LAKESHORE ROAD
ELEPHANT BUTTE STATE PARK
SIERRA COUNTY, NM
NM FLAP SIE 10(1)

FINAL Geotechnical Report

Prepared by
Federal Highway Administration
Central Federal Lands Highway Division

Geotechnical Services Branch
June 2022

SIGNATURE SHEET

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SECTION ONE - Scope and Purpose

This report presents the results of the geotechnical engineering assessment and provides recommendations for the Lakeshore Road work to be performed in Sierra County, New Mexico. The project proposes to construct two new bridges and two new multi-barrel box culverts along Lakeshore Road, which is located within the Elephant Butte State Park. A fifth site with an improved water crossing was proposed within the original project scope but was later removed after the 70% site visit. A site map is presented on Plate 1 of this report.

1.1 BACKGROUND AND LOCATION

Lakeshore Road is a major access route for the North Side of Elephant Butte Reservoir. It also provides primary access to housing subdivisions, and emergency access to the north part of the park. The road has been damaged by heavy rainstorms, and maintenance efforts have been inadequate to address the full extent of the problem. Current drainage structures are undersized for the flows at five major drainage crossings, and New Mexico State Parks does not have the means to make the upgrades necessary to avoid continued deterioration of the roadway. The flooding and washouts cause serious public safety threats.

1.2 SCOPE AND PURPOSE

The purpose of this project is to improve five stream crossing sites by addressing capacity of drainage structures and safety concerns within the Lakeshore Road corridor. The scope of this project includes drainage improvements, bridge construction, and approach road reconstruction. Two new bridges and two new multi-barrel concrete box culverts are proposed to be constructed along Lakeshore Road to allow a greater flow of water and debris, reduce roadway damage, and permit safe passage for the public.

The geotechnical scope of work included a subsurface investigation, analysis, and recommendations for foundation construction and cuts and fills within the project limits for use in design and construction. This involved several tasks including field reconnaissance, subsurface sampling, laboratory testing, interpretation and correlation of field measurements, and geotechnical engineering analysis. Specifically, this investigation was conducted to determine soil profiles at the proposed culvert and bridge locations, and to develop recommendations concerning bridge foundations, culvert foundations, embankments, material shrink/swell, geologic hazards, and construction considerations for the design and construction of bridges, culverts, and slopes within the alignment. The stationing in this report is based on the preliminary 70% design plans, dated February 2022.

SECTION TWO - Geology and Seismicity

2.1 REGIONAL GEOLOGY

The Lakeshore Road project is located within the Mexican Highland section of the Basin and Range physiographic province. Along the eastern extent of this section is the Rio Grande rift; a northerly-trending continental rift zone that extends from northern Colorado to northern Mexico (Kelley, 2021). During the last 70 million years this area has been affected by compression, regional volcanism, and most recently, extension, that lead to the development of the Rio Grande rift 35 million years ago. By far, the majority of structures in the project area are normal and oblique-slip faults related to the Rio Grande rift. Early rift structures are the result of northeast-southwest extension, and late rift structures are the result of east-west extension (Harrison et al., 1993). The regional lithology represents deposits from four episodes of mountain formation events, several major cycles of sea level rise and retreat, and young volcanic eruptions.

The area first experienced a compressional phase associated with the Laramide orogeny during Paleocene to early Eocene time (55 to 45 Ma), forming large fault-propagation folds and thrust faults (Harrison et al., 1993). The compression event formed west-northwest to north-south trending basement uplifts bounded by high-angle reverse faults and low-angle thrust faults (Nelson, 1986; Seager and Mack, 2003; Harrison and Cather, 2004). Following this event, expansion and associated regional volcanism took place from late Eocene to Oligocene (36 to 27 Ma), having an effect mostly in mountain formations west and northwest of the project area. These mountains, the San Mateo Mountains and the Black Range, contain remnants of volcanoes and calderas that formed during this time (Lozinsky et al., 1995). This area, contained within the Mogollon-Datil volcanic field, distributed layers of ash-flow tuff and basalt flows across southern New Mexico. Finally, near the end of the Oligocene (25 Ma), extension lead to the formation of two major deep basins, the Engle and Palomas Basins.

2.2 SITE GEOLOGY

The project alignment begins north of Elephant Butte and west of Elephant Butte reservoir. Across the project, there is an overall consistency and similarity in geology, generally displaying piedmont and axial-fluvial facies. These deposits are derived from shifting streams and drainage networks. All sites are underlain by the Santa Fe Group (Tsf), which includes deposits from the Oligocene through Pleistocene epochs. Of this group, the project area predominately displays the younger deposits from the Quaternary period. These deposits include ancestral (axial) river facies (QTpa) underlain by piedmont facies (QTpp), and create a generalized subsurface profile consisting of a sequence of sand layers with varying clay, silt, and gravel content, interspersed with relatively thin, isolated lenses of clay or gravel and cobbles. Soils overall display little to no cementation, but weak to moderately cemented sand layers may be found locally. Due to the fluvial derivation, deposits may vary both laterally and vertically in thickness and material content/property. While these sedimentary deposits belong to larger formations and groups, they are not classified as rock for engineering purposes. These units are relatively young and have been subject to minimal to moderate consolidation and cementation, typically classifying as very dense soils based on their engineering behavior and rippability.

Refer to Plate 2 to view the geologic map and further unit descriptions that correspond to the four (4) project sites along Lakeshore Road.

2.3 GEOLOGIC HAZARDS

Geologic hazards exist from both the natural environment of the project site and from existing and proposed structures. The main geologic hazards that may exist within the vicinity of the project limits are debris flows and scour. Superficial material consists of loose, fluvial deposits (generally sand, gravel, and cobbles) that will flow easily during periods of high precipitation, risking damage to roadways and clogging of drainage structures. Additionally, as the project is constructed on loose alluvium, these materials may be susceptible to erosion and caving, and should be stabilized as necessary during construction.

2.4 REGIONAL SEISMICITY

Three seismic source faults are mapped within 50 miles of the project area. These faults are summarized below in Table 2.1. The Caballo Fault is located south of the project, the San Andres Mountains Fault to the east, and the Socorro Canyon Fault Zone to the north. All faults exhibit a slip rate of less than 0.0079 inches per year, with the most recent deformation taking place in the last 15,000 years on the San Andres Mountains Fault.

Table 2.1 – Summary of Nearby Faults

FAULT OR FAULT ZONE	DISTANCE FROM CENTER OF PROJECT *(miles)*	FAULT PARALLEL SLIP RATE *(inch/year)*	FAULT LENGTH *(miles)*	TIME OF MOST RECENT DEFORMATION *(years)*
Caballo Fault	9.6	<0.0079	26.1	<750,000
San Andres Mountains Fault	36.1	<0.0079	70.2	<15,000
Socorro Canyon Fault Zone	43.1	<0.079	30.4	<130,000

2.5 SEISMIC DESIGN PARAMETERS

Recommended seismic response parameters for the Lakeshore Road site design are based on the American Association of State Highway and Transportation Officials (AASHTO) LRFD Bridge Design Specifications, 8th Edition, 2017, and represents horizontal peak ground acceleration (PGA) with 7 percent probability of exceedance in 75 years (approximate 1,000-year return period). The 1,000-year return period uniform hazard spectrum for the Lakeshore Road Project site, centrally located at 33°14'28.61"N latitude & 107°12'9.45"W longitude, was obtained in accordance with the AASHTO ground motion maps.

Based on the material encountered and tested during drilling, the average Standard Penetration Test (SPT) blow count (blows per foot) (ASTM D1586) for the top 100 feet of the soil profile was estimated to be greater than 50 blows per foot. Therefore, the site is classified as **Class C** according to the site class definitions specified in Table 3.10.3.1-1 of AASHTO. The recommended spectral acceleration coefficient values for probabilistic design are summarized below in Table 2.2.

Table 2.2 - Summary of Seismic Parameters Corrected for Site Class C

Factored Horizontal Peak Ground Acceleration (A_s)	0.09g
Factored Horizontal Response Spectral Acceleration at Period of 0.2 sec (S_{DS})	0.209g
Factored Horizontal Response Spectral Acceleration at Period of 1.0 sec (S_{D1})	0.095g
Site Factor at Zero-Period of Acceleration Spectrum (F_{PGA})	1.2
Site Factor at Short-Period of Acceleration Spectrum (F_A)	1.2
Site Factor at Long-Period Range of Acceleration Spectrum (F_V)	1.7

Based on the long acceleration coefficient S_{D1} value of 0.095g, the project is assigned to seismic hazard **Zone 1** in accordance with Table 3.10.6-1 of AASHTO. Seismic hazard zones reflect the variation in seismic risk in different regions needing different requirements for design as depicted in Table 4.7.4.3.1-1 in AASHTO. Due to the project location being classified as Zone 1, a seismic analysis is not required per AASHTO 4.7.4.3.1.

SECTION THREE - Subsurface Investigation

3.1 SUBSURFACE EXPLORATION PROGRAM

A subsurface investigation targeting five sites (fifth site removed from project scope post 70% review) along Lakeshore Road was performed by a Central Federal Lands Highway Division (CFLHD) of the Federal Highway Administration (FHWA) geotechnical engineer on January 19 through 23, 2021. The subsurface investigation also included a pavements and hydraulics investigation. The geotechnical subsurface exploration program consisted of drilling a total of seven borings ranging from depths of approximately 39 to 100 feet deep. One boring was drilled at each of the two box culvert locations (Sites 1 and 2), one boring was drilled near each bridge abutment for the two bridge locations (Sites 3 and 4), and one boring was drilled at the low water crossing (Site 5, later removed).

The pavements investigation included three 5-foot borings at Sites 2, 3, and 5. Though originally planned, no additional pavement borings were drilled at sites 1 and 4 as the geotechnical borings, BH21-01 and BH21-05, provided adequate subsurface information and sampled material. Results of the pavements investigation and design are presented under separate cover in the Final Pavements Technical Memorandum dated October 22, 2021.

For both the geotechnical and pavements investigations, a combination of hollow stem auger and ODEX drilling was used. ODEX drilling was utilized at the beginning of the investigation program, but proved inadequate to reach the desired depth at the bridge sites without the casing locking up and unable to advance further due to very dense and flowing sands. Beginning on the third day, January 21, hollow stem auger drilling was used exclusively to drill the remaining geotechnical and pavement borings. For the geotechnical investigation, standard penetration testing (SPT) and sample collection was performed at 5-foot intervals when possible. Bulk bucket samples were collected at each pavement boring and in the first 5 feet of the geotechnical borings BH21-01 and BH21-05. A single bucket sample of streambed material from each site was also collected for the hydraulics investigation.

Subsurface conditions were logged for the subsurface investigations and representative samples were collected and transported to the CFLHD Materials Laboratory in Lakewood, CO, for physical property testing. Logs of the explorations and boring locations are presented in Appendix A and Plates 3 through 7, respectively. Photographs related to this exploration can be found in Appendix C. A summary of the field exploration is provided in Table 3.1.

Table 3.1 - Summary of Field Exploration Program

EXPLORATION DESIGNATION	APPROXIMATE LOCATION[1]	APPROXIMATE GROUND ELEVATION[1] (feet)	APPROXIMATE TERMINATION DEPTH (feet)	APPROXIMATE DEPTH TO GROUNDWATER (feet)
BH21-01 (P-1) [2]	Site 1, Triple Box Culvert, STA 104+00, 8 ft LT	4,456.0	40.0	Not encountered
P-2	Site 2, Double Box Culvert, Pavement Boring, STA 205+61, 8 ft LT.	4,462.0	5.0	Not encountered
BH21-02	Site 2, Double Box Culvert, Sta 205+65.5, 8 ft LT	4,462.0	39.0	Not encountered
BH21-03	Site 3, S. Bridge Abutment, Sta 309+10, 8 ft RT	4,487.0	100.0	Not encountered
BH21-04	Site 3, N. Bridge Abutment, Sta 309+80, 7 ft RT	4,487.0	84.0	Not encountered
P-3	Site 3, Bridge, Pavement Boring, STA 309+87, 7 ft RT	4,487.0	5.0	Not encountered
BH21-05 (P-4) [2]	Site 4, S. Bridge Abutment, Sta 406+30, 8 ft LT	4,465.0	100.0	89.5
BH21-06	Site 4, N. Bridge Abutment, Sta 407+40, 8 ft LT	4,466.0	100.0	90.0
BH21-07	Site 5, Low Water Crossing, Sta 502+55.5, 8.5 ft LT	4,469.0	39.0	Not encountered
P-5	Site 5, Low Water Crossing, Pavement Boring, STA 502+60.5, 8.5 ft LT.	4,469.0	5.0	Not encountered

[1] The exploration locations were estimated relative to existing features. Ground elevations were estimated from Google Earth.
[2] Borings P-1 and P-4 were drilled within the geotechnical borings designated BH21-01 and BH21-05, respectively, and represent the upper 5 feet of the subsurface within the borehole.

3.2 LABORATORY TESTING PROGRAM

Soil samples recovered from the borings by SPT were tested in the laboratory to support the field classifications and to provide an estimate of the engineering characteristics and mechanical properties of the soil. Laboratory tests included moisture content (AASHTO T255), sieve analysis (AASHTO T 11 and T27), classification (AASHTO M145 and ASTM D 2487), and Atterberg limits (AASHTO T89 and T90). When the necessary tests were completed, samples were classified using the Unified Soil Classification System (USCS) and AASHTO soil classification system. Results of the testing are summarized below in Table 3.2 and are presented in Appendix B.

Table 3.2 - Summaries of Laboratory Index Test Results

BORING NUMBER	SAMPLE DEPTH (feet)	PERCENT GRAVEL	PERCENT SAND	PERCENT PASSING #200	LIQUID LIMIT	PLASTIC LIMIT	USCS CLASS.	AASHTO CLASS.
BH21-01 (P-1)	0 - 5	46	39	15	29	14	GC	A-2-6 (0)
BH21-01	10	8	84.8	7.2	NV	NP	SP-SM	A-3 (0)
BH21-01	15 - 35	1	57	42	NV	NP	SM	A-4 (0)
BH21-02	4 - 9	14	75	11	NV	NP	SW-SM	A-1-b (0)
BH21-02	14 - 19	8	85.2	6.8	NV	NP	SP-SM	A-1-b (0)
BH21-02	24 - 29	2	91.6	6.4	NV	NP	SP-SM	A-1-b (0)
P-2	0 - 5	14	72	14	NV	NP	SM	A-2-4 (0)
BH21-03	4 – 9	22	55	23	21	17	SC-SM	A-2-4 (0)
BH21-03	14 – 24	3	89.8	7.2	NV	NP	SP-SM	A-3 (0)
BH21-03	29	1	87	12	NV	NP	SP-SM	A-2-4 (0)
BH21-03	34 – 44	1	91	8	NV	NP	SP-SM	A-3 (0)
BH21-03	59 – 75	3	85	12	NV	NP	SW-SM	A-2-4 (0)
BH21-03	80 – 100	0	95.2	4.8	NV	NP	SP	A-3 (0)
BH21-04	9	21	66	13	NV	NP	SM	A-1-b (0)
BH21-04	19 – 24	2	90.4	7.6	NV	NP	SP-SM	A-3 (0)
BH21-04	29	16	59	25	NV	NP	SM	A-2-4 (0)
BH21-04	34 – 39	2	91.7	6.3	NV	NP	SP-SM	A-3 (0)
BH21-04	39	0	37	63	*	*	*	*
BH21-04	74 – 79	2	89.1	8.9	NV	NP	SP-SM	A-3 (0)
P-3	0 - 5	14	68	18	19	17	SM	A-1-b (0)
BH21-05 (P-4)	0 - 5	24	60	16	21	16	SC-SM	A-1-b (0)
BH21-05	5 - 10	6	61	33	23	18	SC-SM	A-2-4 (0)
BH21-05	15 - 20	2	84	14	NV	NP	SM	A-2-4 (0)
BH21-05	25 - 35	2	92.2	5.8	NV	NP	SP-SM	A-3 (0)
BH21-05	50 - 60	2	91.5	6.5	NV	NP	SP-SM	A-3 (0)
BH21-05	75 - 80	0	89	11	NV	NP	SW-SM	A-2-4 (0)
BH21-05	90 - 95	0	94.5	5.5	NV	NP	SP-SM	A-3 (0)
BH21-06	5 - 10	8	82	10	NV	NP	SP-SM	A-3 (0)
BH21-06	35 - 50	1	93.9	5.1	NV	NP	SP-SM	A-3 (0)
BH21-06	60 - 65	3	91.4	5.6	NV	NP	SP-SM	A-3 (0)
BH21-06	65	0	16	84	63	21	CH	A-7-6 (38)
BH21-06	80 - 85	4	88.1	7.9	NV	NP	SP-SM	A-3 (0)
BH21-06	90 - 100	1	90.4	8.6	NV	NP	SP-SM	A-3 (0)
BH21-07	9	6	83	11	NV	NP	SW-SM	A-1-b (0)
BH21-07	14	3	91.1	5.9	NV	NP	SP-SM	A-3 (0)
BH21-07	19 - 24	4	87.4	8.6	NV	NP	SP-SM	A-3 (0)
P-5	0 - 5	53	42.7	4.3	NV	NP	GP	A-1-a (0)

* Not enough material provided for requested tests. Tests not completed.

Soil test results indicated a range of material types including poorly-graded gravels, well-graded and poorly-graded sands, silty sands, clayey sands, clayey gravels, and fat clays classifying as A-1-a to A-7-6 by AASHTO and GC, GP, SP-SM, SP, SW-SM, SM, SC-SM, and CH by USCS.

Moisture-density (AASHTO T 180 Method D) and R-value (AASHTO T 190) testing was performed on the bucket sample gathered from the first 5 feet in BH21-05 (P-4). Testing results are summarized below in Table 3.3.

Table 3.3 – Summary of Laboratory Engineering Property Tests for Soil Results

BORING NUMBER	SAMPLE DEPTH (FT.)	R-VALUE	OPTIMUM MOISTURE (%)	MAXIMUM DRY DENSITY (PCF)
BH21-05 (P-4)	0 - 5	44	7.1	132.3

3.3 SUMMARY OF SITE CONDITIONS

This section presents the results of the surface reconnaissance and subsurface exploration.

3.3.1 General Topography

The general topography of the project area is characterized by the Jornada del Muerto desert valley. Lakeshore Road lies within the Engle Basin and follows the western perimeter of Elephant Butte Reservoir. The Rio Grande River flows from the north into the Elephant Butte Reservoir. The basin is surrounded by the Black Range and San Mateo Mountains to the west and northwest, and the Fra Cristobal Range to the east. The surrounding mountains and tributary stream networks deposit alluvium within the basin, leading to expansive, loose sedimentary surficial material. Although surrounded by mountains, the terrain is flat to rolling, contains intermittent streams and arroyos, and is vegetated by small shrubs, brush, and scattered trees.

3.3.2 Surface Reconnaissance

Lakeshore Road is paved throughout the project limits and pavement conditions can generally be described as moderate. Pavement damage varies along the alignment from minor to full width cracking. The area surrounding Lakeshore Road consists of loose sand, gravel, and cobbles at or above roadway elevation. Intermittent stream channel networks and arroyos are present at each site and can be found along the entire alignment. Boulders up to 4-feet in diameter can be found downstream of drainage structures (most notably at Sites 3 and 4), and weak to moderately cemented sand layers were observed both near roadway elevation and within drainage channels at Sites 1 through 4. The cemented sand layers in general were able to be broken with the force of a hand, or a single, moderate blow from a geologic hammer, and indented with a fingernail. In addition to the weakly cemented sand, Sites 3 and 4 also contained moderately cemented sand layers where it took 1-3 blows of a geologic hammer to break. The cemented sands were classified as soils based on their observed mechanical behavior and presumed rippability. Boulders appeared to be placed for scour protection as they were only observed downstream of drainage structures.

Evidence for sediment overtopping the roadway during heavy rain events is common and is most notable at Sites 2, 4, and 5. Freshly graded areas are found along the roadway and near drainage structures as a result of clearing the road and inlets of material. In addition, large piles of material have been pushed and stockpiled off the roadway. At the time of the investigation, Site 5 had a thin layer of material partially to fully covering the roadway surface.

Drainage structures currently exist at each project site except Site 5. Other minor drainage structures may exist between site locations based on surficial sediment flow patterns crossing the existing alignment but are not easily identified. Existing structures consist of corrugated metal pipes (CMPs) of various sizes. CMPs were found to either be clear of debris or partially filled (approximately 1/3 or less). In general, the CMPs have grouted riprap or concrete aprons at the outlets. Heavy erosion is present underneath culvert outlets at Sites 1, 2, and 4 (Site 3 less severe). Scour has caused deep and severe undercutting of the CMPs and surrounding concrete protection. The downstream channels are generally deeply incised, ranging in depth from 3 to 10-feet, with locations of near vertical cuts in alluvial soils of the active stream channel.

3.3.3 Subsurface Conditions

The subsurface conditions at Site 1, proposed triple box culvert location, were investigated by drilling boring BH21-01. Hollow stem auger drilling was used from approximately 0 to 40 feet below the ground surface. The ground surface surrounding the boring location consisted of typical alluvial soils: namely silt, sand, gravel, and cobbles. Additionally, weak to moderately cemented sand layers were observed near the roadway surface. The boring encountered clayey gravel with sand to a depth of approximately 10 feet. The material then transitioned to very dense silty sands to the termination depth of 40 feet. Seams of very stiff clay were observed at depth of 32 feet and 35 feet. Neither groundwater nor bedrock was encountered in boring BH21-01.

The subsurface conditions at Site 2, proposed double box culvert location, were investigated by drilling boring BH21-02. ODEX drilling was used from 0 to 39 feet. Similar to Site 1 subsurface conditions, the ground surface consisted of silt, sand, gravel, and cobbles. Additionally, weak to moderately cemented sand layers were observed near the roadway surface. The boring encountered medium dense, well graded silty sand to a depth of approximately 10 feet, with a 1-foot-thick gravel layer at 7 feet. The soil then transitioned to dense silty sand with trace gravel and extended to the termination depth of approximately 39 feet. The subsurface conditions at Site 2 were also investigated by drilling boring P-2. Hollow stem auger drilling was used from 0 to 5 feet. The boring encountered silty sand with gravel to the termination depth. Neither groundwater nor bedrock was encountered in boring BH21-02 or P-2.

The subsurface conditions at Site 3, south abutment of proposed bridge location, were investigated by drilling boring BH21-03. ODEX drilling was used from approximately 0 to 59 feet, where the casing locked up and could no longer advance. Hollow stem auger drilling was then used to the termination depth of approximately 100 ft. The ground surface surrounding the boring location consisted of silt, sand, gravel, and cobbles. Additionally, the downstream channel displayed weak to moderately cemented sand layers and up to 3-foot diameter boulders, presumably placed for scour protection. The boring encountered medium dense clayey sand with gravel to a depth of approximately 12 feet. The material then transitioned to very dense silty sand to approximately 80 feet, and then a very dense poorly graded sand until the termination depth of 100 feet. Zones of clayey sands, up to 2 feet thick, were encountered at various depths throughout the boring and a weak to moderately cemented sand layer was encountered at 29 feet. Sand flowed approximately 6-inches into the casing at 75 feet but did not appear to occur again while drilling to the termination depth of 100 feet. Neither groundwater nor bedrock was encountered in boring BH21-03.

The subsurface conditions at Site 3, north abutment of proposed bridge location, were investigated by drilling boring BH21-04. ODEX drilling was used from approximately 0 to 84 feet. Drilling was terminated at 84 feet where the casing locked up and could no longer advance. Like the south abutment boring BH21-03, the ground surface surrounding the boring location consisted of silt, sand, gravel, and cobbles. Additionally, the downstream channel displayed weak to moderately cemented sand layers and up to 3-foot diameter boulders, presumably placed for scour protection. The boring encountered medium dense silty sand with gravel to a depth of approximately 12 feet. The material then transitioned to very dense, poorly graded sand with silt until a depth of approximately 84 feet. Very stiff clay seams were encountered at approximately 29 feet, 40 feet, 44 feet, 46.5 feet, and 70.5 feet with thicknesses of roughly 3, 1.5, 2, 1.5, and 2 feet, respectively. A weak to moderately cemented sand was encountered at approximately 29 feet within the clay layer. The subsurface conditions at Site 3 were also investigated by drilling boring P-3. Hollow stem auger drilling was used from 0 to 5 feet. The boring encountered silty sand with gravel and varying amounts of clay to the termination depth. Neither groundwater nor bedrock was encountered in boring BH21-03 or P-3.

The subsurface conditions at Site 4, south abutment of proposed bridge location, were investigated by drilling boring BH21-05. Hollow stem auger drilling was used from approximately 0 to 100 feet. The ground surface surrounding the boring location consisted of silt, sand, gravel, and cobbles. Additionally, the downstream channel contained up to 3-foot diameter boulders, presumably placed for scour protection. The boring encountered sand with gravel to a depth of approximately 4 feet. The material then transitioned to medium dense silty clayey sand to a depth of approximately 15 feet. The material then transitioned to very dense sand with silt to the termination depth of approximately 100 feet. Clay seams ranging from 0.5 inches to 5 inches were observed throughout the subsurface. Sand flowed approximately 1 foot into the casing at 100-foot depth. Groundwater was encountered at approximately 89.5 feet below the ground surface, but bedrock was not encountered in boring BH21-05.

The subsurface conditions at Site 4, north abutment of proposed bridge location, were investigated by drilling boring BH21-06. Hollow stem auger drilling was used from a depth of approximately 0 to 100 feet. Similar to the south abutment boring BH21-05, the ground surface surrounding the boring location consisted of silt, sand, gravel, and cobbles. Additionally, the downstream channel contained up to 3-foot diameter boulders, presumably placed for scour protection. The boring encountered sand with gravel to a depth of approximately 3 feet. The material then transitioned to very dense sand with silt to the termination depth of approximately 100 feet. Clay seams ranging from 2 inches to 4 inches were observed throughout the subsurface. Very stiff fat clay was also observed at 66 feet with a thickness of approximately 1 foot, and a weak to moderately cemented sand layer was encountered at approximately 45 feet. Groundwater was encountered at approximately 90 feet below the ground surface, but bedrock was not encountered in boring BH21-06.

The subsurface conditions at Site 5, proposed low water crossing location, were investigated by drilling boring BH21-07. ODEX drilling was used from approximately 0 to 39 feet. Similar to the other sites, the ground surface surrounding the boring location consisted of silt, sand, gravel, and cobbles. The boring encountered poorly graded gravel with sand until approximately 7 feet, and then sand with silt and gravel to the termination depth of approximately 39 feet. Overall, the gravel content tended to decrease with depth and the density tended to increase. Seams of very stiff clay were observed within the subsurface matrix but were not measurable. The subsurface conditions at Site 5 were also investigated by drilling boring P-5. Hollow stem auger drilling was used from 0 to 5 feet. The boring encountered poorly graded gravel with sand to the termination depth. Neither groundwater nor bedrock was encountered in boring BH21-07 or P-5. Improvements at Site 5 were removed from the project scope following the 70% design milestone.

3.3.4 Groundwater

Groundwater was encountered during drilling in boring BH21-05 and BH21-06 (Site 4) at approximately 89.5 and 90 feet below the ground surface for each boring, respectively. Groundwater was not encountered in any other borings or project sites. However, fluctuations in the groundwater level due to seasonal and climatic effects are expected and will likely be affected by water levels in the adjacent reservoir.

SECTION FOUR - Analysis & Recommendations

This section presents analysis and recommendations for the bridge foundations, box culvert foundations, abutment and culvert wingwalls, permanent earthworks, and construction considerations for the design and construction of the Lakeshore Road project. Based on discussions with the project team, proposed improvements included box culverts for Site 1 and Site 2 and new bridge construction for Site 3 and Site 4. Originally proposed improvements to the low water crossing at Site 5 were removed from the project scope following the 70% design milestone. Generalized subsurface profiles were developed based on field reconnaissance, surficial visual evaluation, and subsurface investigations.

4.1 BRIDGE FOUNDATIONS

The existing Site 3 and Site 4 locations consist of multi-run CMPs, which do not provide sufficient capacity for observed runoff. A simple single-span bridge structure is proposed for both bridge locations, with span lengths of 70 and 110-feet for Sites 3 and 4, respectively. Based on the preliminary 70% design plans, the proposed abutment centerline station and cap elevation are shown in Table 4.1.

Table 4.1 – Proposed Bridge Foundation Locations

SITE DESIGNATION	FOUNDATION	STATION[1]	TOP SHAFT ELEVATION[1]
Site 3- Long Point Bridge	Abutment 1 (South)	309+20.00	4,477.00
Site 3-Long Point Bridge	Abutment 2 (North)	309+90.04	4,477.00
Site 4-Cedar Canyon Bridge	Abutment 1 (South)	406+30.00	4,458.50
Site 4- Cedar Canyon Bridge	Abutment 2 (North)	407+40.00	4,457.95

[1] From preliminary 70% plan set.

4.1.1 Bridge Foundation Selection

A drilled shaft foundation system is proposed for both bridge sites along Lakeshore Road due to the deep sandy stratum and potential high scour of subsurface material. Spread footings were considered but determined impractical due to additional materials, time, and cost that would be required for construction. Spread footings would overall likely be less economical due to the size of the associated excavation and may not be able to accommodate the structure loads without being excessively large. Driven piles were also considered but determined impractical due to minimum lateral loading depths, the depths neglected due to scour, and the low density of the sandy alluvial materials to provide support at a reasonable depth.

A drilled shaft foundation is feasible from a geotechnical perspective. Drilled shafts can provide a small footprint, support large foundation loads, and provide lateral resistance at shallower depths than other deep foundation options. Scour potential was determined to be present at the abutments on both bridge sites and is discussed in detail in the Final Hydraulics Report dated May 26, 2022.

The following final bridge loads factored for the strength limit state were provided by the CFL bridge engineer on January 19th, 2022 and are shown in Table 4.2.

Table 4.2 – Bridge Loads and Drilled Shaft Configuration

SITE DESIGNATION	LOADS FACTORED FOR STRENGTH LIMIT STATE (kips)	SHAFT DIAMETER & SHAFTS PER ABUTMENT
Site 3	340 (per shaft)	4 x 30-inch shafts
Site 4	365 (per shaft)	4 x 30-inch shafts

4.1.2 Site Characterization

The subsurface profile was assumed to be entirely sand for analysis purposes. Although gravel, silt, cobbles, clay, and moderately cemented sands were encountered in the overburden materials of the designated boreholes, the soil matrix, in general, was of a sand-like nature and composition. Groundwater was also assumed to be at elevations of 4,437 (50-foot depth) and 4,406 (60-foot depth) feet for Site 3 and Site 4, respectively. These groundwater elevations were estimated from data during the investigation in combination with nearby well logs. A nearby well log to Site 3 encountered water at a depth of 63 feet, and a well log near Site 4 encountered water at a depth of 70 feet. Groundwater was only encountered at site 4 during the investigation at approximately 90 feet. Groundwater depths of approximately 10 feet shallower than the highest observed water table in the well logs were assumed for analysis.

4.1.3 Drilled Shaft Axial Resistance

The drilled shaft axial resistance analysis was performed for 24-inch and 30-inch diameter shafts at the abutments using the Beta Method for cohesionless soils presented in Section 10.8.3.5.2b of AASHTO. For analysis, N values were conservatively set to an upper limit of 50 in instances of refusal or N values more than 50 that did not reach refusal. A comparison between the 24-inch and 30-inch diameter shaft lengths was used to inform the final design selection of 30-inch diameter shafts. The abutment foundations will obtain their resistance through side friction and tip resistance. The factored resistance for the strength limit state was calculated by applying 0.55 and 0.50 resistance factors for side and tip resistance, respectively.

4.1.4 Group Effects and Construction Effects on Axial Resistance

The resistance of a shaft group to the applied axial loads is not necessarily the sum of the axial resistance of individual shafts within the group. The zone of influence from an individual shaft in a shaft group may intersect with other shafts, depending on the shaft spacing. Historically, the efficiency of groups of drilled shafts has not been a concern as long as the center-to-center spacing between shafts is greater than three times the shaft diameter (3D) to avoid interference between adjacent shafts, assuming a single row shaft group configuration. An efficiency factor (η) should be applied for spacing less than 3D as shown in Table 10.8.3.6.3-1.

Besides the effect of overlapping zones of influence, effects of construction on ground conditions in and around the group can be significant. Excavated deep foundation elements in cohesionless soils tend to decrease the effective stress of the surrounding soils. Poorly controlled shaft construction methods can result in soil loosening during drilling and adversely reduce the lateral stress around other shafts within the group. Casing driven in advance of excavation in sands may increase the relative density and effective stress of the surrounding soil and prevents caving of overburden material. If casing is used in construction, the possible effects on axial and lateral resistance may need to be considered. For this analysis, effects on axial and lateral resistance were not considered as it was assumed the casing would be removed or the temporary casing zone would be relatively small compared to the length of the shaft beneath this zone. If a significant amount of temporary casing or permanent casing along the entire shaft is to be used, the Geotechnical engineer should be informed to consider the effects on axial and lateral resistance and its impact on shaft length design.

4.1.5 Lateral Loads on Deep Foundations

Lateral load analysis was performed by the bridge engineer using the software program LPILE developed by Ensoft, Inc. This program analyzes a single pile or shaft considering deflection as a function of design loads, foundation construction, and subsurface conditions. Table 4.3 provides LPILE input parameters for the foundation soils based on available subsurface information and presumptive engineering correlations. It is recommended that lateral support above the scour elevation be neglected due to the potential loss of material during the design flood event.

Table 4.3 - LPILE Input Parameters

APPROXIMATE ELEVATION (FT)	DEPTH BELOW TOP OF BOREHOLE (FT)	LPILE P-Y MODEL	EFFECTIVE UNIT WEIGHT, γ' (PCF)	FRICTION ANGLE, Φ (DEG)	SOIL MODULUS, K_s (PCI)
SITE 3[1]					
4,487.00 to 4,475.00 (Abutment 1 & 2)	0 to 12 (Abutment 1 & 2)	Sand (Reese)	125	30	90
4,475.00 to 4,437.00 (Abutment 1 & 2)	12 to 50 (Abutment 1 & 2)	Sand (Reese)	125	34	225
4,437.00 to 4,387.00 (Abutment 1 & 2)	50 to 100 (Abutment 1 & 2)	Sand (Reese)	62.6	36	125
SITE 4[2]					
4,465.00 to 4,450.00 (Abutments 1) 4,466.00 to 4,451.00 (Abutment 2)	0 to 15 (Abutment 1 & 2)	Sand (Reese)	125	30	90
4,450.00 to 4,405.00 (Abutments 1) 4,451.00 to 4.406.00 (Abutment 2)	15 to 60 (Abutment 1 & 2)	Sand (Reese)	125	34	225
4,405.00 to 4,365.00 (Abutments 1) 4,406.00 to 4,366.00 (Abutment 2)	60 to 100 (Abutment 1 & 2)	Sand (Reese)	62.6	36	125

[1]Neglect support above the scour elevation (4470.7 feet).
[2]Neglect support above the scour elevation (4443.5 feet).

Material properties provided are for single shafts and do not account for the reduced lateral resistance of shafts in a group. P-multipliers are a function of the number of rows of shafts and center-to-center shaft spacing in the direction of loading. P-multipliers are required even for a single row of shafts if the center-to-center spacing is less than 5 shaft diameters. P-multipliers are specified in Table 10.7.2.4-1 in AASHTO. When this analysis method is used, the resistances at the strength limit state as represented by the P-y curves should not be factored since they already represent the nominal conditions.

4.1.6 Settlement

Settlement is expected to be less than 1 inch for both bridges. A resistance factor of 1.0 for the service limit state is recommended to assess the ability of the foundation to meet the specified deflection criteria. Elastic settlements will occur immediately and be essentially complete at the end of construction and are estimated to be less than one inch at all locations based on the loads provided. Differential settlements are not anticipated. Shaft group settlement is not anticipated.

4.1.7 Recommended Shaft Lengths

The final lengths of the drilled shafts are based on both axial and lateral loading. Table 4.4 below shows the required shaft lengths needed for both axial and lateral capacities. This is based on the selected shaft diameter of 30 inches. Plates 12 through 15 of this report present a visual representation of axial, single shaft capacity versus shaft length.

The lateral capacities needed to meet loading requirements were determined to control the design shaft tip elevations for both Site 3 and Site 4 bridges along Lakeshore Road. Minimum tip elevation must be achieved, regardless of estimated tip capacity, and cannot be allowed to terminate at a shallower depth.

Table 4.4 – Required Shaft Lengths for Axial and Lateral Capacity

STRUCTURE ELEMENT	REQUIRED SHAFT LENGTH FOR AXIAL CAPACITY *(feet)*	REQUIRED SHAFT LENGTH FOR LATERAL CAPACITY[1] *(feet)*	MINIMUM TIP ELEVATION *(feet)*
SITE 3 BRIDGE- Lost Canyon Bridge			
Abutment 1 (South)	23	30[1]	4447.00
Abutment 2 (North)	23	30[1]	4447.00
SITE 4 BRIDGE- Cedar Canyon Bridge			
Abutment 1 (South)	33	45[1]	4413.50
Abutment 2 (North)	33	45[1]	4412.95

[2] Controlling case to determine minimum tip elevation.

4.1.8 Field Testing

Steel crosshole sonic logging tubes (1.5-inch diameter steel tubes) should be installed in all drilled shafts prior to concrete placement for integrity testing. The recommended number of access tubes and tube spacing are dependent on the selected shaft diameter, typically one access tube per 12-inches of shaft diameter, with a minimum of three access tubes per shaft. The crosshole sonic logging tests should be conducted in accordance with ASTM D-6760, FP-14, and Special Contract Requirements (SCRs) for quality assurance/quality control of the drilled shafts.

4.1.9 Scour Potential and Erosion

Final long-term degradation, contraction scour, and abutment scour depths were determined by the hydraulics engineer. Total scour elevation was determined to be 4470.7 feet and 4443.5 feet for sites 3 and 4, respectively. A detailed scour depth analysis is presented section 4.5 of the Final Hydraulic Report.

Provision of scour countermeasures can be used to mitigate scour effects and reduce maintenance. Further detail on scour and countermeasure information is presented in the Final Hydraulic Report.

4.2 BOX CULVERT DESIGN

New box culverts are proposed at Sites 1 and 2. The replacement culverts will consist of double barrel series of precast 10-foot by 5-foot concrete box culverts at both Sites 1 and 2. Based on the subsurface exploration, the culverts will be founded on dense silty sand soils.

4.2.1 Bearing Resistance and Settlement

Ultimate bearing resistance of the culverts is dependent on both the length and width of the foundation elements. A foundation length of 122.25 feet and 123 feet were used in analysis for Sites 1 and 2, respectively. These are the proposed box culvert lengths provided by the hydraulic group. Based on knowledge of the geologic conditions near the structure sites, the presumptive bearing resistance can be estimated to be between 6,000-10,000 psf with a recommended value of use of 6,000 psf, not to be exceeded, according to Table C10.6.2.6.1-1 of AASHTO LRFD Bridge Design Specifications, 8th Edition, 2017. The bearing resistance values presented in this table are based on a maximum settlement of one inch and only apply at the service limit state (resistance factor of 1.0). Bearing resistance for the strength, extreme event, and service limit states for Sites 1 and 2 are shown in Plates 8 and 9, respectively. The bearing resistances provided are nominal values and should be modified by the appropriate AASHTO LRFD resistance factors. It is recommended that the base of the footings should be below the depth of frost potential, which is 15 inches according to the state average (Hammerpedia, 2022), and should be protected from scour.

4.2.2 Lateral Loads

The culverts should be designed to resist lateral loads based on the soil parameters reported in Table 4.5 below. These properties were estimated based on typical design values shown in the NAVFAC Design Manual 7.01. The values are unfactored loads and assume that the surface of the soil slope behind the wall is horizontal. The equivalent fluid densities do not include any surcharge for sloping backfill surfaces or other loads. These equivalent fluid densities do not include load factors or factors of safety; the designer should apply appropriate factors based on their design methodology. Below the mean water level, design the culvert for hydrostatic loading.

Lateral loads imposed on the structures are resisted by the development of friction between the base of the structure and the supporting soils. The nominal friction factors presented in Table 4.5 should be used for the design of the culverts.

Table 4.5 – Design Parameters

MATERIAL TYPE	ASSUMED MATERIAL PROPERTIES	CASE	UNFACTORED EQUIVALENT FLUID DENSITY (PCF)[1]	NOMINAL FRICTION FACTOR
Structural Backfill	c = 0 psf ϕ = 34 deg. γ = 125 pcf	Active	35	0.67
		At-Rest	55	0.67
Silty Sand On-site (Native) Soil	c = 0 psf ϕ = 30 deg γ = 125 pcf	Active	42	0.58
		At-Rest	63	0.58

[1]Values are unfactored loads and assume that the surface of the soil slope behind the wall is horizontal

The AASHTO LRFD resistance factors for various limit states are presented in Table 4.6.

Table 4.6 - Resistance Factors (Φ) for each limit state

LIMIT STATE	BEARING	SHEAR RESISTANCE TO SLIDING	PASSIVE PRESSURE RESISTANCE TO SLIDING
Strength I	0.45	0.80	0.50
Service I & Extreme Event I, II	1.00	1.00	1.00

4.3 ABUTMENT AND WINGWALL DESIGN

Bridge abutments and associated wingwalls, along with box culvert wingwalls, are anticipated. Abutments and wingwalls should be designed to resist lateral earth pressures and other applicable lateral loads in accordance with AASHTO. Lateral earth pressure is influenced by the strength of the backfill, the presence or absence of water, and the ability of the wall to move in response to lateral loads. Other loads, such as live loads, construction loads, and soil compaction loads should also be considered in the design.

Unbalanced water behind an abutment or wall adds significant lateral pressure and should be avoided by using free draining gravity outlets for water. Native, on-site soils may be used as fill on top of the culverts, and as backfill for the box culvert wingwalls and stilling basins (Sites 1 & 2). Backfill associated with bridge abutments and wingwalls (Sites 3 & 4) must consist of structural backfill as specified in section 704.04 of the FP-14. Design of concrete structures should be based on the material parameters presented in Table 4.5 above.

4.3.1 Lateral Loads

Retaining structures should be designed to resist lateral pressures depending on the restraint condition. Structures that can deflect (active condition) should be designed to resist loads based on the active equivalent fluid density presented in Table 4.5. Walls that are restrained (at-rest condition) should be designed based on the at-rest equivalent fluid density. If structural backfill is placed within the active or at-rest zones behind the retaining structures, reduced equivalent fluid densities may be used. The equivalent fluid densities do not include any surcharge for sloping backfill surfaces or other loads. The equivalent fluid densities do not include load factors or factors of safety; the designer should apply appropriate factors based on their design methodology. Below the mean water level, design the structures for the full hydrostatic condition.

Lateral loads imposed on the structures is resisted by development of friction between the base of the structure footing and the supporting soils. The nominal friction factors presented above in Table 4.5 may be used for the design of cast-in-place footings established on native soil.

4.3.2 Bearing Resistance

Bearing resistance was not considered for abutment wingwalls. The wingwalls are planned to be cantilevered to the abutment structure and will not have their own separate foundation. The following subsection applies only to the box culvert wingwalls.

Ultimate bearing resistance of the box culvert wingwall foundations is dependent on the length and width of the foundation elements. For these calculations, foundation lengths of 13’-7” and 15’ were selected for Sites 1 and 2, respectively. These values are based on wingwall lengths noted on the 70% plan sheets. Plates 10 and 11 present the ultimate bearing capacity of the foundation soils for various foundation widths. The appropriate resistance factor should be applied to the ultimate capacity to determine the factored capacity. Resistance factors for various limit states are presented in Table 4.6 above.

4.4 EARTHWORKS

4.4.1 Embankment and Fill Construction

Embankment construction will be related to the construction of proposed structures (bridges and box culverts) and approach road reconstruction. Soils in the project area, including existing embankment fills, are typically sands to silty sands with varying amounts of fines, gravel, and cobbles. The existing embankment fills have been constructed at approximately 1V:1.5H and show some evidence of erosion. The embankment areas should be constructed with traditional embankment construction methods. Construct permanent long-term embankments with a maximum slope ratio of 1V:2H to maintain slope stability and reduce potential for erosion.

4.4.2 Cut Slopes

Cut slopes are anticipated for constructions of proposed structures (bridges and box culverts) and approach road reconstruction. Slopes should be cut no steeper than 1V:2H. Existing slopes are approximately 1V:1.5H and are sparsely vegetated; evidence of erosion is present. The subsurface investigation encountered material ranging from clay to cobble sized particles. Although not encountered while drilling, boulders up to four feet in diameter were encountered downstream of drainage structures. Additionally, weak to moderately cemented sand layers were observed at the surface and at depth within select borings. Determining rippability involves numerous factors and is the responsibility of the contractor. A summary of excavation characteristics is presented in Appendix D, for information only.

4.4.3 Shrink/swell Recommendations

On-site soils are generally alluvial deposits and are expected to consist of sand to silty sands with varying amounts of clay, silt, gravel, and cobbles. It is estimated these soils will have a 10% shrink percentage, corresponding to a shrink/swell factor of 0.90. The recommended shrink/swell factor is based on standard tabled values for common materials in the FLH Technical Guidance Manual (2006).

4.5 CONSTRUCTION CONSIDERATIONS

Excavation: Excavate using equipment capable of removing the material while preventing material from moving outside the construction limits.

The Contractor will be required to make the final determination on the rippability characteristics of encountered material based on equipment capabilities and experience. Data correlating seismic velocity to rippability is publicly available through equipment manufacturers and as published charts. CFL is providing an example of this data in Appendix D, but the Contractor is responsible for selecting appropriate rippability data based on the known seismic velocity of the material and anticipated equipment to be used for excavation.

Though not encountered during the subsurface investigation, boulders up to four feet in diameter were visible within the project area. Observed boulders were found downstream of drainage structures and likely placed for erosion protection, but caution may be recommended as there is a possibility they may be present in the subsurface. Removal of potential large rocks may require specialized techniques such as breaking or use of oversized equipment. Additionally, weak to moderately cemented sand layers were observed both on the surface and encountered in various boreholes, along with clay layers. Layers of both clay and weakly cemented sand ranged in thickness of approximately 1 to 36-inches. The cemented sand layers were able to be broken with the force of a hand or 1 to 3 blows from a geologic hammer. The cemented sands were classified as soils based on their observed mechanical behavior and presumed rippability. Additionally, grouted riprap, concrete aprons, and areas of shotcrete slope protection are found across the project site. Equipment capable of removing this material will be required during construction.

Foundation Preparation: For the bridge abutments, abutment wingwalls, box culverts, and box culvert wingwalls, prepare the foundation subgrade according to FP-14 Section 209. The structures are in intermittent streams; therefore, surface and subsurface water may be encountered during construction. Surface water should be diverted around the construction area. If subsurface water is encountered, the foundation excavations should be provided with appropriate dewatering and/or water diversions.

Dewatering: Dewatering may be needed depending on time of construction and the season. Perform dewatering according to section 208.07 of the FP-14.

Drilled Shafts: The contractor will be required to submit a drilled shaft construction plan according to Section 565.04 of the FP-14, which includes outlining the proposed methods to maintain borehole stability in loose sands near the ground surface and potential flowing sands at depth, manage the excavation of boulders, concrete placement, and dewatering.

Boulders were not encountered in any of the boreholes but may be encountered based on surface observations. Weak to moderately cemented sand and clay layers were encountered in various boreholes but hollow stem augers and ODEX were able to advance through these layers without issue during the investigation.

Groundwater was only encountered in two boreholes at approximately 89.5 and 90 feet. Information from nearby well logs indicate groundwater depths between 63 and 70 feet. For design, groundwater was assumed to be at 50- and 60-foot depth for Site 3 and 4, respectively. Groundwater appears to be deep but may be encountered during foundation excavation depending on the season and time of construction.

Issues with flowing sands occurred in the 100-foot borings. Sand flows into the tooling was generally limited to 1-foot or less and did not occur until the exploration depth exceeded approximately 75 feet. While flowing sands occurred deeper than anticipated drilled shaft lengths, it is recommended to develop a plan to mitigate possible flowing sand sections. As mentioned previously in the report, ODEX was used initially in the subsurface program, but hollow stem augers were later utilized after experiencing issues with ODEX locking up in the sand at depth (this occurred as shallow as 59 feet).

Slope Instability: Construction will take place on alluvium that will flow easily during periods of high precipitation. In addition, due to its non-cohesive nature, these materials may be susceptible to erosion and caving and should be stabilized as necessary during construction. Precautions should be taken if movement or cracking is observed. The contractor is responsible for temporary working platforms including those needed for cranes and shaft drilling rigs.

SECTION FIVE - Disclaimer/Limitations Clause

The recommendations in this report are based on the data obtained from exploratory borings, field review, and laboratory test results. The results of these explorations and tests represent conditions at the specific locations indicated. Subsurface variations across the site are likely and may not become evident until excavation is performed. The Analysis and Recommendations sections in this report include interpretations and recommendations developed by the Government in the process of preparing the design. These interpretations are not intended as a substitute for the personal investigation, independent interpretation, and judgement of the Contractor.

SECTION SIX - References

American Association of State Highway and Transportation Officials (AASHTO), 2017. "AASHTO LRFD Bridge Design Specifications." 8th Edition.

Brown, Dan A., Turner, John P., and Castelli, Raymond J., 2010, "Drilled Shafts: Construction Procedures and LRFD Design Methods," NHI Course No. 132014, Geotechnical Engineering circular No. 10, Report No. FHWA NHI-10-016, dated May.

Cikoski, C.T., Nelson, W.J., Koning, D.J., Elrick, Scott, and Lucas, S.G., 2017, Geologic Map of the Black Bluffs 7.5-Minute Quadrangle, Sierra County, New Mexico: New Mexico Bureau of Geology and Mineral Resources, Open-File Geologic Map OF-GM 262, scale 1:24,000

Department of the Navy Facilities Engineering Command, (1986). NAVFAC, DM-7.01, "Soil Mechanics", Design Manual

Federal Highway Administration (FHWA), 2021, "NM FLAP SIE 10(1) Draft Hydraulics Report," dated October.

Federal Highway Administration (FHWA), 2021, "NM FLAP SIE 10(1) Preliminary Pavement & Materials Recommendations (V1) Technical Memorandum," Dated October.

"Frost Line Penetration Map in the U.S." Hammerpedia, <https://www.hammerpedia.com/frost-line-map/

Harrison, R.W., Lozinsky, R.P., Eggleston, T.L., and McIntosh, M.C., 1993, Geologic map of the Truth or Consequences 30 x 60 minute quadrangle, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-File Report 390, scale 1:100,000

Harrison, R.W., and Cather, S.M., 2004, "The Hot Springs fault system of south-central New Mexico - evidence for the northward translation of the Colorado Plateau during the Laramide orogeny." New Mexico Bureau of Geology and Mineral Resources Bulletin 160, 161-179

Kelley, S. A., 2021, "Elephant Butte Lake State Park." New Mexico Bureau of Geology & Mineral Resources, <https://geoinfo.nmt.edu/tour/state/elephant_butte/home.html#:~:text=Rocks>

Lozinsky, R.P., Harrison, R.W., and Lekson, S.H., 1995, "Elephant Butte-eastern Black Range region: Journeys from desert lakes to mountain ghost towns." New Mexico Bureau of Mines and Mineral Resources Scenic Trips to the Geologic Past 16, 169

Lozinsky, R.P. and Hawley, J.W., 1986, "Upper Cenozoic Palomas Formation of south-central New Mexico." New Mexico Geological Society 37th Annual Fall Field Conference Guidebook, 239-247

National Park Service (NPS), 2020, "Basin and Range Province," updated April 15, <https://www.nps.gov/articles/basinrange.htm>.

