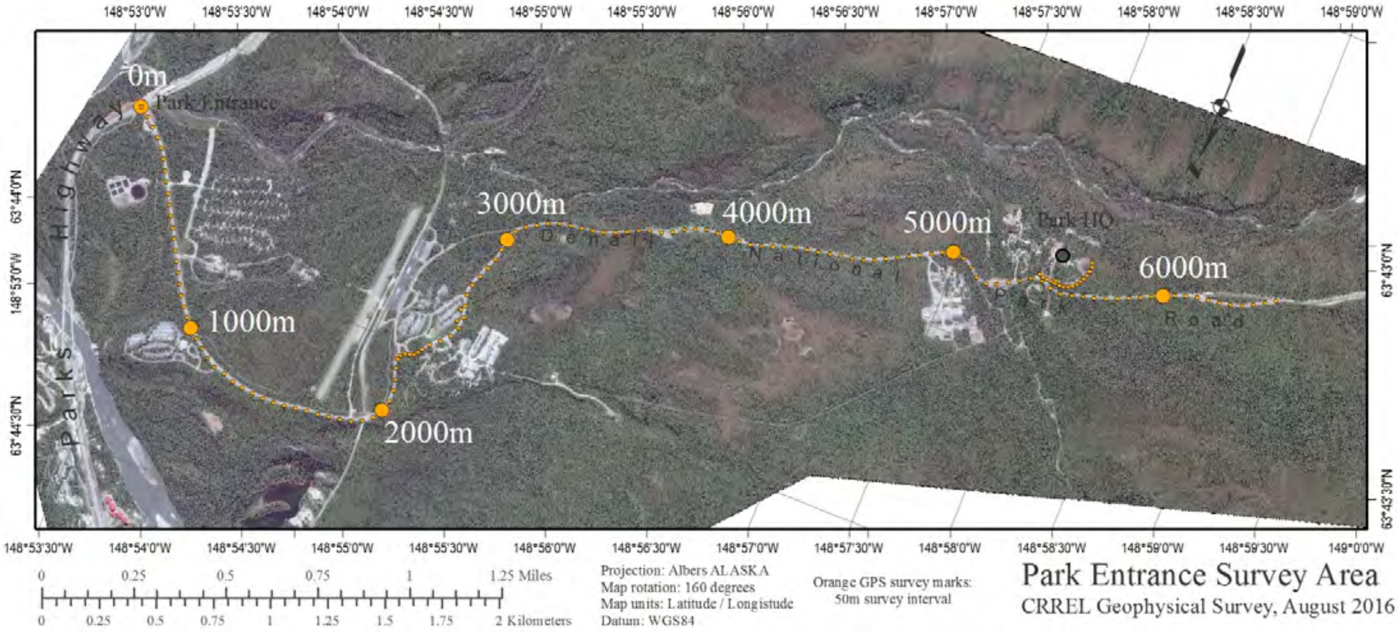

Figure 2. Park Entrance and Park HQ Section. **Note: orientation is is rotated 160° counter-clockwise to better correspond with other figures in this document.

Vegetation in the park entrance area is predominantly boreal forest, including open and closed forest of white and black spruce, and mixed stands of white spruce, paper birch and quaking aspen (I&M 2008; Viereck 1991). Small patches of closed willow and alder shrub are interspersed among the forest types. Sediments are dominated by glaciofluvial/lucustrine (Wahrhaftig, 1958). The distribution and pattern of vegetation in this area suggests permafrost is discontinuous in this area, and that ground-ice content may be highly heterogeneous.

Igloo Forest (mile 31 to 34)

This section begins at the bridge abutment on the western bank of the Teklanika River at mile 31.5 of the Denali Park Road, and continues to mile 34 at the bridge abutment on the northern bank of Igloo Creek, adjacent to the Igloo Creek Campground (Figure 3).

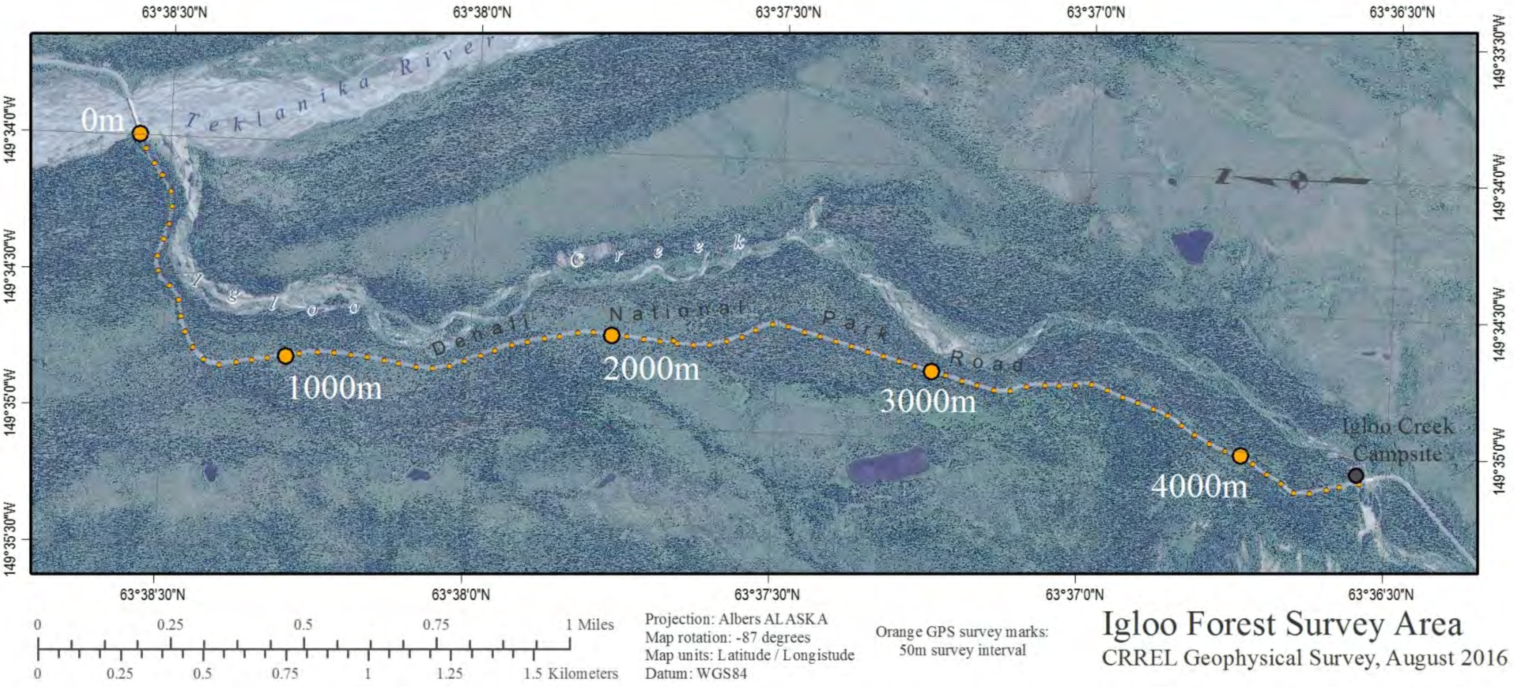

Figure 3. Igloo Forest Section. **Note: orientation is rotated 90° counter-clockwise to better correspond with other figures in this document.

Vegetation along the Igloo Forest section is predominantly floodplain boreal forest, including open and closed white and black spruce, with some mixed stands of white spruce, paper birch and quaking aspen (I&M 2008; Viereck 1991). Areas of low-shrub tundra, mainly closed low shrub birch and closed low shrub willow comprise significant patches among the forest types. Substrates are primarily floodplain alluvium, possibly interspersed with un-eroded till deposits (NPS GRI, 2010). At the southern end of the section nearing the Igloo Creek Campground, the nearby mountainous terrain to the west could be an indication of increasingly more shallow bedrock. It is also possible near surface permafrost is not in existence due to rapid and recent (geologically) alluvial deposition obliterating or burying already existing permafrost.

2.3 Polychrome Pass and Pretty Rocks (mile 44 to 46)

This section stretches from a slight bend in the road at mile 44 to another bend on the west side of Polychrome Pass (Figure 4). This section cuts across a steep south-facing slope (slopes ranging ~ 10° to 45°) composed of bedrock and near-surface bedrock, some of which is heavily weathered and fractured.

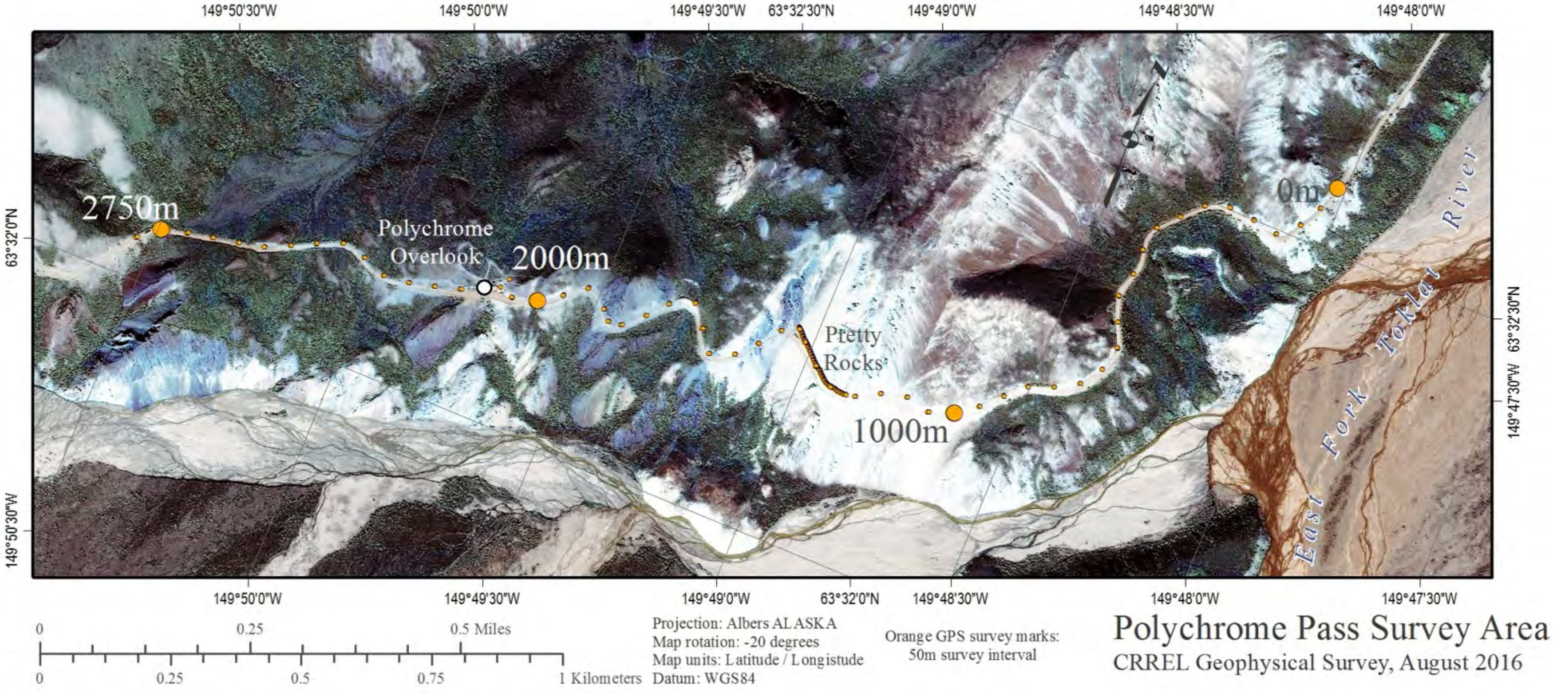

Figure 4. Polychrome Pass and Pretty Rocks Section. **Note: orientation is rotated 20° clockwise to correspond with other figures in this document.

2.4 Stony Overlook (mile 61 to 63)

This section stretches from a hairpin bend on eastern portion of the road over the top of Stony Overlook, descending through two switchbacks, and out onto a small floodplain ending at a culvert at a small creek crossing (Figure 5).

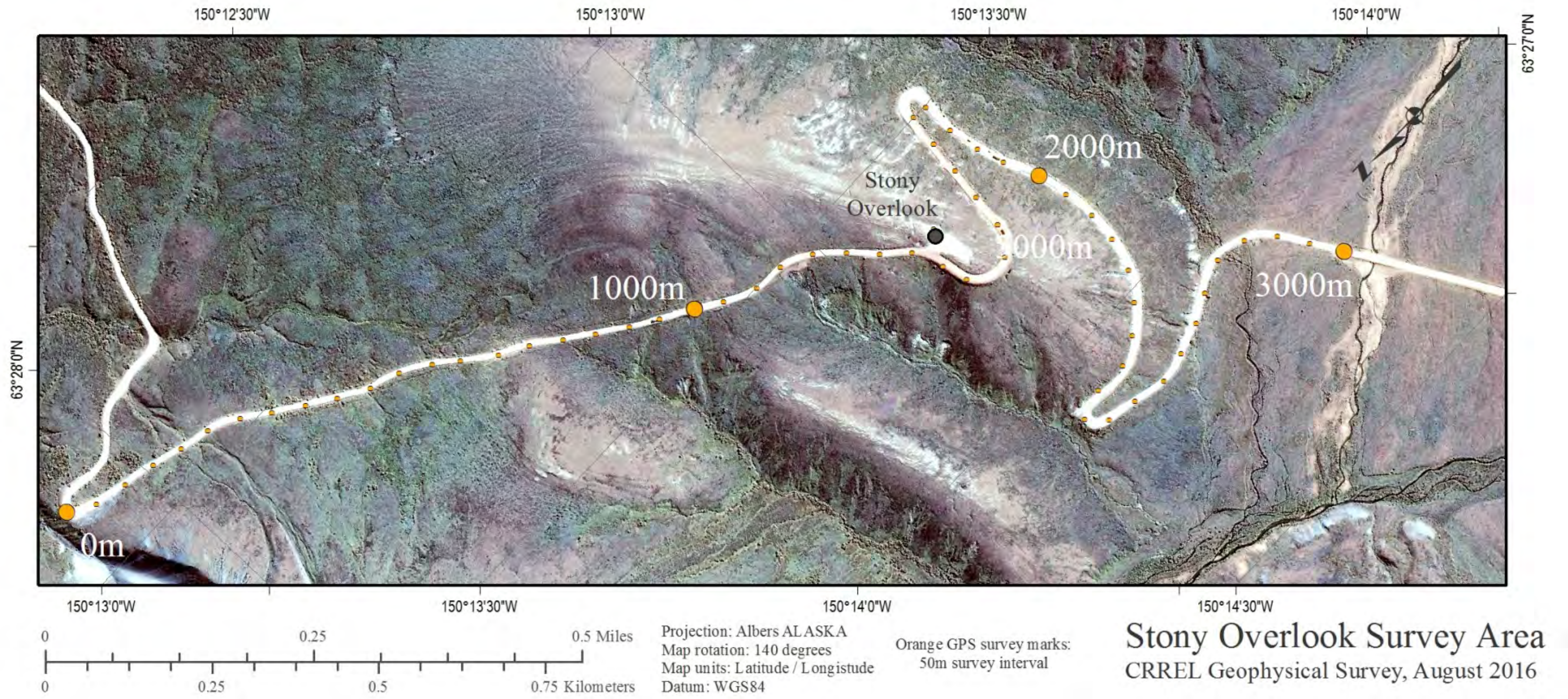

Figure 5. Stony Overlook Section. **Note: orientation is rotated 140° counter-clockwise to correspond with other figures in this document.

Stony Overlook is situated on what most probably is a bedrock dome overlain with glacial derived sediments. Multiple features were noticed on the north side of the road along the western slope of the hill near the overlook which appear morphologically consistent with retrogressive thaw slumps or solifluction lobes.

Vegetation in this area is a combination of low shrub tundra, mainly open low willow shrub in depressions, drainage ways and lower slopes, mixed with dwarf shrub tundra of mainly ericaceous species and non-tussock forming sedges on higher slopes, and on more exposed surfaces with limited soil development.

3 Geophysical Investigation Methods

We conducted our geophysical investigations along the Denali Park Road from August 22 through 26, 2016. Snow-free autumn conditions prevailed, with temperatures primarily between 7°C (45°F) and 18°C (65°F) during our surveys. On a few occasions rain (which, as water on the ground surface, interferes with survey signals) briefly delayed our surveys, but generally there was little precipitation or wind. To best accommodate existing park concession tour bus scheduling and road use, much of the survey work was conducted during nighttime hours.

We used non-intrusive geophysical methods including capacitive-coupled resistivity (CCR) and ground-penetrating radar (GPR), pulled at a smooth and constant rate along road sections we established in the field. The road sections of varying length were each surveyed as a single unit, conducting a full data collection run from the beginning to the end of the section in a single run. Pin flags were placed at precise 50m intervals ('fiducial marks') along each survey section, and were surveyed in using a high-precision real time kinematic (RTK) global positioning system (GPS). These were used to tie geophysical and analytical results from CCR, ERT and GPR to each other, and to ground coordinates with survey-grade accuracy. Another short (250m) section was surveyed in the HQ parking lot / Dog Kennel Loop area. Finally, the 168m 'Pretty Rocks' segment within the Polychrome Pass section was examined using electrical resistivity tomography (ERT), providing additional data at a greater depth for this particular section with special concern. Pin flags placed and surveyed at 2m intervals were used for fiducial marks along this segment.

3.1 Capacitive-Coupled Resistivity Methods (CCR)

Frozen earth materials are resistive to electric current flow, especially those with appreciable ground ice content. Resistivity has been proven to delineate between frozen vs. thawed, and ice-rich vs. ice-poor terrain. The processed data provides a cross-section (pseudo-section) of the subsurface (x,z).

CCR methods use the earth as one conductor of a parallel plate capacitor. The transmitter and receivers are composed of two coaxial cable dipoles. The transmitter sends a continuous current sine wave through the dipole, polarizing the surrounding earth material. The receiver measures the induced polarization, from which resistivity in units of Ohm-meter (Ohm-m) can be measured. For this study, we used a Geometrics OhmMapper TR-5 (OhmMapper) CCR system. We used Res2DInv 3.55 software manufactured by Geotomo Inc. to process OhmMapper resistivity data and develop subsurface pseudo-sections along each section. Resistivity inversion is an iterative process used to reduce the difference between the calculated and measured apparent resistivity values by adjusting the resistivity of each block in a model grid (Loke et al., 2003). Frozen water is resistive to electric current flow and experience has shown that: 0 to 100 ohm-m responses could indicate thawed, potentially wet materials; 100 to 1,000 ohm-m responses could indicate generally ice-poor, frozen coarse-grained material such as sands and gravels; 1,000 to 100,000 ohm-m responses could indicate ice-moderate to ice-rich materials (Hoekstra 1975). In general anomalous high (massive ice) or low (wet-saturated) resistivity locations indicate locations which may warrant specific borehole investigations. The normalized scale used for all CCR surveys is shown in Figure 6.

Figure 6. Normalized ohm-m index used for all CCR surveys including those in Appendix A through F. Blue values are very low resistivity while red to black indicate very high values.

We collected OhmMapper data along each road section (Figure 7). The OhmMapper array consists of one transmitter and up to five receivers connected in series, with each end of the transmitter and receivers attached to a dipole cable of 5m (16.4-ft) length (total 10m [32.8-ft] dipole). The series of receiver dipoles is separated from the transmitter dipole by a length of rope which sets the depth of acquisition for the transmitter/receiver array. The center point of collection of the CCR data is located between receiver 3 and receiver 4 of the array. Because of this offset between the operator location and the center of data collection, it will be seen that when the operator of the array is located at the zero (0m) location, negative (-) distances are reported to indicate that the array is stretched behind the operator. Conversely it will be noticed where the operator stops at the end of the survey transect, the CCR data will terminate prior to that location. All surveys were conducted with a rope separation of 10m (32.8-ft) , with the exception of the Park Road mi 0 to 4 which was collected with a rope separation of 17.5m (57.4-ft). A 10m (32.8-ft) rope results in a surveyed depth of 4.2m (13.8-ft) to 9.8m (32.2-ft) and a 17.5m (57.4-ft) rope separation results in a surveyed depth of 6.4m (21.0-ft) to 13.1m (43.0-ft). A summary of OhmMapper geometry and configuration for each transect is given in Table 1 below.

Figure 7. CCR Survey and GPR Survey. The CCR array (left) is being pulled by truck along the Polychrome Pass section, August 25, 2016. The 200MHz GPR (right) is pulled manually along the Igloo Forest Section, August 24, 2016.

Table 1. Summary of OhmMapper geometry and configuration.

Section	Dipole Length m (ft)	Separation Distance m (ft)	CCR Transect Distance m (ft)
Park Road mi 0 to 4	10 (32.8)	10 (32.8)	6400 (20,997)
HQ/Dog Kennel Loop	10 (32.8)	5 (16.4), 10 (32.8), 17.5 (57.4)	300 (984)
Igloo Forest	10 (32.8)	10 (32.8)	4400 (14436)
Polychrome Pass	10 (32.8)	10 (32.8)	2800 (9186)
Stony Overlook	10 (32.8)	10 (32.8)	2300 (7546)

3.2 Earth Resistivity Tomography (ERT)

This method measures resistivity by injecting a current (galvanic) into the subsurface via two current electrodes, and reading the resultant voltage via two potential electrodes. By measuring the current, voltage, and the geometry of the electrodes, the resistivity of the subsurface can be calculated. Averaging algorithms are then used to calculate the apparent resistivity over a range of depths along an electrode line. This system is time consuming to set as the electrodes must be hammered into the subsurface, and each survey is limited to the length of the cables at maximum electrode spacing. The advantage is much deeper depths are attainable than with the CCR system, and in general the data quality is less noisy than CCR. The system utilized for this study was the Advanced Geosciences Inc., Super Sting R-8.

3.3 Ground Penetrating Radar Methods (GPR)

GPR is a geophysical method that transmits high frequency radio waves (10 megahertz [MHz] to 4 gigahertz [GHz]) into the subsurface and records the reflections of these waves from subsurface discontinuities. The velocity of radar waves are altered due to the differing dielectric permittivity from one substance to another. This contrast results in electrical phase changes that visually produce an image for interpretation. At all the locations generally the conditions were favorable for GPR collection. The surface was relatively planar and obstructions were minimal to aid with smooth data collection. Clay and silt sized earth mineral derivatives are known to absorb radar energy (Arcone 2008), especially when the material is wet or saturated. In some sections of the survey images we noticed radar energy attenuation and the particle size fraction might be the cause.

For all road sections we utilized 200 MHz (center frequency) antenna manufactured by GSSI Inc., with returns visible down to approximately 100 ns. GPR data were processed using Radan 7 software manufactured by GSSI Inc. We corrected the profiles for depth using the migration of hyperboles on metallic targets to adjust the dielectric response. The horizontal distance was normalized by using fiducial marks (surveyed pin flags as ground control) measured in the field to correct for uneven walking speeds. The profiles were correlated to the high resolution aerial and satellite imagery using the fiducial mark ground control in order to match the location of targets on the imagery. GPR radargrams along sections where we collected data using the 200mHz antenna are shown in Appendix B; GPR radargrams along transects where we collected data using the 100 MHz and 400 MHz antennas are also shown in Appendix B.

3.4 Positional Accuracy

Ground penetrating radar accuracy under ideal conditions is approximately sub-meter scale in the horizontal plane and centimeter in the vertical plane. Vertical resolution of this order requires a known depth, to within centimeters, to an object easily discernible in the radargrams, which allows for the exact determination of the dielectric constant. There were few objects of this type along our survey sections, therefore the dielectric constant was not accurately calibrated. Therefore we estimate our vertical accuracy to be approximately at the 0.5m (1.6-ft) range. Typically the OhmMapper system has horizontal and vertical accuracy equal or better than half the electrode spacing. For this case, the electrode spacing was 5m (16.4-ft) so we can assume the accuracy horizontally and vertically is about 2.5m (8.2-ft).

Our method for positional ground control includes establishing fiducial marks equally spaced along a given section with defined beginning and end points. We set pin flags as a visual identifier for the fiducial marks, and then we survey each pin flag using a Trimble R8, dual-frequency, survey-grade global positional system (GPS) device. During geophysical data collection, we electronically ‘mark’ each pin flag in the data file precisely as the instrument passes it. During subsequent processing, these fiducial marks in the dataset are assigned exact distances along the section, and are related with real world coordinates from GPS survey.

Although identified as the same section, the horizontal positions along a transect are processed slightly differently for the GPR transects vs. OhmMapper transects. In addition the total length of the CCR array at 55m (180.4-ft) introduces a degree of error on horizontal positioning in comparison to the GPR which is less than a meter in length, and hilly and curvy transects will tend to exacerbate this issue. These factors combined may provide slight offsets when comparing CCR to GPR in a given transect. Based on the methods used for positional control, conditions encountered in the field, and our experience using these methods, the positional accuracy of OhmMapper in comparison to the GPR may be on the order of 1.5m (4.9-ft) to 3m (9.8-ft).

4 Results

Ground penetrating radar and resistivity are indirect methods which are often complementary for viewing subsurface features. Changes in material type, and organic and moisture content are most often associated with the geomorphology and are often identifiable with geophysics to some degree. For instance, layered structures, which are often associated with near surface materials such as sediments, may be altered, replaced, or destroyed, and these changes in layering can be readily seen in GPR radargrams. Conversely, the processes which alter the layered structures often emplaces new materials and features related to the material, or changes the properties of the materials at that location, such as increased water and organic content, and in the case of permafrost, this may equate to increased or decreased ice content. These types of changes result in contrasts identifiable in the resistivity pseudo-sections.

Therefore we plot the GPR and resistivity data together and this often leads to a more informed hypothesis of what may exist in the subsurface and the process that created them. In addition, we plot these geophysical results overlaid on aerial or satellite photos as the near surface morphology is often identifiable via surface expression such as changes in topography, outcroppings of bedrock, changes in vegetation type and density, evidence of polygonal ground (permafrost terrains), and the existence of surface water (streams, lakes, poorly drained areas). We have plotted the results of all the surveys onto satellite photos, with the resistivity in profile section and with elevation correction, and also the GPR in profile section but not elevation corrected. These are shown in the respective Appendices A through F at the end of this report.

We also have provided drill hole logs plotted adjacent to short sections of the resistivity surveys in an effort to illustrate the accuracy of the technique in discriminating between the earth materials and properties. These are shown in Appendix G. Four sets of drill holes were provided to us; 2016, 2014, Pretty Rocks (2 drill holes), and 1983. We are only presenting those boreholes that had sufficient depth > 1.5m (5 ft.) and were located within 10m of the path of our surveys. All the provided drill hole logs are presented in Appendix H.

5 Discussion

The five transects surveyed are comprised of varying terrain to one another, with each having slightly different measured responses. In no instances was there a problem with measuring or collecting the CCR and ERT data. The GPR however can often be unreliable in some terrains due to the radar attenuation being heavily influenced by ground water and clay mineral content. That being said, we believe the results as presented provide an excellent viewpoint to aid in connecting the dots between calibration points, such as drill holes, outcrops, escarpments, and other terrain features.

5.1 Denali Park Road/HQ and Dog Kennels

The CCR mapped interesting values across this transect with a mix of values and anomalies at the start of the road up to Riley Creek Campground road, but it then settled to consistently show what is possibly inferred as shallow bedrock leading up to the Headquarters Road. Beyond this point, and to the end of the transect, the bedrock signature gives way to a low to moderate moisture content, which is probably a sediment regime. Frozen ground was only indicated in the vicinity of Dog Kennels Loop where massive ice was inferred in conjunction with dramatic thaw settlement seen in the parking lot. The GPR was very successful imaging the inferred shallow bedrock, and was very successful in mapping the parking lot construction and distortion due to thaw settlement.

5.2 Igloo Forest

The CCR demonstrated this section of the road sub-grade is homogeneous in the near surface, where it is inferred the road crosses thawed alluvial deposits for the entire length. If frozen ground exists in this transect, it must be very low moisture content to not have registered with the CCR, and must have been missed with the borehole drilling. The GPR was unfortunately non-remarkable, with most of the transect not providing significant radar returns except for the very near surface, down to 0.5m (1.6-ft). This is believed to be caused by excess moisture and possibly silt or clay minerals attenuating the signal. Igloo Forest has been problematic with a very soft sub-grade and corduroy sections built in years previous.

5.3 Polychrome Pass

This transect provided interesting results with the CCR providing low resistivity values as an indicator of moist/wet locations, or highly conductive minerology sections. Some of these locations are coincident with known landslides such as Bear Cave, Pretty Rocks, and Polychrome Overlook, therefore the moist/wet interpretation appears relevant. Some locations provided high resistivity results, and this is either due to high resistivity bedrock material or ground ice. The high resistivity at the Pretty Rocks landslide is absolutely due to ground ice (segregated syngenetic). Extensive subsurface investigations were performed around the Bear Cave slide in the late 90s. Borings encountered permafrost with some ice layers in many of the borings. The GPR provided spotty results for most of the transect, indicating chaotic bedrock structure in the locations where ground water or clay mineralogy did not attenuate the signal. At the Pretty Rocks landslide, the GPR was very successful in mapping the segregation ice captured in the landslide.

5.4 Stony Overlook

The CCR demonstrated this section of the road sub-grade is relatively homogeneous in the near surface, where it is inferred the road crosses a bedrock knob covered to some extent with glacial till and outwash sediments. Three high resistivity anomalies were discovered. Two test borings (BH16-04 and BH16-08) encountered frozen ground and excess ground ice at depth. The third boring (BH16-06) did not encounter frozen ground. The GPR was successful with most of the transect providing significant radar returns to include the very near surface. Some locations the radar was smeared (attenuated) and these locations coincided with very low resistivity suggesting a higher ground water component.

5.5 Pretty Rocks ERT and GPR

The ERT and GPR that was conducted at the Pretty Rocks landslide location was highly successful, with the ERT and GPR surveys delineating an icy band of segregation ice starting at approximately 2.0m (6.6-ft) to 3.0m (9.8-ft) depth and extending down to 4.5m (14.8-ft) near the road cut on the east end of the landslide. The ERT indicates that high moisture or ground water is prevalent below the icy zone.

6 Conclusions & Recommendations

The utilization of CCR and GPR to provide a continuous record of the changes in base, sub-base, and sub-grade materials of the Denali Park Road was successful. In particular and most important this technique allowed for determining pin-point locations for confirmation borehole drilling. The CCR also provided the useful knowledge for stretches of the surveyed road where conditions change very minimally, negating any future need for redundant drilling along these sections.

The CCR and GPR worked very well to help delineate the anatomy of the Pretty Rocks landslide zone. Significant segregated ice exists just below the active layer depth, and most probably continues down to approximately 15m (50-ft) or so, where it is inferred water was imaged. The CCR was also successful in identifying that high moisture/ground water is co-located with the known landslides failure zones of Bear Cave and the weak clay of Polychrome Overlook.

We recommend that further drilling be conducted at select locations to suit the needs of your current analysis and any future projects. The CRREL is available to assist with the interpretation of these results for further drilling or any other need you may require.

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8 Appendix A - Park Road mile 0 to 4

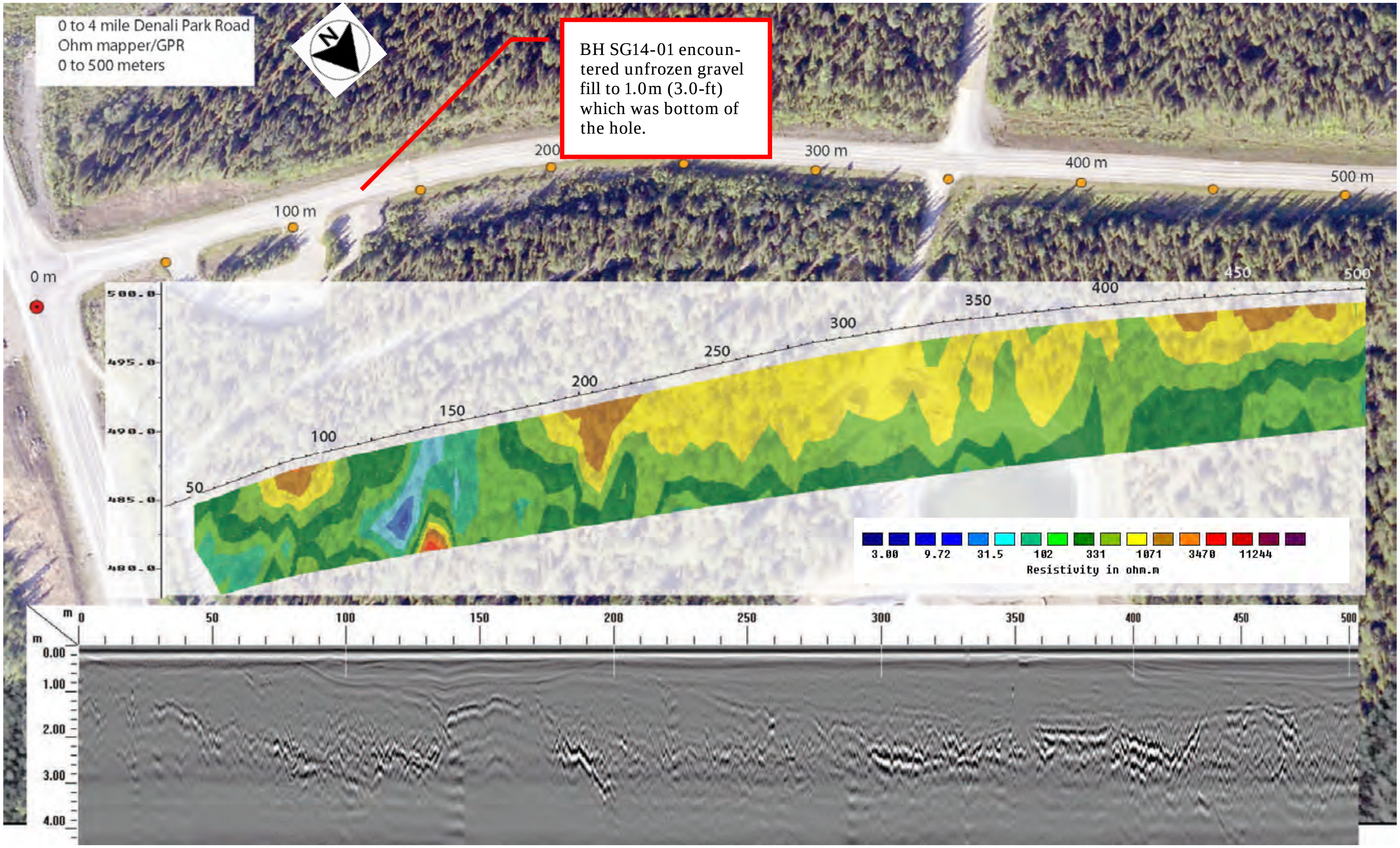
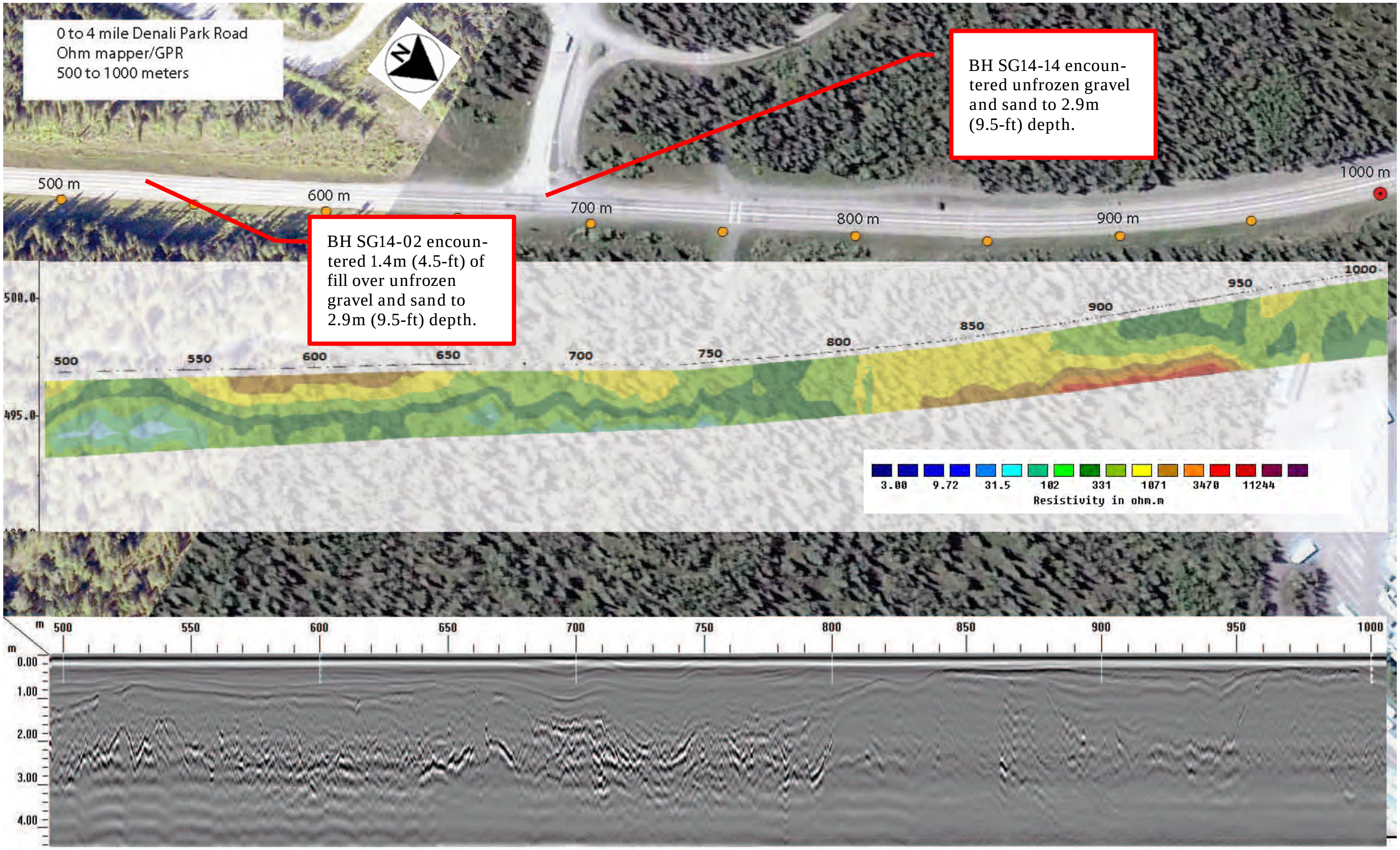


Figure 8. Park Road mile 0 to 4, 0m to 500m (1640-ft), start of transect. The view direction in these images is generally looking south, therefore the transect progresses from left to right, east to west. The starting location was at the junction with the Parks Hwy. The CCR indicates low to moderate resistivity in the near surface for most of this section. The GPR indicates a correlating strong reflector at approximately 2m (6.6-ft) depth. We interpret this to be relatively dry fill material placed for road construction. Near surface frozen ground is not indicated here.

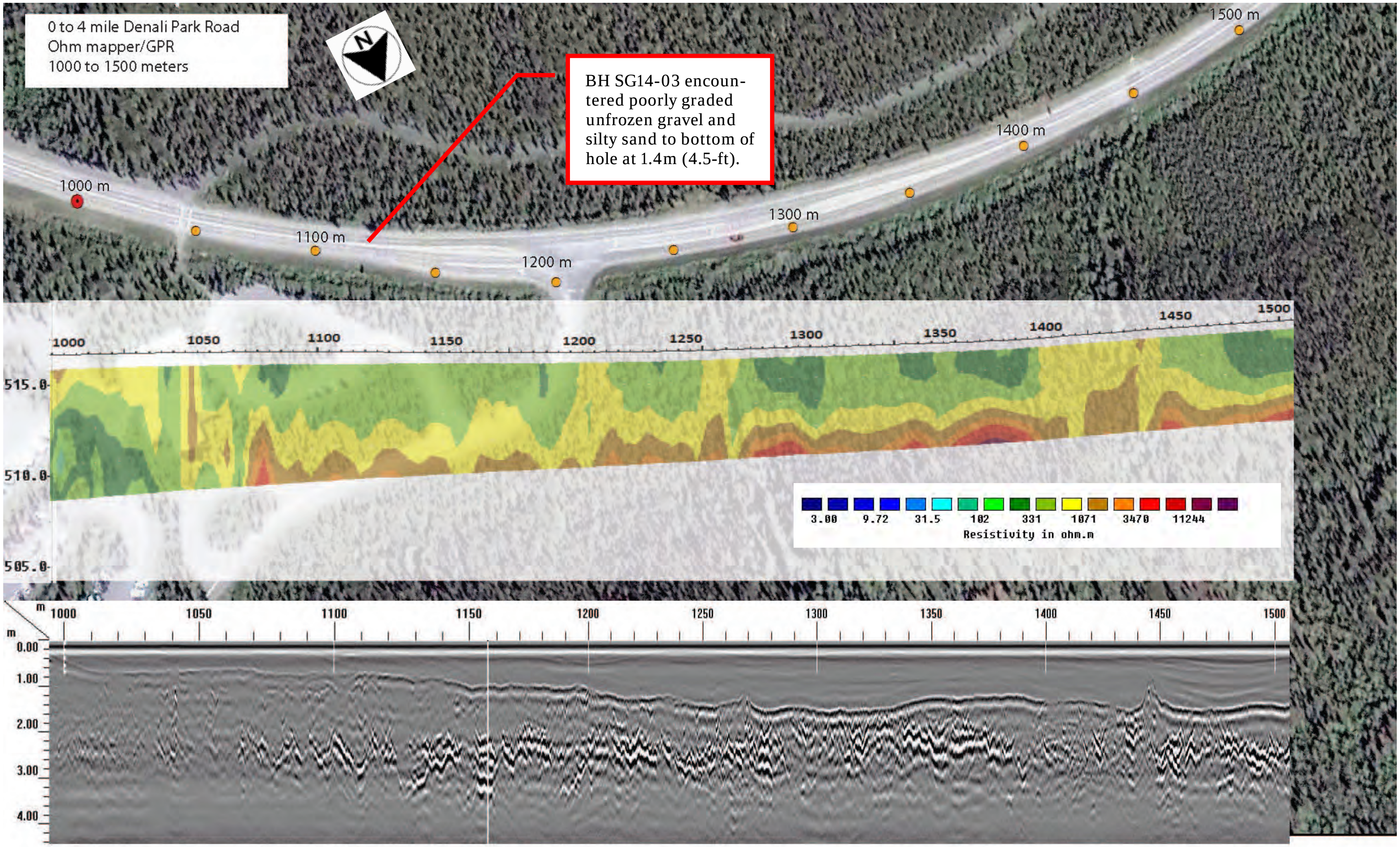


0 to 4 mile Denali Park Road
Ohm mapper/GPR
500 to 1000 meters

BH SG14-14 encountered unfrozen gravel and sand to 2.9m (9.5-ft) depth.

BH SG14-02 encountered 1.4m (4.5-ft) of fill over unfrozen gravel and sand to 2.9m (9.5-ft) depth.

Figure 9. Park Road mile 0 to 4, 500m to 1000m (1640-ft to 3280-ft). The CCR reports low to moderate ohm-m values at the near surface indicating fill material with a definitive low value layer directly below. Ground water may be inferred at approx. 550m and 700m. Significant road deformation was noted at approx. 700m. The GPR reports strong reflections at a depth of 2.5m (8.2-ft). and in the area of 700m these reflectors are very distorted indicating deeper warping which is then reflected at the surface. No frozen ground is indicated at 700m, so this may be related to a buried organic layer or poorly consolidated fine grained layer with excess water. Starting at 800m to 950m the CCR indicates moderate to high ohm-m values and this could indicate three possibilities; 1) deeper ice-rich material, 2) deeper bedrock indication, or 3) deeper clay layer indication, where a lacustrine deposit is known in this area.



0 to 4 mile Denali Park Road
Ohm mapper/GPR
1000 to 1500 meters

BH SG14-03 encountered poorly graded unfrozen gravel and silty sand to bottom of hole at 1.4m (4.5-ft).

Figure 10. Park Road mile 0 to 4, 1000m to 1500m (3280-ft to 4920-ft). The CCR indicates a continuing trend from 1050m to 1500m which was noticed previously from 800m to 950m with deeper, moderate to high resistivity values. The GPR provides strong imaging in this area with a strong reflector boundary suggesting top of the native surface, or top of bedrock lying below roadway fill material. The chaotic reflectors from 2.5m depth indicates rocky material, weathered/fractured rock. Boreholes TH83-1 (MP 0.7), TH83-2 (MP 0.85) and TH83-3 (MP 0.95) (Figures 68, 69, and 70) drilled in this area show sandy angular gravel starting from 2.5m (8.2-ft) depth and this may be an indication of the weathered rock. The CCR and GPR surveys together suggest that weathered bedrock exists over more competent bedrock. No frozen ground is indicated.

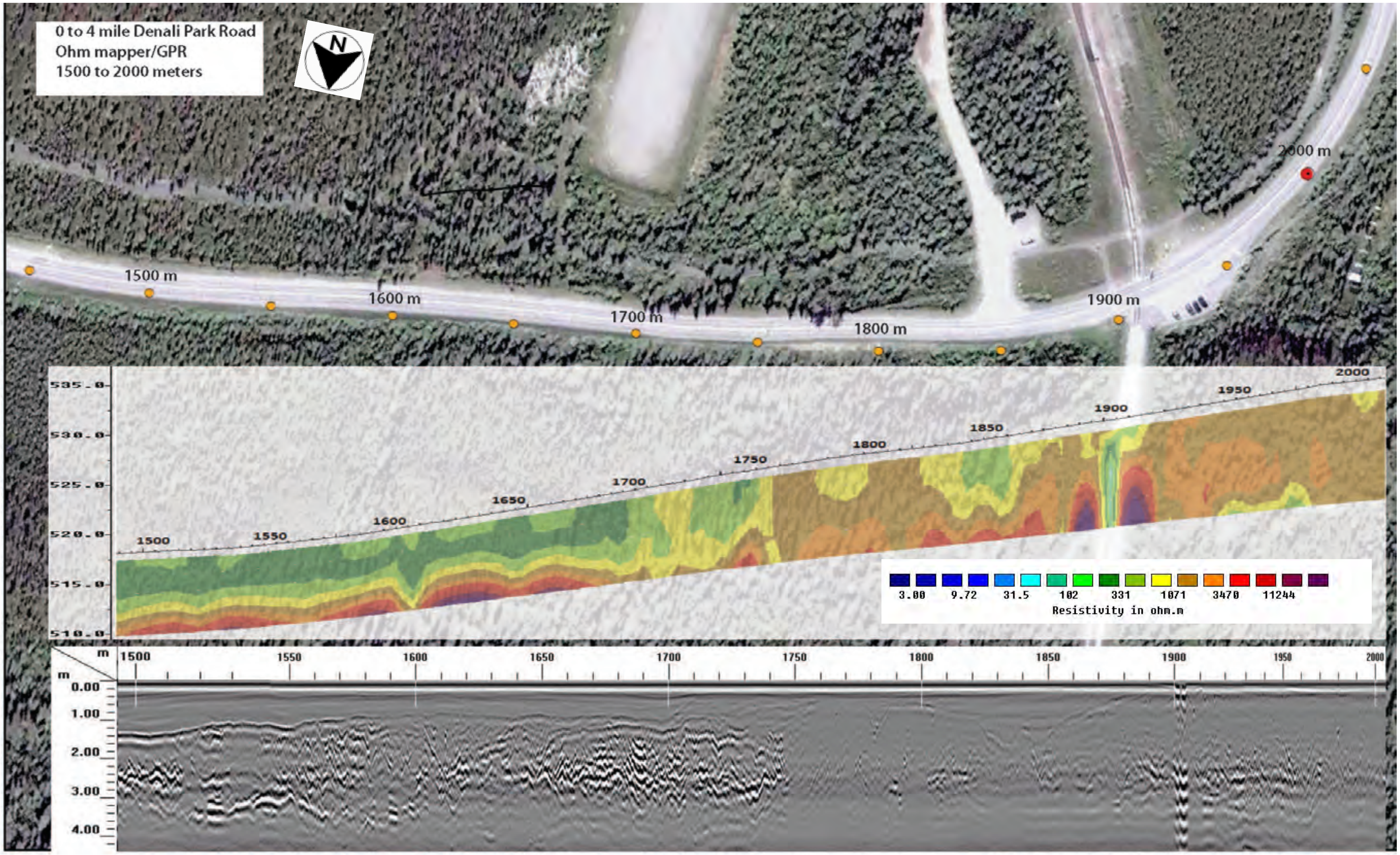
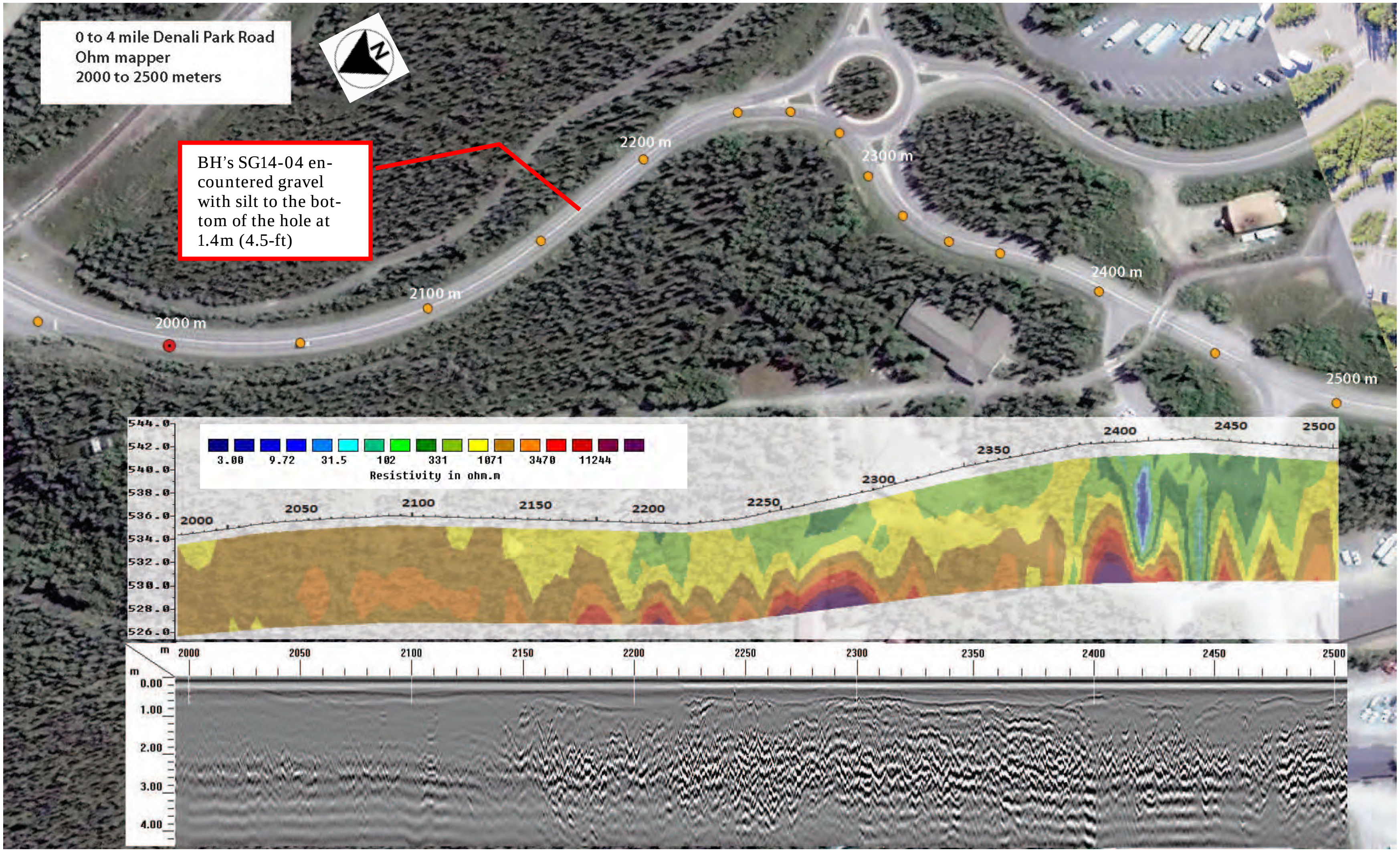


Figure 11. Park Road mile 0 to 4, 1500m to 2000m (4920-ft to 6560-ft). The interpretation of weathered/fractured rock overlying bedrock, as imaged in Figure 10 continues in this figure at depth. Low ohm-m value material overlays possible bedrock from 1500m to 1750m, and the bedrock appears to become more near surface at 1750m in the vicinity of the railroad crossing and beyond. Very high ohm-m values are associated with the railroad tracks specifically. Chaotic GPR reflectors are again noticed from 1500m to 1750m suggesting a rocky layer (weathered/fractured bedrock). Attenuation of the GPR signal occurs coincidentally at 1750m, where attenuated GPR is often associated with excessive clay mineral deposits or water. In this instance we believe clay minerals associated with weathered/fractured bedrock are indicated. No near surface frozen ground is indicated.



BH's SG14-04 encountered gravel with silt to the bottom of the hole at 1.4m (4.5-ft)

Figure 12. Park Road mile 0 to 4, 2000m to 2500m (6562-ft to 8200-ft). The interpretation of weathered/fractured rock overlying bedrock, as interpreted in Figure 10 continues in this figure with very strong chaotic reflectors visible from 2150m to 2500m and coincident high ohm-m values at depth. A near surface high conductivity feature is indicated at ~2400m with low ohm-m values and coincident dropping of the upper strong GPR reflector. A water line crosses the road at approximately 2420m.

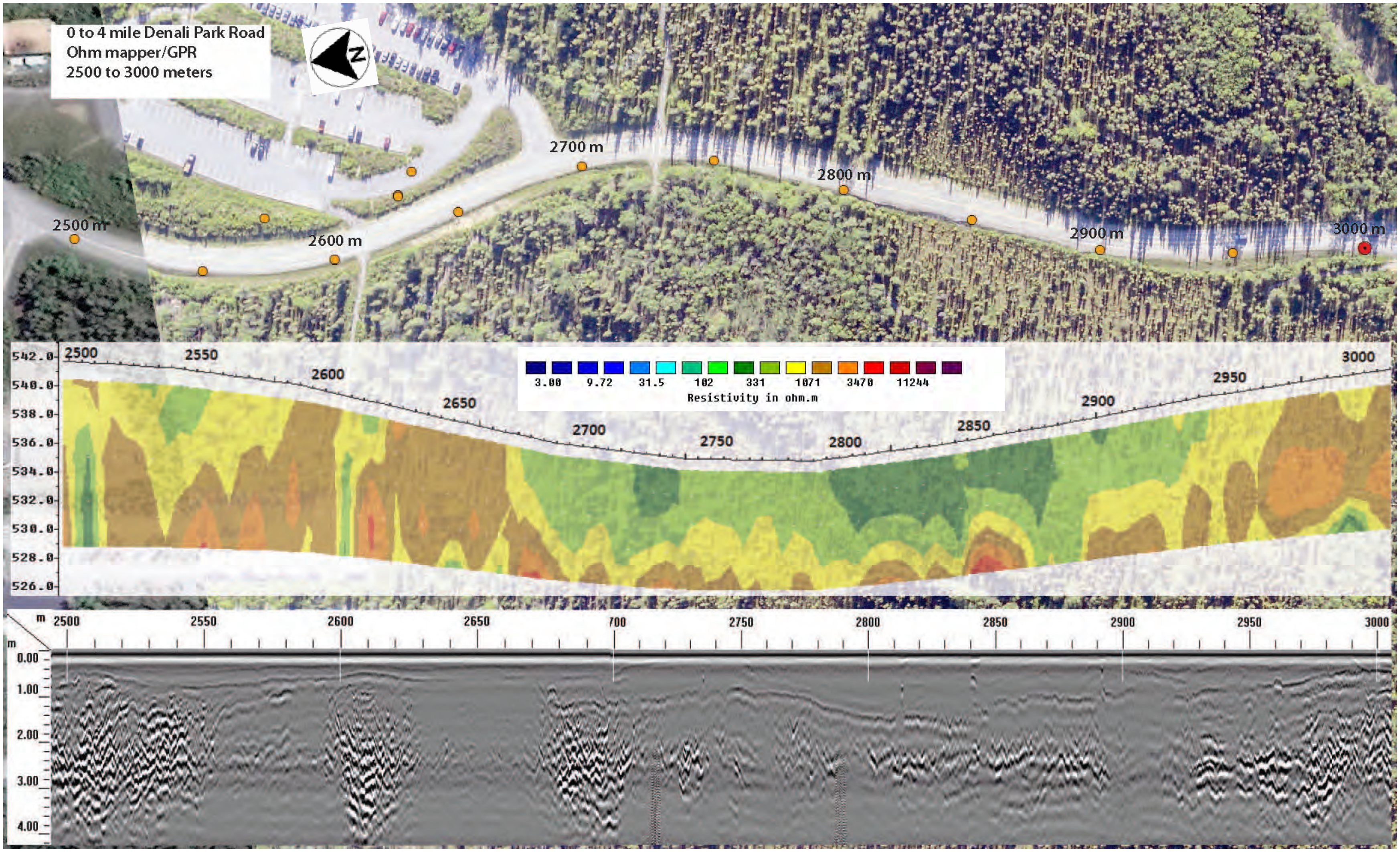


Figure 13. Park Road mile 0 to 4, 2500m to 3000m (8200-ft to 9840-ft). The interpretation of weathered/fractured rock overlying bedrock, as imaged in Figure 11 and previous images continues in this figure. At approximately 2950m it can be seen the chaotic reflectors in the GPR become very near surface. The intermittent attenuated GPR returns, such as at 2650m are interpreted as either wet material or high in clay mineral content.

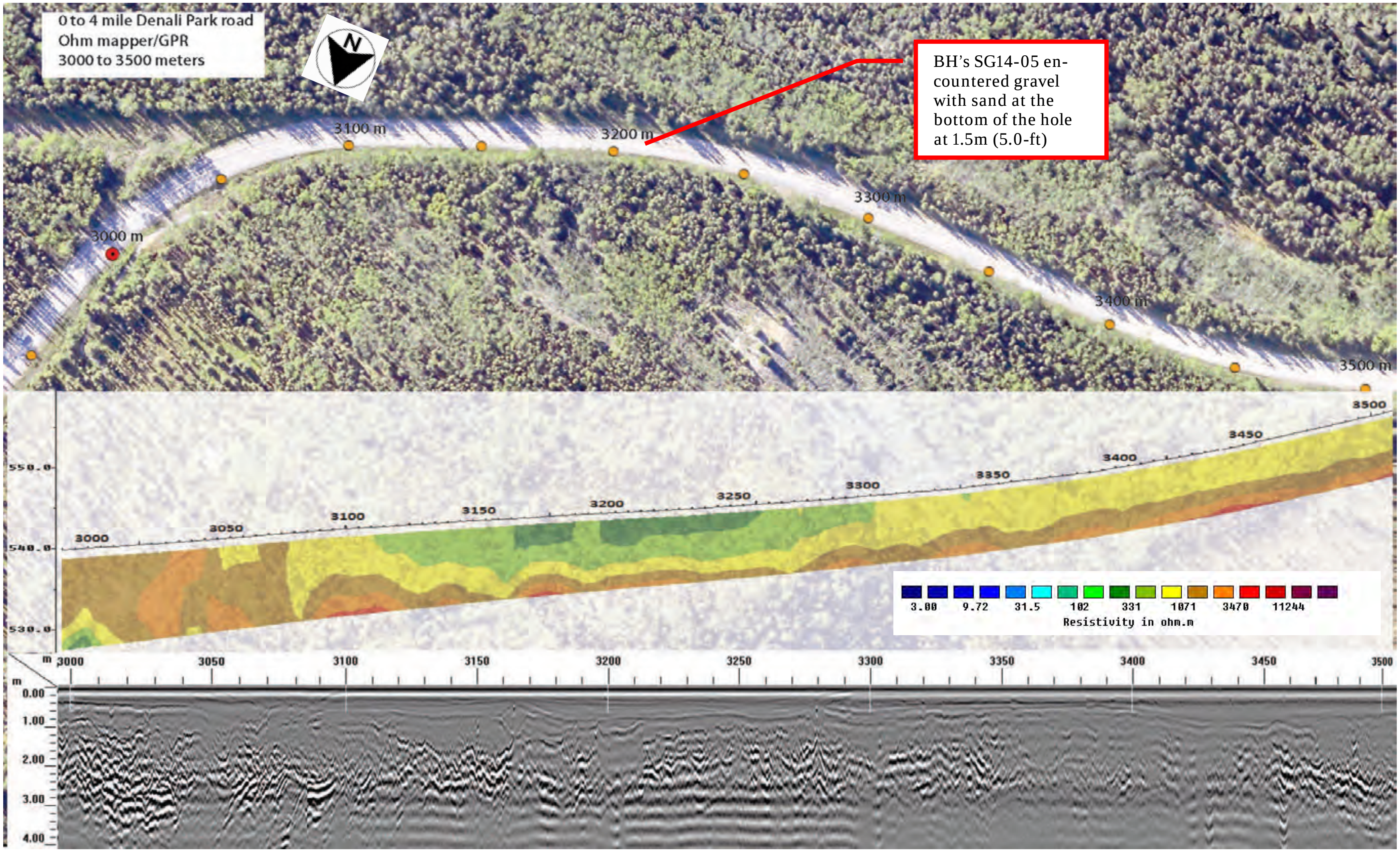


Figure 14. Park Road mile 0 to 4, 3000m to 3500m (9840-ft to 11483-ft). The same interpretation of near surface weathered/fractured rock overlying bedrock continues. Starting at approximately 3100m the bedrock appears to not be as close to the surface as from 2950m to 3100m.

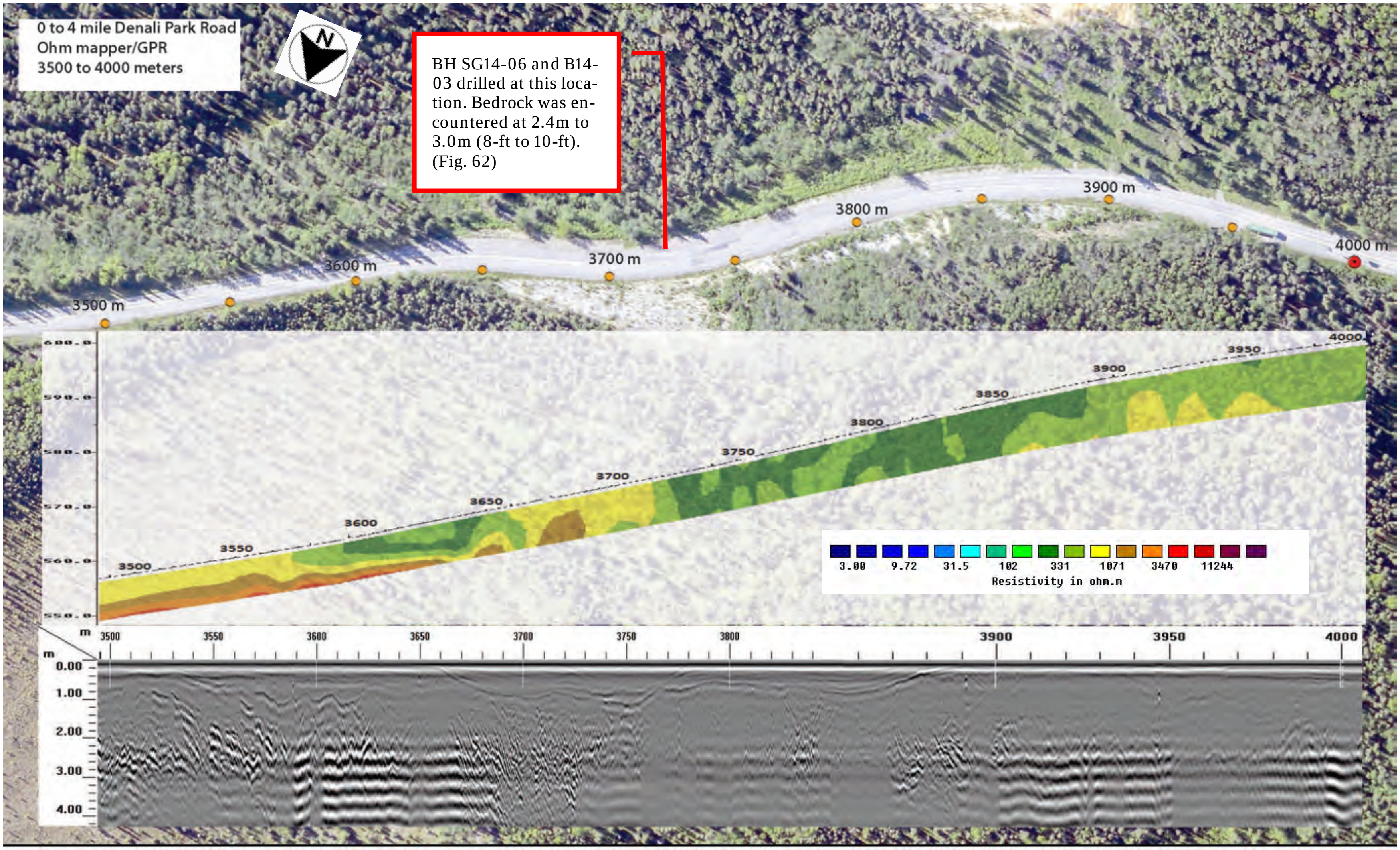
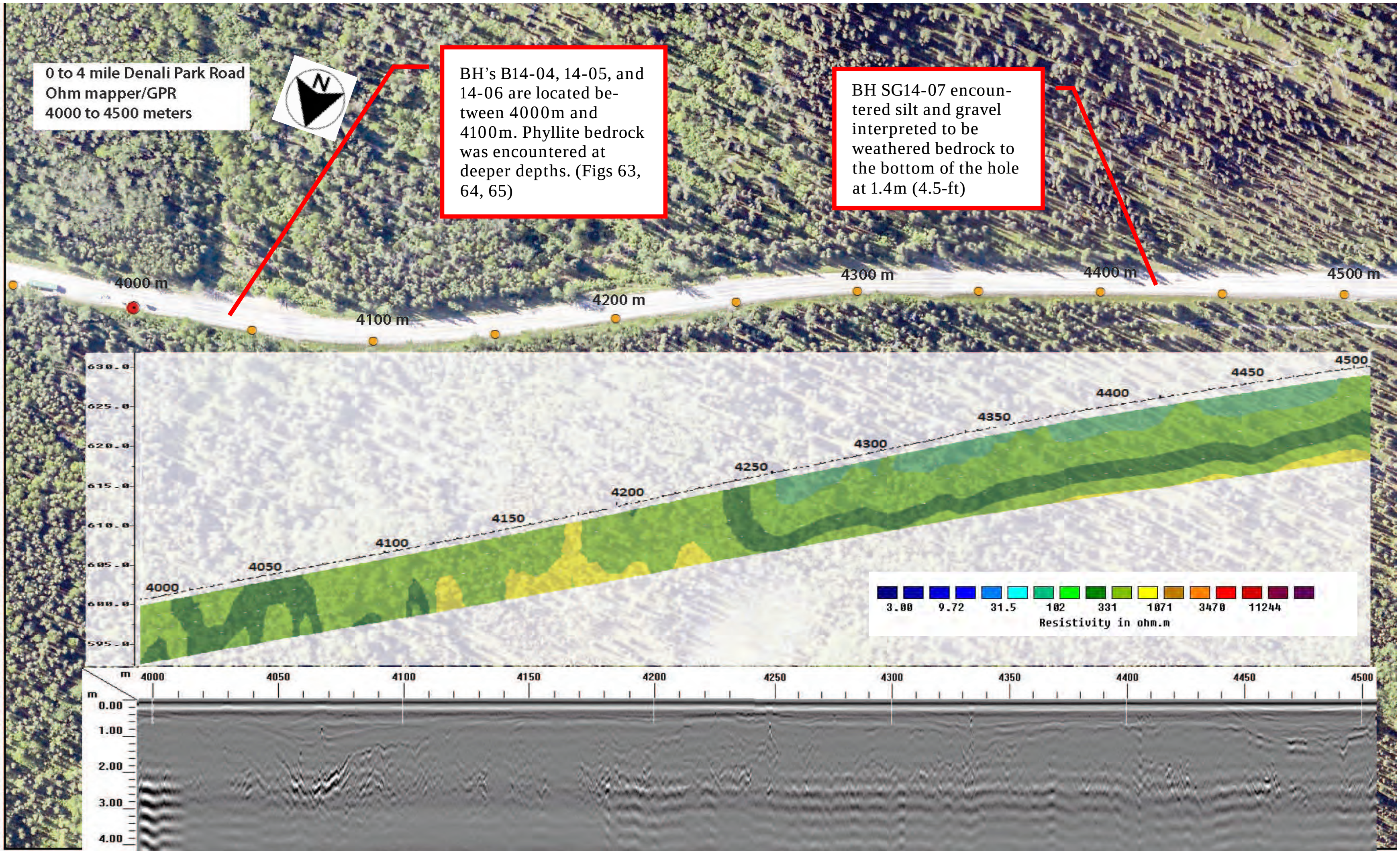


Figure 15. Park Road mile 0 to 4, 3500m to 4000m (11483-ft to 13123-ft). The weathered/fractured rock overlying bedrock interpretation from the previous figures continues. The GPR image shows very strong bedrock fracture inclination at 3550m. At approximately 3700m the ohm-m values are noticed to significantly change. The chaotic near surface GPR reflectors are not as prominent and at greater depth, and the coinciding CCR indicates a change from moderate to consistently low ohm-m values. We infer this to indicate a change in subgrade material from bedrock and fill to substantially more fill material. TH83-4 was drilled in this vicinity and showed bedrock at 2.5m (8.0-ft) (Fig. 71) .



0 to 4 mile Denali Park Road
Ohm mapper/GPR
4000 to 4500 meters

BH's B14-04, 14-05, and 14-06 are located between 4000m and 4100m. Phyllite bedrock was encountered at deeper depths. (Figs 63, 64, 65)

BH SG14-07 encountered silt and gravel interpreted to be weathered bedrock to the bottom of the hole at 1.4m (4.5-ft)

Figure 16. Park Road mile 0 to 4, 4000m to 4500m (13123-ft to 14764-ft). Boreholes B14-04, B14-05, and B14-06 are located between 4000m and 4100m. Comparison of CCR data and the drill logs are shown in figures 63, 64, and 65 respectively. The boreholes report phyllite bedrock at depth with silt. The interpretation of significantly deeper fill material starting at approximately 3700m continues through this section. The CCR continues to report low ohm-m values in the upper most of the surveyed section and the GPR reflectors are non-distinct through most of the section and this may be due to the higher silt content noted in the drill logs. It can be seen that moderate ohm-m values are just beginning to be reported at the very deepest depth of the section.

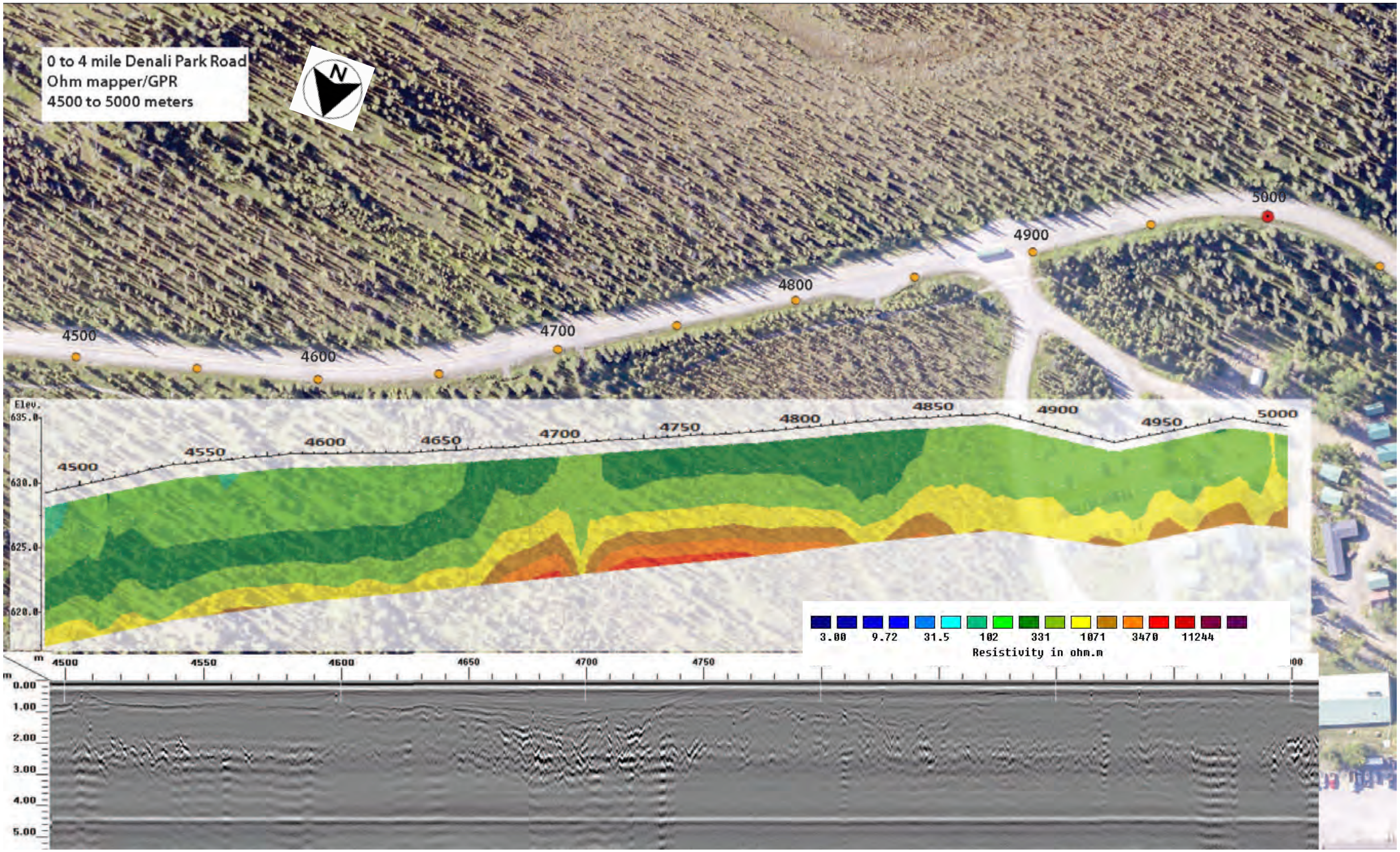


Figure 17. Park Road mile 0 to 4, 4500m to 5000m (14764-ft to 16404-ft). The moderate ohm-m values noticed at the very deepest portion of the previous section are now moving upward and are more easily seen, with moderate to high values seen from 4650m to 4850m. Our first interpretation is again deeper weathered/fractured rock overlying bedrock and becoming increasingly near surface at 4650m to 4850m. It is known ice-rich permafrost is in the area due to thaw-settlement issues ta C-Camp, therefore imaging of ice-moderate to ice-rich frozen ground is not ruled out. Additionally the GPR reflections in this area are indicative of disrupted sub-base and base layer material possibly due to the construction of an appurtenance at approximately 4700m. .

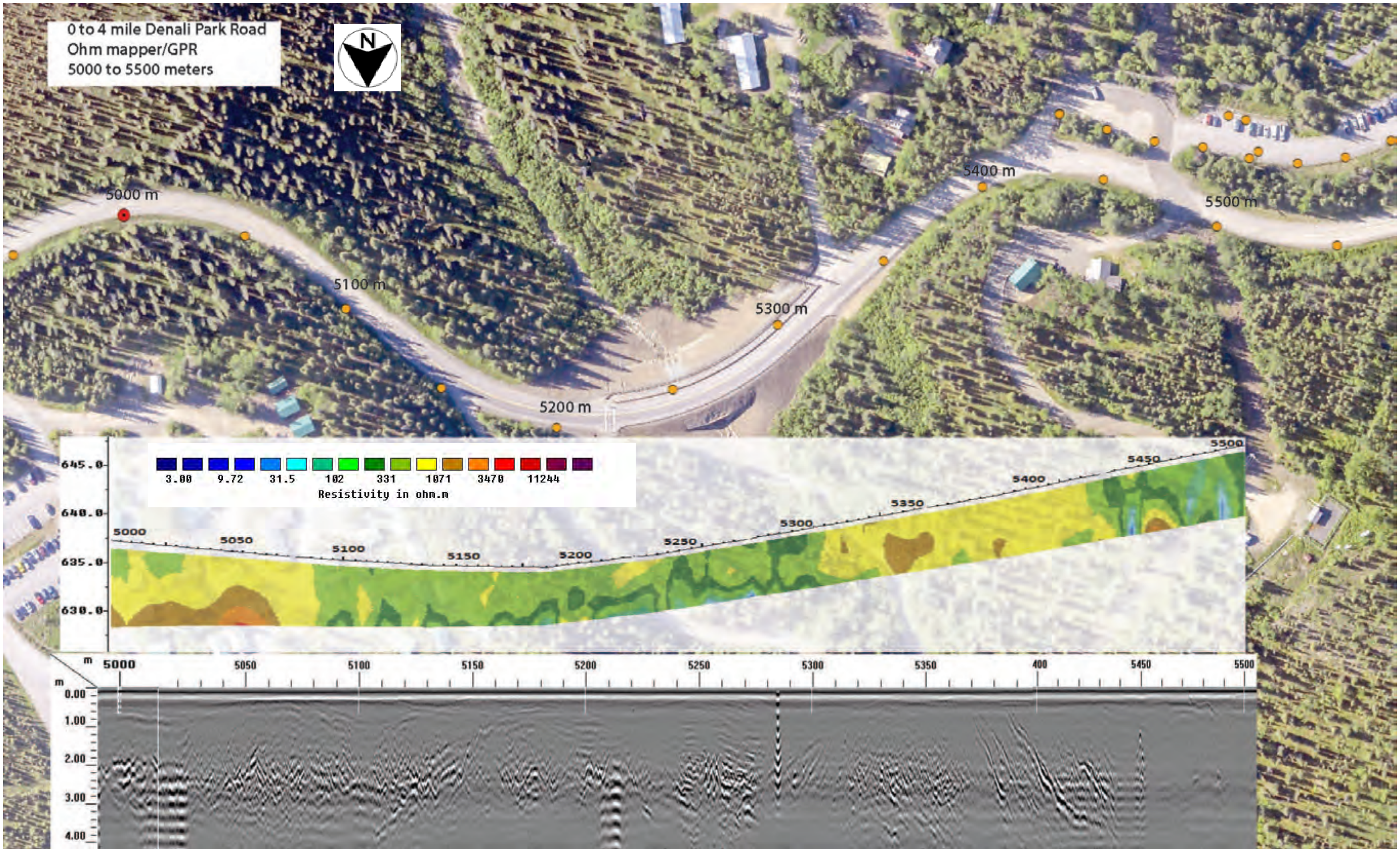
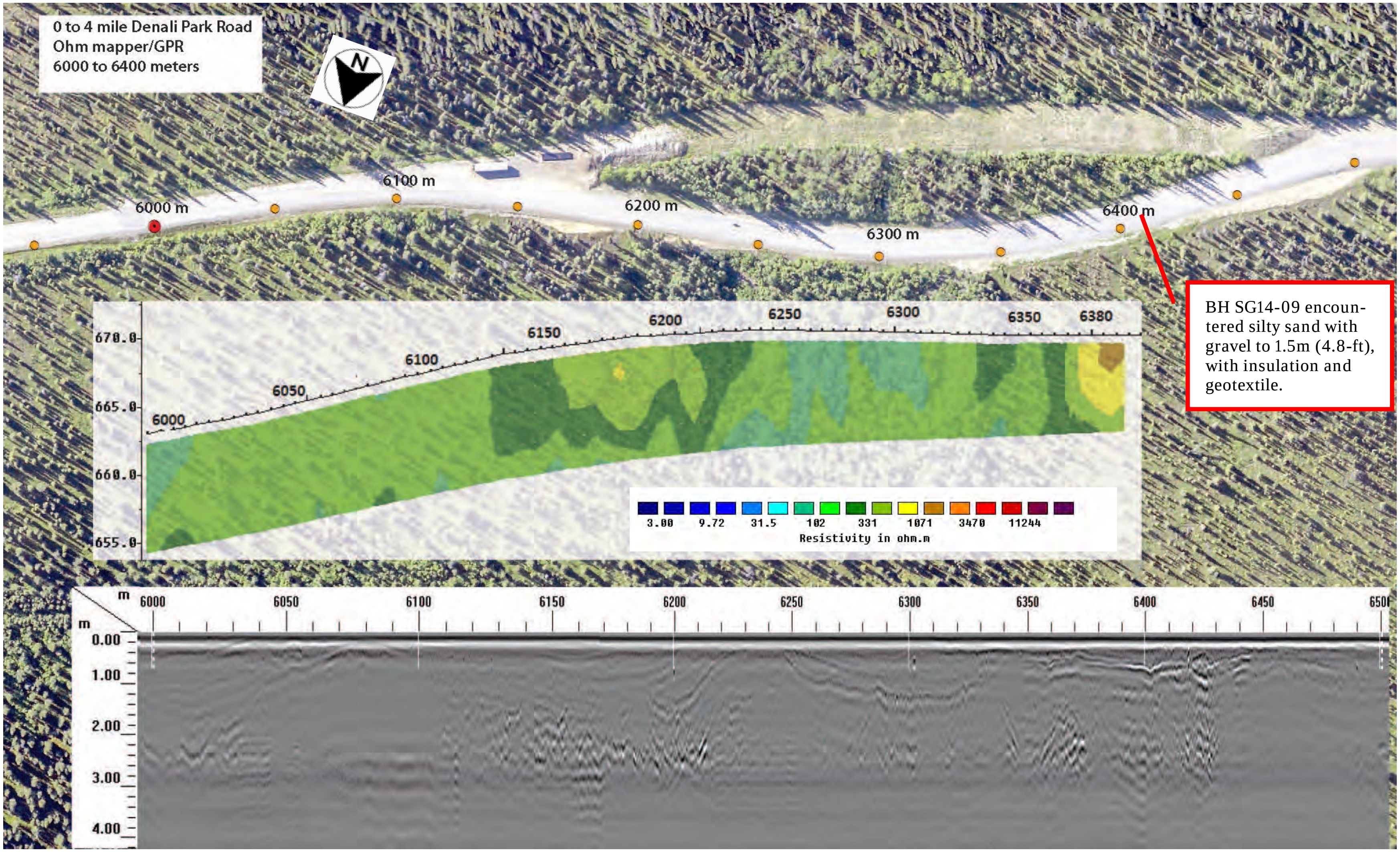


Figure 18. Park Road mile 0 to 4, 5000m to 5500m (16404-ft to 18044-ft). Moderate ohm-m values are reporting at either abutment of the causeway over the creek, starting at 4650m and continues to 5100m. Crossing the creek yields very low ohm-m values consistent with fill material, and very low ohm-m values are noticed at the very deepest section of the fill material and this coincides with the probable increase in moisture below the creek level. The ohm-m values rise again at 5300m to 5400m. These higher ohm-m values either side of the creek could either be weathered/fractured bedrock or ice-moderate to ice-rich permafrost. It was noted that possible permafrost was excavated during the creek causeway construction. The GPR image indicates a clear disruption of the substrate in the vicinity of the reconstructed drainage appurtenance extending from 5150m to 5325m. A steeply inclined reflector is displayed in the GPR at 5400m and this is possibly indicative of bedrock structure. Very low ohm-m values are noticed to start at approximately 5450m to the end of the section, extending nearly full depth, indicating moist conditions.

Figure 19. Park Road mile 0 to 4, 5500m to 6000m (18044-ft to 19685-ft). Very low ohm-m values which started at 5450m in the previous section continue through this section as well. An increase in near surface moisture content is inferred starting at 5750m though to 6000m. Moderate ohm-m values are noted from 5700m to 5900m and this may be a rising bedrock surface or possibly ice-moderate to ice-rich permafrost at depth. The GPR returns are very minimal through this section indicating increase in moisture content or clay mineral composition. TH83-5 drilled in this vicinity showed peat and silty fine sand, unfrozen (Fig. 72).



BH SG14-09 encountered silty sand with gravel to 1.5m (4.8-ft), with insulation and geotextile.

Figure 20. Park Road mile 0 to 4, 6000m to 6400m (19685-ft to 21000-ft), end of transect. Low ohm-m values continue through this section with very low values noticed from 6250m to 6325m, which may be indicative of a 1.0m (3.0-ft) deep sub-excavation with installed geotextile and select fill, with possible increases in the moisture content of the base material. Road realignment occurred at this location due to landslide to the south, and 7.5cm (3.0in) of buried insulation was installed from 6375m to 6475m. Underdrains installed in this area discovered trapped water in the insulated section. The GPR is not overly reflective through this section, however a down drop of a subsurface reflector is clearly seen coincidentally at the inferred high moisture location from 6250m to 6325m, and a strong reflector is visible at approximately 6400m which is very possibly the buried insulation. TH83-6 was drilled in this vicinity (MP 3.9) and showed unfrozen silty sandy gravel with clay at 6.2m (20.5-ft) (Fig. 73).

9 Appendix B – HQ/Dog Kennels

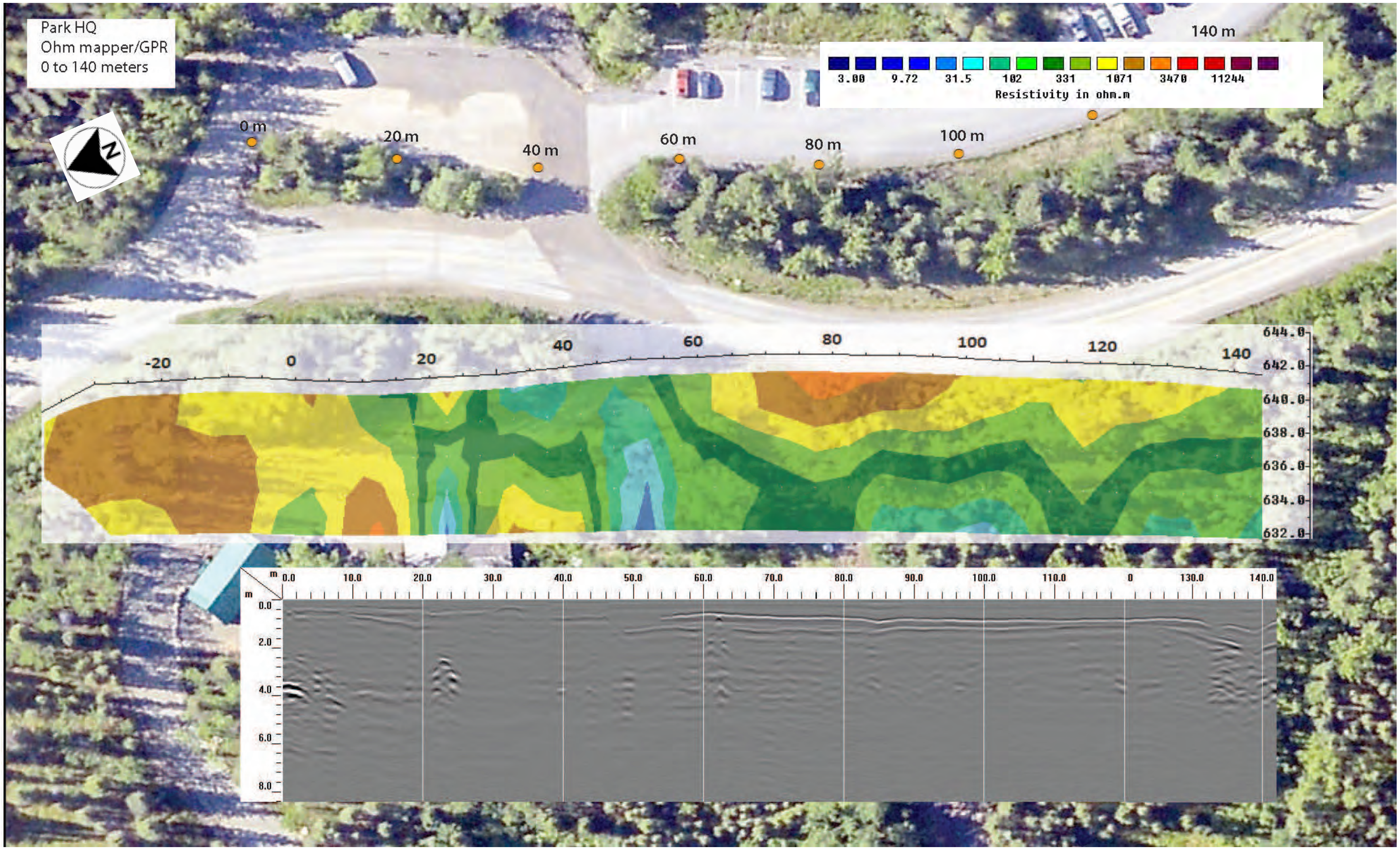
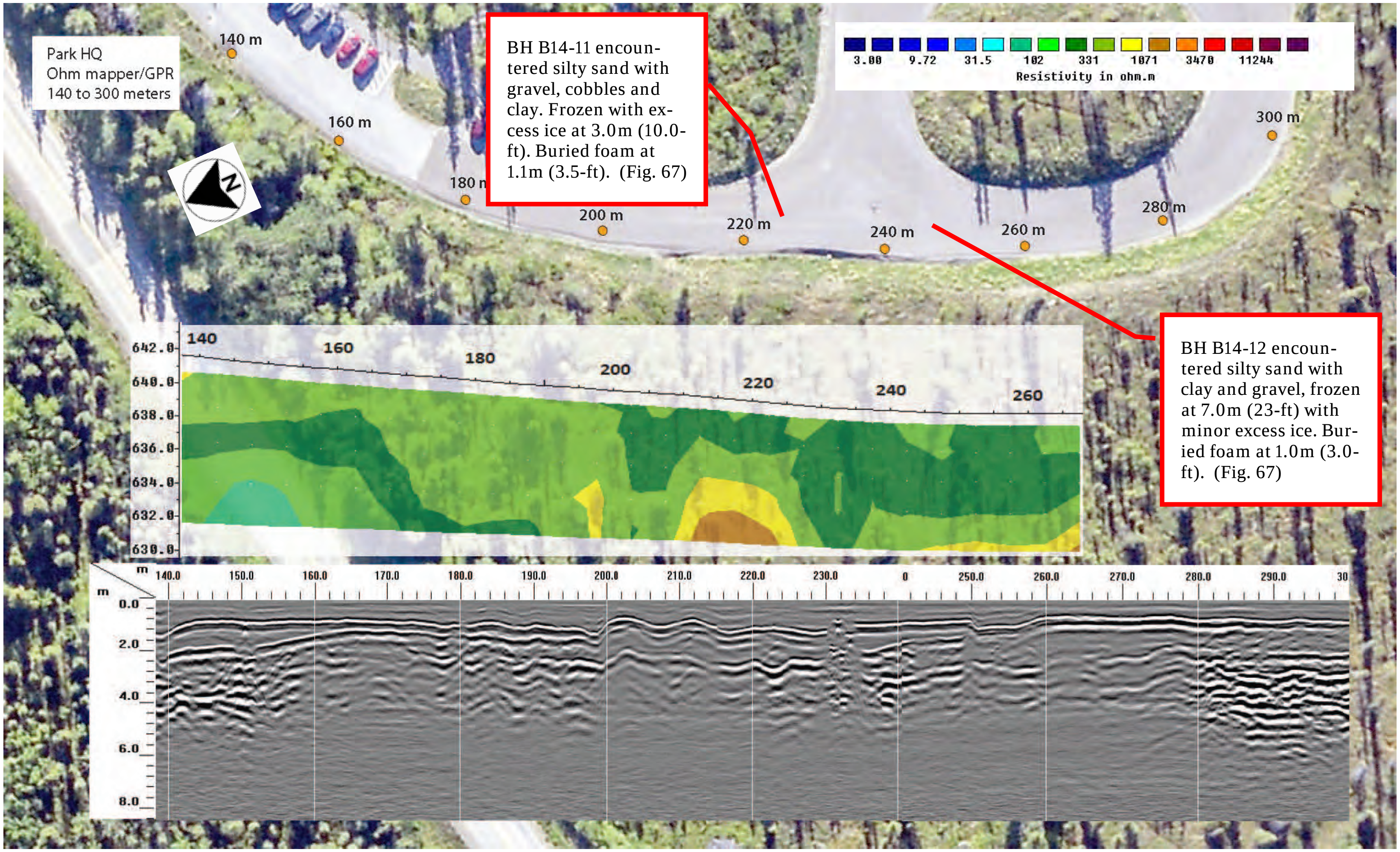


Figure 21. HQ/Dog Kennels Parking Lot 0m to 140m (460-ft), start of transect. The view is looking south and the transect progresses from left to right, east to west. Full depth moderate ohm-m values are reported from the start, -40m (-131-ft) to approximately +20m (65.6-ft), and this coincides with the values reported in Figure 18 from 5325m to 5425m. Starting at 55m a strong GPR reflector is noticed at 0.6m (2.0-ft) depth, which coincides with the start of the parking loop area pavement. This reflector has strong polarity change from black to white to black (- , + , -), indicating a distinct change from a higher dielectric material over a lower dielectric material. We believe this to be a buried insulation layer installed under the paved parking lot, possibly to thermally protect ground ice from thaw. The GPR returns are generally poor through this section. Beginning at 50m very low ohm-m values are noted which

extend under near surface moderate ohm-m values to the end of the section. This may indicate permafrost overlying talik (previously frozen materials), or ice-rich sediments overlying ice-poor sediments.



BH B14-11 encountered silty sand with gravel, cobbles and clay. Frozen with excess ice at 3.0m (10.0-ft). Buried foam at 1.1m (3.5-ft). (Fig. 67)

BH B14-12 encountered silty sand with clay and gravel, frozen at 7.0m (23-ft) with minor excess ice. Buried foam at 1.0m (3.0-ft). (Fig. 67)

Figure 22. HQ/Dog Kennels Parking Lot 140m to 300m, end of transect. The very near surface strong polarity reversal continues through to the end of the transect at 300m. A high resistivity anomaly exists at 220m which is approximately the location of severe settlement observed in the parking lot. Therefore these resistivity values may be inferred as moderate to high ground ice content. The moderate ohm-m values are visible at depth through to the end of the transect. Boreholes BH14-11 and BH14-12 report significant ice at 10 feet and 20 feet depth respectively. The GPR results in this section are very distinctive with chaotic to systematic layering visible, either indicating weather/fractured bedrock at depth, or sequences of sediment or man placed fill material.

10 Appendix C – Igloo Forest

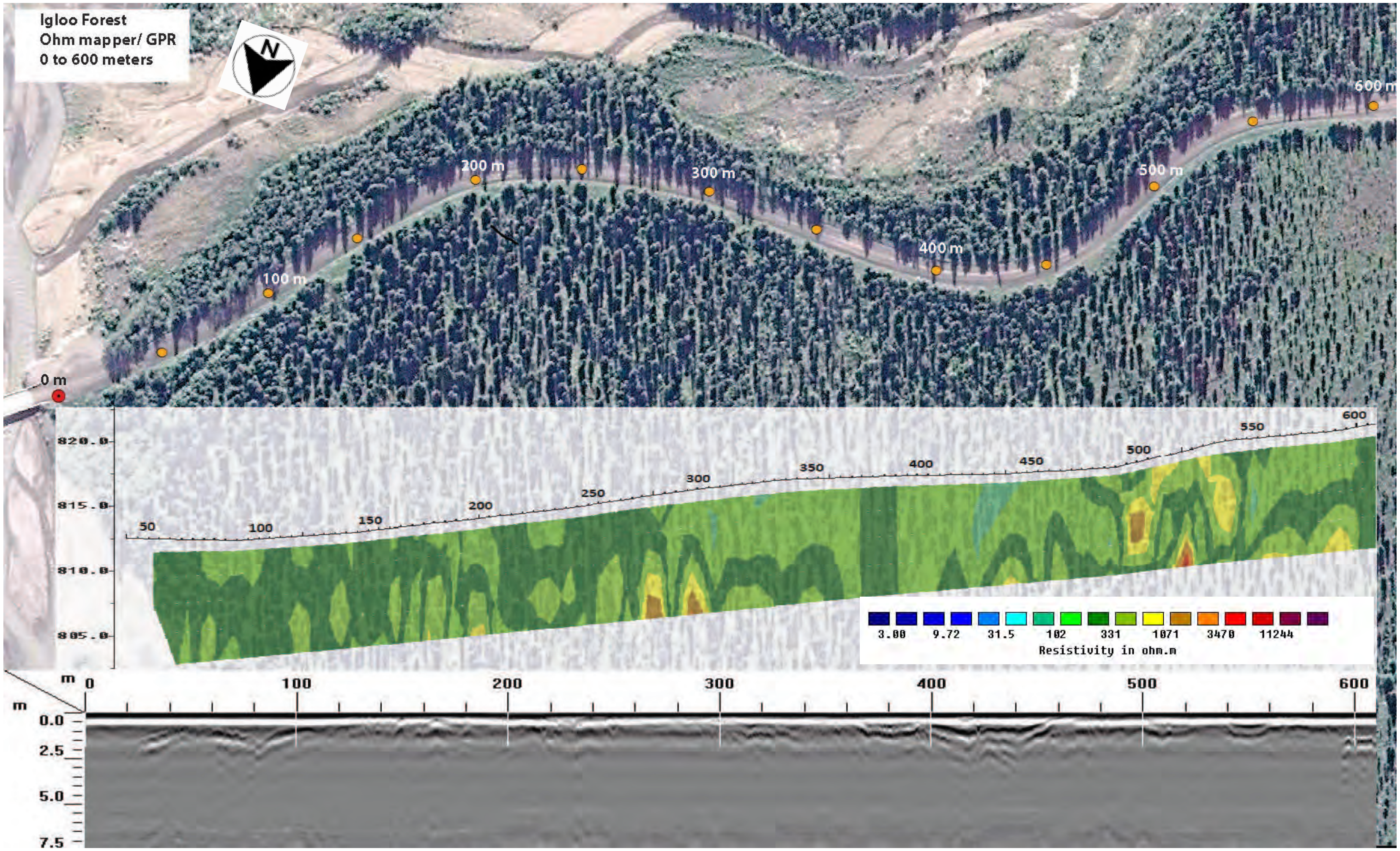


Figure 23. Igloo Forest, 0m to 600m (1969-ft), start of transect. The view direction in these images is generally looking east, therefore the transect progresses from left to right, north to south. This section reports very low ohm-m values through the length of the section to full depth, with sporadic moderate to high ohm-m anomalies. The GPR is non-distinct and this may be due to moderate to high ground water contents and/or mineral clay compositions. No extensive frozen ground is inferred in this section. This terrain does not exhibit surface expression consistent with frozen material at depth.

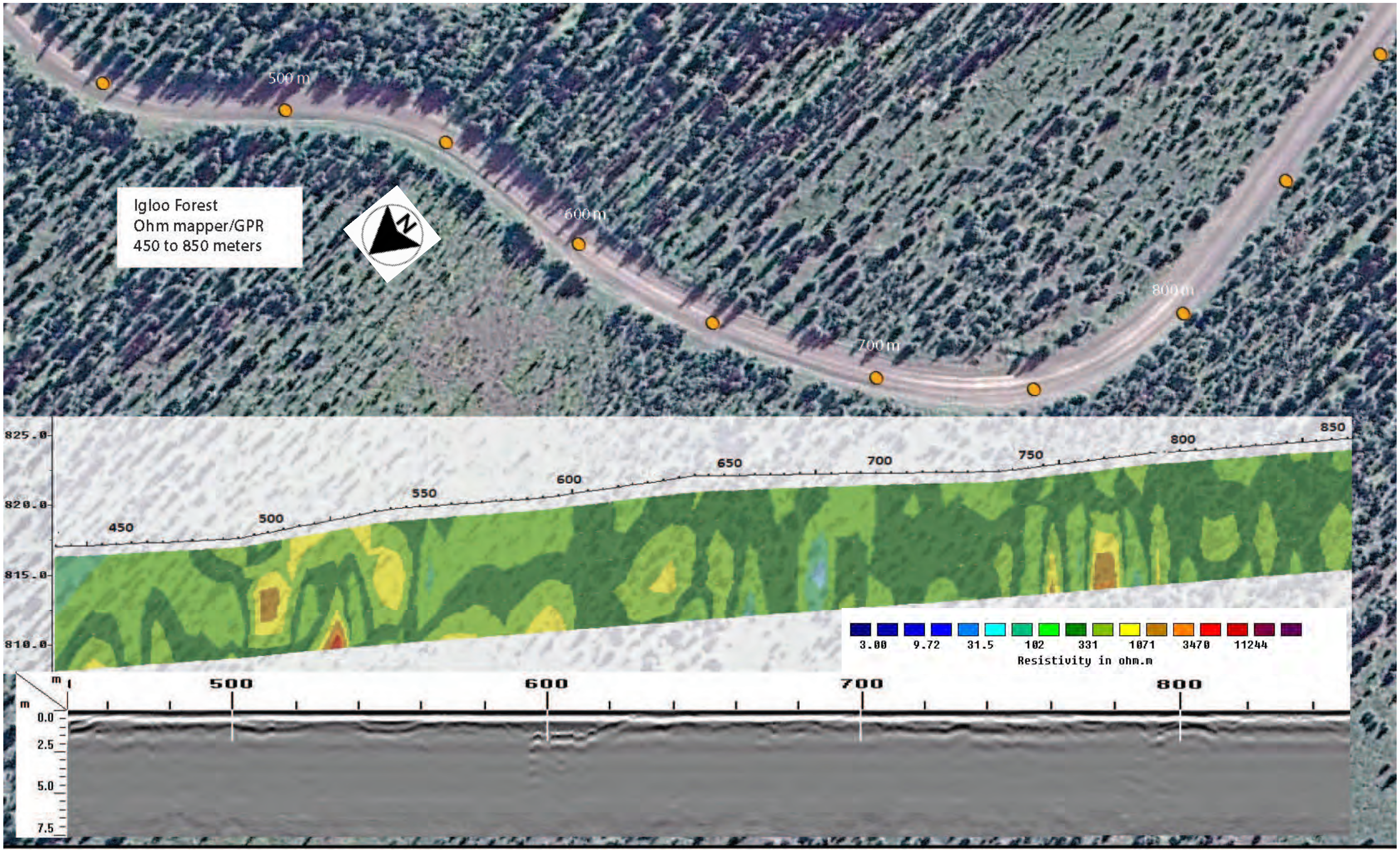
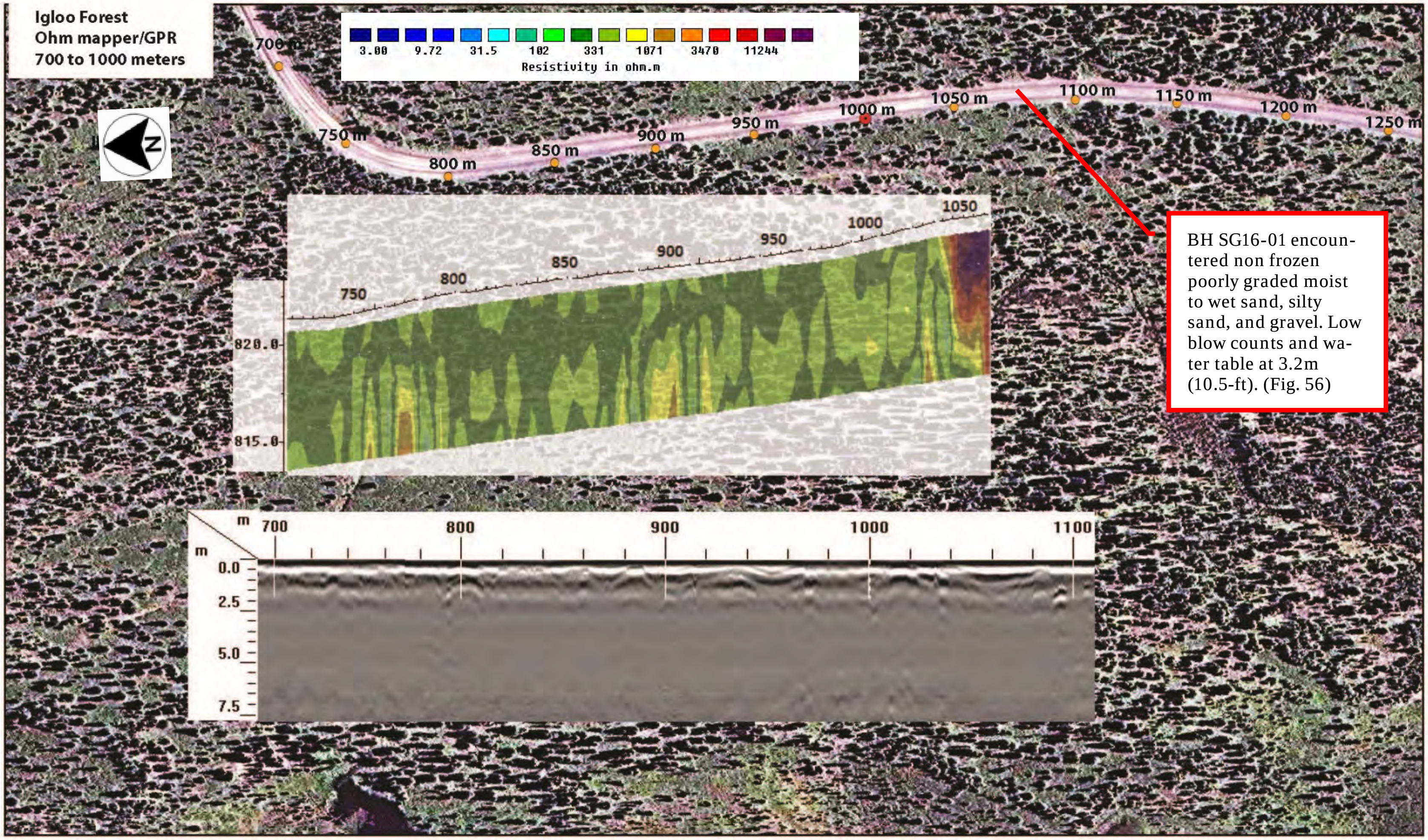
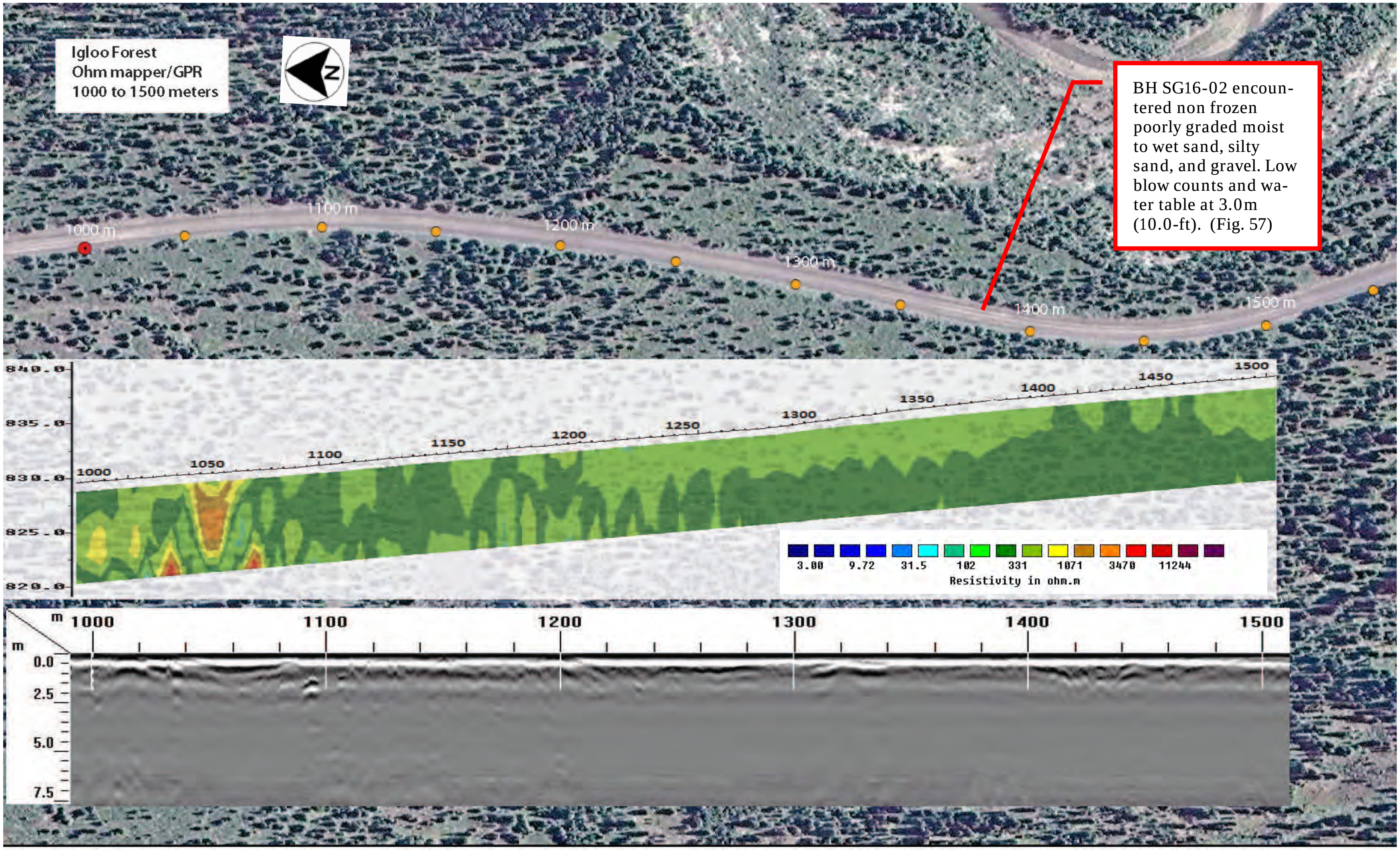


Figure 24. Igloo Forest, 450m to 850m (1476-ft to 2789-ft) . This section reports much the same as in Figure 23. An inferred high moisture anomaly is seen at approximately 670m with very low ohm-m values.



BH SG16-01 encountered non frozen poorly graded moist to wet sand, silty sand, and gravel. Low blow counts and water table at 3.2m (10.5-ft). (Fig. 56)

Figure 25. Igloo Forest, 700m to 1000m (2297-ft to 3280-ft). This section reports much the same as in Figures 23 and 24. However, a distinctive high ohm-m value anomaly is noticed at 1050m, which appears to be located in the near surface. It is unknown the origin of this anomaly.



BH SG16-02 encountered non frozen poorly graded moist to wet sand, silty sand, and gravel. Low blow counts and water table at 3.0m (10.0-ft). (Fig. 57)

Figure 26. Igloo Forest, 1000m to 1500m (3280-ft to 4921-ft). This section is much as the previous sections. The sporadic moderate ohm-m anomalies disappear completely after 1050m. The road becomes closer to the evident flood plain meanders suggesting the sediments at this section may be recently reworked and homogenizing the material. No frozen ground is indicated in this section.

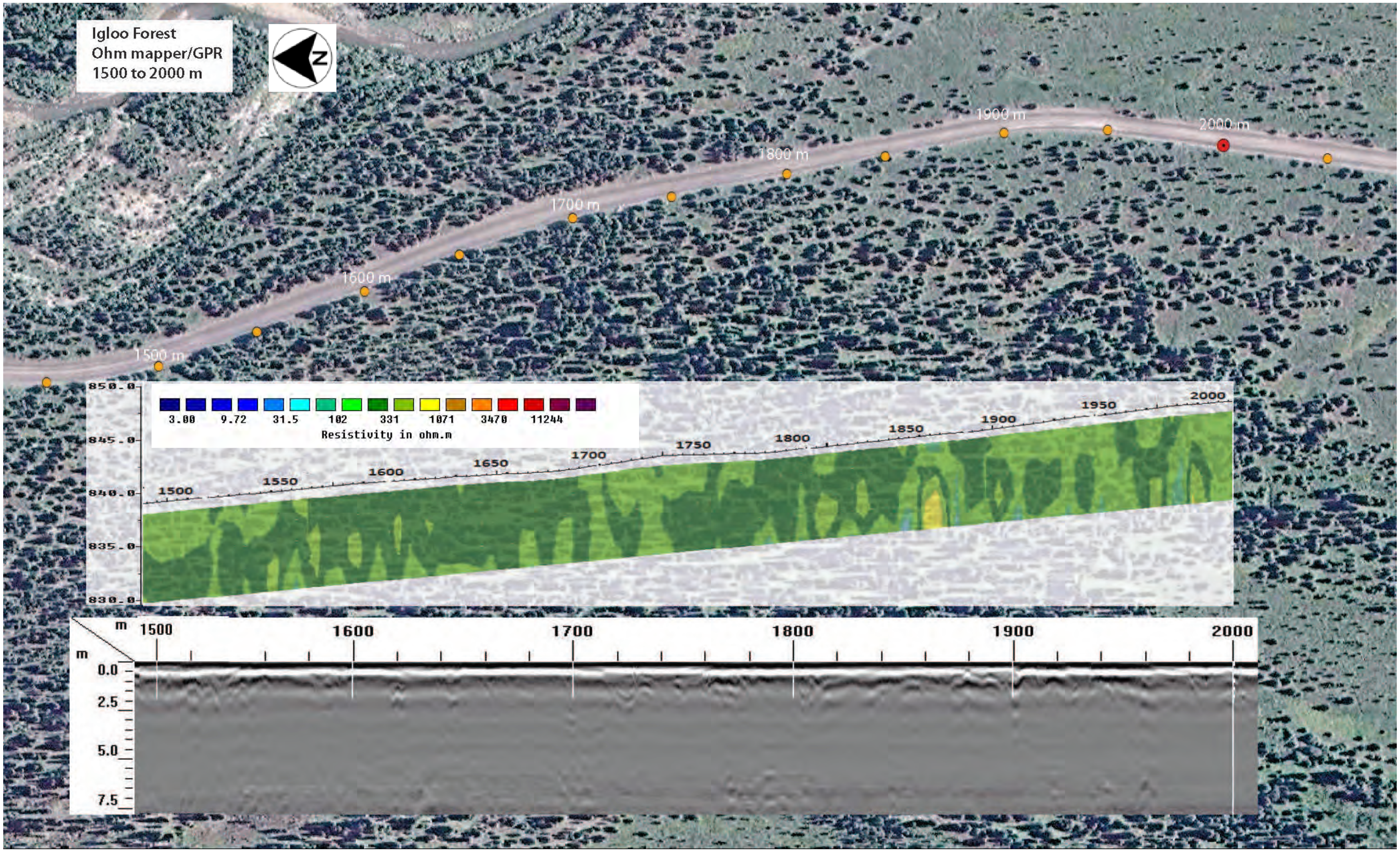


Figure 27. Igloo Forest, 1500m to 2000m (4921-ft to 6562-ft). This section reports much as the previous section.

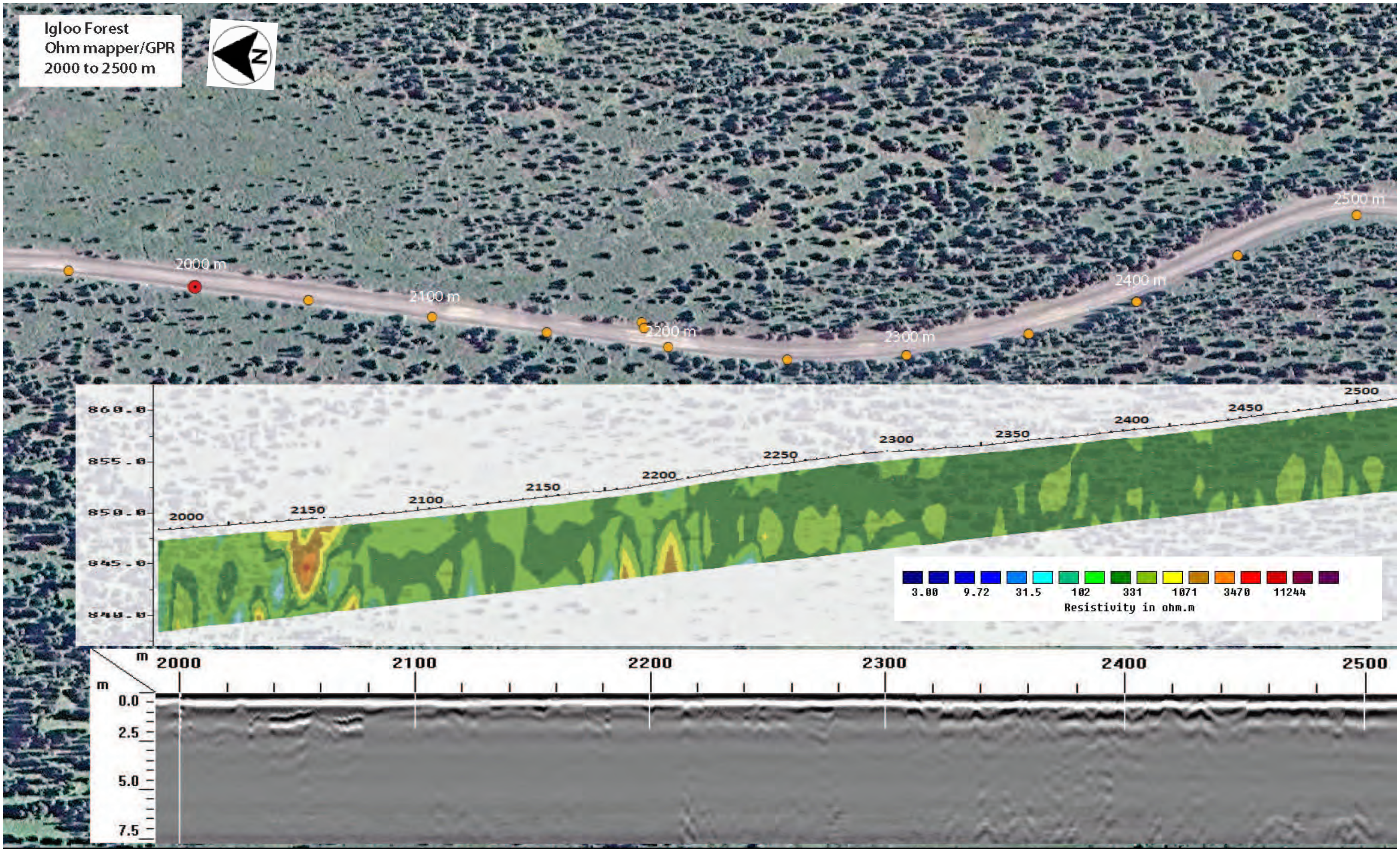


Figure 28. Igloo Forest, 2000m to 2500m (6562-ft to 8202-ft). This section reports much as the previous section. A distinctive higher ohm-m value anomaly exists at 2150m and we infer this to be a roadway drainage appurtenance near the surface. Starting at 2000m to 2250m we see emerging higher ohm-m values with interspersed very low ohm-m values. Two higher ohm-m value anomlies exist side-by-side at 2200m and these either represent deeply buried emplaced massive ice, or possibly the top surface of a bedrock feature. The GPR is unremarkable in this section.

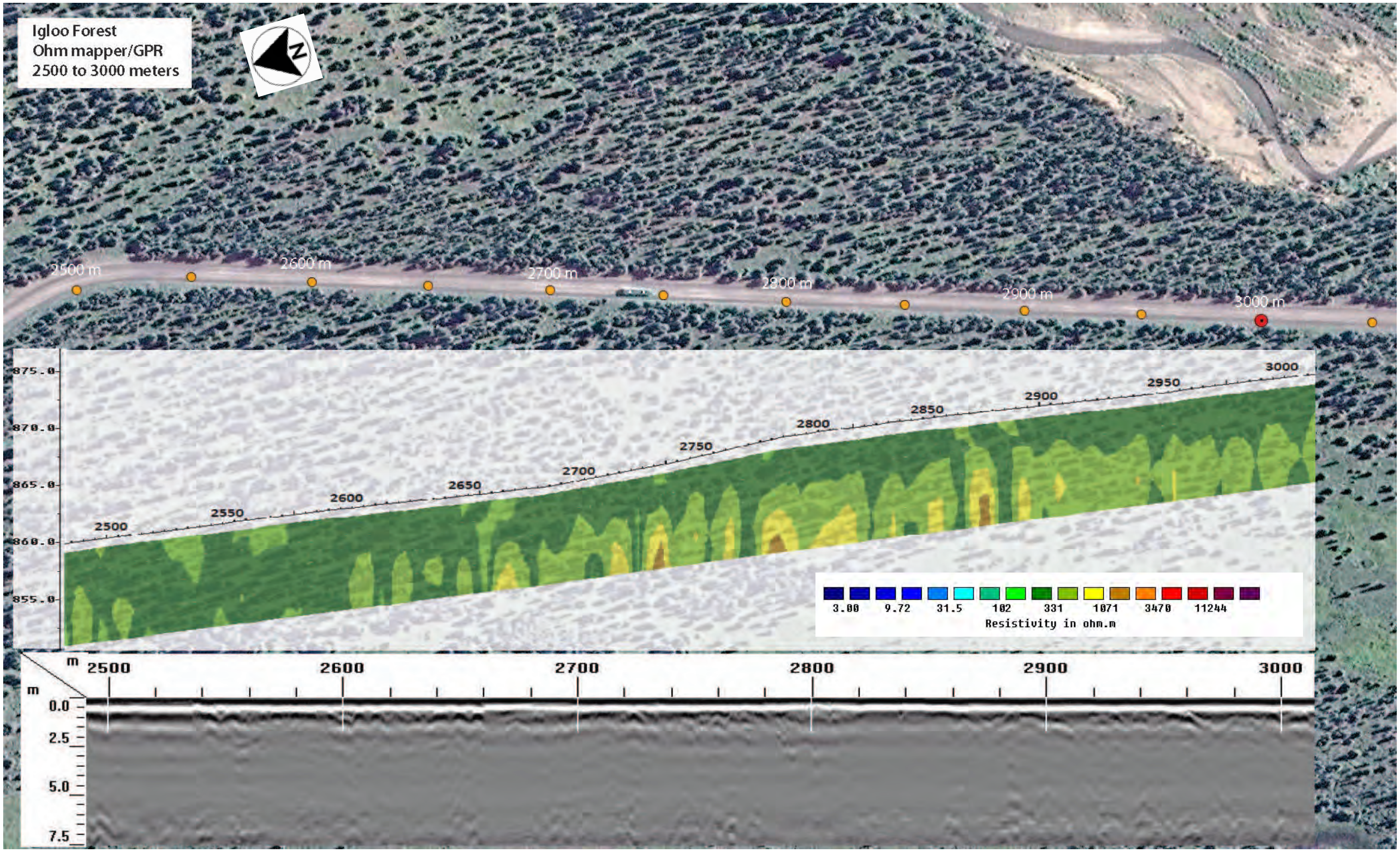


Figure 29. Igloo Forest, 2500m to 3000m (8202-ft to 9843-ft). This section reports much as the previous section. At 2650m higher ohm-m value anomlies begin to appear at depth and these represent deep buried emplaced massive ice, or more probably this the top surface of a deeper bedrock feature. The GPR is unremarkable in this section.

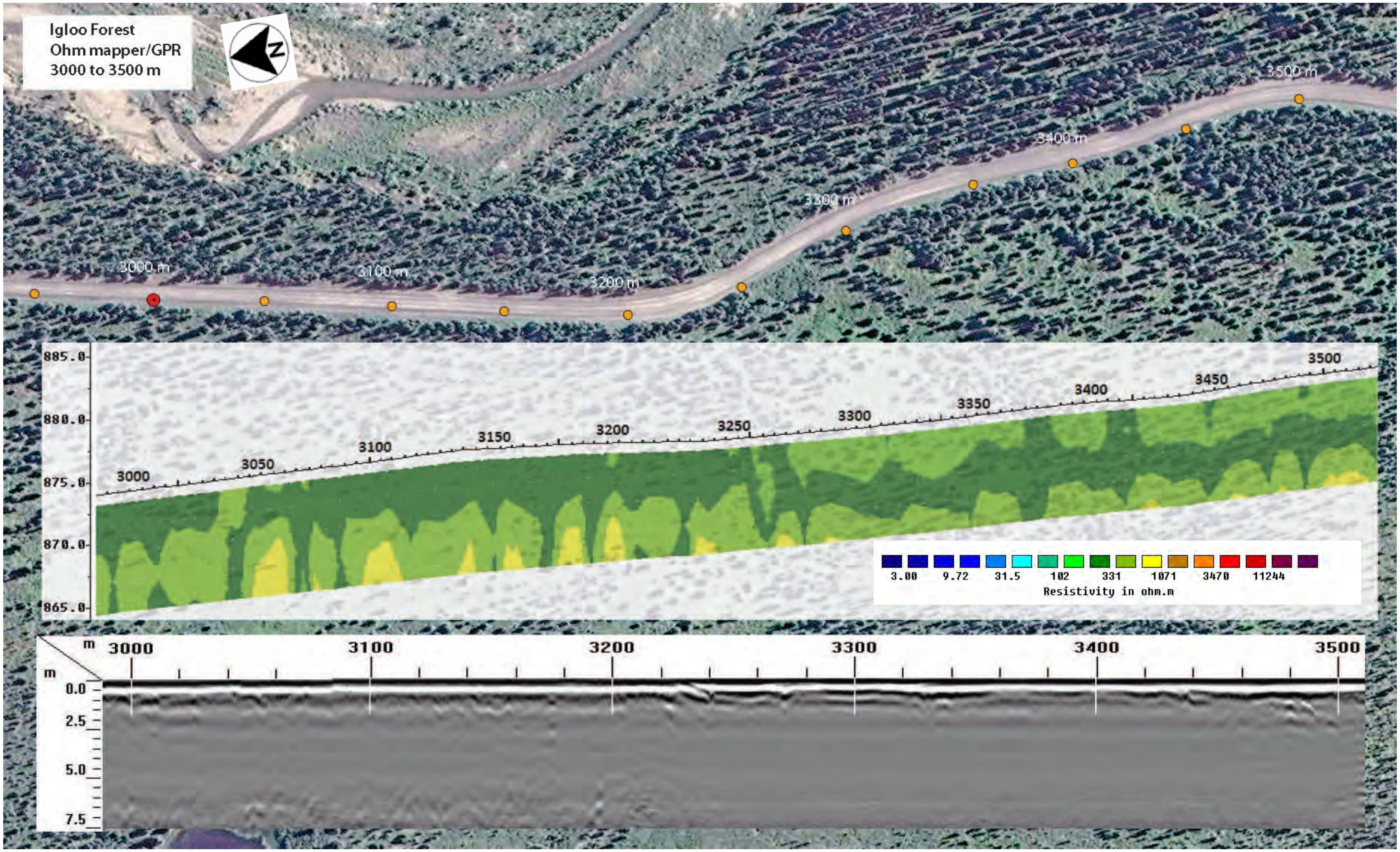


Figure 30. Igloo Forest, 3000m to 3500m (9843-ft to 11,483-ft). This section reports much as the previous section with a continuation of the deeper and moderate ohm-m anomlies which most probably represents the top surface of a deeper bedrock feature. The GPR faintly reports reflectors at depth from 3000m to 3250m, coinciding with the moderate ohm-m values.

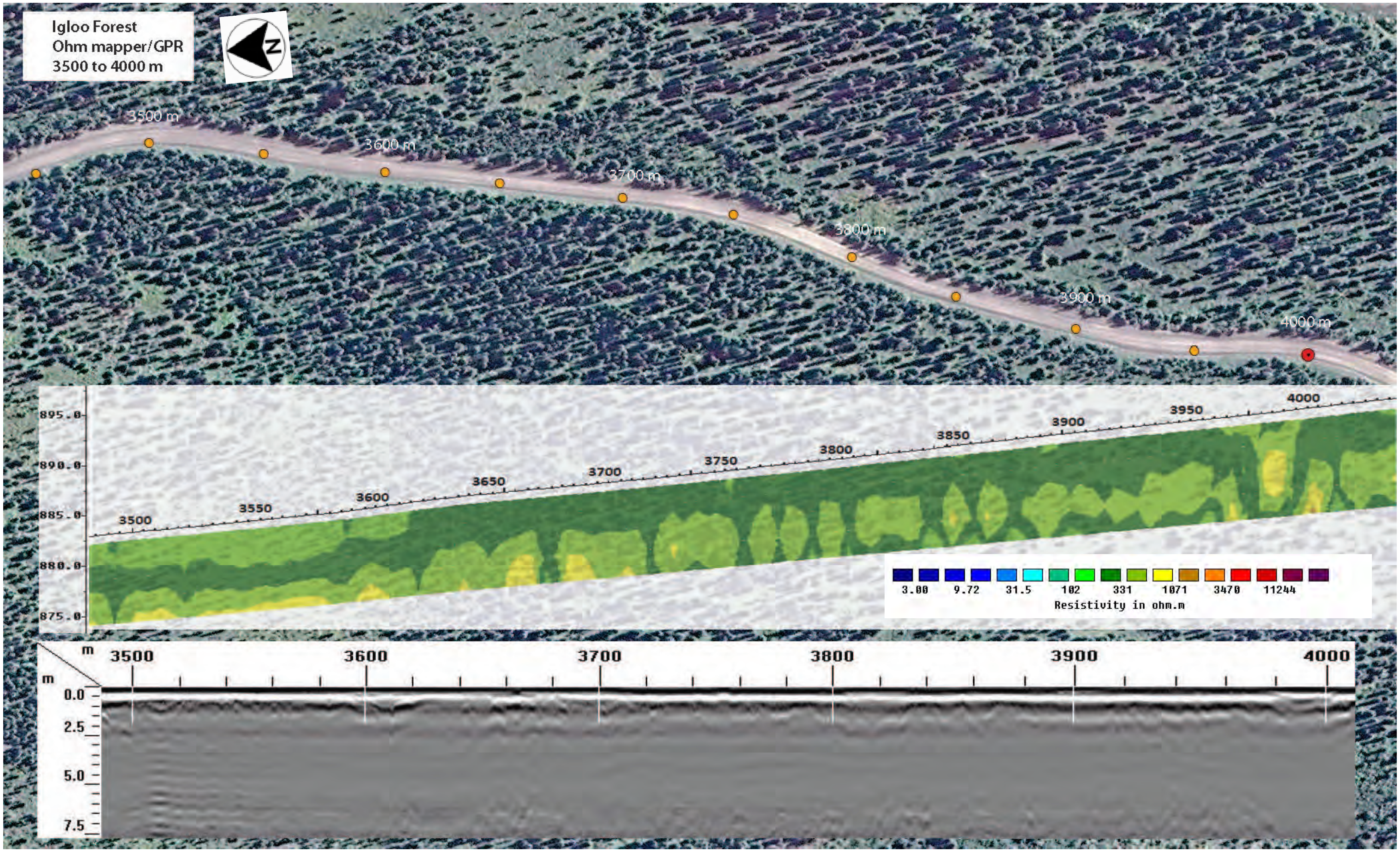
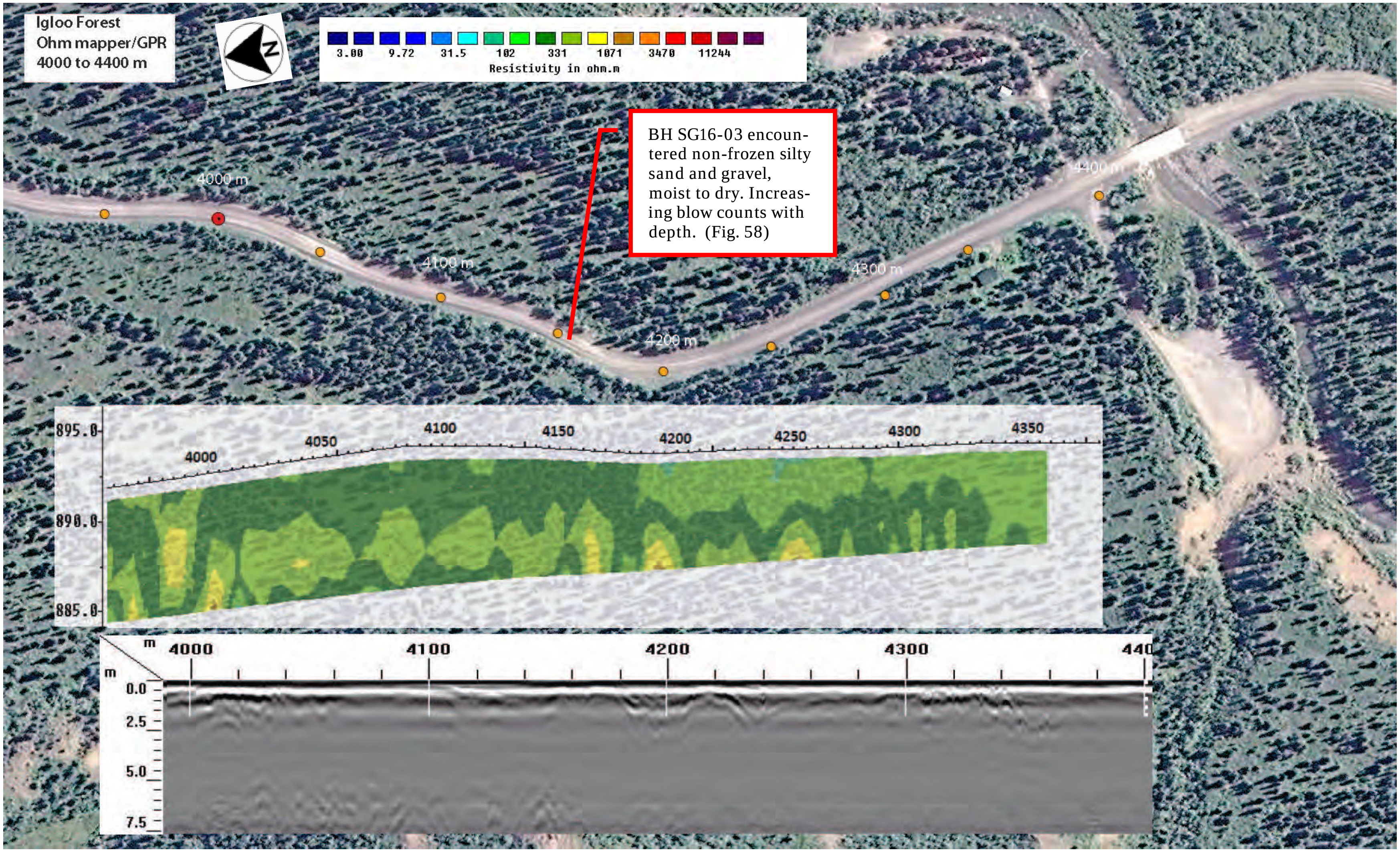


Figure 31. Igloo Forest, 3500m to 4000m (11,483-ft to 13,123-ft). This section reports much as the previous sections with a continuation of the deeper and moderate ohm-m anomlies.



BH SG16-03 encountered non-frozen silty sand and gravel, moist to dry. Increasing blow counts with depth. (Fig. 58)

Figure 32. Igloo Forest, 4000m to 4400m (13,123-ft to 14,435-ft), end of transect. This section reports much as the previous sections with a continuation of the deeper and moderate ohm-m anomlies. The GPR through this entire section was not remarkable.

11 Appendix D – Polychrome Pass

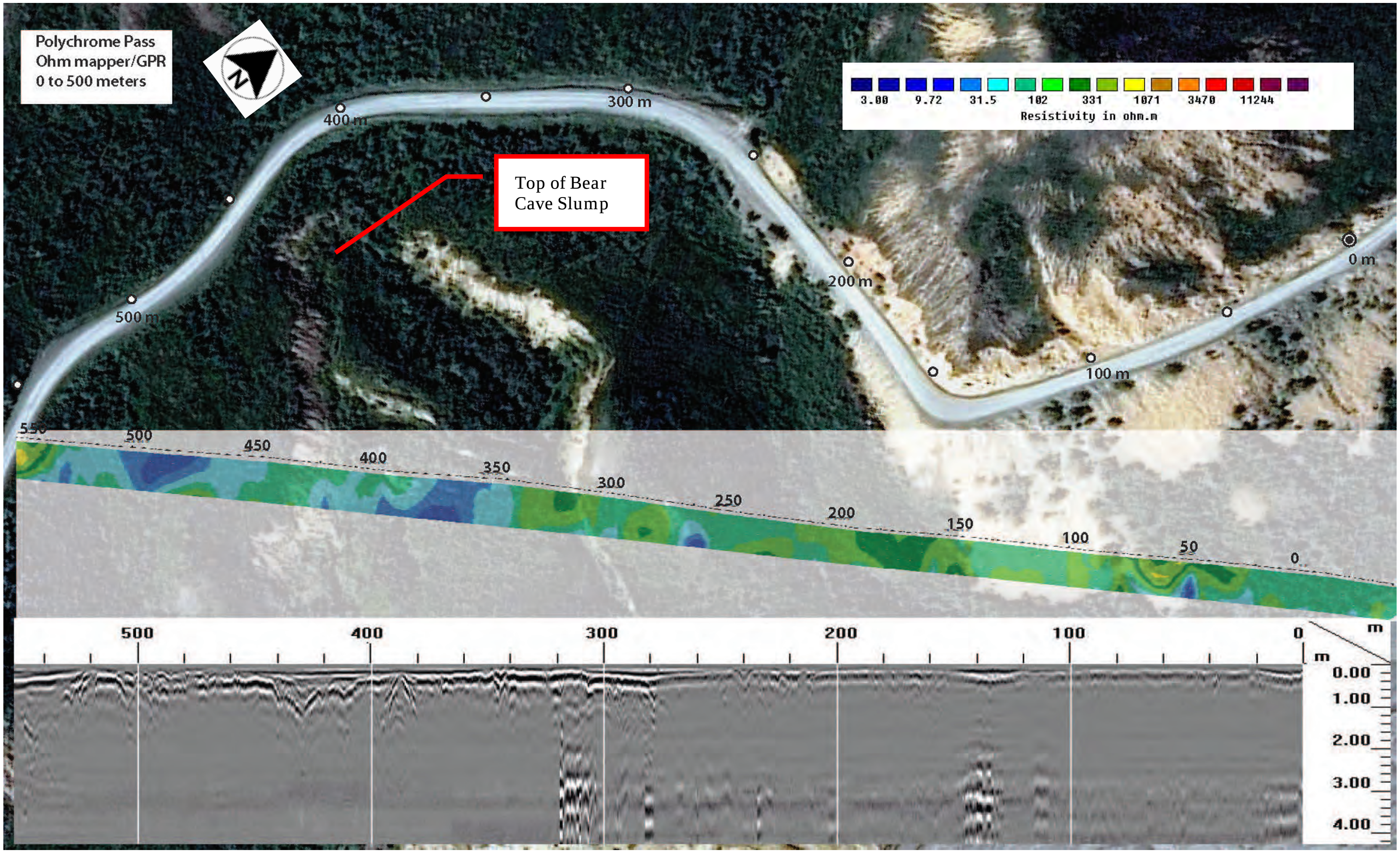


Figure 33. Polychrome Pass, 0m to 500m (1640-ft), start of transect. The view direction of this transect is oriented looking north, therefore the transect moves from right to left, east to west. The ohm-m values are very low through this section, with very low values across and above the headscarp of the Bear Cave Slump, from 250m to 500m possibly indicating higher moisture/ground water. The GPR is not remarkable at depth but a distinct reflector is visible at approximately 0.5m (1.6-ft) in depth, possibly representing the cut surface of the sub-grade. Chaotic structure is not visible in the GPR due to radar energy attenuation possibly from high moisture contents.

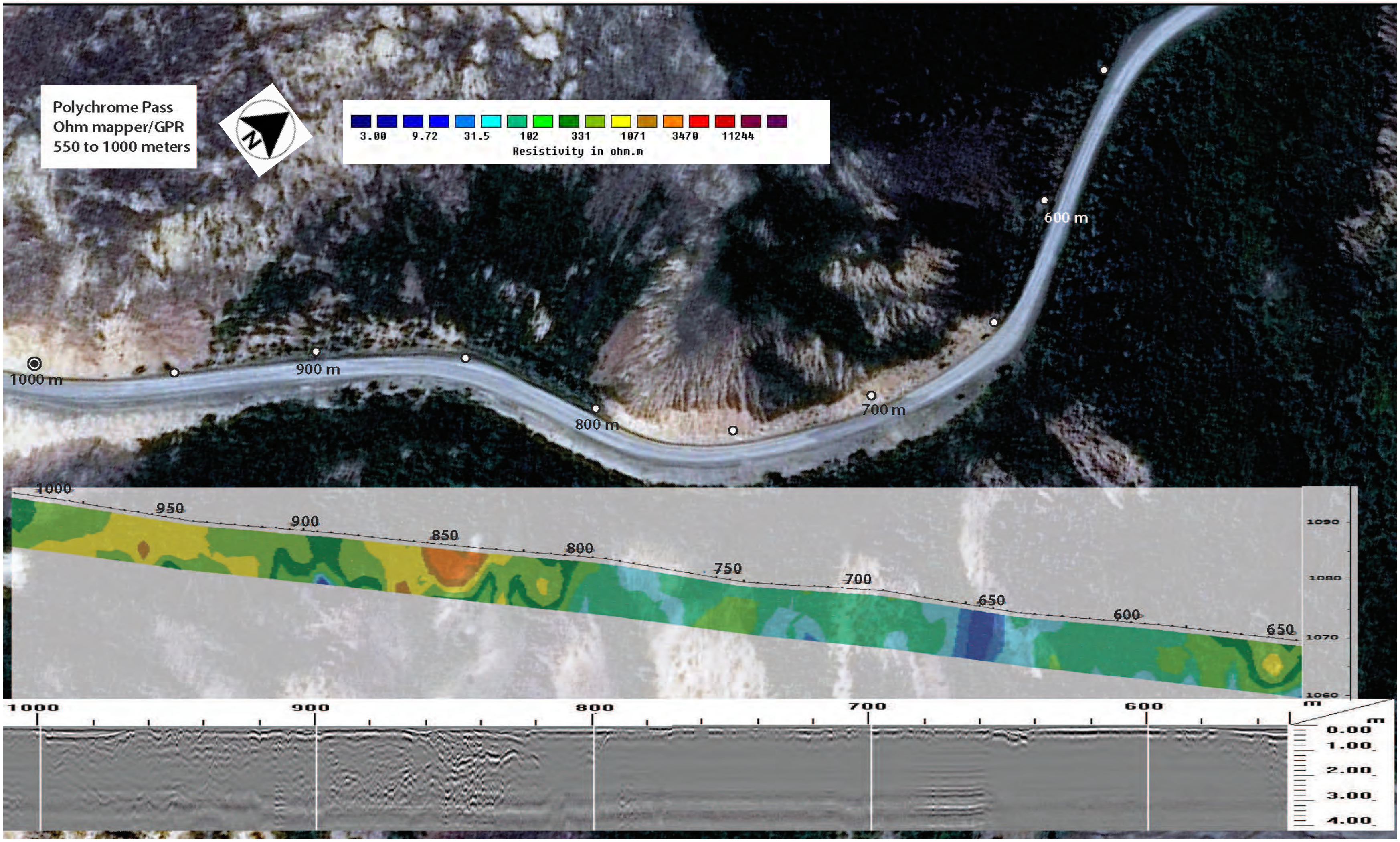


Figure 34. Polychrome Pass, 550m to 1000m ((1804-ft to 3280-ft). The ohm-m values are comprised of two distinct sections. From 650m to 800m the values are very low, indicating either moist/wet conditions, or very conductive mineralogy. At 800m moderate ohm-m values at the near surface coincide with the departure from the roadway rock cut, to a shallow fill section through 950m.The GPR is generally unremarkable except significant structure is visible in the shallow fill area. The ohm-m values and the visible GPR reflections in this portion of the section suggest drier conditions.

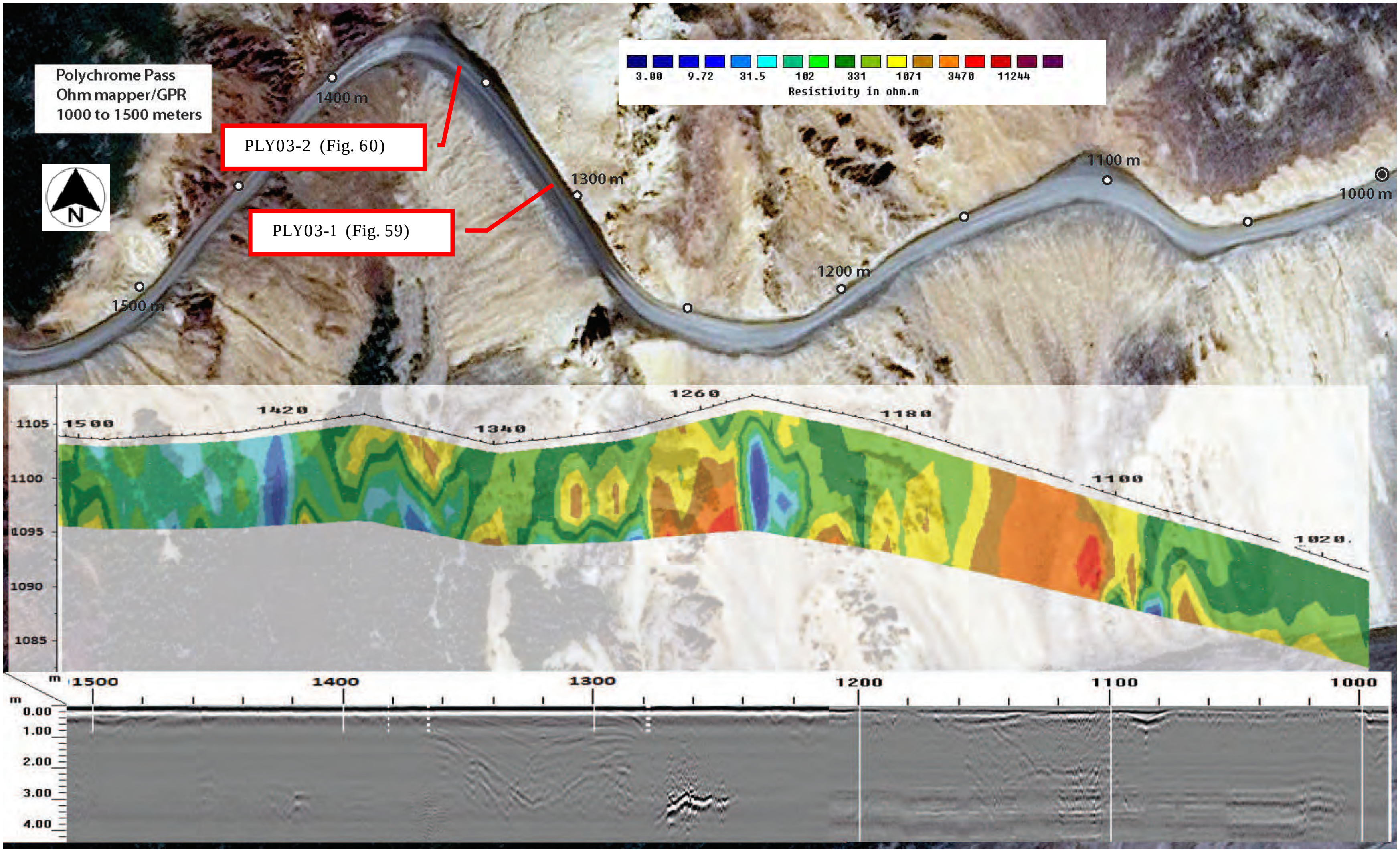


Figure 35. Polychrome Pass, 1000m to 1500m (3280-ft to 4921-ft). The ohm-m values are variable through this section with low values continuing from 950m and up to approximately 1100m. Here the roadway transcends an exposed ridge and much higher values begin and continue as the roadway cuts back into the strata and through a valley to the next ridge which is located at 1200m. This ridge has very low ohm-m values suggesting either very conductive mineralogy or moist/wet conditions at depth. At 1260m the road passes through a cut with high ohm-m values at depth, and then leads into the Pretty Rocks slide section. Through the slide section moderate near surface ohm-m values are measured with very low values at depth suggesting moist/wet conditions. The survey transcends the crotch at approx. 1390m, which is the contact between the mafic strata to the west and the felsic strata (rhyolite) to the east. After this valley, low ohm-m values are measured through to the end of the section. The GPR is very unremarkable through this section except for distinct reflections starting at 1260m where the road passes through the cut.

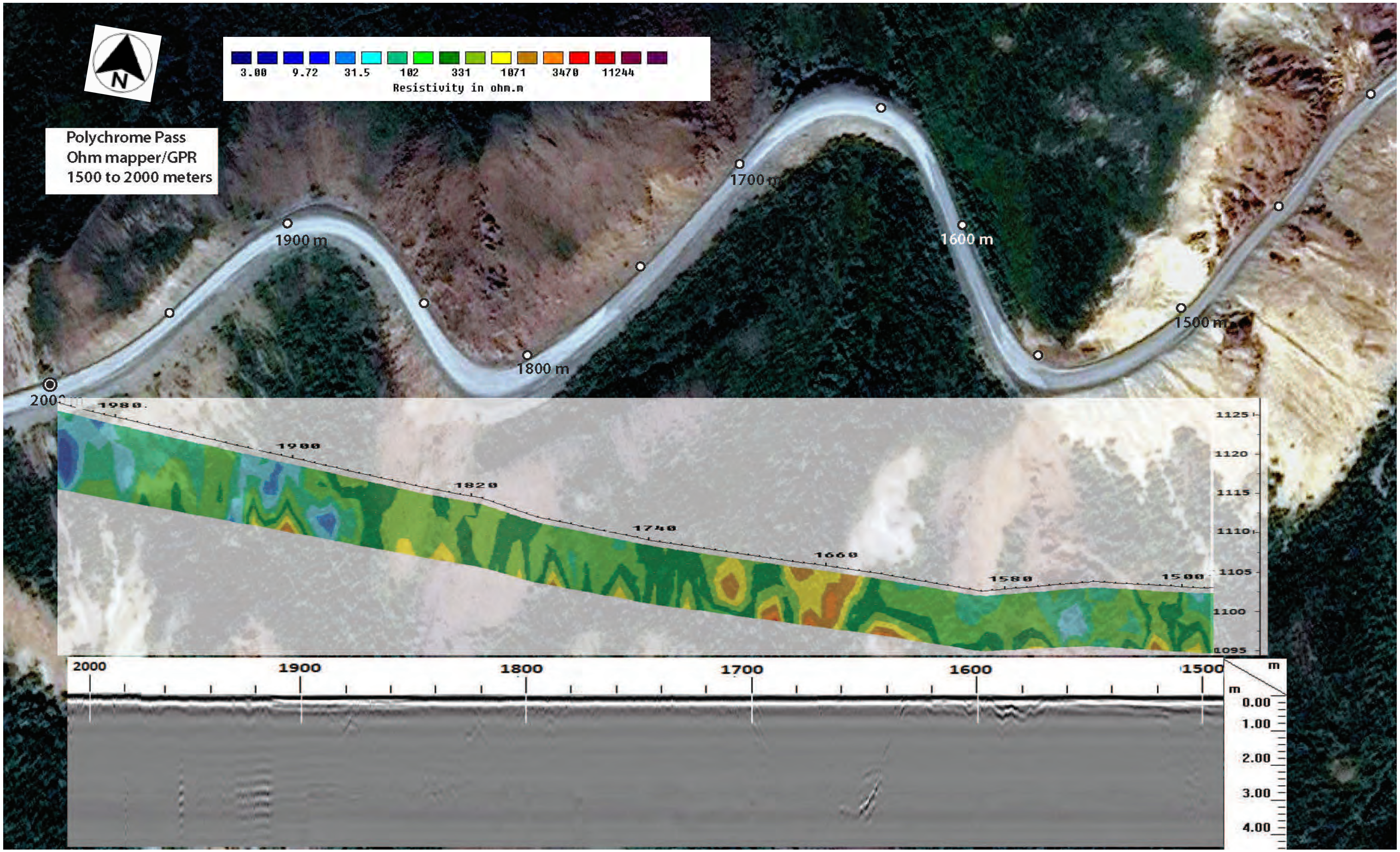


Figure 36. Polychrome Pass, 1500m to 2000m (4921-ft to 6562-ft). The ohm-m values are not as highly varied through this section, with generally low values throughout except for moderate near surface values at 1660m, and moderate values at the extreme depth starting at 1500m to 1900m. The GPR provides no distinct reflections through this area.

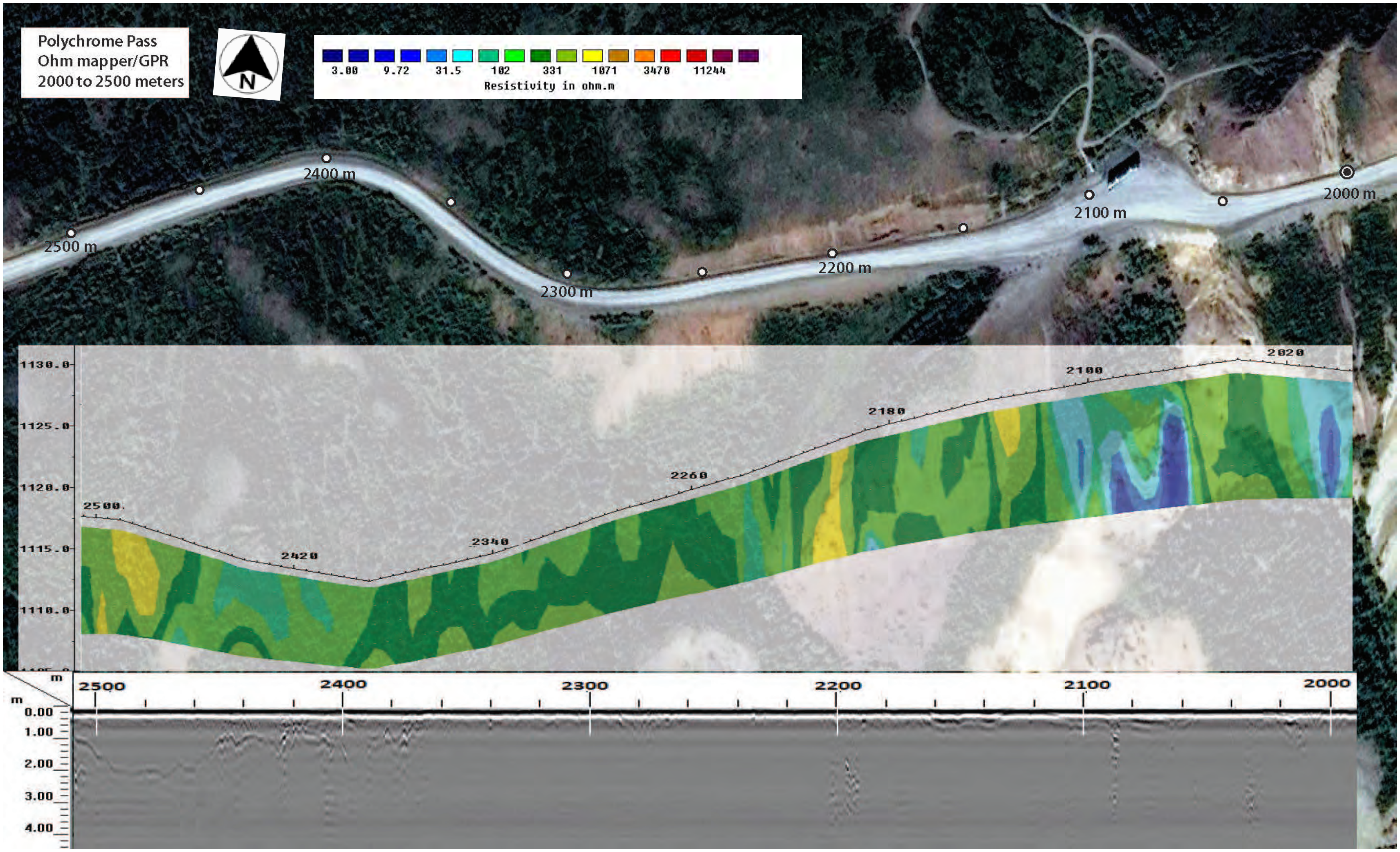
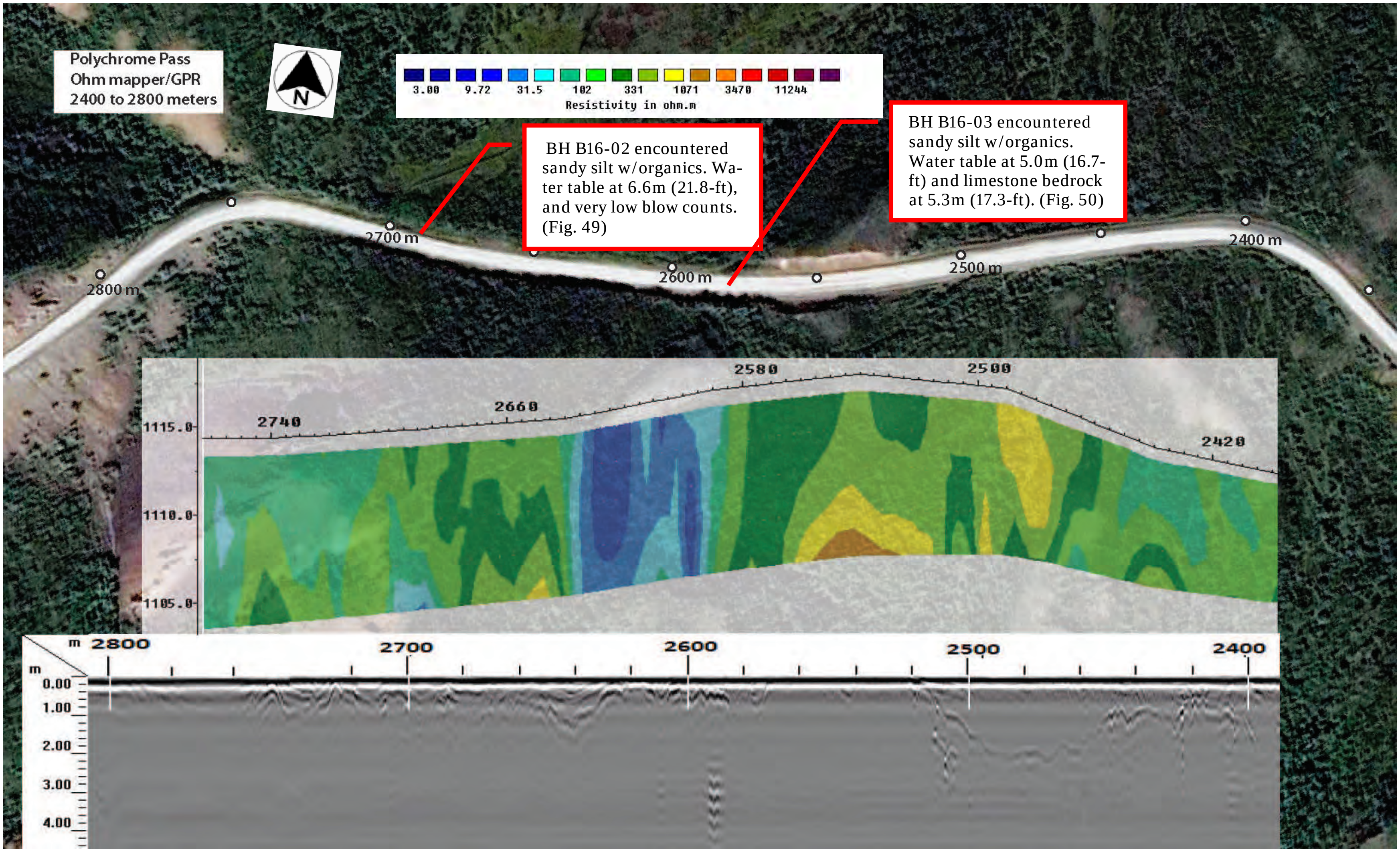


Figure 37. Polychrome Pass, 2000m to 2500m (6562-ft to 8202-ft). The ohm-m values through this section are varied with very low values just before and through the overlook area. These low values are possibly high moisture values of the clayey ash deposit seen on the north side of the overlook, which appears to fold over the two sides of the cut. The values moderate through the remaining section with no distinctive anomalies other than what appears to be lower resistivity at approximately 2400m. The GPR is unremarkable through this section.



BH B16-02 encountered sandy silt w/organics. Water table at 6.6m (21.8-ft), and very low blow counts. (Fig. 49)

BH B16-03 encountered sandy silt w/organics. Water table at 5.0m (16.7-ft) and limestone bedrock at 5.3m (17.3-ft). (Fig. 50)

Figure 38. Polychrome Pass, 2500m to 2800m (8202-ft to 9186-ft), end of transect. The ohm-m values are generally low through this section with the low values continuing from the previous section at 2400m to 2480m. Near surface and deeper values increase while passing through a small road cut at 2540m, indicating bedrock which was encountered in BH B16-03. Very low values are encountered at 2600m to 2640m and this coincides with surface water immediately adjacent to the road on the north side. The values increase only slightly through to the end of the section. The GPR is unremarkable except for distinct near surface reflections visible showing a down drop of the subgrade surface from 2440m to 2500m, and a smaller dip from 2625m to 2660m.

12 Appendix E – Stony Overlook

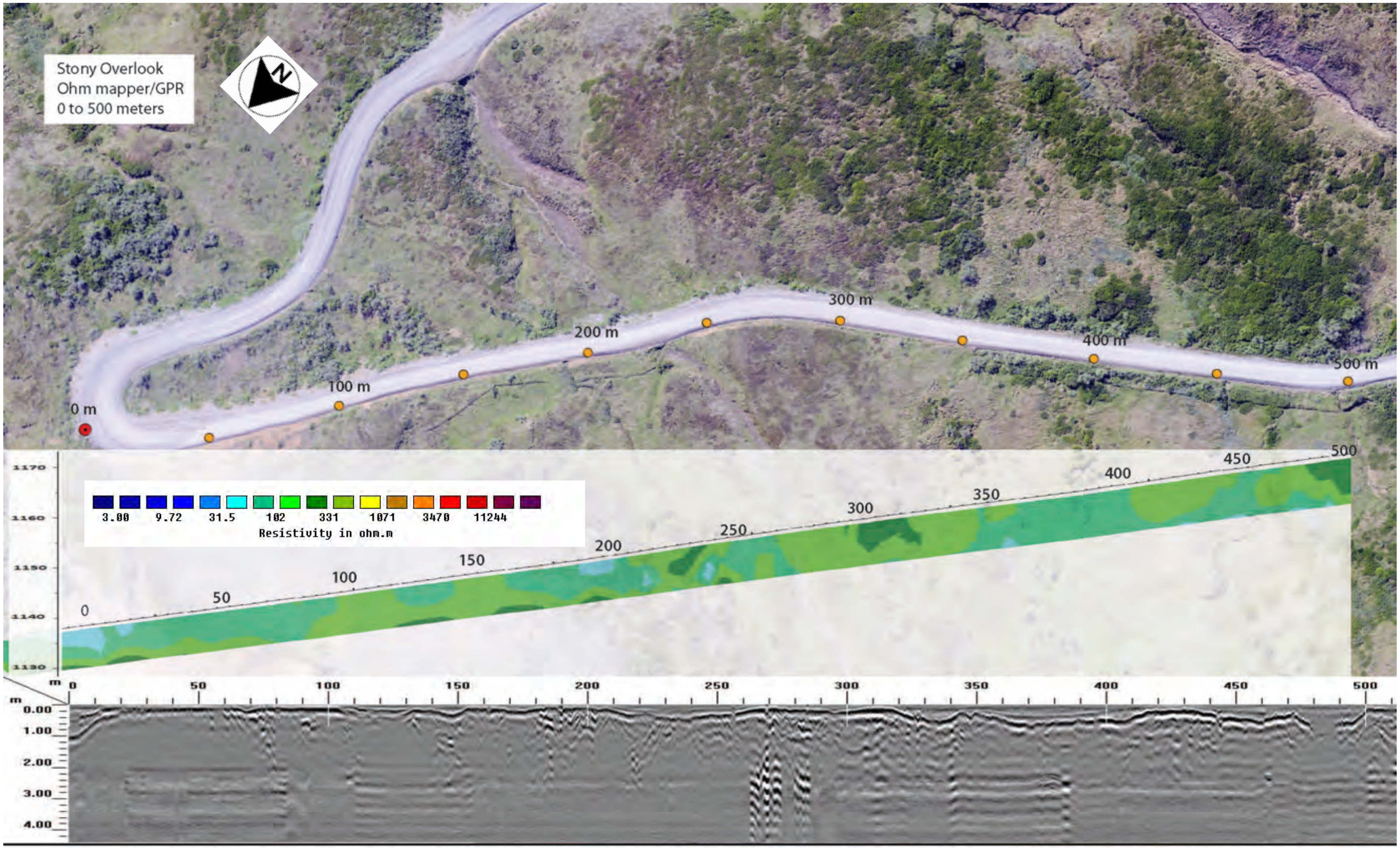
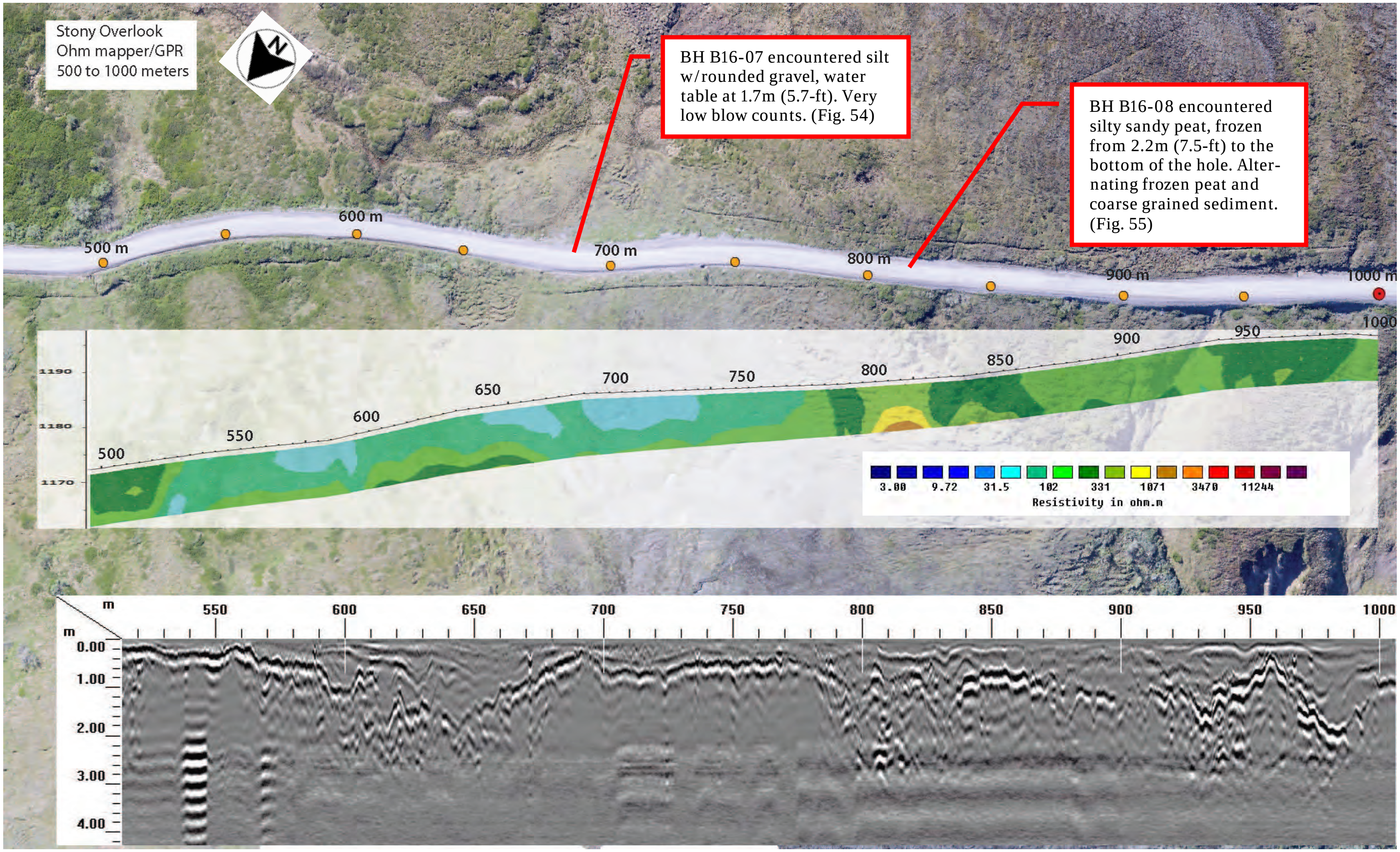


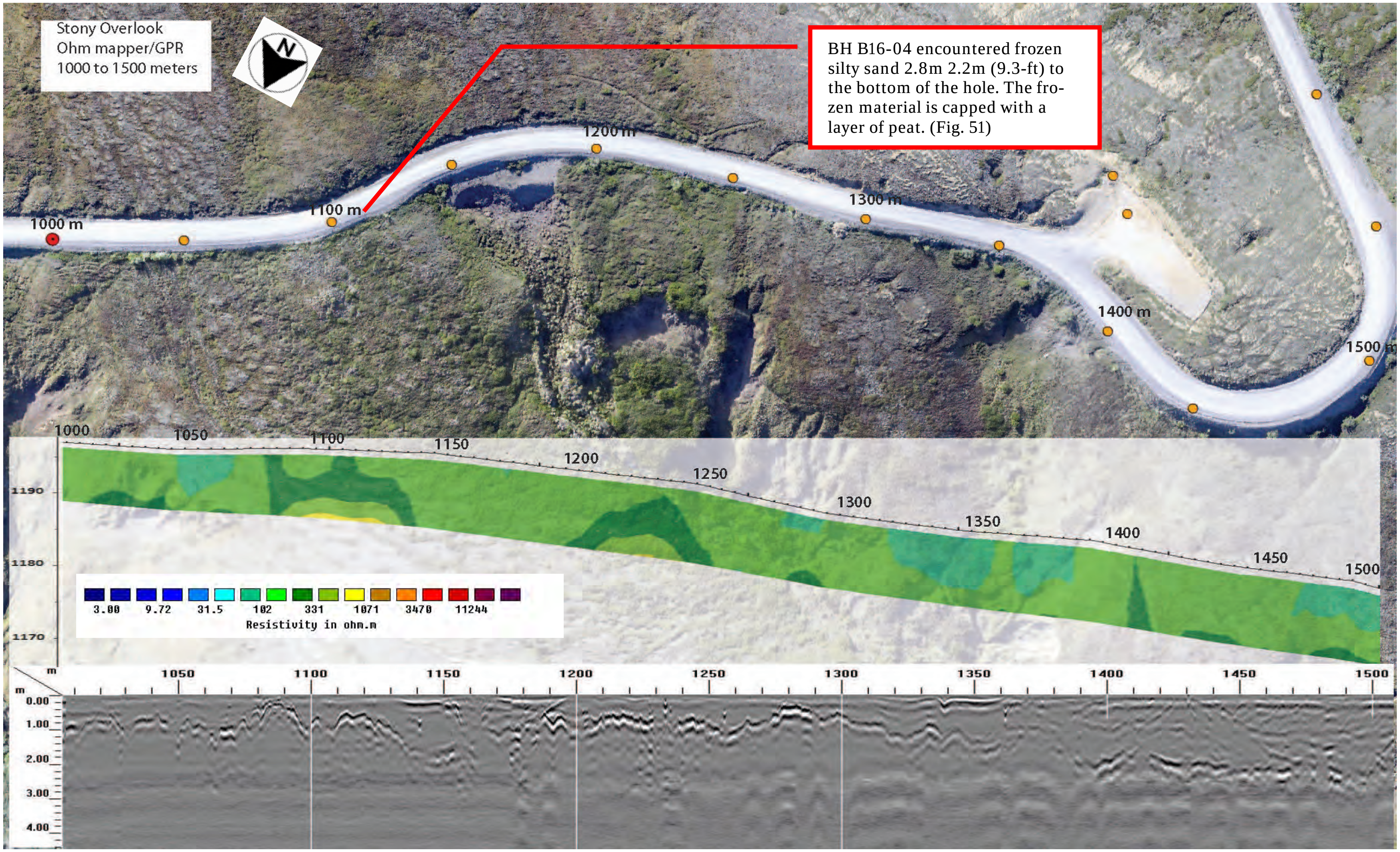
Figure 39. Stony Overlook, 0m to 500m (1640-ft), start of transect. The view direction of this transect is oriented generally looking south, therefore the transect moves from left to right, east to west. The ohm-m values are very low through this first section generally indicating either moist/wet conditions or high conductivity bedrock to depth. The GPR image reports a strong reflector at 0.5m to 1.0m (1.6-ft to 3.3-ft) depth, which is inferred to be the native surface prior to the road construction. No ice-rich frozen ground is indicated in this section.



BH B16-07 encountered silt w/rounded gravel, water table at 1.7m (5.7-ft). Very low blow counts. (Fig. 54)

BH B16-08 encountered silty sandy peat, frozen from 2.2m (7.5-ft) to the bottom of the hole. Alternating frozen peat and coarse grained sediment. (Fig. 55)

Figure 40. Stony Overlook, 500m to 1000m (1640-ft to 3280-ft). The ohm-m values for the portion from 500m to 750m indicates moist/wet conditions nearly full depth. A high resistivity anomaly exists at approximately 800m and appears to be associated with a natural drainage feature on the north side of the road, and drilling indicates buried frozen peat and fine grained sediments. This is followed by slightly elevated ohm-m values vs. the first half of the section. The GPR reflectors are very strong through this section indicating good imaging of what is believed to be the native surface prior to road construction. The primary reflector has a polarity change from white to black to white (+ , - , +), which indicates a higher dielectric material over a lower dielectric material, with one explanation as water perched on the top of a confining layer.Deep natural drainage features at 650m and 980m appear to be filled to level the roadway.



BH B16-04 encountered frozen silty sand 2.8m 2.2m (9.3-ft) to the bottom of the hole. The frozen material is capped with a layer of peat. (Fig. 51)

Figure 41. Stony Overlook, 1000m to 1500m (3280-ft to 4921-ft). The ohm-m values are very low through the entire depth and length of the section. Slightly elevated ohm-m levels are seen at extreme depth at 1100m and 1250m and can be inferred to exist at extreme depth at 1300m and 1400m to 1500m. Drilling at 1100m encountered frozen silty sand to the bottom of the hole. The GPR again reports a strong (+, -, +) phase reversal in the near surface, inferred to be the native surface prior to road construction. A deep fill section is seen at approximately 1150m and deep fill is seen starting at approximately 1300m and extending to the end of the section, presumably this deep fill section of 2.0m (6.6-ft)) was required to make grade on the switch-back turn. Chaotic bedrock structure is not seen below the presumed native surface.

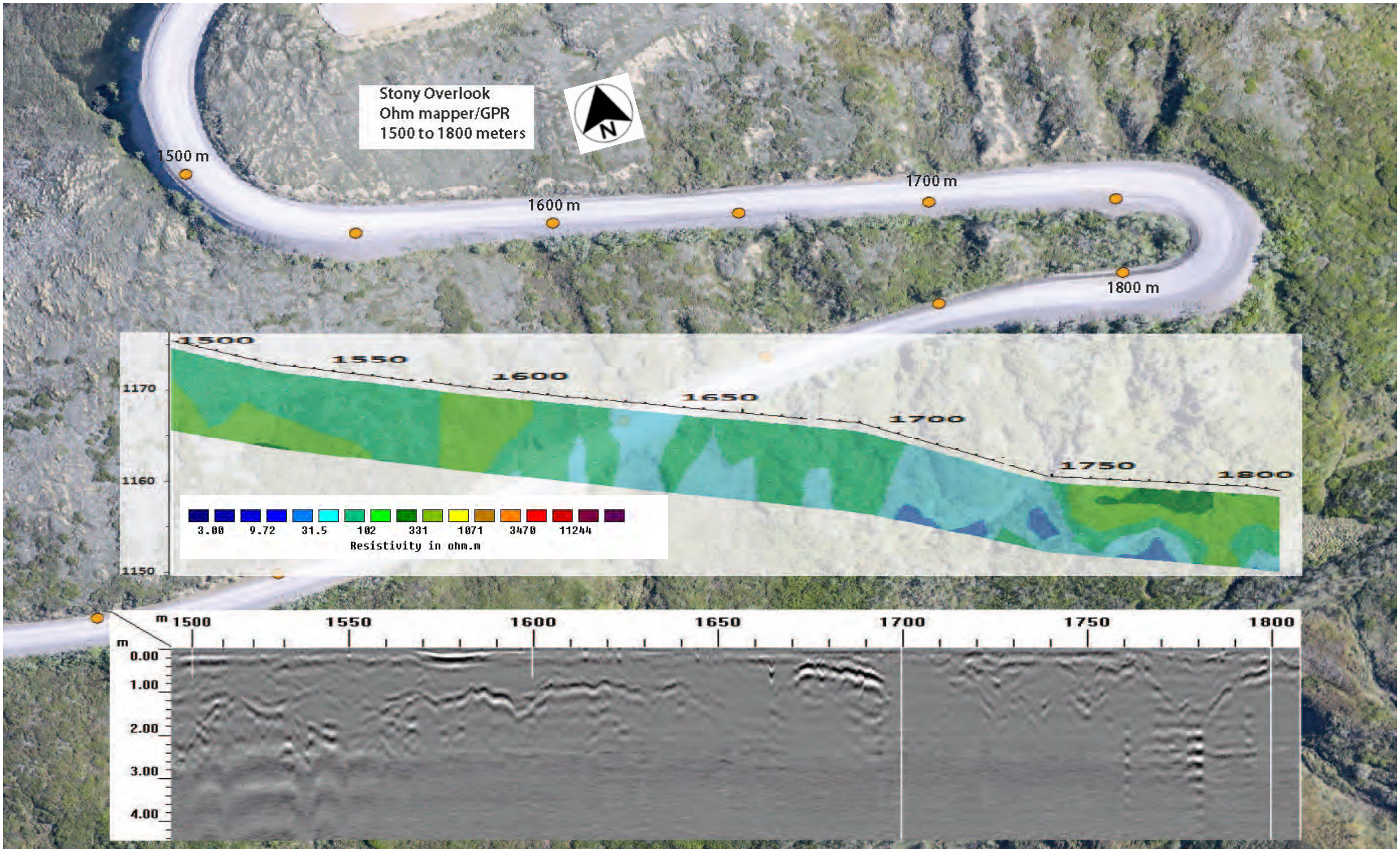
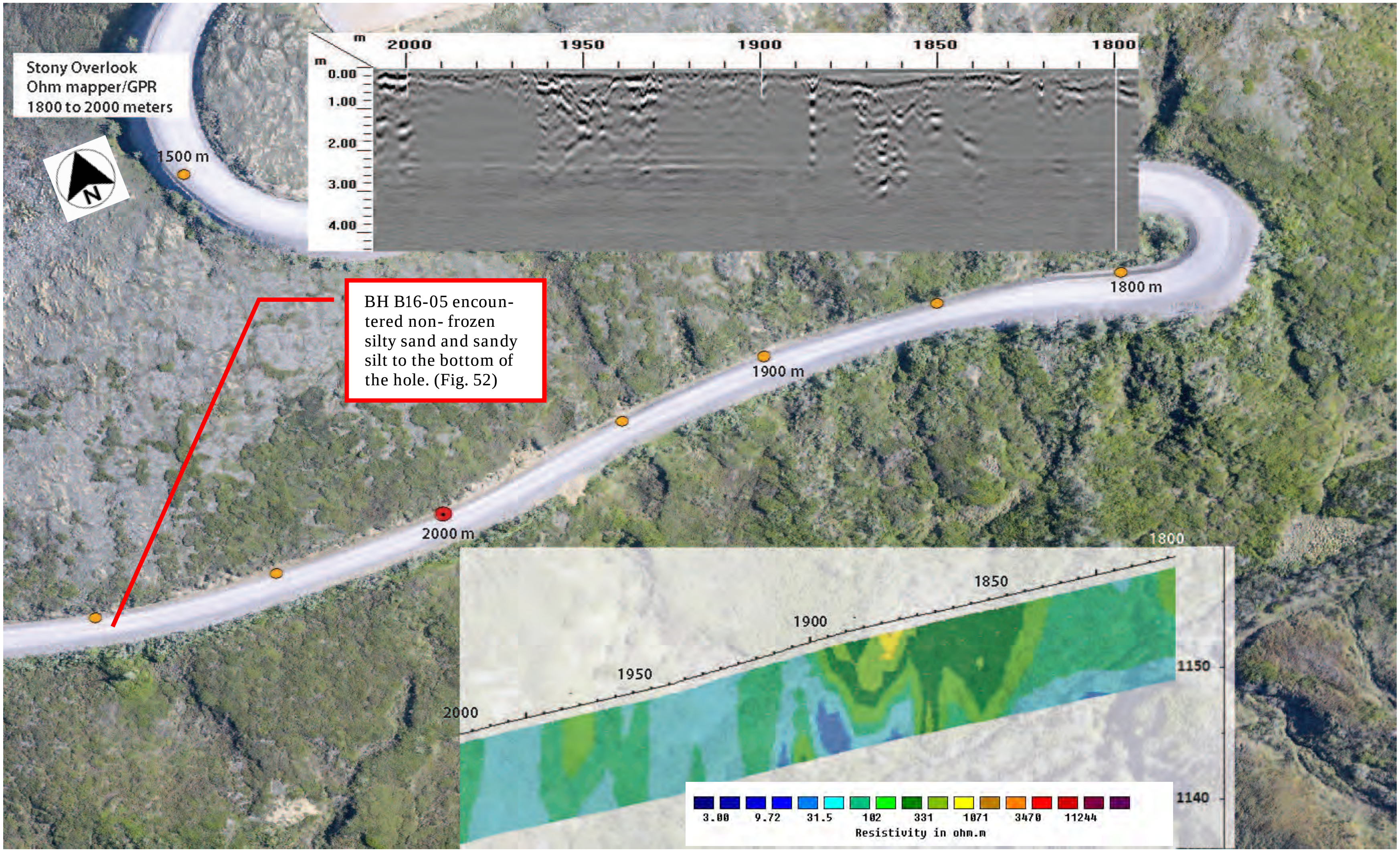


Figure 42. Stony Overlook, 1500m to 1800m (4921-ft to 5906-ft). Very low ohm-m values continue, with moist/wet conditions or high conductivity bedrock from 1625m to 1650m to 1750m. Coincidentally the GPR returns are smeared at these locations strongly indicating radar energy absorption due to water or other material. The GPR indicates the deep fill section noticed at the end of the previous section for the switch-back turn continues starting at 1500m and ending at approximately 1675m.



BH B16-05 encountered non- frozen silty sand and sandy silt to the bottom of the hole. (Fig. 52)

Figure 43. Stony Overlook, 1800m to 2000m (5906-ft to 6562-ft). Very low ohm-m values are recorded on this section leading down to the final switch-back. Moist/wet conditions or high conductivity bedrock are inferred at depth at 1800m to 1850m and at 1900m, also throughout the depth from 1925m to 2000m. A slightly high resistivity anomaly exists at 1880m, and based on the GPR returns we infer this to be a drainage appurtenance. The GPR is not remarkable in this section.

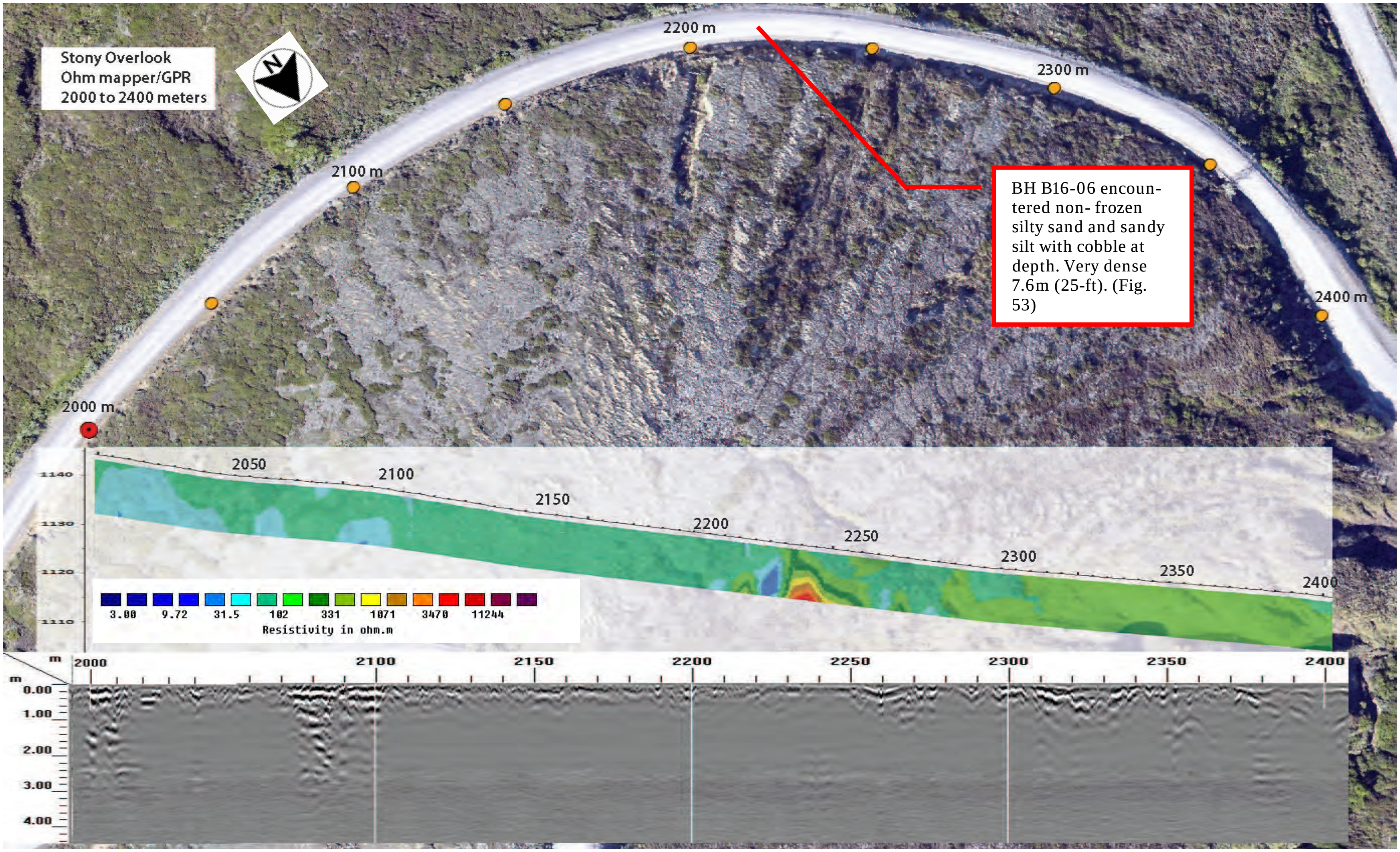


Figure 44. Stony Overlook, 2000m to 2400m (6562-ft to 7874-ft). The ohm-m values for this section are again very low, with possibly moist/wet conditions, or high conductivity bedrock existing from 2000m to 2300m. A very high resistivity anomaly exists at 2225m and lies too deep to be a drainage or other roadway appurtenance. Drilling at this location encountered non-frozen sediments. After 2300m the very low ohm-m values increase slightly. The GPR reflections are not remarkable in this section.

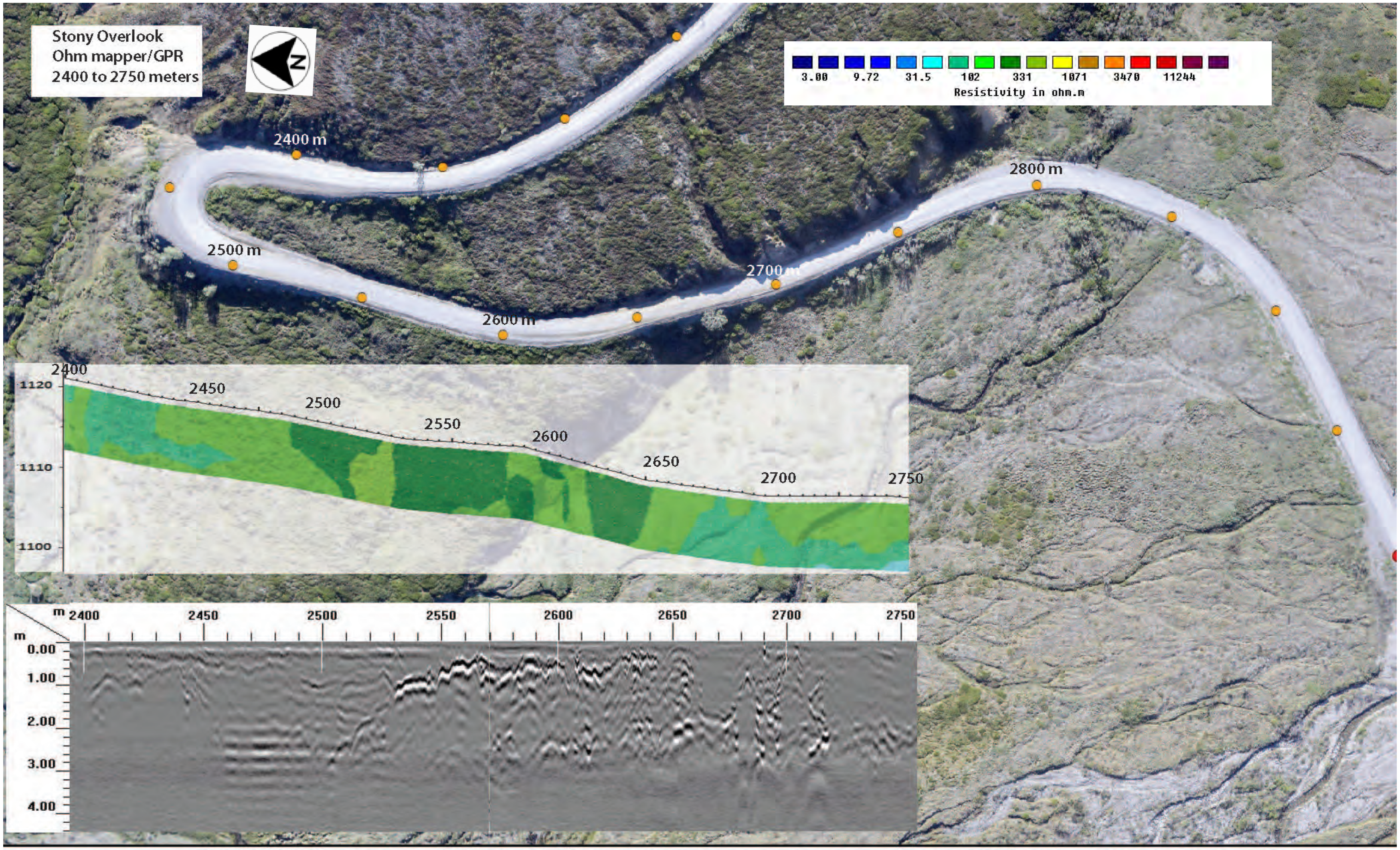


Figure 45. Stony Overlook, 2400m to 2750m (7874-ft to 9022-ft). The ohm-m values for this section are again very low, with possibly moist/wet conditions, or high conductivity bedrock existing for the full section and depth. The GPR imaging reports good imaging of chaotic structure with two distinct reflectors with one at 1.0m (3.2-ft) depth and the other at 2.5m (8.2-ft) depth, or this could be very coarse grained sediment material (outwash or till?). The GPR reflections are strongest where the ohm-m values are higher, indicating wet conditions may prevail elsewhere and the subsurface water is absorbing the radar energy.

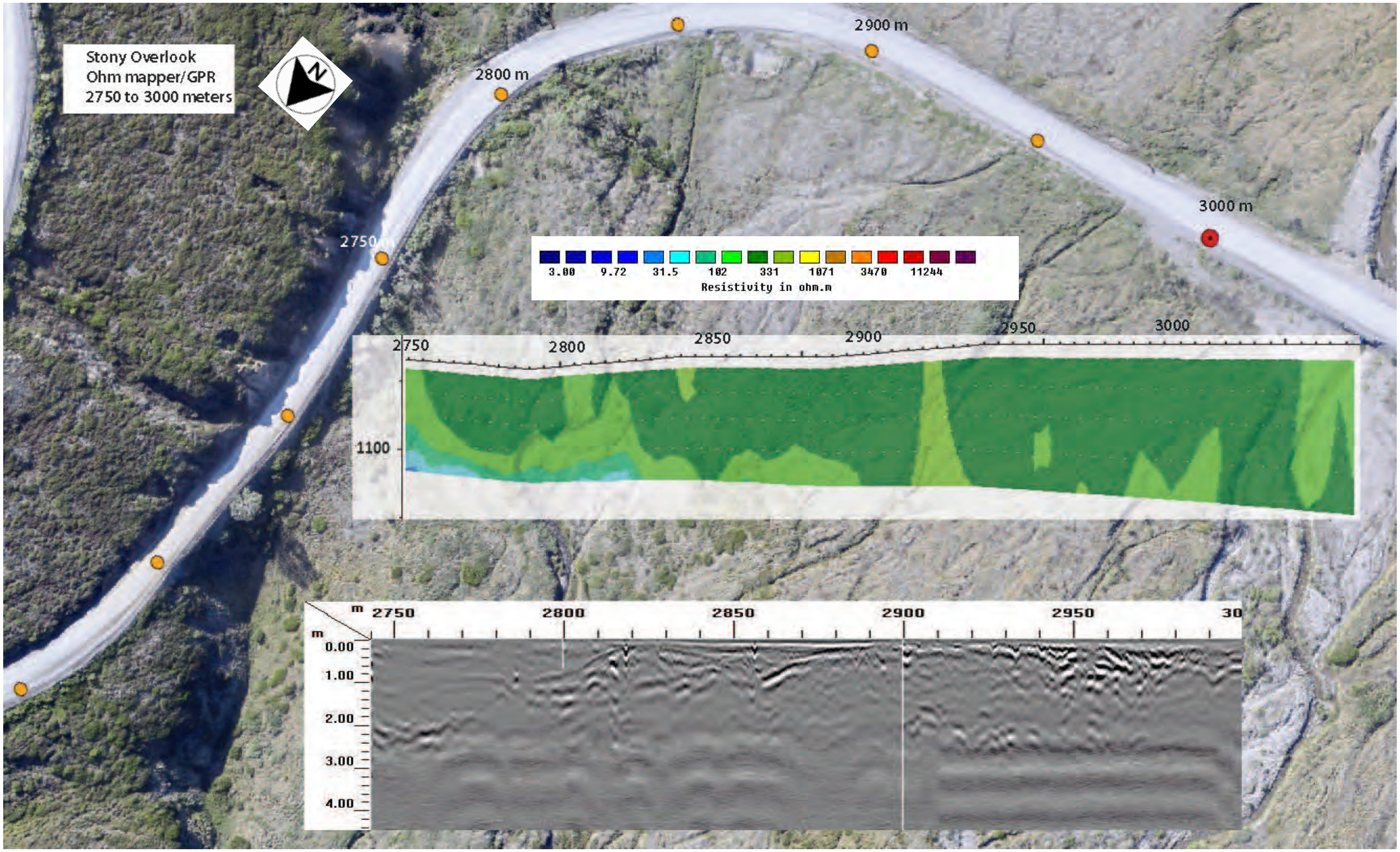
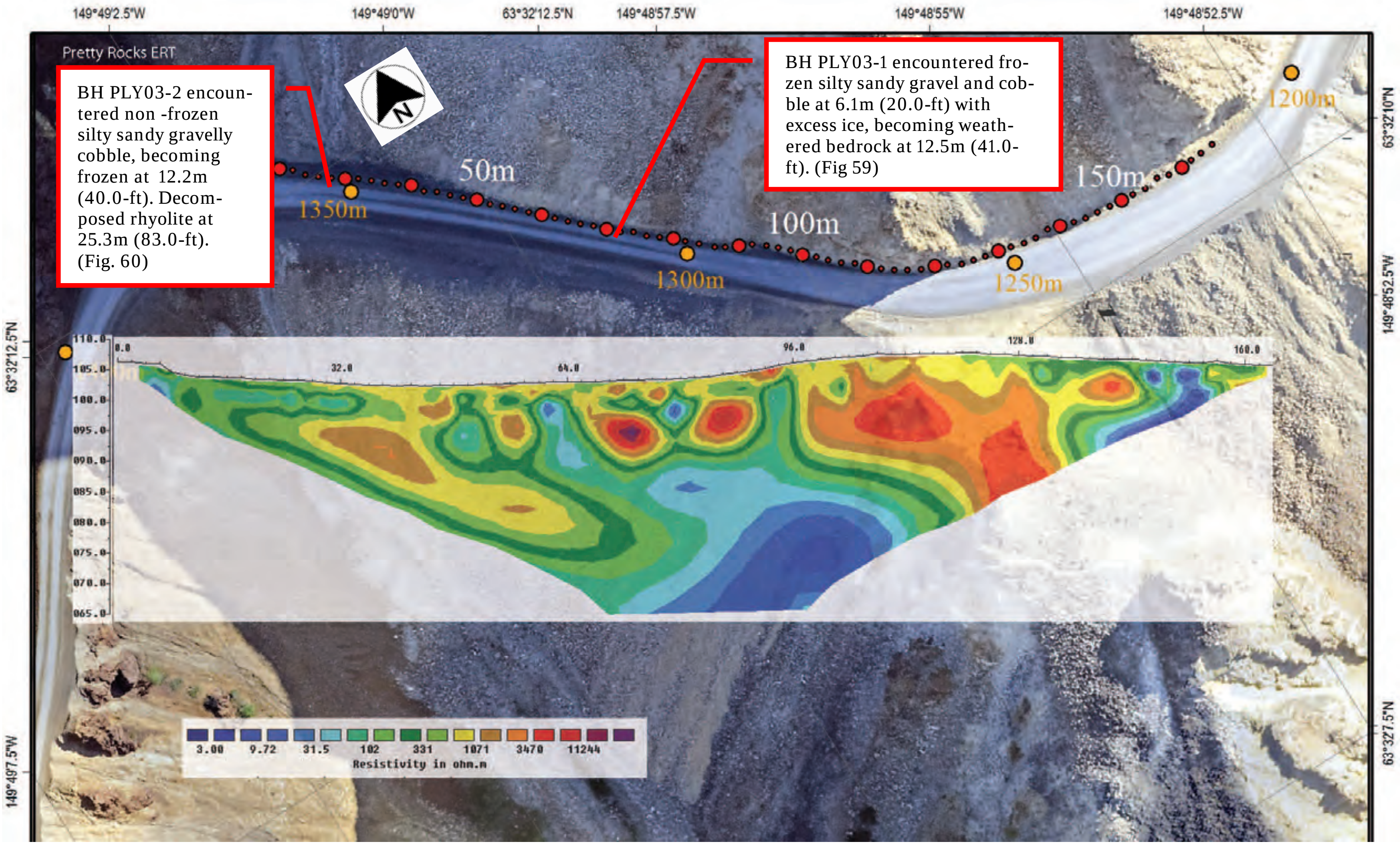


Figure 46. Stony Overlook, 2750m to 3000m (9022-ft to 9843-ft), end of transect. Low ohm-m values dominate this section, with very low values at depth from 2750m to 2825m. The GPR reports good reflections in the near surface with improving clarity of signal with distance along the section.

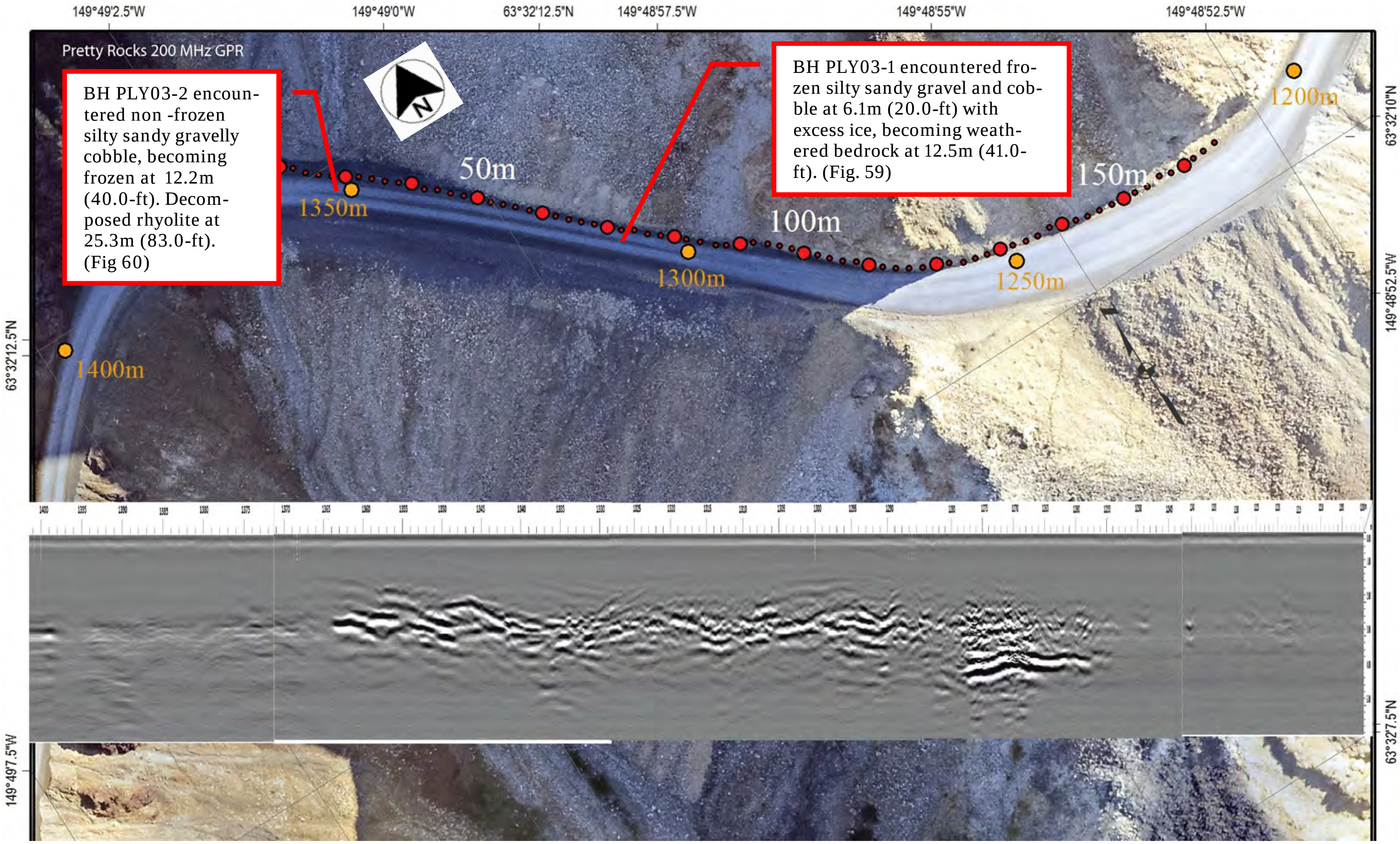
13 Appendix F – Pretty Rocks



BH PLY03-2 encountered non -frozen silty sandy gravelly cobble, becoming frozen at 12.2m (40.0-ft). Decomposed rhyolite at 25.3m (83.0-ft). (Fig. 60)

BH PLY03-1 encountered frozen silty sandy gravel and cobble at 6.1m (20.0-ft) with excess ice, becoming weathered bedrock at 12.5m (41.0-ft). (Fig 59)

Figure 47. Pretty Rocks ERT. The total depth of the processed survey is approx. 40m (130 ft.). The electrical path is assumed to be parallel to the driven axis of the electrodes, which was at an angle nearly vertical in the road ditch. Very high ohm-m values are reported where the road passes through the rock cut at 120m to 130m, and this is interpreted as the natural resistivity of the felsic (rhyolite) strata in the dry condition. At either side of the cut in the debris slope, very low ohm-m values are reported, and we interpret this as moisture/water in the fine grained material of the debris, indicating a lubricated slip surface of the slope failure. The high ohm-m anomalies at 70m and 90m, and at 8m to 10m depth are inferred to be segregation ice that was logged in the two boreholes drilled in the area. The ERT line is oblique to the strike of the felsic strata, therefore we see an oblique cross-section of the slope and debris, and it appears the frozen zone is of limited thickness with a bottom of permafrost at approx. 15m (49 ft.). The ohm-m values are moderate from 20m to 60m, and this is interpreted as drier or moderate ice conditions.

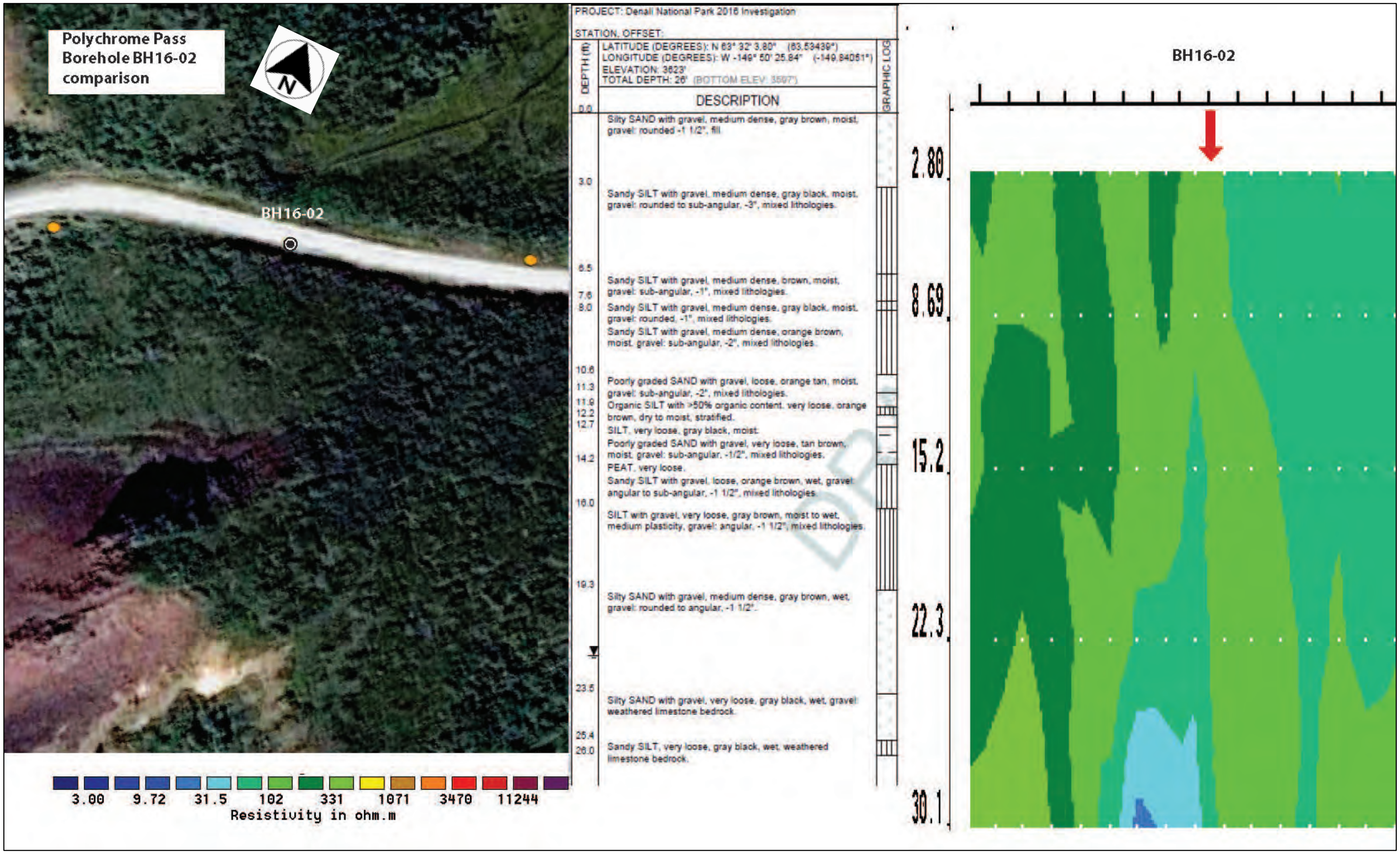


BH PLY03-2 encountered non -frozen silty sandy gravelly cobble, becoming frozen at 12.2m (40.0-ft). Decomposed rhyolite at 25.3m (83.0-ft). (Fig 60)

BH PLY03-1 encountered frozen silty sandy gravel and cobble at 6.1m (20.0-ft) with excess ice, becoming weathered bedrock at 12.5m (41.0-ft). (Fig. 59)

Figure 48. Pretty Rocks GPR. This survey was conducted with the 200MHz antenna system. Very distinctive chaotic reflected bands are imaged starting at approx. 35m continuing up to the rock cut at 120m, here they are approximately at 3.0m (9.8-ft) depth with a thickness of 1.5m to 2.0m (4.9-ft to 6.6-ft). At the road cut they increase in depth, down to 4.5m (14.8-ft), and increase in brightness through the cut to 140m. The primary polarity signature of the reflections is black to white to black (-, +, -), which indicates a lower dielectric material overlying a much higher dielectric material, for example thawed material over ground ice. The boreholes drilled at this location verify that ice exists through this area, therefore we interpret the ice to be multi-generational segregation ice. The segregated ice is created in the intermediate zone between the active layer and the permafrost table, moving downward due to the slope movement, and becoming captured (aggraded) in the permafrost table, out of the reach of subsequent summer thaw. We infer the lower reflector of this icy band at 4.5m to 5.0m (14,8-ft to 16.4-ft) represents the bottom of the permafrost, and this coincides with the ERT data from Figure 47. The much deeper reflector in the road cut at 120m to 130m is inferred to be permafrost protected from the movement of the slope and thawing from the inferred basal water of the slip plane.

14 Appendix G – Bore Logs with Resistivity (2016, 2014, 1983)



PROJECT: Denali National Park 2016 Investigation

STATION, OFFSET:

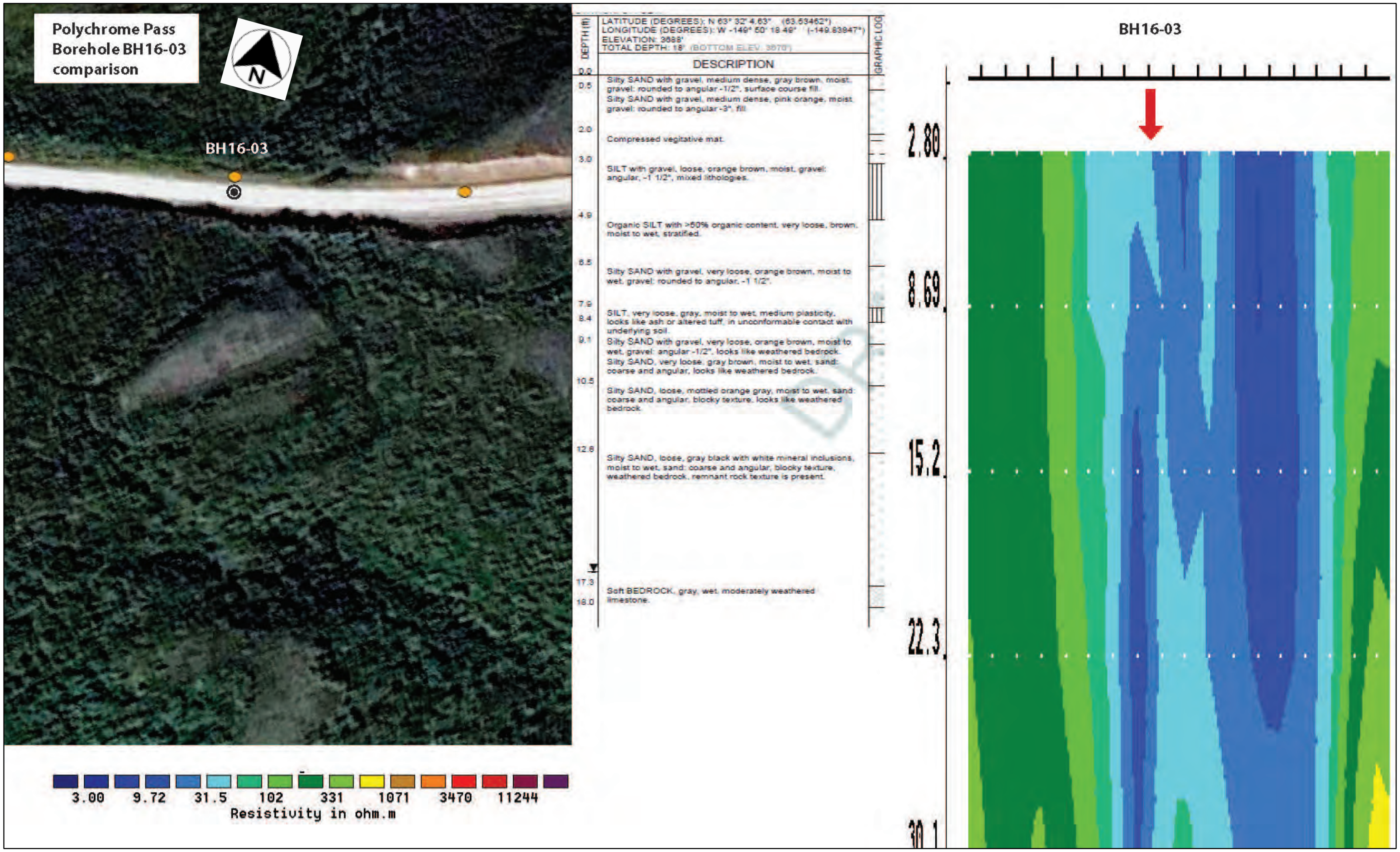
LATITUDE (DEGREES): N 63° 32' 3.80" (63.53439°)
LONGITUDE (DEGREES): W -149° 50' 25.84" (-149.84051°)
ELEVATION: 3623'
TOTAL DEPTH: 26' (BOTTOM ELEV: 3597')

DEPTH (ft)

DESCRIPTION

0.0
Silty SAND with gravel, medium dense, gray brown, moist, gravel: rounded -1 1/2", fill
3.0
Sandy SILT with gravel, medium dense, gray black, moist, gravel: rounded to sub-angular, -3", mixed lithologies.
6.5
Sandy SILT with gravel, medium dense, brown, moist, gravel: sub-angular, -1", mixed lithologies.
7.6
8.0
Sandy SILT with gravel, medium dense, gray black, moist, gravel: rounded, -1", mixed lithologies.
Sandy SILT with gravel, medium dense, orange brown, moist. gravel: sub-angular, -2", mixed lithologies.
10.6
11.3
Poorly graded SAND with gravel, loose, orange tan, moist, gravel: sub-angular, -2", mixed lithologies.
11.9
12.2
Organic SILT with >50% organic content, very loose, orange brown, dry to moist, stratified.
12.7
SILT, very loose, gray black, moist.
Poorly graded SAND with gravel, very loose, tan brown, moist, gravel: sub-angular, -1/2", mixed lithologies.
14.2
PEAT, very loose.
Sandy SILT with gravel, loose, orange brown, wet, gravel: angular to sub-angular, -1 1/2", mixed lithologies.
16.0
SILT with gravel, very loose, gray brown, moist to wet, medium plasticity, gravel: angular, -1 1/2", mixed lithologies.
19.3
Silty SAND with gravel, medium dense, gray brown, wet, gravel: rounded to angular, -1 1/2".
23.5
Silty SAND with gravel, very loose, gray black, wet, gravel: weathered limestone bedrock.
25.4
26.0
Sandy SILT, very loose, gray black, wet, weathered limestone bedrock.

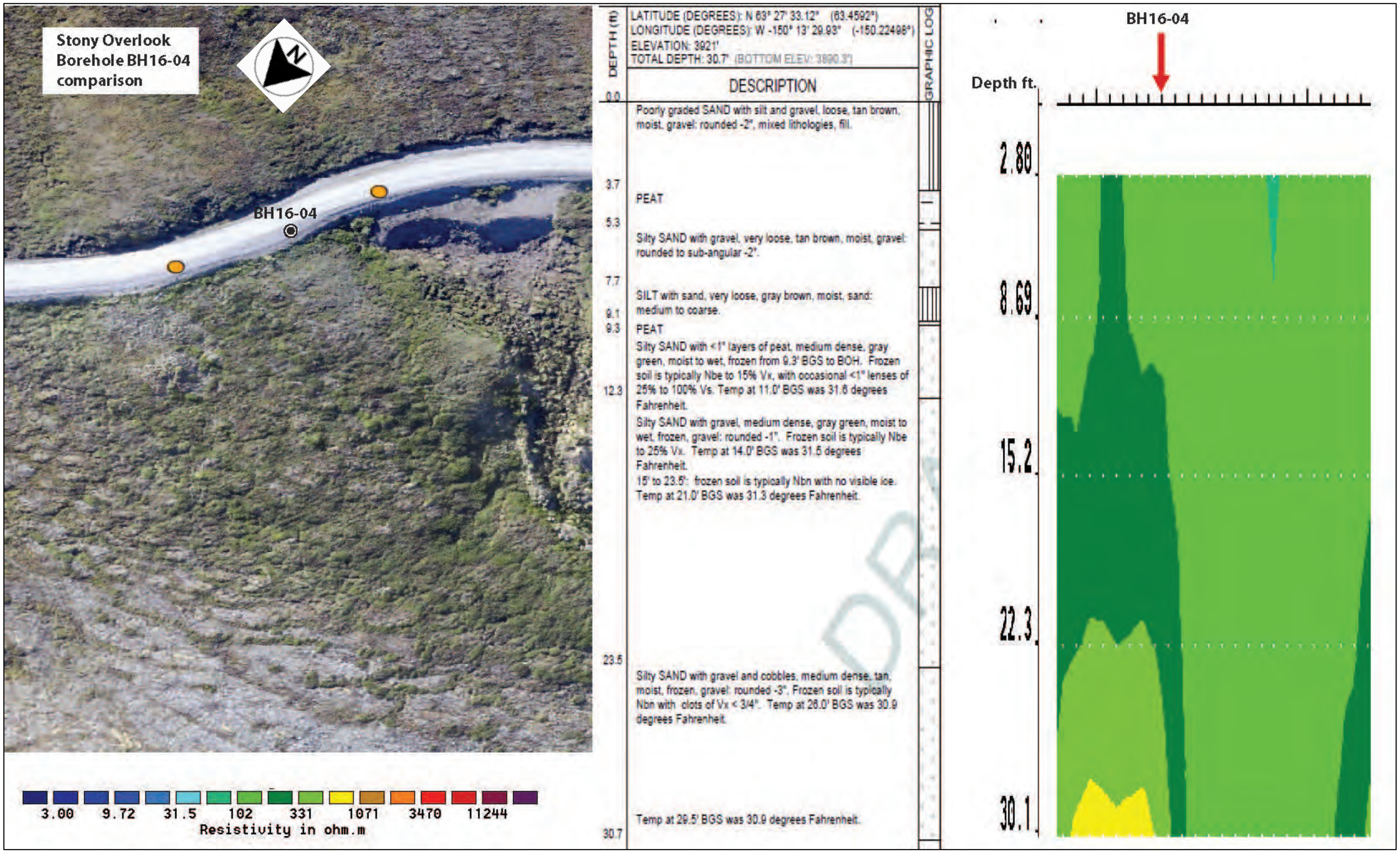
Figure 49. BH16-02 Polychrome Pass. Ohm-m values are very low consistent with the drilling results of silts, sands and peats, indicative of very wet soils.



LATITUDE (DEGREES): N 63° 32' 4.63" (63.53462°)
LONGITUDE (DEGREES): W -149° 50' 18.49" (-149.83947°)
ELEVATION: 3888'
TOTAL DEPTH: 18' (BOTTOM ELEV. 3870')

DEPTH (ft)	DESCRIPTION
0.0	Silty SAND with gravel, medium dense, gray brown, moist, gravel: rounded to angular -1/2", surface course fill.
0.5	Silty SAND with gravel, medium dense, pink orange, moist gravel: rounded to angular -3", fill.
2.0	Compressed vegitative mat.
3.0	SILT with gravel, loose, orange brown, moist, gravel: angular, -1 1/2", mixed lithologies.
4.9	Organic SILT with >50% organic content, very loose, brown, moist to wet, stratified.
6.5	Silty SAND with gravel, very loose, orange brown, moist to wet, gravel: rounded to angular, -1 1/2".
7.9	SILT, very loose, gray, moist to wet, medium plasticity, looks like ash or altered tuff, in unconformable contact with underlying soil.
8.4	Silty SAND with gravel, very loose, orange brown, moist to wet, gravel: angular -1/2", looks like weathered bedrock.
9.1	Silty SAND, very loose, gray brown, moist to wet, sand: coarse and angular, looks like weathered bedrock.
10.5	Silty SAND, loose, mottled orange gray, moist to wet, sand: coarse and angular, blocky texture, looks like weathered bedrock.
12.6	Silty SAND, loose, gray black with white mineral inclusions, moist to wet, sand: coarse and angular, blocky texture, weathered bedrock, remnant rock texture is present.
17.3	Soft BEDROCK, gray, wet, moderately weathered limestone.
18.0	

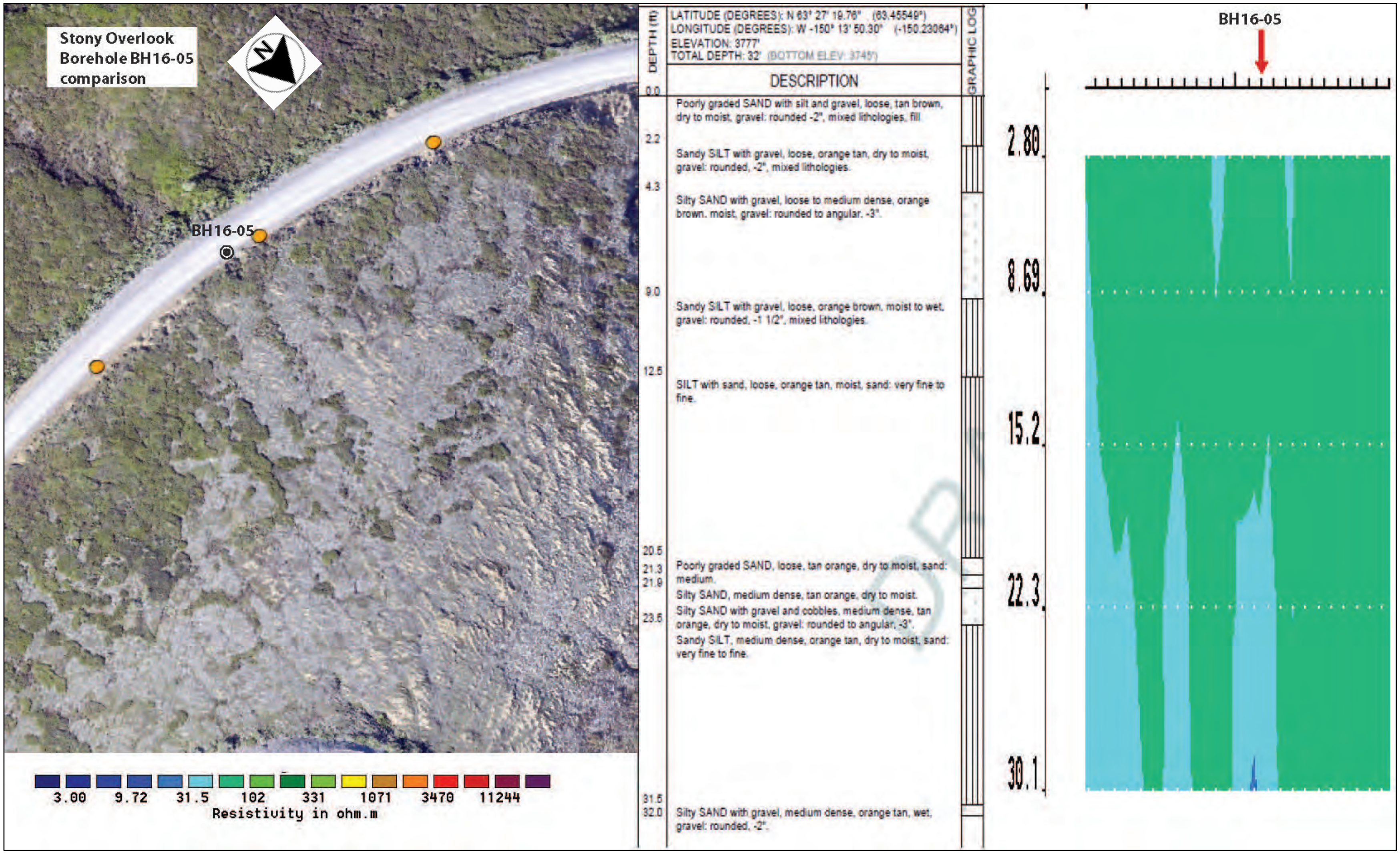
Figure 50. BH16-03 Polychrome Pass. Ohm-m values are very low, consistent with the drilling results of wet silts and sands, indicative of very wet soils.



LATITUDE (DEGREES): N 63° 27' 33.12" (63.4592°)
LONGITUDE (DEGREES): W -150° 13' 29.93" (-150.22498°)
ELEVATION: 3921'
TOTAL DEPTH: 30.7' (BOTTOM ELEV: 3890.3')

DEPTH (ft)	DESCRIPTION
0.0	Poorly graded SAND with silt and gravel, loose, tan brown, moist, gravel: rounded -2", mixed lithologies, fill.
3.7	PEAT
5.3	Silty SAND with gravel, very loose, tan brown, moist, gravel: rounded to sub-angular -2".
7.7	SILT with sand, very loose, gray brown, moist, sand: medium to coarse.
9.1	PEAT
9.3	Silty SAND with <1" layers of peat, medium dense, gray green, moist to wet, frozen from 9.3' BGS to BOH. Frozen soil is typically Nbe to 15% Vx, with occasional <1" lenses of 25% to 100% Vs. Temp at 11.0' BGS was 31.6 degrees Fahrenheit.
12.3	Silty SAND with gravel, medium dense, gray green, moist to wet, frozen, gravel: rounded -1". Frozen soil is typically Nbe to 25% Vx. Temp at 14.0' BGS was 31.5 degrees Fahrenheit. 15' to 23.5': frozen soil is typically Nbn with no visible ice. Temp at 21.0' BGS was 31.3 degrees Fahrenheit.
23.5	Silty SAND with gravel and cobbles, medium dense, tan, moist, frozen, gravel: rounded -3". Frozen soil is typically Nbn with clots of Vx < 3/4". Temp at 26.0' BGS was 30.9 degrees Fahrenheit. Temp at 29.5' BGS was 30.9 degrees Fahrenheit.
30.7	

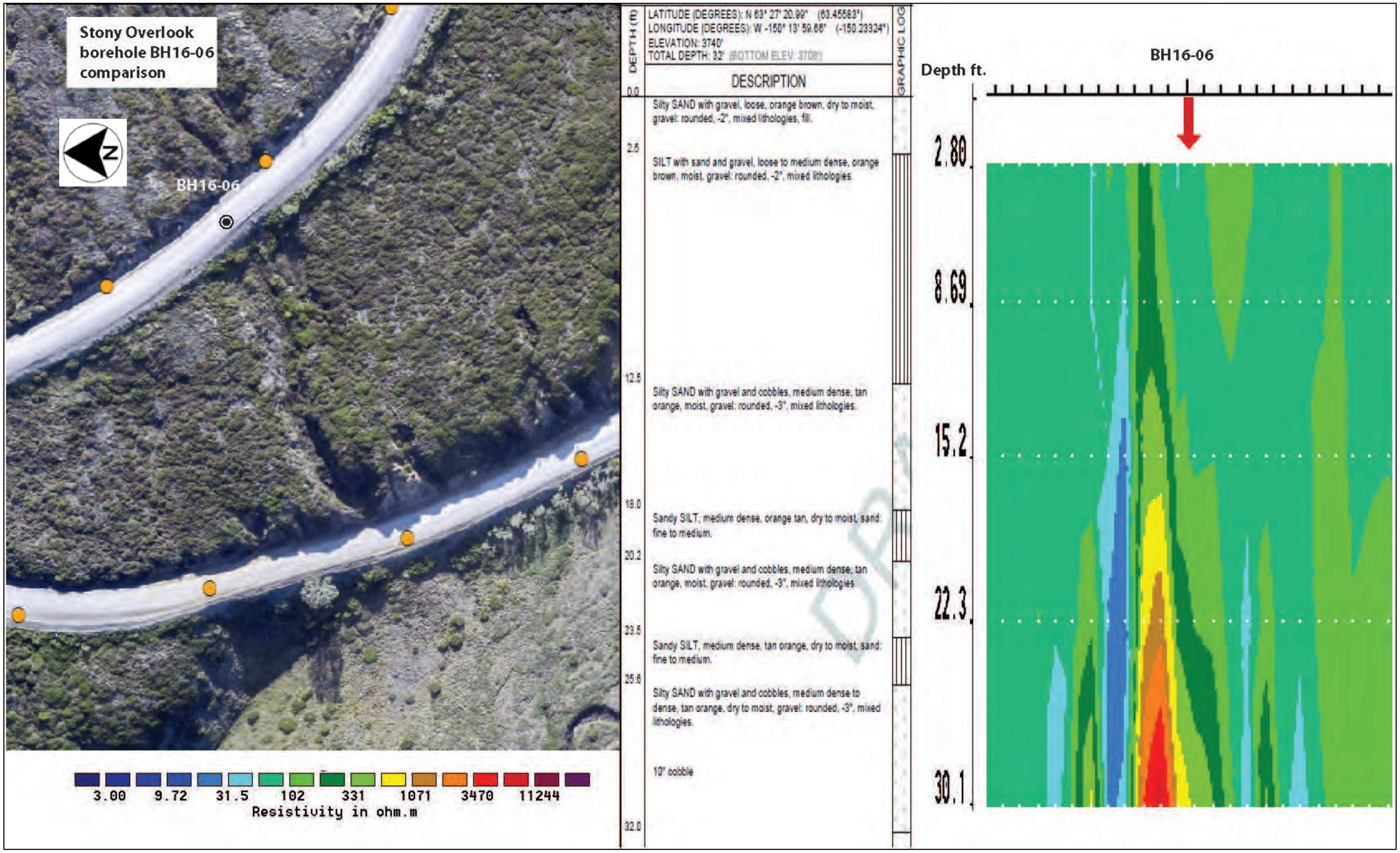
Figure 51. BH16-04 Stony Overlook. The ohm-m values are low at the top of the borehole and this is consistent with the drilling results of thawed silty sands with peat. The hole is frozen from 9.3' to BOH. The frozen material consists of silty sands and gravel, which based on the ohm-m values indicates this coarse grained material is not ice-rich, consistent with coarse grained sediments.



LATITUDE (DEGREES): N 63° 27' 19.76" (63.45549°)
LONGITUDE (DEGREES): W -150° 13' 50.30" (-150.23064°)
ELEVATION: 3777'
TOTAL DEPTH: 32' (BOTTOM ELEV: 3745')

DEPTH (ft)	DESCRIPTION
0.0	Poorly graded SAND with silt and gravel, loose, tan brown, dry to moist, gravel: rounded -2", mixed lithologies, fill
2.2	Sandy SILT with gravel, loose, orange tan, dry to moist, gravel: rounded, -2", mixed lithologies.
4.3	Silty SAND with gravel, loose to medium dense, orange brown. moist, gravel: rounded to angular. -3".
9.0	Sandy SILT with gravel, loose, orange brown, moist to wet, gravel: rounded, -1 1/2", mixed lithologies.
12.5	SILT with sand, loose, orange tan, moist, sand: very fine to fine.
20.5	Poorly graded SAND, loose, tan orange, dry to moist, sand: medium.
21.3	Silty SAND, medium dense, tan orange, dry to moist.
21.9	Silty SAND with gravel and cobbles, medium dense, tan orange, dry to moist, gravel: rounded to angular, -3".
23.6	Sandy SILT, medium dense, orange tan, dry to moist, sand: very fine to fine.
31.5	Silty SAND with gravel, medium dense, orange tan, wet, gravel: rounded, -2".
32.0	

Figure 52. BH16-04 Stony Overlook. The ohm-m values are low at the top of the section becoming very low at the bottom of the section. This is consistent with the drilling results where sandy silt and silty sand was encountered down to 23’, becoming more wet with gravel.



LATITUDE (DEGREES): N 63° 27' 20.99" (63.45583°)
LONGITUDE (DEGREES): W -150° 13' 59.66" (-150.23324°)
ELEVATION: 3740'
TOTAL DEPTH: 32' (BOTTOM ELEV: 3708')

DEPTH (ft)	DESCRIPTION
0.0	Silty SAND with gravel, loose, orange brown, dry to moist, gravel: rounded, -2", mixed lithologies, fill.
2.5	SILT with sand and gravel, loose to medium dense, orange brown, moist, gravel: rounded, -2", mixed lithologies.
12.5	Silty SAND with gravel and cobbles, medium dense, tan orange, moist, gravel: rounded, -3", mixed lithologies.
18.0	Sandy SILT, medium dense, orange tan, dry to moist, sand: fine to medium.
20.2	Silty SAND with gravel and cobbles, medium dense, tan orange, moist, gravel: rounded, -3", mixed lithologies.
23.5	Sandy SILT, medium dense, tan orange, dry to moist, sand: fine to medium.
25.6	Silty SAND with gravel and cobbles, medium dense to dense, tan orange, dry to moist, gravel: rounded, -3", mixed lithologies. 10" cobble
32.0	

Figure 53. BH16-06 Stony Overlook. The ohm-m values at the top of the section are consistent with the drilling results where silty sands and gravel were encountered down to 23'. Silty sands and larger cobble were encountered down to the bottom of the hole, but no frozen material. At approximately 17' the ohm-m values dramatically increase to very high values, within a vertically narrow anomaly suggesting massive ice or an isolated highly resistive material, such as a manmade roadway appurtenance, which neither was encountered in the drilling.

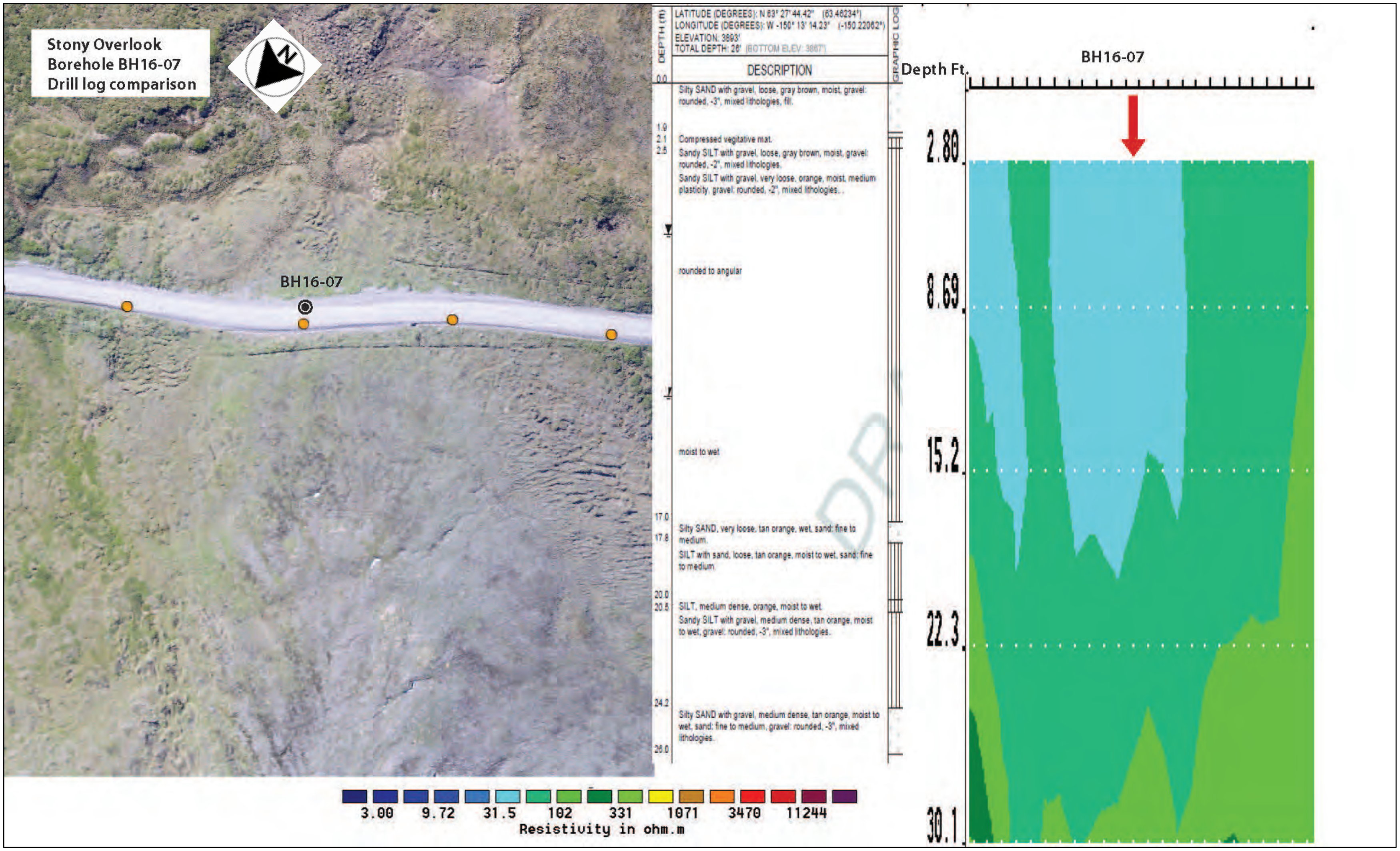
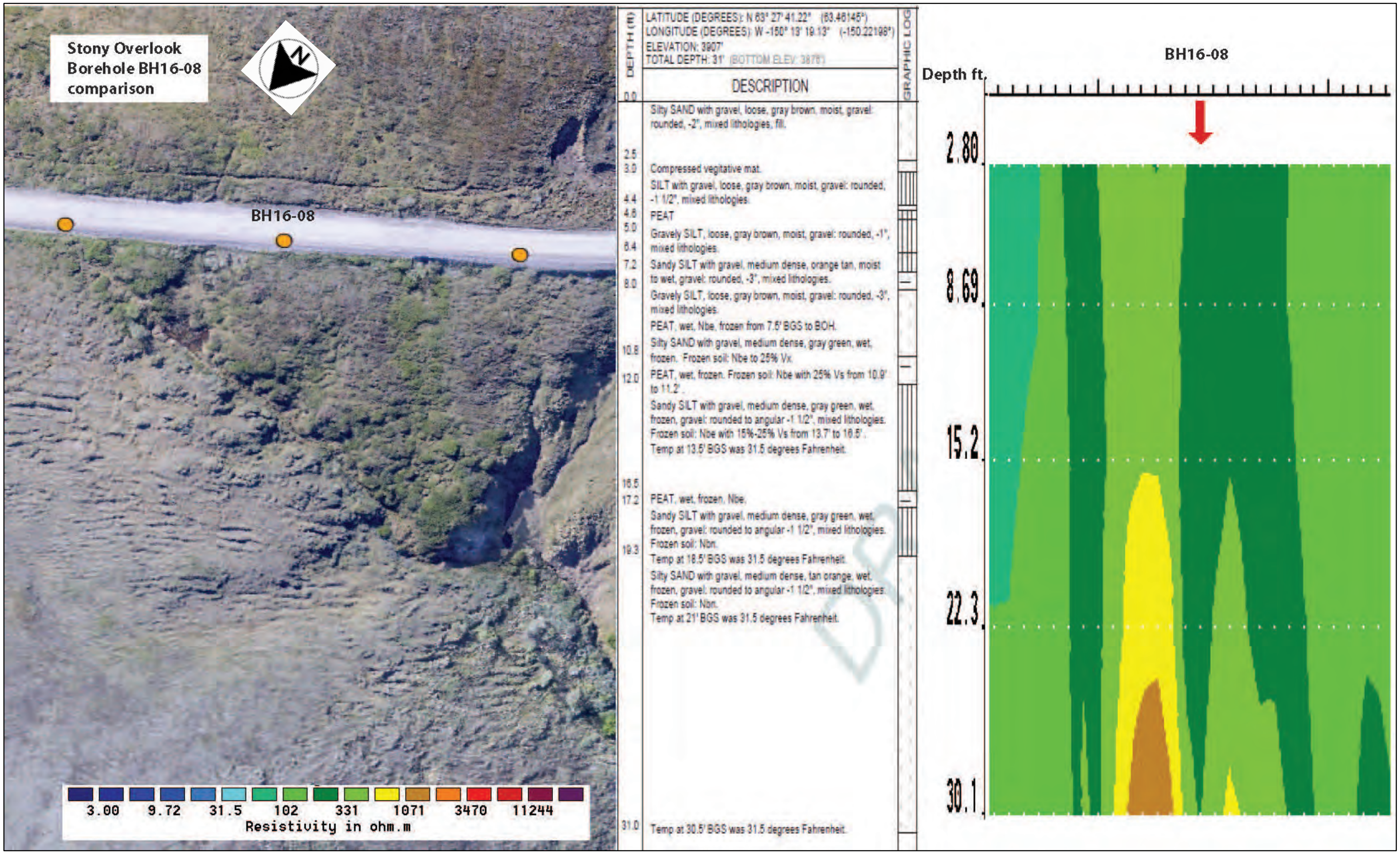


Figure 54. BH16-07 Stony Overlook. The ohm-m values are very low at the top of the section indicating coarse grained wet conditions, and the values increase moderately to the bottom of the section. The drilling results indicate sandy silts with gravel and moist to wet down to the bottom of the hole.