Nelson, E.P., 1986, “Geology of the Fra Cristobal range, south-central, New Mexico.” New Mexico Geological Society Guidebook 37, 83-92.

Seager, W.R., and Mack, G.H., 2003, “Geology of the Caballo Mountains, New Mexico.” New Mexico Bureau of Geology and Mineral Resources Memoir 49, 135

U.S. Department of Transportation, Federal Highway Administration (FHWA). (2017). “Federal Lands Highway, Soil Description and Identification Guidelines.”

U.S. Department of Transportation, Federal Highway Administration (FHWA). (2007). “Geotechnical Technical Guidance Manual.”

U.S. Department of Transportation, Federal Highway Administration (FHWA). (2014). “Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-14.” Publication No. FHWA-FLH-14-001.

U.S. Department of Transportation, Federal Highway Administration (FHWA). (2008). “Project Development and Design Manual”.

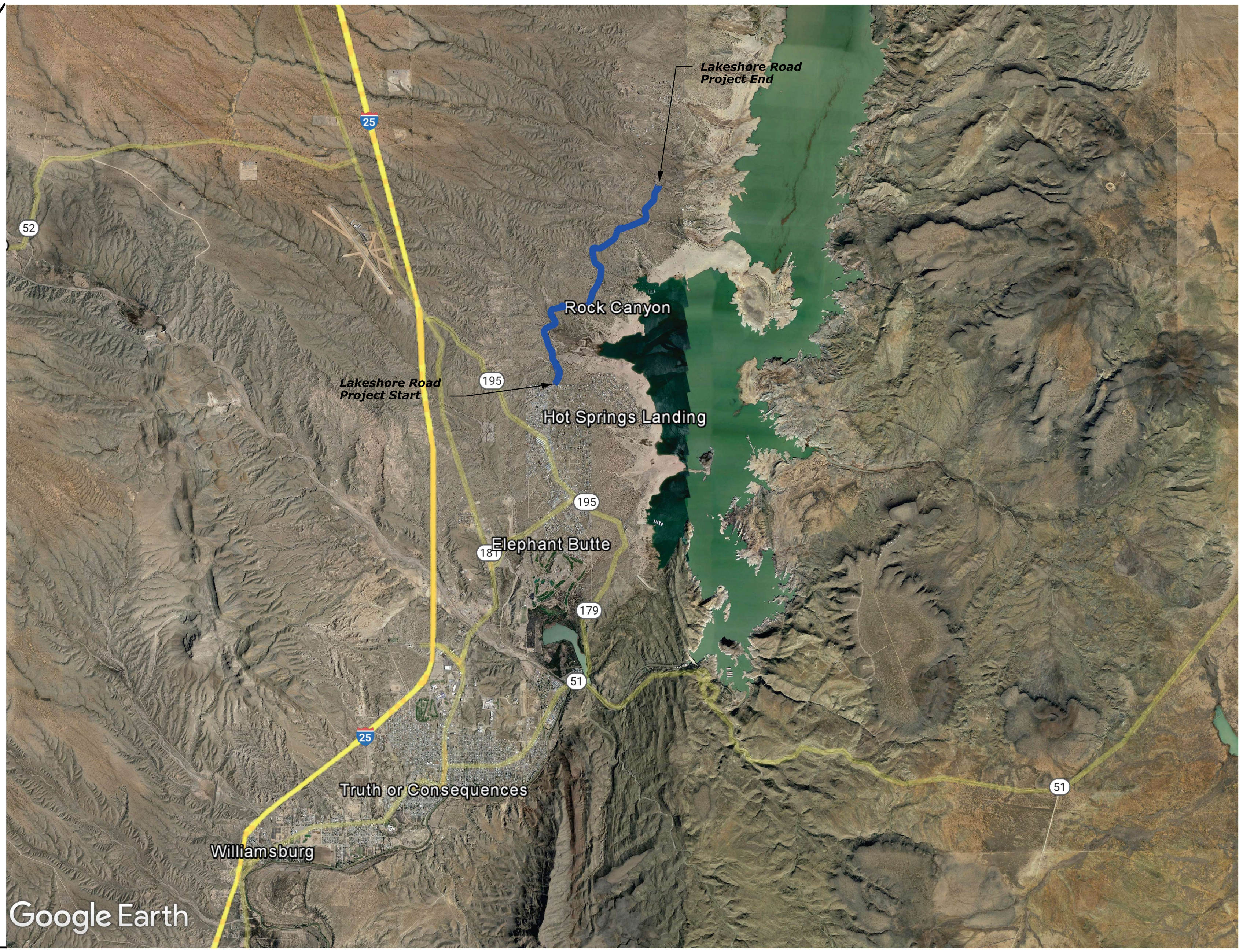
U.S. Geological Survey (2021a). “Quaternary Fault and Fold Database of the United States.” USGS Earthquake Hazards Program, <http://earthquake.usgs.gov/hazards/qfaults/>

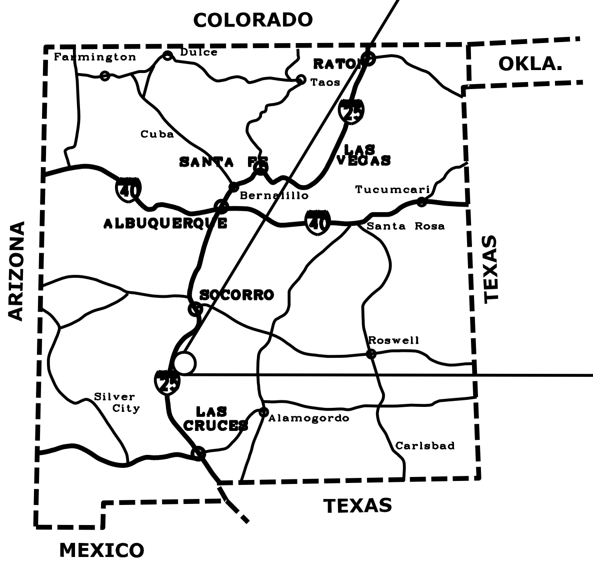
U.S. Geologic Survey (2021b). “U.S. Seismic Design Maps.” USGS Earthquake Hazards Program, <http://earthquake.usgs.gov/designmaps/us/application.php>

PLATES

PROJECT VICINITY MAP, GEOLOGY MAP, GEOTECHNICAL BORING LOCATION MAPS, BEARING RESISTANCE FOR BOX CULVERTS, BEARING RESISTANCE FOR WINGWALLS, & SINGLE DRILLED SHAFT AXIAL CAPACITY

STATE	PROJECT	PLATE
NM	NM FLAP SIE 10(1) LAKESHORE ROAD	1





KEY MAP OF NEW MEXICO

Google Maps, 2022. Lakeshore Road. Google Maps [online]. Accessed 05/18/2022.

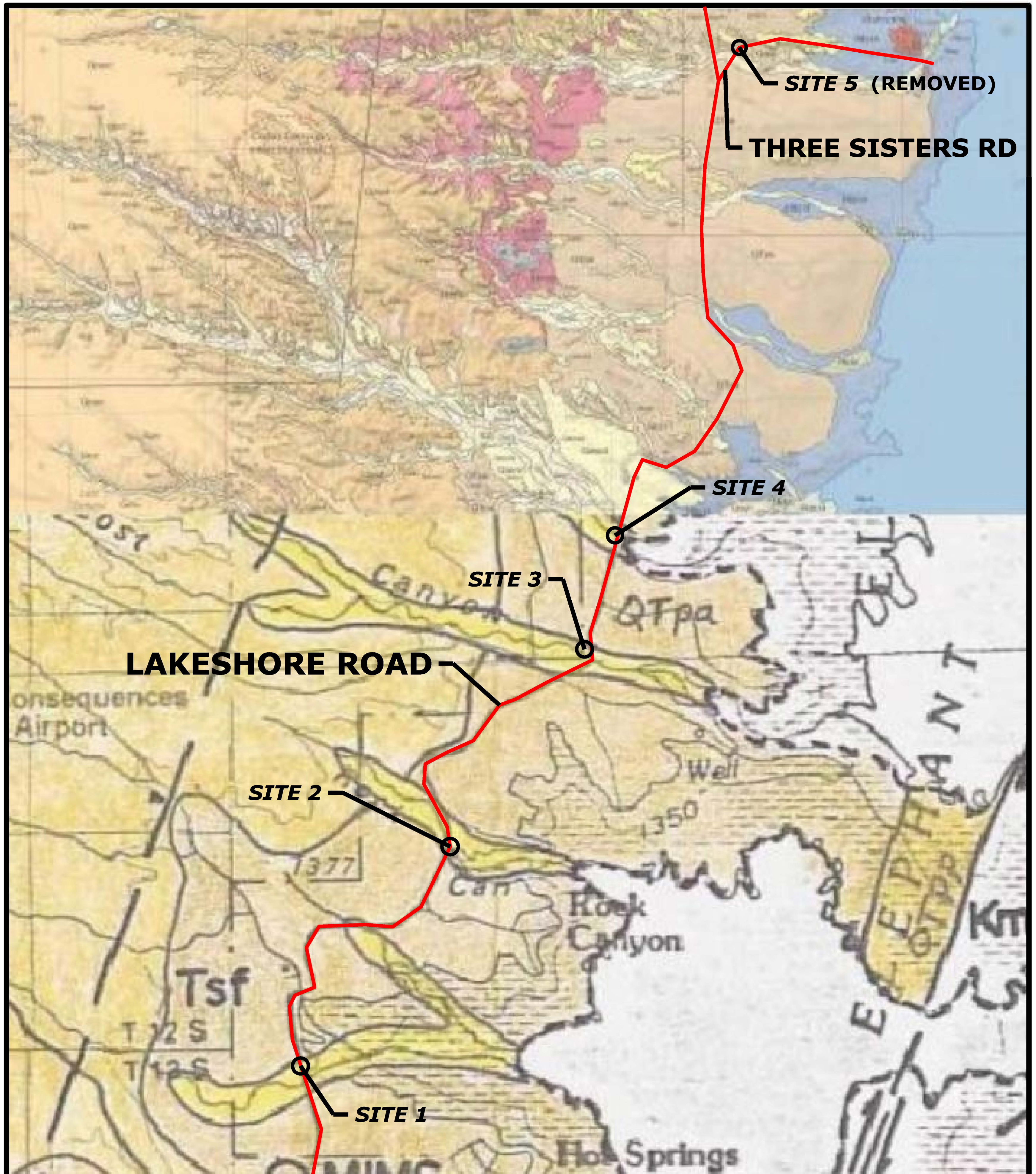
N

NOT TO SCALE

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

PROJECT VICINITY MAP

STATE	PROJECT	PLATE
NM	NM FLAP SIE 10(1) LAKESHORE ROAD	2



Qah — **Historic channelized alluvium**—Poorly or non-vegetated gravels lying along and beneath active drainage channels. Gravels are loose and matrix-poor, commonly in medium-thick, lenticular, often trough cross-stratified beds. Gravel compositions are reflective of upstream exposed materials. No notable soil development. Not uncommon to overtop surrounding **Qay** deposits as thin channel splay or fluvial fan deposits.The deposit thicknesses are <1 to 2 m.

Qafy — **Younger fan alluvium**—Brown sandy pebbles and pebbly sands underlying low-level fan and bajada surfaces emanating from low-order tributary drainages. Gravel and sand compositions are reflective of upstream exposed materials. Fan surfaces typically grade to the younger terrace or historic alluvium levels. Surface soils are weakly-developed, bearing carbonate horizons with no more than Stage I morphology. The deposit thicknesses are <1 to perhaps 2 m.

QTpa — **Axial-fluvial facies of the Palomas Formation**—White to pink to very pale-brown, trough cross-stratified, locally concretionary, variably pebbly siliceous sands/sandstones. Sands are moderately to poorly to well-sorted, subangular to rounded, very fine to very coarse grains of dominantly quartz with minor crystalline siliceous lithics, minor basaltic lithics, and trace each of felsic to intermediate volcanic lithics, chert, feldspars, black ferromagnesian lithics, and detrital clay aggregates, in thin to medium, lenticular beds. Color measurements of 7.5YR-10YR 7/2-7/4 and 8/1-8/2 are common, with local reddish-yellow colors (5YR-7.5YR 6/6) beneath unit **Qpwn**. Clayey mud/mudstone beds are generally traced in abundance but are locally common. Gravels are up to 15% of beds, mainly pebbles with trace cobbles, poorly to moderately sorted, mainly subrounded to well-rounded, and consist of common felsic to intermediate volcanic rocks, variable quartzites and granites, rare cherts and basalts, and trace clastic sedimentary rocks. Cementation is highly localized, and exposures are poor. Base unexposed; unit thickness is at least 60 m.

QTpp — piedmont facies of the Palomas Fm.

Qpwc — **Dominantly gravelly western piedmont deposits of the Palomas Formation**—Yellowish-red to pink, variably cobbly pebble conglomerates with rare sandy conglomerates to sandstones. Gravels are dominantly poorly sorted, subangular to rounded, fine to coarse pebbles with rare cobbles and trace boulders in medium to very thick (max 1.5 m thick), commonly cross-stratified (tangential and trough), matrix-poor (<5%), lenticular beds; locally, cobbles are common (up to 25%), or matrix is more abundant (up to 15%). Gravel are mainly phenocryst-poor rhyolites with absent to rare plagioclase±pyroxene andesitic porphyries, absent to rare quartz-feldspar rhyolitic porphyries, and trace fine-grained limestones. Matrices are poorly sorted clayey fine to very coarse sands; sands are dominantly rhyolitic lithics with lesser but common feldspars and quartz. Clay typically occurs as common medium to coarse films that coat gravels and bridge sand grains; cobbly and sandy beds typically bear less abundant and/or finer clays. Matrix colors were measured at 5YR 5/4-5/8 and 7/4. Unit bears very local buried soils with Bt and Bk horizons with up to Stage II morphology.

Qpwf — **Dominantly sandy western piedmont alluvium of the Palomas Formation**—Pinkish-gray to light-brownish-gray variably muddy sands/sandstones with local gravelly sandstone and conglomerate channel-fills. Sands are dominantly moderately to poorly sorted and very fine- to fine-grained, with rare medium to coarse grains in lenticular channel fills, and consist of common volcanic lithics and quartz, rare to common potassium feldspar, and rare plagioclase in medium to thick beds that are massive and tabular to cross-stratified and lenticular. Gravels are poorly to moderately sorted, mainly pebbles with rare cobbles and trace boulders, of fine-grained rhyolites to subequal rhyolites and plagioclase±pyroxene porphyry andesites, with additional trace fine-grained limestones. Gravelly channel-fills occur as medium to thick (up to 40 cm thick), lenticular, massive, or cross-stratified beds, and constitute 0–50% of exposures, with abundance increasing upsection.

Tsf — Santa Fe Group:
Oligocene and younger basin fill of the Rio Grande drainage west of the Continental Divide: basal beds are intercalated with Oligocene volcanic rocks, are moderately well indurated, more voluminous, younger beds overlie basal beds with angular unconformity and are generally near horizontal in attitude. The Santa Fe Group is dominantly volcaniclastic and heterolithic.

N

NOT TO SCALE

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GEOLOGY MAP

STATE	PROJECT	PLATE
NM	NM FLAP SIE 10(1) LAKESHORE ROAD	3

NOT TO SCALE

Boring Locations				
Boring	Location	Latitude	Longitude	Elevation
BH21-01	STA 104+00, 8 ft Lt.	33.213219°	-107.225261°	4456 ft

Boring locations are approximate. Elevations are estimated from Google Earth.

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GEOTECHNICAL BORING LOCATIONS

SHEET 1 OF 5

STATE	PROJECT	PLATE
NM	NM FLAP SIE 10(1) LAKESHORE ROAD	4

Boring Locations				
Boring	*Location*	*Latitude*	*Longitude*	*Elevation*
P-2	*STA 205+61, 8 ft Lt.*	*33.229267°*	*-107.213797°*	*4462 ft*
BH21-02	*STA 205+65.5, 8 ft Lt.*	*33.229275°*	*-107.213792°*	*4462 ft*

Boring locations are approximate. Elevations are estimated from Google Earth.

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GEOTECHNICAL BORING LOCATIONS

SHEET 2 OF 5

STATE	PROJECT	PLATE
NM	NM FLAP SIE 10(1) LAKESHORE ROAD	5

Boring Locations

Boring	Location	Latitude	Longitude	Elevation
BH21-03	STA 309+10, 8 ft Rt.	33.229275°	-107.213792°	4487 ft
BH21-04	STA 309+80, 7 ft Rt.	33.241417°	-107.202636°	4487 ft
P-3	STA 309+87, 7 ft Rt.	33.241439°	-107.202544°	4487 ft

Boring locations are approximate. Elevations are estimated from Google Earth.
Stationing based on new alignment and was projected out to existing roadway.

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GEOTECHNICAL BORING LOCATIONS

SHEET 3 OF 5

STATE	PROJECT	PLATE
NM	NM FLAP SIE 10(1) LAKESHORE ROAD	6

NOT TO SCALE

Boring Locations				
Boring	Location	Latitude	Longitude	Elevation
BH21-05	STA 406+30, 8 ft Lt.	33.248639°	-107.200556°	4465 ft
BH21-06	STA 407+40, 8 ft Lt.	33.248872°	-107.200486°	4466 ft

Boring locations are approximate. Elevations are estimated from Google Earth.

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GEOTECHNICAL BORING LOCATIONS

SHEET 4 OF 5

STATE	PROJECT	PLATE
NM	NM FLAP SIE 10(1) LAKESHORE ROAD	7

Boring Locations				
Boring	*Location*	*Latitude*	*Longitude*	*Elevation*
BH21-07	*STA 502+55, 8.5 ft Lt.*	*33.280683°*	*-107.191153°*	*4469 ft*
P-5	*STA 502+60, 8.5 ft Lt.*	*33.280697°*	*-107.191144°*	*4469 ft*

Boring locations are approximate. Elevations are estimated from Google Earth.

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GEOTECHNICAL BORING LOCATIONS

SHEET 5 OF 5

EFFECTIVE WIDTH vs. BEARING RESISTANCE (LRFD)
Box Culvert (Site 1) - Lakeshore Road (NM FLAP SIE 10(1))

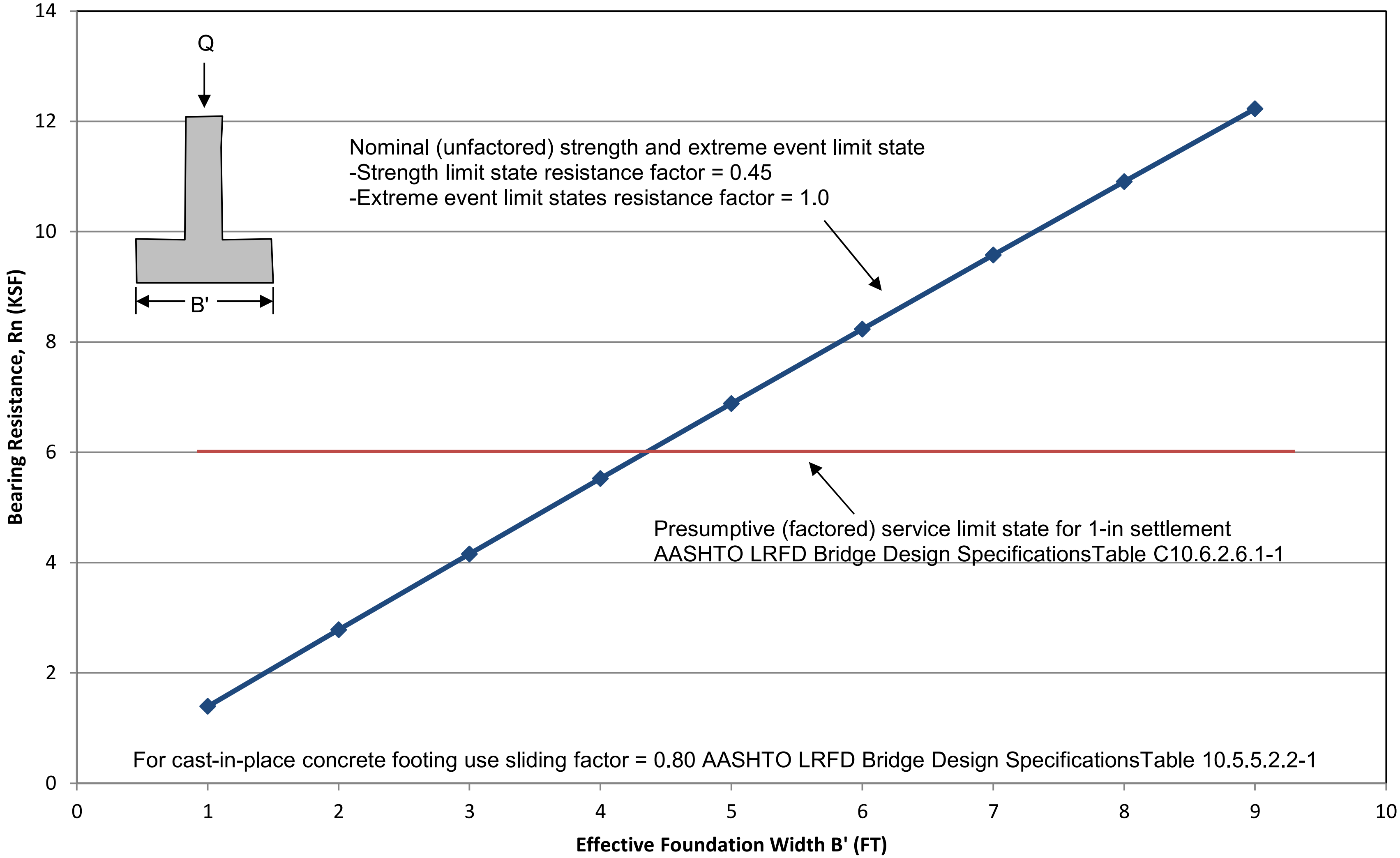

PLATE 8 - Bearing Resistance for Site 1 Box Culvert

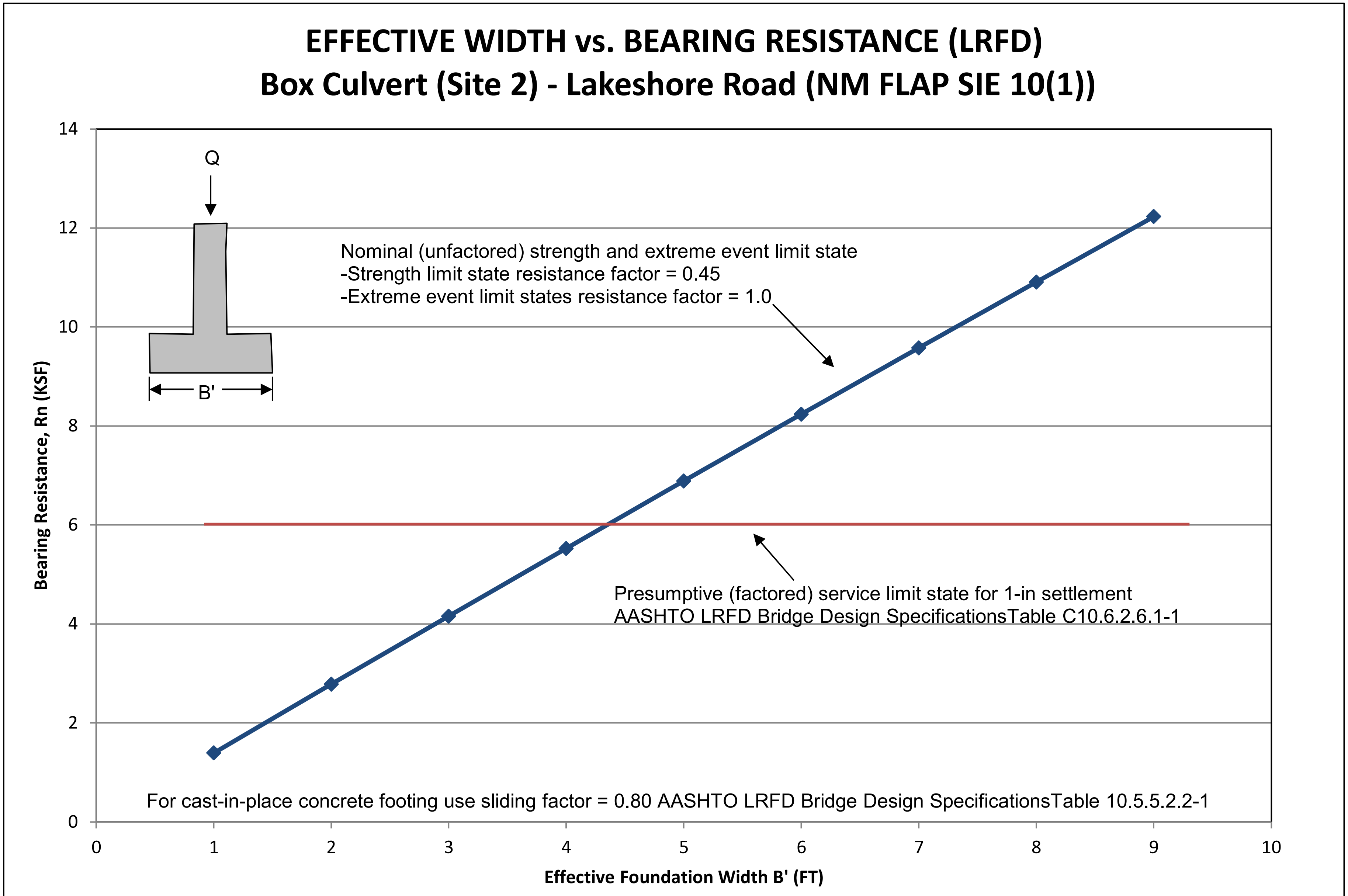

PLATE 9 - Bearing Resistance for Site 2 Box Culvert

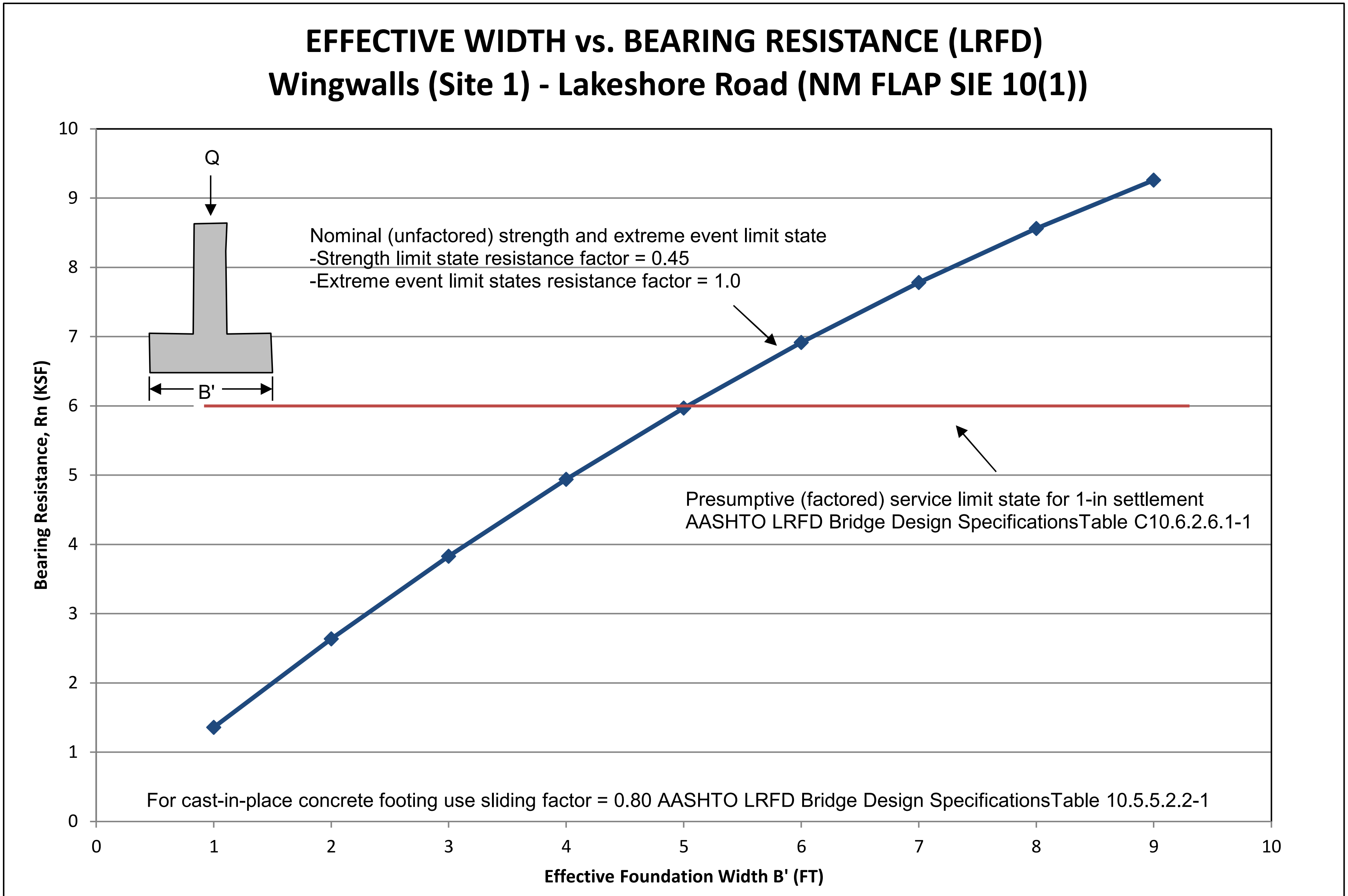

PLATE 10 - Bearing Resistance for Site 1 Wingwalls

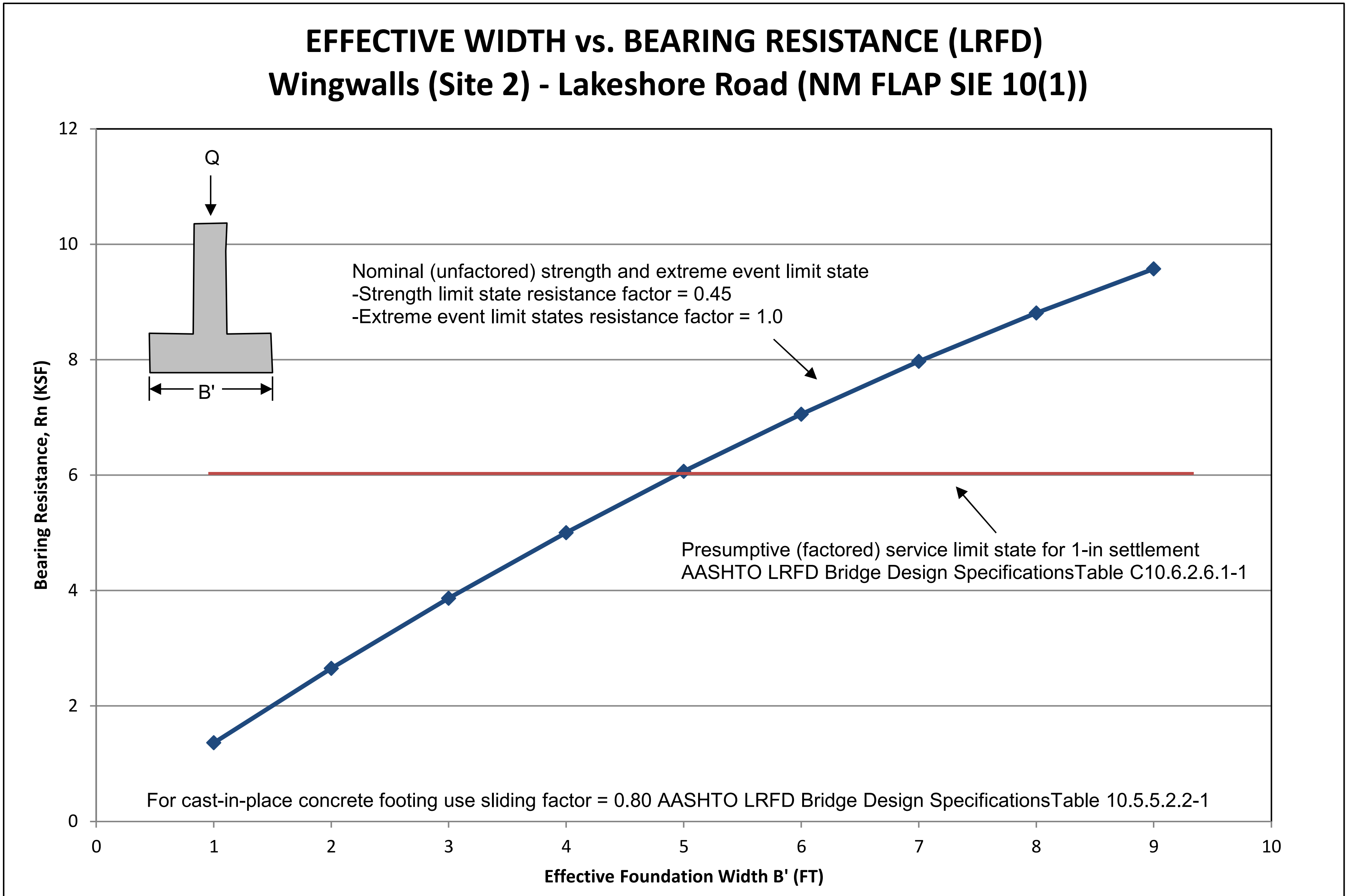

PLATE 11 - Bearing Resistance for Site 2 Wingwalls

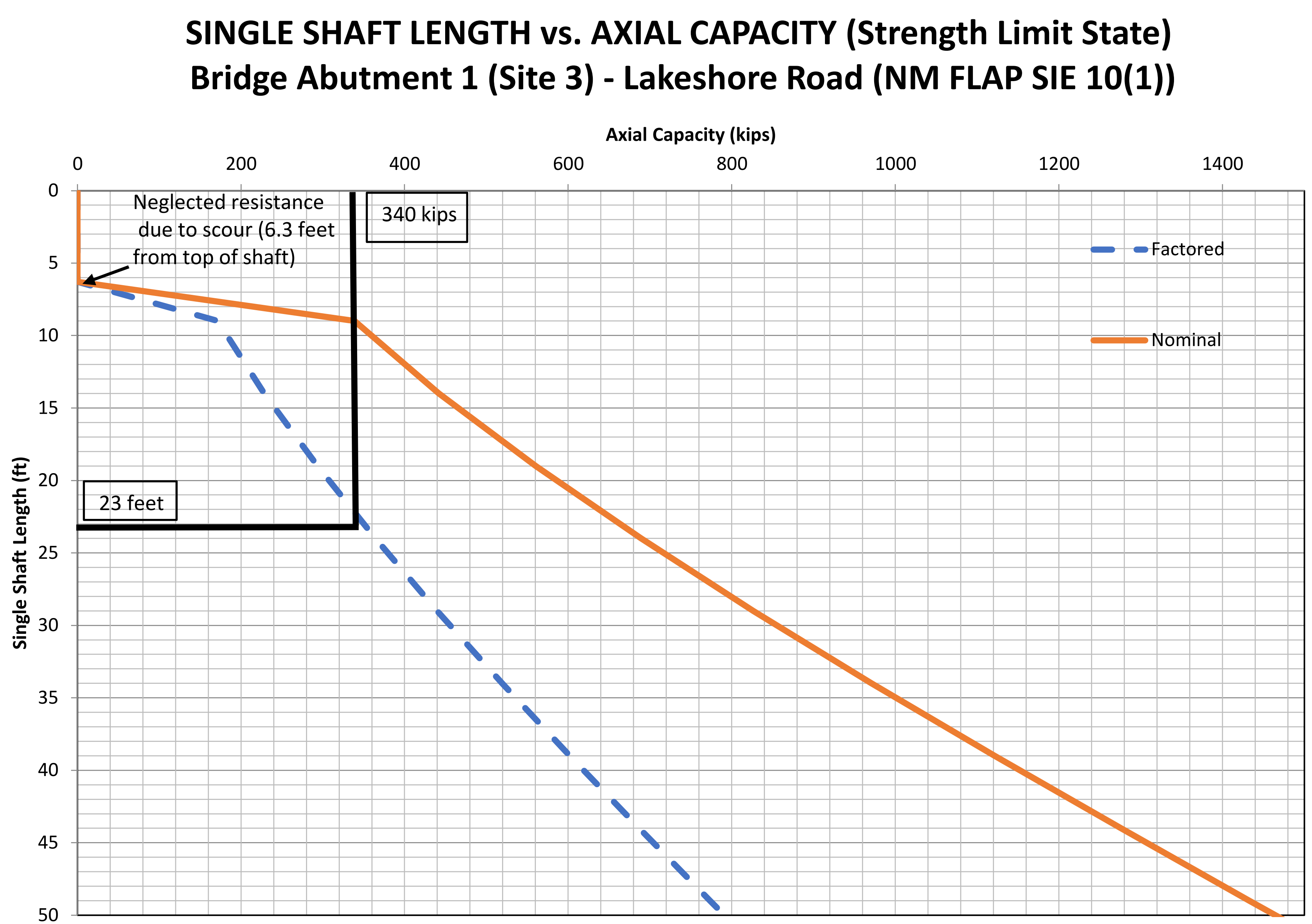

PLATE 12 - Axial Single Shaft Capacity, Lost Canyon Bridge Abutment 1 (Site 3)

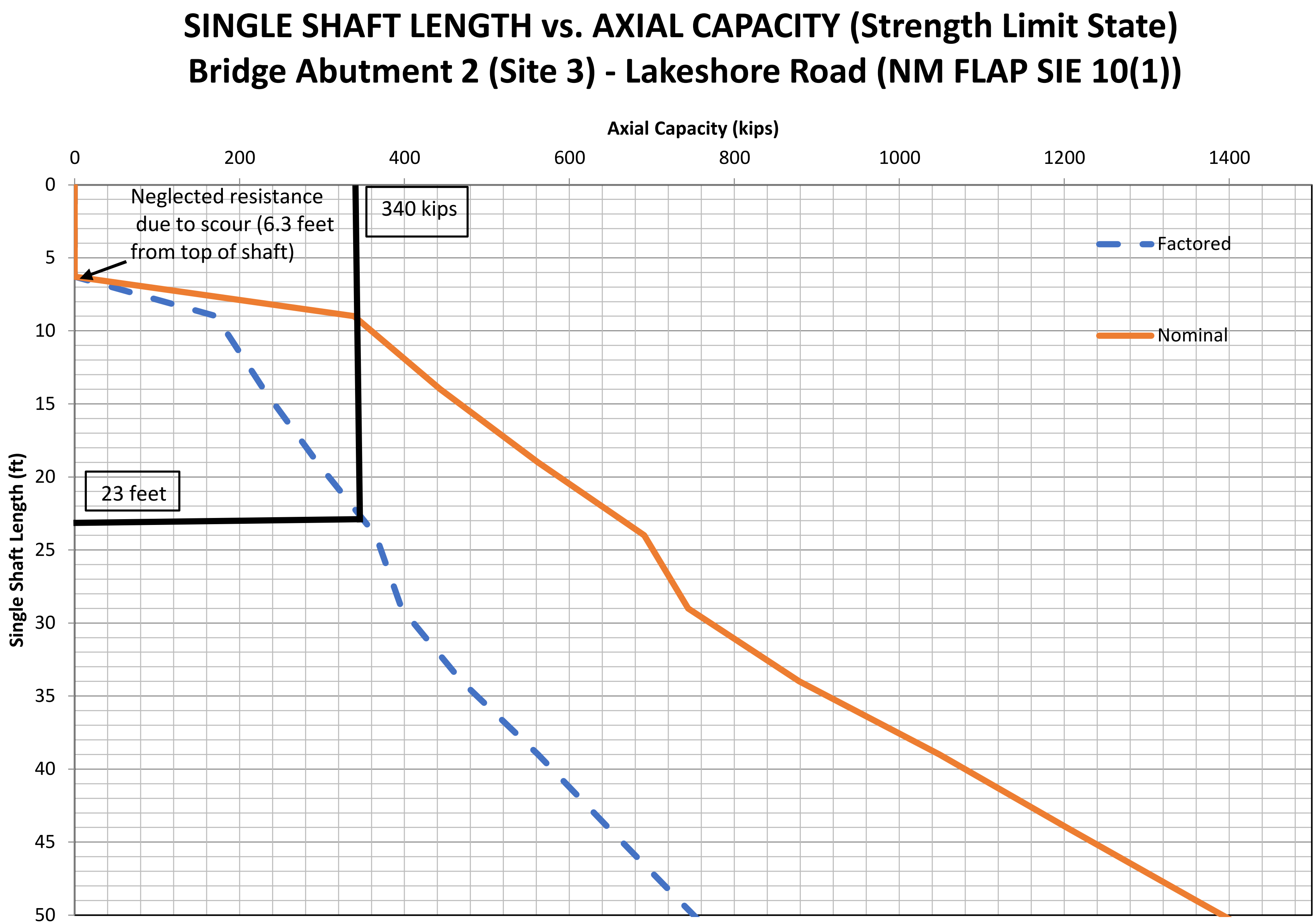

PLATE 13 - Axial Single Shaft Capacity, Lost Canyon Bridge Abutment 2 (Site 3)

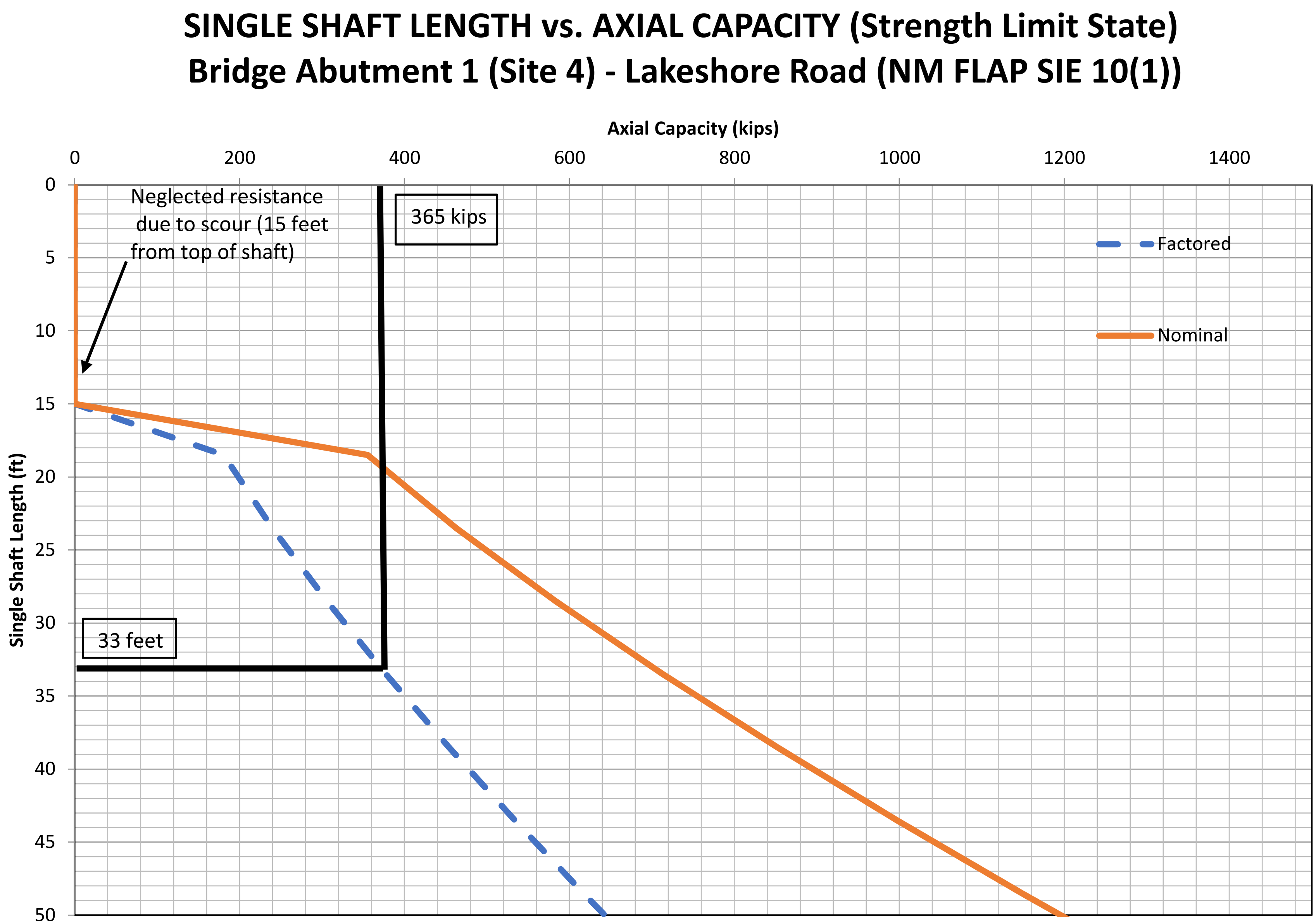

PLATE 14 - Axial Single Shaft Capacity, Cedar Canyon Bridge Abutment 1 (Site 4)

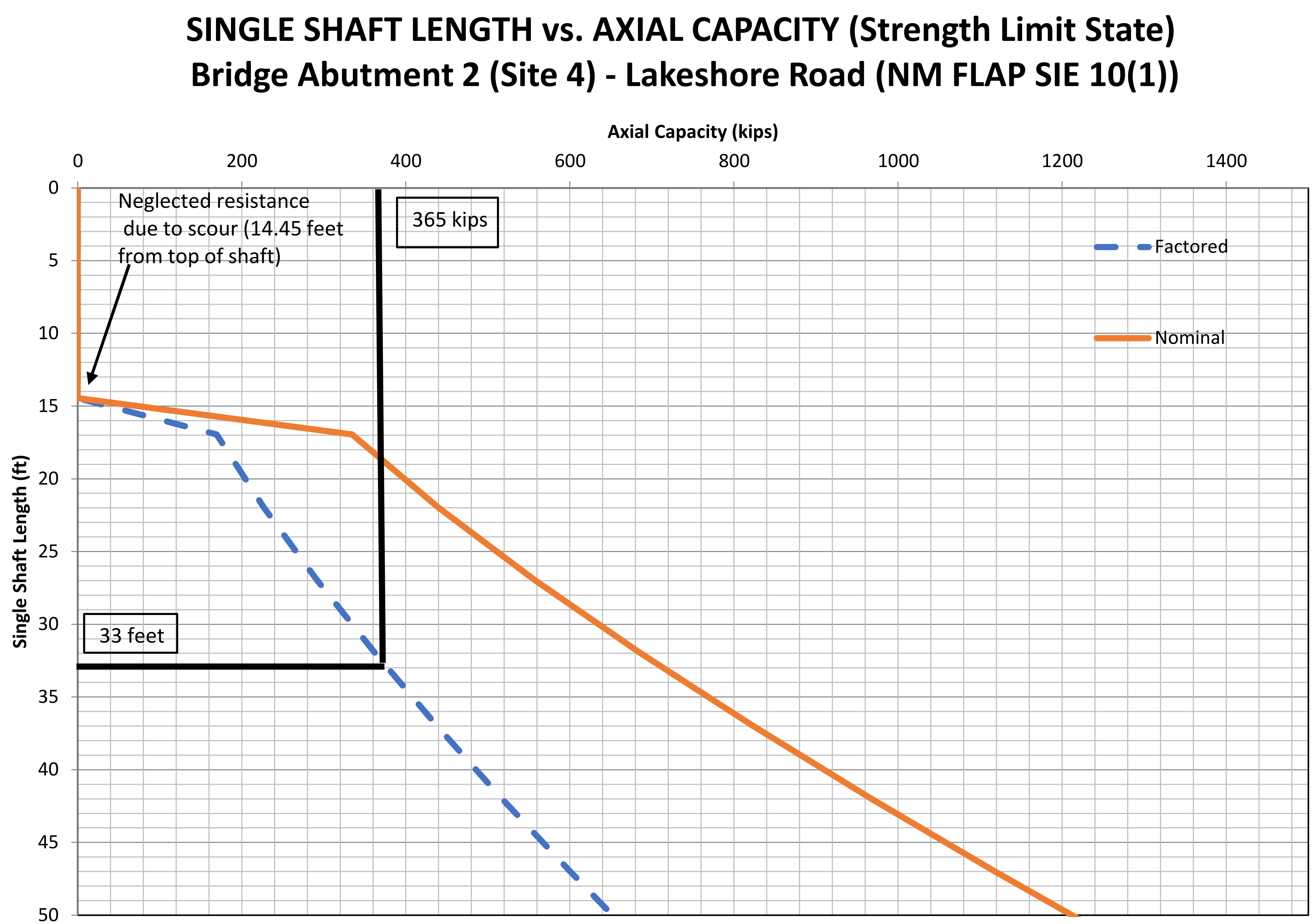

PLATE 15 - Axial Single Shaft Capacity, Cedar Canyon Bridge Abutment 2 (Site 4)

APPENDIX A

FIELD EXPLORATION PROGRAM

APPENDIX A

FIELD EXPLORATION PROGRAM

A.1 INTRODUCTION

The Central Federal Lands Highway Division (CFLHD) Geotechnical Section completed a field exploration program for NM FLAP SIE 10(1) Lakeshore Road, during January 19 through 23, 2021. The scope of work for the field exploration program included drilling a total of seven geotechnical borings and three pavement borings. Each component of the field exploration program was coordinated and observed by a Geotechnical Engineer from CFLHD. Field exploration location plans, as well as individual boring logs are attached. These logs represent a compilation of field and laboratory data and description of the soil samples by CFLHD Geotechnical personnel. The methods used to conduct the field exploration program are described below. Photos of drilling equipment and field exploration activities are included in the attachments. Representative soil samples collected during the field exploration program were transported to the CFLHD Materials Laboratory in Lakewood, Colorado for testing. A summary of the laboratory testing program is provided in Appendix B.

A.2 EXPLORATIONS

Borings

Vine Laboratories of Commerce City, CO provided the drilling services for the soil borings. Borings were completed using a CME 55 drill rig.

A total of three roadway borings (P-2, P-3, and P-5) were completed to 5 feet below the ground surface to explore roadway subgrade conditions. A total of seven geotechnical borings were completed to depths ranging from approximately 40 to 100 feet below ground surface in areas where box culverts, bridges, and low water crossings are proposed. Borings were initially advanced using ODEX, but hollow stem augers were utilized for most of the exploration program as ODEX proved inadequate to reach target depths due to tooling locking up in the sandy subsurface. Drive sampling was utilized in all borings.

If water was encountered at the time of drilling, field personnel measured water levels in the borings. Fluctuations in the ground water level due to seasonal and climatic effects are expected. The location of individual borings were estimated relative to features shown on the plan set and elevations were determined using Google Earth. Boring locations are listed on individual boring logs and may be found on Plates 3 through 7. Following drilling activities, field personnel backfilled the borings with cuttings generated during drilling in accordance with applicable local, state, and federal regulations.

A.3 SOIL AND ROCK SAMPLING

Borings

Disturbed samples were obtained from the borings in accordance with the Standard Penetration Test (SPT), the procedures of which are detailed in AASHTO T-206. The SPT involves driving a 2-inch outside diameter, 1.375-inch inside diameter split spoon sampler a depth of 18 inches with a 140-pound hammer falling a distance of 30 inches. The number of blows required to advance the split-spoon sampler through each of the 6-inch increments was recorded. The SPT resistance, or N-value, is defined as the number of blows required to drive the sampler over the second and third 6-inch increments. The N-value provides a means for evaluating the relative density or compactness of cohesionless (granular) soils and consistency or stiffness of cohesive (fine-grained) soils. An energy corrected N-value, N_{60}, is used to standardize the energy levels of the hammer system in the SPT to 60% efficiency. Recent energy measurements of the automatic hammer system employed for the SPT's on this project indicate an efficiency of 85%. The summary report performed by GRL Engineers, Inc. may be found within this appendix. Representative portions of the split-spoon sample obtained in conjunction with the SPT were placed in plastic baggies and transported to the CFLHD Materials Laboratory for testing.