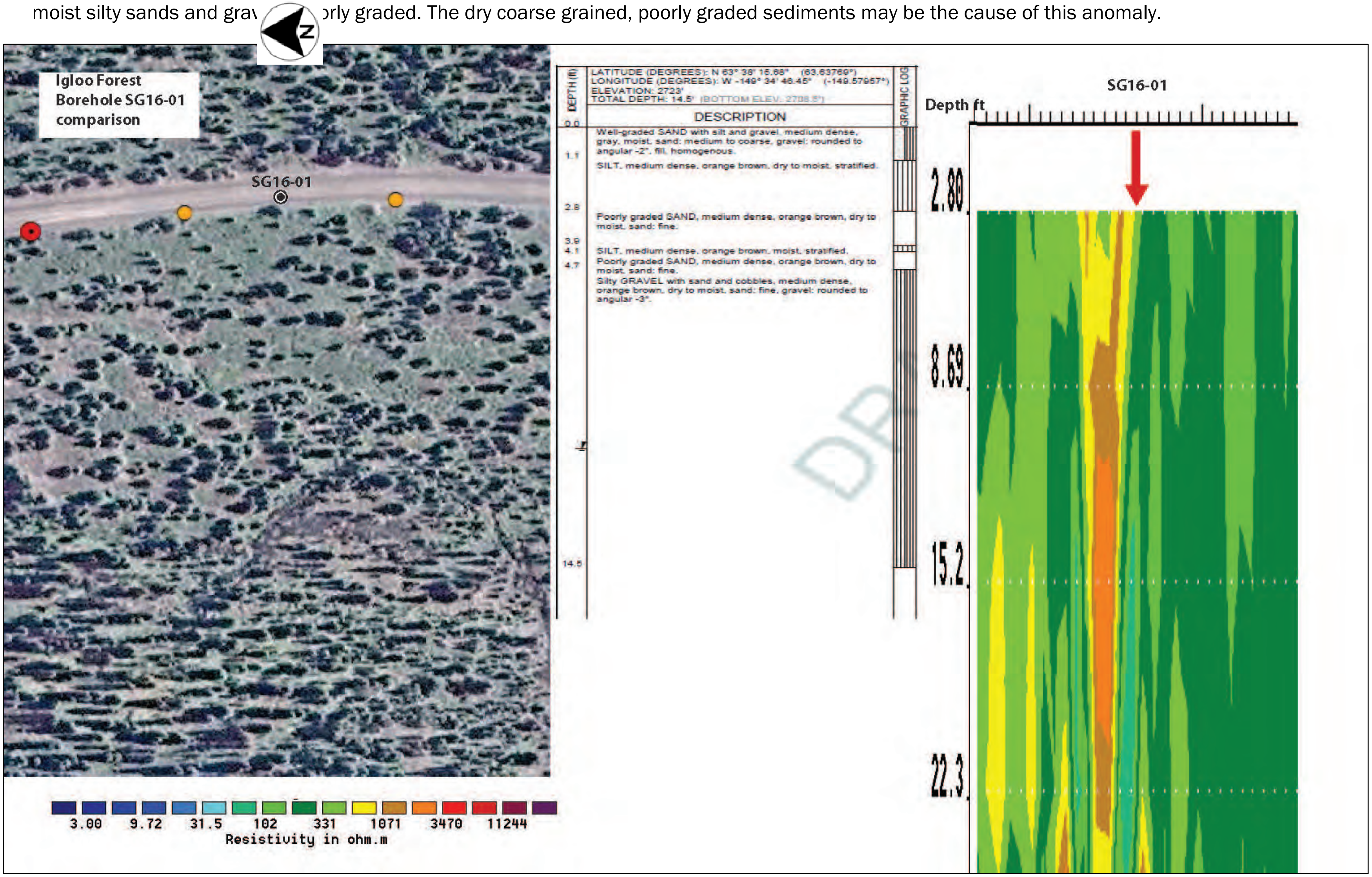
LATITUDE (DEGREES): N 63° 27' 41.22" (63.46145°)
LONGITUDE (DEGREES): W -150° 13' 19.13" (-150.22198°)
ELEVATION: 3907'
TOTAL DEPTH: 31' (BOTTOM ELEV: 3876')

DEPTH (ft)
DESCRIPTION
GRAPHIC LOG

0.0
Silty SAND with gravel, loose, gray brown, moist, gravel: rounded, -2", mixed lithologies, fill.
2.5
3.0 Compressed vegitative mat.
SILT with gravel, loose, gray brown, moist, gravel: rounded,
4.4 -1 1/2", mixed lithologies.
4.6 PEAT
5.0 Gravely SILT, loose, gray brown, moist, gravel: rounded, -1",
6.4 mixed lithologies.
7.2 Sandy SILT with gravel, medium dense, orange tan, moist
8.0 to wet, gravel: rounded, -3", mixed lithologies.
Gravely SILT, loose, gray brown, moist, gravel: rounded, -3", mixed lithologies.
PEAT, wet, Nbe, frozen from 7.5' BGS to BOH.
10.8 Silty SAND with gravel, medium dense, gray green, wet, frozen. Frozen soil: Nbe to 25% Vx.
12.0 PEAT, wet, frozen. Frozen soil: Nbe with 25% Vs from 10.9' to 11.2'.
Sandy SILT with gravel, medium dense, gray green, wet, frozen, gravel: rounded to angular -1 1/2", mixed lithologies. Frozen soil: Nbe with 15%-25% Vs from 13.7' to 16.5'.
Temp at 13.5' BGS was 31.5 degrees Fahrenheit.
16.5
17.2 PEAT, wet, frozen, Nbe.
Sandy SILT with gravel, medium dense, gray green, wet, frozen, gravel: rounded to angular -1 1/2", mixed lithologies.
19.3 Frozen soil: Nbn.
Temp at 18.5' BGS was 31.5 degrees Fahrenheit.
Silty SAND with gravel, medium dense, tan orange, wet, frozen, gravel: rounded to angular -1 1/2", mixed lithologies.
Frozen soil: Nbn.
Temp at 21' BGS was 31.5 degrees Fahrenheit.
31.0 Temp at 30.5' BGS was 31.5 degrees Fahrenheit.

Figure 55. BH16-08 Stony Overlook. The ohm-m values are moderate at the top of the section, and at 15' the values increase significantly in a broader vertical anomaly. This is consistent with the drilling results which indicate thawed gravelly silts and sandy silts with peat down to 7.5', with frozen sandy silts and gravel, with peat, down to the BOH.

Figure 56. SG16-01 Igloo Forest. The ohm-m values are moderate to high from the top of the section to the bottom. The drilling results indicate dry to moist silty sands and grav orly graded. The dry coarse grained, poorly graded sediments may be the cause of this anomaly.



LATITUDE (DEGREES): N 63° 38' 15.68" (63.63769°)
LONGITUDE (DEGREES): W -149° 34' 46.45" (-149.57957°)
ELEVATION: 2723'
TOTAL DEPTH: 14.5' (BOTTOM ELEV.: 2708.5')

DEPTH (ft)	DESCRIPTION
0.0	Well-graded SAND with silt and gravel, medium dense, gray, moist, sand: medium to coarse, gravel: rounded to angular -2", fill, homogenous.
1.1	SILT, medium dense, orange brown, dry to moist, stratified.
2.8	Poorly graded SAND, medium dense, orange brown, dry to moist, sand: fine.
3.9	SILT, medium dense, orange brown, moist, stratified.
4.1	Poorly graded SAND, medium dense, orange brown, dry to moist, sand: fine.
4.7	Silty GRAVEL with sand and cobbles, medium dense, orange brown, dry to moist, sand: fine, gravel: rounded to angular -3".

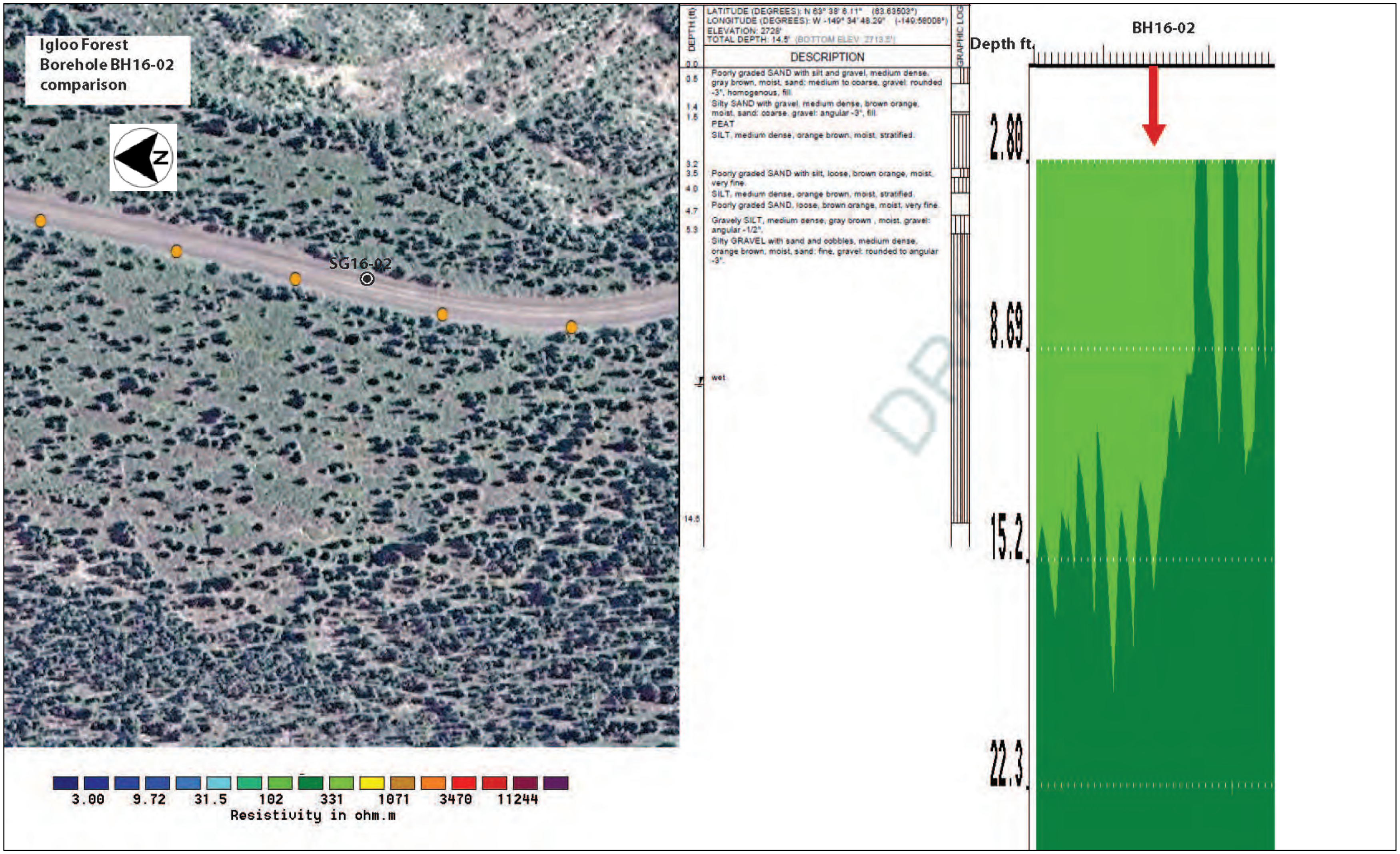
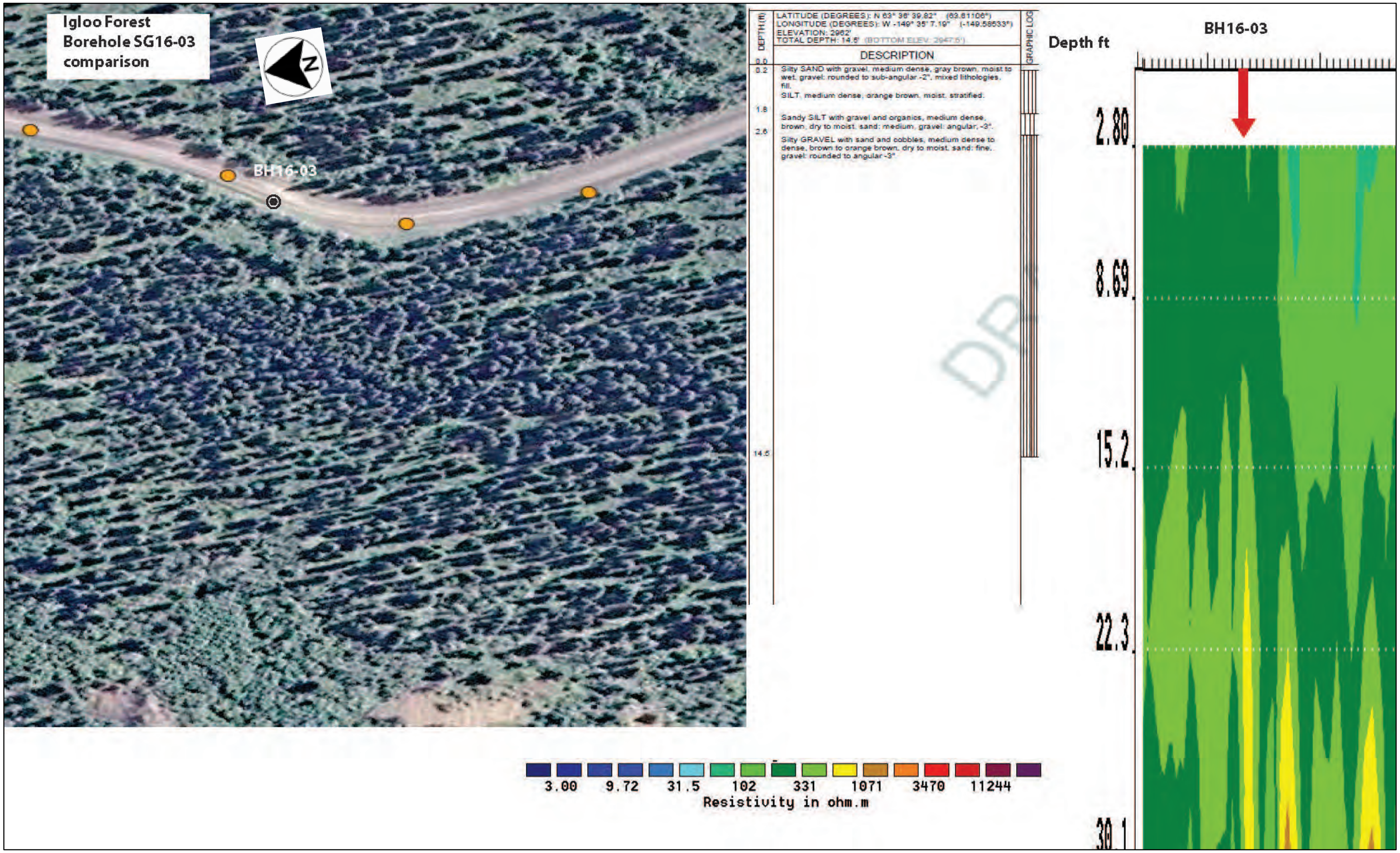


Figure 57. SG16-02 Igloo Forest. The ohm-m values are low from the top to the bottom of the section. This is consistent with the drilling results which found silty sands and gravels, moist to wet.



LATITUDE (DEGREES): N 63° 36' 39.82" (63.61106°)
LONGITUDE (DEGREES): W -149° 35' 7.19" (-149.58533°)
ELEVATION: 2962'
TOTAL DEPTH: 14.5' (BOTTOM ELEV: 2947.5')

DESCRIPTION

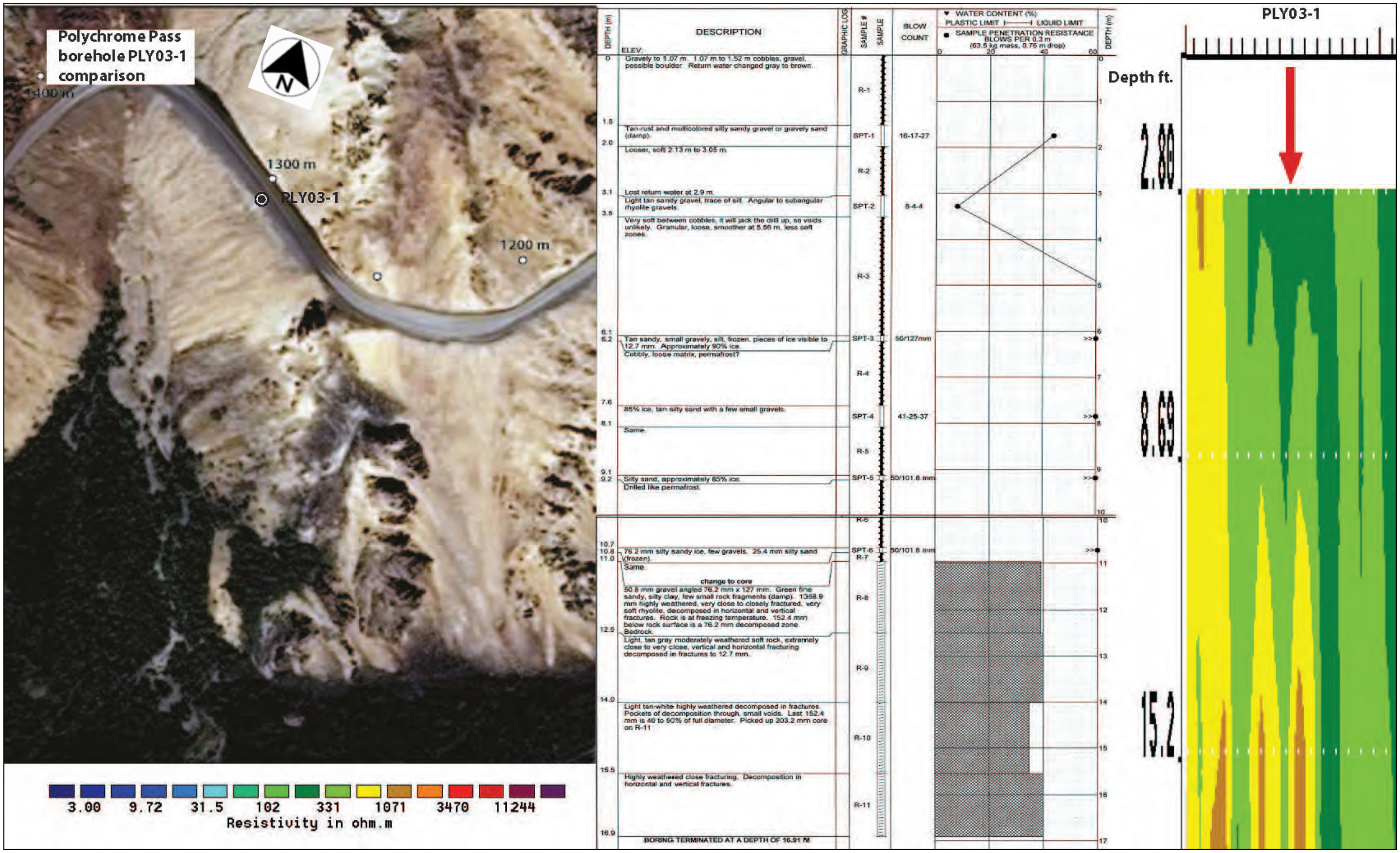
Silty SAND with gravel, medium dense, gray brown, moist to wet, gravel: rounded to sub-angular -2", mixed lithologies, fill.

SILT, medium dense, orange brown, moist, stratified.

Sandy SILT with gravel and organics, medium dense, brown, dry to moist, sand: medium, gravel: angular, -3".

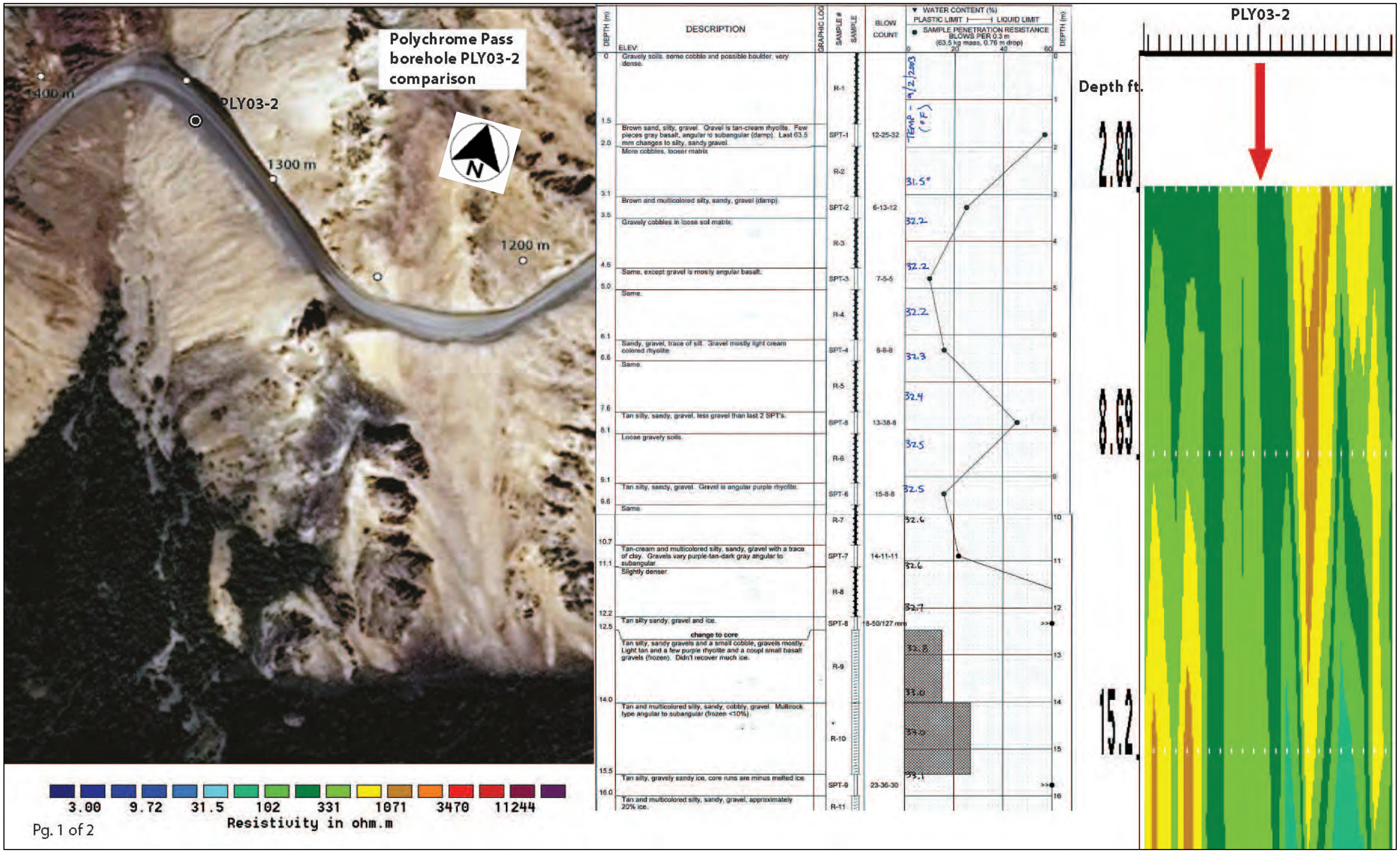
Silty GRAVEL with sand and cobbles, medium dense to dense, brown to orange brown, dry to moist, sand: fine, gravel: rounded to angular -3".

Figure 58. SG16-03 Igloo Forest. The ohm-m values are low at the top of the section, with moderate value anomalies at the lower portion of the section. This coincides with the drilling results as they indicate silty sands and gravels down to the BOH at 14.5'.



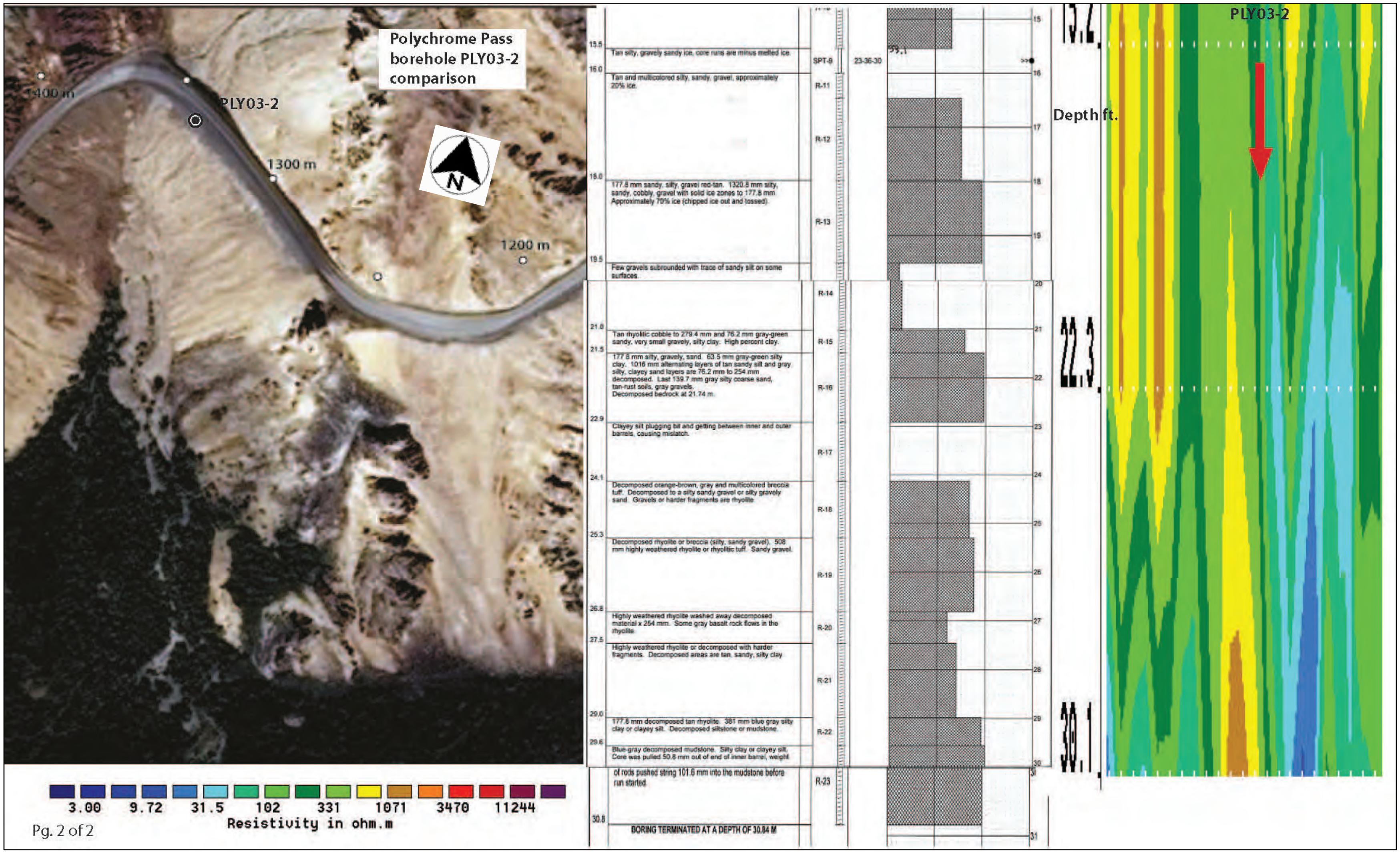
DEPTH (m)	DESCRIPTION	SAMPLE #	BLOW COUNT
	ELEV:		
0	Gravely to 1.07 m. 1.07 m to 1.52 m cobbles, gravel, possible boulder. Return water changed gray to brown.	R-1	
1.5	Tan-rust and multicolored silty sandy gravel or gravely sand (damp).	SPT-1	16-17-27
2.0	Looser, soft 2.13 m to 3.05 m.	R-2	
3.1	Lost return water at 2.9 m. Light tan sandy gravel, trace of silt. Angular to subangular rhyolite gravels.	SPT-2	8-4-4
3.5	Very soft between cobbles, it will jack the drill up, so voids unlikely. Granular, loose, smoother at 5.56 m, less soft zones.	R-3	
6.1 6.2	Tan sandy, small gravely, silt, frozen, pieces of ice visible to 12.7 mm. Approximately 90% ice. Cobbly, loose matrix, permafrost?	SPT-3 R-4	50/127mm
7.6	85% ice, tan silty sand with a few small gravels.	SPT-4	41-25-37
8.1	Same.	R-5	
9.1 9.2	Silty sand, approximately 85% ice. Drilled like permafrost.	SPT-5	50/101.6 mm
		R-6	
10.7 10.8 11.0	76.2 mm silty sandy ice, few gravels. 25.4 mm silty sand (frozen). Same. **change to core** 50.8 mm gravel angled 76.2 mm x 127 mm. Green fine sandy, silty clay, few small rock fragments (damp). 1358.9 mm highly weathered, very close to closely fractured, very soft rhyolite, decomposed in horizontal and vertical fractures. Rock is at freezing temperature. 152.4 mm below rock surface is a 76.2 mm decomposed zone. Bedrock.	SPT-6 R-7 R-8	50/101.6 mm
12.5	Light, tan gray moderately weathered soft rock, extremely close to very close, vertical and horizontal fracturing decomposed in fractures to 12.7 mm.	R-9	
14.0	Light tan-white highly weathered decomposed in fractures. Pockets of decomposition through, small voids. Last 152.4 mm is 40 to 50% of full diameter. Picked up 203.2 mm core on R-11	R-10	
15.5	Highly weathered close fracturing. Decomposition in horizontal and vertical fractures.	R-11	
16.9	BORING TERMINATED AT A DEPTH OF 16.91 M		

Figure 59. PLY03-1, Pretty Rocks. ***Note, the drill log is in meters while the resistivity results are reported in feet.* The ohm-m values are low at the top of the section and increase with depth of the section. Gravel and loose soil was logged at the top of the hole and this is consistent with the ohm-m results which change to moderate to high values at 8 ft. (2.5m). Ice and frozen material was logged starting at 6.1m (20 ft.), and this is consistent with the ohm-m values. The drilling changed to coring at 11m so we assume at this point all ice and permafrost comes to the surface thawed.



DEPTH (m)	DESCRIPTION ELEV:	SAMPLE #	BLOW COUNT
0	Gravely soils. some cobble and possible boulder. very dense.	R-1	
1.5	Brown sand, silty, gravel. Gravel is tan-cream rhyolite. Few pieces gray basalt, angular to subangular (damp). Last 63.5 mm changes to silty, sandy gravel.	SPT-1	12-25-32
2.0	More cobbles, looser matrix	R-2	
3.1	Brown and multicolored silty, sandy, gravel (damp).	SPT-2	6-13-12
3.5	Gravely cobbles in loose soil matrix.	R-3	
4.6	Same, except gravel is mostly angular basalt.	SPT-3	7-5-5
5.0	Same.	R-4	
6.1	Sandy, gravel, trace of silt. Gravel mostly light cream colored rhyolite	SPT-4	8-8-8
6.6	Same.	R-5	
7.6	Tan silty, sandy, gravel, less gravel than last 2 SPT's.	SPT-5	13-38-8
8.1	Loose gravely soils.	R-6	
9.1	Tan silty, sandy, gravel. Gravel is angular purple rhyolite.	SPT-6	15-8-8
9.6	Same	R-7	
10.7	Tan-cream and multicolored silty, sandy, gravel with a trace of clay. Gravels vary purple-tan-dark gray angular to subangular	SPT-7	14-11-11
11.1	Slightly denser	R-8	
12.2	Tan silty sandy, gravel and ice.	SPT-8	18-50/127 mm
12.5	change to core Tan silty, sandy gravels and a small cobble, gravels mostly. Light tan and a few purple rhyolite and a coupl small basalt gravels (frozen). Didn't recover much ice.	R-9	
14.0	Tan and multicolored silty, sandy, cobbly, gravel. Multirock type angular to subangular (frozen <10%).	R-10	
15.5	Tan silty, gravely sandy ice, core runs are minus melted ice.	SPT-9	23-36-30
16.0	Tan and multicolored silty, sandy, gravel, approximately 20% ice.	R-11	

Figure 60. PLY03-2a, Pretty Rocks. ***Note, the drill log is in meters while the resistivity results are reported in feet.* The ohm-m values are low at the top of the section and increase with depth of the section. The ohm-m values are low at the top of the section and down to 17' as shown in this split section. The drill log reports thawed silty gravelly materials and this is consistent with the ohm-m values.



15.5 Tan silty, gravely sandy ice, core runs are minus melted ice.

16.0 Tan and multicolored silty, sandy, gravel, approximately 20% ice.

18.0 177.8 mm sandy, silty, gravel red-tan. 1320.8 mm silty, sandy, cobbly, gravel with solid ice zones to 177.8 mm. Approximately 70% ice (chipped ice out and tossed).

19.5 Few gravels subrounded with trace of sandy silt on some surfaces.

21.0 Tan rhyolitic cobble to 279.4 mm and 76.2 mm gray-green sandy, very small gravely, silty clay. High percent clay.

21.5 177.8 mm silty, gravely, sand. 63.5 mm gray-green silty clay. 1016 mm alternating layers of tan sandy silt and gray silty, clayey sand layers are 76.2 mm to 254 mm decomposed. Last 139.7 mm gray silty coarse sand, tan-rust soils, gray gravels.
Decomposed bedrock at 21.74 m.

22.9 Clayey silt plugging bit and getting between inner and outer barrels, causing mislatch.

24.1 Decomposed orange-brown, gray and multicolored breccia tuff. Decomposed to a silty sandy gravel or silty gravely sand. Gravels or harder fragments are rhyolite.

25.3 Decomposed rhyolite or breccia (silty, sandy gravel). 508 mm highly weathered rhyolite or rhyolitic tuff. Sandy gravel.

26.8 Highly weathered rhyolite washed away decomposed material x 254 mm. Some gray basalt rock flows in the rhyolite.

27.5 Highly weathered rhyolite or decomposed with harder fragments. Decomposed areas are tan, sandy, silty clay.

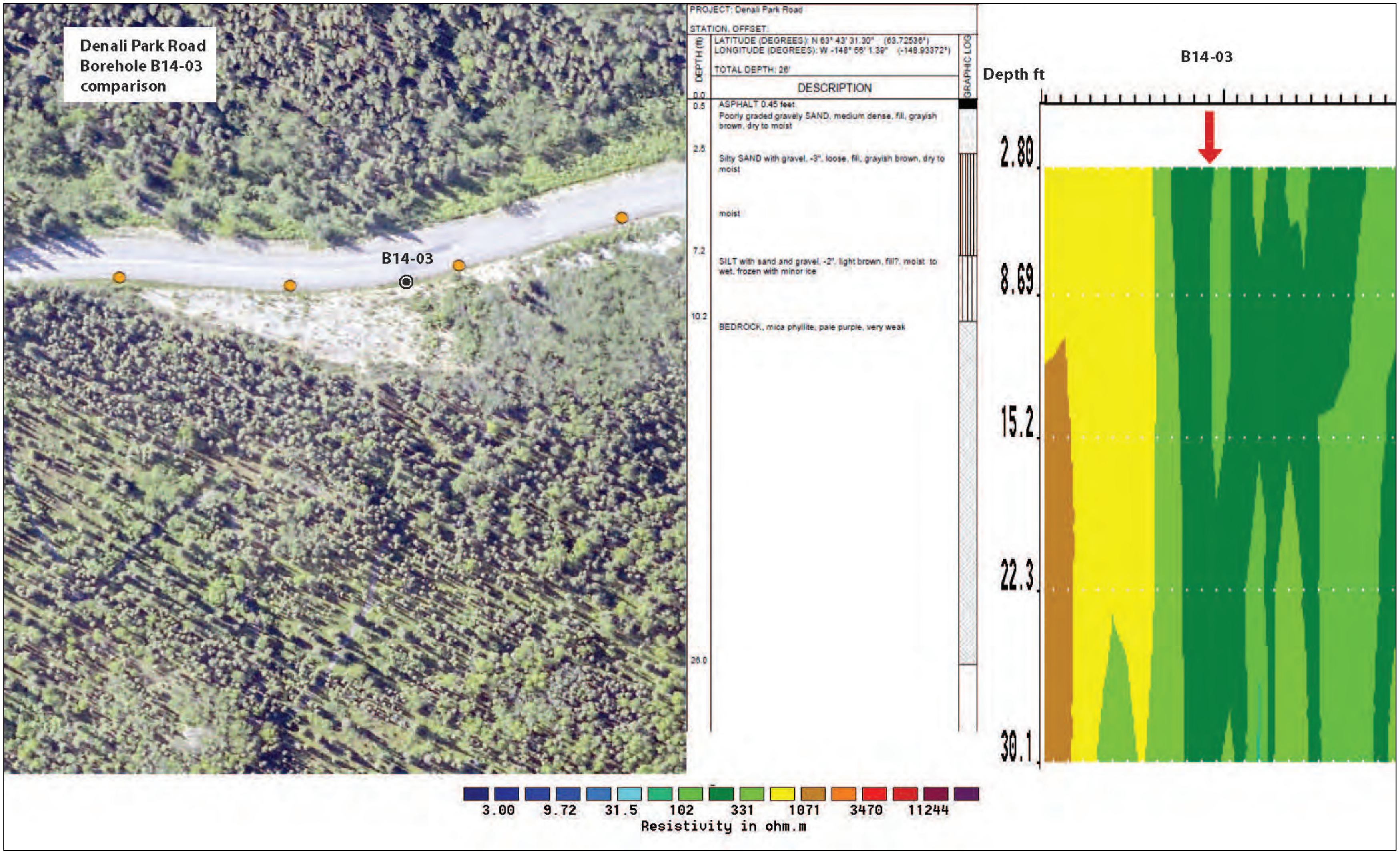
29.0 177.8 mm decomposed tan rhyolite. 381 mm blue gray silty clay or clayey silt. Decomposed siltstone or mudstone.

29.6 Blue-gray decomposed mudstone. Silty clay or clayey silt. Core was pulled 50.8 mm out of end of inner barrel, weight of rods pushed string 101.6 mm into the mudstone before run started.

30.8 BORING TERMINATED AT A DEPTH OF 30.84 M

Figure 61. PLY03-2b, Pretty Rocks. ***Note, the drill log is in meters while the resistivity results are reported in feet*. The drill log reports ice at 12.2m (40 ft.), and this is consistent with the much higher ohm-m values reported starting at approximately 30 ft. (10m).

Figure 62. BH14-03 Denali Park Road. Low ohm-m values are reported from the top of the section to the bottom. The drill log reports mica schist at 10 ft., and which is generally known to be moderately resistive. We believe our plotting of the borehole on the pseudo-section may be in error. The definitive vertical boundary is not consistent with abrupt change from sediment to bedrock.



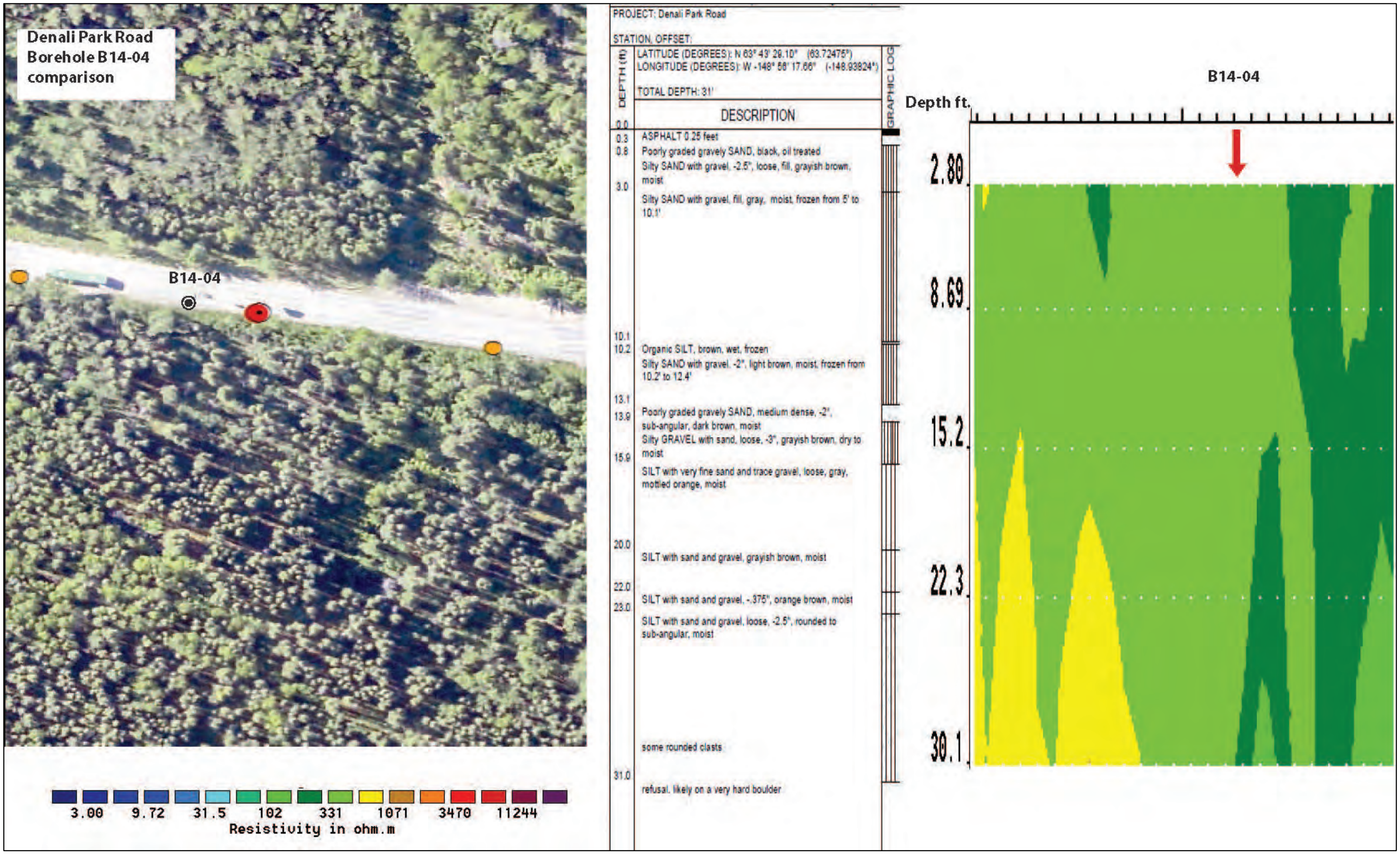
PROJECT: Denali Park Road

STATION, OFFSET:

LATITUDE (DEGREES): N 63° 43' 31.30" (63.72536°)
LONGITUDE (DEGREES): W -148° 56' 1.39" (-148.93372°)

TOTAL DEPTH: 26'

DEPTH (ft)	DESCRIPTION
0.0	
0.5	ASPHALT 0.45 feet Poorly graded gravely SAND, medium dense, fill, grayish brown, dry to moist
2.5	Silty SAND with gravel, -3", loose, fill, grayish brown, dry to moist moist
7.2	SILT with sand and gravel, -2", light brown, fill?, moist to wet, frozen with minor ice
10.2	BEDROCK, mica phyllite, pale purple, very weak
26.0	



PROJECT: Denali Park Road

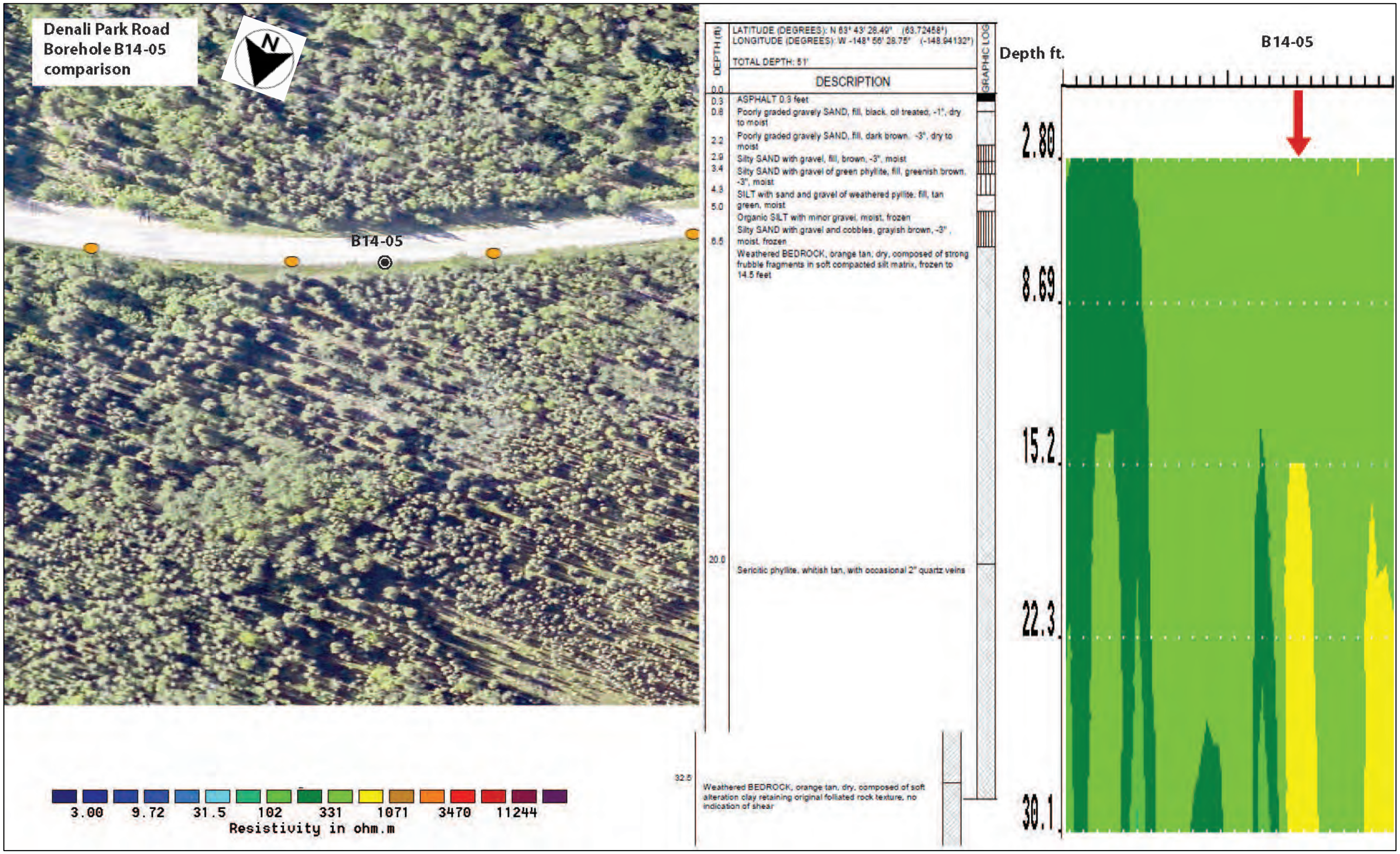
STATION, OFFSET:

LATITUDE (DEGREES): N 63° 43' 29.10" (63.72475°)
LONGITUDE (DEGREES): W -148° 56' 17.66" (-148.93824°)

TOTAL DEPTH: 31'

DEPTH (ft)	DESCRIPTION
0.0	
0.3	ASPHALT 0.25 feet
0.8	Poorly graded gravely SAND, black, oil treated
	Silty SAND with gravel, -2.5", loose, fill, grayish brown, moist
3.0	Silty SAND with gravel, fill, gray, moist, frozen from 5' to 10.1'
10.1	
10.2	Organic SILT, brown, wet, frozen
	Silty SAND with gravel. -2", light brown, moist, frozen from 10.2' to 12.4'
13.1	
13.9	Poorly graded gravely SAND, medium dense, -2", sub-angular, dark brown, moist
	Silty GRAVEL with sand, loose, -3", grayish brown, dry to moist
15.9	SILT with very fine sand and trace gravel, loose, gray, mottled orange, moist
20.0	SILT with sand and gravel, grayish brown, moist
22.0	SILT with sand and gravel, -.375", orange brown, moist
23.0	SILT with sand and gravel, loose, -2.5", rounded to sub-angular, moist
	some rounded clasts
31.0	refusal, likely on a very hard boulder

Figure 63. BH14-04 Denali Park Road. Low ohm-m values are reported from the top of the section to the bottom. The drill log reports silty sand and gravels, and moist. This is consistent with the ohm-m values.

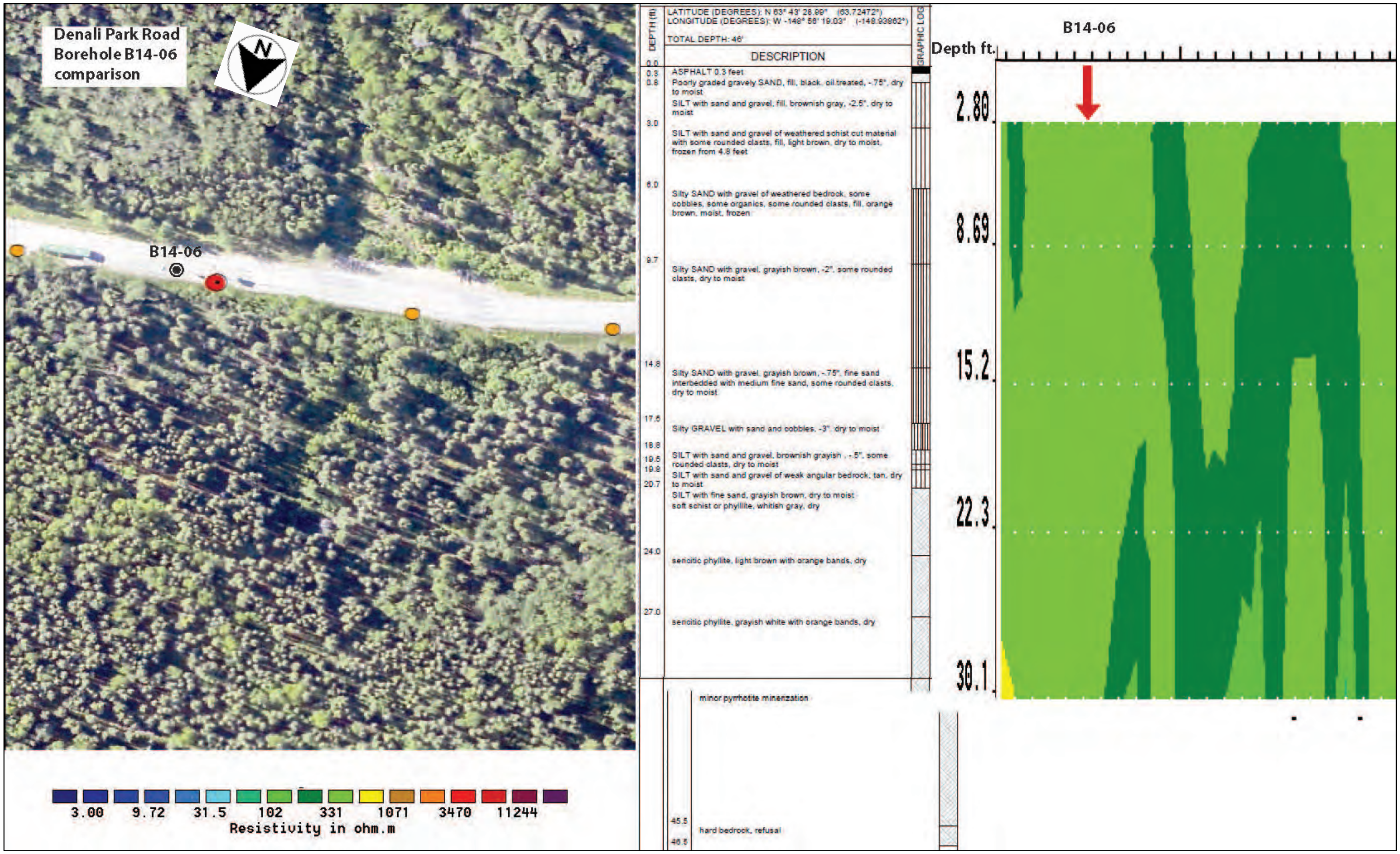


LATITUDE (DEGREES): N 63° 43' 28.49" (63.72458°)
LONGITUDE (DEGREES): W -148° 56' 28.75" (-148.94132°)

TOTAL DEPTH: 51'

DEPTH (ft)	DESCRIPTION
0.0	
0.3	ASPHALT 0.3 feet
0.8	Poorly graded gravely SAND, fill, black, oil treated, -1", dry to moist
2.2	Poorly graded gravely SAND, fill, dark brown, -3", dry to moist
2.9	Silty SAND with gravel, fill, brown, -3", moist
3.4	Silty SAND with gravel of green phyllite, fill, greenish brown, -3", moist
4.3	SILT with sand and gravel of weathered pyllite, fill, tan green, moist
5.0	Organic SILT with minor gravel, moist, frozen
	Silty SAND with gravel and cobbles, grayish brown, -3", moist, frozen
6.5	Weathered BEDROCK, orange tan, dry, composed of strong frubble fragments in soft compacted silt matrix, frozen to 14.5 feet
20.0	Sericitic phyllite, whitish tan, with occasional 2" quartz veins
32.5	Weathered BEDROCK, orange tan, dry, composed of soft alteration clay retaining original folliated rock texture, no indication of shear

Figure 64. BH14-05 Denali Park Road. Low ohm-m values are reported from the top of the section to 15 ft. where moderate values are shown at the bottom of the section. The drill log reports silty sand and gravels, with frozen weather bedrock starting at 6.5 ft. down to 14.5 ft., and continues weathered bedrock down to the BOH at 32.5 ft.. The ohm-m values are not consistent with continuous bedrock at depth.

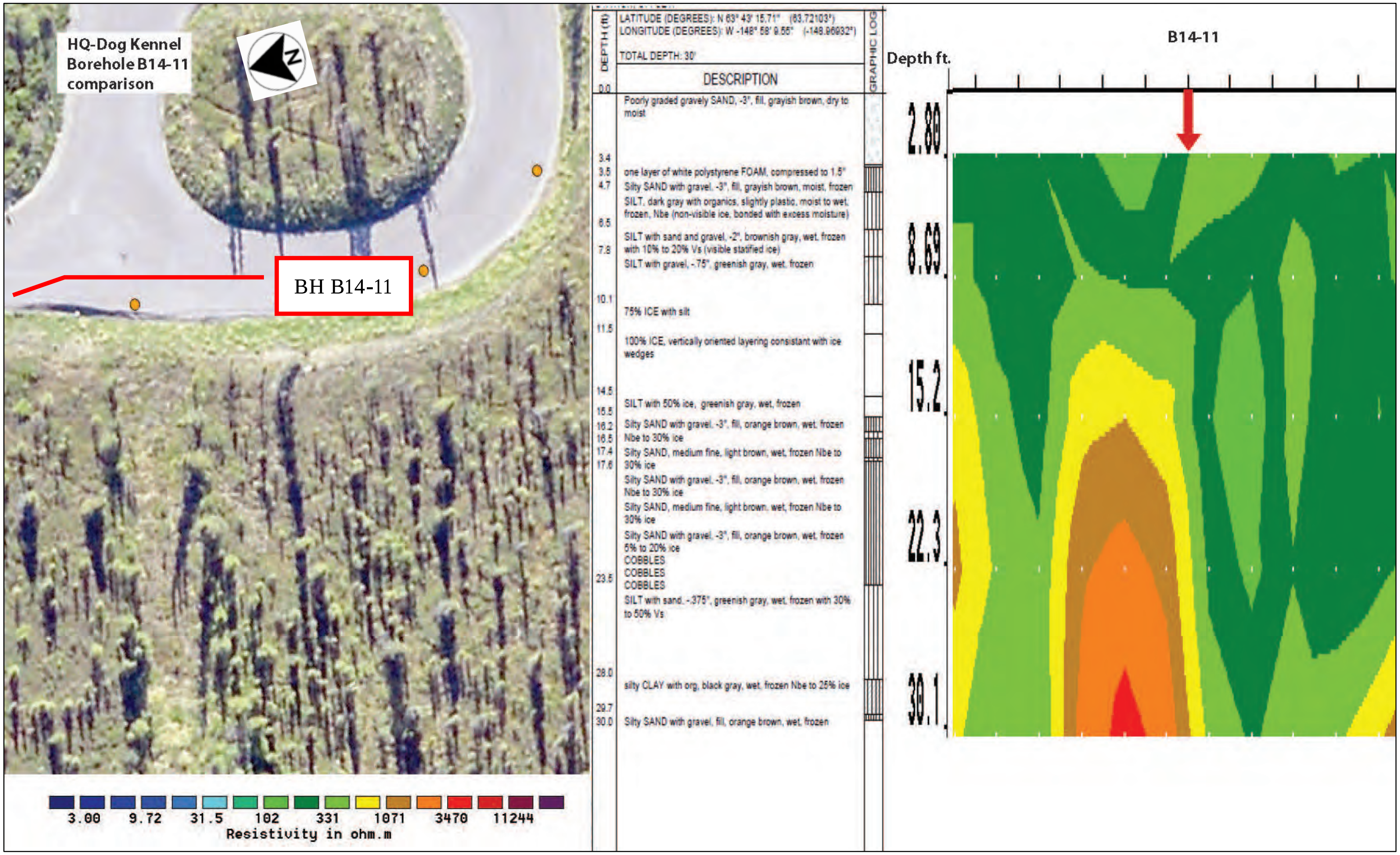


LATITUDE (DEGREES): N 63° 43' 28.99" (63.72472°)
LONGITUDE (DEGREES): W -148° 56' 19.03" (-148.93862°)

TOTAL DEPTH: 46'

DEPTH (ft)	DESCRIPTION
0.0	
0.3	ASPHALT 0.3 feet
0.8	Poorly graded gravely SAND, fill, black, oil treated, -.75", dry to moist
	SILT with sand and gravel, fill, brownish gray, -2.5", dry to moist
3.0	SILT with sand and gravel of weathered schist cut material with some rounded clasts, fill, light brown, dry to moist, frozen from 4.8 feet
6.0	Silty SAND with gravel of weathered bedrock, some cobbles, some organics, some rounded clasts, fill, orange brown, moist, frozen
9.7	Silty SAND with gravel, grayish brown, -2", some rounded clasts, dry to moist
14.8	Silty SAND with gravel, grayish brown, -.75", fine sand interbedded with medium fine sand, some rounded clasts, dry to moist
17.5	Silty GRAVEL with sand and cobbles, -3", dry to moist
18.8	SILT with sand and gravel, brownish grayish , -.5", some rounded clasts, dry to moist
19.5	
19.8	SILT with sand and gravel of weak angular bedrock, tan, dry to moist
20.7	SILT with fine sand, grayish brown, dry to moist soft schist or phyillite, whitish gray, dry
24.0	sericitic phyllite, light brown with orange bands, dry
27.0	sericitic phyllite, grayish white with orange bands, dry
	minor pyrrhotite minerization
45.5	hard bedrock, refusal
46.5	

Figure 65. BH14-06 Denali Park Road. Low ohm-m values are reported for the entire depth of the section. The material logged in the drill hole is silty sand with some gravel, then dry phyllite bedrock at 24 ft.. The ohm-m values coincide with the borehole information, however we would expect to see some change in resistivity at the interface with the bedrock.



LATITUDE (DEGREES): N 63° 43' 15.71" (63.72103°)
LONGITUDE (DEGREES): W -148° 58' 9.55" (-148.96932°)

TOTAL DEPTH: 30'

DESCRIPTION

Poorly graded gravely SAND, -3", fill, grayish brown, dry to moist

one layer of white polystyrene FOAM, compressed to 1.5"

Silty SAND with gravel. -3", fill, grayish brown, moist, frozen

SILT, dark gray with organics, slightly plastic, moist to wet, frozen, Nbe (non-visible ice, bonded with excess moisture)

SILT with sand and gravel, -2", brownish gray, wet, frozen with 10% to 20% Vs (visible statified ice)

SILT with gravel, -.75", greenish gray, wet, frozen

75% ICE with silt

100% ICE, vertically oriented layering consistant with ice wedges

SILT with 50% ice, greenish gray, wet, frozen

Silty SAND with gravel. -3", fill, orange brown, wet, frozen Nbe to 30% ice

Silty SAND, medium fine, light brown, wet, frozen Nbe to 30% ice

Silty SAND with gravel. -3", fill, orange brown, wet, frozen Nbe to 30% ice

Silty SAND, medium fine, light brown, wet, frozen Nbe to 30% ice

Silty SAND with gravel. -3", fill, orange brown, wet, frozen 5% to 20% ice

COBBLES

COBBLES

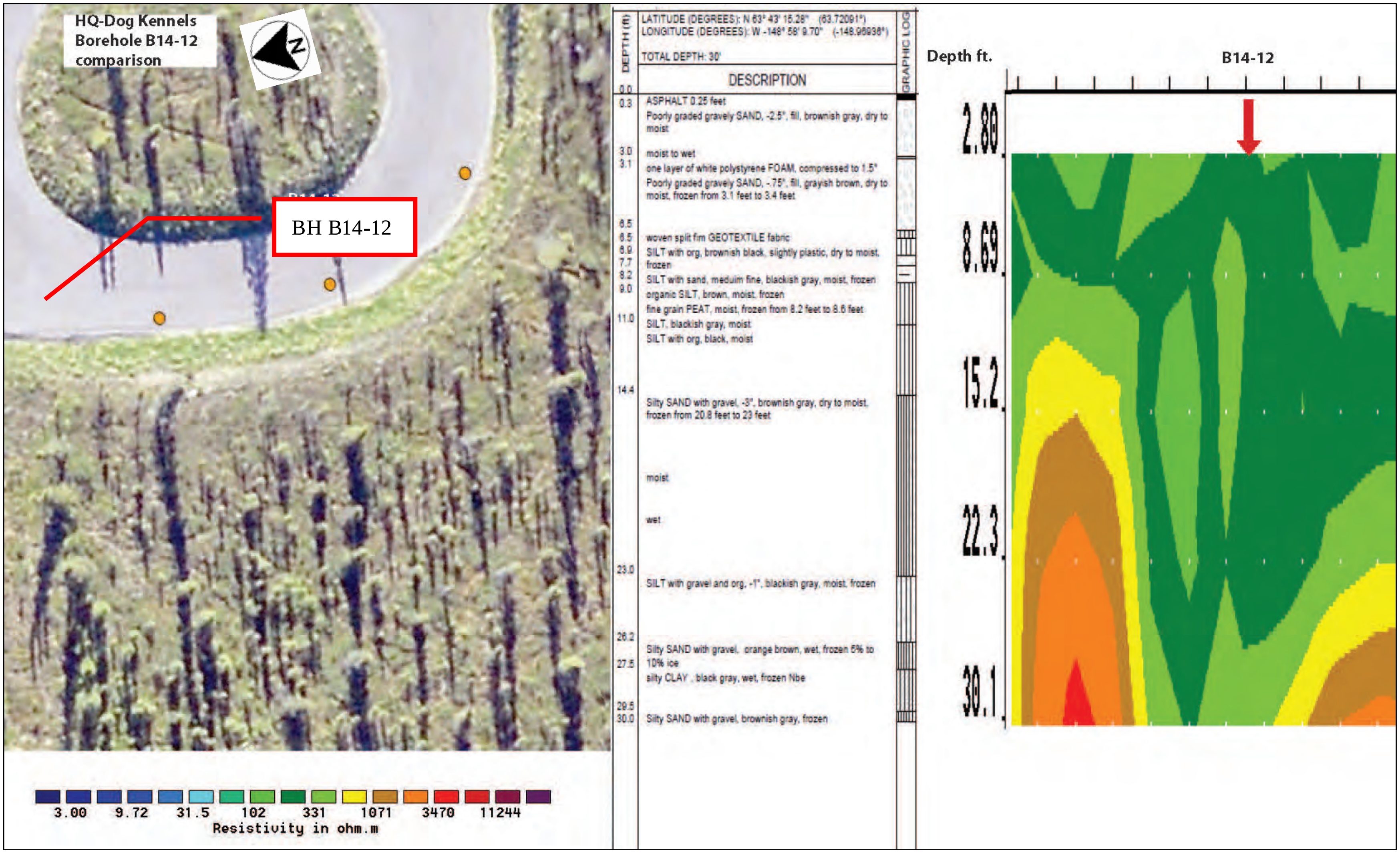
COBBLES

SILT with sand, -.375", greenish gray, wet, frozen with 30% to 50% Vs

silty CLAY with org, black gray, wet, frozen Nbe to 25% ice

Silty SAND with gravel, fill, orange brown, wet, frozen

Figure 66. BH14-11 HQ/Dog Kennel Loop. The ohm-m values are low at the top of the section down to approximately 13 ft. where a rapid increase in resistivity occurs with depth, and the high resistivity anomaly is broad at the base and in close proximity to other high resistivity anomalies. The drill hole results indicate frozen soils with significant ice starting at 4.7 ft. and extending to the BOH at 30 ft.. The CCR results coincide very well with drill results.



LATITUDE (DEGREES): N 63° 43' 15.28" (63.72091°)
LONGITUDE (DEGREES): W -148° 58' 9.70" (-148.96938°)

TOTAL DEPTH: 30'

DESCRIPTION

0.0	
0.3	ASPHALT 0.25 feet
	Poorly graded gravely SAND, -2.5", fill, brownish gray, dry to moist
3.0	moist to wet
3.1	one layer of white polystyrene FOAM, compressed to 1.5"
	Poorly graded gravely SAND, -.75", fill, grayish brown, dry to moist, frozen from 3.1 feet to 3.4 feet
6.5	
6.5	woven split fim GEOTEXTILE fabric
6.9	SILT with org, brownish black, slightly plastic, dry to moist, frozen
7.7	
8.2	SILT with sand, meduim fine, blackish gray, moist, frozen
9.0	organic SILT, brown, moist, frozen
	fine grain PEAT, moist, frozen from 8.2 feet to 8.6 feet
11.0	SILT, blackish gray, moist
	SILT with org, black, moist
14.4	Silty SAND with gravel, -3", brownish gray, dry to moist, frozen from 20.8 feet to 23 feet
	moist
	wet
23.0	SILT with gravel and org, -1", blackish gray, moist, frozen
26.2	Silty SAND with gravel, orange brown, wet, frozen 5% to 10% ice
27.5	silty CLAY , black gray, wet, frozen Nbe
29.5	
30.0	Silty SAND with gravel, brownish gray, frozen

Figure 67. BH14-12 HQ/Dog Kennel Loop. This borehole does not fall directly in the path of the CCR transect, therefore some amount of proximity inference to BH14-11 must be made. The ohm-m values are low at the top of the section down to approximately 18 ft. where a rapid increase in resistivity occurs with depth, and the high resistivity anomaly appears to be broad at the base and in close proximity to other high resistivity anomalies. The drill hole results indicate frozen soils with significant ice starting at 6.9 ft. and extending to the BOH at 30 ft.. In general the CCR results for this area coincide very well with drill results, as these frequent high resistivity anomalies are inferred to be massive ground ice, possibly in the form of wedge ice. It would be expected the intervening soils between the wedge ice contains moderate to high ice contents both in matrix and possibly segregation ice.

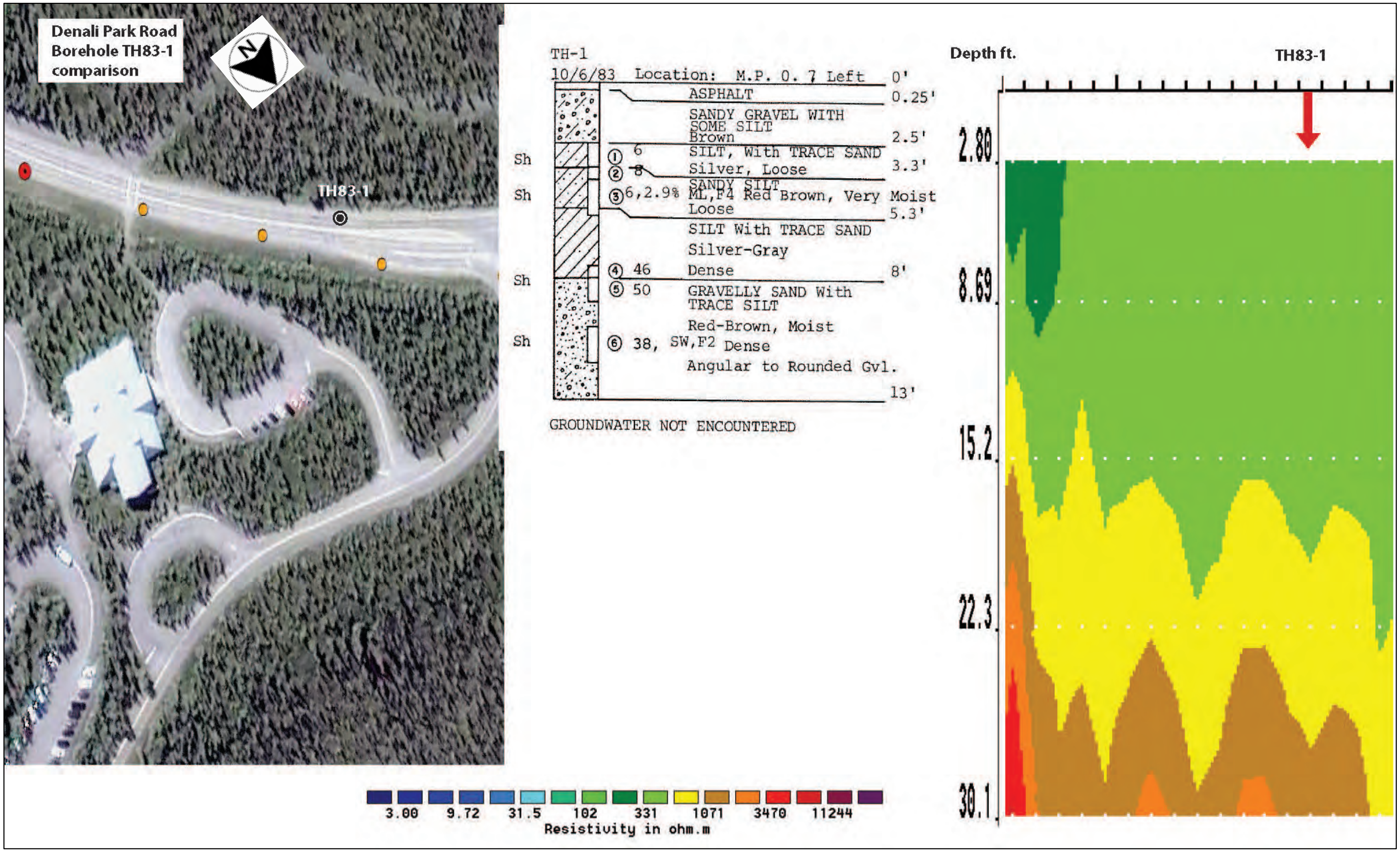


Figure 68. TH83-1 Denali Park Road. The ohm-m values are low at the top of the section. The drill hole reports down to only 13 ft., therefore the thawed sandy silt and gravelly sand coincide with the results.

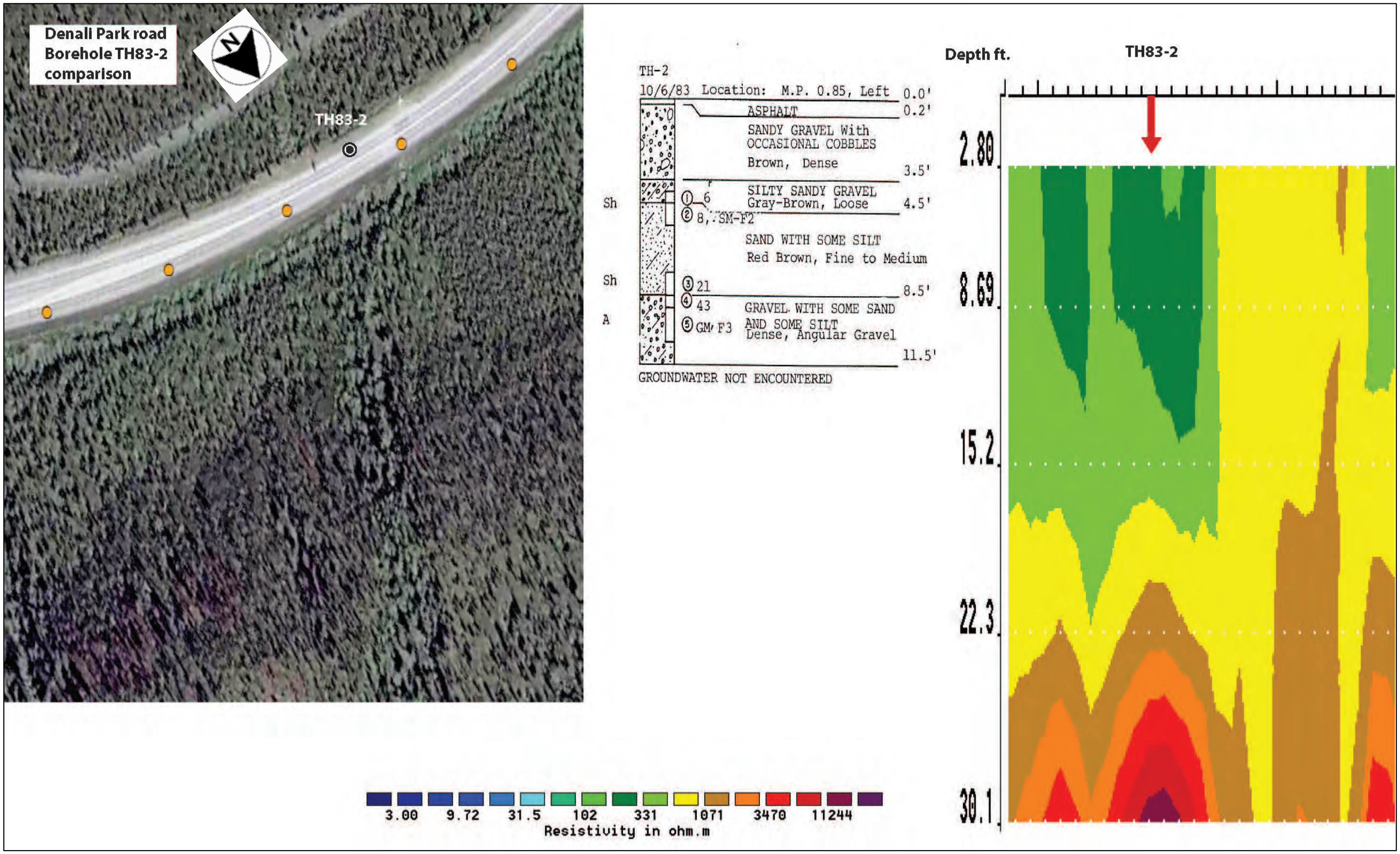
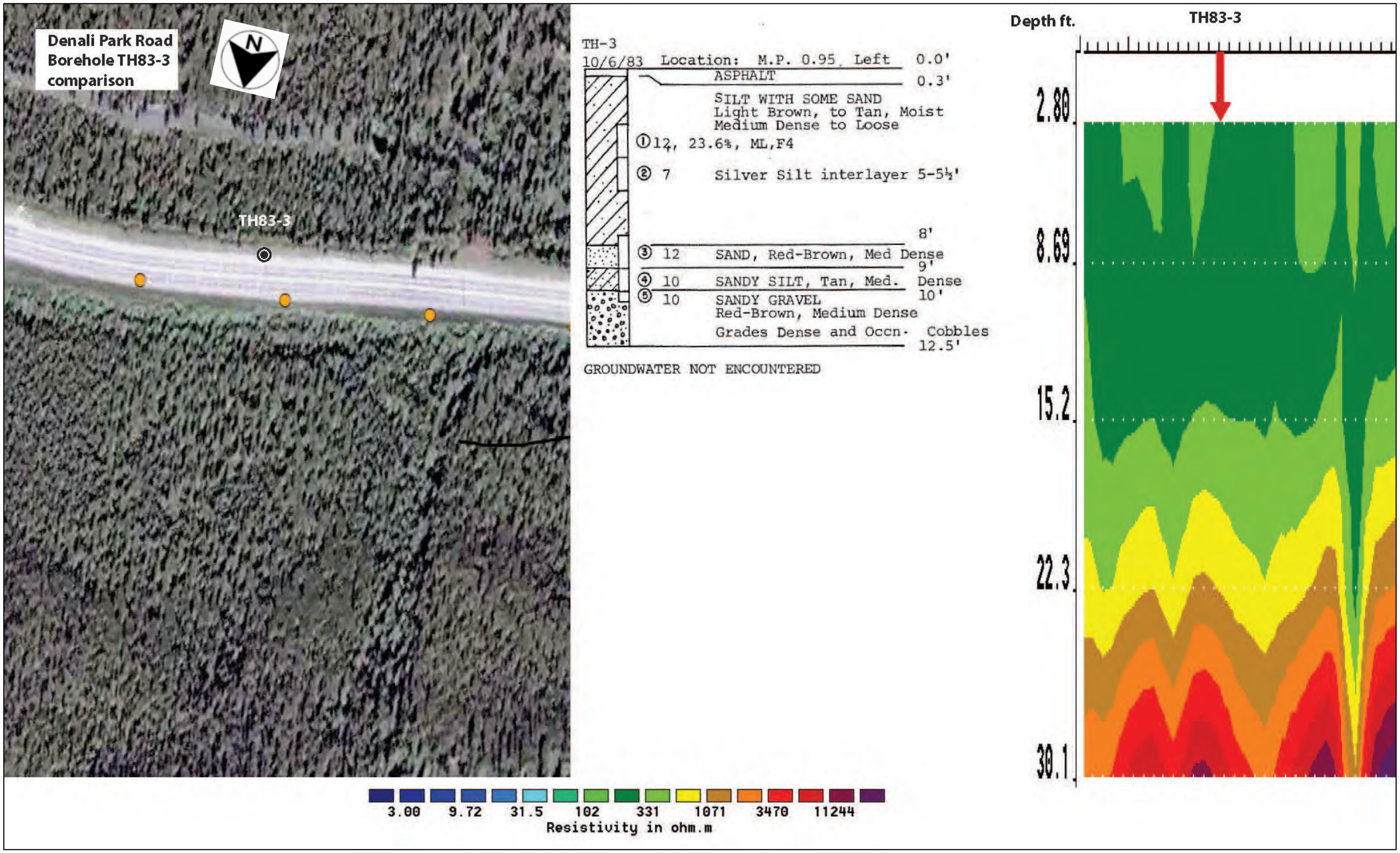


Figure 69. TH83-2 Denali Park Road. The ohm-m values are low at the top of the section but rapidly increase to very high values below the bottom of the borehole at approximately 16 ft., and laterally where a moderate high anomaly is directly adjacent to this borehole for the full depth of the section. The drill hole results report silty sandy gravel down to the BOH at 11.5 ft..



TH-3
10/6/83 Location: M.P. 0.95 Left 0.0'
ASPHALT 0.3'
SILT WITH SOME SAND
Light Brown, to Tan, Moist
Medium Dense to Loose
①12, 23.6%, ML,F4
② 7 Silver Silt interlayer 5-5½'
8'
③ 12 SAND, Red-Brown, Med Dense
9'
④ 10 SANDY SILT, Tan, Med. Dense
⑤ 10 SANDY GRAVEL 10'
Red-Brown, Medium Dense
Grades Dense and Occn. Cobbles
12.5'
GROUNDWATER NOT ENCOUNTERED

Figure 70. TH83-3 Denali Park Road. The ohm-m values are low at the top of the section but rapidly increase to very high values below the bottom of the borehole at approximately 17 ft. The drill hole results report silty sandy gravel down to the BOH at 12.5 ft..

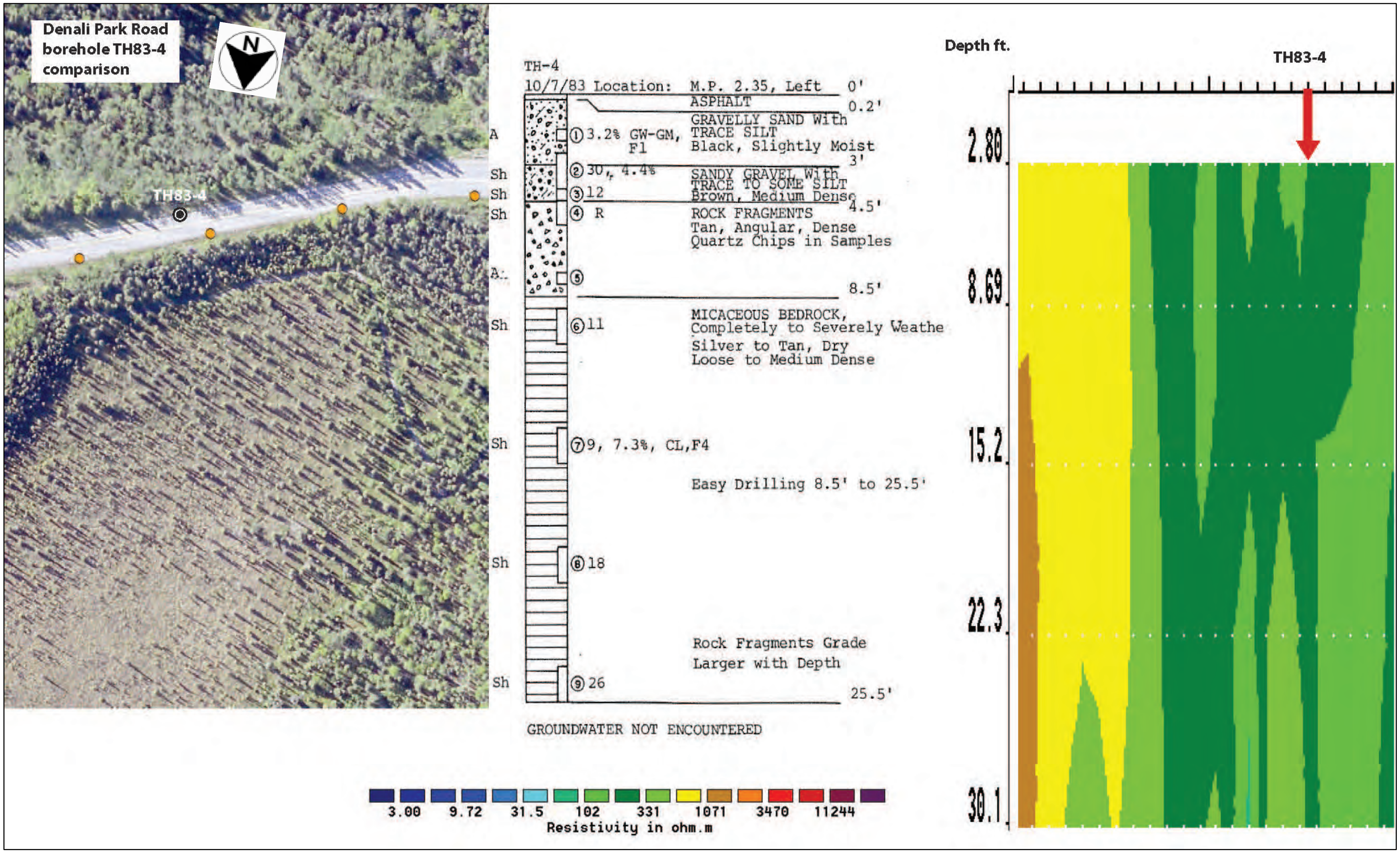


Figure 71. TH83-4 Denali Park Road. The ohm-m values are low are low to the full depth of the section. The drill hole reports silty sandy gravel down to 8.5 ft. with micaceous bedrock down to the BOH at 25.5 ft..

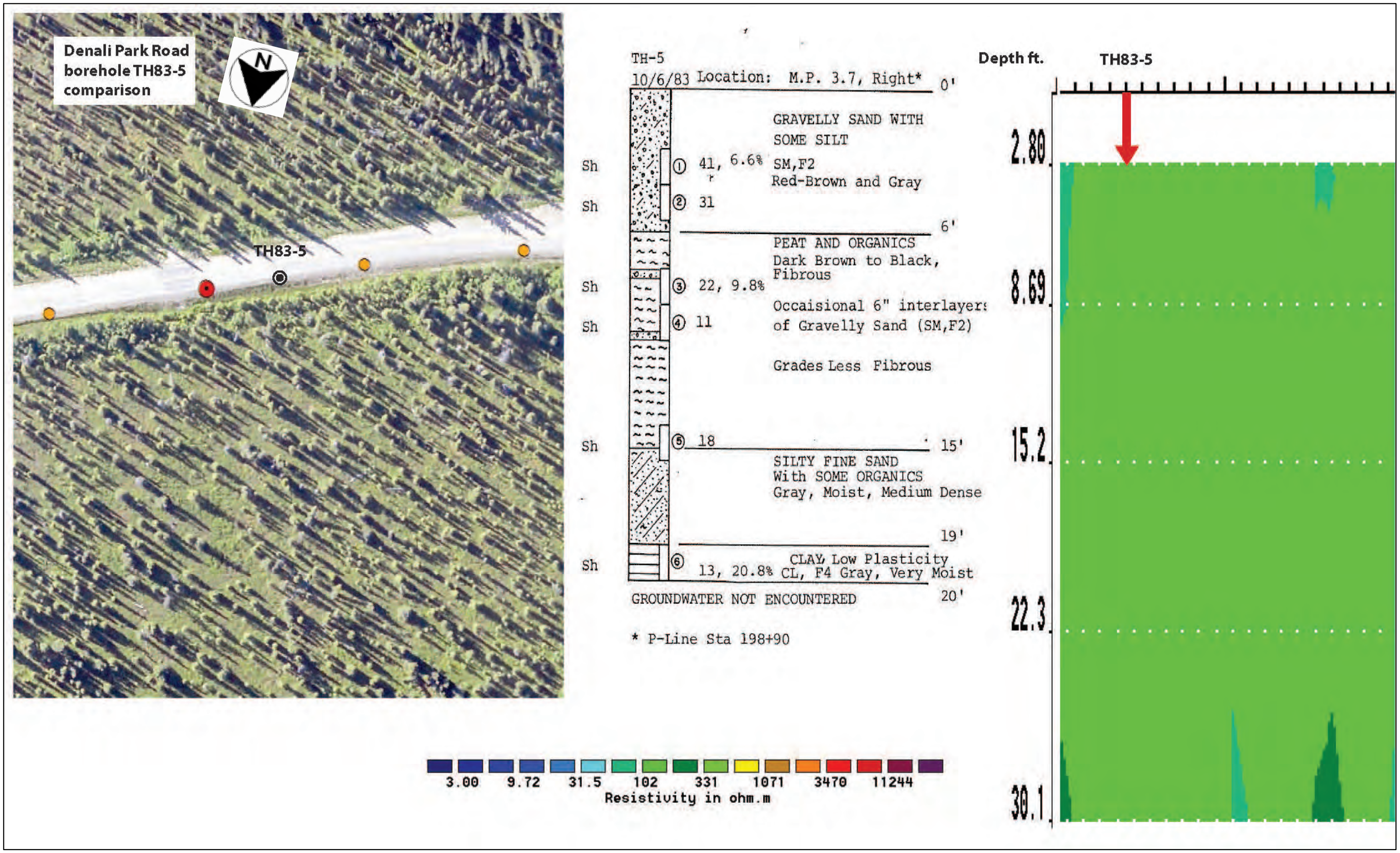


Figure 72. TH83-5 Denali Park Road. The ohm-m values are low for the full depth of the section, and in the immediate lateral vicinity. The drill hole reports a silt layer, peat and organics layer with some gravelly sand, and back to a silty sandy layer with organics. The drilled section becomes more moist with depth. The low resistivity response coincides with this drill report.

15 Appendix H – Drilling Bore Logs (2016, 2014, 1983)

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 9/25/2016
DATE FINISHED: 9/25/2016
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING BH16-02

DRILL: CME 55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem Auger with 3" split spoon and 340# auto hammer

PROJECT: Denali National Park 2016 Investigation

STATION, OFFSET:

NOTES:

LATITUDE (DEGREES): N 63° 32' 3.80" (63.53439°)
LONGITUDE (DEGREES): W -149° 50' 25.84" (-149.84051°)
ELEVATION: 3623'
TOTAL DEPTH: 26' (BOTTOM ELEV: 3597')

DEPTH (ft)	DESCRIPTION
0.0	Silty SAND with gravel, medium dense, gray brown, moist, gravel: rounded -1 1/2", fill.
3.0	Sandy SILT with gravel, medium dense, gray black, moist, gravel: rounded to sub-angular, -3", mixed lithologies.
6.5	Sandy SILT with gravel, medium dense, brown, moist, gravel: sub-angular, -1", mixed lithologies.
7.6	Sandy SILT with gravel, medium dense, gray black, moist, gravel: rounded, -1", mixed lithologies.
8.0	Sandy SILT with gravel, medium dense, orange brown, moist, gravel: sub-angular, -2", mixed lithologies.
10.6	Poorly graded SAND with gravel, loose, orange tan, moist, gravel: sub-angular, -2", mixed lithologies.
11.3	Organic SILT with >50% organic content, very loose, orange brown, dry to moist, stratified.
11.9	SILT, very loose, gray black, moist.
12.2	Poorly graded SAND with gravel, very loose, tan brown, moist, gravel: sub-angular, -1/2", mixed lithologies.
12.7	PEAT, very loose.
14.2	Sandy SILT with gravel, loose, orange brown, wet, gravel: angular to sub-angular, -1 1/2", mixed lithologies.
16.0	SILT with gravel, very loose, gray brown, moist to wet, medium plasticity, gravel: angular, -1 1/2", mixed lithologies.
19.3	Silty SAND with gravel, medium dense, gray brown, wet, gravel: rounded to angular, -1 1/2".
23.5	Silty SAND with gravel, very loose, gray black, wet, gravel: weathered limestone bedrock.
25.4	Sandy SILT, very loose, gray black, wet, weathered limestone bedrock.
26.0	

SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)
53	3" OD Split Spoon (D&M)	2 5 (83" = 1383%) 4 5
54	3" OD Split Spoon (D&M)	2 (100" = 1667%) 3 3 5
55	3" OD Split Spoon (D&M)	2 8 (100" = 1667%) 8 7
56	3" OD Split Spoon (D&M)	1 4 2 (100" = 1667%) 1
57	3" OD Split Spoon (D&M)	.5 .5 1 3 (88" = 1467%)
58	3" OD Split Spoon (D&M)	1 (58" = 967%) 3 2 1
59	3" OD Split Spoon (D&M)	1 (96" = 1600%) 1 2 2
60	3" OD Split Spoon (D&M)	0 (83" = 1383%) 4 4 4
61	3" OD Split Spoon (D&M)	1 (79" = 1317%) 3 2 2

DEPTH (ft)	ELEV (ft)
0.0	3623.0
3.0	3620.0
6.0	3617.0
9.0	3614.0
12.0	3611.0
15.0	3608.0
18.0	3605.0
21.0	3602.0
24.0	3599.0
27.0	3596.0
30.0	3593.0

WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
21.8' ▼ AFTER DRILLING

Ⅱ 3" OD Split Spoon (D&M)

Sheet 1 of 1

DRAFT

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 9/24/2016
DATE FINISHED: 9/24/2016
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING BH16-03

DRILL: CME 55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem Auger with 3" split spoon and 340# auto hammer

PROJECT: Denali National Park 2016 Investigation
STATION, OFFSET:
NOTES:

LATITUDE (DEGREES): N 63° 32' 4.63" (63.53462°)
LONGITUDE (DEGREES): W -149° 50' 18.49" (-149.83847°)
ELEVATION: 3688'
TOTAL DEPTH: 18' (BOTTOM ELEV: 3670')

DEPTH (ft)	DESCRIPTION	SAMPLE #	FIELD BLOW COUNT (Recovery)	DEPTH (ft) ELEV (ft)
0.0				0.0 3688.0
0.5	Silty SAND with gravel, medium dense, gray brown, moist, gravel: rounded to angular -1/2", surface course fill.	45	7 (84" = 1400%) 8 7 3	
	Silty SAND with gravel, medium dense, pink orange, moist, gravel: rounded to angular -3", fill.			
2.0	Compressed vegitative mat.			2.0 3686.0
3.0	SILT with gravel, loose, orange brown, moist, gravel: angular, -1 1/2", mixed lithologies.	46	1 2 (42" = 700%) 2 1.5	4.0 3684.0
4.9	Organic SILT with >50% organic content, very loose, brown, moist to wet, stratified.	47	.5 (67" = 1117%) 1 2 3	6.0 3682.0
6.5	Silty SAND with gravel, very loose, orange brown, moist to wet, gravel: rounded to angular, -1 1/2".			
7.9	SILT, very loose, gray, moist to wet, medium plasticity, looks like ash or altered tuff, in unconformable contact with underlying soil.	48	.5 1 (100" = 1667%) 2 3	8.0 3680.0
8.4	Silty SAND with gravel, very loose, orange brown, moist to wet, gravel: angular -1/2", looks like weathered bedrock.			
9.1	Silty SAND, very loose, gray brown, moist to wet, sand: coarse and angular, looks like weathered bedrock.			10.0 3678.0
10.5	Silty SAND, loose, mottled orange gray, moist to wet, sand: coarse and angular, blocky texture, looks like weathered bedrock.	49	1 3 (100" = 1667%) 4 5	12.0 3676.0
12.8	Silty SAND, loose, gray black with white mineral inclusions, moist to wet, sand: coarse and angular, blocky texture, weathered bedrock, remnant rock texture is present.	50	1 (50" = 833%) 6 6 8	14.0 3674.0
		51	4 (75" = 1250%) 12 11 17	16.0 3672.0
▼ 17.3	Soft BEDROCK, gray, wet, moderately weathered limestone.	52	>50 (100" = 1667%)	
18.0				18.0 3670.0
				20.0 3668.0

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WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
16.7' ▼ AFTER DRILLING

3" OD Split Spoon (D&M)

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 9/22/2016
DATE FINISHED: 9/22/2016
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING BH16-04

DRILL: CME 55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem Auger with 3" split spoon and 340# auto hammer

PROJECT: Denali National Park 2016 Investigation

STATION, OFFSET:

NOTES: Thermistor: Installed a 30 foot DTC with beads on 2' spacing and top bead at a depth of 12" BGS.

LATITUDE (DEGREES): N 63° 27' 33.12" (63.4592°)
LONGITUDE (DEGREES): W -150° 13' 29.93" (-150.22498°)
ELEVATION: 3921'
TOTAL DEPTH: 30.7' (BOTTOM ELEV: 3890.3')

DEPTH (ft)	DESCRIPTION
0.0	Poorly graded SAND with silt and gravel, loose, tan brown, moist, gravel: rounded -2", mixed lithologies, fill.
3.7	PEAT
5.3	Silty SAND with gravel, very loose, tan brown, moist, gravel: rounded to sub-angular -2".
7.7	SILT with sand, very loose, gray brown, moist, sand: medium to coarse.
9.1	PEAT
9.3	Silty SAND with <1" layers of peat, medium dense, gray green, moist to wet, frozen from 9.3' BGS to BOH. Frozen soil is typically Nbe to 15% Vx, with occasional <1" lenses of 25% to 100% Vs. Temp at 11.0' BGS was 31.6 degrees Fahrenheit.
12.3	Silty SAND with gravel, medium dense, gray green, moist to wet, frozen, gravel: rounded -1". Frozen soil is typically Nbe to 25% Vx. Temp at 14.0' BGS was 31.5 degrees Fahrenheit. 15' to 23.5': frozen soil is typically Nbn with no visible ice. Temp at 21.0' BGS was 31.3 degrees Fahrenheit.
23.5	Silty SAND with gravel and cobbles, medium dense, tan, moist, frozen, gravel: rounded -3". Frozen soil is typically Nbn with clots of Vx < 3/4". Temp at 26.0' BGS was 30.9 degrees Fahrenheit. Temp at 29.5' BGS was 30.9 degrees Fahrenheit.
30.7	

SAMPLE #	FIELD BLOW COUNT (Recovery)
11	2
	(100" = 1667%)
	3
	2
	2
	1
12	1
	(79" = 1317%)
	2
	2
13	1
	2
	(100" = 1667%)
14	2
	2
	5
	(100" = 1667%)
15	8
	8
	13
	7
	(100" = 1667%)
	9
	9
	16
16	
17	
18	

3" Continuous Sampler

3" Continuous Sampler

3" Continuous Sampler

DEPTH (ft)	ELEV (ft)
0.0	3921.0
4.0	3917.0
8.0	3913.0
12.0	3909.0
16.0	3905.0
20.0	3901.0
24.0	3897.0
28.0	3893.0
32.0	3889.0
36.0	3885.0
40.0	3881.0

WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Ⅱ 3" OD Split Spoon (D&M)
○ No Recovery

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FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 9/24/2016
DATE FINISHED: 9/24/2016
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING BH16-05

DRILL: CME 55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem Auger with 3" split spoon and 340# auto hammer

PROJECT: Denali National Park 2016 Investigation

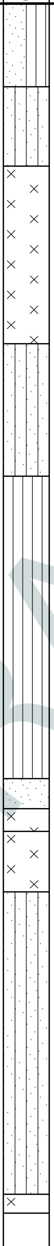
STATION, OFFSET:

NOTES:

LATITUDE (DEGREES): N 63° 27' 19.76" (63.45549°)
LONGITUDE (DEGREES): W -150° 13' 50.30" (-150.23064°)
ELEVATION: 3777'
TOTAL DEPTH: 32' (BOTTOM ELEV: 3745')

DEPTH (ft)	DESCRIPTION
0.0	Poorly graded SAND with silt and gravel, loose, tan brown, dry to moist, gravel: rounded -2", mixed lithologies, fill.
2.2	Sandy SILT with gravel, loose, orange tan, dry to moist, gravel: rounded, -2", mixed lithologies.
4.3	Silty SAND with gravel, loose to medium dense, orange brown, moist, gravel: rounded to angular, -3".
9.0	Sandy SILT with gravel, loose, orange brown, moist to wet, gravel: rounded, -1 1/2", mixed lithologies.
12.5	SILT with sand, loose, orange tan, moist, sand: very fine to fine.
20.5	Poorly graded SAND, loose, tan orange, dry to moist, sand: medium.
21.3	Silty SAND, medium dense, tan orange, dry to moist.
21.9	Silty SAND with gravel and cobbles, medium dense, tan orange, dry to moist, gravel: rounded to angular, -3".
23.5	Sandy SILT, medium dense, orange tan, dry to moist, sand: very fine to fine.
31.5	Silty SAND with gravel, medium dense, orange tan, wet, gravel: rounded, -2".
32.0	

GRAPHIC LOG



SAMPLE #
36
37
38
39
40
41
42
43
44

SAMPLER

FIELD BLOW COUNT (Recovery)
1
(100" = 1667%)
3
5
6
1
(71" = 1183%)
6
6
5
4
(83" = 1383%)
4
3
3
2
(71" = 1183%)
2
2
2
1
(100" = 1667%)
2
4
5
1
(100" = 1667%)
3
4
6
7
9
(100" = 1667%)
9
11
5
(100" = 1667%)
10
15
21
8
11
10
11
(86" = 1433%)

DEPTH (ft)	ELEV (ft)
0.0	3777.0
4.0	3773.0
8.0	3769.0
12.0	3765.0
16.0	3761.0
20.0	3757.0
24.0	3753.0
28.0	3749.0
32.0	3745.0
36.0	3741.0
40.0	3737.0

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WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Ⅱ 3" OD Split Spoon (D&M)

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 9/21/2016
DATE FINISHED: 9/21/2016
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING BH16-06

DRILL: CME 55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem Auger with 3" split spoon and 340# auto hammer

PROJECT: Denali National Park 2016 Investigation

STATION, OFFSET:

NOTES:

LATITUDE (DEGREES): N 63° 27' 20.99" (63.45583°)
LONGITUDE (DEGREES): W -150° 13' 59.66" (-150.23324°)
ELEVATION: 3740'
TOTAL DEPTH: 32' (BOTTOM ELEV: 3708')

DEPTH (ft)	DESCRIPTION
0.0	Silty SAND with gravel, loose, orange brown, dry to moist, gravel: rounded, -2", mixed lithologies, fill.
2.5	SILT with sand and gravel, loose to medium dense, orange brown, moist, gravel: rounded, -2", mixed lithologies.
12.5	Silty SAND with gravel and cobbles, medium dense, tan orange, moist, gravel: rounded, -3", mixed lithologies.
18.0	Sandy SILT, medium dense, orange tan, dry to moist, sand: fine to medium.
20.2	Silty SAND with gravel and cobbles, medium dense, tan orange, moist, gravel: rounded, -3", mixed lithologies.
23.5	Sandy SILT, medium dense, tan orange, dry to moist, sand: fine to medium.
25.6	Silty SAND with gravel and cobbles, medium dense to dense, tan orange, dry to moist, gravel: rounded, -3", mixed lithologies. 10" cobble
32.0	

SAMPLE #	FIELD BLOW COUNT (Recovery)
1	3
	(17" = 283%)
	2
	2
	1
2	1
	(100" = 1667%)
	2
	3
3	3
	1
	(100" = 1667%)
	5
4	5
	8
	2
	(100" = 1667%)
5	4
	8
	11
	2
6	(100" = 1667%)
	10
	12
	13
	3
7	(100" = 1667%)
	11
	15
	16
8	7
	(100" = 1667%)
	11
	14
	20
	3
	(100" = 1667%)
	5
9	12
	18
	6
	(100" = 1667%)
	18
	33
	>50
10	8
	(100" = 1667%)
	12
	20
	28

DEPTH (ft)	ELEV (ft)
0.0	3740.0
4.0	3736.0
8.0	3732.0
12.0	3728.0
16.0	3724.0
20.0	3720.0
24.0	3716.0
28.0	3712.0
32.0	3708.0
36.0	3704.0
40.0	3700.0

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WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Ⅱ 3" OD Split Spoon (D&M)

Sheet 1 of 1

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 9/22/2016
DATE FINISHED: 9/22/2016
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING BH16-07

DRILL: CME 55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem Auger with 3" split spoon and 340# auto hammer

PROJECT: Denali National Park 2016 Investigation

NOTES:

STATION, OFFSET:

LATITUDE (DEGREES): N 63° 27' 44.42" (63.46234°)
LONGITUDE (DEGREES): W -150° 13' 14.23" (-150.22062°)
ELEVATION: 3893'
TOTAL DEPTH: 26' (BOTTOM ELEV: 3867')

DEPTH (ft)	DESCRIPTION
0.0	Silty SAND with gravel, loose, gray brown, moist, gravel: rounded, -3", mixed lithologies, fill.
1.9	Compressed vegitative mat.
2.1	Sandy SILT with gravel, loose, gray brown, moist, gravel: rounded, -2", mixed lithologies.
2.5	Sandy SILT with gravel, very loose, orange, moist, medium plasticity, gravel: rounded, -2", mixed lithologies, .
▼	
	rounded to angular
▽	
	moist to wet
17.0	Silty SAND, very loose, tan orange, wet, sand: fine to medium.
17.8	SILT with sand, loose, tan orange, moist to wet, sand: fine to medium.
20.0	SILT, medium dense, orange, moist to wet.
20.5	Sandy SILT with gravel, medium dense, tan orange, moist to wet, gravel: rounded, -3", mixed lithologies.
24.2	Silty SAND with gravel, medium dense, tan orange, moist to wet, sand: fine to medium, gravel: rounded, -3", mixed lithologies.
26.0	

SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)
19	II	2 (67" = 1117%) 2 6 4
20	II	.5 (63" = 1050%) .5 1 2.5
21	II	.5 (98" = 1633%) .5 1 2.5
22	II	0 (58" = 967%) 1 2.5 3
23	II	1 (38" = 633%) 1 2 2
24	II	0 (75" = 1250%) 1 2 2
25	II	1 (100" = 1667%) 1 2 2
26	II	2 3 7 (100" = 1667%) 7
27	II	4 (100" = 1667%) 8 9 9

DEPTH (ft)	ELEV (ft)
0.0	3893.0
3.0	3890.0
6.0	3887.0
9.0	3884.0
12.0	3881.0
15.0	3878.0
18.0	3875.0
21.0	3872.0
24.0	3869.0
27.0	3866.0
30.0	3863.0

WATER LEVELS
▽ WHILE DRILLING
12' ▽ AT COMPLETION
5.7' ▼ AFTER DRILLING

II 3" OD Split Spoon (D&M)

Sheet 1 of 1

DRAFT

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 9/23/2016
DATE FINISHED: 9/23/2016
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING BH16-08

DRILL: CME 55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem Auger with 3" split spoon and 340# auto hammer, 0'-10' and 30'-31'. Continuous 3" x 5' Sampler, 10'-25'

PROJECT: Denali National Park 2016 Investigation

STATION, OFFSET:

NOTES: Thermistor: Installed a 30 foot DTC with beads on 2' spacing and top bead at a depth of 7" BGS.

LATITUDE (DEGREES): N 63° 27' 41.22" (63.46145°)
LONGITUDE (DEGREES): W -150° 13' 19.13" (-150.22198°)
ELEVATION: 3907'
TOTAL DEPTH: 31' (BOTTOM ELEV: 3876')

DEPTH (ft)	DESCRIPTION
0.0	Silty SAND with gravel, loose, gray brown, moist, gravel: rounded, -2", mixed lithologies, fill.
2.5	
3.0	Compressed vegitative mat.
	SILT with gravel, loose, gray brown, moist, gravel: rounded,
4.4	-1 1/2", mixed lithologies.
4.6	PEAT
5.0	Gravely SILT, loose, gray brown, moist, gravel: rounded, -1",
6.4	mixed lithologies.
7.2	Sandy SILT with gravel, medium dense, orange tan, moist
8.0	to wet, gravel: rounded, -3", mixed lithologies.
	Gravely SILT, loose, gray brown, moist, gravel: rounded, -3", mixed lithologies.
	PEAT, wet, Nbe, frozen from 7.5' BGS to BOH.
10.8	Silty SAND with gravel, medium dense, gray green, wet, frozen. Frozen soil: Nbe to 25% Vx.
12.0	PEAT, wet, frozen. Frozen soil: Nbe with 25% Vs from 10.9' to 11.2' .
	Sandy SILT with gravel, medium dense, gray green, wet, frozen, gravel: rounded to angular -1 1/2", mixed lithologies. Frozen soil: Nbe with 15%-25% Vs from 13.7' to 16.5' . Temp at 13.5' BGS was 31.5 degrees Fahrenheit.
16.5	
17.2	PEAT, wet, frozen, Nbe.
	Sandy SILT with gravel, medium dense, gray green, wet, frozen, gravel: rounded to angular -1 1/2", mixed lithologies.
19.3	Frozen soil: Nbn. Temp at 18.5' BGS was 31.5 degrees Fahrenheit.
	Silty SAND with gravel, medium dense, tan orange, wet, frozen, gravel: rounded to angular -1 1/2", mixed lithologies. Frozen soil: Nbn. Temp at 21' BGS was 31.5 degrees Fahrenheit.
31.0	Temp at 30.5' BGS was 31.5 degrees Fahrenheit.

SAMPLE #	FIELD BLOW COUNT (Recovery)	
28	.5 (92" = 1533%) 1 2	
29	2 .5 (100" = 1667%) 1 3 1.5	
30	1 4 7 (100" = 1667%) 9	3" Continuous Sampler
31		3" Continuous Sampler
32		3" Continuous Sampler
33		3" Continuous Sampler
34		
35	11 (92" = 1533%) 27	

DEPTH (ft)	ELEV (ft)
0.0	3907.0
4.0	3903.0
8.0	3899.0
12.0	3895.0
16.0	3891.0
20.0	3887.0
24.0	3883.0
28.0	3879.0
32.0	3875.0
36.0	3871.0
40.0	3867.0

WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Ⅱ 3" OD Split Spoon (D&M)

DRAFT

File: I:\TECH SERVICES\GEOTECHNICAL SERVICES\001 PROPOSED NEW FILE STRUCTURE\04 BORING LOGS\ALASKA\DENALI PARK ROAD 2016.GPJ Lib: I:\TECH SERVICES\GEOTECHNICAL SERVICES\GINT\LIBRARY\FHWALIBRARY.GLB Printed: 11/18/2016

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 9/30/2016
DATE FINISHED: 9/30/2016
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING SG16-01

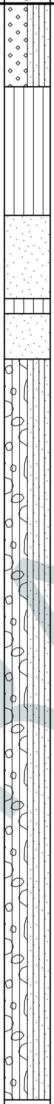
DRILL: CME 55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem Auger with 3" split spoon and 340# auto hammer

PROJECT: Denali National Park 2016 Investigation

STATION, OFFSET:

NOTES:

LATITUDE (DEGREES): N 63° 38' 15.68" (63.63769°)
LONGITUDE (DEGREES): W -149° 34' 46.45" (-149.57957°)
ELEVATION: 2723'
TOTAL DEPTH: 14.5' (BOTTOM ELEV: 2708.5')



DEPTH (ft)	DESCRIPTION	SAMPLE #	FIELD BLOW COUNT (Recovery)
0.0	Well-graded SAND with silt and gravel, medium dense, gray, moist, sand: medium to coarse, gravel: rounded to angular -2", fill, homogenous.	147	14 11 6 (100" = 1667%) 5
1.1	SILT, medium dense, orange brown, dry to moist, stratified.		
2.8	Poorly graded SAND, medium dense, orange brown, dry to moist, sand: fine.	148	1 2 (80" = 1333%) 2 2
3.9	SILT, medium dense, orange brown, moist, stratified.		
4.1	Poorly graded SAND, medium dense, orange brown, dry to moist, sand: fine.		
4.7	Silty GRAVEL with sand and cobbles, medium dense, orange brown, dry to moist, sand: fine, gravel: rounded to angular -3".	149	4 (80" = 1333%) 5 8 9
		150	5 (80" = 1333%) 7 9 11
▽		150	5 (80" = 1333%) 9 11 12
		150	9 (80" = 1333%) 9 7 5
14.5			

DEPTH (ft)	ELEV (ft)
0.0	2723.0
2.0	2721.0
4.0	2719.0
6.0	2717.0
8.0	2715.0
10.0	2713.0
12.0	2711.0
14.0	2709.0
16.0	2707.0
18.0	2705.0
20.0	2703.0

	WATER LEVELS
	▽ WHILE DRILLING
10.5'	▽ AT COMPLETION
	▼ AFTER DRILLING

𝐈 3" OD Split Spoon (D&M)

Sheet 1 of 1

DRAFT

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 9/30/2016
DATE FINISHED: 9/30/2016
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING SG16-02

DRILL: CME 55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem Auger with 3" split spoon and 340# auto hammer

PROJECT: Denali National Park 2016 Investigation

NOTES:

STATION, OFFSET:

LATITUDE (DEGREES): N 63° 38' 6.11" (63.63503°)
LONGITUDE (DEGREES): W -149° 34' 48.29" (-149.58008°)
ELEVATION: 2728'
TOTAL DEPTH: 14.5' (BOTTOM ELEV: 2713.5')

DEPTH (ft)	DESCRIPTION
0.0	Poorly graded SAND with silt and gravel, medium dense, gray brown, moist, sand: medium to coarse, gravel: rounded -3", homogenous, fill.
0.5	Silty SAND with gravel, medium dense, brown orange, moist, sand: coarse, gravel: angular -3", fill.
1.4	PEAT
1.5	SILT, medium dense, orange brown, moist, stratified.
3.2	Poorly graded SAND with silt, loose, brown orange, moist, very fine.
3.5	SILT, medium dense, orange brown, moist, stratified.
4.0	Poorly graded SAND, loose, brown orange, moist, very fine.
4.7	Gravely SILT, medium dense, gray brown , moist, gravel: angular -1/2".
5.3	Silty GRAVEL with sand and cobbles, medium dense, orange brown, moist, sand: fine, gravel: rounded to angular -3".
▼	wet
14.5	

SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)
140	Ⅰ	12 13 (100" = 1667%) 7 4
141	Ⅰ	1 (100" = 1667%) 2 2 2
143	Ⅰ	3 7 (80" = 1333%) 10 13
144	Ⅰ	5 (100" = 1667%) 9 11 11
145	Ⅰ	10 (83" = 1383%) 10 11 15
146	Ⅰ	5 (71" = 1183%) 11 10 12

DEPTH (ft)	ELEV (ft)
0.0	2728.0
2.0	2726.0
4.0	2724.0
6.0	2722.0
8.0	2720.0
10.0	2718.0
12.0	2716.0
14.0	2714.0
16.0	2712.0
18.0	2710.0
20.0	2708.0

WATER LEVELS
▽ WHILE DRILLING
10' ▼ AT COMPLETION
▼ AFTER DRILLING

Ⅰ 3" OD Split Spoon (D&M)

DRAFT

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 9/30/2016
DATE FINISHED: 9/30/2016
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING SG16-03

DRILL: CME 55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem Auger with 3" split spoon and 340# auto hammer

PROJECT: Denali National Park 2016 Investigation

STATION, OFFSET:

NOTES:

LATITUDE (DEGREES): N 63° 36' 39.82" (63.61106°)
LONGITUDE (DEGREES): W -149° 35' 7.19" (-149.58533°)
ELEVATION: 2962'
TOTAL DEPTH: 14.5' (BOTTOM ELEV: 2947.5')

DEPTH (ft)	DESCRIPTION
0.0	
0.2	Silty SAND with gravel, medium dense, gray brown, moist to wet, gravel: rounded to sub-angular -2", mixed lithologies, fill. SILT, medium dense, orange brown, moist, stratified.
1.8	Sandy SILT with gravel and organics, medium dense, brown, dry to moist, sand: medium, gravel: angular, -3".
2.6	Silty GRAVEL with sand and cobbles, medium dense to dense, brown to orange brown, dry to moist, sand: fine, gravel: rounded to angular -3".
14.5	

SAMPLE #	FIELD BLOW COUNT (Recovery)
139	5 (96" = 1600%) 5 6 7
134	5 (75" = 1250%) 9 7 7
135	4 (100" = 1667%) 9 >25
136	3 (92" = 1533%) 11 13 15
137	6 (100" = 1667%) 12 13 12
138	5 (100" = 1667%) 14 18 17

DEPTH (ft)	ELEV (ft)
0.0	2962.0
2.0	2960.0
4.0	2958.0
6.0	2956.0
8.0	2954.0
10.0	2952.0
12.0	2950.0
14.0	2948.0
16.0	2946.0
18.0	2944.0
20.0	2942.0

DRAFT

WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Ⅱ 3" OD Split Spoon (D&M)

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/7/2014
DATE FINISHED: 5/7/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING B14-03

DRILL: CME-55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem

PROJECT: Denali Park Road

STATION, OFFSET:

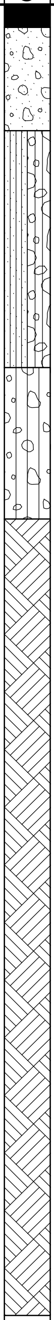
NOTES:

LATITUDE (DEGREES): N 63° 43' 31.30" (63.72536°)
LONGITUDE (DEGREES): W -148° 56' 1.39" (-148.93372°)

TOTAL DEPTH: 26'

DEPTH (ft)	DESCRIPTION	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)
0.0				
0.5	ASPHALT 0.45 feet Poorly graded gravely SAND, medium dense, fill, grayish brown, dry to moist	0066		3 9 6 8
2.5	Silty SAND with gravel, -3", loose, fill, grayish brown, dry to moist	0067		5 6 7 6
	moist	0068		3 5 6 11
7.2	SILT with sand and gravel, -2", light brown, fill?, moist to wet, frozen with minor ice	0069		19 17 13 16
10.2	BEDROCK, mica phyllite, pale purple, very weak	0070		9 14 13 21
		0071		6 9 9 13
		0072		33
		0073		4 7 7 9
26.0				

GRAPHIC LOG



DEPTH (ft): 0.0, 3.0, 6.0, 9.0, 12.0, 15.0, 18.0, 21.0, 24.0, 27.0, 30.0

WATER LEVELS	
▽ WHILE DRILLING	⌶ 2" OD Split Spoon (SPT)
▼ AT COMPLETION	⌶ Split Spoon
▼ AFTER DRILLING	

Sheet 1 of 1

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FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/5/2014
DATE FINISHED: 5/5/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING B14-04

DRILL: CME-55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem

PROJECT: Denali Park Road

STATION, OFFSET:

NOTES:

LATITUDE (DEGREES): N 63° 43' 29.10" (63.72475°)
LONGITUDE (DEGREES): W -148° 56' 17.66" (-148.93824°)

TOTAL DEPTH: 31'

DEPTH (ft)	DESCRIPTION	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)
0.0				
0.3	ASPHALT 0.25 feet			
0.8	Poorly graded gravely SAND, black, oil treated			
	Silty SAND with gravel, -2.5", loose, fill, grayish brown, moist			
3.0	Silty SAND with gravel, fill, gray, moist, frozen from 5' to 10.1'	0039		6 7 9 10
		0040		26 30
		0041		13 27 22 26
10.1				
10.2	Organic SILT, brown, wet, frozen			
	Silty SAND with gravel, -2", light brown, moist, frozen from 10.2' to 12.4'	042		5 15 15 13
13.1				
13.9	Poorly graded gravely SAND, medium dense, -2", sub-angular, dark brown, moist	0043		3 11 12 14
	Silty GRAVEL with sand, loose, -3", grayish brown, dry to moist			
15.9	SILT with very fine sand and trace gravel, loose, gray, mottled orange, moist	0044		5 3 3 6
		0045 0046		1 4 5 9
20.0	SILT with sand and gravel, grayish brown, moist			
22.0	SILT with sand and gravel, -.375", orange brown, moist			
23.0	SILT with sand and gravel, loose, -2.5", rounded to sub-angular, moist	0047		5 4 4 4
	some rounded clasts	0048		3 5 7 18
31.0	refusal, likely on a very hard boulder			

DEPTH (ft)
0.0
4.0
8.0
12.0
16.0
20.0
24.0
28.0
32.0
36.0
40.0

WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

2" OD Split Spoon (SPT)
Split Spoon

Sheet 1 of 1

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FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/5/2014
DATE FINISHED: 5/5/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING B14-04a

DRILL: CME-55
HAMMER:
DRILLING METHODS: Solid Flight

PROJECT: Denali Park Road

STATION, OFFSET:

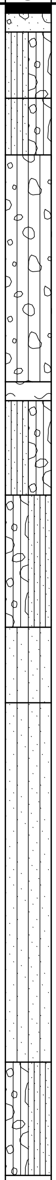
NOTES:

LATITUDE (DEGREES): N 63° 43' 29.10" (63.72475°)
LONGITUDE (DEGREES): W -148° 56' 17.77" (-148.93827°)

TOTAL DEPTH: 31'

DEPTH (ft)	DESCRIPTION
0.0	
0.3	ASPHALT 0.25 feet
0.8	Poorly graded gravely SAND, -1", black, dry to moist, oil treated
2.5	Silty SAND with gravel, -2.5", loose, fill, grayish brown, dry to moist
4.0	Silty SAND with gravel, fill, tan, dry to moist
	SILT with gravel and sand and minor cobbles of weathered schist, loose, fill, gray, dry to moist, frozen from 5' to 10.1'
10.0	
10.5	Organic SILT, brown, moist, frozen
	Silty SAND with gravel, -2", grayish brown, moist, frozen
13.0	
	Silty GRAVEL with sand, -3", grayish brown, dry to moist
16.5	
	SILT with sand, very fine, grayish brown, moist
18.5	
	SILT with sand and gravel, -3", grayish brown, moist
	loose, -3"
28.0	
	Silty GRAVEL with sand, -3", brownish gray, moist
31.0	
	broke solid flight and left 10 feet in ground from 21' to 31'

GRAPHIC LOG



SAMPLE # | SAMPLER | FIELD BLOW COUNT (Recovery)

DEPTH (ft)
0.0
4.0
8.0
12.0
16.0
20.0
24.0
28.0
32.0
36.0
40.0

WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Sheet 1 of 1

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FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/5/2014
DATE FINISHED: 5/6/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

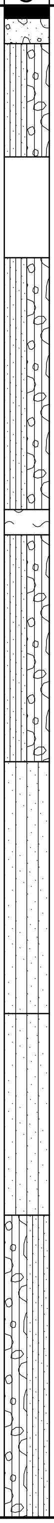
BORING B14-04b

DRILL: CME-55
HAMMER: Automatic
DRILLING METHODS: Solid Flight: 0 to 30 feet
Hollow Stem: 30 to 51 feet

PROJECT: Denali Park Road
STATION, OFFSET:
NOTES:

LATITUDE (DEGREES): N 63° 43' 29.10" (63.72475°)
LONGITUDE (DEGREES): W -148° 56' 17.41" (-148.93817°)
TOTAL DEPTH: 51'

DEPTH (ft)	DESCRIPTION	GRAPHIC LOG	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)
0.0					
0.3	ASPHALT 0.25 feet				
0.8	Poorly graded gravely SAND, fill, black, oil treated, dry to moist Silty SAND with gravel, -2.5", fill, grayish brown, dry to moist				
3.0	Silty SAND with gravel, fill, tan, dry to moist				
5.0	Silty SAND with gravel and minor cobbles, -3", fill, greenish gray, dry to moist, frozen from 5' to 10'				
10.0					
10.5	Organic SILT, brown, moist, frozen Silty SAND with gravel, -2", grayish brown, moist, frozen from 10.5' to 12'				
15.0	SILT with sand, very fine , loose, brown, moist				
20.0	SILT with sand and gravel, grayish brown, moist				
24.0	Silty GRAVEL with sand and cobbles, -3", grayish brown, moist				
30.0					



DEPTH (ft): 0.0, 3.0, 6.0, 9.0, 12.0, 15.0, 18.0, 21.0, 24.0, 27.0, 30.0

WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

⌶ 2" OD Split Spoon (SPT)
⨯ Split Spoon

Sheet 1 of 2

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FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/5/2014
DATE FINISHED: 5/6/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING B14-04b

DRILL: CME-55
HAMMER: Automatic
DRILLING METHODS: Solid Flight: 0 to 30 feet
Hollow Stem: 30 to 51 feet

PROJECT: Denali Park Road
STATION, OFFSET:

NOTES:

LATITUDE (DEGREES): N 63° 43' 29.10" (63.72475°)
LONGITUDE (DEGREES): W -148° 56' 17.41" (-148.93817°)
TOTAL DEPTH: 51'

DEPTH (ft)	DESCRIPTION	GRAPHIC LOG	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)		DEPTH (ft)
	very soft weathered schist with coarse angular gravel of schist rubble, orange tan, foliation oriented at miltiple angles within rubble, no other lithologies present						30.0
							33.0
			0049		5 12 13 14		
							36.0
38.0	soft phyllite with uniform, flat lying, eighth inch foliations, greenish gray, mottled to tan and orange brown						
							39.0
			0050		3 4 5 8		
							42.0
			0051		7 7 7 9		45.0
							48.0
			0052		10 11 7 7		
51.0							51.0
							54.0
							57.0
							60.0

WATER LEVELS	
▽ WHILE DRILLING	⌶ 2" OD Split Spoon (SPT)
▼ AT COMPLETION	╳ Split Spoon
▼ AFTER DRILLING	

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/8/2014
DATE FINISHED: 5/8/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING B14-05

DRILL: CME-55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem

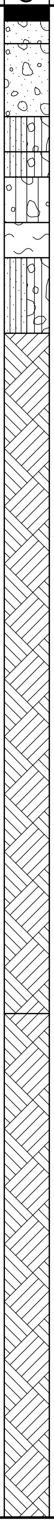
PROJECT: Denali Park Road

STATION, OFFSET:

NOTES:

LATITUDE (DEGREES): N 63° 43' 28.49" (63.72458°)
LONGITUDE (DEGREES): W -148° 56' 28.75" (-148.94132°)

TOTAL DEPTH: 51'



DEPTH (ft)	DESCRIPTION	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)	DEPTH (ft)
0.0					0.0
0.3	ASPHALT 0.3 feet				
0.8	Poorly graded gravely SAND, fill, black, oil treated, -1", dry to moist	0077			
2.2	Poorly graded gravely SAND, fill, dark brown, -3", dry to moist				
2.9	Silty SAND with gravel, fill, brown, -3", moist			3 6	3.0
3.4	Silty SAND with gravel of green phyllite, fill, greenish brown, -3", moist	0078		11 18	
4.3	SILT with sand and gravel of weathered pyllite, fill, tan green, moist	0079		18 36 >50	
5.0	Organic SILT with minor gravel, moist, frozen				
	Silty SAND with gravel and cobbles, grayish brown, -3" , moist, frozen				6.0
6.5	Weathered BEDROCK, orange tan, dry, composed of strong frubble fragments in soft compacted silt matrix, frozen to 14.5 feet	0080		9 19 23 16	9.0
		0081		9 15 13 19	12.0
		0082		8 11 13 16	
		0083		3 6 8 4	15.0
					18.0
20.0	Sericitic phyllite, whitish tan, with occasional 2" quartz veins	0084		8 21 28 >50	21.0
					24.0
		0085		12 9 9 10	27.0
				10 11	30.0

WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

⌶ 2" OD Split Spoon (SPT)
X Split Spoon

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/8/2014
DATE FINISHED: 5/8/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING B14-05

DRILL: CME-55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem

PROJECT: Denali Park Road

STATION, OFFSET:

NOTES:

LATITUDE (DEGREES): N 63° 43' 28.49" (63.72458°)
LONGITUDE (DEGREES): W -148° 56' 28.75" (-148.94132°)

TOTAL DEPTH: 51'

DEPTH (ft)	DESCRIPTION	GRAPHIC LOG	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)	DEPTH (ft)
			0086		11 7	30.0
32.5	Weathered BEDROCK, orange tan, dry, composed of soft alteration clay retaining original folliated rock texture, no indication of shear					33.0
			0087		2 2 2 1	36.0
						39.0
			0088		2 1 2 3	42.0
			0089		2 6 6 7	45.0
						48.0
			0090		2 7 11 21	
51.0						51.0
						54.0
						57.0
						60.0

WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

2" OD Split Spoon (SPT)
Split Spoon

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/7/2014
DATE FINISHED: 5/7/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING B14-06

DRILL: CME-55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem

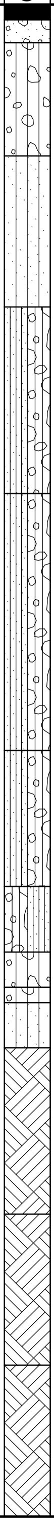
PROJECT: Denali Park Road

STATION, OFFSET:

NOTES:

LATITUDE (DEGREES): N 63° 43' 28.99" (63.72472°)
LONGITUDE (DEGREES): W -148° 56' 19.03" (-148.93862°)

TOTAL DEPTH: 46'



DEPTH (ft)	DESCRIPTION	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)	DEPTH (ft)
0.0					0.0
0.3	ASPHALT 0.3 feet				
0.8	Poorly graded gravely SAND, fill, black, oil treated, -.75", dry to moist				
	SILT with sand and gravel, fill, brownish gray, -2.5", dry to moist	0053			
3.0	SILT with sand and gravel of weathered schist cut material with some rounded clasts, fill, light brown, dry to moist, frozen from 4.8 feet	0054 0055		6 12 8 11 20 19 13 >50	3.0
6.0	Silty SAND with gravel of weathered bedrock, some cobbles, some organics, some rounded clasts, fill, orange brown, moist, frozen	0056		14 31 >50	6.0 9.0
9.7	Silty SAND with gravel, grayish brown, -2", some rounded clasts, dry to moist	0057 0058		8 13 18 28 11 15 9 8	12.0
14.8	Silty SAND with gravel, grayish brown, -.75", fine sand interbedded with medium fine sand, some rounded clasts, dry to moist	0059		2 3 2 3	15.0
17.5	Silty GRAVEL with sand and cobbles, -3", dry to moist				18.0
18.8	SILT with sand and gravel, brownish grayish , -.5", some rounded clasts, dry to moist	0060		3 4 3 8	
19.5	SILT with sand and gravel of weak angular bedrock, tan, dry to moist				
19.8	SILT with fine sand, grayish brown, dry to moist				
20.7	soft schist or phyllite, whitish gray, dry				21.0
24.0	sericitic phyllite, light brown with orange bands, dry	0061		1 2 2 2	24.0
27.0	sericitic phyllite, grayish white with orange bands, dry			2 3	27.0 30.0

WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Solid Stem Auger
2" OD Split Spoon (SPT)
Split Spoon

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FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/7/2014
DATE FINISHED: 5/7/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING B14-06

DRILL: CME-55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem

PROJECT: Denali Park Road

NOTES:

STATION, OFFSET:

LATITUDE (DEGREES): N 63° 43' 28.99" (63.72472°)
LONGITUDE (DEGREES): W -148° 56' 19.03" (-148.93862°)

TOTAL DEPTH: 46'

DEPTH (ft)	DESCRIPTION	GRAPHIC LOG	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)
			0062		3 4
			0063		2 5 3 6
	minor pyrrhotite minerization		0064		3 8 7 12
45.5	hard bedrock, refusal		0065		4 7 11 >50
46.5					

DEPTH (ft)
30.0
33.0
36.0
39.0
42.0
45.0
48.0
51.0
54.0
57.0
60.0

WATER LEVELS
∇ WHILE DRILLING
∇ AT COMPLETION
▼ AFTER DRILLING

Solid Stem Auger
2" OD Split Spoon (SPT)
Split Spoon

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FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

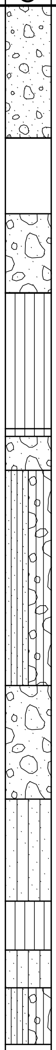
DATE STARTED: 5/1/2014
DATE FINISHED: 5/1/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING B14-09

DRILL: CME-55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem

PROJECT: Denali Park Road
STATION, OFFSET:
NOTES:

LATITUDE (DEGREES): N 63° 43' 14.74" (63.72076°)
LONGITUDE (DEGREES): W -148° 58' 7.18" (-148.96866°)
TOTAL DEPTH: 27'



DEPTH (ft)	DESCRIPTION	SAMPLE #	FIELD BLOW COUNT (Recovery)
0.0	Poorly graded gravely SAND, -.75", medium dense, fill, brownish gray, dry to moist	0009	4 8 8 8
3.4	-1"	0010	3 3 22 >50
3.5	One layer of white polystyrene FOAM, compressed to 1.5"		
5.5	Poorly graded sandy GRAVEL with cobbles, -3", medium dense, fill, brownish gray, dry, frozen	0011	13 35 65
	woven split fim GEOTEXTILE fabric		
7.6	Poorly graded sandy GRAVEL with cobbles, -3", medium dense, fill, brownish gray, dry, frozen		
7.6	woven split fim GEOTEXTILE fabric	0012	7 11 11 12
	SILT, blackish gray, dry to moist, frozen with 1mm-3mm ice layers spaced 1cm-2cm apart		
11.2			
11.4	SILT with organics, brown, frozen Nbe (non-visible ice, bonded with excess moisture)		
12.3	Poorly graded sandy GRAVEL, grayish brown , dry to moist, frozen with 5% to 10% ice		
	Silty SAND with gravel, -3", grayish brown , dry to moist, frozen	0013	
		0014	
18.0	Poorly graded sandy GRAVEL, brown, wet, frozen with < 5% ice	0015	>50
21.0	Sandy SILT composed of interbedded layers of gray SILT and light brown fine to medium SAND, moist to wet, frozen	0016	6 9 6 9
23.7	SILT, grayish black with organics, frozen Nbe (non-visible ice, bonded with excess moisture)		
25.0	Sandy SILT composed of interbedded layers of gray SILT and light brown fine to medium SAND, frozen Nbe (non-visible ice, bonded with excess moisture)		
26.0			
27.5	Silty SAND with gravel, grayish brown , wet, frozen		60

WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Solid Stem Auger
2" OD Split Spoon (SPT)
Split Spoon

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 4/30/2014
DATE FINISHED: 4/30/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING B14-10

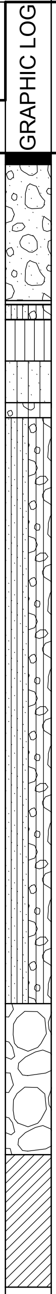
DRILL: CME-55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem

PROJECT: Denali Park Road
STATION, OFFSET:

NOTES:

LATITUDE (DEGREES): N 63° 43' 14.34" (63.72065°)
LONGITUDE (DEGREES): W -148° 58' 7.50" (-148.96875°)

TOTAL DEPTH: 30'



DEPTH (ft)	DESCRIPTION	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)
0.0				
0.3	Asphalt 0.3 feet			
	Poorly graded sandy GRAVEL, -2", loose by drill reaction, fill, grayish brown, dry to moist			
3.9		001		5 2 16 28
4.0	one layer of white polystyrene FOAM, compressed to 1.5"			
4.0	woven split fim GEOTEXTILE fabric	002		
4.4	Silty SAND with gravel, -1.5", fill, grayish brown , wet			
4.4	woven split fim GEOTEXTILE fabric			
5.5	SILT, dark brown with organics, slightly plastic, grayish			
6.6	brown, wet, frozen, Nbn (non-visible ice, bonded with no			
7.0	excess moisture)			
	SILT with sand, -.375", blackish gray, moist, frozen			
	SILT with sand and gravel, -1", angular, blackish gray, moist, frozen	003		
	Silty SAND with gravel, -3" subangular, brownish gray, moist to wet, frozen			
	5% to 15% interstitial ice from 9 feet to 18 feet			
	COBBLES			
		004		
		005		
		006		
	COBBLES			
	COBBLES			
22.5	COBBLES	007		110
	BOULDERS			
26.5				
	CLAY, gray, frozen with 30% to 50% ice in 5mm to 15mm layers	008		7 8 8 6
30.0				

DEPTH (ft): 0.0, 4.0, 8.0, 12.0, 16.0, 20.0, 24.0, 28.0, 32.0, 36.0, 40.0

WATER LEVELS	
▽ WHILE DRILLING	Solid Stem Auger
▼ AT COMPLETION	2" OD Split Spoon (SPT)
▼ AFTER DRILLING	Split Spoon

Sheet 1 of 1

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FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/2/2014
DATE FINISHED: 5/2/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING B14-11

DRILL: CME-55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem

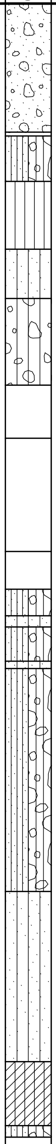
PROJECT: Denali Park Road

STATION, OFFSET:

NOTES:

LATITUDE (DEGREES): N 63° 43' 15.71" (63.72103°)
LONGITUDE (DEGREES): W -148° 58' 9.55" (-148.96932°)

TOTAL DEPTH: 30'



DEPTH (ft)	DESCRIPTION	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)
0.0	Poorly graded gravelly SAND, -3", fill, grayish brown, dry to moist	0027		
3.4	one layer of white polystyrene FOAM, compressed to 1.5"			
3.5	Silty SAND with gravel, -3", fill, grayish brown, moist, frozen	0028		
4.7	SILT, dark gray with organics, slightly plastic, moist to wet, frozen, Nbe (non-visible ice, bonded with excess moisture)	0029		
6.5	SILT with sand and gravel, -2", brownish gray, wet, frozen with 10% to 20% Vs (visible statified ice)			
7.8	SILT with gravel, -.75", greenish gray, wet, frozen	0030		
10.1	75% ICE with silt			
11.5	100% ICE, vertically oriented layering consistant with ice wedges			
14.5	SILT with 50% ice, greenish gray, wet, frozen			
15.5	Silty SAND with gravel, -3", fill, orange brown, wet, frozen Nbe to 30% ice			
16.2	Silty SAND, medium fine, light brown, wet, frozen Nbe to 30% ice	0031		
16.5	Silty SAND with gravel, -3", fill, orange brown, wet, frozen Nbe to 30% ice			
17.4	Silty SAND, medium fine, light brown, wet, frozen Nbe to 30% ice			
17.6	Silty SAND with gravel, -3", fill, orange brown, wet, frozen 5% to 20% ice COBBLES COBBLES COBBLES	0032		
23.5	SILT with sand, -.375", greenish gray, wet, frozen with 30% to 50% Vs			
28.0	silty CLAY with org, black gray, wet, frozen Nbe to 25% ice	0033		
29.7	Silty SAND with gravel, fill, orange brown, wet, frozen			
30.0				

WATER LEVELS
- ▽ WHILE DRILLING
- ▼ AT COMPLETION
- ▼ AFTER DRILLING

2" OD Split Spoon (SPT)
Split Spoon

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/1/2014
DATE FINISHED: 5/1/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING B14-12

DRILL: CME-55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem

PROJECT: Denali Park Road

STATION, OFFSET:

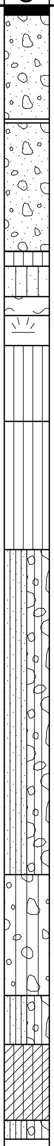
NOTES:

LATITUDE (DEGREES): N 63° 43' 15.28" (63.72091°)
LONGITUDE (DEGREES): W -148° 58' 9.70" (-148.96936°)

TOTAL DEPTH: 30'

DEPTH (ft)	DESCRIPTION
0.0	
0.3	ASPHALT 0.25 feet
	Poorly graded gravely SAND, -2.5", fill, brownish gray, dry to moist
3.0	moist to wet
3.1	one layer of white polystyrene FOAM, compressed to 1.5"
	Poorly graded gravely SAND, -.75", fill, grayish brown, dry to moist, frozen from 3.1 feet to 3.4 feet
6.5	
6.5	woven split fim GEOTEXTILE fabric
6.9	SILT with org, brownish black, slightly plastic, dry to moist, frozen
7.7	
8.2	SILT with sand, meduim fine, blackish gray, moist, frozen
9.0	organic SILT, brown, moist, frozen
	fine grain PEAT, moist, frozen from 8.2 feet to 8.6 feet
11.0	SILT, blackish gray, moist
	SILT with org, black, moist
14.4	
	Silty SAND with gravel, -3", brownish gray, dry to moist, frozen from 20.8 feet to 23 feet
	moist
	wet
23.0	
	SILT with gravel and org, -1", blackish gray, moist, frozen
26.2	
	Silty SAND with gravel, orange brown, wet, frozen 5% to 10% ice
27.5	silty CLAY , black gray, wet, frozen Nbe
29.5	
30.0	Silty SAND with gravel, brownish gray, frozen

GRAPHIC LOG



SAMPLE #	FIELD BLOW COUNT (Recovery)
0018	6 13 10 7
0019	1 18 23
0020	23 11 18 9 10
0021	
0022	
	1 2 4 10
0023	11 27 >50
0024	27 >50
0026	4 4 10 10

DEPTH (ft): 0.0, 4.0, 8.0, 12.0, 16.0, 20.0, 24.0, 28.0, 32.0, 36.0, 40.0

WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

2" OD Split Spoon (SPT)
Split Spoon

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/4/2014
DATE FINISHED: 5/4/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING SG14-01

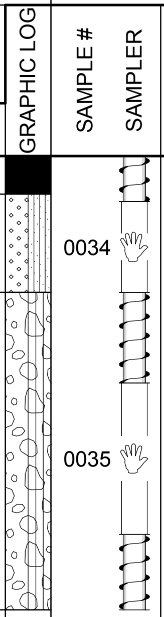
DRILL: CME-55
HAMMER:
DRILLING METHODS: Hollow Stem

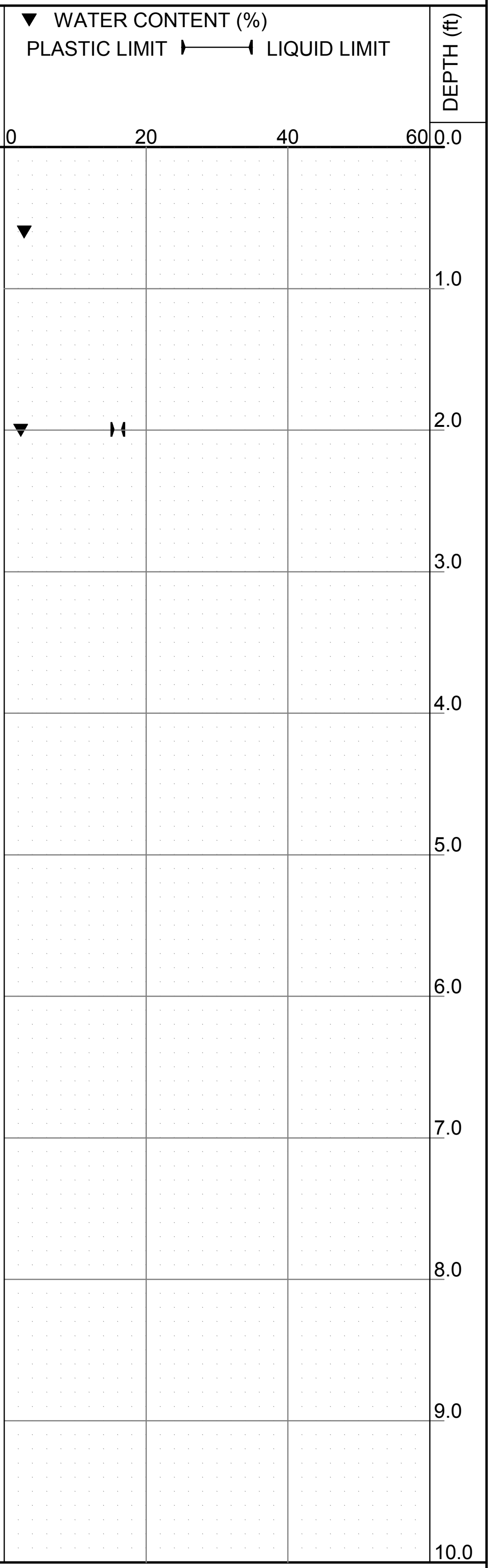
PROJECT: Denali Park Road
STATION, OFFSET: 3+50, 8' RT

NOTES: approx. MP 0.1

LATITUDE (DEGREES): N 63° 43' 45.34" (63.72926°)
LONGITUDE (DEGREES): W -148° 53' 17.59" (-148.88822°)
TOTAL DEPTH: 3'

DEPTH (ft)	DESCRIPTION	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)
0.0	ASPHALT 0.25 feet.		Hollow Stem Auger	
0.3	Well-graded SAND with silt and gravel (SW-SM), grayish brown, dry to moist. Fill. A-1-a	0034	Grab Sample	
0.9	Poorly graded GRAVEL with silt and sand (GP-GM), grayish brown, dry to moist. Fill. A-1-a	0035	Grab Sample	
3.0	Bottom of hole at 3 feet.			





WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Grab Sample
Hollow Stem Auger

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FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/4/2014
DATE FINISHED: 5/4/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

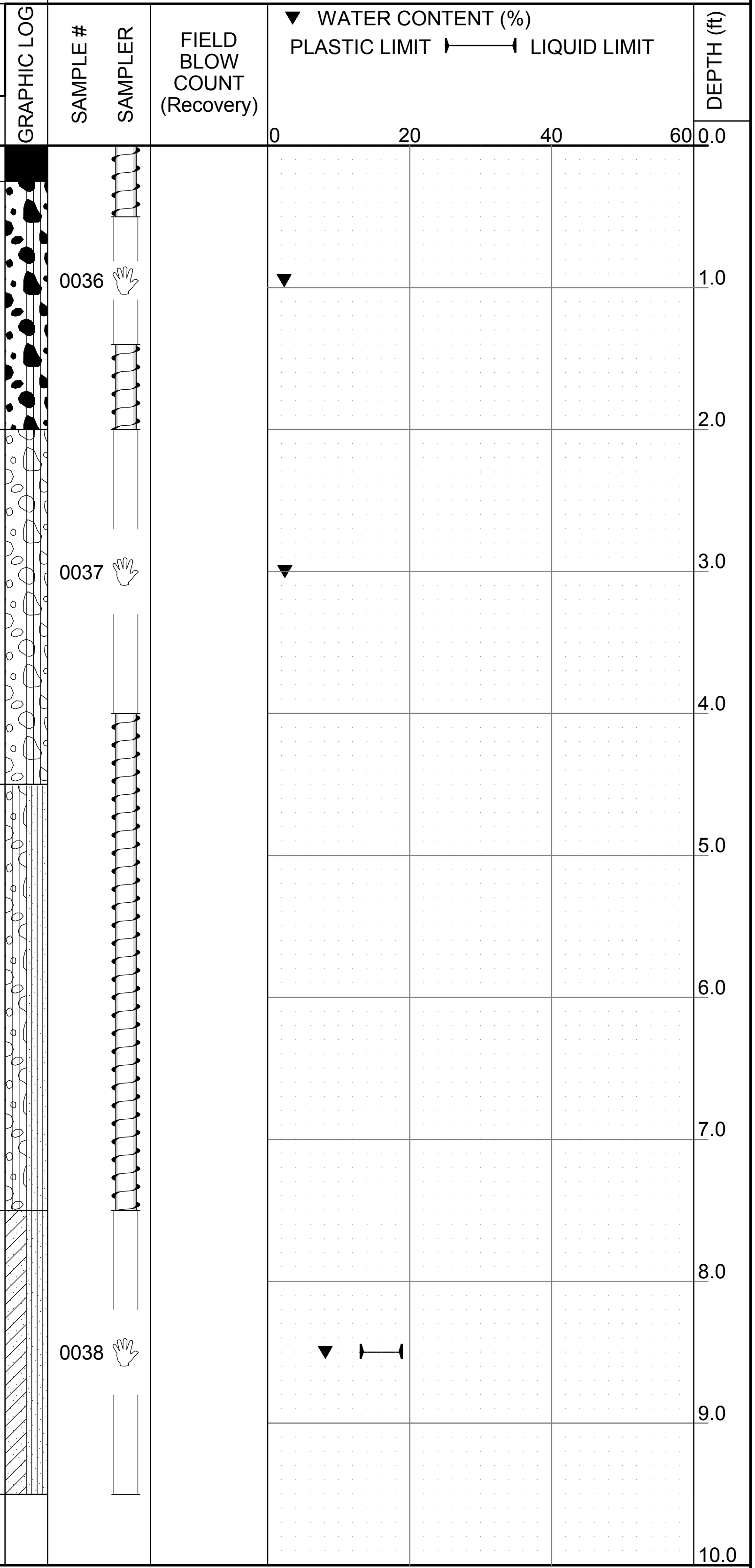
BORING SG14-02

DRILL: CME-55
HAMMER:
DRILLING METHODS: Hollow Stem

PROJECT: Denali Park Road
NOTES: approx. MP 0.3
STATION, OFFSET: 17+20, 7' RT

LATITUDE (DEGREES): N 63° 43' 56.78" (63.73244°)
LONGITUDE (DEGREES): W -148° 53' 33.65" (-148.89268°)
TOTAL DEPTH: 9.5'

DEPTH (ft)	DESCRIPTION
0.0	
0.3	ASPHALT 0.25 feet
	Well-graded GRAVEL with silt and sand (GW-GM), grayish brown, dry to moist. Fill. A-1-a
2.0	Poorly graded GRAVEL with silt and sand (GP-GM), grayish brown, dry to moist. Fill. A-1-a
4.5	Non-woven GEOTEXTILE fabric at 4.5 feet. Silty GRAVEL with sand and cobbles, brownish gray, dry to moist.
7.5	Silty clayey SAND (SC-SM), brownish gray, medium dense, moist. A-4
9.5	Bottom of hole at 9.5 feet.



WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Grab Sample
Hollow Stem Auger

Sheet 1 of 1

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/8/2014
DATE FINISHED: 5/8/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

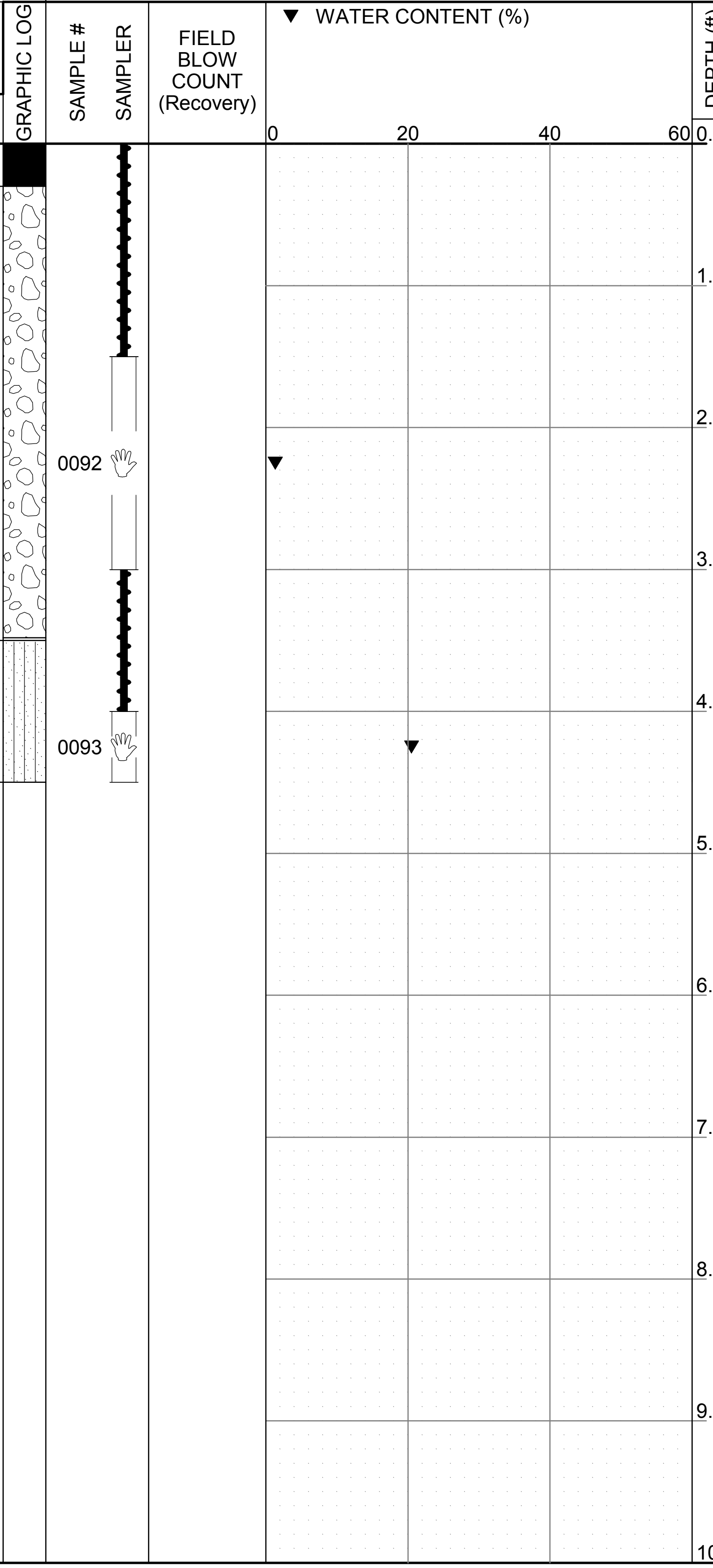
BORING SG14-03

DRILL: CME-55
HAMMER:
DRILLING METHODS: Solid Flight

PROJECT: Denali Park Road
STATION, OFFSET: 37+30, LT lane
NOTES: approx. MP 0.7

LATITUDE (DEGREES): N 63° 44' 11.87" (63.73663°)
LONGITUDE (DEGREES): W -148° 54' 0.22" (-148.90006°)
TOTAL DEPTH: 4.5'

DEPTH (ft)	DESCRIPTION
0.0	ASPHALT 0.3 feet.
0.3	Poorly graded GRAVEL (GP), grayish brown, dry to moist. Fill. A-1-a
3.5	Nonwoven GEOTEXTILE at 3.5 feet.
3.5	Silty SAND (SM), grayish brown to gray, moist to wet, frozen. A-4
4.5	Bottom of hole at 4.5 feet.



WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Solid Stem Auger
Grab Sample

Sheet 1 of 1

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FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/8/2014
DATE FINISHED: 5/8/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING SG14-04

DRILL: CME-55
HAMMER:
DRILLING METHODS: Solid Flight

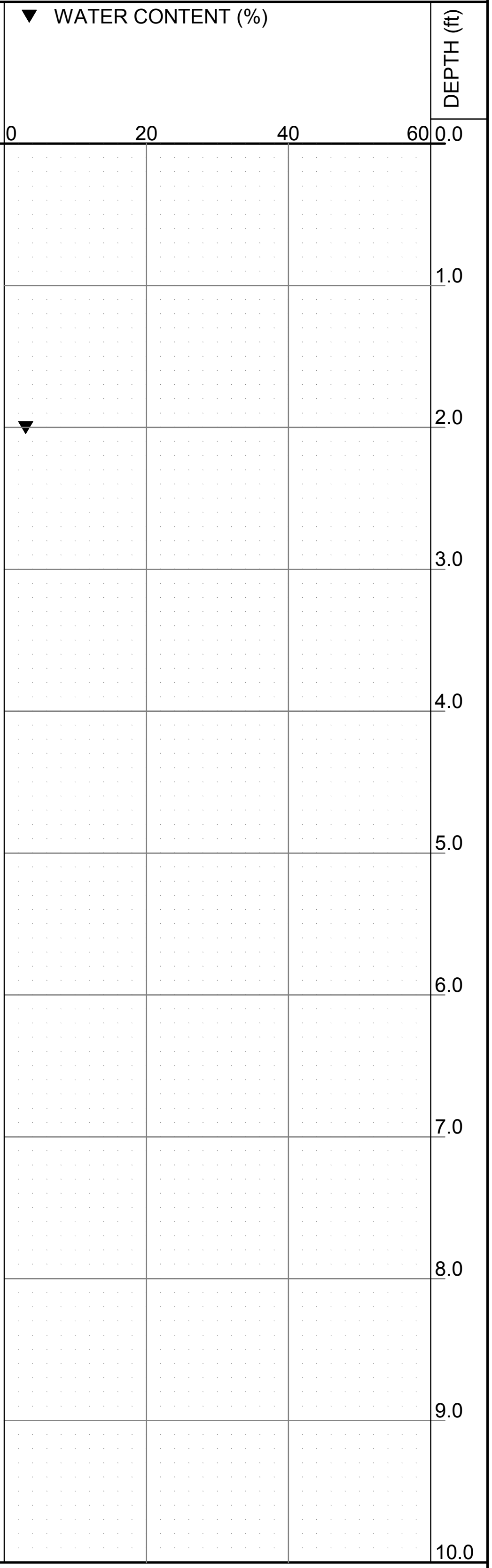
PROJECT: Denali Park Road
STATION, OFFSET: 70+30, 7' RT

NOTES: approx. MP 1.4

LATITUDE (DEGREES): N 63° 44' 4.38" (63.73455°)
LONGITUDE (DEGREES): W -148° 54' 56.77" (-148.91577°)

TOTAL DEPTH: 4.5'

DEPTH (ft)	DESCRIPTION	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)
0.0	ASPHALT 0.25 feet.		Solid Stem Auger	
0.3	Poorly graded gravely SAND, black, oil treated, dry to moist. Fill.		Solid Stem Auger	
1.5	Poorly graded GRAVEL with silt and sand (GP-GM), dark brown, dry to moist. Fill. A-1-a	0094	Grab Sample	
2.5	SILT with very fine sand, light brown, moist to wet.		Solid Stem Auger	
3.5	SILT with sand and gravel, brownish tan, moist to wet.		Solid Stem Auger	
4.5	Bottom of hole at 4.5 feet.			



WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Solid Stem Auger
Grab Sample

Sheet 1 of 1

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FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/8/2014
DATE FINISHED: 5/8/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING SG14-05

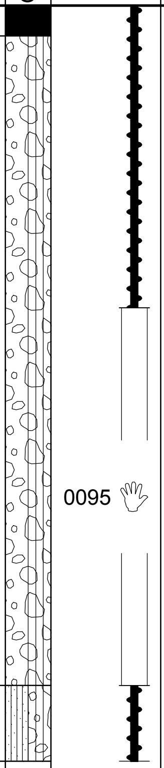
DRILL: CME-55
HAMMER:
DRILLING METHODS: Solid Flight

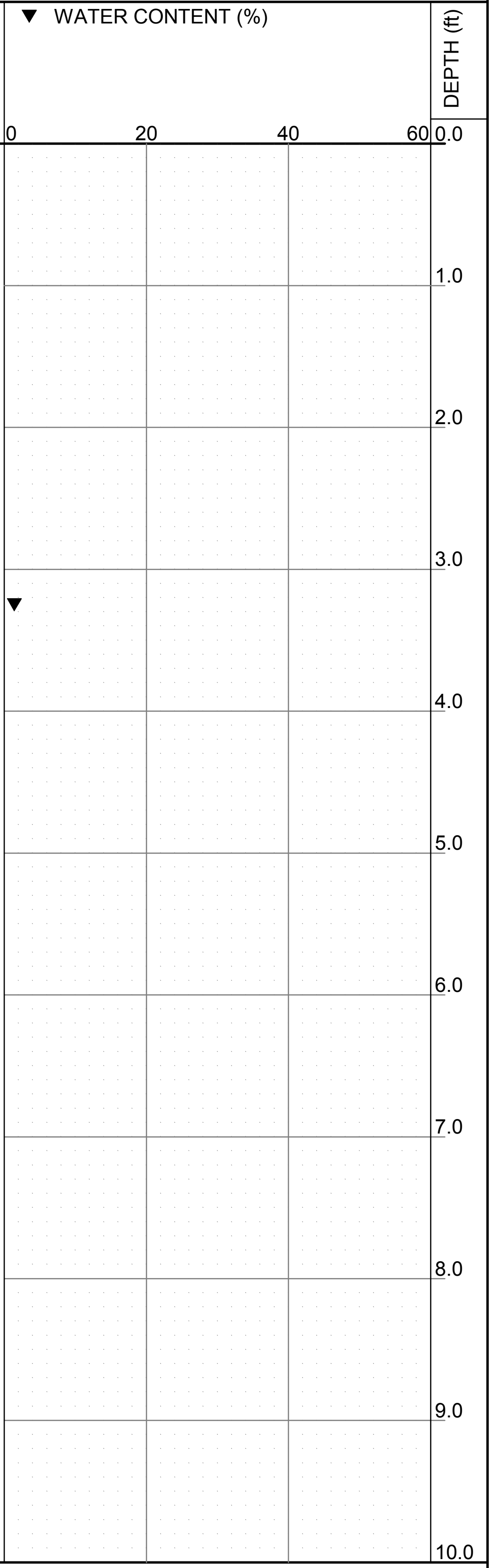
PROJECT: Denali Park Road
STATION, OFFSET: 106+00, LT lane

NOTES: approx. MP 2.0

LATITUDE (DEGREES): N 63° 43' 36.62" (63.72684°)
LONGITUDE (DEGREES): W -148° 55' 24.02" (-148.92334°)
TOTAL DEPTH: 5'

DEPTH (ft)	DESCRIPTION	SAMPLE #	FIELD BLOW COUNT (Recovery)
0.0			
0.2	ASPHALT 0.2 feet.		
	Poorly graded GRAVEL with silt and sand (GP-GM), fill, grayish brown, dry to moist. FIll. A-1-a	0095	
4.5	Silty SAND with gravel, brownish gray, moist to wet.		
5.0	Bottom of hole at 5 feet.		





WATER LEVELS	
▽ WHILE DRILLING	Solid Stem Auger
▼ AT COMPLETION	Grab Sample
▼ AFTER DRILLING	

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/7/2014
DATE FINISHED: 5/7/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING SG14-06

DRILL: CME-55
HAMMER: Automatic
DRILLING METHODS: Solid Flight

PROJECT: Denali Park Road

NOTES: approx. MP 2.3

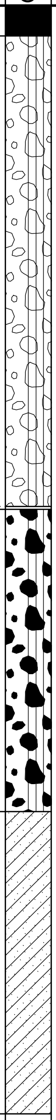
STATION, OFFSET: 121+00, RT lane

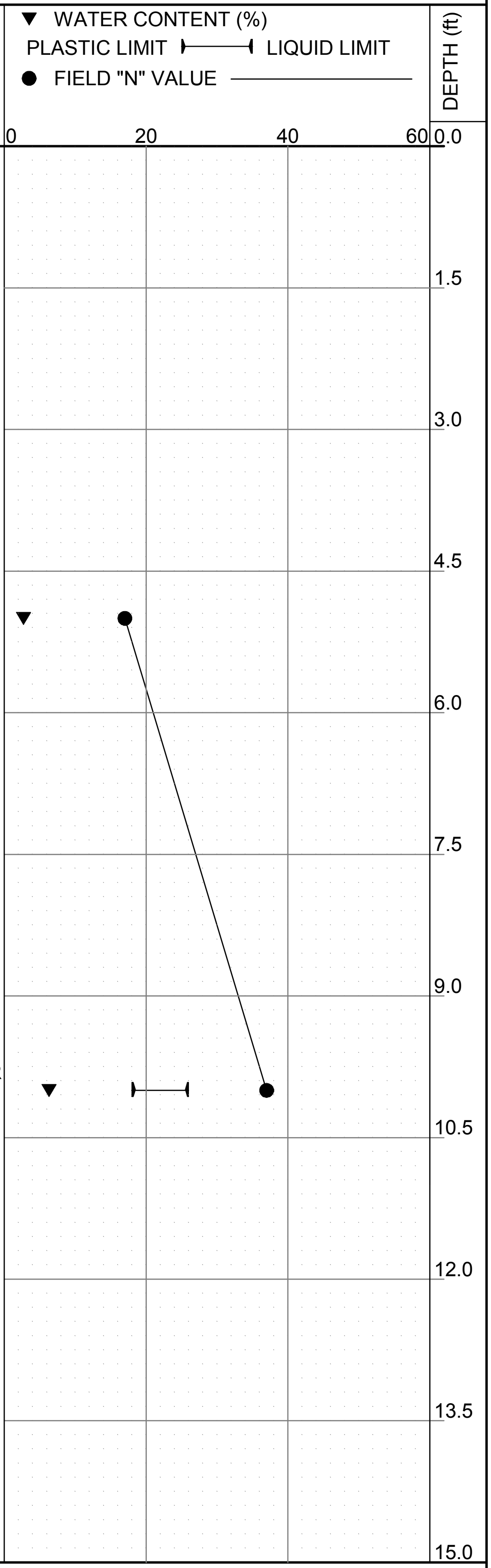
LATITUDE (DEGREES): N 63° 43' 31.55" (63.72543°)
LONGITUDE (DEGREES): W -148° 56' 1.46" (-148.93374°)

TOTAL DEPTH: 11'

DEPTH (ft)	DESCRIPTION	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)
0.0				
0.3	ASPHALT 0.3 feet.			
	Poorly graded GRAVEL with silt and sand (GP-GM), grayish brown, dry to moist. Fill. A-1-a	0074	Grab Sample	
5.0	Woven GEOTEXTILE at 5 feet.			
5.0	Well-graded GRAVEL with silt and sand (GW-GM), orange to tan, dry, frozen from 7.5 to 11 feet. Soil appears to be decomposed bedrock. A-1-a	0075	2" OD Split Spoon (SPT)	10-10-7-11
8.0	Clayey SAND (SC), pale purple, dry, frozen. Soil appears to be decomposed to highly weathered phyllite. A-4	0076	2" OD Split Spoon (SPT)	6-18-19-50R
11.0	Bottom of hole at 11 feet.			

GRAPHIC LOG





WATER LEVELS	
▽ WHILE DRILLING	Solid Stem Auger
▼ AT COMPLETION	Grab Sample
▼ AFTER DRILLING	2" OD Split Spoon (SPT)

Sheet 1 of 1

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/9/2014
DATE FINISHED: 5/9/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING SG14-07

DRILL: CME-55
HAMMER:
DRILLING METHODS: Solid Flight

PROJECT: Denali Park Road
STATION, OFFSET: 144+00, 10' RT

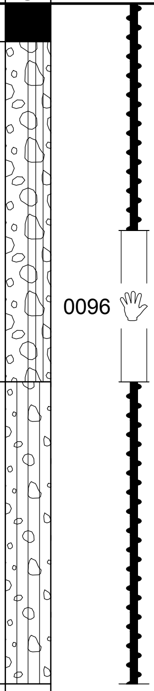
NOTES: approx. MP 2.7

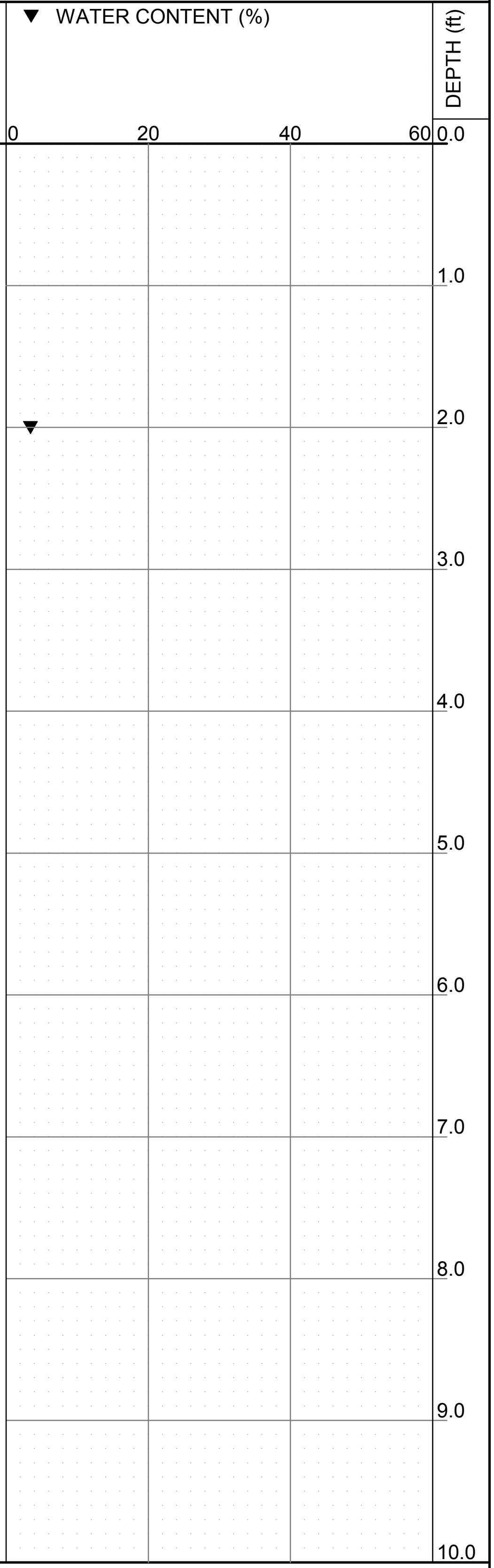
LATITUDE (DEGREES): N 63° 43' 26.15" (63.72393°)
LONGITUDE (DEGREES): W -148° 56' 48.91" (-148.94692°)

TOTAL DEPTH: 4.5'

DEPTH (ft)	DESCRIPTION	SAMPLE #	SAMPLER	FIELD BLOW COUNT (Recovery)
0.0	ASPHALT 0.25 feet			
0.3	Poorly graded GRAVEL with silt and sand (GP-GM), gray black, dry to moist. Fill. A-1-a	0096	🖐	
2.5	SILT with sand and gravel, gray tan, moist. Soil is weathered bedrock.			
4.5	Bottom of hole at 4.5 feet.			

GRAPHIC LOG





WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Solid Stem Auger
Grab Sample

Sheet 1 of 1

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FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/9/2014
DATE FINISHED: 5/9/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING SG14-08

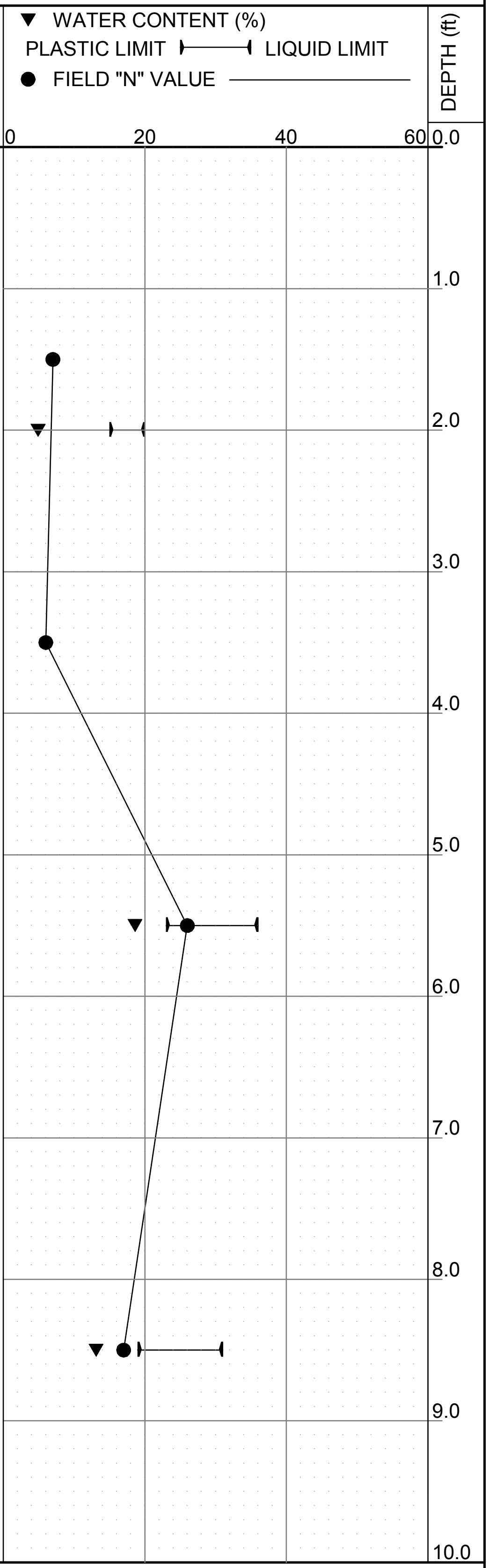
DRILL: CME-55
HAMMER: Automatic
DRILLING METHODS: Hollow Stem

PROJECT: Denali Park Road
STATION, OFFSET: 188+75, 7' LT

NOTES: approx. MP 3.5

LATITUDE (DEGREES): N 63° 43' 16.90" (63.72136°)
LONGITUDE (DEGREES): W -148° 58' 20.03" (-148.97223°)
TOTAL DEPTH: 9.5'

DEPTH (ft)	DESCRIPTION	SAMPLE #	FIELD BLOW COUNT (Recovery)
0.0			
0.2	ASPHALT 0.2 feet.		
	Silty clayey SAND with gravel (SC-SM), blackish gray to grayish brown, dry to moist. A-1-b		
			3-4-3-2
		0097	
2.5	SILT with sand and gravel, high organics, brown, moist. Frozen from 2.6 feet.		
3.0	Organic SILT, brown, moist, frozen.		
3.3	Clayey SAND with gravel (SC), high organics, brown moist. Frozen to 9.2 feet. A-6, A-2-6		1-2-4-5
		0098	6-13-13-22
	cobble		
		0099	4-11-6-5
9.5	Bottom of hole at 9.5 feet.		



WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Grab Sample
Hollow Stem Auger
2" OD Split Spoon (SPT)

Sheet 1 of 1

File: I:\TECH SERVICES\GEOTECHNICAL SERVICES\001 PROPOSED NEW FILE STRUCTURE\04 BORING LOGS\ALASKA\DENALI PARK ROAD 2014.GPJ Lib: I:\TECH SERVICES\GEOTECHNICAL SERVICES\GINT\LIBRARY\FHWALIBRARY.GLB Printed: 11/18/2016

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/9/2014
DATE FINISHED: 5/9/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

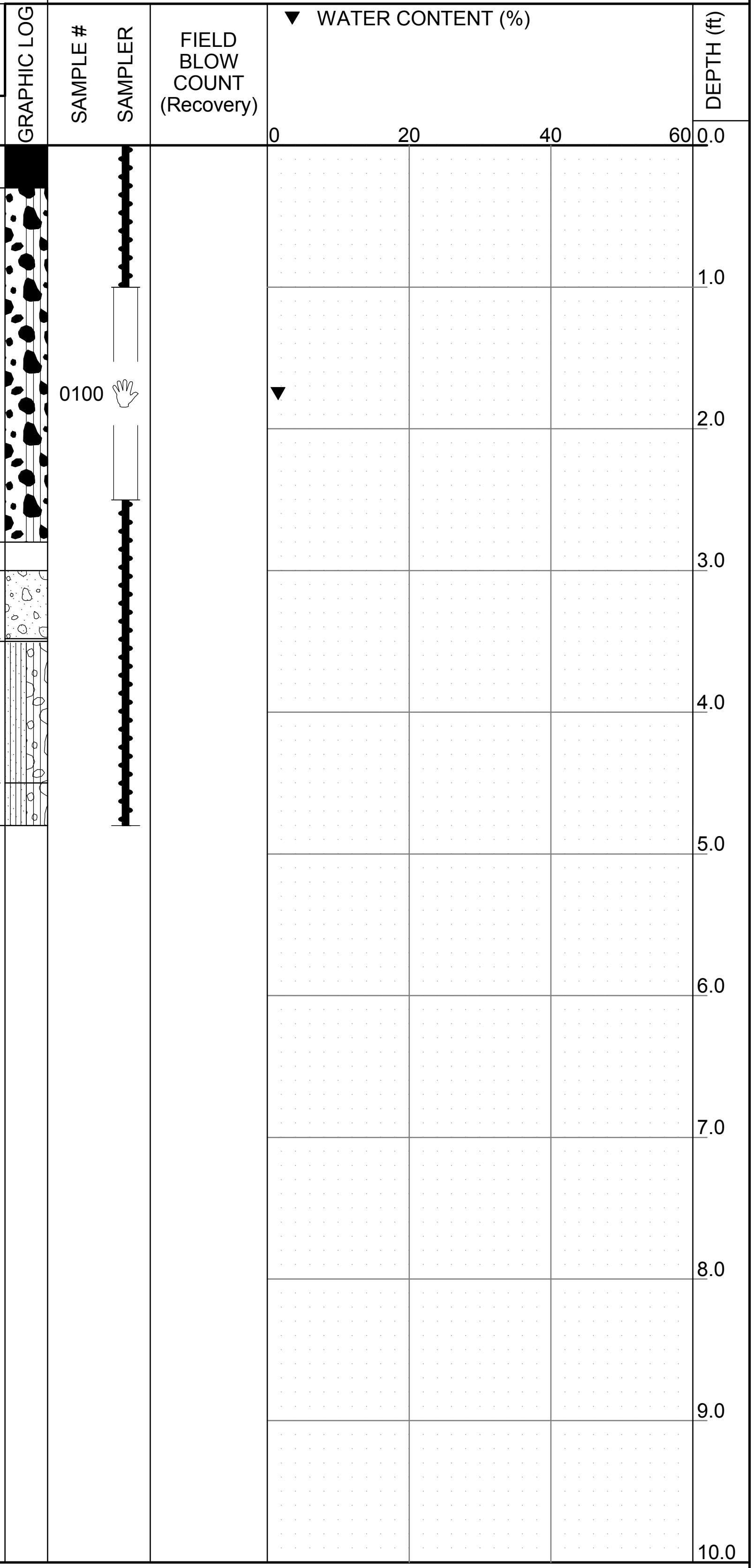
BORING SG14-09

DRILL: CME-55
HAMMER:
DRILLING METHODS: Solid Flight

PROJECT: Denali Park Road
STATION, OFFSET: 210+50, RT lane
NOTES: approx. MP 4

LATITUDE (DEGREES): N 63° 43' 10.34" (63.71954°)
LONGITUDE (DEGREES): W -148° 59' 2.94" (-148.98415°)
TOTAL DEPTH: 4.8'

DEPTH (ft)	DESCRIPTION	SAMPLE #	FIELD BLOW COUNT (Recovery)
0.0	ASPHALT 0.3 feet.		
0.3	Well-graded GRAVEL with silt and sand (GW-GM), grayish brown, dry to moist. Fill. A-1-a	0100	
2.8	Pink foam.		
3.0	Poorly graded gravelly SAND, grayish brown, dry to moist. Fill. Woven GEOTEXTILE at 3.5 feet.		
3.5 3.5	Silty SAND with gravel, brownish gray, dry to moist. Fill, frozen from 4.3 feet.		
4.5	Non-woven GEOTEXTILE at 4.5 feet.		
4.8	Bottom of hole at 4.8 feet.		



WATER LEVELS	
▽ WHILE DRILLING	Solid Stem Auger
▼ AT COMPLETION	Grab Sample
▼ AFTER DRILLING	

Sheet 1 of 1

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FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (US Customary Units)

DATE STARTED: 5/8/2014
DATE FINISHED: 5/8/2014
DRILLER: Shad Parker
COMPANY: Alaska DOT
LOGGER: Kevin Maxwell
WEATHER:

BORING SG14-14

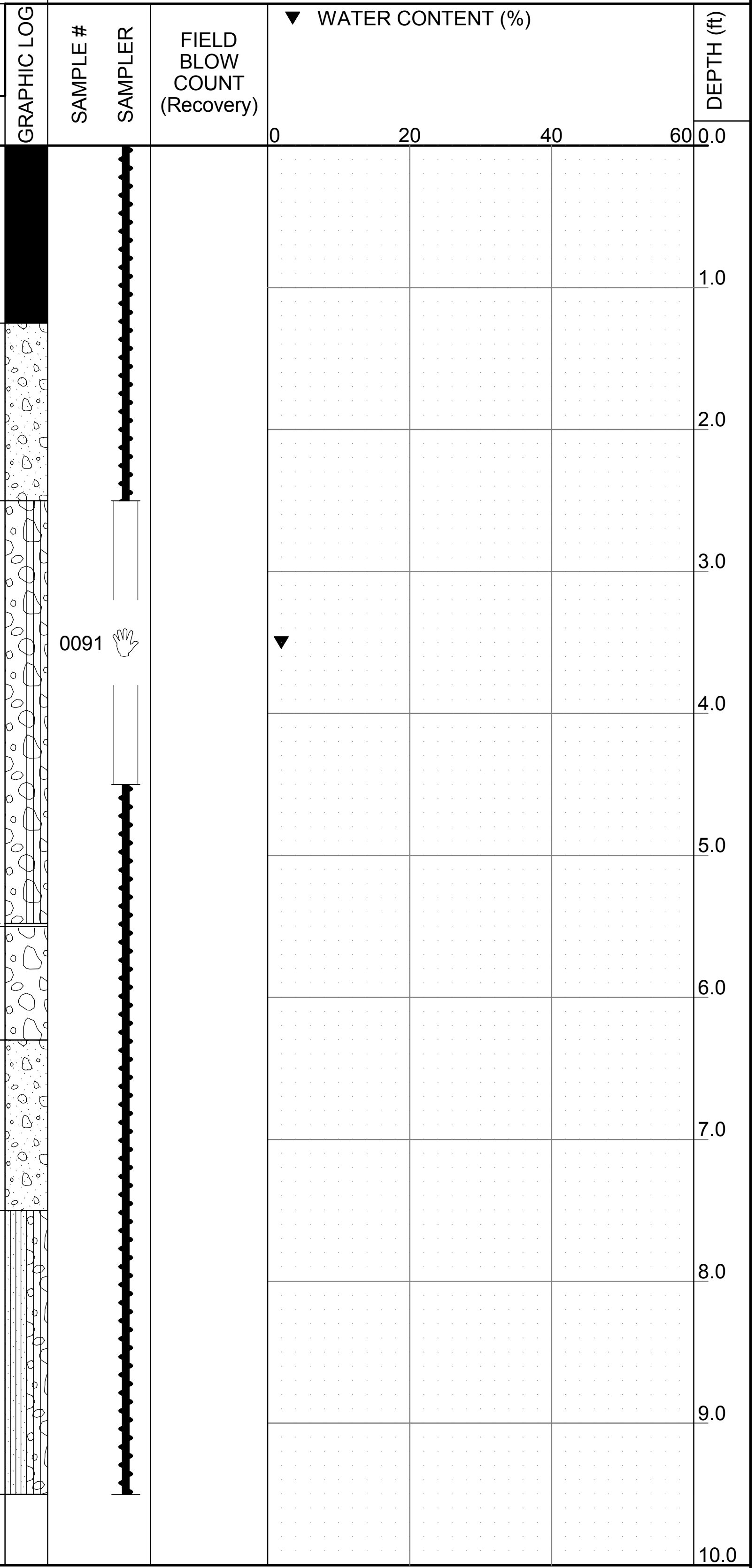
DRILL: CME-55
HAMMER:
DRILLING METHODS: Solid Flight

PROJECT: Denali Park Road
STATION, OFFSET: 22+80, 7' RT

NOTES: approx. MP 0.4

LATITUDE (DEGREES): N 63° 44' 0.85" (63.73357°)
LONGITUDE (DEGREES): W -148° 53' 38.65" (-148.89407°)
TOTAL DEPTH: 9.5'

DEPTH (ft)	DESCRIPTION
0.0	ASPHALT 1.25 feet
1.3	Poorly graded gravely SAND, black, oil treated, dry to moist. Fill.
2.5	Poorly graded GRAVEL with silt and sand (GP-GM), dark brown, dry to moist. Fill. A-1-a
5.5	Nonwoven GEOTEXTILE at 5.5 feet.
5.5	Poorly graded GRAVEL, greenish gray, dry to moist. Fill.
6.3	Poorly graded gravely SAND, grayish brown, dry to moist.
7.5	Silty SAND with gravel and cobbles, brownish gray, dry to moist.
9.5	Bottom of hole at 9.5 feet.



WATER LEVELS
▽ WHILE DRILLING
▼ AT COMPLETION
▼ AFTER DRILLING

Solid Stem Auger
Grab Sample

Sheet 1 of 1

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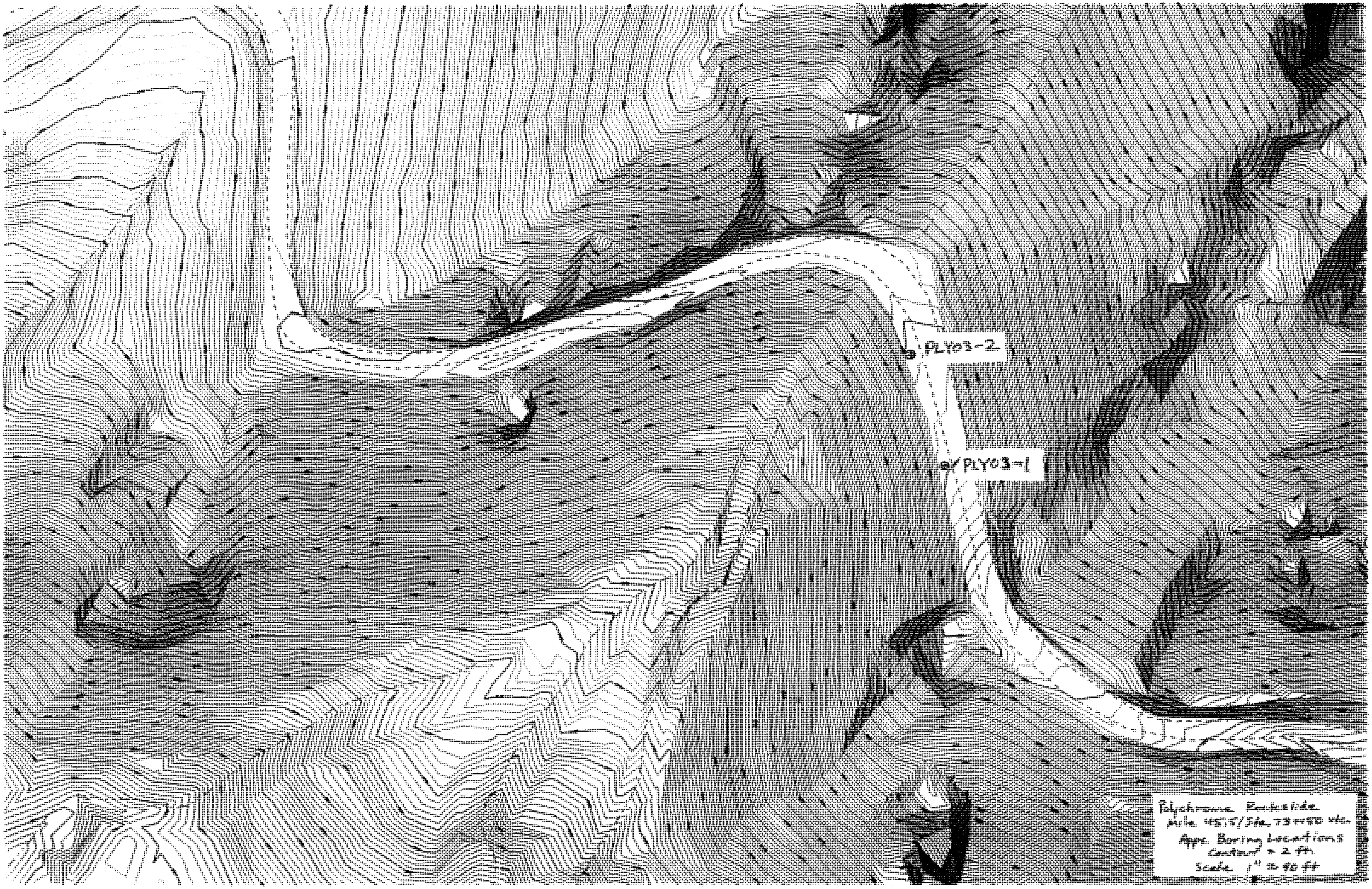

PLY03-2
PLY03-1
Polychrome Rockslide
Mile 45.5/Sta. 73+50 vic.
Appr. Boring Locations
Contour = 2 ft.
Scale 1" = 40 ft

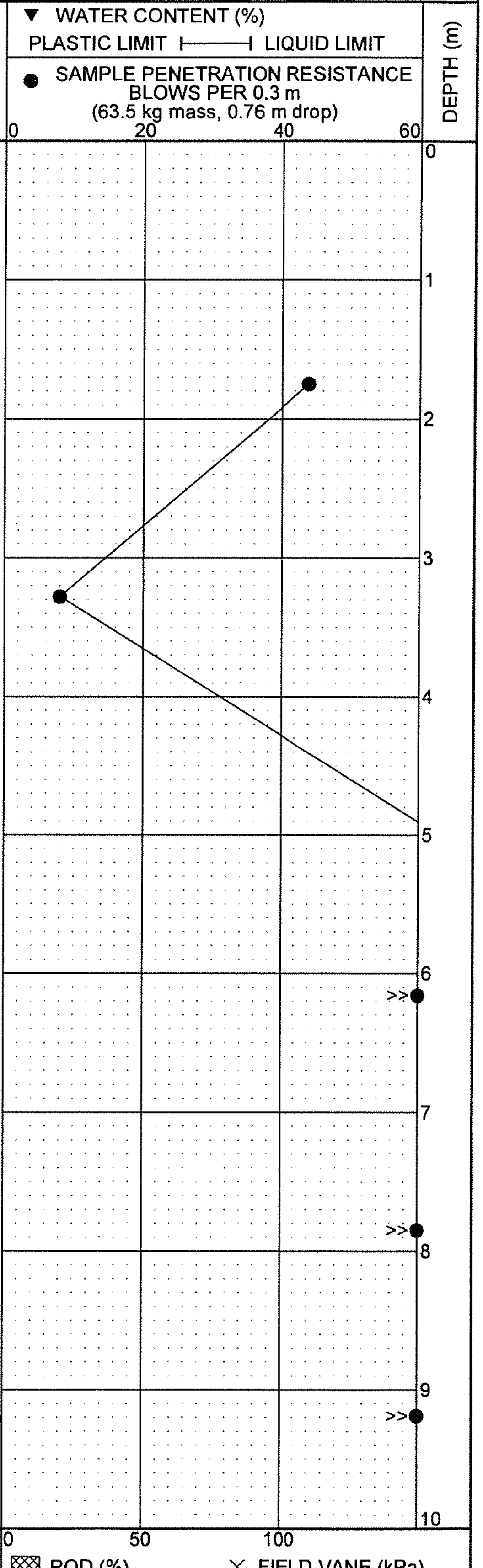
FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (Metric Units)

152 mm H-S AUGER ☐
203 mm H-S AUGER ☐
NQ CORE ☐
HQ CORE ☐
OTHER:

BEGAN: 6/25/03
COMPLETED: 6/26/03
DRILL: CS1000
DRILLER: Chris Peterson
WEATHER:

DEPTH (m)	DESCRIPTION ELEV:	GRAPHIC LOG	SAMPLE #	SAMPLE	BLOW COUNT
0	Gravely to 1.07 m. 1.07 m to 1.52 m cobbles, gravel, possible boulder. Return water changed gray to brown.		R-1		
1.5	Tan-rust and multicolored silty sandy gravel or gravely sand (damp).		SPT-1		16-17-27
2.0	Looser, soft 2.13 m to 3.05 m. Lost return water at 2.9 m.		R-2		
3.1	Light tan sandy gravel, trace of silt. Angular to subangular rhyolite gravels.		SPT-2		8-4-4
3.5	Very soft between cobbles, it will jack the drill up, so voids unlikely. Granular, loose, smoother at 5.56 m, less soft zones.		R-3		
6.1	Tan sandy, small gravely, silt, frozen, pieces of ice visible to 12.7 mm. Approximately 90% ice.		SPT-3		50/127mm
6.2	Cobbly, loose matrix, permafrost?		R-4		
7.6	85% ice, tan silty sand with a few small gravels.		SPT-4		41-25-37
8.1	Same.		R-5		
9.1	Silty sand, approximately 85% ice.		SPT-5		50/101.6 mm
9.2	Drilled like permafrost.				



1.75 in O.D. SPLIT TUBE SAMPLE
2 in O.D. SPLIT TUBE SAMPLE (SPT)
3.25 in O.D. SPLIT TUBE SAMPLE (D & M)
3 in SHELBY TUBE
AUGER
CORE
WATER LEVEL
▨ RQD (%)
▒ RECOVERY (%)
UNCONFINED COMPR. STRENGTH (MPa)
× FIELD VANE (kPa)
✚ POCKET PEN (kPa)

PROJECT: Denali National Park
STATION, OFFSET:

BORING PLY03-1
Sheet 1 of 2

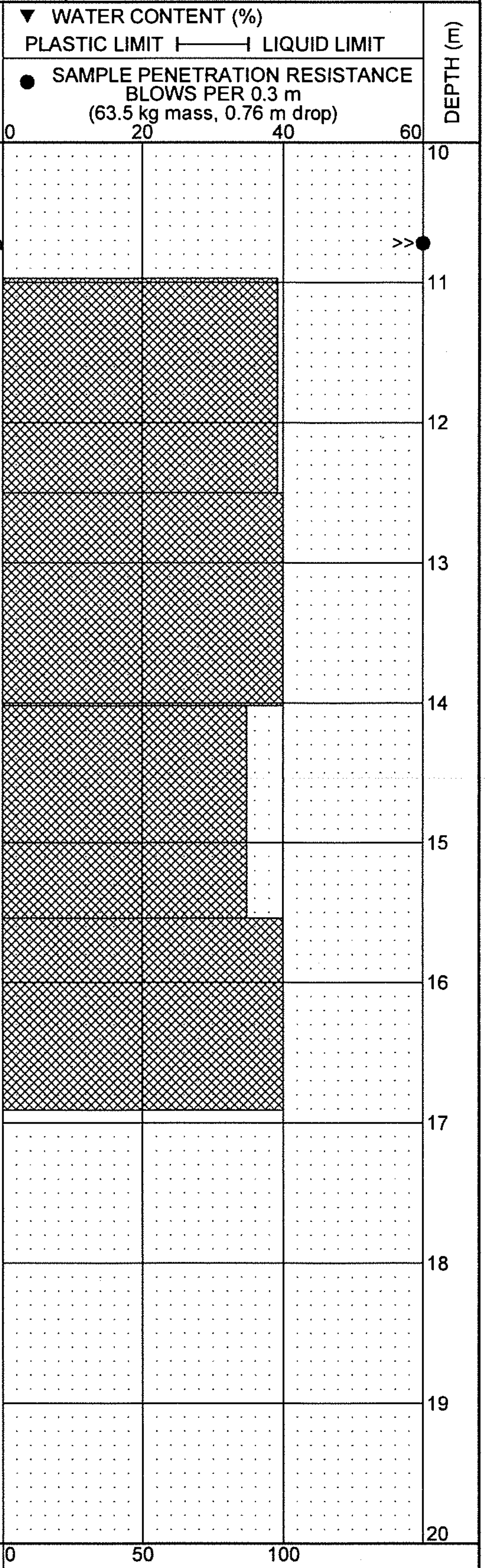
FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (Metric Units)

152 mm H-S AUGER ☐
203 mm H-S AUGER ☐
NQ CORE ☐
HQ CORE ☐
OTHER:

BEGAN: 6/25/03
COMPLETED: 6/26/03
DRILL: CS1000
DRILLER: Chris Peterson
WEATHER:

DEPTH (m)	DESCRIPTION	GRAPHIC LOG	SAMPLE #	SAMPLE	BLOW COUNT
			R-6		
10.7 10.8 11.0	76.2 mm silty sandy ice, few gravels. 25.4 mm silty sand (frozen).		SPT-6 R-7		50/101.6 mm
	Same. **change to core**				
12.5	50.8 mm gravel angled 76.2 mm x 127 mm. Green fine sandy, silty clay, few small rock fragments (damp). 1358.9 mm highly weathered, very close to closely fractured, very soft rhyolite, decomposed in horizontal and vertical fractures. Rock is at freezing temperature. 152.4 mm below rock surface is a 76.2 mm decomposed zone. Bedrock.		R-8		
14.0	Light, tan gray moderately weathered soft rock, extremely close to very close, vertical and horizontal fracturing decomposed in fractures to 12.7 mm.		R-9		
15.5	Light tan-white highly weathered decomposed in fractures. Pockets of decomposition through, small voids. Last 152.4 mm is 40 to 50% of full diameter. Picked up 203.2 mm core on R-11		R-10		
16.9	Highly weathered close fracturing. Decomposition in horizontal and vertical fractures.		R-11		
	BORING TERMINATED AT A DEPTH OF 16.91 M				



1.75 in O.D. SPLIT TUBE SAMPLE
2 in O.D. SPLIT TUBE SAMPLE (SPT)
3.25 in O.D. SPLIT TUBE SAMPLE (D & M)
3 in SHELBY TUBE
AUGER
CORE
WATER LEVEL

▨ RQD (%)
▨ RECOVERY (%)
× FIELD VANE (kPa)
✚ POCKET PEN (kPa)
▨ UNCONFINED COMPR. STRENGTH (MPa)

PROJECT: Denali National Park
STATION, OFFSET:

BORING PLY03-1

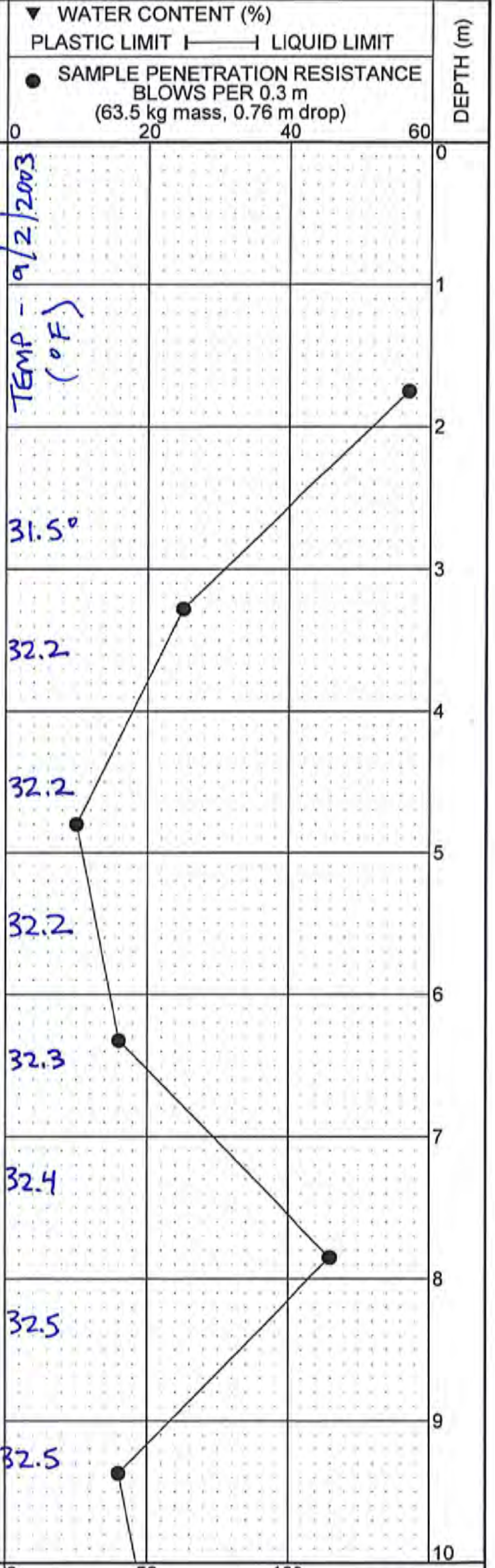
FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (Metric Units)

152 mm H-S AUGER ☐
203 mm H-S AUGER ☐
NQ CORE ☐
HQ CORE ☐
OTHER:

BEGAN: 6/27/03
COMPLETED: 6/1/03
DRILL: CS1000
DRILLER: Chris Peterson
WEATHER:

DEPTH (m)	DESCRIPTION ELEV:	GRAPHIC LOG	SAMPLE #	SAMPLE	BLOW COUNT
0	Gravely soils, some cobble and possible boulder, very dense.		R-1		
1.5	Brown sand, silty, gravel. Gravel is tan-cream rhyolite. Few pieces gray basalt, angular to subangular (damp). Last 63.5 mm changes to silty, sandy gravel.		SPT-1		12-25-32
2.0	More cobbles, looser matrix.		R-2		
3.1	Brown and multicolored silty, sandy, gravel (damp).		SPT-2		6-13-12
3.5	Gravely cobbles in loose soil matrix.		R-3		
4.6	Same, except gravel is mostly angular basalt.		SPT-3		7-5-5
5.0	Same.		R-4		
6.1	Sandy, gravel, trace of silt. Gravel mostly light cream colored rhyolite.		SPT-4		8-8-8
6.6	Same.		R-5		
7.6	Tan silty, sandy, gravel, less gravel than last 2 SPT's.		SPT-5		13-38-8
8.1	Loose gravely soils.		R-6		
9.1	Tan silty, sandy, gravel. Gravel is angular purple rhyolite.		SPT-6		15-8-8
9.6	Same.				



0 50 100
▩ RQD (%)
▨ RECOVERY (%)
▧ UNCONFINED COMPR. STRENGTH (MPa)
× FIELD VANE (kPa)
✚ POCKET PEN (kPa)

1.75 in O.D. SPLIT TUBE SAMPLE
2 in O.D. SPLIT TUBE SAMPLE (SPT)
3.25 in O.D. SPLIT TUBE SAMPLE (D & M)
3 in SHELBY TUBE
AUGER
CORE
▽ WATER LEVEL

PROJECT: Denali National Park
STATION, OFFSET:

BORING PLY03-2
Sheet 1 of 4

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (Metric Units)

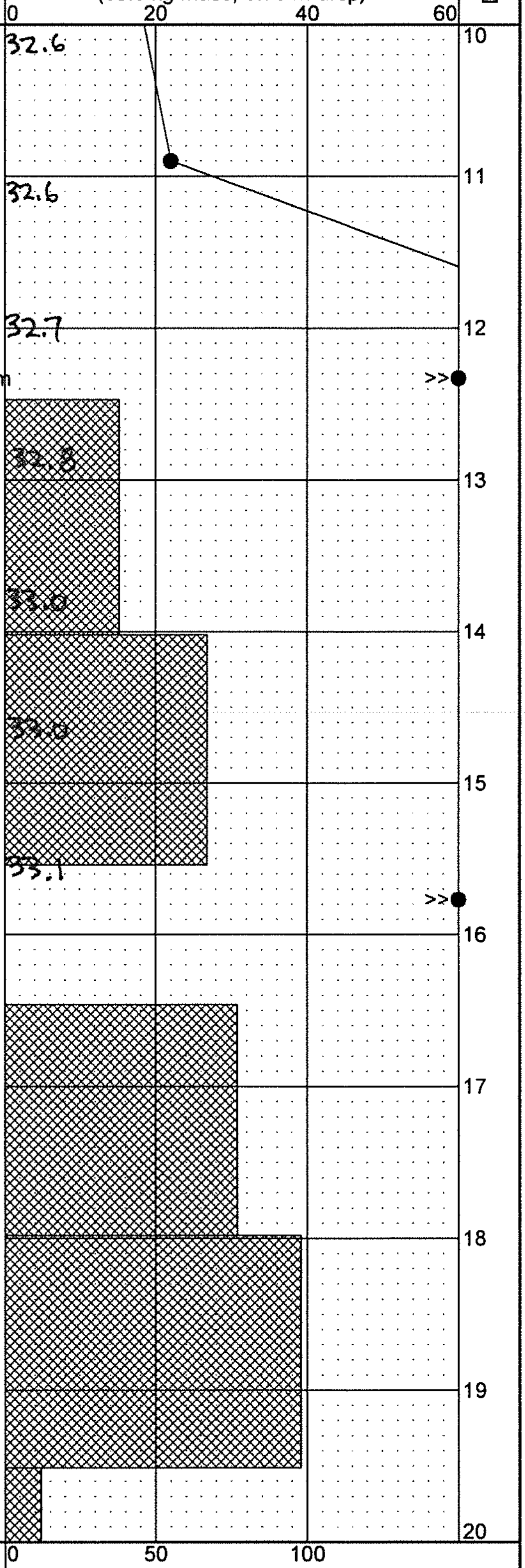
152 mm H-S AUGER ☐
203 mm H-S AUGER ☐
NQ CORE ☐
HQ CORE ☐
OTHER:

BEGAN: 6/27/03
COMPLETED: 6/1/03
DRILL: CS1000
DRILLER: Chris Peterson
WEATHER:

DEPTH (m)	DESCRIPTION	GRAPHIC LOG	SAMPLE #	SAMPLE	BLOW COUNT
			R-7		
10.7	Tan-cream and multicolored silty, sandy, gravel with a trace of clay. Gravels vary purple-tan-dark gray angular to subangular.		SPT-7		14-11-11
11.1	Slightly denser.		R-8		
12.2	Tan silty sandy, gravel and ice.		SPT-8		18-50/127 mm
12.5	**change to core** Tan silty, sandy gravels and a small cobble, gravels mostly. Light tan and a few purple rhyolite and a coupl small basalt gravels (frozen). Didn't recover much ice.		R-9		
14.0	Tan and multicolored silty, sandy, cobbly, gravel. Multirock type angular to subangular (frozen <10%).		R-10		
15.5	Tan silty, gravely sandy ice, core runs are minus melted ice.		SPT-9		23-36-30
16.0	Tan and multicolored silty, sandy, gravel, approximately 20% ice.		R-11 R-12		
18.0	177.8 mm sandy, silty, gravel red-tan. 1320.8 mm silty, sandy, cobbly, gravel with solid ice zones to 177.8 mm. Approximately 70% ice (chipped ice out and tossed).		R-13		
19.5	Few gravels subrounded with trace of sandy silt on some surfaces.				

▼ WATER CONTENT (%)
PLASTIC LIMIT ⊢—⊣ LIQUID LIMIT
● SAMPLE PENETRATION RESISTANCE BLOWS PER 0.3 m (63.5 kg mass, 0.76 m drop)

DEPTH (m)



1.75 in O.D. SPLIT TUBE SAMPLE
2 in O.D. SPLIT TUBE SAMPLE (SPT)
3.25 in O.D. SPLIT TUBE SAMPLE (D & M)
3 in SHELBY TUBE
AUGER
CORE
WATER LEVEL

▨ RQD (%)
▒ RECOVERY (%)
× FIELD VANE (kPa)
✚ POCKET PEN (kPa)
⊠ UNCONFINED COMPR. STRENGTH (MPa)

PROJECT: Denali National Park
STATION, OFFSET:

BORING PLY03-2

FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

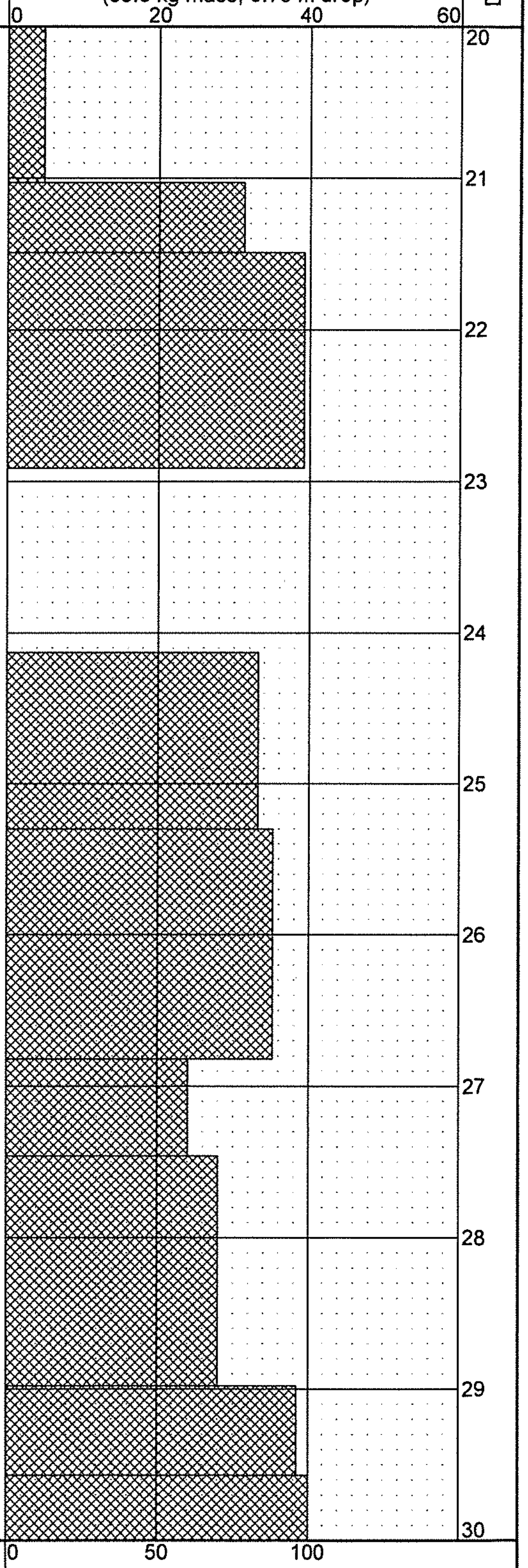
BORING LOG (Metric Units)

152 mm H-S AUGER ☐
203 mm H-S AUGER ☐
NQ CORE ☐
HQ CORE ☐
OTHER:

BEGAN: 6/27/03
COMPLETED: 6/1/03
DRILL: CS1000
DRILLER: Chris Peterson
WEATHER:

DEPTH (m)	DESCRIPTION	GRAPHIC LOG	SAMPLE #	SAMPLE	BLOW COUNT
			R-14		
21.0	Tan rhyolitic cobble to 279.4 mm and 76.2 mm gray-green sandy, very small gravely, silty clay. High percent clay.		R-15		
21.5	177.8 mm silty, gravely, sand. 63.5 mm gray-green silty clay. 1016 mm alternating layers of tan sandy silt and gray silty, clayey sand layers are 76.2 mm to 254 mm decomposed. Last 139.7 mm gray silty coarse sand, tan-rust soils, gray gravels. Decomposed bedrock at 21.74 m.		R-16		
22.9	Clayey silt plugging bit and getting between inner and outer barrels, causing mislatch.		R-17		
24.1	Decomposed orange-brown, gray and multicolored breccia tuff. Decomposed to a silty sandy gravel or silty gravely sand. Gravels or harder fragments are rhyolite.		R-18		
25.3	Decomposed rhyolite or breccia (silty, sandy gravel). 508 mm highly weathered rhyolite or rhyolitic tuff. Sandy gravel.		R-19		
26.8	Highly weathered rhyolite washed away decomposed material x 254 mm. Some gray basalt rock flows in the rhyolite.		R-20		
27.5	Highly weathered rhyolite or decomposed with harder fragments. Decomposed areas are tan, sandy, silty clay.		R-21		
29.0	177.8 mm decomposed tan rhyolite. 381 mm blue gray silty clay or clayey silt. Decomposed siltstone or mudstone.		R-22		
29.6	Blue-gray decomposed mudstone. Silty clay or clayey silt. Core was pulled 50.8 mm out of end of inner barrel, weight				

▼ WATER CONTENT (%)
PLASTIC LIMIT ├──┤ LIQUID LIMIT
● SAMPLE PENETRATION RESISTANCE BLOWS PER 0.3 m (63.5 kg mass, 0.76 m drop)



1.75 in O.D. SPLIT TUBE SAMPLE
2 in O.D. SPLIT TUBE SAMPLE (SPT)
3.25 in O.D. SPLIT TUBE SAMPLE (D & M)
3 in SHELBY TUBE
AUGER
CORE
WATER LEVEL

▨ RQD (%)
▒ RECOVERY (%)
× FIELD VANE (kPa)
✚ POCKET PEN (kPa)
UNCONFINED COMPR. STRENGTH (MPa)

PROJECT: Denali National Park
STATION, OFFSET:

BORING PLY03-2
Sheet 3 of 4

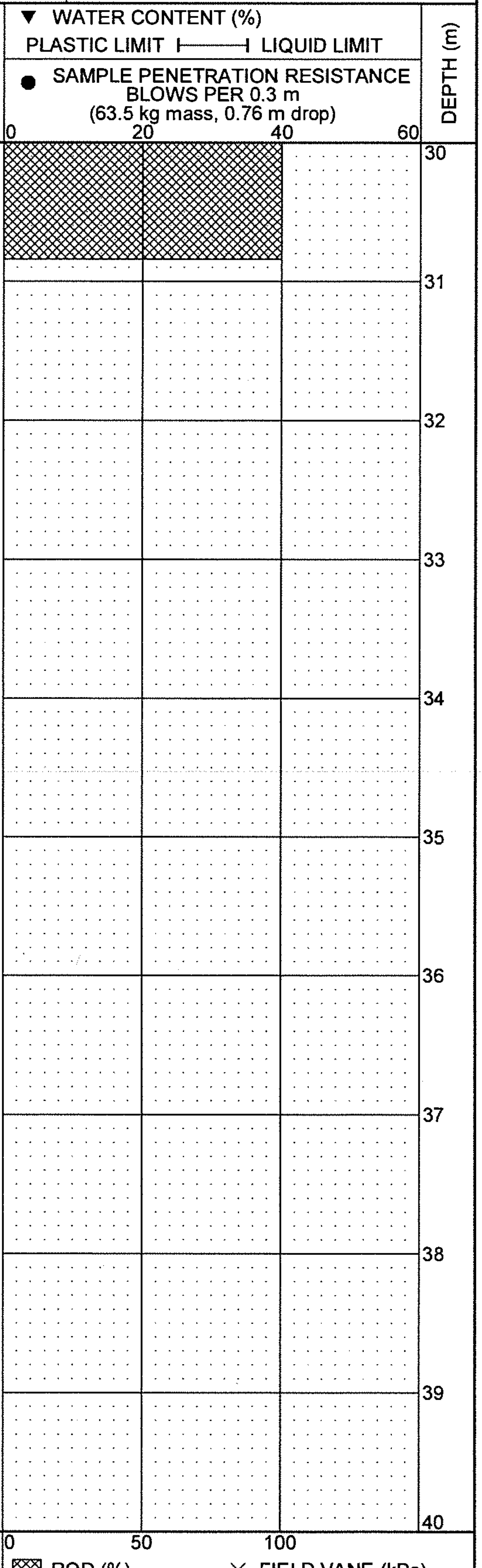
FEDERAL HIGHWAY ADMINISTRATION
VANCOUVER, WASHINGTON
GEOTECHNICAL SECTION

BORING LOG (Metric Units)

152 mm H-S AUGER ☐
203 mm H-S AUGER ☐
NQ CORE ☐
HQ CORE ☐
OTHER:

BEGAN: 6/27/03
COMPLETED: 6/1/03
DRILL: CS1000
DRILLER: Chris Peterson
WEATHER:

DEPTH (m)	DESCRIPTION	GRAPHIC LOG	SAMPLE #	SAMPLE	BLOW COUNT
	of rods pushed string 101.6 mm into the mudstone before run started.		R-23	⌸	
30.8	**BORING TERMINATED AT A DEPTH OF 30.84 M**				



⫼ 1.75 in O.D. SPLIT TUBE SAMPLE
⫼ 2 in O.D. SPLIT TUBE SAMPLE (SPT)
⫼ 3.25 in O.D. SPLIT TUBE SAMPLE (D & M)
⫼ 3 in SHELBY TUBE
⫼ AUGER
⫼ CORE
▽ WATER LEVEL

▨ RQD (%)
░ RECOVERY (%)
☒ UNCONFINED COMPR. STRENGTH (MPa)
× FIELD VANE (kPa)
✚ POCKET PEN (kPa)

PROJECT: Denali National Park
STATION, OFFSET:

BORING PLY03-2
Sheet 4 of 4

SOILS
CLASSIFICATION, CONSISTENCY AND SYMBOLS

CLASSIFICATION: Identification and classification of the soil is accomplished in accordance with the Unified Soil Classification System. Normally, the grain size distribution determines classification of the soil. The soil is defined according to major and minor constituents with the minor elements serving as modifiers of the major elements. For cohesive soils, the clay becomes the principal noun with the other major soil constituents used as modifier; i.e. silty clay, when the clay particles are such that the clay dominates soil properties. Minor soil constituents may be added to the classification breakdown in accordance with the particle size proportion listed below; i.e. sandy silt w/some gravel, trace clay.

no call - 0 - 3% trace - 3 - 12% some - 13 - 30%

SOIL CONSISTENCY - CRITERIA: Soil consistency as defined below and determined by normal field and laboratory methods applies only to non-frozen material. For these materials, the influence of such factors as soil structure, i.e. fissure systems, shrinkage cracks, slickensides, etc., must be taken into consideration in making any correlation with the consistency values listed below. In permafrost zones, the consistency and strength of frozen soils may vary significantly and unexplainably with ice content, thermal regime and soil type.

Cohesionless

	N*(blows/ft)	Relative Density
Loose	0 - 10	0 to 40%
Medium Dense	10 - 30	40 to 70%
Dense	30 - 60	70 to 90%
Very Dense	- 60	90 to 100%

*Standard Penetration "N": Blows per foot of a 140-pound hammer falling 30 inches on a 2-inch OD split-spoon except where noted.

Cohesive

	T - (tsf)
Very Soft	0 - 0.25
Soft	0.25 - 0.5
Stiff	0.5 - 1.0
Firm	1.0 - 2.0
Very Firm	2.0 - 4.0
Hard	- 4.0

DRILLING SYMBOLS

WO:	Wash Out	WD:	While Drilling
WL:	Water Level	BCR:	Before Casing Removal
WCI:	Wet Cave In	ACR:	After Casing Removal
DCI:	Dry Cave In	AB:	After Boring
WS:	While Sampling	TD:	Total Depth

Note: Water levels indicated on the boring logs are the levels measured in the boring at the times indicated. In pervious unfrozen soils, the indicated elevations are considered to represent actual ground water conditions. In impervious and frozen soils, accurate determinations of ground water elevations cannot be obtained within a limited period of observation and other evidence on ground water elevations and conditions are required.

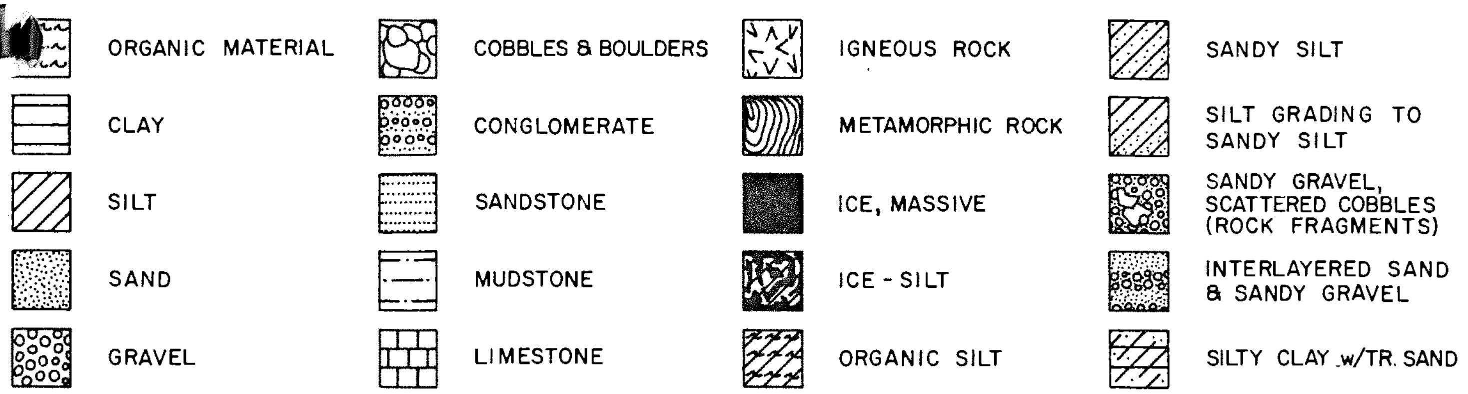
DWN: L.D.S.
CKD: G.L.B.
DATE: 3-1-72
SCALE: N/A

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

GENERAL NOTES

F.B. N/A
GRID N/A
PROJ.NO GENERAL
DWG.NO. B-01

STANDARD SYMBOLS



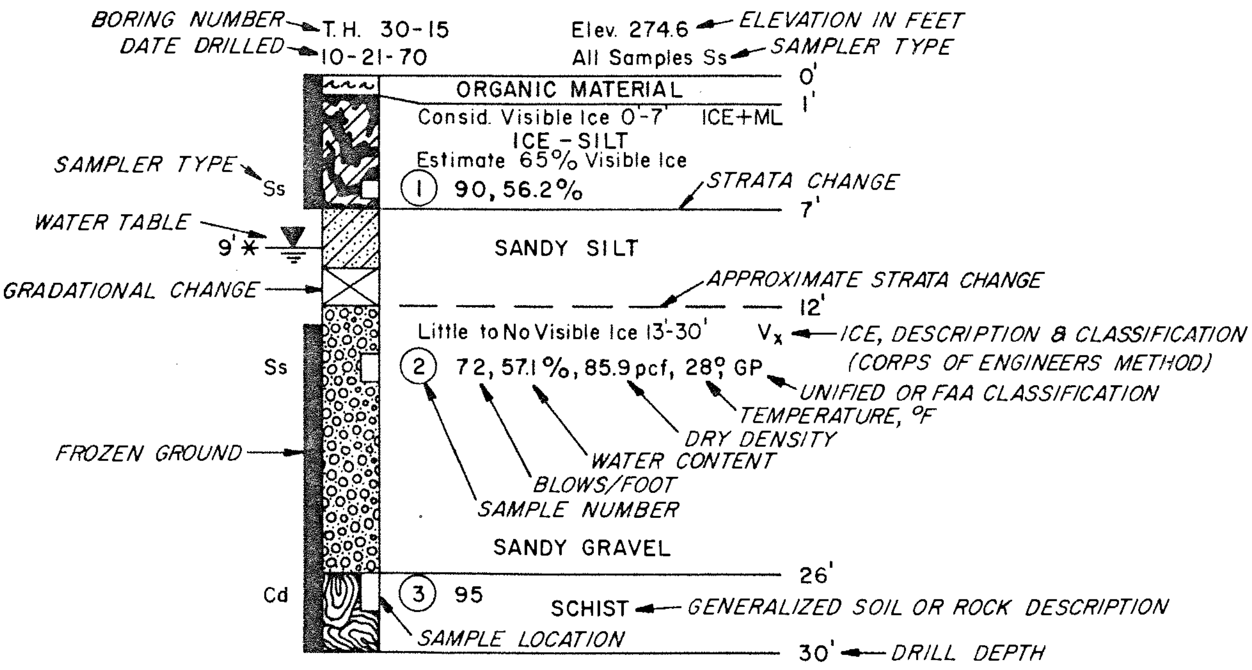
SAMPLER TYPE SYMBOLS

St . . . . . 1.4" SPLIT SPOON WITH 47# HAMMER
Ss . . . . . 1.4" SPLIT SPOON WITH 140# HAMMER
Sl . . . . . 2.5" SPLIT SPOON WITH 140# HAMMER
Sh . . . . . 2.5" SPLIT SPOON WITH 340# HAMMER
Sx . . . . . 2.0" SPLIT SPOON WITH 140# HAMMER
Sz . . . . . 1.4" SPLIT SPOON WITH 340# HAMMER
Sp . . . . . 2.5" SPLIT SPOON, PUSHED
Hs . . . . . 1.4" SPLIT SPOON DRIVEN WITH AIR HAMMER
Hl . . . . . 2.5" SPLIT SPOON DRIVEN WITH AIR HAMMER

Ts . . . . SHELBY TUBE
Tm . . . . MODIFIED SHELBY TUBE
Pb . . . . PITCHER BARREL
Cs . . . . CORE BARREL WITH SINGLE TUBE
Cd . . . . CORE BARREL WITH DOUBLE TUBE
Bs . . . . BULK SAMPLE
A . . . . . AUGER SAMPLE
G . . . . . GRAB SAMPLE

NOTE: SAMPLER TYPES ARE EITHER NOTED ABOVE THE BORING LOG OR ADJACENT TO IT AT THE RESPECTIVE SAMPLE DEPTH.

TYPICAL BORING LOG



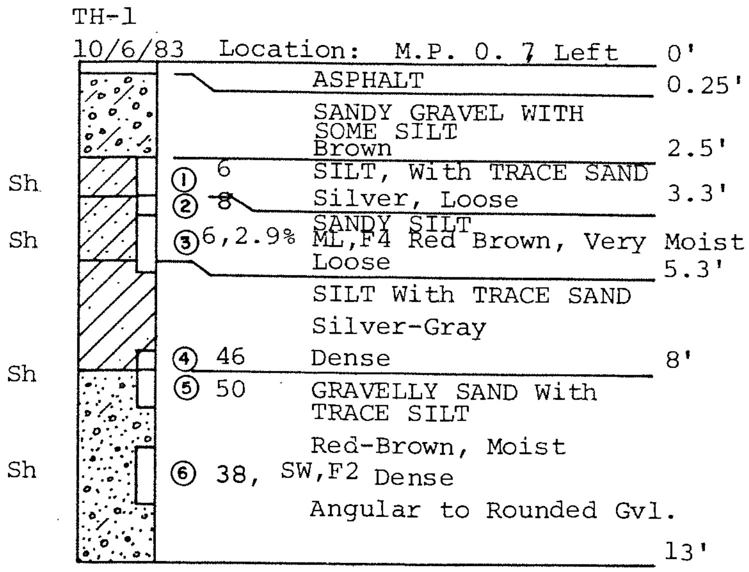
* *W.D. - WHILE DRILLING, A.B. - AFTER BORING*

DWN: L.D.S.
CKD: G.L.B.
DATE: FEB. 1972
SCALE: NONE

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

EXPLANATION
OF
SELECTED SYMBOLS

F.B. N/A
GRID N/A
PROJ.NO GENERAL
DWG.NO. B-02



GROUNDWATER NOT ENCOUNTERED

DWN. O.E.P.
CKD. C.H.R.
DATE. 10/31/83
SCALE. 1" = 5'

R&M CONSULTANTS, INC.
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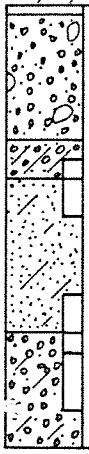
FEDERAL HIGHWAY ADMINISTRATION
GEOTECHNICAL INVESTIGATIONS
DENALI PARK, ALASKA

F.B.
GRID.
PROJ. NO. 351193
DWG. NO. B-03

TH-2

10/6/83 Location: M.P. 0.85, Left



0.0'

ASPHALT 0.2'

SANDY GRAVEL With
OCCASIONAL COBBLES
Brown, Dense 3.5'

SILTY SANDY GRAVEL
Gray-Brown, Loose 4.5'

Sh ① 6

② 8, SM-F2

SAND WITH SOME SILT
Red Brown, Fine to Medium

Sh ③ 21 8.5'

④ 43

A ⑤ GM, F3

GRAVEL WITH SOME SAND
AND SOME SILT
Dense, Angular Gravel

11.5'

GROUNDWATER NOT ENCOUNTERED

DWN.	O.E.P.
CKD.	C.H.R.
DATE.	10/31/83
SCALE.	1" = 5'

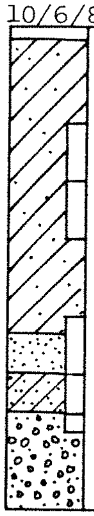
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

FEDERAL HIGHWAY ADMINISTRATION
GEOTECHNICAL
INVESTIGATIONS
DENALI PARK, ALASKA

F.B.	
GRID.	
PROJ.NO.	351193
DWG.NO.	B-04

TH-3

10/6/83 Location: M.P. 0.95 Left 0.0'



ASPHALT 0.3'

SILT WITH SOME SAND
Light Brown, to Tan, Moist
Medium Dense to Loose

Sh ① 12, 23.6%, ML,F4

Sh ② 7 Silver Silt interlayer 5-5½'

8'

Sh ③ 12 SAND, Red-Brown, Med Dense

9'

Sh ④ 10 SANDY SILT, Tan, Med. Dense

⑤ 10 SANDY GRAVEL 10'
Red-Brown, Medium Dense
Grades Dense and Occn. Cobbles

12.5'

GROUNDWATER NOT ENCOUNTERED

DWN. O.E.P.
CKD. C.H.R.
DATE. 10/31/83
SCALE. 1" = 5'

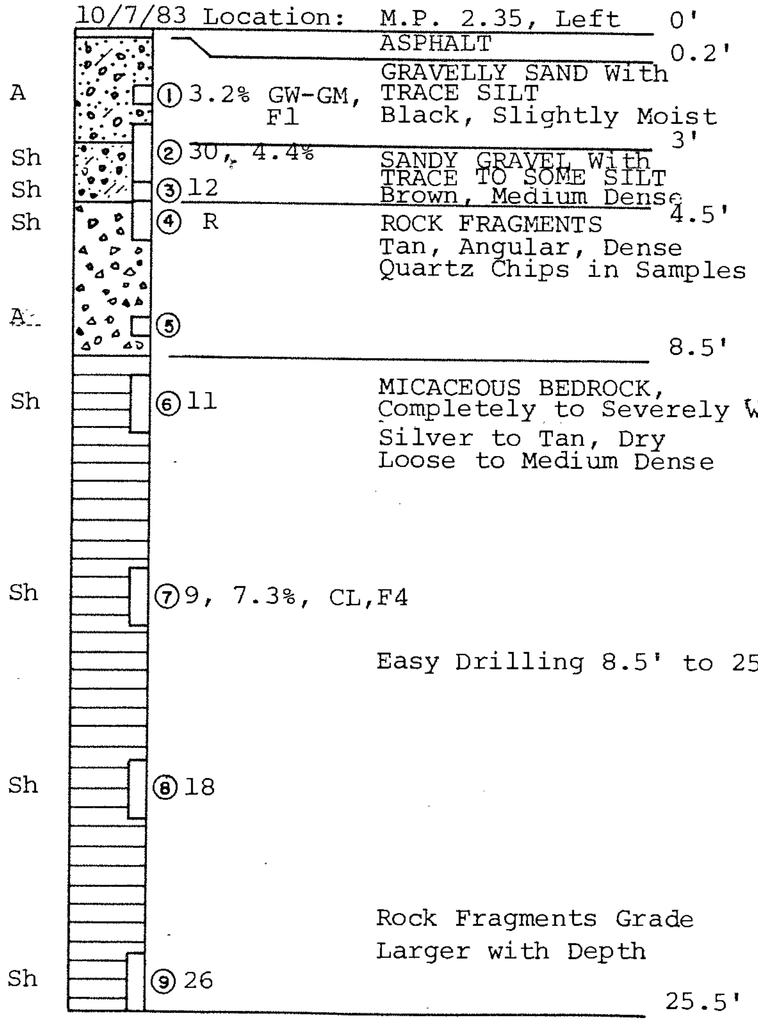
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

FEDERAL HIGHWAY ADMINISTRATION
GEOTECHNICAL INVESTIGATIONS
DENALI PARK, ALASKA

F.B.
GRID.
PROJ.NO. 351193
DWG.NO. B-05

TH-4

10/7/83 Location: M.P. 2.35, Left



0' – 0.2': ASPHALT

0.2' – 3': GRAVELLY SAND With TRACE SILT
Black, Slightly Moist

3' – 4.5': SANDY GRAVEL With TRACE TO SOME SILT
Brown, Medium Dense

4.5' – 8.5': ROCK FRAGMENTS
Tan, Angular, Dense
Quartz Chips in Samples

8.5' – 25.5': MICACEOUS BEDROCK,
Completely to Severely Weathered
Silver to Tan, Dry
Loose to Medium Dense

Easy Drilling 8.5' to 25.5'

Rock Fragments Grade Larger with Depth

25.5'

GROUNDWATER NOT ENCOUNTERED

DWN.	O.E.P.
CKD.	C.H.R.
DATE.	10/31/83
SCALE.	1" = 5'

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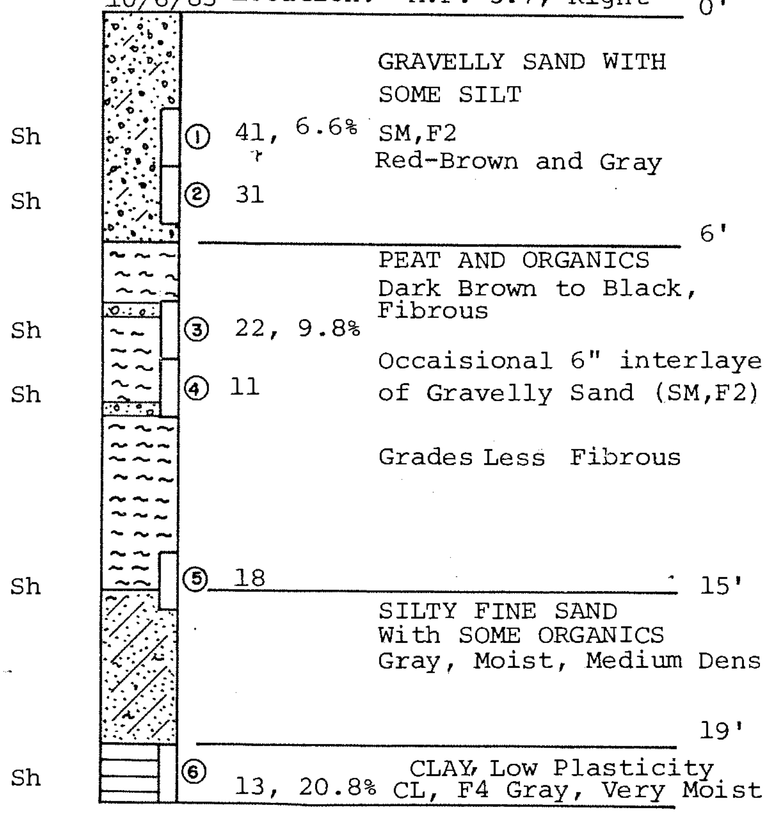
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

FEDERAL HIGHWAY ADMINISTRATION
GEOTECHNICAL INVESTIGATIONS
DENALI PARK, ALASKA

F.B.	
GRID.	
PROJ.NO.	351193
DWG.NO.	B-06

TH-5

10/6/83 Location: M.P. 3.7, Right*



0' – GRAVELLY SAND WITH SOME SILT

SM,F2

Red-Brown and Gray

Sh ① 41, 6.6%

Sh ② 31

6' – PEAT AND ORGANICS

Dark Brown to Black, Fibrous

Occaisional 6" interlayers of Gravelly Sand (SM,F2)

Grades Less Fibrous

Sh ③ 22, 9.8%

Sh ④ 11

Sh ⑤ 18

15' – SILTY FINE SAND

With SOME ORGANICS

Gray, Moist, Medium Dense

19' – CLAY, Low Plasticity

CL, F4 Gray, Very Moist

Sh ⑥ 13, 20.8%

20'

GROUNDWATER NOT ENCOUNTERED

* P-Line Sta 198+90

DWN.	O.E.P.
CKD.	C.H.R.
DATE.	10/31/83
SCALE	1" = 5'

R&M CONSULTANTS, INC.

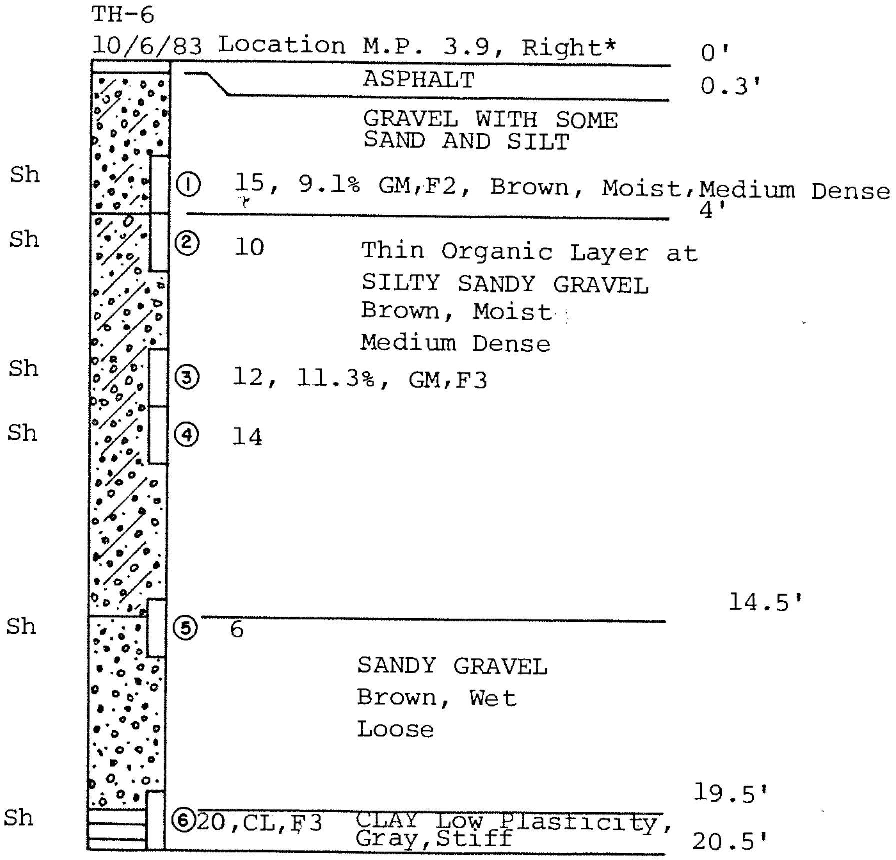
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

FEDERAL HIGHWAY ADMINISTRATION

GEOTECHNICAL INVESTIGATIONS

DENALI PARK, ALASKA

F.B.	
GRID.	
PROJ. NO.	351193
DWG. NO.	B-07



* P-Line STA 210+00

DWN.	O.E.P.
CKD.	C.H.R.
DATE.	10/31/83
SCALE.	1"=5'

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

FEDERAL HIGHWAY ADMINISTRATION
GEOTECHNICAL INVESTIGATIONS
DENALI PARK, ALASKA

F.B.	
GRID.	
PROJ.NO.	351193
DWG.NO.	B-08

APPENDIX I

Contractor Deliverables

I-1: Geophysical Investigation 2018
I-2: Geophysical Investigation 2019

APPENDIX I-1

Geophysical Investigation 2018

GEOPHYSICAL INVESTIGATION
Report

Pretty Rocks Project
Denali National Park, AK

FOR

GeoTek, Alaska, Inc.
Anchorage, AK

by

ENVIROPROBE SERVICE, INC.
81 Marter Avenue, Mt Laurel, NJ 08054

August 2018

ENVIROPROBE
SERVICE
INCORPORATED

August 7, 2018

Scott Votja
GeoTek Alaska, Inc.
2756 Commercial Drive
Anchorage, AK 99501

REPORT: GEOPHYSICAL INVESTIGATION
Pretty Rocks Project
Denali National Park, AK

Dear Mr. Votja:

We are pleased to present our report for the geophysical borehole logging investigation performed at the Pretty Rocks Project in Denali National Park, AK. The investigation was performed between July 17 and August 1, 2018

If you have any questions concerning this report please contact us at 856-858-8584. We look forward to working with you in the future.

Respectfully submitted,

Enviroprobe Service, Inc.

Matthew J. McMillen

Matthew J. McMillen
Senior Geophysicist

1) INTRODUCTION AND PURPOSE

Three geotechnical borings located at the Pretty Rocks Project on Denali Park Road in Denali National Park, AK were the object of this geophysical survey. These boreholes were PR18-01, PR18-02, and PR18-03.

The purpose of the geophysical borehole logging was to investigate lithology, fracture location, and orientation, in the boreholes.

2) GEOPHYSICAL METHODOLOGY

Geophysical borehole logging was conducted using a Mount Sopris mini winch with a Matrix console and Mount Sopris 2PCA-1000 caliper probe and an ALT QL40-OBI-2G optical televiewer. The ALT QL40-2G acoustic televiewer was not used due to the lack of water in the boreholes.

The borehole logs consist of caliper and optical televiewer.

3) INTERPRETATION

Observations of the televiewer logs grouped visible features into two groups on the structure logs and tadpole plots as possible bedding planes and possible geologic features.

The possible geologic features are features which appear to be related to the geology but cannot be identified due to the borehole conditions.

All three borehole walls were coated in mud or rock dust that did not allow for more accurate data interpretation. PR18-01 was entirely covered so no usable information was obtained from the optical televiewer data. Additionally, obstructions in the boring prevented televiewer data acquisition below approximately 83.0 feet.

All depths are based on ground surface at the time of the logging.

Interpretations are on the comments section of the log.

Appendix A has all the geophysical logs. Appendix B has the structure data.

PR18-01

The boring was approximately 105.3 feet in depth before reaming and 105.6 feet after. Approximately 50 feet of augers were in the borehole at the time of logging.

The geophysical logging of this borehole detected significant caliper enlargements at approximately:

1) 87.5 feet
2) 92.4 feet to 94.6 feet

See Appendix A for the logs of this borehole.

PR18-02

The boring was approximately 136.6 feet in depth. Approximately 90.0 feet of augers were in the borehole at the time of logging.

The geophysical logging of this borehole detected significant caliper enlargements at approximately:

1) 90.0 feet to 92.0 feet
2) 92.0 feet to 93.9 feet
3) 97.0 feet to 103.8 feet

See Appendix A for the logs of this borehole.

Appendix B has the structure data.

PR18-03

The boring was approximately 106.5 feet in depth. Approximately 62.0 feet of casing was in the borehole at the time of logging.

The geophysical logging of this borehole detected significant caliper enlargement at approximately:

1) 69.0 feet

See Appendix A for the logs of this borehole.

Appendix B has the structure data.

4) CONCLUSIONS

A geophysical borehole logging investigation of three borings located at Pretty Rocks on the Denali Park Road in Denali National Park, AK was conducted using of caliper and optical televiewer. The purpose of this investigation was to investigate lithology, fracture location, and orientation.

Results are shown as borehole logs. A discussion of the borehole is given in the interpretation section.

No acoustic televiewer data was collected due to the lack of water in the boreholes.

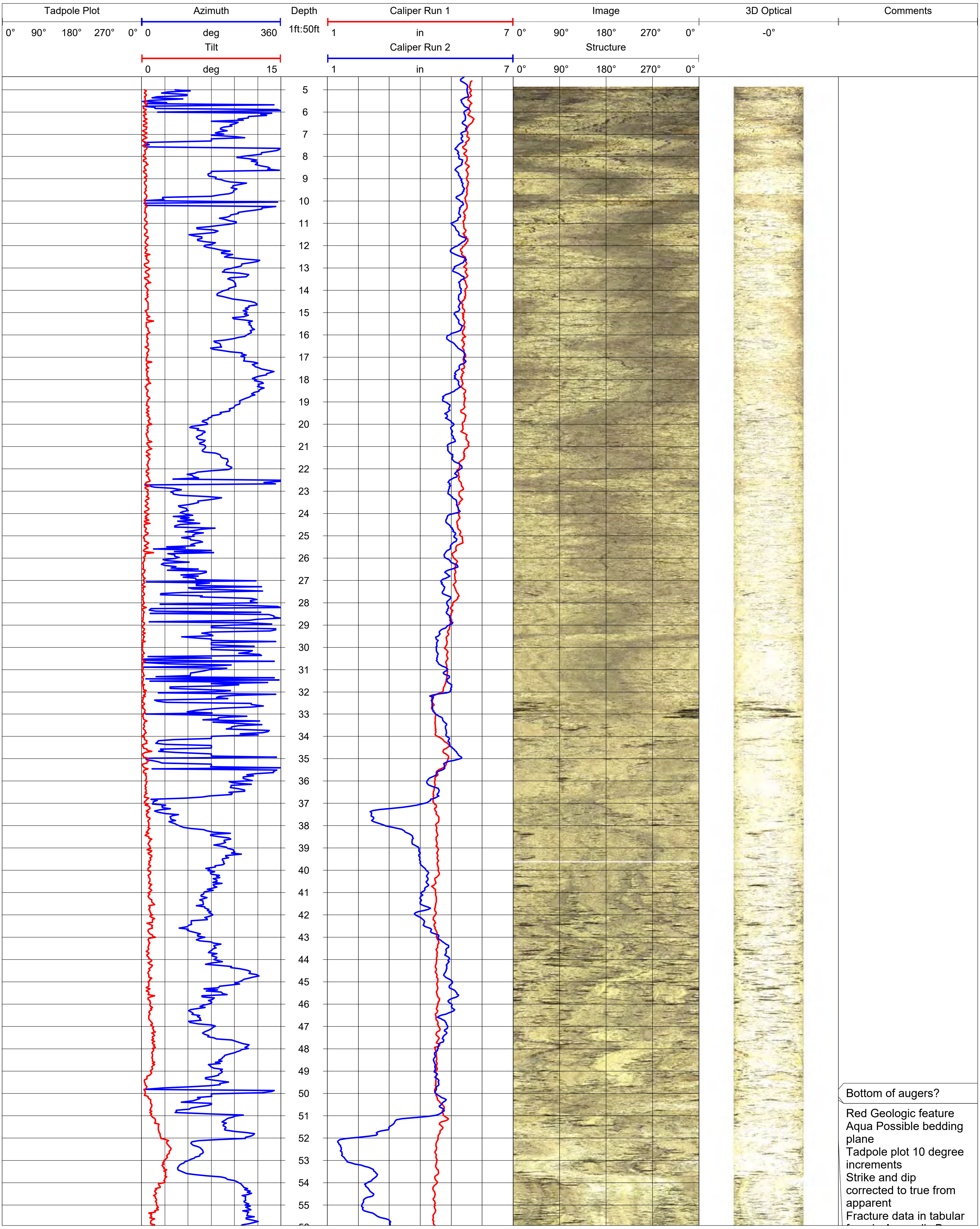
Optical televiewer data was poor due to the borehole walls being coated with clay or rock dust from the drilling.

Appendix A shows the borehole logs.

Appendix B has the structure data.

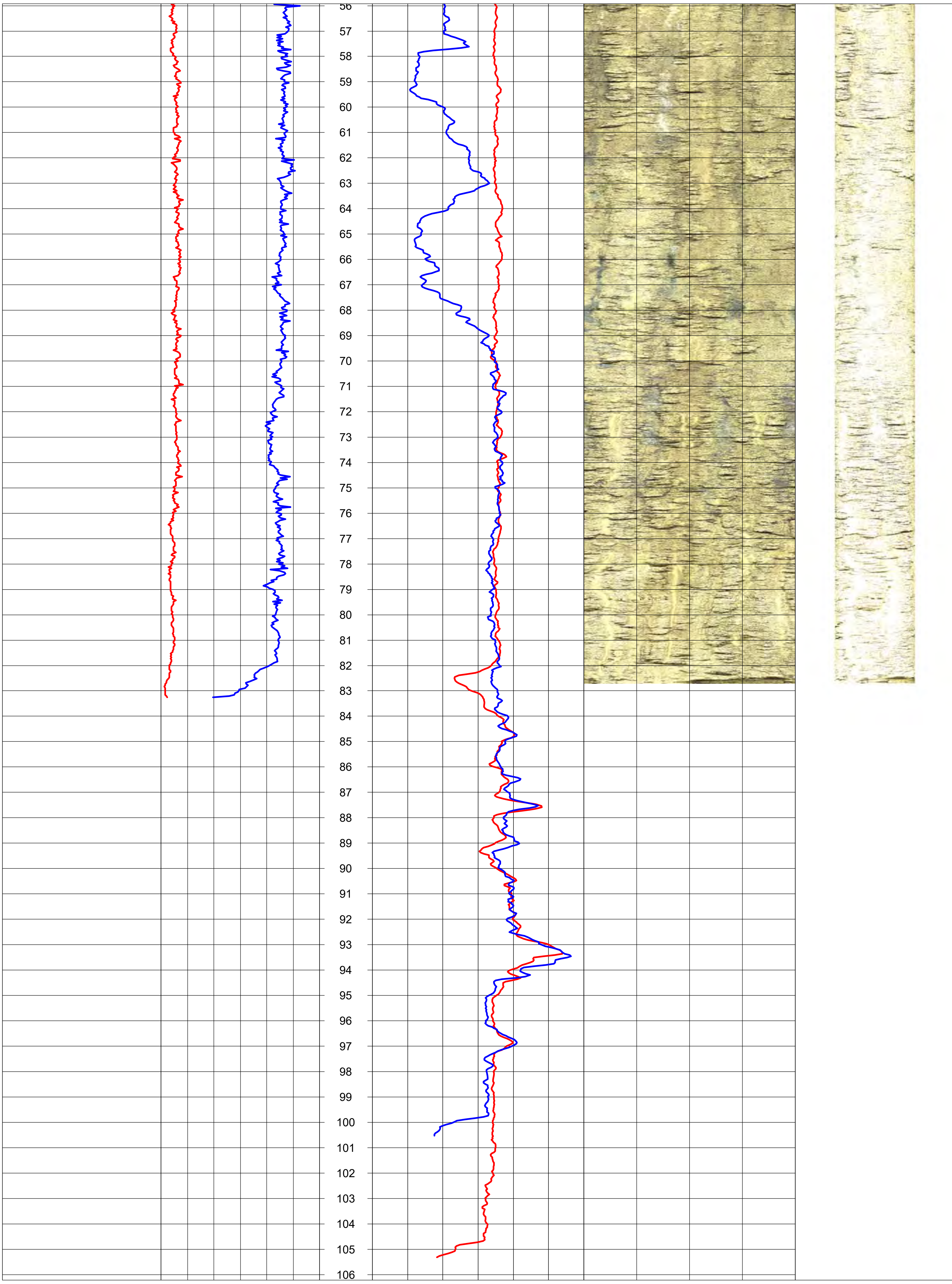
APPENDIX A

PR18-01
Pretty Rocks Project
prepared for
GeoTek Alaska, Inc..
Anchorage, AK
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Caliper and Optical Televiewer



Bottom of augers?