A.4 SOIL AND ROCK CLASSIFICATION SYSTEM

During the completion of borings, CFLHD Geotechnical personnel collected soil samples and prepared field logs of the borings. Soil identification and descriptions, as shown on the field logs, are based on ASTM D2488, a systematic process for identifying and describing individual soil samples by visual and manual means. When sufficient laboratory testing was completed, select samples from borings were classified using the Unified Soil Classification System (USCS) and American Association of State Highway and Transportation Officials (AASHTO) soil classification system. Both the visual soil identification system and the referenced soil classification systems are summarized in the attached Soil Classification Field Reference.

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SOIL CLASSIFICATION CHART & LEGEND

Unified Soil Classification System

MAJOR DIVISIONS					TYPICAL NAMES
COARSE-GRAINED SOILS MORE THAN HALF IS COARSER THAN NO. 200 SIEVE	GRAVELS MORE THAN HALF COARSE FRACTION IS LARGER THAN NO. 4 SIEVE	CLEAN GRAVELS WITH LESS THAN 15% FINES	GW		WELL-GRADED GRAVELS WITH OR WITHOUT SAND
			GP		POORLY-GRADED GRAVELS WITH OR WITHOUT SAND
		GRAVELS WITH 15% OR MORE FINES	GM		SILTY GRAVELS WITH OR WITHOUT SAND
			GC		CLAYEY GRAVELS WITH OR WITHOUT SAND
	SANDS MORE THAN HALF COARSE FRACTION IS FINER THAN NO. 4 SIEVE SIZE	CLEAN SANDS WITH LESS THAN 15% FINES	SW		WELL-GRADED SANDS WITH OR WITHOUT GRAVEL
			SP		POORLY-GRADED SANDS WITH OR WITHOUT GRAVEL
		SANDS WITH 15% OR MORE FINES	SM		SILTY SANDS WITH OR WITHOUT GRAVEL
			SC		CLAYEY SANDS WITH OR WITHOUT GRAVEL
FINE-GRAINED SOILS MORE THAN HALF IS FINER THAN NO. 200 SIEVE	SILTS AND CLAYS LIQUID LIMIT 50% OR LESS		ML		INORGANIC SILTS OF LOW TO MEDIUM PLASTICITY WITH OR WITHOUT SAND OR GRAVEL
			CL		INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY WITH OR WITHOUT SAND OR GRAVEL
			OL		ORGANIC SILTS OR CLAYS OF LOW TO MEDIUM PLASTICITY WITH OR WITHOUT SAND OR GRAVEL
	SILTS AND CLAYS LIQUID LIMIT GREATER THAN 50%		MH		INORGANIC SILTS OF HIGH PLASTICITY WITH OR WITHOUT SAND OR GRAVEL
			CH		INORGANIC CLAYS OF HIGH PLASTICITY WITH OR WITHOUT SAND OR GRAVEL
			OH		ORGANIC SILTS OR CLAYS OF HIGH PLASTICITY WITH OR WITHOUT SAND OR GRAVEL
HIGHLY ORGANIC SOILS			PT		PEAT AND OTHER HIGHLY ORGANIC SOILS

NOTE: Coarse-grained soils with between 5% and 12% passing the No.200 sieve and fine-grained soils with limits plotting in the gray zone on the plasticity chart have dual classifications.

Abbreviations

▽	Water Level at Time of Drilling
▼	Stabilized Water Level
UC	Unconfined Compression
NR	No Recovery
LL	Liquid Limit
PI	Plastic Index
W	Moisture Content
DD	Dry Density
NP	Non Plastic
NV	No Valve

Central Federal Lands Soil Description

1.	Group Name (Pg. 3)	9.	Cementation (Pg. 2)
2.	Group Symbol (Pg. 3)	10.	Organics
3.	Consistency / Relative Density (Pg. 1)	11.	Dry Strength (Pg. 2)
4.	Color (Pg. 1)	12.	Dilatancy (Pg. 2)
5.	Moisture (Pg. 1)	13.	HCL Rxn (Pg. 2)
6.	Particle Size / Shape / Angularity (Pg. 1)	14.	Odor (Pg. 2)
7.	Plasticity (Pg. 2)	15.	Staining (Pg. 2)
8.	Structure (Pg. 2)		

Example, fine-grained soil:	**Lean CLAY with Sand (CL)-** stiff, brown, moist, medium plasticity, laminated
Example, coarse-grained soil:	**Silty SAND with Gravel (SM)-** medium dense, gray, wet, fine to coarse grained, angular to subangular gravel, weakly cemented
Example, fine-grained soil (Long Form):	**Clayey GRAVEL with SAND (CL-ML)-** loose to soft, dark brownish green to pale brownish gray, wet; fine to medium grained, angular, flat sand; coarse grained, rounded elongated gravel, some chert, trace coarse gravel, and cobbles, medium plasticity, dessicated, weak cementation, low dry strength, rapid dilatancy, moderate HCL reaction, hydrocarbon odor, iron oxide staining, alluvium fill, (Quaternary Alluvium), Additional Description.

3. Consistency and Density:

SAND & GRAVEL		SILT AND CLAY				
N	**Density**	**N**	**Consistency**	**Unconfined Compressive Strength q_u (tsf)**	**Undrained Compressive Strength s_u (tsf)**	**Behavior**
0-4	Very Loose	0-1	Very Soft	<0.25	<0.125	Extrudes between fingers when squeezed
5-10	Loose	2-4	Soft	0.25-0.50	0.125-0.25	Remolded by light finger pressure
11-30	Medium Dense	5-8	Firm	0.50-1.00	0.25-0.50	Imprinted easily with fingers, remolded by strong finger pressure
31-50	Dense	9-15	Stiff	1.00-2.00	0.50-1.00	Imprinted with considerable finger pressure, indented by finger nail
>50	Very Dense	16-30	Very Stiff	2.00-4.00	1.00-2.00	Barely imprinted by fingers or indented by finger nail
		>30	Hard	>4.00	>2.00	Not imprinted by fingers or difficult to indent with finger nail

4. Color

Use primary colors or hyphenated compound primary colors. Use "mottled" or "streaked" if necessary.

5. Moisture Content

Dry	Dry to touch, dusty
Moist	Damp but no visible water
Wet	Visible free water

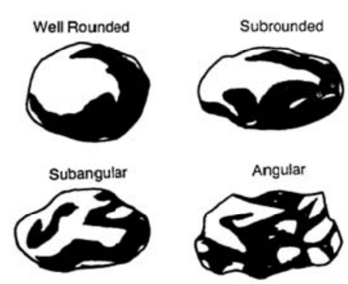
6a. Particle Size

Material		Particle Size Sieve	Approximate Scale
Silt or Clay		< #200	Flour or smaller
Sand	Fine	> #200 to #40	Flour to sugar
	Medium	#40 to #10	Sugar to rock salt
	Course	#10 to #4	Rock salt to pea-sized
Gravel	Fine	#4 to 3/4 in.	Pea-sized to thumb
	Coarse	3/4 in. to 3 in.	Tumb to fist
	Cobble	3 in. to 12 in.	Fist to basketball
	Boulders	> 12 in.	Larger than Basketball

6b. Particle Angularity

Applies to coarse sand, gravel, cobbles and boulders.

Angular	Sharp edges and relatively plane sides.
Subangular	Same as angular with rounded edges.
Subrounded	Nearly plane sides but well-rounded corners and edges.
Rounded	Smooth curved sides and no edges.
Well-Rounded	Very Smooth surfaces, spherical or ovular, no edges.



6c. Particle Shape

Applies to sand, gravel, cobbles and boulders. Length, width and thickness refer to the greatest, intermediate and least dimensions, respectively.

Flat	Width/Thickness >3
Elongated	Length/Width >3
Flat & Elongated	Meets both of the above

Central Federal Lands Soil Description

7. Plasticity

On the basis of observations made during the toughness test, describe plasticity.

Toughness test: Shape the specimen into an elongated pat and rolled on a smooth surface or between the palms into a thread ~1/8". If the sample is too wet to roll, it should be allowed to dry. Fold the thread and reroll repeatedly until the thread crumbles at a diameter of ~1/8". This will be near the plastic limit. Note the pressure required to roll the thread near the plastic limit and the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles. Note the toughness during kneading.

Nonplastic	Thread cannot be rolled at any water content.
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time kneading and rolling to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

8. Structure Terms

Stratified	Alternating layers > 1/4 inch, note thickness.
Laminated	Alternating layers < 1/4 inch, note thickness.
Fissured	Contains shears or separations along planes of weakness.
Slickensided	Shear planes appear polished or glossy, sometimes striated.
Blocky	Cohesive soil can be broken down into harder, angular lumps.
Lensed	Inclusion of small pockets of different soils, note thickenss.
Homogeneous	Same color and appearance throughout.
Mottled	Spots or patches possessing no apparent pattern
Varved	Distinct laminations of lacustrine sediments predominantly clayey
Desiccated	Shrinkage cracks due to dehydration of fine-clayey soil

9. Cementation

Intact coarse-grained soil

Weak	Crumbles with little finger pressure
Moderate	Crumbles with considerable finger pressure
Strong	Will not crumble with finger pressure

11. Dry Strength

1. Mold a ball ~1" diameter until it has the consistency of putty, adding water if necessary.
2. From the ball, make at least 3 ½" diameter balls. Allow to air dry.
3. If the specimen contains natural dry lumps, those that are ~1/2" diameter may be used in place of molded balls.
4. Test the strength of the dry balls or lumps by crushing between the fingers.

None	Crumbles into powder with mere pressure of handling.
Low	Crumbles into powder with some finger pressure.
Medium	Breaks into pieces with considerable finger pressure.
High	Cannot be broken with finger pressure, will break between hard surface and thumb.
Very High	Cannot be broken between hard surface and thumb.

12. Dilatancy

1. Mold soil, adding water if necessary, into ~1/2" diameter ball with soft but not sticky consistency.
2. Smooth in palm of one hand with knife blade. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on the surface.
3. Squeeze by closing the hand or pinching the soil between fingers. The reaction is the speed with which water appears while shaking and disappears while squeezing.
4. After Dilatancy has been determined perform the Toughness test (see explanation in #7).

None	No visible change
Slow	Water appears slowly during shaking and does not disappear or disappears slowly during squeezing.
Rapid	Water appears quickly during shaking and disappears quickly during squeezing.

13. HCL Reaction

None	No visible reaction
Weak	Some reaction, bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

14. Odor

None
Chemical
Hyrodcarbon
Organic

15. Staining

None
Hyrodcarbon
Iron Oxide

Central Federal Lands Soil Description Field Reference

1. & 2. Group Name & Group Symbol

Fine-Grained Soils (50% or more fines)

Group Symbol	Coarse Fraction	Coarse Fraction	Sand or Gravel	Group Name
CL	<30% plus No.200	<15% plus No.200		Lean CLAY
		15-25% plus No.200	% sand ≥ % gravel	Lean CLAY with SAND
			% sand < % gravel	Lean CLAY with GRAVEL
	≥30% plus No.200	% sand ≥ % gravel	< 15% gravel	SANDY lean CLAY
			≥ 15% gravel	SANDY lean CLAY with GRAVEL
		% sand < % gravel	< 15% sand	GRAVELLY lean CLAY
			≥ 15% sand	GRAVELLY lean CLAY with SAND
ML	<30% plus No.200	<15% plus No.200		SILT
		15-25% plus No.200	% sand ≥ % gravel	SILT with SAND
			% sand < % gravel	SILT with GRAVEL
	≥30% plus No.200	% sand ≥ % gravel	< 15% gravel	SANDY SILT
			≥ 15% gravel	SANDY SILT with GRAVEL
		% sand < % gravel	< 15% sand	GRAVELLY SILT
			≥ 15% sand	GRAVELLY SILT with SAND
CH	<30% plus No.200	<15% plus No.200		Fat CLAY
		15-25% plus No.200	% sand ≥ % gravel	Fat CLAY with SAND
			% sand < % gravel	Fat CLAY with GRAVEL
	≥30% plus No.200	% sand ≥ % gravel	< 15% gravel	SANDY fat CLAY
			≥ 15% gravel	SANDY fat CLAY with GRAVEL
		% sand < % gravel	< 15% sand	GRAVELLY fat CLAY
			≥ 15% sand	GRAVELLY fat CLAY with SAND
MH	<30% plus No.200	<15% plus No.200		Elastic SILT
		15-25% plus No.200	% sand ≥ % gravel	Elastic SILT with SAND
			% sand < % gravel	Elastic SILT with GRAVEL
	≥30% plus No.200	% sand ≥ % gravel	< 15% gravel	SANDY elastic SILT
			≥ 15% gravel	SANDY elastic SILT with GRAVEL
		% sand < % gravel	< 15% sand	GRAVELLY elastic SILT
			≥ 15% sand	GRAVELLY elastic SILT with SAND
OL/ OH	<30% plus No.200	<15% plus No.200		ORGANIC SOIL
		15-25% plus No.200	% sand ≥ % gravel	ORGANIC SOIL with SAND
			% sand < % gravel	ORGANIC SOIL with GRAVEL
	≥30% plus No.200	% sand ≥ % gravel	< 15% gravel	SANDY ORGANIC SOIL
			≥ 15% gravel	SANDY ORGANIC SOIL with GRAVEL
		% sand < % gravel	< 15% sand	GRAVELLY ORGANIC SOIL
			≥ 15% sand	GRAVELLY ORGANIC SOIL with SAND

Coarse-Grained Soils (less than 50% fines)

	Fines	Grade	Type of Fines	Group Symbol	Sand/Gravel	Group Name
Gravel	≤ 5%	Well		GW	< 15% sand	Well-graded GRAVEL
					≥ 15% sand	Well-graded GRAVEL with SAND
		Poorly		GP	< 15% sand	Poorly-graded GRAVEL
					≥ 15% sand	Poorly-graded GRAVEL with SAND
	10%	Well	ML or MH	GW-GM	< 15% sand	Well-graded GRAVEL with SILT
					≥ 15% sand	Well-graded GRAVEL with SILT and SAND
			CL or CH	GW-GC	< 15% sand	Well-graded GRAVEL with CLAY
					≥ 15% sand	Well-graded GRAVEL with CLAY and SAND
		Poorly	ML or MH	GP-GM	< 15% sand	Poorly-graded GRAVEL with SILT
					≥ 15% sand	Poorly-graded GRAVEL with SILT and SAND
			CL or CH	GP-GC	< 15% sand	Poorly-graded GRAVEL with CLAY
					≥ 15% sand	Poorly-graded GRAVEL with CLAY and SAND
	≥ 15%		ML or MH	GM	< 15% sand	SILTY GRAVEL
					≥ 15% sand	SILTY GRAVEL with SAND
			CL or CH	GC	< 15% sand	CLAYEY GRAVEL
					≥ 15% sand	CLAYEY GRAVEL with SAND
Sand	≤ 5%	Well		SW	< 15% gravel	Well-graded SAND
					≥ 15% gravel	Well-graded SAND with GRAVEL
		Poorly		SP	< 15% gravel	Poorly-graded SAND
					≥ 15% gravel	Poorly-graded SAND with GRAVEL
	10%	Well	ML or MH	SW-SM	< 15% gravel	Well-graded SAND with SILT
					≥ 15% gravel	Well-graded SAND with SILT and GRAVEL
			CL or CH	SW-SC	< 15% gravel	Well-graded SAND with CLAY
					≥ 15% gravel	Well-graded SAND with CLAY and GRAVEL
		Poorly	ML or MH	SP-SM	< 15% gravel	Poorly-graded SAND with SILT
					≥ 15% gravel	Poorly-graded SAND with SILT and GRAVEL
			CL or CH	SP-SC	< 15% gravel	Poorly-graded SAND with CLAY
					≥ 15% gravel	Poorly-graded SAND with CLAY and GRAVEL
	≥ 15%		ML or MH	SM	< 15% gravel	SILTY SAND
					≥ 15% gravel	SILTY SAND with GRAVEL
			CL or CH	SC	< 15% gravel	CLAYEY SAND
					≥ 15% gravel	CLAYEY SAND with GRAVEL

Central Federal Lands Soil Description Field Reference

SUBSURFACE INVESTIGATION CHECKLIST

Section	No.	Item
PRE-DRILLING	1	has the work order been prepared?
	2	Is the project # or identifier provided?
	3	Has contact info been provided?
	4	Have directions to the site been provided?
	5	Is a description of the anticipated subsurface strata available?
	6	Is there drilling water available?
	7	Is the boring on/near water?
	8	Have utilities been cleared?
	9	Is traffic control necessary? Who is providing TC?
	10	Have any required permits been obtained?
	11	Have site access instructions been provided?
	12	Has a boring layout been provided?
	13	Is info for each boring provided that includes:
		Boring # of identifier
		Total depth
		Sample intervals
		Sample types
		Boring termination criteria
	15	Are there any special instruction for sampling bore sealing, instrumentation, monitoring wells, ground water level readings, field testing, etc?
EQUIPMENT	16	Does the rig have the proper capabilities?
	17	If rock coring; is the rig equipped with gauges that display the drilling pressure applied?
	18	Are the casing and rod the correct sizes and types?
	19	Is there significant length of casing and rod? Are they Straight?
	20	Are the proper samplers provided?
		Are the samplers and thin walls complete and in proper working condition?
		Are there liners and catchers for the split-spoons?
	21	Are the correct bits provided and in good condition?
	22	Do you have the proper sampler containers and transport equipment?
	23	Do you have the proper borehole sealing materials?
	24	Do you have the proper forms? Logging & reference sheets, and this checklist.
DRILLING	25	Is the boring in the correct location?
	26	Was the boring moved from the planned location? (Who authorized)?
	27	Has the boring location been measured off of known landmarks?
	28	Will the drill mast be cleared from overhead utilities?
	29	Are the underground utility markings at a safe distance from the boring?
	30	Is the rig level and plumb?
	31	Is drilling fluid being used? Is it mixed according the mfg recommendations?
	32	If a portable sump is to be used:
		Does it have baffels?
		Is it sealed at the bottom of the tub and ground surface interface or casing?
SOIL SAMPLING	33	Are the requested samplers being used?
	34	Does the borehole appear to be clean prior to sampling?
		Is H.S.A canter plug being used?
	35	Are the samples taken at the correct depths?
	36	Is the requested sample interval being adhered to?
	37	For split spoon sampling:
		Are the tests conducted properly? (ASTM D 1586, AASHTO T206)
		Is sample recovery measured?
		Are samples placed in moisture proof containers, label & stored properly? (ASTM 4220)
	38	For thin walled tube samples:
		Are the tests conducted properly? (ASTM D 1587, AASHTO T207, ASTM D 6519)
		Is sample recovery measured?
		Are the tubes handled with minimal disturbance?
		Are the tubes sealed properly? (ASTM D 1587)
		Are the tubes labeled and stored properly? (ASTM D 1587)
	39	For other soil sample types:
		Are the samples obtained properly (ASTM D 1452)
		Are the samples placed in appropriate moisture proof containers?
		Are the samples labeled & stored properly?

Section	No.	Item
ROCK SAMPLING	40	Is the hole clean and the test performed properly? (ASTM D 2113)
	41	Is the core barrel lowered to the proper depth?
	42	Is the requested length of run being performed?
	43	Is the core barrel; single, double, triple, carbide, diamond, in good condition?
	44	Coring time per foot or per run recorded?
	45	Is down pressure recorded?
	46	Is the removed core specimen handled, boxed and labeled properly? (ASTM M 5079)
	47	Were breaks in the core properly labeled? (ASTM M 5079)
	48	Was the percent recovery (REC) calculated? (ASTM D 2113)
	49	Was the Rock Quality Designation (RQD) calculated? (ASTM D 6032)
WATER LEVEL READINGS – ON LAND	50	Was the ground water level encountered drilling and recorded?
	51	Was the ground water level recorded at hole completion? (ASTM D 4750)
	52	Was GW recorded after stabilizing 24 hrs? (ASTM D 4750)
WATER LEVEL READINGS – ON WATER	53	Was there a change of water level during drilling?
	54	Were changes in water level documented (e.g. tides)?
	55	Was the estimated ground elevation noted?
SEALING	56	Was the borehole sealed in a proper manner?
	57	Was the sealing material type and amount recorded?
PIEZOMETERS/ WELLS	58	Was the instrumentation installed to the correct depth?
	59	Was the instrumentation installed in accordance with the provided instructions?
	60	Was well development performed?
GENERAL SITE OBSERVATIONS	61	Is there any change is surface elevation over the site?
	62	Are there any surface anomalies or irregularities? (i.e. rock outcrops, springs, slope distress, excavations)
	63	Are there any ponds, ditches, or standing water on-site or immediately adjacent?
	64	Are there any wells on-site?
	65	Does the site appear to receive run-off from adjacent properties?
	66	is there any evidence of past fill placement, debris or dumping on-site?
	67	Is there any significant vegetation change over part of the site?
	68	Is there any evidence of surface depressions?
	69	Is there any evidence of distress in adjacent structures?
FIELD LOG	70	Project name and Number
	71	Boring # or identifier
	72	Start date and Completion date including time of day
	73	Boring location (offset/ direction and distance)
	74	Ground water surface elevation. (depth, date, time)
	75	Rig type and Drilling method
	76	Rod and casing sizes OD & ID
	77	Hammer type (Auto/Manuel)
	78	Sample numbers and depths
	79	Sample descriptions
	80	Blows per 6" increments for split spoon
	81	Thin-wall tube/piston sampler type
		Recovery lengths
	82	Rock coring data:
		Run length and time of run
		Drilling pressure/ comments
		%REC and RQD
		Core description
	83	Stratum breaks/ mat'l changes
	84	Bottom of boring depth
	85	Notes/ Comments on:
		Weather (Cloudy, clear, rainy, temp.)
		Losses of circulation (depth; est. amount)
		Rod drops (depth form-depth to) for voids
		Obvious changes in drilling (hard/soft)
PHOTOS	86	Drill rig up and down station for each hole.
	87	Samples prior to shipment. (Core samples should be wet down prior to photo for consistency in color).
	88	General site photographs
	89	Any noted anomalies seen on-site.

Central Federal Lands Rock Core Description Field Reference

Core should be placed in core boxes from left to right, top to bottom. The rock description for each core run should include, in this order:

1	Rock Type (CAPITAL LETTERS) (Pg.1)	6	Discontinuities (Pg.2)
2	Color (Pg.1)		a. Type e. Separation
3	Grain Size or Bedding (Pg.1)		b. Stratification f. Infilling & Weathering
4	Weathering (Pg.1)		c. Spacing g. Roughness
5	Strength (Pg.1)		d. Orientation
		7	Miscellaneous (Pg.2)
		8	Formation or Unit Name (CAPITAL LETTERS)

EXAMPLES

GNEISS- Dark gray, moderately weathered, strong. Biotite foliation, low angle, close. Quartz veins, close, low angle, stepped. Primary joint set, close, low angle, tight, moderately weathered, very narrow with rust surface staining and spotty clay infilling, rough planar. (SLIVER PLUME GRANITE)
GRANODIORITE- Grey to white, medium grained, slightly weathered, strong, joints are moderate to high angle, very close, rough, open to closed, FE stained joints. Poor Circulation.
SANDSTONE- Tan to reddish brown, fine to medium grained, sub rounded, thinly bedded, moderately weathered, strong, joints are low angle, very close, closed, rough. FE surface staining throughout sample, some organics seen in joint sets.

1. Rock Type

Common classifications; gneiss, granite, shale, etc. A modifier may be necessary to describe a sedimentary rock formed from a combination of soil types, i.e., Silty SANDSTONE.

2. Color

For consistency, describe when wet. Use primary or hyphenated compound primary colors.

3a. Grain Size

V. Coarse Grained	> 1/4 in.	
Coarse Grained	3/16-1/4 in.	Easily distinguished by naked eye
Medium Grained	1/16-3/16 in.	Can be distinguished by naked eye
Fine Grained	Up to 1/16 in.	Barley distinguished by naked eye
V. Fine Grained		Cannot distinguished by naked eye

3d. Structure

For Sedimentary Rock

Banded
Bedded
Cross Bedded
Flow Banded
Foliated
Interbedded
Laminated
Massive

3c. Bedding

For Sedimentary Rock

V. thickly bedded	> 3ft
Thickly bedded	18 in. - 3 ft
Thinly bedded	2-18 in.
V. thinly bedded	3/8- 2 in.
Laminated	3/16- 3/8 in.
Thinly laminated	< 3/16 in.

3b. Grain Shape

For Sedimentary Rock

Angular	Show very little wear, grain edges are sharp
Subangular	Show definite effects of wear, grain edges slightly rounded
Subrounded	Shows considerable wear , grain edges rounded smooth
Rounded	Shows extreme wear, grain edges smoothed to broad curves
Well-Rounded	Very Smooth surfaces, spherical or ovular, no edges.

4. Weathering

Fresh	No visible sign of rock material weathering; perhaps slight discoloration on major discontinuity surfaces.
Slightly weathered	Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker externally than in its fresh condition.
Moderately weathered	Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a continuous framework as corestones.
Highly weathered	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a continuous framework as corestones.
Completely weathered (Decomposed)	All rock material is decomposed and/or disintegrated to a soil. The original mass structure is still largely intact.
Residual Soil	All rock mass is converted to a soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the volume has not been significantly transported.

5. Description of Relative Strength / Hardness

Grade	Description	Field Identification	psi
R0	Extremely weak rock	Indented by thumbnail.	50-150
R1	Very weak rock	Crumbles under firm blows with point of geological hammer, can peeled with pocket knife.	150-750
R2	Weak rock	Can be peeled by a pocket knife with difficulty, shallow indentation made by firm blow with point of geologic al hammer.	750- 3,500
R3	Medium strong rock	Cannot be scraped or peeled with a pocket knife, specimen c an be fractured with single firm blow of geological hammer.	3,500-7,500
R4	Strong rock	Specimen requires more than one blow of geological hammer to fracture it.	7,500-15,000
R5	Very strong rock	Spec imen requires many blows of geologic al hammer to fracture it.	15,000- 35,000
R6	Extremely strong rock	Specimen can only be chipped with geological hammer.	> 35,000

Central Federal Lands Rock Core Description Field Reference

6a. Discontinuities

Foliation	Planar arrangement of textural features, usually applied to schistocity or cleavage
Vein	A body of minerals intruded into a joint or fault
Joint	A break of structural origin with no visible displacement
Shear	A discontinuity along which sufficient differential displacement has occurred to produce slickensides
Fault	Major discontinuity with significant displacement, with gouge or adjacent zone of severely fractured rock
Shear or Fault Zone	Band of closely spaced discontinuities along which differential movement has occurred
Bedding	A layered arrangement within the rockmass predominatly sedimentary rock.

6b. Stratification Discontinuities

Lamination	Thin beds (<3/8 in.)
Fissile	Tendency to break along laminations
Parting	Tendency to break parallel to bedding, any scale
Foliation	Segregation and layering of minerals in metamorphic rocks

6c. Spacing Discontinuities

Perpendicular distance between the planes of the discontinuities.

Very Wide	Greater than 10 ft
Wide	3 – 10 ft.
Moderately Close	1 – 3 ft.
Close	2 in. – 1 ft.
Very Close	Less than 2 in.

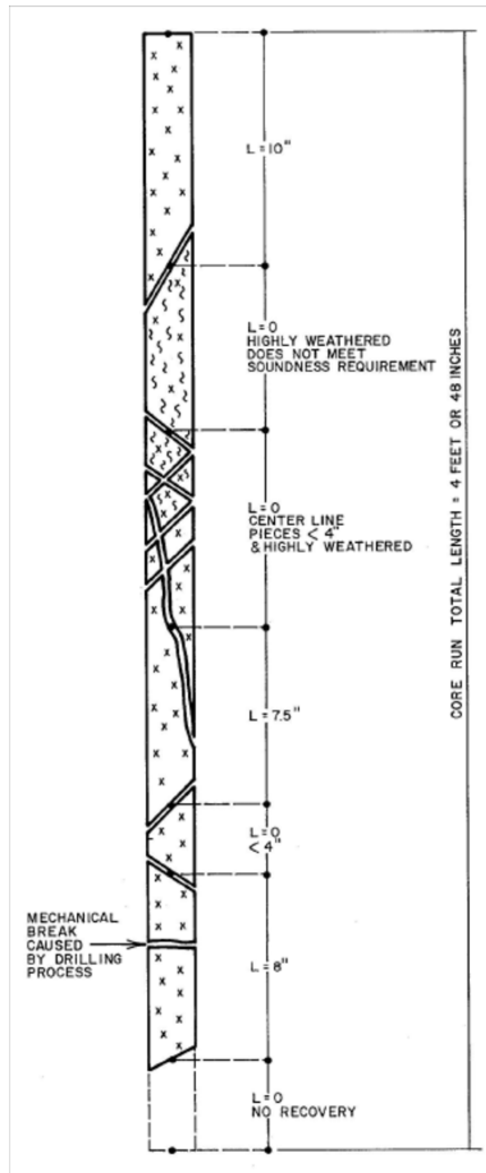
6d. Orientation Discontinuities

Dip angle of discontinuity should be measured with protractor to perpendicular from core axis (0° is perpendicular, 90° is parallel). To describe range of orientations, use the following terms:

Horizontal (for vertical boreholes)	0° - 5°
Low Angle	5°- 35°
Moderate Angle	35° - 55°
High Angle	55° - 85°
Vertical (for vertical boreholes)	85° - 90°

6f. Infilling Discontinuities

Types of common infilling materials include: clay, calcite, chlorite, iron oxide, gypsum/talc., pyrite, quartz, and sand.



6e. Separation Discontinuities

Note: These terms are for core logging, others that describe opening width should be used for outcrop mapping.

Healed	Breaks easily or with difficulty, hairline or seam, usually with infilling.
Closed	Seen as a hairline trace, no infilling.
Open	Core pieces separated or easily separated, may have staining or mineralization on joint surfaces.

6g. Roughness Discontinuities

Large scale – planar, stepped, or undulating. Small scale – use the following terms:

Slickensided	Smooth, glassy surface sometime with striations.
Smooth	Looks and feels smooth.
Slightly Rough	Asperities are distinguishable and can be felt.
Rough	Some ridges and steps are evident, asperities are clearly visible, surface feels very abrasive.
Very Rough	Near-vertical steps and ridges.

$$RQD = \frac{\sum \text{LENGTH OF SOUND CORE PIECES} > 4 \text{ INCHES (100mm)}}{\text{TOTAL CORE RUN LENGTH}}$$

$$RQD = \frac{10 + 7.5 + 8}{48} \times 100\%$$

RQD = 53% (FAIR)

RELATION OF RQD & ROCK QUALITY	
RQD, Rock Quality Designation %	Description of Rock Quality
0-25	Very Poor
25-50	Poor
50-75	Fair
75-90	Good
90-100	Excellent

Core Measurements

Recovery = Total length of recovered core / Total length of run
RQD = Total length of core pieces > 4 in. / Total length of run
(RQD may also be calculated separately for different rock types in one run – be consistent by project.)

7a. Vesicularity

For volcanics only

Term	% by Volume
Some Vesicles	5-25
Highly Vesicular	15-50
Scoriaceous	Greater than 50

7b. Moisture

Damp
Dripping
Dry
Flowing
Wet

7c. Staining

Iron Oxide
Hydrocarbon
None

7d. Odor

None
Slight
Moderate
Strong

7e. HCL Reaction

None	No visible reaction
Weak	Some reaction, bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

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

BORING LOG LEGEND

Project Name: Lakeshore Road
Project Location: Elephant Butte State Park, New Mexico

SAMPLE TYPE SYMBOLS

Grab Sample

No Recovery

Standard Penetration Test (2" OD)

DRILLING METHOD SYMBOLS

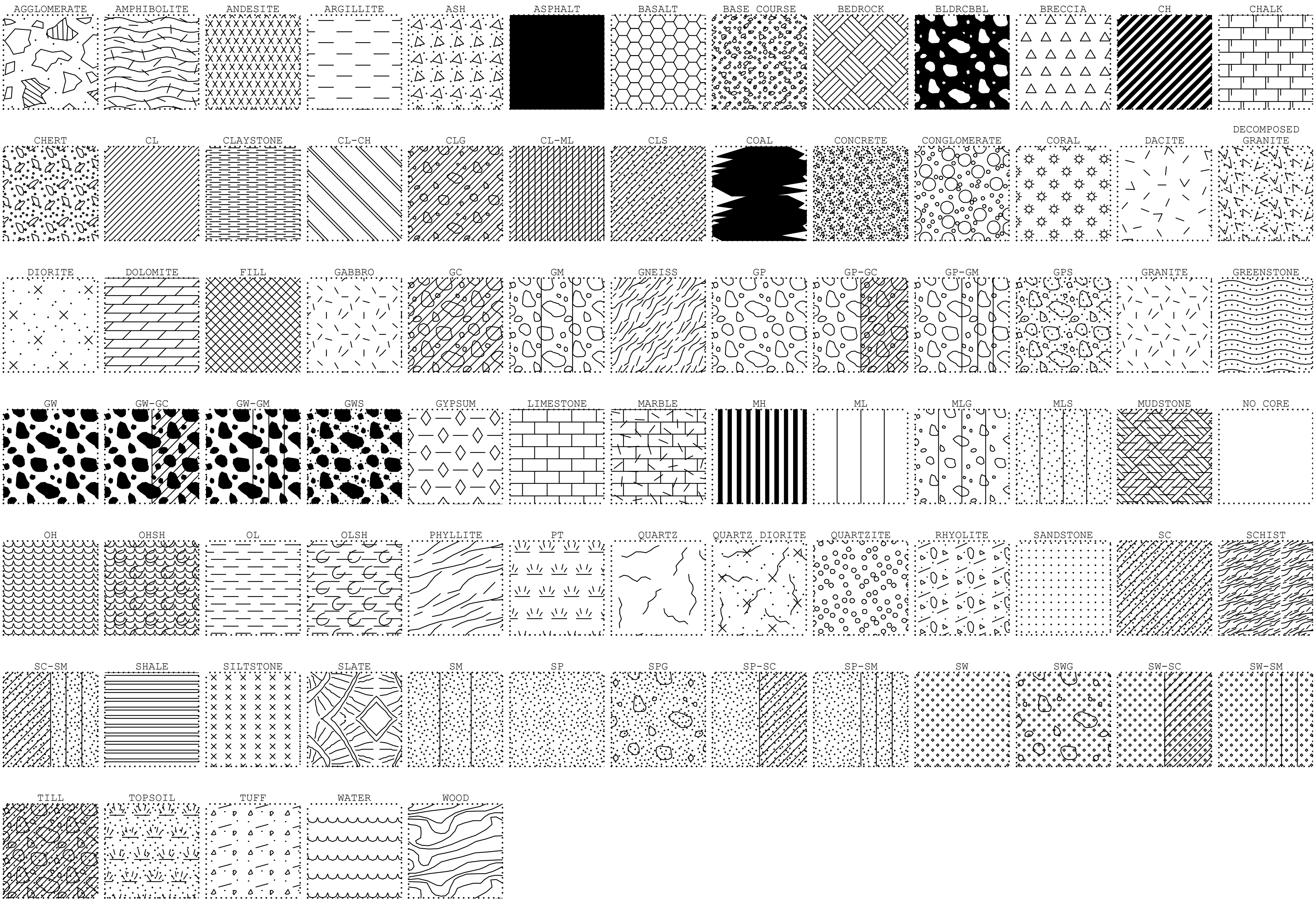
Casing Advancer

Hollow Stem Auger

ABBREVIATIONS

FF	-	Fracture Frequency (fractures per foot)
Fines	-	Percent Passing No. 200 Sieve
LL	-	Liquid Limit (%)
NP	-	Non-Plastic
PL	-	Plastic Limit (%)
PP	-	Pocket Penetrometer Reading
Rec	-	Rock Core Recovery
RQD	-	Rock Quality Designation
SG	-	Specific Gravity
UC	-	Unconfined Compressive Strength
VWP	-	Vibrating Wire Piezometer
WC	-	Water Content (%)

FHWA BORING LOG LEGEND - FHWA_DATATEMPLATE_20171103.GDT - 1/21/22 14:11 - C:\USERS\BRENDAN.MCGARITY\DOCUMENTS\GEOTECH\PROJECTS\NM\SIE10(1)\USE TO FINISH\3_DATA\DRILLING INVESTIGATION 1-18 TO 1-23\BORING LOGS\GINT\NM LAKESHO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AMPHIBOLITE
ANDESITE
ARGILLITE
ASH
ASPHALT
BASALT
BASE COURSE
BEDROCK
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CHERT
CL
CLAYSTONE
CL-CH
CLG
CL-ML
CLS
COAL
CONCRETE
CONGLOMERATE
CORAL
DACITE
DECOMPOSED GRANITE
DIORITE
DOLOMITE
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GREENSTONE
GW
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RHYOLITE
SANDSTONE
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SILTSTONE
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WATER
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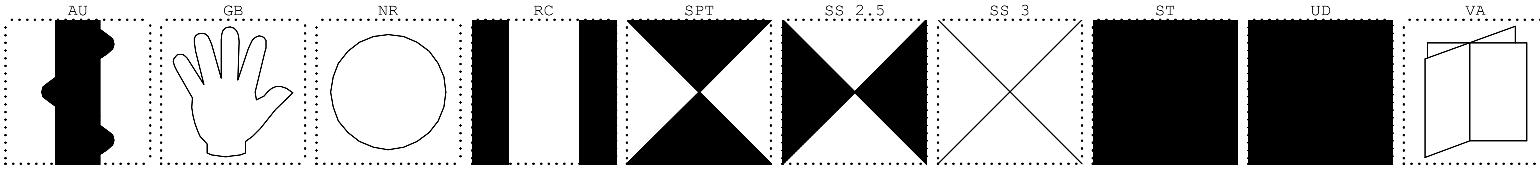
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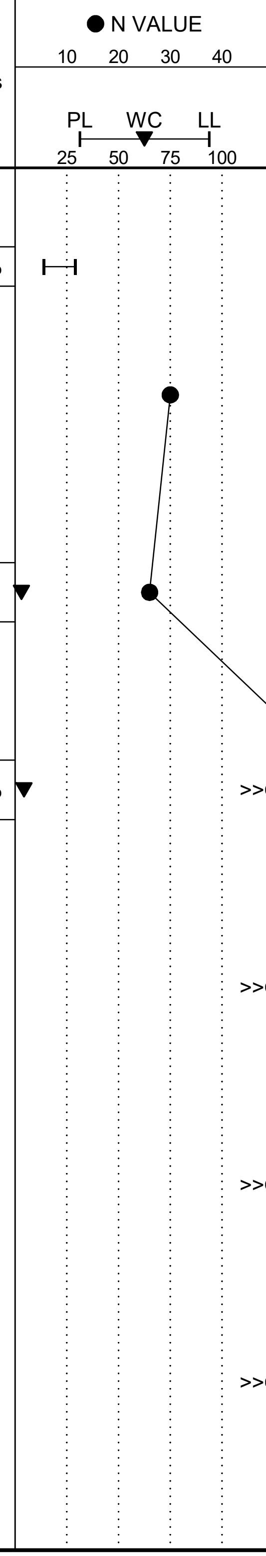
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG BH21-01 (P-1)

Project Name: Lakeshore Road	
Project Location: Elephant Butte State Park, New Mexico	Surface Elevation: 4456 ft
Groundwater Depth:	Station and Offset: 104+00 8 ft Lt.
While Drilling: ---	Date Started: 1/23/21 Date Completed: 1/23/21
At Completion: ---	Driller/Company: Brian Schilling/Vine Laboratories Drill: CME 55
After Drilling: ---	Hammer Type: 140 lbs Automatic Hammer Efficiency: 85 %
Notes:	Logger/Company: B. McGarity/FHWA-CFL
For lab testing, select soil samples of similar composition were combined. The testing results presented in these logs are shown for the highest depth of those samples.	Weather: 45F, sunny

Elevation (ft)	Depth (ft)	Material Description	Drilling Method	Sample Type	No.	Field Blow Count (Recovery)	Test Results
4456	0	ASPHALT	HSA				
4455.75	0.25	Poorly graded SAND with gravel (SP), dark brown.	HSA	Grab	1	(12" = 100%)	Fines = 15%
4455.5833	0.4167	Clayey GRAVEL with sand (GC), medium dense, brown, dry.	HSA	SPT	1	18-16-14 (16" = 89%)	
4446	10	Poorly graded SAND with silt (SP-SM), medium dense, light brown, dry, medium sand, trace gravel.	HSA	SPT	2	8-13-13 (16" = 89%)	Fines = 7%
4441	15	Silty SAND (SM), very dense, light tan, dry, trace gravel, trace clay, fine to coarse grain.	HSA	SPT	3	18-30-36 (18" = 100%)	Fines = 42%
	20	Trace to no gravel with depth	HSA	SPT	4	15-25-37 (18" = 100%)	
	25		HSA	SPT	5	14-25-32 (18" = 100%)	
	30		HSA	SPT	6	17-28-31 (18" = 100%)	
4424.5	31.5	Approx. 6-inch clay layer	HSA				
4424	32	Silty SAND (SM), very dense, light tan, slightly moist, fine to coarse grain.	HSA				



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FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG BH21-01 (P-1)

Project Name: Lakeshore Road

Project Location: Elephant Butte State Park, New Mexico

Elevation (ft)	Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	Sample Type	No.	Field Blow Count (Recovery)	Test Results	N VALUE
4420			El. 4420.67 ft 35.33 ft Approx. 10-inch clay layer El. 4419.837 ft 36.163 ft Silty SAND (SM), very dense, light tan, slightly moist, fine to medium grain. El. 4416 ft 40 ft	HSA		7	13-20-27 (18" = 100%)		
	40		Bottom of borehole at 40 ft.			8	17-35-50/5" (17" = 100%)		>>

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

BORING LOG BH21-02

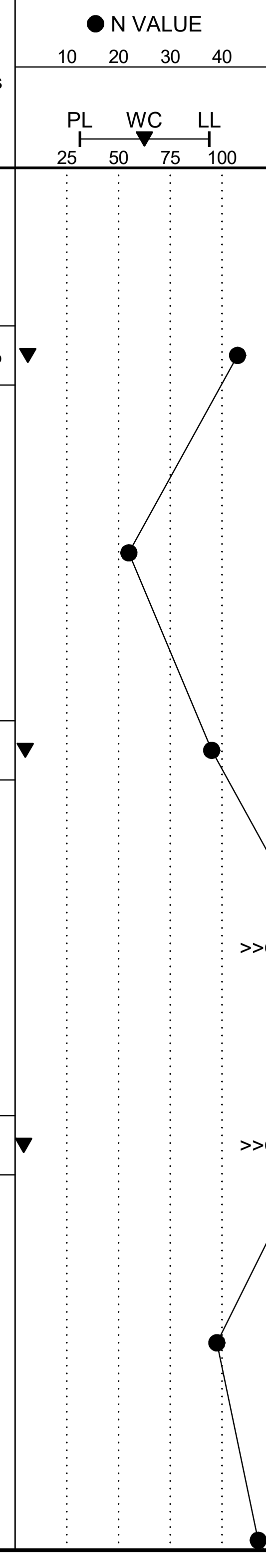
Project Name: Lakeshore Road
Project Location: Elephant Butte State Park, New Mexico
Groundwater Depth:
While Drilling: ---
At Completion: ---
After Drilling: ---
Notes:
For lab testing, select soil samples of similar composition were combined. The testing results presented in these logs are shown for the highest depth of those samples.

Surface Elevation: 4462 ft
Station and Offset: 205+65.5 8 ft Lt.
Date Started: 1/20/21
Date Completed: 1/20/21
Driller/Company: Brian Schilling/Vine Laboratories
Drill: CME 55
Hammer Type: 140 lbs Automatic
Hammer Efficiency: 85 %
Logger/Company: B. McGarity/FHWA-CFL
Weather: 45F, cloudy

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method
	0	ASPHALT	ODEX
4461.75 ft	0.25 ft	Poorly graded SAND with gravel (SP), dark brown, dry.	ODEX
4461.5833 ft	0.4167 ft	Well graded SAND with silt and gravel (SW-SM), brown, medium sand, trace cobbles, dense, slightly moist to dry.	ODEX
El. 4455 ft	7 ft	Approx. 1-foot gravel layer	ODEX
El. 4454 ft	8 ft	Well graded SAND with silt and gravel (SW-SM), brown, coarse sand, medium dense, slightly moist to dry.	ODEX
El. 4452 ft	10 ft	Increased gravel content at 9.5 feet	ODEX
		Poorly graded SAND with silt (SP-SM), light brown, trace gravel, dense to very dense, slightly moist to dry, fine to medium grain sand.	ODEX
		Sand is coarse grained at 19 feet	ODEX
		Sand is coarse grained at 24 feet	ODEX
		Sand is very fine to fine until termination depth	ODEX

Elevation scale: 4460, 4455, 4450, 4445, 4440, 4435, 4430
Depth scale: 5, 10, 15, 20, 25, 30

SAMPLE No.	Field Blow Count (Recovery)	Test Results
1	9-18-25 (18" = 100%)	Fines = 11%
2	10-11-11 (18" = 100%)	
3	12-18-20 (18" = 100%)	Fines = 7%
4	18-28-31 (18" = 100%)	
5	17-27-31 (18" = 100%)	Fines = 6%
6	12-16-23 (18" = 100%)	
7	17-22-25	



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U. S. DEPARTMENT OF TRANSPORTATION
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FEDERAL LANDS HIGHWAY DIVISION

BORING LOG BH21-02

Project Name: Lakeshore Road

Project Location: Elephant Butte State Park, New Mexico

Elevation (ft)	Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery)	SAMPLE Test Results	N VALUE (10 20 30 40); PL WC LL (25 50 75 100)
4425			Poorly graded SAND with silt (SP-SM), light brown, trace gravel, dense to very dense, slightly moist to dry, fine to medium grain sand. *(continued)* El. 4423 ft 39 ft	ODEX			(18" = 100%)		
			Bottom of borehole at 39 ft.			8	19-28-42 (18" = 100%)		>>

U. S. DEPARTMENT OF TRANSPORTATION
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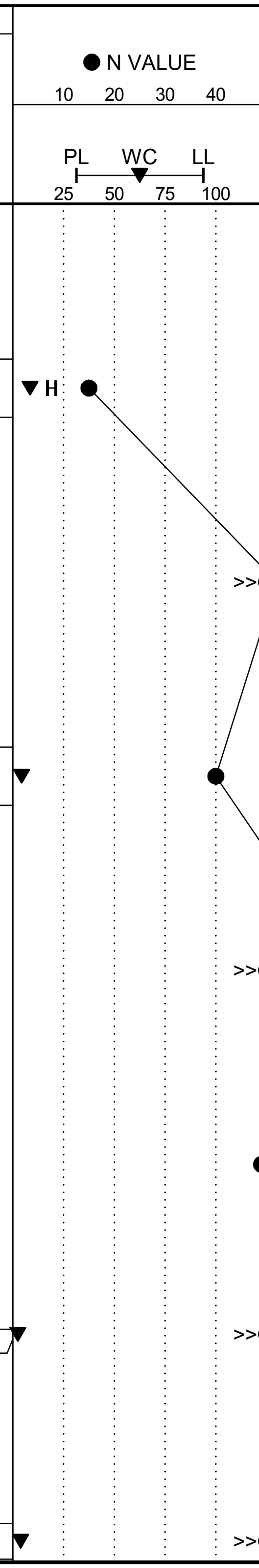
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG BH21-03

Project Name: Lakeshore Road
Project Location: Elephant Butte State Park, New Mexico
Groundwater Depth:
While Drilling: ---
At Completion: ---
After Drilling: ---
Notes:
For lab testing, select soil samples of similar composition were combined. The testing results presented in these logs are shown for the highest depth of those samples.

Surface Elevation: 4487 ft
Station and Offset: 309+10 8 ft Rt.
Date Started: 1/20/21 Date Completed: 1/21/21
Driller/Company: Brian Schilling/Vine Laboratories Drill: CME 55
Hammer Type: 140 lbs Automatic Hammer Efficiency: 85 %
Logger/Company: B. McGarity/FHWA-CFL
Weather: 39F, snow, cloudy

Elevation (ft)	Depth (ft)	Material Description	Drilling Method	Sample No.	Field Blow Count (Recovery)	Test Results
		ASPHALT	ODEX			
El. 4486.875 ft	0.125 ft	Poorly graded SAND with gravel (SP), brown, dry.				
El. 4486.625 ft	0.375 ft	Clayey SAND with gravel (SC-SM), brown, dry, medium dense to very dense.				
		High clay content at 4 feet		1	5-6-9 (18" = 100%)	Fines = 23%
		Decreased clay content at 10 feet		2	14-17-35 (18" = 100%)	
El. 4475 ft	12 ft	Poorly graded SAND with silt (SP-SM), very dense, light brown, dry, with gravel, fine to medium grain.		3	13-17-23 (18" = 100%)	Fines = 7%
		Trace to no gravel with depth		4	19-29-37 (16" = 89%)	
				5	12-21-28 (18" = 100%)	
El. 4462.25 ft	24.75 ft	Approx. 3-inch clay layer				
El. 4462 ft	25 ft	Poorly graded SAND with silt (SP-SM), very dense, light brown, dry, trace gravel, fine to medium grain.				
		Moderately cemented sand from approx. 29 to 29.5-feet		6	50/3" (3" = 100%)	Fines = 12%
				7	29-50/5"	Fines = 8%



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

BORING LOG BH21-03

Project Name: Lakeshore Road
Project Location: Elephant Butte State Park, New Mexico

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Sample No.	Field Blow Count (Recovery)	Test Results	N VALUE
		Poorly graded SAND with silt (SP-SM), very dense, light brown, dry, trace gravel, fine to medium grain. *(continued)*	ODEX		(11" = 100%)		
4450							
	40			8	18-28-27 (15" = 83%)		>>
4445							
		High clay content at 43 feet					
	45			9	23-47-50/5" (17" = 100%)		>>
		El. 4440.5 ft — 46.5 ft					
4440		Approx. 1-foot clay layer					
		El. 4439.5 ft — 47.5 ft					
		Poorly graded SAND with silt (SP-SM), very dense, light brown, dry, fine to medium grain.					
	50			10	17-33-48 (18" = 100%)		>>
4435		High clay content from 52 to 54 feet					
		With gravel at 54 feet					
	55			11	18-28-31 (18" = 100%)		>>
4430							
		El. 4428 ft — 59 ft					
		Well graded SAND with silt (SW-SM), very dense, light brown, dry, fine to medium grain.	HSA				
	60			12	32-30-37 (18" = 100%)	Fines = 12% Casing break at 59 feet. Switched to HSA.	>>
4425							
	65			13	22-43-50/5" (17" = 100%)		>>
4420							
	70			14	24-50/3" (9" = 100%)		>>
		High clay content at 71 feet					
4415							
	75	Slightly moist after 75 feet		15	40-50/6"	Sand flow in	

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

BORING LOG BH21-03

Project Name: Lakeshore Road

Project Location: Elephant Butte State Park, New Mexico

Elevation (ft)	Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery)	Test Results	N VALUE (10, 20, 30, 40); PL / WC / LL (25, 50, 75, 100)
4410			Well graded SAND with silt (SW-SM), very dense, light brown, dry, fine to medium grain. *(continued)*	HSA			(12" = 100%)	top 6 inches	
	80		El. 4407 ft — 80 ft						
			Poorly graded SAND (SP), very dense, light brown, medium sand, trace fine gravel, trace clay, slightly moist.			16	23-42-50/6" (18" = 100%)	Fines = 5%	>>
4405									
	85					17	25-50/4" (10" = 100%)		>>
4400									
	90					18	22-50/6" (12" = 100%)		
4395									
	95					19	24-50/6" (12" = 100%)		
4390									
	100		El. 4387 ft — 100 ft						
			Bottom of borehole at 100 ft.			20	27-50/5" (11" = 100%)		>>

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

BORING LOG BH21-04

Project Name: Lakeshore Road
Project Location: Elephant Butte State Park, New Mexico
Groundwater Depth:
While Drilling: ---
At Completion: ---
After Drilling: ---
Notes:
For lab testing, select soil samples of similar composition were combined. The testing results presented in these logs are shown for the highest depth of those samples.