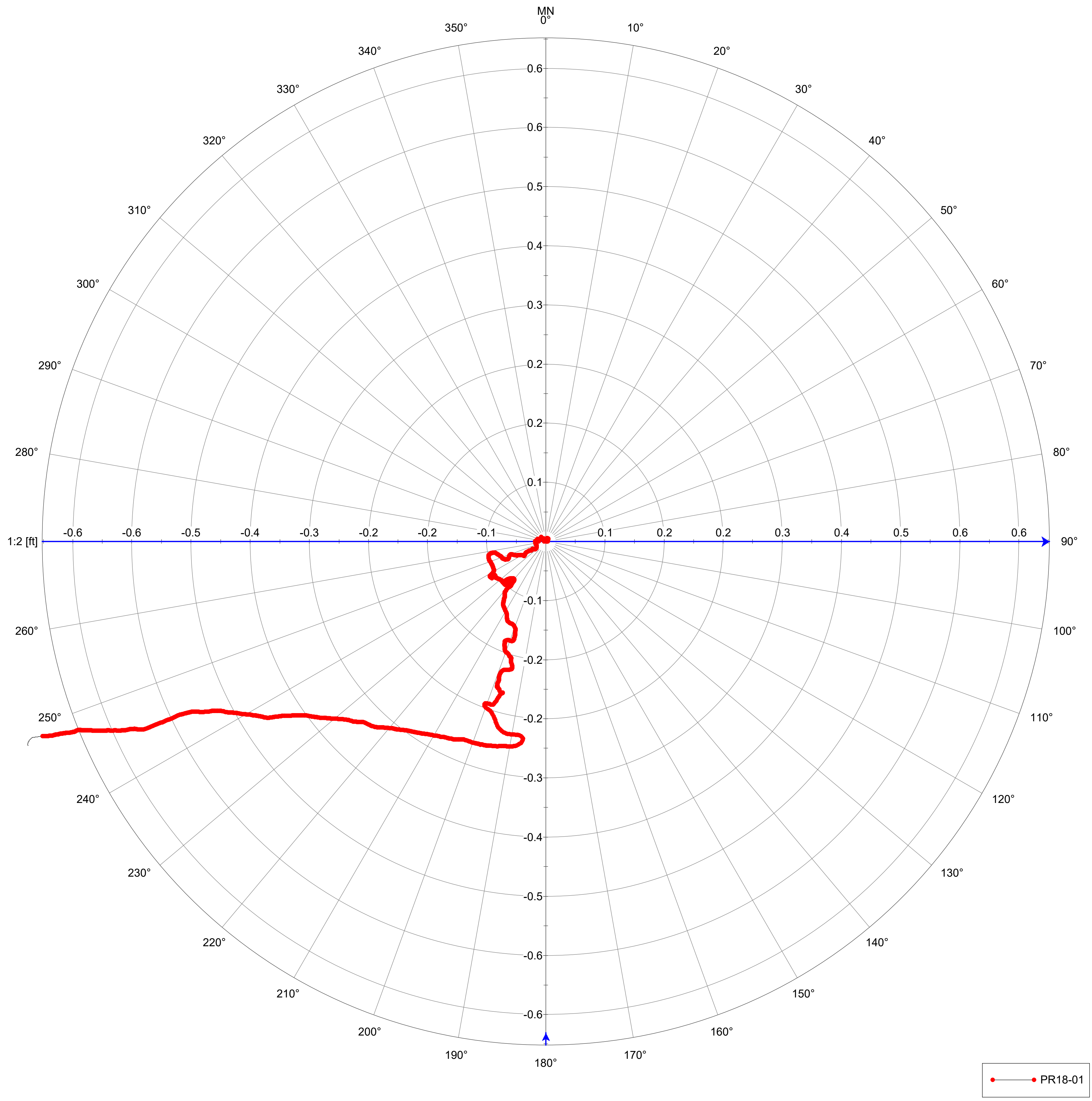
Red Geologic feature
Aqua Possible bedding plane
Tadpole plot 10 degree increments
Strike and dip corrected to true from apparent
Fracture data in tabular

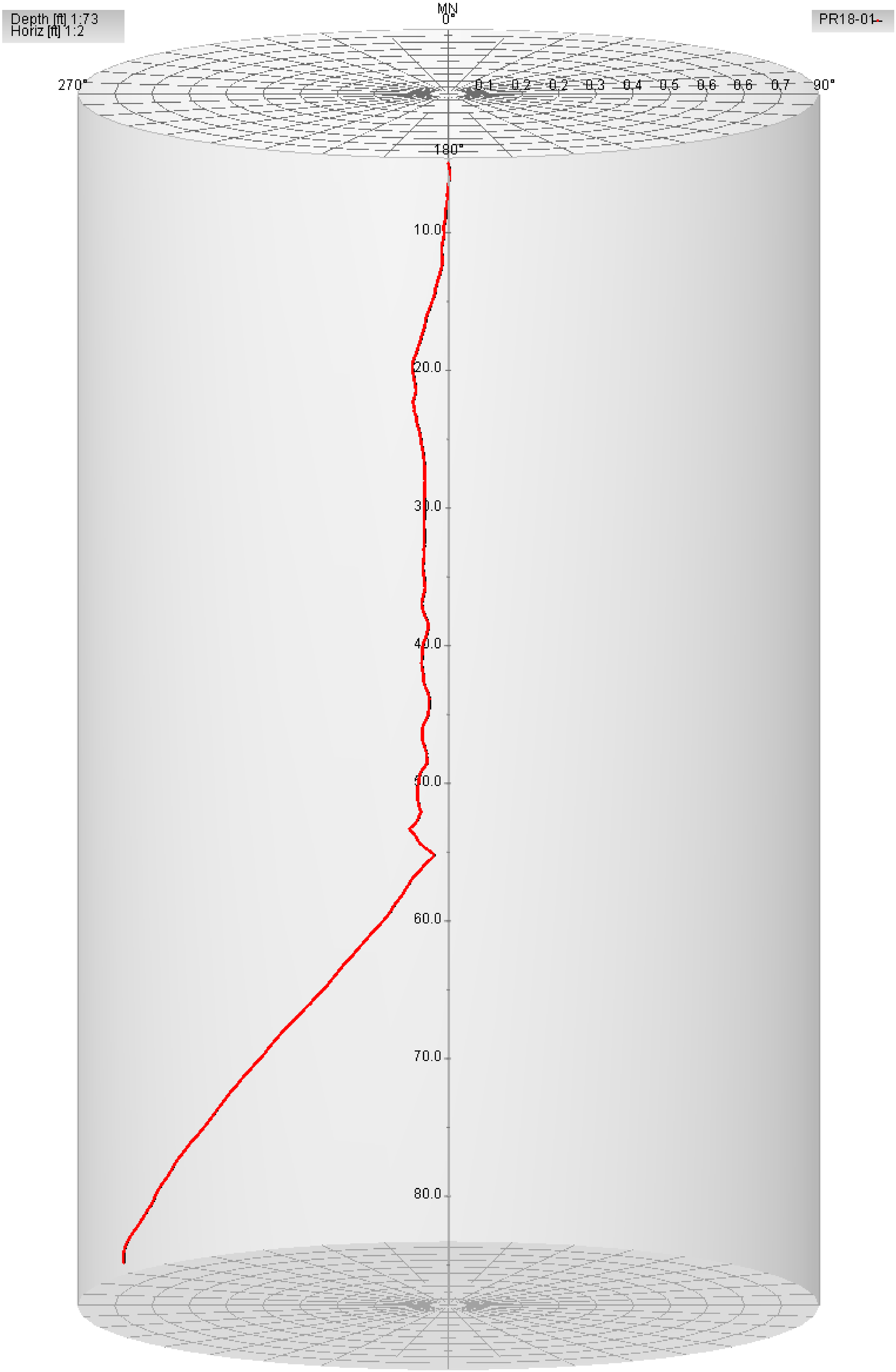


form in Appendix B

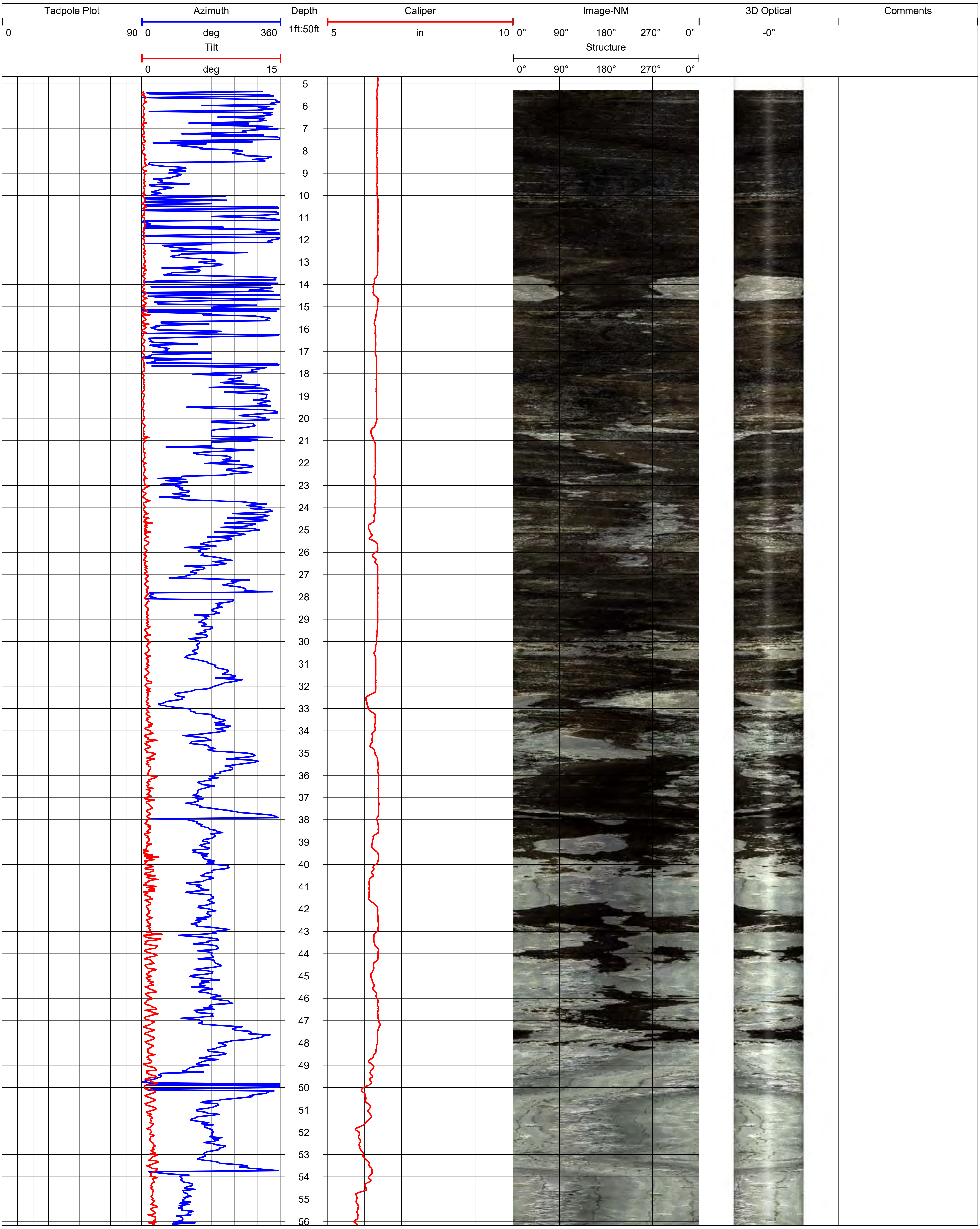
Borehole constriction caliper run 1

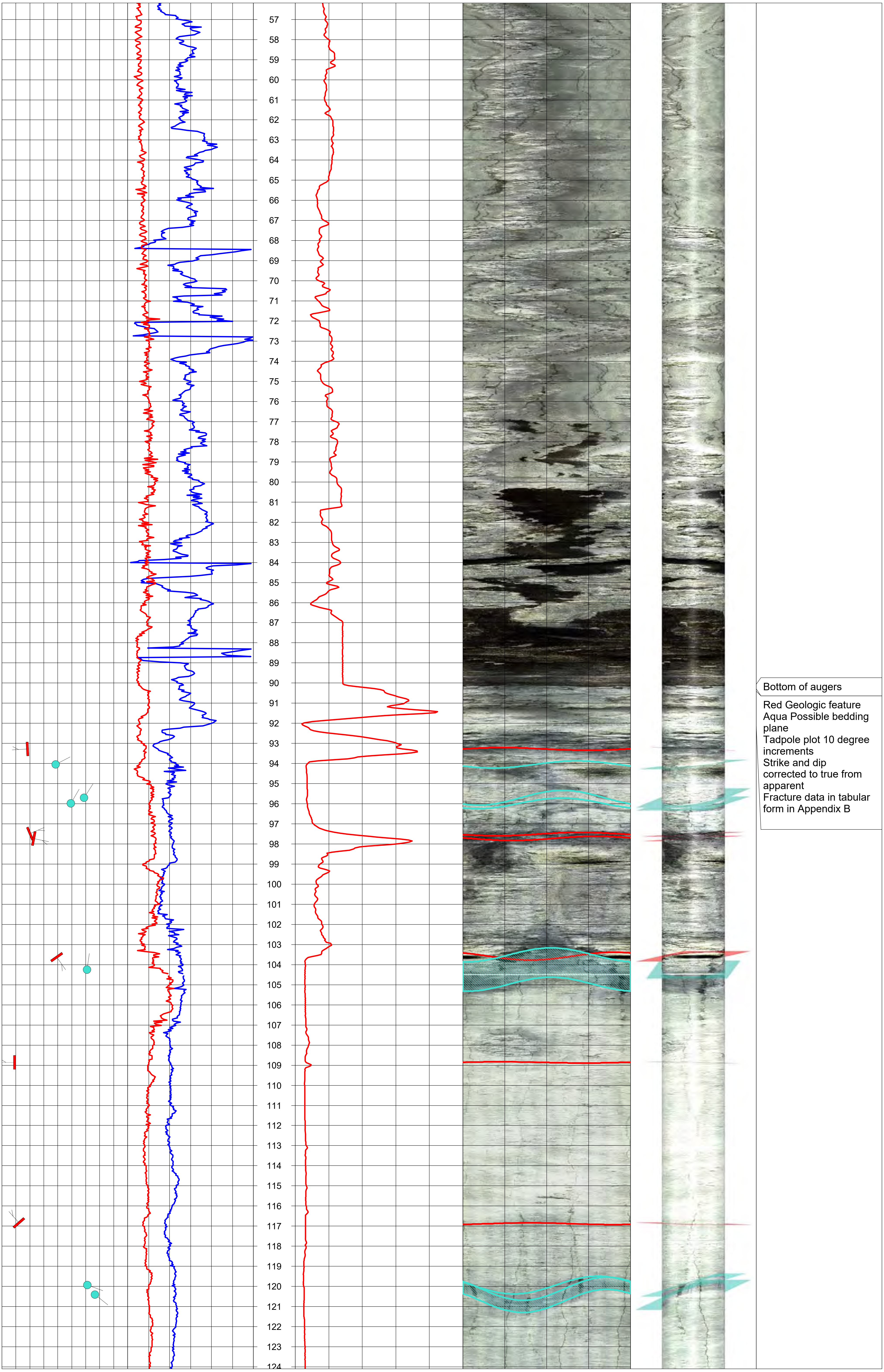
PR18-01
Pretty Rocks Project
prepared for
Geotek Alaska, Inc..
Anchorage, AK
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Deviation Plot




Depth [ft] 1:73
Horiz [ft] 1:2
MN
0°
PR18-01
270°
90°
180°
0.1
0.2
0.2
0.3
0.4
0.5
0.6
0.6
0.7
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0

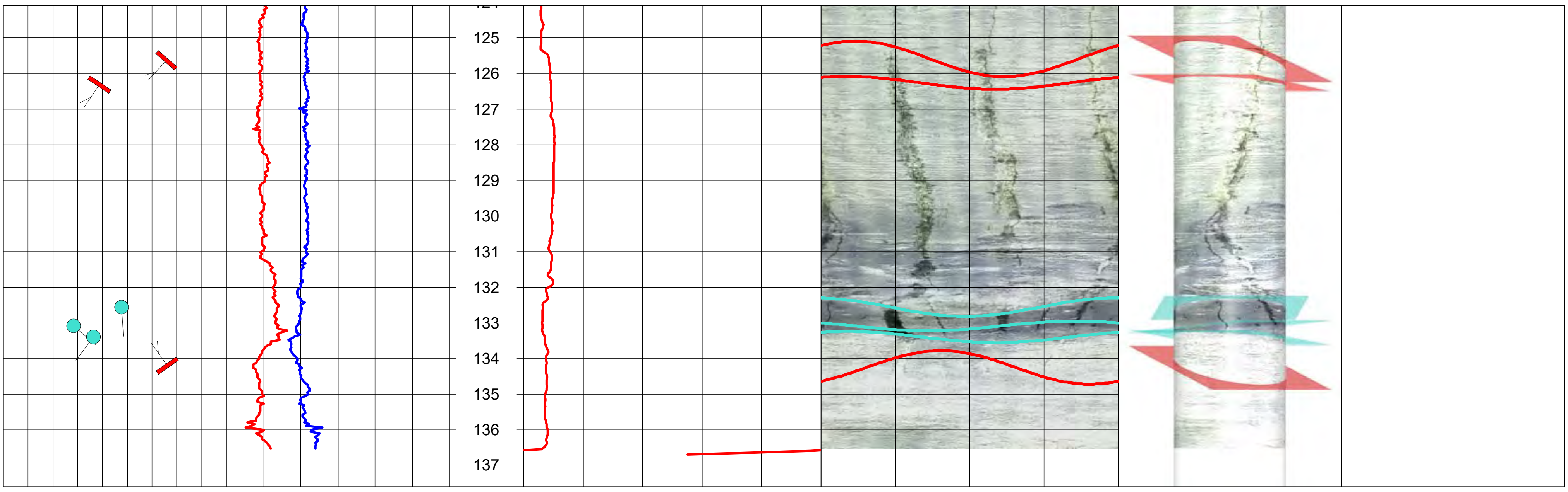
PR18-02
Pretty Rocks Project
prepared for
GeoTek Alaska, Inc..
Anchorage, AK
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Caliper and Optical Televiewer





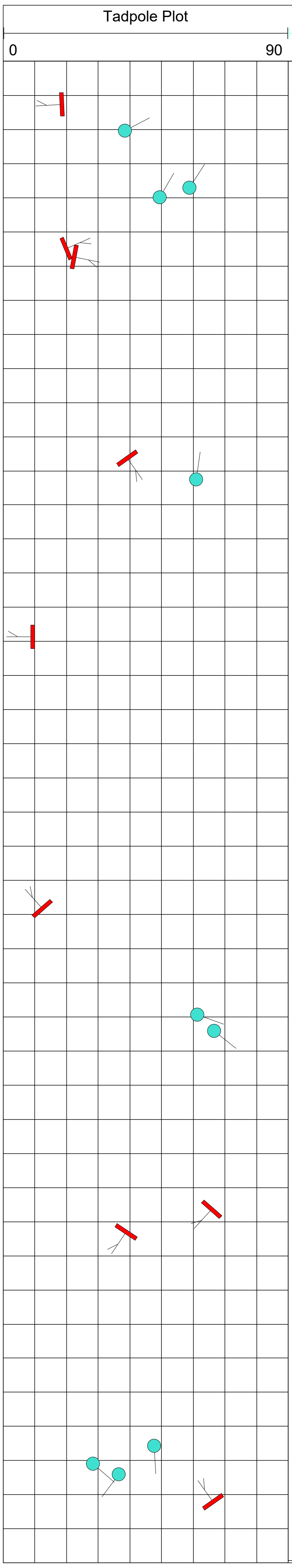
Bottom of augers

Red Geologic feature
Aqua Possible bedding plane
Tadpole plot 10 degree increments
Strike and dip corrected to true from apparent
Fracture data in tabular form in Appendix B


125
126
127
128
129
130
131
132
133
134
135
136
137

PR18-02
Pretty Rocks Project
prepared for
GeoTek Alaska, Inc..
Anchorage, AK
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Rose Diagram

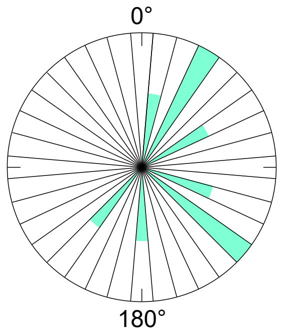
Tadpole Plot



Posssible Bedding Plane

Azimuth - Percent Interval (Count)

Depth: 92.00 [ft] to 135.93 [ft]



Components:	Azimuth
Counts:	9.00
Mean (3D):	86.80
Min:	8.22
Max:	216.65

Depth

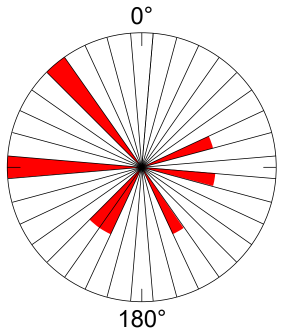
1ft:50ft

93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135

Geologic Feature

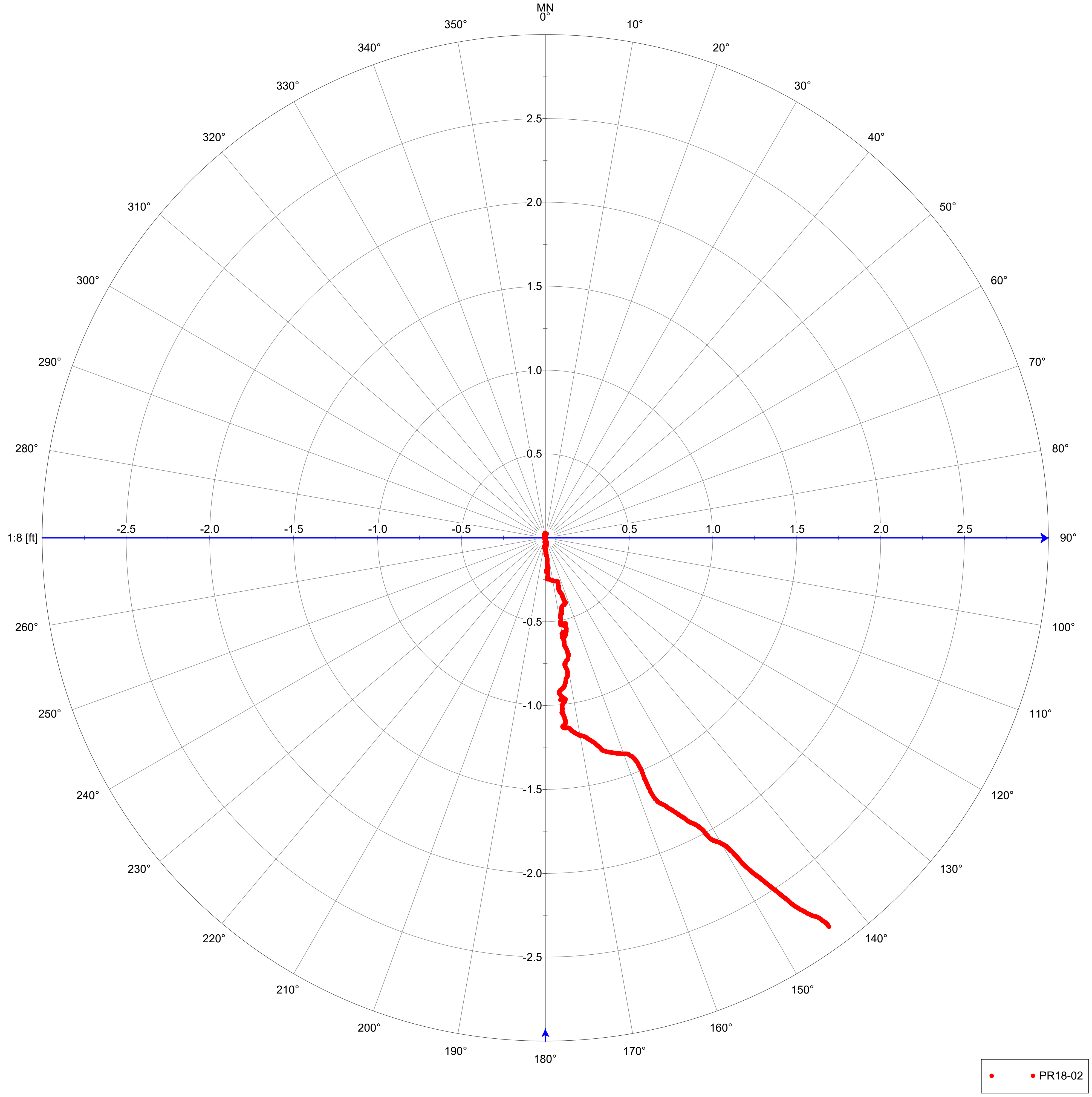
Azimuth - Percent Interval (Count)

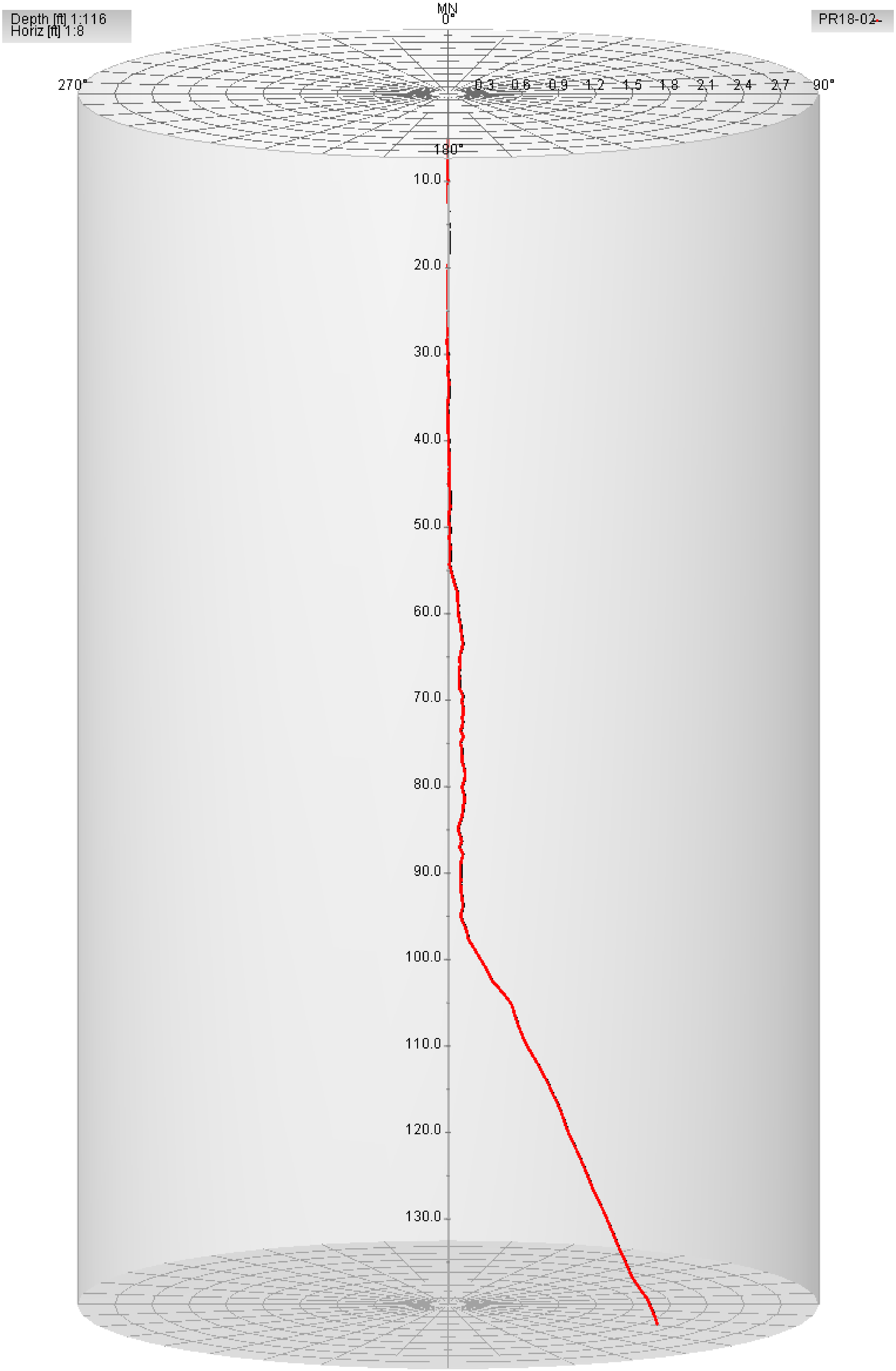
Depth: 92.00 [ft] to 135.93 [ft]



Components:	Azimuth
Counts:	9.00
Mean (3D):	216.07
Min:	66.56
Max:	324.86

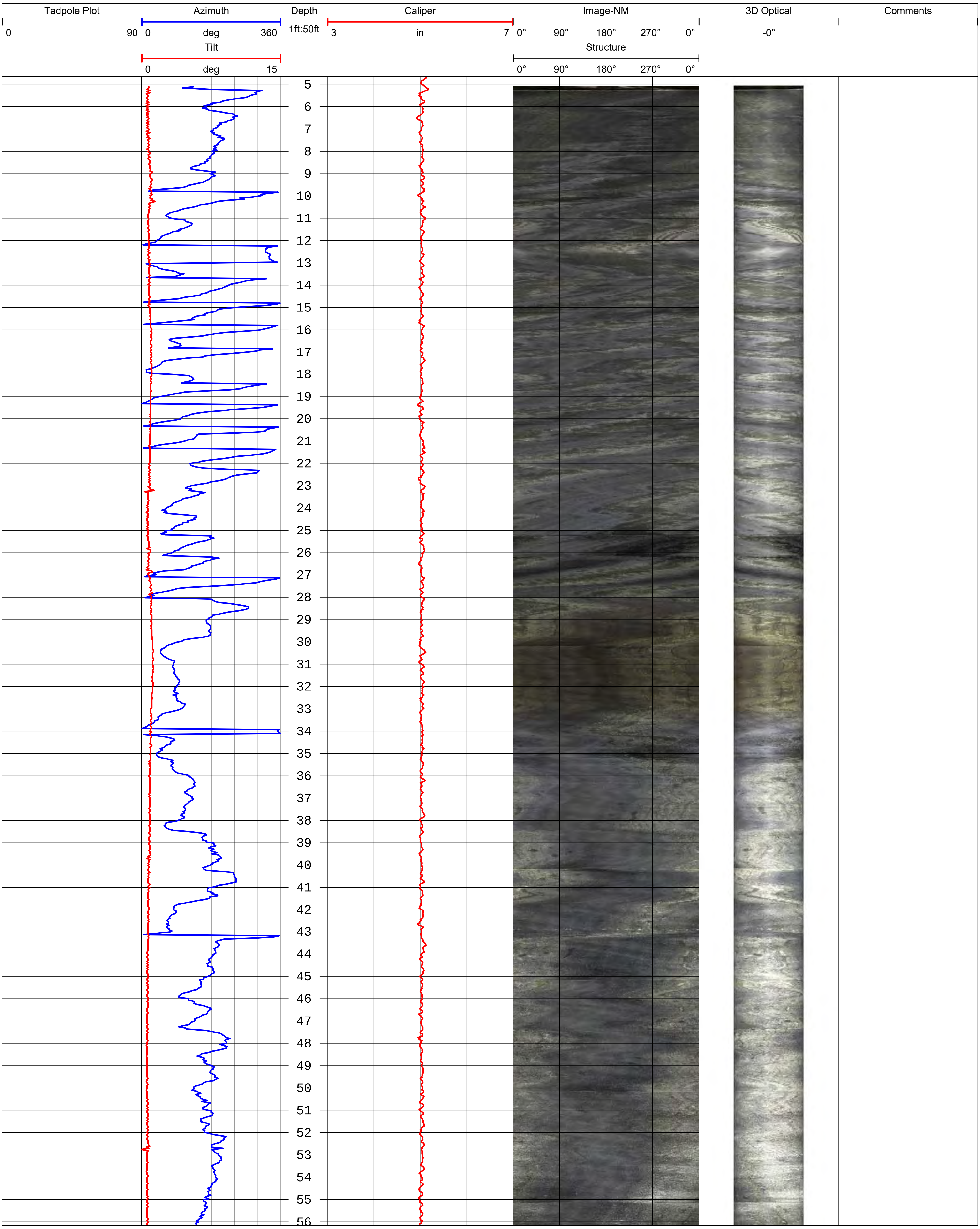
PR18-02
Pretty Rocks Project
prepared for
GeoTek Alaska, Inc.
Anchorage, AK
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Deviation Plot

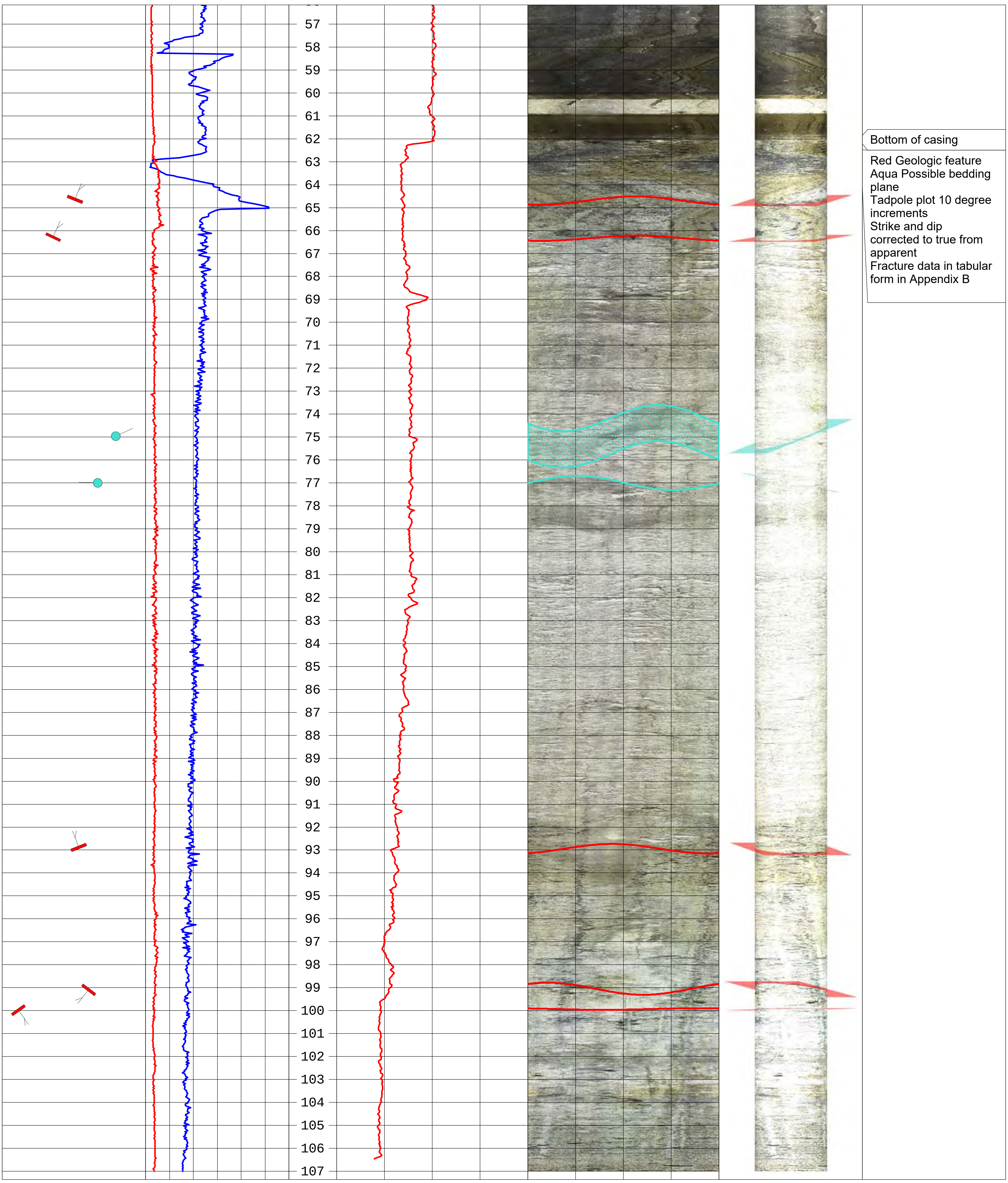



Depth [ft] 1:116
Horiz [ft] 1:8
PR18-02
MN
0°
270°
90°
180°
0.3
0.6
0.9
1.2
1.5
1.8
2.1
2.4
2.7
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0

PR18-03

Pretty Rocks Project
prepared for
GeoTek Alaska, Inc..
Anchorage, AK
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Caliper and Optical Televiewer

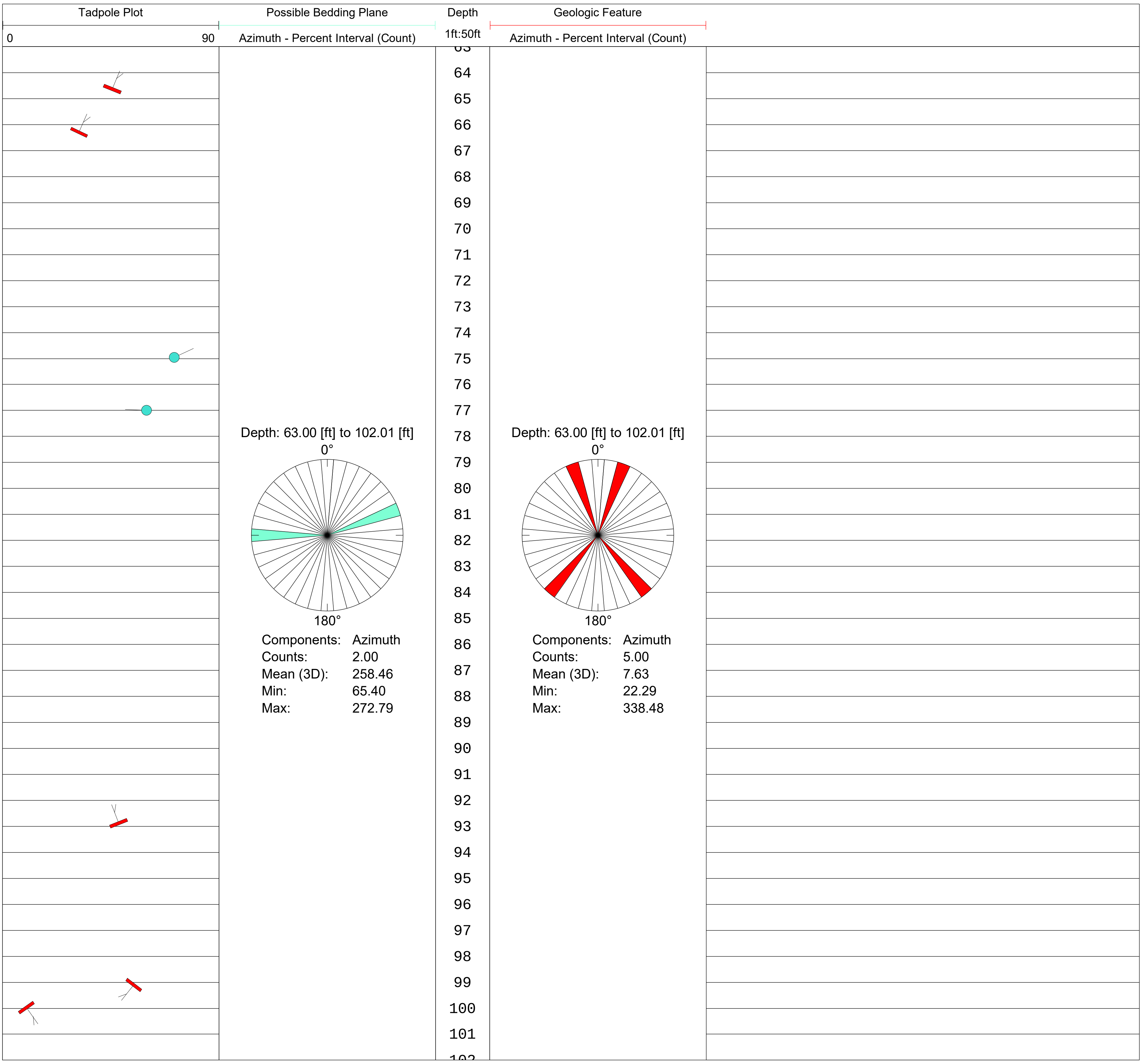




Bottom of casing

Red Geologic feature
Aqua Possible bedding plane
Tadpole plot 10 degree increments
Strike and dip corrected to true from apparent
Fracture data in tabular form in Appendix B

PR18-03
Pretty Rocks Project
prepared for
GeoTek Alaska, Inc..
Anchorage, AK
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Rose Diagram



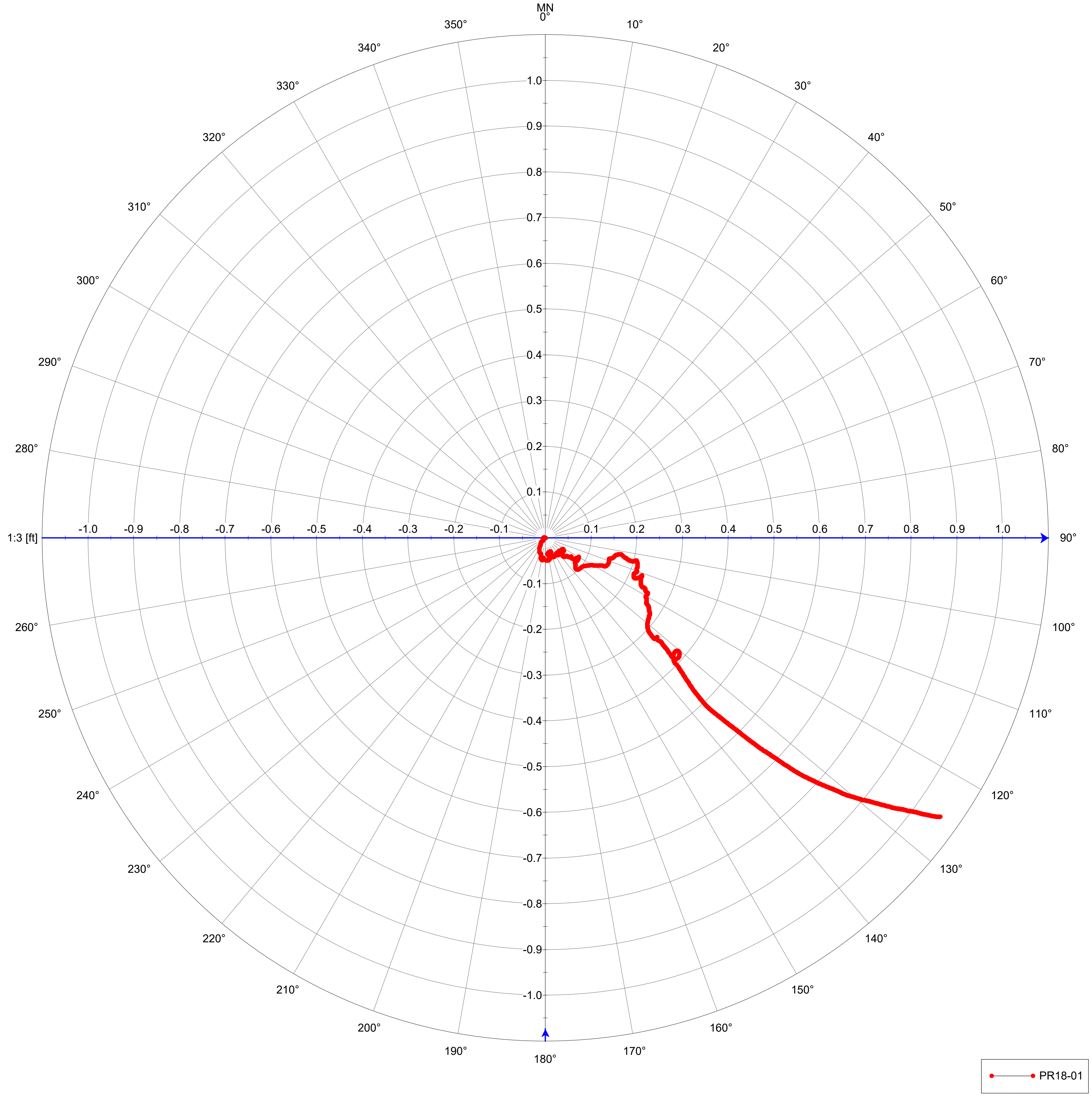
Possible Bedding Plane

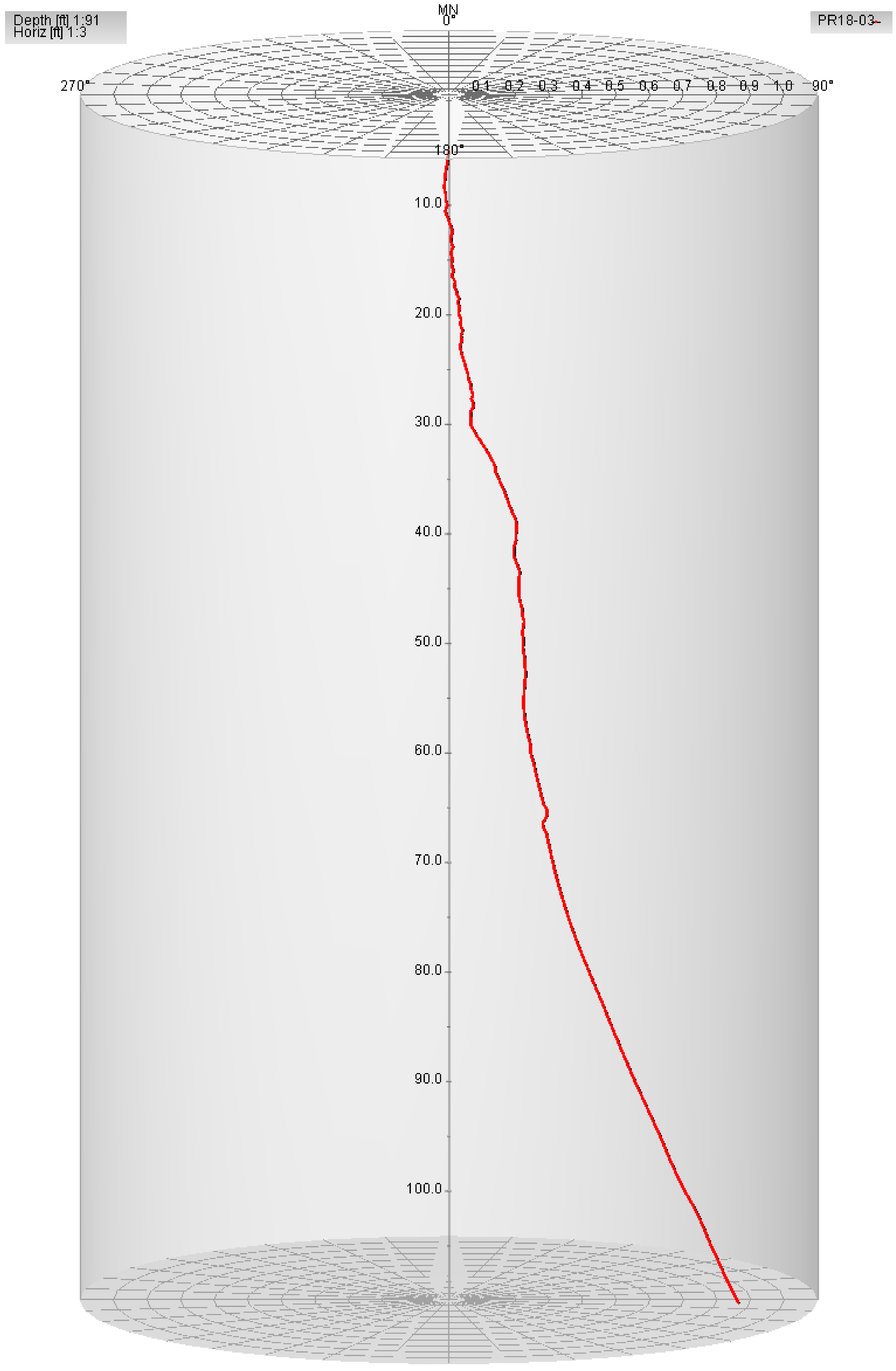
Components:	Azimuth
Counts:	2.00
Mean (3D):	258.46
Min:	65.40
Max:	272.79

Geologic Feature

Components:	Azimuth
Counts:	5.00
Mean (3D):	7.63
Min:	22.29
Max:	338.48

PR18-03
Pretty Rocks Project
prepared for
GeoTek Alaska, Inc.
Anchorage, AK
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Deviation Plot




Depth [ft] 1:91
Horiz [ft] 1:3
MN
0°
PR18-03
270°
90°
180°
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0

APPENDIX B

PR18-02					
Structure Data					
Depth	Azimuth	Dip	Aperture	Fracture	
ft	deg	deg	inch/10		
93.27	266.95	19.15	0	Geologic Feature	
94.04	62.66	38.51	0	Bedding Plane	
95.71	32.59	58.76	0	Bedding Plane	
95.98	29.6	49.42	0	Bedding Plane	
97.51	66.56	19.27	0	Geologic Feature	
97.72	101.89	21.87	0	Geologic Feature	
103.58	145.06	38.79	0	Geologic Feature	
104.25	8.22	60.92	93.62	Bedding Plane	
108.86	270.18	9.89	0	Geologic Feature	
116.88	317.97	12.81	0	Geologic Feature	
119.93	109.35	61.26	0.35	Bedding Plane	
120.42	128.81	66.69	25.74	Bedding Plane	
125.59	222.82	66.31	0	Geologic Feature	
126.26	213.82	39.15	0	Geologic Feature	
132.57	176.92	47.65	0	Bedding Plane	
133.1	131.14	28.34	0	Bedding Plane	
133.4	216.65	36.48	0	Bedding Plane	
134.25	324.86	66.68	0	Geologic Feature	

PR18-03					
Structure Data					
Depth	Azimuth	Dip	Aperture	Fracture2	
ft	deg	deg	inch/10		
64.69	22.29	45.37	0	Geologic Feature	
66.34	23.97	31.6	0	Geologic Feature	
74.96	65.4	71.4	58.27	Bedding Plane	
76.99	272.79	59.9	0	Bedding Plane	
92.94	338.48	48.46	0	Geologic Feature	
99.05	218.09	54.84	0	Geologic Feature	
99.93	144.17	9.62	0	Geologic Feature	

APPENDIX I-2

Geophysical Investigation 2019

GEOPHYSICAL INVESTIGATION
Report

Pretty Rocks Project
Denali National Park, AK

FOR

GeoTek Alaska, Inc.
Anchorage, AK

by

ENVIROPROBE SERVICE, INC.
81 Marter Avenue, Mt Laurel, NJ 08054

September 2019

ENVIROPROBE
SERVICE
INCORPORATED

September 27, 2019

Scott Voitja
GeoTek Alaska, Inc.
2756 Commercial Drive
Anchorage, AK 99501

REPORT: GEOPHYSICAL INVESTIGATION
Pretty Rocks Project
Denali National Park, AK

Dear Mr. Votja:

We are pleased to present our report for the geophysical borehole logging investigation performed at the Pretty Rocks Project on the Denali Park Road in Denali National Park, AK. The investigation was performed between September 1and September 14, 2019.

If you have any questions concerning this report please contact us at 856-858-8584. We look forward to working with you in the future.

Respectfully submitted,

Enviroprobe Service, Inc.

Matthew J. McMillen

Matthew J. McMillen
Senior Geophysicist

1) INTRODUCTION AND PURPOSE

Four geotechnical borings located at the Pretty Rocks Project in Denali National Park, AK were the object of this geophysical survey. These boreholes were PR19 - 06, PR19 - 07, PR19 - 08 and PR19 - 09.

The purpose of the geophysical borehole logging was to investigate lithology, fracture location, and orientation, in the boreholes.

2) GEOPHYSICAL METHODOLOGY

Geophysical borehole logging was conducted using a Mount Sopris mini winch with a Matrix console and Mount Sopris 2PCA-1000 caliper probe, ALT QL40-2G acoustic televiewer, and an ALT QL40-OBI-2G optical televiewer.

The borehole logs consist of caliper, acoustic televiewer, and optical televiewer.

3) INTERPRETATION

Fractures are classified in the structure logs and tadpole plots as three groups; open fractures, partial open fractures, and closed fractures. These classifications are based on geophysical data as detected in the logs and not by ISRM Characterizations of Rock Definitions. Aperture data if able to be determined is shown in Appendix B.

Open fractures are fractures in the rock that appear to be open based on caliper data. Partial open fractures are fractures that appear not to be fully open in the borehole. Closed fractures show as fractures and have no significant caliper enlargement.

Part of the borehole walls of PR19-08 appeared to be coated in mud from 30.0 feet to 69.5 feet and for PR19-09 from 39.0 feet to 76.5 feet, that did not allow for more accurate data interpretation.

All depths are based on ground surface at the time of the logging.

Interpretations are on the comments section of the log.

Appendix A has all the geophysical logs. Appendix B has the structure data.

PR19 - 06

The boring was logged to approximately 43.67 feet in depth due to the borehole collapsing. Depth of drill steel was approximately 24.9 feet. Water level was at approximately 24.3 feet.

The geophysical logging of this borehole detected significant caliper enlargements at approximately:

1) 27.6 feet to 28.5 feet
2) 33.3 feet to 34.6 feet
3) 38.5 feet to 39.1 feet
4) 39.9 feet to 40.6 feet

See Appendix A for the logs of this borehole.

Appendix B has the structure data.

PR19 - 07

The boring was approximately 101.2 feet in depth. Depth of drill steel was approximately 7.2 feet. Water level was at approximately 81.4 feet.

The geophysical logging of this borehole detected significant caliper enlargements in this borehole at approximately.

1) 7.6 feet to 25.8 feet
2) 27.6 feet to 30.8 feet
3) 32.8 feet to 34.3 feet
4) 43.3 feet to 44.8 feet
5) 48.7 feet to 50.6 feet
6) 56.9 feet to 57.9 feet
7) 65.1 feet to 72.3 feet
8) 83.9 feet to 85.0 feet
9) 93.6 feet to 95.3 feet

See Appendix A for the logs of this borehole.

Appendix B has the structure data.

PR19 - 08

The boring was approximately 73.8 feet in depth on first run and 102.6 feet on second run. Depth of drill steel was approximately 17.5 feet on first run and 81.7 feet on second run. Water level was at approximately 76.6 feet only on the second run.

The geophysical logging of this borehole detected significant caliper enlargements in this borehole at approximately:

1) 17.6 feet to 41.4 feet
2) 59.1 feet to 62.9 feet
3) 69.5 feet to 73.8 feet

The boring wall appear to be coated with mud from 30.0 feet to 69.5 feet.

See Appendix A for the logs of this borehole.

Appendix B has the structure data.

PR19 - 09

The boring was approximately 40.8 feet in depth on first run and 78.4 feet on second run. Depth of drill steel was approximately 5.0 feet on first run and 25.1 feet on second run.

The geophysical logging of this borehole detected significant caliper enlargements in this borehole at approximately:

1) 5.0 feet to 16.2 feet
2) 28.6 feet to 29.7 feet
3) 30.0 feet to 38.7 feet
4) 43.4 feet to 44.2 feet

The boring wall appear to be coated with mud from 39.0 feet to 76.5 feet.

See Appendix A for the logs of this borehole.

Appendix B has the structure data.

4) CONCLUSIONS

A geophysical borehole logging investigation of four geotechnical borings located at the Pretty Rocks Project on the Denali Park Road in Denali National Park, AK was conducted using of caliper, acoustic televiewer, and optical televiewer. The purpose of this investigation was to investigate lithology, fracture location, and orientation.

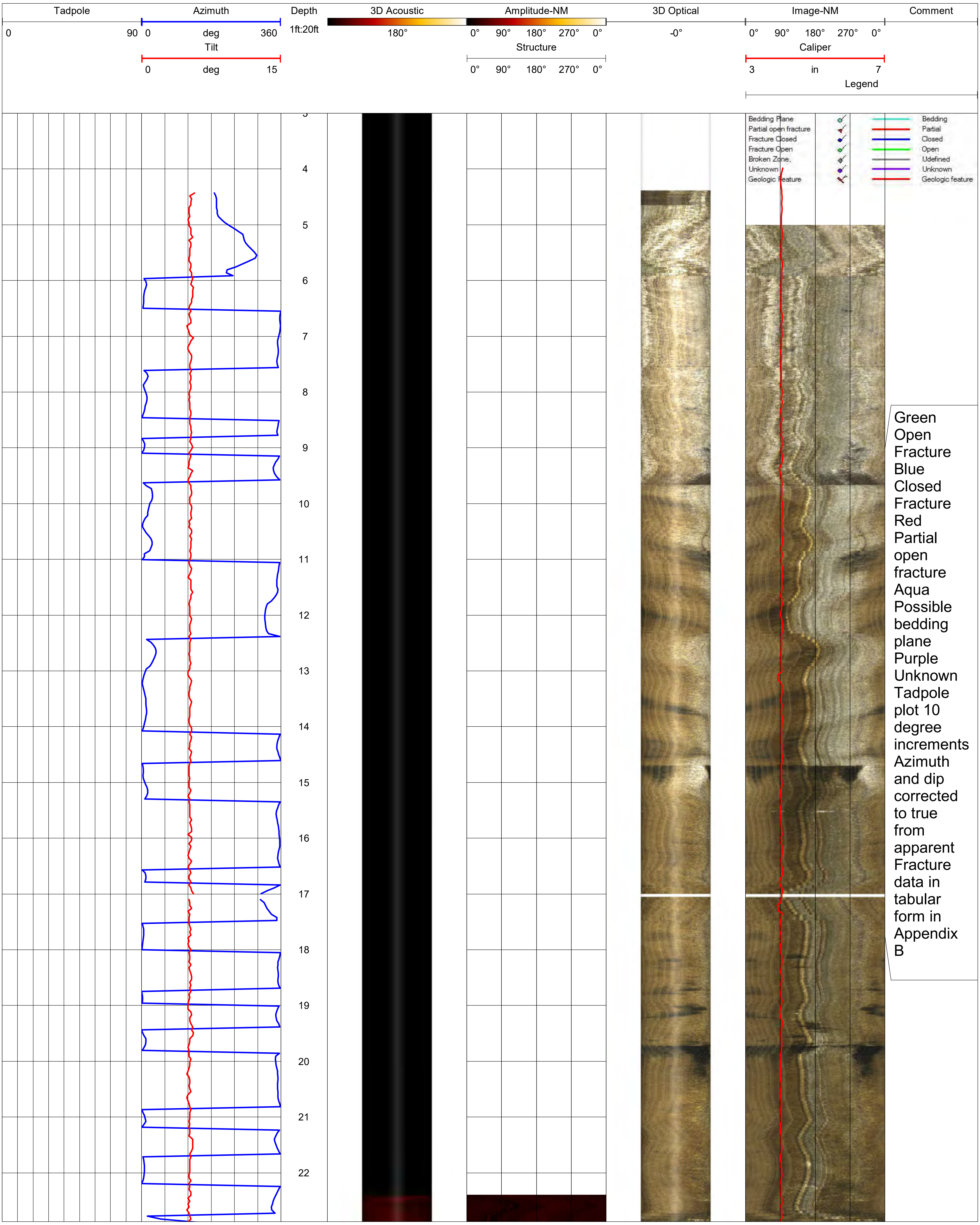
Results are shown as borehole logs. A discussion of the borehole is given in the interpretation section.

Appendix A shows the borehole logs.

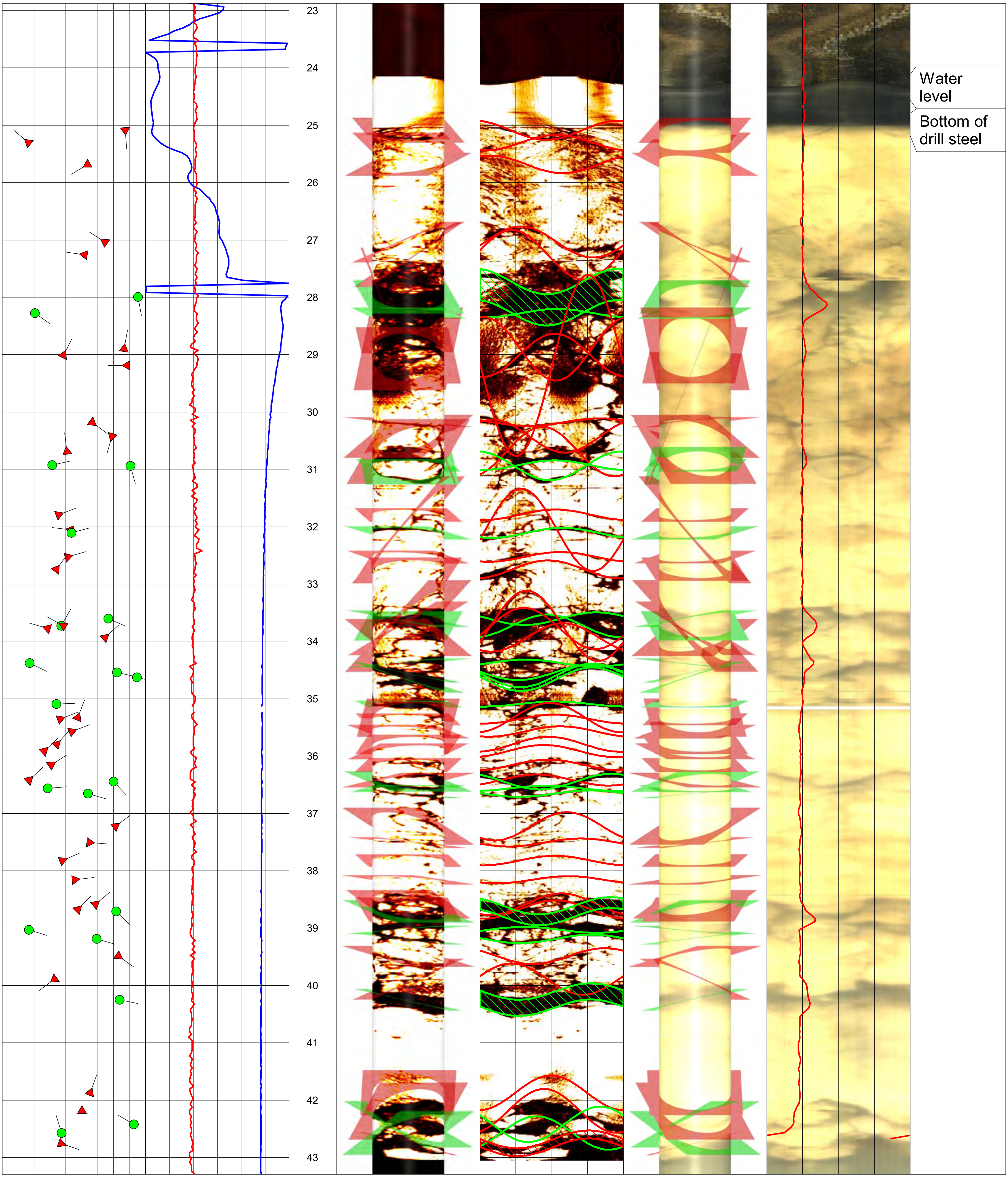
Appendix B has the structure data.

APPENDIX A

PR19-06
Pretty Rocks Project
prepared for
GeoTek Alaska, Inc.
Anchorage, AK
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Caliper, Acoustic and Optical Televiewer



Green Open Fracture Blue Closed Fracture Red Partial open fracture Aqua Possible bedding plane Purple Unknown Tadpole plot 10 degree increments Azimuth and dip corrected to true from apparent Fracture data in tabular form in Appendix B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Water level
Bottom of drill steel
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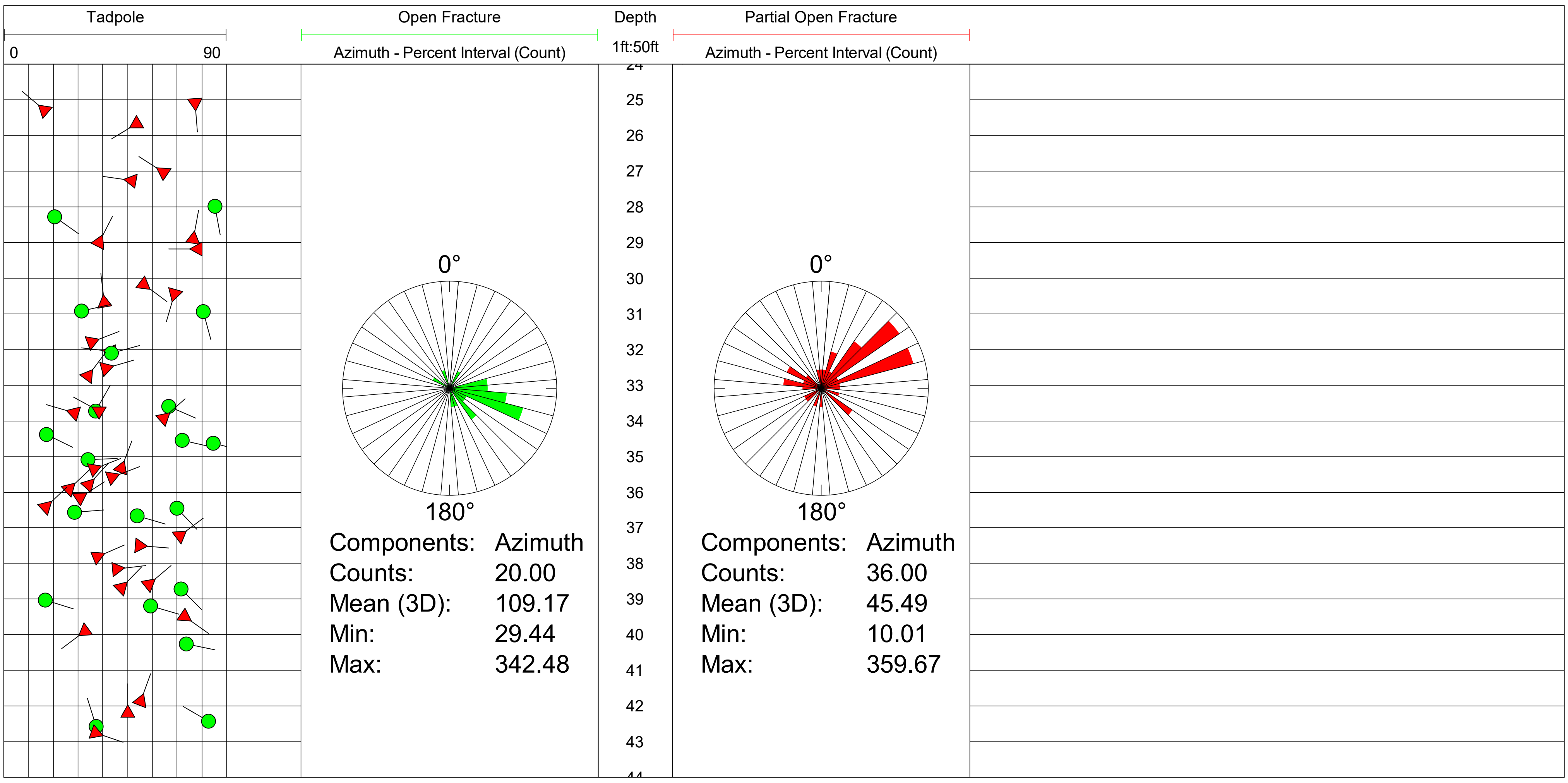
PR19-06
Pretty Rocks Project
prepared for
GeoTek Alaska, Inc.
Anchorage, AK
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Rose Diagram



Open Fracture

Components:	Azimuth
Counts:	20.00
Mean (3D):	109.17
Min:	29.44
Max:	342.48

Partial Open Fracture

Components:	Azimuth
Counts:	36.00
Mean (3D):	45.49
Min:	10.01
Max:	359.67

PR19-06
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by
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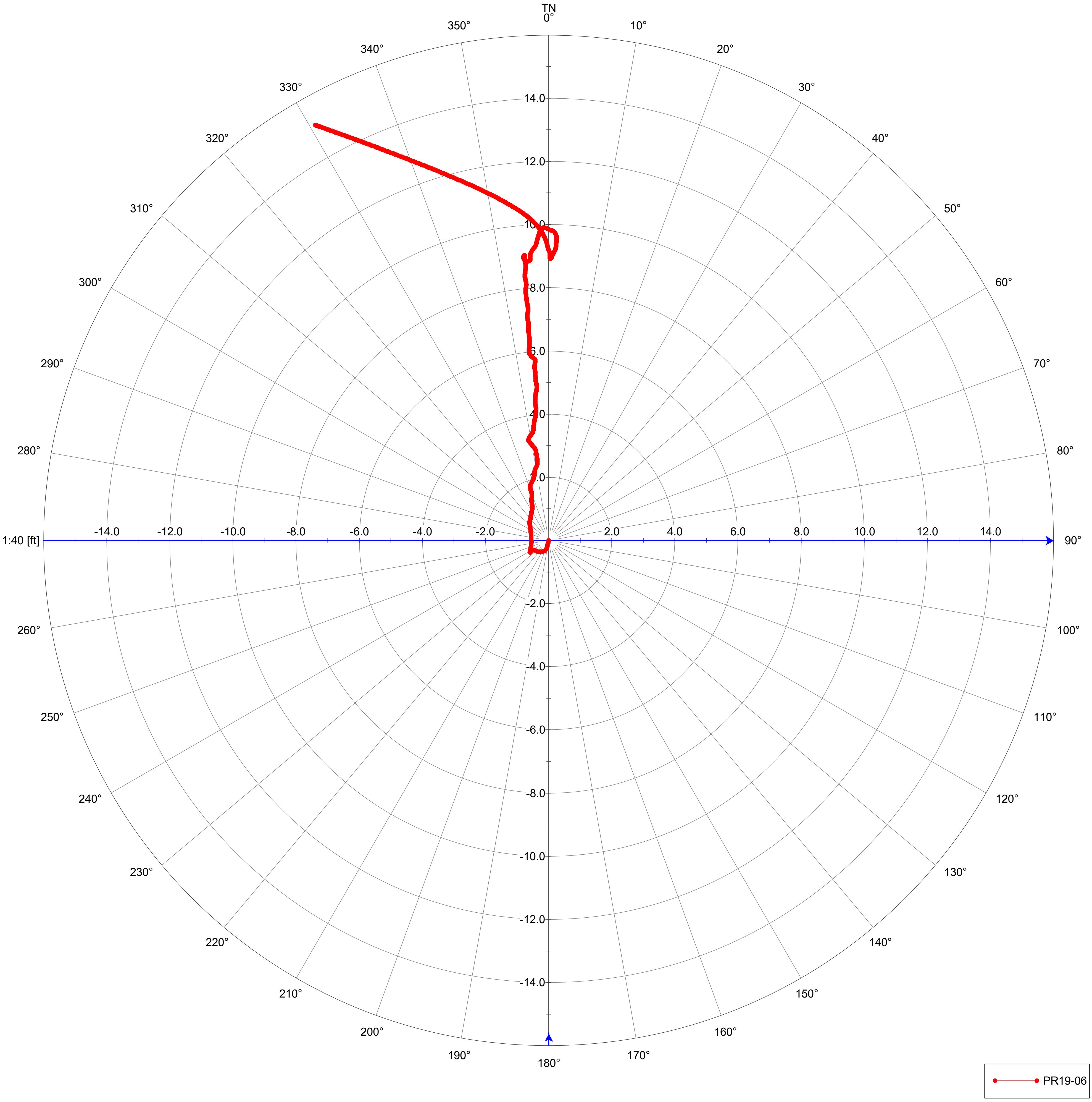
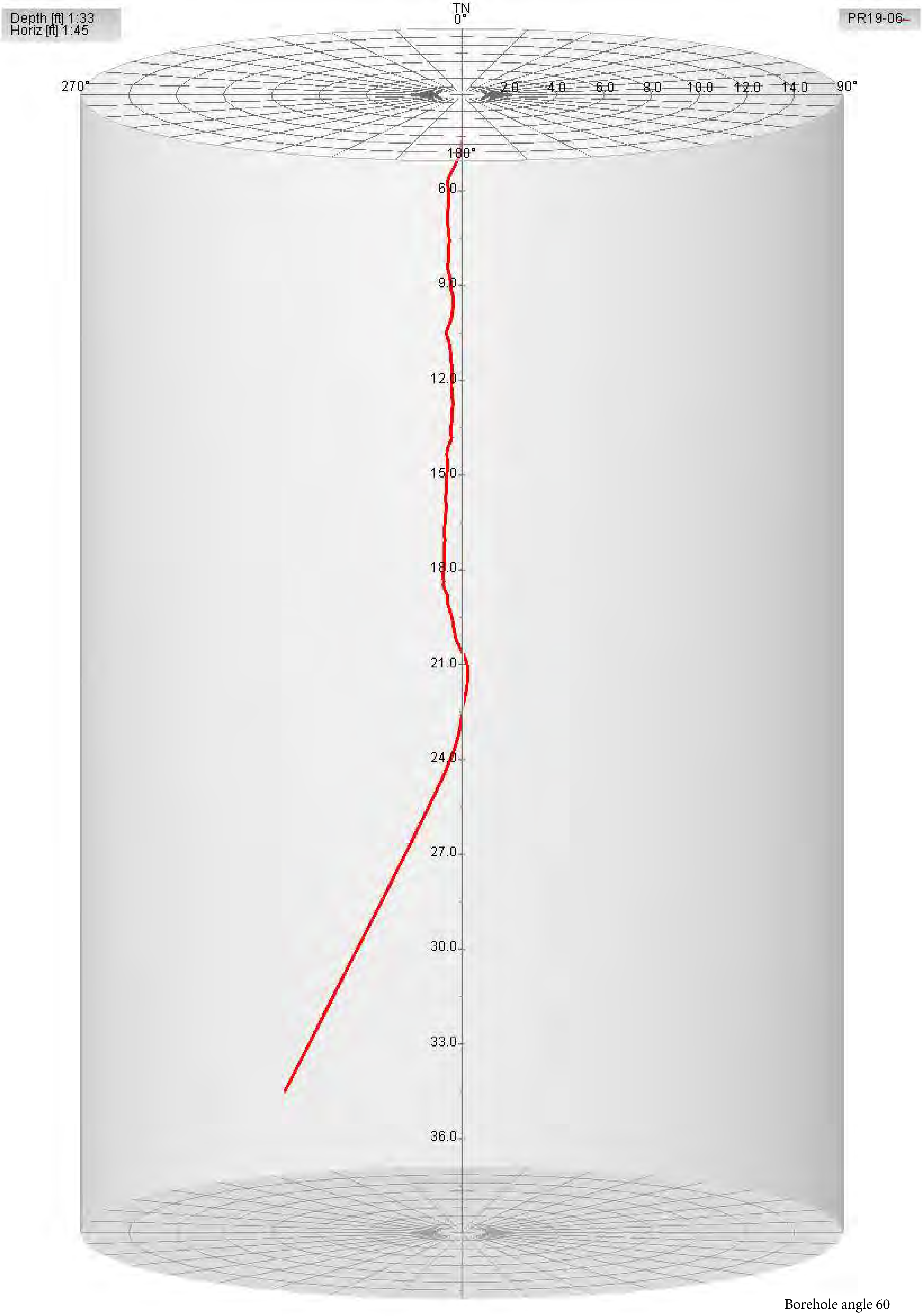
Mount Laurel, NJ
Deviation Plot



Borehole angle 60 degrees from horizontal.



Borehole angle 60 degrees from horizontal.

PR19-07
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by
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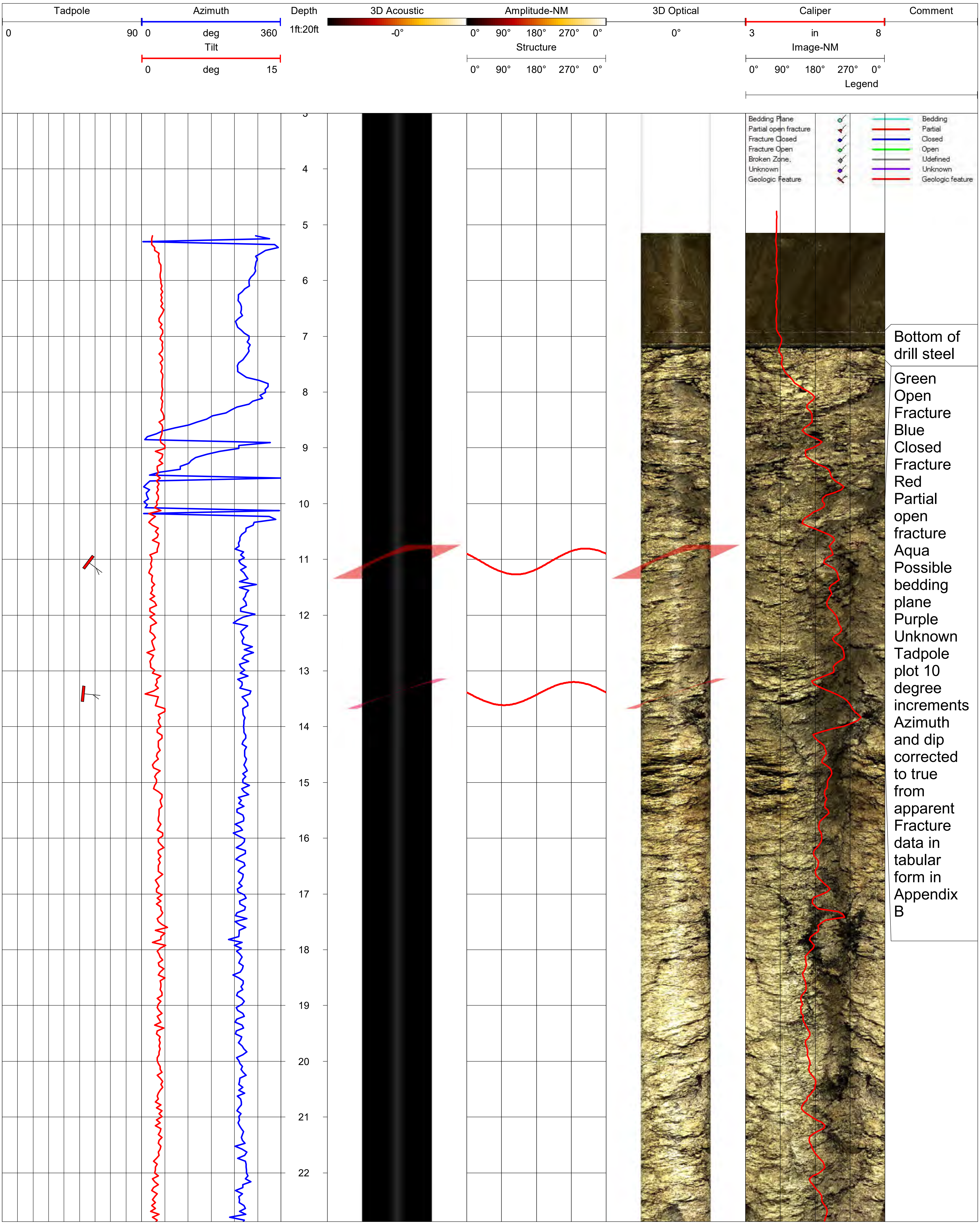
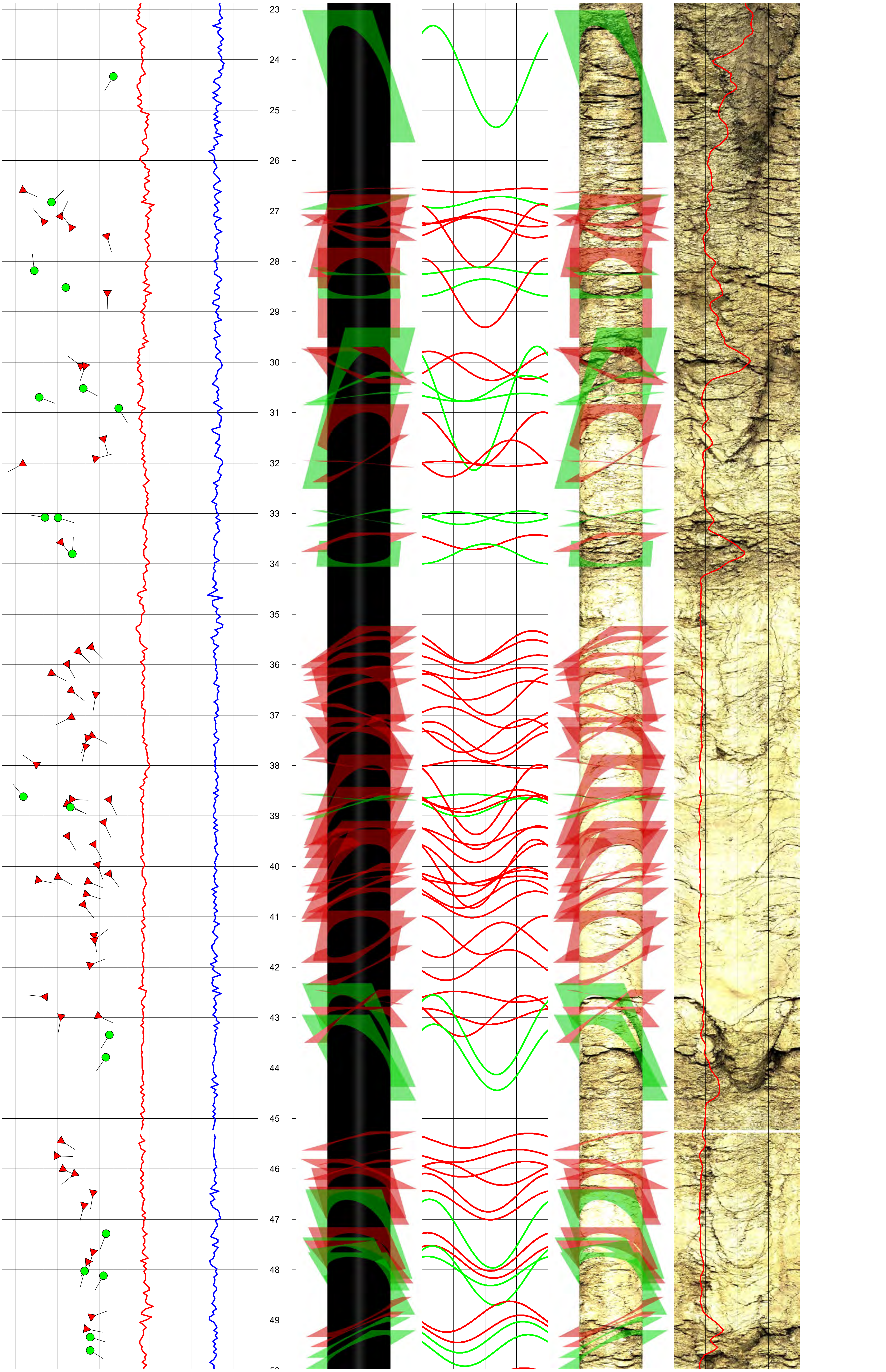
Mount Laurel, NJ
Caliper, Acoustic and Optical Televiewer



Bottom of drill steel

Green Open Fracture Blue Closed Fracture Red Partial open fracture Aqua Possible bedding plane Purple Unknown Tadpole plot 10 degree increments Azimuth and dip corrected to true from apparent Fracture data in tabular form in Appendix B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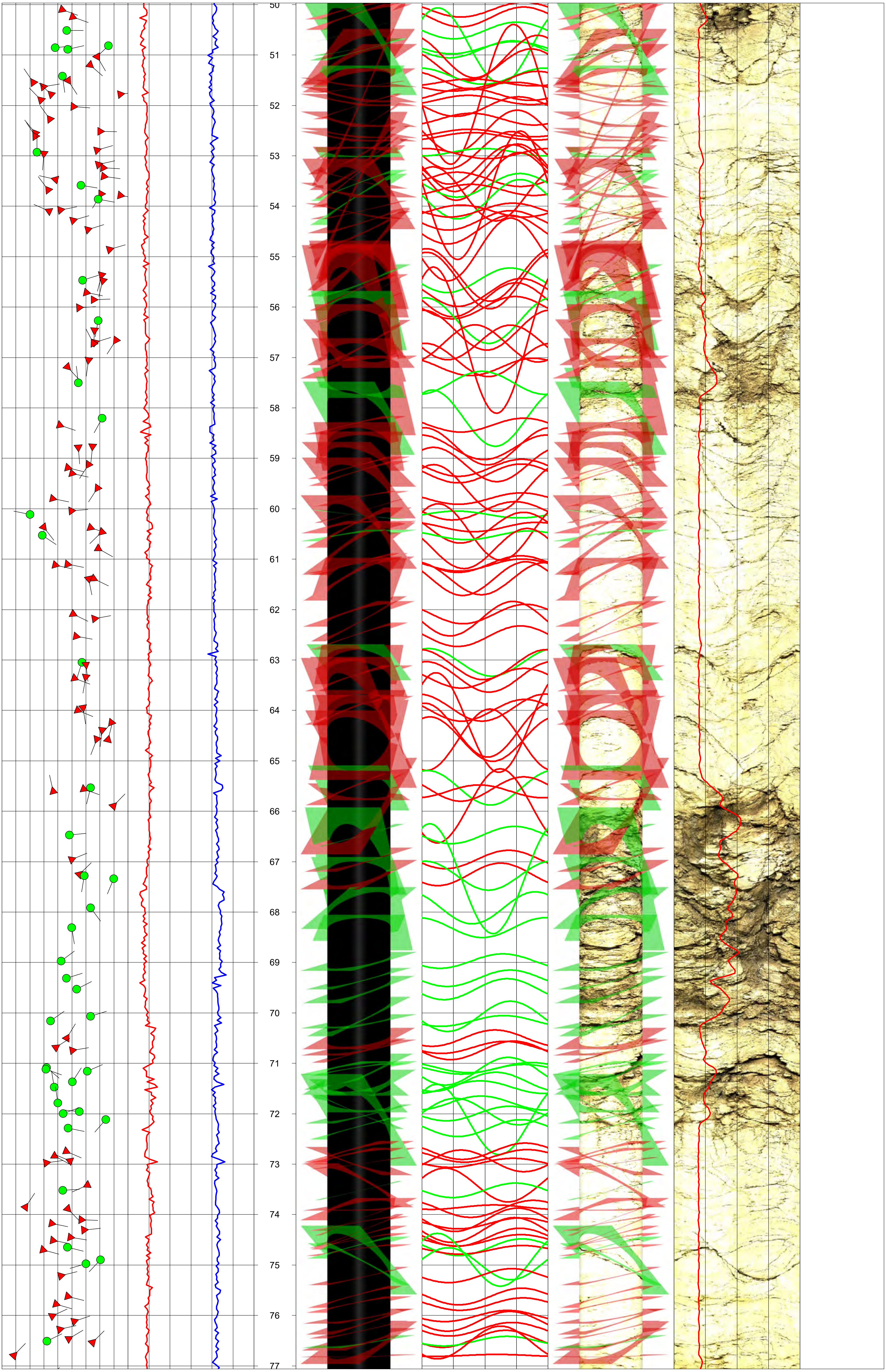
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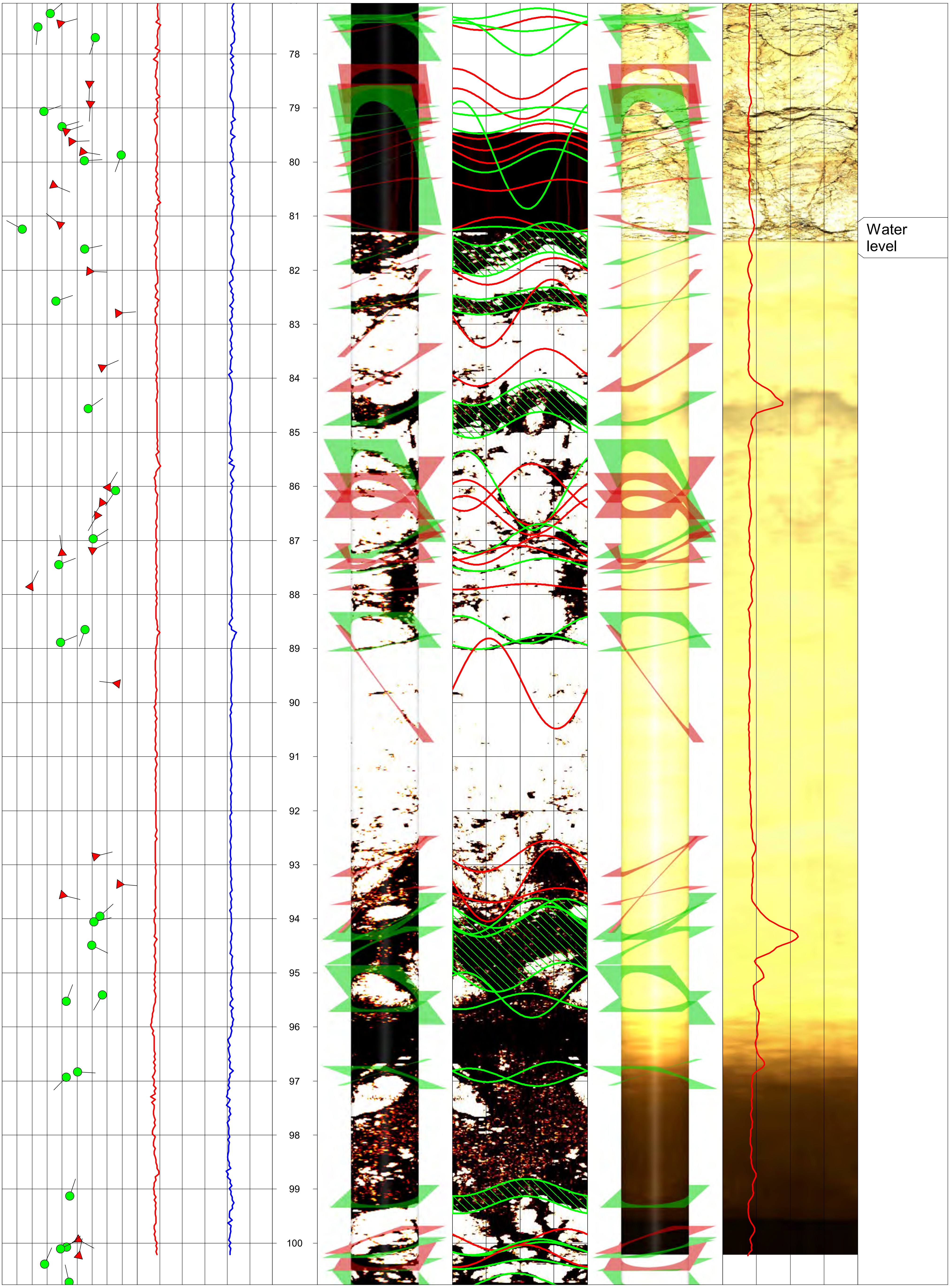

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Water level

PR19-07
Pretty Rocks Project
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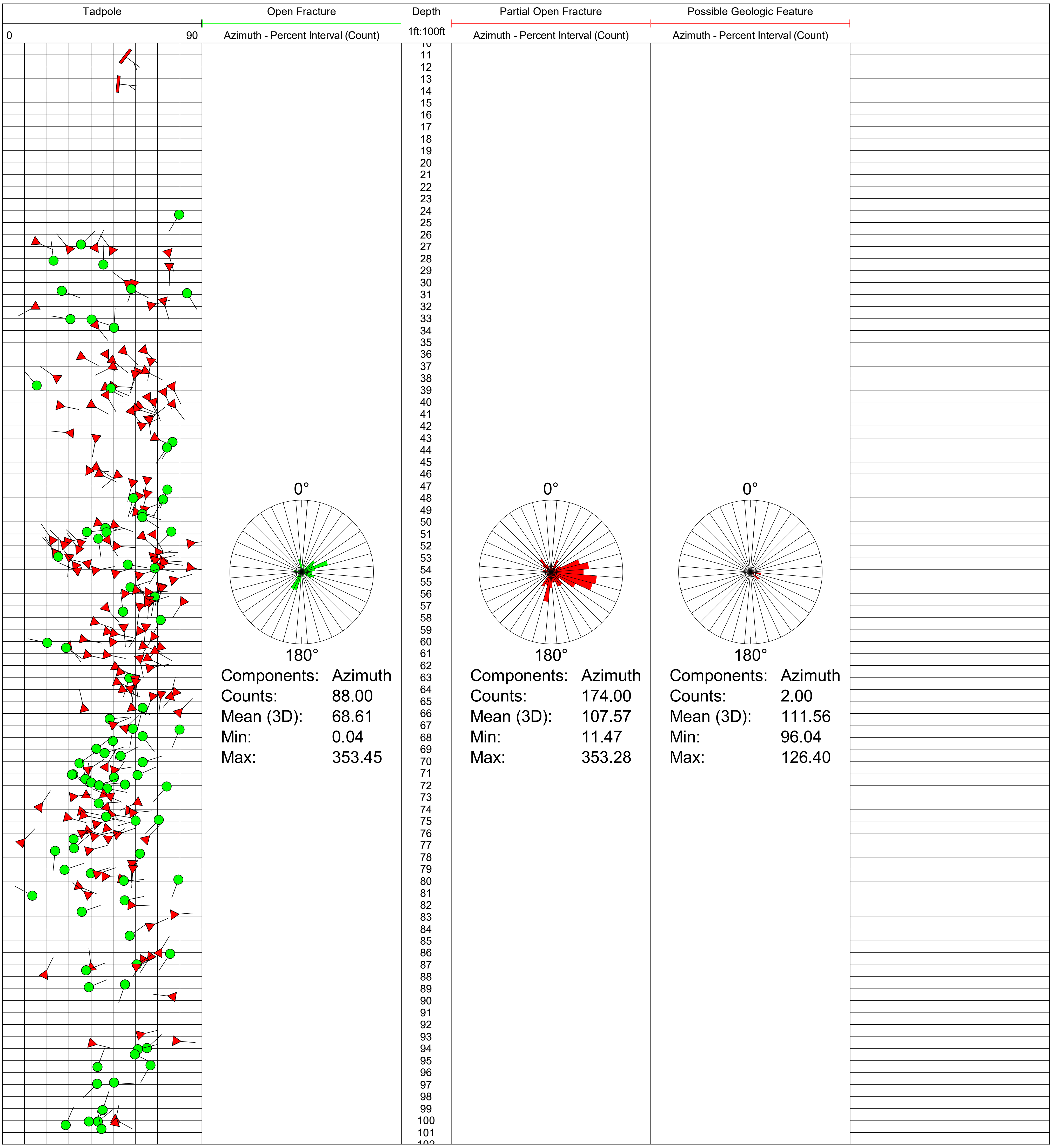
Anchorage, AK
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Rose Diagram



Components:	Azimuth
Counts:	88.00
Mean (3D):	68.61
Min:	0.04
Max:	353.45

Components:	Azimuth
Counts:	174.00
Mean (3D):	107.57
Min:	11.47
Max:	353.28

Components:	Azimuth
Counts:	2.00
Mean (3D):	111.56
Min:	96.04
Max:	126.40

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by
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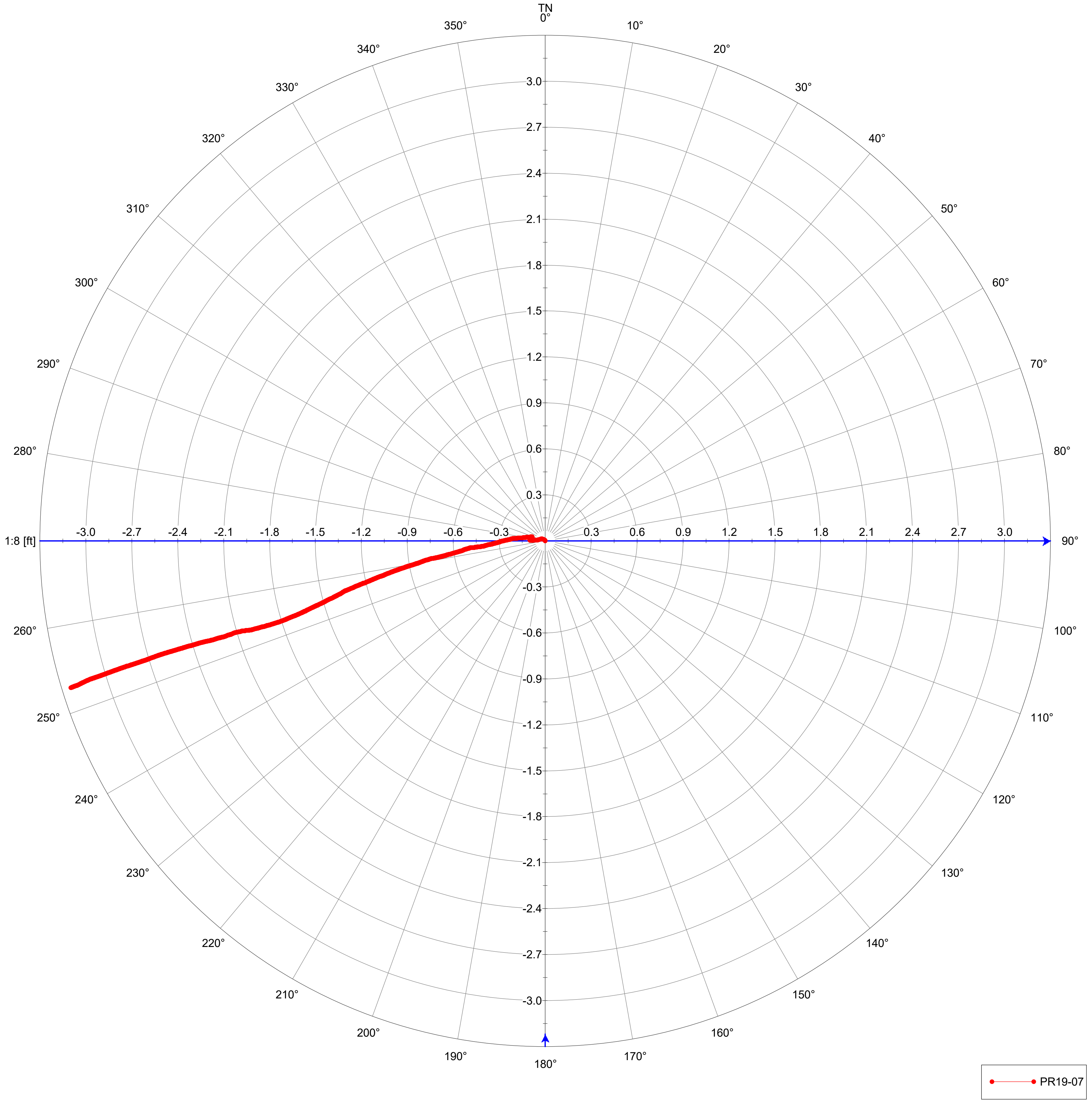
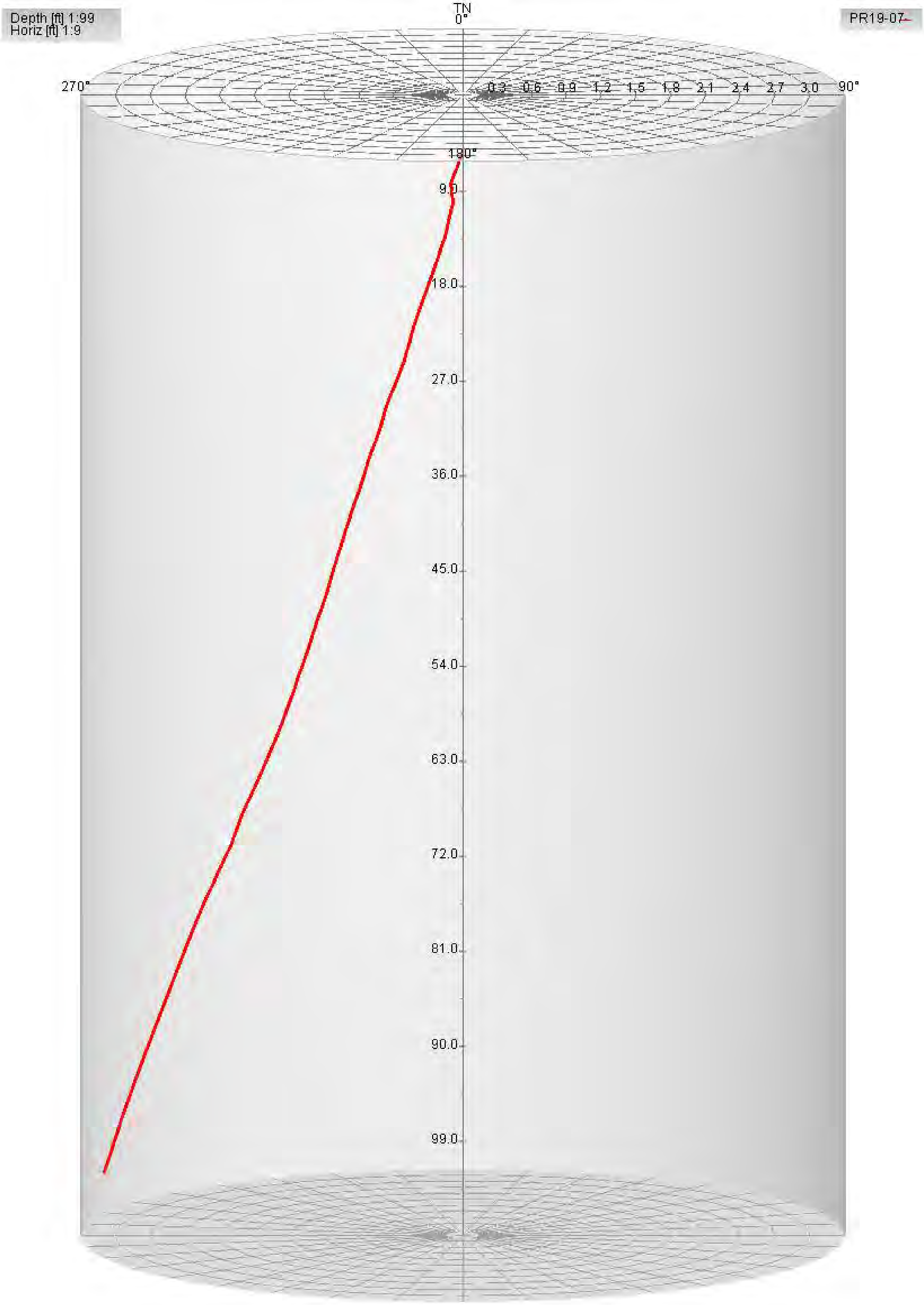
Mount Laurel, NJ
Borehole Deviation



Borehole angle vertical



Borehole angle vertical

PR19-08
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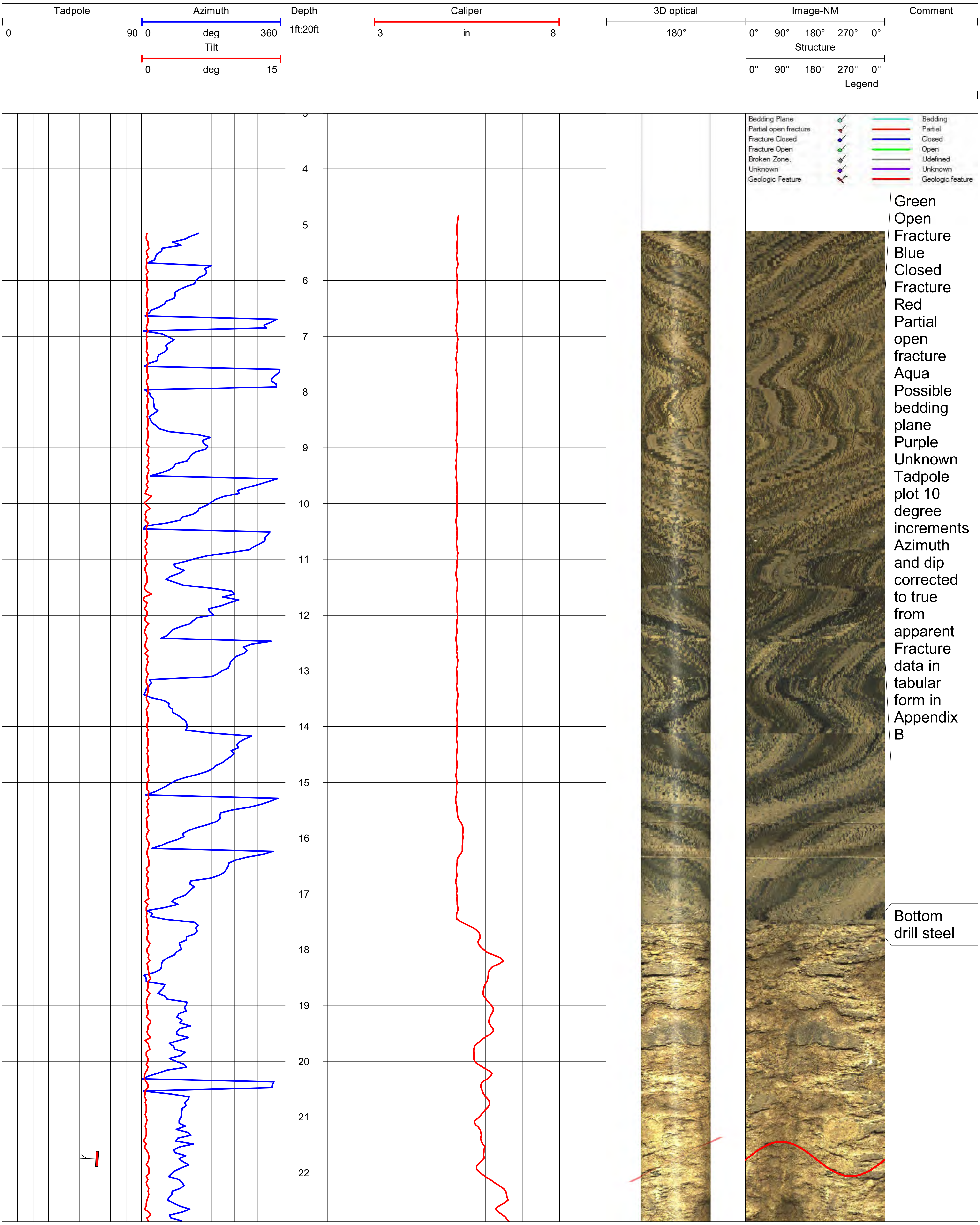
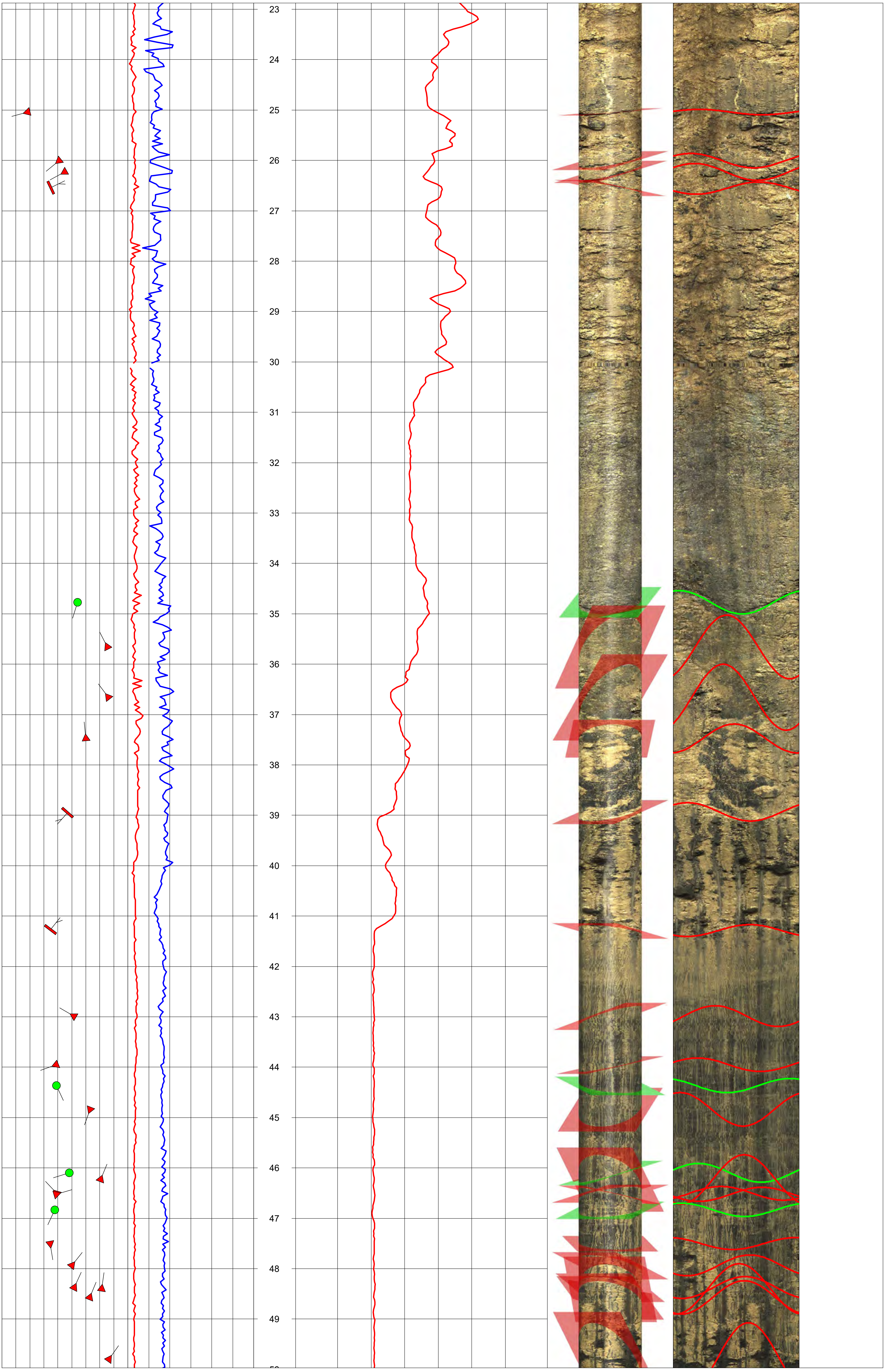
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Caliper and Optical Televiewer



Green Open Fracture Blue Closed Fracture Red Partial open fracture Aqua Possible bedding plane Purple Unknown Tadpole plot 10 degree increments Azimuth and dip corrected to true from apparent Fracture data in tabular form in Appendix B

Bottom drill steel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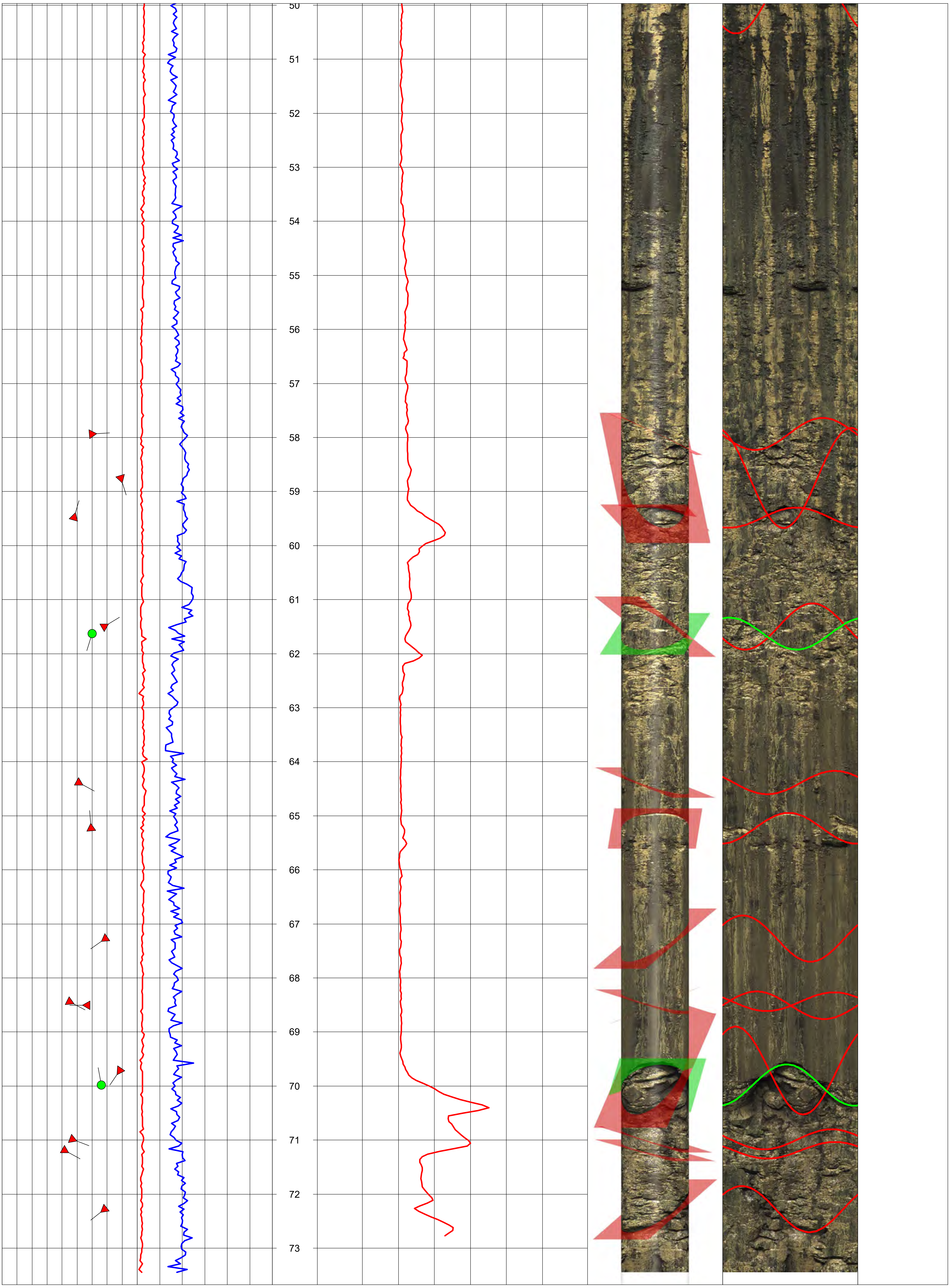
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PR19-08
Pretty Rocks Project
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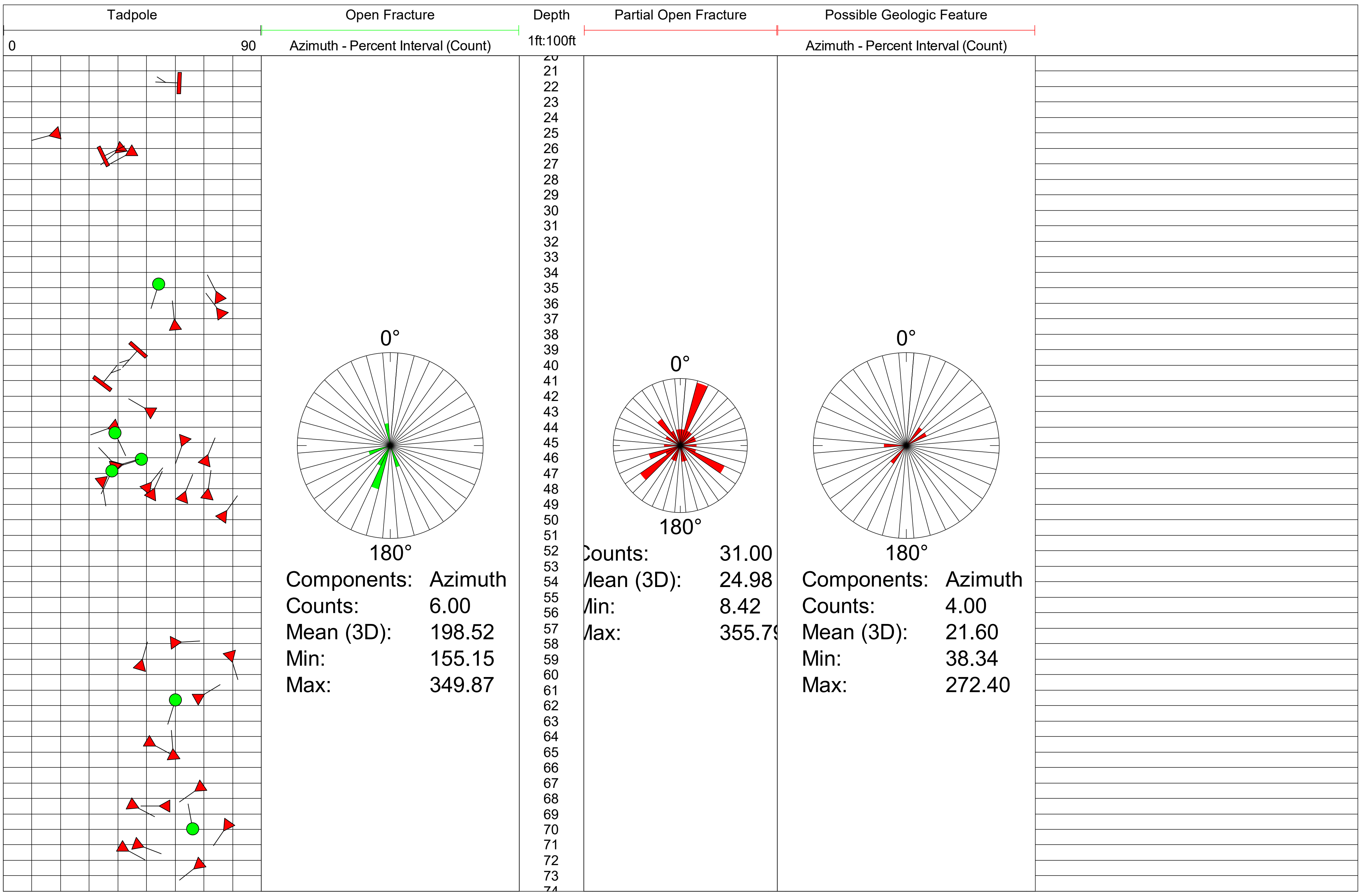
Anchorage, AK
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Rose Diagram



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by
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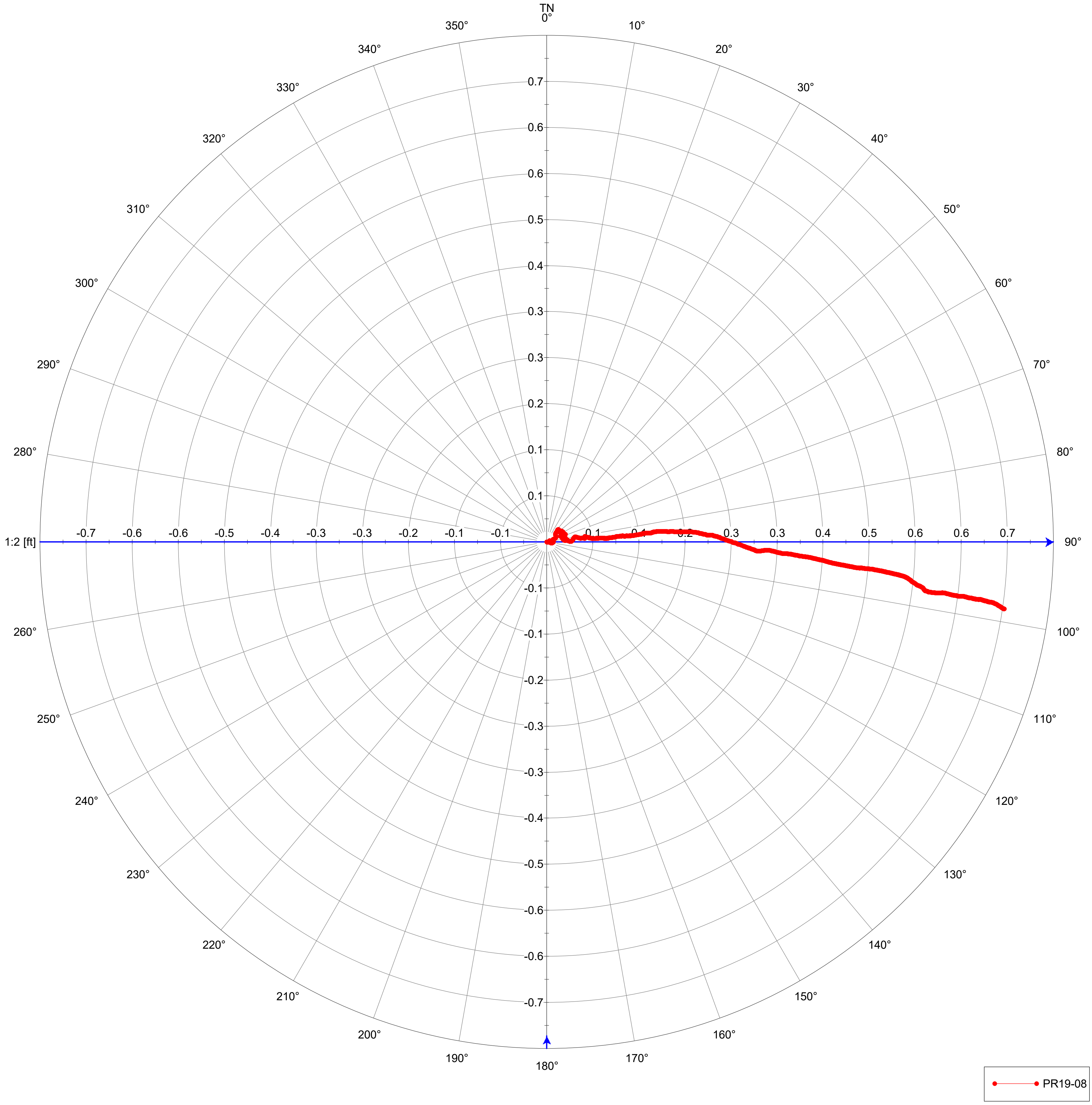
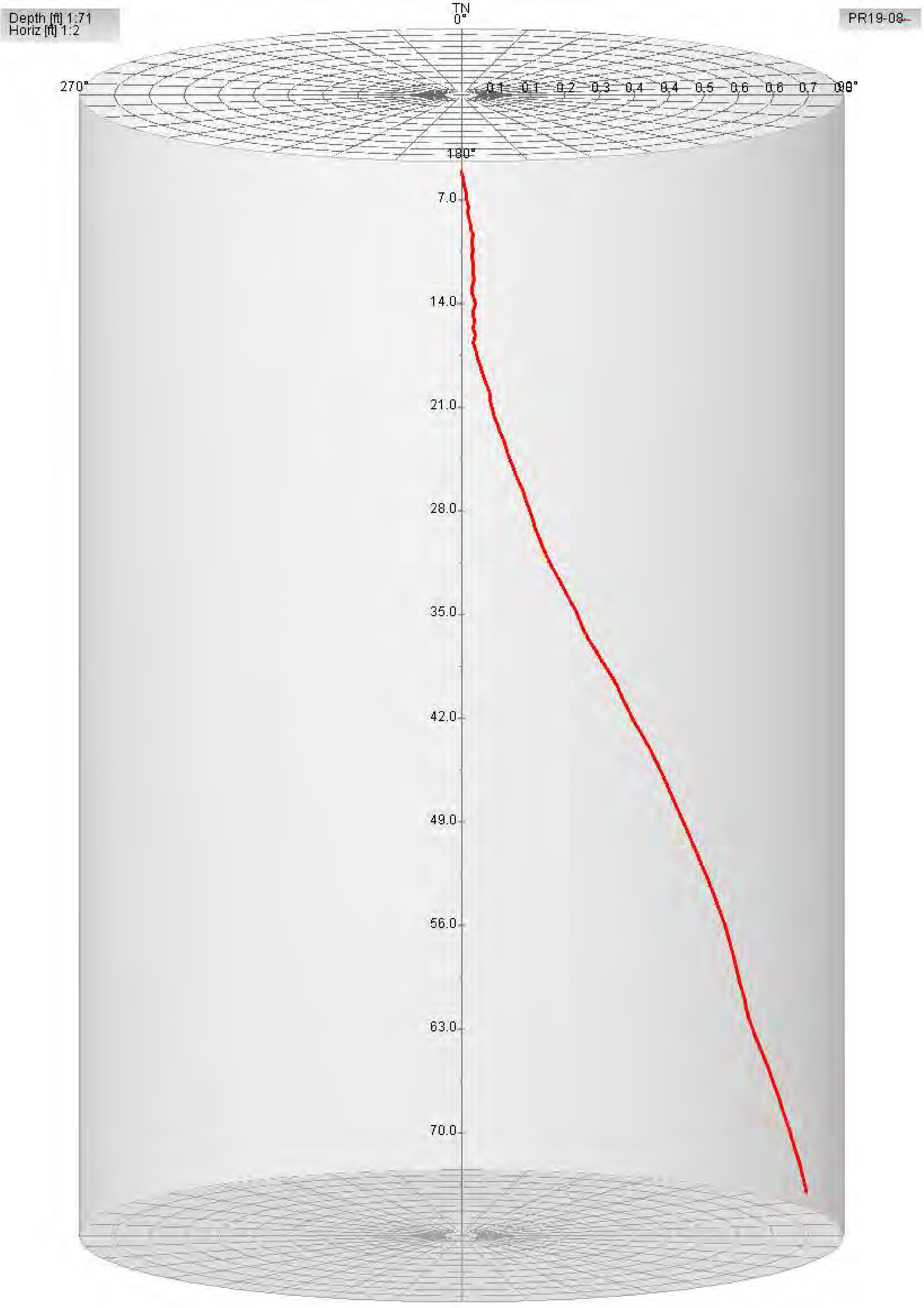
Mount Laurel, NJ
Borehole deviation



Borehole angle vertical



Borehole angle vertical

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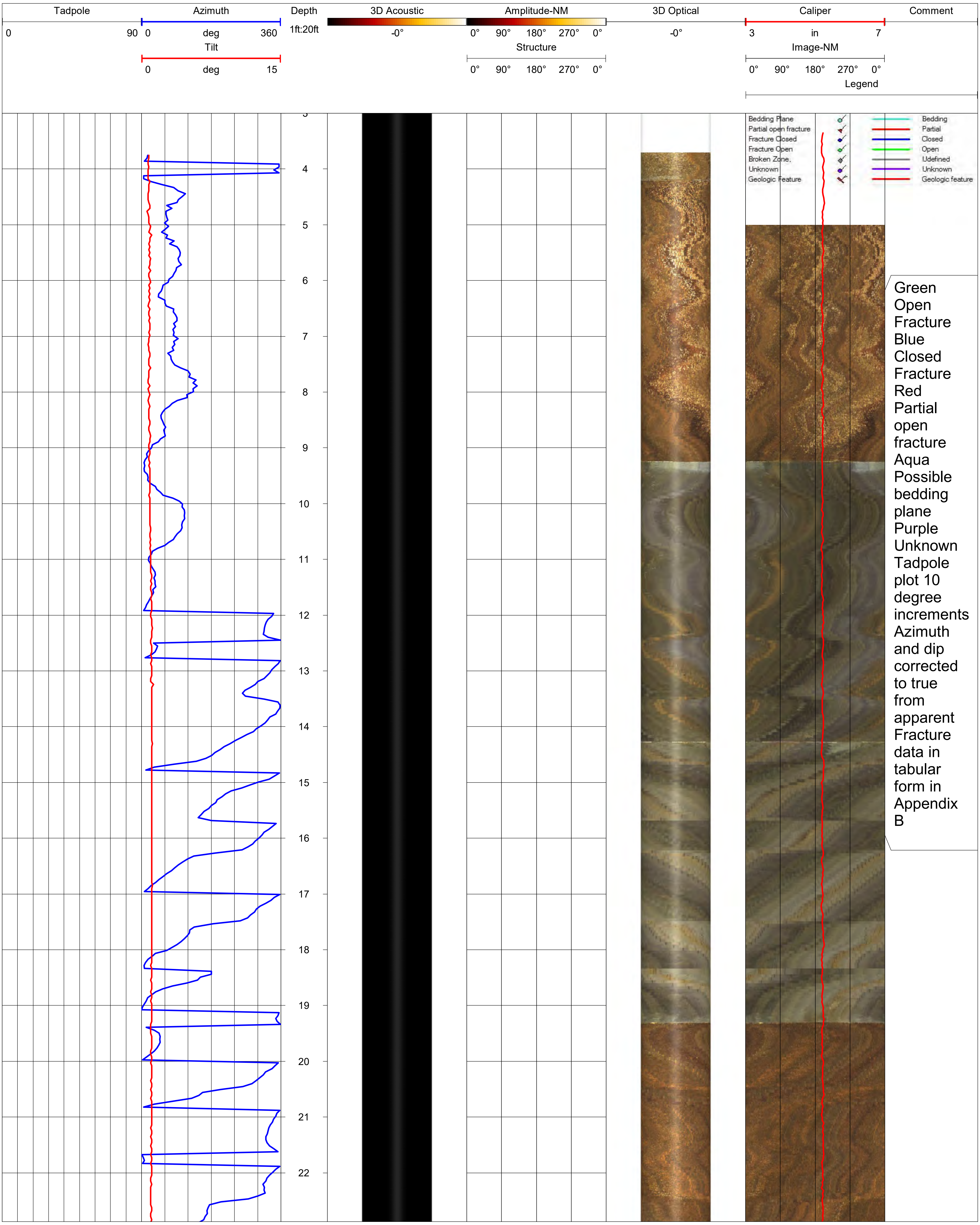
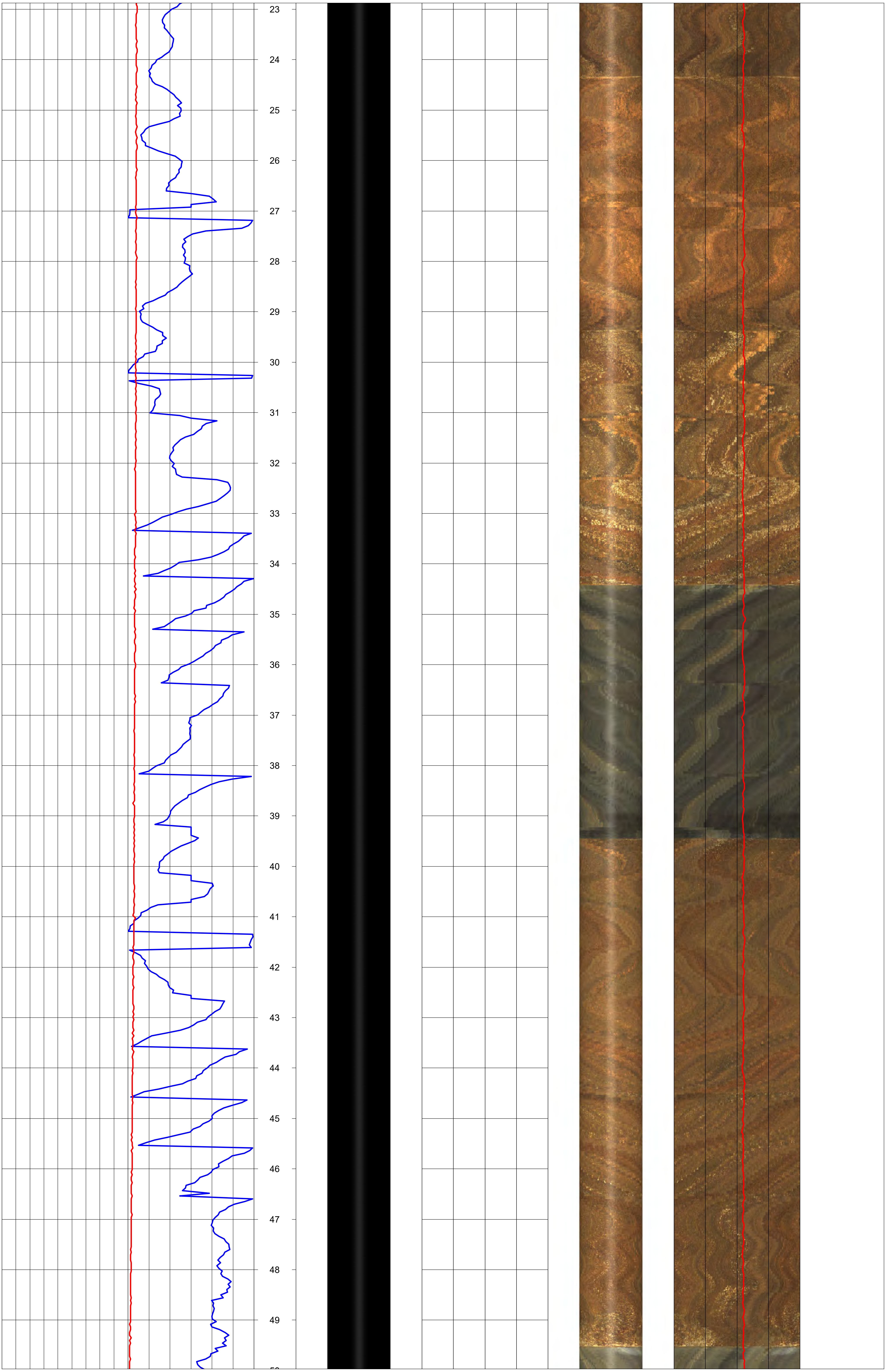
Mount Laurel, NJ
Caliper, Acoustic and Optical Televiewer



Green Open Fracture Blue Closed Fracture Red Partial open fracture Aqua Possible bedding plane Purple Unknown Tadpole plot 10 degree increments Azimuth and dip corrected to true from apparent Fracture data in tabular form in Appendix B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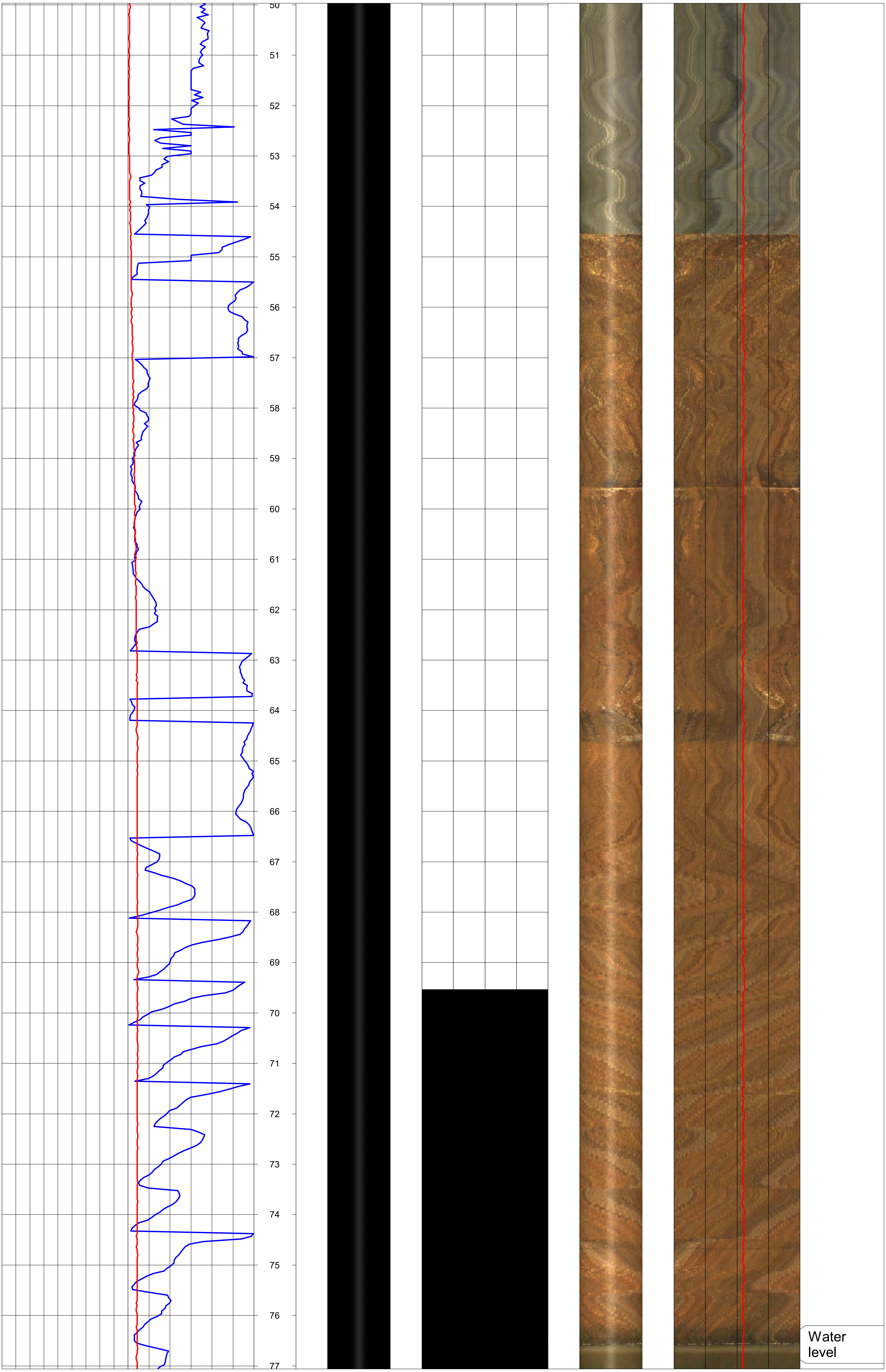
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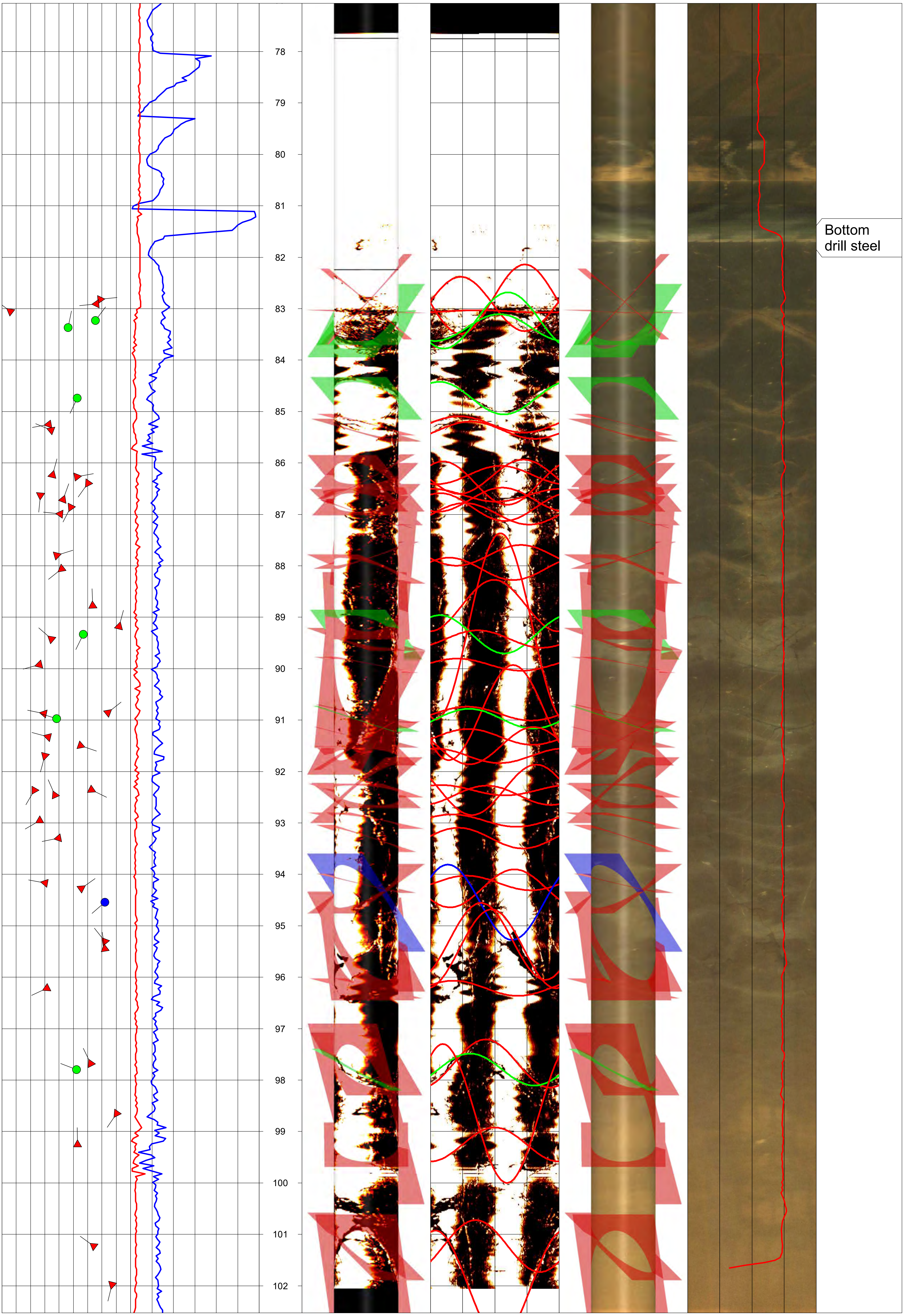
Water level



Bottom
drill steel

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by
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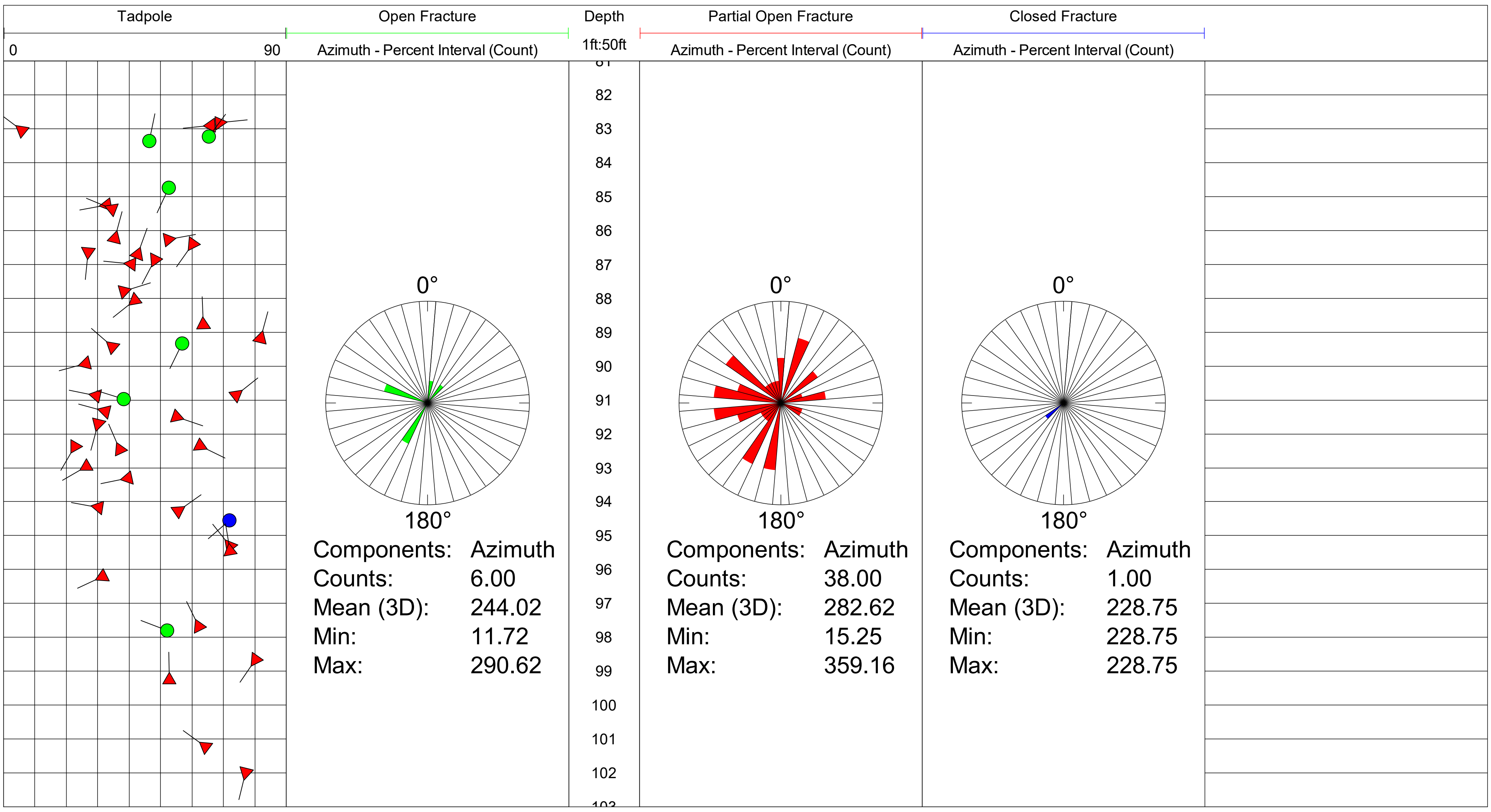
Mount Laurel, NJ
Rose Diagram



	Open Fracture	Partial Open Fracture	Closed Fracture
Components:	Azimuth	Azimuth	Azimuth
Counts:	6.00	38.00	1.00
Mean (3D):	244.02	282.62	228.75
Min:	11.72	15.25	228.75
Max:	290.62	359.16	228.75

PR19-08
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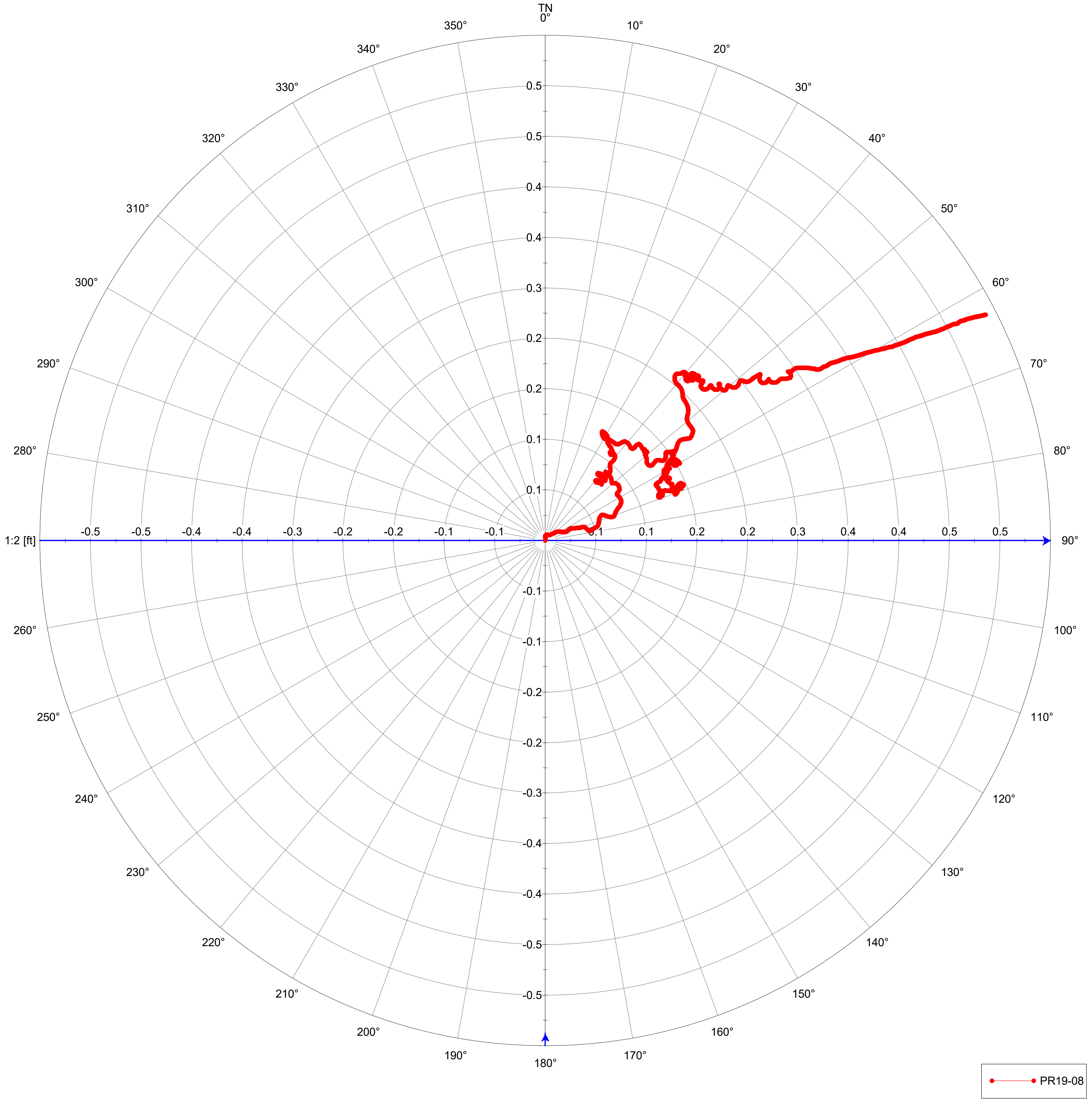
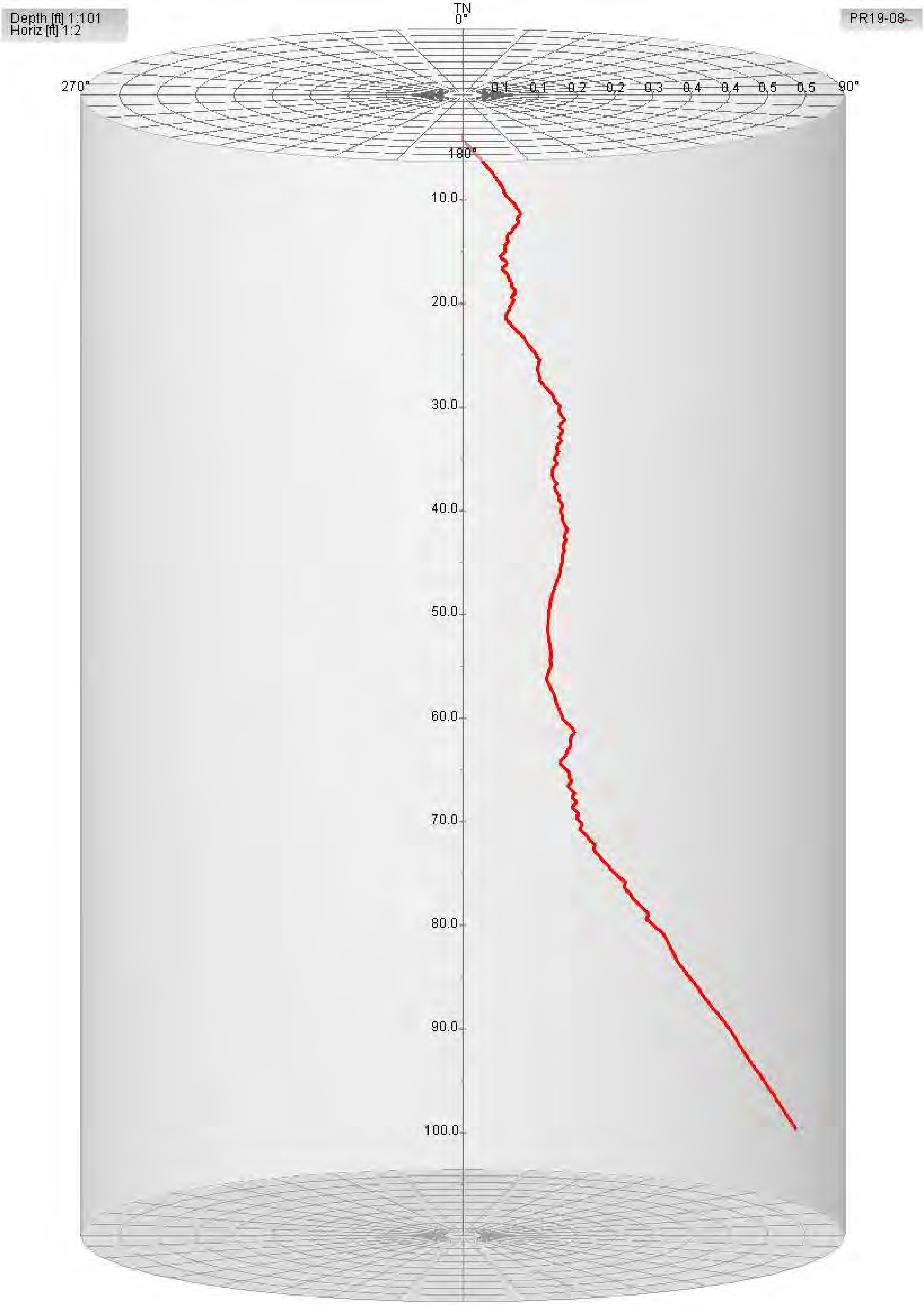
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Borehole Deviation



Borehole angle vertical



Borehole angle vertical

PR19-09
Pretty Rocks Project
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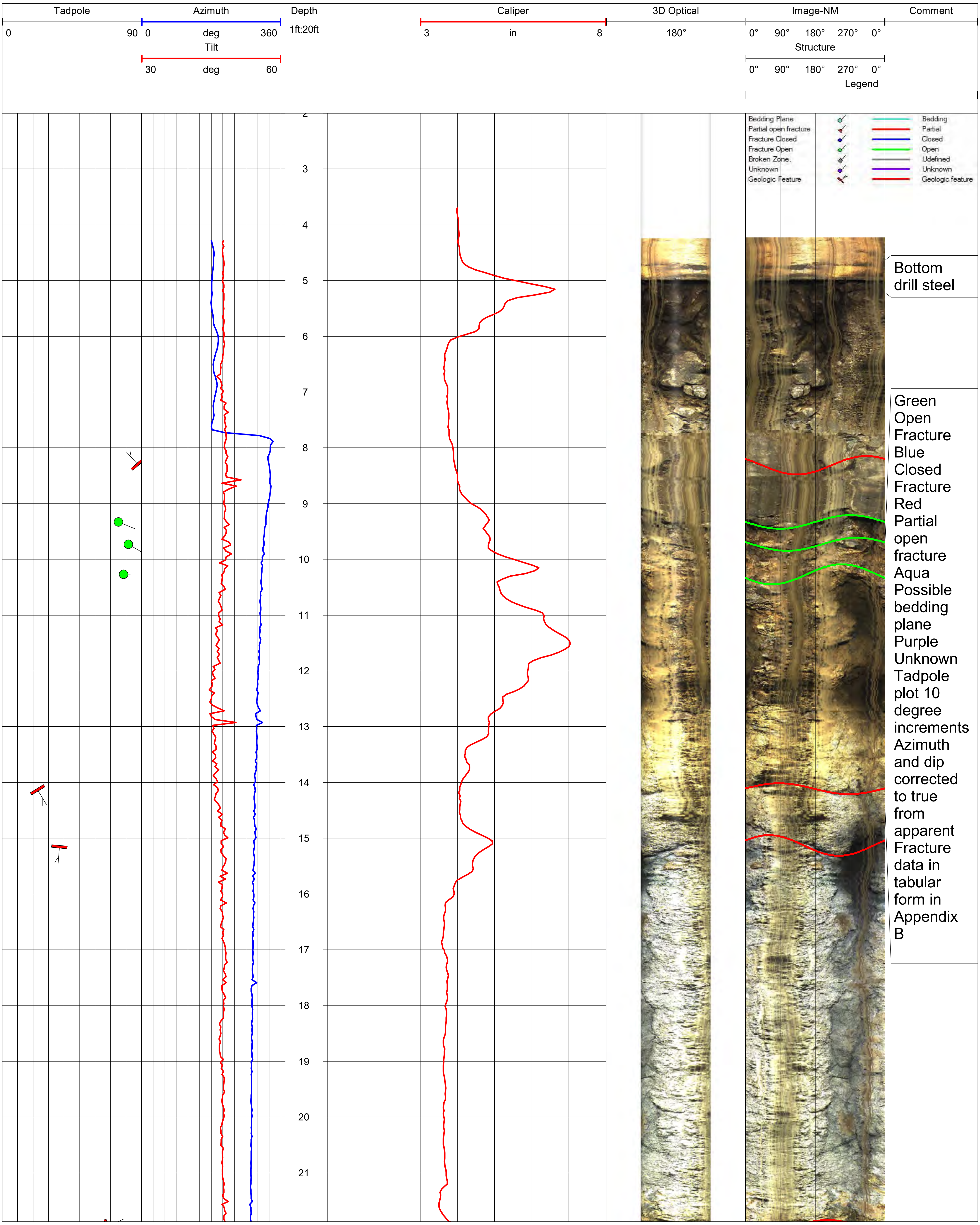
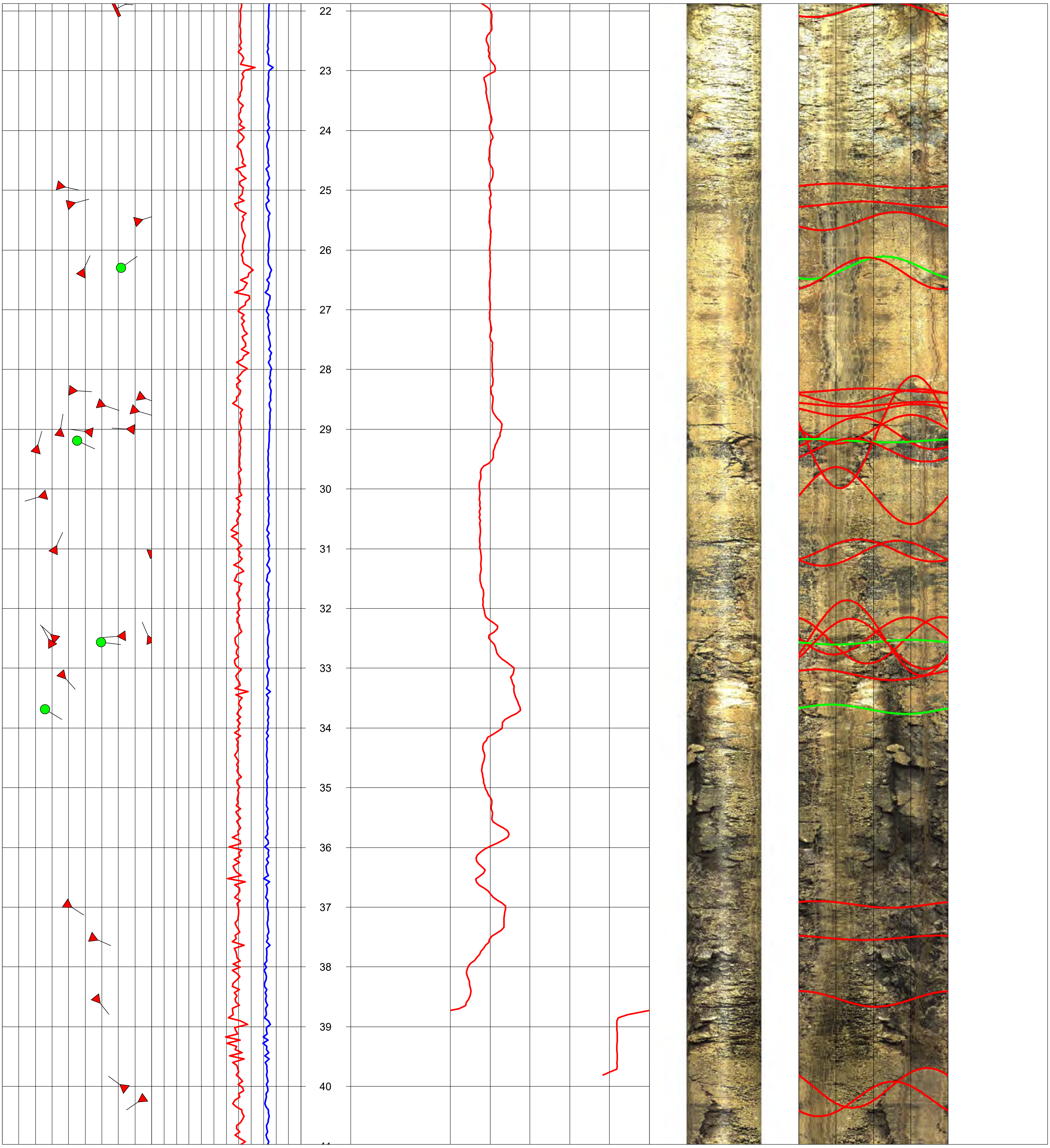
Anchorage, AK
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Caliper and Optical Televiewer



Bottom drill steel

Green Open Fracture Blue Closed Fracture Red Partial open fracture Aqua Possible bedding plane Purple Unknown Tadpole plot 10 degree increments Azimuth and dip corrected to true from apparent Fracture data in tabular form in Appendix B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PR19-09
Pretty Rocks Project
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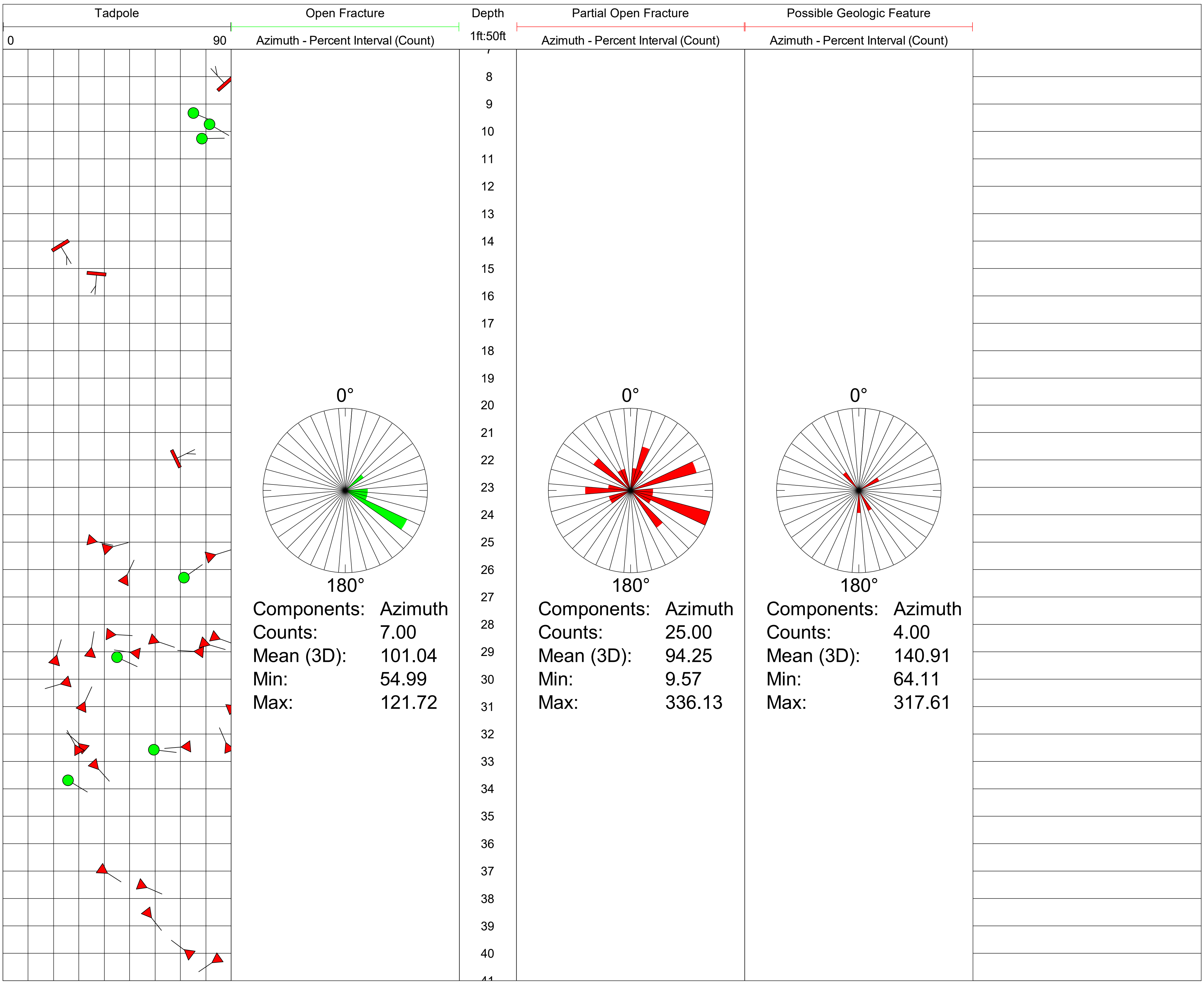
Anchorage, AK
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Rose Diagram



	Open Fracture	Partial Open Fracture	Possible Geologic Feature
Components:	Azimuth	Azimuth	Azimuth
Counts:	7.00	25.00	4.00
Mean (3D):	101.04	94.25	140.91
Min:	54.99	9.57	64.11
Max:	121.72	336.13	317.61

PR19-09
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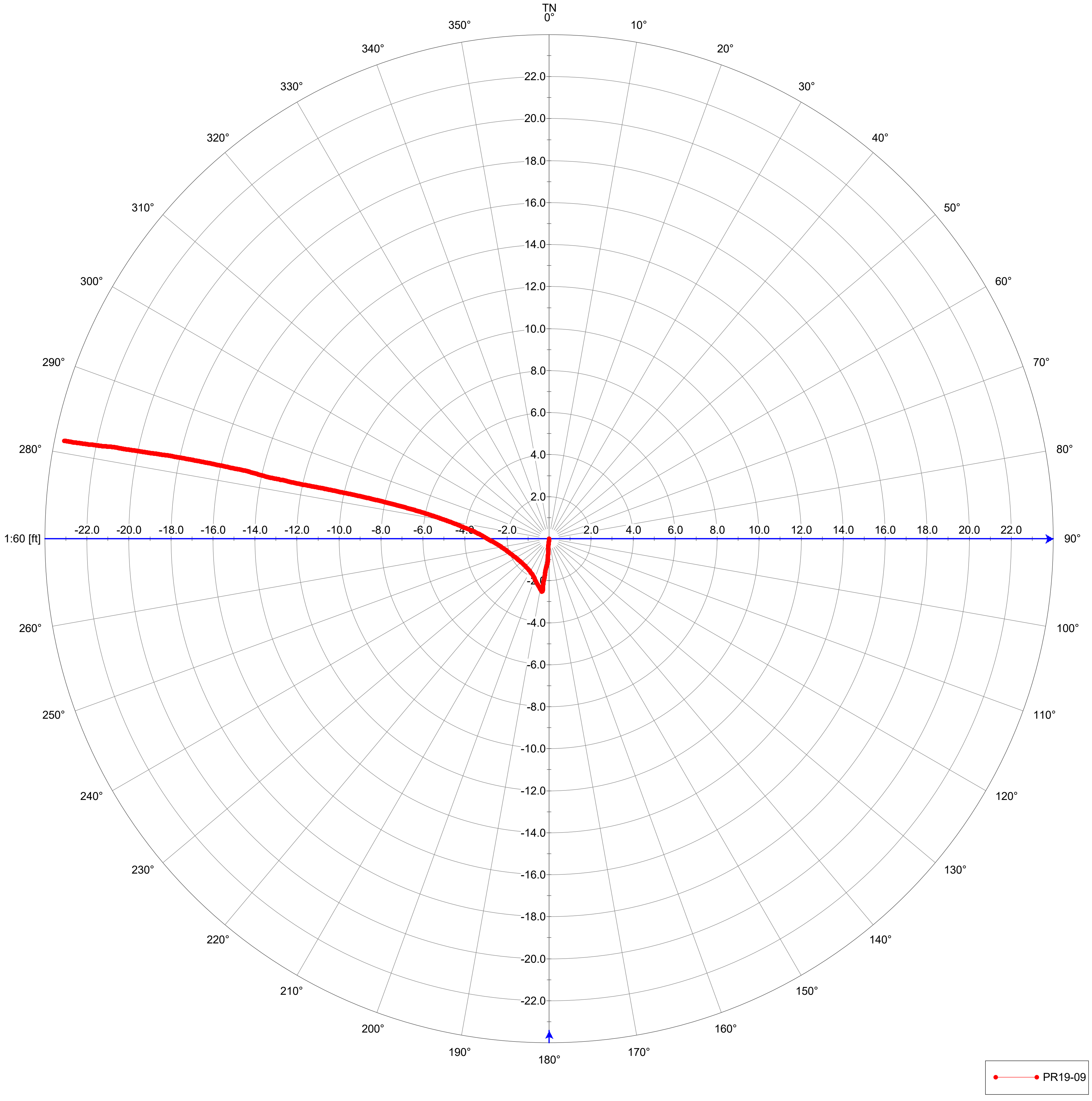
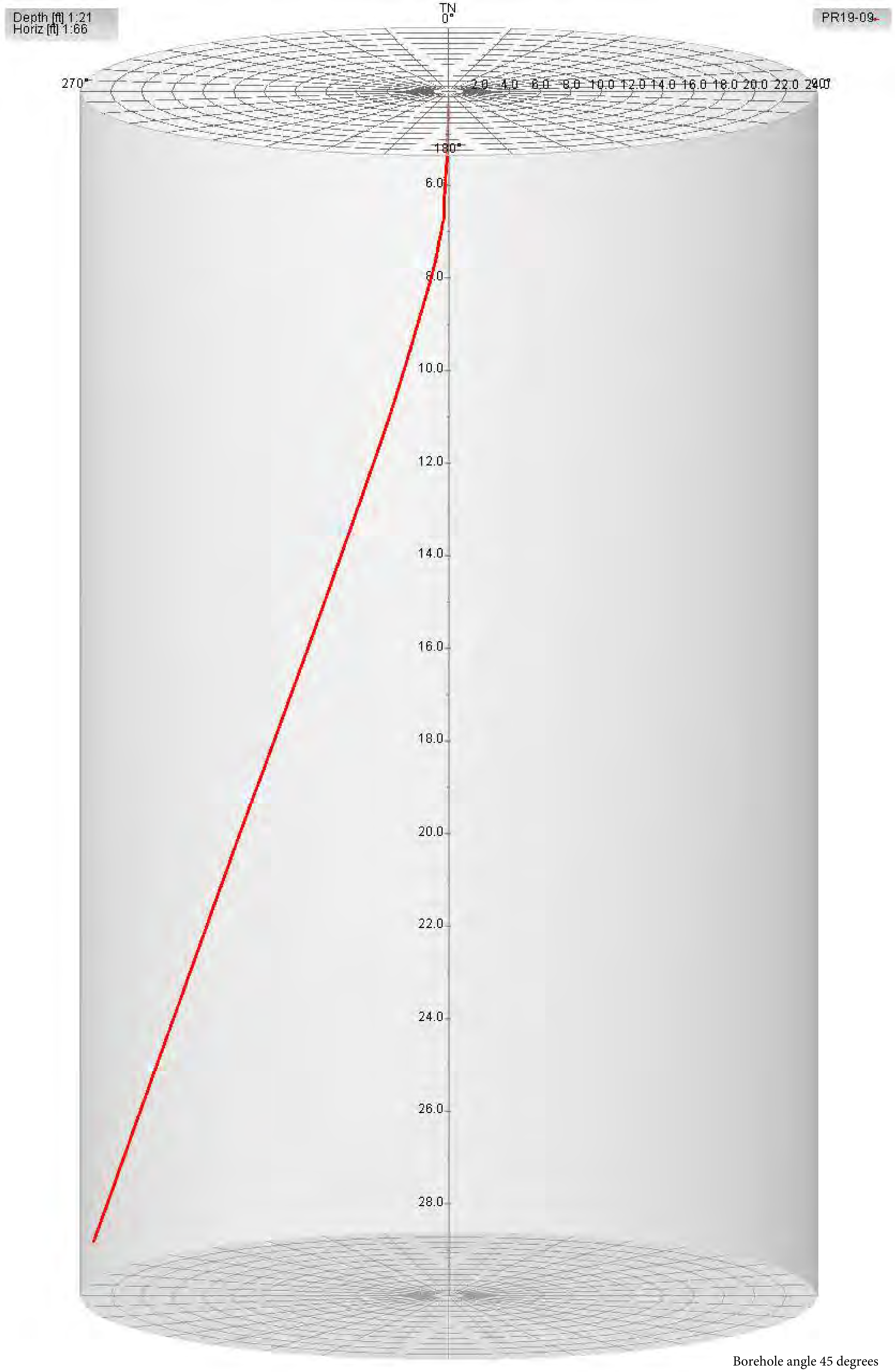
Anchorage, AK
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Borehole Deviation



Borehole angle 45 degrees from horizontal



Borehole angle 45 degrees
from horizontal

PR19-09
Pretty Rocks Project
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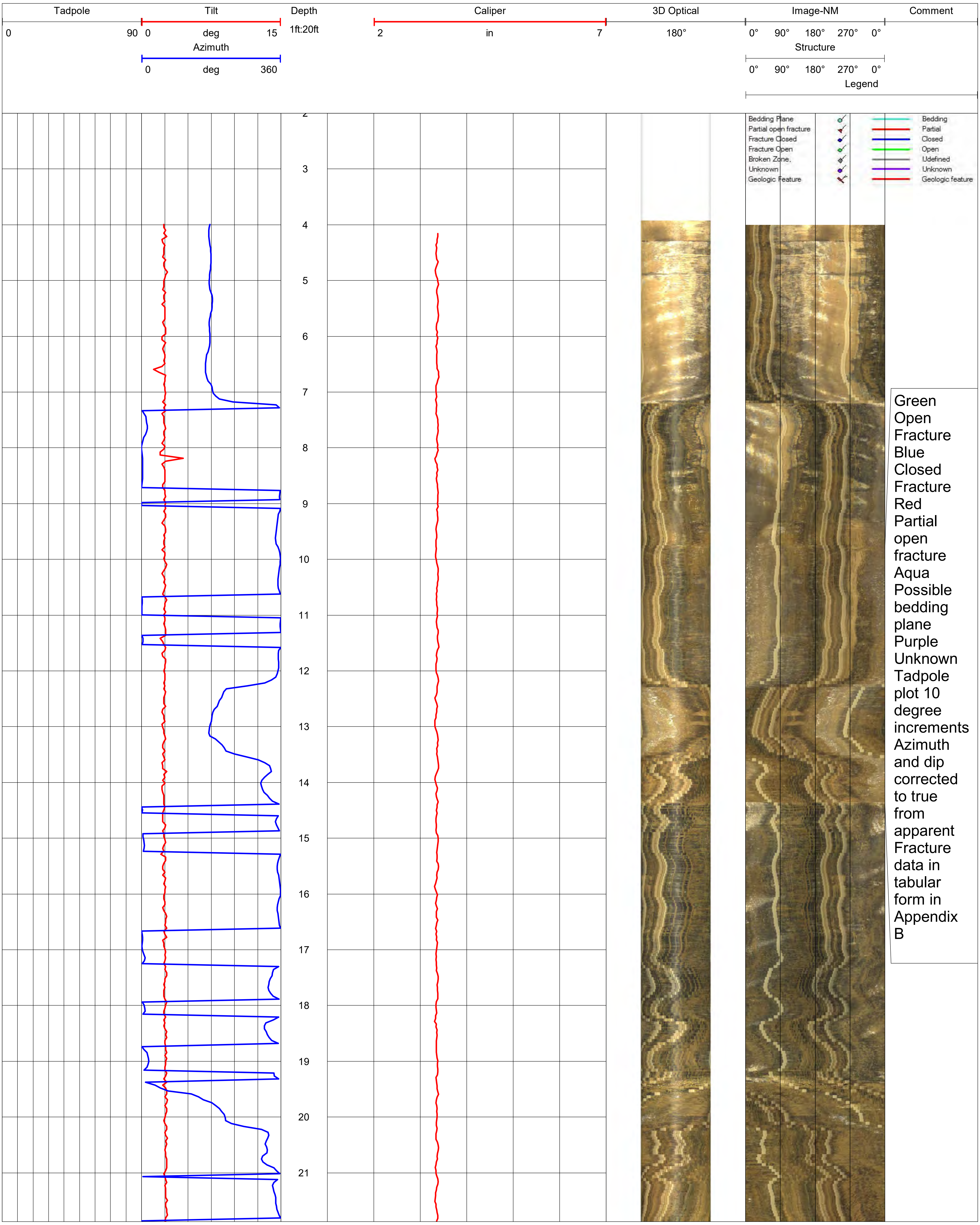
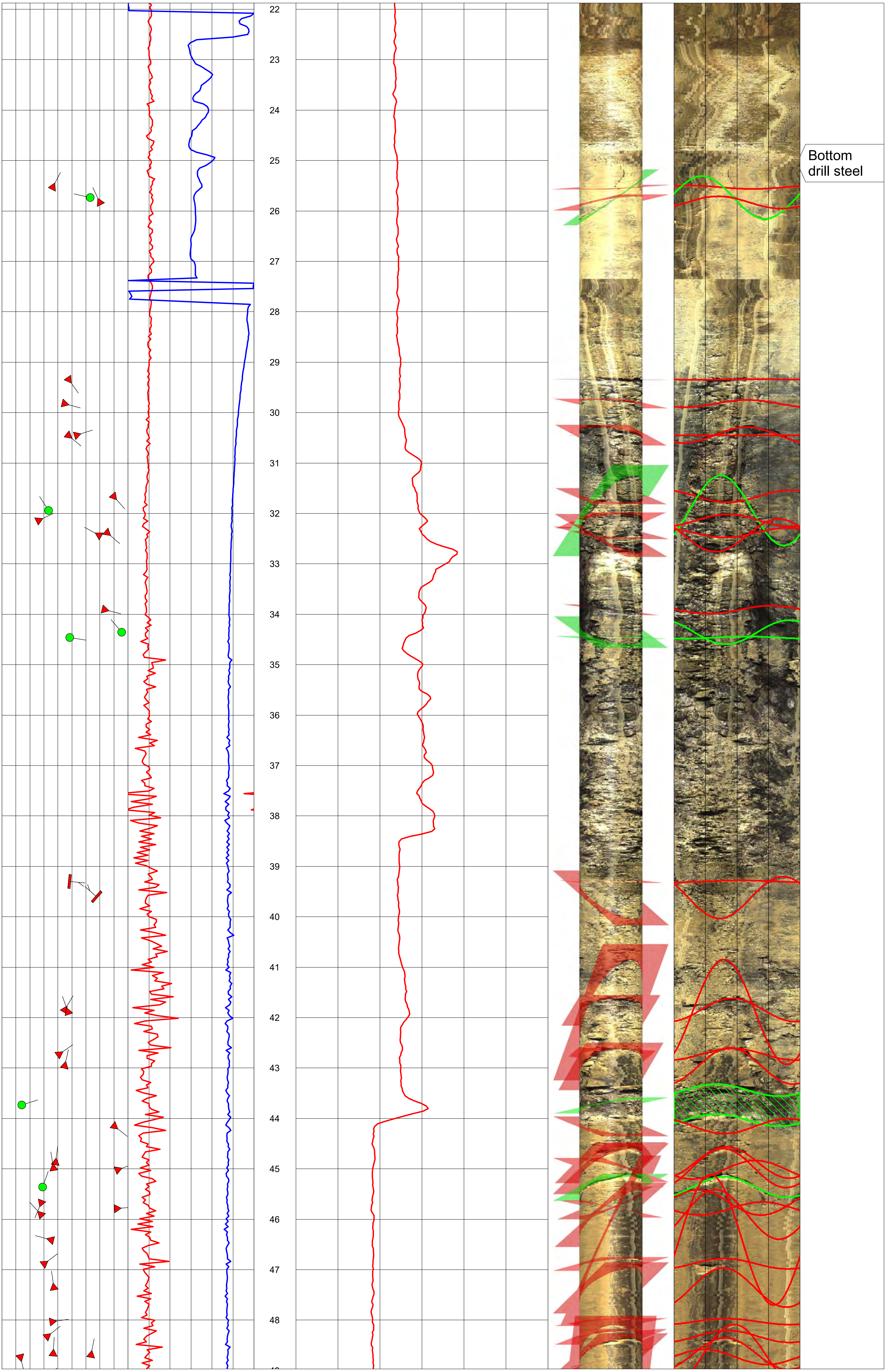
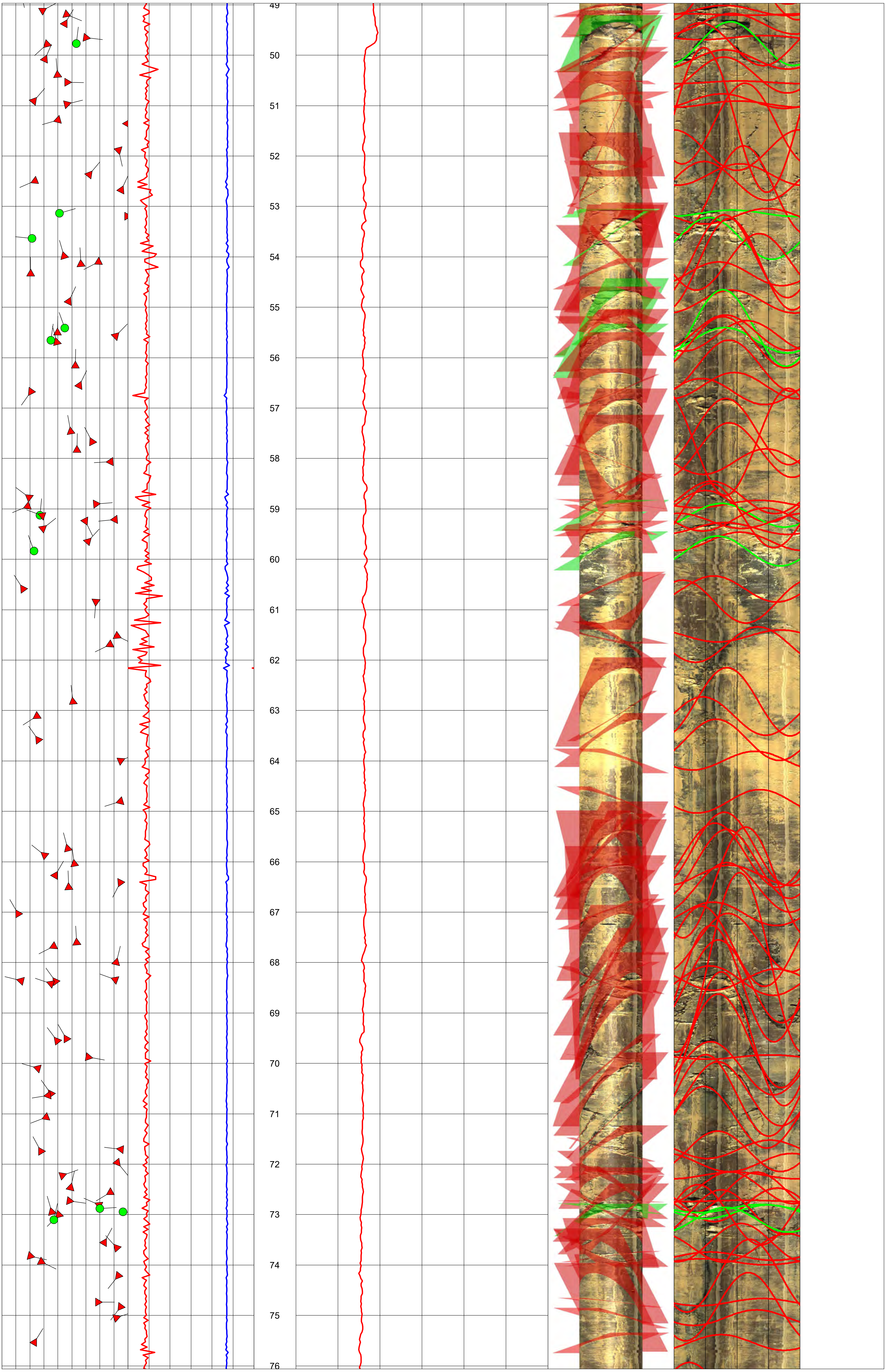
Anchorage, AK
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Caliper and Optical Televiewer



Green Open Fracture Blue Closed Fracture Red Partial open fracture Aqua Possible bedding plane Purple Unknown Tadpole plot 10 degree increments Azimuth and dip corrected to true from apparent Fracture data in tabular form in Appendix B



Bottom drill steel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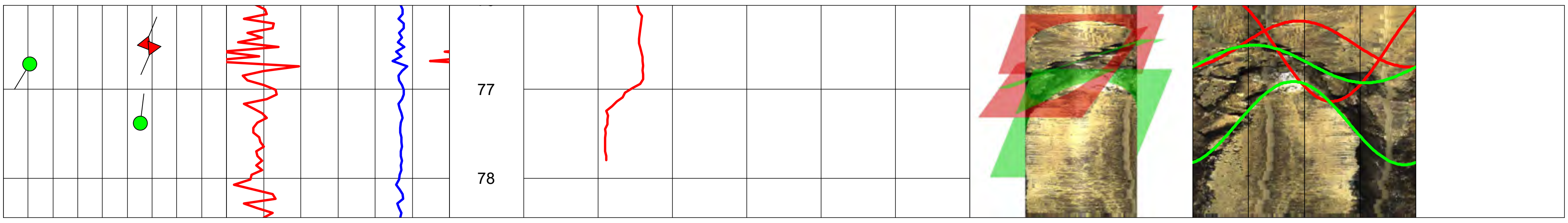
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PR19-09

Pretty Rocks Project
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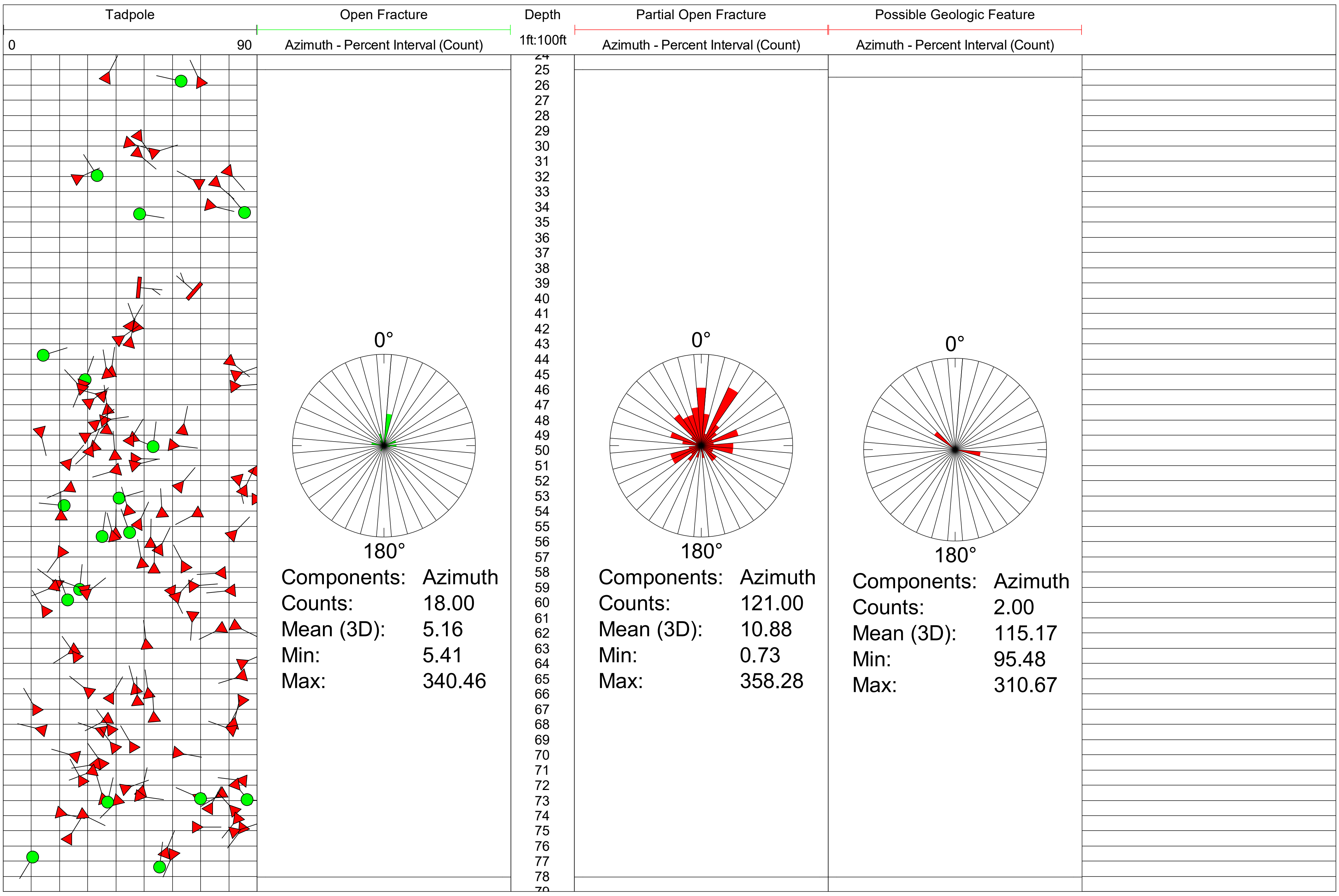
GeoTek Alaska, Inc.
Anchorage, AK
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Rose Diagram



Open Fracture

Components:	Azimuth
Counts:	18.00
Mean (3D):	5.16
Min:	5.41
Max:	340.46

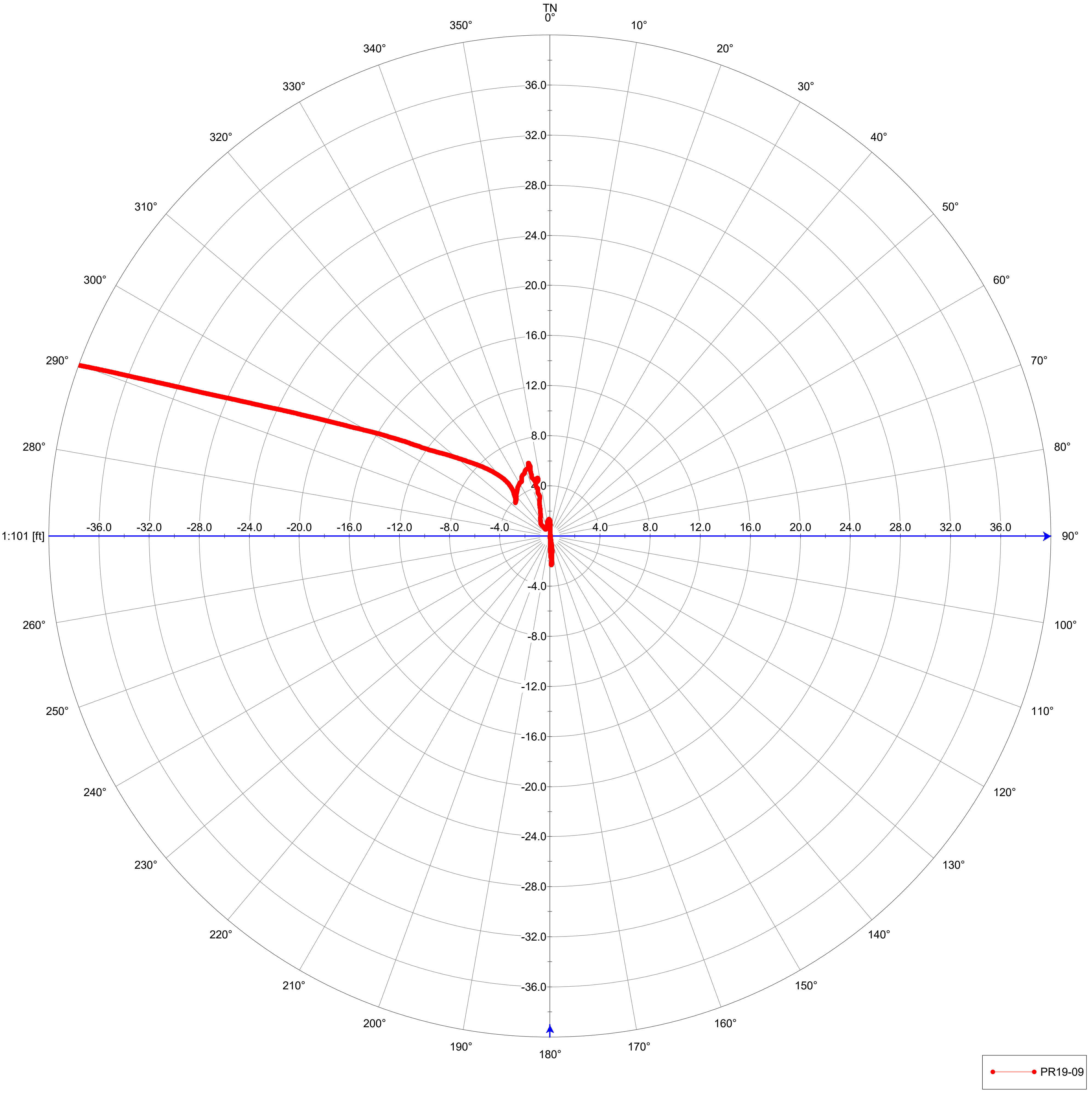
Partial Open Fracture

Components:	Azimuth
Counts:	121.00
Mean (3D):	10.88
Min:	0.73
Max:	358.28

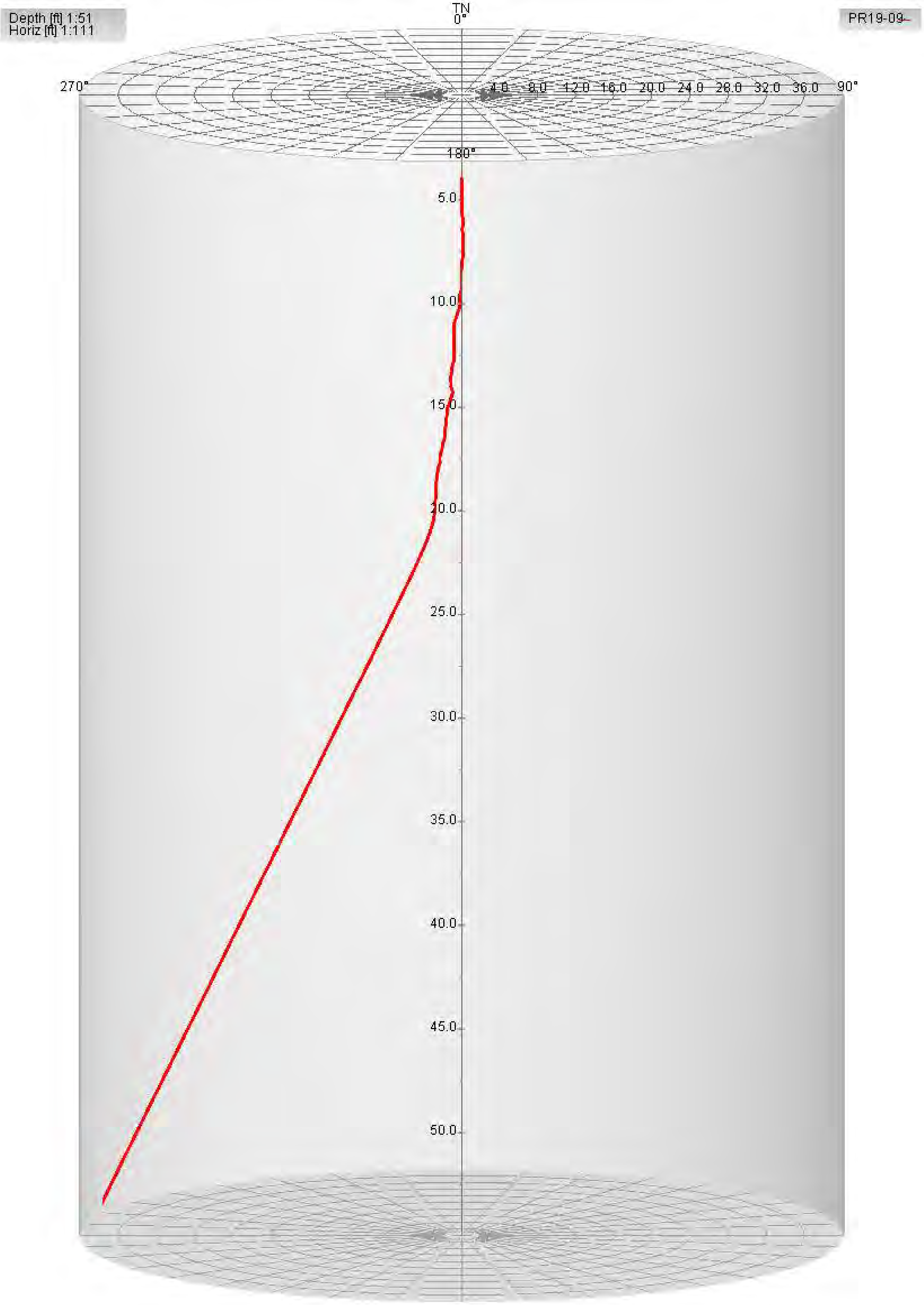
Possible Geologic Feature

Components:	Azimuth
Counts:	2.00
Mean (3D):	115.17
Min:	95.48
Max:	310.67

PR19-09
Pretty Rocks Project
prepared for
GeoTek Alaska, Inc.
Anchorage, AK
by
Enviroprobe Service, Inc.
Mount Laurel, NJ
Borehole Deviation



Borehole angle 45 degrees from horizontal



Borehole angle 45 degrees from horizontal

APPENDIX B

PR19-06 Structure Data				
Depth	Azimuth	Dip	Aperture	Fracture
ft	deg	deg	inch	
25.09	175.03	77.22	0	Partial open fracture
25.3	310.42	16.54	0	Partial open fracture
25.68	238.86	53.59	0	Partial open fracture
27.04	302.67	64.58	0	Partial open fracture
27.26	278.47	51.81	0	Partial open fracture
27.99	170.16	85.27	4.194	Fracture Open
28.28	125.3	20.59	0	Fracture Open
28.9	10.01	76.46	0	Partial open fracture
29.01	26.84	38.5	0	Partial open fracture
29.19	269.58	78.45	0	Partial open fracture
30.18	127.11	56.47	0	Partial open fracture
30.42	196.01	69.03	0	Partial open fracture
30.69	352.62	40.67	0	Partial open fracture
30.93	76.87	31.31	0	Fracture Open
30.94	164.51	80.45	0	Fracture Open
31.8	69.34	35.54	0	Partial open fracture
32.06	276.36	43.22	0	Partial open fracture
32.11	75.37	43.38	0	Fracture Open
32.53	73.56	41.12	0	Partial open fracture
32.74	36.32	34.01	0	Partial open fracture
33.6	113.15	66.67	0	Fracture Open
33.73	29.44	37.09	0	Fracture Open
33.73	298.67	38.52	0	Partial open fracture
33.77	286.12	28.58	0	Partial open fracture
33.93	48.09	64.58	0	Partial open fracture

34.38	115.94	17.28	0	Fracture Open
34.54	102.22	72.13	0	Fracture Open
34.63	103.92	84.66	0.502	Fracture Open
35.09	87.85	33.97	0	Fracture Open
35.33	20.87	47.54	0	Partial open fracture
35.36	68.33	36.3	0	Partial open fracture
35.57	68.67	43.73	0	Partial open fracture
35.79	42.22	34.32	0	Partial open fracture
35.92	46.69	26.43	0	Partial open fracture
36.16	57.74	30.59	0	Partial open fracture
36.42	46.85	17.09	0	Partial open fracture
36.44	136.71	70.03	0	Fracture Open
36.57	85.02	28.6	0	Fracture Open
36.66	106.49	53.85	0	Fracture Open
37.22	53.81	71.1	0	Partial open fracture
37.51	94.6	54.84	0	Partial open fracture
37.82	66.12	37.8	0	Partial open fracture
38.16	83.27	45.66	0	Partial open fracture
38.58	50.14	58.66	0	Partial open fracture
38.67	44.55	47.43	0	Partial open fracture
38.71	135.19	71.65	1.713	Fracture Open
39.03	107.7	16.86	0	Fracture Open
39.19	105.85	59.23	0	Fracture Open
39.49	125.14	73.08	0	Partial open fracture
39.89	233.73	32.76	0	Partial open fracture
40.25	101.67	73.72	2.615	Fracture Open
41.87	20.48	55.21	0	Partial open fracture
42.19	359.67	50.11	0	Partial open fracture
42.42	300.1	82.64	0	Fracture Open

42.57	342.48	37.38	0	Fracture Open
42.76	109.04	37.04	1.652	Partial open fracture

PR19-07 Structure Data				
Depth	Azimuth	Dip	Aperture	Fracture
ft	deg	deg	inch	
11.04	126.4	54.94	0	Geologic Feature
13.4	96.04	51.57	0	Geologic Feature
24.33	211.5	79.7	0	Fracture Open
26.59	114.38	14.91	0	Partial open fracture
26.83	45.24	35.35	0	Fracture Open
27.11	25.83	41.75	0	Partial open fracture
27.21	320.89	30.08	0	Partial open fracture
27.33	323.39	49.52	0	Partial open fracture
27.49	163.9	74.85	0	Partial open fracture
28.18	353.44	23.06	0	Fracture Open
28.52	1.28	45.54	0	Fracture Open
28.62	179.15	75.26	0	Partial open fracture
30.07	306.35	56.47	0	Partial open fracture
30.08	198.84	59.43	0	Partial open fracture
30.52	117.56	58.09	0	Fracture Open
30.7	111.18	26.71	0	Fracture Open
30.91	148.38	83.35	0	Fracture Open
31.52	164.21	72.62	0	Partial open fracture
31.91	75.4	66.92	0	Partial open fracture
32.02	241.16	14.94	0	Partial open fracture
33.08	278.83	30.67	0	Fracture Open
33.08	107.17	40.17	0	Fracture Open
33.57	141.31	42.04	0	Partial open fracture
33.8	3.29	50.32	0	Fracture Open
35.65	134.59	63.76	0	Partial open fracture

35.73	133.9	54.5	0	Partial open fracture
35.99	150.68	46.59	0	Partial open fracture
36.17	117.23	35.52	0	Partial open fracture
36.51	127.67	49.43	0	Partial open fracture
36.59	189.2	67.01	0	Partial open fracture
37.04	243.3	49.7	0	Partial open fracture
37.41	116.87	64.26	0	Partial open fracture
37.45	202.25	61.11	0	Partial open fracture
37.62	192.35	59.74	0	Partial open fracture
37.98	305.83	24.51	0	Partial open fracture
38.62	319.66	15.45	0	Fracture Open
38.67	93.94	49.81	0	Partial open fracture
38.68	154.04	76.54	0	Partial open fracture
38.76	117.34	46.43	0	Partial open fracture
38.83	112.2	48.98	0	Fracture Open
39.12	155.79	72.82	0	Partial open fracture
39.4	150.28	46.76	0	Partial open fracture
39.56	151.32	65.58	0	Partial open fracture
39.97	160.43	68.21	0	Partial open fracture
40.15	143.77	76.64	0	Partial open fracture
40.21	118.56	40	0	Partial open fracture
40.27	101.49	25.68	0	Partial open fracture
40.3	112.02	61.4	0	Partial open fracture
40.55	107.82	60.05	0	Partial open fracture
40.76	142.26	58.13	0	Partial open fracture
41.37	171.9	65.91	0	Partial open fracture
41.46	51.47	66.24	0	Partial open fracture
41.96	68.31	62.77	0	Partial open fracture
42.59	276.25	30.86	0	Partial open fracture

42.97	114.77	68.74	0	Partial open fracture
42.98	190.09	42.2	0	Partial open fracture
43.34	211.9	76.72	0	Fracture Open
43.79	214.17	74.28	0	Fracture Open
45.44	122.16	42.24	0	Partial open fracture
45.74	92.85	38.98	0	Partial open fracture
46.01	114.91	43.51	0	Partial open fracture
46.1	230.86	51.99	0	Partial open fracture
46.47	189.23	65.12	0	Partial open fracture
46.72	194.18	58.57	0	Partial open fracture
47.29	201.51	74.47	0	Fracture Open
47.65	195.14	65.11	0	Partial open fracture
47.84	204.39	61.52	0	Partial open fracture
48.03	195.2	58.94	0	Fracture Open
48.12	209.88	72.45	0	Fracture Open
48.93	69.94	64.05	0	Partial open fracture
49.18	101.28	60.27	0	Partial open fracture
49.34	107.49	63.03	0	Fracture Open
49.6	122.01	62.99	0	Fracture Open
50.1	109.71	43.07	0	Partial open fracture
50.24	109.56	50.52	0	Partial open fracture
50.51	89.65	46.34	0	Fracture Open
50.82	225.27	76.09	0	Fracture Open
50.85	83.89	38.15	0	Fracture Open
50.89	77.67	46.94	0	Fracture Open
51.03	149.62	68.01	0	Partial open fracture
51.19	131.17	62.92	0	Partial open fracture
51.42	171.72	43.19	0	Fracture Open
51.5	147.5	47.34	0	Partial open fracture

51.54	325.26	22.42	0	Partial open fracture
51.63	81.31	29.46	0	Partial open fracture
51.78	312.33	35.24	0	Partial open fracture
51.78	81.51	84.66	0	Partial open fracture
51.89	315.54	27.84	0	Partial open fracture
52.02	94.9	51.12	0	Partial open fracture
52.27	323.87	34.36	0	Partial open fracture
52.51	91.69	70.09	0	Partial open fracture
52.55	320.48	23.81	0	Partial open fracture
52.61	327.58	23.96	0	Partial open fracture
52.89	74.22	67.82	0	Partial open fracture
52.93	0.04	25.09	0	Fracture Open
52.95	184.16	30.12	0	Partial open fracture
53.17	77.24	68.92	0	Partial open fracture
53.23	92.99	72.34	0	Partial open fracture
53.41	97.65	72.65	0	Partial open fracture
53.46	282.89	38.37	0	Partial open fracture
53.58	99.16	56.48	0	Fracture Open
53.68	323.5	33	0	Partial open fracture
53.76	210.81	70.91	0	Partial open fracture
53.78	101.44	84.49	0	Partial open fracture
53.86	100.51	68.67	0	Fracture Open
54.07	79	41.9	0	Partial open fracture
54.1	293.97	33.8	0	Partial open fracture
54.28	73.91	50.84	0	Partial open fracture
54.47	72.34	61.44	0	Partial open fracture
54.86	73.45	76.84	0	Partial open fracture
55.36	193.4	71	0	Partial open fracture
55.47	72.01	57.72	0	Fracture Open

55.47	193.43	72.01	0	Partial open fracture
55.71	101.63	60.29	0	Partial open fracture
55.85	88.26	65.47	0	Partial open fracture
56.01	86.03	55.13	0	Partial open fracture
56.27	189.98	68.67	0	Fracture Open
56.46	183.83	66.08	0	Partial open fracture
56.66	212.93	81.53	0	Partial open fracture
56.7	72.9	66.46	0	Partial open fracture
56.72	332.2	65.45	0	Partial open fracture
57.05	188.37	61.96	0	Partial open fracture
57.19	137.07	46.68	0	Partial open fracture
57.5	353.45	54.45	0	Fracture Open
58.2	208.96	71.48	0	Fracture Open
58.34	108.92	41.46	0	Partial open fracture
58.76	185.4	64.66	0	Partial open fracture
58.78	175.02	54.68	0	Partial open fracture
59.12	212.92	61.9	0	Partial open fracture
59.19	103.91	47.12	0	Partial open fracture
59.3	102.53	50.12	0	Partial open fracture
59.59	213	68.21	0	Partial open fracture
59.8	102.07	36.18	0	Partial open fracture
60.04	85.25	49.56	0	Partial open fracture
60.11	281.22	20.14	0	Fracture Open
60.36	142.24	29.68	0	Partial open fracture
60.37	108.62	63.39	0	Partial open fracture
60.46	225.72	71.26	0	Partial open fracture
60.53	123.57	28.74	0	Fracture Open
60.79	119.36	68.68	0	Partial open fracture
61.1	101.3	46.83	0	Partial open fracture

61.12	102.76	38.05	0	Partial open fracture
61.38	115.54	65.33	0	Partial open fracture
61.39	168.25	61.9	0	Partial open fracture
62.08	115.6	50.81	0	Partial open fracture
62.18	80	66.26	0	Partial open fracture
62.52	100.69	52.95	0	Partial open fracture
63.04	197.92	57.15	0	Fracture Open
63.09	173.66	60.06	0	Partial open fracture
63.33	190.59	60.02	0	Partial open fracture
63.36	110.55	51.62	0	Partial open fracture
63.95	170.49	57.76	0	Partial open fracture
64	112.58	54.12	0	Partial open fracture
64.24	219.58	78.13	0	Partial open fracture
64.39	187.11	71.64	0	Partial open fracture
64.57	201.31	67.74	0	Partial open fracture
64.58	14.26	75.89	0	Partial open fracture
65.53	193.95	63.32	0	Fracture Open
65.56	109.99	58.24	0	Partial open fracture
65.61	347.34	36.72	0	Partial open fracture
65.89	43.86	79.52	0	Partial open fracture
66.47	83.84	48.3	0	Fracture Open
66.95	67.6	49.86	0	Partial open fracture
67.25	45.42	55.24	0	Partial open fracture
67.28	188.76	58.84	0	Fracture Open
67.33	202.66	79.9	0	Fracture Open
67.91	142.56	63.23	0	Fracture Open
68.31	170.61	49.78	0	Fracture Open
68.97	52.68	42.36	0	Fracture Open
69.31	71.94	46.02	0	Fracture Open

69.53	62.97	53.34	0	Fracture Open
70.07	73.06	63.26	0	Fracture Open
70.16	55.03	34.78	0	Fracture Open
70.5	30.9	46.4	0	Partial open fracture
70.68	57.11	38.6	0	Partial open fracture
70.74	81.01	50.4	0	Partial open fracture
71.08	130.16	31.98	0	Fracture Open
71.11	110.26	31.32	0	Fracture Open
71.16	66.52	60.88	0	Fracture Open
71.37	32.33	50.28	0	Fracture Open
71.47	350.52	37.33	0	Fracture Open
71.79	351.76	40	0	Fracture Open
71.95	276.14	55.26	0	Fracture Open
72	69.68	43.59	0	Fracture Open
72.12	221.03	74.08	0	Fracture Open
72.28	101.02	47.29	0	Fracture Open
72.75	113.82	45.74	0	Partial open fracture
72.83	118.94	37.65	0	Partial open fracture
72.93	292.32	48.74	0	Partial open fracture
72.97	82.38	31.72	0	Partial open fracture
73.41	245.6	61.13	0	Partial open fracture
73.52	86.89	43.38	0	Fracture Open
73.86	33.48	16.69	0	Partial open fracture
73.88	135.98	47	0	Partial open fracture
74.11	92.82	56.8	0	Partial open fracture
74.17	101.49	35.41	0	Partial open fracture
74.3	84.47	58.67	0	Partial open fracture
74.45	98.92	48.9	0	Partial open fracture
74.51	101.15	36.35	0	Partial open fracture

74.65	104.47	46.85	0	Fracture Open
74.7	105.38	29.28	0	Partial open fracture
74.89	223.57	70.44	0	Fracture Open
74.98	254.01	60.03	0	Fracture Open
75.21	76.26	42.14	0	Partial open fracture
75.63	103.75	46.98	0	Partial open fracture
75.78	106.8	38.5	0	Partial open fracture
76.01	64.66	35.82	0	Partial open fracture
76.12	71.24	51.8	0	Partial open fracture
76.28	76.85	41.33	0	Partial open fracture
76.47	59.01	47.67	0	Partial open fracture
76.51	63.52	32.1	0	Fracture Open
76.53	44.92	64.71	0	Partial open fracture
76.79	44.11	8.43	0	Partial open fracture
77.25	49.37	32.16	0	Fracture Open
77.44	75.13	38.85	0	Partial open fracture
77.5	185.83	23.81	0	Fracture Open
77.7	199.07	62.05	0	Fracture Open
78.55	182.23	58.46	0	Partial open fracture
78.92	183.67	58.83	0	Partial open fracture
79.06	71.84	27.93	0	Fracture Open
79.35	73.64	39.86	0	Fracture Open
79.43	71.35	42.71	0	Partial open fracture
79.62	87.49	46.26	0	Partial open fracture
79.81	99.51	53.53	0	Partial open fracture
79.87	200	79.31	0	Fracture Open
79.98	86.07	54.7	0	Fracture Open
80.43	112.04	34.21	0	Partial open fracture
81.16	307.93	38.68	0	Partial open fracture

81.24	299.12	13.53	0	Fracture Open
81.61	78.02	55.11	4.06	Fracture Open
82.02	92.77	58.01	0	Partial open fracture
82.57	71.09	35.83	2.83	Fracture Open
82.79	84.9	77.19	0	Partial open fracture
83.8	66.1	66.52	0	Partial open fracture
84.56	54.16	57.47	4.13	Fracture Open
86.02	31.26	70.64	0	Partial open fracture
86.08	213.49	75.57	0	Fracture Open
86.3	213.2	66.72	0	Partial open fracture
86.54	210.35	63.41	0	Partial open fracture
86.97	57.23	60.62	0	Fracture Open
87.18	63.89	60.34	0	Partial open fracture
87.23	353.28	39.99	0	Partial open fracture
87.45	69.13	37.75	0	Fracture Open
87.85	26.74	18.88	0	Partial open fracture
88.65	198.33	55.23	0	Fracture Open
88.89	67.35	39.05	0	Fracture Open
89.65	277.34	76.83	0	Partial open fracture
92.84	75.53	62.09	0	Partial open fracture
93.36	94.41	78.21	0	Partial open fracture
93.56	103.36	40.3	0	Partial open fracture
93.95	47.4	65.12	0	Fracture Open
94.06	76.3	61.13	0.04	Fracture Open
94.49	115.61	59.67	7.43	Fracture Open
95.41	210.53	66.81	0	Fracture Open
95.53	21.43	42.87	0	Fracture Open
96.83	93.65	50.3	0	Fracture Open
96.93	223.85	42.75	0	Fracture Open

99.13	18.18	45.15	2.74	Fracture Open
99.93	118.31	50.86	0	Partial open fracture
100.08	51.63	43.08	0	Fracture Open
100.1	63.2	39.01	0	Fracture Open
100.24	11.47	50.92	0	Partial open fracture
100.39	23.49	28.44	0	Fracture Open
100.72	347.06	44.64	0	Fracture Open

PR19-08 Structure data				
Depth	Azimuth	Dip	Aperture	Fracture
ft	deg	deg	inch	
21.76	272.4	62.02	0	Geologic Feature
25.04	254.43	18.39	0	Partial open fracture
26	230.86	40.9	0	Partial open fracture
26.23	241.23	44.87	0	Partial open fracture
26.55	63.95	34.33	0	Geologic Feature
34.77	197.94	54.18	0	Fracture Open
35.66	333.06	75.25	0	Partial open fracture
36.66	322.89	76	0	Partial open fracture
37.47	354.1	59.93	0	Partial open fracture
38.93	221.99	47.41	0	Geologic Feature
41.29	38.34	34.17	0	Geologic Feature
42.98	299.7	51.42	0	Partial open fracture
43.95	249.89	38.84	0	Partial open fracture
44.37	155.15	39	0	Fracture Open
44.84	200.06	63.16	0	Partial open fracture
46.1	252.57	48.23	0	Fracture Open
46.23	22.52	70.59	0	Partial open fracture
46.51	316.42	39.26	0	Partial open fracture
46.53	73.27	38.72	0	Partial open fracture
46.83	205.12	37.84	0	Fracture Open
47.5	170.77	34.37	0	Partial open fracture
47.93	38.87	50.16	0	Partial open fracture
48.37	24.46	51.68	0	Partial open fracture
48.4	8.42	71.3	0	Partial open fracture
48.57	22.57	62.72	0	Partial open fracture

49.8	34.9	76.46	0	Partial open fracture
57.93	86.05	59.66	0	Partial open fracture
58.75	162.68	79.2	0	Partial open fracture
59.48	15.75	47.85	0	Partial open fracture
61.5	59.26	67.95	0	Partial open fracture
61.63	197.85	59.99	0	Fracture Open
64.38	119.25	51.03	0	Partial open fracture
65.23	355.79	59.31	0	Partial open fracture
67.27	234.1	68.69	0	Partial open fracture
68.44	117.3	44.93	0	Partial open fracture
68.5	270.39	56.88	0	Partial open fracture
69.71	214.53	78.39	0	Partial open fracture
69.98	349.87	66.16	0	Fracture Open
70.98	110.53	46.76	0	Partial open fracture
71.19	119.3	41.68	0	Partial open fracture
72.28	231.45	68.35	0	Partial open fracture

PR19-08 Structure data				
Depth	Azimuth	Dip	Aperture	Fracture
ft	deg	deg	inch	
82.82	84.02	68.79	0	Partial open fracture
82.91	264.42	66.1	0	Partial open fracture
83.05	307.32	5.86	0	Partial open fracture
83.23	36.98	65.43	0	Fracture Open
83.37	11.72	46.4	0	Fracture Open
84.74	205.27	52.61	0	Fracture Open
85.25	260.11	32.95	0	Partial open fracture
85.36	291.83	34.48	0	Partial open fracture
86.23	15.25	35.35	0	Partial open fracture
86.26	80.17	52.46	0	Partial open fracture
86.39	215.21	60.29	0	Partial open fracture
86.63	185.3	26.85	0	Partial open fracture
86.71	19.83	42.68	0	Partial open fracture
86.86	207.2	48.16	0	Partial open fracture
86.99	275.62	40.79	0	Partial open fracture
87.79	72.77	38.33	0	Partial open fracture
88.06	232.11	41.85	0	Partial open fracture
88.77	357.41	63.55	0	Partial open fracture
89.18	15.64	81.9	0	Partial open fracture
89.33	206.4	56.86	0	Fracture Open
89.43	311.21	34.71	0	Partial open fracture
89.92	254.78	26.23	0	Partial open fracture
90.86	51.1	74.12	0	Partial open fracture
90.87	281.61	29.58	0	Partial open fracture
90.97	287.44	38.2	0	Fracture Open

91.33	285.25	32.46	0	Partial open fracture
91.5	108.55	55.06	0	Partial open fracture
91.69	194.97	30.05	0	Partial open fracture
92.36	116.29	62.62	0	Partial open fracture
92.37	210.14	22.73	0	Partial open fracture
92.46	336.05	37.12	0	Partial open fracture
92.95	240.41	26.38	0	Partial open fracture
93.3	258.22	39.74	0	Partial open fracture
94.17	280.43	30.31	0	Partial open fracture
94.28	54.71	55.61	0	Partial open fracture
94.54	228.75	71.95	0	Fracture Closed
95.3	321.01	72.03	0	Partial open fracture
95.45	350.77	72.07	0	Partial open fracture
96.21	245.18	31.51	0	Partial open fracture
97.68	334.22	62.17	0	Partial open fracture
97.8	290.62	52.13	0	Fracture Open
98.65	214.43	80.27	0	Partial open fracture
99.25	359.16	52.87	0	Partial open fracture
101.23	306.11	64.36	0	Partial open fracture
101.97	193.95	77.03	0	Partial open fracture

PR19-09 Structure Data				
Depth	Azimuth	Dip	Aperture	Fracture
ft	deg	deg	inch	
8.32	317.61	88.04	0	Geologic Feature
9.33	112.3	75.2	0	Fracture Open
9.73	120.41	81.42	0	Fracture Open
10.27	88.77	78.48	0	Fracture Open
14.11	148.61	22.39	0	Geologic Feature
15.13	184.55	37.06	0	Geologic Feature
21.98	64.11	67.74	0	Geologic Feature
24.92	102.15	34.74	0	Partial open fracture
25.23	74.95	40.86	0	Partial open fracture
25.52	72.9	81.51	0	Partial open fracture
26.3	54.99	71.48	0	Fracture Open
26.39	25.29	47.92	0	Partial open fracture
28.35	93.33	42.14	0	Partial open fracture
28.46	109.82	83.5	0	Partial open fracture
28.58	108.71	59.26	0	Partial open fracture
28.68	106.33	79.27	0	Partial open fracture
29	273.16	77.85	0	Partial open fracture
29.05	278.32	52.58	0	Partial open fracture
29.07	9.57	34.63	0	Partial open fracture
29.19	115.18	45.01	0	Fracture Open
29.35	15.95	20.5	0	Partial open fracture
30.11	253.98	25.14	0	Partial open fracture
31.03	24.25	31.43	0	Partial open fracture
31.07	69.55	89.77	0	Partial open fracture
32.46	265.01	72.55	0	Partial open fracture

32.49	311.62	31.77	0	Partial open fracture
32.53	336.13	88.99	0	Partial open fracture
32.57	96.92	59.47	0	Fracture Open
32.59	331.25	29.52	0	Partial open fracture
33.11	138.32	36.18	0	Partial open fracture
33.69	121.72	25.66	0	Fracture Open
36.95	122.61	39.14	0	Partial open fracture
37.51	112.96	54.64	0	Partial open fracture
38.54	141.99	56.98	0	Partial open fracture
40.03	307.06	73.55	0	Partial open fracture
40.21	235.38	84.46	0	Partial open fracture

PR19-09 Structure Data				
Depth ft	Azimuth deg	Dip deg	Aperture inch	Fracture
25.53	27.07	36.42	0	Partial open fracture
25.73	282.4	63.14	0	Fracture Open
25.83	335.47	69.93	0	Partial open fracture
29.34	144.1	47.82	0	Partial open fracture
29.82	105.53	44.55	0	Partial open fracture
30.45	72.12	53.41	0	Partial open fracture
30.45	129.85	47.45	0	Partial open fracture
31.66	138.96	79.73	0	Partial open fracture
31.94	327.8	33.24	0	Fracture Open
32.14	65.08	26.31	0	Partial open fracture
32.38	131.3	75.11	0	Partial open fracture
32.44	298.98	69.37	0	Partial open fracture
33.91	103.94	73.17	0	Partial open fracture
34.35	320.24	85.55	0	Fracture Open
34.46	98.97	48.41	0	Fracture Open
39.3	95.48	47.42	0	Geologic Feature
39.62	310.67	68.25	0	Geologic Feature
41.85	29.8	44.95	0	Partial open fracture
41.89	340.22	47.34	0	Partial open fracture
42.73	55.01	40.94	0	Partial open fracture
42.96	12.62	44.85	0	Partial open fracture
43.74	72.55	14.19	5.76	Fracture Open
44.15	128.52	80.4	0	Partial open fracture
44.87	7.74	38.19	0	Partial open fracture
44.99	350.92	36.91	0	Partial open fracture

45.02	69.61	82.59	0	Partial open fracture
45.36	20.02	29	0	Fracture Open
45.67	202.08	28.09	0	Partial open fracture
45.79	85.26	81.87	0	Partial open fracture
45.9	316.9	27.76	0	Partial open fracture
46.41	284.58	35.13	0	Partial open fracture
46.88	53.58	30.27	0	Partial open fracture
47.35	352.29	36.99	0	Partial open fracture
48.03	81.61	35.81	0	Partial open fracture
48.33	51.68	32.46	0	Partial open fracture
48.67	3.39	36.67	0	Partial open fracture
48.69	11.34	63.66	0	Partial open fracture
48.74	166.43	13.14	0	Partial open fracture
49.11	60.88	28.98	0	Partial open fracture
49.19	112.67	46.1	0	Partial open fracture
49.38	31.53	44.97	0	Partial open fracture
49.65	97.39	60.09	0	Partial open fracture
49.77	7.36	53.2	0	Fracture Open
49.78	227.08	32.24	0	Partial open fracture
50.09	24.13	30.63	0	Partial open fracture
50.39	355.77	39.7	0	Partial open fracture
50.54	91.25	46.53	0	Partial open fracture
50.91	41.17	22.72	0	Partial open fracture
50.97	75.64	46.33	0	Partial open fracture
51.29	253.6	40.13	0	Partial open fracture
51.36	28.09	89.34	0	Partial open fracture
51.88	167.07	83.34	0	Partial open fracture
52.37	39.88	62.33	0	Partial open fracture
52.49	246.73	23.67	0	Partial open fracture

52.67	25.32	85.3	0	Partial open fracture
53.13	73.95	41.18	0	Fracture Open
53.19	91.65	89.39	0	Partial open fracture
53.63	275.51	21.58	0	Fracture Open
53.99	344.07	44.38	0	Partial open fracture
54.1	242.08	68.99	0	Partial open fracture
54.14	356.44	56.39	0	Partial open fracture
54.34	358.28	20.5	0	Partial open fracture
54.89	25.34	47.77	0	Partial open fracture
55.41	340.1	44.89	0	Fracture Open
55.5	0.73	39.78	0	Partial open fracture
55.57	44.73	81.23	0	Partial open fracture
55.66	8.55	35.03	0	Fracture Open
55.7	345.46	39.19	0	Partial open fracture
56.16	1.62	52.34	0	Partial open fracture
56.55	25.85	55.26	0	Partial open fracture
56.67	215.29	20.73	0	Partial open fracture
57.47	350.06	49.24	0	Partial open fracture
57.67	332.39	64.46	0	Partial open fracture
57.83	1.23	53.58	0	Partial open fracture
58.07	266.24	77.68	0	Partial open fracture
58.77	306.41	19.26	0	Partial open fracture
58.9	85.35	67.07	0	Partial open fracture
58.95	247.54	18.31	0	Partial open fracture
59.13	5.41	27.07	0	Fracture Open
59.13	289.48	28.86	0	Partial open fracture
59.21	264.81	80.88	0	Partial open fracture
59.24	154.51	59.64	0	Partial open fracture
59.39	51.98	29.35	0	Partial open fracture

59.64	42.45	61.32	0	Partial open fracture
59.83	340.46	22.88	0	Fracture Open
60.59	326.89	15.09	0	Partial open fracture
60.84	184.96	67.16	0	Partial open fracture
61.52	116.47	82.2	0	Partial open fracture
61.69	243.67	77.35	0	Partial open fracture
62.83	353.37	50.8	0	Partial open fracture
63.11	237.71	25.09	0	Partial open fracture
63.58	324.24	25.96	0	Partial open fracture
63.99	66.24	84.74	0	Partial open fracture
64.8	253.1	84.83	0	Partial open fracture
65.74	344.6	46.91	0	Partial open fracture
65.87	308.69	30.54	0	Partial open fracture
66.04	351.57	51.63	0	Partial open fracture
66.27	30.52	38	0	Partial open fracture
66.41	206.78	84.64	0	Partial open fracture
66.51	357.17	47.63	0	Partial open fracture
67.03	330.3	11.67	0	Partial open fracture
67.6	357.06	53.44	0	Partial open fracture
67.68	243.11	37.07	0	Partial open fracture
68	13.4	81.62	0	Partial open fracture
68.34	290.03	81.1	0	Partial open fracture
68.36	283.31	13.81	0	Partial open fracture
68.37	323.93	38.31	0	Partial open fracture
68.42	288.58	34.91	0	Partial open fracture
69.52	330.32	46.01	0	Partial open fracture
69.55	322.68	39.43	0	Partial open fracture
69.87	100.29	61.73	0	Partial open fracture
70.1	285.91	25.73	0	Partial open fracture

70.6	324.46	35.03	0	Partial open fracture
70.63	260.95	33	0	Partial open fracture
71.07	248.79	31.75	0	Partial open fracture
71.7	276.39	85.03	0	Partial open fracture
71.75	331.07	27.95	0	Partial open fracture
71.97	140.53	82.41	0	Partial open fracture
72.22	70.5	43.21	0	Partial open fracture
72.47	13.25	49.06	0	Partial open fracture
72.56	239.15	77.58	0	Partial open fracture
72.73	98.54	48.25	0	Partial open fracture
72.8	294.19	69.53	0	Partial open fracture
72.88	86.53	69.96	0	Fracture Open
72.94	94.06	86.45	0	Fracture Open
72.95	343.67	35.56	0	Partial open fracture
73	225.22	40.52	0	Partial open fracture
73.1	12.62	37.08	0	Fracture Open
73.55	29.03	72.95	0	Partial open fracture
73.66	318.19	81.91	0	Partial open fracture
73.83	102.7	20.22	0	Partial open fracture
73.93	116.06	28.1	0	Partial open fracture
74.21	218.67	83.06	0	Partial open fracture
74.74	89.9	68.4	0	Partial open fracture
74.83	216.34	84.87	0	Partial open fracture
75.05	71.89	81.81	0	Partial open fracture
75.54	31.9	23.08	0	Partial open fracture
76.49	21.86	57.43	0	Partial open fracture
76.53	203.48	60.27	0	Partial open fracture
76.72	211.06	10.53	0	Fracture Open
77.38	6.38	55.39	0	Fracture Open

APPENDIX K

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

WESTERN FEDERAL LANDS HIGHWAY DIVISION
FEDERAL HIGHWAY ADMINISTRATION

GEOTECHNICAL REPORT 10-20 AK NPS DENA 10 (49)

DENALI PARK ROAD – POLYCHROME PASS
EXPERT-BASED RISK ASSESSMENT

FINAL

PROJECT NO.: 2000003

DATE: August 20, 2020

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1.0 INTRODUCTION

Long-term geotechnical risks to various alternative Denali Park Road alignments through an area known as Polychrome Pass were assessed at an Expert-based Risk Assessment (EBRA) workshop held May 5 through 7, 2020. The road alignment alternatives include the existing alignment that requires rehabilitation and modifications with considerable capital investment, a northern alignment and two variants of a southern alignment, which also have significant capital investment needs (Figure 4-7). The workshop was to be held at Denali National Park, though, given travel restrictions, it was held remotely as a series of web-based meetings. This report documents the outcomes and results of the EBRA workshop. The EBRA results identify elements of work (earthwork, structures, landslides, etc.) where the risks are judged high and low, and, as a compilation of the various elements, alignments where the risks are judged high and low. The results do not include recommendations.

The purpose of this EBRA is to estimate the geotechnical risks associated with owning and operating the Denali Park Road on each of the proposed alternative alignments. Risk is a combination of likelihood of events occurring and the consequences if they do. The consequences are defined in the EBRA process and structure, which then relies upon experts to assess the likelihood of these events occurring.

The criteria applied for selection of information included in this report and in the planned workshop involved a judgement of how beneficial the information would be in improving an expert's understanding for the project objectives, and also the EBRA objectives. For example, where practical, we have excluded material related to anticipated difficulty in construction, or consideration of cultural or environmental impacts or risks as these are not primary inputs into geotechnical risk assessment. These other risk sources are important considerations and will be considered along with the findings of this work in subsequent value analysis and alternatives selection processes.

The necessary project background was provided by Western Federal Lands Highway Division (WFLHD) and the National Park Service (NPS) in three ways. First, written materials were provided in advance of the workshop and were summarized by BGC Engineering Inc. (BGC) in a report of existing conditions (Appendix A). Second, a Draft Project Delivery Plan was prepared by WFLHD to document plans for how alternatives have been advanced to date, and how future project development is planned (Appendix C). The third way information was transferred was through presentations made to BGC and the EBRA panel as part of the workshop agenda (Appendix B). The workshop was attended by WFLHD staff representing project management and the technical disciplines of highway design, hydrology and hydraulics, structure design, geology and geotechnical engineers, and construction; by NPS staff from Denali National Park (Park) and the NPS region and headquarters offices and contractors, representing management, maintenance and operations, landscape architecture, natural and cultural resources, and geology; and by BGC staff and the panel of four experts assembled by BGC.

BGC Engineering Inc. (BGC) prepared this report at the request of WFLHD and through subcontract with Jacobs Engineering Inc. under Contract No. DTFH7015D00004, Task Order No. 69056720F000025, dated December 10, 2019.

2.0 BASIS FOR THE RISK ASSESSMENT APPROACH

The risk assessment is based on expert opinion and the recognition that expert opinion can be quantified for use in decision making. Similar to probability estimates based on statistics or other logic, subjective probability estimates can be used to estimate risks for complex events. The background for this approach is summarized in the following references, which span 50 years of geotechnical practice: *Role of "calculated risk" in earthwork and foundation engineering – The Terzaghi Lecture*, Arthur Casagrande, 1965, ASCE Journal of the Soil Mechanics and Foundation Division; *Degrees of Belief – Subjective Probability and Engineering Judgment*, Steven G. Vick, 2002, ASCE Press; *Risk-Informed Decision Making (RIDM) – Risk Guidelines for Dam Safety*, Federal Energy Regulatory Commission, Version 4.1, March 2016.

For complex problems or cascading paths to failure, it is useful to decompose the risk analysis into smaller steps because this allows independent probabilities to be assessed for each step. The analysis can then be recomposed, and the probabilities combined to support risk-informed decisions or recommendations. Usually, a re-composition assessment evaluates conditional probability scenarios, which estimate the probability of an event occurrence that is due to the occurrence of a prior separate event. Re-composition using conditional probabilities is the approach used here for a number of segments of construction, and then the segments are combined using a series-logic for each alignment alternative. This captures the relative influence of each step in the most accurate way.

Risk is the product of probability and consequence, and consequence can be defined in different ways. Exceptional maintenance requirements, unpredictable reliability, and long-term closure represent three different examples of consequences. If each of these is defined by way of a threshold event, the consequence becomes simply that the threshold is crossed, and exactly what that means in terms of dollars, time or other measures is tied to the definition of the threshold. The estimated probability of the event of crossing a threshold is therefore equal to the risk of it occurring (consequence is given the value of unity (1.0), for example). The basis of the risk assessment is the expert opinion of these probabilities of crossing between condition states.

3.0 EXPERT-BASED RISK ASSESSMENT APPROACH AND SCOPE

An EBRA was convened to estimate the long-term geotechnical risks to long-term performance of the Polychrome Pass segment of the Denali Park Road. For the purpose of the EBRA, the process for assessment of long-term performance was confined to a 50-year life cycle of the rehabilitated or realigned road section. The 50-year life is somewhat arbitrary, but it serves the purpose to direct attention on long-term performance, not soon after construction. The assessment compares alternative alignments that include major improvements generally along the existing alignment (known as Option 1), and previously determined alternatives that bypass the segment on entirely new alignments to the north (known as Option 2) and south (known as Options 3A and 3B) (Figure 4-7).

The EBRA was conducted by a panel of four experts, with facilitation by BGC staff members who also have relevant technical experience. The approximate time allotment for each panelist was 40-50 professional hours per person for review, meeting, assessment, and summary. This time allotment means that extensive research was not assumed to have been completed by any panelist. The limitation is appropriate given that the designs are currently conceptual, and that relatively little is known about the subsurface and site conditions for each specific alternative alignment. As more data become available, it will be possible to make more-informed judgments with less uncertainty and it may be desired to do so for some of the alignments considered here.

The original intent was to conduct the EBRA workshop at Denali National Park, with two days of office review and one day site visit to gain the understanding that typically only comes from being onsite. The COVID-19 pandemic made getting everyone together in any one location, and getting the panel to the site, impossible without delaying the project schedule. Instead, a multi-day web-based meeting was convened to bring people together. Onsite understanding was shared using augmented-reality technology on the Ada Platform™[1] and the Microsoft HoloLens™ allowing holograms to be viewed jointly.

3.1. Context

The existing Denali Park Road is a gravel road that crosses landslides and unstable slopes along Polychrome Pass. This section of the road is typically only open to professional bus drivers, employees of the National Park Service, and holders of Denali Park Road passes. It is not open to the general public. Several recurring and ongoing slide movements have required geotechnical attention and repair investments for decades. The Pretty Rocks landslide has been most impactful to the serviceability and safety of the road and its movement has generally been increasing over the past several years, as described in Appendix A.

To improve safety and travel reliability in the corridor, Denali National Park is considering a major capital investment, either along the existing alignment or along one of the possible new alignment

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[1] The Ada Platform™ is software that combines geology, geotechnical, terrain and survey data, engineering designs, and computer graphics into a augmented-reality environment that allows users interact in a virtual environment from any angle, at any point in time – past, present, or future.

alternatives. Each alternative is in close proximity or contact with known landslides and geohazards such as alluvial fans, permafrost, muskeg, braided rivers and steep terrace slopes. Concept-level total project cost estimates are approximately $50 million for Option 1, and between $200-275 million for Options 2, 3A, and 3B. Construction cost estimates vary because of the structures and lengths of roadway involved.

Denali National Park is concerned about making such a large investment and impact to environment and user experience, only to encounter a continued or different set of geotechnical problems of equal or greater magnitude than already exist. Denali National Park is addressing this concern in partnership with the WFLHD by using what information it currently has available to quantify an estimate of long-term geotechnical risks for the alternative alignments.

3.2. Performance Objectives

Denali National Park's performance objectives are long-term and represent an assumed 50-year service life analysis period for the road. Risks associated with construction of the various alternatives are important; for example, from construction materials availability, schedule, change orders from site conditions, and contract escalation, and they should be evaluated in other efforts. However, these non-geotechnical sources of risk are not assessed in this EBRA except in evaluating how they might affect long-term performance objectives for the roadway.

WFLHD and the NPS will follow their standard practice in the design and construction of any alternative alignment to deliver essentially equivalent traffic and geohazard safety standards and roadway design standards among alignment options. Alternatives that would not provide an essentially equivalent level of safety and design standards are not being considered and are not part of this study. All roads are expected to provide a certain level of service, and these are the performance objectives for the road. For state highway systems, they often include objectives like rideability (smoothness), mobility (vehicles per day at safe speed) and reliability (lack of congestion and closures).

The Denali Park Road has these objectives, but they are not the objectives that best define the purpose of the road or the goal of major construction on the existing or new alignments. To attempt to better address this goal, we captured objectives from conversations with WFLHD and Denali National Park, and used the Denali National Park Mission Statement, as it might apply from the perspective of the road. The mission statement is as follows: *"We protect intact, the globally significant Denali ecosystems, including their cultural, aesthetic, and wilderness values, and ensure opportunities for inspiration, education, research, recreation and subsistence for this and future generations."*

Using this approach, the performance objectives stated for the EBRA are defined as follows:

1. **Resiliency and Low Life Cycle Cost**: The Federal Highway Administration resiliency definition[2] is "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions" and it will be applied here.

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[2] FHWA Order 5520: https://www.fhwa.dot.gov/legsregs/directives/orders/5520.cfm

Something with a high degree of resilience serves its function by being robust and resistant to disruption, or able to recover function quickly, or both. Regardless of the alignment alternative or element of work on that alignment, this attribute will be built in. It is what is known as the initiating event in the process the EBRA will follow. A changing climate and thawing of permafrost are anticipated as disruptions, and there are other geohazard disruptions as well. Resiliency can lead to lower life cycle costs because, in theory, expensive problems don't keep recurring, but low life cycle cost is not guaranteed by resilient designs because of possible high initial capital costs or ongoing operation costs. Achievement of a low life cycle cost objective will be strived for through solutions that can be operated and maintained at low annual cost.

2. **Natural Environment**: The park mission statement is: "We protect intact, the globally significant Denali ecosystems, including their cultural, aesthetic, and wilderness values, and ensure opportunities for inspiration, education, research, recreation and subsistence for this and future generations." Achieving this mission is a performance objective and it has two parts. From a transportation perspective 'ensuring opportunities' relates to ensuring mobility – and an open road when and where it is needed. To 'protect intact' relates to not severing a connection. From a transportation perspective, this can be related to complete closure and abandoned infrastructure, and the impacts that would bring to ecosystems and especially their cultural, aesthetic and wilderness values.
3. **Continuity of safe access**: The amount of time the road would be open and without closure impacts for construction or maintenance activities through a 50-year lifetime is the context for this objective, not varying levels of road-user safety. Safety is not a trade-off that is being considered, nor is it substantially impacted by the differing geohazards on each alternative. This measure also includes the predictability of safe access – for example, the tourism industry can depend on the road being open and having a certain capacity for the summer season. The continuity of safe access ties to the mission statement goal of 'ensuring opportunities'.
4. **Feasibility of construction**: The availability of means, methods and materials to build and maintain a road in this environment is part of what is required for an alternative to be feasible. In addition, the evaluation of feasibility is also about how well the prior three performance objectives are met. For the purpose of this EBRA, feasibility will be considered like road-user safety: all alternatives are considered to be safe and feasible. Future value or constructability analysis may determine that the alternatives are not equally feasible, and that feasibility of construction is an important criterion for selection of the most valuable alignment.

3.3. Condition States

For the purpose of the EBRA, which is to assess the likelihood of meeting the multiple performance objectives and consideration of the consequences of failing to do so, these performance objectives can be summarized and simplified as:

1. Achieve resilient, low life cycle cost solution.
2. Ensure opportunities through continuity of access.
3. Hold cultural, aesthetic and wilderness values intact.

When arranged in this way, there is a hierarchy to the objectives for Denali Park Road. If Objective No. 1 is achieved, then Objectives 2 and 3 will also be achieved (with respect to transportation and the road). Furthermore, even if Objective No. 1 is not achieved, it is still possible to achieve Objectives 2 and 3. If attempts to achieve Objective No. 2 also fail, it is still possible to achieve Objective No. 3. Each objective can be considered conditional on the prior objective if it is taken that efforts will first be made to operate a low life cycle cost and resilient section of road, and then, if that fails, on ensuring predictable and reliable access, and then, if that fails, on simply holding the corridor together so that it doesn't sever the cultural, aesthetic and wilderness values that it supports.

If the objectives are conditional upon one another in this way, numerical conditional probabilities can be assigned to each of the "if" questions and these represent the likelihood that the road stays in a certain condition state (e.g., 90% or 0.9). One minus that probability is the likelihood that it fails to stay in that more desirable state and drops into a lower condition state (e.g., 1 – 0.9 = 0.1 or 10% likelihood). Lower condition states don't support the performance objectives as well as higher ones, and so the consequence from falling to a lower state is greater. This is the risk that is assessed by the EBRA process for many probabilistic scenarios.

For the Denali Park Road over Polychrome Pass, and the performance objectives outlined above, the following condition states are defined:

Condition State A: When considered over a 50-year life cycle, the total annual maintenance costs and activities are typical for the portion of the road known as NR Segment C (Figure 3-1) and stable (e.g., predictable); they are not escalating when compared to other parts of the road. Segments are in State A after initial construction and remain in State A if the type and frequency of issues addressed for NR Segment C, Mile Point (MP) 31-66, are not exceeded. The following actions appear typical and are periodically required at various sites along NR Segment C, as based on the presentation given to the EBRA panel by park maintenance staff:

- Partial use of permitted 11,000/cubic yards/year aggregate
- Raising road elevation 1 foot for settlement
- Management of drainage
- Some deep patch completed, more could be installed
- Occasional rockfall
- Small slumps above and below road
- Debris flow cleanup.

Note that Figure 3-1 shows a 'telescoping' road section in the direction of Kantishna, such that maintenance activities and expectations are different in CA-1 (NR Segment A) than in CA-4 (NR Segment D). Typical vs. exceptional maintenance is based on activities reported during the EBRA within approximate limits of CA-3 (NR Segment C).