Surface Elevation: 4487 ft
Station and Offset: 309+80 7 ft Rt.
Date Started: 1/19/21
Date Completed: 1/19/21
Driller/Company: Brian Schilling/Vine Laboratories
Drill: CME 55
Hammer Type: 140 lbs Automatic
Hammer Efficiency: 85 %
Logger/Company: B. McGarity/FHWA-CFL
Weather: 50-60 F windy, partly cloudy

Drilling Method: ODEX

MATERIAL DESCRIPTION

ASPHALT.
El. 4486.833 ft — 0.167 ft

Well graded SAND with gravel (SW), medium dense, light brown to brown, dry, with cobbles, fine to coarse sand, subangular to subrounded gravel.
Cobbles at 4 feet. Some clay content with depth.
El. 4479.5 ft — 7.5 ft

Silty SAND with gravel (SM), medium dense, brown, dry, medium sand, trace clay.
El. 4475 ft — 12 ft

Poorly graded SAND with silt (SP-SM), light brown, dry, with gravel, medium dense to very dense.
El. 4458 ft — 29 ft

Fat CLAY with sand (CH), stiff, brown, dry, yellow staining. Moderately cemented sand in bottom of sampler
El. 4455 ft — 32 ft

Poorly graded SAND with silt (SP-SM), light brown, dry, trace gravel, medium dense to very dense, fine to medium grain.

SAMPLE

No.	Approx. Depth (ft)	Field Blow Count (Recovery)	Test Results
1	5	11-13-10 (0" = 0%)	
2	10	13-14-18 (15" = 83%)	Fines = 13%
3	15	11-13-14 (11" = 61%)	
4	20	15-30-34 (17" = 94%)	Fines = 8%
5	25	13-25-37 (18" = 100%)	
6	29.5	50/5" (5" = 100%)	Fines = 25%
7	35	17-41-50/5"	Fines = 6%

N VALUE: 10 20 30 40
PL WC LL: 25 50 75 100
>> (samples 4–7)

BORING LOG BH21-04

Project Name: Lakeshore Road

Project Location: Elephant Butte State Park, New Mexico

MATERIAL DESCRIPTION

Poorly graded SAND with silt (SP-SM), light brown, dry, trace gravel, medium dense to very dense, fine to medium grain. *(continued)*

El. 4447 ft — 40 ft

Fat CLAY with sand (CH), very stiff, brown, dry, yellow and red staining.

El. 4445.5 ft — 41.5 ft

Poorly graded SAND with silt (SP-SM), dense, light brown, dry, trace gravel, fine to medium grain.

El. 4443 ft — 44 ft

Approx. 2-foot clay layer

El. 4441 ft — 46 ft

Poorly graded SAND with silt (SP-SM), light brown, dry,

El. 4440.5 ft — 46.5 ft

Approx. 1.5-foot clay layer

El. 4439 ft — 48 ft

Poorly graded SAND with silt (SP-SM), very dense, light brown, dry, trace gravel, very fine to medium grain.

El. 4416.5 ft — 70.5 ft

Fat CLAY (CH), very stiff, brown, trace sand.

El. 4414.5 ft — 72.5 ft

Poorly graded SAND with silt (SP-SM), very dense, light brown, dry, trace gravel, fine to medium grain.

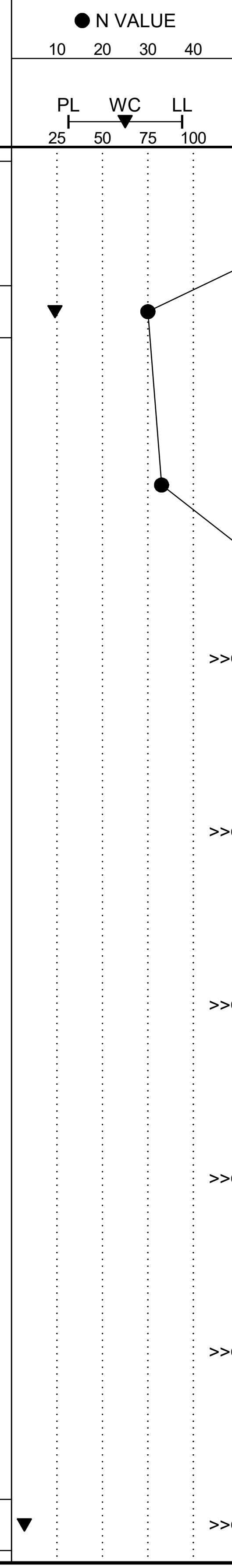
Drilling Method: ODEX

SAMPLE

No.	Field Blow Count (Recovery)	Test Results
	(17" = 100%)	
8	16-13-17 (18" = 100%)	Fines = 63%
9	14-17-16 (18" = 100%)	
10	18-36-46 (18" = 100%)	
11	21-29-46 (18" = 100%)	
12	16-35-50/6" (18" = 100%)	
13	15-30-40 (18" = 100%)	
14	28-41-49 (18" = 100%)	
15	24-41-50/6" (18" = 100%)	Fines = 9%

Elevation (ft): 4450, 4445, 4440, 4435, 4430, 4425, 4420, 4415

Depth (ft): 40, 45, 50, 55, 60, 65, 70, 75



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BORING LOG BH21-04

Project Name: Lakeshore Road

Project Location: Elephant Butte State Park, New Mexico

Elevation (ft)	Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	SAMPLE No.	SAMPLE Field Blow Count (Recovery)	SAMPLE Test Results	N VALUE (10 20 30 40) / PL WC LL (25 50 75 100)
4410			Poorly graded SAND with silt (SP-SM), very dense, light brown, dry, trace gravel, fine to medium grain. *(continued)* High clay content at 77 feet	ODEX					
	80					16	13-30-47 (18" = 100%)		>>
4405			El. 4403 ft — 84 ft					Casing broke at 84 feet. No sample taken.	

Bottom of borehole at 84 ft.

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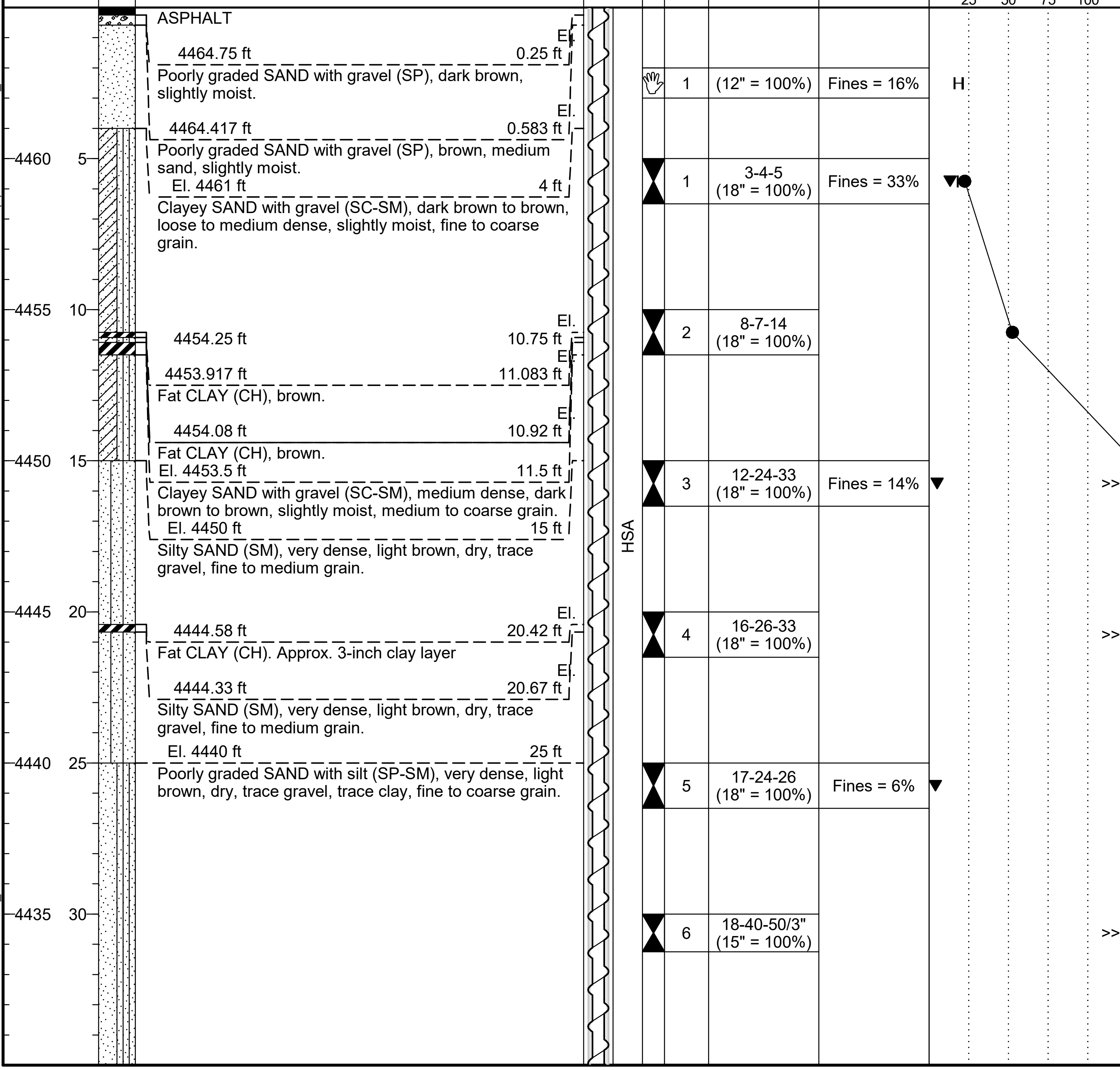
U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY DIVISION

BORING LOG BH21-05 (P-4)

Project Name: Lakeshore Road
Project Location: Elephant Butte State Park, New Mexico
Groundwater Depth:
While Drilling: 89.5 ft / Elev 4375.5 ft
At Completion: ---
After Drilling: 0 hrs 94 ft / Elev 4371 ft
Notes:
For lab testing, select soil samples of similar composition were combined. The testing results presented in these logs are shown for the highest depth of those samples.

Surface Elevation: 4465 ft
Station and Offset: 406+30 8 ft Lt.
Date Started: 1/22/21 Date Completed: 1/22/21
Driller/Company: Brian Schilling/Vine Laboratories Drill: CME 55
Hammer Type: 140 lbs Automatic Hammer Efficiency: 85 %
Logger/Company: B. McGarity/FHWA-CFL
Weather: 35F, foggy/misty

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Sample No.	Field Blow Count (Recovery)	Test Results
		ASPHALT	HSA			
El. 4464.75 ft	0.25 ft	Poorly graded SAND with gravel (SP), dark brown, slightly moist.		1	(12" = 100%)	Fines = 16%
El. 4464.417 ft	0.583 ft	Poorly graded SAND with gravel (SP), brown, medium sand, slightly moist.				
El. 4461 ft	4 ft	Clayey SAND with gravel (SC-SM), dark brown to brown, loose to medium dense, slightly moist, fine to coarse grain.		1	3-4-5 (18" = 100%)	Fines = 33%
				2	8-7-14 (18" = 100%)	
El. 4454.25 ft	10.75 ft					
El. 4453.917 ft	11.083 ft	Fat CLAY (CH), brown.				
El. 4454.08 ft	10.92 ft	Fat CLAY (CH), brown.				
El. 4453.5 ft	11.5 ft	Clayey SAND with gravel (SC-SM), medium dense, dark brown to brown, slightly moist, medium to coarse grain.		3	12-24-33 (18" = 100%)	Fines = 14%
El. 4450 ft	15 ft	Silty SAND (SM), very dense, light brown, dry, trace gravel, fine to medium grain.		4	16-26-33 (18" = 100%)	
El. 4444.58 ft	20.42 ft	Fat CLAY (CH). Approx. 3-inch clay layer				
El. 4444.33 ft	20.67 ft	Silty SAND (SM), very dense, light brown, dry, trace gravel, fine to medium grain.				
El. 4440 ft	25 ft	Poorly graded SAND with silt (SP-SM), very dense, light brown, dry, trace gravel, trace clay, fine to coarse grain.		5	17-24-26 (18" = 100%)	Fines = 6%
				6	18-40-50/3" (15" = 100%)	



BORING LOG BH21-05 (P-4)

Project Name: Lakeshore Road
Project Location: Elephant Butte State Park, New Mexico

Elevation (ft)	Depth (ft)	MATERIAL DESCRIPTION	Drilling Method	Type	No.	Field Blow Count (Recovery)	Test Results	N VALUE
		Poorly graded SAND with silt (SP-SM), very dense, light brown, dry, trace gravel, trace clay, fine to coarse grain. *(continued)*	HSA		7	24-41-49 (18" = 100%)		>>
4425	40				8	20-27-41 (18" = 100%)		>>
4420	45				9	34-50/4" (10" = 100%)		>>
4415	50				10	26-50/6" (12" = 100%)	Fines = 7%	
4410	55				11	23-42-50/5" (17" = 100%)		>>
4405	60				12	19-46-50/5" (17" = 100%)		>>
4400	65	Moisture content changed to slightly moist			13	22-39-50/5" (17" = 100%)		>>
4395	70	El. 4395 ft 70 ft						
		Fat CLAY (CH), green to gray. El. 4394.83 ft 70.17 ft			14	30-40-50/4" (16" = 100%)		>>
		Well graded SAND with silt (SW-SM), very dense, light brown, trace gravel, slightly moist, fine to medium grain, weak cementation at beginning of layer (approx. 1-inch).						
4390	75					20-34-39		>>

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

BORING LOG BH21-05 (P-4)

Project Name: Lakeshore Road

Project Location: Elephant Butte State Park, New Mexico

Elevation (ft)	Depth (ft)	Material Description	Drilling Method	Sample Type	No.	Field Blow Count (Recovery)	Test Results	N Value
		Well graded SAND with silt (SW-SM), very dense, light brown, trace gravel, slightly moist, fine to medium grain, weak cementation at beginning of layer (approx. 1-inch). *(continued)*	HSA		15	(18" = 100%)	Fines = 11%	
4385	80				16	29-42-50/5" (16" = 94%)		>>
		El. 4383.75 ft, 81.25 ft — Fat CLAY (CH), gray to brown.						
		Well graded SAND with silt (SW-SM), very dense, light brown, trace gravel, slightly moist, fine to medium grain.						
4380	85				17	25-32-50/5" (17" = 100%)		>>
		El. 4378 ft, 87 ft — High clay content						
		Poorly graded SAND with silt (SP-SM), very dense, light brown, trace clay, trace gravel, slightly moist, fine to medium grain. Wet after 89.5-feet						
4375	90				18	30-50/5" (14" = 79%)	Fines = 6%	
4370	95				19	32-50/4" (16" = 100%)		
4365	100	El. 4365 ft, 100 ft — Bottom of borehole at 100 ft.			20	50/2" (2" = 100%)	Sand flowed 1-foot into the casing	>>

N VALUE scale: 10, 20, 30, 40. PL / WC / LL scale: 25, 50, 75, 100.

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

BORING LOG BH21-06

Project Name: Lakeshore Road
Project Location: Elephant Butte State Park, New Mexico
Groundwater Depth:
- While Drilling: 90 ft / Elev 4376 ft
- At Completion: ---
- After Drilling: 0 hrs 96 ft / Elev 4370 ft

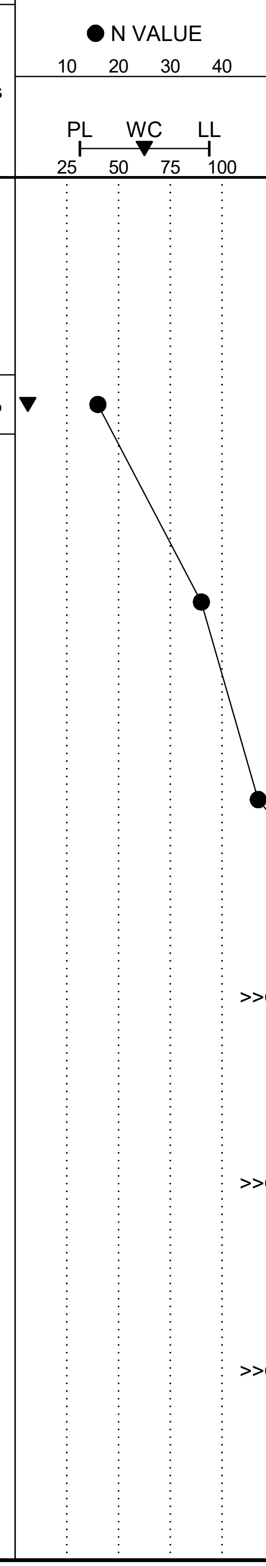
Notes:
For lab testing, select soil samples of similar composition were combined. The testing results presented in these logs are shown for the highest depth of those samples.

Surface Elevation: 4466 ft
Station and Offset: 407+40 8 ft Lt.
Date Started: 1/22/21 Date Completed: 1/22/21
Driller/Company: Brian Schilling/Vine Laboratories Drill: CME 55
Hammer Type: 140 lbs Automatic Hammer Efficiency: 85 %
Logger/Company: B. McGarity/FHWA-CFL
Weather: 55F, sunny (mist/rain in the morning)

Elevation (ft)	Depth (ft)	Material Description
4466	0	ASPHALT
El. 4465.75 ft	0.25 ft	Poorly graded SAND with gravel (SP), dark brown.
El. 4465.5 ft	0.5 ft	Poorly graded SAND with gravel (SP), brown.
El. 4463 ft	3 ft	Poorly graded SAND with silt (SP-SM), medium dense, dark brown to brown, some clay, little gravel, fine to medium grain, slightly moist to moist.
El. 4461.5 ft	4.5 ft	Fat CLAY (CH), brown to gray.
El. 4461.17 ft	4.83 ft	Poorly graded SAND with silt (SP-SM), dense, dark brown to brown, some clay, little gravel, fine to medium grain, slightly moist to moist.
El. 4451 ft	15 ft	Poorly graded SAND with silt (SP-SM), very dense, light brown, dry, trace gravel, fine to coarse grain.

Drilling Method: HSA

Sample No.	Field Blow Count (Recovery)	Test Results
1	6-5-11 (18" = 100%)	Fines = 10%
2	8-15-21 (17" = 94%)	
3	14-21-26 (18" = 100%)	
4	16-30-48 (12" = 67%)	
5	18-50/5" (11" = 100%)	
6	50/5" (5" = 100%)	



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Elevation (ft)	Depth (ft)	Material Description	Drilling Method	Sample No.	Field Blow Count (Recovery)	Test Results	N Value
4430		Poorly graded SAND with silt (SP-SM), very dense, light brown, dry, trace gravel, fine to coarse grain. *(continued)*	HSA	7	14-23-39 (18" = 100%)	Fines = 5%	>>
4425	40		HSA	8	22-35-50/6" (18" = 100%)		>>
4420	45	Weak to moderately cemented sand in bottom of sampler	HSA	9	50/1" (1" = 100%)		>>
4415	50		HSA	10	24-47-50/4" (16" = 100%)		>>
4410	55	El. 4411 ft, 55 ft: Fat CLAY (CH), gray to brown.	HSA				
		El. 4410.83 ft, 55.17 ft: Poorly graded SAND with silt (SP-SM), very dense, light brown, trace gravel, fine to coarse grain, dry to slightly moist.	HSA	11	24-47-50/5" (17" = 100%)		>>
4405	60	Moisture content changed to slightly moist	HSA	12	18-34-50/5" (17" = 100%)	Fines = 6%	>>
4400	65		HSA	13	11-50/5" (11" = 100%)	Fines = 84%	>>
		El. 4400.17 ft, 65.83 ft: Fat CLAY (CH), very stiff, gray to brown, slightly moist.	HSA				
		El. 4399.5 ft, 66.5 ft: Poorly graded SAND with silt (SP-SM), very dense, light brown, trace gravel, slightly moist, fine to medium grain.	HSA				
4395	70		HSA	14	23-46-50/5" (17" = 100%)		>>
	75		HSA		25-42-44		>>

N VALUE: 10, 20, 30, 40
PL, WC, LL: 25, 50, 75, 100

BORING LOG BH21-06

Project Name: Lakeshore Road

Project Location: Elephant Butte State Park, New Mexico

Elevation (ft)	Depth (ft)	Material Description	Drilling Method	Sample No.	Field Blow Count (Recovery)	Test Results	N Value
		Poorly graded SAND with silt (SP-SM), very dense, light brown, trace gravel, slightly moist, fine to medium grain. *(continued)*	HSA	15	(17" = 94%)		
4385	80			16	22-41-50/4" (16" = 100%)	Fines = 8%	>>
4380	85	With gravel and clay from approx. 85 to 86.5 feet		17	29-39-50/5" (17" = 100%)		>>
4375	90	Moisture content changed to wet		18	24-37-50/6" (18" = 100%)	Fines = 9%	>>
4370	95			19	34-42-50/4" (16" = 100%)		>>
El. 4366 ft	100	Bottom of borehole at 100 ft.		20	27-50/4" (16" = 100%)		

N VALUE: 10 20 30 40
PL WC LL: 25 50 75 100

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

BORING LOG BH21-07

Project Name: Lakeshore Road
Project Location: Elephant Butte State Park, New Mexico
Groundwater Depth:
While Drilling: ---
At Completion: ---
After Drilling: ---
Notes:
For lab testing, select soil samples of similar composition were combined. The testing results presented in these logs are shown for the highest depth of those samples.

Surface Elevation: 4469 ft
Station and Offset: 502+55.5 8.5 ft Lt.
Date Started: 1/21/21 Date Completed: 1/21/21
Driller/Company: Brian Schilling/Vine Laboratories Drill: CME 55
Hammer Type: 140 lbs Automatic Hammer Efficiency: 85 %
Logger/Company: B. McGarity/FHWA-CFL
Weather: 40F, cloudy

Elevation (ft)	Depth (ft)	Material Description	Drilling Method	Sample Type	Sample No.	Field Blow Count (Recovery)	Test Results	N Value
4469	0	ASPHALT El. 4468.67 ft — 0.33 ft	ODEX				During first 3 feet, air escaping through surface approximately 4-feet south of boring.	
		Poorly graded SAND with gravel (SP), dark brown. El. 4468.417 ft — 0.583 ft						
4465	5	Poorly graded GRAVEL with sand (GP), dense, light brown, dry, trace silt, cobbles present until approximately 4 feet. Yellow staining and weak cementation at 4 feet El. 4462 ft — 7 ft		SPT	1	15-16-20 (18" = 100%)		36
4460	10	Well graded SAND with silt (SW-SM), very dense, light tan to tan, dry, some gravel, medium to coarse sand, subrounded to subangular gravel. High clay content at 9.5 feet El. 4454 ft — 15 ft		SPT	2	11-25-38 (18" = 100%)	Fines = 11%	>>
4455	15	Poorly graded SAND with silt (SP-SM), very dense, light brown, dry, trace gravel, fine to coarse grain.		SPT	3	16-27-48 (18" = 100%)	Fines = 6%	>>
4450	20			SPT	4	17-27-40 (18" = 100%)	Fines = 9%	>>
4445	25	El. 4444.5 ft — 24.5 ft Yellow staining at 24 feet Fat CLAY (CH), very stiff, brown, dry. El. 4444 ft — 25 ft Poorly graded SAND with silt (SP-SM), very dense, light brown, trace gravel, dry to moist.		SPT	5	5-14-18 (18" = 100%)		32
4440	30	Moisture content changed to moist		SPT	6	25-47-50/5" (17" = 100%)		>>
4435	35			SPT	7	18-32-48		>>

N VALUE scale: 10, 20, 30, 40
PL — WC — LL scale: 25, 50, 75, 100

FHWA BORING LOG - FHWA_DATATEMPLATE.GDT - 1/25/22 13:59 - C:\USERS\BRENDAN.MCGARITY\DOCUMENTS\GEOTECH\PROJECTS\NM\SIE10(1)\USE TO FINISH\3_DATA\DRILLING INVESTIGATION 1-18 TO 1-23\BORING LOGS\GINT\NM LAKESHORE.GPJ

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

BORING LOG BH21-07

Project Name: Lakeshore Road

Project Location: Elephant Butte State Park, New Mexico

Elevation (ft)	Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	No.	Field Blow Count (Recovery)	Test Results	N VALUE (10 20 30 40); PL WC LL (25 50 75 100)
			Poorly graded SAND with silt (SP-SM), very dense, light brown, trace gravel, dry to moist. *(continued)*	ODEX			(18" = 100%)		
			High clay content at bottom of boring						
4430	39 ft		El. 4430 ft						
			Bottom of borehole at 39 ft.			8	14-31-48 (18" = 100%)		>>

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

BORING LOG P-2

Project Name: Lakeshore Road
Sheet: 1 of 1
Project Location: Elephant Butte State Park, New Mexico
Surface Elevation: 4462 ft
Groundwater Depth:
Station and Offset: 205+61 8 ft Lt.
While Drilling: ---
Date Started: 1/20/21
Date Completed: 1/20/21
At Completion: ---
Driller/Company: Brian Schilling/Vine Laboratories
Drill: CME 55
After Drilling: ---
Hammer Type: 140 lbs Automatic
Hammer Efficiency: 85 %
Notes:
Logger/Company: B. McGarity/FHWA-CFL
Weather: 55F, sunny

Elevation (ft)	Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	No.	Field Blow Count (Recovery)	Test Results	N VALUE (10 20 30 40) / PL WC LL (25 50 75 100)
			ASPHALT El. 4461.833 ft 0.167 ft	HSA					
4460			Poorly graded SAND with gravel (SP), dark brown. El. 4461.67 ft 0.33 ft		Grab	1	(12" = 100%)	Fines = 14%	
	5		Silty SAND with gravel (SM), brown, trace cobbles. El. 4457 ft 5 ft						

Bottom of borehole at 5 ft.

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

BORING LOG P-3

Project Name: Lakeshore Road
Sheet: 1 of 1
Project Location: Elephant Butte State Park, New Mexico
Surface Elevation: 4487 ft
Groundwater Depth:
Station and Offset: 309+87 7 ft Rt.
While Drilling: ---
Date Started: 1/19/21
Date Completed: 1/19/21
At Completion: ---
Driller/Company: Brian Schilling/Vine Laboratories
Drill: CME 55
After Drilling: ---
Hammer Type: 140 lbs Automatic
Hammer Efficiency: 85 %
Notes:
Logger/Company: B. McGarity/FHWA-CFL
Weather: 50F, cloudy, windy

Elevation (ft)	Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	No.	Field Blow Count (Recovery)	Test Results	N VALUE (10 20 30 40); PL WC LL (25 50 75 100)
			ASPHALT El. 4486.833 ft 0.167 ft	HSA					
4485			Poorly graded SAND with gravel (SP), brown, dry. El. 4486.5 ft 0.5 ft	HSA	Grab	1	(12" = 100%)	Fines = 18%	
	5		Silty SAND with gravel (SM), light brown, dry, some clay, with cobbles. High clay content El. 4482 ft 5 ft	HSA					

Bottom of borehole at 5 ft.

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

BORING LOG P-5

Sheet: 1 of 1

Project Name:	Lakeshore Road		
Project Location:	Elephant Butte State Park, New Mexico	Surface Elevation:	4469 ft
Groundwater Depth:		Station and Offset:	502+60.5 8.5 ft Lt.
While Drilling:	---	Date Started:	1/21/21
		Date Completed:	1/21/21
At Completion:	---	Driller/Company:	Brian Schilling/Vine Laboratories
		Drill:	CME 55
After Drilling:	---	Hammer Type:	140 lbs Automatic
		Hammer Efficiency:	85 %
Notes:		Logger/Company:	B. McGarity/FHWA-CFL
		Weather:	50F, partly cloudy

Elevation (ft)	Depth (ft)	Graphic Log	MATERIAL DESCRIPTION	Drilling Method	SAMPLE Type	No.	Field Blow Count (Recovery)	Test Results	N VALUE (10 20 30 40) / PL WC LL (25 50 75 100)
			ASPHALT	HSA					
			El. 4468.67 ft 0.33 ft						
			Poorly graded SAND with gravel (SP), dark brown, dry.		Grab	1	(12" = 100%)	Fines = 4%	
			El. 4468.417 ft 0.583 ft						
4465	5		Poorly graded GRAVEL with sand (GP), brown to light brown, dry, with cobbles.						
			El. 4464 ft 5 ft						

Bottom of borehole at 5 ft.

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GRL engineers, inc.
Dynamic Measurements and Analyses

Job No. 212002-1.1

Report on: Energy Measurement for Dynamic Penetr.
Rig(s): CME 55
Serial Number 332955
Standard Penetration Tests (SPT)
Commerce City, Colorado

Prepared for Vine Laboratories, Inc.
By Camilo Alvarez, P.E. and
Anna M. Klesney, MSCE, E.I.T.

January 14, 2021

www.GRLengineers.com info@GRLengineers.com

GRL Dynamic Measurements and Analyses
engineers, inc.

January 14, 2021

Amy Norwood, President
Vine Laboratories, Inc.
6455 East 56th Avenue
Commerce City, Colorado 80022

Re: Energy Measurement for Dynamic Penetrometers
Rig(s): CME 55 Serial Number 332955
Standard Penetration Tests (SPT)
Denver County, Colorado GRL Job No. 212002-1

Dear Ms. Amy Norwood:

This report transmits our findings from energy measurements and related data analysis conducted by GRL Engineers, Inc. (GRL) for one drill rig, with measurements collected near Commerce City, Colorado. One automatic hammer and penetrometer system was monitored during Standard Penetration Tests. Dynamic testing summarized in this report was conducted on January 7, 2021.

A Pile Driving Analyzer® Model 8G recorded, processed and displayed the dynamic data to meet the objectives of the hammer system calibration. Discussions on the test methods, limitations and implementation are provided in Appendix A. The energy measurement results are summarized in Table 1 with the average and standard deviation provided in Appendix B, and representative plots of force and normalized velocity provided in Appendix C. Supplemental documents can be found in Appendix D.

EQUIPMENT

Hammer and Penetrometer System

Energy measurements were recorded during standard penetration tests conducted for one automatic hammer and the following drill rig type(s) and serial number(s).

Drill Rig Type	Drill Rig Serial Number
CME 55	332955

Measurements were recorded for one boring location. Vine Laboratories, Inc. (VINE) advanced the penetrometer to a depth of an approximate 20.0 feet prior to energy measurements. The instrumented subassembly was connected to the top of the drill rod string and measurements recorded at generally continuous intervals for five depths of data.

Measurements were recorded for every blow required to advance the sampler 18 inches or terminated upon encountering refusal conditions. Results are provided for the final 12 inches or less of the sampler advancement alone (i.e., excluding the initial 6 inches of advancement). ASTM Standard D4633 states that tests for energy evaluation should be limited to SPT N-values between 10 and 50. Energy measurements of sample(s) not meeting the lower bound N-value have been excluded from the reported averages.

The following drill rod dimensions, of rod size AWJ, were employed during testing.

Drill Rod Area sq. inch	Outside Diameter Inch	Inside Diameter inch
1.20	1.75	1.23
Depth of Penetrometer feet	Drill Rod Section Lengths feet	Transducer to Penetrometer Length ᵻ feet
20.0	20	23.79
25.0	25	28.33
30.0	30	33.79
35.0	35	38.33
40.0	40	43.79

* A (CME 55 Serial Number 332955).

ᵻ Two splitspoon samplers with drive heads were used, of different total length, and alternated for subsequent depths.

Instrumentation

A Pile Driving Analyzer was employed for recording, processing, and displaying the dynamic data. An instrumented subassembly, inserted at the top of the drill rod string below the hammer and anvil system and above the drill rods to record force and acceleration data. The subassembly was instrumented with two foil strain gages in a full bridge circuit and two piezoresistive accelerometers attached on diametrically opposite sides of the subassembly. Data sampling frequency was 50.0 kHz.

The Model 8G utilizes a digital system, and with the employed sampling frequency of 50.0 kHz, the signal conditioning conforms to ASTM D4633. Results for the maximum hammer operating rate, rod top force and velocity, and transferred energy are provided in Appendix B and summarized in Table 1. Discussions on the test method and its limitations can be found in Appendix A.

MEASUREMENTS AND CALCULATIONS

The primary objective of testing was the measurement of the energy transmitted from the hammer impact through the anvil into the instrumented subassembly and drill rods. Strain transducers and accelerometers were employed for the calculation of the transferred energy using force, F(t) and velocity v(t), records as follows:

$$EMX = \int_b^a F(t)v(t)dt$$

where time "b" is to the beginning of the energy transfer and time "a" is to the time at which the energy transfer reaches a maximum. Force is calculated as the product of the measured strain, elastic modulus and cross-sectional area, and measured acceleration is integrated to velocity.

Integrated over the complete impact event and calculated from measured force and velocity, the energy transferred to the top of the drill rod was calculated as a function of time. The maximum transferred energy (i.e., EMX or also referred to as EFV) is used as an indicator of the energy content of the event. The described method is the only theoretically correct method of measuring energy transfer and automatically corrects for rod non-uniformities such as connector masses or loose joints. The EF2 method results included in Appendix B are inherently incorrect and included in Appendix B for reference alone.

TEST RESULTS

Result Discussion

Dynamic data was evaluated for the hammer operating rate, rod top force and velocity, and transferred energy. Appendix B provides the evaluated quantities for blows making up the SPT N-value, with their averages and standard deviation, plotted and printed as a function of depth for the monitored sequences of the standard penetration tests. Measurements collected for all samples are presented herein.

The plots in Appendix B include:

- FMX – the maximum measured rod top force
- VMX – the maximum measured rod top velocity
- BPM – the hammer operating rate in blows per minute
- BLC – the equivalent penetration resistance or count of impacts per each 6 inches set
- EFV – the maximum calculated energy transferred to the rod top
- EF2 – the maximum of the integral of the square of force, theoretically incorrect energy transfer calculation

Corresponding tables also include:

- CSX – the maximum measured rod top compressive stress, averaged over the cross-sectional area
- CSI – the maximum measured, compressive stress at an individual foil strain gage
- ETR – ratio of transferred energy (EFV) to the maximum theoretical potential energy

The maximum theoretical potential energy is the product of the standard 140 lb hammer impact mass dropped the standard 30 inches (i.e., equivalent to 350 ft-lb).

A representative plot of force and normalized velocity versus time for a typical blow from each data set is provided in Appendix C to demonstrate the data quality.

Summary of Results

I. One automatic hammer was monitored during standard penetration tests conducted on January 7, 2021. The average energy transfer ratio calculated with the EFV method for the monitored sequences is tabulated below together with the corresponding, average hammer operating rate.

Drill Rig Serial Number	Energy Transfer Ratio percent	Operating Rate bpm
332955	85	55

II. The uncorrected N-values encountered during all monitored sequences ranged from 8 blows to refusal conditions.

III. To convert the uncorrected N-values for the employed hammer and penetrometer system and operators, the Schmertman correction for adjustment to 60 percent transfer efficiency is

$$N_{60} = \left(\frac{e_m}{60}\right) N_m$$

where N_{60} is the corrected hammer N-value, e_m is the percent energy transfer efficiency (i.e., e_m = 100*ETR) and N_m is the measured SPT N-value. N_{60} values for all measurements and monitored depths are presented in the appended tables. The measured overall energy transfer ratio(s) tabulated above produces an N_{60} equivalent of roughly $1.4N_m$. Further corrections due to overburden stresses in the soil, etc. have not been considered herein.

We appreciate the opportunity to be of assistance to you on this project. Please contact our offices should you have any questions regarding the contents of this report, or if we may be of further service.

Respectfully,
GRL ENGINEERS, INC.

01/14/2021

Camilo Alvarez, P.E. Colorado
Senior Engineer

Exp: 10/31/2021

Anna M. Klesney, MSCE, E.I.T.
Project Engineer

TABLE 1: Summary of Field Results
Energy Measurement for Dynamic Penetrometers

Rig Serial No.	Depth(s)	Uncorrected N value (1)	Corrected N value (2)	Hammer Operating Rate (BPM)	Average Transferred Energy (EFV) (3)	Energy Transfer Ratio (ETR) (3)	Maximum Compressive Measured Top Stress (CSX) (4)	Maximum Compressive Impact Top Force (FMX) (5)
	ft	blows	N_{60}	bpm	ft-lbs	%	ksi	kips
CME 55 Serial Number 332955								
	20.0 - 21.5	8	12	54	321	92	24.0	29
	25.0 - 26.5	43	61	56	297	85	22.0	26
	30.0 - 31.5	17	25	55	308	88	22.0	26
	35.0 - 36.5	41	58	55	296	84	21.9	26
	40.0 - 40.7	50 for 2.0"	- - -	55	292	83	22.9	27
	Overall System Performance			55	298	85	22.2	27
	Standard Deviation			1	7	2	0	1

Notes

1. Uncorrected N-value, number of hammer blows required to advance sampler the final 12 inches, unless noted otherwise.
2. Corrected N-value, number of hammer blows required to advance sampler the final 12 inches, corrected for calculated energy transfer ratio (ETR).
3. Average transferred energy at transducer location; ratio of transferred energy to theoretical potential energy of hammer.
4. Average, measured Compressive driving Stress averaged over the drill rod cross section at transducer location.
5. Average, measured Compressive driving Force at transducer location.

APPENDIX A

APPENDIX A
AN INTRODUCTION INTO SPT DYNAMIC TESTING

The following has been written by GRL Engineers, Inc. and may only be copied with its written permission.

1. BACKGROUND

The Standard Penetration Test is frequently conducted as an in-situ assessment of soil strength. This test requires that a 140 lb weight is dropped 30 inches onto a drive rod at whose bottom a sampler is usually installed. The sampler is driven for 18 inches; the number of blows required for the last 12 inches of driving is the so-called N-value. The N-value may be used as a strength indicator for foundation design or as a means of assessing the liquefaction potential of soils.

Obviously, the SPT hammer efficiency is an important consideration when using the N-values for design purposes. Measurements have indicated that the energy in the drive rod is sometimes only 30% and and may reach 90% of the potential or rated energy of the SPT hammer (E-rated = 0.35 kip-ft or 0.475 kJ). The type of hammer used to drive the rod is the main reason for these variations. On the average, the energy in the drive rod is 60% of the standard rated energy.

Because of the variability of energy, methods based on N-values are considered unreliable. However, measurements during SPT testing using the Case Method can be done on a routine basis and these measurements yield the transferred energy values. With measured energy, EMX, known, an adjustment of the measured N-value, N_m, can be made as follows.

$$N_{60} = N_m \, [E_m \, / \, (0.6 E_r)] \qquad (1)$$

Thus, if the measured energy value is equal to the normally expected transferred energy of 60% of E-rated then the adjusted and measured N-values are identical. On the other hand, if the measured energy is only 30% then the adjusted blow count will be reduced by 50%.

2. DYNAMIC TESTING AND ANALYSIS METHODS APPLIED TO SPT

The Case Method of dynamic pile testing, named after the Case Institute of Technology where it was developed between 1964 and 1975, requires that a substantial ram mass (e.g. a pile driving hammer) impacts the pile top such that the pile undergoes at least a small permanent set. Thus, the method is also referred to as a “High Strain Method”. The Case Method requires dynamic measurements on the pile or shaft under the ram impact and then a calculation of various quantities. Conveniently, for SPT applications, the measurements and analyses are done by a single piece of equipment: the SPT Analyzer. The Pile Driving Analyzer® (PDA) is also suitable to perform these measurements and data processing.

A related analysis method is the “Wave Equation Analysis” which calculates a relationship between bearing capacity, pile stresses, transferred energy and field blow count. The GRLWEAP™ program performs this analysis and provides a complete set of helpful information and input data. This program can be used very effectively to simulate the SPT driving process.

3. MEASUREMENTS

GRL uses equipment manufactured by Pile Dynamics, Inc. The system includes either an SPT-Analyzer™ (SPTA) or a Pile Driving Analyzer® (PDA), an instrumented rod section and two accelerometers. SPT energy testing is very closely related to and borrows procedures from dynamic pile testing. Those interested in the basis of the SPT energy testing method may obtain extensive literature on dynamic pile testing from GRL Engineers, Inc.

3.1 SPT Analyzer or Pile Driving Analyzer

The basis for the results calculated by the SPTA or PDA are strain and acceleration measured in an instrumented rod section. These signals are converted to rod top force, F(t), and rod top velocity, v(t). The SPTA or PDA conditions, calibrates and displays these signals and immediately computes average pile force and velocity thereby eliminating bending effects. The product of these two measurements is then integrated over time which yields the energy transferred to the instrumented section as a function of time (see Section 4.1).

For convenience and accuracy, strain measurements are usually taken on an instrumented section of SPT drive rod. Ideally, the section properties of the instrumented rod and those of the drive rod are the same, however, using subs, other sections can also be utilized.

For the instrumented section, PDI provides a force calibration in such a way that the output of the instrumented rod is directly calculated without the need for an accurate elastic modulus or cross sectional area of the rod section.

The acceleration measurements are often demanding in the SPT environment, because of high frequency and high acceleration motion components. An experienced measurement engineer, therefore, has to evaluate the quality of this data before final conclusions are drawn from the numerical results calculated by SPTA or PDA.

SPTA or PDA records are taken while the standard N-value is acquired in the conventional manner. This then allows a direct correlation between N-value and average transferred energy.

3.2 HPA

The SPT hammer's ram velocity may be directly obtained using radar technology in the Hammer Performance Analyzer™. The impact velocity results can be automatically processed with a PC or recorded on a strip chart. HPA measurements yield a hammer kinetic energy, but not the energy transferred to the drive rod.

4 RECORD EVALUATION BY SPTA OR PDA

4.1 HAMMER PERFORMANCE

The PDA calculates the energy transferred to the pile top from:

$$E(t) = \int_0^t F(\tau)v(\tau)\, d\tau \qquad (2)$$

The maximum of the E(t) curve is often called **ENTHRU or EMX;** it is the most important quantity for an overall evaluation of the performance of a hammer and driving system. **EMX** allows for a classification of the hammer's performance when presented as, e_T, the rated transfer efficiency, also called energy transfer ratio (**ETR**) or global efficiency.

$$e_T = EMX/E_R \qquad (3)$$

where E_R is the hammer manufacturer's rated energy value or 0.35 kip-ft (0.475 kJ) in the case of the SPT hammer.

Often in the SPT literature one finds also reference to the EF2 energy. This evaluation is based on assumed proportionality between force and velocity (see also Section 5):

$$v(t) = F(t) / Z \qquad (4)$$

where Z = EA/c is the pile impedance, E is the elastic modulus, A is the cross sectional area and c is the speed of the stress wave in the pile material..

Combining equations 2 and 4 leads to

$$EF(t) = \int_0^t F(\tau)^2 / Z\, d\tau \qquad (5)$$

The EF2 transferred energy value is the EF-value at the time t = 2L/c, where L is the drive rod length and c is the stress wave speed in steel (16,800 ft/s or 5,124 m/s). Since the force is easier to measure than both force and velocity, Equation 5 is preferred by some test engineers. However, the EF method is fraught with errors and certain correction factors have to be applied to make it approximately correct. Among the error sources are the following:

- Proportionality is often violated prior to time 2L/c. The proportionality between force and velocity in a downward traveling wave only holds if the wave does not encounter a disturbance prior to reflecting off the pile toe. Such disturbances include a change in cross sectional area, an open or loose splice or joint, or resistance along the shaft.

- Using only one force measurement precludes a data quality check based on the proportionality between force and velocity. Thus, a force measurement that is for some reason in error may not be detectable, which will lead to errors in the EF2 value. Data quality checks will be discussed further in Section 5.

The use if EF2 is therefore not recommended but it is often included in result presentations for the sake of completeness.

4.2 STRESSES

During SPT monitoring, it is also of interest to monitor compressive stresses at both the top of the drive rod and at its bottom.

At the pile top (location of sensors) the maximum compression stress averaged over the rod's cross section, **CSX**, is directly obtained from the measurements. Note that this stress value refers to the instrumented section. If the rod has a different cross sectional area then the stress in the rod will be different from CSX.

The SPTA or PDA can also calculate, in an approximate manner, the force at the rod bottom, **CFB**. To obtain the corresponding stress, this force value should be divided by the appropriate cross sectional area, e.g. by the rod area just above the sampler or by the sampler area itself. Of course, non-uniform stress components as they might occur at the sampler tip due to a sloping rock are not considered in this calculation.

5. DATA QUALITY CHECKS

Quality data is the first and foremost requirement for accurate dynamic testing results. It is therefore important that the measurement engineer performing SPTA or PDA tests has the experience necessary to recognize measurement problems and take appropriate corrective action should problems develop. Fortunately, dynamic pile testing allows for certain data quality checks because two independent measurements are taken that have to conform to the so-called proportionality relationship.

As long as there is only a wave traveling in one direction, as is the case during impact when only a downward traveling wave exists in the rod, force and velocity measured at its top are proportional

$$F = v\,Z \qquad (5)$$

where Z is again the pile impedance, Z = EA/c. This relationship can also be expressed in terms of stress

$$\sigma = F/A = v\,(E/c) \qquad (6)$$

or strain

$$\epsilon = \sigma/E = v / c \qquad (7)$$

This means that the early portion of strain times wave speed must be equal to the velocity unless the proportionality is affected by high friction near the pile top or by a pile cross sectional change not far below the sensors. Checking the proportionality is an excellent means of assuring meaningful measurements but is only truly meaningful for perfectly uniform rods. Open or loose splices, for example, will lead to a non-proportionality. For SPT rods it is fortunate that usually no soil resistance acts along the shaft and for that reason, proportionality can exist until the stress wave returns from sampler top or rod bottom unless connectors are not sufficiently tightened or have a significant mass.

Velocity data quality can also be checked by looking at the final displacement, DFN, which is calculated from the acceleration by double integration. If the calculated final displacement is much higher or lower than indicated by the N-value, the accelerometer attachment may be loose or the sensor may be faulty. If major drift in the velocity is observed, the EMX value may be in error, even though proportionality from impact to time 2L/c exists. In this case, it may be useful to evaluate the energy transferred to the drill rod at time 2L/c, which is calculated by the PDA or SPTA as the E2E quantity.