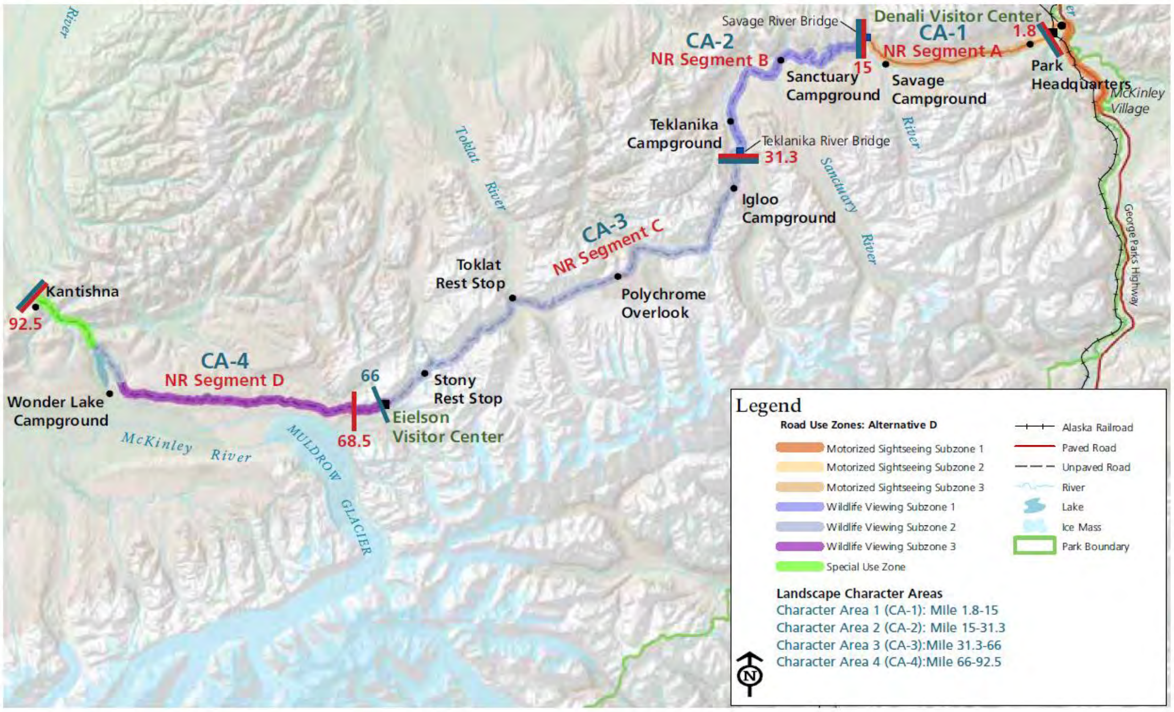


Figure 3-1. Roadway Maintenance (Provided by NPS during the May 5-7, 2020 EBRA meeting).

Condition State B: Annual costs are equal to or higher than typical and/or they are not stable, but roadway assets provide an acceptable continuity of safe access and ensuring opportunities for visitors. Polychrome Pass has been in this state since approximately 2000. Exceptional maintenance activities are required, meaning that specialty contractors may be needed and that impacts to traffic such as temporary closures or heavy construction traffic are expected.

Condition State C: Visitor opportunities are curtailed significantly by road condition and closures. Access cannot be assured during open road season, resulting in unpredictable reliability. Condition State C would have broader economic impacts because tourism industries require greater reliability of access to be attractive. Condition state C has not been realized on the road at Pretty Rocks landslide or on Polychrome Pass in the past – it is worse than the worst condition state observed so far.

Condition State D: Seasonal or longer closure is incurred because of failure of earthwork(s) or structure(s) to the point where route abandonment is considered, or special legislative acts are required to rebuild or restore. The current road would be in Condition State D, for example, if Pretty Rocks landslide moved 100s of feet downslope in a single accelerated movement cycle, making it practically impossible to restore to grade. In Condition State D, the road, which is already present, and will remain present or be rebuilt after falling to Condition State D, has failed to serve the purpose of holding cultural, aesthetic and wilderness values intact.

3.4. Project Approach – Expert-Based Risk Assessment (EBRA)

The risk associated with failing to achieve performance objectives is equated to the likelihood of that event and it is estimated using judgment of a panel of experts. An event is a degrading of condition state (A to B, B to C, etc.) and the consequence of each event is embodied in the definition of condition states, so the panel judgment is with respect to its likelihood (probability) of occurrence.

The panel is comprised of people with overlapping expertise and experience with the type of geologic and climatic setting, the type of design and construction proposed, and experience with highway maintenance and repair. Though WFLHD and the NPS have maintenance staff, and engineers and geologists that would meet these requirements, the panel was independent as a means of reducing potential bias. WFLHD and NPS expertise informed the independent panel through a workshop, as described below.

Additional attributes of panel members include the willingness to offer an opinion based on limited factual information, and the willingness to reconsider their opinion based on debate with others. Panel members recognized that even the precise engineering and geological studies that follow standard investigation, design and construction practices, can sometimes produce performance outcomes that do not meet expectations. Panel members also recognized that the assumed design, construction, and eventual maintenance and preservation work here will meet the standard of practice, but might not exceed it, and be able to factor these realizations into their judgments.

During a 3-day web-based workshop, the panel had a briefing session with WFLHD and NPS experts to convey both factual observations and opinions for consideration and then convened for an augmented-reality-based ‘site visit’ using the BGC Ada Platform^{TM} viewer and Microsoft HoloLens^{TM}. The agenda for the workshop is included in Appendix B.

The panel had numerous reference materials available to inform their assessments, including presentations given by WFLHD and NPS, Ada Platform^{TM} holograms, lidar, geohazard mapping, InSAR, and the appended existing conditions report and the Polychrome Pass Project Delivery Plan (Appendix C).

Following these forms of briefing, the panel members were asked to provide their independent judgment on the likelihood (probability) of moving from one condition state to the next. This was facilitated through a structured process and the decomposition of the complex problem.

Decomposition allows for estimates to be made for smaller components of the problem and then to be combined using the principles of probability, and it is a key principle in this type of assessment. The assumption of conditional probability – that State B will be achieved only after the failure to maintain State A, and so on through State D, is one way the problem was decomposed. Another way this was done is through breaking alignments into segments.

Segments were selected based on the primary construction type in that part of an alignment – earthwork, geohazard mitigation or bridge, and also the geologic and topographic setting. An additional consideration is to not make this assessment prohibitively complicated by having too many input variables, and yet still having limited data upon which to base judgments. With these considerations, 13 segments were defined for each alignment (Figure 4-7). After general site knowledge from WFLHD and NPS was shared, and the approach further described, the panel considered each one of the 13 segments individually and the performance of that type of construction in that environment. The segment assessments were later combined to compare the long-term geotechnical risks for each of the alternative alignments.

Some of the factors impacting the expected change of condition state are as follows:

- Permafrost and muskeg considerations
- Landslide widths, lengths and depths
- Rate of movement for active landslides
- Triggers needed to initiate movement of inactive landslides
- Differential movement at landslide margins
- Incipient instability where no landslides are mapped now
- Impact of climate on landslide activity
- Impact of climate on design features (cuts, fills, bridges)
- Impact of time on new design features and their environment
- Resilience of similar design features in similar environments
- Ability to modify, augment or make large change to constructed works in the future.

The process was facilitated to arrive at a consensus opinion through debate where opinions differ significantly or to establish likelihood bounds where this was not possible. When each of these segments was assessed, they were compared to one another for consistency of approach, and then combined, as appropriate for a given alignment.

Thus, the process was to inform the experts about regional site conditions (applying to all segments on all alignments) and then, one segment at a time, to provide information on what is known about the geologic setting and what is known about the design features specifically for that segment. The panel estimated conditional probability of advancing through the four condition states for each segment. Since it is desired to stay in the higher state with less adverse impacts, the probability that this doesn’t occur can be considered as the conditional probability of failure. The formulation of an event tree was used to track the estimates and calculate conditional probabilities. An event tree of this type is shown in Figure 3-2.

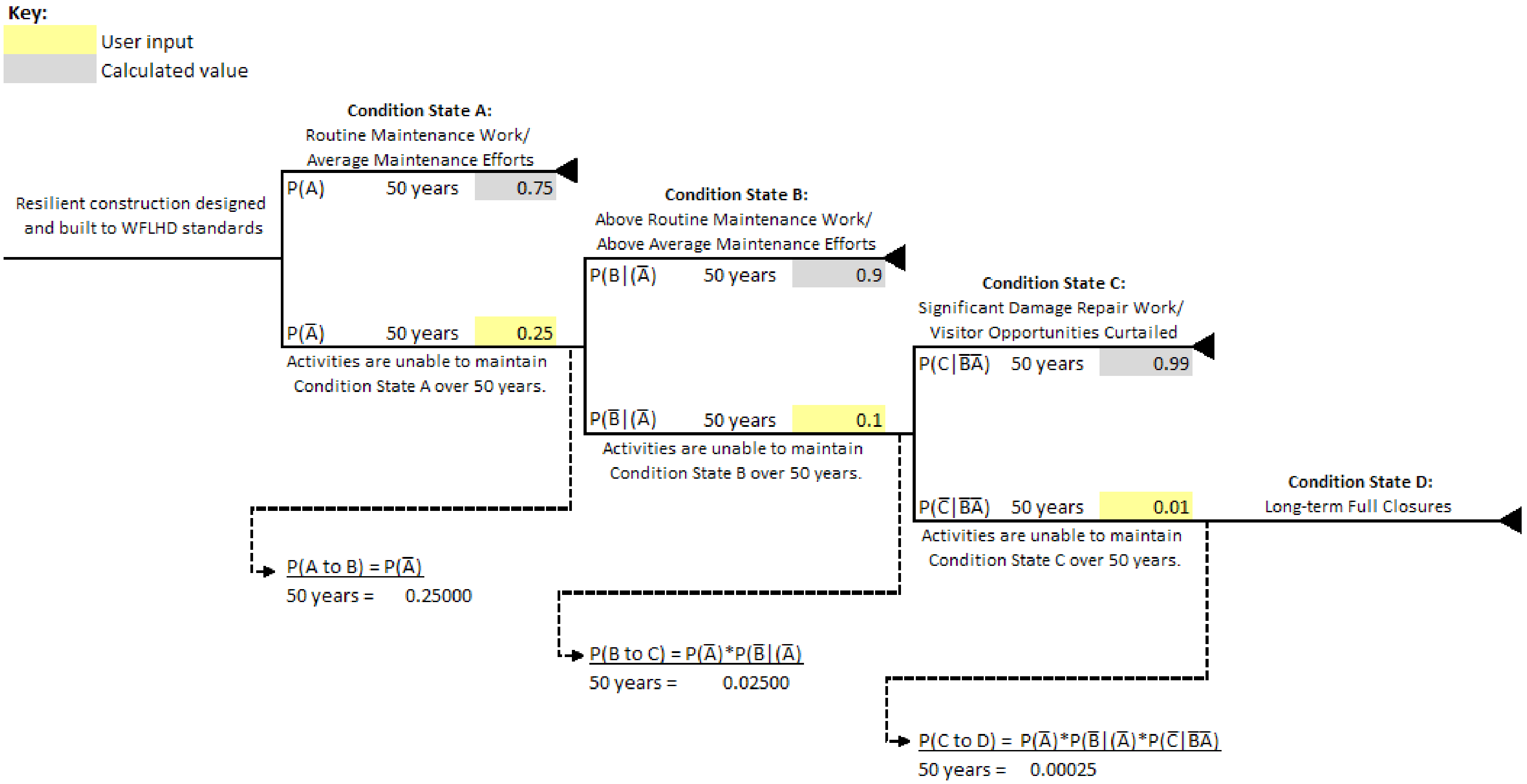


Figure 3-2. Representative event tree.

4.0 CONDUCTING THE RISK ASSESSMENT

4.1. Assembling the Panel

The panel members selected for this EBRA were:

- George Machan, PE, Senior Associate Engineer, Landslide Technology, Oregon
- Jeff Currey, PE, Northern Region Materials Engineer for Alaska Department of Transportation & Public Facilities, Alaska
- Kenneth Johnson, Ph.D., C.E.G., PE, Senior Geological Engineer, WSP USA, California
- Lukas Arenson, Dr.Sc.Techn.ETH, P.Eng. (BC, YT, NT/NU), BGC Engineering, British Columbia, Canada.

The panel represents more than 100 years of experience with road and bridge construction, landslide study, permafrost engineering, in Alaska, across the US, and internationally. There is a balance of geologists and engineers, consultants and a DOT employee, and a mutual respect for the experience that each brought to the panel. As explained further below, WFLHD and NPS expertise was shared with the panel, but they were not part of the panel, nor were they part of the panel deliberations. Thus, the opinions rendered by the panel are independent.

4.2. Facilitation

The panel members were provided review material that explained the objective, process, and project background prior to convening for a three-day virtual EBRA meeting. The meeting was held virtually on May 5-7 due to travel restrictions during the COVID-19 pandemic. The meeting agenda is provided in Appendix B. The first two days were spent familiarizing the panel with the site and the EBRA process. Presentations were given by WFLHD and NPS staff, as indicated on the agenda, and the project reports in Appendix A and C were referenced. WFLHD and NPS staff left the meeting before the afternoon session of Day 2 began and did not return for the remainder of the EBRA, allowing it to be completed independently by the panel.

The remainder of the EBRA meeting was dedicated to working sessions during which the expert panel came to a consensus on definitions of Condition States A, B, C, and D, systematically reviewed all available information and as a group estimated the probability of each segment moving from Condition State A to B, B to C, given that it was already in Condition State B, and then to C and D, given that it was already in Condition State C, within a 50-year time period. BGC facilitators used their expert experience and familiarity with the EBRA structure and process, and the Denali Park Road project, to guide the discussion and the consideration of various inputs, but did not offer opinions, nor challenge estimates provided by panelists.

4.3. Deliberations and Assumptions

After examining what is known about the project, the alignments and the performance objectives were reviewed, and the panel was convened alone by BGC, certain key considerations were summarized. This was done in an effort to keep the understanding as consistent as possible between the panelists. The key considerations included the following.

- Resiliency: Regardless of the alignment alternative or element of work on that alignment, this attribute will be built into the selected alternative.
- Construction: Only to the extent that construction methods impact long-term performance are they considered in the EBRA.
- Bridges constructed over the East Fork Toklat River and its tributaries will span the full floodplain and will not use causeways to shorten span lengths. This is in accordance with the preliminary design concept prepared by WFLHD.
- The current alignments on the map represent a 5% design – it is very conceptual and would be revised to avoid obvious and easily avoided geohazard conflicts.
- It is assumed that engineered solutions will always be used to defend against falling to a worse condition state.
- WFLHD and the NPS will follow a design development process that includes value analysis (VA), review and innovations compatible with the standard of practice for 2020 in Alaska.
    - Examples are GRS abutments, bridges and/or longer decks to set abutments back from slopes, use of embankments rather than cuts, timing of earthwork, avoiding thermokarst and solifluction areas where possible, and additional water control (i.e., culverts).
- Typical roadway sections and structures will be as presented by WFLHD in the Draft Project Development Plan (PDP) (Appendix C).
- Planned activities on existing alignment to be completed as presented by WFLHD Appendix C).
- Climate is changing and non-stationarity is expected (past climate and its effects will not be constant in the future).

In conducting the EBRA, the panel elected to review each alignment separately and within each alignment to progress through the different types of segments in sequence. For example, all structures were evaluated in sequence within one alignment, and then all earthwork segments, etc. A synopsis of the alignments and identification of the segments is provided in Section 4.4.

The approach for each segment was generally as follows:

- Review the geohazard map with segments identified (Figure 4-7).
- Review the lidar.
- Evaluate InSAR results as deemed appropriate.
- Review workshop presentation content and photographs available (Figure 4-1 to Figure 4-6 are examples).
- Panel members consider if they have reviewed enough information to make an informed assessment regarding Condition State. If not, the panel revisits the resources at hand.
- Panel members make individual assessments of State A to B, State B to C and State C to D.

- Share and search for consensus on the estimates, review data and HoloLens^{TM} scenes as needed.
- Record one or more outcomes following debate (the panel always settled on one outcome as a group).
- Record key observations of the panel that might be considered to reduce risk.
- Advance to next Segment and consider new data in sequence above. Consider how the next segment compares to the previous.

4.4. Alternative Alignments

4.4.1. Existing Alignment (Option 1)

The existing alignment traverses a precipitous section of road known as Polychrome Pass. Built in the 1920s and 1930s and known as the high-line route, this scenic section of road is at roughly the mid-way point on the 92-mile long road. The Pretty Rocks Landslide (Figure 4-1 and Figure 4-2) at MP 45.3 is one of several known landslides in that general area. Recent data indicates the rate of movement in this area increased significantly during the late summer of 2019 following warm seasonal average temperatures in the region and historic summer rain events in August 2019.

A 6.4-mile section of the road, between approximately MP 42 and MP 48.4, is being considered for comparison with the proposed alternative north and south alignments. For the EBRA, Pretty Rocks Landslide and Bear Cave Landslide were assumed to be mitigated according to WFLHD’s PDP (Appendix C), and all the Unstable Slope Management Program (USMP) sites would be improved to at least a “fair” condition.

Figure 4-1. Denali Park Road at the Pretty Rocks Landslide. NPS photo (Date unknown).

Figure 4-2. Denali Park Road at the Pretty Rocks Landslide. FHWA photo (2018).

4.4.2. North Alignment (Option 2)

The proposed 6-mile-long north alignment would depart the existing alignment near the East Fork Toklat River Bridge (MP 43) and rejoin the road near MP 48 (Figure 4-7). The alignment crosses several rivers and drainages, as well as several areas identified as permafrost and landslides. The general character of the landscape along the north alignment is shown in Figure 4-3 and Figure 4-4.

Figure 4-3. The north alignment traverses a valley. FHWA photo (2019).

Figure 4-4. Landslide near north alignment. Note the stream at the bottom of the valley. FHWA photo (2019).

4.4.3. South Alignments (Option 3A and 3B)

There are currently two proposed south alignments – Option 3A and Option 3B (Figure 4-7). The 6.2-mile and 5.3-mile-long south alignments would depart the existing alignment near the East Fork Toklat River Bridge (MP 42.1 and MP 44.3, respectively) and rejoin the road near MP 48. The south alignments traverse a broad valley with wide floodplains, discontinuous permafrost, and “muskeg,” which is generally referred to as “wetlands” within the park (Figure 4-6), and would bridge several active braided river and stream channels (Figure 4-5).

Figure 4-5. Braided channel characteristic of the south alignment. FHWA photo (2019).

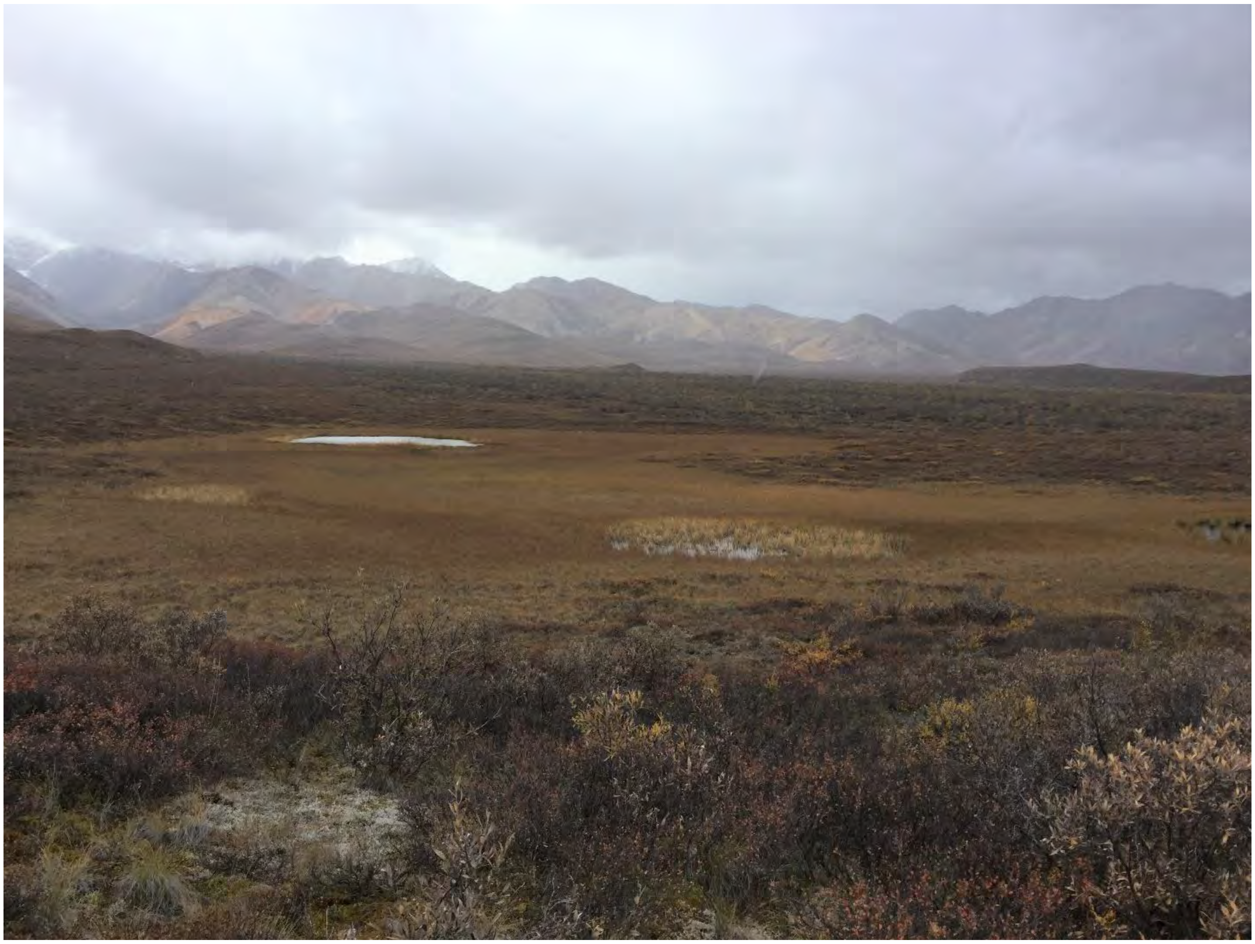
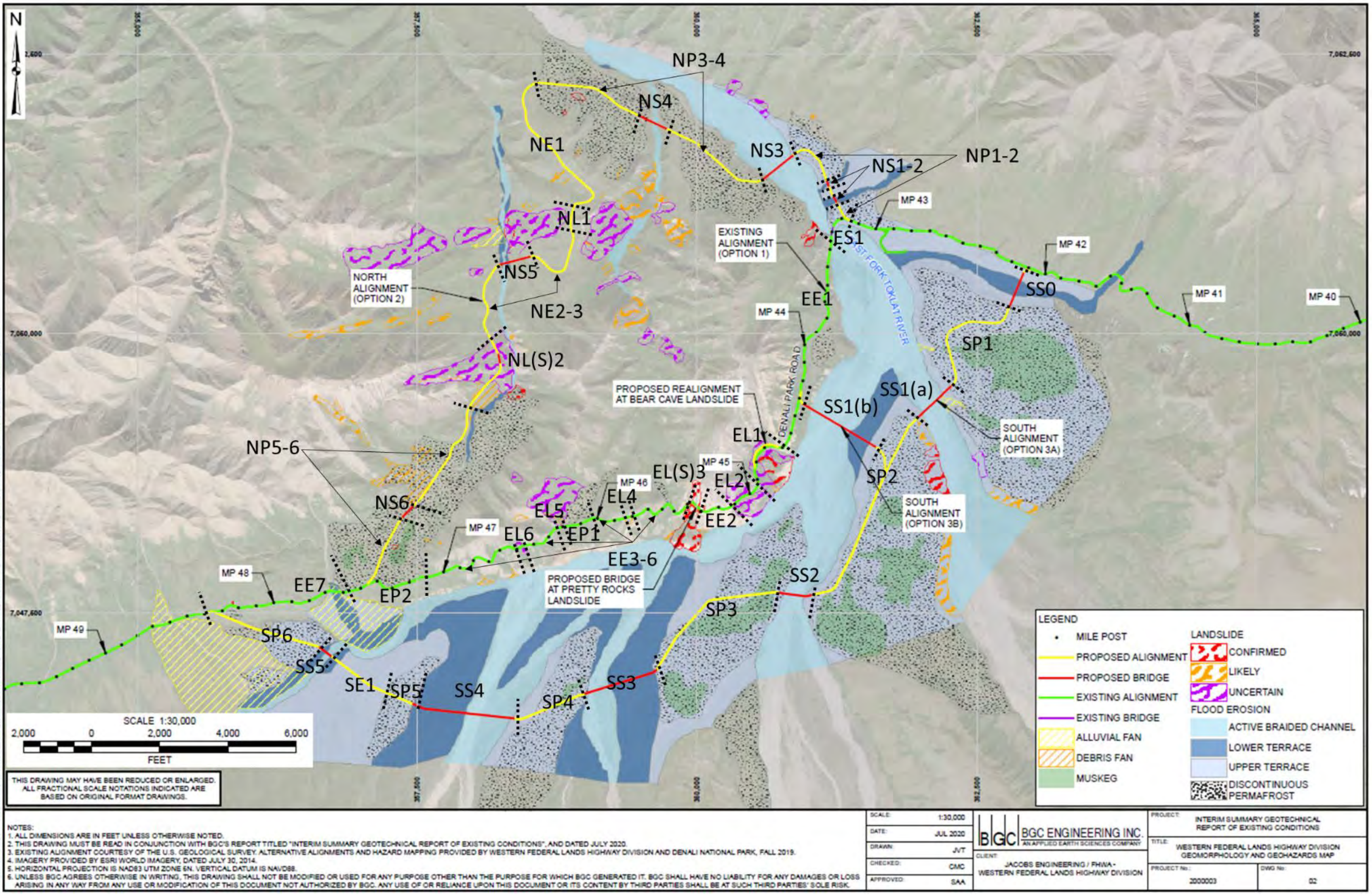


Figure 4-6. Tundra characteristic of the south alignment. FHWA photo (2019).

4.5. Segments

Segments were selected based on the primary construction type or geohazard in that part of an alignment – earthwork, landslide, permafrost, structure. With these considerations, 13 segments comprise each alignment (Figure 4-7). Each segment is labeled using the following structure: Alignment [South (S), North (N), Existing (E)] + Type [Earthwork (E), Landslide (L), Permafrost (P), Structure (S)] + Number [i.e., 0, 1, 2, etc., or combined segments, i.e., 1-2, 3-4]. For example, segment SS2 is South Alignment-Stucture-2, NP1-2 is North Alignment-Permafrost-1 and 2 combined, and NL(S)2 is North Alignment-Structure-2 (within a landslide).



NOTES:
1. ALL DIMENSIONS ARE IN FEET UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "INTERIM SUMMARY GEOTECHNICAL REPORT OF EXISTING CONDITIONS", AND DATED JULY 2020.
3. EXISTING ALIGNMENT COURTESY OF THE U.S. GEOLOGICAL SURVEY. ALTERNATIVE ALIGNMENTS AND HAZARD MAPPING PROVIDED BY WESTERN FEDERAL LANDS HIGHWAY DIVISION AND DENALI NATIONAL PARK, FALL 2019.
4. IMAGERY PROVIDED BY ESRI WORLD IMAGERY, DATED JULY 30, 2014.
5. HORIZONTAL PROJECTION IS NAD83 UTM ZONE 6N. VERTICAL DATUM IS NAVD88.
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Figure 4-7. Alternative alignments and segments.

Table 4-1. Alignments and segments.

Segment	Type	Alignments			
		South (Option 3A)	South (Option 3B)	Existing (Option 1)	North (Option 2)
SS0	Structure	✓			
SP1	Permafrost	✓			
SS1a	Structure	✓			
SS1b	Structure		✓		
SP2	Permafrost	✓	✓		
SS2	Structure	✓	✓		
SP3	Permafrost	✓	✓		
SS3	Structure	✓	✓		
SP4	Permafrost	✓	✓		
SS4	Structure	✓	✓		
SP5	Permafrost	✓	✓		
SE1	Earthwork	✓	✓		
SS5	Structure	✓	✓		
SP6	Permafrost	✓	✓		
ES1	Structure		✓	✓	
EE1	Earthwork		✓	✓	
EL1	Landslide			✓	
EL2	Landslide			✓	
EE2	Earthwork			✓	
EL(S)3	Landslide (+ Structure)			✓	
EE3-6	Earthwork			✓	
EL4	Landslide			✓	
EP1	Permafrost			✓	
EL5	Landslide			✓	
EL6	Landslide			✓	
EP2	Permafrost			✓	
EE7	Earthwork			✓	✓
NP1-2	Permafrost				✓
NS1-2	Structure				✓
NS3	Structure				✓
NS4	Structure				✓
NP3-4	Permafrost				✓
NE1	Earthwork				✓
NL1	Landslide				✓
NE2-3	Earthwork				✓
NS5	Structure				✓
NL(S)2	Landslide (+ Structure)				✓
NP5-6	Permafrost				✓
NS6	Structure				✓

5.0 RESULTS

The results of the EBRA are estimates of likelihood, which is equivalent to the probability of occurrence. Here, the estimated likelihood is the probability of failing to maintain a more desired condition state and the consequence is the difference in service provided by the two condition states. Because the consequence is defined by the description of the condition states, the likelihood estimates by the panel are evaluated as probabilities, and they represent risk, and are the final result.

The results identify elements of work where the risks are judged highest and lowest, and alignments where the risks are judged highest and lowest, but they do not provide recommendations. It is understood that WFLHD and the NPS will use the understanding of long-term geotechnical risk, along with other factors such as construction feasibility, cost and environmental impacts, to select a preferred road alignment alternative at a later stage.

5.1. Segment Results

The panel was asked to estimate the probability of each segment moving from Condition State A to B, B to C, and C to D in 50 years. When a segment moves from Condition State A to Condition State B, exceptional maintenance is required; when it moves from Condition State B to C, there is unpredictable reliability; and, when it moves from Condition State C to D a segment experiences long-term closure. All estimates assume that condition state changes are sequential through all states. Though there is no assumption of time within a given state, the assumption of sequence means that conditional probabilities can be estimated for each state transition and recompiled using the equations of conditional probability. This concept is illustrated in Figure 3-2 and explained in Table 5-1. It is also assumed that no other condition states exist: each segment is in one and only one of the four condition states at any given time.

Table 5-1. Probability of deteriorating conditions with respect to transitioning from one condition state to another.

Conditions	Condition State Transitions	Probability Formulas
Exceptional Maintenance Required	Transition from Condition State A to Condition State B	$P(\text{A to B}) = P(\overline{A})$
Unpredictable Reliability	Transition from Condition State B to Condition State C	$P(\text{B to C}) = P(\overline{A})*P(\overline{B}\vert(\overline{A})$
Long-term Closure	Transition from Condition State C to Condition State D	$P(\text{C to D}) = P(\overline{A})*P(\overline{B}\vert(\overline{A})*P(\overline{C}\vert\overline{B}\overline{A})$

It is difficult to assign subjective probability estimates to events that are either very unlikely or very likely, and that is one reason why the EBRA process relies on decomposition of a problem, and then using conditional probability rules to estimate low probability events. As facilitators, BGC guided the work and reminded the panel of information to consider the significance of assumptions such as the conditional probability assumptions, and how the decomposed estimates will be recomposed for each alignment alternative.

BGC recorded the panel's probability estimates for each segment in Table D-1 of Appendix D. Each cell in Table D-1 is a unique, consensus opinion made by the panel, and this is their primary work product. The assessments represented in each cell were challenged internally by the panel as the work was completed, and reviewed subsequently, and confirmed as the panel's consensus judgment based on the data available to them and the process described herein. The calculated the conditional probability of deteriorating conditions for each segment is shown in Table D-2 of Appendix D. The resulting probability of deteriorating conditions for all segments are shown in Figure 5-1 through Figure 5-6. Figures are grouped by condition state transitions: Exceptional Maintenance Required, Unpredictable Reliability, and Long-term Closure.

The probability of "exceptional maintenance requirements" (transition from Condition State A to B) for each segment is shown in Figure 5-1 and Figure 5-2, which are sorted by alignment and by type (earthworks, landslides, permafrost, and structures), respectively. Probabilities range from greater than 90% to less than 10%. Option 2 (North) contains the greatest number of segments with a high probability of exceptional maintenance. Several landslide, earthworks, and permafrost segments have probabilities greater than 50% probability, while structure segments have the lowest average probability of exceptional maintenance.

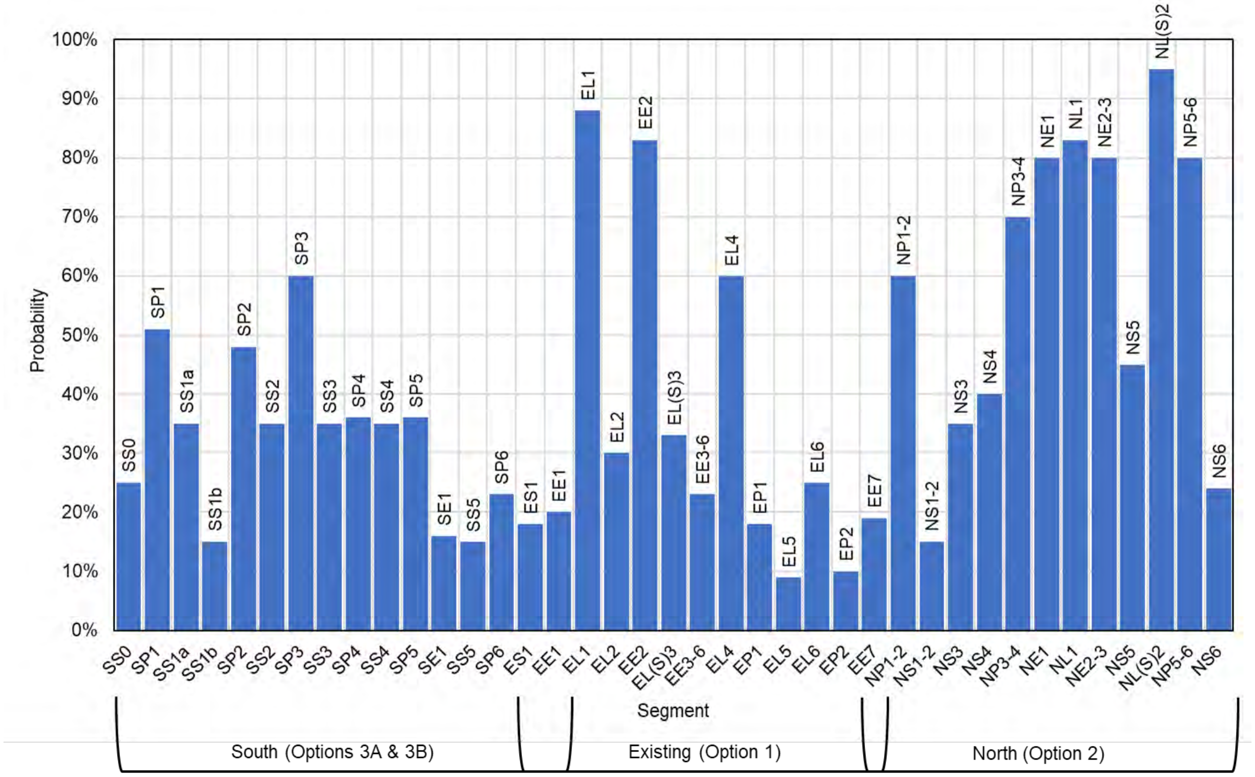

Figure 5-1. The probability of each segment moving from Condition State A to B (exceptional maintenance required), sorted from east to west along each alignment. Refer to Figure 4-7 for segment locations.

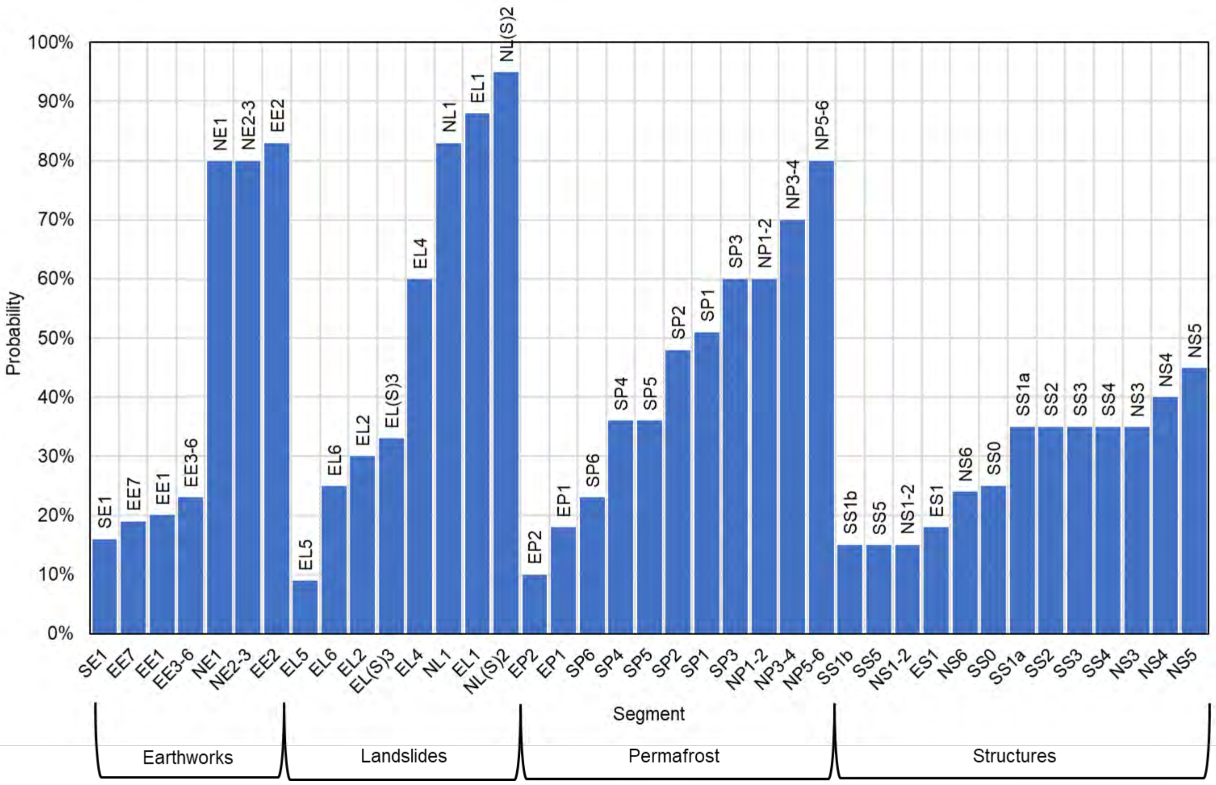

Figure 5-2. **The probability of each segment moving from Condition State A to B (exceptional maintenance required), shown in order of increasing probability for each segment type: Earthworks, Landslides, Permafrost, and Structures. Refer to Figure 4-7 for segment locations.**

The probability of “unpredictable reliability” (transition from Condition State B to C) for each segment is shown in Figure 5-3 and Figure 5-4, which are sorted by alignment and by type (earthworks, landslides, permafrost, and structures), respectively. Probabilities range from greater than 80% to nearly 0%. Option 2 contains the greatest number of segments with a probability of unpredictable reliability greater than 10% and contains the segment with the highest probability (NL(S)2). Landslide segments have the highest probability of unpredictable reliability, followed by permafrost, earthworks, and structures segments, respectively. That is, landslide segments are the least reliable and structure segments are the most reliable.

The probability of “long-term closure” (transition from Condition State C to D) for each segment is shown in Figure 5-5 and Figure 5-6, which are sorted by alignment and by type (earthworks, landslides, permafrost, and structures), respectively. Option 1 and the Option 2 each have two segments with a probability of long-term closure greater than 1%. Option 2 has the segment with the highest probability of long-term closure (24%).Landslide segments – NL(S)2, EL1, NL1, and EL(S)3, have the highest probability of long-term closure, whereas most other segments have a probably of long-term closure near 0%.

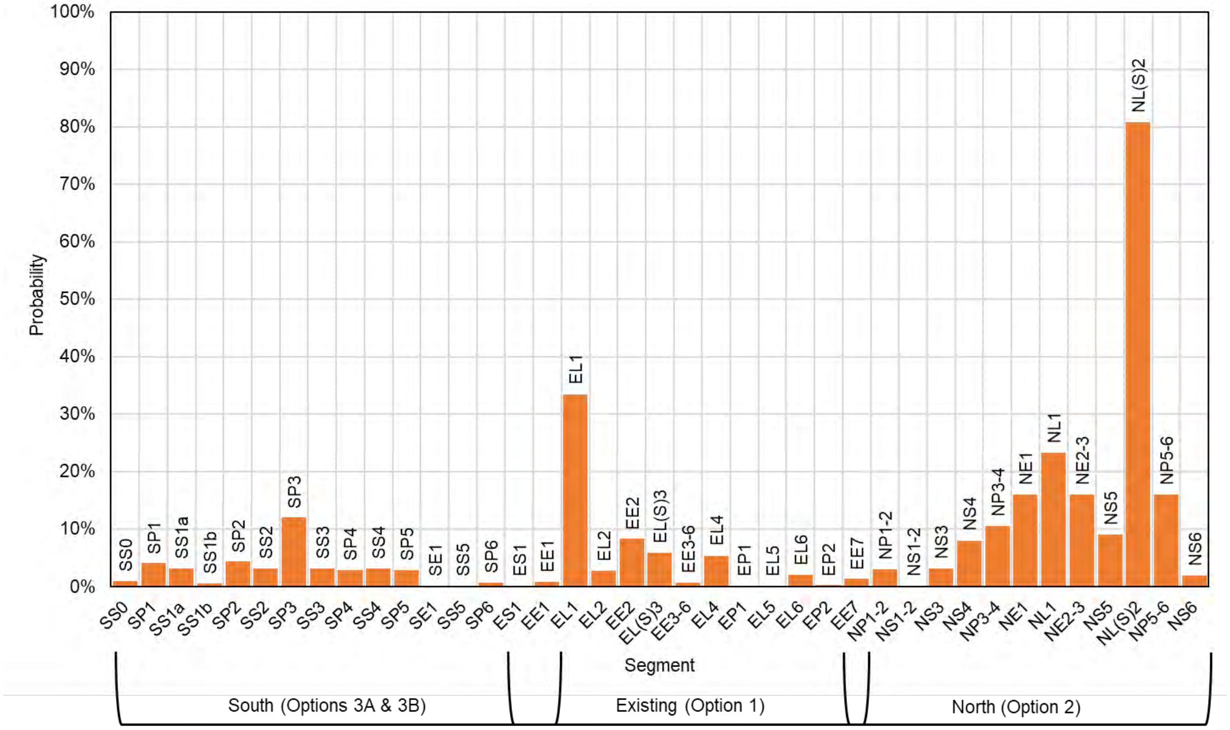

Figure 5-3. The probability of each segment moving from Condition State B to C (unpredictable reliability), sorted from east to west along each alignment. Refer to Figure 4-7 for segment locations.

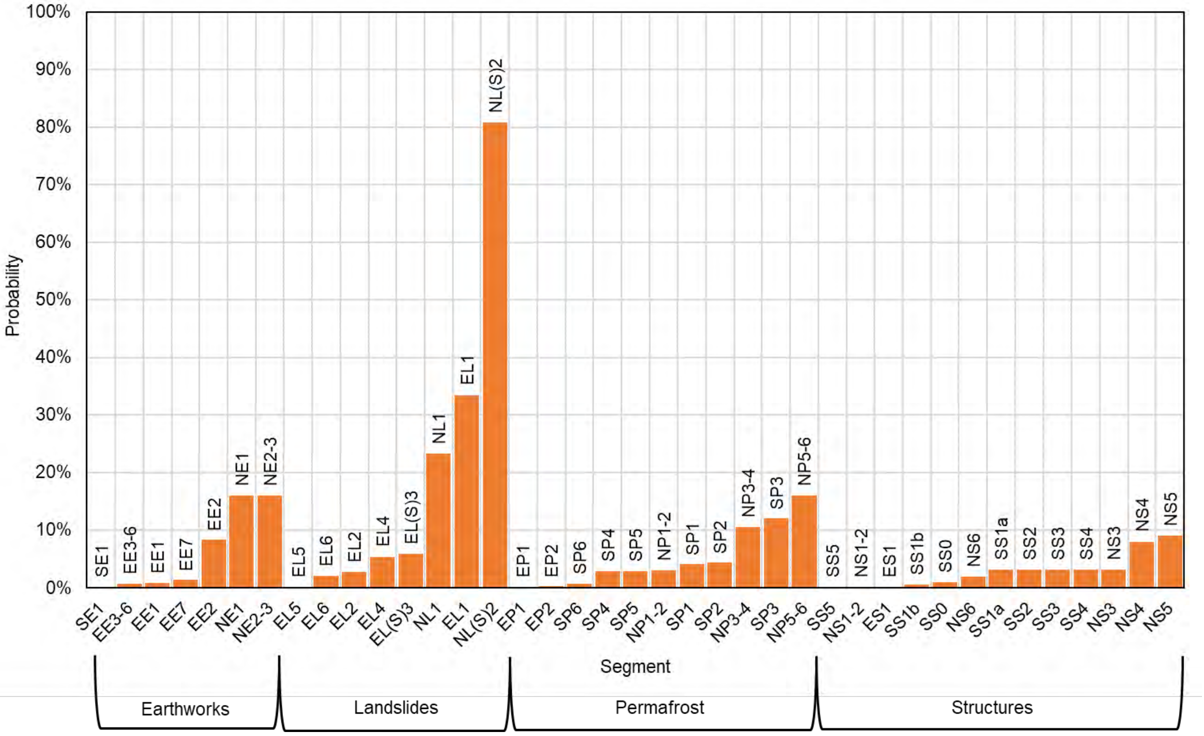

Figure 5-4. The probability of each segment moving from Condition State B to C (unpredictable reliability), shown in order of increasing probability for each segment type: Earthworks, Landslides, Permafrost, and Structures. Refer to Figure 4-7 for segment locations.

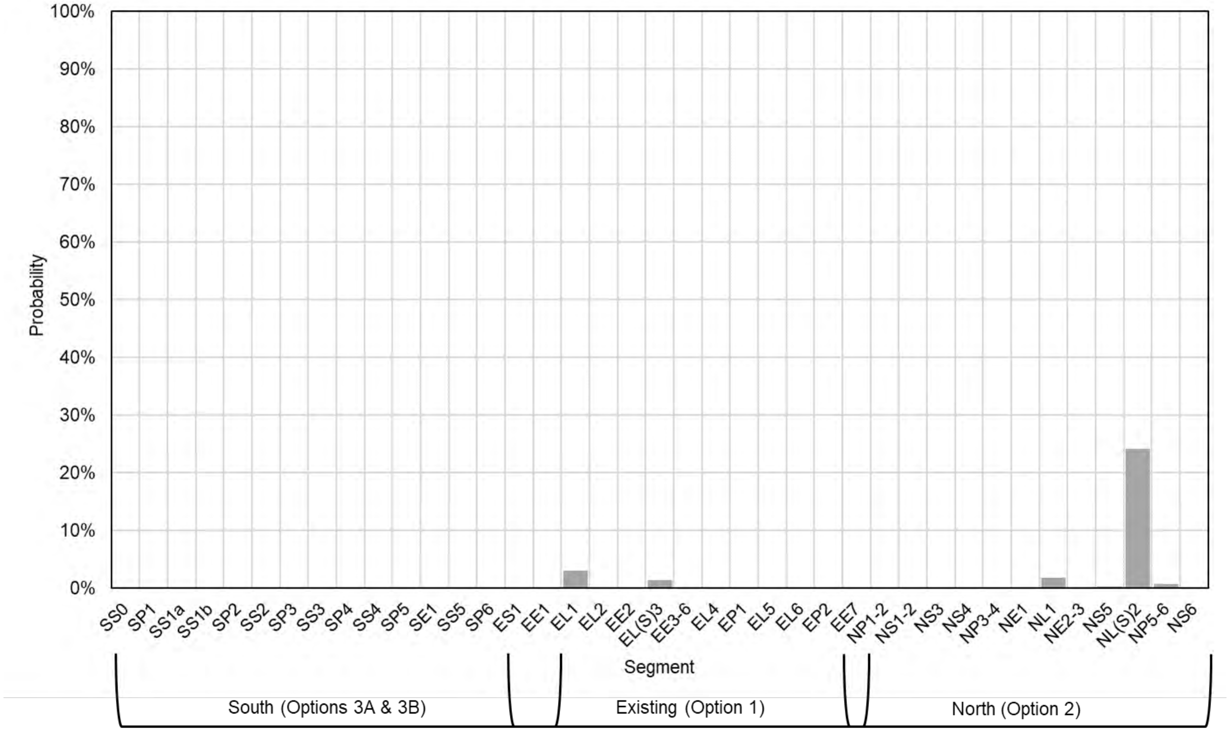

Figure 5-5. **The probability of each segment moving from Condition State C to D (long-term closure), sorted from east to west along each alignment. Refer to Figure 4-7 for segment locations.**

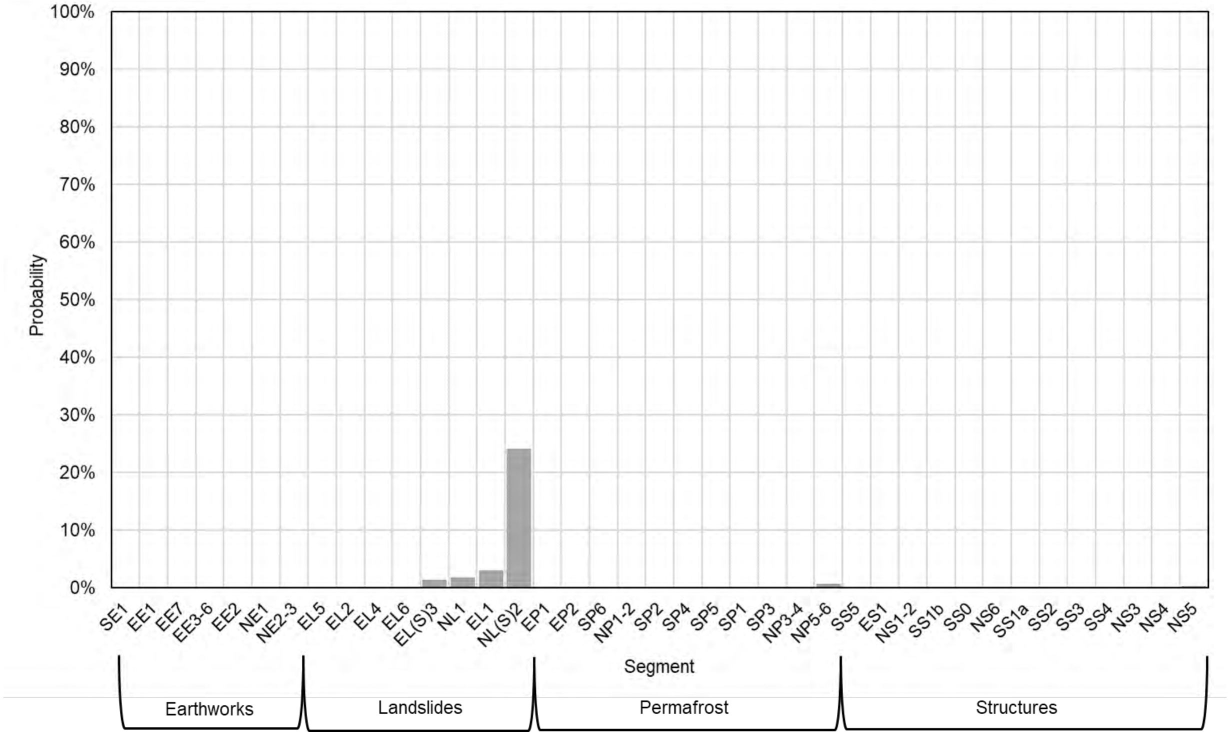

Figure 5-6. **The probability of each segment moving from Condition State C to D (long-term closure), shown in order of increasing probability for each segment type: Earthworks, Landslides, Permafrost, and Structures. Refer to Figure 4-7 for segment locations.**

5.2. Alternative Alignment Results

Each alternative alignment is made up of thirteen segments and there are multiple ways the estimates can be combined. With respect to "Unpredictable Reliability" and "Long-term Closure," it is easy to visualize the segments as links in a chain, where if one link fails, the chain fails. Thus, the segments work as a system, and the probability of system failure can be calculated using Equation 5-1, where p_1, p_2, and p_n are the probabilities associated with the segments making up an alignment. The formula used to calculate the probability of transitioning from Condition State B to C for the North (Option 1) Alignment is shown in Equation 5-2. Values for P_1 through P_{13} in Equation 5-2 come from Table D-2 in Appendix D. For example, $P_1 = 0.01$ and $P_2 = 0.03$ are the probabilities of Segment EE7 and NP1-2 transitioning from Condition State B to C, respectively. The calculated probability of the North (Option 1) alignment (considering all 13 segments) moving from Condition State B to C is equal to 0.94, which is presented in Table 5-2 below and in Table D-3 of Appendix D.

$$\mathrm{P(A\ to\ B, B\ to\ C, or\ C\ to\ D)} = 1 - (1 - p_1) \times (1 - p_2) \times \ldots \times (1 - p_n) \qquad \text{[Eq. 5-1]}$$

$$\begin{aligned}\mathrm{P(B\ to\ C)} = 1 - (1 - 0.01) \times (1 - 0.03) \times (1 - 0.002) \times (1 - 0.03) \times (1 - 0.08) \\ \times (1 - 0.11) \times (1 - 0.16) \times (1 - 0.23) \times (1 - 0.16) \times (1 - 0.09) \\ \times (1 - 0.81) \times (1 - 0.16) \times (1 - 0.02) = 0.94\end{aligned} \qquad \text{[Eq. 5-2]}$$

The logic of the segments working together as a system is not as representative for "exceptional maintenance" as for the others, but for consistency, the system logic is adopted and used to combine segments into alignments. To supplement this, the average probability of exceptional maintenance for the segments that comprise each alignment was also quantified to help differentiate the alignments. The use of the average as an indicator is based on the idea that maintenance requirements can be thought of as cumulative in nature, both in terms of cost and interruption to road users.

System failure probabilities for the alignments are summarized in Table 5-2 and in Figure 5-7. The probability of exceptional maintenance P(A to B) for all alignments is near 100%; however, as explained above, it is more useful in this case to examine the average probability of exceptional maintenance for the segments that comprise each alignment, which are shown as the dashed line on the blue bars in Figure 5-7. Average probabilities for exceptional maintenance in Options 1, 3A, and 3B range from 30-35% and Option 2 segments have an average probability of 56%. The probability of unpredictable reliability P(B to C) begins to differentiate the options more clearly. Unpredictable reliability probabilities range from 30% (Option 3B) to 94% (Option 2). The probability of long-term closure P(C to D) further differentiates the alignments. Probabilities for long-term closure on Options 3A and 3B are near 0%, Option 1 is 5%, and Option 2 is 27%.

Overall, Options 3A and 3B have nearly identical probabilities of deteriorating conditions, Option 1 has slightly higher probabilities, and Option 2 has the highest.

Table 5-2. Probability of deteriorating conditions for each alignment.

Probability of Deteriorating Conditions	Alignment			
	South (Option 3A)	South (Option 3B)	Existing (Option 1)	North (Option 2)
Exceptional Maintenance Required P(A to B) = 1-(1-p_1)×(1-p_2)×…×(1-p_n)	100%	99%	100%	100%
Unpredictable Reliability P(B to C) = 1-(1-p_1)×(1-p_2)×…×(1-p_n)	34%	30%	50%	94%
Long-term Closure P(C to D) = 1-(1-p_1)×(1-p_2)×…×(1-p_n)	0.2%	0.2%	5%	27%

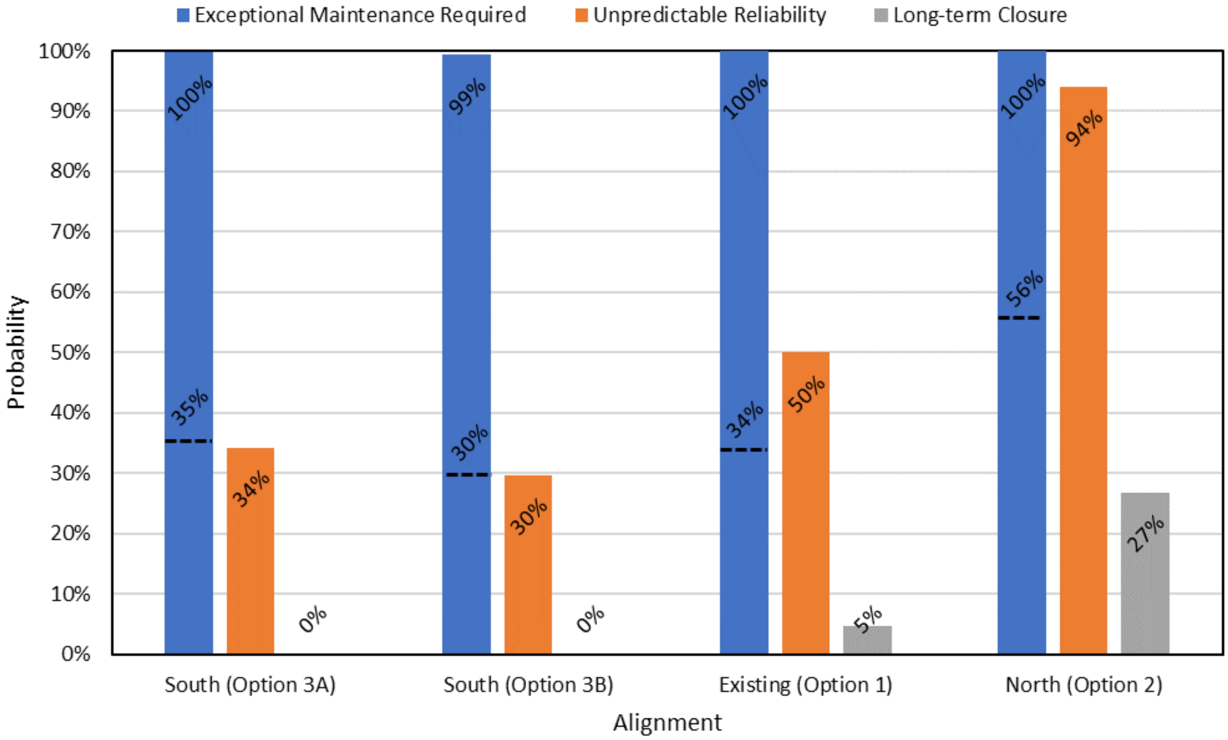

Figure 5-7. Probability of deteriorating conditions for each alignment as a series of segments. The dashed lines represent average segment maintenance expectation.

6.0 OBSERVATIONS AND CONCLUSIONS

6.1. Observations

Discussion amongst the panel during the EBRA process led to several key insights. The first being an early recognition that the original alignment of Option 3A, particularly segments SSO and SP1, were high-risk, and that there seemed to be an easy realignment option. This early recognition allowed WFLHD to make an update to the Option 3A alignment with enough time for the panel to reassess probabilities for segments SSO and SP1 prior to the VA or other design development. Results in this report reflect the revised Option 3A alignment.

Another important observation is that there are specific “problem segments” for each alignment that could be addressed by further study to improve understanding which could have a large impact on the risk assessment. There are a few segments that have a relatively high probability of “unpredictable reliability” and “long-term closure.”

For Option 3A and 3B, segment SP3 is the most problematic, mostly due to the alignment’s proximity to the side-slope down to the floodplain, which could likely be mitigated be moving the alignment further away from the slope. Doing so does not move it from the permafrost and muskeg geohazards, but it does reduce concerns related to the slope.

For Option 2, segment NL(S)2 poses the highest risk. This segment contains a roadway section and a structure within a large mapped landslide and a roadway section within a debris fan. An investigation to gain a better understanding of the landslide extent, mechanism, and activity level, and a reassessment of whether a bridge structure is needed would reduce the uncertainty around this segment and could potentially result in reduced probability of deteriorating conditions over 50 years.

For Option 1, segments EL1 (Bear Cave Landslide) and EL(S)3 (Pretty Rocks Landslide) are the main geotechnical concern, while there are a few other segments that do contribute to the overall risk. Several segments contain sites previously identified in the USMP. The panel operated under the assumption that Pretty Rocks Landslide and Bear Cave Landslide would be mitigated according to WFL’s PDP, and that all the USMP sites would be improved from “poor” to at least “fair” condition. The panel relied upon the idea that USMP sites would be addressed, and that further work should confirm that the improvement of the site ratings would be achieved. For the results to be valid it is important that these mitigations be completed. Even so, the panel felt that the proposed solution at Bear Cave Landslide (EL1) may be short-lived – with respect to the 50-year life considered. This sentiment is reflected in the results with relatively high probabilities assigned to EL1, because there are no obviously reliable, long-term solutions based on current knowledge of the site and the potential for changing climate-based conditions.

Several other important observations were made throughout the EBRA process. A changing climate is to be expected over the next 50 years, and that could have an impact on performance of the road, especially with respect to permafrost. The subarctic permafrost regime is very important to expectations of long-term performance and it was discussed at length by the panel throughout the process. Typical roadway sections presented by WFLHD in the PDP for building in these types of environments were generally considered appropriate by the panel for basing earthwork expectations upon, and the panel considered that bridge abutments would be designed to current standards to meet appropriate bank stability and setback requirements. The panel also felt that drainage systems, such as culverts, would be particularly important in managing water along the road. For example, where segment EE7 crosses an alluvial fan, the panel felt that the road could benefit from a large box culvert or small bridge.

6.2. Conclusions

The Denali Park Road crosses landslides and unstable slopes along Polychrome Pass. Several recurring and ongoing slide movements have required geotechnical attention and repair investments for decades. The Pretty Rocks landslide has been most impactful to the serviceability and safety of the road and its movement has generally been increasing over the past several years.

An EBRA was convened virtually to estimate the long-term geotechnical risks to long-term performance of the Polychrome Pass segment of the Denali Park Road. The original intent was to conduct the EBRA workshop at Denali National Park, with two days of office review and one day site visit to gain the understanding that typically only comes from being onsite; however, due to the COVID-19 pandemic, a multi-day web-based meeting was convened to bring people together.

The assessment compares alternative alignments that include major improvements generally along the existing alignment (known as Option 1), and previously determined alternatives that bypass the segment on entirely new alignments to the north (known as Option 2) and south (known as Options 3A and 3B). Other risks, such as construction cost and duration and other non-geotechnical sources of risk are not part of this risk assessment except in evaluating how they might affect long-term performance objectives for the roadway.

This EBRA provides a relative comparison between alternative alignments at or around Polychrome Pass. Denali National Park's performance objectives are long-term and represent an assumed 50-year service life analysis period for the road and "condition states" were defined specifically for this project. As such, this assessment is confined to this section or road and cannot be directly extrapolated to other areas inside or outside the park. Also, Option 1 is not considered a "no action alternative", even though it maintains the existing road, since it includes several mitigation actions and infrastructure projects.

Results of the EBRA show a significant expectation of "exceptional maintenance" activities, so maintenance will likely be higher than typical for many segments in all alignments. Another important conclusion is that the expectation of transition to a state of "unpredictable reliability" is a key differentiator between alternatives. The probability of "long-term closure" is low for all segments except for Option 2 segment NL(S)2.

Although the bridge structures will be large at many crossings of branches of the East Fork of the Toklat river, the panel felt that they have the lowest probability of deterioration compared to other segment types, such as earthwork and those crossing geohazards. Accordingly, Option 3A and 3B are judged most likely to meet long-term performance objectives. These alignments scored nearly identically for probability of “unpredictable reliability” (30 and 34%) and probability of long-term closure (approximately 0%); whereas Options 1 and 2 scored higher (50% and 90% for unpredictable reliability, respectively; and, 5% and 27% for long-term closure, respectively) (see Figure 5-7).

In general, the outcome of the EBRA indicates Option 2 (north alignment) has the highest long-term geotechnical risk, which is an attribute that will need to be considered along with apparent other attributes of high cost, a long construction period, and potential impacts on visual, cultural, and environmental resources. Option 1 has lower risk than Option 2. Its other attributes include an apparently shorter construction period, but it is on the existing alignment and traffic will be impacted during construction.

Options 3A and 3B have the lowest long-term geotechnical risk. This finding will need to be considered along with its apparently high cost, long construction period, and potential visual, cultural, and environmental impacts or risks. These attributes should be considered along with the findings of this work in subsequent value analysis and alternatives selection processes.

CLOSURE

We appreciate the opportunity to assist you on this project and trust the above satisfies your requirements at this time. Should you have any questions or comments, please do not hesitate to contact us.

Yours sincerely,

BGC ENGINEERING INC.
per:

Scott A. Anderson, Ph.D.
Principal Geotechnical Engineer

Cole Christiansen, M.Sc.
Geological Engineer

Reviewed by:

Mark Vessely, M.Sc.
Principal Geotechnical Engineer

SA/MV/sf/syt

APPENDIX B
EBRA WORKSHOP AGENDA

Agenda – Denali Park Road, Polychrome Pass, Expert-Based Risk Assessment for Performance of Alternatives

May 5-7, 2020

May 5, 2020

	AK Times	Leader
Session 1 – Introduction	**0800-0915 (1:15)**	
NPS/DENA/WFLHD Kickoff	0:15	WFLHD
BGC Introductions	0:15	BGC
EBRA explanation	0:15	BGC
Meeting outcome	0:10	BGC
Flyover of Denali Park Road	0:05	BGC
Alignment review	0:15	WFLHD
Session 2 – Climate, Permafrost and Rivers	**0945-1100 (1:15)**	**BGC**
Permafrost	(0:30)	BGC
Climate discussion (hydrology)	(0:15)	DENA
Past bridge performance	(0:30)	WFLHD
Session 3a – HoloLens Training	**1100-1130 (0:30)**	**BGC**
Lunch	**1130-1300 (1:30)**	
Session 3b – HoloLens Q/A	**1300-1330 (0:30)**	**BGC**
Q/A and demo (for self exploration)		
Session 4 – Geology and Roadway	**1330-1430 (1:00)**	
Background	(0:30)	BGC
Maintenance of roadway	(0:30)	DENA
Session 5 – Unstable Slope Management	**1500-1600**	
USMP Methods	(0:30)	DENA/WFLHD
USMP Sites	(0:30)	DENA
End of Day 1		-

May 6, 2020

Session 6 – Existing Conditions	**0800-0930 (1:30)**	
Geohazard Mapping	(0:30)	WFLHD
Summary Report Review	(0:30)	BGC
Session 7 – Polychrome Pass	**1000-1130 (1:30)**	**WFLHD**
Pretty Rocks Slope Stability and Existing Conditions	(0:45)	WFLHD
Other Mitigation designs/sections	(0:45)	WFLHD
Lunch (incl. HL2 Pt 2)	**1130-1230 (1:00)**	
Optional HoloLens instruction Pt. 2	**1230-1300 (0:30)**	
Session 8 – Visualizations & Recap	**1300-1445 (1:45)**	**BGC**
InSAR results	(0:15)	BGC
Fodar or other recap	(0:15)	BGC
HoloLens fly-through	**(0:45)**	**BGC**
Recap and EBRA structure	(0:30)	BGC
End of Open Session	**1445**	**End of Open Session**

EBRA PANEL SESSIONS

Session 9 – EBRA Panel Getting Started	**1500-16:30 (1:30)** – panel only	
End of Day 2		-

May 7, 2020

Session 10 – South Alignment Alternative	**0730-0930 (2:00)**
Session 11 – North Alignment Alternative	**1000-1200 (2:00)**
Lunch	**1200-1300 (1:00)**
Session 12 – Existing Alignment Alternative	**1300-1500 (2:00)**
Session 13 – Parking Lot and Closeout (Panel Only)	**1530-1630 (1:00)**

APPENDIX L

Denali National Park and Preserve

Denali Park Road - Polychrome Area Re-route

Value Analysis Recommendations Report

August 2020

Prepared by: DJ&A, P.C.

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AERIAL PHOTO

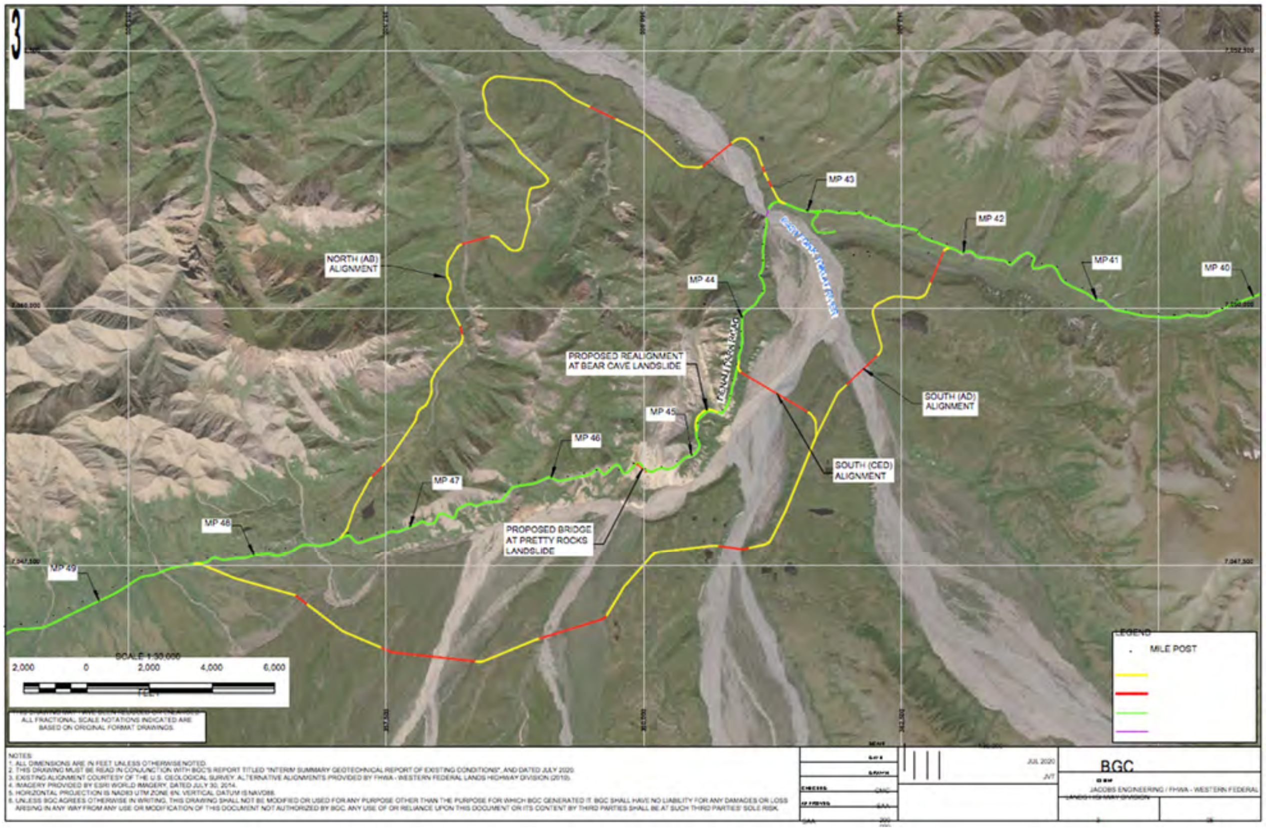

Figure 1: Aerial Photo showing Polychrome Area of the Denali Park Road

FOREWORD

This report presents the recommendations derived from the Value Analysis for the Polychrome Area Re-Route project at Denali National Park and Preserve. The Value Analysis was conducted on July 13-16, 2020.

This is to certify that the Value Analysis Study was led by the undersigned Value Analysis Facilitator and was conducted in accordance with National Park Service value analysis principles and guidelines.

Paul Schrooten
Value Analysis Facilitator

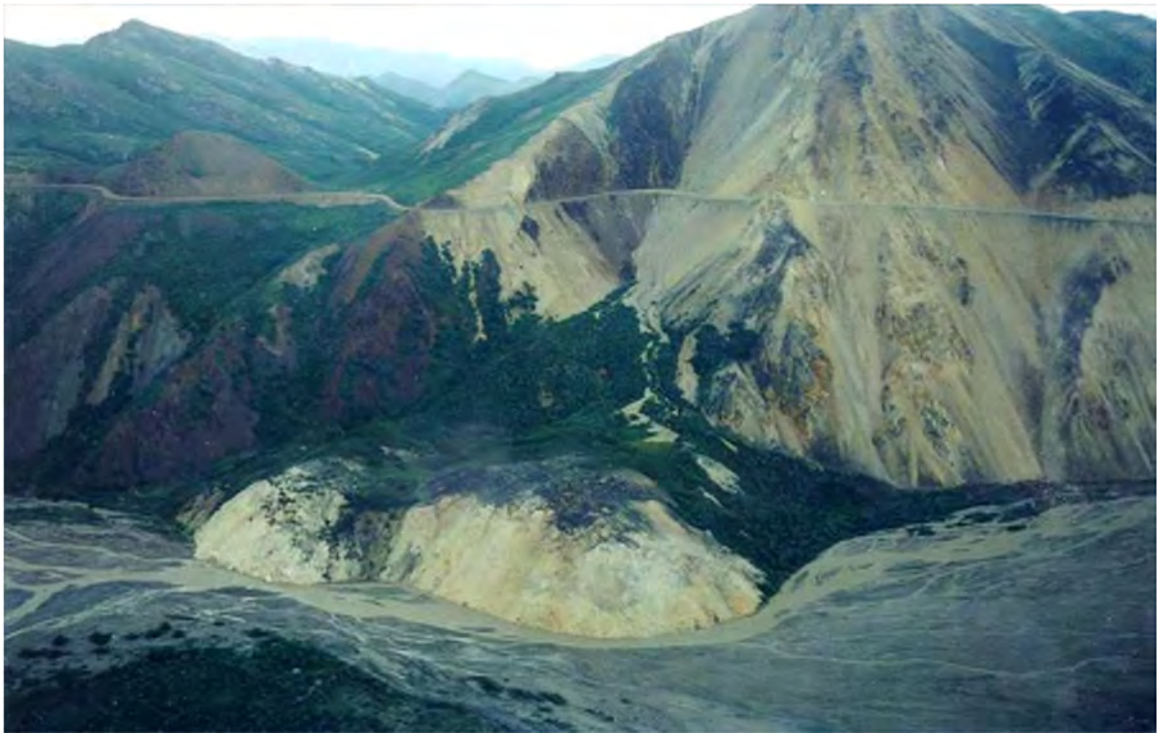

Figure 2: Pretty Rocks Landslide at MP 45.3 - Denali National Park and Preserve

SECTION A: EXECUTIVE SUMMARY

The National Park Service (NPS), in cooperation with the Federal Highway Administration (FHWA) – Western Federal Lands Highway Division (WFLHD) is developing a design solution in response to the ongoing landslides in the Polychrome area (MP 43.5) on the Denali Park Road.

This project will realign the park road to avoid unpredictable and unstable steep-slope conditions, some of which have been identified by WFLHD as severe and potentially harmful to employees and visitors. The project will provide reliable, lower-risk access while maintaining connectivity along the entire 93-mile road. It will also re-evaluate the minimum roadway width allowable per park road standards at this point on the road.

A value analysis study of the project was conducted on July 13-16, 2020 as a series of virtual sessions on Microsoft Teams.

Summary Description of Project

The park road between miles 42 and 49 spans a highly active landslide zone previously identified in the park's Unstable Slope Management Plan (USMP). The road provides crucial access to the Toklat Operations Center, Eielson Visitor Center, Wonder Lake Campground, and Kantishna historic mining district. Therefore, it is imperative that a satisfactory alternative is found to alleviate the repetitive short-term maintenance demands and the long-term uncertainty of a catastrophic road collapse in this area.

Depending upon the design selected, this project may also address sight distance concerns, which may requireadjustments to the horizontal and vertical road alignment. It may also require alteration of side slopes immediately to the south and west of the current East Fork Bridge (MP 43.3). Contradictory guidance between the Denali National Park and Preserve (DENA) Park Road Standards (2007) and the National Register of Historic Places nomination form may need to be resolved if alteration to side slopes is needed during or after construction.

Project costs include construction demolition and removal of existing road, construction of new bridge structure(s) designed to new seismic standards, drainage culverts, intervisible pullouts where necessary, stabilized cut and fill slopes, and stabilized subexcavation of the road profile to accommodate intermittent or continuous soil permafrost conditions.

The Polychrome area is an essential stretch along the only road into DENA's backcountry and Kantishna area businesses at the western end of the road. The road in this area was designed and constructed in the 1930's as a "highline" route that would provide spectacular views over the panorama of the Plains of Murie, across the Toklat River basin, and beyond to Mount Denali.

A 2017 WFLHD USMP evaluation of this section of the road identified several potential landslides that will likely continue to occur throughout the coming years. It further defined specific zones that are incrementally migrating down slope. Over the last few years, increasing movement of the uphill slope has caused a 300-foot section of road at Pretty Rocks (MP 45.4) to slip and drop vertically between 3 feet and 20 feet per year. The studies completed to date indicate that the long-term stability of this section of road is at serious risk, both now and into in the future.

An Expert-Based Risk Assessment (EBRA) for the project was completed on May 5-7, 2020 (Appendix C). The EBRA concluded that Option 3A or 3B (Toklat River floodplain alignments) is most likely to meet long-term performance objectives, as defined by the NPS.

The long-term performance objectives included:

1. Achieve resilient, low life cycle cost solution
2. Ensure opportunities through continuity of access
3. Hold cultural, aesthetic, and wilderness values intact

Recommendations for bridge maintenance included periodic removal of soil and debris from expansion joints, cleaning and painting of all bearings, spot painting beams and diaphragms, replacement of missing and bent anchor bolts, and repair of erosion to slopes in front of the abutments. Recommendations for road maintenance included ditch cleaning, vegetative management, aggregate surface replenishment, and prolonging culvert integrity through regular inspections and timely spring thawing.

The critical need for access provided by this road section combined with the high cost of continuing to maintain service justifies development of a sustainable design solution.

Project Schedule

The project schedule is as follows:

November 2020	Submittal to Development Advisory Board
August 2021	Construction Documents Submittal
May 2022	Construction Starts
October 2024 or later	Substantial Completion

Value Study Objectives

The general objectives of the value analysis study include:

- Use a structured and reasoned analysis to arrive at an optimal solution
- Meet all functional requirements of the roadway
- Confirm:
    - all viable options are considered
    - evaluation factors are sound
    - benefits to cost are considered
    - project review includes an independent second opinion
    - clear documentation of decision-making is provided
    - best solution/best value is achievable

Options Considered

Option 1: Mainline (Existing Alignment)

The mainline alignment calls for a bridge constructed over the active Pretty Rocks Landslide and a minor roadway shift, upslope and away from the retrogressing Bear Cave Landslide.

Option 2: Northern Alignment

This alignment reroutes Denali Park Road near the existing East Fork Toklat River Bridge site at MP 43, then westerly through approximately 6 miles of mountainous terrain, crossing rivers and several drainages.

Option 3A: Southern Alignment

This alignment begins just east of the existing East Fork Toklat River Bridge near MP 43. The road alignment then traverses a broad valley, known as the Plains of Murie, with wide floodplains, discontinuous permafrost, and muskeg. The road reconnects to the existing mainline road at MP 48.5.

Option 3B: Southern Alignment

This alignment begins west of the existing East Fork Toklat River Bridge at MP 44.3. The road alignment then traverses a broad valley, known as the Plains of Murie, with wide floodplains, discontinuous permafrost, and muskeg. The road reconnects to the existing mainline road at MP 48.5.

Summary of Recommendations

The Value Analysis team considered four different options representing a range of appropriate site solutions. These options were evaluated through the Choosing by Advantage (CBA) process. Using this process, the team recommends that **Option 1**--the mainline (existing) alignment--provides the greatest value to the project stakeholders. The VA team confirmed the efficiency and value of the proposed project. The team looked for significant savings and reduced disruption by examining how the work would be packaged to reduce mobilization costs and minimize disruption to park staff and visitors.

The advantages of the recommended option include the following:

- Provides the optimal recreational opportunities for visitors through 10-12 fewer years of construction and most likely to allow continued long-term access to the west end of the Park (paramount advantage).
- Prevents the greatest loss of cultural resources by maintaining almost all of the historic road alignment as well as all of the historic views.
- Prevents the greatest loss of natural and cultural resources by minimal extension into designated Wilderness and no new social trails.
- Prevents the greatest loss of natural resources with little to no effect on wolf denning sites, sheep migration during construction, the Sable wildlife closure zone, and riverine/wetland habitats.
- Improves the sustainability of park operations through the use of the least amount of aggregate for road construction and thereby eliminates the need for generating new aggregate source sites in designated Wilderness.
- Prevents the greatest limitation to park operations elsewhere in the park through 10-12 years less of increased construction traffic and no need for the use of new staging areas.
- Most closely meets the original aesthetic design intent of the road alignment.
- Improves recreational opportunities for visitors through no disturbance of backcountry experience.
- Prevents the greatest loss of paleontological features in the Cantwell and Usibelli formations.

- Improves the efficiency of park operations through fewer bridge inspections, minimal required maintenance, and easier snow removal due to good solar orientation.

Summary of Individual Recommendations

The VA team confirmed the efficiency and value of the proposed project using the CBA process. The team looked for significant savings and reduced disruption examining the method by which the work will be packaged to reduce mobilization costs and minimize disruption to park staff and visitors. The specific recommendations include:

- Further design and develop solutions to the Bear Cave area at mile 45.
- Build in additional contingencies for the entire section of road, prioritizing areas needing improvement, particularly with respect to traffic safety along the entire road corridor.
- Consider utilizing the Construction Manager/General Contractor (CM/GC) method of delivering the project whereby the client or project owner hires a Contractor to serve as the Construction Manager and provide feedback during the design phase and prior to construction in order to gain cost efficiencies and benefit of insight into practical execution.
- Consider extending spring construction further into the visitor season and commencing fall construction earlier, before the visitor season normally ends in order to complete the project in the planned two-year time frame.
- Consider new interpretive opportunities at this location to help describe the alteration to the road, its environment, and the conditions that led to the change in alignment.
- Incorporate structural and aesthetic bridge elements that are complementary to the cultural landscape and historic integrity where feasible and cost effective, following the Park CLR where possible.
- Attempt to re-use rock excavated from the Pretty Rocks area for other portions of the project and for future Park projects.
- Complete a Risk Management Plan prior to proceeding with any further planning or design to address the many high risks identified in the VA risk assessment (see checklist).
- Consult with the National Capitol Region regarding the Memorial Bridge in Washington, D.C. to gain insight and advice on public affairs regarding a large, complex project.
- Based on the successful application of the Microsoft HoleLens platform to provide 3D imagery of the project, invest in an animated visualization to better translate project issues and simulated design solution(s) for public information.

SECTION B: VALUE ANALYSIS

PHASE I – INFORMATION

Value Analysis Specifics and Objectives

The VA team consisted of staff from Denali National Park and Preserve (DENA), the Alaska Regional Office of the National Park Service (AKRO), the NPS Denver Service Center (DSC), and the Federal Highway Administration – Western Federal Lands Highway Division (WFLHD). A list of VA team participants is included on the following page.

The study team was composed of a mix of professional disciplines and individuals with experience in planning, compliance, cultural resources, geology, landscape architecture, bridge design, highway engineering, transportation construction management, facility operations, and road maintenance. Members of the park staff grounded the team with knowledge of the intricacies of operating and working on this site and members of WFLHD brought road and bridge expertise to the discussion. Some team members had experience working on prior VA studies as well as having completed Value Analysis training.

The specific value analysis objectives of this study included:

- Value enhancements including risk mitigation, quality/performance improvements, schedule/phasing coordination, etc.
- Improvements to the cost effectiveness of the project
- Creation of a higher level of confidence in the scope and implementation strategies for the project
- Identification of further opportunities for sustainability improvements

The team reviewed the design documents and budgetary cost estimates prepared by the project design team and the park as part of the workshop agenda (Appendix A).

Attendance List

Project: Denali Park Road - Polychrome Area Re-Route

Location: **Denali National Park and Preserve**
Date: **7/13/20 to 7/16/20**

PARTICIPANTS:

Name/ Title:	Job Function:	Organization/Address:	Phone/e-mail:
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Project Background

Denali National Park and Preserve is home to the tallest peak in North America, measuring 20,310 feet in elevation, and is the home to an abundance of wildlife. Tourism is the critical driver of the regional economy. In 2019, 601,000 people visited Denali National Park and Preserve and spent $613 million in the local region. That spending supported nearly 7,500 local jobs and had a cumulative benefit to the local economy of nearly $874 million, according to a National Park Service Report.

The existing alignment traverses a precipitous section of road known as Polychrome Pass. Built in the 1920s and 1930s as a scenic high-line route that overlooks the Plains of Murie, this section of road between MP 43 and MP 48 is approximately mid-way on the 92-mile long road. The Cultural Landscape Report outlines the importance of the park road (Appendix D). The roadway through Polychrome Pass is critical to the park as it is the only access to major viewing sites, campgrounds, and in holder-owned private land.

Figure 3: Denali Park Road at the Pretty Rocks Landslide

The Denali Park Road over Polychrome pass is vital and serves as the sole access road to the western regions of the park, including the town of Kantishna. Pretty Rocks Landslide (see photo above) impacts approximately 350 feet of the Denali Park Road near MP 45.3. While private vehicles are only allowed access up to MP 15, and on a very limited basis during road lottery in September each year from MP 15 to MP 93, professionally trained drivers provide access for the vast majority of visitors to the park between MP

15 and MP 92. The exception to general road access rules, between MP 15 and MP 92, is the private vehicles and commercial deliveries for Kantishna residents and lodges that use the Park Road to the Park Boundary (MP 89); where the road continues to MP 92, but is under the jurisdiction of the State of Alaska Department of Transportation and Public Facilities to the town of Kantishna.

The Pretty Rocks Landslide at MP 45.3 is one of several known (soil and rock) unstable slopes along the route. If road access at Pretty Rocks is cut off by landslide movement, road access in the park will no longer provide access to major attractions such as the Toklat Rest Stop, Stony Hill Overlook, Eielson Visitor Center, Wonder Lake Campground, and the historic mining town of Kantishna. Iconic, scenic views of the park would be inaccessible by road to park visitors should these sites become unreachable. Furthermore, a primary aggregate source and west end Park housing facilities would not be accessible by road at the Toklat Rest Area and Camp (MP 53).

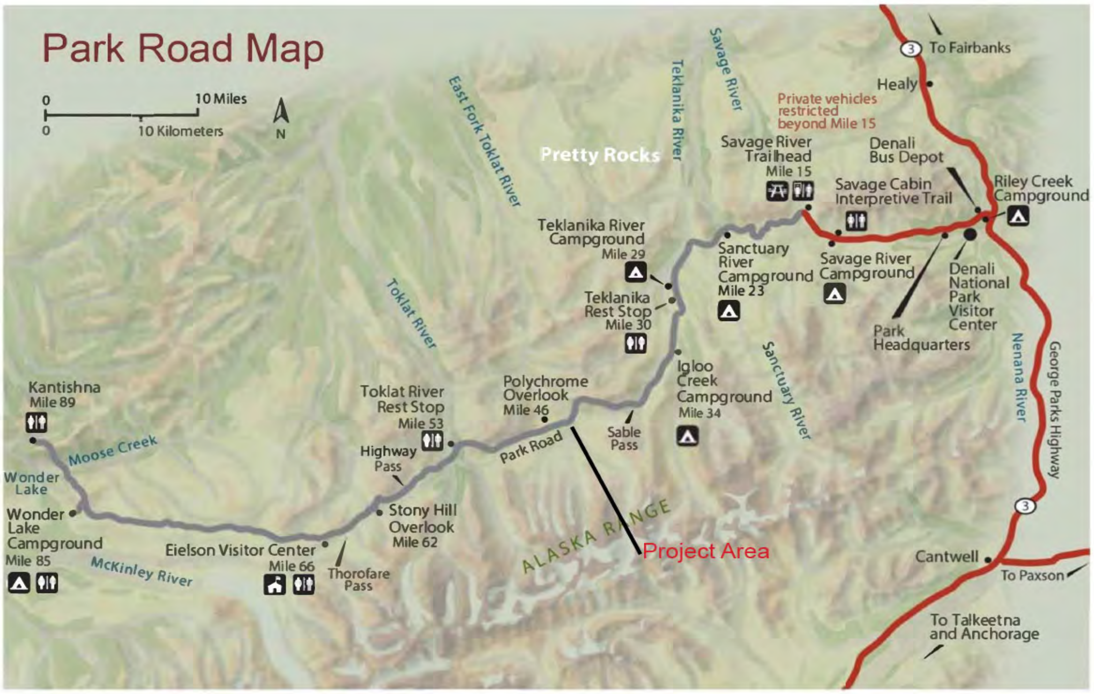


Figure 4: Park Map

Along the Denali Park Road are over 140 unstable slopes with varying degrees of operational impact potential. There are three locations of particular concern within the Polychrome Pass area: Bear Cave Landslide (Mile Post (MP) 44.8), Pretty Rocks Landslide (MP 45.3) and the Polychrome Rest Stop/Outlook area (MP 45.8 to 46.2). The Pretty Rocks Landslide's rate of movement has increased in recent years. In Spring 2018, the road movement was measured at approximately 0.2 to 0.3 inches per day and was difficult to maintain through the summer season by Park maintenance crews. From September 2018 to March 2019, road surface movement measurements had increased to 0.4 inches per day. Following record warm average temperatures in the summer of 2019 and monsoonal rain events in August 2019, the rate of road subsidence has increased significantly at the Pretty Rocks Landslide. From August 2019 to January 2020, landslide surface change measurements have been, on average, 2 inches per day.

Options Considered

The Value Analysis Team considered a project for re-routing the road in the Polychrome Pass area. To ensure that the accessibility is both safer and more sustainable for the long term, the NPS, with technical support from the WFLHD, evaluated four options for a more resilient roadway corridor between MP 43 and 48.3. These options, explained in this report, focus on roadway improvement in the Polychrome Pass area along this critical transportation corridor. The following figure shows a plan view of the options. Option 3A was altered after the initial concept was developed and the revised alignment is reflected in the Updated Options Location Map. Essentially, the route begins further east on the existing park road at Mile 42.2 instead of Mile 42.9

- Option 1: Mainline (Existing Alignment)
- Option 2: Northern route
- Option 3A: Southern route beginning just east of the existing East Fork Toklat River Bridge
- Option 3B: Southern route beginning to the west of the existing East Fork Toklat River Bridge

Figure 5: Options Location Map

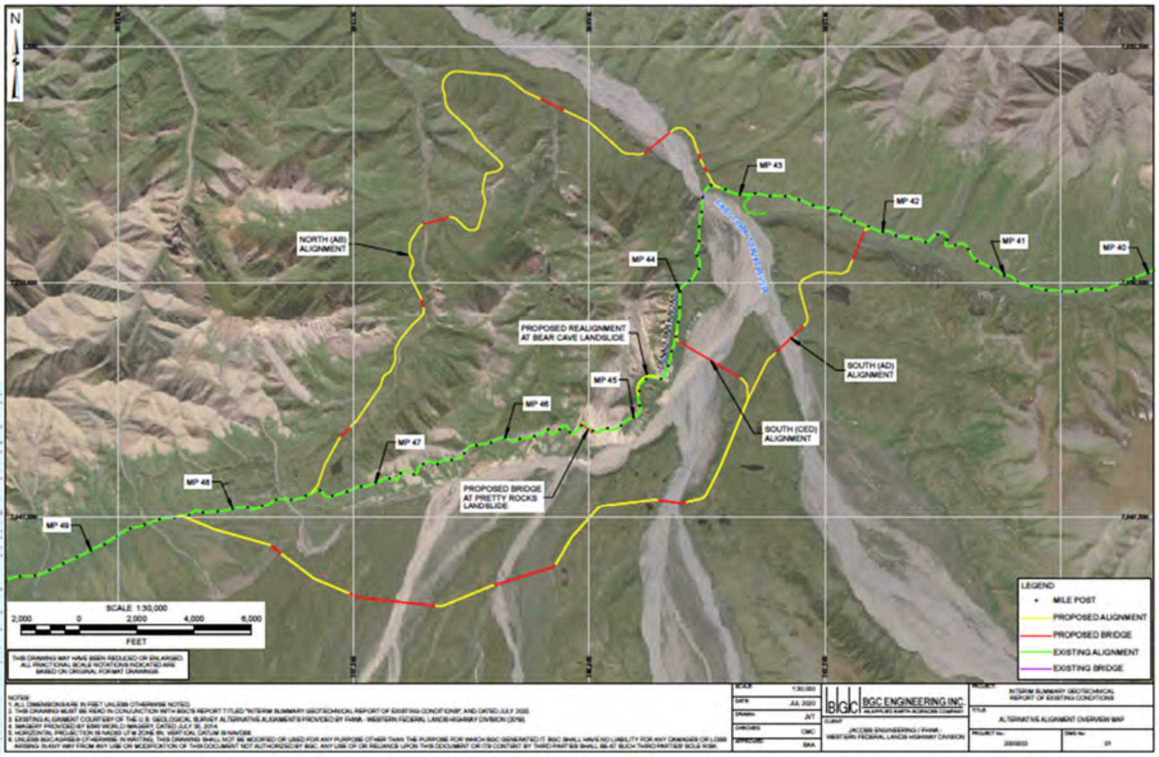


Figure 6: Updated Options Location Map

Option 1: Mainline (Existing Alignment)

The mainline alignment calls for a bridge constructed over the active Pretty Rocks Landslide and a minor roadway shift, upslope and away from the retrogressing Bear Cave Landslide. This work includes drainage improvements, and the improvement of several highly rated unstable slope sites along the existing Polychrome Pass road corridor that require slope scaling and reinforcement of loose rock and unsupported features. Several sites with highly rated (soil and rock) unstable slopes along this corridor are shown in red, per the following figure, and site-specific hazard and risks are detailed in the Denali National Park Unstable Slope Management Program (USMP). The bridging option is feasible and constructible but will have impacts due to temporary closures to existing road access in order to be completed in two construction seasons.

Figure 7: Option 1 - Mainline (Existing Alignment)

Option 2: Northern Alignment

This alignment reroutes Denali Park Road, near the existing East Fork Toklat River Bridge site at MP 43, then westerly through approximately 6 miles of mountainous terrain, crossing rivers and several drainages, and includes up to 8 bridges with spans ranging from 225 to 1,175 feet, with the largest bridge crossing the East Fork Toklat River. Option 2 roadway traverses large areas of discontinuous permafrost and landslide features with differing levels of observed activity and rejoins the road near MP 48.

Figure 8: Option 2 - Northern Alignment

Option 3A: Southern Alignment

Option 3A begins just east of the existing East Fork Toklat River bridge near MP 42, and is 6 miles in length. The road then traverses a broad valley, known as the Plains of Murie, with wide floodplains, discontinuous permafrost, and muskeg. Bridges will likely be required to bridge several active, braided river and stream channels. This option crosses large open drainage areas, which may require bridges between 450 and 3000 feet long.

Figure 9: Option 3 - Southern Alignment

Option 3B: Southern Alignment

Option 3B begins west of the existing East Fork Toklat River bridge at MP 44.3 (5.3 miles), per the following figure. The road then traverses a broad valley, known as the Plains of Murie, with wide floodplains, discontinuous permafrost, and muskeg. Bridges will likely be required to bridge several active, braided river and stream channels. This option crosses large open drainage areas, which may require bridges between 450 and 3000 feet long, with one of the longest ones crossing the East Fork Toklat River at the beginning of Option 3B at 2,500 feet-long.

Figure 10: Option 3B - Southern Alignment

Engineering Pro Forma for All Options

All four options assumed a 50-year life cycle cost (Appendix B).

Life cycle costs for all options include annualized costs for maintenance and repairs assume typical park maintenance practices.

Stakeholders

In an effort to understand the context for this project, the following list of "stakeholders", or persons with an active interest in project decisions and outcomes is provided:

#	Stakeholders	Primary Interest
1	Visitors • Independent Traveler • Package Tours • Local Users	• Visual Experience and Quality o Reliable Quality Experience
2	Congressional Delegations	• Local Economy • Project Cost • Public Access
3	Environmental Community	• Protection of Resources – Wilderness • Incremental Impact of Development
4	EPA	• Regulatory Compliance
5	State Government (DEC, DOT)	• Regulatory Compliance • Regional Economy • Local Economy
6	National Park Service • Servicewide • Park o Management o Fire Management o Law Enforcement o Dispatch o Maintenance o Operations o Natural Resources o Cultural Resources o Visitor Services/Concession • Alaska Regional Office o Planning Design and o Maintenance o Procurement	• Protection of Resources • Employee Health, Safety and Welfare • Efficiency of Park Operations • Project Cost • Quality of Life • Deferred Maintenance • Project Management • Contracting • Environmental/Geohazard
7	• Business Partners o Vendors o Contractors o Alaska Geographic o In-holders	• Ease of Access • Traffic Circulation • Safety • Construction Staging Areas • Local Economy/Business Viability
8	• Others?	

Risk Model

ELEMENTS	RISK AREAS	N/A	LOW	MEDIUM	HIGH
A. MANAGEMENT, FINANCIAL & ADMINISTRATIVE RISKS					
	Changing government regulations (bridge inspection requirements)		x		
	Public and political perspectives (conservation community concerns)				x
	Budget limitations, approvals process, & other constraints				x
	Budget sequencing			x	
	Permitting delays				x
	Agency jurisdictions and conflicts	x			
	Project mgt., organ., decision-making processes, info. flow (see below)			x	
	Labor issues		x		
	Other: park staff workload; stakeholders			x	
B. ENVIRONMENTAL & GEOTECHNICAL RISKS					
	Inclement weather, storms, floods			x	
	Unanticipated hazardous waste		x		
	Environ. restrictions (air quality, noise, toxic mat., etc.)			x	
	Environmental Assessment schedule/decision				x
	Contaminated soils remediation		x		
	Weed-free gravel acquisition (assume local source)			x	
	Groundwater remediation		x		
	Frozen ground construction				x
	Inadequate subgrade testing			x	
	Unanticipated archaeological or historical findings		x		
	Wildlife Closures (nesting/moose)			x	
	Wetlands				x
	Backcountry zoning		x		
	Other: Catastrophic event road closure (landslide)				x
C. TECHNICAL RISKS					
	Systems, processes, and material			x	
	New, unproven systems, processes and materials			x	
	Other:				
D. IMPLEMENTATION RISKS					
1. Design	Design approvals and changes by park management			x	
	Design errors and omissions (inadequate as-builts)		x		
	Untested and unproven design features and innovations			x	
	Insufficient design contingencies			x	
	Other:				
2. Contractor					
	Availability of qualified contractors or skills (competitive environment)			x	
	Construction material requirements			x	
	Inadequate or unclear specs for mat'ls & workmanship		x		

ELEMENTS	RISK AREAS	N/A	LOW	MEDIUM	HIGH
	Labor negotiations/work stoppages		x		
	Operator training/certification		x		
	Management of subcontracts (shortage of subcontractors)			x	
	Low construction contingency				x
	Cost impact of SBA contracting			x	
	Bidding climate			x	
	Other: Familiarity with NPS, design rqmts, site, etc.			x	
3. Change Orders					
	Design Changes			x	
	Field Changes, owner directed			x	
	Other: differing site conditions				x
4. Equipment & Materials					
	Availability:			x	
	Rejects, defects (items shipped)		x		
	Malfunctions or failures		x		
	Other:				
5. Project Controls					
	Planning: scope evolution			x	
	Scheduling (future funding uncertainties)				x
	Accuracy of Estimating (SD, DD, CD)			x	
	Other:				
6. Logistics, Transportation					
	Laydown areas limitations				x
	Traffic congestion at site or access to site (conflicts w/ local users)				x
	Transportation difficulties for construction mat'ls (deliveries)				x
	Other: Scheduling while keeping road open				x
7. Interference and Maintenance of Services					
	Interference with other work (Other road or park projects)				x
	Maintenance of certain essential services during const.				x
	Tie-ins/cutovers with utilities		x		
	Other: impact on visitor services				x
8. Condition of Existing Road Corridor (for renovation, rehab. repair projects)					
	Condition of existing road profile and material				x
	Tie-ins			x	
	Removals or restoration			x	
9. Safety and Hazards During Construction					
	Safety to contractor personnel				x
	Safety to owner and non-project personnel				x
	Other:				

ELEMENTS	RISK AREAS	N/A	LOW	MEDIUM	HIGH
10. Process Start-up & Commissioning					
	Testings and test planning and scheduling	X			
	Malfunctions and failures	X			
	Inadequate documentation and/or training	X			
	Adequacy of operating budget	X			
	Other				

Cost Projections

A projection summarizing the costs associated with the four options was prepared focusing on the major elements of the design. This allowed the study team to identify and evaluate the major cost components contributing to each option. These cost estimates follow below;

Option 1: Mainline Alignment

Component Cost Model
Denali Park Road - Polychrome Area Re-Route
Denali National Park and Preserve
Budget Estimates

	Component:	**Total**	**PCT**
	Option 1 Mainline Alignment		
1	Mobilization	$4,864,000	9.5%
2	Clearing & Grubbing	$12,600	0.0%
3	Roadway Excavation	$4,380,000	8.6%
4	Unclassified Borrow	$980,000	1.9%
5	Select Borrow	$238,500	0.5%
6	Separation-Stabilization Geotextile, Class 1, Type C	$30,200	0.1%
7	Polystyrene Foam, Type V	$307,500	0.6%
8	Roadway Aggregate, Method 2	$105,600	0.2%
9	Structures	$15,400,000	30.2%
10	Geotechnical	$4,038,000	7.9%
11	Temporary Traffic Control	$3,059,100	6.0%
12	Permanent Traffic Control	$764,800	1.5%
13	Soil Erosion Control	$1,274,700	2.5%
14	Drainage	$2,549,300	5.0%
15	Re-vegetation	$382,400	0.7%
16	Construction Scheduling	$382,400	0.7%
17	Contractor QC/QA and Testing	$1,274,700	2.5%
18	Survey and Staking	$255,000	0.5%
19	20% Contingency	$5,098,500	10.0%
20	Inflation (3%/year for 4 years)	$5,668,700	11.1%
	Total	***$51,066,000***	*100.0%*

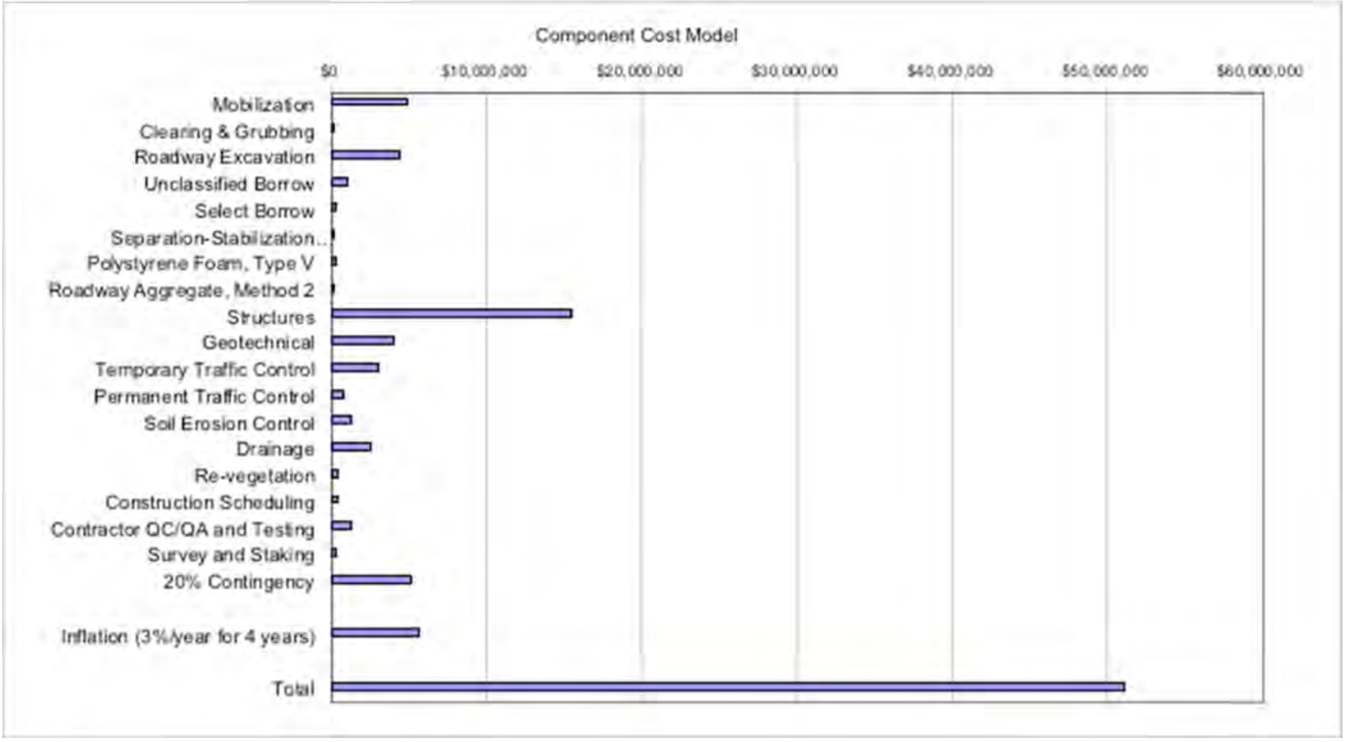


Figure 11: Component Cost Model – Option 1

Option 2: Northern Alignment

Component Cost Model
Denali Park Road - Polychrome Area Re-Route
Denali National Park and Preserve
Budget Estimates

	Component:	**Total**	**PCT**
	Option 2 Northern Alignment		
1	Mobilization	$15,063,000	9.5%
2	Clearing & Grubbing	$628,900	0.4%
3	Roadway Excavation	$109,000	0.1%
4	Unclassified Borrow	$29,084,000	18.4%
5	Select Borrow	$2,620,700	1.7%
6	Separation-Stabilization Geotextile, Class 1, Type C	$321,600	0.2%
7	Polystyrene Foam, Type V	$3,265,900	2.1%
8	Roadway Aggregate, Method 2	$1,266,300	0.8%
9	Structures	$49,872,000	31.5%
10	Geotechnical	$0	0.0%
11	Temporary Traffic Control	$2,615,100	1.7%
12	Permanent Traffic Control	$2,615,100	1.7%
13	Soil Erosion Control	$4,358,500	2.8%
14	Drainage	$3,486,800	2.2%
15	Re-vegetation	$1,307,600	0.8%
16	Construction Scheduling	$1,307,600	0.8%
17	Contractor QC/QA and Testing	$4,358,500	2.8%
18	Survey and Staking	$871,700	0.6%
19	20% Contingency	$17,433,700	11.0%
20	Inflation (3%/year for 4 years)	$17,554,000	11.1%
	Total	***$158,140,000***	*100.0%*

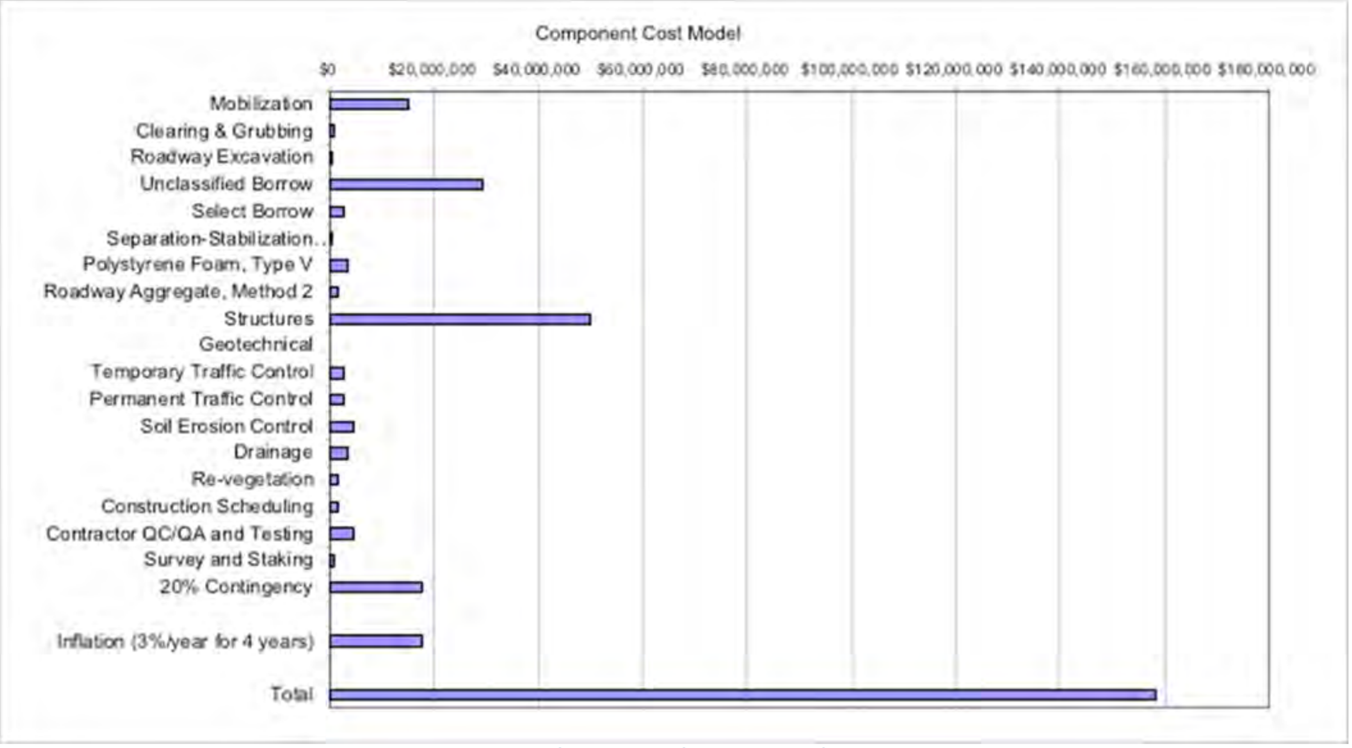


Figure 12: Component Cost Model – Option 2

Option 3A: Southern Alignment

Component Cost Model
Denali Park Road - Polychrome Area Re-Route
Denali National Park and Preserve
Budget Estimates

	Component:	Total	PCT
	Option 3A Southern Alignment East of East Fork River		
1	Mobilization	$21,073,000	9.5%
2	Clearing & Grubbing	$712,400	0.3%
3	Roadway Excavation	$3,440,000	1.6%
4	Unclassified Borrow	$14,108,000	6.4%
5	Select Borrow	$2,946,800	1.3%
6	Separation-Stabilization Geotextile, Class 1, Type C	$325,900	0.1%
7	Polystyrene Foam, Type V	$3,242,900	1.5%
8	Roadway Aggregate, Method 2	$1,101,300	0.5%
9	Structures	$96,072,000	43.4%
10	Geotechnical	$0	0.0%
11	Temporary Traffic Control	$3,658,500	1.7%
12	Permanent Traffic Control	$3,658,500	1.7%
13	Soil Erosion Control	$6,097,500	2.8%
14	Drainage	$4,878,000	2.2%
15	Re-vegetation	$1,829,300	0.8%
16	Construction Scheduling	$1,829,300	0.8%
17	Contractor QC/QA and Testing	$6,097,500	2.8%
18	Survey and Staking	$1,219,500	0.6%
19	20% Contingency	$24,389,900	11.0%
20	Inflation (3%/year for 4 years)	$24,558,700	11.1%
	Total	***$221,239,000***	*100.0%*

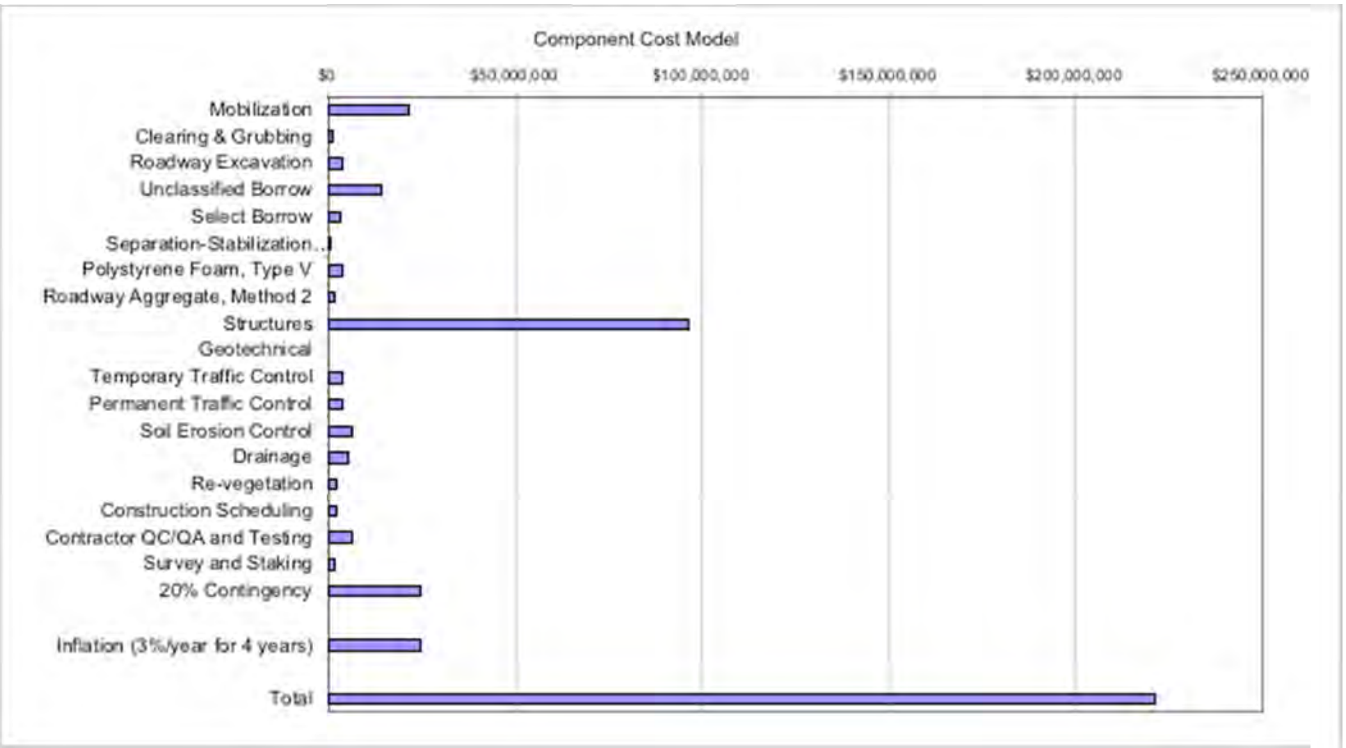


Figure 13: Component Cost Model – Option 3A

Option 3A: Southern Alignment

Component Cost Model
Denali Park Road - Polychrome Area Re-Route
Denali National Park and Preserve
Budget Estimates

	Component:	**Total**	**PCT**
	Option 3B Southern Alignment West of East Fork River		
1	Mobilization	$21,524,000	9.5%
2	Clearing & Grubbing	$426,000	0.2%
3	Roadway Excavation	$13,200	0.0%
4	Unclassified Borrow	$8,364,000	3.7%
5	Select Borrow	$2,396,000	1.1%
6	Separation-Stabilization Geotextile, Class 1, Type C	$255,600	0.1%
7	Polystyrene Foam, Type V	$2,525,700	1.1%
8	Roadway Aggregate, Method 2	$857,700	0.4%
9	Structures	$109,728,000	48.6%
10	Geotechnical	$0	0.0%
11	Temporary Traffic Control	$3,736,900	1.7%
12	Permanent Traffic Control	$3,736,900	1.7%
13	Soil Erosion Control	$6,228,100	2.8%
14	Drainage	$4,982,500	2.2%
15	Re-vegetation	$1,868,500	0.8%
16	Construction Scheduling	$1,868,500	0.8%
17	Contractor QC/QA and Testing	$6,228,100	2.8%
18	Survey and Staking	$1,245,700	0.6%
19	20% Contingency	$24,912,200	11.0%
20	Inflation (3%/year for 4 years)	$25,079,400	11.1%
	Total	***$225,977,000***	*100.0%*

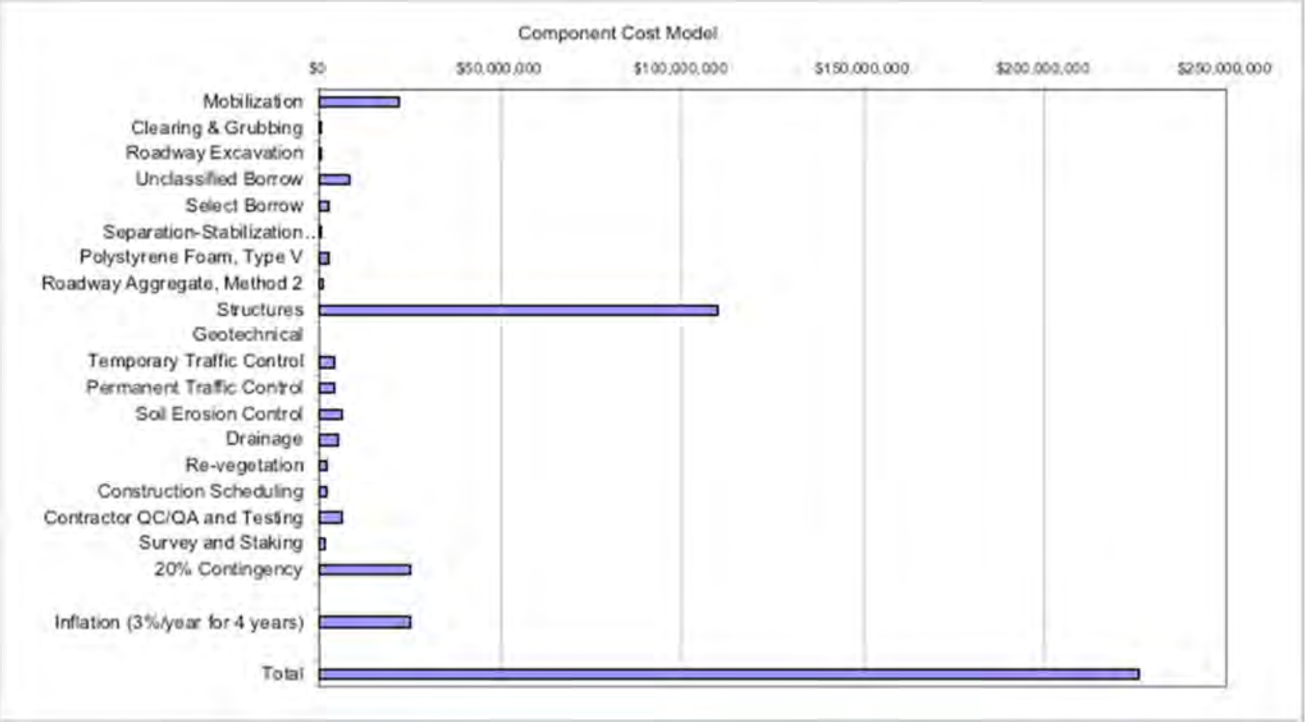


Figure 14: Figure 15: Component Cost Model – Option 3B

PHASE II – FORCE FIELD ANALYSIS/CREATIVITY

The value study team examined the four options, evaluated the strongest and weakest features and developed proposals for improving the designs. The strongest features were identified so that they could be retained or incorporated into other options. The weakest features were identified so that they could be improved. The findings are summarized on the following pages.