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APPENDIX B

ENERGY MEASUREMENT RESULTS

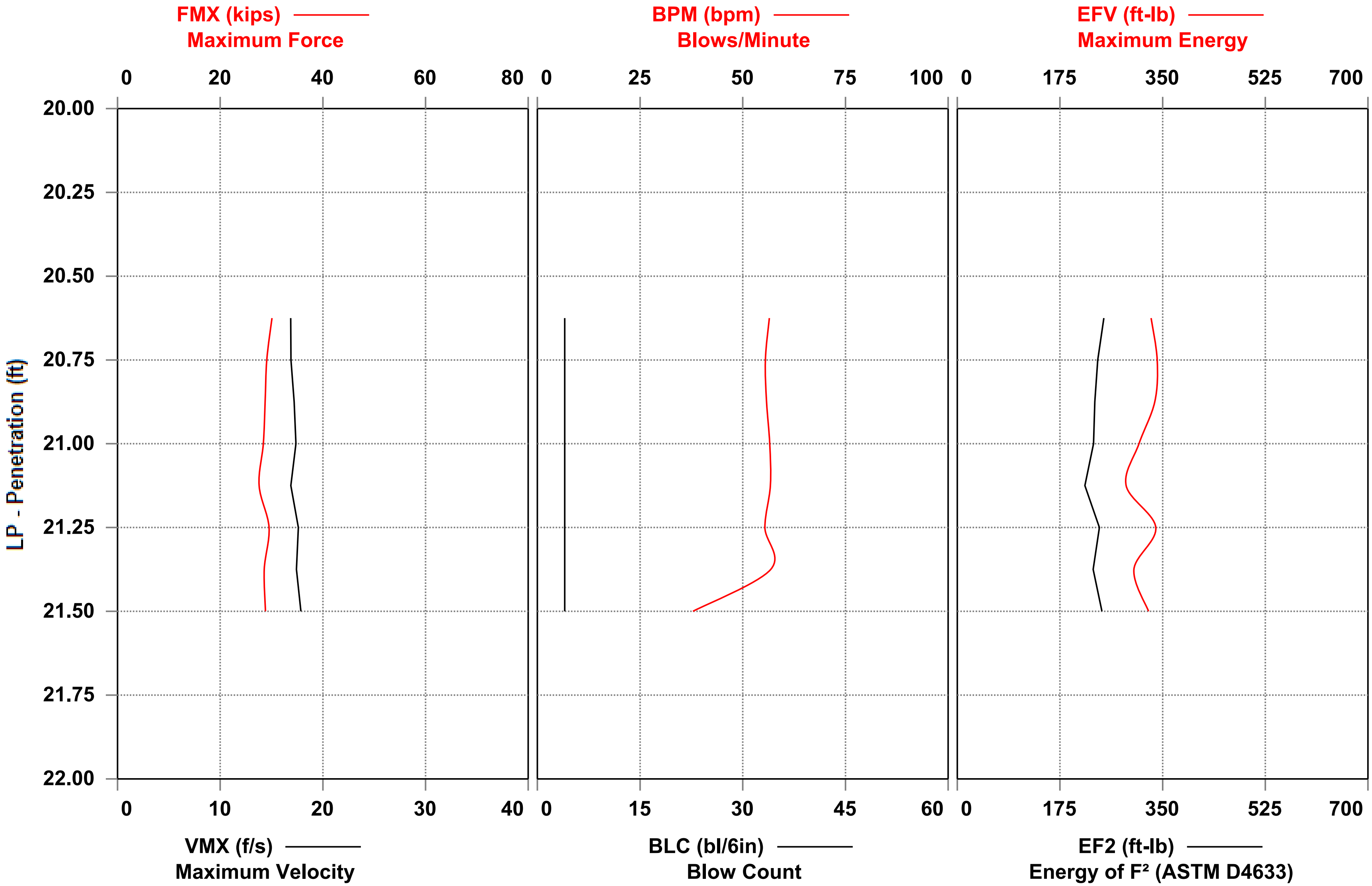
CME 55 Serial Number 332955

GRL Engineers, Inc. - PDIPLOT2 Ver 2020.1.60.3 - Case Method & iCAP® Results

Printed: 14-January-2021 Test started: 07-January-2021

CME 55 Serial Number 332955 - CME 55 at 20.0 to 21.5 feet

AWJ



Case Method & iCAP® Results

CME 55 Serial Number 332955 - CME 55 at 20.0 to 21.5 feet AWJ
OP: AK Date: 07-January-2021

AR: 1.20 in² SP: 0.492 k/ft³
LE: 23.79 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.00

CSX: Compression Stress Maximum
CSI: Comp Stress Max-Individual Sens
FMX: Maximum Force
VMX: Maximum Velocity
BPM: Blows/Minute
EFV: Maximum Energy
EF2: Energy of F² (ASTM D4633)
ETR: Energy Transfer Ratio - Rated

BL#	Depth	BLC	CSX	CSI	FMX	VMX	BPM	EFV	EF2	ETR
	ft	bl/6in	ksi	ksi	kips	f/s	bpm	ft-lb	ft-lb	(%)
10	20.63	4	25.1	25.4	30	16.9	56	330	250	94
11	20.75	4	24.2	24.6	29	16.9	56	341	239	97
12	20.88	4	24.0	24.1	29	17.2	56	337	234	96
13	21.00	4	23.7	24.0	28	17.4	57	310	232	88
14	21.13	4	23.0	23.2	28	16.9	57	288	217	82
15	21.25	4	24.6	24.8	30	17.6	55	338	242	97
16	21.38	4	23.8	24.1	29	17.4	57	301	232	86
17	21.50	4	24.0	24.2	29	17.9	38	326	247	93
		Average	24.0	24.3	29	17.3	54	321	237	92
		Std. Dev.	0.6	0.6	1	0.3	6	18	10	5
		Maximum	25.1	25.4	30	17.9	57	341	250	97
		Minimum	23.0	23.2	28	16.9	38	288	217	82

Total number of blows analyzed: 8

BL# Sensors

10-17 F1: [215 AWJ-1] 213.7 (1.00); F2: [215 AWJ-2] 213.0 (1.00); A3: [K10734] 434.2 (1.00); A4: off

Time Summary

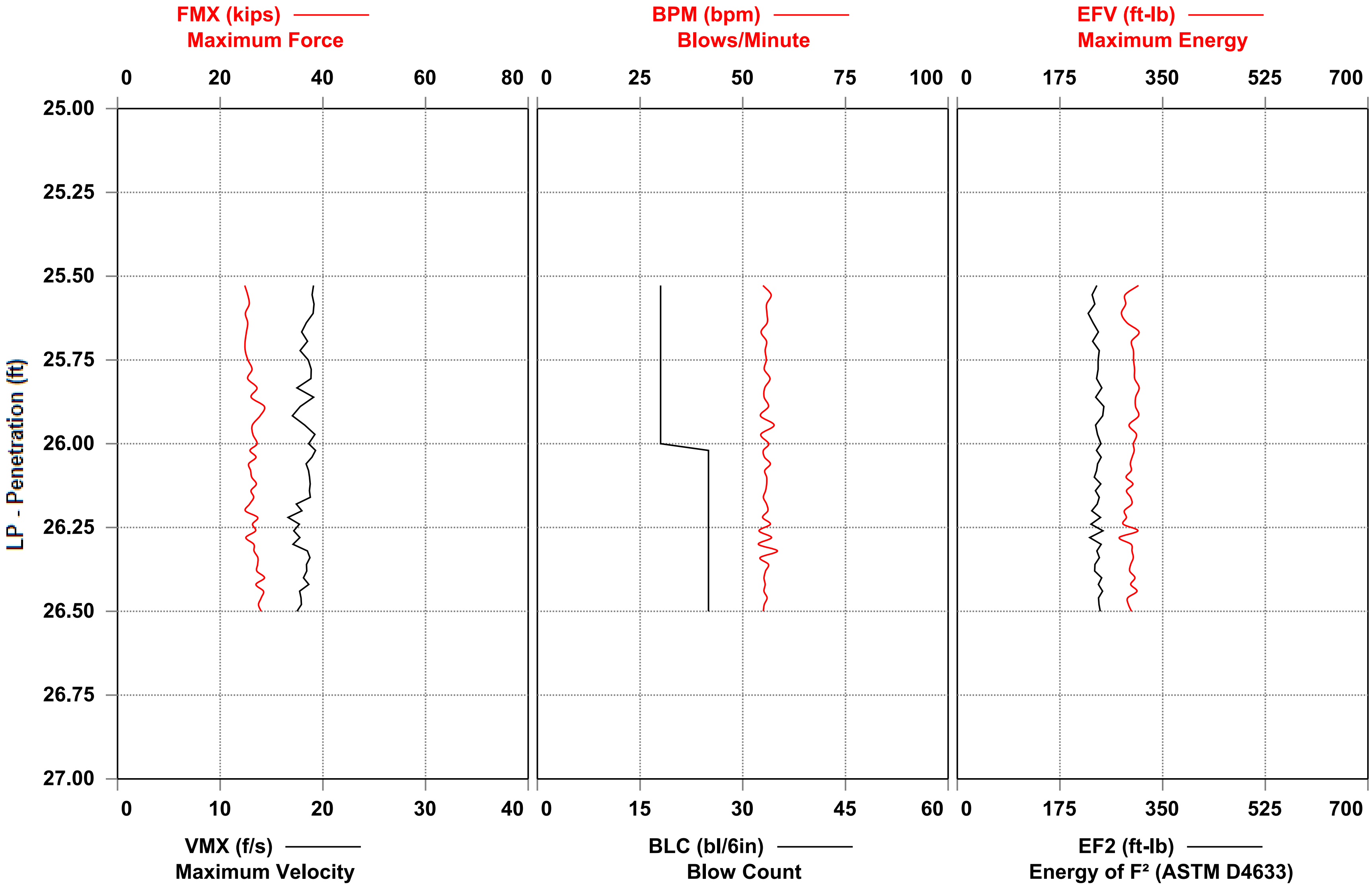
Drive 17 seconds 1:13 PM - 1:13 PM BN 1 - 17

GRL Engineers, Inc. - PDIPLOT2 Ver 2020.1.60.3 - Case Method & iCAP® Results

Printed: 14-January-2021 Test started: 07-January-2021

CME 55 Serial Number 332955 - CME 55 at 25.0 to 26.5 feet

AWJ



Case Method & iCAP® Results

CME 55 Serial Number 332955 - CME 55 at 25.0 to 26.5 feet AWJ
OP: AK Date: 07-January-2021

AR: 1.20 in² SP: 0.492 k/ft³
LE: 28.33 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.00

CSX: Compression Stress Maximum BPM: Blows/Minute
CSI: Comp Stress Max-Individual Sens EFV: Maximum Energy
FMX: Maximum Force EF2: Energy of F² (ASTM D4633)
VMX: Maximum Velocity ETR: Energy Transfer Ratio - Rated

BL#	Depth	BLC	CSX	CSI	FMX	VMX	BPM	EFV	EF2	ETR
	ft	bl/6in	ksi	ksi	kips	f/s	bpm	ft-lb	ft-lb	(%)
12	25.53	18	20.7	20.7	25	19.1	55	309	238	88
13	25.56	18	21.1	21.2	25	19.0	57	286	230	82
14	25.58	18	21.4	21.4	26	19.1	56	287	234	82
15	25.61	18	20.7	20.8	25	19.1	56	280	223	80
16	25.64	18	21.1	21.2	25	18.4	56	289	231	83
17	25.67	18	20.9	21.1	25	17.9	54	310	240	88
18	25.69	18	20.7	20.8	25	18.5	56	297	231	85
19	25.72	18	20.7	20.9	25	17.8	55	300	242	86
20	25.75	18	21.2	21.3	25	18.6	56	300	240	86
21	25.78	18	21.8	21.9	26	18.9	55	302	240	86
22	25.81	18	21.1	21.2	25	18.8	57	302	237	86
23	25.83	18	22.6	22.8	27	17.5	55	310	246	89
24	25.86	18	21.7	21.7	26	19.1	55	304	236	87
25	25.89	18	23.8	24.0	29	17.8	56	304	250	87
26	25.92	18	23.2	23.4	28	17.0	54	309	248	88
27	25.94	18	21.9	22.1	26	18.2	58	293	236	84
28	25.97	18	22.0	22.1	26	19.2	54	305	239	87
29	26.00	18	22.7	22.8	27	18.6	56	300	245	86
30	26.02	25	21.5	21.7	26	19.3	55	302	237	86
31	26.04	25	22.5	22.6	27	18.9	55	298	245	85
32	26.06	25	21.3	21.5	26	18.4	57	295	239	84
33	26.08	25	21.6	21.8	26	18.6	55	297	237	85
34	26.10	25	21.8	22.0	26	18.7	56	288	234	82
35	26.12	25	22.5	22.8	27	18.8	56	299	245	85
36	26.14	25	21.7	22.0	26	18.7	56	288	236	82
37	26.16	25	22.1	22.3	27	18.8	55	295	242	84
38	26.18	25	21.4	21.8	26	17.4	56	297	239	85
39	26.20	25	20.7	21.0	25	18.0	56	285	229	81
40	26.22	25	22.7	23.1	27	16.6	55	288	244	82
41	26.24	25	21.9	22.1	26	17.7	57	283	228	81
42	26.26	25	22.4	22.8	27	17.2	54	308	248	88
43	26.28	25	20.8	21.1	25	17.8	57	276	226	79
44	26.30	25	22.1	22.4	27	17.1	54	296	245	85
45	26.32	25	22.2	22.3	27	18.5	58	298	238	85
46	26.34	25	22.8	22.9	27	18.7	54	300	242	86
47	26.36	25	22.7	22.9	27	18.4	56	296	235	84
48	26.38	25	22.6	22.8	27	18.4	56	294	234	84
49	26.40	25	23.9	24.1	29	18.1	55	303	246	87
50	26.42	25	22.5	22.6	27	18.6	55	296	240	84
51	26.44	25	23.7	23.9	28	17.7	55	306	248	87
52	26.46	25	23.3	23.5	28	17.9	56	290	241	83
53	26.48	25	22.9	23.1	27	17.9	55	292	242	83
54	26.50	25	23.3	23.6	28	17.5	55	297	244	85
		Average	22.0	22.2	26	18.3	56	297	239	85
		Std. Dev.	0.9	0.9	1	0.7	1	8	6	2
		Maximum	23.9	24.1	29	19.3	58	310	250	89

Case Method & iCAP® Results

CME 55 Serial Number 332955 - CME 55 at 25.0 to 26.5 feet AWJ
OP: AK Date: 07-January-2021

BL#	Depth	BLC	CSX	CSI	FMX	VMX	BPM	EFV	EF2	ETR
	ft	bl/6in	ksi	ksi	kips	f/s	bpm	ft-lb	ft-lb	(%)
		Minimum	20.7	20.7	25	16.6	54	276	223	79

Total number of blows analyzed: 43

BL# Sensors

12-54 F1: [215 AWJ-1] 213.7 (1.00); F2: [215 AWJ-2] 213.0 (1.00); A3: [K10734] 434.2 (1.00);
A4: [K1514] 354.0 (1.00)

Time Summary

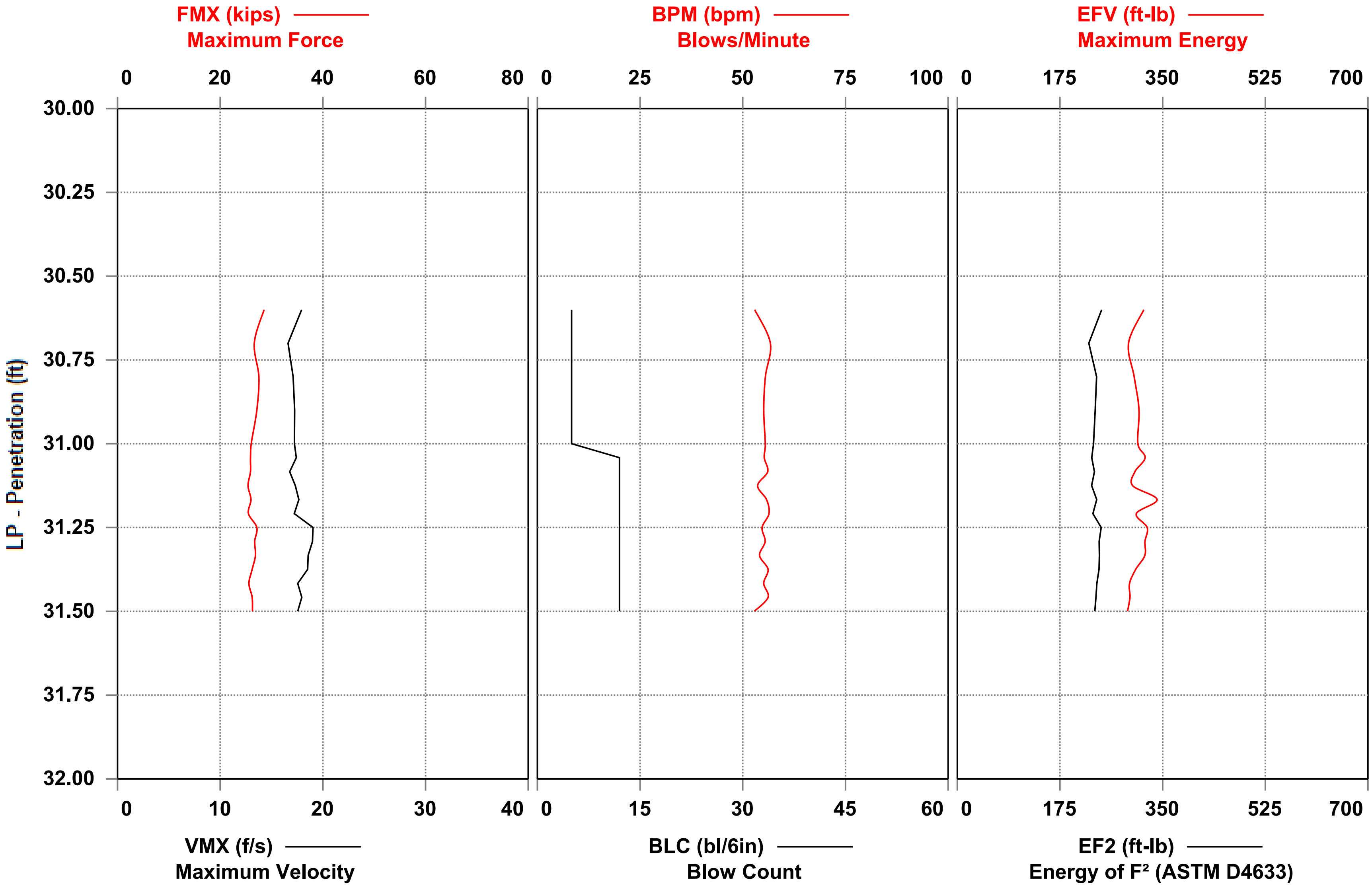
Drive 57 seconds 1:20 PM - 1:21 PM BN 1 - 54

GRL Engineers, Inc. - PDIPLOT2 Ver 2020.1.60.3 - Case Method & iCAP® Results

Printed: 14-January-2021 Test started: 07-January-2021

CME 55 Serial Number 332955 - CME 55 at 30.0 to 31.5 feet

AWJ



Case Method & iCAP® Results

CME 55 Serial Number 332955 - CME 55 at 30.0 to 31.5 feet AWJ
OP: AK Date: 07-January-2021

AR: 1.20 in² SP: 0.492 k/ft³
LE: 33.79 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.00

CSX: Compression Stress Maximum BPM: Blows/Minute
CSI: Comp Stress Max-Individual Sens EFV: Maximum Energy
FMX: Maximum Force EF2: Energy of F² (ASTM D4633)
VMX: Maximum Velocity ETR: Energy Transfer Ratio - Rated

BL#	Depth	BLC	CSX	CSI	FMX	VMX	BPM	EFV	EF2	ETR
	ft	bl/6in	ksi	ksi	kips	f/s	bpm	ft-lb	ft-lb	(%)
5	30.60	5	23.8	24.3	29	17.9	53	318	246	91
6	30.70	5	22.2	22.7	27	16.6	57	292	224	83
7	30.80	5	22.9	23.5	28	17.1	56	301	238	86
8	30.90	5	22.6	22.8	27	17.3	55	310	235	89
9	31.00	5	21.7	21.7	26	17.2	55	308	232	88
10	31.04	12	21.6	21.7	26	17.4	55	320	229	91
11	31.08	12	21.6	21.6	26	16.8	56	303	234	86
12	31.13	12	21.2	21.3	25	17.3	54	299	229	85
13	31.17	12	21.7	21.7	26	17.7	56	340	238	97
14	31.21	12	21.2	21.3	25	17.2	56	305	231	87
15	31.25	12	22.6	22.7	27	19.0	55	324	245	92
16	31.29	12	22.3	22.4	27	19.0	55	320	242	91
17	31.33	12	22.4	22.4	27	18.6	54	320	242	91
18	31.38	12	21.9	21.9	26	18.5	56	304	242	87
19	31.42	12	21.3	21.4	26	17.5	55	294	238	84
20	31.46	12	21.9	21.9	26	17.9	56	294	236	84
21	31.50	12	21.9	22.0	26	17.5	53	290	234	83
		Average	22.0	22.2	26	17.7	55	308	236	88
		Std. Dev.	0.7	0.8	1	0.7	1	13	6	4
		Maximum	23.8	24.3	29	19.0	57	340	246	97
		Minimum	21.2	21.3	25	16.6	53	290	224	83

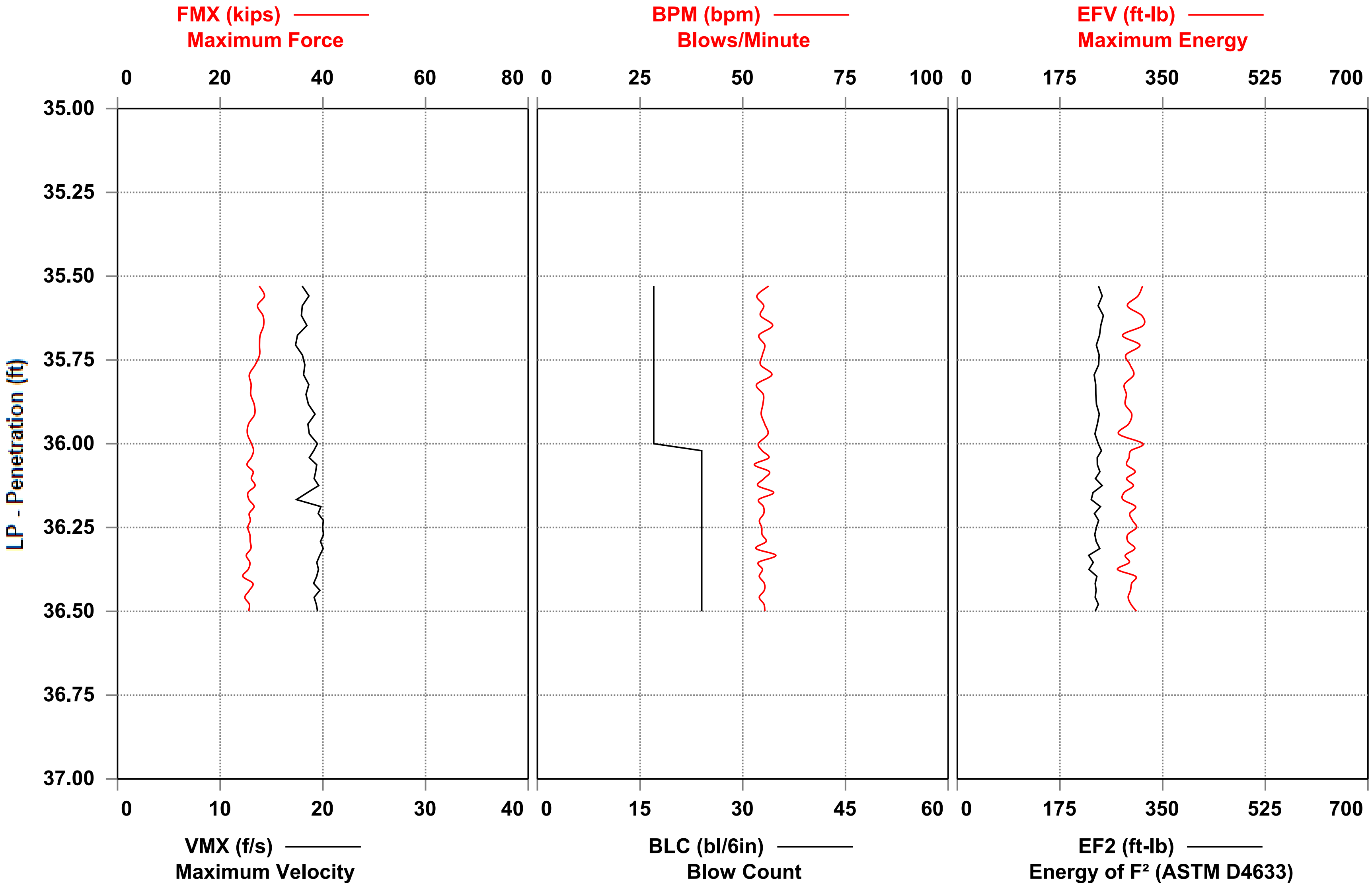
Total number of blows analyzed: 17

BL#	Sensors
5-14	F1: [215 AWJ-1] 213.7 (1.00); F2: [215 AWJ-2] 213.0 (1.00); A3: [K10734] 434.2 (1.00); A4: [K1514] 354.0 (1.00)
15-17	F1: [215 AWJ-1] 213.7 (1.00); F2: [215 AWJ-2] 213.0 (1.00); A3: [K10734] 434.2 (1.00); A4: off
18-21	F1: [215 AWJ-1] 213.7 (1.00); F2: [215 AWJ-2] 213.0 (1.00); A3: [K10734] 434.2 (1.00); A4: [K1514] 354.0 (1.00)

Time Summary

Drive 21 seconds 1:31 PM - 1:31 PM BN 1 - 21

GRL Engineers, Inc. - PDIPLOT2 Ver 2020.1.60.3 - Case Method & iCAP® Results
Printed: 14-January-2021 Test started: 07-January-2021
CME 55 Serial Number 332955 - CME 55 at 35.0 to 36.5 feet
AWJ



Case Method & iCAP® Results

CME 55 Serial Number 332955 - CME 55 at 35.0 to 36.5 feet AWJ
OP: AK Date: 07-January-2021

AR: 1.20 in² SP: 0.492 k/ft³
LE: 38.33 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.00

CSX: Compression Stress Maximum
CSI: Comp Stress Max-Individual Sens
FMX: Maximum Force
VMX: Maximum Velocity
BPM: Blows/Minute
EFV: Maximum Energy
EF2: Energy of F² (ASTM D4633)
ETR: Energy Transfer Ratio - Rated

BL#	Depth	BLC	CSX	CSI	FMX	VMX	BPM	EFV	EF2	ETR
	ft	bl/6in	ksi	ksi	kips	f/s	bpm	ft-lb	ft-lb	(%)
8	35.53	17	23.0	23.3	28	18.0	56	316	241	90
9	35.56	17	23.9	24.0	29	18.6	53	308	247	88
10	35.59	17	22.7	22.7	27	18.0	55	290	240	83
11	35.62	17	23.6	23.9	28	17.9	54	314	249	90
12	35.65	17	23.7	23.9	28	18.4	57	317	245	90
13	35.68	17	23.1	23.3	28	17.5	54	282	242	81
14	35.71	17	23.0	23.2	28	17.3	55	311	237	89
15	35.74	17	23.1	23.1	28	18.0	55	287	242	82
16	35.76	17	22.3	22.4	27	18.2	54	295	241	84
17	35.79	17	21.4	21.6	26	18.1	57	301	233	86
18	35.82	17	21.7	21.9	26	18.6	53	285	236	81
19	35.85	17	21.6	21.7	26	18.4	55	288	236	82
20	35.88	17	22.2	22.3	27	18.6	55	286	237	82
21	35.91	17	22.3	22.4	27	19.2	54	297	242	85
22	35.94	17	21.3	21.4	26	18.5	55	292	239	83
23	35.97	17	21.1	21.3	25	18.7	56	275	235	79
24	36.00	17	21.7	22.1	26	19.5	54	316	240	90
25	36.02	24	22.1	22.3	27	19.1	55	296	246	85
26	36.04	24	21.7	21.9	26	18.7	56	293	239	84
27	36.06	24	21.0	21.4	25	19.4	53	289	239	82
28	36.08	24	22.0	22.3	26	19.3	56	303	243	87
29	36.10	24	21.7	22.0	26	19.1	55	289	236	82
30	36.13	24	22.3	22.6	27	19.6	54	300	247	86
31	36.15	24	21.2	21.4	25	18.5	58	284	231	81
32	36.17	24	21.3	21.5	26	17.4	54	282	228	81
33	36.19	24	22.2	22.5	27	19.8	55	304	244	87
34	36.21	24	21.4	21.8	26	19.5	55	294	234	84
35	36.23	24	21.6	21.9	26	20.0	54	299	241	85
36	36.25	24	21.1	21.5	25	20.0	55	305	237	87
37	36.27	24	21.5	21.9	26	20.1	55	291	235	83
38	36.29	24	21.5	21.9	26	19.8	56	291	237	83
39	36.31	24	21.7	22.0	26	20.0	53	303	243	86
40	36.33	24	20.9	21.2	25	19.7	58	286	224	82
41	36.35	24	21.5	21.7	26	19.4	54	293	232	84
42	36.38	24	21.2	21.6	25	19.6	55	273	224	78
43	36.40	24	20.3	20.7	24	19.4	54	304	238	87
44	36.42	24	22.0	22.1	26	19.1	55	297	235	85
45	36.44	24	21.4	21.7	26	19.7	55	295	236	84
46	36.46	24	20.7	21.0	25	19.1	54	291	235	83
47	36.48	24	21.4	21.7	26	19.4	55	296	241	85
48	36.50	24	21.3	21.5	26	19.5	55	305	235	87
		Average	21.9	22.1	26	18.9	55	296	238	84
		Std. Dev.	0.8	0.8	1	0.8	1	11	5	3
		Maximum	23.9	24.0	29	20.1	58	317	249	90
		Minimum	20.3	20.7	24	17.3	53	273	224	78

Total number of blows analyzed: 41

Case Method & iCAP® Results

CME 55 Serial Number 332955 - CME 55 at 35.0 to 36.5 feet AWJ
OP: AK Date: 07-January-2021

BL#	Depth	BLC	CSX	CSI	FMX	VMX	BPM	EFV	EF2	ETR
	ft	bl/6in	ksi	ksi	kips	f/s	bpm	ft-lb	ft-lb	(%)

BL#	Sensors
8-12	F1: [215 AWJ-1] 213.7 (1.00); F2: [215 AWJ-2] 213.0 (1.00); A3: [K10734] 434.2 (1.00); A4: off
13-48	F1: [215 AWJ-1] 213.7 (1.00); F2: [215 AWJ-2] 213.0 (1.00); A3: [K10734] 434.2 (1.00); A4: [K1514] 354.0 (1.00)

Time Summary

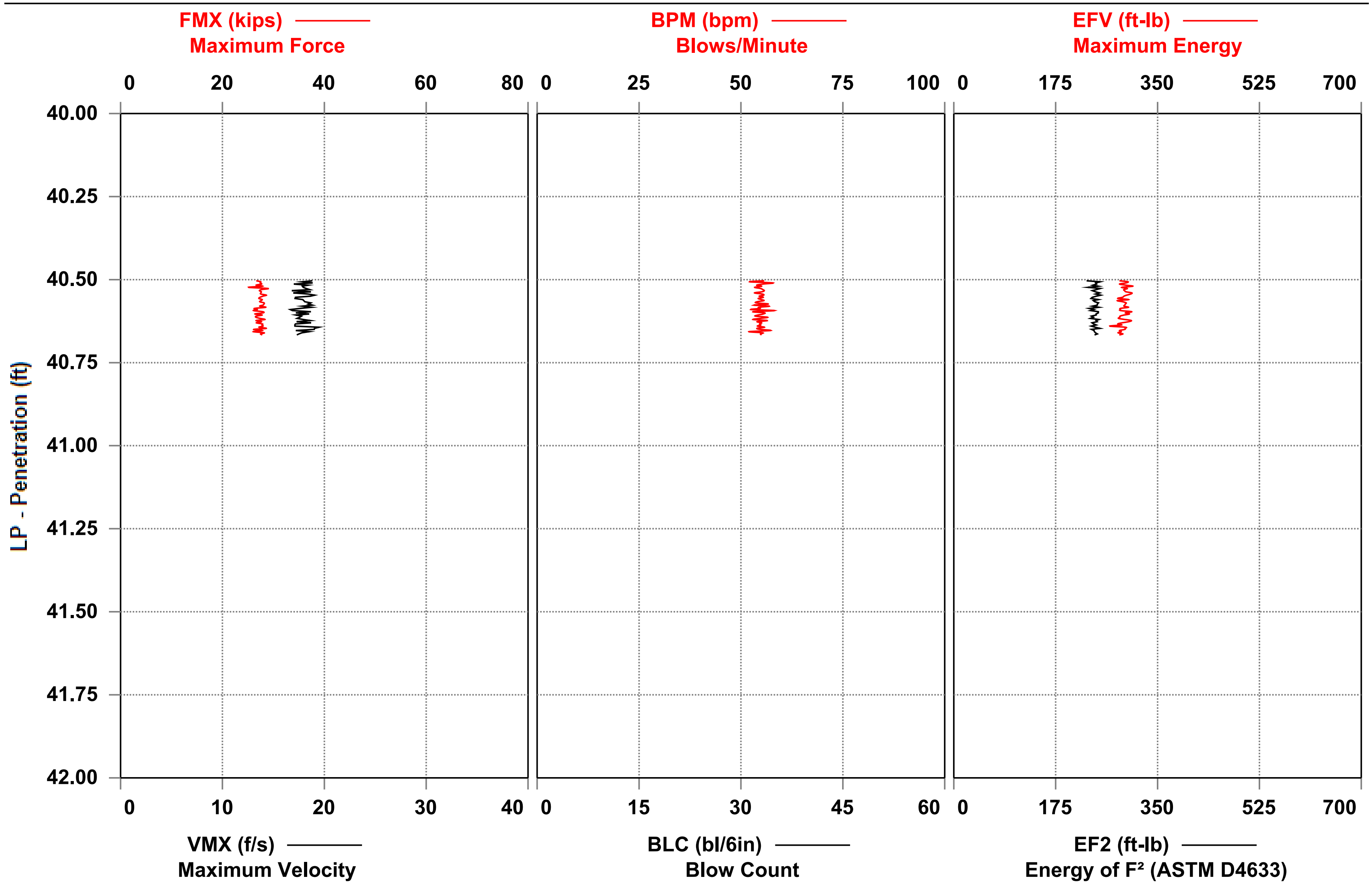
Drive 51 seconds 1:41 PM - 1:41 PM BN 1 - 48

GRL Engineers, Inc. - PDIPLOT2 Ver 2020.1.60.3 - Case Method & iCAP® Results

Printed: 14-January-2021 Test started: 07-January-2021

CME 55 Serial Number 332955 - CME 55 at 40.0 to 40.7 feet

AWJ



Case Method & iCAP® Results

CME 55 Serial Number 332955 - CME 55 at 40.0 to 40.7 feet AWJ
OP: AK Date: 07-January-2021

AR: 1.20 in² SP: 0.492 k/ft³
LE: 43.79 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.00

CSX: Compression Stress Maximum BPM: Blows/Minute
CSI: Comp Stress Max-Individual Sens EFV: Maximum Energy
FMX: Maximum Force EF2: Energy of F² (ASTM D4633)
VMX: Maximum Velocity ETR: Energy Transfer Ratio - Rated

BL#	Depth	BLC	CSX	CSI	FMX	VMX	BPM	EFV	EF2	ETR
	ft	bl/6in	ksi	ksi	kips	f/s	bpm	ft-lb	ft-lb	(%)
18	40.50	150	22.2	22.3	27	18.8	56	285	228	81
19	40.51	150	22.9	23.2	28	17.8	52	299	251	85
20	40.51	150	22.8	22.9	27	18.9	58	296	244	84
21	40.51	150	23.1	23.4	28	17.0	55	285	245	81
22	40.52	150	22.2	22.5	27	18.4	54	296	239	85
23	40.52	150	23.2	23.5	28	17.8	55	307	248	88
24	40.52	150	21.0	21.4	25	17.9	53	289	231	82
25	40.53	150	24.1	24.3	29	18.2	55	298	252	85
26	40.53	150	23.0	23.3	28	18.6	55	292	245	83
27	40.53	150	22.7	23.1	27	16.8	56	293	238	84
28	40.54	150	23.0	23.3	28	18.7	55	296	243	84
29	40.54	150	22.9	23.4	28	16.9	53	306	251	87
30	40.54	150	23.0	23.3	28	18.4	55	304	243	87
31	40.55	150	23.9	24.1	29	19.1	56	297	252	85
32	40.55	150	23.3	23.5	28	18.6	54	292	245	84
33	40.55	150	22.8	23.2	27	17.2	55	290	238	83
34	40.56	150	22.6	22.9	27	17.1	54	282	236	81
35	40.56	150	23.2	23.7	28	17.9	55	300	248	86
36	40.56	150	23.0	23.3	28	18.0	56	281	240	80
37	40.57	150	22.8	23.0	27	18.1	54	290	242	83
38	40.57	150	23.5	23.6	28	18.7	54	296	249	85
39	40.57	150	23.5	23.5	28	18.4	57	295	247	84
40	40.58	150	23.3	23.4	28	18.8	53	294	247	84
41	40.58	150	22.8	22.9	27	17.8	57	292	238	84
42	40.58	150	23.8	23.9	29	18.7	54	300	249	86
43	40.59	150	21.9	22.0	26	17.6	55	286	233	82
44	40.59	150	22.4	22.4	27	16.7	52	286	241	82
45	40.59	150	21.8	21.8	26	16.9	58	287	235	82
46	40.60	150	23.3	23.4	28	18.7	53	306	248	87
47	40.60	150	23.3	23.4	28	17.2	56	295	248	84
48	40.60	150	22.0	22.1	26	18.5	55	302	244	86
49	40.61	150	23.2	23.2	28	17.2	54	293	245	84
50	40.61	150	22.2	22.2	27	17.8	54	286	236	82
51	40.61	150	22.1	22.3	27	17.6	57	285	240	81
52	40.62	150	22.8	22.8	27	17.3	55	283	235	81
53	40.62	150	23.6	23.7	28	17.9	53	294	249	84
54	40.62	150	22.2	22.3	27	18.6	56	305	244	87
55	40.63	150	23.0	23.1	28	17.3	54	301	246	86
56	40.63	150	22.2	22.4	27	18.7	55	289	238	83
57	40.63	150	23.2	23.3	28	17.2	55	282	240	81
58	40.64	150	23.1	23.2	28	17.1	55	288	245	82
59	40.64	150	23.3	23.3	28	17.1	54	268	236	77
60	40.64	150	22.7	22.9	27	19.5	56	295	243	84
61	40.65	150	23.8	24.0	29	19.0	54	294	251	84
62	40.65	150	21.8	21.9	26	19.0	55	294	237	84
63	40.65	150	23.2	23.2	28	17.2	57	285	241	81

Case Method & iCAP® Results

CME 55 Serial Number 332955 - CME 55 at 40.0 to 40.7 feet AWJ

OP: AK Date: 07-January-2021

BL#	Depth	BLC	CSX	CSI	FMX	VMX	BPM	EFV	EF2	ETR
	ft	bl/6in	ksi	ksi	kips	f/s	bpm	ft-lb	ft-lb	(%)
64	40.66	150	21.7	21.8	26	18.5	52	288	242	82
65	40.66	150	23.5	23.5	28	17.8	55	282	243	81
66	40.66	150	22.9	22.9	28	17.5	55	290	246	83
67	40.67	150	23.2	23.2	28	17.3	55	284	242	81
		Average	22.9	23.0	27	18.0	55	292	243	83
		Std. Dev.	0.6	0.6	1	0.7	1	8	6	2
		Maximum	24.1	24.3	29	19.5	58	307	252	88
		Minimum	21.0	21.4	25	16.7	52	268	228	77

Total number of blows analyzed: 50

BL# Sensors

18-67 F1: [215 AWJ-1] 213.7 (1.00); F2: [215 AWJ-2] 213.0 (1.00); A3: [K10734] 434.2 (1.00);
A4: [K1514] 354.0 (1.00)

Time Summary

Drive 1 minute 12 seconds 1:56 PM - 1:58 PM BN 1 - 67

APPENDIX C

REPRESENTATIVE PLOTS

CME 55 Serial Number 332955

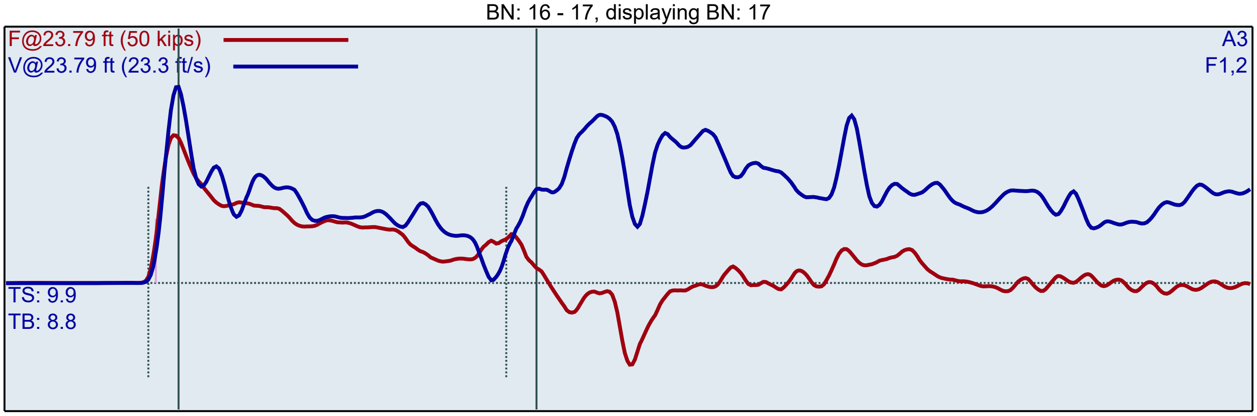
CME 55 Serial Number 332955
AK
AWJ

CME 55 at 20.0 to 21.5 feet
Interval start: 1/7/2021

AR: 1.2 in^2
LE: 23.79 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

BN: 16 - 17, displaying BN: 17



F1 : [215 AWJ-1] 213.68 PDICAL (1) FF6
F2 : [215 AWJ-2] 212.98 PDICAL (1) FF6

A3 (PR): [K10734] 434.2 mv/6.4v/5000g (1) VF6

CSX: Compression Stress Maximum
CSI: Compression Stress Maximum - Individual Sensor
FMX: Maximum Force
VMX: Maximum Velocity

BPM: Blows/Minute
EFV: Maximum Energy
EF2: Energy of F^2 (ASTM D4633)
ETR: Energy Transfer Ratio - Rated

BL#	BC	CSX	CSI	FMX	VMX	BPM	EFV	EF2	ETR
	/6"	ksi	ksi	kips	ft/s	bpm	ft-lb	ft-lb	%
16	0	23.8	24.1	29	17.4	56.8	301	232	86.0
17	0	24.0	24.2	29	17.9	37.9	326	247	93.1
	Average	23.9	24.1	29	17.6	47.3	314	239	89.6
	Std Dev	0.1	0.0	0	0.2	9.5	12	7	3.6
	Maximum	24.0	24.2	29	17.9	56.8	326	247	93.1
	Minimum	23.8	24.1	29	17.4	37.9	301	232	86.0

N-value: 2

Sample Interval Time: 1.56 seconds.

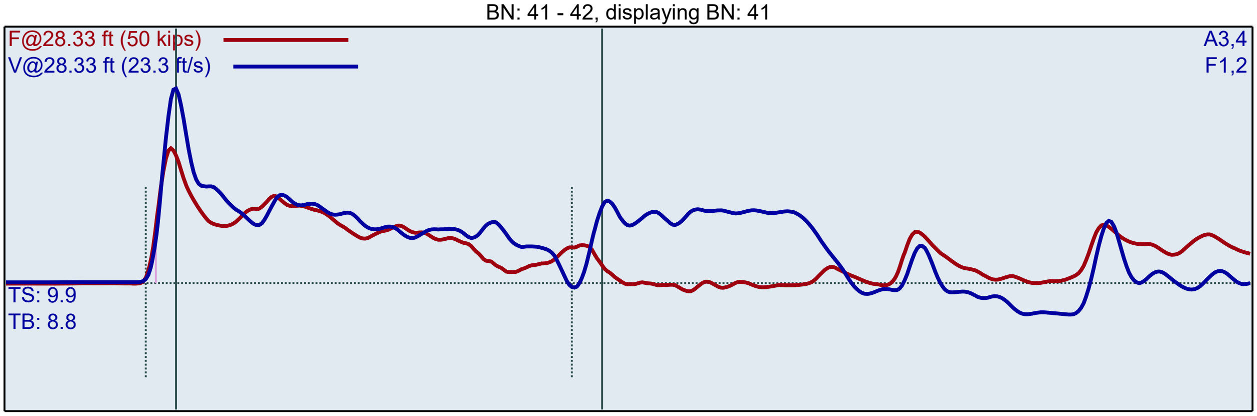
CME 55 Serial Number 332955
AK
AWJ

CME 55 at 25.0 to 26.5 feet
Interval start: 1/7/2021

AR: 1.2 in^2
LE: 28.33 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

BN: 41 - 42, displaying BN: 41



F1 : [215 AWJ-1] 213.68 PDICAL (1) FF6
F2 : [215 AWJ-2] 212.98 PDICAL (1) FF6

A3 (PR): [K10734] 434.2 mv/6.4v/5000g (1) VF6
A4 (PR): [K1514] 354 mv/6.4v/5000g (1) VF6

CSX: Compression Stress Maximum
CSI: Compression Stress Maximum - Individual Sensor
FMX: Maximum Force
VMX: Maximum Velocity

BPM: Blows/Minute
EFV: Maximum Energy
EF2: Energy of F^2 (ASTM D4633)
ETR: Energy Transfer Ratio - Rated

BL#	BC	CSX	CSI	FMX	VMX	BPM	EFV	EF2	ETR
	/6"	ksi	ksi	kips	ft/s	bpm	ft-lb	ft-lb	%
41	0	21.9	22.1	26	17.7	56.7	283	228	80.8
42	0	22.4	22.8	27	17.2	54.0	308	248	87.9
	Average	22.2	22.4	27	17.4	55.3	295	238	84.4
	Std Dev	0.2	0.3	0	0.3	1.4	12	10	3.6
	Maximum	22.4	22.8	27	17.7	56.7	308	248	87.9
	Minimum	21.9	22.1	26	17.2	54.0	283	228	80.8

N-value: 2

Sample Interval Time: 1.14 seconds.

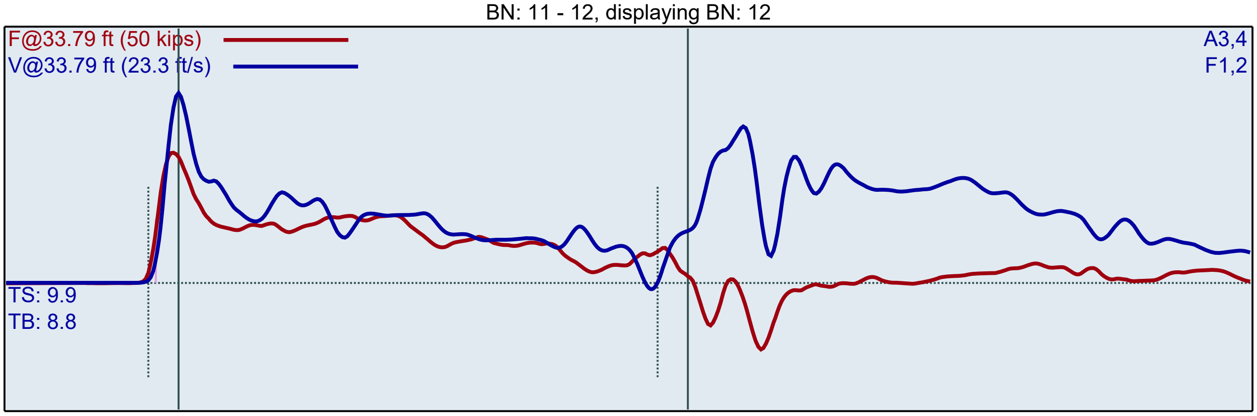
CME 55 Serial Number 332955
AK
AWJ

CME 55 at 30.0 to 31.5 feet
Interval start: 1/7/2021

AR: 1.2 in^2
LE: 33.79 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

BN: 11 - 12, displaying BN: 12



F1 : [215 AWJ-1] 213.68 PDICAL (1) FF6
F2 : [215 AWJ-2] 212.98 PDICAL (1) FF6

A3 (PR): [K10734] 434.2 mv/6.4v/5000g (1) VF6
A4 (PR): [K1514] 354 mv/6.4v/5000g (1) VF6

CSX: Compression Stress Maximum
CSI: Compression Stress Maximum - Individual Sensor
FMX: Maximum Force
VMX: Maximum Velocity

BPM: Blows/Minute
EFV: Maximum Energy
EF2: Energy of F^2 (ASTM D4633)
ETR: Energy Transfer Ratio - Rated

BL#	BC	CSX	CSI	FMX	VMX	BPM	EFV	EF2	ETR
	/6"	ksi	ksi	kips	ft/s	bpm	ft-lb	ft-lb	%
11	0	21.6	21.6	26	16.8	56.1	303	234	86.5
12	0	21.2	21.3	25	17.3	53.6	299	229	85.4
	Average	21.4	21.4	26	17.0	54.8	301	231	86.0
	Std Dev	0.2	0.1	0	0.3	1.2	2	2	0.5
	Maximum	21.6	21.6	26	17.3	56.1	303	234	86.5
	Minimum	21.2	21.3	25	16.8	53.6	299	229	85.4

N-value: 2

Sample Interval Time: 1.09 seconds.

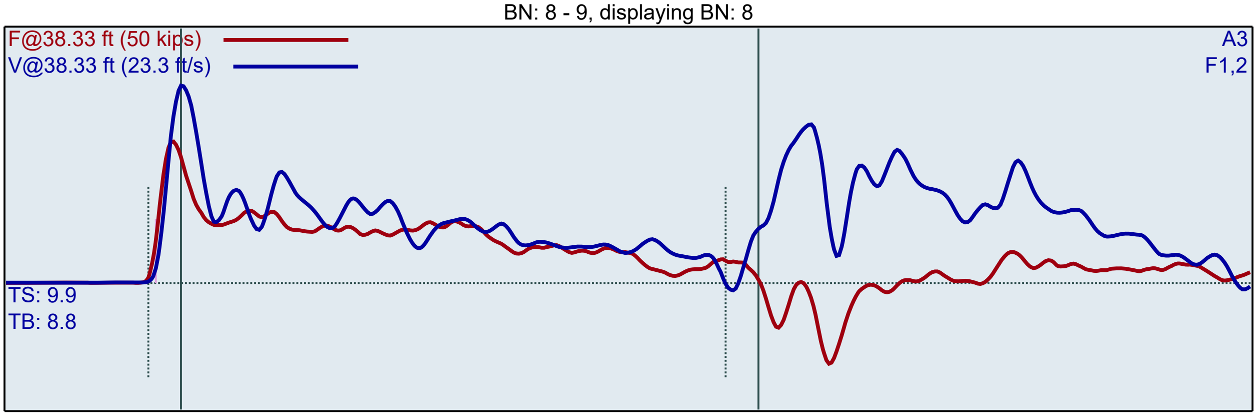
CME 55 Serial Number 332955
AK
AWJ

CME 55 at 35.0 to 36.5 feet
Interval start: 1/7/2021

AR: 1.2 in^2
LE: 38.33 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

BN: 8 - 9, displaying BN: 8



F1 : [215 AWJ-1] 213.68 PDICAL (1) FF6
F2 : [215 AWJ-2] 212.98 PDICAL (1) FF6

A3 (PR): [K10734] 434.2 mv/6.4v/5000g (1) VF6

CSX: Compression Stress Maximum
CSI: Compression Stress Maximum - Individual Sensor
FMX: Maximum Force
VMX: Maximum Velocity

BPM: Blows/Minute
EFV: Maximum Energy
EF2: Energy of F^2 (ASTM D4633)
ETR: Energy Transfer Ratio - Rated

BL#	BC	CSX	CSI	FMX	VMX	BPM	EFV	EF2	ETR
	/6"	ksi	ksi	kips	ft/s	bpm	ft-lb	ft-lb	%
8	0	23.0	23.3	28	18.0	56.3	316	241	90.2
9	0	23.9	24.0	29	18.6	53.5	308	247	88.0
	Average	23.4	23.6	28	18.3	54.9	312	244	89.1
	Std Dev	0.4	0.4	1	0.3	1.4	4	3	1.1
	Maximum	23.9	24.0	29	18.6	56.3	316	247	90.2
	Minimum	23.0	23.3	28	18.0	53.5	308	241	88.0

N-value: 2

Sample Interval Time: 1.11 seconds.

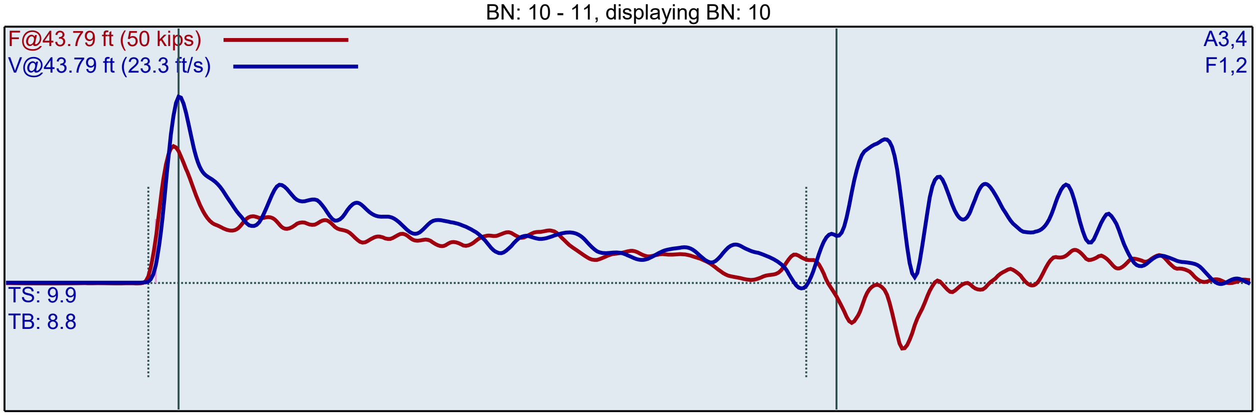
CME 55 Serial Number 332955
AK
AWJ

CME 55 at 40.0 to 40.7 feet
Interval start: 1/7/2021

AR: 1.2 in^2
LE: 43.79 ft
WS: 16807.9 ft/s

SP: 0.492 k/ft3
EM: 30000 ksi

BN: 10 - 11, displaying BN: 10



F1 : [215 AWJ-1] 213.68 PDICAL (1) FF6
F2 : [215 AWJ-2] 212.98 PDICAL (1) FF6

A3 (PR): [K10734] 434.2 mv/6.4v/5000g (1) VF6
A4 (PR): [K1514] 354 mv/6.4v/5000g (1) VF6

CSX: Compression Stress Maximum
CSI: Compression Stress Maximum - Individual Sensor
FMX: Maximum Force
VMX: Maximum Velocity

BPM: Blows/Minute
EFV: Maximum Energy
EF2: Energy of F^2 (ASTM D4633)
ETR: Energy Transfer Ratio - Rated

BL#	BC	CSX	CSI	FMX	VMX	BPM	EFV	EF2	ETR
	/6"	ksi	ksi	kips	ft/s	bpm	ft-lb	ft-lb	%
10	0	22.3	22.3	27	17.0	54.9	294	236	84.1
11	0	22.6	22.6	27	17.0	54.9	294	244	84.1
	Average	22.4	22.5	27	17.0	54.9	294	240	84.1
	Std Dev	0.1	0.1	0	0.0	0.0	0	4	0.0
	Maximum	22.6	22.6	27	17.0	54.9	294	244	84.1
	Minimum	22.3	22.3	27	17.0	54.9	294	236	84.1

N-value: 2

Sample Interval Time: 1.08 seconds.

APPENDIX D

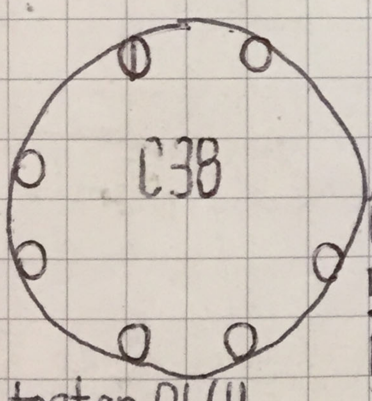
SUPPLEMENTAL DOCUMENTS

Drill Rig Name and Serial Number CME 55 SN 332955 A Date: 01/07

Splitspoon Length CME 55 SN 404685 B

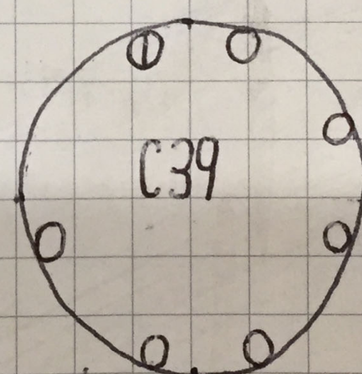
Sample	Depths	Lengths			N-value	
A 1	20.0-21.5	SS+5x4	33½	23.79	9/4/4	8
2	25.0-26.5	SS+5x5	28"	28.33	11/18/25	43
3	30.0-31.5	SS+5x6	33½	33.79	4/5/12	17
4	35.0-36.5	SS+5x7	28"	38.33	7/17/24	41
5	40.0-41.5	SS+5x8	33½	43.79	17/50 for [illegible]	
B 1	22.0-23.0	CS+5x5	21¼	27.77	16/17	
2	27.0-27.8	CS+5x6	21¼	32.77	50 for 9"	
3	32.0-32.7	CS+5x7	21¼	37.77	50 for 8"	
4	37.0-38.0	CS+5x8	21¼	42.77	18/32	

Project No Contract C 0704-241 Date: 01/11



1	58.53	46.3
2	58.49	45.3
3	58.55	47.4
4	58.53	45.5
5	58.53	43.3
6	58.525	42.0
7	58.51	43.0

test on 01/11



1	58.53	57.0
2	58.52	58.6
3	58.52	56.0
4	58.55	56.9
5	59.39	66.7
6	58.52	56.0
7	59.41	68.3

test on 01/11

C38:

1-2 29.1
2-3 29.5
3-4 31.4
4-5 25.9
5-6

1-3 59.3
1-4 63.0
1-5 58.2
1-6 45.4
1-7 26.0

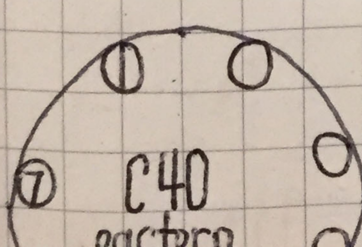
4-6 45.5
4-7 58.2
2-4 53.5

C39:

1-2 24.8
2-3 27.8
3-4 26.0
4-5 27.5
5-6 24.5

1-3 48.5
1-4 60.0
1-5 62.0
1-6 52.0
1-7 31.5

4-6 47.5
4-7 60.2
2-4 48.0
6-7 27.8



1	58.6	43.2
2	59.41	52.8
3	59.41	54.0
4	59.33	53.5

1-2 22.3
2-3 24.8
3-4 23.0
4-5 22.8

1-3 44.3
1-4 57.3
1-5 63.0
1-6 55.0

4-6 48.0
4-7 63.0
2-4


PULLDOWN PRESSURE
PRIMARY SYSTEM HYD. PRESSURE
CME
CENTRAL MINE EQUIPMENT CO.
SAINT LOUIS, MISSOURI, USA
MODEL CME 55
SERIAL NO. 332955
DATE
DETENT FEED
UP HOIST
UP HOIST

APPENDIX B

LABORATORY TEST RESULTS

APPENDIX B

LABORATORY TEST RESULTS

B.1 INTRODUCTION

Laboratory test were completed on select soil samples recovered for the field exploration program in general accordance with the American Association of State Highway and Transportation Officials (AASHTO) and ASTM testing methods. The laboratory testing program was completed to provide data for engineering studies and to classify the materials into similar geologic groups. The testing program included index tests and geotechnical engineering property tests. The following sections describe the laboratory testing procedures.

B.2 INDEX TESTS

Classification and index laboratory testing included identification by visual and manual means, and tests to determine natural water content, unit weight, grain size distribution, fines content, and Atterberg limits. When sufficient laboratory testing was completed, select samples from borings were classified using the Unified Soil Classification System (USCS) and American Association of State Highway and Transportation Officials (AASHTO) soil classification system. Both the visual soil identification system and the referenced soil classification systems are summarized in the Soil Classification Field Reference in Appendix A. Index tests are generally conducted on disturbed or remolded soil samples. The following sections describe individual index test procedures.

Moisture Content

Water content was determined for samples retrieved from the exploration in general accordance with AASHTO T 265 (ASTM D 2937). To perform this test method, the sample was weighed before and after oven drying, and the water content was calculated. The moisture content of soils, when combined with data obtained from other tests, produces significant information about the characteristics of the soil, including general correlations with strength, settlement, and workability.

Gradation

The grain size distribution of selected samples was determined in general accordance with the AASHTO T 311 and ASTM D 1140. These tests aid in the classification of soils and provide correlating data with engineering properties of soils, such as permeability, strength, swelling potential, and susceptibility to frost action.

Atterberg Limits

Liquid and plastic limit tests were performed on selected fine-grained samples. The tests were completed in general accordance with AASHTO T 89 and T 90 (ASTM D 4318). The Atterberg limits include liquid limit (LL), plastic limit (PL), and plasticity index (PI), which is the plastic limit subtracted from the liquid limit. These limits are generally used to assist in classification of soils, to indicate soil consistency, and to provide correlation to engineering properties.

B.3 GEOTECHNICAL ENGINEERING PROPERTY TESTS FOR SOIL

Geotechnical engineering property testing for soil included moisture-density and R-value. Geotechnical engineering property test results are presented in the attached laboratory reports. The following sections describe these test procedures for soil.

Moisture-Density

In the construction of highway embankments, retaining walls, structure foundations, and many other facilities, loose soils may be compacted to increase their density, strength, and stiffness characteristics. The results of the moisture-density test provide the maximum dry density attainable under a specified compaction energy for a given soil and the moisture content corresponding to this density. These results of this test aid in the construction quality assurance of compacted soils.

The moisture-density (compaction) relationship of soils along the alignment was performed in general accordance with AASHTO T 99 (ASTM D 698) or AASHTO T 180 (ASTM D 1557) using a 5.5-pound rammer and a 12-inch drop height or a 10-pound rammer and an 18-inch drop height, respectively. The results of these tests are presented as graphs of water content versus dry unit weight.

R-value

R-value tests were completed to evaluate the stiffness of soils that may be used in the subgrade of the roadway. Tests were performed on selected remolded samples in general accordance with AASHTO T 190 (ASTM D 2844). The results of these tests are reported as a value representing the stiffness of subgrade soils, which is utilized in pavement structural section design.

U.S. Department of Transportation
Federal Highway Administration

Central Federal Lands Highway Division Laboratory

An AASHTO and ISO Accredited Laboratory
1 Denver Federal Center, Building 52
Denver, Colorado 80225

Report of Soil or Aggregate Tests

AASHTO ACCREDITED

Project: New Mexico FLAP SIE 10(1) Lakeshore Road
Submitted By: Brendan McGarity
Date Reported: 3/23/2021

Sample Number	Lab Number		21-153-SB	21-154-SB	21-155-SB	21-156-SB	21-157-SB
	Hole Number		21-01	21-01	21-02	21-02	21-02
	Field Number		SPT-02	SPT-03,04,05,06,07(Sand)	SPT-01 & 02	SPT-03 & 04	SPT-05 & 06
Sample Location	Station/Location		104+00/Site 1	104+00/Site 1	205+65.5/Site 2	205+65.5/Site 2	205+65.5/Site 2
	Offset		8L	8L	8L	8L	8L
	Depth		10	15-35	4-9	14-19	24-29
AASHTO T 11 & T 27 Washed Sieve Analysis % Passing	3"	75.0 mm					
	1 1/2"	37.5 mm					
	1"	25.0 mm	100		100	100	
	3/4"	19.0 mm	98		98	98	
	1/2"	12.5 mm	97		96	98	100
	3/8"	9.5 mm	96	100	93	97	99
	#4	4.75 mm	92	99	86	92	98
	#8	2.36 mm					
	#10	2.00 mm	88	99	79	87	96
	#16	1.18 mm	85	97	75	83	92
	#30	600 µm					
	#40	425 µm	56	79	49	47	50
	#50	300 µm					
	#100	150 µm	13	50	16	11	11
	#200	75 µm	7.2	42	11	6.8	6.4
AASHTO T 255	Moisture, %		3.1	4.3	6.1	4.9	4.1
AASHTO T 89 & T 90	Liquid Limit		NV	NV	NV	NV	NV
	Plasticity Index		NP	NP	NP	NP	NP
Soil Classification	AASHTO M 145		A-3 (0)	A-4 (0)	A-1-b (0)	A-1-b (0)	A-1-b (0)
	ASTM D 2487		SP-SM	SM	SW-SM	SP-SM	SP-SM
AASHTO T 190	R - Value						
AASHTO T 288	Min. Resistivity, ohm x cm						
AASHTO T 289	pH						
AASHTO Method	Optimum Moisture, %						
	Maximum Dry Density, pcf						

Distribution:	Num. / Project File
Geotechnical	Brendan McGarity/Dominic Monarco
Const Ops Engineer	Jim Rathke
Project Manager	Solomon Haile
Technical Services	Gary Strike

Remarks:

Sampling Method: SPT
Environmental Conditions: Not Furnished
Disclaimer: CFLHD Materials Laboratory is responsible for the quality of the tests upon receipt of the sampled materials. However, CFLHD Materials Laboratory has no control over field material sampling, therefor has no responsibility for any sampling error, the sample integrity, and shipping methods prior to receipt in the laboratory.
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Reported By:

Patrick Kowing
Laboratory Team Leader

U.S. Department of Transportation
Federal Highway Administration

Central Federal Lands Highway Division Laboratory

An AASHTO and ISO Accredited Laboratory
1 Denver Federal Center, Building 52
Denver, Colorado 80225

Report of Soil or Aggregate Tests

AASHTO ACCREDITED

Project: New Mexico FLAP SIE 10(1) Lakeshore Road
Submitted By: Brendan McGarity
Date Reported: 3/23/2021

Sample Number	Lab Number		21-158-SB	21-159-SB	21-160-SB	21-161-SB	21-162-SB
	Hole Number		21-03	21-03	21-03	21-03	21-03
	Field Number		SPT-01 & 02	SPT-03,04,05	SPT-06	SPT-07,08,09	SPT-12,13,14,15
Sample Location	Station/Location		Site 3-SW Abut.	Site 3-SW Abut.	Site 3-SW Abut.	Site 3-SW Abut.	Site 3-SW Abut.
	Offset		Not Furnished	Not Furnished	Not Furnished	Not Furnished	Not Furnished
	Depth		4-9	14-24	29	34-44	59-75
AASHTO T 11 & T 27 Washed Sieve Analysis % Passing	3"	75.0 mm					
	1 1/2"	37.5 mm	100				
	1"	25.0 mm	99	100			
	3/4"	19.0 mm	98	99			100
	1/2"	12.5 mm	93	99			99
	3/8"	9.5 mm	90	98	100	100	99
	#4	4.75 mm	78	97	99	99	97
	#8	2.36 mm					
	#10	2.00 mm	70	96	96	99	95
	#16	1.18 mm	65	95	93	99	92
	#30	600 µm					
	#40	425 µm	51	71	75	77	66
	#50	300 µm					
	#100	150 µm	31	13	21	17	18
	#200	75 µm	23	7.2	12	8.0	12
AASHTO T 255	Moisture, %		8.5	4.3	2.5	3.8	6.8
AASHTO T 89 & T 90	Liquid Limit		21	NV	NV	NV	NV
	Plasticity Index		4	NP	NP	NP	NP
Soil Classification	AASHTO M 145		A-2-4 (0)	A-3 (0)	A-2-4 (0)	A-3 (0)	A-2-4 (0)
	ASTM D 2487		SC-SM	SP-SM	SP-SM	SP-SM	SW-SM
AASHTO T 190	R - Value						
AASHTO T 288	Min. Resistivity, ohm x cm						
AASHTO T 289	pH						
AASHTO Method	Optimum Moisture, %						
	Maximum Dry Density, pcf						

Distribution:	Num. / Project File
Geotechnical	Brendan McGarity/Dominic Monarco
Const Ops Engineer	Jim Rathke
Project Manager	Solomon Haile
Technical Services	Gary Strike

Remarks:

Sampling Method: SPT
Environmental Conditions: Not Furnished
Disclaimer: CFLHD Materials Laboratory is responsible for the quality of the tests upon receipt of the sampled materials. However, CFLHD Materials Laboratory has no control over field material sampling, therefor has no responsibility for any sampling error, the sample integrity, and shipping methods prior to receipt in the laboratory.
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Reported By:

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Laboratory Team Leader

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Denver, Colorado 80225

U.S. Department of Transportation
Federal Highway Administration

Report of Soil or Aggregate Tests

AASHTO ACCREDITED

Project: New Mexico FLAP SIE 10(1) Lakeshore Road
Submitted By: Brendan McGarity
Date Reported: 3/23/2021

Sample Number	Lab Number		21-163-SB	21-164-SB	21-165-SB	21-166-SB	21-167-SB
	Hole Number		21-03	21-04	21-04	21-04	21-04
	Field Number		SPT-16,17,18,19,20	SPT-02	SPT-04 & 05	SPT-06	SPT-07 & 08(TOP)
Sample Location	Station/Location		Site 3-SW Abut.	Site 3-NE Abut.	Site 3-NE Abut.	Site 3-NE Abut.	Site 3-NE Abut.
	Offset		Not Furnished	Not Furnished	Not Furnished	Not Furnished	Not Furnished
	Depth		80-100	9	19-24	29	34-39
AASHTO T 11 & T 27 Washed Sieve Analysis % Passing	3"	75.0 mm					
	1 1/2"	37.5 mm		100			
	1"	25.0 mm		96			
	3/4"	19.0 mm		96	100	100	100
	1/2"	12.5 mm		93	99	98	99
	3/8"	9.5 mm		89	99	94	99
	#4	4.75 mm	100	79	98	84	98
	#8	2.36 mm					
	#10	2.00 mm	98	70	98	77	96
	#16	1.18 mm	96	66	98	74	95
	#30	600 µm					
	#40	425 µm	57	45	76	56	66
	#50	300 µm					
	#100	150 µm	9	19	17	34	13
	#200	75 µm	4.8	13	7.6	25	6.3
AASHTO T 255	Moisture, %		4.4	4.2	3.6	7.4	4.8
AASHTO T 89 & T 90	Liquid Limit		NV	NV	NV	NV	NV
	Plasticity Index		NP	NP	NP	NP	NP
Soil Classification	AASHTO M 145		A-3 (0)	A-1-b (0)	A-3 (0)	A-2-4 (0)	A-3 (0)
	ASTM D 2487		SP	SM	SP-SM	SM	SP-SM
AASHTO T 190	R - Value						
AASHTO T 288	Min. Resistivity, ohm x cm						
AASHTO T 289	pH						
AASHTO Method	Optimum Moisture, %						
	Maximum Dry Density, pcf						

Distribution:	Num. / Project File
Geotechnical	Brendan McGarity/Dominic Monarco
Const Ops Engineer	Jim Rathke
Project Manager	Solomon Haile
Technical Services	Gary Strike

Remarks:

Sampling Method: SPT
Environmental Conditions: Not Furnished
Disclaimer: CFLHD Materials Laboratory is responsible for the quality of the tests upon receipt of the sampled materials. However, CFLHD Materials Laboratory has no control over field material sampling, therefor has no responsibility for any sampling error, the sample integrity, and shipping methods prior to receipt in the laboratory.
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Federal Highway Administration

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Denver, Colorado 80225

AASHTO ACCREDITED

Report of Soil or Aggregate Tests

Project: New Mexico FLAP SIE 10(1) Lakeshore Road
Submitted By: Brendan McGarity
Date Reported: 3/23/2021

Sample Number	Lab Number		21-168-SB	21-169-SB	21-170-SB	21-171-SB	21-172-SB
	Hole Number		21-04	21-04	21-05	21-05	21-05
	Field Number		SPT-08 (BOT)	SPT-15 & 16	SPT-01 & 02	SPT-03 & 04	SPT-05,06,07
Sample Location	Station/Location		Site 3-NE Abut.	Site 3-NE Abut.	406+30/Site 4	406+30/Site 4	406+30/Site 4
	Offset		Not Furnished	Not Furnished	8L	8L	8L
	Depth		39	74-79	5-10	15-20	25-35
AASHTO T 11 & T 27 Washed Sieve Analysis % Passing	3"	75.0 mm					
	1 1/2"	37.5 mm					
	1"	25.0 mm					
	3/4"	19.0 mm			100	100	
	1/2"	12.5 mm		100	99	99	100
	3/8"	9.5 mm		99	98	99	99
	#4	4.75 mm	100	98	94	98	98
	#8	2.36 mm					
	#10	2.00 mm	97	95	91	96	97
	#16	1.18 mm	95	91	89	96	93
	#30	600 µm					
	#40	425 µm	86	57	72	73	62
	#50	300 µm					
	#100	150 µm	67	19	43	20	15
	#200	75 µm	63	8.9	33	14	5.8
AASHTO T 255	Moisture, %		23.9	7.1	13.3	5.1	4.0
AASHTO T 89 & T 90	Liquid Limit		*	NV	23	NV	NV
	Plasticity Index		*	NP	5	NP	NP
Soil Classification	AASHTO M 145		**	A-3 (0)	A-2-4 (0)	A-2-4 (0)	A-3 (0)
	ASTM D 2487		**	SP-SM	SC-SM	SM	SP-SM
AASHTO T 190	R - Value						
AASHTO T 288	Min. Resistivity, ohm x cm						
AASHTO T 289	pH						
AASHTO Method	Optimum Moisture, %						
	Maximum Dry Density, pcf						

Distribution:	Num. / Project File
Geotechnical	Brendan McGarity/Dominic Monarco
Const Ops Engineer	Jim Rathke
Project Manager	Solomon Haile
Technical Services	Gary Strike

Remarks:
*There was not enough material provided to perform AASHTO T89 & T90 testing.
**There was not enough material provided to perform AASHTO M145 and ASTM D 2487.

Sampling Method: SPT
Environmental Conditions: Not Furnished
Disclaimer: CFLHD Materials Laboratory is responsible for the quality of the tests upon receipt of the sampled materials. However, CFLHD Materials Laboratory has no control over field material sampling, therefor has no responsibility for any sampling error, the sample integrity, and shipping methods prior to receipt in the laboratory.
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Reported By:
Patrick Kowing
Laboratory Team Leader

Central Federal Lands Highway Division Laboratory

U.S. Department of Transportation
Federal Highway Administration

An AASHTO and ISO Accredited Laboratory
1 Denver Federal Center, Building 52
Denver, Colorado 80225

Report of Soil or Aggregate Tests

AASHTO ACCREDITED

Project: New Mexico FLAP SIE 10(1) Lakeshore Road
Submitted By: Brendan McGarity
Date Reported: 3/23/2021

Sample Number	Lab Number		21-173-SB	21-174-SB	21-175-SB	21-176-SB	21-177-SB
	Hole Number		21-05	21-05	21-05	21-06	21-06
	Field Number		SPT-10,11,12	SPT-15 & 16	SPT-18 & 19	SPT-01 & 02	SPT-07,08,09,10
Sample Location	Station/Location		406+30/Site 4	406+30/Site 4	406+30/Site 4	407+40/Site 4	407+40/Site 4
	Offset		8L	8L	8L	8L	8L
	Depth		50-60	75-80	90-95	5-10	35-50
AASHTO T 11 & T 27 Washed Sieve Analysis % Passing	3"	75.0 mm					
	1 1/2"	37.5 mm				100	
	1"	25.0 mm				98	100
	3/4"	19.0 mm				96	99
	1/2"	12.5 mm				95	99
	3/8"	9.5 mm	100			94	99
	#4	4.75 mm	98	100	100	92	99
	#8	2.36 mm					
	#10	2.00 mm	96	98	99	90	99
	#16	1.18 mm	94	94	99	88	98
	#30	600 µm					
	#40	425 µm	65	53	86	64	75
	#50	300 µm					
	#100	150 µm	14	16	12	17	11
	#200	75 µm	6.5	11	5.5	10	5.1
AASHTO T 255	Moisture, %		5.9	6.7	20.7	6.2	4.2
AASHTO T 89 & T 90	Liquid Limit		NV	NV	NV	NV	NV
	Plasticity Index		NP	NP	NP	NP	NP
Soil Classification	AASHTO M 145		A-3 (0)	A-2-4 (0)	A-3 (0)	A-3 (0)	A-3 (0)
	ASTM D 2487		SP-SM	SW-SM	SP-SM	SP-SM	SP-SM
AASHTO T 190	R - Value						
AASHTO T 288	Min. Resistivity, ohm x cm						
AASHTO T 289	pH						
AASHTO Method	Optimum Moisture, %						
	Maximum Dry Density, pcf						

Distribution:	Num. / Project File
Geotechnical	Brendan McGarity/Dominic Monarco
Const Ops Engineer	Jim Rathke
Project Manager	Solomon Haile
Technical Services	Gary Strike

Remarks:

Sampling Method: SPT
Environmental Conditions: Not Furnished
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Reported By:

Patrick Kowing
Laboratory Team Leader

Central Federal Lands Highway Division Laboratory

U.S. Department of Transportation
Federal Highway Administration

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1 Denver Federal Center, Building 52
Denver, Colorado 80225

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Report of Soil or Aggregate Tests

Project: New Mexico FLAP SIE 10(1) Lakeshore Road
Submitted By: Brendan McGarity
Date Reported: 3/23/2021

Sample Number	Lab Number		21-178-SB	21-179-SB	21-180-SB	21-181-SB	21-182-SB
	Hole Number		21-06	21-06	21-06	21-06	21-07
	Field Number		SPT-12,13 (TOP SAND)	SPT-13 (CLAY)	SPT-16 & 17	SPT-18,19,20	SPT-02
Sample Location	Station/Location		407+40/Site 4	407+40/Site 4	407+40/Site 4	407+40/Site 4	502+55.5/Site 5
	Offset		8L	8L	8L	8L	8.5L
	Depth		60-65	65	80-85	90-100	9
AASHTO T 11 & T 27 Washed Sieve Analysis % Passing	3"	75.0 mm					
	1 1/2"	37.5 mm					
	1"	25.0 mm			100		100
	3/4"	19.0 mm	100		99		98
	1/2"	12.5 mm	99		99		98
	3/8"	9.5 mm	99		98	100	96
	#4	4.75 mm	97		96	99	94
	#8	2.36 mm					
	#10	2.00 mm	95		94	99	90
	#16	1.18 mm	91	100	92	99	84
	#30	600 µm					
	#40	425 µm	58	96	55	88	40
	#50	300 µm					
	#100	150 µm	10	90	19	21	15
	#200	75 µm	5.6	84	7.9	8.6	11
AASHTO T 255	Moisture, %		6.6	31.0	6.2	18.6	2.8
AASHTO T 89 & T 90	Liquid Limit		NV	63	NV	NV	NV
	Plasticity Index		NP	42	NP	NP	NP
Soil Classification	AASHTO M 145		A-3 (0)	A-7-6 (38)	A-3 (0)	A-3 (0)	A-1-b (0)
	ASTM D 2487		SP-SM	CH	SP-SM	SP-SM	SW-SM
AASHTO T 190	R - Value						
AASHTO T 288	Min. Resistivity, ohm x cm						
AASHTO T 289	pH						
AASHTO Method	Optimum Moisture, %						
	Maximum Dry Density, pcf						

Distribution:	Num. / Project File
Geotechnical	Brendan McGarity/Dominic Monarco
Const Ops Engineer	Jim Rathke
Project Manager	Solomon Haile
Technical Services	Gary Strike

Remarks:

Sampling Method: SPT
Environmental Conditions: Not Furnished
Disclaimer: CFLHD Materials Laboratory is responsible for the quality of the tests upon receipt of the sampled materials. However, CFLHD Materials Laboratory has no control over field material sampling, therefore has no responsibility for any sampling error, the sample integrity, and shipping methods prior to receipt in the laboratory.
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Reported By:

Patrick Kowing
Laboratory Team Leader

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U.S. Department of Transportation
Federal Highway Administration

Central Federal Lands Highway Division Laboratory

An AASHTO and ISO Accredited Laboratory
1 Denver Federal Center, Building 52
Denver, Colorado 80225

Report of Soil or Aggregate Tests

AASHTO ACCREDITED

Project: New Mexico FLAP SIE 10(1) Lakeshore Road
Submitted By: Brendan McGarity
Date Reported: 3/23/2021

Sample Number	Lab Number		21-183-SB	21-184-SB			
	Hole Number		21-07	21-07			
	Field Number		SPT-03(BOT) & 03 (TOP)	SPT-04,05 (TOP),05 (BOT)			
Sample Location	Station or Location		502+55.5/Site 5	502+55.5/Site 5			
	Offset		8.5L	8.5L			
	Depth		14	19-24			
AASHTO T 11 & T 27 Washed Sieve Analysis % Passing	3"	75.0 mm					
	1 1/2"	37.5 mm					
	1"	25.0 mm		100			
	3/4"	19.0 mm	100	99			
	1/2"	12.5 mm	99	99			
	3/8"	9.5 mm	98	98			
	#4	4.75 mm	97	96			
	#8	2.36 mm					
	#10	2.00 mm	96	94			
	#16	1.18 mm	95	92			
	#30	600 µm					
	#40	425 µm	69	69			
	#50	300 µm					
	#100	150 µm	13	20			
	#200	75 µm	5.9	8.6			
AASHTO T 255	Moisture, %		3.5	5.8			
AASHTO T 89 & T 90	Liquid Limit		NV	NV			
	Plasticity Index		NP	NP			
Soil Classification	AASHTO M 145		A-3 (0)	A-3 (0)			
	ASTM D 2487		SP-SM	SP-SM			
AASHTO T 190	R - Value						
AASHTO T 288	Min. Resistivity, ohm x cm						
AASHTO T 289	pH						
AASHTO Method	Optimum Moisture, %						
	Maximum Dry Density, pcf						

Distribution:	Num. / Project File
Geotechnical	Brendan McGarity/Dominic Monarco
Const Ops Engineer	Jim Rathke
Project Manager	Solomon Haile
Technical Services	Gary Strike

Remarks:

Sampling Method: SPT
Environmental Conditions: Not Furnished
Disclaimer: CFLHD Materials Laboratory is responsible for the quality of the tests upon receipt of the sampled materials. However, CFLHD Materials Laboratory has no control over field material sampling, therefor has no responsibility for any sampling error, the sample integrity, and shipping methods prior to receipt in the laboratory.
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Reported By:

Patrick Kowing
Laboratory Team Leader

Central Federal Lands Highway Division Laboratory

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Federal Highway Administration

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Denver, Colorado 80225

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Report of Soil or Aggregate Tests

Project: New Mexico FLAP SIE 10(1) Lakeshore Road
Submitted By: Marty Fey
Date Reported: 2/24/2021

Sample Number	Lab Number		21-124-S	12-125-S	21-126-S	21-127-S	21-128-S
	Hole Number		Not Furnished	Not Furnished	Not Furnished	Not Furnished	Not Furnished
	Field Number		P-1 (BH21-01)	P-2	P-3	P-4 (BH21-05)	P-5
Sample Location	Station or Location		Not Furnished	Not Furnished	Not Furnished	Not Furnished	Not Furnished
	Offset		Not Furnished	Not Furnished	Not Furnished	Not Furnished	Not Furnished
	Depth	Feet	Bulk 0-5	Bulk 0-5	Bulk 0-5	Bulk 0-5	Bulk 0-5
AASHTO T 11 & T 27 Washed Sieve Analysis % Passing	2 1/2"	63.0 mm					100
	2"	50.0 mm					99
	1 1/2"	37.5 mm	100	100	100	100	98
	1"	25.0 mm	98	99	99	99	91
	3/4"	19.0 mm	95	98	99	98	83
	1/2"	12.5 mm	83	95	96	93	71
	3/8"	9.5 mm	74	93	94	88	64
	#4	4.75 mm	54	86	86	76	47
	#10	2.00 mm	41	81	79	69	34
	#16	1.18 mm	35	79	73	65	29
	#30	600 µm					
	#40	425 µm	26	57	48	48	17
	#50	300 µm					
	#100	150 µm	18	21	23	21	6
	#200	75 µm	15	14	18	16	4.3
AASHTO T 255	Moisture, %						
AASHTO T 89 & T 90	Liquid Limit		29	NV	19	21	NV
	Plasticity Index		15	NP	2	5	NP
Soil Classification	AASHTO M 145		A-2-6 (0)	A-2-4 (0)	A-1-b (0)	A-1-b (0)	A-1-a (0)
	ASTM D 2487		GC	SM	SM	SC-SM	GP
AASHTO T 190	R - Value					44	
AASHTO T 288	Min. Resistivity, ohm x cm						
AASHTO T 289	pH						
AASHTO T 180 Method D	Optimum Moisture, %					7.1	
	Maximum Dry Density, pcf					132.3	

Distribution:	Num. / Project File
Pavements	Marty Fey
Const Ops Engineer	Jim Rathke
Project Manager	Solomon Haile
Technical Services	Gary Strike

Remarks:

Sampling Method: Not Furnished
Environmental Conditions: Not Furnished
Disclaimer: CFLHD Materials Laboratory is responsible for the quality of the tests upon receipt of the sampled materials. However, CFLHD Materials Laboratory has no control over field material sampling, therefor has no responsibility for any sampling error, the sample integrity, and shipping methods prior to receipt in the laboratory.
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Reported By:

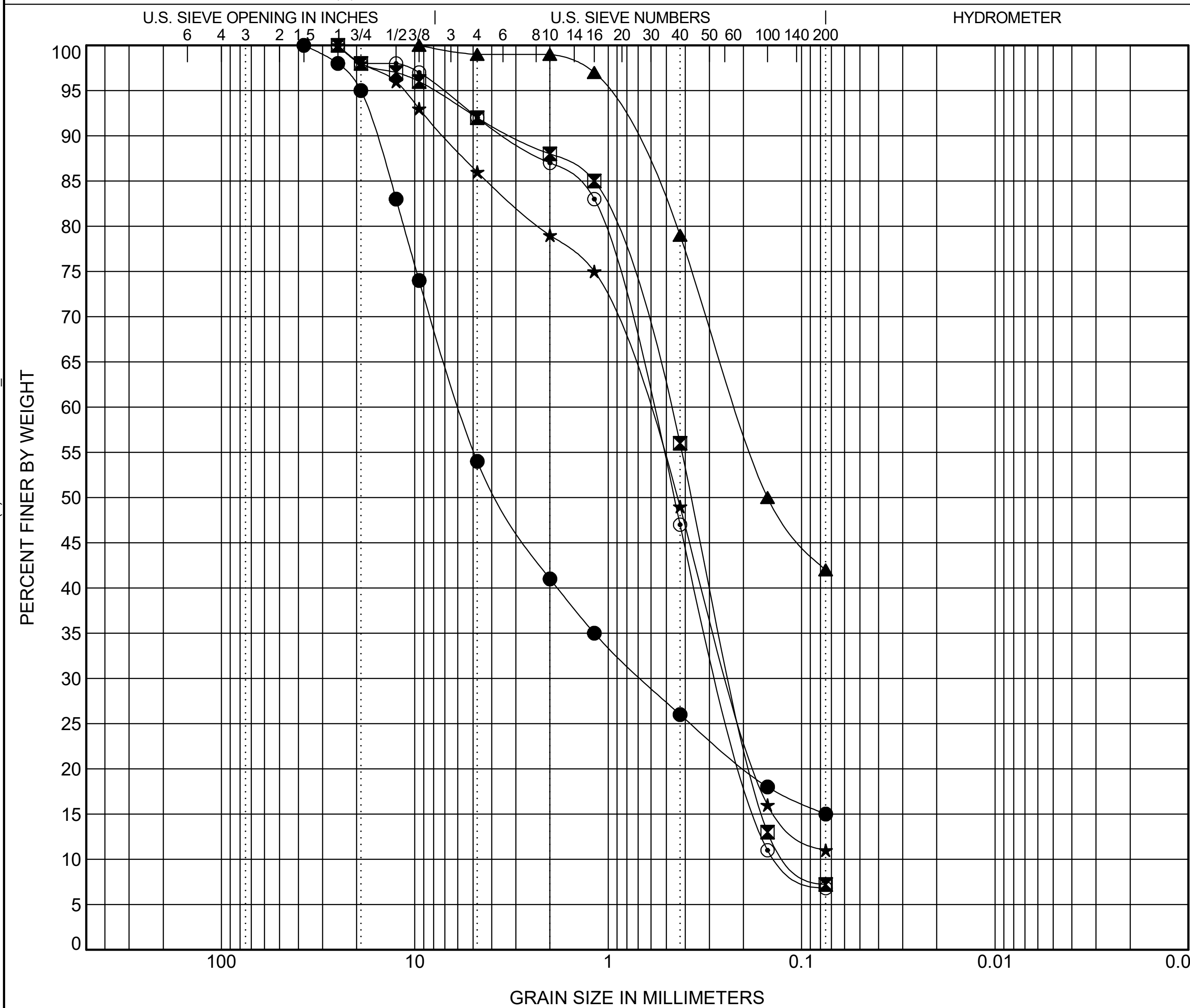
Patrick Kowing
Laboratory Team Leader

U.S. Department of Transportation
Federal Highway Administration

GRAIN SIZE DISTRIBUTION

CLIENT New Mexico State Parks **PROJECT NAME** Lakeshore Road

PROJECT NUMBER NM FLAP SIE 10(1) **PROJECT LOCATION** Elephant Butte State Park, New Mexico



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BOREHOLE	DEPTH	Classification	LL	PL	PI	Cc	Cu
●	BH21-01 (P-1)	2.0	CLAYEY GRAVEL with SAND(GC)	29	14	15		
⊠	BH21-01 (P-1)	10.0					1.00	4.67
▲	BH21-01 (P-1)	15.0						
★	BH21-02	4.0					1.27	10.03
⊙	BH21-02	14.0					0.86	4.83

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	BH21-01 (P-1)	2.0	37.5	5.848	0.669		46.0	39.0	15.0	
⊠	BH21-01 (P-1)	10.0	25	0.489	0.226	0.105	8.0	84.8	7.2	
▲	BH21-01 (P-1)	15.0	9.5	0.215			1.0	57.0	42.0	
★	BH21-02	4.0	25	0.655	0.233		14.0	75.0	11.0	
⊙	BH21-02	14.0	25	0.615	0.26	0.127	8.0	85.2	6.8	

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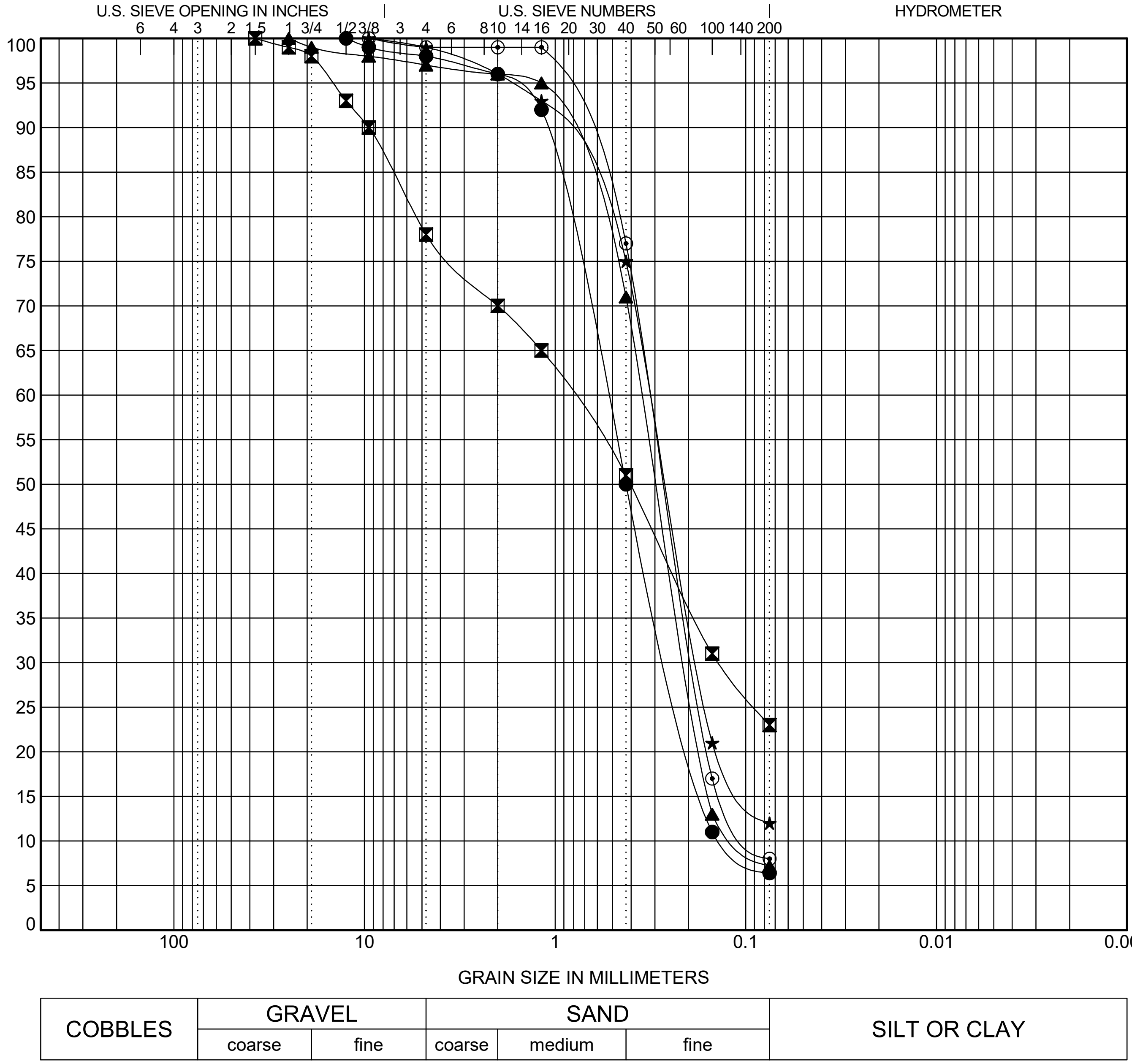
U.S. Department of Transportation
Federal Highway Administration

GRAIN SIZE DISTRIBUTION

CLIENT New Mexico State Parks **PROJECT NAME** Lakeshore Road

PROJECT NUMBER NM FLAP SIE 10(1) **PROJECT LOCATION** Elephant Butte State Park, New Mexico



BOREHOLE		DEPTH	Classification	LL	PL	PI	Cc	Cu
●	BH21-02	24.0					0.89	4.20
⊠	BH21-03	4.0	SILTY, CLAYEY SAND with GRAVEL(SC-SM)	21	17	4		
▲	BH21-03	14.0					1.13	3.33
★	BH21-03	29.0					1.56	4.95
⊙	BH21-03	34.0					1.28	3.62

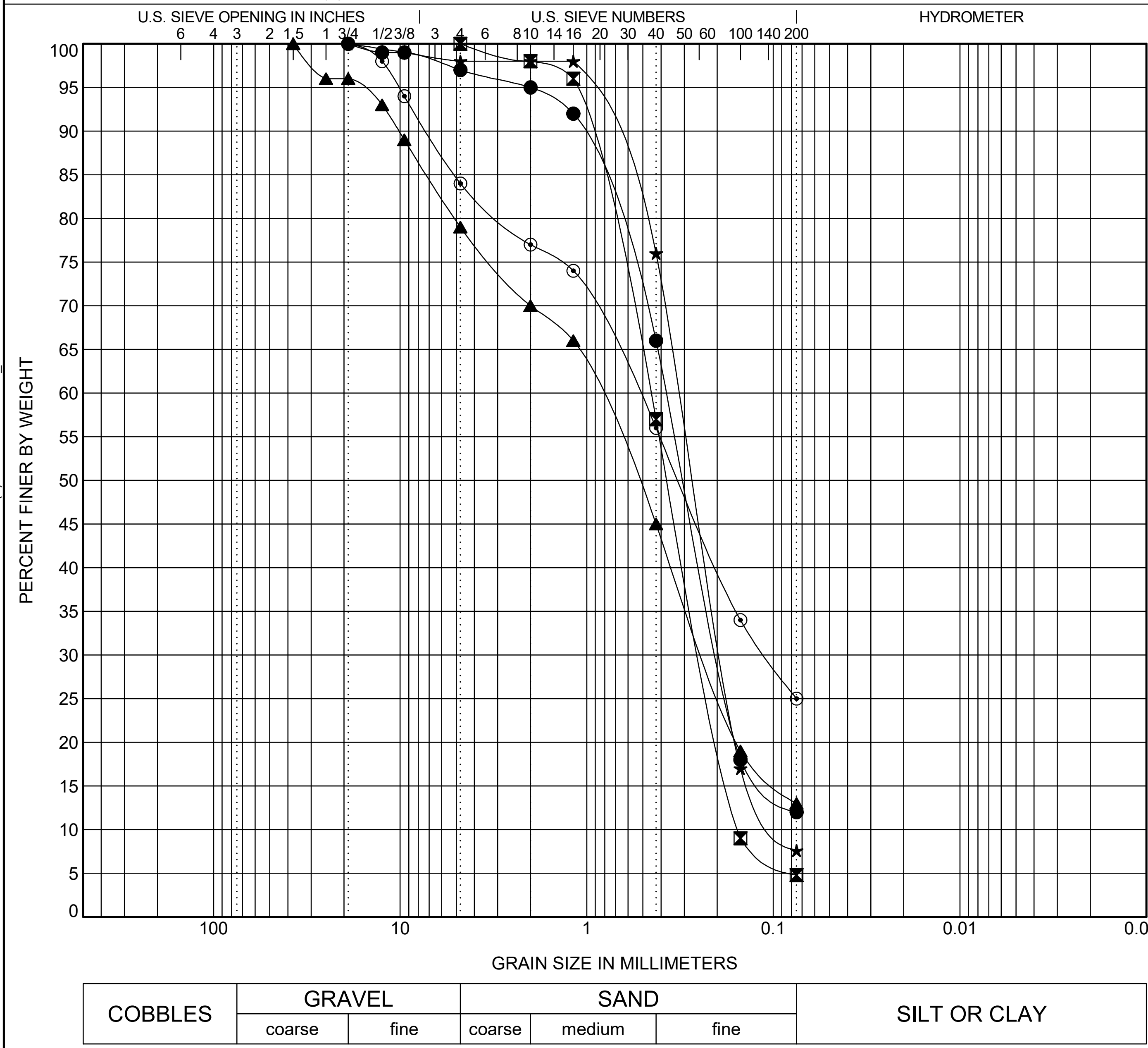
BOREHOLE		DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	BH21-02	24.0	12.5	0.542	0.249	0.129	2.0	91.6	6.4	
⊠	BH21-03	4.0	37.5	0.819	0.138		22.0	55.0	23.0	
▲	BH21-03	14.0	25	0.349	0.204	0.105	3.0	89.8	7.2	
★	BH21-03	29.0	9.5	0.318	0.178		1.0	87.0	12.0	
⊙	BH21-03	34.0	9.5	0.316	0.188	0.087	1.0	91.0	8.0	

U.S. Department of Transportation
Federal Highway Administration

GRAIN SIZE DISTRIBUTION

CLIENT New Mexico State Parks **PROJECT NAME** Lakeshore Road

PROJECT NUMBER NM FLAP SIE 10(1) **PROJECT LOCATION** Elephant Butte State Park, New Mexico



	BOREHOLE	DEPTH	Classification	LL	PL	PI	Cc	Cu
●	**BH21-03**	**59.0**					**1.71**	**6.27**
⧗	**BH21-03**	**80.0**	**POORLY GRADED SAND(SP)**				**0.79**	**3.00**
▲	**BH21-04**	**9.0**						
★	**BH21-04**	**19.0**					**1.24**	**3.58**
⊙	**BH21-04**	**29.0**						

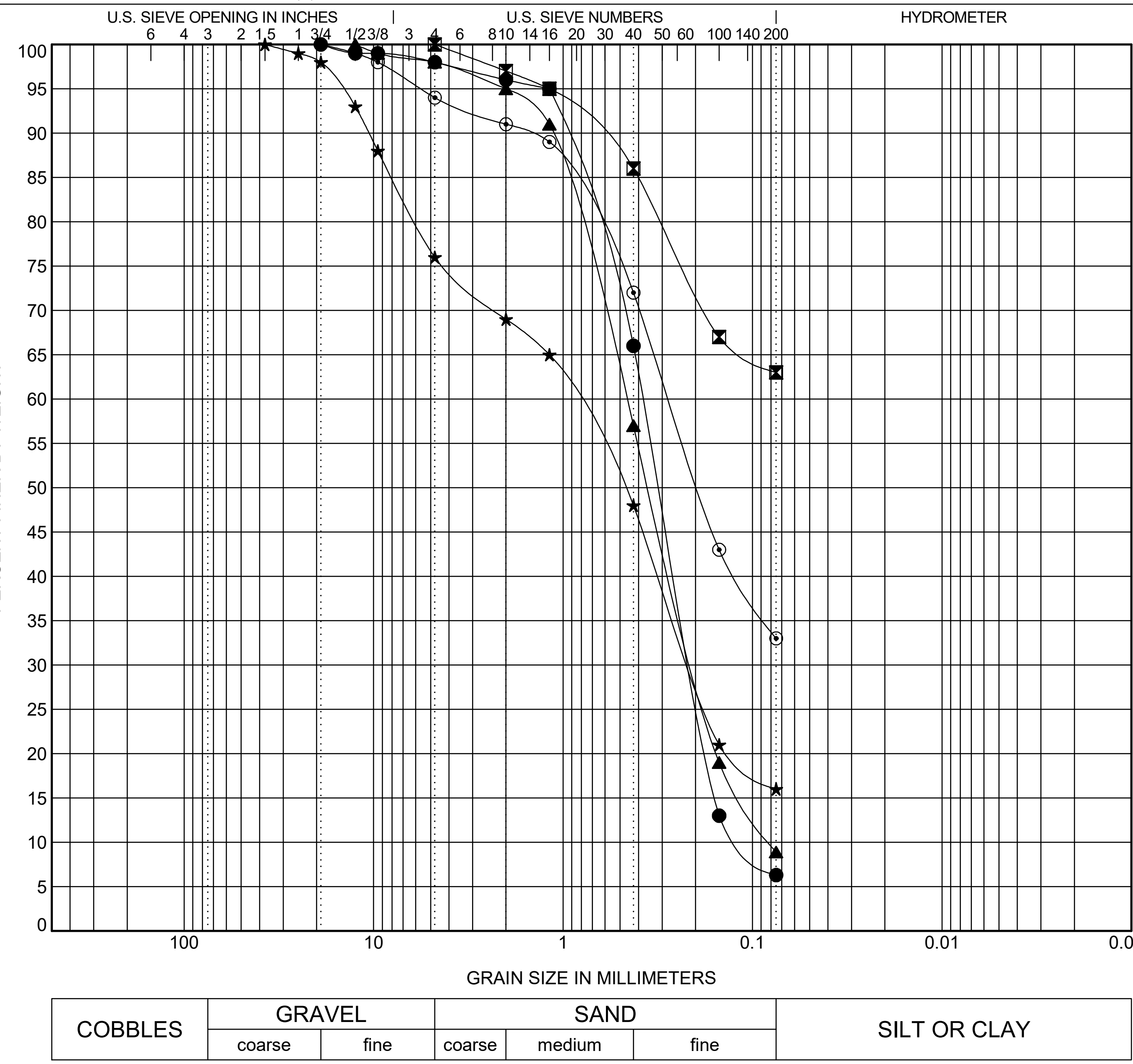
	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BH21-03**	**59.0**	**19**	**0.373**	**0.195**		**3.0**	**85.0**	**12.0**	
⧗	**BH21-03**	**80.0**	**4.75**	**0.46**	**0.237**	**0.153**	**0.0**	**95.2**	**4.8**	
▲	**BH21-04**	**9.0**	**37.5**	**0.881**	**0.233**		**21.0**	**66.0**	**13.0**	
★	**BH21-04**	**19.0**	**19**	**0.32**	**0.189**	**0.09**	**2.0**	**90.4**	**7.6**	
⊙	**BH21-04**	**29.0**	**19**	**0.533**	**0.11**		**16.0**	**59.0**	**25.0**	

GRAIN SIZE DISTRIBUTION

U.S. Department of Transportation
Federal Highway Administration

CLIENT New Mexico State Parks **PROJECT NAME** Lakeshore Road

PROJECT NUMBER NM FLAP SIE 10(1) **PROJECT LOCATION** Elephant Butte State Park, New Mexico



	BOREHOLE	DEPTH	Classification	LL	PL	PI	Cc	Cu
●	**BH21-04**	**34.0**					**1.06**	**3.43**
⧗	**BH21-04**	**39.0**						
▲	**BH21-04**	**74.0**					**1.09**	**5.75**
★	**BH21-05 (P-4)**	**2.0**	**SILTY, CLAYEY SAND with GRAVEL(SC-SM)**	**21**	**16**	**5**		
⊙	**BH21-05 (P-4)**	**5.0**	**SILTY, CLAYEY SAND(SC-SM)**	**23**	**18**	**5**		

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BH21-04**	**34.0**	**19**	**0.378**	**0.209**	**0.11**	**2.0**	**91.7**	**6.3**	
⧗	**BH21-04**	**39.0**	**4.75**				**0.0**	**37.0**	**63.0**	
▲	**BH21-04**	**74.0**	**12.5**	**0.465**	**0.203**	**0.081**	**2.0**	**89.1**	**8.9**	
★	**BH21-05 (P-4)**	**2.0**	**37.5**	**0.874**	**0.212**		**24.0**	**60.0**	**16.0**	
⊙	**BH21-05 (P-4)**	**5.0**	**19**	**0.276**			**6.0**	**61.0**	**33.0**	