Figure 16: Aerial view of the Pretty Rocks Landslide area on the Denali Park Road from November 5, 2019 (Williams, 2019)

VALUE OPPORTUNITIES
Force Field Analysis

Denali Park Road - Polychrome Area Re-Route
Denali National Park and Preserve
Option 1 Maintain Alignment

Best Features	Worst Features
1. Maximizes use of existing road alignment	1. Bridge location requires considerable slope alteration
2. Preserving the cultural/historical character	2. Width/narrowing could be unnerving
3. Least impactful to cultural resources	3. Potential for failing at bear cave and others not addressed
4. Hazards are more well known	4. Major changes/excavation to Polychrome area
5. Preserve visitor enjoyment from Polychrome Overlook	5. Most short-term/moderate impact to traffic of all alignments
6. Iconic Polychrome view	6. Potential for long-term heavy impact to traffic for bridge construction
7. Minimal additional impact	7. Truss bridge type does not match ex/historic park character
8. Least impactful to wilderness character	8. Bear Cave has no easy solution
9. Shortest projected period of construction	9. Ex conditions of alignment are substandard (site distance, critical width)
10. Lowest projected cost	10. Interruptions could result in longer closures
11. Least impactful to natural resources	
12. Risk is concentrated to one location (Bear Cave)	

Ideas for Value Enhancement
1. Customize bridge appearance (materials, paint scheme) to emulate cultural resource values
2. The treatment at Bear Cave could enhance this option through innovative techniques
3. Opportunities for interpretation to describe landscape/natural environment/story
4. Can the alignment be enhanced to address additional concerns/undercutting of the road at the west end
5. Chose materials that blend in to the native environment

VALUE OPPORTUNITIES
Force Field Analysis

Denali Park Road - Polychrome Area Re-Route
Denali National Park and Preserve
Option 2 Northern Alignment

Best Features	Worst Features
1. Offers new viewshed opportunities previously unseen	1. Considerable soil and slope challenges
2. Preserves the Polychrome viewscape for non-vehicular use	2. Unknown impacts to cultural resources (has not been surveyed)
3. Limited impact to traveling public	3. Considerable wetland/natural resource impacts
4. Improved/new visitor experience	4. Considerable impact to wilderness and wilderness character
5. Opportunity for maintaining use of historic alignment	5. High cost
6. Earthwork sections use latest 2020 technology for permafrost	6. Long construction time
7. Road crosses slide at lower angle	7. Will need to continue to keep mainline operable during construction (need interim solution)
8. Opportunity for construction challenges to be addressed without visitor interruptions	8. Less southern exposure, prolonged melt/runoff concerns, harder to dry out road
	9. Potential/real landslide concerns for maintenance/long term closure
	10. Road crosses slide at toe (more active)
	11. Change order potential high due to unknown conditions
	12. Potential for increased maintenance
	13. Adverse impact to park road's historic district
	14. Shorter open season for traffic

Ideas for Value Enhancement
1. Narrow road with intervisible turnouts (key viewpoints/interpretive)
2. Substantial opportunity to make beautiful roadway
3. Mitigation of landslide features
4. Use existing alignment for alternative uses (hiker-biker, vehicle restricted) with maintenance
5. Opportunities for interpretation to describe landscape/natural environment/story
6. Ability to build road in line with design standards
7. Potential ability to maintain Polychrome as spur access on west side of pass (with maintenance)

VALUE OPPORTUNITIES

Force Field Analysis

Denali Park Road - Polychrome Area Re-Route
Denali National Park and Preserve
Option 3A Southern Alignment East of the East Fork River

Best Features	Worst Features
1. Eliminates most known landslide areas	1. Exposes new section of road to flood events
2. Southerly exposure potentially increases season to public	2. Takes out existing bridge prematurely
3. Less snow maintenance	3. Impact view from Polychrome if route is maintained
4. More consistency in exposure	4. Considerable impact to cultural resources
5. Reduces "fear factor" when passing/traveling on road	5. Considerable impact to wetland/natural resources
6. Less safety hazard/better access for emergencies	6. Considerable impact to wilderness area
7. New viewscape	7. Impact to Sable Pass Wildlife Closure
8. Reduces landslide impacts	8. Adverse impact to park road historic district
9. Less likely that bridge will fail than road be impacted by slides	9. High confidence of ice rich permafrost, long-term maintenance required
10. Access to ex algn would be maintained during construction	10. Most visually impactful, series of engineered structures
	11. Least sinuous/landscape sensitive design, does not match design guidelines
	12. Long term maintenance will be high (floodplain)
	13. Significant impact to historic/treasured viewscape
	14. Settlement and drainage problems along length of road
	15. High cost
	16. Long construction time

Ideas for Value Enhancement
1. Moderate bridge spans to balance hydrological functions with less structure
2. Design to be more in-line with historic design guidance
3. Opportunity to reduce width of bridge, one-lane bridge for shorter spans

VALUE OPPORTUNITIES
Force Field Analysis

Denali Park Road - Polychrome Area Re-Route
Denali National Park and Preserve
Option 3B Southern Alignment West of East Fork River

Best Features	Worst Features
1. New view from high bridge	4. Crosses critical area where river bends to cross under existing bridge
5. Eliminates most known landslide areas	6. Exposes new section of road to flood events
7. Southerly exposure potentially increases season to public	8. Impact view from Polychrome if route is maintained
9. Less snow maintenance	10. Considerable impact to cultural resources
11. More consistancy in exposure	12. Considerable impact to wetland/natural resources
13. Reduces "fear factor" when passing/traveling on road	14. Considerable impact to wilderness area
15. Less safety hazard/better access for emergencies	16. Adverse impact to park road historic district
17. New viewscape	18. High confidence of ice rich permafrost, long-term maintenance required
19. Reduces landslide impacts	20. Most visually impactful, series of engineered structures
21. Less likely that bridge will fail than road be impacted by slides	22. Least sinuous/landscape sensative design, does not match design guidelines
23. Access to ex algn would be maintained during construction	24. Long term maintenance will be high (floodplain)
25. Maintains more of existing alignment for a little longer	26. Significant impact to historic/treasured viewscape
27. Maintains a portion of the existing cultural resource	28. Settlement and drainage problems along length of road
	29. High cost
	30. Long construction time
	31. New bridge will be right in the middle of viewscape
	32. More rockfall issues when compared to 3A

Ideas for Value Enhancement
4. Create one land bridges with optimal sight distance
5. Moderate bridge spans to balance hydrological functions with less structure
6. Design to be more in-line with historic design guidance
7. Ability to make high bridge less intrusive/lower
8. Opportunity to reduce width of bridge, one-lane bridge for shorter spans

PHASE III - EVALUATION (Part 1 - Evaluation Factors)

As the first task of the evaluation phase, the VA Team developed and discussed the factors against which the criteria would be evaluated.

The NPS Factors 1-5, shown below, were established for the NPS servicewide priority setting process and are derived from NPS National Leadership Council guidance. These Factors formed a framework for evaluation.

The team defined specific project considerations and subfactors to tailor the evaluation factors to the needs of this project.

Factor 1: Provide Safe Visits and Working Conditions for Vehicles and Pedestrians

Advantages in Protecting *Public* Health, Safety and Welfare
Advantages in Protecting *Employee* Health, Safety and Welfare

Subfactor 1A: *Protecting Public and Employee Health, Safety and Welfare by Providing Vehicular and Pedestrian Access*

- Adequate Passing Width
- Optimal Sight Distance

Subfactor 1B: *Protecting Public and Employee Health, Safety and Welfare by Providing Vehicular and Pedestrian Access*

- Eliminate or Manage Steep, Severe Slopes

Factor 2: Protect Natural and Cultural Resources

Advantages in Protection of or Preventing the Loss of Resources

Subfactor 2A: *Preventing the Loss of Natural Resources by*

- Effect on Wolf Denning Sites
- Effect on Sheep Gap (Timing of Migration)
- Effect on Sable Area Wildlife Closure
- Effect on Sensitive Wildlife Species
- Effect on Riverine, Alpine and Wetland Environments

Subfactor 2B: *Preventing the Loss of Cultural Resources by*

- Effect on Cultural Resources
- Effect on Park Road Historic District and Cultural Landscape

Subfactor 2C: *Preventing the Loss of Natural and Cultural Resources by*

- Minimizing Disturbance of Paleontological Features

Subfactor 2D: *Preventing the Loss of Natural and Cultural Resources by*

- Avoiding Designated Wilderness
- Avoiding New Social Trails

Factor 3: Improve Visitor Enjoyment through Better Service and Educational and Recreational Opportunities

Advantages in Improving Visitor Enjoyment through Better Service and Educational and Recreational Opportunities

Subfactor 3A: *Maintaining or Improving Visitor Services Through*
- Reliable and Resilient Vehicular and Pedestrian Access

Subfactor 3B: *Not used*

Subfactor 3C: *Improving Recreational Opportunities for Visitors Through*
- Creating New Recreational Opportunities

Subfactor 3D: *Improving Recreational Opportunities for Visitors Through*
- Avoidance of Disturbing Backcountry Experience

Subfactor 3E: *Improving Recreational Opportunities for Visitors Through*
- Minimizing the Number of Seasons of Construction
- Minimizing Visibility of Construction to Visitors
- Minimizing Potential Impact to West Access

Factor 4: Improve the Efficiency, Reliability and Sustainability of Park Operations

Advantages in Improving the Efficiency, Reliability and Sustainability of Park Operations

Subfactor 4A: *Improving Efficiency of Park Operations Through*
- Ease of Spring Road Opening
- Extent and Frequency of Inspections

Subfactor 4B: *Not used*

Subfactor 4C: *Improving Sustainability of Park Operations Through*
- Use of Available Materials Within the Park
- Use of Renewable Resources

Subfactor 4D: *Preventing Limitation of Park Operations Elsewhere in the Park Through*
- Minimizing Construction Traffic

Factor 5: Provide Cost-Effective, Environmentally Responsible and Otherwise Beneficial Development to the National Park System

Advantages in Providing Cost-Effective, Environmentally Responsible and Otherwise Beneficial Development to the National Park System

Subfactor 5: *Providing Cost-Effective, Environmentally Responsible and Otherwise Beneficial Development to the National Park System Through*
- Adherence to Original Aesthetic Design Intent

PHASE III - EVALUATION (PART 2 - CHOOSING BY ADVANTAGES)

After identifying the best and worst features of each of the options and rating them against the evaluation factors, it was determined that all four options were viable.

The options were further evaluated using a process called Choosing by Advantages, whereby decisions are based on the importance of advantages between options. The evaluation involves the identification of the attributes or characteristics of each option relative to the evaluation criteria, a determination of the advantages for each option within each evaluation factor, and the weighing of importance of each advantage.

The highest importance advantage is identified in each factor. The paramount advantage, across factors, was determined and assigned a weight of 100. Remaining advantages were rated on the same scale. Rough cost estimates (Class C) were developed for each option. Recommendations are then based on a balance of cost and importance.

The evaluation forms the basis for comparing the location options. The evaluation tables present many types of information. Attributes of an option are shown above the dotted line in the tables. Advantages between options are shown below the dotted line. An anchor statement summarizes those advantages. The advantage with the highest importance within a factor is indicated by bolding the text in the advantage cell. The advantages are all rated on a common scale.

Choosing By Advantages

Project/Location: **Denali Park Road - Polychrome Area Re-Route**
Component: **Site**
Function: **Denali Park Road Connection at MP 43-48**

Factor	**Option 1** Mainline Alignment with New Bridge at Pretty Rocks		**Option 2** Northern Alignment		**Option 3A** Beginning just east of existing East Fork Toklat River bridge near MP 43		**Option 3B** Beginning just west of existing East Fork Toklat River bridge near MP 43	
Provide Safe Visits and Working Conditions for Vehicles and Pedestrians								
Subfactor 1A: *Protecting Public and Employee Health, Safety and Welfare by Providing Vehicular and Pedestrian Access through* • **Adequate Passing Width** • **Optimal Sight Distance**								
Attributes:	**2675 lf of road (9%) with adequate passing width with the entire length having intervisible pullouts, numerous road points with short sight distance**		27700 lf of road (88%) with adequate passing width, some road points with short sight distance		31498 lf of road (99%) with adequate passing width, very few road points with short sight distance		31831 lf of road (99%) with adequate passing width (first mile past east fork bridge may not be of adequate passing width), very few road points with short sight distance	
Advantages:		**0**	**25025 LF (79%) more passing width, fewer road points with short sight distance than option 1**	**30**	**28823 LF (90%) more passing width, considerably fewer road points with short sight distance than option 1**	**48**	**29156 LF (90%)more passing width, considerably fewer road points with short sight distance with some question as to the first mile which would include intervisible pullouts, than option 1**	**34**
Provide Safe Visits and Working Conditions for Vehicles and Pedestrians								
Subfactor 1B: *Protecting Public and Employee Health, Safety and Welfare by Providing Vehicular and Pedestrian Access* • **Eliminate or Manage Steep, Severe Side Slopes**								
Attributes:	4747 LF (17%) of steep or severe side slope		11500 LF (30%) of steep or severe side slope		6001 LF (19%) of steep or severe side slope		4709 LF (17%) of steep or severe side slope	
Advantages:	6753 LF (13%) less steep and severe side slopes than option 2	**82**		**0**	5499 LF (11%) less steep and severe side slopes than option 2	**71**	**6791 LF less (13%) less steep and severe side slopes than option 2**	**82**
Protect Natural and Cultural Resources								
Subfactor 2A: *Preventing the Loss of Natural Resources by* • **Effect on Denning sites** • **Effect on sheep gap** • **Effect on Sable wildlife closure** • **Effect on sensitive wildlife species** • **Effect on riverine, alpine and wetland environments**								
Attributes:	No additional effect on denning, sheep, Sable, impact on sheep during Spring construction, some alpine habitat loss, no impact to Sable wildlife closure		No expected impact on denning, significant sheep impact during all seasons of construction and especially in the Spring, alpine and wetland habitat losses and impacts, no impact to Sable wildlife closure		Potential significant denning impact (construction and operation), improvement in sheep migration, disturbance to wolves, extensive riverine/wetland impacts, reduction in alpine habitat, some impact to the Sable wildlife closure		Less significant impact to denning, disturbance to wolves, reduction in function of sheep gap during construction, extensive riverine/wetland/alpine impacts, reduction in alpine habitat, no impact to Sable wildlife closure	
Advantages:	**Little to no effect compared to option 2**	**91**		**0**	Greater disturbance to denning and wolves, improved sheep habitat, some impact to Sable Wildlife closure	**6**	In comparison to option 2, slightly more impact to denning but more impact to wolves, improved sheep habitat	**15**
Subfactor 2B: *Preventing the Loss of Cultural Resources by* • **Effect cultural resources** • **Effect on park road historic district / cultural landscape**								
Attributes:	Adds an incompatible feature to the historic district and preserves historic alignment and viewscape, no other cultural resources affected		Does not preserve historic alignment but preserves opportunity for historic viewscape, potential for many other cultural resources to be affected		Does not preserve historic alignment, does not preserve historic viewscape, will affect two archeology sites, potential for many other cultural resources to be affected		Preserves some historic alignment and does not preserve historic viewscape, impacts views from other sections of the park road, will affect two archeology sites, potential for many other cultural resources to be affected	
Advantages:	**Maintains almost all of the historic alignment, has the least impact on cultural resources, and retains the existing historic views, least impactful to the park road historic views**	**94**	Doesn't maintain any of the historic alignment, high potential for impact to other cultural resources, retains the potential for existing historic views	**24**	Doesn't maintain any of the historic alignment, high potential for impact to other cultural resources, high impact to the existing historic views	**4**		**0**

Choosing By Advantages

Project/Location: **Denali Park Road - Polychrome Area Re-Route**
Component: **Site**
Function: **Denali Park Road Connection at MP 43-48**

Subfactor 2C: *Preventing the Loss of Natural and Cultural Resources by* **• Minimizing disturbance of paleontological features**								
Attributes:	No new impacts, known existing impacts		2.5 miles of impacts to Cantwell formation (known to contain abundant fossils)		0.2 miles of impacts to Usibelli group of formations, 0.5 miles of impacts to Cantwell formation		0.5 miles of impacts to Cantwell formation	
Advantages:	**2.5 miles less impact to the Cantwell formation, no impact to Usibelli group formations**	**65**		**0**	2.0 miles less impact to the Cantwell formation but still impact to Usibelli group	**18**	2.0 miles less impact to the Cantwell formation, no impact to Usibelli group formations	**23**
Subfactor 2D: *Preventing the Loss of Natural and Cultural Resources by* **• Avoiding designated wilderness** **• Avoiding new social trails**								
Attributes:	Project limits extend into designated wilderness at the west end of the proposed bridge and Bear Cave (45 ac), no new opportunities for social trails		Project limits extend almost entirely into designated wilderness (747 ac), opportunities for social trails		Project limits extend almost entirely into designated wilderness (830 ac), opportunities for social trails		Project limits extend mostly into designated wilderness (783 ac), opportunities for social trails	
Advantages:	**Extends into wilderness 785 ac less than option 3A, no new social trails**	**92**	Extends into wilderness 83 ac less than option 3A, potential for extensive social trails on generally less durable surfaces	**5**		**0**	Extends into wilderness 47 ac less than option 3A, potential for extensive social trails but on more durable surfaces	**9**
Improve Visitor Enjoyment Through Better Service and Educational and Recreational Opportunities								
Subfactor 3A: *Maintaining or Improving Visitor Services Through* **• Reliable and resilient vehicular and pedestrian access**								
Attributes:	An expectation that exceptional maintenance will be required is about 34%, the delay in seasonal road opening is 50%, that long term road closure will be 5%		An expectation that exceptional maintenance will be required is about 56%, the delay in seasonal road opening is 94%, that long term road closure will be 27%		An expectation that exceptional maintenance will be required is about 35%, the delay in seasonal road opening is 34%, that long term road closure will be 1%		An expectation that exceptional maintenance will be required is about 30%, the delay in seasonal road opening is 30%, that long term road closure will be 1%	
Advantages:	Exceptional maintenance is 22% less than option 2, the delay is 44% less, road closure is 22% less	**70**		**0**	Exceptional maintenance is 21% less than option 2, the delay is 60% less, road closure is 26% less	**81**	**Exceptional maintenance is 26% less than option 2, the delay is 64% less, road closure is 26% less**	**90**
Subfactor 3C: *Improving Recreational Opportunities for Visitors by* **• Creating new recreational opportunities**								
Attributes:	No new recreational opportunities		Potential for development of Mainline Bike/Ped trail, different access points for recreation users, allows further access into the northern backcountry, improves backcountry access to day hikers		Potential for development of Mainline Bike/Ped trail, different access points for recreation users, allows further access into the southern backcountry		Potential for development of Mainline Bike/Ped trail, different access points for recreation users, allows further access into the southern backcountry	
Advantages:		**0**	**Provides new day hike access to an underutilized area compared with option 1**	**34**	Provides day hike access to currently utilized areas compared with option 1	**10**	Provides day hike access to currently utilized areas compared with option 1	**10**
Subfactor 3D: *Improving Recreational Opportunities for Visitors Through* **• Avoidance of disturbing backcountry experience**								
Attributes:	Would not disturb existing backcountry experience		Would disturb backcountry user experience in an area north of the existing road, majority of which is out of view of current road alignment		Would disturb backcountry user experience on the Plains of Murie, majority is in view of existing road alignment		Would disturb backcountry user experience on the Plains of Murie, majority is in view of existing road alignment	
Advantages:	**No change to the existing backcountry experience**	**68**	Likely impacts fewer backcountry users than Option 3. Enhances the experience on the Plains of Murie. Impacts backcountry users on the north side.	**31**		**0**		**0**

Choosing By Advantages

Project/Location: **Denali Park Road - Polychrome Area Re-Route**
Component: **Site**
Function: **Denali Park Road Connection at MP 43-48**

Subfactor 3E: *Improving Recreational Opportunities for Visitors Through* • **Minimizing the number of seasons of construction** • **Minimizing visibility of construction to visitors** • **Minimizing potential impact to west access**								
Attributes:	An estimated 12 months (2 summer or 4 shoulder) of construction, isolated exposure within construction zone, potential west access if construction during shoulder season		An estimated12-14 years of construction, isolated exposure as seen from the road to both ends of construction zone, potential west access via mainline route if mainline maintained		An estimated11-13 years of construction, broad exposure as seen from existing road, potential west access via mainline route if mainline maintained		An estimated11-13 years of construction, broad exposure as seen from existing road, potential west access via mainline route if mainline maintained	
Advantages:	**10-12 fewer years of construction, least amount of exposure to construction, most likely to allow continued access to the west end of Park**	**100**	1-2 more years of construction than option 3B, much less exposure of construction, slightly better potential for access than 3B	**19**	Same number of years of construction, similar but slightly less broad exposure, similar potential for access	**6**		**0**
Improve the Efficiency, Reliability and Sustainability of Park Operations								
Subfactor 4A: *Improving Efficiency of Park Operations Through* • **Ease of spring road opening** • **Extent and frequency of inspections**								
Attributes:	South facing road, no major clearing issues (can off load), some avalanche issues, 1 bridge (400 lf) with inspections and maintenance required		Mostly eastern exposure, expected runoff generated, expected need for snow and ice removal, bigger but fewer culverts, 8 bridges (4475 lf) with inspections and maintenance required		Open exposure, more but smaller culverts, snow accumulation is less, snow drifting can occur, 8 bridges (9350 lf) with inspections and maintenance		Open exposure, snow accumulation is less, snow drifting can occur, 5 bridges (9175 lf) with inspections and maintenance	
Advantages:	**Fewer bridge inspections and maintenance required, easier snow clearing, good solar orientation**	**34**		**0**	Much longer length of bridge to inspect and maintain, snow clearing possibly better than option 2 due to generally less snow	**11**	Longer length of bridge to inspect and maintain, snow clearing possibly better than option 2 due to generally less snow	**19**
Subfactor 4C: *Improving Sustainability of Park Operations Through* • **Use of Available Materials Within the Park** • **Use of Renewable Resources**								
Attributes:	32K cy of aggregate for initial construction		Need for 810K cy of aggregate for initial construction		Need for 450K cy of aggregate for initial construction		Need for 290K cy of aggregate for initial construction	
Advantages:	**778k cy less aggregate needed than option 2**	**78**		**0**	**360k cy less aggregate needed than option 2**	**10**	**520k cy less aggregate needed than option 2**	**26**
Subfactor 4D: *Preventing Limitation to Park Operations Elsewhere in the Park Through* • **Minimizing construction traffic**								
Attributes:	An estimated 12 months (2 summer or 4 shoulder) of increased construction traffic and impacts to general park operations on the first 43 miles of road, need for 2 existing staging areas		An estimated12-14 years of increased construction traffic and impacts to general park operations on the first 43 miles of road, no need for use of ex staging areas		An estimated11-13 years of increased construction traffic and impacts to general park operations on the first 43 miles of road, no need for use of ex staging areas		An estimated11-13 years of increased construction traffic and impacts to general park operations on the first 43 miles of road, no need for use of ex staging areas	
Advantages:	**10-12 years less of increased construction traffic, need use of ex staging areas**	**76**		**0**	1-2 years less than option 2	**8**	1-2 years less than option 2	**8**

Choosing By Advantages

Project/Location: **Denali Park Road - Polychrome Area Re-Route**
Component: **Site**
Function: **Denali Park Road Connection at MP 43-48**

Provide Cost-Effective, Environmentally Responsible and Otherwise Beneficial Development to the National Park System								
Subfactor 5: *Providing Cost-Effective, Environmentally Responsible and Otherwise Beneficial Development to the National Park System Through* • **Adherence to original aesthetic design intent**								
Attributes:	Adheres to the original aesthetic alignment as designed		Aligns to the natural terrain of the northern pass in line with the original aesthetic intent		Alignment doesn't conform to the natural landscape features, not inline with the original aesthetic design intent		Uses a portion of the original alignment and retains a portion of the original aesthetic, has some portion that does not conform to the natural landscape features and is not in line with the original design intent	
Advantages:	**Most closely meets the original aesthetic design intent**	**72**	Somewhat meets the original aesthetic design intent	**66**		**0**	**Other than the portion on the original road, does not align with the original aesthetic design intent**	**6**
Total Importance of Advantages (Benefits)		**922**		**209**		**273**		**322**
Initial Cost	$46,296,000		$185,928,000		$275,329,200		$255,266,400	
Benefit to Cost Ratio Initial Cost	**1.99**		**0.11**		**0.10**		**0.13**	
Life Cycle Cost	$158,615		$234,408		$278,318		$232,596	
Benefit to Cost Ratio Life Cycle Cost	**581.28**		**89.16**		**98.09**		**138.44**	

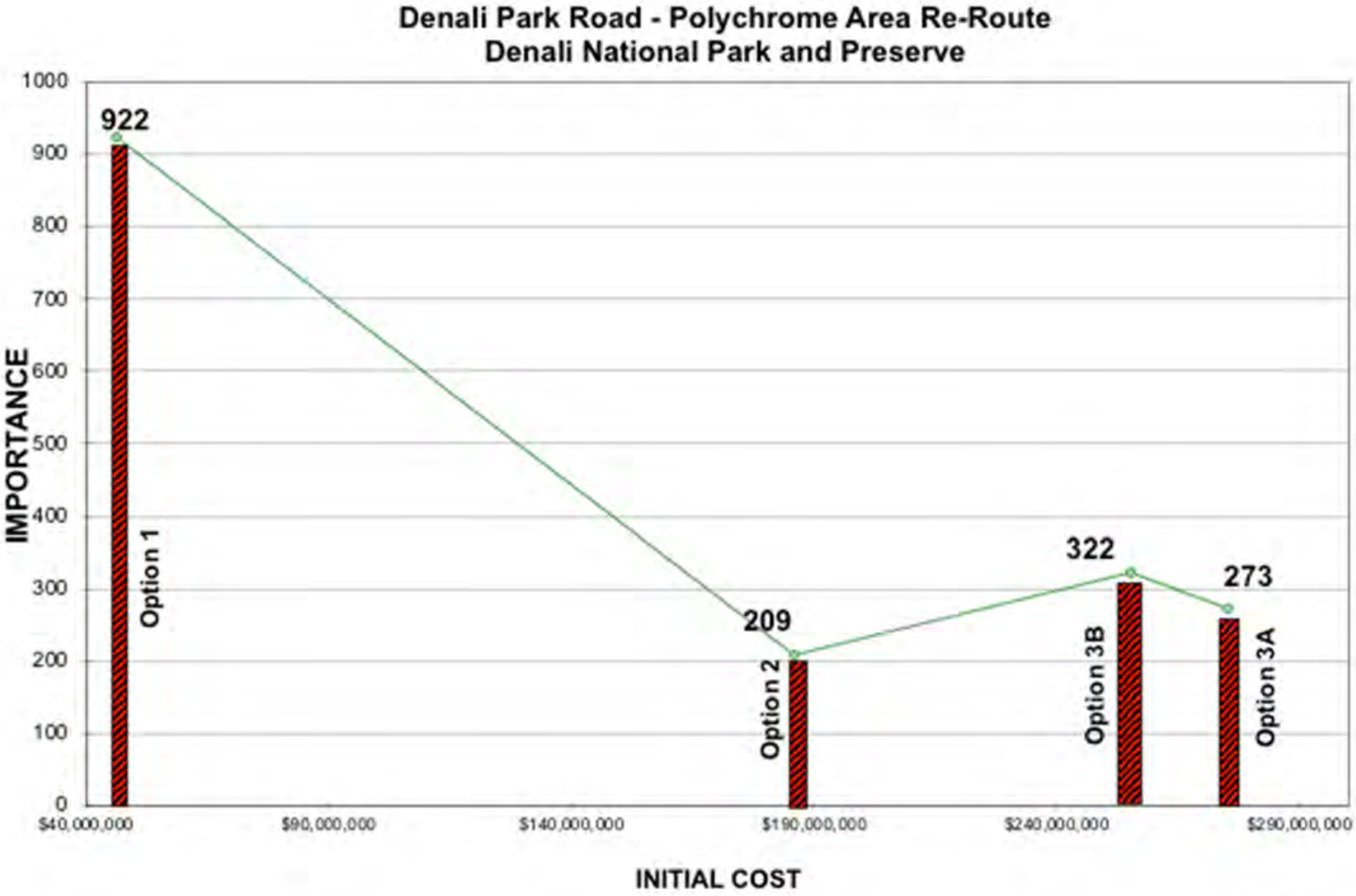

Denali Park Road - Polychrome Area Re-Route
Denali National Park and Preserve
IMPORTANCE
1000
900
800
700
600
500
400
300
200
100
0
922
Option 1
209
Option 2
322
Option 3B
273
Option 3A
$40,000,000
$90,000,000
$140,000,000
$190,000,000
$240,000,000
$290,000,000
INITIAL COST

Figure 17:

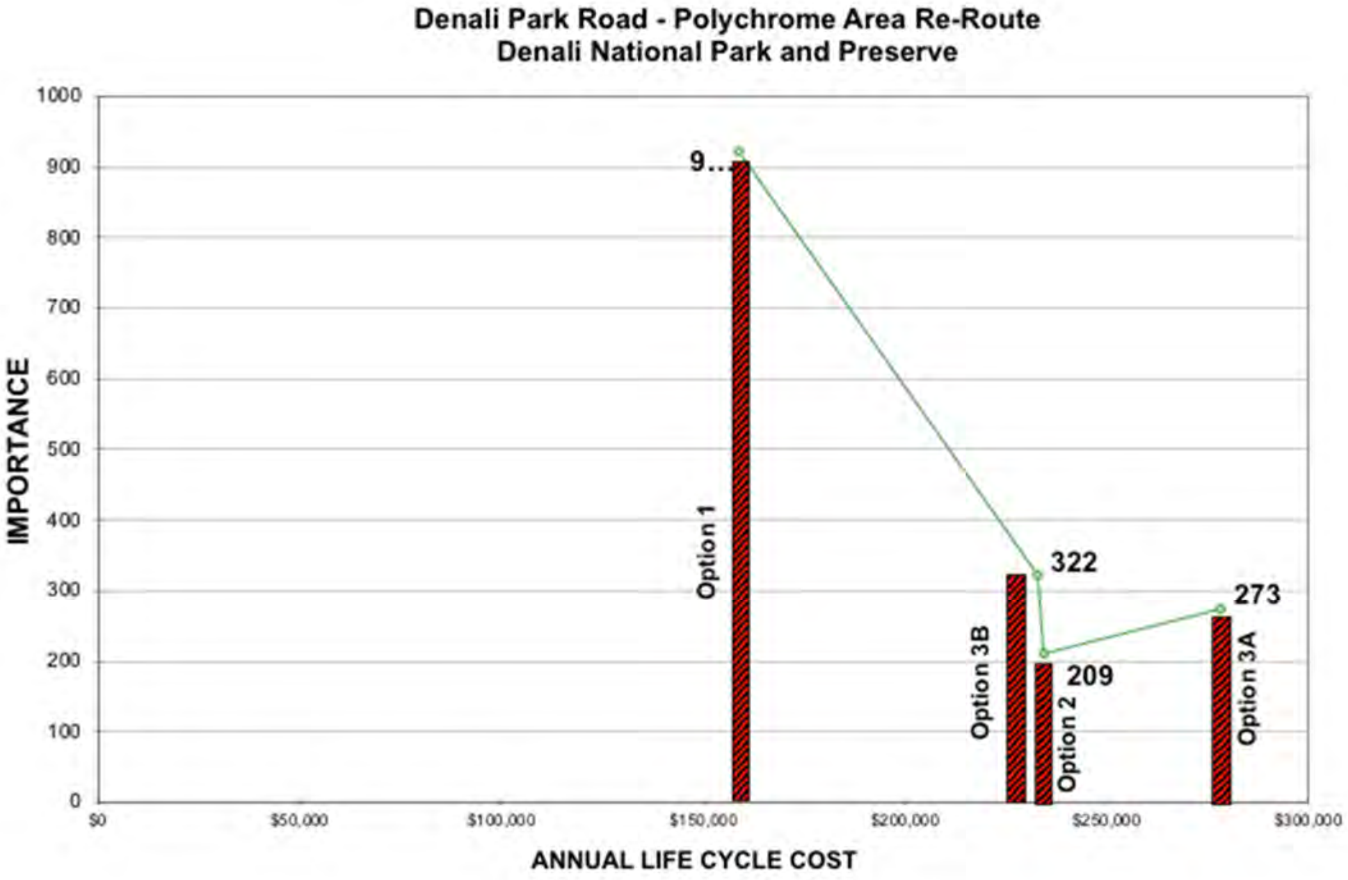


Figure 18: Annul Life Cycle Cost – All Options

Analysis

The study team evaluated the benefit (or importance) of the advantages for each option, as well as the initial costs and life cycle costs. The results were graphed with importance on the vertical scale and cost on the horizontal scale. The analysis was performed using initial cost and life cycle cost separately. The results are summarized on charts in the preceding pages.

The downward slope from Option 1 (Mainline Alignment) relative to the other options suggests considerably less value for those options that require additional capital investment. This holds true when evaluating both initial construction costs and life cycle costs.

Option 1 had the highest benefit-to-cost ratio in the CBA analysis due mainly to very low initial cost of construction and low life cycle cost. It is possible that the estimated life cycle cost does not adequately take into account the continued damage that could occur to the area over a 50-year lifespan due to any changes in landslide conditions that might affect the new bridge at Pretty Rocks or steep slopes above and below Bear Cave. Option 3A or 3B (Southern Alignments) are not recommended by the VA team because they involve considerable disruption to designated Wilderness, do not resolve the unnecessary impacts to floodplain, and do not offer any more in numeric advantages than Option 1. Additionally, the net construction cost of these options is 5 times greater with a construction period of 10-12 additional years. Option 2 (Northern Alignment) is also not recommended because of its disturbance to designated Wilderness and uncertain improvement to avoiding landslides or questionable permafrost soils. That results in some question as to adequate, safe passage of vehicles by placing another road back in the same location as problematic geotechnical issues that have prompted relocation in the first place. This option is also 3.5 times more expensive than Option 1 in net construction cost.

The VA team recommends Option 1: Mainline Alignment, which provides the greatest combination of benefits for a very reasonable cost.

PHASE IV - DEVELOPMENT

The Value Analysis Team determined that the options were adequately developed with regards to understanding alignments and features. Each option was refined by the ideas suggested for value enhancement developed during the Creativity phase of the value study.

The team also developed a model to identify potential risks to the project and ways to mitigate those risks. Further development of risk mitigation will be necessary as the project progresses to design and construct a successful project.

PHASE V - RECOMMENDATIONS/WRAP-UP

Specific recommendations for additional value enhancement include the following items:

- Design and develop solutions to the Bear Cave area at mile 45.
- Build in additional contingencies for the entire section of road, rating areas needing improvement, particularly with respect to traffic safety along the entire road corridor.
- Consider utilizing the Construction Manager / General Contractor (CM/GC) method of delivering the project whereby the client or project owner hires a contractor to provide feedback during the design phase before the start of construction in order to gain optimal cost efficiencies and benefit of insight into practical execution.
- Consider extending spring construction further into the visitor season and commencing fall construction earlier before the visitor season normally ends to ensure optimal opportunity to complete the project in the planned two-year time frame.
- Consider new interpretive opportunities at this location to help describe the alteration to the road, its environment and the conditions that led to the change in alignment.
- Incorporate structural and aesthetic bridge elements that are complementary to the cultural landscape and historic integrity where feasible and cost effective, following the Park CLR where possible.
- Attempt to re-use rock excavated from the Pretty Rocks area for other portions of the project or for future Park projects.
- Complete a Risk Management Plan prior to proceeding with any further planning or design to address the many high risks identified in the VA risk assessment (see checklist).
- Consult with the National Capitol Region regarding the Memorial Bridge in Washington, D.C. to gain insight and advice on public affairs regarding a large, complex project.
- Based on the successful application of the Microsoft HoleLens platform to provide 3D imagery of the project, the NPS should invest in an animated visualization to better translate project issues and simulated design solution(s) for public information.

PHASE VI - IMPLEMENTATION

Implementation of the value study recommendations is the responsibility of the design team and the client team, as work progresses on the next stages. Additional value analysis studies (mini-VA's) may be performed to evaluate specific project components such as road construction, bridge connections, and drainage improvements.

SECTION C: APPENDICES

A. Value Study Agenda

B. Life Cycle Costs, Cost Estimate Background information

C. FHWA DENA Expert-Based Risk Assessment Summary

D. High Line Road Cultural Resource Report

Appendix A: Value Study Agenda

Value Study Agenda

Polychrome Area Re-Route of the Denali Park Road
Denali National Park and Preserve
July 13 – July 16, 2020 (Monday – Thursday)
Value Analysis Work Plan

Microsoft Teams Virtual Meeting

Conference Call via Microsoft Teams

Monday, July 13: Join Microsoft Teams Meeting
Tuesday, July 14: Join Microsoft Teams Meeting
Wednesday, July 15: Join Microsoft Teams Meeting
Thursday, July 16: Join Microsoft Teams Meeting

Backup phone conference line:
Call-in number: 1-866-810-1272 Participant Code: 5366629 Leader Code: 1627394

Participants:
Paul Schrooten, DJ&A, facilitator (landscape architect)
Peter Walker-Keleher, DJ&A, facilitation support and scribe (senior planner)
Caroline Stanley, DJ&A, facilitation support and scribe (civil engineering intern)

Value Analysis Team
Denny Capps, NPS-DENA, (geologist, natural resources)
Paul Franke, NPS-DENA, (roads & trails supervisor, operations)
Phoebe Gilbert, NPS-DENA, (cultural resources program manager, cultural resources)
Michael Baron, FHWA-WFLHD, (construction operations engineer)
Benjamin Oltmann, FHWA-WFLHD, (engineer, bridge/structures functional manager)
Kevin Doniere, NPS-AKRO, (landscape architect, transportation/facilities)
Kristie Franzmann, NPS Denver Service Center, (landscape architect, chief of transportation division)

Supporting Attendees
Miriam Valentine, NPS-DENA (External Affairs)
Brandon Stokes, FHWA-WFLHD (project manager)
Michael MarcAurele, NPS-AKRO (engineer, acting regional facilities manager)
Scott Anderson, BGC Engineering Inc, (geotechnical engineer, EBRA facilitator)

Monday, July 13, 2020

1:00p **Introductions and Opening Remarks** *Paul Schrooten, DJ&A*

Value Analysis Team and Participant Intros
Virtual Meeting General Practices and Protocols
Park Superintendent Welcoming Remarks

1:45p **Project Purpose** *Kevin Doniere, NPS*

Statement of Need and Study Objectives
Project Timeline and Current Status
NPS Value Analysis Requirements and Guidance
Agenda Review

2:15p **Expert-Based Risk Assessment (EBRA)** *Scott Anderson, BGC*

EBRA Approach
Final Report Executive Summary
Q&A
Value Added Benefits

3:15p *Break*

3:30p **VA Phase I: Information Sharing/Gathering** *Miriam Valentine, NPS*

Park Management Parameters (Regulatory Framework)
Project Overview (Photos and Mapping)
Character of Area (Natural and Cultural Setting)
Project Description (Scope, Function, and Services)

4:15p **EBRA Virtual Site Visit** *Scott Anderson, BGC and Brandon Stokes, WFL*

Risk Assessment Context
HoloLens Site Visit Set Up
Overview of Project Road Options
Preferred and Tabled Road Options
Q&A

5:15p *Close for the day*

Tuesday, July 14, 2020

8:00a **VA Phase II: Speculation/Creativity** *Paul Schrooten, DJ&A*

Road Option Alignments
Presentation of Road Options
Initial Construction Cost and Life Cycle Cost Estimates
Cost Model Breakdown
Q&A

9:30a *Break*

9:45a **Risk Model** *Paul Schrooten, DJ&A*

Risk Model Checklist
Summary of High and Low Risk Elements
Discussion/Q&A

10:45a **VA Phase II: Speculation/Creativity (continued)** *Paul Schrooten, DJ&A*

Best Road Features
Weakest Road Features
Initial Ideas to Enhance Options
Identify High Cost Elements for Value Enhancement

12:00 *Lunch*

1:00p **VA Phase III: Analysis/Evaluation of Road Options** *Paul Schrooten, DJ&A*

Review of Standards, Criteria, and Regulatory Requirements
Choosing By Advantages (CBA) Primer
Evaluation of Options (CBA)
Develop/Review Evaluation Factors (*Safe Visits and Working Conditions)*
List Attributes
List Advantages

2:45p *Break*

3:00p **VA Phase III: Analysis/Evaluation of Road Options** *Paul Schrooten, DJ&A*

Evaluation of Options (CBA) continued
Develop/Review Evaluation Factors (*Safe Visits and Working Conditions*)
List Attributes
List Advantages

4:30p **VA Phase III: Analysis/Evaluation of Road Options** *Paul Schrooten, DJ&A*

Evaluation of Options (CBA) continued
Develop/Review Evaluation Factors (*Protect Natural/Cultural Resources*)
List Attributes

	List Advantages
5:15p	*Close for the day*

Wednesday, July 15, 2020

8:00a **VA Phase III: Analysis/Evaluation of Road Options** *Paul Schrooten, DJ&A*

Evaluation of Options (CBA) continued
Develop/Review Evaluation Factors (*Protect Natural/Cultural Resources*)
List Attributes
List Advantages

8:45a **VA Phase III: Analysis/Evaluation of Road Options** *Paul Schrooten, DJ&A*

Evaluation of Options (CBA) continued
Develop/Review Evaluation Factors (*Visitor Enjoyment…*)
List Attributes
List Advantages

10:15a *Break*

10:30a **VA Phase III: Analysis/Evaluation of Road Options** *Paul Schrooten, DJ&A*

Evaluation of Options (CBA) continued
Develop/Review Evaluation Factors (*Improve… Park Operations)*
List Attributes
List Advantages

11:45a *Lunch*

1:00p **VA Phase III: Analysis/Evaluation of Road Options** *Paul Schrooten, DJ&A*

Evaluation of Options (CBA) continued
Develop/Review Evaluation Factors (*Provide…Otherwise Beneficial…*)
List Attributes
List Advantages

2:00p **VA Phase III: Analysis/Evaluation of Road Options** *Paul Schrooten, DJ&A*

Evaluation of Options (CBA) continued
Decide Importance and the Paramount Statement
Determine Total Importance (Scoring Attribute Advantage Statements)
Predicting Best Value Option

3:45p *Break*

4:00p **VA Phase III: Analysis/Evaluation of Road Options** *Paul Schrooten, DJ&A*
Evaluation of Options (CBA) continued (*continued*)
Determine Total Importance (Scoring Attribute Advantage Statements)
Identification/Confirmation of Best Value Option

5:30p *Close for the day*

Thursday, July 16, 2020

8:00a **VA Phase IV: Development/Implementation** *Paul Schrooten, DJ&A*

Development of Best Value Alternative
Develop/Rank Ideas for Road Option Enhancements

Aesthetics
Sustainability Enhancements
Other Value Enhancements

Implementation Process

9:15a **Construction and Construction Management Options** *Brandon Stokes WFL*

Feasible Construction Techniques and Phasing
Possible Project Delivery Options
Suggested Construction Management Needs

10:30a *Break*

10:45a **VA Phase V: Summary Findings/Implementation** *Paul Schrooten DJ&A*

Summary of Value Enhancement and Potential Cost Savings
Adjustments to Project Options (Funding, Planning and Design, Construction and Construction Management)
Presentation of Findings/Recommendations to Park Management
NPS Closing Remarks

11:30a **Final Summary** *Paul Schrooten DJ&A*

Daily Wrap
Announcements
Q&ATBD

12:00 *Adjourn*

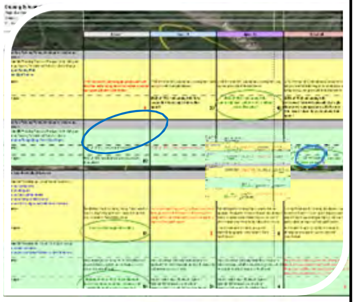
Appendix B: Life Cycle Costs, Cost Estimate Background Information

LIFE CYCLE COST ANALYSIS

Project/Location: **Denali Park Road - Polychrome Area Re-Route**
Subject: **Conceptual Design Options**
Function: **Denali Park Road Connection at MP 43-48**
Project Life Cycle = **50 Years**
Discount Rate = **7.00%**
Present Time = **Date of Occupancy**

						Option 1		Option 2		Option 3A		Option 3B	
						Mainline Alignment with New Bridge at Pretty Rocks		Northern Alignment		Beginning just east of existing East Fork Toklat River bridge near MP 43		Beginning just west of existing East Fork Toklat River bridge near MP 43	
INITIAL PROJECT COSTS						**Est.**	**PW**	**Est.**	**PW**	**Est.**	**PW**	**Est.**	**PW**
Construction Costs													
A.	Construction Cost					46,296,000	46,296,000	185,928,000	185,928,000	275,329,200	275,329,200	255,266,400	255,266,400
B.						0	0		0		0		0
C.	Other Project Costs					10,213,200	10,213,200	31,628,000	31,628,000	44,247,800	44,247,800	45,195,400	45,195,400
Total Initial Project Cost						Rounded=	56,509,200	Rounded=	217,556,000	Rounded=	319,577,000		300,461,800
Initial Project Cost Savings (Compared to Option 3B)							243,952,600		82,905,800		(19,115,200)		
REPLACEMENT COST/ SALVAGE VALUE													
	Description		**Year**		**PW Factor**								
B.	Structural bridge repair (minor)		25		0.1842	130,000	23,952	220,000	40,534	350,000	64,487	300,000	55,274
C.	Structural bridge repair (major)		50		0.0339	420,000	14,258	600,000	20,368	900,000	30,552	800,000	27,158
P.	Replace culvert		10		0.5083	0	0	1,480,000	752,356	2,220,000	1,128,535	1,700,000	864,193
Q.	Unstable slope repair (major)		5		0.7130	20,000	14,259	40,000	28,519	0	0	0	0
Q.	Unstable slope repair (major)		3		0.8163	0	0	0	0	5,000	4,081	5,000	4,081
Q.	Unstable slope repair (major)		2		0.8734	0	0	25,000	21,835	0	0	0	0
S.	Aggregate replacement		10		0.5083	124,000	63,035	486,400	247,261	564,800	287,115	466,000	236,890
T.	B-annual bridge inspection		2		0.8734	20,000	17,468	30,000	26,203	60,000	52,406	60,000	52,406
U.													
V.						0	0	0	0	-	0	0	0
Total Replacement/Salvage Costs						Rounded=	133,000	Rounded=	1,137,000	Rounded=	1,567,000	Rounded=	1,240,000
ANNUAL COSTS													
	Description	**Quantity**	**Unit Cost**		**PWA**								
A.	Remove vegetation and road debris			0.0%	13.801	2,500	34,502	2,500	34,502	2,500	34,502	2,500	34,502
B.	Routine inspection			0.0%	13.801	2,500	34,502	2,500	34,502	1,250	17,251	1,250	17,251
C.	Snow removal			0.0%	13.801	2,500	34,502	5,000	69,004	2,500	34,502	2,500	34,502
D	Unstable slope repair (minor)			0.0%	13.801	5,000	69,004	5,500	75,904	5,000	69,004	5,000	69,004
E	Aggregate replacement			0.0%	13.801	134,000	1,849,300	124,000	1,711,293	136,000	1,876,901	114,000	1,573,285
F.	Stormwater runoff repairs			0.0%	13.801	2,500	34,502	2,500	34,502	2,500	34,502	2,500	34,502
G.	Culvert Maintenance			0.0%	13.801	0	0	10,000	138,007	15,000	207,011	15,000	207,011
H.				0.0%	13.801	0	0	0	0	0	0	0	0
I.				0.0%	13.801	0	0	0	0	0	0	0	0
J.				0.0%	13.801	0	0	0	0	0	0	0	0
K.				0.0%	13.801	0	0	0	0	0	0	0	0
L.				0.0%	13.801	0	0	0	0	0	0	0	0
Total Annual Costs (Present Worth)						Rounded=	2,056,000	Rounded=	2,098,000	Rounded=	2,274,000	Rounded=	1,970,000
Total Life Cycle Costs (Present Worth)							2,189,000		3,235,000		3,841,000		3,210,000
Life Cycle Savings (Compared to Option 3A)							1,652,000		606,000				631,000
					PP Factor								
Total Life Cycle Costs (Annualized) without ICC					0.0725	158,615	Per Year	234,408	Per Year	278,318	Per Year	232,596	Per Year

Appendix C: FHWA DENA Expert-Based Risk Assessment Summary

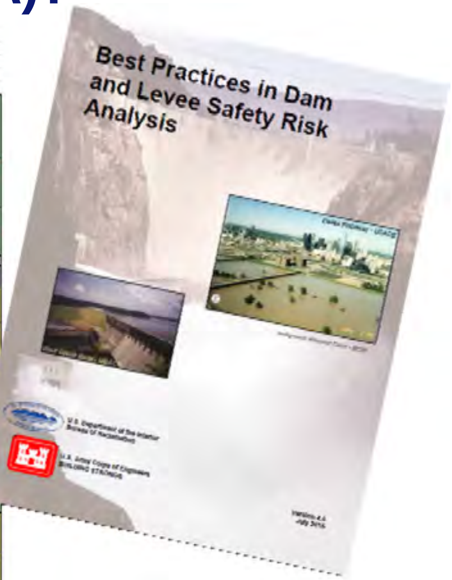


Polychrome Area Re-Route of the Denali Park Road

Expert-Based Risk Assessment (EBRA)

Presented by: Scott Anderson
Date: July 13, 2020

What is an expert-based risk assessment (EBRA)?



Best Practices in Dam and Levee Safety Risk Analysis

U.S. Department of the Interior Bureau of Reclamation

U.S. Army Corps of Engineers BUILDING STRONG

Version 4.0
July 2015

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May 5-7 2020 Meeting

- Introductions of Expert Panel and Team
- Definitions and understanding of process/approach
- Knowledge transfer
- Debate, dialogue and assessment
- Transparently derived, objective outcome

Knowledge Transfer

- Design details (new and existing)
- Bridge performance
- Climate
- USMP and sliding, Pretty Rocks and beyond
- Maintenance history
- Permafrost and arctic road building experience

Performance Objectives

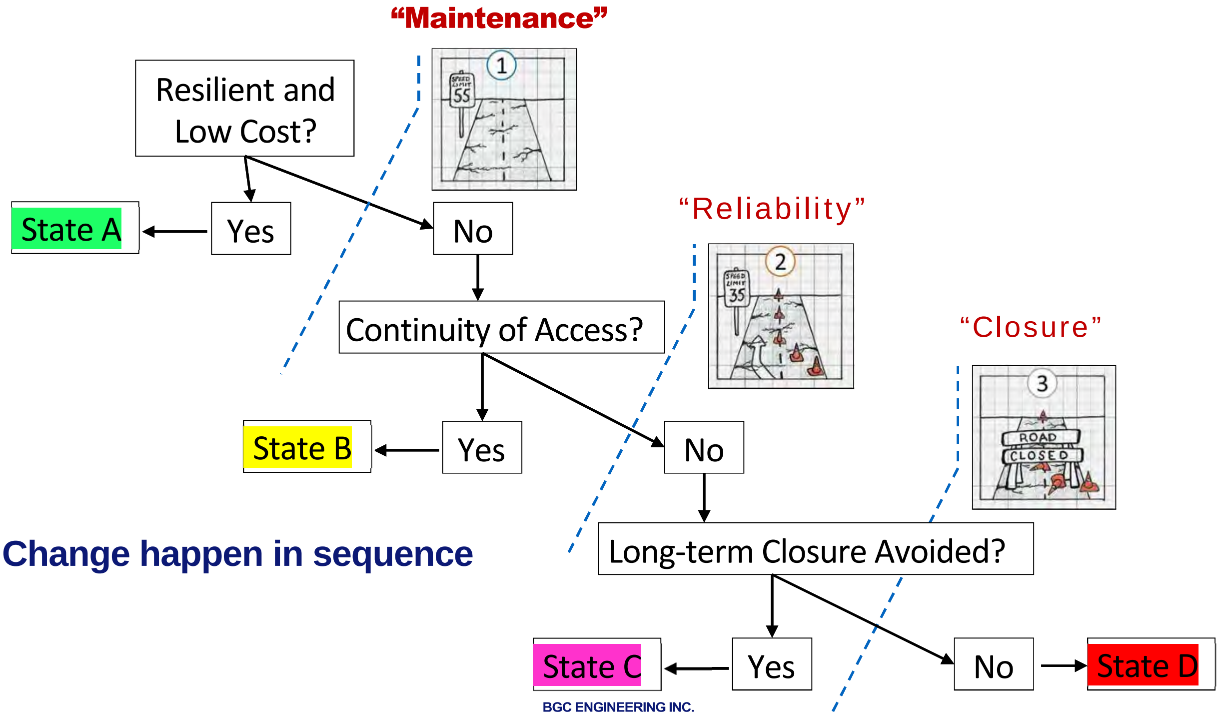
1. Achieve resilient, low life cycle cost solution
2. Ensure opportunities through continuity of access
3. Hold cultural, aesthetic and wilderness values intact

Condition States can describe how well these objectives are being met.

Condition States are tangible and have references that are objective

"We protect intact, the globally significant Denali ecosystems, including their cultural, aesthetic, and wilderness values, and ensure opportunities for inspiration, education, research, recreation and subsistence for this and future generations."

The Denali National Park Mission Statement



“Maintenance”

“Reliability”

“Closure”

Resilient and Low Cost?

Yes → State A

No

Continuity of Access?

Yes → State B

No

Long-term Closure Avoided?

Yes → State C

No → State D

Change happen in sequence

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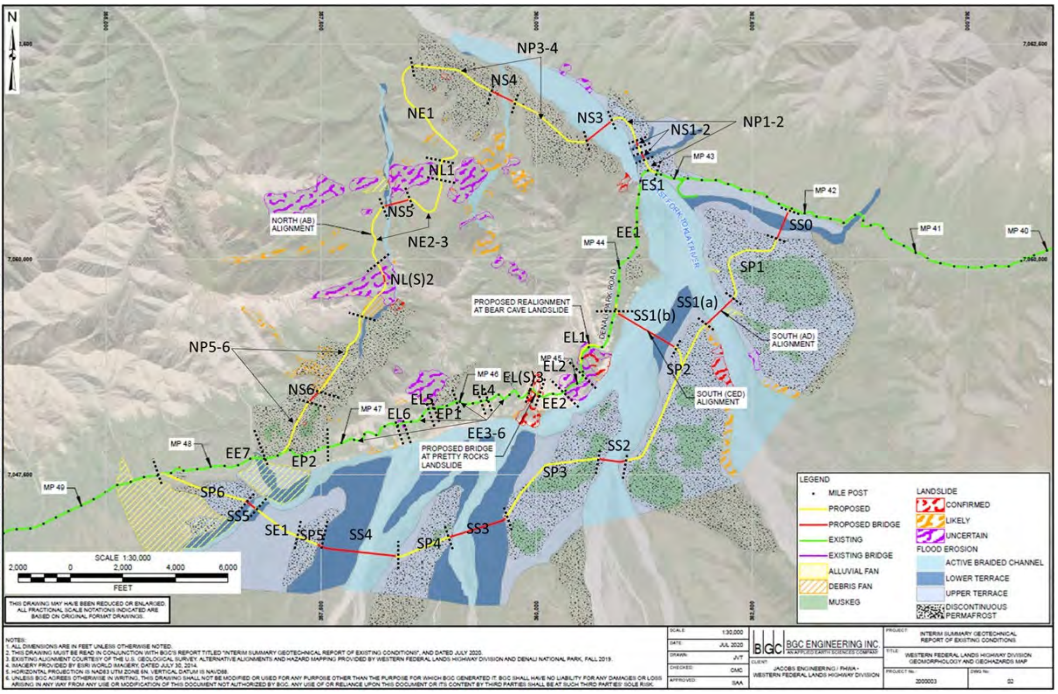
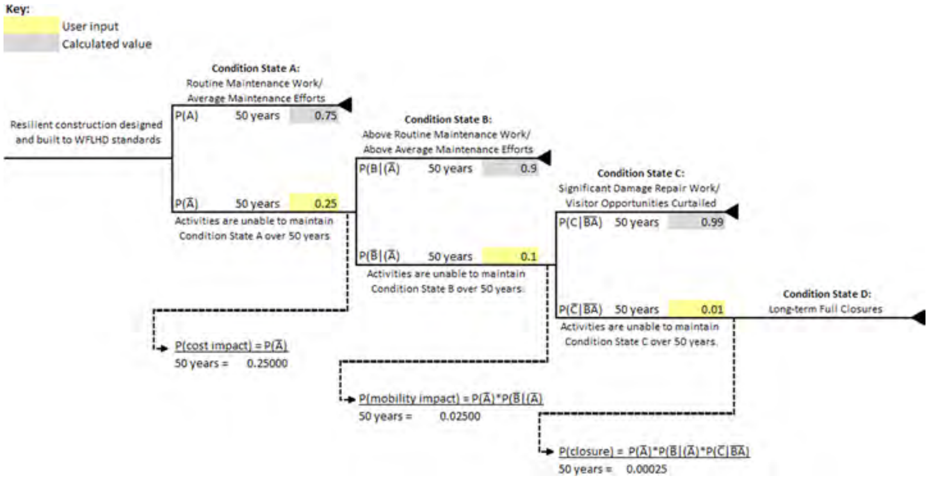
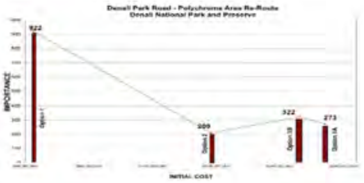
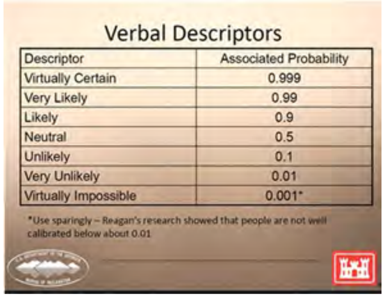
Decomposing a complex problem



Decomposing a complex problem







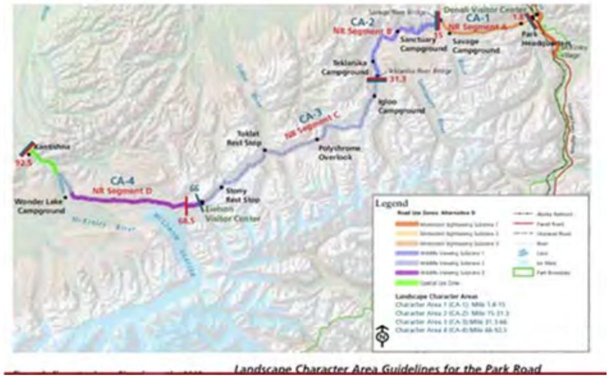
Verbal Descriptors

Descriptor	Associated Probability
Virtually Certain	0.999
Very Likely	0.99
Likely	0.9
Neutral	0.5
Unlikely	0.1
Very Unlikely	0.01
Virtually Impossible	0.001*

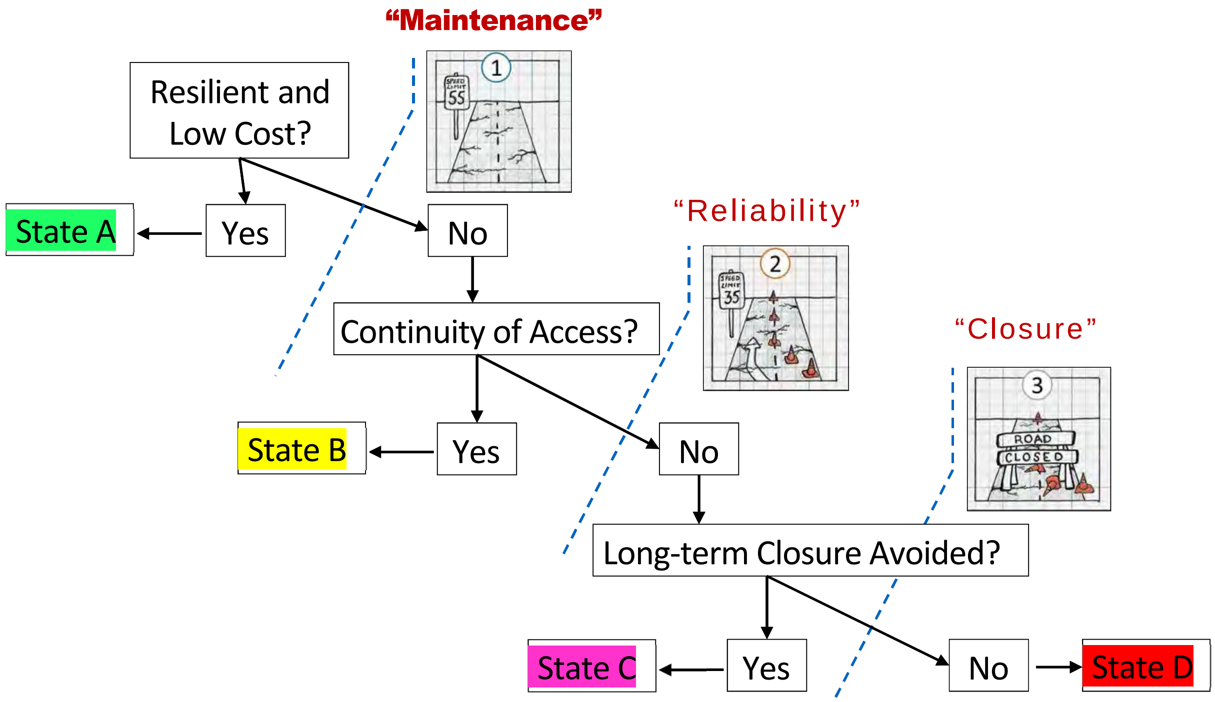
*Use sparingly – Reagan's research showed that people are not well calibrated below about 0.01

Condition States

- State A: When considered over a 50-year life cycle, the total annual costs are typical for NR Segment C and stable (e.g. predictable); they are not escalating when compared to other parts of the road.
- Segments are in State A after initial construction and remain in State A if the type and frequency of issues addressed shown in *Roadway Maintenance Doc. For MP 31-66* are not exceeded.
  - Partial use of permitted 11,000/cy/yr. aggregate
  - Raising road elevation 1 foot for settlement
  - Management of drainage
  - Some deep patch completed, more could be installed
  - Occasional rockfall
  - Small slumps above and below road
  - Debris flow cleanup



Landscape Character Area Guidelines for the Park Road



"Maintenance"

"Reliability"

"Closure"

Resilient and Low Cost?

Yes → State A

No

Continuity of Access?

Yes → State B

No

Long-term Closure Avoided?

Yes → State C

No → State D

Condition States

- State B: Annual costs are not lower than typical and/or they are not stable, but roadway assets provide an acceptable continuity of safe access and ensuring opportunities for visitors.
- Polychrome Pass *has been* in this state since approximately 2000. Exceptional maintenance activities are required.

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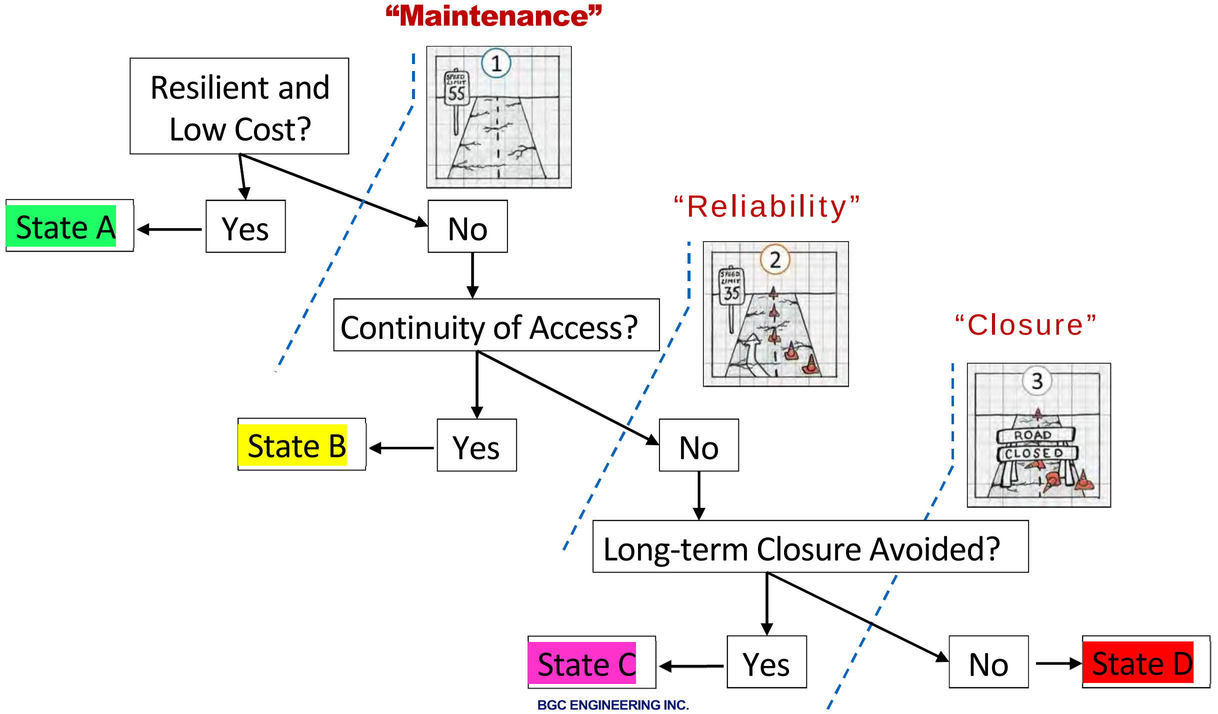


Resilient and Low Cost?

State A ← Yes | No

Continuity of Access?

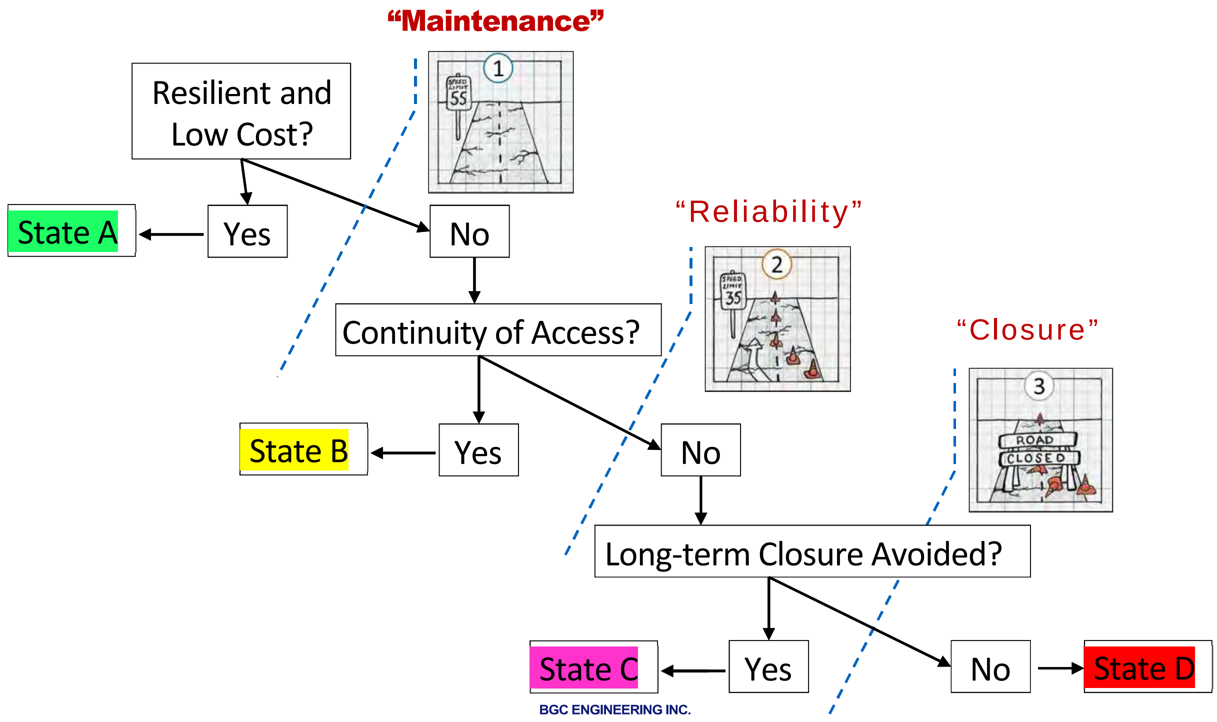
State B ← Yes | No

Long-term Closure Avoided?

State C ← Yes | No → State D

Condition States

- State C: Visitor opportunities are curtailed significantly by road condition and closures. Access cannot be assured during open road season, resulting in unpredictable reliability.
- State D: Seasonal or longer closure is incurred because of failure of earthwork(s) or structure(s) to the point where route abandonment is considered, or special legislative acts are required to rebuild or restore.



"Maintenance"

Resilient and Low Cost?

State A ← Yes

No

Continuity of Access?

State B ← Yes

No

"Reliability"

Long-term Closure Avoided?

State C ← Yes

No → State D

"Closure"

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Deliberations and Assumptions

1. Resiliency: The Federal Highway Administration resiliency definition is "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions" and it will be applied here. Something with a high degree of resilience serves its function by being robust and resistant to disruption, or able to recover function quickly, or both.
   - Regardless of the alignment alternative or element of work on that alignment, this attribute will be built in.
     - It is what is known as the initiating event in the process the EBRA will follow.
   - A changing climate and thawing of permafrost are anticipated as disruptions, and there are other geohazard disruptions as well.
2. Construction: Only to the extent that construction methods impact long-term performance are they considered in the EBRA.

Deliberations and Assumptions

1. The current lines on the map represent a 5% design – very conceptual.
2. WFLHD and the NPS will follow a design development process that includes VA, review and innovations compatible with the SOP for 2020 in Alaska.

➢ *Examples are GRS abutments bridges and/or longer decks to set abutments back from slope, use of embankments rather than cuts, timing of earthwork, avoiding thermokarst and solifluction areas, additional water control (i.e. culverts).*

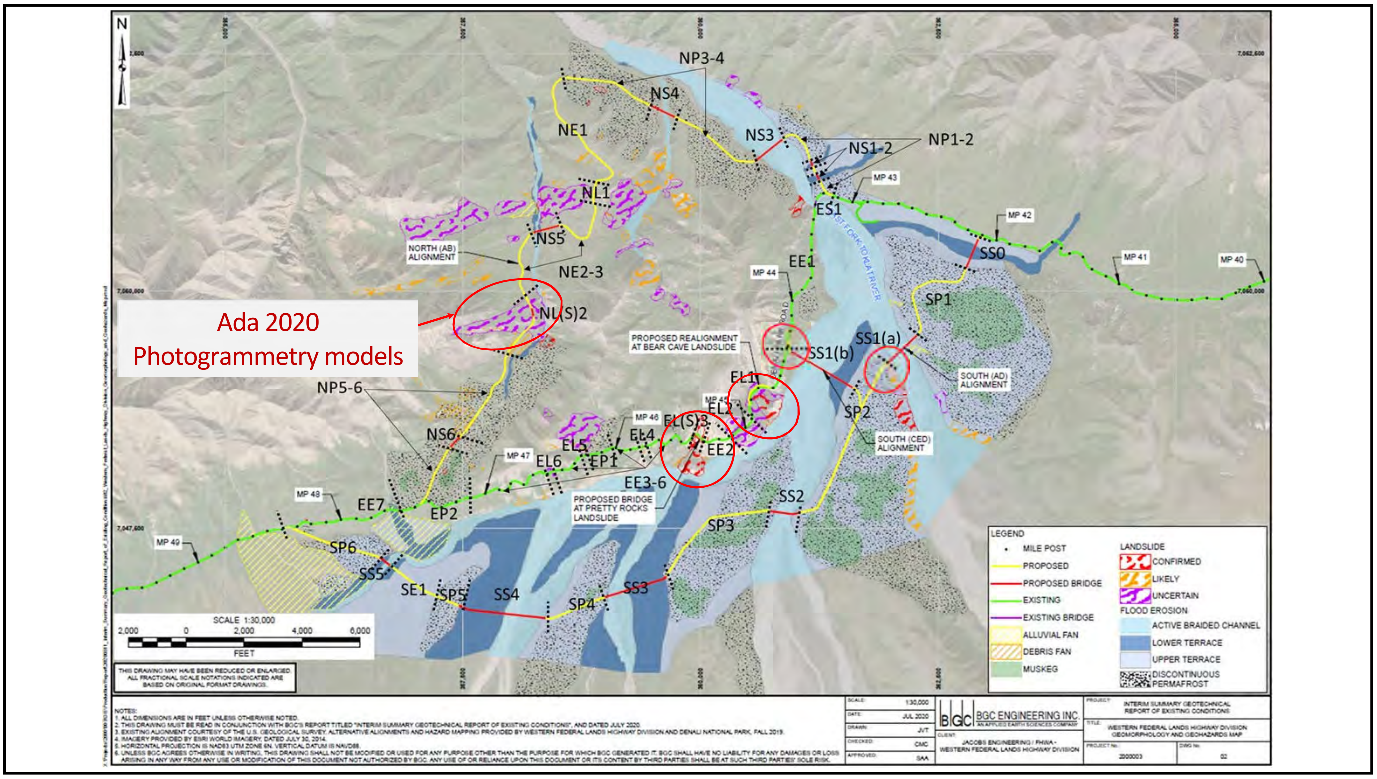
3. Typical roadway sections and structures as presented by WFLHD.
4. Planned activities on existing alignment to be completed as presented by WFLHD.
5. Climate is changing and stationarity is not expected.

Approach

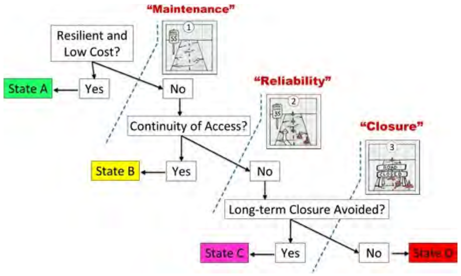
Use the following approach for each alignment, segments in sequence. Independent use of HoloLens at any time.

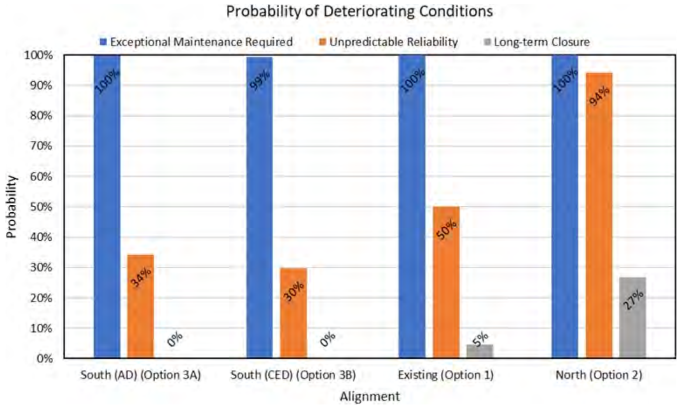
- Geohazard map with Segments identified
- Lidar evaluation of surroundings
- Evaluation of InSAR as appropriate
- Review of presentation content and photographs available
- Ask: Do we have enough information to make assessment regarding Condition State? If not, what is needed?
- Make individual assessments of State A to B, State B to C and State C to D
- Share and search for consensus on the estimates, review data and HoloLens as needed
- Record one or more outcomes following debate (always got to one)
- Record key observations of the panel that might be considered to reduce risk
- Advance to next Segment and consider new data in sequence above. Are there

indicators that would make advance more or less likely?

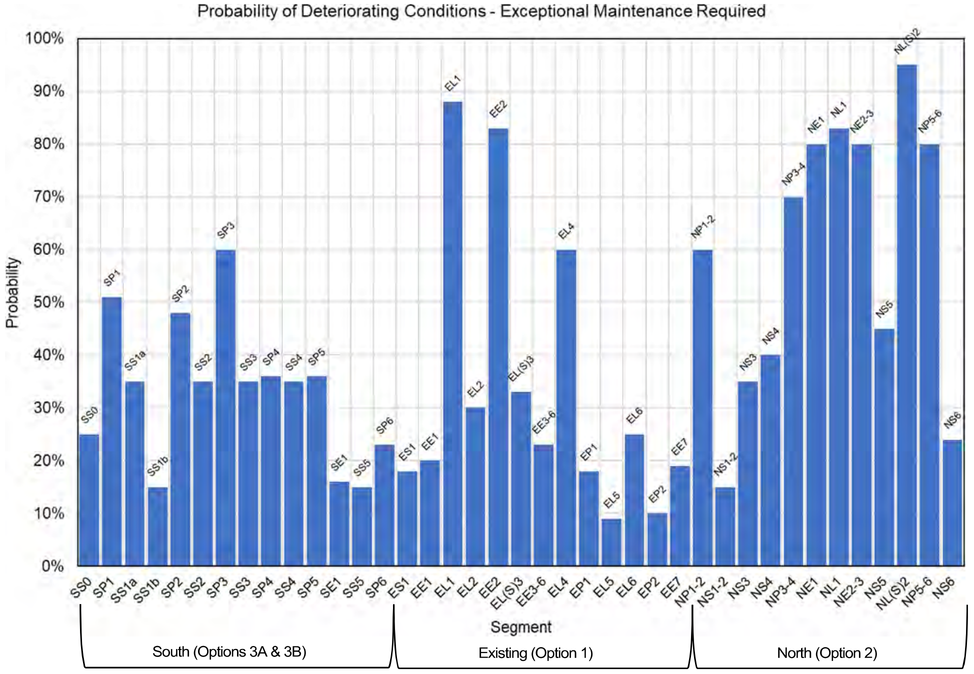


EBRA Results
Alignments





EBRA Results
Segments
(Sorted by Alignment)



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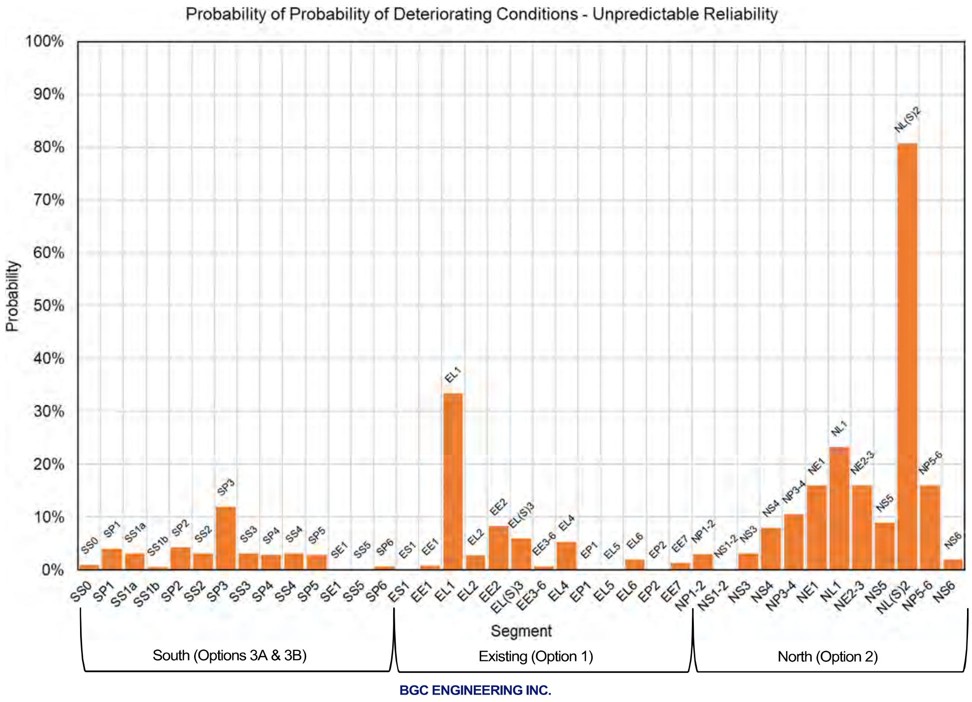
Probability of Probability of Deteriorating Conditions - Unpredictable Reliability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Probability
SS0
SP1
SS1a
SS1b
SP2
SS2
SP3
SS3
SP4
SS4
SP5
SE1
SS5
SP6
ES1
EE1
EL1
EL2
EE2
EL(S)3
EE3-6
EL4
EP1
EL5
EL6
EP2
EE7
NP1-2
NS1-2
NS3
NS4
NP3-4
NE1
NL1
NE2-3
NS5
NL(S)2
NP5-6
NS6
Segment
South (Options 3A & 3B)
Existing (Option 1)
North (Option 2)
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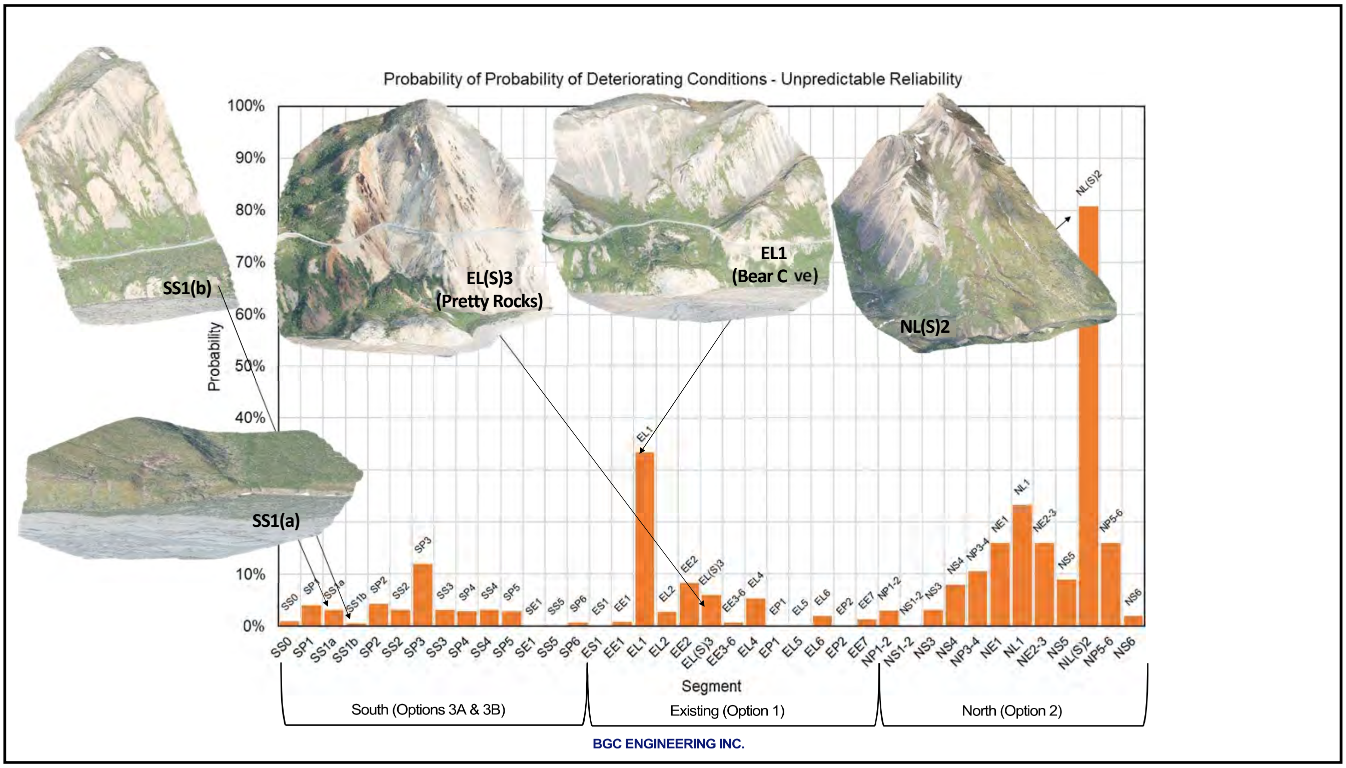
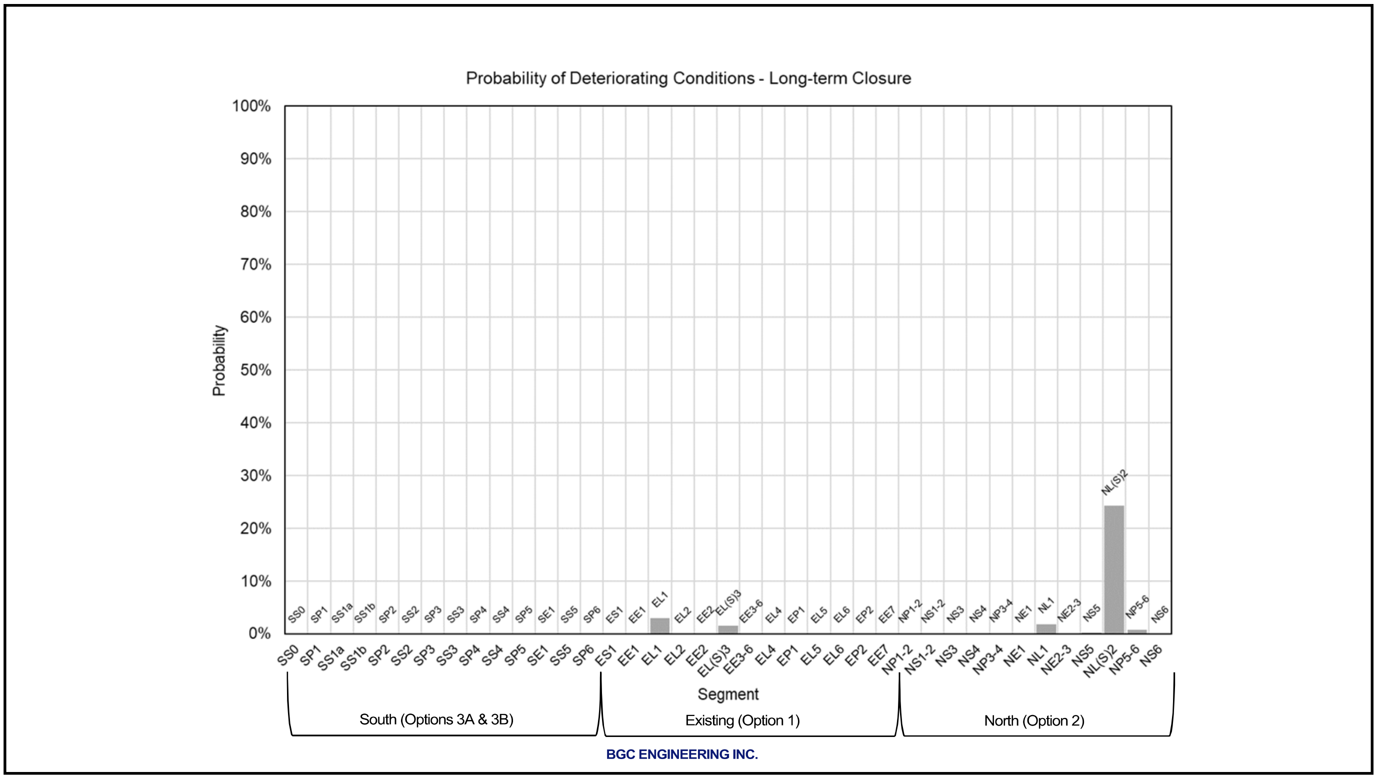

Probability of Probability of Deteriorating Conditions - Unpredictable Reliability
Probability
100%
90%
80%
70%
60%
50%
40%
10%
0%
SS1(b)
SS1(a)
EL(S)3
(Pretty Rocks)
EL1
(Bear C ve)
NL(S)2
SS0 SP1 SS1a SS1b SP2 SS2 SP3 SS3 SP4 SS4 SP5 SE1 SS5 SP6 ES1 EE1 EL1 EL2 EE2 EL(S)3 EE3-6 EL4 EP1 EL5 EL6 EP2 EE7 NP1-2 NS1-2 NS3 NS4 NP3-4 NE1 NL1 NE2-3 NS5 NL(S)2 NP5-6 NS6
Segment
South (Options 3A & 3B)
Existing (Option 1)
North (Option 2)
BGC ENGINEERING INC.


Probability of Deteriorating Conditions - Long-term Closure
Probability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
SS0 SP1 SS1a SS1b SP2 SS2 SP3 SS3 SP4 SS4 SP5 SE1 SS5 SP6 ES1 EE1 EL1 EL2 EE2 EL(S)3 EE3-6 EL4 EP1 EL5 EL6 EP2 EE7 NP1-2 NS1-2 NS3 NS4 NP3-4 NE1 NL1 NE2-3 NS5 NL(S)2 NP5-6 NS6
Segment
South (Options 3A & 3B)
Existing (Option 1)
North (Option 2)
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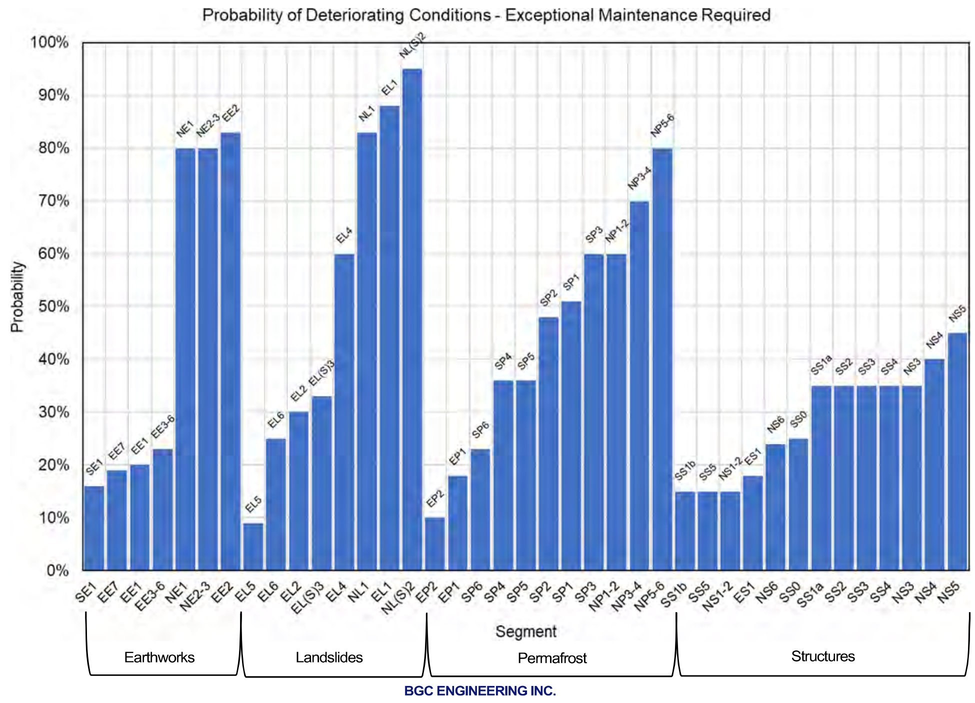
EBRA Results
Segments
(Sorted by Earthwork, Landslides, Permafrost, and Structures)


Probability of Deteriorating Conditions - Exceptional Maintenance Required
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Probability
SE1
EE7
EE1
EE3-6
NE1
NE2-3
EE2
EL5
EL6
EL2
EL(S)3
EL4
NL1
EL1
NL(S)2
EP2
EP1
SP6
SP4
SP5
SP2
SP1
SP3
NP1-2
NP3-4
NP5-6
SS1b
SS5
NS1-2
ES1
NS6
SS0
SS1a
SS2
SS3
SS4
NS3
NS4
NS5
Segment
Earthworks
Landslides
Permafrost
Structures
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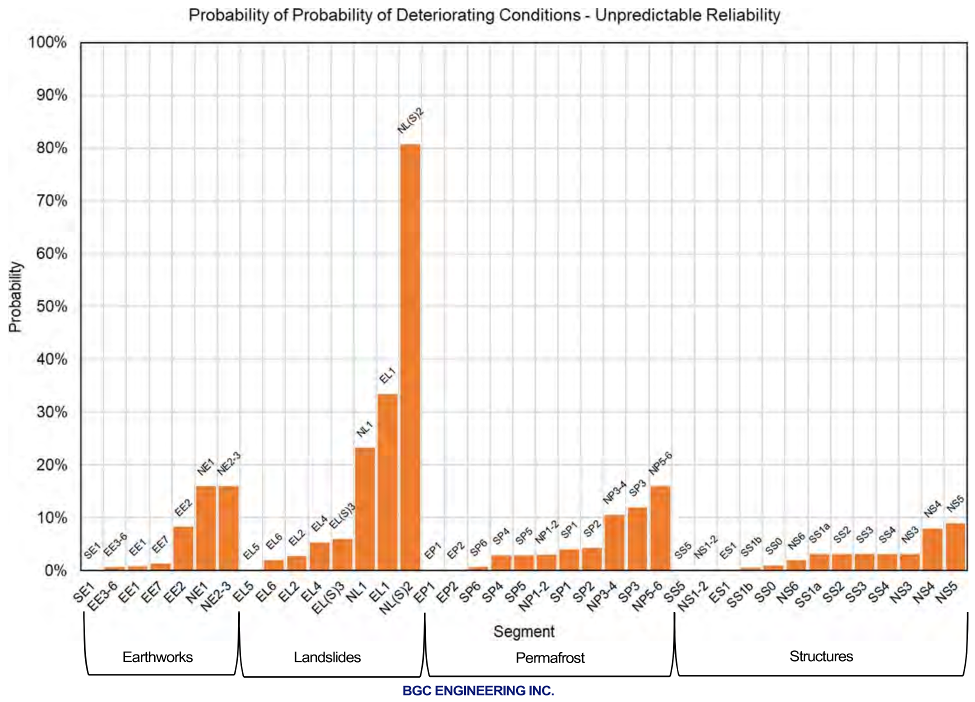
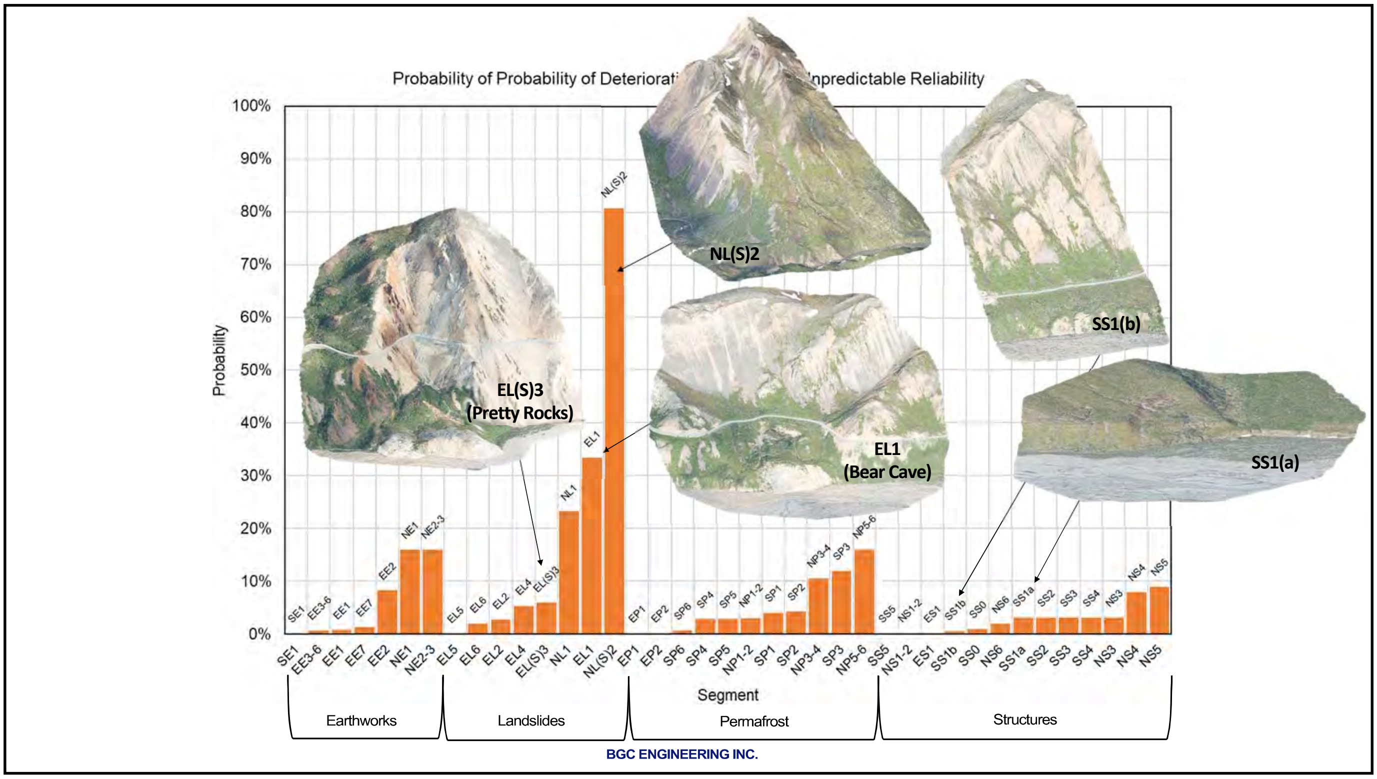
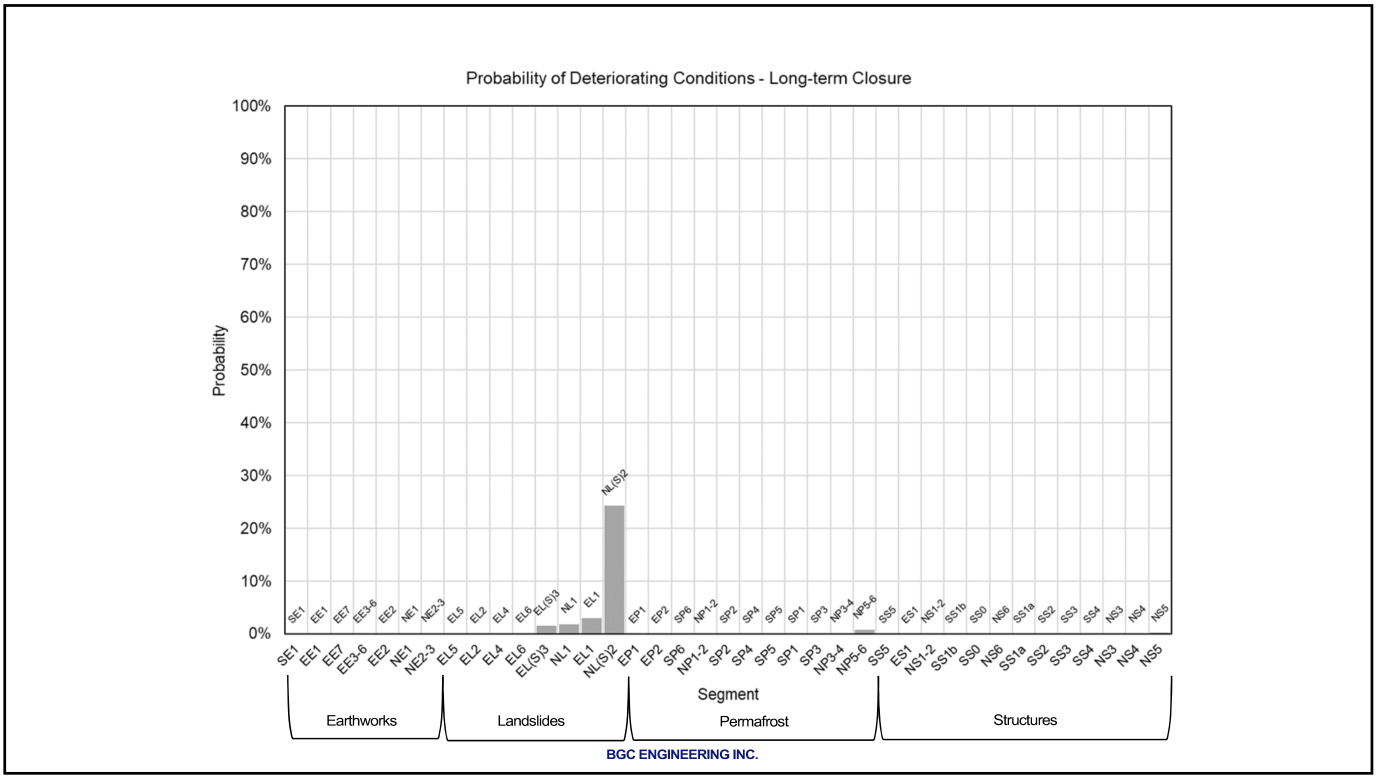

Probability of Probability of Deteriorating Conditions - Unpredictable Reliability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Probability
SE1
EE3-6
EE1
EE7
EE2
NE1
NE2-3
EL5
EL6
EL2
EL4
EL(S)3
NL1
EL1
NL(S)2
EP1
EP2
SP6
SP4
SP5
NP1-2
SP1
SP2
NP3-4
SP3
NP5-6
SS5
NS1-2
ES1
SS1b
SS0
NS6
SS1a
SS2
SS3
SS4
NS3
NS4
NS5
Segment
Earthworks
Landslides
Permafrost
Structures
BGC ENGINEERING INC.


Probability of Probability of Deteriorat… …npredictable Reliability
Probability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
SE1 EE3-6 EE1 EE7 EE2 NE1 NE2-3 EL5 EL6 EL2 EL4 EL(S)3 NL1 EL1 NL(S)2 EP1 EP2 SP6 SP4 SP5 NP1-2 SP1 SP2 NP3-4 SP3 NP5-6 SS5 NS1-2 ES1 SS1b SS0 NS6 SS1a SS2 SS3 SS4 NS3 NS4 NS5
Segment
Earthworks
Landslides
Permafrost
Structures
NL(S)2
EL(S)3
(Pretty Rocks)
EL1
(Bear Cave)
SS1(b)
SS1(a)
BGC ENGINEERING INC.


Probability of Deteriorating Conditions - Long-term Closure
Probability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
SE1 EE1 EE7 EE3-6 EE2 NE1 NE2-3 EL5 EL2 EL4 EL6 EL(S)3 NL1 EL1 NL(S)2 EP1 EP2 SP6 NP1-2 SP2 SP4 SP5 SP1 SP3 NP3-4 NP5-6 SS5 ES1 NS1-2 SS1b SS0 NS6 SS1a SS2 SS3 SS4 NS3 NS4 NS5
Segment
Earthworks
Landslides
Permafrost
Structures
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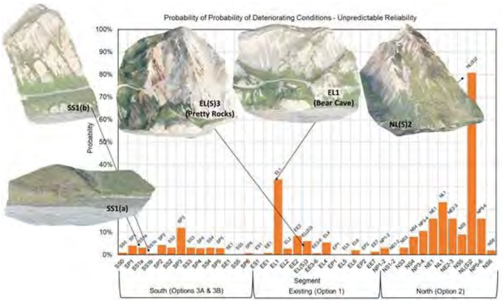
Discussion

- EBRA evaluated risk to long-term performance objectives
- “Maintenance” activities for many segments will likely be higher than typical
- “Reliability” is a key differentiator between alternatives
- Greatest “Closure” potential at NL(S)2
- Option 3 is judged most likely to meet long-term performance objectives (as defined for EBRA)
- Potential re-evaluation by judgment
- Potential data-driven assessment



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Appendix D: High Line Road Cultural Report

National Park Service
U.S. Department of the Interior

The "High Line" Road

A Summary of the Decision to Build the Park Road into the Mountainside at Polychrome Pass

Cultural Resource Report 2019-DENA-014

Value Analysis Study
Denali Park Road - Polychrome Area Re-Route
Denali National Park and Preserve
July 13-16, 2020

ON THE COVER
Photograph of Bus going over the “High Line” section of the Park Road
Photograph courtesy of the National Park Service (DENA 2262)

The “High Line” Road

A Summary of the Decision to Build the Park Road into the Mountainside at Polychrome Pass

Cultural Resource Report 2019-DENA-014

Erik K. Johnson

National Park Service
Denali National Park
PO Box 9
Denali, AK 99755

June 2019

U.S. Department of the Interior
National Park Service
Cultural Resources Program
Alaska Regional Office

The Alaska Road Commission (ARC) began the process of building the trans-park road into Mount McKinley National Park in 1922. That year, the ARC brushed a trail across the park via Sable, Polychrome, Highway, and Thorofare Passes to the foot of Muldrow Glacier, then to the McKinley River and the north out of the boundary towards Wonder Lake and on to the Kantishna Post Office located near the confluence of Moose and Eureka Creek.[1] The process of road construction followed this rough 1922 alignment for the next sixteen years.

In 1922, the Alaska Road Commission brushed a trail from McKinley Park Station to Kantishna. They erected tripods and mileposts to mark the trail and also erected eight 10'x10' tents for shelter at 12 to 15 mile intervals. This tent was located near the site of the current East Fork Cabin. ARC maps indicate that the initial trail was on a lowland route through the Polychrome Area. (Photo by George Flood in 1923 or 1924, DENA 10501).

Detailed road plans were never drafted, but the National Park Service's (NPS) desired road standard was documented in 1924 correspondence between Assistant NPS Director Arno Cammerer and ARC President James Steese. Cammerer wrote:

> The Service [NPS] desires to have observed in the location and construction of this road; namely, that special attention be given to its location to the best advantage in giving the visitor going over the road the best possible views and vistas of the country, avoiding straight line in road location and consequent cutting through hillside and forest growth merely to constitute it the shorter way between two points; in other words, in our road projects in the parks we desire to avoid long straight lines that some road engineers in this country have considered desirable in many cases . . . You, Major Gotwals, and I discussed

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[1] "1923 Report of Director of National Park Service," Bill Brown Collection, Box 31, DENA Museum.

> this while you were here, and we were all of one mind in this matter. I am merely mentioning it here to put it on record as a reminder of our chat.[2]

ARC leaders began using Cammerer's 1924 letter as the road standard. Malcolm Elliott, who succeeded Steese as ARC President, wrote a 1928 road report to the NPS emphasizing that the road was "located with a view to developing the scenic possibilities of the route." In the same report he indicated that the road was constructed to Mile 40 but the location west of that point was undetermined.[3]

A major recommendation regarding road placement occurred when NPS Landscape Architect Thomas Vint arrived at the park in August 1929. The mission of his visit was to identify a location for a park hotel and to inspect road construction.[4] By 1929, ARC had built the park road as far as the East Fork River and was set to build through to the middle fork of the Toklat via an area called Polychrome in 1930. Several months after his visit, Vint drafted a report, and much of what is known about the decision to construct the park road up high alongside the mountains in Polychrome Pass comes from this document. Vint was ultimately adhering to the scenic values stated by Cammerer five years prior.

Thomas Vint visited Mt. McKinley National Park in 1929 and made the decision to build the "High Line" road over Polychrome Pass. He traveled with ARC District Superintendent M.C. Edmunds, Park Superintendent Harry Liek, Mt. McKinley Tourist & Transportation Company President Jim Galen, and Judge Albert Galen of Montana (Vint Report, RG 79, Central Classified Files, 1907-1949, Entry 10, Box 373, NARA College Park).

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[2] Cammerer letter to Steese, April 9, 1924, Bill Brown Collection, Box 30, DENA Museum.

[3] 1928 Alaska Road Commission Annual Report to the National Park Service, Bill Brown Collection, Box 30 DENA Museum.

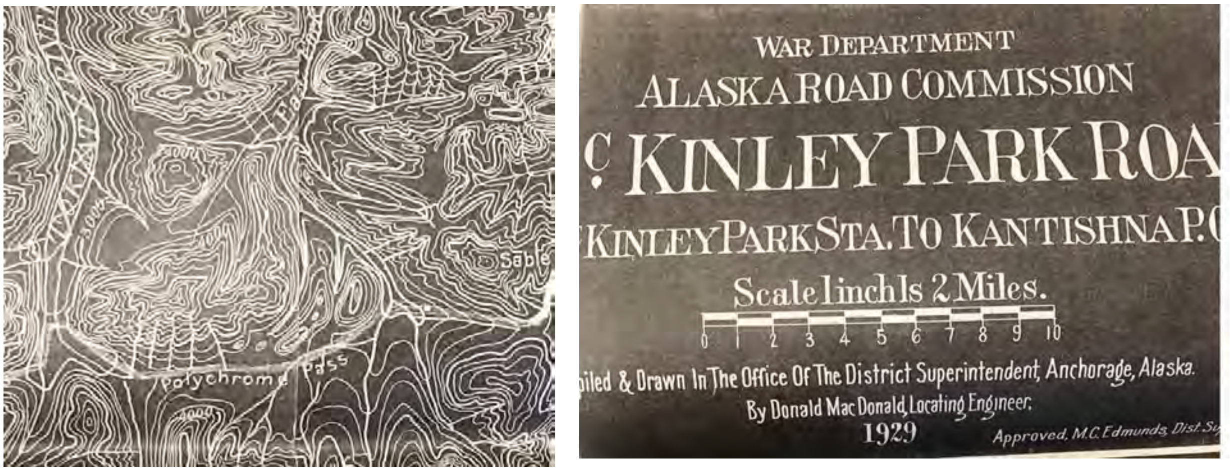
[4] Thomas C. Vint, "Report on Mt. McKinley National Park," (San Francisco: 1929), 9.

Before Vint discussed the alignment of the road, he detailed the lack of ARC road construction plans, “Like many organizations that do both engineering and construction, there is a minimum engineering work done. Sufficient surveying is done to supervise the construction, but no road plans are prepared and no quantities are available.”[5]

Vint also described road building challenges:

> Construction is difficult and unusual in this type of country. It is first necessary to remove the moss cover and build ditches along the right of way to allow the subsoil to thaw and drain, for a season. The next season the grading is done. For several seasons following the subsoil continues to thaw and settle so more or less grading must be done each year until the grade is established. Stage construction is necessary due to these special conditions. The standard of width is a one way road with turnouts. This is ample for the traffic that will be using this road for many years to come.[6]

In judging the road work that still needed to be accomplished, Vint outlined the necessary approach. He wrote, “The serious point of the road program by the Road Commission is the matter of engineering standards. From a park viewpoint and a landscape viewpoint this is important as we should avoid building sections of road that will be rebuilt. The location should be made according to the best standards in order that as far as we can foresee we will have but one road scar in the park.”[7]



A 1929 Alaska Road Commission map shows the Polychrome road alignment between the East Fork and the main Toklat River. The map shows the proposed road taking a lowland route. Vint recommended a “High Line” scenic route after his 1929 visit and the road was built into the Polychrome mountainside (1929 Alaska Road Commission Annual Report to the National Park Service, Bill Brown Collection, Box 30 DENA Museum).

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[5] Vint Report, 11.
[6] Vint Report, 12
[7] Vint Report, 12.

The "High Line" Decision

During Vint's visit to the park, road construction was almost complete to the East Fork River, but where the road would be built next was not clear to him in the ARC plans. Vint made a recommendation that became known as the "High Line" route:

> At present no plans are available to see what is planned. The survey stakes are all preliminary and few seem to be along the route of the survey that will be used. One section, between the East Fork Bridge and Polychrome Pass crosses two streams to avoid some heavy work. In discussing this, it was agreed that the road would finally be built on the location requiring the heavier work. The difference in cost is not known as both routes have not been surveyed. The heavier one is shorter, eliminates two bridges and is on a permanent location. I recommend that you authorize the more expensive line Superintendent Liek
>
> and Superintendent Edmunds of the Road Commission, know the conditions and the location being herewith recommended.[8]

By early 1930, NPS Director Albright supported and authorized Vint's recommendation in his report regarding the "High Line" route. Albright praised him for his report on Mount McKinley National Park which he described as "the most useful report that has yet been submitted on this park." In written correspondence, Albright informed Vint that the NPS was implementing his recommendation, "the more expensive location of the road between the East Fork Bridge and Polychrome Pass." The ARC engineers were "advised to stay on the same side of the stream throughout this section of highway." Albright also sent a telegram to ARC President Malcolm Elliott, which approved "relocation of highway between East Fork Bridge and Polychrome Pass which avoids all stream crossings but takes heavier excavation per Vint's discussion with [District Superintendent] Edmunds."[9]

Malcom Elliott wrote a letter to the NPS in August of 1930 explaining additional costs associated with building the "High Line" route and added praise for selecting the alignment:

> The increased cost due to the adoption of the high-line location is estimated by Mr. Edmunds at $30,000 but we cannot be certain that this will cover it as the amount of work will be dependent on the volume of rock which will be put in motion by cutting into the loose material along the bluff. . . . I completed recently an inspection of the work in McKinley Park and am very pleased with the progress. The high-line location at East Fork is going to be a very picturesque route and I believe well worth the cost.[10]

In his letter, Elliott also included the following seven photographs:

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[8] Vint Report, 13.

[9] Albright Letter to Vint, March 17, 1930, RG 79, Central Classified Files, 1907-49, Box 373, NARA College Park; Albright Memo to Elliott, January 18, 1930, RG 79, Central Classified Files, 1907-49, Box 375, NARA College Park.

[10] Elliot Letter to NPS, August 4, 1930, RG 79 Central Classified Files, 1907-49, Box 375, NARA College Park.

Foot trail on permanent road location. High Line, McK. P. July 1930

Figure 1. Malcolm Elliott High Line Photos (RG79, Box 379, Central Classified Files, 1907-1949, Roads Budget, NARA College Park)

Foot trail on permanent road location. High Line, McK. P., July 1930

Figure 2. Malcolm Elliott High Line Photos (RG79, Box 379, Central Classified Files, 1907-1949, Roads Budget, NARA College Park)

Figure 3. Malcolm Elliott High Line Photos (RG79, Box 379, Central Classified Files, 1907-1949, Roads Budget, NARA College Park)

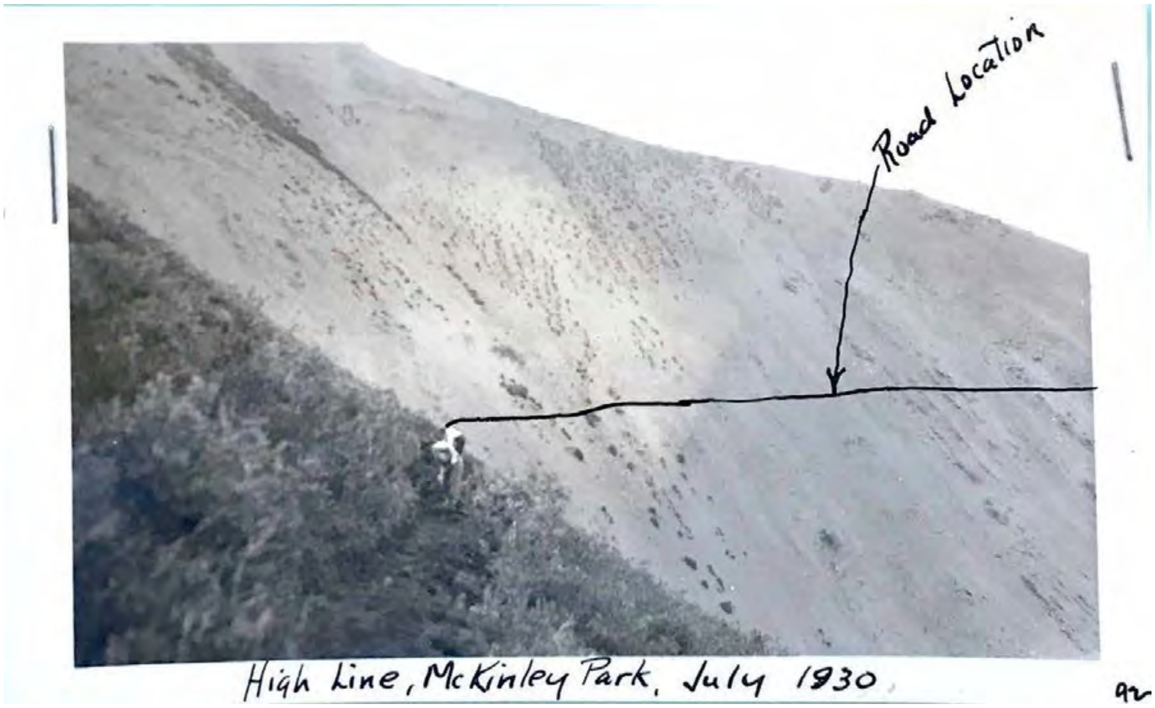

Figure 4. Malcolm Elliott High Line Photos (RG79, Box 379, Central Classified Files, 1907-1949, Roads Budget, NARA College Park)

High Line, McK. Park, July, 1930. Drilling 104

Figure 5. Malcolm Elliott High Line Photos (RG79, Box 379, Central Classified Files, 1907-1949, Roads Budget, NARA College Park)

Grading High Line McK. Park July 1930 1c

Figure 6. Malcolm Elliott High Line Photos (RG79, Box 379, Central Classified Files, 1907-1949, Roads Budget, NARA College Park)

Compressor on High Line, McK. Park, 1930

Figure 7. Malcolm Elliott High Line Photos (RG79, Box 379, Central Classified Files, 1907-1949, Roads Budget, NARA College Park)

A 1930 report of the NPS Director described the slow progress being made on the road and also expressed satisfaction with the route selected:

> From Mile 43 the road extends along the side of a mountain for a distance of about 5 miles and as 8 miles of this are heavy roadwork, the progress has been rather slow in this section. This part of the highway is the first in the park from a scenic standpoint, and is known as the High Line, as it reaches an altitude of about 1,000 feet above the rivers and affords an unexcelled view of Mount McKinley and Muldrow Glacier.[11]

NPS Director Horace Albright arrived at the park in 1931 to inspect progress on the road and also looked into potential park hotel locations. Albright commended Vint for his recommendation to build the scenic “High Line” route, “I inspected the so-called ‘High-Line’ road between the East Fork Toklat and the main Toklat River which you suggested two years ago when you were here. This road is on a splendid location, and is one of the most scenic highways in the National Park system. I want you to know that I am immensely pleased with this road.”[12]

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[11] “1930 Report of the NPS Director,” William Brown Collection, Box 31, DENA Museum.

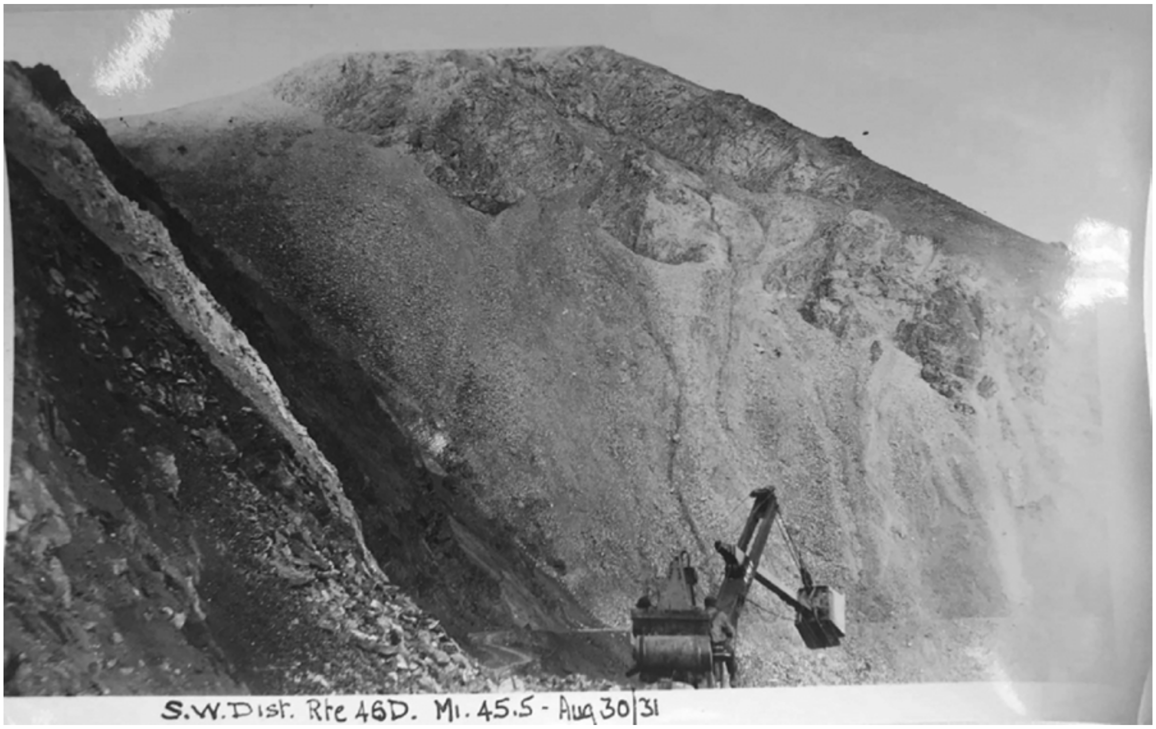
[12] Albright Letter to Vint, Aug 18, 1931, RG79, Central Classified Files, 1907-49, Box 273, NARA College Park.

Building the High Line route (Alaska State Library, Alaska Road Commission Collection, 61-2-230)

Blasting the High Line route (Alaska State Library, Alaska Road Commission Collection, 61-18-127).

In his letter to Vint expressing praise, Albright reaffirms his commitment to the road standards in place but also admits that the "High Line" is an exception to the standard, "I shall hold to the present standards of highway building, except, of course, in the case of opportunities such that you seized between the East Fork and the main Toklat."[13]

The 1931 NPS Report of the Director proudly described the new section of the road that was completed that summer, "The new Polychrome Pass section was opened late in August, and is one of the great sections of national park highway. Built to all modern standards, except in width, this stretch of road affords a spectacular outlook over Polychrome Pass, the Alaska Range, and the branches of the Toklat River."[14]



High Line Road being built in 1931 (Edmunds Collection, Box 1, Anchorage Museum)

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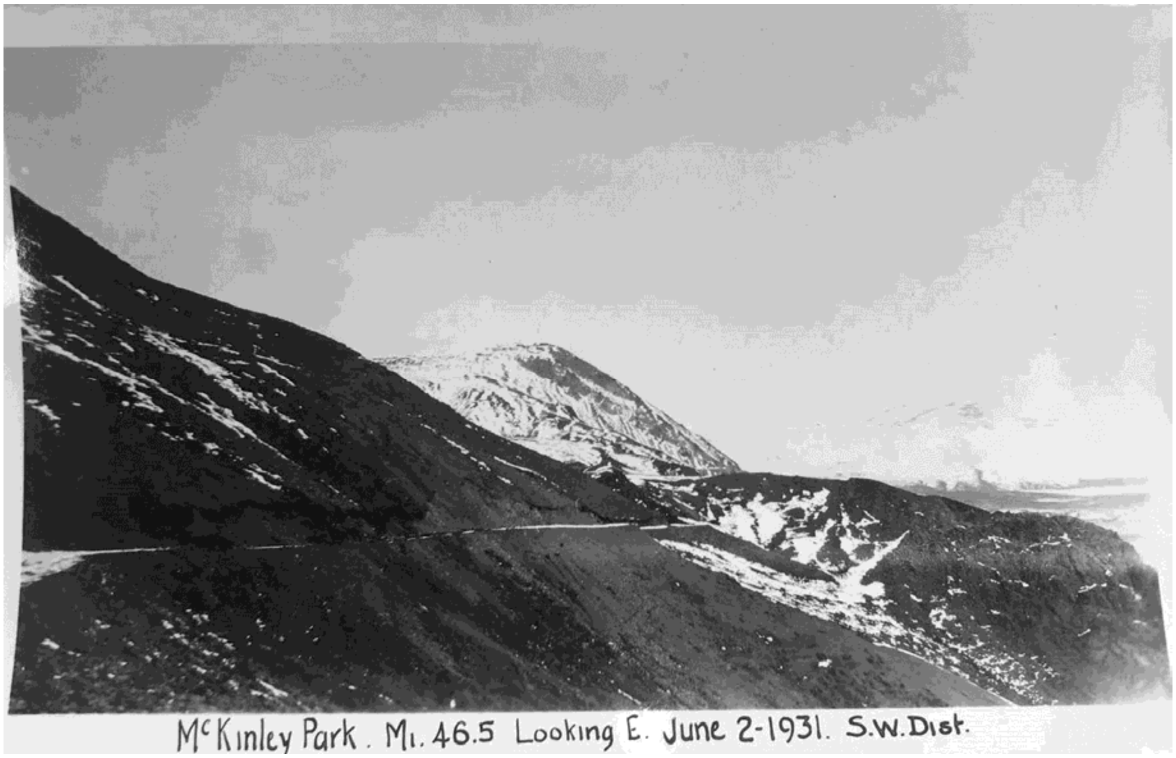
[13] Albright Letter to Vint, Aug 18, 1931.
[14] 1931 Report of the Director of the National Park Service, William Brown Collection, Box 31, DENA Museum.

High Line Road being built in 1931 (Edmunds Collection, Box 1, Anchorage Museum)



High Line Road being built in 1931 (Edmunds Collection, Box 1, Anchorage Museum)

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