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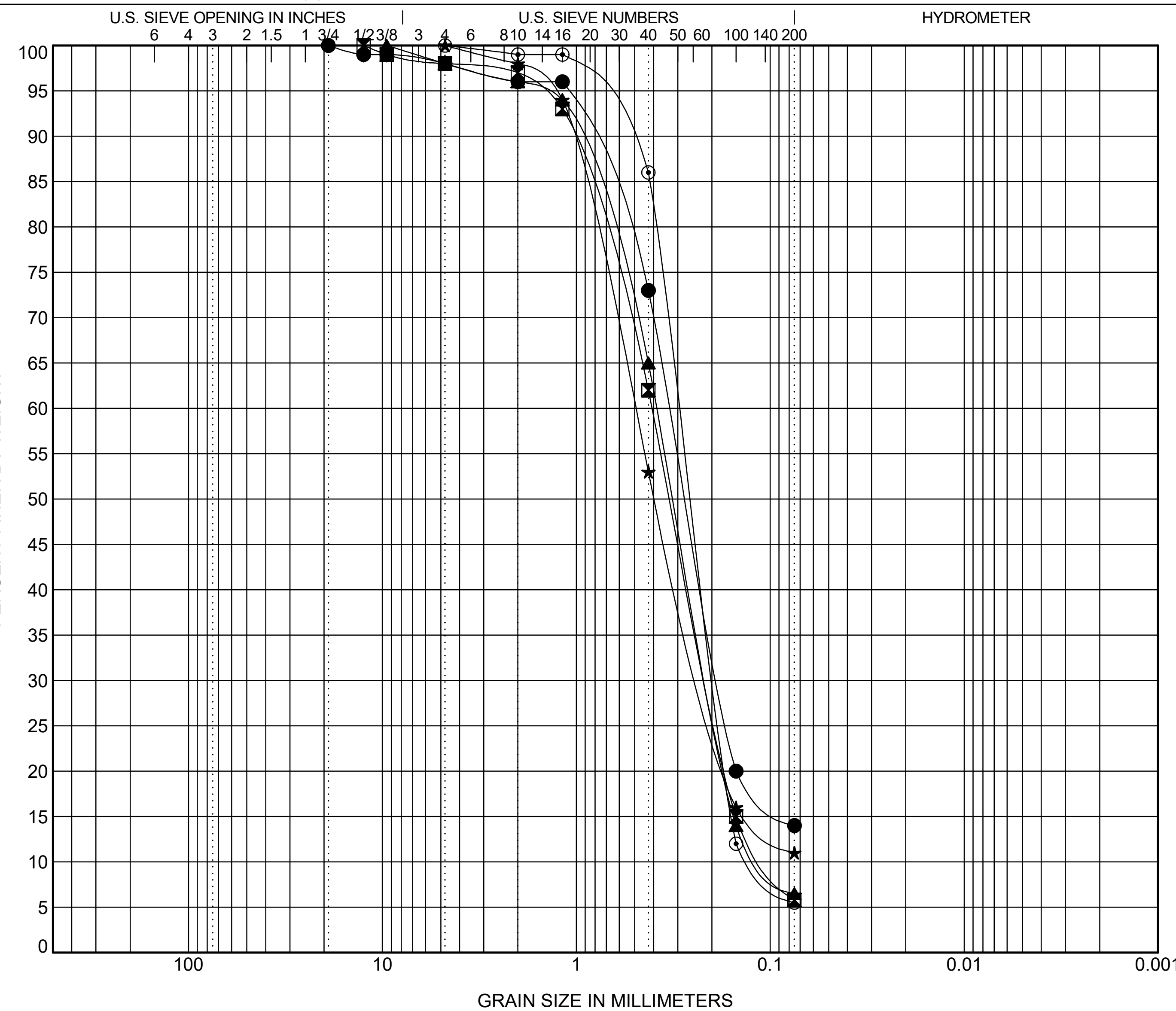
U.S. Department of Transportation
Federal Highway Administration

GRAIN SIZE DISTRIBUTION

CLIENT New Mexico State Parks **PROJECT NAME** Lakeshore Road
PROJECT NUMBER NM FLAP SIE 10(1) **PROJECT LOCATION** Elephant Butte State Park, New Mexico



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BOREHOLE	DEPTH	Classification	LL	PL	PI	Cc	Cu
●	**BH21-05 (P-4)**	**15.0**						
⧗	**BH21-05 (P-4)**	**25.0**					**1.05**	**3.95**
▲	**BH21-05 (P-4)**	**50.0**					**1.09**	**3.70**
★	**BH21-05 (P-4)**	**75.0**					**1.50**	**7.75**
⊙	**BH21-05 (P-4)**	**90.0**					**1.05**	**2.43**

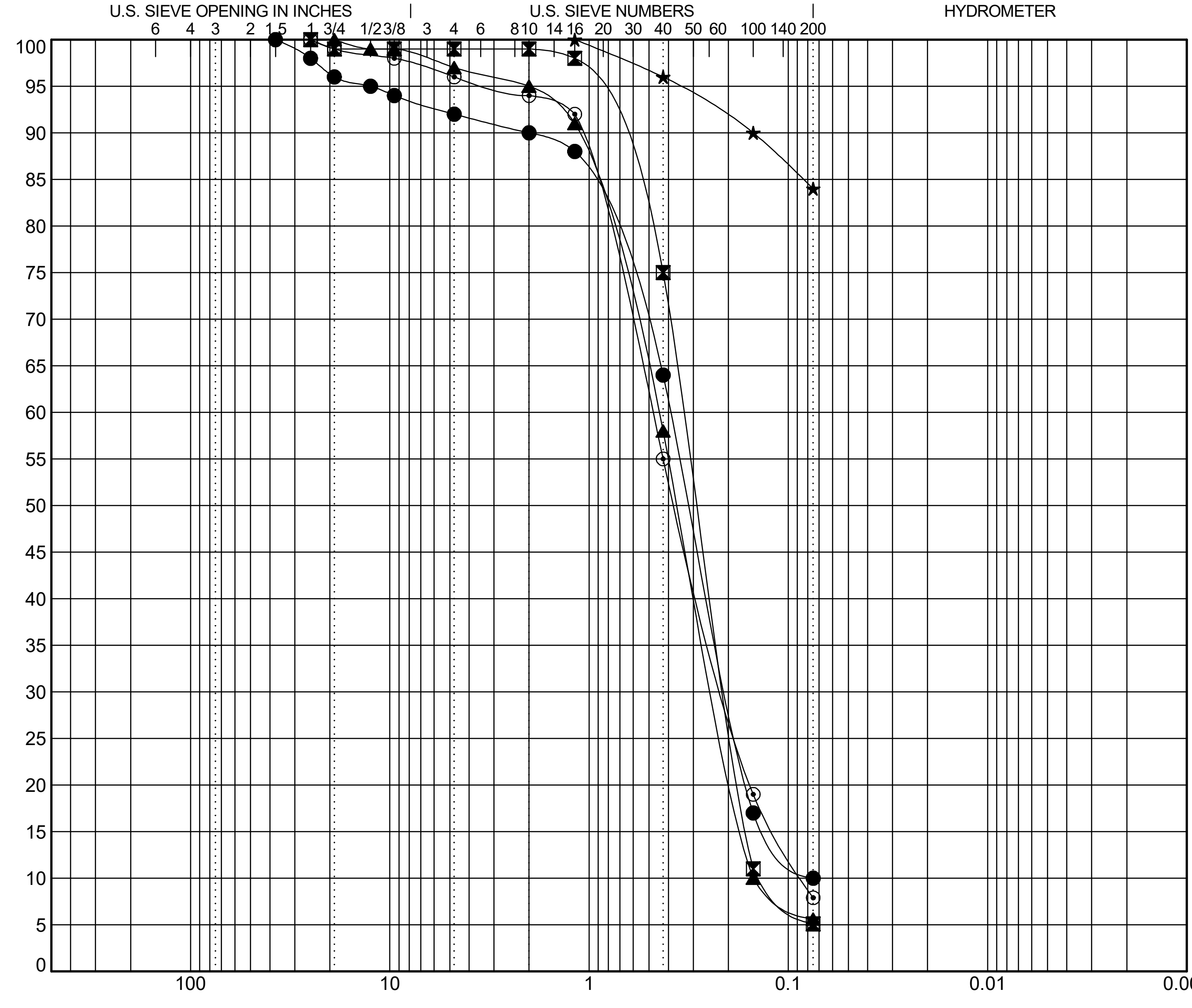
	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BH21-05 (P-4)**	**15.0**	**19**	**0.329**	**0.183**		**2.0**	**84.0**	**14.0**	
⧗	**BH21-05 (P-4)**	**25.0**	**12.5**	**0.407**	**0.209**	**0.103**	**2.0**	**92.2**	**5.8**	
▲	**BH21-05 (P-4)**	**50.0**	**9.5**	**0.384**	**0.208**	**0.104**	**2.0**	**91.5**	**6.5**	
★	**BH21-05 (P-4)**	**75.0**	**4.75**	**0.506**	**0.222**		**0.0**	**89.0**	**11.0**	
⊙	**BH21-05 (P-4)**	**90.0**	**4.75**	**0.295**	**0.193**	**0.121**	**0.0**	**94.5**	**5.5**	

GRAIN SIZE - FHWA_DATATEMPLATE_20171103.GDT - 1/18/22 11:31 - C:\USERS\BRENDAN.MCGARITY\DOCUMENTS\GEOTECH\PROJECTS\NM\SIE10(1)\USE TO FINISH\3_DATA\DRILLING INVESTIGATION 1-18 TO 1-23\BORING LOGS\GINT\NM LAKESHORE.GPJ

U.S. Department of Transportation
Federal Highway Administration

GRAIN SIZE DISTRIBUTION

CLIENT New Mexico State Parks
PROJECT NAME Lakeshore Road
PROJECT NUMBER NM FLAP SIE 10(1)
PROJECT LOCATION Elephant Butte State Park, New Mexico



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BOREHOLE	DEPTH	Classification	LL	PL	PI	Cc	Cu
●	**BH21-06**	**5.0**					**1.37**	**5.19**
⧗	**BH21-06**	**35.0**					**0.94**	**2.50**
▲	**BH21-06**	**60.0**					**0.79**	**3.01**
★	**BH21-06**	**65.0**	**FAT CLAY with SAND(CH)**	**63**	**21**	**42**		
⊙	**BH21-06**	**80.0**					**1.02**	**5.71**

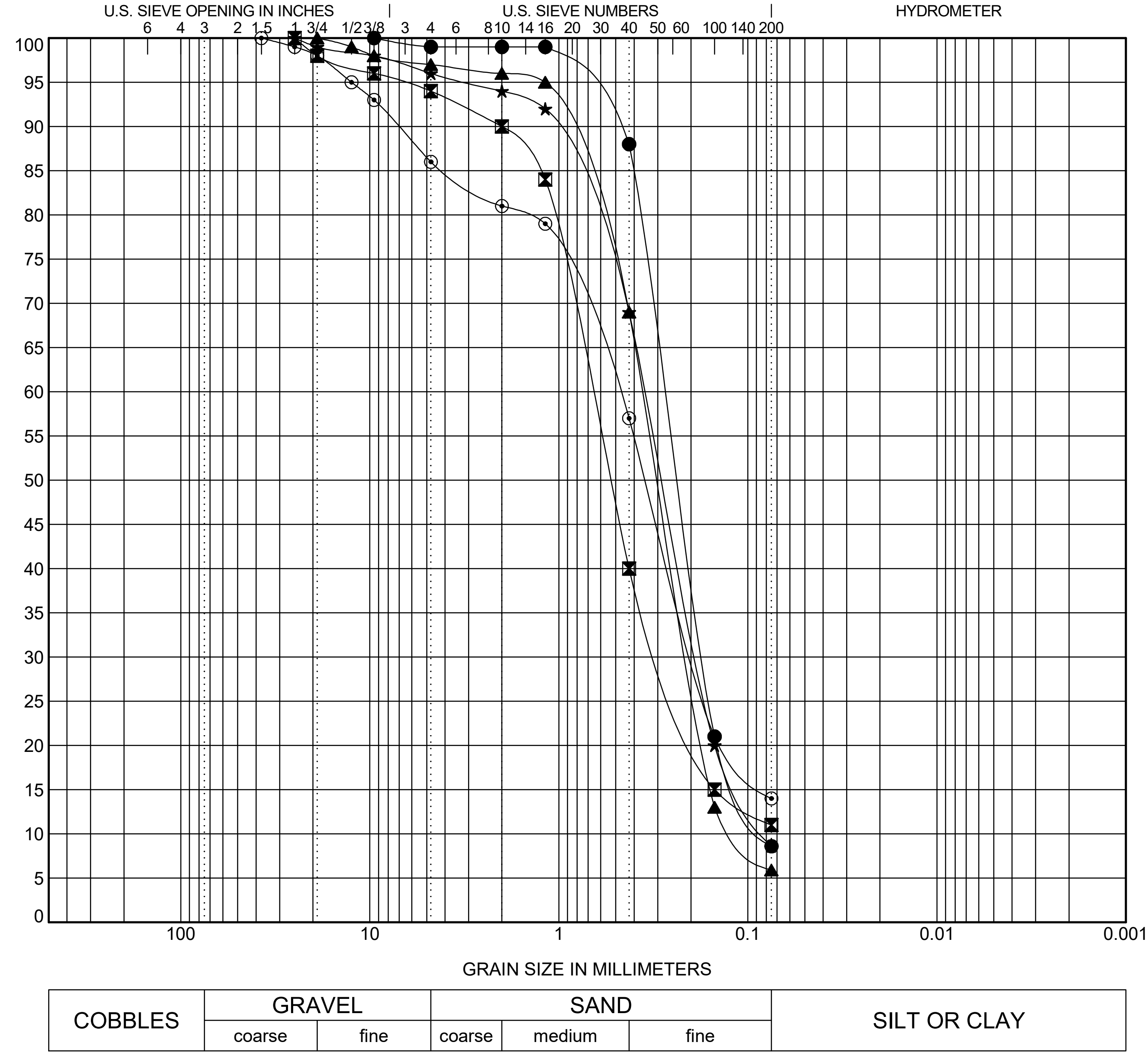
	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BH21-06**	**5.0**	**37.5**	**0.389**	**0.2**	**0.075**	**8.0**	**82.0**	**10.0**	
⧗	**BH21-06**	**35.0**	**25**	**0.333**	**0.204**	**0.133**	**1.0**	**93.9**	**5.1**	
▲	**BH21-06**	**60.0**	**19**	**0.452**	**0.231**	**0.15**	**3.0**	**91.4**	**5.6**	
★	**BH21-06**	**65.0**	**1.18**				**0.0**	**16.0**	**84.0**	
⊙	**BH21-06**	**80.0**	**25**	**0.488**	**0.206**	**0.086**	**4.0**	**88.1**	**7.9**	

U.S. Department of Transportation
Federal Highway Administration

GRAIN SIZE DISTRIBUTION

CLIENT New Mexico State Parks **PROJECT NAME** Lakeshore Road

PROJECT NUMBER NM FLAP SIE 10(1) **PROJECT LOCATION** Elephant Butte State Park, New Mexico



	BOREHOLE	DEPTH	Classification	LL	PL	PI	Cc	Cu
●	**BH21-06**	**90.0**					**1.33**	**3.39**
⧗	**BH21-07**	**9.0**					**1.84**	**10.72**
▲	**BH21-07**	**14.0**					**1.05**	**3.21**
★	**BH21-07**	**19.0**					**1.20**	**4.30**
⊙	**P-2**	**2.0**						

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**BH21-06**	**90.0**	**9.5**	**0.275**	**0.173**	**0.081**	**1.0**	**90.4**	**8.6**	
⧗	**BH21-07**	**9.0**	**25**	**0.676**	**0.28**		**6.0**	**83.0**	**11.0**	
▲	**BH21-07**	**14.0**	**19**	**0.359**	**0.206**	**0.112**	**3.0**	**91.1**	**5.9**	
★	**BH21-07**	**19.0**	**25**	**0.351**	**0.186**	**0.082**	**4.0**	**87.4**	**8.6**	
⊙	**P-2**	**2.0**	**37.5**	**0.489**	**0.195**		**14.0**	**72.0**	**14.0**	

GRAIN SIZE DISTRIBUTION

U.S. Department of Transportation
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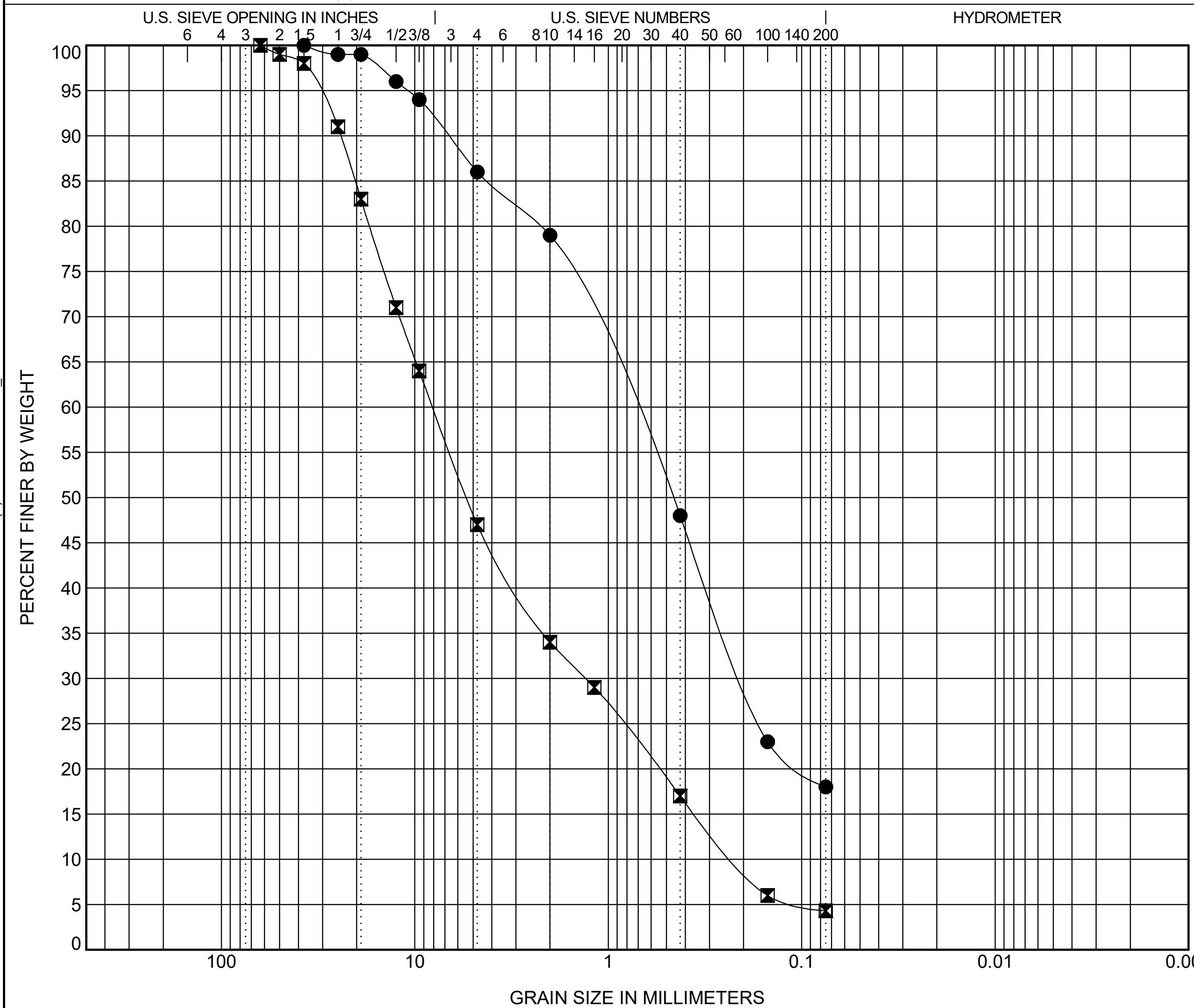
CLIENT New Mexico State Parks **PROJECT NAME** Lakeshore Road

PROJECT NUMBER NM FLAP SIE 10(1) **PROJECT LOCATION** Elephant Butte State Park, New Mexico



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	BOREHOLE	DEPTH	Classification	LL	PL	PI	Cc	Cu
●	**P-3**	**2.0**	**SILTY SAND(SM)**	**19**	**17**	**2**		
⊠	**P-5**	**2.0**	**POORLY GRADED GRAVEL with SAND(GP)**				**0.97**	**36.84**

	BOREHOLE	DEPTH	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**P-3**	**2.0**	**37.5**	**0.774**	**0.201**		**14.0**	**68.0**	**18.0**	
⊠	**P-5**	**2.0**	**63**	**8.07**	**1.311**	**0.219**	**53.0**	**42.7**	**4.3**	

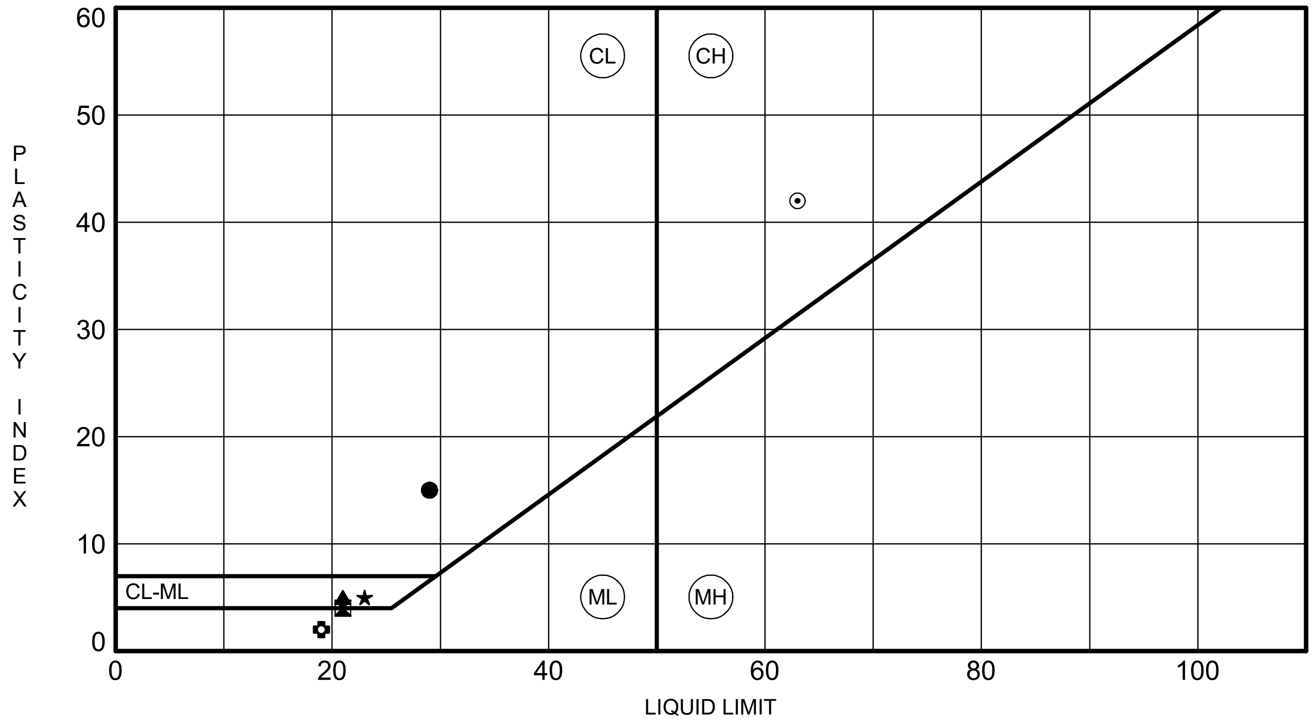
GRAIN SIZE - FHWA_DATATEMPLATE_20171103.GDT - 1/18/22 11:31 - C:\USERS\BRENDAN.MCGARITY\DOCUMENTS\GEOTECH\PROJECTS\NM\SIE10(1)\USE TO FINISH\3_DATA\DRILLING INVESTIGATION 1-18 TO 1-23\BORING LOGS\GINT\NM LAKESHORE.GPJ

ATTERBERG LIMITS - FHWA_DATATEMPLATE_20171103.GDT - 1/18/22 11:30 - C:\USERS\BRENDAN.MCGARITY\DOCUMENTS\GEOTECH\PROJECTS\NM\SIE10(1)\USE TO FINISH\3_DATA\DRILLING INVESTIGATION 1-18 TO 1-23\BORING LOGS\GINT\NM LAKESHORE.GI

U.S. Department of Transportation
Federal Highway Administration

ATTERBERG LIMITS' RESULTS

CLIENT New Mexico State Parks
PROJECT NAME Lakeshore Road
PROJECT NUMBER NM FLAP SIE 10(1)
PROJECT LOCATION Elephant Butte State Park, New Mexico



	BOREHOLE	DEPTH	LL	PL	PI	Fines	Classification
●	**BH21-01 (P-1)**	**2.0**	**29**	**14**	**15**	**15**	**CLAYEY GRAVEL with SAND(GC)**
⧗	**BH21-03**	**4.0**	**21**	**17**	**4**	**23**	**SILTY, CLAYEY SAND with GRAVEL(SC-SM)**
▲	**BH21-05 (P-4)**	**2.0**	**21**	**16**	**5**	**16**	**SILTY, CLAYEY SAND with GRAVEL(SC-SM)**
★	**BH21-05 (P-4)**	**5.0**	**23**	**18**	**5**	**33**	**SILTY, CLAYEY SAND(SC-SM)**
⊙	**BH21-06**	**65.0**	**63**	**21**	**42**	**84**	**FAT CLAY with SAND(CH)**
✿	**P-3**	**2.0**	**19**	**17**	**2**	**18**	**SILTY SAND(SM)**

APPENDIX C

PHOTOS

SITE CONDITION PHOTOS

SITE 1

Photo 1: Downstream CMP View

Photo 2: CMPs Concrete Armory

Photo 3: Lakeshore Road Northbound View

Photo 4: CMP View from Upstream

Photo 5: Surrounding Surface Cover

SITE 2

Photo 6: Lakeshore Road Southbound View

Photo 7: Lakeshore Road Northbound View

Photo 8: CMPs View from Downstream

Photo 9: CMPs View from Upstream

Photo 10: CMPs View from Upstream

SITE 3

Photo 11: Lakeshore Road Northbound View

Photo 12: CMPs View from Downstream

Photo 13: CMPs View from Upstream

Photo 14: Downstream Channel View from the Road

Photo 15: Downstream Channel Walls

SITE 4

Photo 16: Lakeshore Road Southbound View

Photo 17: CMPs View from Downstream

Photo 18: Significant Plowing of Eroded Material

Photo 19: CMPs View from Upstream

SITE 5

Photo 20: Lakeshore Road Northbound View

Photo 21: Upstream Channel View from the Road

Photo 22: Downstream Channel View from the Road

Photo 23: Downstream Channel Wall View

DRILLING PHOTOS

SITE 1 BH21-01

Photo 24: BH21-01, Hollow Stem Auger Drilling

Photo 25: BH21-01, SPT-01

Photo 26: BH21-01, SPT-02 Bagged Sample

Photo 27: BH21-01, SPT-02 Sample Close Up

Photo 28: BH21-01, SPT-03

Photo 29: BH21-01, SPT-04

Photo 30: BH21-01, SPT-05

Photo 31: BH21-01, SPT-06

Photo 32: BH21-01, SPT-07

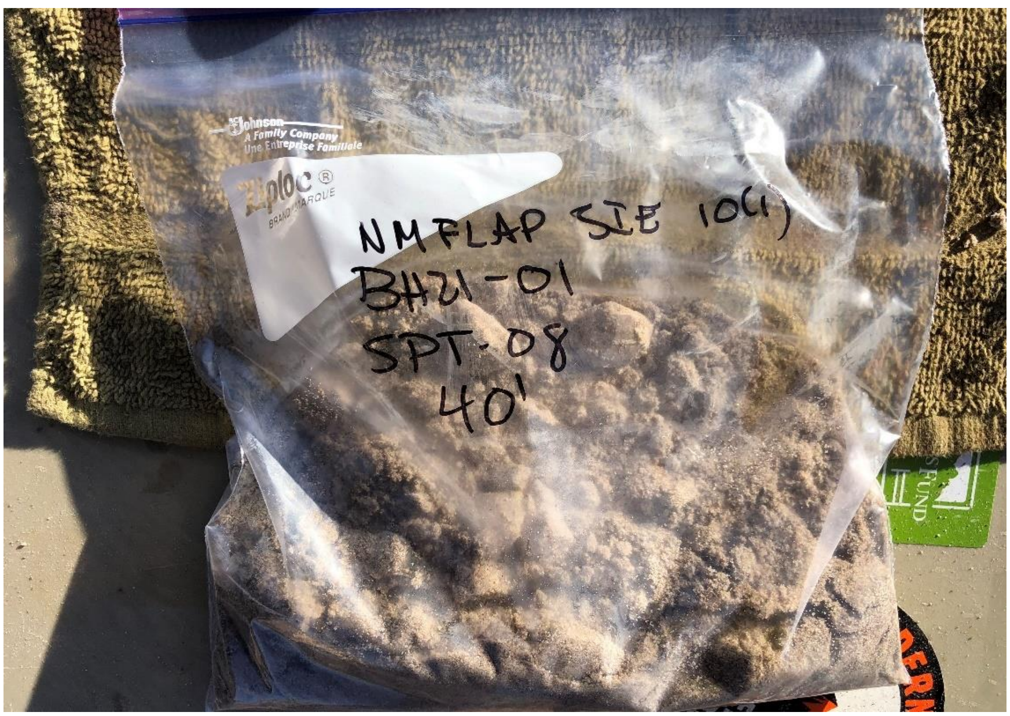


Photo 33: BH21-01, SPT-08 Bagged Sample

Photo 34: BH21-01, SPT-08 Sample Close Up

SITE 2 BH21-02

Photo 35: BH21-02, SPT-07 Drilling Set Up

Photo 36: BH21-02, SPT-01

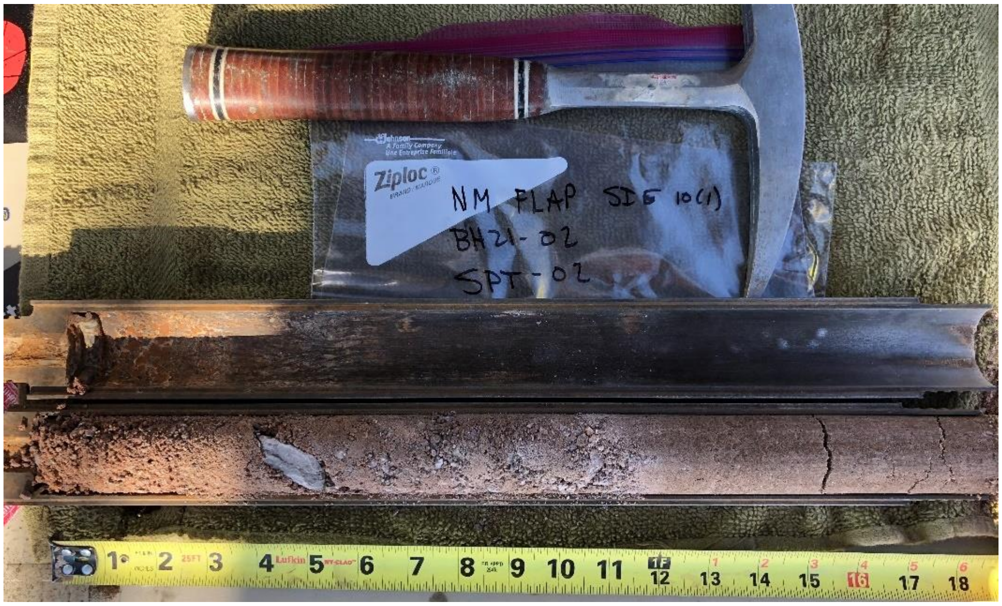


Photo 37: BH21-02, SPT-02

Photo 38: BH21-02, SPT-03

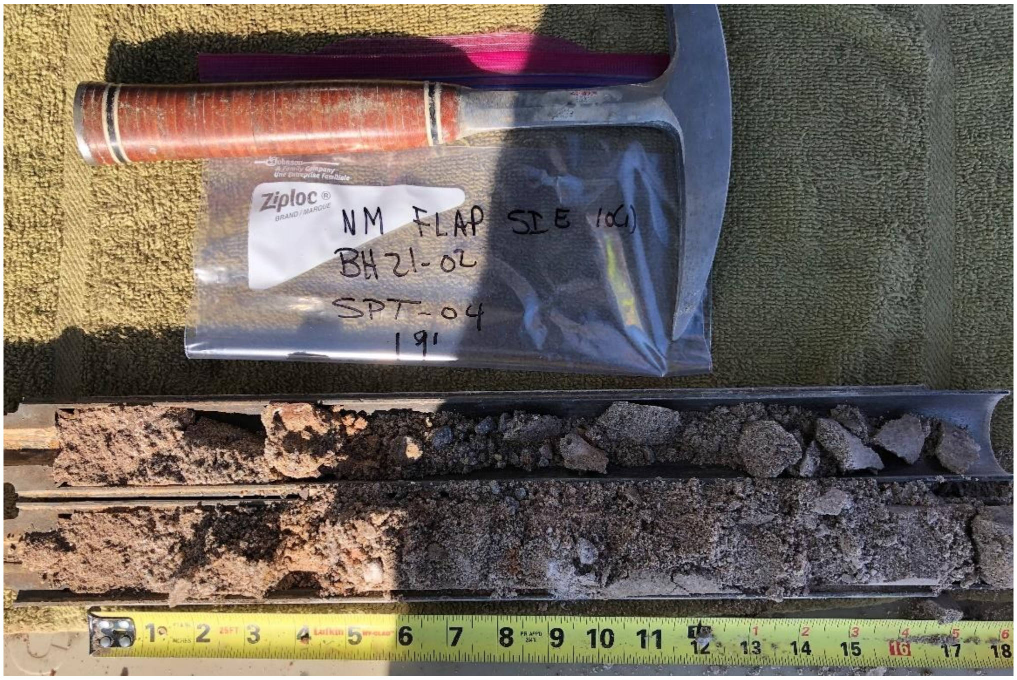


Photo 39: BH21-02, SPT-04

Photo 40: BH21-02, SPT-05

Photo 41: BH21-02, SPT-06 Bagged Sample

Photo 42: BH21-02, SPT-06 Sample Close Up

Photo 43: BH21-02, SPT-07

Photo 44: BH21-02, SPT-08

SITE 3 BH21-03

Photo 45: BH21-03, Down Hole Hammer (ODEX) Drilling

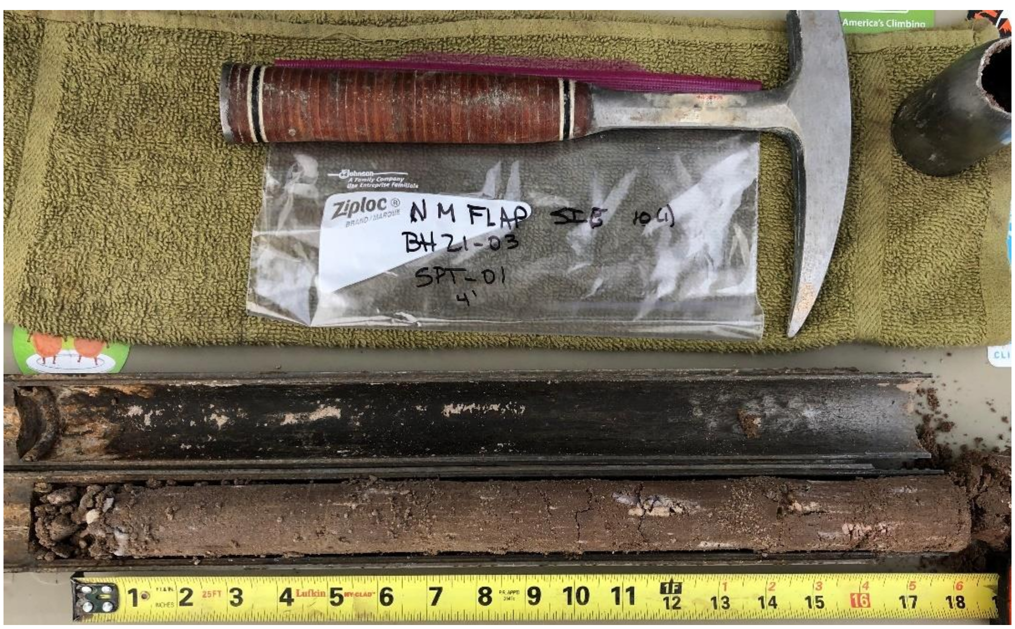


Photo 46: BH21-03, SPT-01

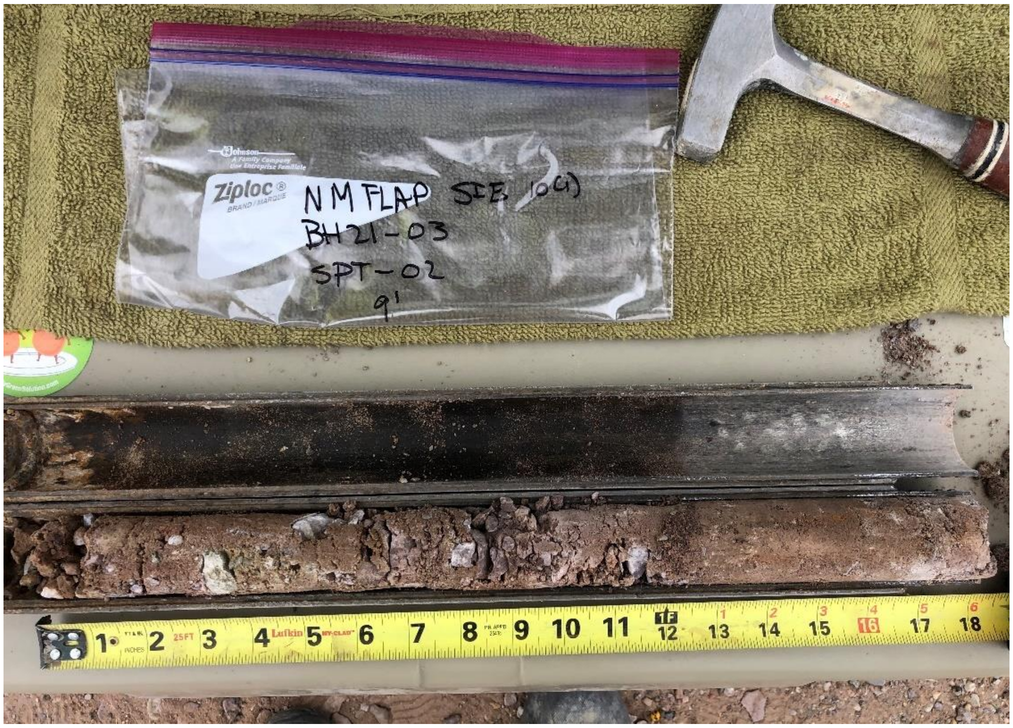


Photo 47: BH21-03, SPT-02

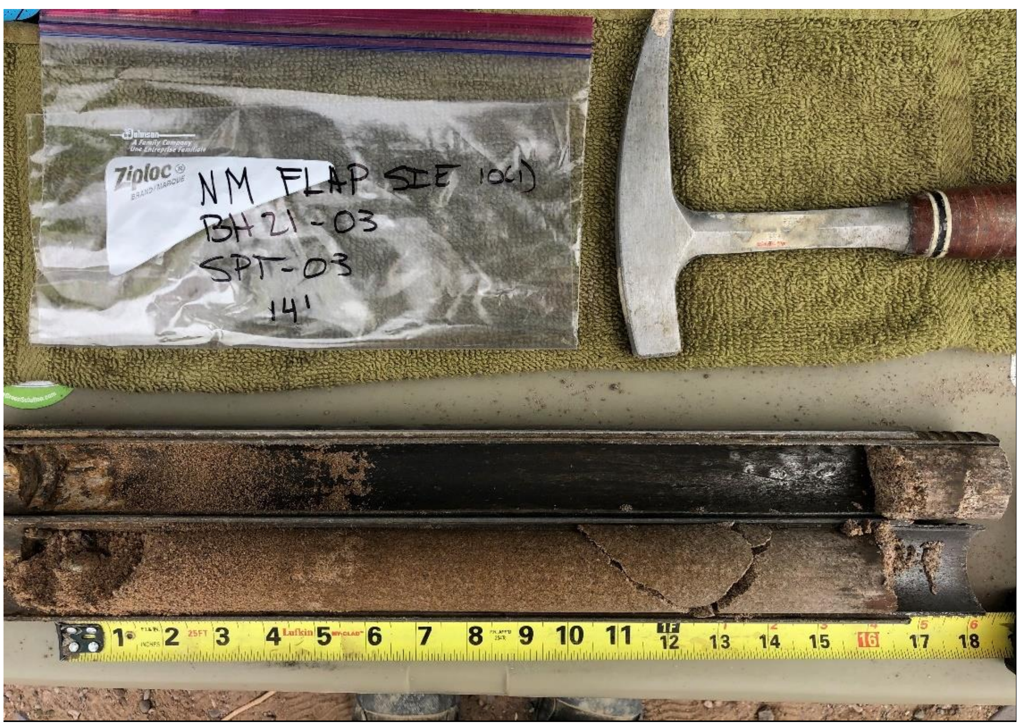


Photo 48: BH21-03, SPT-03

Photo 49: BH21-03, SPT-04

Photo 50: BH21-03, SPT-05

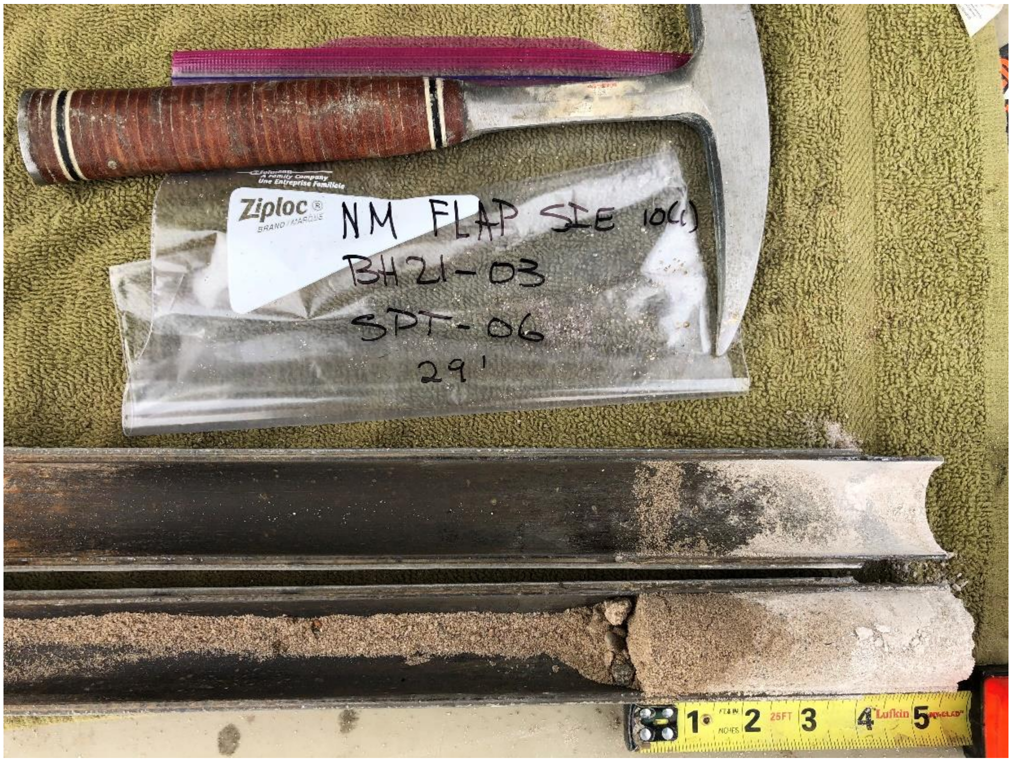


Photo 51: BH21-03, SPT-06

Photo 52: BH21-03, SPT-07

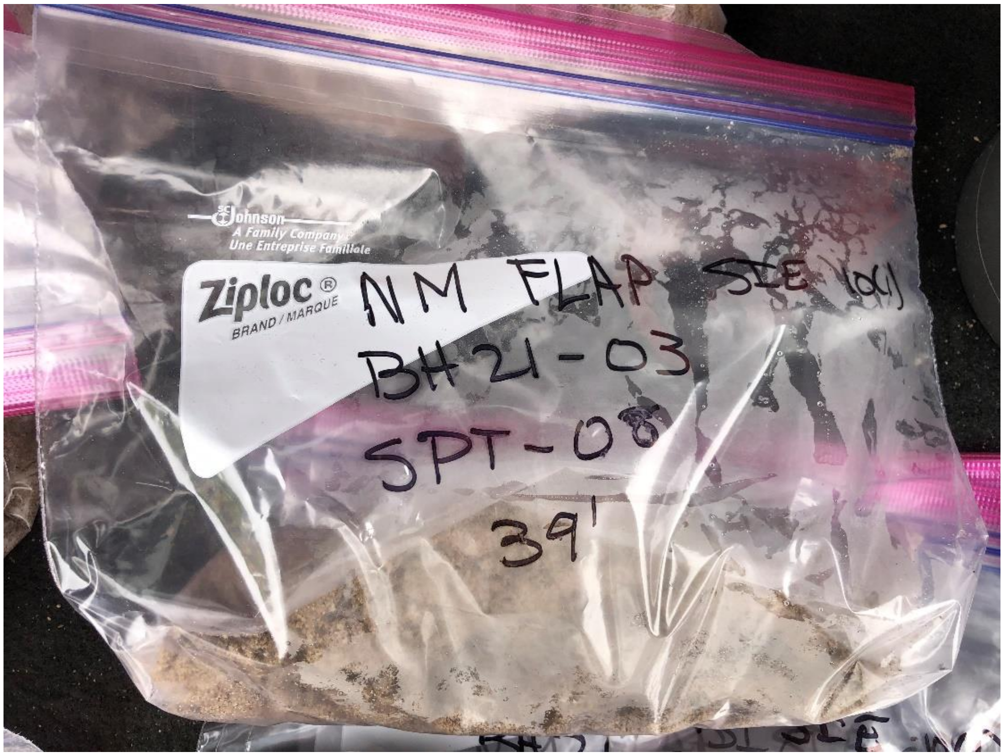


Photo 53: BH21-03, SPT-08 Bagged Sample

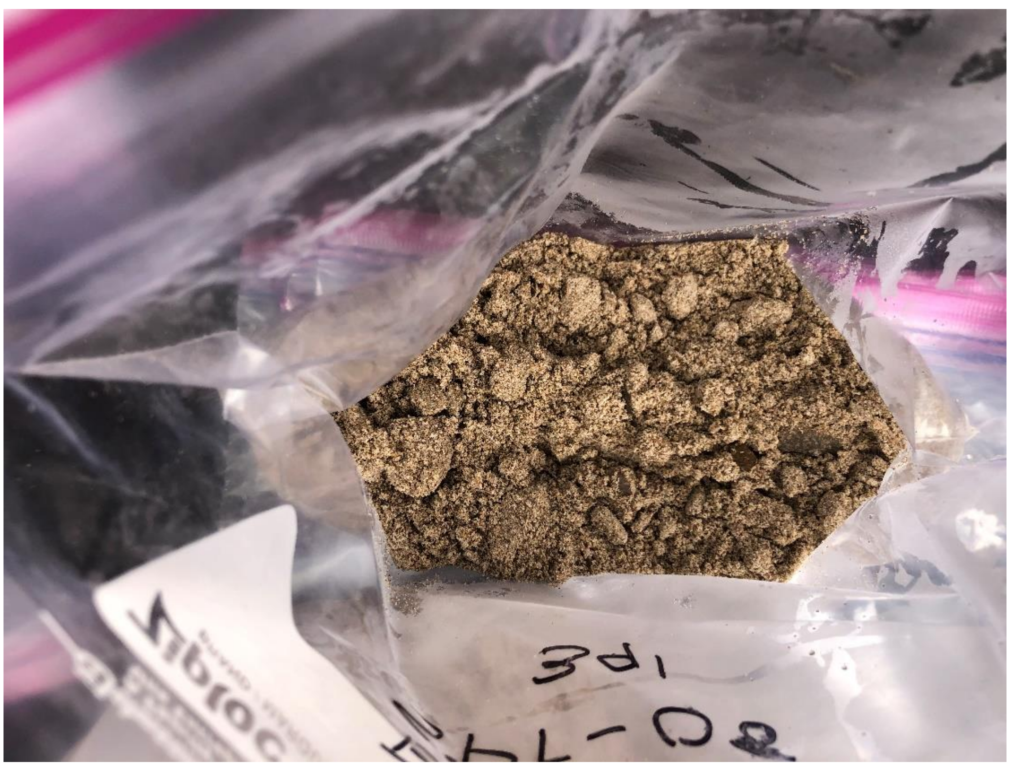


Photo 54: BH21-03, SPT-08 Sample Close Up

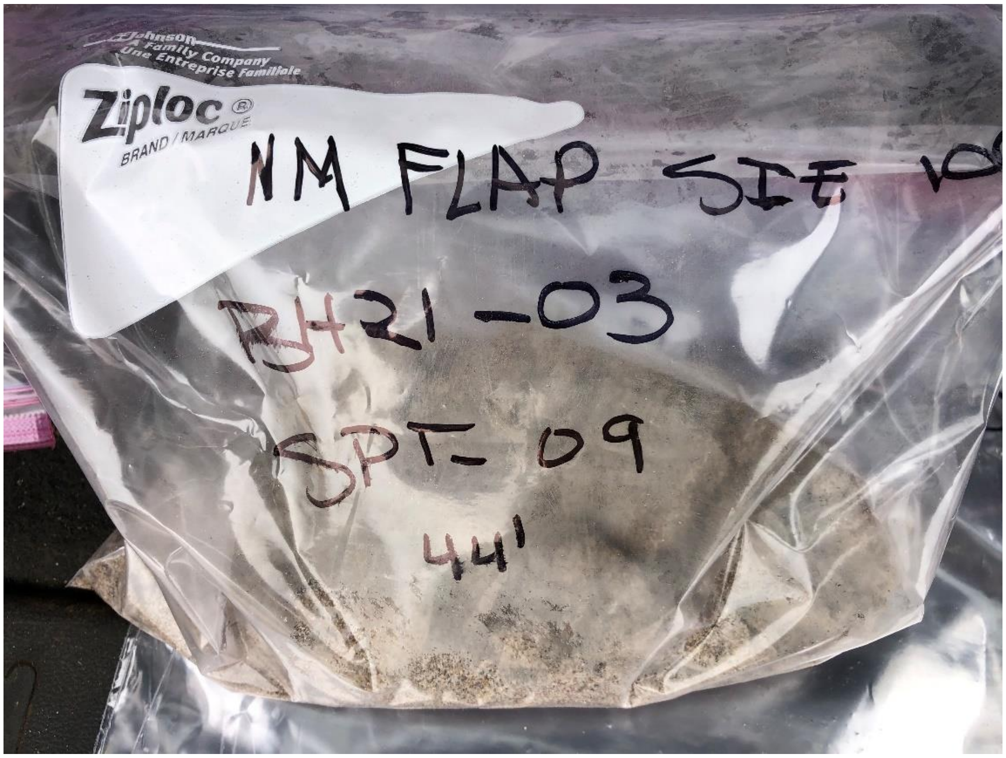


Photo 55: BH21-03, SPT-09 Bagged Sample

Photo 56: BH21-03, SPT-09 Sample Close Up

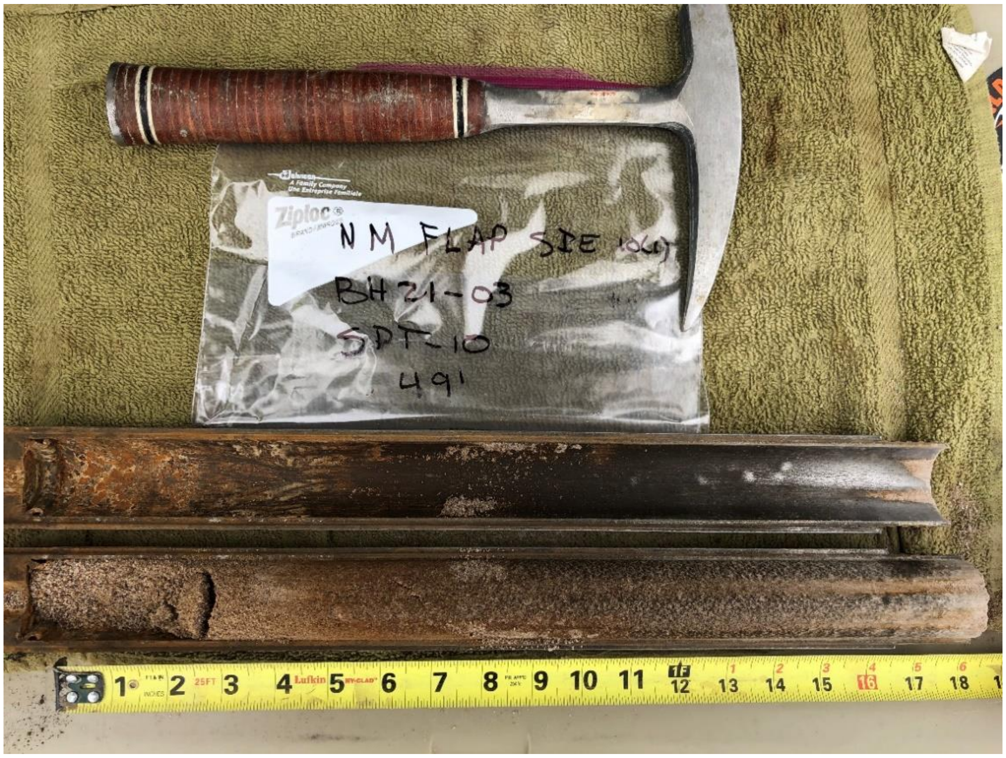


Photo 57: BH21-03, SPT-10

Photo 58: BH21-03, SPT-11

Photo 59: BH21-03, SPT-12

Photo 60: BH21-03, SPT-13

Photo 61: BH21-03, SPT-14

Photo 62: BH21-03, SPT-15

Photo 63: BH21-03, SPT-16

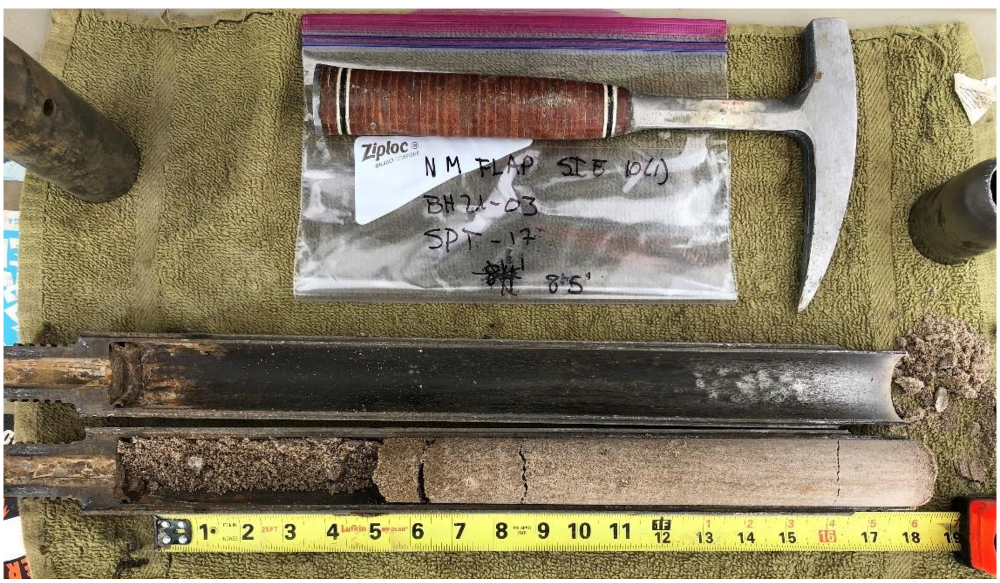


Photo 64: BH21-03, SPT-17

Photo 65: BH21-03, SPT-18

Photo 66: BH21-03, SPT-19

Photo 67: BH21-03, SPT-20

SITE 3 BH21-04

Photo 68: BH21-04, Down Hole Hammer (ODEX) Drilling

Photo 69: BH21-04, SPT-02

(Note: SPT-01 not pictured. No recovery.)

Photo 70: BH21-04, SPT-03

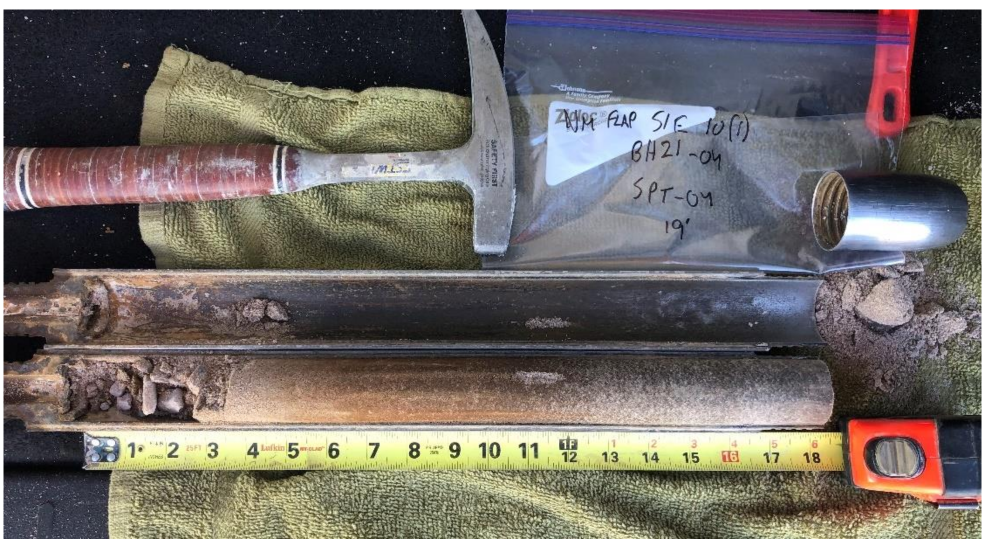


Photo 71: BH21-04, SPT-04

Photo 72: BH21-04, SPT-05

Photo 73: BH21-04, SPT-06

Photo 74: BH21-04, SPT-07

Photo 75: BH21-04, SPT-08

Photo 76: BH21-04, SPT-09

Photo 77: BH21-04, SPT-10

Photo 78: BH21-04, SPT-11

Photo 79: BH21-04, SPT-12

Photo 80: BH21-04, SPT-13

Photo 81: BH21-04, SPT-14

Photo 82: BH21-04, SPT-15

Photo 83: BH21-04, SPT-16

SITE 4 BH21-05

Photo 84: BH21-05, Hollow Stem Auger Drilling

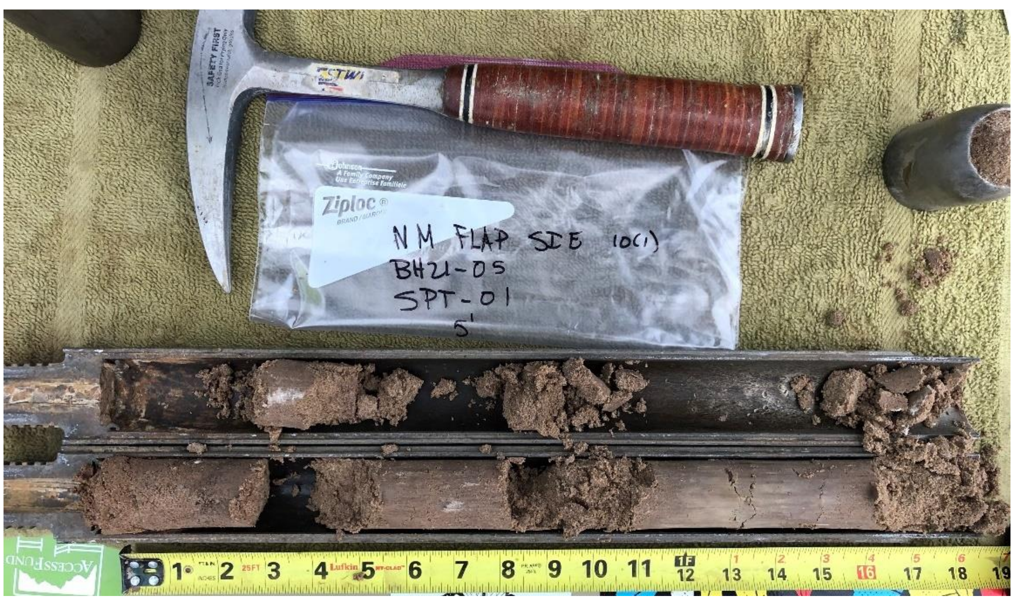


Photo 85: BH21-05, SPT-01

Photo 86: BH21-05, SPT-02

Photo 87: BH21-05, SPT-03

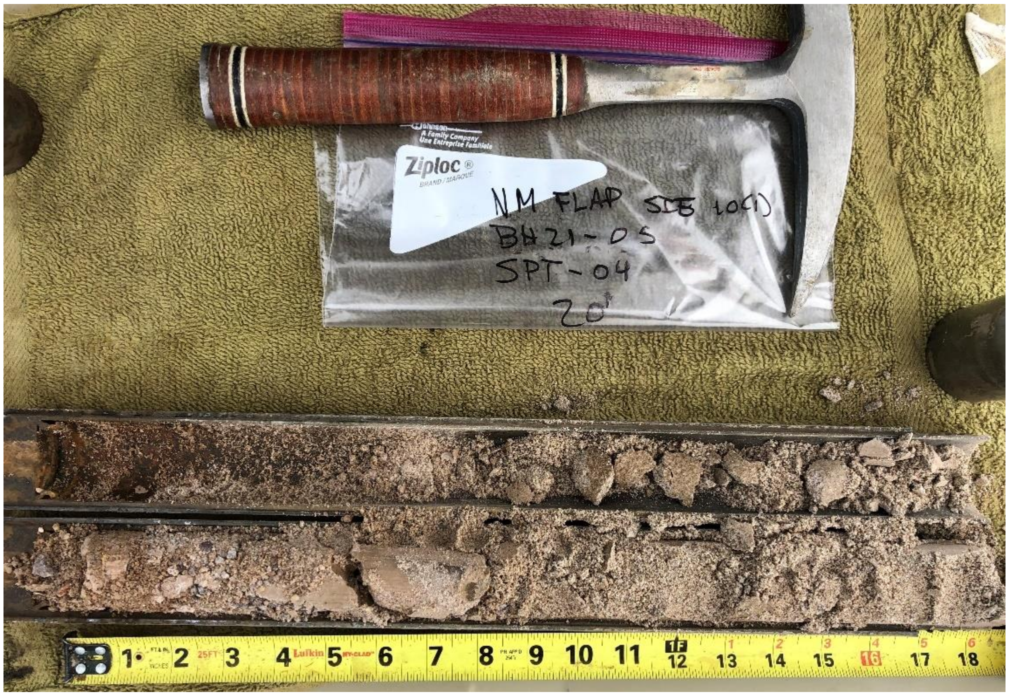


Photo 88: BH21-05, SPT-04

Photo 89: BH21-05, SPT-05

Photo 90: BH21-05, SPT-06

Photo 91: BH21-05, SPT-07

(Note: SPT-08 was not photographed.)

Photo 92: BH21-05, SPT-09

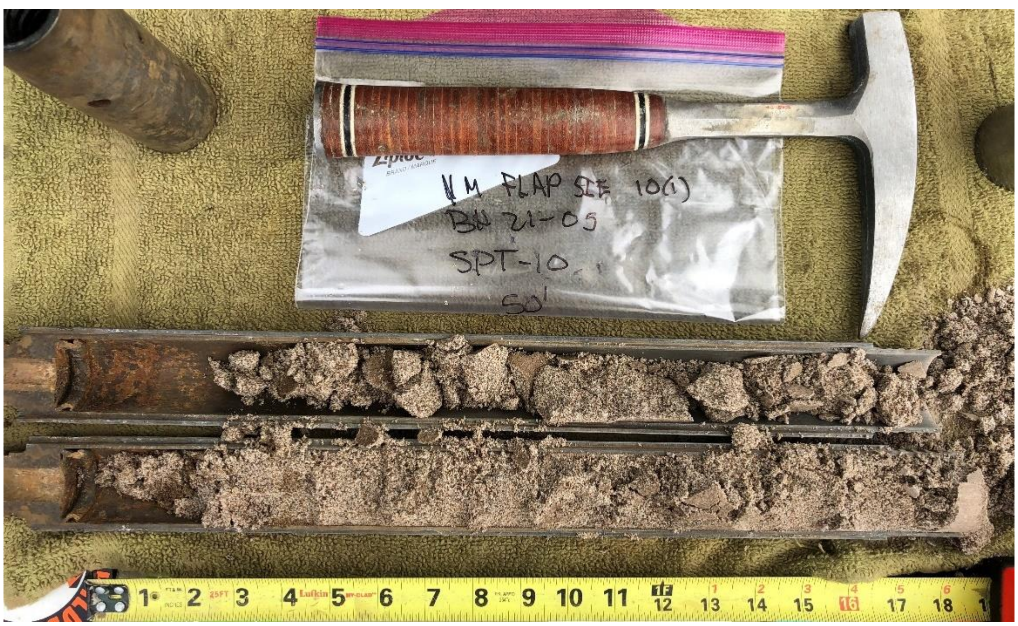


Photo 93: BH21-05, SPT-10

Photo 94: BH21-05, SPT-11

Photo 95: BH21-05, SPT-12

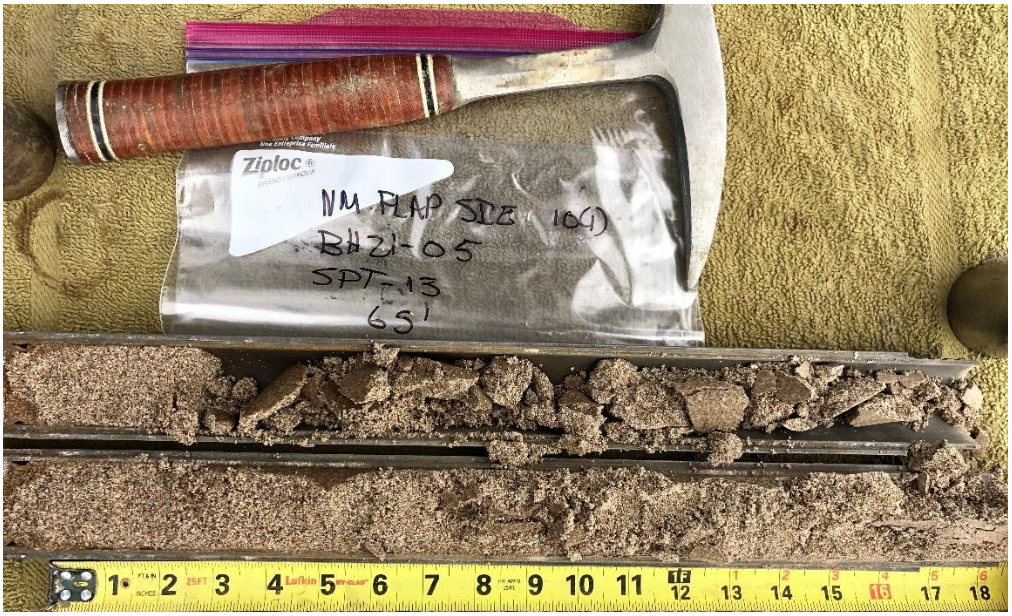


Photo 96: BH21-05, SPT-13

Photo 97: BH21-05, SPT-14

Photo 98: BH21-05, SPT-15

Photo 99: BH21-05, SPT-16

Photo 100: BH21-05, SPT-17

Photo 101: BH21-05, SPT-18

Photo 102: BH21-05, SPT-19

(Note: SPT-20 not pictured. Flowing sand in tooling.)

SITE 4 BH21-06

Photo 103: BH21-06, Hollow Stem Auger Drilling

Photo 104: BH21-06, SPT-01

Photo 105: BH21-06, SPT-02

Photo 106: BH21-06, SPT-03

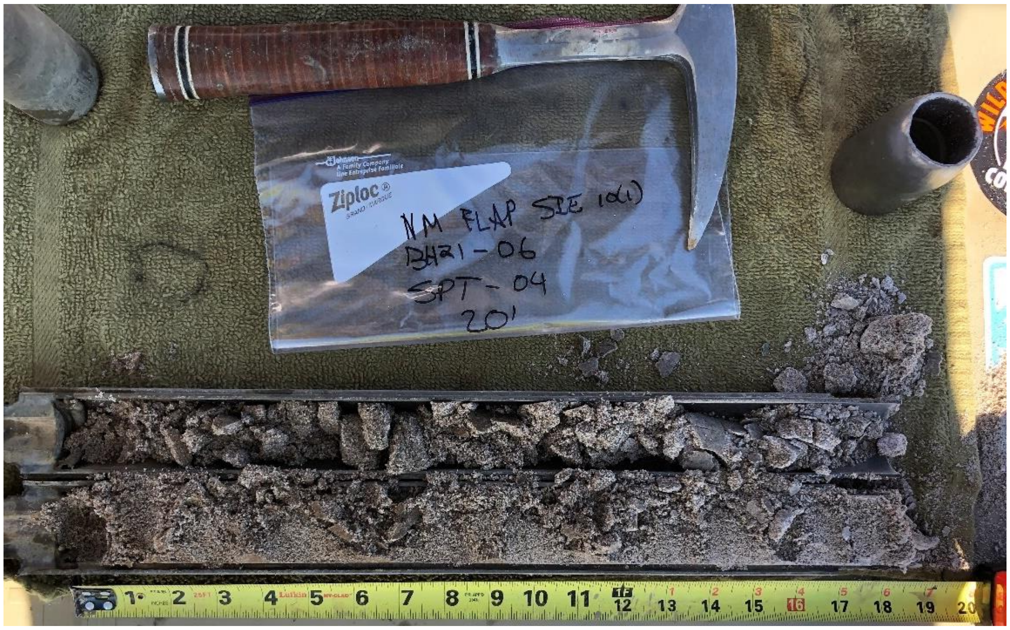


Photo 107: BH21-06, SPT-04

Photo 108: BH21-06, SPT-05

Photo 109: BH21-06, SPT-06

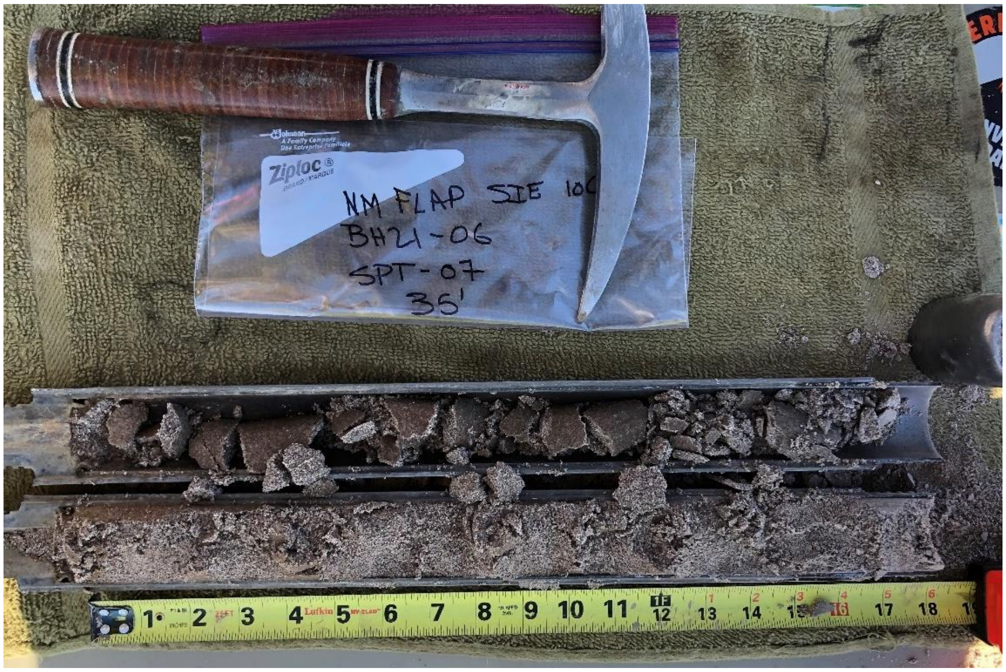


Photo 110: BH21-06, SPT-07

Photo 111: BH21-06, SPT-08

Photo 112: BH21-06, SPT-09

Photo 113: BH21-06, SPT-10

Photo 114: BH21-06, SPT-11

Photo 115: BH21-06, SPT-12

Photo 116: BH21-06, SPT-13

Photo 117: BH21-06, SPT-14

Photo 118: BH21-06, SPT-15

Photo 119: BH21-06, SPT-16

Photo 120: BH21-06, SPT-17

Photo 121: BH21-06, SPT-18

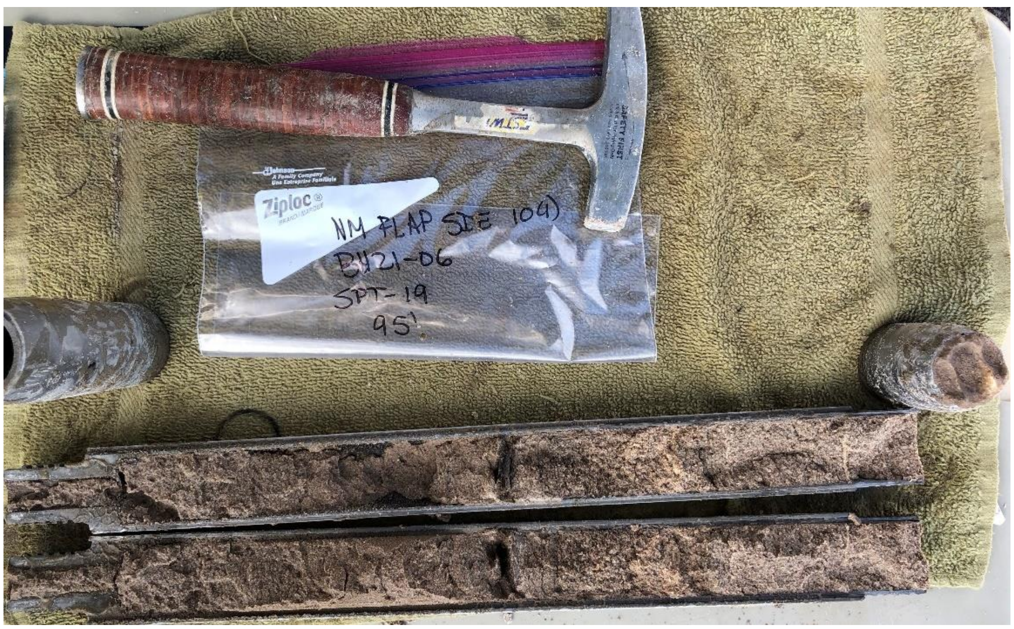


Photo 122: BH21-06, SPT-19

Photo 123: BH21-06, SPT-20

SITE 5 BH21-07

Photo 124: BH21-07, Drilling Set Up

Photo 125: BH21-07, SPT-01

Photo 126: BH21-07, SPT-02

Photo 127: BH21-07, SPT-03

Photo 128: BH21-07, SPT-04

Photo 129: BH21-07, SPT-05

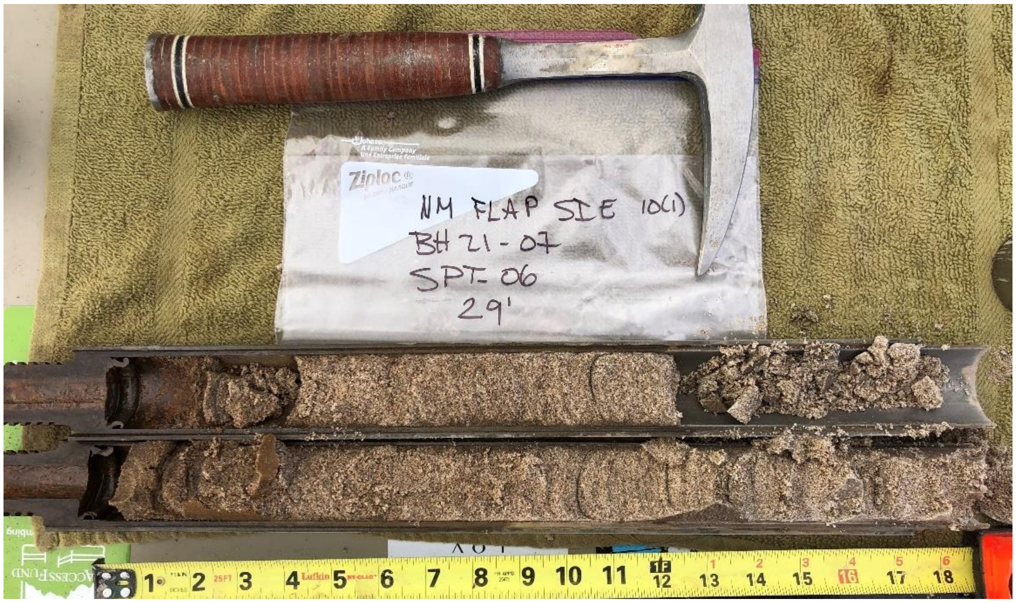


Photo 130: BH21-07, SPT-06

Photo 131: BH21-07, SPT-07

Photo 132: BH21-07, SPT-08

APPENDIX D

EXCAVATION CHARACTERISTICS OF ROCK

APPENDIX D

EXCAVATION CHARACTERISTICS OF ROCK & RIPPABILITY CHARTS

(Provided by Various Sources)

Table D.1: Rock Hardness and Excavation Characteristics[1]

Rock Hardness Description	Identification Criteria	Unconfined Compressive Strength		Seismic Compression (P-Wave) Velocity		Excavation Characteristics
		MPa	psi	m/s	f/s	
Very Soft Rock	Material crumbles under firm blows with sharp end of geological pick; can be peeled with a knife; too hard to cut a triaxial sample by hand. SPT will refuse. Pieces up to 3-c, thick can be broken by finger pressure.	1.7-3.0	246-435	450-1,200	1,475-3,935	Easy Ripping
Soft Rock	Can just be scraped with a knife; indentations 1-mm to 3-mm show in specimen with firm blows of the pick point; has dull sound under hammer.	3.0-10.0	435-1,450	1,200-1,500	3,935-4,920	Hard Ripping
Hard Rock	Cannot be scraped with a knife; hand specimen can be broken with a pick with a single firm blow; rock rings under hammer.	10.0-20.0	1,450-2,900	1,500-1,850	4,920-6,070	Very Hard Ripping
Very Hard Rock	Hand specimen breaks with a pick after more than one blow; rock rings under hammer.	20.0-70.0	2,900-10,150	1,850-2,150	6,070-7,050	Extremely Hard Ripping or Blasting
Extremely Hard Rock	Specimen require many blows with geological pick to break through intact material; rock rings under hammer.	> 70.0	> 10,150	> 2,150	>7,050	Blasting

[1]Table from Weaver (1975).

Table D.2: Excavation Characteristics of Rock[2]

Classification Elements	Class I **Very hard ripping to blasting**	Class II **Hard ripping**	Class III **Easy ripping**
	Rock material requires drilling and explosives or impact procedures for excavation may classify as rock excavation (NRCS Construction Spec. 21). **Must fulfill all conditions below:**	Rock material requires ripping techniques for excavation may classify as rock excavation (NRCS Construction Spec. 21). **Must fulfill all conditions below:**	Rock material can be excavated as common material by earth-moving or ripping equipment may classify as common excavation (NRCS Construction Spec. 21). **Must fulfill all conditions below:**
Headcut erodibility index, k_h (NEH628.52)	$k_h \geq 100$	$10 < k_h < 100$	$k_h \leq 10$
Seismic velocity, approximate (ASTM D5777 and Caterpillar Handbook of Ripping, 1997)	> 2,450 m/s (> 8,000 ft/s)	2,150-2,450 m/s (7,000-8,000 ft/s)	< 2,150 m/s (< 7,000 ft/s)
Minimum equipment size (flywheel power) required to excavate rock. All machines assumed to be heavy-duty, track-type backhoes or tractors equipped with a single tine, rear-mounted ripper.	260 kW (350 hp), for $k_h < 1{,}000$ 375 kW (500 hp), for $k_h < 10{,}000$ Blasting, for $k_h > 10{,}000$	185 kW (250 hp)	110 kW (150 hp)

[1]The classification is a general guide and does not prescribe the actual contract payment method to be used, nor supersedes NRCS contract documents. The classification is for engineering design purposes only.

[2]Table from USDA (2012).

USE OF SEISMIC VELOCITY CHARTS[1]

The charts of ripper performance estimated by seismic wave velocities have been developed from field tests conducted in a variety of materials. Considering the extreme variations among materials and even among rocks of a specific classification, the charts must be recognized as being at best only one indicator of rippability.

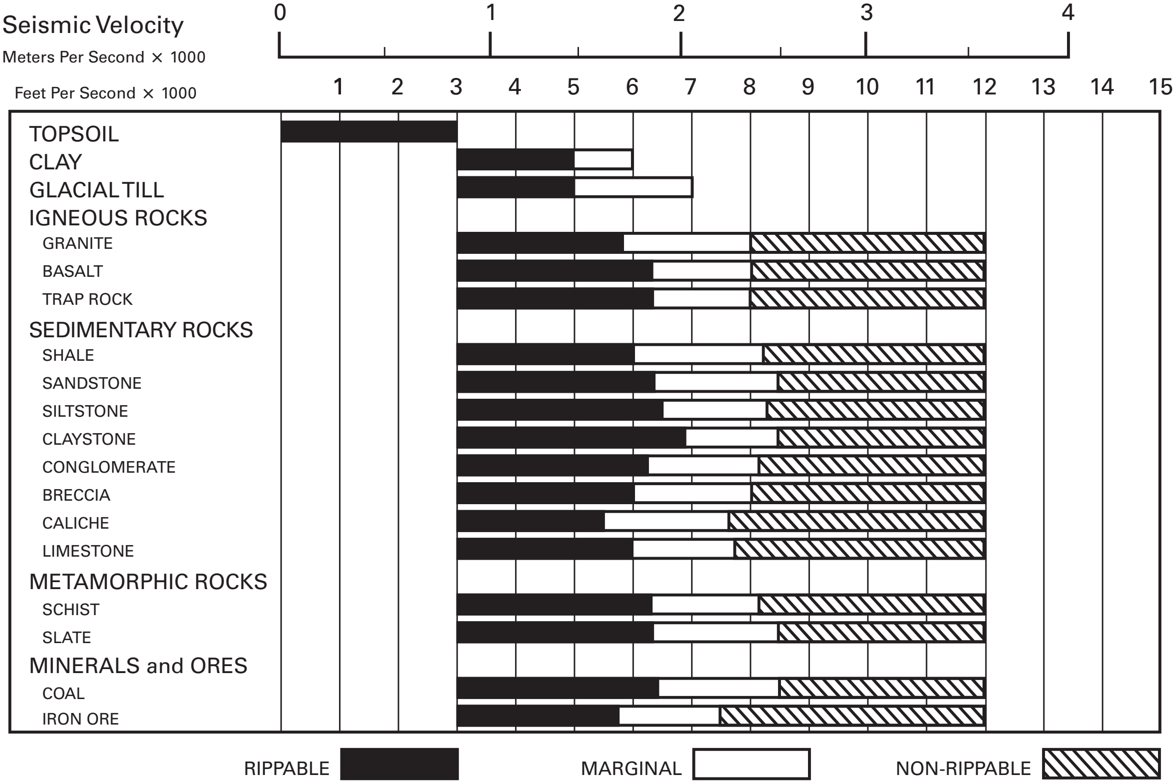
Accordingly, consider the following precautions when evaluating the feasibility of ripping a given formation:

- Tooth penetration is often the key to ripping success, regardless of seismic velocity. This is particularly true in homogeneous materials such as mudstones and claystones and the fine-grained caliches. It is also true in tightly cemented formations such as conglomerates, some glacial tills and caliches containing rock fragments.
- Low seismic velocities of sedimentaries can indicate probable rippability. However, if the fractures and bedding joints do not allow tooth penetration, the material may not be ripped effectively.
- Pre-blasting or “popping” may induce sufficient fracturing to permit tooth entry, particularly in the caliches, conglomerates and some other rocks; but the economics should be checked carefully when considering popping in the higher grades of sandstones, limestones and granites.

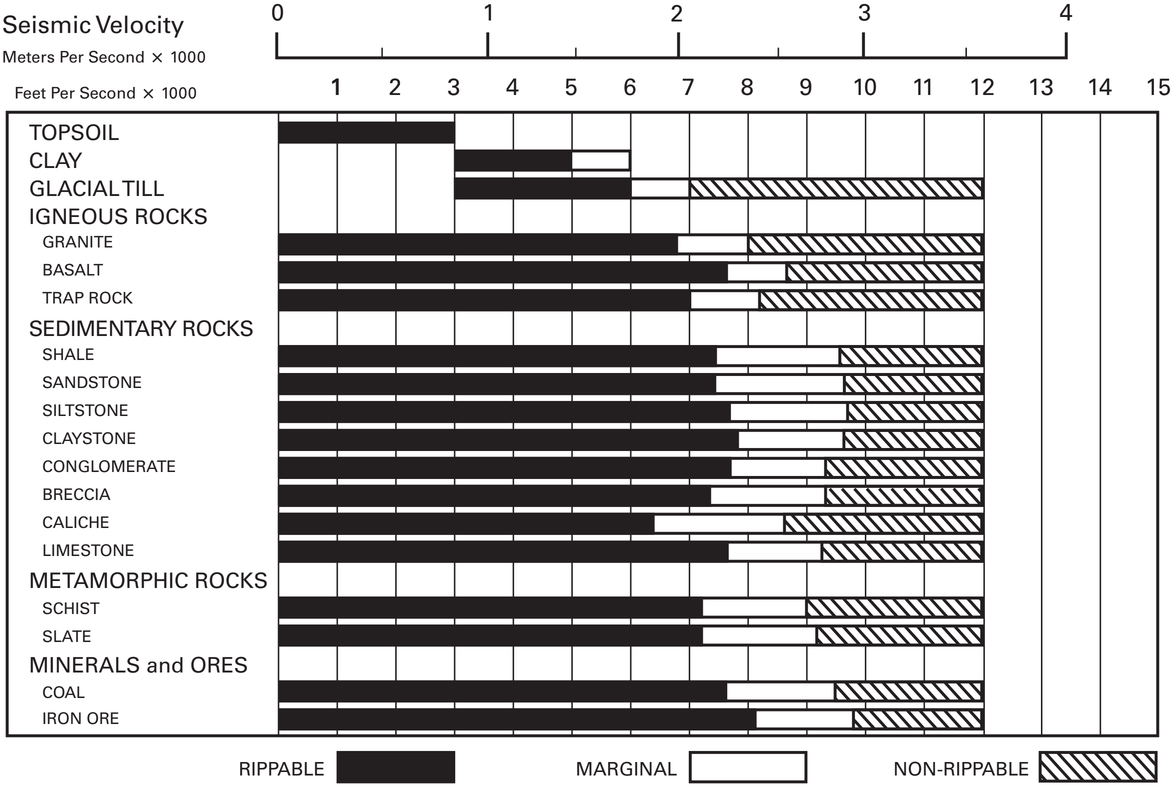
Ripping is still more art than science, and much will depend on operator skill and experience. Ripping for scraper loading may call for different techniques than if the same material is to be dozed away. Cross-ripping requires a change in approach. The number of shanks used, length and depth of shank, tooth angle, direction, throttle position all must be adjusted according to field conditions. Ripping success may well depend on the operator finding the proper combination for those conditions.

[1]Text and the following tables from Hawthorne Cat (2018).

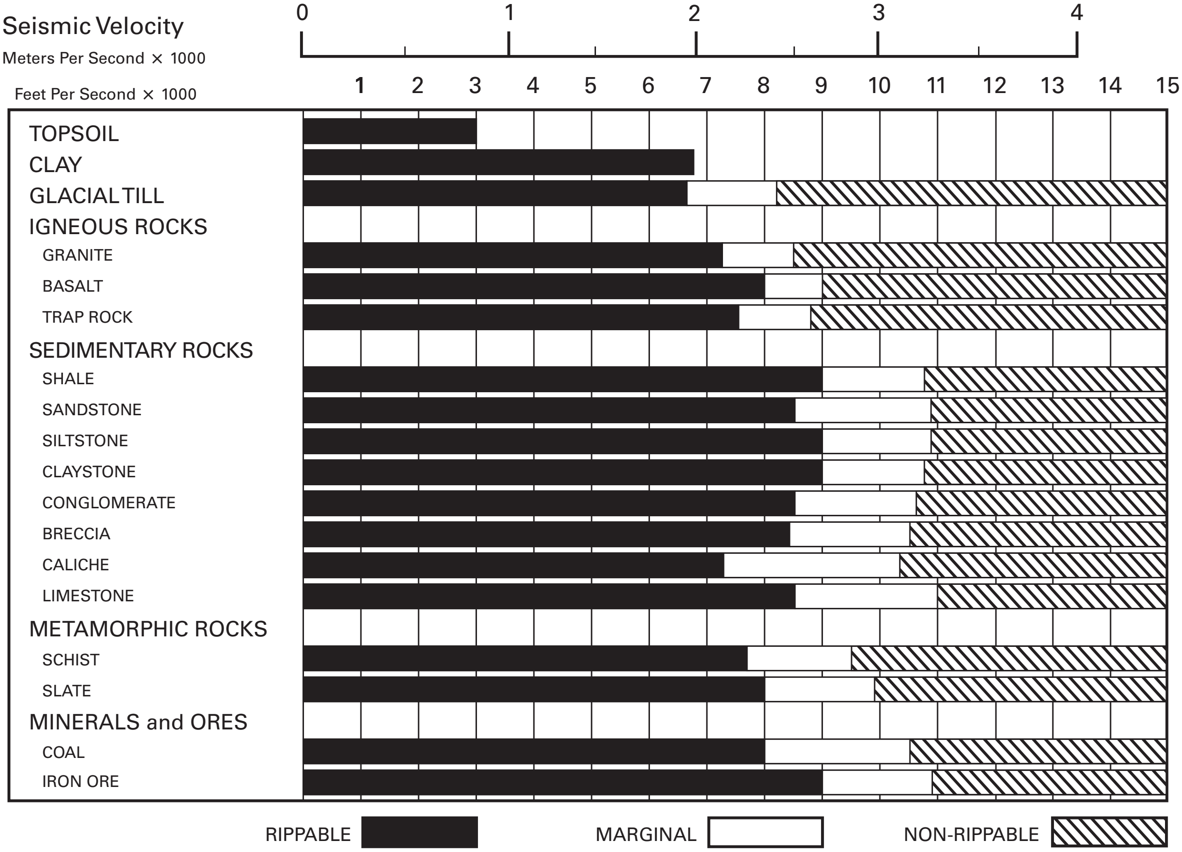
D8R/D8T
● Multi- or Single Shank No. 8 Ripper
● Estimated by Seismic Wave Velocities



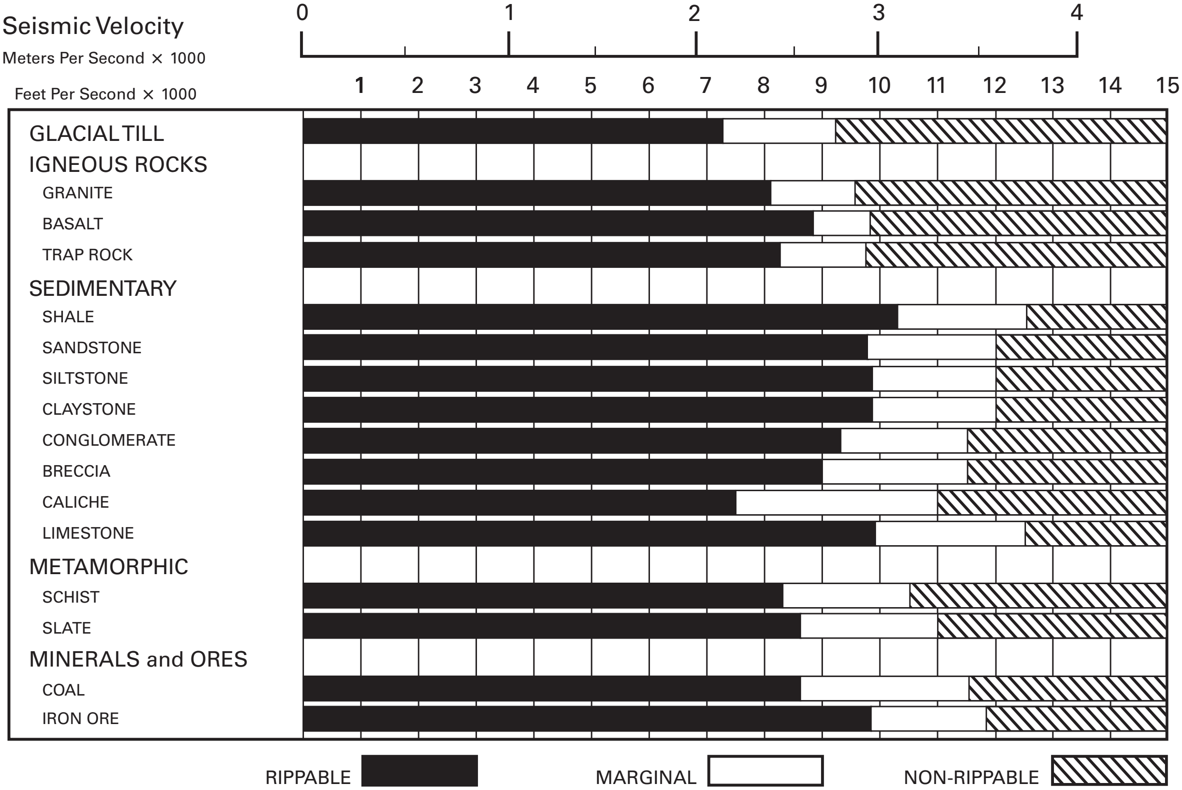
D9R/D9T
● Multi- or Single Shank No. 9 Ripper
● Estimated by Seismic Wave Velocities



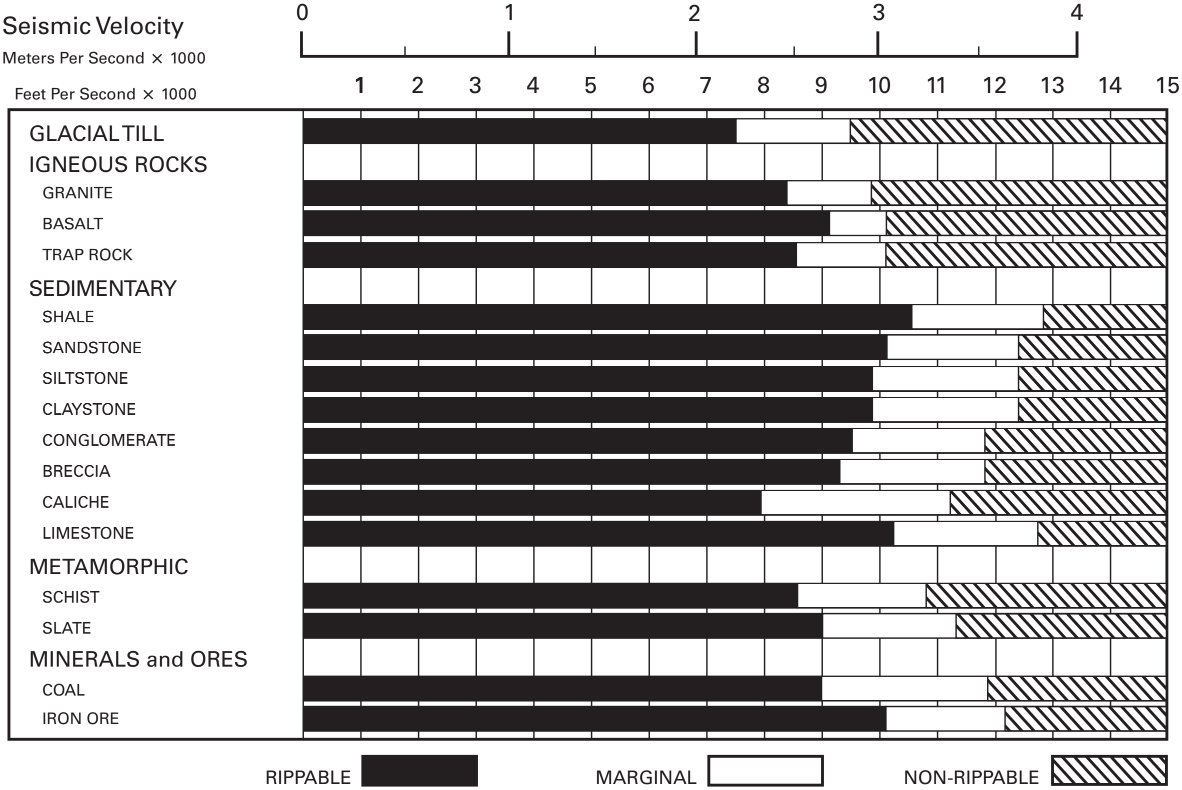
D10T2
- **Multi- or Single Shank No. 10 Ripper**
- **Estimated by Seismic Wave Velocities**



D11T
● Multi- or Single Shank No. 11 Ripper
● Estimated by Seismic Wave Velocities



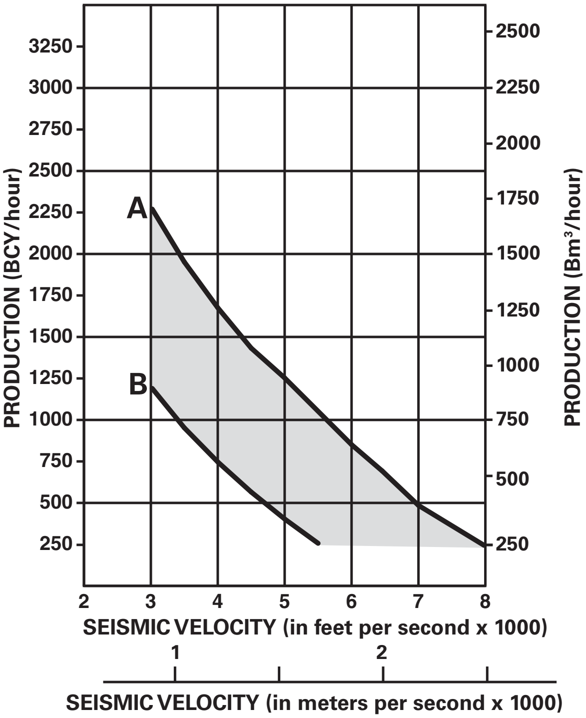
D11T CD
- **Single Shank No. 11 Ripper**
- **Estimated by Seismic Wave Velocities**



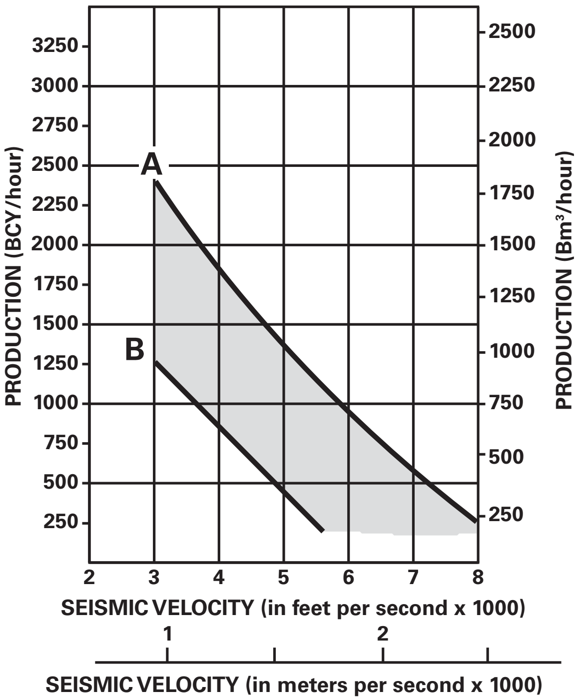
CONSIDERATIONS FOR USING PRODUCTION ESTIMATED GRAPHS:

- Machine rips full-time — no dozing.
- Power shift tractors with single shank rippers.
- 100% efficiency (60 min hour).
- Charts are for all classes of material.
- In igneous rock with seismic velocity of 8000 fps (2450 mps) or higher for the D11T, and 6000 fps (1830 mps) or higher for the D10T2, D9R/D9T and D8R/D8T, the production figures shown should be reduced by 25%.
- Upper limit of charts reflect ripping under ideal conditions only. If conditions such as thick lamination, vertical lamination or any factor which would adversely affect production are present, the lower limit should be used.

D8R/D8T WITH SINGLE SHANK

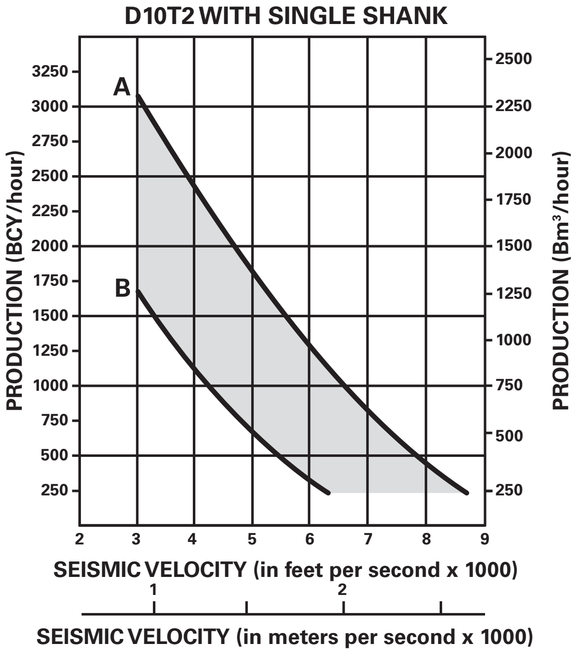


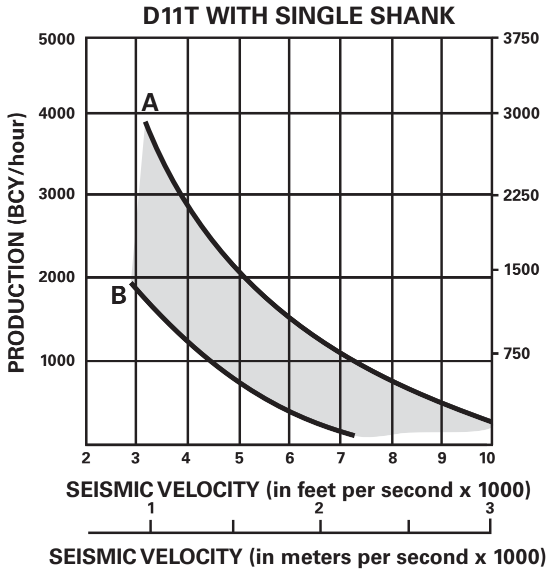
D9R/D9T WITH SINGLE SHANK

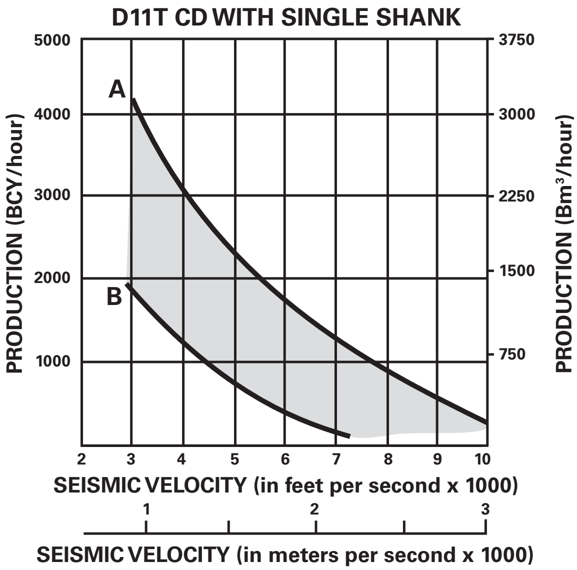


KEY
A — IDEAL
B — ADVERSE

Rippers | Estimated Ripper Production Graphs
● D10T2 ● D11T ● D11T CD







KEY
A — IDEAL
B — ADVERSE